Continuous Risk Management and Its Impact on Constellation's Ares 1-X Simulator Rocket Development: 2009 Launch

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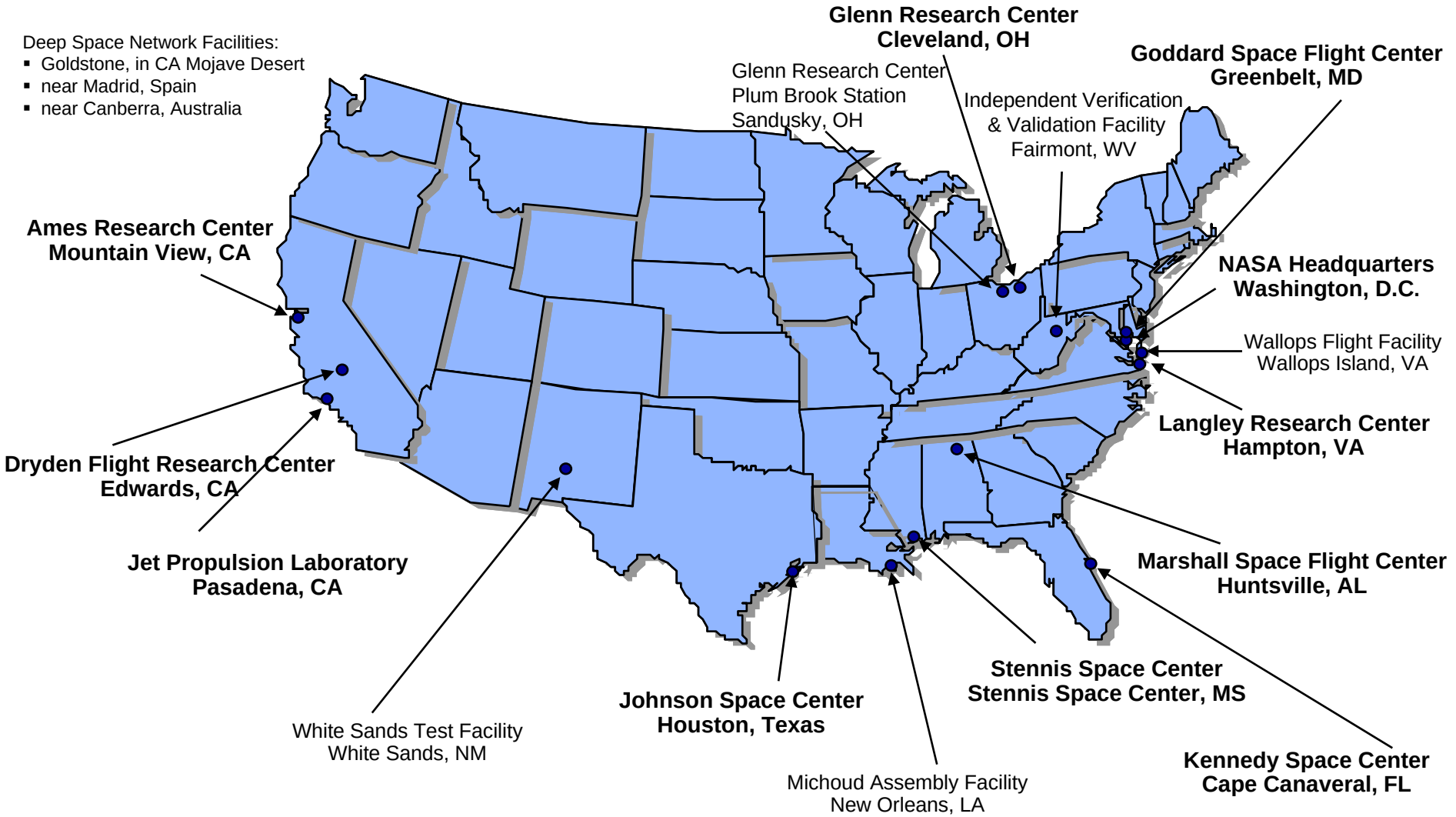
Frank Robinson
NASA Glenn Research Center
Cleveland, Ohio (USA)
frank.robinson-1@nasa.gov

NASA Mission

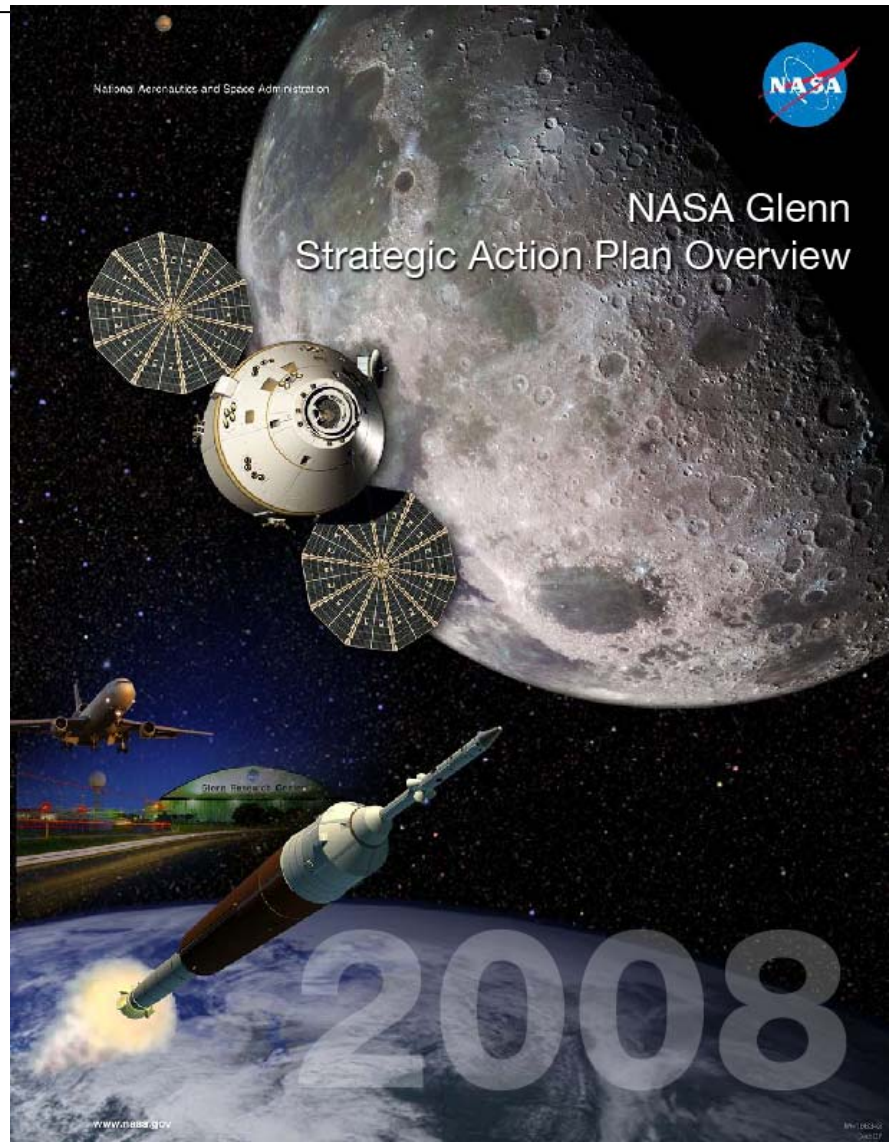
To Pioneer the Future in Space Exploration, Scientific Discovery, and Aeronautics Research

NASA Centers and Installations



Glenn Research Center Goals

- **Be Valued as a Leader in Space Flight Systems Development**
- **Be Known for Excellence in Project Management**
- **Excel in Aeronautics and Space Research**
- **Become an Integral Part of the Ohio Community and the Nation**



The President's Vision

On January 14, 2004, speaking from NASA Headquarters, the President outlined his space exploration vision to the nation.

