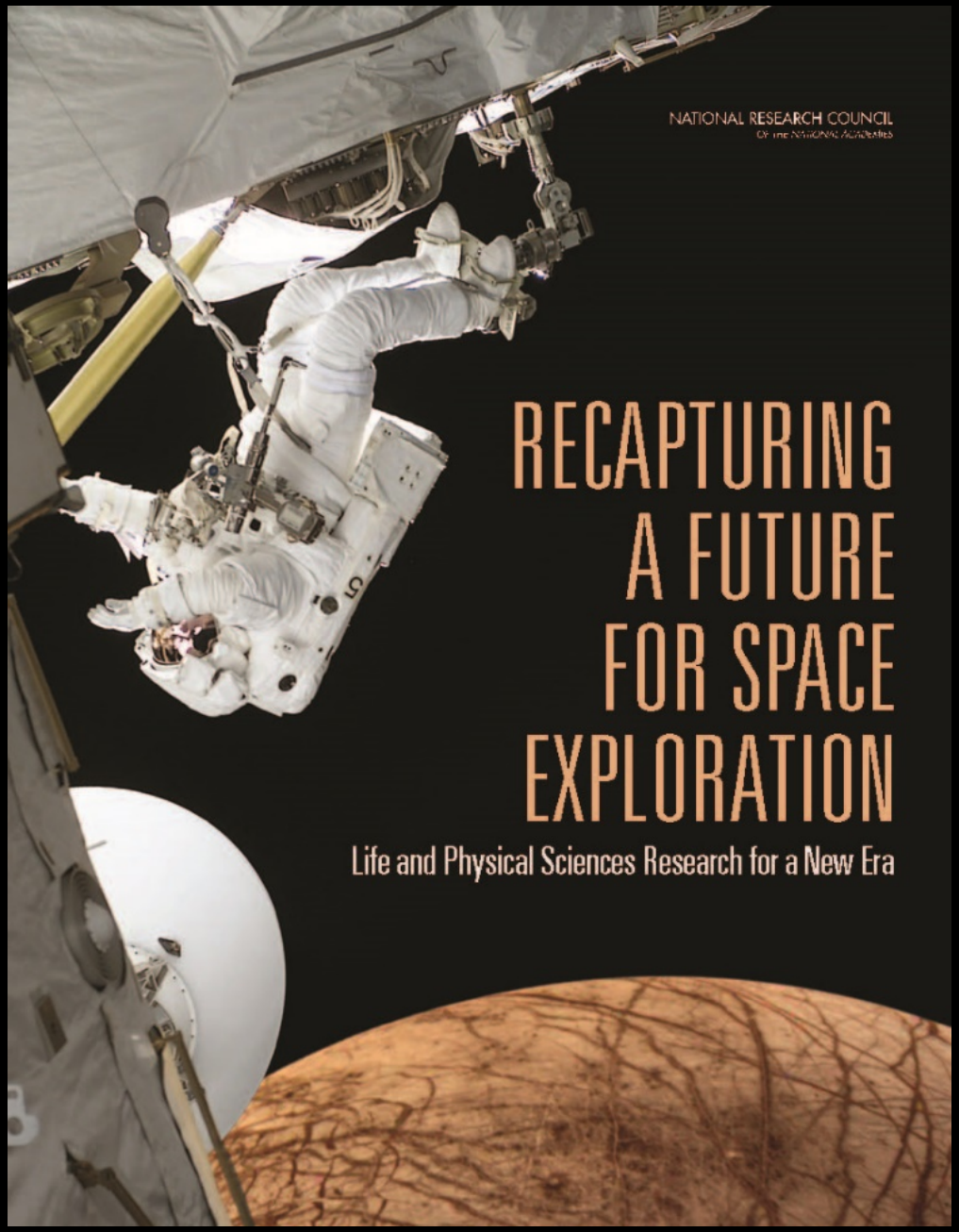
Life and Physical Sciences on the ISS, the Decadal, and the Future

