Leadership and Its Influence on Program Planning

SICSA Alumni Talks

Sasakawa International Center for Space Architecture
University of Houston
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The Ups and Downs of Presidential Administrations

How This Translates into Program Planning

A Brief Primer on Writing Requirements

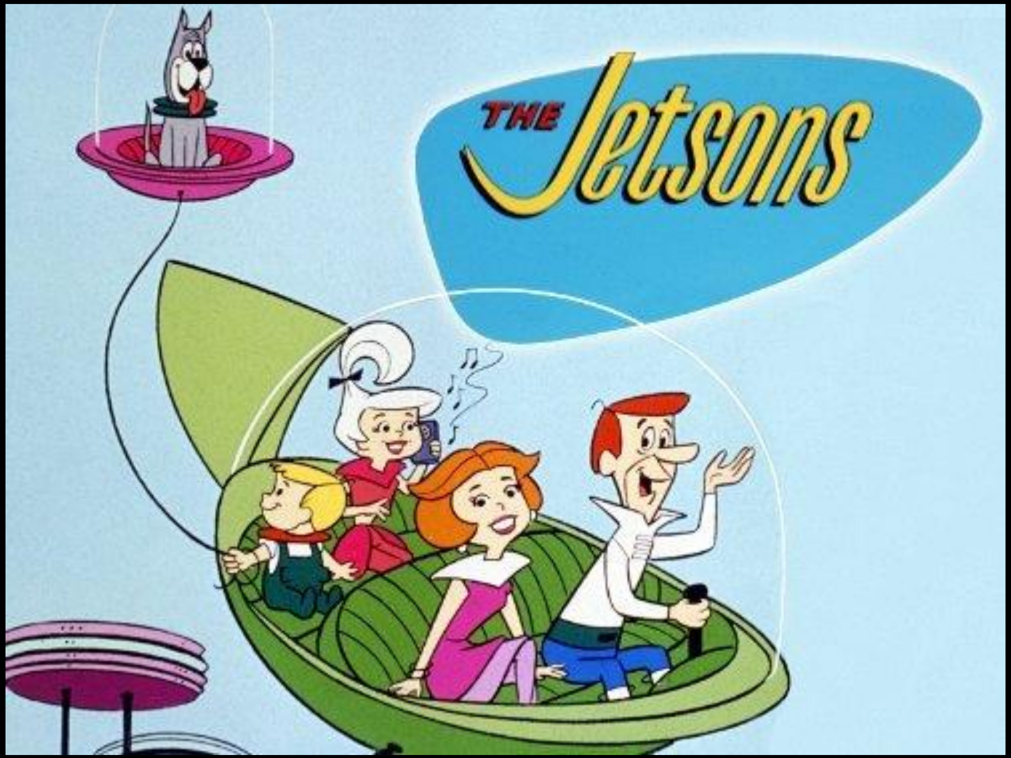
Sep 12, 1962

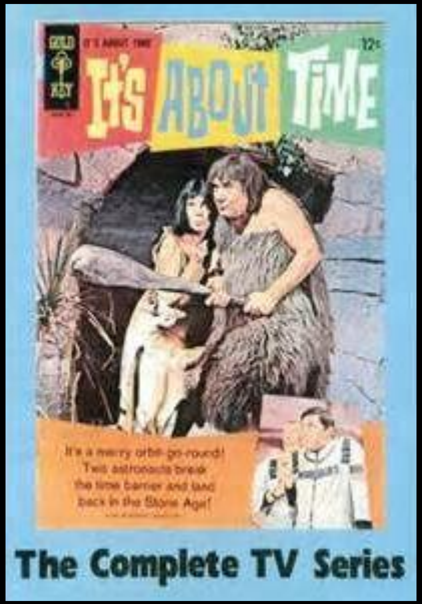
President Kennedy
Rice Stadium
Houston, TX

“But why, some say, the moon? Why choose this as our goal? And they may well ask why climb the highest mountain? Why, 35 years ago, fly the Atlantic? Why does Rice play Texas?

We choose to go to the moon. We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard.”

1960s


THE Jetsons

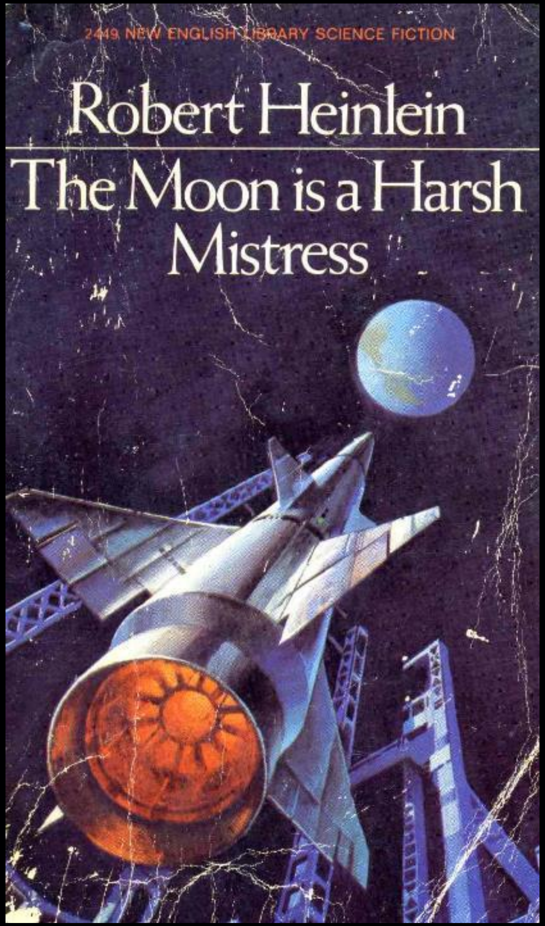

GOLD KEY
IT'S ABOUT TIME
12¢
It's About Time
It's a merry orbit-go-round! Two astronauts break the time barrier and land back in the Stone Age!
The Complete TV Series

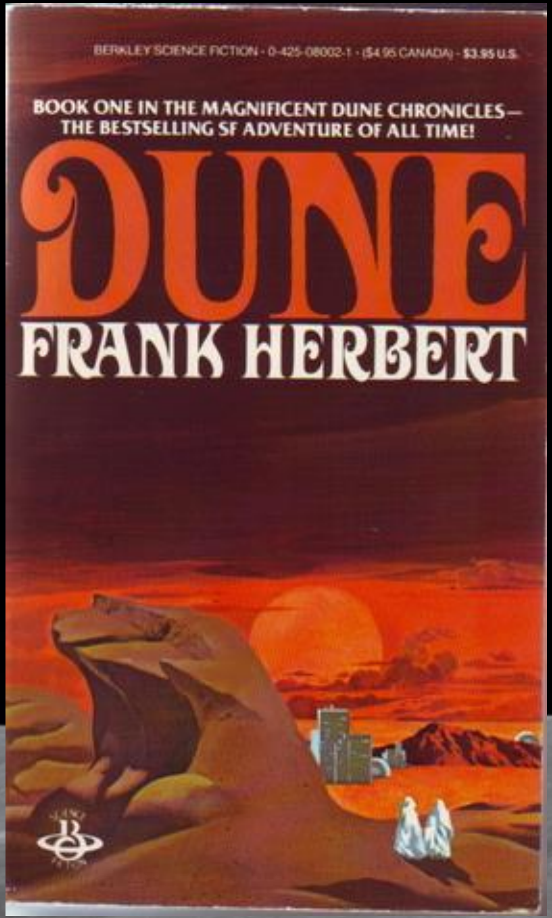

THE CLASSIC SCI-FI ADVENTURE SERIES
Irwin Allen's
Lost in Space
SEASON THREE VOLUME TWO

