Engineering Authority

Implementation at Goddard

Richard Day
Director of Mission Success

Engineering Authority

Implementation at Goddard

Wide spectrum of project scope, complexity and acceptable risk

Clear accountability and authority for safety and mission success

Robust, independent systems of checks and balances

Knowledge-based decision making and enhanced performance as a learning organization

Goddard Space Flight Center

Created Oct. 1, 1958

- First research Center created specifically to support the new National Aeronautics and Space Administration

Programs

- $2.5 B total annual budget
- $400 M reimbursable work

Major Facilities

Greenbelt - 1,121 acres

33 major buildings, 40 minor buildings

People (all sites)

3350 civil servants

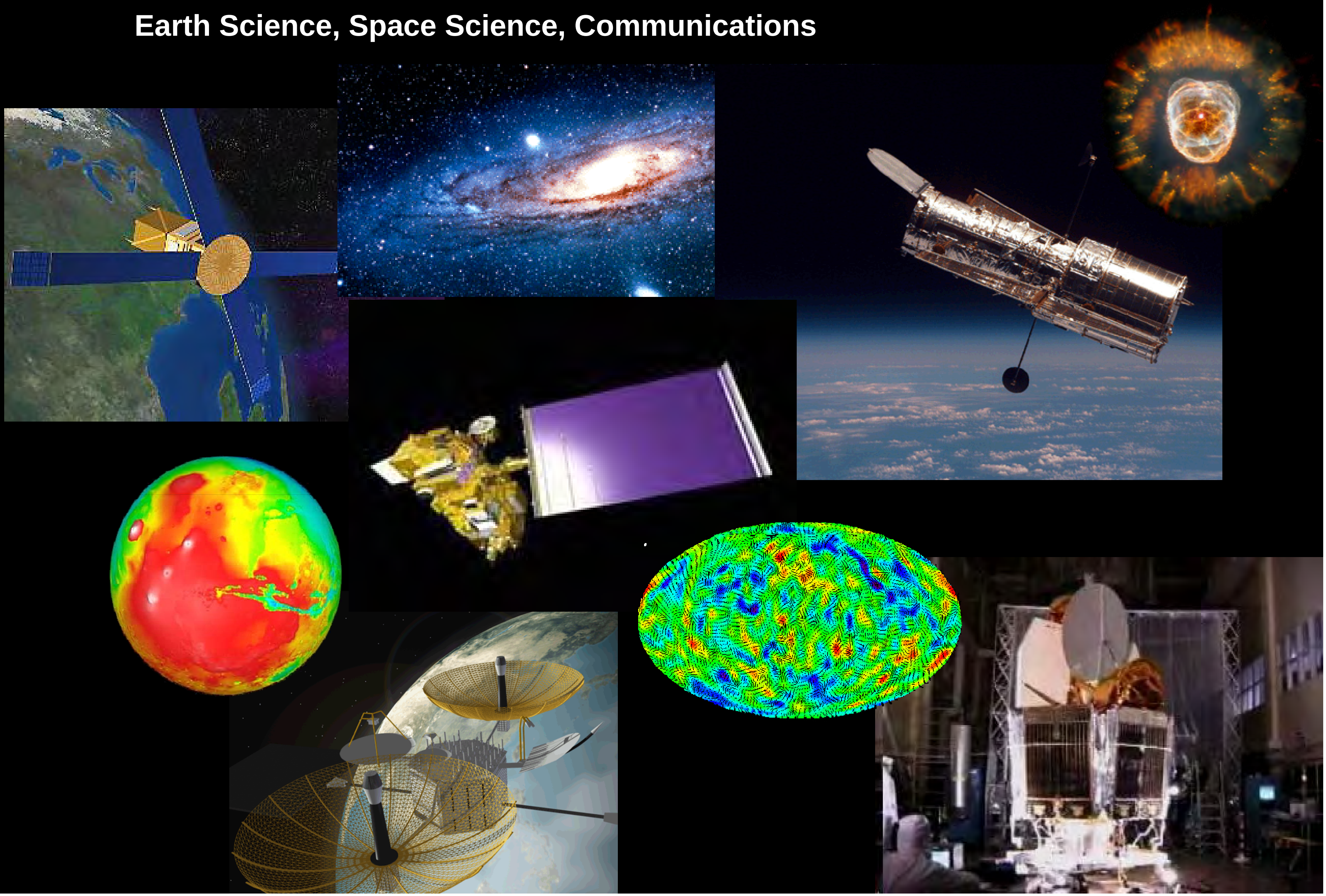
4000 on-site support contractors

Goddard Space Flight Center

Goddard Space Flight Center, Maryland
Wallops Flight Facility, Virginia
IV&V Facility, West Virginia
GISS, New York
White Sands Ground Station, New Mexico

Goddard Space Flight Center

Earth Science, Space Science, Communications



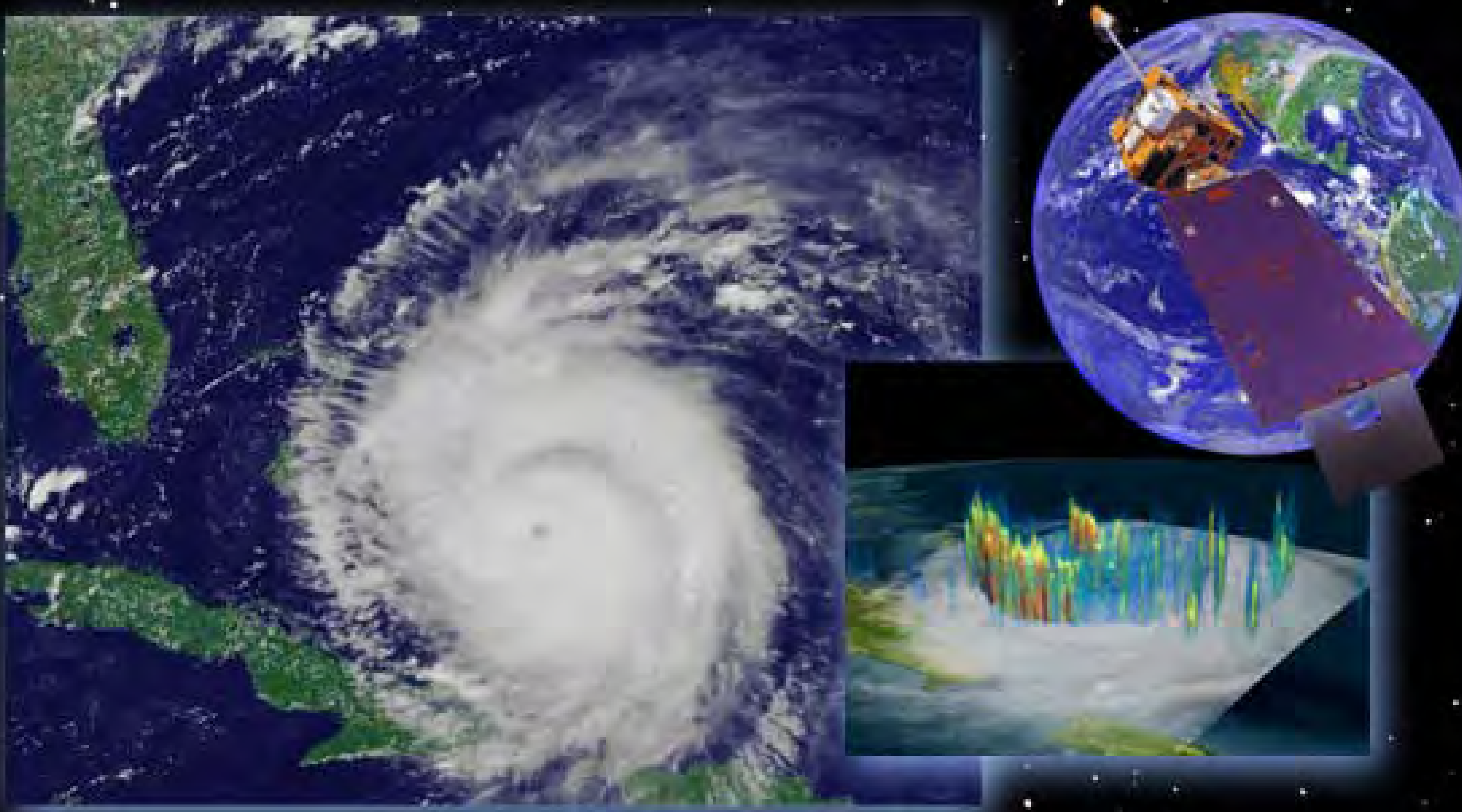
Goddard Space Flight Center

Suborbital and Special Projects

- Wallops Flight Facility – 6,188 acres
- 100 major buildings, 142 minor buildings

Goddard Space Flight Center

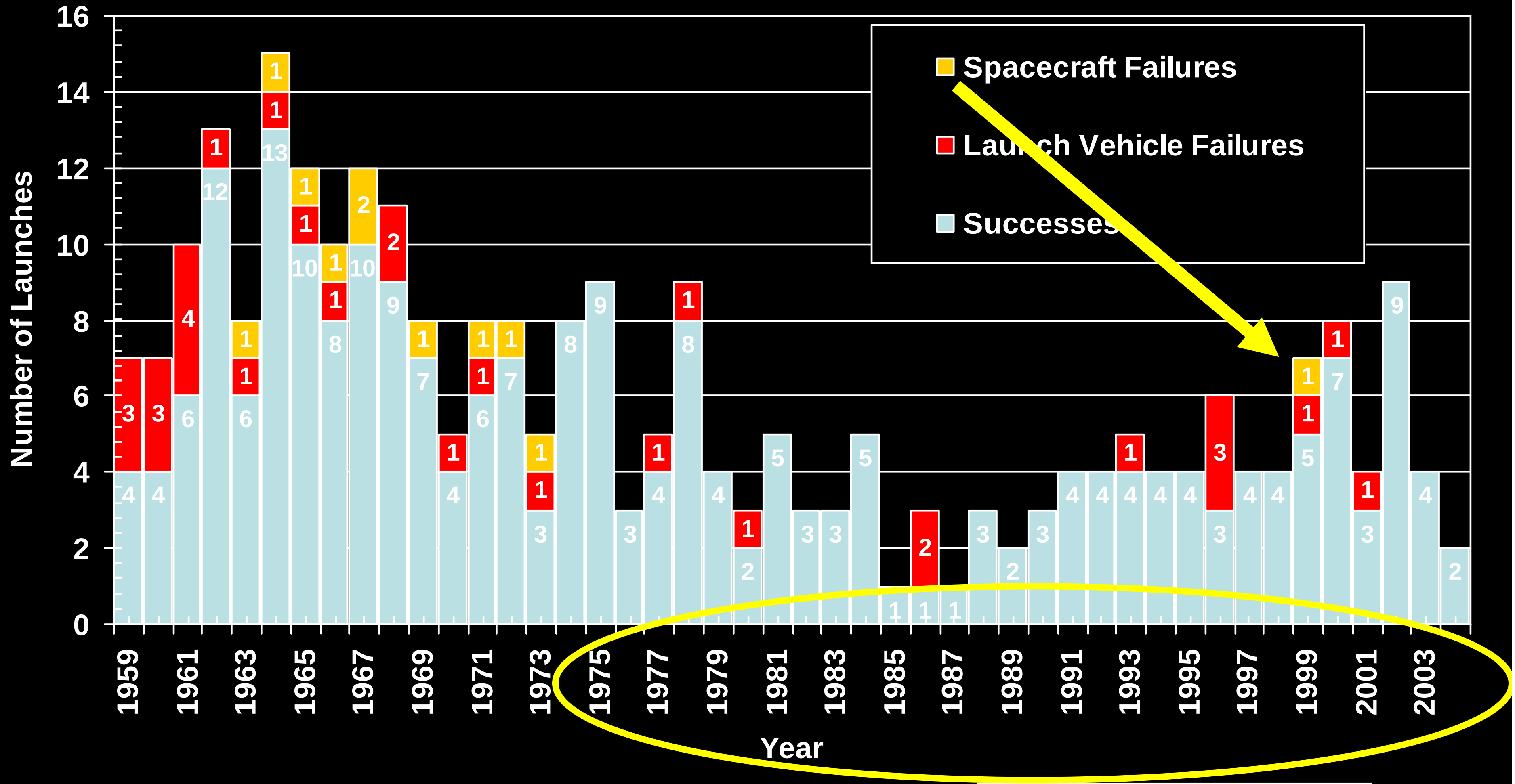
Since 1974, GSFC has supported NOAA in the successful orbit of 26 Geostationary and Polar Weather Satellites which are the Nation’s vanguard for hurricane warnings and tracking



Lunar Reconnaissance Orbiter is the beginning of an extended program of lunar exploration

Sample Analysis at Mars (SAM) instrument suite for the Mars Science Laboratory

Goddard Mission Success Over 45 Years



Successes = 235 95.5%
Launch Vehicle Failures = 32
Spacecraft Failures = 11

1 spacecraft failure in 30 years
99.2% success rate

Lessons Learned from WIRE

Engineering peer reviews

"Test as you fly"

"Fly as you test"

Worst case analysis

"What can go wrong?"

Learning from Mishaps 1999-2004

- Mar 1999 Wide Infrared Explorer (WIRE) Failure
- May 1999 Terriers Failure
- July 1999 STS-93 Anomalies/Shuttle Wiring Problems
- Sep 1999 Mars Climate Orbiter (MCO) Failure
- Nov 1999 X-33 Liquid Hydrogen Tank Qual Test Failure
- Dec 1999 Mars Polar Lander/Deep Space 2 Failures

Oct 2000 NASA Integrated Action Team Report

- July 2002 CONTOUR Mission Failure
- Feb 2003 Columbia Accident

Aug 2003 Columbia Accident Investigation Board Report

- Sep 2003 NOAA N’ Mishap
- Sep 2004 Genesis Mishap

NIAT Common Themes of Mishap Reports

Inadequate/Poor:

- **Independent Review**
- **Risk Management/Assessment**
- **Testing, Simulation, Verification & Validation**
- **Communications**
- **Health Monitoring During Critical Operation**
- **Safety/Quality Culture**
- **Resources/Staffing**

Themes from CAIB
Applicable to Goddard Projects

- Requirements management
  - Documented derivation of requirements
  - Disciplined control and verification of requirements
- Commitment to a Safety Culture
  - Disciplined hazard identification, analysis and control
  - Proactive "what could go wrong" attitude
- Accepted risk
  - Requires that risks are well understood and communicated
  - Small risks can accumulate over time to an unacceptable level
- Conditioned by Success
  - Engineering curiosity, skepticism
  - Facing facts objectively and with attention to detail

Themes from CAIB
Applicable to Goddard Projects

- Avoiding Oversimplification
  - Avoiding “normalization of deviance”
  - Alert to “low-level” signals
- Schedule pressure
  - Schedule pressure, or perceptions of pressure, must not be allowed to overshadow safety and mission success considerations
- Significance of Redundancy
  - Redundant processes
  - Systems of independent checks and balances
  - Adequate surveillance
- Importance of Communication
  - Concise and timely communication of problems using redundant paths
  - Encouraging alternative opinions and “bad news”
  - Documentation, training, sharing expectations & lessons learned

Actions Taken

- **Strengthened individual & organizational accountability**
  - Reaffirmed checks & balances
  - Center PMC project certification processes and implementation
  - Strengthened surveillance/assessment of contractor performance
- **Improved rigor and discipline in system engineering**
  - Instituted rigorous process and product requirements
  - Implemented system engineering peer reviews
  - System Engineering Excellence Development program
- **Clarified mandatory requirements, variance process**
  - Codified rules for design, verification and operations of flight projects
  - Strengthened entry/exit criteria for critical milestone review gates
  - Updated standards for environmental verification testing

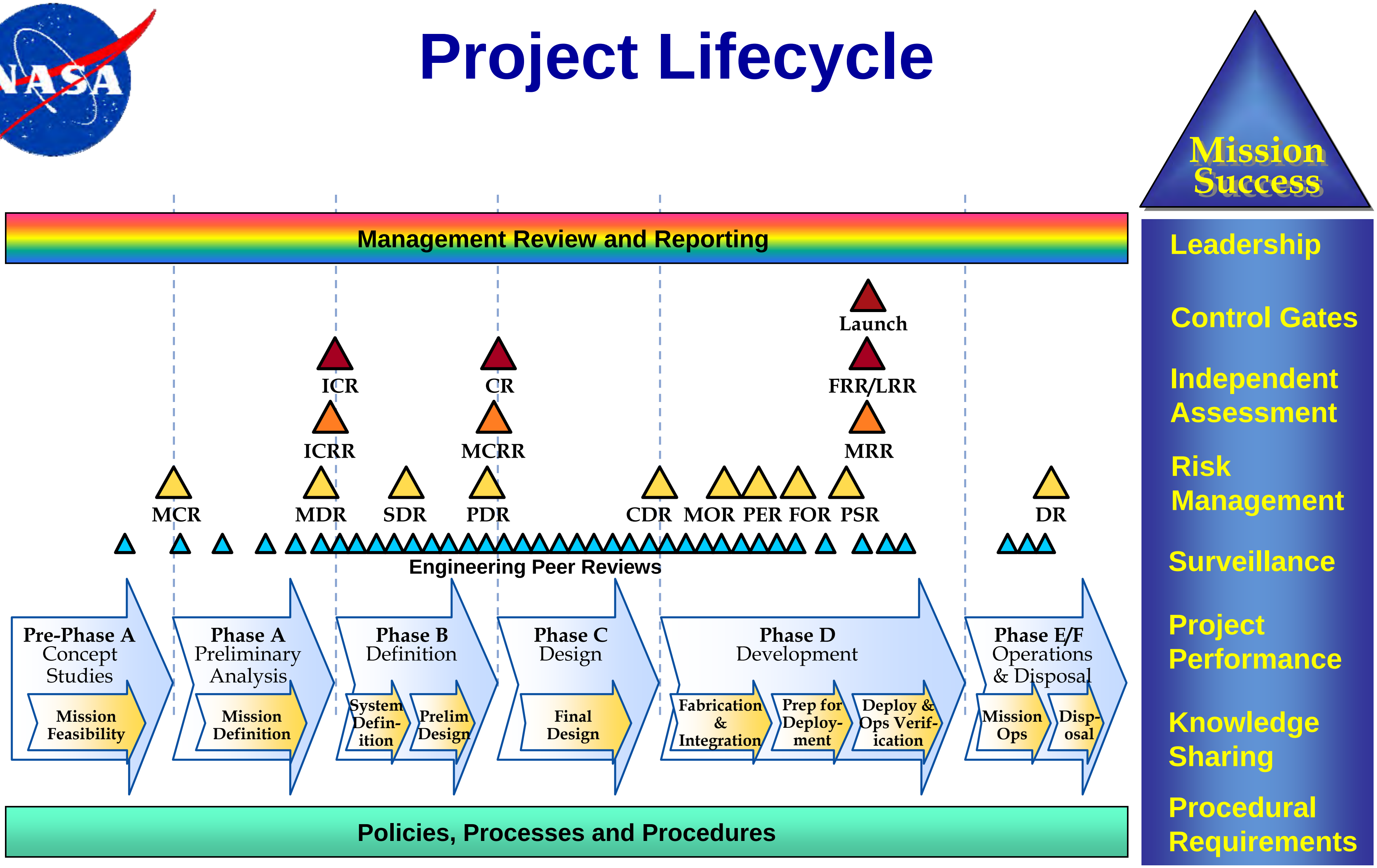
Actions Taken

- **Integrated risk identification, analysis and control**
  - Strengthened risk analysis and reporting requirements
  - Improved processes and systems to document, characterize, analyze and trend problems, failures and anomalies
  - Systematic performance/risk assessment across portfolio

