NASA Procedural Requirements

NPR 8831.2F
Effective Date: October 07, 2015
Expiration Date: June 30, 2023

COMPLIANCE IS MANDATORY FOR NASA EMPLOYEES

Facilities Maintenance and Operations Management (Updated w/Change 1 on September 2, 2016)

Responsible Office: Facilities Engineering and Real Property Division

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1	9/02/16	Replacement of Obsolete Items from $1 million to "None", and change is located in Chapter 2.3.3, Table 2-2, page 23 and Appendix H, Section 3.1.5 Repair and Trouble Calls, page 289.

Preface

P.1 Purpose

a. This directive establishes minimum NASA management of facilities maintenance objectives, standards, and requirements in support of NASA Policy Directive (NPD) 8831.1 and NPD 8700.1. In addition to stressing the NASA Administrator's emphasis on the importance of strict compliance with safety regulations, practices, and procedures, it requires the practice of several proactive methods for meeting those objectives and standards, including the adoption of the Reliability Centered Maintenance (RCM) philosophy and procedures (NASA Reliability Centered Maintenance Guide for Facilities and Collateral Equipment), use of Predictive Testing and Inspection (PT&I) technologies, and maximum use of fixed-price, performance-based contracts coupled with good business practices that are cost effective to accomplish maintenance.

b. This document fixes commonality of facilities maintenance definitions Agency-wide among the NASA Centers and Component Facilities, thereby permitting the application of uniform measures of facilities conditions; allowing meaningful, quantitative metrics in terms common throughout the Agency. This provides the ability to statistically analyze relative variances, compile an information database using terminology and definitions common to and recognized by commercial software products and other industrial and Government applications, and thereby add credibility to the NASA facilities maintenance budgeting process through standardization.

P.2 Applicability

a. This NPR is applicable to NASA Headquarters and NASA Centers, including Component Facilities and Technical and Service Support Centers.

b. Because of the differences in NASA Center organizations, this NPR does not assume or require a typical facilities maintenance organization. Instead, it uses a systems approach to describe the functions that should be included in any facilities maintenance management system, regardless of its organizational structure.

c. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The terms: "may" or "can" denote discretionary privilege or permission, "should" denotes a good practice and is recommended, but not required, "will" denotes expected outcome, and "are/is" denotes descriptive material.

d. In this directive, all document citations are assumed to be the latest version unless otherwise noted.

P.3 Authority

a. The National Aeronautics and Space Act, 51 U.S.C. § 20113(a).

b. NPD 8831.1, Maintenance and Operations of Institutional and Program Facilities and Related Equipment.

P.4 Applicable Documents and Forms

a. Energy Policy Act (EPAct) 2005, Pub. L. 109-58, 119 Stat. 594 (205).

b. Federal Buildings Personnel Training Act of 2010, Pub. L. 111-308, 124 Stat. 3283 (2010).

c. Strengthening Federal Environmental, Energy, and Transportation Management, E. O. 13423.

d. Protection of Historic Properties, 36 CFR pt. 800.

e. Federal Acquisition Regulation (FAR), 48 CFR Chapter 1.

f. NPD 7330.1, Approval Authorities for Facility Projects.

g. NPD 8700.1, NASA Policy for Safety and Mission Success.

h. NPD 8710.5, Policy for Pressure Vessels and Pressurized Systems.

i. NPD 8820.2, Design and Construction of Facilities.

j. NPR 1441.1, NASA Records Management Program Requirements.

k. NPR 8553.1, NASA Environmental Management System.

l. NPR 8570.1, NASA Energy Management Program.

m. NPR 8715.3, NASA General Safety Program Requirements.

n. NPR 8800.15, Real Estate Management Program.

o. NPR 8820.2, Facility Project Requirements (FPR).

p. NPR 9090.1, Reimbursable Agreements.

q. NASA-STD 8719.9, Standard for Lifting Devices and Equipment.

r. NASA-STD 8719.12, Safety Standard for Explosives, Propellants, and Pyrotechnics.

s. NASA-STD 8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PV/S).

t. ASTM E1557, Standard Classification for Building Elements and Related Sitework-UNIFORMAT II.

u. NASA Reliability Centered Building and Equipment Acceptance Guide, July 2004.

v. Reliability-Centered Maintenance Guide for Facilities and Collateral Equipment, September 2008.

w. Manual on Uniform Traffic Control Devices.

x. Federal Accounting Standards Advisory Board (FASAB) Handbook of Federal Accounting Standards and Other Pronouncements, as Amended , June 30, 2014, Federal Financial Accounting Standards 6, 8,14,35, 40, 42, and 44.

P.5 Measurement/Verification

a. To determine compliance, Facility Maintenance and Operations Program Engineers assigned to Headquarters Facilities and Real Estate Division (FRED) will perform annual Maintenance and Operation program reviews at the Centers. Reviews entail making random site visits, reviewing Maintenance and Operation Programs and Projects, and evaluating performance and effectiveness in relation to the Annual Performance Metrics and Deferred Maintenance Assessment.

P.6 Cancellation

a. NPR 8831.2E, Facilities Maintenance and Operations Management, dated November 18, 2008.

Chapter 1. NASA's Facilities Maintenance and Operation Program

1.1 Introduction

1.1.1 NASA's facilities maintenance and operation philosophy is to support NASA's mission by aggressively and proactively pursuing and adopting the safest, most cost-effective, and best blend of Reliability Centered Maintenance (RCM) techniques, sustainability, safety procedures, and other best practices to provide safe, sustainable, efficient, and reliable facilities.

1.1.2 NPD 8831.1 states that the policy for managing facilities maintenance in support of the stated NASA policy, while following good business practices and minimizing life-cycle facilities costs, is the following:

a. Provide maintenance and repair of facilities and collateral equipment that:

(1) Protects the health and safety of personnel.

(2) Protects and ensures good stewardship of the environment.

(3) Protects and preserves NASA's capabilities and capital investment.

(4) Reduces energy consumption.

(5) Enables mission performance.

b. Manage and perform facilities maintenance work cost effectively and efficiently by using state-of-the-art maintenance management systems and RCM techniques. Management systems shall, as a minimum, include a standardized and meaningful annual work plan, accurate facility condition assessment techniques, and NASA-owned (NASA- or contractor-maintained) Computerized Maintenance Management System (CMMS) databases.

c. Use accepted standards as a guideline to assist in determining facilities' maintenance funding requirements, such as NASA's Deferred Maintenance analysis, NASA's Facility Sustainment model, NASA Baseline Services Level Study, NASA Maintenance and Operations Cost Study, and the National Research Council's (NRC) recommended 2 to 4 percent of the facility's current replacement value for its facilities and equipment maintenance and repair program.

d. Continuously and proactively improve technical and managerial processes to minimize life-cycle maintenance and repair costs. These include Centers' designating a single point of contact to communicate and coordinate facilities maintenance and management issues with NASA Headquarters for maximum efficiency and effectiveness; benchmarking and the identification of "best practices"; preparing and adhering to annual and 5-year maintenance plans; performing self-assessments and applying reengineering or process-improvement techniques where appropriate; applying NASA RCM principles, as detailed in the NASA Reliability Centered Maintenance Guide for Facilities and Collateral Equipment, in program development and improvement; implementing Predictive Testing and Inspection (PT&I) techniques in maintenance, and Condition-based maintenance, as well as new construction acceptance testing, where appropriate and whenever possible; and maximizing the population of available CMMS databases.

e. Provide for the lowest life-cycle costs, improve the safety, and establish initial baselines for the subsequent PT&I of facilities and equipment through the acceptance process by enforcing the construction contractor's quality control responsibilities during construction and particularly at the time of equipment acceptance. Centers should strive for a 10-year maximum performance based/hybrid contract, which generally will include fixed price, cost plus, and indefinite-delivery/indefinite-quantity (IDIQ) portions to suit the requirement. Coordination with HQ Office of Procurement is required to obtain a FAR deviation for the recommended 10-year performance period.

f. Use performance-based contracts with clearly defined scopes to capitalize on the contractor's experience and ingenuity; contract for results and not just best efforts; maximize value through the use of fixed pricing and unit cost pricing with competition; improve quality through contractor selection based on past performance, measuring against prescribed, objective, and measurable performance standards; and follow a formal Quality Assurance Plan.

g. Implement processes and technologies recommended by the NASA Operations and Maintenance of Facilities Innovations Team (OMFIT) and Engineering and Construction Innovations Committee (ECIC) to improve the operations and maintenance of existing facilities over their entire life cycles and to promote the sustainability concept of maintainability for new construction, renovations, rehabilitations, and repairs.

1.2 Center Participation

1.2.1 Videoconferences. NASA Center maintenance management personnel and support contract maintenance management personnel are strongly encouraged to participate in the monthly facility maintenance video/teleconferences. These conferences provide an opportunity to educate personnel in new tools available, facilitate the adoption of best practices, and disseminate information and lessons learned Agency wide.

1.2.2 Facility Maintenance Conferences and Workshops. All NASA Center civil service and support contractor maintenance management personnel are strongly encouraged to attend facility maintenance conferences and workshops. These conferences and workshops are an opportunity to exchange ideas, make contacts with other Centers' maintenance personnel, and learn new maintenance practices that can be used in Center programs.

1.2.3 Center Points of Contact. Each Center and Component Facility will establish a single point of contact for interfacing with the NASA Headquarters, Facilities and Real Estate Division's Maintenance Team concerning facilities maintenance matters.

1.3 Pillars of the Maintenance Program

1.3.1 Safety. Per NPD 8700.1, it is NASA's policy to protect the public and NASA workforce; high-value equipment and property; and the environment from potential harm as a result of NASA activities and operations by factoring safety as an integral feature of programs, projects, technologies, operations, and facilities. Safety is the Agency's number one core value. Accordingly, in the operations and maintenance of a Center's facilities, the maintenance organization shall make every effort to ensure that this NASA policy for safety is adhered to in all of its activities and that the procedural requirements contained in NPR 8715.3 are incorporated into their daily activities.

1.3.2 Maintenance Funding and Reporting. As the steward of its facilities, NASA is responsible for reporting to higher authorities, Office of Management and Budget (OMB) and the Congress, on ways its facilities maintenance funds are spent. Centers shall use Work Breakdown Structure (WBS) Codes to account for and report to Headquarters their facilities maintenance funding. Additionally, for accuracy and credibility, it is necessary for Centers to capture all costs associated with facilities maintenance work. NASA has adopted the National Research Council's recommendation that 2 to 4 percent of the Current Replacement Value (CRV) should be targeted only for facilities maintenance and minor repair. (See Chapter 2 for information on the NASA Baseline Services Level Study and the NASA Maintenance and Operations Cost Study.) OMB has also established a Facility Condition Index (FCI) Goal of 4.0 for NASA.

1.3.3 Maintenance Management Program. Maintenance management consists of all aspects of defining the requirements, job planning, and job execution and analysis. An effective facilities maintenance management program maximizes the useful life of the facilities and equipment, minimizes unplanned downtime, provides an improved work environment, and produces information to make management decisions, all within a given resource level. The approach is mission focused and customer oriented. The challenge for NASA, both at Headquarters and across the Agency, is for continuous improvement within the available resources, as measured and monitored by meaningful and reliable Headquarters and Center performance metrics and trend analysis, and capitalizing on the very best and latest information available through benchmarking and the adoption of best practices. (See chapter 3.)

1.3.4 Annual Work Plan. The annual work plan (AWP) provides Centers with a vehicle to display long- and short-range facility requirements by articulating their needs based on mission impact and the most probable facility availability outcomes under varying budget scenarios. The plan shall be designed so that it can be integrated smoothly into NASA's strategic management process, afford Center Facilities Maintenance Managers and other senior managers the ability to make risk-based decisions regardless of the budget environment, and also allow Center facility maintenance organizations to pursue and measure their continuous improvement efforts. Centers should also maintain 5-Year Facilities Maintenance Plans for resource planning beyond the Annual Work Plans. (See Chapter 4.)

1.3.5 Maintenance Execution. Maintenance execution consists of work request, work reception and tracking, work order preparation, and work execution. The maintenance execution phase should be developed based on the guidance of this NPR, best practices, and available resources and should be customized to address most satisfactorily the needs of each Center. (See Chapter 5.)

1.3.6 Computerized Maintenance Management System. Facilities maintenance managers at NASA Centers are to use modern maintenance management systems and methods to control work activities, account for resources, and monitor and report work execution through the use of various industry standard metrics and other management indicators. All Computerized Maintenance Management System (CMMS) databases will remain the property of NASA, regardless of whether, NASA or the contractor populates and maintains them, and any applicable maintenance contracts will explicitly include language to that effect. (See Chapter 6.)

1.3.7 Reliability Centered Maintenance. NASA's policy is to apply Reliability Centered Maintenance (RCM) principles in program development and improvement. Implementing this policy emphasizes the use of RCM concepts and its supporting programs to reduce life-cycle costs of facilities and systems of varying criticality and failure impact on NASA missions. RCM is to be used as early as possible in the planning and design stages to set technical tolerances, performance criteria, and PT&I

standards. RCM concepts are to be used by planners, designers, equipment procurement specialists, construction managers, Operations and Maintenance (O&M) civil service and contractor personnel, and anyone else involved in NASA facilities planning, design, construction, equipment procurement, and maintenance and operations. (See Chapter 7.)

1.3.8 Reliability Centered Building and Equipment Acceptance. The NASA Reliability Centered Building and Equipment Acceptance (RCB&EA) Guide focuses on reducing facility life-cycle costs (especially infant mortality costs those occurring in the earliest life-cycle stages) by integrating PT&I techniques into the construction contractor's quality control program for equipment acceptance. In today's tight budget environment for facilities operations and maintenance, it is advantageous to use the construction contractor's quality control function to perform noninvasive diagnostic tests to verify equipment condition and installation prior to the contractor's exit from the job site. The NASA RCB&EA Guide focuses on using PT&I technologies to test and accept new systems during equipment installation, repair, or rework and the contractor's making installation modifications, as necessary, to meet the prescribed standards. The result is an initial database of equipment condition for the subsequent maintenance program, the avoidance of premature wear caused by latent manufacturing defects or faulty installation, better information upon which RCM decisions will be based, longer equipment life, and ultimately minimum overall facility operating costs. (See Chapter 8.)

1.3.9 Deferred Maintenance. NASA's Deferred Maintenance (DM) will be the term used in benchmarking with other agencies. With increased funding cutbacks and the need to manage available funding more efficiently, there is a requirement ensuring that NASA's DM is realistic and that any ensuing funding is spent wisely. (See Chapter 9.)

1.3.10 Facility Condition Assessment. Facility Condition Assessment (FCAs) provide NASA Centers with information to properly develop 5-year and annual work plans and priorities for critical facilities and facilities maintenance, repair, and revitalization. Headquarters needs adequate FCA information to ensure the proper stewardship over facilities entrusted to NASA, as well as to assist Agency Senior Management and higher authorities in projecting facilities budgetary needs in conjunction with NASA's meeting its mission as directed by the President and Congress. Despite their importance, formal FCAs are time-consuming and costly to perform. Maximum use of RCM procedures and PT&I techniques that monitor facility and equipment condition and continuous inspection that incorporates historic information from the CMMS database, ongoing maintenance and repair efforts, and customer and user feedback are necessary to provide Centers with valuable FCA information that in the past had to be developed manually. This continuous inspection coupled with minimal facility condition inspections provides the FCA without the formal process. Each facility shall have an FCA every 5 years, as a minimum. (See Section 10.6.)

1.3.11 Central Utility Plant Operations and Maintenance. Central Utility Plant Operations and Maintenance (O&M) is included here because of its close operational and organizational association with facilities maintenance management. The management of utility system inspection and maintenance is directed toward maintaining safety, minimizing system downtime, minimizing cost, and minimizing waste. To provide safety, reliability, high quality, and economical utility services, utilities management should ensure that equipment and distribution systems are maintained in top working order and that distribution line losses are identified and corrected. Standard Operating Procedures (SOPs) shall be developed to cover routine operations, startup and shutdown, operator maintenance, preventive maintenance, and other emerging actions such as load shedding. (See Chapter 11.)

1.3.12 Performance-based Contracting. NASA is implementing the use of Performance-based Contracting (PBC) to the maximum extent possible. Under the PBC concept, the Government contracts for specific services and outcomes, not resources. Contractor flexibility is increased, Government oversight is decreased, and attention is devoted to managing performance, results, and ultimate outcomes. Contractor/Government partnering is highly recommended to achieve mutually supportive goals. The PBC should encourage the use of contractor best practices and cutting-edge maintenance practices used in the private sector to give NASA the best product. Data Requirements Documents (DRDs) will be generated that include metric reports as described in this NPR. (See Chapter 12.)

1.3.13 Energy Management and Control System Operations. The Energy Management and Control System (EMCS) is a building automation system that provides remote visibility and monitoring of building systems and utilities. As such, the EMCS is a cornerstone to energy efficiency and for the cost-effective operation and maintenance of modern facilities.

1.4 Facilities Maintenance Definitions

1.4.1 To implement the policies in NPD 8831.1 and the requirements in this document, it is necessary to standardize definitions and have a commonality of all facilities maintenance Agency wide among NASA Centers and the Centers' Component Facilities. This permits the application of uniform measures of facilities condition; allows meaningful, quantitative metrics in terms common throughout the Agency and the ability to statistically analyze variances; enables compiling an information data base using terminology and definitions common to and recognized by commercial software products and other industrial and Government applications; and adds credibility to the NASA facilities maintenance budgeting process through standardization. In addition to the definitions listed in Appendix A, Centers shall use the definitions and, specifically, the nine facilities maintenance work elements defined in the sections below, to identify, classify, and analyze facilities maintenance trends, to prepare the Center's Annual Work Plan and 5-year plan, and for all other Agency-wide facilities maintenance applications:

a. Facility. A term used to encompass land, buildings, other structures, and other real property improvements, including utility systems and collateral equipment. The term does not include operating materials, supplies, special tooling, special test equipment, and noncapitalized equipment. The term "facility" is used in connection with land, buildings (facilities having the basic function to enclose usable space), structures (facilities having the basic function of a research or operational activity), and other real property improvements.

b. Equipment. In NASA, equipment is divided into two categories, collateral equipment and noncollateral equipment. These are defined as follows:

(1) Collateral Equipment. Encompasses building-type equipment, built-in equipment, and large, substantially affixed equipment/property and is normally acquired and installed as part of a facility project, typically to support the function of the facility.

(a) Building-Type Equipment. A term used in connection with facility projects to describe equipment that is normally required to make a facility useful and operable. It is built in or affixed to the facility in such a manner that removal would impair the usefulness, safety, or environment of the facility. Such equipment includes elevators; heating, ventilating, and air conditioning systems; transformers; compressors; and other like items generally accepted as being an inherent part of a building or structure and essential to its utility. Such equipment also includes general building systems and subsystems such as electrical, plumbing, pneumatic, fire protection, and control and monitoring systems.

(b) Built-in or Large, Substantially Affixed Equipment. A term used in connection with facility projects of any type other than building-type equipment that is to be built in, affixed to, or installed in real property in such a manner that the installation cost, including special foundations or unique utilities service, or the facility restoration work required after its removal is substantial.

(2) Noncollateral Equipment. Includes all equipment other than collateral equipment. Such equipment, when acquired and used in a facility or a test apparatus, can be severed and removed after erection or installation without substantial loss of value or damage thereto or to the premise(s) where installed. Noncollateral equipment imparts to the facility or test apparatus its particular character at the time (e.g., furniture in an office building, laboratory equipment in a laboratory, test equipment in a test stand, machine tools in a shop or fabrication facility, computers in a computer facility) and is not required to make the facility useful or operable as a structure or building.

c. Facilities Maintenance. The recurring day-to-day work required to preserve facilities (buildings, structures, grounds, utility systems, and collateral equipment) in such a condition that they can be used for their designated purpose over an intended service life. It includes the cost of labor, materials, and parts. Maintenance minimizes or corrects wear and tear and thereby forestalls major repairs. Facilities maintenance includes preventive maintenance (PM), PT&I, grounds care, programmed maintenance, repair, trouble calls (TCs) (facilities repair), replacement of obsolete items (ROI), and service requests (SR) (Not a maintenance item but is work performed by maintenance organizations). Facilities maintenance does not include fire department protection services personnel, security and custodial services, new work, or work on noncollateral equipment. The elements of facilities maintenance are defined in the following nine sections. Centers should be prepared to report their planned and actual facilities maintenance effort, including costs of parts, labor, and materials by these nine elements when requested by NASA Headquarters.

(1) Preventive Maintenance. The planned, scheduled periodic inspection (including safety), adjustment, cleaning, lubrication, parts replacement, and minor repair (no larger than TC scope) of equipment and systems for which a specific operator is not assigned. PM consists of many checkpoint activities on items that, if disabled, would interfere with an essential Center operation, endanger life or property, or involve high cost or long lead time for replacement. PM is the cornerstone of any good maintenance program. A weak or nonexistent PM program could result in safety and/or health risks to employees, much more emergency work, and costly repairs.

(2) Predictive Testing and Inspection. Those planned testing and inspection activities for facility items that generally require more sophisticated means to identify maintenance requirements than in PM. For example, specialized tests are used to locate thinning of pipe walls and fractures (e.g., eddy current testing, radiographic inspections, ultrasonic testing, television cameras, or aural leak detectors); to detect roof weaknesses or wet insulation areas (e.g., infrared thermographic viewers or nuclear density devices); to identify large equipment wear problems (e.g., vibration analyzers and oil analysis for wear metals and lubricant properties); and to locate charge or heat buildup in electrical equipment (e.g., infrared thermography).

(3) Grounds Care. Grounds care is the maintenance of all grassy areas, shrubs, trees, sprinklers, rights-of-way and open fields, drainage ditches, swamps and water holding areas (lakes, ponds, lagoons, canals), fences, walls, grates, and other similar improvements (capitalized assets) to land that are included in the NASA Real Property Management System, and exterior pest and weed control. The maintenance tasks include mowing, spreading fertilizer, trimming hedges and shrubs,

clearing ditches, snow removal, and related work. Included in this category is the cost of maintaining grounds care equipment such as mowers and tractors.

(4) Programmed Maintenance (PGM). Planned programmed maintenance consists of those maintenance tasks whose cycle exceeds one year, such as painting a building every fifth year. (This category is different from PM in that if a planned cycle is missed the original planned work still remains to be accomplished, whereas in PM, only the next planned cycle is accomplished instead of doing the work twice such as two lubrications, two adjustments, or two inspections.) Examples of PGM include painting, roof maintenance (flood coat, flashing, patching, incidental repair by replacement), road and parking lot maintenance (overlays, seal coating, and patching), utility system maintenance (pigging of constricted lines), and similar functions.

(5) Repair. The facility work required to restore a facility or component thereof, including collateral equipment, to a condition substantially equivalent to its originally intended and designed capacity, efficiency, or capability. It includes the substantially equivalent replacements of utility systems and collateral equipment necessitated by incipient or actual breakdown.

(6) Trouble Calls. TCs (a subset of repair) are unplanned and generally called in by telephone or submitted electronically by occupants of a facility (or facility managers or maintenance workers). Where the calls are for nonfacility work (not of a facility maintenance or repair nature) the call shall be coded so that it is not included with TCs included in funding level calculations. Examples of nonfacility work are interior pest control and janitorial work, such as cleaning up a spill or cleaning carpets. TCs are composed of two types of work as follows:

(a) Routine Calls. Routine calls are unplanned minor facility problems that are too small to be estimated (usually less than about 20 work hours or $2,000). They generally are responded to by grouping according to craft and location.

(b) Emergency Calls. Emergency calls require immediate action to eliminate hazards to personnel or equipment, to prevent loss of or damage to Center property, or to restore essential services that have been disrupted. Emergency work is usually a response-type work effort, often initially worked by TC technicians. Due to its nature, emergency work is not restricted to a level of effort such as routine Calls (although in many cases it falls within the work hour and/or dollar limit of routine calls).

(7) Replacement of Obsolete Items. There are many collateral components of a facility that should be programmed for replacement because they are becoming obsolete (no longer parts-supportable at the end of service life), do not meet electrical or building codes, or are unsafe but are still operational and would not be construed as broken and needing repair. Examples include, but are not limited to, electric switchgear, breakers, and motor starters; elevators; control systems; boiler and central heating, ventilating, and air conditioning (HVAC) systems and controls; fire detection systems; cranes and hoists; and air conditioning systems using chlorofluorocarbon (CFC) refrigerants.

(8) Service/IDIQ Requests. Service requests are not maintenance items, but are so often performed by facilities maintenance organizations that they become a part of the baseline. Service requests are requests for facilities-related work that is new in nature and, as such, should be funded by the requesting organization. Service requests are initiated by anybody at the Center; often require approval by someone before any action is taken; usually are planned and estimated, materials procured, and shop personnel discretely scheduled to accomplish the work. Examples of these requests include installation of an outlet to support a new copier machine, providing a compressed

air outlet to a new test bench, renovating an office, and installing special cabinetry. (9) Operations. Operations include those recurring activities required to maintain a facility so that it can reliably perform its intended function, but which are not considered PM, repairs, or PT&I. These activities would include, but not be limited to, items such as periodic site visits and inspections, equipment logging, central utility or plant staffing, and freeze and storm plan maintenance activities.

(a) General. There are many operational items that are required to maintain the reliability and function of facilities, but which are not part of some central utility or control/monitoring operation. These operations can include items such as logging of small chillers and boilers, monitoring generators and replenishing fuel levels, maintaining refrigerant inventory and records, and freeze and storm plan maintenance activities. These operations are most often performed by the same shops and personnel that perform PM and repair maintenance, but these activities differ from these other categories of maintenance in that they do not intend to perform any identifiable preventive or repair work. Their intended function is only to detect the need of PM or repair activities before a failure or extensive damage occurs. Operations are a necessary element (along with RCM, PT&I, and PM) in establishing a proactive maintenance program.

(b) Central Utility Plant Operations and Maintenance. This category is unique in that it includes the cost of operations in addition to maintenance costs. It should be used only to capture the costs of operating and maintaining institutional central utility plants, such as a central heating or steam plant, wastewater treatment plant, or central air conditioning (A/C) (chiller) plant. The concept is that operators are assigned full time to operate the plant, but they perform maintenance between various operating tasks, making it almost impossible to segregate operational and maintenance costs. Therefore, the costs of the full-time operators (and their materials) are shown in this category. This facilities maintenance element does not include any work outside of the 5-foot line of the utility plant or project-type work.

(c) EMCS Work Station or Central Console staffing. This operation plays a key role in most maintenance organizations in that this staff not only operates and monitors site-wide conditions visible on the EMCS, but also often receives trouble calls and notifications. As such, these operators are the focal point in the real-time management of the site maintenance by initiation of work orders or by mitigating or dictating immediate maintenance activities according to the priority and criticality of alarms and calls. Often this operation serves as the only manned maintenance function after normal working hours or on weekends and holidays. No modern facility could operate efficiently and reliably without some level of EMCS operation.

1.4.2 Deferred Maintenance. DM is the unfunded facilities maintenance work required to bring facilities and collateral equipment to a condition that meets acceptable facilities maintenance standards. The key word is "unfunded." If resources are or will be available to do the work during the current year, the work is considered to be scheduled and is not part of the DM.

Chapter 2. Resources Management

2.1 Introduction

2.1.1 This chapter discusses resources management as it relates to facilities maintenance. It covers NASA directives, policy, resources management requirements, maintenance funding levels, the Annual Budget Call by the NASA Headquarters CFO, currently called Planning, Programming, Budgeting, and Execution (PPBE), and reimbursable funds.

2.2 Publications

2.2.1 Table 2-1 lists NASA Headquarters publications that apply to facilities maintenance resources management.

Table 2-1 NASA Headquarters Instructions, Procedures Guides, and Manuals

Publication	Title
NPD 7330.1	Approval Authorities for Facility Projects.
NPD 8800.14	Policy for Real Estate Management.
NPR 8800.15	Real Estate Management Program.
NPD 8810.2	Master Planning for Real Property.
NPR 8810.1	Center Master Planning.
NPD 8820.2	Design and Construction of Facilities.
NPR 8820.2	Facility Project Requirements (FPR).
NPD 8831.1	Management and Operations of Institutional and Program Facilities and Related Equipment

2.3 Maintenance Funding Levels

2.3.1 In NPD 8831.1, NASA Headquarters recognizes the annual funding level of 2 to 4 percent of CRV recommended by the Federal Facilities Council, NRC (Appendix C.4, resource 1), as a reasonable funding target necessary to maintain facilities in a steady-state condition. This level is recognized as an adequate standard until an independent analysis of facilities condition assessment trends indicates otherwise. The minimum Baseline Services Level (BSL) annual funding requires 1.6 % of Active Facilities CRV (June 21, 2010). An O&M Cost Study was done in 2014 to determine, by modeling actual facilities, what NASA should be spending to sustain and operate facilities, based on "recommended" requirements. (See Chapter 9.)

2.3.2 Funding Level Scope. Only Center-funded work of facilities maintenance and repairs should be included in the 2 to 4 percent of CRV annual funding level. Figure 2-1 identifies the facilities maintenance expenditures that are to be allocated to the 2 to 4 percent of CRV goal. The percentage goal does not include DM, service requests (because they are for new work), grounds care, central utility plant O&M, and nonfacilities maintenance work as described in section 2.3.4.

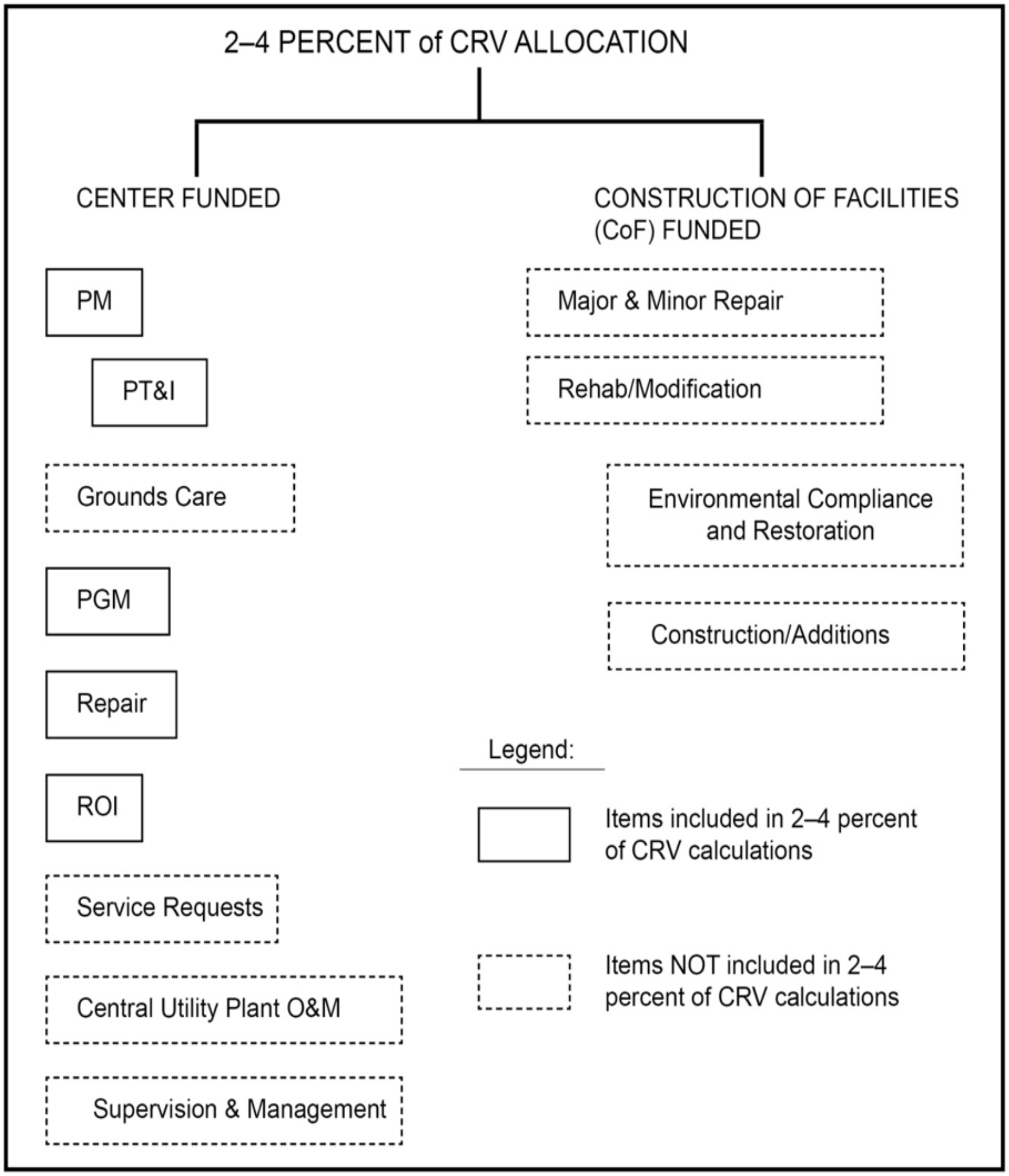


Figure 2-1 Expenditures Allocable to 2 to 4 percent of CRV Standard

2.3.3 Funding Thresholds. NPR 8820.2 specifies facility project funding sources and thresholds. Table 2-2 summarizes the facilities maintenance work-type funding thresholds.

Table 2-2 Facilities Maintenance Funding Thresholds

Facilities Maintenance Work Elements	Center Funding Limitations
Preventive Maintenance	None
Predictive Testing & Inspection	None
Grounds Care	None
Programmed Maintenance	None
Central Utility Plant O&M	None
Repair 1,2,3	None
Trouble Calls	
- Routine 1	Not to exceed $1 million
- Emergency 1,2,3	None
Replacement of Obsolete Items1,2,3	None

Service Requests (A New Work Requirement)1	Not to exceed $1 million

Note: 1.Limitation is per project or per incident. For facilities work estimated to cost $100,000 or more, NASA Form 1509, Facility Project - Brief Project Document, documentation is required. 2.Projects over $1 million require review and approval by HQ through the 1509 process to ensure projects are funded from the correct appropriation. 3.Typically, Emergency Repair, Repair, and ROI projects are systems or components of a major system, per Definitions in Appendix A. A typical ROI example is the replacement of a chiller or air handler for an existing HVAC system."

2.3.4 Nonfacilities Maintenance Work. The following types of nonfacilities maintenance work, although related to facilities maintenance and sometimes performed by facilities maintenance organizations, are not counted toward the NRC-recommended 2 to 4 percent of CRV calculations:

a. Custodial and interior pest control.

b. Refuse collection, recycling, and disposal.

c. Operations such as fire protection and security.

d. Mobile equipment operation and maintenance.

e. Environmental operations, remediation, recycling, and disposal.

f. Research and development (R&D) shop support, such as model fabrication.

g. Management and supervision overhead.

h. Maintenance of noncollateral equipment (NASA Equipment Management Systems (NEMS) tagged equipment).

i. Facilities alterations.

j. Facilities construction.

2.4 Facilities Maintenance Budget

2.4.1 NASA uses the PPBE process as the method for aligning the Agency's resources to support its mission and Vision. The Annual Budget Call is an internal name used to describe part of the budgeting phase. The Annual Budget Call is issued by NASA's Office of the Chief Financial Officer (OCFO) and requests time-phased work programs expressed in terms of dollars and other resources required to accomplish NASA objectives for the budget year. This serves as the basis for developing the NASA operating budget to support appropriation of funds by Congress, for apportionment requests to Office of Management and Budget (OMB), to distribute resource authority within NASA, and to plan for the efficient and effective use of resources in attaining mission goals.

2.4.2 Annual Budget Call by NASA's OCFO. Each year, NASA's OCFO issues guidance to the Centers for submitting their budget requests. The OCFO coordinates this through the Mission Directorates and the Mission Support Offices.

2.4.3 Annual Budget Call Fiscal Years. Each Annual Budget Call covers a 7-year period consisting of past year, current year, and budget year, defined as follows, plus 4 future years:

a. Prior Year. The fiscal year immediately preceding the current year. Prior year costs are actual, not estimated.

b. Current Year. The fiscal year immediately preceding the budget year.

c. Budget Year. The fiscal year for which estimates are being submitted.

2.4.4 Requirements Development and Costing

2.4.4.1 All Centers should establish and maintain facilities maintenance classification codes with all work classified to be used with their CMMS. One of the uses of the classification is for budgeting. The Annual Budget Call requests budget estimates. Thus, it is possible to prepare the budget by aggregating the actual expenditures of prior-year historical data and the current-year-to-date accounting data. The current-year-to-date figures can then be extrapolated to the full current year using the current-year Annual Work Plan (AWP). The budget year requirements can then be projected by comparing the prior and current-year work requirements with the budget year from the 5-Year Facilities

Maintenance Plan and adjusting the estimates using the standard inflation factors supplied by NASA Headquarters. Through this process, information is available for preparing the budget documentation for submittal.

2.4.4.2 In accordance with the requirements of section 2.3, Maintenance Funding Levels, Centers should, as a goal, work toward a budget for facilities maintenance and repair of 2 to 4 percent of CRV funding. Figure 2-1 identifies the facilities maintenance expenditures that are to be allocated to the 2 to 4 percent of CRV goal. Per section 2.3.2, Funding Level Scope, the 2 to 4 percent does not include DM, service requests, grounds care, central utility plant O&M, and nonfacilities maintenance work as described in section 2.3.4, Nonfacilities Maintenance Work.

2.4.4.3 Because estimated funding requirements are prepared 14 to 19 months in advance of the budget year, many things can occur to change the budget estimates before Annual Budget Calls are executed. The following are some examples:

a. Congressional decisions reflected in the final authorization and appropriations acts.

b. Changes in the Center resource requirements (possibly due to emergency conditions).

c. Change in restraints imposed by NASA Headquarters.

2.4.5 Annual Budget Call Submittal. The Centers submit their responses to the Annual Budget Call requests through the Mission Directorates and the Mission Support Offices.

2.5 Reimbursable Services

2.5.1 Many Centers' facilities maintenance organizations perform work on facilities occupied by agencies other than NASA for which the cost is reimbursed by the occupying agencies. They also perform nonfacilities maintenance work that should be reimbursed by the requesting customers. For specific information on policies and procedures for obtaining reimbursement related to NASA facilities occupied by another agency, refer to NPR 9090.1. This reimbursable work is not included in the annual facilities maintenance budget that the Centers submit to NASA Headquarters. However, reimbursable work should be included in the Center AWPs. The annual budgets and the AWPs address the total facilities maintenance workload, regardless of fund source.

2.5.2 Types of Reimbursable Services

2.5.2.1 Customer-Requested Work. Centers should perform the following types of work with funds provided by the customer requesting the work to avoid impacting the limited funds available for facilities maintenance:

a. Construction, addition, and modification work below the $1 million CoF threshold.

b. Service Request work.

c. Nonfacilities maintenance work (see section 2.3.4, Nonfacilities Maintenance Work).

2.5.2.2 Tenant and Other Occupying Agencies Services. The Centers provide three basic types of services to tenants and other occupying agencies on a reimbursable basis. These services are described in the following sections:

a. Occupancy Services. Occupancy services are essential, Center-wide support services. Services such as facilities maintenance, utilities costs, and janitorial services are a function of the square footage of the buildings occupied. Other services may be related to the number of personnel resident at the Center. Typically, the rate for occupancy services should be constant during each fiscal year to allow Center customers to budget for the services. The interagency agreements should state when the rates are scheduled to change.

b. Demand Services. Demand services provide technical support or specific deliverable products not available within the capabilities of the customer. Typically, demand services are specifically requested by the user and are user unique. Each demand service is separately priced; if possible, the unit price should be constant during each fiscal year to allow Center customers to estimate their fund requirements and to budget for the funds. Demand services are often requested in writing and are classified by specific functional area. The following are examples of demand services:

(1) Service requests.

(2) Engineering design services.

(3) Construction projects.

(4) Heavy equipment services.

c. Other Services. Other services are those paid directly by the customer at the time of use, such as food services, or billed periodically based on use, such as metered utilities. Few, if any, facilities maintenance services are billed at the time of use.

2.5.3 Cost Allocation. The determination of reimbursable costs should be based on the concept of full cost sharing. This concept provides for common cost sharing of services. Therefore, the costs charged to each tenant should directly reflect the tenant's portion of the total cost to NASA for the services. Cost allocations should be reviewed and recalculated annually.

2.5.3.1 Occupancy Services. The per-unit rates charged for occupancy services should be the same for all occupants, both tenants and NASA activities, for like services. The annual charges should be computed from prior-year costs with inflationary and expected use-change adjustments. Occupancy services are usually provided by the facilities maintenance organization or by facilities support services contractors.

2.5.3.2 Occupancy services are separated into those applicable to the employee population and those applicable to the floor space occupied. These costs generally are calculated as follows:

a. Population. A projected fiscal year total of all civil service and contractor employees is developed for each occupying organization. The total portion of the shared cost associated with personnel is divided by the total of all Center personnel. The result is the fiscal year per-person rate that is applied to each occupant.

b. Floor Space. The square footage should be summed for each occupant by the type of space occupied as per the following example:

(1) Type I— Air-conditioned offices, laboratories, storage, and technical spaces.

(2) Type II— Non-air-conditioned shops, work areas, or technical spaces (also to be used for any non-air-conditioned space other than warehouses or storage facilities).

(3) Type III— Non-air-conditioned warehouses and storage facilities.

2.5.3.3 The total shared cost associated with floor space is divided by the weighted sum of all three types of floor space to determine the Type III base rate. The Type I and II base rates are determined by multiplying the base rate by the weighting factor for each type. The square footage totals are multiplied by the respective rates to determine the cost for each occupant. The weighting factors are determined historically from the actual cost of cleaning and maintaining each type of space.

2.5.3.4 Personnel and floor space costs are then added together to determine the total occupancy cost.

2.5.3.5 Demand Services. The cost to tenants for demand services is generally developed by adding a surcharge to the incremental Center costs incurred by the demand service work order. Since the surcharges are an integral part of Center operational costs and are routinely expensed by the Centers, they are not identified separately and are not shown on reimbursable work orders. The standard surcharges developed by each Center should consider the full cost-sharing concept. However, some costs are borne by NASA, such as acquisition and depreciation of shop equipment, which do not enter the standard surcharge and, therefore, are not reimbursed by tenants because they are within the NASA institutional budget base. Typically, monthly billings for demand services either are sent to the tenants or are charged to standing accounts.

2.5.4 Interagency Agreements. While Memorandums of Agreement (MOAs) and Memorandums of Understanding (MOUs) are helpful in defining Center and tenant services and responsibilities, they are vital in the case of reimbursable services. MOAs and MOUs avoid misunderstandings about how rates are determined and how bills are rendered, certified, and paid by the tenant. They are critical for long-range planning and budgeting because they enable the Centers to forecast their levels of reimbursement. In the case of facilities maintenance, the accuracy of the AWP depends on the accuracy of the level and type of reimbursable work defined in MOAs and MOUs.

2.5.5 Out-lease of NASA Property. All leases of NASA property to a tenant (Federal or non-Federal) should include agreements on maintenance of the leased space. These agreements should follow the direction in section 2.5 regarding the types of services provided and the structure for charges for those services. This includes Space Act Agreement, standard leases, Enhanced-Use Leases (EUL), and other lessor agreements. Information on the agreements, procedures, and requirements for out-lease of NASA property can be found in NPR 8800.15.

Chapter 3. Facilities Maintenance Management

3.1 Introduction

3.1.1 This chapter describes the concepts for and approach to facilities maintenance management within NASA. It describes generic facilities maintenance management system based on proven techniques. It also provides the flexibility needed at each Center for NASA's diverse, high-technology mission. The purposes of this chapter are as follows:

a. To present the methodology and value of sound facilities maintenance planning.

b. To present factors for consideration while developing a facilities maintenance organizational structure.

c. To describe the functional relationships in a facilities maintenance management system.

d. To explain methods of analyzing maintenance functions and their relationship to planning and work performance.

3.1.2 A facilities maintenance management system provides for integrated processes that give managers control over the maintenance of all facilities and collateral equipment from acquisition to disposal. The management system should provide at least the following:

a. Address all resources involved.

b. Accommodate all methods of work accomplishment.

c. Effectively interface and communicate with related and supporting systems ranging from work generation through work performance and evaluation.

d. Support each customer's mission.

e. Ensure communication with each customer.

f. Provide feedback information for analysis.

g. Reduce costs through effective maintenance planning.

h. Provide a system for accumulation of historical facilities maintenance data.

i. Incorporate RCM and Leadership in Energy and Environmental Design (LEED) Building Design & Construction (BD&C) and O&M principles into CMMS data fields and work order processes to account for equipment criticalities.

3.1.2.1 The goal is to optimize scarce resources (workforce, equipment, material, and funds) to maintain the facilities and collateral equipment needed to support the Center's mission in a safe and efficient manner. An effective facilities maintenance management system maximizes the useful life of facilities and equipment, ensures safety of facilities and systems, minimizes unplanned downtime, and provides an improved work environment within a given resource level. It also produces information for management decisions.

3.1.3 Functional Approach

3.1.3.1 This procedure adopts a functional approach to facilities maintenance. The thrust is to identify those functions and processes required to provide an effective facilities maintenance program without specifying an organizational structure.

3.1.3.2 The following sections cover maintenance management controls, maintenance management concepts, maintenance-related functions and processes, and other factors for consideration in establishing a facilities maintenance organization. The process for establishing the maintenance organization should accommodate Center-unique requirements and conditions.

3.1.4 Mission/Customer versus Condition Approach

3.1.4.1 Facilities maintenance normally is regarded as the total responsibility of the facilities maintenance manager, who determines with what and when to accomplish maintenance based on the physical condition of the facilities and appropriate maintenance practices. With limited resources, however, the facilities maintenance manager should work with the customer to provide quality facilities maintenance services as required to support the customer's mission. The facilities maintenance manager should coordinate with the customer in developing attainable solutions to facilities maintenance-related mission-support problems.

3.1.4.2 Facilities maintenance decisions, such as whether to accomplish work now or defer it, require a knowledge and understanding of the present and future need for the facility under consideration, as well as the economic and safety impact associated with those facilities. Thus, the facilities maintenance manager should maintain perspective in evaluating necessary maintenance requirements and in considering mission criticality and the need for preserving deteriorating facilities. Both mission and customer inputs are integral components of the facilities maintenance system.

3.2 Facilities Maintenance Functions

3.2.1 Facilities maintenance may be described as a number of interrelated functions and processes that directly or indirectly lead to the accomplishment of facilities maintenance work. Those functions that are not accomplished by the facilities maintenance organization are outside the responsibility of the primary users of these requirements. This also may be the case when the scope of the work exceeds applicable facilities maintenance funding or resource thresholds (e.g., CoF projects). However, functions are listed to ensure that all related services are considered when establishing a facilities maintenance organization and management system.

3.2.2 The relationships among the major functions related to managing facilities maintenance are depicted in Figure 3-1, Whole Maintenance Universe, along with the required information flow and internal communication. The five functional responsibilities at the core of the whole maintenance universe that reside in the Center's maintenance organization are:

a. Manage Facilities and Equipment. This includes overall management responsibilities for operations and maintenance functions regarding infrastructure systems, equipment, and components.

b. Maintain Building Environment. This is defined as the nine broadly defined systems associated with typical building occupancy (i.e., Structure, Roof, Exterior Finish, Interior Finish, Plumbing, Heating Ventilation and Air Conditioning (HVAC), Electrical, Conveyance (Elevators, Cranes, etc.), and Program Support Equipment). These are detailed in the annual NASA Deferred Maintenance Assessment Report generated for each NASA Center.

c. Provide Utilities Services. This includes, but is not necessarily limited to, electricity, water (potable, and non-potable), natural gas, steam, storm, and sanitary sewers.

d. Employ and Manage Contracts. This includes all contracts NASA implements for the purpose of accomplishing typical building operations and maintenance functions.

e. Manage Materials and Tools. This includes management responsibility for materials and tools necessary for conducting the building operations and maintenance functions. Particularly significant in this management area are potential environmental issues related to the use of solvents, lubricants, and various other chemicals and reactions relative to operational, maintenance, and occupancy of a building.

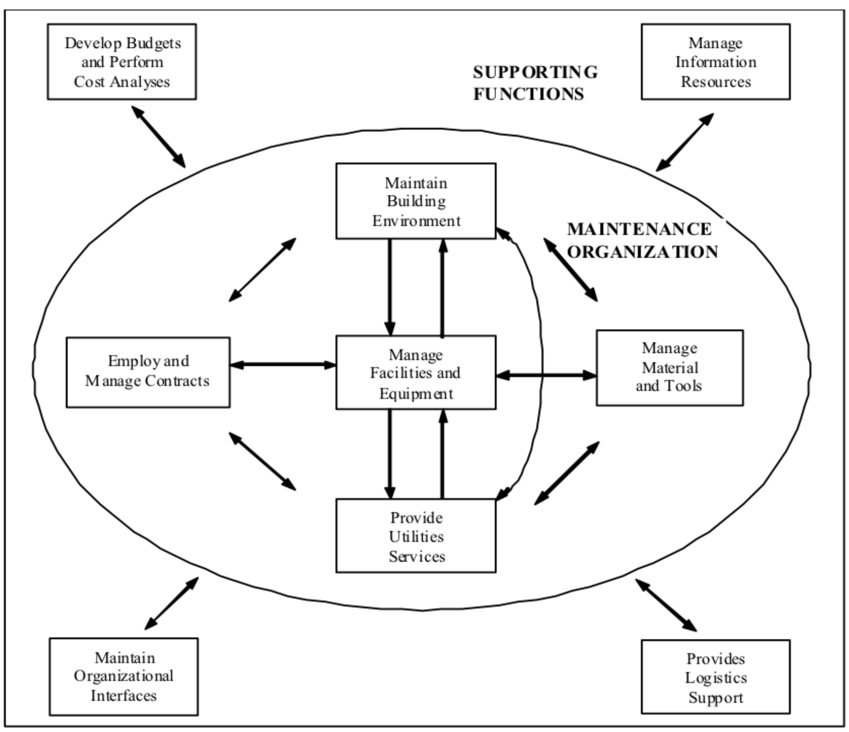


Figure 3-1 Whole Maintenance Universe

3.2.3 The support functions in Figure 3-1, shown outside the maintenance organization, are as follows:

3.2.3.1 Develop Budgets and Perform Cost Analyses. Although the maintenance organization performs cost analyses and develops an annual budget request, it is only an input to the Center and Agency's budget development. See section 2.4, Facilities Maintenance Budget, for the maintenance organization's budget development.

3.2.3.2 Manage Information Resources. There are a number of information resources in other organizations supporting the maintenance organization. Personnel, cost accounting, and similar staffs are required to manage a Center's maintenance operation. A major function in the maintenance organization is the management of its information systems, such as its CMMS (see Chapter 6, Facilities Maintenance Management Automation). Management of information technology (IT) systems may be performed by an IT contractor.

3.2.3.3 Provide Logistical Support. A maintenance organization requires logistical support for functions such as mobile equipment (particularly large specialized items), transportation, and vehicle fuel. It also should be provided storage for recyclable or reusable equipment and material. The maintenance organization may maintain a small warehouse for supplies and parts commonly used in its operations. Additional parts and supply support is required from the Center's logistics organization.

3.2.3.4 Maintain Organizational Interfaces. A major part of a maintenance organization's operation is its interface with other organizations. Working relationships and procedures shall be established to ensure that facilities maintenance functions are performed in an efficient and economical manner to meet Center requirements. These requirements include safety and health, legal, training, security, environmental, fire protection services, and specific requirements received in the form of TCs, service requests, and similar requests.

3.3 Management of Facilities Maintenance Program

3.3.1 Maintenance at NASA Centers is more than just repairing a leaking pipe or restoring power. It involves the coordinated effort of many talented people to ensure that facilities are in the best possible condition to support the Center's mission. To accomplish this, the maintenance program should be managed to provide the maximum benefits from the available resources without waste.

3.3.2 A CMMS is an integral component of a Center's facilities maintenance management operations. This automated system is designed to assist facilities maintenance managers in work reception, work planning, work control, work performance, work evaluation, and work reporting. This system, discussed in Chapter 6, Facilities Maintenance Management Automation, is usually linked to other database systems, such as integrated asset program management (IAPM), material management, and personnel management.

3.3.3 Figure 3-2 depicts the basic facilities maintenance management program. The program has four major aspects: requirements definition, planning, execution, and analysis. Requirements definition includes analyzing facilities condition assessments and the Center's mission to identify, quantify, and document Center operation and maintenance requirements. The Planning and Execution sections of the figure are discussed in Chapter 4, Annual Work Plan, and Chapter 5, Facilities Maintenance Program Execution. Analysis is discussed in detail in sections 3.11, Management Indicators, and 3.12, Management Analysis. The following sections briefly describe Figure 3-2 in a clockwise flow (starting at "Requirements Definition").

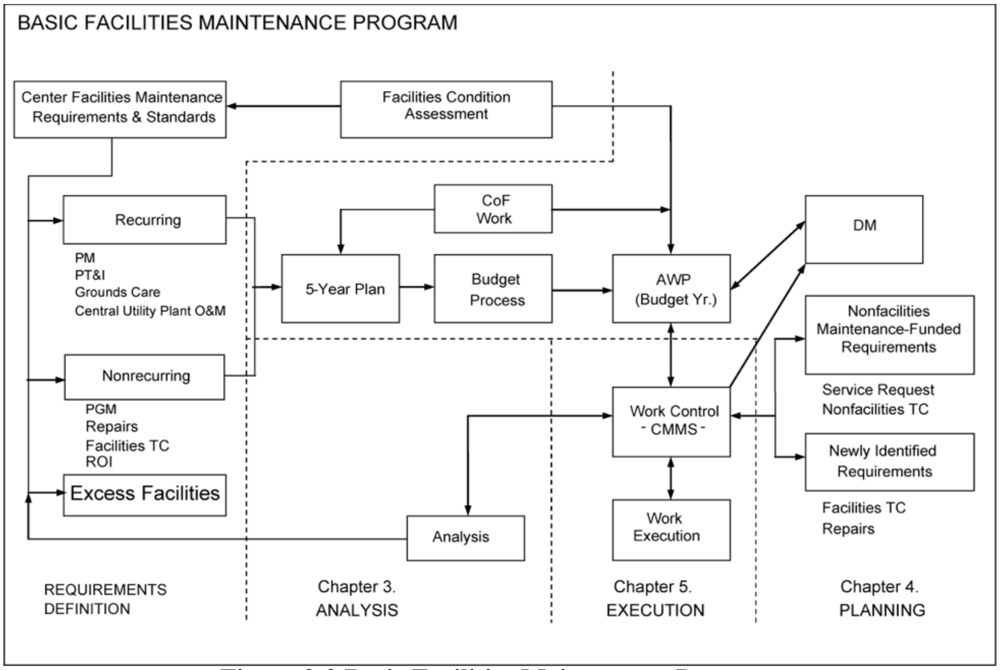


Figure 3-2 Basic Facilities Maintenance Program

3.3.3.1 Requirements Definition

a. Facilities Inventory. The facilities inventory is the cornerstone of facilities maintenance management. It is included in the Center Facilities Maintenance Requirements & Standards block in Figure 3-2. It provides the detailed identification of what is inspected, operated, and maintained. Without an accurate inventory, maintainable items may not receive required maintenance, and maintenance budgeting, planning, and scheduling cannot be effective. The inventory is not static; it includes continuous updates based on facility and equipment changes.

b. Recurring Maintenance. After identification of what is inspected, operated, and maintained, a Center's Reliability Centered Maintenance Program starts with identifying recurring maintenance requirements utilizing the decision logic tree shown in Figure 7-1. The requirements will be derived from analyzing the Center's mission to reflect consideration of the Mission Dependency Index and from facilities inventory and utilizing a well-established set of local standards. The standards used in assessing facilities and determining what recurring maintenance and operations effort is needed to maintain the Center at NASA's specified quality level shall include statutory, regulatory, and compliance requirements. Requirements are continually updated to include new facilities and changes based on the RCM analysis of work data provided during the acceptance process, which sets the baseline (see Chapter 8, Reliability Centered Building and Equipment Acceptance).

c. Nonrecurring Maintenance. Nonrecurring requirements are determined by facilities condition assessments and analyzing historical data, current inventory, and mission requirements. A component of nonrecurring work is facility repairs (breakdown maintenance), including facility TCs.

3.3.3.2 Planning

a. Priorities set by management based on mission requirements are important considerations in determining what is to be accomplished and in what order. The 5-Year Maintenance Plan (see section 4.6, 5-Year Facilities Maintenance Plan) is an invaluable reference for the budgeting process, providing the information needed to plan allocation of resources.

b. Upon receipt of the annual budget, the 5-Year Maintenance Plan (including the maintenance organization's CoF work) is reviewed again, together with updated facility needs. Because resources are constrained and only a portion of the needed work can be accomplished, alternative funding is obtained where possible. The remaining required maintenance work that cannot be funded in the current fiscal year is added to the DM.

c. A result of the budget process and the review is the well-documented AWP that is discussed in Chapter 4, Annual Work Plan. The AWP is used to guide the majority of the day-to-day maintenance work. The AWP also serves as a baseline reference for the facilities maintenance manager when accommodating nonfacilities and newly identified facilities maintenance requirements.

d. Throughout the planning process with the requirements, priority setting, 5-year plan, and the AWP, an essential element is requirements definition. In order for the planning to be effective and in concert with the goals of the Center, there should be continual, two-way communication between the facilities maintenance manager and the Center staff. Proper direction will ensure that maintenance work is prioritized, planned, and performed in accordance with the Center's mission goals.

3.3.3.3 Execution

a. During execution (see Chapter 5, Facilities Maintenance Program Execution), the use of the AWP as a basis for work control helps to schedule work in a steady, efficient flow pattern. The nonfacilities maintenance requirements and newly identified requirements are handled by adjusting priorities and rearranging the work-flow patterns as required.

b. In addition to performing maintenance and repair work, it is very important to document the work accomplished in the Center's CMMS and on facility drawings as necessary. This documentation, as well as historical data entered in the CMMS, is essential when analyzing the work performed and in work planning.

3.3.3.4 Analysis. The analysis section of the maintenance management program is often neglected. Proper analysis is an important management function to point out inefficiencies and ways to better execute maintenance requirements by using alternative procedures and avoiding waste. Also, analysis may identify local standards that are overly stringent for mission needs or a priority system that requires "everything to be done yesterday," thereby interrupting scheduled work unnecessarily.

3.4 System Concepts

3.4.1 In creating an organization and system to perform facilities maintenance, the concepts discussed in the following sections should be applied in implementing the basic maintenance program depicted in Figure 3-2.

3.4.2 Separation of Functions. The responsibility for generating, planning and estimating, and authorizing work should be separate from the responsibility for performing work. Similarly, it is preferable for the quality assurance (QA) functions to be the responsibility of an autonomous organization, apart from those ordering and performing the work. This provides the system with checks and balances and freedom from the appearance of conflict of interest.

3.4.3 Planning and Estimating. Work should be planned and estimated in enough detail to define the resources and tasks required to perform the work and to communicate this information to everyone involved. This information should be clear to customers, approving authorities, schedulers, material managers, and craft personnel.

3.4.4 Estimating Standards. Estimating standards should be the basis for work planning and estimating to permit realistic resource allocation, scheduling, work performance, and evaluation. Several commercial, industrial, and governmental standards are available to assist in work order estimating. Chapter 10, Facilities Maintenance Standards and Actions, provides information on estimating standards.

3.4.5 Workforce Load Planning. Work planning should provide a sufficient volume of work, well in advance of the required completion date, to permit balancing the facilities maintenance workload among the shops, acquiring material, arranging timely contract support, achieving priorities, and coordinating all the elements. Work should be planned on at least a quarterly basis.

3.4.6 Continuous Inspection. A program for inspection of facilities and collateral equipment should, on a timely basis, identify facilities condition, maintenance deficiencies, work required, and changing conditions. PT&I and Facilities Condition Assessment methods should be part of the continuous inspection program. Chapter 10, Facilities Maintenance Standards and Actions, provides detailed information on continuous inspection and condition assessment.

3.4.7 Five-Year Facilities Maintenance Plan. Centers should develop long-range facilities maintenance plans covering both level of effort and specific or one-time work requirements. These plans should reflect the total maintenance requirements and their prioritization in support of Center mission needs. Such management planning requires developing and justifying resource requirements on a multiyear basis. Centers shall prepare both the 5-Year Facilities Maintenance Plans and the AWPs. Chapter 4, Annual Work Plan, provides information on both of these plans.

3.4.8 Work Grouping

a. Personnel performing TCs, small service requests, and small repair jobs should be organizationally separated from personnel performing large facilities maintenance projects when possible. A suggested upper limit on the scope of these small jobs is 20 hours of effort. Assigning these small jobs to a single shop avoids interrupting the workforce devoted to PM, PT&I, PGM, and larger repair jobs. The organization of the shops or groupings within a given shop should be based on factors such as work volume, geographic proximity, availability of transportation, materials, and craft mix.

b. Work grouping also allows crafts personnel to productively complete small jobs by "batching" (i.e., providing crafts personnel with multiple TCs at once, grouping work in a particular building or area, or providing transportation with commonly used tools and materials). This reduces indirect time associated with processing small jobs (such as travel time or obtaining tools, equipment, and materials).

3.4.9 Work Scheduling. Work should be scheduled in an orderly manner considering safety, customer requirements, time constraints, material and tool/equipment availability, priority, workforce availability, and work-site availability along with necessary equipment or utility outages.

3.4.10 Work Status. The CMMS should include reporting systems that provide facilities maintenance managers the status of all work and any significant problems so they can take timely corrective action. Chapter 6, Facilities Maintenance Management Automation, discusses the use of CMMS.

3.4.11 Quality Assurance. Both Government- and contractor-performed work should be subject to inspections for quality. Quality control is the contractor's (or civil service, if applicable) program in place to ensure that the product or service meets the quality requirements of the specification or work order. QA is the Government's program that validates the product or service quality and, by extension, ensures that an effective quality control program is in place and is performing as previously approved by the Government. In performance-based contracts, written QA plans shall be prepared to guide these inspections and should be an integral part of all maintenance work. See Chapter 12, Contract Support, for detailed information on Quality Assurance Plans.

3.4.12 Condition Assessment/DM. The continuous assessment of the condition of facilities and collateral equipment coupled with the current DM defines the major portion of that total maintenance required to bring facilities up to NASA safety and condition standards. When evaluated with respect to a Center's safety and its mission requirements, the DM is a key element in management planning, budgeting, and allocating facilities maintenance resources. This process is discussed in Chapters 9, Deferred Maintenance, and 10, Facilities Maintenance Standards and Actions.

3.5 Factors Affecting Facilities Maintenance Organizations

3.5.1 Physical Characteristics. The physical characteristics of a Center such as size, geographical distribution, climate, equipment, architectural style, and construction materials have a significant impact on the facilities maintenance organization. They directly affect the need for central shop spaces, remote job sites, travel time, special facilities maintenance equipment, facilities maintenance standards, and emergency response plans and equipment.

3.5.2 Mission. The mission of a Center influences the facilities maintenance organization because it determines the facilities maintenance standards, the equipment mix, the workforce skills mix, work priorities, acceptable planned and unplanned down time, and resource levels. The maintenance organization should be structured to respond to the Center's mission.

3.5.3 Workforce Composition. Workforce composition is driven in large part by the Center's mission and physical characteristics. It affects the organizational structure and the division between contract and Government workforces. For example, a workforce with a large number of electricians and A/C mechanics may dictate an organization with a separate shop for each craft. With a small workforce, these crafts may be in one shop.

3.6 Organization and Staffing

3.6.1 Organizational Considerations. Organizations plan, organize, perform, control, and evaluate work. The factors in the following sections are important considerations when designing the organizational structure.

3.6.1.1 Contract Versus In-house. The proportion of the facilities maintenance work accomplished by support contractors significantly impacts the organizational structure. As the contracted portion increases, the Government workforce becomes more involved in contract administration and surveillance. The optimum mix of support contractor and Government personnel should be based on local conditions and priorities and should be consistent with the guidance contained in OMB Circular A-76 and the FAR. The principles of sound facilities maintenance management apply equally to in-house and contract work. In NASA Centers utilizing a maintenance support contractor, the contractor is a key partner in implementing and operating a successful maintenance management program.

3.6.1.2 Labor Agreements. Labor agreements may dictate certain procedures, practices, consultations, and other action. These influence the organizational structure and the Government's flexibility in making changes to the organization, work methods, or work assignments. The human resources department may provide assistance in this area.

3.6.1.3 Functional Lines. The facilities maintenance functions are vital in support of the Center's mission. Where more than one organization has responsibility for performing facilities maintenance, close coordination is necessary. The facilities maintenance organization interfaces closely, with potential for overlap, with related processes such as master planning, major facilities acquisition, and transportation and utilities management. It may be logical to organize along functional lines; however, care should be taken to ensure that lines of communication are open and maintained among all related functions and organizational elements. Senior managers should encourage communication and liaison at all levels.

3.6.2 Staffing Considerations. A number of factors will influence the staffing of a facilities maintenance organization. In cases where a PBC is utilized to perform the facilities maintenance functions, the contractor is responsible for determining the staffing and skill mix of the workforce to meet the contractual requirements. The following factors apply to staffing plan development:

3.6.2.1 Workload Balance. The facilities maintenance organization staffing should match the workload characteristics. The personnel resources available in each craft should closely match the amount of work included in the AWP, taking into consideration work priorities and alternative methods of accomplishment. Consider using temporary or part-time employees or one-time contracts to accomplish seasonal, surge, intermittent, or one-time work requirements.

3.6.2.2 Education and Training. The facilities maintenance organization should ensure that personnel have and maintain the skills needed to cope with changing technology to effectively carry out the facilities maintenance program. Skill requirements are identified through periodic reviews of all the organization workload. Comparing skill requirements with the assigned personnel skill inventory will identify shortages for correction through education, training, recruiting, or other action. Skill inventories and requirements identification should address all facilities maintenance program phases, including shop crafts, administrative skills, PT&I technologies, environmental and hazardous materials training, and the use of computers.

a. As an example, training plays a major role in reaching and maintaining skill levels required for an effective RCM program. The training should be both of a general nature and technology/equipment specific. Management and supervisory personnel benefit from training that presents an overview of the RCM process, its goals, and its methods. Technician and engineer training should include the training on specific equipment and technologies, RCM analysis, and PT&I methods.

b. RCM training is available from professional organizations, consultants, equipment manufacturers, and vendors. The following are examples of specific areas of training and possible sources for the training:

(1) Infrared thermography (IRT) is complex and difficult to measure and analyze. Training is available through infrared imaging system manufacturers and vendors.

(2) Vibration monitoring and analysis training is available from equipment vendors. The Vibration Institute has published certification guidelines.

(3) Electricians, electrical technicians, and engineers should be trained in electrical PT&I techniques, such as motor current signature analysis, motor circuit analysis, complex phase impedance, and insulation resistance readings and analysis. Equipment manufacturers and consultants specializing in electrical testing techniques provide classroom training and seminars to teach these techniques.

3.6.2.3 Licenses, Permits, and Certifications. The license, permit, or certification requirements in the following sections are applicable to Government employees and contractors. When work requiring licenses, permits, or certifications is included in a contract, the contract shall state clearly that the contractor should obtain all applicable NASA, State, and/or local government, licenses, permits, or certifications before performing the work.

a. Specialized personnel and facilities often are required to have licenses, permits, or certifications. These requirements apply to central utility plant personnel and to environmentally or safety-sensitive facilities. To the maximum extent possible, such licenses, permits, and certificates should be issued by the State or local government rather than by Centers to avoid administrative duplication. Centers should issue only those licenses, permits, and certificates that are NASA unique and, therefore, not available through other existing regulatory organizations. Detailed training and certifications requirements may be found in specific safety standards, e.g., NASA-STD-8719.9 or NASA-STD-8719.12. Additional hazardous operation safety certification requirements may be designated by each Center safety official or designee, but should include the minimum as listed in Chapter 4 of NPR 8715.3.

b. Operators of central utility plants, such as at water treatment plants, boiler plants, and wastewater treatment plants, should be licensed by applicable State and local governments. Also, when required by State or local governments, permits for such things as incinerators, licenses for other facilities maintenance-related operations such as pest control and herbicide applicators, and certificates for equipment such as pressure vessels, lifting devices, and elevators shall be obtained.

c. Maintenance Certification programs like Certified Maintenance and Reliability Professional (CMRP), is an experience-based, American National Standards Institute (ANSI) accredited certification program for maintenance and reliability professionals provided by the Society of Maintenance and Reliability Professionals (SMRP). This program was a result of the lack of consistent, well-defined standards for the body of knowledge and capabilities that maintenance and reliability practitioners should have to be effective. In addition, there was no way to differentiate those who have mastered the various elements of excellence from those who simply hold the job. (For more information go to http://www.smrp.org/files/SMRPCO%20Candidate%20Guide%20for%20Certification%20Recertification_5%209%2013.pdf .) To obtain certification candidates shall submit an application and pass a 110â??question exam. The subjects tested on the exam include:

(1) Business and Management

(2) Manufacturing Process Reliability

(3) Equipment Reliability

(4) Organization & Leadership

(5) Work Management

3.6.2.4 Federal Buildings Personnel Training Act of 2010. The Federal Buildings Personnel Training Act of 2010 (FBPTA) requires all personnel (both civil service and contractor) performing building operations and maintenance, energy management, or facilities safety and design functions to demonstrate knowledge in the core competencies identified by GSA as they apply to the individual's job. The General Services Administration (GSA) in conjunction with Department of Energy (DOE) has identified the competencies required and developed a Web-based tool for personnel to register, conduct a gap analysis on an individual's competencies and develop training requirements for that individual to become fully compliant. The tool is available at http://www.fmi.gov/ . All civil servants whose primary function is performing building operations and maintenance, energy management, facilities safety, and design should register in the system. This requirement initially focuses on civil service employees with contractor guidance to follow at a later date.

3.6.2.5 The Chief of Facilities at each NASA Center should ensure that they can meet all competencies required for their facilities within their employee and contract support competencies.

3.7 Customer Relations

3.7.1 Everyone who works at or uses Center facilities is a customer of the facilities maintenance organization. Some are direct customers, requesting and receiving specific services such as TCs or Service Requests. Others are indirect customers, using the facilities and collateral equipment such as HVAC systems maintained by the facilities maintenance organization. Facilities maintenance, which provides institutional, as well as program support, plays a major role in keeping these customers satisfied. This does not occur automatically. Customer relations should be a primary consideration in all facilities maintenance decisions. Facilities maintenance may be the key factor in developing and maintaining the professional reputation of Center institutional managers.

3.7.2 Communication

3.7.2.1 The facilities maintenance organization cannot operate effectively without open communication. Communication is extremely important within the organization to ensure coordination of competing resources. Communication with customers and other Center entities is necessary to ensure that the correct work is accomplished at the correct time and within allocated resources. Communications between the maintenance organization and their customers should be an integral part of the CMMS. The system should provide for customer access to submit requirements and for the customers to obtain status of their requests from submittal through completion. Day-to-day communications may also utilize other Center electronic means, including e-mail and Web page access. Facilities maintenance personnel should be alert to the following barriers to communication:

a. Cryptic, incomplete work requests.

b. Misinterpreting the scope of work specified as "the supervisor wants."

c. Customers' misinterpreting technical answers to their questions on project status.

d. Differing understandings of mission needs.

3.7.2.2 Two-way communication should be encouraged, with the customer articulating customer desires and the maintenance organization providing constructive and continuous feedback through the CMMS or other electronic systems, including e-mail, where possible. This may provide an early warning of changes in workload and identify potential problems. It facilitates orderly workload planning by the facilities maintenance organization and its customers. This is particularly important during periods of limited funding because the maintenance organization often can help a customer translate desires into realistic facilities requirements, thereby obtaining an optimum solution or, at least, an adequate solution within the resources available. A well-informed maintenance organization and a "maintenance informed" Center are in a much better position to produce necessary results within available resources.

3.7.2.3 The reputation of the facilities maintenance organization is built as much on perception as on performance. A positive image of the facilities maintenance organization is created by proactive communications, i.e., keeping the customer informed about the status of the work, responding quickly to the requests, informing the customer in advance about the cost of the work, and reflecting the costs accurately in reimbursable billings and reports. The maintenance organization should have a customer liaison representative to work with each customer organization. The customer liaison should participate in the development of MOAs, AWPs, funding plans, and in the day-to-day support of the customer. However, every member of the facilities maintenance organization is an ambassador for the organization and should be sensitive to each customer's needs and perceptions.

3.7.2.4 The maintenance organization should have open communications with the following personnel and organizations:

a. Customers.

b. Health and safety.

c. Environmental office and agencies.

d. Engineering.

e. Mission personnel.

f. Center planners.

g. Support contractors.

h. Resource management personnel.

i. Local, State, and Federal regulatory agencies.

j. NASA Headquarters administrative and support offices.

k. Center Historic Preservation Officer

3.7.3 Funding Sources. The facilities maintenance organization may find that a significant portion of its work is customer funded. This is especially the case with service requests and work directly supporting R&D programs. In establishing the organizational structure, the variability, time phasing, and duration of customer-funded work should be considered. Provision should be made for estimating and managing customer-funded work. Where the level of customer-funded work is variable or cyclical, use of contracts or temporary workers may be desirable to accommodate peaks and valleys in the workload. When temporary workers are utilized, additional funding may be required to account for additional training and safety oversight.

3.7.4 Customer Mission. Customer relations should facilitate accomplishing the specific job that the customer requested. It includes understanding the customer's mission requirements and using this understanding to communicate with the customer and guide the customer's expectations. Thus, the facilities maintenance organization should understand the mission of each of its customers. This understanding will lead to better resource allocation decisions, enable the organization to meet each customer's needs, and improve the facilities maintenance organization's credibility by meeting real needs within the time and other resources available. Actually, the facilities maintenance organization's real mission is to support the Center mission using the most cost-effective means available.

3.7.5 Memorandums of Agreement

3.7.5.1 MOAs and other formalized agreements spell out support between organizations and agencies. MOAs may cover agreements between the facilities maintenance organization and other Center departments, other Federal agencies, or local governments. Typically, MOAs outline details of services provided and funding responsibilities. It is possible for a Center to be both a receiver of services from and a provider of services to another organization. These services may be provided on a reimbursable or nonreimbursable basis. Examples include provision of utilities, shared use of operational facilities such as runways, provision of fire protection services, and maintenance of special facilities such as aviation fueling systems. Examples of MOAs from other Federal agencies are training and support from the U.S. Navy and the GSA.

3.7.5.2 MOAs may offer significant advantages through better use of facilities and avoid duplication of effort. The facilities maintenance organization should be alert for opportunities to use MOAs. Where services are available under an MOA, the facilities maintenance organization would not need to dedicate organizational resources to provide the service. The increased scope of the combined service may make it possible for the provider to perform the service at a reduced unit cost to all customers by realizing economies of scale. Properly managed, the increased scope also may provide flexibility and increased capability during a time of emergency. An assessment of the impact of MOAs should be made while developing AWPs.

3.8 Interfaces with Other Support Organizations

3.8.1 Facilities and equipment maintenance program effectiveness often depends on the support provided by other Center organizations. For example, the Office of the Chief Financial Officer may prepare budgets and allocate funds, the Office of Human Resources and Management may control staffing, the Office of Procurement may handle requests for material, and the various supporting staff offices may handle reproduction and correspondence services. Responsibility for facilities planning and engineering, including major facilities and equipment acquisition, may rest with a separate organization, such as the Facilities Engineering Office. Essential services, such as utilities, may be purchased commercially or provided by a separate Government or host activity. The facilities maintenance organization should maintain close communication and cooperation with other supporting organizations, working together to plan and manage the workload.

3.8.2 Safety and Health. It is NASA's policy to "avoid loss of life, personal injury or illness, property loss or damage, or environmental harm from any of its activities and ensure safe and healthful conditions for persons working at or visiting NASA facilities." (See NPD 8700.1.) To accomplish this, all individuals should act responsibly in matters of safety. The Center facilities maintenance organization is responsible for its role in safety by maintaining facilities in a safe condition and by performing tasks in a safe manner in accordance with NASA policy.

3.8.3 Environmental Compliance. Although environmental compliance is not typically one of the primary responsibilities of the Center facilities maintenance organization, virtually every facilities maintenance action has a potential impact on the environment. For this reason, facilities maintenance personnel should be knowledgeable about environmental requirements, adhere to applicable environmental rules and regulations, become involved to the limit of their responsibilities, and maintain open communication links with cognizant NASA environmental protection staff and regulatory officials. Environmental regulation compliance is a primary input item to establish standards.

3.8.4 Energy Management. The Center facilities maintenance organization is a prime participant in the Center's energy management program as developed in accordance with NPR 8570.1. The maintenance organization participates in identifying and is responsible for implementing O&M procedures and/or process improvements that are in the Center's Energy Efficiency and Water Conservation 5-Year Plan. Responsible maintenance organization staff members help conduct energy audits. Analysis of the Center's EMCS data will be included in the maintenance organization's planning to identify changes that indicate maintenance problems or imminent equipment or system breakdowns. All of this energy management program support should be integrated into the maintenance organization's AWP and 5-year plan.

3.8.5 Contract Support

3.8.5.1 Much of the Center facilities maintenance work is performed by contract, either by separate, specific, one-time CoF contracts; specific facilities maintenance contracts (using non-CoF funds); or support services contracts. In the case of the specific, one-time contracts, the facilities maintenance organization's responsibility is limited to initial facilities maintenance and repair requirements identification, perhaps preliminary scope definition or cost estimate preparation, observing the facility's acceptance testing (as appropriate), acceptance of initial baseline data, and resumption of the maintenance responsibility after the contract is complete. For facilities maintenance support services contracts, the facilities maintenance organization has a greater responsibility. It should be involved throughout the acquisition process in each of the following functions:

a. Determining the need for the contract.

b. Serving as a member of the acquisition team.

c. Drafting the acquisition schedule and milestones.

d. Preparing the needs analysis.

e. Writing the acquisition plan.

f. Writing the statement of work and providing plans and specifications, as required.

g. Assisting the Office of Procurement in determining the contract type.

h. Writing the quality assurance plan.

i. Conducting quality assurance surveillance during contract performance.

3.8.5.2 Close coordination with the cognizant procurement office is essential in obtaining quality services in a timely fashion. Additionally, emphasis should be placed on advance acquisition planning to ensure continuity of services.

3.8.6 Historic Preservation

3.8.6.1 For work on existing facilities with potentially historic significance, the Facilities Maintenance Manager shall contact the Center Historic Preservation Officer (HPO) for determination of historic eligibility and ensure the work complies with 36 CFR, Part 800, Protection of Historic Properties, before starting or awarding the task. The HPO will require concurrence from the State Historic Preservation Officer for major work before starting or awarding the task.

3.9 Physical Plant Information

3.9.1 Initially, the maintenance organization shall know the facility activity status to establish a facility's maintenance requirement. The status may range from active to abandoned with each status requiring a different level of maintenance. (See section 3.9.5, Facility Activity Status.)

3.9.2 Information describing the facilities and collateral equipment at a Center is essential for planning facilities maintenance actions, efficiently performing facilities maintenance, documenting maintenance histories, following up on maintenance performance, energy reporting, and management reporting. Without this information, neglect of essential systems is likely, leading to inefficient operation, system failure, or loss of service.

3.9.3 With the increasing use of CMMS, obtaining the information in computer-readable format is strongly recommended. Chapter 6, Facilities Maintenance Management Automation, addresses CMMS requirements and usage.

3.9.4 Complete physical plant information consists of several databases distinguished by the type of information they contain. Chapter 6, Facilities Maintenance Management Automation, discusses databases from the perspective of facilities maintenance management automation. The following sections examine the physical plant information databases in terms of the type of information they contain.

3.9.5 Facility Activity Status. The following sections provide insight into some of the facility status classifications. Each status has its own level of maintenance required, ranging from full maintenance for an active facility to no maintenance for a facility with an abandoned status. For detailed information on maintenance requirements for each inactive facility status, see NPR 8800.15.

a. Active facility. Any facility that has a specific and present or near-term program or institutional requirement. Space utilization would normally be at least 50 percent, and/or the usage level exceeds 50 percent of the available time for use.

b. Inactive facility. Any facility that has no specific and present or near-term program or institutional requirement. The inactive facility may be placed in a "Standby," "Mothballed," or "Abandoned" status. The following generally apply to all levels of inactive facilities:

(1) No personnel occupy the facility.

(2) Utilities are curtailed, other than as required for fire, security, or safety.

(3) Facility is secured to prevent unauthorized access and injury to personnel. (4) Facility does not receive funding for renewal or other significant improvement.

3.9.6 Descriptive Data

3.9.6.1 Descriptive data is the detailed identifying information on the items to be maintained. The data falls into the following two classes:

a. Facilities data describing buildings, structures, utilities lines, and grounds improvements.

b. Collateral equipment data describing built-in equipment that is part of a facility or utilities distribution system but maintained as a separately identifiable entity.

3.9.6.2 Each separately identified and maintained item may be part of a hierarchy of systems and subsystems. For example, a motor may be a component of the water circulating subsystem of an A/C system in a facility.

3.9.6.3 Descriptive data should identify items to their related systems and subsystems. The number of hierarchical levels depends on Center requirements, but four levels of system/subsystem is the suggested minimum. For equipment, the descriptive data should include the equipment classification or grouping.