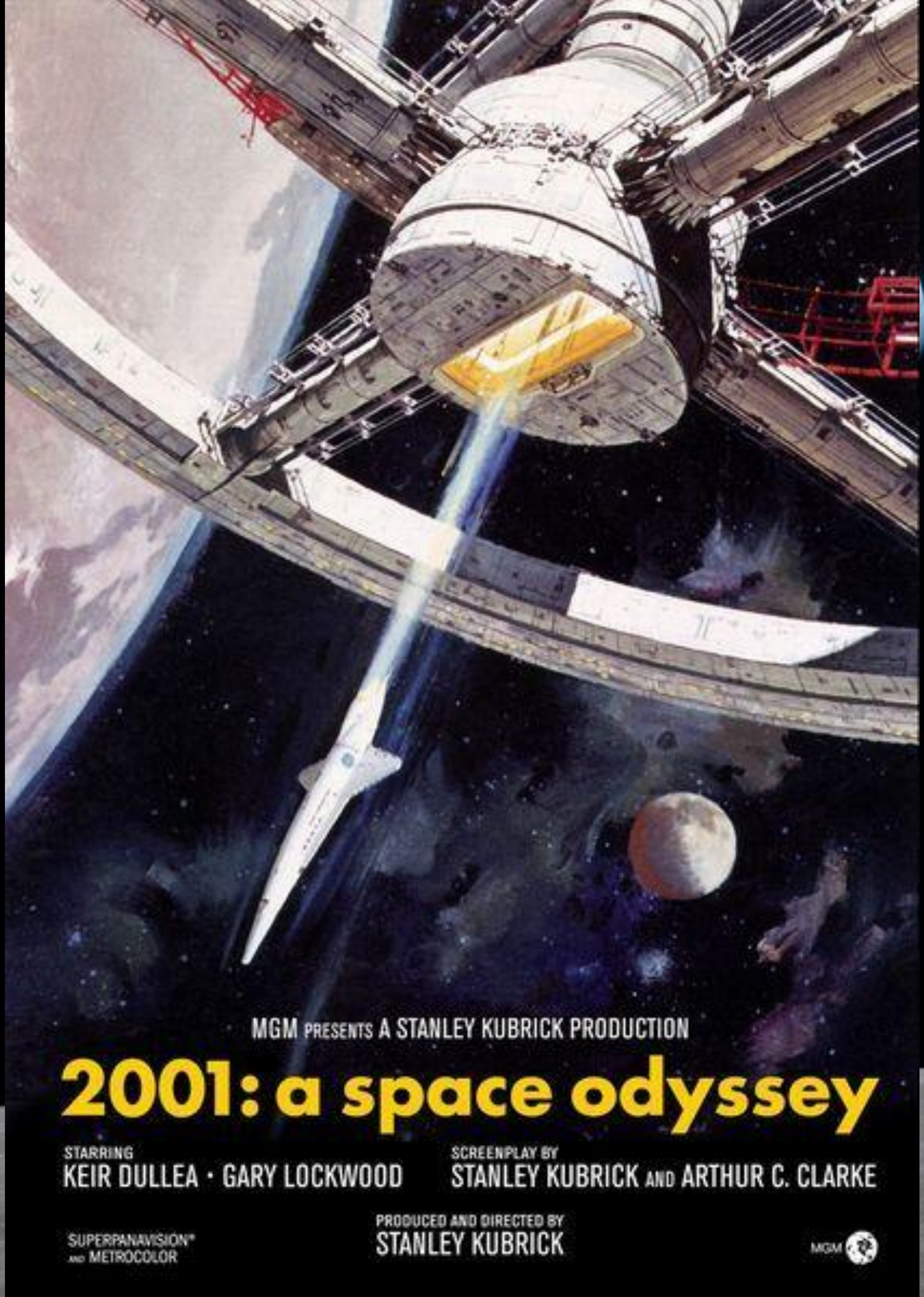

I Dream of Jeannie

1960s

1969
Oscar Winner







1970s

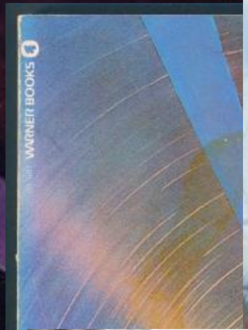


Image: Wikimedia.org

1980s

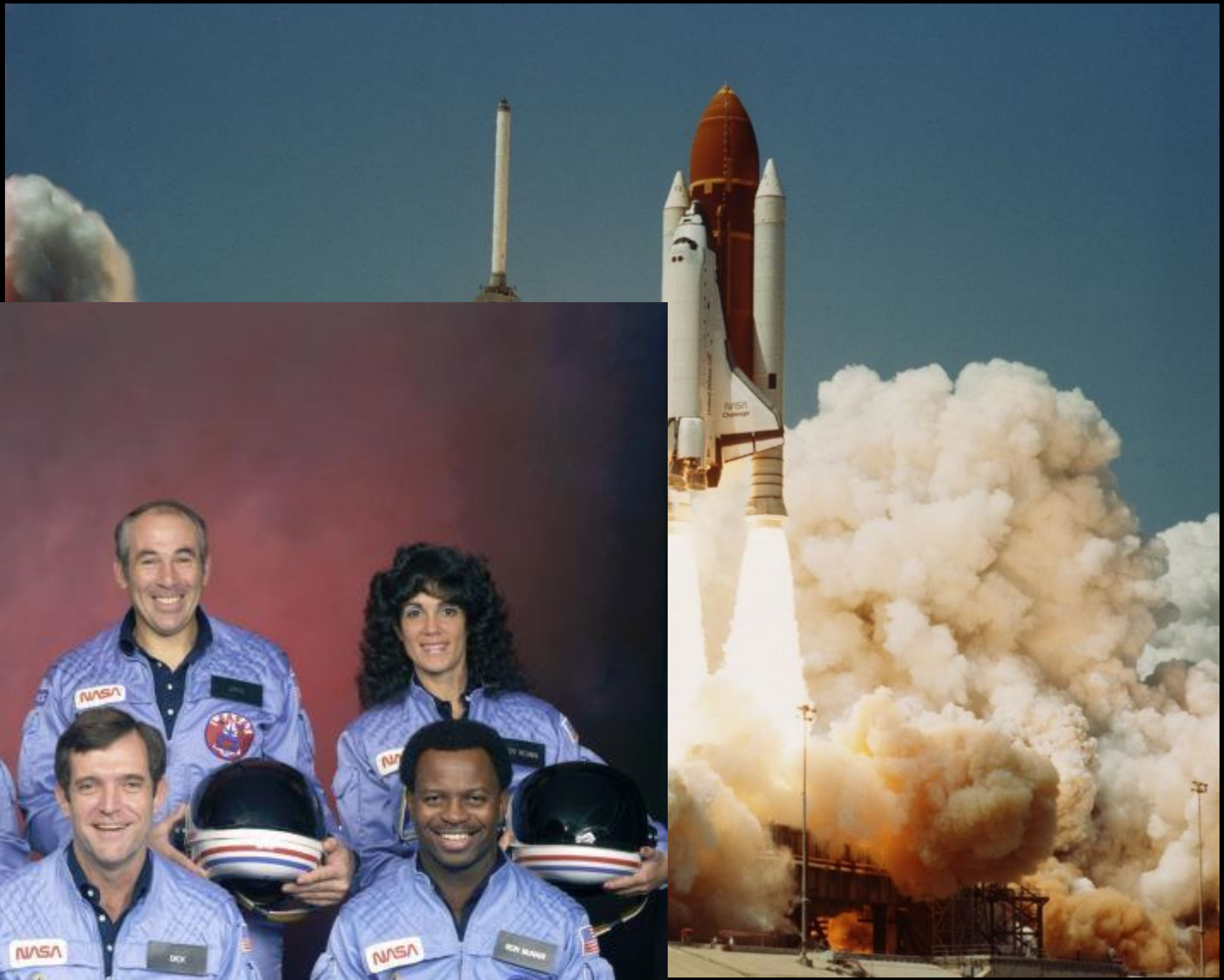
Ronald Reagan (40)

Space Shuttle

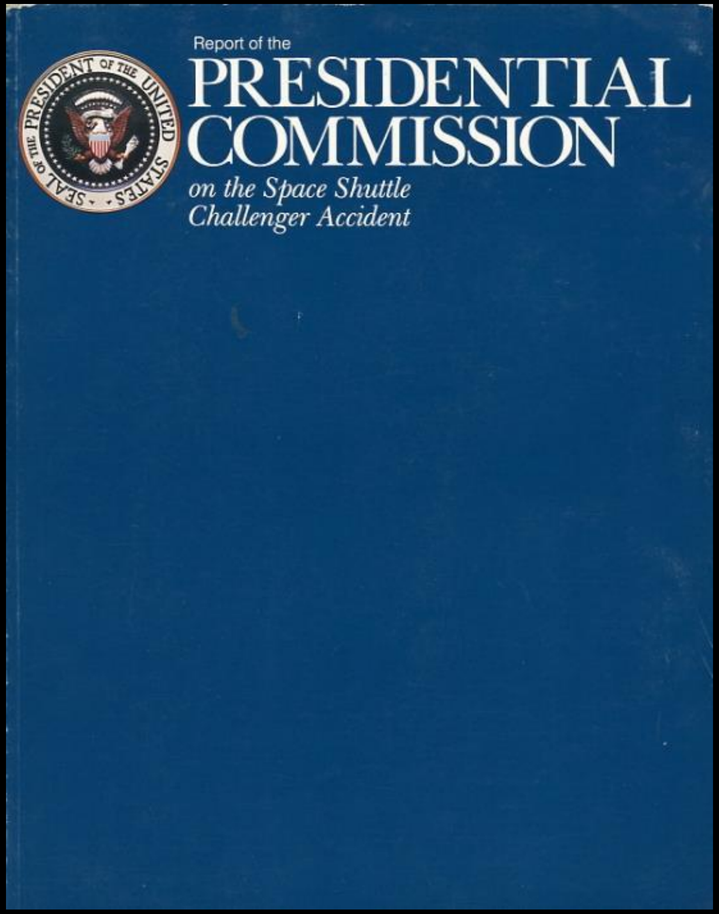
Space Station *Freedom*

The *Challenger* Accident

- Schedule Pressure
- NASA Culture



Leadership Lessons Learned from *Challenger*



- Recommendations:
  - The Shuttle Program Structure should be reviewed…vital program information frequently bypass the National STS (Shuttle) Program Manager. A redefinition of the Program Manager's responsibility is essential.
  - NASA should establish a Safety Advisory Panel and Safety Office reporting directly to the Administrator
  - **Improved Communications**… because of a tendency [of] management isolation… failed to provide full and timely information….
  - Flight Rate. NASA must establish a flight rate that is consistent with its resources

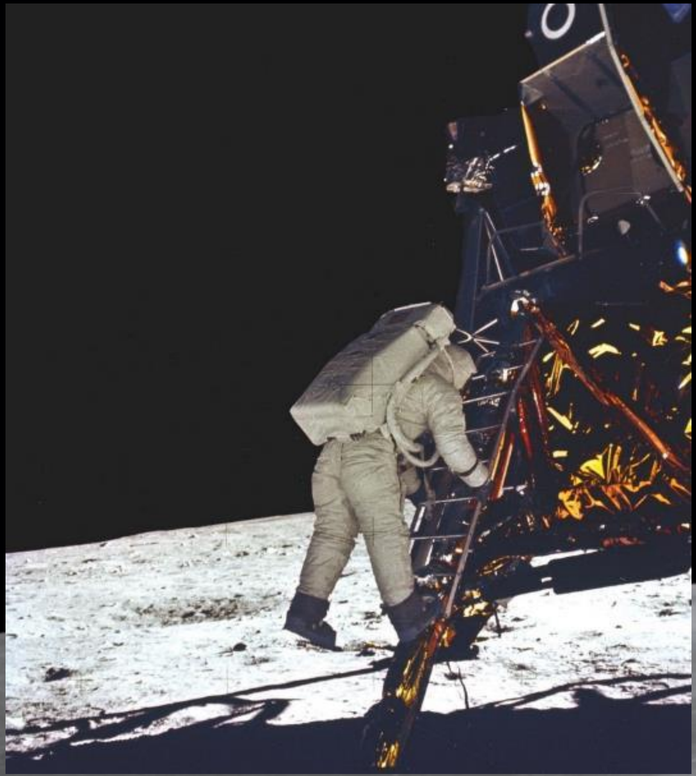
1989-1993

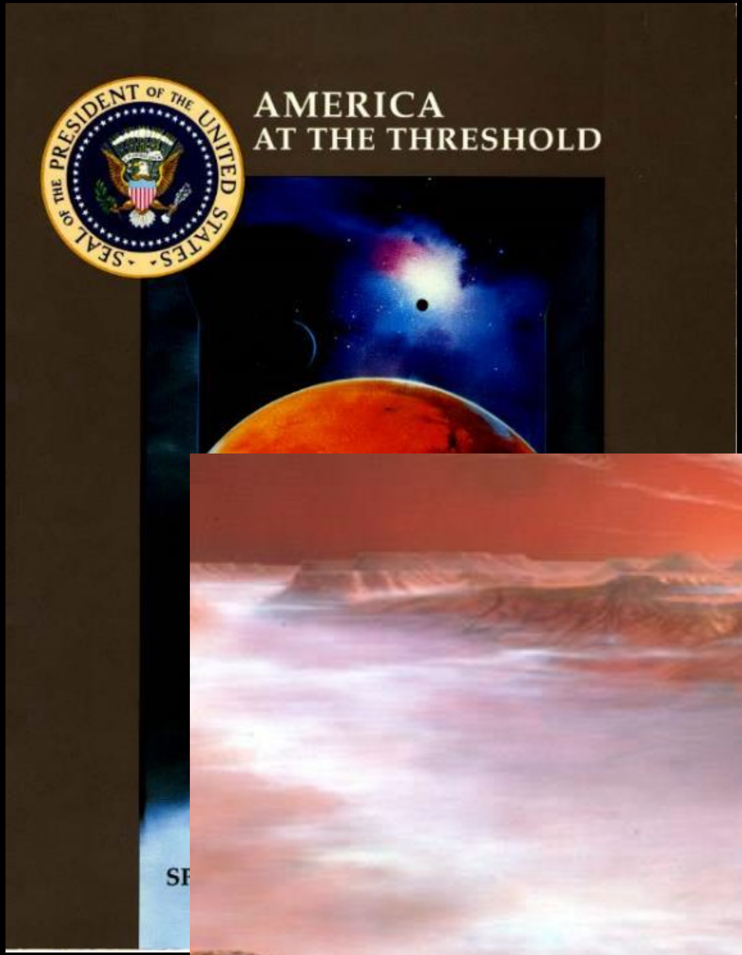
George H.W. Bush Administration (41)

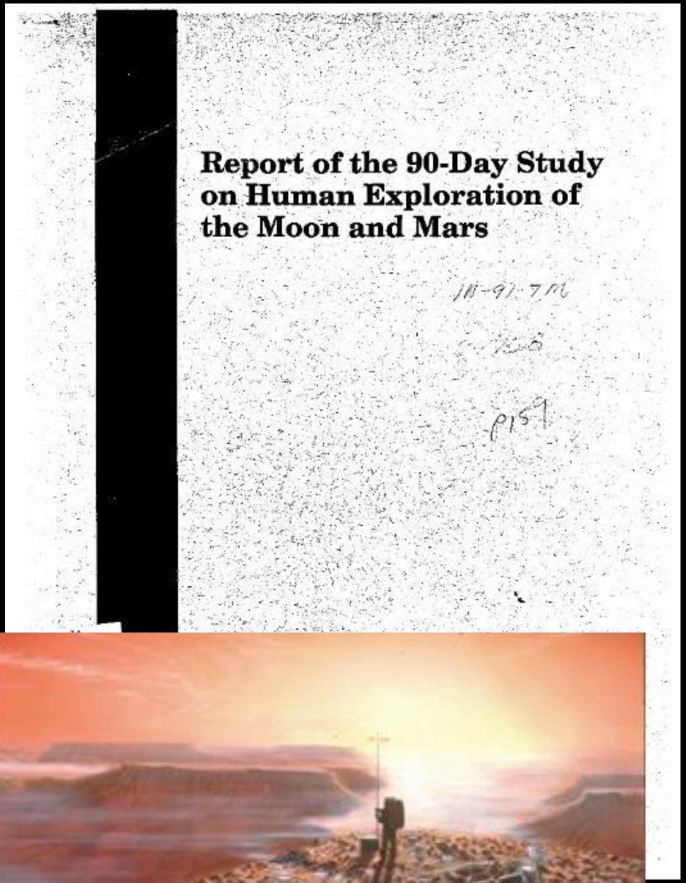
July 20, 1989– 20th Anniversary of the Moon Landing

