Overview of ISS Utilization and Technology Development

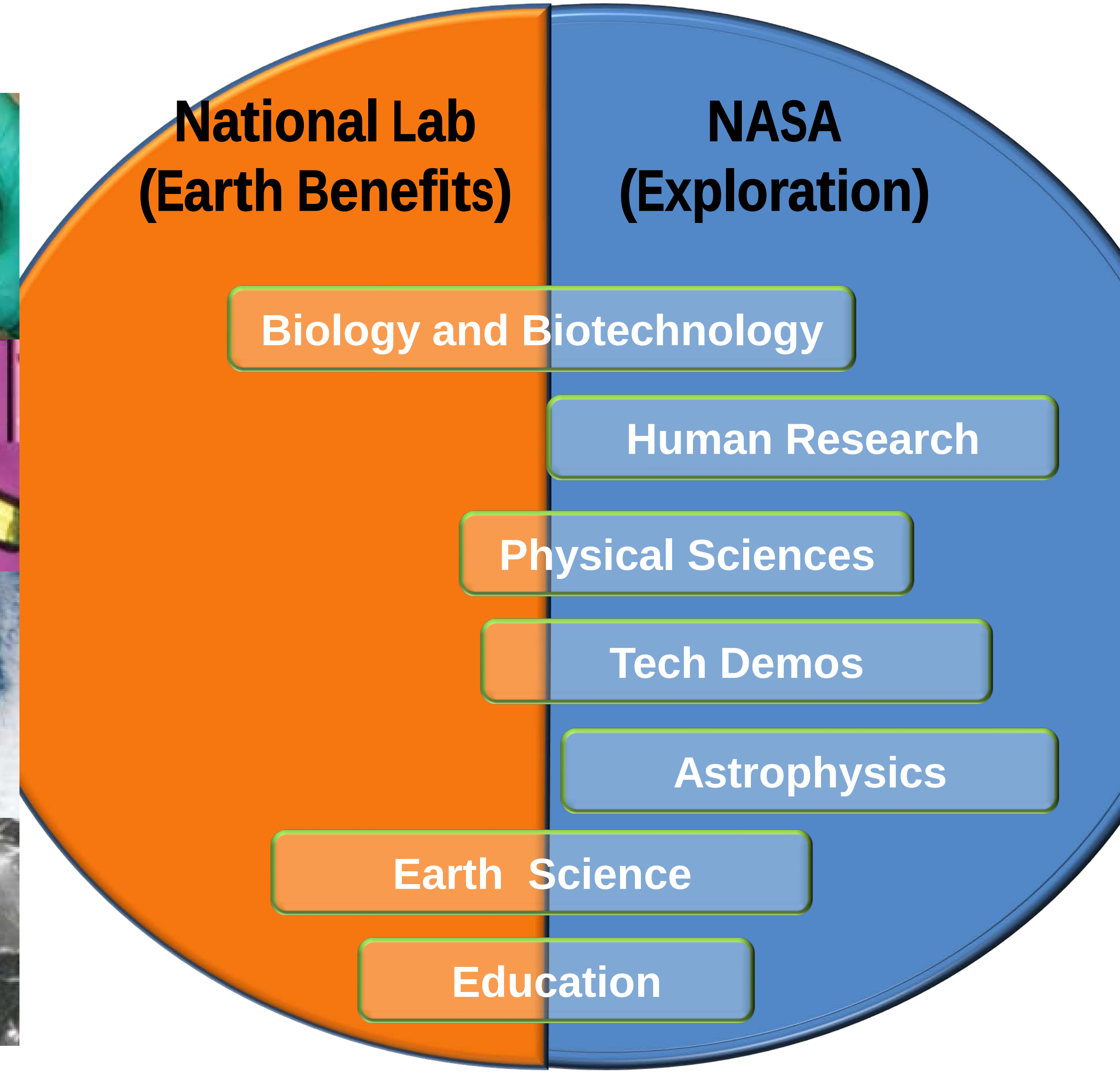
Aerospace & Space Engineering Board
NRC Beckman Center, Irvine, CA

Julie A. Robinson, Ph.D.,
ISS Program Scientist, NASA
julie.a.robinson@nasa.gov
9 November 2012

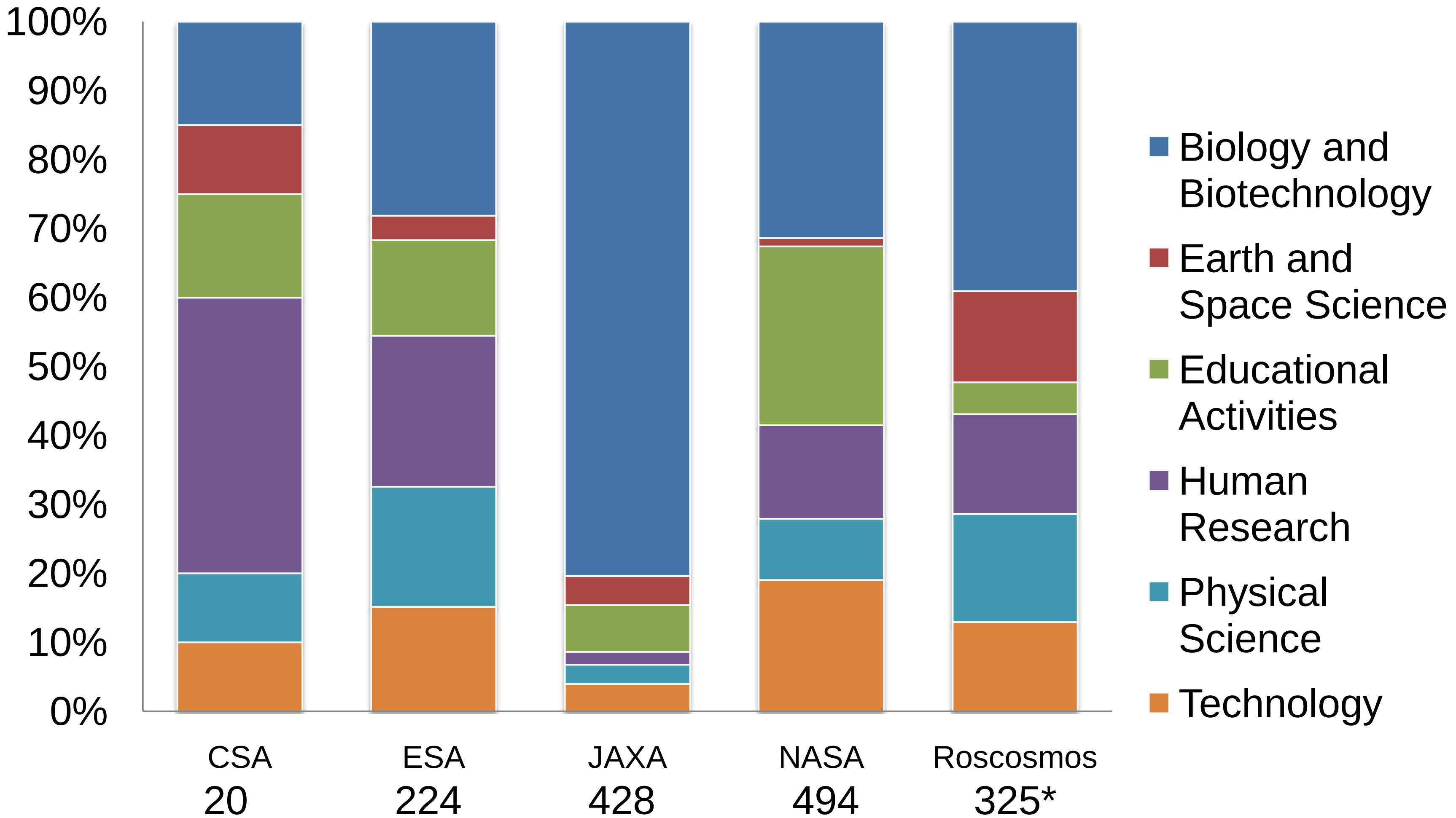
Presentation Overview

- What are we doing on ISS today?
  - Disciplines
  - Record throughput
  - Growth of ISS National Lab/CASIS-sponsored research
- What are the facilities and capabilities for technology demonstration
  - Internal accomodations
  - External accomodations
- What is the current state of planned and proposed technology demonstrations on ISS

What are we doing on ISS today?

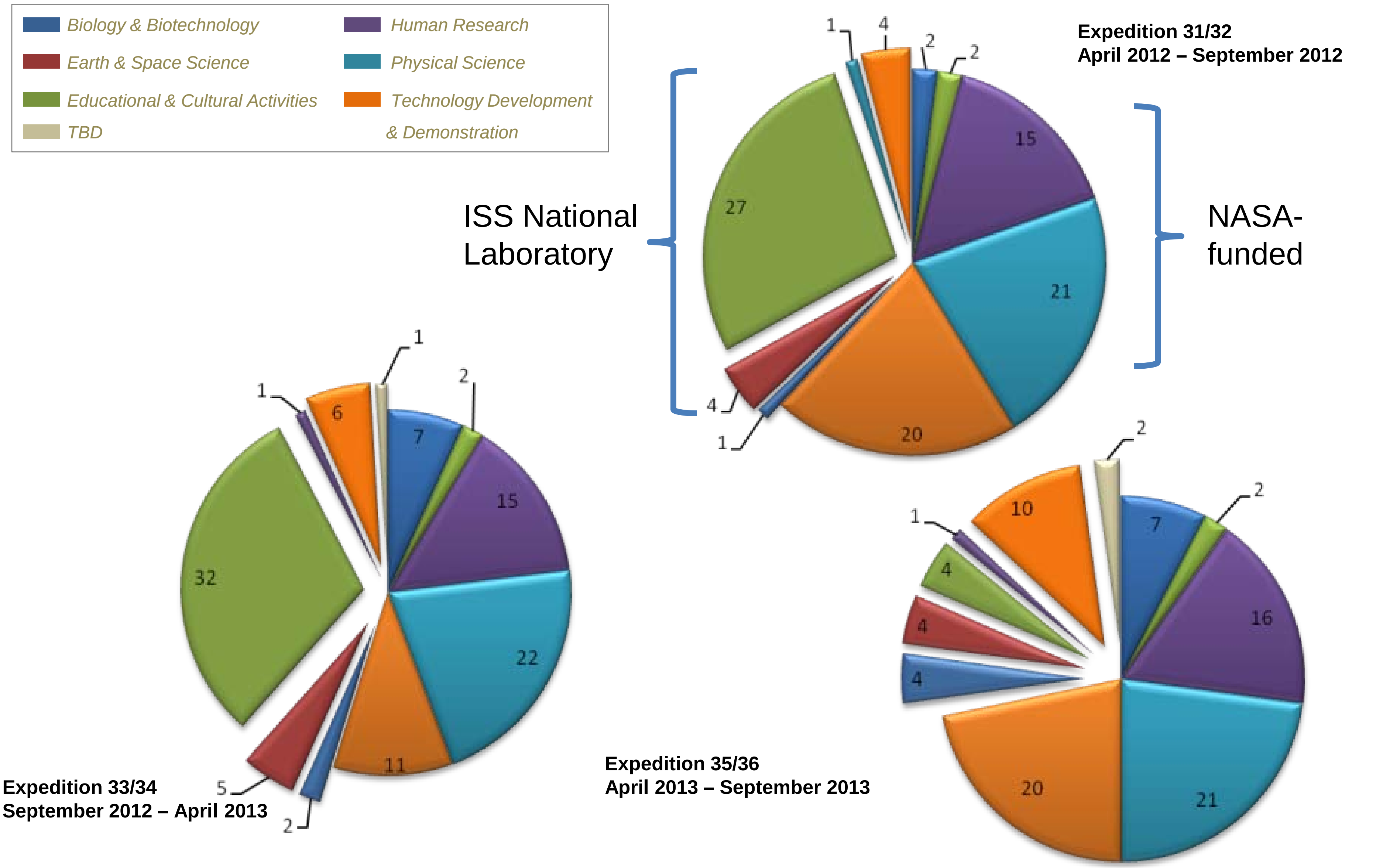


ISS Utilization Number of Investigations (Expeditions 0-30)



*** Estimated**
† Draft

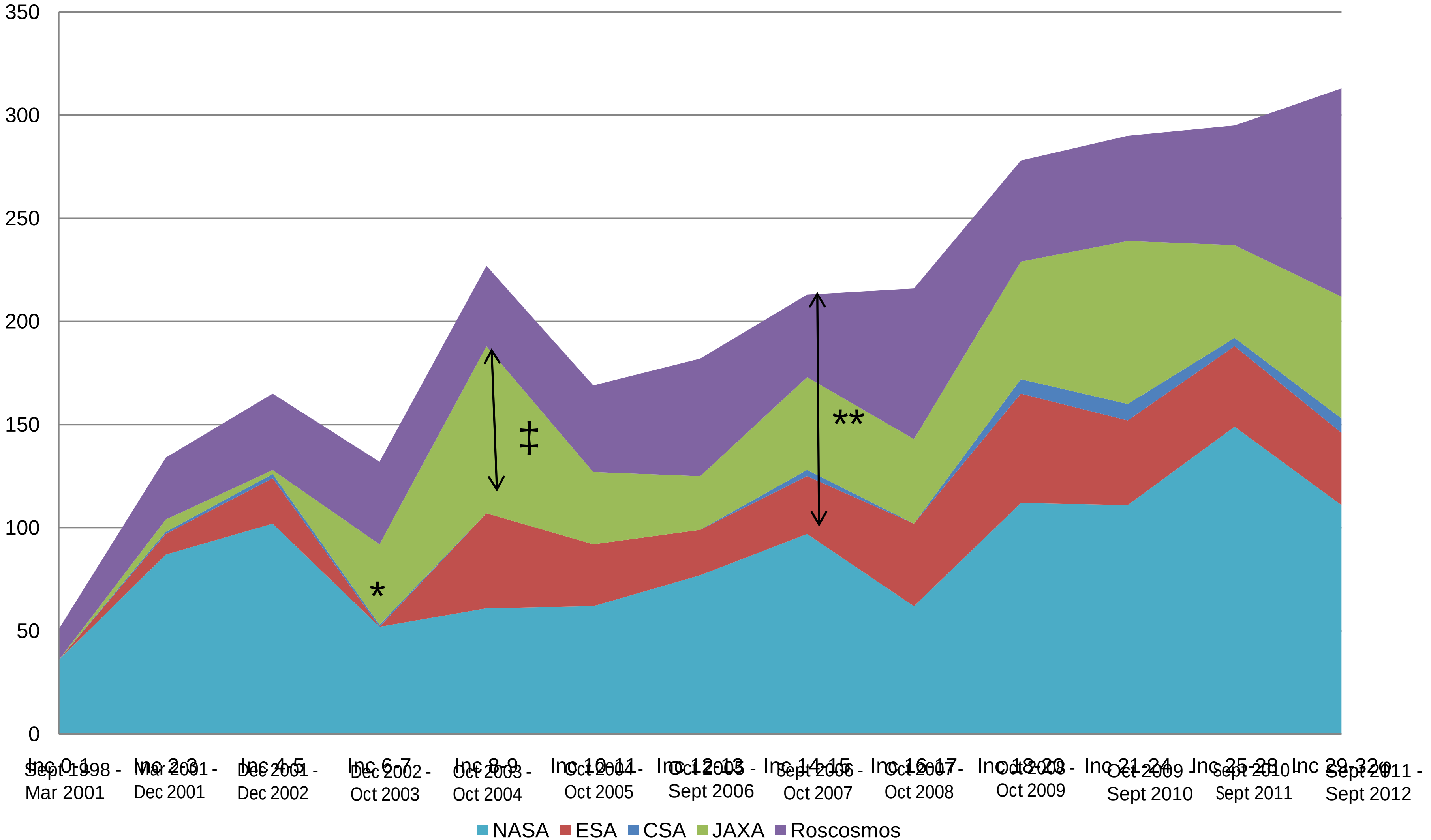
ISS National Laboratory as a portion of the US research portfolio



Growth of ISS National Lab

- From 2005-2012 “National Lab Pathfinders”
  - By 2011, Approximately 25% of ISS investigations were National Lab Pathfinders
- 2011-2013 Transition to CASIS management
  - First research solicitations open now
  - First CASIS-selected experiments will fly in Expeditions 37/38 (about 1 year from now)
  - Some pathfinders will end, some will transition to CASIS management

