Managing Programs and Projects at NASA

Jeffrey D. Smith
Kennedy Space Center

18 July 2019



AGENDA

- NASA Overview
- Mission Development Model
- Managing Costs
- Communicating Progress
- Collaborations with International Partners

CONTEXT

- Framework for the discussion is mission success
- Many components to success:
  - Technical: scientific return, lifetime, location, services, training, supply chain, technology transfer
  - Programmatic: cost, schedule, socio-economic, workforce
- Many challenges to success
  - Management: Economic climate, supplier availability and capability, changing technologies, changing policies. human factors, ITAR, etc.
  - Technical: Parts reliability, facility capability, etc
- Development is not a linear process, many things happen simultaneously and recursively
- Many sources of learning
- Longer development times exacerbate the challenges



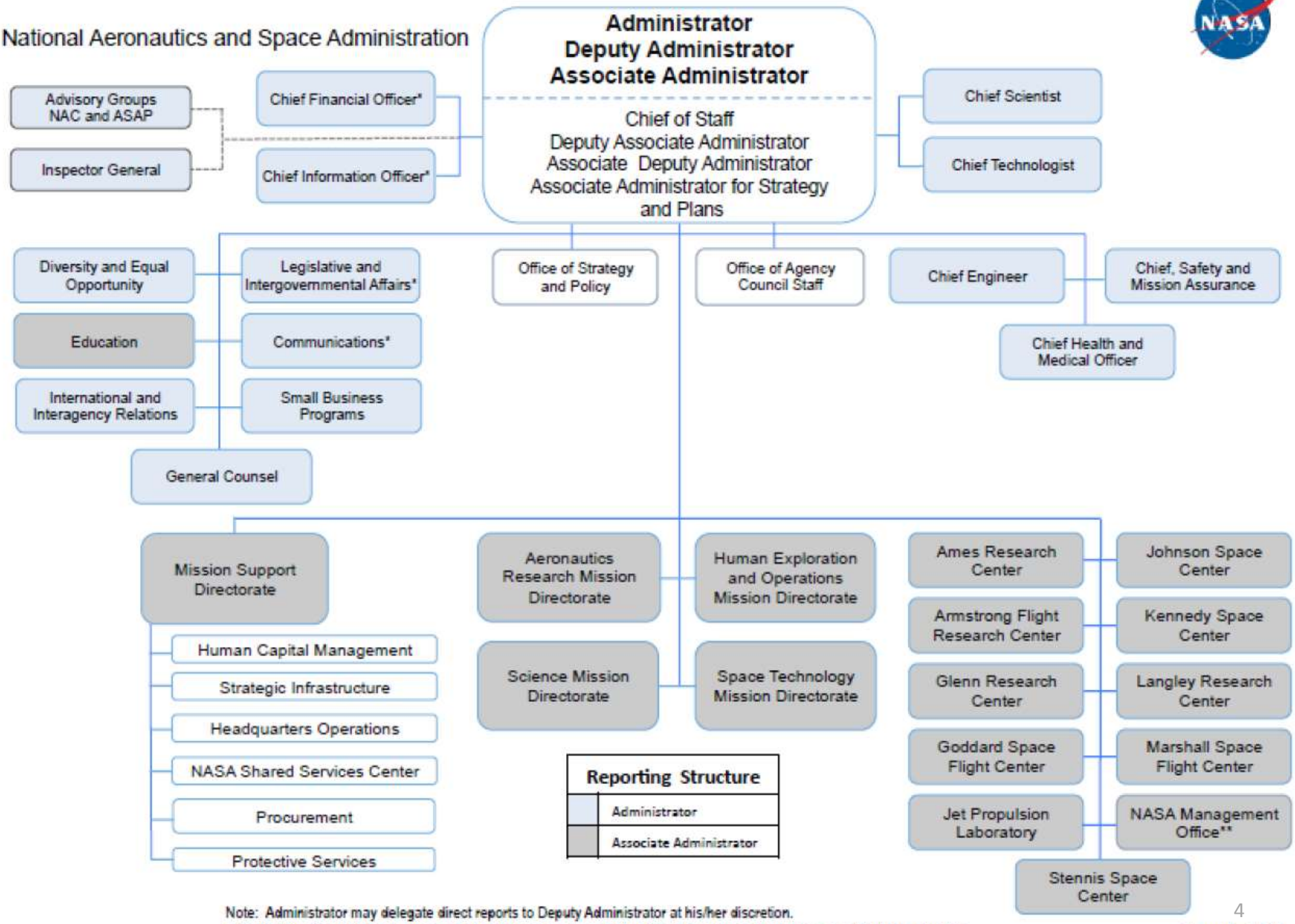







NASA Overview

National Aeronautics and Space Administration



Note: Administrator may delegate direct reports to Deputy Administrator at his/her discretion.

* Center functional office directors report to Agency functional AA or Chief. Deputy and below report to Center leadership.

** NMO oversees the Jet Propulsion Laboratory and other Federally Funded Research and Development Center work

National Aeronautics and Space Administration

NASA Organizational Leadership (June 2019)

Office of the Administrator

Administrator: Jim Bridenstine
Deputy Administrator: Jim Morhard
Associate Administrator: Steve Jurczyk
Deputy Associate Administrator: Melanie Saunders
Chief of Staff: Janet Karika
Associate Administrator for Strategy and Plans: Thomas Cremins



Mission Directorates

Aeronautics Research
Associate Administrator: Jaiwon Shin



Human Exploration and Operations
Associate Administrator: William Gerstenmaier

Science
Associate Administrator: Thomas Zurbuchen



Space Technology
Associate Administrator: James Reuter



Administrator Staff Offices

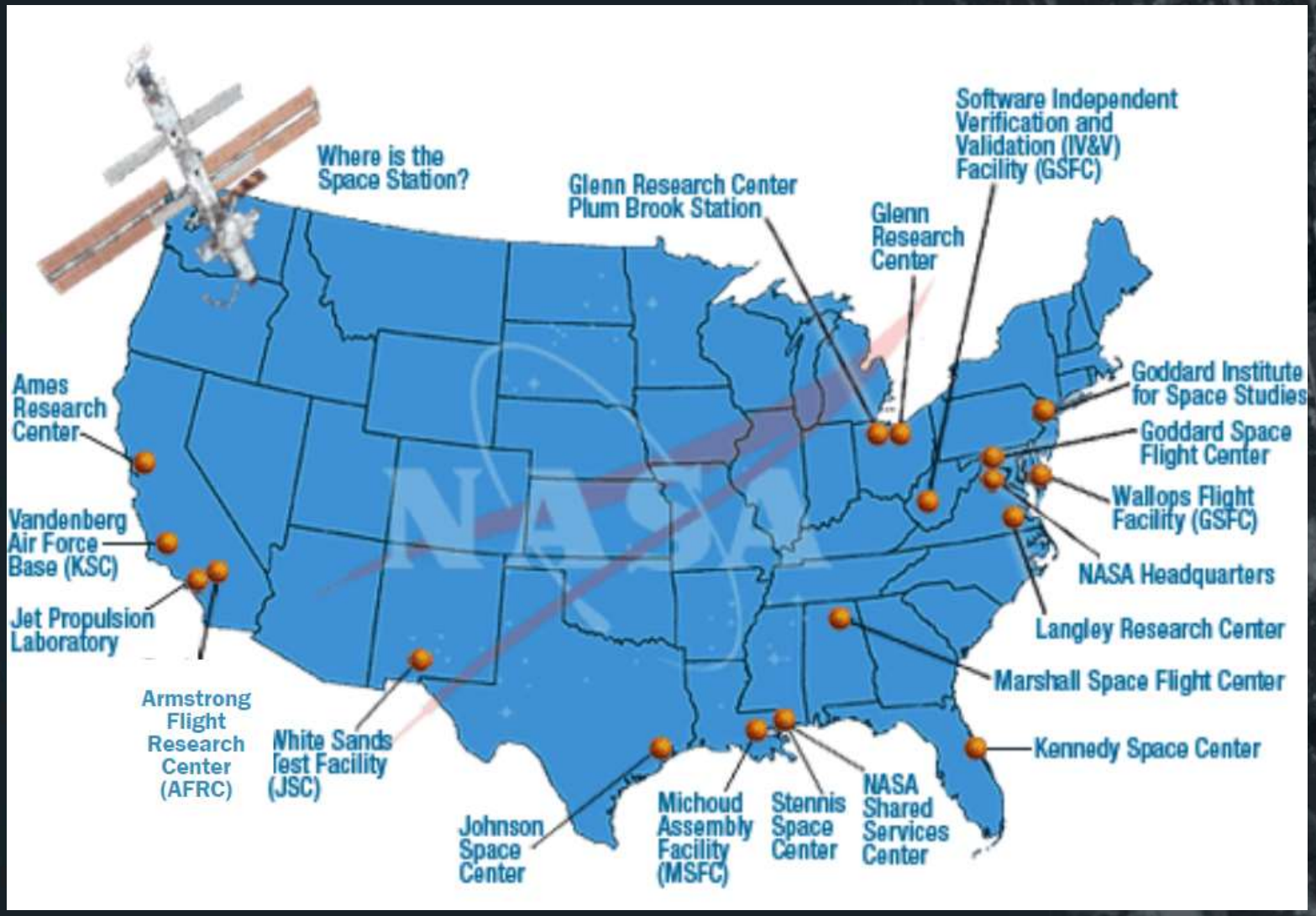
Chief Engineer: Ralph Roe
Chief Financial Officer: Jeff DeWit
Chief Information Officer: Renee Wynn
Chief Scientist: Jim Green
Chief Technologist: Douglas Terrier
Chief Health and Medical Officer: Dr. James D. Polk
Chief, Safety and Mission Assurance: Terrence W. Wilcutt
Diversity and Equal Opportunity:
Associate Administrator: Stephen T. Shih
STEM Engagement:
Associate Administrator for STEM Engagement: Mike Kincaid
International and Interagency Relations:
Associate Administrator: Al Condes
General Counsel: Sumara M. Thompson-King
Legislative and Intergovernmental Affairs:
Associate Administrator: Suzanne Gillen
NASA Management Office:
Director: Marcus Watkins
Office of Communications
Associate Administrator: Bettina Inclán
Small Business Programs:
Associate Administrator: Glenn Delgado

Mission Support Directorate

Mission Support Directorate
Associate Administrator: Daniel J. Tenney
Human Capital Management:
Assistant Administrator: Bob Gibbs
Strategic Infrastructure:
Assistant Administrator: Calvin F. Williams
Headquarters Operations:
Executive Director: Jay M. Henn
NASA Shared Services Center:
Executive Director: Anita Harrell
Procurement:
Assistant Administrator: Monica Manning
Protective Services:
Assistant Administrator: Joseph S. Mahaley

https://www.nasa.gov/about/org_index.html#center

NASA Centers and Installations



NASA Portfolio – FY2019 Budget and Out-Year Plan

With Amendment

October 2018 – September 2019

https://www.nasa.gov/news/budget/index.html

Fiscal Year (FY)	Encated		New PBR	Out Year Estimates			
$ in millions	2019	Augment	2020	2021	2022	2023	2024
Science	6,905.7	90.0	6,393.7	6,319.0	6,319.0	5,846.5	5,815.0
Aeronautics	725.0	-	666.9	673.6	680.3	587.1	587.0
Exploration Technology (STMD)	926.9	132.0	1,146.3	976.1	995.4	964.4	943.1
Deep Space Exploration Systems	5,050.8	1,374.7	6,396.4	5,295.5	5,481.4	6,639.0	7,042.3
Exploration Systems Development	4,092.8	651.0	4,092.7	3,441.0	3,468.4	3,788.5	3,654.7
Exploration Research & Technology	958.0	-321.0 1,044.7	2,303.7	1,854.5	2,013.0	2,850.4	3,387.6
LEO and Spaceflight Operations	4,639.1	-	4,285.7	4,369.5	4,369.5	4,235.5	4,182.3
Safety, Security, STEM and Mission Services	2,865.0	-	3,084.6	3,084.6	3,084.6	2,871.6	2,871.6
Consturction and Environmental Compliance and Restoration	348.2	-	600.4	468.8	468.8	468.8	387.8
Inspector General	39.3	-	41.7	42.1	42.5	43.0	43.4
NASA Total	**21,500.0**	**1,596.7**	**22,615.7**	**21,229.2**	**21,441.5**	**21,655.9**	**21,872.5**

