HSF Transition: ISS, LEO and beyond to cislunar space

“Buona notte” *Kelly at 180 days onboard the ISS*

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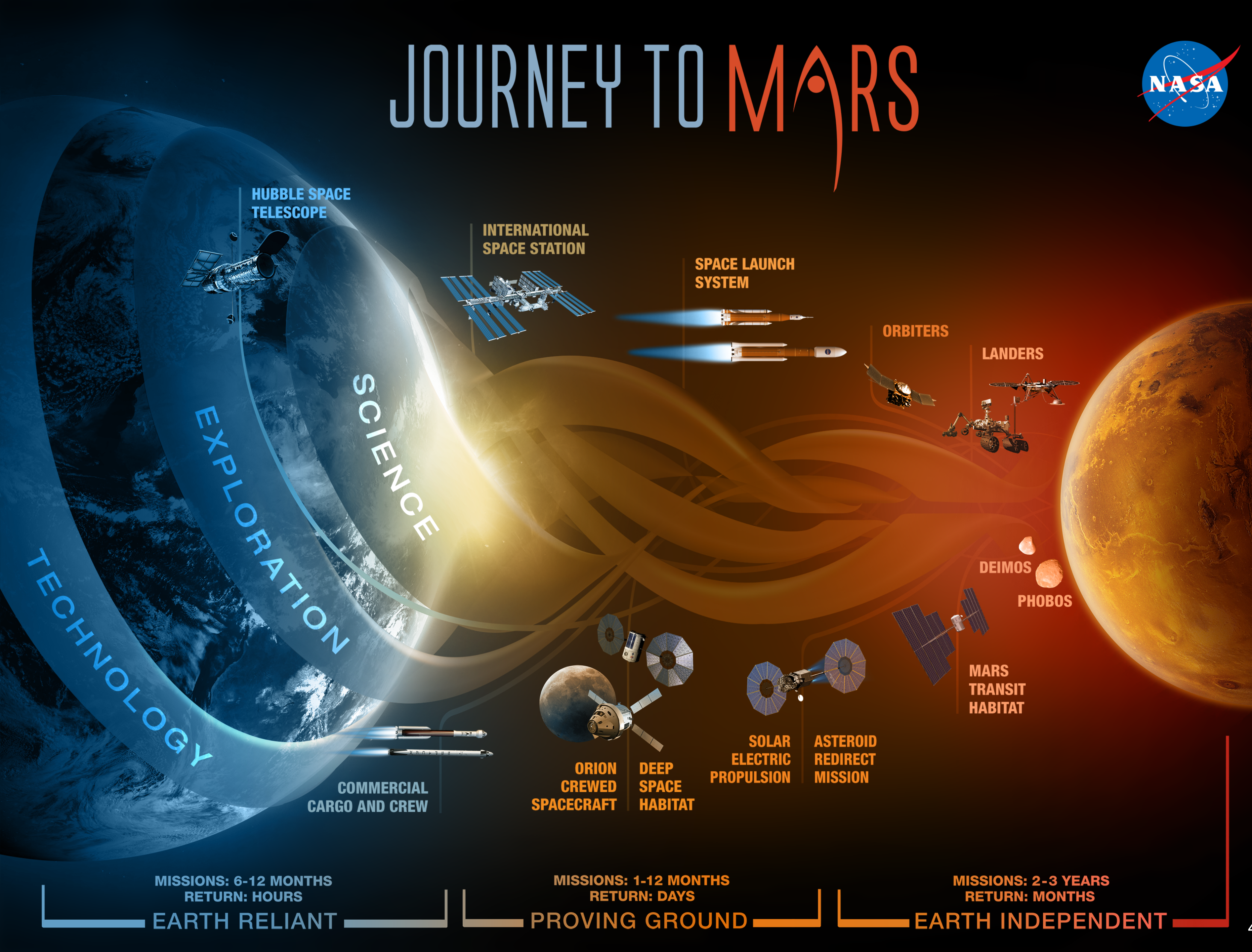
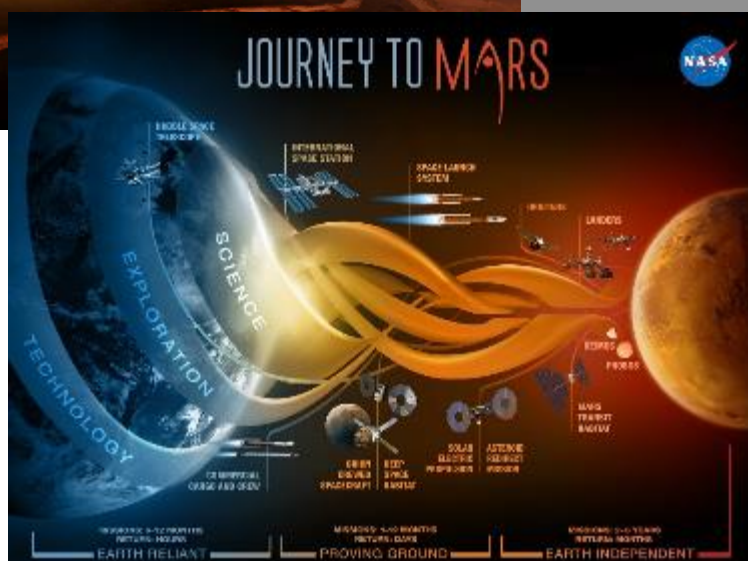