- **Integrated continuum of independent assessment**
  - Increased rigor in engineering peer review process
  - Additional discipline in the independent review process
  - More comprehensive and timely internal audit program

- **Addressed performance as a learning organization**
  - Established knowledge management focal point & working group
  - Case study based knowledge sharing workshops
  - “Road to Mission Success” training program to assure employees understand values and requirements for the way we do business

Project Lifecycle



Life cycle processes and activities are grounded in established and proven methods to develop and operate flight systems

Guiding Principles of Management and Technical Reviews

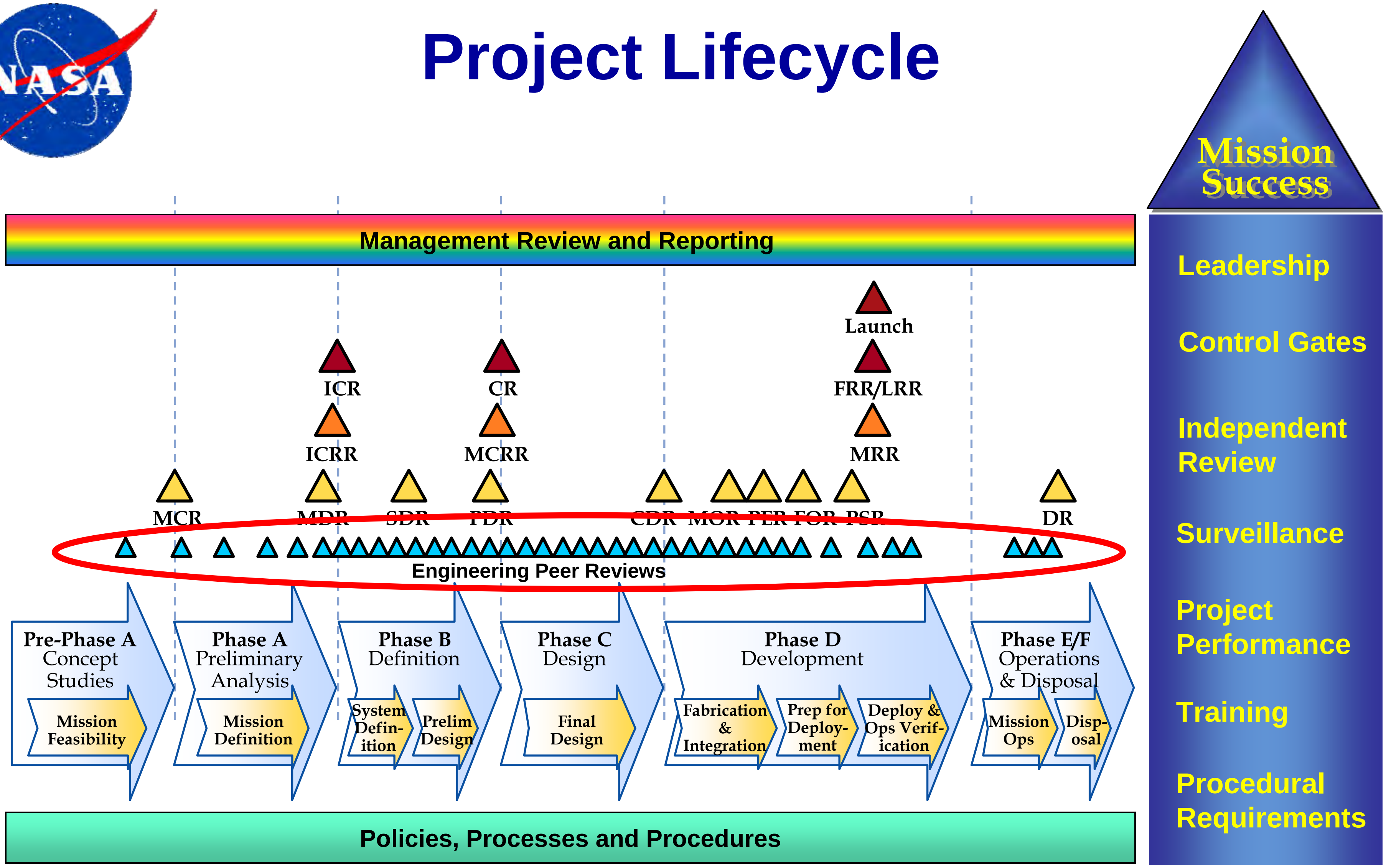
Reviews are a resource

They offer an opportunity to add value to the products and to the sharing of knowledge by inviting outside experts that can provide confirmation of the approach and/or recommend options.

Reviews are a tool for communication

Opportunity to organize, assess, and communicate critical data and information between providers, customers, and stakeholders.

Project Lifecycle



Life cycle processes and activities are grounded in established and proven methods to develop and operate flight systems

Engineering Peer Reviews

Goddard Procedural Requirements

Directive No.	GPR 8700.6	APPROVED BY Signature:
Effective Date:	March 10, 2003	NAME: Edward J. Weiler
Expiration Date:	March 10, 2008	TITLE: Director

COMPLIANCE IS MANDATORY

Resp. Office: 170 Office of Mission Success

Title: Engineering Peer Reviews

PURPOSE
This procedure defines the process for Engineering Peer Reviews of applicable Goddard Space Flight Center (GSFC) products.

APPLICABILITY
This procedure applies to all systems development products within the scope of the GSFC Quality Management System. The EPR process applies to project/product formulation and implementation subprocesses. The formal peer review process defined in this GPR does not apply to sounding rockets, balloons, and aircraft or their associated instruments/payloads. Small Shuttle Payloads (Hitchhiker, Space Experiment Module, and Get-away-Specials) are also excluded. However, product managers for these types of missions shall define and implement an effective peer review process commensurate with the level of risk associated with their specific missions.

AUTHORITY
NPD 1280.1, NASA Management System Policy

REFERENCES
GPR 1280.1, The GSFC Quality Manual
GPR 8700.4, Integrated Independent Reviews

CANCELLATIONS
GPG 8700.6, Engineering Peer Reviews

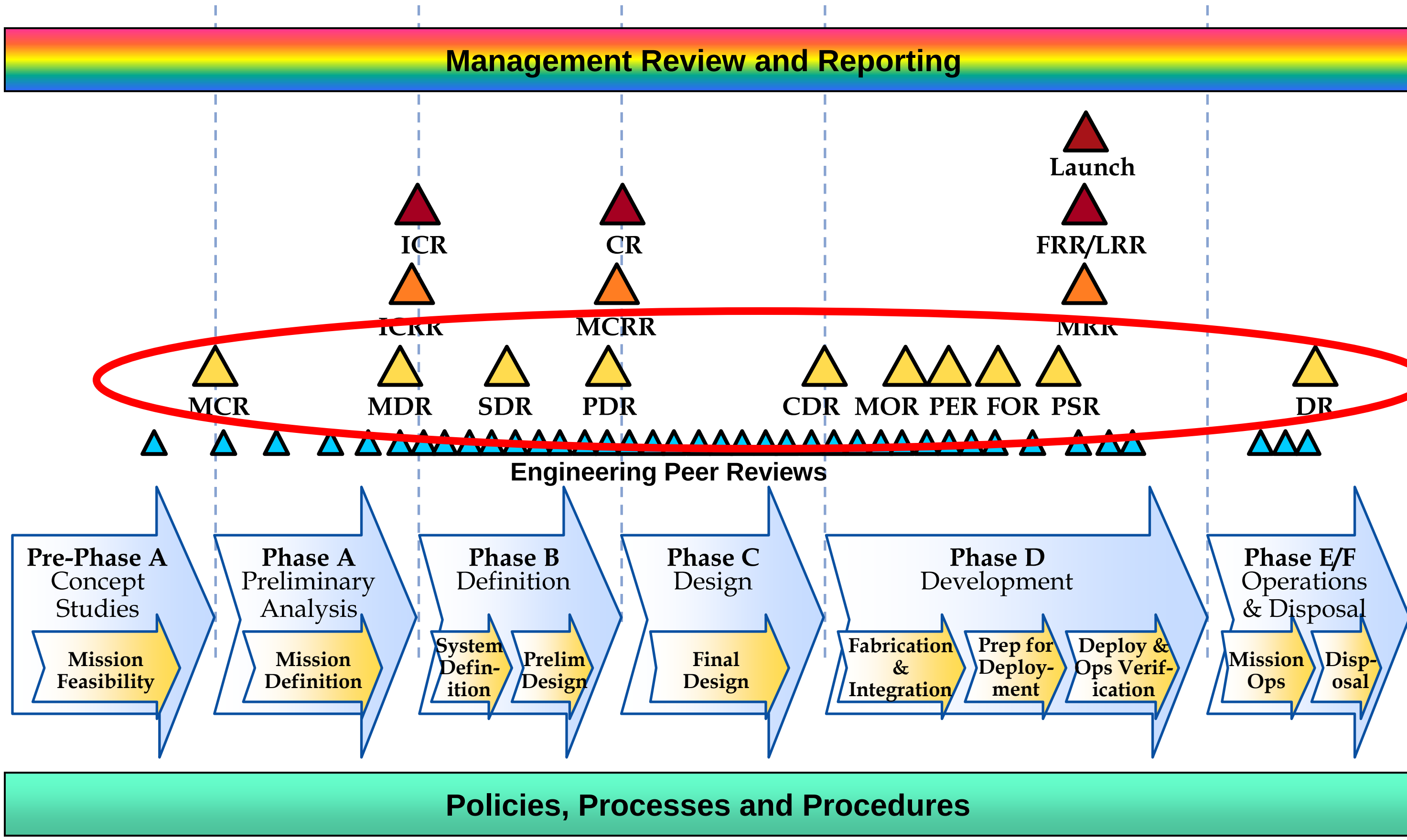
SAFETY
Not applicable.

CHECK THE GSFC DIRECTIVES MANAGEMENT SYSTEM AT http://gdms.gsfc.nasa.gov TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

GSFC 3-17 (10/04)

- Project teams shall prepare a comprehensive EPR Plan
  - Itemize subsystem, component & cross-cutting areas to be reviewed at appropriate milestones
  - Assess adequacy of EPRs at system-level reviews
- Emphasizes table top review of drawings, analysis, test data
- Review teams are experts independent of project team
- Closed loop closure of RFAs
- Results summarized at higher level reviews

Project Lifecycle



Life cycle processes and activities are grounded in established and proven methods to develop and operate flight systems

Integrated Independent Reviews

Goddard Procedural Requirements

Directive No.	GPR 8700.4	APPROVED BY Signature:
Effective Date:	March 10, 2003	NAME: Edward J. Weiler
Expiration Date:	March 10, 2008	TITLE: Director

COMPLIANCE IS MANDATORY

Resp. Office: 170 Office of Mission Success

Title: Integrated Independent Reviews

P.1 PURPOSE

This procedure establishes the process for planning, conducting, and reporting Integrated Independent Reviews for Goddard Space Flight Center (GSFC) products.

P.2 APPLICABILITY

The Goddard Integrated Independent Review (IIR) process fulfills the NASA imposed requirement within NPR 7120.5 for both Independent Reviews and Critical Milestone Reviews of projects.

Except as noted below, the IIR process applies to all GSFC products within the scope of the GSFC Quality Management System. Typically, IIRs are used to evaluate the status of a flight project at the mission system level and at the major system element level (i.e.: spacecraft, instrument(s), and ground system). IIRs are supported by project-conducted Engineering Peer Reviews (EPRs) which assess the status of subsystem or lower assembly levels. The results of the EPRs comprise a key input to the IIRs.

When the GSFC end-item product consists of a deliverable sub-system or instrument, this IIR process does apply. In that case, the review sequence described within this document may be modified as appropriate, subject to approval in the IIR Plan.

The IIR process does not apply to non-flight products, to sounding rockets and associated payloads, to balloons and associated payloads, to deliverable aircraft instruments and payloads, nor to Shuttle Small Payloads (Hitchhiker, Space Experiment Module, Get-Away-Specials).

P.3 AUTHORITY

NPD 1280.1, NASA Management System Policy

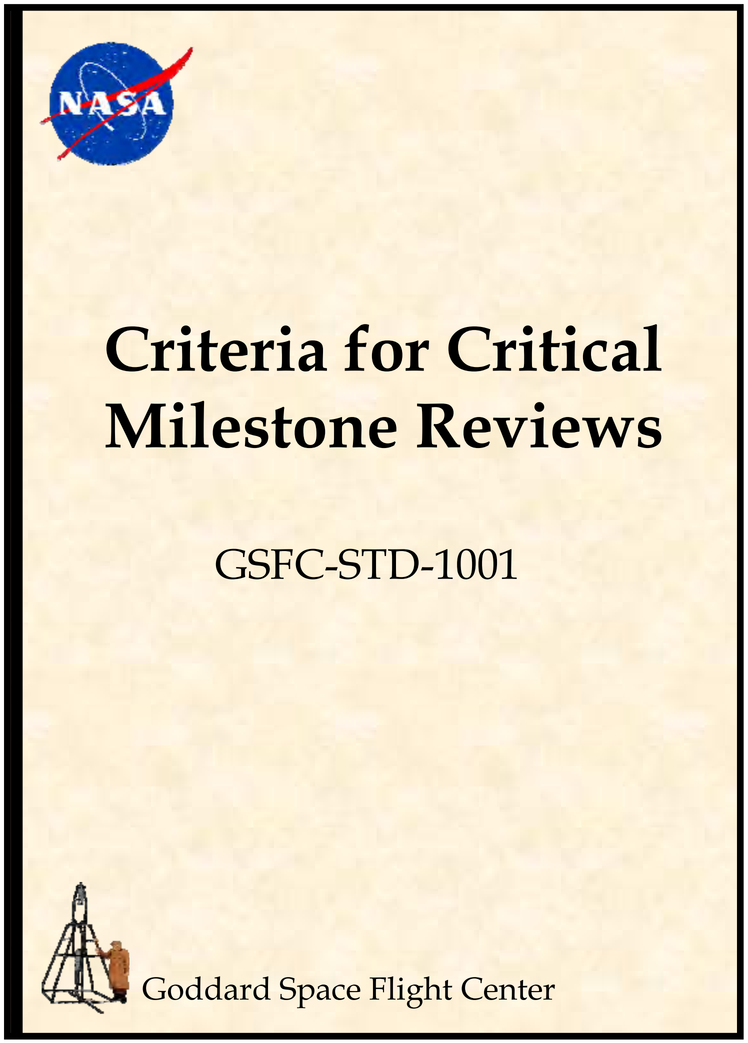
NPR 7120.5, NASA Program and Project Management Processes and Requirements

CHECK THE GSFC DIRECTIVES MANAGEMENT SYSTEM AT http://gdms.gsfc.nasa.gov TO VERIFY THAT THIS IS THE CORRECT VERSION PRIOR TO USE.

GSFC 3-17 (10/04)

- Requires an approved Review Plan for each project
- Defines the critical milestone reviews
- Defines review team selection and approval process
- Procedural requirements for the planning and conduct of reviews
- Defines reporting requirements and report content
- Requires closed loop disposition of Requests For Action (RFA) with the review team chair and initiator
- Invokes resource materials:
  - Criteria for Critical Milestone Reviews
  - Project Management Checklist
  - 10 Systems Management Processes

Standard Review Criteria



- Defines the criteria for:
  - Mission Concept Review
  - Mission Definition Review
  - System Definition Review
  - Preliminary Design Review
  - Critical Design Review
  - Mission Operations Review
  - Pre-Environmental Review
  - Flight Operations Review
  - Pre-Ship Review
  - Disposal Review

- Describes for each review:
  - Purpose
  - Timing
  - Objectives
  - Criteria for successful completion
  - Results of review

Systems Management Practices Assessment

Sample

10 Key Systems Management Practices	SRR	PDR	CDR
1. Organization, Communication, Teamwork	Green	Green	Yellow
2. Systems Management Processes	Yellow	Yellow	Green
3. Safety	Green	Green	Green
4. Risk Analysis and Management	Red	Green	Green
5. Mission Assurance	Green	Green	Green
6. Physical and Analytical Integration	Green	Green	Green
7. Verification and Validation	Red	Yellow	Green
8. Operations Planning	Yellow	Green	Green
9. Engineering Peer Reviews	Yellow	Green	Green
10. Integrated Independent Reviews	Yellow	Green	Green

Legend: **Green** - To date, activities are fully compatible with good practice for similar successful projects.

