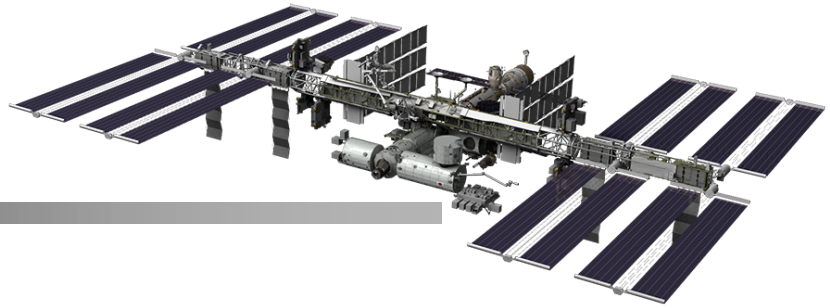
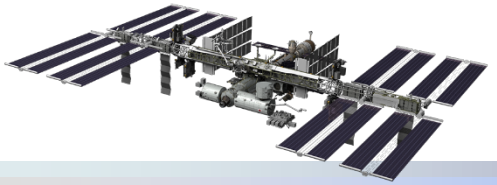


HEO NAC
International Space Station Status and ISS Transition

Sam Scimemi – ISS Director

November 2017



Flight Plan

- 12/3/17 – Orbital ATK CRS-8 unberth
- 12/8/17 – SpaceX CRS-13 launch (Space Debris Sensor, Total and Spectral Irradiance Sensor)
- 12/14/17 – Soyuz 51S return (NASA/Breznik, Russia/Ryazansky, ESA/Nespoli)
- 12/17/17 – Soyuz 53S launch (Russia/Shkaplerov, NASA/Tingle, JAXA/Kanai)
- 1/4/18 – SpaceX CRS-13 return
- 2/11/18 – Progress 69P launch

- Two EVAs scheduled in January for SSRMS maintenance

Increment 53 Overview: Crew

51S Dock 7/28/17
51S Undock 12/14/17

Sergei Ryazansky
Soyuz CDR (R) – 51S

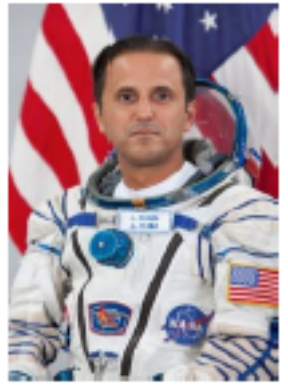
Randy Bresnik
FE (US) – 51S
CDR Inc 53

Paolo Nespoli
FE (ASI) – 51S

52S Dock 9/13/17
52S Undock 2/26/18

Alexander Misurkin
Soyuz CDR (R) – 52S
(CDR Inc 54)

Mark Vande Hei
FE (US) – 52S



Joe Acaba
FE (US) – 52S

Increments 53 & 54

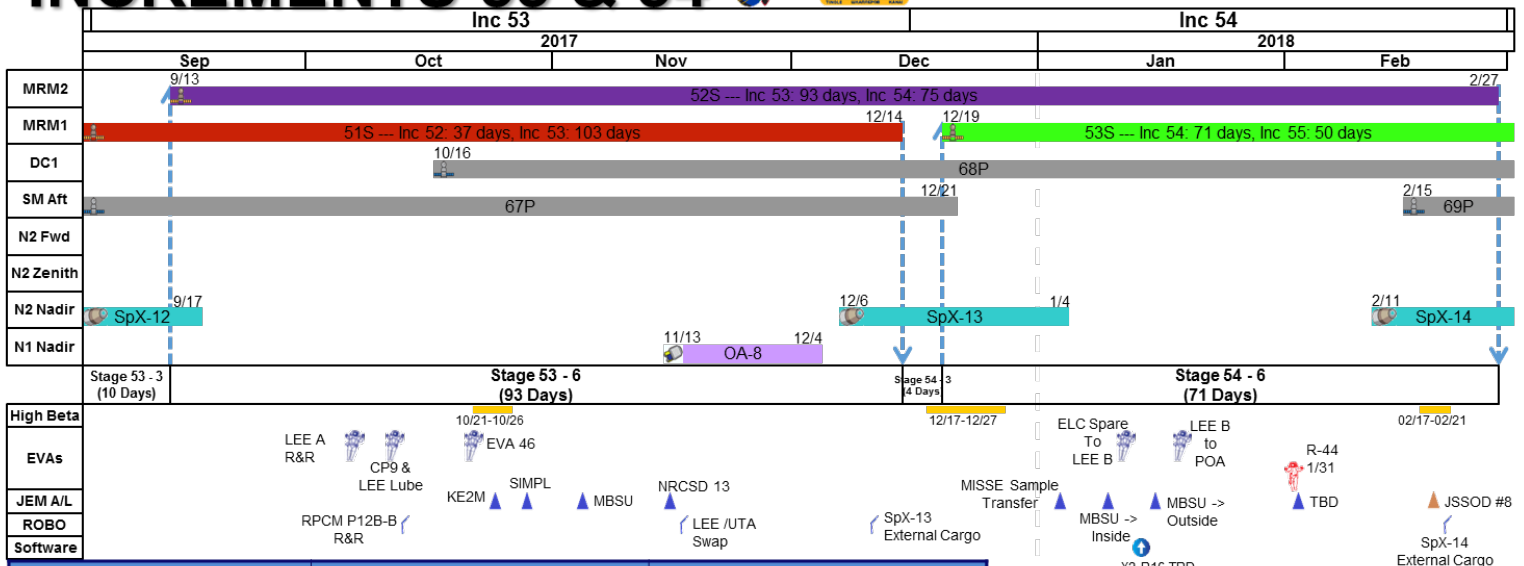
Increment 53: 103 days

- **Stage 53-3: 50S undock to 52S dock: 10 days**
- **Stage 53-6: 52S dock to 51S undock: 93 days**

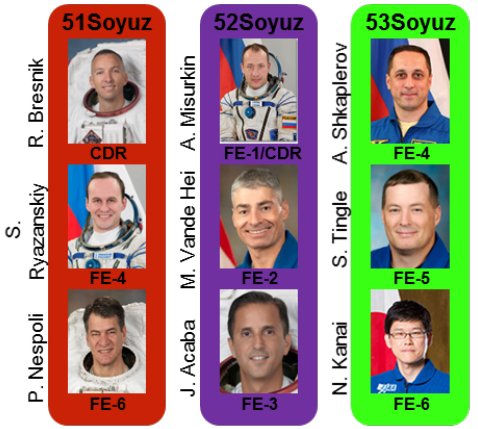
- US Triple EVA Tasks
  - » Remove degraded LEE A (s/n 202) from the SSRMS
  - » Install LEE (s/n 203) on LEE A location
  - » Install LEE (s/n 202) on POA
  - » WIF Adapter Install on LEE A
  - » Install EHDC CP3 ETVCG
- Cargo vehicles:
  - » SpX-12 Unberth (9/17)
  - » OA8 berth (11/13), release (12/3 TBC)
  - » SpX-13 berth (12/6), release (1/4 TBC)
- Science/Utilization:
  - » Rodent Research 9
  - » SARCOLAB
  - » Cell Science Validation
  - » KABER deployments
  - » NRCSD deployments
  - » JSSOD deployments
  - » SpX-13 (SDS, MISSE FF, TSIS)
  - » Multi-Omics-Mouse
- Maintenance/Outfitting:
  - » BEAM "Demo" and "Build Out" for Stowage
  - » HTV-7 Rack Install Prep for the Life Support Rack, Water Storage System, and Life Sciences Glovebox
  - » T2 Subject Loading System Installation

INCREMENTS 53 & 54

Updated 10/14/2017: All Dates GMT



	Increment 53	Increment 54
Utilization	√Rodent Research 9 Cell Science Validation Kestrel Eye, SIMPL, and NRCSD deployments √Multi-Omics-Mouse SDS, MISSE FF, TSIS launch/install (SpX-13 external cargo)	Rodent Research 6 Mouse Stress Defense Invitrobone Arthrospira Airway Monitoring MISSE sample transfer RRM3, ASIM launch/install (SpX-14 external cargo)
EVAs, Resupply and Outfitting	US triple EVA: √LEE A R&R √CP9 & LEE Lube EVA 46	US double EVA: ELC Spare/ LEE B Swap LEE B/ POA Swap RS EVA R-44 Preparation for ER-9B, LSR, and LSG installation PFCS R&R (SpX-14 external)
S/W & Av Updates		X2R16

