NASA and the International Space Station

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HEO NAC
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December 10, 2013

The International Space Station is essential to meeting the Nation's goals in space

Returning benefits to humanity through research

Enabling a self-sustaining commercial LEO market

Laying the foundation for long-duration spaceflight beyond LEO

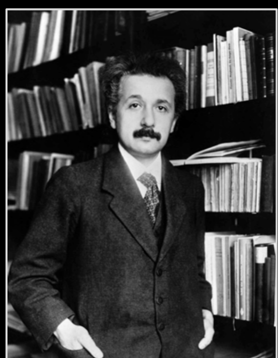
Leading the world in an exploration partnership

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

Tana French

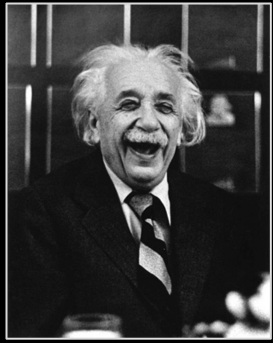
Time to complete a study in orbit

– 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 to 20 years (shorter for technologies, longer for drug development)

Historical Micro-G Research Perspective

Exploratory | Survey | Application

1973-1979

1981-2011

1994-1998

1998

2011
Assembly Complete

~1.5 years of productive on-orbit micro-g research

M. Uhran, Positioning the ISS for the Utilization Era

Some of the Benefits to Humanity To-date

- **Discoveries**
  - Cool flames vaporize without visible flame in space (*Combustion and Flame*)
  - Human immune cells adapt to weightlessness (J. *Leukocyte Biology*)
  - MAXI black hole swallowing star (*Nature*)
  - Vision impacts and intracranial 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

- **Results with potential human benefits**
  - Amgen bone loss drug testing aided by ISS mouse research model
  - Hyperspectral 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

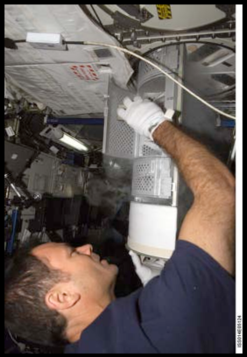
Science Mission Directorate Uses of ISS

- ISS Included as a platform in Science Mission DirectorateD solicitations since 2011
  - Explorer-AO; SALMON: Stand Along Missions of Opportunity; SMEX: Small Mission Explorer; ROSES-APRA: Research Opportunities in Space and Earth Sciences – Astrophysics Research Announcement; Earth Venture
- Selections based on decadal survey priorities among proposals on any platform
  - Astrophysics selected CREAM (Cosmic Ray Energetics and Mass) for ISS under ROSES-APRA
  - Astrophysics selected NICER (X-ray navigation) for ISS under Earth Venture-Instrument
- Funded by ESD with ISS support for integration and pointing device
  - SAGE-III (upper atmosphere composition)
  - OCO-3 (atmospheric CO2 sources and sinks)
- Instruments funded by ISS, support for science/ops from ESD
  - CATS (cloud lidar), technology demonstration
  - RapidScat (winds, hurricanes), etc., fills data gap following QuikScat end of life
- International Astrophysics instruments leveraging
  - CALET (Calorimetric Electron Telescope
  - JEM-EUSO (tentatively), JAXA/ESA/ASI/Roscosmos collaboration

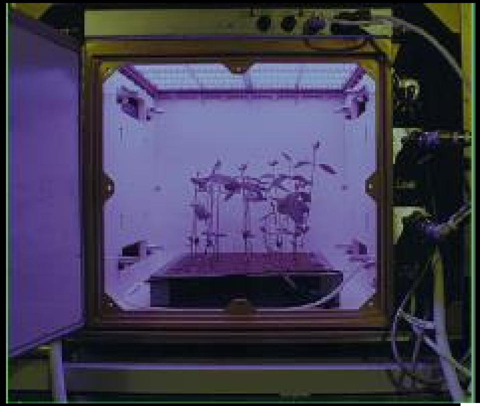
Expansion of ISS Research Capabilities
Enabling Greater Scientific and Commercial Return

Rodent Research System

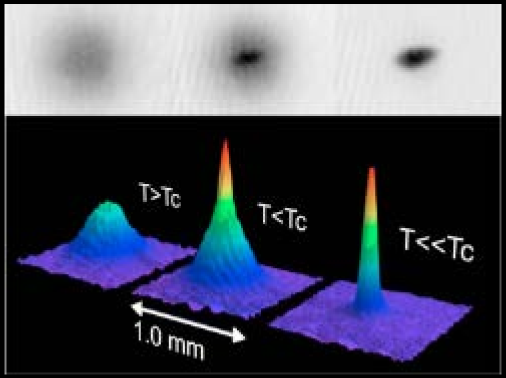
Drosophila (Fruit Fly) Habitat and Centrifuge