3.9.6.4 Facilities. Table 3-1 provides a list of descriptive factors and attributes used to develop a facilities database. This list is a suggested minimum for facilities management. The items on this list generally are self-explanatory.

Table 3-1 Facilities Descriptive Data

Facility Number	Material
Facility Title	Finish
Location Status	Inspection Cycle (years) PGM Checklist/Guide No.
Facility Component (e.g., ceiling, door, floor, flashing, wall, drainage, parapet)	Estimated Design Life (years) Funding Source
Facility System (e.g., exterior, interior, roof, tank, fence, grounds)	Construction Date Condition Code

3.9.6.5 Collateral Equipment. Table 3-2 is a list of descriptive factors and attributes used to develop a collateral equipment database. This list is a minimum for collateral equipment maintenance management. Centers with PT&I programs will have additional equipment data elements such as location of test points.

Table 3-2 Collateral Equipment Descriptive Data

Inventory Number Nomenclature Location Building Floor Room	Estimated Life Cost Size Capacity HP Voltage Weight Current Dimensions	Classification Use/User Priority Funding Source PM Cycle Identifiers PM Guide No.

Zone Manufacturer Vendor/Supplier Model Serial Number Date Acquired	Systems Major System Subsystem Major Component Component	Inspection Identifiers Condition Code

3.9.7 Drawings

3.9.7.1 Drawings and other graphical data are a significant portion of the physical plant information, especially for buildings, structures, utilities systems, real estate, and land improvements. They also may be a significant portion of the available information for equipment in the form of shop drawings, schematics, photographs, and assembly drawings. Drawings may exist in many forms, including paper, photographs (such as microfilm, microfiche, and aperture cards), video images, and computerized data. Computerized forms include Computer-Aided Design and Drafting (CADD), Geographic Information Systems (GIS), Building Information Model (BIM), or vector-based drawings. Drawings may be linked to work orders through a CMMS database.

3.9.7.2 Significant challenges in drawing management include keeping drawings up to date, maintaining an indexed library of drawings, and maintaining a linkage between the drawings and the systems they represent. To the maximum extent possible, Centers should require all drawings for new or modified facilities and equipment to be delivered to the Government in computer-readable and revisable form. However, the wholesale conversion of existing drawings to computerized form may not be practical. All drawings should be filed and retained in accordance with guidance provided in NPR 1441.1.

3.10 Data Gathering

3.10.1 It is necessary to gather facilities and collateral equipment data to support the facilities maintenance program.

3.10.2 Existing Databases

3.10.2.1 Existing databases maintained by the Center provide a starting point for developing an inventory of maintainable facilities and collateral equipment items. However, databases developed for other purposes, such as financial accounting, will not identify all maintainable items, systems, subsystems, and components. Further, they may include items not relevant for facilities maintenance management purposes. Using these databases as a starting point requires screening entries for inclusion in the facilities maintenance database. Where a unified Center database exists, this might take the form of flagging records as part of the facilities maintenance management program. Where the existing data is in a computerized database, it also may be possible to arrange for electronic transfer of portions of the data. This may simplify loading the data into the facilities maintenance management database. Potential existing databases include the NASA Real Property Management System and Center-unique industrial plant, personal, and minor property or collateral equipment inventory systems.

3.10.2.2 Creation of separate databases with common data elements carries the risk of having conflicting data. If separate databases are created, a methodology should be developed and implemented to update the data from one database to the others to avoid inconsistencies.

3.10.3 Physical Inventory. A physical inventory may be necessary to verify the data imported from other databases and to gather supplemental information to identify maintainable items and their associated systems, subsystems, and components not previously inventoried. Identification tags placed on collateral equipment during the inventory will help to ensure that all maintainable collateral equipment is picked up for entry into the database. Using identification tags also helps to avoid duplication.

3.10.3.1 In-house. It is possible to perform a complete physical inventory using in-house workforce as part of the continuous inspection and PM programs. However, this effort may take a long time and could result in the diversion of a significant portion of the facilities maintenance workforce, thereby adversely impacting routine facilities maintenance.

3.10.3.2 Contract. Contracting for the inventory is an effective method of obtaining the data. The contract may be a separate action, in conjunction with a comprehensive condition assessment, or it may be part of the development of Maintenance Support Information. (See section 10.9, Maintenance Support Information.)

3.10.3.3 Inventory Maintenance. Once developed, the facilities and collateral equipment inventory requires continuous updating to reflect additions, deletions, or changes to the physical plant. Normally, this effort is part of the continuing inspection program.

3.10.3.4 Identification Tags. Equipment identification tags should be clearly visible. Using permanent, machine-readable tags, such as preprinted bar code labels, eases maintenance and inventory automation and reduces the potential for data-entry errors.

3.10.4 User Information. Equipment users or custodians also are a source of inventory information as they receive new equipment or determine that equipment they already have requires maintenance. The initial identification typically will take the form of a request for equipment installation or maintenance. It may also be a response to a call for inventory assistance from the facilities maintenance organization. In either case, the information provided may not be enough for facilities maintenance management purposes. A field investigation may be necessary to obtain all of the maintenance information.

3.11 Management Indicators

3.11.1 Section 3.11.5, Work Element Relationships, discusses the total facilities maintenance effort and relationships among the individual work-element efforts. However, there are a number of other relationships typically used in the facilities maintenance community for indicating the effectiveness of the facilities maintenance operation and for comparing current performance with goals and objectives. These relationships are called management indicators, performance measures, or simply "metrics."

3.11.2 As shown in Figure 3-3, management indicators may be expressed as words (such as "outstanding" or "excellent") or numbers (metrics). Current management theory holds that one cannot manage an operation effectively unless one measures it. Metrics are preferable to word descriptions because they may be trended more easily. Also, they tend to be more precise and objective than words. Regardless of what metrics are used by individual Centers, some system of measurement is vital to the process of continuous improvement.

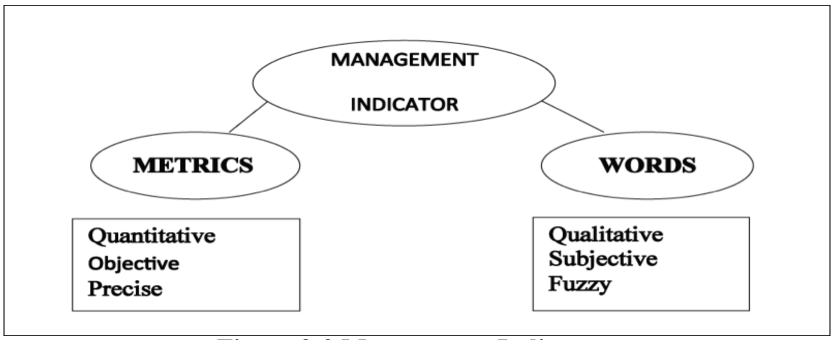


Figure 3-3 Management Indicators

3.11.3 NASA's policy is to continuously improve technical and managerial processes to minimize life-cycle maintenance and repair costs. One process to use is benchmarking. Using benchmarking and its related metrics, Center facilities maintenance managers can evaluate maintenance performance, compare performance against maintenance standards, and identify trends. This process will help managers in identifying and implementing best practices and can provide a basis for performance projections to be used in preparing the AWP and the Center's 5-Year Plan.

3.11.4 The following sections provide a general definition of a metric, its components, and its attributes. They also discuss the role metrics play in the continuous improvement processes and present examples of metrics used by facilities maintenance organizations.

3.11.5 Work Element Relationships

3.11.5.1 There are relationships among the facilities maintenance work elements that indicate the strengths and weaknesses of a facilities maintenance program. Table 3-3 shows typical ranges of effort for the principal work elements at a large physical plant of diverse age and complexity.

Table 3-3 Work Element Percentages and Indicators

Work Element*	Average Range as Percentage of Total Work Effort
Preventive Maintenance (PM).	15â?"18
Predictive Testing & Inspection (PT&I).	10â?"12
Programmed Maintenance (PGM).	25â?"30
Repair (other than TC).	15â?"20
Trouble Calls (TC).	5â?"10
Replacement of Obsolete Items (ROI).	15â?"20
Service Requests (SR).	0â?"5

Total	100%
Key performance indicators for facilities maintenance.	
Facility Condition Index (FCI): Upward trend (Agency-wide goal of 4.0).	
DM: Downward trend.	
Planned Work (PM, PT & I, PGM, and some ROI): Upward trend.	
Unplanned Work (TC, Emergency Repairs, some ROI): Downward trend.	

3.11.5.2 The percentages in Table 3-3 apply to the total facilities maintenance effort. The percentage ranges are guides only. For example, if repairs exceed 20 percent by a significant amount, it may indicate that more effort should be put into PM, PT&I, and PGM. Likewise, if TCs exceed 10 percent, it may indicate that PM and PT&I effort should be increased. The greatest effort, 50 to 60 percent, should be applied to PM, PT&I, and PGM. The limit on service request work is suggested only because of the potential for a large amount of service request work to detract from the maintenance effort.

3.11.5.3 The ranges in Table 3-3 are recommended as a basis for self-evaluation until each Center accumulates sufficient data to reflect its unique situation. Thereafter, analysis should be based on the relationships appropriate to the Center.

3.11.5.4 Two of the work elements do not appear in Table 3-3: Central Utility Plant Maintenance and Operations and Grounds Care. Both depend on local circumstances and vary too widely to estimate a meaningful range.

3.11.5.5 As a general rule, the percentage of work authorized by work order should increase, the percentage of scheduled work should increase, and the percentage of unscheduled work should decrease.

3.11.5.6 Metrics Definition

a. Metrics are meaningful measures. For a measure to be meaningful, it should present data that encourages the right action. The data should be customer oriented and be related to and support one or more organizational objectives. Metrics foster process understanding and motivate action to continually improve the way a process is performed. This is what sets metrics apart from measurement. Measurement does not necessarily result in process improvement. Effective metrics always will. Projecting this improvement, metrics can be used in preparing a Center's AWP and 5-Year Plan.

b. A more useful definition for managers is that a metric is a measurement that is made repeatedly at prescribed intervals and that provides vital information to management about trends in the performance of a process or activity or in the use of a resource.

c. Each metric consists of a descriptor and a benchmark. A descriptor is a word description of the units used in the metric. A benchmark is a numerical value of the metric or the limits within which the metric is to be kept that management selects as the goal against which the measured value of the metric is compared. For example, a typical metric is the ratio of planned maintenance work (dollars) over total maintenance work (dollars) expressed as a percentage and shown in the following equation:

Planned Maintenance Work (dollars)

Total Planned Work (dollars)

d. The planned maintenance work and total planned maintenance work are the descriptors, the units of which are dollars. In the example, 80 percent is the goal or benchmark.

3.11.5.7 Metrics Attributes

a. Metrics have common attributes that should be considered when they are being developed. A good metric has many of the following attributes:

(1) It is customer oriented.

(2) It is linked to a goal or objective.

(3) It is process/action oriented.

(4) It distinguishes good from bad or desirable from undesirable results.

(5) It is derived from data that is readily collectable.

(6) It is trendable.

(7) It is repeatable.

(8) It is simple.

(9) It expresses realistic/achievable goals.

b. Customer orientation is important because the ultimate success of facilities maintenance services is partly dependent on how they are perceived by the customer. A metric should be action oriented, which means that the organization should have the capability to change the metric parameters. Just as what cannot be measured cannot be managed effectively, there is no need to measure what cannot be controlled. A metric should distinguish good from bad, which again is based on a standard or goal, i.e., movement toward the goal is good, and conversely, movement away from the goal is bad. The data for the metric should be collectable, preferably already contained within the accounting system or the CMMS. A metric should be trendable so that successive readings can be compared with meaningful results. It should be simple, so that those who use it, carry it out, or are affected by it can understand it. Finally, the metric should be realistic. If it is clearly not achievable, workers will not strive to achieve it.

3.11.5.8 Metrics' Role in Continuous Improvement

a. The role of metrics in the continuous improvement process is illustrated in Figure 3-4. This figure illustrates the simple closed loop in any management system. The first step is to select the descriptor and establish the benchmark, which together make up the metric. Establishment of the metric should consider the factors listed in section 3.11.5.7, Metrics Attributes.

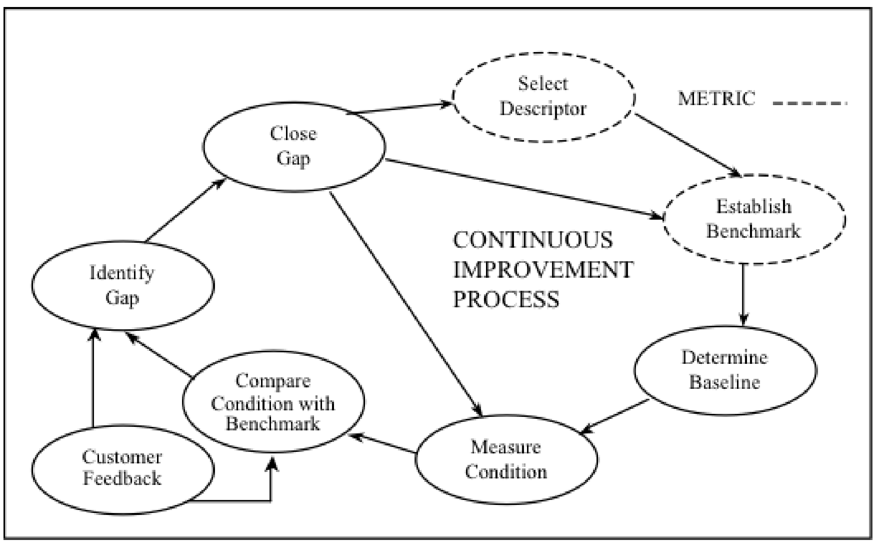


Figure 3-4 Continuous Improvement Process

b. When the metric is implemented, management should establish the baseline, i.e., where the organization is with respect to the benchmark. Preferably, this information is known, at least approximately, and used when setting the goal (benchmark). Then management can develop a system to measure and report the descriptor condition regularly over uniform periods of time (e.g., daily, weekly, monthly). The measured value is compared with the benchmark to identify the gap between the two. Management then acts to close the gap. After several iterations, it may become apparent that either the descriptor is not appropriate or the benchmark is unrealistic. If this is the case, the metric should be revised and a new baseline determined. If the original metric is both suitable and realistic, the measurement cycle should be repeated with the gap between the benchmark and the measured value becoming progressively smaller. In this situation, true continuous improvement is occurring.

3.11.5.9 Benchmarking. Two organizations that promote the use of metrics for continual improvement are the American Productivity and Quality Council (APQC) and the American Society for Quality (ASQ). While the APQC's emphasis is on benchmarking, the ASQ promotes customer satisfaction as the means to achieve continuous improvement. One of the best methods for achieving continuous facilities maintenance improvement is using metrics with benchmarking. Benchmarking is the process of continuously identifying, measuring, and comparing processes, products, or services against those of recognized leaders to achieve superior performance.

a. Objectives. The objectives of benchmarking are as follows:

(1) Accelerate the change process.

(2) Achieve both incremental and breakthrough improvements.

(3) Achieve greater customer satisfaction.

(4) Learn from the best to avoid reinventing (applying lessons learned).

(5) Apply best practices using the latest feasible technology.

b. Types of Benchmarking:

(1) Internal. A comparison of internal operations, for example, within a Center or NASA-wide.

(2) Competitive. A competitor-to-competitor functional comparison.

(3) Functional. A comparison of similar functions within NASA Centers or with industry leaders.

(4) Generic. A comparison of functions or processes that are the same regardless of Center or industry.

c. Approaches to Benchmarking. The NASA approach found to be successful has been generic benchmarking using the hybrid approach. Benchmarking approaches are as follows:

(1) Centralized. Managed by a single corporate entity, e.g., by NASA Headquarters.

(2) Decentralized. Managed at the local level, e.g., by individual Centers.

(3) Hybrid. A combination of the centralized and decentralized approaches.

d. Facilities Maintenance Management Indicators:

(1) The benchmark depends on the Center baseline and goal or objective. More important, a specific metric by itself is the recognition of its usefulness in proactively establishing patterns, trends, and correlation with other data to describe past, current, and anticipated conditions. Center maintenance managers should utilize metrics continuously to evaluate the effectiveness of their management.

(2) A major benefit of the metric information is its evaluation over several periods to obtain trends. Metrics may be maintained visually using graphs, bar charts, or other methods. The periods may be monthly, quarterly, annually, or by contract evaluation period. The benchmark of "Local" means that the individual Center should establish its own benchmarks based on experience and look for improvement trends and irregularities.

(3) The metrics presented in Appendix G should be used by Center maintenance managers for evaluating various maintenance areas on a continual basis. Individual metrics can refer to the maintenance organization as a whole or by individual shops, crafts, contracts, or subcontracts. These are essentially tools for facilities maintenance managers in evaluation of their operations and for providing NASA Headquarters metrics data.

3.11.5.10 Examples

a. Center Metrics. Metrics can be classified using categories, such as facility condition, work performance, work elements, budget execution, and many others. Examples shown in Table 3-4 are some of the metrics that are recommended for Center self assessments. These and additional metrics that might be utilized in evaluating a maintenance program and benchmarks are contained in Appendix G. The corresponding WBS codes also are provided in Appendix G.

b. Center Facilities Maintenance Functional Performance Metrics Summary Sheet. Table 3-4 is the metrics sheet. The Center's metrics data shown in the table is usually submitted to NASA Headquarters in November of each year. The following sections provide additional insight into the metrics data shown in the table.

Table 3-4 Sample Management Metrics

CALCULATED from DATA PROVIDED		
FYxx Center Facilities Maintenance Functional Performance Metrics Summary		
	AGENCY PARAMETRIC MEASURES	**UNIT**
	FYxx Facilities Deferred Maintenance (DM)	$M
	FYxx Current Replacement Value (CRV from FYxx DMA Report)	$M

	FYxx Facility Condition Index (FCI)	#
DATA INPUT FROM CENTERS		
1	Unconstrained Maint. and Repair (M&R) Requirement, FYxx (w/out CoF)	$M
2	Initial Operating Plan for Maintenance & Repair (M&R), FYxx	$M
3	Actual Annual Maintenance and Repair (M&R) Funding (Without CoF)	$M
4	Cost of Scheduled Work	$M
5	Cost of Unscheduled Work and Breakdown Repair	$M
6	Number of PT&I "Finds"	#
7	Repair Cost of PT&I "Finds"	$M
8	Unfunded Cost to Repair Breakdowns/Failures	$M
9	Number of Trouble Calls	#
10	Reportable Incident Rate (RIR)	#
11	Lost Workday Case Incident Rate (LWCIR)	#
a.	Scheduled Maintenance Cost as a percentage of Total Maintenance Cost	$M
b.	Unscheduled Repair Cost as a percentage of Total Maintenance Cost	$M
c.	FYxx Total Site CRV	$M
d.	Initial Operating Plan as a percentage of CRV	%
e.	Maintenance and Repair Funding as a percentage of CRV	%
f.	Cost of Deferred Maintenance as a percentage of CRV	%
ENERGY/UTILITY USAGE METRICS (HQ Energy Manager)		
12	Energy Used/Consumed	MWH
13	Water Used/Consumed	Gal
14	Natural Gas and Oil Used/Consumed	Cu Ft

Note: Additional Benchmarks for metrics are in Appendix G.

$B	Billions of Dollars
CoF	Construction of Facilities
DM	Deferred Maintenance
FSM	Facilities Sustainment Model
LWCIR	Lost Workday Case Incident Rate (aka DART, Days Away, Restricted, and Job Transfer)
$M	Millions of Dollars

M&R	Maintenance and Repair
MWH	Megawatt Hour
PGM	Programmed Maintenance
PM	Preventive Maintenance
PT&I	Predictive Testing and Inspection
RIR	Reportable Incident Rate
ROI	Replacement of Obsolete Items
TC	Trouble Call

Abbreviations:

$B = billions of dollars; $M = millions of dollars; CoF = Construction of Facilities; DM = Deferred Maintenance; Lost Workday Case Incident Rate (aka DART, Days Away, Restricted, and Job Transfer); M&R = Maintenance and Repair; MWH = Megawatt Hour; PGM = Programmed Maintenance; PT&I = Predictive Testing and Inspection; RIR = Reportable Incident Rate; ROI = Replacement of Obsolete Items; TC = Trouble Call; # = Number.

Notes:

1	The unconstrained Center-level funding including PGM, PM, PT&I, ROI, TC, and non-CoF repair amount that represents a manager's reasonable estimate of the full annual requirement that would maintain the Center's facility inventory in a "good commercial" level of condition, while not allowing DM to grow further, and providing a level of reliability that the supported programs find acceptable for their missions. A minor amount of DM reduction could be included in this figure.
2	Initial Operating Plan for annual center-level maintenance & repair funding consisting of PGM, PM, PT&I, ROI, non-CoF repair, and TC.
3	Annual Center-level M&R funding including PGM, PM, PT&I, ROI, TC, and non-CoF repair.
4	Scheduled Work consisting of PGM, PM, PT&I, ROI, and PT&I "Finds" repair costs.
5	Unscheduled Work, typically Repair and TC costs.
6	The Number of PT&I Finds.
7	The annual cost to repair PT&I Finds.
8	The annual Unfunded Cost Estimate to Repair Breakdowns / Failures
9	The annual Number of Trouble Calls
10	Reportable Incident Rate during FYxx for O&M and support services contracts. RIR = (Total annual # of injuries incurred x 200,000)/(Total annual # of hours worked).
11	Lost Workday Case Incident Rate during FYxx for O&M and support services contracts. LWCIR represents the number of injuries and illnesses per 100 full-time equivalent workers and calculated as: (N/EH) x 200,000, where N = the number of injuries and illnesses, EH = the total hours worked by all employees during the calendar year, and 200,000 is the base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year).

3.12 Management Analysis

3.12.1 The maintenance requirements at each of the NASA Centers change continually, as does the maintenance technology. As a result, maintenance programs should be analyzed periodically at both micro and macro levels by facilities maintenance managers. These analyses should be based on personal observations of work being performed, customer feedback, reports (informal and formal), supervisor evaluation, metrics evaluations, and reports from the CMMS.

3.12.2 Performance Review. Facilities maintenance managers should review the performance indicators periodically to evaluate progress and readjust the maintenance program. Performance reviews may be formal or informal, based on the needs of the organization and the personal style of the manager. The manager analyzes the information contained in the metrics and, when available, the information provided through benchmarking. The manager's performance reviews should consider how to improve the way of doing business rather than continuing to operate in the old ways. The lessons learned from benchmarking often are helpful in determining the actions that should be taken as a result of performance reviews. The following are candidate areas to review:

a. Standards of maintenance may require modification because of changing mission requirements or changes in the use of facilities.

b. New maintenance techniques or materials may provide savings, thereby enabling additional work to be accomplished within the same level of resources.

c. Initial priorities may be set higher than necessary because of incorrect perceptions, lack of management preparation, or lack of insight, which may result in expediting work unnecessarily. This, in turn, may lead to worker inefficiency and extra management and supervisory effort.

3.12.3 Cost Avoidance. Cost-avoidance opportunities are not always obvious from the day-to-day observation of maintenance operations. When looking at the costs to maintain or repair a facility, the manager and all maintenance personnel should consider measures to avoid facility damage or equipment breakdown. Cost-avoidance action seeks to eliminate all maintenance efforts resulting from inefficiencies, misdirection, and mismanagement. Also, customers should recognize their role in optimizing the expenditure of maintenance funds. Most individuals take reasonable care of the facilities they use; however, waste may result when proper consideration is not given to the care and use of facility assets. The following factors, while not new ideas, should be considered in identifying cost-avoidance measures:

a. Preventing facility damage.

b. Minimizing wear and tear on facilities.

c. Eliminating the waste of energy.

d. Recognizing opportunities for multiple use or ways to reuse excess or underutilized facilities.

e. Eliminating, containing, or controlling hazardous material contamination with its consequent impact on the use of facilities.

3.12.4 Productivity Enhancements. Facilities maintenance productivity may be enhanced by actions such as the following:

a. Improving customer feedback to reduce customer calls to management for information.

b. Using a priority system that enables workers to complete one job before starting another.

c. Empowering maintenance personnel to report problems when found and changes to facilities or equipment otherwise not known (e.g., customer-made changes).

d. Reviewing data-entry procedures to ensure that different personnel do not enter data several times into different systems.

e. Reviewing work-order execution times to identify wasted labor caused by material, transportation, or support delays.

f. Monitoring to look for improved scheduling and travel consolidation efficiencies.

3.12.4.1 Two major detriments to productivity enhancements are excessive reporting without reason and the natural tendency to resist change.

3.12.4.2 One of the most important productivity enhancers is keeping personnel well motivated and encouraging a sense of ownership toward the facilities. This applies for both Government and contractor personnel.

3.12.5 Alternative Procedures. Maintenance and repair work does not decrease when resources are scarce. On the contrary, more items tend to be deferred, and the maintenance problems grow worse. Accordingly, efforts should be devoted to finding alternative methods to accomplish the same results. The following should be considered:

a. PT&I technology with remote sensing of equipment status replacing periodic, on-site manual inspection and reporting.

b. Increasing PM crew capabilities to reduce the number of separate crews required to perform maintenance on a particular item of equipment.

c. Replacing scheduled PMs with PT&I schedules. Process improvement/reengineering.

3.12.6 AWP Monitoring. The program analysis depicted in Figure 3-2 not only refers to management indicators but also refers to the AWP since it is the baseline or guide for the year's work. The plan should be updated with new information as appropriate. The following questions should be asked when comparing actual performance with the AWP:

a. Is the organization within budget?

b. What is the cause of any budget variances?

c. Is scheduled maintenance being performed on schedule?

d. Should RCM root-cause analysis be applied to any identified problem?

e. Were there any significant emergencies?

f. Is productivity improving? Is it being hampered by institutional factors?

g. Have there been any mission changes affecting facilities?

h. Has there been any customer changes affecting facilities?

i. What customer feedback has been received?

3.12.7 Performance Indicator Use. The performance indicators discussed in section 3.11, Management Indicators, only are beneficial when they are analyzed by management for use in improving the total program. These may be broken down into internal and external indicators as follows:

a. Internal indicators are those where the information is all directly available to the facilities maintenance manager and the indicators assist the manager in improving operations. A sample of these indicators is shown in Table 3-5. Most of these indicators evaluate timeliness, efficiency, and maintenance effectiveness.

Table 3-5 Internal Performance Indicators

Indicator	Performance Measured
Average Duration of Work Order Processing	Processing Timeliness
Actual Work Order Cost versus Estimated Work Order Cost	Performance Efficiency
Completion Date versus Estimated Date	Timeliness
Emergency Trouble Call Response Time	Responsiveness
Routine Trouble Call Response Time	Responsiveness
Equipment Availability Rate	RCM Effectiveness
Mean Time Between Equipment Breakdown	RCM Effectiveness
Percentage of Overdue PMs at End of Month	RCM Management Effectiveness

b. External indicators are based on information provided by the customer or on information that affects the support to the customer. A sample of these indicators is shown in Table 3-6. These indicators help to inform the facilities maintenance manager of the level of customer satisfaction and how well the maintenance organization is performing for the customer.

Table 3-6 External Performance Indicators

Indicator	Performance Measured

Customer Feedback, Score, and Number of Call Backs	Customer Satisfaction
Actual Cost versus Estimate Provided to Customer	Customer Satisfaction (indirect)
Completion Date versus Estimate Provided to Customer	Customer Satisfaction (indirect)
Number of Emergency Trouble Calls/Month and Repeat TCs	RCM Program Effectiveness
Cost of Unplanned versus Planned Work	Condition Assessment and Work-Generation Effectiveness
Deferred Maintenance Estimate	Level of Maintenance Funding

c. All of these indicators, both internal and external, are derived from metrics and applied to the specific Center. Appendix G provides an additional list and discussion of metrics that may be used to evaluate performance.

Chapter 4. Annual Work Plan

4.1 Introduction

4.1.1 In a 1998 commissioned study (Appendix C.4, resource 2) addressing the inadequate funding of Government facilities maintenance and repair, the National Research Council (NRC) concluded that agencies' facilities M&R programs were underfunded relative to their CRV, noncompetitive with operations programs, inconsistent between Agencies, overextended, mismanaged, and difficult to quantify and justify, and their funding was often and easily diverted. A well-conceived and comprehensive AWP will clearly substantiate the need for good, strong, and well-articulated justification for requesting, managing, and properly allocating M&R funds for the responsible stewardship of NASA facilities.

4.1.2 NASA has adopted a maintenance philosophy that emphasizes using the optimal mix of strategies to provide required facility availability and reliability at minimum cost in supporting current and planned NASA programs. This chapter emphasizes the use of Reliability Centered Maintenance program data in identifying long- and short-range facility requirements based not only on mission impact, but on ensuring that NASA maintenance programs continue to progress toward proactive modes of operation versus reactive modes. A template for preparing an Annual and 5-Year Maintenance Work Plan is provided in Appendix H.

4.1.3 The AWP is a tool used by the facilities maintenance manager for the following purposes:

a. To justify funding for the maintenance and repair of facilities and equipment in an organized manner for presentation to the Congress and others.

b. To identify, with a reasonable degree of accuracy, the Center's DM.

c. To ensure that all resources are used effectively to provide Center maintenance support in a manner that reflects priorities relative to mission criticality.

4.1.4 A well-developed AWP will provide a guide for the year's activity to ensure that NASA Center priorities are followed and the maintenance program progresses in a proactive versus a reactive mode of operation. Excessive reactive maintenance requires correspondingly excessive maintenance management that could be better spent in program planning, proactive maintenance, work evaluation, and analysis of resource expenditure effectiveness. The AWP balances estimated emergency and urgent reactive maintenance with predefined RCM activities such as PGM, PT&I, PM, and proactive maintenance. The plan will promote the adoption of new maintenance technologies and document the maintenance requirements for the year.

4.1.5 The added value of the AWP to the facilities maintenance program is in providing a sense of direction that the maintenance workforce can follow, thereby defining their contribution to the organization's accomplishments and enabling them to be more productive. The baseline of work defined by the AWP is then used together with the metrics and benchmarking methodology discussed in Chapter 3, Facilities Maintenance Management, and in Appendix G to evaluate progress and guide future efforts.

4.1.6 The AWP should be prepared prior to the start of the fiscal year and be ready to execute on schedule. Work that is necessary but unfunded through the regular budget and alternative funding should be identified where possible. Work that is still necessary and unfunded at the end of the fiscal year is added to the DM and monitored for later funding. The AWP will be a flexible working document, incorporating changes throughout the year to accommodate emerging mission and customer requirements and requirements identified during facility condition assessments that cannot wait for the next budget cycle.

4.2 The Link between Planning and Execution

4.2.1 Based on the previously gathered information about the Center, the AWP can be developed into the foundation of the maintenance management program. The AWP links the total maintenance requirements, as analyzed and prioritized, and integrates the budget constraints with day-to-day work control and work execution. This linkage is shown in Figure 3-2.

4.2.2 Before an AWP can be prepared, the facilities maintenance manager should understand the mission of the Center and the impact of facilities condition on that mission. Because of the nature of the overall NASA scientific mission, its continual change should be taken into consideration. Important long-range plans such as the Center Master Plan, 5-Year CoF Plan, and 5-Year Maintenance Plan (see section 4.6, 5-Year Facilities Maintenance Plan) are dynamic and will be updated annually as the AWP is developed. Further, facility requirements change as individual customers, supervisory direction, and missions change.

4.2.3 Short-term changes also have an impact on maintenance. The AWP should be flexible enough to accommodate these changes without invalidating the basic plan structure. The following are examples:

a. A change in a specific supporting research task may allow the use of alternative facilities rather than requiring an expensive alteration.

b. Scientific operations could preempt previously scheduled work in a given facility for a period of time, thereby causing a delay in a programmed maintenance project.

c. A change in a test program may demand more reliable power for a particular testing period, thereby requiring more preventive or predictive maintenance than normally programmed.

d. The criticality of a specific scientific project or support to a space flight could necessitate scheduling a special maintenance activity before the launch.

4.3 Content

4.3.1 The AWP is a compilation of all maintenance and repair work to be accomplished during the year, including an estimate for unforeseen work. This compilation is the result of analyzing the total work requirements and integrating them with the budget, as shown in Figure 3-2.

4.3.2 Figure 4-1 shows the specific elements making up a facilities maintenance AWP. Each element can be developed and considered as a separate entity. (In the figure, PM and PT&I are separated by a broken line because PT&I is considered a subset of PM. The same is true of Repairs and TCs. Cumulatively, the elements define the total facilities maintenance program planned at a Center for a given year and the estimated cost in dollars and other resources (i.e., labor, materials, and equipment). However, only routine maintenance and repairs are included as part of NRC's 2 to 4 percent of CRV recommended maintenance budget.

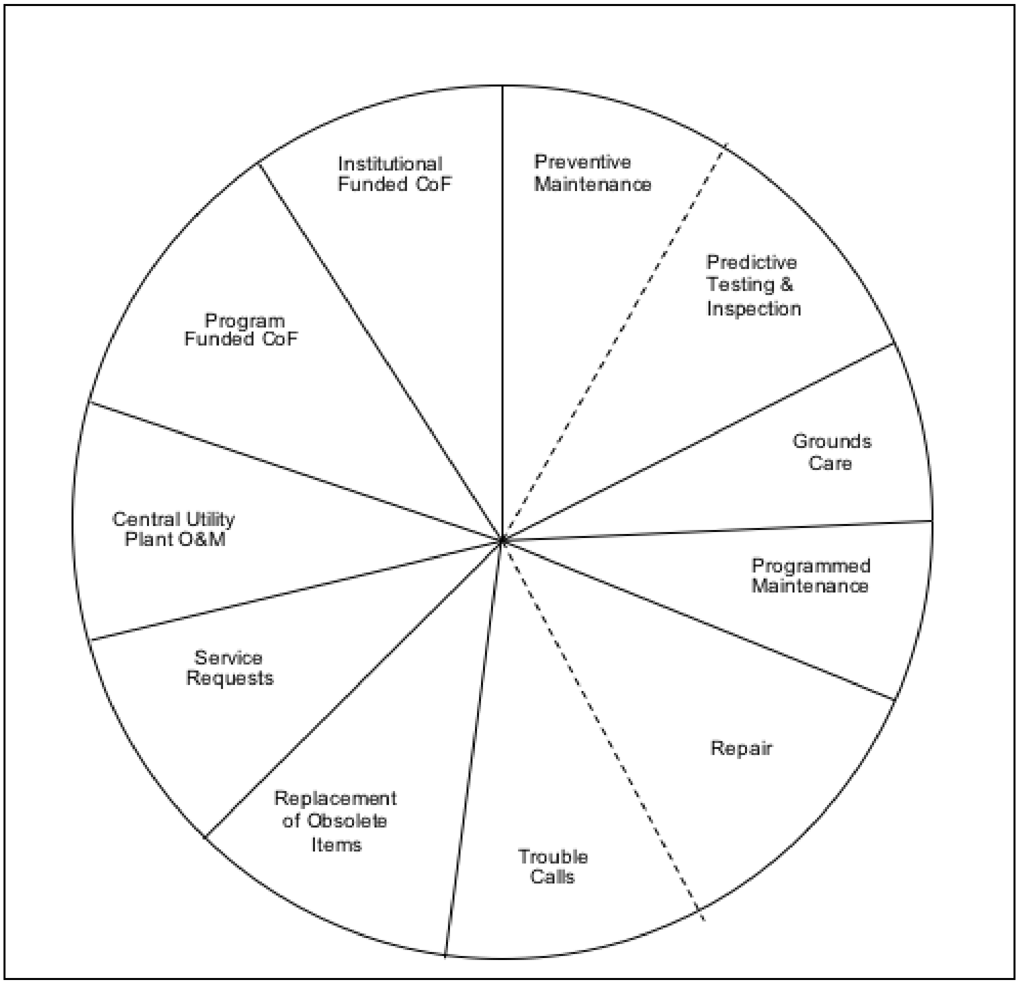


Figure 4-1 Facilities Maintenance Annual Work Plan Elements

4.3.3 The AWP should include an estimate and allowance for reimbursable work. This is to ensure that reimbursable work will complement rather than compete with necessary maintenance work.

4.3.4 The dollar limits for a work package in each facilities maintenance work element are shown in Table 2-2. CoF projects, although not normally executed by the maintenance organization, are documented in the AWP to ensure coordination of construction and maintenance activities. Besides a listing of projects to be accomplished, the AWP should document any pertinent maintenance-related information that was identified during the design and development of the CoF projects.

4.4 Information Sources

4.4.1 Preparing an AWP requires specific information. The facilities and collateral equipment inventory, coupled with the RCM database (in Center CMMS), constitutes the basic information needed. Such an inventory database should be augmented by a variety of files and other key documents, including mission statements and objectives from the NASA and Center Strategic Plans and other policy documents, PM requirements, a continuous inspection program, historical funding data, Energy Efficiency and Water Conservation 5-Year Plan, and facilities history records. The

CMMS is a valuable source of information on facility and equipment maintenance histories, criticality codes, priorities, performance metrics, TC histories, and other unforeseen requirements on which to base a reasonable estimate of the required level of effort for each season of the year. See Appendix H for additional information on suggested information sources.

4.4.2 The NASA Strategic Plan and Center Mission Statements. Pertinent excerpts from these documents set the stage for justifying to Congress and others why funding is required and the ramifications to big-picture Government interests if the funding is not provided. From their guidance, the AWP should identify and illustrate why short- and long-term facilities maintenance funding is crucial to ensuring facility availability for NASA's critical missions. The AWP builds on the mission statements to provide guidance on setting priorities based on facilities and equipment criticality relative to mission, current condition, and long-range plans that will affect real property assets and future maintenance requirements.

4.4.3 Center Master Plan and Other Planning Data. This planning documentation will identify not only future construction, acquisition, and disposal plans for the Center that will ultimately impact maintenance and resource requirements, but will also identify other short- and long-range planning information, such as anticipated civil servant and contractor staffing requirements and opportunities for interservice support agreements. Information such as the expected staffing population is important to the AWP in that it is indicative of the level of work being performed at the Center at any time and can provide justification for adequate maintenance funding.

4.4.4 RCM (PM/PT&I) Database. This database, usually found in the CMMS, is required to develop PM and PT&I funding requirements for the next 5 years, including all labor, parts, materials, and special tools. RCM may identify the most effective maintenance in terms of retaining the highest reliability at the lowest cost. It may even recommend that no maintenance action be taken on specific items, appearing contradictory to traditional maintenance philosophies. The RCM and PM/PT&I databases should provide the following:

a. Inventory of maintainable items.

b. Facility and equipment criticality and condition codes.

c. Specific inspections and maintenance tasks to be performed on each maintainable item of unattended, maintainable collateral equipment. These are periodic tasks to keep equipment items in good operating condition for improved reliability and to maximize their service lives.

d. The parameter (e.g., maximum allowable pressure drop, maximum allowable bearing temperature, recommended time interval between PM/PT&I service) defining when each PM/PT&I task should be performed.

e. The estimated resources required to perform each PM/PT&I task in terms of work hours (by craft), materials, tools, and equipment. The total of these estimated resource requirements becomes the basis for the PM/PT&I portion of the AWP, workforce staffing, and work scheduling. Also, these estimates can be used to balance the program.

f. Specific instructions for obtaining condition assessment information as part of each maintainable collateral equipment PM/PT&I. The information to be recorded includes the condition of the overall item of equipment and, in some cases, of a part or subsystem of the equipment item. Instructions should also define a procedure for describing and documenting the results of the condition assessment.

4.4.5 Facilities/Equipment History Database

4.4.5.1 Concurrent recording within the historical database of the condition of the items receiving PM/PT&I is one important product of the PM and PT&I programs. A continuous inspection program should be established to provide a basis for determining PGM and repair requirements for items such as roofs, doors, walls, and windows that are not included in the PM or PT&I programs.

4.4.5.2 Once the facilities inventory is in place, it should be updated continuously to keep the inventory current and to maintain a detailed record of facilities condition. This is accomplished using the continuous inspection program. Historical files are a repository for all of the information on inventory items that is useful in preparing an AWP. These files shall be structured carefully so that they include all necessary data, including the following:

a. Records of PM and PT&I work accomplished (i.e., identifying work completed, dates of performance, and costs in work hours and dollars).

b. Records of PGM and repair work accomplished (i.e., identifying PGM and repair work done, dates of work performance, and costs in work hours and dollars).

c. Condition assessment information developed during maintenance work.

d. Condition assessment information developed during the continuous inspection program.

e. Designation of candidate items for ROI.

f. Designation of candidate items for disposal or declaring excess.

4.5 Structure and Interrelationship of AWP Elements

4.5.1 Preventive Maintenance. The PM requirements for maintainable collateral equipment items are defined using manufacturers' recommendations, R.S. Means Cost Data or similar guides, historical information, the technical expertise and experience of the maintenance staff, task and periodicity guidance from other Centers for like equipment, and other sources. After defining and summarizing the PM requirements relative to the work standards and identified tasks, their estimated costs in work hours and dollars for a fiscal year will be calculated. These totals define the level of effort (i.e., labor and funds) required to accomplish the unconstrained PM program. Those figures would then be evaluated in terms of projected facilities maintenance funding and labor levels and the estimated requirements for the other elements of the AWP. Such an evaluation is used to establish target resource allocations for the PM program on an annual basis during the 5-year planning period. See Table 2-2 for dollar limitations.

4.5.2 Predictive Testing & Inspection. PT&I involves gathering condition data on potential sources of failure. A PT&I program provides some of the condition data needed to carry on other elements (e.g., PGM or repair) of an AWP. Because it entails a dedicated effort drawing upon facilities resources, PT&I is an element of the AWP. PT&I can greatly impact an AWP because it extends the reach of the inspection program. For example, vibration analysis of a generator might be the basis for either accelerating or deferring a scheduled major overhaul. Or, infrared testing of a roof might indicate the need for small repairs now and avert a major CoF repair project in the future. See Table 2-2 for dollar limitations.

4.5.3 On-line Condition Based Maintenance Monitoring. On-line Condition Based Maintenance

(CBM) Monitoring is the process of remotely monitoring operating parameters of an asset (vibration, temperature, current, voltage, etc.), in order to identify a significant change which is indicative of a developing fault. The use of conditional monitoring allows decisions to be made through expert analysis about whether to perform preventive maintenance, repair, replace, or take other actions to prevent failure and avoid its consequences. Condition monitoring has a unique benefit in that conditions that would shorten normal lifespan can be addressed before they develop into a major failure. On-line CBM Monitoring can be a very expensive undertaking and should only be applied to the most critical assets. Centers should determine the most cost effective approach for meeting their goals. Including this in the AWP, helps focus the effort so it doesn't continue getting deferred because of tactical priorities.

4.5.4 Grounds Care. Grounds care normally is accomplished with a relatively constant level of effort during the growing season. The level of effort can be predicted with a high degree of accuracy. See Table 2-2 for dollar limitations.

4.5.5 Programmed Maintenance

4.5.5.1 PGM work refers to recurring work performed at longer than 1-year cycles and is best laid out in the 5-Year Maintenance Plan. It involves predefined, specific work tasks. PGM work schedules often are determined on the basis of actual conditions, rather than by fixed intervals. Because of this reliance on condition data to schedule PGM tasks, a continuous inspection program that includes PT&I and user input is required. See Table 2-2 for dollar limitations.

4.5.5.2 Condition codes should be established and recorded in the RCM and facilities history databases for each applicable inventory item maintenance function. They should be structured to trigger the identification of candidate PGM work when a certain condition level is recorded through the PT&I and continuous inspection programs.

4.5.5.3 Candidate PGM work can be costed and evaluated for programming in a particular annual program on the basis of projected funding levels. It is a case of analyzing all of the PGM requirements against other AWP requirements and allocating resources based on priorities. Work can be accomplished by civil service employees, incumbent support service contractors (if the work is determined to be within the scope of the contracts), or by a separate new contract.

4.5.6 Repair

4.5.6.1 Repair implies urgency because it involves fixing something broken or failing. It is work planned and executed as a single function, e.g., replacing a boiler or repairing leaking tanks. Repairs can be further divided into two categories: (1) repair as a result of PT&I (scheduled), and (2) repair as a result of breakdowns (unscheduled). Non-CoF repair work should be within the Center Director's funding authority. See Table 2-2 for dollar limitations.

4.5.6.2 Repair requirements are identified from the RCM and continuous inspection programs, including input from users, occupants, and facility maintenance personnel. A clear distinction cannot always be made between PGM and repair. For example, pavement sealing and painting of entire structures are considered PGM, but repairing potholes and spot painting are considered repair. As a rule of thumb, repair usually involves fixing portions of an overall facility or system, whereas PGM involves some restoration of the entire system.

4.5.6.3 Local replacement criteria should be established. For example, barring extenuating circumstances, an item should be a candidate for replacement rather than repair if the repair cost exceeds 50 percent of the replacement cost.

4.5.7 Trouble Calls. TCs address items that break or are damaged unexpectedly. While a facilities maintenance manager uses the historical information in the CMMS to estimate in the AWP the expected level of TC effort, the manager should adjust the estimate upward to reflect inflation and physical plant additions or downward to reflect improvements in the maintenance program and decreases in the size of the physical plant. See Table 2-2 for dollar limitations.

4.5.8 Replacement of Obsolete Items. ROI requirements are identified through a variety of sources, particularly RCM analysis. For example, trends indicating that several same-year, same-model mechanical units used in a particular application are likely to fail in the near future may be indicative that the best course of action would be to replace all of them, regardless of past individual maintenance history; the breakdown of one of several same-model pumps may lead to the discovery that parts are no longer available for that pump; PM inspection reports may identify equipment items failing to meet new electrical code requirements; or manufacturer's data for a newly purchased pump may indicate that similar onsite pumps are no longer parts-supportable. RCM database and equipment history files need to be structured and procedures established to recognize this type of information and to flag the associated equipment item as an ROI candidate. The facilities maintenance manager can then prioritize ROI candidates and evaluate them for replacement on the basis of safety and operational impact. See Table 2-2 for dollar limitations.

4.5.9 Service Requests. Small service requests are often performed by the same organization that performs TC work. While service requests are nonmaintenance work and do not fit within NRC's 2 to 4 percent of CRV suggested funding, small service requests are similar to small TCs in that they consist of minor facilities support work needed to maintain routine installation operations. An analysis of the TCs accomplished and the service request records identifies the relative levels of effort allocated to each of these similar elements of the AWP. Caution should be exercised to ensure that service request work does not take disproportionate precedence over important maintenance work. Normally, outside contractors perform work generated by large service requests. Service request work includes facilities construction and additions costing less than the CoF $1 million threshold (unless the CoF process as outlined in NPR 8820.2 is followed). See Table 2-2 for dollar limitations.

4.5.10 Central Utility Plant Operations and Maintenance. Central utility plant O&M normally requires a nearly constant level of effort (depending on the season), adjusted for inflation, and the addition or deletion of facilities. See Table 2-2 for dollar limitations.

4.5.11 Rehabilitation, Modification, Repair, Construction, and Additions. Rehabilitation, modification, repair, construction, and additions are CoF categories described in NPD 8820.2, NPR 8820.2, and NPD 7330.1.

4.6 5-Year Facilities Maintenance Plan

4.6.1 Facilities maintenance organizations in both the public and private sectors widely accept the concept of an AWP as an aid for both the budgetary and the work-execution processes. The AWP can assist the facilities maintenance manager in establishing goals within projected resources and in planning to meet those goals. The AWP should evolve from a multiyear plan derived from a complete and continuously updated list of facilities requirements as shown in Figure 3-2. Such multiyear planning promotes achieving long-range goals and consistent direction in facilities maintenance management.

4.6.2 The 5-Year Maintenance Plan is based on the total maintenance requirements, which in turn, are based on mission, criticalities, and established standards. This plan provides the necessary information for budget forecasting and initial planning and preparation of the AWP (see section 4.6.1). This procedure ensures that the highest priority of maintenance work is scheduled and not lost in the budgeting process. The plan should provide a balance of RCM to minimize the deferral of maintenance along with a realistic estimate of emergency and routine maintenance and repair. The plan should provide for the management of the DM such that the DM is controlled by a steady reduction of requirements or stabilized within the locally established guidelines of the Center.

4.6.3 Appendix H provides a template for producing 5-Year and Annual Maintenance Plans. The 5-Year Maintenance Plan is the result of a conscious evaluation of the NASA Strategic Plan, Center Master Plan, 5-Year CoF Plan, and mission goals of the Center. A well-developed and up-to-date 5-Year Maintenance Plan ensures that major maintenance repair or replacement is not wasted by the execution of a large CoF project or facility-use change. Further, additional PM and PT&I funding can be programmed in advance to accommodate new growth and mission changes. This will ensure immediate and continued maintenance of new facilities as they come on line, thereby reducing future deterioration and premature failures.

4.7 Facilities Work Requirements

4.7.1 Total Requirements

4.7.1.1 An elusive goal of facilities maintenance managers is to develop and maintain a system to define a complete, unconstrained list of all existing and predictable facilities maintenance work requirements. Such a list should include not only the DM but also current and continuing requirements for PM, PT&I, Grounds Care, PGM, Repair, TCs, ROI, and projections for new work to respond to evolving organizational and facilities maintenance requirements.

4.7.1.2 The total requirements should include estimates of unforeseen work that has a high degree of predictability (e.g., weather-related events, such as thunderstorms and snowstorms). These requirements can easily add up and, unfortunately, are performed at the expense of routine maintenance, thereby increasing the DM. When this unforeseen work is quantified and programmed, it can be used to reduce DM during years when the unforeseen work is light.

4.7.1.3 The total maintenance requirements (shown in Figure 3-2), both identifiable and unforeseen, can be compiled as a list or database to serve as the basis for defining the 5-Year Facilities Maintenance Plan and the AWP. The database would then contain all potential facilities maintenance work. Thus, it should be the task of the facilities maintenance manager to use the database to construct the balanced AWP that most effectively responds to conflicting priorities within programmed resources.

4.7.2 Deferred Maintenance

4.7.2.1 DM is the total of essential, but unfunded, facilities maintenance work necessary to bring Centers to the required facilities maintenance standards. It is work that should be accomplished during the year but cannot be accomplished within available resources. It does not include new construction, additions, or modifications, but does include unfunded CoF repair projects.

4.7.2.2 DM is an excellent indicator of the condition of Center facilities and collateral equipment. It reflects the cumulative effects of underfunding facilities maintenance and repair. Review of DM trends and comparison of DM with the CRV and facilities maintenance funding provide indications of the adequacy of the resources devoted to facilities maintenance.

4.7.2.3 An annual reevaluation of the DM is necessary for the development of the AWP. This not only authenticates the work that continues to be deferred as DM, but it also identifies work items in the DM covering deficiencies that have progressed to the point where they need to be included in the AWP. See Chapter 9, Deferred Maintenance, for a more detailed discussion on DM.

4.8 Resources

4.8.1 While most AWP preparation focuses on defining the requirements and matching those requirements to projected funding levels, the personnel resources required to execute an AWP are also a critical aspect of the planning process. The timely mobilization of personnel with the requisite skills is a complex task. Generally, three categories of personnel are available to execute the AWP: Civil service personnel, support services contractors, and outside contractors.

4.8.2 As the 5-Year Facilities Maintenance Plan evolves, the facilities maintenance manager should explore alternatives for matching projected work with personnel resources. The earlier the manager can define the work requirements, the more efficient mobilization of those resources can be. For example, if the 5-Year Facilities Maintenance Plan indicates that electrical work will exceed current shop resources in three years, the manager can take steps early to adjust the support services contract or identify specific work to be performed by outside contractors.

4.8.3 The construction of new or altered facilities also may increase maintenance work requirements that should be planned for in advance. Otherwise, when the new or expanded facilities are accepted, there may be insufficient maintenance resources to accommodate them. This often leads to premature failures since no maintenance is provided for the new facilities, thereby increasing the life-cycle cost of facilities and equipment. Over time, this can also result in additions to the DM.

4.9 Tracking

4.9.1 Centers should routinely monitor adherence to the AWP by use of AWP tracking reports that show maintenance work plan element actuals compared to the AWP estimates for budget and work completed to date. See Appendix G for additional info.

Chapter 5. Facilities Maintenance Program Execution

5.1 Introduction

5.1.1 This chapter describes the work functions required to execute a maintenance program. These functions begin with work generation and proceed through work reception and tracking, work-order preparation, and work execution. The various steps required to perform these functions are described. They are not meant to present an organizational structure but to include suggested functional work areas required to implement a maintenance program. Additionally, in this chapter, the term "shops" is used to refer to the facilities maintenance workforce, including both civil service employees and, in most cases in NASA, support services contract employees.

5.2 Key Processes Overview

5.2.1 The AWP is the basis for a year's initial work planning. (See Chapter 4, Annual Work Plan.) This plan is augmented with customer requests, identification of new requirements, equipment breakdowns, and other emergent requirements. It is important to document the specific maintenance work items in the AWP and all requests for maintenance, repair, and service work. Work requested is received, processed, and, if approved, converted into a work order as shown in Figure 5-1. Work disapproved is returned to the customer with an explanation or request for clarification. Work that is valid but cannot be accomplished within the immediate resources is then deferred. If it is still valid at the end of the year and cannot be funded, it will be considered for inclusion in next year's AWP or the DM. All documents should be filed and retained in accordance with guidance provided in NPR 1441.1

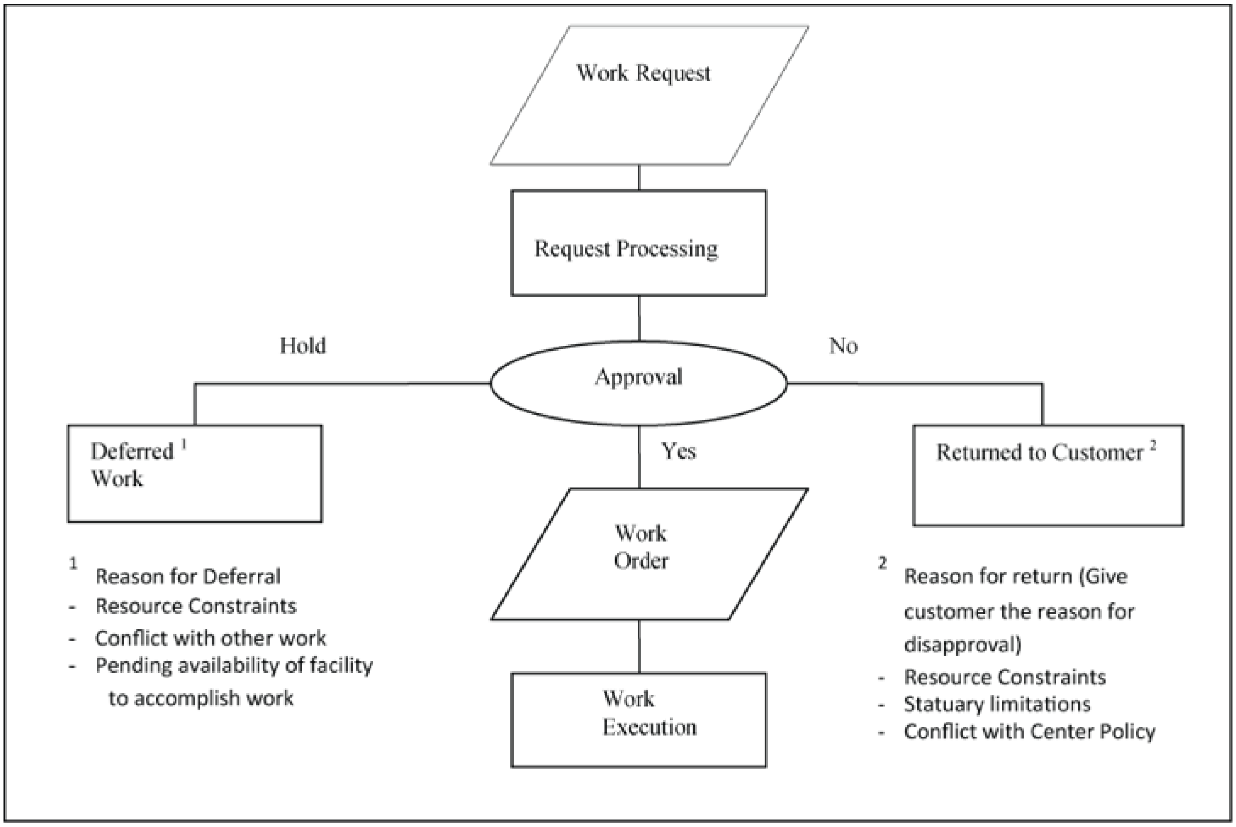


Figure 5-1 Work Request Processing

5.2.2 Centers should have work control systems that receive, classify, identify, estimate, approve, schedule, track, account for, analyze, and report all work throughout the facilities maintenance process, from inception to completion as shown in Figure 5-2. In NASA Centers, the control system utilizes CMMS. It comprises the tools, techniques, checks, management controls, and documentation needed for effectively managing the workflow with an automated system. (See Chapter 6, Facilities Maintenance Management Automation.)

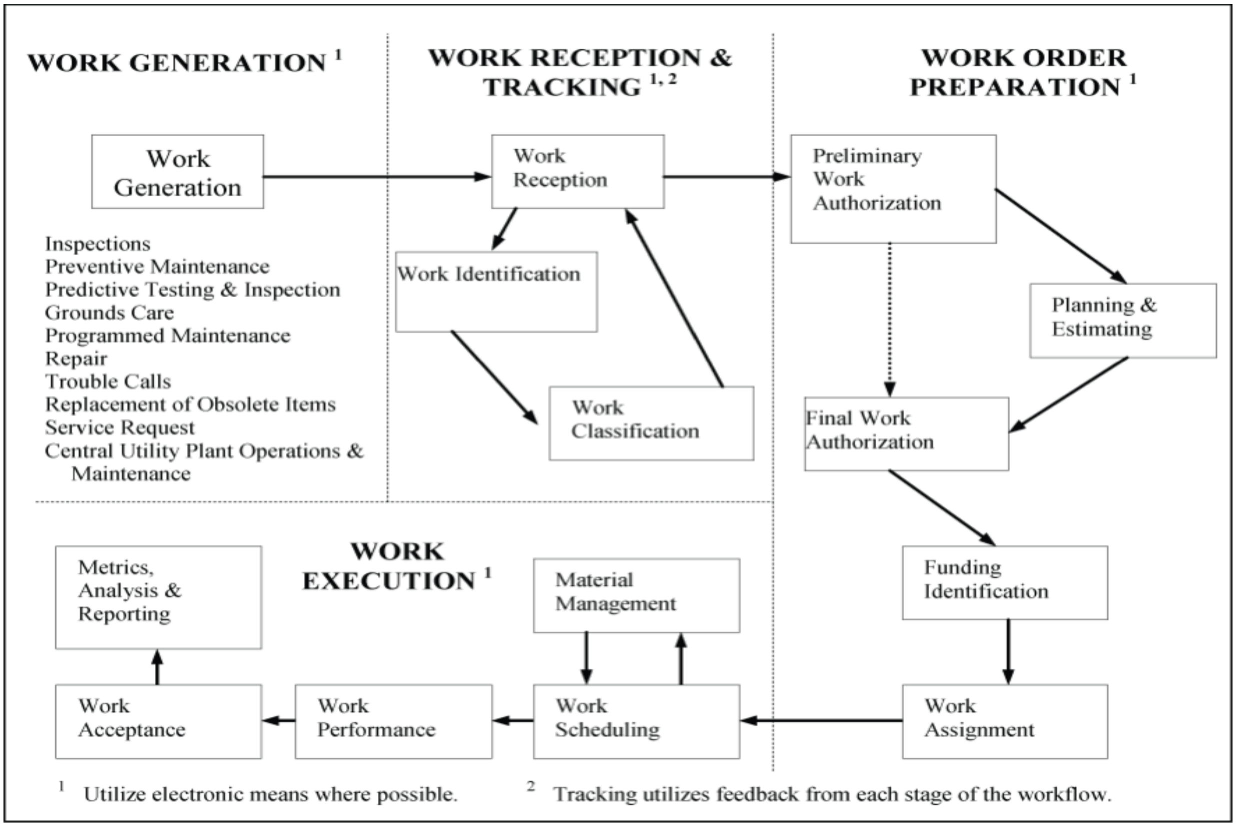


Figure 5-2 Stages in Work Generation, Control, and Performance

5.3 Work Generation

5.3.1 Work generation is the process of determining the maintenance workload in the facilities maintenance management system. A part of work generation is documenting the workload in the CMMS. Facilities maintenance work comprises recurring and nonrecurring maintenance work. Recurring work includes PM, PT&I, grounds care, central utility plant O&M, and the facilities condition assessment program. The recurring maintenance programs, customer needs, and facilities and equipment failures generate nonrecurring maintenance work in most cases.

5.3.2 Facilities Maintenance Work. A significant portion of the facilities maintenance workload results from ownership and inventory. This is largely recurring/repetitive work that can be predicted based on knowledge of the maintainable facilities and collateral equipment and utilizing NASA's RCM program. (See Chapter 7, Reliability Centered Maintenance.) This work forms the basic elements of the AWP. Examples of this work include PM, PT&I, PGM, and recurring work, such as grass cutting and relamping. The scope and extent of these kinds of work are typically defined when a facility is acquired. (See Chapter 8, Reliability Centered Building and Equipment Acceptance.)

5.3.3 Facilities Condition Assessment Program. In effective facilities maintenance programs, most of the facilities maintenance work other than PM and operator maintenance is generated from the facility condition assessment program and predictive testing conducted by or under the auspices of the facilities maintenance organization. Condition assessments are evaluations of Center facilities, including collateral equipment, utilizing continuous inspections, PT&I, and CMMS data. The inspections include those occurring during day-to-day maintenance operations; operator, user, and facility manager inspections; and separate supplemental inspections. The Center's CMMS, TC, and repair data are evaluated as part of the condition assessment to determine trends that can be used in evaluating the condition of a facility and its maintenance program. The facility condition assessments are used to validate and update the Center's AWP, DM, ROI, and 5-Year Plan. Chapter 10, Facilities Maintenance Standards and Actions, describes the condition assessment program and its inspections.

5.3.4 Trouble Calls

5.3.4.1 Normally, TCs are reported to the work reception desk. Operating the work reception desk is one of the functions performed by the work control center (see section 5.4, Work Control Center). It is recognized that at some Centers, the term "trouble call" means anything that is wrong and needs correcting. Therefore TCs coming to a work control center shall be evaluated.

5.3.4.2 Only facilities maintenance and repair items should be included in the facilities program. Other items such as a coffee spill on a carpet, weeds that need to be removed, a floor needing to be cleaned, supplies needed in a restroom, ants or bugs in a desk needing pest control, should be assigned or passed along to the appropriate program. TCs shall be properly coded to maintain records for facilities evaluations and budgets.

5.3.4.3 Although TCs can be placed by anyone, the recommended practice is to designate one individual in each major building or organization as the point of contact for placing TCs. This minimizes duplication of effort and simplifies work tracking. Emergency calls are accepted from anyone. In recognition of the limited scope of work covered by a TC, it is normally not estimated or scheduled, but it is tracked for execution. Appendix D, Figure D-1, is a sample format with data element definitions for a TC ticket that can be used to document and track TCs. This format should be automated to permit entering the request in the CMMS at a computer terminal and automatically issuing the work order to the shops. All documents and records should be filed and retained in accordance with guidance provided in NPR 1441.1.

5.3.5 Service Requests. A service request is new work requested by a customer. It may be either a small job that does not require planning and estimating or a large job that requires planning, estimating, and scheduling. The request may be submitted on a Request for Facilities Maintenance Services form as shown in Appendix D, Figure D-2. The form should be automated for submitting, recording, and processing the request. Normally, service requests are customer funded. All documents and records should be filed and retained in accordance with guidance provided in NPR 1441.1.

5.3.6 Other Requests. Other requests for facilities maintenance work include work not identified as part of the facilities maintenance inspection program. Examples are maintenance deficiencies found during a fire safety inspection or a request for repairs for a problem that has occurred since the last facilities maintenance inspection. These requests should be tracked separately to provide status and execution feedback to the customer and to monitor the effectiveness of the facilities maintenance inspection program.

5.4 Work Control Center

5.4.1 The Work Control Center (WCC) is the nerve center for facilities maintenance management. It is the preferred central location for managing the execution of facilities maintenance work. The following are WCC functions:

a. Receiving and logging work generated from all sources.

b. Assigning a unique identifier or designator to each work item.

c. Assigning initial classifications to the work.

d. Tracking the work as it progresses through the facilities maintenance system.

e. Maintaining records on requested work, inspections, jobs in progress, and completed work.

5.4.2 The work control function may be assigned to any organizational element in the facilities maintenance organization; however, it is suggested that it be assigned directly under the facilities maintenance manager, independent of the shops or planning and estimating functions. It may be staffed and operated by civil service or contract employees. However, if operated by a support services contractor, care should be taken to ensure that the contract specifies detailed performance requirements and that an effective quality-assurance program is maintained. In addition, if the contractor is tasked with operating and maintaining the CMMS, the contract shall provide for direct Government access to the CMMS facilities maintenance management database and report generators. This is required for purposes of queries on work status, analysis of work statistics, preparation of facilities maintenance reports, and facilities maintenance management surveillance. Providing CMMS terminals at designated Government offices will enable the Government to accomplish this.

5.5 Work Reception and Tracking

5.5.1 The major work reception functions, in addition to ensuring that requested work is defined as clearly as circumstances permit, are as follows:

5.5.2 Work Reception. Work reception accepts and records work requirements resulting from the work-generation process. Emergencies are evaluated when they are received in work control and the appropriate action is taken to ensure the emergency situation is stabilized (see section 5.3.4, Trouble Calls). Work reception initiates the administrative control of the work-management data as the work progresses through the maintenance-management system.

5.5.3 Work Identification. Each item of work is given a unique identifier or designator, much like a serial number. This identifier permits tracking the work item through its life cycle of planning, approval as a work order, execution, and historical documentation. The identification scheme should meet the Center's needs. The use of automation simplifies the identification process. For example, CMMS-generated identifiers can be purely sequential numbers because the computer can track all of the attributes such as fiscal year, work classification, and fund source associated with each identification number. The work identifier should not be changed once it is assigned, even if the work is combined with another work item. The computer can provide the cross-reference to the combined identifier.

5.5.4 Work Classification

5.5.4.1 Work classification provides the ability to subject work to the proper levels of review and control and to perform management analyses of the workload. The suggested categories for work classification are discussed below. These categories extend beyond the minimum required for financial accounting and budgeting and provide additional detail for managing the facilities maintenance organization. They are important for managing the workload and understanding where resources are expended.

5.5.4.2 The use of automated systems permits ready accumulation and analysis of the data. Centers may wish to add additional classifications for local use. The following are some methods of classifying work:

a. Funds type.

b. Approval level.

c. Work elements.

d. Special interest.

e. Size.

f. Method of accomplishment.

5.5.4.3 Each method is discussed below. Note that the work classification within any of these categories may be changed during the course of the work planning. Thus, the use of an unchanging, unique identification system, such as described in section 5.5.3, Work Identification, is particularly important.

a. Funds Type. Funds type describes whether the work is reimbursable or nonreimbursable. If the work is reimbursable, the fund citation normally identifies the customer; if it is nonreimbursable, the funds citation normally identifies the appropriation and project or program. Funds type is not the same as funds source because funds source does not identify the specific reimbursable customer, program, or project.

b. Approval Level. Approval level identifies who has the authority to approve the work. Specific approval levels are determined by Center policy and, when documented, become a local "standard." Common practice is to delegate work-approval authority to permit routine and recurring work approval at the lowest responsible level in the facilities maintenance organization. Some work, such as TCs of an emergency or routine nature, may be preapproved within specific guidelines. The designation of individuals authorized to approve work based on a hierarchy of cost, urgency, or other management considerations should be documented in the WCC.

c. Work Elements. Work element identifies which of the following standard work elements (see section 1.4, Facilities Maintenance Definitions) applies and is useful in analyzing the relationships described in section 3.11.5, Work Element Relationships:

(1) PM and PM Finds.

(2) PT&I and PT&I Finds.

(3) Grounds Care.

(4) PGM.

(5) Repair.

(6) TC.

(7) ROI.

(8) Service Request.

(9) Central Utility Plant O&M.

d. Special Interest. This classification identifies and permits the accumulation of statistics on the work performed in support of specific or special interest programs or initiatives, or work not otherwise accounted for by special funding programs. Examples include the following:

(1) Energy Conservation.

(2) Safety.

(3) Environmental Compliance.

(4) Handicapped Access.

(5) Community Relations.

(6) Bridge Inspections. (See section 10.5.3.6 for additional guidance for Bridge Inspections.)

e. Size. Work size, grouped in dollar or level-of-effort ranges, indicates the amount of management effort required. This classification is useful in determining the type of funds used, the approval level, and the method of accomplishment.

f. Method of Accomplishment. The method of accomplishment identifies whether the work will be accomplished by civil service employees, by established support service contractors (if the work is determined to be within the contract scope), or under a separate, new contract.

5.5.5 Work-Tracking System

5.5.5.1 A work-tracking system enables work tracking from the time the work enters the facilities maintenance system until it is either disapproved or completed. A Center's CMMS is the tool to be utilized for work tracking and status reporting.

5.5.5.2 Work status refers to the state of work progress in the facilities maintenance system as it proceeds from generation to completion. It includes the identification of actions completed, actions pending, responsible parties, and milestone dates. Work status is a key element in maintaining good customer relations by making it possible to provide responsive feedback to the customer. The CMMS should provide the means for documenting and reviewing work status. A suggested way of accomplishing this is assigning status codes or milestone data to each item of work. Personnel with CMMS access can then examine the status information and use it when preparing reports.

5.5.5.3 At a minimum, the CMMS should contain the estimated or actual start and completion dates and identify the responsible party for each of the following milestones in the facilities maintenance process:

a. Work Reception (including classification and identification phases).

b. Planning and Estimating.

c. Final Authorization.

d. Scheduling.

e. Material Management.

f. Work Performance.

g. Final Inspection.

5.5.5.4 Not all milestones are applicable to all work. For example, for TCs, only status information related to work reception and work performance would be tracked. Data for final authorization, scheduling, material, work performance, and final inspection would not be recorded for requests for cost estimates only. The shop load plan and master schedule typically contain material and work performance status information for scheduled work.

5.6 Work Order Preparation

5.6.1 The work order (Appendix D, Figure D-3) is the document directing facilities maintenance work execution once the requested work has been approved. Normally, planners and estimators (P&E) prepare work orders. An exception is the TC ticket discussed in section 5.6.2 below. The work order includes an estimate of the resources required to perform the job (work hours by craft, materials, equipment, tools, and specialized support); the steps or tasks required performing the job; and documentation of coordination and outages required. It should also include safety requirements, job priority, job accounting information, and any other information required by management and the shops to schedule, perform, and evaluate the work. Safety requirements should include, but not be limited to, appropriate safety items such as confined space entry, lockout/tag out, oxygen depletion, chemical or explosive handling, fall protection, safety training and certification requirements, and any other specific safety requirements associated with the task to be accomplished under the work order. (Refer to NPR 8715.3, section 8.3) The work-order form should be automated (included in the CMMS).

5.6.2 For small jobs, typically less than 20 work hours, the cost of detailed planning and estimating and scheduling may exceed the benefit. However, the craft supervisor responsible for the TC shall review the TC task and specify safety requirements such as those in section 5.6.1 above. In these cases, use of a TC ticket format (Appendix D, Figure D-1) is suggested. This ticket should be automated (included in the CMMS).

5.6.3 Work Review, Screening, and Authorization. Work review, screening, and authorization is typically a two-step process. Requests for work receive an initial screening prior to job planning and estimating. The second step provides final approval and release of the planned and estimated work order for scheduling. In the case of TCs and work on small jobs, this may be accomplished in one step, within the decision authority of the work reception desk, bypassing planning and estimating. In Figure 5-2, the dotted arrow connecting the preliminary and final work authorization blocks symbolizes this.

5.6.3.1 Preliminary Work Authorization. Authorization is the process by which facilities maintenance work is approved for performance. This may be a phased process in which preliminary approval is obtained prior to detailed planning and estimating as shown in Figure 5-2. The preliminary screening determines if requested work should be accepted for continued processing, rejected, returned to the customer for additional information, or given preliminary approval for detailed planning and estimating. For work of limited scope, it may also serve as the final authorization if funds are available.

5.6.3.2 Final Authorization

a. Once the work order is planned and estimated, it is forwarded for final authorization. The review process checks the work order to ensure that it is responsive; complies with applicable safety, health, environmental, and security standards; is within the scope of the AWP; and is within funding and approval levels. This review normally takes place in the facilities maintenance organization. However, on complex or critical jobs, the customer should review the work order to check its technical adequacy.

b. When reviews are completed and funds are available, the work order is authorized for execution by the appropriate approving official. (See section 5.5.4.3b, Approval Level.)

5.6.4 Planning and Estimating. Center work control systems should contain a planning and estimating function. This function provides the detailed definition of maintenance tasks or steps to be taken, the resources required (material, equipment, tools, and labor), and special considerations such as safety outages and coordination. It supports budgeting, resource allocation, and work performance decision processes and provides a benchmark for work performance evaluation. A part of the planning and estimating function is the process of developing the work order documenting the detailed work tasks and preparing an estimate of the resources required. The work order includes statements of the job steps or phases for each craft, a list of the required materials, and the identification of special tools or equipment needed. It includes an estimate of the time required for each phase, copies of sketches or drawings, the identification of safety requirements and required outages, and allowances for staging, travel, site cleanup, and other job-related actions. For contracted work, the work order is replaced by the Statement of Work (SOW) that includes sketches, a job specification or performance work statement, and a cost estimate appropriate to the contract form used. Planning and estimating provide the basis for the following:

a. Deciding to approve, disapprove, or defer work.

b. Developing costs and budget estimates.

c. Determining the method of accomplishment.

d. Preparing the shop load plan, the master schedule, and the shop schedule.

e. Evaluating shop or contractor performance and efficiency.

f. Establishing contract costs.

5.6.4.1 Facilities Maintenance Standards. Facilities maintenance standards are discussed in Chapter 10, Facilities Maintenance Standards and Actions. They establish the level and condition in which facilities and equipment are maintained. Standards serve as guides in determining the facilities maintenance work. P&Es determine the job tasks by comparing existing conditions with the prescribed maintenance standards and then selecting job tasks (maintenance actions) that bring the facility up to those standards.

5.6.4.2 Performance Standards. Planning and estimating is a skill requiring substantial knowledge of the crafts and methods involved. However, it is unlikely that one person is expert in all aspects of a craft. There are a number of estimating guides and standards available to assist P&Es in preparing work orders and estimates (see list in Appendix C). Equipment manufacturers also produce standards. All standards should be applied with care, taking into consideration local conditions, area cost factors, and experience. However, use of cost-estimating guides and standards is encouraged as a means of improving the quality, reliability, and consistency of estimates.

5.6.4.3 Work Planning. Work planning consists of identifying specific tasks to be performed, phasing those tasks, identifying the skills and crafts required for the tasks, and specifying the material and equipment for the tasks. It includes identifying specific health and safety requirements, coordination, outages, equipment availability, and other constraining parameters. As with the other P&E functions, established standards also can provide assistance in work planning. Table 5-1 provides examples of selected facilities maintenance tasks, with the cycle or interval between performances of the task suggested for use by NASA Centers. The intervals listed assume average conditions. Centers may adjust these to suit local use and environmental conditions.

Table 5-1 Selected Facilities Maintenance Cycles

Task **Examples**	**Suggested Cycle (Years)**
Painting	
Interior	
Office areas, corridors, restrooms	5
Industrial areas, high bays, hangars, machine shops, clean rooms	15
Exterior	
Personnel doors and jambs, overhead doors	4
Steel siding, piping, exhausters, air dryers	8
Wind tunnel shells, vacuum spheres, high- pressure gas bottles	10
Pavement	
Asphalt	
Sealcoat, slurry coat	6-8
Overlay (1-1/2 in.)	
Roads	15
Parking lots	20
Restriping	
Roads	2-4
Parking lots	5-8
Concrete	
Joint sealant, replace 10%/year	10
Crack repairs, average linear feet/year	2
Sidewalks	
Replace broken curbs, 10% of total/year	10

Replace broken/deteriorated sidewalks, 10% of total ft2/year	10
Roofing	
Floodcoat built-up roofs, 10% of total/year	10
Refasten flashing, cut and patch bubbles, clean/repair gutters/downspouts, 20%/year	5

Note: These cycles should be adjusted locally based on historical experience and environmental conditions.

5.6.4.4 Cost Estimating. Cost estimates are developed by multiplying unit labor, equipment, and material costs by job task quantities, and adding the appropriate burden rates for overhead and indirect costs. The exact type of the cost estimate depends on its intended use. For example, overhead costs, profit, bond expense, and taxes required for contract work are omitted for in-house work. Cost estimates can be classified based on the amount of detail considered in their preparation as scoping estimates or final estimates. Cost estimates normally are prepared using industry-accepted standards (see R.S. Means Company, Inc., Appendix C) or historical data. These factors are discussed in the following sections:

a. Scoping Estimate. This estimate is based on broad unit cost guidelines; it does not involve a detailed job plan or design. It is not appropriate as the basis for job performance evaluation or contract negotiations. The scoping estimate is used in situations that do not call for details and high accuracy. Examples include estimates for developing budgets, estimates to aid in screening work packages to be included in the DM, or preliminary estimates for initial decision making on a request for work.

b. Final Estimate. This estimate is based on detailed job plans (as found in a facilities maintenance work order) or final contract plans and specifications. It is more reliable than a scoping estimate. Job performance evaluations, contract negotiations, or other exacting uses should be based on a final estimate because it reflects a detailed knowledge of the individual facilities maintenance actions and the resources required. A final estimate can substitute for a scoping estimate, but it is more costly to produce. c. Historical Estimate. The historical estimate uses prior performance of the maintenance tasks involved as its basis. It can have excellent validity, provided the new job tasks and methods are comparable to the historical database used in preparing the estimate. There is minimal cost in developing a historical estimate. However, care should be taken to ensure that the historical data applies to the current job scope. Periodic validation of historically based estimates against estimating standards is necessary to ensure that they are in line with accepted standards. This type of estimate is especially valuable for repetitive or recurring tasks such as PM.

5.6.4.5 Funding Identification. Funding identification covers the identification, allocation, and authorization of the proper funds. It includes Center operating funds, customer reimbursable funds, and special funds.

5.6.4.6 Each work order includes a funding citation and accounting data identifying which funds to charge for the work. In some cases, funds are customer furnished (reimbursable). In others, funds are specifically budgeted by the Center for facilities maintenance. When work is customer funded, appropriate funding documents should be furnished in a timely manner to ensure that work is not delayed unnecessarily. A correct funding citation ensures that the proper account is charged and provides valid accounting data for management reporting.

5.6.4.7 Customer-funded work could be time sensitive to support a given mission. As a result, a suspense system should be in place to track work requests waiting for funding so as to preclude unnecessary administrative delays and customer dissatisfaction.

5.6.5 Priority Systems

5.6.5.1 The work-order system should make provision for differing work priorities. This allows high-priority work to be done first while managing all work to ensure its accomplishment in accordance with Center needs. Table 5-2 shows a sample priority system. The priority is normally determined as part of the work-review process. It guides material procurement, scheduling, and work execution.

Table 5-2 Sample Priority System

General Maintenance Work Priority System	
Priority/Description	**Narrative**
1. Emergency	Safety of life or property threatened; immediate mission impact; loss of utilities. Begin immediately; divert resources as necessary; overtime may be authorized.
2. Urgent	Maintenance or repair work required for continued facility operation; should be completed to ensure continuous operation of the facility and to restore healthful environment. Not a life-threatening emergency. Respond upon completion of current work but within a specified period of time (specified by local Center, such as same day or within 4 hours).
3. Priority	Work that is to support the mission on a priority basis or to meet project deadlines. Complete in order of receipt with mission work taking priority.
4. Routine	The facilities maintenance work can be scheduled routinely within the capability of the facilities maintenance organization. Facilities work is subject to availability of resources and may be consolidated by facility or zone or as directed to obtain efficiency of operation.
5. Discretionary	Work that is desired but not essential to protect, preserve, or restore facilities and equipment; typically, new work that is not tied to a specific mission milestone.
6. Deferred	Work that may be safely, operationally, and economically postponed. The work should be done, but cannot be scheduled because of higher priority work, funds shortage, work site access, or conditions outside the control of the maintenance organization. The work may be reclassified if conditions permit or included in the DM.

5.6.5.2 Priorities require periodic review to ensure that they conform to organization and mission needs. When using a CMMS, a special designator can be added to the database to help track high-visibility projects. An example would be safety items from an inspection. While these items could fall in several of the priorities shown in Table 5-2, they may need to be tracked as a group for accomplishment. A special local code designation will ensure that they can be readily highlighted for management purposes.

5.7 Work Execution

5.7.1 After planning and approval comes work execution, which includes the following:

a. Obtaining material, tools, and equipment.

b. Scheduling the work.

c. Performing the work.

d. Monitoring work accomplishment.

e. Final inspection.

f. Reporting work completion.

