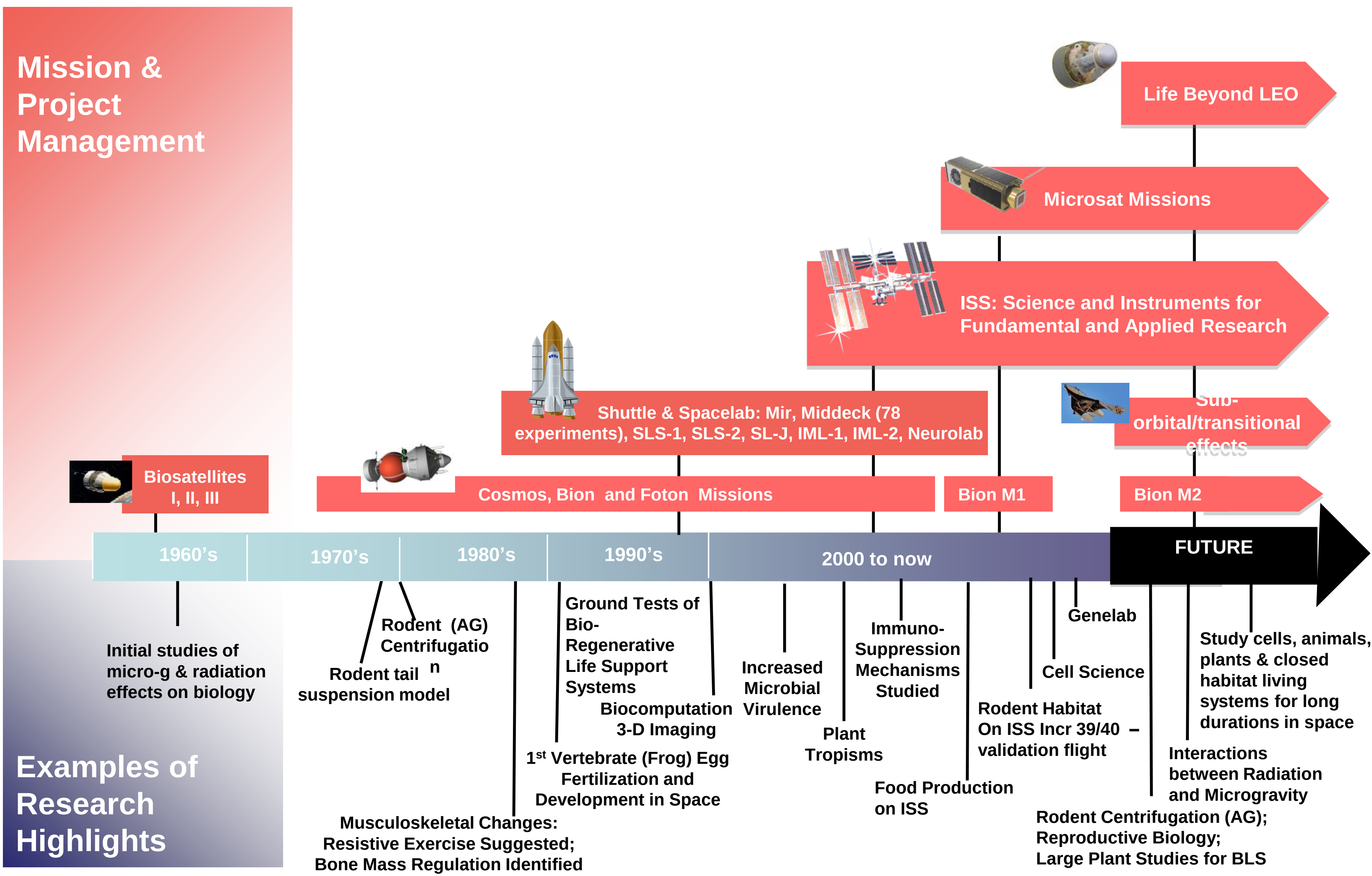
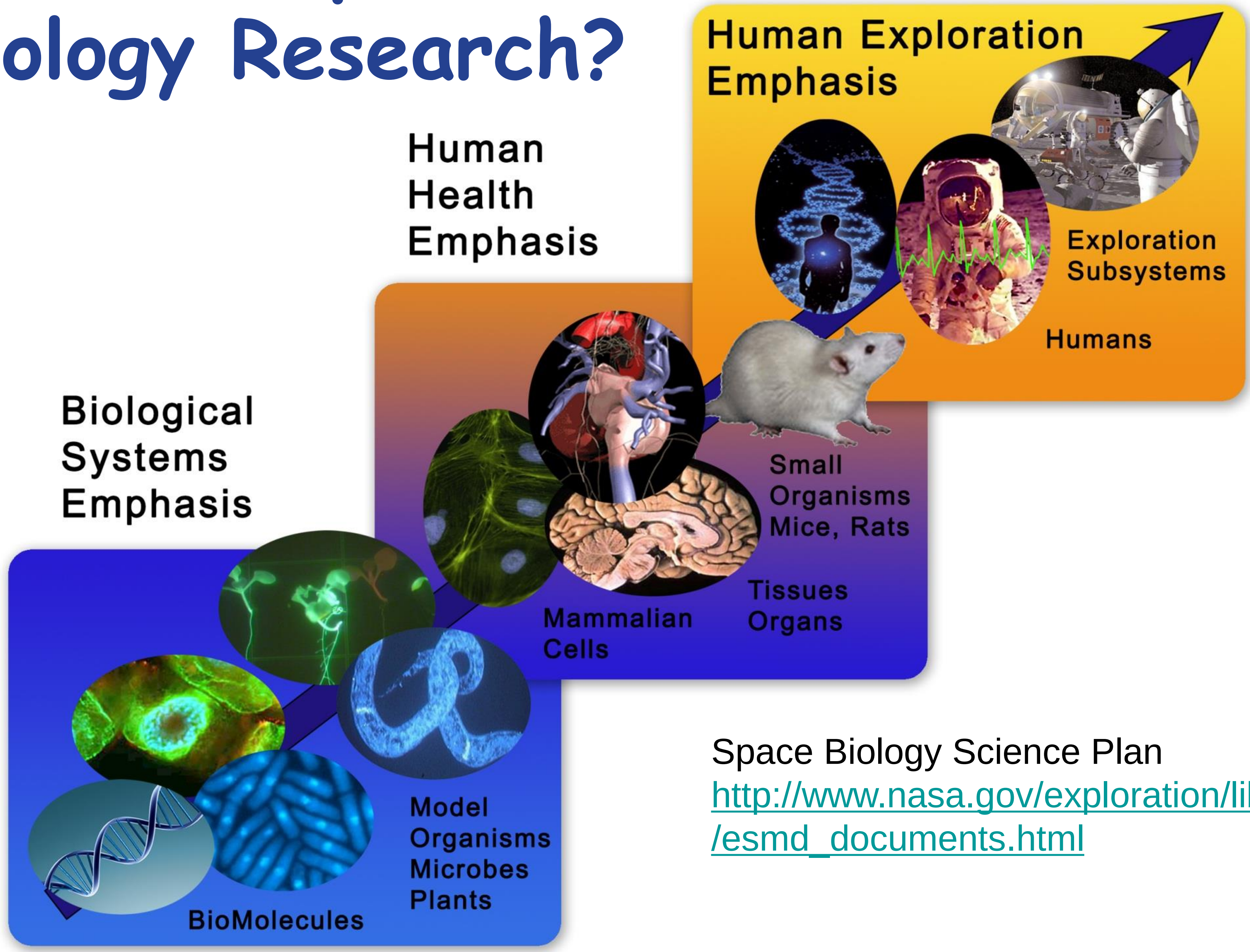
Current Status of NASA Space Biology
National Research Council
Committee on Biological & Physical Sciences in Space