JOURNEY TO MARS
NASA
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
DEIMOS
PHOBOS
MARS TRANSIT HABITAT
COMMERCIAL CARGO AND CREW
ORION CREWED SPACECRAFT
DEEP SPACE HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

Strategic Principles for Sustainable Exploration

- Implementable in the ***near-term with the buying power of current budgets*** and in the longer term with budgets commensurate with economic growth*;*
- ***Exploration enables science* and *science enables exploration***, *leveraging robotic expertise for human exploration of the solar system*
- Application of ***high Technology Readiness Level*** (TRL) technologies for near term missions, while focusing sustained investments on ***technologies and capabilities*** to address challenges of future missions;
- ***Near-term mission opportunities*** with a defined cadence of compelling and integrated human and robotic missions providing for an incremental buildup of capabilities for more complex missions over time;
- Opportunities for ***U.S. commercial business*** to further enhance the experience and business base;
- ***Resilient architecture featuring multi-use, evolvable space infrastructure,*** minimizing unique major developments, with each mission leaving something behind to support subsequent missions; and
- Substantial ***new international and commercial partnerships***, leveraging the current International Space Station partnership while building new cooperative ventures.
- ***Continuity of human spaceflight is essential to sustain progress;*** we will establish a regular cadence of crewed missions to cislunar prior to the end of ISS ***.***

The Bigger Picture



Near-term execution

Planning the transition from ISS to cislunar space

- **Instead of declaring a definite end date for ISS, NASA will focus on considerations such as**
  - Short term crewed habitation missions are being executed in cis-lunar space while ISS is still operational and being utilized
  - Exploration research and technology/system development activities requiring ISS as a testbed are essentially complete
  - There is an expanded commercial market and broad private/government/academic demand for LEO-based platforms that are based on private and/or public/private business models
  - Value benefit of the ISS has been sufficiently achieved
  - Maximizing international ISS partnership and participation
  - Safe sustainment of the ISS will remain paramount

- **Based on todays planning and reasonable progress towards our goals, transitioning HSF could be expected in the mid-2020s**
  - NASA is working with stakeholders, International Partners and industry to develop plans for transitioning the ISS and the Partnership
  - The Partnership should explore possible outcomes for the ISS platform at its' end-of-life
    - De-orbit, disassemble, turn over portions to private industry, maintain government ownership, others ideas

NASA vision for LEO beyond ISS

Vision: Sustained economic activity in LEO enabled by human spaceflight, driven by private and public investments creating value and benefitting Earth through commercial supply and public and private demand

GOALS

1) LEO commercialization enabled by leveraging ISS

- User-friendly ISS process improvements
- Maximize throughput
- Demonstrate & communicate value proposition of ISS
- Foster "success stories"
- Utilize more commercial acquisition strategies

2) The policy and regulatory environment promotes commercialization of LEO

- Establish interagency working group to address policy and regulatory issues
- Investigate economic cluster potential
- Address barriers such as IP retention, liability, ITAR