Lunar Science → 90.0

Lunar Tech → 132.0

SLS & Orion → 651.0

Gateway → -321.0

Human Lander → 1,044.7

Aeronautics Research Mission Directorate

(https://www.nasa.gov/aeroresearch)



Strategic Thrusts

1: Safe, Efficient Growth in Global Operations

2: Innovation in Commercial Supersonic Aircraft

3: Ultra-Efficient Commercial Vehicles

4: Transition to Low-Carbon Propulsion

5: In-Time System-Wide Safety Assurance

6: Assured Autonomy for Aviation Transformation



Advanced Air Vehicles Program (AAVP)



Airspace Operations and Safety Program (AOSP)



Integrated Aviation Systems Program (IASP)



Transformative Aeronautics Concepts Program (TACP)

Aeronautics Project Highlights

https://www.nasa.gov/aeroresearch

NASA Drops a Fokker Full of [Crash Test] Dummies for Science



The Fokker F-28 hangs from the Landing and Impact Research Facility at NASA's Langley Research Center in Hampton, Virginia, moments before drop.

Following the crash, NASA and the National Transportation Safety Board will analyze data and aircraft structure to better understand and help improve aircraft safety

Low-Boom Flight Demonstration



X-59 Quiet SuperSonic Technology aircraft

- Contract award, Feb. 2016, Lockheed Martin
- CDR planned for Sep. 2019
- First Flight planned in 2020

Goals:

1) Design/build a piloted, large-scale supersonic X-plane with technology that reduces the loudness of a sonic boom to that of a gentle thump
2) fly over select U.S. communities to gather data on human responses to the low-boom flights and deliver that data set to U.S. and international regulators.

Science Mission Directorate

NASA is home to the nation's largest organization of combined scientists, engineers and technicians that build spacecraft, instruments and new technology to study Earth, the Sun, our solar system and the universe



Reaching for new heights to reveal the unknown so that what we do and learn will benefit all human kind

OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer) https://www.nasa.gov/osiris-rex

The first US mission to collect samples from the Near-Earth asteroid, Bennu, and bring them back to Earth



Key Mission Milestones & Dates:
Launch: Sept. 8, 2016
Earth Flyby: September 2017
Asteroid Operations: Begin August 2018
Detailed mapping of asteroid surface: 2019
Touch-And-Go Sample Collection: July 2020
Asteroid Departure Maneuver: March 2021
Sample Return to Earth: Sept. 24, 2023

Spacecraft
Spacecraft Mass: 4,652 pounds (2,110 kilograms)
Mission Design and Management: NASA GSFC / University of Arizona
Spacecraft Design/Build/Operations: Lockheed Martin, Colorado
Scientific Instruments: Camera Suite, Laser Altimeter, Visible, IR, Thermal and X-Ray Spectrometers, Touch-and-Go Sample Acquisition Mechanism

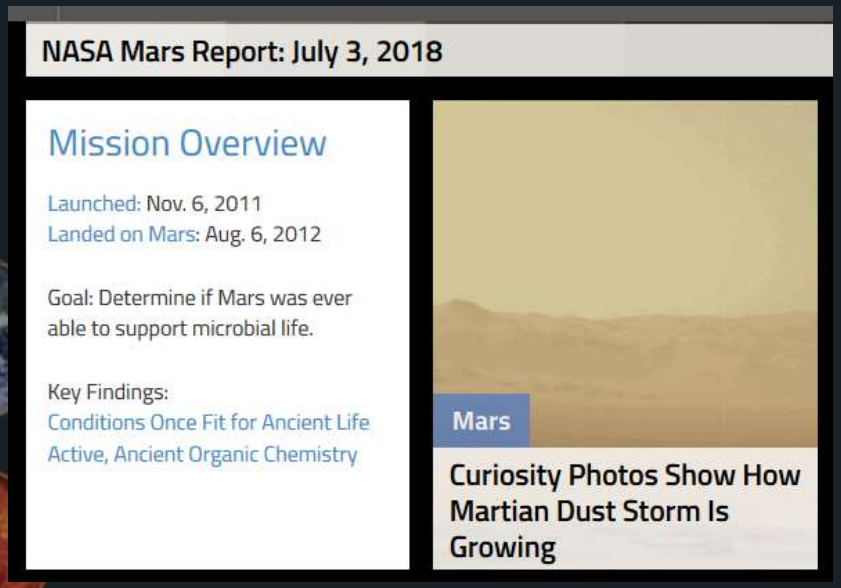
The spacecraft will briefly touch Bennu's surface to collect at least 60 grams of dirt and rocks (and up to 2 kg).



- Originated in the asteroid belt
- Broke off from another asteroid in a collison 1-2 billion years ago
- Moved into close Earth orbit.
- Closest approach to Earth every 6 years
- About 500 meters in diameter
- About 30% denser than water, loosely packed
- Rotates about once every 4.3 hrs

Curiosity Mars Rover (2537 Sols on Mars)

(https://www.nasa.gov/mission_pages/msl/index.html)





Low-angle self-portrait at the drill site into a rock target called "Buckskin" on lower Mount Sharp. Credits: NASA/JPL-Caltech/MSSS (August 5, 2015)

Recent new findings – “tough” organic molecules in three-billion-year-old sedimentary rocks near the surface, as well as seasonal variations in the levels of methane in the atmosphere – appear in the June 8 edition of the journal Science.

Curiosity mission is part of NASA’s Mars Exploration Program. The mission is managed for NASA by by the Jet Propulsion Laboratory (JPL), a division of the California Institute of Technology in Pasadena, CA.

National Aeronautics and Space Administration

Space Technology Mission Directorate

Develops crosscutting, pioneering, new technologies and capabilities to achieve NASA's current and future missions.



Stakeholders

- ARMD
- HEOMD
- SMD
- White House
- Congress
- NAC
- Industry
- Others

Mega-Drivers → *Major Societal Trends*
Example: "Access to Space for All"

Strategic Thrusts → *Overarching Vision*

1. *Expand Utilization of Near-Earth Space*
2. *Develop Efficient & Safe Transportation Through Space*
3. *Increase Access to Planetary Surfaces*
4. *Enable Humans to Live and Explore on Planetary Surfaces*
5. *Enable the Next Generation of Science Missions*

Outcomes → *Concrete, Measureable and Achievable Goals*

- *Near-term examples (5 years):*
  - *Demonstrate 40 kW solar power for Electric Propulsion*
  - *1.25Gb/s Near-Earth Communications*
  - *1 kW fission surface power system*
- *Mid-term examples (5-15 years):*
  - *Demonstrate 10x advancement in Deep Space Communication*
  - *Demonstrate 150 kW solar power for Electric Propulsion*

Technical Challenges → *Problems to be solved by Programs*

Examples:

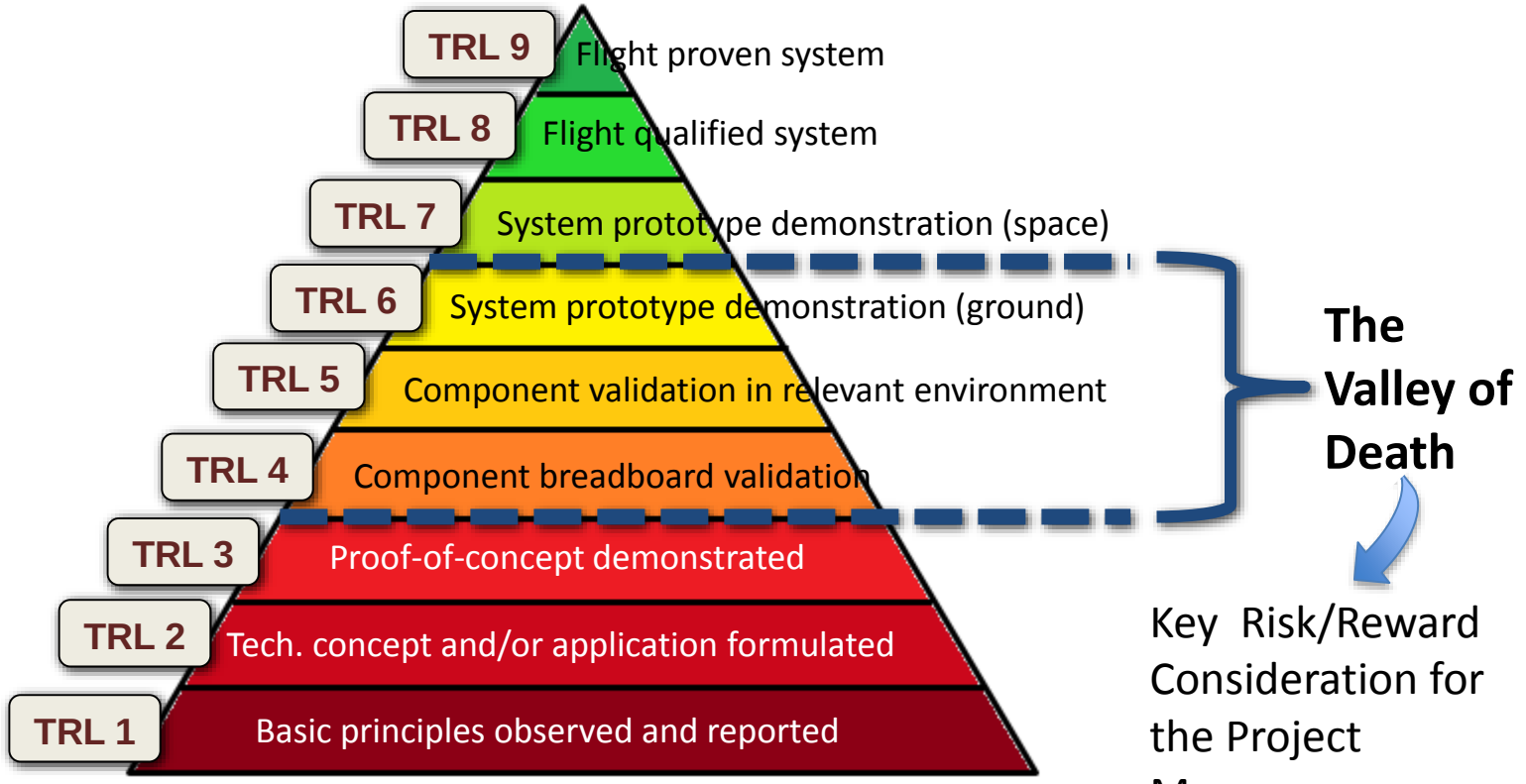
- *Advanced TPS materials able to withstand 3x heat flux*
- *Supersonic retro-propulsion*
- *Low-cost rocket propulsion*
- *Terrain Relative Navigation*
- *…*

National Aeronautics and Space Administration

Space Technology Mission Directorate



Advancing Space Technology Readiness Level



Game Changing, disruptive new technology can open new avenues for space exploration and, also, bring new "spinoff" technology back down to Earth to improve our everyday lives

New Technology Development at KSC

Swamp Works and the Science and Technology Projects Division

Orbital Syngas/Commodity Augmentation Reactor (OSCAR)

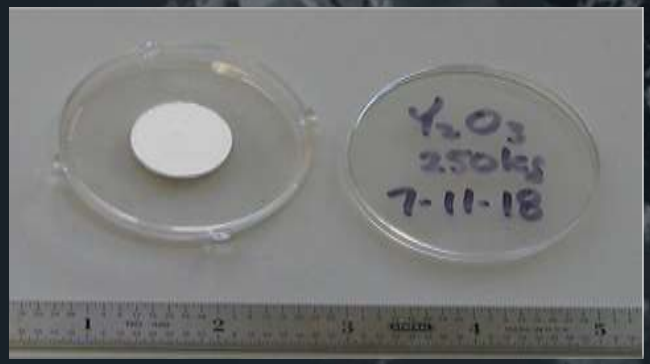


A microgravity demonstration of mission waste conversion to reduce mass, vent gas and recover raw materials. Recent drop tower testing at Glenn Research Center

Innovative Liquid Hydrogen Storage to Support Space Launch System



https://www.nasa.gov/feature/innovative-liquid-hydrogen-storage-to-support-space-launch-system



Solar White - Selective Surface: development of thermal control coating for passive cryogenics storage and superconductivity in deep space.



