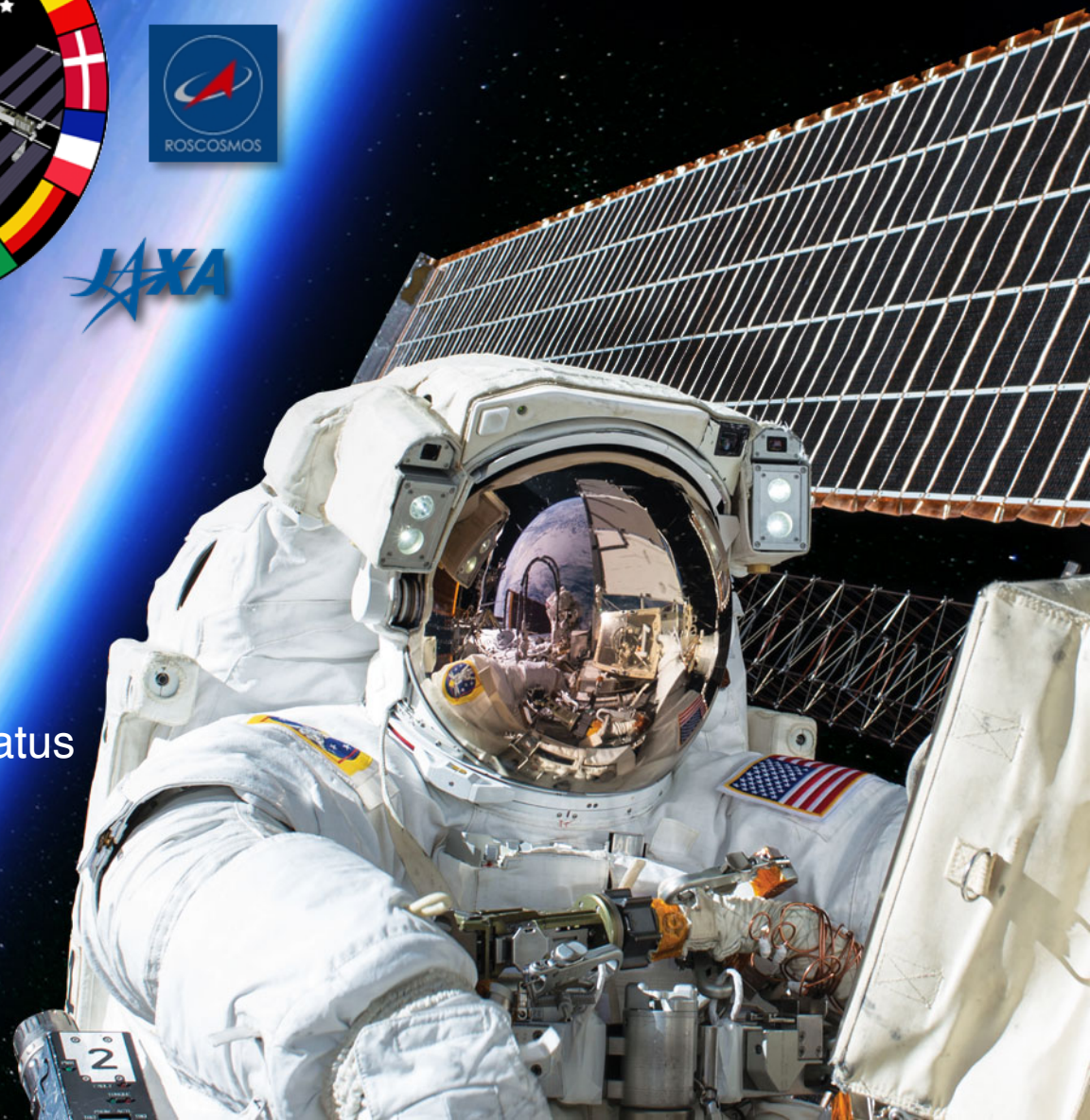
National Aeronautics and Space Administration

EXPLORE HUMANS *in* SPACE

HEO NAC
International Space Station Status

Sam Scimemi– ISS Director

May 2019



Agenda

- ISS Increment Overview
- Exploration Research and Technology Highlights (including HRP)
- Utilization Summary
- ISS National Lab Highlights
- ISS Operational Status
- ISS Transition and LEO Commercialization

Flight Plan – Increment 59

- 3/14/19 – Soyuz 58S Launch (NASA/Koch, NASA/Hague, Roscosmos/Ovchinin)
- 3/15/19 – Soyuz 58S Docking (NASA/Koch, NASA/Hague, Roscosmos/Ovchinin)
- 3/22/19 – US EVA #52 (P4 Battery R&R)
- 3/29/19 – US EVA #53 (P4 Battery R&R)
- 4/04/19 - Progress 72P Launch/Docking
- 4/08/19 - US EVA #54 (Truss Jumpers)
- 4/17/19 – NG CRS-11 Launch
- 4/19/19 – NG CRS-11 Capture/Berth
- 5/04/19 – SpX CRS-17 Launch
- 5/06/19 – SpX CRS-17 Capture/Berth
- 5/29/19 - RS EVA #46
- 6/03/19 – SpX CRS-17 Release/Splashdown
- 6/04/19 - Progress 71P Release
- 6/24/19 - Soyuz 57S Undock/Landing (NASA/McClain, CSA/Saint-Jacques, Roscosmos/Kononenko)

Increment 59 Overview: Crew

57S Dock 12/3/18
57S Undock 6/24/19

Anne McClain
FE (NASA) – 57S

Oleg Kononenko
Soyuz CDR (R) - 57S
(CDR Exp 58 & 59)

David Saint-Jacques
FE (CSA) – 57S

58S Dock 3/15/19
58S Undock 10/3/19

Nick Hague
FE (NASA) – 58S

Aleksey Ovchinin
Soyuz CDR (R) - 58S
(CDR Exp 60)

Christina Koch
FE (NASA) – 58S

Increment 59

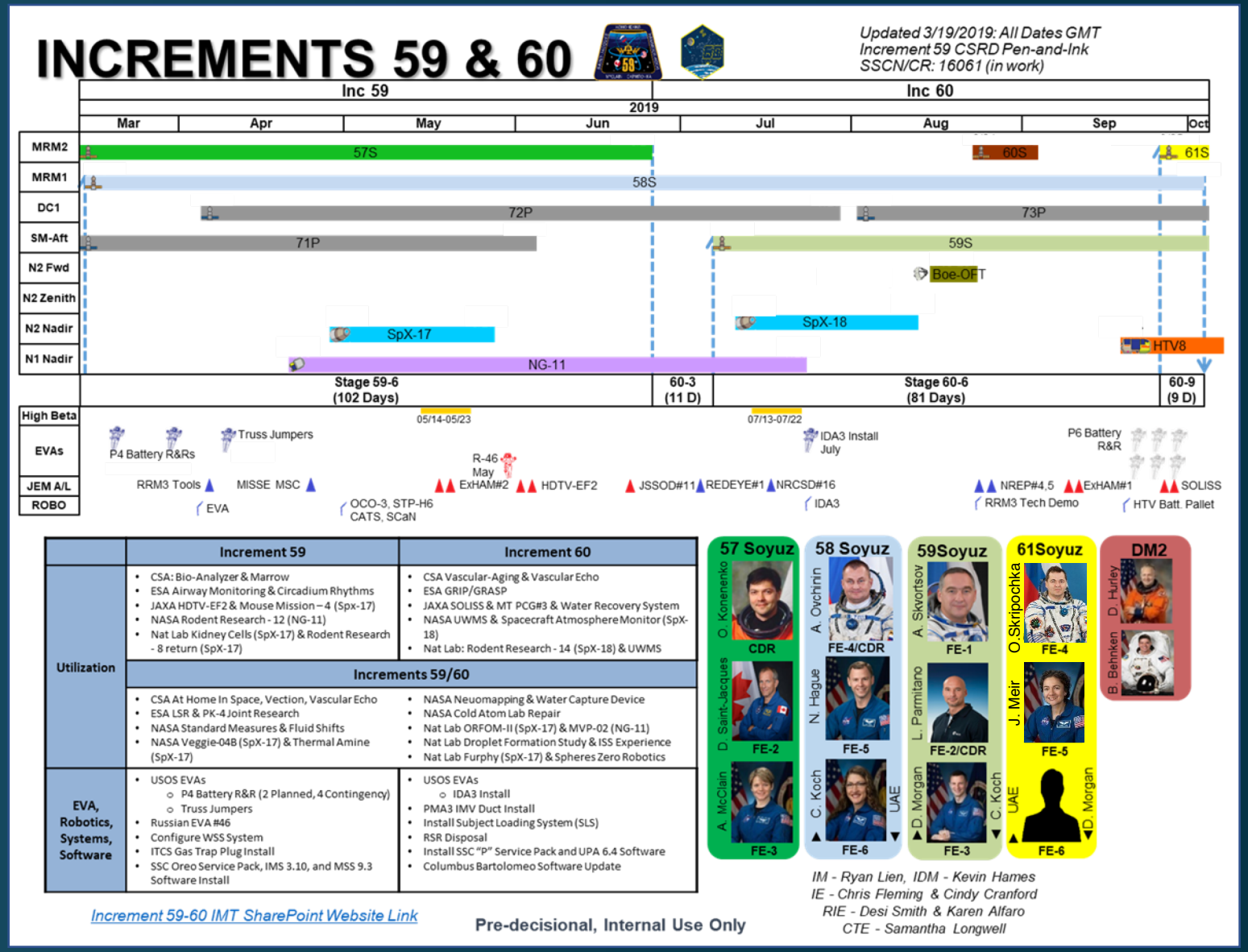
Increment 59: 102 days

Visiting vehicles:

- 71P (11/18 – 6/4/19)
- 72P (4/4 -7/29)
- NG CRS-11 (4/19 -7/23)
- SpX CRS-17 (5/2-5/31)

Science/Utilization:

- CSA: Bio-Analyzer & Marrow
- ESA Airway Monitoring & Circadium Rhythms
- JAXA HDTV-EF2 & Mouse Mission – 4 (Spx-17)
- NASA Rodent Research - 12 (NG-11)
- Nat Lab Kidney Cells (SpX-17) & Rodent Research – 8 return (SpX-17)
- CSA At Home In Space, Vection, Vascular Echo
- ESA LSR & PK-4 Joint Research
- NASA Standard Measures & Fluid Shifts
- NASA Veggie-04B (SpX-17) & Thermal Amine (SpX-17)
- NASA Neuromapping & Water Capture Device
- NASA Cold Atom Lab Repair
- Nat Lab ORFOM-II (SpX-17) & MVP-02 (NG-11)
- Nat Lab Droplet Formation Study & ISS Experience
- Nat Lab Furphy (SpX-17) & Spheres Zero Robotics