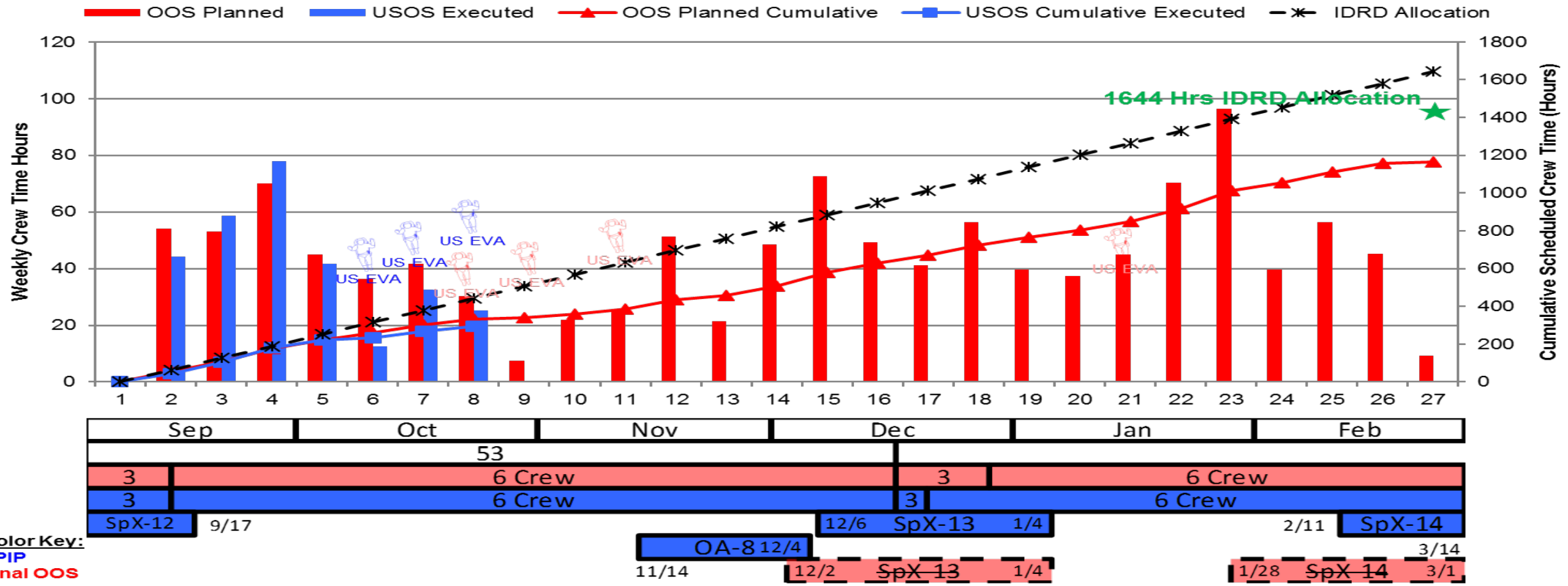


IM - Ryan Lien (281-244-7284), IDM - Lisa Leech (281-244-1101)
IE - Mark Stovall (281-244-1752), Jarrett Quasny (281-483-6903)
IPE - Desiree Smith (281-244-8218), CTE- Jill Holm (281-244-

https://iss-www.jsc.nasa.gov/nwo/mio/riit/inc_53/web/

Pre-decisional, Internal Use Only

Inc 53-54 Utilization Crew Time



Executed through Increment Wk (WLP Week) 8 :	6.8	of 24 work weeks	(28.3% Complete)
USOS Actuals:	292.88	hours -> 43.07 hours/week	
USOS IDRD Allocation:	1,644.00	hours-> 68.50 hours/week	(17.8% Complete)
OOS USOS Planned Total:	1,164.94	hours	(25.1% Complete)
Voluntary Science Totals to Date:	0	hours (not included in the above totals or graph)	
RSA/NASA Joint Utilization to Date:	32.25	hours (not included in the above totals or graph)	

Pre-Decisional, For Internal Use Only
30-Oct-17

ISS Research Statistics

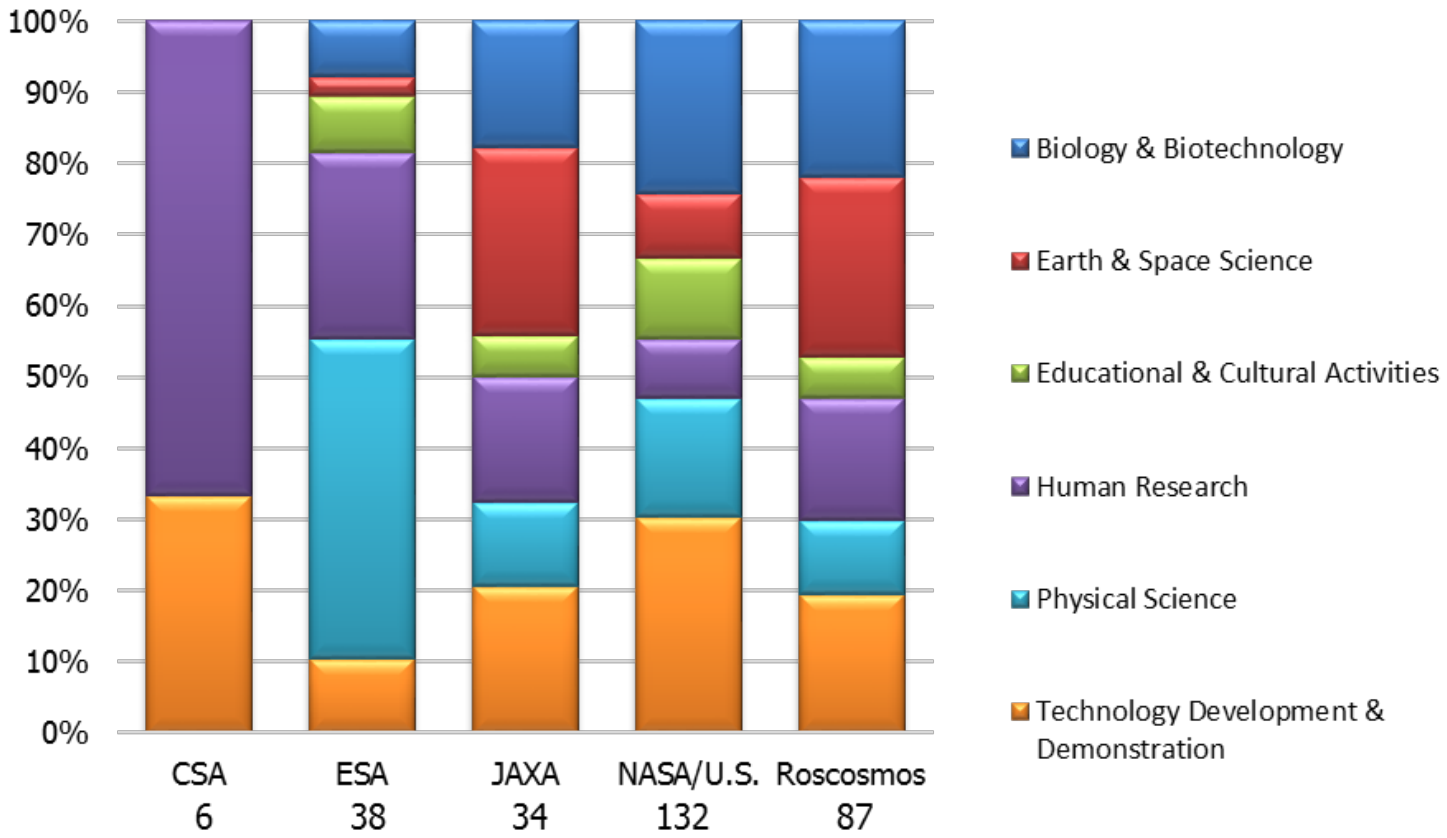
- 132 NASA/U.S.-led investigations
- 165 International-led investigations
- 57 New investigations
  - 0 CSA
  - 5 ESA
  - 9 JAXA
  - 40 NASA/U.S.
  - 3 Roscosmos

