National Aeronautics and Space Administration

Exploration Committee

Dick Kohrs

Feb. 10-11, 2011

2010-2012 NAC Exploration Committee

- Mr. Richard Kohrs, Exploration Committee Chair
- Mr. Bohdan (Bo) I. Bejmuk – Co Chair
- Ms. Nancy Ann Budden
- Mr. Joseph Cuzzupoli
- Ms. Carolyn Griner
- Dr. John Logsdon
- David E. Longnecker, M.D.
- General Lester L. Lyles
- Mr. Dick Mallow

Fact Finding Meetings Held

- December 2, 2010 telecon: discussed HEFT
- January 11, 2011 meeting: discussed ESMD status and NASA Exploration Affordability Workshop results

FACA - NAC Meeting Agenda

Exploration Program Status

Doug Cooke, Associate Administrator,
NASA Exploration Systems Mission Directorate (ESMD)

Human Exploration Framework Team Phase 2

Dr. John Olson, Director, ESMD Directorate Integration Office

Status of Commercial Crew Initiative

Phil McAlister, ESMD Commercial Crew Planning Lead

Final Report of the Ad-Hoc Task Force on Planetary Defense

Dr. Tom Jones, Task Force Co-Chair

Discussion, Recommendations

Public Comments

A New Path: The NASA Authorization Act of 2010

- **The Congress approved and the President signed the National Aeronautics and Space Administration Authorization Act of 2010**
  - Bipartisan support for human exploration beyond Low Earth Orbit

- **The law authorizes:**
  - Extension of the International Space Station until at least 2020
  - Strong support for a commercial space transportation industry
  - Development of a multi-purpose Crew Vehicle and heavy lift launch capabilities
  - A “flexible path” approach to space exploration opening up vast opportunities including near-Earth asteroids and Mars
  - New space technology investments to increase the capabilities beyond Low Earth Orbit

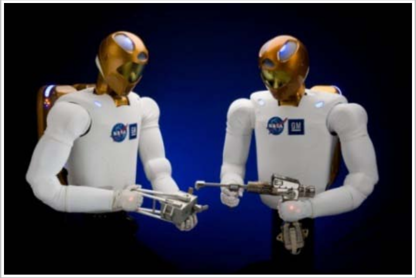
ESMD Positioned to Respond to Authorization Act

- Currently operating under a Continuing Resolution until March 4, 2011
- Using internal study teams to provide plans in response to NASA Authorization Act of 2010
  - Orion, Heavy Lift, Commercial Crew & Cargo, Technology and Exploration Precursor Robotics all reworking plans in response to the Act's provisions
- Study Team efforts are informed by Auth Act direction and results of Human Exploration Framework Team (HEFT) ongoing analysis
- HEFT is the architectural planning and analysis function for human exploration, providing decision support to NASA senior leadership on end-to-end HSF needs, which drive near-term priority decisions
  - Not a decision-making body
  - Analyses consider technical, programmatic, and fiscal constraints; their trade studies seek to drive out affordable multi-destination architecture options that meet stakeholder priorities
  - Analyses enable Agency – level strategic and technical decisions

Technology to Enable the Next Explorers To Go Beyond: Robonaut 2 (R2) ISS Flight Demo

- **Experimental Objectives**
  - Test dexterous manipulation in 0g
  - Test robot-crew safety in 0g
  - Refine control based on tests
- **Experiment Plan**
  - R2 Tested IV (IV=intra-vehicle) on fixed stanchion
  - R2 Shipped with IV taskboard
  - Crew will add new experiments
- **Future Upgrades**
  - Upgrade software with revisions
  - Add mobility with 0g climbing legs
  - Upgrade backpack for mobility
  - Upgrade torso for EVA

http://robonaut.jsc.nasa.gov/

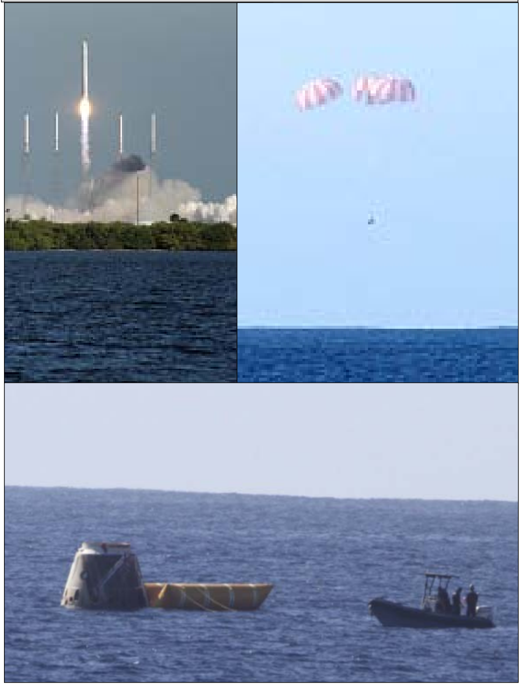


SpaceX Status

- Milestones 1-17 and 20 completed for payments to date of $258M out of $278M.
- Falcon 9 maiden flight successfully reached orbit on June 4.
- COTS Milestone 17 - Demo Flight 1 successfully accomplished on December 8.
  - All primary mission objectives successfully demonstrated
    - Falcon 9 launch and Dragon insertion to orbit
    - Dragon separation
    - Safe reentry
  - All other mission objectives successful
- Demo Flight 2 mission planned for June 2011.
  - Rendezvous and proximity operations with ISS
  - ISS communication demonstration
- Demo Flight 3 mission planned for September 2011.
  - Berthing operations with ISS
  - Cargo transfer demonstration
- SpaceX has proposed combining Demo Flight 2 and 3. NASA is considering that proposal.

