National Aeronautics and Space Administration

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2022 Cost and Schedule Symposium

Eric Plumer I 2022 Version

Cost Analysis Data Requirements document (CADRe)

2022 Cost and Schedule Symposium

Eric Plumer

April 27, 2022

Agenda

Section	*Slide*
I. CADRe Overview and Execution, Inputs/Outputs *Provides overview of Cost Analysis Data Requirement* *Contains information on the organization of a CADRe document*	4-15
II. CADRe Policy Improvements *Provides status on CAP for Class D/Cat III, New NPR 7120.5F and new CAP Initiative for FFP.*	16-21
III. CADRe Recent Progress *Provides status of recently completed CADRes*	22-24
IV. CADRe Resource for Analogous Missions *Provides understand of available CADRes to support analogous mission comparisons.*	25-31
V. CADRe Work In-Process/Forward Work *Provides a clear understanding how CADRe is a foundational document for PP&C analysis at NASA.*	32-43

Overview of CADRe

- **What is CADRe:**
  - The CADRe is a means to collect and track, by Milestone, a project's historical programmatic, technical, and cost information.
  - CADRe consists of three parts:
    - **Part A:** provides general descriptive information
    - **Part B:** provides technical data
    - **Part C:** contains project cost, schedule, and risk data
  - The CADRes are stored in the One NASA Cost Engineering (ONCE) database to facilitate expansion of the NASA cost, schedule, and technical communities.

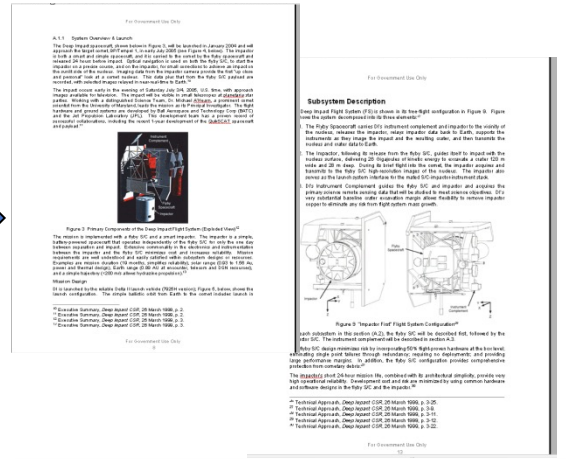
CADRe is an essential component to NASA cost estimating and a key pillar for programmatic stewardship

- **Why is CADRe important:**
  - CADRes describe project mission and approach that facilitates understanding of what is driving costs.
  - Serves as a baseline document for NASA cost, schedule, and technical communities.
  - The CADRe contains actual & verified technical data that tend to drive costs.
  - Data helps better estimate future similar projects.
  - Facilitates consistent Agency data retrieval for a given project.

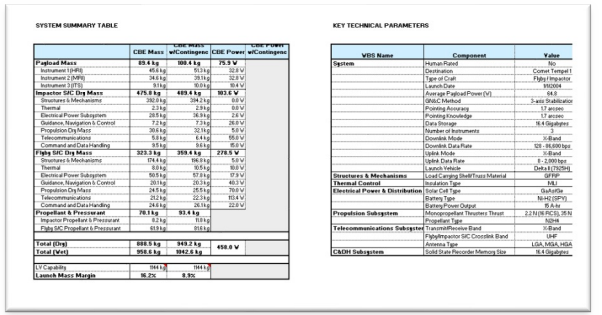
CADRe acts like a FLIGHT RECORDER for Projects

What Can I Get From CADRe?

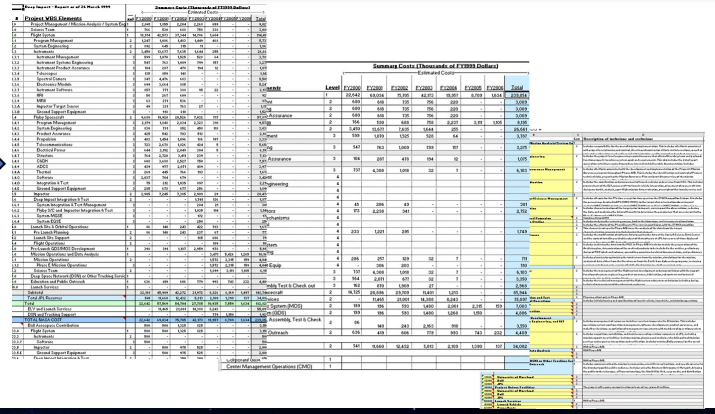
- Part A (Word Document)
  - Quick understanding of the project
  - Changes that occurred between milestones during development are documented
  - Context on the complexity of the project and new technology



- Part B (Excel Workbook)
  - Spacecraft and Payload Technical Parameters including detailed mass, power and many other parameters
  - Software cost driving parameters & metrics
  - Risk Class, Mission Cat, Design life, Contractor infor, Heritage Ratings, Power modes



- Part C (Excel Workbook)
  - Life Cycle, Cost Estimates
  - Risk Posture, Risk Registers
  - Summary and detailed level Schedule data
  - Cost Assumptions, BOEs



Importance of Part A's

RECENT REQUEST:
Find the wet mass for AIM, IBEX, THEMIS, FAST, GALEX, IRIS, NuStar, CYGNSS, TROPICS

Part As showed that only IBEX and THEMIS had Propulsion System (thrusters, tanks, propellant) and therefore any wet mass. All others maintain Attitude Control through reaction wheels and torque rods

- AIM - *Reactions wheels, magnetic torquer bars*
- NuStar - *Four Goodrich 16B32 reaction wheels, Three Goodrich 300 m2 electromagnetic torque rods*
- GALEX - *Reaction wheels, magnetic torquers*
- FAST - *Magnetic torquer coils*
- IRIS - *Reaction wheels and torque rods*
- CYGNSS - *These micro-sat spacecraft do not contain onboard thrusters and therefore depend solely on differential drag to achieve all delta-velocity.*
- TROPICS - *The TROPICS CubeSats do not use a propulsion subsystem. Instead, attitude control is handled with reaction wheels and torque rods.*

CADRe
Follows & Improves on Best Practices

Technical Baseline for Cost Analysis

- Establishment of realistic Technical Baseline is a very critical part of the estimating process.
  - **NASA ➡ Cost Analysis Data Requirements (CADRe)**
    NASA Procedural Requirement (NPR) 7120.5F
  - DOD ➡ Cost Analysis Requirements Description (CARD)
    DoD 5000.4M
  - Intelligence DNI, NRO ➡ Intelligence Capability Baseline Description (ICBD) IC Policy Guidance (ICPG) 105.1
  - Homeland Security ➡ Cost Estimating Baseline Document (CEBD) DHS Acquisition Instruction #102-02-001
  - DOE ➡ Conceptual Design Report DOE Estimating Guide 413.3-2

Agencies use a Technical Baseline Document to perform Cost and Schedule Analysis

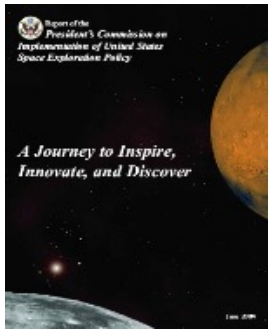
CADRe Policy History

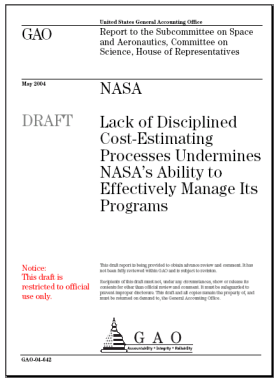
CADRe a NASA requirement in 7120.5

NASA Initiates Improvements for Agency Wide Cost and Schedule Estimating Practices

2003 CAD Established

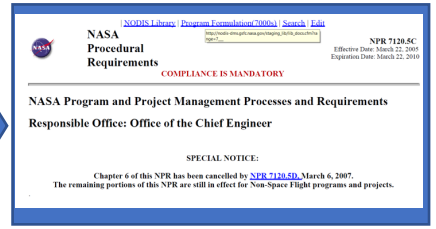
- Early Concepts of CADRe design
- Early socialization of CADRe to Centers and JPL/APL





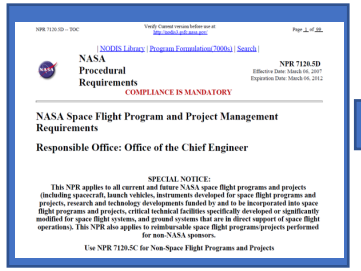
2004 GAO and Aldridge Commission Recommendations

- NASA needs to establish standard LCCE framework
- NASA needs to maintain database of historical cost information
- NASA needs to Include cost risk analysis as part of LLC reviews
- NASA needs Independent cost estimating activities



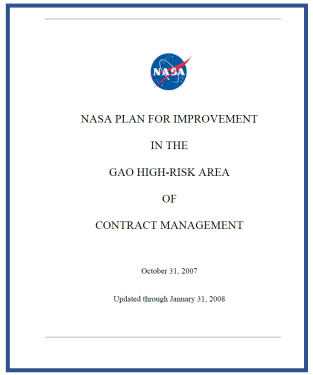
7120.5C (2005)

- CADRe formally established
- CADRe is NASA's version of the DoD CARD
- For CAT I and CAT II Projects



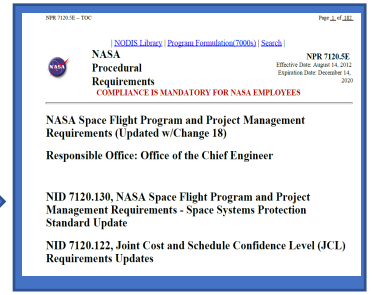
7120.5D (2007)

- For CAT I and CAT II Projects
- Defines CADRe Parts A,B,C
- Defines Milestones for Delivery



2007 GAO High Risk Corrective Action Plan

- CADRe is NASA's process to ensure more realistic cost estimates. Collection and dissemination of planned and actual project descriptions, technical driver data, schedules, and costs through the CADRe document



7120.5E (2012)

- Adds SIR (KDP-D) CADRe
- CADRe details moved to PM handbook

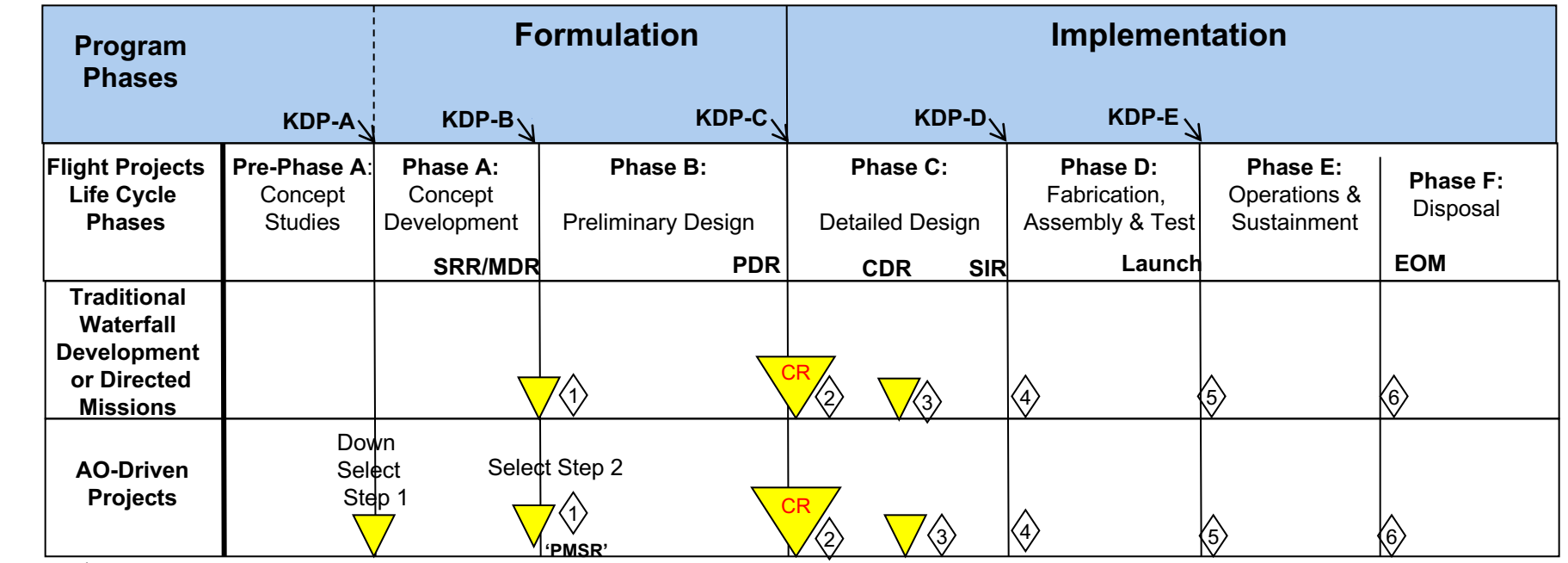
7120.5F (2021)