5.7.2 Material Management

5.7.2.1 Material management includes ordering, stocking, storing, staging, issuing, and receiving material for use on work orders. Material management can be performed by an element of the facilities maintenance organization, a central supply department not a part of the facilities maintenance organization, or a combination of these. (Tool management may be assigned to the same organization that has the material management responsibility.) Working from material requirements lists prepared by P&Es as part of the work order, the material manager is responsible for obtaining the material and advising the work schedulers when the material is available for job accomplishment. In the case of PM, other recurring and standing work, and TCs, material managers should have available, or provide ready access to, frequently used parts and supplies. This material may be preexpended shelf stock, or it may be available from vendors by use of a Government credit card or from vendors who are accessible under quick procurement instruments such as blanket purchase agreements.

5.7.2.2 The range and depth of material stocked should be based on historical demand, standby items (spares for critical systems), and projected requirements for future work. Inventory high and low limits should be established based on use rates, economic reorder quantities, and delivery times to minimize investment in inventory. Where advantageous, alternate material management strategies can be used such as "just-in-time" parts delivery. The benefits available are the reduction in inventory costs associated with storage, management, pilferage, and cannibalization. Many automated maintenance management systems include support for computerized material management functions. Bar coding is used extensively in material management to speed data entry and reduce data-entry errors.

5.7.3 Scheduling. Scheduling work orders is necessary to ensure a balanced flow of work to the shops in accordance with priorities, external factors (such as weather), and operational considerations. It facilitates optimum use of resources and provides information to optimize the distribution of shop staffing by craft. The AWP identifies resource levels for each facilities maintenance program work element. It also identifies major work items to a fiscal year. However, most facilities maintenance work orders, including Service Requests, will not have individual visibility in the AWP. They are included as part of a level-of-effort resource allocation for the fiscal year. Within the fiscal year, work scheduling may be done at three levels: the shop load plan, the master schedule, and the shop schedule. The relationship of these plans is depicted in Figure 5-3.

5.7.3.1 Shop Load Plan

a. The shop load plan is usually maintained by the organizational element responsible for the work control function. It schedules work to the shops on a periodic basis, typically quarterly, and looks several quarters into the future. This plan reflects the backlog of estimated work as defined in the AWP for the current and following year. Work may be added or shifted among the schedule periods as new work is identified or work priorities change, although the plan for the next schedule period should be fairly stable. A Center may find it convenient to divide the next quarter's shop load plan into a short-term (30-day) plan and a midterm (following 60 days) plan for closer scheduling.

b. The shop load plan considers available production resources (i.e., work hours by craft, tools and special equipment, and contract limitations), availability of items to be maintained such as times for shutdowns and external factors such as weather. It considers work already scheduled or in progress; allowances for recurring work such as PM, PT&I, and TCs; and long-lead-time material requirements. With these factors in mind, the planner loads work orders into each quarter to balance the workload for each maintenance resource and to ensure optimum employment of that resource within the work-order priority system.

c. The shop load plan also facilitates analyzing the workforce composition compared to the workload. It identifies personnel or skill shortages or excesses and gives facilities maintenance managers time to respond. Close coordination with the master schedule regarding the status of work in progress is required. Appendix D, Figure D-6, contains a sample shop load plan.

5.7.3.2 Master Schedule. The master schedule is maintained in the shop organization, usually under the direction of the senior shop supervisor. Within the scheduling framework of the shop load plan, it is the week-by-week shop schedule, identifying jobs to individual shops. It covers a shorter time period than the shop load plan, typically 6-to-12 weeks. Work orders are initially placed in the master schedule and noted as awaiting material. When material is available and the job is ready to start, it is firmly scheduled. Close coordination with the shop load plan and shop schedules is required. The master schedule changes as priorities are adjusted, new work is identified, and material status changes. The shop load plan can be used as a model for the master schedule. Appendix D, Figure D-7, contains a sample master schedule.

5.7.3.3 Shop Schedule. Within the framework of the master schedule, the shop schedule is used to schedule the day-by-day work orders and craft personnel within a shop. It is maintained by the shop supervisor and used to assign work and track progress. The shop schedule can be patterned after the master schedule. Appendix D, Figure D-8, includes a sample shop schedule.

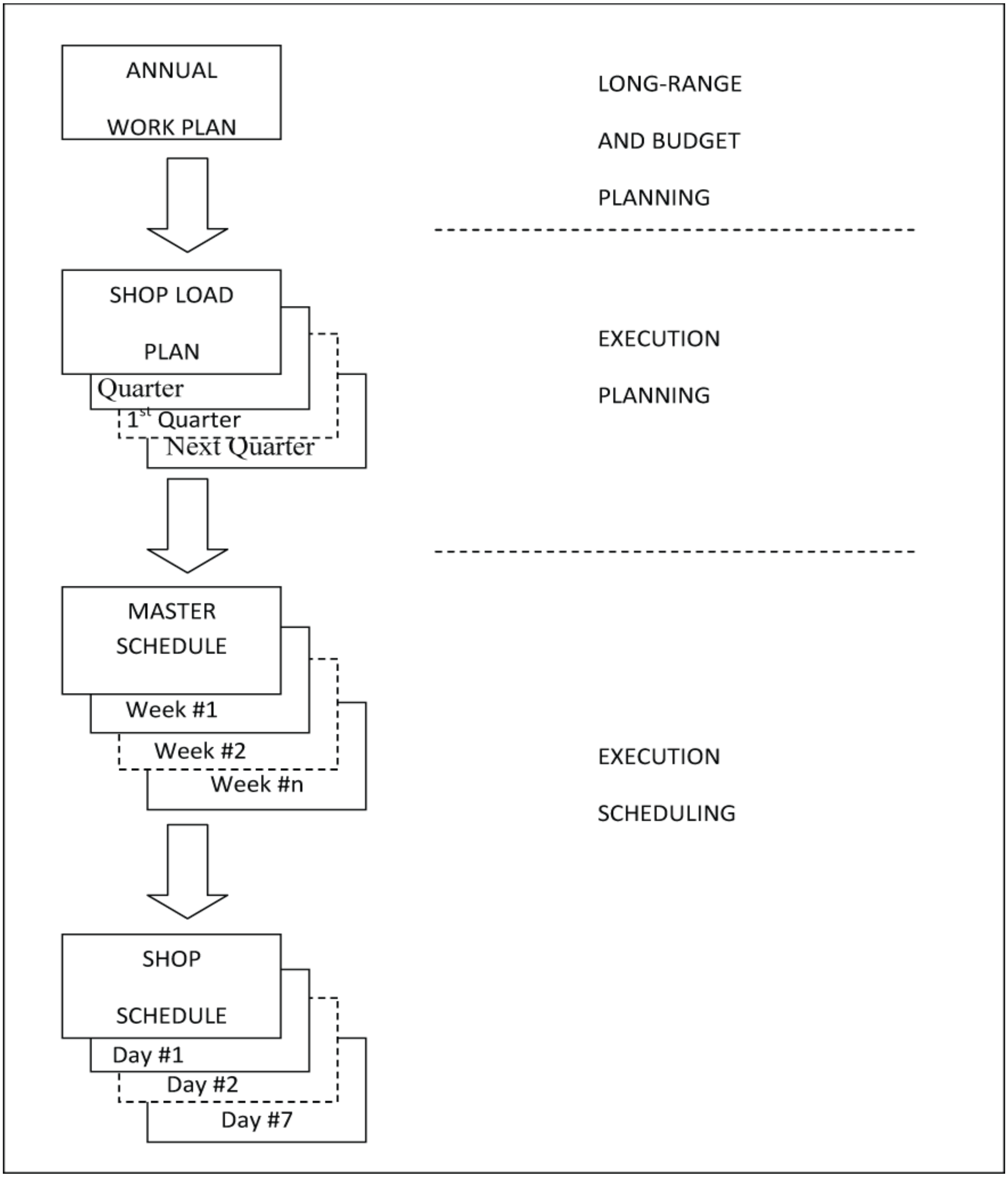


Figure 5-3 Work Scheduling Relationships

5.7.3.4 Schedule Automation. The shop load plan, master schedule, and shop schedule are all based on the same database, differing slightly in the information displayed and the period covered. It is possible to maintain a single scheduling system on a networked CMMS working from a shared database, provided the CMMS has the necessary scheduling features. This gives the added advantage of automatically coordinating the schedules and changes at all levels of management. Some CMMSs may have an integrated scheduling module (See Appendix E, section 8, Work Management, for a sample work scheduling module) that provides functional equivalents to the shop load plan, the master schedule, and the shop schedules that can be used to prepare detailed project schedules for the more complex work projects.

5.7.3.5 Scheduling Considerations

a. The following work types should be considered in scheduling work performance after discussing with customer:

(1) Preventive Maintenance. PM (including PT&I) provides the baseline workload for the facilities maintenance shops. An effective PM program minimizes the need for TCs and repair. Efficiencies can be obtained by using employees dedicated to PM work because they become familiar with the equipment. PM work orders should be scheduled and grouped by facility or geographical area to minimize travel.

(2) One-time Work Orders. Work orders for one-time jobs require the greatest scheduling coordination and management effort. This is due to the unique requirements of each job.

(3) Repetitive Work Orders. These are similar to PM jobs in that they are a predictable level of effort and frequently are a continuing or repeating work requirement such as Grounds Care, street sweeping, relamping, and Central Utility Plant Operations Maintenance. Like PM, they are scheduled as part of the baseline shop workload.

(4) Trouble Calls. TCs of an emergency nature are assigned to the shop most qualified to address the problem and take precedence over any other work, including work in progress. This TC work proceeds until the situation is corrected or stabilized. To complete the correction of a problem, such as a water-main break, may require the subsequent issue of a repair work order. Most routine TCs can be accomplished by the work center assigned to perform small jobs, as discussed in section 3.4.8, Work Grouping. Equipping key facilities maintenance workers with radios, cell phones, or pagers can enhance their response and productivity.

(5) Small Jobs. Small jobs, typically those requiring less than 20 work hours and issued on TC tickets, are normally worked on a first-come, first-served basis, subject to the availability of material. Because they can represent a fairly constant level of effort and normally involve routine methods and materials, it is common practice to have a shop dedicated to this size work.

b. When a TC shop is used, it should be able to complete about 90 percent of TCs and small work orders; the remaining 10 percent are used as fill-in work for other shops. This shop should be sized to be able to complete urgent (nonemergency) work within the day and non-emergency routine work within 5 to10 workdays of receipt, subject to material availability. The size and type of the TC shop depends on local conditions and historical data such as volume, nature of work, geographic proximity, and availability of transportation and materials. In the interest of efficiency and minimizing travel time, small jobs may be grouped by building or geographic area. The use of dedicated, radio-equipped vehicles stocked with preexpended, commonly used facilities maintenance material and proper tools will improve productivity.

5.7.4 Work Performance. When all material is available and coordination and scheduling are completed, the work order is executed. Work proceeds to completion in accordance with the approved work order. However, the shops should be free to communicate with the P&Es to resolve questions about the work. If field conditions differ substantially from the work order or the effort and material required differ substantially from the work-order estimate, the supervisor should check with the P&E for an amendment or clarification and review the priority and schedule to ensure that completion dates will not be missed. The threshold for a work-order amendment is based on Center management needs; however, a 20-percent or greater increase from the estimate is suggested as a deviation requiring a work-order amendment.

5.7.4.1 Quality Control. This function is a responsibility of the organization executing the work. Shop supervisors usually have the primary responsibility for work quality control based on policies and procedures of the organization responsible for the work.

5.7.4.2 Quality Assurance. Regardless of who performs work, it should be subject to inspections for quality and compliance with work requirements. See section 3.4.11, Quality Assurance, and Chapter 12, Contract Support, for details on quality assurance programs.

5.7.5 Work Acceptance

5.7.5.1 Final Inspection. Final inspections are performed as appropriate depending on the nature and size of the completed work. If the work to be inspected is for a customer, the customer should participate in the final inspection to accept the work. If customer expectation goes beyond the work-order scope, the job should be reviewed promptly for resolution.

5.7.5.2 Defective Work. Defective or rejected work occurs for a number of reasons, including poor workmanship, an incorrectly scoped and prepared work order, defective material, or poorly defined customer requirements.

a. When defective work is discovered, it shall be corrected by the performing organization to satisfy the work requirements.

b. Correction of safety-related deficiencies shall likewise be accomplished immediately by the performing organization.

5.7.5.3 Rework Causes and Correction. A decision to rework a job should be based on cost-benefit considerations, including Center operational commitments, cost to rework the job, expected added benefit as a result of rework, and availability of resources. Separate work orders should be established to accumulate rework data. Other situations that would require rework are jobs that do not meet safety regulations and/or other mandatory laws. The evaluation process should address causes of defective work and methods of reducing rework. Remedial actions may include revising internal procedures such as quality control procedures, providing additional employee training and skill development, changing material specifications, adding early material acceptance inspections, revising facilities maintenance standards and requirements, and increasing customer involvement with work order preparation and approval. Each Center should have a policy for handling rework. In cases where rework of contract efforts is being considered, the cognizant procurement office shall be consulted.

a. In general, the customer should not have to bear the cost of facilities maintenance rework resulting from errors by another party, and the Government should not have to bear the cost of rework that results from a contractor's error or negligence.

b. Inspection clauses shall be included in contracts to require the contractor to perform rework at the contractor's own expense, to reimburse the Government for rework performed by the Government, or to reduce contractor payments for rework not performed. The amount of rework should be considered as an evaluation factor when determining contract award fees.

5.7.5.4 Completion Reporting. When the work has been completed and accepted, a completion report is submitted. This reporting involves recording in the CMMS the work completion, the resources used, and closing the work order. Care shall be exercised to identify and record all of the work accomplished, particularly when the initial request is sketchy or incomplete. The labor and material used are recorded for record and accounting purposes. The results are recorded in the facility or equipment history files, and evaluation action is initiated. The information reported should include unanticipated conditions encountered, a concise description of the work accomplished, and additional material used but not listed in the work order. Work order forms (including TC tickets) should include space for the technician to enter completion data. Shop supervisors should review the completion data. All documents and records should be filed and retained in accordance with guidance provided in NPR 1441.1.

5.7.6 Management Information (Metrics, Analysis, and Reporting). The loop on the maintenance management system is closed by evaluating completed work to compare actual work performance with estimates for quality assurance (whether performed in-house or by contract) and to ensure conformance with work-order instructions, standards, customer satisfaction, and accuracy of completed work for costing and reporting purposes. It appraises the performance of each element of the facilities maintenance management system and initiates corrective action when needed. Thus, evaluation provides for the continuous improvement of workflow through the organization and the CMMS.

5.7.6.1 Determining Information Requirements. Reports, charts, and other displays that do not directly contribute to facilities maintenance management, or other Centers' or NASA Headquarters' needs are a waste of scarce resources. Therefore, information should be collected, processed, or documented to support a clear need. A summary of recommended facilities maintenance indicators and reports is given in section 5.7.6.3, Analysis, Reports, and Records. Centers should specify the information to be displayed and distributed in their reports. Data that is not required to support management functions should not be collected or maintained. Over time, data loses its value to the manager. For example, a summary of last year's TCs by month and by trade would be more useful to the manager at this point than a voluminous record of all the actual calls. Managers shall develop archiving plans to reduce the volume of outdated data in the active database while retaining those elements of the data that are useful for trending and analysis.

a. The archived data also shall be maintained for possible future use in providing historical data for performance-based contracts.

5.7.6.2 Covered Functions. As discussed in Chapter 6, Facilities Maintenance Management Automation, the Center's CMMS includes day-to-day work records and historical data. This electronic data and information from other electronic systems that may or may not interface with the CMMS can be used to cover the full range of facilities maintenance functions.

5.7.6.3 Analysis, Reports, and Records

a. One major function of a CMMS is to provide maintenance data for automated analysis and reports to support management needs. The analysis should examine both status and trends. Graphical presentation of numerical data and trends will aid managers in understanding the implications of the data. The following is a discussion of several types of analyses and reports that may be important to a facilities maintenance manager.

b. Information provided in the reports is available for analysis with metrics, as discussed in section 3.11, Management Indicators, and Appendix G. This analysis is a portion of the facilities maintenance program shown in Figure 3-2.

c. The following descriptions are intentionally unstructured. Managers should select and tailor them to fit local data and needs.

(1) Status Reports. The following reports provide a "snapshot" of where maintenance operations are at a given time:

(a) Inventory. This report could include displays of facilities and maintainable collateral equipment inventory statistics, use, user, age profiles, and similar data. Significant portions of this information can be used in space management and planning.

(b) Status of Funds. This type of report would provide up-to-date status of funds by source, including amounts authorized, reserved, and obligated. It would also include a comparison of planned versus actual expenditure rates.

(c) Status of Work. This report, which should be obtained from CMMS data, could provide the status of all work submitted to the facilities maintenance organization. It would show a short title for the work, work-generation date, who or which organizational element has action, and an estimated completion date, if applicable. Variations of this report could include arranging the information by customer, work classification, status (grouping work items with similar status into one report), or facility. It could take the form of a history of selected work items showing work progress through the facilities maintenance system.

(d) Status of Major Projects. This report would include major undertakings such as CoF projects, major facilities maintenance projects, and projects of special Center interest. The reports should reflect cost estimates, project milestones, and progress against those milestones.

(e) AWP Execution Status. The CMMS should provide a display of annual resource requirements and the status for the major line items within each element that makes up the AWP. This includes PM, PT&I, Grounds Care, PGM, repair, TC, ROI, Service Requests, Central Utilities Plant Operations & Maintenance, CoF, and related factors. It also should display current budget estimates for out-years and the DM. Status of DM. This report should give the facilities maintenance manager an update on the amount of DM by facility and facility classification (Mission Critical, Mission Support, and Center Support) and total for the Center. It should also include the amount of DM by system, such as roofs; heating, ventilating, and air conditioning (HVAC) systems; structures; roads; and other systems. This will facilitate long-range programming in the 5-Year Maintenance Plan and provide information for the NASA Headquarters metrics.

(a) Contracts. This report could include the status of contracts, contract execution, pending and executed modifications, and delivery orders. This should cover support service, one-time facilities maintenance, and CoF contracts.

(b) Materials. This report could include the status of materials inventory, orders, and jobs awaiting material.

(2) Work Performance Reports

(a) Work Input. Reports on work input include statistics on work generation and the characteristics of that work. They may include information on service requests (arranged and tabulated by date of request, customer, special interest area, facility number, and craft) and work orders generated by the inspection program (PM inspections, PT&I, continuous inspections, operator inspections, and specialized inspections), PM program, PGM program, repair program, and TCs.

(b) Work Execution. Reports on work execution include information on shop schedules, planned work, job status, estimated versus actual job performance, delayed or late jobs, and related performance indicators. They also include progress on the PM, PGM, PT&I, and condition assessment programs.

(c) Utilities. This report would contain information on production, consumption, costs, conservation measures and targets, and related factors such as weather profiles.

(d) Other Reports. This category is a catchall for those reports not directly tied to facilities maintenance but closely related to or supporting facilities maintenance efforts. Examples include personnel status, correspondence tickler and tracking system, and automation system statistics.

Chapter 6. Facilities Maintenance Management Automation

6.1 Introduction

6.1.1 A requirement exists for facilities maintenance managers throughout NASA to use modern maintenance systems and methods to control their work activities, account for resources they are provided, and monitor and report work execution through the full use of various industry standard metrics and other management indicators. Because of the scope, complexity, and high value of the NASA Center facility inventories, all NASA Centers and Component Facilities use CMMS.

6.1.2 All NASA Centers and Component Facilities use a common CMMS throughout the Agency to streamline and simplify reporting, consolidate and centrally manage seat licenses, and reduce CMMS costs. NASA Centers and Component Facilities that are acquiring new CMMS systems shall purchase the common system.

6.1.3 All data, including all resource costs (labor, materials), equipment, and incidentals, should be available for Government use and retention for historical purposes, regardless of whom, Government or contractor, is responsible for populating and maintaining the database. Where a contractor operates the CMMS, it shall be made clear in the contractor's contract that the CMMS maintenance data is Government property and will be turned over to the Government at the end of the contract.

6.2 CMMS Requirements and Usage

6.2.1 Chapter 3, Facilities Maintenance Management, discusses the functions, processes, management concepts, and system of controls recommended for facilities maintenance. Centers should evaluate their maintenance management data requirements and establish their electronic data needs prior to investigating and acquiring a new common system version CMMS or modifying an existing common system version CMMS. Centers should acquire only what is required to accomplish the maintenance organization goals.

6.2.2 Centers shall budget resources to initially populate the systems (modules) and to maintain the CMMS data.

6.2.3 Centers shall use their CMMS for day-to-day operations and management of the Center's maintenance program to be cost effective. Periodic review of the CMMS data should be made to keep the system abreast of current requirements, deleting unnecessary data entries and adding new ones as required.

6.3 Automated System Interfaces

6.3.1 Facilities maintenance management automation brings the benefits of automation to facilities maintenance functions and processes. Chapter 3, Facilities Maintenance Management, not only discusses functions recommended for facilities maintenance but also identifies closely related supporting functions and processes. The CMMS should directly support or interface with existing related automated systems such as the financial accounting module of the System Application Products (SAP), RCM databases, and personnel administration systems.

6.4 CMMS Essential Functions

6.4.1 The Center's CMMS shall support the major functions discussed in the following sections as they apply to facilities maintenance. Information entered in the functional areas of the CMMS is critical for the day-to-day maintenance operations, management of the Center's maintenance program, providing data to support the budget process, and providing historical information critical for use in performance-based contracting.

6.4.2 In all of the functional areas, items entered should contain key management information such as criticality codes, condition codes, and downtime associated with an item. Descriptive nomenclature of items shall be standardized to permit the sorting of data.

6.4.3 If data is available in separate databases, Centers shall provide a link between those and the CMMS to collect total maintenance costs, including material and subcontract costs. See Appendix E for typical monitor screen CMMS images used for various functions.

6.4.3.1 Managing Facilities and Equipment. This function contains the facilities maintenance processes and procedures to be used in managing the facilities maintenance workload. In addition to the automation of the administrative processing associated with maintenance management, the major advantage of having a CMMS is the capability to process a large amount of data to identify trends that would not be readily apparent by reviewing individual work orders. This processing provides the data needed for benchmarking and for preparing facility condition assessments. A major effort of the CMMS is tying together the various RCM activities. This function also includes facilities planning and processes normally associated with CoF funding and shall support those portions of CoF work that are a logical outgrowth of the facilities maintenance effort, such as repair, modification, or rehabilitation. The following sections highlight files/modules that are a part of most CMMSs and that are used in managing maintenance programs.

6.4.3.2 Facility/Equipment Inventory. These data files/modules contain a detailed inventory of all facilities and maintainable collateral equipment subject to the facilities maintenance management system (and could include other information, if needed, for planning, space management, or accounting purposes). For facilities, these files/modules include information such as identifier, size, cost, date acquired, category codes, uses, location, users, material condition codes, and other similar information. For equipment, they include nomenclature, manufacturer, part number, cost, serial number, date acquired, size, location, identifiers to major system or use, warranty, specific facilities maintenance requirements, life expectancy, and similar information. Current and reliable data will enhance analysis and budget preparation and may be needed in developing customer charges under NASA's Cost Accounting System. Tables 3-1 and 3-2 list representative data elements.

6.4.3.3 Work Input, Control, and Scheduling. This data file/module contains information on work requested by customers, work generated internally, and work status as it proceeds from requirement identification to work completion or request disapproval. It includes information on customer, cost estimate, funding, scheduling for execution, and execution status for each work order. This data provides the ability to track facilities projects, requests for facilities maintenance, TCs, and SRs. The CMMS may include the capability to receive work requests and accomplish the approval process electronically. Centers should establish a Web site on the local Intranet to provide customers with a link to work status reports and any other appropriate maintenance information. A selective combination of electronic and voice interface with customers provides the best support. Appendix D provides sample forms for use in facilities maintenance, including several in CMMS database formats.

6.4.3.4 Reliability Centered Maintenance. This data file/module contains information on facilities and equipment criticality codes, maintenance requirements, and schedules. It contains data on required maintenance actions for equipment and facilities predictive testing test points, diagnostic aids, references to or excerpts from original equipment installation and O&M manuals and equipment drawings, schedules, frequency, materials, safety requirements, and related procedures. Linked with the inventory, the combined data files can be used to create PT&I schedules, PM schedules, and work orders or PM task descriptions for use by technicians and mechanics. Criticality codes will be recorded and updated on an iterative basis as missions and environments change. The CMMS should include the ability to analyze PT&I results, process parameters (including normal baseline temperature, pressure, and flow readings), diagnose the possible causes of abnormal readings, project trends in test results, and schedule facilities maintenance actions or further inspection based on the trends. PT&I "finds" and their corrective work shall be identified in the CMMS to ensure that priority work is highlighted and tracked. Information and data in the PT&I database should be made available to maintenance engineers, managers, and craftspersons through the CMMS. This will ensure that pertinent information needed for maintenance and failure analysis is readily available.

6.4.3.5 Correlation of Maintenance Data. Benefits can be realized by correlation of various metrics, trends, and data from the PM, PT&I, and other databases. An important function of a CMMS is to automate that correlation, with limit alarms, as new input is made for followup action.

6.4.3.6 Continuous Inspection. This data file/module contains information for the continuous inspection program. (See section 10.5, Continuous Inspection.) It should include facilities maintenance standards, facility condition inspection schedules, and inspection and test procedures. Linked with the inventory, it can be used to create the inspection orders and work sheets used by inspectors. The results of inspections from PT&I, PMs, operators, facility managers, facility users, and facility condition inspections should be entered in the CMMS history files for use in the FCA.

6.4.3.7 Facility/Equipment History. These data files/module contain summaries of the maintenance histories of the facilities and collateral equipment. They contain summaries of PM, PGM, repairs, TC, rehabilitation, modifications, additions, construction, and other work affecting the configuration or condition of the items. They include completed and canceled work orders. These files also include the current material condition assessment of each item, derived from the continuous inspection program, for use in developing the FCA and the DM. By using the CMMS to tie the FCA to the continuous inspection program and specifically to the PT&I database, condition assessments will be more current and equipment condition information, short- and long-term repair and replacement requirements, and DM information are available to the facilities maintenance managers and craftspersons when needed. The maintenance history records can be used to support proactive maintenance techniques, such as root-cause failure analysis and reliability engineering.

6.4.4 Additional Database Functions. The functions discussed above are typically found in NASA Center CMMSs. The functions in the following paragraphs may be included in the CMMS or, in most cases, in separate databases that should be interfaced with the Center's CMMS.

6.4.4.1 Providing Utilities Services. Utilities services are essential to a Center in that no operations would be possible without the electric power, steam, water, and related services they provide. Utilities also represent a major cost of operations. Computer support, both in terms of direct control of system components and analyses to identify losses in efficiency, is vital to energy conservation efforts as well as to effective system maintenance and management for optimal reliability and cost efficiency. The utilities data file/module contains detailed information on utilities consumption, distribution, use, metering, allocation to users, and cost. It could include modeling capability and linkage to utility control systems.

6.4.4.2 Assistance in Formulating and Administering Contracts. Contracts provide the majority of Center facilities support services. In many cases this extends to both recurring facilities maintenance efforts and one-time, specific facilities maintenance projects. Computerized support for contract preparation and administration in support of the Contracting Officer is essential for a well-managed facilities maintenance program. This data file/module contains information on contracts supporting the broad spectrum of facilities maintenance management as required by the Contracting Officer, Contracting Officer's Representative (COR), and Quality Assurance Evaluators (QAE). With other database files, it provides a picture of each contractor's past performance, current loading, and planned work. It could include information on specifications, Government-furnished property, quality assurance, payment processing, delivery orders issued, schedules, and related matters. It should cover both contracts for specific facilities maintenance requirements and support services contracts.

6.4.4.3 Developing Budgets and Performing Cost Analyses. Management is largely the process of allocating and directing resources to accomplish an organization's goals. The functions listed above focus on facilities maintenance work and work methods. The budget and cost analysis functions obtain and track resources. In an environment of competition for limited resources to perform an ever-expanding workload, managers need sophisticated tools and techniques to account for resources, demonstrate efficient use of resources, and prepare persuasive requests for future resource allocations. Computer support to perform in-depth analyses of requirements is essential to meet this end. Refer also to Chapter 2, Resources Management.

6.4.4.4 Reports and Metrics. This function can be customized for each Center's use as part of the CMMS, provided other key information, such as complete cost information and project management data, is available. Management should define for all maintenance and operations the management information required from the contractor and civil service staff so that results/performance-oriented reports and metrics can be developed in the CMMS and tracked. This will ensure that the Government can analyze and evaluate performance and overall maintenance management at that Center.

6.4.4.5 Job Estimating. This data file may contain shop or flat rate guides, estimating tables, work performance (time and motion) standards, such as engineered performance standards, labor and material rates, and local cost and time factors in computer-usable form. Sources include commercial services, Government-developed standards, developed Facilities Engineering Job Estimating (FEJE) software, and local experience. After the P&Es define the work elements comprising a job, they can use this data file to estimate task and work order crafts, materials, equipment, tools, time, and costs.

6.4.4.6 Tools/Materials. Tools and material data files typically contain the inventory of centrally managed tools and materials for use in support of facilities maintenance. The material data file aids in assigning materials to work orders, supports the preparation of material requisitions, tracks the receipt of materials on order, and documents related information. Also, these data files record accountability data for shop tools and equipment.

6.4.4.7 Environment. This data file contains environmental information, including permits, licenses, the history of violations and citations, potential hazards, environmental compliance and related actions underway, and tracking of work or materials of special environmental interest. For example, it might include data on polychlorinated biphenyl (PCB) or asbestos hazards. This file can track the disposal of hazardous waste and hazardous materials or the need for and processing of renewals of discharge permits. Environmental Protection Agency (EPA) rules require detailed records on the management of ozone-depleting substances such as CFCs and hydrochlorofluorocarbons (HCFCs) used as refrigerants. These records can be accommodated readily in a computerized database.

6.4.4.8 Space Management/Planning. This data file typically includes user name and user data for each facility, space within the facility, or other managed asset. It may include other information for use in managing the space, such as configuration, utilities services, finishes, furnishings, environment, communications, assigned function or task, environment, communications, and accounting information.

6.4.4.9 Facility Graphic Documentation and Configuration Control

a. Computer Aided Design and Drafting (CADD), Geographic Information System (GIS), Building Information Model (BIM), and similar mapping and facilities management systems permit the electronic management of spatial data and related attributes for large bases, facilities, or individual buildings. This data can include maps, drawings, photos, and other documentation. Many of these systems offer a three-dimensional model of a facility plus associated databases that together provide a powerful facilities engineering configuration management and decision support environment. For example, a GIS for a facility could include data describing precise location of buildings, streets, parking, sidewalks and underground utilities networks (water, gas, electricity, sewage, storm drainage). Modern implementations of these spatial data technologies, such as GIS, fully integrate numerous discrete map features and their attributes. This integration allows visualization and analysis such as traffic volume, pavement condition, utility capacity, and landscaping.

b. The Environmental Systems Research Institute (ESRI) GIS system is a well-known and very powerful spatial data management and analysis tool. This suite of tools has been site licensed by NASA and is available for use by all Centers. The ESRI GIS environment is best known for managing plant-level data; however, it may also be used to manage building interior data. Alternatively, the tool that is best known for building-level design modeling for construction is AutoDesk's REVIT. Both of these products support digitization, attribution of features, overlaid display, and analysis of various data. These technologies hold great promise for facilities maintenance applications, such as improved efficiencies in locating specific equipment.

c. Spatial data documentation can include references to electronic data files such as: digitized manual drawings, manufacturers' shop drawings, as-built drawings, and drawings prepared at the Center. Master plan documentation is another example of the use of this information. Centers should require the submission of all drawings, particularly those for facilities projects, in an electronic format that is compatible with the spatial data management environment they chose. Also, Centers should consider digitizing or scanning existing drawings and documents for inclusion in their electronic spatial data management environment.

6.4.4.10 Providing Management Support. Management support functions provide the routine internal organizational, administrative, and overhead processes. They include functions related to internal administrative support, document tracking, and personnel accounting performed within the facilities maintenance organization. While the internal management support functions do not interface directly with the facilities maintenance customers, shortcomings in this area directly impact customer support. Dealing with largely administrative matters, management support function productivity can improve through automation. Well-established computer software programs are available for these areas. However, automation of management support and administrative functions is outside the scope of this NPR.

6.5 CMMS Optional Capabilities

6.5.1 The following functions may be integrated into a center's CMMS or may be provided by other software packages that interface with CMMS or stand alone.

6.5.1.1 Peripheral Systems. There are peripheral systems that can be integrated into the CMMS to enhance facilities maintenance operations. These systems can be more efficient, reduce paperwork, and provide more accurate and complete records in accomplishing maintenance tasks. The selection of a system should be based on the specific maintenance requirements, a cost study, and resource availability. The following are some systems that could be considered.

a. Bar Coding Systems. There are a number of bar coding systems available that can be employed in a Center's facilities maintenance program. These systems vary from the simple identification of an equipment item to sophisticated systems that permit input and downloading of data. Systems are available that permit bar code tags to include such things as the equipment item's history and its preventive maintenance program. These tags are updated along with the CMMS as changes take place, thereby, providing current status at any time. Systems include software that shall be integrated into the Center's CMMS and handheld bar code readers (terminals) with high-contrast liquid crystal displays (LCD) and a keyboard system that can be used by the technician performing the work. Systems may include a beeper subsystem that confirms scanner and keyboard entries and alerts the operator of error conditions.

b. Radio-frequency identification (RFID) is the wireless, noncontact use of radio frequency electromagnetic fields to transfer data for automatically identifying and tracking tags attached to objects. The tags contain electronically stored information. Some tags are powered by and read at short ranges (a few meters) via magnetic fields (electromagnetic induction). Others use a local power source, such as a battery, or have no battery but collect energy from the interrogating electromagnetic field, and then act as a passive transponder to emit microwaves or UHF radio waves (i.e., electromagnetic radiation at high frequencies). Battery-powered tags may operate at hundreds of meters. Unlike a barcode, the tag does not necessarily need to be within line of sight of the reader and may be embedded in the tracked object.

(1) RFID tags can be attached to cash, clothing, everyday possessions, or even implanted within people. The possibility of reading personally-linked information without consent has raised privacy concerns. RFID tags are not new technology, but they are fairly new in the facilities arena. In 2011, less than 10% of the construction industry had implemented some form of RFID-enabled asset management system, experts estimated. When RFID tag readers are readily available through a smart phone application, the cost will drop significantly, at which time RFID Tags will start to replace Barcodes for equipment identification and information.

(2) In one system, a technician's daily schedule and task instructions are downloaded from the CMMS into a handheld terminal and given to the craft person at the start of the shift. When the technician arrives at the work site, the equipment bar code tag is scanned. This registers the arrival time and displays the equipment item maintenance functions to be performed. As each work item is completed, the technician checks it off using the terminal keyboard. This process continues until all functions have been completed. Any comments are entered, and the equipment bar code tag is scanned again to record the completion time. The technician then proceeds to the next work location

and goes through the same scenario. When the day's work is completed, the handheld terminal is returned for downloading into the CMMS where the equipment files are electronically updated. The next day's work schedule and instructions are then downloaded to the handheld terminal for use on the next shift where the process is repeated.

(3) Another system utilizes a radio frequency or a cellular digital system to communicate with the Center's CMMS. In this system, a technician is given a handheld terminal at the start of the shift. A paper copy of the day's work schedule is provided to the technician or the schedule has been downloaded from the CMMS into the handheld terminal. When the technician arrives at the work site, the equipment bar code tag is scanned. Using the bar code tag identification the handheld terminal is connected by radio frequency, or a cellular digital system, to the CMMS where the equipment item's history and the day's work functions can be displayed on the handheld terminal's LCD, as needed. As work is completed, the information is entered in the handheld terminal by the technician and through the wireless system recorded in the CMMS. With this system, the real time status of assigned work is recorded in the CMMS for review at any time.

c. Handheld Tablet Computers. This is another CMMS peripheral system that is available for use in a Center's maintenance program. This is a wireless system where information flows to and from the Center's CMMS. The system could be used to eliminate paper-based work orders, particularly those for TCs, small SRs, and minor repair jobs. This would reduce the workload on the work control center and the technicians. With this system, the technician receives work orders, work order changes, and updates electronically. The technician reports work start electronically, and when work is completed, the completion report and comments are entered electronically. Because information flows wirelessly to and from the CMMS, the work control center sees the exact status of every assigned work order, from assignment through work start to completion. At the end of a technician's shift, the handheld computer is returned for the next shifts' use.

d. Quality Assurance Database. At least one NASA Center has developed software that assists QA evaluators (QAEs) in monitoring performance-based contracts (Payment Analysis and Support System developed by Johnson Space Center (JSC)). Typically, QAEs inspect and evaluate the contractor's performance using Surveillance Guides associated with each contract line item number. Summary results are entered into the database by portable data collectors, and the program tabulates all entries and calculates deductions for unsatisfactory work and work not performed. The advantages of using this and similar databases are labor reduction by reducing redundant operations and mathematical calculations and by maintaining good contract documentation without the paper.

Chapter 7. Reliability Centered Maintenance

7.1 Introduction

7.1.1 Refer to the NASA Reliability Centered Maintenance Guide for Facilities and Collateral Equipment for a more extensive discussion and detailed information on RCM than that provided in this document.

7.1.2 RCM is the process used to determine the most effective approach to maintenance. It involves identifying actions that, when taken, will reduce the probability of failure and that are the most cost effective. It seeks the optimal mix of proactive maintenance and reactive maintenance. RCM is an ongoing process that gathers data from operating systems' performance and uses this data to improve design and future maintenance. These maintenance strategies, rather than being applied independently, are integrated to take advantage of their respective strengths to optimize facility and equipment operability and efficiency within the given constraints.

7.1.3 The RCM philosophy employs proactive maintenance and reactive maintenance techniques in an integrated manner to increase the probability that a machine or component will function in the required manner over its design life cycle. Proactive maintenance practices includes PM and PGM. Reactive maintenance includes repair or run to fail. The goal of the philosophy is to provide the stated function of the facility, with the required reliability and availability at the lowest cost. RCM is data driven and requires that maintenance decisions be based on maintenance requirements supported by sound technical and economic justification. As with any philosophy, there are many paths or processes that lead to a final goal. This is especially true for RCM, where the consequences of failure can vary dramatically.

7.1.4 NASA has adopted a streamlined approach to the traditional or rigorous RCM process practiced in some industries. This is due to the high-analysis cost of the rigorous approach, the relatively low impact of failure of most facilities systems, the type of systems and components maintained, and the amount of redundant systems in place. Underlying NASA's RCM approach is the concept that maintenance actions should result in real benefits in terms of improved safety, required uninterrupted operational capability, and reduced life-cycle cost. It recognizes that unnecessary maintenance is counterproductive and costly and can lead to an increased chance of failure.

7.2 RCM Principles

7.2.1 The primary principles upon which RCM is based are the following:

a. RCM is function oriented. It seeks to preserve system or equipment function, not just operability for operability's sake. Redundancy of function through multiple equipment improves functional reliability but increases life-cycle cost in terms of procurement and operating costs.

b. RCM is system focused. It is more concerned with maintaining system function than individual component function.

c. RCM is reliability centered. It treats failure statistics in an actuarial manner. The relationship between operating age and the failures experienced is important. RCM is not overly concerned with simple failure rate; it seeks to know the conditional probability of failure at specific ages (the probability that failure will occur in each given operating age bracket).

d. RCM acknowledges design limitations. Its objective is to maintain the inherent reliability of the equipment design, recognizing that changes in inherent reliability are the province of design rather than maintenance. Maintenance can, at best, only achieve and maintain the level provided for by design. However, RCM recognizes that maintenance feedback can improve on the original design. In addition, RCM recognizes that a difference often exists between the perceived design life and the intrinsic or actual design life and addresses this through the Age Exploration (AE) process.

e. RCM is driven by safety and economics. Safety shall be ensured at any cost; thereafter, cost-effectiveness becomes the criterion.

f. RCM defines failure as any unsatisfactory condition. Therefore, failure may be either a loss of function (operation ceases) or a loss of acceptable quality (operation continues).

g. RCM uses a logic tree to screen maintenance tasks. This provides a consistent approach to the maintenance of all types of equipment. (See Figure 7-1.)

h. RCM tasks shall be applicable, address the failure mode, and consider the failure mode characteristics.

i. RCM tasks shall be effective, reduce the probability of failure, and be cost effective.

j. RCM acknowledges two types of maintenance tasks and run-to-failure. The tasks are interval time- or cycle-based and condition-based. In RCM, run-to-failure is a conscious decision and is acceptable for some equipment.

k. RCM is a living system. It gathers data from the results achieved and feeds this data back to improve design and future maintenance. This feedback is an important part of the Proactive Maintenance element of the RCM program.

7.3 Requirements Analysis

7.3.1 Using RCM facilitates developing maintenance standards for ensuring, even in the procurement and installation phases, that a system meets its designed reliability or availability. RCM determines maintenance requirements by considering the following questions:

a. What does the system do? What is its function?

b. What failures are likely to occur?

c. What are the likely consequences of failure?

d. What can be done to reduce the probability of the failure, identify the onset of failure, or reduce the consequences of the failure?

7.3.2 Figure 7-1 provides a decision logic tree for use in RCM analysis to determine the type of maintenance appropriate for a given maintainable facilities equipment item. Note that the logic, as presented, results in a decision in the bottom blocks concerning whether a particular piece of equipment should be reactively maintained ("Accept Risk" and "Install Redundant Units"), PMed ("Define PM Task and Schedule"), or predictively maintained ("Define PT&I Task and Schedule").

7.4 Failure

7.4.1 Failure is the cessation of proper function or performance. RCM examines failure at several levels: the system level, subsystem level, component level, and sometimes even the parts level. The maintenance approach shall be based on a clear understanding of the consequences of failure at each level. For example, a failed lamp on a control panel may have little effect on overall system performance. However, several combined, minor components in degraded conditions could collectively cause a failure of the entire system.

7.4.2 Identify the System Functions. This step involves examining the capability or purpose of the system. Some items, such as a circulating pump, perform an on-line function (constantly circulating a fluid); their operational state can be determined immediately. Other items, such as a sump pump, perform an off-line function (intermittently evacuating a fluid when its level rises); their condition can be ascertained only through an operational test or check. Functions may be active, such as pumping a fluid, or passive, such as containing a fluid. Also, functions may be hidden, in which case there is no immediate indication of a failure. This typically applies to an emergency or protective system such as a circuit breaker that operates only in the case of a short circuit (electrical failure of another system or component).

7.4.3 Identify Failures. The proactive approach to maintenance analysis identifies potential system failures and ways to prevent them. Proactive maintenance, along with human observations during normal operations or maintenance tasks, also identifies prefailure conditions that indicate when a failure is imminent. (The latter is a basis for selecting PT&I applications.) Table 7-1 is a list of failure codes that may be used to identify recurring problems by category. These will provide a means of identifying areas, systems, and equipment where root cause failure or other proactive analysis may be applied. The CMMS and work order form shall include fields for failure codes to maintain historical data.

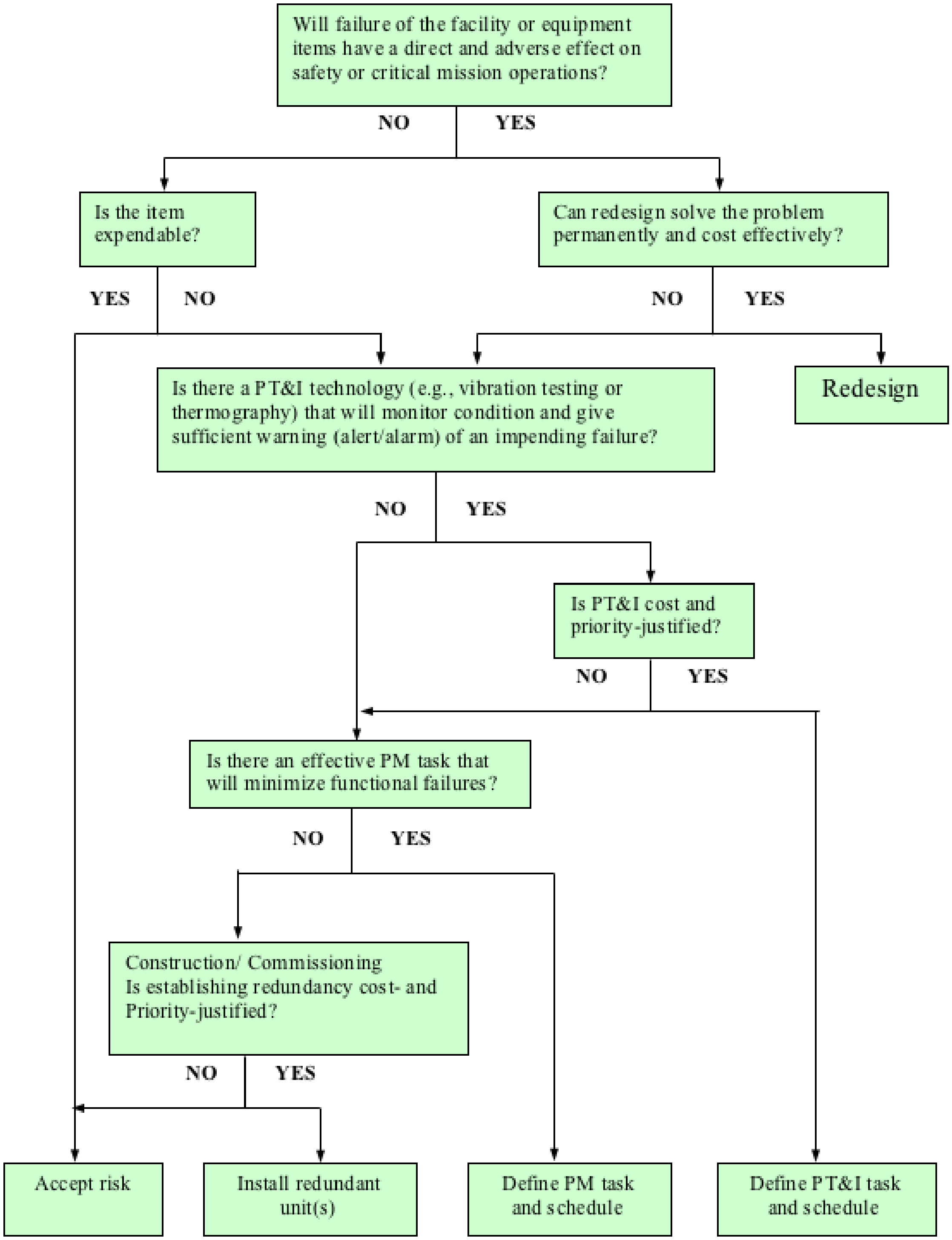


Figure 7-1 Reliability Centered Maintenance (RCM) Decision Logic Tree

Table 7-1 Failed Equipment Codes

CATEGORY	CODE		CATEGORY	CODE		CATEGORY	CODE
Drain	DRAN		Power supply	PSPL			
Engine	ENGN		Pressure switch	PSWC			

Elevator	LVTR		Pulley	PULL			
EMCS	EMCS		Pump	PUMP			
Bearings	BRGS		Enclosure	NCLS		Regulator	RGLT
Belts	BLTS		Evaporator	EVAP		Rheostat	RSTT
Breaker	BRKR		Fastener	FSNR		Roof	ROOF
Cable, power	CABL		Filter	FLTR		Seal	SEAL
Capacitor	CPTR		Flashing	FLSH		Shell	SHLL
Commutator	CMTR		Gear	GEAR		Shaft	SHFT
Compressor	CPRS		Generator	GNTR		Starter	STRT
Computer	CPTR		Humidistat	HSTT		Stator	STTR
Condenser	CNDN		Impeller	IMPL		Support/base	SPPT
Connector	CNTR		Inductor	NDCT		Switch	SWCH
Controller	CNTL		Light	LGHT		Thermistor	THMS
Cooler, swamp	COLS		Logic, PLC	PLOG		Timer	TMER
Cooling Coil	COIL		Lubrication	LUBE		Transformer	TRAN
Coupling	CPLG		Meter	METR		Tube, boiler	TUBE
Crane	CRNE		Motor	MOTR		Valve	VLVE
Damper	DMPR		Packing	PCKG		Winding	WNDG
Door, power	PDOR		Pipe	PIPE		Window	WIND
			Piston	PSTN			

7.4.4 Identify the Consequences of Failure. The most important consequence of failure is a threat to safety. Next, is a threat to the environment or mission accomplishment (operating capability). The RCM analysis should pay close attention to the consequences of the failure of infrequently used, off-line equipment and hidden function failures. Also, it should consider the benefit (reduced consequences of a failure) of redundant systems.

7.4.5 Identify the Failure Process. Determining the methods and root causes of failures provides insight into ways to detect or avoid failures. The examination, which investigates the cause of the problem and not just its effect, should consider factors such as wear, overload, fatigue, or other processes.

7.4.6 Verify the System. Before efforts are expended on a system, it is important to verify that the system was installed or is being used as originally designed. This review of the design and maintenance support information may reveal the root cause of a past or anticipated problem. Although the existing design may have been correct, the installation, while functional, may have been improper, or there may have been latent manufacturing defects. These deficiencies should be discovered and corrected by the contractor during the acceptance process, before the equipment is accepted by the Government and the contractor leaves the job site. If, after acceptance, the installation is still under warranty, the problem may be resolved without an additional expenditure of NASA resources. Changes in the intended use of equipment can also create problems leading to excessive wear and premature failure.

7.4.7 Modify the System. Redesigning the system to eliminate the weakness may be the most desirable solution since it can eliminate a potential cost. However, redesign may not be possible in many facilities maintenance situations.

7.4.8 Define the Maintenance Task. The following factors should be considered when defining the maintenance task:

a. Once it has been determined that the failure of a facility or equipment item will have a direct effect on the safety or mission operation and redesign cannot improve its reliability, then a PT&I, PM, or PGM task or combination of tasks should be identified that will lessen the chances or consequences of a failure. Where applicable, predictive technologies should be used to monitor the condition of the facility or equipment. If the technology or local expertise is not available, a preventive maintenance program is normally applicable.

b. Maintenance tasks can be time directed (e.g., every 8 weeks), condition directed (e.g., when pH is greater than 7.3), or inspection directed (e.g., if a component is found worn). A particular bearing can be monitored for vibration (PT&I), routinely lubricated and checked (PM), or replaced prior to its expected failure point (PGM).

c. The total system should be evaluated to ensure that all the individual tasks maintain the system at the same degree of reliability. The tasks should also be grouped to ensure that they can be executed in the most economical manner. This may be accomplished by grouping multiple tasks on an individual equipment item or by grouping like tasks on numerous items of equipment in a given facility or zone of several facilities.

7.4.9 Install Redundant Unit(s). Situations exist where, despite all effective maintenance efforts, the risk of a potential failure is still unacceptable. Very critical areas such as a mission control or communication center may require uninterrupted facility equipment to maintain power or climatic control. The criticality may preclude even shutdown for maintenance purposes. In these situations, redundancy is justified and recommended. The problem may be corrected through additional distribution or switching of power or ventilation ducts, provided the system can accept the additional loads. The need for a redundant system should be determined before the situation becomes critical. This will preclude premature failure resulting from a lack of maintenance on a system that cannot be shut down. Often, the loss to the mission would be of much greater cost than the redundant system. This need requires close coordination and communication with the customer.

7.4.10 Accept the Risk. It may be that further safety or environmental precautions are not possible or that the economic or operational cost of a failure is insignificant or substantially less than the cost of any effective redesign or maintenance procedure. In the former case, the accepted risk should be identified and quantified, and all parties concerned should be made aware of the risk and appropriate recovery procedures. In the latter situation, it does not make business sense to implement a PM or PGM task. This philosophy is known as "run-to-failure."

7.5 RCM Program Benefits

7.5.1 Safety. Per NPD 8700.1, NASA Policy for Safety and Mission Success, NASA policy is to "Avoid loss of life, personal injury or illness, property loss or damage, or environmental harm from any of its activities and ensure safe and healthful conditions for persons working at or visiting NASA facilitiesâ?¦." By its very features, including analysis, monitoring, taking decisive action on systems before they become problematic, and thorough documentation, RCM is highly supportive of and an integral part of the NASA safety policy.

7.5.2 Reliability. RCM places great emphasis on improving equipment reliability, principally through the feedback of maintenance experience and equipment condition data to facility planners, designers, facilities maintenance managers, craftspersons, and manufacturers. This information is instrumental in continually upgrading the specifications for equipment to provide increased reliability. The increased reliability that comes from RCM leads to fewer equipment failures and, therefore, greater availability for mission support and lower maintenance costs.

7.5.3 Cost. Due to the initial investment required in obtaining the technological tools, training, and equipment condition baselines, a new RCM program typically results in a short-term increase in maintenance costs. This increase is relatively short lived. The cost of repair decreases as failures are prevented and preventive maintenance tasks are replaced by condition monitoring. The net effect is a reduction of both repair and total maintenance cost. Often, energy savings are also realized from the use of PT&I techniques.

7.5.4 Scheduling. The ability of a condition-monitoring program to forecast maintenance provides time for planning, obtaining replacement parts, and arranging environmental and operating conditions before the maintenance is done. PT&I eliminates unnecessary maintenance performed by a time-scheduled maintenance program, which tends to be driven by the minimum "safe" intervals between maintenance tasks. Additionally, a principal advantage of RCM is that it obtains the maximum use from equipment. With RCM, equipment replacement is based on equipment conditionâ?"not on the calendar. This condition-based approach to maintenance thereby extends the operating life of the properly maintained facility and its equipment.

7.5.5 Efficiency/Productivity. Safety is the primary concern of RCM. The second most important concern is cost-effectiveness. Cost-effectiveness takes into consideration the priority or mission criticality and then matches a level of cost appropriate to that priority. The flexibility of the RCM approach to maintenance ensures that the proper type of maintenance is performed on equipment when it is needed. Maintenance that is not cost effective is identified and not performed.

7.6 Impact of RCM on the Facilities Life Cycle

7.6.1 The facilities life cycle is often divided into two broad stages, acquisition (planning, design, construction, and acceptance) and operations. RCM affects all phases of the acquisition and operations stages to some degree, as shown in Table 7-2. Decisions made early in the acquisition cycle profoundly affect the life-cycle cost of a facility. Even though expenditures for plant and equipment may occur later during the acquisition process, their cost is committed at an early stage. As shown conceptually in Figure 7-2, planning (including conceptual design) fixes two-thirds of the facility's overall life-cycle costs. The subsequent design phase determines an additional 29 percent of the life-cycle costs, leaving only about 5 percent of the life-cycle costs that can be impacted by the later phases.

Table 7-2 RCM Facility Life-Cycle Implications

Life-Cycle Phase	Acquisition Implications	Operations Implications
Planning	Requirements Validation Contract Strategy RCM Implementation Strategy Funding Estimates Construction Equipment (Collateral/R&D) Labor Training Operations A&E Scope of Work BIM	Requirements Development Modifications Alterations Upgrades A&E Scope of Work Funding Estimates O&M Considerations Annual Cost Labor Spare Parts
Design	A&E Selection Drawings Specifications Acceptance Testing Requirements Commissioning BIM	A&E Selection Drawings Specifications Acceptance Testing Requirements Commissioning
Construction	Contractor Selection Mobilization Construction Activation (R&D) Commissioning BIM	Contractor Selection Construction Acceptance Testing Commissioning
Acceptance	Equipment Acceptance and Handoff Establishing Baselines Contract Closeout Commissioning BIM	Equipment Acceptance and Handoff Establishing Baselines Documentation Commissioning
O&M	BIM Commissioning Assets captured for CMMS RCM Analysis Training/Certification	BIM Commissioning Assets captured for CMMS RCM Analysis Training/Certification

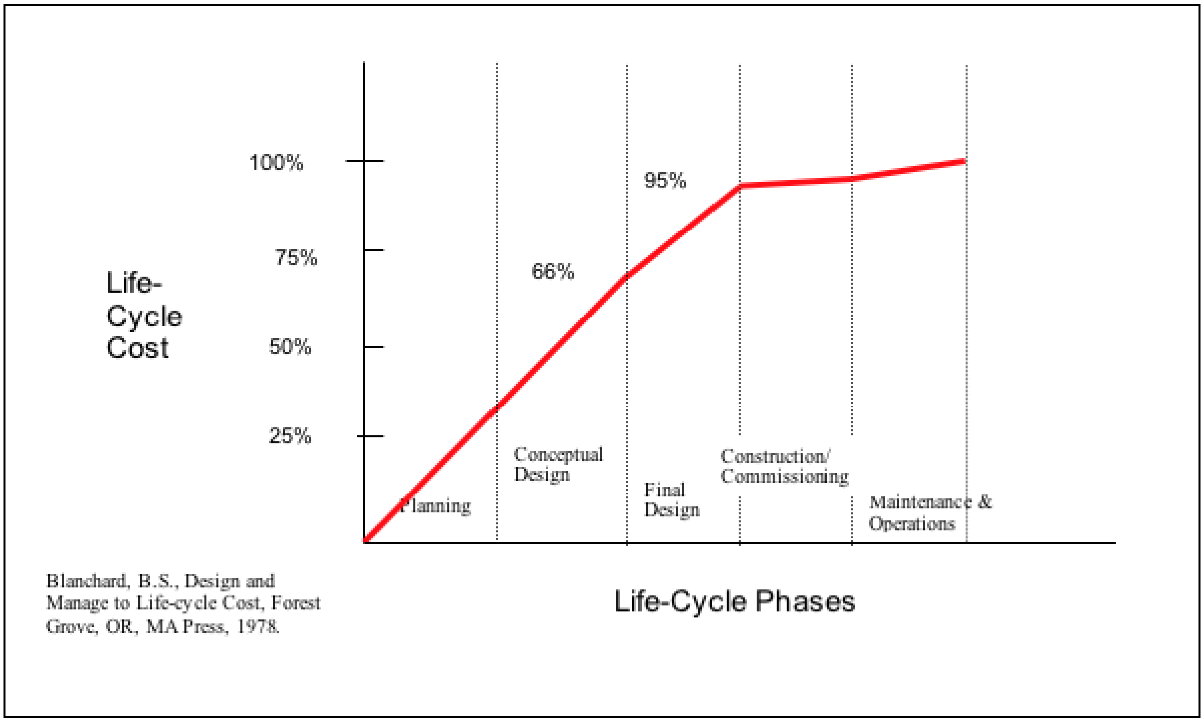


Figure 7-2 Stages of Life-Cycle Cost Commitment

7.6.2 The decision to include a facility in the RCM program, including PT&I, is best made during the planning phase. As RCM decisions are made later in the life cycle, it becomes more difficult to achieve the maximum possible benefit from the RCM program.

7.6.3 Even though maintenance is a relatively small portion of the overall life-cycle cost, three to 5 percent of a facility's operating cost, RCM is still capable of introducing significant savings during the O&M phase of a facility's life. Savings of 30- to 50-percent in the annual maintenance budget are often obtained over time through the implementation of a balanced RCM program.

7.7 RCM Program Components

7.7.1 An RCM program includes reactive and proactive maintenance. Refer to the *NASA Reliability Centered Maintenance Guide for Facilities and Collateral Equipment* for more in-depth information.

7.7.2 Reactive Maintenance. Reactive Maintenance also is referred to as breakdown, repair, or run-to-failure maintenance. When applying this technique, maintenance or equipment repair or replacement occurs only when the deterioration in an equipment's condition causes a functional failure.

7.7.2.1 There is no ability to influence when the failures occur because no (or minimal) action is taken to control or prevent them. When this is the sole type of maintenance practiced, a high percentage of unplanned maintenance activities, high replacement part inventories, and inefficient use of the maintenance effort often result. A purely reactive maintenance program ignores the many opportunities to influence equipment survivability. On the other hand, reactive maintenance can be used effectively when it is performed as a conscious decision based on the results of an RCM analysis that compares the risk and cost of failure with the cost of the maintenance required to mitigate that risk and the cost of failure. For example, periodic maintenance on a standard, inexpensive bathroom fan could not be cost-effective. Typically this type of fan would be run-to-failure and simply replaced at that time, since the cost of maintenance or repair would probably exceed the cost of a replacement fan. Table 7-3 suggests the criteria to be used in determining the priority for repairing or replacing the failed equipment in the reactive maintenance program.

Table 7-3 Reactive Maintenance Priorities

		Priority
Number	**Description**	**Criteria Based on Consequences of Equipment/System Failure**
1	Emergency	Safety of life or property threatened. Immediate serious impact on mission.
2	Urgent	Continuous facility operation threatened. Impending serious impact on mission.
3	Priority	Degrades quality of mission support. Significant and adverse effect on project.
4	Routine	Redundancy available. Impact on mission insignificant.
5	Discretionary	Impact on mission negligible. Resources available.
6	Deferred	Impact on mission negligible. Resources available.

7.7.3 Proactive Maintenance

7.7.3.1 A proactive maintenance program is the capstone of the RCM philosophy. Proactive maintenance improves maintenance through better design, installation, maintenance procedures, workmanship, and scheduling. The ten most commonly recognized proactive techniques to extend machinery life, described in detail in the *NASA Reliability Centered Maintenance Guide for Facilities and Collateral Equipment,* are the following:

a. Preventive Maintenance.

b. Predictive Maintenance.

c. Specification for new/rebuilt equipment.

d. Precision rebuild and installation.

e. Failed-part analysis.

f. Root-cause failure analysis.

g. Reliability engineering.

h. Rebuild certification/verification.

i. Age exploration.

j. Recurrence control.

k. Condition Based Maintenance

l. Condition Monitoring

7.7.3.2 The characteristics of proactive maintenance are the following:

a. It uses feedback and communications to ensure that changes in design or procedures are promptly made available to designers and managers.

b. It employs a life-cycle view of maintenance and supporting functions.

c. It ensures that nothing affecting maintenance occurs in isolation.

d. It employs a continuous process of improvement.

e. It optimizes and tailors maintenance techniques and technologies to each application.

f. It integrates functions (that support maintenance) into maintenance program planning.

g. It uses root-cause failure analysis and predictive analysis to maximize maintenance effectiveness.

h. It adopts an ultimate goal of on-going equipment maintenance.

i. It periodically evaluates the technical content and performance interval of maintenance tasks (PM and PT&I).

7.7.3.3 A successful maintainability program will have the following attributes:

a. Corporate commitment.

b. Program support.

c. Maintainability planning.

d. Maintainability implementation.

e. Program updating.

7.7.3.4 An additional critical step in implementing an effective proactive maintenance program is the design for maintainability process. Design for maintainability was a NASA-sponsored research project conducted by the Construction Industry Institute. Design for maintainability integrates facility operations and maintenance knowledge and experience at an early stage in the project-delivery process. Incorporating maintainability concepts, including RCM, early in the life of a project, where influence potential is high, will result in the principal benefits of less rework, smoother startup and turnover, and less costly maintenance after project turnover. Design for maintainability represents a method to formally incorporate proactive maintenance into construction projects. It will allow active participation of operation and maintenance staff in determining facility project design requirements and ensure these requirements are satisfied. Additional information on this concept is available from Construction Industry Institute publications.

7.7.3.5 The design for maintainability model process has six major milestones:

a. Management commitment to maintainability. Demonstrated through commitment of resources, development policies, and designating a maintainability champion.

b. Establishing a maintainability program. Demonstrated through development of a maintainability staff, procedures, and a lessons-learned database.

c. Obtaining maintainability capabilities. Demonstrated by establishing project-level maintainability responsibility and developing resources for project maintainability reviews.

d. Planning maintainability implementation. Demonstrated by forming project cross-functional teams, defining maintenance strategies and maintainability goals, and integrating appropriate RCM technology.

e. Implementing maintainability. Demonstrated by conducting project maintainability meetings, applying maintainability concepts to design and construction, providing documentation, and conducting maintenance training.

f. Updating the maintainability program. Demonstrated by evaluating program effectiveness and updating the process in the lessons-learned database.

7.7.3.6 Within the ideal process milestones and the success attributes, maintainability shall be accomplished through several different approaches applied individually or in combination. These approaches are:

a. Standard design practice.

b. Contract specifications, such as Specification-kept-intact (SPECSINTACT), having appropriate maintainability and RCM clauses included.

c. Cross-functional project teams.

d. Pilot maintainability programs.

e. Integration of maintainability into existing project programs and processes.

f. Formal maintainability program.

g. Comprehensive tracking of lessons learned.

7.7.3.7 In summary, design for maintainability is the first step of an effective maintenance program, linking proactive maintenance and RCM goals to the design and construction process. If adequate measures for cost-effective maintainability are not integrated into the design and construction phases of a project, the risk increases that reliability will be adversely impacted and total life-cycle costs increase significantly. Appropriate levels of maintainability seldom occur by chance. It requires upfront planning, setting objectives, disciplined design implementation, and feedback from prior projects. It is vital to identify critical maintainability and reliability issues and integrate them into facility project designs to achieve long-term facility owning and operating benefits.

7.7.4 Preventive Maintenance. PM consists of regularly scheduled inspection, adjustments, cleaning, lubrication, parts replacement, calibration, and repair of components and equipment. It is performed without regard to equipment condition. PM schedules periodic inspection and maintenance at predefined intervals in an attempt to reduce equipment failures for susceptible equipment. As equipment ages, the frequency and number of checkpoints may need to be reevaluated using the age exploration process. This is a process that uses PT&I and other methods to extend the period between PM tasks while maintaining equipment condition. This process can result in substantial maintenance savings. These savings are dependent on the PM intervals set, which can result in a significant decrease in inspection and routine maintenance. However, it should also reduce the frequency and seriousness of unplanned machine failures for components with defined, age-related wear patterns.

7.7.4.1 Traditional PM is keyed to failure rates and times between failures. It assumes that these variables can be determined statistically. Therefore, a part due for failure can be replaced before it fails. PM assumes that the overhaul of machinery by disassembly and replacement of worn parts restores the machine to like-new condition with no harmful side effects and that the new components are less likely to fail than the old components of the same design.

7.7.4.2 Failure rate, or its reciprocal, mean-time-between-failures, is often used as a guide to establishing the interval at which maintenance tasks should be performed. The major weakness in the application is that failure-rate data determines only the average failure rate. In reality, failures are equally likely to occur at random times and with a frequency unrelated to the average failure rate. For some items, failure is not related to age, and consequently, timed maintenance can often result in unnecessary maintenance. PM can be costly and ineffective when it is the sole type of maintenance practiced.

7.7.5 Predictive Testing and Inspection.

7.7.5.1 PT&I, also known as predictive maintenance or condition monitoring, uses primarily nonintrusive testing techniques, visual inspection, and performance data to assess machinery condition. It replaces arbitrarily timed maintenance tasks with maintenance that is scheduled only when warranted by equipment condition. Continuing analysis of equipment condition-monitoring data allows for the planning and scheduling of maintenance or repairs in advance of catastrophic and functional failure. Collected PT&I data is used for trend analysis, pattern recognition, data comparison, tests against limits and ranges, correlation of multiple technologies, and statistical process analysis to determine the condition of the equipment and to identify the precursors of failure. PT&I does not lend itself to all types of equipment or possible failure modes and, therefore, should not be the sole type of maintenance practiced.

7.7.5.2 A variety of PT&I methods are used to assess the condition of systems and equipment. These technologies include intrusive and nonintrusive methods as well as the use of process parameters to determine overall equipment condition. The data acquired permits an assessment of the system or equipment performance degradation from the as-designed condition. The most common PT&I technologies, described in greater detail in Appendix F and the *NASA Reliability Centered Maintenance Guide for Equipment and Collateral Equipment,* are the following:

a. Vibration Analysis.

b. Lubricant and Wear Particle Analysis.

c. Thermal Imaging and Temperature Measurement.

d. Passive (Airborne) Ultrasonics.

e. Electrical Testing and Motor Current Analysis.

f. Flow Measurement and Leak Detection.

g. Valve Operation.

h. Corrosion Monitoring.

i. Process Parameters.

j. Visual Observations.

7.7.6 Condition Based Maintenance (CBM) is maintenance when the need arises. In CBM, the performance of the asset is generally continuously monitored during operation and results are compared to asset baselines. Maintenance is performed after one or more indicators show that equipment is going to fail or that equipment performance is deteriorating. CBM is implemented to improve maintenance agility and responsiveness, increase operational availability, and reduce life cycle total ownership cost.

7.7.6.1 CBM is implemented on assets that are large, very expensive, operate at high energy, are costly to tear down to maintain, and have high or very high Risk Assessment Codes. Investment in several different real time monitors of each asset is required. The level of investment depends on the Risk Assessment Code of the asset. Sufficient monitoring is required to provide decision-making information to knowledgeable system managers so that they will operate high-energy assets safely at low risk and maintain those assets when necessary.

7.8 Other RCM Applications

7.8.1 In addition to their applicability during the operations and maintenance phase of equipment life cycles, RCM principles should be used in performing the FCAs and in preparing the AWP; during facilities planning, design, new construction, modification, equipment procurement; in the preparation of architect and engineering (A&E), construction, equipment procurement, and maintenance and operation contracts; in the acceptance testing of new or major repaired equipment by the contractor during the acceptance process; and in the quality assurance of performance-based contracts. Appropriate RCM clauses and criteria shall be included in all Requests for Proposals, Requests for Quotations (RFQs), and in the contracts themselves.

7.8.2 Facilities Condition Assessment. (See also Chapters 4, Annual Work Plan, and 9, Deferred Maintenance.) RCM is valuable during the continuous FCA process. Individual system reliability and O&M costs and numbers of TCs, plotted over the equipment's service life, can be tracked by the CMMS. Equipment condition relative to other similar equipment can be tracked by reviewing the PT&I data and can be statistically trended in a spreadsheet. Similarly, other indices, such as PT&I alarms and equipment availability, can be tracked. The sum of all of this data will result in a rank ordering of the equipment in terms of condition, availability, and cost to maintain the function.

7.8.3 Annual Work Plan. (See also Chapter 4, Annual Work Plan, for a more detailed discussion.) RCM principles, and particularly PM and PT&I, are integrated into the Center's maintenance program through the Annual- and 5-Year Work Plans. These are required to develop PM and PT&I funding requirements for the next 5 years, including all labor, parts, materials, and special tools. RCM will identify the most effective maintenance, in terms of retaining the highest reliability at the lowest cost, and include criticality codes based on mission support, condition code, specific inspections and maintenance tasks to be performed, equipment parameters, the estimated resources required, and specific instructions for obtaining condition assessment information as part of each maintainable collateral equipment PM/PT&I.

7.8.4 Deferred Maintenance. (See also Chapter 9, Deferred Maintenance, for a more detailed discussion.) Facilities maintenance within NASA is crucial in ensuring facility availability for critical missions throughout the Agency and in NASA's stewardship of the Government facilities with which it is entrusted. The effect of reduced maintenance is not always noticeable immediately, and therefore, it is essential that Centers have sufficient management information available to plan long- and short-term maintenance requirements properly, recognize adverse funding trends, and be able to articulate the effects of reduced maintenance on facility availability and the mission. After the RCM process is used to identify facility and equipment availability and condition deficiencies, the DM identifies to higher authorities, i.e., OMB and Congress, unfunded facilities maintenance work for those items necessary to support the Center mission and the consequences of inadequate funding.

7.8.5 Specifications-Kept-Intact (SPECSINTACT)

7.8.5.1 Early in the planning of a new facility, consideration shall be given to the extent RCM analysis and PT&I techniques will be used to maintain the facility and equipment. The fundamental determination is the amount of built-in condition monitoring, data transfer, and sensor connections to be used. It is more economical to install this monitoring equipment and connection cabling during construction than later. Planning, designing, and building-in the condition monitoring capability ensures that it will be available for the units to be monitored. Continuously monitored equipment tied into performance analyzers permits the monitoring of its function and signs of any degradation. Installed systems also reduce labor requirements relative to obtaining the data manually.

7.8.5.2 NASA has integrated RCM principles into its standard construction specifications, SPECSINTACT. The emphasis is to design new equipment with a high degree of reliability, at the lowest reasonable cost, thereby, achieving improved maintainability and ease of monitoring. Maintainability and monitoring factors that should be considered by the designer include the following:

a. Access. Equipment, its components, and facilities should be accessible for maintenance. There should be clear access to collect equipment-condition data with portable data loggers or fluid sample bottles.

b. Material. Materials shall be chosen for durability, ease of maintenance, availability, and value.

c. Standardization. Use of special or one-of-a-kind materials, fittings, or fixtures is to be minimized, and the use of common equipment component parts maximized. Standard equipment that can have multiple uses should be selected, where feasible.

d. Quantitative Maintenance Goals. Quantitative measures of maintenance (such as mean-time-between-maintenance (MTBM) and maintenance downtime) should be used during design to set maintainability goals.

e. On-line Data Collection. Installed data-collection sensors and links may be justified for high-priority, high-cost equipment or inaccessible equipment.

f. Management Indicators. Management indicators and the analysis method should be incorporated into the system design. Often, the performance parameters monitored for equipment or system control can be used to monitor equipment condition.

g. Performance Measures. RCM performance measures such as operating time or equipment loading are directly equipment related. The data to be used and the collection method are incorporated into the system design.

7.8.6 Acceptance. (See also Chapter 8, Reliability Centered Building and Equipment Acceptance, for a more detailed discussion.) In today's tight budget environment for facilities operations and maintenance, there is great advantage to NASA in using the construction contractor's quality control function, prior to the contractor's receipt of final payment and exit from the job site, to perform noninvasive diagnostic tests (PT&I) to verify that there are no latent manufacturing defects and the quality of the installation of newly installed equipment.

7.8.7 Performance-based Contract Monitoring. (See also Chapter 12, Contract Support, for a more detailed discussion.) Performance-based contract and outcome monitoring require the contractor to meet specific standards of performance. These are often based on metrics and indicators that are derived from RCM principles and obtained through PT&I technologies. Percentage availability, for example, is a performance metric that is compared to a standard set by the Center based on baseline data obtained at the time of equipment acceptance or during RCM analysis. Further, the degree of QA required of the Government is dependent not only on the contractor's performance, but also on the RCM criticality codes applied to each facility and equipment. PT&I techniques may be prescribed in the Government's formal QA Plan as methods used to inspect the contractor's work and RCM analysis may be used by the QAE to observe overall trends. For example, trends identifying increased TCs or downtime for specific units of equipment may be indicative of a lack of preventive maintenance that the contractor is obligated to perform.

Chapter 8. Reliability Centered Building and Equipment Acceptance

8.1 Introduction

8.1.1 During the course of new construction, major repair, or rehabilitation of facilities, it is not unusual to discover installed systems or equipment that are out of alignment and balance, that contain latent defects from manufacturing and installation, or that simply do not operate as intended. For example, evaluations of new construction of at least two NASA Centers revealed that 85 to 100 percent of the rotating equipment was misaligned, out of balance, or contained defective bearings. These types of systems or equipment defects result in premature failures, which require unbudgeted corrective action by O&M staff. Given today's tight facilities O&M budgets, each Center shall, for new construction, major repair, or rehabilitation of facility projects, employ an acceptance process that includes the use of PT&I to verify system and equipment condition. This should be done prior to acceptance of the work and the contractor's departure from the job site and turning the keys over to the operations and maintenance staff. The expected result is a facility that is safer and is less costly to maintain. The acceptance process can achieve these results by:

a. Ensuring there are no latent factory or installation defects.

b. Verifying building systems and equipment performance through functional performance testing.

c. Providing full documentation and training for the O&M staff to improve their performance.

8.1.2 Building and equipment acceptance is one element of a larger, more comprehensive construction quality program known as "commissioning." Currently, there are four variations of commissioning being practiced: Traditional commissioning, total building commissioning, total building recommissioning, and NASA's customized application of a portion of commissioning called, Reliability Centered Building and Equipment Acceptance (RCB&EA).

8.1.3 Traditional Commissioning. Traditional commissioning involves performing random tests and checks on facility systems to ensure that they are properly balanced, functionally operational, and comply with the design intent. It systematically checks operating parameters such as pressure, temperature, minimum and maximum air flow, lighting levels, electrical amperage and voltage, torque, fluid volumes, and other thermodynamic measures at key locations, as well as balanced conditions. It is a method of acceptance testing that, when performed on a random basis at random sampling points, checks to ensure that the outcome indices at those points are in compliance with the outcome requirements stated in the design specification. Although the method ensures that the installation meets the design requirements, traditional commissioning reflects the conditions in a snapshot in time, specifically on the day(s) that the system is being inspected for acceptance. Also, it generally fails to emphasize the quality of the equipment installation itself, such as latent manufacturing and installation defects. Even if the installation is in compliance with the design and reflects the proper process parameters at the time of equipment acceptance, these undetected defects may result in premature equipment failure and operational and maintenance problems due to misalignment or similar conditions discovered at a later date. The problem then becomes one of many warranty issues, which, based on typical NASA history, often are inadequately enforced.

8.1.4 Total Building Commissioning. Total building commissioning is a continuous, systematic process of ensuring that facility systems are planned, designed, installed, tested, and capable of being operated and maintained to perform according to the design intent and the user's needs. Use of a third party Commissioning Agent is the preferred practice. The total building commissioning process is optimally applied to all phases of a construction projectâ?"program planning, design, construction/installation, acceptance, and postacceptance/occupancy. Commissioning team involvement begins at the earliest stages of project planning, where the team's expertise in such areas as system sizing, code compliance, maintainability, user-friendliness, product quality and reliability, ergonomics, and projected life-cycle costs are applied to the design. The commissioning staff is also involved in monitoring the quality of the construction in terms of workmanship, specification, and code compliance throughout the construction, using traditional commissioning tests and inspection procedures for quality assurance and for system acceptance. Finally, the quality team monitors the installed system following acceptance to ensure that there are no latent installation defects or degradation of system performance and operational quality. This rigorous commissioning process is intended to provide the following benefits:

a. Ensure that a new facility begins its life with systems at optimal productivity.

b. Improve the likelihood that the facility will maintain this level of performance.

c. Restore an existing facility to high productivity.

d. Ensure facility renovations and equipment upgrades function as designed.

8.1.5 Total Building Recommissioning (also referred to as LEED-O&M). The commissioning of existing buildings is known as building recommissioning and is a low-cost method to improve building performance. Over time, the efficiency of a building's systems can decline, especially if they were never commissioned or where improperly commissioned during building acceptance. Recommissioning finds and corrects equipment problems and also tunes up systems and equipment, ensuring they operate in an integrated manner. Based on energy savings, recommissioning can deliver simple paybacks that rarely exceed four years and are often two years or less. In addition to saving energy, recommissioning:

a. Extends equipment life and reduces premature equipment failure.

b. Reduces operating and maintenance costs.

c. Decreases risk and increases the asset value of the building.

d. Helps ensure a healthy, comfortable, and productive working environment for occupants.

8.1.6 Recommissioning existing buildings helps to restore and improve the original intended operating performance. The U.S. Green Building Council (USGBC) has developed a recommissioning program for existing buildings known as LEED-O&M. Similar to the LEED-BD&C program, LEED-O&M provides owners and operators of existing buildings a method to implement sustainable operations and maintenance practices and reduces the environmental impact of a building over its functional life cycle. LEED-O&M requires that existing building commissioning (recommissioning) be performed to verify that fundamental building systems and assemblies are performing as intended to meet current needs and sustainability requirements.

8.1.7 Retrocommissioning is another tool in the facility manager's arsenal that can be used to restore a facility to design conditions and reduce the energy consumption. It can also be used to increase the overall reliability and maintainability of the facility. Retrocommissioning is used largely in facilities that have never been commissioned. In many cases, NASA Centers are using facilities built before modern, standard commissioning practices were enabled. This led to many facilities being constructed without a commissioning process or plan being in place leading to facilities that possibly never were aligned with the design purposes of the original architects. With the many modifications performed throughout the years on facilities due to constantly changing missions, these facilities likely moved further and further from the original intent of the facility. Often projects are performed that affect one system with no regard to how it might affect other systems in the facility. For example, a lighting project might occur to upgrade to LED fixtures. The electrical personnel might not have noticed that removing light fixtures with return air openings and replacing them with fixtures without them robbed the air handling unit serving the area of return air. Additionally, the ever-decreasing maintenance budget has led to cuts being required in the scope of equipment being maintained. Due to this, issues such as incorrectly operating variable air volume dampers, misadjusted air handler sheaves, and malfunctioning exhaust fans can reduce a facility's performance and energy efficiency. Retrocommissioning is a way to realign these facilities with the original design intent.

8.1.7.1 The terms retrocommissioning and recommissioning are often used interchangeably. Retrocommissioning is usually a one-time event that is used to set a building up to be recommissioned on a periodic basis. As with the other types of commissioning, the process for retrocommissioning is largely the same. Retrocommissioning typically has a larger initial cost than other processes, such as recommissioning, due to the up-front workload of compiling diagnostic test forms, functional test forms, and other documentation for systems that were never initially developed or may be difficult to develop due to the age of the existing equipment.

8.1.7.2 It is best to implement this process utilizing a phased approach method. This is beneficial both in terms of funding levels and also various contract timing issues. With the amount of manpower involved in compiling information and performing testing that might have never been done on equipment, it can be beneficial to contract with an outside organization or company that specializes in commissioning and retrocommissioning to perform the majority of the work in larger projects. Their help can be beneficial in developing testing and certification procedures where they likely do not exist for aged equipment. The local O&M contractor can then provide support and repair services as problems are found during the process.