ISS Lifetime

- Estimated Number of Investigations Expedition 0-54: 2447*
- Over 3000 Investigators represented (Exp 0 – present)
- Over 1400 scientific results publications (Exp 0 – present)

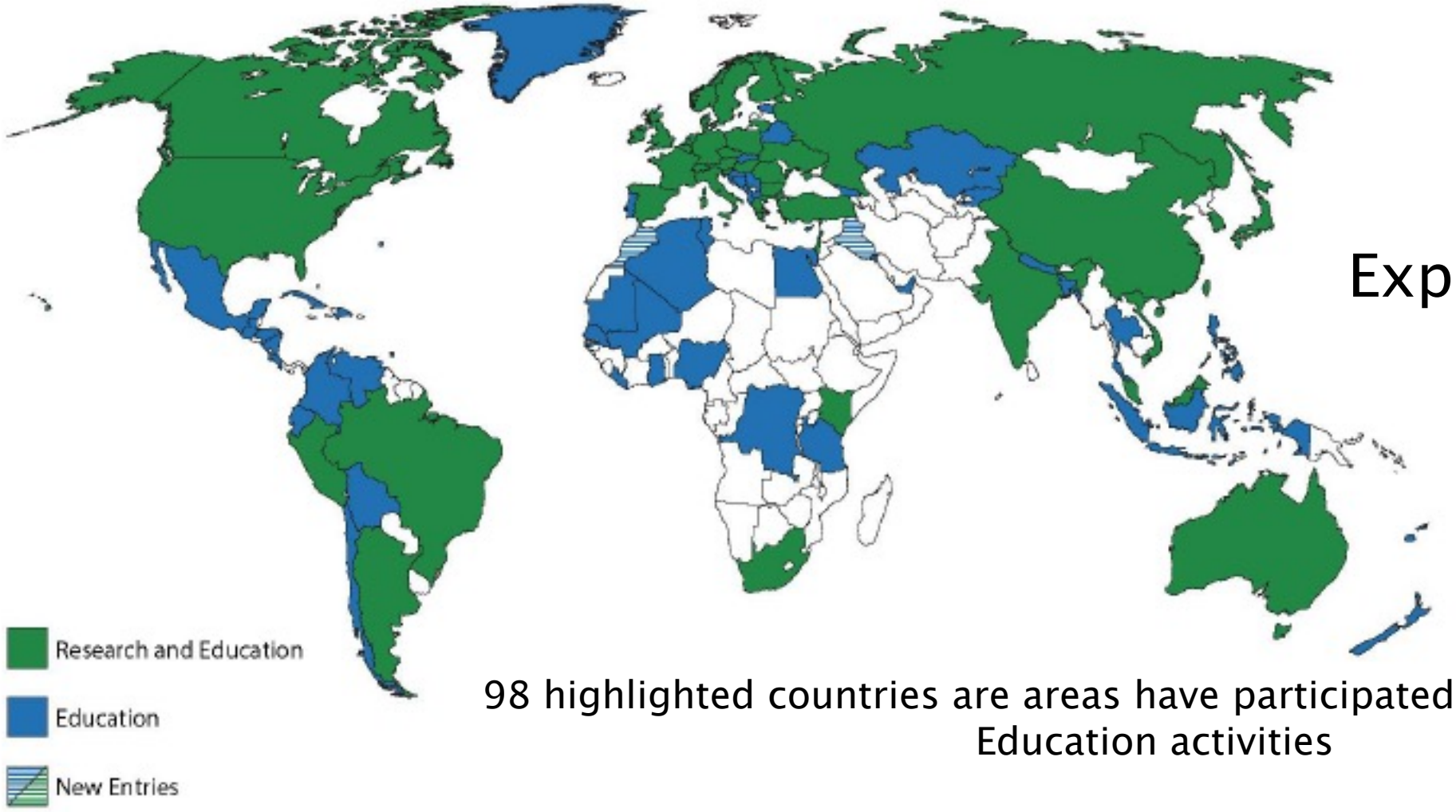
Number of Investigations for 53/54: 297

Expeditions 53/54
Research and Technology Investigations



Working data as of Sept 302017
*Pending Post Increment Adjustments

Global Involvement in Utilization



Expeditions 0-48

98 highlighted countries are areas have participated in ISS Research and Education activities

New participating countries: Iraq, Morocco, and the Republic of Malta

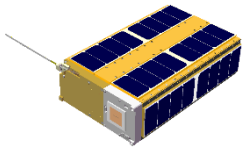
Featured Investigation

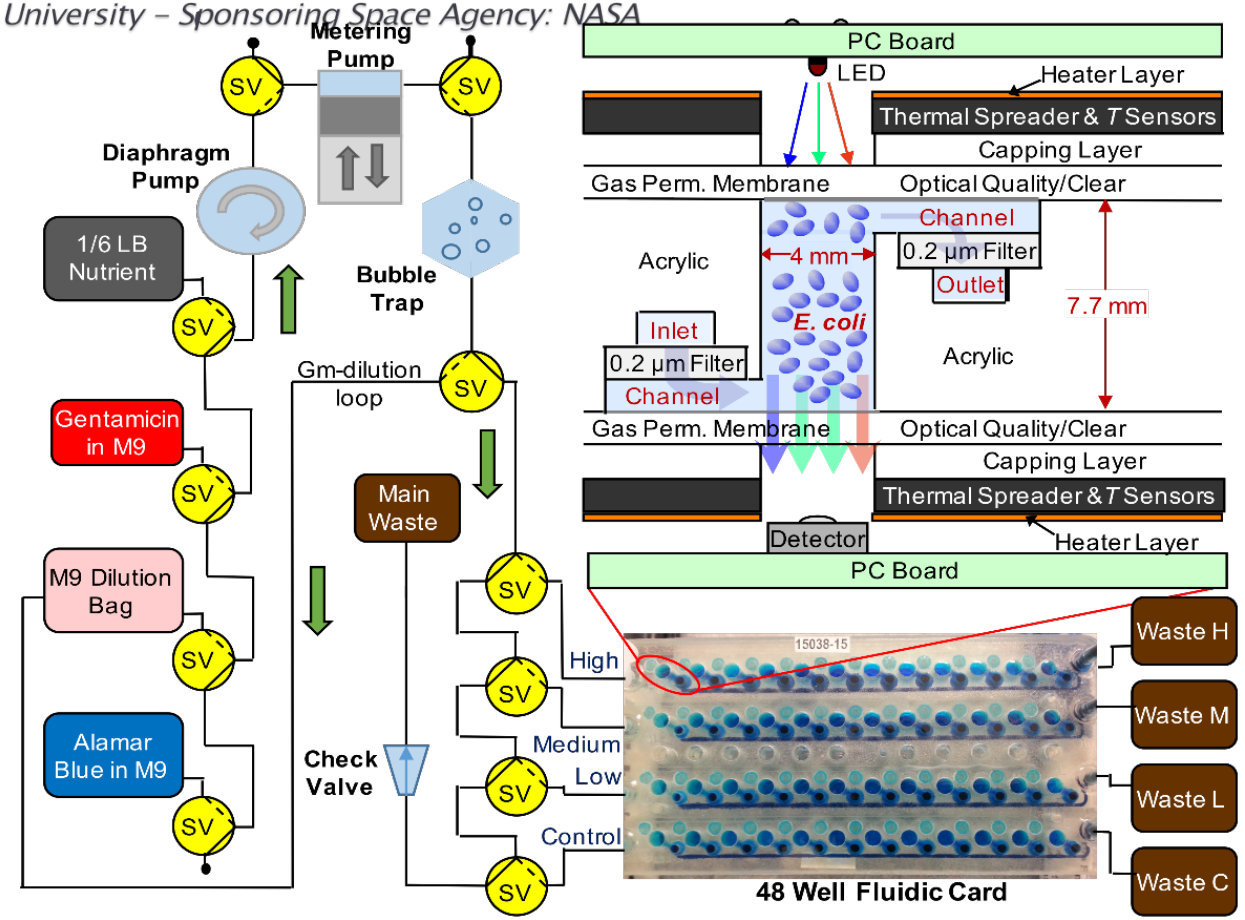
EcAMSat

Effect of Spaceflight on Antibiotic Resistance of a Pathogenic Bacterium and its Genetic Basis

PI: A.C. Matin, Stanford University – Sponsoring Space Agency: NASA

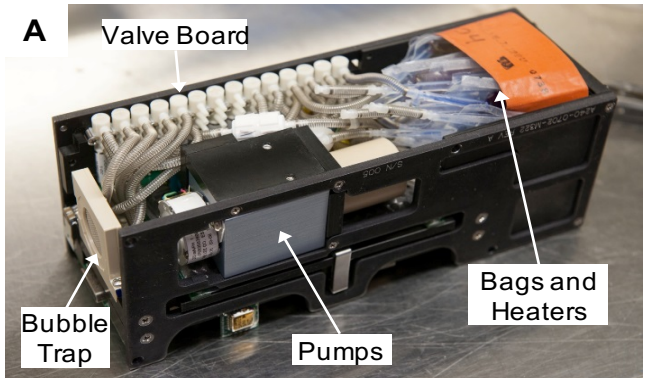
The EcAMSat mission will investigate space microgravity effect on the antibiotic resistance of *E. coli*, a bacterial pathogen responsible for urinary tract infections in humans, aboard a free-flying "nanosatellite".