Human Exploration and Operations Mission Directorate

Leads NASA's space operations for human exploration in and beyond low-Earth orbit

Human Exploration and Operations Mission Directorate

How are we going farther?

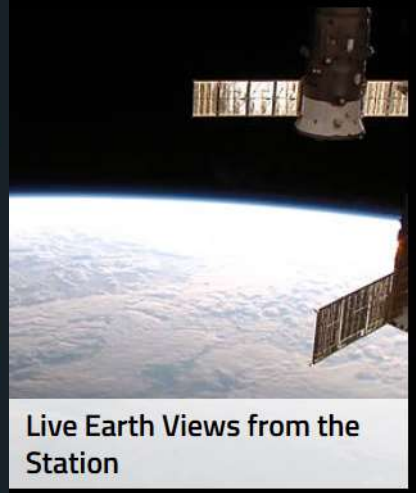


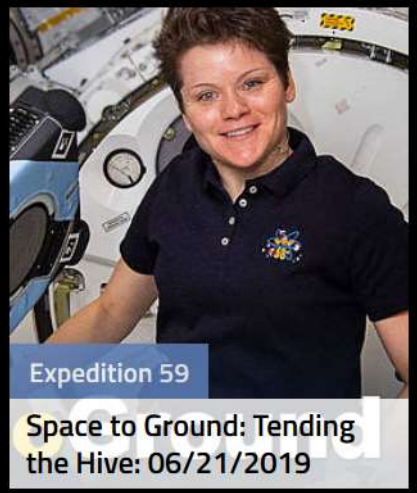
- Utilize the International Space Station
- Research the human body and mind
- Grow international partnerships
- Partner with commercial industry
- Build the *Deep Space Exploration System*
- Explore multiple destinations

ISS In the News













https://www.nasa.gov/mission_pages/station/main/index.html

ISS Near-Term Mission Planning Schedule

Planning Date	Event
Jun 28, 2018	Dragon SpX-15 Launch atop Falcon 9
Jun 30, 2018	Dragon SpX-15 Rendezvous & Berth to Harmony
Jul 10, 2018	Progress MS-09 Launch & Docking to Pirs
Jul 2018	Dragon SpX-15 Unberthing, Departure & Landing
Aug 18	Cygnus OA-9 Unberthing & Departure
Aug 8, 2018	Russian EVA-45 – MLM Prep & Icarus
Aug 16, 2018	HTV-7 Launch atop H-IIB
Aug 21, 2018	Progress MS-08 Undocking from Zvezda
Aug 22, 2018	HTV-7 Rendezvous, Capture & Berthing
Aug/Sep 2018	SpX-DM1 Dragon Demonstration Flight (Uncrewed)
Aug/Sep 2018	Boe-OFT Starliner Demonstration Flight (Uncrewed)
Sep 14, 2018	Soyuz MS-10 Launch & Docking
Sep 18	U.S. EVA-52 & 53 (Battery R&R; 4 Contingency EVAs)
Oct 4, 2018	Soyuz MS-08 Undocking & Landing
Oct 2018	Russian EVA-46 (Nuka Pre-Outfitting)

Planning Date	Event
Oct 20, 2018	HTV-7 Unberthing & Departure
Oct 31, 2018	Progress MS-10 Launch
Nov 2, 2018	Progress MS-10 Docking to Zvezda
Nov 8, 2018	Cygnus OA-10 Launch atop Antares 230
Nov 11, 2018	Cygnus OA-10 Rendezvous & Berth to Unity
Nov18, 2018	Dragon SpX-16 Launch atop Falcon 9
Nov 20, 2018	Dragon SpX-16 Rendezvous & Berth to Harmony
Dec 2018	U.S. EVA (IDA-3 Install & Outfitting)
Dec 13, 2018	Soyuz MS-09 Undocking & Landing
Dec 20, 2018	Soyuz MS-11 Launch & Docking
Dec 23, 2018	Progress MS-09 Undocking
Dec 26, 2018	Dragon SpX-16 Departure & Landing
NET 12/31/18	SpX-DM2 or Boe-CFT Crewed Test Flight
Jan 10, 2019	Cygnus OA-10 Unberthing & Departure (for long free flight demo)
NET 1/17/19	SpX-DM2 or Boe-CFT Crewed Test Flight
Feb 1, 2019	Dragon SpX-17 Launch atop Falcon 9
Feb 3, 2019	Dragon SpX-17 Rendezvous & Berth to Harmony

CRS

Intl.

CCP

http://spaceflight101.com/iss/iss-calendar/ (all dates subject to change)

Moon to Mars: Orion Ascent Abort-2 Flight Test

Planned: July 2019

NASA's Orion spacecraft is scheduled to undergo a design test in July 2019 of the capsule's launch abort system (LAS), which is a rocket-powered tower on top of the crew module built to very quickly get astronauts safely away from their launch vehicle if there is a problem during ascent



https://www.nasa.gov/feature/nasa-orions-ascent-abort-2-flight-test/

The test will last less than three minutes with the test crew module reaching an average speed of Mach 1.5, roughly 1020 miles per hour, at approximately 32,000 feet in altitude.

Major Partners:

NASA Johnson: producing the fully assembled and integrated crew module and separation ring, including development of unique avionics, power, software and data collection subsystems and several elements of ground support equipment.

Langley Research Center: primary structure of the crew module test article and a separation ring

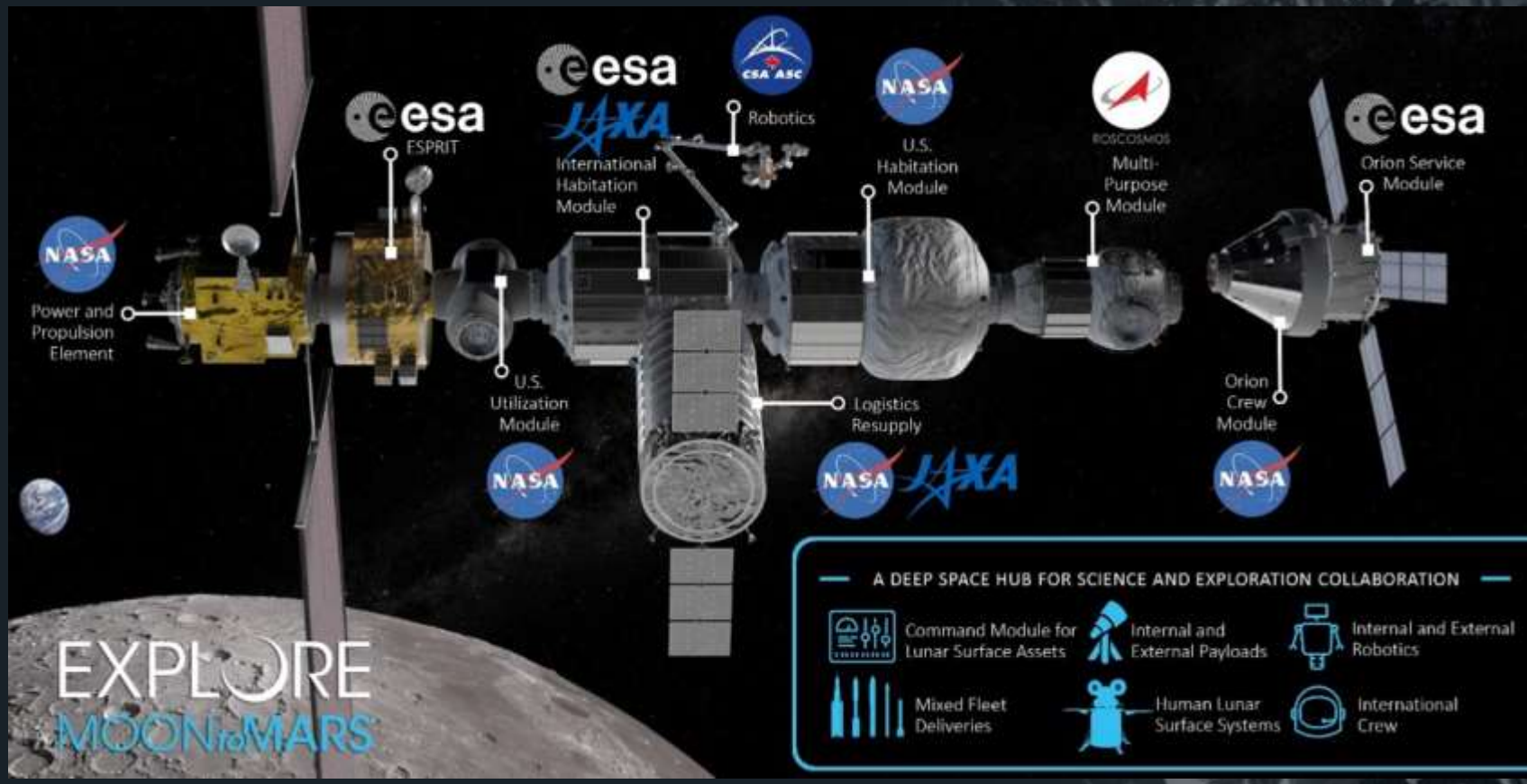
Armstrong Flight Research Center: critical sensors and instruments used to gather data during the test.

Kennedy Space Center in Florida is processing the vehicle before launch.

NASA's prime contractor, Lockheed Martin: providing the fully functional Orion LAS, and the crew module to service module umbilical and flight design retention and release mechanisms.

Gateway Configuration Concept

circa November 2018



NASA shall establish a Gateway to enable a sustained presence around and on the Moon and to develop and deploy critical infrastructure required for operations on the lunar surface and at other deep space destinations.

National Aeronautics and Space Administration

The NASA Charge to the Moon

March 26, 2019

Space Policy Directive-1: “Lead an innovative and sustainable program of exploration… …the United States will lead the return of humans to the Moon… …followed by human missions to Mars and other destinations.”

In keeping with SPD-1, NASA is charged with landing the first American woman and next American man at the South Pole of the Moon by 2024, followed by a sustained presence on and around the Moon by 2028.