	Increment 59	Increment 60
Utilization	• CSA: Bio-Analyzer & Marrow • ESA Airway Monitoring & Circadium Rhythms • JAXA HDTV-EF2 & Mouse Mission – 4 (Spx-17) • NASA Rodent Research - 12 (NG-11) • Nat Lab Kidney Cells (SpX-17) & Rodent Research - 8 return (SpX-17)	• CSA Vascular-Aging & Vascular Echo • ESA GRIP/GRASP • JAXA SOLISS & MT PCG#3 & Water Recovery System • NASA UWMS & Spacecraft Atmosphere Monitor (SpX-18) • Nat Lab: Rodent Research - 14 (SpX-18) & UWMS
	Increments 59/60	
	• CSA At Home In Space, Vection, Vascular Echo • ESA LSR & PK-4 Joint Research • NASA Standard Measures & Fluid Shifts • NASA Veggie-04B (SpX-17) & Thermal Amine (SpX-17)	• NASA Neuomapping & Water Capture Device • NASA Cold Atom Lab Repair • Nat Lab ORFOM-II (SpX-17) & MVP-02 (NG-11) • Nat Lab Droplet Formation Study & ISS Experience • Nat Lab Furphy (SpX-17) & Spheres Zero Robotics

EVA, Robotics, Systems, Software	• USOS EVAs
	  ○ P4 Battery R&R (2 Planned, 4 Contingency)
	  ○ Truss Jumpers
	• Russian EVA #46
	• Configure WSS System
	• ITCS Gas Trap Plug Install
	• SSC Oreo Service Pack, IMS 3.10, and MSS 9.3 Software Install
		• USOS EVAs
		  ○ IDA3 Install
		• PMA3 IMV Duct Install
		• Install Subject Loading System (SLS)
		• RSR Disposal
		• Install SSC "P" Service Pack and UPA 6.4 Software
		• Columbus Bartolomeo Software Update

Increment 59-60 IMT SharePoint Website Link

Pre-decisional, Internal Use Only

IM - Ryan Lien, IDM - Kevin Hames
IE - Chris Fleming & Cindy Cranford
RIE - Desi Smith & Karen Alfaro
CTE - Samantha Longwell

Exploration Research and Technology Highlights

FY18-19 Agency Priority Goal

Use the International Space Station (ISS) as a testbed to demonstrate the critical systems necessary for long-duration missions. Between October 1, 2017, and September 30, 2019, NASA will initiate at least eight in-space demonstrations of technology critical to enable human exploration in deep space.

- **Goal focuses on Exploration-enabling demonstrations to be conducted on ISS**
- **Includes demonstrations funded by ISS, AES, HRP, Orion, and STMD**
- **Demonstrations completed in FY18**
- **Aerosol sampler**
- **Combination Acoustic Monitor**
- **Demonstrations currently planned in FY19:**

Q1	Q2	Q3	Q4
✓ Refabricator	✓ Hybrid Electronic Radiation Assessor (HERA)	✓ Siloxane control technology (CHIPS filters) ✓ Thermal Amine ✓ Astrobee	• RFID Enabled Autonomous Logistics Management (REALM)-2 • SAM Major Constituents Analyzer • T2 Augmented Reality • Spacesuit Evaporation Rejection Flight Experiment (SERFE)

Featured Exploration Technology – Upcoming

Astrobee

Free-Flying Robot for IVA Tasks and Guest Science

PM: Maria Bualat, NASA Ames Research Center, Moffett Field, California

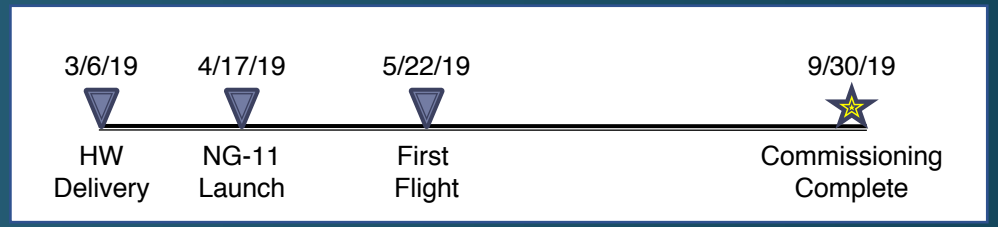
Next generation space robot
- 3 robots + docking station (2 robots on station currently)
- Smartphone-based avionics and open-source software
- Autonomous and telerobotic operations

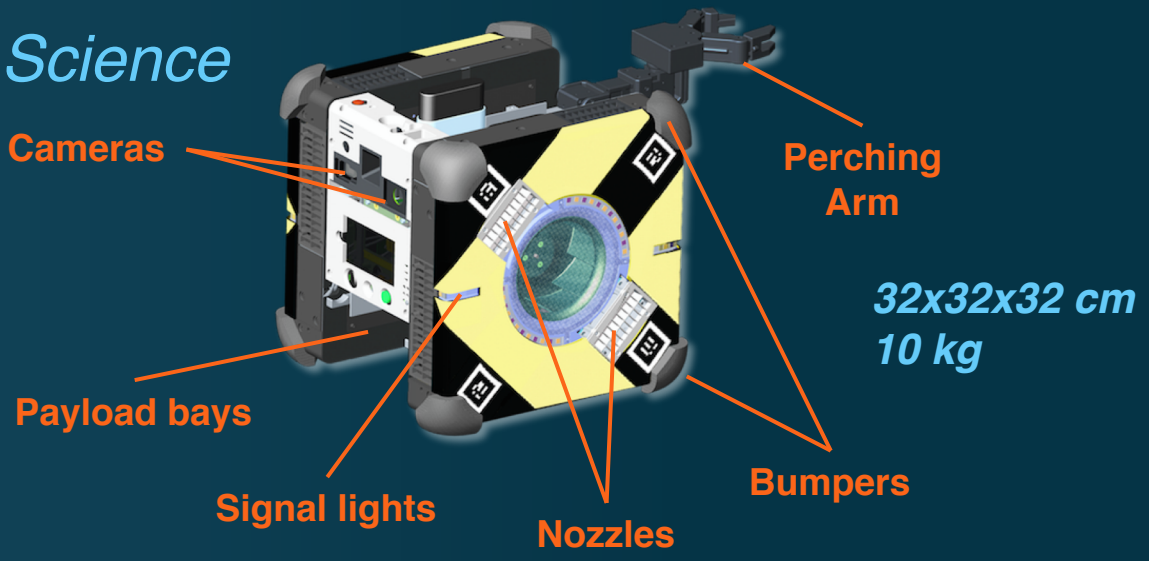
Supports IVA tasks in human spacecraft
- Perform mobile IVA surveys (inventory, sensor readings, etc)
- Perform mobile camera work (increase mission control awareness)

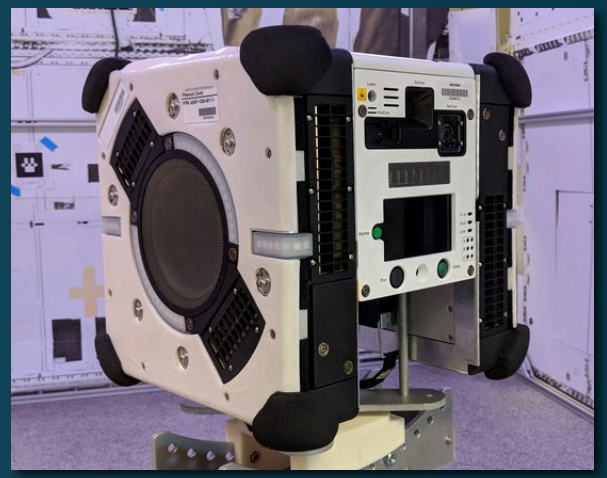
Successor to SPHERES (micro-gravity robotics testbed)
- Astrobee has multiple expansion ports for new payloads
- Can perform experiments/tests independent of crew
- 7 guest science projects currently in development

Technology development for Deep Space Gateway
- Support HEOMD and STMD IVA robotics engineering (FY19+)
- Mobile robot for in-flight maintenance (preventive and corrective)
- Perform inventory, monitoring, logistics support during uncrewed periods

Launched on NG-11 in April 2019



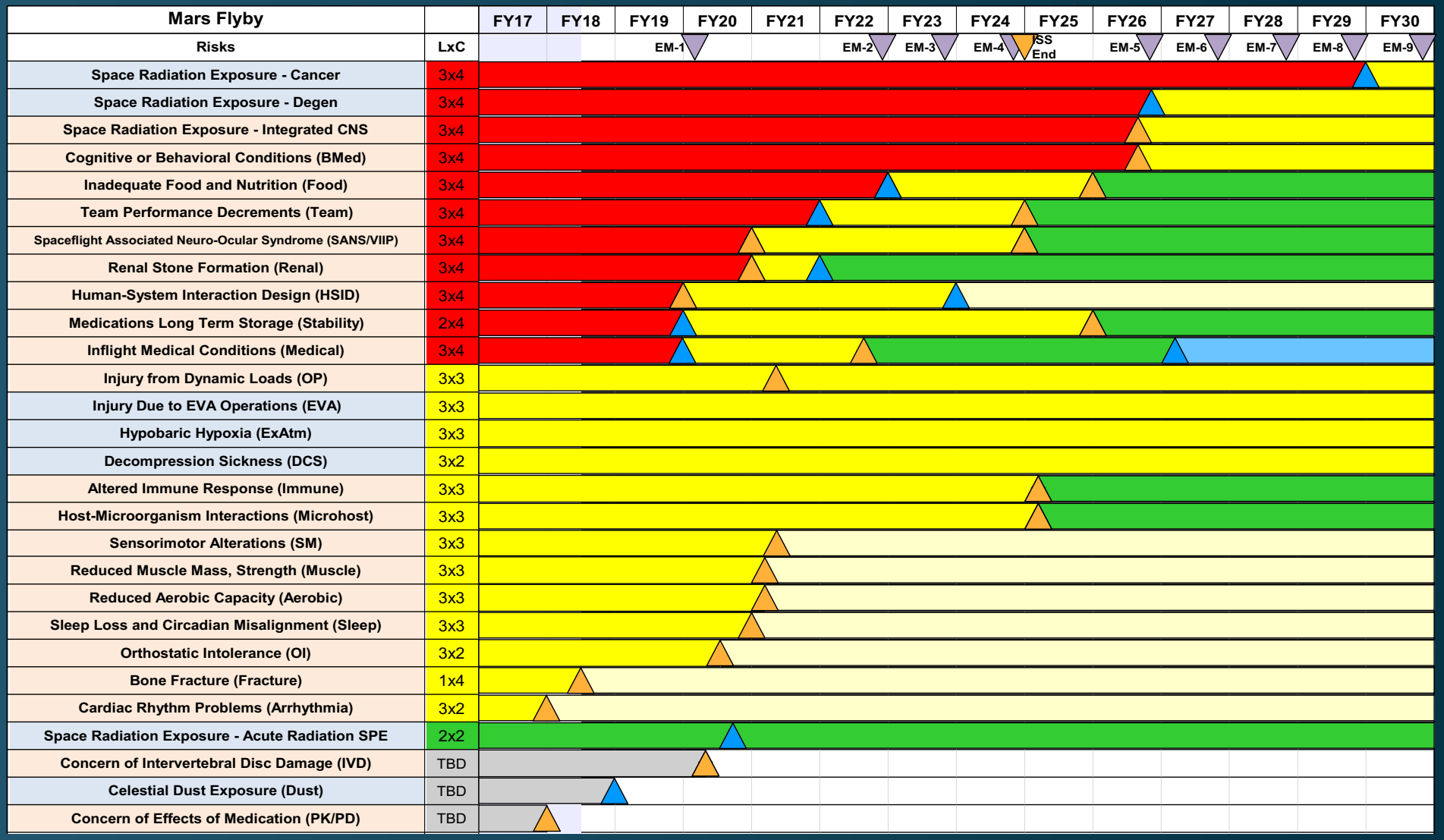




Certification Unit (8/2018)