- CADRe Req'd for all flight projects regardless of CAT or CLASS

CADRe scope increased with each release of 7120.5

CADRe Execution

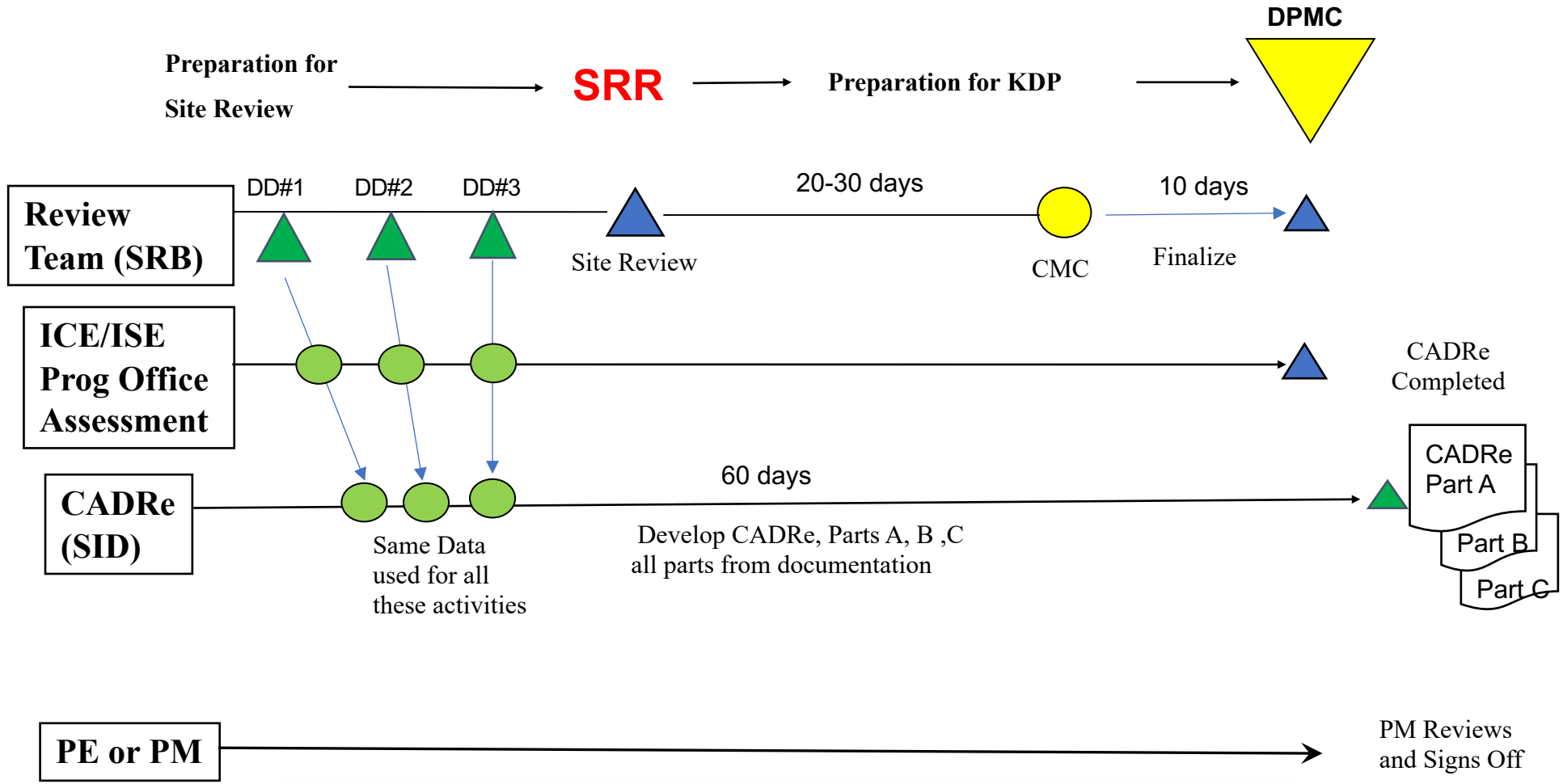
When are CADRes Required?



Legend

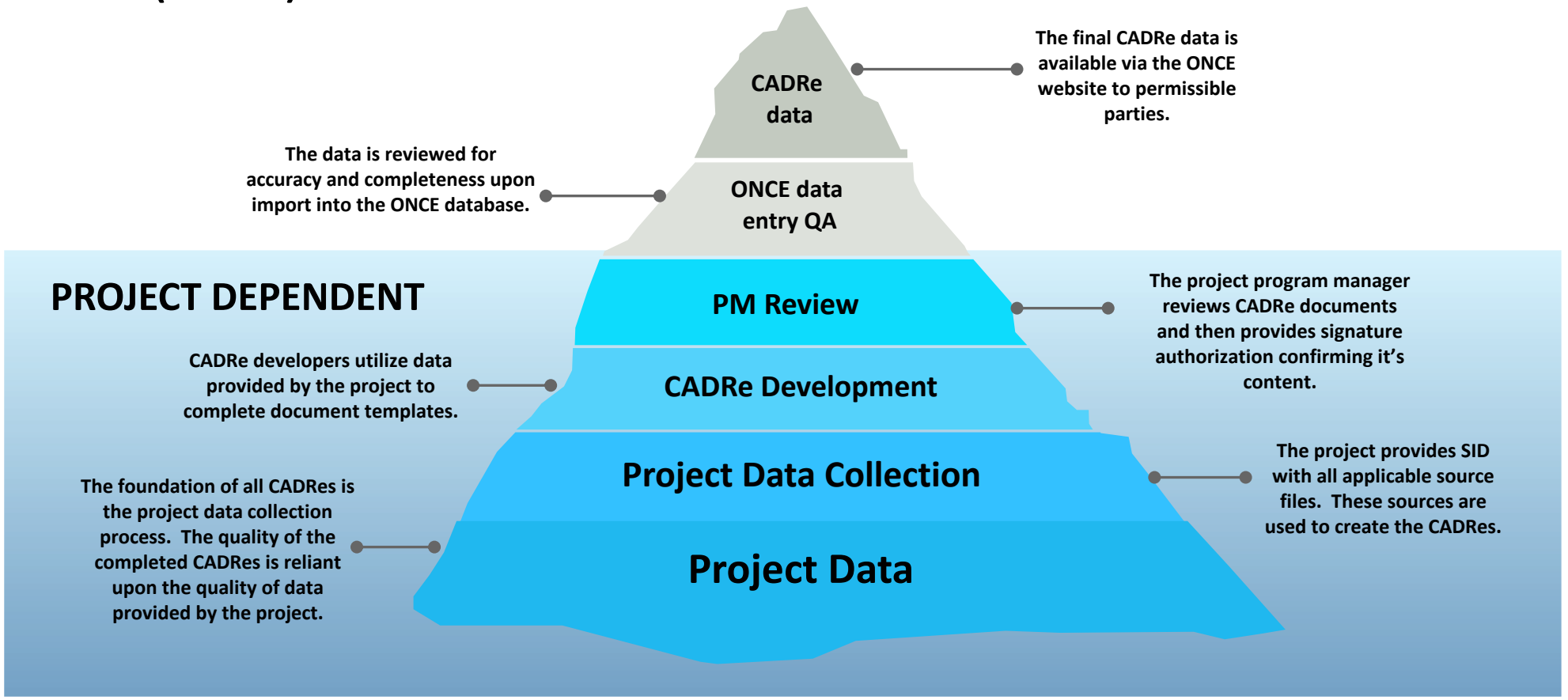
- Mission Decision Review
- (1) CADRe provided to project 30-45 days after KDP-B using SRR/MDR/PMSR material
- (2) CADRe updated to project 30-45 days after KDP-C using PDR material.
- (3) CADRe updated to project 60 days after CDR.
- (4) CADRe updated to project 30-45 days after KDP-D using SIR material.
- (5) CADRe provided to project approx. 90 days after launch using 'as built' mass and final development costs.
- (6) Update Part C only at the End of Planned Mission to capture final MOS/GDS costs.

CADRe Rhythm



CADRe is prepared in parallel with review cycle

CADRe Dependency On Projects



CADRe Inputs and Outputs

What Is Needed to Build a CADRe (Inputs)

Part A: Descriptive Information

- Project Plan
- Acquisition Plan
- System Engineering Mgt Plan (SEMP)
- Architecture Description Document
- Risk Mitigation Plan
- Software Management Plan
- Concept of Operations
- Concept Study Proposal (if applicable)
- Milestone Briefing Packages (SRR, PDR, CDR etc)
- Subsystem Briefing Packages (SRR, PDR, CDR etc)
- Instrument Briefing Packages (SRR, PDR, CDR etc)
- Mission Assurance Implementation Plan (MAIP)
- Monthly Status Reports

Part B: Technical Data

- Master Equipment Lists (MEL)
- Power Equipment Lists (PEL)
- Other Mass Property Reports
- Software Metrics (Source Lines of Code or other)
- Technical Performance Measures (TPMs)
- Documented TRLs and assumptions

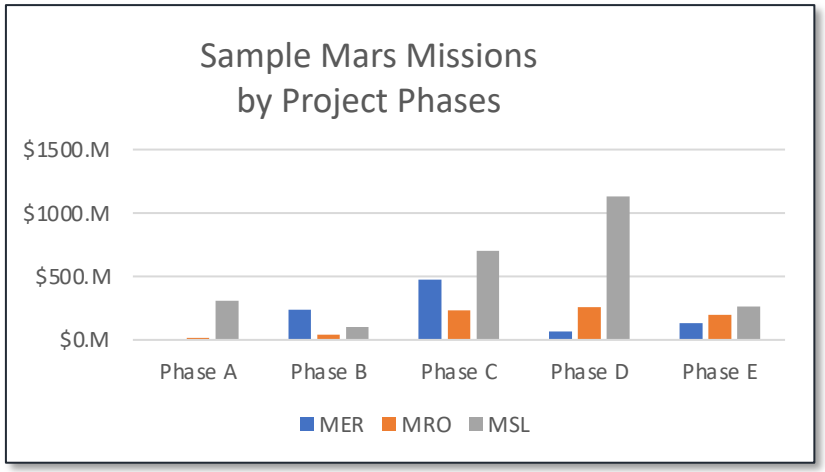
Part C: Programmatic Data

- Project Life Cycle Cost Estimate LCCE (WBS, FY, Phase)
- Risk 5X5s and Risk Registers
- WBS Dictionary
- Schedules (Gantt Charts and IMS- MS Project Files)
- Work Force (FTEs and WYEs) and Prime Workforce if avail
- Ground Rules and Assumptions