90 Day Study

Space Exploration Initiative






Report of the 90-Day Study on Human Exploration of the Moon and Mars

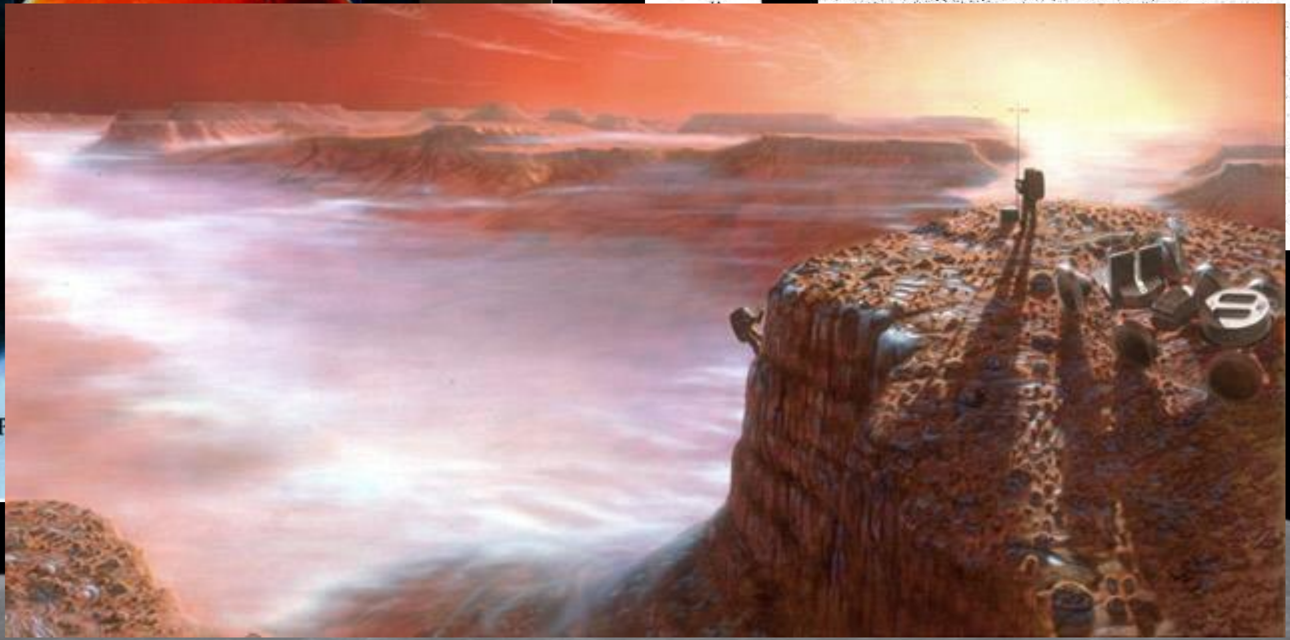


Illustration by Pat Rawlings © NASA

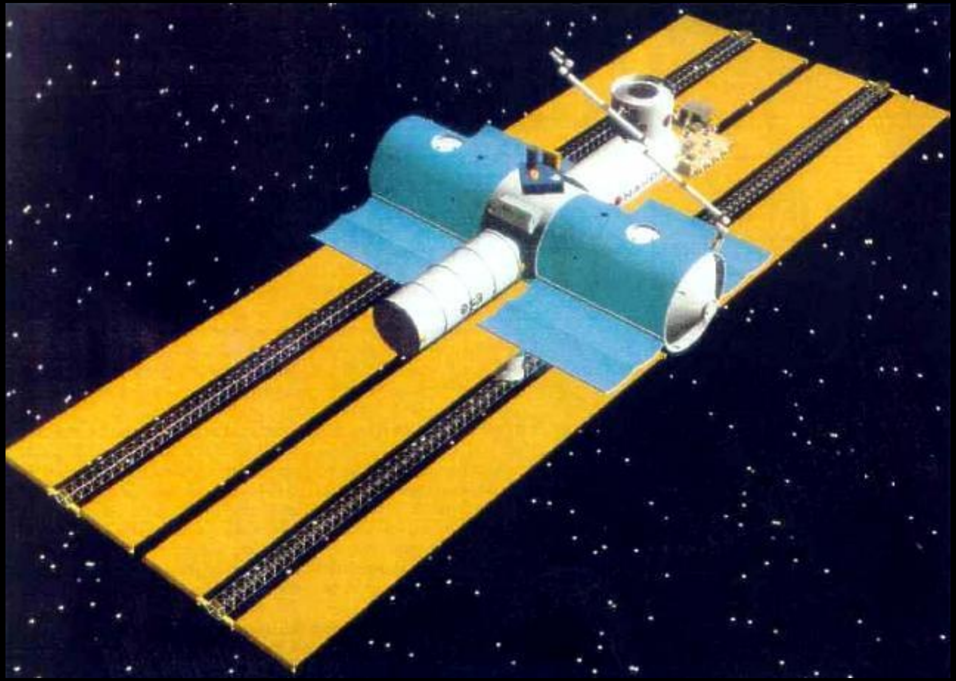
1993-1996

Bill Clinton Administration (42)

From Space Station Freedom

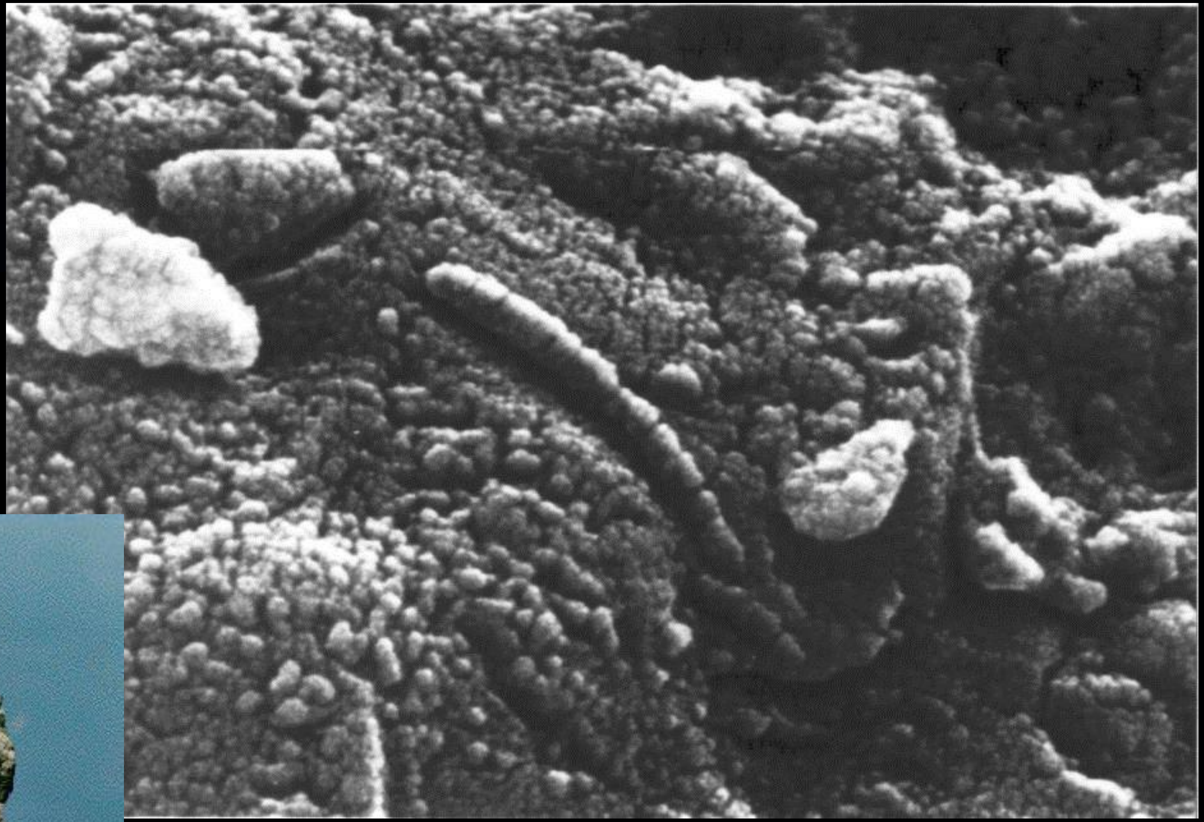
to Alpha

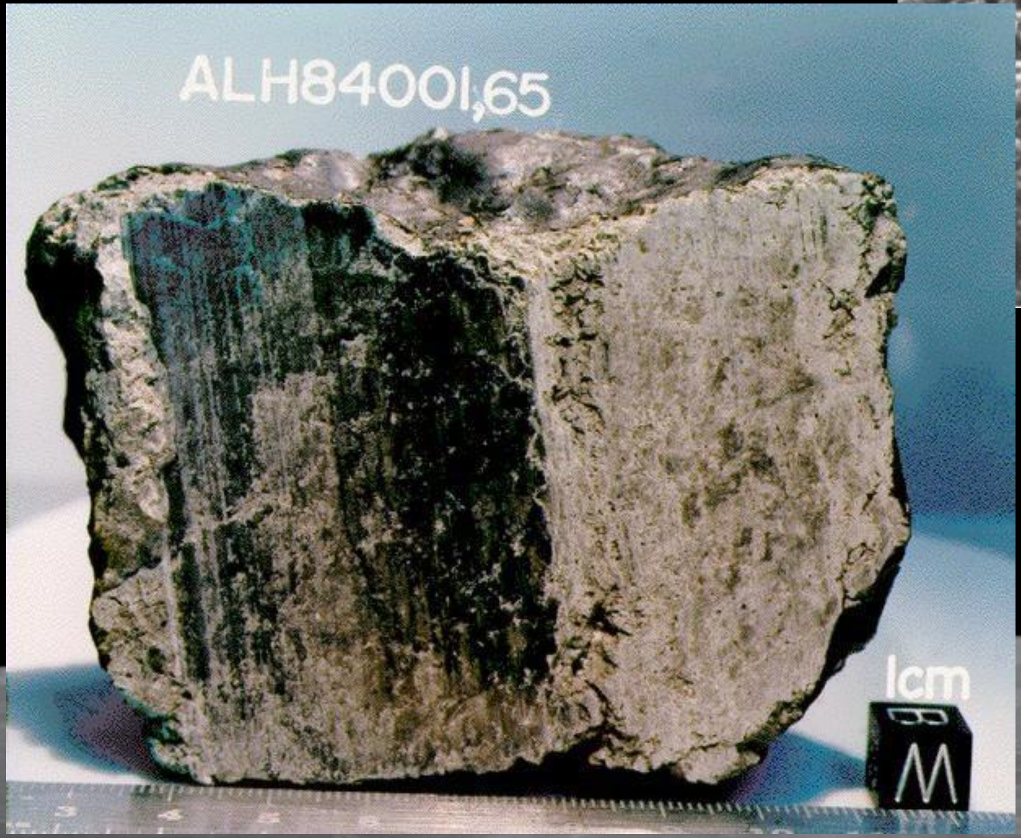
to R-Alpha and ISS



1996-2000
Exploration Begins Its Comeback

Discovery of potential proof of life on Mars



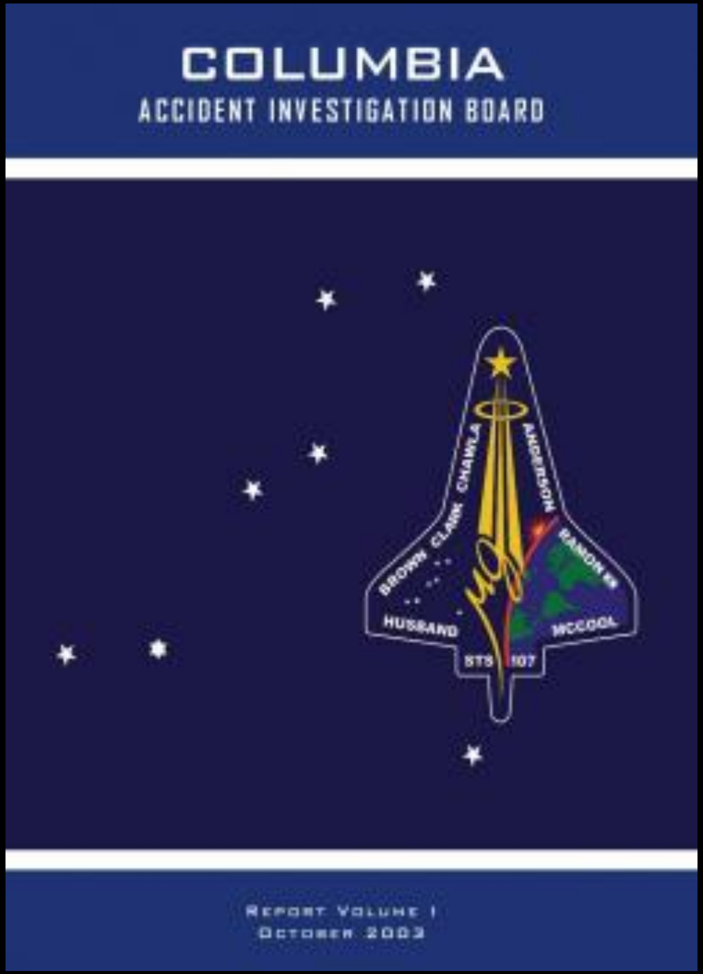


2001-2003

George W. Bush (43)

Loss of *Columbia*

Leadership Lessons Learned from *Columbia*



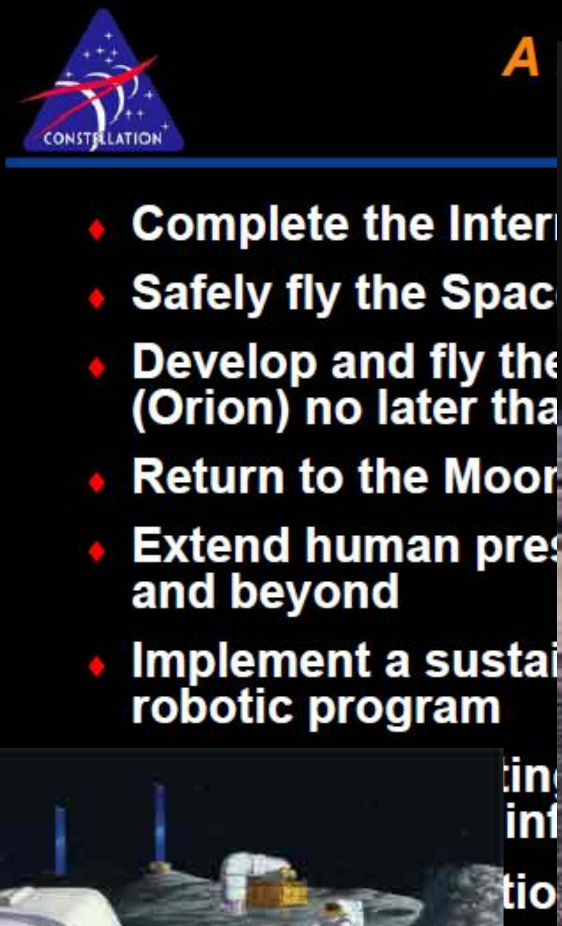
- CAIB Recommendations:
  - Adopt and maintain a Shuttle flight **schedule** that is consistent with available resources.
  - Implement an expanded training program …safety contingencies beyond launch and ascent.
  - Establish an independent Technical Engineering Authority…
  - NASA Headquarters Office of Safety and Mission Assurance should have direct line authority … and should be independently resourced.