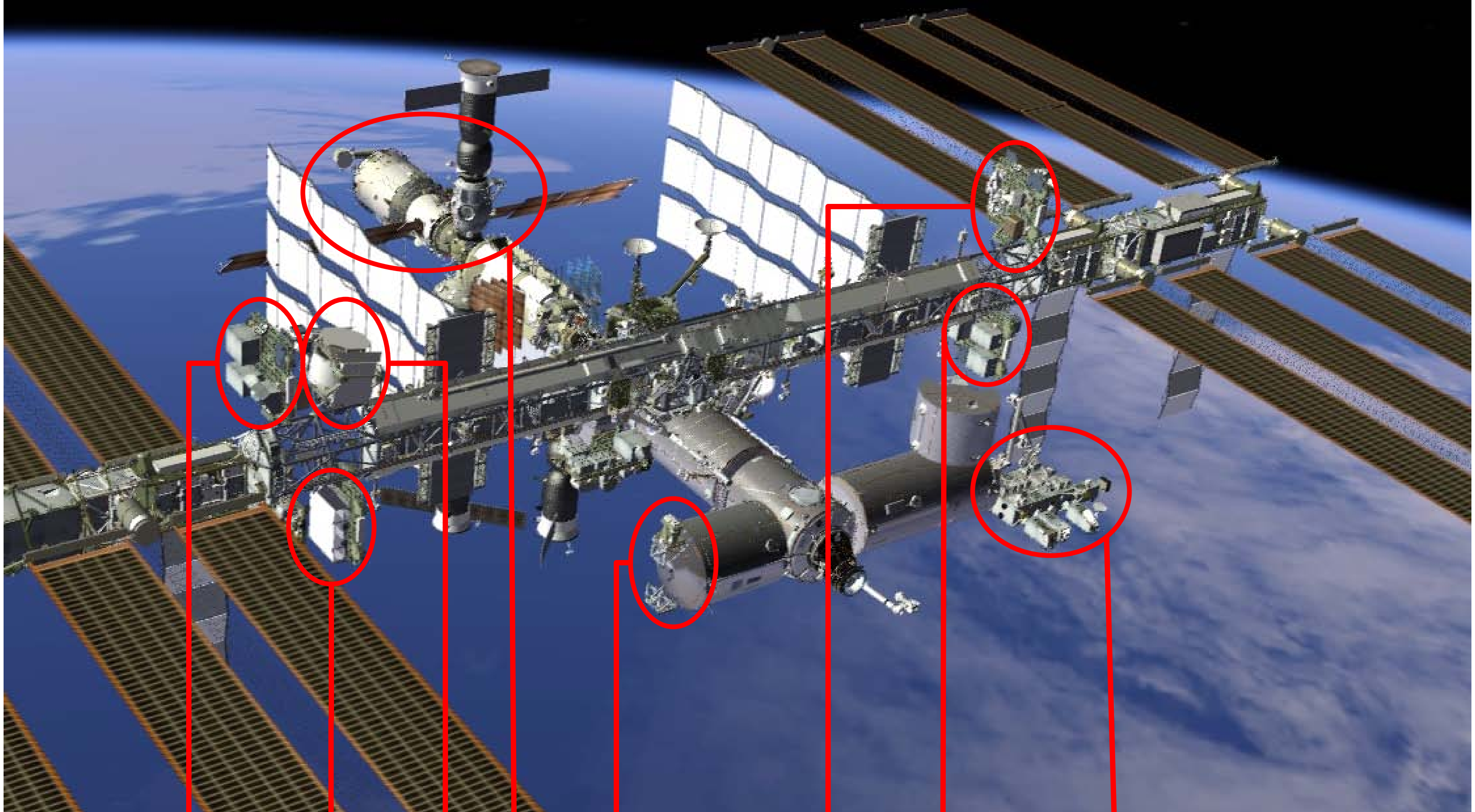
Research and Technology Investigations
December 1998 - September 2012



* Post- Columbia ‡ Japanese investigation surge in protein crystal growth ** Shuttle Return to Flight φ Estimated Numbers

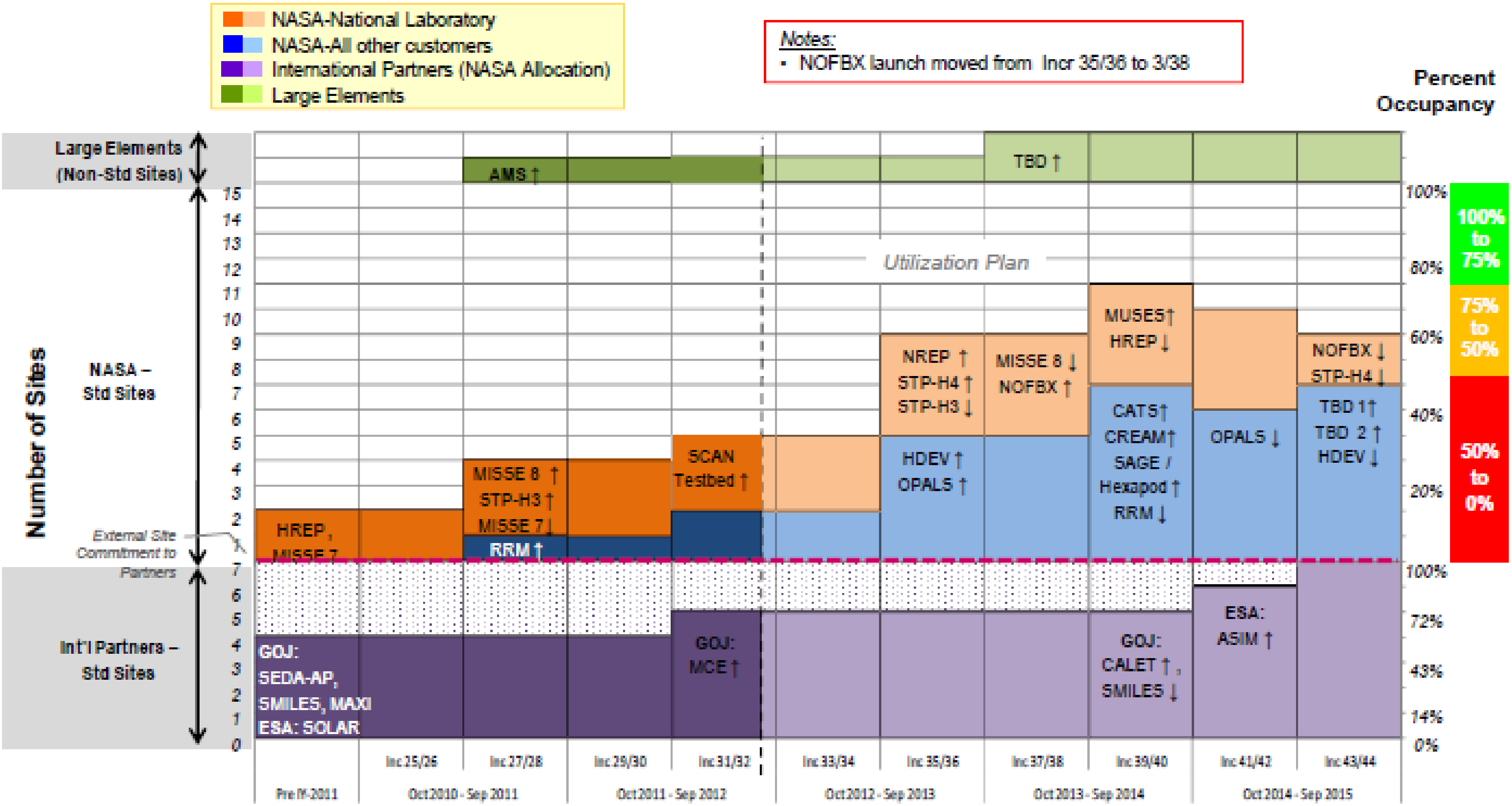
External Facilities

Overview of External Payload Attachment Sites



External Instrument Sites

All good Earth- and nadir-viewing sites full by 2016



Multi-Increment Payload Resupply and Outfitting Model (MiPROM)
Working Version 10/09/2012
NOTE: This is a strategic plan and subject to change.

Indicates site available during 2015 per current plans

last update 10/09/2012		Increment-Year		2015	
				2015-1	***2015-2***
		Period Start (Calendar Date)		Oct-14	Apr-15
Carrier	Location	Site Number	Viewing		
ELC 1	P3 Lower	3	Outboard / Ram / Nadir		
		8	Inboard / Wake / Nadir		
ELC 4[1]	S3 Lower Inboard	2	Inboard / Wake / Nadir	MUSES	MUSES
		3	Inboard / Ram / Nadir	SAGE III/Hexapod (w/NVP)	SAGE III/Hexapod (w/NVP)
ELC 2	S3 Upper Outboard	3	Inboard / Ram / Zenith		
		7	Outboard / Ram / Zenith		
ELC 3	P3 Upper	3	Inboard / Ram / Zenith	SCAN Testbed	SCAN Testbed[2] ê
		5	Outboard / Wake / Zenith		
Columbus	EPF SOZ		Overhead / Zenith	SOLAR	SOLAR
	EPF SOX		Overhead / Ram		
	EPF SDX		Deck / Ram	RapidScat	RapidScat ê - - - - - - - - ASIM é
	EPF SDN		Deck / Nadir	HDEV	HDEV ê

Multi-Increment Payload Resupply and Outfitting Model (MiPROM)
Working Version 10/09/2012
NOTE: This is a strategic plan and subject to change.

Indicates site available during 2015 per current plans

last update 10/09/2012		Increment-Year		2015	
				2015-1	***2015-2***
		Period Start (Calendar Date)		Oct-14	Apr-15
Carrier	Location	Site Number	Viewing		
JEM-EF	1		Ram, Nadir	MAXI	MAXI
	3		Ram, Nadir	CATS	CATS
	5		Ram, Nadir		
	7		Ram, Nadir	*ICS*	
	9		Port, Zenith, Nadir	CALET	CALET
	2		Wake, Nadir	CREAM	CREAM
	4		Wake, Nadir	NREP	NREP
	6		Wake, Nadir		
	8		Wake, Nadir	MCE	MCE
	10		*Wake, Nadir*	*EPMP*	
	11		*Zenith only*	SEDA-AP	SEDA-AP
	12		*Zenith only*	*Temp Stow*	
Non-Standard Sites					
S3 Upper Inboard				AMS	AMS
Node 3				[BEAM]	BEAM ↑

Multi-Increment Payload Resupply and Outfitting Model (MiPROM)
Working Version 10/09/2012
NOTE: This is a strategic plan and subject to change.

Indicates site available during 2018 per current plans

last update 10/09/2012		Increment-Year		2018	
				2018-1	***2018-2***
		Period Start (Calendar Date)		Oct-17	Apr-18
Carrier	Location	Site Number	Viewing		
ELC 1	P3 Lower	3	Outboard / Ram / Nadir	***Candidate***	***Candidate***
		8	Inboard / Wake / Nadir	***Candidate***	***Candidate***
ELC 4	S3 Lower Inboard	2	Inboard / Wake / Nadir	MUSES	MUSES
		3	Inboard / Ram / Nadir	SAGE III/Hexapod (w/NVP)	SAGE III/Hexapod (w/NVP)
ELC 2	S3 Upper Outboard	3	Inboard / Ram / Zenith	MISSE-X	MISSE-X
		7	Outboard / Ram / Zenith	***Candidate***	***Candidate***
ELC 3	P3 Upper	3	Inboard / Ram / Zenith	***Candidate***	***Candidate***
		5	Outboard / Wake / Zenith	***Candidate***	***Candidate***
Columbus	EPF SOZ		Overhead / Zenith	Candidate	Candidate
	EPF SOX		Overhead / Ram	***Candidate***	***Candidate***
	EPF SDX		Deck / Ram	ASIM	ASIM
	EPF SDN		Deck / Nadir	ACES	ACES

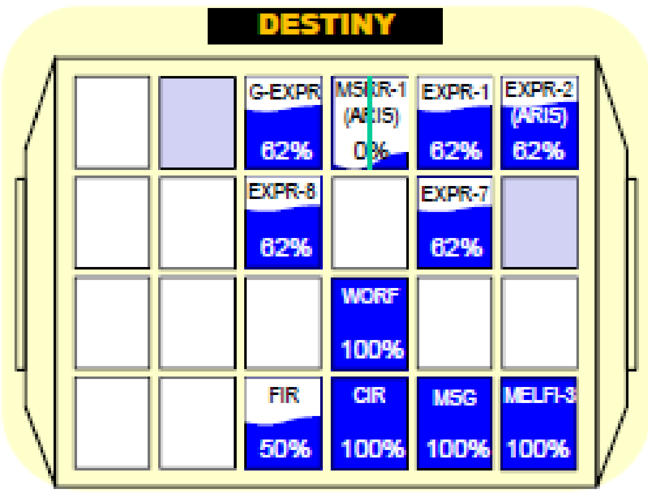
Multi-Increment Payload Resupply and Outfitting Model (MiPROM)
Working Version 10/09/2012
NOTE: This is a strategic plan and subject to change.

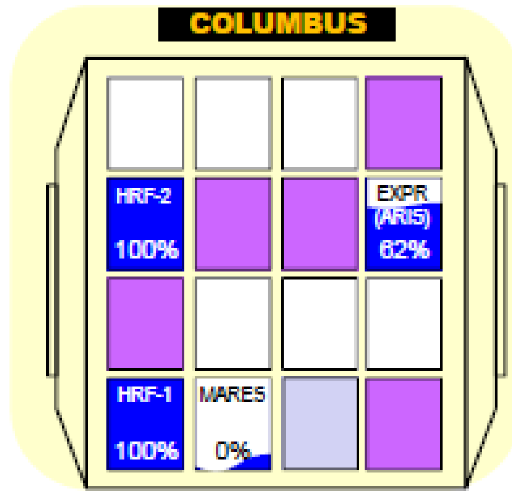
Indicates site available during 2018 per current plans

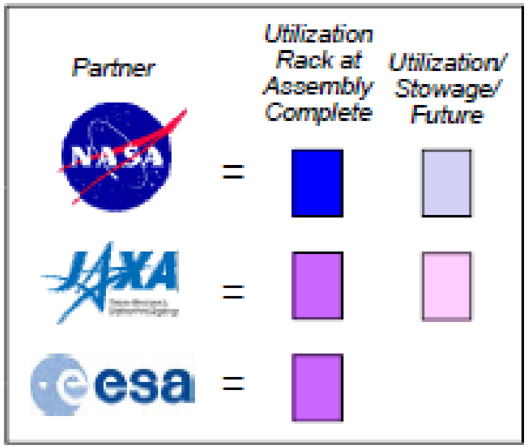
last update 10/09/2012		Increment-Year		2018	
				2018-1	**2018-2**
		Period Start (Calendar Date)		Oct-17	Apr-18
Carrier	Location	Site Number	Viewing		
JEM-EF	1		Ram, Nadir	MAXI	MAXI
	3		Ram, Nadir		
	5		Ram, Nadir	TBD J-5	TBD J-5
	7		Ram, Nadir	*ICS*	
	9		Port, Zenith, Nadir	CALET	CALET
	2		Wake, Nadir		
	4		Wake, Nadir	NREP	NREP
	6		Wake, Nadir	OCO-3	OCO-3
	8		Wake, Nadir	***Candidate***	***Candidate***
	10		*Wake, Nadir*	*EPMP*	
	11		*Zenith only*	SEDA-AP	SEDA-AP
	12		*Zenith only*	*Temp Stow*	
Non-Standard Sites					
S3 Upper Inboard				AMS	AMS
Node 3					