3) A robust, self-sustaining, and cost effective supply of US commercial services to/in/from LEO accommodates public and private demands

- Leverage NASA NEXTSteps BAA studies and follow-on to enable commercial LEO capabilities
- Enable Earth-similar laboratory capabilities for ISS that can transition to commercial platforms
- Transition from NASA-supplied to commercially-supplied services and capabilities once available

4.0 Broad sectors of the economy using LEO for commercial purposes

- Establish consortia for potential high-payoff, market-enabling microgravity and LEO applications with public and private funds to support development (e.g. protein crystallization, exotic fibers, lightweight alloys, 3D tissues, earth observing, etc)
- Establish commercial LEO utilization university curriculum and programs

Transition framework from ISS to Cislunar Space

Ends with testing, research and demos complete*

Today

Phase 0: Exploration Systems ***Testing on ISS***

Asteroid Redirect-Crewed Mission Marks Move from Phase 1 to Phase 2

Phase 1: ***Cislunar Flight Testing*** of Exploration Systems

Ends with one year crewed Mars-class shakedown cruise

Phase 2: ***Cislunar Validation*** of Exploration Capability

2030

Mid-2020s

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

Draft - Top-Level Phase Objectives

Phase 0: Exploration Research and Systems Testing on ISS

- Test Mars-capable **habitation systems** – ECLS, environmental monitoring, crew health equipment, exploration generation EVA suit, fire detection/suppression, radiation monitoring
- Complete **human health & performance** research and risk reduction activities
- Demonstrate **exploration related technologies and operations**
  - Autonomous crew operations
  - Docking, prox ops

enables

- Robotic manipulation technology and techniques demonstrations
- Remote presence technology development and demonstrations
- Earth/space science
- Enable development of LEO commercial market

Phase 1: Cis-lunar Flight Testing of Exploration Systems

- Demonstrate that **SLS and launch processing systems** can insert both Orion and co-manifested payloads into cis-lunar space
- Demonstrate that **Orion and mission operations** can conduct crewed missions in cis-lunar space at least for 21 days
- Demonstrate **Mars-extensible systems and mission operations** that reduce risk for future deep space missions (with EVA) beyond 21 days

enables

- Validate cis-lunar as staging orbits
- Use of high power SEP for deep space missions
- Asteroid related origins of the solar system science objectives
- Demonstrate real-time robotic lunar surface activities
- In situ resource utilization demonstrations

Phase 2: Cis-lunar Validation of Exploration Capability

- Validate **Mars class habitation** and habitation system functionality and performance
- Validate **Mars class human health and performance**
- Validate operational readiness to leave Earth-Moon system via **one year+ "shakedown cruise"** (no resupply/crew exchanges, limited ground interaction, etc.)

enables

- Origins of the universe, lunar rover volatile sample return
- Other scientific or research objectives?

Phase 0 Research and Technology Development that feeds forward to the Proving ground

Habitation Systems Goals

System	Includes	Today	Mars Goal
Life Support	Air revitalization, water recovery, waste collection and processing	42% recovery of O_2 from CO_2; 90% recovery of H_2O; <6 mo MTBF for some components	>75% recovery of O_2 from CO_2; >98% recovery of H_2O; >2 yr MTBF
Environmental Monitoring	atmosphere, water, microbial, particulate, and acoustic monitors	Limited, crew-intensive on-board capability; rely on sample return to Earth	On-board analysis capability with no sample return; identify and quantify species and organisms in air & water
Crew Health	exercise equipment, medical treatment and diagnostic equipment, long-duration food storage	Large, cumbersome exercise equipment, limited on-orbit medical capability, food system based on frequent resupply	Small, effective exercise equipment, on-board medical capabilities, long-duration food system
EVA	Exploration suit	ISS EMU's based on Shuttle heritage technology; not extensible to surface ops	Next generation spacesuit with greater mobility, reliability, enhanced life support, operational flexibility
Fire	Non-toxic portable fire extinguisher, emergency mask, combustion products monitor, fire cleanup device	Large CO_2 suppressant tanks, 2-cartridge mask, obsolete fire products. No fire cleanup other than depress/repress	Unified fire safety approach that works across small and large architecture elements
Radiation Protection	Low atomic number materials including polyethylene, water, or any hydrogen-containing materials	Node 2 CQ's augmented with polyethylene to reduce the impacts of trapped proton irradiation for ISS crew members	Solar particle event storm shelter based on optimized position of on-board materials and CQ's with minimized upmass to eliminate major impact of solar particle event on total mission dose