Falcon 9 Maiden Flight, Cape Canaveral

Demo Flight 1 Images



Orbital Status

- Milestones 1-16, and 19 completed for payments to date of $157.5M out of $170M total.
- COTS Milestone 19 – Cargo Integration Demo, completed at Thales Alenia in Italy Dec 1-3.
- NK-33 engine successfully tested in Russia and first AJ-26 hot fired at Stennis Space Center.
- Ground infrastructure at Wallops Flight Facility under construction.

NK-33 1st Stage Engine Testing

Pressurized Cargo Module

TII 1st Stage Static Test Article

Launch Pad Construction at WFF

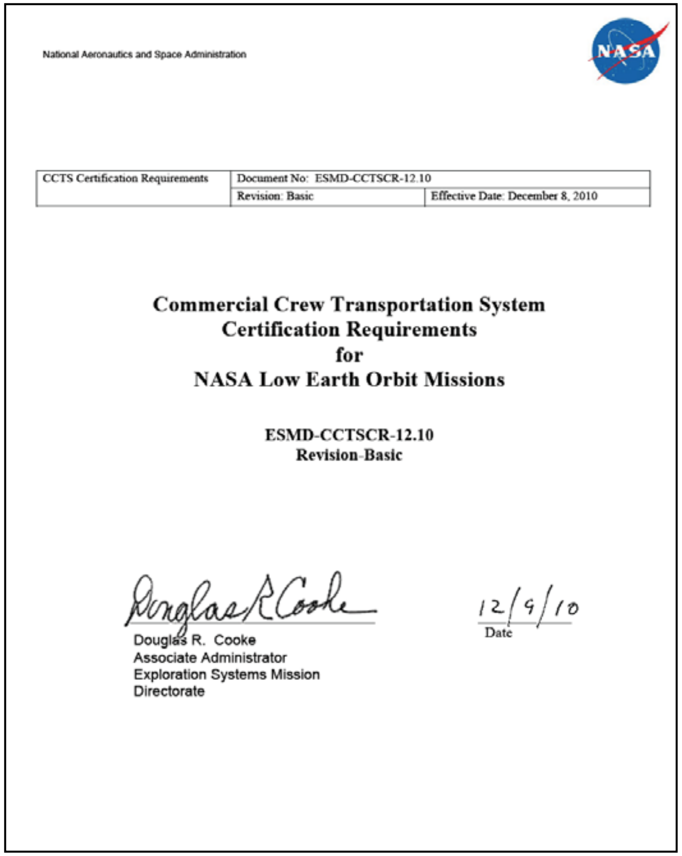
- COTS demo flight planned for October 2011, demonstrating:
  - Launch vehicle operations
  - Cygnus orbital operations
  - ISS proximity and berthing operations
  - ISS departure and destructive re-entry ops

Commercial Crew Development Round 2

- CCDev 2 Announcement for Proposals was released to industry on October 25, 2010. Proposals were due on December 13, 2010.
- The goals of CCDev 2 investments are to:
  - advance orbital commercial crew transportation system (CTS) concepts
  - and enable significant progress on maturing the design and development of elements of the system, such as launch vehicles and spacecraft, while ensuring crew and passenger safety,
  - with the overall objective of accelerating the availability of U.S. CTS capabilities.
- New competition open to all U.S. commercial providers for NASA Space Act Agreements (SAAs).
- Pay-for-Performance milestones, April 2011 to no later than May 2012.
- CCDev 2 awards are planned to coincide with the FY11 appropriation (estimated for March) which will determine the exact amount available for awards.
- ***NASA is currently in a BLACK-OUT period with industry regarding CCDev 2. All information above is public and has been previously disclosed.***

NASA's Human Rating Requirements Status

- In May 2010, NASA released to industry the first version of our commercial human rating requirements in a document titled, Commercial Human Rating Plan (CHRP).
- NASA received extensive input from industry on the CHRP and began revising it.
- NASA developed and adopted a concept known as "crew transportation system certification", as opposed to "human rating".
- NASA Authorization Act of 2010, Section 403 (b)(1), required NASA to release its human ratings processes and requirements NLT December 10, 2010.
- On December 9, NASA baselined and released the Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions document (see right).



National Aeronautics and Space Administration

CCTS Certification Requirements	Document No: ESMD-CCTSCR-12.10	
	Revision: Basic	Effective Date: December 8, 2010

