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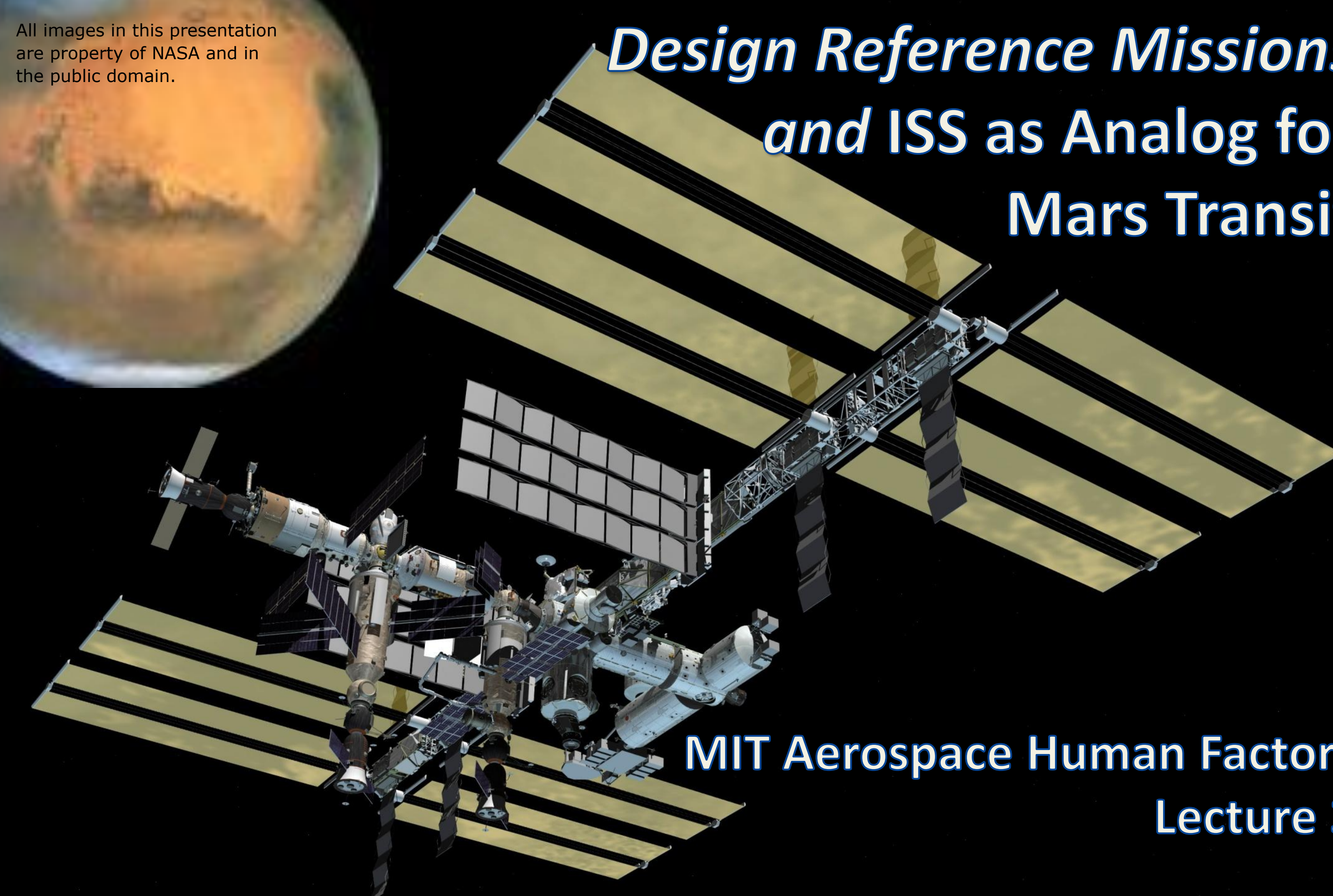


Design Reference Missions and ISS as Analog for Mars Transit

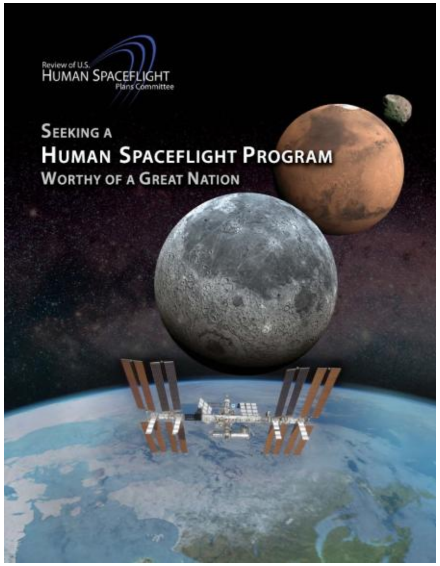
MIT Aerospace Human Factors

Lecture 3

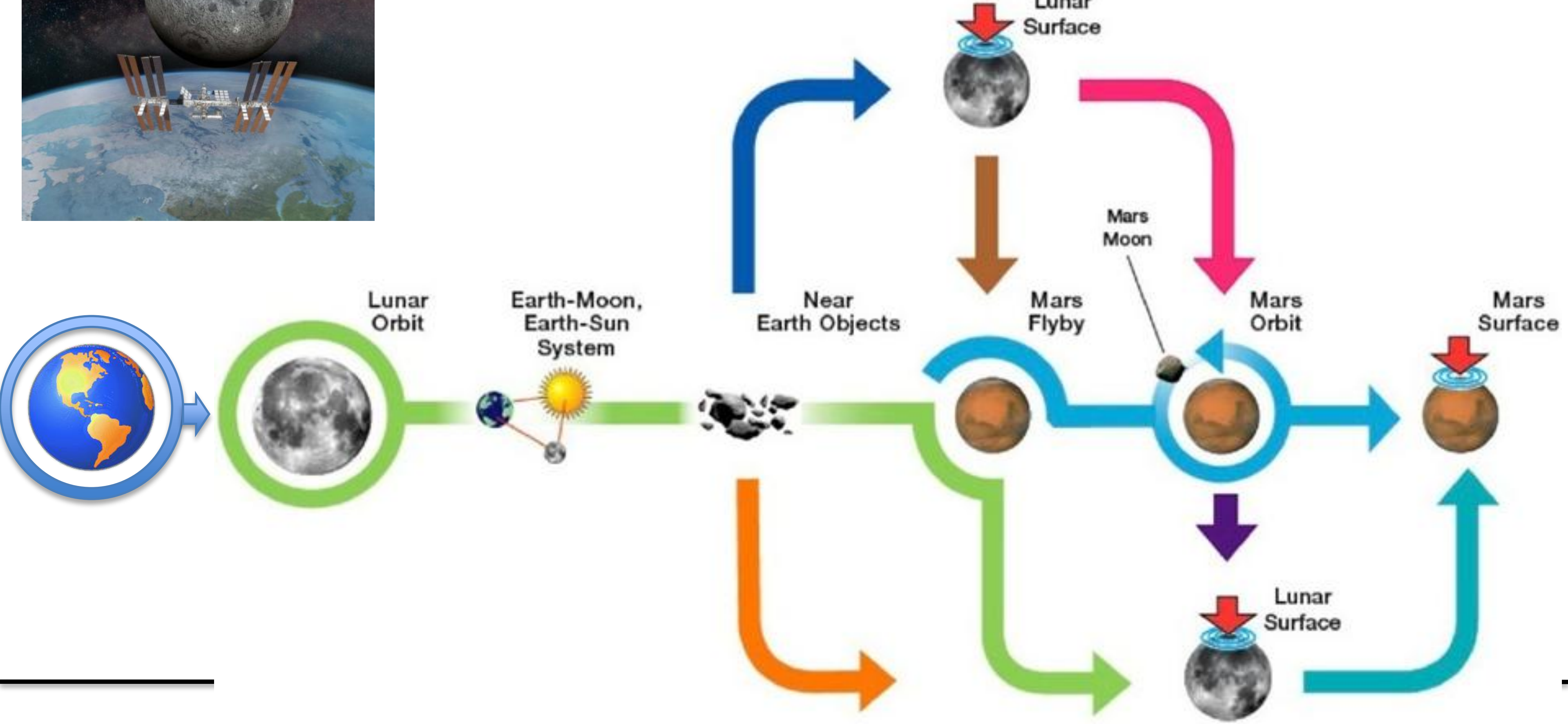
John B. Charles, Ph.D.

chief scientist, NASA Human Research Program

Where to Next? The Flexible Path



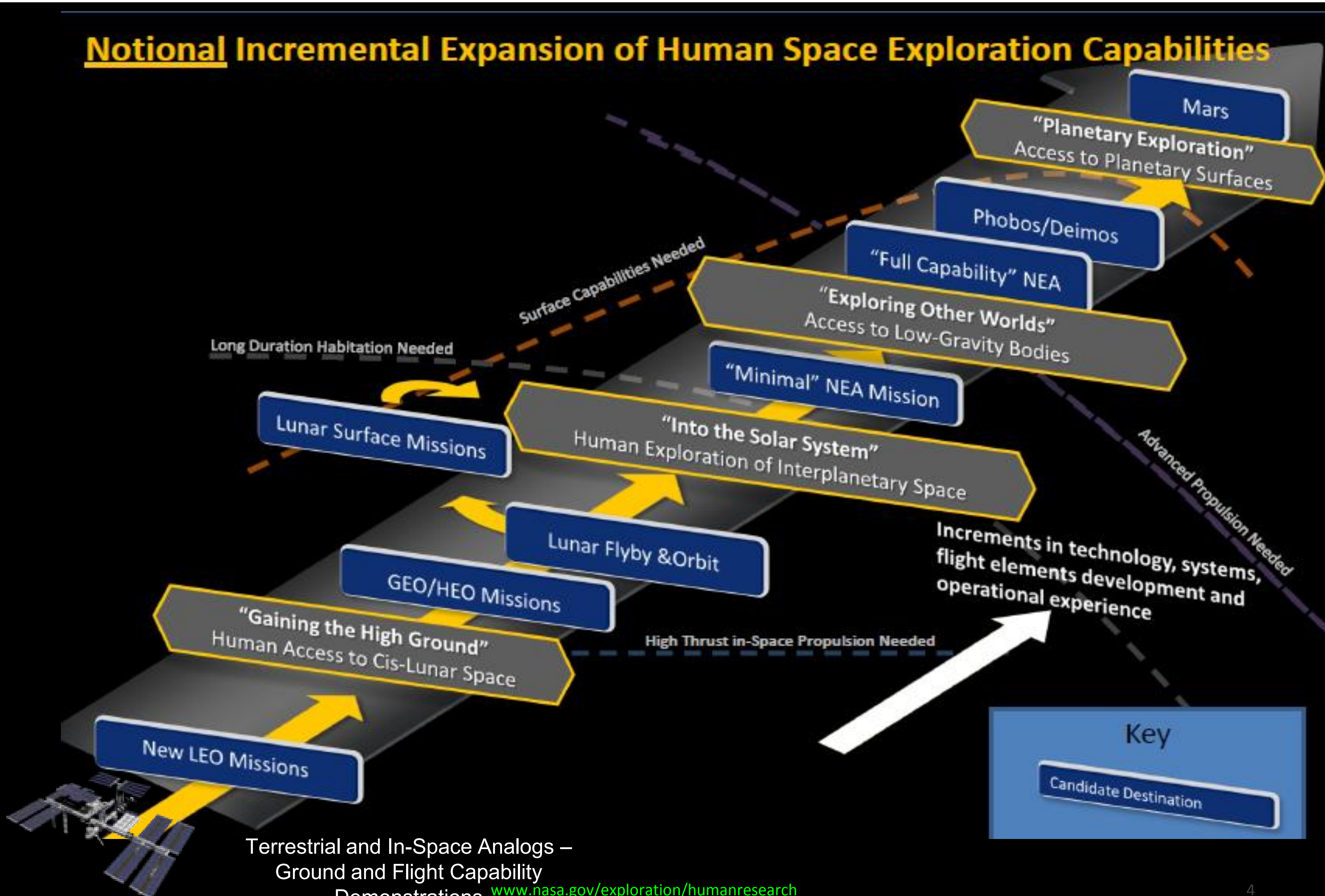
- October 2009
- Delivered to NASA Administrator and Office of Science and Technology Policy
- Provides context for discussing future destinations