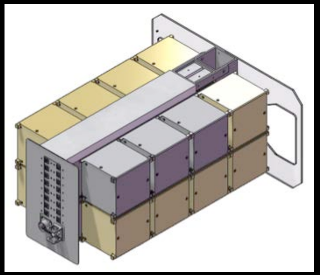
Microbial Observatory



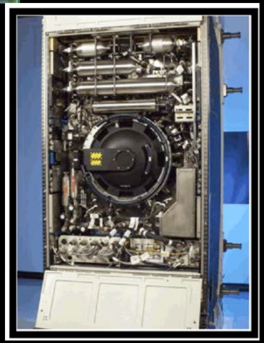
Advanced Plant Habitat



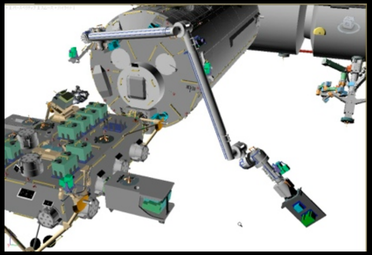
Cold Atom Laboratory



NanoRacks Enhancements



ACME Gaseous Combustion

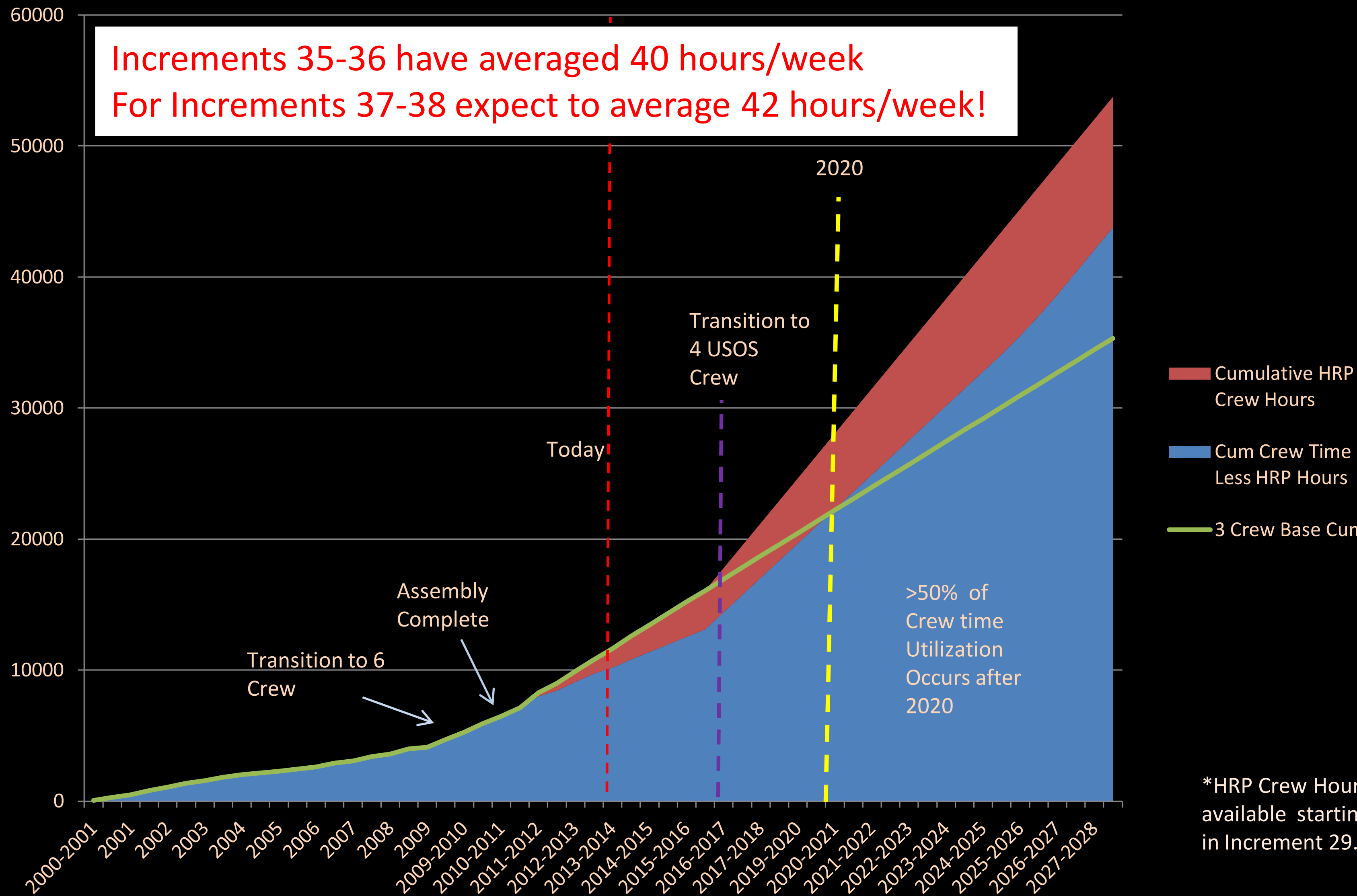


CubeSat Launchers

What would it mean if ISS were extended beyond 2020 for research

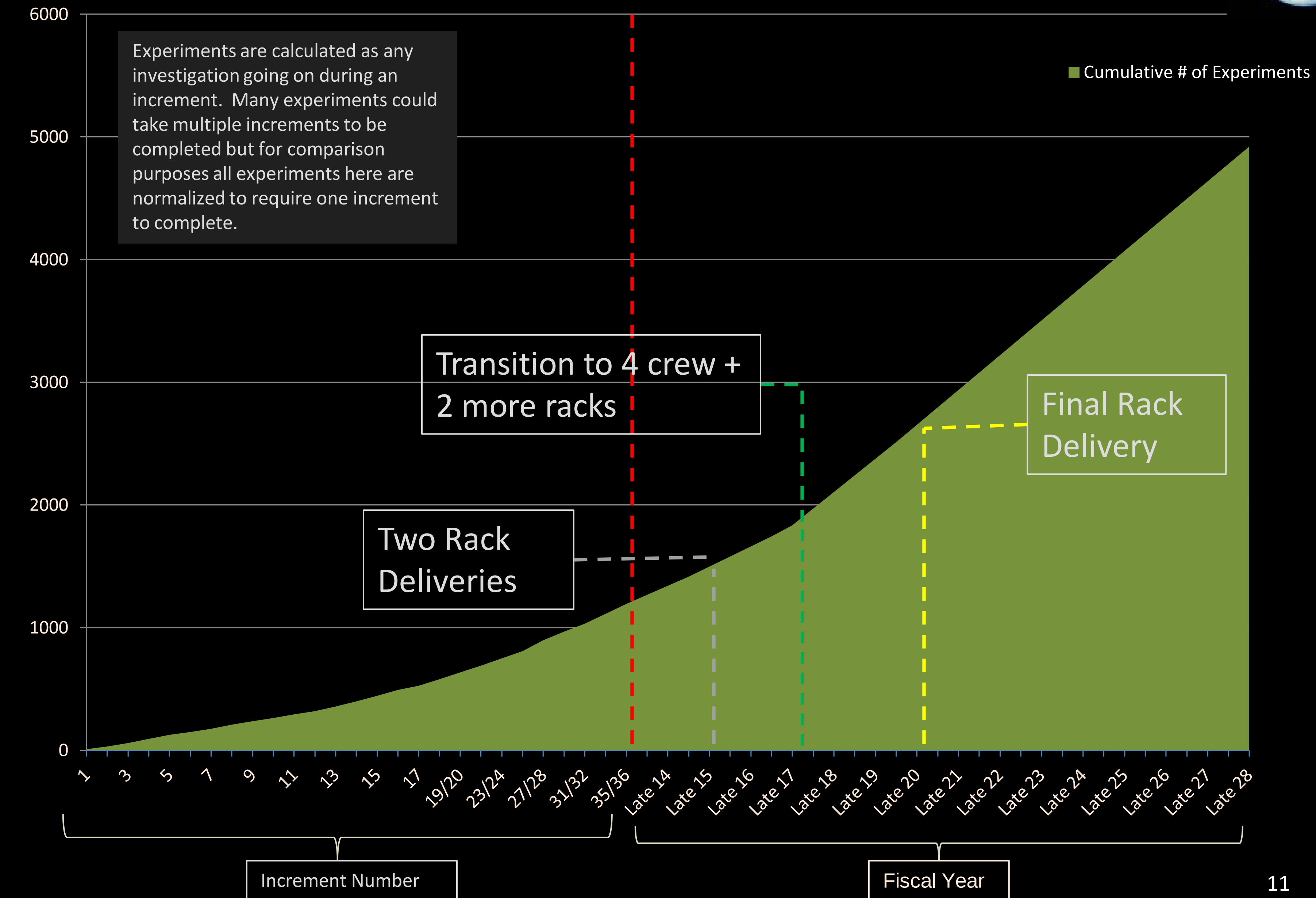
Cumulative Crew Time

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



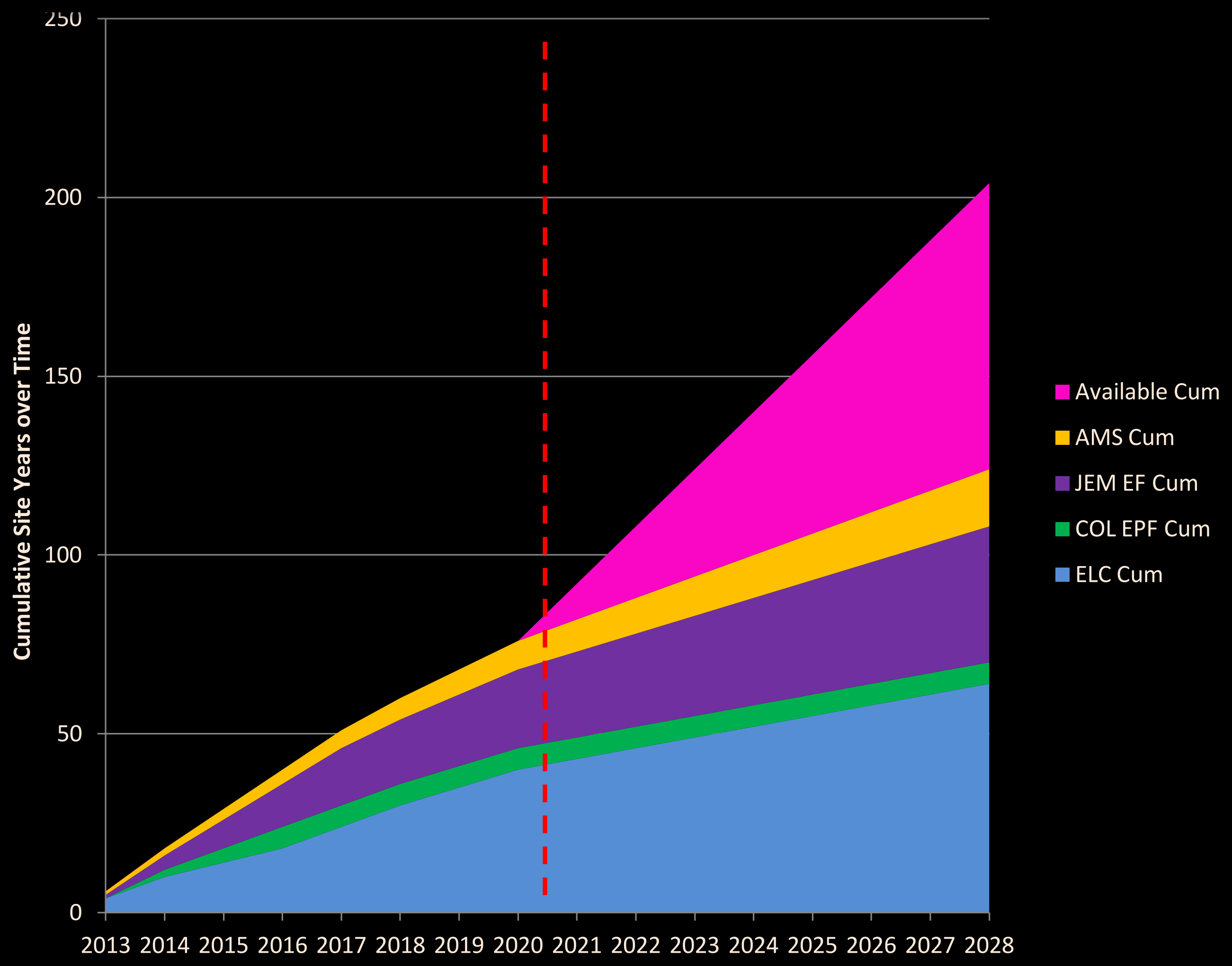
*HRP Crew Hours available starting in Increment 29.

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



Cumulative External Site Use and Opportunities

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



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
- enables new and innovative use of the complete ISS system