Space Biology Team
Presented by David L. Tomko, Ph.D
Life & Physical Sciences Division
Human Exploration & Operations Mission Directorate
October 7, 2014

Six Decades of Space Biology Research



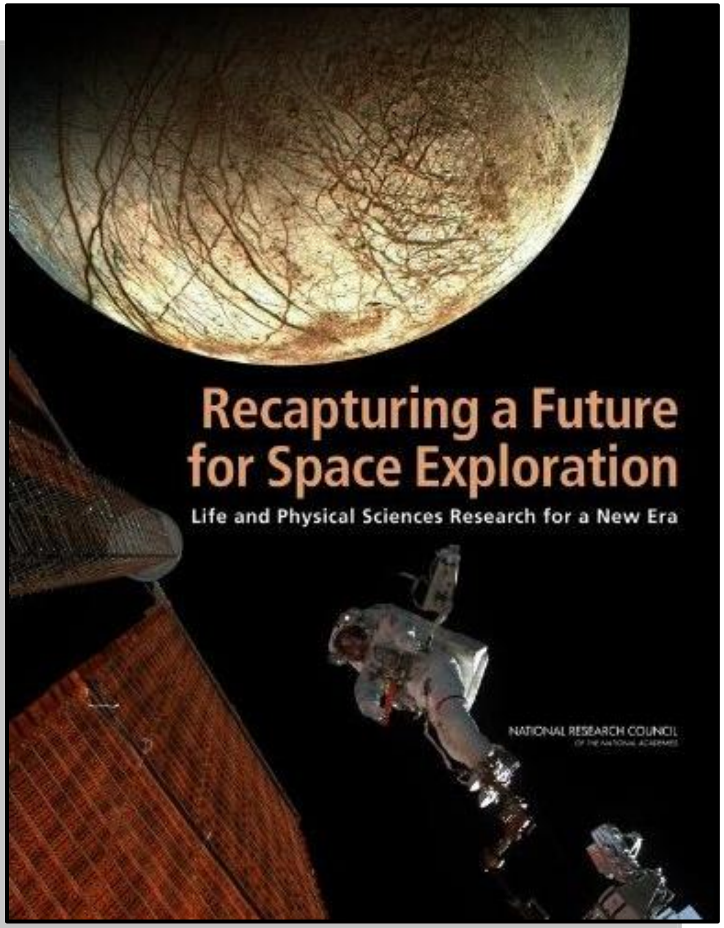
What is Space Biology Research?



Space Biology Science Plan
http://www.nasa.gov/exploration/library/esmd_documents.html

Space Life Sciences Recommendations for 2010-2020: NRC Decadal Study 2011

- Plant and Microbial Biology
  - Multigenerational studies
  - Responses to spaceflight
  - Plants and microbes in closed-loop life support
- Animal and Human Physiology
  - Bone and muscle studies
  - Drug/countermeasure evaluations
  - Vascular and interstitial pressure changes during spaceflight
  - Orthostatic intolerance
  - Deposition of aerosols in lung
  - T-cell and immune system studies
  - Multi-generation and early development
- Cross-Cutting Issues for Humans in Space
  - Artificial-G as a countermeasure
  - Animal studies to assess radiation risks
  - Cellular studies to define biomarkers for radiation toxicity
  - Understanding gender differences in adaption to spaceflight



http://www.nap.edu/catalog.php?record_id=12944

NASA Space Biology is Addressing the Highest Priority Recommendations of the Decadal Survey

ID	Recommendation
Plant and Microbial Biology	
P1	Microbial Observatory
P2	Plant and microbial growth and physiological responses to space
P3	Roles of microbial-plant systems in long-term life support systems
Animal and Human Biology	
AH2	Preservation/reversibility of bone structure/strength
AH3	Bone loss studies of genetically altered mice
AH4	New osteoporosis drugs should be tested in animal models
AH5	Underlying mechanisms regulating net skeletal muscle protein balance
AH7	Flexor and extensor muscles of the neck, trunk, arms, and legs
AH8	Basic mechanisms, vascular/interstitial pressures (Starling forces)
AH9	Microgravity and partial g (3/8 or 1/6 g) enabling levels of work capacity.
AH10	Integrative mechanisms of orthostatic intolerance (both 1 g and 3/8 g)
AH14	mechanism(s) of the changes in the immune system
AH15	Perform mouse studies of immunization and challenge on the ISS
AH16	Multigenerational studies
Crosscutting Issues for Humans in the Space Environment	
CC2	Determine whether artificial gravity (AG) is needed
CC8	Expand the use of animal studies to assess space radiation risks
CC10	Expand understanding of gender differences in adaptation to space