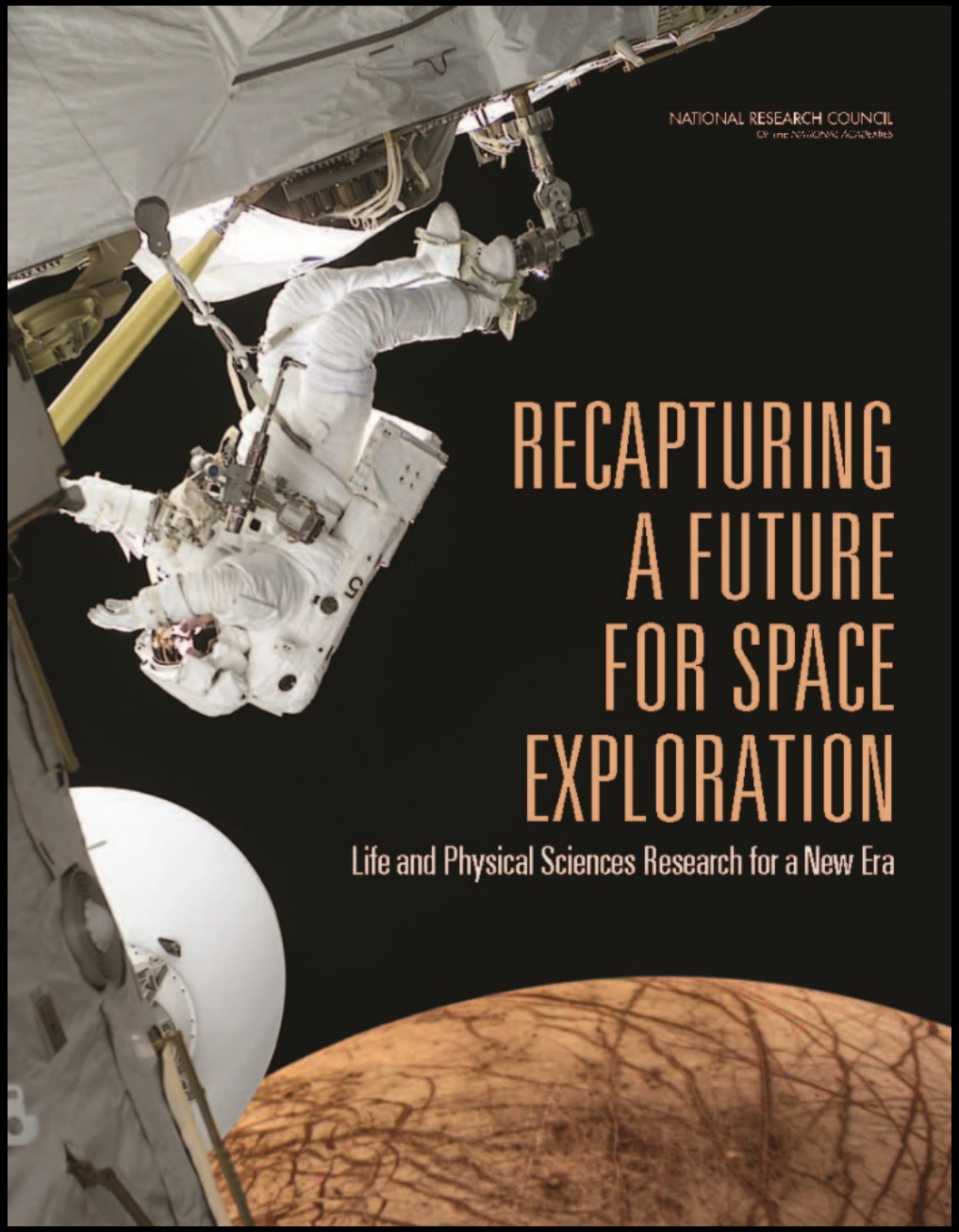


Life and Physical Sciences on the ISS, the Decadal, and the Future

Transition to the present

- Time
- Volume
- Opportunity

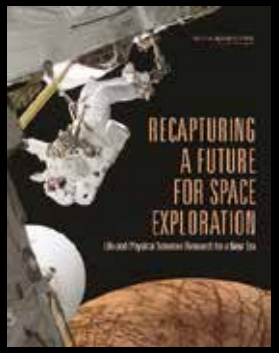
Transition to the future



- Transition from sortie mission science scenarios
- Longer term science
- Keep on the shelf
- Better opportunities
- X and Y more fully explored

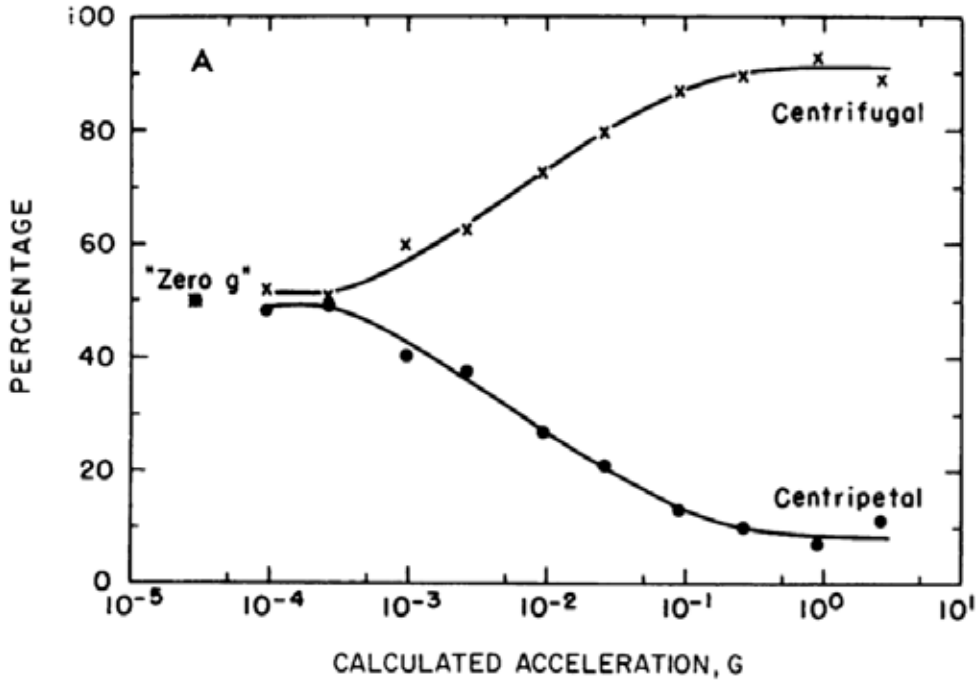
- Full biology time on orbit
- Repeated studies and evolution of projects
- Bigger better instruments for physics and physical sciences that were not good for shuttle