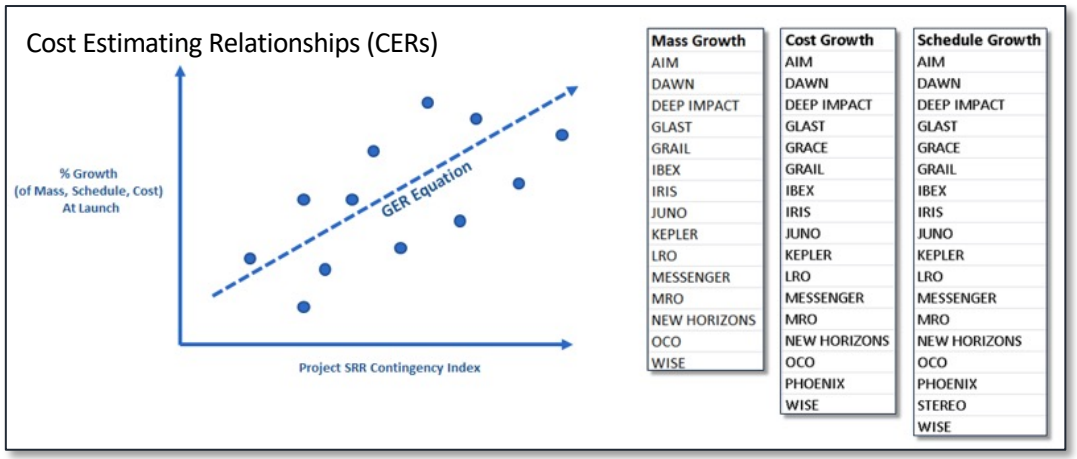
Amount of Documentation Varies with Project Size, Class, and Category

CADRe Sample of Analysis (Outputs)

Analogy Estimating



Cost Models



Mass Growth
AIM
DAWN
DEEP IMPACT
GLAST
GRAIL
IBEX
IRIS
JUNO
KEPLER
LRO
MESSENGER
MRO
NEW HORIZONS
OCO
WISE

Cost Growth
AIM
DAWN
DEEP IMPACT
GLAST
GRACE
GRAIL
IBEX
IRIS
JUNO
KEPLER
LRO
MESSENGER
MRO
NEW HORIZONS
OCO
PHOENIX
WISE

Schedule Growth
AIM
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GRACE
GRAIL
IBEX
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KEPLER
LRO
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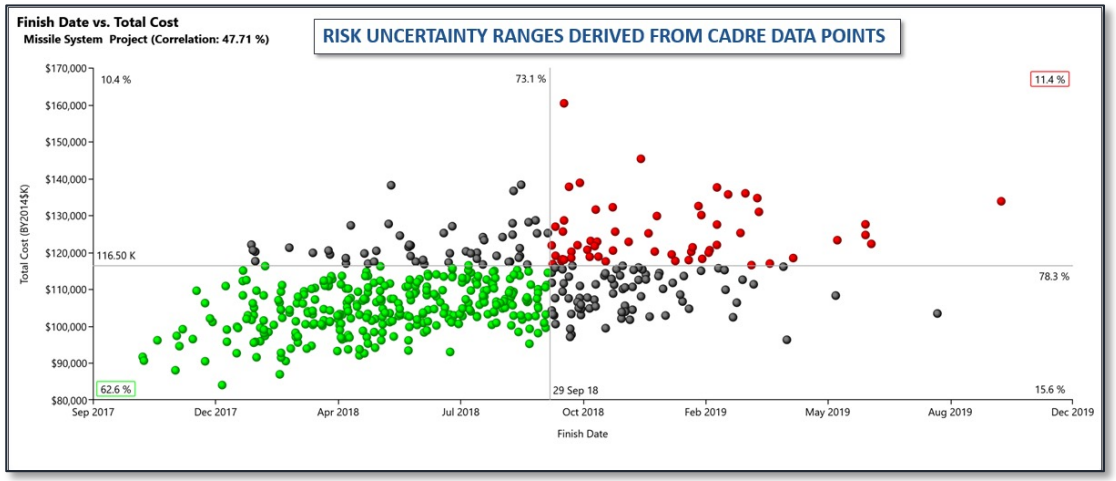
MRO
NEW HORIZONS
OCO
PHOENIX
STEREO
WISE

Joint Confidence Level Analysis



Milestone Metrics

	SMEX	MIDEX	Discovery	SMEX	SMEX	ESSP	MIDEX	
NASA CADRe Database	NuSTAR	WISE*	Kepler*	OCO	GALEX	Cloudsat	MAP	Average Duration (all)
KDP-B to PDR (months)	12	11	12	11	3	7	7	9.0
PDR to CDR (months)	10	13	10	25	9	11	5	11.7
CDR to SIR (months)	8	17	19	19	26	14	37	20.1
SIR to Launch (months)	17	13	11	11	19	18	11	14.3
KDP-B to Launch (months)	47	54	52	66	57	50	60	55.1

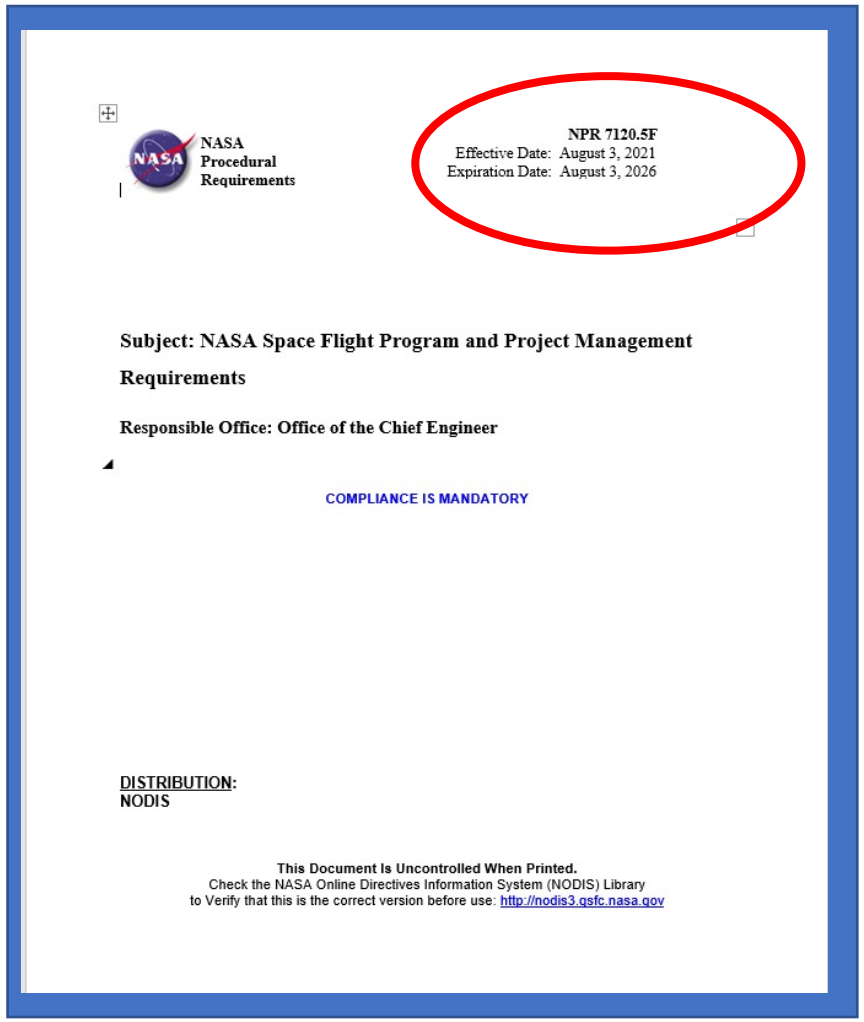
* Adjusted timeline from CADRe

CADRe Policy Improvements

Improved CADRe Guidance

Clarified CADRe policy as part of the NPR 7120.5F Release

AUGUST 3, 2021



NASA Procedural Requirements

NPR 7120.5F
Effective Date: August 3, 2021
Expiration Date: August 3, 2026

Subject: NASA Space Flight Program and Project Management Requirements

Responsible Office: Office of the Chief Engineer

COMPLIANCE IS MANDATORY

DISTRIBUTION:
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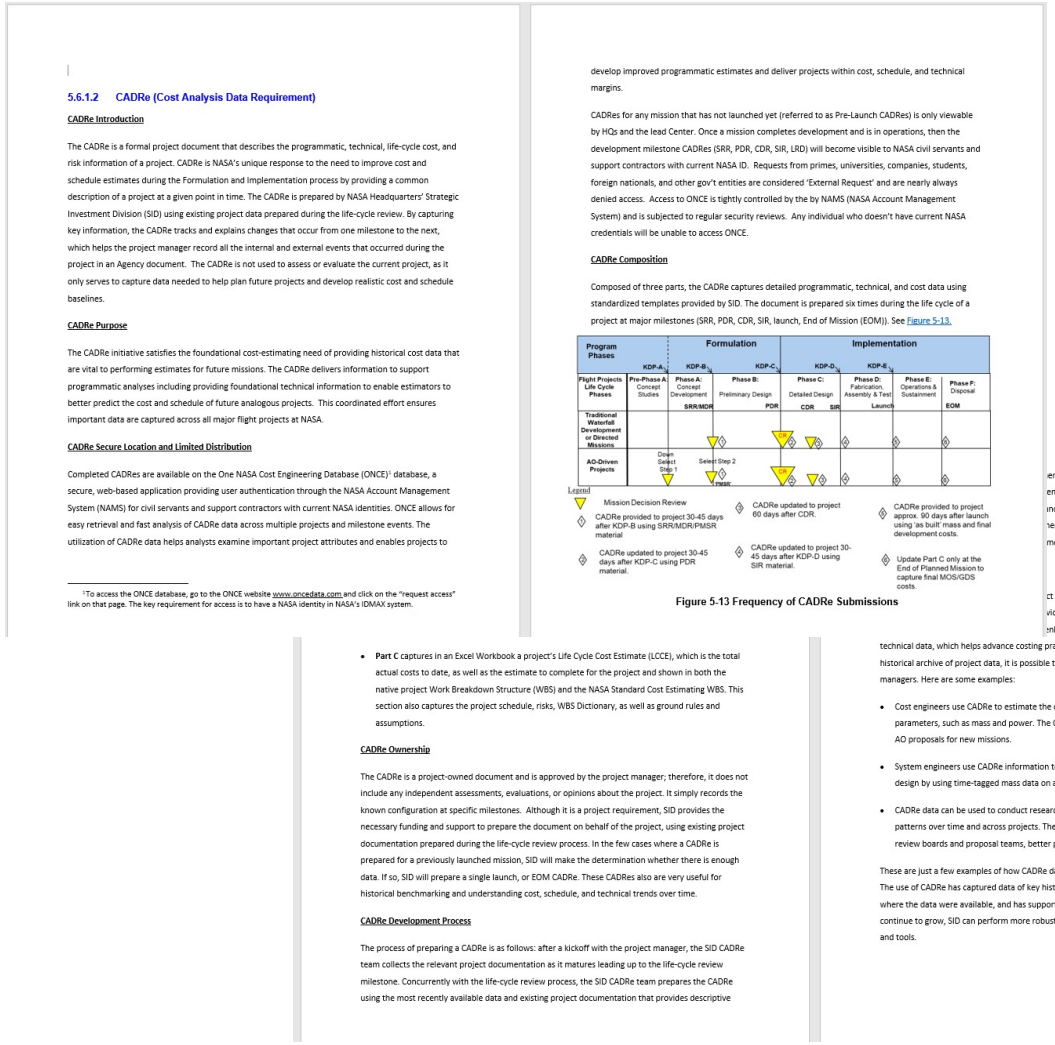
Cost Analysis Data Requirement. A three-part document required for tightly coupled programs, loosely coupled programs, single-project programs, and projects (regardless of Category or Class) that provides critical data to assist NASA in developing high fidelity cost and schedule estimates for new NASA projects. CADRe consists of Part A "Narrative" and Part B "Technical Data" in tabular form, provided by the program or project using existing program or project material. The program or project team produces the project life-cycle cost estimate, schedule, and risk identification which is appended as Part C.

