National Aeronautics and Space Administration

Human Exploration and Operations Committee Status

Ken Bowersox
Committee Chair
March 31st, 2016

NAC HEO Committee Members

- Ms. Bartell, Shannon
- Mr. Bowersox, Ken, ***Chair***
- Ms. Budden, Nancy Ann
- Dr. Chiao, Leroy
- Dr Condon, Stephen "Pat"
- Mr. Cuzzupoli, Joseph W.
- Mr. Holloway, Tom
- Mr. Lon Levin
- Dr. Longenecker, David E.
- Mr. Lopez-Alegria, Michael
- Mr. Malow, Richard N.
- Mr. Odom, Jim (James)
- Mr. Sieck, Robert
- Mr. Voss, James

Major Events Since Last NAC Meeting

- One Year Crew – Mission Complete
- Cygnus OA-4 and OA-6
- Progress 62P cargo mission
- Soyuz 46 launch and 44 landing
- Full electrical power capability restored at ISS with EVA repair
- CRS 2 Awards to Orbital ATK, SpaceX, and Sierra Nevada
- ARM FAST Team Report Complete
- Steady progress on Commercial Crew, Orion, SLS and Ground Systems
- Steady ISS science activity

NAC HEO Meeting Summary November, 2015

NAC HEO Committee Meeting

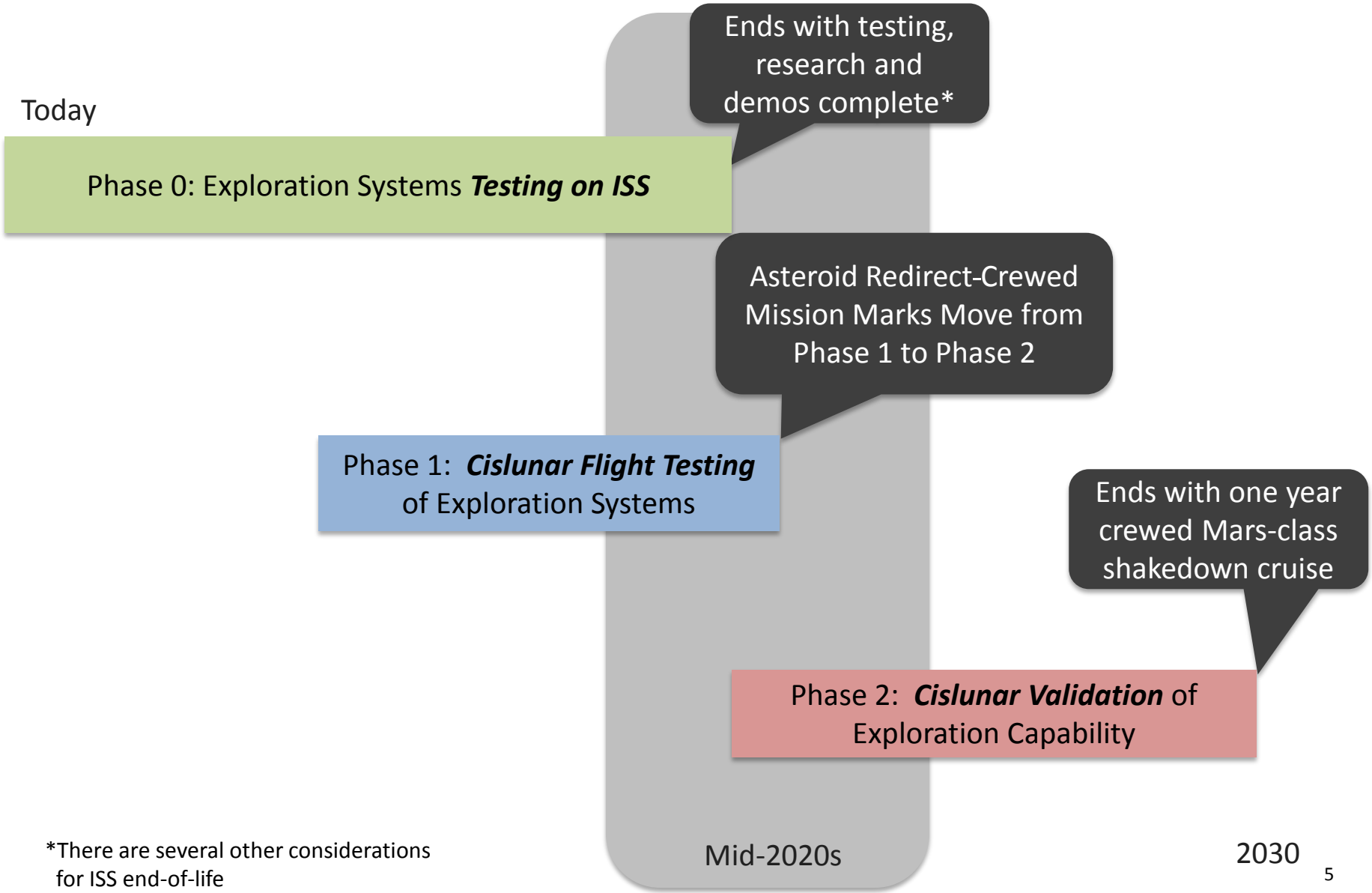
Wednesday, March 2nd 2016

- Human Exploration Progress and Plans
  - Human Spaceflight Transition Plans
  - ISS
  - Commercial Crew
  - Exploration Systems Development
  - ARM

Thursday, March 3rd 2016

- Budget Status
- Program Management Process Update
- Committee Discussion and Deliberation

Transition from ISS to Cislunar Space: Framework



*There are several other considerations for ISS end-of-life

International Space Station Status
HEO NAC

Sam Scimemi/Director, ISS
March 2016

ISS Flight Plan

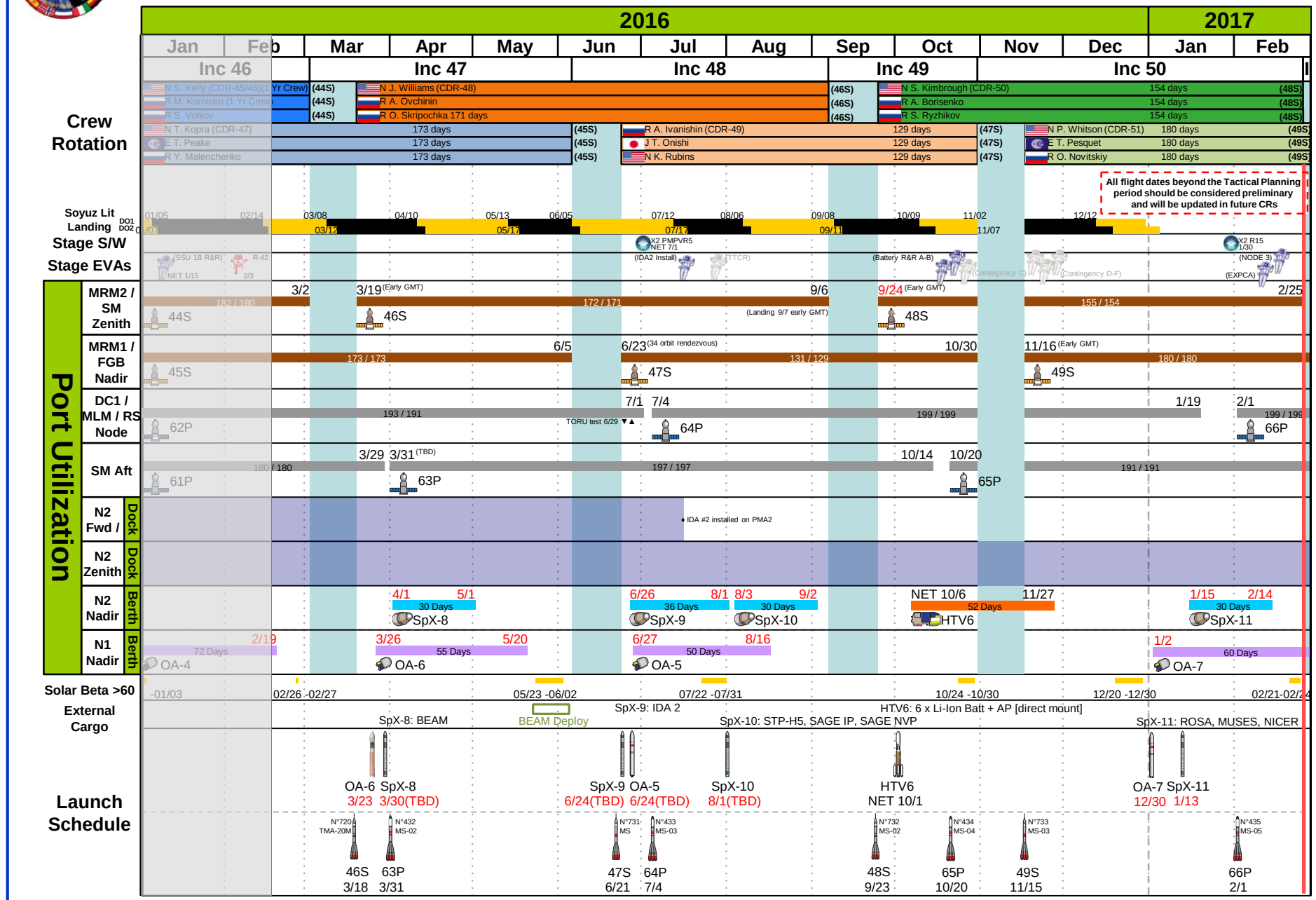
Flight Planning Integration Panel (FPIP)

(Pre-decisional, For Internal Use, For Reference Only)

For current baseline refer to SSP 54100 Multi Increment Planning Document (MIPD)

NASA: OC4/John Coggeshall
MAPI: OP/Randy Morgan

Chart Updated: February 18th, 2016



Increment 47 Overview: Crew

45S Dock 12/15/15
45S Undock 6/5/16 (“in work” FPIP)