SLPS + ISS Funded:

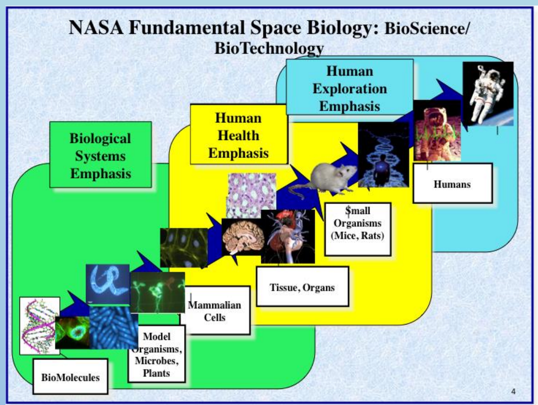
- Proposers required to identify link to Decadal Survey
- Grants for ground and flight research
- Core facilities for rodents, plants, fruit flies, and cells on ISS
- 1/yr flight rate for major research facilities on ISS (2/yr for rodents)
- Limited in-situ analytical capabilities
- geneLAB and Microbial Observatory

Not Funded (yet):

- Facilities to increase scientific throughput on-orbit
- Live animal return
- Multi-gen and gender rodent studies
- AG Facilities & Research
- Research beyond LEO
- Cross program integration

Implementing NASA Space Biology

NASA Fundamental Space Biology (FSB) Science Plan 2010-2020



GOALS

- Sponsor competitively solicited FSB research to create new knowledge of how biological systems adapt to space
- Use ISS, free-flyer, ground-based analogues or other venues to conduct cutting-edge FSB research
- Maintain an internationally competitive United States FSB scientific community
- Develop cutting edge technologies to facilitate conduct of biological research in space flight
- Train and inspire the next generation of U.S. Space Biologists

Goals

- Enhance our understanding of fundamental biological processes.
- Enable Biology research and technology to develop foundations for safe, productive human space exploration.
- Improve U.S. competitiveness, education, and the quality of life on Earth.

Research Emphases

- Microbiology
- Cell and Molecular Biology
- Organismal & Comparative Biology
- Developmental Biology
- Systems Biology Approach

Platforms

- Ground (hind limb suspension, Hyper-g, RWV, *etc.*)
- ISS / SpaceX / *etc.*
- Free Flyers (*e.g.* Bion, NanoSats, Sub-orbital)

NASA Space Biology 2009 Science Plan Priorities 2010-2020

Priority	2011-2015		Priority	2016-2020
High	Cell, Microbial and Molecular Biology on ISS		High	Animal and Plant research on ISS
	Development of Plant and Animal Habitats			Cell, Microbial and Molecular Biology on ISS
	Expanded Ground Res.: Plants, Animals, Cells			Free Flyers: Bion-M3
	Free Flyers: Bion-1, Bion-M2			Microsatellites
Medium	Microsatellites		Medium	Ground & Flt Research - Developmental Biology
	Advanced Technologies for ISS and Free Flyers			Ground Research - Plants, Animals, Cells
	Ground Research - Developmental Biology			Advanced Technologies for ISS and Free Flyers
	Education and Outreach			Education and Outreach
Low	Flight Research - Developmental biology		Low	Sub-Orbital Research

IMPLEMENTATION STRATEGY

1. Regular Research Solicitations
2. Experiments using most appropriate model & venue (e.g., Ground-based, sub-orbital, free fliers, ISS)
3. Hardware development driven by science requirements
4. Advanced Technology Development to achieve scientific goals
5. Education of the next generation of American scientists