- Twin studies = time
- Plants over generations and life cycle - huge thing
- Full development of complex eukaryotes
- Microbial evolution
- Time on station, including loiter and options time
- Don Petit and other sorts of "time" issues on station
- Iterative deeply probing science where theory meets practice



Jeff Williams harvesting TAGES plants to KFT on orbit

- 50 years since theory laid down



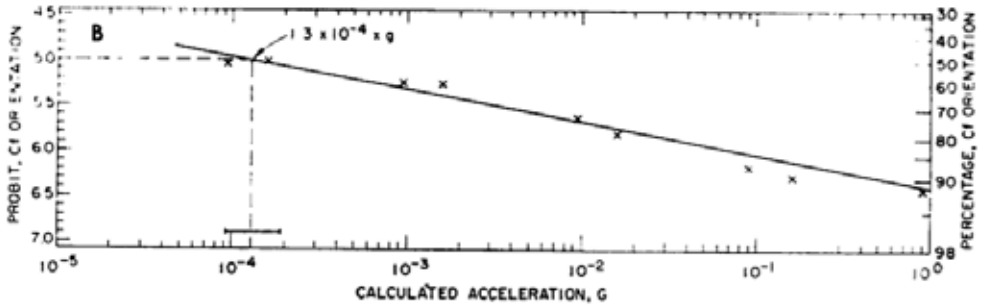


FIG. 8. Distribution of root orientations under various centrifugal accelerations (approx. 20 plants at each acceleration). A) observed distributions; B) probit/log regression fit of the data.

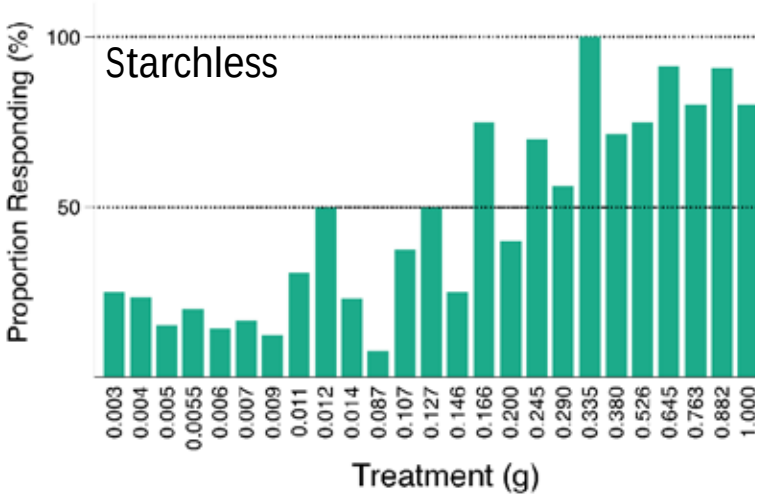
From Shen-Miller, J., Hinchman, R., & Gordon, S. (1968). Thresholds for Georesponse to Acceleration in Gravity-Compensated Avena Seedlings. Plant Physiology, 43(3), 338–344. https://doi.org/10.1104/pp.43.3.338

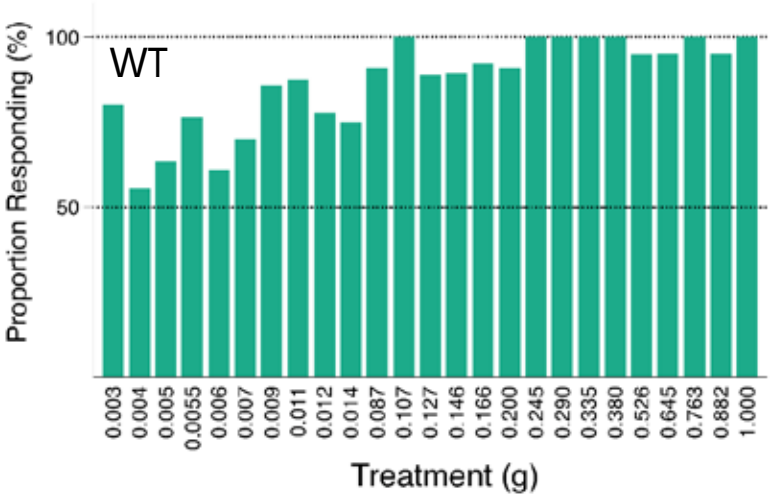
- 50 years since theory laid down - now shown experimentally

Characterizing Plant Gravity Perception Systems – ISS experiment conducted
January through April 2018

- Overall Objective: Test the effects of gravity as a continuous variable on plant growth using wild-type and starchless mutants, which lack a key component of gravity sensing.
- Used the EMCS centrifuge on the ISS to apply a range of accelerations from 0.003 g up to 1.0 g while collecting images for morphometric analyses; plant tissue was frozen at -80º C on board and returned for analysis of gene expression changes across continuum.
- Key Findings: Majority of WT roots responded to ≥ 0.003 g of acceleration, while starchless mutants showed >50% response rate only at or above 0.2 g. Statolith sedimentation system is key for maximum gravity perception.