Tim Kopra
CDR Inc 47 (US) - 45S

Yuri Malenchenko
FE (R) – 45S

Tim Peake
FE (E) – 45S

46S Dock 3/19/16 (“in work” FPIP)
46S Undock 9/7/16 (“in work” FPIP)

Jeff Williams
FE (US) – 46S
(CDR Inc. 48)

Oleg Skripochka
FE (R) – 45S

Alexey Ovchinin
FE (R) – 46S

Increments 47 & 48 Research Plan - Investigation List

Human Research

Bone & Muscle Physiology
Bisphosphonates (Control), Sprint, Marrow, Tbone (P), Brain-DTI (P), CARTILAGE (P), EDOS-2, Muscle Biopsy (P)

Cardiovascular & Respiratory Systems
Cardio Ox, Vascular Echo, Airway Monitoring, IPVI

Crew Healthcare Systems
Skin-B

Habitability & Human Factors
Body Measures, Fine Motor Skills, Habitability

Human Behavior & Performance
Cognition, At Home in Space, Circadian Rhythms
Synergy (P)

Human Microbiome
Microbiome

Immune System
Salivary Markers, IMMUNO-2, Multi-Omics

Integrated Physiology & Nutrition
Biochem Profile, Telomeres (P), Repository, Dose Tracker, Energy, MARES
Biological Rhythms 48hrs

Nervous & Vestibular Systems
NeuroMapping, Field Test (P)
Space Headaches, Straight Ahead in Microgravity (P)

Vision
Fluid Shifts, Ocular Health

Biology and Biotechnology

Animal Biology
Rodent Research-3
Space Pup, Mouse Epigenetics-1

Cellular Biology
Micro 9, Micro 10, NanoRacks Mod-28, Heart Cells*, WetLab-2
Stem Cells, Cell Mechanosensing-3
Spheroids, Cytoskeleton

Macromolecular Crystal Growth
CASIS PCG 4, NanoRacks PCG, PCG Crystal Hotel, JAXA PCG Demo 2, JAXA PCG

Microbiology
Microbe-IV , Myco, BRIC-NP*, BRIC-23*
Microbial Observatory-2

Plant Biology
Auxin Transport
Plant RNA Regulation*
Veg-03
NanoRacks Mod -33 (Agar)
Plant Gravi Sensing-3

Physical Sciences

Combustion Science
Cool Flame Investigation (CFI), FLEX 2*

Complex Fluids
ACE H2*, ACE T-1
ACE T-9*

Fluid Physics
Marangoni-UVP, Two-Phase Flow, ZBOT, PBRE* Microchannel Diffusion

Fundamental Physics
DOSIS-3D

Materials Science
EML Batch – 1 & 2 , MSL 2b, SODI
DSC Mix*,Manufacturing Device, Synthetic Muscle*, NanoRacks Module -40*,ELF Batch #3,4

Earth & Space Science

Astrobiology/Astrophysics/Heliophysics
AMS-02 (E), Meteor, NanoRacks Mod-24*, Solar-SOLACES/SOLSPEC (E)
CALET (E)[4], MAXI (E)

Earth Remote Sensing
CATS (E), HICO-RAIDS (HREP) (E), ISS-RapidScat (E)
NREP Inserts

Near-Earth Space Environment
SEDA-AP (E), Ex-HAM #1 (E), #2 (E)

Technology Development and Demonstration

Characterizing Experiment Hardware
ESA-Haptics-1,-2*, IN SITU (ASI), Biomolecular Sequencer, NanoRacks Mod-29*, MVIS Microcontroller -1

Communications & Navigation
METERON , Vessel ID System, Maritime Awareness*, Scan Testbed, OPALS

Fire Suppression and Detection
Saffire I/II

Multipurpose
Programmable Isolation Mount*

Power and Thermal Management Systems
Phase Change HX, Universal Battery Charger.

Radiation Measurements & Shielding
Area PADLES, PS-TEPC, Radi-N2, REM

Avionics & Software
SNFM, Telescience Resource Kit*

Life Support and Habitation
Mini Exercise Device-2, UBNT

Air, Water and Surface Sampling
Personal CO2 Monitor*

Robotics & Imaging
HDEV (E), Gecko Gripper*, Robonaut, RRM Phase 2 (E)

Spacecraft and Orbital Environments
Strata-1, REALM, SPHERES Halo*
SPHERES Tether*

Space Structures and Materials
BEAM, Manufacturing Device, REBR-W

Small Satellites & Control Technologies
NanoRacks NRCSD ext*, JSSODM-1, JSSOD#5, EFU Adapter RTcMISS, SPHERES UDP*, SPHERES Slosh*

Educational Activities

Educational Competitions
SPHERES-Zero-Robotics

Educational Demos
ESA-EPO-PEAKE, ISS Ham Radio, Story Time Demo*
JAXA EPO
Sally Ride EarthKAM

Student-Developed Investigations
CASIS Edu 3, NR Modules-16, -18, -20, -21, -22, -51
NanoRacks Module-9, Mod-48*, NR SMiLE*, Genes in Space*

Classroom Versions of ISS Investigations
Windows on Earth

To Be Defined
Payload Card-X, JAXA Commercial, JAXA EFU Adapter and HDTV

Key: NASA, NatLab, CSA, ESA, JAXA

↓Ascent/Descent, **(P)** Pre/Post only, * Added by CEF, **(E)** External Payload

Total ISS Consumables Status

Consumable – based on current, ISS system status	T1: Current Capability		T2: Current Capability + OA-6	
	Date to Reserve Level	Date to zero supplies	Date to Reserve Level	Date to zero supplies
Food – 100%	June 24, 2016	August 10, 2016	August 18, 2016	October 14, 2016
KTO	August 05, 2016	September 27, 2016	September 17, 2016	November 09, 2016
Filter Inserts	January 18, 2017	> January 31, 2017	> January 31, 2017	> January 31, 2017
Toilet (ACY) Inserts	August 06, 2016	September 29, 2016	October 04, 2016	November 26, 2016
EDV + TUBSS (UPA Operable)	December 10, 2016	> January 31, 2017	December 27, 2016	> January 31, 2017
Pre-Treat Tank	August 31, 2016	> January 31, 2017	August 31, 2016	> January 31, 2017
Water (Nominal Usage)	September 05, 2016	December 28, 2016	September 05, 2016	December 28, 2016
Consumable - based on system failure				
EDV + TUBSS (UPA Failed)	July 31, 2016	September 25, 2016	August 09, 2016	October 04, 2016
Water, if no WPA (Ag & Iodinated)	June 25, 2016	August 29, 2016	June 25, 2016	August 29, 2016
O_2 if Elektron supporting 3 crew & no OGA	February 28, 2016	July 26, 2016	March 31, 2016	August 10, 2016
O_2 if neither Elektron or OGA	February 09, 2016	April 15, 2016	February 09, 2016	April 23, 2016
LiOH (CDRAs and Vozdukh off)	~0 Days	~14 Days	~0 Days	~14 Days

Human Exploration and Operations

Human Research Program:
Human Risks Disposition for all Design Reference Missions

	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
Human System Risks 07/01/15	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/Habitation	Deep Space Journey/Habitation	Planetary	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/Habitation	Deep Space Journey/ Habitation	Planetary
	6 Months	12 Months	30 Days	1 year	1 Year	3 years	6 Months	12 Months	30 Days	1 year	1 Year	3 years
VIIP	A	A	A	A	RM	RM	A	A	A	A	RM	RM
Renal Stone Formation	A	A	A	A	RM	RM	RM	RM	RM	RM	RM	RM
Inadequate Food and Nutrition	A	A	A	A	A	RM	A	A	A	A	A	RM
Space Radiation Exposure	A	A	A	A	A	TBD*	A	A	A	RM	RM	RM
Medications Long Term Storage	A	A	A	A	A	RM	A	A	A	A	A	RM
Acute and Chronic Carbon Dioxide	A	A	A	A	RM	RM	A	A	A	A	A	A
Inflight Medical Conditions	A	A	A	RM	RM	RM	A	A	A	RM	RM	RM
Cognitive or Behavioral Conditions	A	RM	A	RM	RM	RM	A	A	A	A	A	RM
Bone Fracture	A	A	A	A	A	RM	A	A	A	A	A	A
Human-System Interaction Design	A	A	A	RM	RM	RM	A	A	A	A	A	A
Team Performance Decrements	A	A	A	A	RM	RM	A	A	A	A	A	A
Cardiac Rhythm Problems- Under Review	A	A	A	A	RM	RM	A	A	A	A	A	A
Reduced Muscle Mass, Strength	A	A	A	A	A	RM	A	A	A	A	A	RM
Reduced Aerobic Capacity	A	A	A	A	A	RM	A	A	A	A	A	RM
Sensorimotor Alterations	A	A	A	RM	RM	RM	A	A	A	A	A	RM
Injury from Dynamic Loads	A	A	RM	RM	RM	RM	A	A	RM	RM	RM	RM
Sleep Loss	A	A	A	A	RM	RM	A	A	A	A	RM	RM
Altered Immune Response	A	A	A	A	A	RM	A	A	A	A	A	RM
Celestial Dust Exposure	N/A	N/A	TBD	A	TBD	TBD	N/A	N/A	TBD	A	TBD	TBD
Host-Microorganism Interactions	A	A	A	A	A	RM	A	A	A	A	A	RM
Injury due to EVA Operations	A	A	A	RM	A	RM	A	A	A	RM	A	RM
Decompression Sickness	A	A	RM	A	RM	A	A	A	A	RM	A	RM
Toxic Exposure	A	A	A	A	A	A	A	A	A	A	A	A
Hypobaric Hypoxia	RM	RM	A	RM	RM	RM	RM	RM	A	RM	RM	RM
Space Adaptation Back Pain	A	A	A	A	A	A	N/A	N/A	N/A	N/A	N/A	N/A
Urinary Retention	A	A	A	A	A	A	A	A	A	A	A	A
Hearing Loss Related to Spaceflight	A	A	A	A	A	A	A	A	A	A	A	A
Orthostatic Intolerance	A	A	A	A	A	A	A	A	A	A	A	A
Injury from Sunlight Exposure	A	A	A	A	A	A	A	A	A	A	A	A
Electrical shock	A	A	A	A	A	A	A	A	A	A	A	A
Concern of Intervertebral Disc Damage upon and immediately after re-exposure to Gravity												
Concern of Medication PK/PD												