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

2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
	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
Progress	Progress	Progress	Progress	Progress	Progress	Progress	Progress	Progress	Progress	Progress	Progress
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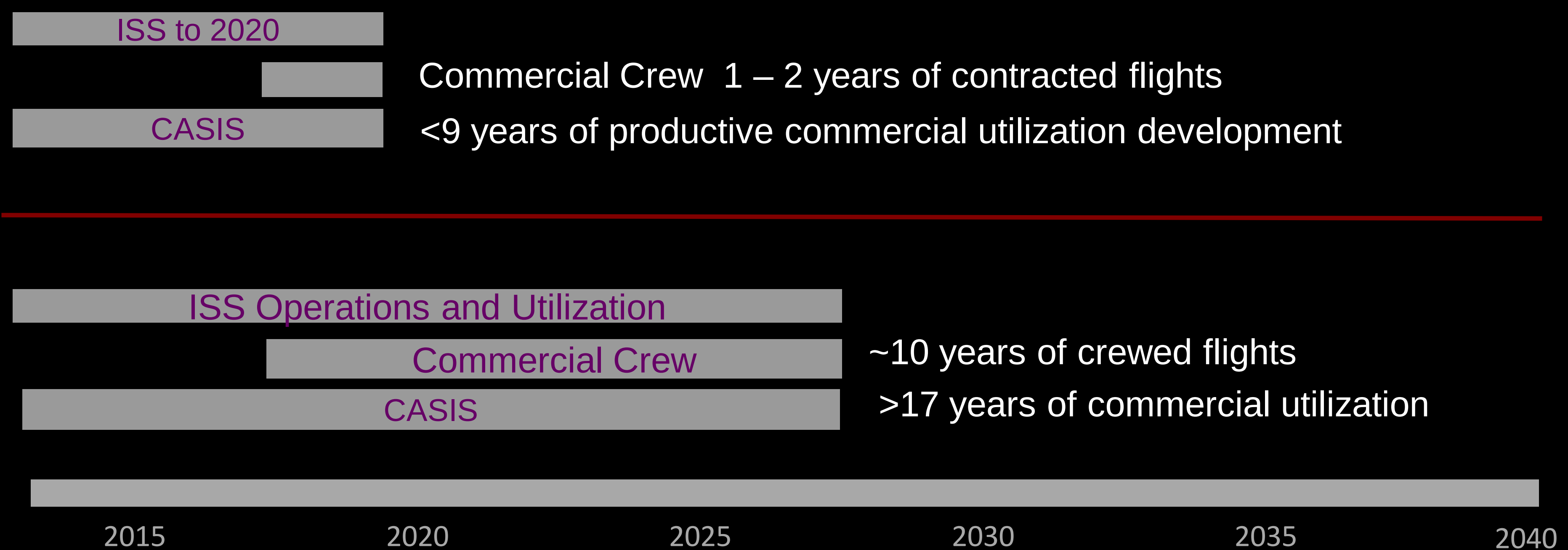
Progress	HTV	Progress	HTV	HTV	HTV	HTV	Progress	Progress	Progress	Progress	Progress
HTV	ATV	HTV	Orbital	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo
ATV	Orbital	Orbital	Orbital	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo
Orbital-D	Orbital	Orbital	Orbital	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	Cargo	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

Enable a commercial demand driven market in LEO

Extending ISS beyond 2020 enables a stable demand for commercial crew flights and a commercial demand for space research



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 platform

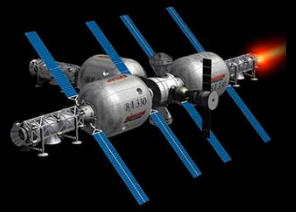
- Utilize additional commercial crew seats and access to ISS for non-NASA uses including research, tourism or other private initiatives

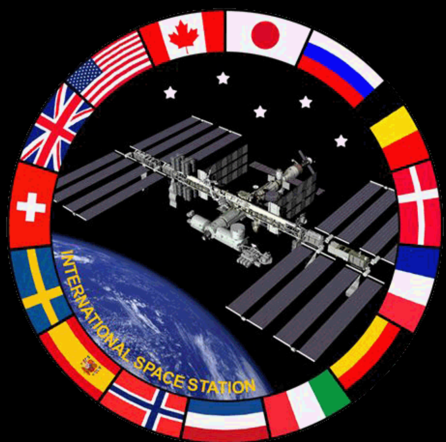
It is likely that NASA will still have research needs in LEO beyond the life of the ISS

ISS Operations and Utilization

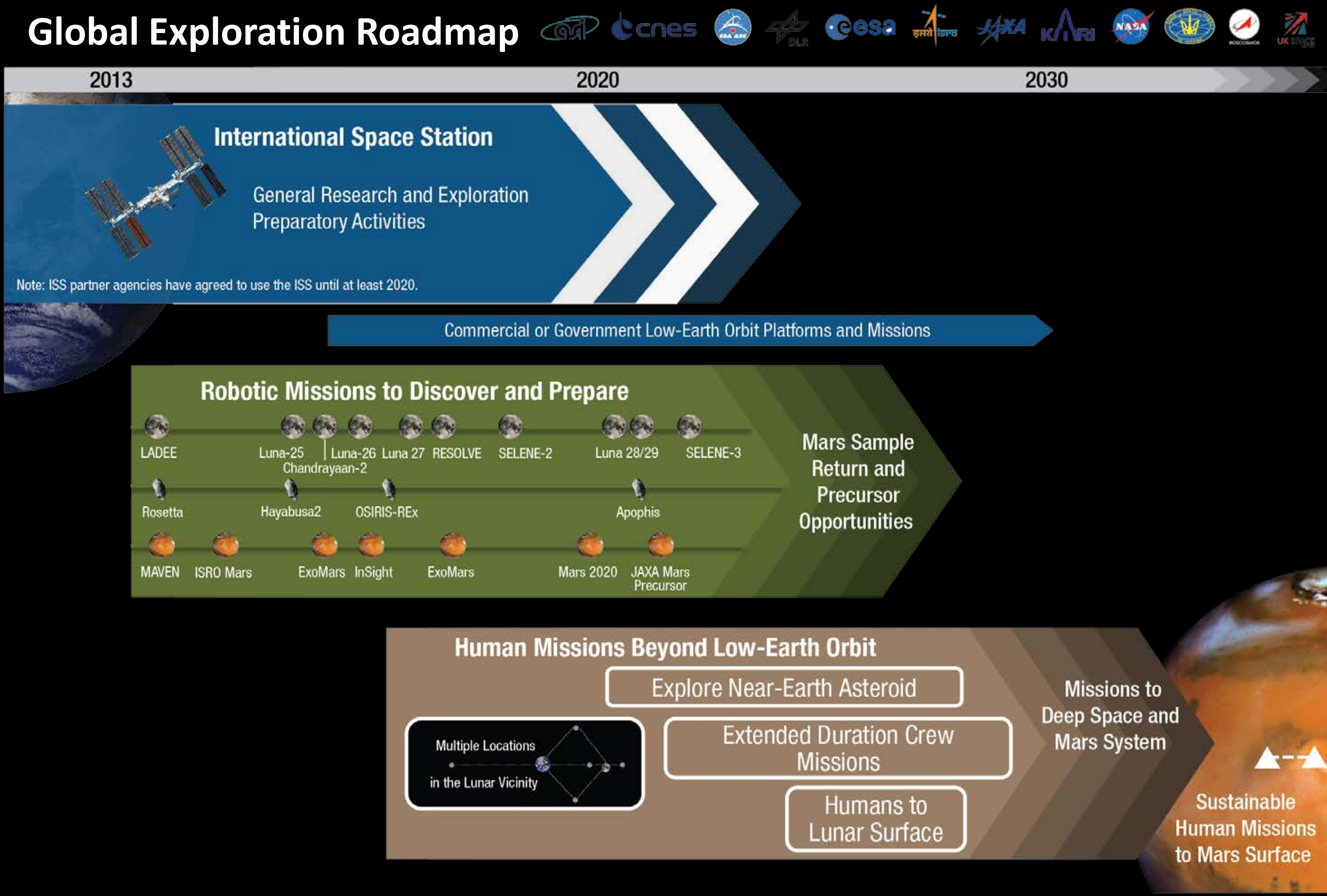
Commercial Crew — ~10 years of crewed flights

Commercial Research — >17 years of scientific discovery since assembly complete

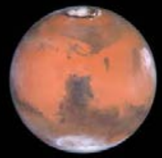



INTERNATIONAL SPACE STATION

Global Exploration Roadmap



Critical path viewpoint for long duration, deep space human spaceflight

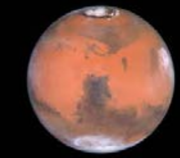


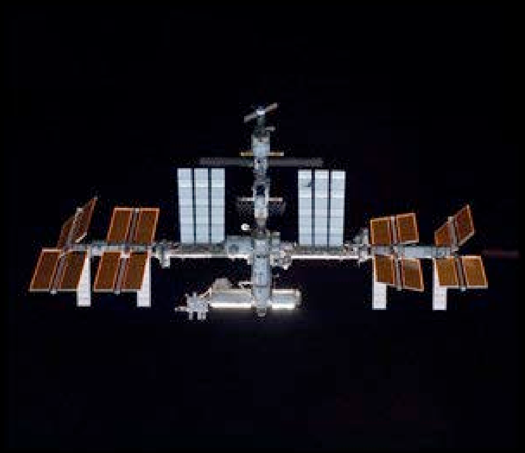
In-space segment

- *Life support*
- *Spacecraft reliability, supportability and maintainability*
- *Human performance for long durations in deep space*
- *Transportation system performance*

Access to the surface: landing on, operating on, and then ascending from Mars

Station is on the critical path to getting humans to Mars





In-space segment
- *Life support*
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Access to the surface: landing on, operating on, and then ascending from Mars