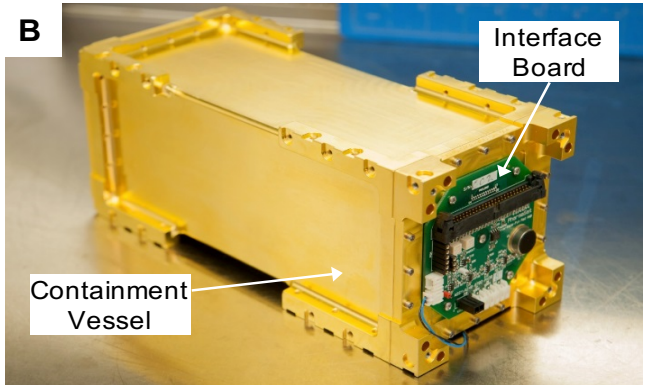




Schematic diagram of EcAMSat fluidic system and fluidic card

EcAMSat payload system and ops timeline





C

Growth 48 hr	Challenge 48 hr	Measure 56 hr
Pumping: Growth to Stationary w/ 1/6 LB	Pumping: Antibiotic Incubation	Pumping: Alamar Blue Viability Measurements

Temp control ON: Incubate at 37°C

Optics ON: 15 min Readings

[Images from A.C. Matin *et al.*, *Life Sciences in Space Research* 15 (2017) 1–10]

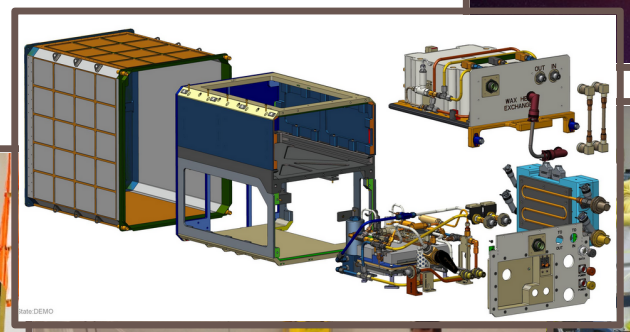
Featured Exploration Technology

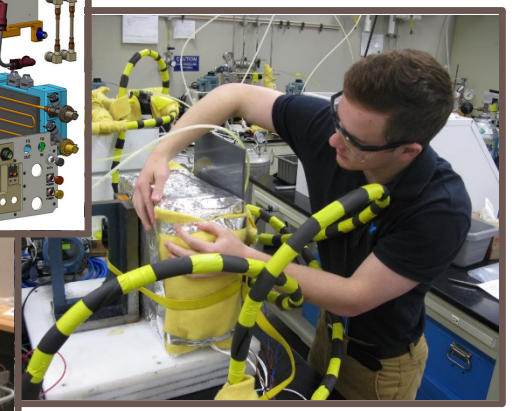
Phase Change Material Heat Exchanger (PCM HX) for Orion

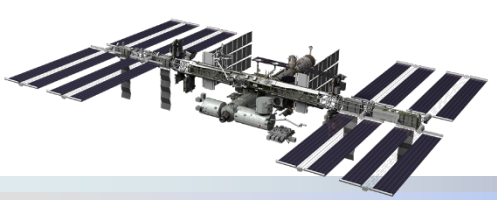
Microgravity Characterization Tests of Orion's PCM HX on ISS

Rubik Sheth, NASA Johnson Space Center

- Orion's radiators will not be sufficient for heat rejection during some exploration missions
- Phase Change Material Heat Exchangers have been baselined for use with risk associated to HX integrity during phase change
- Payload developed to test PCM HX on ISS
- Payload launched July 2016 and returned on SpX-12 in Sept 2017
- On-orbit characterization has proven the need for design modifications due to unexpected pressure increases within HX.





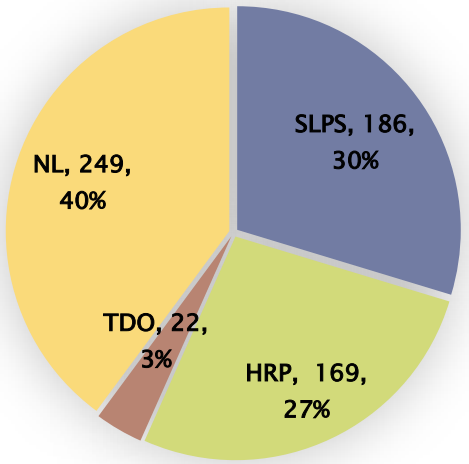


Increment 53/54 (Sept '17– Feb '18) Crew Time by Sponsor

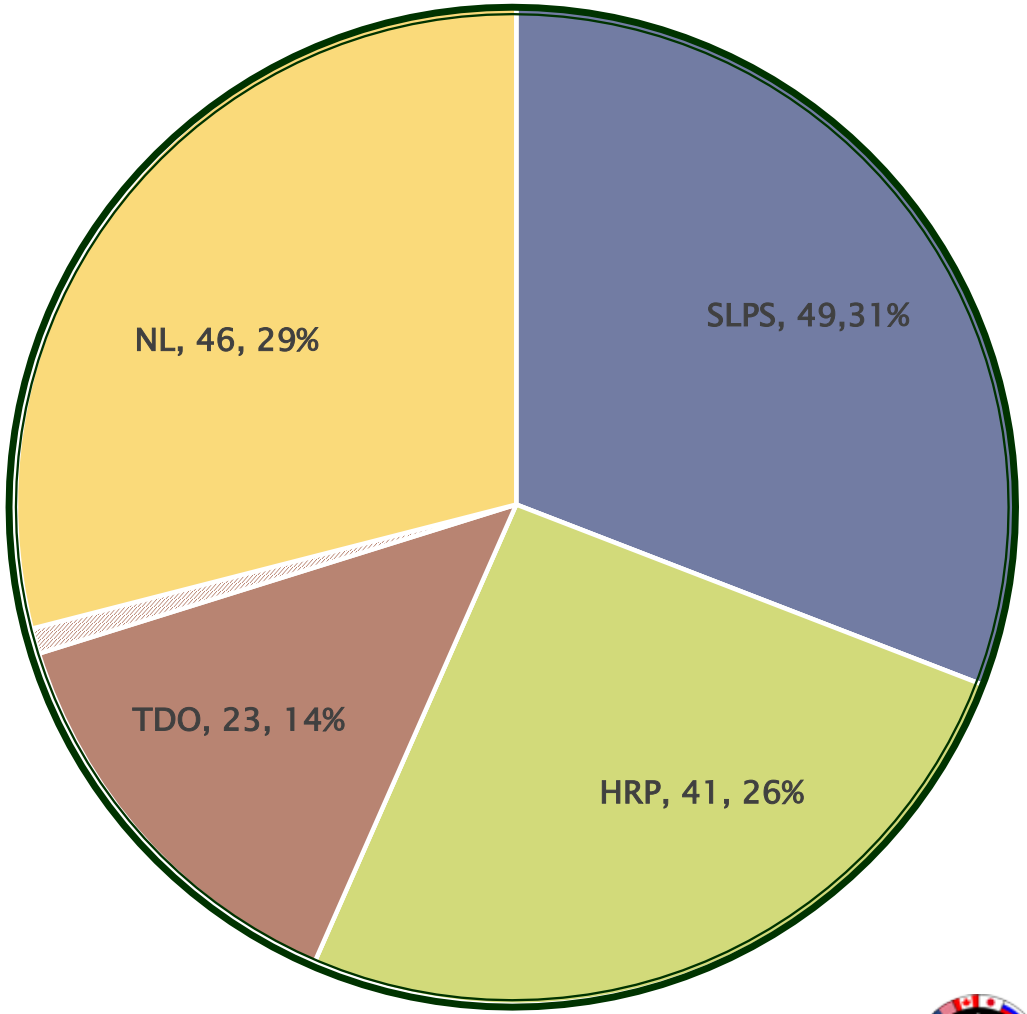
- Enablers
  - Operationally-ready reserve complement
  - Russian Crew Time for EarthKAM (NL), MARES Sarcolab-3 (ESA), EML (ESA)
- Challenges
  - Utilization hardware anomalies (e.g., CIR/ACME, FIR/LMM, Robonaut, DECLIC)
  - Loss of research requirements due to slip of HTV7 and part of SpX-14 flights from Increment Pair
- Delta Explanations
  - Implemented the majority of the available science, including reserve science, for all sponsors as permitted by constraints, including facility throughput