A - Accepted based on current standards & countermeasures

RM - Requires Mitigation

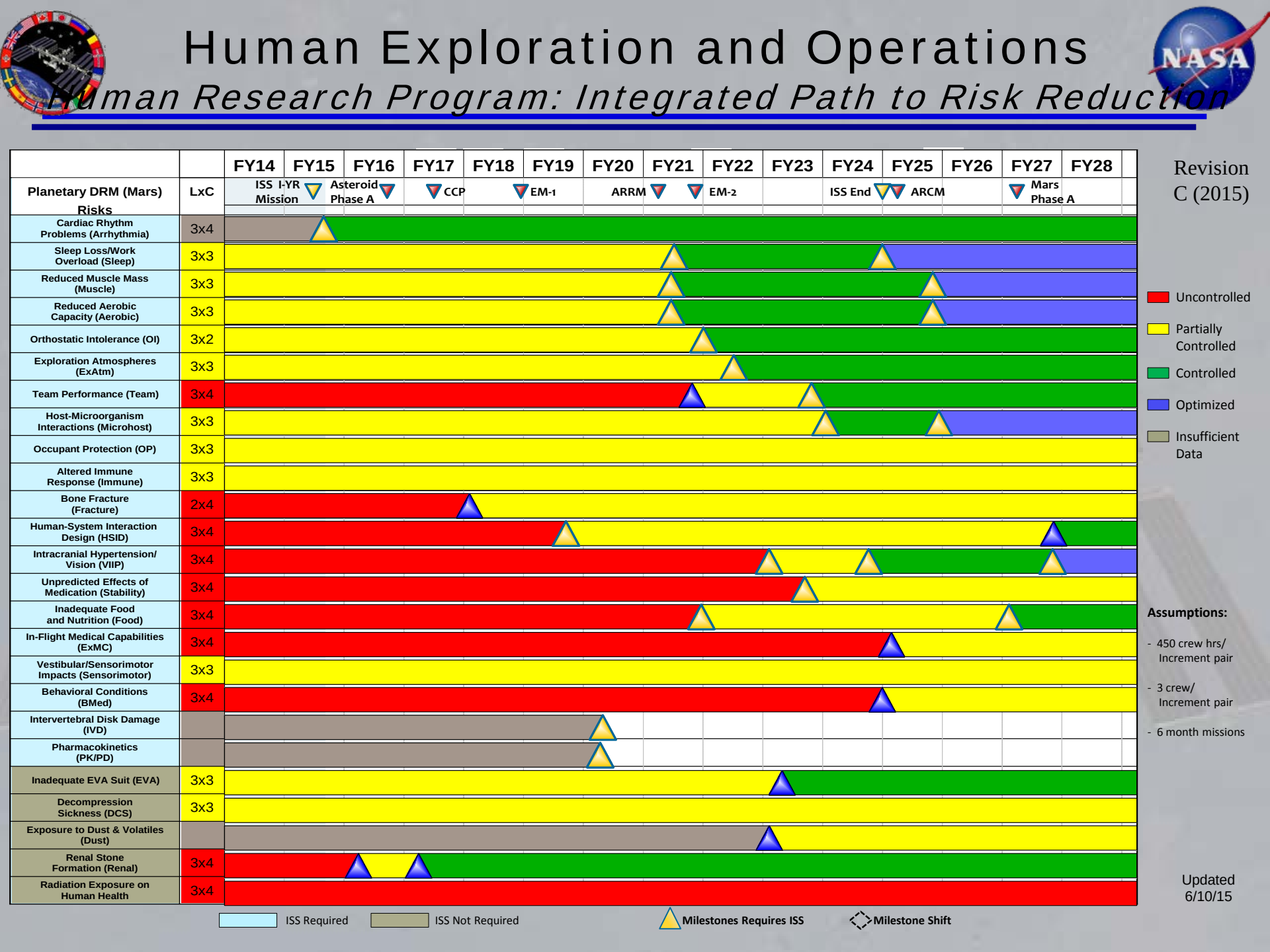
TBD* - Disposition to be officially determined by the HSRB in the near future

TBD - DRMs have not been assessed to provide rating and disposition

Green – low/very low consequence Yellow – low to medium consequence Red – high consequence

Human Exploration and Operations

Human Research Program: Integrated Path to Risk Reduction



Revision C (2015)

- Uncontrolled
- Partially Controlled
- Controlled
- Optimized
- Insufficient Data

Assumptions:

- 450 crew hrs/ Increment pair
- 3 crew/ Increment pair
- 6 month missions

Updated 6/10/15

EVA 35 SEMU 3011 Anomaly

- During EVA 35 on 1/15/16, EV1/Kopra reported water in his EMU helmet at PET 4:07 and the decision was made to terminate the EVA
  - Decision to terminate was made based on procedures and other operational products implemented after EVA 23
  - Following airlock repress the crew assessed the water in EV1's helmet
    - Rough estimate of total water is 200– 250 cc as compared to 1000-1500 cc on EVA 23
  - On-orbit troubleshooting was performed in order to learn more about the failure mechanism
    - Troubleshooting results indicated that the Fan/Pump/Separator (which was the cause of the EVA 23 anomaly) was performing nominally during the test
    - Troubleshooting also indicated that other parts of the EVA system were not leaking
      - Test results do not rule out an intermittent failure which could have occurred during EVA 35 and then cleared
      - Troubleshooting continues

Commercial Resupply Services CRS-2 Status

- **CRS-2 Contract award was announced on 1/14/16**
  - Awardees are Orbital-ATK, SpaceX, and Sierra Nevada Corporation
  - Contract post award briefings will be conducted in Mar/Apr
  - A minimum of six missions will be ordered from each provider
  - CRS-2 missions are planned for launch beginning in 2019
  - To bridge the launch gap, the current CRS contracts were extended to provide ordering through Dec 2018

Commercial Crew Program Status

Phil McAlister
NASA Headquarters
March 2, 2016

Highlights

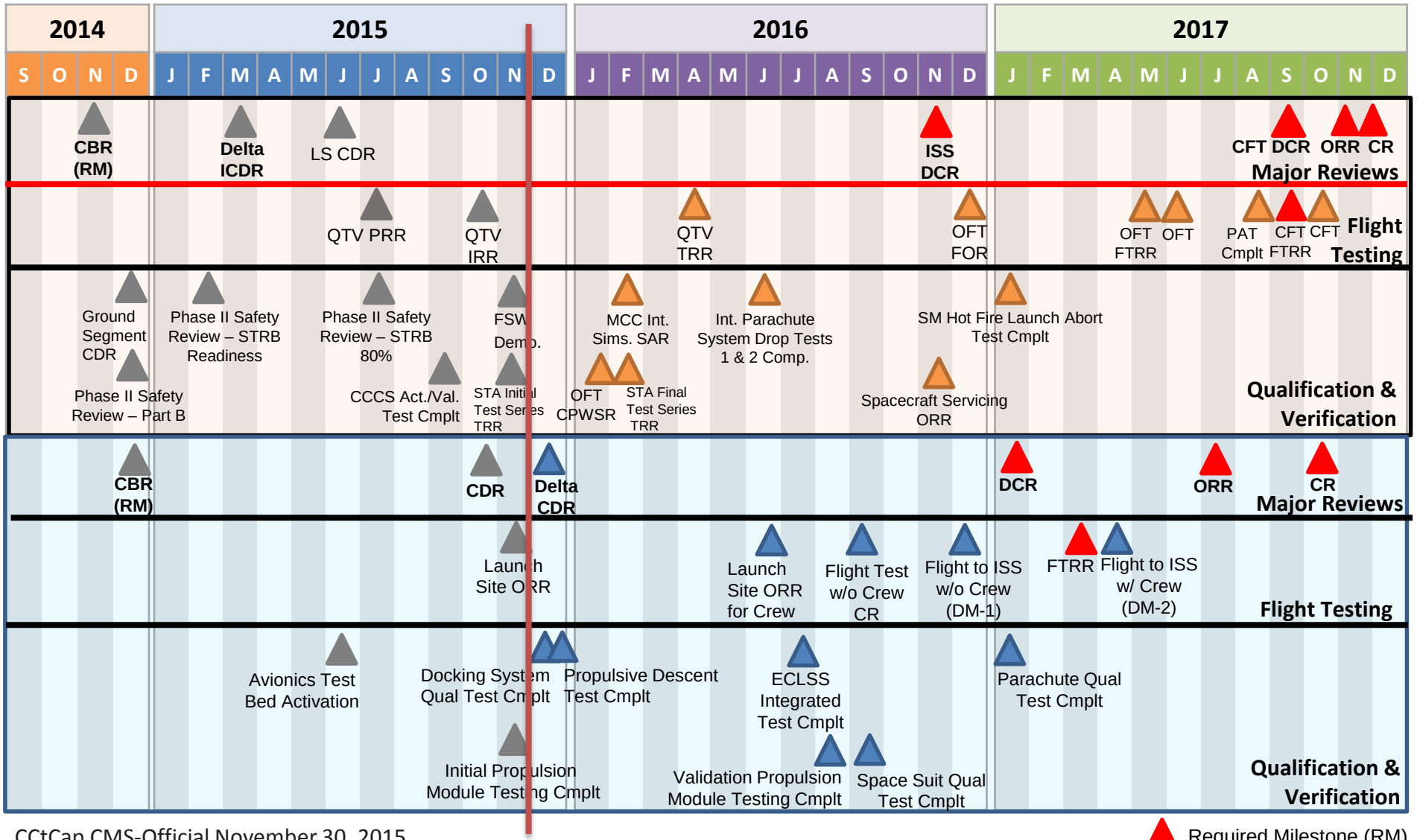
CCP has made significant progress over the last quarter, notably:

- **Continue to burn down key products with the providers**
  - Over 60% of the Alternate Standards have been dispositioned
  - Over 40% of the Variances have been dispositioned

- **Updated NASA Certification Plan and baselined the Certification of Flight Readiness (CoFR) Plan**

- **Awarded Post Certification Missions (PCMs)**
  - For SpaceX:
    - PCM-1 awarded November 2015; Completed one milestone to date
    - PCM-2 award expected in August 2016
  - For Boeing:
    - PCM-1 awarded May 2015; Completed three milestones to date
    - PCM-2 awarded in December 2015; Completed one milestone to date

CCtCap Combined Milestone Summary



CCtCap CMS-Official November 30, 2015

Required Milestone (RM)

Boeing Milestone

SpaceX Milestone.