Objectives:

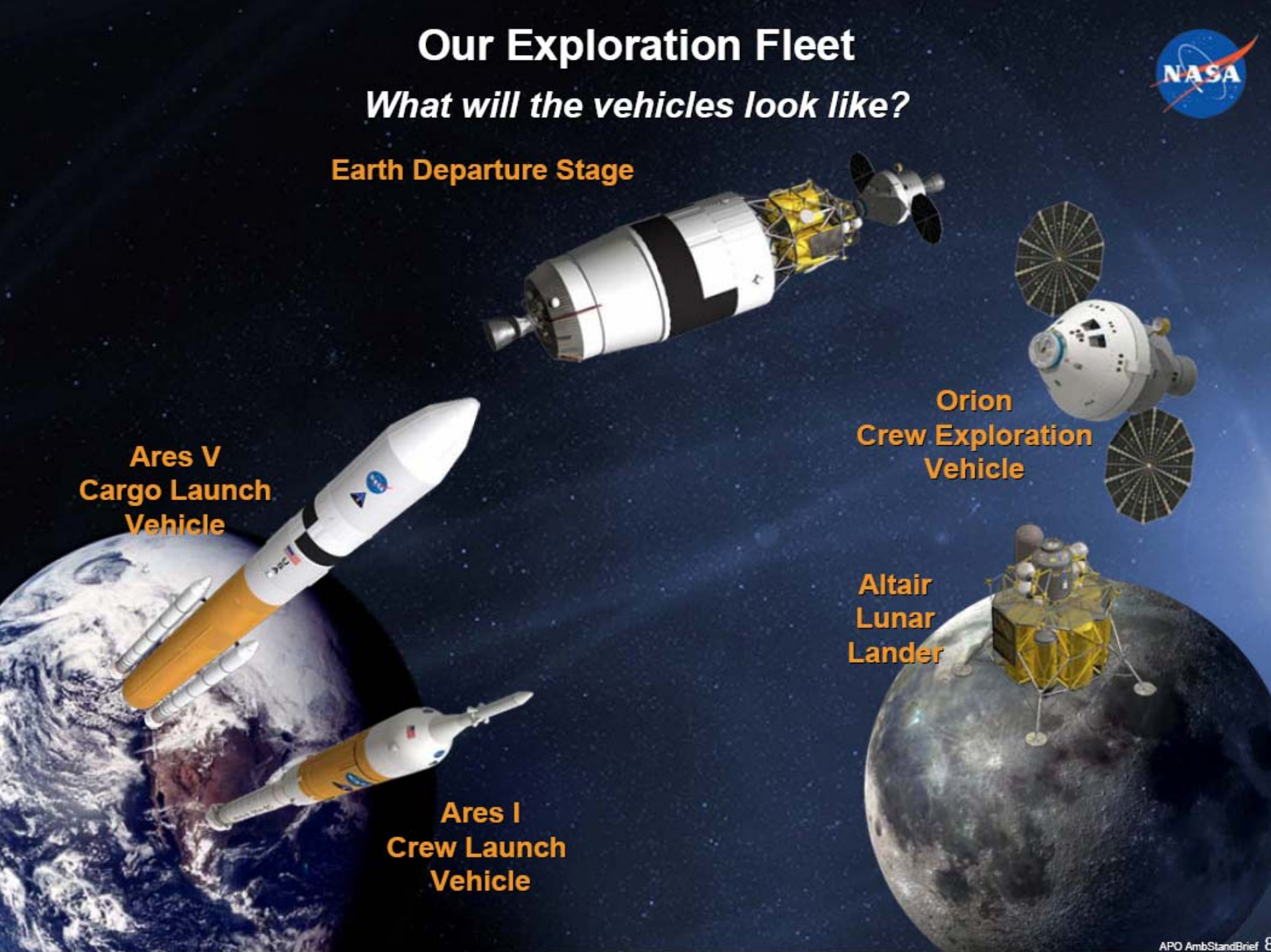
1. Return the Shuttle to flight
2. Complete ISS and retire Shuttle by 2010
3. Create a new crew vehicle for use beyond Low Earth Orbit (LEO)
4. Re-establish human presence outside Low Earth Orbit by sending both robotic and human missions to the moon by 2020
5. Continue on to Mars…and beyond

"We do not know where this journey will end, yet we know this: Human beings are headed into the cosmos."

