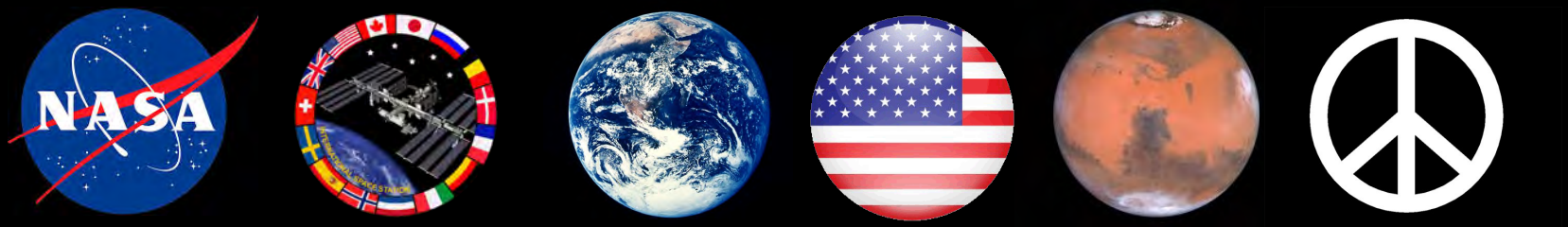
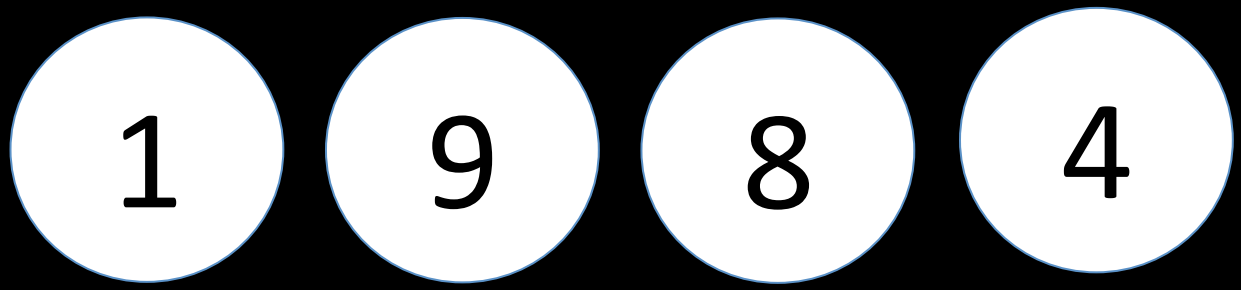


NASA and the Legacy of the International Space Station

Sam Scimemi
Director, International Space Station
NASA Headquarters

NASA Advisory Council
HEO Committee
July 29, 2013

In the beginning….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Exerpt form President Reagan's State of the Union Address in 1984

Nowhere is there more important than our next frontier: space. Nowhere do we so effectively demonstrate our technological leadership and ability to make life better on Earth. The Space Age is barely a quarter of a century old. But already we've pushed civilization forward with our advances in science and technology. Opportunities and jobs will multiply as we cross new thresholds of knowledge and reach deeper into the unknown.

→ American leadership & benefits on earth

Our progress in space - taking giant steps for all mankind - is a tribute to American teamwork and excellence. Our finest minds in government, industry, and academia have all pulled together. And we can be proud to say: We are first; we are the best; and we are so because we're free.

→ American ingenuity

America has always been greatest when we dared to be great. We can reach for greatness again. We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight, I am direct ing NASA to develop a permanently manned space station and to do it within a decade.

⇒ Mission Direction

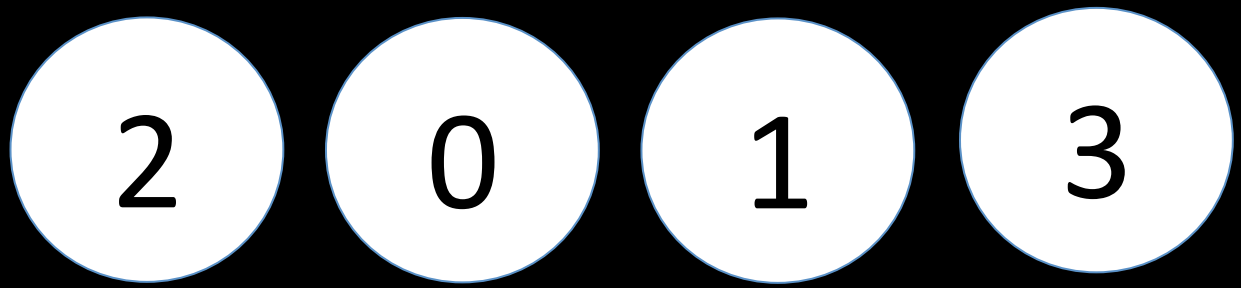
A space station will permit quantum leaps in our research in science, communications, in metals, and in lifesaving medicines which could be manufactured only in space. We want our friends to help us meet these challenges and share in their benef its. NASA will invite other countries to part icipate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals.

→ Promise of discovery

→ Diplomatic mission

Just as the oceans opened up a new world for clipper ships and Yankee traders, space metals, and in lifesaving medicines which could not manufactured only in space. We want surpass our capacity to develop it. Companies interested in put ting payloads into space must have ready access to private sector launch services.