Summary

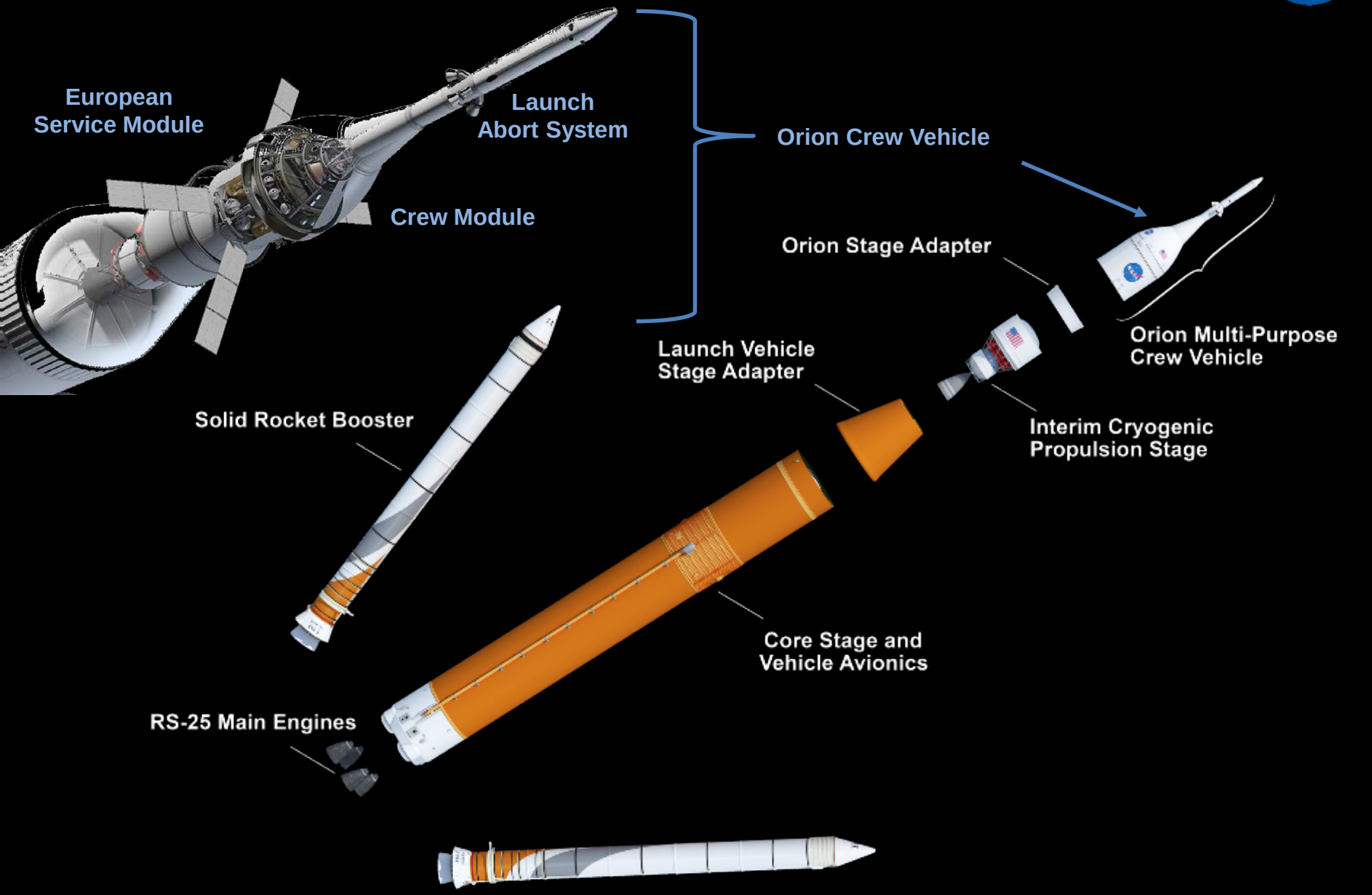
- **Boeing and SpaceX are advancing their design concepts**
  - Actively building and testing hardware to inform design
  - Engaging in meaningful insight with NASA
  - Addressing important design challenges
- **CCP has robust and efficient processes for certification including addressing waivers and deviations**
- **In preparation for flight, there is significant work ahead**




Exploration Systems Development

NASA Advisory Council Meeting
March 2, 2016

EM-1 Vehicle Stack



Space Launch System Accomplishments

Launch Vehicle Stage Adapter Test Article Fabrication

Nozzle installation into the aft booster segment for QM-2

RS-25 flight engine 2059 installed for testing at Stennis Space Center

Steel towers rising for new SLS test stands at Marshall Space Flight Center

SLS Core Stage test article progress, Michoud Assembly Facility

Interim Cryogenic Propulsion Stage test article complete

Ground Systems Development & Operations Accomplishments

First Work Platform for Space Launch System Installed in VAB

Conducted the Critical Design Review

Completed Phase A Testing of the Orion Service Module Umbilical

Started Construction of Flame Trench at Launch Pad B

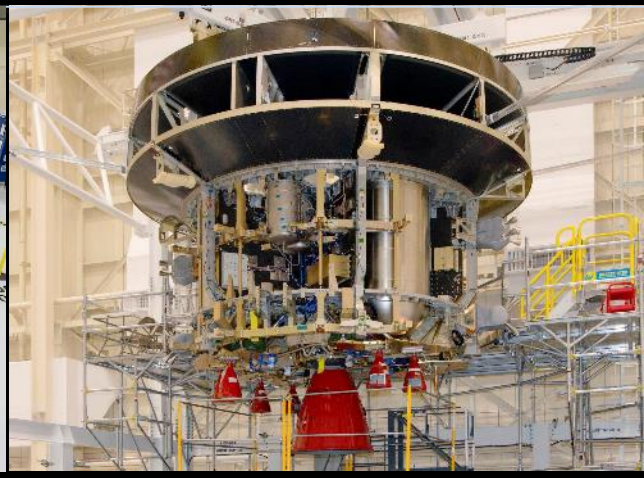
Completed Command and Control Software Release 3.2

Received First Shipment of Booster Pathfinder Hardware for V&V Testing at RPSF

Orion Accomplishments

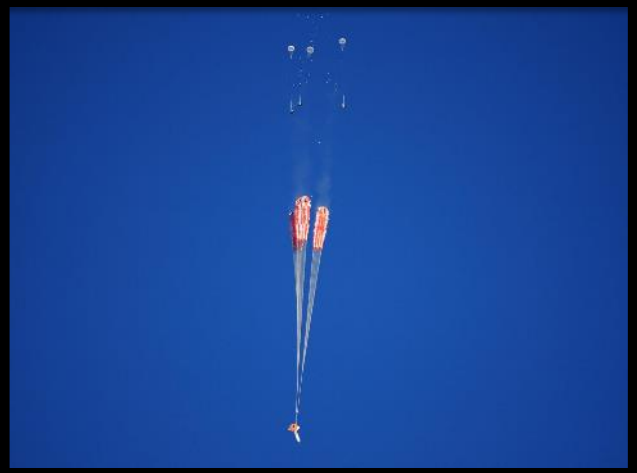
Orion EM-1 crew module pressure vessel welding is completed at Michoud Assembly Facility in New Orleans

The completed pressure vessel arrives at the Operations and Checkout Building at the Kennedy Space Center

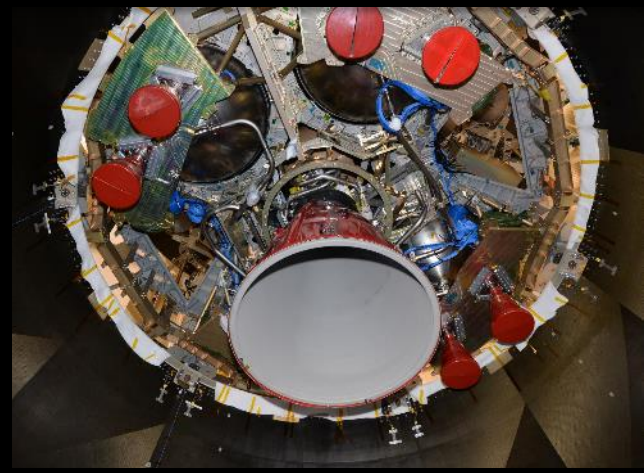


European Service Module Structural Test Article (ESM STA) at Glenn Research Center Plum Brook Station in Ohio

Launch Abort Motor structural qualification test at Orbital ATK in Utah



Final Engineering Parachute Drop Test, Army Yuma Proving Ground in Arizona



Orbital Maneuvering Engine on the ESM STA at Glenn Research Center Plum Brook Station in Ohio

Based on Month-End December 2015

ESD EM-1 INTEGRATED MISSION MILESTONE SUMMARY

NASA ESD
Chart Updated: 2/2/2016

2015 | 2016 | 2017 | 2018 | 2019

J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J

ENTERPRISE

HEO / ESD: Design-to Sync K/O; Build-to Sync K/O; Build-to Sync Board; MIR (U/R); Integration Review; Agency FRR; EM-1 Uncrewed; Post Flight Assessment & Review (PFAR)