Addressing the Space Biology Plan

Objectives in the Science Plan	Status
NRAs for ground and flight research	✓- Frequent NRAs augmented by ILSRA – "robust" ground-based research not fully implemented yet
Cell and Molecular Research	Core capability close to being established. Need on-orbit culturing and analysis
Organismal and Comparative Research	Core capability close to being established. Need flight centrifuge(s) for 1g control and fractional gravity. Need live animal return
Developmental Biology	? Need rodent research facilities to support dev bio studies in space
Nanosat	✓ 4 missions funded thru FY20
Bion	✓ 3 missions funded thru FY20
Free-flyer	? Need free flyer and secondary payloads for studies beyond LEO
In-situ analysis and advanced technology	Need more analytical equipment on-orbit to enable full laboratory capability on ISS
STEM	Need to augment research fellowships, new investigations and education outreach efforts

Regularly-Occurring Research Solicitations - 2000-2014

	Solicitation Number	Description	Step 1s/NOIs	Proposals received	Proposals Selected	Selection %
2014	NNH14ZTT002N	Research Opportunities for Flight Experiments in Space Biology (ILSRA 2014)	45	38	TBD	
2014	NNH14ZTT001N	Spaceflight Research Opportunities in Space Biology	112	92	26	28%
2012	NNH12ZTT001N	Research Opportunities in Space Biology	116	100	31	31%
2011	NNH11ZTT002N	Research Opportunities in Space Biology	52	52	15	29%
2011	NNH08ZDA009O-SCMAFSB	Small Complete Missions of Opportunity in Astrobiology and Fundamental Space Biology	10	6	2	33%
2009	NNH09ZTT004N	Research Opportunities for Flight Experiments in Space Life Sciences: Biological Research In Canisters for Arabidopsis	0	4	4	100%
2009	NNH09ZTT003N	Research Opportunities in Space Life Sciences: Fundamental Space Biology - Animal Physiology	25	25	5	20%
2009	NNH09ZTT002N	Research Opportunities for Flight Experiments in Space Life Sciences (ILSRA 2009)	13	11	6	55%
2008	NNH08ZTT003N	Research Opportunities for Fundamental Space Biology Investigations in Microbial, Plant and Cell Biology	71	69	17	25%
2007	NNH07ZTT001N	Research Opportunities for Space Flight Experiments: Bion-M1 Project	43	33	10	30%
2004		Research Opportunities for Flight Experiments in Space Life Sciences (ILSRA 2004)	154	148	12	8%
2003		Fundamental Space Biology NRA 03	120	118	28	24%
2001		Fundamental Space Biology 2001	119	100	28	28%
2001		STS-107 Biospecimen Sharing Plan	0	8	3	38%
2000		Life Sciences Intl Flight NRA (ILSRA 2000)	172	115	11	10%
2000		Fundamental Space Biology NRA 2000	217	157	31	20%
		TOTAL (2000-2014)	**1269**	**1038**	**229**	**22%**
2012	NNH12ZTT001L	NASA Request for Information (RFI) on Development of Strategies for the Collection, Management, and Distribution, or access to, 'Omics-type' Data Collected in the Course of Space Biology Research	21			

NNH14ZTT001N Selection STATISTICS

TYPE OF PROPOSAL	NEW TO SB	FORMER	INTRAMURAL	EXTRAMURAL
TOTAL # OF PROPOSALS = 92	69 (75%)	23 (25%)	16 (17%)	76 (82%)
TOTAL # PASSED PEER REVIEW = 49	32 (65%)	17 (35%)	11 (22%)	38 (68%)
TOTAL SELECTED FOR DEFINITION = 26	16 (62%)	10 (38%)	5 (19%)	21 (81%)

Space Biology Current Content

	Flight	Ground	Total
2014	38	36*	74
2013	41	24	65
2012	38	19	57
2011	32	19	51
2010	33	23	56
2009	24	22	46
2008	13	25	38
2007	15	68	83
2006	20	101	121
2005	19	119	138
2004	19	136	155

*FY2014 Ground includes 8 New Investigation Grants

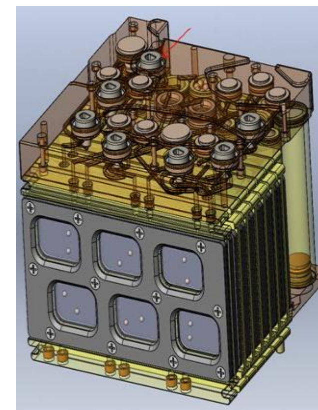
NASA Space Biology 2009 Science Plan: Status of Priorities 2010-2015