8.1.7.3 The first step in this process is typically the planning phase. This is largely the preparatory section of the project. In this phase the project objectives need to be clearly defined. Also, the equipment or systems that will be analyzed for function and improvements need to be listed. a. The HVAC/mechanical sections are going to be the largest systems to analyze but will also lead to the biggest effect on the bottom line cost for a particular facility. This is where the decision needs to be made if O&M personnel will be responsible for the work or if the services of an outside Commissioning Agent (CxA) will be required. Many companies now offer services of this type so it is best to look for companies that have had experience in the type of project commensurate with the facility involved, whether it is offices, laboratories, industrial areas, etc. It is wise to ensure the O&M staff is involved to provide expertise on the daily operations of the facility and the equipment. It is also a good idea to involve the local commissioning agent where available as well.

b. Once the team is assembled, the retrocommissioning plan can be developed. This plan should contain basic general building information, the objectives of the retrocommissioning project, the scope of the project, equipment and systems to be included in the project, points of contact, and team members. This plan should also contain a list of deliverables due at the end of the project.

During this phase, the majority of the document collection occurs. This information should include construction drawings for original construction, as well as any/all modifications performed throughout the years. In most cases, no master drawing exists displaying the current configuration of the facility. Equipment baseline data and utility and energy usage also should be obtained. The team should also gather any control sequences of operation, previous testing, adjusting, and balancing (TAB) reports, and required key performance indicators. As a final step in the planning phase, a preinspection survey should be sent to facility occupants and managers to determine existing conditions of the facility and any ongoing issues.

8.1.7.4 The second phase is the discovery phase, which is where the field work begins in the facility. During this stage, the team performs reviews of the documents obtained in the planning phase. A facilities requirements document also can be obtained through interviews with the building occupants and/or the facility manager to determine what needs the occupants currently have in regards to the systems being evaluated (e.g., temperature and humidity requirements for special areas). This is also the phase in which the testing of the equipment selected in the project scope begins. During this phase the operation of all components of the equipment are tested, the control sequences and building automation systems are tested for validity and proper operation, and TAB work is performed if part of the scope. While this work is being performed, a list of deficiencies and improvements is generated.

8.1.7.5 The third phase is the corrections phase, which largely occurs in concurrence with the discovery phase due to the nature of the work being performed. For example, as problems are found during TAB work, some repairs have to be made in order to continue the process. This is a phase that can be broken up due to funding or personnel availability. Repairs that are required to finish the project can be funded, while additional repairs/improvements can be forestalled until funding allows with the knowledge that this will reduce the impact of the project.

8.1.7.6 The fourth and final phase is the hand-off phase, the phase in which all the deliverables are submitted, such as the final commissioning report. A good deliverable to request from the project is a redline drawing of how the system actually exists in its current state, as these types of documents are often hard to find on older systems that have undergone many modifications. Additionally, a postinspection survey should be sent to the facility occupants to find out the effectiveness of the project. All of these things can be taken in to account and a lessons-learned document should be generated at the conclusion of the project to aid in future retrocommissioning projects.

8.1.8 NASA's Building and Equipment Acceptance. NASA's application of commissioning is a customization of a portion of the traditional and total commissioning processes that NASA calls Reliability Centered Building and Equipment Acceptance. NASA recognizes that there can be substantial benefits even when commissioning concepts are applied only to the acceptance phase of a construction project. These benefits can be gained during acceptance by using available PT&I technologies in addition to traditional operational parameters to identify latent manufacturing, shipping, and installation-induced defects. Identifying and correcting these defects can reduce premature failures, increase safety and reliability, and decrease life-cycle costs. NASA's portion of the commissioning concept concentrates on facility and equipment acceptance rather than on total commissionings' cradle-to-grave detailed oversight and evaluations because of the following:

a. NASA's placing safety as a top priority.

b. The current Federal budget process and constraints.

c. NASA's emphasis on reducing life-cycle costs within available and limited resources.

d. The institution of a strong and vibrant RCM program in place Agency-wide.

8.1.9 Many of the problems, safety concerns, and associated costs inherited during the O&M phase are the result of inadequate or nonexistent standards and procedures for equipment acceptance. Thus, the focus of NASA's equipment acceptance is on ensuring that the contractor detects latent manufacturing and installation defects through an effective quality control program before final acceptance of the installation by the Government.

8.1.10 This chapter provides a brief overview of NASA's acceptance process. Refer to the NASA Reliability Centered Building and Equipment Acceptance Guide for more detailed information and extensive discussion of the subject.

8.2 RCMâ?"Integral to Acceptance

8.2.1 The RCM approach takes a life-cycle view of facilities and collateral equipment and seeks to ensure that facilities and collateral equipment are properly built and installed to reduce the probability of premature failure. A key element in the transition from good design to full operation is the construction and acceptance phase.

8.2.2 Initial Planning and Design. The long-term reliability of an installation or refurbishment begins with the initial planning and design. The initial criteria and equipment design determines the inherent equipment reliability, maintainability, and supportability. Moreover, as discussed in Chapter 7, Reliability Centered Maintenance, about 95 percent of the total equipment cost is determined by the end of the planning and design phase. Even though expenditures for plant and equipment may occur later during the acquisition process, their cost is committed at an early stage. The decision to include a facility in the RCM program, including PT&I, is best made during the planning phase. As RCM decisions are made later in the life cycle, it becomes more difficult to achieve the maximum possible benefit from the RCM program. It has been estimated by NASA facilities and collateral equipment designers that the cost to make a system change once the system is built is anywhere from 10 to 1,000 times more than if the change was incorporated during the system design. Clearly, the planning and design phase of facilities and collateral equipment life cycle is the time to focus on the ability to sustain operation through the use of effective acceptance testing, proper trending, necessary maintenance, and the performance of timely repair, when needed.

8.2.3 Construction and Acceptance. Contracts for construction work at NASA Centers shall require contractor responsibility for an adequate quality control program in place for the proper installation of the facility and equipment in accordance with the design requirements.

a. Throughout the installation and at the time of acceptance, PT&I shall be performed to verify that not only is the installation acceptable, i.e., that there are no latent factory or installation defects, but also, that the required baselines are established.

b. Consequently, any contractor performing work at NASA Centers shall have an understanding of the RCM process and how it affects the project.

c. NASA contracts shall require the contractor to use personnel who are trained and certified in the appropriate PT&I technologies for acceptance testing to ensure that the results are accurate and consistent.

d. The Center's Construction Manager shall ensure that all interim testing is performed and that the results meet the specifications and are documented and included with the final acceptance documentation.

e. The Construction Manager shall ensure that the acceptance testing has been performed and determine if the acceptance testing results are within the required tolerances.

f. When all acceptance criteria have been met, the Construction Manager shall collect all of the required documentation, including all manufacturers' manuals, redline drawing, and acceptance testing data, and deliver them to the appropriate Center operations and maintenance personnel.

8.2.4 Maintenance and Operations. RCM can introduce significant savings during the Maintenance and Operations phase of a facility's life. Savings of 30-to-50 percent in the annual maintenance budget are often obtained through the introduction of a balanced RCM program. O&M personnel are ultimately responsible for the proper operation and maintenance of systems and equipment. However, how the facility and its equipment will be operated and maintained shall be considered during the planning, design, and construction phases. During these phases, maintenance and operations needs are best served by carefully and realistically identifying and defining the PT&I and PM requirements. Although the performance of maintenance and operations occurs during the operations stage of the life cycle, some preparatory activities can be carried out during the acceptance stage. These activities can include O&M personnel selection, training requirements, procedure preparation, review of specifications, and collection of baseline condition monitoring data from the Construction Manager. Refer to Chapter 7, Reliability Centered Maintenance, of this document and to the NASA Reliability Centered Maintenance Guide for Facilities and Collateral Equipment for guidance on the use of RCM during facilities operations and maintenance.

8.3 Acceptance Testing

8.3.1 After construction is complete, it is important to verify that the systems and equipment are operating in accordance with the construction specifications. NASA's contracts shall accomplish this by requiring the contractor to verify, as an element of the contractor's quality control program, that the equipment specified is properly installed in accordance with design and local codes and standards, that there are no latent manufacturing or installation defects, and that individual and integrated systems and equipment operation is in accordance with the design intent. During NASA's acceptance process, individual equipment is acceptance-tested using PT&I that focuses on equipment performance and by traditional thermodynamic testing. Providing this initial baseline data for comparisons and trending allows for planning and scheduling PM or repairs in advance of failure. (See Section 8.1.4, Total Building Commissioning.)

8.3.2 Facilities contain myriad equipment and systems, from the simplest light switch to a computer-controlled air conditioning system. While all equipment can benefit from the reliability centered acceptance process, it is not always cost effective to perform an acceptance test even though one is available,. The decision to perform reliability centered acceptance should be based on the RCM techniques in the NASA RCM Guide for Facilities and Collateral Equipment and the NASA Reliability Centered Building and Equipment Acceptance Guide.

8.3.3 Table 8-1 indicates the most appropriate and commonly used PT&I technologies with respect to the most common acceptance testing applications. These PT&I tests have become some of the most effective methods for testing new and in-service equipment for hidden defects.

8.3.4 Preliminary and final acceptance testing and documentation of the test results is to be performed by the contractor as part of the contractor's QC program.

a. The contractor shall correct all detected deficiencies.

b. The condition monitoring data shall be retaken prior to acceptance of the facility and/or equipment by NASA.

c. The NASA Center shall observe and monitor this condition testing, analysis, and documentation as part of its QA program and ensure that the contractor provides all preliminary and final condition monitoring and analysis data to the Construction Manager.

8.4 Acceptance Scope

8.4.1 The acceptance scope includes, but is not limited to, the following:

Table 8-1 Applicable PT&I Technologies

PT&I Technology	Equipment to be Tested																
	Air Compressors	Brine Chillers	Bearings	Coolers	Circuit Breakers	Diesel Generators	Electrical Distribution	Gearbox	Heat Exchanger	Hydraulic Equipment	Main Drive	Motor (Auxiliary)	Piping/Tank	Pumps (all)	Rheostat	Optating Exciters	Valves
Airborne Ultrasonics	•	•	•	•	•	•	•		•		•	•			•	•	•
Electrical Testing																	
Insulation Resistance					•	•	•				•	•				•	
MCE											•	•					
Motor Current Signature Analysis (MCSA)											•	•			•	•	•
Other					•	•	•					•			•	•	
Parameters																	
Operation Data	•	•		•	•	•			•	•	•	•	•	•		•	
Recip Trap	•					•											
NDE/NDT																	
Acoustic Emissions													•				
Eddy Current				•													
Imaging/ Thickness			•										•				
Magnetic Particle	•										•						
Temperature																	
Contact	•	•	•	•		•		•	•		•						
Infrared			•	•	•		•		•		•	•	•	•	•	•	•
Tribology																	
Oil Condition	•	•	•			•		•		•	•						
Particle Count										•							
Wear Particle	•	•	•			•		•									
Valve Testing																	
Electrical																	•
Pneumatic																	•
Vibration Analysis																	
Proximity			•								•						
Seismic	•	•	•			•		•			•	•	•	•		•	
Torsional	•					•											

a. Documenting the design intent. Verifying that equipment and systems have been properly installed in accordance with the contract documentation and the manufacturer's written installation instructions.

b. Verifying the performance of each piece of equipment and each system, documenting the equipment and system performance, and ensuring that there are no latent manufacturing and installation defects.

c. Verifying that equipment has been placed into operation with the manufacturer's observation and/or approval. Verifying that adjusting, balancing, and system testing has been properly performed.

d. Assembling and submitting record drawings.

e. Training Center and/or the user's personnel in the proper operation of each piece of equipment and each system.

f. Documenting warranty start and end dates.

g. Assembling and submitting all records of code authority inspections and approvals.

h. Validating the accessibility of all work relative to the maintenance requirements of each piece of equipment and promptly advising NASA of items of noncompliance.

i. Identifying, documenting, and reporting all deficiencies of the work relative to the contract documents for tracking and correction through a deficiency-tracking program.

j. Submitting acceptance documents in an approved format.

8.5 Applications

8.5.1 Roofs. Roofs are normally constructed layer by layer and comprise many different types of materials. Moisture shall not be allowed to enter the roof structure or materials during the construction phase, as any trapped moisture will eventually degrade the roof and structure and can cause a premature failure of the roofing system. Whereas traditional roof inspections usually look for the effects of leaks, infrared thermography should be used to look for wet insulation caused by water ingress during construction, improper installation, or roof boundary failures.

8.5.2 Insulation/Building Envelope. Building insulation is installed during construction but, in most cases, prior to the building's being completed. Consequently, acceptance inspections shall occur before the walls and ceilings are completed.

a. On completion of the insulation installation, a construction detail showing the insulation material type, amount, and location shall be generated and submitted by the contractor.

b. This information shall be forwarded to the appropriate RCM official for inclusion in the maintenance database. Infrared thermography or ultrasonic mapping should be used during acceptance to identify insulation voids, insulation settling, and areas of moisture intrusion.

8.5.3 Piping Systems. Industry-standard acceptance tests for water, plumbing, and air systems first require a pressure test of all piping and fittings. During this test, an ultrasonic scan should be performed on all accessible aboveground piping to help discover any leaks. For hot water systems, after the pressure and hydro tests have been completed and after piping insulation has been installed, the system should be charged with hot water, and an infrared scan should be performed to verify insulation integrity. For steam systems, ultrasonic scans should be performed on steam traps.

8.5.4 Mechanical Systems

8.5.4.1 Vibration Analysis. Analysis of system and equipment vibration levels is one of the most commonly used PT&I techniques to determine the condition of rotating equipment and its structural stability in a system. It will detect deficiencies associated with wear, imbalance, misalignment, mechanical looseness, bearing damage, belt flaws, sheave and pulley flaws, gear damage, flow turbulence, cavitation, structural resonance, and fatigue.

a. Vibration measurements in the acceptance process shall be performed by technically qualified persons who are trained, experienced, and certified in vibration measurement.

b. Measurements shall be taken under specified operating conditions.

8.5.4.2 Test documentation, including machine layout drawings indicating vibration measurement locations, shall be submitted to, validated by, and signed by the NASA Construction Manager or other authorized official prior to final equipment acceptance.

8.5.4.3 Balance. Only 10 to 20 percent of rolling element bearings achieve their design life. Premature bearing failure is frequently due to excessive vibration caused by imbalance, misalignment, improper installation, and outside structural stresses. Acceptance testing for precision balance by the contractor at the time of equipment acceptance of motor rotors, pump impellers, and fans is one of the most critical and cost-effective techniques for achieving increased bearing life and resultant equipment reliability. NASA contracts shall require that balance measurements be performed by a technically qualified person trained, experienced, and certified in machinery balancing.

8.5.4.4 Alignment. The forces of vibration from misalignment cause gradual deterioration of seals, couplings, bearings, drive motor windings, and other rotating elements where close tolerances exist. The use of precision equipment and methods at the time of acceptance, such as reverse dial and laser systems, is necessary to bring alignment tolerances within precision standards. Precision alignment will increase the average bearing life, thus, increase machinery reliability and availability and decrease maintenance costs.

8.5.4.5 Lubrication and Hydraulic Fluids. Lubricating and hydraulic fluid analysis is performed during acceptance for three reasons: To determine the machine mechanical wear condition; to determine the fluid condition; and to determine if the fluid has become contaminated. There is a wide variety of tests to provide information on these, usually packaged by independent testing laboratories to address all three areas. In addition to assessing the condition of the fluids at the time of equipment acceptance, these tests are necessary to provide a baseline for future RCM actions.

8.5.4.6 Ultrasonic Testing. Airborne ultrasonics are used by the contractor during equipment acceptance to hear noises associated with leaks, mechanical anomalies, corona discharges, and other high-frequency events. In addition to evaluating heat exchangers, ultrasonics can be used to verify boiler casing and associated piping integrity and the proper operation of steam traps.

8.5.5 Electrical Systems

8.5.5.1 Infrared Imaging. Infrared thermography (IRT) is a noncontact technique used during acceptance to identify hot and cold spots in energized electrical equipment, large surface areas such as boilers and building walls, and other areas where "stand off" temperature measurement is necessary. More specifically, IRT is used to detect faulty conditions in transformers, motor control centers, switchgear, substations, switchyards, and power lines. In mechanical systems, IRT is used to identify blocked flow conditions in heat exchangers, condensers, transformer-cooling radiators, and pipes and to verify fluid levels in large containers such as fuel storage tanks. IRT is also used to identify misaligned drive belts and sheaves, drive couplings, motor bearing, and missing or bad insulation in roofs. Sections 8.5.1 through 8.5.3 discuss IRT's applications specific to structural systems.

8.5.5.2 Power Factor Testing. Providing the optimum power factor maximizes the efficient use of electrical power. Power factor, sometimes referred to as dissipation factor, a measure of the power loss, is a dimensionless ratio that is expressed in percentage of the resistive current flowing through insulation to the total current flowing. Consequently, the power factor test is used for making routine comparisons of the condition of an insulation system and for acceptance testing to verify that the equipment was manufactured and installed properly. The test is nondestructive, and regular maintenance testing will not deteriorate or damage insulation. Its most frequent applications are with electric motors, circuit breakers, motor control centers, switchgears, and transformers.

8.5.5.3 Insulation Resistance Testing. An insulation resistance test is a nondestructive direct current (DC) test used during acceptance to determine the condition of the insulation of electrical systems. It indicates that the insulation under test can withstand the voltage being applied. The insulation resistance is generally accepted as a reliable indication of the presence of contamination or degradation. Its most frequent applications are with motors, switchgears, motor control centers, circuit breakers, and transformers.

8.5.5.4 Insulation Oil Testing. High- and medium-voltage transformers, some high- and medium-voltage breakers, and some medium-voltage switches are supplied with mineral oil as an insulation medium. Performing oil tests prior to turnover is needed to ensure that proper oil is installed, that the necessary inhibitors have been added, and to ensure that no combustible gas products are present. Further, when insulation systems are subjected to stresses, such as fault currents and overheating, combustible gas generation can change dramatically. In most cases, these stresses can be detected early on; the presence and quantity of the individual gases can be measured and the results analyzed to indicate the probable cause of generation.

8.5.5.5 Motor Circuit Evaluation (MCE) and Motor Circuit Analysis (MCA). MCE is used during acceptance to evaluate the condition of motor power circuits. Any impedance imbalances in a motor will result in a voltage imbalance. Voltage imbalances in turn will result in higher operating current and temperatures, which will weaken the insulation and shorten the motor's life. MCA is a method of detecting the presence of broken or cracked rotor bars or high-resistance connections in end rings. While MCA is an effective test on in-service motors, it is not generally used for acceptance testing. It is, however, normally performed at initial startup so a baseline can be established.

8.5.5.6 Battery Impedance Testing. As a battery ages and begins to lose capacity, its internal impedance rises. This is a parameter that can be trended, comparing the current value with the original value taken at acceptance, with previous readings, and with other identical batteries in the same battery bank. Additionally, battery impedance testing will indicate the existence of an internal short in the battery, an open circuit in the battery, and premature aging due to excessive heat or discharges. There are no set guidelines or limits for this test. Each type, style, and configuration of battery will have its own impedance, so it is important to take these measurements during acceptance to establish a baseline.

8.5.5.7 Airborne Ultrasonics. Deficiencies in electrical systems, such as corona discharges, loose switch connections, and internal arcing in deadfront electrical connections, can all be discovered during acceptance using ultrasonic test devices. Corona discharge is normally associated with high-voltage distribution systems and is produced as a result of a poor connection or insulation problem. The discharges generally occur at random, are the precursor to a failure, and are in the ultraviolet region and not normally detectable using thermography.

8.6 Acceptance Data Sheet

8.6.1 Acceptance data shall be recorded on a formal Acceptance Data Sheet and provided to the Center Construction Manager as part of the facility or equipment documentation package. A separate sheet will be filled out for each equipment unit being evaluated during the acceptance process and may result in a voluminous total package. Refer to the NASA Reliability Centered Building and Equipment Acceptance Guide for Acceptance Data Sheet samples.

Chapter 9. Deferred Maintenance

9.1 Introduction

9.1.1 Inadequate funding for maintenance and repair programs throughout the Federal Government has historically been a standing problem. Agencies' needs have received little sympathy from the highest levels of Government for several reasons, including the following:

a. There is an assumption that maintenance can always be put off for a month, a year, or even 5 years in favor of current operations with higher visibility and perceived as better payback on the investment.

b. The Federal Government decision making authority for maintenance and repair programs is widely dispersed and is not structured in a manner that properly places accountability and responsibility for the care of facilities on a specific steward.

c. The relationship of facilities to Agency missions has not been recognized adequately in the Federal strategic planning and budgeting process.

d. Definitions and calculations of facilities-related budget items, methodologies for developing budgets, and accounting and reporting systems for tracking and repair expenditures are inconsistent. A concern is that inappropriate items have been included in the maintenance backlog to inflate the overall estimate as justification for a higher budget appropriation.

e. Agencies have not satisfactorily convinced higher authority about the implications of deferral of funds that, when invested in preventive and timely maintenance, will be cost effective, protect the quality and functionality of the facilities, and protect the taxpayers' investment.

f. All of these are indicative of the reasons why good, convincing, standardized, and accurate data, presented in an organized and meaningful way, is so important to NASA.

9.1.2 This chapter discusses DM. (See the related discussions in Chapter 4, Annual Work Plan, and on Facility Condition Assessment in Section 10.6). DM is one of the metrics used by NASA and other Federal agencies to assess the condition of their real property assets. The trending of DM and other metrics help guide decision makers toward spending priorities for these assets in support of the Agency's mission. DM has become the topic of renewed interest, concern, and scrutiny within the highest levels of the Federal Government, including the U.S. Congress, the Office of Management and Budget (OMB), the Department of Defense, and the Department of the Treasury.

9.1.3 Definition. DM is the total of essential, but unfunded, facilities maintenance work necessary to bring facilities and collateral equipment to the required acceptable facilities maintenance standards. It is the total work that should be accomplished but that cannot be achieved within available resources. It does not include new construction, additions, or modifications. DM does include unfunded maintenance requirements, repairs, ROI, and CoF repair projects.

9.1.4 DM, when applied correctly, can be an excellent overall indicator of the condition of Center facilities and collateral equipment as a group. It reflects the cumulative effects of underfunding facilities maintenance and repair. Review of DM trends and comparison of DM with the CRV and facilities maintenance funding provide indications of the adequacy of the resources devoted to facilities maintenance.

9.1.5 Accurate and complete maintenance and repair program data is critical for NASA's obtaining the budget appropriations necessary to maintain its facilities so that they operate adequately and cost effectively, their functionality and quality are preserved, and they provide a safe, healthy, productive environment for the people who work and visit them every day. Further, as the steward of the facilities under its custody, NASA, and by extension, each Center, has an obligation to the public to realistically and truthfully report its critical, unfunded maintenance requirements and its impacts on mission. The DM is one of the tools by which the overall facility conditions, unfunded requirements, and the impacts on missions are reported. It should be kept in mind that, while the DM functions to report the conditions, it has not historically resulted in consistent or specific funding to address the shortfalls in maintenance funding. Recognizing and integrating the DM into the existing funding request process will be key to the success of obtaining actual funding in reducing DM.

9.1.6 With this perspective in mind, the work of communicating the funding needs for maintenance has not been completed until the DM results have been translated into funding requests, such as ROI, CoF, and program funded projects. Maintenance organizations should take an active leadership role in providing input to these various funding mechanisms. Input should include clear and concise language that defines the requirements, justifications, criticality, and urgency of these items as they relate to meeting mission and safety requirements. Through this methodology, maintenance organizations set the stage by which DM items become visible and take their proper place in the competition for funding among other construction and program needs.

9.2 Facility Life Cycle

9.2.1 Most constructed facilities are designed to provide at least a minimum acceptable level of shelter and service for 30 years. With proper management and maintenance, buildings may perform adequately well beyond their intended design life cycle and may adapt and serve several different functions.

9.2.2 The service life of a facility depends on many factors, such as the quality of the building's design, the durability of the construction materials and component systems, the incorporated technology, the location and climate, the use and intensity of use, and damage caused by human error and acts of God. These all influence how well and how quickly a facility ages and the amount of maintenance and repair it requires over its life cycle. Although a building's performance inevitably declines because of aging, wear and tear, and functional changes, its service life can be optimized through adequate and timely maintenance and repairs, as illustrated in Figure 9-1. Conversely, when maintenance and repair activities are continuously deferred, the result can be an irreversible loss of service life.

9.2.3 Facilities that are functionally obsolete, are not needed to support NASA's mission, are not historically significant, and are not suitable for transfer, adaptive reuse, stand by, or mothball, should be placed on the demolition list.

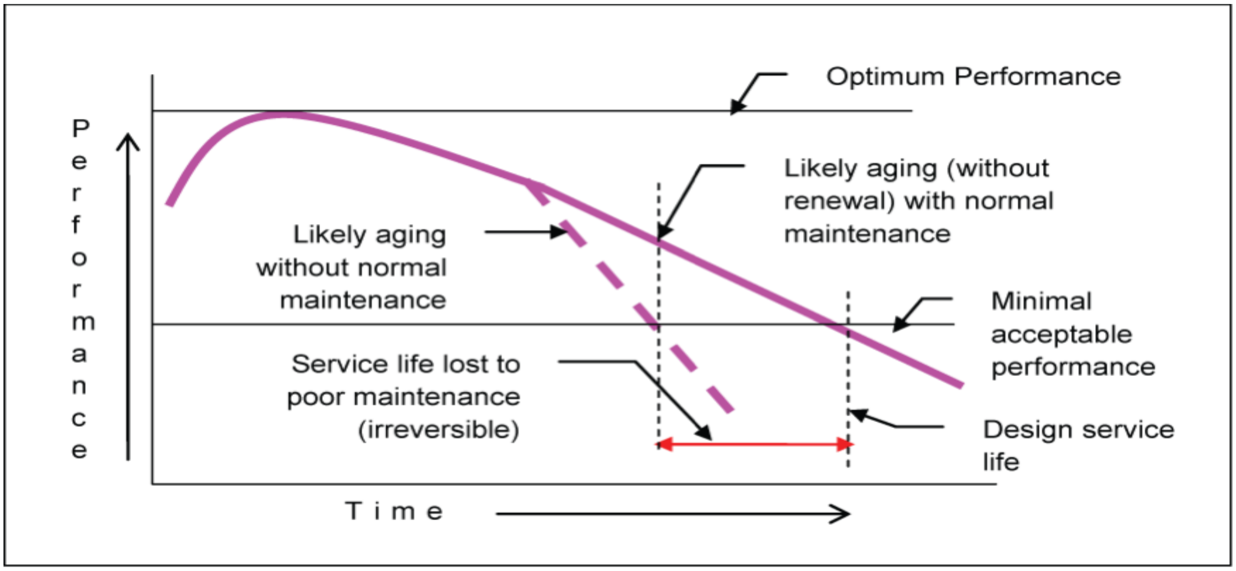


Figure 9-1 Effect of Adequate and Timely Maintenance and Repairs on the Service Life of a Building (Appendix C.1, resource 21)

9.3 General Principles

9.3.1 To be credible, the maintenance and repair estimates should be developed on the basis of a condition assessment of all facilities as follows:

a. All maintenance deficiencies should be identified and cost-estimated based on a current facilities condition assessment that includes input from continuous inspections.

b. Deficiencies that will be corrected as part of the current year AWP shall be subtracted from the estimates upon completion.

c. Deficiencies in facilities that do not support the Center's long-term or near-term mission goals, as articulated in the master plan, shall be included in the estimates.

d. The developed estimates should be reevaluated annually. This not only authenticates the work that continues to be deferred, but it also identifies work items in the estimates covering deficiencies that have progressed to the point where they absolutely need to be included in the AWP.

9.4 National Research Council's 2 to 4 Percent Guidance

9.4.1 There is no single, agreed-upon guideline that determines how much funding is required to adequately maintain facilities. However, in 1990, the NRC (Appendix C.4, resource 1) recommended that, "An appropriate budget allocation for routine Maintenance and Repair (M&R) for a substantial inventory of facilities will typically be in the range of 2 to 4 percent of the aggregate current replacement value of those facilities."

9.4.2 Lacking an actual requirements-driven budget, the annual facilities maintenance budget should average 2 to 4 percent of CRV. (See Figure 2-1.) However, this rule of thumb applies only when the facilities have reached a steady-state maintenance condition (i.e., when the backlog has been reduced to an acceptable level). What an acceptable level is depends on the nature of the backlog and the mission of the Center. For example, a large backlog for interior painting may be acceptable, while a large backlog of roof repairs may indicate serious problems and should be reduced quickly.

9.4.3 Figure 9-2 illustrates the relationship between the backlog and annual maintenance funding levels as a percentage of CRV. It shows also a method of backlog reduction.

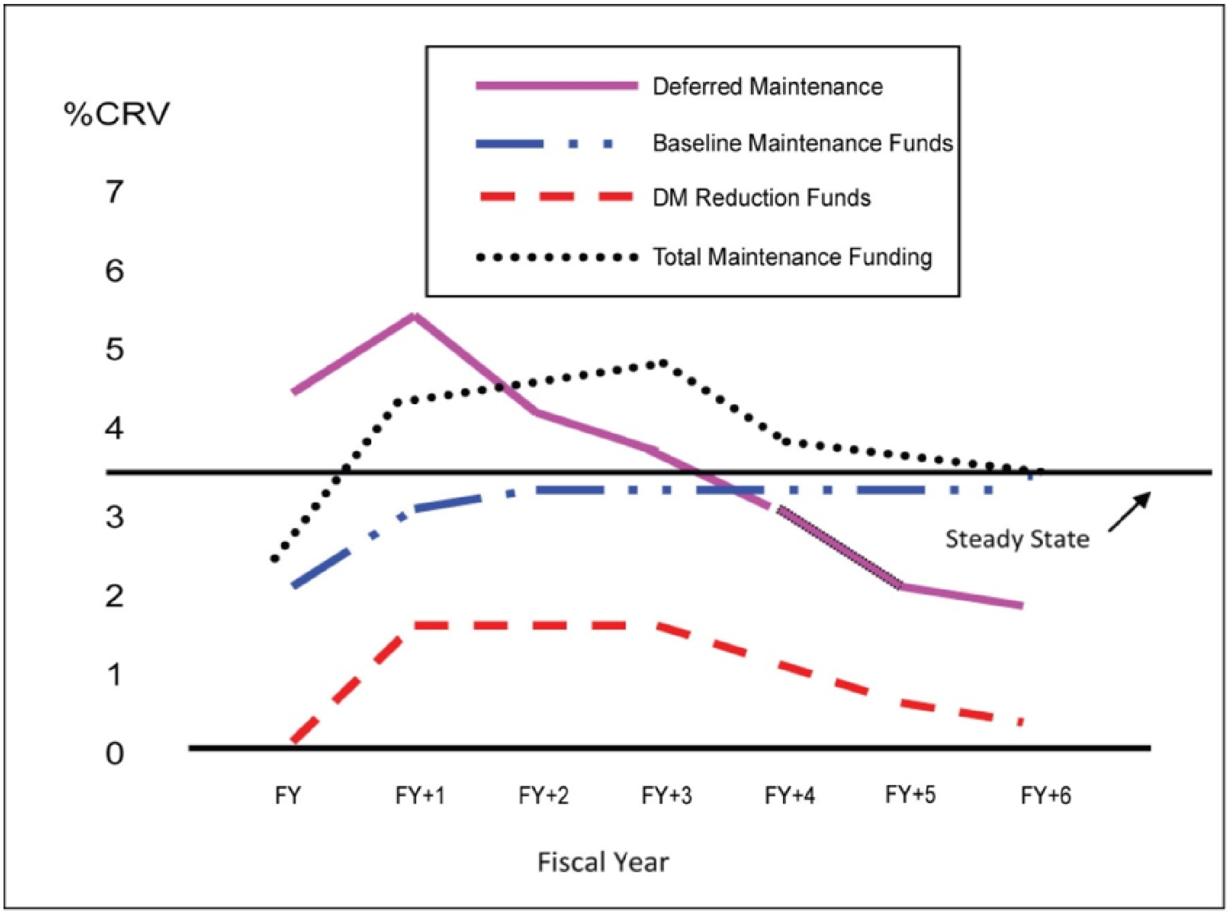


Figure 9-2 Typical DM Reduction Funding Profile

For illustrative purposes only, Figure 9-2 assumes that 3.5 percent of CRV is the optimum steady state maintenance funding level and that a backlog under 2 percent of CRV is acceptable. In this example, annual maintenance funding initially averages 2 percent of CRV, and the backlog is increasing each year. Then, baseline annual maintenance funding increases to 5 percent over a 2-year period, and additional funding is programmed for backlog reduction over a 6-year period. As the backlog is reduced to below 2 percent of CRV, special funding for backlog reduction decreases, but baseline maintenance funding remains at 3.5 percent. If the backlog begins to increase, maintenance funding should be increased again to reduce the backlog to below 2 percent of the CRV.

9.4.4 Metrics. Evaluation of DM and other maintenance performance indicators against a baseline is discussed in Section 3.11, Management Indicators, and listed in Appendix G. An elimination of the DM is not always possible or desirable since DM can provide an ability to balance resources in the long term. Appendix G lists other metrics, of which DM is a factor.

9.5 Maintenance and Operations Cost Study

9.5.1 The FRED Maintenance & Operations Cost Study was done to determine, by modeling actual facilities, what NASA should be spending to sustain and operate facilities based on recommended requirements. Sustainment was defined as the amount of money required to properly maintain a facility without any degradation in condition from one year to the next, i.e. constant facility condition index (FCI). The ultimate goal of this study was to have another source of traceable documentation to use to justify maintenance budgets. To date, four types of NASA facilities were studied with the results shown in Table 9-1.

Table 9-1 FRED Maintenance & Operations Cost Study Results

Building Type	Maintenance and Repair (% of CRV)	Operations (% of CRV)	Total M & R & Operations (% of CRV)	Total Cost/GSF (M & R and Operations)
Administrative Buildings	2.2	2.3	4.5	$11.46
Propulsion Test Facilities	0.7	0.7	1.5	$14.04
Communications Buildings/Data Centers	5.3	4.7	10	$42.40
Space Science R & D Facilities	1.9	2.1	4.1	$18.16

Notes:

1. *Maintenance and Repair includes all required M&R plus planned end of life replacement of building components and systems.*
2. *Operations include utilities, grounds (including snow removal), and custodial (including trash removal, recycling, and pest control).*
3. *Figures are in 2012 Dollars.*

9.5.2 In recent years, NASA has typically been funding maintenance at less than 0.9% of CRV. For years, people have been quoting the infamous 2% to 4 % from Committing to the Cost of Ownership (1990), but as can be seen, the costs vary significantly depending on facility type and use. The maintenance costs for propulsion buildings are low primarily because of intermittent use and the facilities consist of test cells filled with program support equipment for which the maintenance costs were not captured; however, the communications building maintenance costs— which includes data centers that run 24/7— are very high.

9.6 Baseline Services Level Study (June 21, 2010)

9.6.1 The minimum Baseline Services Level (BSL) annual funding requires 1.6% of Active Facilities CRV. Contact HQ FRED for additional information or a copy of the final report.

9.7 Facilities Condition Assessment

9.7.1 Maintenance and repair requirements and equipment condition are determined and validated through the facility condition assessment process. (See Chapter 10, Facilities Maintenance Standards and Actions, for more detailed discussion.) This assessment should be conducted continuously during normal PM and PT&I inspections, observations by the facility manager or other responsible individuals, and other work order repairs. It is important for the FCA process to focus on what is really important—mission; life, health, and safety issues; and systems most critical to a facility's performance—to optimize available resources, provide timely and accurate data for formulating maintenance and repair budgets, and provide critical information for the ongoing management of facilities.

9.7.2 NASA Centers shall identify and quantify facility conditions to support annual and 5-year work plans. The DM is the delta between the work requirements identified in the FCA and those that can be satisfied within the funding available. Adoption of the RCM philosophy, PT&I, CMMS, and proactive maintenance approaches provide Centers with information related to facility condition that was not previously available. These new information sources, coupled with increased customer and user input, have the potential to provide valuable FCA data without having to perform many of the discrete inspections required under the traditional FCA processes.

9.7.3 NPD 8831.1 requires that Centers continuously assess facility conditions to identify and quantify their DM so as to be 80-percent accurate at any time. Since a Center's facilities are in a constant state of change due to normal wear and tear, renewal tasks, and reconfiguration, the FCA process should be dynamic if an accurate estimate of a Center's condition is to be obtained. To facilitate this, all DM shall be maintained in the Center's CMMS in a format that can be updated with the results of the continuous inspection program and with additions to and deletions from the facilities and equipment inventory. The CMMS records should identify DM by facility and classify each item as mission critical, mission support, or Center support and further classify each item by the type of system, such as roofs, HVAC systems, structures, roads, or similar systems.

Chapter 10. Facilities Maintenance Standards

10.1 Introduction

10.1.1 Maintenance standards provide the basic information that identifies what portions of the facilities asset inventory receive maintenance and to what level they are to be maintained. They also provide the benchmarks for conducting condition assessments and estimating workload. This chapter discusses maintenance standards in detail. Section 3.12, Management Analysis, discusses the use of metrics and benchmarking in setting and updating maintenance standards.

10.2 Facilities Maintenance Standards

10.2.1 Centers should use generally accepted facilities maintenance standards, as detailed in this NPR and the references contained in Appendix C, appropriate for the NASA objective of providing facilities to support safe, "world class" research and operations. The standards, which form a part of the PM programming, should be the basis for evaluating the condition of the facilities and for determining the minimum and desired material condition of facilities and collateral equipment. Centers should develop and use maintenance cycles that take into account the manufacturers' recommended maintenance, the level of local use, and environmental conditions.

10.2.2 In addition to the facilities maintenance standards used to identify deficiencies not visually discernible and those outlined in Appendix C, the following types of deficiencies would be expected to be prioritized and remedied according to safety and mission-impact significance. Any of the deficiencies listed below that are not remedied in a reasonable amount of time may be indicative of a Center that does not have a proactive facilities maintenance program:

a. Peeling or flaking paint.

b. Rust stains or corrosion.

c. Stained or mildewed concrete surfaces.

d. Leaking roofs.

e. Leaking pump seals.

f. Failed asphalt or concrete paving.

g. Debris on grounds or in mechanical areas.

h. Spalled or scaling concrete.

i. Tripping hazards.

j. Leaking steam traps.

k. Stained or broken ceiling tile.

l. Worn or broken floor tile.

m. Painted surfaces worn through to base materials.

n. Carpet wear paths or ripples.

o. Electrical or mechanical equipment not meeting current codes.

p. Unsecured or failed pipe insulation.

q. Overheated motors or other electrical devices.

r. Abandoned-in-place conduit, wiring, cables, piping, and other equipment (unless facility is to be excessed).

s. Traffic signs and markings not meeting the Manual on Uniform Traffic Control Devices.

t. Faded or illegible building signs.

u. Leaking and nonoperational components.

v. Broken or cracked windows.

w. Permanent electrical extension cords.

x. Equipment and systems operating well past life cycle.

y. Unaddressed environmental issues, such as lead paint, asbestos, and PCBs.

z. Failed foundations and structures.

aa. Outdated maintenance IT support software and hardware.

bb. Outdated building automation, fire, security, and safety systems configurations.

cc. Substandard PM programs.

dd. Unmetered utilities.

ee. Energy-inefficient equipment and systems.

ff. Inadequate brush clearance around buildings in fire hazard areas.

10.2.3 As a general rule, Centers should have appropriate landscaping, color-coded and identified piping, efficient and reliable heating and air conditioning equipment, and other amenities suitable for facilities to support the safe, "world class" research and operations that are NASA's goal.

10.2.4 Centers shall use maintenance standards, conduct periodic condition assessments of their facilities against the maintenance standards, and determine and carry out the maintenance actions required to meet the standards.

10.2.4.1 To set the standards and accomplish these actions, maintenance support information (MSI) shall be collected. This chapter provides suggested methods to collect the MSI and then develop and implement maintenance standards, continuous inspections, condition assessments, and maintenance actions. By using the following, a facilities maintenance organization can maximize its capabilities:

a. Following standards.

b. Using good planning and estimating practices.

c. Accurately recording work accomplishment.

d. Analyzing internal work through metrics and benchmarking.

e. Accepting improvement changes.

10.3 Facilities Condition Standards

10.3.1 A maintenance standard is the expected condition or degree of usefulness of a facility or equipment item. It is often a statement of the desired condition or a minimum acceptable condition beyond which the facility or equipment is unsatisfactory. Maintenance standards shall be applied not only when inspecting facilities and equipment currently on hand, but also when specifying or accepting facilities and equipment being procured or installed.

10.3.2 Recorded facility or equipment conditions may vary based on the perspective of the individual inspector. Therefore, clear, unambiguous standards are necessary to ensure that there is consistency in the inspection results obtained by the individuals performing the inspections.

10.3.3 Types

10.3.3.1 Facilities condition standards may take many forms. The following are some examples:

a. Error or leakage rate.

b. Wear (e.g., remaining tire tread).

c. Elapsed time since last overhaul.

d. Chemical composition.

e. Vibration level.

f. Availability.

g. Maximum allowable deflection.

h. Operating temperature.

10.3.3.2 The applicable standard depends on the item, its intended use, and the mission criticality or health and safety aspects of that use. Thus, identical items can have different standards when used for different applications. Maintenance standards provide benchmarks for FCAs, PT&I, PM, operator inspection, and determination of maintenance requirements.

10.3.4 Sources

10.3.4.1 There are many sources of maintenance standards, each with different force, effect, and applicability. Appendix C contains a list of publications that provide information on maintenance standards. Some cover specific types of facilities and equipment; others are more general. Common sources include the following:

a. Laws and regulations.

b. Manufacturers or vendors.

c. Trade or industry associations.

d. Government publications.

e. Locally developed standards.

f. Specialized standards.

g. Energy efficiency and reduction standards.

10.3.4.2 The MSI discussed in section 10.9, Maintenance Support Information, contains much of the information necessary to develop the condition or performance standards for facilities and installed equipment. This information is then evaluated against legal requirements, regulations, industry standards, intended use, and mission-supporting requirements to determine the applicable maintenance standard for the item.

10.3.5 Setting Standards

10.3.5.1 Existing Facilities

a. Normal practice is to set standards while establishing a maintenance program for a facility or equipment item. The source of the standard used is that which best covers the operational use of the facility or equipment. Where individualized standards are necessary, knowledgeable operations and maintenance personnel should work together with reliability engineers, where applicable, to develop and document an appropriate standard.

b. Care should be taken when developing a local standard. Many existing standards may be outdated, obsolete, and may not reflect recent changes in technology. Consequently, they may be inadequate, typically addressing only very general or minimal performance criteria.

c. Section 10.9, Maintenance Support Information, discusses the process of collecting MSI to support standards development.

10.3.5.2 New Facilities and Equipment. Historically, the vendor or construction/installation contractor has been the source of maintenance standards and related information (including maintenance procedures) for new facilities and equipment. An alternative is to develop facilities MSI for the new facility or equipment as part of the design process. In fact, this is one of the primary functions of a proactive maintenance program, which bases the specifications for new facilities and equipment on such maintenance-related information as facility and equipment history, reliability, and life-cycle cost data obtained from maintaining and operating the equipment and facilities being replaced.

10.3.5.3 Methods of Setting Standards

a. Due to the unique nature of certain NASA facilities, existing maintenance standards or requirements may be inappropriate. As a result, it may be difficult to develop a comprehensive and efficient maintenance plan for an individual item. In any case, however, standards can be researched and developed by Centers, either in house or by an A&E contractor, as described in sections 10.4, Work Performance Standards, and 10.9, Maintenance Support Information.

b. Standards should be tailored to the specific needs and missions of the Center. One philosophy used in setting and using standards is described in Chapter 7, Reliability Centered Maintenance.

10.4 Work Performance Standards

10.4.1 Standards of work for specific tasks are necessary to plan work properly, to evaluate the quality of the work performed, and to evaluate the efficiency of the work control process. This is particularly important in the case of maintenance work because most of the work orders are relatively small compared to major repair work. Additionally, the jobs are normally spread out over a large area. When uncontrolled, typical maintenance work can involve an extensive amount of travel time as compared with work performance time. Repetitive jobs, in particular, should be evaluated with respect to applicable standards and reviewed for possible improvements in efficiency.

10.4.2 Preventive maintenance is a primary example of repetitive work, typically with similar tasks performed on many items of equipment in many different locations. A well-designed PM program incorporates standard time estimates. Actual performance times are recorded for subsequent evaluation and for reference when planning and scheduling future PM cycles. A facilities maintenance manager can evaluate the effectiveness of a PM crew by the amount of time expended on a job versus the standard time. Further, the manager can look for trends as explained in Chapter 3, Facilities Maintenance Management.

10.4.3 Maintenance Work Standards

10.4.3.1 The construction industry has developed work standards primarily for cost estimating. Commercial bids are tracked, and the associated cost and time estimates are analyzed and used to publish construction industry standards. Some of these construction cost and time standards can be applied to maintenance work, principally to larger projects such as the replacement of major items.

10.4.3.2 This data is updated and published annually for use in estimating, budgeting, and planning maintenance work on a per-project or annual basis. These publications cover areas such as maintenance and repair task, time, and cost data; PM task, time and cost data; equipment rental costs; city cost indexes; historical cost indexes; audit information; and life-cycle costing. These standardized task descriptions, times, and costs are developed for both in-house workforces and contractor operations. This or similar data can be used along with local data to develop initial maintenance work orders that can be updated with experience. (See Appendix C for a list of these publications.)

10.4.4 Engineered Performance Standards

10.4.4.1 Engineered performance standards (EPS) are a comprehensive tool for planning and estimating facilities maintenance and related facilities work. They provide methodology and a series of standard maintenance tasks and task times, which are combined to develop a work order plan and work order estimate. The system builds the estimate by aggregating the incremental times for tasks and adding time allowances for setup, cleanup, travel time, and local factors. EPS can be applied manually or by computer.

10.4.4.2 The work order plans and estimates that the EPS produces are consistent and repeatable, and, thus provide good benchmarks for planning work and evaluating performance. EPS estimates are based on average crafts personnel working with proper tools under average conditions. A well-qualified crew will beat the EPS estimate consistently, and an inexperienced crew is likely to lag the EPS estimate.

10.4.4.3 Publications are available to provide detailed EPS guides. (See Appendix C for a list of those publications.) A computerized version of EPS is also available.

10.4.5 Local Standards. Local experience documented in maintenance history files is a valuable source of information for work order planning and estimating and may be used as a basis for standards. However, actual maintenance tasks and performance times for past work should be spot checked against standards to ensure that the times are reasonable and work practices are efficient, effective, and in line with current codes, standards, and technology. A major value of a CMMS is to provide completed work information to validate the appropriateness of the standards used and to help tailor them to local conditions.

10.4.6 Other Standards. A variety of facilities cost estimating standards is available. Many are focused on new construction, renovation, or facilities repair tasks. However, they can be useful in estimating maintenance work, especially work that is similar to construction, provided adjustments are made for job scope. One example of this is SPECSINTACT, as managed by the Director, Facilities and Real Estate Division, NASA Headquarters.

10.4.7 Reliability Centered Maintenance. Critical to RCM are the design, construction, acceptance, and performance standards associated with equipment and the various PT&I technologies. Chapter 7, Reliability Centered Maintenance, in this guide, the NASA Facilities RCM Guide, and the NASA Facilities and Equipment Acceptance Guide all discuss standards in detail and provide acceptable ranges for performance. Equipment approaching the limits of or operating outside of the acceptable range are candidates for remedial action.

10.4.8 Reliability Centered Building and Equipment Acceptance. Centers shall employ equipment acceptance standards, an element of the facility and equipment acceptance process, and noninvasive diagnostic tests that verify systems and equipment condition and installation prior to the exit of the installing contractor from the job site. The purpose of the standards and testing is to verify that the system performs according to design intent with no latent manufacturing or installation defects. It is less costly to maintain and meets the required operational efficiencies. Facilities and equipment commissioning and acceptance is discussed in Chapter 8, Reliability Centered Building and Equipment Acceptance.

10.4.9 Failure Modes and Effects Analysis. The NASA Reliability Centered Maintenance Guide for Facilities and Collateral Equipment discusses the use of Failure Modes and Effects Analysis (FMEA) to identify the multiple failure modes associated with every function within a facility system, subsystem, or component.Â Effects of these failures may be used to determine the maintenance standards required to address the criticality of the system, subsystem, or component.

10.5 Continuous Inspection

10.5.1 Inspections are the cornerstone of facilities maintenance management. They identify needed maintenance work, provide feedback on the effectiveness of the facilities maintenance program, and form the basis for changes to the program. NASA Centers should continuously assess facility conditions in a manner that results in the identification and quantification (in terms of dollars) of the repair needs that will address the deferred maintenance.

10.5.2 General Inspection Requirements

10.5.2.1 During an inspection, if the inspector uncovers unsafe conditions, the inspector shall notify the individual in charge of the operation and determine whether people and/or property are in imminent danger.

10.5.2.2 If so, there should be a strong consideration by the operator to cease operations until corrective action is taken.

10.5.2.3 The Center's safety office shall be notified of the situation as soon as possible.

10.5.2.4 Safety is recognized as a leading value in the maintenance process and, therefore, an important part of the inspection program. Facility and equipment deficiencies identified in the continuous inspection program will be evaluated for failure and failure consequences (risk assessment) to identify safety impacts.

10.5.2.5 Centers should develop a procedure for performing and documenting risk assessments of deficiencies identified in the continuous inspection program, for notifying the Center's safety office of any safety deficiencies, and for ensuring that the deficiencies are made safe.

10.5.3 Inspection Types. A Center's continuous inspection program should include the following:

10.5.3.1 Predictive Testing & Inspection. PT&I uses advanced technology to sense building, electrical equipment, and machinery operating characteristics, such as vibration spectra, temperature, noise, and pressure and to compare the measured values of these characteristics with historical data or other established criteria to assess the items' conditions. PT&I permits condition-based rather than time-based initiation of the maintenance effort to correct any problems identified. Evaluation of the PT&I data can be used to project future maintenance requirements for inclusion in the AWP or 5-Year Plan. See Chapter 7, Reliability Centered Maintenance, for additional information about PT&I.

10.5.3.2 Preventive Maintenance. Inspections are a major part of preventive maintenance and are performed on a time- or other interval-based schedule, normally using prespecified checklist items. These inspections may include minor adjustments and minor repairs (no larger in scope than TCs) of equipment included in a PM program. The inspection results should include a condition assessment documented in the Center's CMMS for use in projecting future maintenance requirements. PMs typically cover untended equipment.

10.5.3.3 Operator Inspections. Operator inspections are the examinations, lubrication, minor repairs (no larger in scope than TCs), and adjustments of equipment and systems that have an operator assigned. Typically, they apply to equipment or systems such as those in a central utility plant. Operators should provide condition assessments for documentation in the CMMS.

10.5.3.4 Facility Manager/Management Inspection. Periodic inspections should be performed by the Facility Manager. These inspections should include common spaces, hallways, equipment rooms, roofs, grounds, and other areas not covered by individual facility users. Users of private spaces, such as offices, should be evaluated as described in section 10.5.3.5, Facility User/Occupant Inspection. The facility manager should document the facility condition on, at least, a semiannual basis.

10.5.3.5 Facility User/Occupant Inspection. The facility user should be surveyed on a semiannual basis. The user's inspection input could be reported on a form such as the one shown in Figure 10-1. This is in addition to the facility manager's inspection. Figure 10-2 should be printed back-to-back with the Figure 10-1 form to ensure that the facility user's input can be coded into the CMMS for data integration and analysis.

10.5.3.6 Bridge Inspections. All public and nonpublic bridges are required to be inspected every 2 years in accordance with the Department of Transportation (DOT) Federal Highway Administration (FHWA), National Bridge Inspection (NBI) Program. FHWA NBI requires a specific 432-character report for Public Bridges. Reference Code of Federal Regulations, 23 CFR 650, Subpart C, and Structural Inventory and Appraisal of the Nation's Bridges: FHWA-PD-96-001. Centers shall submit their required inspection reports to NASA HQ by 30 September of their inspection year. Consult with HQ Facilities and Real Estate Division for additional information and guidance. FRED is planning to provide a NASA Bridge Inspection Guide, which will also reference the FHWA requirements and frequencies.

OFFICE CONDITION

LOCATION: Facility No. __________ Room No. ______ DATE: ________

NO CHANGE SINCE LAST INSPECTION

Inspected By: _______________ Phone No. _________

SKETCH OFFICE HERE

DESK

Please indicate the following on the above office outline:

Ceiling Tiles: No. Missing _____ No. Broken _____ No. Stained _____

Windows: Mark Locations Cracked or Broken _____ Leaks _____

Electrical Outlets and Switches: Mark Location Missing _____ Cracked _____

Doors: Mark Locations Handle, Hinges or Lock

Walls: Paint ____ Cracks ____

Lighting: Good ____ Poor ____

Ventilation: Airflow _____ Air Quality _____ Temperature Control _____

Carpet: Stains _____ Rips _____ Frayed _____

Resilient Tiles: No. Cracked _____ No. Stained: _____

Overall Appearance: Good _____ Fair _____ Poor _____

Comments: ____

Work Control No. ______________
Date Received ______________
Date Cleared ______________

Signature ______________________

Figure 10-1 Facility User Inspection

Circle a number from the two furthest-left columns to identify which item failed.
Circle a letter from the right column to identify how item failed.

Which Equipment?

PLUMBING
(1–15)

1. Urinal
2. Toilet
3. Water line
4. Valve
5. Faucet
6. Fuel line
7. Sewer
8. Steam
9. Storm
10. Natural Gas line
11. Fire Sprinkler
12. Irrigation
13. Heater
14. Pump
15. Container

ELECTRICAL
(70–83)

70. Switch
71. Outlet
72. Panel
73. Fixture
74. Light (lamp)
75. Ballast
76. Battery
77. Wiring
78. Breaker
79. Conduit
80. Timer
81. Cords
82. Transformer (isol.)
83. Other ____________ Specify

HVAC
(20–25)

20. Control
21. Thermostat
22. Filters
23. Duct
24. Refrigerant
25. Steam Trap

BUILDING TRADES
(40–61)

40. Door
41. Window
42. Hinge
43. Lock
44. Handle/Knob
45. Push/pull gate
46. Stops
47. Glass
48. Closures
49. Ceiling/floor tiles
50. Carpet
51. Partitions
52. Ext. Bldg.Struct.
53. Signs
54. Asphalt
55. Concrete
56. Fencing
57. Curbs
58. Shop equipment
59. Steps
60. Wall
61. Vehicle equip.

DISCREPANCY?

A. Broken
B. Burned out
C. Damaged
D. Disconnected
E. Faulty Ground
F. Flood
G. Gas smell/leak
H. Leak
I. Loose
J. Low level
K. Low/No charge
L. Missing
M. No hot water
N. No insulation
O. No power
P. Noisy
Q. Out of adjustment
R. Out of setting
S. Overflow
T. Plugged
U. Smoke/odor
V. Stuck open/closed
W. Tripped
X. Spill
Y. Fell off
Z. Programming
AA. Contamination
AB. Other ____________ Specify

NOTE: Figure 10-2 should be printed back-to-back with the Figure 10-1 form

Figure 10-2 Equipment/Discrepancy Classification Form

10.5.4 Inventory. The facilities and equipment inventory is the baseline for what is inspected and maintained. The inventory should permit identifying inspected items, items subject to PM inspection, and items subject to operator inspection. Chapter 3, Facilities Maintenance Management, discusses facilities and equipment inventories.

10.5.5 Frequency of Inspection

10.5.5.1 As the name implies, continuous inspections should be ongoing, with all facilities and equipment inspected periodically. The frequency of inspection depends on a number of factors, including the following:

a. Importance of the facility.

b. Legal or regulatory requirements.

c. Likelihood of condition changes since the last inspection.

d. Safety considerations.

e. Availability of inspection resources.

10.5.5.2 Table 10-1 provides suggested inspection intervals for a number of facilities and systems. These apply to facilities and equipment under average conditions supporting routine operations. Centers should adjust the frequencies to suit local conditions, regulatory requirements, known equipment conditions as a result of PM and PT&I, operational requirements, and user inputs.

10.5.6 Inspection Procedures. Preparing for and conducting an inspection involves many of the following steps, some of which may not apply in the case of PM inspections and operator inspections:

a. Identify the items to be inspected, based on the inventory.

b. Obtain the facility or equipment history. This includes information on completed and pending work orders, as well as the results of past inspections and the current use of the facility or equipment.

c. Review the applicable physical condition standards with a view toward the planned use of the facility or equipment. (Facilities or equipment scheduled for disposal or deactivation normally will have lower maintenance standards.)

d. Identify planned changes to the configuration and use of the facility or equipment.

e. Identify the inspector skills, specialized tools, and equipment required for the inspection.

f. Schedule the inspection and set the inspection route, considering the operational requirement for the facility, the availability of inspectors, and related factors. Factors such as safety certification requirements, mission criticality, observed rate of deterioration or condition change, and system availability determine inspection schedules and frequency.

g. Conduct the field inspection and document the conditions found, includes noting of appropriate asset identification (ID) tags. The documentation should be a clear and concise presentation of the conditions found and permit determining and estimating corrective action. Serious and safety-related deficiencies shall be entered into the work control system for immediate action.

Table 10-1 Suggested Inspection Intervals under Routine Operations and Average Conditions

Item Inspected	Interval (years)
1. Antenna-supporting Towers & Masts	2
2. Boilers and Water Heaters	1
3. Bridges	2
4. Building Structure	3
5. Building Electrical Systems	2
6. Bulk Fuel Storage	2
7. Cathodic Protection Systems	0.5
8. Chimneys and Stacks	2
9. Drainage and Erosion Control	1
10. Dredging and Moorings	3
11. Electrical Distribution Systems	1
12. Electrical Vaults, Manholes	1 or 2, determined by site location
13. Elevators, Lifts, and Dumbwaiters	1
14. Exhaust Systems	1
15. Explosive Storage Buildings	2
16. Explosive Building Grounding Systems	0.5
17. Fences and Walls	2
18. Fresh Water Storage	2
19. Fuel Facilities (Receiving and Issue)	1
20. Grounds	3
21. HVAC Systems	1
22. Inactive Buildings and Facilities	5
23. Pavements	1
24. Piers, Wharves, and Other Waterfront Structures	1
25. Plumbing	2
26. Power Switches, Instruments, and Potheads	2
27. Railroads	1
28. Roofs	1
29. Sewage Collection and Treatment Systems	1
30. Steel Power Poles and Structures	2
31. Trusses	1
32. Water Treatment and Distribution Systems	1
33. Wood Poles	2

10.5.7 Inspection Followup. The following actions are normally taken with regard to deficiencies found during an inspection:

10.5.7.1 Reporting Conditions and Recommendations. Inspections are intended to be used for determining and initiating corrective action. Therefore, it is important that problems be reported and a recommended corrective action be submitted to cognizant facilities maintenance managers for decisions on corrective action. The following are a range of corrective actions:

a. Issuing work orders.

b. Expanding the types and increasing the frequencies of PT&I tests to allow for closer monitoring of the problem. Tag or retag assets with appropriate ID tags.

c. Including corrective action in the AWP or 5-Year Plan.

d. Preparing a facility project.

e. Modifying maintenance standards or actions.

f. Including the deficiency as part of the DM.

g. A combination of the above.

10.5.7.2 Estimating Corrective Actions. The cost estimate associated with an inspection report typically is a scoping estimate. However, repair work orders normally require a detailed estimate. All of the information obtained during the identifying and estimating process should be documented, including any impact on the customer. All information is then entered into the work control process for further determination of prioritization, approval or deferral, and scheduling for accomplishment, as discussed in Chapter 5, Facilities Maintenance Program Execution.

10.5.7.3 Asset Impairment. Real property assets are considered impaired when there is a significant and permanent decline in the service utility of the asset in accordance with SFFAS 44, Accounting for Impairment of General Property, Plant, and Equipment Remaining in Use. During the course of inspections, real property assets shall be assessed for decline in service utility.Â If the decline in service utility is significant and unexpected, it is likely that an impairment has occurred.Â

a. Cognizant facilities maintenance managers shall document the description of the impairment and the methodology used to determine the impairment.

b. The Center Operations Director will gather information and data from Center Facilitates, Engineering, Planning and Real Property staff to provide to the Center CFO for review and appropriate financial accounting treatment.Â

c. The Center Operations Director and Center CFO will then coordinate the outcomes with Headquarters Facilities & Real Estate Division and Headquarters CFO Property Management.

10.6 Facilities Condition Assessment

10.6.1 NASA Centers will identify and quantify facility conditions to support Annual and 5-Year Work Plans. The FCA is the method by which the Centers meet this obligation. Each facility shall have an FCA every Five Years, as a minimum. Traditional methods of FCA have proven costly and, historically, have diverted money from needed maintenance. However, adoption of the RCM philosophy, PT&I, CMMS, CBM, and proactive maintenance approaches provide Centers with information related to a facility condition that was not previously available. These new information sources, coupled with increased customer and user input, have the potential to provide valuable FCA data without having to perform many of the discrete inspections required under the traditional FCA processes.

10.6.1.1 Any facility and equipment deficiencies identified in the FCA will be evaluated for failure and failure consequences (risk assessment) to identify safety impacts. When the evaluation identifies a safety impact (hazard to personnel or NASA property) the Center's safety office shall be notified, and appropriate action taken to alleviate the hazard.

10.6.1.2 In addition to safety deficiencies, appropriate followup action shall be taken to correct any other deficiencies identified.

10.6.2 NASA Headquarters also requires adequate FCA information to ensure its proper stewardship over facilities entrusted to NASA, as well as to assist the Agency senior management and higher authorities (Congress, OMB) in projecting facilities' budgetary needs relative to NASA's mission.

10.6.3 A third use of the FCA process is as a tool to evaluate contractor performance under a performance-based contract. While the FCA cannot address all aspects of the contractor's performance, it can be used to ascertain the direction in which the Center is headed. For example, an increase in the number of equipment units in a PT&I alarm condition and/or an increase in the normalized TC rate may be leading indicators of a degrading condition for specific facilities, systems, and equipment.

10.6.4 NPD 8831.1 requires that Centers continuously assess facility conditions to identify and quantify their DM so as to be 80-percent accurate at any time. This includes electrical, mechanical, and utility systems; buildings; roads; and grounds. FCAs are inspections and evaluation of data to ascertain condition only and do not include such maintenance actions as adjustments, lubrication, or repair. Since a Center's facilities are in a constant state of change due to normal wear and tear, renewal tasks, and reconfiguration, the FCA process should be dynamic if an accurate estimate of a Center's condition is to be obtained.

10.6.5 Following the general philosophy of maintaining reliable performance at the least cost, the FCA process should be more heavily weighted towards system function and customer (facility user), than on age and appearance. Further, the process should not be labor intensive and should be at the least cost. To meet these requirements, Centers should utilize all of the inspection techniques listed in section 10.5, Continuous Inspection, as appropriate, along with their CMMS databases. Maintaining strict database management and accuracy is essential if a real-time FCA process is to exist. The assessment should determine the condition or operational status of each item of equipment or facility as compared to a predetermined facilities condition baseline. Appropriate followup action should be taken to correct any deficiencies identified to include them in the AWP and to update the Center's DM and ROI records and the 5-Year Plan.

10.6.6 Facility Classification. A consistent facilities-type classification process should be used that allows like facilities to be compared to one another statistically and financially. All facilities shall be classified into one of the following:

a. Office.

b. R&D Facility.

c. Computer (Special Purpose) Facility.

d. Hangar/Aircraft Support.

e. Production Facility.

f. Non-Buildings (trailers, temporary structures, air- or tension-supported facilities).

g. Laboratories.

h. Central Utility/Power Plant Facilities.

i. Utility Distribution Systems.

j. Roads and Grounds.

k. Other Miscellaneous Facilities.

10.6.7 Facility Criticality. Facility and infrastructure criticality is defined in terms of safety, impact on the mission, impact on the Center, and other categories listed in Table 10-2. Single points of failureâ?"equipment that, when it fails, causes the entire system to failâ?"should also be considered.

Table 10-2 Criticality Selection Criteria

Criticality	Criteria
1.	Environment, health, safety impact with a single point of failure.
2.	Mission impact, single point of failure.
3.	Environment, health, safety impact, multiple failures required.
4.	Mission impact, multiple failures required.
5.	Center impact (nonmission).
6.	Significant economic consequences.
7.	Employee morale.
8.	Public relations.

10.6.8 FCA Process Model. Figure 10-3 is a sample basic model for Centers to use in establishing an FCA program. CMMS data, statistical analysis, facility user, and Facility

10.6.9 Manager input should be used in conjunction with the TC, PM, and PT&I databases.

10.6.10 FCA Analysis

10.6.10.1 Use of CMMS Data. The assessment should use CMMS data as an integrated part of its evaluation. The data can be analyzed statistically and searched for patterns or clusters that indicate changes in the condition of facilities and equipment, provided that the CMMS has been populated with accurate and complete data. For maximum benefit to the FCA analysis, the data for the CMMS fields should be collected as shown in Figure 10-3.

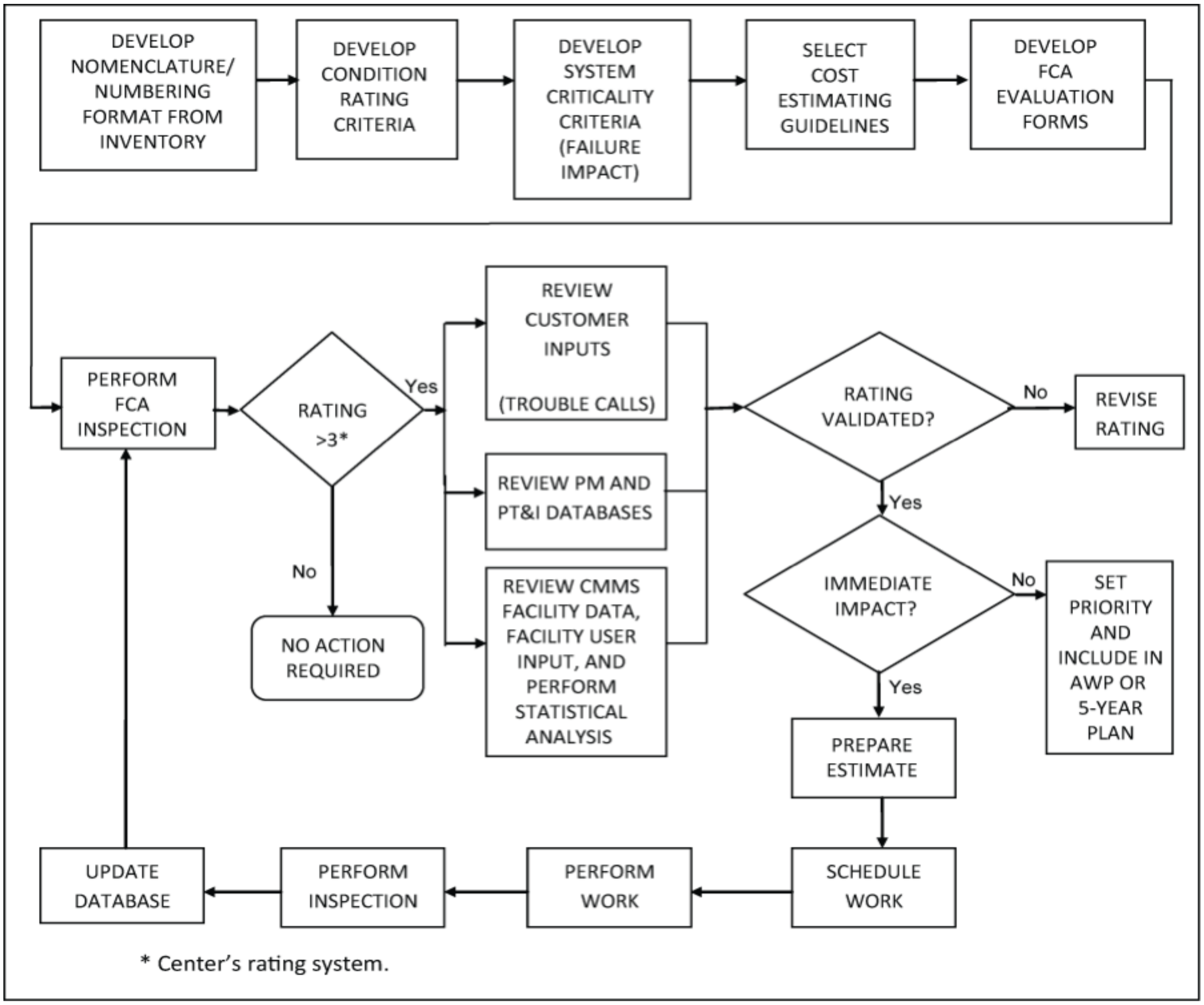


Figure 10-3 Sample FCA Process Model

a. Condition codes.

b. Failure codes.

c. Cost data (labor and material).

d. Facility type.

e. System criticality.

f. Functionality.

g. Age of the equipment.

h. Parts availability.

i. Repair history.

j. Serviceability.

k. Energy efficiency.

10.6.10.2 Statistical Analysis of CMMS Data. The data should be normalized by, among other things, the type of facility, square footage and the number of occupants, and the normal and standard deviations determined and trended over time. The trend line ideally should have a negative slope, indicating an improved condition.

10.6.10.3 Analysis of Energy Management and Control System Data. EMCS data should be analyzed as part of the FCA process to determine energy efficiency/consumption changes, which may indicate a deteriorating equipment or system condition that requires O&M action.

10.7 Maintenance Work Actions

10.7.1 Maintenance actions are the specific work tasks performed by the maintenance workers. These actions are the basis for work orders, workforce scheduling, and preparing budget estimates and work plans. Maintenance actions used in work orders are normally detailed, covering task specifics, while actions used for budgeting and long-range planning are more often generic or statistically derived.

10.8 Center Appearance and Grounds Care

10.8.1 Standards. Facilities design, colors, facades, and landscaping should fit in with other external architectural features, including signage, traffic flow, and visual and acoustic barriers. The resultant system should blend with local community standards and decor and properly represent NASA to the public. Where possible, the plan should emphasize low-maintenance features. Specific design guidelines are beyond the scope of this NPR. Facilities master plans often include landscaping plans, standards, and guidelines prepared by landscape architects. Landscape plans should include recommended maintenance actions. Facilities maintenance planning, including inspections and recurring maintenance, should ensure that facilities and grounds appearance represent NASA's best interests.

10.8.2 Grounds Care Guidelines. A large number of resources are available for obtaining guidelines for grounds care. These include Government publications, local agricultural extension services, trade and industry publications, and commercial grounds care services. Grounds maintenance plans should conform with the Center's master plan and have the support and approval of senior Center managers. Grounds care frequently involves using controlled chemicals, such as pesticides and herbicides, fertilizers, and other materials with potentially adverse environmental impacts. All work plans shall include appropriate environmental and safety requirements.

10.8.2.1 Maintenance Levels a. Based on land use, frequency of visitation, and visibility, Centers may wish to vary the quality (and cost) of grounds maintenance services specified for different parts of the Center. The following four levels are suggested:

(1) Level I - Administrative areas.

(2) Level II - Industrial, warehouse areas.

(3) Level III - Open storage, waterfront areas.

(4) Level IV - Railroad and power line rights-of-way.

b. Each maintenance level contains a distinctive mix of service requirements.

c. The service quality decreases as the maintenance level increases (e.g., grass cutting weekly in Level 1, every two weeks in Level II, monthly in Level III, and quarterly in Level IV (sufficient to reduce the fire hazard)).

10.8.2.2 Level of Service. There are three methods of specifying the level of grounds care maintenance: Frequencies, standards, and outcomes. Grounds care contract experience over many years at different locations has shown that specifying frequencies is preferable to specifying standards. Frequencies are easy to plan, schedule, enforce, and estimate costs. Grounds Care standards such as grass height or shrubbery appearance are difficult to estimate and enforce. Specifying outcomes, such as "lawns shall be green and well maintained at all times" is highly subjective and reliant on the contractor's proposed plan as part of the selection criteria, but is used with increasing frequency with outcome-based contracts.

10.8.2.3 Performance Requirements Summary. Grounds care contracts should contain a performance requirements summary in simple tabular form. Table 10-3 is a sample of a performance requirements summary. Chapter 12, Contract Support, discusses grounds maintenance and other performance and outcome-type contracts in greater detail.

10.8.2.4 Baseline Services Level (BSL) Study (June 21, 2010). The minimum Baseline Services Level (BSL) annual funding requires 1.6% of Active Facilities CRV. Contact HQ FRED for additional information or a copy of the final report.

Table 10-3 Sample Grounds Care Performance Requirements Summary

Performance Indicator	Standard of Performance	MADR* Percentage	Method of Surveillance	Percentage of Cost
1.A CONTRACT REQUIREMENT: GRASS CUTTING, MAINTENANCE LEVEL I				
A. Grass cutting and trimming completed during specified periods and as scheduled.	Attachment J-C1, Contractor's approved schedule in SOW.	5	Planned sampling	15
B. Debris removal	Collected prior to cutting, removal from site, no clippings left on walks, streets, etc. (Paragraph ___ in SOW)	5	Planned sampling	15
C. Grass Cutting	Uniform height between __ and __ inches, clippings distributed (Paragraph ___ in SOW)	5	Planned sampling	20
D. Trimming	Matches height and appearance of surrounding mowed area (Paragraph ___ in SOW)	5	Planned sampling	20
1.B CONTRACT REQUIREMENT: EDGING, MAINTENANCE LEVEL I				
A. Edging completed during specified period(s) and as scheduled	Attachment J-C1, contractor's approved schedule (Paragraph ___ in SOW)	5	Planned sampling	15
B. Quality edging	Clear zone provided 1/2" wide by 1" deep, vegetation removed from cracks, etc. (Paragraph ___ in SOW)	5	Planned sampling	15
C. Vegetation/debris removal	Debris from edging removed off site same date (Paragraph ___ in SOW)	5	Planned sampling	15
1.C CONTRACT REQUIREMENT: PLANT AND SHRUB PRUNING, MAINTENANCE LEVEL I				
A. Pruning completed during specified period(s) and as scheduled	Attachment J-C1, contractor's approved schedule (Paragraph ___ in the SOW)	10	Planned sampling	15
* MADR - Maximum Allowable Defect Rate				

10.9 Maintenance Support Information

10.9.1 Gathering MSI is a process of collecting life-cycle maintenance information on facilities and equipment. Table 10-4 is a list of typical MSIs. Some may not apply in all cases. This table provides a basis for an MSI checklist.

Table 10-4 Typical Maintenance Support Information

Operating Instructions	Safety Precautions Operator Prestart Startup, Shutdown, and Post-shutdown Procedures Normal Operations Emergency Operations Operator Service Requirements Environmental Conditions
Preventive Maintenance	Lubrication, Inspection, and Adjustment Data PM Plan and Schedule
Predictive Testing & Inspection	Applicability and Methods (Technology) PT&I Plan and Schedule
Repair	Troubleshooting Guides and Diagnostic Techniques Wiring Diagrams and Control Diagrams Maintenance (Including Overhaul) Procedures Removal and Replacement Instructions Spare Parts and Supply Lists Repair Work Hour Estimates
Proactive Maintenance	Equipment Family Breakdown History Equipment/Facility Condition Trends Equipment Tolerances and Process Parameters (Including Normal Temperature, Pressure, and Volume)
Other Data	Parts Identification Warranty Information Personnel Training Requirements Testing Equipment and Special Tool Information Calibration Data Contractor/Vendor Information

10.9.2 Historically, collecting, documenting, organizing, and maintaining facilities and collateral equipment MSI has been difficult. Modern CMMSs can be used to perform most of these functions automatically.

10.9.3 Maintenance Support Information Library

10.9.3.1 NASA facilities are aging, and there is a reduction in the frequency of replacement. Therefore, more attention shall be given to maintaining existing facilities effectively and to collecting and recording MSI for those facilities. This requires a managed maintenance library system. Maintenance documentation becomes more valuable as facilities age.

a. The library control procedures in the maintenance organization shall ensure that MSI documents are identified, cataloged, and maintained so that they are available during the entire life cycle of the facilities and equipment.

b. All documents and records should be filed and retained in accordance with guidance provided in NPR 1441.1.

10.9.3.2 The MSI library can be dispersed if it is controlled and periodically inventoried. The library is most useful when it is readily available to the personnel who need the information and can obtain it without undue effort. In the long term, this information will improve the effectiveness of the total maintenance operation. As MSI is incorporated into the CMMS, more of the maintenance personnel in the shop areas have access to the information, and necessary control is afforded by the CMMS itself.

10.9.3.3 MSI control is particularly important during the turnover of maintenance operations between contractors or from in-house to contractor operation. MSI that is considered unimportant during a transition period may become vital when an item of equipment starts to fail.

10.9.3.4 For new facilities and equipment, the vendor or construction contractor frequently provides MSI. However, it often is not in a form or in an amount sufficient to meet facilities maintenance needs. Further, personnel are not always available to develop facilities maintenance standards and procedures based on vendor- or contractor-provided information. Training provided by the contractor or vendor may or may not be adequate.

10.9.3.5 NPR 8820.2 makes provisions for obtaining MSI as part of the facilities project preparation and implementation process.

10.9.4 Section 10.9.3, Maintenance Support Information Library, discusses the library and the need for having all existing MSI documents under library control. The following sections address obtaining MSI for new facilities as part of the design process. Similar procedures can be used to obtain an A&E to gather information for existing facilities.

10.9.5 Planning

10.9.5.1 Identifying MSI should be an integral part of the planning process for new facilities. Its cost should be included in budget estimates for project design. MSI should be a deliverable prepared by the A&E designer. MSI should be due when the facility is nearing completion, prior to beneficial occupancy. In this way, maintenance requirements should receive full consideration in the design process. This should result in a more easily maintained facility with full maintenance data and systems support at the time of occupancy.

10.9.5.2 Where the Center lacks adequate MSI for existing facilities, especially mission-critical facilities, use of an engineering services contract to gather MSI is recommended. This contract may be combined with a condition assessment or inventory contract or handled as a separate contract solely for MSI.

10.9.6 Procedures

10.9.6.1 While the management of A&E contracts may fall outside the responsibility of the facilities maintenance organization, the facilities maintenance organization should take an active role in developing MSI requirements. The following sections describe a typical approach to the development of MSI and the organizations responsible for the necessary actions.

a. Centers shall:

(1) Determine whether a new or existing facility or equipment requires MSI and budgeting for the acquisition of MSI.

(2) Include a requirement for MSI in an appropriate contract (i.e., in the A&E's design scope of work for a new facility, as part of the scope of work for an engineering services contract for condition assessment or inventory, or as the scope of work solely for MSI development). This includes determining the level of MSI detail, submission form, and formats required from the contractor.

b. The Center and the contractor should work together to identify items that require MSI.

c. The A&E contractor may be tasked to provide any or all of the following items:

(1) For new facilities or collateral equipment, specifying the MSI required from the construction, equipment installation, supply contractor, or equipment vendor. For existing facilities or collateral equipment, obtaining the information directly from the manufacturers or vendors of the existing facilities and equipment.

(2) Integrating the contractor-furnished information with the facility design features and using the facility data (including Center operational requirements) to update the facility and equipment inventory and to document appropriate maintenance standards and procedures.

(3) Assembling the MSI into the required deliverable formats.

d. If any of these items are required, the requirements documents (and resultant contract) shall reflect the project needs and deliverables accordingly.

10.9.7 Deliverables

10.9.7.1 The deliverables required by the MSI specifications may take several forms. In the past, hard copies of manuals, drawings, and maintenance procedures have been the most common deliverables required. However, other formats are possible. Where automated inventory and maintenance management systems are in use, the MSI acquisition should include uploading the MSI into the CMMS. Deliverables should be in computer-readable formats, including computer-aided design and drafting (CADD) drawings and GIS data files. MSI specifications should call for linkages between drawings, drawing components, and CMMS databases where appropriate.

Chapter 11. Utilities Management

11.1 Introduction

11.1.1 This chapter provides guidance for utilities planning and management and describes the concepts and philosophy for the O&M of central and satellite utility plants, such as central heating plants, central chilled water (chiller) plants, air compressor plants, and water and wastewater treatment plants. These central utility plants are normally operated and maintained by a Center's facilities maintenance organization.

11.1.2 Comprehensive planning and management of utilities are essential for securing adequate and cost-effective supplies of current and expected needs of electricity, natural gas, steam, water, and wastewater treatment for NASA. Current requirements affecting the planning and management of utilities are: NPR 8570.1, NPR 8553.1, Energy Policy Act (EPAct) 2005, and Executive Order 13423, Strengthening Federal Environmental, Energy, and Transportation Management. The intent is to secure the most reliable utility services at the lowest cost consistent with NASA's mission, environmental standards, and waste reduction. The utilities are required to support various energy-consuming systems at NASA facilities. Some of the primary energy-consuming systems commonly found at NASA facilities include the following:

a. Heating and power plants.

b. Steam production and distribution systems.

c. Hot water and chilled water production and distribution systems.

d. Electrical generation and distribution systems.

e. Compressed-air production and distribution systems.

f. Wind tunnels.

g. Data centers.

h. Manufacturing facilities.

11.2 Planning and Management

11.2.1 While existing utility requirements are satisfied, future growth, as well as emergency situations, should be anticipated and properly planned for. Factors to consider are the future needs of the utilities and system capabilities, potential threats to existing services, alternative solutions to ensure adequate future supply, and finding and developing new sources of the energy products. Where necessary, utility systems upgrades should be implemented where new sources have not been identified. Utility planning and management instituted to promote system efficiency should also include emergency preparedness.