Background

- NASA Authorization Act of 2010 "Sec 202: HSF and Exploration Goals and Objectives"
  - Long term goal – *To expand permanent human presence beyond LEO and so where practical, in a manner involving international partners*
  - Key objectives (as related to ISS as an analog for exploration):
    - *Sustain the capability for long-duration presence in LEO*
    - *Determine if humans can live in an extended manner in space with decreasing reliance on Earth, starting with utilization of LEO infrastructure*
- NASA established Human Exploration Framework Team (HEFT) in 2010 to develop insights for future human exploration missions esp. systems requirements and technology drivers required for mission success
  - Provided impetus of "capability driven framework"
  - Note: HEFT superseded by Human Architecture Team (HAT) in 2011.
- Results of these ongoing efforts are utilized in identifying technology investments and mission planning for across NASA

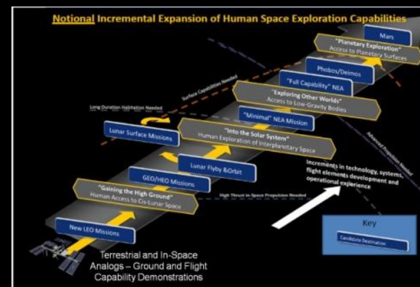
Capability Driven Exploration

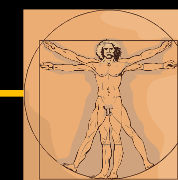


www.nasa.gov/exploration/humanresearch

Common Capabilities Identified for Exploration

Capability Driven Human Space Exploration





Capability Driven Architecture Elements (Building Blocks)


Ground Operations


Commercial Cargo/Crew


SLS


MPCV

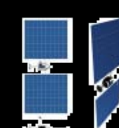

Robotic Systems


SEV


EVA Systems


CPS


DSH


Advanced Propulsion


Destination Systems


Mission Operations

Cross Cutting Systems

- Small Payload Return
- Robotic Free Flyer inspection
- Satellite Servicing Robot
- Standardized Energy Storage
- Suit Port
- ECLSS
- Logistics to Living
- Prop. Mgt and Storage
- Power Module
- Modular Solar Arrays
- ISRU
- Radiation Protection
- Comm/ Nav
- Light Weight Long-Life Universal Docking System
- Personal Space Mobility System
- Robotic Assistant
- EP Thrusters
- Prop from Waste Gasses
- EVA Suit
- EVA Suit Exoskeleton
- Asteroid Anchoring Tools
- Self-Healing Systems
- Thermo-electric Generation
- Modeling and Simulation
- Autonomous Ops
- Surface Stairs / Ramp System

Technologies, Research, and Science

OCT Cross Cutting Technology Developments

Human Exploration Specific Research (such as ECLSS, EVA)

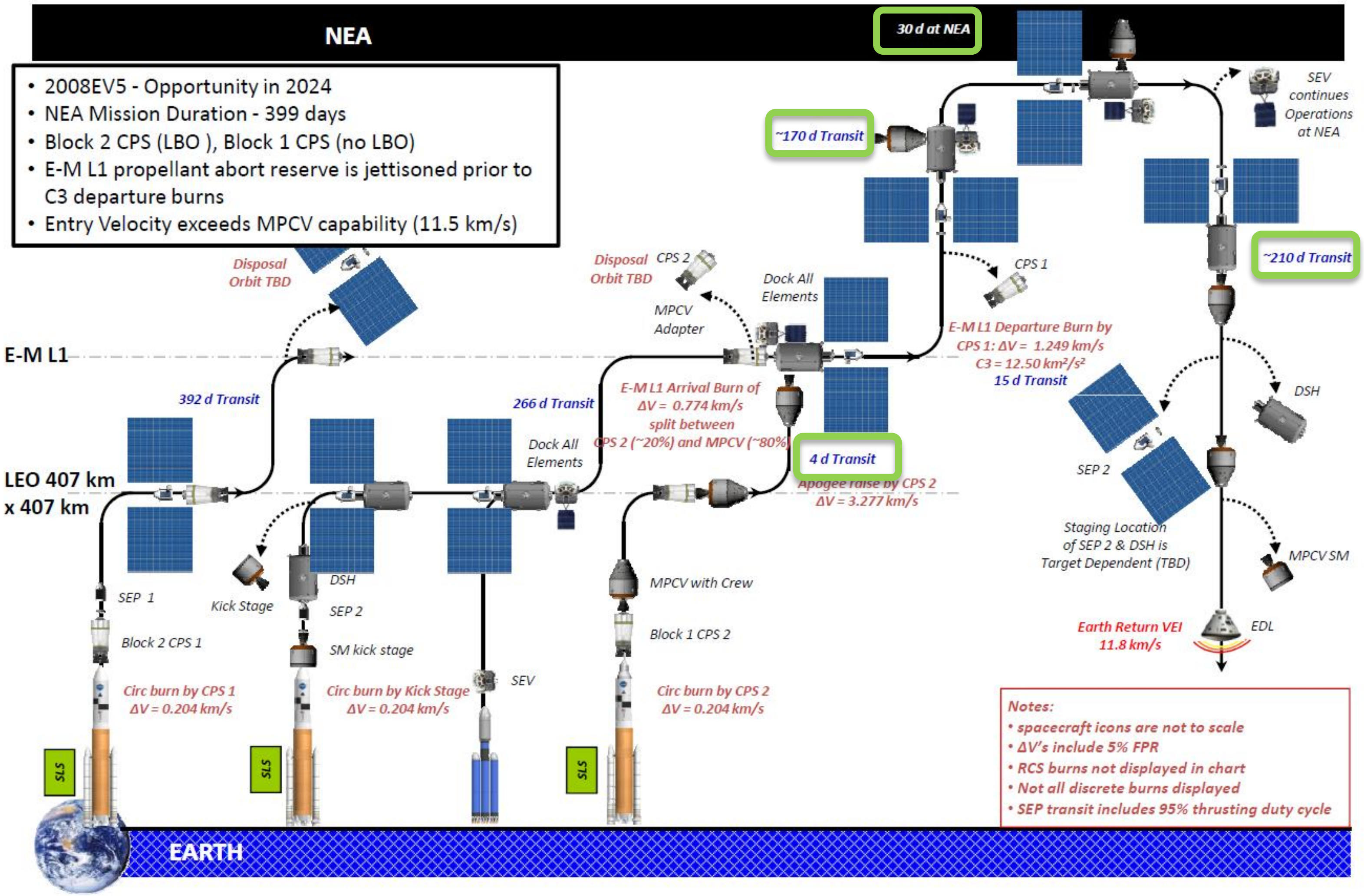
HEO and SMD Cross Cutting Research & Science

Human Exploration Specific Technologies

www.nasa.gov/exploration/humanresearch

A Sequence for an Asteroid

Reference NEA Mission: DRM 34B (NEA 2008EV5 with SEP)

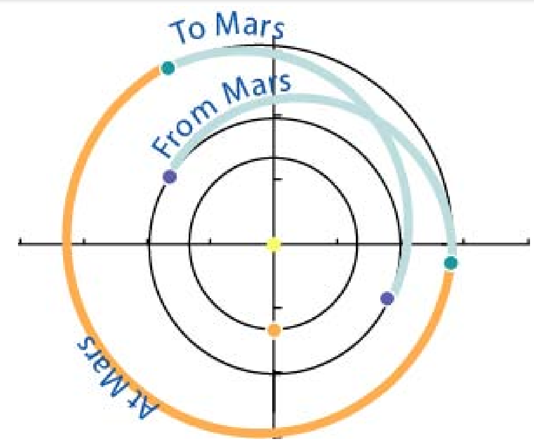


Mars Design Reference Architecture

- **Based on “Human Exploration of Mars, DRA 5.0” NASA-SP-2009-566, July 2009.**
  - Transition to Mars of ~180 days [max of 210 days]
  - Stay of up to 18 months on the surface
  - Return to earth ~180 days [max of 210 days] transition
  - Early launch of cargo and habitat prior to human launch

- **Long-surface Stay + Forward Deployment**
  - Mars mission elements pre-deployed to Mars prior to crew departure from Earth
    - Surface habitat and surface exploration gear
    - Mars ascent vehicle
  - Conjunction class missions (long-stay) with fast inter-planetary transits
  - Successive missions provide functional overlap of mission assets

- **Benefits from this DRA**
  - Mars DRA spans the spectrum of possible HSF exploration missions (NEA, Moon, or Mars)
  - Identifies the core risks for exploration