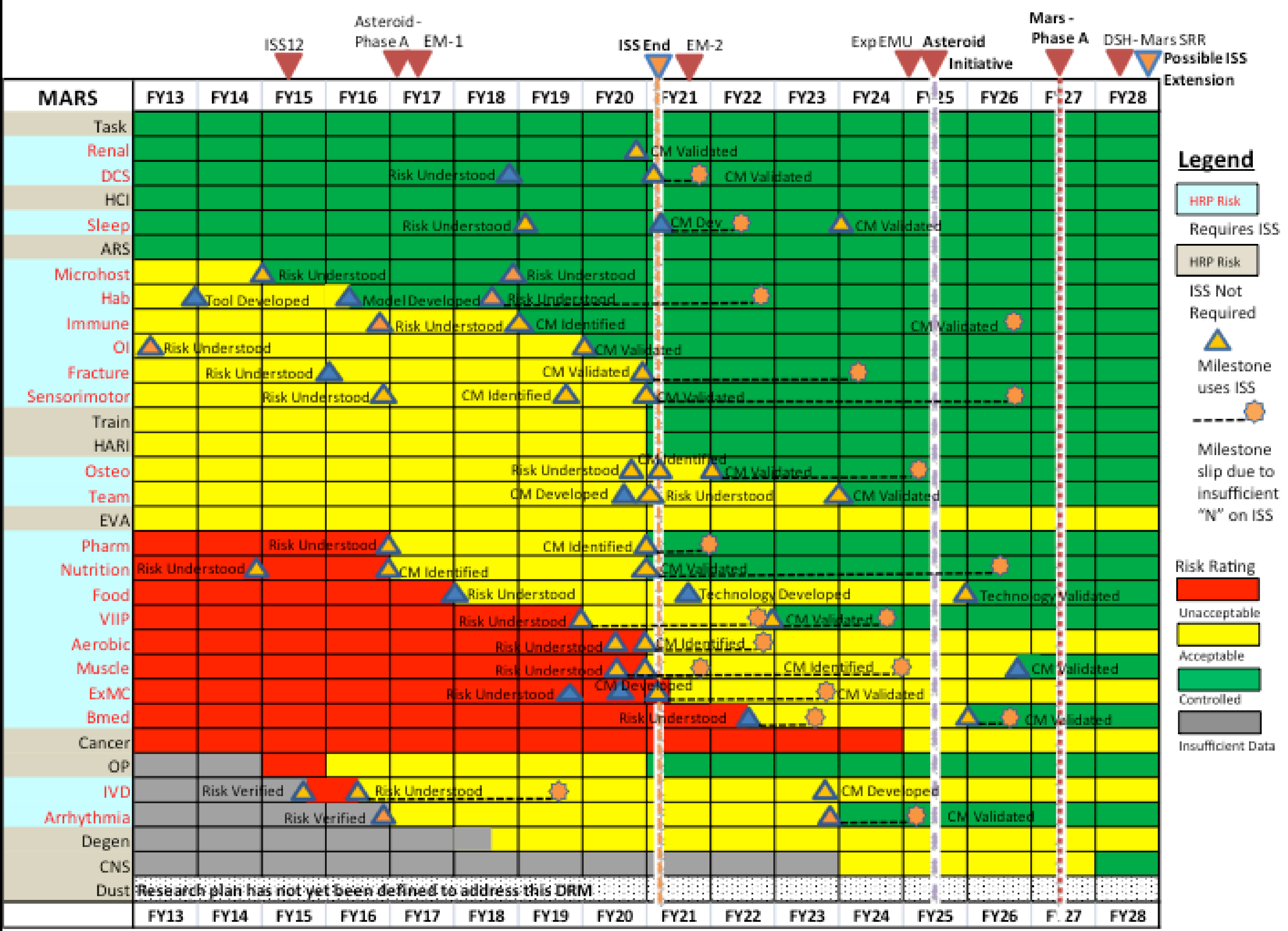
Critical path research and demonstration activities onboard the ISS will not be complete until about the mid-2020’s timeframe

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

Some of the primary drivers for the length of research onboard ISS are:
- Number of subjects
- Pharmacology
- Visual Impairment and Intracranial Pressure
- Muscle
- Exploration 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.

Life support and habitation systems

ISS is the only platform to demonstrate the critical systems and technology needed to get humans to Mars

Some of the critical demonstrations unique to deep space/long duration missions are:

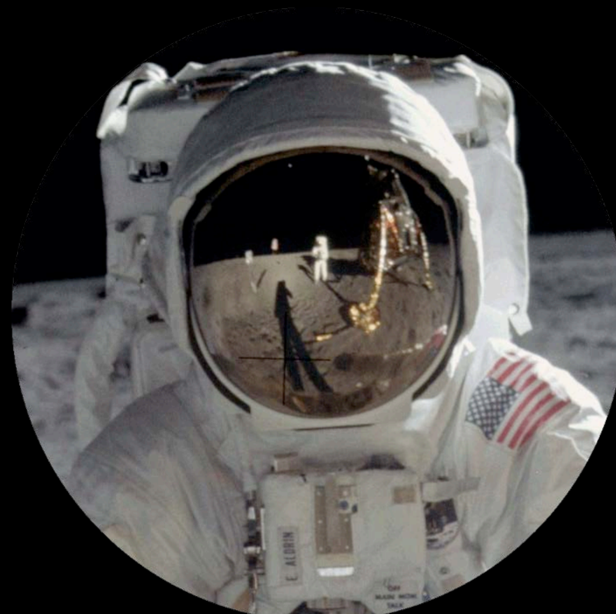
- onboard analysis of crew health and atmospheric samples
- ECLSS operations without maintenance for 1 year or more
- Crew exercise equipment operation for 1 year without maintenance
- Demonstration of exploration EVA suit before deep space missions
- Docking system
- Habitation materials

Based on current development and operational constraints, demonstrations will not be complete until the mid-2020’s

Exploration Systems and Technology Demonstration

Capability Gap	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
ECLSS															
CO2 Removal with no bed maintenance	▲		▲	TBD future upgrades pending CDRA-4 performance											
Reliable O2 Gen							▲								
High pressure O2 for EVA					▲										
Reliable urine processing >85%			▲				▲								
Reliable water processing w/ reduced expendables				▲		▲									
Common biocide with on orbit replenishment						▲									
Tolerate dormancy								▲							
Universal compact commode				▲											
Additional O2 recovery from CO2						▲				▲					
Additional water from brine							▲								
Environmental Monitoring															
Trace Gas	▲				▲										
Targeted Gases				▲											
Water					▲										
Microbial				▲											
Major Constitutents						▲									
EVA															
Exploration Suit						▲									
Modified ACES Suit 0-g demo (incl nutrition deliv)				▲											
Fire Safety and Response															
Emergency Mask (funding for single cartridge)	▲ dual		single	▲											
Contingency Air Monitor					▲										
Smoke Eater				▲											
Water Mist PFE (scaled to Exploration size)	▲			▲											
Exercise Equipment and Sensors		▲			▲		▲								
Cryo															
CPST				▲											
ZBOT		▲				▲			▲						
Solar Power					▲										
Thermal															
Phase Change Material			▲			▲									
Variable Heat Rejection						▲									
High temp heat rejection						▲									
Comm & Nav															
DTN	▲		▲												
Optical Comm	▲			▲											
Lightweight Structures & Materials		▲													
Radiation Monitoring	▲														
EDL - Entry Heat Shield							▲								
Autonomous Operations			▲	▲											
Robotics															
Robotic refueling	▲		▲												
Human assist robots	▲		▲	▲											
Telerobotics			▲												

▲ Projected ISS demo



Basis for international exploration partnership

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

If the ISS Partnership dissolves prematurely, it is not likely that a new partnership would be established anytime in the near future.

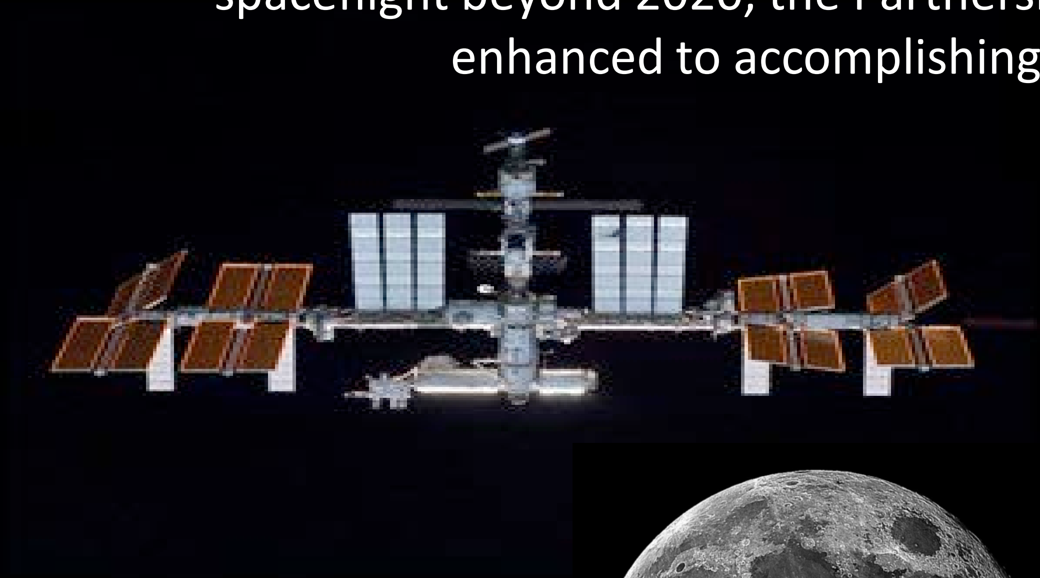
?

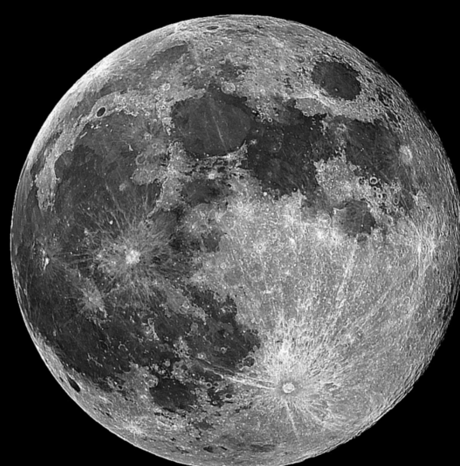
2015 2020 2025 2030 2035 2040

Countries that are following the U.S. leadership in space research, education, and exploration

Station is the glue that holds the international human spaceflight community together

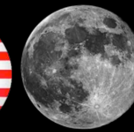
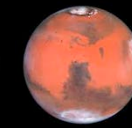
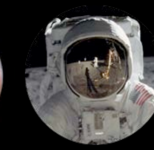
With the ISS Program and Partnership fully engaged in human spaceflight beyond 2020, the Partnership can be maintained and enhanced to accomplishing our objectives.