Chris Wolverton, Ph.D.
Professor of Botany,
Ohio Wesleyan Univ.





WT, 0.003 g

starchless, 0.006 g

ISS NATIONAL LAB TODAY

DEMAND

ACADEMIC, NONPROFIT, & OGA PROJECTS (144)
NIH, NSF, MIT, MJFF, ORNL, Emory, Stanford, UCSD, & others

INDUSTRY PROJECTS (165)
AstraZeneca, Delta Faucet, Goodyear, Merck, & others

SUPPLY

AEROSPACE INDUSTRY PARTNERS
NASA, Airbus, Axiom, Bigelow, Sierra Nevada Corp., & others

COMMERCIAL IMPLEMENTATION PARTNERS (38)
BioServe, Space Tango, Techshot, MIS, Nanoracks, Teledyne Brown, & others

INVESTMENT

MEMBER INVESTOR NETWORK (164)

GOVERNMENT FUNDING PARTNERS
NASA, NIH, NSF, DoD, etc.

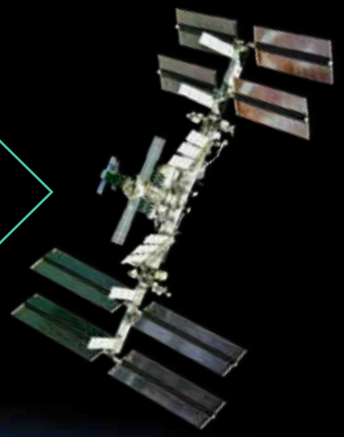
INDUSTRY FUNDING PARTNERS
Boeing, Apple, Target, etc.

499
PAYLOADS

ISS U.S. NATIONAL LABORATORY SPONSORSHIP

17
COMMERCIAL FACILITIES

3
COMMERCIAL RESUPPLY SERVICES (CRS) PROVIDERS



ADVANCED MATERIALS AND MANUFACTURING PORTFOLIO

9 Payloads flown

25 Projects in the portfolio, supported by **9** Implementation Partners

$13M in grant commitments from multiyear programs with NSF, including the new 2020 NSF/CASIS Transport Phenomena solicitation

9 payloads planned for FY20

3 patents and 1 product as a result of ISS National Lab R&D in this area

2019 Workshop Report with NASA

2019 Annual Results Highlights

Twin Study *(Science. Apr 2019; 364: 20 pp.)*

- This study demonstrated on the molecular level the resilience and robustness of how one human body adapted to the spaceflight environment compared to the Earth-bound twin.
- Results showed several spaceflight specific effects: decreased body mass, changes in chromosomes, carotid artery distension and a thickening of artery walls, alterations in eye structure, impacts to metabolism, changes in DNA activity, alterations in gut bacteria and impacts to cognitive processing.
- Several changes returned to baseline levels within 6 months after returning to Earth. The persistent changes observed after 6 months on Earth included a subset (8.7%) of changes in gene expression, increased DNA damage from chromosomal inversions, increased numbers of short telomeres, and attenuated cognitive function.

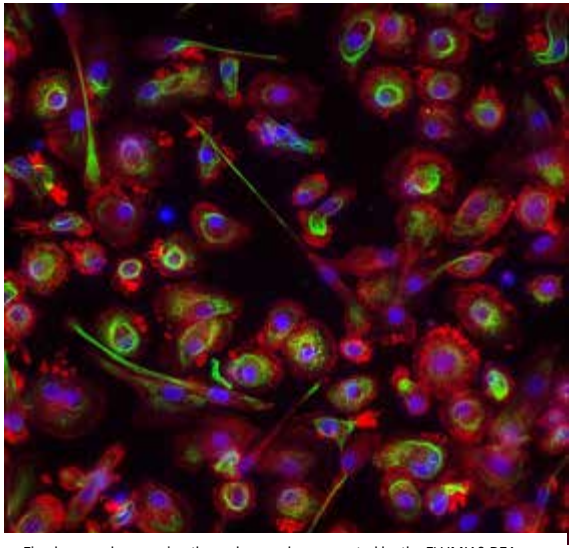
EXPLORATION

ISS crew member Scott Kelly (right) along with his twin brother, former astronaut Mark Kelly (left), prior to the 1-year mission aboard the ISS (JSC2015E004212).