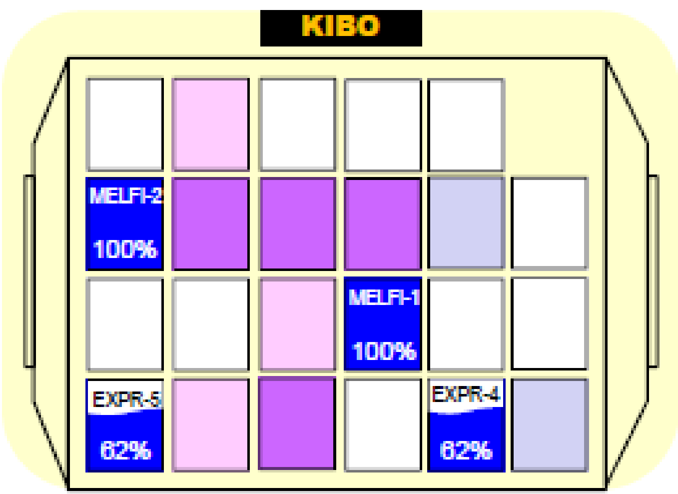
Internal Facilities

Internal Rack Capacity





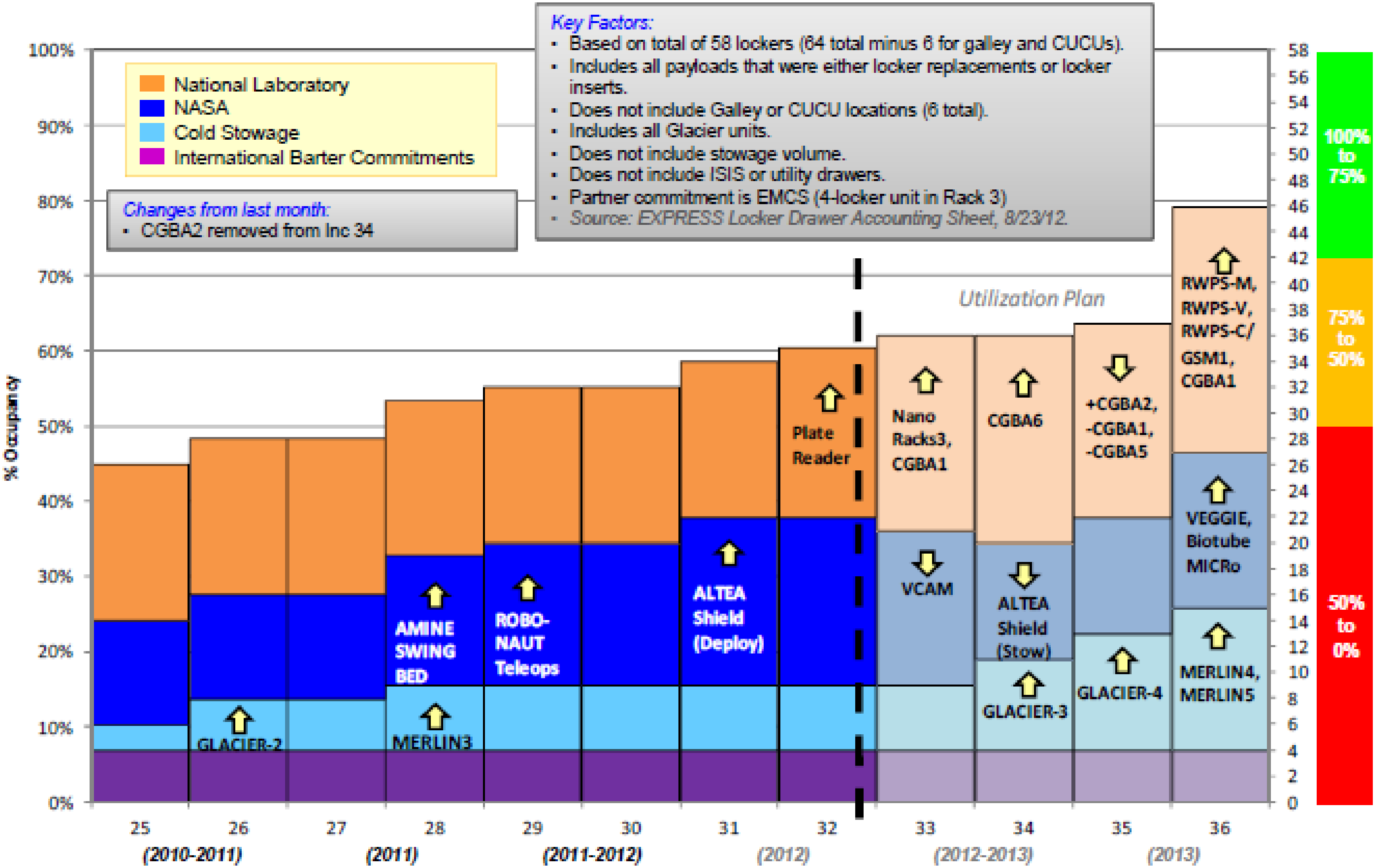




U.S. Facility Occupancy – Current To Date and Planned by End of FY 2012

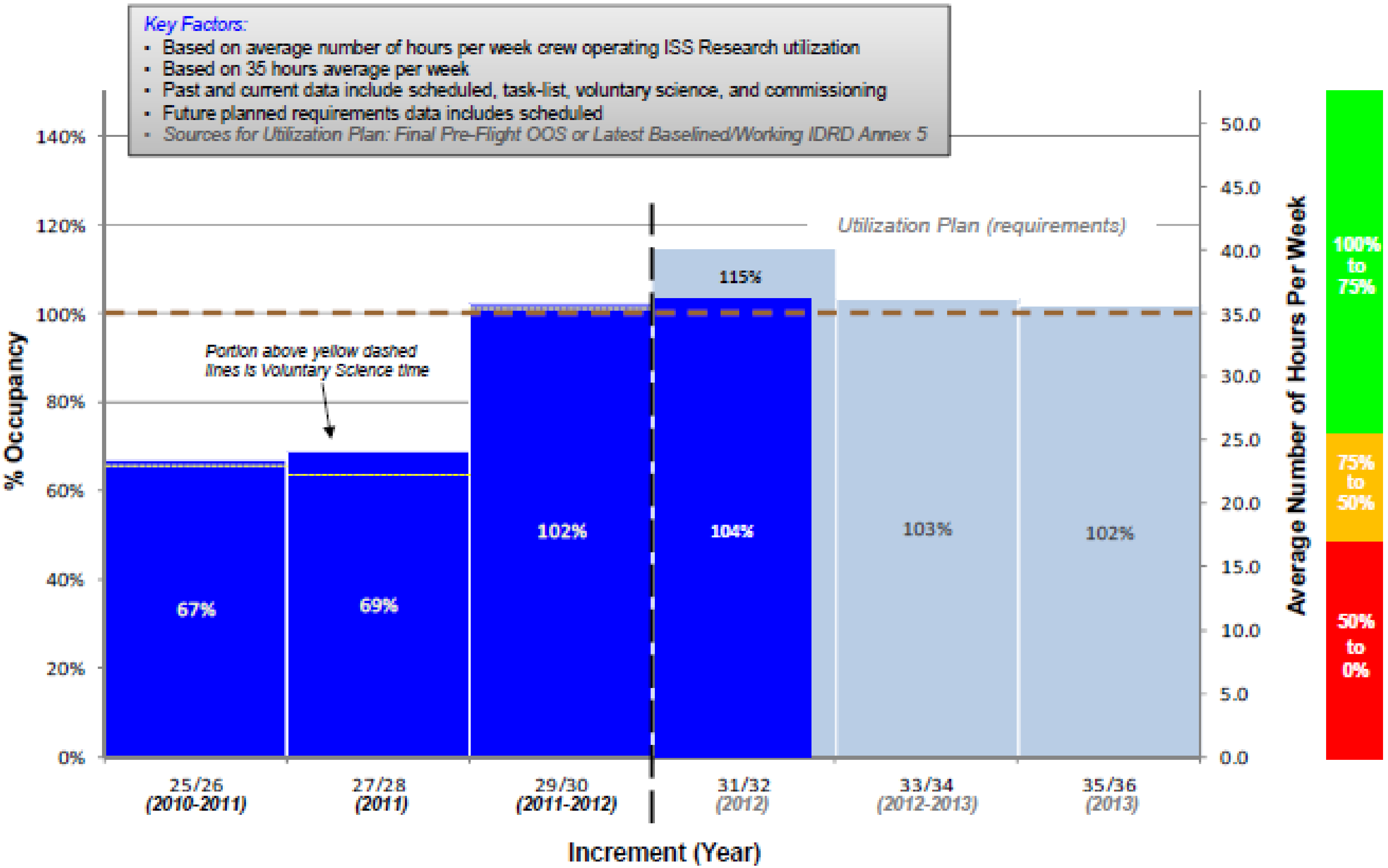
Facility	Notes	To-Date Percentage	End of FY12 Percentage	Number of Racks (Weighting Factor)
EXPRESS	36 of 58 lockers	58.6%	62%	7.25 Racks (excluding Galley & CUCU)
HRF	Standby equipment	100%	100%	2
MARES	First use in FY13	0%	0%	1
MSG	SODI, SLICE, BASS, INSPACE-3	100%	100%	1
CIR	FLEX-2	100%	100%	1
FIR	CVB, PACE-2, ACE-1	60%	50%	1
MSRR/MSL	12 cartridges/yr @ 1 cartridge/wk	0%	0%	0.5
MSRR Open Bay	Currently used for payload stowage but scarred for payload	0%	0%	0.5
WORF	ISSAC, EarthKAM	100%	100%	1
MELFI	3 MELFIs full or standby	100%	100%	3
	Total	12.85	13.0	18.25
	Weighted Percentage	70.4%	71.2%	--

Facilities in Express Racks



USOS Crew Time

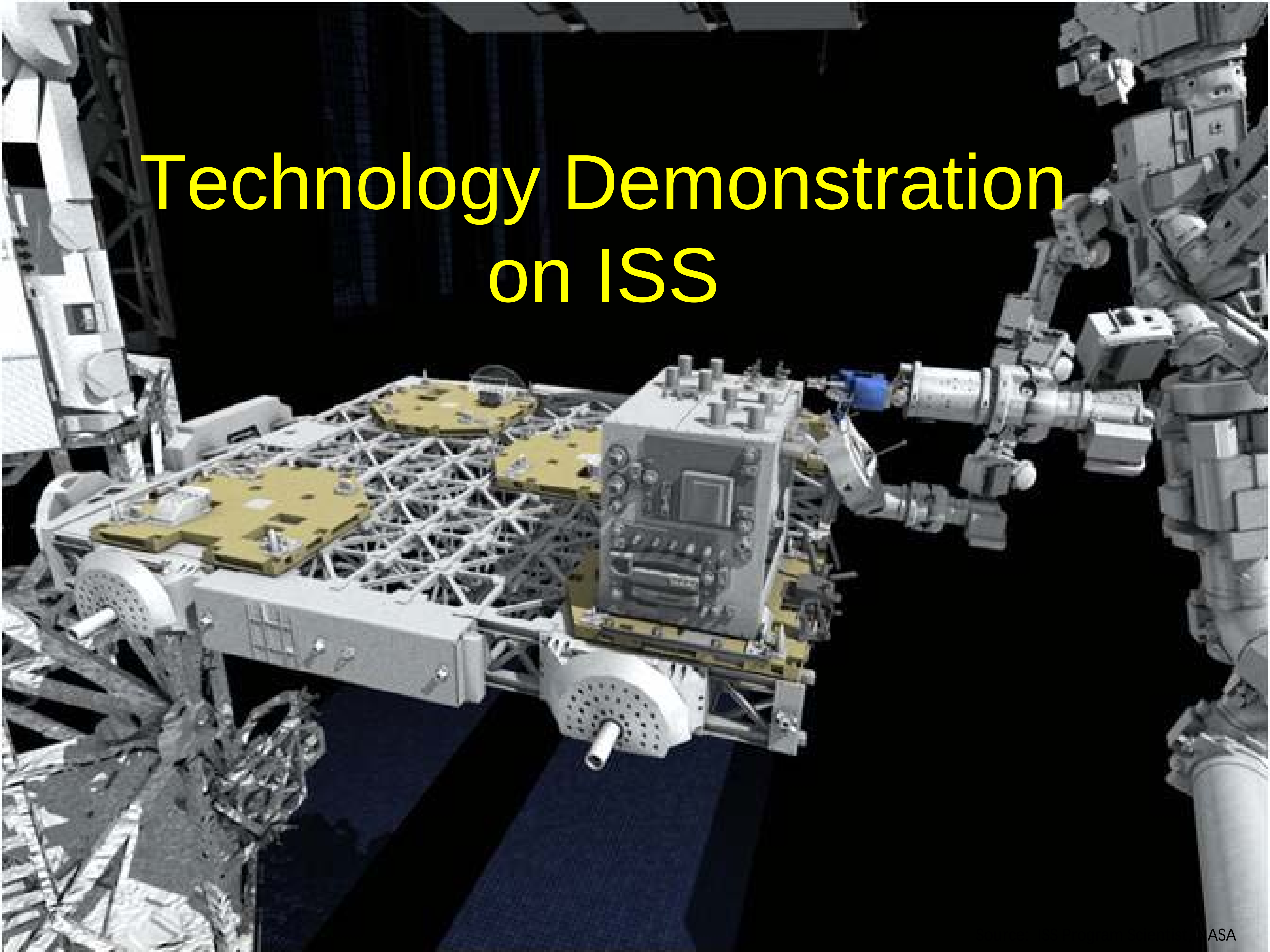
Now at strategic goal (USOS 35 hrs/wk), but our users need more



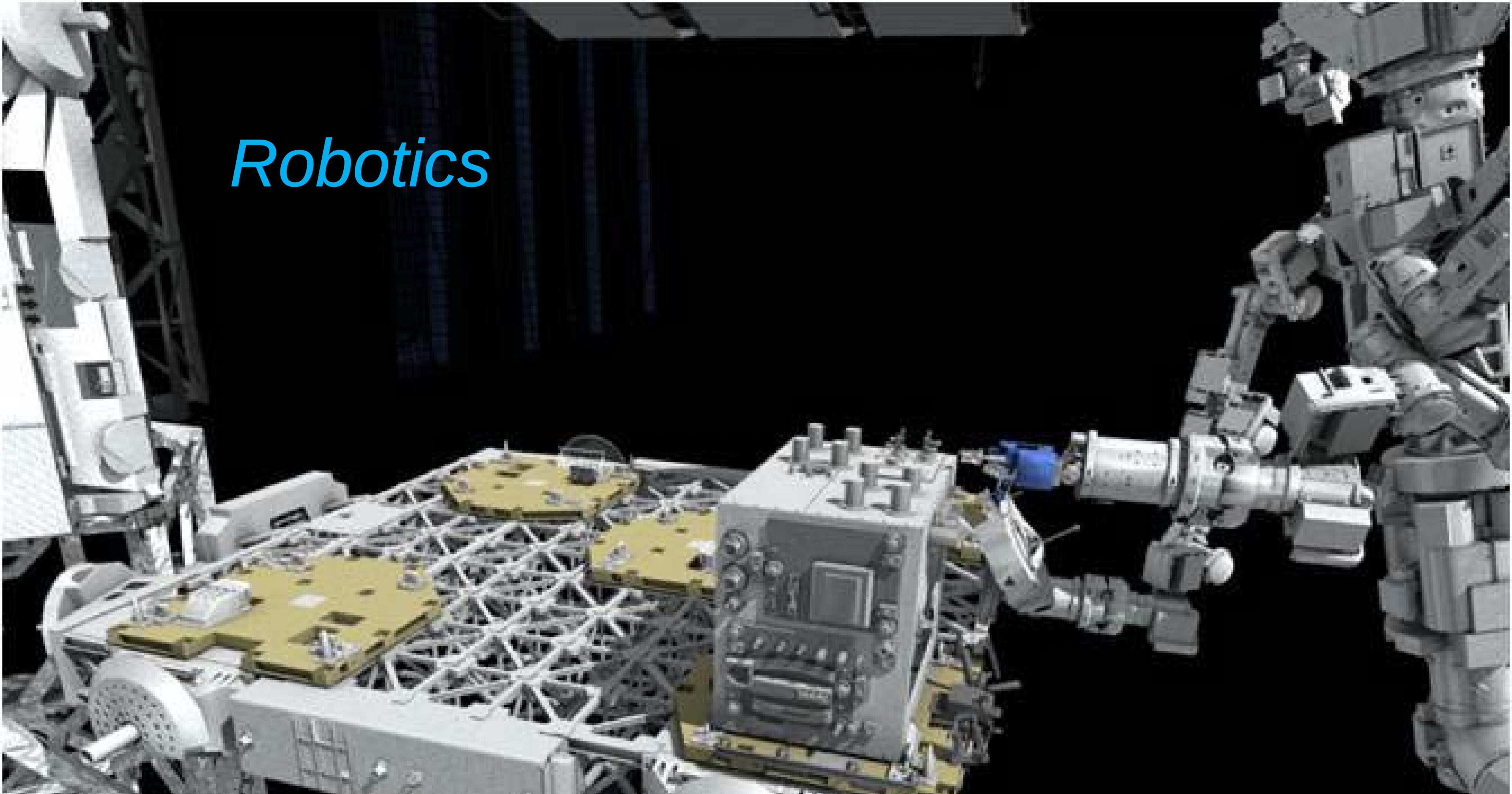
How do we know we are at full utilization?