Yellow - To date, activities exhibit weakness that warrants change to control risk.

Red - To date, activities are deficient and immediate corrective action is essential to minimize risk.

Rocket Science Is Not Folklore

Challenge:

Most valued system engineering principles and sound engineering practices are not recorded in a single, easily accessed, reference source

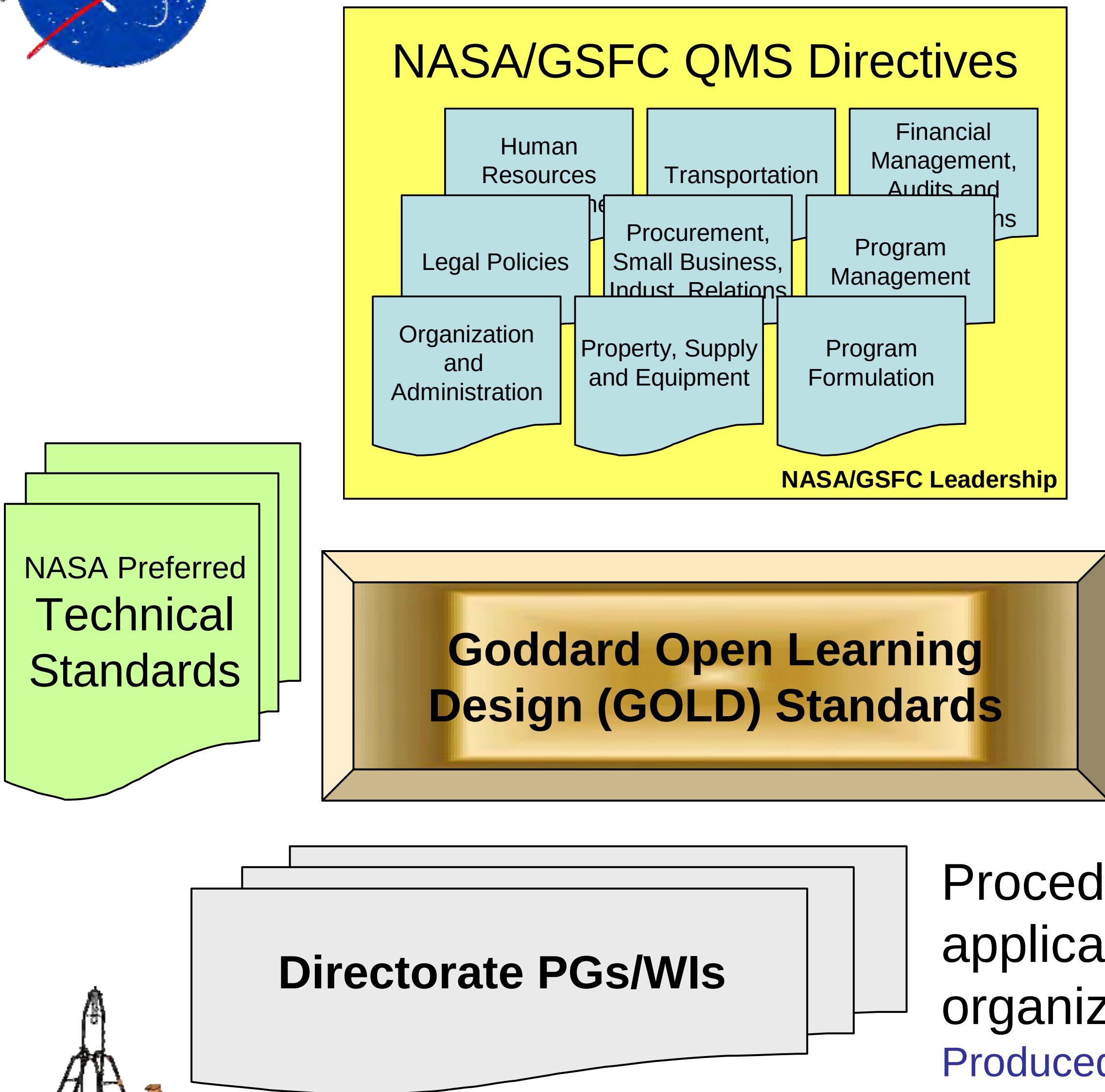
- Some are literally passed down through oral traditions and are at risk of being lost, misunderstood, or ignored.
- Not uniformly applied to projects.
- Rationale and context need to be documented and articulated in a manner that builds on the logic and experience behind them.

Solution:

The GOLD Rules are a major step in addressing the challenge

- Powerful tool to methodically and uniformly document, communicate, and apply our most valued rules and practices.
- GOLD Rules will aid the early identification, understanding, communication, mitigation and acceptance of mission risk
- Reinforces our behavior as a learning organization.

Requirements Hierarchy



Policy direction and high-level procedural requirements

Approval: Administrator/Center Dir.

Production/maintenance: Offices of Primary Responsibility (OPR) through Management System Council

Standards applicable to all projects

Approval: Goddard PMC

Production/maintenance: Office of Mission Success

Procedures and work instructions applicable to specific projects, line organizations, engineering disciplines

Produced, approved and maintained by: Goddard Directorates

GOLD Rules

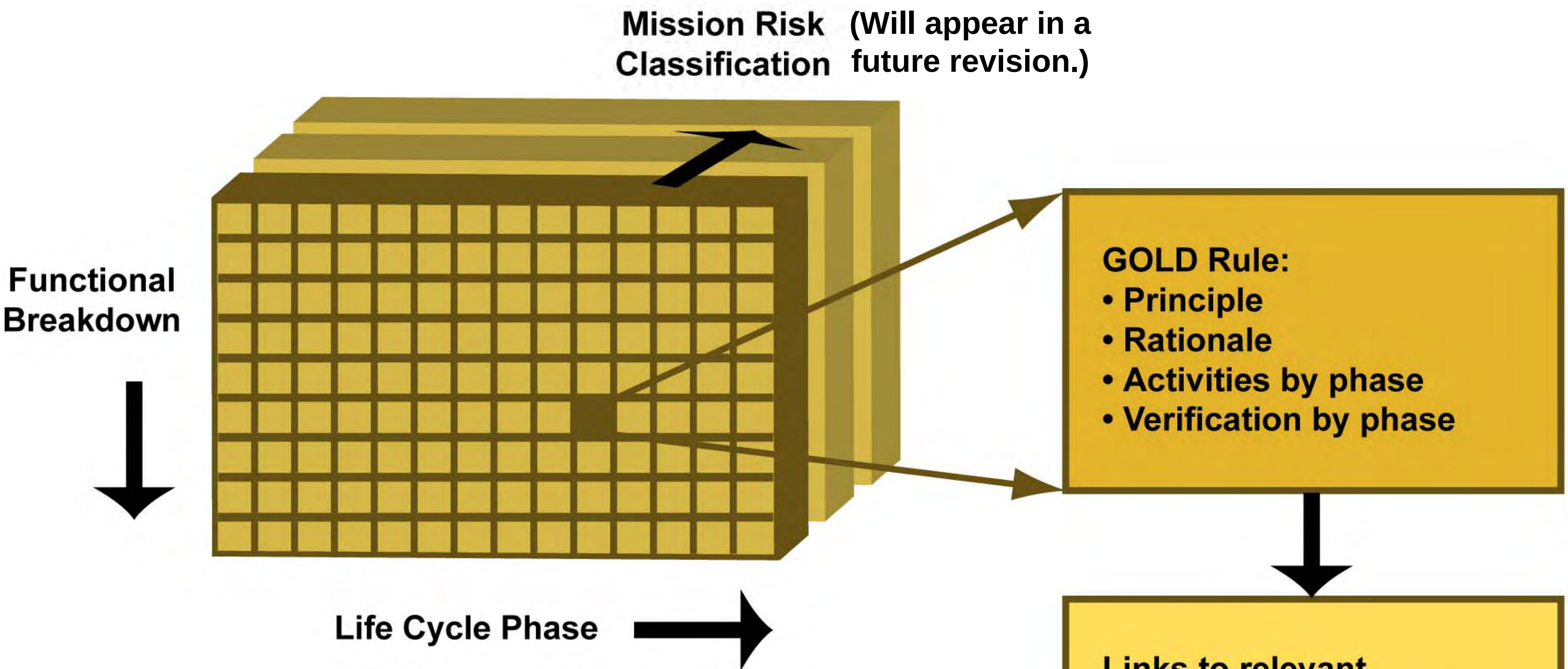
Goddard Space Flight Center

Rules for the Design, Development, Verification, and Operation of Flight Systems

GSFC – STD – 1000
Baseline Release
December 10, 2004

- High-value principle to guide methodology and thinking
- Important enough to require compliance for all projects
- Rationale based on sound engineering practice
- System engineering product identified at milestones

GOLD Standard Architecture



Links to relevant standards, additional guidance, handbooks, experts, lessons learned, case studies, etc.

Goddard Open Learning Design (GOLD) Rules

- a hyper linked knowledge portal

Template of a Rule

Domain: The technical discipline(s) where a rule resides.

1.33 **Polarity Checks of Critical Components** | **Observatory Subsystems**

Principle: A declarative sentence that uses a "shall" statement.

All hardware shall verified by test or inspection of the proper polarity, orientation, and position of all components (sensors, switches, and mechanisms) for which these parameters affects performance.

Rationale: A sentence that explains why a rule is necessary.

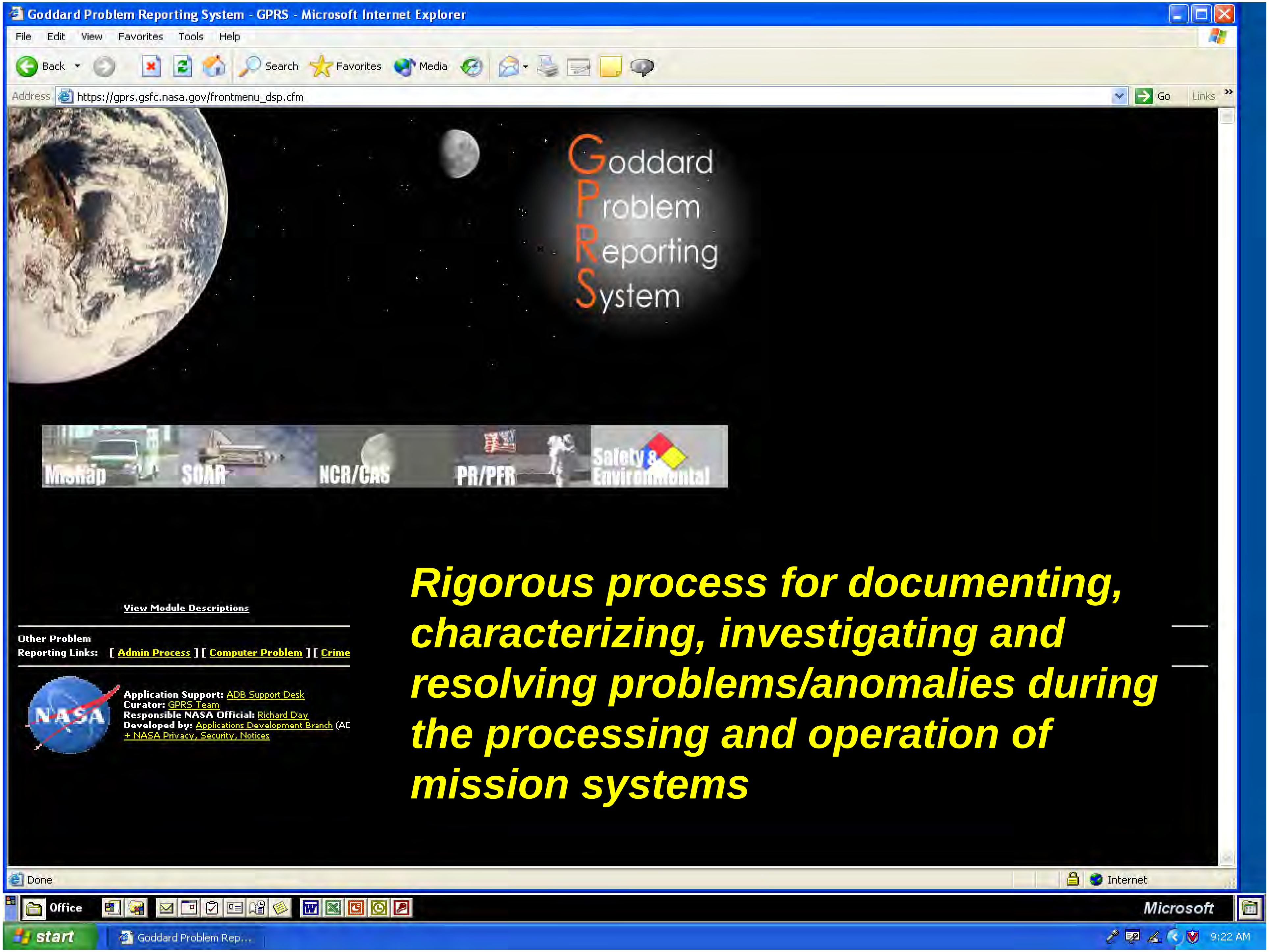
Each spacecraft and instrument contains many components that can be reversed easily during installation. Unless close inspections are performed, and proper installations are verified by test, on-orbit failures can occur when these components are activated.

Activities: A sentence that states the activities or products necessary to fulfill a rule in a given phase.

Verification: A sentence that explains how the risk associated with fulfilling the principle will be assessed.

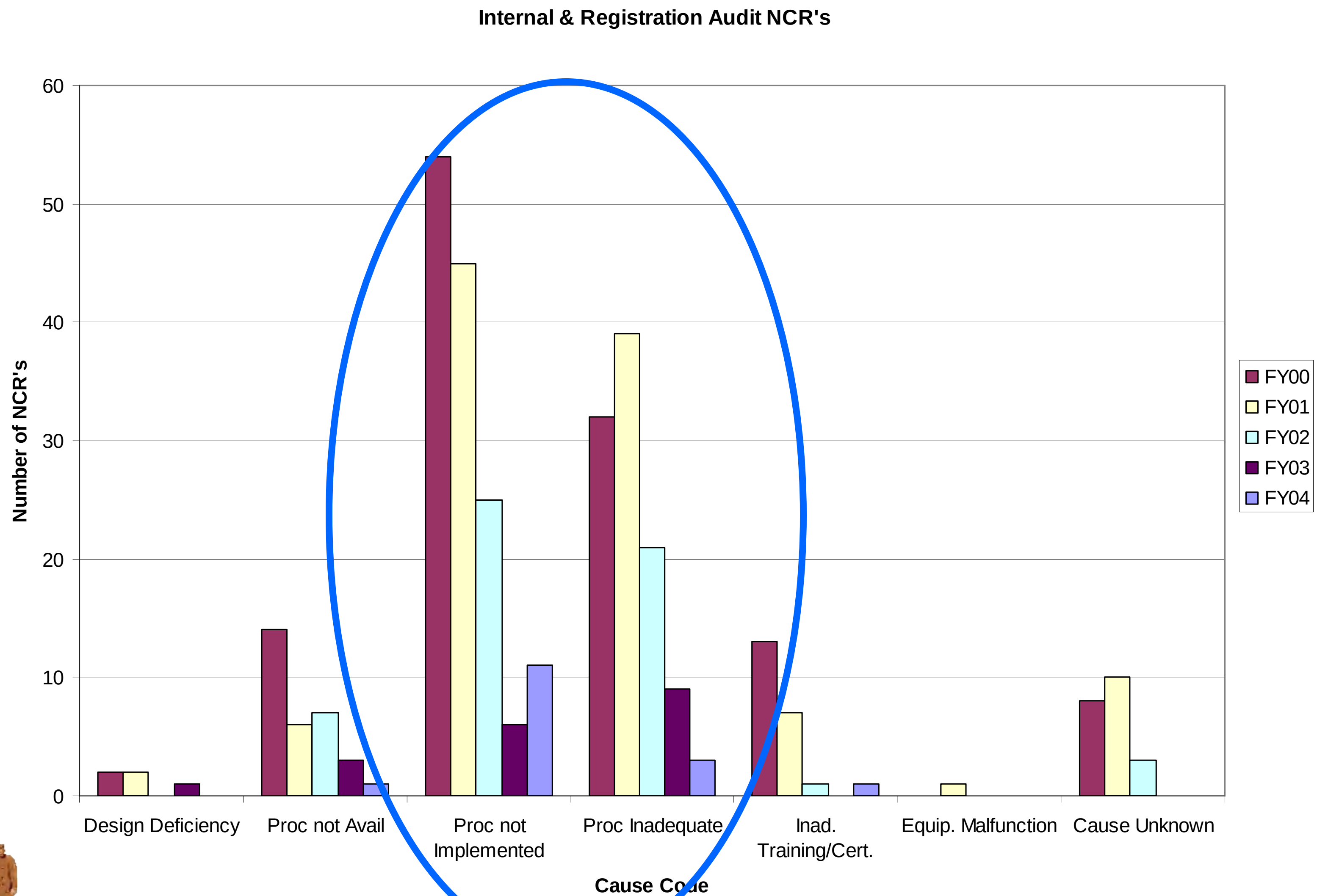
	A	A	B	C	D	E	F
Activities	N/A	1. Identify all polarity-dependent components in the spacecraft design concept. 2. Ensure that design concept provides capability for testing functionality of polarity-dependent components at end-to-end mission system level, in addition to subsystem level.	1. Identify all polarity-dependent components in the spacecraft prelminary design. 2. Ensure that preliminary design provides capability for testing functionality of polarity-dependent components at end-to-end mission system level, in addition to subsystem level. 3. Develop test plan for polarity-dependent components.	1. Identify all polarity-dependent components in the spacecraft detailed design. 2. Ensure that detailed design provides capability for testing functionality of polarity-dependent components at end-to-end mission system level, in addition to subsystem level. 3. Develop test procedures for polarity-dependent components.	1. Execute polarity tests at subsystem and end-to-end mission system levels.	N/A	N/A
Verification	N/A	1. Verify through peer review and at MDR.	1. Verify through peer review and at PDR.	1. Verify through peer review and at CDR.	1. Verify through peer review, at PER, and at PSR.	N/A	N/A