11.2.2 At the Center level, utilities management has the following major functions:

a. System development. System development is directed toward the design or planned improvement of generation, distribution, and collection facilities to achieve efficient and economical system operation. Inherent in system development is the evaluation of alternatives, such as the types of energy to be used, centralized versus decentralized systems, and the means to acquire utility services.

b. Operations and distribution. Operations and distribution are directed toward maximizing the efficiency of production, distribution, and collection equipment using minimum labor and materials.

c. Inspection and maintenance. Inspection and maintenance are directed toward minimizing cost and system downtime while ensuring safety.

d. Usage control. Usage control is directed toward minimizing waste, optimizing consumption, and educating customers.

e. Identifying single points of failure that would affect utility availability; advocating for redundancy or critical spares for mission-essential facilities.

11.2.2.1 In addition to ensuring adequate, reliable, and cost-effective utility services, proper utilities planning and management requires attention to such external factors as privatization initiatives, electric utility deregulation, utility purchasing options, and the future of demand-side management. This includes reviewing utility invoice, rate schedules to determine best value.

11.2.2.2 Utilities and central plants should normally be interfaced and controlled with modern building automation systems (BAS) or energy management and control systems (EMCS) for control technology. This will allow for modern energy efficient control, visibility, monitoring, trending, and metering. Interface of these larger systems with modern controls technology is necessary to optimize both energy and maintenance efficiency through use of trending, utility-use tracking, load-shedding planning, and establishing baselines for future equipment modeling and cost analyses. Proper interface of these technologies will greatly enhance the possibility of cost-saving measures such as peak shaving and possible energy-saving performance contracts.

11.2.3 Privatization

11.2.3.1 The privatization of utility functions is the transfer of in-house operations to private entities. Privatization can be executed by outsourcing or by asset sale. Outsourcing is contracting services through a competitive bidding process, while maintaining financial, management, and policy control over the services. Asset sale is the transfer of ownership to the private sector, where the Government has no role in the oversight of the sold assets. The goal of privatization is to achieve savings resulting from the introduction of new technologies, increased worker productivity, and improved operating efficiencies. The following factors will greatly reduce the risk in privatization:

a. Clear need and demand for service.

b. Visible total cost of in-house service.

c. Capability to provide oversight of and monitor the effectiveness of contractors.

d. Local control of decision to privatize.

e. Clearly defined goods and services.

f. Ability to define acceptable quality in measurable terms.

g. Flexibility to balance cost and quality.

h. Competitive markets.

11.2.3.2 The focus of many privatization efforts is to achieve a high level of reliability while optimizing in-house resources. In-house expertise shall be maintained to facilitate contractor relations. Careful communication and planning with personnel are imperative when it comes to alleviating the perceived threat of contracted services. The best available in-house skills are needed to establish contractor accountability and review performance evaluations. The benefit of privatization is that the burden of daily operations is transferred to the contractor who has greater flexibility to hire the necessary expertise and implement technology on an as-needed basis, thereby optimizing resources.

11.2.4 Fuel Source Planning

11.2.4.1 Dual-fuel capability is any technology that provides the ability to switch from one fuel source to another for generating energy, thus reducing dependence on any one source of supply. A facility with dual capability can switch relatively easily and quickly to a second fuel if the first fuel is either unavailable or more expensive per delivered BTUs than the second fuel. Note that EPA Boiler National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations can preclude shifting fuel types for economic reasons without additional routine boiler testing's being performed. Field installations should pursue alternative energy sources and identifying candidate projects. For many NASA Centers, the most feasible of these is natural gas conversion, but other possibilities, as diverse as refuse-fired steam plants or geothermal heat exist. The benefits of such initiatives include reduced susceptibility to petroleum market forces, less pollutant emissions, and possible reduction in facility maintenance requirements. Expansion of natural gas usage could allow replacement of high-energy-consuming electrical equipment and appliances with gas-fired units.

11.2.4.2 The main practical application of multiple-fuel capability is to support the purchase of natural gas on the "spot" market an alternative contracting mechanism for purchasing natural gas. The spot market refers to the purchase of gas from the producer rather than the local gas utility. The end user can make spot purchases either directly from the producer or indirectly via a gas marketer. Spot market transactions are usually short-term, "interruptible" purchases. Interruptible deliveries can be interrupted by any one of a number of contingencies: unusually cold weather, producer shutdowns, and/or a temporary lack of pipeline capacity.

11.2.4.3 Short-term interruptible contracts make supplies less certain. In addition, while spot market gas is normally cheaper than gas purchased under long-term contracts, prices can increase more quickly. Both possibilities make dual-fuel capability almost essential when purchasing spot gas. When natural gas is unavailable or undergoes a rapid escalation in price, a facility can switch dual-fuel boilers relatively quickly to burn fuel oil instead. Such a facility can then switch back to natural gas when it becomes available and affordable. Some local distributors will reduce the price of their natural gas if the field installation agrees to switch to an alternative fuel during a time when capacity has been curtailed. Such an arrangement can result in savings for both the local distribution company and the field installation.

11.2.4.4 The spot market for natural gas expanded dramatically when the Natural Gas Policy Act (NGPA) of 1978 deregulated the market. All field installations with the potential for participation in wholesale natural gas contracting may participate in the central procurement program offered by the Defense Logistics Agency (DLA). Field installations interested in taking advantage of the potential cost savings available in the spot market for natural gas should contact the Defense Energy Support Center (DESC) for information about their Competitive Direct Supply Natural Gas Program. The

GSA National Center for Utilities Management also provides contracting support to Federal agencies.

11.2.5 Electric Utility Deregulation National Status

11.2.5.1 Electricity competition in the United States is continuing to reshape the electric utility business. Historically, electric utilities have been vertically integrated utilities regulated by State Public Service Commissions (PSC), which are also known as Public Utility Commissions (PUC). The commissions have allowed the utilities to operate as natural monopolies within defined geographic boundaries. The typical electric customer purchased power in a packaged deal electricity production, transmission and distribution, metering, billing, and special services. The transmission and distribution services will continue under the regulatory guidelines set forth by the PUC.

11.2.5.2 The functional operations of a utility will not change. However, the power generation, and energy services will be contracted in a nonregulated environment that fosters competition. The Federal Government has shared the responsibility of implementation to the States since each State has different operational concerns in electric service. In some States, the authority to implement retail has different operational concerns in electric service. In some states, the authority to implement retail competition, be it the State legislature or the PUC, has not been clearly defined.

11.2.6 NASA Host State Electric Utility Deregulation Update. Various aspects of electric utility economics functions are being scrutinized by individual states as the Nation transitions into a competitive electric power market. States that have been the most aggressive in passing laws and implementing open-access transmission on the retail level are those states where the average cost of electricity is 20- to 60-percent above the national average. Contact information regarding the electric utility deregulation status for each NASA host State can be found in Appendix C.

11.2.7 Utility Purchasing Options. Many different utility purchasing options exist. However, the purchase process has become more complex due to utility deregulation. Being aware of energy utilization enables our understanding of rate applicability and appropriateness.

11.2.7.1 Rate Structures

a. Utility providers design rate structures that capture the cost of production and delivery of the commodity. The components of the rate structure vary depending on the volume, time of use, and customer size. The price mechanisms used to set rate structures include the cost for capital investment, service delivery, operating expenses, pollution control, and environmental and social externalities.

b. Rate structures imposed usually reflect consumption patterns and users. Most electric utilities offer one of the four following models as follows:

(1) General rate structures are geared toward users with low-consumption volume that is variable and difficult to forecast.

(2) Stable-volume rate structures are for users with predictable loads and minimum time-of-use or seasonal variation.

(3) Interruptible rates are for users with alternative power supplies. At the request of the utility supplier, service may be interrupted or curtailed for a limited period during the supplier's peak. The user can receive credit for helping to relieve the supplier's burden of peak supply.

(4) Modular rates are for users whose consumption is difficult to forecast. Typically, consumption is

sufficiently high to qualify for these rates.

c. Within the rate structures mentioned, price components may vary depending on mechanisms imposed or negotiated. Bill components may include the basic customer service charge, energy-use charge, energy-demand charge, taxes, and environmental-compliance recovery. High-consumption users can take advantage of other pricing mechanisms that may yield alternative cost-saving opportunities, such as real-time pricing (RTP), voltage-service discounts, and riders.

(1) RTP is the hourly energy pricing usually purchased a day in advance. Typically, rates are higher during peak use periods. With RTP, facility managers can plan to implement energy-use strategies to reduce consumption during high-price periods. Depending on the energy supplier, RTP can be applied to usage that exceeds baseload definitions. The baseline capacity is purchased at standard rates. The RTP rates are supplied to the customer a day in advance. If the next day's usage exceeds the baseline, then the RTP rates are charged. For usage below the baseline, the customer receives a credit at the RTP rates per unit of the commodity.

(2) Electric utilities offer discounts to customers who take advantage of high-voltage service. The utility feeds the high-voltage service directly to customer-owned distribution equipment such as transformers, switchgear, and safety equipment.

(3) Riders are associated with the use of new technology and participation in pilot programs or experimental services. Riders may be special charges or discounts applied to existing rate schedules. The rider type and amount will vary with the utility provider.

11.2.7.2 Load Aggregation

a. Load aggregation is the grouping of facilities with similar energy requirements and energy-use patterns for the purpose of creating a conglomerate to increase purchasing power, thereby, reducing the energy costs.

b. Load aggregation includes central collection of energy use data from geographically dispersed sites. With the proper instrumentation, energy load data can be gathered to explore the best available rate options for a defined group of uses at multiple service accounts or facilities. If the user profiles are similar, the composite information can result in an attractive energy use profile and load factor. The attractiveness comes in the consistency and predictability of energy use patterns, which reduces the power producer's risk in generating electricity, thereby reducing the price. With load aggregation, measuring when and how energy supplies are used enables the aggregators to negotiate the best price for energy contracts.

c. Differences in climates, occupants, and building construction are additional issues of concern when considering the potential for load aggregation.

d. Load aggregation enables the end-users to develop competitive leverage against host utilities.

e. Energy demand management, also known as demand side management (DSM), is the modification of demand for energy through methods usually involving financial incentives. The goal of DSM is to encourage the use of less energy during peak hours or to move the time of energy use to off-peak times such as nighttime and weekends.

11.2.7.3 Unbundled Services. Transmission and distribution services will still be regulated to ensure accessibility, safety, and reliability. Transmission entities will be regulated by the Federal Energy Regulatory Commission and will provide service via the power exchange or independent system operators. The distribution entity will remain as at present wires will still be used to supply electricity in compliance with State regulations. Generation companies, the owners of power plants, will sell power to power pools and distribution companies. They will also have opportunities to contract with the power exchange, independent system operators, and retail customers. Competitive energy services, dubbed as retail services, will introduce a broad range of energy-efficiency programs and services in a deregulated environment. The energy retailer will have opportunities to market customers, procure power for customers, and provide account management services.

11.2.7.4 Competitive Bidding. Competitive bidding is the process of comparing bids solicited from individual contractors. All bids shall be evaluated under the same guidelines. The contract award usually goes to the bidder offering the best-value solution.

11.2.7.5 Existing Utility Service Providers. Local utility providers will still play an important role in future electricity procurement. They will still provide transmission and distribution services for NASA Centers. The purchasing options are as follows:

a. Continue all services with the local utility company. Sometimes this equates to sole-source. Select a hybrid arrangement with the utility supplying base loads and an alternative provider supplying critical or excessive loads.

b. Select alternative providers for generation and energy services.

11.2.7.6 Federal Support for Power Procurement

a. Two Government entities, the DESC and the GSA, offer varying degrees of electricity procurement support. The DESC's mission is to provide the DoD and other Government agencies with comprehensive energy support in the most effective and economical manner possible.

b. GSA's Public Utilities Division also provides electricity procurement services for Federal agencies. GSA has organized a Center of Expertise to facilitate activities relative to energy conservation and management, deregulation and utilities, and other public utilities interests. Each GSA region will assist facilities with price negotiations and contracting services. Appendix C contains the list of regions along with the geographic areas of coverage, regional energy coordinators, and model area-wide contract.

11.2.7.7 Alternative Utility Service Providers

a. The competitive power market will involve a variety of agents to coordinate electricity transactions: utility companies, power producers, independent system operators, and power marketers.

b. Utility companies will be the basic electric service providers with an obligation to serve incumbents and those who live within the service area. Utilities will be regulated, with the mandate to provide universal service, ensure social and environmental responsibility, and construct and maintain all distribution lines. The only changes in the core business of the utility and transmission service will be the price and terms of electric service, since the utility will be the reseller of electricity from the market.

c. Nonutility power producers will engage in a competitive bidding process to provide electricity. The end user will be responsible for arranging delivery services. The diversity of power producers increases the opportunity to coordinate generation operations and maintenance. However, strict scheduling will be needed to ensure the delivery of safe and reliable power.

d. An independent system operator will be commissioned to maintain network efficiency and reliability of the generation and transmission system. The independent system operator will also be charged with monitoring fair and open access to the transmission system. Controlled service areas will be or will have been established in order for the independent system operator to maintain a balance of supply resources with user demands and to dispatch generators accordingly.

e. Power marketers typically serve as intermediaries between buyers and sellers, reduce prices, and offer value-added services. As commodity brokers, power marketers compete with each other to find and deliver the most economical and reliable power available to the customers.

11.2.7.8 Alternative Contract Mechanisms. Alternative contract mechanisms for implementing energy-efficiency improvements, as well as the installation of renewable energy sources, are specified in NPR 8570.1 and NPR 8820.2. The utility manager should work closely with the Center or site energy manager when considering these programs, which include:

a. Utility Energy Service Contracts (UESC) - a partnership between a Federal agency and a serving or franchised utility company. The utility company arranges funding to cover the capital costs of a project, which are repaid over the contract term from cost savings generated by the energy efficiency measures.

b. Energy Service Performance Contracts (ESPC) - a partnership between a Federal agency and an energy service company (ESCO). The ESCO conducts a comprehensive energy audit for the Federal facility and identifies improvements to save energy and water. In consultation with the Federal agency, the ESCO designs and constructs a project that meets the agency's needs and arranges the necessary funding. The ESCO guarantees that the improvements will generate energy and water cost savings sufficient to pay for the project over the term of the contract. After the contract ends, all additional cost savings accrue to the agency.

c. Purchased Power Agreements (PPA) - a partnership authorized or allowed by some States, between a Federal agency and a renewable energy developer. The developer installs a renewable energy system on Federal land or facilities. In exchange, the Federal agency agrees to purchase the power generated by the system throughout a contract term per a contract rate. These power purchase payments repay the developer over the contract term. The developer owns, operates, and maintains the system for the life of the contract.

11.2.7.9 Other Utility and Federal Programs. When considering these programs the Center or site energy manager can be a valuable resource. Other utility and Federal programs that provide incentives that should be considered include:

a. Demand Response Programs (DR) - are changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time or incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability has been reduced.

b. Rebate Programs - many local utility companies offer rebate programs for installing energy- or water-efficient equipment. When replacing energy or water consuming equipment, the utility manager or maintenance contractor should check with the local utility provider to see if rebates are available.

c. EPA Energy Star, EPA Water Sense, and DOE FEMP Designated Products - Life Cycle Cost Analysis (LCCA) has been performed on these products by the Environmental Protection Agency (EPA) and the Federal Energy Management Program (FEMP). These products are not only life cycle cost effective, they use less energy and Federal agencies are required to purchase these products by the Federal Acquisition Regulations (FAR).

11.2.8 Data Management

11.2.8.1 The modern building automation industry has developed utility management systems that integrate the ability to collect billing-grade metering, process, bill, trend, evaluate/manage, and control utilities. This can often be accomplished with minimal investment, through use of the existing building automation infrastructure.

11.2.8.2 Metering of all utilities, including process-related services, provides sufficient data to review billing transactions, usage patterns and levels, and system efficiencies. Data management packages the metered information in a manner that provides visual identification of problems and opportunities. Performance problems can be quickly identified followed by immediate corrective action. Opportunities for energy-efficiency projects can be evaluated and justified with data. This knowledge base helps energy managers and facility management personnel with proper resource allocation.

11.2.8.3 Some utilities are currently offering group billing to consolidate accounts for those customers with multiple facility metering. Electronic files are available upon the customer's request. These services reduce the burden on energy accounting and reporting functions. Data management provides the following services:

a. Streamlined billing process that reduces accounts payable encumbrance and simplifies data entry.

b. Utility bill validation that identifies incorrect billing factors and provides usage versus weather statistics.

c. Energy analysis that identifies building or system inefficiencies, tenant-usage patterns, and billed versus actual demand.

d. Rate schedule appropriateness that verifies account ownership and ensures best available rates for service, late fees, taxes, and surcharges.

e. Retrofit evaluation that assesses energy retrofit cost avoidance and determines effectiveness of energy management programs.

f. Budget preparation that provides data for preparing cost and usage trending reports.

11.3 Central Utility Plant Operations and Maintenance

11.3.1 Objectives. The objective of the O&M of central utility plants is to provide reliable, economical, and efficient central plant and utility services to support Center needs and missions, while complying with all regulatory requirements.

11.3.2 Plant Operations and Maintenance Considerations. The concept for the O&M of a central utility plant is that operators are assigned full time to operate the plant, but they perform maintenance between various operating tasks. Operator maintenance, as it is often referred to, involves a significant integration of facilities and equipment inspection and maintenance with routine watch-standing operations.

11.3.2.1 Staffing. Central utility plant operations and maintenance normally require a nearly constant level of effort, varying only with seasonal changes. Operators as a minimum shall meet license, permit, and certification requirements per section 3.6.2.3, Licenses, Permits, and Certifications.

a. In addition to these requirements, plant operators shall be thoroughly familiar with the assigned plant and its operating, maintenance, and safety requirements. Staffing levels can be greatly reduced (although not eliminated), while greatly enhancing reliability, through the application of BAS or EMCS technology.

b. Critical failure and out-of-tolerance conditions shall be established as alarmable points for the EMCS operator work station. While application of this type technology has been an industry practice in the HVAC industry, the modern trend and capability exists to expand this approach to cover electrical system, potable water treatment and distribution, waste water handling and treatment, chemical treatment, and other operations.

11.3.2.2 Maintenance Actions. Condition-monitoring (PT&I) and PM actions are frequently a part of the operating procedures for central utility plants and are performed by the operators as part of their routine watch-standing duties. Where possible, monitored equipment condition or hours of operation should drive maintenance actions. Additionally, plant operators may be directly involved with the repairs, ROI, and PGM on those portions of the plant they operate. Maintenance action development should use the techniques discussed in Chapter 7, Reliability Centered Maintenance.

11.3.2.3 Standards. Central utility plants are usually process oriented, production, and service focus for standards that emphasize equipment and system availability. These standards should identify conditions that require nonoperator assistance, as well as conditions addressed by the operators. The methods for setting standards discussed in section 10.3, Facilities Condition Standards, are applicable and should be used.

11.3.2.4 Operator Maintenance (Inspections). Operator maintenance is the examination, lubrication, minor repair (usually no larger in scope than TC), and adjustment of equipment and systems in the assigned plant. This maintenance and the inspections are directed toward minimizing system downtime and minimum cost. Operators should provide condition assessments for documentation in the CMMS as a part of the continuous inspection program.

11.3.2.5 Standard Operating Procedures.

a. Standard operating procedures shall be developed to cover routine operations, startup and shutdown, operator maintenance, PM, PT&I, and emergency actions such as load-shedding plans, emergency customer notification, and local utility company coordination.

b. Contingency plans shall be developed and kept current.

11.3.2.6 Inspection and Certification. All central utility plant boilers and unfired pressure vessels shall be inspected and certified in accordance with NPD 8710.5 and NASA-STD-8719.17.

11.3.3 Heating Plant Operations. The operation of a central heating plant includes startup and shutdown of heating equipment and operator maintenance and inspection. Operations include the efficient and economical production of steam or high-temperature hot water to ensure its availability to the Center at the lowest-possible cost. This work also includes record keeping of operations and conditions and analysis of records to correct nonoptimal practices. It includes water treatment; monitoring warranties; testing operations and capabilities of the central heating plant; periodic operation and inspection of idle equipment; and cleaning, preservation, lubrication, and adjustment of plant equipment. Also included are boiler emissions testing and record keeping for environmental regulations and permit compliance. Heating plant operations require control of the following functions:

11.3.3.1 Equipment Scheduling. Equipment scheduling requires matching heat generation with heat load requirements. This requires knowledge of demand curves, unit-cost curves (with selection of single-boiler operation or multiboiler operation), banking and startup costs, loading factors, and monitoring of both equipment selection and scheduling.

11.3.3.2 Equipment Operation. Equipment should be operated to achieve operating efficiency at operating loads. To accomplish this, boiler performance should be analyzed based on actual operational data taken from logbooks or recorded data and used to identify changes required to achieve optimum efficiency in steam/hot water production. Hourly log entries shall include weather data; stack temperature; feed water data; steam/hot water quantities, pressures, and temperatures; and carbon dioxide and oxygen readings. The optimum thermal efficiency curve for each unit should be obtained from the boiler manufacturer and used in operating the boilers. Many of these logged data points, which have historically been manual, can be obtained with automation technology. Likewise, energy efficiency and reliability should be enhanced through use of EMCS automated control strategies that optimize the selection and quantities of equipment that operate for a given plant load.

11.3.3.3 Water Testing and Treatment. At each daily shift turnover that a plant is in operation, the operators should collect feedwater, boiler water, and condensate samples from each operating boiler for testing and inspect corrosion coupons. Tests results should be maintained within Center-established limits for phosphate, sulfite, pH range, hardness, causticity (alkalinity as OH), and total dissolved solids. Test results should be recorded with plant reports and logs.

11.3.3.4 Plant Reports and Logs. The operators shall maintain operating logs on all operating equipment that note operator checks and adjustments and a record file noting normal or abnormal operating conditions, deficiencies or malfunctions, and corrective action taken. All recording charts and logs should be filed chronologically and kept in accordance with Center policy.

11.3.4 Central Chilled Water (Chiller) and Air Compressor Plants. Plant operations shall be conducted in accordance with applicable manufacturer's recommendations (such as manuals, specifications, brochures, literature, directives, and pamphlets), and Center-established policies including, but not limited to, safety, energy conservation, and specific mission requirements. A part of operations should be the performance of any needed minor adjustments and repairs (see section 11.3.2, Plant Operations and Maintenance Considerations).

11.3.4.1 Cooling Tower Systems. The O&M of cooling tower systems should include the performance of any needed minor adjustments and repairs to structures and components and monitoring and treating circulating water to prevent accumulation by precipitation of scale, corrosion, biological growths, and other foreign materials. Also included should be flushing and cleaning the cooling tower pans (sumps) and disposal of sludge from the pans. Sludge disposal shall be in accordance with environmental rules and regulations since sludge is considered hazardous waste.

11.3.4.2 Chemical Treatment of Closed-Loop Distribution Systems. Centers shall establish and maintain a chemical treatment program for the central cooling plant distribution systems. Inspection checks and subsequent adjustments should be made to chemicals at least every 90 days to maintain pH limits of 7.0 to 10.0, and nitrite levels of 500 to 1,000 ppm as NO2. Detailed records of the results of all inspection checks and chemical treatments should be maintained.

11.3.4.3 Plant Reports and Logs. Equipment deficiencies beyond the scope of operator maintenance shall be noted on operational log sheets or recorded in the CMMS.

a. Log sheets shall be filled out as part of each operational check.

b. Cooling tower and closed-loop distribution system data shall be recorded in the CMMS for future contracting purposes. (See Chapter 12, Contract Support.)

11.3.4.4 Modern trends in the operation and control of chillers have resulted in great improvements to the efficiency and reliability of chilled water plants. Strategies for equipment staging, variable flow to reduce low-temperature differential, and reduced condenser water temperature capabilities of some modern equipment allow for reduced maintenance problems and improved water-temperature control and quality, while greatly improving energy efficiency. Even with these trends, many plants are still operated with constant high condenser water temperatures and manual-operator selection of equipment. Since these plants are a primary consumer of energy and maintenance, there is a potential of huge payback through optimizing these operations. Also, staffing levels can be greatly reduced (although not eliminated), while greatly enhancing reliability, through the proper application of BAS or EMCS technology. Critical failure and out-of-tolerance conditions shall be established as alarmable points for the EMCS operator work station.

11.3.5 Water Treatment Plants. These plants include water pumping and treatment equipment and storage tanks. The plants should be operated and maintained as recommended by the equipment manufacturers and in accordance with Center, local, State, and Federal laws, rules, and regulations. A certified water treatment plant operator should operate the plant. The potable water should be free of taste and odor and meet required water quality standards.

11.3.6 Wastewater Treatment Plants. Centers shall comply with all requirements of their National Pollutant Discharge Elimination System (NPDES) permits, as imposed by the EPA (or as imposed by the State or local government).

11.3.6.1 Properly qualified personnel with required State certification shall operate the wastewater treatment facilities.

11.3.6.2 All certifications shall be maintained current and valid.

11.3.6.3 General Waste Water Treatment Operations.

a. Wastewater treatment facility operations should provide continuous, cost effective, and efficient treatment of all wastewater delivered to the facility. Such operations include general operation of plant equipment, valves and piping, sampling and lab analyses, waste and effluent disposal, and other related services. Treatment facility conditions shall meet applicable health and safety standards and be maintained clean and orderly at all times.

b. Operations shall be accomplished with proper regard to equipment and components to ensure operating efficiency and longevity of service life.

11.3.6.4 Waste Disposal. Waste shall be disposed of at a frequency sufficient to maintain clean and orderly collection sites with no overflow of waste material.

a. Wastes (including sludge, grit, screenings, and other waste solids) shall be routinely collected and transported to a properly classified disposal site.

b. Wastes deemed hazardous shall be transported and disposed of in accordance with Department of Transportation (DOT) and EPA requirements.

c. All waste disposal practices shall be accomplished in accordance with all applicable environmental regulations.

d. All records, receipts, manifests, and log entries shall be maintained in accordance with NPDES permit and State and local requirements.

11.3.6.5 Sampling and Laboratory Analysis. Sampling and laboratory analytical services shall be provided to support regulatory agency operating requirements.

a. Such sampling and testing procedures shall be accomplished in accordance with applicable operating permit conditions.

b. A complete set of laboratory records shall be kept for all laboratory tests, including: date and time of sampling, type of sample, name of sample, sampling location, test performed, and test results.

c. In addition, results of such laboratory analyses shall be assembled into reports to conform to the procedures and requirements of the NPDES permit (or other State and local permits, if applicable) and submitted to the EPA (or State and local agency).

(1) Copies of all testing records and associated correspondence shall be maintained on file by the NASA organization responsible for operating the system and related equipment.

(2) These records shall be part of the CMMS records.

Chapter 12. Contract Support

12.1 Introduction

12.1.1 Historically, NASA has contracted for support of its maintenance activities. Typically, contracts would specify a level of effort to be provided, rather than specifying the results to be achieved. However, the following are some of the problems associated with that approach:

a. It provides no incentive for contractors to be innovative or efficient.

b. It is uneconomical for the Government because it hires a "marching army" of contractor employees for a term of employment, instead of contracting for a job to be completed.

c. It may foster a personal services environment wherein NASA is perceived as the "employer" who supervises the efforts of contractor "employees."

d. It can contribute to a breakdown of project discipline (e.g., when the project office becomes concerned with how to keep the contractor busy, unplanned and often unnecessary "extras" may be added to the contractor's tasking).

e. It creates the opportunity for unnecessary enrichment of the labor skill mix, thereby, driving up labor costs.

f. It requires the Government to perform extensive surveillance because, absent clearly stated contract objectives, the contractor should receive continual clarification from Government technical representatives.

12.1.2 NASA's policy is to "Utilize performance-based contracts and best-value principles to the maximum extent feasible and practical to shift cost risk to contractors and maximize competitive pricing." It is also NASA's policy to include risk management as an essential element of the entire procurement process, including contract surveillance. In following these policies, NASA has committed to converting its method of procuring facilities maintenance services from a cost-reimbursement approach to a fixed-price, performance-based contracting approach.

12.2 Performance-based Contracting

12.2.1 Under the PBC concept, the Government contracts for specific services and outcomes, not resources. Contractor flexibility is increased, Government oversight is decreased, and attention is devoted to managing performance and results and ultimate outcomes.

a. The SOW contains explicit, measurable performance requirements ("what"), eliminates process-oriented requirements ("how"), and includes only minimally essential reporting requirements that are based on risk. The Government employs a measurement method (e.g., project surveillance plan) that is clearly communicated to the contractor and where the contractor is held fully accountable. Incentives can be used, but should be relevant to performance and center on the areas of value to NASA and those of high risk that are within the control of the contractor. The SOW should encourage the use of contractor best practices and also include the requirement for the contractor to use cutting-edge maintenance practices, as utilized in the private sector, to give NASA the best product.

b. NASA's policy is to maximize the use of firm-fixed-price contracts, combined with IDIQ unit-price provisions where necessary. In implementing this policy, as much "core" work as possible should be included in the firm-fixed-price portion of the contract. IDIQ work should be held to a minimum because of its cost.

(1) Fixed-Price Work. To shift cost risk to the contractor, fixed pricing and fixed-unit pricing are used to the maximum extent feasible and practical. Because the contract requirements (time, location, frequency, and quantity) are known or adequate historical data is available to allow a reasonable estimate to be made, the contractor can agree to perform for a total price similar to a single work order. The contractor does not get paid for work that is unsatisfactorily performed or not performed at all, and deductions are made in accordance with the Schedule of Deductions (Section E of the contract).

(2) IDIQ Unit-Price Work. Not every item of work can be adequately quantified at contract inception to allow it to be firm, fixed priced. For example, few can predict the frequency and quantity of environmental spill cleanup actions that may be required over a given year or the exact number of chairs and other preparations required for VIP visits and special occasions two years away. Often, historical data is inadequate to enable fixed pricing certain services. Indefinite quantity contract requirements are performed on an "as ordered" basis. A fixed-unit price to perform one occurrence or a given quantity of each type of work is bid for the requirement implementation. Payment is based on the unit price bid per unit (Section B of the contract) times the number of units performed or on an agreed-to price. Because each instance of IDIQ work is ordered and paid for separately, each delivery order shall be inspected and accepted as being satisfactorily completed before payment is made, as if each were a separate mini-contract. Contract prices for unit-priced tasks include all labor, materials, and equipment for performing that specific work. The unit prices

offered are multiplied by the quantity of units estimated to be ordered during the contract term, but only for purposes of proposal evaluation. Work will only be paid for as ordered and completed.

c. The contract should be a completion type (something is accomplished) as opposed to a term/level-of-effort type of contract (effort is expended). If level of effort, staffing levels, or a skill mix of workers is specified, the contract is not performance based.

d. Contractor-Government partnering is highly recommended to achieve mutually supportive goals (see section 12.4, Partnering).

e. The Center Procurement Office should be contacted for assistance. The contracting officer will determine the appropriate contract type.

12.2.2 Facility Organization's Responsibilities. The Center's facilities organizations shall work together with the users. It is recommended that the facilities organization participate in the preparation of the activities noted in the sections B, C, E, J, L, and M shown in Figure 12-1, at a minimum, and in the activities noted in the sections A, D, F, G, H, I, and K at the discretion of the contracting officer. This includes identifying all functions and services to be included in the contract, developing the functional tree diagram (which shows the relationships of the functions in the contract), and preparing a WBS for the technical section (Section C) and the Performance Requirements Summary (PRS), which is precisely coordinated with the tree diagram.

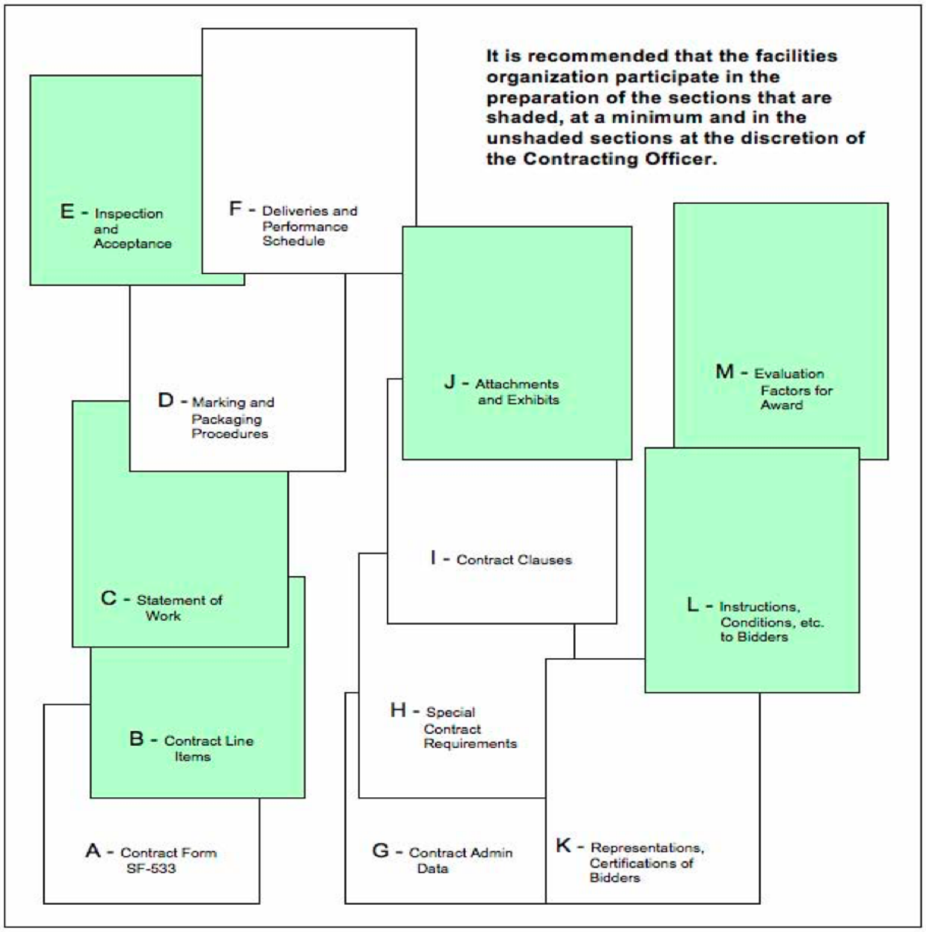


Figure 12-1 Contract Sections

12.2.3 The maintenance organization shall ensure the contract states that maintenance data entered in a CMMS is Government property and, as such, be available for Government use and retention for historical purposes, regardless of which, Government or contractor, is responsible for populating and maintaining the database.

12.2.3.1 Where the contractor operates the CMMS, it shall be made clear in the contract that the CMMS maintenance data is Government property and will be turned over to the Government at the end of the contract.

12.2.3.2 The WBS shall include all contract requirements to be purchased.

12.2.4 Functional Diagram. Figure 12-2 is an example of a functional diagram at one NASA Center. It represents graphically the highest level of the WBS and should be the starting point in preparing the PBC documentation. It identifies, graphically, each function that is included in the PBC. Each of these functions will be individually addressed and will have a counterpart subsection in Section C of the contract where the requirements, performance indicators, and other supplemental information are discussed. In this specific example, each shaded box represents a function discussed in the technical sections of the contract Subsections C.8 through C.27. The large hashed-shaded area indicates that the five functions within it include operations support as well as maintenance. The white box functions are not in the contract, but are shown to indicate relationships. Functional diagrams will vary by Center, depending on the functions being contracted. However, their preparation and use are important and are the basis of the WBS and the contract documentation.

12.3 Outcome Specifications

12.3.1 Performance-based specifications can be stated in terms of outputs or outcomes. For example, a typical performance-based contract will have numerous output requirements for maintaining facilities, such as performing PM, testing and treating circulating water in HVAC cooling towers, and performing certain operational checks. An outcome requirement, however, simply might be that "buildings are available and fully functional to the user when needed" and integrates all service necessary to produce that result. Contractor flexibility is increased by allowing the contractor to decide what work tasks are needed and to propose cutting-edge technologies and techniques that may be more effective than traditional approaches. Government oversight is decreased, and attention is devoted to managing final results. A certain amount of risk is introduced for NASA by transferring additional responsibility to the contractor and, therefore, is not appropriate for all functions. The use of output (versus outcome) requirements is suggested for the following circumstances:

a. The Center determines that the criticality of the function is too important to allow a contractor to deviate from proven work methods.

b. There is a mandated regulation or operational procedure that requires a specific work method to be followed.

c. A procedural requirement is mandatory for safety considerations.

d. The function has very high visibility and a proven methodology has provided excellent results in the past.

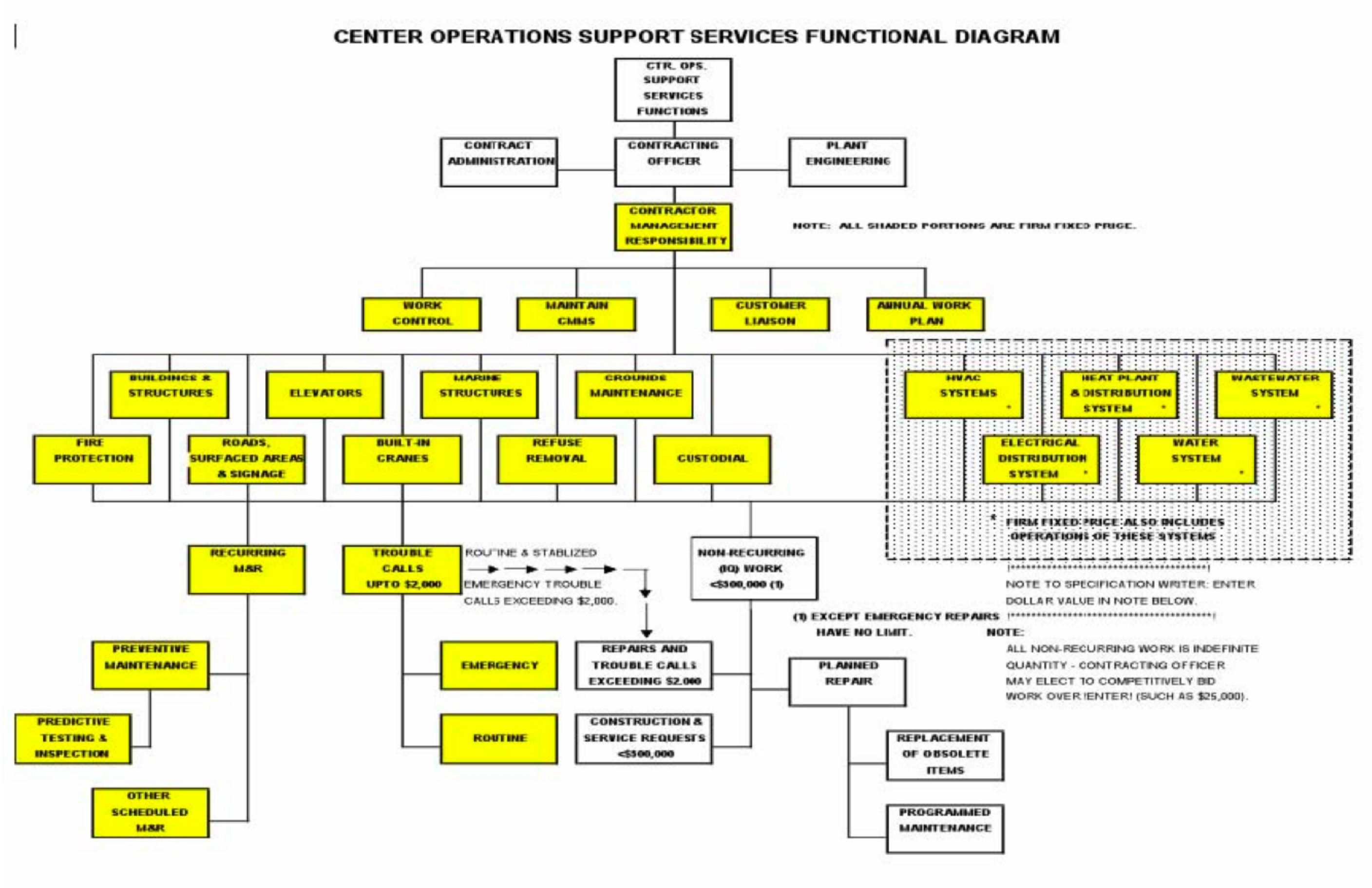


Figure 12-2 Functional Diagram

12.3.2 Use of Metrics. Performance specifications require the identification of a standard of performance for the contractor's work.

For example, an appropriate outcome specification may require the contractor to achieve a certain equipment availability. That is an outcome requirement. The metric or indicator associated with that requirement is percent availability. The percentage number that the contractor will achieve is the standard (benchmark), set by the Center based on the current baseline performance that is acceptable to and being achieved by contractor or civil service forces at the Center. Unless these metrics are known, there is no rational basis for which to require a standard, and the use of the outcome specification may not be justified.

12.3.3 Refer to the NASA Guide Performance Work Statement for Center Operations Service Support Addendum (July 1999) for additional, detailed information on outcome specifications.

12.4 Partnering

12.4.1 Partnering describes how well the customer and the contractor work together, i.e., how well they communicate, how they resolve disputes, and how they execute the contract to fulfill each other's needs. It is a commitment by both parties to cooperate, to be fair, and to understand each other's expectations and values. It is an agreement between NASA and the contractor to work cooperatively as a team, to identify and resolve problems, and to achieve mutually beneficial performance and result goals.

12.4.2 Partnering is a relationship between organizations where the following occurs:

a. All parties seek win-win solutions to problems rather than solutions that favor one side.

b. Value is placed on the relationship. There is an interdependence wherein if one party succeeds, all parties will benefit.

c. Trust and openness are a normal part of the relationship. The sharing of ideas and problems without fear of reprisal or exploitation promotes fair and rapid solutions to problems.

d. An environment of cost savings and profitability exists.

e. All understand that no one benefits from the exploitation of the other party.

f. Innovation is encouraged.

g. Each party is aware of the needs and concerns of the other. No actions are taken without first considering the effect they have on each party.

h. Each individual has unique talents and values that add value to the group.

i. Overall performance is improved. Gains for one party help the whole group and are not at the expense of another party.

12.4.3 NASA Centers should seek to partner with their support contractors. Benefits that are usually achieved by participating organizations include improvements in contractor-customer relationships, reduction in claims, reduction in time growth, reduction in cost growth, and fair and mutual interpretations of the specifications.

12.5 Incentives in Government Service Contracts

12.5.1 In contracting for support, it is assumed that the contractor will perform as specified in the contract. Experience has shown that contractors can meet contract requirements with performance ranging from a minimum of acceptable to a top performance of excellent. Incentives in Government service contracts are generally more negative than positive, with emphasis on deductions in invoice for poor work or work not performed. Rather than just deductions, incentives can be used to encourage the contractor to expend effort and resources and employ cutting-edge, breakthrough maintenance practices as used in industry to attain top performance. Following are examples of incentives that could be used.

12.5.2 Incentive Fee. An incentive-fee provision can be included in a contract to encourage the contractor, through a suitable monetary incentive, to provide the management, equipment, materials, labor, and supervision necessary for performance improvement. Most often when positive fee-type incentives are used, the fee starts at 100 percent and then is reduced for subjective opinions of areas of dissatisfaction. A better incentive is the reverse, i.e., starting at zero and increasing for areas or instances of greater, objectively measurable performance.

12.5.3 Award Term. The award term is an innovative incentive approach, similar to ones used in private industry. This incentive approach potentially allows continued performance of the contracted effort for an additional period of time, not to exceed some specific potential total contract period, based on overall contractor performance. A provision for a reduction in the contract term for poor contractor performance, such as up to 18 months, could also be included. As an example of an award-term contract, a contract base period could be two or three years with the first year being a startup period wherein the evaluation results would not be included in any award-term decision. Each subsequent year, the contractor's technical performance would be evaluated and the results would be used to reduce, maintain, or increase the contract term depending on the contractor's performance. The performance requirements could also increase over a period of time. For example, if the contract is a three-year core-term contract. If performance is rated as very good for the second and third years, then years four and five are added. If the 4th-year rating is excellent, a 6th year is added. If the 5th year is rated excellent, a 7th year is added, and so on for a maximum contract term of 10 years. An award-term evaluation plan will be used in this process.

12.6 Quality Assurance

12.6.1 QA is a program undertaken by NASA to provide some measure of the quality of goods and services purchased from a contractor. How much QA is necessary depends on the quality of the contractor, criticality of the services, and the nature, amount, and assumption of risk involved. The QA plan should be developed concurrently with the Performance Work Statement, Section C, since the latter defines the work outputs and the quality standards, while the former defines how the work outputs will be observed and measured.

12.6.2 Risk Management. Risk management is an organized method of identifying and measuring risk and developing, selecting, and managing options for handling these risks. It is NASA's policy to include risk management as an essential element of the entire procurement process, including contract surveillance. It implies the control of future events is proactive rather than reactive and comprises four elements:

a. Risk Assessment. Identifies and assesses all aspects of the contract requirements and contractor performance where there is an uncertainty regarding future events that could have a detrimental effect on the contract outcome and on NASA programs and projects. As the contract progresses, previous uncertainties will become known and new uncertainties will arise.

b. Risk Analysis. Once risks are identified, each risk should be characterized as to the likelihood of its occurrence and the severity of its potential consequences. The analysis should identify early warning signs that a problem is going to arise.

c. Risk Treatment. After a risk has been assessed and analyzed, action is taken. Actions include the following:

(1) Transfer. Transfer the risk to the contractor. For example, modify the contract requirements so that the contractor has more or less direct control over the outcome.

(2) Avoidance. Determine that the risks are so great that the current method is removed from further consideration and an alternative solution is found. For example, delete a specific element of work from the contract to have it assumed by the on-site researchers.

(3) Reduction. Minimize the likelihood that an adverse event will occur or minimize the risk of the outcome to the NASA program or project. For example, increase the frequency of surveillance, change the type of surveillance or identify alarm situations, and promptly meet with the contractor to resolve this and future potential occurrences.

(4) Assumption. Assume the risk if it can be effectively controlled, if the probability of risk is small, or if the potential damage is either minimal or too great for the contractor to bear. For example, allow the contractor's own QC of certain custodial functions at a remote location be the sole QA surveillance method for the Center for that work.

(5) Sharing. When the risk cannot be appropriately transferred, or is not in the best interest of the Center to assume the risk, the Center and contractor may share the risk.

d. Lessons Learned. After problems have been encountered, the Center should document any warning signs that, with hindsight, preceded the problem, what approach was taken, and what the outcome was. This will not only help future acquisitions but could help identify recurring problems in the existing contract.

12.6.3 As part of the cost-conscious emphasis practiced throughout NASA, it is undesirable to perform a 100-percent inspection on all work performed, but rather, considering risk as discussed in section 12.6.2, select the optimum combination of inspection methods, frequencies, and populations The contract vehicle is a combination firm-fixed-price and IDIQ-negotiated procurement based on evaluating technical and cost proposals and past performance.

12.6.3.1 The Request for Technical Proposals' evaluation criteria heavily consider past performance and require the offerors (and their subcontractors) to address how they intend to meet the quality standards for the specific contract.

12.6.3.2 Award is based on a best-value consideration of price and technical merit and past performance.

12.6.3.3 A partnering concept and agreement are in force to reduce adversarial relationships and foster a team approach to providing the required services.

12.6.3.4 In general, this approach starts with minimal performance evaluation, recognizing the high expectations of good performance from a quality contractor. The follow-on degree and type of monitoring of the contractor's work depends on the overall performance and the perception of increased or decreased risk to the desired outcomes. Closer scrutiny may be in order if there is a downward trend in performance, if the degree of unacceptable risk increases, or if the performance is otherwise unacceptable. Less frequent inspections or a less stringent method may be selected if the contractor's performance is constantly superb, if there is a greater comfort level in risk to the desired outcome, and if there is a high degree of satisfaction. The key is flexibility in assigning available Quality Assurance Evaluators assets where they are needed most. Consult the NASA GPWS for

COSS for a more detailed discussion of the QA program.

12.6.4 Quality Assurance Methods of Surveillance. There are seven generally recognized QA surveillance methods. The successful QA plan, considering the number of QAEs, will use a combination of any or all of these, based on the population of items inspected, their characteristics and criticality, and the location of the service. Where sufficient Government QAEs are not available, a third party (contractor) could be used to perform the QA function for the Government. These seven methods are as follows:

a. 100-percent Inspection. Usually used for services that are considered critically important, have no redundancy, have relatively small monthly populations, or are included in the indefinite quantity portion of the contract.

b. Random Sampling. Uses statistical theory to determine the performance of the whole while evaluating only a sample that, when applied to a sample population, will be indicative of the whole. The use of an ISO-9000-type QA program is predicated on a properly selected, statistical sample. Random sampling tables are used to determine the required sample sizes, and random number generators are used to determine the samples to be evaluated. Random sampling is useful when evaluating a large, homogeneous population.

c. Planned Sampling. Similar to random sampling (less the statistical accuracy) in that it is based on evaluating only a portion of the work for estimating the contractor's performance. Samples are selected based on subjective rationale, and the sample sizes are arbitrarily determined. Planned sampling is most useful when population sizes are not large or homogeneous enough to make random sampling practical.

d. Unscheduled Inspections. These types of inspections should not be used as the primary surveillance method but, rather, in a supportive role. This inspection method may be used where there has already been an indication of poor performance or excessive complaints. The additional, unscheduled inspection could confirm the situation.

e. Validated Customer Feedback. A valuable method of evaluating the contractor's performance with minimal QA assets expended. It is important that the QAE validates all feedback prior to addressing the situation with the contractor. This evaluation method is most valuable for routine, recurring, and noncritical work such as custodial services, grounds maintenance, and refuse collection.

f. RCM Metrics and Trends. Another surveillance method is the use of RCM-based metrics and reliability trending. The QAE can use metrics to assess the performance and effectiveness of maintenance actions as discussed in section 7.8.7, Performance-based Contract Monitoring. See Appendix G for some of the metrics that may be used for this QA method.

g. Contractor-Centered Quality Control. Obtaining self-assessment feedback from the contractor's program and validating it, as necessary, is the least labor-intensive method for NASA QAEs. It relies on the quality of the contractor's own QC program. It is best used when the contractor's performance is repeatedly excellent and reliable, the work is relatively noncritical, and it is in conjunction with other inspection methods. In addition to the contractor's QC program, the contractor may be required to perform QA of the QC program. In the contractor's QA program, the contractor would have a specific approach to monitoring end services to ensure that they have been performed in accordance with the specifications and that the QC program is performing satisfactorily. The contractor QA reports could be used by the QAE as one input in evaluating the contractor's performance.

12.6.5 Performance Requirements Summary

12.6.5.1 The Performance Requirements Summary summarizes the work requirements, standards of performance, and Maximum Allowable Defect Rates (MADRs) for each contract requirement. It is used by the QAEs in the QA program and by the Contracting Officer in making payment deductions for unsatisfactory performance or nonperformance of the contract requirements.

12.6.5.2 Maximum Allowable Defect Rates. MADRs are defect rates, or a specific number of defects, above which the contractor's quality control is considered unsatisfactory for any particular work requirement. The MADR value selected for any particular work requirement should reflect that requirement's importance. For example, the MADR for timely emergency TC response should be less than that for routine TC response. It is important to understand that in fixed-price contracts, the contractor does not get paid for work not performed or that is unacceptable relative to the performance requirements summary, regardless of the MADR. However, the MADR is that point where the contractor should receive a formal notice of deficiency or where more serious administrative action is warranted. There is no need for the Government to advise the contractor of how much leeway is authorized for nonperformance and, therefore, no requirement to advise the contractor of the value of the MADR.

12.6.6 Quality Assurance Plans. QA plans are systematic procedures that, in a planned and uniform manner, provide guidance for the QAEs in their methods and degree of scrutiny to be used in surveillance of contract-performance requirements. Each QA plan may have one or more surveillance guides for inspecting subtasks. Items to be addressed include the following:

a. Identification of the contract requirements.

b. Work requirements and standards of performance.

c. Primary methods of surveillance to be employed.

d. Maximum allowable defect rate.

e. Quantity of work to be performed.

f. Level of surveillance to be employed.

g. Size of the sample to be evaluated.

h. Evaluation procedures.

i. How the results will be analyzed.

12.6.6.1 Each QA plan is a self-contained document written in sufficient detail to preclude extensive reference to other documents or manuals. The use of QA plans ensures conformity, consistency, and standardization in how QA inspections and evaluations will be made over time and between different QAEs monitoring like functions.

12.6.6.2 QA plans can be modified and should be maintained up to date as necessary. The QA plan supplements, but is not part of, the contract and, as such, the contractor should be advised of the existence and use of a formal QA plan but not provided access to it.

12.6.7 Quality Assurance Evaluator Staffing. The QAE assists in evaluating the adequacy of the contractor's performance under each work requirement in the Schedule of Prices (Section B of the contract). The following are specific QAE responsibilities:

a. Accomplishing surveillance required by the contract surveillance plan.

b. Completing and submitting to the COR inspection reports as required in the contract surveillance plans.

c. Recommending to the COR the verification of satisfactorily completed work, payment deductions, liquidated damages, and other administrative actions for poor or nonperformed work.

d. Assisting the COR in identifying necessary changes to the contract, preparing Government estimates, and maintaining work files.

e. Making recommendations to the COR regarding changes or revisions to the PWS and contract surveillance plan.

f. Maintaining accurate and up-to-date documentation records of inspection results and follow-on actions by the contractor.

12.6.7.1 Minimization. Ideally, QAE staffing should be based on a predetermined number of contract inspections and related work requirements rather than on the availability of QAEs. Realistically, personnel constraints dictate that flexibility be used and the number of QAEs determined by adjusting the degree of QA performed in terms of population and degree of scrutiny from month-to-month, depending on the contractor's performance for the previous period and the criticality of the work being performed. QA evaluations, based solely on customer feedback and documentation for relatively routine, noncritical work, require very few, if any, QAEs. One hundred-percent inspections of critical, research-related processes, on the other hand, would likely require an extraordinary amount of QAE support. Where adequate staffing is not available, all or part of the QA function may be contracted to a third party as a solution.

12.6.7.2 QAE Qualifications. Personnel tasked with monitoring the contractor's performance shall be experienced in the technical area being evaluated and adequately trained in QA methods and procedures. Skills required include QA plan development, inspection techniques, PT&I techniques (if appropriate), and contract administration skills such as documentation, making deductions, and calculating recommended payments.

12.7 Credit Card Procurement

12.7.1 As a means of reducing contract administration, small IDIQ purchases are successfully being procured by credit cards at several NASA Centers. NASA management issues Government credit cards to various authorized Government employees for use in obtaining materials, equipment, and work or services for the Center. When the contractor is contacted by the authorized cardholder requesting work or services, the contractor and requestor define and mutually agree on the task to be provided. Once agreement is reached concerning the scope, schedule, and fixed price to accomplish the task, a credit card is presented by the requestor and accepted by the authorized contractor representative to consummate and document the understanding. All transactions and historical information shall be recorded in the CMMS.

Appendix A. Definitions

Addition. A physical increase to a real property facility that adds to the overall dimensions of the facility.

Agency Execution Plan (AEP). A detailed financial plan based on the Agency Operating Plan and used to determine how funds will be distributed below the apportionment level, but within any controls established in the appropriation and apportionment.

Agency Operating Plan (AOP). An internal plan based on the Congressional Operating Plan and the budget which sets forth the specifics on how NASA intends to apply Agency financial resources during the fiscal year to fulfill its mission. It includes all programs and projects.

Allocation. The formal administrative assignment of funding targets below suballotment to the program, project, and Center levels to incur obligations within a specific amount. Overobligation or overexpenditure of an allocated funding target is not a violation of the Antideficiency Act (ADA) unless it results in overobligation or overexpenditure of appropriation, apportionment, allotment, or suballotment. However, overobligation or overexpenditure of an allocated funding target is subject to administrative action.

Allotment and Suballotment. The formal administrative division and subdivision of budget authority delegated to incur obligations within a specific amount pursuant to OMB apportionment or reapportionment action or other statutory authority making funds available for obligation at the mission (allotment) and theme (suballotment) levels. Making or authorizing an overobligation or overexpenditure of an allotment or suballotment is a violation of the ADA and need to be reported.

Assessment. The portion of joint or indirect cost assigned to a specific objective, such as program, function, project, job, or service. (NASA's Office of the Chief Financial Officer uses this term to distinguish the process from funds distribution.)

Alterations. Work that changes the configuration of a facility (not maintenance or repairs) but that does not increase the value of the facility, e.g., moving a door or electrical outlet.

Annual Budget Call by NASA's OCFO. An internal term used for the Agency's Planning, Programming, Budgeting, and Execution (PPBE) process and the data calls issued during this process. The data requested outlines time-phased work programs expressed in dollars and other resources required to accomplish NASA objectives for the applicable years. The approved budget then serves as a basis for the request and distribution of funds, which NASA coordinates with Mission Directorates and Mission Support Offices.

Annual Work Plan (AWP). A plan prepared on an annual basis, prior to the start of the applicable fiscal year, that systematically lays out the maintenance and repair work to be accomplished within the budget constraints of the Center. The AWP is based on the 5-Year Maintenance Plan and the mission of the Center.

Apportionment/Reapportionment. A distribution or change to the distribution of amounts available for obligation in an appropriation or fund account into amounts available for specified time periods, programs, activities, projects, objectives, or any combinations of these. Amounts need to be apportioned annually by OMB prior to obligation, and the apportioned amount limits the obligations that may be incurred. An apportionment may be further subdivided by an agency into allotments, suballotments, and allocations. Overobligation or overexpenditure of an apportionment is a violation of the ADA and need to be reported.

Appropriation. A provision of law (not necessarily in an appropriations act) authorizing the expenditure of funds for a given purpose. Usually, but not always, an appropriation provides budget authority. Appropriations may be annual (one-year), multiyear (more than one year but with a definite ending date), or no-year, which refers to the period the funds are available for new obligations. During the period of availability, appropriations are often referred to as "current."

Assets. Any item of economic value owned by NASA. The item may be physical (tangible) or a right to ownership (intangible) that is expressed in terms of cost or some other value.

Authorization Act. A law that established and continues the operation of a Federal program or agency, either indefinitely or for a specific period, or that sanctions a particular type of obligation or expenditure within a program.

Availability. The ratio of the actual run time of a machine or system divided by the scheduled time for the machine or system. Usually expressed as a percentage. For example, if an air handler is scheduled to run from 6 a.m. to 6 p.m., 5 days a week and, in fact, does run during those times, its availability was 100 percent. If the air handler was stopped one day during the week for one hour, its availability for that week was 98.3 percent (59 hours divided by 60 hours). Bar Code. A series of parallel lines with width and spacing that represents a number when scanned by a laser reader.

Benchmark. A standard against which something is measured.

Benchmarking. Seeking the best examples of methods, processes, procedures, and products to establish a standard and assess one's performance in terms of quality, productivity, or cost.

Book Value. The original capitalized value of an asset, adjusted for modifications where appropriate, as stated in the Agency's accounting records.

Breakdown Maintenance. See Repair.

Budget. A formal estimate of future revenues, obligations to be incurred, and outlays to be made during a definite period and, when determined to be appropriate, upon the basis of accrued expenditures and costs to be incurred.

Budget Authority. The authority provided by law to incur financial obligations that will result in outlays. NASA has two forms of budget authority: appropriations and spending authority from offsetting collections (working capital funds and reimbursables).

Budget Cycle. The period that elapses from the initiation of the budget process to the completion thereof for a particular fiscal year.

Budget Execution. The processes by which financial resources are made available to Agency organizations and are managed to achieve the purposes and objectives for which the budget was approved, including operating plans, execution plans, funds distribution, obligations, expenditures, and reporting requirements.

Budget Year. The fiscal year (FY) for which estimates are submitted. Budget submissions generally contain data concerning the prior year (the FY immediately preceding the current year), the current year (the FY immediately preceding the budget year), the budget year (the FY for which estimates are submitted), and 4 subsequent years.

Buildings. The classification that includes the cost of buildings, capital improvements of buildings, and fixed equipment that is normally required for the functional use of the buildings and becomes permanently attached to and made a part of the buildings and that cannot be removed without cutting into the walls, ceilings, or floors, such as plumbing, heating, and lighting equipment; elevators; central air-conditioning systems; and built-in safes and vaults. Also included is all equipment of any type built in, affixed to, or installed in real property in such manner that the installation cost, including special foundations or unique utilities or services, or the facility restoration cost after removal is substantial.

Capitalized Equipment. Individual items of property, plant, and equipment (PP&E) that have an acquisition cost of $100,000 or more, an estimated useful life of two years or more, is not intended for sale in the ordinary course of operations, is acquired or constructed with the intention of being used or is available for use by the Agency, and have an alternative future use. If an item, when originally installed, consists of "severable components," each component will be individually subjected to the capitalization criteria. Maintenance costs involving collateral equipment will be tracked as an expense versus a capitalization. These criteria are retroactive to October 1, 1997. (See NPR 8800.15.)

Center Support. A building, area, or system that supports the overall operation of the Center/Facility but does not meet the mission critical or mission support criteria.

Central Utility Plant Operations and Maintenance. This category is unique in that it includes the cost of operations in addition to maintenance costs. It should be used only to capture the costs of operating and maintaining institutional central utility plants, such as a central heating or steam plant, wastewater treatment plant, or a central air-conditioning (chiller) plant. The concept is that operators are assigned fulltime to operate the plant, but they perform maintenance between various operating tasks, making it almost impossible to segregate operational and maintenance costs; therefore, the costs of the full-time operators and operations personnel (and their materials) are included in this category.

Collateral Equipment. Encompasses building-type equipment, built-in equipment, and large, substantially affixed equipment/property and is normally acquired and installed as part of a facility project as described below (also see Noncollateral Equipment):

a. Building-Type Equipment. A term used in connection with facility projects to connote the equipment normally required to make a facility useful and operable. It is built in or affixed to the facility in such a manner that removal would impair the usefulness, safety, or environment of the facility. Such equipment includes elevators, heating, ventilating, and air-conditioning systems, transformers, compressors, and other like items generally accepted as being an inherent part of a building or structure and essential to its utility. It also includes general building systems and subsystems, such as electrical, plumbing, pneumatic, fire protection, and control and monitoring systems.

b. Built-in or Large, Substantially Affixed Equipment. A term used in connection with facility projects of any type other than building-type equipment that is to be built in, affixed to, or installed in real property in such a manner that the installation cost, including special foundations or unique utilities service, or the facility restoration work required after its removal is substantial.

Commissioning. Traditional commissioning involves performing random tests and checks on facility systems to ensure that they are properly balanced, functionally operational, and comply with the design intent. It systematically checks operating parameters, such as pressure, temperature, minimum and maximum air flow, lighting levels, electrical amperage and voltage, torque, fluid volumes, and other thermodynamic measures at key locations, as well as balanced conditions. It is a method of acceptance testing that, when performed on a random basis at random sampling points, checks to ensure that the outcome indices at those points are in compliance with the outcome requirements stated in the design specification.

Building and equipment acceptance is one element of a larger, more comprehensive construction quality program known as "commissioning." Currently, there are four variations of commissioning being practiced: Traditional commissioning, total building commissioning, total building recommissioning or retrocommissioning, and NASA's customized application of a portion of commissioning called, Reliability Centered Building and Equipment Acceptance (RCB&EA). The Facility Engineering Division, ECIC, and the OMFIT are developing a Commissioning Guide.

Component Facility. Center organizations that are geographically separated from the parent Center.

Computerized Maintenance Management System (CMMS). A set of computer software modules and equipment databases containing facility data with the capability to process the data for facilities maintenance management functions. They provide historical data, report writing capabilities, job analysis, and more. The data describe equipment, parts, jobs, crafts, costs, step-by-step instructions, and other information involved in the maintenance effort. This information may be stored, viewed, analyzed, reproduced, and updated with just a few keystrokes. The maintenance-related functions typically include the following:

a. Facility/equipment inventory.

b. Facility/equipment history.

c. Work input control.

d. Job estimating.

e. Work scheduling and tracking.

f. Preventive and predictive maintenance.

g. Facility inspection and assessment.

h. Materials management.

i. Utilities management.

j. Corrective maintenance and repair.

Condition Assessment. The inspection and documentation of the material condition of facilities and equipment, as measured against the applicable maintenance standards. It provides the basis for long-range maintenance planning as well as annual work plans and budgets.

Condition-Based Maintenance (CBM). Facility and equipment maintenance scheduled only when the condition of the facility or equipment requires it. CBM replaces maintenance scheduled at arbitrary time or usage intervals. It usually involves the application of advanced technology to detect and assess the actual condition. See Predictive Testing & Inspection and Reliability Centered Maintenance.

Condition Monitoring. Also known as Predictive Maintenance. The continuous or periodic monitoring and diagnosis of systems and equipment to forecast failure. Also see Predictive Testing & Inspection.

Construction. The erection, installation, or assembly of a new or replacement facility, or an addition in area, volume, or both to an existing facility.

Construction Project. A facility project relating to the erection, installation, or assembly of a new facility, replacement facility, or an addition in area, volume, or both to an existing facility.

Continuous Inspection. A program of periodic, scheduled inspections of facilities and equipment to determine their condition with respect to specified standards (including safety).

Contracting Officer's Representative. Any person who, by appointment in accordance with procedures prescribed by the NASA FAR Supplement (see Appendix C.2, resource 4), has the authority to enter into and administer contracts and to make determinations and findings with respect thereto, or has any part of such authority.

Contractor. The supplier of the end item and associated support items to the Government under the terms of a specific contract.

Contracts. All types of agreements and orders for the procurement of supplies or services. Includes awards and notices of award; contracts of a fixed-price, cost, cost-plus-a-fixed-fee, or incentive type; contracts providing for the issuance of job orders, task orders, or task letters thereunder; letter contracts; and purchase orders. It also includes supplemental agreements with respect to any of the foregoing.

Corrective Maintenance. See Repair.

Current Replacement Value. Escalated value of the initial cost of an asset including all subsequent modifications for all facilities. CRV is developed by escalating facility and collateral equipment acquisition cost and any incremental book value changes to current-year dollars using the Engineering News Record (ENR) Building Cost Index (BCI). (See NPR 8800.15 for dollar value.)The NASA Real Property Management System is used in performing the required calculations. CRV is solely an escalated value and should not be used as an actual replacement cost.

Current Year. The fiscal year immediately preceding the budget year. Deferred Maintenance (DM). DM is the total of essential, but unfunded, facilities maintenance work necessary to bring facilities and collateral equipment to the required acceptable facilities maintenance standards. It is the total work that should be accomplished but that cannot be achieved within available resources. It does not include new construction, additions, or modifications. DM does include unfunded maintenance requirements, repairs, ROI, and CoF repair projects.

Descriptor. A description of the relationship of the work units used in a metric.

Design. This term encompasses both preliminary design and final design for facility projects. Design costs are normally funded under the CoF appropriation. Design costs of facility projects proposed for funding under appropriations other than CoF are normally funded under the same appropriation from which the facility project is to be funded with such costs being identified separately from the facility project cost estimate.

Drawings. Graphic data, including drawings as defined in MIL-STD 100A and prepared in accordance with MIL-STD-1000, Category D; aperture cards in accordance with MIL-C-9877; and graphs or diagrams in accordance with industry standards and industry specifications on which details are represented with sufficient information to define completely, directly, or by reference the end result for use in the selection, procurement, and manufacture of the item required.

Emergency Repair. The restoration of an existing facility or the components, thereof, when such facilities or components have been made inoperative by major breakdown, accident, or other circumstances that could not be anticipated in normal operations and the repair, thereof, is of such urgency that it cannot await programming and accomplishment in the normal budget cycle. In the process of emergency repair, the replacement of components or materials will be of the size or character currently required to meet firm demands or needs.

Estimated Cost. A calculated, anticipated amount, as distinguished from an actual outlay, based on related cost experience, prevailing wages and prices, or anticipated future conditions, usually for the purposes of contract negotiation, budgetary control, or reimbursement.

Facilities Condition Assessment. See Condition Assessment

Facility Condition Index. See Appendix G.

Facilities Contract. A contract type under which Government facilities and equipment are provided to a contractor by the Government for use in connection with the performance of separate, related procurement or support services contract(s) for supplies or services. The term includes facilities acquisition contracts, facilities-use contracts, and consolidated facilities contracts.

Facilities Management. The planning, prioritizing, organizing, controlling, reporting, evaluating, and adjusting of facility use to support NASA activities based on customers' facility needs and Center mission requirements. See also Facilities Maintenance Management.

Facilities Maintenance. The recurring day-to-day work required to preserve facilities (buildings, structures, grounds, utility systems, and collateral equipment) in such condition that they may be used for their designated purpose over an intended service life. It includes the cost of labor, materials, and parts. Maintenance minimizes or corrects wear and tear and, thereby, forestalls major repairs. Facilities maintenance includes PM, PT&I, grounds care, PGM, repair, TCs, ROI, and SRs (not a maintenance item but work performed by maintenance organizations). Facilities maintenance does not include new work, work on noncollateral equipment, or maintenance performed in the Central Plant by plant operations personnel.

Facilities Maintenance Management. The planning, prioritizing, organizing, controlling, reporting, evaluating, and adjusting of facilities maintenance operations to support NASA activities with quality facilities based on customers' facility needs and predetermined maintenance goals at minimum cost.

Facility. A term used to encompass land, buildings, other structures, and other real property improvements, including utilities and collateral equipment. The term does not include operating materials, supplies, special tooling, special test equipment, and noncapitalized equipment. The term facility is used in connection with land, buildings (facilities having the basic function to enclose usable space), structures (facilities having the basic function of a research or operational activity), and other real property improvement.

Facility Improvement. That construction necessary to upgrade or replace obsolete facilities or to expand a facility to improve the operating efficiency of an installation.

Facility Project. The consolidation of applicable, specific individual types of facility work, including related collateral equipment, which is required to fully reflect all of the needs, generally relating to one facility, which have been or may be generated by the same set of events or circumstances that are required to be accomplished at one time to provide for the planned, initial operational use of the facility or a discrete portion thereof.

Find. Discovery utilizing PT&I of an impending failure or degrading condition of a facility, system, or equipment that indicates action is required to prevent failure.

Fiscal Year. In the Federal Government, it is the 12-month period from October 1 of one calendar year through September 30 of the following year.

5-Year Maintenance Plan. The plan for maintenance work anticipated for the 5-year period beginning with the budget year. It comprises the maintenance (planned, level-of-effort, and anticipated unknowns) required to support the Center mission needs and to correct the deficiencies identified by the current assessment of facilities.

Full-Time Equivalents. The total number of regular straight-time hours (i.e., not including overtime or holiday hours) worked by employees divided by the number of compensable hours applicable to each fiscal year. Annual leave, sick leave, compensatory time off, and other approved leave categories are considered "hours worked" for purposes of defining full-time equivalent employment that is reported in the employment summary. The number of compensable hours is specified in OMB Circular No. A-11, Section 85.5.

Funding Availability. The amount of obligating authority provided by appropriations, contract authorizations, actual transfers to or from other appropriations, and anticipated reimbursements, which have an approved apportionment for the current year.

Funds Distribution. The formal administrative distribution/delegation of budget authority below the apportionment level through allotments, suballotments, and allocation of funding targets.

Grounds Care. The maintenance of all grassy areas , shrubs, trees, sprinklers, rights-of-way and open fields, drainage ditches, swamps and water holding areas (lakes, ponds, lagoons, canals), fences, walls, grates, similar improvements to land that are included in the NASA Real Property Management System, and exterior pest and weed control. The maintenance tasks include mowing, spreading fertilizer, trimming hedges and shrubs, clearing ditches, snow removal, and related work. Also included in this category is the cost of maintaining grounds care equipment such as mowers and tractors.

Improvements. Additions to land, buildings, other structures, and other attachments or annexations to land that are intended to remain so attached or annexed such as sidewalks, drives, tunnels, utilities, and installed collateral equipment.

Inventory. The facilities and equipment inventory is the foundation of an effective facilities maintenance management program. It is the baseline for what is to be maintained. The inventory permits identifying maintainable items, including those subject to preventive maintenance or operator maintenance.

Life-Cycle Costs (LCC). A form of economic analysis that considers the total cost of owning, operating, and maintaining a building over its useful life. Life-cycle costs are the sum of the present value of the following:

a. Investment costs less salvage values at the end of the study period.

b. Nonfuel operation and maintenance costs.

c. Replacement costs of replaced building systems less salvage costs.

d. Energy costs.

Major Facility Work (Discrete Institutional or Program Funded). Construction and revitalization work in excess of $5 million, Land Acquisition, and Emergency Repair approved under the provisions of Section 308(b) of the National Aeronautics and Space Act of 1958, as amended, at any cost.

Metrics. Meaningful measures. For a measure to be meaningful, it will present data that encompasses the right action. In the context of this NPR, metrics refer to management and performance measures.

Minor Facility Work (Institutional or Program Funded). Construction and revitalization work in excess of $1 million but not exceeding $5 million. Mission Critical. A building, area, or system that is critical to the Center's mission or is essential for Center of Excellence performance.

Mission Support. A building, area, or system that provides support to the Center's primary mission or Center of Excellence assignment.

Modification. See Rehabilitation and Modification.

Noncollateral Equipment. All equipment other than collateral equipment. Such equipment, when acquired and used in a facility or a test apparatus, can be severed and removed after erection or installation without substantial loss of value or damage, thereto, or to the premises where installed. Noncollateral equipment imparts to the facility or test apparatus its particular character at the time (e.g., furniture in an office building, laboratory equipment in a laboratory, test equipment in a test stand, machine tools in a shop facility, or computers in a computer facility) and is not required to make the facility useful or operable as a structure or building. (See also Collateral Equipment.)

Obligation. A legally binding agreement that will result in the outlay or expenditure of funds immediately or in the future. A bona fide is required to create an obligation, such as when a contract is awarded, an order is placed, or a service is received.

Operator Maintenance. The examination, lubrication, minor repair (usually no larger than trouble call scope) and adjustment of equipment and systems in the assigned plant.

Outage. The planned or unintentional interruption or termination of a utility service such as electricity, water, steam, chilled water, or communication.

Past Year. The fiscal year immediately preceding the current year.

Payback. The amortization period, in years, calculated by dividing the budget estimate by the total expected annual savings.

Planned Repair. Repair performed prior to failure. Material condition degradation, usually identified through PM, PT&I, or other inspection, is repaired to prevent catastrophic failure. Also, see Repair.

Planning, Programming, Budgeting, and Execution (PPBE). An Agency-wide methodology for aligning resources in a comprehensive, disciplined, top-down approach that supports the Agency's

Vision and mission. It focuses on translating strategy into actionable programs and bringing together Agency priorities and strategic outcomes within the Agency's resource constraints. The four phases of alignment are:

a. Planning. The analysis of changing internal and external conditions, trends, threats, and technologies that will affect NASA's mission. This includes examining alternative strategies, defining long term strategic goals, multiyear outcomes, and short-term performance goals.

b. Programming. The defining and analyzing of programs and projects and their multi-year resource implications and evaluating alternatives and risks. Programming also serves to balance and integrate resources among the various programs according to identified priorities.

c. Budgeting. The formulation and justification of the budget to OMB and Congress.

d. Budget Execution. The process by which financial resources are made available to Agency organizations and are managed to achieve the purposes and objectives for which the budget was approved.

Predictive Testing & Inspection (PT&I). The use of advanced technology to assess machinery condition. The PT&I data obtained allows for planning and scheduling preventive maintenance or repairs in advance of failure. Also, see Condition Monitoring and Condition-Based Maintenance.

Preventive Maintenance (PM). Also called time-based maintenance or interval-based maintenance. PM is the planned, scheduled periodic inspection (including safety), adjustment, cleaning, lubrication, parts replacement, and minor (no larger than trouble call scope) repair of equipment and systems for which a specific operator is not assigned. PM consists of many checkpoint activities on items that, if disabled, would interfere with an essential Center operation, endanger life or property, or involve high cost or long lead time for replacement. To progress away from reactive maintenance, PM schedules periodic inspection and maintenance at predefined time or usage intervals in an attempt to reduce equipment failures. Depending on the intervals set, PM can result in a significant increase in inspection and routine maintenance. However, a weak or nonexistent PM program can result in safety and/or health risks to employees, much more emergency work, and costly repairs.

Proactive Maintenance. The collective efforts to identify, monitor, and control future failure with an emphasis on understanding and eliminating the cause of failure. Proactive maintenance activities include development of design specifications to incorporate maintenance lessons learned and to ensure future maintainability and supportability, development of repair specifications to eliminate underlying causes of failure, and performing Root Cause Failure Analysis (RCFA) to understand why in-service systems failed.

Program Year. A concept of accounting for funds, obligations, and outlays under a multi-year or no-year appropriation by the identification of transactions by the initial year in which an appropriation was available to the Agency for obligations.

Programmed Maintenance (PGM). Those maintenance tasks whose cycle exceeds one year, such as painting a building every fifth year. (This category is different from PM in that if a planned cycle is missed, the original planned work still remains to be accomplished. Whereas in PM, only the next planned cycle is accomplished instead of doing the work twice, such as two lubrications, two adjustments, or two inspections.)

Project. Within a program, this is an undertaking with a scheduled beginning and ending that normally involves one of the following primary purposes: (1) Design, development, and demonstration of major advanced hardware items; (2) design, construction, and operation of a new launch vehicle (and associated ground support) during its R&D phase; or (3) construction and operation of one or more aeronautical or space vehicles; this includes the necessary ground support to accomplish a scientific or technical objective.

Reactive Maintenance. See Repair.

Real Property. Land, buildings, structures, utility systems, and improvements and appurtenances, thereto, permanently annexed to land. Also includes collateral equipment (i.e., building-type equipment, built-in equipment, and large substantially affixed equipment).

Real Property Management System. A NASA-wide data system for real property that serves as an automated method for maintaining and reporting real property data. The RPMS includes the forms, codes, and procedures used in the RPMS that conform to NASA guidance and requirements. The RPMS contains information on all NASA real estate including land, buildings, structures, utility systems, improvements, and appurtenances thereto, permanently annexed to land. The data in the RPMS includes age, classification, CRV, and other information.

Recurring Maintenance. Maintenance performed on an item of equipment that is planned and performed on a set work schedule. The work and work schedules are based on established standards.

Rehabilitation and Modification. Facility work required to restore and enhance, alter, or adjust a facility or component, thereof, including collateral equipment, to such condition that it can be more effectively used for its presently designated purpose or to increase its functional capability. To simplify facility project titles, work may be properly identified as rehabilitation provided the primary reason for accomplishment is that the basic restoration work will be done in any event. It is prudent to accomplish any related enhancement, alteration, or adjustment work concurrently. If the pressing requirement is for alteration and adjustment work to achieve an increase in functional capability, then this may be simply classified as "modification," even though restoration is also involved.

Reimbursements. Amounts collected or to be collected for commodities, work, or services furnished or to be furnished to another appropriation or fund or to an individual, firm, or corporation that, by law, may be credited to an appropriation or fund account. Amounts to be collected include accounts receivable, reimbursements earned but not billed, and amounts anticipated for the remainder of the year. They may also include interagency orders accepted and on hand for which delivery has not been made, to the extent that the order is a valid obligation of the ordering agency, and the collection will be credited to the appropriation being reported.

Reliability Centered Building and Equipment Acceptance (RCB&EA). The use of RCM and PT&I technologies in conjunction with traditional and total building commissioning process prior to and during the equipment startup/checkout phase of new construction, repair, and rehabilitation projects to ensure quality installation and accurate baseline documentation.

Reliability Centered Maintenance (RCM). The process that is used to determine the most effective approach to maintenance. It involves identifying actions that, when taken, will reduce the probability of failure and that are the most cost effective. It seeks the optimal mix of Condition-Based Actions, other Time- or Cycle-Based actions, or a Run-to-Failure approach. (See also Condition-Based Maintenance, Predictive Testing & Inspection.)

Repair. Facility work required to restore a facility or component, including collateral equipment, to a condition substantially equivalent to its originally intended and designed capacity, efficiency, or capability. It includes the substantially equivalent replacements of utility systems and collateral equipment necessitated by incipient or actual breakdown. It includes restoration of function, usually after failure. (Also, see Planned Repair.)

Replacement of Obsolete Items (ROI). There are many components of a facility system that should be programmed for replacement as a result of becoming obsolescent (no longer parts-supportable), not meeting electrical or building codes, or being unsafe. The components, however, are still operational and would not be construed as a system repair. Examples are as follows:

a. Electric switchgear, breakers, and motor starters.

b. Elevators.

c. Control systems.

d. Boiler and central HVAC systems and controls.

e. Fire detection systems.

f. Cranes and hoists.

g. A/C and other systems using CFC refrigerants.

Resources. The actual assets of a governmental unit, such as funds, human resources, and material.

Root-Cause Failure Analysis (RCFA). The process of exploring, in increasing detail, all possible causes related to a machine failure. Failure causes are grouped into general categories for further analysis. For example, causes can be related to machinery, people, methods, materials, policies, environment, and measurements.

Service Requests. Service requests are not maintenance items, but are so often performed by facilities maintenance organizations that they become a part of the baseline. Service requests are requests for facilities-related work that is new in nature and, as such, should be funded by the requesting organization. Requests are initiated by anybody at the Center, are usually submitted on a form, often require approval by someone before any action is taken, and usually are planned and estimated. Materials are procured and shop personnel are discretely scheduled to accomplish the work. Examples of these requests include installation of an outlet to support a new copier machine, providing a compressed air outlet to a new test bench, renovating an office, and installing special cabinetry.