FLUMIAS-DEA (*International Journal of Molecular Sciences*. Apr 2019; 20(8))

- The ISS crew successfully demonstrated the ability of the three-dimensional high-resolution fluorescence microscope to generate digital images of human T-cell
- This microscope can be used for real-time analysis of cell behavior during long-duration spaceflight.
- This fast imaging capability is needed to monitor cellular and molecular reactions that can occur more quickly in altered gravity environments.
- The implementation of real-time analysis methods on the ISS dramatically extends our knowledge about the dynamics of cellular reactions and adaptations to the space environment, a requirement for evidence-based medical risk assessment, abnormal cell monitoring and countermeasure development against diseases for exploration-class missions.

EXPLORATION



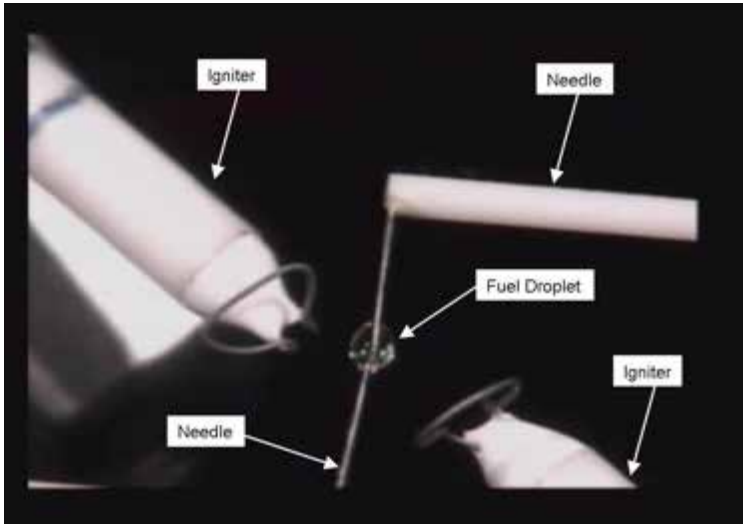
Fixed macrophages using three chromophores created by the FLUMIAS-DEA miniaturized fluorescence microscope during Science Verification Test. Image courtesy of Airbus (JSC2019E051831).

2019 Annual Results Highlights
Physical Sciences

FLEX (*Acta Astronautica. Feb 2019; j.actaastro.2019.01.045*

DISCOVERY

- Confirmed the existence of two high and low n-heptane burning regimes. The extinction of visible flame around a droplet resulted in a cool flame that continued to burn while invisible to the visualization system.
- The low temperature diffusion combustion for an isolated droplet has never been proposed or suggested before the FLEX-ROSCOSMOS investigation.
- The FLEXROSCOSMOS investigation analyzed data provided by NASA from NASA's FLEX experiment.

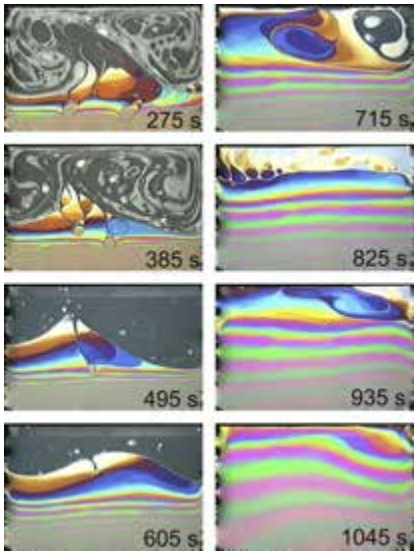


Video screen shot of Multi-user Droplet Combustion Apparatus Flame Extinguishment Experiment Ignition 1 on March 5, 2009 (GMT 64/17:21). Igniters continue to cool. Combustion event continues (Image courtesy of NASA).

OASIS (*New Journal of Physics. Jun 2019; 21(6): 063033)*

DISCOVERY

- OASIS demonstrates that Marangoni flow of liquid crystal film can transport inclusions, a mechanism that could be used in practical applications such as droplets of reactants for chemical reactions or microprobes in chemical sensors.
- OASIS demonstrates that when the film is heated in a region far from a meniscus, material is transported against the temperature gradient
- The hot region can grow by an expansion of existing holes or by the shrinkage of islands. Further growth of a homogeneous film region requires the creation of new holes by thermocapillary forces.



Climbing of smectic layers in a vertically suspended film under the influence of a vertical temperature gradient. A thermostated block at the lower frame edge was set to a temperature of Th = 70°C. The top of the frame was not heated; it remained approximately at room temperature (25°C). During the first 10 minutes, hot air flowing upward induces a pair of convection rolls in the upper thin film region (thickness ≈80 nm). The thicker regions that climb up are less sensitive to air flow, thus the convection ceases (Image courtesy of Stannarius R, et al. New Journal of Physics, 2019).