Revision Status:	Owner:	Reference:
Baseline Release December 10, 2004	GN&C Systems Engineering Branch (591)	

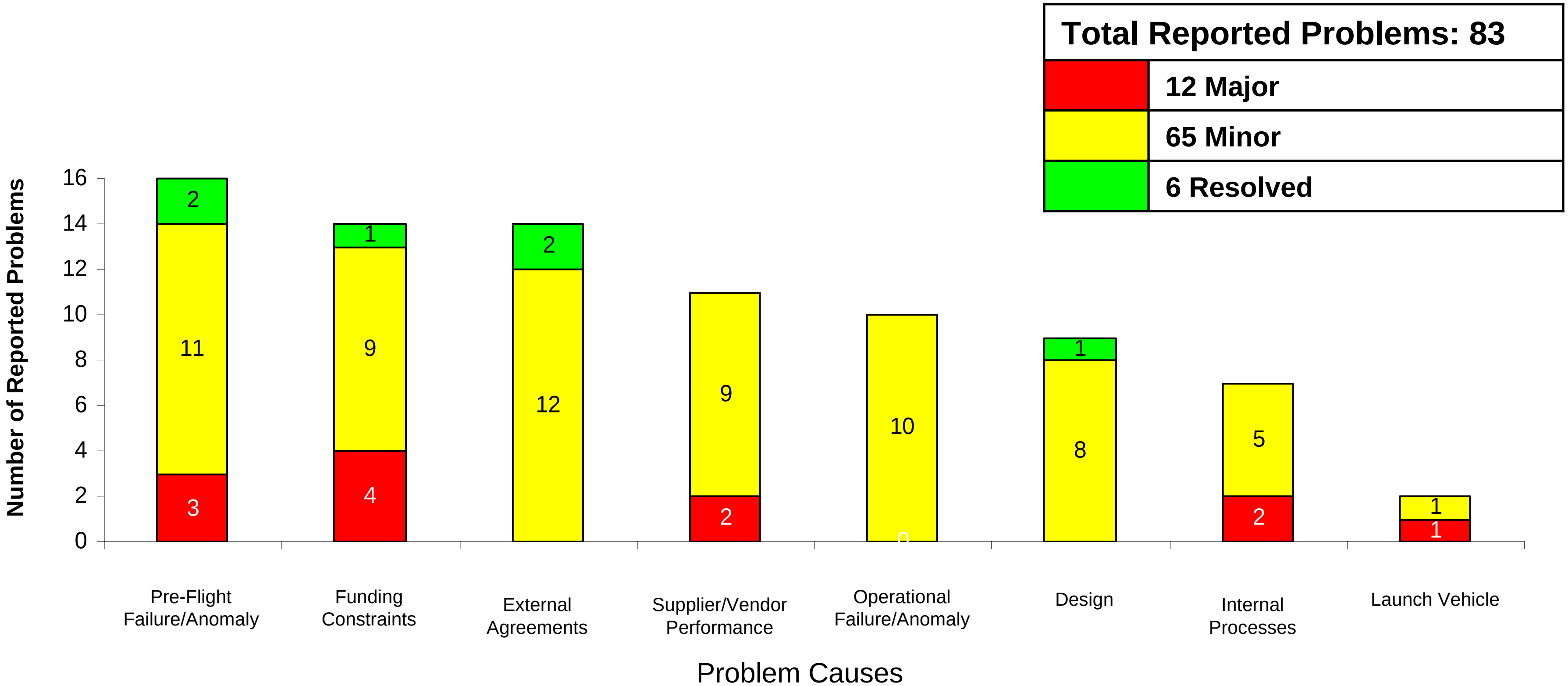


Rigorous process for documenting, characterizing, investigating and resolving problems/anomalies during the processing and operation of mission systems