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?

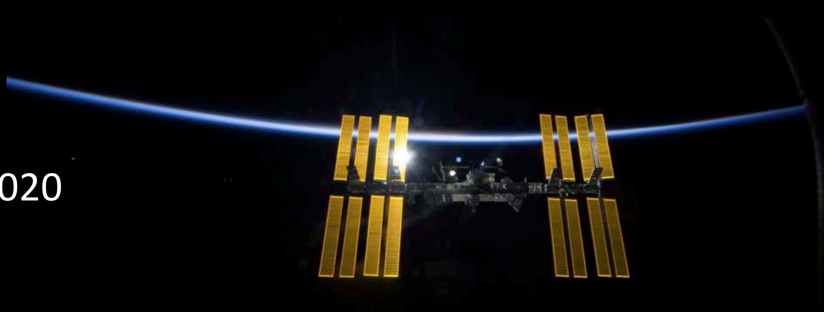
Has a non-government commercial demand for micro-gravity research and application been established?

Basis for international exploration cooperation

Has an exploration partnership been established?

12 10 13

Programmatics to 2020



All the ISS Partners have certified the life of ISS up to 2020
- nearly complete certification to 2028

Soyuz crew flights are contracted thru 2017 Spring return

Currently expect commercial crew flight to begin late 2017

Expect Orbital and SpaceX to develop a regular flight rhythm in 2014-2015

Continue to enhance utilization support equipment
- Additional racks, common support equipment – CAL, rodent habitats, others

Accommodating Science Mission Directorate instruments for Earth and Space Science

Continue exploration research and technology/system demonstration activities
- Execution of HRP roadmap, 1-year crew, ECLSS, environmental monitoring, exercise equipment, etc.

Refining de-orbit plan with International Partners

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

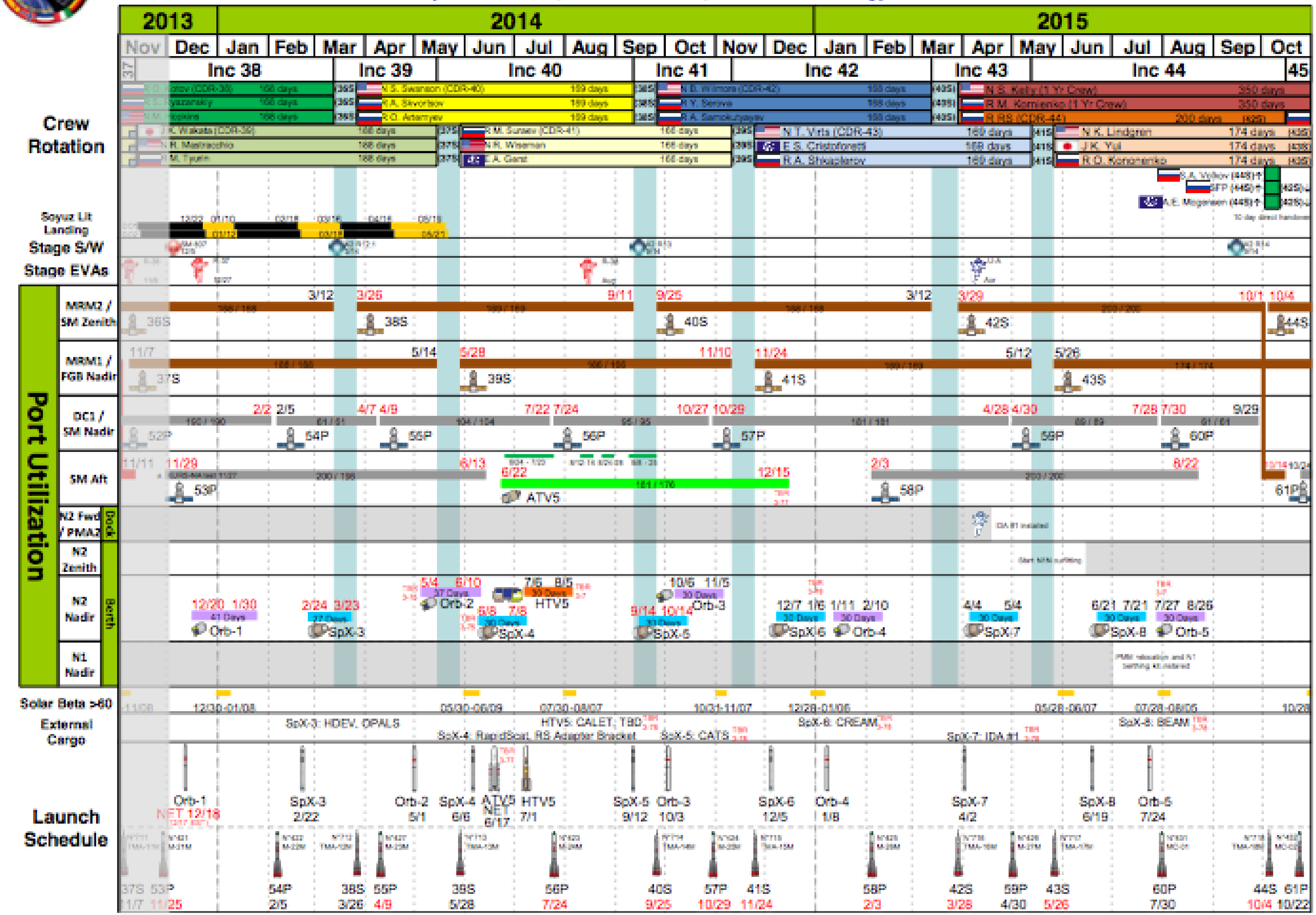
ISS Flight Plan

Flight Planning Integration Panel (FPIP)

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

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

Chart Updated: Dec 02nd, 2013
SSCN/CR: 13955A + 14004 (In-Work)



37 Soyuz Launch/Expedition 38
November 2013 – May 2014

Vehicle: 37 Soyuz, TMA-11M

Launch: November 7, 2013 (with 4 orbit rendezvous)

Docking: November 7, 2013

Undock/Landing: May 14, 2014

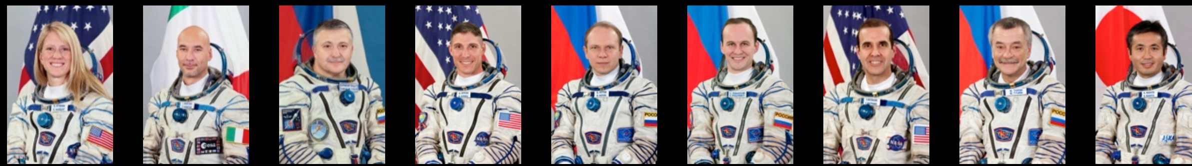
37 Soyuz Crew Expedition

Mikhail Tyurin Soyuz Commander & ISS Flight Engineer
Rick Mastracchio ISS Flight Engineer
Koichi Wakata (JAXA) ISS Flight Engineer & Expedition 39 Commander

37 Soyuz crew joined 35 Soyuz and 36 Soyuz crew already on orbit

Oleg Kotov Soyuz Commander & Expedition 38 Commander
Michael Hopkins ISS Flight Engineer
Sergey Ryazanskiy ISS Flight Engineer

Expedition 37
9-Crew (3 Soyuz) Operations



Nyberg Parmitano Yurchikhin Hopkins Kotov Ryazanskiy Mastracchio Turin Wakata

- **Vehicle Traffic**: 3 Soyuz vehicles were docked to RS from 11/7-11/11/13 (9 crew on board)
  - 35S relocation from MRM1 → SM Aft on 11/1/13 to enable 9-crew period and 37S docking
  - 37S docking to MRM1 on 11/07/13
  - RS EVA 36 (Kotov, Ryazanskiy) performed on 11/9/13
    - Olympic Torch being taken put for EVA
  - 35S undocking (ISS CDR Yurchikhin) from SM Aft, landed on 11/11/13
- **ECLSS - Water, CO2, and O2**: No issues
  - Water Processing Assembly (WPA) and Urine Processing Assembly (UPA) operational with ~1,800 L of water in CWC-I storage
  - Node3 and Lab CDRAs operational and can operate in dual bed mode; Vozdukh operational
  - OGA operating to build up stack for 9-crew with ~28kg reserve O2 in 52P (hatch closed during 9-crew)

Expedition 37 Objectives
(September 2013 – November 2013)

Performed an average of 44 hrs/week for payload investigations. New investigations include:

- **Biochem Profile** - *Will provide critical information about the time course of inflight biochemical changes for multiple physiological systems, allowing better insight into countermeasure effectiveness. Blood and urine samples obtained during pre-, in- and post-flight phases of ISS missions will be collected, processed and stored. A database of the sample analysis results will support metabolic profiles of the effects of spaceflight on human physiology.*
- **Salivary Markers –** *Is aimed at determining if spaceflight induced immune system dysregulation increases infection susceptibility or poses significant risk to crewmembers onboard the International Space Station. The data from this study will serve as a foundation for future countermeasure developments and detection technology for exploration, and may lead to a greater understanding of how the immune system is affected by different factors.*
- **NanoRacks Module 9 S/N 1007-** *Consists of seven experiments in areas such as antibacterial resistance, hydroponics, cellular division, microgravity oxidation, seed germination, and bacterial growth.*
- **NanoRacks Module 9 S/N 1009 -** *Includes four experiments in areas such as photosynthesis, antibacterial products, and food making processes in microgravity.*
- **Body Measures -** *Will quantify the impacts of microgravity on anthropometry to ensure optimal crew performance, fit, and posture. In addition, this study will assess in-flight physical changes of neutral body postures during extended exposure to microgravity.*