Specifications. A document that stipulates methods, materials, performance, testing, limitations, or other criteria that need to be adhered to during the construction of a facility.

Standard. Maintenance standards are defined as the expected condition or degree of usefulness of a facility or equipment item. A maintenance standard may be stated as both a desired condition and a minimum acceptable condition beyond which the facility or equipment is deemed unsatisfactory.

Time-Based Maintenance. See Preventive Maintenance.

Trouble Calls. Trouble calls are generally submitted by telephone or electronically by occupants of a facility (or facility managers or maintenance workers). This category is composed of two types of work:

a. Routine Calls are minor facility problems that are too small to be estimated (usually less than about 20 work hours or $2,000) and generally are responded to by grouping trouble calls by craft and location.

b. Emergency Calls, which normally start as trouble calls, require immediate action to eliminate hazards to personnel or equipment, to prevent loss of or damage to Center property, or to restore essential services that have been disrupted. Emergency work is usually a response-type work effort, often initially worked by trouble call technicians. Due to its nature, emergency work is not restricted to a level of effort, as are trouble calls.

Unconstrained Maintenance and Repair (M&R). Maintenance and repair work that a reasonable manager would estimate is needed to maintain a facility inventory in a "good commercial" level of condition without funding restraints. The estimate would not allow DM to grow and would provide a level of reliability that the supported programs would find acceptable for their missions.

Work Control Center (WCC). The central organizational point for receipt, tracking, and management of work generated from all sources.

Work Generation. The process of identifying and documenting maintenance deficiencies and requirements.

Work Order. The document directing shops to perform certain items of maintenance work. It includes the specific maintenance task requirements (usually by craft), labor, material, and equipment estimates; coordinating instructions; and administrative and financial information.

Work Request. A written or oral request from a customer or internal maintenance personnel who has observed a deficiency and perceives a need for maintenance or repair work or who has a request for new work. The work request is evaluated by management and, if approved, converted into a work order for accomplishment.

Work-Year Equivalents (WYE). Contract hours computed by dividing the total hours compensated (includes regular hours, leave, compensatory time used, and overtime, but excluding leave without pay) by 2,087 hours.

Appendix B. Acronyms

A&E	Architect and Engineer
A/C	Air-Conditioning
ADA	Antideficiency Act
AEP	Agency Execution Plan
AOP	Agency Operating Plan
APQC	American Productivity and Quality Council
ASQ	American Society for Quality
AWP	Annual Work Plan
BCI	Building Cost Index
BY	Budget Year
CADD	Computer Aided Design and Drafting
CBM	Condition Based Maintenance
CFC	Chlorofluorocarbons
CFO	Chief Financial Officer
CMMS	Computerized Maintenance Management System
CoF	Construction of Facilities
COR	Contracting Officers Representative
COSS	Center Operations Support Services
CRV	Current Replacement Value
DESC	Defense Energy Support Center
DM	Deferred Maintenance
DoD	Department of Defense
EMCS	Energy Monitoring and Control System
ENR	Engineering News Record
EPA	Environmental Protection Agency
EPS	Engineered Performance Standards
ESPC	Energy Savings Performance Contract
FAR	Federal Acquisition Regulation
FCA	Facility (Facilities) Condition Assessment
FCI	Facility Condition Index
FEJE	Facilities Engineering Job Estimating
FM	Facility Management
FMS	Functional Management System

FRED	Headquarters Facilities and Real Estate Division
FY	Fiscal Year
GIS	Geographic Information System
GSA	General Services Administration
HPO	Historic Preservation Officer
HQ	NASA Headquarters
HVAC	Heating, Ventilating, and Air-Conditioning
IDIQ	Indefinite Delivery/Indefinite Quantity
IRT	Infrared Thermography
IT	Information Technology
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCC	Life Cycle Cost
LCD	Liquid Crystal Display(s)
LEED	Leadership in Energy and Environmental Design
M&R	Maintenance and Repair
MADR	Maximum Allowable Defect Rate
MCA	Motor Circuit Analysis
MCE	Motor Circuit Evaluation
MDS	Material Data Sheet
MIL-STD	Military Standard
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MSFC	Marshall Space Flight Center
MSI	Maintenance Support Information
NASA	National Aeronautics and Space Administration
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPD	NASA Policy Directive
NPDES	National Pollutant Discharge Elimination System
NPR	NASA Procedural Requirements
NRC	National Research Council
NSN	National Stock Number
O&M	Operations and Maintenance
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
OSPO	Occupational Safety Program Office

P&E	Planning and Estimating (or Planner and Estimator)
PBC	Performance-Based Contract(ing)
PEC	Performance Evaluation Committee
PGM	Programmed Maintenance
PM	Preventive Maintenance
POC	Point of Contact
POP	Program Operating Plan
PP&E	Property Plant and Equipment
PPBE	Planning, Programming, Budgeting and Execution
PRS	Performance Requirements Summary
PT&I	Predictive Testing and Inspection
PUC	Public Utility Commission
PWS	Performance Work Statement
QA	Quality Assurance
QAE	Quality Assurance Evaluator
R&D	Research and Development
RCB&EA	Reliability Centered Building and Equipment Acceptance
RCFA	Root-Cause Failure Analysis
RCM	Reliability Centered Maintenance
ROI	Replacement of Obsolete Items
RPMS	Real Property Management System
RTP	Real-Time Pricing
SOP	Standard Operating Procedure
SOW	Statement of Work
SR	Service Request
TC	Trouble Call(s)
WBS	Work Breakdown Structure
WCC	Work Control Center
WYE	Work-Year Equivalents

Appendix C. Resources

This appendix contains a representative sample of publications and information sources for facilities maintenance managers. The information presented, including telephone numbers and points of contact, is based on information available at the time of publication. This is not an all-inclusive list. Commercial publications contained herein are only representative and not all-inclusive of any organization or source and are not specifically endorsed or promoted by NASA.

C.1 NASA Publications

(1) NPD 1440.6 NASA Records Management.

(2) NPR 1441.1 NASA Records Retention Schedules.

(3) NPR 1800.1 NASA Occupational Health Program Procedures.

(4) NPD 1800.2 NASA Occupational Health Program.

(5) NPD 7330.1 Approval Authorities for Facility Projects.

(6) NPD 8500.1 NASA Environmental Management.

(7) NPR 8553.1 NASA Environmental Management System.

(8) NPR 8570.1 NASA Energy Management Program.

(9) NPR 8621.1 NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping.

(10) NPD 8700.1 NASA Policy for Safety and Mission Success.

(11) NPD 8710.5 Policy for Pressure Vessels and Pressurized Systems.

(12) NPR 8715.3 NASA General Safety Program Requirements.

(13) NPD 8730.5 NASA Quality Assurance Program Policy.

(14) NPR 8800.15 Real Estate Management Program.

(15) NPD 8820.2 Design and Construction of Facilities.

(16) NPR 8820.2 Facility Project Requirements.

(17) NPD 8831.1 Maintenance and Operations of Institutional and Program Facilities and Related Equipment.

(18) NASA Environmental Management Reference Manual.

(19) NASA GPWS for Center Operations Support Services (COSS).

(20) NASA GPWS for Center Operations Support Services (COSS) Addendum.

(21) Reliability Centered Maintenance Guide for Facilities and Collateral Equipment.

(22) NASA Reliability Centered Building and Equipment Acceptance Guide.

(23) NASA-STD-8719.9, Standard for Lifting Devices and Equipment

(24) NASA-STD-8719.12, Standard for Explosives, Propellants, and Pyrotechnics

(25) NASA-STD-8719.17, NASA Requirements for Ground-Based Pressure Vessels and Pressurized Systems (PVS)

C.2 Other Government Agency Publications

(1) U.S. General Accounting Office, NASA Maintenance: Stronger Commitment Needed to Curb Facility Deterioration, Report to the Chair, Subcommittee on VA, HUD, and Independent Agencies, Committee on Appropriations, U.S. Senate, Washington, DC, December 1990.

(2) U.S. General Accounting Office Report to the Chairman, House Republican Task Force on Privatization, March 1997, Privatization Lessons Learned by State and Local Governments.

(3) Office of Management and Budget, U.S. Government Performance of Commercial Activities (OMB Circular A-76 Revised), Washington, DC, May 2003.

(4) U.S. Office of the Federal Register, National Archives and Records Administration, Federal Acquisition Regulation (FAR), 48 CFR.

(5) U.S. General Accounting Office Report to the Committee on Oversight and Government Reform, House of Representatives, October 2008, Federal Real Property Government's Fiscal Exposure from Repair and Maintenance Backlogs is Unclear.

(6) Office of Inspector General, March 2, 2011, Audit of NASA's Facilities Maintenance, IG-11-015.

(7) Office of Inspector General, February 12, 2013, Efforts to Reduce Un-needed Infrastructure and Facilities, IG-13-008.

C.3 Other Government Agency Sources of Information

Organization	Description	Available from
Naval Facilities Engineering Command (NAVFAC)	Engineered Performance Standards are available in a computerized format as part of the Public Works Management Automation (PWMA), Facilities Engineering Job Estimating (FEJE) program, available for IBM-AT-compatible computers. FEJE is composed of three submodules that cover scoping estimates, detailed estimates, and Preventive Maintenance and Inspection (PM&I). The FEJE	NAVFAC technical publications may be available at http://www.navfac.navy.mil/products_and_services/ci/about_us/resources.html. FEJE is available from: National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161

	program permits addition of locally developed estimating standards to the EPS database.	(703) 487-4650, http://www.ntis.gov.
U.S. Army Center for Public Works Publications	None available.	Publications are available online through the Army Corps of Engineers, Construction Engineering Research Laboratory homepage at http://www.cecer.army.mil. U.S. Army Publications are also available from: National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161. (703) 487-4650, http://www.ntis.gov.
General Services Administration	None available.	General Services Administration National Forms and Publications Center (7CAFW), Warehouse 4, Dock No. 1, 4900 South Hemphill Street, Fort Worth, TX 76102. (817) 334-5500, http://www.gsa.gov.
U.S. Environmental Protection Agency	None available.	Publications are available from the EPA Web site or through: U.S. Environmental Protection Agency Public Information Center (PM-211B) 401 M Street SW Washington, DC 20460. (202) 260-2080, http://www.epa.gov.

Federal and State Agencies with Utility Restructuring Information for NASA Host States		
Organization	Description	Available from
Naval Facilities Engineering Command (NAVFAC)	Engineered Performance Standards are available in a computerized format as part of the Public Works Management Automation (PWMA), Facilities Engineering Job Estimating (FEJE) program, available for IBM-AT-compatible computers. FEJE is composed of three sub modules that cover scoping estimates, detailed estimates, and Preventive Maintenance and Inspection (PM&I). The FEJE program permits addition of locally developed estimating standards to	NAVFAC technical publications may be available through the NAVFAC Library. FEJE is available from: National Technical Information Service U.S. Department of Commerce 5285 Port Royal Road Springfield, VA 22161. (703) 487-4650, http://www.ntis.gov.

	the EPS database.	
U.S. Army Center for Public Works Publications	None available.	Publications are available online through the Army Corps of Engineers, Construction Engineering Research Laboratory homepage at http://www.cecer.army.mil. U.S. Army Publications are also available from: National Technical Information Service U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161. (703) 487-4650 http://www.ntis.gov.
General Services Administration	None available.	General Services Administration National Forms and Publications Center (7CAFW) Warehouse 4, Dock No. 1, 4900 South Hemphill Street, Fort Worth, TX 76102. (817) 334-5500, http://www.gsa.gov.
U.S. Environmental Protection Agency	None available.	Publications are available from the EPA Web site or through: U.S. Environmental Protection Agency Public Information Center (PM-211B) 401 M Street SW Washington, DC 20460. (202) 260-2080 http://www.epa.gov.

General Services Administration Regions and Model Area-Wide Contracts

Organization	**Address**
Region 1 - New England (CT, ME, MA, NH, RI, VT)	(866) 734-1727.
Region 2 - Northeast and Caribbean (NJ, except areas covered by Region 3; NY; Puerto Rico, Virgin Islands)	26 Federal Plaza, New York, NY 10278. (212) 264-3305.
Region 3 - Mid-Atlantic (DE, MD, except areas covered by Region 11; NJ, except areas covered by Region 2; PA, VA, except areas covered by Region 11; WV)	The Strawbridge Building, 20 North Eighth Street Philadelphia, PA 19107-3191. (215) 446-5100

Region 4 - Southeast Sunbelt (AL, FL, GA, KY, MS, NC, SC, TN)	77 Forsyth Street, Suite 600, Atlanta, GA 30303. (404) 331-3200, Fax: (404) 331-0931
Region 5- Great Lakes (IL, IN, MI, MN, OH, WI)	Room 3700, 230 S. Dearborn St., Chicago, IL 60604. (312) 353-5395, Fax: (312) 886-5595
Region 6 - Heartland (IA, KS, MS, NE)	1500 E. Bannister Rd., Kansas City, MO 64131-3009. (816) 926-7201, Fax: (816) 926-7513
Region 7 - Greater Southwest (NM, OK, TX, AK, LA)	819 Taylor Street, Suite 11A00 Ft. Worth, TX 76102-0000. Phone: (817) 978-2321, Fax: (817) 978-4867
Region 8 - Rocky Mountain (CO, MT, ND, SD, UT, WY)	Denver Federal Center Building 41, Denver, CO 80225-0006. (303) 236-7329, Fax: (303) 236-7280
Region 9 - Pacific Rim (AZ, CA, HI, NE, American Samoa, Diego Garcia, and the Indian Ocean, Guam, Japan, Korea, and Saipan)	450 Golden Gate Avenue, San Francisco, CA 94102. (415) 522-3001
Region 10 - Northwest/Arctic (AK, ID, OR, WA)	400 15th Street, SW, Auburn, WA 98001. (253) 931-7000
Region 11 - National Capital (DC, MD—Montgomery and Prince George's Counties; Virginia—City of Fairfax, Arlington, Fairfax, Loudoun, and Prince William Counties)	301 7th Street, SW, Washington, DC 20024. (202) 708-9100, Fax: (202) 708-9966

C.4 Trade and Research Organizations Publications

(1) National Research Council, Building Research Board, Committing to the Cost of Ownership: Maintenance and Repair of Public Buildings, Washington, DC, 1990.

(2) National Research Council, Stewardship of Federal Facilities - A Proactive Strategy for Managing the Nation's Public Assets, National Academy Press, Washington, DC, 1998. http://www.nap.edu/catalog.php?record_id=6266.

(3) Federal Facilities Council Standing Committee on Operations and Maintenance, Federal Facilities Council Technical Report #141, Deferred Maintenance Reporting for Federal Facilities - Meeting the Requirements of the Federal Accounting Standards Advisory Board Standard Number 6, as Amended, National Academy Press, Washington, DC, 2001 http://www.nap.edu/catalog.php?record_id=10095.

(4) The Construction Specifications Institute, MasterFormat - 2004 Edition Numbers & Titles, Alexandria, VA, October 2005.

(5) Construction Specifications Institute, MasterFormat - Manual of Practice, Alexandria, VA, 2004. CSI MasterFormat Manual of Practice 2004 Edition: Builder's Book, Inc. Bookstore.

(6) The Association of Higher Education Facilities Offices (APPA), The Building Commissioning Handbook, Second Edition, John A. Heinz & Rick Casault, Alexandria, VA. https://www.appa.org//bookstore/index.cfm?.

(7) Leadership in Energy and Environmental Design (LEED), US Green Building Council, 2101 L Street NW, Suite 500, Washington, DC 20037, (800) 795-1747, http://www.usgbc.org/leed.

(8) Whole Building Design Guide, National Institute of Building Sciences, 1090 Vermont Avenue, NW, Suite 700, Washington, DC 20005-4950, (202) 289-7800, http://www.wbdg.org/.

(9) Building Owners and Managers Association (BOMA) International, 1101 15th Street, NW, Suite 800, Washington, DC 20005, (202 408-2662, info@boma.org.

(10) Investments in Federal Facilities: Asset Management Strategies for the 21st Century (2004), National Academy Press, Washington, DC, 20001, http://www.nap.edu/catalog.php?record_id=11012.

(11) National Research Council, Predicting Outcomes from Investments in Maintenance and Repair for Federal Facilities (2012), National Academy Press, Washington, DC, 20001, http://www.nap.edu/catalog.php?record_id=13280.

C.5 Other Trade and Research Association Sources of Information

The following is a sample of organizations that produce publications applicable to the maintenance and repair of NASA Centers. A listing of publications and special reports is available upon request from each of the organizations.

Air-Conditioning, Heating and Refrigeration Institute
4100 North Fairfax Drive, Suite 200, Arlington, VA 22203
(703) 524-8800, Fax (703) 528-3816, http://www.ahrinet.org/site/1/Home.

American National Standards Institute (ANSI)
1819 L Street, NW, 6th floor, Washington, DC 20036
(202) 293-8020, Fax (202) 293-9287, http://www.ansi.org/.

American Public Works Association (APWA)
2345 Grand Boulevard, Suite 700, Kansas City, MO 64108-2625
(800) 848-APWA, Fax (816) 472-1610, http://www.apwa.net/.

American Society for Quality (ASQ)
PO Box 3005, Milwaukee, WI 53201-3005
(800) 248-1946, Fax (414) 272-1734, http://www.asq.org/.

American Society for Training and Development
1640 King St., Alexandria, VA 22313-1443
(800) 628-2783, Fax (703) 683-1523, http://www.astd.org/.

American Society of Civil Engineers (ASCE)
1801 Alexander Bell Drive, Reston, VA 20191-4400
(800) 548-2723, http://www.asce.org/.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, (ASHRAE)
1791 Tullie Circle, NE, Atlanta, GA 30329
(404) 636-8400, Fax (404) 321-5478, http://www.ashrae.org/.

American Society of Mechanical Engineers (ASME)
Three Park Ave., New York, NY 10016-5990,
(800) 843-2763, http://www.asme.org/.

Association of Energy Engineers (AEE)
4025 Pleasantdale Rd., Suite 420, Atlanta, GA 30340
(770) 447-5083, ext. 210, Fax (770) 446-3969, http://www.aeecenter.org/.

Association for Facilities Engineering (AFE)
12100 Sunset Hills Road, Suite 130, Reston, VA 20190
(703) 234-4066, http://www.afe.org/.

Association of Physical Plant Administrators of Universities and Colleges (APPA)
1643 Prince Street, Alexandria, VA 22314-2818
(703) 684-1446, Fax (703) 549-2772, http://www.appa.org/.

Board on Infrastructure and the Constructed Environment (BICE), The National Academies
500 Fifth Street, NW, Keck WS938, Washington, DC 20001
(202) 334-3505/ Fax (202) 334-3718, http://sites.nationalacademies.org/DEPS/BICE/index.htm.

The Construction Specifications Institute
99 Canal Center Plaza, Suite 300, Alexandria, VA 22314-1588
(800) 689-2900, Fax (703) 684-8436, http://www.csinet.org/.

Institute for Electrical and Electronic Engineers (IEEE)
455 Hoes Ln., Piscataway, NJ 08854-4141
(800) 701-IEEE, Fax (732) 981-9667, http://www.ieee.org/.

International Facility Management Association (IFMA)
1 E. Greenway Plaza, Suite 1100, Houston, TX 77046-0194
(713) 623-4362, Fax (713) 623-6124, http://www.ifma.org/.

International Organization for Standardization
(Note: ANSI is the United States affiliate.)
1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20 Switzerland
Telephone +41 22 749 01 11, http://www.iso.ch/.

National Association for Corrosion Engineers (NACE)
1440 South Creek Drive, Houston, TX 77084-4906 USA
(800) 797-NACE (6223), Fax (281) 228-6300, http://www.nace.org/.

National Association of Power Engineers (NAPE)
1 Springfield St., Chicopee, MA 01013
(413) 592-6273, http://www.powerengineers.com/.

National Electrical Manufacturer's Association (NEMA)
1300 North 17th St., Suite 1752, Rosslyn, VA 22209
(703) 841-3200, Fax (703) 841-5900, http://www.nema.org.

National Fire Protection Association
1 Batterymarch Park, Quincy, MA 02169-7471
(800) 344-3555, Fax (800) 593-6372, http://www.nfpa.org.

The National Institute of Building Sciences
1090 Vermont Avenue, NW, Suite 700, Washington, DC 20005-4905
(202) 289-7800, Fax (202) 289-1092, http://www.nibs.org.

Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)
4201 Lafayette Center Drive, Chantilly, VA 20151-1209
(703) 803-2980, Fax (703) 803-3732, http://www.smacna.org.

Society for Maintenance and Reliability Professionals (SMRP)
8201 Greensboro Drive, Suite 300, McLean, Virginia 22102
(800) 950-7354, Fax (703) 610-9005, http://www.smrp.org.

Society of American Military Engineers (SAME)
607 Prince Street, Alexandria, VA 22314,
(703)-549-3800, http://same.org.

C.6 Commercial Publications

RSMeans Company, Inc.
P O Box 800, Kingston, MA 02364-9988; http://www.rsmeans.com/
The RSMeans Company, Inc. offers a series of cost-estimating guides that should be referred to, as appropriate. Most of the guides are oriented toward facilities construction and repair work. However, they can be used for estimating construction-like facilities maintenance work. The Means Facilities Cost Data guide contains entries for facilities maintenance. The Means guides are updated each year. Means offers more than 35 publications related to cost estimating.

Whitestone Research, 2050 Alameda Padre Serra, Suite 200, Santa Barbara, CA 93103, (800) 210-0137, contact@whitestoneresearch.com.

C.7 Sources of Information on Predictive Testing Techniques

In addition to publishing their own professional journals, many of the organizations listed below serve as clearinghouses for textbooks, technical papers, presentations, and other publications that are available at a reasonable cost. The magazines and groups listed below usually have advertisements and articles related to condition monitoring technologies. Some of the magazines are free to "qualified" individuals, while others are available only to members.

AFE Facilities Engineering Journal Association for Facilities Engineering (AFE) 12100 Sunset Hills Road, Suite 130, Reston, VA 20190, (703) 234-4066, http://www.afe.org.

IEEE Spectrum Institute for Electrical and Electronic Engineers (IEEE) 455 Hoes Ln., Piscataway, NJ 08854-4141, (800) 701-IEEE, Fax (732) 981-9667, http://www.ieee.org.

Maintenance Technology Applied Technical Publications, Inc. 1300 S. Grove Ave., Suite 105, Barrington, IL 60010, (847) 382-8100, Fax (847) 304-8603, http://www.mt-online.com.

Industrial Maintenance and Plant Operation (IMPO) Advantage Business Media 100 Enterprise Drive, Suite 600, Box 912, Rockaway, NJ 07866-0912, (973) 920-7174, Fax (973) 607-5530, http://www.impomag.com.

Buildings, The Facilities Construction and Management Magazine Stamats Communications, Inc. 615 Fifth St. SE, PO Box 1888, Cedar Rapids, IA 52406-1888, (319) 364-6167, Fax (319) 364-4278, http://www.buildings.com/.

Trade Press Media Group. 2100 W. Florist Ave., Milwaukee, WI 53209, (414) 228-7701, Fax (414) 228-1134. http://www.tradepress.com/

Society for Machinery Failure Prevention Technology (MFPT) 5100 Springfield Street, Suite 420, Dayton, OH 45431-1264, (937) 256-2285, Fax (937) 256-2603, http://www.mfpt.org.

Society for Maintenance and Reliability Professionals (SMRP) 8201 Greensboro Drive, Suite 300, McLean, VA 22102, (800) 950-7354, Fax (703) 610-9005, http://www.smrp.org.

The International Society for Optical Engineering (Thermosense Working Group) 1000 20th Street, PO Box 10, Bellingham, WA 98227-0010, (888) 504-8171, Fax (360) 647-1445, http://www.spie.org.

Vibration Institute 6262 S. Kingery Highway, Suite 212, Willowbrook, IL 60527, (630) 654-2254, Fax (630) 654-2271, http://www.vibinst.org.

Plant Services Putman Publishing Company 555 West Pierce Rd., Suite 301, Itasca, IL 60143, (630) 467-1300, http://www.plantservices.com/.

The American Society of Nondestructive Testing (ASNT) 1711 Arlingate Lane, PO Box 28518, Columbus, OH 43228-0518, (800) 222-2768, Fax (614) 274-6899, http://www.asnt.org/.

Uptime Magazine PO Box 60075, Ft. Myers, FL 33906, (888) 575-1245, http://www.uptimemagazine.com/.

Appendix D. Sample Maintenance Management Forms and Documents

This appendix recommends sample forms for use in facilities maintenance management. The information in the forms should be part of a Computerized Maintenance Management System (CMMS) database. The forms should be tailored to meet the needs of the users, the capabilities of the CMMS, and the other automation systems used. (The sample forms also should prove useful when comparing reports and formats during the evaluation of candidate CMMSs.)

D.1 Trouble Call Ticket, Telephone or E-mail

D.1.1 Sample Trouble Call Ticket. Figure D-1 is a sample TC ticket. It is used with TCs, may be used as an alternative to a standard work order for small jobs (typically involving 20 work hours or less effort), and is used for work that usually is not planned or estimated. It contains data fields considered essential for effectively managing TC and small jobs. Usually, it is printed on half-size sheets (often card stock) or is in electronic format on palm-top computers for use by technicians in the field. A printer may be located in the shops, remote from the work reception center, to speed TC ticket delivery.

D.1.2 Data Elements. The following data elements are recommended for the TC ticket system. The elements provide the information that the crafts personnel need to perform the work and that management needs to analyze the work. All listed information need not be recorded if it is available in the CMMS or can be obtained from other data elements. For example, the FMS code does not need to be recorded if it can be obtained from the accounting data.

Data Fields	Definition
1. Date	The date the work was received by the work reception desk.
2. Time	The time the work was received by the work reception desk.
3. Work Order Number	The unique identifying number assigned to the TC ticket. On the example, it is shown in bar code as well as in numerals. (The use of bar codes can speed data entry and reduce data entry errors.)
4. Location	The facility number and any other pertinent data regarding the location or work site of the requested work.
5. Priority	The work priority rating.
6. POC	Point of Contact (POC), the name of the person requesting the work.
7. Phone	The telephone number of the POC.
8. Title	A short description of the work. This should contain descriptive key words that can be used later for database searches for similar work.
9. Work	A detailed statement of the work.
10. Comments	A space for the shops to record comments on the work performed.
11. Material Used	The material used for the TC ticket if beyond that carried as bench stock or in preexpended bins.
12. Shop	The craft shop performing the work. (The form permits entering up to three shops.)
13. Hours	Hours, the amount of labor used to complete the TC ticket by each shop involved.
14. Mech	Mechanic, the initials (or other identifier) of the mechanic performing the work.
15. Acct	Accounting, the accounting data or charge number for financial accounting.
16. Class	Class, a locally definable descriptor for the work that can be used for analysis of TC tickets.
17. Type	Work Element, defined in section 1.5.1.c.
18. SI	Special Interest, the indicator defined in section 5.5.4.3.d.
19. Rcvd By	Received By, the person receiving the request for work.
20. Checked By	The person checking the completed work, if any (usually the supervisor).
21. D/C	Date Completed, date work completed (could include time also).

TROUBLE CALL TICKET

012345

(3)

Date: (1) Time: (2)

Location: (4)

Priority: (5)

POC: (6) Phone: (7)

Title: (8)

Work: (9)

Comments: (10)

Material Used: (11)

Shop: (12)	Shop:	Shop:
Hrs: (13)	Hrs:	Hrs:
Mech: (14)	Mech:	Mech:

Acct: (15)

Class: (16) Type: (17)

SI: (18) Rcvd By: (19)

Checked By: (20) D/C: (21)

Figure D-1 Sample Form: Trouble Call Ticket

D.1.3 Instructions for Use. The TC ticket should be automated as part of the CMMS. Initial data entry can then be accomplished at a computer terminal by the work reception clerk as the work is received. In many cases, requests will be received by telephone. However, they may be received by electronic mail. A TC ticket may be the means of issuing facilities maintenance work requested by other means, such as a request for facilities maintenance services (see section D.2, Request for Facilities Maintenance Services), or as the result of an inspection, when the scope of work is small. The following discusses use of the form.

a. The work order number is normally assigned by the CMMS. However, this can be accomplished manually. If it is assigned manually, it should be checked for duplications. The use of a bar code can speed subsequent processing and closing the TC ticket while reducing data-entry errors. (Most CMMSs support printing of bar codes.)

b. The work reception clerk enters the Date, Time, Location, Priority, POC, Phone, Title, and Work data. Normally, this information is obtained during the initial telephone request. The clerk will use the Center's priority system when assigning the priority. The Work data entry may take the form of a description of the problem or the desired result; for example, "Door closer is broken" or "Fix leaking sink." The Work data entry also can include special coordination instructions or specific due dates. It is essential that the POC and Phone data entries be correct to permit the shops to obtain additional information, if required. Based on the foregoing information, the work reception clerk determines and enters the Scope, Type, Special Interest (SI), and accounting data (Acct). The clerk completes the form by entering the name or other identifier in the Rcvd By block. (Bar coding can expedite completion of the ticket by using a dictionary of standard terms, phrases, and other data available to the work reception clerk. The clerk can scan a bar code dictionary entry in lieu of typing a data field. This offers the dual advantages of reducing keyboard errors and using standard vocabulary for the data element.) Once this data is entered, the TC ticket is sent to the shops.

c. The shop supervisor reviews the TC ticket and assigns it to a mechanic for accomplishment, in accordance with its priority. Routine work is normally grouped by location and craft to minimize time lost in travel. In some cases a job may require specialized skills not found in the shop that normally performs TC tickets, in which case, it is assigned to another shop for completion; for example, machining a special fitting.

d. The mechanic performing the work enters the work performed in the Comments area and the Material Used if material beyond that carried as bench stock or in preexpended bins is required. Alternatively, the Materials Used information may be obtained as part of a materials management module in the CMMS when the material is issued to the mechanic. Unusual conditions encountered are noted in the Comments block as well. The mechanic initials the form upon completion.

e. The shop supervisor enters the identification and the labor hours used on the TC ticket. The shop supervisor checks the completed form to ensure that all entries are made and returns it to the work control center to be closed. If the supervisor or other official inspects the competed work, this is indicated by initialing the "Checked By" block.

f. When the completed form is returned to the work control center, it is closed by entering the completion data in the CMMS. This will normally include labor and material expenditures, completion date, and applicable comments on work performed. The information becomes part of the maintenance history file. A hard copy of the TC ticket need not be retained if the data is stored in the CMMS and backed up. If it is determined by the mechanic or supervisor that followup action is required, the work reception clerk enters the required action into the work control system. This may take the form of another TC ticket or a request for facilities maintenance services. (See section D.2, Request for Facilities Maintenance Services.)

D.2 Request for Facilities Maintenance Services Electronic

D.2.1 Sample Form: Request for Facilities Maintenance Services, Figure D-2, is a sample form to be used by customers to document SRs or to request other facilities maintenance services. The primary purpose for this form is to document requests for work. The key factors are ensuring that sufficient data is obtained to identify, describe, and manage the work; that the work is properly authorized; that the work is properly tracked; and that accountability is maintained. The work may be accomplished as a TC ticket, a work order, or by separate contract, depending on its urgency, scope, and cost. The determination on how the work is accomplished is made as part of the facilities maintenance management process.

REQUEST FOR FACILITIES MAINTENANCE SERVICES			
Originator: (1)			Date: (2)
POC: (3)		Phone: (4)	Cust. No.: (5)
Location: (6)			Priority: (7)
RCD: (8)	Estimate Only: (9) Y___ N___	Customer Signature: (10)	
Requested Work: (11)			
Special Instructions: (12)			

APPROVAL/ACTION/ESTIMATE				
WICN: (13)	Date Rcvd: (14)	W.O. # (15)	ESTIMATED COSTS->	Labor: (16)
Approval Status: (21) APPROVED: __ APPROVED (Subject to customer funding): __ DISAPPROVED: __				Material: (17)
Comments: (22)				Equipment: (18)
				Other: (19)
				Total Est: (20)

CUSTOMER FUNDING DATA	
Fund Citation/Accounting Data: (23)	
Authorizing Signature: (24)	Date: (25)

Figure D-2 Sample Form: Request for Facilities Maintenance Services

D.2.2 Data Elements

Data Fields:	Definition:
1. Originator:	The name (or other identifier) of the requesting organization/customer.
2. Date:	The date the request is submitted.
3. POC:	Point of Contact, the name of the person to be contacted regarding the request.
4. Phone:	The telephone number for the POC.
5. Cust. No.:	Customer Number, an identification number assigned by the submitting organization. (This is optional, but it gives the originator the ability to assign the organization's own identification or tracking number.)
6. Location:	The facility number and any other pertinent data regarding the location where the work is to be done.
7. Priority:	The work priority rating.
8. RCD:	Requested Completion Date, the completion date requested for the services.
9. Estimate:	An indicator that the originator wants a cost estimate only for the work requested rather than immediate performance of the work.
10. Customer Signature:	The signature of an individual authorized to submit requests from the requesting organization. (Other validation systems may be used, such as an authorization number if received by electronic mail.)

11. Requested Work:	A description of the requested work and a justification for the request if it is for other than maintenance.
12. Special Instructions:	Any special permits, coordination, outages, or other requirements the originator is aware of that apply to this work.
13. WICN:	Work Input Control Number, a unique identifier assigned by the facilities maintenance organization to identify the request for subsequent tracking by the facilities maintenance organization.
14. Date Rcvd:	The date the request is received by the facilities maintenance organization's work reception desk.
15. W.O. #:	Work Order Number, the identifying number of the work order that the requested work is being accomplished under, if applicable.
16. Labor:	Estimated labor cost for the work.
17. Material:	Estimated material cost for the work.
18. Equipment:	Estimated equipment cost for the work.
19. Other:	Estimated other costs for the work. (This could include items such as one-time contracts for portions of the work.)
20. Total Est:	Total estimated cost.
21. Approval Status:	An indicator to document the fact that the work: (a) Is approved and will be performed by the facilities maintenance organization using the funds cited in block 23, (b) is approved subject to funding by the originator, or (c) is disapproved.
22. Comments:	Additional information, such as the reason for disapproval or a note regarding sketches or attachments to a returned estimate.
23. Fund Citation:	A fund citation or accounting data to cover the work.
24. Authorizing Signature:	Signature by competent authority granting approval to charge the funds in the Fund Citation data field for the work.
25. Date:	The date the authorizing signature is affixed.
26. Internal Status:	This information is not shown on the sample printed form, but should be contained in the CMMS database. It is a series of status tracking data fields used by the facilities maintenance organization. The status data includes the date and current processing status of the request as well as who has the request for action and what actions have been completed.

D.2.3 Instructions for Use. The Request for Facilities Maintenance Services should be automated as part of the CMMS. However, because it originates with a customer, entry into the CMMS may not take place until after it is submitted by the originator and received by the work control center. Where electronic mail is available or customers have network access to the CMMS, it may be possible to automate the submission and initial data entry. The form is used as follows:

a. The originator provides the required information for data fields 1 through 12, 23, 24, and 25. The remaining fields are the responsibility of the facilities maintenance organization. Normally, fields 1 through 12 are filled in at the time of the initial submission. The Estimate Only "Y" block is selected if the originator is requesting only a cost estimate.

b. When the facilities maintenance work reception desk, in the Work Control Center (WCC), receives the request, the work reception clerk enters the date received and assigns a work input control number for tracking purposes.

c. The WCC (typically the work reception clerk) screens the request to determine what action is required. If the request is for work properly accomplished as a TC ticket, the WCC prepares a TC ticket and notes this in the Work Order block (15) and the Comments block (22). The WCC notifies the originator by completing the Approval Status (21) and returning a copy to the originator.

d. If the request is for an estimate only, the WCC forwards it to the estimators. When the P&Es complete the estimate, they fill in the Labor, Material, Equipment, Other, and Total blocks (16-20) and return it to the WCC. The WCC notifies the originator by returning a copy of the request with the estimate data. The returned package may include the detailed estimate and job plan prepared by the P&E, a request for funds, and a tentative or conditional scheduling window for the work.

e. If the request is for the performance of work that requires planning and estimating and it has received preliminary approval, the WCC forwards it to the P&Es for detailed job planning and estimating. When the P&Es complete the job package (including a work order), they return it to the WCC. The WCC then forwards it to the proper official for final review and approval.

f. If approved, the WCC completes the Work Order #, Approval Status, and Comments blocks (15, 21, and 22) and notifies the originator. If the originator should fund the job, it proceeds as a request for estimate as discussed in section D.2.3d. The reasons for originator funding should be stated in the comments. If the originator provided funding data for the request, it is entered into the shop load plan for execution when final approval is given.

g. If the request is disapproved, the WCC enters this in the Approval Status and Comments blocks (21 and 22) and notifies the originator. Because disapprovals can cause customer discontent, the WCC should ensure review by an appropriate manager in the facilities maintenance organization before notifying the originator.

h. The Internal Status data elements (item 26, not shown on the form) are used to track the status and progress of the request. As the request moves through the facilities maintenance management process and facilities maintenance organization, the WCC enters the date, status, and responsible action party. This provides a history of the request.

D.3 Facilities Maintenance Work Order (Paper or Electronic)

D.3.1 Sample Form: Facilities Maintenance Work Order. Figure D-3 is a sample facilities maintenance work order form. The form is generic, but it illustrates the information recommended for a work order. The form shown in Figure 10-2, Equipment/Discrepancy Classification Form, also generic, can be used to identify work items, usually Trouble Call work, that do not have identification numbers. Using these standardized equipment terms and discrepancies will allow the work to be coded into the CMMS for data integration and analysis. Figure D-4 is a sample continuation sheet that supports the sample facilities maintenance work order form. Figure D-5 is a sample facilities maintenance work order material/equipment requirements form that can be used to document the materials and equipment required for the work order. The actual forms used should be tailored to the Center's needs and the CMMS used.

FACILITIES MAINTENANCE WORK ORDER				W. O. # **(1)** 012345
WICN: **(2)**	Priority: **(3)**	RSD: **(4)**	RCD: **(5)**	
Type: **(6)**	SI: **(7)**	Class: **(8)**	Facility #: **(9)**	UDF: **(10)**
Accounting Data: **(11)**				UDF: **(12)**
POC: **(13)**			Phone: **(14)**	Equip. #: **(15)**
Title: **(16)**				
General Description: **(17)**				

WORK ORDER ESTIMATE								
WORK BREAKDOWN				ESTIMATE SUMMARY **(25)**				
Line #	Shop	WORK TASKS	HRS	Shop	HRS	Labor	Mtl.	Total
(18)	**(19)**	**(20)**	**(21)**					
Special Instructions: **(22)**				Subtotal:				
				Contingency:				
Continuation: **(23)**				Overhead, etc.:				
Sketches: **(24)**				Total Estimate:				

Approved: **(26)**	Date: **(27)**	Estimate Basis: **(28)**	Completed: **(29)**

Figure D-3 Sample Form: Facilities Maintenance Work Order

FACILITIES MAINTENANCE WORK ORDER CONTINUATION			W. O. # (1) 012345
Line #	Shop	WORK TASK	HRS
(18)	(19)	(20)	(21)
		Page: of	

Figure D-4 Sample Form: Facilities Maintenance Work Order Continuation Sheet

WORK ORDER MATERIAL/EQUIPMENT REQUIREMENTS					W.O. # (1) 012345		
Item #		Stock #	UM	Qty	Unit Cost	Total	Avail
(30)	(31)	(32)	(33)	(34)	(35)	(36)	(37)
Approved: (26)		Priority: (3)				Page: of	

Figure D-5 Sample Form: Facilities Maintenance Work Order Material/Equipment Requirements

D.3.2 Data Elements

1. W. O. #: Work Order Number, this number is used to track the work order and related actions throughout the life of the work order. On the sample, it is shown both as a bar code and as numerals. One work order may be issued to cover more than one work request.
2. WICN: Work Input Control Number, a unique number assigned by the facilities maintenance organization to identify a request for facilities maintenance services for subsequent tracking of the request. One work request may result in more than one work order.
3. Priority: The work priority rating. This may not be the same as the priority requested by the originator on the Request for Facilities Maintenance Services form.
4. RSD: Required Start Date, the date work can or will start as applicable. This may be determined by the availability of the facility or the time required to meet the completion date.
5. RCD: Required Completion Date, the required completion date for the work order. Where possible, this should be the same date as on the Request for Facilities Maintenance Services form.
6. Type: The type of work as defined in section 1.5.1.c.
7. SI: Special interest, an indicator as defined in section 5.5.4.3.d or locally.
8. Class: Class, a locally definable descriptor for the work that can be used for analysis of work.

9.	Facility #:	The facility number as recorded in property records.
10.	UDF:	User definable field, a locally definable descriptor for the work that can be used for analysis of work.
11.	Accounting Data:	The applicable accounting data for the work order.
12.	UDF:	User definable field, a locally definable descriptor for the work that can be used for analysis of work.
13.	POC:	Point of Contact, the name of the customer organization's POC responsible for this request. This is needed by the shops for coordination purposes.
14.	Phone:	The telephone number for the POC.
15.	Equipment #:	The equipment inventory number, as recorded in property records. This field applies only when the work is to be done on an equipment item. It can be the principal equipment item if the work order covers multiple equipment items.
16.	Title:	Short descriptive title of the work order.
17.	General Description:	A narrative description of the scope and intent of the work order.
18.	Line #:	Sequential task numbers.
19.	Shop:	Shop, the shop or craft group planned to perform the task.
20.	Work Tasks:	A statement of each task required to complete the work order.
21.	HRS:	Hours, the amount of labor required to complete the task. Normally, this is based on an estimating standard.
22.	Special Instructions:	Any special instructions or directions not covered in the listed work tasks.
23.	Continuation:	Statement that material and continuation sheets are provided where all tasks and material/equipment requirements are not entered on this form. Continuation sheets are forms that contain the work order number and additional work breakdown lines (see Figure D-4).
24.	Sketches:	Reference to drawings or sketches. Ideally, drawings would be from a graphics information system or CADD system that is integrated with the CMMS. The drawings, sketches, and other graphics would be prepared, printed, and attached to the work order.
25.	Estimate Summary:	This multifield section is a summary of the work order estimate by shop, listing the estimated hours, labor cost, material cost, and total costs, together with any overall reservations for contingencies, overhead, or surcharges, and the total estimate.
26.	Approved:	Signature authorizing release and execution of the work order.
27.	Date:	Date the work order is approved for execution.
28.	Estimate Basis:	A field to identify the basis of the cost estimate or the estimating standard used.
29.	Completed:	The date the work order is completed.

The work order material/equipment requirements form (Figure D-5) includes the following additional data elements:

30.	Item #:	Sequential number of items on the requirements list.
31.	Stock #:	The stock number of the required item. This may be a local stock number, a National Stock Number (NSN), a manufacturer's part number, or other identifier. If other than a local stock number or NSN, supporting information (e.g., the identity of the manufacturer) should be given with the description.
32.	Description:	Nomenclature, supplier, and other descriptive data of the required item or equipment.
33.	UM:	Unit of measure (e.g., lf, ea, gal, hr).
34.	Qty:	Quantity required.
35.	Unit Cost:	Unit cost of the item.
36.	Total:	Total cost of the specified quantity of the item.
37.	Avail:	Availability of the material. Enter the material delivery due date or a symbol to show that the material is in stock and ready for issue to the shops.

D.3.3 Instructions for Use

a. The facilities maintenance work order form provides the work authorization and direction to the shops. It also documents the work phases and cost estimate. Except for the accounting data and approval signatures, the work order form, continuation form, and material/equipment requirements forms usually are prepared by the P&Es. Normally, the accounting data is assigned as part of the final approval process. The use of a bar code on the work order form, the work order continuation form, and the material/equipment requirements form speeds subsequent processing, material issue, and closing of the work order while reducing data entry errors. (Most CMMSs support printing of bar codes.)

b. After the work order has final approval, it is distributed to the shops, the material manager, the customer (in the case of customer-requested work), and others as determined by Center policy. Distribution may be accomplished electronically if e-mail is available, or if the CMMS work order database is shared on a network. The form shown contains all information concerning the work order and goes beyond the information requirements of many users of the form. For example, the material manager may not need the detailed task breakdown. With electronic distribution, it is possible for users to receive only necessary extracts of the data.

c. When the work order is completed, it is closed, and the information is added to the facility history files. The completion date is recorded and reported to the work control center.

D.4 Shop Load Plan

D.4.1 Sample Form: Shop Load Plan. Figure D-6 (see reproducible and enlargeable page at the end of this appendix) is a sample shop load plan form. The CMMS used by the Center should support computer-aided scheduling, including interactive labor and other resource scheduling and schedule balancing. The shop load plan should be automated as a standard report in the CMMS. A single database should support all three levels of scheduling (i.e., shop load plan, master schedule, and shop schedule) in a networked system. While it is possible to examine the shop load plan on a video display terminal, the practical limitation on the number of lines and columns that can be displayed at one time makes a printout on wide paper convenient for use by managers.

D.4.2 Data Elements. The following data elements are shown on the Shop Load Plan. The information either is contained in the CMMS database or is derived from the CMMS database. It is defined below as an aid to understanding the schedule format. The only item that should require entry in the scheduling process is for the scheduling period. The rest of the information is based on other data entered in the CMMS during the work reception and planning process or extracted from other databases, such as labor accounting.

1.	Period Covered:	The period this schedule considers. Normally, for the Shop Load Plan, this is a quarter. However, the immediate next three months may be subdivided into a one-month short-term and a two-month midterm load plan for additional scheduling control.
2.	Shop:	The shop or craft group being scheduled, e.g., carpenters. (The sample form shows 12 shops; this should be adjusted to meet local needs.)
3.	No. of Employees:	The average number of employees available in each shop.
4.	Gross Work Hours Avail:	The total number of work hours available in each shop during the schedule period.
5.	Adjustments:	The number of work hours that will not be available in each shop for facilities maintenance work due to leave, training, jury duty, and similar nonproduction activities. (This may be presented on more than one line if a line for each type of adjustment is desired.)
6.	Net Work Hours Avail:	The net work hours available in each shop for facilities maintenance work, computed as item four less item five.
7.	TC LOE:	Trouble Call ticket LOE, the number of hours allocated by shop for jobs issued under TC tickets. Usually, this is based on experience.
8.	PM Scheduled:	The number of hours for scheduled PM work by shop. This is determined from the PM schedule contained in the CMMS database.
9.	PT&I Scheduled:	The number of hours for scheduled PT&I work by shop. This is determined from the PT&I schedule contained in the CMMS database.
10.	Scheduled, Recurring:	The number of hours by shop for other scheduled recurring work. This may be determined from the CMMS database. It may be presented on more than one line if grouped, such as by type or work order.
11.	Total LOE Scheduled:	Total hours committed to items 7, 8, 9, and 10 above.
12.	Carryover from Prior Period	Work scheduled or started in the prior period, but not completed and, thus, carried over to this period. This may be automatically computed by comparing work order labor estimates against labor charges to date.
13.	Available to Schedule:	Net Work hours available (6) less item Total LOE Scheduled (11), and Carryover (12). This is the workforce available for scheduling new work orders.
14.	W.O. #:	Work Order number for each work order listed.
15.	Description:	An entry giving a short title for each work order. The number of hours estimated for each shop for the work order follows on the same line.

16. RSD:	Requested start date for the work order.
17. RCD:	Required completion date for the work order.
18. PRI:	Priority of the work order.
19. MAT:	Material status indicator. Normally, this block contains the date on which the required material is expected to be available, or that the material is available. This is the overall status of the field "Avail" on the Work Order Material/Equipment Requirements form, Figure D-5.
20 Work hours:	The estimated work hours for the work order for each shop.
21. Total:	The total labor hours for the work order for all shops.
22. Labor:	Estimated total labor cost for the work order.
23. Mtl:	Estimated total material cost for the work order.
24. Other:	Estimated total other cost for the work order. This would include items such as equipment rentals and contracted services.
25. Total:	The total cost for the work order.

D.4.3 Instructions for Use

a. Normally, the shop load plan is prepared quarterly. However, shop load plans should be prepared and maintained looking 18 months into the future. The last period should include all work that is in an "estimated and approved but unscheduled" status. A Center also may wish to extract a short-term (next month) and a midterm (following two months) shop load plan for closer work scheduling and management. After final approval of a work order, it is assigned to a shop load plan. Normally, this level of scheduling is done by a senior maintenance planner, not in the shop's organization. This starts the work performance phase and triggers material acquisition to ensure that the required material is available for the assigned start period. Approved work orders remain in the shop load plan until completed or canceled.

b. The primary purpose of the shop load plan is to provide for orderly scheduling of work in accordance with the Center's mission priorities, to assist in resource scheduling and management, and to provide senior managers with information on pending work. It also provides a valuable tool for evaluating the workforce skill mix against workload requirements. If the shop load plan consistently shows a significant amount of overscheduling or unscheduled backlog in a shop coupled with underscheduling in another shop, realignment of workforce assets from the underscheduled to the overscheduled shop may be in order.

D.5 Master Schedule

D.5.1 Sample Form: Master Schedule. Figure D-7 (see reproducible and enlargeable page at the end of this appendix) is a sample form for a master schedule. The master schedule is based on the shop load plan. However, its focus is on scheduling work performance to a specific week and tracking material status of work orders that are due for master scheduling in the future according to the current and approaching shop load plans. Normally, master schedules are prepared covering six to ten weeks into the future. Jobs with long-lead-time material requirements may be scheduled further in the future. Of special interest is the Work Orders Waiting Material section. This is used to highlight the material status of work orders waiting material that need to start during the master schedule period covered.

D.5.2 Data Elements. The following data elements are shown on the master schedule form. As with the shop load plan, the information either is contained in the CMMS database or is derived from the CMMS database by manipulation and calculation. The data elements are defined below as an aid to understanding the schedule form. The only data that should require entry in the scheduling process is for the period during which the work order is being scheduled (normally, the specific workweek). The rest is based on other data entered in the CMMS during the work reception and planning process, the material management process, or extracted from other databases such as labor accounting.

1. Period Covered:	The period this schedule considers. Normally, for the master schedule, this is a workweek.
2. Shop:	The shop or craft group being scheduled; e.g., shop 01, carpenters.
3. No. of Employees:	The average onboard workforce in each shop during the schedule period.
4. Gross Work hours Avail:	The total number of work hours in each shop available during this period.
5. Adjustments:	The number of work hours that will not be available for facilities maintenance work due to leave, training, jury duty, and similar nonproduction activities. This may be presented on more than one line if a line for each type of adjustment is desired.
6. Net Work hours Avail:	The net available work hours for facilities maintenance work
7. TC LOE:	TC ticket LOE, the number of hours allocated for jobs, usually issued under TC tickets. Usually, this is based on experience.
8. PM Scheduled:	The number of hours for scheduled PM work.
9. PT&I Scheduled:	The number of hours for scheduled PT&I work.
10. Scheduled & Recurring:	The number of hours for other scheduled or recurring work. This may be presented on more than one line if grouped, such as by type or work order.
11. Total LOE, Scheduled:	Total hours committed to items 7, 8, 9, and 10.
12. Available to Schedule:	Net work hours available (item 6) less item 11. This is the workforce available for scheduling specific work orders.

13. W.O. #:	Work order number for each specific work order listed.
14. Description:	Entry giving a short title for each work order. Also, the number of work hours scheduled for the work order by each shop during this schedule period is entered under the shop number on the same line.
15. RSD:	Requested start date for the work order.
16. RCD:	Requested completion date for the work order.
17. PRI:	The work order priority rating.
18. MAT:	Material status indicator. Normally, this entry is the date on which material required for the work order is expected to be available or a code indicating that the material is currently available.
19. Total:	Total labor hours for the shops.
20. Labor:	Expended labor hours. The total labor hours used or scheduled for the work order prior to this schedule period.
21. Mtl:	Cumulative material cost of material used for work order.
22. Other:	Cumulative costs of other than labor and material used for the work order. This includes such items as equipment rentals and contracted services.
23. Total:	Cumulative total cost.

D.5.3 Instructions for Use

a. The master schedule is used to direct and coordinate the execution of work in the shops. It provides the coordinating linkage between the shops on jobs involving more than one shop, and it highlights the material status of pending work orders. Normally, it is maintained under the direction of the shop supervisor working in close coordination with the other shop supervisors and the maintenance planners. Work is scheduled by assigning it to a specific workweek; the automation program used should perform all necessary calculations, including computing estimated carryover work and resources expended (or projected to be expended) up to the period under consideration.

b. It is essential for the master schedule to give close attention to balancing the work to each shop to ensure that all forces are productively employed. To this end, the master scheduler will assign labor hours to each scheduled job within available workforce and job-phasing requirements.

c. While it is possible to examine the master schedule on a video display terminal, the practical limitation on the number of lines and columns that can be displayed at one time makes it difficult to see all work that is subject to scheduling. Accordingly, printouts on wide paper and wall-mounted scheduling boards normally are used to display job status.

D.6 Shop Schedule

D.6.1 Sample Form: Shop Schedule. A form for a shop schedule is provided as Figure D-8 (see reproducible and enlargeable page at the end of this appendix). The shop schedule provides the day-to-day scheduling/assignment of workers and equipment to work orders. It is used by the shop supervisor as an aid in scheduling personnel and shared equipment assets.

D.6.2 Data Elements. The following data elements are shown on the Shop Schedule form. The information either is contained in the CMMS database or is derived from the CMMS database by manipulation and calculation. The data elements are defined below as an aid to understanding the schedule form. The only data elements that should be entered during the scheduling process are the assigned hours for each work order and employee being scheduled. The remaining data elements should be provided by the computer based on other data entered in the CMMS during the work reception and planning process, the material management process, or extracted from other databases.

1. Period Covered:	The period this schedule considers. Normally, for the shop schedule it is a specific day.
2. Shop:	The shop or craft group being scheduled; e.g., shop 01, carpenters.
3. Employee:	The name or other identifier of the worker being scheduled.
4. Gross Work hours Avail:	The total number of work hours available for each worker during this period, normally eight.
5. Adjustments:	The number of work hours that will not be available for facilities maintenance work due to leave, training, jury duty, and similar nonproduction activities. This may be presented on more than one line if a line for each type of adjustment is desired.
6. Net Work Hrs. Avail:	The net available work hours for each employee for facilities maintenance work.
7. W.O. #:	Work order number for each work order listed.
8. Description:	An entry giving a short title for each work order. The hours assigned to each employee for each work order number follows on the same line under the employee's identification.
9. RSD:	Requested start date for the work order.
10. RCD:	Requested completion date for the work order.
11. PRI:	The work order priority rating.
12. MAT:	Material status indicator. Normally, this is a code or symbol indicating that the material is currently available.

13. Total: Total hours for all employees.

14. Labor: Cumulative labor hours for the work order prior to this schedule period. This information is provided as part of the labor distribution/timekeeping process.

15. Mtl: Cumulative cost of material used for the work order.

16. Other: Cumulative cost of other than labor and material used for the work order. This includes such items as equipment rentals and contracted services.

17. Total: Cumulative total cost.

D.6.3 Instructions for Use. The shop supervisor, in scheduling and managing craft personnel, uses the shop schedule. It is typically prepared on a weekly basis for each day of the following week, based on jobs scheduled in the master schedule. The shop supervisor enters the hours each employee is scheduled to work on each assigned job for each day. The workforce availability is determined from leave, training, and related activities that are scheduled through the shop supervisor.

PERIOD COVERED: (1) **SHOP LOAD PLAN**

SPECIFIC WORK/ITEM			WORK HOURS													COST EST	REMARKS
WORKFORCE AVAILABILITY		(2) SHOP ->	01	02	03	04	05	06	07	08	09	10	20	30	Total		
	No. of Employees (3)																
	Gross Work hours Avail. (4)																
	Adjustments (5)																
	Net Work hours Avail. (6)																

W.O. #	DESCRIPTION	RSD	RCD	PRI	MAT	01	02	03	04	05	06	07	08	09	10	20	30	Total	La-bor	Mtl.	Oth-er	Total	
COMMITTED WORKFORCE	TC LOE (7)																						
	PM Scheduled (8)																						
	PT&I Scheduled (9)																						
	Scheduled, Recurring (10)																						
	Total LOE, Scheduled, etc. (11)																						
	Carry-over from Prior Period (12)																						
	AVAILABLE TO SCHEDULE (13)																						
(14)	(15)	(16)	(17)	(18)	(19)	(20)												(21)	(22)	(23)	(24)	(25)	
	[list specific work orders]																						
	[as many lines as needed]																						
	Net hours over/under scheduled																						

Figure D-6 Sample Form: Shop Load Plan

PERIOD COVERED: (1)						MASTER SCHEDULE																	
SPECIFIC WORK/ITEM						WORK HOURS													USED TO-DATE				REMARKS
WORKFORCE AVAILABILITY		(2)			SHOP ->	01	02	03	04	05	06	07	08	09	10	20	30	Total					
	No. of Employees (3)																						
	Gross Work hours Avail. (4)																						
	Adjustments (5)																						
	Net Work hours Avail. (6)																						
W.O. #	DESCRIPTION	RSD	RCD	PRI	MAT	01	02	03	04	05	06	07	08	09	10	20	30	Total	Labor	Mtl.	Other	Total	
COMMITTED WORKFORCE	TC LOE (7)																						
	PM Schedule (8)																						
	PT&I Schedule (9)																						
	Scheduled and Recurring (10)																						
	Total LOE, Scheduled, etc. (11)																						
	AVAILABLE TO SCHEDULE (12)																						
(13)	(14)	(15)	(16)	(17)	(18)													(19)	(20)	(21)	(22)	(23)	
	(list specific work orders)																						
	(as many lines as needed)																						
	Net hours over/under scheduled																						
WORK ORDERS WAITING MATERIAL																							
	(as many lines as needed)																						
	Total waiting material																						

Figure D-7 Sample Form: Master Schedule

PERIOD COVERED: (1)						SHOP SCHEDULE													For Shop: (2)				
SPECIFIC WORK/ITEM						WORK HOURS													USED				REMARKS
		(3)			EMPLOYEE ->													Total					
	Gross Work hours Avail. (4)																						
	Adjustments (5)																						
	Net Work hours Avail. (6)																						
W.O. #	DESCRIPTION	RSD	RCD	PRI	MAT													Total	Labor	Mtl.	Other	Total	
(7)	(8)	(9)	(10)	(11)	(12)													(13)	(14)	(15)	(16)	(17)	
	(assigned work orders)																						
	(as many lines as needed)																						
	Net hours over/under scheduled																						

Figure D-8 Sample Form: Shop Schedule

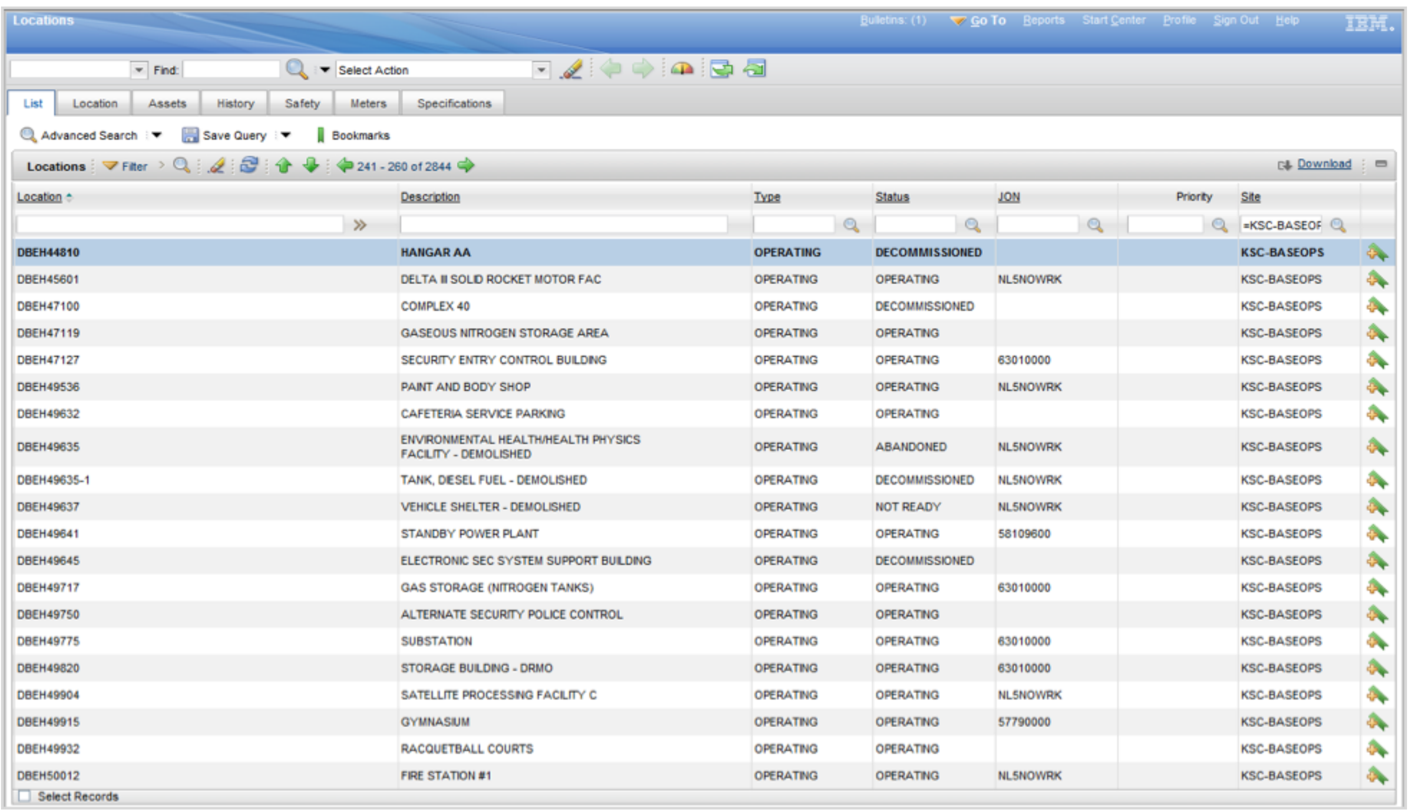
Appendix E. CMMS Sample Screens

E.1 Introduction

This appendix includes sample computer screens for various facilities maintenance functions that may be included in a Center's CMMS. These samples are from a commercially available system and are presented as a sample of some of the types of data-handling capability available.

E.2 Operating Locations

The sample screens in Figure E-1 is from an operating location application within the CMMS system that allows the operator to enter and track locations of equipment and organize these locations into logical hierarchies or network systems. Operating locations are the locations in which equipment operates. Work orders can then be written either against the location itself or against the equipment in the operating location. Using locations allows for tracking the equipment's life cycles (history) and provides the capability to track equipment's performance at specific sites.



Location	Description	Type	Status	JON	Priority	Site
						=KSC-BASEOF
DBEH44810	HANGAR AA	OPERATING	DECOMMISSIONED			KSC-BASEOPS
DBEH45601	DELTA II SOLID ROCKET MOTOR FAC	OPERATING	OPERATING	NL5NOWRK		KSC-BASEOPS
DBEH47100	COMPLEX 40	OPERATING	DECOMMISSIONED			KSC-BASEOPS
DBEH47119	GASEOUS NITROGEN STORAGE AREA	OPERATING	OPERATING			KSC-BASEOPS
DBEH47127	SECURITY ENTRY CONTROL BUILDING	OPERATING	OPERATING	63010000		KSC-BASEOPS
DBEH49536	PAINT AND BODY SHOP	OPERATING	OPERATING	NL5NOWRK		KSC-BASEOPS
DBEH49632	CAFETERIA SERVICE PARKING	OPERATING	OPERATING			KSC-BASEOPS
DBEH49635	ENVIRONMENTAL HEALTH/HEALTH PHYSICS FACILITY - DEMOLISHED	OPERATING	ABANDONED	NL5NOWRK		KSC-BASEOPS
DBEH49635-1	TANK, DIESEL FUEL - DEMOLISHED	OPERATING	DECOMMISSIONED	NL5NOWRK		KSC-BASEOPS
DBEH49637	VEHICLE SHELTER - DEMOLISHED	OPERATING	NOT READY	NL5NOWRK		KSC-BASEOPS
DBEH49641	STANDBY POWER PLANT	OPERATING	OPERATING	58109600		KSC-BASEOPS
DBEH49645	ELECTRONIC SEC SYSTEM SUPPORT BUILDING	OPERATING	DECOMMISSIONED			KSC-BASEOPS
DBEH49717	GAS STORAGE (NITROGEN TANKS)	OPERATING	OPERATING	63010000		KSC-BASEOPS
DBEH49750	ALTERNATE SECURITY POLICE CONTROL	OPERATING	OPERATING			KSC-BASEOPS
DBEH49775	SUBSTATION	OPERATING	OPERATING	63010000		KSC-BASEOPS
DBEH49820	STORAGE BUILDING - DRMO	OPERATING	OPERATING	63010000		KSC-BASEOPS
DBEH49904	SATELLITE PROCESSING FACILITY C	OPERATING	OPERATING	NL5NOWRK		KSC-BASEOPS
DBEH49915	GYMNASIUM	OPERATING	OPERATING	57790000		KSC-BASEOPS
DBEH49932	RACQUETBALL COURTS	OPERATING	OPERATING			KSC-BASEOPS
DBEH50012	FIRE STATION #1	OPERATING	OPERATING	NL5NOWRK		KSC-BASEOPS

Figure E-1 Sample Operating Locations Drilldown Screen

E.3 Equipment

Figure E-2 is a sample screen from an equipment module that allows the operator to keep accurate and detailed records of each piece of equipment. Accurate historical data can be used to help make cost-effective replace or repair decisions. All equipment-related data is available, such as bill of material, preventive maintenance schedule, service contracts, safety procedures, measurement points, multiple meters, inspection routes, specification data (nameplate), equipment downtime, and related documents. This equipment data is used for managing day-to-day operations. The data can be used to develop additional management information, such as developing equipment downtime failure code hierarchies to use in maintenance management metrics.

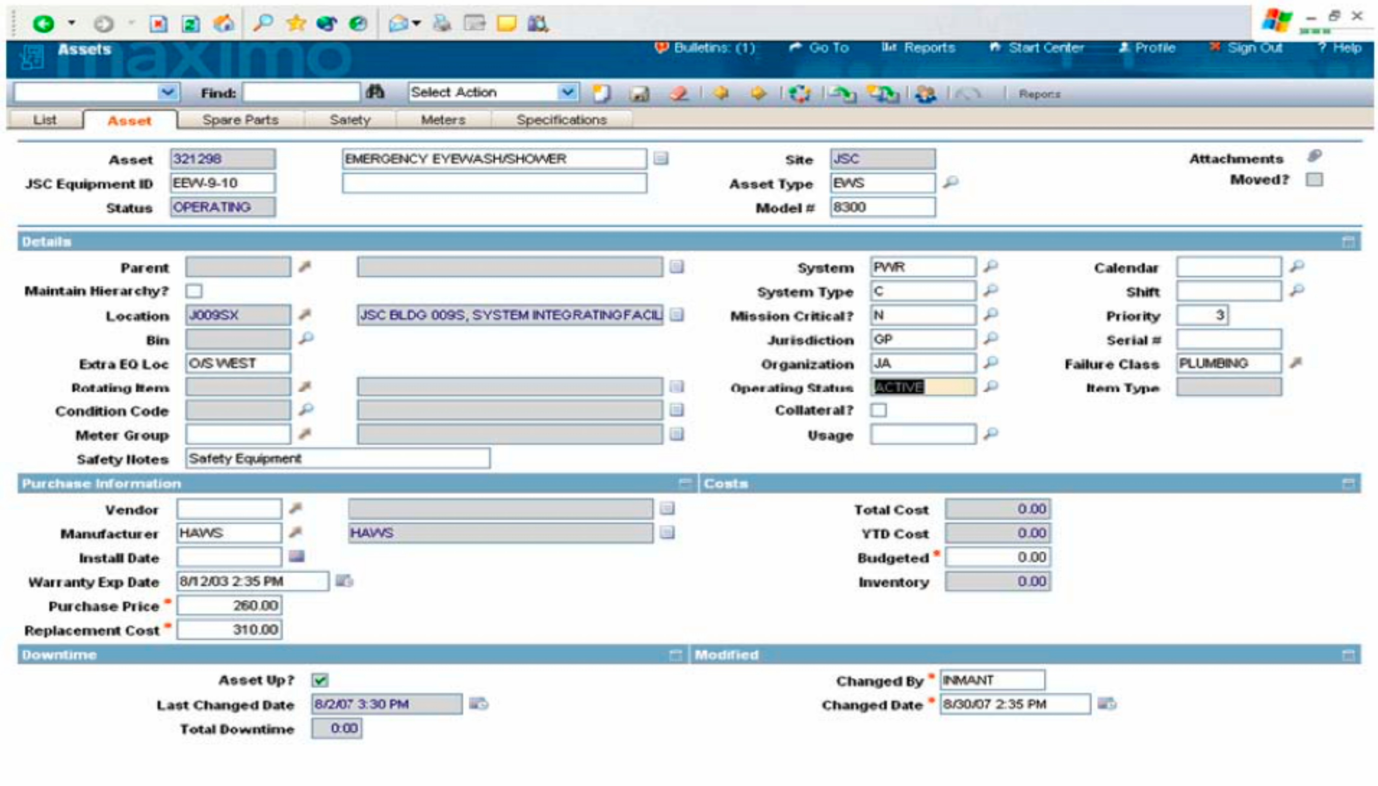


Figure E-2 Sample Equipment Screen

E.4 Safety Plans

Figure E-3 shows the tag-out screen of the safety plan module of this example system. With the emphasis placed on safety in NASA, this module or similar capability is an important addition to the CMMS. This sample module provides the following capabilities:

a. Manual or automatic safety plan numbering.

b. Safety plans can be built ad hoc for special work or defined for reuse in the safety plans application.

c. Track hazards for multiple equipment and locations.

d. Multiple precautions can be associated to a hazard.

e. Track hazardous materials for multiple equipment and locations.

f. Once hazards and precautions are entered, convenient pop-up list in this sample system is available for reference and data entry.

g. Track ratings for health, flammability, reactivity, contact, and material safety data sheet (MSDS) for hazardous materials.

h. Define lockout/tag-out procedures.

i. Define tag identifications for specific equipment and locations.

j. Define safety plans for multiple equipment or locations.

k. View link documents.

l. Associate safety plans to job plans, to preventative maintenance masters, and to work orders.

m. Safety plans are printed automatically on work orders.

n. Flexible business rules allow tag-outs procedures to be associated to hazards or directly to locations, equipment, safety plans, or work orders.

o. Copy existing safety plans to new safety plans.

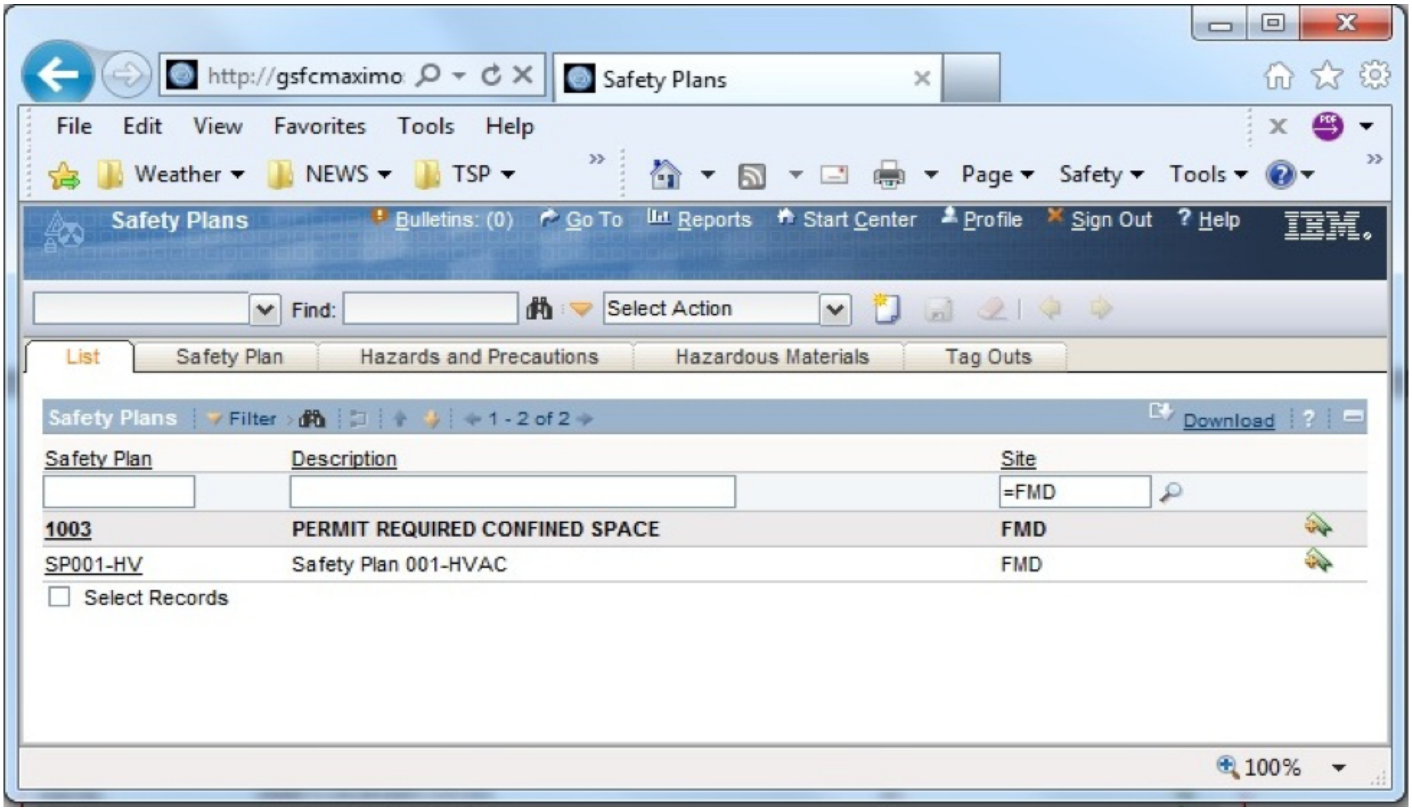
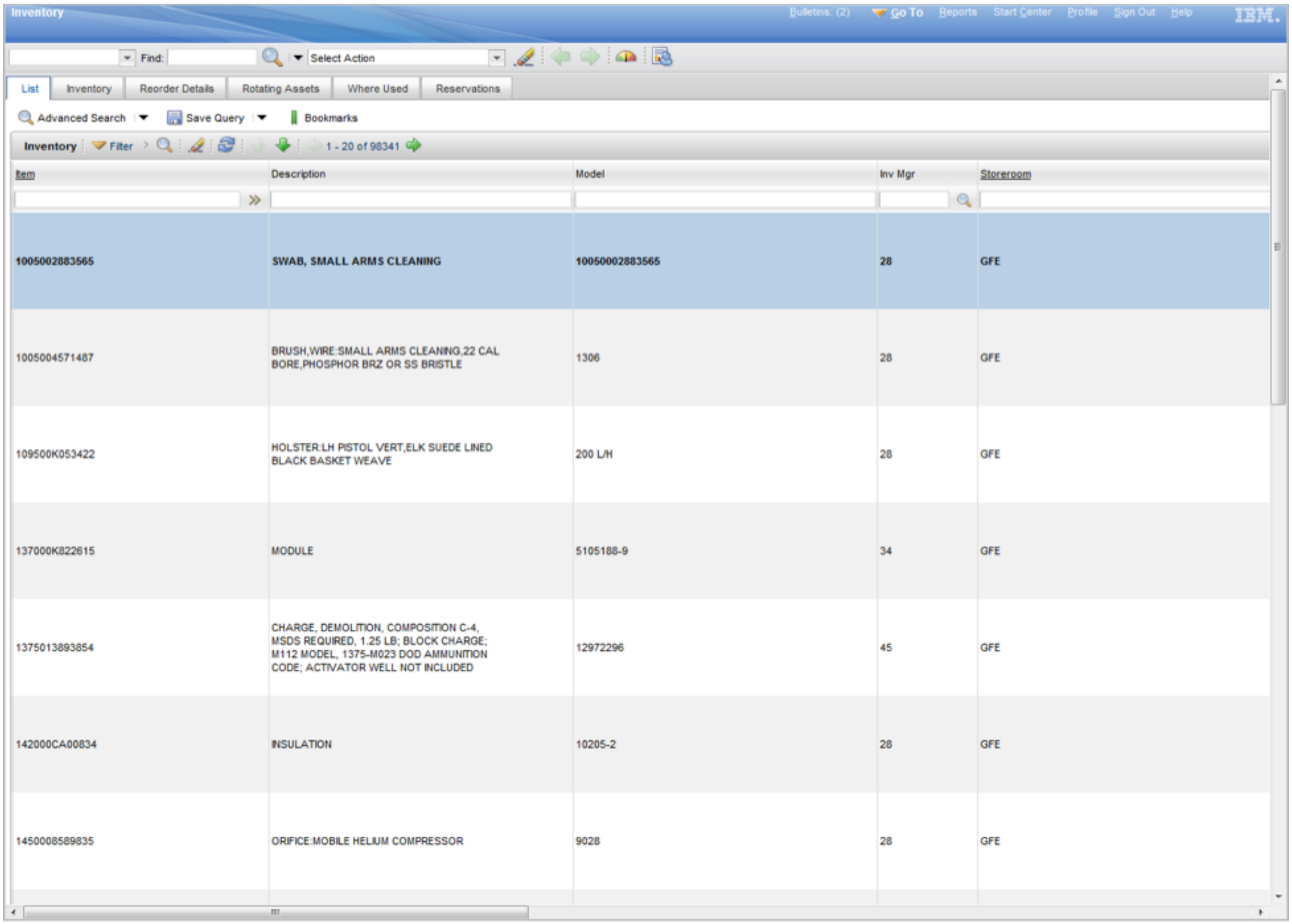


Figure E-3 Sample Safety Plans Screen

E.5 Inventory Control

The inventory control application shown in Figure E-4 allows the operator to track inventory movement, such as move items in or out of inventory, or from one location to another. Stocked, nonstocked, and special order items can be tracked. The application, as shown in Figure E-5, also allows tracking item vendors, the locations where an item can be found, item cost information, and the substitute or alternate items that can be used if necessary.



Item	Description	Model	Inv Mgr	Storeroom
1005002883565	SWAB, SMALL ARMS CLEANING	10050002883565	28	GFE
1005004571487	BRUSH,WIRE:SMALL ARMS CLEANING,22 CAL BORE,PHOSPHOR BRZ OR SS BRISTLE	1306	28	GFE
109500K053422	HOLSTER:LH PISTOL VERT,ELK SUEDE LINED BLACK BASKET WEAVE	200 L/H	28	GFE
137000K822615	MODULE	5105188-9	34	GFE
1375013893854	CHARGE, DEMOLITION, COMPOSITION C-4, MSDS REQUIRED, 1.25 LB; BLOCK CHARGE; M112 MODEL, 1375-M023 DOD AMMUNITION CODE; ACTIVATOR WELL NOT INCLUDED	12972296	45	GFE
142000CA00834	INSULATION	10205-2	28	GFE
1450008589835	ORIFICE:MOBILE HELIUM COMPRESSOR	9028	28	GFE

Figure E-4 Sample Inventory Control Screen

E.6 Work Request

Figure E-5 is a sample work request screen that could be used by anyone at a Center to enter requests, such as trouble calls, or by work control to record requests. The easy-to- use data-entry screen was designed for minimal data entry. The work order number is assigned manually or automatically. A requester would enter minimal data, as shown on the sample, with work control entering additional information as required. Data is entered once, and pop-up tables in this system eliminate the need to memorize codes. This computer system could be used by a Center in their CMMS rather than the Trouble Call Ticket shown in Appendix D.