- Updating Table I-2: Tightly Coupled Program products *and* Table I-6: Single-Project Program product
- Include CADRe in the SIR milestone as an "update"
- SID working on a Pre-Approved Waiver process for projects below $50M to allow data collection at the Start and Completion of small projects.
- Encouraging PM review/sign offs – Can be delegated to PE level especially for CAT III/CLASS D

Improved CADRe Guidance

CADRe Section Rewritten for the new PM Handbook



5.6.1.2 CADRe (Cost Analysis Data Requirement)

CADRe Introduction

The CADRe is a formal project document that describes the programmatic, technical, life-cycle cost, and risk information of a project. CADRe is NASA's unique response to the need to improve cost and schedule estimates during the Formulation and Implementation process by providing a common description of a project at a given point in time. The CADRe is prepared by NASA Headquarters' Strategic Investment Division (SID) using existing project data prepared during the life-cycle review. By capturing key information, the CADRe tracks and explains changes that occur from one milestone to the next, which helps the project manager record all the internal and external events that occurred during the project in an Agency document. The CADRe is not used to assess or evaluate the current project, as it only serves to capture data needed to help plan future projects and develop realistic cost and schedule baselines.

CADRe Purpose

The CADRe initiative satisfies the foundational cost-estimating need of providing historical cost data that are vital to performing estimates for future missions. The CADRe delivers information to support programmatic analyses including providing foundational technical information to enable estimators to better predict the cost and schedule of future analogous projects. This coordinated effort ensures important data are captured across all major flight projects at NASA.

CADRe Secure Location and Limited Distribution

Completed CADRes are available on the One NASA Cost Engineering Database (ONCE)[1] database, a secure, web-based application providing user authentication through the NASA Account Management System (NAMS) for civil servants and support contractors with current NASA identities. ONCE allows for easy retrieval and fast analysis of CADRe data across multiple projects and milestone events. The utilization of CADRe data helps analysts examine important project attributes and enables projects to

[1]To access the ONCE database, go to the ONCE website www.once.data.com and click on the "request access" link on that page. The key requirement for access is to have a NASA identity in NASA's IDMAX system.

develop improved programmatic estimates and deliver projects within cost, schedule, and technical margins.

CADRes for any mission that has not launched yet (referred to as Pre-Launch CADRes) is only viewable by HQs and the lead Center. Once a mission completes development and is in operations, then the development milestone CADRes (SRR, PDR, CDR, SIR, LRD) will become visible to NASA civil servants and support contractors with current NASA ID. Requests from primes, universities, companies, students, foreign nationals, and other gov't entities are considered 'External Request' and are nearly always denied access. Access to ONCE is tightly controlled by the by NAMS (NASA Account Management System) and is subjected to regular security reviews. Any individual who doesn't have current NASA credentials will be unable to access ONCE.

CADRe Composition

Composed of three parts, the CADRe captures detailed programmatic, technical, and cost data using standardized templates provided by SID. The document is prepared six times during the life cycle of a project at major milestones (SRR, PDR, CDR, SIR, launch, End of Mission (EOM)). See Figure 5-13.

Figure 5-13 Frequency of CADRe Submissions

- **Part C** captures in an Excel Workbook a project's Life Cycle Cost Estimate (LCCE), which is the total actual costs to date, as well as the estimate to complete for the project and shown in both the native project Work Breakdown Structure (WBS) and the NASA Standard Cost Estimating WBS. This section also captures the project schedule, risks, WBS Dictionary, as well as ground rules and assumptions.

CADRe Ownership

The CADRe is a project-owned document and is approved by the project manager; therefore, it does not include any independent assessments, evaluations, or opinions about the project. It simply records the known configuration at specific milestones. Although it is a project requirement, SID provides the necessary funding and support to prepare the document on behalf of the project, using existing project documentation prepared during the life-cycle review process. In the few cases where a CADRe is prepared for a previously launched mission, SID will make the determination whether there is enough data. If so, SID will prepare a single launch, or EOM CADRe. These CADRes also are very useful for historical benchmarking and understanding cost, schedule, and technical trends over time.

CADRe Development Process

The process of preparing a CADRe is as follows: after a kickoff with the project manager, the SID CADRe team collects the relevant project documentation as it matures leading up to the life-cycle review milestone. Concurrently with the life-cycle review process, the SID CADRe team prepares the CADRe using the most recently available data and existing project documentation that provides descriptive

ents, schedules, risk list, and life-cycle cost estimates, as end to drive costs. The SID CADRe team delivers the nd signature shortly after the capstone KDP briefing, such hedule positions are finalized. The PMs are expected to month(s) from the time of receiving the initial version.

ct at successive key milestones, the ONCE database vious projects and their associated cost and schedule nhanced insight and management of historical cost and technical data, which helps advance costing practices and analyses across the Agency. With a large historical archive of project data, it is possible to determine trends that can be very useful to project managers. Here are some examples:

- Cost engineers use CADRe to estimate the cost of future systems based on known technical parameters, such as mass and power. The CADRe data are also used to help SOMA evaluators assess AO proposals for new missions.
- System engineers use CADRe information to perform mass architecture trades earlier in concept design by using time-tagged mass data on all major NASA projects.
- CADRe data can be used to conduct research to help understand cost and schedule trends and patterns over time and across projects. The results of this research help NASA analysts, including review boards and proposal teams, better plan for cost and schedule risks.

These are just a few examples of how CADRe data can be used to help program and project managers. The use of CADRe has captured data of key historical missions looking back approximately 16 years, where the data were available, and has supported several NASA studies. As the number of CADRes continue to grow, SID can perform more robust analyses resulting in more advanced costing practices and tools.

CADRe Section in new PM Handbook reflects new 7120.5F

Sections Include:

- CADRe Introduction
- Purpose and Project Support
- Secure Location and Distribution
- CADRe Composition Parts A, B, C
- CADRe Ownership
- Development Process
- CADRe Utility for Analysis

High Risk Corrective Action Plan (CAP)

Background

- The Government Accountability Office (GAO) routinely tracks areas of the federal government deemed High Risk for fraud, waste, abuse, and mismanagement or that need transformation. The GAO publishes a new High Risk List each January of odd-numbered years, coinciding with the start of the newly elected Congress.

- NASA's acquisition management has been designated as a **High-Risk** area since **1990**.

- There are five criteria that must be met in order to have the High-Risk designation removed; noted on the star in the graphic to the right.

- NASA's High Risk Corrective Action Plan (CAP) enacted December 2018 by the APMC fulfills the Action Plan criterion and includes initiatives the Agency is pursuing to meet the capacity, demonstrated progress, and leadership commitment criteria.
    - The monitoring criterion is partially fulfilled by the semi-annual high risk metrics report, which captures aggregate agency performance, and also by demonstrating continued program performance monitoring like the BPR.

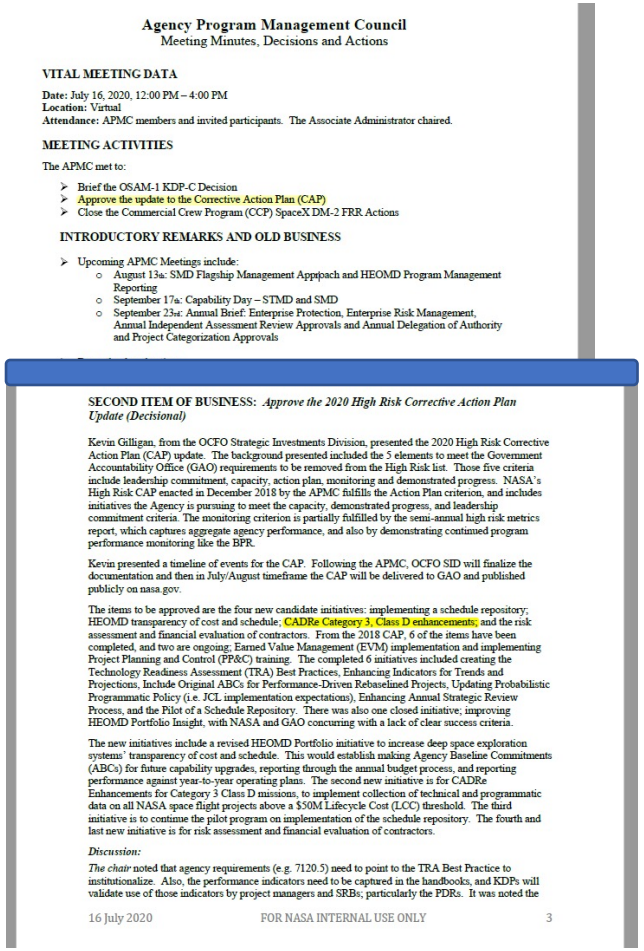
- The 2018 CAP includes mechanisms for CAP updates ahead of future High-Risk reports, which GAO begins to draft in the summers of the even-numbered years.

Source: GAO analysis. | GAO-19-157SP

CAP Update for Smaller Projects

Cat III/Class D projects that are between $50 and $150 million

APPROVED



Agency Program Management Council
Meeting Minutes, Decisions and Actions

VITAL MEETING DATA

Date: July 16, 2020, 12:00 PM – 4:00 PM
Location: Virtual
Attendance: APMC members and invited participants. The Associate Administrator chaired.

MEETING ACTIVITIES

The APMC met to:

- Brief the OSAM-1 KDP-C Decision
- Approve the update to the Corrective Action Plan (CAP)
- Close the Commercial Crew Program (CCP) SpaceX DM-2 FRR Actions

INTRODUCTORY REMARKS AND OLD BUSINESS

- Upcoming APMC Meetings include:
  - August 13a: SMD Flagship Management Approach and HEOMD Program Management Reporting
  - September 17a: Capability Day – STMD and SMD
  - September 23a: Annual Brief: Enterprise Protection, Enterprise Risk Management, Annual Independent Assessment Review Approvals and Annual Delegation of Authority and Project Categorization Approvals

SECOND ITEM OF BUSINESS: *Approve the 2020 High Risk Corrective Action Plan Update (Decisional)*

Kevin Gilligan, from the OCFO Strategic Investments Division, presented the 2020 High Risk Corrective Action Plan (CAP) update. The background presented included the 5 elements to meet the Government Accountability Office (GAO) requirements to be removed from the High Risk list. Those five criteria include leadership commitment, capacity, action plan, monitoring and demonstrated progress. NASA's High Risk CAP enacted in December 2018 by the APMC fulfills the Action Plan criterion, and includes initiatives the Agency is pursuing to meet the capacity, demonstrated progress, and leadership commitment criteria. The monitoring criterion is partially fulfilled by the semi-annual high risk metrics report, which captures aggregate agency performance, and also by demonstrating continued program performance monitoring like the BPR.

Kevin presented a timeline of events for the CAP. Following the APMC, OCFO SID will finalize the documentation and then in July/August timeframe the CAP will be delivered to GAO and published publicly on nasa.gov.