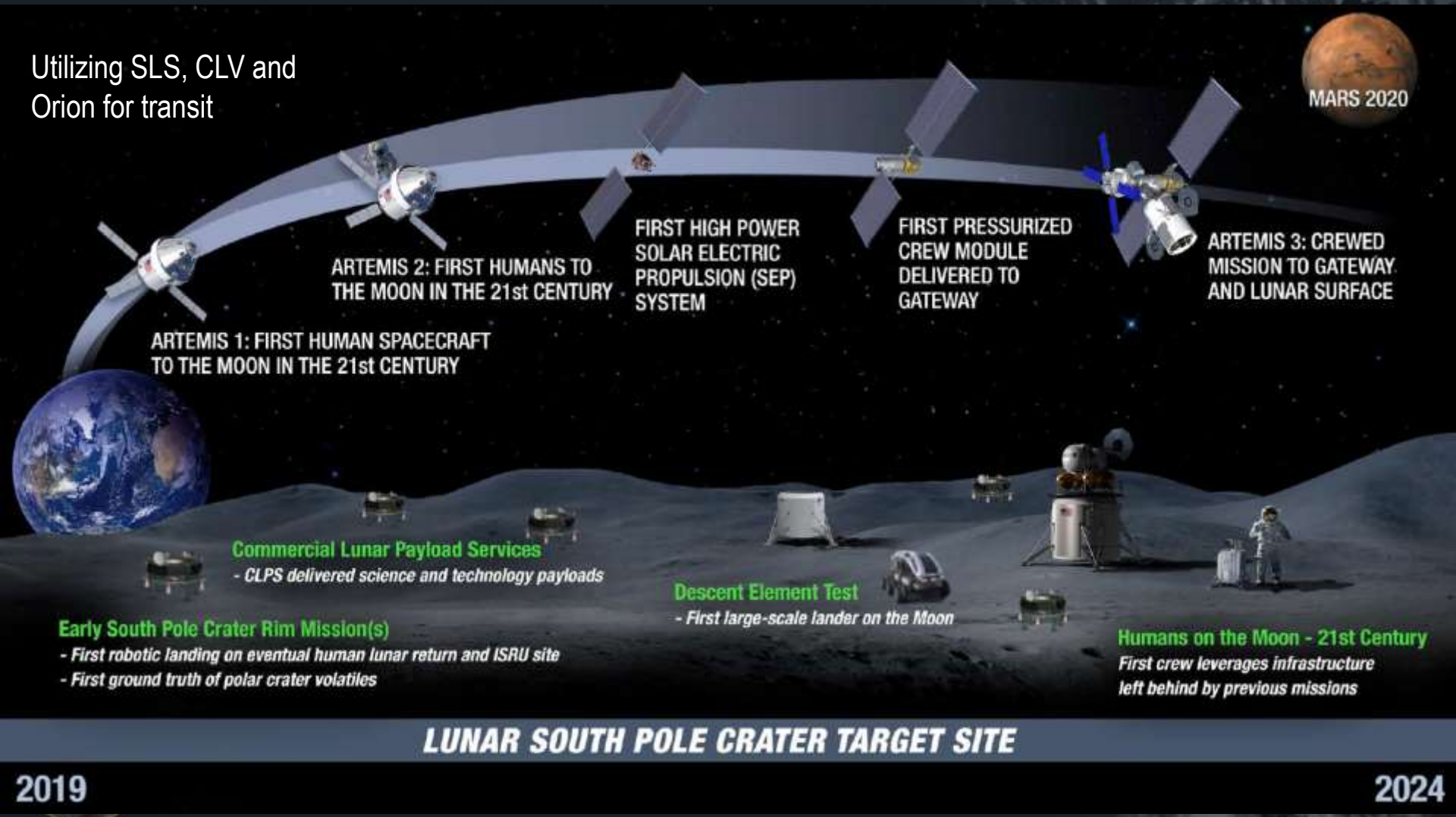
NASA will “use all means necessary” to ensure mission success in moving us forward to the Moon.



Vice President Mike Pence speaks about NASA’s mandate to return American astronauts to the Moon and on to Mars at the U.S. Space & Rocket Center in Huntsville, Alabama.

National Aeronautics and Space Administration

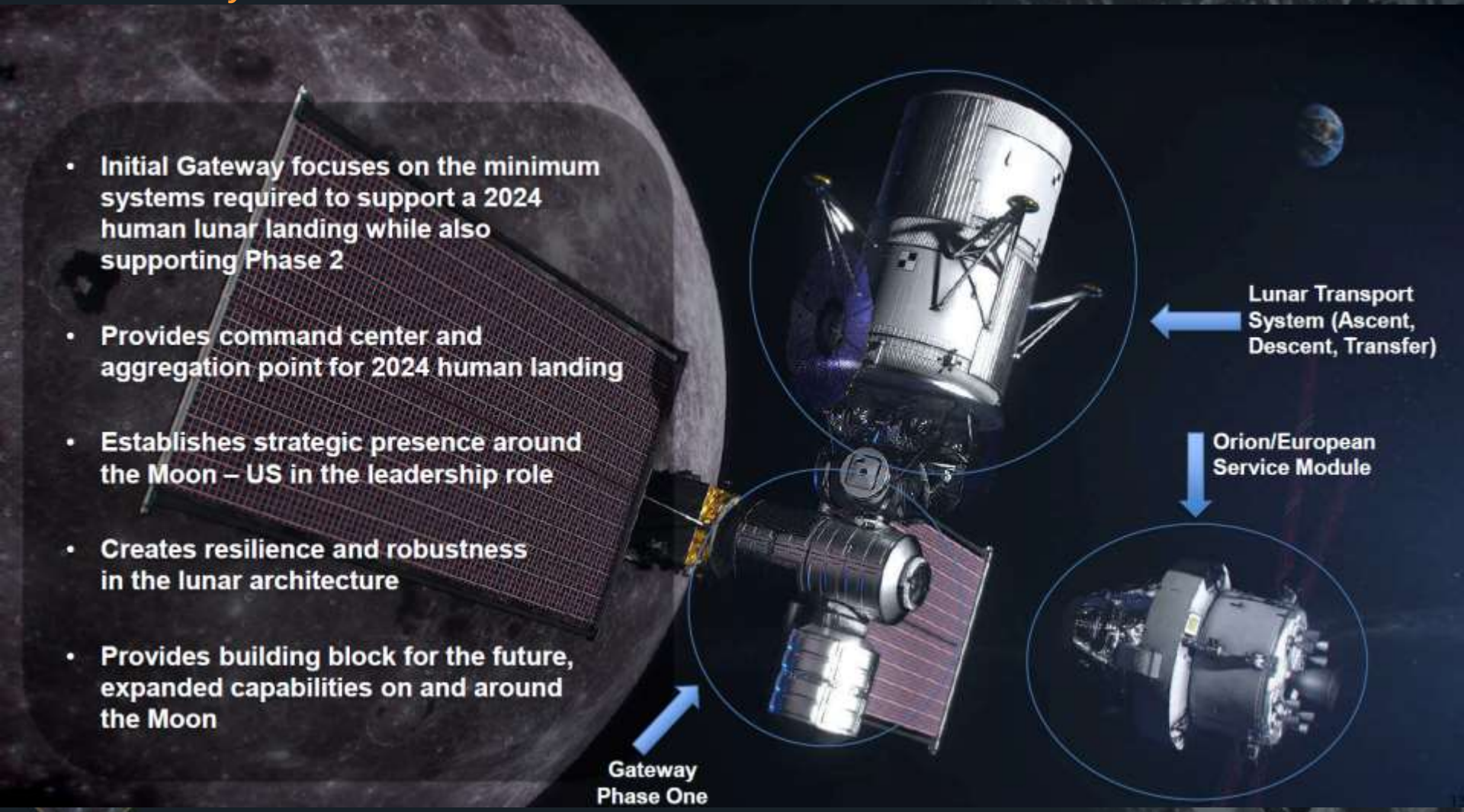
Artemis Phase 1: To the Lunar Surface by 2024



Gateway [Phase 1] is Essential for 2024 Landing

circa May 2019

- Initial Gateway focuses on the minimum systems required to support a 2024 human lunar landing while also supporting Phase 2
- Provides command center and aggregation point for 2024 human landing
- Establishes strategic presence around the Moon – US in the leadership role
- Creates resilience and robustness in the lunar architecture
- Provides building block for the future, expanded capabilities on and around the Moon



Why Go to the Moon?

Establishes American leadership and strategic presence

Proves technologies and capabilities for sending humans to Mars

Inspires a new generation and encourages careers in STEM

Leads civilization changing science and technology

Expands the U.S. global economic impact

Broadens U.S. industry & international partnerships in deep space





NASA Mission Development Model

Lifecycle of a NASA Mission

Construction
Project teams develop, manufacture, and integrate technology to build the mission to the requirements

Test
Project teams tests all missions to ensure each project will survive launch and the conditions of space to operate as intended

Launch
Engineers provide telemetry, tracking, and other support for launches from across the world

Design
Scientists and engineers work jointly to develop missions that will capture the observations needed



Operations
Spacecraft mission operations ensure data is returned timely and missions remain operational

Idea
Scientists take foundational ideas to map them into methods for exploring

Data Analysis
Data informs scientists to influence missions of the future; data is also used to drive development of new technology

NASA is capable of managing a mission from concept to operations utilizing expertise and resources from partners, industry, and in-house to execute to the requirements

Mission Development Model



- Document goals, requirements, and descopes
- Consider mission type - cost constrained vs. requirements or schedule driven

- Determine availability of technology

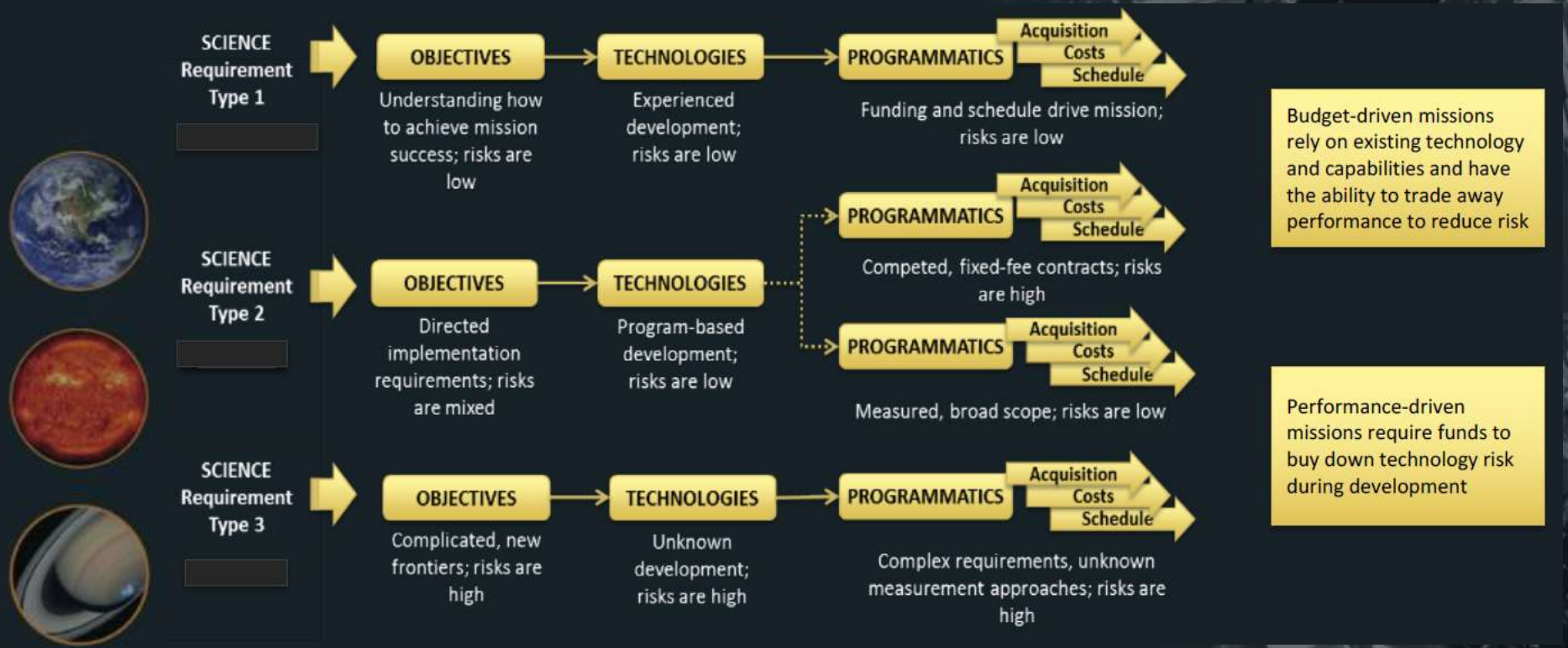
- Select acquisition strategy – procured vs. in-house, cost plus, fixed price
- Assess stability of the industry, budget, and leadership
- Identify number and type of partnerships
- Establish required reporting