ISS Utilization Statistics: Expeditions 0-58
December 1998 – March 2019

Research Investigations	ISS Expeditions 55/56 Feb 2018 — Oct 2018	ISS Expeditions 57/58 Oct 2018 — Mar 2019	ISS Expeditions 0-58 Dec 1998 — Mar 2019
Total Investigations	356	303	2775
New Investigations	140	93	-
Completed/Permanent Investigations	103	79	2098
Number of Investigators with Research on the ISS	975	851	4022
Countries/Areas with ISS Investigations	58	49	108

Research Resources	ISS Expeditions 55/56 Feb 2018 — Oct 2018	ISS Expeditions 57/58 Oct 2018 — Mar 2019	ISS Expeditions 0-58 Dec 1998 — Mar 2019
Upmass	4114 kg	2814 kg	78514 kg
Downmass	1064 kg	833 kg	23559 kg
Crew Time	2997 hrs	1144 hrs*	43099 hrs

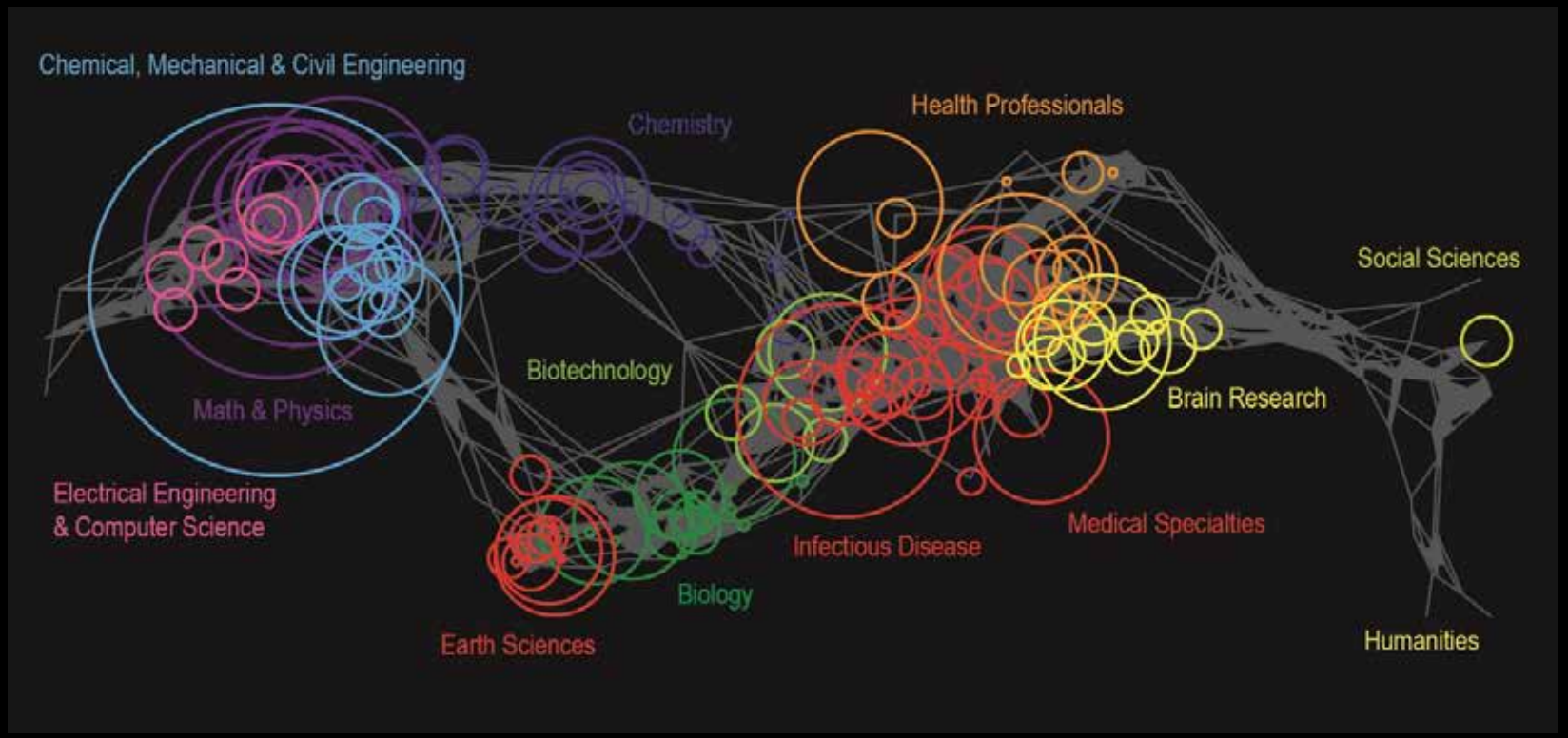
Number of Current Investigations on the International Space Station ‡	ISS Expeditions 59/60 Mar 2019 — Sep 2019
Total Investigations	388
New Investigations	139
Number of Investigators with Research on the ISS	982
Countries/Areas with ISS Investigations	36

‡ The investigations statistics represented in the Current Investigations reflect research planned for Expeditions 59/60. Future utilization projections are expected to increase as new integration process allows later manifesting of experiments. The numbers of investigations actually performed will be reported after completion of the expeditions.

* Expedition 57/58 crew time is lower than average due to the 56S launch anomaly and 3 crew on board.