→ Driver for private initiative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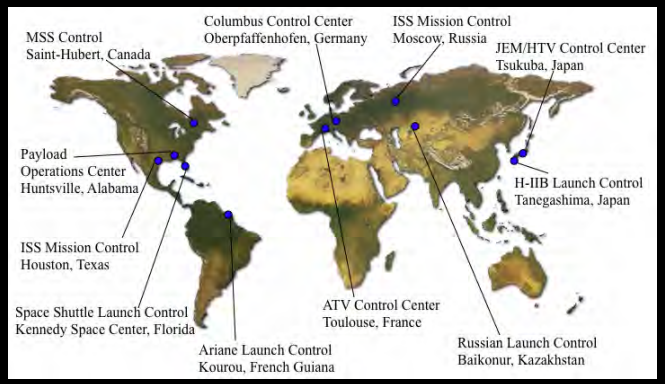
The International Space Station Today

- International in-space research and technology development endeavor in partnership with 5 space agencies
  - US, Russian, European, Japanese and Canadian space agencies
- First element in-orbit since November 1998
- Permanently crewed since November 2000
- 207 different people from 15 countries have visited ISS
- Operational at least through 2020
- Supplied by crew and cargo vehicles from across the partnership
- Large as a football field
- Nearly 1 million pounds in-orbit
- Habitable volume of a 5 bedroom house
- Ground control, training, operations and launch facilities in 8 countries



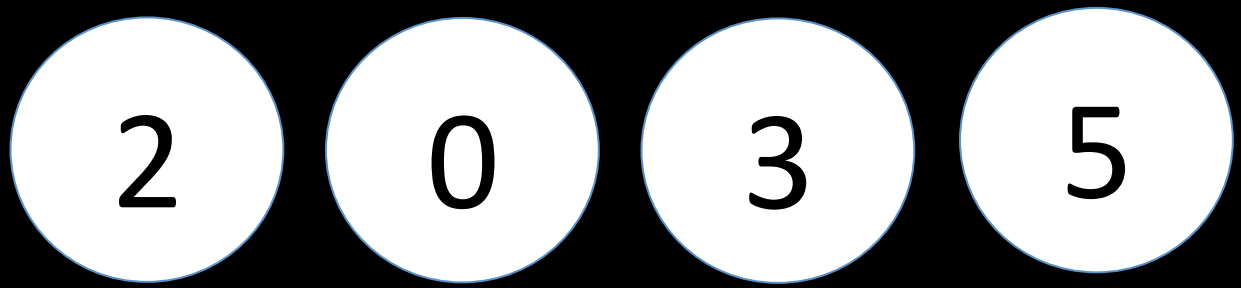
What's the purpose of ISS?

Advance benefits to humanity through research

Enable a commercial demand driven market in LEO

Enable long duration human spaceflight beyond LEO

Basis for international exploration partnership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This is what we would like to be saying about the ISS in 2035

Discoveries made on ISS enabled new medicines and treatments that saved or improved the lives of millions of people

The government demand for commercial services in LEO spawned a self sustaining non-government commercial demand driven market

Research and demonstrat on activities onboard the ISS enabled human missions to Mars

Astrophysics research on ISS created a new branch of scientific knowledge

The ISS International Partnership spawned a global partnership that lead many nations in the peaceful pursuit of human missions to Mars

The extension of Station beyond 2020
is essential to meeting this Legacy

"Time works so hard for us, if only we can let it."

Tana French

Time to complete a study in orbit

- 2 weeks to 5+ years

Time from completion of study in orbit to first publication

- 1 to 3 years for majority of investigations

Time from publication or patent to product being in the marketplace

- 3-20 years (shorter for technologies, longer for drug development)

Primary Categories of ISS Research

Major factors influencing research use of ISS

Resource limitations (e.g., upmass, crewtime)

- Flight delays to resupply and return plan
- Operations scenarios that reduce crew time for research

Cost to use the platform

- Transportation costs (now provided for all)
- Costs of payload development (National Lab enabling funding)

Strategies to tip the balance: diverse transportation providers, procure upmass for more users, simplify integration, communicate successes

Research Demand

- NASA Funding
- Non-NASA Funding
- Research breakthroughs that drive funding (Earth benefits & applications)

Recent Research Activities

- **Discoveries**
  - Cool flames vaporize without visible flame in space
  - Human immune cells adapt to weightlessness
  - MAXI black hole swallowing star *(Nature)*
  - Vision impacts and intercranial pressure (*Opthalmology*)
  - Microbial virulence *(Proc. Nat. Acad. Sci.)*

- **Technology Spinoffs**
  - NeuroArm image-guided robot for neurosurgery translates Canadarm technology to the operation room
  - Dusty plasmas applications for medical applications and neutralizing drug-resistant bacteria
  - "Smart" fluids (colloids) phase transition to solid-like states
  - TiO2 for filtering bacteria from the air in daycares
  - Remotely-guided ultrasound for maternal care in remote areas