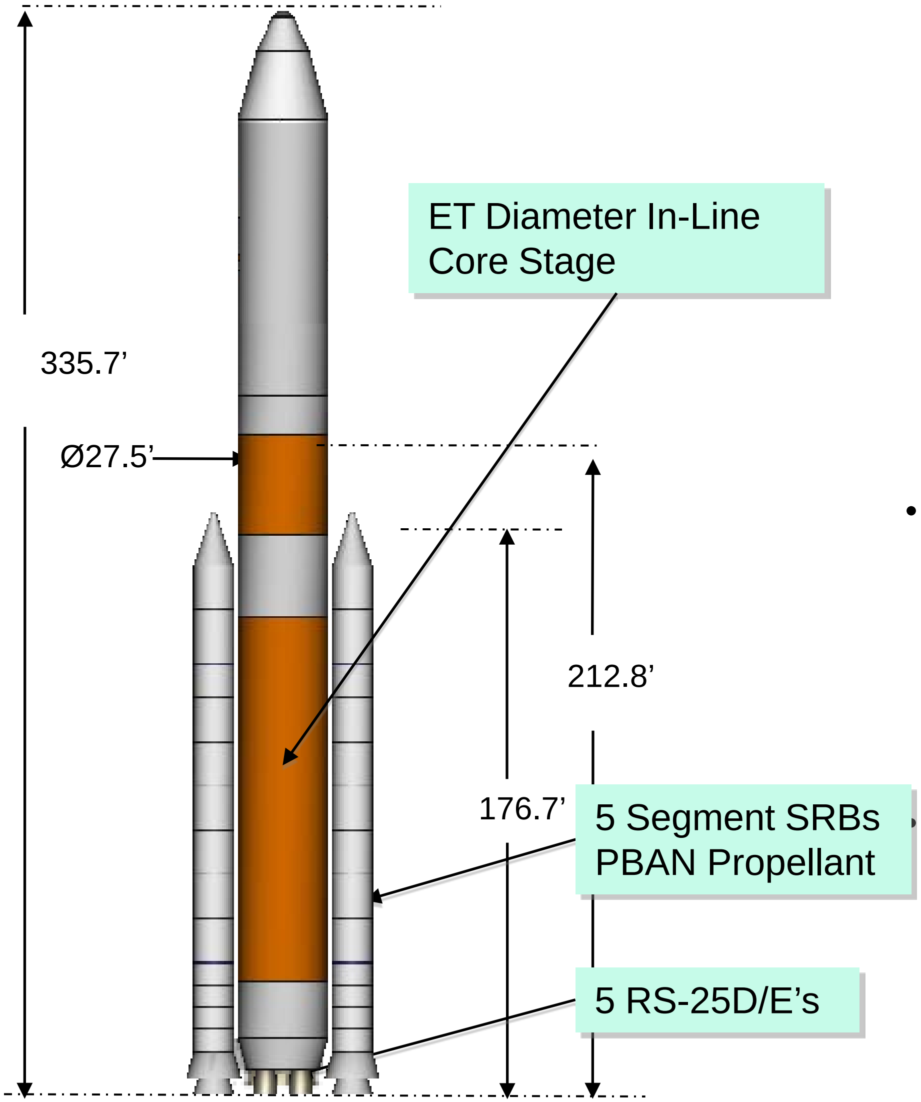
Commercial Crew Transportation System
Certification Requirements
for
NASA Low Earth Orbit Missions