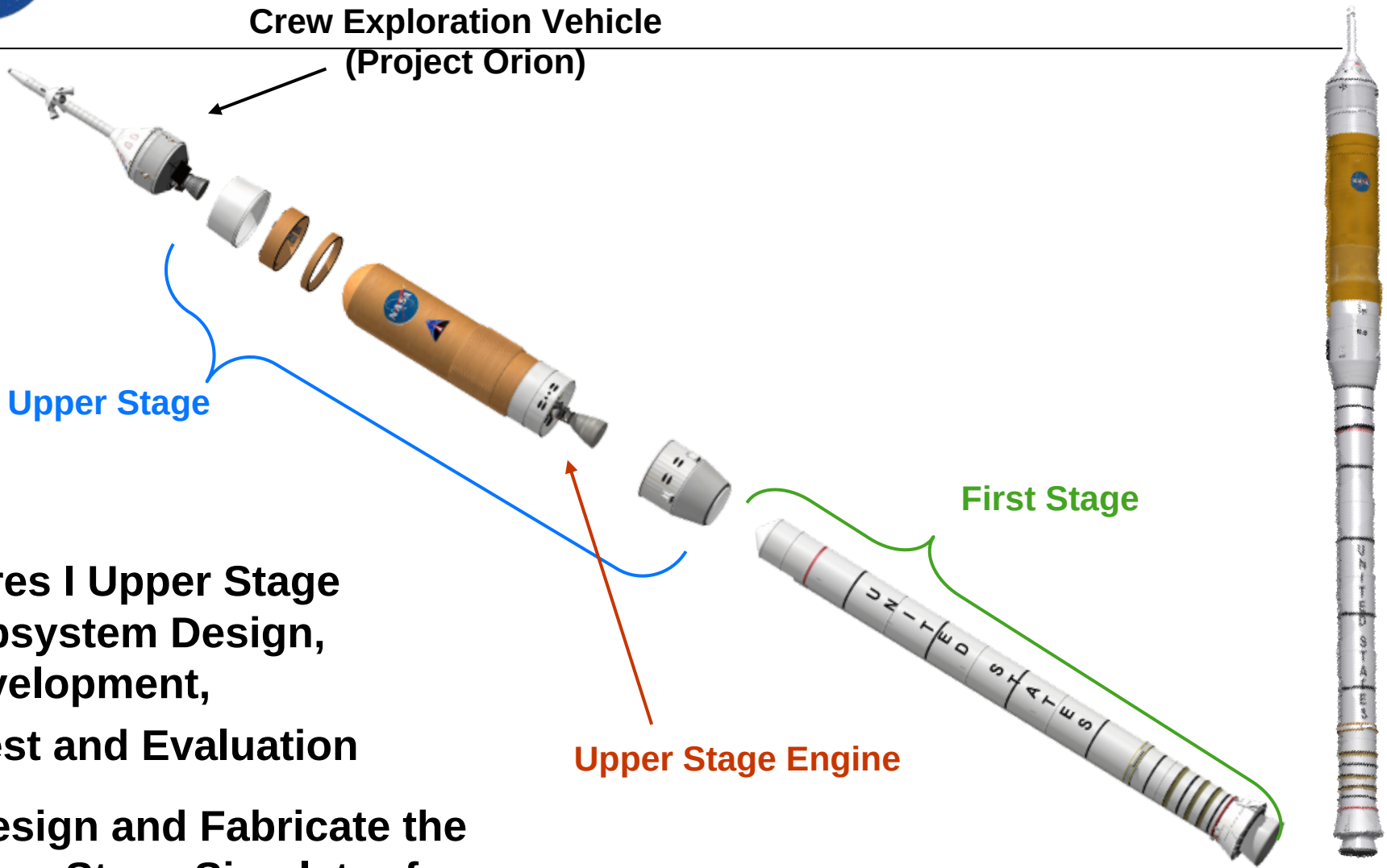
--President George W. Bush

Our Exploration Fleet

What will the vehicles look like?



Ares I Elements



- **Ares I Upper Stage Subsystem Design, Development,**

  Test and Evaluation

- **Design and Fabricate the Upper Stage Simulator for Ares I-X**

Ares I–X Test Flight

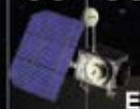
- **Demonstrate and collect key data to inform the Ares I design:**
  - Vehicle integration, assembly, and launch operations
  - Staging/separation
  - Roll and overall vehicle control
  - Aerodynamics and vehicle loads
  - First stage entry dynamics for recovery

- **Performance Data:**

	Ares I–X	Ares I
First Stage Max. Thrust (vacuum):	14.1M N (3.13M lbf)	15.8M N (3.5M lbf)
Max. Speed:	Mach 4.7	Mach 5.84
Staging Altitude:	39,624 m (130,000 ft)	57,453 m (188,493 ft)
Liftoff Weight:	834k kg (1.8M lbm)	927k kg (2.0M lbm)
Length:	99.1 m (327 ft)	99 m (325 ft)
Max. Acceleration:	2.46 g	3.79 g

NASA's Exploration Roadmap

05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25…

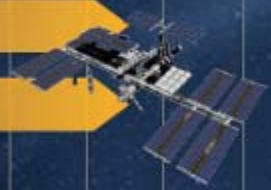


Exploration and Science Lunar Robotics Missions

Lunar Outpost Buildup

Mars Expedition ~2030

Research and Technology Development on ISS



Commercial Orbital Transportation Services for ISS

Space Shuttle Operations

SSP Transition

Ares I and Orion Development

Operations Capability Development
(EVA Systems, Ground Operations, Mission Operations)

Ares I-X Test Flight April 2009

Orion and Ares I Production and Operation

Altair Development

Ares V & Earth Departure Stage

Surface Systems Development

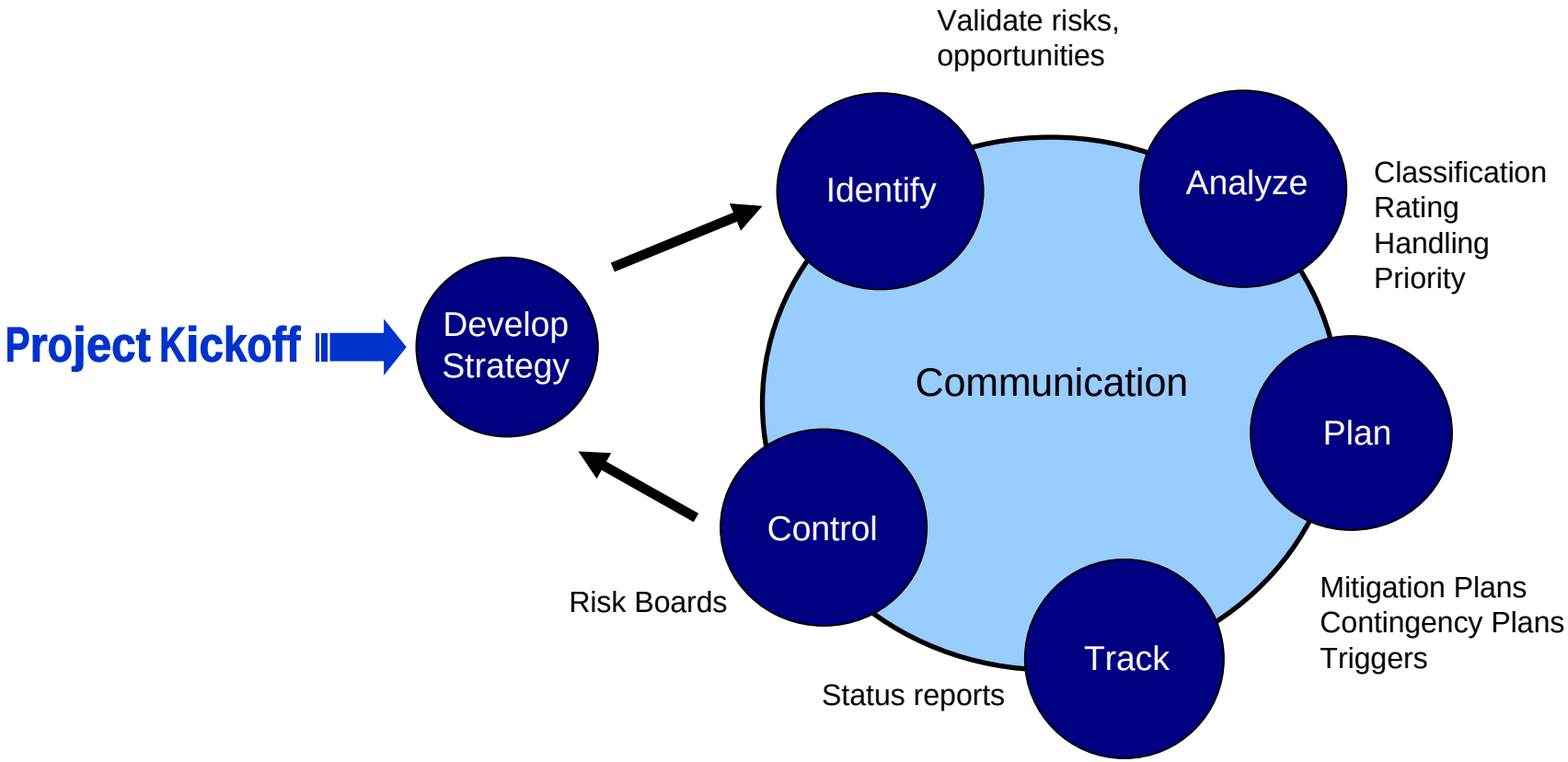
Ares 1-X Flight

CRM and Ares 1-X USS

Incorporating Continuous Risk Management into the Ares 1-X Project

(Specifically to the Upper Stage Simulator [USS])