Two Astrobees moving cargo (artist concept)

HRP Path to Risk Reduction



Featured Investigation

Rodent Research - 12

Tetanus Antibody Response by B cells In Space (TARBIS)

- TARBIS examines the effects of spaceflight on the function of antibody production and immune memory
- Limited research on spaceflight's effect following an actual challenge to the body's immune system
- Using a mouse model makes this possible, as the mouse immune system closely parallels that of humans
- May advance development of measures to counter spaceflight's effects on the immune system, helping to maintain crew health during future long-duration space missions.

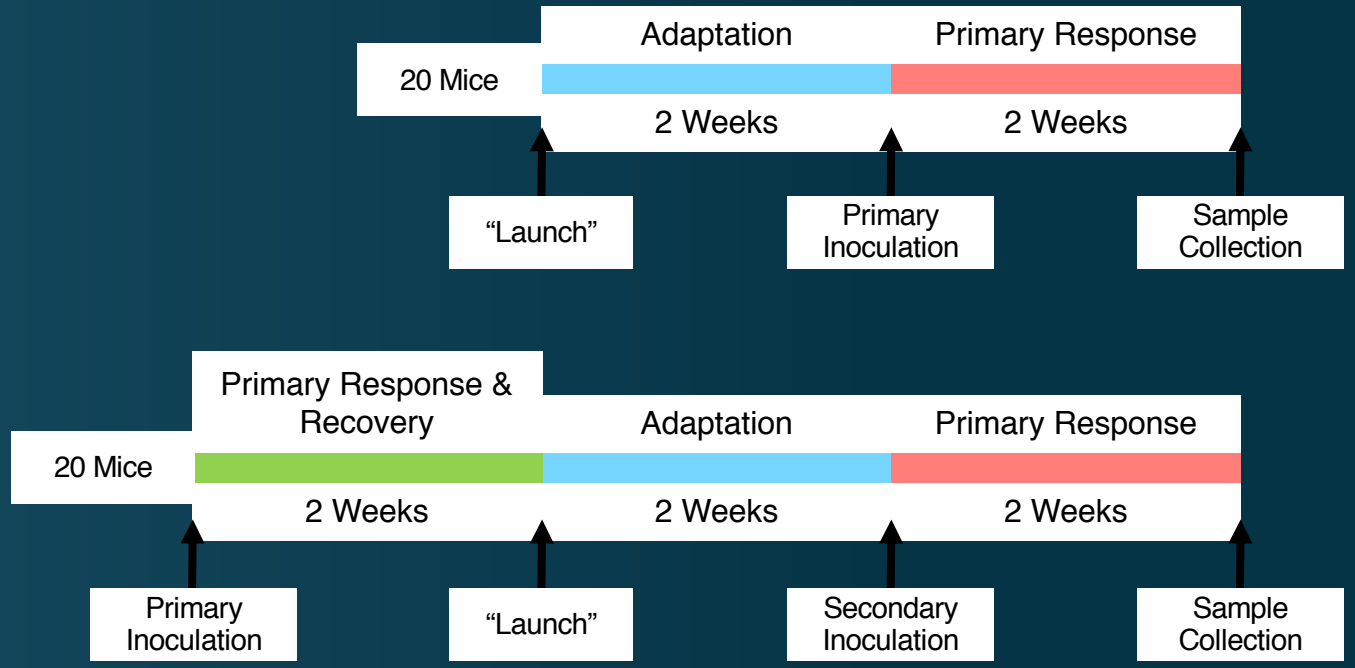
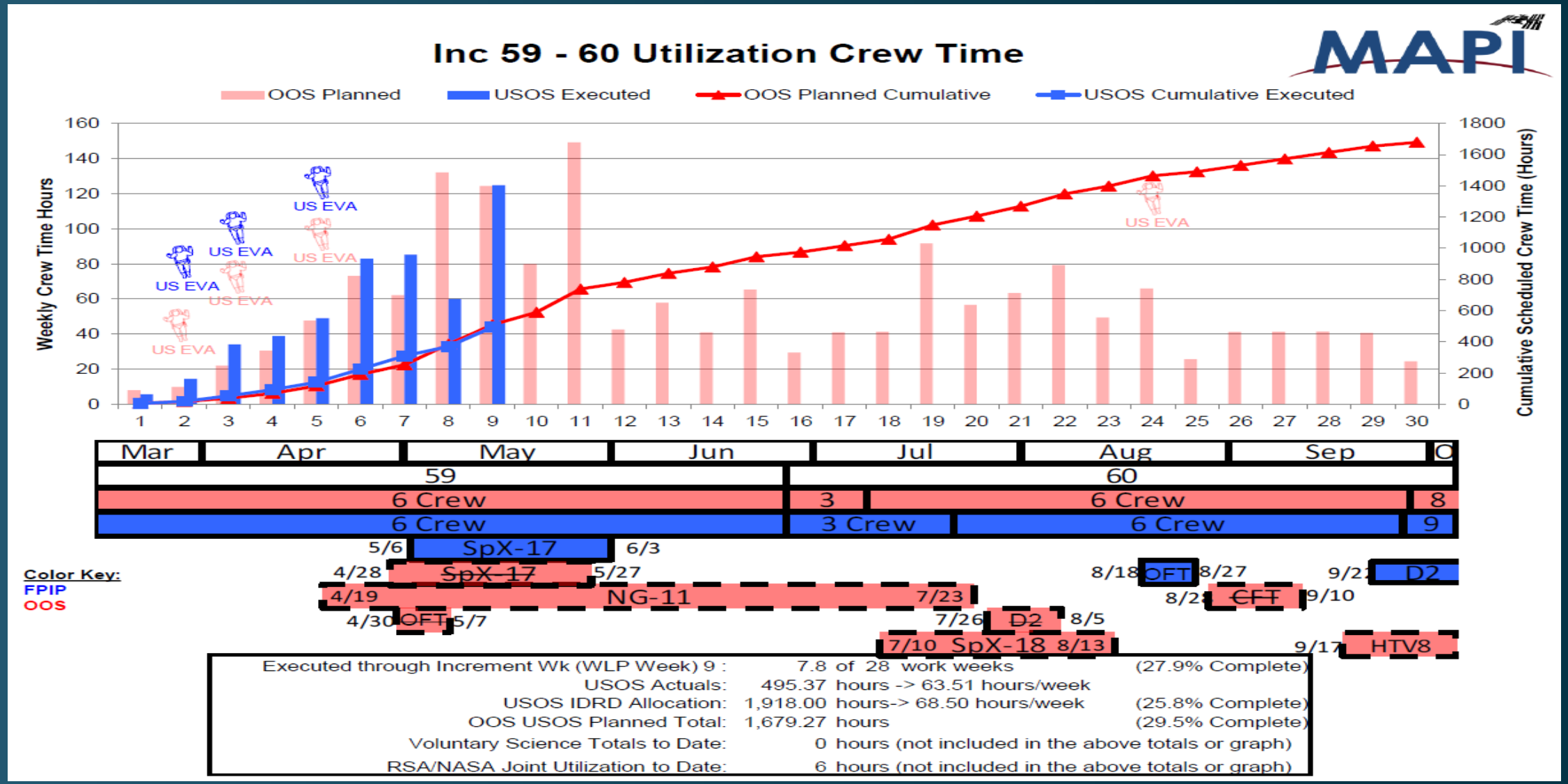