ESMD-CCTSCR-12.10
Revision-Basic

Douglas R. Cooke
Associate Administrator
Exploration Systems Mission
Directorate

12/9/10
Date

SLS Reference Vehicle Design
Baseline SLS Path: Ares/Shuttle-derived System

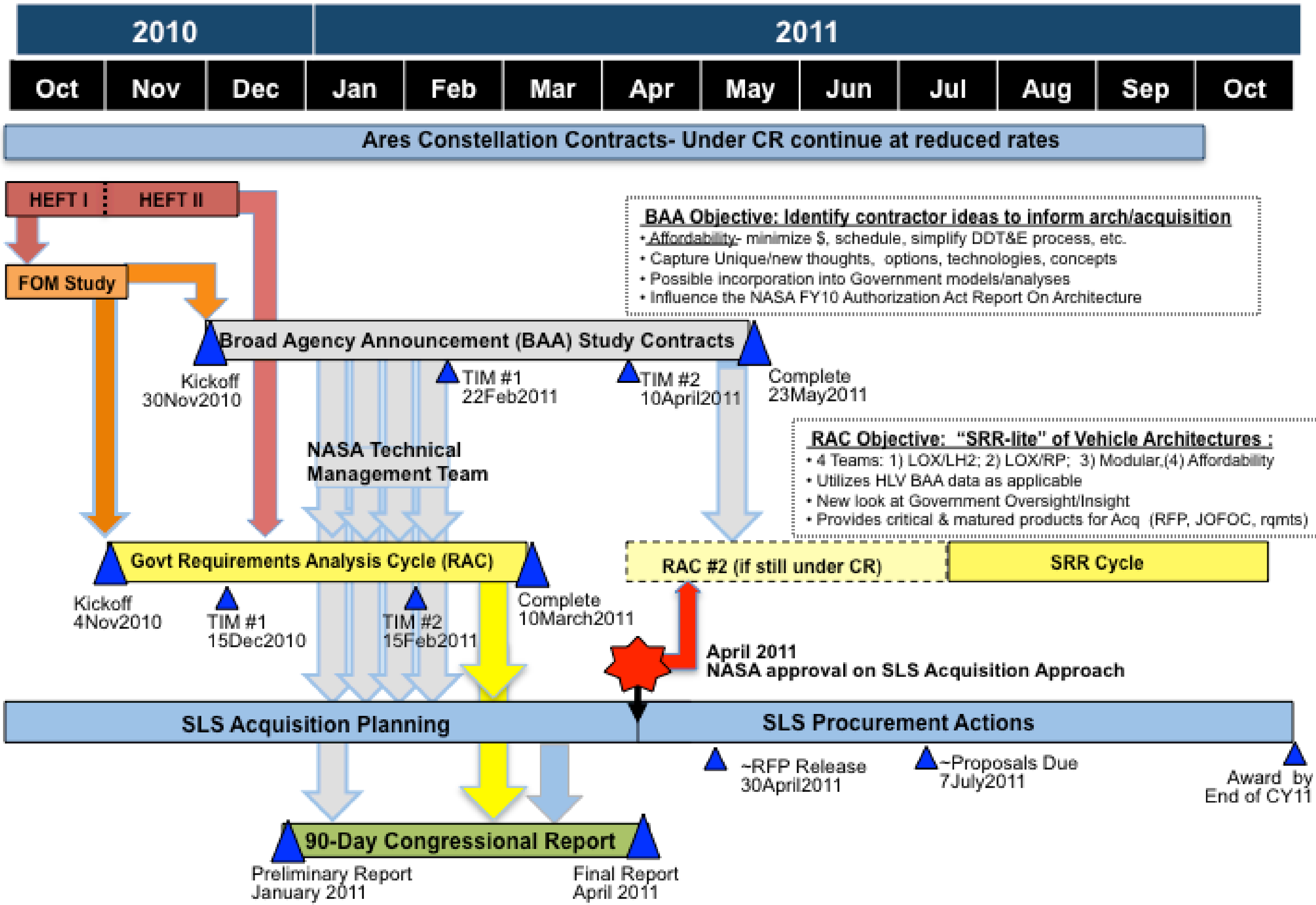


- Key Auth Act Direction
  - The Administrator shall, to the extent practicable, extend or modify existing vehicle development and associated contracts
  - The initial capability of the core elements, without an upper stage, of lifting payloads weighing between 70 tons and 100 tons into low-Earth orbit
  - The capability to lift the multipurpose crew vehicle
  - The capability to serve as a backup system for supplying and supporting ISS cargo requirements or crew delivery requirements not otherwise met by available commercial or partner-supplied vehicles
- SLS Reference Vehicle Design
  - 27.5’ Diameter LOX/LH2 Core Stage
  - Five RS25 based engines using Shuttle assets then RS25E expendable derivative
  - Two 5-Segment Ares derived SRBs
  - Delivers 108.6t to 30x130 nmi
- Evolved System to 130mT
  - Upper stage with one or two J-2X upper stage engines (trades pending)
  - Draft FY11 CR language dictates concurrent development of upper stage with core vehicle

Space Launch Systems (SLS) Approach

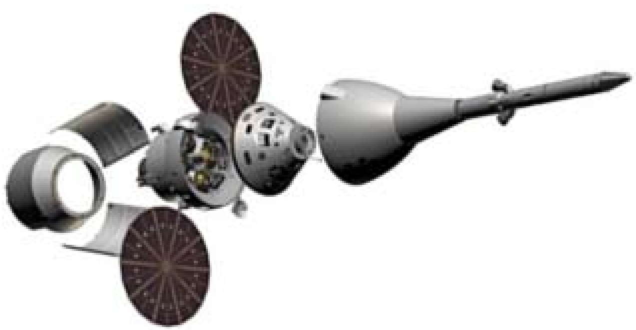
- NASA Reference Vehicle Design for SLS is an Ares/Shuttle-derived LOX/LH2 solution
  - This vehicle comes closest to meeting schedule FOM with opportunities for affordability that could bring costs down to acceptable levels
- NASA will use recently-awarded BAA study contracts and Government Requirements Analysis Cycle to validate decisions through rigorous technical and acquisition process
  - Work with industry on multiple affordability options for heavy lift
  - Validate that Ares/Shuttle derived solution is truly most cost effective
  - Provide alternative acquisition plan in event Reference Vehicle Design is unaffordable
- In parallel with SLS acquisition activities, the Constellation Ares contracts will continue through FY11 to minimize workforce disruptions
- Final decisions on NASA's plans for the SLS will be made during the Acquisition Strategy review process in early 2011.

SLS Near-term Activities



Multi-Purpose Crew Vehicle (MPCV)

- NASA Authorization Act of 2010 calls for an MPCV which:
  - Continues to advance development of the human safety features, designs, and systems in the Orion Project.
  - Serves as primary crew vehicle for missions beyond LEO
  - Conducts regular in-space operations in conjunction with payloads delivered by the Space Launch System or other vehicles in cis-lunar space (rendezvous, docking, EVA)
  - Provides means of delivering crew and cargo to the ISS as a back-up to commercial crew and international partners
- Based on these requirements, NASA has selected the beyond-LEO version of the Ori



Reference Vehicle Design

- Provides crew launch, return, and operation in deep space
- Crew size: 2 to 4
- Crewed mission duration: 21.1 days
- Delta V capability: 5233 ft/s
- Main engine thrust: 7,500 pounds
- Pressurized volume: 690.6 cubic feet
- Net habitable volume: 316 cubic feet
- Skip entries up to 4,800 nmi from lunar return trajectories
- Water landing off California coast
- 5.4 nmi landing accuracy

- Fin ... he MPCV will be made during the Acquisition Strategy review process in early 2011.