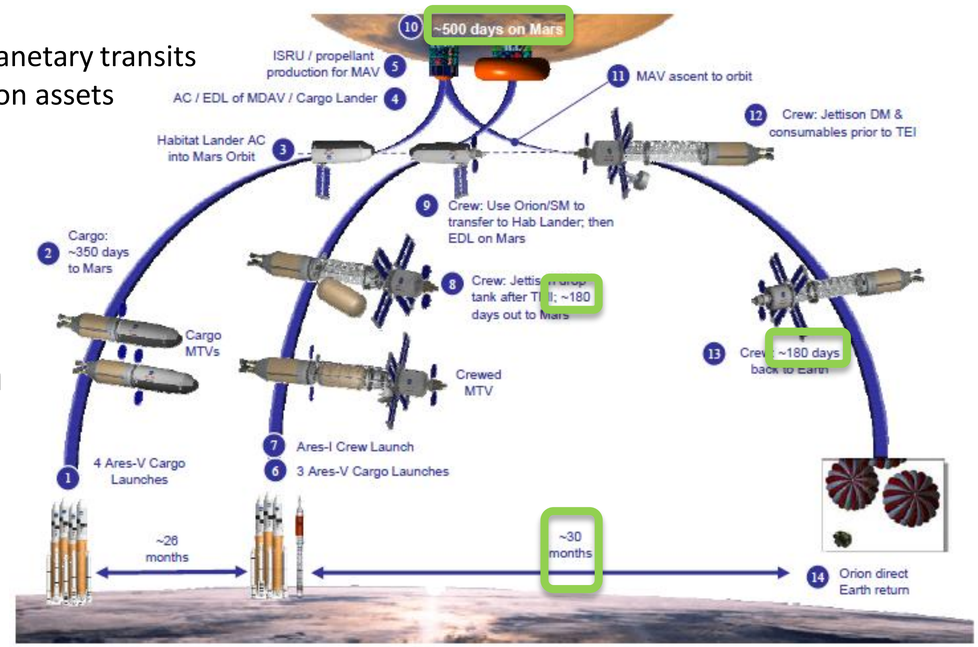


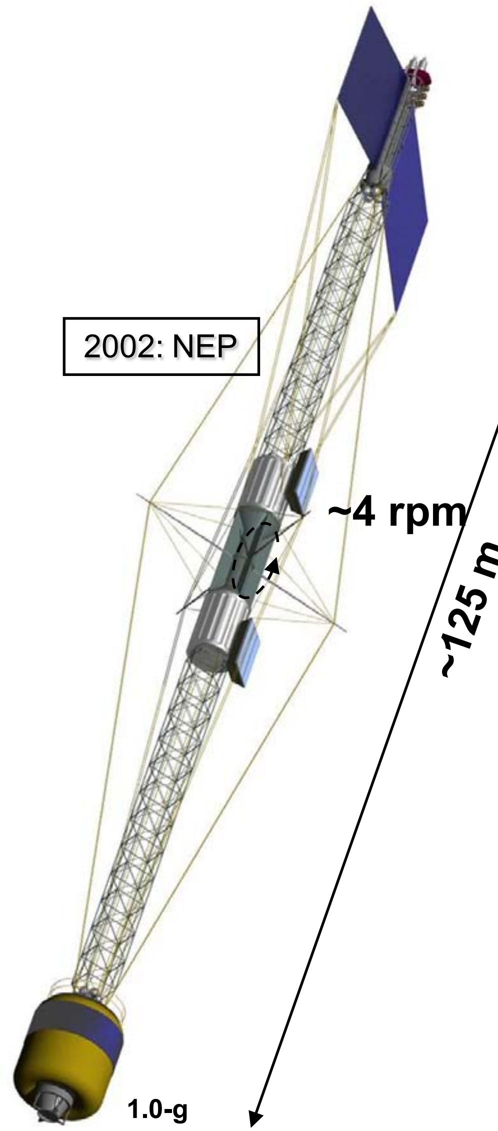
Figure 2-2. Mars Design Reference Architecture 5.0 mission sequence summary (NTR reference).

Design Reference Missions

- **Near-Earth Asteroids, 6-month (12-month?) missions**
- **Mars, 30-month missions**
  - Artificial gravity option under consideration for new DRM

1999: Bimodal NTR

1969: NERVA



2002: NEP

Exploration Mission Risks

Reference: Human Spaceflight Architecture Team (HAT)

ID	Exploration Mission RISK	ISS Demo Candidate (DRAFT)
M-EDL	EDL of large Mars payloads	
E-EDL	Earth re-entry at high velocities	
LV	Launch vehicle failures	
Lndr	Lander propulsion systems failure	
CSM	Long duration low/zero boiloff cryo-storage and management	X
CFT	In-space cryogenic fluid transfer	X
ISP	In-space propulsion failures	X
A-ISP	Reliability verification of advanced in-space propulsion	
Env	Environmental risks: radiation, MMOD, dust, electromagnetic	X
Dock	Docking/assembly failures	X
Sys	Systems failures: ECLSS, power, avionics, thermal	X
EVA	EVA system/suit failure	X
Comm	Operations under time delayed communication	X
Aut	Autonomous crew/vehicle operation	X
Health	*Crew health: behavioral, health care/remote medical, micro-gravity*	*X*
SW	Software failure	X
Hum	Human error	X
ISRU	ISRU equipment failure: propellant, consumables	X

Analogs and Risk Reduction

ID	HAT Exploration Mission RISKS
M-EDL	EDL of large Mars payloads
E-EDL	Earth re-entry at high velocities
LV	Launch vehicle failures
Lndr	Lander propulsion systems failure
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SW	Software failure
Hum	Human error
ISRU	ISRU equipment failure: propellant, consumables

HAT

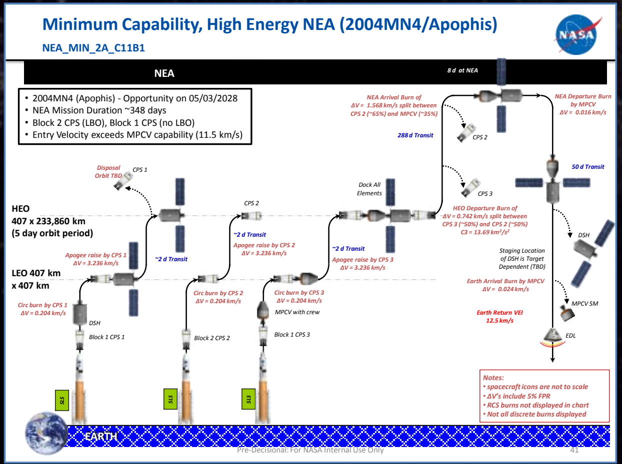
Candidate Analog Exploration Proposals

Evaluate proposed candidates -

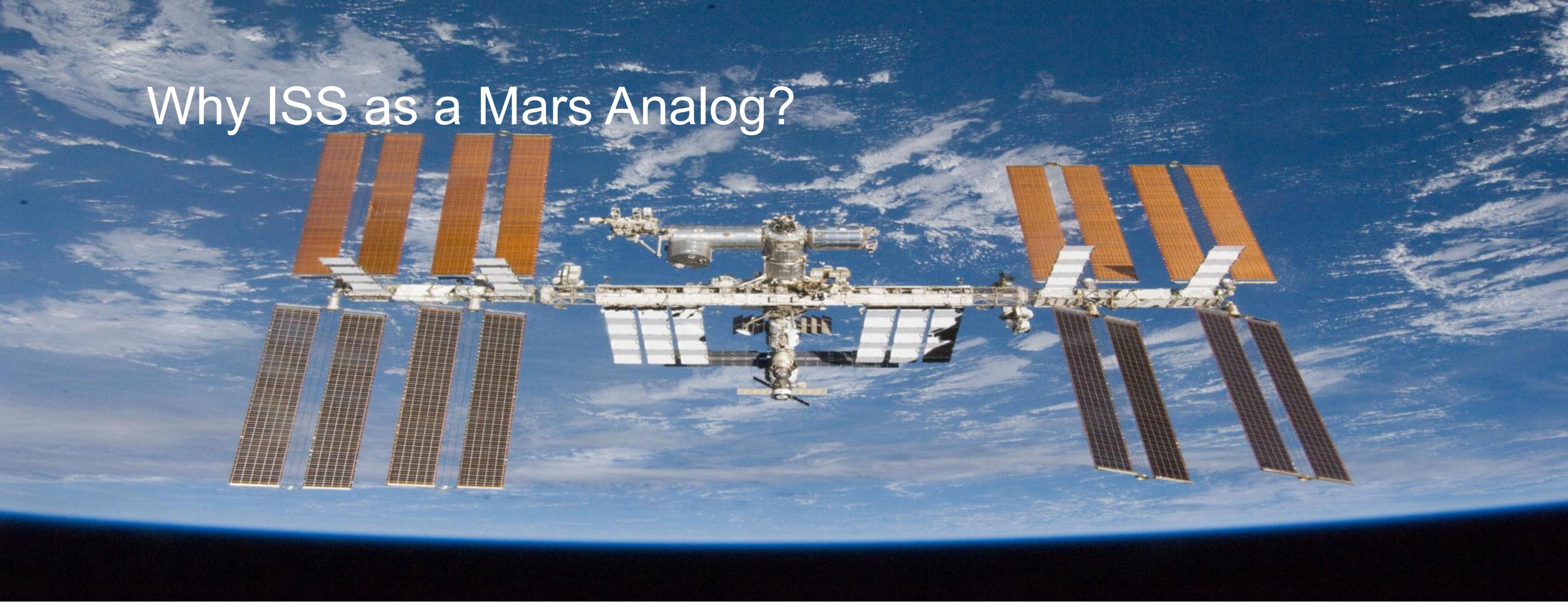
- Risk reduction, need, priority, feasibility
- Analog integration [Are we using the right analog to buy down the risk?]

Analog Platforms

- Terrestrial Analogs
  - DRATS, Haughton-Mars, Mars-500
- Partial Gravity
  - NEEMO, NBL, bedrest
- No gravity
  - ISS



Why ISS as a Mars Analog?



- Crew durations that mimic Mars transit phase (approx 6 mos)
- Continuous operations in zero-g provides systems durations that span the Mars mission – validates system performance requirements
- Long duration “microgravity” environment – pressurized and un-pressurized payloads
- Science laboratories from four international space agencies: US, Europe, Japan, Russia
- Life support, power, data, and facilities for 6 astronauts (subjects and operators)
- Ground control and on-orbit support for 24/7 operations

Potential Exploration Candidates for ISS Testing Roadmap

2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019

Robotic Systems

- R2 0-G Mobility System IVA/EVA
- RCS Sled / Manipulators
- Robotic Free Flyer Inspector
- Robotic Free Flyer Satellite Servicing

EVA Systems

- Super Safer Personal Mobility System
- Adv. Suits and PLSS

SEV

- Exploration Test Vehicle w/Suit Port
- SEV w/Adv Suits
- SEV ECLSS sub-system Test
- ISS Airlock to Test Exploration Atmosphere and EVA ops
- Exploration Comm Loop

DSH

- Modular Power Systems (Batteries, PV)
- Exploration Optical Comm Loop
- Radiation Mitigation Testing
- Advanced Logistics and Waste Mgt.
- ISS/DSH Reliable ECLSS
- Hab. Vol w/Robust ECLSS, Rad Protection, Adv Docking System

CPS

- CPS Protoflight Test

Human Health

Mission Operations

- Time Delayed Mission Ops → Autonomous Mission Ops

Human research on ISS supports crew health and performance for current and future space missions

- Pre-screening
- Exercise
- Nutrition
- Pharmaceuticals
- Operational workarounds
- Other countermeasures as needed

ISS as an Exploration Test Bed - Objectives

- **Evaluate new exploration technologies as they become available**
- **Advance preparations for crew autonomous operations for Mars or NEA exploration**
- **Exercise ground elements training and technology development**
- ***Long Term Goal***

……Conduct long duration Mars Transit and Landing Transition simulations using technology and operational tools & concepts developed and tested during previous On-Orbit and Earth-based Analogs

What can ISS offer to human research in a simulated Mars transit?