Image Credit: NASA's Goddard Space Flight Center

Utilization Summary

Inc 59/60 Utilization Crew Time



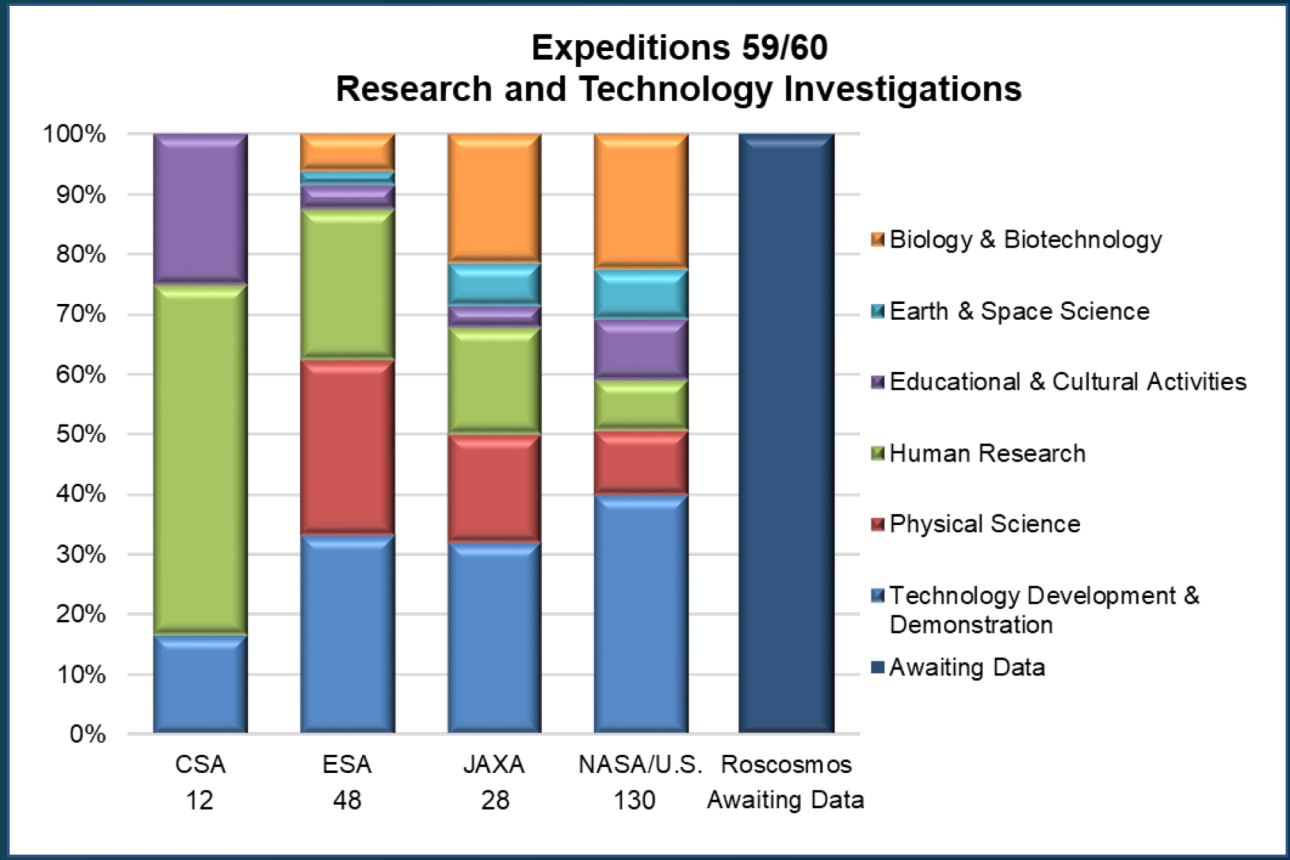
ISS Research Statistics

Number of Investigations for 59/60: 218

- 130 NASA/U.S.-led investigations
- 88 International-led investigations
- 70 New investigations
  - 2 CSA
  - 4 ESA
  - 6 JAXA
  - 58 NASA/U.S.
  - TBD Roscosmos

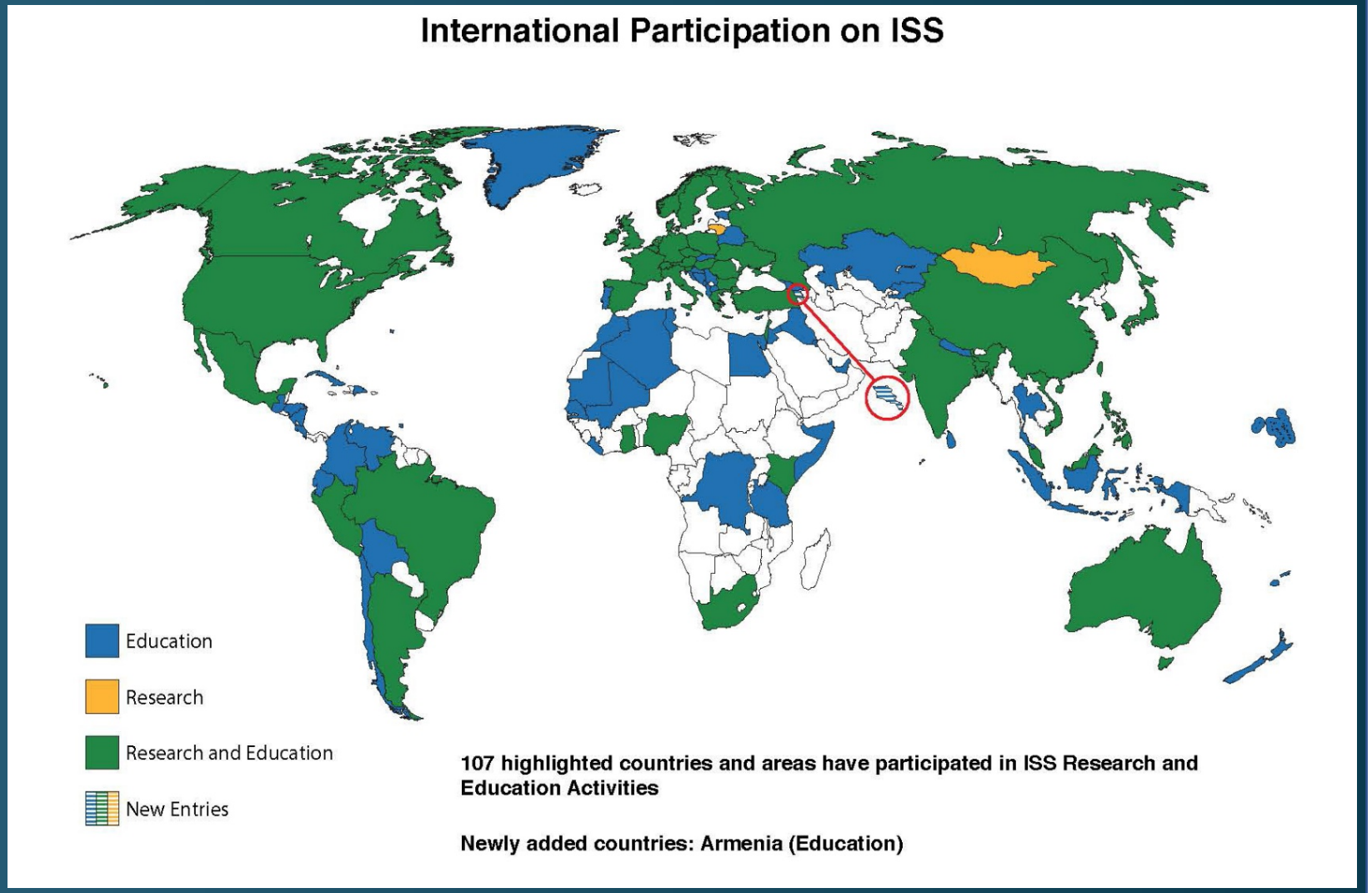
ISS Lifetime

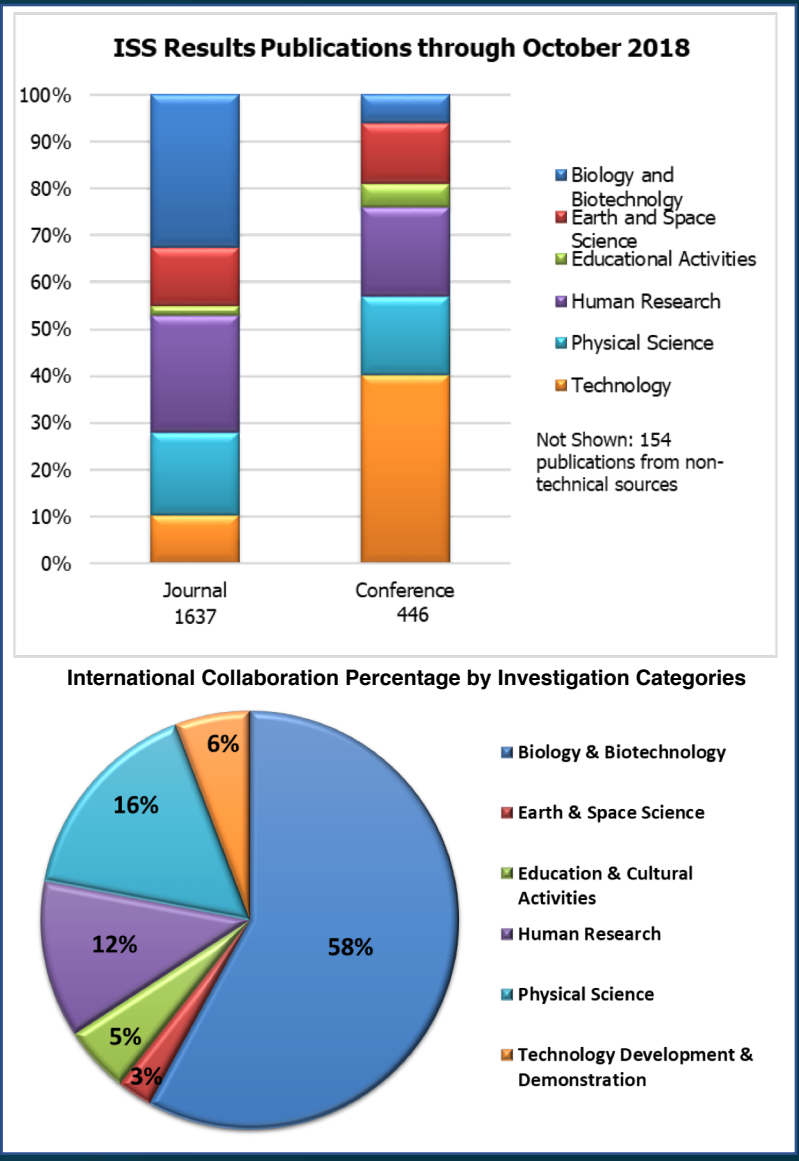
- Estimated Number of Investigations Expedition 0-58: 2808*
- Over 3612 Investigators represented (Exp 0 – present)
- Over 1700 scientific results publications (Exp 0 – present)
- 106 Countries/Areas with ISS Research and Educational Investigations (Exp 0 – present)



Working data as of Feb 28, 2019*
Pending Post Increment Adjustments

Global Involvement in Utilization (Inc 0-56)





Increments 59 & 60 Research Plan - Investigation List

Human Research

Bone & Muscle Physiology
EDOS-2
Muscle Biopsy (P)
Myotones
Medical Proteomics
Marrow
MVP Cell-01

Cardiovascular & Respiratory Systems
Cerebral Autoregulation
Vascular Aging
Vascular Echo
Airway Monitoring

Crew Health Care Systems
Acoustic Diagnostics

Habitability & Human Factors

Human Behavior & Performance
Behavioral Core Measures
Lighting Effects
Team Task Switching
Circadian Rhythms
Time Perception in Micro-g
At Home in Space

Immune System
IMMUNO-2
Functional Immune
Probiotics

Integrated Physiology & Nutrition
ASI NutrISS
Food Acceptability
Repository
Food Physiology↑ (hardware for Inc 61/62)

Nervous & Vestibular Systems
Neuromapping
GRASP
GRIP_GRASP
GRIP
Straight Ahead in Microgravity (P)
Vection

Vision
Fluid Shifts

Cross-Disciplinary/Other
Standard Measures
Cell Free Epigenome
Flow Cytometer

Prime: 464.25 hrs Reserve: 51.00 hrs

Facilities

Actiwatch Spectrum	Polar	Faraday Rsch Facility	NRCSD (Cygnus)	EML	EFU Adapter (E)
Cold Atom Lab	SAMS-II	Nanorack GoProFusion	Tangolab #11, #12	EPM	ExHAM #1 (Exp 4&5), #2 (E)
Hermes	Spectrum	Manufacturing Device	SlingShot	FSL/MultiScale Boiling	
HRF-1 & 2, Centrifuge	Ultrasound 2	MISSE-FF (E)	Bio-Analyzer (com)	IceCubes	J-SSOD #11, #12, R1
LSG	Veggie	Mocchi	Bio-Monitor	Kubik	Kobairo Rack
Mass Measure Device	ADSEP	MUSES (E)	Bartolomeo (E)	LSR (ACLS)	MSPR/ELF
MERLIN	BioCulture	NanoRacks Plt Rdr	ECHO maintenance	MSL	Ryutai
MELFI	Biofabrication	NanoRacks Platforms	EDR	CBEF-L	Saibo
Plant Habitat	Bone Densitometer	NREP (E)	EMCS	ELF	