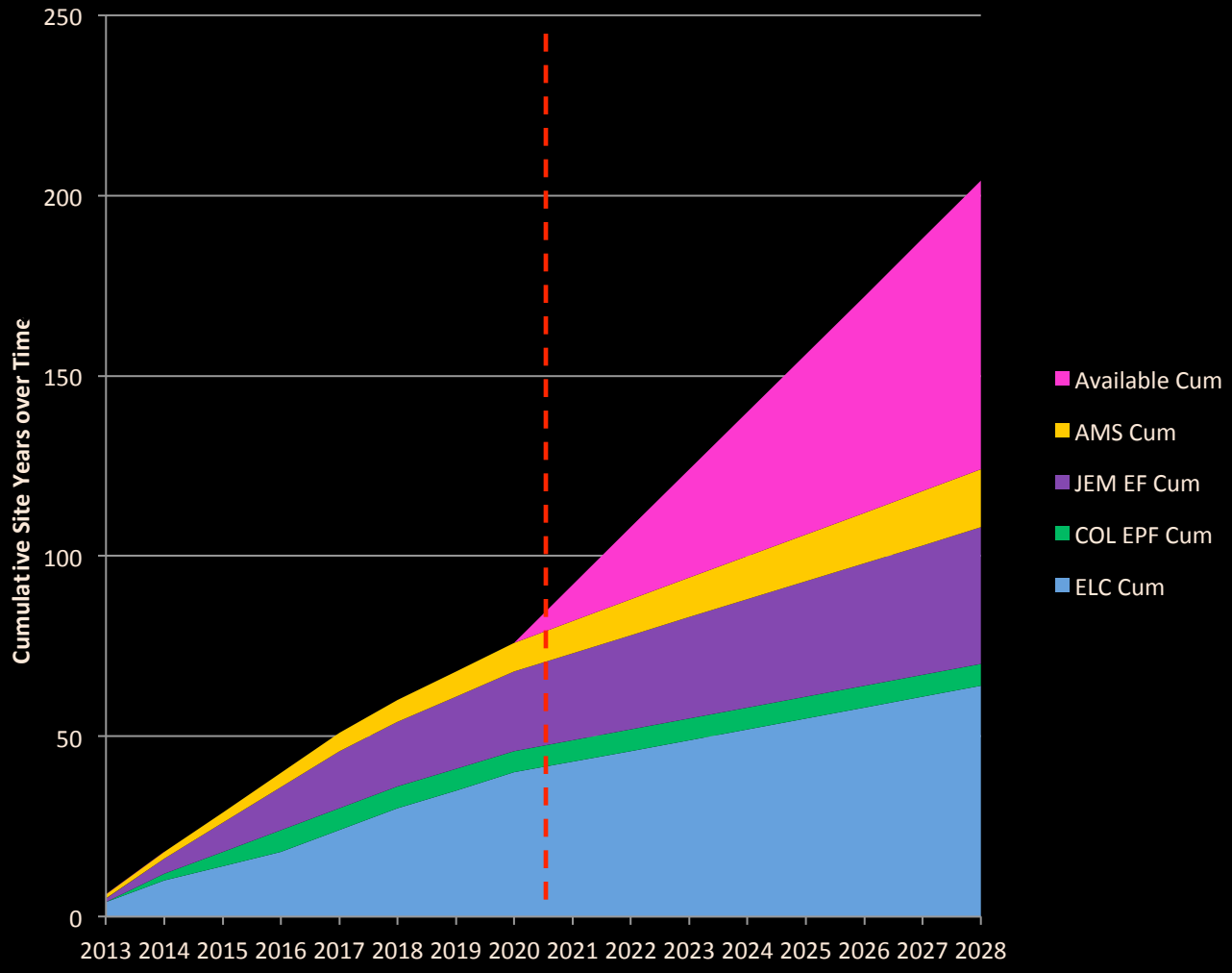
- **NASA Exploration Mission**
  - Software defined radios reconfigurable via ground commands
  - Environmental control and life support sustaining and reliability
  - Success in bone health maintenance resistive exercise *(J. Bone Mineral Res.)*
  - Satellite servicing, repair and refueling demonstrations on ISS
  - Models for Atomic Oxygen erosion in orbit

- **Results with potential Earth benefit**
  - Amgen bone loss drug testing aided by ISS mouse research model
  - Hyperpectral imaging for environmental monitoring
  - YouTube Space Lab global contest for 14 - 18 year old students
  - Candidate vaccines for Salmonella and MRSA
  - Candidate treatment for prostate cancer
  - Candidate treatment for Duschenne's muscular dystrophy

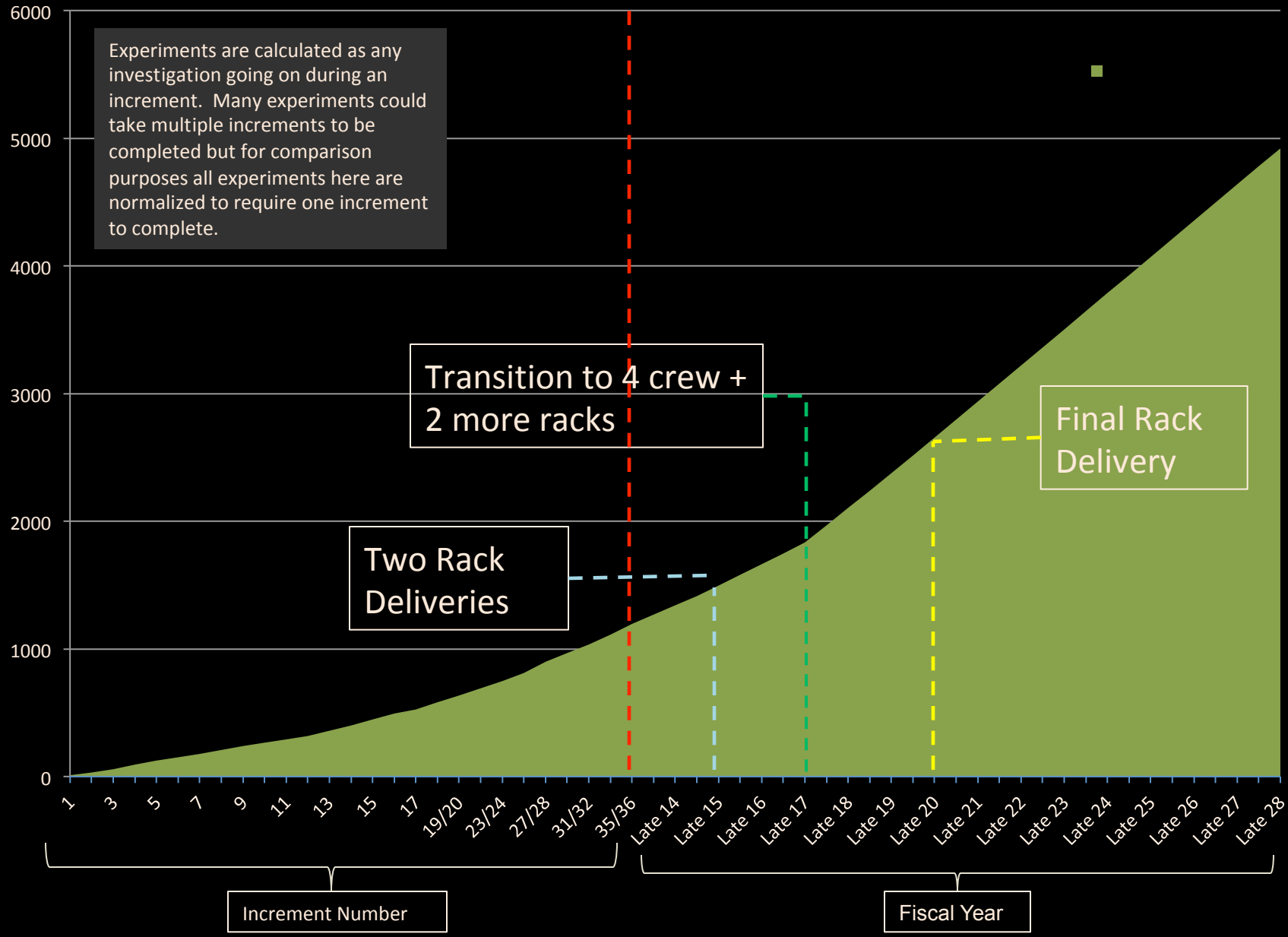
If the life of the ISS was extended beyond 2020…