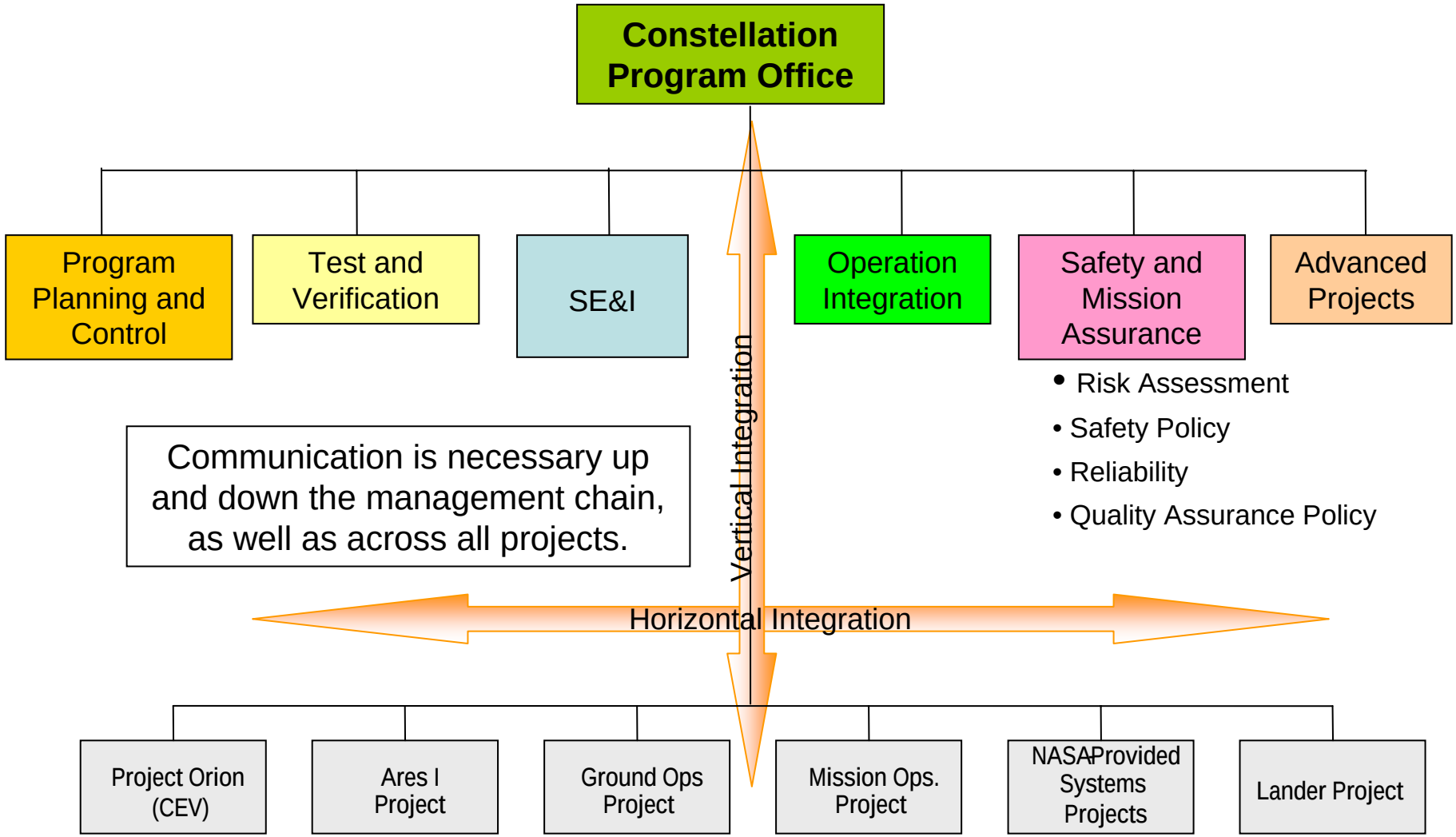
Elements of a Successful Risk Management Program
- Simple Processes -



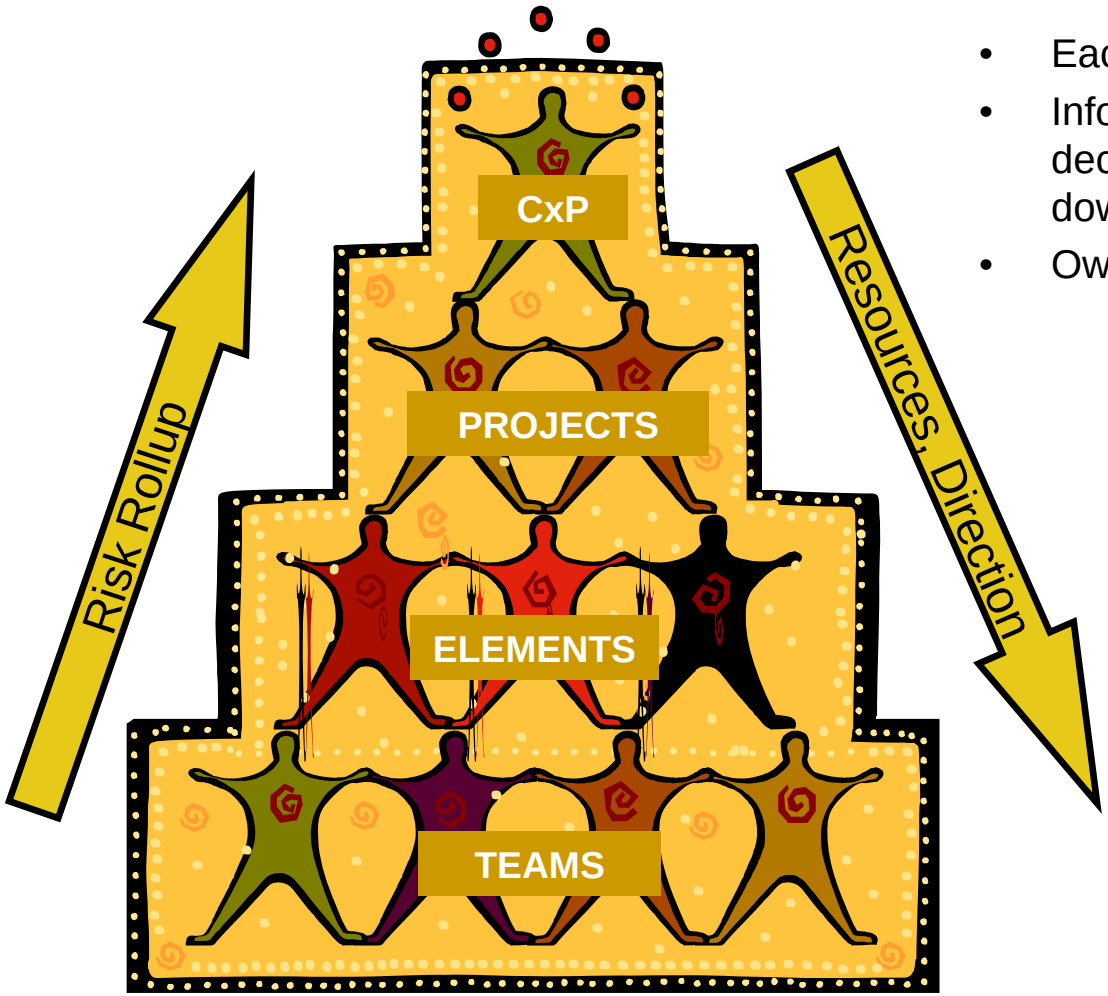
Why Formal Risk Management?