Overarching Objective is to Assure Mission Success

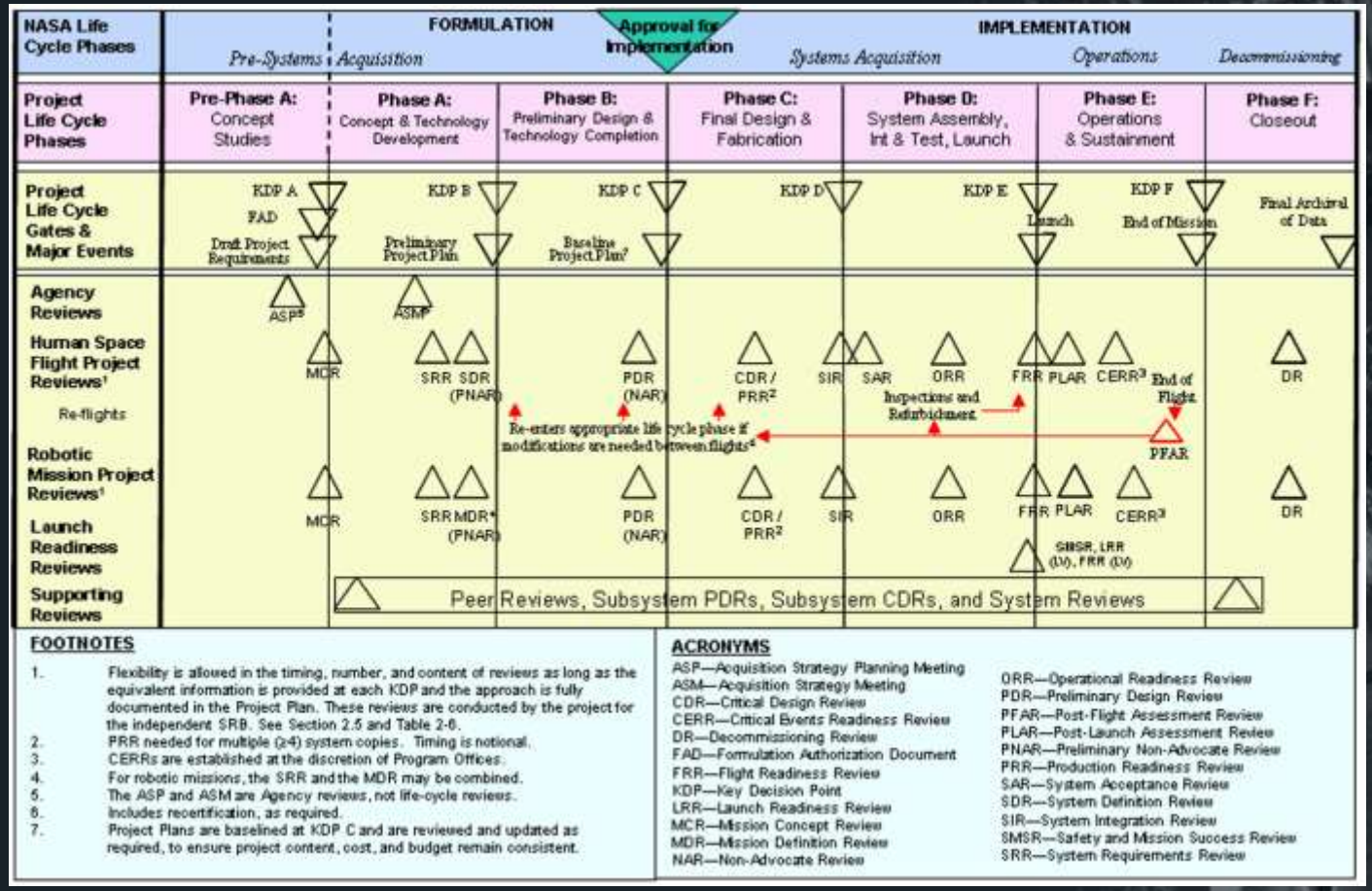
Science Drives Technology Solutions

Scientific scope defines the risk that must be tolerated to be successful:



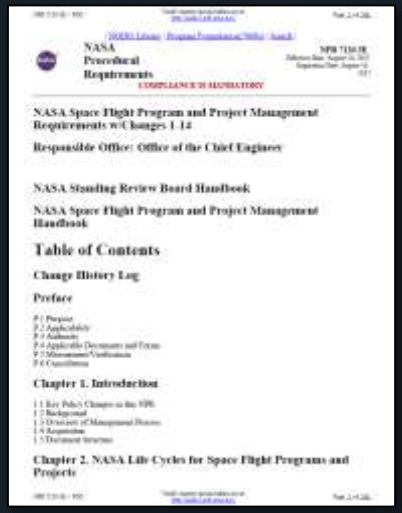
***Buying down risk* – at time of launch risk is as low as realistic**

Lifecycle Management – Project Gateway Reviews



Lifecycle reviews represent essential elements for conducting, managing, evaluating, and approving space flight programs/project. Documents the plan, reports progress, maintains continuity, clear objectives, scope, and changes

NASA Program and Project Management Requirements


NASA Procedural Requirements

NASA Space Flight Program and Project Management Requirements w/Changes 1-14

Responsible Office: Office of the Chief Engineer

NASA Standing Review Board Handbook

NASA Space Flight Program and Project Management Handbook

Table of Contents

Change History Log

Preface

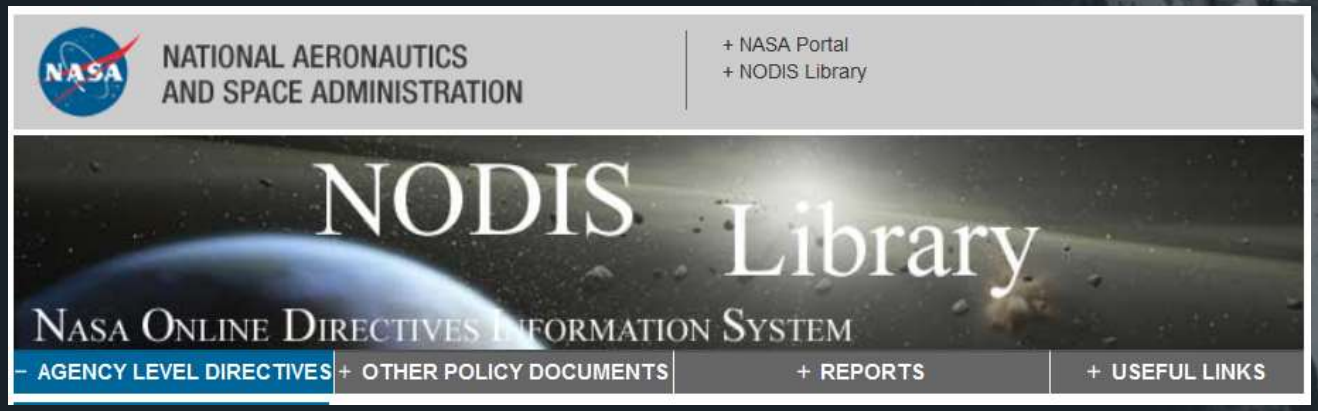
Chapter 1. Introduction

Chapter 2. NASA Life Cycles for Space Flight Programs and Projects

NPR 7120.5E: NASA Space Flight Program and Project Management Requirements

NPR 7120.7: NASA Information Technology and Institutional Infrastructure Program and Project Management Requirements

NPR 7120.8: NASA Research and Technology Program and Project Management Requirements



https://nodis3.gsfc.nasa.gov/

NASA Technical Authority


NASA Procedural Requirements

COMPLIANCE IS MANDATORY

Subject: NASA Space Flight Program and Project Management Requirements w/Changes 1-15

Responsible Office: Office of the Chief Engineer

Chapter 3. Program and Project Management Roles and Responsibilities

NPR 7120.5E: NASA Space Flight Program and Project Management Requirements

Chapter 3: Program and Project Management Roles and Responsibilities

3.1 The governance model prescribes a management structure that employs ***checks and balances*** among key organizations to ensure that decisions have the benefit of different points of view and are not made in isolation.

3.3.1.1: ***TA originates with the Administrator and is formally delegated*** to the NASA AA and then to the NASA Chief Engineer for Engineering Technical Authority; the Chief, Safety and Mission Assurance for SMA Technical Authority; and then to the Center Directors.

3.3.2.2 formal concurrence by the responsible ***TA is required on decisions*** related to technical and operational matters involving safety and mission success residual risk.

3.3.3 TA Duties (partial listing)

- ***Serve as board members*** of program or project control boards, change boards, and internal reviews.
- Ensure that requests for ***waivers or deviations from TA requirements*** are submitted to and acted on by the appropriate level of TA.
- ***Assist the program or project in making risk-informed decisions***
- ***Raise a Dissenting Opinion*** (see Section 3.4) on a decision or action, when appropriate.
- ***Serve as an effective part of NASA's overall system of checks and balances***.