- Real estate bottom line:
  - Racks 71% occupied
  - EXRESS 60% occupied, expect 80% by the end of 2014
  - External Sites 35% occupied, expect 75% by end of 2014
  - Best external sites (best viewing with good Nadir or Zentith views) are mostly claimed through 2020
- Crew time bottom line:
  - Scheduled time oversubscribed (>100%)
  - Crew as human subjects oversubscribed (multi-year queue carefully managed by HRP, a big issue for our partners, limits CASIS research)
  - NASA and CASIS users are soon going to compete for this limited resource unless we are able to expand availability
- Upmass/downmass bottom line:
  - Mass not limiting--No backlog on the ground today, projected mass capacity is good
  - Our on-orbit freezers are nearly full (>100%), dependent on regular SpaceX return
  - User demand for powered launch and return cannot be met (>100%) due to Biotech and Biology interest

Technology Demonstration on ISS



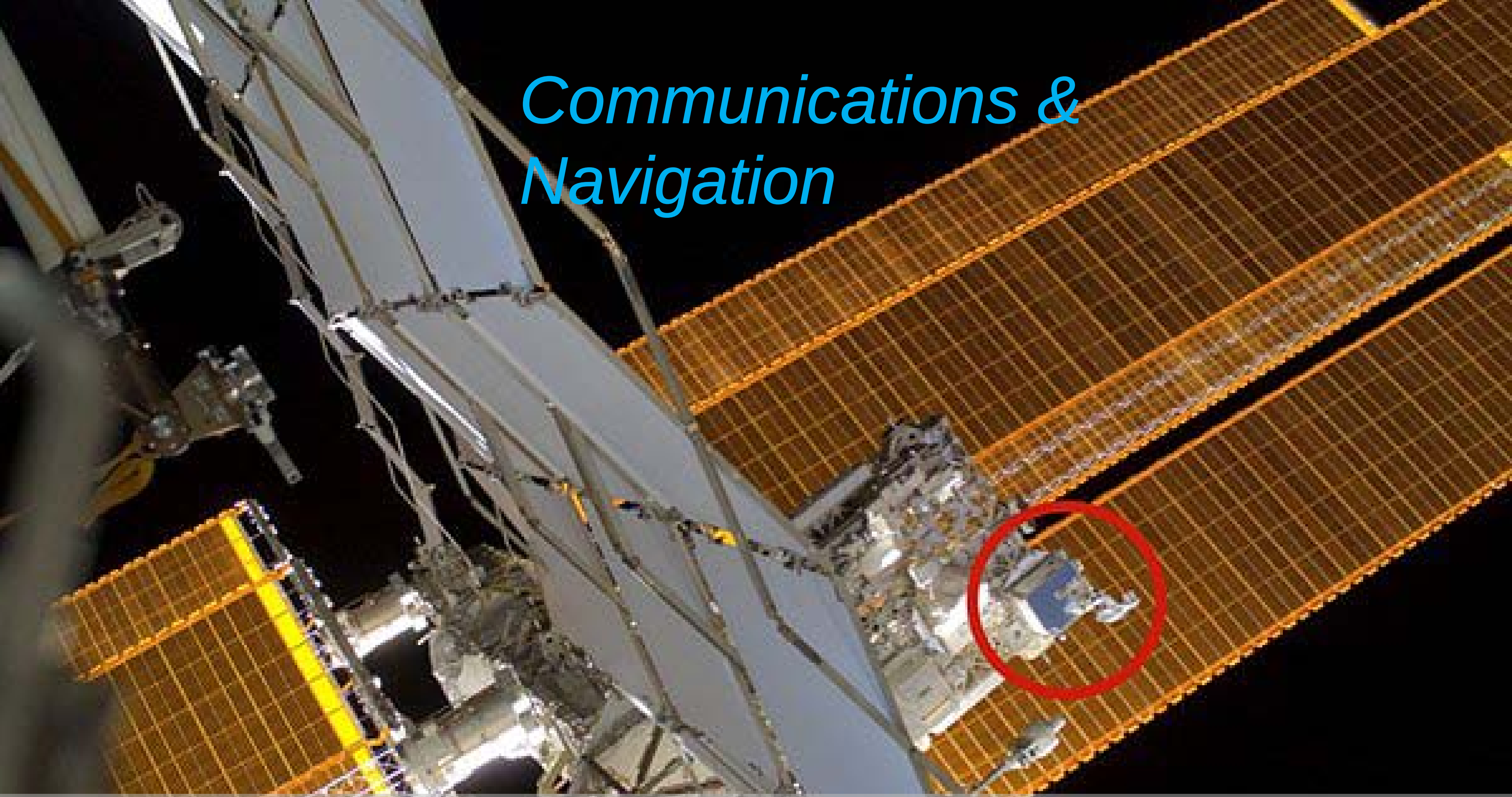
Robotics



Robotic Refueling Mission (RRM) is an external ***International Space Station*** experiment that paves the way for future robotic refueling missions. It demonstrates robotic refueling tasks and servicing technologies in a zero-g environment. It uses of the ISS Special Purpose Dexterous Manipulator (also known as "Dextre") to validate tasks, tools, and techniques needed to repair "legacy" satellites not designed to be refueled in orbit. Robotic refueling extends the lifetime of satellites, allowing owners and operators to gain additional years of use from assets already operating in space.

Source: ISS Program Scientist, NASA

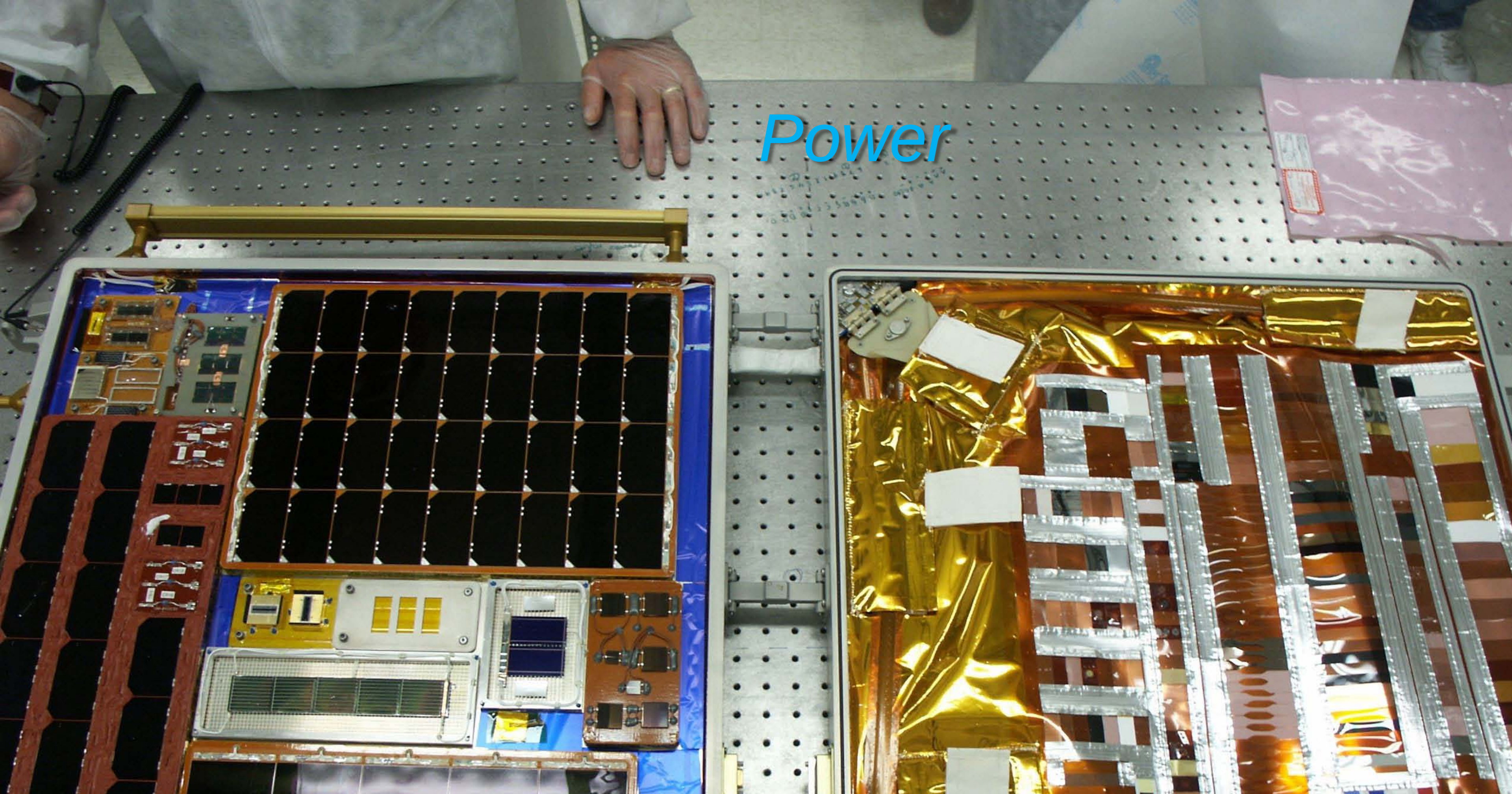
Communications & Navigation



Software Communications and Navigation (SCaN Testbed) is an external ***International Space Station*** that will provide an orbiting laboratory on space station for the development of Software Defined Radio (SDR) technology. It includes three SDR devices, each with different capabilities. These devices will be used by researchers to advance a new generation of space communications so that future NASA space missions will be able to return more scientific information and add new functions to accommodate changing mission needs.

Source: ISS Program Scientist, NASA

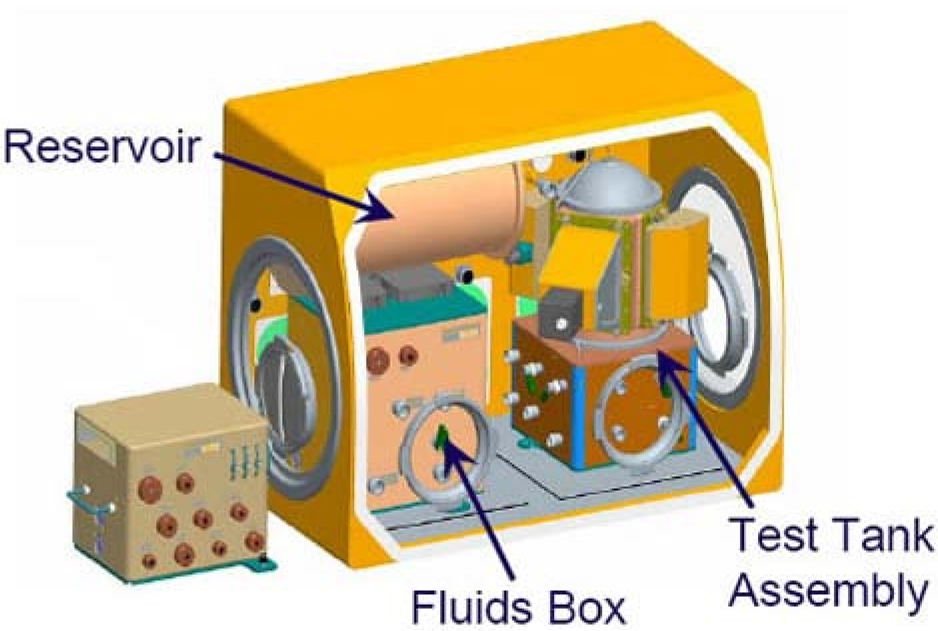
Power

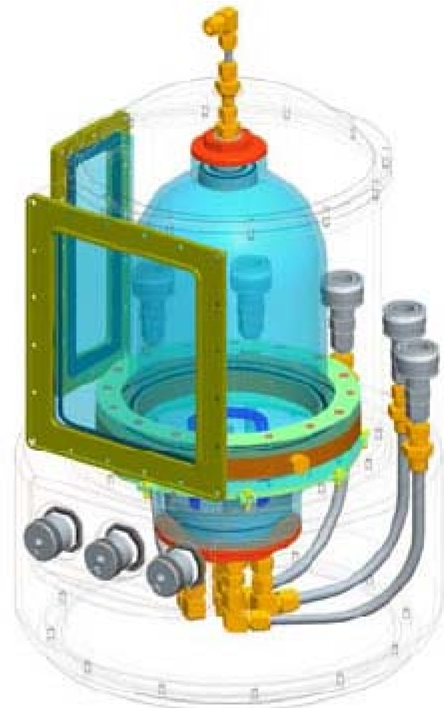


Software Communications and Navigation (SCaN Testbed) is an external The **Forward Technology Solar Cell Experiment (FTSCE), part of Materials ISS Experiment-5 (MISSE-5)** spent *International Space Station* characterized the durability and the electrical output of 39 advanced solar cell samples that could be used on future space exploration vehicles. Solar cells degrade over time when exposed to the space environment. Some samples flown had two orders of magnitude better performance than solar cell materials currently in use.

Source: ISS Program Scientist, NASA

Thermal Control





Zero Boil-Off Tank Experiment (ZBOT) is an ***International Space Station*** demonstration to be conducted in the Microgravity Sciences Glovebox in late 2014. It will aid the design of long-term storage systems for cryogenic fluids. Simulated by Perfluoro-normal-Pentane (P-n-P), it will validate a Computational Fluid Dynamics (CFD) model for cryogenic storage in 1g and microgravity. This will support reductions in launch mass while insuring cost effective and reliable cryogenic storage for both life support and propulsion systems.

Source: ISS Program Scientist, NASA

Closed-loop ECLSS

Amine Swingbed is a prototype Carbon Dioxide removal system being testing on the ***International Space Station.*** Vacuum Regenerated Amine Systems have traditionally been applied to relatively short duration human space flight missions because water vapor is removed along with the CO_2. Long duration missions need to recycle water. This system combines water recovery with the vacuum regeneration approach to measure its performance. This combined system uses less power and it is smaller in size than current technologies (note the small size compared to the fingers in the photo)..

Source: ISS Program Scientist, NASA

Fire Safety

The Smoke Aerosol Measurement Experiment (SAME) on the ***International Space Station*** has revolutionized our understanding of the nature of smoke and soot in spacecraft fires, defining new requirements for future fire safety systems. Now ongoing on ISS, **Burning and Suppression of Solids in Space (BASS)** is looks at flames from a variety of burning materials with different shapes. Researchers use this investigation to assess the effectiveness of nitrogen in suppressing microgravity fires.