Strategies and Design Reference Missions (DRMs)

- Four different strategies were developed in the HEFT Phase 2 Architecture Analysis Cycle.
  - Strategies 1, 1' and 2: Built an integrated manifest with the respective element schedule and cost data
  - Strategy 3: Capability Driven Framework not manifested in HEFT 2 [Early Forward Work in Jan 2011]

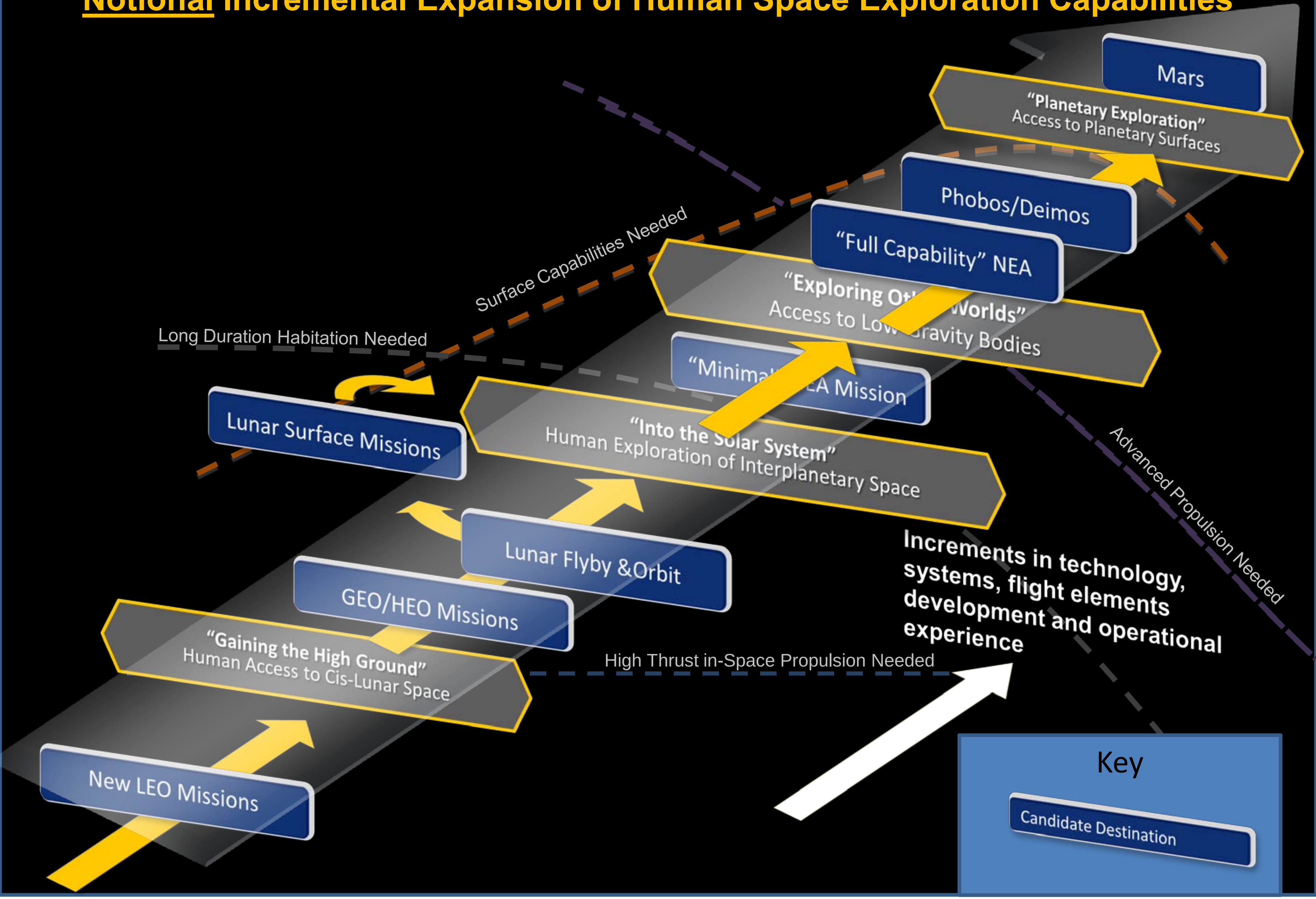
Strategy	Description	DRM	Simple Result Description
1 – Fixed Initial Conditions: Mission to a NEA when Affordable	A fixed cost and initial milestone-constrained assessment, consistent with the NASA 2010 Authorization for the DRM 4B *(NEA mission)* only. Manifest changed to incorporate HLLV test flight. Utilized updated design & cost estimates, that include some lean development options	4B	Over-constrained. Does not meet all schedule, budget, and performance requirements. Results heavily dependent upon budget availability and phasing.
1 Prime – Affordability Centric	Same as Strategy 1. Combines Expendable Launch Vehicles flights into an HLLV flight. Utilized updated design and cost estimates that include some lean development options	4B	Small improvement, but still didn't close on budget in out-years. Key insights into necessary affordability measures.
2 – NEA by 2025	Deadline and cost-constrained assessment to reach a NEA by 2025 utilizing a "minimal" set of systems/elements and an "easy" target	5B	Not prudent: Sprint with minimum capability mission to asteroid too costly for sustained benefit/ROI.
3 – Capability-Driven Framework	Journey, not destination. Builds capabilities that enable many potential paths w/DRMs to GEO, L1/2, Lunar, NEA< Mars Orbits/Moons	Multiple	Departure from long-standing destination-focused approach – **Best path given constraints.**

Capability-Driven Framework Overview

- Objective: Facilitates a capability-driven approach to human exploration rather than one based on a specific destination and schedule
- Evolving capabilities would be based on:
  - Previously demonstrated capabilities and operational experience
  - New technologies, systems and flight elements development
  - Concept of minimizing destination-specific developments
- Multiple possible destinations/missions would be enabled by each discrete level of capability
- Would allow reprioritization of destination/missions by policy-makers without wholesale abandonment of then-existing exploration architecture

A Capability-Driven Framework enables multiple destinations and provides increased flexibility, greater cost effectiveness, and sustainability.