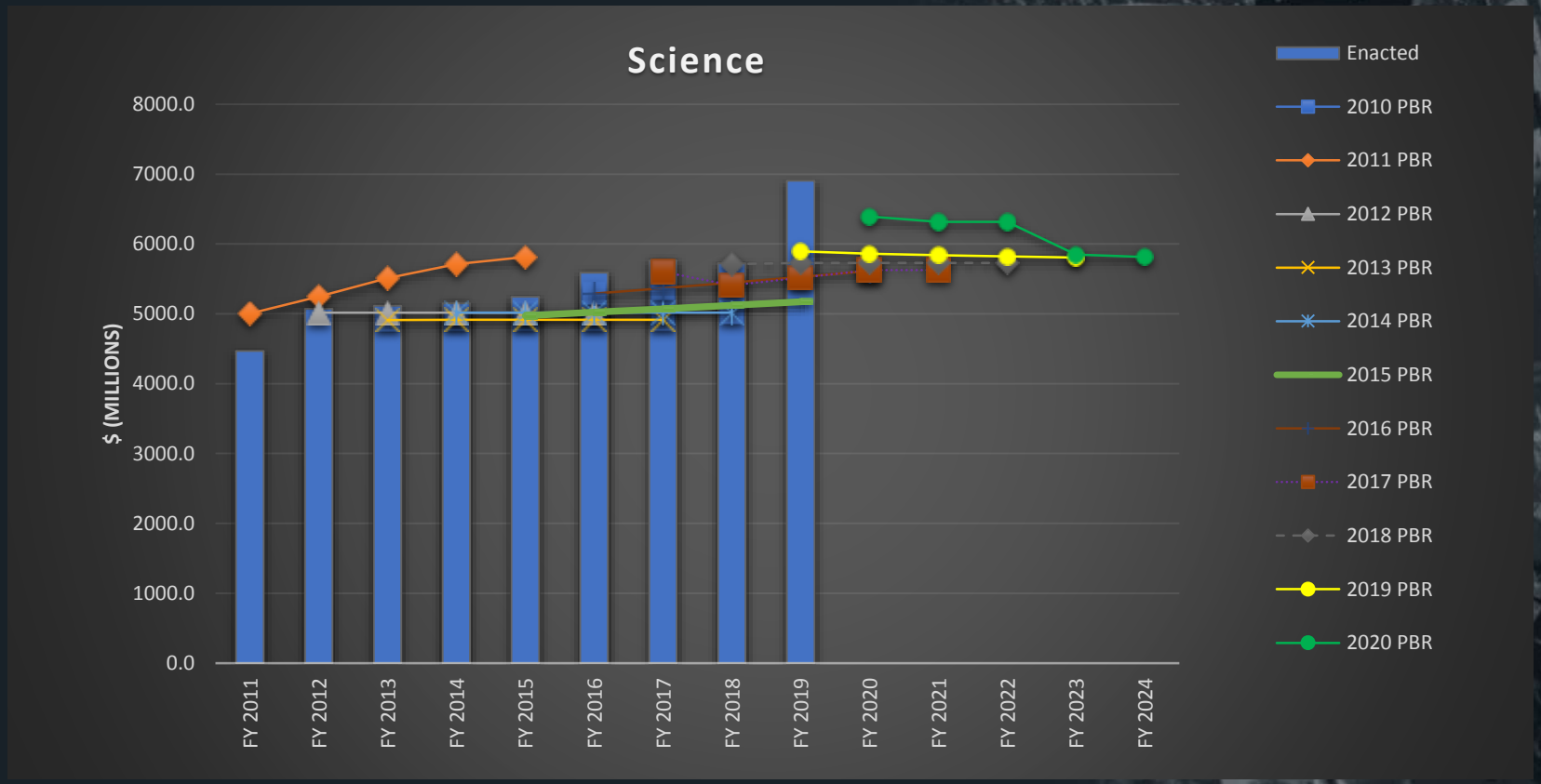




Managing Costs

Fiscal Stability

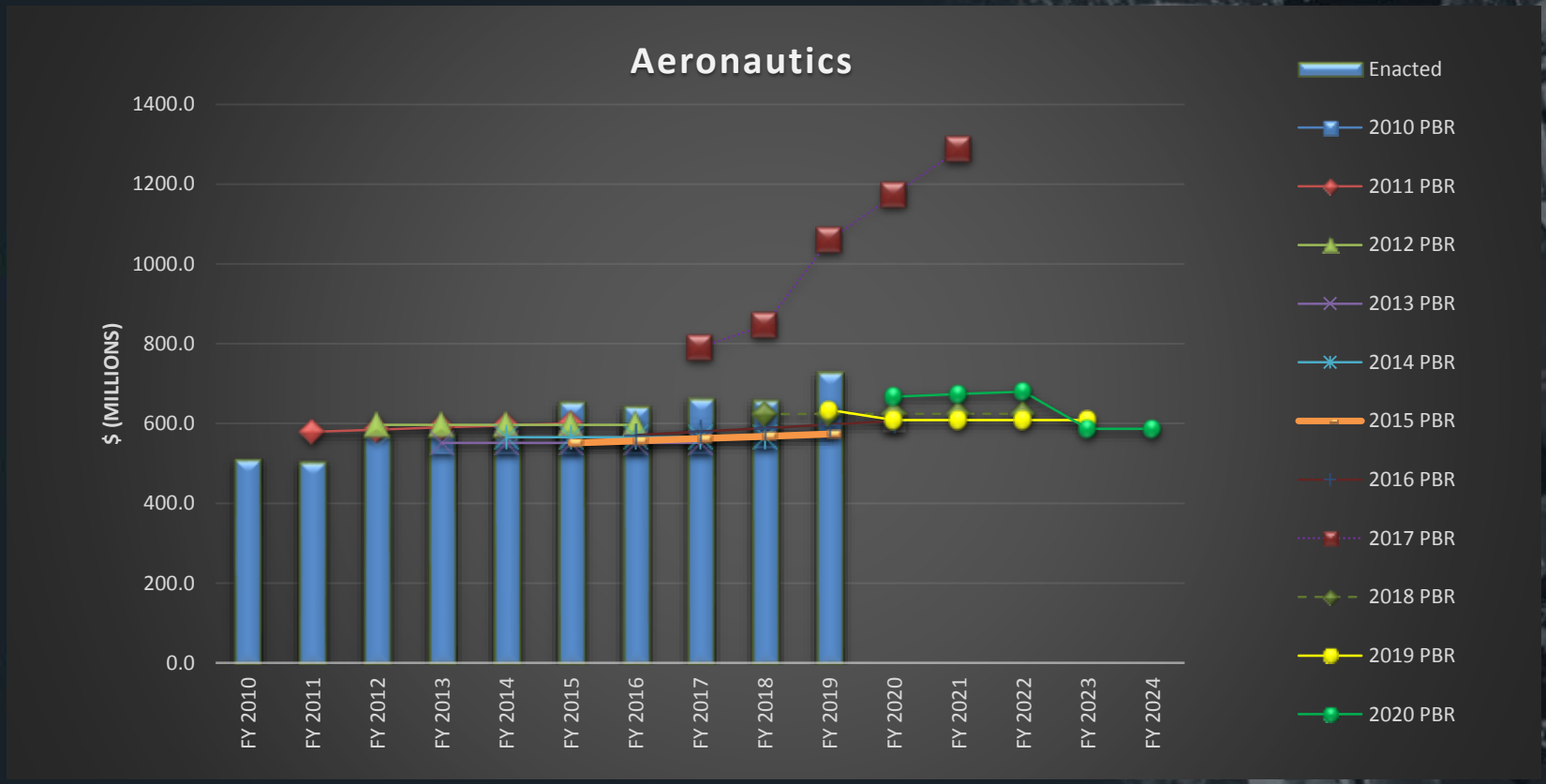
FY 2011 – FY 2020 President's Budget Request: Science Mission Directorate ($M)



Budget profile including reserves are required to assure stability for mission success!

Fiscal Stability

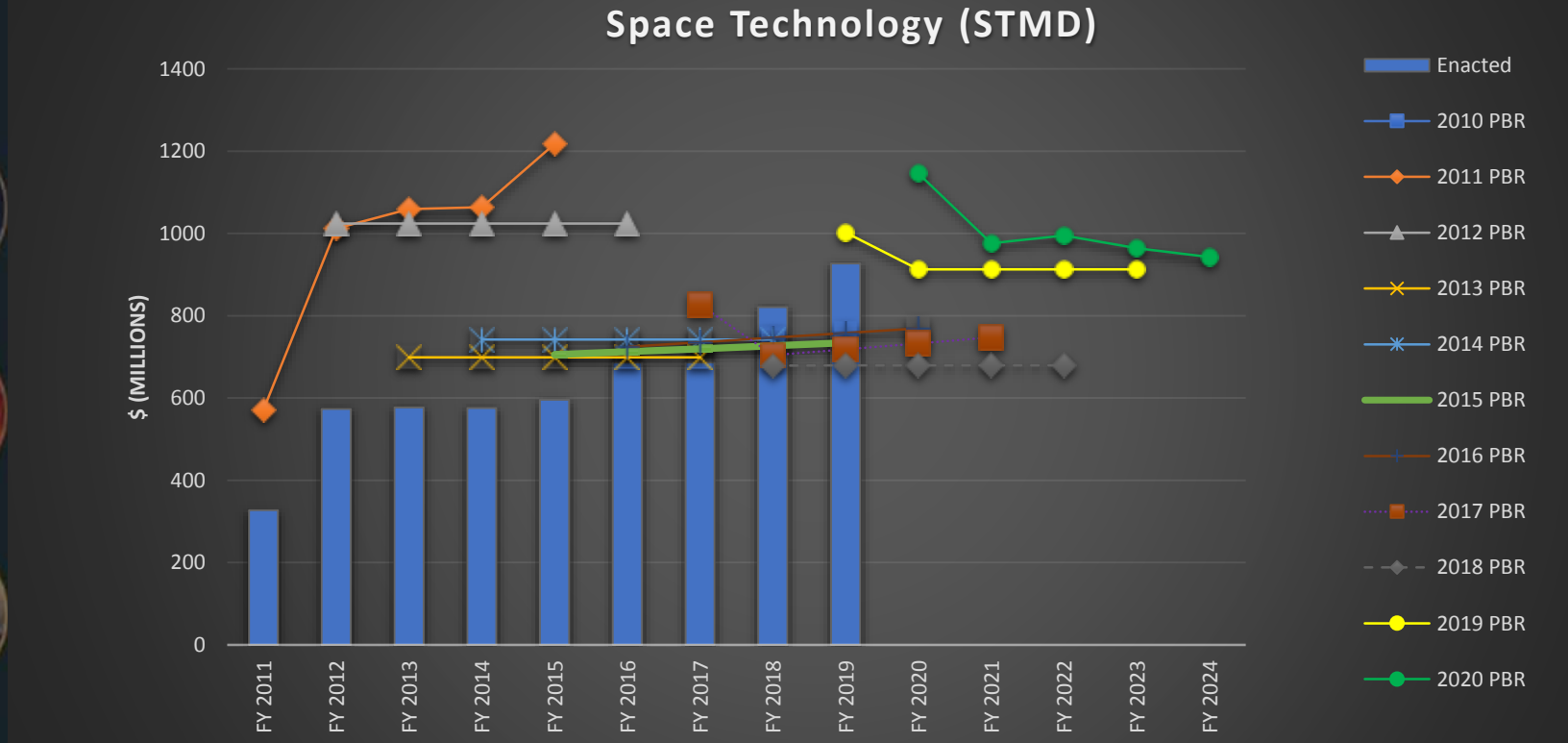
FY 2011 – FY 2020 President's Budget Request: Aeronautics Mission Directorate ($M)



Recognize that objectives and scope correspond to a specific budget, If budget changes, so must objectives and scope.