Cumulative External Site Use and Opportunities

Extension from 2020-2028 offers 166% more research on ISS

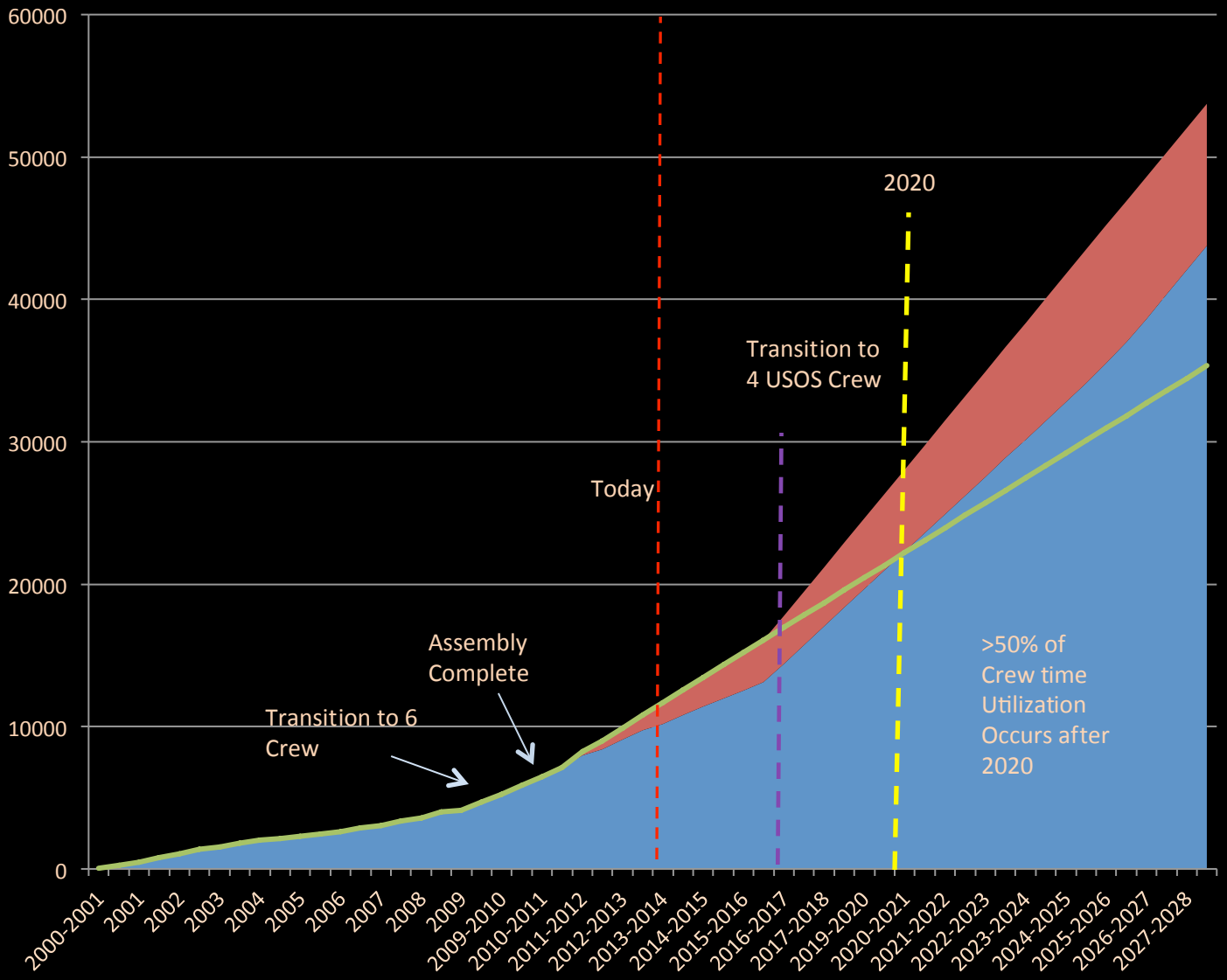


Cumulative # of Internal Experiment Opportunities
Extension from 2020-2028 offers 85% more research



Cumulative Crew Time

Extension from 2020-2028 offers 103% more crew time for research



*HRP Crew Hours available start ing in Increment 29.