Strengths

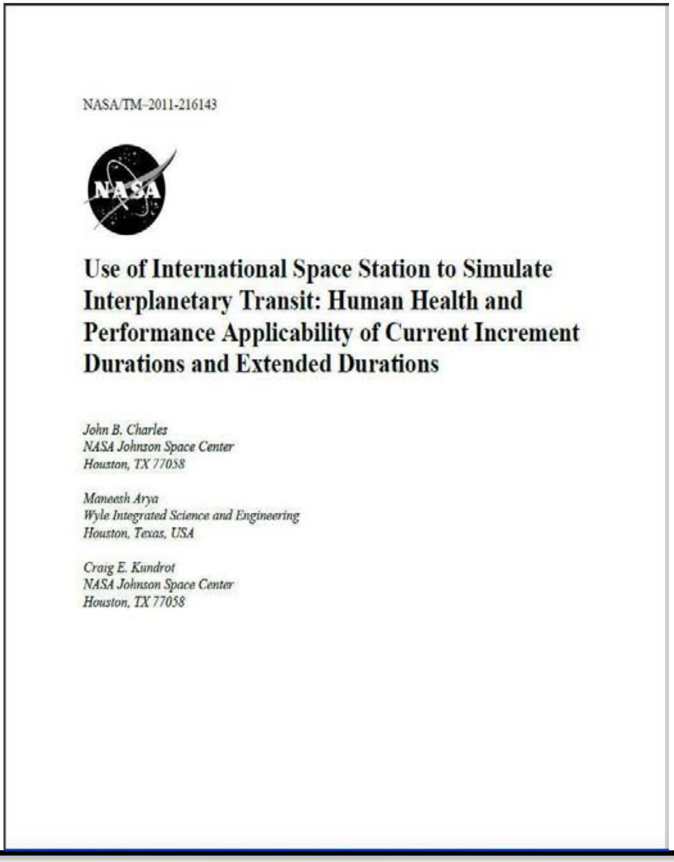
- **Weightless duration comparable to opposition-class mission Earth-to-Mars and Mars-to-Earth transits**
  - Physiology and countermeasures development and validation
- **High-fidelity representation of astronauts in a spacecraft in the flight environment with operational tasks and facing meaningful risks**
  - Behavioral health and performance
  - Human factors

Weaknesses

- **Shielded from deep-space radiation environment**
- **Proximity to Earth**
  - Minimal time delay in communications
  - Frequent abort opportunities
  - Earth is always just outside the window

Exploration-related NASA biomedical planning

- **"Mars Surface Analog Project"**
  - NASA JSC, 2002-2003
  - Three workshops of long-duration astronauts, flight medicine specialists, biomedical researchers
  - Discussed capabilities of astronauts on Mars immediately after 6-month transit
  - ISS Expedition 6, May 2003
  - Bloomberg, Functional Task Test
- HRP established in 2005 for Mars-focused human research and technology
- **"ISS Crew Increment Durations: Extension and Simulation of Mars Missions"**
  - NASA HRP/JSC/ARC, Sep. 2009
  - A workshop of NASA subject matter experts
  - How to extend ISS crew increments to 9-12 months?
  - How to use ISS to mimic a Mars mission?
- **"ISS as Testbed for Analog Research (ISTAR)"**
  - NASA-wide since Sep. 2010
    - HRP planning meeting "Toward a unified HRP perspective on ISS as Mars transit analog," Jan. 2011
    - Bill Gerstenmaier quoted in *Aviation Week & Space Technology*, Mar. 7, 2011
  - Early ISTAR emphasis includes time-delay, crew autonomy aspects of simulated Earth-Mars transit


NASA/TM-2011-216143

Use of International Space Station to Simulate Interplanetary Transit: Human Health and Performance Applicability of Current Increment Durations and Extended Durations

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Wyle Integrated Science and Engineering
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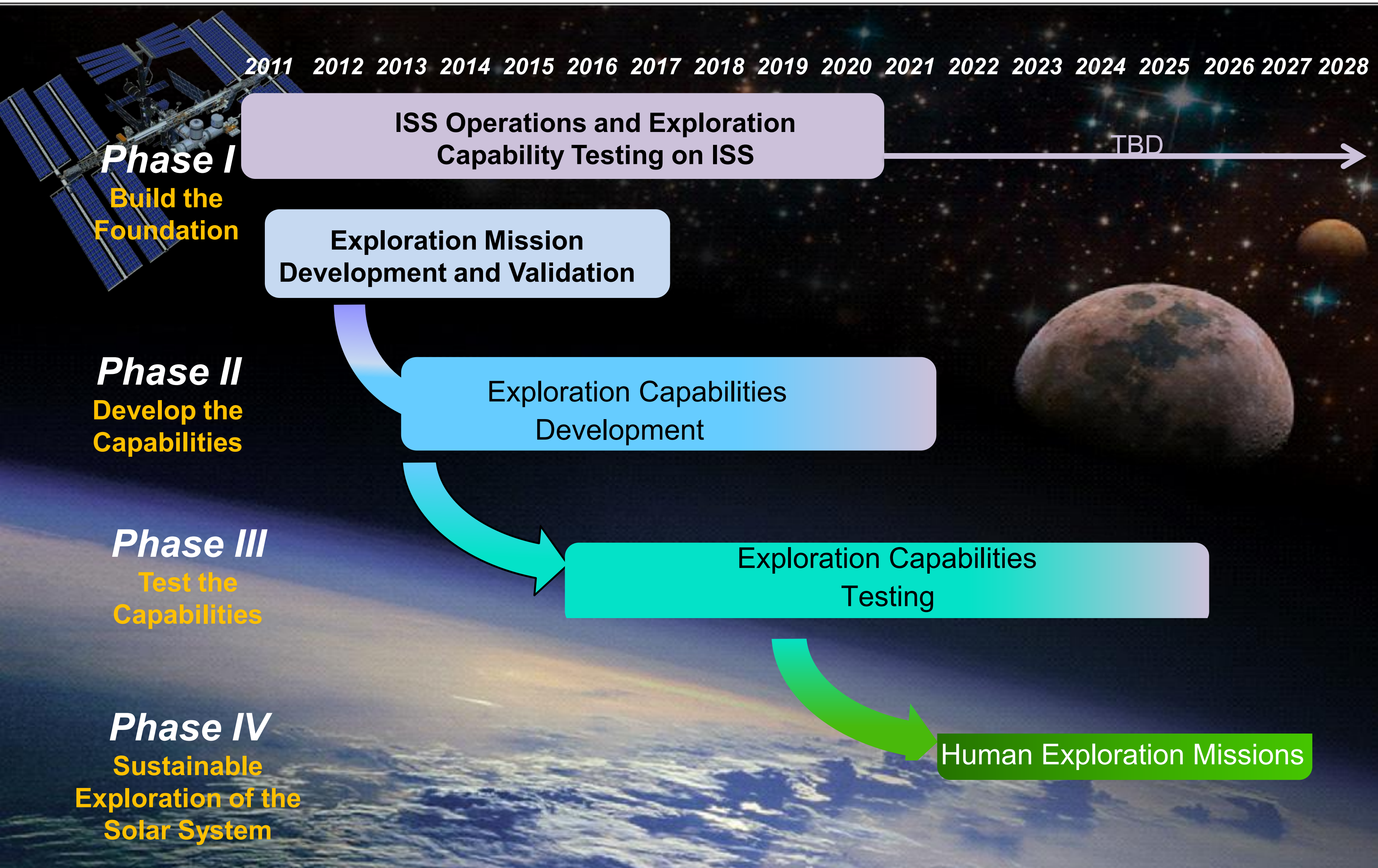
Houston, TX 77058

Exploration Capability Phased Development Strategy



International Space Station Test bed for Analog Research (ISTAR)

- **ISTAR is a joint collaboration project between NASA's Exploration and International Space Station (ISS) Programs**
  - An ISTAR Integrated Product Team (IPT) has been established
    - NASA Multi-center team including Exploration Systems, Exploration Analogs, Flight Crew, Human Research Program, Mission Operations, ISS Utilization, Engineering
  - Defines and ranks Exploration Development Test Objectives (xDTOs)

- **ISTAR xDTO categories established to mitigate Key Exploration Risks and answer Architectural Questions**
  - Human Research including Behavioral, Medical, and Performance
  - Autonomous Operations
  - Mission Planning & Execution
  - Exploration Technology Demonstration

- **ISTAR collaborates with NASA Earth-based analogs**
  - DRATS - Desert Research and Technology Studies
  - NEEMO - NASA Extreme Environment Mission Operations
  - PLRP – Pavillion Lake Research Project
  - Space Station Training Facility (SSTF), Neutral Buoyancy Lab (NBL), MCC (!), etc.

4 Phased Approach for ISS as Mars or NEA Testbed

Phase	Major features of plan
A Eval ISS capabilities [2011]	ISTAR will use planned ISS operations and activities for Mars and NEA Risk Abatement. Operational, experimental protocols to protect safety, health, efficiency of ISS crewmembers are evaluated for their applicability to Mars (and NEA) missions. Other analog environments are reviewed to ensure maximum utilization & lessons learned prior to manifesting on ISS.
B Short-period simulations & experiment packages [2012-2013]	An initial Mars transit mission simulation is planned for Summer 2012. This simulation will include evaluation of countermeasures for communications delays , medical and behavioral experiments, technology / process improvement research and human/robot interactions. Crew procedures and MCC oversight will be modified to provide more realistic experience in autonomous operations to both crew and ground personnel. Emphasis on crew and ground behavioral and performance measures, autonomy. Architectural risk mitigation limited due to hardware development, processing and manifesting timelines.
C Longer-period simulations & experiment packages [2014-2016]	Longer periods of autonomy will be simulated. Comm delays will be used to simulate those that will be encountered in Mars transitions. Crew procedures and MCC oversight continue to be modified to provide more realistic experience in autonomous operations to both crew and ground personnel. Other technology and process improvement research experiments will also be conducted. Increasing emphasis on DTOs for hardware, subsystems, food systems, logistics, etc. May include IV and EV experiments. Post-landing multi-day activities will be conducted.
D 6 month mission and crew [2016-2020]	Transits to Mars (and NEAs) will be simulated as rigorously as feasible in low Earth orbit with existing infrastructure. Progressively increasing communications delays may be introduced, reaching the maximum delay after 6 months to mimic Mars proximity. On-board science operations to be compatible with Mars-like mission parameters. Emphasis gradually shifting to efficacy of countermeasures for behavioral, health and performance. Subsystem level hardware analysis, e.g. ECLSS, EPS, etc. Post-landing exploration mission analogs will be expanded.