Improved Procedures
Adequacy and Compliance

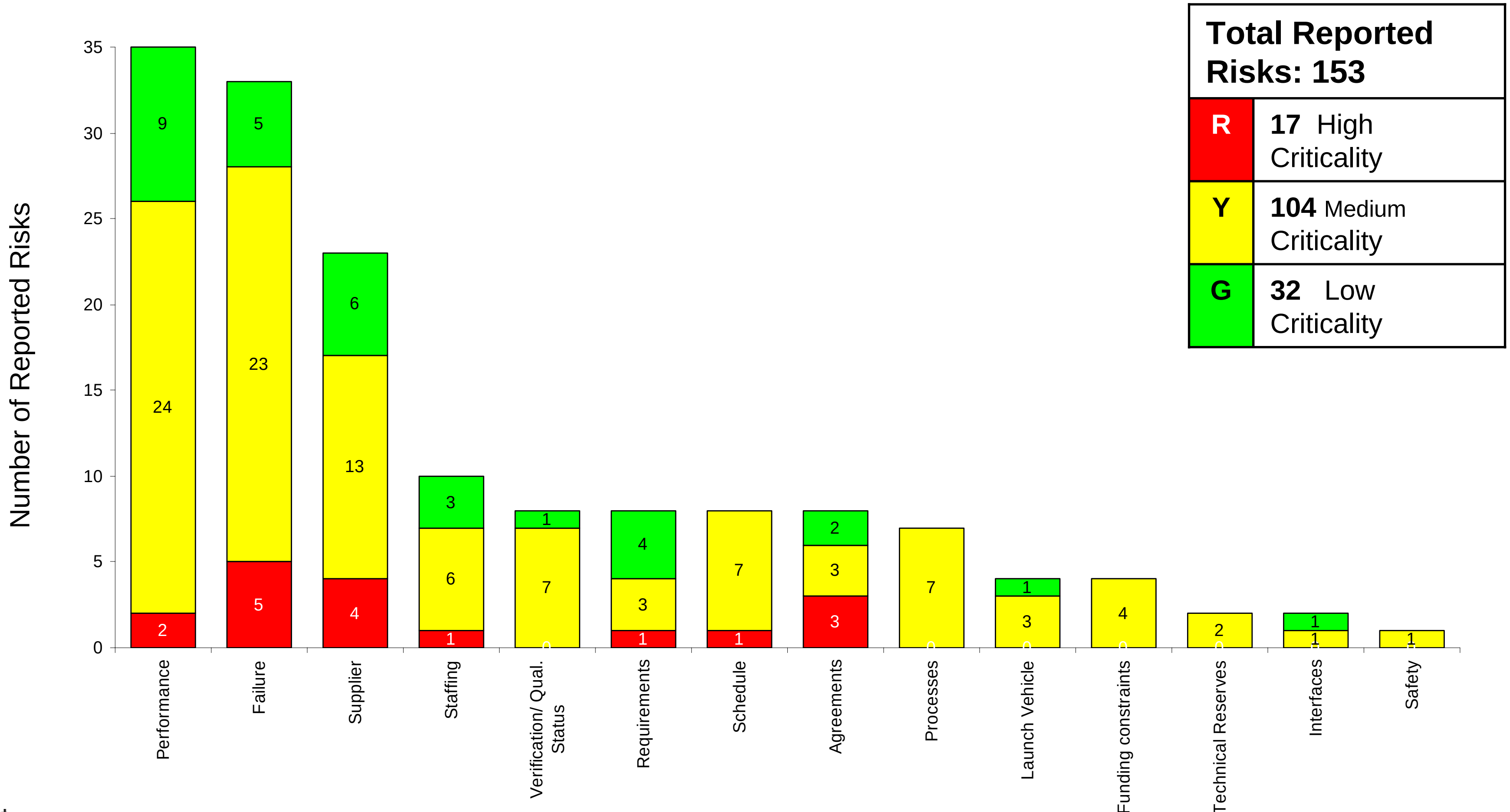


Project Reported Problems/Issues



Analyze and trend problems over entire portfolio of projects

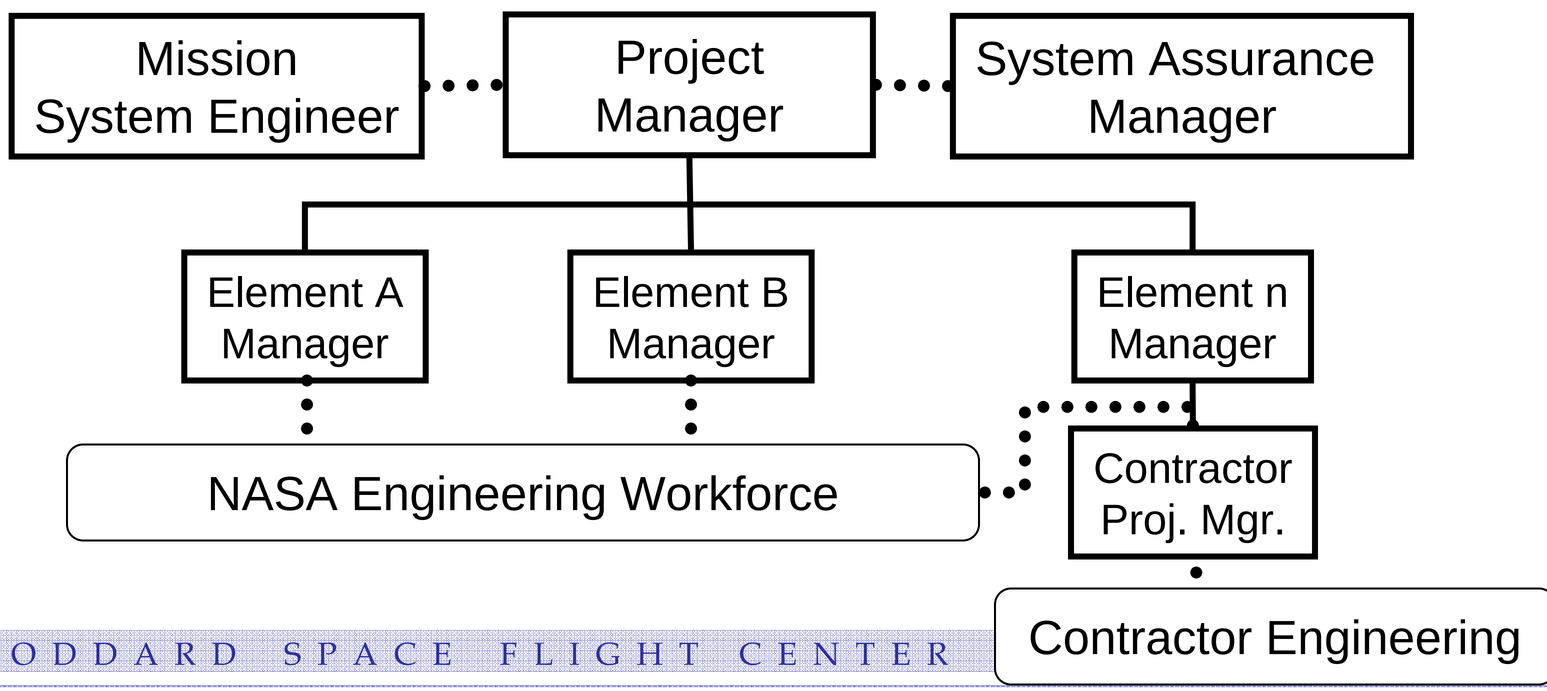
Project Reported Risks



Analyze/trend risks over entire portfolio of projects

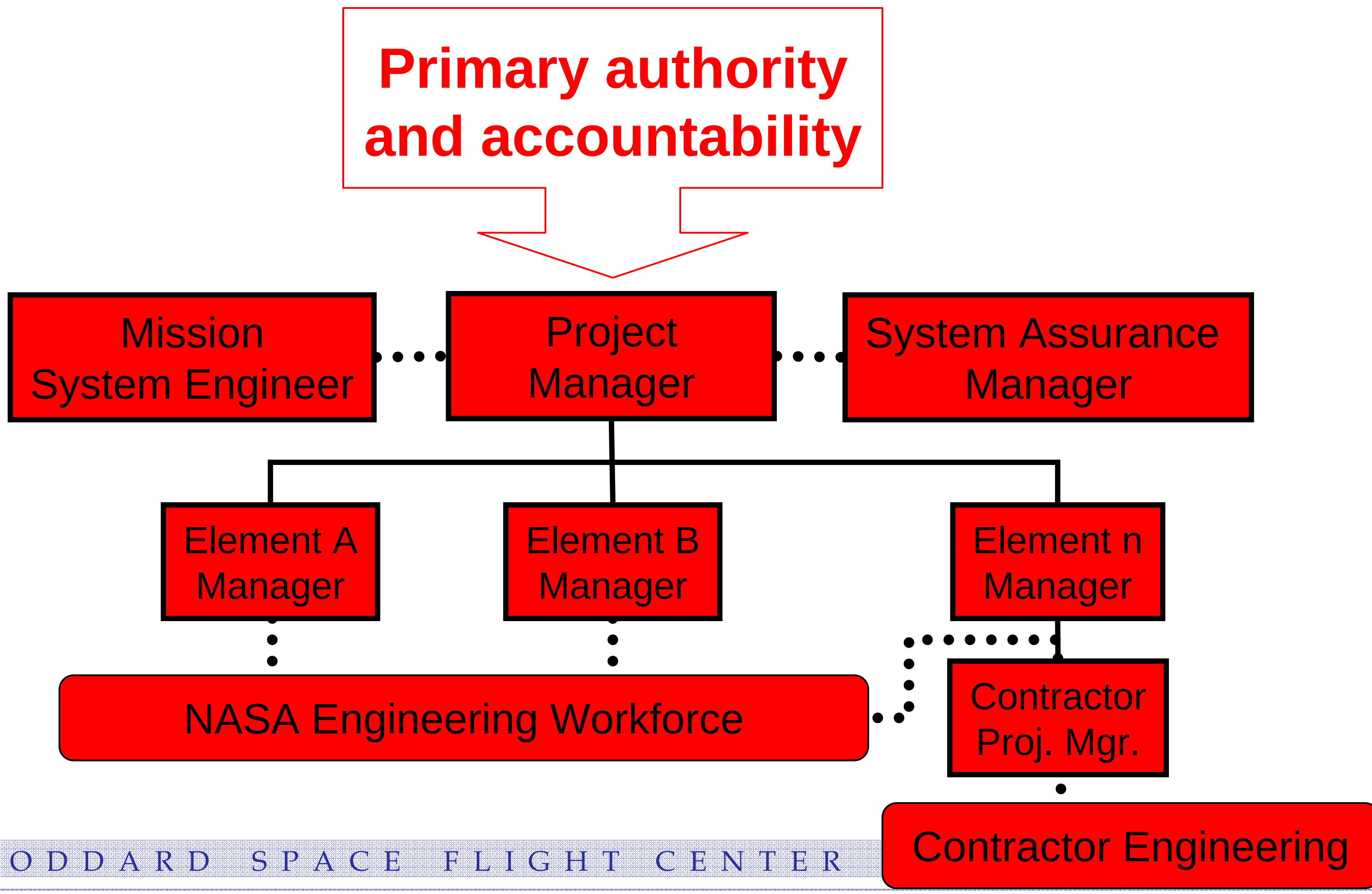
Project Team Structure

Project Manager leads and Integrates a matrix project team

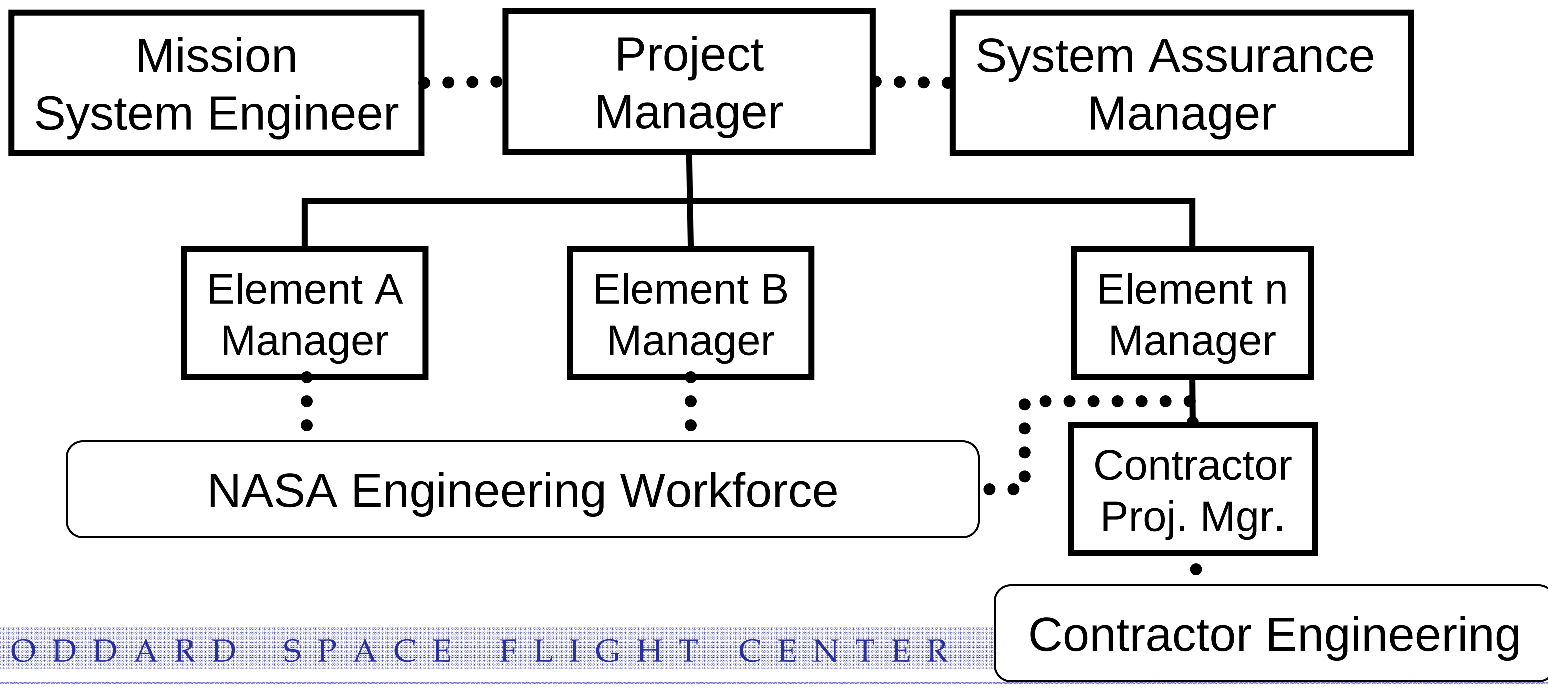


Project Team Structure

Accountability for Mission Success

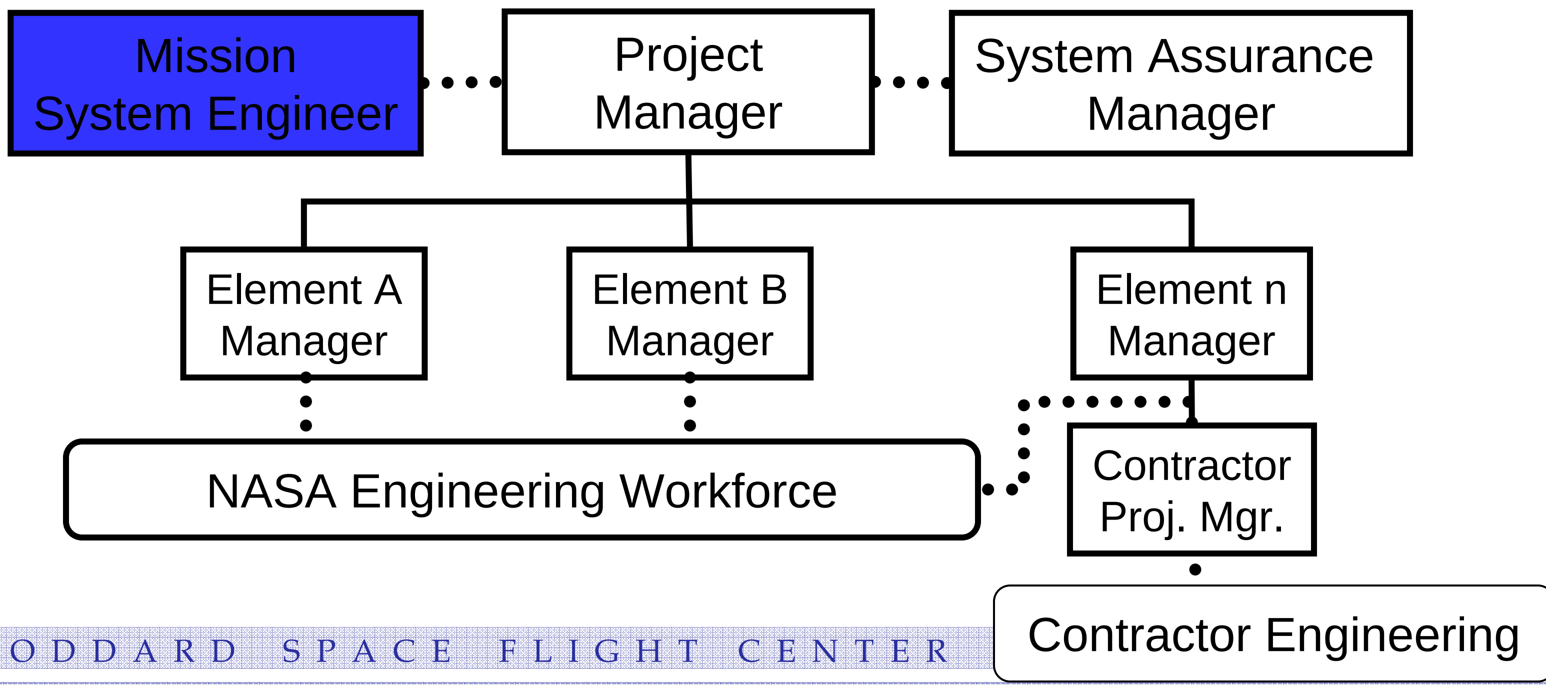


Checks and Balances in the Project Team Structure



Checks and Balances in the Project Team Structure

Mission System Engineer is the engineering authority for the project



Checks and Balances in the Project Team Structure

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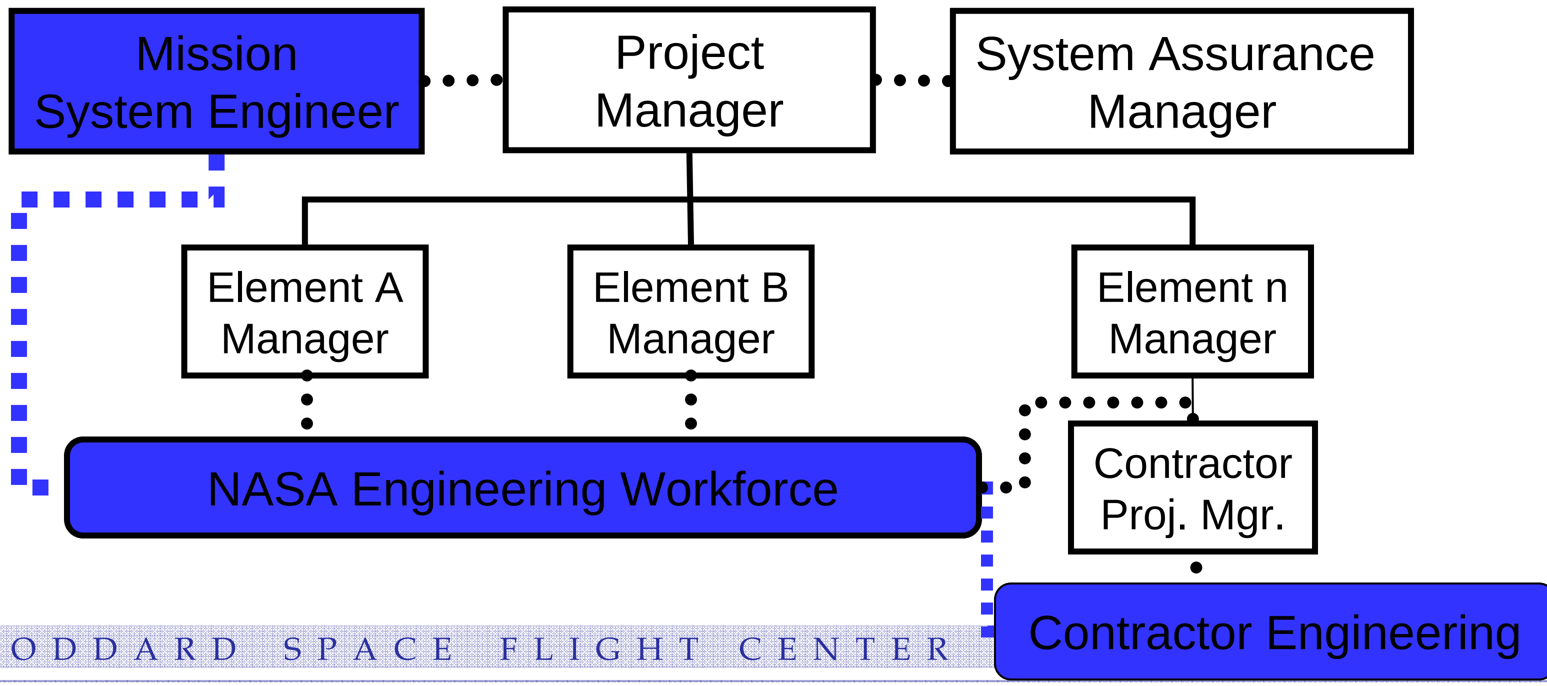
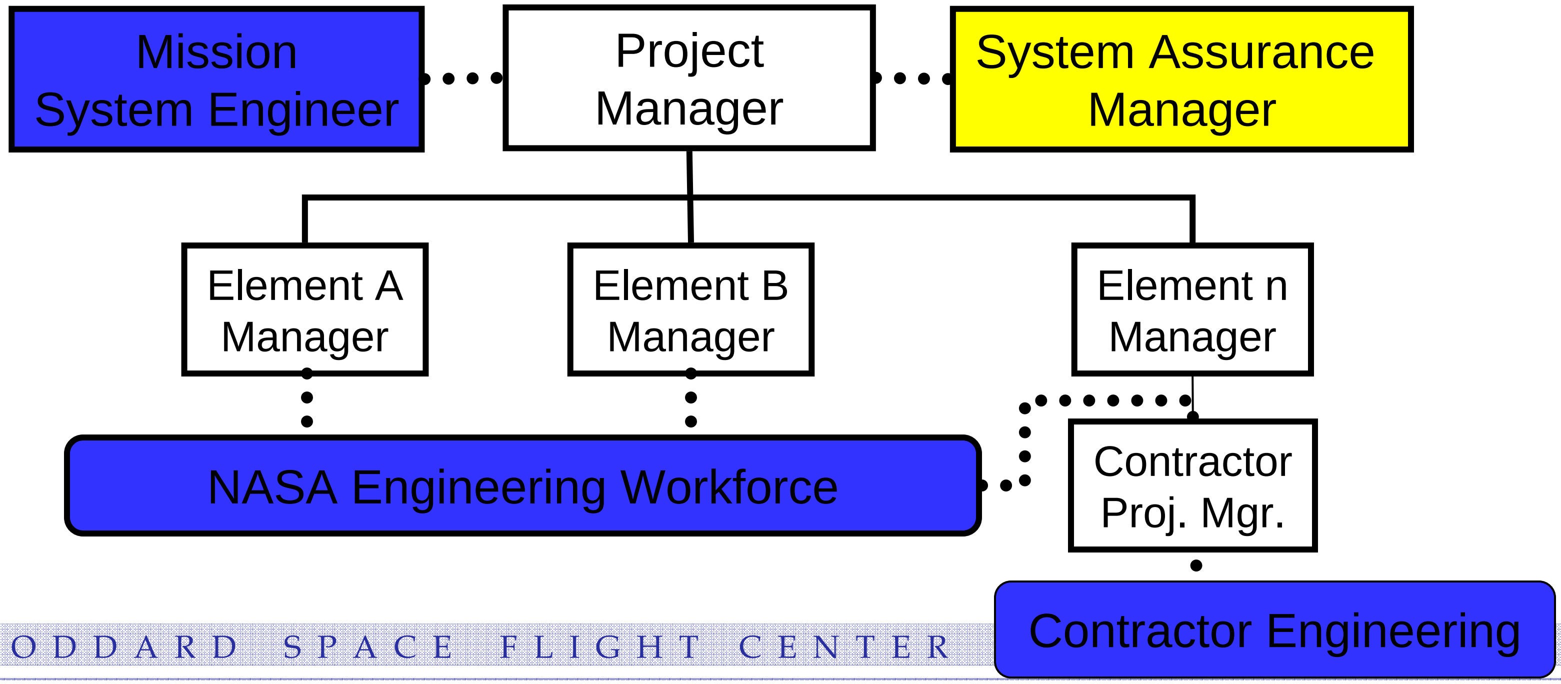


Checks and Balances in the Project Team Structure

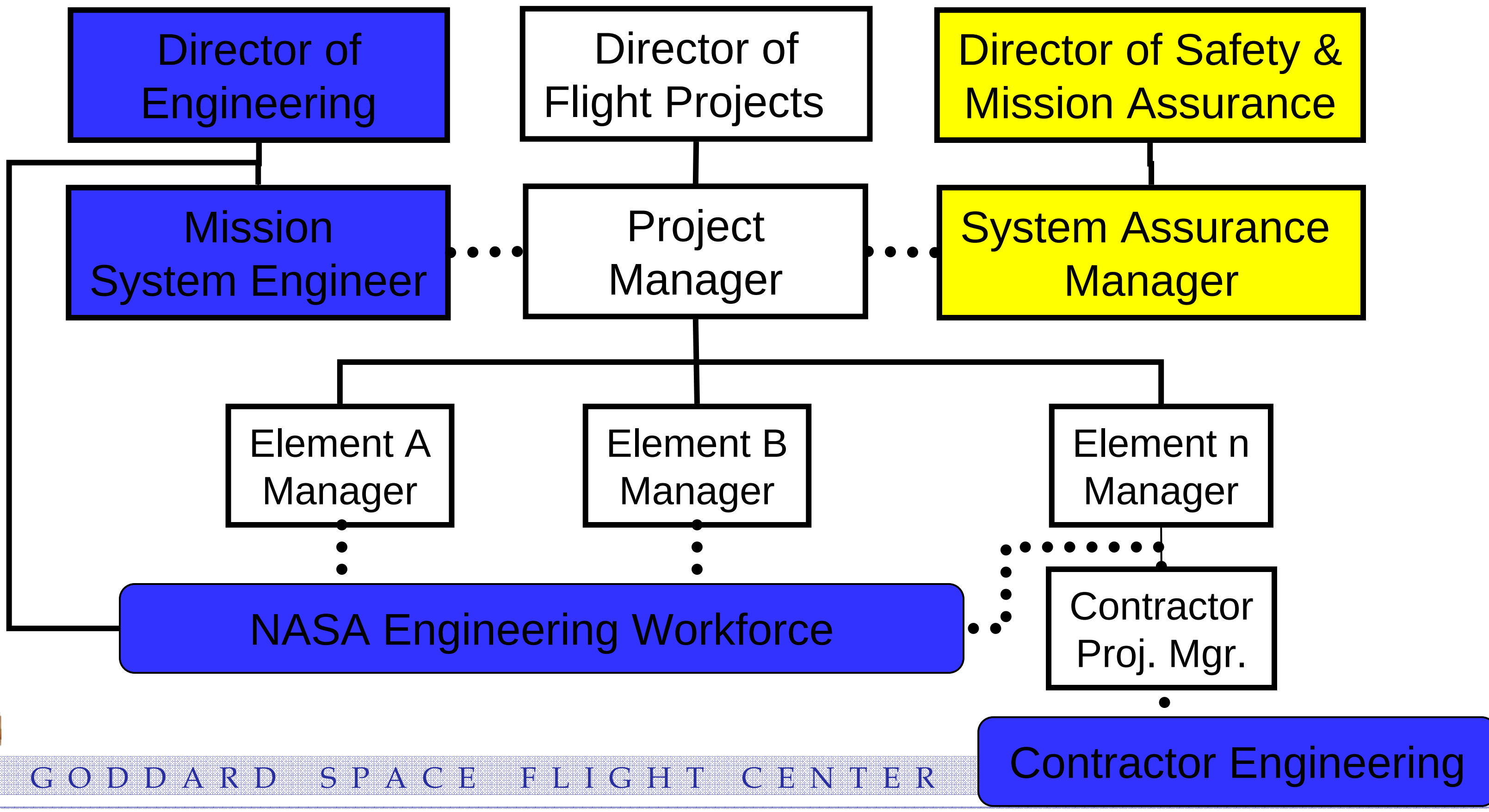
Mission System Engineer is the engineering authority for the project