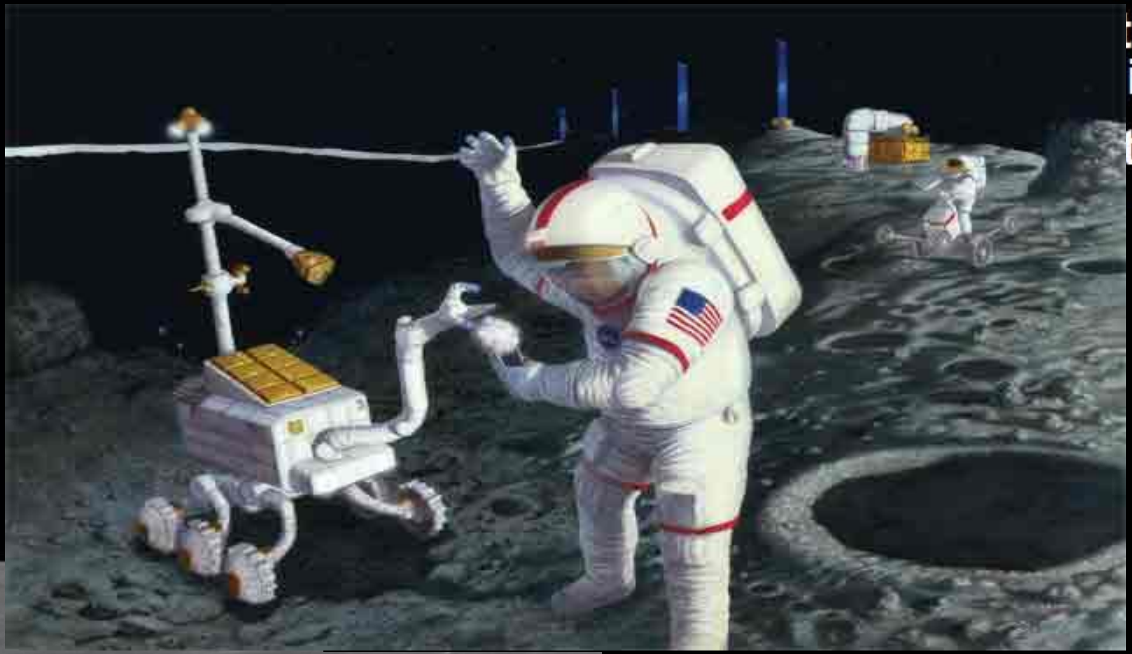
2004-2009
Back to the Moon and On to Mars

George W. Bush (43)

Vision for Space Exploration

A Unified Congress





Images by Pat Rawlings © NASA

2005 – 2009

Establishing Constellation

A New Administrator

Focused Goals

Broad Support

2010

Obama Administration (44)

Cancelation of Constellation 2010

Space on NBCNEWS.com

2/2/2010

NASA grieves over canceled program

Administrator says end of moon program is like 'death in the family'

President Obama's 2011 budget request for NASA cut the agency's Constellation program completely, effectively canceling a five-year, $9 billion effort to build new Orion spacecraft and Ares rockets.

The new space vehicles were slated to replace NASA's three aging space shuttles (due to retire this year) and launch astronauts into orbit and on to the moon.

2010-Present

Acceleration of Commercial Crew Program

Asteroid Mission

What's Next?

So What Does this Mean?

- US Space Program is an extension of the Presidential Administration
- NASA develops the options, the President decides the direction
- Political pressure not only shapes programs but also can lead to deadly consequences

Outline

The Ups and Downs of Presidential Administrations

How This Translates into Program Planning

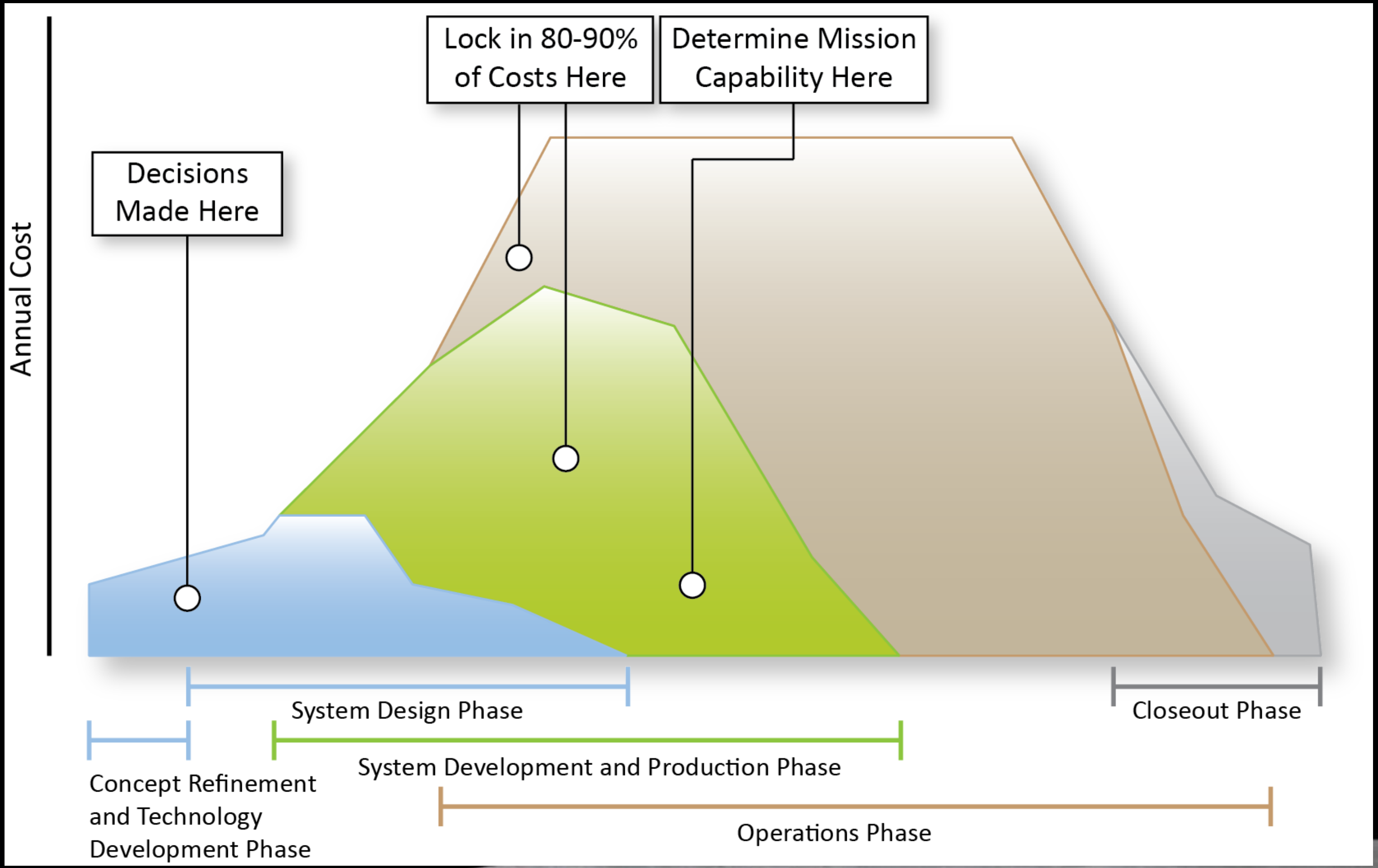
A Brief Primer on Writing Requirements

The Importance of Good Planning

High cost of going into space

Cost is locked in early

Need for process



The Systems Engineering “V”

Requirements and Design

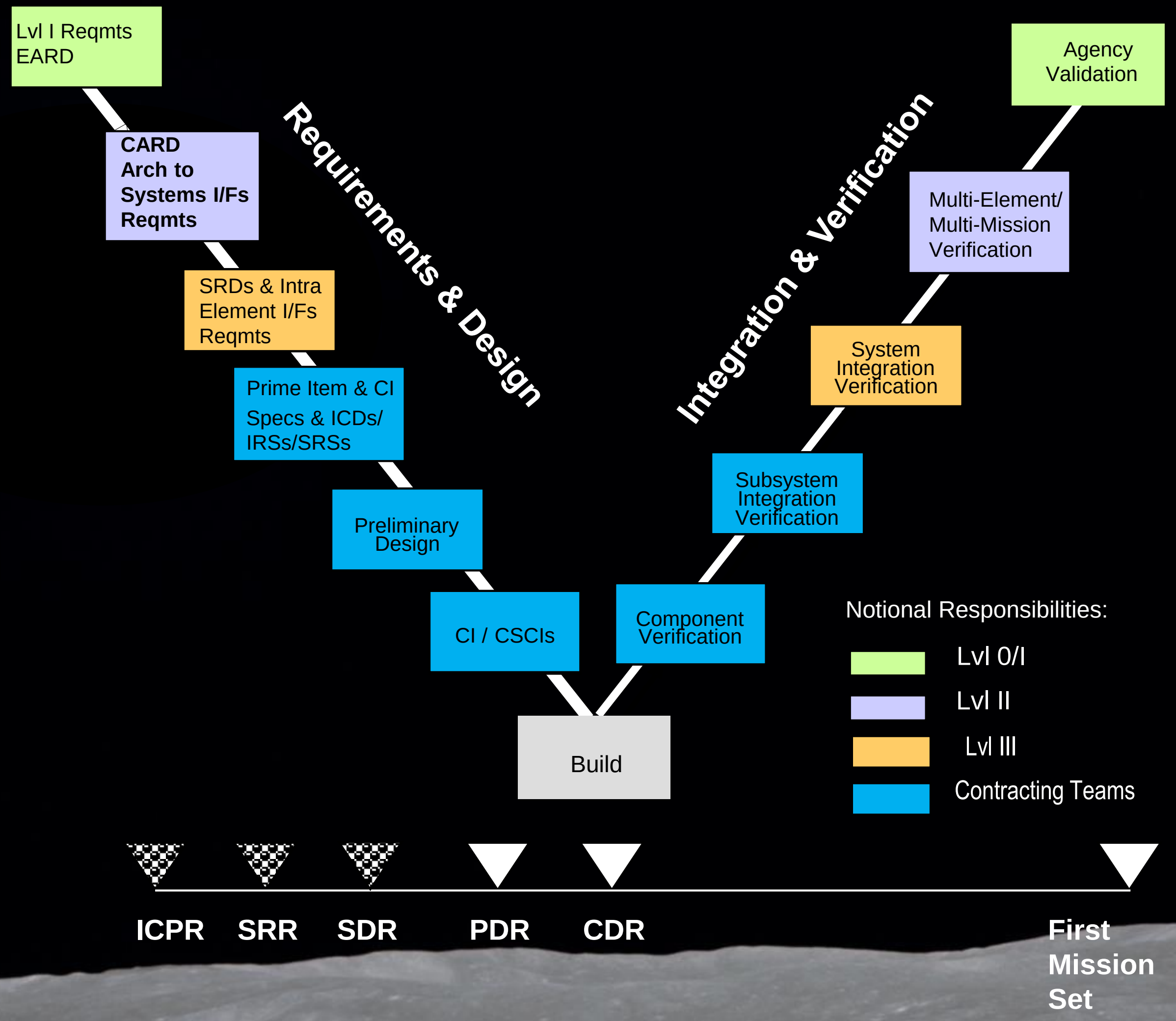
What do I want?

How can I do it?

Integration & Verification

Let’s put it together

Does it do what I wanted it to do?



Systems Engineering "Engine"

- NASA's Systems Engineering Handbook
  - It really is rocket science
  - Use the numbering system to navigate
- Key takeaways
  - Systems engineering is a combination of analysis, synthesis, and management processes
  - Program and project definition are iterative

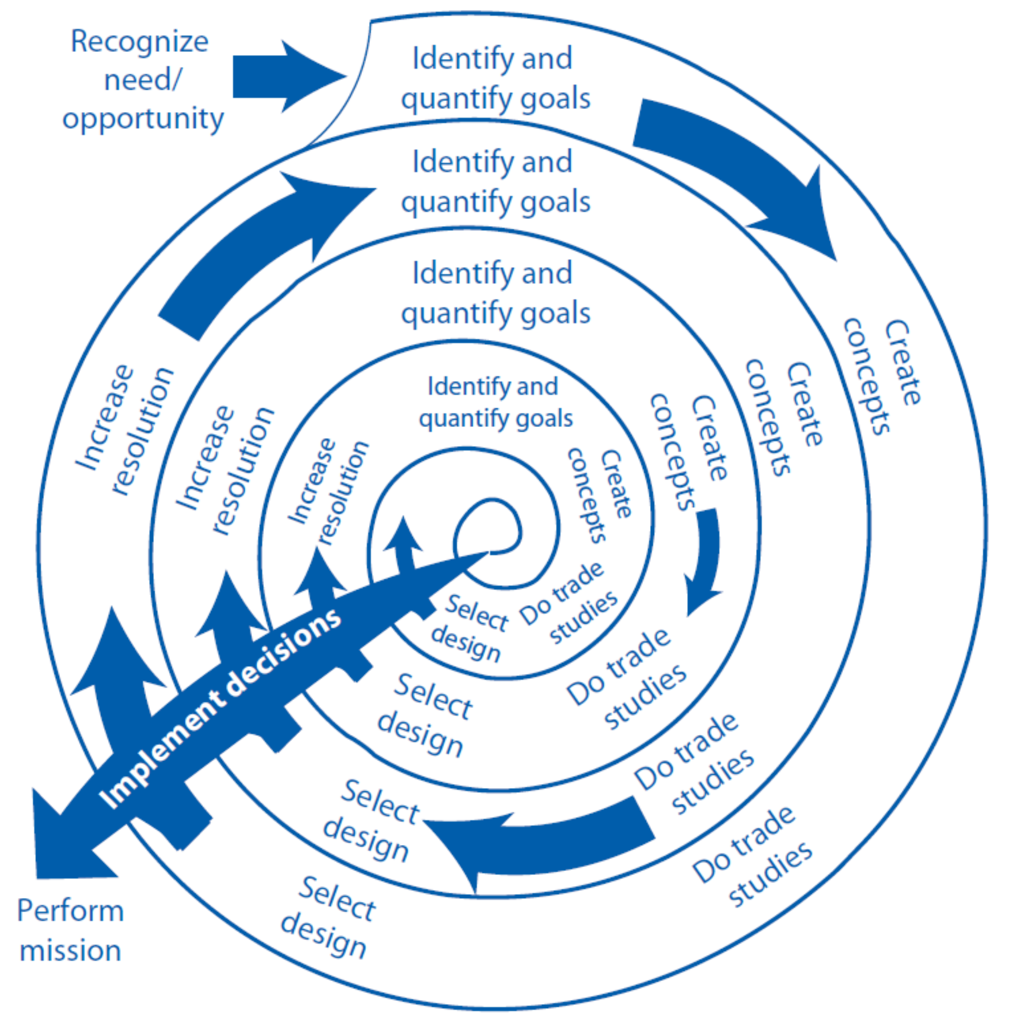


Figure 4.4-2 The doctrine of successive refinement

Figure Credit: NASA SP 6015 NASA Systems Engineering Handbook

NASA's Design Phases

Pre-Phase A
- What does my customer want?
- What are the possibilities?