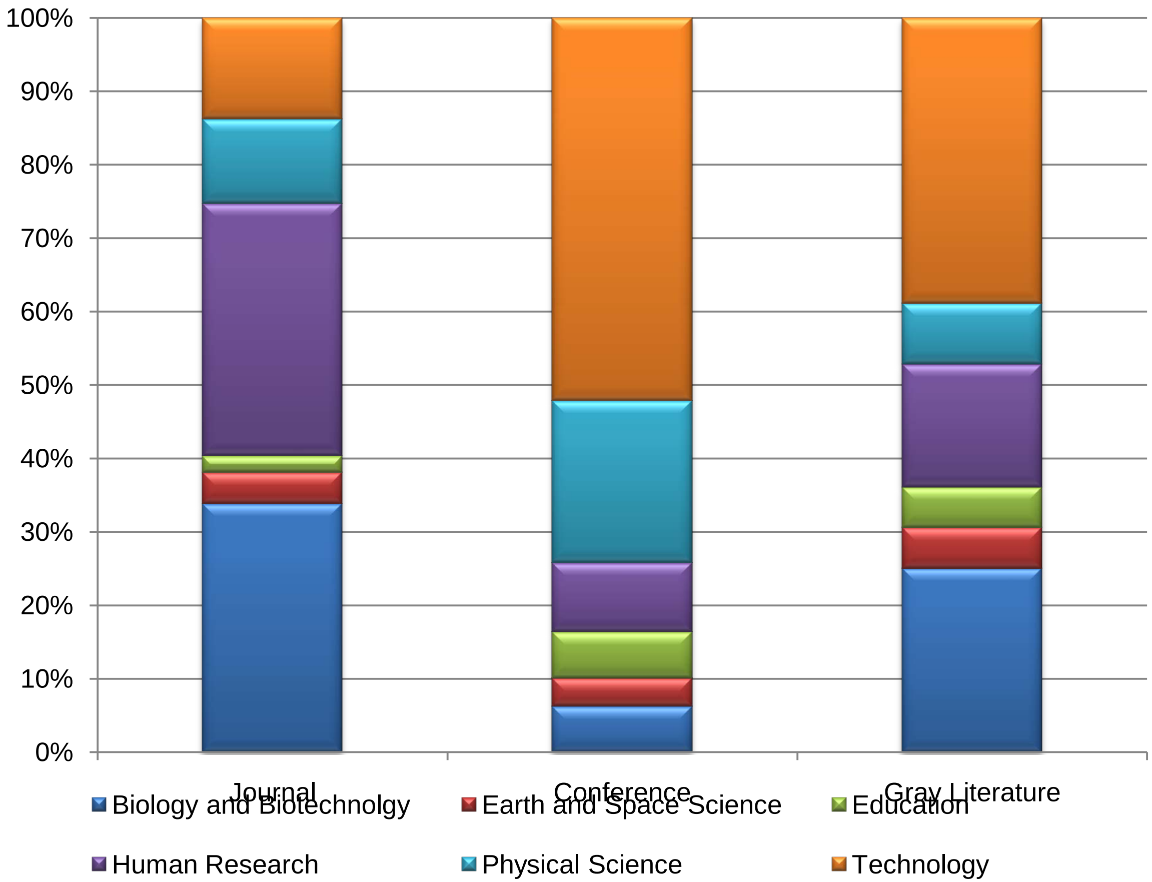
Source: ISS Program Scientist, NASA

Current, Planned, or Proposed ISS Technology Demonstrations

Italic = NRC High Priority Technology that would benefit from ISS access
Underline = NRC High Priority Technology (focus for next 5 years)

- Robotics
  - *Next Gen Canadarm testing (CSA)*
  - *Robotic Assisted EVA's (Robonaut, NASA)*
  - METERON (ESA) and Surface Telerobotics
  - Delay Tolerant Network Robotic Systems
  - *Robotic Refueling Mission (CSA, NASA)*
  - <u>*Robotic assembly to optical tolerances (OPTIIX, NASA)*</u>
- Comm and Nav
  - OPALS – Optical Communication
  - X-Ray Navigation, (NICER/SEXTANT, NASA)
  - *Software Defined Radio (CoNNeCT/SCAN, NASA)*
  - Delay tolerant space networks
  - <u>*Autonomous Rendezvous & Docking advancements (ESA/JAXA)*</u>
  - <u>*Advanced optical metrology (sensing/mat'ls)*</u>
- Power
  - Regenerative fuel cells
  - <u>*Advanced solar array designs [FAST, IBIS, or other]*</u>
  - <u>*Advanced photovoltaic materials*</u>
  - *Battery and energy storage advancements [Li-Ion or other]*
- Thermal Control
  - High efficiency radiators
  - <u>*Cryogenic propellant storage & transfer*</u>
  - Advanced materials testing
- Closed Loop ECLSS
  - Atmospheric monitoring: ANITA2 (ESA), MIDASS (ESA), AQM (NASA)
  - <u>*Air Revitalization: Oxygen production, Next Gen OGA [Vapor Feed or other] (NASA)*</u>
  - <u>*Contaminated gas removal*</u>
  - <u>*Carbon Dioxide recovery: Amine swingbed and CDRA bed advancements*</u>
  - <u>*Advanced Closed-loop Life Support ACLS (ESA), MELiSSA (ESA),*</u>
  - <u>*Water/Waste: Electrochemical disinfection, Cascade Distillation System, Calcium Remediation, [Electrodialysis Metathesis or other]*</u>
- Other
  - *Spacecraft Fire Safety Demonstration*
  - <u>*Radiation protection/mitigation/monitoring*</u>
  - On-board parts repair and manufacturing
  - <u>*Inflatable Module (BEAM)*</u>

ISS Result Publications



- As of 10/5/12 a total of 783 results publications have been collected for ISS investigations for all of the partners.
- Of these:
  - 588 Journals
  - 159 Conferences
  - 36 Gray Literature (patent, book, magazine, technical paper, DVD)

Top Journals with ISS Results by Impact Factor/Eigenfactor

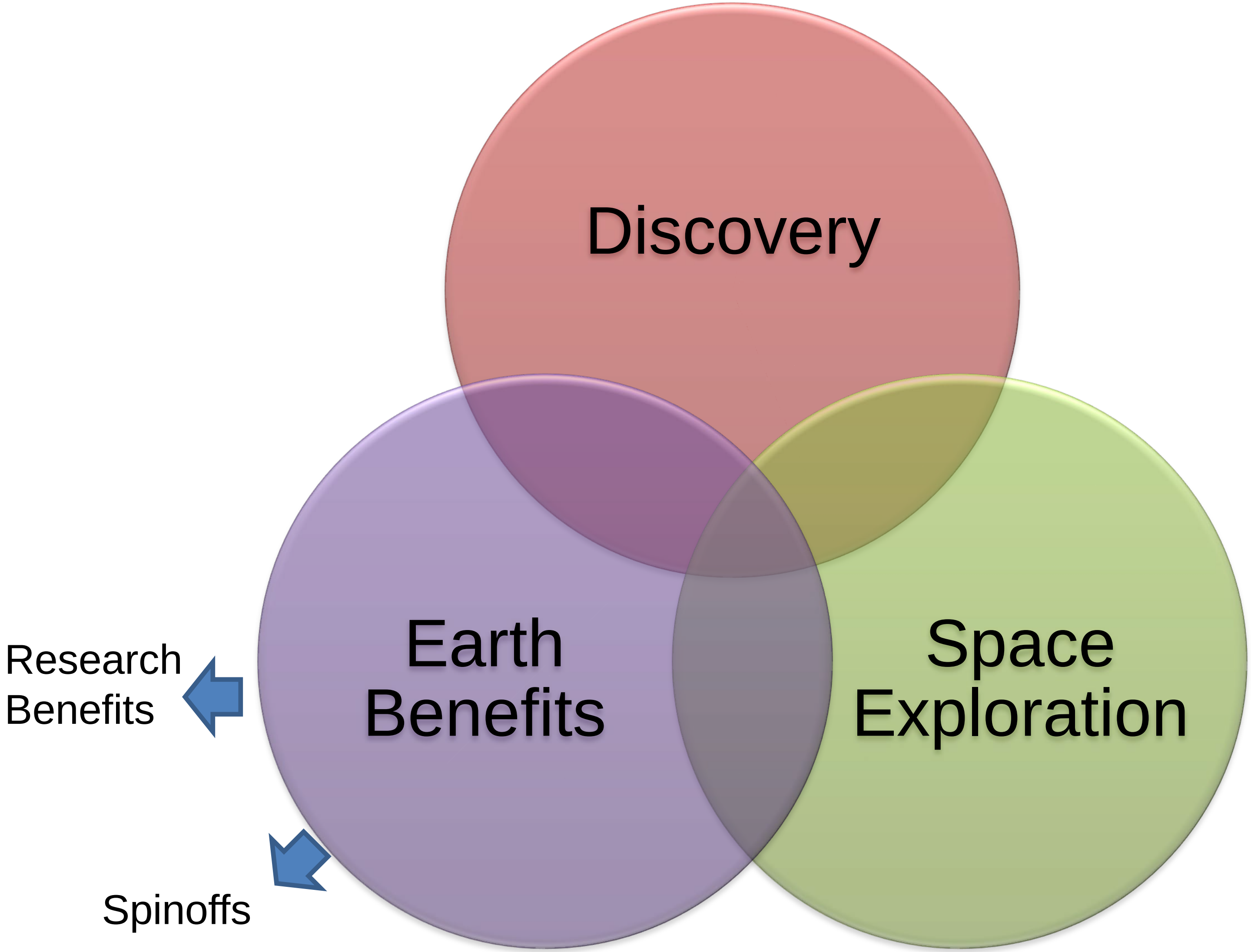
Journals	1Year Impact Factor	5 year Impact Factor	Eigenfactor
Nature	36.280	36.235	1.65524
Proceedings of the National Academy of Sciences of the United States of America	9.681	10.472	1.60168
Physical Review Letters	7.370	7.013	1.14457
Journal of Biological Chemistry	4.773	5.117	0.74213
PLoS ONE	4.092	4.537	0.50162
Journal of Neuroscience	7.115	7.915	0.44963
Journal of Geophysical Research	3.021	3.441	0.33245
Journal of Physical Chemistry B	3.696	4.061	0.24652
Geophysical Research Letters	3.792	3.759	0.23991
Langmuir	4.186	4.514	0.22322
NeuroImage	5.895	6.608	0.15356
Applied and Environmental Microbiology	3.829	4.453	0.12769
New Journal of Physics	4.177	3.773	0.11881
Brain Research	2.728	2.739	0.09356
FASEB Journal	5.712	6.340	0.08876
Journal of Urology	3.746	3.856	0.08303
Radiology	5.726	6.380	0.07346
American Journal of Physiology: Heart and Circulatory Physiology	3.708	3.878	0.06857
New Phytologist	6.645	6.693	0.06386
Opthalmology	5.454	5.567	0.05634
Acta Crystallographica Section D: Biological Crystallography	12.619	7.038	0.05384

ISS Patents from Research*

Discipline	Investigation	Patent
Facility	**CRIM-M**	Robyn Rouleau, Lawrence Delucas, Douglas Keith Hedden. Patent US6761861. High Density Protein Crystal Growth. Lawrence Delucas, Robyn Rouleau, Kenneth Banasiewicz. Patent US6623708. High Density Protein Crystal Growth.
Biology and Biotechnology	**MEPS**	Dennis R. Morrison. Patent 7295309. Microparticle analysis system and method.
Biology and Biotechnology	**NLP Vaccine**	Timothy G. Hammonds, Patricia L. Allen. Patent US20090258037. Vaccine Development Strategy using Microgravity Conditions.
Technology Development	**Amine Swingbed**	Walter C. Dean II. Patent 7637988. Swing Bed Canister with Heat Transfer Features.
Physical Science	**CFE**	Donald R. Pettit, Mark M. Wieslogel, Paul Concus, Robert Finn.Patent 8074827. Beverage cup for drinking use in spacecraft or weightless environments. Christopher M. Thomas, Yohghui Ma, Andrew North, Mark M. Weislogel. Patent 7913499. Microgravity condensing heat exchanger. Mark M. Wieslogel, Evan A. Thomas, John C. Graf . Patent 7905946. Systems and methods for separating a multiphase fluid.

* Does not include the patents from ISS systems development

What kind of benefits come from ISS research?



Julie A. Robinson, ISS Program Scientist

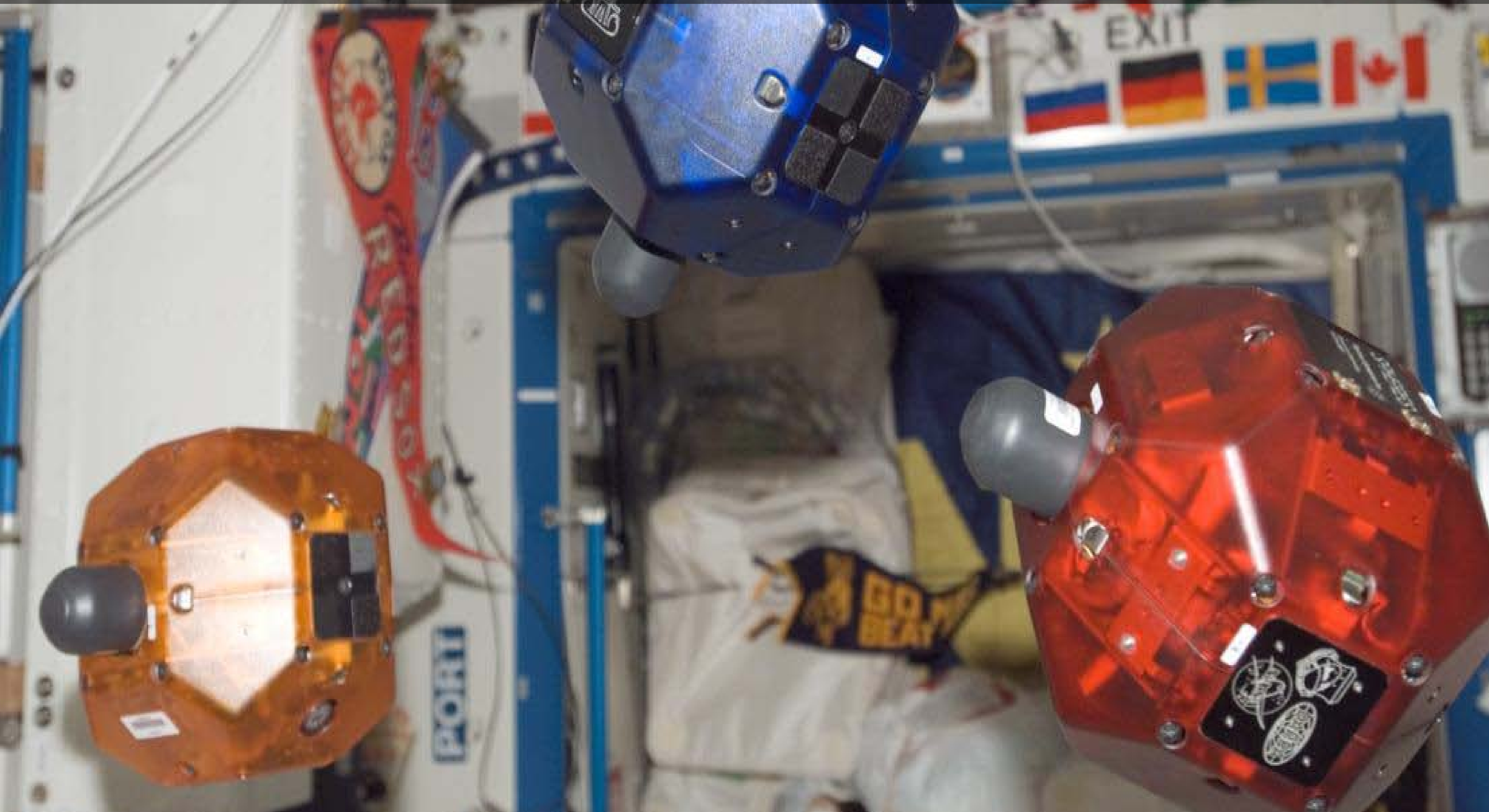
Human Helpers - Co-developed with General Motors (GM), Robonaut is the first humanoid robot in space, and its primary job for now is demonstrating how a dexterous robot can manipulate mechanisms in a microgravity environment, operate in the space environment for extended periods of time, assist with ***International Space Station*** tasks, and eventually interact with astronauts. GM plans to use the results in future advanced vehicle safety systems and manufacturing plant applications.

Source: ISS Program Scientist, NASA

Portable Test System - Handheld devices enable crew on the ***International Space Station*** to rapidly detect a variety of biological and chemical substances of concern to crew safety. This type of environmental testing technology has Earth-based, as well as future exploration missions and planetary protection applications.