Enable a commercial demand driven market in LEO

Over the next 10 years, the FAA predicts that commercial crew and cargo flight to the ISS will account for 57% of the non-GEO launch market

- FAA 2013 Commercial Space Transportation Forecasts, May 2013

Worldwide there are 14-15 flights to the ISS per year

- ISS represents a substantial demand for LEO launch access
- enables immediate access to space and ISS resources

US Cargo	68
US Crew	15
International Cargo	57
International Crew	33
Total Launches	173

	Soyuz		Soyuz	US Crew	US Crew	US Crew					
Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	US Crew	US Crew	US Crew	US Crew	US Crew	US Crew	US Crew
Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	US Crew	US Crew	US Crew	US Crew	US Crew
Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz
Soyuz	Progress	Soyuz	Progress	Progress	Progress	Progress	Soyuz	Soyuz	Soyuz	Soyuz	Soyuz
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Progress	HTV	Progress	HTV	HTV	HTV	HTV	Progress	Progress	Progress	Progress	Progress
HTV	ATV	HTV	Orbital	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo
ATV	Orbital	Orbital	Orbital	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo
Orbital-D	Orbital	Orbital	Orbital	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo
Orbital	SpaceX	SpaceX	SpaceX	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo
SpaceX	SpaceX	SpaceX	SpaceX	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo
SpaceX	SpaceX	SpaceX	SpaceX	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo
2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**

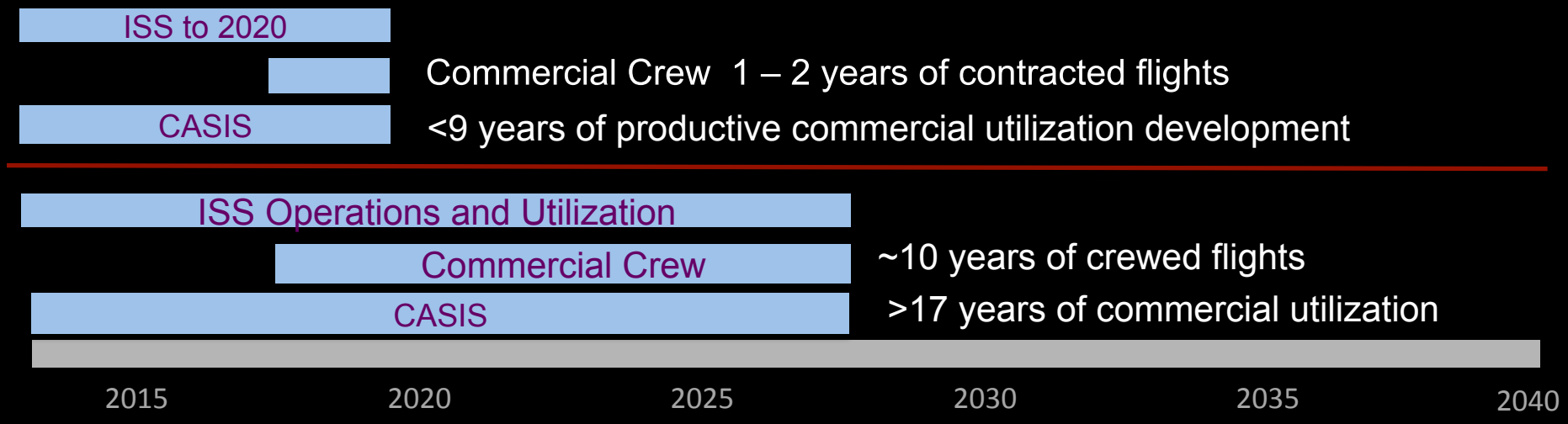
Enable a commercial demand driven market in LEO

Without a definitive commitment to extend the ISS beyond 2020 it is not practical to continue with commercial crew development activities with less than 2 years of contracted crew flights

Furthermore, if ISS ends in 2020, there would be no need to purchase additional CRS cargo flights beyond the current contract

- the much delayed current manifest would be stretched out

Ending the ISS in 2020 would also limit the ability of CASIS to develop the commercial use of ISS and LEO



How can commercial utilization be achieved

- Demonstrate that the fundamental questions regarding microgravity can be answered
- Create opportunities to address these questions – seed funding, partnerships, grant challenges, outreach
- Familiarize the research community at large with the CASIS business model and utility of ISS
- Streamline process while preserving safety and integrity of crew and vehicle
- Achieve repeatability, reduce time to flight, and lower cost

CASIS Commercial Activities

- To date >$15M obligated for ISS NL research across 40 projects
- >$2M non-NASA funds committed to targeted flight opportunities
- Commercial Partnerships with Boston Museum of Science, MD Anderson, Baylor College of Medicine, MIT, MassChallenge, Boeing, NSTA, The Broad Institute, etc.
- Flight Project Agreements with P&G, Merck, Cobra Puma, numerous universities
- MOAs in place and/or in development with NIH, NOAA, USDA, VA, DoD, NRL (Navy)

Enable a commercial demand driven market in LEO

ISS can also enable the demand for commercial uses and applications in LEO that could lead to a commercially provided LEO plat form

- Utilize additional commercial crew seats and access to ISS for non-NASA uses including research, tourism or other private initiatives

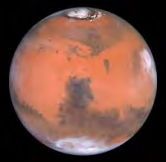
It is likely that NASA will st ill have research needs in LEO beyond the life of the ISS

ISS Operations and Utilization

Commercial Crew ~10 years of crewed flights

Commercial Research >17 years of scientific discovery since assembly complete

Enable long duration human spaceflight beyond LEO



It is generally accepted that the driving mission capabilities for human spaceflight beyond LEO are missions to Mars

- human health and performance
- system performance (propulsion, ECLS)
- mission capability (EDL, In-situ)
- partnerships

We are here today

~ 2 days transit time

Communications (near real-time)

Crew exchanges

Crew supplies and logistics

Crew and atmosphere samples

Modified hardware

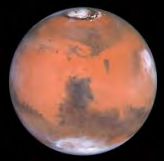
Emergency Crew Return

Trash

390 kilometers

“car camping in space”

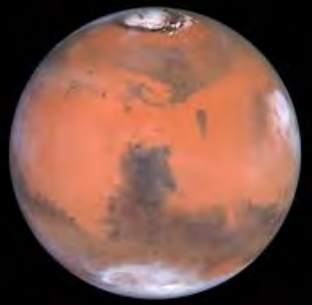
There is only one link between Mars and Earth



