Program	source	orig. number in source	Subject Area	Lesson
Skylab	1	2.2.11	Cleaning, optics	**On-Board Cleaning and Storage of Optics**. Skylab optical cleaning kits for accessible optics consisted of a mild detergent solution, distilled water, lint free cotton, brush, lens tissues and air syringe and have been successful in removing contamination from certain Skylab surfaces. However, these techniques will not remove many contaminants such as deposits outgassed from external sources. Storage of optics in both GN2 and vacuum has been satisfactory. *The capability to clean accessible optics and the development of techniques to clean remote optics are highly desirable. New techniques for contaminant detection and cleaning include Auger spectroscopy, binary scattering, metastable beams, ion sputtering and activated plasmas.*
Skylab	1	2.3.2	EVA, mobility aids	**Translation and Stability Aids for Extravehicular Activity (EVA)**. Work on the jammed Workshop solar array was hampered by the lack of emergency aids on the Workshop exterior. A handrail was devised with on-board equipment (solar shield deployment rods and a cutte head) and used as a trnslation aid to maneuver to the damaged area. *The EVA access area should not be lomited by the lack of EVA handholds or stability aids, but should encompass the entire vehicle. These aids could either be integral to the exterior design or allow for the simple attachment of portable devices.*
Skylab	1	2.6.1	IFM, design	**In-Flight Maintenance: Criteria for Design**. *Initial design concepts shoul include in-flight maintenance provisions, with the necessary design features to facilitate failure detection, isolation, corrective action and verification of repair. Provisions should be made for tools, spares, maintenance equipment and space for maintenance work. Accessibility to equipment attaching hardware, electrical connections and plumbing is imperative, even in areas where maintenance is not planned. All contingencies cannot be anticipated, but corrective maintenance action can be taken if the general design is consistent with this approach.* In much of the unplanned Skylab repair work, it was necessary to remove cover plates held in place by an inordinate number of fasteners, which were not always of the design best suited for operational removal. Allen head screws and hexagon head bolts were much preferred over other types by the crew. A substantial effort has to be spent in identifying, to and by the crew, components, cables, and tubing to be repaired or replaced. A simple system of decals should be used to facilitate identification.
Skylab	1	2.6.2	IFM, tools	**In-Flight Maintnenance: Selection of Tools**. Tools initially selected fo Skylab were primarily those required for specific tasks. A few contingency tools were included such as a pry bar, a hammer, and the Swiss Army knife, which proved to be valuable assets. Wrenches were provided only for specific applications. The crew activities and evaluation indicate a tool kit should contain all the tools normally found in a tool collection for comprehensive home usage, as well as the special tools required for special aerospace hardware. Good quality off-the-shelf hand tools are adequate and no special features are required for use in space. An improved tool caddy for carrying tools from place to place should be developed for easy location of the needed tool after arriving at the work station. Transparent material would be desirable. The caddy should also hold small parts in an accessible manner as the work is done, since containing and locating these items was a problem in zero gravity.