The items to be approved are the four new candidate initiatives: implementing a schedule repository; HEOMD transparency of cost and schedule; CADRe Category 3, Class D enhancements; and the risk assessment and financial evaluation of contractors. From the 2018 CAP, 6 of the items have been completed, and two are ongoing; Earned Value Management (EVM) implementation and implementing Project Planning and Control (PP&C) training. The completed 6 initiatives included creating the Technology Readiness Assessment (TRA) Best Practices, Enhancing Indicators for Trends and Projections, Include Original ABCs for Performance-Driven Rebaselined Projects, Updating Probabilistic Programmatic Policy (i.e. JCL implementation expectations), Enhancing Annual Strategic Review Process, and the Pilot of a Schedule Repository. There was also one closed initiative; improving HEOMD Portfolio Insight, with NASA and GAO concurring with a lack of clear success criteria.

The new initiatives include a revised HEOMD Portfolio initiative to increase deep space exploration systems' transparency of cost and schedule. This would establish making Agency Baseline Commitments (ABCs) for future capability upgrades, reporting through the annual budget process, and reporting performance against year-to-year operating plans. The second new initiative is for CADRe Enhancements for Category 3 Class D missions, to implement collection of technical and programmatic data on all NASA space flight projects above a $50M Lifecycle Cost (LCC) threshold. The third initiative is to continue the pilot program on implementation of the schedule repository. The fourth and last new initiative is for risk assessment and financial evaluation of contractors.

Discussion:

The chair noted that agency requirements (e.g. 7120.5) need to point to the TRA Best Practice to institutionalize. Also, the performance indicators need to be captured in the handbooks, and KDPs will validate use of those indicators by project managers and SRBs; particularly the PDRs. It was noted the

16 July 2020 FOR NASA INTERNAL USE ONLY 3

Description:

- To implement CADRe requirement enhancements that will continue NASA's commitment to collect robust technical and programmatic data on Category 3 Class D projects; expand data collection efforts to all NASA space flight projects above a $50M LCC threshold
- Addresses GAO desire to continue CADRe as a meaningful document to underpin cost and schedule capabilities at NASA

Expected Benefits:

- Significantly increase the available information on smaller missions, which will enable NASA to better estimate cost/schedule and ensure NASA continues to be a "smart buyer" of hardware and services
- Continue to demonstrate that CADRe development does not add a burden on projects (OCFO/SID resources)
- Cost models calibrated specifically to NASA projects

In Process or Completed:

- Clarify policy in NPR 7120.5 revision efforts **(COMPLETED)**
- Kick Off CADRes with new Cat III/Class D projects (LCC between $50M and $150M) Explain all realized benefits of CADRe over the last decade **(Good Progress)**
- Conduct training on the access and use of CADRe data
- Develop methods to track and report compliance, **(Good Progress)**
- Particularly with respect to Cat III / Class D, an extension to existing tracking and reporting processes **(Good Progress)**

Challenges:

- After 2014 policy change, some Centers/FFRDC's began aggressively waiving CADRe requirements for Cat 3 Class D missions making it difficult to work with PM's
- Communicating direction and Agency expectations

CAP Initiative for FFP

Exploring Methods to Collect *Some* Data on Firm Fixed Price Contracts

In Process

Problem Statement: NASA is currently not receiving adequate cost data from FFP procurements

- FFP acquisitions are becoming more common for high value assets (e.g., PPE, HLS, etc)
- Lack of insight hinders Agency's ability to utilize past investments for future estimating capability

Description:

- To implement Contractual mechanism to enable collecting relevant programmatic data to provide insight into NASA's large FFP contracts.
- **Obtaining actual FFP Cost Data at "Subsystem Level" is crucial to the success of the PP&C community.**

In Process or Completed:

- Working with relevant PP&C community to gather options and defining the trade-space for effective implementation
- Assembling all known challenges and impediments

Expected Benefits:

- Increase the available information on smaller missions, which will enable NASA to better estimate cost/schedule and ensure NASA continues to be a "smart buyer" of hardware and services
- Cost models calibrated specifically to NASA projects

Challenges:

- Past Efforts- Hooks in 7120.5, Modify 9501.2D 533 Reporting
- Internal Objections-Perceived Add'l Costs, Not a value to PM
- Vendor Objections- Financial System implementation, Perceived Additional Costs to implement

CADRe Recent Progress

New CADRe 2021-2022

Completed CADRes

AWE CDR
Deep Space Atomic Clock EOM
Dragonfly SRR
EPFD SRR
EscaPADE PDR
Europa Clipper CDR
GALEX EOM
Gateway KPD-0
GLAST EOM
GLIDE PDR
IMAP PDR
IXPE LRD
JPSS-2 SIR
Janus PDR
Janus CDR
Libera SRR
Lunar Trailblazer PDR
Lunar Trailblazer CDR
MEGANE CDR
M2020 LRD
Ni-SAR SIR
PREFIRE CDR
PUNCH PDR
Psyche SIR
ROMAN CDR
Sentinal-6 LRD
Space Weather FO- SRR
Space Weather FO - PDR
SunRise CDR
SWOT SIR
TRACERS SRR
TSIS-2 PDR
VIPER PDR

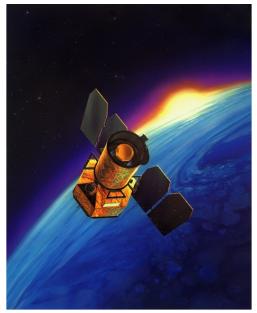
New Launch CADRes 2021-2022

Mars2020 Perseverance

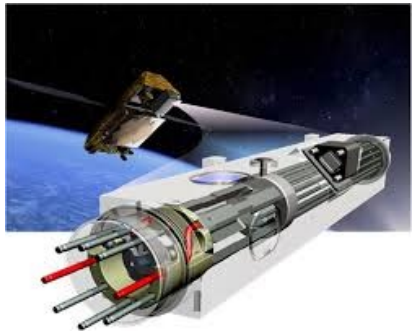
Ingenuity Helicopter

Michael Freilich (Sentinal-6)

IXPE



GALEX EOM



Deep Space Atomic Clock EOM

GPIM EOM

GOES-T

Coming Soon LRD CADRes

- JWST- Nearly complete
- GOES-T Nearly complete
- Landsat-9 - final cost collection
- Lucy –Waiting for completion of Phase D

Completed Launch and EOM CADRes

CADRe: Resource for Analogous Missions

CADRe: Resource for Analogous Missions

HELIOPHYSICS SCIENCE

Helio Missions (Sun-Pointed)

- STEREO 535 kg (2006)
- Solar Dynamics Observatory 1,542 kg (2010)
- IRIS 185 kg (2013)
- Parker Solar Probe 558 kg (2018)
- Solar Orbiter Collaboration (Insts only) (2020)
- SunRise (6-CubeSats)

Helio Missions on ISS

- TSIS-1 257 kg (2017)
- GOLD 37 kg (2018)
- AWE 49 kg

In Development

Helio Lagrange Point Missions

- ACE 750 kg (1997)
- Genesis 350 kg (2001)
- IMAP 518 kg

Helio Missions (Earth Orbiting)

- FAST 190 kg (1996)
- TRACE 241 kg (1998) polar
- IMAGE 493 kg (2000)
- TIMED 591 kg (2001)
- RHESSI 291 kg (2002)
- Suzaku (ASTRO-E II) 77kg (2005)
- AIM 190 kg (2007) sun-synchronous
- THEMIS 513 kg (2007)
- MMS 928 kg (2015)
- ASTRO H 424 kg (2015)
- ICON 276 kg (2019)
- XRISM 425 kg (instrument)
- TSIS-2 256 kg
- PUNCH
- TRACERS
- GLIDE
- EZIE

CADRe: Resource for Analogous Missions

PLANETARY SCIENCE

Mars Orbiters
- MGS 620 kg (1996)
- Mars Odyssey 3,539 kg (2001)
- MRO 981 kg (2005)
- MAVEN 805 kg (2013)
- ExoMars TGO (2016)
- MEGANE 12 kg (2024)
- EscaPADE

Lunar Missions
- MMM 8.3 kg (instrument) (2008)
- LCROSS 2884 kg (2009)
- LRO 1,019 kg (2009)
- GRAIL 193 kg (2011)
- LADEE 243 kg (2013)
- VIPER 386 kg (Lander)
- Lunar Trailblazer

Pluto Mission
- New Horizons 400 kg (2006)

Jupiter Missions (incl moons)
- Galileo 1,791kg (1989)
- JUNO 1,559 kg (2011)
- Europa 2,854 kg

Comet/Asteroid Missions
- NEAR 468 kg (1996)
- Stardust 299 kg (1999)
- Deep Space-1 369 kg (1998)
- CONTOUR 384 kg (2002)
- Deep Impact 878 kg (2005)
- DAWN 565 kg (2007)
- OSIRIS-REx 925 kg (2016)
- NEA Scout 10 kg (Cubesat)
- DART 493 kg
- LUCY 748 kg
- Psyche 1,598 kg
- NEOSM 1,131 kg
- Janus

Mars Landers
- Mars Pathfinder 800 kg (1996)
- MER 997 kg (2003)
- Phoenix 597 kg (2007)
- MSL (Curiosity) 3,421 kg (2011)
- InSight 622 kg (2012)
- M2020 (Perseverance) 3,539 kg (2020)
- Mars Sample Return

Saturn Missions (incl moons)
- Cassini 2,580 kg (1997)
- Dragonfly

Mercury Mission
- Messenger 506 kg (2004)

Earth Orbiting Missions
- Kepler 1,040 kg (Earth Trailing Orbit) (2009)
- TESS 311 kg (High Elliptical Orbit) (2018)

In Development

CADRe: Resource for Analogous Missions

EARTH SCIENCE

Earth Orbiters (Small/Medium)
- QuikSCAT 910 kg (1999)
- ACRIMSat 126 kg (1999)
- EO-1 556 kg (2000)
- Jason-1 472 kg (2001)
- GRACE 450 kg (2002)
- ICESAT 880 kg (2003)
- SORCE 260 kg (2003)
- CALIPSO 553 kg (2006)
- CloudSat 500 kg (2006)
- OSTM 464 kg (2008)
- OCO, OCO-2 403 kg (2009,2014)
- GLORY 487 kg (2011)
- SMAP 863 kg (2015)
- Jason-3 482 kg (2016)
- GRACE FO 568 kg (2018)
- GeoCarb 157 kg (early 2020s)
- Sentinal-6 983 kg (2020)
- TEMPO 136 kg

ISS EARTH Missions
- RBI 81 kg (canceled)
- SAGE III 521 kg (2017)
- ECOSTRESS 460 kg (2018)
- GEDI 526 kg (2018)
- OCO-3 539 kg (2019)
- MAIA 64 kg (2021)
- PREFIRE 11.96 kg
- CLARREO PF 240 kg

Meteorological Missions
- GOES I-M, N-P 2,258 kg (2001)
- POES-KLMN-N+ 1245 kg (2009)
- NPP 1792 kg (2011)
- JPSSCGS (2016)
- GOES-R, S, T, U 2,813 kg (2016)
- JPSS-1, 1868 kg (2017)
- JPSS-2 3&4 2,038 kg

In Development

Lagrange Point (Space Weather)
- DSCOVR 416 kg (2015)
- Space Weather Follow On

Earth Orbiters (Large)
- TRMM 2,620 kg (1997)
- Landsat-7 1,857 kg (1999)
- Terra 4,415 kg (1999)
- Aqua 2,808 kg (2002)
- Aura 2,808 kg (2004)
- Aquarius 1,088 kg (2011)
- LDCM 2,150 kg (2013)
- GPM 3,043 kg (2014)
- ICESAT II 1,354 kg (2018)
- Landsat-9 2,428 kg (2021)
- SWOT 1687 kg
- NISAR 2,110 kg
- PACE 1,224 kg

Earth System Pathfinders
- CALIPSO 553 kg (2006)
- CYGNSS 29 kg each (MicroSats) (2016)
- TROPICS 5.4 kg each (CUBESATs) (2022)
- EMIT 186 kg (2022)
- Libera

CADRe: Resource for Analogous Missions

ASTROPHYSICS SCIENCE

ASTRO Observatory Missions (Large)