- Supported planned visiting vehicle traffic:
  - Orb-D1 launch, Sept 18
  - 36S launch, Sept 25
  - 36S dock, Sept 26
  - Orb-D1 berth, Sept 29
  - Orb-D1 unberth, Oct 22
  - ATV4 undock, Oct 28
  - 35S relocation, Nov 1
  - 37S launch and dock, Nov 7
  - 35S undock, Nov 11

- Significant tasks:
  - RS EVA 36, condcuted Nov 10th (Relaying the Olympic torch, disconnect the DC1 Kurs-P antenna feeder unit from the SM Kurs-P system, connect SM Kurs-P to Kurs-P antenna feeder unit, remove the third Biorisk-MSN container on DC1, replace the adaptor frame (17КС.600Ю1110А-0) with the adapter beam (17КС.600Ю1135А-0) and re-installing TMTC units (17КС.600Ю), remove PK-21-8 unit and cables
  - 4K Ultra HDV System checkout
  - New Emergency Mask deployment (replaces existing ammonia respirators)

Expedition 38 Objectives
(November 2013 – March 2013)

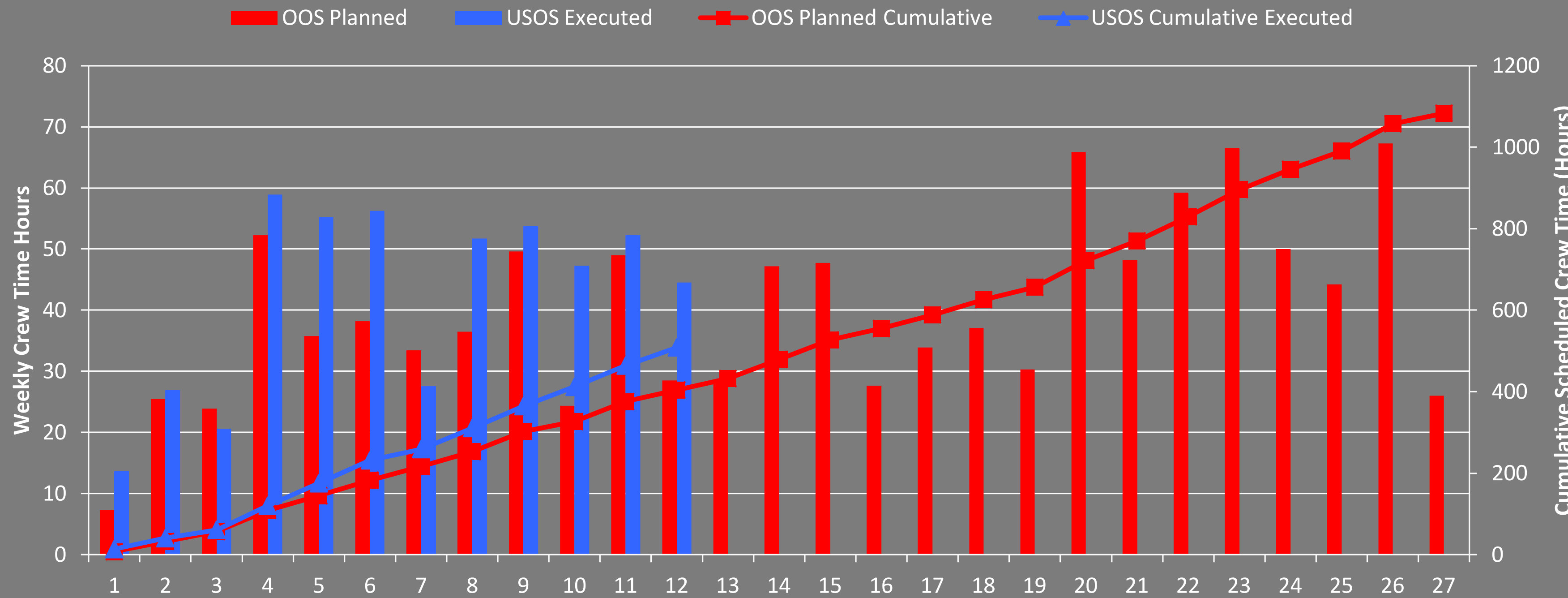
Perform an average of 44 hrs/week for payload investigations. New investigations include:

- **SODI-DCMIX 2 (Selectable Optical Diagnostic Instrument – Diffusion Coefficient in Mixtures 2)** - *Will measure diffusion coefficients of selected ternary mixtures taking advantage of the reduced gravity environment available onboard the ISS. Understanding the fundamentals of thermodiffusion and thereby being able to predict its effects is of direct interest, for example, to oil companies that use computer simulations to model underground oil reservoirs and to optimize their exploitation.*
- **Space Pup** - *Represents the first step towards studying the effects of space radiation on mammalian reproduction, which must be understood to sustain life beyond Earth. This starts by holding freeze-dried mouse sperm aboard the International Space Station for one, 12, and 24 months, and then fertilizing mouse eggs on Earth to produce mouse pups to study the effects of space radiation.*
- **Cardio Ox** (**Cardiovascular Oxidative Damage)** - Is aimed at *measuring levels of substances in blood and urine that are affected by oxidative and inflammatory stress and correlate them to the risk of developing atherosclerosis (hardening of the arteries) before, during, and after long duration spaceflight.*
- **T-Cell Activation in Aging** - *Seeks the cause of a depression in the human immune system while in microgravity. T-cells, a type of white cell, are coated with chemical receptors that must trigger together to activate the body's immune system properly. T-cells from flight crews and ground volunteers in a range of ages are analyzed to determine changes in protein production and gene response on the ground and in microgravity.*
- **Multi-Gas Monitor** *- Is a portable, laser spectroscopy device that can simultaneously measure oxygen, carbon dioxide, ammonia, and water vapor. Future space exploration vehicles and habitats would benefit from similar low-power, real-time air sensors*.
- **Gravi 2 (Threshold Acceleration for Gravisensing – 2)** *- Grows lentil seedling roots under various gravity conditions on board the International Space Station (ISS) to determine the amount of acceleration force sufficient to stimulate the direction of root growth.*
- **Soret-Facet-** *Studies Soret physics under steady/non-steady conditions including supercooled liquid phase on the ISS, providing the first verification results to link Soret physics and thermodynamics, with applications to mass transport phenomena such as crystal growth, crude oil refinement, planet formation, etc.*

- Support planned visiting vehicle traffic:
  - 53P Launch, Nov 25
  - 53P Dock, Nov 29
  - Orb-1 Launch, NET Dec 15
  - Orb-1 Berth, Dec 18
  - Orb-1 Unberth, Jan 30
  - 52P Undock, Feb 2
  - 54P Dock, Feb 5
  - SpX-3 Launch, Feb 22
  - SpX-3 Berth, Feb 24
  - 36S Undock, Mar 12

- Significant tasks:
  - SM 8.07 transition
  - SSC 5
  - COL Cycle 14
  - US EVA 3011 suit checkout
  - RS EVA 37, planned in December
  - Deploy HDEV and OPALS
  - RS EVA 38, planned in February
  - 4K Ultra HDV System checkout
  - JEMRMS SFA Demo #2

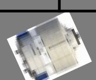
Inc 37 - 38 Utilization Crew Time



<u>**Color Key:**</u>
Completed
Final OOS
FPIP Plan

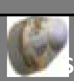
3-Crew	**6- Crew**		**9-Cr**	**6-Crew**			
Increment 37			**Increment 38**				
Sept	**Oct**		**Nov**	**Dec**	**Jan**	**Feb**	**Mar**

Orb-D1
Berth 9/22/13
Berth 9/29/13
Unberth 10/22/13
Unberth 10/22/13



ATV4
Undock 10/28/13
Undock 10/28/13

Orb-1
Berth 12/11/13
Berth 12/18/13
Unberth 01/10/14



SpX-3
Berth 2/24/14
Berth 01/26/14
Unberth 02/25/14

OC/OZ reconciliation is completed as of Week 11.
There are 40 minutes included in week 8 for OCT tech demo if OZ approves.