GSDO: CDR K/O; CDR Board; RPSF ORD; VAB Stacking ORD; Spacecraft Offline ORD; ITCO/Pad/Landing & Recovery ORD; Launch Readiness Window

Integrated Launch Readiness Date No Later Than Nov 2018

Orion: KDP-C DPMC; CDR K/O; CDR Board; ESM CDR (U/R); ESM Integration TRR

SLS: SPIE CDR Board Pt.1; CDR K/O; CDR Board; SPIE CDR Board Pt.2; Booster DCR Board; SPIE DCR Board; SLS DCR Board; CS DCR Board

ELEMENT | LOCATION

Orion S/W — ITL
Flight S/W PDR Board; ITL-01: Core EGSE & Lab Infrastructure Complete; ITL 02: Dual String C&DH Integration Complete; ESM S/W Emulator Delivery; Orion Emulator delivery to SLS; ITL-03a CM Power-On Procedure Valid. Complete; ITL 03b CSM Power-On Procedure Valid. Complete; ITL-04 External I/F Integration Complete; Final Flight S/W Release

LAS — LM → LASF
ACM Mass Sim. Start; AM Mass Sim. Start; EM-1 Ogive Production Start; EM-1 JM Build start; LAS AM & ACM Assy Complete; JM Delivery to KSC (LASF); LAS AM & ACM Mass Sim. Del. to KSC (LASF); LAS & Ogive Del. to GSDO; CSM/LAS/MSA Integration @LASF

CM — MAF → O&C
First EDU Power Dist. Unit Delivered; First CM Pathfinder Weld; Heat Shield Design Complete; CM Structure Delivery to O&C; CM Pressure Proof Test; CM Prop Proof & Leak Test; Initial Power On (IPO); EM-1 CM/SM Mate; CSM Delivery to GSDO; CSM to O&C; CSM to LASF; First EM-1 Weld (tunnel to bulkhead); ESM STA Arrival at Plum Brook; PB; CSM to Plumbrook for T-Vac; MPPF; Post-Flight CM Transport & Deservicing (EM-1)

ESA SM — PB → Torino/Bremen
ESM STA Ready for Test; ESM STA Plum Brook Testing Complete; ESM European Testing Complete; ESM Delivery to O&C; ESM FM-1 Structural Assy Complete; ICPS to VAB; Orion/MSA to VAB

ICPS — ULA
ICPS Flight Unit 1 Production Start; ICPS STA Production Complete; ICPS Flight Unit 1 Production Complete; ICPS/LVSA/MSA Integ. STA Structural Test Complete; ICPS Delivery to GSDO

MSA/LVSA — MSFC
MSA Flight Unit 1 Production Start; LVSA Flight Unit 1 Production Start; LVSA STA Production Complete; Flight LVSA Assy Operations at AWF Complete; LVSA Flight Unit1 Production Complete; MSA Flight Unit 1 Production Complete; MSA Delivery to GSDO; LVSA Delivery to GSDO; PAD 39B; Final Pad Ops; Roll-out #1 and DRT; Roll-out For Launch

Core Stage — MAF → VAB HB3
VAC Base Plate Alignment; ESAB VAC Handover (to Boeing); Start VAC Weld Confidence Article; Flight IT Panels to MAF; VAC Welding Complete; LOx, ES, LH2, IT STA Test Fac. Complete; SITF-Q Testing Complete; Start CS1 Final Integration; Core Stage to SSC; Start SITF-Q Testing; CS1 STA VAC Welds Complete; Engine Controller EM5 Del. to SSC; Dev. Testing Complete; SSC B-2; B-2 Activation; CS1 Green Run Hotfire (U/R); CS1 Fill & Drain Test; Core Stage Delivery to GSDO; Booster Integration *then* Core Stage Integration *then* Partial Modal Test *then* LVSA & ICPS Integration *then* Orion Integration *then* Full Modal Test

Engines — AR
First SLS RS-25 EM-1 ECU Testing Complete; Engine Controller EM4 Del. to SSC; Flight Engine 1,2 Del. to MAF; Flight Engine 3,4 Del. to MAF; Fwd, Ctr, Aft Segs to GSDO

Boosters — ATK
QM-1 Static Test; Start Flight Motor Casing Refurb.; EM-1 Motor First Segment Cast (Aft); QM-2 Static Test; EM-1 Motor Aft Segments Complete; EM-1 Fwd/Ctr Segments Complete; RPSF; LH & RH SRB Ready for VAB; BFF; Booster Aft Skirts & Cones to GSDO; Fwd Assembly to GSDO

SLS S/W — SIL
SIL Infrastructure Build-up Complete; S/W Rel. 12 (Engineering Release); S/W Rel. 13 (Func Qual Test); SIL Certification; S/W Rel. 14 (Green Run & Flight); Vehicle Cert; S/W Regression Complete; SLS S/W Emulator Deliveries Complete

Ground — KSC/JSC
VAB Platform K Tower E Side Del.; Pad B Flame Trench/Def. Construction Start; VAB Ready for M-E V&V; Pad B Ready for M-E V&V; SCCS 3.0/3.2 Valid. Test Complete; Umbilical Install Complete; ML/VAB M-E V&V Complete; MPPF Ready for Spacecraft Offline SAR/ORR; MCC ORR; ML Structural Mods Complete; ML Ready for GSE Install; SCCS 3.0/3.2 System Test Complete; SCCS 3.3/3.4 Valid. Complete; SCCS 4.0 Verif. Complete; ML GSE Install Complete; Pad B Flame Trench/Deflector Construction Complete; SCCS 4.1 Valid. Complete; GFAST Ready (Flight)

KEY:
- Control Milestone
- Completed milestone
- Future milestone
- Indicates changed milestones
- Primary Critical Path
- Secondary Critical Path
- Tertiary Critical Path
- Software Critical Path
- Not on Critical Path
- (U/R) Under Review

For comments contact mark.e.ogles@nasa.gov

Exploration Systems Development Top Concerns

Concern	Current Status
Integrated avionics and software verification and validation (V&V), Integrated Test Lab (ITL) capacity, distributed V&V process, emulator performance, agile software development process productively metrics and cross-program interdependencies.	In-work: Limited deferred content and re-planning has occurred and is a watch item, Integrated Avionics Software-Integrated Technical Team (IAS ITT) metrics established. ITL use improving.
Integrated test and verification (T&V) plan involving distributed multi-site activities such as structural dynamics testing, environmental test, and functional check out leading to integrated flight certification traceable to requirements closure and Certification of Flight Readiness (COFR) with sufficient resources and test.	In-work: CDRs data informing T&V, Enterprise V&V Team (EVVT) focus planning in work, T&V resources a watch item, T&V activities are currently in progress.
Funding uncertainty impacts to program/cross-program technical integration.	Improving: favorable FY 2016 appropriations received. Funding uncertainty for out years remains a watch item.
Schedule threats related to integrated critical path: Orion Command Module (CM) and European Space Agency (ESA) service module, core stage delivery for green run, readiness of ground software to support final system integration.	Watch item: ESA SM CDR and FM-1 delivery to Bremen under review. GSDO GFAS re-plan, and SLS post VAC ATP are watch items.
GSDO mobile launch outfitting and V&V including ground system control software/Ground Flight Application Software (GFAS) and dependencies on cross-program flight/ground hardware interfaces and software. Ground processing first flight learning curve.	In-work: GFAS re-plan complete but post re-plan status is a watch item, final dependency agreements are still in work. Platforms and Mobile Launcher are making progress.
Orion ESA Service Module (ESM) prop system redundancy and associated impacts on schedule/CDR completion. CM/ESM structural analysis and environmental T&V planning and resource availability for parallel Operations and Checkout (O&C) and GRC work, flight computer processor throughput, preparations for CM outfitting at O&C.	Orion T&V plan to be completed by March, ESA CDR delay and FM delivery to Bremen under review, ESM prop redundancy issues resolved by NLT design implementation, T&V resources a watch item.
SLS implementation of post VAC ATP welding and assembly operations at MAF through green run test. SLS ascent acoustic loads analysis. Interim Cryogenic Propulsion Stage (ICPS) safety analysis to support EM-1. EUS design development for EM-2.	Improving: VAC weld schedules complete, weld confidence articles in work. EUS is baseline for EM-2. Green run test schedule under review.
Long term productions and operations sustainability at the rate of 1 flight per year after EM-2 by reducing cost. Mission planning for EM-2 and beyond including on-ramp for low-cost opportunities for development tech objectives and capability enhancements. EM-2 co-manifested payload options being evaluated.	P&O Study as part of PPBE to further identify cost reduction opportunities, numerous program efforts also in work. Dedicated mission planning team established. Mission planning resources - watch item.
On-orbit Micro Meteoroid and Orbital Debris (MMOD) exposure risk and related mission planning including EM-2 first crewed flight trajectory options.	In-work: MMOD environment, vehicle susceptibility, and EM-2 mission profile being evaluated.