Program	source	orig. number in source	Subject Area	Lesson
Skylab	1	2.6.3	IFM, spares	**In-Flight Maintnenance: Selection of Spares.** Spares selection should include repair parts for critical items whose design permits in-flight bench repair, as well as replaceable assemblies. Skylab has proven that the crew, when provided the proper tools, procedures and parts, is capable of performing bench repair of failed assemblies beyond prior expectations. Although there were initially no repair parts aboard, these were provided on subsequent revisits and used successfully. A good example is the tear-down of tape recorders by the crew of SL-3 and the subsequent furnishing of repair parts and repair by the SL-4 crew. This reduced the voluem requirements for resupply by providing a few repair parts instead of an entire new assembly. This philosphy could reduce the number of primary spares required on board initially, if the capability to repair the failed items is provided. Other examples of detail repair on Skylab were the repair of the teleprinter and replacement of the printed circuit boards in the video tape recorder. The flight backup and test units on limited-production programs should be considered as spares sources within reasonable refurbishment effort, launch delay, and reprocurement time considerations.
Skylab	1	3.1.39	Fluid systems, servicing	**Reservicing Capability for Fluid Loops.** In-flight reservicing capability should be provided for critical fluid systems, especially in long-duration missions.
Skylab	2	14	Spares	**Lack of Spares.** *It is not always economical to provide only one flight article without a ready spare* . Background: As a cost avoidance measure, back-up flight units were eliminated from the experiment development programs in most instances. Since many of the experiments interfaced directly with the major flight modules, when an experiment malfunctioned during prflight test, a back-up unit could not be immediately substituted, thereby permitting the readiness work to flow uninterrupted. Instead, the failed experiment had to be removed, analyzed, repaired, reverified, and reinstalled. In th emeantime, the main hardware test sequences were stopped or work-around procedures developed. The former course was, of course, unacceptable while the latter course necessitated multiple planning sequences and was, therfore, costly.
Skylab	2	40	Prevetive maintenance, lubrication	**Lubrication of Rotating Machinery.** If possible, positive lubrication methods should be included in the design of lon-life rotating machinery, such as control moment gyros. Background: Two of the Skylab CMG's experienced bearing anomalies (temperature increases) and one (CMG #1) failed on day 194. Analysis indicates that poor lubrication caused bearing failure. The CMG's were designed with an automatic lubrication metering system which was chosen to minimize the need for active control, to maximize bearing life, and to prevent contamination by containing all oil. Life tests conducted on the ground far exceeded the required life. In retrospect, it appears as if the forces on the oil in zero gravity caused it to seek different locations than in one-g where full lubication was possible. Since fluid flow in zero-g is not yet fully understood, it appears prudent to design a system with positive control.
Skylab	2	45	Design, fluid lines	**Eliminate B-Nuts. Braze all Fluid Lines.** *All plumbing should be brazed or welded and B-nuts (mechanical connections) should be used only when no other solution is possible in order to minimize the number of joints where leakage can occur* . Background: Skylab used B-nut fittings extensively on the airlock module coolant loop. This allowed for ease of manufacturing but it was impossible to a ssure a complete seal. Despite stringent controls during manufacture, a coolant loop leak developed in flight. The location of the leak was never discovered but it could have been internal to the cabin (a trace of coolant was found in the ECS charcoal absorber whic was brought back for analysis).
Skylab	2	46	Design, fluid lines	**B-Nuts.** *Where B-nuts must be used in fluid lines, insure that a known torque can be applied during assembly and that the torque can be rechecked later. Design in a positive lock to insure that launch vibrations do not loosen the nut. Do not safety wire two movable parts (e.g. nuts) together* . Background: The CSM RCS line leak probably stemmed from a B-nut whic was not properly installed and torques. Subsequently, checking of B-nuts on later vehicles revealed that the torque was difficult to apply, was hard to measure, and in many instances, was below specification value. Some of the nuts could not be chacked because of the location. At least one instance was found where safety wire was installed in such a manner as to not inhibit opening of the nut.