- Cell, Microbial and Molecular Biology on ISS (FY2014 tasks)
- Cell Biology – 6
- Microbiology -7 (5 Team & 1 individual proposals passed peer review in ILSRA 2014)
- Mouse – 11 (5 Team, 3 Tissue sharing & 1 individual proposals passed peer review in ILSRA 2014)
- Plant – 11 (1 Team & 1 individual proposals passed peer review in ILSRA 2014)
- Invertebrate – 2 (3 individual proposals passed peer review in ILSRA 2014)
- Development of Plant and Animal Habitats
- Expanded Ground Research –Plants, Animals and Cells (FY2014 tasks)
- Cell Biology – 3
- Mammals – 12
- Microbiology – 3
- Plant – 6
- Invertebrate – 4
- Free Flyers – Bion M1 and M2
- Microsatellites – EcamSat, Sporesat, Eu:Cropis
- Advanced Technologies for ISS and Free Flyers
- Ground Research on Developmental Biology
- Education and Outreach
- Flight Research – Developmental Biology

Cell culture and microbial culture incubator system (CGBA)

Micro 8 - Nielsen-Preiss

(Candida albicans – biofilms)



Micro-5 Nickerson

(C. elegans & Salmonella Videography upgrade)

Micro-5

PI: Cheryl Nickerson, Arizona State University
Co-Is: John Alverdy, University of Chicago; C. Mark Ott, NASA, JSC; Catherine Conley, NASA, HQ.
PS: Macarena Parra
***PM:** Jake Freeman (BioServe Technologies)*
Engineering Team: BioServe Technologies

Objective:
1) Determine the effect of spaceflight on the host-pathogen interaction in real time as a function of media ion composition when both *C. elegans* (host) and *S. typhimurium* (pathogen) are simultaneously exposed to spaceflight.
2) Determine the evolutionarily conserved role for spaceflight-responsive RNA binding proteins in both *C. elegans* and *S. typhimurium* as a function of media ion composition before and after infection when both the host and the pathogen are simultaneously exposed to spaceflight.
3) Evaluate the use of phosphate and Polyethylene Glycol as a nutritional countermeasures to protect *C. elegans* against *S. typhimurium* induced lethality as a function of media ion composition when both host and pathogen are simultaneously exposed to spaceflight.

Relevance/Impact:
This experiment responds to the 2011 NRC Decadal Survey highest priority recommendation P2 and the 2010 Space Biosciences Roadmap – Cell, Microbial, and Molecular Biology. Previous studies show that pathogens are more virulent in microgravity while host immune systems are compromised. Therefore, further understanding the host-pathogen interactions in the spaceflight environment are critical to our ability to treat infections during long term spaceflight. This is the first study to examine host pathogen interactions during an on-orbit infection.

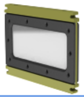
Development Approach:
1) Experiment development and biocompatibility testing in the hardware are complete
2) Testing to define and verify optimal storage conditions for samples
3) Integrated tests using the flight hardware
4) Experiment Verification Test to verify procedures and hardware settings (risk mitigation)
5) Facility Trail Run at KSC to verify supplied space and equipment will support the pre-flight operations

Instrumentation & Experiment Summary

1) Pre-flight, bacteria and nematodes are loaded in separate hardware compartments in stasis.
2) On orbit, both organisms are activated with growth media and allowed to grow/recover.
3) The Commercial Generic Bioprocessing Apparatus (CGBA) is used to provide temperature control and video capabilities.
4) Bacteria (control and Salmonella) are used to infect the nematodes and viability is tracked using video from a scanning camera system
5) At predetermined time points the hardware is removed and samples are withdrawn for microscopy (fixed with Paraformaldehyde) and RNA studies (fixed with RNALater)