Phase A
- Have I included all stakeholders?
- What's the best approach?

Phase B
- What does it really look like?

Phase C
- What are the piece parts and the final design?

Phase D
- Put it all together and ensure it works

Phase E
- Use it!!

Phase F
- The mission is done

	Phase	Purpose	Typical Output
Formulation	Pre-Phase A Concept Studies	To produce a broad spectrum of ideas and alternatives for missions from which new programs/projects can be selected. Determine feasibility of desired system, develop mission concepts, draft system-level requirements, identify potential technology needs.	Feasible system concepts in the form of simulations, analysis, study reports, models, and mockups
Formulation	Phase A Concept and Technology Development	To determine the feasibility and desirability of a suggested new major system and establish an initial baseline compatibility with NASA's strategic plans. Develop final mission concept, system-level requirements, and needed system structure technology developments.	System concept definition in the form of simulations, analysis, engineering models, and mockups and trade study definition
Formulation	Phase B Preliminary Design and Technology Completion	To define the project in enough detail to establish an initial baseline capable of meeting mission needs. Develop system structure end product (and enabling product) requirements and generate a preliminary design for each system structure end product.	End products in the form of mockups, trade study results, specification and interface documents, and prototypes
Implementation	Phase C Final Design and Fabrication	To complete the detailed design of the system (and its associated subsystems, including its operations systems), fabricate hardware, and code software. Generate final designs for each system structure end product.	End product detailed designs, end product component fabrication, and software development
Implementation	Phase D System Assembly, Integration and Test, Launch	To assemble and integrate the products to create the system, meanwhile developing confidence that it will be able to meet the system requirements. Launch and prepare for operations. Perform system end product implementation, assembly, integration and test, and transition to use.	Operations-ready system end product with supporting related enabling products
Implementation	Phase E Operations and Sustainment	To conduct the mission and meet the initially identified need and maintain support for that need. Implement the mission operations plan.	Desired system
Implementation	Phase F Closeout	To implement the systems decommissioning/disposal plan developed in Phase E and perform analyses of the returned data and any returned samples.	Product closeout

Figure Credit: NASA SP 6015 NASA Systems Engineering Handbook

The Vision

What

When

Where

Range of detail

A Bold Vision for Space Exploration, Authorized by Congress

- Complete the International Space Station
- Safely fly the Space Shuttle until 2010
- Develop and fly the Crew Exploration Vehicle (Orion) no later than 2014
- Return to the Moon no later than 2020
- Extend human presence across the solar system and beyond
- Implement a sustained and affordable human and robotic program
- Develop supporting innovative technologies, knowledge, and infrastructures
- Promote international and commercial participation in exploration

First Steps in Defining a Program or Project

Establish Needs, Goals, Objectives & Constraints

Needs – What we want to do: our Mission

Goals – Strategies for accomplishing

Objectives – Tactics for accomplishing the goal

Constraints – The boundaries (cost, schedule, political, etc.)

Illustration by Pat Rawlings © NASA

Transforming the Vision into a Mission Statement

Advance US scientific, security and economic interests through a robust space exploration program

- Expand human presence across the Solar System
- Conduct advanced searches for Earth like planets and habitable environments around other stars
- Promote intra-agency, international, commercial and public participation in exploration to further US scientific, security and economic interests

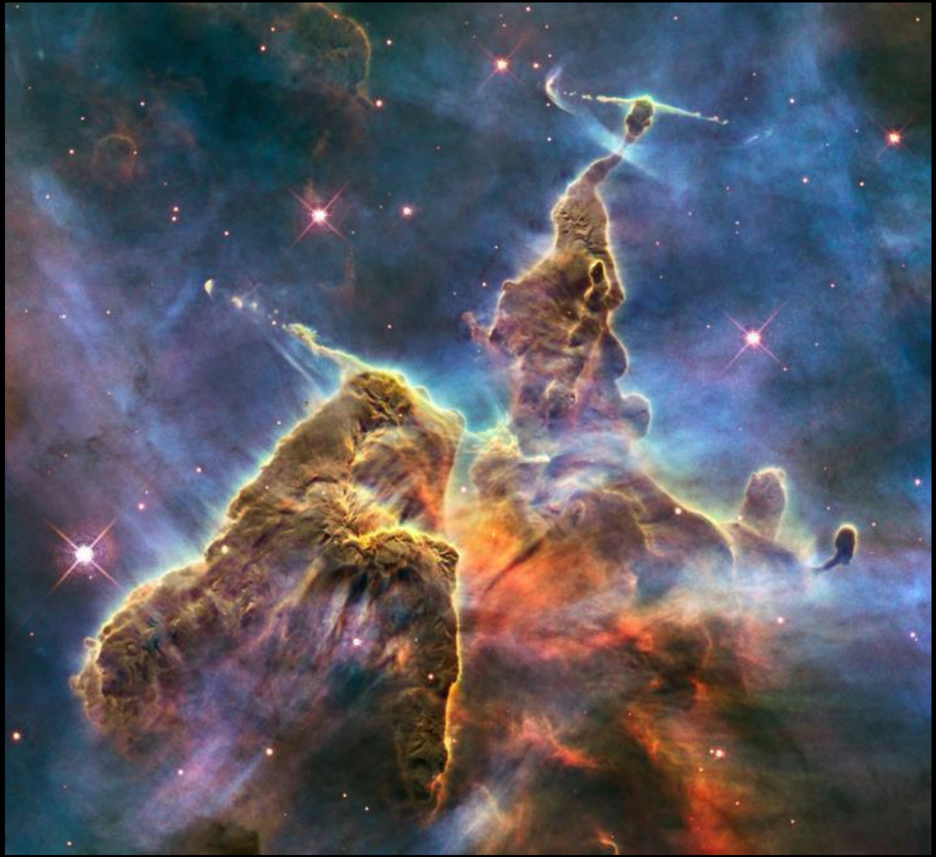


Illustration by Pat Rawlings © NASA

Teasing out the Specifics

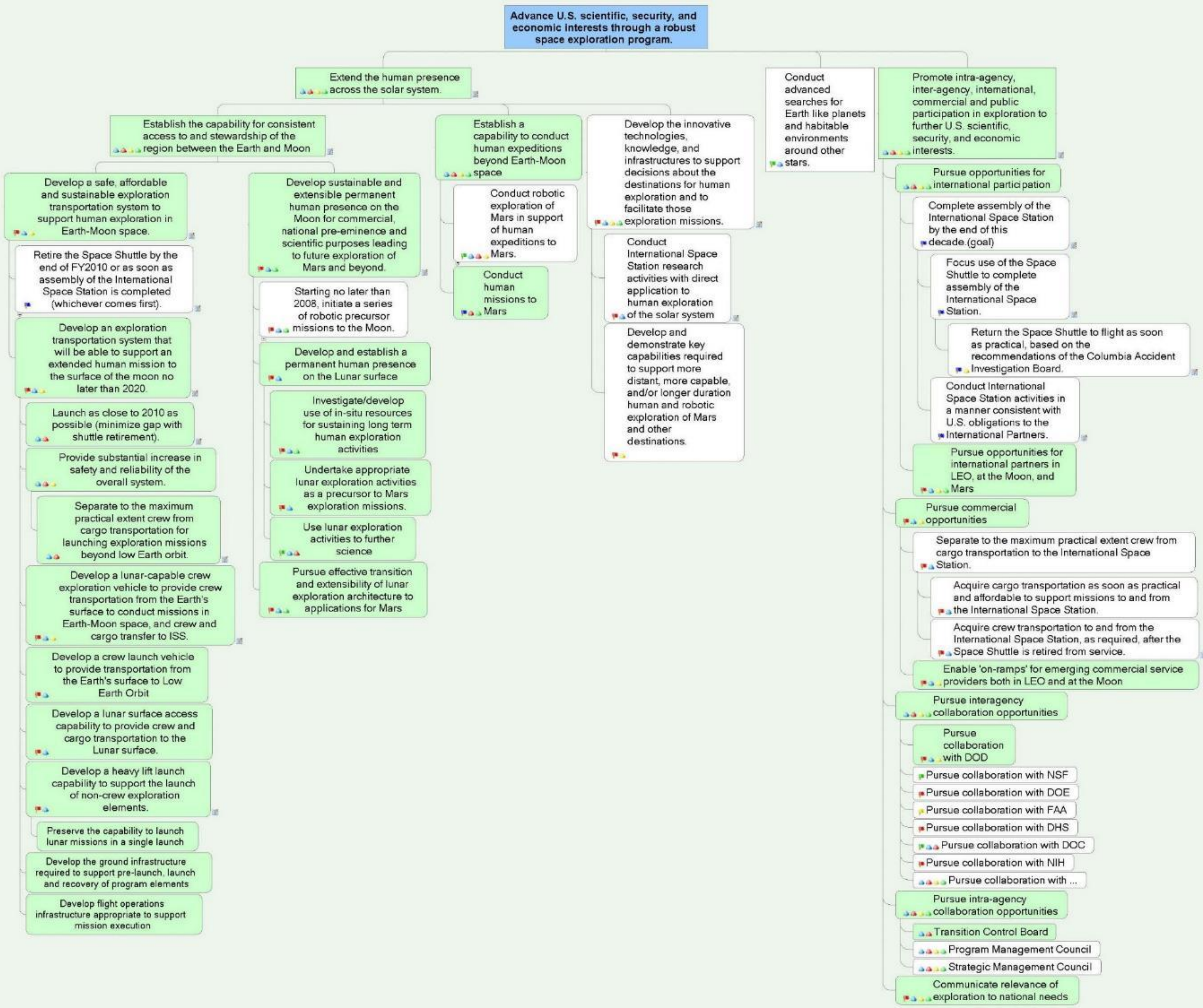
Driving requirements are the key

Start with the Mission Statement

Break it down into logical groups

Drill down in detail

Focus on the pieces that are yours



Teasing out the Specifics

Driving requirements are the key

Start with the Mission Statement

Break it down into logical groups

Drill down in detail

Focus on the pieces that are yours

Constellation Program

Need, Goals and Objectives

8 Feb 2005 First Draft

Need Statement: Develop a safe, affordable and sustainable exploration transportation system to support human exploration of the solar system

Goals and Objectives

1 **Develop an exploration transportation system that will be able to support an extended human mission to the surface of the moon no later than 2020.**

1.1 Launch as close to 2010 as possible (minimize gap with shuttle retirement).

1.2 Provide a substantial increase in safety and reliability of the overall system.

1.2.1 Separate to the maximum practical extent crew from cargo transportation for launching exploration missions beyond low Earth orbit.