Executed through Increment Wk 12 (WLP Week 11) =	11.0	of 25.2 work weeks (43.65% through the Increment)
USOS IDRD Allocation:	1082.00	hours (42.9 hrs/week)
OOS USOS Planned Total:	1083.41	hours
USOS Actuals:	508.67	hours
	47.01%	through IDRD Allocation
	46.95%	through OOS Planned Total
Total USOS Average Per Work Week:	46.24	hours/work week
Voluntary Science Totals to Date:	5.25	Hours (not included in the above totals or graph)

USOS ISS Consumables Status: USOS On-orbit Capability
21-Nov-13 Orb-1 SORR, Orb-1 (Berth 18-Dec-2013)

	U1: Current Capability with 53P		U2: Current Capability with 53P and Orb-1	
Consumable – based on current, ISS system status	**Date to Reserve Level**	**Date to zero supplies**	**Date to Reserve Level**	**Date to zero supplies**
Food – 100% (1)	April 3, 2014	May 28, 2014	May 29, 2014	July 12, 2014
KTO	May 6, 2015	June 30, 2015	May 6, 2015	June 30, 2015
Filter Inserts	June 20, 2015	August 3, 2015	June 20, 2015	August 3, 2015
Toilet (ACY) Inserts	February 26, 2015	April 18, 2015	February 26, 2015	April 18, 2015
EDV (UPA Operable) (2)	September 18, 2014	March 31, 2015	September 18, 2014	March 31, 2015
Utilization		March 13, 2014		March 30, 2014
Consumable - based on system failure				
EDV (UPA Failed)	January 16, 2014	March 1, 2014	January 16, 2014	March 1, 2014
Water, if no WPA (Ag & Iodinated) (3)	February 17, 2014	April 7, 2014	February 17, 2014	April 7, 2014
O_2 if neither Elektron or OGA (4)	December 28, 2013	March 9, 2014	December 28, 2013	March 9, 2014
LiOH (CDRAs and Vozdukh off)	~0 Days	~13.3 Days	~0 Days	~13.3 Days

(1) Includes food on Soyuz. **(2)** A-RFTA operations assume 75% recovery rate and no RS urine processing. **(3)** RS processes all condensate in event of WPA failure. **(4)** Includes metabolic O2 for 45 day/6-crew reserve and the O2 for greater of CHeCs or 4 contingency EVAs.

USOS System Challenges / Update

- Ku – Band Antenna Group 2 (AG2) Forward Link Anomaly
  - EVA 22 conducted on July 9th and performed an R&R of the transmitter/receiver controller. Nominal operations restored.

- Loss of Columbus Water Pump Assembly
  - Spare pump was flown on ATV-4 in June. New pump installed successfully and nominal operations restored.

- Advanced Resistive Exercise Device (ARED) Cylinder leakage
  - Over the past several months, higher then expected cylinder evacuations were required for proper exercise (almost daily)
  - Replacement cylinders accelerated for deployment in early 2014
  - Self healed – over the past month, leakage has stopped and nominal evacuations are being conducted, continuing to monitor

- 2B Photo-Voltaic Thermal Control System (PVTCS) leak
  - EVA 21 conducted with a successful R&R of the pump, continuing to monitoring but all indications are that this “fixed” the leak

USOS System Challenges / Update

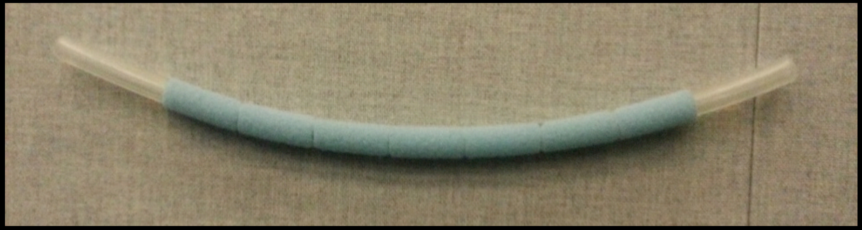
- Node 3 Carbon Dioxide Removal Assembly (CDRA)
  - Excessive sticking of the ASV 102 led to significant ground operations overhead to perform nominal scrubbing cycles
  - 2 valves were onboard that required cleaning prior to installation
  - Cleaning performed and ASV 102 valve was R&R'd, restoring nominal operations to N3 CDRA
  - 2 spare ASV valves in preparations for launch (Orb-1 and SpaceX-3)

EVA 23 – Water in the Helmet Anomaly

- EV2 (Parmitano) experienced a build-up of free water in the EMU helmet during US EVA #23
  - Crew report of ~1.5 liters of water in the helmet at helmet doffing was confirmed by the Post-EVA water recharge of the EMU feedwater tanks
  - Post-EVA, crew reported water was very cold indicating that it came from the EMU cooling loop, not the in-suit drink bag
- EVA was terminated at 1:05 PET with a final PET of ~ 1.5 hours
  - During translation to the Airlock, water migrated to EV2's face affecting his eyes, ears and nose
  - As a result, EV2's communications and vision were degraded
- An expedited suit doffing was performed, removing EV2's helmet at 1:41 PET
- Failure is out of family with previous water in helmet experience which manifests as streaks or "rain" on the visor, not as a significant amount of water in the helmet
- EV2 was using EMU s/n 3011
  - EMU 3011 launched to ISS on STS-132 (May 2010)
  - EMU 3011 had been used on 5 EVAs prior to US EVA 23

Contingency EVA Status

- Operational response to water in helmet and additional risk mitigations developed to restore contingency EVA capability
  - Helmet Absorption Pad (HAP) and snorkel developed as additional risk mitigation
    - HAP Velcroed to inside of helmet vent pad and absorbs ~800 mls of water
    - Snorkel placed between drink bag and Hard Upper Torso (HUT) and used as a last resort if water surrounds the nose/mouth
  - If crewmember notes water pooling/increasing in helmet or senses water in HAP, helmet purge valve is opened, fan is turned off (isolates water and ventilation circuits) and EVA is terminated
    - Operational response based on crewmember's ability to determine magnitude of the water problem prior to taking action, at which time existing water can migrate in helmet
  - Unknown root cause, so could be EMU fleet-wide issue (e.g., water contamination)
  - Can get affected crewmember inside, need to tightly manage margins considering the four hazards (excess water/drowning, excess CO2, overheating and insufficient O2)
- Residual risks are captured in ISSP NCR and will be weighed against failure impact to ISS and need for contingency EVA

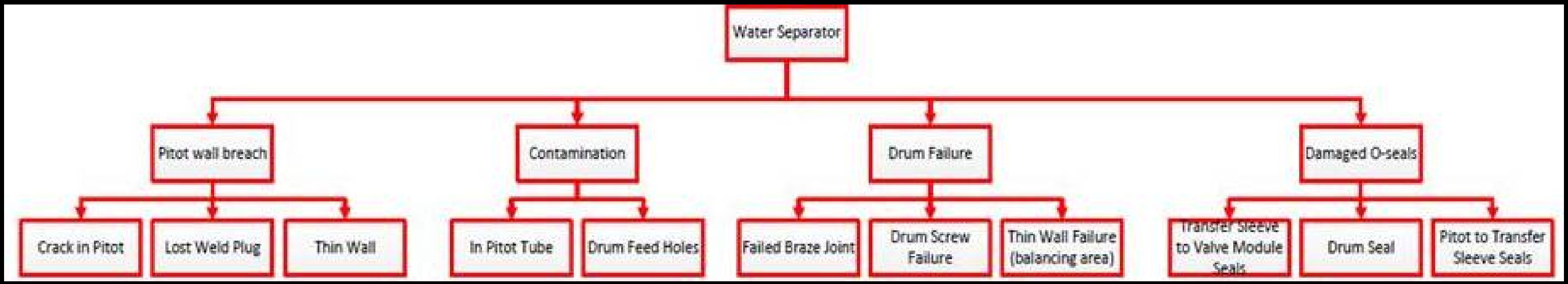


Snorkel

Helmet Absorption Pad

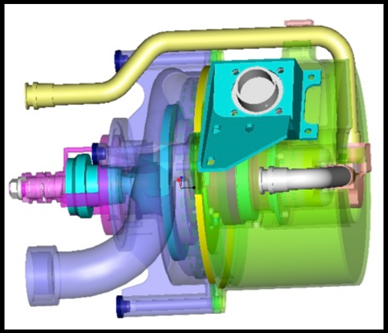
Fault Tree Investigation

- Fault tree contains 44 possible failures/events
- On-orbit testing and component R&R points to failure in water separator circuit (Item 123 fan/pump/separator or surrounding manifold blockage)
- Fault tree closure follows same process as other major ISS anomalies
  - Three independent reviewers (EA, EC, NA) required for closure
  - Higher likelihood failures (14 of 44) are also reviewed by EVA Recovery Team
- All fault tree legs that aren't directly associated with water separator circuit have been closed

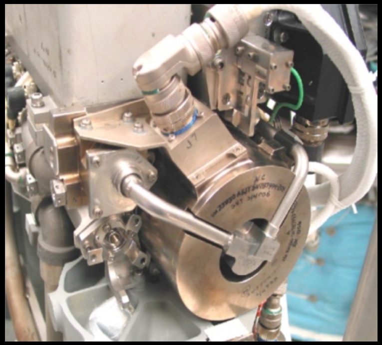


Item 123 Fan/Pump/Separator R&R

- EMU 3011 Item 123 FPS R&R successfully completed on 10/24
  - Subsequent EMU screening test performed and resulted in no water carryover
  - Test pressurizes cooling loop and runs fan/pump/separator
- FPS removal exposed areas of the suit that allowed for additional inspections and FOD clearing opportunities
  - Small piece of FOD (couple mm) found inside FPS cavity
  - Other observations were in family with ground suit experience
  - Wipes and FOD were packaged with FPS for return on 35S (11/11)
- Following the 123 R&R, all parts of the water separator circuit on the fault tree were changed out, probed, inspected or flushed
- Post return FPS evaluation plan includes CT scan, teardown, test, inspection and possible N-Ray scans