Key: NASA/ASI | National Lab | CSA | ESA | JAXA | (P) Pre/Post Only | (E) External Payload | *CEF approval pending | ↑/↓ Launch Return Only

Increments 59 & 60 Research Plan - Investigation List

Biology & Biotechnology

Animal Biology – Invertebrates
CASIS PCG18
CASIS PCG19

Animal Biology – Vertebrates
JAXA Mouse Mission
Space Pup
Rodent Research-12
Rodent Research-14

Cellular Biology
Cell Science-02
Mobile SpaceLab
BioChip Spacelab
Kidney Cells
BioFabrication Facility
Nanoparticle Formulation
STaARS BioScience-3
Nano Antioxidants
CBEF-L

Macromolecular Crystal Growth
JAXA PCG #16
JAXA Low Temp PCG#6
JAXA Med Temp PCG #3, #5, #6
Perfect Crystals
CASIS PCG10
CASIS PCG15

Microbiology
BioNutrients
Micro 14
Micro 15
Biorock
ASI Amyloid Aggregation
MVP Cell-02
Veggie Monitoring

Macrobiology

Microencapsulation
STaARS BioScience-11

Plant Biology
BRIC-Light Emitting Diode (LED)
Veg-04B
MicroAlgae
Veggie PONDS validation
Space Moss

Prime: 637.0 hrs
Reserve: 72.0 hrs

Physical Science

Complex Fluids
PK-4
Soft Matter Dynamics
ACE-T-4, T-5, T-10, T-11
Ring Sheared Drop
NanoRack Module-73

Fluid Physics
SODI-DCMIX#4
FLUIDICS
Two-Phase Flow
Capillary Drvn MicroFluids
PBRE-2
Ring Sheared Drop
Droplet Formation Study

Fundamental Physics
DOSIS 3D
Cold Atom Lab

Materials Science
Advanced Nano Step
ELF Investigations
MSL Batch 2b
EML Batch-2
Hermes Cassette-1
NanoRack Module79
ORFOM-II
Space Fibers

Prime: 139.0 hrs
Reserve: 34.0 hrs

Earth & Space Science

Astrophysics
ISS-CREAM (E)
NICER (E)
AMS-02 (E)
CALET (E)
MAXI (E)

Earth Remote Sensing
ECOSTRESS (E)
OCO-3 (E)
SAGE III-ISS (E)
TSIS (E)
ASIM (E)
MUSES (E)
NREP inserts

Near-Earth Space Environment
SEDA-AP (E)

Other
GEDI (E)

Prime: 1.0 hrs
Reserve: 0.0 hrs

Key: NASA/ASI | National Lab | CSA | ESA | JAXA | (P) Pre/Post Only | (E) External Payload | *CEF approval pending | ↑/↓ Launch Return Only

Increments 59 & 60 Research Plan - Investigation List

Technology Development & Demonstration

Air, Water and Surface Monitoring
Spacecraft Atmosphere Monitor
Mini CO2 Scrubber

Avionics & Software
Telescience Resource Kit
AMO Express 2.5
SPHERES ReSwarm Test
Faraday-BlockChain-1

Characterizing Experiment Hardware
ECHO
STPSat-4
Mochii
SoundSee Mission
Furphy
MVIS-1 Controller

Commercial Demonstrations
SOLISS (IP agreement)
Made in Space Fiber Optics
Mobile Companion

Communication & Navigation
Vessel ID (unattended)

Food and Clothing Systems
Nanorack Module 81

Imaging Technology
HDEV (E)
HDTV_EF

Life Support Systems & Habitation
Thermal Amine System
Water Capture Device
Nanoracks Module 73
UWMS (port flush)
Photobioreactor
JEM Water Recovery System

Microbial Populations in Spacecraft
MATISS-2

Radiation Measurements & Shielding
Radi-N2
RadMap Telescope
AstroRad vest
HELIOS
Fiber Dosimeter

Repair & Fabrication Technologies
T2 Treadmill Augmented Reality Pr.

Robotics
Astrobee/Astrobatics

Refrigerator
Cyro Chiller
Glovebox Freezer

Spacecraft & Orbital Environments
STP-H6 (E- ELC3)
STP H5 (E)

Spacecraft Materials
MISSE-11
STP-H5 (E- ELC1)

Thermal Management Systems

Fluid Dynamics

Other
SERFE (EVA system)

Small Satellites and Control Tech
RED-EYE
Gecko-Inspired Adhesive Grasping
NRCSD#16

Prime: 244.0 hrs Reserve: 17.0 hrs

Educational & Cultural Activities

Educational Competitions
CASIS PCG14
SPHERES-Zero-Robotics
Genes in Space 6
Faraday-SBS-1
CSA Communications and Outreach
Canadarm2 Model Workshop

Educational Demonstrations
ISS Ham Radio (ARISS)
Sally Ride EarthKam
Story Time from Space
Story Time from Space-6
AstroPi
Tomatosphere 6

Commercial Demonstration
Kakuda Space Rice
The ISS Experience
NG CMG Demonstration
JAXA Commercial

Other
ESA EPO

Prime: 179.0 hrs
Reserve: 60.0 hrs

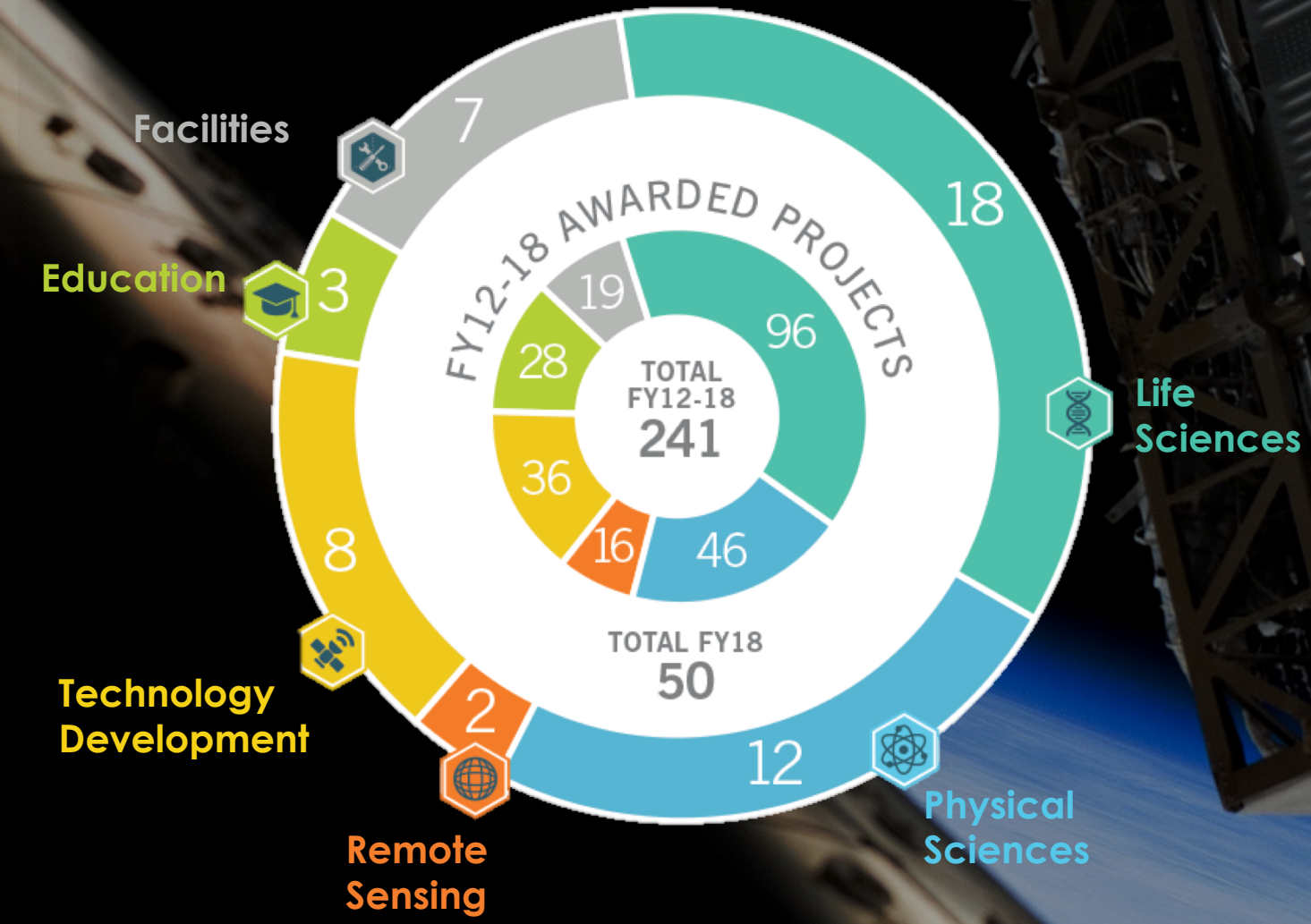
Key: NASA/ASI | National Lab | CSA | ESA | JAXA | (P) Pre/Post Only | (E) External Payload | *CEF approval pending | ↑/↓ Launch Return Only

ISS National Lab Highlights

A Diversified R&D Portfolio

Examples of newly selected projects in FY18:

- IBM: Artificial intelligence
- Lockheed Martin: Radiation monitoring
- MIT: Satellite technology
- Colgate-Palmolive: Oral microbiome
- Princeton: Solar energy
- Sanofi Pasteur: Vaccine development
- National Cancer Institute: Drug discovery