Fiscal Stability

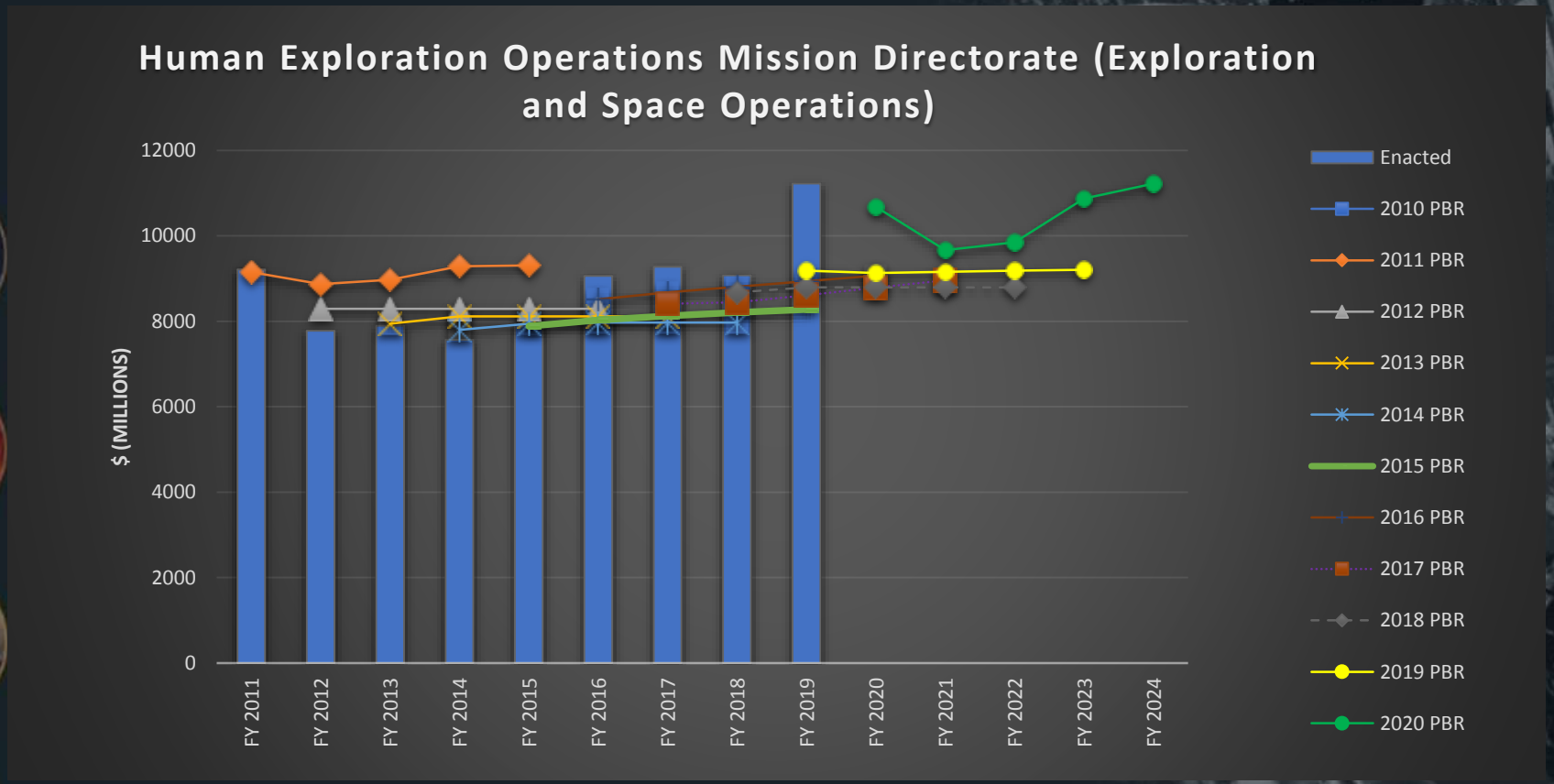
FY 2011 – FY 2020 President's Budget Request: Space Technology Mission Directorate ($M)



Workforce development: in-house training and growth, maintain core competencies and capabilities

Fiscal Stability

FY 2011 – FY 2020 PRESIDENT'S BUDGET REQUEST with AMENDMENT: HEO Mission Directorate ($M)



Predictable budget and established, unwavering requirements

Mission Cost and Schedule Performance

NASA Science Mission Portfolio			
Programmatic Performance			
Mission	Development Cost	Launch Readiness	On Track to Complete Mission Success
Juno	-4%	On Time	✓
S-NPP	-6%	Early (-4 mos)	✓
MSL	3%	On Time	✓
NuStar	5%	Delayed (+4 mos)	✓
RBSP (Van Allen Probes)	-6%	Delayed (+3 mos)	✓
LDCM	-17%	Early (-4 mos)	✓
IRIS	1%	On Time	✓
LADEE	14%	Early (-2 mos)	✓
MAVEN	-14%	On Time	✓
GPM	-12%	Delayed due to Furlough (+2 mos)	✓



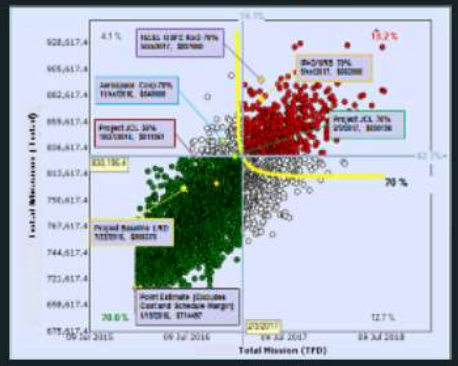



"We do what we say we are going to do"

Cost and Schedule Management and Controls

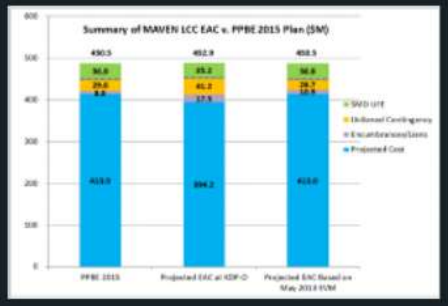
Single Instance, Confidence Check

Joint Confidence Level

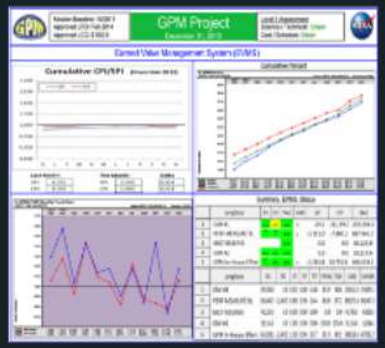


Ongoing, Progress Assessment

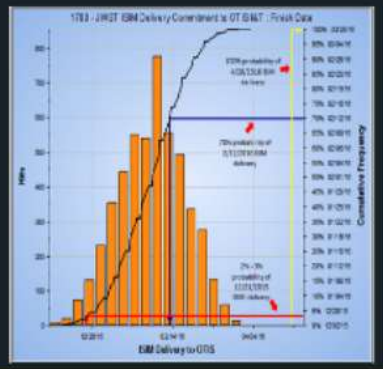
EAC Business Assessment



EVM Analysis



Schedule Risk Analysis



Schedule Performance – Baseline Execution



Schedule Health Checks



Cost and schedule performance is assessed by the project and independently to validate progress and enable proactive mitigation of negative trends

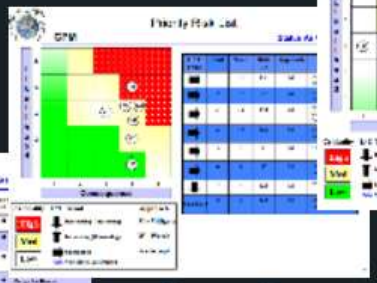
Risk Management



PHASE A - FORMULATION



PHASE B - FORMULATION



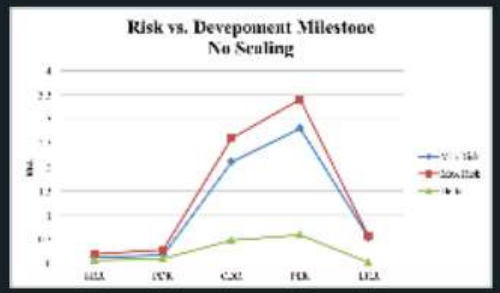
PHASE C - DEVELOPMENT



PHASE D - DEVELOPMENT



PHASE D – 1 MONTH TO LAUNCH





PHASE D – 2 MONTHS AFTER LAUNCH; 1 MONTH PRIOR TO PHASE E

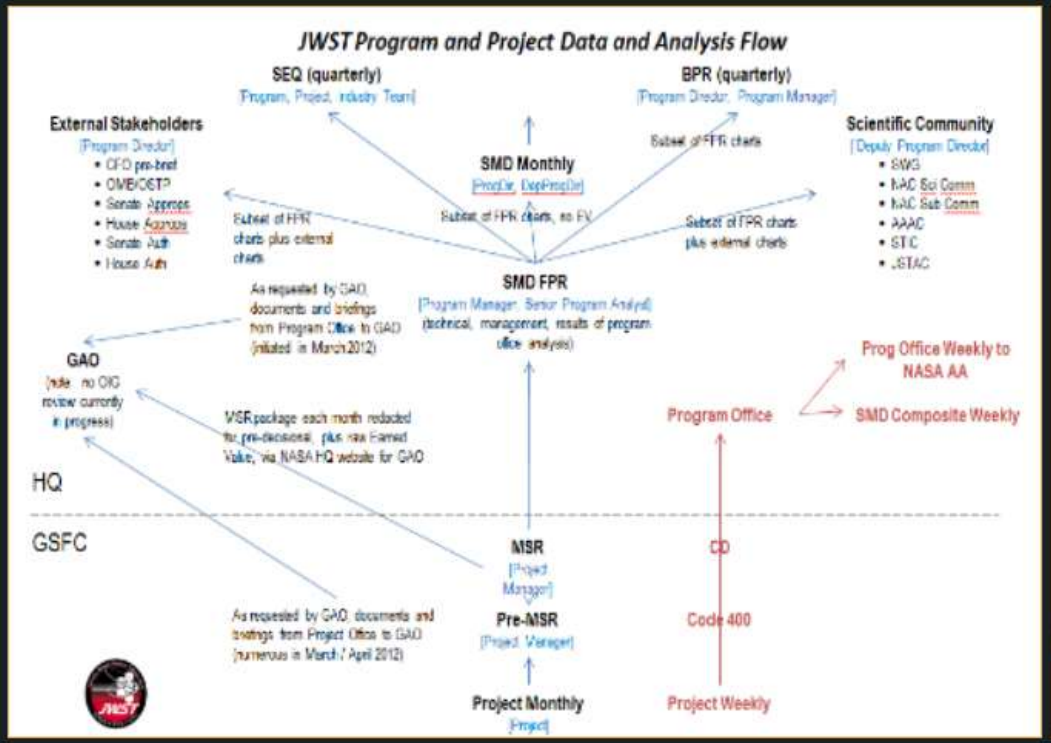
Risks are monitored throughout mission development; risks will increase throughout the lifecycle, yet the project is typically launched with low risks