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Skylab	2	47	Design, fluid lines	**Fluid Lines and Cables.** *Insure that fluid lines and cables cannot inadvertantly be installed backwards* . Background: The Skylab 3 CSM developed a leak in the RCS oxidizer line (in the thruster housing) because of a series of misadventures which began with the installation of the plumbing upside down, which prevented a good fit. Cables should also have indexed connectors which will prevent adjacent cables from being interchanged.
Skylab	3	SLL No. 1-1	IFM, crew	**Man as Scientific Observer and In-Flight Repairman.** The Skylab missions demonstrated that man can serve as a scientific observer and in-flight repairman to a substantially greater extent than anticipated before the first Skylab mission. The crews found that the absence of gravity was not a hindrance in performing their planned activities. In many respects, the crews were able to do more than expected. Background: Before the Skylab missions, there were uncertainties as to the ability of the astronauts to perform in-flight repairs (either scheduled or unscheduled). The Skylab experience showed that the crews were not hampered by the lack of gravity in any restrictive way. Suitable restraints were needed for all tasks, but existing structure frequently served as suitable restraint.
Skylab	3	SLL No. 1-2	IFM	**In-Orbit Repair and Maintenance.** In-orbit repair and maintnenace can be performed satisfactorily in zero g. In flight maintenance guidelines should include the following: 1. Consider extravehicular activity (EVA) as a normal means of repair. 2. Provide proper procedures, tools, and equipment for crew usage. 3. Design equipment to facilitate potential in-flight maintenance. 4. Consider EVA inspection and repair during the design requirements phase of a program. 5. Provid for the effective containment of nuts, bolts, washers, tools, hardware components, etc., by means of tool and/or retainer boxes, bungee cords, etc. 6. Provide for a worksite, repair bench, or equivalent equipped with adequate restraints for tools and equipment. 7. Provide spares for those hardware items most likely to require servicing and/or replacement. 8. Promote the use of standard-size screws, bolts, etc., in the spacecraft design. 9. Provide a high-fidelity maintenance training simulator. 10. Provide the capability to reservice fluid and gas systems from the interior of the spacecraft. Fluid/gaseous connectors (B-nuts, weld or solder joints) should be located and configured such that they can be inspected by the crew for leaks. 11. Design panels to allow replacement of indicator lights from the front of the panels. 12. Design external protective covers for experiments and other
Skylab	3	SLL No. 1-11	Facilities, on-orbit	**Writing and Worktable for In-Orbit Use**. Frequent and extensive paperwork activities were required on board Skylab to update checklists, flight plans, etc., and to accomplish routine experimental and operational logging requirements. A suitable writing table or workstation is needed at which this type of activity can be effectively perfomed. A table or workstation is also needed to accommodate maintenance items to be disassembled. It should be equipped with some method of restraining multiple small components during the maintenance task. Background. Writing and managing multiple piece parts in zero g are difficult chores in that environment. Excessive time is consumed doing such routine and simple tasks when proper facilities are not available. The wardroom table did not serve the required purpose because it did not include the tpe of restraints needed for books and papers. Also, the need to prepare and consume food and to clean up afterwards limited the times whenthe table was available.
Skylab	3	SLL No. 1-15	Design, standardization	**Standardization of Hardware**. Crew-use hardware such as fasteners, electrical and plumbing connectors, switches, circuit breakers, and screws, etc., should be standardized as much as possible to facilitate crew operations, reduce crew errors, and reduce crew training requirements. Each common usage also reduces total sparing levels. This approach will simplify design, documentation, sparing, and actual in-orbit usage. Background. With many different types of devices to manipulate, the crew will require more extensive training and is more likely to make errors. These errors could result in lost data, damaged equipment, or in the worst case crew hazards. Minimizing the number of different types of devices will reduce the chance of error and may result in cost savings by limiting inventory requirements.