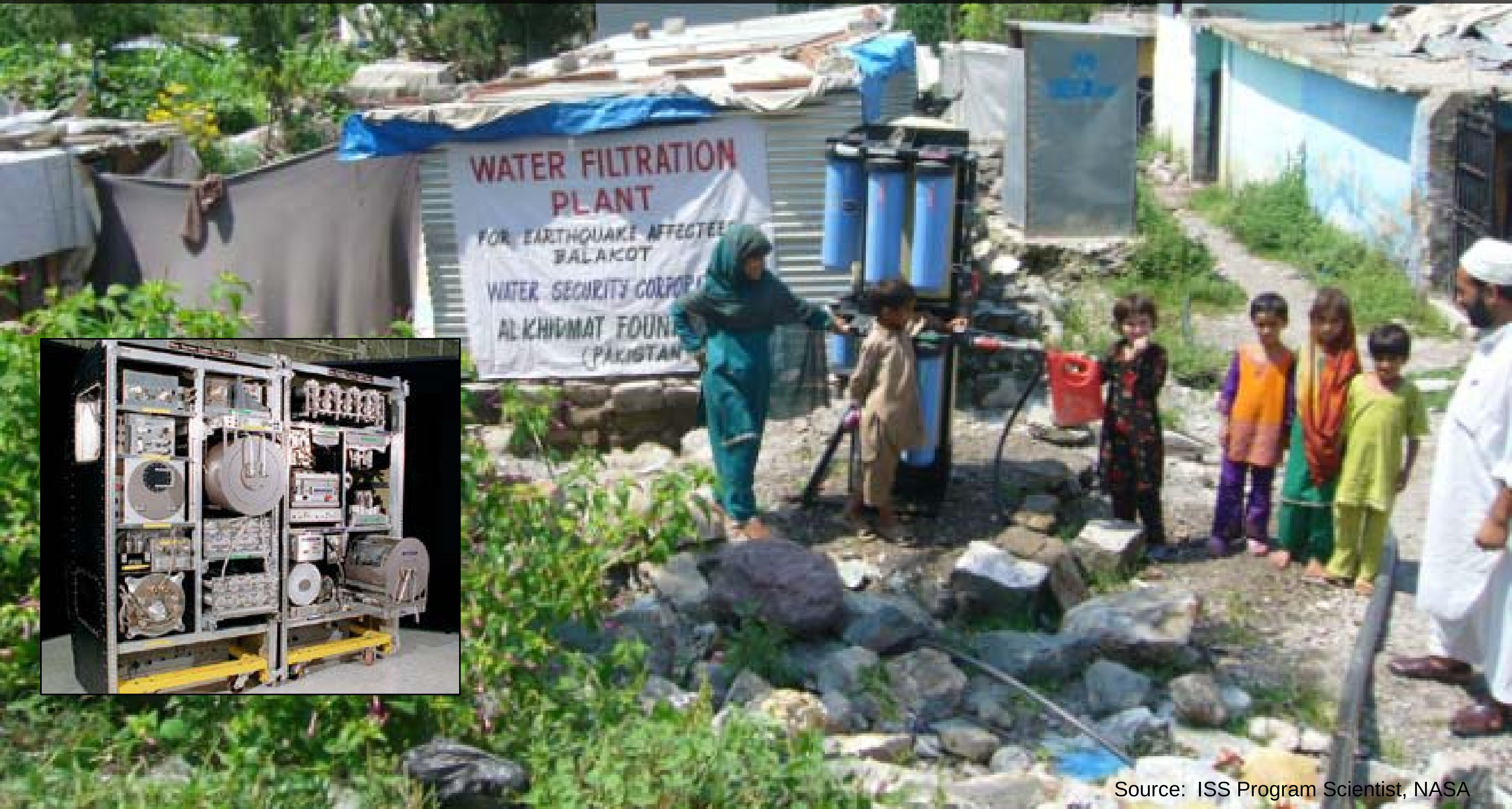
Source: ISS Program Scientist, NASA

Multi-body Maneuvering in Space – The Massachusetts Institute of Technology (MIT) is using color coded bowling-ball sized spherical satellites to demonstrate space-based autonomous rendezvous and docking on the ***International Space Station***. The results have applications for satellite servicing, space-based vehicle assembly and formation flying spacecraft configurations.



Source: ISS Program Scientist, NASA

Regen ECLSS – Water recycling, oxygen generation, and carbon dioxide removal are critical technologies for reducing the logistics re-supply requirements for human spaceflight. The ***International Space Station*** demonstration project is applying lessons learned form operational experiences to next generation technologies. The resin used in the ISS water processor assembly have been developed as a commercial water filtration solution for use in disaster and humanitarian relief zones.



Source: ISS Program Scientist, NASA

Examples of Major ISS Benefits from the Decade of Assembly

- Discoveries
  - MAXI black hole swallowing star (*Nature*)
  - Vision impacts and intracranial pressure (*Opthalmology*)
  - Microbial virulence (*Proc. Nat. Acad. Sci.)*
- Results with potential Earth benefit
  - Candidate vaccines for Salmonella and MRSA
  - Candidate treatment for prostate cancer
  - Candidate treatment for Duschenne's muscular dystrophy
- NASA Exploration Mission
  - Life support sustaining and reliability
  - Success in bone health maintenance resistive exercise (*J. Bone Mineral Res.*)
  - Models for Atomic Oxygen erosion in orbit
- Technology Spinoffs
  - Robotic assist for brain surgery
  - TiO2 for filtering bacteria from the air in daycares
  - Remotely-guided ultrasound for maternal care in remote areas

ISS benefits for Humanity Document

ISS Research & Technology

http://www.nasa.gov/iss-science/

@ISS_Research

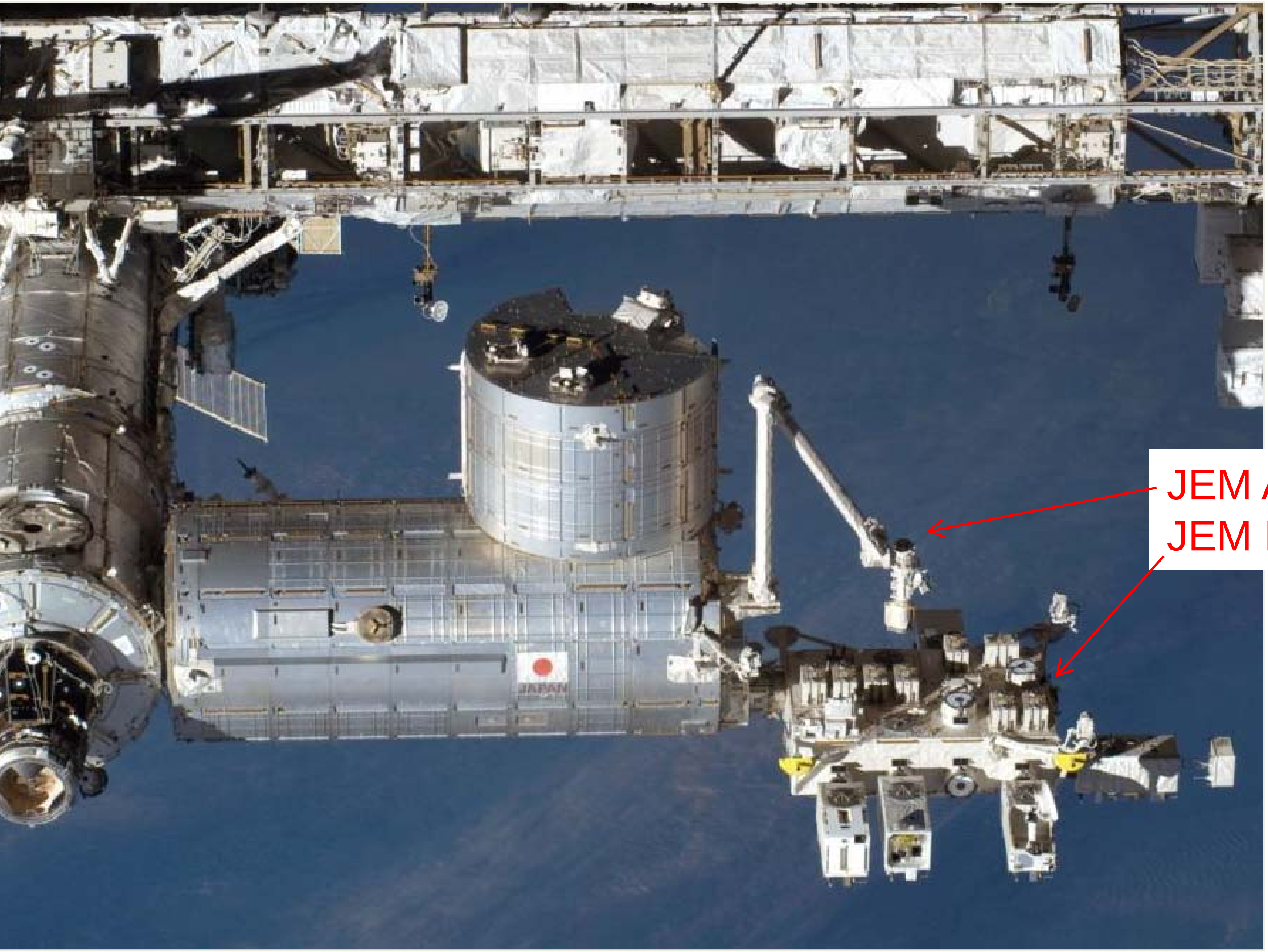
ISS Research Blog "A Lab Aloft"

http://go.usa.gov/atI

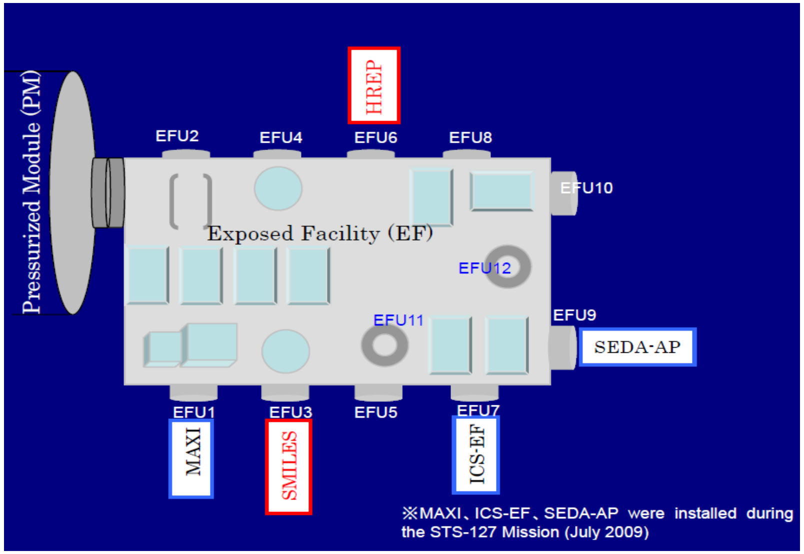
Backup

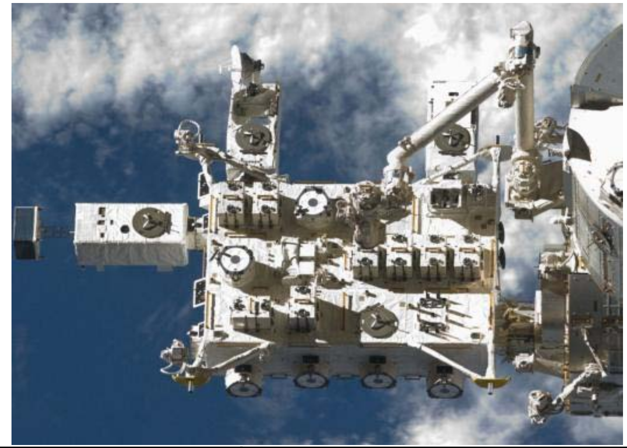
Details on External Facilities

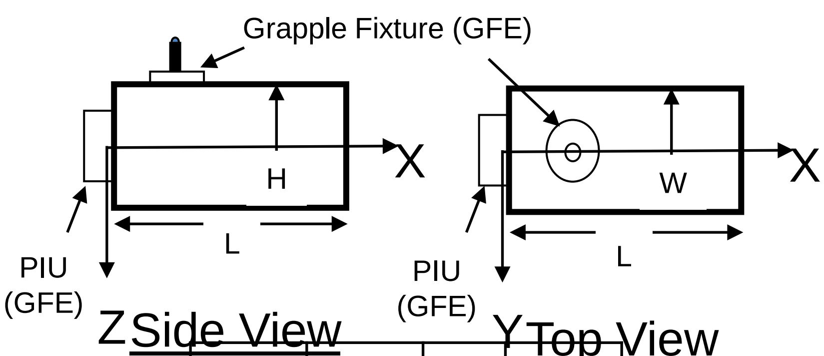
Japanese Experiment Module - *Kibo*



JEM EF External Research Accommodations





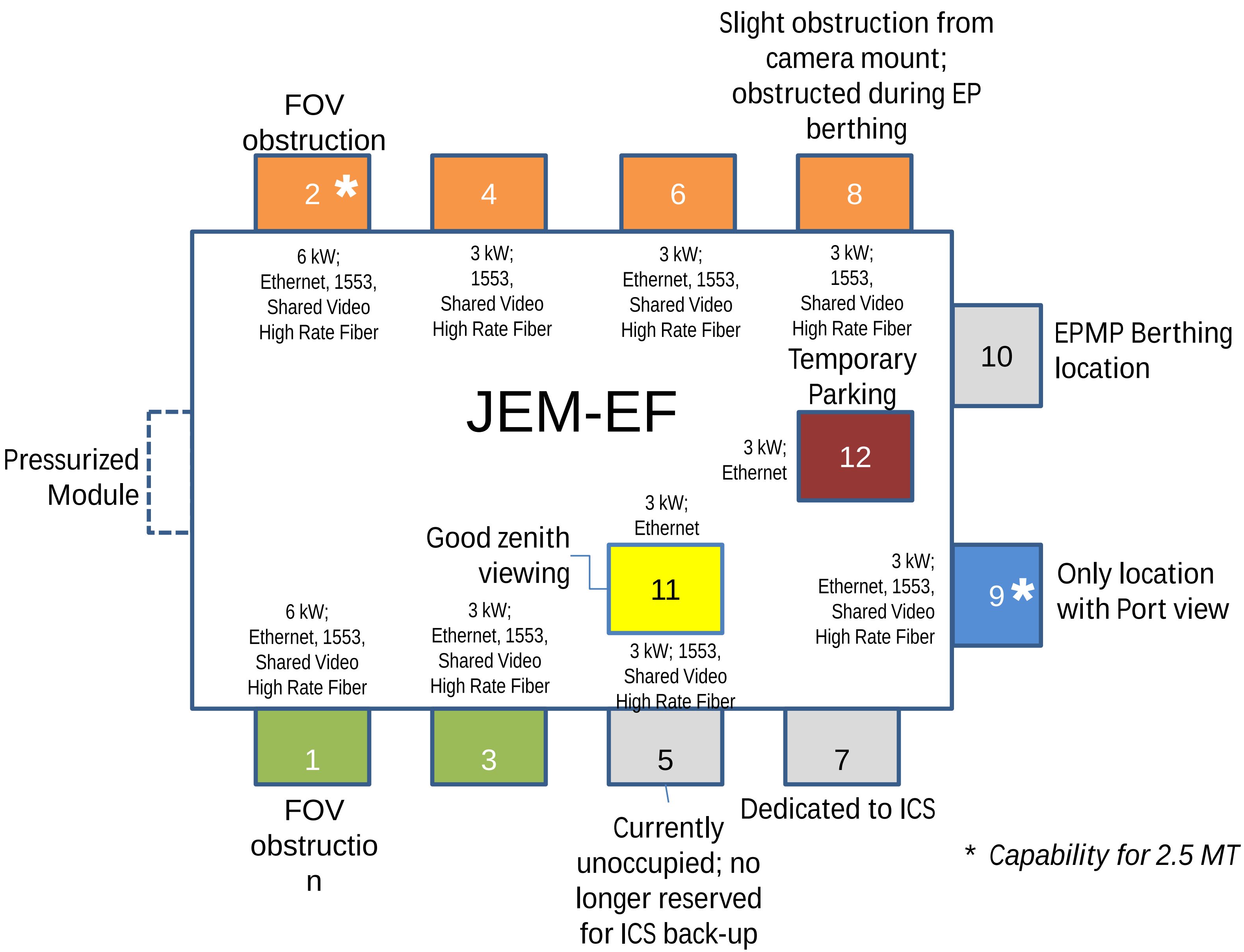


Axis	mm	ft	inch
W	800	2	7.50
H	1000	3	3.37
L	1850	6	0.83

Mass capacity	550 kg (1,150 lb) at standard site 2,250 kg (5,550 lb) at large site
Volume	1.5 m^3
Power	3-6 kW, 113 – 126 VDC
Thermal	3-6 kW cooling
Low-rate data Medium-rate data	1 Mbps (MIL-STD-1553, two way) 1EEE-802.3(10BASE-T, two way) *
High-rate data	43 Mbps (shared, one way downlink)
Sites available to NASA	5 sites (of 10 total)