Notional Incremental Expansion of Human Space Exploration Capabilities



Example DRM Mission Space to Common Element Mapping

DRM TITLE	MINIMUM ELEMENTS									
	Commercial LV	SLS - HLLV	MPCV	CPS	REM/SEV	EVA Suit	Lunar Lander & Elements	DSH	SEP	Mars Elements
LEO missions	R	B	B			R				
HEO/GEO vicinity without pre-deploy		D	D	D	D	R				
HEO/GEO vicinity with pre-deploy	R	R	R	R	D	R				
Lunar vicinity missions		R	R	R		R				
Low lunar orbital mission		R	R	R		R				
Lunar surface mission		R	R	D		D	D			
Minimum capability NEA		R	R*	D	D	R		R		
Full capability NEA		D	D*	D	D	D		D	D	
Martian moons: Phobos/Deimos		R	R*	R		D		R	R	
Mars landing		D	R*	R		D		R	D	D

* MPCV entry velocity could be driven by these missions for certain targets, if selected.

D	Driving Case
R	Required Elements
B	Back-Up Capability

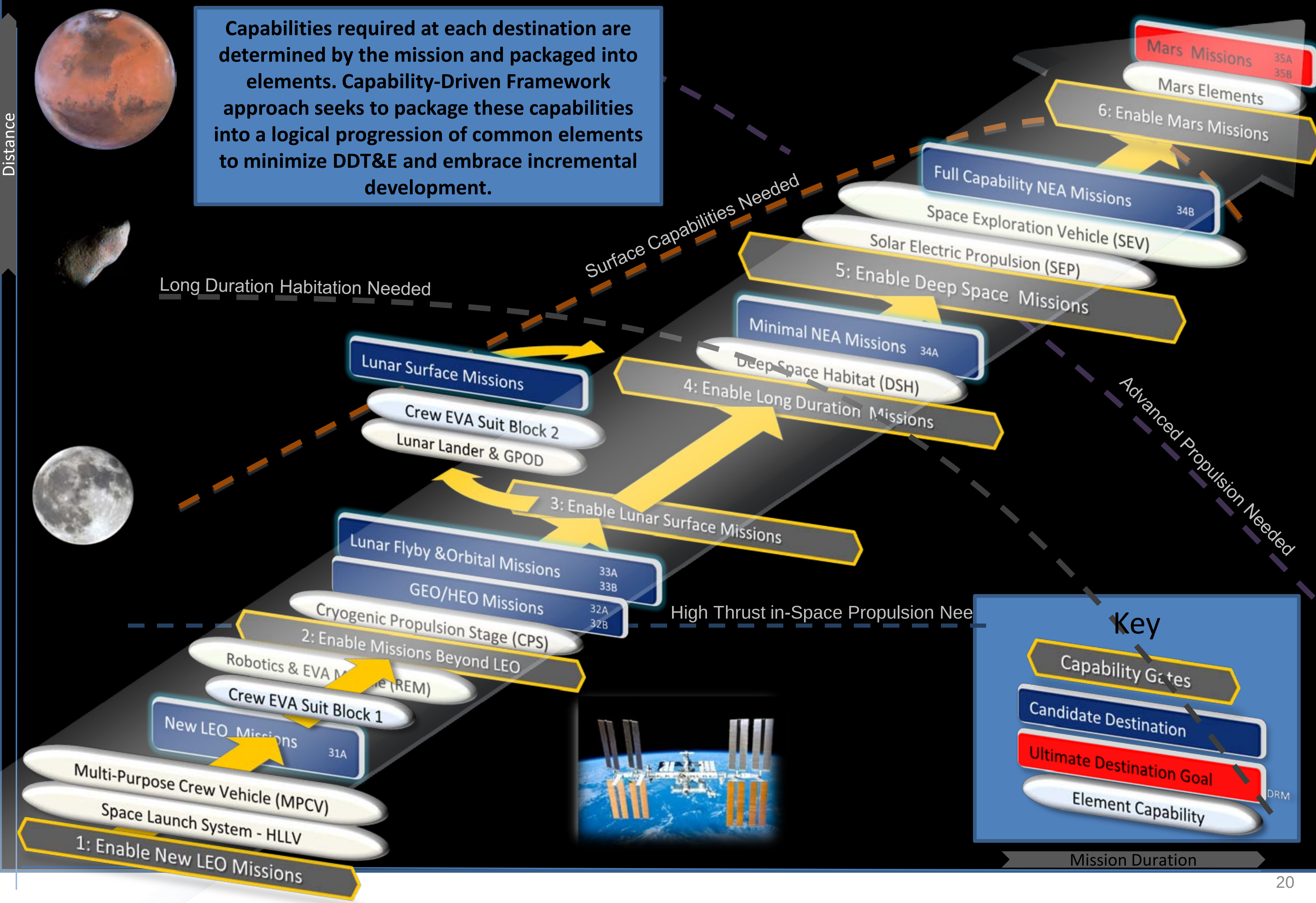
D/R/B Element allocations based on Authorization Act and other conditions. Different constraint basis would result in different element allocations/options.