- COBE 2,204 kg (1989)
- SPIZTER (SIRTF) 785 kg (2003)
- SIM 6,211 kg (canceled) (2006)
- SOFIA 3,244 kg (2007)
- Gamma-ray Large Space Telescope (GLAST) 3947 kg (2008)
- JWST 5,848 kg (2021)
- ROMAN 7,090 kg
- CGI (ROMAN) 302 kg

ASTRO Lagrange Point Missions

- MAP 763 kg (2001)

ASTRO MISSIONS on ISS

- NICER 262 kg (2017)

In Development

Astro Missions Earth Orbiting

- SAMPEX 165 kg (1992)
- SWAS 282 kg (1998)
- WIRE 253 kg (1999)
- CHIPSAT 60 kg (2003)
- GALEX 287 kg (2003)
- SWIFT 1485kg (2004)
- ST-8 152 kg (canceled)
- GEMS 254 kg (canceled)
- IBEX 160 kg (2008)
- WISE 645 kg (2009)
- Van Allen Probes 1,210 kg (2012)
- NuSTAR 348 kg (2012)
- IXPE 311 kg (2021)
- XRISM 425 kg
- PUNCH 167 kg
- SPHEREx 375 kg

CADRe: Resource for Analogous Missions

Human Missions

Historical Missions

- Apollo CSM
- Apollo LM
- Saturn S-1C, S-11, S-1VB
- Skylab
- Spacelab
- Shuttle (External Tank, Booster)

Constellation Program

- Constellation Integration
- Constellation Ares I
- Constellation Orion
- Constellation Ground System Dev
- Constellation Mission Operations

International Space Station (ISS) Tier 2 Projects

- C2V2 (Communications for Visiting Vehicles)
- NORS (Nitrogen Oxygen Replenishment System)
- Li-Ion Battery Upgrade

In Development Missions

- **Orion**
- **SLS**
- **EGS**
- **Gateway**
- **Human Landing System (HLS)**

In Development

CADRe: Resource for Analogous Missions

Technology Demonstration Missions

ISS Tech Demo Missions
- Cold Atom Laboratory 319 kg

Ground Tech Demo Missions
- eCryo 34,389 lbs

Earth Orbiter Tech Demo Missions
- Solar Sail Demonstrator 140 kg (canceled)
- Deep Space Optical Communications (DSOC) 38 kg
- Green Propellant Infusion (GPIM) 129 kg
- Deep Space Atomic Clock (DSAC) 40 kg
- Low-Density Supersonic Decelerator (LDSD) 1383 kg
- Laser Communications Relay Demonstration (LCRD) 180 kg
- Low-Earth Orbit Flt Test Inflatable Decelerator (LOFTID) 1,027 kg
- OSAM-1 2,421 kg

Space Communication Missions

Space Communication
- TDRS K&L 1778 kg
- TDRS M 1880 kg
- SGSS Ground N/A

In Development

Balloon Missions

Planetary Balloon Missions
- BOPPS 1856 kg
- BRRISON 1864 kg

ASTRO Balloon Missions
- GUSTO 1,171kg

Aeronautics Missions
- Low Boom Flight Demonstrator
- Electrified Powertrain Flight Demonstration
- X-57

CADRe Work In-Process/New Developments

New CUI Directive

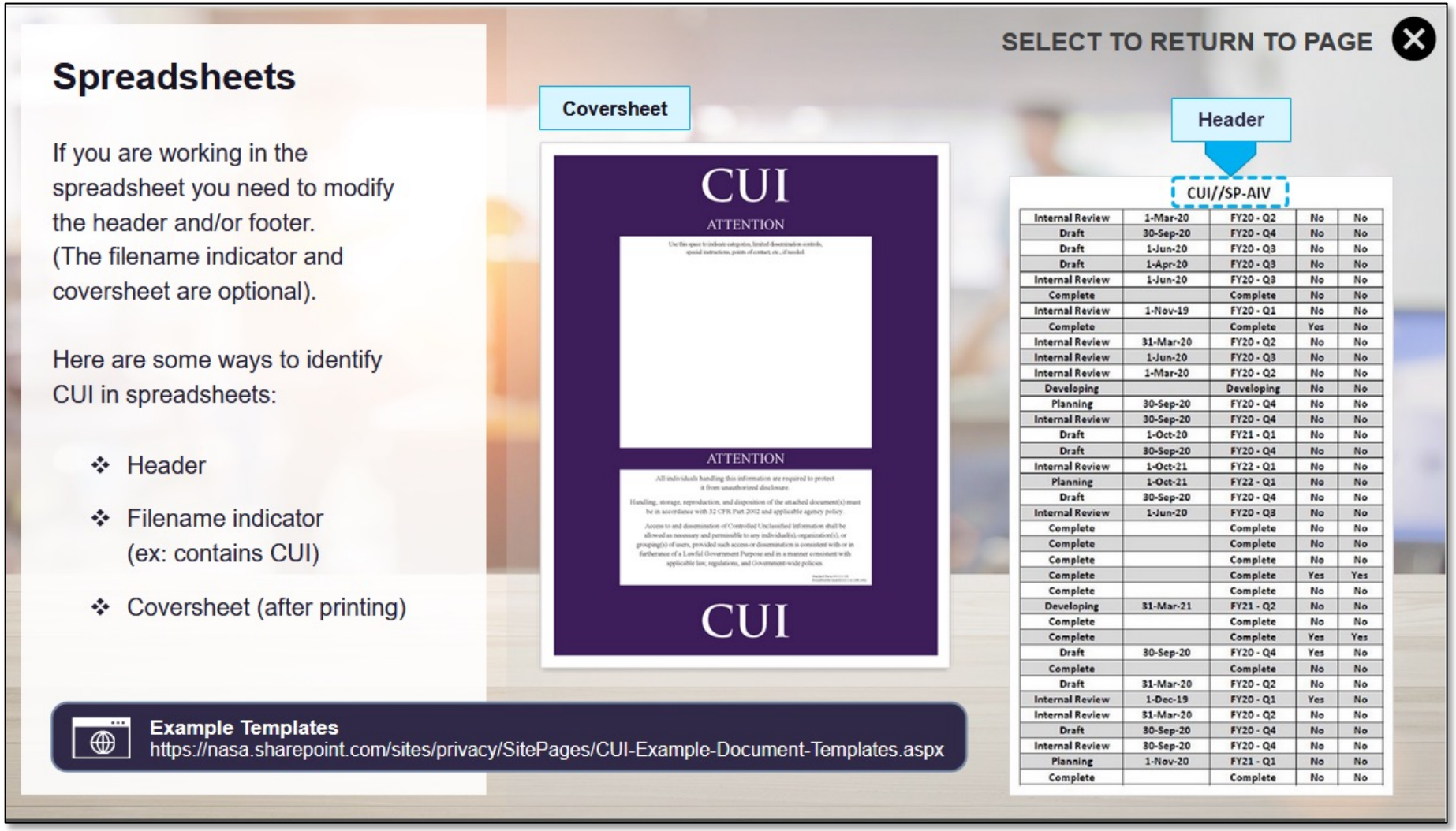
Both Current and Previously Prepared CADRes are Compliant

For CADRes After Oct 2021

All Parts A,B,C have CUI cover sheets as part of the document

For CADRes Before Oct 2021

Any Dowloaded CADRe will Be a Zip file which includes CUI Cover Sheet as part of the Download



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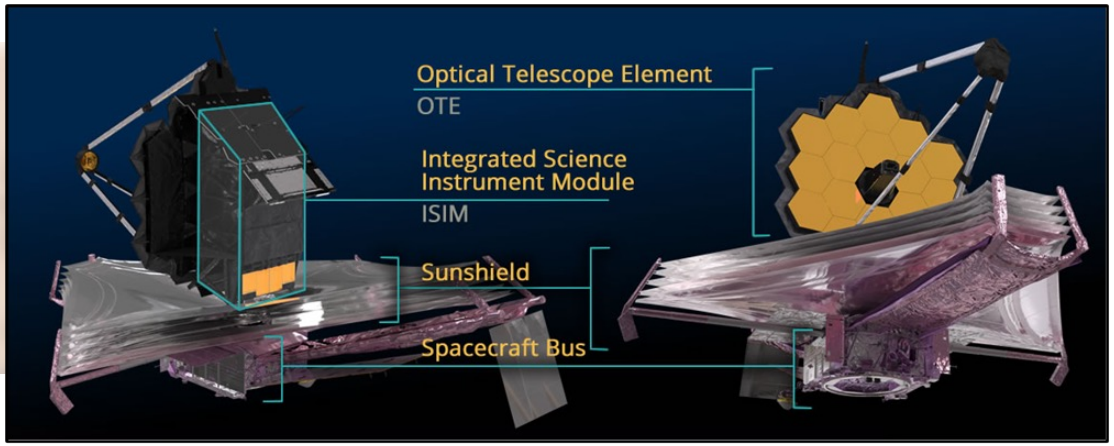
Draft	30-Sep-20	FY20 - Q4	No	No
Draft	1-Jun-20	FY20 - Q3	No	No
Draft	1-Apr-20	FY20 - Q3	No	No
Internal Review	1-Jun-20	FY20 - Q3	No	No
Complete		Complete	No	No
Internal Review	1-Nov-19	FY20 - Q1	No	No
Complete		Complete	Yes	No
Internal Review	31-Mar-20	FY20 - Q2	No	No
Internal Review	1-Jun-20	FY20 - Q3	No	No
Internal Review	1-Mar-20	FY20 - Q2	No	No
Developing		Developing	No	No
Planning	30-Sep-20	FY20 - Q4	No	No
Internal Review	30-Sep-20	FY20 - Q4	No	No
Draft	1-Oct-20	FY21 - Q1	No	No
Draft	30-Sep-20	FY20 - Q4	No	No
Internal Review	1-Oct-21	FY22 - Q1	No	No
Planning	1-Oct-21	FY22 - Q1	No	No
Draft	30-Sep-20	FY20 - Q4	No	No
Internal Review	1-Jun-20	FY20 - Q3	No	No
Complete		Complete	No	No
Complete		Complete	No	No
Complete		Complete	No	No
Complete		Complete	Yes	Yes
Complete		Complete	No	No
Developing	31-Mar-21	FY21 - Q2	No	No
Complete		Complete	No	No
Complete		Complete	Yes	Yes
Draft	30-Sep-20	FY20 - Q4	Yes	No
Complete		Complete	No	No
Draft	31-Mar-20	FY20 - Q2	No	No
Internal Review	1-Dec-19	FY20 - Q1	Yes	No
Internal Review	31-Mar-20	FY20 - Q2	No	No
Draft	30-Sep-20	FY20 - Q4	No	No
Internal Review	30-Sep-20	FY20 - Q4	No	No
Planning	1-Nov-20	FY21 - Q1	No	No
Complete		Complete	No	No

JWST Mapping

DETAIL COST SHEET FROM NORTHROP GRUMMAN

	434	STRUCTURES AND MECHANISM
	434	SC THERMAL CONTROL SUBSYSTEM
	434	PROPULSION SUBSYSTEM
	434	ATTITUDE CONTROL SUBSYSTEM
	434	SV/OTE ELECTRICAL HARNESS
	434	ELECTRICAL POWER SUBSYSTEM
	434	SC COMMUNICATIONS SUBSYSTEM
	434	SC COMMAND AND DATA HANDLING
	434	DEPLOYMENT CONTROL SUBSYSTEM
44		SUNSHIELD
45		TEST BEDS [deleted -- xfer included in 46]
46		OBSERVATORY I&T
47		CRYOCOOLER SYSTEMS INTEGRATION
5		OPTICAL TELESCOPE ELEMENT
	511	OTE MGMT
	512	OTE SE
	513	OTE INTEGRATION & TEST
	514	OTE SIMULATORS
	515	OTE STRUCTURE
	516	WAVEFRONT SENSING & CONTROL
	517	BALL SUBCONTRACT
	518	ADIR STRUCTURE
	519	OTE PATHFINDER