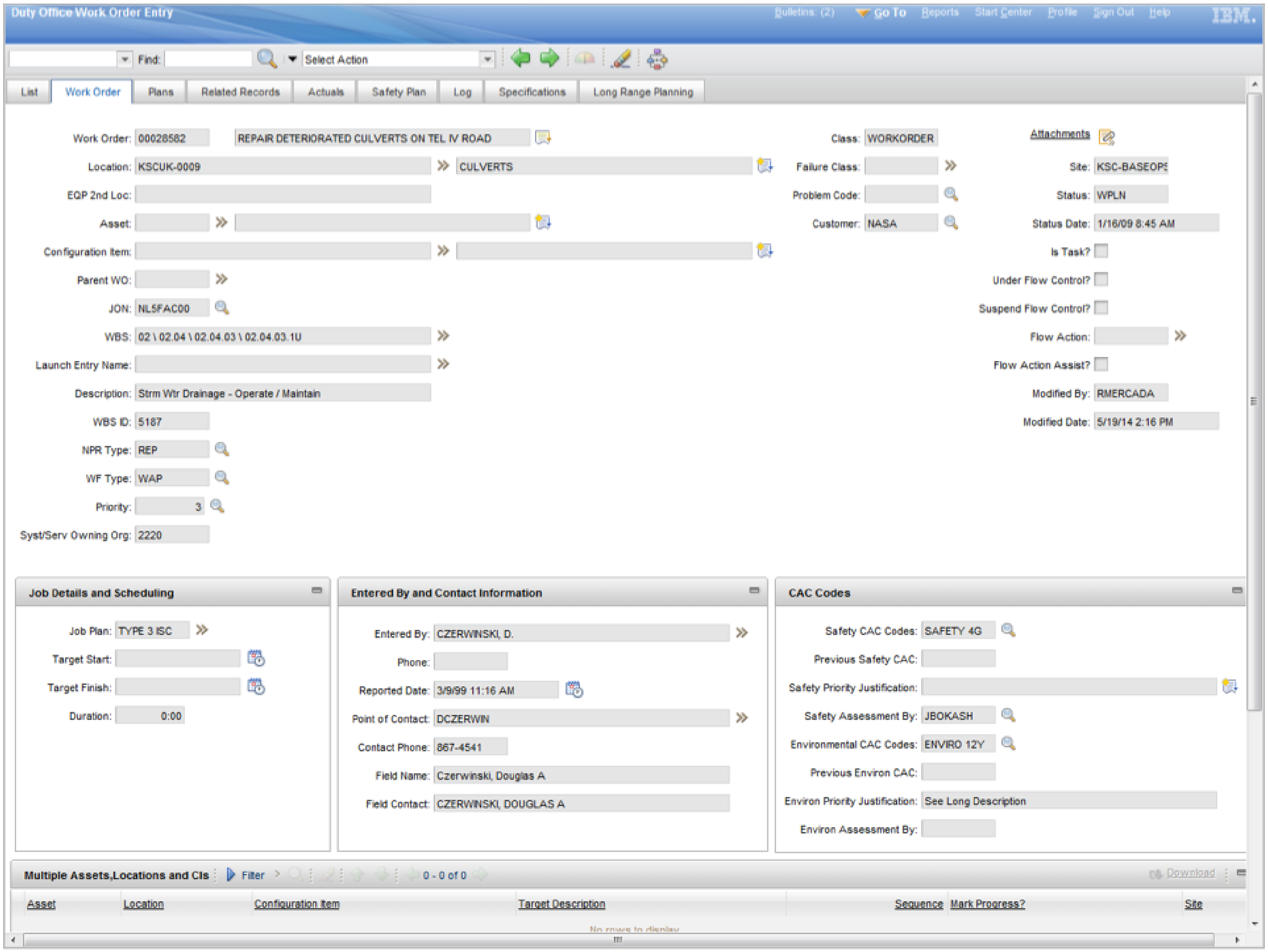


Figure E-5 Sample Work Request Screen

E.7 Work Order Tracking

The Sample Work Order Tracking Screen shown in Figure E-6 is the heart of a work order system. The data is entered once, and pop-up tables eliminate the need to memorize codes. This tracking system provides instant access to all of the information needed for detailed planning and scheduling, including work plan operations, labor, materials, tools, costs, equipment, blueprints, related documents, and failure analysis. Of course, this is dependent on how many modules have been installed and how much information has been entered in the system.

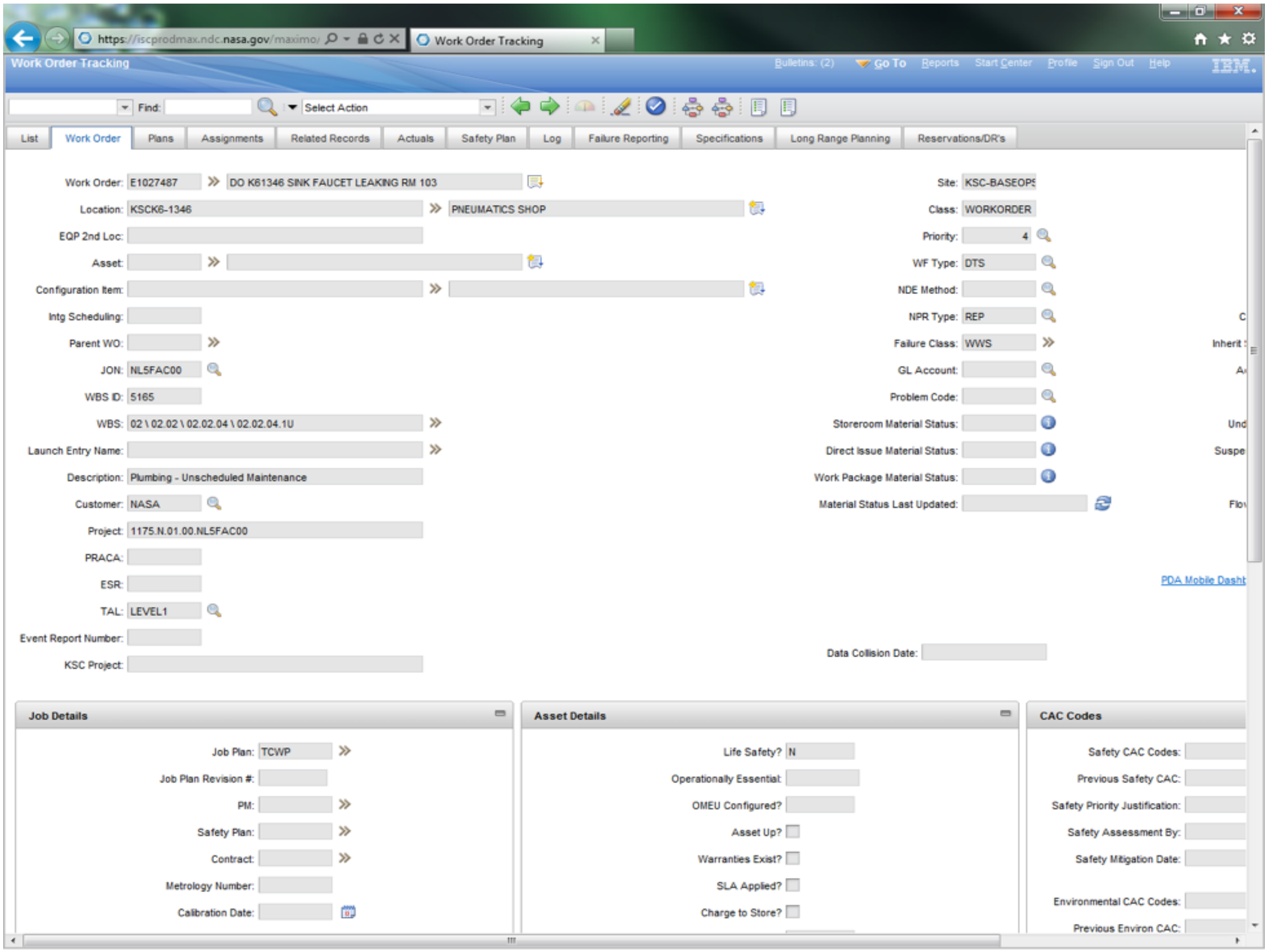


Figure E-6 Sample Work Order Tracking Screen

E.8 Work Management

a. The Work Manager module in this example system lets the planner specify which labor to apply to specific work order tasks and when.

b. In the planning mode shown in Figure E-7, labor assignments are planned for future shifts. Each person's calendar availability is considered when the assignments are made. The assignments are created sequentially over the shift, filling each person's daily schedule with priority work for the craft. It can even split larger jobs over multiple shifts automatically.

In the dispatch mode, labor assignments are carried out as soon as possible. The system in this example can even begin tracking labor time from the instant the assignment is made. The system operator can interrupt work already in progress to reassign labor resources to more crucial work.

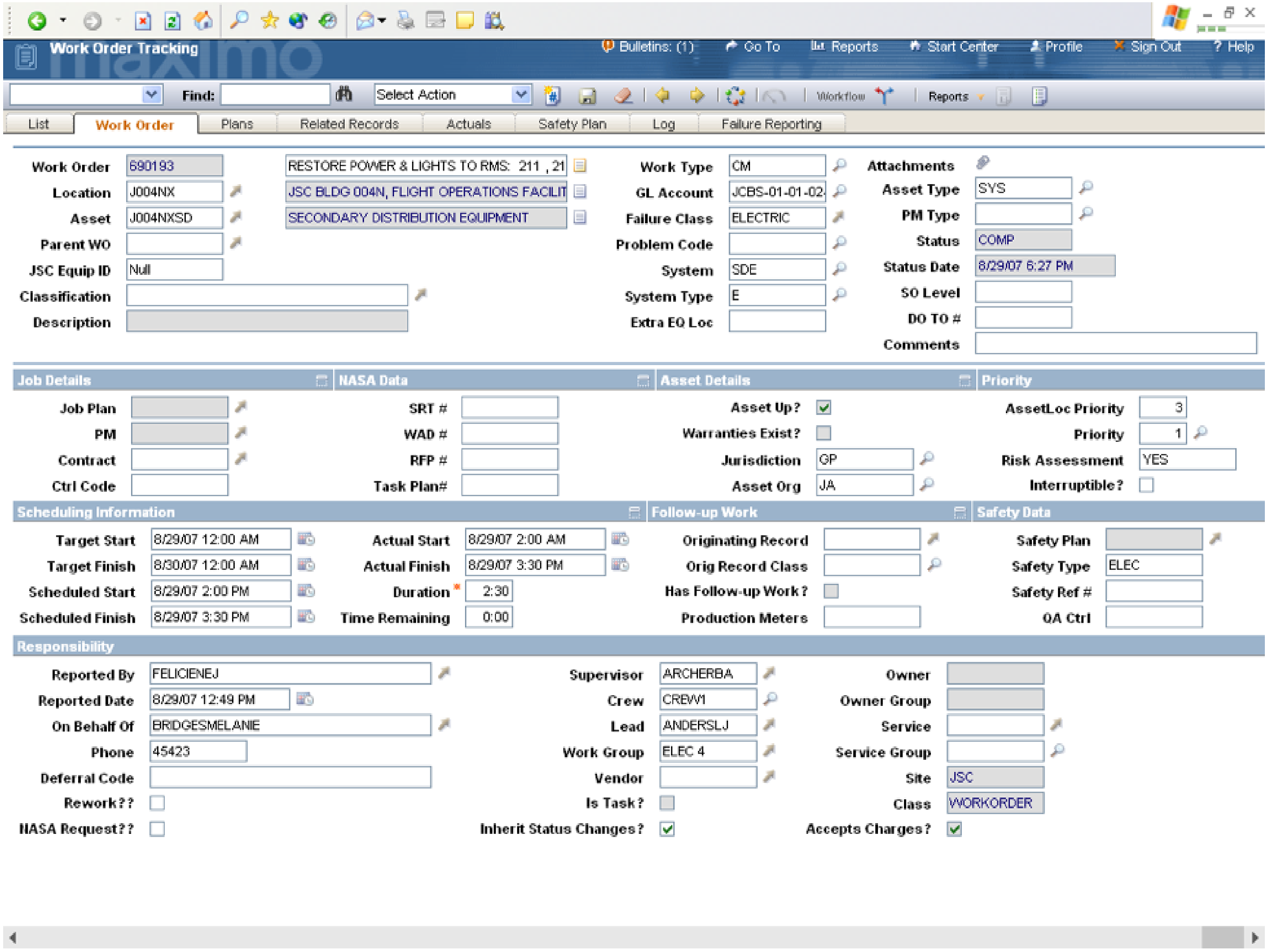


Figure E-7 Work Order Tracking/Work Management Plan Sample Screen

E.9 Quick Reporting

Figure E-8 shows a sample Quick Reporting screen that provides a rapid and easy means for opening, reporting on, and closing work orders; reporting work on small jobs after the fact; and even creating work orders on the fly. Labor, materials, failure codes, completion date, and downtime can all be reported on this one screen.

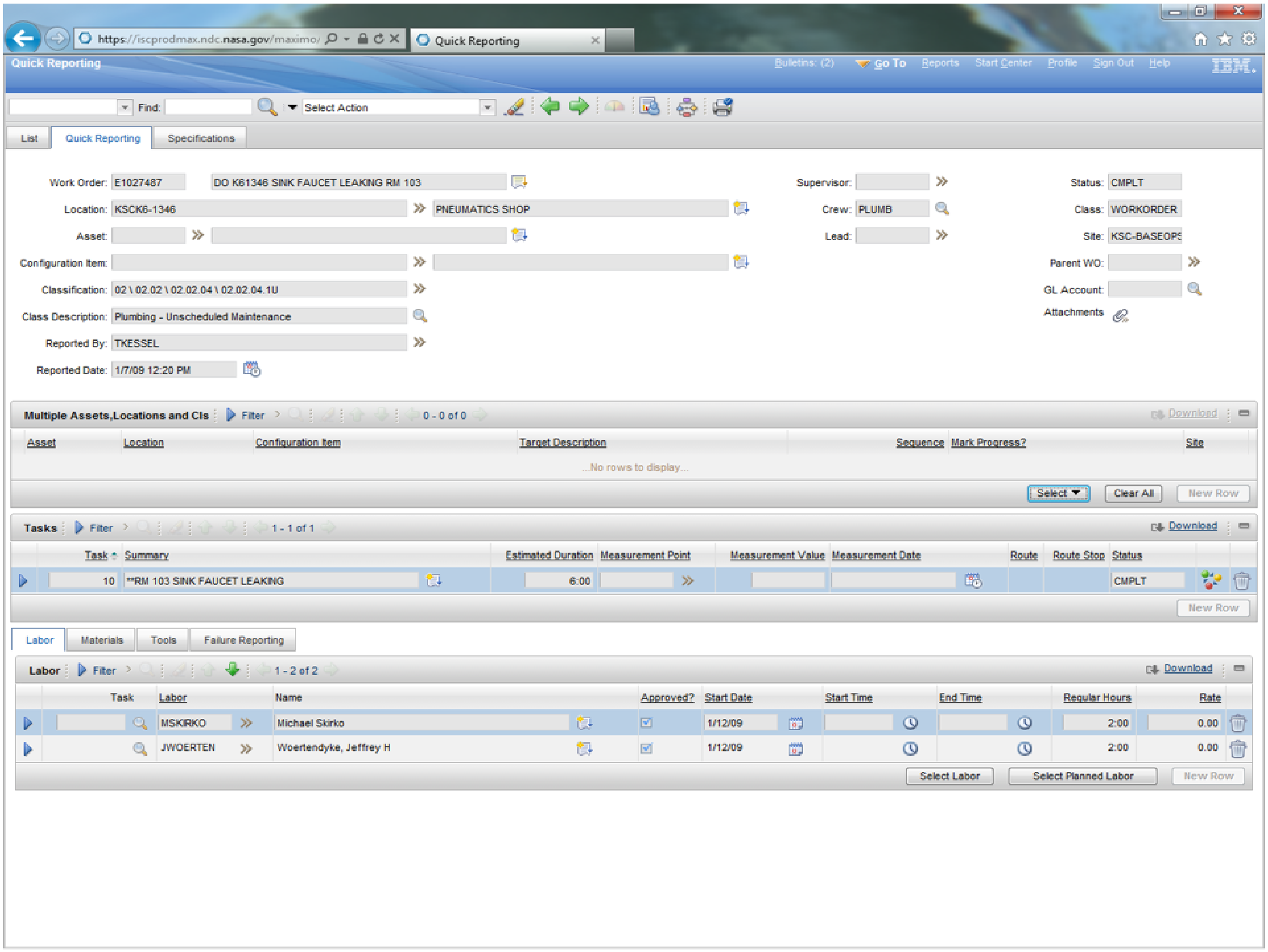


Figure E-8 Sample Quick Reporting Screen

E.10 Preventive Maintenance

Sample preventive maintenance screens are shown in Figures E-9a and E-9b. The following capabilities provided in this sample system are listed to show how a CMMS can be utilized in managing a Center's PM program:

a. Supports multiple criteria for generating PM work orders. If a PM master has both time-based and meter-based frequency information, the program uses whichever comes due first and then updates the other.

b. Generates time-based PM work orders based on last generation or last completion date. Next due date and job plans are displayed.

c. Permits and tracks PM extensions with adjustments to next due date.

d. Triggers meter-based PMs by two separate meters.

e. Prints sequence job plans upon request.

f. Creates a PM against an item so that new parts have PMs automatically generated on purchase.

g. Specifies the number of days ahead to generate work orders from PM masters that may not yet have met their frequency criteria.

h. Consolidates weekly, monthly, and quarterly job plans on a single master.

i. Assigns sequence numbers to job plans to tell the system which job plan to use when a PM work order is generated from a PM master.

j. Permits overriding frequency criteria to generate PM work orders when required by plant conditions.

k. Routes PMs with multiple equipment or locations.

l. Generates work orders in batch or individually for only the equipment requested. Can be used with the system scheduler to forecast resources and budgets.

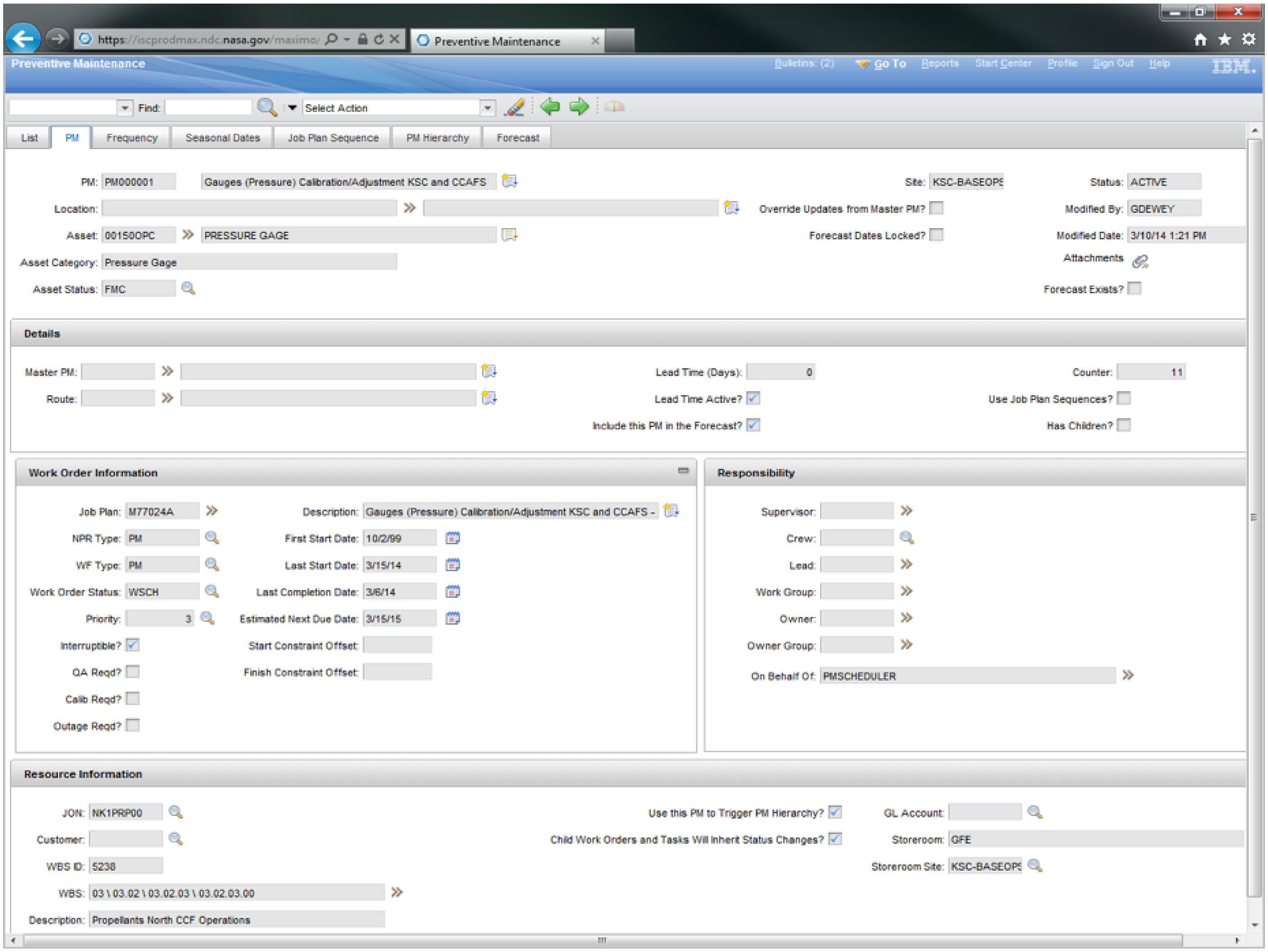


Figure E-9a Sample Preventive Maintenance Screen

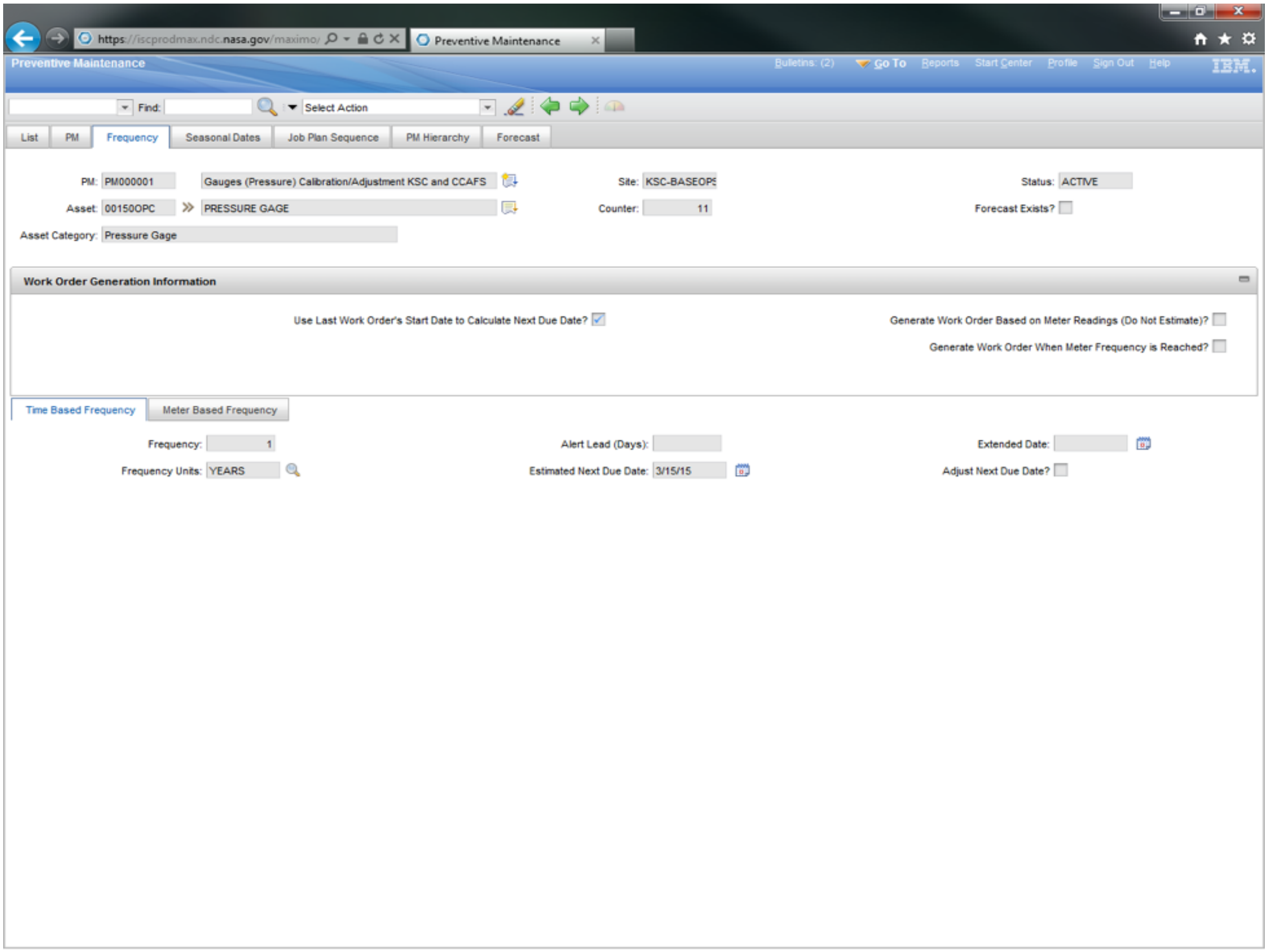


Figure E-9b Sample Preventive Maintenance Screen

Appendix F. Predictive Testing and Inspection (PT&I)

F.1 Descriptions of Predictive Testing Techniques This appendix provides brief descriptions of the most commonly used predictive testing techniques, reference sources, detailed data sheets on those techniques that are considered state of the art, and applications of miscellaneous inspection techniques. Refer to the *NASA Reliability Centered Maintenance Guide for Facilities and Collateral Equipment* for a more comprehensive and detailed discussion of PT&I.

F.1.1 Vibration Analysis

a. Frequency and Time Domain Measurement. Analyzes the spectra of frequencies to identify the main causes of rotating equipment mechanical problems (e.g., mechanical vibration, imbalance, and misalignment).

b. Shock Pulse. Evaluates the condition of bearings; measures the high-frequency noise generated when the moving elements in a bearing strike a defect and release mechanical energy.

c. Torsional Vibration Monitoring. Employs a pair of matched sensors to detect vibration of the equipment housing or structure caused by gear rotation and shaft torque.

F.1.2 Tribology and Lubricant Analysis (Condition Analysis)

a. Physical Analysis. Evaluates the color, appearance, and purity of a given oil, fuel, or grease sample to determine the presence of contaminants, breakdown of additives, corrosiveness, and viscosity.

b. Infrared Spectrography. Compares new oil and fuel samples with samples that have been in service to determine the degree of degradation that has occurred.

F.1.3 Tribology and Lubricant Analysis (Wear Particle Analysis)

a. Direct Reading Ferrography. Measures the concentration of wear particles found in a fluid, segregates them by size using a graduated magnetic field, and trends the data.

b. Analytical Ferrography. After segregating wear particles, uses microscopic and other technical means to identify their types and compositions and then compares their characteristics with reference photographs to determine the severity of wear.

c. Magnetic Chip/Particle Counters. Online systems that measure solid particles, ranging in size from 200 to 1,000 microns, in lubricating or hydraulic oil.

d. Graded Filtration/Micropatch. Passes a sample of the oil through a series of sequentially sized (graded) filters or a single micropatch and examines the filter or patch to determine the size and composition of particles in the sample.

F.1.4 Temperature Monitoring

a. Infrared Thermography. A noncontact technique employing either a video system or a scanning-type temperature probe that measures infrared radiation emitted and reflected from surfaces. The technique is also effective in detecting thermal cavities and roof leaks.

b. Contact Devices. Devices such as thermometers, resistance temperature detectors, thermocouples, decals, and crayons that detect temperatures within 0.25°C.

c. Deep-Probe Temperature Analysis. Using temperature probes inserted into the soil near buried pipes carrying steam or hot fluid to determine the degree of leakage and energy loss.

F.1.5 Electrical Testing

a. Megohmmeter Testing. Using a hand-held generator to determine the insulation phase-to-phase and phase-to-ground resistance from which the polarization index is calculated and the data trended to determine system degradation.

b. High-Potential Testing (Hipot). Applies twice the operating voltage plus 1,000 volts to motor windings to test new and rewound motors. Caution is advised, because the test can induce premature failure.

c. Surge Testing. Using two capacitors and an oscilloscope to determine the condition of motor windings by measuring the current generated by applying a voltage pulse to two windings simultaneously. Like Hipot, applies a voltage equal to twice the operating voltage plus 1,000 volts and, consequently, it can induce premature failure.

d. Conductor Complex Impedance. Measures the total resistance of a conductor to detect motor coil degradations, worn or missing motor insulation, the presence of moisture, and other abnormalities.

e. Time Domain Reflectometry. Precisely locates cable faults by sending a fast-rise voltage pulse through a conductor and measuring the time delay in receiving a fault-caused reflected pulse.

f. Motor Current Signature Analysis. Using motor current spectra to determine if broken or cracked rotor bars or high-resistance end ring connections are present in motors.

g. Radio Frequency Monitoring. Monitors and trends radio frequency emissions from arcing caused by broken windings in generators.

h. Power Factor and Harmonic Distortion. Determines the phase relationship between voltage and current, from which power factor is calculated and electrical power reduction decisions can be made.

i. Starting Current and Time. Measures the amount of current drawn, the sequence, and the time for equipment to come to operating speed to assess the operation of electrically driven equipment. For example, misaligned equipment may require more starting torque and, consequently, a higher peak and duration of startup current.

j. Motor Circuit Analysis. Combines several of the previously defined tests and factors to detect motor circuit voltage imbalances caused by such conditions as loose connections, corrosion, bad solder joints, and maladjusted contacts.

k. Insulation Power Factor Testing. Determines the phase relationship between the test currents and voltages. From this information, insulation impedance changes can be calculated and trended. Premature failures can then be predicted using operational and industry standards.

F.1.6 Leak Detection

a. Vibration Monitoring. Detects leaking steam traps by measuring vibration levels upstream, downstream, on the trap itself, and then comparing the vibration spectra.

b. Acoustic Emissions. Involves the use of two acoustic sensors that operate in the 100-200 kHz range to listen for sounds made by fault or failure conditions, such as leaks in pressurized or vacuum systems.

c. Airborne Ultrasonics. Uses either contact or standoff devices, similar in purpose to stethoscopes, to detect emitted high-frequency (over 20 kHz) sound as a liquid or gas flows through an orifice.

F.1.7 Flow Measurement

a. Doppler Shift. Measures flow rates by comparing the frequency shift between transmitted and reflected signals. Usually used in fluids with entrained particles or gas bubbles.

b. Time of Flight. Employs two transmitters and detectors separated by some predetermined distance and measures the difference in time of flight between upstream and downstream detectors.

c. Tracer Element. Inserts a tracer element in the fluid and measures the elapsed time and amount of dilution when the tracer element arrives at a predetermined downstream location.

F.1.8 Imaging

a. Macro Imaging. Employs fiber optics, endoscopes, borescopes, and miniature cameras to archive on film or to record digitally the actual condition of equipment and components.

b. Ultrasonic Imaging. Uses a pulse-echo thickness gauge to determine the presence of subsurface flaws, their size, and their orientation.

c. Radio Imaging. Uses portable x-ray, gamma-ray, or neutron-ray equipment to identify flaws; operates on the theory that the film will be darker where there is less wall thickness.

F.1.9 Corrosion Monitoring

a. Dewpoint Monitoring. Calculates the dewpoint of a compressed gas system by determining pressure and temperature conditions within the system. When temperature drops below the dewpoint, water vapor condenses and corrosion increases.

b. Conductivity Monitoring. Measures the conductivity of ionic impurities in a fluid from which corrosion rates can be calculated.

c. Ultrasonic Corrosion Monitoring. Measures the thickness of metal ultrasonically by sending high-frequency sound waves into an object and measuring the amount of time for them to be reflected back.

F.1.10 Process Parameters/Visual Inspection

a. Diagnostic Monitoring. Recording process-related data, such as temperature and pressure and using changes in those parameters to identify emergence of a problem.

b. Visual Inspection. Visual detection of problems such as oil leaks that are not detected by other, more technical means.

F.1.11 Other Flaw Detection Techniques

a. Acoustic Emissions Detection. Uses special equipment to listen for sounds made by fault or failure conditions, such as leaks in pressurized or vacuum systems. One application uses multiple sensors and computer algorithms to locate shear defects resulting from subsurface intragranular flaws. As these defects grow in size, they emit high-frequency, highly directional noise in the 100-500 kHz range. Drawbacks in using this technique are: (1) analysis is hampered by other noises in the same frequency range, and (2), while this technology measures changes in the flaw size, it does not measure the size of the flaw itself.

b. Sulfur Hexaflouride (SF6). Finds leaks in systems by filling them with SF6 gas and then using special detectors to sense above-normal SF6 concentrations, which indicate the locations of the leaks.

c. Eddy Current Testing. Uses an induced magnetic field to detect cracks in metal test objects, such as heat exchanger tubes. Current flow caused by the magnetic field is reduced by electrical resistance at the defects and forms distinguishable current patterns. These patterns are then amplified and visually displayed, allowing the analyst to determine both the flaw location and its size.

d. Liquid Penetrant Testing. Uses a low-viscosity liquid, penetrating dye, and developer to penetrate and highlight surface defects.

e. Magnetic Flux. Magnetizes a specimen, causing fine, sprayed-on iron particles to concentrate at surface discontinuities.

f. Insulating Oil Test. Examines the oil properties such as dielectric strength, power factor, contaminant levels, acidity, and combustible gas content.

g. Replication. Makes a plastic foil casting of a portion of an item, then subjects the casting to microscopic examination. Defects such as stress cracks show up in the casting.

h. Electromagnetic Pipe Location. Locates and maps underground piping systems. It traces a piping system by directly applying or inducing a signal in the system and then uses an induction coil pickup to detect the signal.

i. Radar Mapping. Uses ground-penetrating radar to locate and map underground systems and to detect buried items.

j. Holographic Interferometry. Records deformations caused by stress or vibration. Determines degree of deformation by comparing the interference patterns that arise with normal conditions.

k. Boring. Bores holes into the tested item such as a utility pole and determines the item's condition by examining the shavings.

l. Holiday and Fault Location. Finds breaks in the insulation of piping and cable systems by detecting electrical signal leakage above the pipe or cable.

F.2 PT&I Techniques

F.2.1 Vibration Analysis

a. Purpose

(1) Vibration analysis is used to detect, identify, and isolate specific component degradation and its causes prior to serious damage or actual failure. Vibration monitoring helps to determine the condition of rotating equipment, a system's structural stability, and potential sources of airborne

noise.

(2) When equipment is known to be operating properly, its vibration baseline is established by taking vibration measurements at that time. Subsequent vibration readings can then be compared to the baseline, the components causing deviant readings can be identified, and the rate of component deterioration and the magnitude of any problems determined.

b. Techniques

(1) Frequency and time domain measurement.

(2) Shock pulse analysis.

(3) Torsional vibration monitoring.

c. Applications

(1) All rotating and reciprocating equipment, i.e., motors, pumps, turbines, compressors, engines and their bearings, shafts, gears, pulleys, blowers, belts, couplings.

(2) Induction motors (to diagnose for broken rotor bars, cracked end rings, high-resistance connections, winding faults, casting porosity, and air-gap eccentricities).

(3) Structural support resonance testing, equipment balancing, and faulty steam trap detection.

d. Effects

(1) Detects equipment component wear, imbalance, misalignment, mechanical looseness, bearing damage, belt flaws, sheave and pulley flaws, gear damage, flow turbulence, cavitation, structural resonance, and fatigue. Can provide several weeks or months warning of impending failure.

(2) When measurements of both amplitude and frequency are available, diagnostic methods (spectrum analysis) are used to determine both the magnitude of the problem and its probable cause.

(3) Vibration analysis systems are composed of microprocessor data collectors, vibration transducers, equipment-mounted sound discs, and a host personal computer with software for analyzing and trending vibration data, establishing alarm points, and assisting in diagnostics.

e. Operators

(1) Requires personnel with the ability to understand the basics of vibration theory and possessing a basic knowledge of machinery and failure modes.

(2) Though site-dependent, usually one experienced vibration analyst plus two level I-trained technicians are sufficient.

f. Training

(1) Training is available through equipment vendors and trainers such as:

(a) Technical Associates of Charlotte, P.C., 347 North Caswell Road, Charlotte, NC 28204. Internet: http://www.technicalassociates.net; Phone: 704-333-9011 ; Fax: 704-333-1728

(b) Vibration Institute, 2625 Butterfield Road, Suite 128N, Oak Brook, IL 60523-3415, Internet: http://www.vi-institute.org ; Phone: 630-654-2254; Fax: 630-654-2271.

(2) The Vibration Institute and Technical Associates of Charlotte have published certification guidelines for vibration analysts. Passing a written examination is required for certification. The Vibration Institute's certification tests do not allow open book tests, only closed book certification. Technical Associates of Charlotte tests allow for an open book or closed book certification. (Vibration analysis training and/or certification costs range from $1,300 to $2,500 (price as of August 2007, not including travel).)

g. Data Collector Cost

The cost of data collection is $12,000 to $70,000 for a single-channel, multichannel, or online vibration data logger (price varies with degree of technology), software, and primary training.

F.2.2 Tribology and Lubricant Analysis (Condition Analysis)

a. Purpose

(1) Oil analysis is used to determine the condition of a given oil, fuel, or grease sample by testing for viscosity; particle, fuel, and water contaminants; acidity/alkalinity (pH); breakdown of additives; and oxidation.

(2) Coupled with other technologies, such as vibration and temperature measurements, oil analysis identifies the equipment condition and aids in identifying the root cause of failures.

b. Techniques

(1) Physical analysis.

(2) Infrared spectrography.

c. Applications

(1) Engines, compressors, turbines, transmissions, gearboxes, sumps, transformers, and storage tanks.

(2) Receipt inspection of incoming lubricating and fuel oil and grease supplies for condition, viscosity, and contamination.

(3) Spot-checking new, rebuilt, or repaired equipment as part of the acceptance process.

d. Effects

(1) Monitoring the condition of lubricants determines whether they are suitable for continued use or should be changed.

(2) Analysis of both the quantity and type of metal particle contamination in a sample can identify the specific component experiencing wear.

(3) Maintaining exceedingly clean lubricating fluids extends the life of bearings and other components. Maintaining proper acidity/alkalinity and the proper composition of additives keeps the corrosiveness of the lubricant in check.

(4) Lubricant monitoring protects equipment warranties that otherwise would not be honored based on manufacturer allegations that the equipment operated with contaminated oil.

(5) Use of oil analysis as part of the quality control associated with an equipment acceptance test will

indicate if all lubrication or hydraulic systems were properly installed, cleaned, flushed, and filled with the appropriate lubricant.

(6) Long-term trending of oil analysis data can identify poor maintenance or repair practices that contribute to high maintenance costs, downtime, and reduced machine life.

e. Equipment Required. Extensive and expensive laboratory equipment is required for detailed analysis; thus, in-plant analysis is not justified. However, portable, stand-alone analyzers are now available for prescreening samples on site to determine if a more thorough or specific analysis is warranted.

f. Operators. One individual should be trained in tribology and should, in turn, train equipment operators and maintenance craft personnel on proper sample-taking techniques.

g. Training Available. Training is available from equipment vendors and from independent laboratories that perform oil analysis.

h. Cost.

(1) "Free" to approximately $150 per sample, depending on the type of analysis desired, disposal fees, and the level of service provided by the vendor.

(2) $13,000 to $20,000 for equipment (on-site, stand-alone analyzer for prescreening) and tribology training.

F.2.3 Tribology and Lubricant Analysis (Wear Particle Analysis)

a. Purpose

(1) Wear particle analysis is a technique that determines the condition of a machine or machine components through examining particles contained in a lubricating oil sample. Wear particles are separated and subjected to ferrographic and microscopic analysis.

(2) Coupled with other technologies, such as vibration and temperature measurements, wear particle analysis identifies the equipment condition and aids in identifying the root cause of failures.

b. Techniques

(1) Direct reading ferrography.

(2) Analytical ferrography.

(3) Magnetic chip/particle counters.

(4) Graded filtration/micropatch.

c. Applications. Engines, compressors, turbines, transmissions, gear boxes, electrical transformers, etc.

d. Effects

(1) Analysis of both the quantity and type of metal particle contamination in a sample can identify the specific component experiencing wear, the magnitude of the wear, and the type of wear being experienced.

(2) Particle count indicates the effectiveness of existing filtration and measures overall system

cleanliness.

(3) Long-term trending of oil analysis data can identify poor maintenance or repair practices that contribute to high maintenance costs, downtime, and reduced machine life.

(4) Oil analysis of electrical transformers shows presence of moisture, viscosity, insulation value, and carbon caused by the presence of electrical arcing

e. Equipment Required. Extensive and expensive laboratory equipment is required for detailed analysis; thus, in-plant analysis is not justified. However, portable, stand-alone, direct-reading contamination monitors and analyzers are now available for prescreening samples on site to determine if a more thorough or specific analysis is warranted.

f. Operators. One individual should be trained in tribology and should, in turn, train equipment operators and maintenance personnel on proper sample-taking techniques.

g. Training Available. Training is available from equipment vendors and from independent laboratories that perform oil analysis. One such vendor is: Predict Ferrographic and Oil Analysis training. 9555 Rockside Road, Suite 350; Cleveland, OH 44125. Phone 800-543-8786. Fax 216-642-3223. Web site: www.predictusa.com. Training costs about $900 to $1,200 depending on course taken.

h. Oil Sample Analysis Cost

(1) "Free" to approximately $250 per sample, depending on the type of analysis desired, disposal fees, and the level of service provided by the vendor.

(2) Equipment Costs - $1,000 to $40,000 for equipment (on-site for prescreening or stand-alone full analyzer).

F.2.4 Temperature Monitoring

a. Purpose

(1) Noncontact- and contact-type devices are used to detect temperature variances in machines, electrical systems, heat transfer surfaces, and structures and the relative magnitude of those temperature variances (use recently begun in medical fields). Large changes in temperature often precede equipment failure.

(2) Infrared thermography, in particular, is a reliable technique for finding roof leaks and determining the thermal efficiency of heat exchangers, boilers, building envelopes, etc.

(3) Deep-probe temperature analysis can detect buried pipe energy loss and leakage by examining the temperature of surrounding soils. The technique can be used to quantify energy loss and its cost.

(4) Temperature monitoring can be used as a damage-control tool to locate mishaps such as fires and leaks.

b. Techniques

(1) Infrared thermography (noncontact)

(2) Contact devices (thermometers, resistance temperature detectors, thermocouples, decals, and crayons).

(3) Deep-probe temperature analysis.

c. Applications. Heat exchangers; electrical distribution and control systems; roofing; building envelopes; direct-buried pipes carrying steam, hot or chilled water; bearings; conveyors; piping; valves; steam systems; air handlers; chiller and boiler insulation, casing; various tanks and tubes.

d. Effects

(1) Temperature-monitoring techniques are used to locate temperature variations due to loose, corroded, or dirty electrical connections; friction; damaged or missing insulation; and thermal system cavities, leaks, and blockages. Mechanical defects in belts, sheaves, bearings, and other rotating equipment.

(2) Infrared thermography successfully locates roof leaks and is used in energy conservation programs by locating sources of heating and air-conditioning losses through building envelopes.

(3) The use of deep probes for measuring soil temperatures near buried pipes will detect insulation system failures and leaks. With knowledge of soil properties, the losses can then be estimated. This technique requires knowledge of piping locations.

(4) Noncontact heat measurement can be done from a distance and will accurately measure temperatures on items that are hard to reach, such as power lines or equipment that is normally inaccessible.

e. Equipment Required

(1) Equipment ranges from simple contact devices such as thermometers and crayons to full-color imaging and computer-based systems that can store, recall, assist in analysis, and print thermal images.

(2) The deep-probe temperature technique requires temperature probes, analysis software, and equipment to determine the location of piping systems.

f. Operators

(1) Operators and mechanics with minimal training can perform temperature measurements and analyses using contact-type devices.

(2) Because thermographic images are highly complex and difficult to measure and analyze, training is required to obtain accurate and repeatable thermal data and to interpret the data. With adequate training (level I and level II) and certification, this technique can be performed by electrical/mechanical technicians and/or engineers.

(3) Although deep-probe temperature monitoring is often contracted because of the technician's required familiarity with soil properties, this technique can be applied by maintenance personnel with adequate training.

g. Training Available

(1) Training is available through infrared imaging system manufacturers and vendors.

(2) The American Society of Nondestructive Testing (ASNT), P.O. Box 28518, Columbus, OH 43228-0518, Web site: www.asnt.org has established guidelines for thermographer certification. General background, work experience, and thermographic experience and training are all

considerations for certification.

h. Cost

(1) Point-of-use black-and-white scanners are less than $1,000. Full-color microprocessor systems with data storage and print capability range from about $25,000 to $70,000. Point and spot temperature devices range from $100 to $500. The costs for the newest cameras are declining due to technology advances.

(2) Average thermographic system rental is approximately $1,500 per week.

(3) Subcontractor services are approximately $1,000 per day; for deep probe temperature analysis, the cost for contract services ranges from $1,500 to $2,000 per day with $5,000 to $6,000 for the first day.

(4) Operator-training costs are approximately $1,250 per week.

F.2.5 Electrical Testing

a. Purpose

(1) Electrical testing is used to measure the complex impedance of electrical conductors, starters, and motors and their insulation resistance. By various methods, it detects faults such as broken windings, broken motor rotor bars, voltage imbalances, cable faults, etc.

(2) Current, voltage, and power factor also are monitored to determine power quality and to form a basis for reducing energy costs.

(3) Coupled with other technologies such as temperature monitoring and ultrasound, electrical testing identifies equipment condition and aids in identifying the root cause of failures.

b. Techniques

(1) Megohmmeter testing.

(2) High-potential testing (Hipot).

(3) Surge testing.

(4) Conductor complex impedance.

(5) Time domain reflectometry (TDR).

(6) Insulation power factor testing.

(7) Motor current signature analysis.

(8) Radio frequency (RF) monitoring.

(9) Power factor and harmonic distortion.

(10) Starting current and time.

(11) Motor circuit analysis (MCA).

> *NOTE: Hipot and surge testing should be performed only with caution. The high voltage being applied in these tests may induce premature failure of the units being tested. For that reason,*

they normally are not recommended for condition monitoring.

c. Applications. Electrical distribution and control systems, motor controllers, cabling, transformers, motors, generators, and circuit breakers.

d. Effects

(1) Electrical testing is used to monitor the condition or test the remaining life expectancy of electrical insulation; motor and generator components such as windings, rotor bars, and connections; and conductor integrity.

(2) Electrical testing is used as a quality-control tool during commissioning and acceptance tests of electrical systems such as new or rewound motors.

(3) During equipment startup, electrical testing is used to check proper motor starting sequencing, in-rush starting voltage, and power consumption.

(4) Electrical testing is used to monitor power factor so that improvements can be made in the interest of reducing electricity consumption.

e. Equipment Required. A full electrical testing program would include the following equipment: multimeters/volt-ohmmeters, current clamps, time domain reflectometers, motor current signature analysis software, and integrated motor circuit analysis testers.

f. Operators. Electricians, electrical technicians, and engineers should be trained in electrical PT&I techniques such as motor current signature analysis, motor circuit analysis, complex phase impedance, and insulation resistance readings and analysis.

g. Training Available. Equipment manufacturers and RCM consultants specializing in electrical testing techniques provide classroom training and seminars to teach their testing techniques.

h. Cost

(1) Equipment costs vary from $20 for a simple multimeter to more than $25,000 for integrated MCA testers. A full inventory of electrical testing equipment should range from about $30,000 to $50,000.

(2) Training averages between $750 and $1,000 per week. One company that provides this training is PdMA Corporation, 5909-C Hampton Oaks Parkway, Tampa, FL 33610. Phone 800-476-6463, fax 813-620-0206, Web site: pdma.com.

F.2.6 Leak Detection

a. Purpose. Leak detection techniques measure the sound or vibration resulting from cavitation, flow turbulence, or influx (in the case of vacuum systems) or escape of gas or liquid.

b. Techniques

(1) Vibration monitoring.

(2) Acoustic detectors.

(3) Airborne ultrasonics.

c. Applications. Piping and process systems, compressed gas and vacuum systems, boiler and heat exchanger tubes, steam traps, refrigeration systems, electrical switchgear, and rotating machinery.

d. Effects (1) Leak detection techniques are used to detect gas, liquid, and vacuum leaks; locate areas of turbulent or restricted flow; and measure corrosion and erosion in piping and vessels.

(2) In addition to detecting leaks, ultrasonic technology also can be used to detect electrical switchgear malfunctions, gear noise, faulty rolling element bearings, and other harmful friction in plant equipment. Ultrasonic frequencies range between 20,000 and 100,000 kHz.

e. Equipment Required

(1) Ultrasonic monitoring scanner for airborne sound or ultrasonic detector for contact mode through metal rod.

(2) Vibration monitoring equipment (see section 2.1 of this appendix).

f. Operators. Maintenance technicians and engineers.

g. Training Available. Minimal training required. Typical training cost ranges from $750 to $1,200 per week. One company that provides this training is UE Systems Inc., 14 Hayes Street, Elmsford, NY 10523, phone 800-223-1325, fax 914-347-2181, Web site: www.uesystems.com.

h. Equipment Costs: Scanners and accessories range from less than $1,000 to about $8,000.

F.2.7 Flow Measurement

a. Purpose. Liquid or gas flow rates are measured using either intrusive or nonintrusive flow measuring devices to aid in determining the condition of heat exchangers, pumps, and other plant components.

b. Techniques

(1) Intrusive flow measurement devices (venturis and pitot tubes).

> *Note: Use of these devices may not be feasible because of hazards involved in breaching the integrity of the system being monitored.*

(2) Nonintrusive flow measurement techniques (doppler shift, time of flight, tracer elements).

c. Applications. Equipment instrumentation, pumps, heat exchangers, process piping systems, hot and cold piping systems.

d. Effects

(1) Flow measurement techniques are used to check the accuracy of instrumentation installed on equipment.

(2) Flow measurement techniques are used to determine pump and heat exchanger performance and whether scale buildup or fouling is affecting system efficiency.

(3) Flow measurement techniques are used to check flow of product (hot or cold water, etc.) through piping systems to determine volume flow rate and/or velocity.

e. Equipment Required. Required equipment for nonintrusive flow measurement is generally nonspecialized (e.g., flowmeters, two pairs of transmitters and receivers, and dyes or other tracer elements).

f. Operators. Maintenance technicians and engineers.

g. Training Available. Minimal (on-the-job) training required for basic inspections. Formal training of higher-end testing equipment is required.

h. Cost. Flowmeters, transmitters, and scanners can be purchased for less than $1,000 and up to $50,000.

F.2.8 Imaging

a. Purpose. Imaging techniques are used to monitor on film, or other visual display, the actual condition, including material flaws, faulty welds, and blockages of equipment and facility components.

b. Techniques

(1) Macro imaging.

(2) Ultrasonic imaging.

(3) Radiographic imaging.

c. Applications. Mechanical and electrical equipment. High- and low-pressure piping, tank walls, valve and pump casings, and shafts.

d. Effects

(1) Macro imaging employs fiber optics, endoscopes, borescopes, and miniature cameras to archive on film, or to record digitally, the actual condition of equipment and facility components.

(2) Ultrasonic imaging in its simplest form uses a pulse-echo thickness gauge that makes point measurements and determines the presence of subsurface flaws, their size, and their orientation.

(3) Radio imaging uses portable x-ray or gamma-ray equipment to identify flaws; it operates on the theory that the film will be darker where there is less wall thickness.

e. Equipment Required. Imaging equipment includes the following types: ultrasonic thickness gauges, flaw detectors, ultrasonic imagers, and video devices.

f. Operators. Imagining should be performed by technicians trained in nondestructive testing techniques.

g. Training Available. Training is available from equipment vendors. Additional information is available from the American Society of Nondestructive Testing (ASNT), P.O. Box 28518, Columbus, OH 43228-0518, Web site: www.asnt.org.

h. Cost

(1) The cost of imaging equipment ranges from about $3,000 for basic hand-held ultrasonic thickness gauges to about $250,000 for ultrasonic imageries.

(2) Training costs vary, but average about $1,000 per week.

F.2.9 Corrosion Monitoring

a. Purpose. Corrosion monitoring techniques are used to detect the presence of corrosion in a system and to monitor its progression so that its causes can be treated and damage repaired before it progressively damages other components and systems.

b. Techniques

(1) Dewpoint monitoring.

(2) Conductivity monitoring.

(3) Ultrasonic corrosion monitoring.

(4) Mechanically installed visual corrosion viewports.

c. Applications. Chilled water, condensate, and pure water systems; compressed air systems; boiler water interfaces, and storage tanks.

d. Effects

(1) Corrosion monitoring techniques determine the conditions under which condensation is likely to take place (dewpoint monitoring), the amount of ionic impurities in a fluid (conductivity monitoring), and the rate at which corrosion is taking place (ultrasonic corrosion monitoring).

(2) By knowing the degree and cause of corrosion in a system, timely actions can be implemented to prevent or to control corrosive deterioration. These include the proper selection of materials, sound engineering design, dehumidification, use of neutralizing alkalis in an acidic environment, application of protective coatings, and the addition of inhibitors in anodic and cathodic reactions.

e. Equipment Required

(1) Dewpoint monitoring uses relatively simple devices such as temperature and pressure gauges and steam tables to determine water vapor pressure, temperature, and saturation temperature.

(2) Conductivity monitoring uses a low-voltage generator and probes and a volt-ohmmeter to determine the conductivity of the fluid being monitored.

(3) Ultrasonic corrosion monitoring requires an ultrasonic measuring device and a personal computer and software for downloading data for evaluation.

f. Operators. Maintenance technicians and engineers with an understanding of the causes and effects of corrosion.

g. Training Available. Minimal (on-the-job) training is required.

h. Cost. The cost of ultrasonic monitoring equipment is less than $5,000; software costs are approximately $9,000.

F.2.10 Process Parameters/Visual Inspection

a. Purpose. Knowledge of normal process-related factors such as pressure, temperature, amperage, flow data information, etc., for a given equipment item, coupled with visual inspection of the equipment often identifies the emergence of a problem not otherwise detected by other predictive technologies.

b. Techniques

(1) Diagnostic monitoring.

(2) Visual inspection.

c. Applications. Virtually all facilities and plant equipment.

d. Effects

(1) By recording process-related data such as temperature, pressure, etc., when equipment operators and maintenance personnel operate, monitor, or repair an equipment system, the information can be stored in a database and support other predictive efforts in cause-and-effect analyses.

(2) Visual inspection is an effective predictive technique that may detect problems, such as an oil leak not noticed by other, more technical means. Visual inspections should be habitual and continuous.

e. Equipment Required. No specialized testing equipment is necessary.

f. Operators. Operators and maintenance technicians. Any observant individual can assist by notifying maintenance personnel of apparent problems.

g. Training Available. Minimal (on-the-job) training is required to become a trained observer.

h. Cost. None.

F.3 Training and Certifications

Listed below are the organizations that offer training and certification in PT&I technologies and reliability. This list is by no means complete, as changes in the industry occur constantly:

AVO International Training Institute, Inc. (All Electrical Certifications)
4271 Bronze Way, Dallas, TX 75237-3156
Phone: 877-594-3156; Fax: 214-331-7363
Web site: www.avotraining.com

Bently-Nevada Corporation
1631 Bently Parkway South
Minden, NV 89423
Phone: 775-215-1387; Fax: 775-215-2865
Web site: ge-energy.turnstilesystems.com/ProgramHome.aspx.

Computational Systems Inc. (CSI) (Vibration Levels I, II, & III, and IRT Levels I & II)
835 Innovation Dr.
Knoxville, TN 37932
Phone: 800-675-4726; Fax: 865-218-1411
Web site: http://www.emersonprocess.com/education/training/knoxville-tn.asp

Rockwell Automation
Phone: 440-646-3434
Web site: www.rockwellautomation.com/global/services/training/overview.page?

EPRI M&D Center (Electrical Testing Training)
3 Industrial Highway
Eddystone, PA 19022

Phone: 800-745-9982

Infrared Training Center (FLIR Systems)
9 Townsend West
Nashua, NH 03063
Phone: 866-872-4647; Fax: 603-324-7791
Web site: www.infraredtraining.com

Ludeca, Inc. (Alignment Training)
1425 NW 88th Avenue
Doral, FL 33172
Phone: 305-591-8935; Fax: 305-591-1537
Web site: www.ludeca.com/training.php

National Environmental Balancing Bureau (NEBB)
8575 Grovemont Circle
Gaithersburg, MD 20877
Phone: 301-977-3698; Fax: 301-977-9589
Web Site: www.nebb.org

PdMA Corporation (Motor Testing Training)
5909-C Hampton Oaks Parkway
Tampa, FL 33610
Phone: 800-476-6463; Fax 813-620-0206
Web site: www.pdma.com/PdMA-training.php

Trico Corporation
1235 Hickory St
Pewaukee, WI 53072-3999
Phone: 800-558-7008
Web site: www.tricocorp.com/services/training

Update International Inc. (Vibration Levels I, II & III)
6320 W. Lakeridge Road
Lakewood , CO 80227
Phone: (800) 530-4215; Fax: 303-985-3950
Web site: http://www.update-intl.com/index.htm

Vibra Metrics
195 Clarksville Road
Princeton Jct, NJ 08550
Phone: 609-716-4130; Fax: 609-716-0706
Web site: http://www.vibrametrics.com/
Technical Associates of Charlotte
1230 West Morehead Street, Suite 400
Charlotte, NC 28208
Phone: 704-333-9011; Fax: 704-333-1728
Web site: www.technicalassociates.net/on-site-training.html

Vibration Institute
2625 Butterfield Road

Suite 128N
Oak Brook, IL 60523-3415
Phone: 630-654-2254; Fax: 630-654-2271
Web site: www.vi-institute.org

The Snell Group
322 N Main St
Suite 8
Barre, Vermont 05641
Phone: 800.636.9820; Fax: 802.479.7171
Web site: www.thesnellgroup.com/infrared-training

F.4 Application of Other Flaw-Detection Techniques

F.4.1 Utility Systems: Compressed Air

	INFRARED	ULTRASOUND	ACOUSTIC EMISSIONS	SULFUR HEXAFLUORIDE	RADIOGRAPHY	EDDY CURRENT	LIQUID PENETRANT	MAGNETIC FLUX	INSULATING OIL TEST	VIBRATION SIGNATURE	DEEP-PROBE TEMPERATURE	DIAGNOSTIC MONITORING	FIBER OPTICS/BORESCOPES	REPLICATION	ELECTROMAG. PIPE LOCAT.	RADAR MAPPING	HOLOGRAPHIC INTER.	BORING	HOLIDAY & FAULT LOCAT.	ELECT. EQUIP. TESTS
Controls-Electric	X														X				X	
Controls-Thermal	X																			
Electric Drive	X									X		X								
Steam Drive	X	X								X		X								
Motor Drive	X									X		X								
Compressor										X		X								
-Vibrations			X							X		X								
-Hot Stuffing Box	X									X		X								
-Hot Bearings, Belts, Gears	X											X								
-Valves and Seats	X		X		X		X	X						X						
- Pistons, Rings, Cyls., Rods	X	X	X		X	X	X	X		X		X		X						
- Rotor, Stator Wear	X	X	X		X	X	X	X		X		X	X							
Intercoolers/Aftercoolers	X	X	X		X	X		X					X	X						
Traps					X			X				X			X					
Receiving Tanks		X	X		X			X				X			X	X	X		X	
Drip Legs					X			X							X					
Distribution, Service Lines		X	X		X			X					X		X	X	X		X	
Valves		X	X		X		X	X						X	X	X				
Fittings		X	X		X		X	X					X	X	X	X				
Welds		X	X		X		X	X					X	X						
Cathodic Protection															X				X	
Conduits				X												X				
Pipe Supports/Anchors															X					

Source: Draft report *Utilities Inspection Technologies*, Naval Energy and Environmental Support Activity, Port Hueneme, CA, June 1990.

F.4.2 Utility Systems: Electrical

	INFRARED	ULTRASOUND	ACOUSTIC EMISSIONS	SULFUR HEXAFLUORIDE	RADIOGRAPHY	EDDY CURRENT	LIQUID PENETRANT	MAGNETIC FLUX	INSULATING OIL TEST	VIBRATION SIGNATURE	DEEP-PROBE TEMPERATURE	DIAGNOSTIC MONITORING	FIBER OPTICS/BORESCOPES	REPLICATION	ELECTROMAG. PIPE LOCAT.	RADAR MAPPING	HOLOGRAPHIC INTER.	HOLOGRAPHIC INTER.	HOLIDAY & FAULT LOCAT.	ELECT. EQUIP. TESTS
Capacitors	X								X											
Insulating Liquid	X	X							X											
Motor Windings	X																			X
Motor Connections	X									X		X								
Bearings, Belts, Gears	X									X		X								
Generator Retaining Rings							X	X												
Generator Windings																				X
Generator Brushes			X																	
Rotor Stator		X			X	X		X		X			X							
Oil-Insulated Transformers		X	X						X											X
Conductors	X					X									X	X			X	X
Suspension Insulators	X																			X
Steel Pole, Welds		X			X			X							X					
Gas-Insulated (SF_6) Equip.				X																X
Switchgear and Breakers	X								X											X
Buses, Connections	X																			X
Post Insulators	X																			X
Transformer Bushings	X																			
Conductors	X															X			X	
Distribution Transformers	X		X						X											
Suspension Insulators	X																			X
Pin and Cap Insulators	X																			X
Wood Poles		X			X													X		
Power Lines and Splices	X														X	X			X	

Source: Draft report *Utilities Inspection Technologies*, Naval Energy and Environmental Support Activity, Port Hueneme, CA, June 1990.

F.4.3 Utility Systems: Natural Gas

	INFRARED	ULTRASOUND	ACOUSTIC EMISSIONS	SULFUR HEXAFLUORIDE	RADIOGRAPHY	EDDY CURRENT	LIQUID PENETRANT	MAGNETIC FLUX	INSULATING OIL TEST	VIBRATION SIGNATURE	DEEP-PROBE TEMPERATURE	DIAGNOSTIC MONITORING	FIBER OPTICS/BORESCOPES	REPLICATION	ELECTROMAG. PIPE LOCAT.	RADAR MAPPING	HOLOGRAPHIC INTER.	HOLOGRAPHIC INTER.	HOLIDAY & FAULT LOCAT.	ELECT. EQUIP. TESTS
Feeder, Distr., Supply Mains			X	X		X				X				X	X	X	X	X	X	
Drip Legs			X			X														
Valves			X	X		X		X		X					X	X				
Pipe Fittings			X	X		X		X		X				X	X	X			X	
Welds			X	X		X		X		X				X					X	
Cathodic Protection															X	X	X		X	

Source: Draft report *Utilities Inspection Technologies*, Naval Energy and Environmental Support Activity, Port Hueneme, CA, June 1990.

F.4.4 Utility Systems: Steam

	INFRARED	ULTRASOUND	ACOUSTIC EMISSIONS	SULFUR HEXAFLUORIDE	RADIOGRAPHY	EDDY CURRENT	LIQUID PENETRANT	MAGNETIC FLUX	INSULATING OIL TEST	VIBRATION SIGNATURE	DEEP-PROBE TEMPERATURE	DIAGNOSTIC MONITORING	FIBER OPTICS/BORESCOPES	REPLICATION	ELECTROMAG. PIPE LOCAT.	RADAR MAPPING	HOLOGRAPHIC INTER.	HOLOGRAPHIC INTER.	HOLIDAY & FAULT LOCAT.	ELECT. EQUIP. TESTS
Boiler Tank	X	X	X		X	X		X				X	X				X			
Tubes/Headers	X	X	X		X	X	X	X				X	X	X			X			
Steam Drum		X	X		X	X		X				X		X			X			
Superheaters / Reheaters		X	X		X	X	X	X				X	X	X			X			
Economizers		X	X		X	X	X	X				X	X	X			X			
Turbines		X	X			X		X		X		X		X						
Forced / Induced Draft Fans			X							X		X								
Stack	X											X								
Feedwater Storage Tanks		X	X		X	X		X				X					X			
Pumps			X					X		X		X		X						
Gears, Belts, Bearings	X									X										
Pipes	X	X	X		X			X			X	X	X		X	X	X		X	
Valves	X		X		X		X	X			X			X						
Fittings, Connections, Welds	X	X	X		X		X	X			X		X	X	X	X			X	
Condensers	X									X		X								
Evaporators	X									X		X								
Conduits											X				X	X				
Traps	X			X				X				X								
Cathodic Protection															X	X			X	
Seals			X								X									
Insulation	X	X									X									
Expansion Tank		X	X		X	X		X				X					X			
Electrical Equipment	X											X								
Drip Legs					X	X		X												

Source: Draft report *Utilities Inspection Technologies*, Naval Energy and Environmental Support Activity, Port Hueneme, CA, June 1990

F.4.5 Utility Systems: Hot Water

	INFRARED	ULTRASOUND	ACOUSTIC EMISSIONS	SULFUR HEXAFLUORIDE	RADIOGRAPHY	EDDY CURRENT	LIQUID PENETRANT	MAGNETIC FLUX	INSULATING OIL TEST	VIBRATION SIGNATURE	DEEP-PROBE TEMPERATURE	DIAGNOSTIC MONITORING	FIBER OPTICS/BORESCOPES	REPLICATION	ELECTROMAG. PIPE LOCAT.	RADAR MAPPING	HOLOGRAPHIC INTER.	HOLOGRAPHIC INTER.	HOLIDAY & FAULT LOCAT.	ELECT. EQUIP. TESTS
Boiler-Tank	X	X	X		X	X		X				X	X				X			
- Tubes/Headers	X	X	X		X	X	X	X				X	X	X			X			
Controls-Electrical	X																			
Conduits				X							X					X				
Feeder/Distr./Svc. Mains	X	X	X		X	X		X			X	X	X	X	X	X	X		X	
Meters		X																		
Valves	X		X		X		X	X			X			X	X					
Measurement Controllers		X																		
Fittings/Connections	X		X		X	X	X	X			X		X	X	X	X			X	
Cathodic Protection															X	X			X	
Pumps			X					X		X		X								X
Insulation	X										X									
Expansion Tanks		X	X		X	X		X				X					X			
Heat Exchangers	X	X	X		X	X	X	X				X	X	X			X			
Fans			X			X				X		X								X
Driving Equipment	X									X		X								X
Stack	X											X								

Source: Draft report *Utilities Inspection Technologies*, Naval Energy and Environmental Support Activity, Port Hueneme, CA, June 1990.

Appendix G. Performance Measurement

G.1 Facilities Maintenance Management Metrics

This appendix provides maintenance management metrics from various sources. Centers and Component Facilities should consider their use, as applicable, as a means of measuring performance.

G.1.1 Facility Condition

The annual maintenance funding and resultant trends are a function of the DM and the needs of the Center. If the DM is high and increasing or staying the same, a positive trend would be observed. A downward trend would be expected if the backlog is low or decreasing. Elimination of the DM is not always possible or desirable, since DM can provide an ability to balance resources in the long term. The following represents the applicable metrics and corresponding benchmarks:

a. Annual Maintenance Funding ($) should be between 2 percent and 4 percent.
Current Replacement Value ($)

b. Annual Maintenance Funding ($) should show a downward () or stable trend.
Current Replacement Value ($)

G.1.2 Work Performance

The following metrics and corresponding benchmarks are used to trend work performance:

a. Emergency TC Response (hours) should show a downward trend.

b. Emergency TC Completion (hours) should show a downward trend.

c. Average completion time for routine TC (hours) should show a downward trend.

d. Average completion time for repairs (days) should show a downward trend.

e. Jobs Completed as Scheduled (Number) should be 100 percent.
Total Jobs Scheduled (Number)

f. Service Requests Completed (Number) should be 100 percent.
Service Requests Committed (Number)

G.1.3 Work Element

G.1.3.1 The following metric may have a positive trend if repair rates are high, equipment/facilities systems are not realizing their full useful life, or there is very little PT&I usage. A negative trend should develop if PT&I is increasing and repair rates are stable or decreasing. The benchmark is between 15 percent and 18 percent (See Table 3-3):

Preventive Maintenance ($)
Total Maintenance Cost ($)

G.1.3.2 The following metric should develop a positive trend as the maintenance program shifts from reactive and time-based maintenance to condition-based maintenance. The benchmark is between 10 percent and 12 percent:

Predictive Testing and Inspection ($)
Total Maintenance Cost ($)

G.1.3.3 The following metrics should develop a negative trend as the maintenance program shifts from reactive and time-based maintenance to condition-based maintenance:

a. Programmed Maintenance Repair ($) should be between 25 percent and 30 percent.
Total Maintenance Cost ($)

b. Repair ($) should be between 15 percent and 20 percent.
Total Maintenance Cost ($)

c. Trouble Calls ($) should be between 5 percent and 10 percent.
Total Maintenance Cost ($)

G.1.3.4 The following metric should show an upward trend if a backlog of this type of work exists, and a negative trend if not much of this type of work exists at the Center. The benchmark is between 15 percent and 20 percent:

Replacement of Obsolete Items ($)
Total Maintenance Cost ($)

G.1.3.5 The following metric should show a negative trend, demonstrating increased focus on maintenance, and should be distinguished from customer reimbursed service requests. The benchmark is between 0 percent and 5 percent:

Service Requests ($)
Total Maintenance Cost ($)

G.1.4 RCM Performance Metrics

RCM analysis is an excellent indicator of performance.

G.1.4.1 Equipment Availability. The following metric is an indicator of equipment availability. The benchmark is 96 percent:

Hours Each Unit of Equipment is Available to Run at Capacity
Total Hours During the Reporting Period

G.1.4.2 Maintenance Overtime Percentage. The following metric is an indicator of maintenance overtime percentage. The benchmark is 5 percent or less:

Total Maintenance Overtime Hours During the Period
Total Regular Maintenance Hours During the Period

G.1.4.3 Emergency Percentage. The following metric is an indicator of the level of effort dedicated to emergency work. The benchmark is 10 percent or less:

Total Hours Worked on Emergency Jobs
Total Hours Worked

G.1.4.4 Percentage of Candidate Equipment Covered by PT&I. The following metric is an indicator of the amount of candidate equipment covered by PT&I. The benchmark is 100 percent:

Number of Equipment Items in the PT&I Program

Total Equipment Candidates for PT&I

G.1.4.5 Percentage of Emergency Work to PT&I and PM Work. The following metric is an indicator of the amount of emergency work relative to PT&I and PM work. The benchmark is 20 percent or less:

$$\frac{\text{Total Emergency Hours}}{\text{Total PT\&I and PM Hours}}$$

G.1.4.6 Percentage of Faults Found in Thermographic Surveys. The following metric is an indicator of the percent of faults found through infrared thermography. The benchmark is 3 percent or less:

$$\frac{\text{Number of Faults Found}}{\text{Number of Devices Surveyed}}$$

G.1.4.7 Percentage of Faults Found in Steam Trap Surveys. The following metric is an indicator of the percentage of faults found during steam trap surveys. The benchmark is 10 percent or less:

$$\frac{\text{Number of Defective Steam Traps Found}}{\text{Number of Steam Traps Surveyed}}$$

G.1.4.8 Ratio of PM/PT&I Work to Reactive Maintenance Work. The following metric is an indicator of the percentage of planned work relative to unplanned work. The goal is 20%; world-class organizations keep reactive maintenance below 10%:

A = 80% PM/PT&I

B = 20% Reactive Maintenance where,

$$A\% = \frac{\text{Manhours of PM/PT \& I Work}}{\text{Manhours of Reactive} + \text{PM/PT \& I Work}}$$

$$B\% = \frac{\text{Manhours of Reactive Work}}{\text{Manhours of Reactive} + \text{PM/PT \& I Work}}$$

A% + B% = 100%

G.1.5 Safety

a. Reportable Incident Rate (RIR) for O&M and Support Services Contracts:

$$RIR = \frac{\text{Total Annual No. of Injuries Incurred x 200,000}}{\text{Total Annual No. of Hours Worked}}$$

a. Lost Workday Case Incident Rate (LWCIR) for O&M and Support Services Contracts. LWCIR represents the number of injuries and illnesses per 100 full-time equivalent workers.

$$LWCIR = \frac{N}{EH} \times 200{,}000$$

Where N = the number of injuries and illnesses.

EH = the total hours worked by all employees during the calendar year.

200,000 is the base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year).

G.2 Budget Execution. The following metrics indicate how well the facilities maintenance budget is being executed:

a. Prior Year Execution ($) should be 100%.
Prior Year Budget ($)

b. Current Year Expenditures to Date ($) should be 100%.
Current Year Budget to Date ($)

G.3 Other Metrics. The following are miscellaneous metrics used by organizations to measure performance. Their use by Centers is highly encouraged:

a. New Construction + Service Requests or New Work ($ or hours)
PM + PT&I + PGM + Repairs + ROI Maintenance ($ or hours) should show a downward trend (?).

b. Repairs + Trouble Calls Corrective Actions ($)
PM + PT&I + PGM + ROI or Preventive Actions ($) ?should show a downward trend (?).

c. Average Age of Equipment (years)
Average Useful Life of Equipment (years) should show a downward trend (?)

d. The number of disabling accidents per year should show a downward trend (?).

e. The number of routine trouble calls per year should show a downward trend (?).

f. The number of work orders (reactive) per year or month should show a downward trend (?).

g. The number of emergency trouble calls per year or month should show a downward trend (?).

h. Customer satisfaction, as measured by a numerical grade assigned to positive or negative feedback should show a positive, or upward, trend (?).

i. The number of unplanned electric power outages should show a downward trend (?).

j. The number of environmental violations should be zero.

k. The number of OSHA violations should be zero.

l. Maintenance Overtime (hours)
Total Maintenance (hours) should be less than 5%.

m. PMs Completed (number)
PMs Scheduled (number) should show an upward trend (?).

n. Scheduled Work (hours)
Total Work (hours) should show an upward trend (?).

o. Actual Cost of Work ($)
Estimated Cost of Work ($) should be within ± 10% of the estimated cost.

p. Jobs Planned and Estimated (number)
Total Jobs (number) should show an upward trend (?).

q. Jobs Planned and Estimated ($)
Total Jobs ($) should show an upward trend (?).

r. Supervision (hours)
Direct Labor (hours) should be less than 10%.

s. Downtime Caused by Breakdown (hours)
Total Downtime (hours) should show a downward trend (?) .

t. Breakdown Labor (hours)
Total Labor (hours) should show a downward trend (?).

G.3.1 The following two metrics should be carefully used on a job-by-job or like-work basis. This may create conflict between shops and management. Care should be exercised to preclude adversarial relationships between the shops and management.

a. Actual Hours per Job (hours)
Scheduled Hours per Job (hours) should be within ± 10% of the Scheduled Hours.

b. Maintenance Work Orders Completed (number
Maintenance Work Planned and Scheduled (number)) should show an upward trend (?).

G.3.2 A downward trend of the spare parts inventory is desirable, provided that the maintenance response time and completion times are not adversely affected. Given that, the desired metric is:

Inventory value of spare parts should show a downward trend (?).

G.4.1 WBS Level 3 Definitions - Facilities (WBS 736466.06.0x)

.01	Utilities	Includes electricity, steam, natural gas, water, sewage, fuel oil, other energy sources, and energy conservation
.02	Scheduled (proactive) Maintenance	Includes preventive maintenance, predictive testing and inspection, planned repair projects, programmed maintenance, replacement of obsolete items, and restoration/modernization associated with building systems/components.
.03	Unscheduled (reactive) Maintenance	Includes trouble calls and breakdown repairs
.04	Operations	Includes building and central plant operations, utilities control systems, CMMS, custodial/refuse collection/landfill costs, interior pest control
.05	Inactive Buildings & Structures	Includes minimal maintenance costs to preserve an asset needed in the future (includes standby and mothballed facilities). Also includes minimal maintenance costs associated with preservation of historic facilities and, in rare cases, minimal costs associated with abandoned facilities if required for safety or security purposes.
.06	New Capabilities	Includes construction projects that provide new capability at a Center. (e.g., a new addition to a building; a new parking lot; additional electrical capacity)

.07	Other Facilities Services	Includes engineering support, configuration control, service requests, cost estimating support, real property management, master planning support, GIS support, surveys, permitting, ADA compliance, Center funded safety improvements, and renovation and modernization projects associated with workspace improvements.
.08	Facilities Management	Includes all facilities civil service management (labor and travel). Does not include contractor management (must be allocated to service categories) or civil service or contractor craft labor.
.09	Roads & Grounds Maintenance	Includes roads and grounds maintenance, landscaping, exterior pest control, grass cutting, snow removal

Appendix H. Annual and 5-Year Maintenance Work Plan Template

H.1 Introduction

NASA has adopted a maintenance philosophy that emphasizes using the optimal mix of strategies to provide required facility availability and reliability at minimum cost to support current and planned NASA programs.

One of the recognized deficiencies in complying with this philosophy is the lack of an effective long- and short-range planning process at most of the Centers and their Component Facilities across NASA. Since all the Centers are moving toward a fully implemented Reliability Centered Maintenance (RCM) program, the next step is to provide them with a vehicle to display long- and short-range facility requirements in a manner that can be used to articulate needs based on mission impact and most probable facility availability outcomes under varying budget scenarios.

This document provides an Annual and 5-Year Maintenance Work Plan template. A business plan approach has been used to integrate smoothly into NASA's strategic management process, afford Center Facility Management (FM) and senior managers the ability to make risk-based decisions regardless of the budget environment, and allow Center FM organizations to pursue and measure their continuous improvement efforts.

H.2 Background

Factors considered in developing the template include NASA's Integrated Enterprise Management Program (IEMP) and full-cost accounting, the asset management initiative, Performance Based Contracting (PBC) conversion initiative, and Agency-wide metrics requirements recently incorporated in the facilities maintenance self-assessment policy.

This is a template, a suggested approach to structuring (format and content) an Annual and 5-Year Maintenance Work Plan. It has been designed to assist Center FM managers in preparing sound strategies, performing risk-based management, and identifying the required resources to help enable Center and Agency goals. Center FM managers have maximum flexibility in tailoring the plan to meet individual Center needs.

Funding throughout the plan is based on current year dollars. All funding amounts within any category should reflect fully loaded (that is, all support costs) funds. For example, if a NASA contractor is developing a plan, which may become part of a larger plan, then all funding should reflect the fully loaded price to NASA. The fully loaded price would include all costs and fees (profit). In some cases, the plan will reflect contract fixed prices.

Funding needs are developed within the requirements analysis in section 3. When coupled with criticality issues, such as effect on mission or safety, it becomes an effective tool for identifying work that cannot be accomplished if the budget is reduced, as well as the highest priority backlogged work that could be accomplished if additional resources were made available.

The Annual Work Plan (AWP) is the first year, or base year, of this plan. The base year information should be as complete and accurate as possible. In addition, the base year should identify work that will be deferred if the proposed budget is not completely funded and the effect on the Center/Facility if that work is not performed. The outyears, beyond the base year, are estimates that will form the basis of future AWPs.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Annual and 5-Year (Facilities or Area) Maintenance Work Plan

Center Name
Starting Fiscal Year <INSERT YEAR>
(October 1, <INSERT YEAR> through September 30, <INSERT YEAR>)

Prepared By: xxxx
POC: Name
Telephone: (xxx) xxx–xxxx
e-mail: abc@nasa.gov

Executive Summary

NOTE TO AUTHOR: The Executive Summary will summarize the long- and short-term goals and funding requirements for the facilities maintenance organization. The objective is to present the "big picture" including any requirements that cannot be accomplished within the established budget guidelines. Any adverse trends that could affect facility availability need to be described along with their probability of occurrence and their effects on safety, mission, or other costs. This is the opportunity to clearly articulate potential problems from reduced funding and the adverse impact they could have on mission support. If space allows, describe new initiatives and objectives, successes achieved to date, other initiatives outside of facilities maintenance, and funding requirements to continue them.

An effective Executive Summary should be short and concise. A good length is two to five pages. The goal is to have no surprises. If it is important, it should be mentioned here. Details shall be provided somewhere within the plan for every item mentioned in this summary. The details are backup information such as a table, an appendix, or a reference to other Center data.

Table H-1 Funding History

All funds are in actual/current year dollars (identify if K$ or M$).

Funding	Actual		Projected				
Source	FY(X–2)	FY(X–1)	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
R&D							
Other							
Other							
Total							

NOTE TO AUTHOR: The funding chart above will show "big picture" funding for all fund sources (FS) received in current and previous fiscal years as well as proposed for the 5-year period. Adverse trends depicted in the chart should be identified and their impact on mission support described. The text that follows provides an example of what could be included in this section.

The term "Center" is inclusive of its Component Facilities, as applicable.

The funding history and projected requirements to support facility maintenance for <INSERT CENTER NAME> are shown above. The funding for <INSERT CATEGORY> has been < INSERT "INADEQUATE," "FALLS SHORT" ETC.> and has resulted in <INSERT ADVERSE EFFECTS>. If additional funding is not made available, < INSERT POTENTIAL FUTURE PROBLEMS>.

The following chart, together with backup details, is the proposed < INSERT CENTER NAME> Annual Work Plan for the upcoming fiscal year.

Table H-2 Spending by NASA Category - (Current Year <X> and Budget Year <X+1>)

All funds are in current year dollars (identify if K$ or M$).

Work Element	FY <X>	% Effort	FY <X+1>	% Effort
PM/PT&I				
CBM				
Grounds Care				
PGM				
Repair				
Trouble Calls				
ROI				
Plant O&M				
Subtotal				
DM/Def. Work				
Special Programs				
Service Requests				
Subtotal				
CoF - Discrete				
CoF - Minor				
Total		100		100

NOTE TO AUTHOR: The chart above should show all NASA categories of work and all other categories of work to be managed by the facilities maintenance group. The Work Element column in the chart can include any number of items. Keep in mind, to be effective, the chart should limit the items by rolling up funds from the details contained within this plan. Backup details of specific requirements within each Work Element item should be available in an appendix, within the plan, or in a specifically referenced document or source. The percentage effort refers to the percentage of overall effort that the particular category represents. Include other charts and graphs to highlight performance and new initiatives. Include pictures here and in the body of the Plan if they add value.

Facilities Assessment Summary

NOTE TO AUTHOR: The following section is an overall assessment of past, present, and future funding trends, anticipated needs, and the ability of current budget estimates to meet needs required to successfully support the Center mission. This section is a summary of Section 4.3 and Appendix F. An example of information that can be portrayed is shown below.

State of <INSERT CENTER NAME> Facilities in Supporting the Center's Mission and Center of Excellence Responsibilities

<INSERT CENTER NAME> mission is to <INSERT MISSION> and is NASA's Center of Excellence for <INSERT COE RESPONSIBILITY>. Facilities maintenance organization's vision and mission are <INSERT VISION AND MISSION>. Major active facilities maintenance programs include <INSERT MAJOR PROGRAMS TO SUPPORT MISSION>. Future Center programs planned include <INSERT FUTURE PROGRAMS PLANNED>. The current state of <INSERT CENTER NAME> facilities for providing the required reliability and availability to support these programs is <INSERT "GOOD," "FAIR," "MARGINAL," OR "POOR">.