228,000,000 kilometers

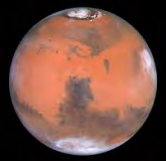
~1 - 3 years transit time

Communications (up to 42 minutes)

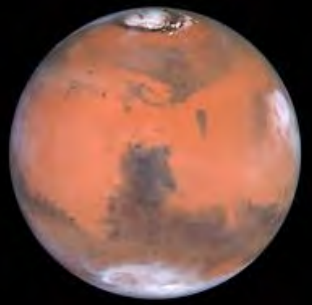


“ recreate living on Earth capability”

Links to the Earth must be broken



228,000,000 kilometers



~1 - 3 years transit time

Communications (up to 42 minutes)

~ 2 days transit time

Communications (near real-time)

Crew exchanges

Crew supplies and logistics

Crew and atmosphere samples

Modified hardware

Emergency Crew Return

Trash

“ recreate living on Earth capability”

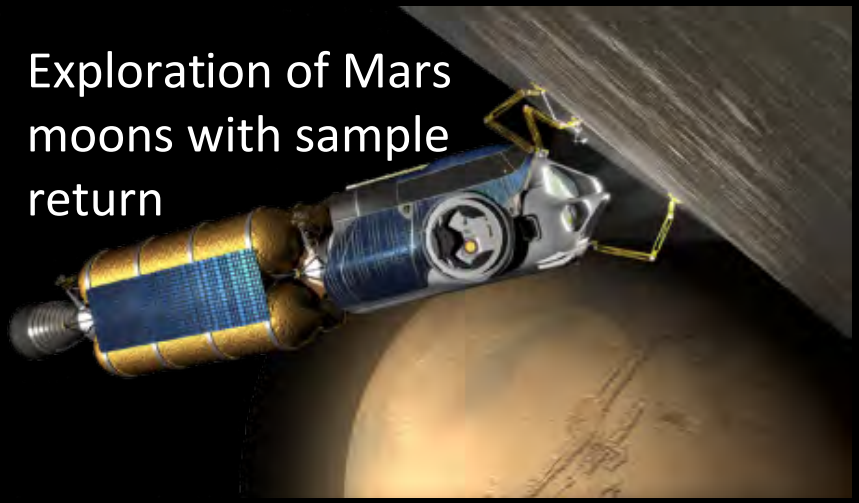
390 kilometers

“car camping in space”

4 Corners Mars DRM's

Mars Moons Mission

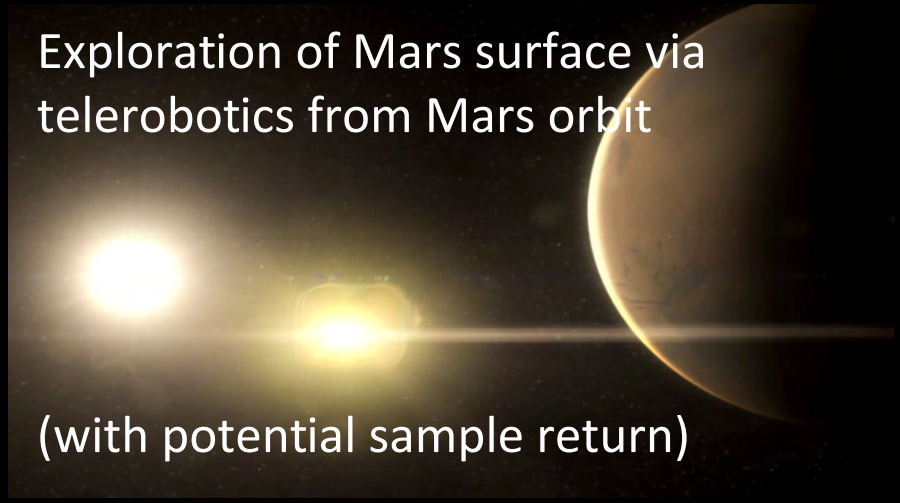
Exploration of Mars moons with sample return



Mars Orbit Mission

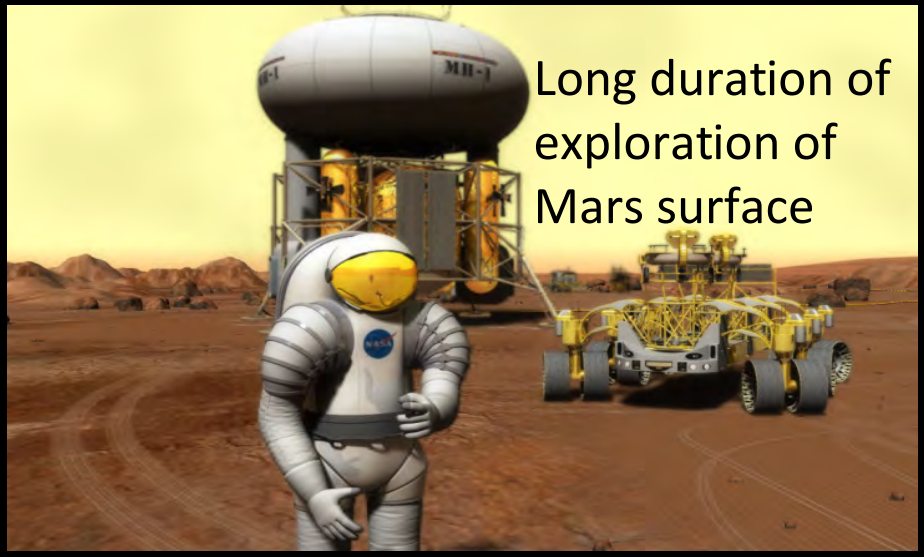
Exploration of Mars surface via telerobotics from Mars orbit

(with potential sample return)