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Skylab	3	SLL No. 1-18	Facilities, ground	**Maintenance and Repair Depot for Experiment Hardware**. Provide a depot repair, maintenance and modification capability for delivered experiment hardware. Schedule and manpower expenditures were minimized because of the quick turnaround capability afforded by the depot concept of operation and the physical location of the depot in relation to the receiving and shipping docks. The ability to repair items in the depot or to go directly to the proper specialty manufacturing area within the company greatly enhanced the time it took to achieve needed repairs. Subsequent repairs and tests were accomplished more efficiently because of the experience of the personnel involved. The depot provided a suitable location for the mission support testing to assist in the investigationof in-orbit anomalies during the Skylab missions. Background. The Skylab depot was a dedicated enclosed area located within the inventory building at the Martin Marietta Corporation Denver plant. It was established to suport the NASA Lyndon B. Johnson Space Center experiment repairs and modifications. Reference: Skylab Program, Postdelivery Operations plan, JSC-03137.
Skylab	3	SLL No. 2-68	Design, avionics	**Use of Swaging Technique in Lieu of "Z" Wires on Printed Circuit Boards**. It is recommended that a swaging technique be used instead of "Z" wires as interfacia connections through plated-through holes in printed circuit (pc) boards. This technique offers the following advantages over "Z"wires: 1. Easier and faster installation; 2. Less damage to printed wiring circuits because of tool slippage, sharp wire edges, etc.; 3. No rework of "Z" wires turning away from the circuit pattern during reflow soldering; 4. Simplified removal of the through connector; 5. No decrease in effectiveness of the interconnection. Background. Rework of any printed wiring connection necessitates the application of heat and someforce to effect component replaceent on PC boards. During rework of the S94 printed wiring boards, a combination of these factors caused liftoff lands when the tolerance of the land to adhere to the board was exceeded. The lands lifted when "Z" wires were removed to allow the addition of hard wires for engineering changes. The swaging technique, which subsequently proved very successful, was implemented to facilitate PC board changes and to prevent lifting of the land.
ISS	4	N/A	Requirements	**Availability Requirements and Manufacturer Accountability**. In negotiation between government and contractor over hardware requirements, poorly written requirements caused a bad situation for both sides. Design solutions that catered to weight/cost savings degraded maintainability. Most maintainability/reliability requirements were really stated as goals, so when contractors asked for changes, the results would be poorly stated goals. If requirements had been written as requirements, then negotiation would have concerned revising requirements based on what the designers felt they could have delivered versus what the government expected. Government would still have had quantifiable requirements against which to measure contractor performance.
ISS	4	N/A	ILS	**ILS Process**. Program should adopt an ILS process as well as an ILS product format. MIL-STD-1388-1A is a detailed process to define, refine and provide for up front system support. The program, in levying 1388-2A without 1A, levied a format without the analytical/management process to back it.
ISS	4	N/A	ILS	**ILS Manager**. The manager in charge of ILS should be in a senior-level position and should be dedicated to this function. Organizations that are successful in developing supportable systems at reasonable costs have a high level ILS manager.

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ISS	4	N/A	ILS	**Maintenance Concept.** A maintenance concept must be defined at the earliest stages of a program. It is the maintenance concept that drives how the system will be supported. It affects all functions, including operations. In all books and discussions about Logistics, the maintenance concept is one of the first things that is discussed. It is from the maintenance concept that all your support comes. It lets everybody know what you intend to do when you have a failure. If you want to affect your design, reliability, maintainability, robotics, sparing, resupply, tech manuals, facilities, manpower and personnel, training and PHS&T then you have to say how you intend to do maintenance at ALL levels of maintenance.
ISS	4	N/A	Repair, ground	**Repair by Government vs. Contractors**. In the beginning of a program, it is usually cheaper to have contractors repair the hardware. They have the necessary tools, test equipment and people in place to the job. No start up costs. If you want the Government to do the repair right from the beginning you will have to pay the start up costs, i.e., facilities, tools, test equipment, training, manuals, people etc. In this scenario, you will have some overlap and be paying double for a while. If you rely strictly on the contractors for the life of the program, then your down stream costs will usually be more, especially on a small quantity program like this. You'll be paying for the contractor to keep someone and something around to do the infrequent repairs. The best scenario is to have the Government repair the items at a facility that is already established to do the repair and all they have to do is expand their current scope of work.
ISS	4	N/A	ILS	**Operations concept**. This should be in conjunction with the maintenance concept.
ISS	4	N/A	ILS	**Concurrent Engineering**. Assign/co-locate experienced Logisticians to the product design teams. These Logistics engineers can provide supportability perspectives to the design environment real time. Instead of assessing designs, they can concurrently contribute to the designs.
ISS	4	N/A	ILS	**Design Supportability Responsibility**. As a Logistician, avoid assuming the responsibility for design supportability. It is not the responsibility of the Logistician to ensure this design is supportable. If you do, then you become another design characteristic advocate, and may find yourself in an adversarial role with the designer and other design requirements/demands. Design supportability is the responsibility of the overall program (Program manager and the Chief Engineer). The Logistician should provide the tools to identify and quantify the supportability of a system. He/she should be the trainer and the consultant.
ISS	4	N/A	ILS	**Early ILS Education for the Program**. Communicate to program and engineering management, at the start of the program, the roles and contribution of ILS. Challenge the paradigm that ILS is spares and deferrable. Emphasize supportability contribution (MIL-STD-1338-1A) and the systems approach. Challenge and change the culture.
ISS	4	N/A	ILS	**ILS Personal Training**. Design the ILS program from the start to integrate Logistics product development and personal training. The Logistics Supportability Assessments proved to be a satisfactory self-teach tool as they forced the Logistician to learn the hardware under analysis (drawings and specifications); communicate with the product/design engineers; understand supportability concepts including Life Cycle Costs (LCC) maintainability, support equipment, operating environments, reliability, overhaul and repair, levels of maintenance, spares and maintenance documentation; then effectively write the results of the analysis and brief their peers, management and the project engineer.
ISS	4	N/A	Requirements	**Verifiable Logistics Design Requirements**. Ensure that when specific design-to requirements are inserted into the design specifications, that they are verifiable. Never use "as a design goal", always use "shall".