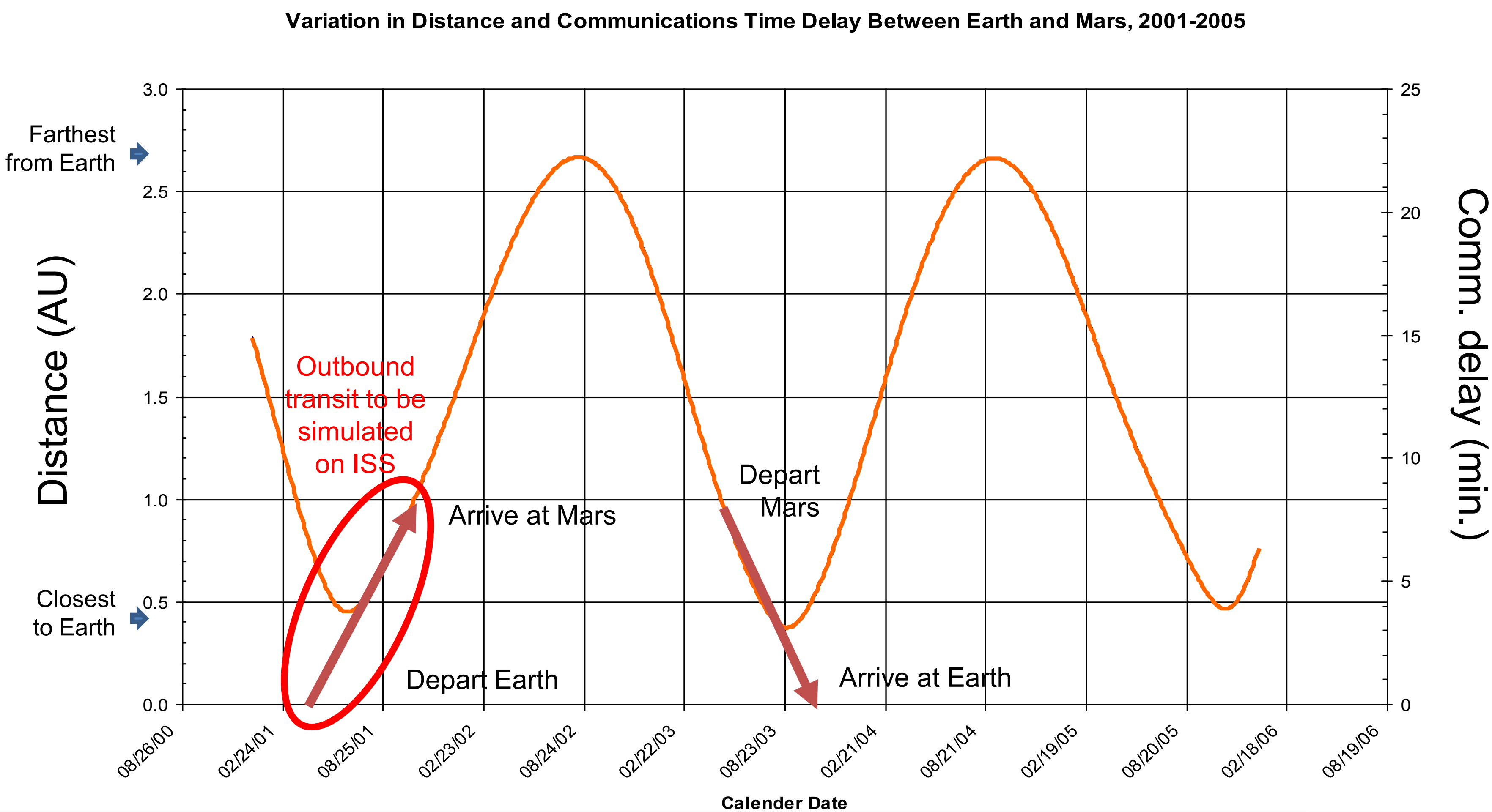
ISTAR - 5 Year Strategic Plan

- **Utilizes *phased approach* to reduce Exploration Risks, answer Architectural Questions, and execute long-duration Exploration Mission Simulations**
  - Begin with short duration ISTAR Analogs to test risk mitigating technologies & operational tools
  - Establish baselines for crew performance, behavior, and medical procedure; develop and test countermeasures
  - Increase periods of Crew/Vehicle Autonomy Simulations
    - Crew procedures & Mission Control operations will be modified to provide more realistic experience to crew/ground control personnel.
    - Perform Comm Delays leading to full (voice/data/command) Mars Transit-delays by 2016 (<u>Notional</u>) ***~ 12 minutes each way***
  - Post-landing exploration mission analogs will be added eventually
- **Continue development of ISTAR Analog Groundrules & Constraints**
- **Continue working with technology & science experiment developers of risk mitigating xDTOs candidates and map them to future ISS Increments**
- **ISTAR 5 Year Plan will be integrated with larger multi-year plan for all Exploration Analogs**

Assumptions

- **No Mars Mission related test will place ISS vehicle or astronauts at risk**
  - Develop rules for simulation breakouts for ISS nominal events and anomalies, while maximizing continuous simulation time
  - Assume an ISS flight control team for comm, timelines, systems experts
- **Effects on "non-Mars" payloads to be minimized**
- **Agreement by, and involvement of, all ISS partners is sought**
- **Use current Soyuz crew rotation scheme, and preserve or accommodate original ISS visiting vehicle schedule**
- **Involve flight crewmembers <u>and</u> ground elements *(possibly up to and including families)* <u>and</u> technology development**
- **This will not be a one-time event**
  - Multiple opportunities throughout ISS operational life
    - Initial tests: days to weeks to evaluate test protocols
    - Later: weeks to months to evaluate complex FTO's
  - Exploit early (low cost or no cost) opportunities for ISS to advance preparations for Mars and NEO missions

Variation in Distance and Communications Delay Between Earth and Mars (example: 2001-2005)



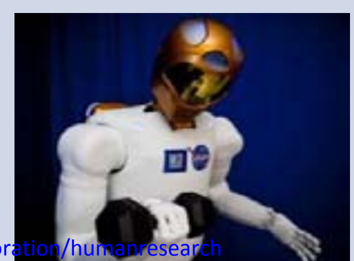
Calendar date

ISTAR Comm Delay Status

- Human Research Program (HRP) is developing a comm delay research investigation JSC-HRP-076 [Voice Comm Delay] to fly on Incr 35/36.

- In preparation for HRP comm delay research, the ISTAR team has prepared a proposal for Incr 31/32 and 33/34 to evaluate operational countermeasures for the crew and ground to use when voice comm is not available [video clips, text, voice sound clips (eg: MP3 files)]

- Objectives for Incr 31/32
  - Evaluate comm-delay countermeasures for use in long duration zero-g missions
  - Begin training the FCT for more autonomous crew operations

ISTAR 1 xDTOs Planned for ISS Increment 31-32 (Mar – Sep 2012)	Risk Reduction				
ISTAR ID Proposer xDTO Name **Description of Candidate**	**Aut Ops**	**EVA**	**Sys Fail**	**Env**	**Crew Health**
JSC- HEDS-001 HEDS Communications Delay Countermeasures Evaluate countermeasures for voice communication delays. Identify what types of tasks are most affected by a comm delay and which countermeasures provide the best results. Participants include flight crew and ground crew. Survey the flight and ground crews in flight for lessons learned that can be incorporated for additional testing later in the increment.  	X				
JSC-011 JSC/SF2 Active Shielding Proof of Concept Radiation Shielding: Gather real-time in-orbit data on power consumption and particle trajectories to assess the feasibility of implementing a large-scale magnetic field to shield crew. No new hardware required. Will utilize Alpha Magnetic Spectrometer (AMS) measurements. [Requires PI approval]				X	X
JSC-017 ARC SPHERES Free Flyer Simulated EVA Inspection The Human Exploration Telerobotics project is working to upgrade the capabilities of the Synchronized Position Hold Engage Reorient Experimental Satellites (SPHERES) to enable interactive control (with crew or from the ground) and utilize an integrated vision system to inspect small IVA features to simulate EVA inspections for MMOD damage. Demonstrate how robotic inspection tasks can reduce the time required for inspections that are normally conducted by the crew.	X	X			
JSC-091 JSC/ER4 Robonaut 2 Simulated EVA Routine and Emergency Operations Robonaut 2 (R2) brings an unprecedented level of robotics dexterity to ISS. Initially, R2 will earn its stripes in the IVA environment and a fixed base progressing over time toward mobility and EVA. In preparation for transitioning to an EVA version of R2, it is proposed to conduct EVA-like tasks using the IVA R2. 	X	X			

Phased approach to exploring implications of communications delays between space and ground

- **Phase A (Inc 31/32, Inc 33/34):**
  - Focus on how to deal with <u>communications delays</u>
    - Methods, countermeasures for <u>communications delays</u>
    - Begin developing criteria for <u>autonomous</u>ly executable procedures
    - Countermeasures tested under normal communications environment (no delay)
  - Utilize USOS crew and MCC-H (see xDTO JSC-HEDS-001)
  - ISTAR IPT to collect and review results and determine when ready to proceed to next Phase
    - Allow time to implement lessons learned from Phase A for Phase B
    - Review results and determine anything needed for Phase B
- **Phase B (Inc 35/36…):**
  - Continue testing from Phase A plus <u>comm delay</u>
  - Support for HRP <u>comm delay</u> investigations
- **Phases C and Beyond: Increase complexity and depth of communications delays – <u>more autonomy</u>**

Timeline of Research on Autonomy: NASA Efforts

- 2006-2008: Research on Autonomy in Analog Environments: Nick Kanas
- 2009: Autonomy Workshop
- 2010: Autonomy Literature Review
- 2010: Monitoring Technology Development (SBIR)
- 2010: NEEMO 14 Autonomy Study
- 2010: Autonomy NRA

Research: Nick Kanas

Analog	High Autonomy Condition	Low Autonomy Condition
NEEMO	Measures: •Profile of Mood States •Group Environment Scale •Cohesion •Work Environment Scale	
Haughton Mars-Project		
Mars 105 Study		

- **Across these analogs, results suggest that participants react positively in autonomous environment**
- **Results also suggest some negative affective outcomes for some of the ground controllers that participated in these**
  - May suggest that autonomy may have adverse impacts on those that are affected by changes in autonomy during a space mission, especially if participants experience a lack of job clarity and role assignment
  - Thus, important to consider space crews AND ground control

Other Relevant Evidence

	Participants	Protocol	Measures	Outcomes
MARS 105 (April 2009 – July 2009)	6 crewmembers in habitat (4 Russians and 2 Europeans); 19 mission control	First 10 weeks of 15 week protocol, real time com; last 5 weeks, 40-minute two-way with outside (also varied autonomy over schedule)	Weekly POMS, GES, WES, subjective performance assessment	•Communication delay was feasible to implement – no adverse outcomes •Crewmembers found high autonomy to be positive, depending less on others for directions •Russian crewmembers reported increased work pressure •Mission control reported more tension, confusion and less task orientation •No findings reported specific to communication delay
MARS 500 (June 2010 – Nov 2011)	6 crewmembers in habitat (three Russian, two European and one Chinese); mission control	First and last month, real time audio with mission control. For remaining time, only written com w/ mission control, with delay up to 24 minutes (delay varies from 8 sec to 24 minute two-way, with maximum delay on flight day 351; connection disruptions)		Ongoing
HMP – Telemedicine (2007)	Case study evaluating simulated appendectomy through telemedicine with a 15 minute, one-way delay in com bet. locations	Remote expert provided video instructions via 15 minute transmission delay to site. Non-expert conducted operation and provided video of procedure back to expert via 15 minute transmission delay to consulting location.	Subjective assessment of operations	Delay during operative procedure feasible •Total time required to perform appendectomy was 2.25 h, which included 1.5 h of built-in communication delays •The simulated appendectomy was performed by a minimally trained operator using just-in-time education combined with remote asynchronous guidance delayed for extreme communication distances
NEEMO 12	4 NASA crewmembers and 8 “topside” personnel	five days of low autonomy and five days of high autonomy (where crewmembers had more flexibility to plan their own work schedule and experienced a 40-minute two-way communication delay with mission control)	At the middle and end of mission, completed a questionnaire containing many of the subscales from the POMS, GES, and WES.	•High autonomy condition was successfully employed in NEEMO 13 with no adverse results. • Confusion increased for topside personnel during high autonomy condition •No findings reported specific to communication delay •Anecdotal report from NEEMO coordinator that NEEMO commander and crew demonstrated high compliance to following communication delays in accordance with protocol