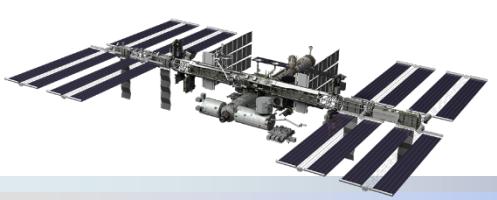
April '17 – Sept '17	Planned	Actual (as off 11/1)
Research Hours	625	160
Total Crew Days (USOS)	456	156
Cargo Flights	OA-8 SpX-13 SpX-14	
# EVAs	4	3
Russian Crew hours	0	TBD

Planned Hours



Actual Hours



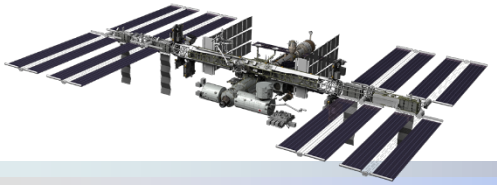


Recently Completed US EVAs

- US EVA 44 – Oct 5, 2017
  - Crew: Randy Bresnik
    Mark Vande Hei
  - EVA Time – 6:55
  - Planned tasks completed:
    - Remove degraded LEE A (s/n 202) from the SSRMS
    - Temp stow the degraded LEE (s/n 202) to handrail on CETA Cart
    - Retrieve LEE (s/n 203) from POA
    - Install LEE (s/n 203) on LEE A location
    - Install LEE (s/n 202) on POA
  - Get-Ahead tasks completed:
    - Release of the ESP2 Spare FHRC Stinger Launch Bolts and Struts
    - Removal of the EPS2 DCSU MLI

- US EVA 45 – Oct 10, 2017
  - Crew: Randy Bresnik
    Mark Vande Hei
  - EVA Time – 6:26
  - Planned tasks completed:
    - LEE A (s/n 203) Lube – Rigidize Ball Screw
    - CP9 ETVCG R&R & EHDC Installation
    - Spare PFSC/ESP-1) Removal & Rotation on Grid 2 of ESP-1
    - WIF Adapter Install on LEE A
    - MBS Mast CLPA Lens Cover
    - Node 3 EWC HR Removal
    - Airlock HPGT Handle Wire Tie
    - WIF Adapter Removal on LEE (s/n 202)
  - Get-Ahead tasks completed:
    - BCDU MLI (ELC-1)
    - LEE A (s/n 203) Lube Four Latch Ballscrews

- US EVA 46 – Oct 20, 2017
  - Crew: Randy Bresnik
    Joe Acaba
  - EVA Time – 6:49
  - Planned tasks completed:
    - SPDM EOTP Fuse R&R
    - Install EHDC CP3 ETVCG
    - Remove Spare MBSU MLI and tie back MBSU MLI skirt on ESP-2
    - Tie back DCSU skirt on ESP-2
    - Remove and Replace failed CLA Camera on LEE A with IV Spare
  - Get-Ahead tasks completed:
    - LEE A Linear Bearing Lube
    - Pump Module Prep on ELC-1
      - Pump Module Prep on ESP
      - Break torque and re-torque Pump Module bolts not completed
    - Install 2 Forward Port RGB T
      Handles



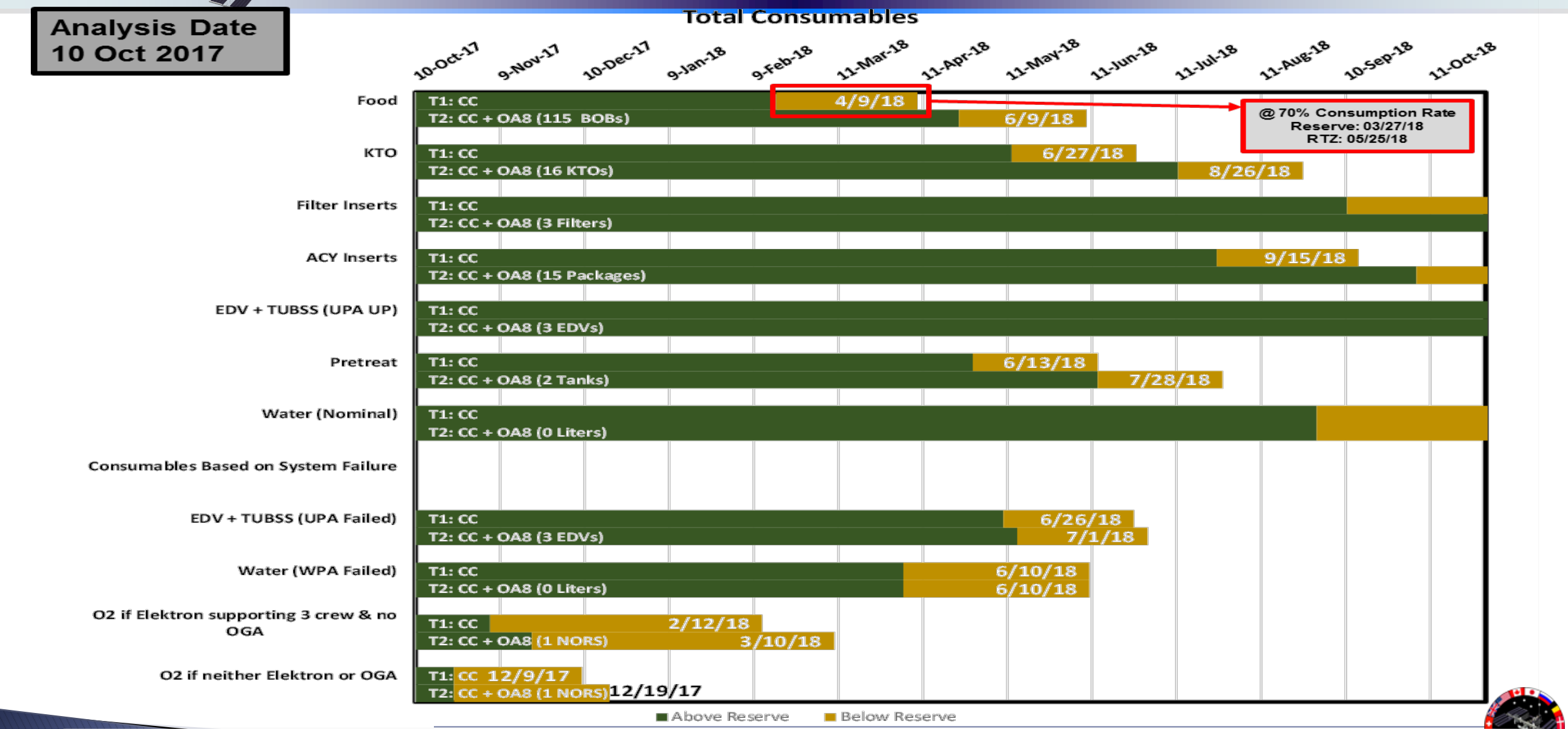
Upcoming US EVAs

US EVAs – Jan/Feb 2018:

- Double EVA
  - Move Degraded LEE B (Snare cable with broken wires) to POA
  - Install spare LEE on the LEE B location
  - Remove the POA LEE (old LEE A) and bring it IVA
- NBL development in work to define EVA timeline and determine if any other tasks can be accommodated into the double EVA plan (first run scheduled for 10/26/17)
- Plans to robotically move the spare LEE from ELC-1 to ESP-2 is currently in work. ECD – November 2017
  - This puts the spare LEE in a more "EVA friendly" position near the POA and LEE B worksites
  - Due to bolt access concerns, the SSRMS will move the ESP2 FHRC onto the EOTP for the duration of the EVAs
- There are initial rumors that a third EVA could be added to this timeframe if SpX-14 slips out.