Project Provided WBS Sheet:

JWST provided detailed costs from Northrop from Northrop Grumman

OTE = Optical Telescope Assembly

Challenge on where to map OTE

OPTICAL TELESCOPE ELEMENT	
OTE MGMT	
OTE SE	
OTE INTEGRATION & TEST	
OTE SIMULATORS	
OTE STRUCTURE	
WAVEFRONT SENSING & CONTROL	
BALL SUBCONTRACT	
ADIR STRUCTURE	
OTE PATHFINDER	

JWST Mapping

Technology Development	3
Payload(s)	**2**
Integrated Science Instruments Module (ISIM)	**3**
Integrated Science Instruments Module (ISIM) "Infrastructure"	**3**
Integrated Science Instruments Module Management	4
Integrated Science Instruments Module System Engineering	4
Structures & Mechanisms	4
Thermal Control	4
Instrument Detectors	4
Harness & Cabling	4
C&DH	4
Flight Software	4
Integration and Test Support Systems	4
NIRCam OTE Simulator (NOTES)	4
OTE Simulator (OSIM)	4
Integration, Assembly Test & Check out	4
Near Infrared Camera (NIRCam)	**3**
Near Infrared Spectrograph (NIRSpec)	**3**
NIRSpec Management	4
Sensors/Detectors	4
Optics -- Microshutter	4
Mid Infrared Instrument (MIRI)	**3**
FGS	**3**
Flight System \ Spacecraft	**2**
Optical Telescope Element (OTE)	**3**
OTE Management	4
OTE Systems Engineering	4
Optics	4
Structures & Mechanisms	4
Pointing Subsystem -- Wavefront Sensing and Control	4
Ground Support Equip -- OTE Simulators	4
Integration, Assembly Test & Check out	4
Flight System Project Management	**3**
Government Observatory Support	4
Prime Contract Management	4
Contract Fee	4
ICOM	4
Undistributed Budget	4

Project WBS & LCCE | Project WBS Dictionary | NASA

Mapping of OTE

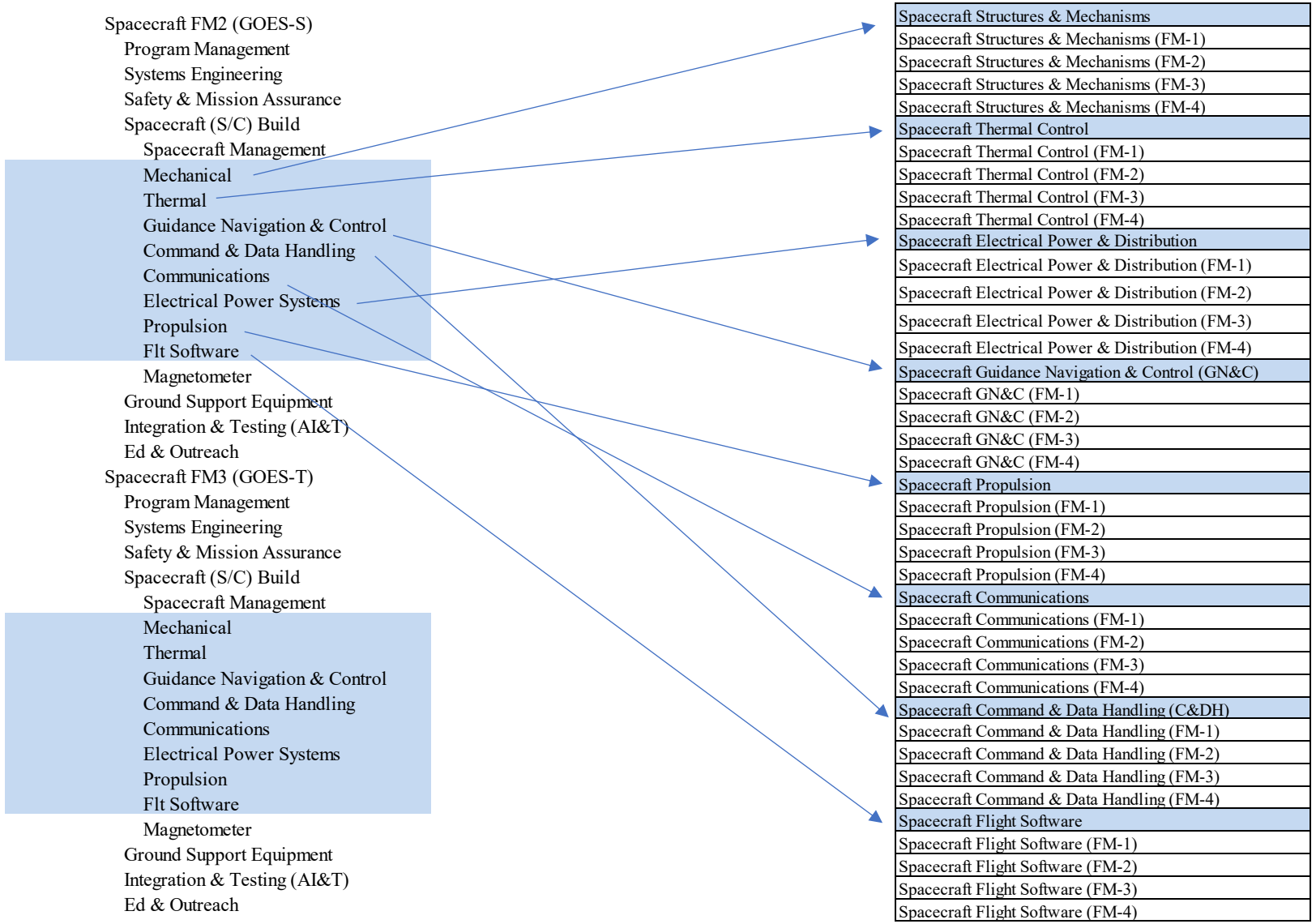
- Following how JWST maps OTE as part of Flight System/Spacecraft which is all part of the Observatory
- Observatory Includes all elements Except ISIM- Contains all Instruments
- Early Milestone CADRes don't show OTE breakout so have to keep within Spacecraft Observatory

GOES-T Mapping

GOES CADRe Costs per Each Spacecraft R, S, T, U

Breakouts out Subsystems for each Spacecraft

- Mechanical
- Thermal
- Guidance & Nav
- C&DH
- COMM
- EPS
- Propulsion
- Software-



CADRes for CAT III CLASS D Missions

AWE- Atmospheric Waves Experiment

CLARREO Path Finder -Climate Absolute Radiance and Refractivity Observatory

COSI -Compton Spectrometer and Imager

CYGNSS -Compton Spectrometer and Imager

DSAC - Deep Space Atomic Clock

DSOC- Deep Space Optical Communications (DSOC)

ECOSTRESS -ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

EscaPADE -The Escape and Plasma Acceleration and Dynamics Explorers

EZIE - Electrojet Zeeman Imaging Explorer

GUSTO - Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory

GLIDE - Global Lyman-alpha Imagers of the Dynamic Exosphere

IRIS - Interface Region Imaging Spectrograph

IXPE - Imaging X-ray Polarimetry Explorer

Janus

LCRD- Laser Communications Relay Demonstration

LOFTID- Low-Earth Orbit Flight Test of an Inflatable Decelerator

NICER -Neutron star Interior Composition Explorer

NuSTAR -Nuclear Spectroscopic Telescope Array

PREFIRE -Polar Radiant Energy in the Far Infrared Experiment

PUNCH - Polarimeter to Unify the Corona and Heliosphere

SUNRISE - Sun Radio Interferometer Space Experiment

TRACERS - Transition Region and Coronal Explorer

TROPICS - Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

TSIS-2 Total Spectral Irradiance Sensor -2

CADRe Instrument Categorization

CADRe Part B (Instrument Parameters)

1. Fields	1.1. Electric Field	
		1.1.1 Double Probe
		1.1.2 Electron Drift
	1.2. Magnetometer	
		1.2.1 Fluxgate
		1.2.2. Search Coil
		1.2.3 Ionized Gas Vapor
		1.2.4 Magnetoresistive
2. Particles	2.1 Mass Spectrometer	
		2.1.1 Quadrupole MS
		2.1.2 Time-of-Flight MS
		2.1.3 Sector Field MS
		2.1.4 Ion Cyclotron Resonance MS
	2.2. Charge and X-ray Detector	
		2.2.1 High Energy Particle Detector
		2.2.2 Low Energy Particle Detector
	2.3. Plasma Instrument	
		2.3.1 Plasma Probe
		2.3.2 Retarding Potential Analyzer
		2.3.3 Ion Drift Meter
	2.4. Dust Detector	
3. XRT		
4. Optical	4.1. Passive Optical	
		4.1.1 Cryo-cooled Passive Optical
		4.1.2 Optical Telescope Assembly
		4.1.3 Radiometer
		4.1.4 Pyrheliometer
		4.1.5 Film Camera
		4.1.6 Interferometer
		4.1.7 Single-band Imager
		4.1.8 Natural Color Imager
		4.1.9 Multi-spectral Imager/Spectrometer
		4.1.10 Hyper-spectral Imager/Spectrometer
	4.2. Active Optical	
		4.2.1 Laser Ranging
		4.2.2 Laser Velocimeter / Vibrometer
		4.2.3 Laser Imager
		4.2.4 Laser Scatterometer
5. MW/RF	5.1. Passive MW/RF	
	5.2. Active MW/RF	
		5.2.1 MW/RF Ranging
		5.2.2 MW/RF Imager
		5.2.3 MW/RF Scatterometer
6. Support	6.1 Scan Platform	
	6.2 Deployment Mechanism	
	6.3 Robotic Arm	
	6.4 Data Processing Unit	
	6.5 Cryogenic Systems	
		6.5.1 Cryogenic Radiator
		6.5.2 Expendable Cryogen Cooler
		6.5.3 Mechanical Cryocooler
	6.6 Accelerometer	
	6.7 Ultra Stable Oscillator	
	6.8 Mirror Target	
	6.9 Positioning Receivers	
7. Atmospheric & Surface	7.1 Entry and Descent Sensor	
	7.2 Meterological Station	
	7.3 Sample Collector	
	7.4 Sample Analyzer	
	7.5 Seismographer	
8. Comm	8.1 MW/RF Communications	
	8.2 Laser Communications	
9. Other		

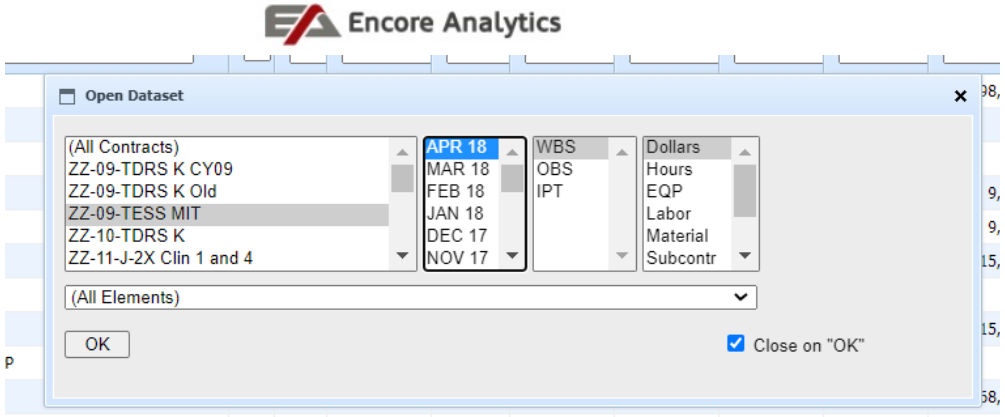
Payload	Instrument 1	Instrumen
Instrument Name		
Instrument Builder Name		
Instrument Category Level 1	Optical	
Instrument Category Level 2		
Instrument Category Level 3		
Instrument Category : Submitted		
Comments		
Instrument Builder Category		
Contract Type		
Remote Sensing or In-Situ		
Remote Sensing Type (if applicable)		