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ISS	4	N/A	Requirements	**Logistics Requirements Flowdown**. Locate, understand, and document all Logistics requirements from the highest program document down to the lowest. Prepare a tracking system to follow their fulfillment through PDR and CDR.
ISS	4	N/A	ILS	**System Engineering**. Ensure that Integrated Logistics System (ILS) is an element of the system engineering process. System engineering often is performed on the flight hardware only and fails to consider the complete system, which includes design supportability maximization to minimize life cycle costs, especially in the operational phase. Essentially, the design must perform efficiently in the flight and the operational support environments.
ISS	4	N/A	Design	**Design for Robustness**. It has been observed that we generally design to meet the minimum design requirements. There is a belief that robustness costs money or adds weight. The customer expects the product to survive. Robustness is a feature to minimize life cycle costs.
ISS	4	N/A	ILS	**Quantify Design Supportability**. Design supportability is often subjective. At best, it can be articulated using Life Cycle Cost figures. But, in the design development phase, a method is needed to score designs for their supportability characteristics. This scoring method must be designed to be as objective as possible. Additionally, for this to be effective, program/engineering management and the customer must recognize and use this tool.
ISS	4	N/A	ILS	**Contract Incentives for Supportability**. Realistically, to ensure that supportability is weighed equally in the design trade enviroment, the customer must provide equal award incentives for this characteristic. It has been observed that when the incentives were placed sequentially on weight, power availability, cost, or schedule, the big loser was always design supportability and Life Cycle Cost.
ISS	4	N/A	Design, obsolescence	**Design Obsolescence**. This feature should be addressed in all supportabilty assessments. This allows better palnning for spares. High risk parts are integrated circuits.
ISS	4	N/A	Design, commonality	**Interchangability and Commonality**. When dealing with a modular design such as SSF, interchangability and commonality of hardware should be adhered to as closely as possible. Total spares program costs can be greatly reduced by increasing commonality of components within different assemblies. Vendor discounts for larger purchase orders, along with reduced engineering efforts would account for the majority of these savings. The draw back to this approach is possible loss of specific hardware performance characteristics due a reduction of exotic hardware types.
ISS	4	N/A	ILS	**LSA Tailoring**. This is a critical activity to ensure that the customer gets what he needs for what he can afford. Both the LSA [Logistics Support Analysis](1388-1A) tasks and the LSAR [Logistics Support Analysis Record] (1388-2A/B) data elements must be addressed. Think and be lean. The more data that must be created, the more configuration management and resources are needed to maintain it. If it goes obsolete, it is useless.
ISS	4	N/A	ILS	**Duplication of LSAR and Manuals**. In the CALS/electronic data management enviroments, it is inefficient to create these two maintenance documents. One or the other. We enhanced the fidelity of the LSARD records to incorporate detailed procedural information (cautions/warnings) and validation information.
ISS	4	N/A	ILS	**Subcontractor Data Requirements DRs.** Develop detailed data requirements documents for the subcontractors. The DRs should provide in detail the LSA products (LSA trade studies, RCM, RLA, and LSAR) as well as RSPL and maintenance manuals. Develop the DRs similar to the DoD Data Item Descriptions.
ISS	4	N/A	ILS	**Early Subcontractor Activity.** Brief the subcontractor program management/engineering at the beginning of the program on the role of ILS in design supportability, specific design requirements expected, the supportability scoring system, and deliverable ILS products. This objective is to ensure they do not continue with the old Logistics paradigms.