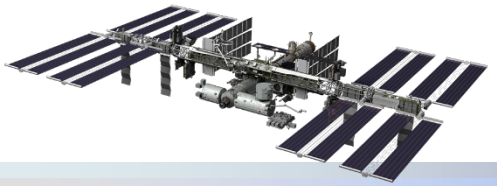
Total Consumables

Analysis Date
10 Oct 2017



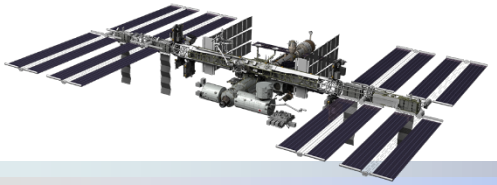
SpaceX-12 Mission Success

- Mission Planning
  - Launched successfully on 8/14/17
  - Berthed on 8/16/17
  - Release and Splashdown successfully occurred on 9/17/17
  - Post Flight Review (PFR) successfully conducted on 10/17/17
- Pressurized Cargo – 1628 kg; 1702 kg return
  - Launch: 3 Polars, 1 AEM-T, 1 JAXA Mouse Habitat Unit (MHU)
  - Return: 3 Polars, 1 AEM-T, 1 JAXA MHU
- Unpressurized Cargo – 1258 kg
  - Cosmic Ray Energetics and Mass (CREAM) payload extraction completed 8/21/17, installed on the JEM-EF
  - No disposal payloads
- Vehicle Status
  - SpX-12 used a new Dragon vehicle build
  - Nominal Falcon 9 performance during launch



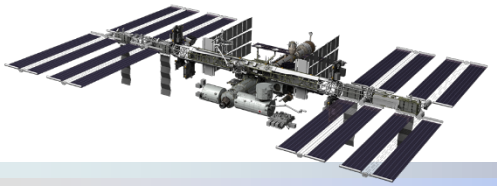
SpaceX-13 Mission Status

- Mission Planning
  - Stage Operations Readiness Review (SORR) successfully completed 11/1/17
- Pressurized Cargo – 1850 kg planned; 1900 kg return estimated
  - Launch: 2 AEM-Ts, 1 Cell Science Validation
  - Return: 1 AEM-T, 1 Cell Science Validation, 3 Polars
- Unpressurized Cargo – 1080 kg; 553 kg disposal
  1. Space Debris Sensor (SDS)
  2. Materials International Space Station Experiment Flight Facility (MISSE-FF)
  3. Total and Spectral Solar Irradiance Sensor (TSIS)
  - RapidScat planned for disposal
  - External cargo on dock is planned for 11/6/17
- Dragon Status (8R)
  - Second reuse of a Dragon capsule (Dragon 8R flew on SpX-6)
  - Capsule and trunk planned to ship to Cape on 11/1/17
- Falcon 9 Status
  - Planned first flight from refurbished Pad 40
  - Baseline Stage 1 is a new build awaiting Stage Acceptance Test ~11/2/17
  - Reuse Stage 1 assessment nearing completion (previously flown on SpX-11)
  - Stage 2 expected to be ready for Stage Acceptance Test the week of 11/6/17



OA-8 Mission Status

- Mission Planning
  - Flight Readiness and Certification Review (FRCR) successfully completed 10/5/17
  - Stage Operations Readiness Review (SORR) successfully completed on 10/19/17
- Pressurized Cargo ~3350 kg ascent; 1950 kg disposal
  - 2 Polar, 1 MERLIN
  - Initial Cargo Loading completed on 10/7/17
  - Late Load and Final Load planned to be complete by 11/7/17
- Unpressurized Cargo
  - NanoRacks CubeSat Deployer (NRCSD) deploys planned after unberth from ISS
- Cygnus Status
  - Cygnus mate to Antares is planned for 10/30/17
- Antares Status
  - Vehicle transferred to Transport Erector Launcher (TEL) on 10/10/17
  - Launch Vehicle Assessment (LVA) successfully completed on 10/17/17
  - Rollout planned for 11/9/17



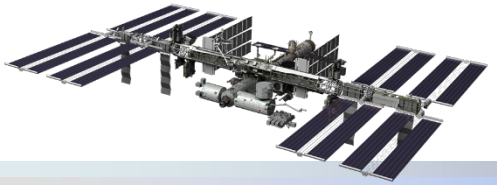
Commercial Resupply Services CRS-2 Status

- ISS Integration Review (IR) Milestones
  - IR #1, Kickoff, #2, System Requirements Review, and #3 Preliminary Design Review (PDR) for all three contracts were successfully completed

- ISS IR Milestone – #4 Critical Design Reviews (CDR)
  - Reviews have begun and are expected to complete in mid-2018
    - Orbital-ATK IR#4 Systems delta CDR successfully completed 6/28/17
    - SpaceX IR#4 Part A successfully completed on 6/13/17; IR#4 Part B planned for Nov 7-8, 2017
    - Sierra Nevada Corporation (SNC) IR#4 planned for Spring 2018

- CRS-2 missions are planned for launch beginning in 2019

ISS Transition



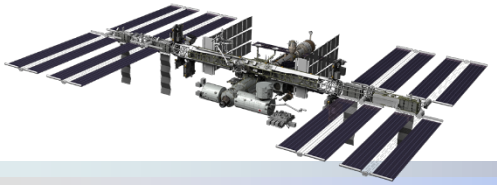
ISS Transition

- 2017 NASA Authorization Act requires a "ISS Transition Report"
  - 6 pages of questions and content to be included in the report
  - Requires input from CASIS, International Partners, scientific community and commercial industry

- Due to Congress on December 1, 2017

- Held an ISS Stakeholder Workshop in Washington, DC on August 9
  - Discussed policy and programmatic issues related to ISS and LEO
  - 4 breakout sessions
    - LEO Market
    - ISS Value Proposition
    - Public Private Partnerships
    - Access to Space for HSF

  - Discussion is captured at the following website:
    https://www.nasa.gov/content/international-space-station-stakeholder-workshop



ISS Transition

(a) Findings.—Congress finds that—

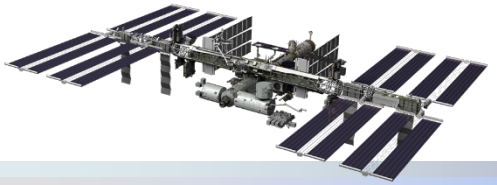
(1) NASA has been both the primary supplier and consumer of human space flight capabilities and services of the ISS and in low-Earth orbit; and

(2) according to the National Research Council report "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration" extending ISS beyond 2020 to 2024 or 2028 will have significant negative impacts on the schedule of crewed missions to Mars, without significant increases in funding.

(b) Sense Of Congress.—It is the sense of Congress that—

(1) an orderly transition for United States human space flight activities in low-Earth orbit from the current regime, that relies heavily on NASA sponsorship, to a regime where NASA is one of many customers of a low-Earth orbit commercial human space flight enterprise may be necessary; and

(2) decisions about the long-term future of the ISS impact the ability to conduct future deep space exploration activities, and that such decisions regarding the ISS should be considered in the context of the human exploration roadmap under section 432 of this Act.