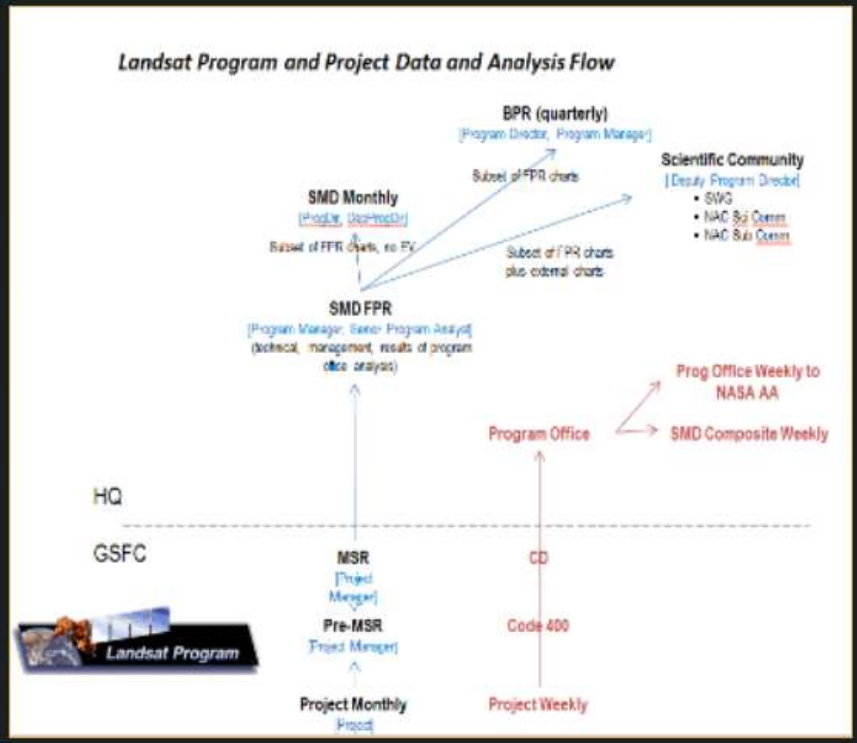




Communicating Progress

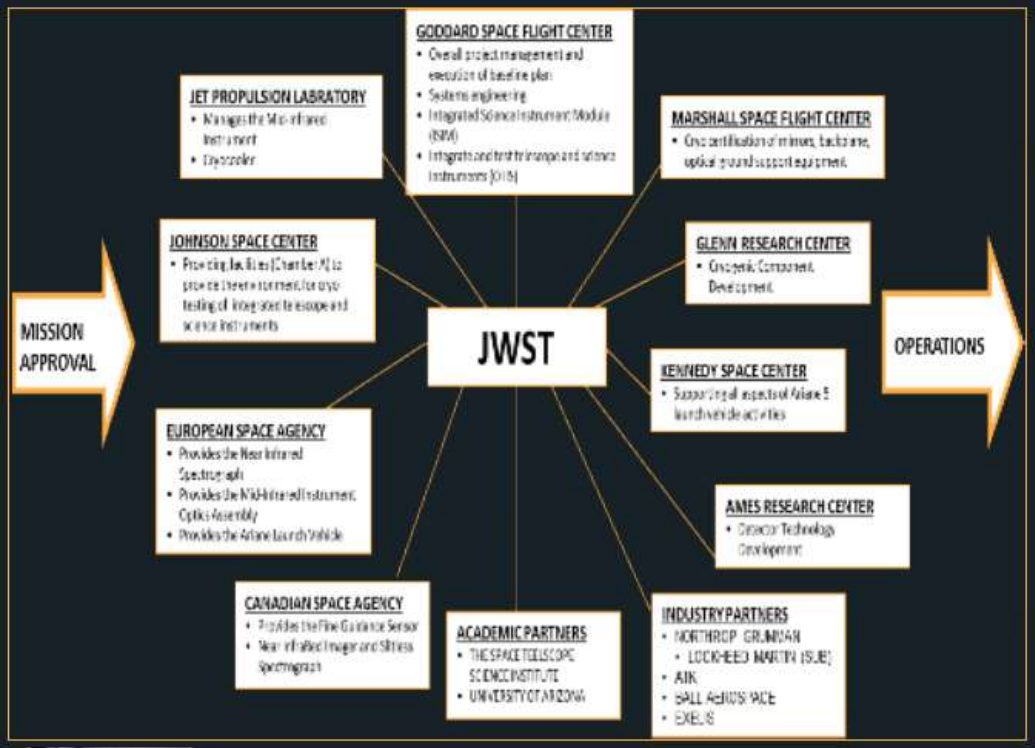
Project Reporting and Coordination

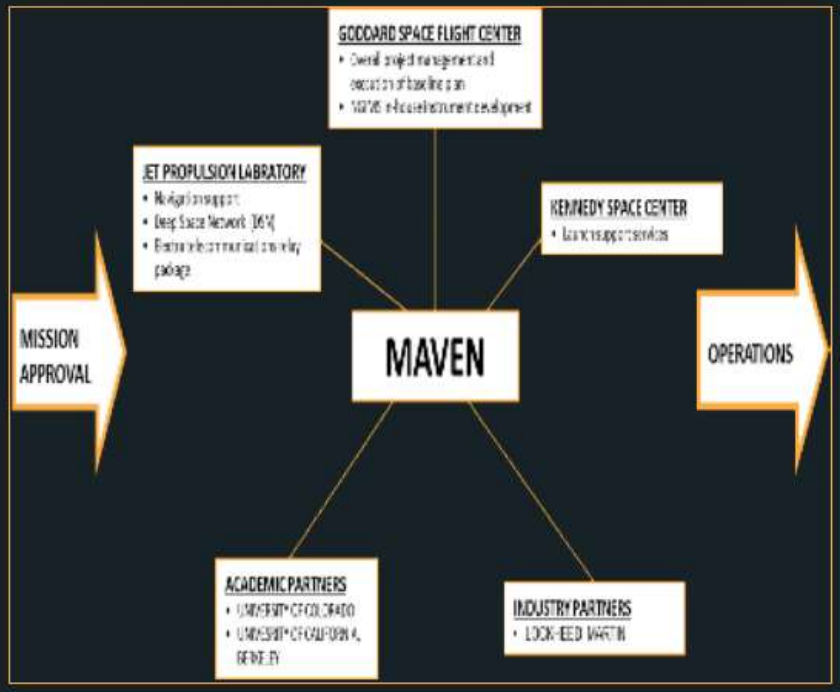




- Reporting structure is tailored to each individual program/project
- Communication must be clear and timely through all phases, to all stakeholders

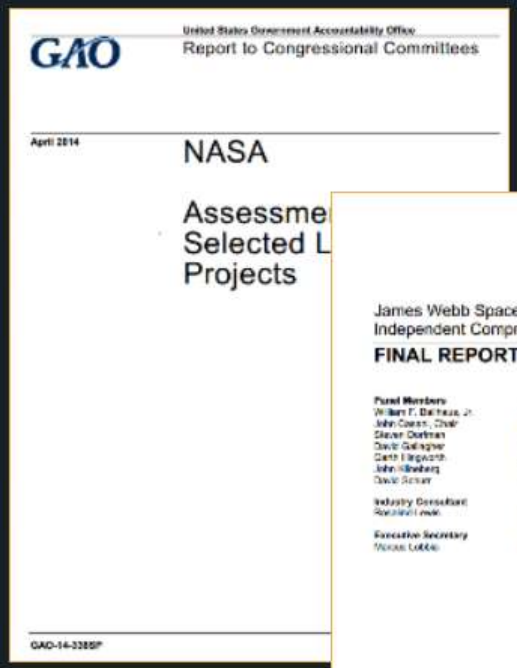
Project Interfaces



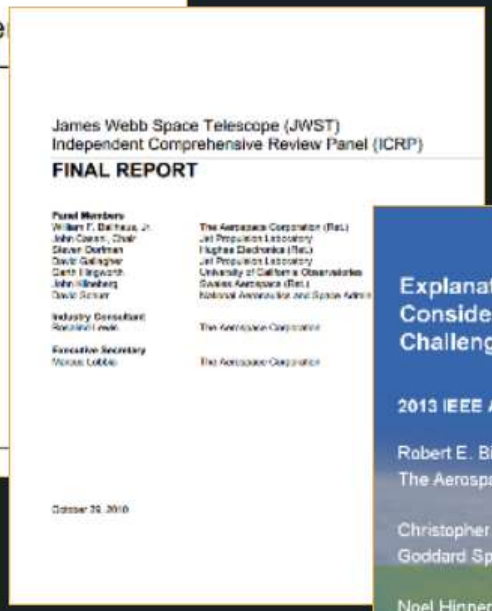


- NASA projects are highly matrixed and distributed
- NASA projects leverage partner capabilities to develop missions

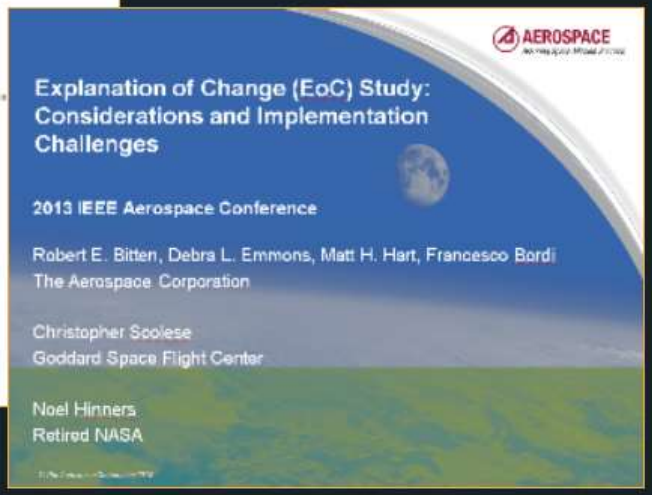
NASA is a Learning Organization



✓ **21 Recommendations Implemented and Completed**



✓ **22 Recommendations Implemented and Completed**



✓ **9 Considerations Implemented and Completed**









NASA conducts comprehensive evaluations of program planning and control methods to implement best practices to improve cost, schedule, and overall performance of the portfolio





Collaborations With International Partners

NASA's International Relationships

- **International cooperation has been part of NASA since its inception**
  - Directed by the 1958 National Aeronautics and Space Act
    - NASA will cooperate with other nations
    - Disseminate information as broadly as practicable
  - Goal of the 2010 National Space Policy: Expand international cooperation on mutually beneficial space activities to:
    - broaden and extend the benefits of space;
    - further the peaceful use of space;
    - and enhance collection and partnership in sharing of space-derived information
- **Current international cooperation:**
  - Over 600 active international agreements
  - 8 partners account for 50% of the agreements (France, Germany, ESA, Japan, UK, Italy, Canada, Russia)
  - By mission area: 2/3 are in science missions
  - By region: 1/2 are with partners in Europe






Challenges to Cooperation

- **Management Complexity**
  - Decision-making; Communications difficulties; and differing specifications, standards and assumptions
- **Technical and Programmatic Risk**
  - The "critical path" question; Interfaces difficult to manage at a distance; and
  - Difficult to monitor progress and get early warning of problems
- **Political Risk**
  - Budgetary and bureaucratic uncertainties
  - Potential linkage to activities unrelated to the cooperation
- **Linkage to missile technology and other nonproliferation concerns**
  - Iran, North Korea, and Syria Nonproliferation Act PL 106-178, as amended *(has impact on NASA procurements with Russia)*
  - Launch of US spacecraft on certain foreign launch vehicles
- **Potential barriers to enhanced cooperation with nontraditional partners:**
  - Partner capacity; Limited financial resources; Lack of infrastructure; Government bureaucracy; and Sovereignty issues



Partnerships enable and enhance missions!

International Space Exploration Coordination Group (ISECG)



Why do we rise to this challenge together?

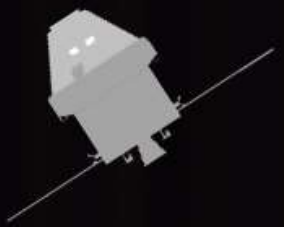
Human Exploration of Mars is Hard

20-30 tons
Ability to land large payloads needed

Reliable in-space transportation:
Total continuous transportation power

130 tons
Heavy-lift mass means **multiple** launches per mission

Thin atmosphere and dusty conditions for surface operations.



13.5 km/s Earth re-entry speed

44 minute max two-way communication delay
2-week blackout every 26 months when Earth and Mars are on opposite sides of the sun



800-1100 days away from Earth in micro gravity and high levels of radiation

20 tons of oxygen needed for ascent to orbit: In-Situ Resource Utilization (ISRU)





Closing

Recap – Lessons Learned

- **Initial conditions establish environment for success**
  - *A Priori* agreement on all parties' objectives, scope, and programmatic factors
- **Fiscal stability is critical for success**
  - Predictable budget and established, unwavering requirements
  - Recognition that objectives and scope correspond to a specific budget (and budget profile)
    - If budget changes, so must objectives and scope
  - Workforce development: in-house training and growth, maintain core competencies and capabilities
- **Open Communication**
  - Clear and timely
  - Maintained through all phases
  - To all stakeholders
  - Training and knowledge sharing
- **Agreements must be clear and enforceable**
  - Unanimous understanding of agreed upon resources – or the plan must be changed
- **Document the plan and progress**
  - Maintain continuity through organizational change
  - Clear statement of objectives , scope, and changes



Observations on Collaborating with NASA

- Project Managers at NASA come from a variety of personal and NASA program and NASA Center backgrounds.
- The management styles of NASA PMs also vary with the individual
- But regardless of these differences NASA PMs all follow the same basic policies and procedures.
- And we all face the same constraints: ITAR, limited access to our facilities, travel restrictions.
- We tend to be informal and often quite blunt... though we do try to appreciate and respect cultural differences. (This IPM course helps us do that!)
- We appreciate transparency and openness in our relationships with our counterparts.
- When possible we like to get to know our international partners informally.
- We sometimes may choose an informal (outside of work) setting to discuss difficult issues with our partners









We look forward to working with each of you!