Crisis Management		Risk Management
Confusion whether risk is valid	→	Understood concern and consequence
Different understandings of “Red”	→	Common frame of reference
Ambiguous approach	→	Measurable mitigation steps
Risks are not revisited once identified	→	Vigilant risk monitoring
Blame	→	Accountability
“Shoot the Messenger”	→	Reward for good risk management
History repeats itself	→	Lessons are learned
Failures are known	→	Successes are known
Heroic efforts by a few people	→	Team approach and focus

Elements of a Successful Risk Management Program
- Communication -



Elements of a Successful Risk Management Program
- Engaged Program/Project Leadership -



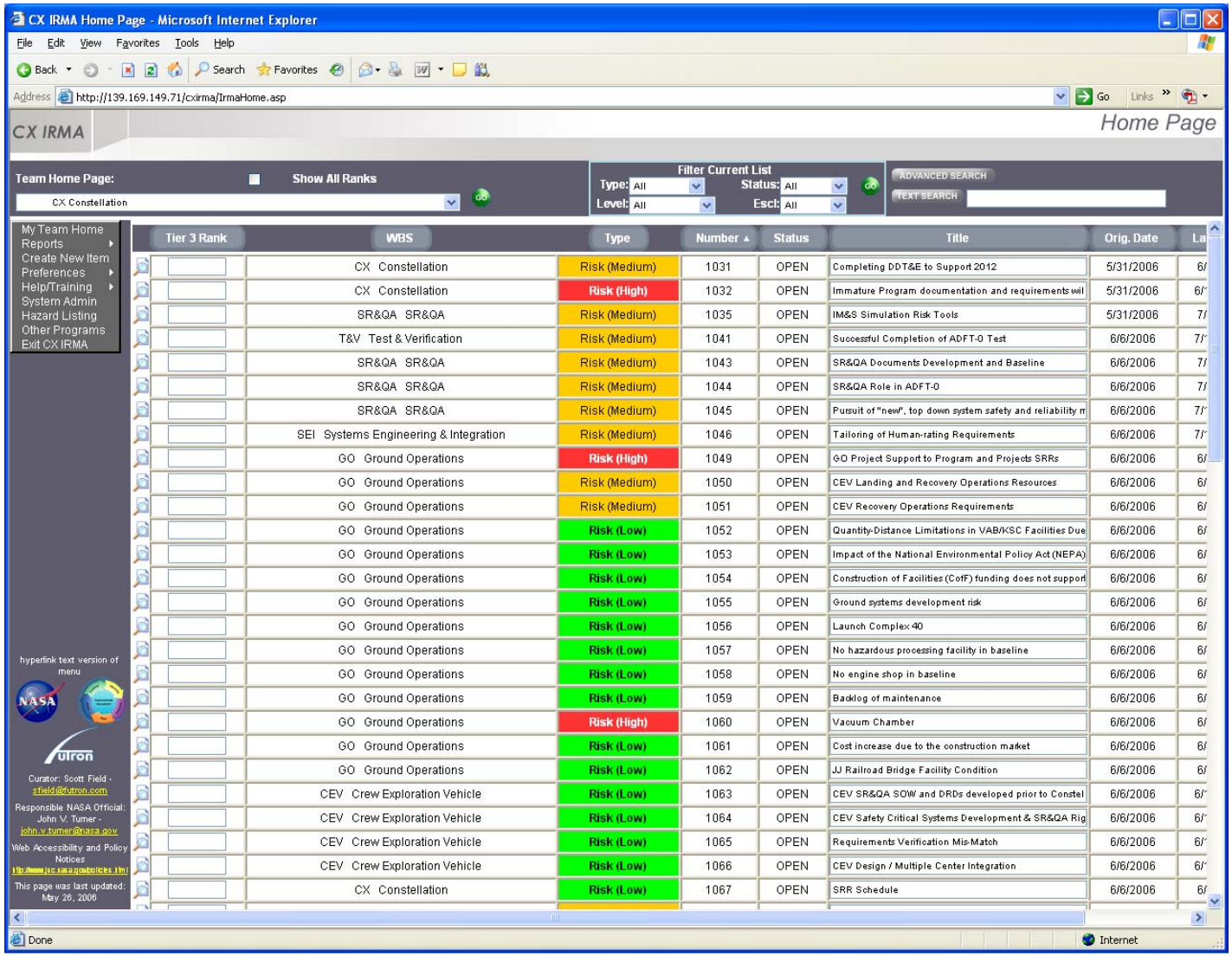
- Each layer “rolls up” to the next
- Information passes up, decisions/resources to mitigate pass down, as needed
- Ownership remains at the action level

Risk Management for USS

- Conducted in accordance with the Ares 1-X Risk Management Plan
- Risks formally discussed and dispositioned with the USS Engineering Review and Control Board (ERCB)
- Risk Facilitators participate in the Ares 1-X Risk Management Working Group (RMWG)

Strong support and interaction with USS Project Management

Elements of a Successful Risk Management Program - Understandable Tool: CxIRMA -



Tier 3 Rank	WBS	Type	Number	Status	Title	Orig. Date	La
	CX Constellation	Risk (Medium)	1031	OPEN	Completing DDT&E to Support 2012	5/31/2006	6/
	CX Constellation	Risk (High)	1032	OPEN	Immature Program documentation and requirements wil	5/31/2006	6/
	SR&QA SR&QA	Risk (Medium)	1035	OPEN	IM&S Simulation Risk Tools	5/31/2006	7/
	T&V Test & Verification	Risk (Medium)	1041	OPEN	Successful Completion of ADFT-0 Test	6/6/2006	7/
	SR&QA SR&QA	Risk (Medium)	1043	OPEN	SR&QA Documents Development and Baseline	6/6/2006	7/
	SR&QA SR&QA	Risk (Medium)	1044	OPEN	SR&QA Role in ADFT-0	6/6/2006	7/
	SR&QA SR&QA	Risk (Medium)	1045	OPEN	Pursuit of "new", top down system safety and reliability m	6/6/2006	7/
	SEI Systems Engineering & Integration	Risk (Medium)	1046	OPEN	Tailoring of Human-rating Requirements	6/6/2006	7/
	GO Ground Operations	Risk (High)	1049	OPEN	GO Project Support to Program and Projects SRRs	6/6/2006	6/
	GO Ground Operations	Risk (Medium)	1050	OPEN	CEV Landing and Recovery Operations Resources	6/6/2006	6/
	GO Ground Operations	Risk (Medium)	1051	OPEN	CEV Recovery Operations Requirements	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1052	OPEN	Quantity-Distance Limitations in VAB/KSC Facilities Due	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1053	OPEN	Impact of the National Environmental Policy Act (NEPA)	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1054	OPEN	Construction of Facilities (CofF) funding does not support	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1055	OPEN	Ground systems development risk	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1056	OPEN	Launch Complex 40	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1057	OPEN	No hazardous processing facility in baseline	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1058	OPEN	No engine shop in baseline	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1059	OPEN	Backlog of maintenance	6/6/2006	6/
	GO Ground Operations	Risk (High)	1060	OPEN	Vacuum Chamber	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1061	OPEN	Cost increase due to the construction market	6/6/2006	6/
	GO Ground Operations	Risk (Low)	1062	OPEN	JJ Railroad Bridge Facility Condition	6/6/2006	6/
	CEV Crew Exploration Vehicle	Risk (Low)	1063	OPEN	CEV SR&QA SOW and DRDs developed prior to Constel	6/6/2006	6/
	CEV Crew Exploration Vehicle	Risk (Low)	1064	OPEN	CEV Safety Critical Systems Development & SR&QA Rig	6/6/2006	6/
	CEV Crew Exploration Vehicle	Risk (Low)	1065	OPEN	Requirements Verification Mis-Match	6/6/2006	6/
	CEV Crew Exploration Vehicle	Risk (Low)	1066	OPEN	CEV Design / Multiple Center Integration	6/6/2006	6/
	CX Constellation	Risk (Low)	1067	OPEN	SRR Schedule	6/6/2006	6/

Risk USS-5

Ares I-X USS Fracture

- **Risk USS-5: Ares I-X USS Fracture -** Given that an undetected flaw larger than the Critical Initial Flaw Size (CIFS) could originate in the skin to flange weld, there is a possibility that the flaw could propagate, potentially resulting in loss of the vehicle.