	Participants	Protocol	Measures	Outcomes
NEEMO 14	N/A	N/A	N/A	Study protocols did not include communication delay as independent variable; crew however tested feasibility of communication delay for future studies Anecdotal reports from NEEMO indicate that NEEMO commander and crew tested communication delay casually in accordance with no formal protocol
Laboratory Simulations John Hopkins (2004-2008)	Three-person mixed gender crews conducting a computer-based task (collecting 'samples')	Study A: drop in both audio and text com. Study B: three minute delay in text and whiteboard com and five second delay in audio.	Total value of collection samples	Study A: drop in total communication lead to decrease in performance Study B: 5-sec audio delay lead to decrease in performance Seeing trend of text/written com preferred over audio. Considerations: w/i crew interdependency and unanticipated communication changes

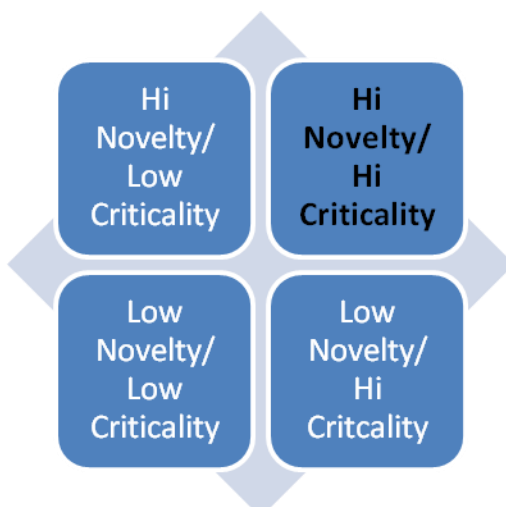
These investigations demonstrate:

- It is feasible to implement communication delay in space analogs
- Additional investigations are needed to accurately characterize the impact of a systematic communication delay on performance
- Accurate selection criteria and "communication milestones" (designated times where necessary information is relayed to mission control) can offset adverse outcomes (Otto, HMP Telemedicine)
- Essential to isolate variables to minimize confounds and provide more conclusive results; lack of findings specific to communication delays in RCS-105 and NEEMO 12 due to varying other criteria
- Participants should be "on board" with the protocol and attempts should be made to promote perception of "bounded autonomy" and/or communication delay (e.g., approach to communication delay varied between NEEMO 12 and NEEMO 14. NEEMO 12 provided clear protocol and buy-in from crew).

Autonomy Workshop (2009)

- ***Bounded Autonomy: involves the conditions, constraints, and limits that influence the degree of discretion by the individual and [crew/team] over their choices, actions and support in accord with standard operating procedures.***

- **Important tasks to target:**



Overall, results suggest difference in performance cohesion (and other team results) between low and high autonomy conditions

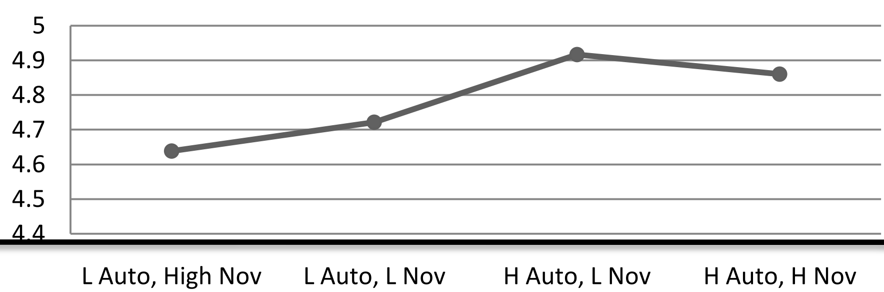
Cohesion

Positive effects of increased autonomy on:

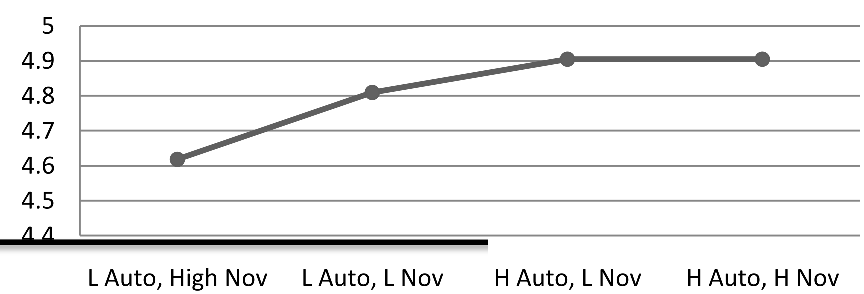
- **crew performance**
- **crew dynamics (teamwork)**
- **crew cohesion**

Well-Being

Subjective Performance



Cohesion

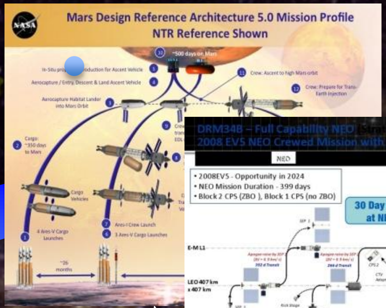


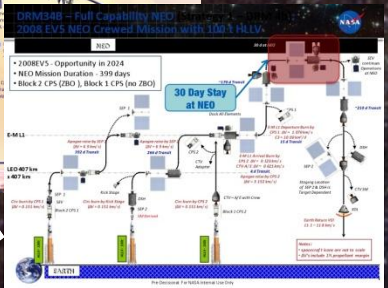
ISTAR - ISS International Partner Participation

- **Some ISTAR xDTOs will seek International Partner (IP) participation or use of IP facilities**
  - "Behavioral" and "Crew Autonomy" investigations may impact visiting vehicle or spacewalk (EVA) scheduling
    - Communications/Data delay xDTOs could impact other operations (e.g. payloads)
    - Multilateral agreements will be required
  - New crew planning and execution tool xDTOs are planned
    - All ISS Partners' Mission Control Center (MCC) procedures and tools for planning and execution are integrated and must stay in sync
  - Post-Landing (if it affects landing site ops or crew return)
- **ISSP has initiated discussions with IPs to seek their cooperation**
  - Positive but reserved initial reaction received at ISS multi-lateral forums
  - ISS IPs have expressed interest in executing their own xDTOs
  - Process to integrate IPs' initiatives is in development

ISTAR International Space Station Test Bed for Analog Research

National Aeronautics and Space Administration





Design Reference Missions and Architectures

Human & Architectural Risks

ID	RISK – Human Spaceflight Architecture Team (HAT)
M-EDL	EDL of large Mars payloads
E-EDL	E
LV	La
Lndr	La
CSM	Lc m
CFT	In
ISP	In
A-ISP	R pı
Env	E el
Dock	D
Sys	Sy
EVA	E
Comm	O
Aut	A
Health	C m
SW	S
Hum	H
ISRU	ISRU equipm

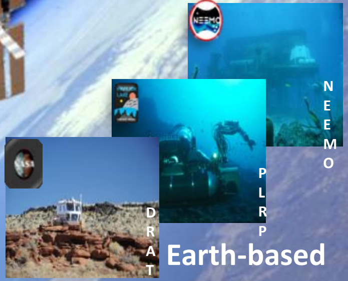
ID	Architectural Question
Q1	What is the safest way to approach a small/non-cooperative/non-stable o
Q2	What is
Q3	What E mission
Q4	What a operati
Q5	What a IVA acti
Q6	What is (3 and
Q7	What is time de
Q8	What ir
Q9	What is orbit m
Q10	How dc
Q11	What is Moon/
Q12	Given c interac at desti
Q13	What le benefit

HRP Risk	NEO (Notional)			Mars
Mission Duration: Conditions continue to worsen with time of exposure to the flight environment (ex. Microgravity, radiation, confined living).				
Risk of radiation carcinogenesis and Risk of degenerative tissue or other health effects from radiation exposure	U	U	U	U
Risk of Microgravity-Induced Visual Alterations/ICP (proposed)	U	U	U	U
Risk of acute & late central nervous system effects from radiation exposure Risk of acute radiation syndromes due to solar particle events (SPEs)	A	A	A	A
Risk of adverse behavioral conditions and psychiatric disorders	A	A	U	U
Risk of impaired performance due to reduced muscle mass, strength & endurance Risk of reduced physical performance due to reduced aerobic capacity	A	U	U	U
Risk of crew adverse health event due to altered immune response	C	A	A	A
Risk of early onset osteoporosis due to spaceflight	A	A	A	A
Distance: Distance impacts communication and evacuation.				
Risk of inability to adequately recognize and treat an ill or injured crew member	A	A	U	U
Risk of performance decrements due to inadequate cooperation, coordination, communication, psychosocial adaption within a team	A	A	A	A
Vehicle/System Design: Risk related to vehicle or subsystem design; medical issues not related to mission duration.				
Risk of compromised EVA crew health and performance due to inadequate EVA suit systems	A	A	A	A
Risk of inadequate nutrition & Risk of performance decrement and crew illness due to an inadequate food system	C	A	A	U
Risk of error due to inadequate information Risk of reduced safety and efficiency due to an inadequately designed vehicle, environment, tools or equipment	C	A	A	A
Risk of therapeutic failure due to ineffectiveness of medication	C	C	A	A
Risk of cardiac rhythm problems & Risk of orthostatic intolerance during re-exposure to microgravity & Risk of intervertebral disc damage	A	A	A	A
Risk of renal stone formation & Risk of bone fracture & Risk of Performance errors due to fatigue resulting from sleep loss, circadian desynchronization, extended wakefulness, and work overload	C	C	C	C
Risk of adverse health effects due to alternations in host-microorganism interactions	A	A	A	A

"Using ISS as an analog test platform to develop and demonstrate new technologies and operational concepts. ISTAR xDTOs mitigate the risks and challenges facing astronauts on long distance voyages to asteroids, planet Mars and perhaps destinations even further from Earth."

ISTAR Process

- xDTO Solicitation
- xDTO Screening
- Increment Planning
- xDTO Candidates Selection
- Collaboration with Earth based Analogs



Earth-based Analogs

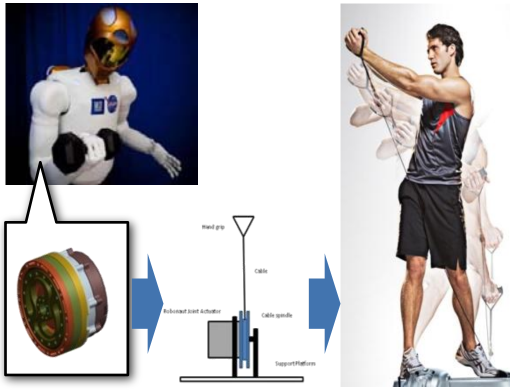
Coming to NASA Summer 2012


National Aeronautics and Space Administration
NASA
The End.
Questions?

Table of Contents

Example – Page 1a (Investigation Summary Overview)

Miniature Exercise Device (MED)



RESEARCH OBJECTIVES:

- The Miniature Exercise Device will demonstrate key motion system technology required to reduce the volume and weight of countermeasure equipment that will be needed for long term space flight.
- The goal is to develop countermeasure systems that are small and an order of magnitude lighter than existing systems.