* **Ethernet bus is tested to 100BASE-T capacity. Upgrade to 100BASE-T is being worked by JAXA**

JEM EF EFU Location Overview

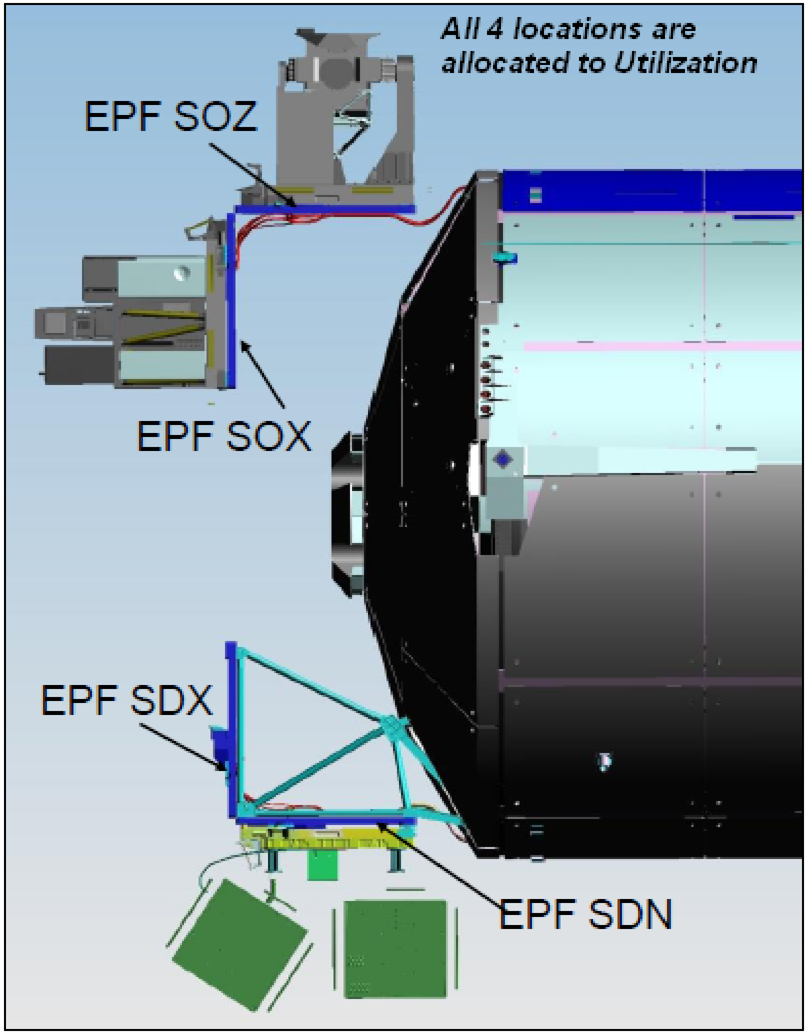


** Capability for 2.5 MT payload*

JEM-EF Detailed Accommodations by Site

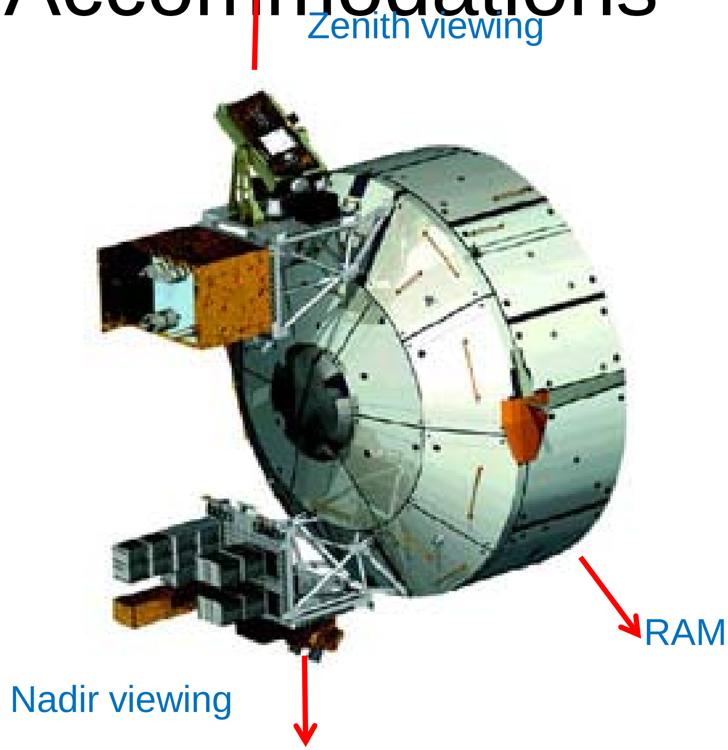
Location	Viewing	Payload Size	Description / Notes	Power	Data
1	Ram, Nadir, Zenith	500 kg	Ram field of View (FOV) obstruction by JEM module	6 kW	Ethernet, 1553, Video, High Rate
3	Ram, Nadir, Zenith	500 kg	Clear view	3 kW	Ethernet, 1553, Video, High Rate
5	Ram, Nadir, Zenith	500 kg	Formerly used as ICS System back-up site ; now available for use	3 kW	Ethernet, 1553, Video, High Rate
7	Ram, Nadir, Zenith	500 kg	ICS-dedicated	-	-
9	Port, Zenith, Nadir	2.5 MT	Best volumetrically for large payloads (up to 2.5 MT), but not necessarily the best viewing	3 kW	Ethernet, 1553, Video, High Rate
2	Wake, Nadir, Zenith	2.5 MT	Can hold large payloads, but has an FOV obstruction by JEM module	6 kW	Ethernet, 1553, Video, High Rate
4	Wake, Nadir, Zenith	500 kg	Clear view	3 kW	1553, Video, High Rate
6	Wake, Nadir, Zenith	500 kg	Clear view	3 kW	Ethernet, 1553, Video, High Rate
8	Wake, Nadir, Zenith	500 kg	Obstruction during EP berthing, slight obstruction from camera mount	3 kW	1553, Video, High Rate
10	Wake, Nadir, Zenith	500 kg	EPMP berthing site	-	-
11	Zenith only	500 kg	Good Zenith viewing	3 kW	Ethernet
12	Zenith only	500 kg	Temporary stowage location	3 kW	Ethernet

Columbus EF Overview



Location	Viewing	Payload Size	Power	Data
SOZ	Zenith	226 kg + CEPA	1.25 kW at 120 VDC 2.5 kW max	Ethernet, 1553
SOX	Ram			
SDX	Ram			
SDN	Nadir			

Columbus EF External Research Accommodations



Mass capacity	550 kg (1,150 lb) at standard site 2,250 kg (5,550 lb) at large site
Mass capacity	230 kg (500 lb)
Volume	1 m^3
Power	2.5 kW total to carrier (shared)
Thermal	Passive
Low-rate data	1 Mbps (MIL-STD-1553, two way)
Medium-rate data	2 Mbps (shared, two way) *
Sites available to NASA	2 sites (of 4 total)

*** Ethernet bus is tested to 100BASE-T capacity. Upgrade to 100BASE-T is being worked by NASA ODAR project**

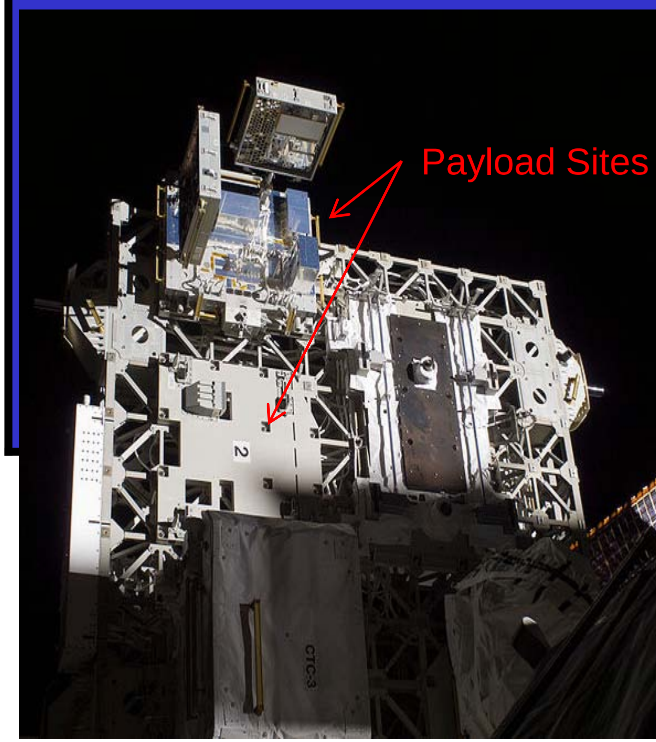
External Research Accommodations

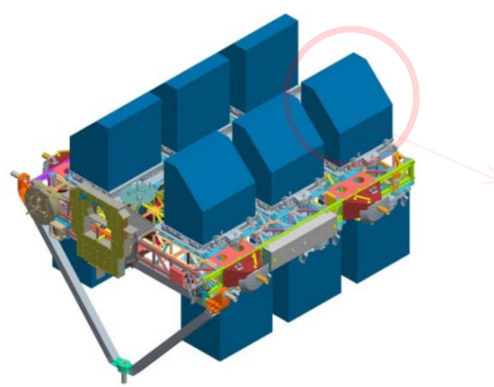
Express Logistic Carrier

ELC Single Adapter Resources

(2 NASA payload sites per ELC)

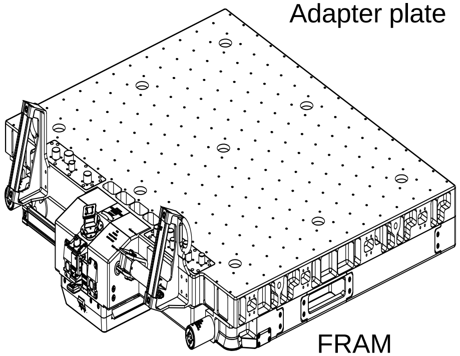
Mass capacity	227 kg (500 lb)
Volume	1 m^3
Power	750 W, 113 – 126 VDC; 500 W at 28 VDC/adapter
Thermal	Active heating, passive cooling
Low-rate data	*1 Mbps (MIL-STD-1553)
Medium-rate data	*6 Mbps (shared) - Return link (payload to ISS) only
Sites available per ELC	2 sites
Total ELC sites available	8 sites





Research Payload ExPA (see next chart)

Express Pallet Adapter (ExPA) Assembly
(GFE)

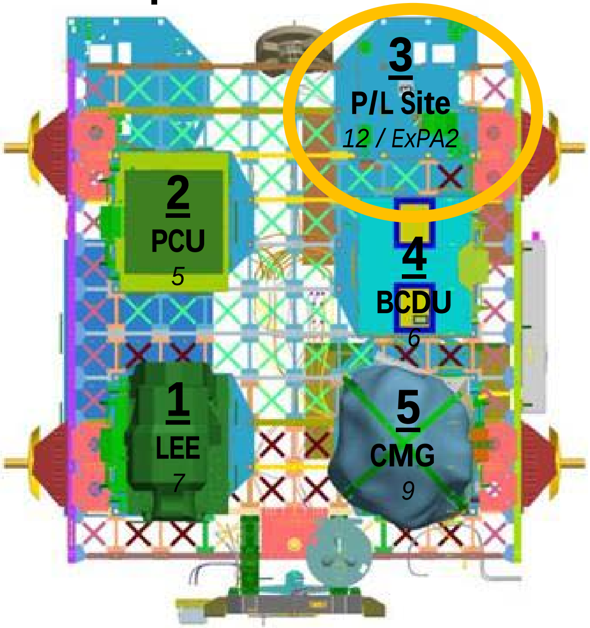
Express Pallet Adapter (ExPA) Assembly		
	ExPA overall Mass	255 lb
	ExPA overall dimension	46.05" x 47" x 13.06" (H)
	ExPA payload carrying capability	34" x 46" x 49" (H) and 500 lb"
	Payload electrical interface	Power(120VDC & 28VDC): Four NATC connectors Data (1553, Ethernet): Six NATC connectors
	Payload thermal interface	Active heating, passive cooling
	Payload structural interface	2.756" X 2.756" Grid with 250-28 UNF Locking Inserts and 1.625" diameter Shear Boss Provisions
	EVA compatibility	EVA handrail provisions
	EVR compatibility	All EVR interfaces on ExPA