Initial Score: (L3 x C5) 21 **Current Score:** (L1 x C1) 1
Context: Current project inspection standards can find flaws smaller than what the CIFS predicts (see GRC-ARES-I-X RPT-081, AIX USS Deterministic Critical Initial Flaw Size Analysis Report). Project can meet section 3.0 of GRC-ARES-I-X-PLAN-025, AIX USS Element Fracture Risk Mitigation Plan (mitigation steps for this risk do not conflict with Section 3.0).
Strategy: Mitigate
Submitter: S. Numbers **Owner:** A. Narvaez-Legaza
Current Status 18-SEP-08: Mitigation steps 6 and 7 still ongoing. No change since last month.

USS-5	Fracture risk	A. Narvaez-Legaza					
Event ID	Event Title	Start Date	Due Date	Completion Date	Likelihood	Consequence	Score
0	Boarded	1-Dec-06	1-Dec-06	1-Dec-06	3	5	21
1	Conservative design/material selection/standards	1-Dec-07	20-Apr-07	1-May-07	2	5	17
2	Manufacturing (welding techniques)	1-Dec-07	31-May-07	1-Jul-07	2	4	14
3	Analysis (deterministic and probabilistic CIFS analysis)	15-Mar-07	31-Aug-07	31-Aug-07	2	4	14
4	Demonstrate final welding and NDE techniques on Upper Stage (US)-2 weldment	1-Aug-07	15-Sep-07	31-Oct-07	1	3	5
5	Demonstrate successful test & inspection (destructive evaluation, residual stress measurements, non-destructive evaluation (NDE) decision flow, non-destructive evaluation, fracture toughness test) of charge 1 segments per REQ-061.	1-Dec-07	4-Oct-07	31-Oct-07	1	1	1
6	NESC to repeat fracture toughness testing on samples that reflect the final weld configuration.		30-Sep-08		1	1	1
7	Calculate final CIFS using final fracture toughness value		31-Dec-08		1	1	1

Ares 1-X USS
- Safety -

- Tremendous size and weight of the ARES 1-X USS posed a new challenge for GRC and the ARES 1-X Project Office (*10 ton, bulky hardware*)
- Risks included: safety & manufacturing personnel not trained in safe lifting and handling practices; adequate design and build of fixturing assembly stands and transportation carts
- Safety personnel added to ensure all lifting procedures were written, reviewed and approved by trained safety engineers prior to lifting activities
- Manufacturing personnel trained to understand all aspects of safe lifting and handling procedures
- Safety engineers kept a constant, close vigilant watch on daily operations so that any unsafe practices could be quickly identified and acted upon
- For stands and carts, loads analyses performed to ensure designs were adequate and thorough material selection/inspection completed to assure hardware would not fail causing serious injury or death

Ares 1-X USS
- Inspection -

- “How much inspection do we perform?”
- Risks included: as-built not meeting the as-designed configuration; lack of experience with welding large hardware; not enough experienced and certified staff to perform welding and inspection work
- Degreed welding engineers utilized to develop the welding processes and procedures - also established welder certification and qualification procedures to qualify new welders
- GRC welding engineers kept a constant vigilance (surveillance) on the quality of the welding work that went on during a two shift operation
- Contractors utilized to provide certified NDE III inspectors to assure all critical inspections were identified and executed
- Reliability and system safety engineers worked together with the quality engineers to develop the Mandatory Inspection Points (MIPs) and Government Mandatory Inspection Points (GMIPs)

Ares 1-X USS
- AS-9100 -

- AS-9100 mandated by NASA Headquarters for the design and fabrication of the ARES 1-X vehicle

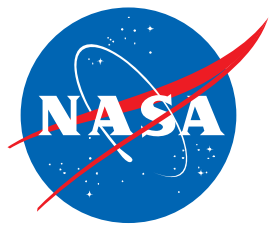
- Risks included: GRC was not very experienced nor did they have the resources to establish a complete and proven AS-9100 program; project budgets and schedules posed additional challenges

- GRC SMA organization identified several elements of the ISO/9000 and AS-9100 that were very important to be practiced in order to assure that a project such as ARES 1-X was successfully designed, built, and delivered

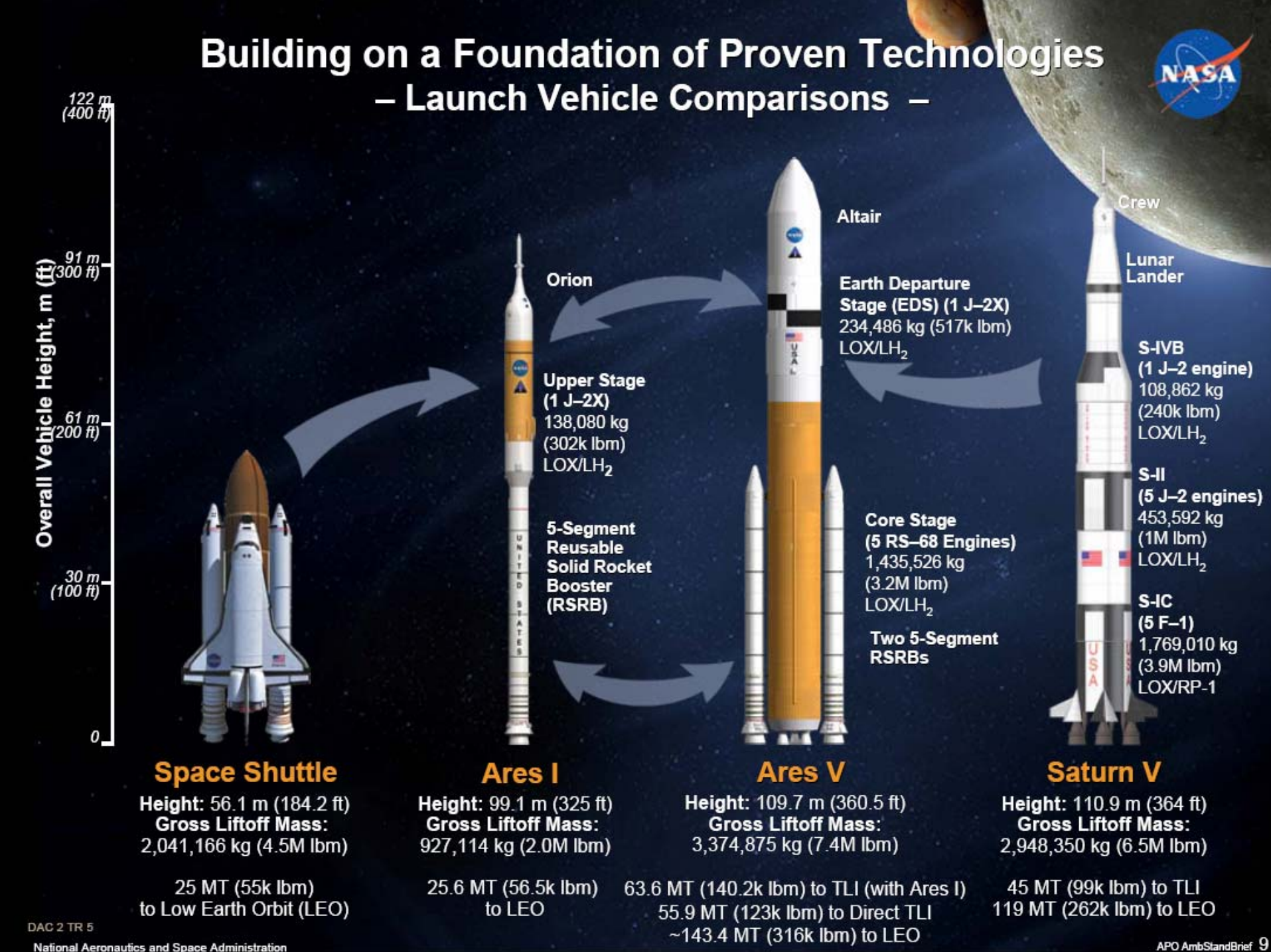
- Critical areas of AS-9100 that had to be implemented were identified as:
  - Procurement and Flow Down of Requirements
  - Inspection
  - Process procedures and documentation
  - Control of non-conforming material
  - Control of Special Processes
  - Material Review Board
  - Configuration Control
  - Training and certification of personnel