FPS



FPS Installed on EMU

Water Separator

Pitot

FPS Removed; FOD in Bore

EMU Sparing and Redundancy

- Four EMUs are flown/maintained on-board to provide redundancy and to meet crew sizing needs while minimizing HUT changeouts
- On-board EMUs
  - Two are functional (S/N 3005 and 3010)
  - 3011 has a water cross-over failure (No-Go for EVA)
  - 3015 has a failed/clogged sublimator (No-Go for EVA) and is planned for return on SpaceX-3
- EMU 3011 will be returned to service with a series of on-orbit checkouts
  - EMU 3011 is no longer in its pre-flight certified/tested configuration
    - Working to repair and replace several items
  - On-orbit analog checkouts developed based on ground procedures for testing following R&R of the above items
    - Safety review and hazard assessment will be conducted for EMU 3011 following on-orbit checkouts
- EMU 3003 manifested on SpaceX-3
  - Two additional EMUs can be flown this year (Summer and Fall)
    - If proximate or root cause is determined to be a fleet concern, this is the first opportunity for FPS corrective action

Orbital Demonstration Mission

- Orbital successfully launched on 9/18 and berthed to ISS on 9/29
- Delivered 589 kilograms (about 1,300 pounds) of cargo
- Unberthed successfully on 10/22 carrying 1293 kg of disposal cargo

Orbital Demo successfully launched on 9/18/13


Cygnus Demo successfully captured on 9/29/13


Cygnus Demo released on 10/22/13

Orbital Demonstration Flight Anomaly that delayed berthing

Space Integrated GPS (Global Positioning System) INS (Inertial Navigation System) (SIGI) Incompatibility Anomaly

- Problem was traced to a difference in the GPS week outputs for the JEM SIGI and the Orbital SIGI
  - The GPS constellation broadcasts GPS week number as 1 to 1023
  - JEM SIGI GPS receivers outputs GPS week number exactly as the GPS constellation broadcasts it, only as a number between 0 and 1023
  - Orbital SIGI GPS receivers output the GPS week number as true weeks since Jan 6, 1980, meaning the GPS week can be >1023

- Resolution/Mitigation
  - Cygnus flight SW patch (essentially 1 line of code) created to add 1024 to the received JEM GPS week output, thereby making it match the Cygnus SIGI
  - Orb-1 will re-use same SW patch used on Demo. Orb-2 and subsequent missions will have code change in new SW release

Orbital-1 Mission Status

- Pressurized Cargo complement, 1,288 kg / 102 CTBE
  - Commercial Generic Bioprocessing Apparatus (CGBA) active payload (late load)
  - 2 passive lockers (late load)
  - 1 double cold bag (late load)
- Mission Status
  - Joint Multi Segment Trainings (JMSTs) #1 – 4 were completed in Nov and Dec
  - Joint Software Stage Testing was completed on 11/15
  - Orbital Flight Readiness and Certification Review (FRCR) was conducted on 11/19
  - Stage Operations Readiness Review (SORR) was conducted on 11/21
  - PROX checkout is scheduled from 12/9 – 12/10
  - Final Mission Dress Rehearsal is scheduled for 12/13
- Cygnus Status
  - Cygnus completed fueling and was transported to the HIF
  - Mate to Antares is scheduled for 12/9
  - Late/final cargo load is scheduled for 12/13
  - Rendezvous with ISS is planned for 12/21
- Antares Status
  - Transfer to Transport Erector Launcher (TEL) is planned for 12/6
  - Rollout to the pad is scheduled for 12/14

- **Completed Orb-1 milestones**
  - Authority To Proceed
  - Long Lead Order Placement
  - Vehicle Baseline Review
  - SM Propulsion Sys Manufacturing Readiness Review
  - Mission Integration Review
  - Service Module Integration and Test
  - Receipt of Long Lead Items
  - Cargo Integration Review

Antares First & Second Stages Mated


Orb-1 SM/PCM mated

SpaceX-3 Mission Status

- **Pressurized cargo (Expecting full launch/return complement of 1580kgs, 3476 lbs)**
  - Powered Middeck Lockers:
    - ***Launch*****:** 1 GLACIER ; Micro-7 and Biotube Micro; 2 MERLINs, and 5 Cold Bags
    - ***Return*****:** 2 GLACIERs ; Micro-7 and Biotube Micro Experiments, and 5 Cold Bags
  - Launching a T-Cell experiment used to test the immune system
  - Launching a Short Extravehicular Mobility Unit (SEMU)
- **External Cargo**
  - High Definition Earth Viewing (HDEV) Camera on NASA Columbus External Payloads Adapter (CEPA)
  - Optical PAyload for Lasercomm Science (OPALS) on SpX Express Payload Adapter (ExPA) (first use of SpX built ExPA)
  - Poly-Picosatellite Orbital Deployer (P-POD) is secondary payload
- **Dragon 5 Status**

  Trunk is scheduled for shipment to the Cape on 12/3

  HDEV/OPALS integration to trunk is planned for 12/12

  Dragon capsule arrival at the Cape is planned for 12/17

  Final software Stage Test is planned for early Jan 2014

F9v1.1 (F9-9) Status

Second Stage and Interstage are planned to be at the Cape in early Jan 2014

First Stage is planned to be at the Cape in mid Jan 2014

- **Completed SpX-3 milestones**
  - Authority To Proceed
  - Vehicle Baseline Review
  - External Cargo Baseline
  - FRAM LON
  - Mission Integration Review
  - External Integration Review
  - Cargo Integration Review

Dragon 5 pressure section in clean room

International Space Station Commercial Resupply Services Status

- **SpaceX**
  - Completed demonstration flight on May 31, 2012; completed first and second Commercial Resupply Services (CRS) missions (SpX-1 and SpX-2) on Oct 28, 2012 and Mar 27, 2013, respectively
  - Seven missions currently in flow (SpX-3 through SpX-9)
    - Final milestone for SpX-1 met in December 2012
    - Final milestone for SpX-2 met in June 2013
    - Hardware production, cargo integration, and external hardware manufacturing and integration activities are proceeding for the future flights
- **Orbital Sciences Corporation (OSC)**
  - Demonstration status: Maiden test flight successfully completed on Apr 21, 2013; Demo flight successfully launched to ISS on Sep 18, 2013, berthed on Sep 29, 2013, and unberthed on Oct 22, 2013
  - Seven missions currently in flow (Demo (post-flight review) + Orb-1 through Orb-6)
    - Hardware production and cargo integration activities are proceeding
  - OSC is relying on NASA assets at Stennis Space Center (SSC) for engine testing and Wallops Flight Facility (WFF) for launch vehicle processing and integration

ISS Top Program Risk Matrix
Post October 25, 2013 PRAB

Score: 2 x 2
- ▲ 6347 - Temporary Urine and Brine Stowage System Catastrophic leak of a Tox-2 Fluid - (OB) - (C,S,T,Sa)
- ▲ 6039 - Carbon Dioxide Removal Assembly (CDRA) Function - (OB) - (C,T,Sa)
- ▲ 6032 - On-Orbit Stowage Short-Fall (Pressurized Volume) - (OC) - (T,Sa)

LIKELIHOOD	1	2	3	4	5
5				2	1
4			2	3	
3			5		5
2		3			
1					

CONSEQUENCE

Low	Medium	High

C – Cost	S – Schedule	T – Technical	Sa – Safety

▲ – Top Program Risk (TPR)

Added: 6475, 6452, 6439, 6438, and 6039

Removed: 6413 – ELC ExPCA Low Voltage Power Supply (LVPS) Board Design Flaw, 6399 – Budget and Schedule (FY13), and 6368 – NORS Development.

Rescored: 6420

Corrective/Preventative Actions

None

Watch Items

None

Continual Improvement

None

Score: 5 x 5
- ▲ 6352 – Lack of Assured Access to ISS - (OH) - (C,S,T,Sa)

Score: 5 x 4
- ▲ 6370 - ISS Pension Harmonization - (OH) - (C)
- ▲ 6344 - ISS Operations Budget Reduction - (OH) - (C)

Score: 4 x 4
- ▲ 6475 - ISS Budget and Schedule - (OH) - (C,S,T)
- ▲ 6372 - Full ISS Utilization at 3 Crew - Level 1 - (OZ) - (C,S)
- ▲ 6169 - Visual Impairment / Intracranial Pressure - (SA) - (C,S,T,Sa)

Score: 3 x 5
- ▲ 6450 - Potential Inability to Support ISS Critical Contingency (& other) EVA Tasks - (XA) - (C,S,T,Sa)
- ▲ 6444 - ISS Cascading Power Failure - (OM) - (C,S,T,Sa)
- ▲ 6382 - Structural Integrity of Solar Array Wing (SAW) Masts due to MMOD Strikes - (OB) - (S,T,Sa)
- ▲ 5688 - ISS Solar Array Management Operations Controls and Constraints - (OM) - (C,S,T,Sa)
- ▲ 2810 - Russian Segment (RS) capability to provide adequate MM/OD protection - (OM) - (C,S,T,Sa)

Score: 4 x 3
- ▲ 6438 - C2V2 Comm Unit Vendor Misinterpreting ISS Requirements - (OG) - (C,S,T,Sa)
- ▲ 5269 - The Big 13 Contingency EVA's - (OB) - (S,T,Sa)

Score: 3 x 3
- ▲ 6452 - Lack of Sufficient Sparing for the Ku-Band Space to Ground Transmitter Receiver Controller (SGTRC) to reach 2020 - (OD) - (S,T)
- ▲ 6439 - EPROM Memory Leakage - (OD) - (T,Sa)
- ▲ 6420 - NDS Qualification Schedule - (OG) - (C,S,T,Sa)

- ▲ 5184 - USOS Cargo Resupply Services (CRS) Upmass Shortfall - 2010 through 2016 - (ON) - (C,S,T,Sa)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