ISS Results Are Large and Diverse

"Maps of Science (knowledge maps) can be used as a reference system to chart career trajectories, the location of emerging research frontiers, or the expertise profiles of institutes or nations"*. *Broner et al. 2012. *PLoS One July 7(7):*e39464



Life and Physical Sciences on the ISS, the Decadal, and the Future

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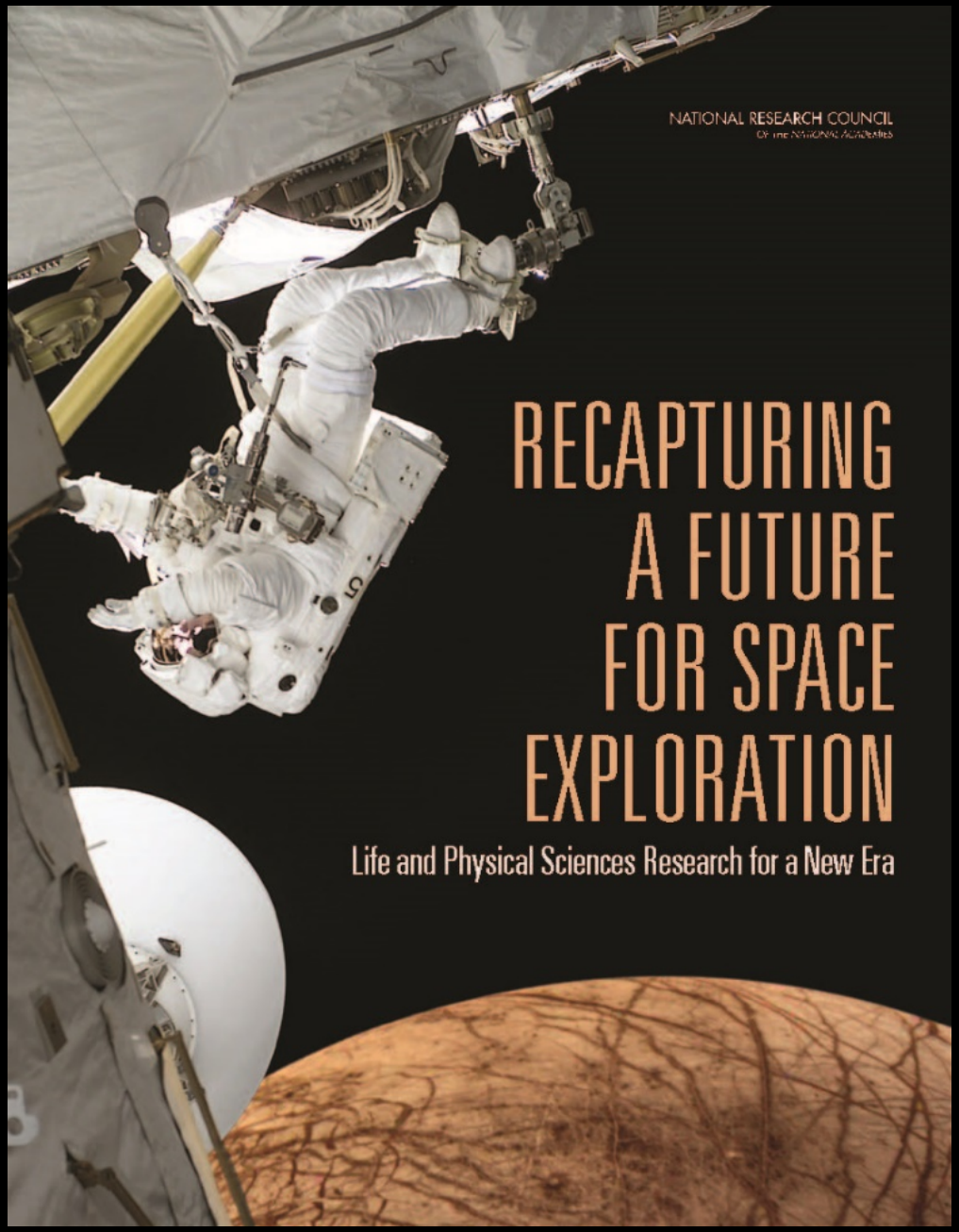
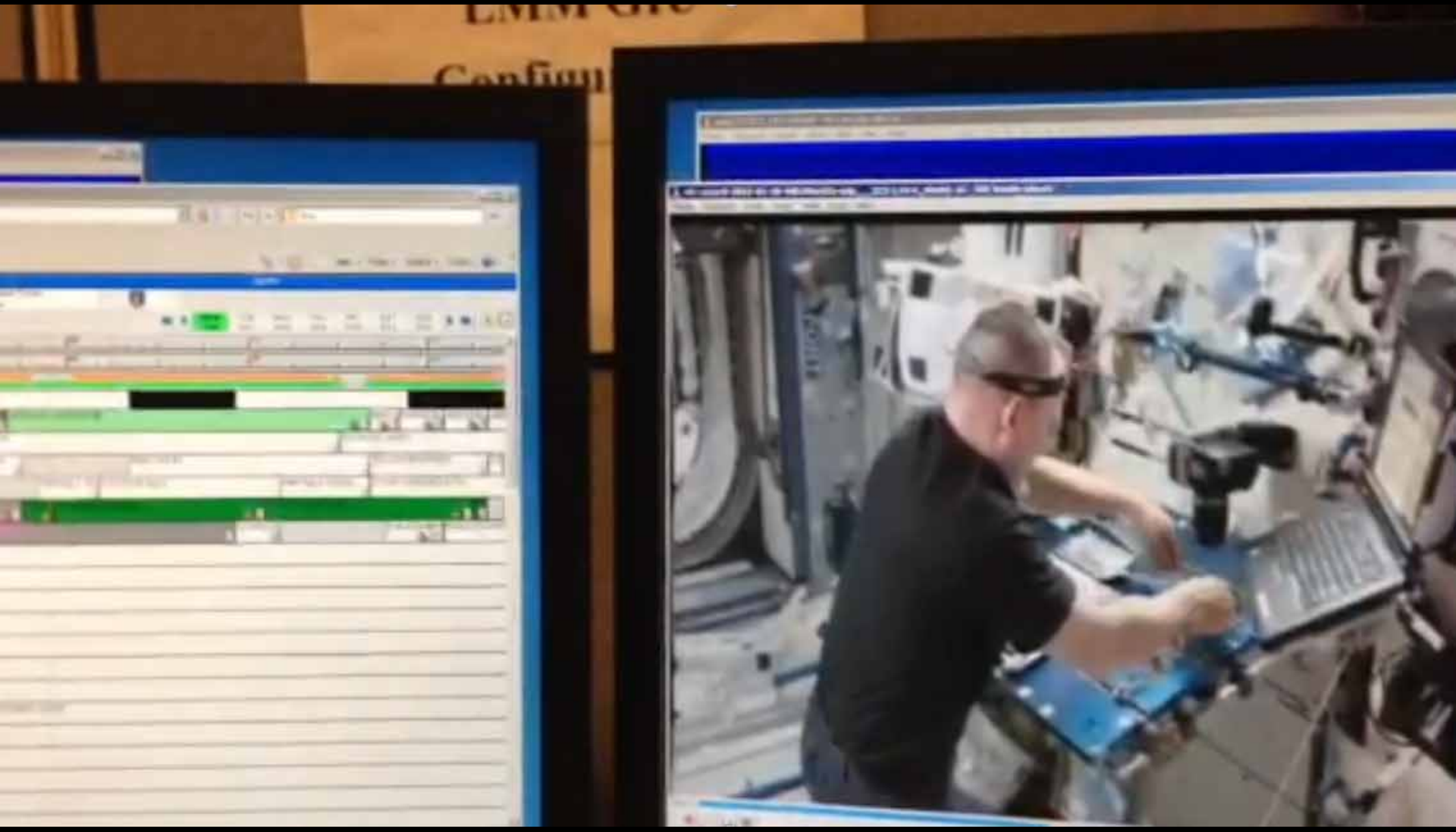
- Time
- Volume
- Opportunity