1.2.2 Provide a substantial increase in safety and reliability of the launch and landing phases of mission operations.

2 **Develop a lunar-capable crew exploration vehicle to provide crew transportation from the Earth's surface to conduct missions in Earth-Moon space, and crew and cargo transfer to ISS.**

3 **Develop a crew launch vehicle to provide transportation from the Earth's surface to Low Earth Orbit**

4 **Develop a lunar surface access capability to provide crew and cargo transportation to the Lunar surface.**

5 **Develop a heavy lift launch capability to support the launch of non-crew exploration elements.**

5.1 Preserve the capability to launch lunar missions in a single launch

6 **Develop the ground infrastructure required to support pre-launch, launch and recovery of program elements**

7 **Develop flight operations infrastructure appropriate to support mission execution**

8 **Make systems sustainable and maintainable**

8.1 Provide documentation of sufficient detail to perform upgrades, replacements

8.2 Provide demonstrable progress (e.g. flight tests, demos, accumulation of infrastructure and capability)

8.3 Effectively utilize all 10 NASA center resources and workforce

8.4 Effectively communicate the benefits of exploration to the public and key stakeholders

8.5 Minimize the operations and maintenance burden during mission execution

9 **Make systems affordable**

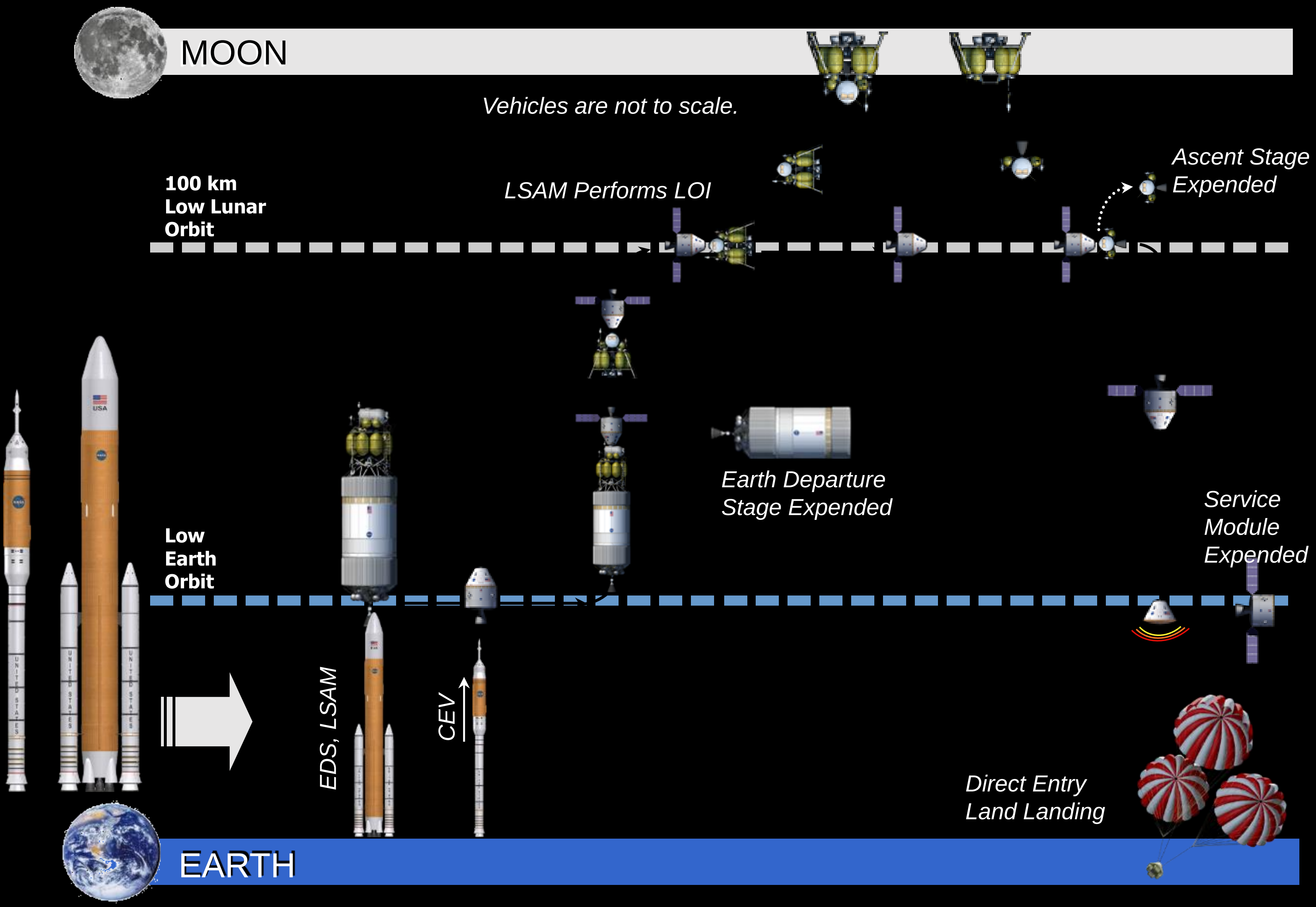
9.1 Design for simplicity and robustness

9.2 Provide early and constant attention to lifecycle costs

9.3 Use existing technology to reduce schedule risk as feasible

DRMs and Ops Cons (aka ConOps)

- Needed to round out the program/project assumptions
- DRMs provide the top level design concept
- Help identify the major functions and elements required to execute the mission
- Determine many of the constraints
- Operational Concepts then define the specifics



DRMs and Ops Cons (aka ConOps)

Needed to round out the program/project assumptions

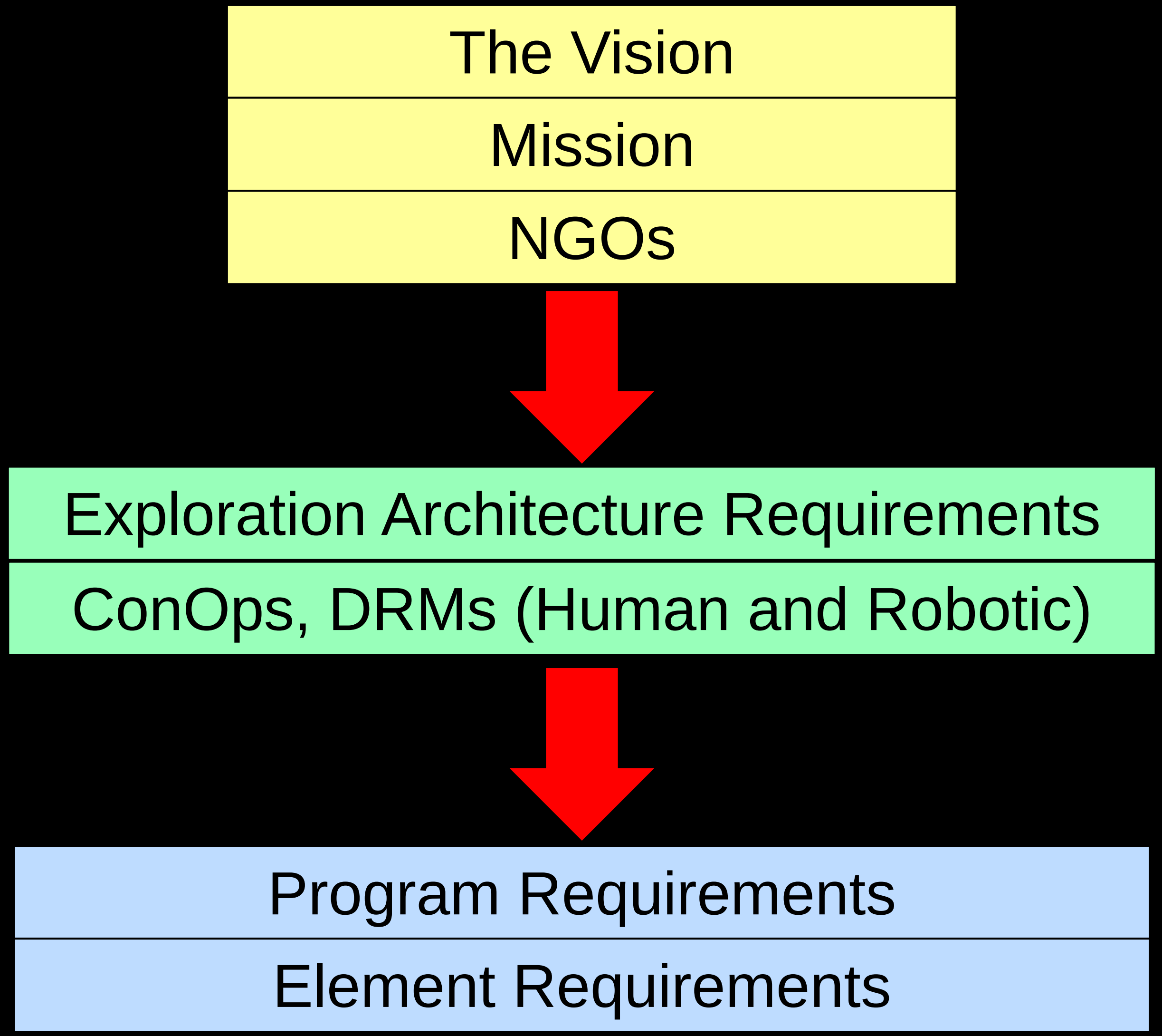
DRMs provide the top level design concept

Help identify the major functions and elements required to execute the mission

Determine many of the constraints

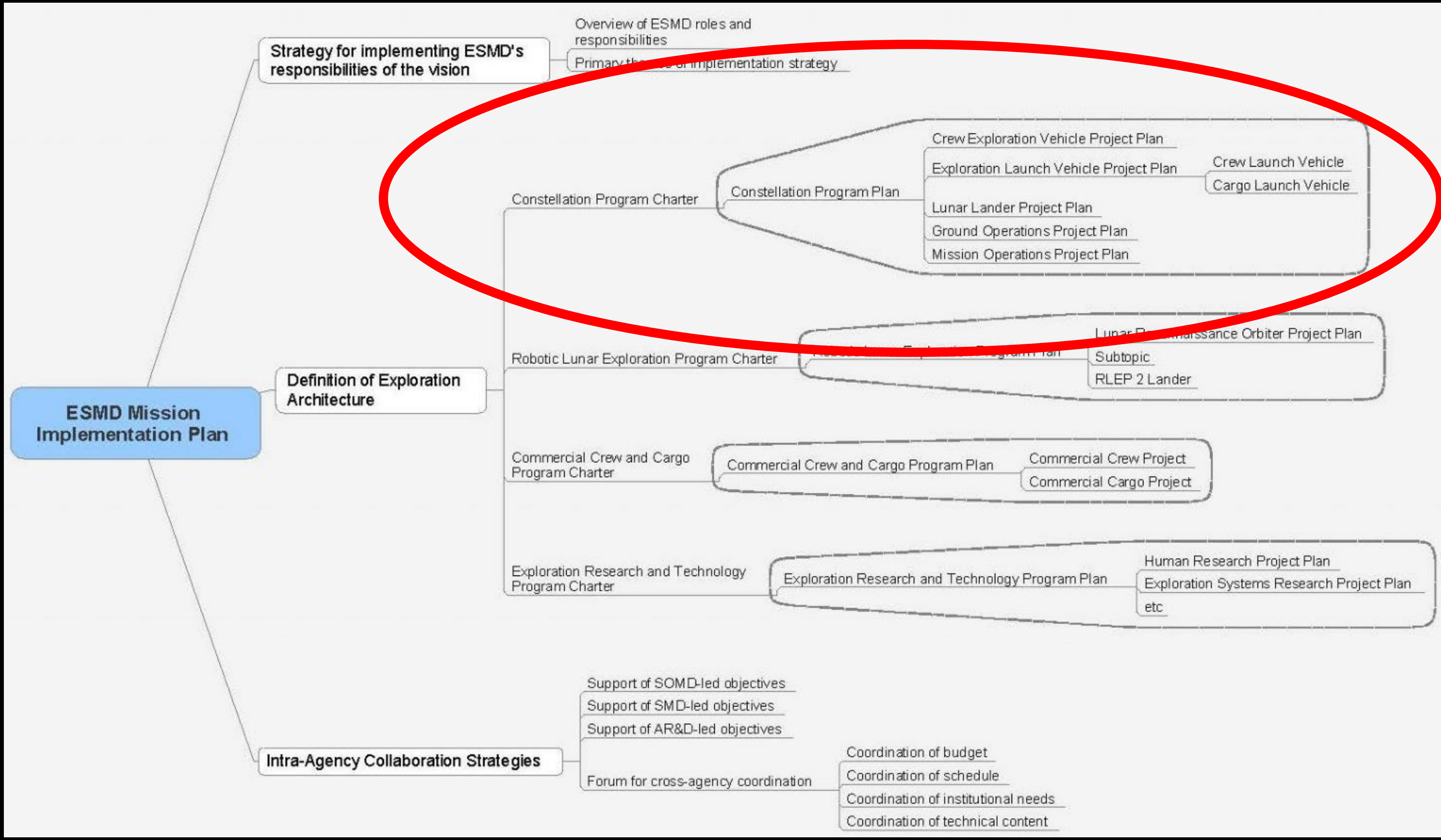
Operational Concepts then define the specifics