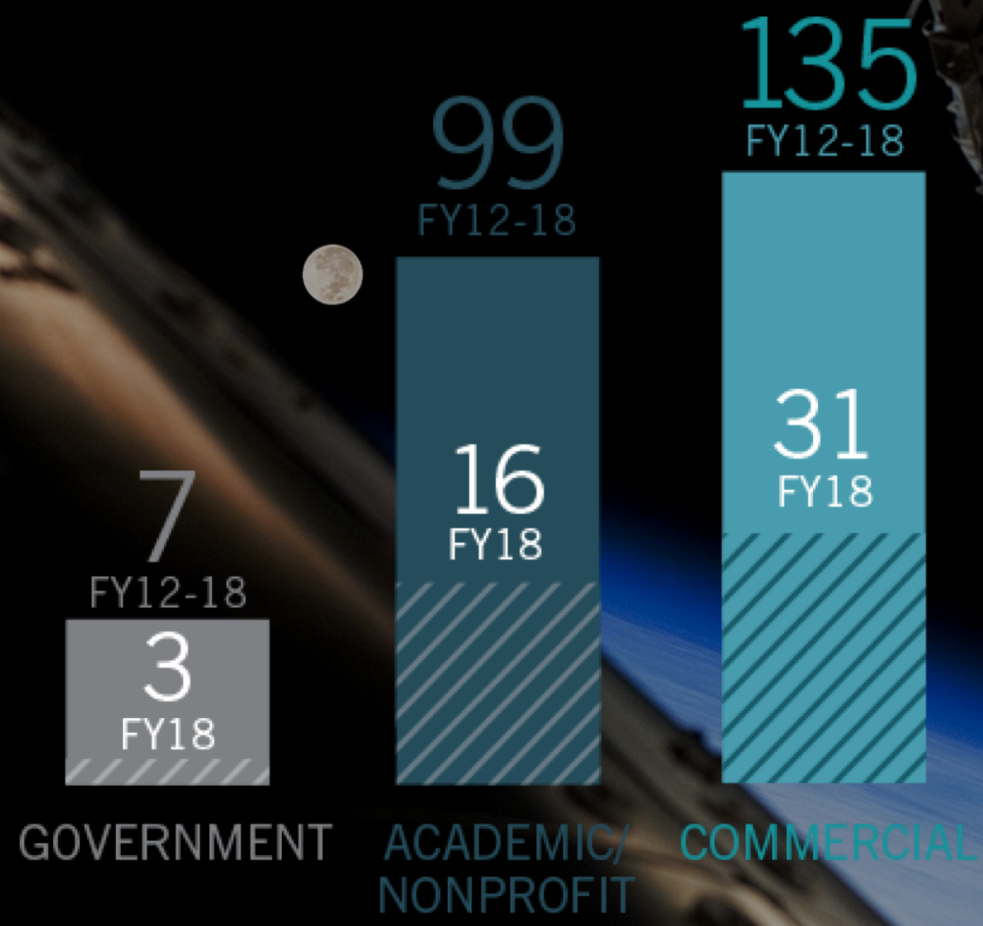


ISS U.S. NATIONAL LABORATORY

NASA

Demonstrated Demand

- 62% of newly selected projects in FY18 represent commercial users
- 70% of FY18 payloads flown had significant private-sector involvement
- 24 new-to-space customers in FY18



ISS
U.S. NATIONAL LABORATORY

NASA

ECONOMIC INNOVATION SOCIAL

ISS NATIONAL LAB
DIMENSIONS OF IMPACT

FY18 Research Success

17 publications, bringing the total to 127

2 patents granted to P&G, related to product formulation and stability

1 patent granted to FOMS, related to ZBLAN production on the ISS

Apple product released: 4k imagery of Earth will reach millions of Apple TV users

THE SPACE ECONOMY

SUPPLY CHAIN ECONOMICS (2013-2018)

106
ACADEMIC, NONPROFIT, & OGA CUSTOMERS
MIT, MJFF, ORNL, Emory, etc.

135
INDUSTRY CUSTOMERS
Apple, Delta, Goodyear, Target, Merck, etc.

INDUSTRY ASSOCIATES
Airbus, Bigelow, Sierra Nevada, etc.

45
IMPLEMENTATION PARTNERS
Teledyne, NanoRacks, Space Tango, MIS, etc.

INDUSTRY FUNDING PARTNERS
Boeing, Apple, Target, etc.

118
MEMBER INVESTOR NETWORK

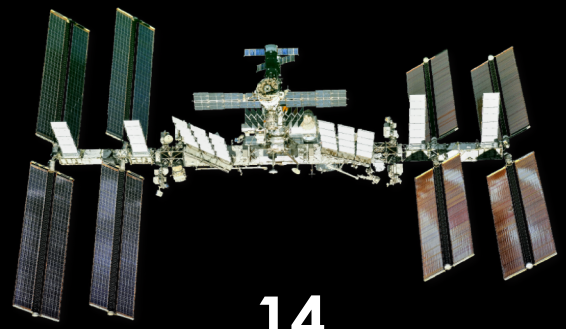
GOV'T FUNDING PARTNERS
NIH, NSF, NASA, MLSC, DoD, etc.

275
PAYLOADS

$225M

$75M
NASA

$150M
EXTERNAL FUNDING



14
COMMERCIAL LAB FACILITIES

ISS U.S. NATIONAL LABORATORY

NASA

External Investment

- From 2013 to 2018, $150M+ in third-party, non-NASA funding had been committed to support individual research projects on the ISS National Lab
- This is double the ISS National Lab government funding of $75M and originates from:
  - Government funding partners (*e.g., NIH, NSF, DoD*)
  - Industry funding partners (*e.g., Target Corp., Boeing*)
  - Investor network activity (*118 members*)
  - Customer contributions (*50%+ of FY18 projects required no ISS National Lab funding*)

ISS Operational Status

Increment 57/58 (October ‘18-March ‘19) Crew Time by Sponsor

Enablers

- Crew performance contributions in executing and completing the research plan

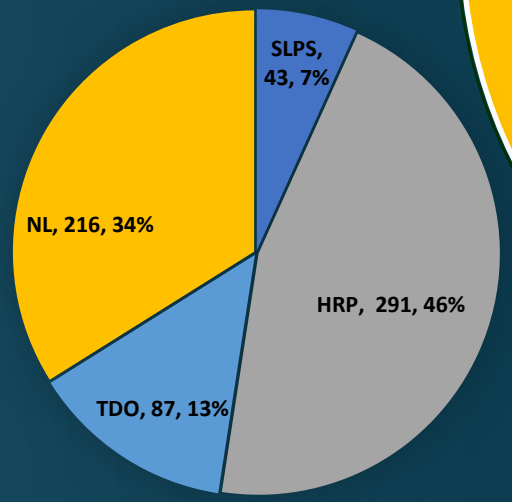
Challenges

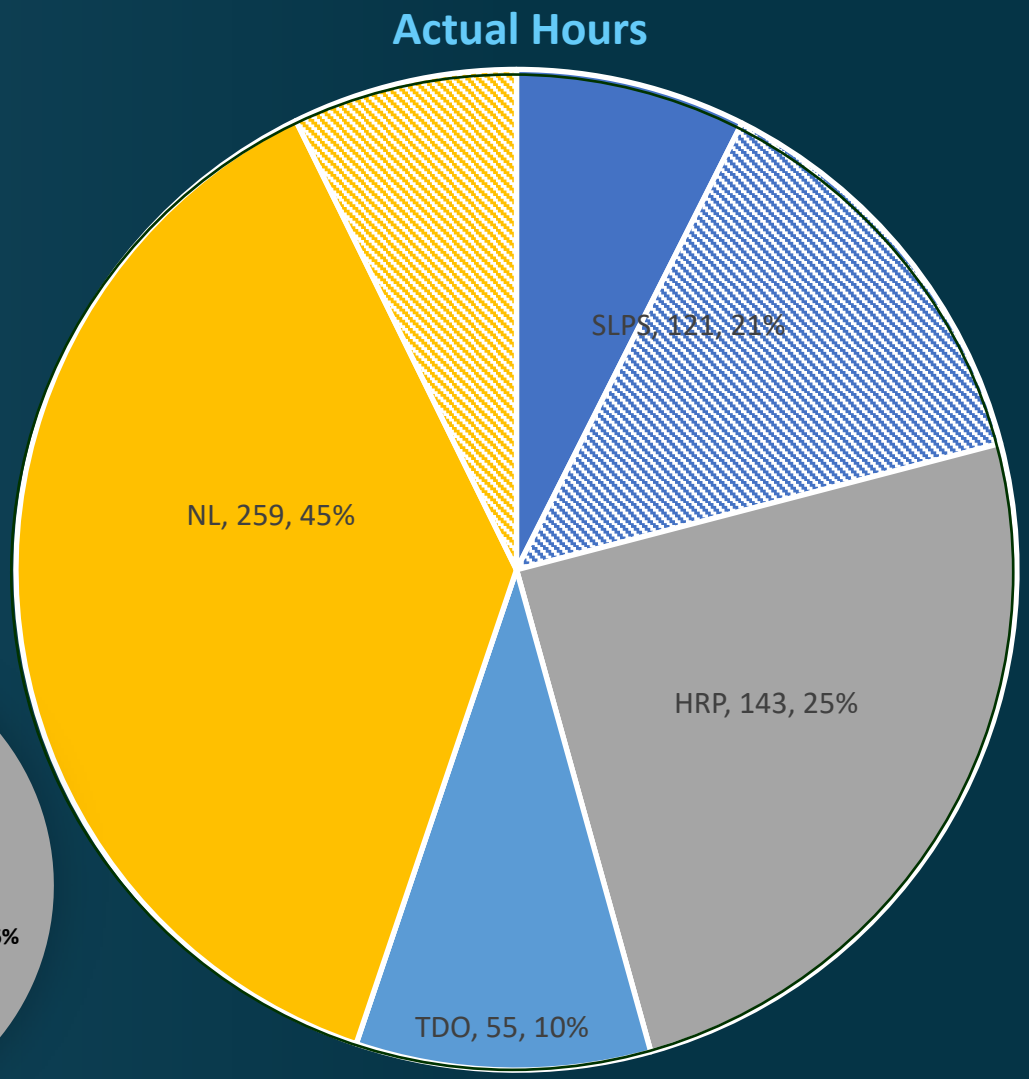
- Reduced crew due to 56S anomaly
- Rescheduling the Increment with 2 vs. 3 crew

Delta Explanations

- When comparing Actual to Planned, Research hours and Crew delays reduced due to 56S related crew reduction

October ’18- March‘19	Planned	Actual
Research Hours	640	578
Total Crew Days (USOS)	394	120
Cargo Flights	HTV 7 NG-10 SpX16	HTV 7 NG-10 SpX16
# EVAs	2	0
Russian Crew hours	40	37.8





*Hatched wedges indicate increase from plan

Upcoming EVA Overview

- USOS EVAs:
  - Increment 60 – summer 2019
    - International Docking Adapter (IDA) 3 Install (1 EVA)
      - IDA to be delivered on SpX-18
      - Crew - TBD
  - Increment 61 – Fall 2019
    - P6 Battery Remove & Replace EVAs – (~4-6 EVAs)
      - Batteries delivered on HTV-8
      - Crew - TBD
- RS EVAs:
  - Increment 59/Stage 59-6
    - RS EVA #46 – Multiple tasks
      - May 29, 2019 planned date
      - Crew – A. Ovchinin & O. Kononenko