Express Logistics Carriers Overview

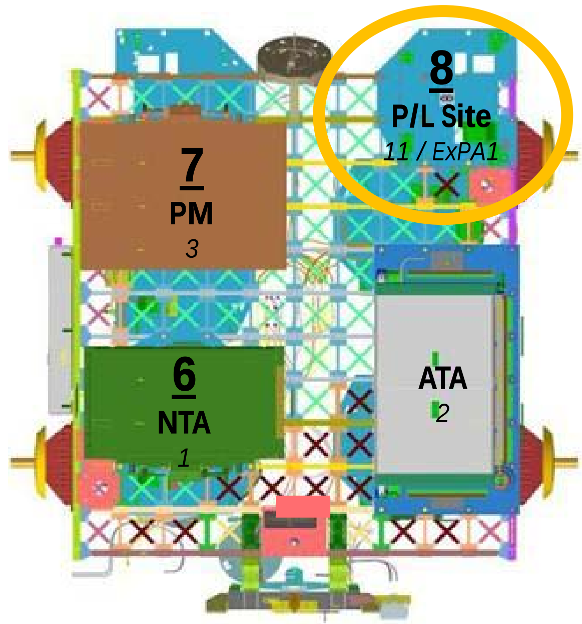
Payload Locations Circled

ELC-1
Port lower
2 Nadir payload sites

Top Side/Port Face

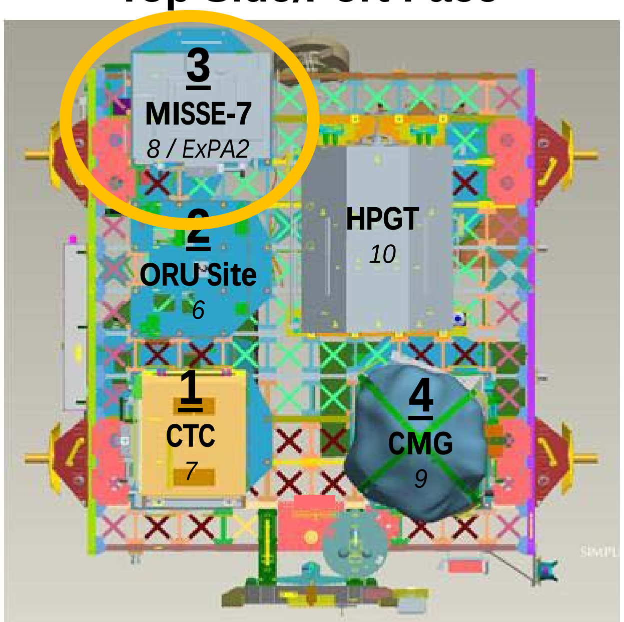


Keel Side/Starboard Face

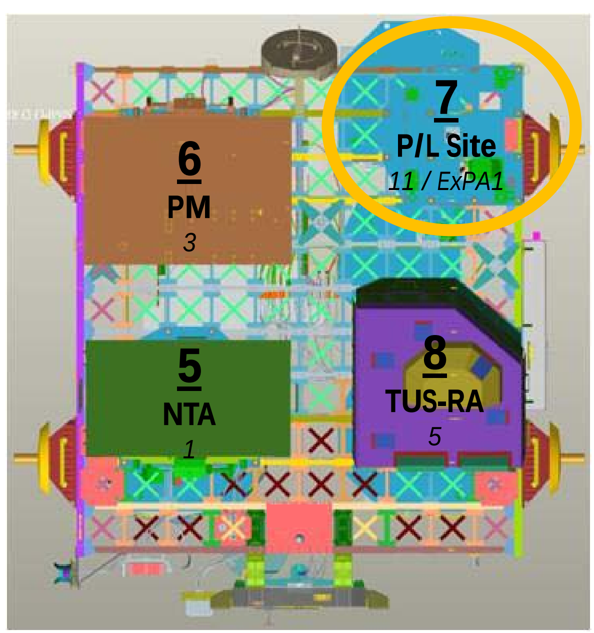


ELC-2
Starboard upper
2 Zenith payload sites

Top Side/Port Face



Keel Side/Starboard Face

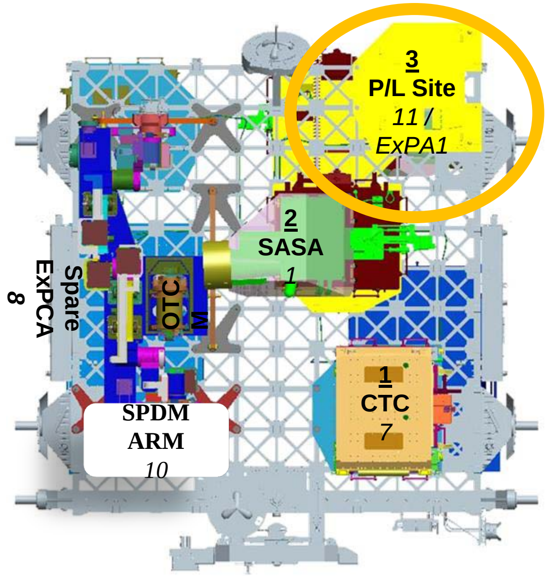


Express Logistics Carriers Overview

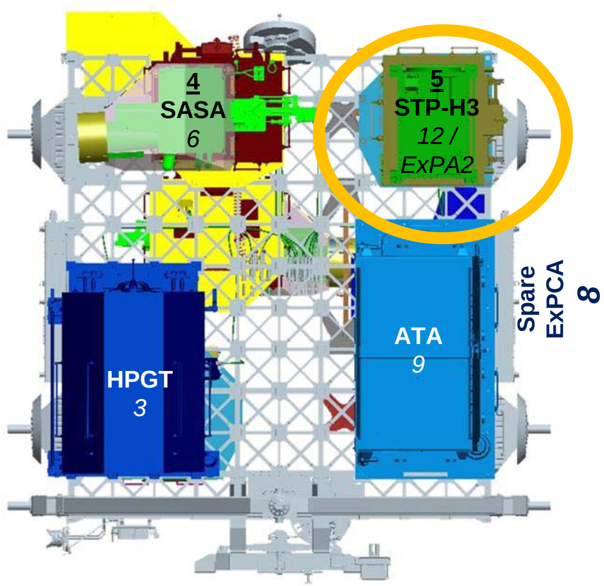
Payload Locations Circled

ELC-3
Port lower
2 Zenith payload sites

SSP Top Side / ISS Starboard Face

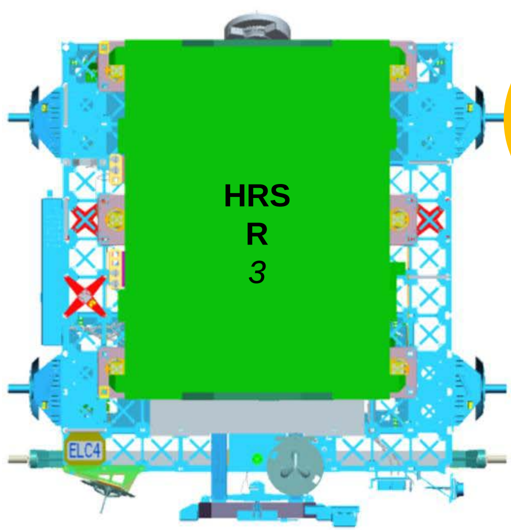


SSP Keel Side / ISS Port Face

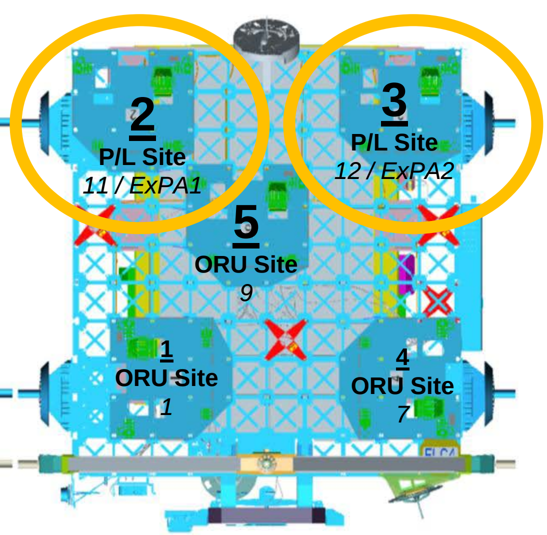


ELC-4
Starboard lower
2 Nadir payload sites

SSP Top Side / ISS Starboard Face



SSP Keel Side / ISS Port Face



Backup

ISS Results citations

(Top Journals)

Top ISS Results Citations

Journal	Citations
Nature	**MAXI:** Burrows, D. N., J. A. Kennea, G. Ghisellini, V. Mangano, B. Zhang, K. L. Page, and others, 'Relativistic Jet Activity from the Tidal Disruption of a Star by a Massive Black Hole', *Nature*, 476 (2011), 421–424 <doi:10.1038/nature10374>
Proceedings of the National Academy of Sciences of the United States of America	**InSPACE-2:** Swan, J. W., P. A. Vasquez, P. A. Whitson, E. M. Fincke, K. Wakata, S. H. Magnus, and others, 'Multi-scale Kinetics of a Field-directed Colloidal Phase Transition', *Proceedings of the National Academy of Sciences*, epub (2012) <doi:10.1073/pnas.1206915109> **Microbe:** Wilson, J. W., C. M. Ott, K. H. zu Bentrup, R. Ramamurthy, L. Quick, S. Porwollik, P. Cheng, et al. "Space Flight Alters Bacterial Gene Expression and Virulence and Reveals a Role for Global Regulator Hfq." *Proceedings of the National Academy of Sciences* 104, no. 41 (September 27, 2007): 16299–16304.<doi:10.1073/pnas.0707155104>
Physical Review Letters	**EXPPCS:** Manley, S., L. Cipelletti, V. Trappe, A. Bailey, R. Christianson, U. Gasser, and others, 'Limits to Gelation in Colloidal Aggregation', *Physical Review Letters*, 93 (2004) <doi:10.1103/PhysRevLett.93.108302>
Journal of Biological Chemistry	**JAXA-GCF:** Aritake, K., 'Structural and Functional Characterization of HQL-79, an Orally Selective Inhibitor of Human Hematopoietic Prostaglandin D Synthase', *Journal of Biological Chemistry*, 281 (2006), 15277–15286 <doi:10.1074/jbc.M506431200>

Top ISS Results Citations

Journal	Citations
PLoS ONE	**MDRV:** Wilson, James W., C. Mark Ott, Laura Quick, Richard Davis, Kerstin Höner zu Bentrup, Aurélie Crabbé, and others, 'Media Ion Composition Controls Regulatory and Virulence Response of Salmonella in Spaceflight', *PLoS ONE*, ed. by Frederick M. Ausubel, 3 (2008), e3923 <doi:10.1371/journal.pone.0003923> **FIT:** Marcu, Oana, Matthew P Lera, Max E Sanchez, Edina Levic, Laura A Higgins, Alena Shmygelska, and others, 'Innate Immune Responses of Drosophila Melanogaster Are Altered by Spaceflight', *PloS One*, 6 (2011), e15361 <doi:10.1371/journal.pone.0015361> **CERISE:** Etheridge, Timothy, Kanako Nemoto, Toko Hashizume, Chihiro Mori, Tomoko Sugimoto, Hiromi Suzuki, and others, 'The Effectiveness of RNAi in Caenorhabditis Elegans Is Maintained During Spaceflight', *PLoS ONE*, ed. by Anne C. Hart, 6 (2011), e20459 <doi:10.1371/journal.pone.0020459>
Journal of Neuroscience	**JAXA-GCF:** Mohri, Ikuko, Masako Taniike, Hidetoshi Taniguchi, Takahisa Kanekiyo, Kosuke Aritake, Takashi Inui, and others, 'Prostaglandin D2-mediated Microglia/astrocyte Interaction Enhances Astrogliosis and Demyelination in Twitcher', *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, 26 (2006), 4383–4393 <doi:10.1523/JNEUROSCI.4531-05.2006>
Journal of Geophysical Research	SMILES: Kikuchi, Ken-ichi, Toshiyuki Nishibori, Satoshi Ochiai, Hiroyuki Ozeki, Yoshihisa Irimajiri, Yasuko Kasai, and others, 'Overview and Early Results of the Superconducting

Top ISS Results Citations

Journal	Citations
Journal of Physical Chemistry B	**Ice Crystal:** Yokoyama, Etsuro, Izumi Yoshizaki, Taro Shimaoka, Takehiko Sone, Tatsuo Kiyota, and Yoshinori Furukawa, 'Measurements of Growth Rates of an Ice Crystal from Supercooled Heavy Water Under Microgravity Conditions: Basal Face Growth Rate and Tip Velocity of a Dendrite', *The Journal of Physical Chemistry B*, 115 (2011), 8739–8745 <doi:10.1021/jp110634t>
Geophysical Research Letters	**CEO:** Scambos, Ted, Olga Sergienko, Aitbala Sargent, Douglas MacAyeal, and Jim Fastook, 'ICESat Profiles of Tabular Iceberg Margins and Iceberg Breakup at Low Latitudes', *Geophysical Research Letters*, 32 (2005) <doi:10.1029/2005GL023802>
Langmuir	**CSI-02:** Cartwright, Julyan H E, Bruno Escribano, C Ignacio Sainz-Díaz, and Louis S Stodieck, 'Chemical-garden Formation, Morphology, and Composition. II. Chemical Gardens in Microgravity', *Langmuir: The ACS Journal of Surfaces and Colloids*, 27 (2011), 3294–3300 <doi:10.1021/la104193q>
NeuroImage	**Enose:** Kateb, Babak, M.A. Ryan, M.L. Homer, L.M. Lara, Yufang Yin, Kerin Higa, and others, 'Sniffing Out Cancer Using the JPL Electronic Nose: A Pilot Study of a Novel Approach to Detection and Differentiation of Brain Cancer', *NeuroImage*, 47 (2009), T5–T9 <doi:10.1016/j.neuroimage.2009.04.015>
Applied and Environmental Microbiology	**Microbe:** Crabbe, A., M. J. Schurr, P. Monsieurs, L. Morici, J. Schurr, J. W. Wilson, and others, 'Transcriptional and Proteomic Responses of Pseudomonas Aeruginosa PAO1 to Spaceflight Conditions Involve Hfq Regulation and Reveal a Role for Oxygen', *Applied and Environmental Microbiology*, 77 (2010), 1221–1230 <doi:10.1128/AEM.01582-10>

Top ISS Results Citations

Journal	Citations
New Journal of Physics	**ALTEA:** Narici, L, ‘Heavy Ions Light Flashes and Brain Functions: Recent Observations at Accelerators and in Spaceflight’, *New Journal of Physics*, 10 (2008), 075010 <doi:10.1088/1367-2630/10/7/075010>
Brain Research	**Neurocog:** Cheron, G., A. Leroy, C. De Saedeleer, A. Bengoetxea, M. Lipshits, A. Cebolla, and others, ‘Effect of Gravity on Human Spontaneous 10-Hz Electroencephalographic Oscillations During the Arrest Reaction’, *Brain Research*, 1121 (2006), 104–116 <doi:10.1016/j.brainres.2006.08.098>
FASEB Journal	**ROALD:** Battista, Natalia, Maria A Meloni, Monica Bari, Nicolina Mastrangelo, Grazia Galleri, Cinzia Rapino, and others, ‘5-Lipoxygenase-dependent Apoptosis of Human Lymphocytes in the International Space Station: Data from the ROALD Experiment’, *The FASEB Journal: Official Publication of the Federation of American Societies for Experimental Biology*, epub (2012) <doi:10.1096/fj.11-199406>
Journal of Urology	**Renal Stone:** Whitson, Peggy A., Robert A. Pietrzyk, Jeffrey A. Jones, Mayra Nelman-Gonzalez, Edgar K. Hudson, and Clarence F. Sams, ‘Effect of Potassium Citrate Therapy on the Risk of Renal Stone Formation During Spaceflight’, *The Journal of Urology*, 182 (2009), 2490–2496 <doi:10.1016/j.juro.2009.07.010>
Radiology	**VIIP:** Kramer, Larry A, Ashot E Sargsyan, Khader M Hasan, James D Polk, and Douglas R Hamilton, ‘Orbital and Intracranial Effects of Microgravity: Findings at 3-T MR Imaging’, *Radiology*, 263 (2012), 1–9 <doi:10.1148/radiol.12111986>

Top ISS Results Citations

Journal	Citations
American Journal of Physiology: Heart and Circulatory Physiology	**Cardiocog-2:** Aubert, A. E., B. Verheyden, C. d' Ydewalle, F. Beckers, and O. Van den Bergh, 'Effects of Mental Stress on Autonomic Cardiac Modulation During Weightlessness', *AJP: Heart and Circulatory Physiology*, 298 (2009), H202–H209 <doi:10.1152/ajpheart.00865.2009> **CCISS:** Zuj, K. A., P. Arbeille, J. K. Shoemaker, A. P. Blaber, D. K. Greaves, D. Xu, and others, 'Impaired Cerebrovascular Autoregulation and Reduced CO2 Reactivity After Long Duration Spaceflight', *AJP: Heart and Circulatory Physiology*, epub (2012) <doi:10.1152/ajpheart.00029.2012> **Vascular:** Arbeille, P., P. Kerbeci, L. Mattar, J. K. Shoemaker, and R. Hughson, 'Insufficient Flow Reduction During LBNP in Both Splanchnic and Lower Limb Areas Is Associated with Orthostatic Intolerance After Bedrest', *AJP: Heart and Circulatory Physiology*, 295 (2008), H1846–H1854 <doi:10.1152/ajpheart.509.2008>
New Phytologist	**Tropi:** Millar, Katherine D. L., Prem Kumar, Melanie J. Correll, Jack L. Mullen, Roger P. Hangarter, Richard E. Edelmann, and others, 'A Novel Phototropic Response to Red Light Is Revealed in Microgravity', *New Phytologist*, 186 (2010), 648–656 <doi:10.1111/j.1469-8137.2010.03211.x> **Multigen:** Solheim, B. G. B., A. Johnsson, and T.-H. Iversen, 'Ultradian Rhythms in Arabidopsis Thaliana Leaves in Microgravity', *New Phytologist*, 183 (2009), 1043–1052 <doi:10.1111/j.1469-8137.2009.02896.x>

Top ISS Results Citations

Journal	Citations
Opthalmology	**VIIP:** Mader, Thomas H., C. Robert Gibson, Anastas F. Pass, Larry A. Kramer, Andrew G. Lee, Jennifer Fogarty, and others, 'Optic Disc Edema, Globe Flattening, Choroidal Folds, and Hyperopic Shifts Observed in Astronauts After Long-duration Space Flight', *Ophthalmology*, [Epub ahead of print] (2011) <doi:10.1016/j.ophtha.2011.06.021>
Acta Crystallographica Section D: Biological Crystallography	**PCG-STES**: Vahedi-Faridi, Ardeschir, Jason Porta, and Gloria E. O. Borgstahl, 'Improved Three-dimensional Growth of Manganese Superoxide Dismutase Crystals on the International Space Station', *Acta Crystallographica Section D Biological Crystallography*, 59 (2003), 385–388 <doi:10.1107/S0907444902020310> **PCG-EGN:** Kundrot, C E, Snell, E H, Barnes, C L. Thaumatin crystallization aboard the International Space Station using liquid-liquid diffusion in the Enhanced Gaseous Nitrogen Dewar (EGN). Acta Crystallographica Section D: Biological Crystallography. 2002; 58 (Pt 5): 751-760. **CPCG-H:** Miele, A E, Federici, L, Sciara, G, Draghi, F, Brunori, M, Vallone, B. Analysis of the effect of microgavity on protein crystal quality: the case of a myoglobin triple mutant. Acta Crystallographica Section D: Biological Crystallography. 2004; D59: 928-988. **APCF:** Vergara, A, Carotenuto, L, Piccolo, C, Zagari, A, Castagnolo, D. Crystalization of the collagen-like polypeptide (PPG)10 aboard the International Space Station. 3. Analysis of residual acceleration-induced motion. Acta Crystallographica Section D: Biological Crystallography. 2003; 59 (pt4): 773-776.