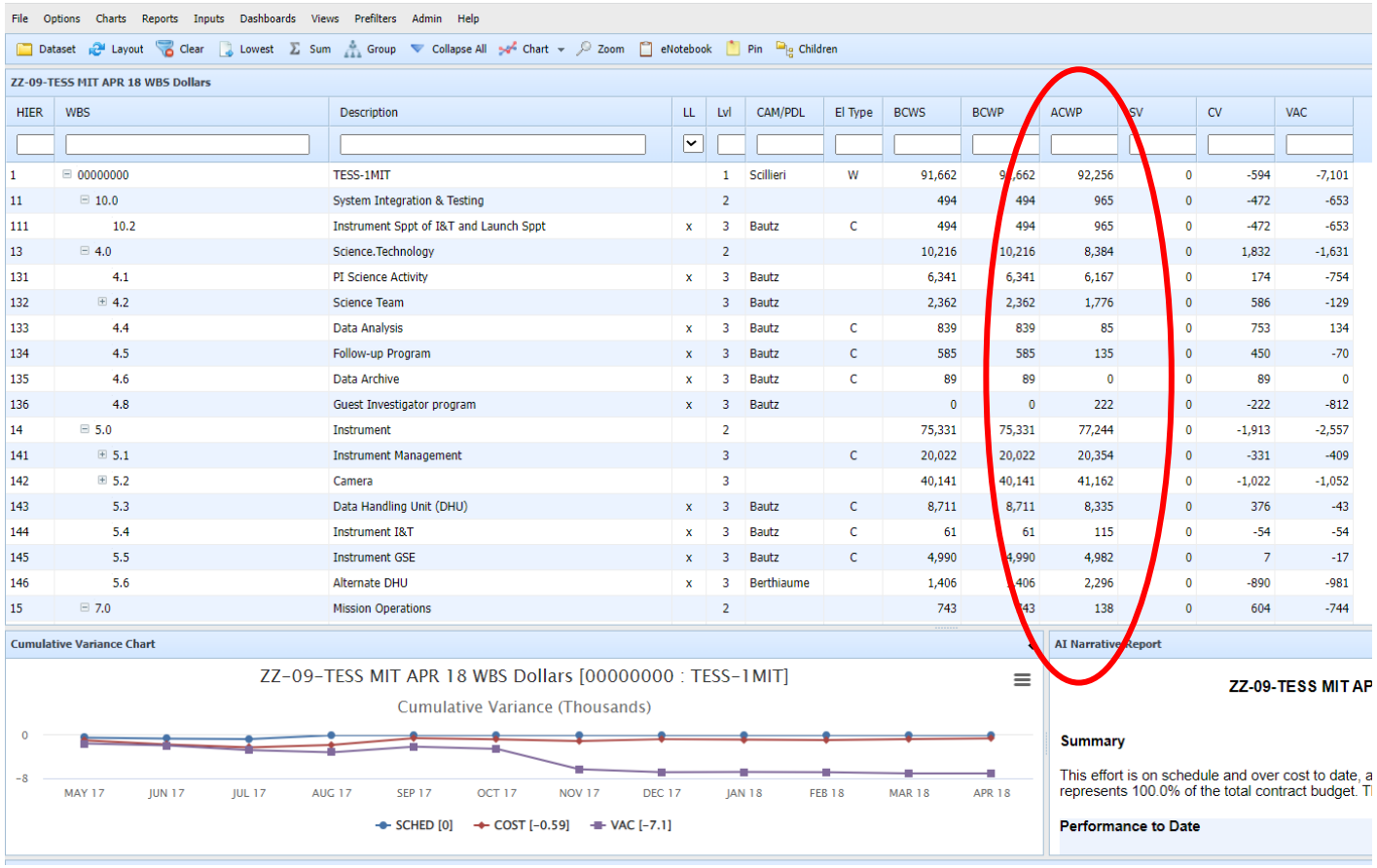
Passive_Optical
Active_Optical
Undetermined
Other
Multiple Families

- Coordinating with NICM team to refine before implementation into final CADRe templates and ONCE
- Capability for unique comments for instruments that cross multiple categories
- For Historical CADRes following NICM lead for instrument categorization

Updating CADRe Template Part B to include the 3-level instrument taxonomy

Incorporating EVM into CADRes





Use of EMPOWER System

- Empower Administrators were able to rename all historical project dataset names to begin with “ZZ”, instead of using a separate database
- Categorization of “zz” projects-for completed projects open to PP&C community
- CADRe collects ACWPs by WBS totals
- Flows into by expanding lower level WBSs at total level

Empower is the first and only browser-based analytical tool that integrates earned value, schedule, work authorization, and other key performance data to enable proactive management of complex projects

Incorporating EVM into CADRes

Reworked Spacecraft costs based on NG EVM data Found in EMPOWER

.1	Flight System Project Management	3	
.2	Flight System Systems Engineering	3	
.3	Flight System Product Assurance	3	
.4	Spacecraft	3	$ -
	Spacecraft Bus		$ -
	Old Orbital - NNG12FG01C		$ -
	Orbital - NNG14FC04C		$ -
	Adjustments to Cost Cap		$ -
	Misc.		$ -
	TESS Spacecraft (KSC)		$ -
4.1	Spacecraft Management	4	
4.2	Spacecraft Systems Engineering	4	
4.3	Spacecraft Product Assurance	4	
4.4	Spacecraft Structures & Mechanisms Total	4	$ -
4.1	Structures/Mech. Management	5	
4.2	Structures/Mech. Systems Engineering	5	

1.6.3	Flight System Product Assurance	3	
1.6.4	Spacecraft	3	$ -
	TESS Spacecraft (KSC)		$ -
1.6.4.1	Spacecraft Management	4	$ -
1.6.4.2	Spacecraft Systems Engineering	4	$ -
1.6.4.3	Spacecraft Product Assurance	4	$ -
1.6.4.4	Spacecraft Structures & Mechanisms Total	4	$ -
1.6.4.5	Spacecraft Thermal Control	4	$ -
1.6.4.6	Spacecraft Electrical Power & Distribution	4	$ -
1.6.4.6.1	EPS	5	$ -
1.6.4.6.1	Harness	5	$ -
1.6.4.7	Spacecraft GN&C	4	$ -
1.6.4.8	Spacecraft Propulsion	4	$ -
1.6.4.9	Spacecraft Communications	4	$ -
1.6.4.10	Spacecraft C&DH	4	$ -
1.6.4.11	Spacecraft Software	4	$ -
1.6.4.12	Spacecraft I&T	4	$ -
1.6.7	Spacecraft Retirement & Disposal	3	$ -
1.6.4.13	Spacecraft Other	4	$ -
1.6.4.13.1	Ground Support Equipment	5	$ -

Hubble Space Telescope CADRe

Cost, Schedule, Technical, and Risks

- CADRe will capture: Design, Development, Assembly and Operations
  - Optical Telescope Assembly
  - Spacecraft systems
  - Initial instruments
  - Ground support
  - Computer systems and data processing
- CADRe will also capture more than telescope data
  - Challenger disaster, delays, and eventual launch in 1990
  - Flawed mirror
    - Origin of the problem
    - Design of a solution
  - Servicing Missions 1, 2, 3A, 3B, and 4
  - Equipment failures
    - Gyroscope rotation sensors
    - Instruments and electronics

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CADRe Summary

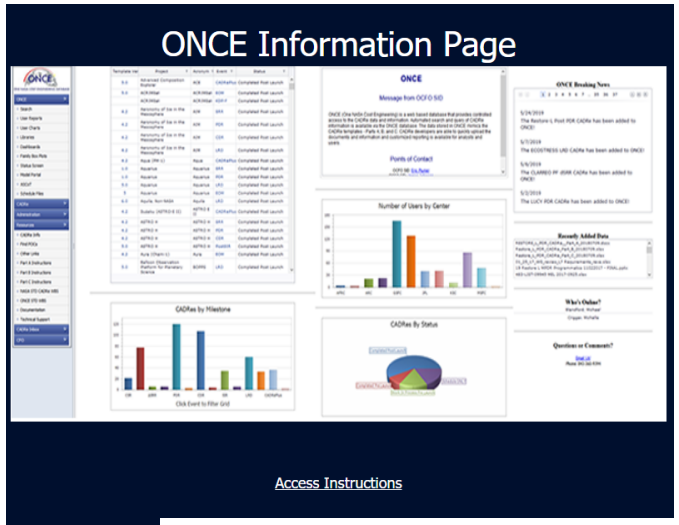
- **CADRe reports are critical for cost, schedule, and risk analysis and modeling and benefits NASA across all Centers and major offices.**

- **CADRe is a tool to gather data directly from the project.**
  - The data and it's level of detail is directly dependent upon the data provided by the project.
  - There is no normalization of technical or PP&C data. Adding to or editing any data outside of project resources would corrupt configuration management and provenance of the data.

- **Have you found a potential issue with CADRe data or level of detail?**
  - Please contact us so that we can look into it.
  - All data in CADRe is traceable to project source documents capturing thousands of data points.
    - Differences often related to source document
      - Primary, Secondary and Tertiary
      - Lifecycle maturity (changing design parameters)
    - Spotting a potential anomaly and not sharing with the CADRe team is not beneficial.
  - If an update is required then CADRe has a robust process to correct and reload.

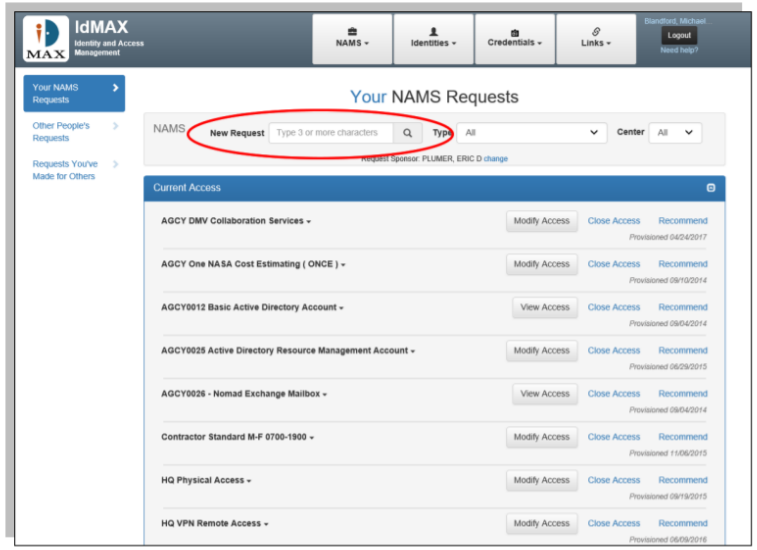
- CADRe POCs:
  - Eric Plumer, NASA SID, eric-plumer-1@nasa.gov, 202-358-5178
  - Mike Blandford, SAIC, michael.blandford@nasa.gov, 843-360-9394

CADRe Access Instructions



www.ONCEDATA.COM

Public site with all the instructions



3) Search for "ONCE" in the "New Request" field.
   a. Alternatively search for "One NASA Cost Estimating"
   b. Matching results will show below:

Go to IDMAX
https://idmax.nasa.gov

- Click on "Your NAMS Requests" hyperlink
- Type ONCE in the search
- Click to Add "One NASA Cost Estimating"
- List Eric Plumer as your sponsor

Thank You

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