Human Health and Performance Research Transition from ISS to Cis-Lunar Space

ISS Goals for Space Exploration (investigate, develop, and test)

- Human health risks and capabilities to mitigate these risks
- Exploration biomedical technologies and tools
- Extend mission durations to one-year to test six-month research and countermeasures
- Visual impairment/intracranial pressure risk and assess countermeasures
- Space radiation protection/monitoring systems
- Long-duration spaceflight stressors to the immune system and microbiome
- Exploration food system technologies
- Crew habitation standards and models

Mars Goals for Cis-lunar Space (validate)

- Advanced countermeasures against deconditioning (bone, muscle, cardiovascular)
- Crew performance, psychological well-being, and intervention for Mars flight operations
- Integrated medical capabilities (autonomous medical diagnosis and treatment)
- Human and environmental health in a closed Mars spacecraft (immune system, microbiome)
- Mars mission food system
- Space radiation protection/monitoring systems
- Crew habitation systems (human computer/ robotic/vehicle interfaces)
- Robustness/reliability of crew exercise systems

Next slides will focus on a discussion of Phase 1 objectives

Draft - Cis-lunar Flight Testing of Exploration Systems

Phase 1: ***Cislunar Flight Testing*** of Exploration Systems

Asteroid Retrieval Crewed Mission Marks Move from Phase 1 to Phase 2

EM-1

OBJECTIVES:

- Demonstrate integrated SLS/Orion capability from launch through recovery in cis-lunar space
- Obtain ascent and in-space environments data
- Demonstrate performance of communications, network, and tracking capabilities
- Demonstrate ground processing and operational support
- Deploy secondary payloads

MISSION ELEMENTS AND CAPABILITIES:

- SLS Block 1 (EM-1)
- Orion
- Secondary Payload deployment

Considerations, Constraints, and Unknowns:

- Initial mission design driven by need to meet flight test objectives

Draft - Cis-lunar Flight Testing of Exploration Systems

Phase 1: ***Cislunar Flight Testing*** of Exploration Systems

Asteroid Retrieval Crewed Mission Marks Move from Phase 1 to Phase 2

EM-2

OBJECTIVES:

- Demonstrate SLS/Orion crewed cislunar transportation and trajectory capability in cislunar space up to 21 days w/ 4 crew
- Demonstrate co-manifested payload capability in cis-lunar space (~ 5MT or better)

MISSION ELEMENTS AND CAPABILITIES:

- SLS Block 1B (EM-2 and subsequent)
- Orion
- Co-manifested capability (in work)

Considerations, Constraints, and Unknowns:

- Initial mission design driven by need to meet flight test objectives
- Initial co-manifesting planning driven by conservative analysis
- Proximity operations under evaluation

Draft - Cis-lunar Flight Testing of Exploration Systems

Phase 1: ***Cislunar Flight Testing*** of Exploration Systems

Asteroid Redirect Crewed Mission Marks Move from Phase 1 to Phase 2

EM-Next 2-3

OBJECTIVES:

- Demonstrate extended crewed operations in cis-lunar space with 4 crew beyond 21 days
- Demonstration of crew health and performance systems particularly exercise, medical, and radiation protection
- Demonstrate deep space EVA capability
- Deploy co-manifested element(s) in cislunar space
- Perform ARCM mission objectives

MISSION ELEMENTS AND CAPABILITIES:

- SLS Block 1B
- Orion
- Co-manifested element(s) with docking, power, propulsion and mission augmentation capabilities to support increasingly ambitious missions in Phase 2
- (ARM robotic spacecraft)

Considerations, Constraints, and Unknowns:

- Mission(s) orbit driven by ARCM mission objectives
- Co-manifesting capability under analysis
- Partner discussions continue on execution of ARM and ARCM missions and co-manifested elements
- Number of additional missions required to execute ARCM dependent on risk buy-down of previous missions and eventual co-manifesting capability

Discussion