Summary

- Applying Continuous Risk Management to the Ares 1-X Project enabled project personnel to attack each issue and to break down the risks, piece by piece.
- Each aspect of the risk was worked until an acceptable and safe solution could be reached.
- Mitigation plans and steps provided a path for the teams to communicate and to avoid serious problems or injury.
- Applying CRM to any project will certainly help ensure the success of the project.



Building on a Foundation of Proven Technologies
– Launch Vehicle Comparisons –



Space Shuttle
Height: 56.1 m (184.2 ft)
Gross Liftoff Mass:
2,041,166 kg (4.5M lbm)

25 MT (55k lbm)
to Low Earth Orbit (LEO)

Ares I
Height: 99.1 m (325 ft)
Gross Liftoff Mass:
927,114 kg (2.0M lbm)

25.6 MT (56.5k lbm)
to LEO

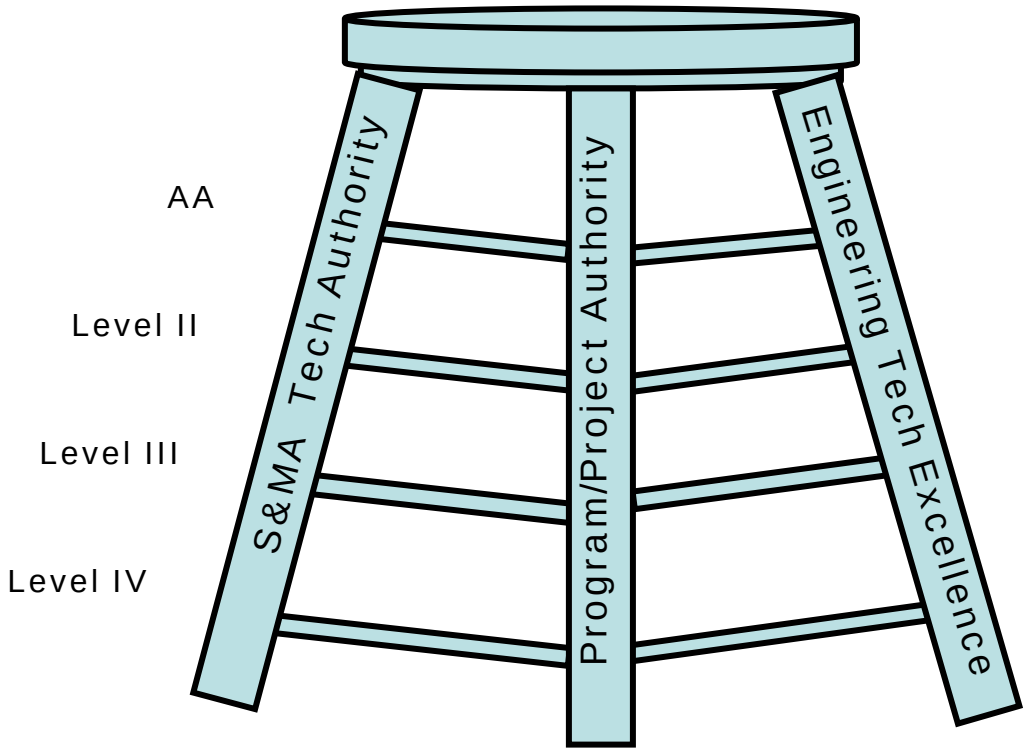
Ares V
Height: 109.7 m (360.5 ft)
Gross Liftoff Mass:
3,374,875 kg (7.4M lbm)

63.6 MT (140.2k lbm) to TLI (with Ares I)
55.9 MT (123k lbm) to Direct TLI
~143.4 MT (316k lbm) to LEO

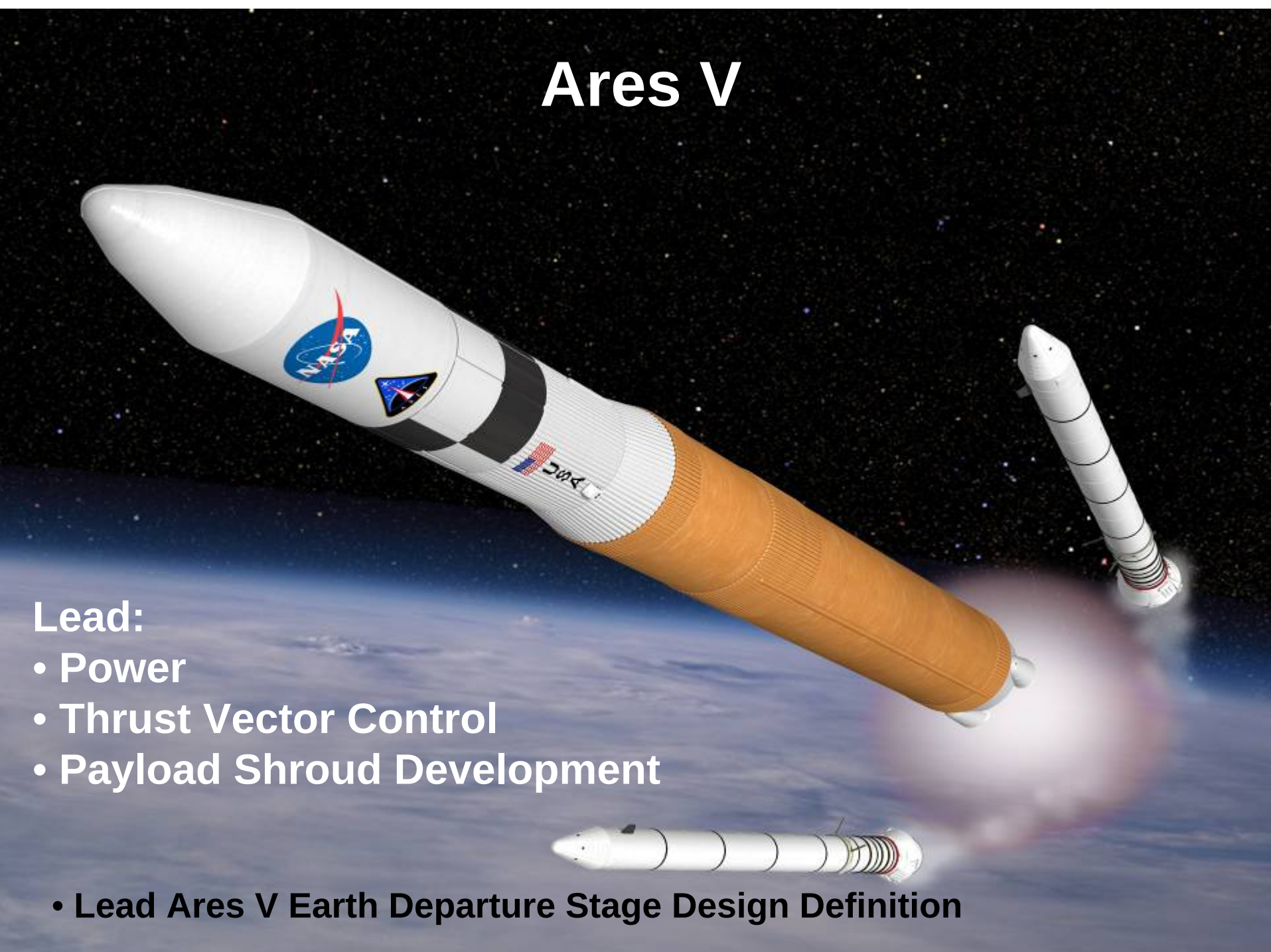
Saturn V
Height: 110.9 m (364 ft)
Gross Liftoff Mass:
2,948,350 kg (6.5M lbm)