Requirements flow from both



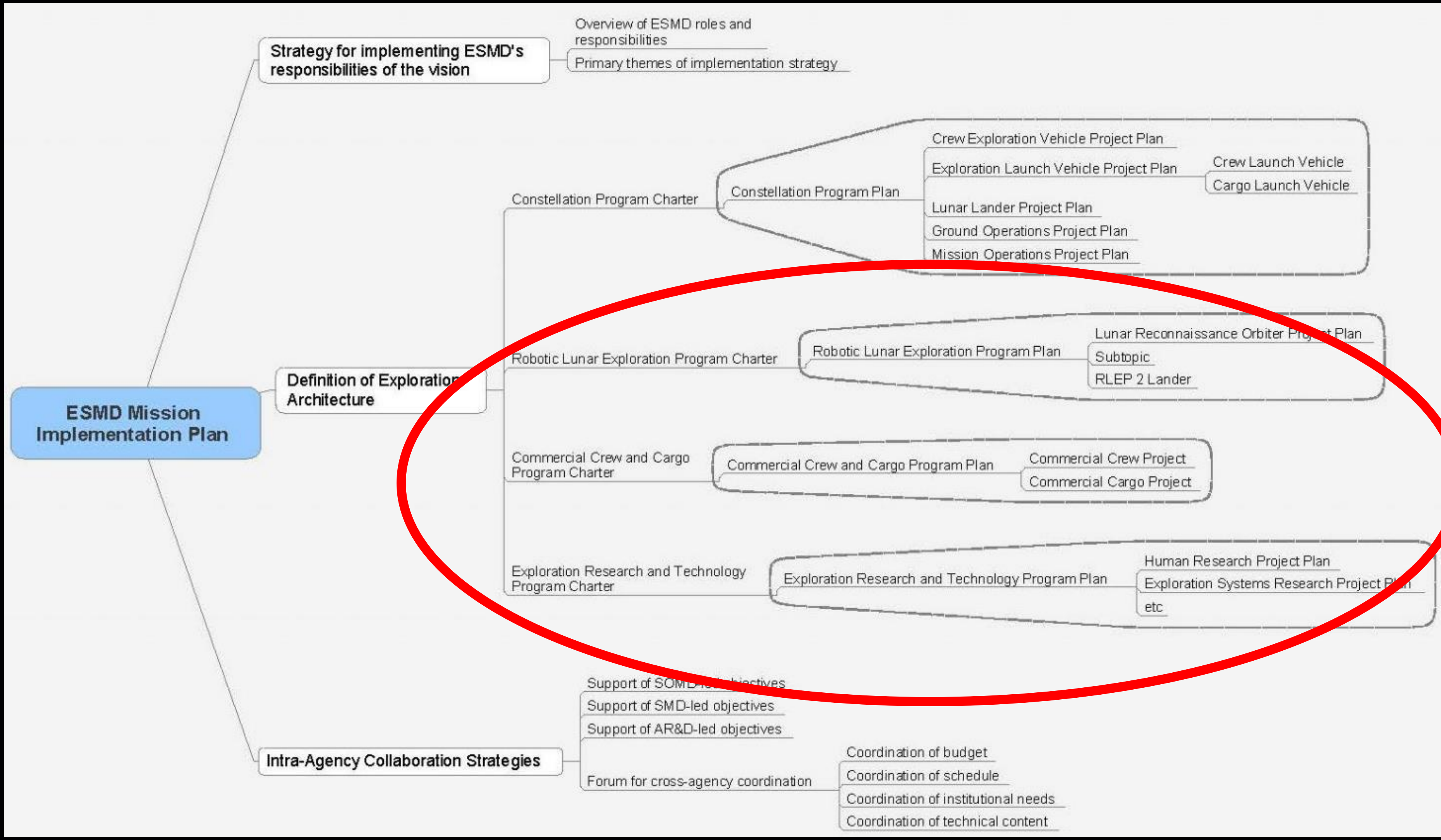
NASA Approach

- Structure to execute the Vision
- Constellation Program- one piece of a larger puzzle



NASA Approach

- Structure to execute the Vision
- Constellation Program- one piece of a larger puzzle
- Other programs in parallel



From NGOs to Requirements

Each level of management owns their level of requirements

The President/Administrator is Level 0

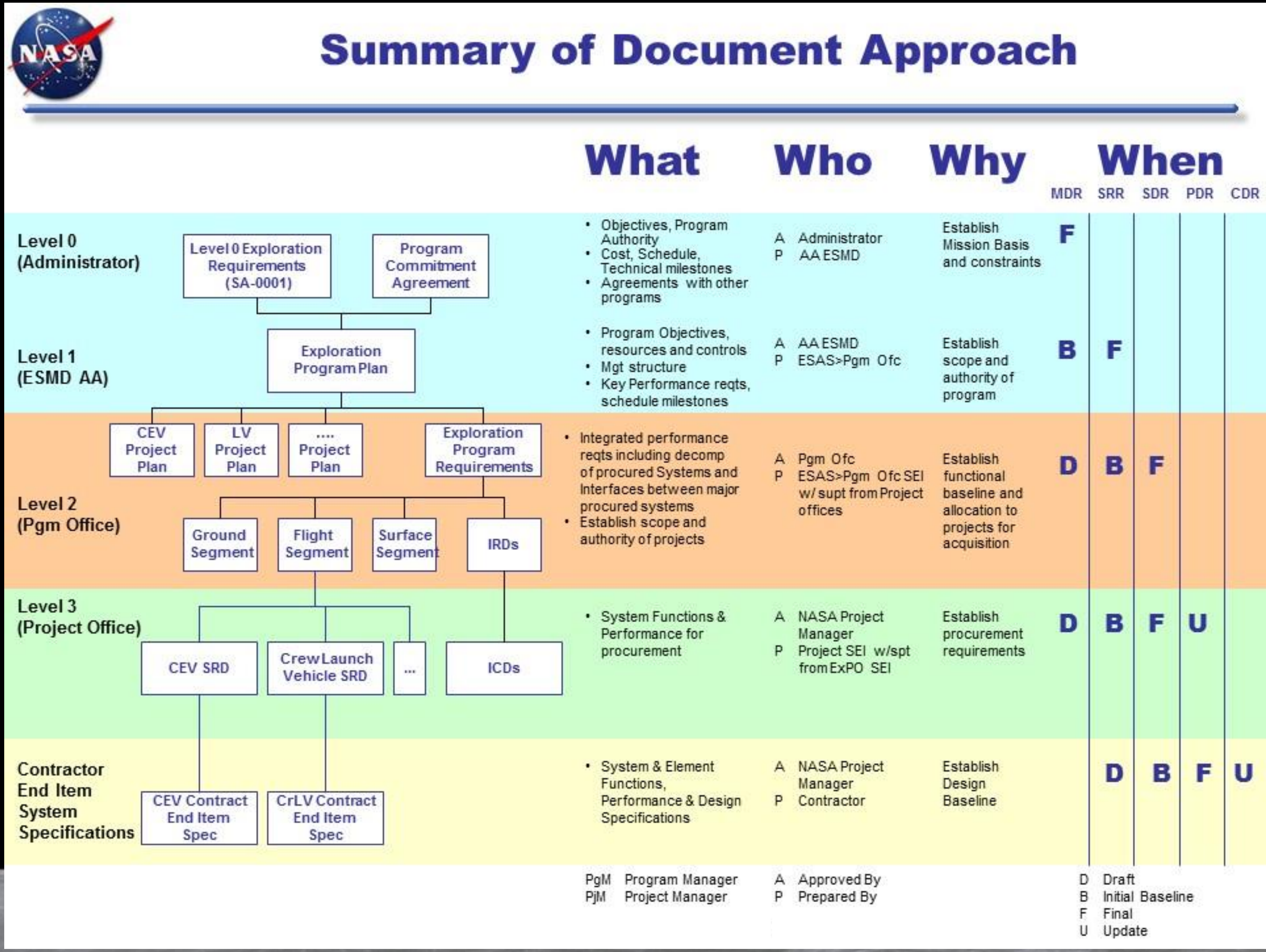
NASA HQ AA is Level 1

Program Office is Level 2

Project Office is Level 3

Contractor End Item Specs

- Translate NASA requirements into something that can be built



Level O/1 Requirements

Top level, sweeping requirements

Agency controlled detailed requirements

TABLE 4-1 – EXPLORATION MISSION RELIABILITY

Mission	Loss of Mission (LOM)	Loss of Crew (LOC)	Earth Ascent Loss of Crew (LOC)	Earth Entry Loss of Crew (LOC)
ISS	1/55	1/270	1/1000	1/1000
Lunar Sortie	1/20	1/100	1/1000	1/1000
Lunar Outpost Crew	1/(TBD-EARD-016)	1/(TBD-EARD-018)	1/1000	1/1000
Lunar Outpost Cargo	1/(TBD-EARD-015)	N/A	N/A	N/A
Mars DRAFT	1/(TBD-EARD-017)	1/(TBD-EARD-019)	1/1000	1/1000

National Aeronautics and Space Administration

Directorate Integration Office

Headquarters
Washington, DC 20546

4 EXPLORATION ARCHITECTURE REQUIREMENTS

[Ex-0001] The Exploration Architecture shall deliver crew and cargo to the ISS and return them safely to Earth.

> *Rationale:* Establishes the top-level Architecture requirement for missions to safely ferry crews between the Earth and the ISS, as well as providing a capability to ferry cargo to/from the ISS. Planned implementation approaches are commercial service providers and Constellation Systems. Some cargo return may require conditioning, such as cold stowage or vacuum seal. Some cargo may need to be deployed or released. (See glossary for definition of cargo.)

[Ex-0002] The Exploration Architecture shall deliver crew and cargo to the lunar surface and return them safely to Earth.

> *Rationale:* Establishes the top-level Architecture requirement for lunar crewed mission to safely ferry crews between the Earth and the lunar surface, as well as providing a capability to ferry cargo to/from the lunar surface. Some cargo return may require conditioning, such as cold stowage or vacuum seal. (See glossary for definition of cargo.)

[Ex-0003] The Exploration Architecture shall provide the capability to establish and support a permanent habitable outpost on the lunar surface.

> *Rationale:* Required to achieve goal to "Develop the capability for a sustainable and extensible permanent human presence on the Moon for commercial, national pre-eminence and scientific purposes leading to future exploration of Mars and beyond." The specific outpost site selection criteria will be developed and documented in a separate (TBD-EARD-006) Headquarters (HQ)-controlled document, as was done during Apollo. The intent of the requirement is for the capability to place an outpost at any longitude/latitude on the lunar surface, but not necessarily in every environment such as permanently-shadowed craters and significantly-inclined slopes.

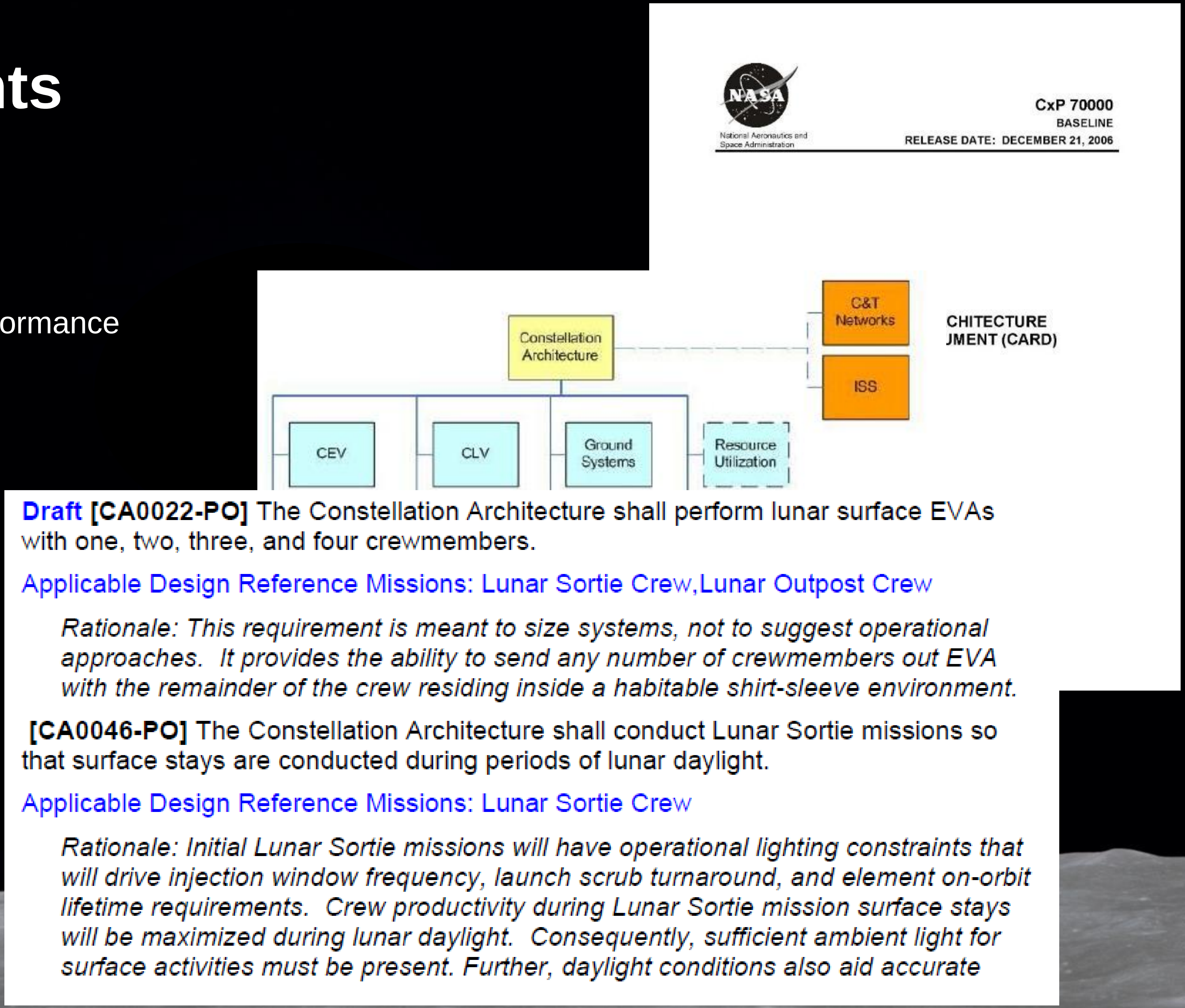
FORE USE

Level 2 Requirements

Decompose the Level 1 requirements

Define the major elements and interfaces

Define the overarching functional and performance requirements



Draft [CA0022-PO] The Constellation Architecture shall perform lunar surface EVAs with one, two, three, and four crewmembers.