Driving: There is something in this DRM that is "driving" the performance requirement of the element.
Example : Entry speeds for MPCV driven by NEO DRM.
Required: This element must be present to accomplish this DRM.
Example : SEV required for Full Capability NEO, but not for other DRMs

Flexible mission space analysis validates that several fundamental building blocks, including the SLS and MPCV, are needed to support multiple destinations.

- LV=Launch Vehicle
- SLS=Space Launch System
- MPCV=Multi-person Crew Vehicle
- CPS=Cryogenic Propulsion Stage
- REM=Robotics & EVA Module
- EVA=Extravehicular Activity
- DSH=Deep Space Hab
- SEP=Solar Electric Propulsion

Incremental Expansion of Human Exploration Capabilities

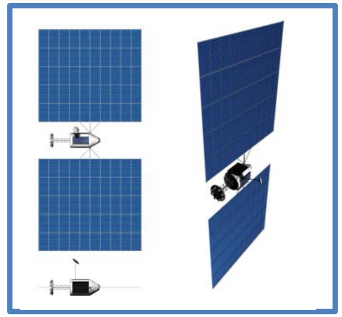


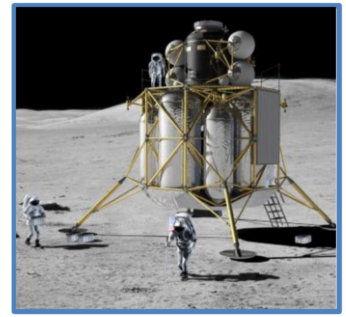
Notional Architecture Elements

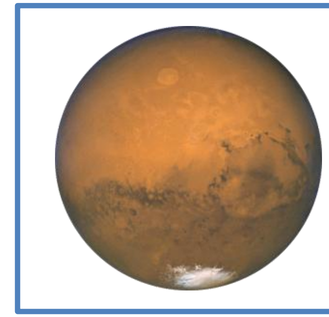

Space Launch System (SLS)-HLLV


Multi-purpose Crew Vehicle (MPCV)


Cryogenic Propulsion Stage (CPS)

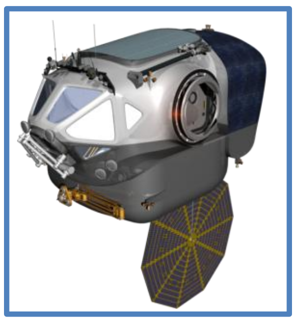

Solar Electric Propulsion (SEP)

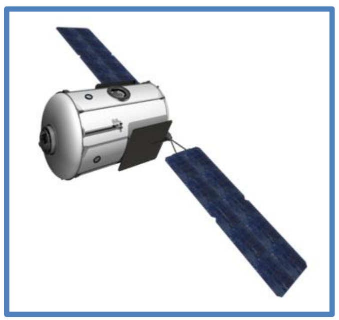

Lander


Mars Elements

Graphics are Notional Only – Design and Analysis On-going


EVA Suit


Multi-Mission Space Exploration Vehicle (MMSEV)


Deep Space Habitat (DSH)

Robotics & EVA Module (REM)


Kick Stage


NEA Science Package

Technology Applicability to Destination Overview (1)

	LEO (31A)	Adv. LEO (31B)	Cis-Lunar (32A,B & 33A,B)	Lunar Surface - Sortie (33C)	Lunar Surface - GPOD (33X)	Min NEA (34A)	Full NEA (34B)	Mars Orbit	Mars Moons (35A)	Mars Surface (35B)
LO2/LH2 reduced boiloff flight demo			May be required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
LO2/LH2 reduced boiloff & other CPS tech development			May be required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
LO2/LH2 Zero boiloff tech development					May be required	May be required	May be required	Probably required	Probably required	Probably required
In-Space Cryo Prop Transfer										
Energy Storage	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Electrolysis for Life Support (part of Energy Storage)					Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Fire Prevention, Detection & Suppression (for 8 psi)		May be required	May be required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Environmental Monitoring and Control		May be required	May be required		Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
High Reliability Life Support Systems					Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Closed-Loop, High Reliability, Life Support Systems					Probably required	May be required	May be required	Probably required	Probably required	Probably required
Proximity Communications			Probably required	Required technology	Required technology	Required technology	Required technology	Probably required	Required technology	Required technology
In-Space Timing and Navigation for Autonomy			Probably required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
High Data Rate Forward Link (Ground & Flight)			May be required	May be required	May be required	Required technology	Required technology	Required technology	Required technology	Required technology
Hybrid RF/Optical Terminal (Communications)								Required technology	Required technology	Required technology
Behavioral Health					Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Optimized Exercise Countermeasures Hardware					Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Human Factors and Habitability	Probably required	Probably required	Required technology	Required technology	Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Long Duration Medical			May be required	Required technology	Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Biomedical countermeasures					Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Space Radiation Protection – Galactic Cosmic Rays (GCR)					Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Space Radiation Protection – Solar Proton Events (SPE)	Required technology	Required technology	Required technology	Required technology	Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Space Radiation Shielding – GCR & SPE			Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Vehicle Systems Mgmt		Probably required	Probably required	Probably required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Crew Autonomy					Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Mission Control Autonomy		Probably required	Probably required	Probably required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Common Avionics	May be required	Probably required	Probably required	Probably required	Probably required	Required technology	Required technology	Required technology	Required technology	Required technology
Advanced Software Development/Tools					Required technology	May be required	May be required	Required technology	Required technology	Required technology
Thermal Management (e.g., Fusible Heat Sinks)					Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Mechanisms for Long Duration, Deep Space Missions					Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Lightweight Structures and Materials (HLLV)					May be required	May be required	May be required	Required technology	Required technology	Required technology
Lightweight Structures and Materials (In-Space Elements)					May be required	May be required	May be required	Required technology	Required technology	Required technology