45 MT (99k lbm) to TLI
119 MT (262k lbm) to LEO

What progress have we made?


AA
Level II
Level III
Level IV
S&MA Tech Authority
Program/Project Authority
Engineering Tech Excellence

Ares V

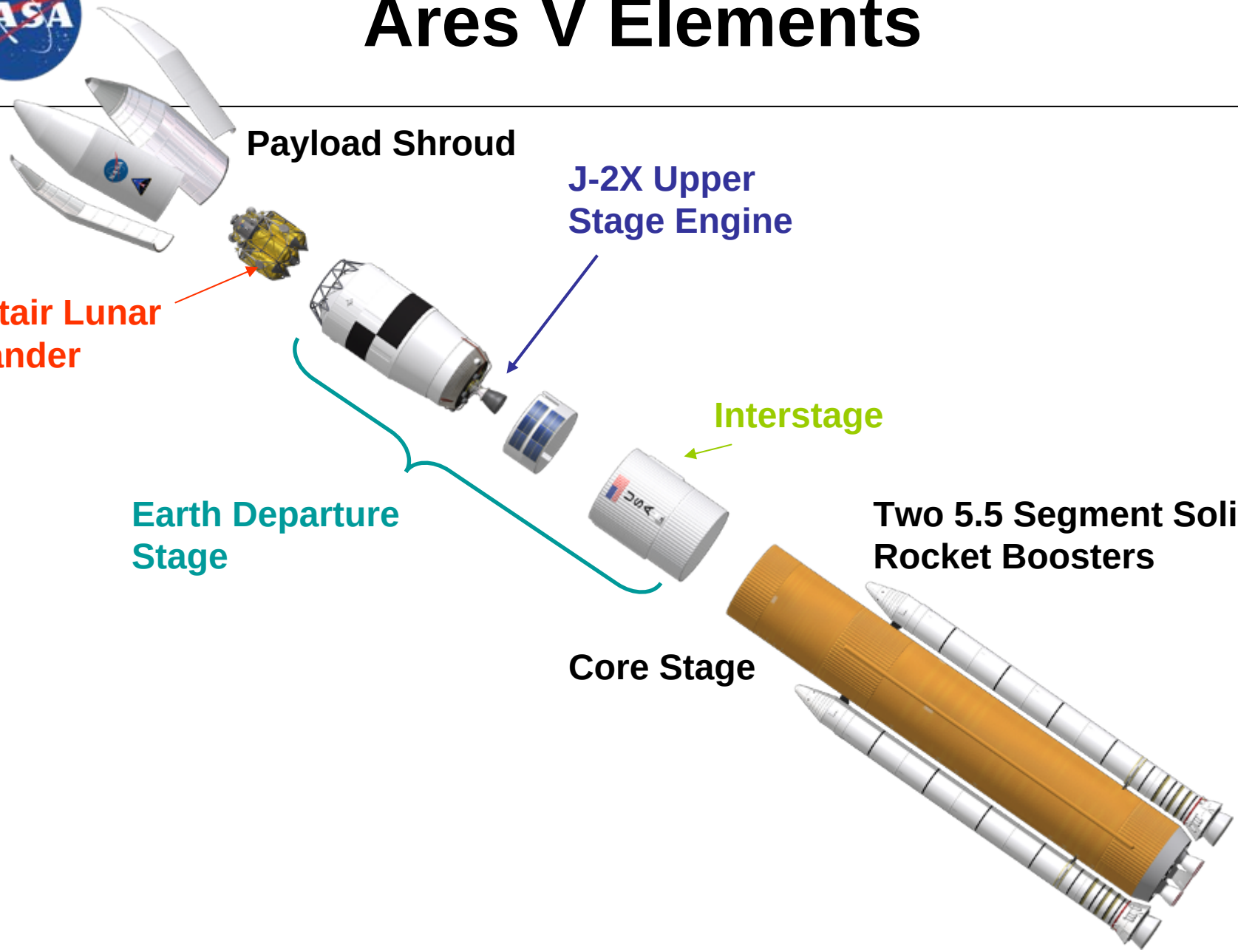


Lead:

- **Power**
- **Thrust Vector Control**
- **Payload Shroud Development**

- **Lead Ares V Earth Departure Stage Design Definition**

Ares V Elements



Shuttle and International Space Station

Space Shuttle Program

- Engineering and Mission Management Support

International Space Station (ISS)

- Electrical Power System ustain Engineering
- Develop and Operate ISS Experi
- Support Human Researc

Lunar Surface Access Module

Lunar Lander

Subsystem Lead:

- Ascent Stage Propulsion
- Ascent and Descent Stage Power Generation, Management, and Energy Storage Systems

Lead:

- Lunar Lander Environmental Testing


Lead:
• Power Generation and Management, Energy Storage Systems and Element Environmental Testing
Support:
• In-Situ Resource Systems
• Surface Mobility Systems

Elements of a Successful Risk Management Program

1. Communication
2. Simple Processes
3. Understandable Tool
4. Engaged Program Leadership

Ares Launch Vehicle Elements

LAS

Crew Exploration Vehicle (CEV)
(Crew Module / Service Module)

Spacecraft Adapter

Forward Skirt

Upper Stage

J-2X Upper Stage Engine

Interstage

First Stage
(5-Segment RSRB)

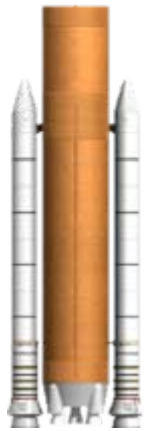
Ares I

Composite Shroud

Lunar Surface Access
Module (LSAM)

<u>Earth Departure Stage</u>
LOx/LH_2
1 J-2X Engine
Al-Li Tanks/Structures

Interstage



<u>Core Stage</u>
LOx/LH_2
5 RS-68 Engines
Al-Li Tanks/Structures

5-Segment
2 RSRBs

Ares V

Ares I - Crew Launch Vehicle

- Serves as the long term crew launch capability for the U.S.
- 5 Segment Shuttle Solid Rocket Booster
- New liquid oxygen / liquid hydrogen upperstage
  - J2X engine
- Large payload capability

Ares 1-X is the test vehicle for Ares 1