System Assurance Manager has similar independent authority

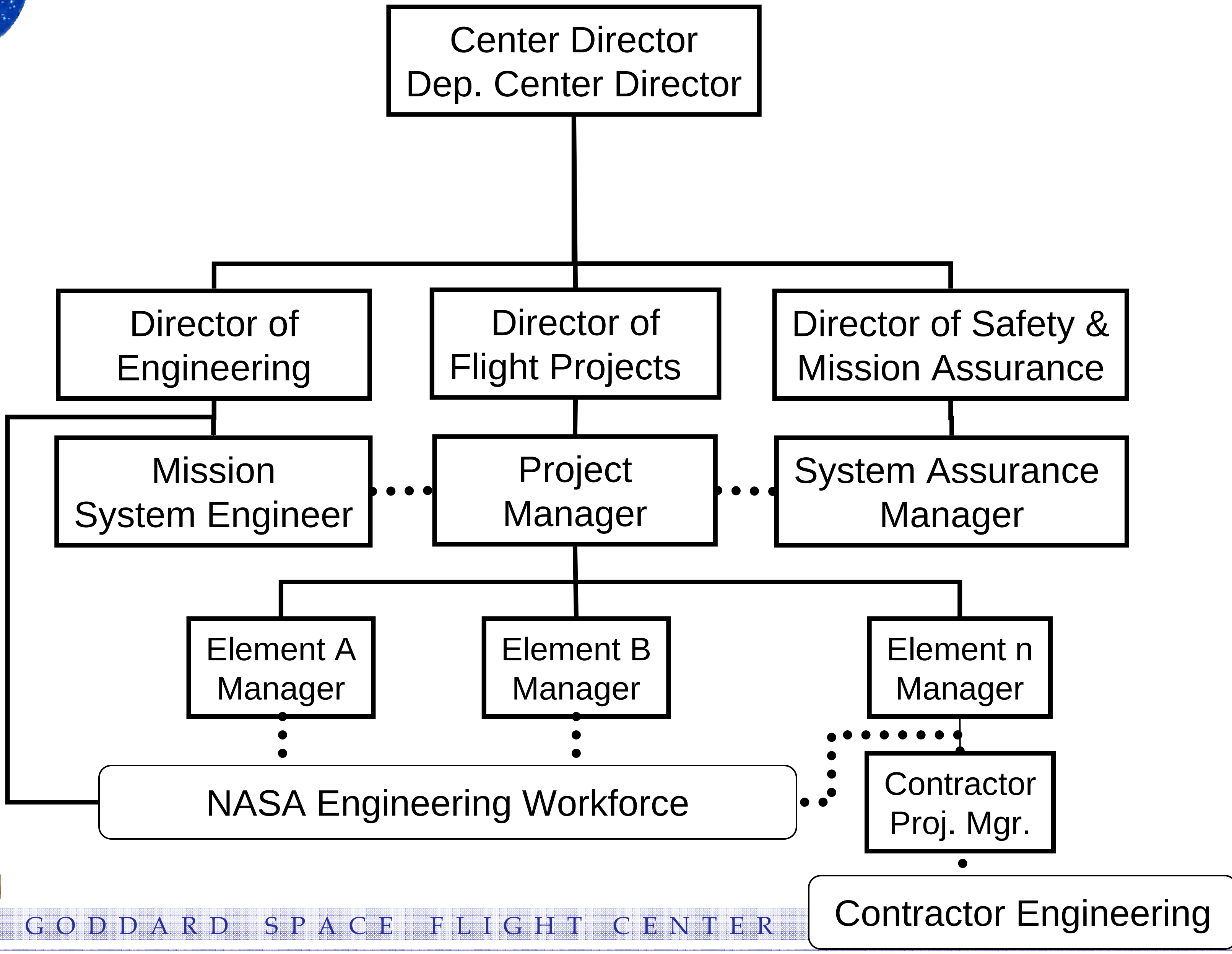


Center Leadership Structure

"Directors of" oversee the work of their employees and the project teams



Center Leadership Structure



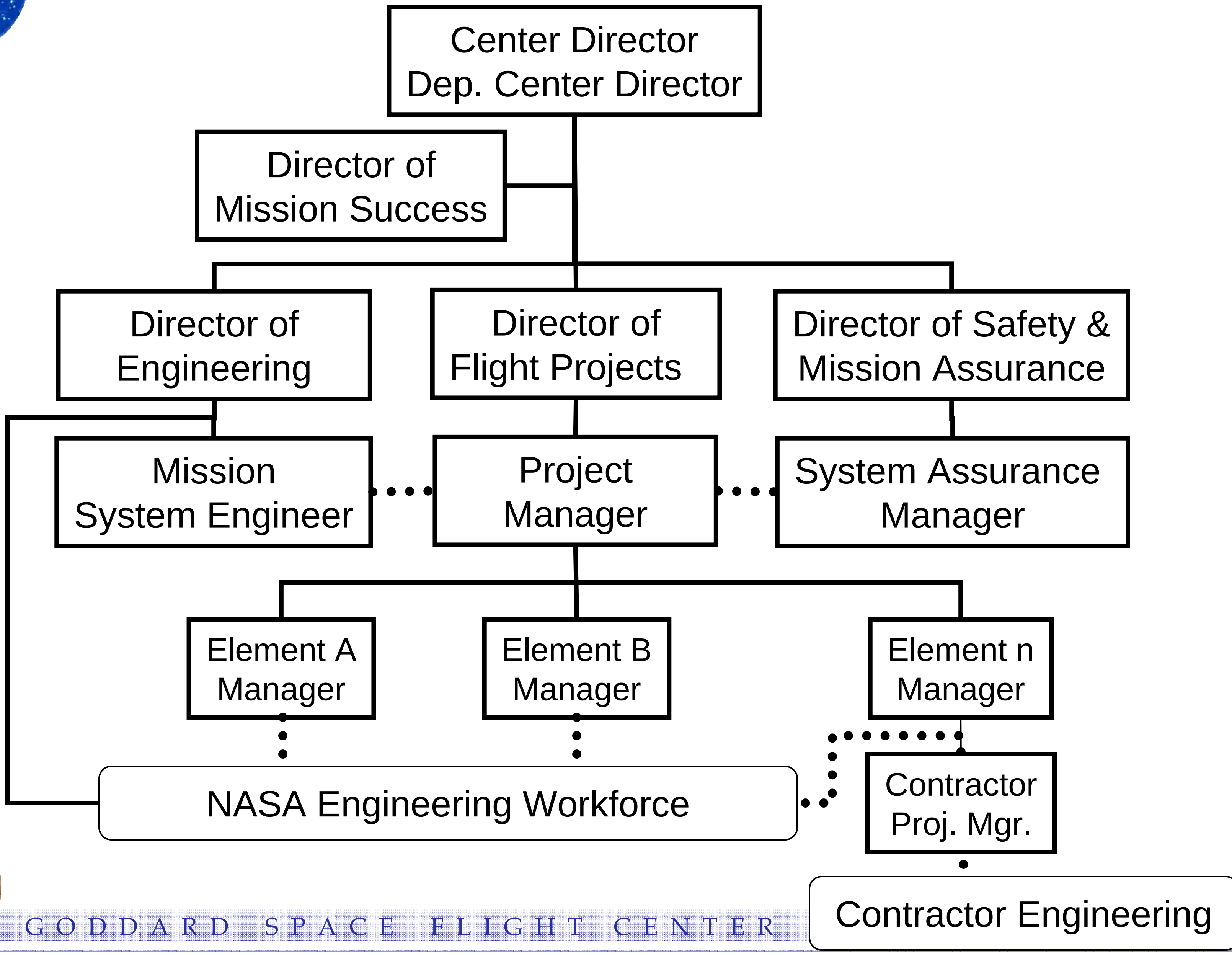
Director of Mission Success

- Looks across project management, engineering, SMA and other organizations to develop an integrated assessment of Center performance
- Evaluates composite risk of Center portfolio of projects and assesses the impact of committing to new projects
- Chairs the Management System Council and provides leadership for the Goddard Management System
- Establishes technical standards for the design, verification & operation of flight systems, leads variance approval process
- Charters project critical milestone reviews and assures the appropriate experts are engaged in independent review and assessment of projects

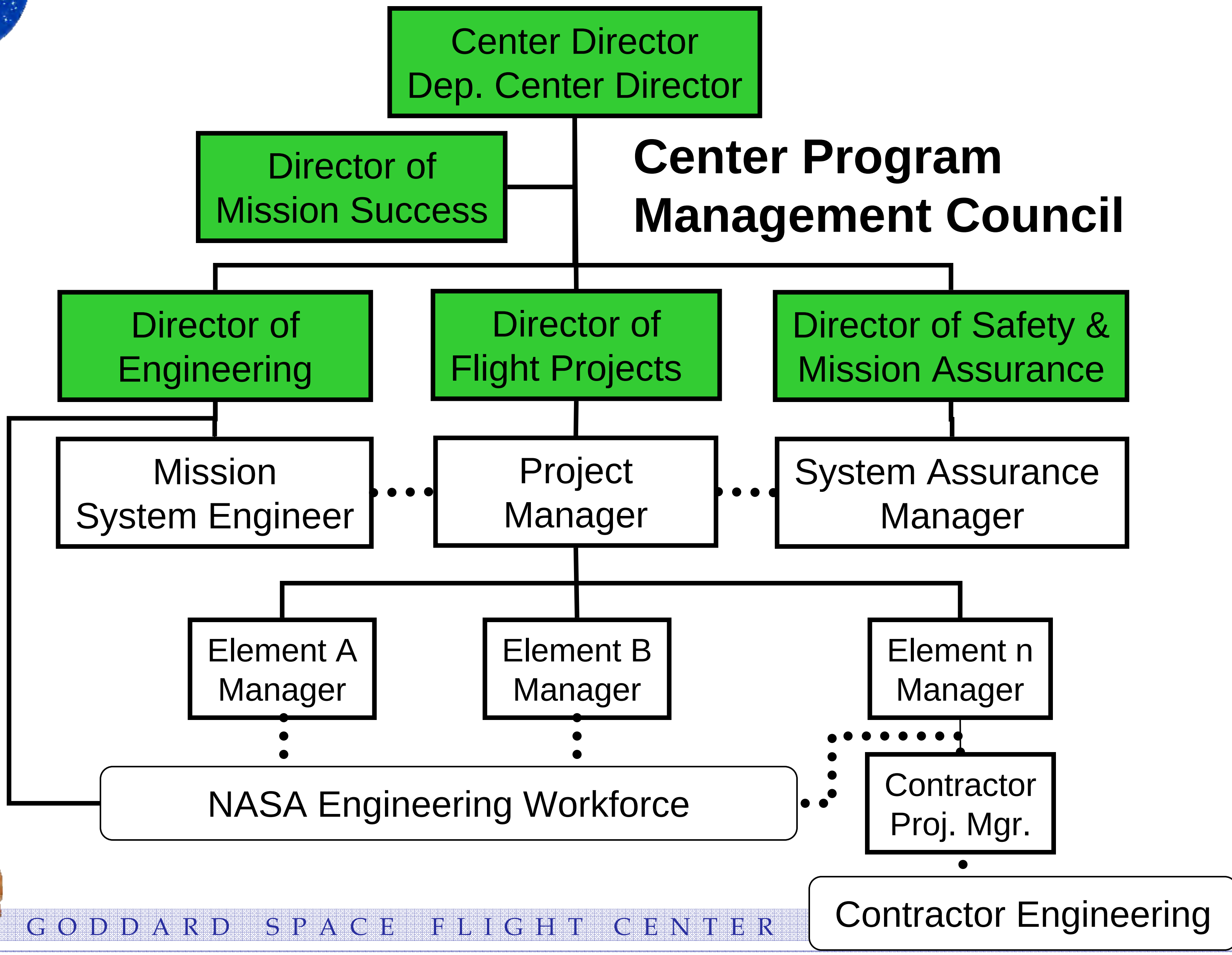
Director of Mission Success

- Owns and integrates Center risk management processes, assesses the implementation on projects, and assures that key products are independently reviewed and approved
- Establishes requirements for non-conformance, problem and anomaly reporting, characterization and resolution, evaluates residual risks and conducts trend analysis
- Develops external partnerships to access knowledge from outside organizations, assess broader trends in the aerospace community, and improve mission performance
- Enhances Center performance as a learning organization through lessons learned, case studies, knowledge sharing, and training initiatives

Center Leadership Structure



Center Leadership Structure

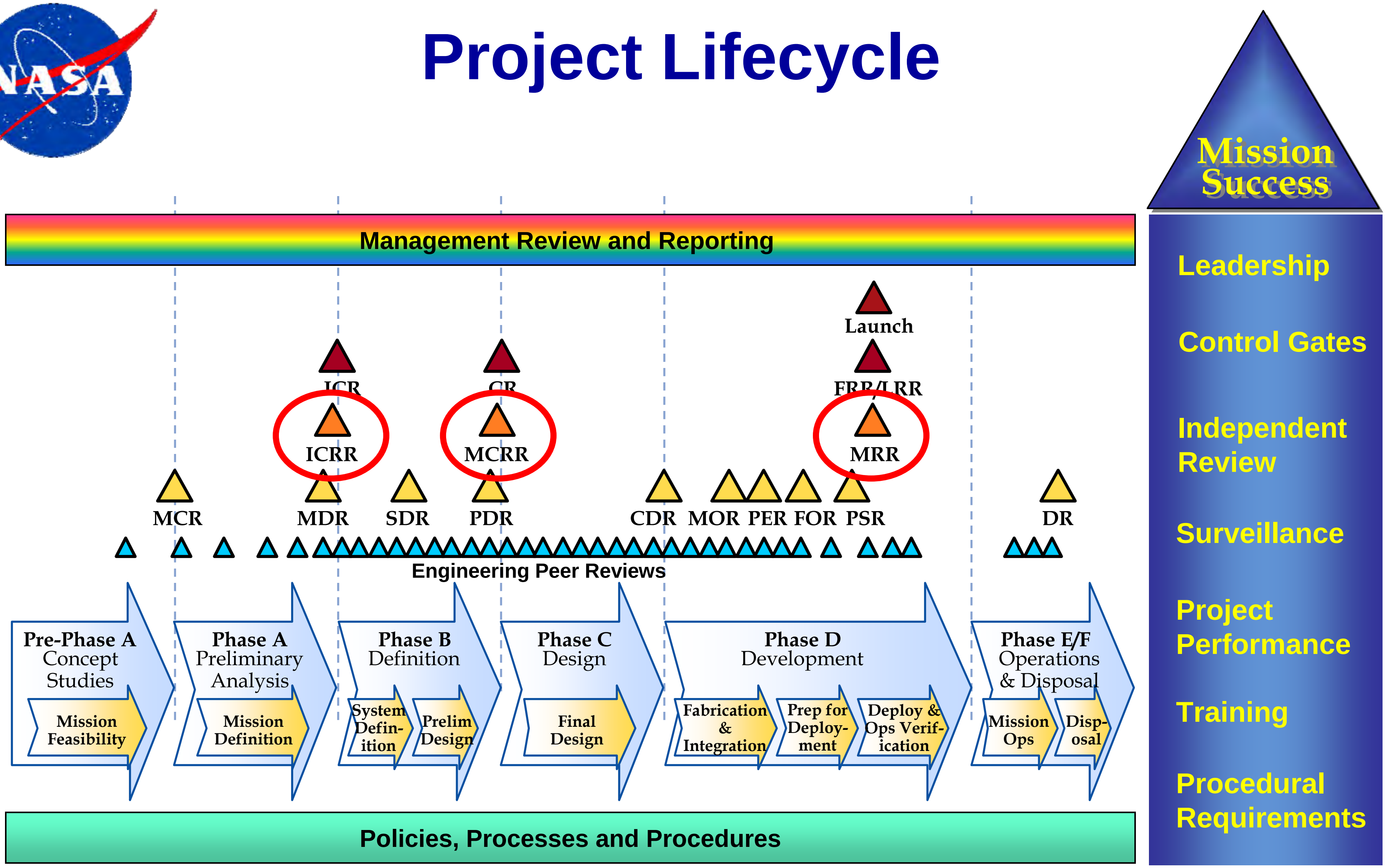


GSFC Program Management Council

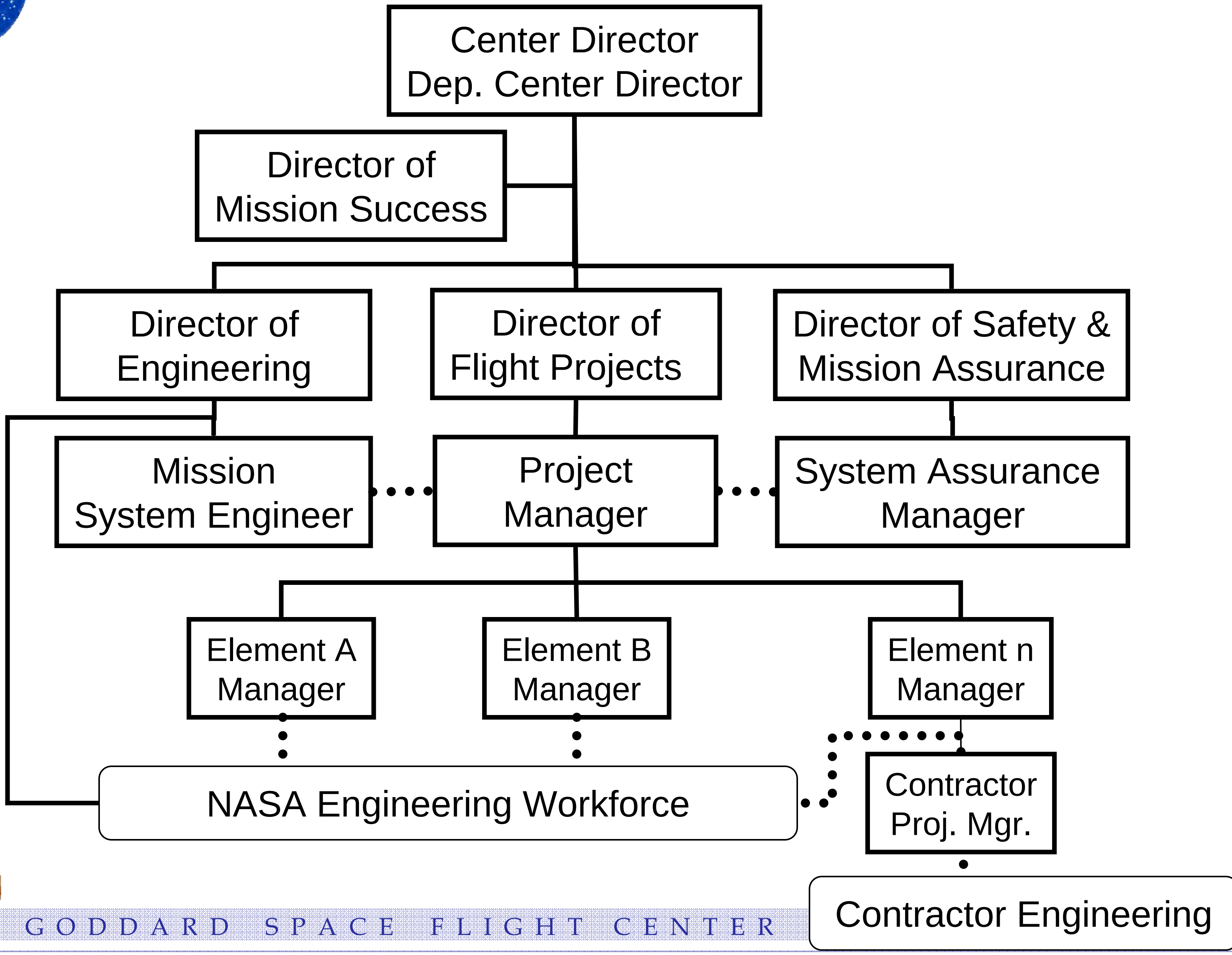
Nexus of all space flight mission certification processes