Not applicable	(white)	Probably required	(light green)
May be required	(yellow)	Required technology	(green)

Technology Applicability to Destination Overview (2)

	LEO (31A)	Adv. LEO (31B)	Cis-Lunar (32A,B & 33A,B)	Lunar Surface - Sortie (33C)	Lunar Surface - GPOD (33X)	Min NEA (34A)	Full NEA (34B)	Mars Orbit	Mars Moons (35A)	Mars Surface (35B)
Robots Working Side-by-Side with Suited Crew		Required	Probably required	Probably required	Required	Required	Required	Probably required	Required	Required
Telerobotic control of robotic systems with time delay					Required	Required	Required	Probably required	Required	Required
Surface Mobility				Required	Required					Required
Suitport		May be required	May be required	Probably required	Required		Required		Required	Probably required
Deep Space Suit (Block 1)		Required	Required			Required	Required	May be required	Required	
Surface Space Suit (Block 2)				Required	Required					Required
NEA Surface Ops (related to EVA)							Required		Required	
Environment Mitigation (e.g., dust)				Required	Required	Probably required	Probably required		Probably required	Required
Autonomously Deployable very large Solar Arrays							Required	Required	Required	Required
SEP demo							Required	Required	Required	Required
Solar Electric Propulsion (SEP) Stage							Required	Required	Required	Required
Fission Power for Nuclear Electric Propulsion (NEP)								May be required	May be required	May be required
Nuclear Thermal Propulsion (NTP) Engine								May be required	May be required	May be required
Fission Power for Surface Missions					May be required					Required
Inflatable Habitat Flight Demo (flight demo launch)								Probably required	Probably required	Probably required
Inflatable Habitat Tech Development (including demo)								Probably required	Probably required	Probably required
In-Situ Resource Utilization (ISRU)					Probably required					Required
TPS -- low speed (<11.5 km/sec; Avcoat)			Required	Required	Required	Required	Required	Required	Required	Required
Thermal Protection System (TPS) -- high speed						May be required	May be required	Probably required	Probably required	Probably required
NEA Auto Rendezvous, Prox Ops, and Terrain Relative Nav				Probably required	Probably required	Required	Required		Required	Required
Precision Landing				Probably required	Probably required					Required
Entry, Decent, and Landing (EDL)						May be required	May be required	Required	Probably required	Required
Supportability and Logistics								May be required	May be required	Probably required
LOX/Methane RCS				May be required	May be required					Probably required
LOX/Methane Propulsion Stage - Pressure Fed				May be required	May be required					Probably required
LOX/Methane Propulsion Stage - Pump Fed				May be required	May be required					Probably required
In-Space Chemical (Non-Toxic Reaction Control System)						May be required	May be required		May be required	
HLLV Oxygen-Rich Staged Combustion Engine	May be required	May be required	May be required	May be required	May be required	May be required	May be required	May be required	May be required	May be required

Not applicable	(white)	Probably required	(light green)
May be required	(yellow)	Required technology	(green)

Finding

- The NAC Exploration Committee applauds the Human Exploration Framework Team (HEFT) report. The HEFT approach has evolved over the last months with a strategy able to support multiple mission options that could be selected in future decisions, based on budget availability. The Committee agrees with HEFT's conclusion that a capabilities-based strategy for future exploration can be an excellent basis for a sustainable, realistic, and affordable space exploration program.
- The committee is concerned about how NASA will handle the management aspects of this strategy ; e.g. acquisition strategy, contract incentives, internal organization within NASA. The committee also encourages NASA to continue its dialogue with external organizations to seek best-practices and benchmarks for successful affordability initiatives. (This includes initiatives currently underway in the Air Force, and the initiatives defined in the Defense Science Board's 'Adaptability Study.')

Committees should meet together at least once a year

- Committee: Exploration Committee Chair: Dick Kohrs Date: Jan. 11, 2011

- **Recommendation**: The NAC recommends to the Administrator that its nine committees meet together at least once a year with an agenda that cuts across the interests of all committees, and with an opportunity to hear from the Administrator and share their perspectives on issues related to NASA's activities.
- **Reason**: The previous administrator had a NAC that operated as one unit, with all members attending the Advisory Council meeting. The current administrator has chosen to organize the NAC into nine NAC committees that operate somewhat independently and are represented at the Advisory Council only by the Committee chairs. Prior experience indicates that potential efficiencies are gained by shared deliberations and "cross pollination" of information and expertise among disciplines. Some committees have met jointly to share their experience with each other and have brought forward joint observations, findings, and recommendations. It would be beneficial to NASA to have all committees come together at least annually to integrate efforts, hold cross-discipline meetings and explore systems approaches that can potentially lead to increased quality, efficiency, cost reduction, risk reduction, etc. that might not be apparent when working separately. Further, this would allow NASA leadership to efficiently communicate priorities, introduce new directions and receive feedback.
- **Consequences**: Without this coordination, the various committees may perform redundant work, offer advice that fails to recognize unintended consequences, or provide recommendations that are not well informed.