The current budget <INSERT EITHER "MEETS" OR "FALLS SHORT OF"> anticipated needs to ensure facilities maintain a reasonably high probability of supporting current mission needs. <INSERT THE FOLLOWING APPROPRIATE ITEMS WHEN REQUIREMENTS ARE GREATER THAN RESOURCES AVAILABLE – "THE FOLLOWING IDENTIFIES ACTUAL RESOURCE REQUIREMENTS, RESOURCE SHORTFALLS, REQUIRED WORK THAT CANNOT BE ACCOMPLISHED WITHIN THE AVAILABLE BUDGET, AND POTENTIAL MISSION IMPACT OF NOT ACCOMPLISHING THE REQUIRED WORK:" >

Preventive/Predictive Maintenance - <IDENTIFY RESOURCE REQUIREMENTS, RESOURCES BUDGETED, REQUIREMENTS THAT CANNOT BE ACCOMPLISHED, AND SHORT- AND LONG-TERM PROJECTED MISSION IMPACTS>

Programmed Maintenance **-** <SAME AS PM/PT&I >.

Repairs - < SAME AS PM/PT&I >.

Replacement of Obsolete Items **-** < SAME AS PM/PT&I >.

Utility Plant Operations - < SAME AS PM/PT&I >.

Grounds Care - < SAME AS PM/PT&I >.

Proactive Maintenance - < IDENTIFY COST EFFECTIVE METHODS REQUIRED TO MINIMIZE FAILURES NOT ABLE TO BE ACCOMPLISHED DUE TO BUDGET SHORTFALLS AND THE POTENTIAL SHORT- AND LONG-TERM IMPACTS >.

Special Programs – <INSERT SPECIAL PROGRAMS NOT ABLE TO BE ACCOMPLISHED DUE TO BUDGET SHORTFALLS AND INSERT THEIR BENEFITS AND POTENTIAL IMPACTS ON THE CAPABILITY TO SUPPORT MISSION >.

CoF Repairs/Revitalization - < IDENTIFY CURRENT YEAR NEEDS, FUNDED PROJECTS, AND POTENTIAL IMPACT OF UNFUNDED PROJECTS >.

Deferred Maintenance (DM), is currently at <INSERT $$ VALUE> or <INSERT %> of Current Replacement Value (CRV), and is expected to increase/decrease by <INSERT VALUE> in the coming year due to < INSERT PRIMARY CAUSE>. Primary mission impacts of existing DM are as follows:

1. <INSERT MOST SIGNIFICANT IMPACTS>.
2. ETC.

Facilities systems having a **high probability of incurring unplanned downtime** due to system condition and the most probable mission impact are as follows:

1. <INSERT SYSTEM #1 AND PROBABLE IMPACT>.

2. ETC.

Facilities systems having a **medium probability of incurring unplanned downtime** due to system condition and the most probable mission impact are as follows:

1. <INSERT SYSTEM #1 AND PROBABLE IMPACT>.

2. ETC.

Table of Contents

1.0 Introduction

NOTE TO AUTHOR: This section of the Annual and 5-Year Maintenance Work Plan provides the opportunity to explain what the plan is, why it was prepared, and how it can be used. The text that follows provides examples of subjects that may be included in this section.

The term "Center" is inclusive of its Component Facilities, where appropriate.

This document describes the Annual and 5-Year Maintenance Work Plan for < INSERT CENTER NAME> and represents a business plan for the facilities maintenance organization. The Plan identifies long-term and short-term maintenance requirements, describes the resources available and required to manage and accomplish facility maintenance, and outlines the maintenance philosophy and approach for < INSERT CENTER NAME>. Further, it will allow managers to make risk-based decisions on the work to be accomplished regardless of the budget environment, and it identifies specific areas to improve the overall effectiveness of facility maintenance. Overall effectiveness means PROVIDING THE REQUIRED FACILITY AVAILABILITY AT THE LOWEST COST. The plan identifies metrics to be used in tracking progress toward accomplishing these improvements. The AWP is the first year, or base year, of this plan. The outyears, beyond the base year, are estimates that will form the basis of future AWPs.

Throughout this document, the term maintenance is used to represent the compilation of activity undertaken to ensure the required facility availability at the lowest cost. That activity includes traditional maintenance, work done to reduce the probability of failure; repair, the restoration of function following failure; custodial, work done to maintain appearance or sanitation; and some operations. Sometimes it is difficult to place a single activity within one of the above categories. For example, painting provides both a failure prevention and appearance function. In addition, often the most effective maintenance approach is based on monitoring a system or machine condition and performing some activity based on that condition. Is the resultant activity maintenance or repair? This document will provide guidance for working through these issues. The activities include all of the elements identified in *NPR 8831.2*, *Facilities Maintenance Management*. Abbreviations and acronyms are contained in Appendix A. Other definitions, which are based on the NPR, other NASA documents, and discussions with NASA personnel, are contained in Appendix B.

Facilities maintenance at < INSERT CENTER NAME> is crucial in ensuring facility availability for its critical missions. The effect of reduced maintenance is not always felt immediately. It is, therefore, essential that sufficient management information is available to plan short-term and long-term maintenance requirements properly, recognize adverse funding trends, make the right decisions on what work is not accomplished, and be able to articulate the effect of reduced maintenance on facility availability and the mission.

The plan builds upon < INSERT CENTER NAME> existing mission statements to develop guidance on categorizing facilities and equipment in terms of their criticality and current condition and considers long-range plans that will affect real property assets and future maintenance requirements.

2.0 Center Mission

NOTE TO AUTHOR: This section of the plan builds upon the Center mission, defines the facilities supported and their priority relative to that mission, and looks at long-term facility changes to support the mission. Sample statements are provided below:

The <INSERT CENTER NAME> mission is <INSERT MISSION> and is NASA's Lead Center of Excellence (COE) for <INSERT COE RESPONSIBILITY>. The key mission elements at <INSERT CENTER NAME> that directly and indirectly affect facilities are:

< DEFINE KEY ELEMENTS THAT AFFECT FACILITIES, BASED ON THE CENTER'S STRATEGY TO IMPLEMENT THE MISSION>.

NOTE TO AUTHOR: Categorize facilities (Table 2-1) in terms of mission criticality (determined in partnership with site users and managers), square footage, and CRV for comparison/analysis purposes. One way to do that is to identify the entire Center by core or support function categories. The following terms, currently being considered for use Agency wide, are suggested:

Mission Critical: A building, area, or system that is critical to the Center mission or essential for Center of Excellence performance.

Mission Support: A building, area, or system that provides support to the Center primary mission or Center of Excellence assignment.

Center Support: A building, area, or system that supports the overall operation of the Center but does not meet the Mission Critical or Mission Support criteria.

An example of how to collect and categorize the facilities is provided in Appendix C. An appendix is useful for providing detailed information that is summarized in tables in this section. A map of the Center may also be useful to identify building and area locations.

NOTE TO AUTHOR: Describe any specific requirements that will drive priorities or philosophy of maintenance accomplishment. Describe any known mission changes, funded or unfunded, that will impact existing or future maintenance requirements. Information may be available from the Installation Master Plan, which is prepared and maintained by the Facilities Planning Office. Describe new facilities or facility modifications/repairs that will increase or decrease current maintenance requirements. Sample statements are shown below:

Over the next <INSERT PERIOD> the following known mission changes will have the following impact on maintenance responsibility:

<INSERT KNOWN MISSION CHANGES AND THEIR EXPECTED INCREASE AND/OR DECREASE IN MAINTENANCE RESPONSIBILITY>

Additionally the scope of maintenance coverage will be <INSERT INCREASES AND DECREASES IN TOTAL AREA TO BE MAINTAINED, BUILDINGS, OR AREAS THAT WILL BE BUILT, MODIFIED, BECOME REACTIVATED OR INACTIVE>.

Table H2-1 categorizes facilities in terms of mission criticality, square footage, and CRV for comparison analysis purposes.

Table H2-1 Mission Criticality

NOTE TO AUTHOR: Buildings/areas are based on detailed breakdown (usually in an appendix). Space is gross floor space and does not include grounds (which may be separately identified). CRV is in base year dollars and includes noncollateral equipment (collateral and noncollateral equipment may be separately identified).

Mission	Actual		Projected				
Category	FY(X–2)	FY(X–1)	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Mission Critical							
Buildings/Areas (No.)							
Space (gross sq. ft.)							
CRV ($)							
Mission Support							
Buildings/Areas (No.)							
Space (gross sq. ft.)							
CRV ($)							
Center Support							
Buildings/Areas (No.)							
Space (gross sq. ft.)							
CRV ($)							
Totals							
Buildings/Areas (No.)							
Space (sq. ft.)							
CRV ($)							

Note: Space is gross floor space and does not include grounds. CRV is in base year dollars and includes noncollateral equipment.

NOTE TO AUTHOR: Identify the staffing of the Center. This may provide an indication of the level of work being performed at the Center. The staff may be NASA civil servants, other Government civil servants, or contract personnel. For fixed-price contracts, personnel figures may not be available or meaningful. A table, similar to the one below, is often effective:

Table H2-2 identifies the actual and projected staffing requirements at <INSERT CENTER NAME>.

Table H2-2 Staffing

Numbers are Full-Time Equivalent Employees.

Staff Source	Actual		Projected				
	FY(X–2)	FY(X–1)	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
NASA							
Other Gov.							
Contractor							
Contractor							
Total							

3.0 Requirements Analysis

NOTE TO AUTHOR: This section is used to develop facility maintenance requirements. Because each Center is unique in its mission, physical plant, and available resources, the method used in determining requirements will vary. To accurately identify overall maintenance requirements, key information will need to be available. Some examples of this information include: (1) clear identification of the assets to be maintained (facilities and equipment); (2) their relative importance from a mission/safety/cost standpoint; and (3) indicators of their current material condition from PT&I data and routine or special testing, operational performance data, failure rates, or, in some cases, visual presentation. Comparison to historical funding information will indicate any potential funding shortage and identify backlogs. For all elements defined in this section, an appendix may need to be developed or data outside the plan be referenced that will document a source. Estimates, when used, should be clearly identified.

Tables have been developed for this section to identify maintenance funding requirements and to articulate those needs throughout the organization. It is important that the plan build upon the suggested elements, adding and deleting as needed, and settle on a final array of needed data. When that is completed, the people who have the facility knowledge can be called upon to provide the data. This template builds upon the information and definitions detailed in *NPR 8831.2, Facilities Maintenance Management*. Expansion of definitions or clarification of information is provided when necessary to help in formulating the plan.

This section identifies the facility maintenance requirements at <INSERT CENTER NAME>. The tables that follow identify the assets (facilities and equipment) that shall be maintained, their relative importance to the mission of <INSERT CENTER NAME>, and their current condition, operational performance data, and failure rates. Historical funding data, including funding shortfalls and consequent maintenance backlogs, are also presented.

3.1 Requirements by Building or Area

NOTE TO AUTHOR: This section is used to develop facility maintenance requirements for each building or area identified in section 2. This section provides suggested elements to consider. The building/area approach is suggested to ensure a systematic development and prioritization of needs for varying budget scenarios, and to enable gathering information from knowledgeable people, such as systems engineers and building or area managers. Those systems that provide broad Center support, such as utilities, are documented in section 3.2.

This section identifies the facility maintenance requirements for each building or area identified in section 2. Those systems that provide broad Center support, such as utilities, are discussed in section 3.2.

3.1.1 Criticality and Condition

NOTE TO AUTHOR: Even if a building or area is Mission Critical, not all systems within that area are necessarily critical. It is expected that some systems that provide Center support will be important from a maintenance perspective. It is, therefore, necessary to identify systems within the building or area (or, if needed, subsystems) by a criticality code.

Several methods for assigning criticality have been developed to support the RCM evaluation process and other reliability efforts. The methods are discussed in Appendix D, Developing System Criticality.

In addition to criticality, the condition of a facility component or item of equipment is also an important factor in identifying long-term requirements and their relative priorities. Condition codes, based on *NPR 8831.2, Facilities Maintenance Management*, have been expanded and are listed in Table 3-1 below. As written in the NPR, the codes focus on age and appearance. The expanded definitions, while still subjective in nature, build upon NASA's PT&I and other monitoring capabilities.

Centers may want to use Table 3-1 in their plan. When Table 3-1's listing of systems and their Criticality and Condition Codes is prepared using a spreadsheet or database program, it can be sorted easily on any one of the columns. The table is useful in that it establishes a relationship between criticality and condition for all systems within the building or area. If the table is included in the plan, it should be in an appendix.

Table H3-1 is a listing of systems and their Criticality and Condition Codes based on an expanded version of the definitions in *NPR 8831.2, Facilities Maintenance Management*, as follows:

Condition Code 5 - Excellent – No work required - Good for at least 5 years.

Condition Code 4 - Good – Only scheduled maintenance and/or condition monitoring required – Good for at least 5 years.

Condition Code 3 - Fair – Minor repairs required – Repair/replace within three to 5 years.

Condition Code 2 - Poor – Significant repairs required within one to two years.

Condition Code 1 - Bad – Replacement required now.

The expanded definitions, while still subjective in nature, build upon NASA's PT&I and other monitoring capabilities.

The table correlates criticality and condition for all systems within their respective buildings or areas.

Table H3-1 System List with Criticality and Condition Codes

Criticality Codes are based on the Dual-Code Method (see Appendix D).

System	Criticality Code		Condition Code
	Function	Cost	
Chiller 5	3	1	4
Air Handler 20	4	4	3
Air Handler 9	3	1	4
Lift Pump 1	2	1	2
Lighting System A	4	2	5
Motor Control Center 4A	1	1	5

NOTE TO AUTHOR: Keep in mind that the material condition (as reflected in the Condition Code) is a snapshot in time. Plan on updating the condition, at a minimum, every 5 years. Most organizations try to update the condition of at least 20 percent of all systems each year, as part of their Facilities Condition Assessment (FCA) programs. Condition monitoring (PT&I) will provide a much more accurate indication of condition because the data is collected and analyzed on a more frequent basis.

Table H3-2 provides a summary of the number of systems within each condition code category. For example, in Table H3-1, two systems have Function Code 3 and Cost Code 1 (Chiller 5 and Air Handler 9). Also from Table H3-1, those two systems are Condition Code 4. So, in the following summary table below, there would be the number 2 in row 3,1.

Table H3-2 Systems by Condition and Critical Code

Table contains the number of systems that meet the criticality and condition criteria.

Criticality Codes		Condition Code (1-Bad, 2-Poor, 3-Fair, 4-Good, 5-Excellent)				
Function	Cost	1	2	3	4	5
1	1					1
1	2					
1	3					
1	4					
2	1		1			
2	2					
2	3					
2	4					
3	1				2	
3	2					
3	3					
3	4					
4	1					
4	2					1
4	3					
4	4			1		
Total		0	1	1	2	2

3.1.2 PM and PT&I

NOTE TO AUTHOR: Use this section to develop PM and PT&I funding for the next 5 years. Funding requirements are the funds needed to perform the scheduled PM and PT&I on all equipment covered by this plan and include all labor, parts, materials, and special tools. A listing of the equipment covered is normally available from the Computerized Maintenance Management System (CMMS) and/or the PT&I database. This could also be specified in a fixed-price contract, if one is in place. The RCM process enables clear identification of what is the most effective maintenance, i.e., what activity provides the highest reliability (reduced probability of failure) at the lowest cost. When systems are analyzed using the RCM process, it is often the case that the existing PM is identified as ineffective and can be replaced with PT&I or a run-to-fail approach. PT&I is used to monitor the system condition and take action (which can be a maintenance or repair activity) when conditions change. Therefore, this section should identify changes expected as the RCM process is used. For fixed-price contracts, this may be a step change when the contract ends (due to changes in the maintenance approach over the life of the contract). Note that PM and PT&I are scheduled activities. Work resulting from changing material conditions, as monitored by PT&I, is not part of this category. System and equipment changes (additions or deletions) may also result in changes in this section. Only major changes (for example, deactivation of a building wing or removal of a test area) need to be discussed.

Table H3-3 identifies required PM and PT&I funding for the next 5 years. Funding requirements are the funds needed to perform the scheduled PM and PT&I on all equipment covered by this plan and include all labor, parts, materials, and special tools.

Table H3-3 PM and PT&I Funding

All funds are in current year dollars (identify if K$ or M$).

Activity	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
PM					
PT&I					
Total					

3.1.3 Grounds Care

NOTE TO AUTHOR: Usually grounds care funding requirements are for broad Center areas and should be identified in section 3.2. Include the funding in this section only if it is clearly associated with this building or area. As was the case for PM and PT&I, funding requirements are the funds needed to perform the scheduled work (grass cutting, plant trimming, etc.) for the building or area covered by this section of the plan and includes all labor, parts, materials, and special tools. A listing of the grounds care may be available from the CMMS or in a fixed-price contract. To improve planning and management, the work to be performed may be identified by area, zone, or season.

Table H3-4 identifies grounds care for a specific area or zone.

Table H3-4 Grounds Care Funding

All funds are in current year dollars (identify if K$ or M$).

Grounds Care	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Area/Zone 1					
Area/Zone 2					
Area/Zone 3					
Total					

3.1.4 Programmed Maintenance (PGM)

NOTE TO AUTHOR: PGM is similar to PM and PT&I in that it is a scheduled activity intended to prevent failure. However, as identified in *NPR 8831.2, Facilities Maintenance Management*, the activity occurs on a greater than one-year cycle. Use this section to identify funding requirements which, by the nature of the work, are not expected to be a "level" amount. In addition, this section needs to be adjusted based on emerging conditions as discussed in the NPR. Ensure that these requirements are not duplicated in any other category of work.

Table H3-5 identifies PGM requirements for a specific area or zone.

Table H3-5 Programmed Maintenance Funding

All funds are in current year dollars (identify if K$ or M$).

	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
PGM Area/Zone 1					
PGM Area/Zone 2					
PGM Area/Zone 3					
Total					

3.1.5 Repair and Trouble Calls

NOTE TO AUTHOR: From *NPR 8831.2, Facilities Maintenance Management*, repair is "...fixing something broken or failing." This means to restore the function within the funding guidelines identified in the NPR. Trouble calls are a subset of repair in that they are low-cost repairs. The funding limit guidelines for repairs and trouble calls (currently $1 million and $2,000 respectively) are identified in the NPR and may change from time to time.

Individual failures are usually unplanned events. However, they are not unexpected. In fact, one outcome of the RCM analysis process could be that RTF may be the most cost-effective maintenance approach for some equipment. When this is the case, the equipment or system is usually a low-cost, noncritical, easily repaired item. This section is used to budget funds to provide for repairs and trouble calls. Funding requirements are the funds needed to perform repairs and trouble calls on all equipment covered by this plan and include all labor, parts, materials, and special tools. The systems to be repaired may have items not included in the CMMS and/or the PT&I database.

The repair and trouble call budget is built upon history. First, determine how much repair work this building or area has required in the past, then factor in the material condition and the maintenance approach established by the RCM process. For example, suppose a large amount of scheduled maintenance is reduced and replaced with monitoring through a PT&I program. Initially, repair cost would be expected to increase because the PT&I program is uncovering degraded conditions that shall be repaired. They are repaired to reduce the effects of catastrophic failure and to improve the availability to perform operations, testing, research, or whatever the building or area is designed to produce. Then, over time, the repair cost should decrease as the systems perform at a higher level of reliability.

This work may be specified in a fixed-price contract, if one is in place, and will have an upper-level limit on the amount of money the contractor shall commit to repair an item (sometimes called the limit of liability). There may be a need to budget for repair beyond the upper limit or to budget for trouble calls above a level specified in the contract.

Carefully consider other funding categories that may influence the outyear projections. For example, a Replacement of Obsolete Items project (discussed in the next section) would be expected to reduce the projected repair costs.

Table H3-6 identifies funding requirements needed to perform repairs and trouble calls on all equipment covered by this plan and includes all labor, parts, materials, and special tools.

Table H3-6 Repair and Trouble Calls Funding

All funds are in current year dollars (identify if K$ or M$).

Activity	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Repair					
Trouble Calls					
Total					

3.1.6 Replacement of Obsolete Items (ROI)

NOTE TO AUTHOR: ROI is a category of systems that are cheaper to replace than to continue to operate or repair. Candidates for ROI are identified through RCM analysis, periodic review of repair costs, and the PT&I program. This section provides the opportunity to present ROI items and to discuss the cost and availability implications of not completing them. One result may be increased repair costs or reduced safety margins. Another result could be extended loss of availability of the building or area if a failure were to occur.

Table 3-7 identifies total planned ROI for a specific building or area. The table also shows any projected increase in other categories (such as repair and TCs) if the ROI is not funded.

Table H3-7 ROI Funding

All funds are in current year dollars (identify if K$ or M$).

	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
ROI Project 1					
ROI Project 2					
Total ROI					
Increase Due to Unfunded ROI					
Repair					
Trouble Calls					
Total Other					

3.1.7 Service Requests (SR)

NOTE TO AUTHOR: SR requirements can be stated as a lump-sum item or by area/zone. Funding for SRs is provided by the requester. Budget estimates are developed from historical levels of work and are useful for estimating staffing or subcontracting levels.

Table H3-8 identifies SR requirements, where they are shown as lump-sum items or by area/zone.

Table H3-8 Service Request Funding

All funds are in current year dollars (identify if K$ or M$).

Service Requests	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Area/Zone 1					
Area/Zone 2					
Area/Zone 3					
Total					

3.1.8 Central Utility Plant Operations and Maintenance (O&M)

NOTE TO AUTHOR: As discussed in *NPR 8831.2, Facilities Maintenance and Operations Management*, the central utility plant O&M funds account for operators and operator-performed maintenance. (Other facilities work may also fit this category. For example, research facilities may utilize the same personnel to perform operations and maintenance.) Do not include funding for other work performed in the building or area, such as PT&I or repair. There is also a need to account for automation improvements, including online condition monitoring systems that could reduce the funding requirements.

Table H3-9 identifies central utility plant funding requirements.

Table H3-9 Central Utility Plant O&M Funding

All funds are in current year dollars (identify if K$ or M$).

Central Utility Plant O&M	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Total					

3.1.9 Construction of Facilities (CoF)

NOTE TO AUTHOR: In this section, identify funding to perform or support projects, including all CoF and environmental projects. Do not include funding controlled or used by other organizations to perform or support the CoF work. Only facilities maintenance funds are included here. For example, funding to support the construction, acceptance, and baseline condition monitoring/testing of a new building (or portion of this building or area), if performed or managed by the facilities maintenance organization, should be included in this section.

If available, evaluate the 5-Year CoF plan. Requirements for both construction and repair categories should be detailed in the CoF plan and include restoration, modernization, rehabilitation, and repair projects. Projects less than $1 million are normally funded by the Center. Minor program CoF projects are those between $1 million and $5 million. Major program or discrete CoF projects are greater than $5.0 million. Environmental projects are normally funded from a special-fund source.

The information in this section should also relate to other sections. For example, a CoF project scheduled for completion in FY 2002 could result in increased PM and PT&I in FY 2003 as new systems are maintained or monitored. This section of the plan should fully develop the life-cycle maintenance implications of CoF and other projects that will eventually be maintained by the organization. This includes projected funding needs for the completed project. Once the project is completed, the outyear funding would be integrated with the other sections of the plan (for example, any PM/PT&I that is accounted for here will become part of the PM/PT&I section once the project is completed).

Table H3-10 identifies funding to perform or support projects, including all CoF and environmental projects.

Table H3-10 CoF Funding

All funds are in current year dollars (identify if K$ or M$).

Project	Fiscal Year				
Type	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
CoF - Major					
CoF - Minor					
Other					
Total					

3.1.10 Deferred Maintenance (DM)

NOTE TO AUTHOR: NPR 8831.2, Facilities Maintenance and Operations Management, provides a detailed discussion regarding DM. From the NPR, DM is unfunded facilities maintenance work. Only those items that support the Center's mission goals are to be included in the DM calculation. In this section, two tables are needed to present DM history and plans to reduce DM. The first table, the history, documents the DM for the previous 5 years to identify the DM trend. The second table identifies needed DM reduction funds. This section should discuss the DM priorities and the effect of not completing the DM. Ensure that DM requirements are not duplicated in any other category of work. The tables can be prepared for each of the facility types (mission critical, mission support, and center support) if desired.

Table H3-11 documents the DM for the previous 5 years to identify the DM trend.

Table H3-11 DM History

All funds are in actual dollars (identify if K$ or M$). Start is DM at start of the fiscal year. Reduction is reduction of DM during the year. End is the remaining DM at year's end (and becomes the next year start).

DM	Fiscal Year				
	FY(X–5)	FY(X–4)	FY(X–3)	FY(X–2)	FY(X–1)
Start					
Reduction					
End					

Table H3-12 identifies needed DM reduction funds.

Table H3-12 DM Reduction Plan

All funds are in current year dollars (identify if K$ or M$). Start is DM at start of the fiscal year. Reduction is planned reduction of DM during the year. End is the remaining DM at year's end (and becomes the next year Start).

DM	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Start					
Needed Reduction					
End					

3.1.11 Special Programs

NOTE TO AUTHOR: This section of the plan identifies funding requirements for special programs not identified elsewhere in the Plan. Special programs could include completing an RCM analysis and implementing changes, initiating or expanding the PT&I program, planning and performing CMMS upgrades, refrigerant conversion, building closures, or special training not accounted for elsewhere. This section should discuss the program, the source of funding, the expected benefits or reason for the program, and the implication or effect of not completing the program. Other work may also be included in this section. For example, custodial work is not a work area separately identified elsewhere in the plan. If custodial work is part of the organization's responsibility, the decision may be to include it here. This may also be a good place to budget for special events and weather-related contingencies, such as snow removal or wind damage. Funds not used for the contingency can be applied to DM.

Table H3-13 provides funding requirements for special programs not identified elsewhere in the plan.

Table H3-13 Special Program Funding

All funds are in current year dollars (identify if K$ or M$).

Special Programs	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Implement RCM					
Implement CBM					
CMMS Upgrade					
Special Program A					
Special Program B					
Special Program C					
Custodial Work					
Total					

3.2 Requirements for Broad Center Support

NOTE TO AUTHOR: This section is optional. If used, the section develops the facility maintenance requirements for broad Center support items, such as utilities. The list of broad support items is identified in section 2. This section should be developed for all detailed topics used in section 3.1.

This section identifies the facility maintenance requirements for the broad Center support items identified in section 2.

<INSERT THE REQUIRED DATA FOLLOWING THE SAME FORMAT PRESENTED IN SECTION 3.1 FOR SPECIFIC FACILITIES AND AREAS>.

3.3 5-Year Funding Plan

NOTE TO AUTHOR: Table 3-14 consolidates the funding requirements identified in section 3.1 and section 3.2. and provides the projected facilities maintenance funding requirement for the Center. The table in this section may be all that is required.

Table H3-14 consolidates the funding requirements identified in section 3.1 and in section 3.2. and provides the projected facilities maintenance funding requirement for <INSERT NAME OF CENTER>.

Table H3-14 5-Year Funding Rollup

All funds are in current year dollars (identify if K$ or M$).

Work Element	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
PM/PT&I					
Grounds Care					
PGM					
Repair					
Trouble Calls					
ROI					
Plant O&M					
Subtotal					
DM					
Special Programs					
Service Requests					
Subtotal					
CoF – Discrete					
CoF – Minor					
Total					

4.0 Facilities Maintenance

NOTE TO AUTHOR: In this section, discuss how Center facilities maintenance will be implemented and monitored. Since each Center is unique in terms of organization, conduct of business, expectations, new initiatives, and planned improvements, the following subsections (4.1 through 4.2.5) describe numerous examples of information that could be included. Each Center should use this section to describe and analyze its own particular situation.

4.1 Maintenance Organization

<IDENTIFY THE MAINTENANCE ORGANIZATION, KEY PEOPLE, AND CONTRACT SUPPORT. DISCUSS THE SUPPORT LEVEL (THAT IS, TO WHAT LEVEL ARE MAINTENANCE AND REPAIR ACTIVITIES PERFORMED ONSITE, LOCAL OUTSIDE SUPPORT, AND OTHER SUPPORT, AS FAR INTO THE FUTURE AS POSSIBLE) AND THE CONTRACT BASIS FOR THAT SUPPORT (LEVEL OF EFFORT, FIXED PRICE, PERFORMANCE-BASED, ETC.). DISCUSS OR PROVIDE THE FACILITIES ORGANIZATION'S MISSION STATEMENT.>

4.2 Maintenance Performance

<DISCUSS HOW BUSINESS IS CURRENTLY BEING CONDUCTED AND IMPROVEMENTS THAT ARE PLANNED>.

4.2.1 Expectations

<PROVIDE THE ORGANIZATION'S EXPECTATIONS AND HOW THEY ARE RELATED TO THE CENTER'S MISSION. CONSOLIDATE EXPECTATIONS BASED ON THE VARIOUS WAYS THE BUILDINGS OR AREAS ARE USED. FOR EXAMPLE, THE EXPECTATION FOR ADMINISTRATIVE BUILDINGS MAY BE TO PROVIDE A SUITABLE WORK ENVIRONMENT, MONDAY THROUGH FRIDAY, FROM 6 A.M. TO 6 P.M. THE EXPECTATION FOR A TEST AREA MAY BE TO ENSURE AVAILABILITY OF TEST SUPPORT FACILITIES AT ANY TIME WITH 48 HOURS ADVANCE NOTICE>.

4.2.2 Initiatives

<IDENTIFY WHAT IS BEING DONE, OR WOULD BE DESIRED, TO IMPROVE PERFORMANCE (FOR EXAMPLE, BAR CODING). HOW WILL THIS SUPPORT THE CENTER'S MISSION? WHAT WILL IT COST, AND WHAT IS THE EXPECTED PAYBACK OR AVOIDED COST? DO NOT DOUBLE COUNT ITEMS DISCUSSED IN SECTION 3 (SUCH AS SPECIAL PROGRAMS), BUT THIS SECTION MAY BE USED TO DEVELOP ITEMS TO BE INCLUDED IN SECTION 3. IDENTIFY WHERE THE FUNDING NEED IS INCLUDED IN SECTION 3. INCLUDE A PLAN OF ACTION AND A MILESTONE CHART (MAY BE IN A SEPARATE DOCUMENT OR AN APPENDIX).>

Table H4-1 Initiative Analysis

All funds are in current year dollars (identify if K$ or M$).

Initiative	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Expected Cost					
Avoided Cost					
Total					

4.2.3 Performance Monitoring

NOTE TO AUTHOR: How well are expectations being met and at what cost? In this subsection, develop the indicators to be used to assess performance. Indicators can be event metrics or global metrics.

Event metrics are those items that are useful for measuring progress toward event-type goals, measuring the effect of new initiatives, or winning support for a new approach. While useful, event metrics shall be carefully used. For example, when the PT&I program is young, it will often be possible to identify a significant amount of machinery degradation that can be repaired before catastrophic failure occurs (often avoiding a higher cost for the repair and the associated downtime). Measuring "finds" every month, and the avoided costs, are good event metrics because they show how well the new program is working. However, over a long period, as the material condition of machinery systems is raised, the number of monthly finds can be expected to reduce to a fairly stable low level. That could imply (to people unfamiliar with the role of PT&I) that the PT&I program has become ineffective. But why have the PT&I program? The PT&I program's goal to reduce the probability of unexpected failure. So a good global (or strategic) measure would be the number of unexpected failures of monitored equipment or the improved availability (for testing, research, etc.) due to reduced facility equipment failures. Both of these items should improve with time and should be strategically in line with the Center's mission.

Both *NPR 8831.2, Facilities Maintenance and Operations Management*, and the *Reliability Centered Maintenance Guide for Facilities and Collateral Equipment* provide examples of event and global metrics. Existing data collection systems may need to be tailored or a new system added to efficiently collect and monitor performance metrics.

An example is breaking down repairs (including trouble calls) into subcategories. Repair means to fix something when it fails; the restoration of function. Sometimes items are repaired before they fail. Is this maintenance or repair? Most people consider any action that improves the material condition or extends the life of the condition to be a repair, not maintenance. The general exception to this is the replacement of low-cost, worn components, such as belts and filters that do not require significant disassembly of the system or machine and are scheduled PM. As the RCM process is implemented, it is expected that ineffective PM will be replaced with more effective PT&I. With increased PT&I, there will be an increase in identification of degraded material conditions that shall be repaired to avoid catastrophic failure. Some equipment will be allowed to fail; no PM or PT&I will be performed because it is not cost effective. However, it is still a repair when it is fixed. The following table below has been structured to collect repair costs in meaningful subcategories to demonstrate progress toward overall lower repair costs and increased availability.

Table H4-2 illustrates repair costs at <INSERT NAME OF CENTER> by subcategories for the past four years and demonstrates progress toward overall lower repair costs and increased availability as a direct result of performance monitoring.

Table H4-2 Repair Cost Analysis

All funds are in actual year dollars (identify if K$ or M$). Planned repair means that degraded condition has been detected and repair action was scheduled prior to catastrophic failure.

Repair Subcategory	Fiscal Year			
	FY(X–4)	FY(X–3)	FY(X–2)	FY(X–1)
Run-to-Fail Equipment				
Trouble Calls				
All Other Repair				
Subtotal Run-to-Fail				
PT&I Monitored Equipment				
Planned Repair				
Failed Prior to Planned Repair				
Trouble Calls				
Other Unexpected Failure				
Subtotal PT&I Monitored				
All Other Equipment				
Trouble Calls				
Other Unexpected Failure				
Subtotal All Other Equipment				
Total – All Repair				

4.2.4 Staffing and Training Plan

NOTE TO AUTHOR: Based on the information in section 2 and in section 3, what are projected staff and training requirements? Use this section to identify what will be needed such as specialized certifications and licenses, and what will happen if the staffing is not available or if the training is not provided. Carefully factor in new facilities and mission, regulatory requirements, industry standards, and new technologies. If needed, develop a stand-alone needs analysis for staffing and training and display requirements as shown in the following tables:

Tables H4-3 and H4-4 display the projected staff and training requirements at <INSERT NAME OF CENTER> for the next 5 years. Additionally, the following specialized certifications and licenses are required: <INSERT SPECIALIZED CERTIFICATION/LICENSE REQUIREMENTS>.

If these staffing, training, certification, and licensing requirements are not satisfied, the impact on <INSERT NAME OF CENTER> will be: <INSERT SPECIFIC IMPACTS>.

Table H4-3 Staffing Analysis

Numbers are Full-Time Equivalent Employees.

Staff Function	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Management					
Support					
Engineers					
Planners					
Crafts/Trades					
Others					
Total					

Table H4-4 Training Analysis

All funds are in current year dollars (identify if k$ or M$).

Training Requirement	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Staff Development					
Regulatory Requirement					
Other Training					
Total					

4.2.5 Special Tools and Test Equipment

NOTE TO AUTHOR: This section is similar to the previous. That section discussed staffing needs. This section concerns tools and test equipment. Identify any expected requirements. Also discuss any major scrap issues related to changing requirements.

Table H4-5 displays the projected special tool or equipment requirements at <INSERT NAME OF CENTER> for the next 5 years. If these special tool and equipment requirements are not satisfied, the impact on <INSERT NAME OF CENTER> will be: <INSERT SPECIFIC IMPACTS>.

Table H4-5 Tools and Equipment Analysis

All funds are in current year dollars (identify if K$ or M$).

Tools or Test Equipment	Fiscal Year				
	FY(X)	FY(X+1)	FY(X+2)	FY(X+3)	FY(X+4)
Item 1					
Item 2					
Item 3					
Total					

4.3 Budget Shortfall

NOTE TO AUTHOR: Use this section to plan for various budget scenarios. When reductions are proposed, it will be necessary to identify what work will not be performed. And, if not performed, what will be the expected consequence. Should the possibility of a budget "plus-up" occur, it shall be possible to identify the highest-priority backlogged items and their positive impact on mission if additional resources are made available. The mission criticality in section 2 identifies building and area importance and the system criticality and condition, identified in section 3, builds upon that to present a total picture of relative importance. Based on their importance and condition, and their projected future use, where would work not be performed if the budget were cut? Several issues shall be evaluated. Will the probability of failure increase, and if so, are the consequences of that failure acceptable? If there is an RTF approach for some systems (low-cost, low-risk, easy to fix systems), can repairs be deferred? If the building or area has a limited useful life (perhaps a research or testing effort will be completed relatively soon), can performing maintenance be stopped and a failure risked? In other words, can the resource be consumed? There is a sample Work Priority System in *NPR 8831.2* (See Table 5-2). This same prioritization process can be used to determine work that would be done if additional resources become available.

The table below can be used to summarize what will be done if the budget is reduced. In developing a reduction plan, keep in mind that some work may be part of fixed price contracts that may not be able to be changed without incurring a penalty. A similar table (Table 4-7) should be developed for a "plus-up" situation.

Table H4-6 summarizes the incremental plan to accommodate budget decreases.

Table H4-6 Budget Shortfall Action Plan

All funds are in current year dollars (identify if K$ or M$).

Budget Shortfall Action Plan - FY <INSERT>		
% Shortfall	$ Amount	Planned Action
1		Defer or eliminate the planned maintenance items identified on Shortfall List 1 (See Appendix F for an example). Change in DM in $.
5		In addition to the above, defer or eliminate the planned maintenance items identified on Shortfall List 2. Change in DM in $.
10		In addition to the above, defer or eliminate the planned maintenance items identified on Shortfall List 2. Change in DM in $.
15		In addition to the above, defer or eliminate the planned maintenance items identified on Shortfall List 2. Change in DM in $.

Table H4-7 summarizes the incremental plan to accommodate budget increases.

Table H4-7 Budget Plus-up Action Plan

All funds are in current year dollars (identify if K$ or M$).

Budget Plus-up Action Plan - FY <INSERT>		
% Plus-up	$ Amount	Planned Action
1		Add work up to this $ amount, as identified in the Priority List of Deferred Work (See appendix F for an example). Change in DM in $.
5		Add work up to this $ amount, as identified in the Priority List of Deferred Work. Change in DM in $.
10		Add work up to this $ amount, as identified in the Priority List of Deferred Work. Change in DM in $.
15		Add work up to this $ amount, as identified in the Priority List of Deferred Work. Change in DM in $.

5.0 Center Function Categories (Example)

This appendix provides examples of one Center's facilities using the following criteria:

Mission Critical: A building, area, or system that is critical to the Center's mission or essential for Center of Excellence performance.

Mission Support: A building, area, or system that provides support to the Center's primary mission or Center of Excellence assignment.

Center Support: A building, area, or system that supports the overall operation of the Center but does not meet the mission critical or mission support criteria.

Center Mission (Currently - KSC example) –

Assemble, integrate, and check out Space Shuttle elements.

Assemble, integrate, and check out payloads, including the Spacelab, Space Station, and Upper Stages.

Conduct launch, recovery, and landing operations.

Design, develop, build, operate, and maintain launch, recovery, and landing facilities and ground support equipment required to process launch vehicle systems and associated payloads.

Ensure the operation and maintenance of ground support equipment, facilities, and logistics support for all NASA activities at the Center and supported activities.

Manage orbiter flight hardware logistics.

Provide Government oversight of NASA's expendable vehicle launches and NASA-sponsored payloads on both the East and West Coasts.

Table H5-1 Listing by Area, Building, or System

If helpful, include a map at end of the appendix.

Area, Building/System Number, Title	Function Category
H2-1198 Jay Jay Railroad Bridge	Mission Support
J6-2262 Orbiter Mate/Demate Device	Mission Critical
J7-0182 Liquid Oxygen(LOX) Facility	Mission Critical
J7-0288 Water Tank	Mission Critical
J7-0337 Launch Pad 39B	Mission Critical
J7-1388 Industrial Water Pump Station	Mission Support
K6-0494 Rotating/Processing Facility	Mission Critical
K6-0696 OPF Hi Bay 3	Mission Critical
K6-0947 Utility Annex	Mission Critical
K6-1091 Emergency Power Station	Mission Support
K6-1096 Operations Support Building	Center Support
K6-1141 Power Substation	Mission Critical
K6-1247 Launch Equipment Shop	Mission Support
K6-1547 Logistics Building	Mission Critical
K7-0853 High-Pressure Gas Storage Building	Mission Critical
K7-1005 Barge Terminal Facility	Mission Support
L6-0146 Engineering and Administration Building	Center Support
L6-0147 Chiller Building	Mission Support
M3-003 Indian River Bridge	Center Support
M6-0399 Center Headquarters	Center Support
M6-0409 Spaceport Central	Center Support
M6-0495 Dispensary	Center Support
M6-0595 Heat Plant	Center Support
M6-0744 Central Supply	Center Support
M7-0505 Payload Support Building	Center Support
M7-0657 Parachute Refurbishment Facility	Mission Support
M7-0777 Canister Rotation Facility	Mission Support
M7-1354 Payload Hazardous Servicing Building	Mission Support
UK-004 Bituminous Roads	Center Support
UK-034 Firex System	Mission Support

Table H5-2 Listing by Function Category

Function Category	Area, Building/System Number, Title
Mission Critical	
	J6-2262 Orbiter Mate/Demate Device
	J7-0182 Liquid Oxygen(LOX) Facility
	J7-0288 Water Tank
	J7-0337 Launch Pad 39B
	K6-0494 Rotating/Processing Facility
	K6-0696 OPF Hi Bay 3
	K6-0947 Utility Annex
	K6-1141 Power Substation
	K6-1547 Logistics Building
	K7-0853 High-Pressure Gas Storage Building
Mission Support	
	H2-1198 Jay Jay Railroad Bridge
	J7-1388 Industrial Water Pump Station
	K6-1091 Emergency Power Station
	K6-1247 Launch Equipment Shop
	K7-1005 Barge Terminal Facility
	L6-0147 Chiller Building
	M7-0657 Parachute Refurbishment Facility
	M7-0777 Canister Rotation Facility
	M7-1354 Payload Hazardous Servicing Building
	UK-034 Firex System
Center Support	
	K6-1096 Operations Support Building
	L6-0146 Engineering and Administration Building
	M3-0003 Indian River Bridge
	M6-0399 Center Headquarters
	M6-0409 Spaceport Central
	M6-0495 Dispensary
	M6-0595 Heat Plant
	M6-0744 Central Supply
	M7-0505 Payload Support Building
	UK-004 Bituminous Roads

6.0 Developing System Criticality

Several methods for assigning criticality have been developed to support the RCM evaluation process and other reliability efforts. This appendix describes these methods. Regardless of the method used to assign criticality, there is very real benefit to completing the process. That is, once complete, there is a clear understanding of which system failures will have the most significant effect on safety and mission.

Dual-code Method

This method uses two codes, one for function and another for cost. Within the function code, the key elements are safety & environment and mission. Within the cost code, the key elements are operations & maintenance cost and initial (procurement and installation) cost.

Safety & Environment: Does the system perform a safety and environment function? Will a failure of the system hurt people or the environment?

Mission: Does the system support the mission function? Will functional degradation or failure delay or stop the mission? Will functional degradation or failure cause additional significant collateral damage to other systems that will delay or stop the mission? Keep in mind that NASA has a very dynamic environment that results in shifting mission requirements. A system may have a very important function today but have a limited contribution to the Mission a few years from now.

Operations & Maintenance Cost: Does the system have a high operations and maintenance cost (consider all labor and materials including subcontracted work)? High operations and maintenance cost might be defined as $5,000/year or more. This can be any value, as long as it is applied consistently.

High Initial Cost: Did the system have a high initial cost (total installation cost)? Define high initial cost as $50,000 or more. As with high operations and maintenance costs, this can be any value, as long as it is applied consistently.

Answering the above questions resulted in establishing the dual codes as follows:

Function Code 1 - Yes to Safety & Environment and Yes to Mission.
Function Code 2 - Yes to Safety & Environment and No to Mission.
Function Code 3 - No to Safety & Environment and Yes to Mission.
Function Code 4 - No to Safety & Environment and No to Mission.

Cost Code 1 - Yes to Operations & Maintenance and Yes to High Initial.
Cost Code 2 - Yes to Operations & Maintenance and No to High Initial.
Cost Code 3 - No to Operations & Maintenance and Yes to High Initial.
Cost Code 4 - No to Operations & Maintenance and No to High Initial.

Table H8-1 lists the codes so that all possible combinations are represented, with the most critical items listed first. The advantage of this method is that it weighs four key elements to define the system criticality.

Table H6-1 Dual-Code Criticality

Function Code	Cost Code	Comment
1	1	Very Highly Critical: Safety & Environment and Mission are both issues.
1	2	
1	3	
1	4	
2	1	Highly Critical: Safety & Environment Is an issue.
2	2	
2	3	
2	4	
3	1	Moderately Critical: Mission or collateral damage is an issue.
3	2	
3	3	
3	4	
4	1	Low Critical: No Safety & Environment or Mission issues.
4	2	
4	3	
4	4	

Streamlined System

This system uses four categories that define criticality of the equipment based on its tie to mission, safety, environmental constraints, and cost. There are variations of this system. For example, the current *Reliability Centered Maintenance Guide* has a similar approach using six categories.

- Critical Code 1 - Mission Critical/High Risk/Catastrophic Impact if Failure Occurs. Equipment shall be online for continued mission operation. Loss of any component will result in a system outage and adversely impact mission operations. Also includes all equipment that has extraordinary, high repair costs or excessive spare parts procurement time. Environmental and safety equipment may be included in this classification because failure to conform to law could have grave consequences with regard to mission operations.
- Critical Code 2 - Critical/Process Sensitive/ Major Impact if Failure Occurs. Mission operations would be severely limited if the facility or equipment were disabled. All equipment with chronic maintenance and repair histories or very high repair or replacement costs are in this classification.
- Critical Code 3 - Serious/ Mission Support/ Minor Impact if Failure Occurs. The equipment is costly to maintain but does not directly impact mission. A redundant system would be classified in this category since the online spare could provide the required service. Facilities and equipment seriously impacting other operations, project deadlines, and costs may be within this classification.
- Critical Code 4- Exceptional/ Noncritical/ Discretionary/Deferred/ Negligible Impact if Failure Occurs. All other equipment that does not impact mission is in this category, including equipment that could be maintained but is not essential or equipment that would be maintained if unlimited resources were available.

Process Criticality

Another method for ranking critical systems is adapted from the automotive industry and identifies ten categories.[1] Table H8-2 details the system as follows.

Table H6-2 Process Criticality

Ranking	Effect	Comment
1	None	No reason to expect failure to have any effect on safety, health, environment, or mission.
2	Very Low	Minor disruption to facility function. Repair to failure can be accomplished during trouble call.
3	Low	Minor disruption to facility function. Repair to failure may be longer than a trouble call but does not delay the mission
4	Low to Moderate	Moderate disruption to facility function. Some portion of mission may need to be reworked or the process delayed.
5	Moderate	Moderate disruption to facility function. 100% of the mission may need to be reworked or process delayed.
6	Moderate to High	Moderate disruption to facility function. Some portion of the mission is lost. Moderate delay in restoring function.
7	High	High disruption to facility function. Some portion of the mission is lost. Significant delay in restoring function.
8	Very High	High disruption to facility function. All of the mission is lost. Significant delay in restoring function.
9	Hazard	Potential Safety, Health, or Environment issue. Failure will occur with warning.
10	Hazard	Potential Safety, Health, or Environment issue. Failure will occur without warning.

[1] *Reliability, Maintainability, and Supportability Guidebook, Third Edition*, Society of Automotive Engineers, Inc., Warrendale, PA, 1995.

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7.0 Sources of Data (Example)

This appendix describes the sources of data for the work element requirement tables in section 3 that are available to NASA and the Institutional M&O contractor at the Kennedy Space Center. These sources are cited as examples for other Centers/Facilities to use in developing their short- and long-term requirements.

Sources of Data:

Databases/files within the CMMS (MAPCON) – the PM/PT&I Master File, the Work Order History File and the Equipment File are maintained in the Maintenance Management Office of the Institutional M&O contractor.

AMDAHL is a work management system database maintained in the Work Control Office of the Institutional M&O contractor. This system is a unique and separate database to Kennedy Space Center (KSC) and is not tied to the CMMS but tracks service requests (called WAPS at KSC) and facility projects.

The facility projects listing is a locally developed database that is maintained in the Contract Integration Office of the Institutional M&O contractor.

The Facility Project Management System is a NASA-wide database maintained in NASA's Facility Project Management Office.

JAMIS is a financial accounting database maintained in the resources office of the Institutional M&O contractor.

Requirements:

PM/PT&I – Requirements are available from the PM/PT&I Master File and historical information for projections is available from the Work Order History File.

Grounds Care – Historical information for projections is available from the Work Order History File.

Programmed Maintenance – Requirements are available from AMDAHL for in-house work and the facilities projects listing for subcontracted work. Historical information for projections is available from the Work Order History File for in-house work and AMDAHL for subcontracted work.

Repairs – Requirements are available from AMDAHL for in-house work and the facilities projects listing for subcontracted work. Historical information for projections is available from the Work Order History File for in-house work and AMDAHL for subcontracted work.

Trouble Calls - Historical information for projections is available from the Work Order History File.

Replacement of Obsolete Items - Requirements are available from AMDAHL for in-house work and the facilities projects listing for subcontracted work. Historical information for projections is available from the Work Order History File for in-house work and AMDAHL for subcontracted work.

Service Requests - Requirements are available from AMDAHL for in-house work and the facilities projects listing for subcontracted work. Historical information for projections is available from the Work Order History File for in-house work and AMDAHL for subcontracted work.

Utility Plant O&M - Historical information for projections is available from the Work Order History File.

CoF Programs - Requirements are available from the Facility Project Management System.

DM – Requirements are available from the facility project listing (subcontracts) and the Facility Project Management Database System (CoF projects). Historical information for projections is available from AMDAHL (subcontracts) and the Facility Project Management System (CoF).

Special Programs - Requirements information for these type of programs (including special training requirements) are normally identified, tracked, and maintained in a separate work order or facility project database created to support the specific program.

8.0 Budget Shortfall/Plus-up Planning Sheets

Use tables similar to the ones below to detail planned maintenance items to be deferred or eliminated, or added to the budget. Some repair items may also be included.

Column 1 - Item. Ascending numbers/priorities.

Column 2 - Building/area. Identify building or area by name. Include mission criticality code (MC – Mission Critical, MS – Mission Support, CS – Center Support).

Column 3 - Discussion. Identify the system or machine. Identify maintenance to be deferred, eliminated, or added.

Column 4 – Risk/value. Identify what may happen due to not performing work, the consequences of failure, and the probability of the failure or, in the case of a plus-up, the positive effects of accomplishing the work.

Column 5 – DM . Identify DM increase or decrease, if any.

Column 6 - Funds. Identify budget reduction/requirement based on this action.

Table H8-1 Sample Budget Shortfall Planning Sheet - FY xx

List 1 (1% Shortfall)

All funds are in current year dollars (K$)

Page 1 of ___

Item	Building/Area	Discussion	Risk	DM	Funds
1	Test Area 1(MC)	Reduce grass cutting by 50%	None, appearance only.	0	25
2	Building 54 (MC)	Eliminate all PT&I and PM for facilities systems. Selectively perform trouble calls.	Low. All testing in this building is scheduled to be completed this year. Building will be closed at that time. Failures, if they occur, can be repaired with minimal effect on remaining testing. All safety-related maintenance will be performed.	0	80
3	Switchyard (MS)	Defer ROI project to replace aging switchgear	Increased probability of failure. Cannot be quantified. If failure occurs, approx. one-third of the Center will be without power for 5 days.	250	250
4					
Total				250	355

Table H8-2 Sample Budget Plus-up Planning Sheet - FY xx

List 1 (1%)

All funds are in current year dollars (k$)

Page 1 of ___

Item	Building/Area	Discussion	Value	DM	Funds
1	Building 4240(MC)	Replace electrical distribution system.	Eliminate antiquated system, thereby eliminating high repair costs.	100	100
2					
3					
4					
Total				100	100

9.0 Long-Term Budget Planning Sheet

Use a table similar to the one below to detail planned maintenance items beyond the 5-Year window. Some repair items may also be included.

Column 1 - Item. Ascending numbers.

Column 2 - Projected fiscal year and type of work (ROI, CoF, etc.).

Column 3 - Building/area. Identify building or area by name. Include mission criticality code (MC – Mission Critical, MS – Mission Support, CS – Center Support).

Column 4 - Discussion. Identify the system or machine. Identify project/work.

Column 5 - Identify projected funding (if possible).

Table H9-1 Long-Term Facilities Budget Items

All funds are in current year dollars (K$)

Page 1 of ___

Item	FY/Type Work	Building/Area	Discussion	Funds
1	2004/CoF	Test Area 4(MC)	Reactivate test area	
2	2005/ROI	Building 32 (MS)	Replace switchgear	
3				
4				
5				
6				
7				
8				

Appendix I. NASA-Wide Standardized Deferred Maintenance Parametric Estimate Method

I.1 Introduction

The NASA Deferred Maintenance (DM) Parametric Estimating Method was adopted in August 2001. NASA commissioned a pilot of the DM method at the Marshall Space Flight Center (MSFC) in late 2001. Three two-person teams completed the MSFC assessments. The analysis from that test resulted in minor adjustments to the method. During the full assessment, the DM method was further refined as the data from various inspections was analyzed.

This process of documenting DM is designed to be a simplified approach based on existing empirical data. The method assumes that:

- condition assessments are performed at the system level rather than the component level.
- simple condition levels are used.
- there are a limited number of systems to assess.
- the current replacement values (CRV) of the systems and the facility they support are available.

For additional information, please refer to The NASA Deferred Maintenance Parametric Estimating Guide.

I.1.1 Establish Deferred Maintenance Facility Category Codes

The first steps in the process are to determine the facilities to be assessed and to group them by categories. The category codes group facilities whose systems are similar and have approximately the same relative system CRV percentage values. For example, one category may be administrative buildings. These are facilities that function like office buildings and have a structure, a roof, an exterior, interior finishes, and typical mechanical systems (HVAC, electrical, and plumbing). Another category may be laboratories. Laboratories have the same systems as an administrative building, with structure, roof, exterior, interior finishes and mechanical systems. But, their percentage of contribution to the CRV will be different, so, these building types need to be separate in the model. Other facilities may include antennas, fueling stations, and other structures that have correspondingly different cost models for purposes of estimating DM. Correct mapping of like facilities is essential to ensure that all systems' contributions to the CRV, and thus the DM, are accounted for.

I.1.2 Determine Facility Systems to be Assessed

Once the facilities are categorized, the facility systems to be assessed are identified by using building system classification. An example of such a system is the American Society for Testing of Materials (ASTM) UNIFORMAT II Classification for Building Elements. The system includes, but is not limited to, structure, roof, exterior, interior finishes, and mechanical systems.

To perform the deferred maintenance estimate, a parametric cost estimate model similar to Figure I-1 is used. This model uses cost estimating relationships (CERs) based on existing engineering data and associated algorithms to establish cost estimates. For example, detailed cost estimates for the repair of a building system (e.g., its plumbing system) can be developed using very precise work measurement standards. However, if history has demonstrated that repairs have normally cost about 25% of the original value, then a detailed estimate need not be performed and can simply be computed at the 25% (CER) level. It is important, though, that any CERs used be carefully tested for validity using standard statistical approaches.

Parametric techniques focus on the cost drivers, not the miscellaneous details. The drivers are the controllable system design or planning characteristics that dominate system cost. This technique uses the few important parameters that have the most significant cost impact on the deferred maintenance of systems within a facility.

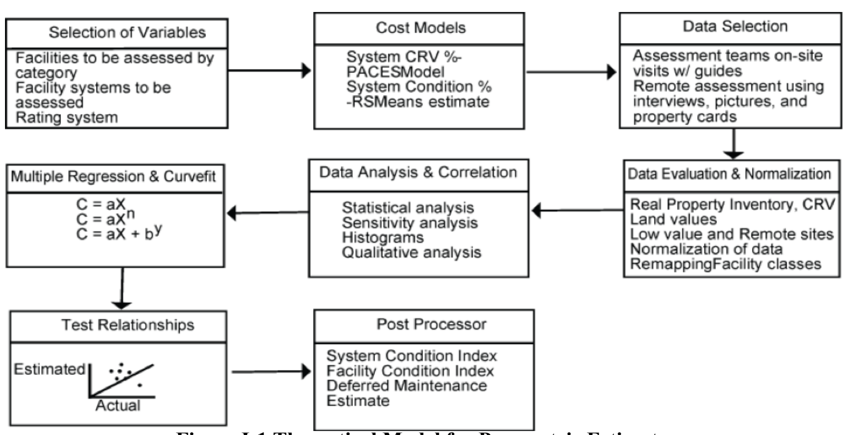

Figure I-1 Theoretical Model for Parametric Estimates

I.1.3 Determine System CRV Percentages

Each system is then assigned representative cost factors based on the estimated percentage of contribution of the major system to the total CRV of the facility within a facility category. For example, in a simple administrative building, the structure may contribute 35% to the CRV, the roof 15%, the exterior 10%, the interior 10% and the mechanical systems 30%â?"all contributing to equal 100% of the CRV. In complex laboratory and testing facilities, electrical systems make up a larger percentage of the overall building cost, so the breakdown might be structure 25%, roof 15%, exterior 10%, interior 10%, and the mechanical systems 40%. The system's CRV percentages are derived from existing engineering data and adjusted, if necessary, to meet unique facility types.

I.1.4 Condition Assessment Rating Scheme

The NASA condition rating scheme is a simple five-tiered condition code system shown in Table I-1. The DM model breaks a facility down into nine major components. An inspector will rate each of the nine facility components with a condition rating between zero and five. The rating is entered into the database and, depending on the asset class of the facility (a launch pad, for example, would have more structural system weighting than a substation), it computes the DM.

Table I-1 Condition Assessment Level

5	Excellent	Only normal schedule maintenance required.

4	Good	Some minor repairs needed. System normally functions as intended.
3	Fair	More minor repairs and some infrequent larger repairs required. System occasionally unable to function as intended.
2	Poor	Significant repairs required. Excessive wear and tear clearly visible. Obsolete. System not fully functional as intended. Repair parts not easily obtainable. Does not meet all codes.
1	Nonfunctional	Major repair or replacement required to restore function. Unsafe to use.
0	Non-existent	The zero rating identifies that this system does not exist within the facility.

I.1.5 Determine System Condition CRV Percentage

A significant component of the DM estimate is the application of a system condition CRV percentage based on the assigned condition rating for each system. The system condition CRV percentages, based on existing engineering data, increase as the condition of the system gets lower ratings, creating a larger DM estimate. For example, if the structure of a facility receives a 5 rating, its contribution to DM is 0 percent of the system CRV because there is typically no deferred maintenance for this rating (See Table I-7). However, if the structure receives a 3 rating, its contribution to the DM will be 10 percent of the CRV of the system. The system condition percentages also vary by system. Continuing with the example, in the same building, a 3 rating for the electrical system would contribute 13 percent of the electrical system CRV, while a 3 rating for the roof system would contribute 38 percent of the system CRV to the facility's overall DM.Â

I.1.6 Facility Condition Index Calculations

After the condition-rating scheme was established, teams went to the field to assess the facilities using the rating system above. The teams rated each system in each facility and entered that information into a database from which is generated a System Condition Index (SCI) for each system, and a Facility Condition Index (FCI) for each facility, site, and the Agency as a whole. SCI is calculated by first determining the CRV of the system in question by multiplying the facility CRV by the percent system CRV. The value of these system CRVs are then totaled. Next, the system CRV for each facility is normalized or weighted by dividing the system CRV by the sum of all the system CRVs. This quotient is then multiplied by its respective assessment rating. These "weighted" SCIs are then added to determine the facilities SCI. The SCI calculation can be calculated for the site, installation, Center, Mission Directorate, or Agency levels.

The FCI is the CRV normalized sum of the condition ratings for each system within each facility. The building FCI is a simple calculation that weights each of the nine system condition ratings by its associated system CRV percentage per DM category. In each system, the rating is multiplied by its system CRV percentage to get a weighted SCI. The sum of the nine weighted SCIs equals the facility's FCI. Table I-2 is an example. If a facility does not have one of the nine system components, that component is rated zero and will have no weighting, and so does not contribution to FCI and DM.

Table I-2 Facility FCI Example

		STRUC		EXT		ROOF		HVAC		ELEC		PLUMB		CONV		INTF		EQUIP		FCI
Facility Description	Facility CRV $	Insp Rat	% Sys CRV	Insp Rat	% Sys CRV	Insp Rat	% Sys CRV	Insp Rat	% Sys CRV	Insp Rat	% Sys CRV	Insp Rat	% Sys CRV	Insp Rat	% Sys CRV	Insp Rat	% Sys CRV	Insp Rat	% Sys CRV	
WAREHOUSE	1,172,019	4	0.40	3	0.19	2	0.06	0	0.18	3	0.20	0	0.02	0	0	3	0.15	0	0	3.3
COVERED STORAGE	102,267	5	0.63	5	0.22	5	0.11	0	0.03	5	0.04	0	0.01	0	0	0	0.04	0	0	5.0
FEMA EQUIPMENT STORAGE SHED	92,789	5	0.48	5	0.17	5	0.05	0	0.15	5	0.15	0	0.15	0	0	5	0.15	0	0	5.0
GENERAL WAREHOUSE	7,781,631	4	0.60	4	0.15	4	0.10	3	0.04	3	0.06	4	0.01	0	0	4	0.04	0	0	3.9
ADMINISTRATION BUILDING	12,166,903	5	0.19	5	0.17	3	0.06	4	0.16	4	0.18	4	0.05	5	0.03	5	0.16	0	0	4.4
AUDITORIUM	6,306,944	3	0.22	4	0.17	4	0.06	4	0.16	2	0.18	4	0.05	0	0.03	2	0.16	0	0	3.1
MAIN LIBRARY	5,716,090	5	0.19	4	0.17	4	0.06	4	0.16	4	0.18	4	0.05	4	0.03	4	0.16	0	0	4.2
PHOTOTECHNOLOGY LAB.	10,960,633	4	0.18	3	0.19	4	0.04	3	0.15	4	0.20	4	0.04	5	0.01	5	0.15	5	0.04	3.9

Table I-3 is an example of an FCI for a Center. The Center FCI value is the sum of each facility's CRV-normalized FCI. Each facility CRV is divided by the total Center CRV. That quotient is then multiplied by each facility's FCI producing a CRV-normalized FCI. Weighted FCI = (Facility CRVÃ· Center CRV) Ã Facility FCI. The sum of these weighted facility FCIs provides a total Center FCI.

Table I-3 Center FCI Example

Center "A"		**Facility FCI**	**Weighted FCI**
Facility Description	**Facility CRV $**		
WAREHOUSE	1,172,019.00	3.3	0.1
COVERED STORAGE	102,267.00	5.0	0.0
FEMA EQUIPMENT STORAGE SHED	92,789.00	5.0	0.0
GENERAL WAREHOUSE	7,781,631.00	3.9	0.7
ADMINISTRATION BUILDING	12,166,903.00	4.5	1.2
AUDITORIUM	6,306,944.00	3.1	0.4

MAIN LIBRARY	5,716,090.00	4.2	0.5
PHOTOTECHNOLOGY LAB.	10,960,633.00	3.9	1.0
Center "A" Totals	44,299,276.00	Â	3.9

I.1.7 Deferred Maintenance Calculation

The facility DM estimate is determined by adding the DM estimates of the nine facility systems. Table I-4 provides a sample DM estimate for an administrative facility (DM category 5) with a CRV of $10 million.

Table I-4 Sample Deferred Maintenance Calculation

System	System %	CRV Total $	System Rating	System Condition CRV %	DM $
Structure	0.18	1,800,000	5	0.00	0
Exterior	0.17	1,700,000	4	0.05	85,000
Roofing	0.05	500,000	4	0.05	25,000
HVAC	0.16	1,600,000	3	0.15	240,000
Electrical	0.18	1,800,000	4	0.05	90,000
Plumbing	0.05	500,000	3	0.15	75,000
Conveying	0.06	600,000	5	0.00	0
Interior Finishes	0.15	1,500,000	3	0.20	300,000
Facility Equipment	0.00	0	0	0.00	0
Total	1.00	10,000,000			$815,000

I.2 The Model as Used

I.2.1 Deferred Maintenance Facility Category Codes

Using the NASA Real Property Management System (RPMS), the first step in building the DM database was to map each of the more than 400 NASA facility classes into 42 DM facility categories, as shown in Table I-5. It was necessary to reduce the number of NASA classes to simplify data management. It is important to develop the correct facility category to provide a more complete reflection of the system CRV percentages in the different facility types, ultimately creating a more representative DM estimate. The categories were determined based on facility similarity. For example, DM Category 12, Communication and Tracking Buildings, includes NASA facility classes 131 and 140. Category 13, Communications and Tracking Facilities, includes NASA facility classes 132 and 141. These facilities may include antennas, fueling stations, or other structures that have correspondingly different cost models for purposes of estimating DM from those in Category 12.

Table I-5 Mapping of NASA facility classes into DM Facility Categories

Facility Type	NASA Facility Category Class
R&D and Test Buildings	220-11, 220-12, 220-13, 310-10, 310-15, 310-20, 310-21, 310-22, 310-30, 310-40, 310-41, 310-50, 310-60
R&D Structures and Facilities	320-10, 320-20, 320-21, 320-22, 320-30, 320-40, 320-41, 320-50, 320-70, 390-00
Wind Tunnels	330-10, 330-20, 330-30, 330-40, 330-60, 330-70, 331-10, 331-20, 331-30, 331-40, 331-60, 331-70
Engine/Vehicle Static Test Facilities	340-10, 340-20, 345-10, 345-50, 350-10, 350-20, 355-10, 355-20, 355-30, 355-40, 355-50
Administrative Buildings	141-20, 610-10, 610-20, 610-90
Training Buildings	171-00, 179-00
Trailers	630-30, 630-31, 630-32, 630-34, 630-36, 630-37
Storage Buildings	153-10, 153-90, 442-10, 610-30
Storage Facilities	345-20, 421-30, 432-10, 432-90, 442-20, 442-30, 442-40, 442-50, 442-60, 442-90, 452-10, 452-11, 452-12, 471-10, 471-20, 471-30, 471-40
Fuel Storage Tanks	126-90, 411-10, 411-20, 411-30, 411-40, 411-50, 411-60, 411-90, 423-10, 423-20, 423-90, 461-10, 461-20, 461-30, 461-90
Specialized Liquid Storage Tanks	
Fueling Stations and Systems	121-10, 121-20, 121-90, 122-10, 122-20, 122-90, 123-10, 123-90
Magazines	421-90, 422-15, 422-20, 422-30, 422-90, 424-10, 424-20, 424-30

Communication and Tracking Buildings	131-10, 131-15, 131-20, 131-25, 131-30, 131-35, 131-40, 131-45, 131-50, 131-90, 140-10, 140-20, 140-30, 140-40, 140-50, 140-90
Communication and Tracking Facilities	132-10, 132-20, 132-30, 132-40, 132-50, 132-90, 141-30, 141-40, 141-50, 141-90
Large Antennas	
Small Antennas	320-60
Mission Control Operations Buildings	381-10
Lighting	136-10, 136-20, 136-30, 136-50, 136-90, 812-20, 812-40, 812-50, 812-70, 812-80
Electrical Distribution System	382-70, 811-90, 812-30, 812-35, 812-90
Power Generation/Power Plant	811-10, 811-20, 811-30, 811-40, 811-50, 811-60, 811-70, 811-80
Electric Substations, Switchgear & Transformer Yards	812-10, 812-60
HVAC Distribution	822-10, 822-20, 823-20, 823-30, 824-10, 824-20, 824-30, 824-40, 842-10, 890-10, 890-15, 890-20, 890-25, 890-30, 890-35, 890-45, 890-50, 890-60, 890-65, 890-70, 890-85, 890-90
HVAC Generation	821-10, 821-20, 821-30, 821-40, 821-50, 890-40, 890-55, 890-75, 890-80
Waste Water Collection & Disposal System	831-20, 832-10, 832-20, 832-30, 832-40, 832-90, 871-60
Waste Water Facilities & Treatment Plants	831-10, 831-30, 831-40, 831-50, 831-90
Storm drains, Ditches, Dams, Retaining walls	871-10, 871-20, 871-30, 871-40, 871-50, 871-90
Potable Water Distribution System	345-40, 841-20, 841-30, 841-35, 841-40, 841-45, 841-50, 841-55, 842-12, 842-15, 842-30, 842-35, 843-10, 843-20, 843-30, 843-40, 843-50, 843-60
Potable Water Facilities & Treatment Plants	841-10, 841-70
Launch Pads	382-10, 382-11, 382-14, 382-60, 382-80
Launch support camera pads	382-13
Launch propellant & high pressure gas facilities	382-30, 382-31
Pavement	111-10, 111-11, 111-12, 111-20, 111-21, 111-22, 112-10, 112-11, 112-12, 113-20, 113-21, 113-22, 141-10, 851-10, 851-11, 851-12, 851-20, 851-22, 851-90, 851-91, 851-92, 852-10, 852-11, 852-12, 852-20, 852-21, 852-22, 852-30, 852-31, 852-32, 852-90, 852-91, 852-92, 860-10, 860-30, 860-40
Rail	
Maintenance Facilities and PW Shops	219-10, 219-11, 219-20, 220-10
Operational maintenance facilities	212-10, 212-20, 212-30, 212-40, 212-50, 220-14
Other Buildings	381-20, 381-30, 381-40, 381-50, 381-60, 382-15, 510-00, 641-10, 641-20, 641-30, 641-40, 711-00, 712-00, 730-10, 730-20, 730-25, 730-40, 730-65, 730-70, 730-90, 740-18, 740-26, 740-30, 740-33, 740-40, 740-43, 740-46, 740-53, 740-54, 740-56, 740-73, 740-76, 740-83, 740-88, 740-90, 740-95, 872-20, 872-30, 872-90
Other Facilities	126-10, 152-20, 152-40, 152-60, 152-90, 154-10, 154-20, 154-30, 154-90, 163-10, 163-20, 163-30, 163-90, 164-10, 164-20, 164-30, 164-90, 361-10, 361-20, 361-30, 361-40, 631-10, 631-20, 631-30, 631-40, 690-10, 690-20, 690-90, 750-10, 750-20, 750-30, 750-40, 750-50, 750-60, 750-90, 750-95, 833-10, 833-20, 833-30, 833-40, 833-90, 860-20, 860-50, 860-90, 872-10, 872-40, 872-50, 880-10, 880-20, 880-30, 880-40, 880-50, 880-90, 890-95

Land & Easements	911-10, 911-20, 911-21, 911-22, 911-30, 911-31, 911-32, 911-33, 911-40, 911-50, 912-10, 912-11, 912-13, 912-20, 913-10, 913-20, 913-30, 913-40, 913-50, 913-60, 913-61, 913-62, 913-63, 914-10, 914-20, 921-10, 921-20, 921-30, 921-40, 921-50, 921-60, 921-90, 922-10, 922-20, 922-30, 923-10, 923-20, 923-40, 923-50, 923-60, 932-10, 932-20, 932-30, 932-40, 932-50, 932-60, 932-90
Compressed Air Distribution	
Compressed Air Generation	
Prefabricated buildings, various uses	620-10, 620-90, 630-10, 630-11, 630-12, 630-14, 630-16, 630-17, 630-20, 630-21, 630-22, 630-24, 630-26, 630-27
Berthing and Housing	

I.2.2 Facility Systems

The DM facility systems were developed from a review of other DM estimating methods for facilities and ASTM E1557, Standard Classification for Building Elements and Related Sitework-UNIFORMAT II. The following nine systems were selected for the NASA DM method:

a. Structure: foundations, superstructure, slabs and floors, and pavements that are adjacent to, and considered part of, the facility.

b. Exterior: wall coatings, windows, doors, and exterior sealants.

c. Roofing: roof coverings, openings, gutters, and flashing.

d. HVAC: heating, ventilating, and air-conditioning systems, including controls and balancing devices.

e. Electrical: service and distribution, lighting, communications, security and fire protection wiring, and controls.

f. Plumbing: water, sewer, and fire protection piping, or piping for steam, gas, or water distribution in specialty systems (e.g., tanks, generation plants).

g. Conveying: elevators, escalators, cranes, and other lifts.

h. Interior: all interior finishes including wall coverings, flooring, and ceilings.

i. Program Support Equipment: equipment installed in the facility to provide support for operational testing or research. For example, additional ventilation equipment or separate HVAC systems required only to support special testing or programs.

I.2.3 Current Replacement Value and Facility System CRV Percentages

The NASA RPMS contains the CRV for each facility. Table I-6 shows how the CRV is apportioned between each of the 9 facility systems for each of the 42 NASA DM facility categories. The CRV system percentages are derived from the Parametric Cost Estimating System (PACES)[2], an accepted estimating tool for Federal construction projects. The PACES method was derived from an evaluation of more than $40 billion of Federal facilities projects.

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[2] PACES is an integrated, PC-based parametric budgeting and cost estimating system developed by Earth Tech (http://www.wbdg.org/tools/paces.php?a=1) that prepares parametric cost estimates for new facility construction and renovation. It was developed for military facility application and will soon be commercialized for use in the general building, industrial facilities, and transportation industries. PACES is available to military personnel via the U.S. Air Force. A U.S. Government employee can obtain a copy of the current military version of PACES by contacting the Air Force Civil Engineer Support Agency.

Table I-6 DM Categories with CRV Percentage Values

DM Cat	NASA_BLDG	STRUC	EXT	ROOF	HVAC	ELEC	PLUMB	CONV	INTF	EQUIP	SUM
1	R&D and Test Buildings	0.18	0.19	0.04	0.15	0.20	0.04	0.01	0.15	0.04	1.00
2	R&D Structures and Facilities	0.40	0.17	0.01	0.06	0.25	0.02	0.02	0.03	0.04	1.00
3	Wind Tunnels	0.30	0.05	0.01	0.01	0.15	0.01	0.01	0.01	0.45	1.00
4	Engine/Vehicle Static Test Facilities	0.38	0.03	0.01	0.04	0.26	0.01	0.03	0.02	0.22	1.00
5	Administrative Buildings	0.19	0.17	0.06	0.16	0.18	0.05	0.03	0.16	0.00	1.00
6	Training Buildings	0.18	0.20	0.05	0.12	0.21	0.05	0.01	0.18	0.00	1.00
7	Trailers	0.20	0.19	0.06	0.18	0.20	0.02	0.00	0.15	0.00	1.00
8	Storage Buildings	0.60	0.15	0.10	0.04	0.06	0.01	0.00	0.04	0.00	1.00
9	Storage Facilities	0.55	0.22	0.11	0.03	0.04	0.01	0.00	0.04	0.00	1.00
10	Fuel Storage Tanks	0.70	0.13	0.02	0.00	0.10	0.05	0.00	0.00	0.00	1.00

10.1	Specialized Liquid Storage Tanks	0.51	0.13	0.02	0.00	0.14	0.20	0.00	0.00	0.00	1.00
10.2	Fueling Stations & Systems	0.40	0.10	0.05	0.05	0.15	0.20	0.00	0.05	0.00	1.00
11	Magazines	0.33	0.30	0.05	0.06	0.15	0.02	0.00	0.09	0.00	1.00
12	Comm. & Tracking Buildings	0.21	0.20	0.05	0.16	0.18	0.05	0.00	0.15	0.00	1.00
13	Comm. & Tracking Facilities	0.55	0.10	0.02	0.05	0.26	0.00	0.00	0.02	0.00	1.00
13.1	Large Antennas	0.20	0.20	0.02	0.05	0.15	0.02	0.01	0.02	0.33	1.00
13.2	Small Antennas	0.50	0.30	0.00	0.00	0.10	0.00	0.00	0.00	0.10	1.00
14	Mission Control Operations Buildings	0.22	0.13	0.05	0.15	0.20	0.04	0.02	0.10	0.09	1.00
15	Lighting	0.17	0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.00	1.00
16	Electrical Distribution System	0.39	0.03	0.00	0.00	0.58	0.00	0.00	0.00	0.00	1.00
16.1	Power Generation / Power Plant	0.30	0.10	0.05	0.10	0.39	0.01	0.00	0.05	0.00	1.00
16.2	Electric Substations, Switchgear & Transfer Yards	0.10	0.07	0.00	0.00	0.83	0.00	0.00	0.00	0.00	1.00
17	HVAC Distribution	0.30	0.10	0.00	0.00	0.33	0.27	0.00	0.00	0.00	1.00
17.1	HVAC Generation	0.20	0.10	0.05	0.35	0.10	0.15	0.00	0.05	0.00	1.00
18	Waste Water Collection & Disposal System	0.50	0.02	0.02	0.00	0.05	0.41	0.00	0.00	0.00	1.00
18.1	Waste Water Facilities & Treatment Plants	0.34	0.10	0.05	0.03	0.15	0.32	0.00	0.01	0.00	1.00
18.2	Storm Drains, Ditches, Dams, Retaining Walls	0.90	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	1.00
19	Potable Water Distribution System	0.38	0.05	0.02	0.00	0.05	0.50	0.00	0.00	0.00	1.00
19.1	Potable Water Facilities & Treatment Plants	0.25	0.05	0.05	0.03	0.24	0.37	0.00	0.01	0.00	1.00
20	Launch Pads	0.51	0.10	0.03	0.03	0.25	0.04	0.02	0.02	0.00	1.00
20.1	Launch Support Camera Pads	0.80	0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	1.00
20.2	Launch Propellant & High Pressure Gas Facilities	0.48	0.05	0.02	0.00	0.20	0.25	0.00	0.00	0.00	1.00
21	Pavement	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
22	Rail	0.95	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	1.00
23	Maintenance Facilities & PW Shops	0.20	0.14	0.06	0.13	0.30	0.09	0.00	0.08	0.00	1.00

23.1	Operational Maintenance. Facilities	0.20	0.14	0.06	0.13	0.28	0.09	0.02	0.08	0.00	1.00
24	Other Buildings	0.22	0.15	0.12	0.10	0.15	0.11	0.00	0.15	0.00	1.00
25	Other Facilities	0.71	0.10	0.02	0.05	0.10	0.01	0.00	0.01	0.00	1.00
26	Land & Easements	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
27	Compressed Air Distribution	0.50	0.00	0.00	0.00	0.10	0.40	0.00	0.00	0.00	1.00
27.1	Compressed Air Generation	0.25	0.10	0.05	0.05	0.15	0.35	0.00	0.05	0.00	1.00
28	Prefab Buildings, Various Uses	0.18	0.17	0.05	0.15	0.15	0.15	0.00	0.15	0.00	1.00
29	Berthing & Housing	0.15	0.17	0.09	0.16	0.18	0.07	0.02	0.16	0.00	1.00

12.7.2 I.2.4 Estimated Repair Cost as a Percentage of CRV by System Condition

Each condition rating has a corresponding system condition CRV percentage. These percentages vary by system type and are provided in Table I-7. This table is crucial to the applicability of the DM method and, as such, was analyzed by several engineering sources. Through the use of a survey of major and minor repairs at KSC, combined with an estimated original construction cost using R.S. Means [3] estimating tools, system condition percentages have been developed for each of the nine systems for each of the five ratings. Actual repair costs for a variety of facilities at KSC, such as the Landing Aids Control Building, the cafeteria (Multi-Function Facility), Electromagnetic Lab, Operations Building #1, and Logistics Facility were used to establish the repair costs. The CRVs of these facilities ranged from $602,000 to $22 million.

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[3] R.S. Means. CostWorks 2003 Version 6.1; 1996â?"2003. R.S. Means is North Americaâ??s leading supplier of construction cost information. A product line of Reed Construction Data, R.S. Means provides accurate and up-to-date cost information that helps owners, developers, architects, engineers, contractors, and others to carefully and precisely project and control the cost of both new building construction and renovation projects.

The estimates for the various levels of repair work were compared to an estimated cost for the system construction. These comparisons (expressed as percentages) translate into the DM condition percentages used in the DM model. The process began with the 1 rating, where the cost for a major repair was established. That cost was then compared to the estimated original construction cost, producing a maximum system condition percentage. For example, a 1 rating in structure equates to 150% of the maximum repair cost of the structure of a facility including some demolition and disposal cost. The system condition percentages for 2 through 4 were then established using the same method.

Table I-7 System Condition Percentages

SYSTEM	5	4	3	2	1
STRUC	0	1	10	25	150
EXT	0	1	10	50	101
ROOF	0	9	38	75	150
HVAC	0	2	13	63	133
ELEC	0	2	13	63	133
PLUMB	0	2	10	57	121
CONV	0	2	13	50	100
INTF	0	1	10	50	101
EQUIP	0	2	13	50	100

(Percentages greater than 100 account for demolition and disposal costs.)

However, according to the U.S. Army Corps of Engineers (USACE), 50% of the replacement value is the decision point to determine whether a system should be repaired or replaced. Because a 2 rating is where this decision point falls, the USACE standard was applied as a rule, so, 2 ratings were set at a maximum of 50% of the 1 rating system condition percentage. For example, even though the calculated value for a 2 rating for roofing was 90% for KSC, the highest the rating could be is half of the calculated value for the 1 rating (150% in this case), which equals 75%, because that is when the replacement of the roof would most likely occur. The 5 rating was left at 0% because any small DM that would occur in this rating would be negligible.