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ISS	4	N/A	ILS	**Subcontractor ILS Program Reviews.** Conduct regularly scheduled ILS product meetings/telecons with the subcontractors. These meetings should be formally structured to status product development progress and supportability issues. This will ensure that the subcontractor remains in the main-stream of the program.
ISS	4	N/A	Spares, acquisition	**Subcontractor and NASA Spares Contract.** Place into the statement of work a requirement to plan for spares. Spares Acquistion Integrated with production (SAIP) planning should be a requirement and should be reflected in their schedules. Impacts caused by schedule slips should be addressed. It is important that this be in the SOW and not buried in a plan of a secondary requirements document. Hold the subs accountable to present this at each Program Management Review (PMR).
ISS	4	N/A	Spares, vendors	**Vendor Availabilty.** Make this an early issue with program management. This impacts spares availability and LCC. Program Office and Logistics should be appraised of any potential loss of vendors, especially before spares orders are let.
HST	?	N/A	ILS	**Assess Criticality of Failure to HST.** Develop a rating system to assess the effects of failures: a. Failure results in mission termination; b. Failure could cause uncorrectable decrease in science data throughput/quality; c. Failure will force operational work-arounds to maintain same level of science throughput/quality; d. Failure can be dealt with only minor inconveniences; e. Failure has no impact on science yet decreases overall observatory redundancy or flexibility.
HST	?	N/A	Failure response	**Trade Off Ways to Substitute ORU Functionality.** Replacing an ORU with its spare is not always the preferred solution. Substituting its functionality within another unit may be the best approach.
HST	?	N/A	Failure response	**Value of flexibility in response to failures**. Some of the on-orbit failures experienced by HST have not been predicted. Flexibility is the key to handling these situations.
HST	?	N/A	Design, changes	**Timing of design changes**. Incorporation of different technology/design modifications late in the design cycle. - Earlier is always better. - Late changes may have system impacts that cannot be fully evaluated.
HST	?	N/A	Environment	**Impact of unanticipated environmental effects**. Unanticipated enviromental effects resulted in significant anomalies.
HST	?	N/A	Upgrades	**Strategy for upgrades**. Leave “Hooks” in the design for possible incorporation of such evolving technologies that could take advantage of on-orbit performance margins. - Identify users that could benefit from on-orbit margins. - Assess possible new technologies to accommodate the above and Identify their potential interfaces. - Formulate a technology infusion strategy and plan.
HST	?	N/A	Design, Standard	**Standard interfaces**. Avoid mission unique interfaces wherever possible. Standard interfaces allow a wider range of advanced technologies without impacts to other subsystems.
HST	?	N/A	Design life	**Life extension**. Consider the possibility of extending life tests for units which exceed their specific flight lives and show no anomalous behavior.