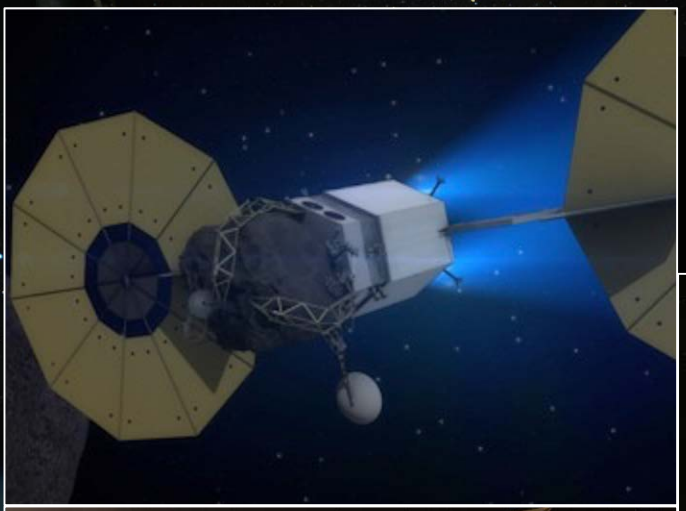
National Aeronautics and Space Administration

Asteroid Redirect Mission Update

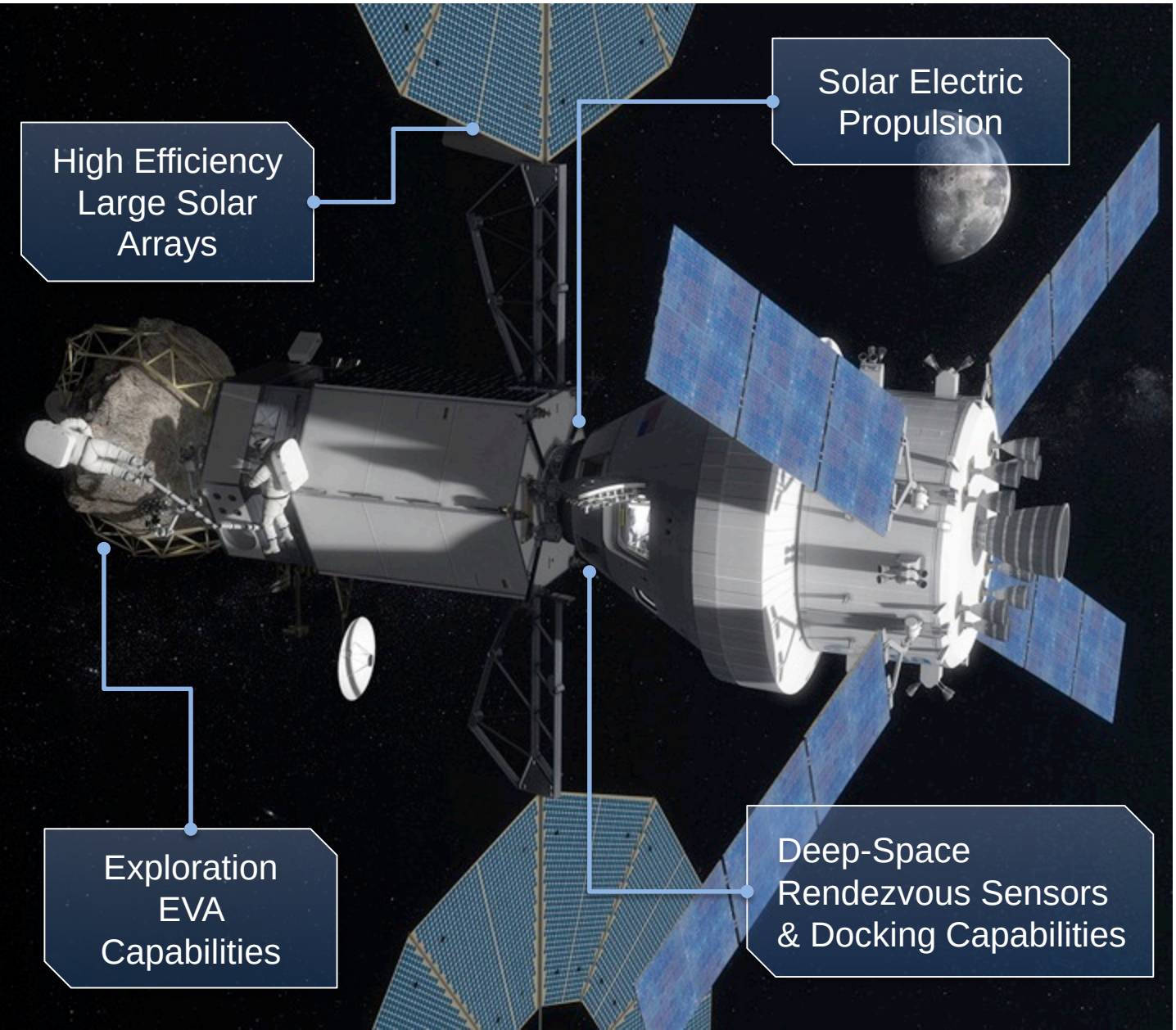
NAC Human Exploration and Operations Committee

Dr. Michele Gates

March 2, 2016



ARM: An Early Mission in the Proving Ground of Cislunar Space



IN-SPACE POWER & PROPULSION:

- High efficiency 40kW SEP extensible to Mars cargo missions
- Power enhancements feed forward to deep-space habitats and transit vehicles

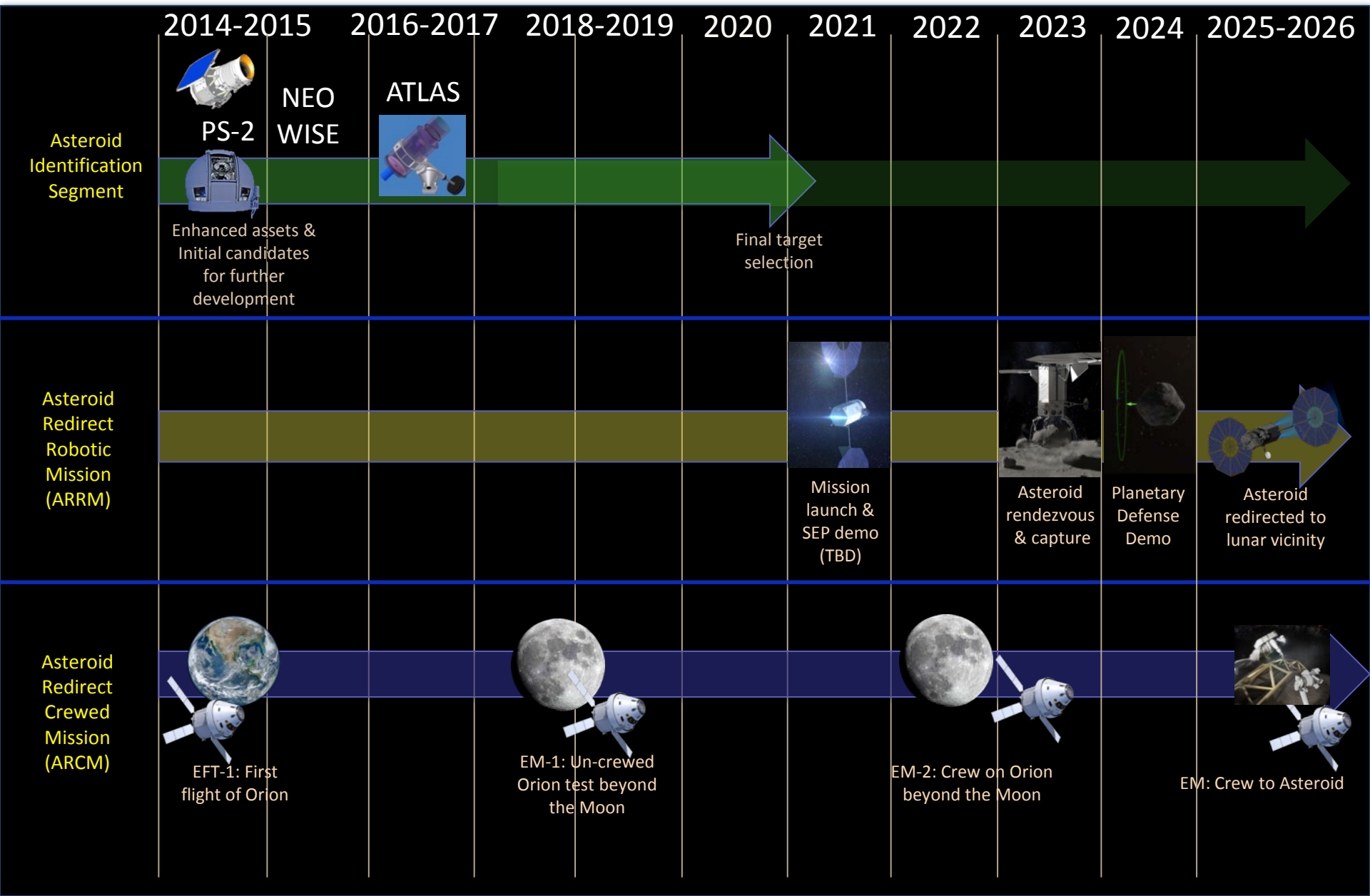
EXTRAVEHICULAR ACTIVITIES:

- Two in-space EVAs of four hours each
- Primary Life Support System design accommodates Mars
- Sample selection, collection, containment, and return

TRANSPORTATION & OPERATIONS:

- Capture and control of non-cooperative objects
- Common rendezvous sensors and docking systems for deep space
- Cislunar operations are proving ground for deep space operations, trajectory, and navigation

Asteroid Redirect Mission Alignment Strategy



ARRM Formulation Guidance Update Feb 3

Updated Formulation Guidance toward ARRM KDP-B*

- **Revised draft Level 1 requirements Target robotic mission launch date Dec 2021**
- **Robotic mission cost cap $1.25B not including launch vehicle and mission operations (Phase E)**
- **Target crewed mission launch date by Dec 2026**

* Target Dates are expected to continue to be refined as the mission proceeds through formulation.

Formulation Assessment and Support Team and Investigation Team

- **ARM Formulation Assessment and Support Team (FAST) effort completed.**
  - Two-month effort to support the ARRM Requirements Closure Technical Interchange Meeting on December 15-16, 2015.
  - 18 scientists and engineers selected from 100 applicants from academia and industry along with three NASA leaders.
  - Draft report made available for public comment.
  - Final report, including public comments, released on February 18, 2016.

FAST & ARRM Project Team Members.

- **ARM Investigation Team (IT) and coordination with additional ARRM investigations and associated hardware is in process.**
  - Call for membership planned following KDP-B.
  - IT will include domestic and international participation.
  - IT will support ARM through mission implementation, which includes the operational phases of both the ARRM and the ARCM.