OPERATIONS:

- The ISS Crew will train for installation and operations of the MED. This training is expected to be about 2 to 4 hours.
- The crew will install the MED device on the Advanced Resistive Exercise Device (ARED).
- The crew will use the MED at various load levels and modes of operation. Data will be recorded by the instrumentation on the MED and sent to the ground for evaluation.
- The crew will report observations on the performance of MED to the ground team.
- The ground team will analyze the data and determine control parameter adjustments as needed to tune the MED
- After making changes to the control parameters the crew will use the MED at various load levels and modes of operation.
- This cycle is repeated for a total of not less than 3 sessions.

National Aeronautics and Space Administration

Autonomy 'Tutorial': Mars/ISS Analog Mission

BHP Research Element

Autonomy Literature Review

Autonomy Report

Human Research Program
Behavioral Health & Performance Element
Space Medicine Division

March 24, 2010

Cristina Rubino, M.A.
Kathryn E. Keeton, Ph.D.

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

Behavioral Health & Performance Research Element

Human Research Program

Space Medicine Division

Team Gap 6: Given the context of long duration missions, what are the optimal ways to support and enable multiple distributed autonomous teams to support task performance, teamwork, and psychosocial performance?

Decision Point: Are additional studies are needed in regards to Autonomy?

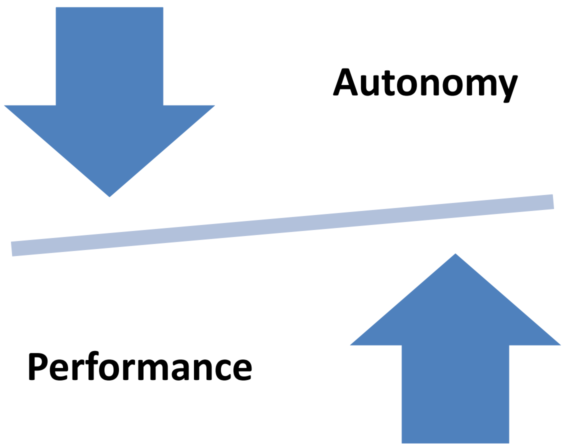
Summary:

The Behavioral Health & Performance Element (BHP) is one of six elements within the Human Research Program and is comprised of four Risks, namely the Risk of Behavioral Conditions, the Risk of Psychiatric Disorders (BMed), the Risk of Performance Decrements due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team (Team), and the Risk of Performance Errors due to Sleep Loss, Circadian De-synchronization, Fatigue, and Work Overload (Sleep).

The Team Risk is comprised of four primary risk factors: cooperation, coordination, communication, and psychosocial adaptation. These primary risk factors represent the dimensions of teamwork as well as the component of individual and team adaptation to the unique spaceflight environment. Within the Team Risk there are also specific gaps that represent the areas in which critical knowledge is unknown or an adequate mitigation strategy is not yet developed. As long-duration missions are expected to have increased autonomy as a

SBIRs

- BHP oversaw two proposals that plan to develop a technology that will monitor level changes of autonomy based upon a theoretical framework that models autonomy over time



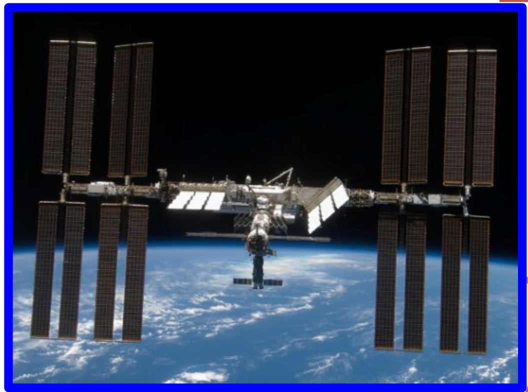
Forward Plan

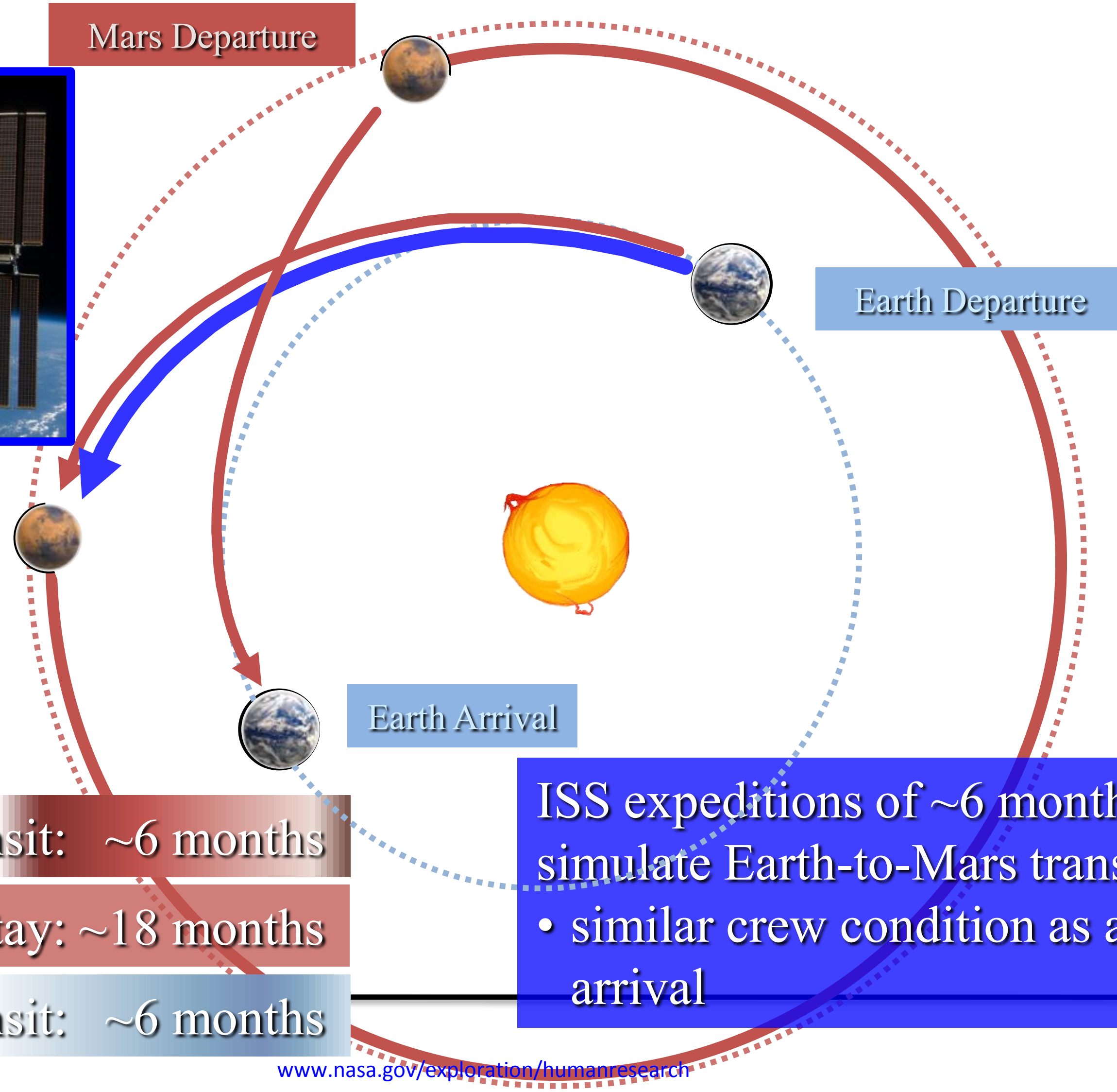
- **Continue near term ISTAR efforts to mature exploration capabilities via DTO's on ISS**
  - DTO's are being proposed for future Increments

- **More complex system level candidate proposals, from Candidate Roadmap, are being developed jointly between Exploration and ISS teams**
  - White papers are being developed for EVA, ECLSS, Communication and Exploration Test Module (ECD = Fall 2011)

Overview of *Hypothetical* Mars Expedition

Based on: Human Exploration of Mars, DRA 5.0, NASA-SP-2009-566, July 2009





Earth-to-Mars transit: ~6 months

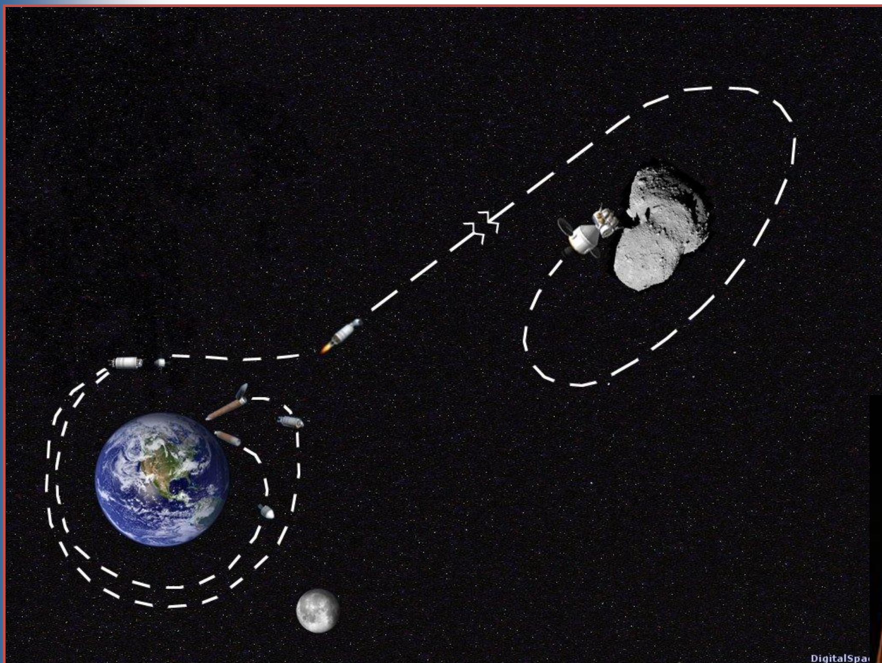
Mars surface stay: ~18 months

Mars-to-Earth transit: ~6 months

ISS expeditions of ~6 months duration simulate Earth-to-Mars transit

- similar crew condition as at Mars arrival

Overview of *Hypothetical* NEA Expedition

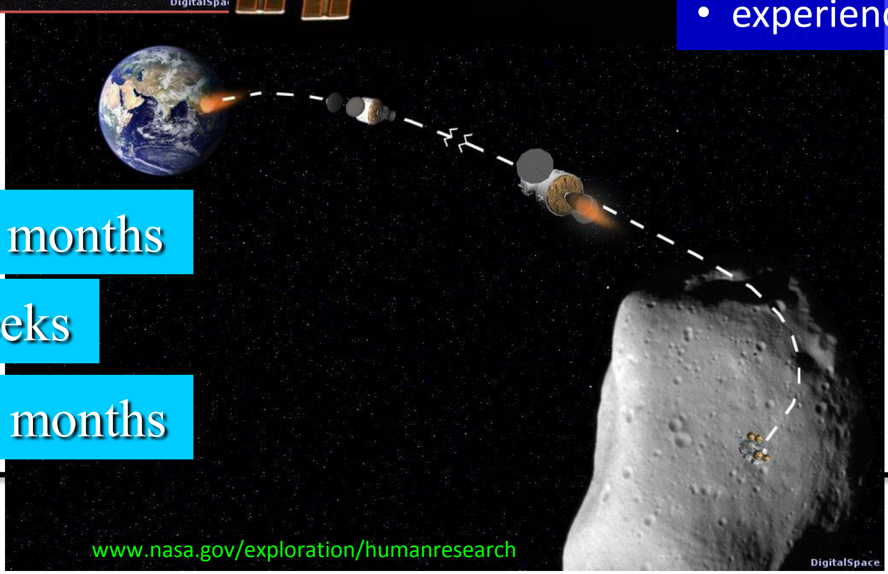


NEA expeditions

- Validate technologies and procedures for Mars missions
- Acquire additional unique deep-space data
  - Dust on and near asteroids
  - Near-NEA radiation environment
  - Behavioral health & performance