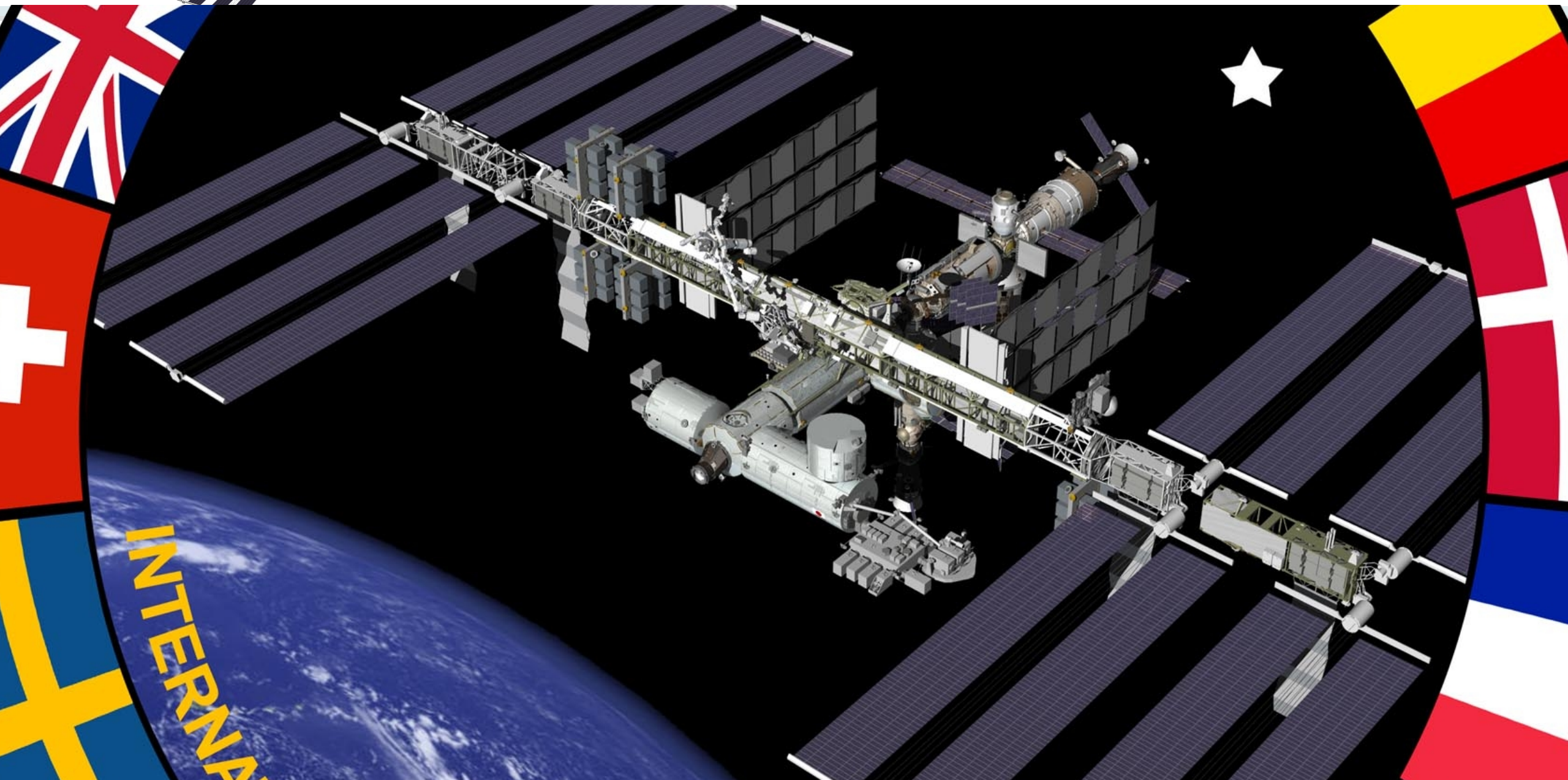
ISS Transition

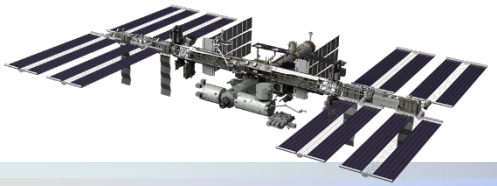
(c) Reports.—Section 50111 of title 51, United States Code, is amended by adding at the end the following:

"(c) ISS Transition Plan.—

"(1) IN GENERAL.—The Administrator, in coordination with the ISS management entity (as defined in section 2 of the National Aeronautics and Space Administration Transition Authorization Act of 2017), ISS partners, the scientific user community, and the commercial space sector, shall develop a plan to transition in a step-wise approach from the current regime that relies heavily on NASA sponsorship to a regime where NASA could be one of many customers of a low-Earth orbit non-governmental human space flight enterprise.

International Space Station Today



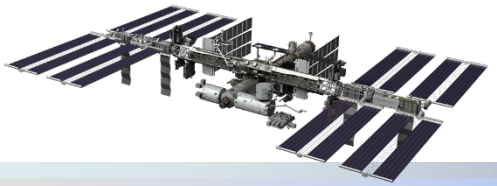


Current State

- **US continuous human presence in LEO**
  - Continuous US human presence has been sustained over the past 16+ years
    - Commercial crew will add an additional crew member
    - US human spaceflight missions have been a part of American prominence and culture for over half a century

- **US Leadership in Human Space Flight**
  - Current ISS Inter-Government Agreements (IGA) have been in place for nearly 20 years and provide treaty-level agreements between US, Russia, Canada, Europe and Japan

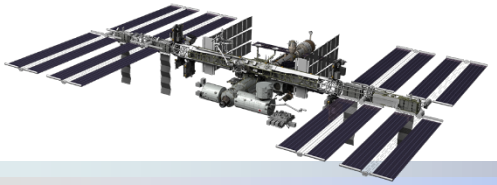
- **Development of commercial markets in LEO**
  - Cargo and crew already supplied by private industry (~52% cost of current ISS)
  - Commercial crew and cargo support commercial launch industry
    - ~17% of US launch market goes to ISS (2017)
  - Research and tech dev demand development via National Lab/CASIS



Current State

- **Deep space – long duration Exploration**
  - Requirements for human health and performance research and technology/system demonstrations for habitation systems, and other exploration systems are currently planned to be completed by 2024/2025

- **Research and Development**
  - NASA sponsored research across life and physical sciences, human health, astrophysics, earth sciences, space science, many others
  - National Lab users have been greatly expanded into private industry and other government agencies via CASIS
    - Pharma, materials, manufacturing, human health, model organisms, consumer products
    - NASA continues to fund NL activities at $15M/year + transportation, crew time, power, data, etc. for no cost
    - Currently, private industry and OGA's are probably not in a position to fully pay for capabilities (transportation, crew time, power, etc.) without ongoing NASA support