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HST	?	N/A	Knowledge transfer	**Corporate knowledge**. Establish mechanisms for training/cross-training new or replacement personnel. Provide means for passing on “Corporate Memory” from the original hardware and software architects and designers. Do not rely solely on documentation.
HST	?	N/A	Design, Standard Osolescence	**Replacements for obsolete items**. Avoid mission specific interfaces. Standard interfaces allow more flexibility for cases where failed units’ vendor go out of business and a comparable unit must be used as a replacement.
HST	?	N/A	Configuration management, Hardware	**Configuration management of on-orbit hardware**. Configuration management becomes more critical, and harder to implement with mission life. All crew activities affecting configuration need to be carefully recorded and cycled into the configuration management system (on-orbit H/W, simulators, spares, models and requirements validation that relied on model inputs).
HST	?	N/A	Anomaly resolution	**Infrastructure to support anomaly resolution**. Establish and maintain an infrastructure for the resolution of failures and anomalies. This infrastructure should incude: Team Members; Simulators; Analysis tools and databases for rapid troubleshooting; and a Process for feed-back into hardware/operations. The team should consist of operations personnel and hardware personnel all of whom have previously mentioned cross-training with original hardware and software designers. High fidelity mechanical and electrical simulators - the fidelity of the simulator will be crucial during an anomaly investigation. Maintain up-to-date subsystem analytical models, tools and databases for quick evaluation. Once again, fidelity is crucial during these efforts.
HST	5	N/A	Facilities, on-orbit	**Servicing system design**. The servicer system (launch accommodations, replacement hardware, crew and robots, handling equipment and tools, operations procedures) provides the means needed to service the facility as is. The facility is typically built optimally for its mission purpose, and may or may not have accommodations for servicing.
HST	5	N/A	Facilities, on-orbit	**Design for supportability**. The facility architecture should accommodate interfaces for servicing interventions, including enhancements, repairs, addition and expansion, with minimal impact to mission purpose or overall cost.
HST	5	N/A	Facilities, on-orbit	**System supportability design integration**. Servicer-facility design integration for compatibility may be limited, since the separate contributing organizations may have their own goals and requirements, and their common mission is a subset of their respective overall missions.
HST	5	N/A	Design	**Reliability**. Design and build reliable hardware.
HST	5	N/A	Configuration management	**Life cycle configuration management**. Document (via text, drawings, and photographs) the original build carefully and completely. Maintain the as-serviced documentation.
HST	5	N/A	Design, diagnostics	**Built-in test**. Design built-in test capability and instrumentation from the start.
HST	5	N/A	Design, operations	Provide more than one way to do every critical operation, including safety and mission performance.
HST	5	N/A	Design, operations	Provide alternate means of operation and protection during servicing. Provide means to disable automatic functions and use workaround or rebuilt operations.
HST	5	N/A	Design	**Docking and berthing systems**. Design large capture envelopes and converge through stages of closure to attain required final alignments.

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HST	5	N/A	Design, standard	**Cost-benefit of standardization**. Standardized interfaces provide a generalized versatility. The true cost/benefit has to be assessed case-by-case in terms of mission goals.
HST	5	N/A	Facilities, ground	**Ground testbed**. Maintain a high-fidelity ground test bed and database for software, electrical, and mechanical compatibility testing and for training.
HST	5	N/A	Spares	**Spares inventory**. Maintain an inventory of spare modules and the ability to rapidly develop replacements, including testing capability.
HST	5	N/A	Test	**Testing**. Test, test, and retest. Understand the real hardware limitations and capabilities.
HST	5	N/A	Operations, training	**Training**. Train, train, and retrain. Build robust procedures and extensive contingency plans, and enough hardware to use them. Develop thorough familiarity with hardware and procedures.
HST	5	N/A	Knowledge capture	**Corporate knowledge**. Structure staff into teams which share detailed knowledge and cross-support each other constantly. Use this structure to develop ongoing in-depth expertise among newcomers before senior people move on.
HST	5	N/A	ILS	**Life cycle perspective**. Review all subsystems and systems limitations, capabilities, and operations from a mission life cycle viewpoint.
HST	5	N/A	ILS	**Risk assessment**. Estimate risk/payoff trades fairly from a comprehensive viewpoint. Note that lack of knowledge does not constitute knowledge of danger or anything else.
HST	5	N/A	Anomaly resolution	**Robust anomaly response capabilities**. Prepare to handle real surprises with a generalized capability and a flexible replanning organization. It will be necessary to quickly understand the real issues at stake, the real costs, and the real possibilities.
HST	5	N/A	Anomaly resolution	**Value of human presence**. Human presence in-situ will provide benefits otherwise unobtainable (perception, interactive investigation, assessment, real-time response, anticipation, replanning, etc.).

ref. 1. NASA-TM-X-64860, MSFC Skylab Lessons Learned, 1974.

ref. 2. NASA-TM-X-73073, Skylab Lessons Learned as Applicable to A Large Space Station, 1976.

ref. 3 JSC-09096, Lessons Learned on the Skylab Program, 1974.

ref. 4. W.W. Robbins, International Space Station Program Office, internal memorandum, 2001.

ref. 5. R. Moe, internal memorandum, 2000.