Applicable Design Reference Missions: Lunar Sortie Crew,Lunar Outpost Crew

Rationale: This requirement is meant to size systems, not to suggest operational approaches. It provides the ability to send any number of crewmembers out EVA with the remainder of the crew residing inside a habitable shirt-sleeve environment.

[CA0046-PO] The Constellation Architecture shall conduct Lunar Sortie missions so that surface stays are conducted during periods of lunar daylight.

Applicable Design Reference Missions: Lunar Sortie Crew

Rationale: Initial Lunar Sortie missions will have operational lighting constraints that will drive injection window frequency, launch scrub turnaround, and element on-orbit lifetime requirements. Crew productivity during Lunar Sortie mission surface stays will be maximized during lunar daylight. Consequently, sufficient ambient light for surface activities must be present. Further, daylight conditions also aid accurate

Level 2 Requirements

Decompose the Level 1 requirements

Define the major elements and interfaces

Define the overarching functional and performance requirements

Enough detail to be able to allocate requirements to Level 3 elements

[CA0056-PO] Orion shall return the crew and cargo from Lunar Rendezvous Orbit (LRO) to the Earth surface.

Applicable Design Reference Missions: Lunar Sortie Crew,Lunar Outpost Cargo,Lunar Outpost Crew

> *Rationale: CxP 70007, Constellation Design Reference Missions and Operational Concepts, indicates that Orion is the Constellation system that will return the crew and cargo to the Earth surface. Orion includes the propulsion system and propellant to perform the TEI from LRO and any subsequent trajectory correction maneuvers. Orion includes the heat shield needed for reentering the Earth's atmosphere and the landing systems needed for return to the Earth surface.*

[CA5312-PO] Orion shall deliver the crew and cargo from the Earth surface to the ISS.

Applicable Design Reference Missions: ISS Crew

> *Rationale: The requirement is consistent with CxP 70007, Constellation Design Reference Missions and Operational Concepts, which indicates that Orion is the Constellation System designated to deliver the crew and cargo to the ISS. Orion design must provide for safe launch, free flight, rendezvous, proximity operations, docking and other joint operations with the ISS. Orion is required to provide a capability to deliver active and passive cargoes in the pressurized cabin environment and the unpressurized section. The amount of either type of cargo will be determined on a per mission basis. For unpressurized cargo, the ISS Control Moment Gyroscope (CMG) is the benchmark for mass, volume, dimensions, and delivery capability.*

Level 3 Requirements

Rinse and repeat

Focus is on enabling a contract

Detail depends on contracting approach

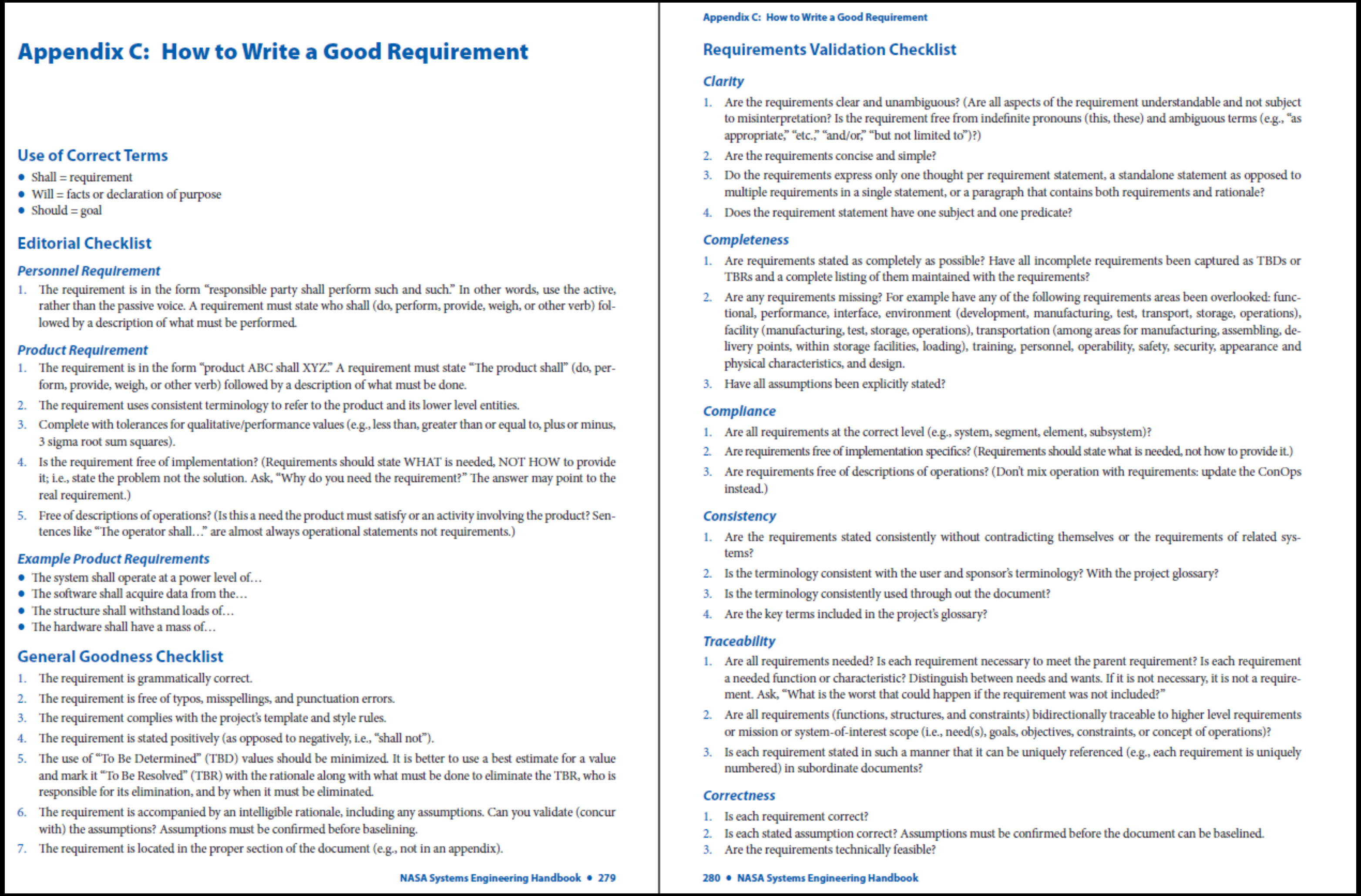
Orion – standard government contract

Commercial Crew – higher level

CV0077	**Orion Hatch - EVA Crew Ingress**
	The Orion shall provide a hatch sized for egress and ingress by pressurized suited EVA crew per the Orion to EVA IRD, CxP 70033, Constellation Program Orion To Extravehicular Activity Systems Interface Requirements Document.
	Rationale: This capability is required for the contingency EVAs. Crew may be in surface suits or launch/entry/abort/contingency EVA suits. The suit architecture is still being defined. (CA3166)
CV0303	**Maximum Design Pressure**
	The Orion crew module maximum design pressure (MDP) shall be 107.2 kPa (15.55 psid).
	Rationale: This provides a test and design-to number for the Orion crew module pressure vessel. The Orion will maintain the internal-to-external pressure less than the MDP, including transient pressure excursions. (Derived project requirement)
CV0315	**LIDS Interface**
	The Orion shall dock using the Low Impact Docking System (LIDS).
	Rationale: The LIDS mechanism was selected by the ESAS team as mating mechanism for Constellation elements for the lunar mission. This decision was based on many considerations including levels of size, fault tolerance, and ability to dock or berth. The LIDS mechanism will be provided as Government Furnished Equipment. (CA0316)

Writing “Good” Requirements

Systems Engineering Handbook
Appendix C



Appendix C: How to Write a Good Requirement

Use of Correct Terms

- Shall = requirement
- Will = facts or declaration of purpose
- Should = goal

Editorial Checklist

Personnel Requirement

1. The requirement is in the form “responsible party shall perform such and such.” In other words, use the active, rather than the passive voice. A requirement must state who shall (do, perform, provide, weigh, or other verb) followed by a description of what must be performed.

Product Requirement

1. The requirement is in the form “product ABC shall XYZ.” A requirement must state “The product shall” (do, perform, provide, weigh, or other verb) followed by a description of what must be done.
2. The requirement uses consistent terminology to refer to the product and its lower level entities.
3. Complete with tolerances for qualitative/performance values (e.g., less than, greater than or equal to, plus or minus, 3 sigma root sum squares).
4. Is the requirement free of implementation? (Requirements should state WHAT is needed, NOT HOW to provide it; i.e., state the problem not the solution. Ask, “Why do you need the requirement?” The answer may point to the real requirement.)
5. Free of descriptions of operations? (Is this a need the product must satisfy or an activity involving the product? Sentences like “The operator shall…” are almost always operational statements not requirements.)

Example Product Requirements

- The system shall operate at a power level of…
- The software shall acquire data from the…
- The structure shall withstand loads of…
- The hardware shall have a mass of…

General Goodness Checklist

1. The requirement is grammatically correct.
2. The requirement is free of typos, misspellings, and punctuation errors.
3. The requirement complies with the project’s template and style rules.
4. The requirement is stated positively (as opposed to negatively, i.e., “shall not”).
5. The use of “To Be Determined” (TBD) values should be minimized. It is better to use a best estimate for a value and mark it “To Be Resolved” (TBR) with the rationale along with what must be done to eliminate the TBR, who is responsible for its elimination, and by when it must be eliminated.
6. The requirement is accompanied by an intelligible rationale, including any assumptions. Can you validate (concur with) the assumptions? Assumptions must be confirmed before baselining.
7. The requirement is located in the proper section of the document (e.g., not in an appendix).

Requirements Validation Checklist

Clarity

1. Are the requirements clear and unambiguous? (Are all aspects of the requirement understandable and not subject to misinterpretation? Is the requirement free from indefinite pronouns (this, these) and ambiguous terms (e.g., “as appropriate,” “etc.,” “and/or,” “but not limited to”)?)
2. Are the requirements concise and simple?
3. Do the requirements express only one thought per requirement statement, a standalone statement as opposed to multiple requirements in a single statement, or a paragraph that contains both requirements and rationale?
4. Does the requirement statement have one subject and one predicate?

Completeness

1. Are requirements stated as completely as possible? Have all incomplete requirements been captured as TBDs or TBRs and a complete listing of them maintained with the requirements?
2. Are any requirements missing? For example have any of the following requirements areas been overlooked: functional, performance, interface, environment (development, manufacturing, test, transport, storage, operations), facility (manufacturing, test, storage, operations), transportation (among areas for manufacturing, assembling, delivery points, within storage facilities, loading), training, personnel, operability, safety, security, appearance and physical characteristics, and design.
3. Have all assumptions been explicitly stated?

Compliance

1. Are all requirements at the correct level (e.g., system, segment, element, subsystem)?
2. Are requirements free of implementation specifics? (Requirements should state what is needed, not how to provide it.)
3. Are requirements free of descriptions of operations? (Don’t mix operation with requirements: update the ConOps instead.)

Consistency

1. Are the requirements stated consistently without contradicting themselves or the requirements of related systems?
2. Is the terminology consistent with the user and sponsor’s terminology? With the project glossary?
3. Is the terminology consistently used through out the document?
4. Are the key terms included in the project’s glossary?

Traceability

1. Are all requirements needed? Is each requirement necessary to meet the parent requirement? Is each requirement a needed function or characteristic? Distinguish between needs and wants. If it is not necessary, it is not a requirement. Ask, “What is the worst that could happen if the requirement was not included?”
2. Are all requirements (functions, structures, and constraints) bidirectionally traceable to higher level requirements or mission or system-of-interest scope (i.e., need(s), goals, objectives, constraints, or concept of operations)?
3. Is each requirement stated in such a manner that it can be uniquely referenced (e.g., each requirement is uniquely numbered) in subordinate documents?

Correctness

1. Is each requirement correct?
2. Is each stated assumption correct? Assumptions must be confirmed before the document can be baselined.
3. Are the requirements technically feasible?

NASA SP 6015 NASA Systems Engineering Handbook

Outline

The Ups and Downs of Presidential Administrations

How This Translates into Program Planning

A Brief Primer on Writing Requirements

A Definition

re·quire·ment

[rəˈkwī(ə)rmənt]

NOUN

a thing that is needed or wanted:

"choose the type of window that suits your requirements best"

a thing that is compulsory; a necessary condition:

"applicants must satisfy the normal entry requirements“

How NASA Uses Requirements

- Policy Documents
  - Process
- Statements of Work
  - Tasks
- Program/Project Documents
  - Define what the govt wants
- Standards
  - Best practice
- End Item Specifications
  - Used to build hardware/software

Terminology

- Shall = requirement – binding
- Will = facts or declaration of purpose
- Should = goal – not mandatory

Characteristics

- Must be VERIFIABLE
  - The provider can show concrete evidence that the requirement has been met
- Is Clear
  - One thought
  - Unambiguous
- Stated Positively
  - Shall vs shall not

Exercise

The lander shall provide adequate design margin to accommodate a range of conditions.

The rover shall carry up to 6 crew.

The docking hatch shall be sized to sufficiently accommodate large crewmembers unless otherwise authorized.

- **What’s Wrong?**