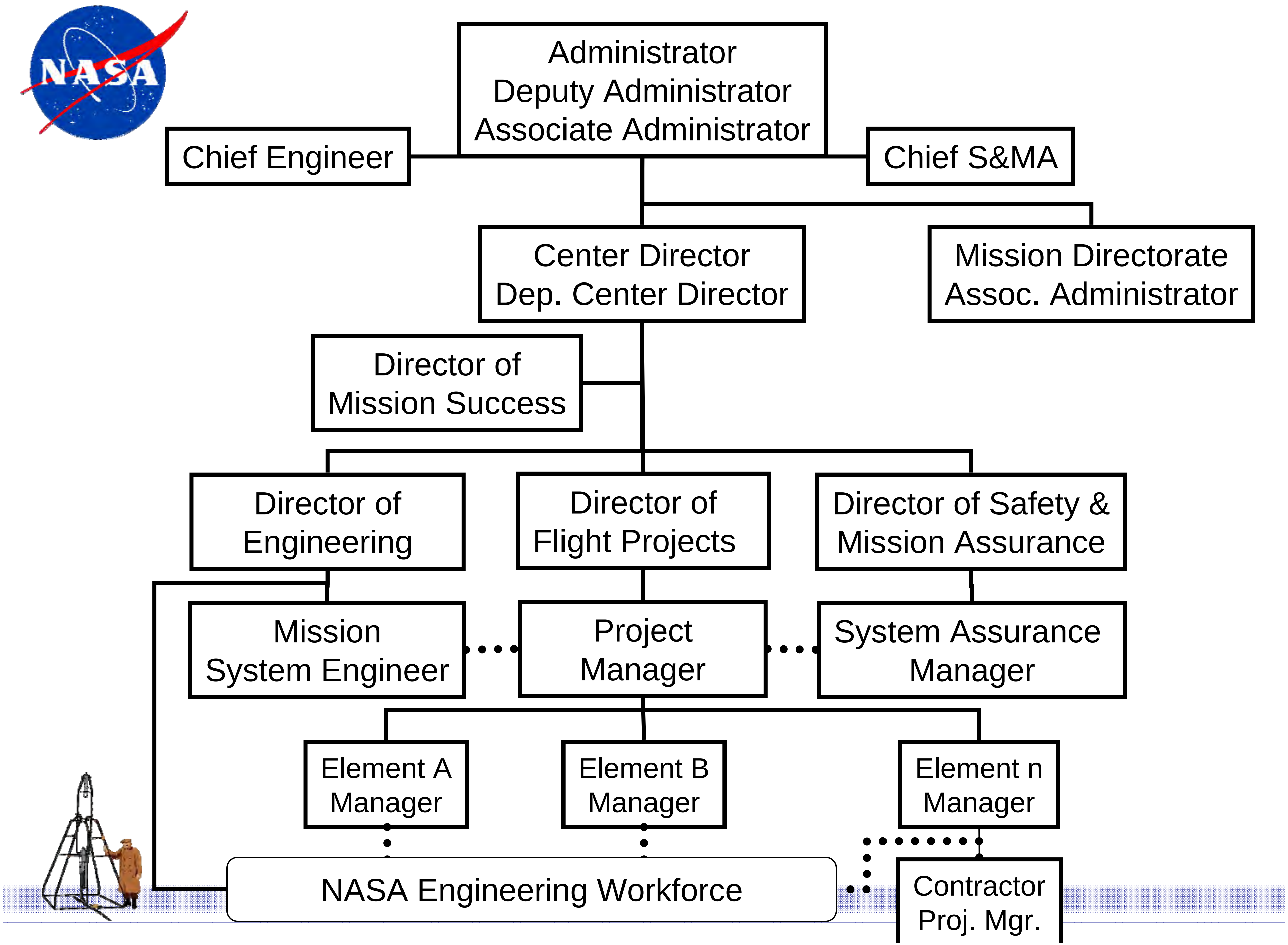
- Chaired by the Deputy Center Director
  - Membership consists of senior leadership directly involved in the execution and oversight of projects
  - HQ Mission Directorate representation invited
- Assesses project planning and implementation
  - Provides oversight and direction as appropriate
- Conducts/charters a continuum of reviews including:
  - Monthly Status Reviews (MSRs)
  - Quarterly Status Reviews (QSRs)
  - Project Critical Milestone Reviews (IIRs)
  - Mission Confirmation Readiness Reviews (ICRRs, MCRRs)
  - Mission Readiness Reviews (MRRs)
  - Ad Hoc Reviews (Failure/Mishap Review Board findings, Re-baseline Reviews, End-of-Mission Planning, etc)

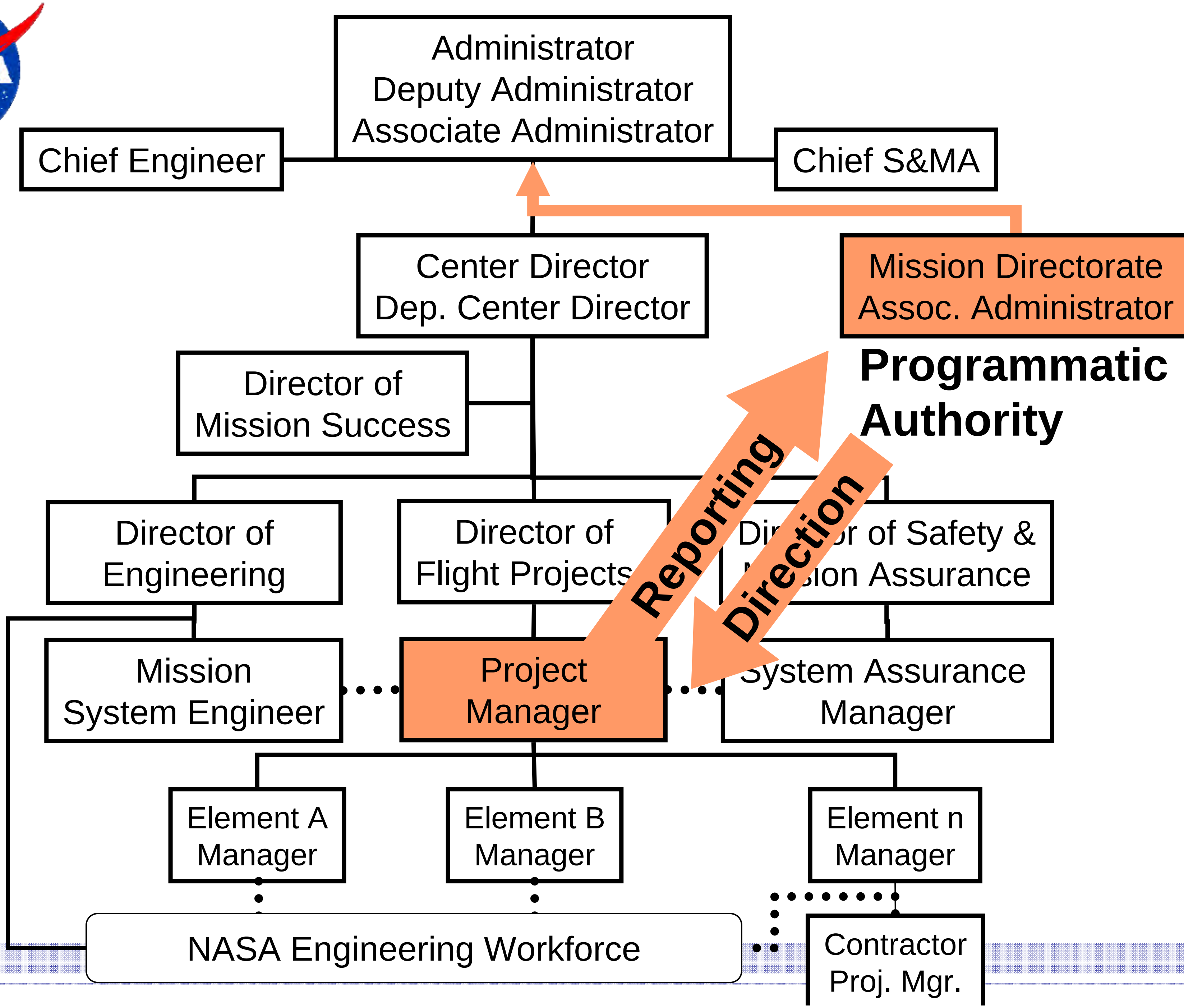
Project Lifecycle



Life cycle processes and activities are grounded in established and proven methods to develop and operate flight systems


Center Director
Dep. Center Director
Director of
Mission Success
Director of
Engineering
Director of
Flight Projects
Director of Safety &
Mission Assurance
Mission
System Engineer
Project
Manager
System Assurance
Manager
Element A
Manager
Element B
Manager
Element n
Manager
NASA Engineering Workforce
Contractor
Proj. Mgr.
Contractor Engineering


Administrator
Deputy Administrator
Associate Administrator
Chief Engineer
Chief S&MA
Center Director
Dep. Center Director
Mission Directorate
Assoc. Administrator
Director of
Mission Success
Director of
Engineering
Director of
Flight Projects
Director of Safety &
Mission Assurance
Mission
System Engineer
Project
Manager
System Assurance
Manager
Element A
Manager
Element B
Manager
Element n
Manager
NASA Engineering Workforce
Contractor
Proj. Mgr.



Administrator
Deputy Administrator
Associate Administrator
Chief Engineer
Chief S&MA
Center Director
Dep. Center Director
Mission Directorate
Assoc. Administrator
Programmatic
Authority
Director of
Mission Success
Director of
Engineering
Director of
Flight Projects
Reporting
Direction
Dir
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System Engineer
Project
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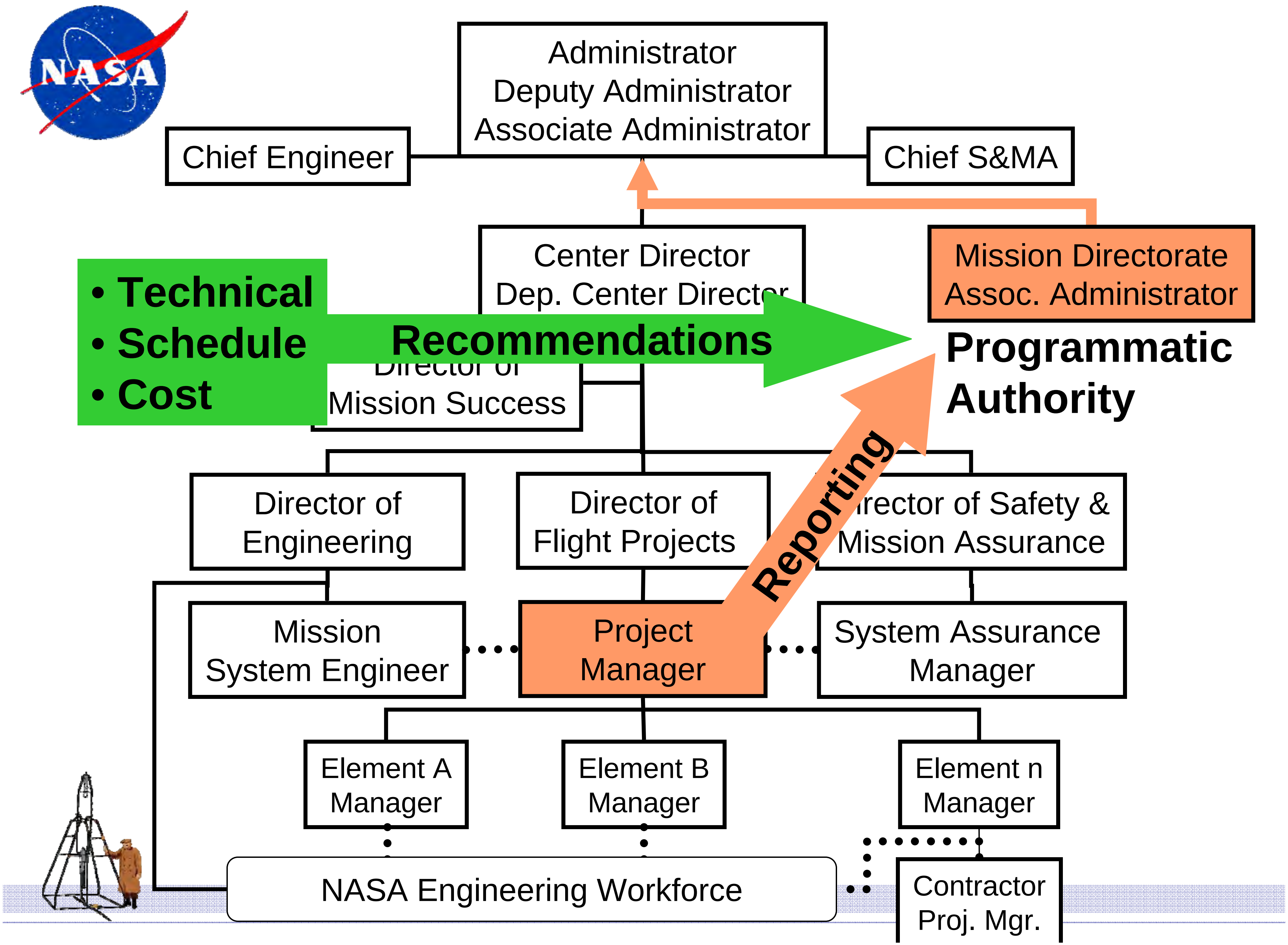
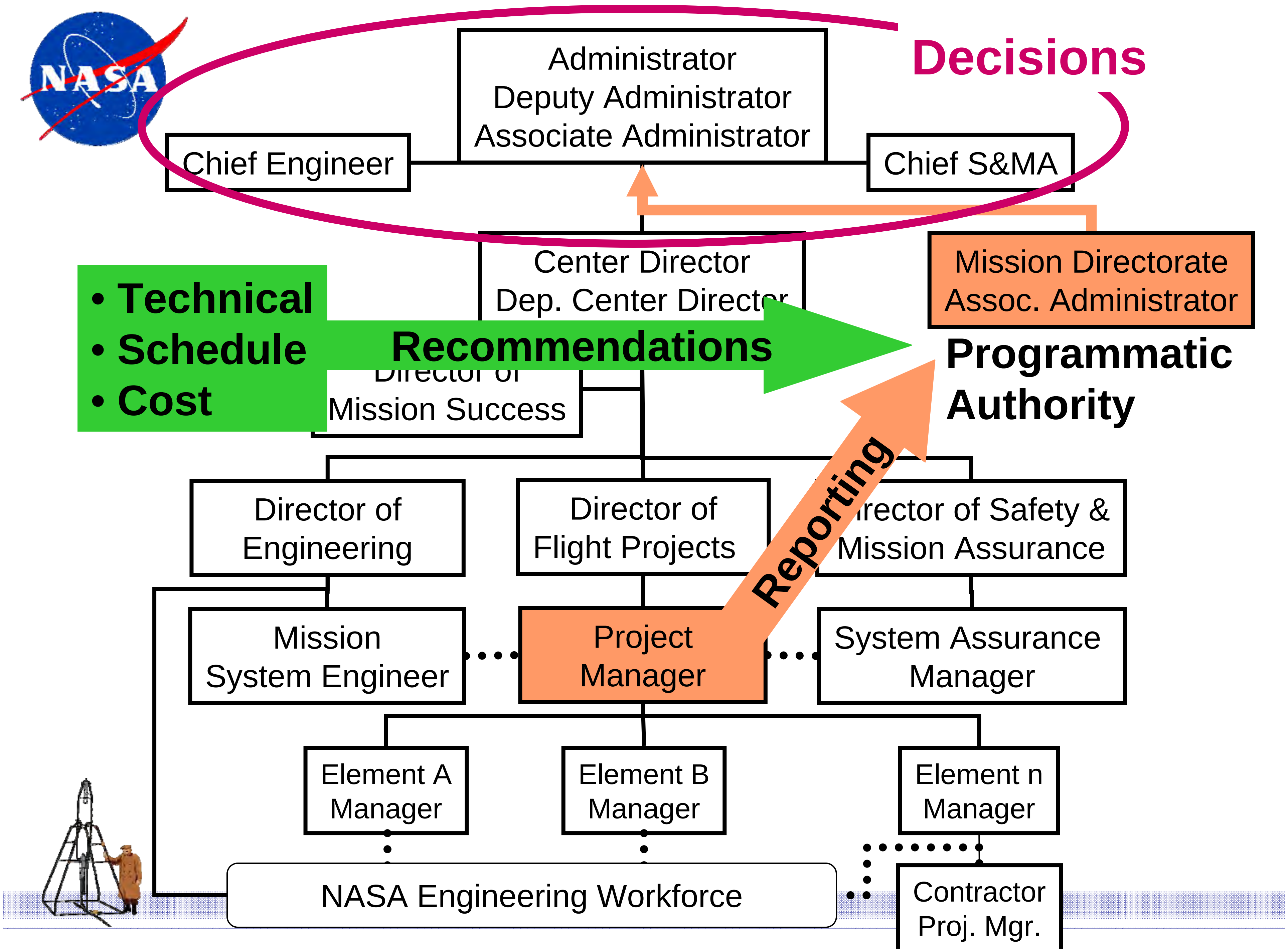
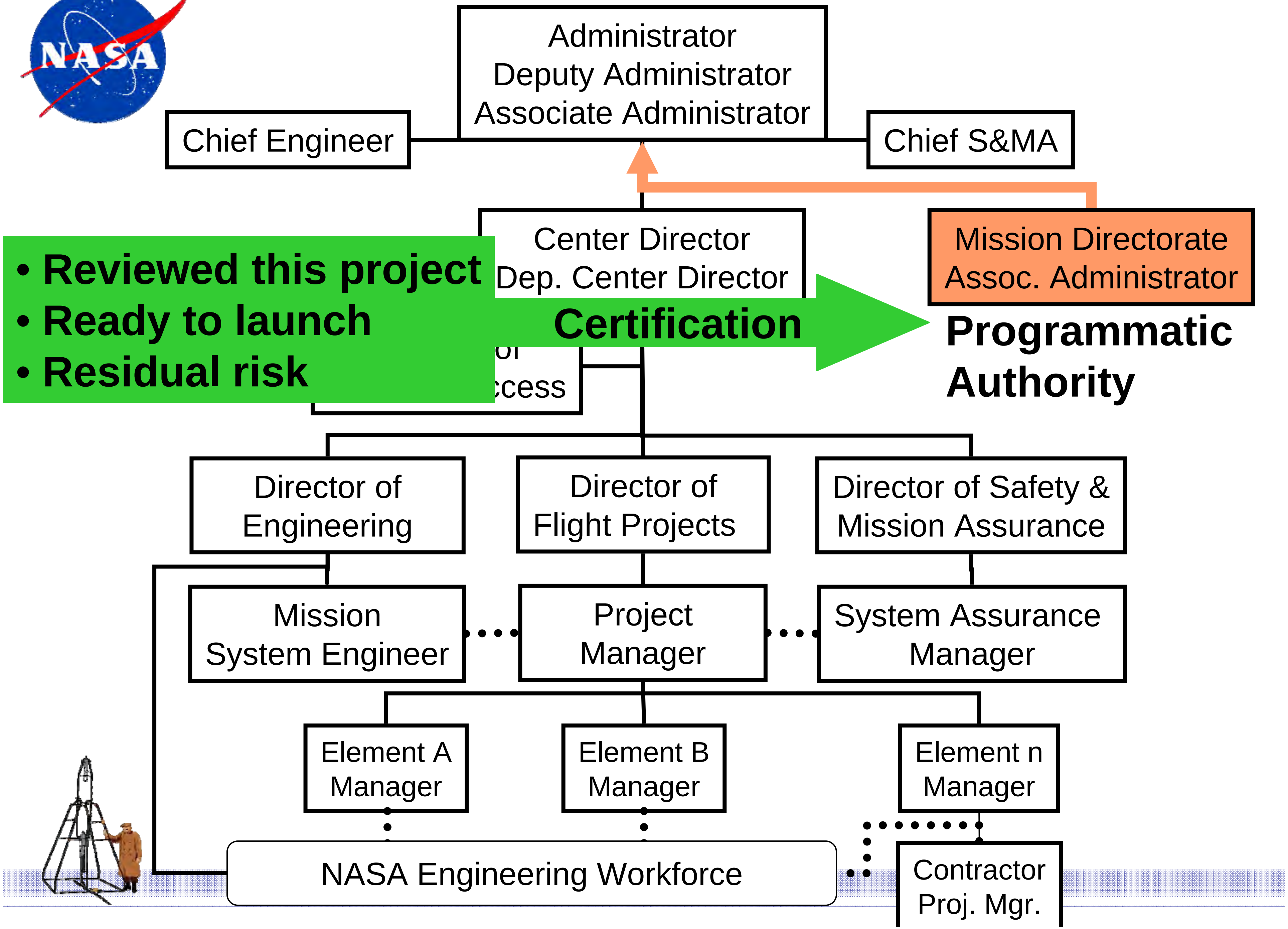
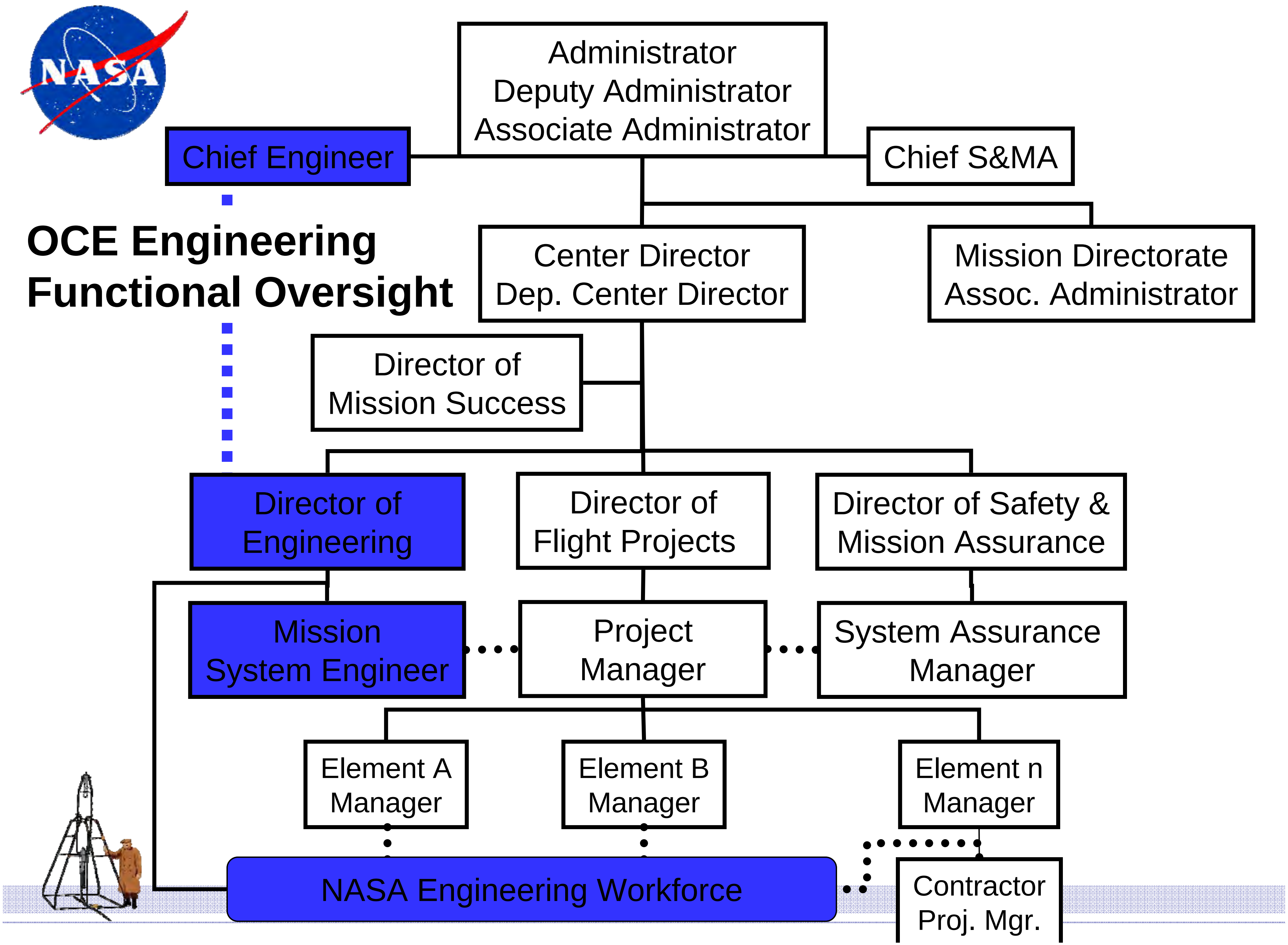
NASA Engineering Workforce
Contractor
Proj. Mgr.