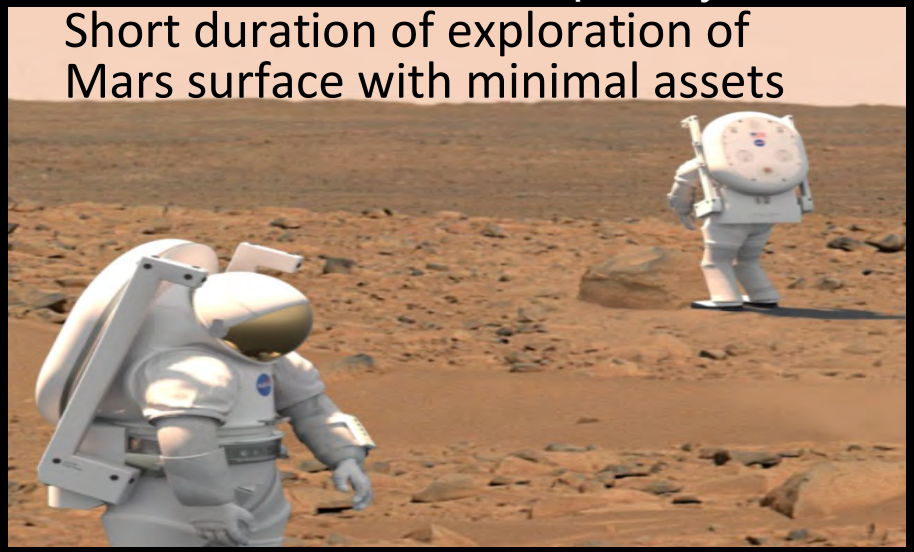
Mars Surface Mission

Long duration of exploration of Mars surface

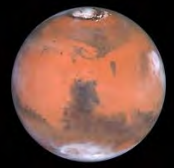


Mars Surface "Minimal Capability" Mission

Short duration of exploration of Mars surface with minimal assets



Research and demonstrations on ISS can close the gaps in green, partial in yellow



Technologies & Capabilities

- ECLSS & Environmental Monitoring
- EVA
- Fire Safety
- Entry Heat Shield
- Communications & Navigation
- Long duration Cryogenic Storage Systems
- Fission Power
- Electric Propulsion
- Mars Entry, Descent & Landing Systems
- High Power Solar Power
- Variable, low mass thermal systems
- ISRU
- Habitation and Lightweight Structures
- Nuclear Propulsion
- Docking systems
- Autonomous AR&D

Human Health

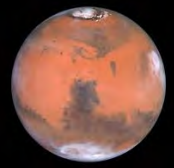
- Long Duration Health & Performance
- Microgravity Biomedical Countermeasures/ Exercise Equipment
- Radiation Monitoring
- Radiation Protection

Operations

- Crew Autonomy, Comm Delay
- Telerobotics
- Robotic crew assist

HEOMD PPBE 2015 inputs for ISS, HRP, SCaN, and AES have content to execute closure of these gaps

Closing the gap in Human Health and Performance



The ISS is necessary to mitigate 21 of the 32 human health risks anticipated on exploration missions

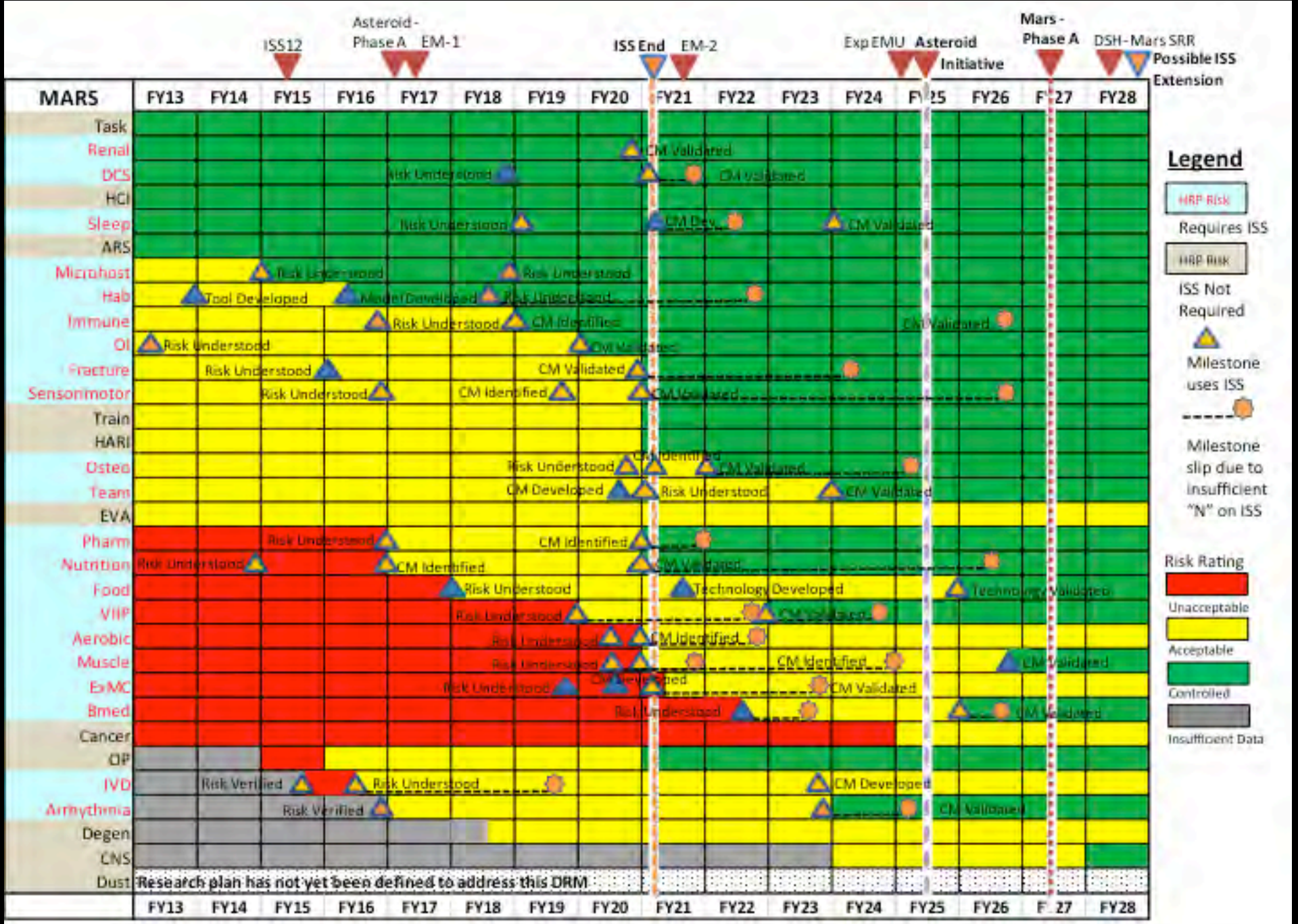
The overall flight resources available to HRP are insufficient to complete the research that requires access to ISS prior to 2020