Increment 59 Overview: EVA Summary

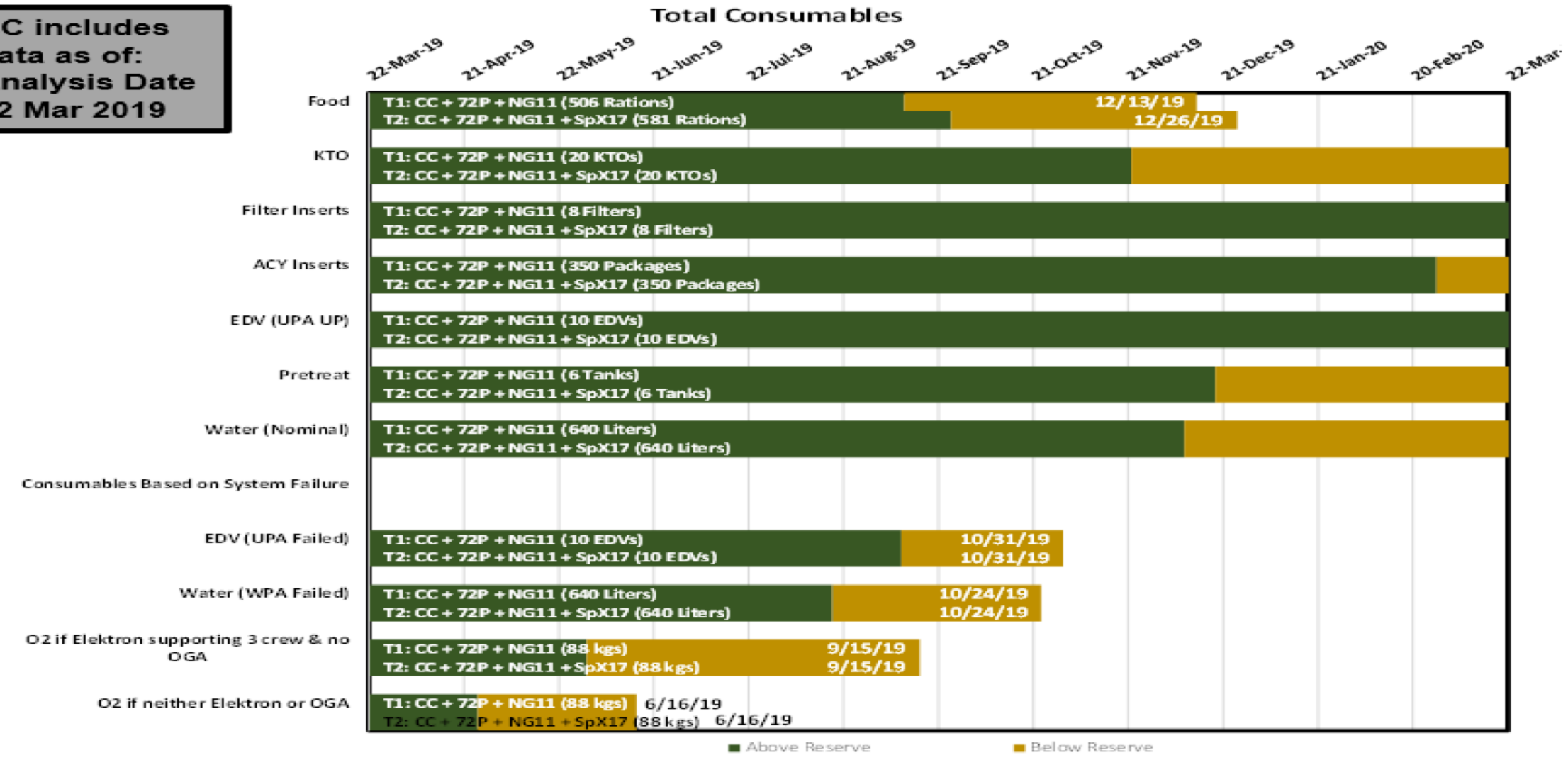
US EVA 54 (04/08/19)

NASA astronauts Anne McClain and David Saint-Jacques completed the third spacewalk in under a month on the exterior of the International Space Station. This spacewalk established a redundant path of power to the Canadian-built robotic arm, known as Canadarm2, and install cables to provide for more expansive wireless communications coverage outside the orbital complex, as well as for enhanced hardwired computer network capability.

This spacewalk marked the 216th spacewalk in support of ISS assembly and maintenance. The team spent about six-and-a-half hours installing truss jumpers to provide a redundant power source for the Canadarm2 robotic arm. They also completed a reconfiguration of a battery from U.S. EVA 52/53

Total Consumables

CC includes data as of: Analysis Date 22 Mar 2019



SpaceX Demo-1 Mission Success!

- Launch 3/2/18; docking 3/3/19; undock/splashdown on 3/8/19
- Upmass – 204 kg; Return - 154 kg
- Crew – None (uncrewed test flight)
- Pressurized Cargo – cargo bags and lockers

Demo-1 Undock

Demo-1 splashdown

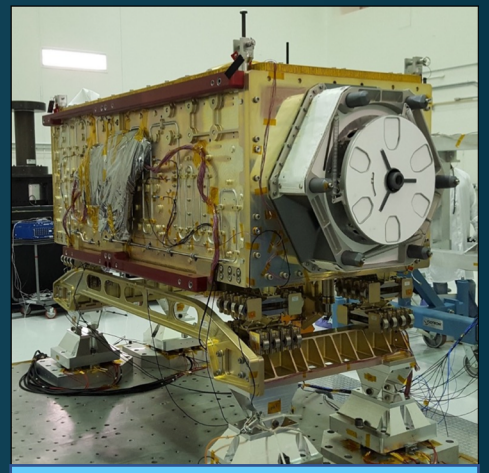
NG CRS-11 Mission Status

- Launched successfully on 4/17/2019
  - Berthed 4/19/2019; Release planned for 7/23/19
- Upmass – 3,334 kg manifested; Disposal - 3500 kg estimated
- Pressurized Cargo
  - Ascent: 2 AEM-T units, 1 AEM-E unit, and 1 POLAR
  - First flight items: rodent capability, L-24 hour final cargo load, and scrub turnaround capability (48 hours)
- Unpressurized Cargo
  - Operations post ISS departure: Nanoracks External CubeSat Deployer, Seeker Payload (mass part of Nanoracks), CMG Experiment

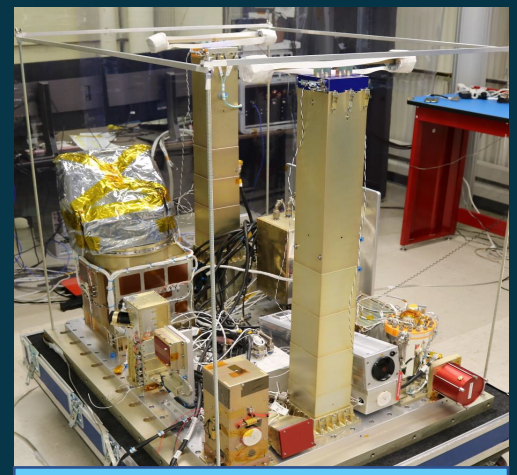
NG Antares Team Demonstrates New Capability to Load Cargo Just Before Launch

SpaceX CRS-17 Mission Status

- Launched successfully on 5/4/2019
  - Berthed 5/6/2019; Release tentatively planned for 6/3/2019.
- Upmass – ~2,442 kg manifested; Return/disposal – ~2,500 kg estimated
- Pressurized Cargo
  - Ascent: 1 Polar, 1 MERLIN, 1 JAXA MHU, 1 Kidney Cells, 1 PAUL
  - Return: 5 Polar, 1 JAXA MHU
- Unpressurized Cargo
  - Orbiting Carbon Observatory-3 (OCO-3)
  - Space Test Program-Houston6 (STP-H6)
  - Disposal: Cloud-Aerosol Transport System (CATS) & Space Communications and Navigation (SCaN)



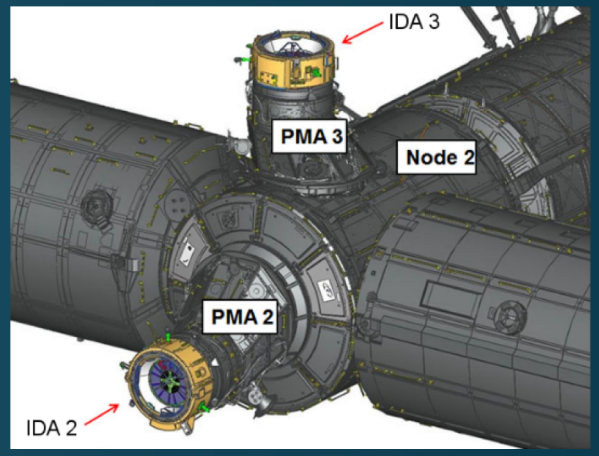
OCO-3

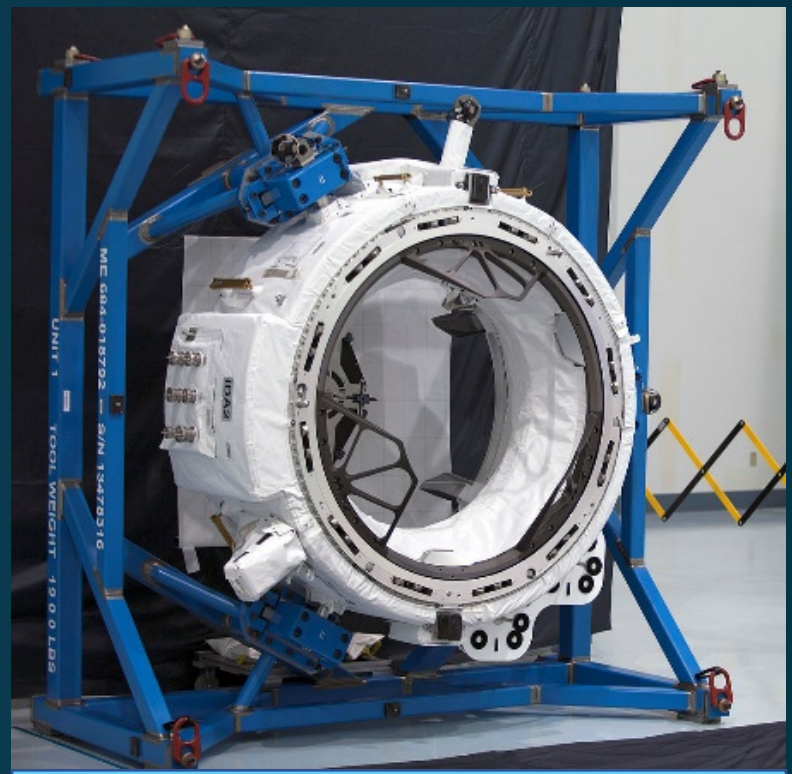


STP-H6

SpaceX CRS-18 Mission Status

- Mission Planning
  - Launch tentatively planned for July 2019.
- Upmass – 3,310 kg estimated; Return/disposal – 2,500 kg estimated
- Pressurized Cargo
  - Ascent: 2 Polar, 2 AEM-T, Bioculture
  - Return: 4 Polar, 1 AEM-T, 1 MERLIN
- Unpressurized Cargo
  - International Docking Adaptor (IDA)-3





IDA-2 upright

ISS Transition and LEO Commercialization

LEO Commercialization Studies

LEO Commercialization Studies

- 12 companies completed 4-month-long studies on the commercialization of LEO and ISS
- Variety of independent market consulting firms, transportation and habitat suppliers, and market demand service providers
- Study objectives included:
- Commercialization concepts and technical configurations for commercial habitable platforms in LEO (using ISS or free-flying) - “Destinations”
- Business plans that explore the viability of commercial destinations
- Role of government and evolution of ISS in the roadmap to commercialization of LEO
- “Destination” concepts included:
- Spent upper stages converted into habitable volumes
- Inflatable modules
- New modules, traditionally-built but modernized
- Re-use of ISS components
- Use of Gateway program ‘copi

Companies that Performed Studies

How do Commercial "Destinations" Make Money?