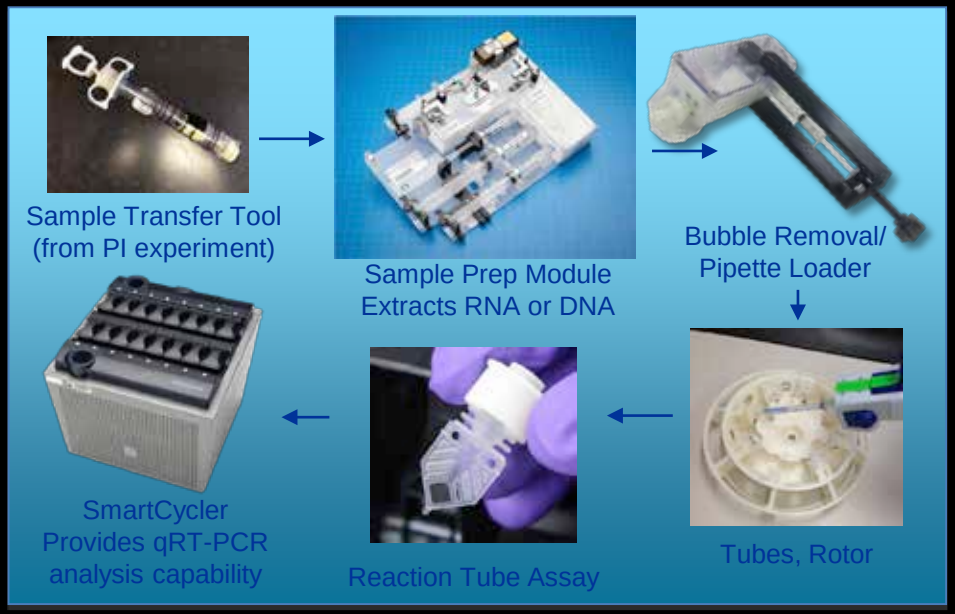
Transition to the future

- Time
- Volume
- Opportunity
- People





Life Sciences Sample Analysis Capabilities



Sample Preparation System: extracts RNA or DNA and prepares samples to be analyzed