Formulation Assessment and Support Team (FAST)

Organization
NASA Langley Research Center (Mission Investigator)
NASA Johnson Space Center (Deputy Investigator)
NASA Langley Research Center (IT Analysis and Integration Lead)
Arizona State University
Penn State University
Arizona State University
Southwest Research Institute
University of Central Florida
University of Central Florida
Jet Propulsion Laboratory
John Hopkins University-Applied Physics Laboratory
NASA Johnson Space Center
Missouri University of Science and Technology
NASA Goddard Space Flight Center
University of Maryland
Planetary Science Institute
NASA Goddard Space Flight Center
University of Colorado
TransAstra
United States Geological Survey
Honeybee Robotics

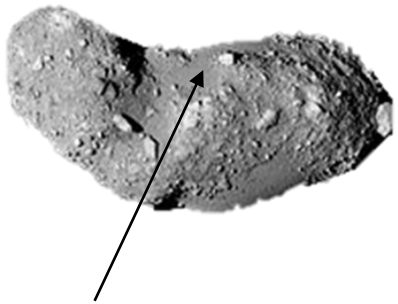
FAST Leadership

FAST Participants

- **Provided information on the nature of the asteroid target and boulders**
- **Provided ideas and recommendations to enhance the scientific return including a wide range of observations and instruments**

Current Candidate Parent Asteroids

ITOKAWA

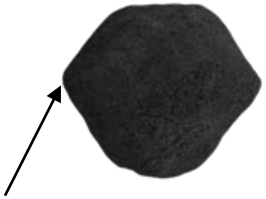


Muses C –
Hayabusa landing

BENNU

Radar –
OSIRIS-REx target

2008 EV5



Radar – boulders and extremely pronounced bulge at equator suggests movement of loose material

1999 JU3

Expected valid target - Hayabusa 2 target

Asteroids not to scale

Comparison of current candidate parent asteroids

	Itokawa	Bennu	2008 EV_5	1999 JU_3
Size	535 x 294 x 209 m	492 x 508 x 546 m	420 x 410 x 390 m	870 m diameter
V_∞	5.68 km/s	6.36 km/s	4.41 km/s	5.08 km/s
Aphelion	1.70 AU	1.36 AU	1.04 AU	1.42 AU
Spin Period	12.13 hr	4.297 hr	3.725 hr	7.627 hr
Type	S	B (C-grp volatile rich)	C (volatile rich)	C (volatile rich)
Precursor	Hayabusa (2005)	OSIRIS-REx (9/2016 launch, 8/2018 arrival)	None currently planned (boulders implied from 2008 radar imaging)	Hayabusa 2 (launched 12/4/2014, 7/2018 arrival)

NASA continues to look for additional targets in accessible orbits.

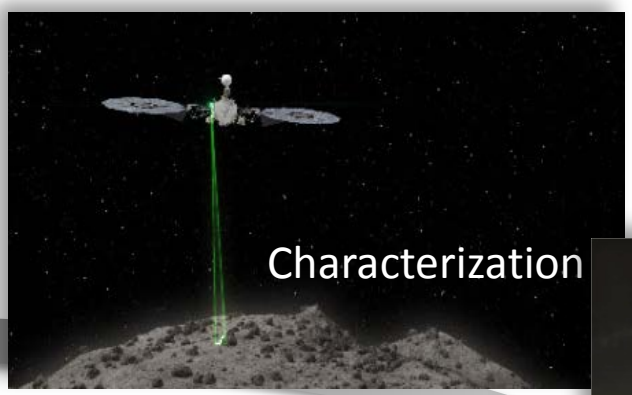
Reference ARRM Target

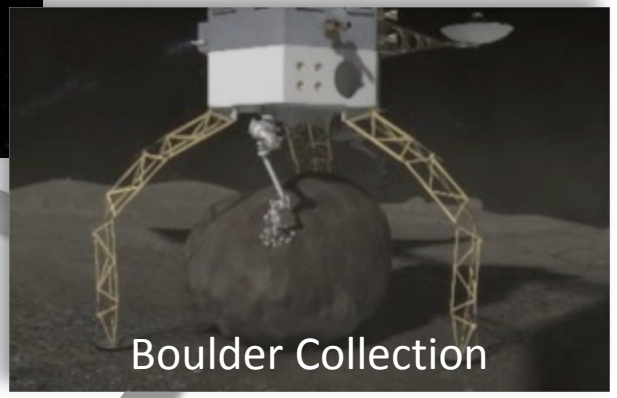
Capture Phase Overview
Asteroid Redirect Robotic Mission

Approach
14 days

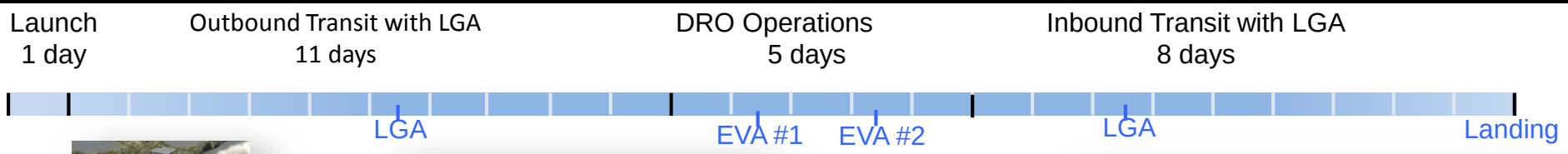
Characterization
85 days

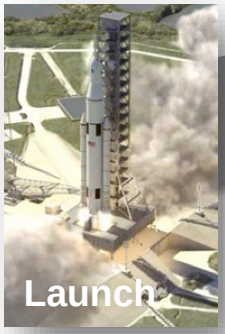
Boulder Collection
60 days + 30 day margin

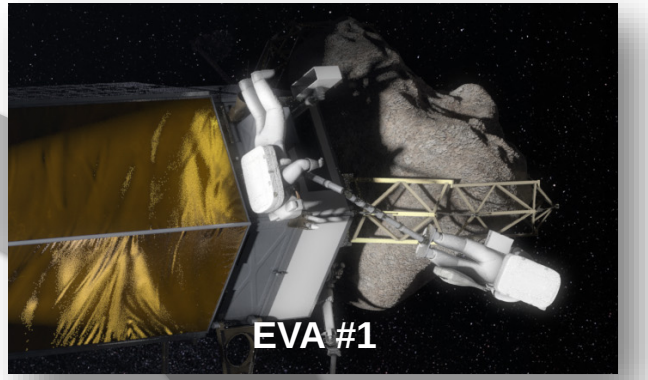




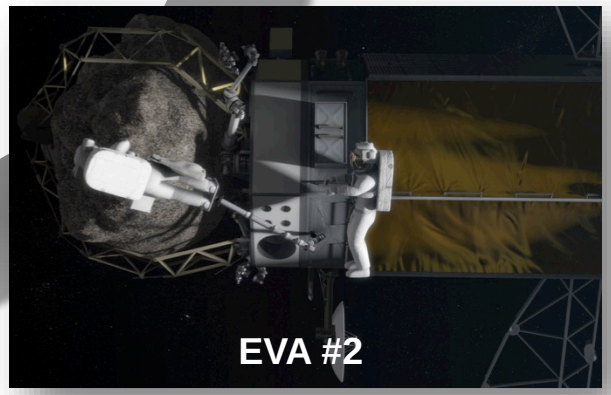
Asteroid Redirect Crewed Mission Summary







- Total mission duration 24.3 Days
- A 2-person crew is launched aboard an Orion augmented with the ARCM mission kits.
- Rendezvous and dock with the robotic spacecraft in a ~ 71,000 km lunar DRO.
- Conduct 2 four-hour EVAs to observe, document and collect asteroid samples.
  - Orion performs 20˚ yaw prior to EVAs to ensure proper EVA worksite thermal conditions and adequate space-to-ground communication coverage.
- Crew safely returns to Earth with samples.



Small Bodies Assessment Group Engagement

- **Summary briefing of the FAST effort provided at the 14th Meeting of the NASA Small Bodies Assessment Group (SBAG) on January 28, 2016.**

- **ARM draft finding was released by SBAG on February 4, 2016:**

"SBAG continues to appreciate NASA's efforts to engage and communicate with the planetary defense and small bodies science communities regarding the Asteroid Redirect Mission (ARM). **The 100 applications for the Formulation Assessment and Support Team (FAST) show the high level of interest of the community in participating in the formulation of ARM.** SBAG thanks the ARM team for creating the FAST and the community members that volunteered and were selected for the FAST, for the substantial work completed in a short timeframe. **SBAG encourages the continued engagement between the ARM team and the small bodies community as the mission moves forward and supports the plan for a competed opportunity this year to establish the Investigation Team membership.** Consistent with previous findings, for science-driven missions, SBAG continues to support the priorities identified in the Decadal Survey to guide use of Planetary Science Division (PSD) resources and funds."

SMPAG Statement on Asteroid Orbit Deflection Demos

- **Statement on Asteroid Orbit Deflection Demonstrations – agreed at the 6th Space Mission Planning Advisory Group meeting, February of 2016:**

  "Given the degree of international interest in asteroid research and awareness of the impact hazard, advantage should be taken of opportunities to investigate asteroid deflection physics, techniques and effects as a part of science and technology demonstration missions. While general science and technology efforts are vital, the Space Mission Planning Advisory Group (SMPAG) has identified the need to gain sufficient confidence in the viability of any proposed technique to deflect an asteroid from an impact trajectory. **Therefore the performance of the deflection technique to be utilized must have been actively demonstrated in a realistic planetary defence scenario to increase the current level of confidence.**

  The SMPAG encourages actual demonstration of the kinetic impactor technique with a space mission, as it appears at this point in time to be the most technologically mature method of asteroid deflection. **SMPAG also supports the investigation of the gravity tractor technique for demonstration as a part of any space mission using ion or other low-thrust propulsion technology planned to visit an asteroid.** SMPAG also encourages the investigation and technology maturation of other potential deflection and impact mitigation techniques to determine their viability, particularly in combination with other missions."