ISS expeditions of ~6 months duration simulate ~6-month+ Earth-to-NEA round trip

- 0-g baseline
- experience base



Earth-to-NEA transit: ~3-4 months

NEA surface ops: ~2 weeks

NEA-to-Earth transit: ~1-3 months

ISTAR - Phased Approach for ISS as Exploration Test Bed

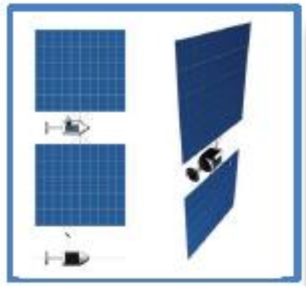
Phase	Major features of plan
A Eval ISS capabilities [2011-2012]	Primarily current ISS operations and activities. Operational, experimental protocols to protect safety, health, efficiency of ISS crewmembers are evaluated for their applicability to Mars (and NEO) missions.
B Short-period sims [2013-2014]	Discrete Mars-forward activities inserted, such as intermittent multi-day periods of different degrees of bounded autonomy by ISS crew, including communications delays typical of Mars missions. Sets of assigned tasks to be accomplished with minimal intervention by MCC, but few alterations to on-board procedures and MCC monitoring of ISS systems. Minimize impact to non-Mars onboard science operations. Flight rules specify threshold at which simulation is broken in case of emergency or system malfunction. Add "exploration" tasks to post-landing timeline.
C Longer-period sims [2014-2015]	More rigorous, longer periods of autonomy. Crew procedures, MCC oversight modified to provide more realistic experience in autonomous operations to both crew and ground personnel. Some impact to onboard non-Mars science operations. Post-landing multi-day exploration analogs.
D 6 month mission and crew deconditioning [post 2015]	Transits to Mars (and NEOs) simulated as rigorously as feasible in low Earth orbit with existing infrastructure. Progressively increasing communications delays may be introduced, reaching the maximum delay after 6 months to mimic Mars proximity. On-board science operations to be compatible with Mars-like mission parameters. Expanded post-landing exploration mission analogs

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

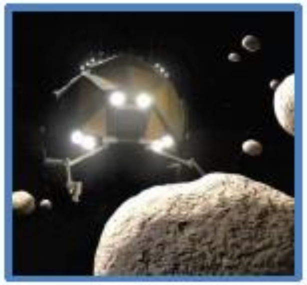
EVA Suit

Multi-Mission Space Exploration Vehicle (MMSEV)

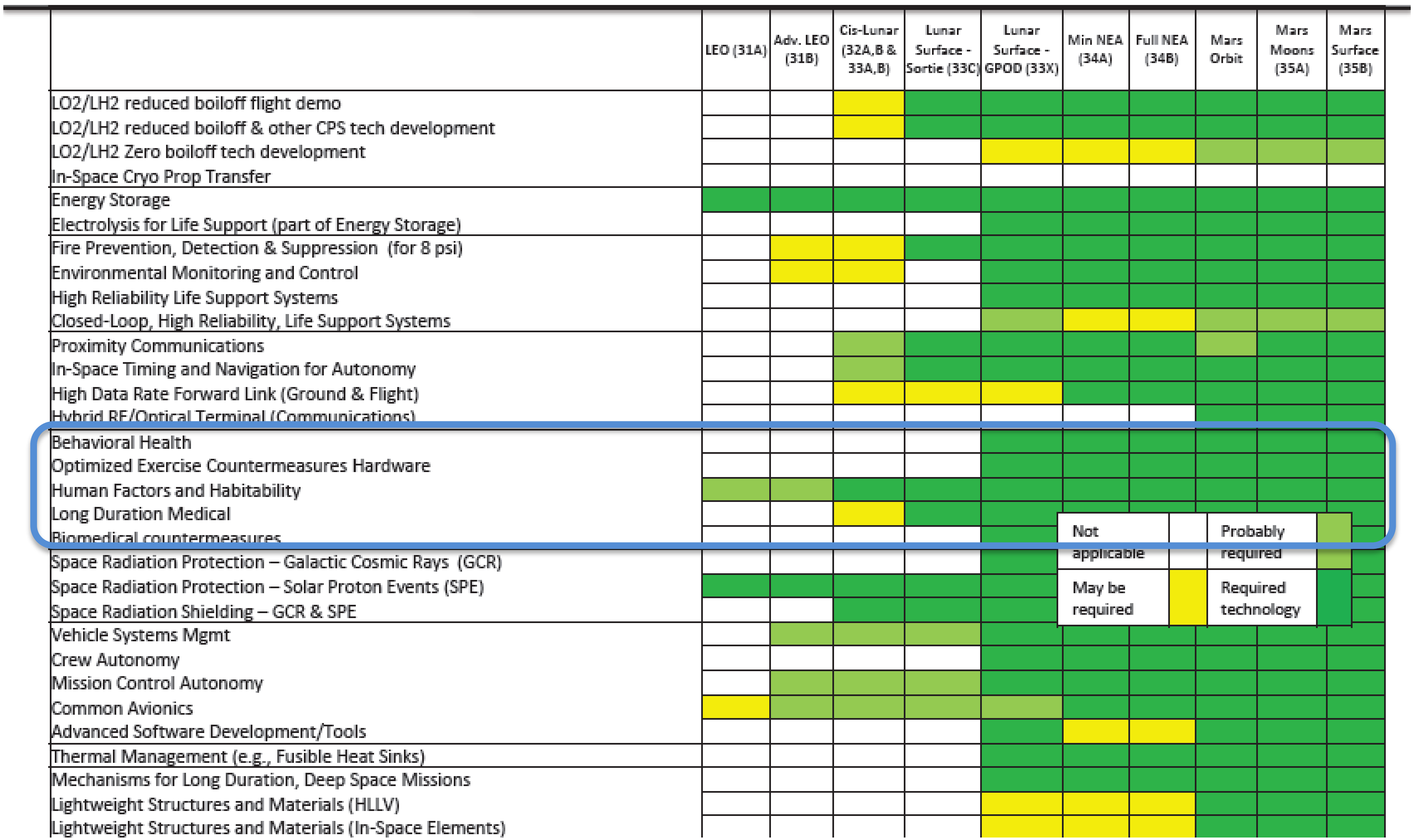
Deep Space Habitat (DSH)

Robotics & EVA Module (REM)

Kick Stage

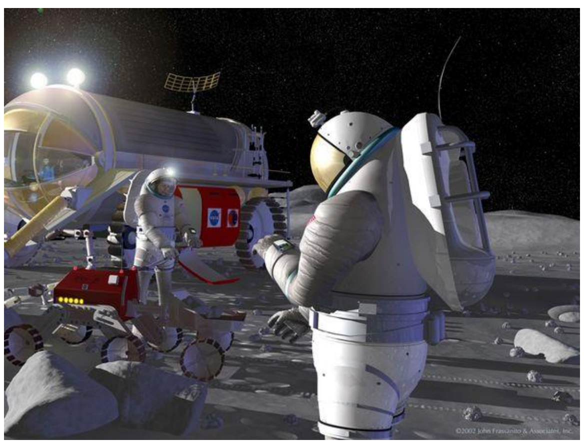


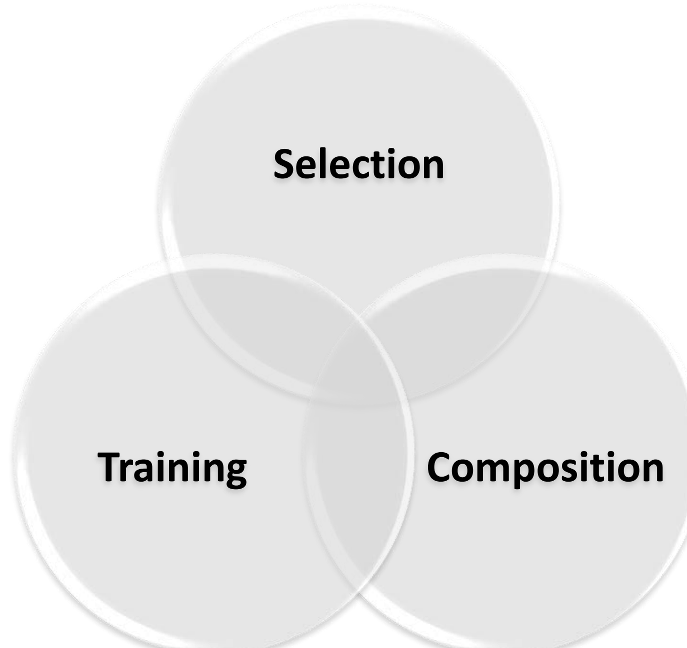
NEA Science Package


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
LO2/LH2 reduced boiloff & other CPS tech development
LO2/LH2 Zero boiloff tech development
In-Space Cryo Prop Transfer
Energy Storage
Electrolysis for Life Support (part of Energy Storage)
Fire Prevention, Detection & Suppression (for 8 psi)
Environmental Monitoring and Control
High Reliability Life Support Systems
Closed-Loop, High Reliability, Life Support Systems
Proximity Communications
In-Space Timing and Navigation for Autonomy
High Data Rate Forward Link (Ground & Flight)
Hybrid RF/Optical Terminal (Communications)
Behavioral Health
Optimized Exercise Countermeasures Hardware
Human Factors and Habitability
Long Duration Medical
Biomedical countermeasures
Space Radiation Protection – Galactic Cosmic Rays (GCR)
Space Radiation Protection – Solar Proton Events (SPE)
Space Radiation Shielding – GCR & SPE
Vehicle Systems Mgmt
Crew Autonomy
Mission Control Autonomy
Common Avionics
Advanced Software Development/Tools
Thermal Management (e.g., Fusible Heat Sinks)
Mechanisms for Long Duration, Deep Space Missions
Lightweight Structures and Materials (HLLV)
Lightweight Structures and Materials (In-Space Elements)
Not applicable
Probably required
May be required
Required technology

Autonomy NRA

- BHP developed a call to study autonomy for spaceflight in a NRA that was posted this summer
- Focused on mitigation strategies for space crew as well as ground control





16.400 / 16.453 Human Factors Engineering
Fall 2011