Administrator
Deputy Administrator
Associate Administrator
Chief Engineer
Chief S&MA
Center Director
Dep. Center Director
Mission Directorate
Assoc. Administrator
• Technical
• Schedule
• Cost
Recommendations
Programmatic
Authority
Mission Success
Reporting
Director of
Engineering
Director of
Flight Projects
irector of Safety &
Mission Assurance
Mission
System Engineer
Project
Manager
System Assurance
Manager
Element A
Manager
Element B
Manager
Element n
Manager
NASA Engineering Workforce
Contractor
Proj. Mgr.



Decisions
Administrator
Deputy Administrator
Associate Administrator
Chief Engineer
Chief S&MA
Center Director
Dep. Center Director
Mission Directorate
Assoc. Administrator
• Technical
• Schedule
• Cost
Recommendations
Programmatic
Authority
Mission Success
Reporting
Director of
Engineering
Director of
Flight Projects
irector of Safety &
Mission Assurance
Mission
System Engineer
Project
Manager
System Assurance
Manager
Element A
Manager
Element B
Manager
Element n
Manager
NASA Engineering Workforce
Contractor
Proj. Mgr.


Administrator
Deputy Administrator
Associate Administrator
Chief Engineer
Chief S&MA
Center Director
Dep. Center Director
Mission Directorate
Assoc. Administrator
• Reviewed this project
• Ready to launch
• Residual risk
Certification
Programmatic
Authority
Director of
Engineering
Director of
Flight Projects
Director of Safety &
Mission Assurance
Mission
System Engineer
Project
Manager
System Assurance
Manager
Element A
Manager
Element B
Manager
Element n
Manager
NASA Engineering Workforce
Contractor
Proj. Mgr.



Administrator
Deputy Administrator
Associate Administrator
Chief Engineer
Chief S&MA
OCE Engineering
Functional Oversight
Center Director
Dep. Center Director
Mission Directorate
Assoc. Administrator
Director of
Mission Success
Director of
Engineering
Director of
Flight Projects
Director of Safety &
Mission Assurance
Mission
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NASA Engineering Workforce
Contractor
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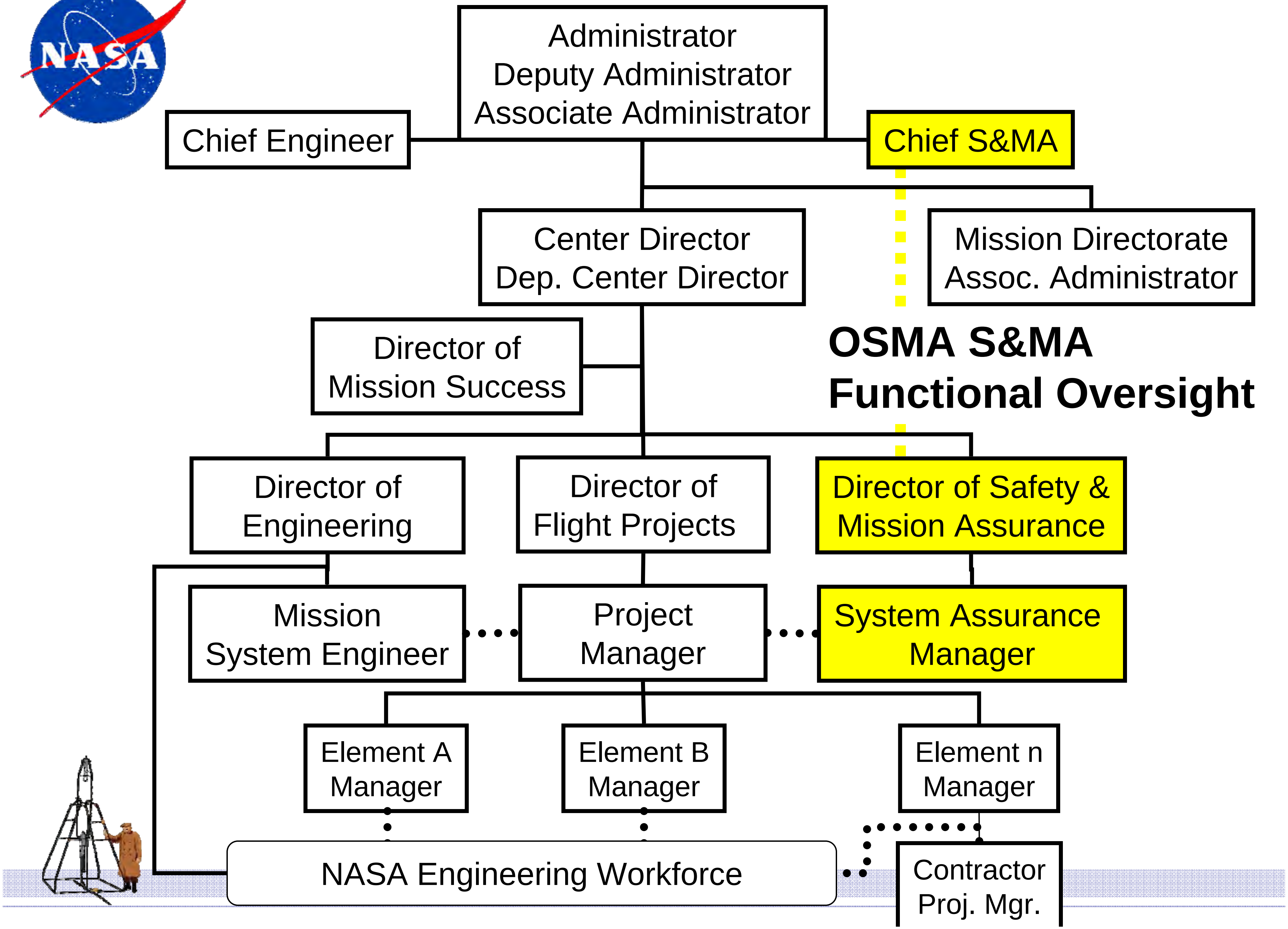

Administrator
Deputy Administrator
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Chief Engineer
Chief S&MA
Center Director
Dep. Center Director
Mission Directorate
Assoc. Administrator
OSMA S&MA
Functional Oversight
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Engineering
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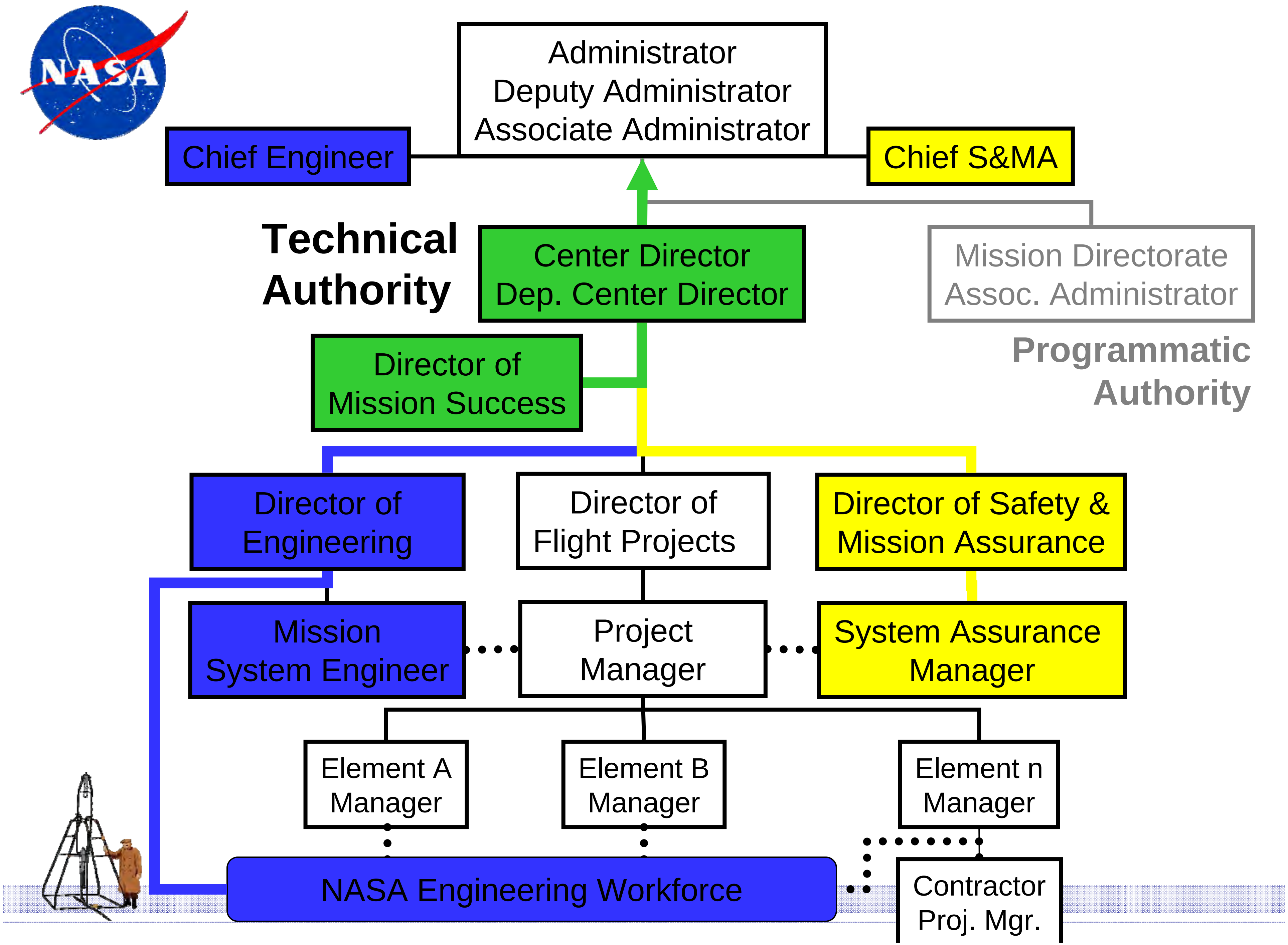
Administrator
Deputy Administrator
Associate Administrator
Chief Engineer
Chief S&MA
Technical Authority
Center Director
Dep. Center Director
Mission Directorate
Assoc. Administrator
Programmatic Authority
Director of Mission Success
Director of Engineering
Director of Flight Projects
Director of Safety & Mission Assurance
Mission System Engineer
Project Manager
System Assurance Manager
Element A Manager
Element B Manager
Element n Manager
NASA Engineering Workforce
Contractor Proj. Mgr.

Summary

- Goddard missions span a wide spectrum of project scope, complexity and work environments
- Individual and organizational accountability and authority for safety and mission success
- Independent checks and balances are robust and built into the Goddard leadership organization
- Striving to continually enhance our performance as a learning organization


Safety
Mission
Success
Teamwork
Integrity