ARM Upcoming Events

- **Electric Propulsion Thruster and PPU contract award** **May 2016**

- **ARRM Key Decision Point – B** **Summer 2016**
- **Investigation Team Call Release** **Summer 2016**
- **Completion of study contracts and initiation of Phase 2 for spacecraft bus** **Summer 2016**
- **Actuated prototype of contact and restraint system complete** **Sep 2016**

Human Exploration and Operations Mission Directorate

Budget Status for
NASA Advisory Council
Human Exploration and Operations Committee

Toni Mumford
Director, HEO Resources Management Office

March 3, 2016

Human Exploration and Operations

Program Financial Plan

Budget Authority ($ in Millions)	Actual FY 2015	Enacted FY 2016	Request FY 2017	Notional FY 2018	Notional FY 2019	Notional FY 2020	Notional FY 2021
Human Exploration and Operations	**8,168**	**9,059**	**8,413**	**8,443**	**8,611**	**8,784**	**8,959**
Exploration	**3,543**	**4,030**	**3,337**	**3,530**	**4,082**	**4,244**	**4,262**
Exploration Systems Development	**3,212**	**3,680**	**2,860**	**2,923**	**3,062**	**3,092**	**3,142**
Orion	1,190	1,270	1,120	1,120	1,124	1,135	1,153
Space Launch System	1,679	2,000	1,310	1,361	1,485	1,500	1,524
Exploration Ground Systems	343	410	429	441	453	458	465
Exploration Research and Development	**331**	**350**	**477**	**607**	**1,020**	**1,151**	**1,119**
Human Research Program	142	-	153	178	178	180	183
Advanced Exploration Systems	189	-	324	429	842	971	937
Space Operations	**4,626**	**5,029**	**5,076**	**4,913**	**4,530**	**4,540**	**4,698**
Space Shuttle Program	**8**	-	-	-	-	-	-
Space Shuttle Program	8	-	-	-	-	-	-
International Space Station	**1,525**	-	**1,431**	**1,555**	**1,537**	**1,539**	**1,585**
ISS Systems Operations and Maintenance	1,113	-	1,109	1,246	1,196	1,193	1,233
ISS Research	412	-	322	309	340	347	353
Space Transportation	**2,254**	-	**2,758**	**2,475**	**2,119**	**2,144**	**2,214**
Commercial Crew	805	-	1,185	732	173	36	36
Crew and Cargo	1,449	-	1,573	1,743	1,946	2,109	2,178
Space and Flight Support	**839**	-	**887**	**883**	**874**	**856**	**899**
21st Century Space Launch Complex	35	-	12	-	-	-	-
Space Communications and Navigation	579	-	612	616	598	576	615
Human Space Flight Operations	100	-	128	130	140	142	144
Launch Services	81	-	87	89	89	90	91
Rocket Propulsion Test	44	-	48	48	48	48	49
Construction and Environmental Compliance	**87**	**36**	**37**	-	-	-	-
Exploration	**68**	**10**	**9**	-	-	-	-
Space Launch System	21	5	6	-	-	-	-
Exploration Ground Systems	47	5	3	-	-	-	-
Space Operations	**19**	**26**	**29**	-	-	-	-
International Space Station	-	6	-	-	-	-	-
21st Century Space Launch Complex	5	3	3	-	-	-	-
Space Communications and Navigation	14	18	24	-	-	-	-
Launch Services	1	-	1	-	-	-	-

FY 2015 reflects funding amounts specified in the September 2015 Operating Plan per Public Law 113-235.

FY 2016 reflects only funding amounts specified in Public Law 114-113, Consolidated Appropriations Act, 2016. FY 2016 funding levels are subject to change pending finalization of the FY 2016 Operating Plan.

FY 2017 includes $173 million in mandatory funding (Orion $66.4, SLS $80.4 and EGS $26.2).

Totals may not add due to rounding

Human Exploration and Operations

Budget Overview (continued)

- Establishes a new theme in Space Operations, Space Transportation, which includes Crew and Cargo and Commercial Crew Programs
- Purchases reliable cargo resupply services from U.S. private sector companies
- Develops U.S. commercial crew capability to ISS by the end of 2017, ending sole reliance on Russia for U.S. crew access to space
- Utilizes International Space Station (ISS) as a research and technology test platform through at least 2024
  - Provide advanced human systems research and technology to enable safe, reliable, and productive human exploration beyond LEO required for Journey to Mars
  - Enable National Laboratory for commercial research and other government agencies
- Provides mission-critical enabling capabilities for HEO, other NASA, and other U.S. Government missions
  - Deliver space communications and navigation services necessary for success of NASA science and human missions and U.S. Government and commercial customer missions
  - Provide affordable and reliable launch access to space for NASA and civil sector missions
  - Continue crew training and operations, crew health and safety, and propulsion test activities required for successful U.S. crewed space missions

Program Project Management Board (PPMB)

7120.5E Implementation Support

NAC Human Exploration and Operations Committee

March 2016

Ellen Stigberg

Office of the Chief Engineer

Program/ Project Management Board (PPMB)
Added Chartered Functions

- Specifically the PPMB will serve as a one-stop forum to adjudicate all 7120.5E issues, waivers, deviations and tailoring.
- Reconstituted membership to align with this new role.
- Requirement owners retain authority to approve tailoring, waivers, and deviations, and support issue resolution through this forum as needed.
- PPMB forms tiger teams, as needed, to proactively support programs and projects and assist with tailoring, EVM, JCL or any other issues with 7120.5E

Program/ Project Management Board (PPMB) Membership

- Members represent their respective organization with authority to make decisions on program/project implementation of PPM policy
  - NASA Chief Engineer, Chair
  - Office of Chief Financial Officer
  - Chief Safety and Mission Assurance Officer
  - NASA Mission Directorates' Senior Program Management Official, as defined by each MDAA
  - One representative from each Center and the Jet Propulsion Laboratory, selected by the Center Director. This representative should be the Principal Program or Project Management Official at the Center
  - Other invited members as needed, including representatives from the Program and Project Management Policy requirement owner organizations

Observations from HEOMD Presentations

- Progress continues on Commercial Crew capability with full funding in 2016. Critical work and process definition ahead to achieve program goals on the projected schedule with reasonable risk.

- Continued progress on SLS and Orion with no major schedule adjustments due to technical issues.

- HEOMD has added detail to plans for human exploration missions in the 2020's using a buildup approach to develop capabilities beyond low earth orbit.

- HEOMD approach for human exploration planning is reasonable considering current political and economic environment, but the committee is eager to see additional detail in exploration plans beyond 2030.

- ARM planning and development is continuing with completion of the Formulation and Assessment Team's report.

Top Concerns

- Lack of US launched crew transportation to Low Earth Orbit
- Current level of definition for Mars exploration architecture impedes effort to generate support.
- Bureaucratic processes that NASA imposes on itself do not always add value to balance their load on the organization and are a threat to accomplishment of NASA's exploration mission.
- Low SLS and Orion Launch rate pose future risks for proficiency of the operations team and reduce program resilience in the event of mission failure

- Budget uncertainty and reduced flexibility in funding accounts make it more difficult than ever for program managers to meet technical and schedule objectives.

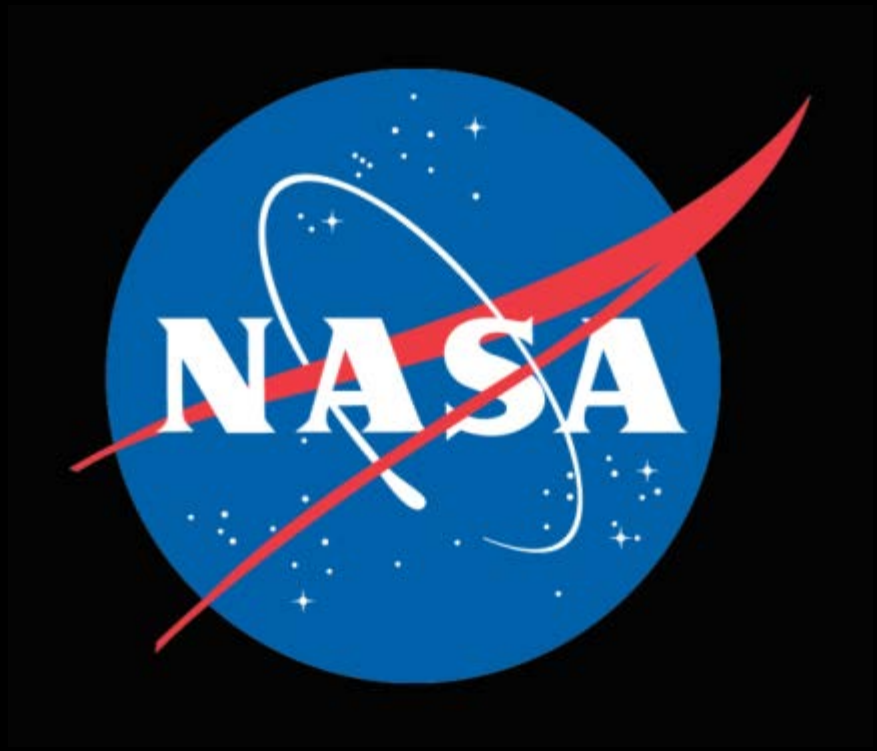
Special Topics at Future HEO Committee Meetings

Future Special Topics:

- International Participation in Future Human Exploration
- Plans for Transition of Administration
- ISS Research
- ISS Component Reliability
- Lunar Distant Retrograde Orbit
- Briefings from Selected System Maturation Team Leads

Items for Continued Review

- NASA Management Processes
- Certification of readiness process for commercial crew
- Integration and Standardization
- ISS Uses for Exploration Development, Transition, and Exploration Plans Beyond ISS
- Commercial Involvement in Future Human Exploration



www.nasa.gov