- "Accommodations" – sleep stations, toilet, galley, etc. for tourists or foreign/US governments
- Research & Development – use of facilities or space and power/utilities for customer facilities, and possibly commercial crewmember time to conduct experiments
- In-space manufacturing of unique materials or products – use of facilities or space and power/utilities
    - Items made in space and then sold on the ground: For example, fiber optics
    - Items made in space for on-orbit use: For example, parts for maintaining or assembling spacecraft
- Entertainment – films, documentaries, sporting events
- Sponsorship and Advertising
- Transportation of people and cargo to/from Low Earth Orbit
- Large Structure and Satellite Assembly

Some Observations from the Studies

- Commercial market predictions vary, making forecast difficult
  - The markets are emerging – some might ‘take off’ and some might fail
  - Competition for revenue includes terrestrial, parabolic/sub-orbital flights, and other space stations (commercial or non-U.S.)
- Early on, NASA’s use of and payment to destinations will be a key enabler for the emerging commercial market
  - NASA was often considered the “anchor tenant” of the commercial destinations in the studies
  - Studies generally assumed some number of NASA crew in Low Earth Orbit at all times, and NASA would pay ‘rent’ to a landlord Destination to accommodate them
  - Because NASA has a need for microgravity research and exploration testing in Low Earth Orbit in the future, many studies assumed their destinations housed U.S. government research

Some Observations from the Studies

- High crew and cargo transportation costs to/from LEO negatively affect both station costs and commercial market demand
  - Transportation costs make up a very large portion of the cost of a space station over time – on the order of 2/3 of annual costs are spent on crew and cargo missions
  - A reduction in the seat cost to transport tourists to orbit from 10's of millions of dollars down to a few million dollars could significantly increase the number of potential tourists that can afford a trip
  - The cost is very high to transport raw materials into space, convert them into something else (such as fiber optics) and return them to the ground – so the end product must sell at a very high price
- Continuing ISS use over the next few years supports commercial industry growth
  - Businesses want to use ISS directly, for example by attaching a commercial module to an ISS port, or if free-flying, they prefer to be co-located in orbit near ISS

Demand Stimulation

Stimulate Sustainable Demand

- ISS National Lab accommodating many industry R&D projects
  - Promising projects will transition from ISS NL post-R&D to enter production
- In Space Manufacturing Projects underway (funded by ISS to date):
  - Exotic Optical Fibers (3 projects) - 2 on NG-11
    - 1 on SpX-16
  - Bioprinting - on SpX-17
  - Industrial Crystallization - NET SpX-20
  - Super Alloy Casting - NET NG-12
  - Ceramic Stereolithography - NET SpX-19
- New ISS Utilization NRA Focus Areas now open for new projects leading to scalable, sustainable demand
  - In-space manufacturing, regenerative medicine/bioengineering, other concepts
  - Commercial concepts to create “space lab” research capabilities that mirror ground lab capabilities
- Intent is to continue building a pipeline of projects through ISS life, migrate successful projects to commercial lab(s) in LEO

Stimulate Sustainable Demand (cont.)

- Seeking targeted studies to better understand real and perceived barriers of potential new market entrants, and to address broad ideas which could help stimulate demand (e.g. reducing launch cost, etc.)
- Seeking to expand feeder pipeline of potential new entrants into use of LEO environment
  - Planning to coordinate across microgravity access community to strengthen integration, simplify user access, and reduce real and perceived barriers to entry
    - Drop Towers
    - Parabolic and Suborbital Flights (e.g. Flight Opportunities Program)
    - ISS (e.g. SLPSRA and ISS National Lab)
  - Coordinate outreach with consistent messaging to magnify and expand awareness of potential benefits of microgravity research in industrial and academic research communities
- New ISS commercial use policy
  - Industry enabled to pursue new and emerging markets
  - ISS access will facilitate validation and enable growth of new and emerging markets

Commercial LEO Development Framework

Current/Near-Term

Objectives

- Support NASA's R&D needs and ISS National Laboratory needs
- Leverage ISS capabilities to stimulate demand and catalyze new markets

Activities

- Document and share with industry NASA's comprehensive approach to Commercial LEO Development:

1) Establish ISS commercial use and pricing policy
2) Enable private astronaut missions to ISS
3) Initiate process for commercial development of LEO destinations
4) Seek out and pursue opportunities to stimulate demand
5) Quantify NASA's long-term needs for activities in LEO

Mid-Term

Objectives

- Support NASA's R&D needs and ISS National Laboratory needs
- Initiate phased transition from ISS to Commercial with attached (initially) and/or free flyers
- Stimulate demand and catalyze new markets

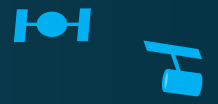
Activities

- Partner with industry to develop and demonstrate new LEO destinations
- Initiate phased transition to acquire needed services from commercial destinations rather than ISS
- Avoid competition from ISS
- Seek out and pursue opportunities to stimulate demand
- Initiate transition of ISS assets

Long-Term

Objectives

- Turn over LEO operations to the private sector
- Purchase NASA's needed R&D Services from commercial provider at lower cost than ISS
- Shift NASA focus and resources towards exploration



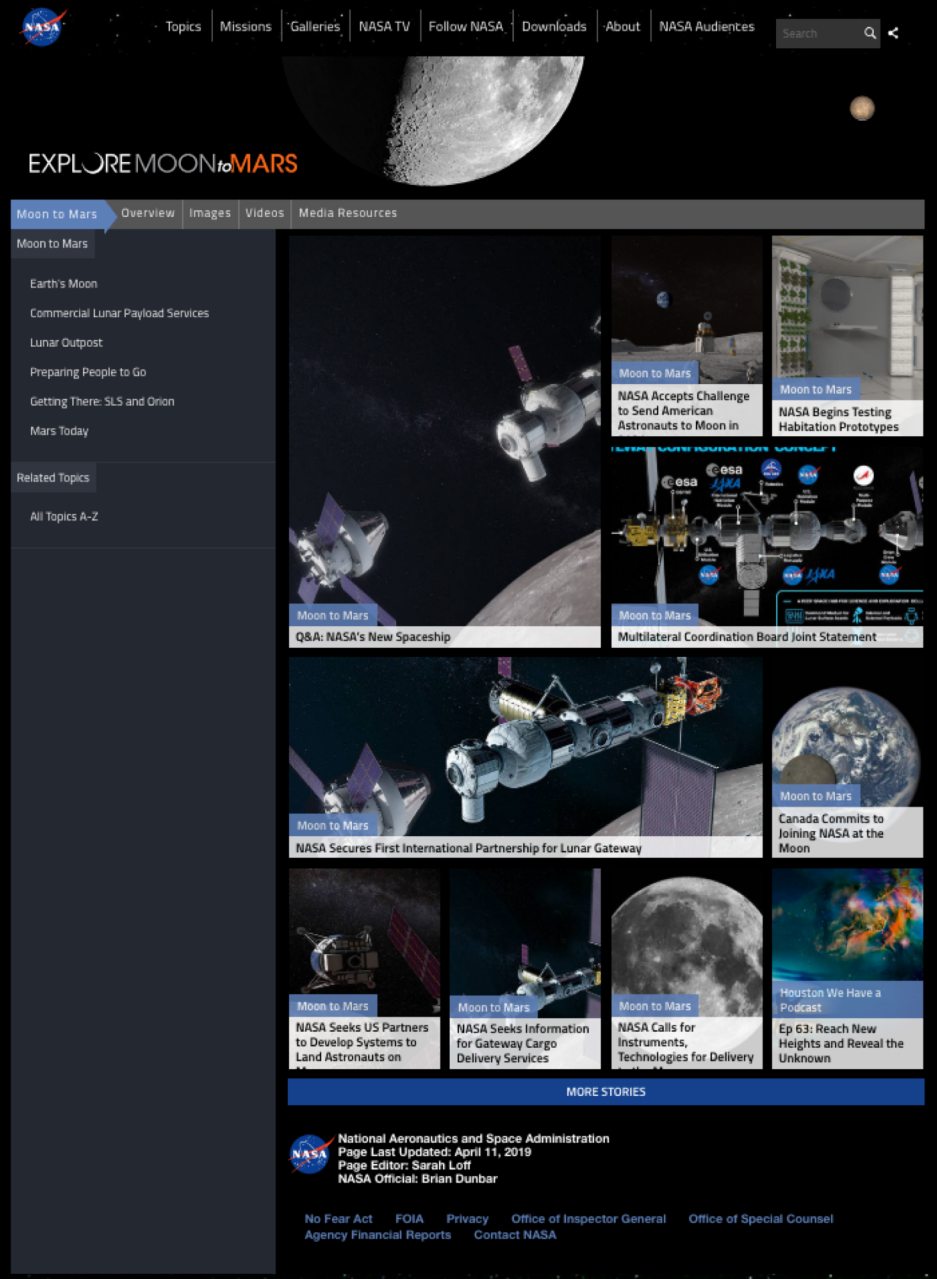
Activities

- Complete transition of ISS assets at end of life
- Conduct NASA's needed R&D on commercial destinations in LEO
- Purchase 'LEO National Lab' services from commercial provider?

National Aeronautics and
Space Administration

NASA EXPLORES

with the INTERNATIONAL SPACE STATION



Stay Connected Between Committee Meetings

- Space Station Updates Blog
- Space Station Research & Technology
- Here's Looking at You! Astrobee's First Robot Completes Initial Hardware Checks in Space (May 2019)
- A Look at the Science Ahead for Christina Koch and Andrew Morgan (April 2019)
- NASA Calls for Proposals to Stimulate Sustainable Demand for Low-Earth Orbit Services (April 2019)

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