This issue is further confounded by potential conflicts or interactions between research studies.

Some of the primary drivers for the length of research onboard ISS are:

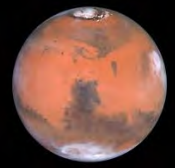
- Number of subjects
- Pharmacology
- Visual Impairment and Intracranial Pressure
- Muscle
- Explorat ion Medical Capability
- Arrhythmia

Given the current number of subjects expected, HRP research and mitigations for long duration deep space missions should be mature enough by the mid-2020's



DRAFT - Initial Assessment. Will be refined further as updated Integrated Research Plan is finalized.

Example of goals to close the gap



HEOMD is working to develop a similar chart to HRP for all the gaps

Technologies & Capabilities

ECLSS & Environmental Monitoring

ECLSS Goal: Demonstrate highly reliable Mars ECLSS on ISS for at least 2 years

- CO_2 removal with no bad maintenance
- Reliable and less complex O_2 generation
- High pressure O_2 for EVA
- Minimum 85% water recovery from urine
- Water recovery system reliability and life improvements
- Common biocide with replenishment on orbit
- Tolerate dormancy
- Universal compact commode
- Additional loop closure (O_2 from CO_2, water from urine brine)

Environmental Monitoring Goal: Demonstrate common suite of monitors that do not rely on ground sample return & resupply

- Improved major constituent analyzer
- On-board trace gas monitor
- Targeted gas monitor
- Water monitor with identification/speciation
- Microbial monitor with identification/ quantification

Closing the gap in time

2013

Since this is our goal

Begin Sending Humans to Mars

2015 2020 2025 2030 2035 2040

Then this is true

Begin Sending Humans to Mars

Freeze design
(*pencils down*)

2015 2020 2025 2030 2035 2040

Then this is also true

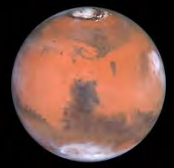
Begin Sending Humans to Mars

Architecture & Partnership baseline

Freeze design (*pencils down*)

2015 2020 2025 2030 2035 2040

And this is true



- Human health and performance
- Operations and simulations
- ECLS, Env Monitoring, Exercise equipment, etc.

Performance Expectations

Design

Architecture & Partnership baseline

Freeze design (*pencils down*)

Begin Sending Humans to Mars

NASA must complete its Mars related research and technology demonstrations on ISS in the med-2020's

2015 2020 2025 2030 2035 2040

Basis for international exploration partnership

The ISS Program is sufficiently complex to engage the major space fairing nations in a common endeavor.

If the ISS Partnership dissolves prematurely, it is not likely that a new partnership could be established in time to fulfill the objective of getting to Mars with humans in the 2030's timeframe.

?

2015 2020 2025 2030 2035 2040

Basis for international exploration partnership

With the ISS Program and Partnership fully engaged in human spaceflight through its' certification life, the Partnership can be maintained and enhanced to accomplishing our Mars objectives.

2015 2020 2025 2030 2035 2040

How do we know when we are done with ISS

Advance benefits to humanity through research

Has the ISS life been fully exploited to the benefit of science and research?

Enable human missions beyond LEO

Has the critical technologies to conduct human and robotic exploration mission been demonstrated?

Has the fly off plan to reduce human health and performance risk for long duration deep space mission been completed?

Has extended crew health and performance operations been fully demonstrated?

Enable commercial demand driven LEO market

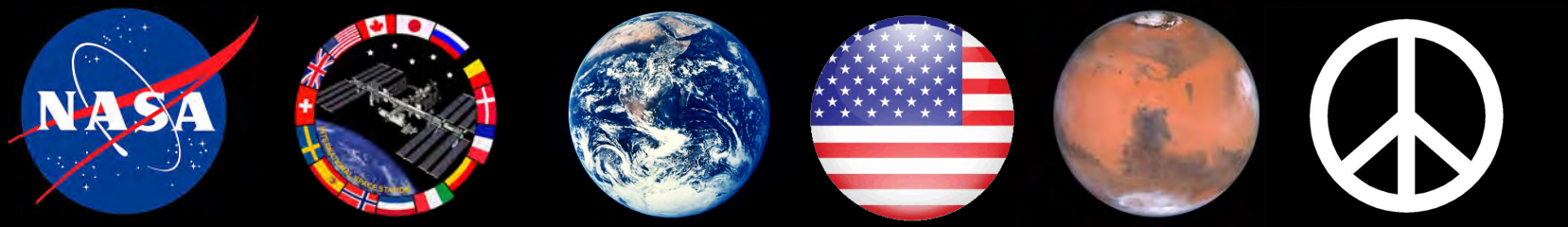
Has a non-government commercial crew/cargo transportation market DEMAND been established in LEO?

Has a commercial LEO platform been established that could satisfy government needs?

Has a non-government commercial demand for micro gravity research and application been established?

Basis for international exploration cooperation

Has an exploration partnership been established?



NASA and the Legacy of the International Space Station