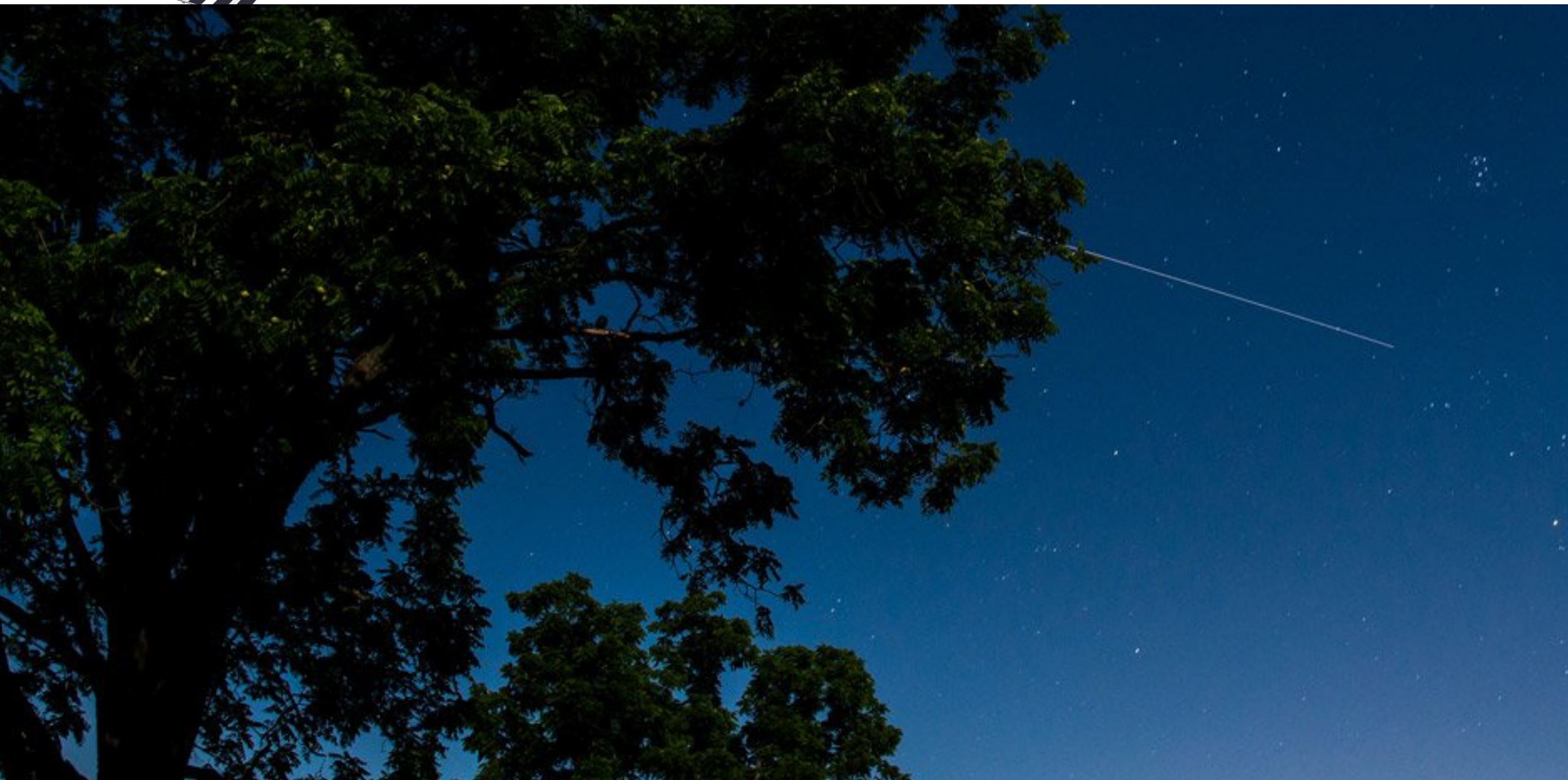
Cost to Enable

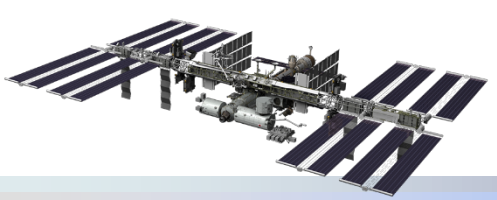
- **Primary cost driver for ISS is transportation**
- **Other drivers include**
  - Infrastructure and logistics needed to keep 6 crew members on-board year round
  - Complexity and scale of the on-orbit platform
  - Cost needed to carry international obligations

ISS Budget	Average FY18–22*
Total	$3.4B
O&M	$1.2B
Crew/cargo	$1.8B
Research	$0.4B
NL (within Research)	$15M

*based on FY18 President's Budget Request

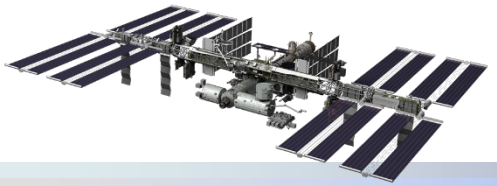
Fast Forward to 2024





Looking to the future in 2024 – A Fair Amount of Certainty

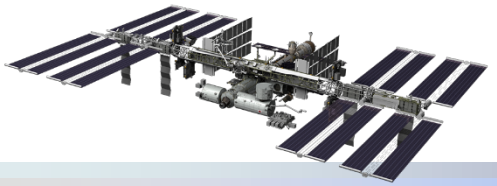
- Continuous US human presence sustained for over 24 years
- China is operating their newly complete space station with participation from other countries, possibly including some of the ISS Partners (and potentially in a significant manner)
- Commercial crew has increased US crew from 3 to 4
- Exploration related human research and technology/system demonstrations in LEO are nearly complete, with focus shifting to deep space
  - Minimal ongoing LEO needs to support long-term deep space missions.
- Transportation costs have been validated
- NASA is conducting human spaceflight missions in cislunar space



Looking to the future in 2024 – Less Certainty

- Private industry users may have established a business case for funding (a portion) of the integration, transportation and execution of their research or technology development
- Other government agencies hopefully have established long term requirements for conducting research in LEO and have allocated funds to pay for their overhead costs
- Commercial market demand (tourism, marketing, in-space manufacturing, etc.) may or may not have been established

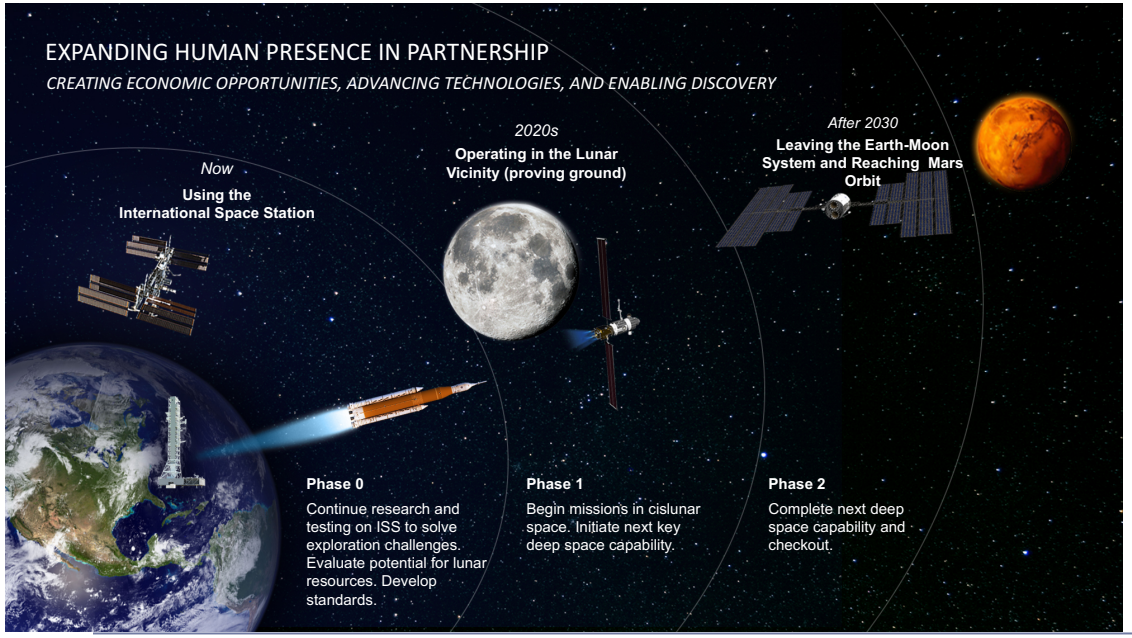
Considerations

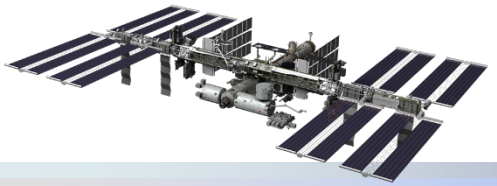


Considerations

- Transition indicators
  - Completion of exploration-related research and technology development requiring ISS
  - Demand from government and private industry including research and for-profit motivated activities, and whether that demand will support private LEO platforms and associated transportation costs
  - Establishment of cislunar Gateway capabilities and execution of missions beyond LEO

- Affordability in the larger HSF Exploration context





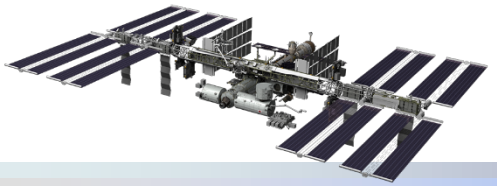
Considerations

- Foreign Policy Considerations
  - US leadership in HSF
  - Other LEO space stations

- Future of the National Lab
  - Role of the government in fostering R&D across private industry and non-NASA government agencies

- Re-use of on-orbit ISS elements
  - Many elements will have considerable structural life after 2028
  - Some systems, including the solar arrays,
    will need to be replace by the end of the 2020s
    in order to maintain the current configuration
  - Maintenance levels less than originally anticipated
  - Value of the nation's investment is considerable

Element	Year Launched	+30 years
FGB/Node 1	1998	2028
US Lab	2001	2031
Node 2	2007	2037
Columbus/JEM	2008	2038
Node 3/Cupola	2010	2040
Truss segments	2000-2009	2030-2039



Considerations

- Long-term NASA requirements for LEO research and utilization
  - NASA is currently assessing its LEO long term requirements and utilization needs

- Scope of public-private partnership models
  - There is a large range of private partnership arrangements that could be considered
    - Proper role of the government vs. private industry would need to be explored
    - International Partner agreements
    - Ability for private industry to do business outside of government constraints
    - Scope of government needs for LEO in the long term