Module

Biocell



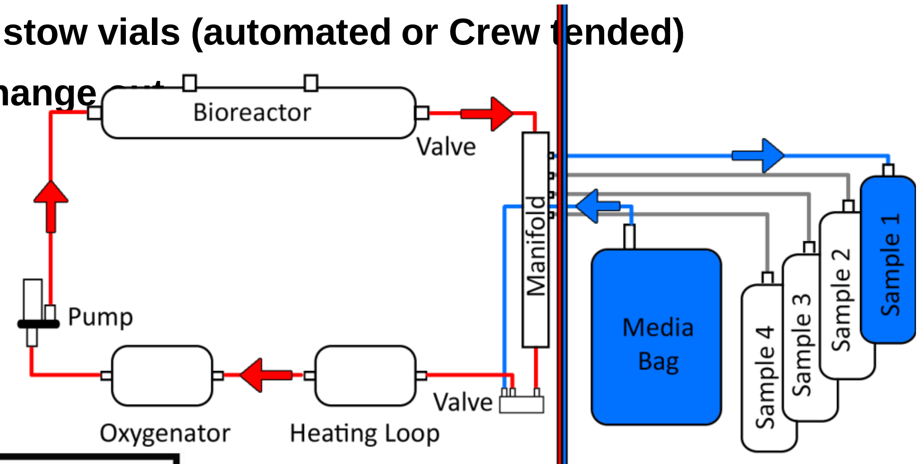
CGBA

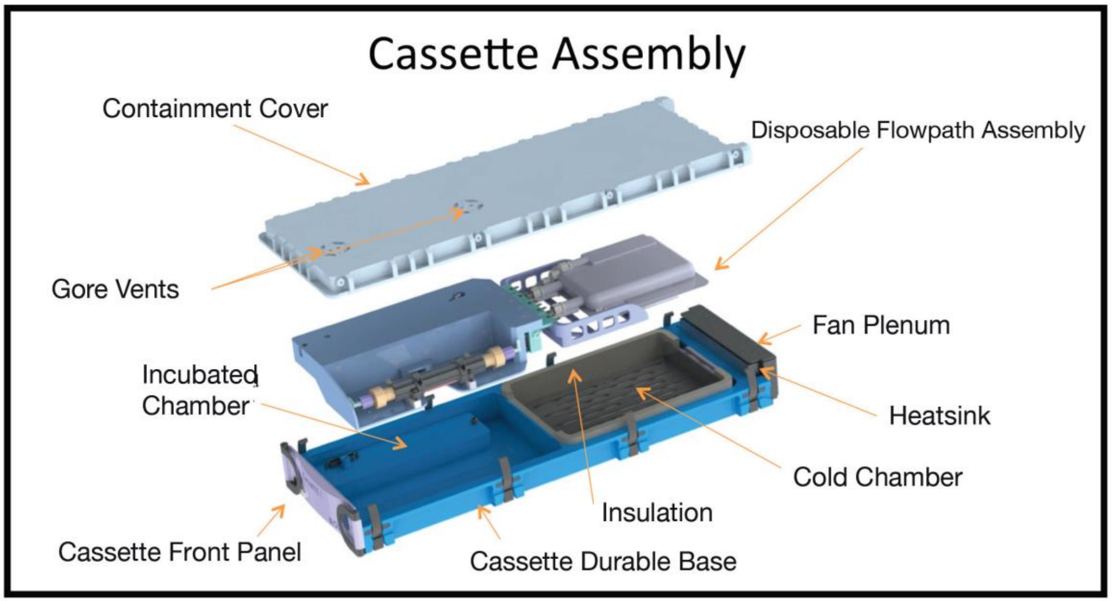
Biological and Physical Science Requirements

Accommodation (carrier)	CGBA on ISS
Upmass (kg) (w/o packing factor)	25 kg
Volume (m^3) (w/o packing factor)	1 MLE
Power (kw) (peak)	0.090 kW (ascent) 0.070 kW
Crew Time (hrs)	10 hrs
Autonomous Ops (hrs)	Approximately 24 hr
Launch/Increment	SpX-3; Nov. 28, 2013 (returned on SpX-3)

Bioculture System

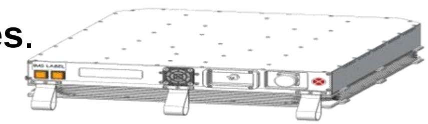
- Adherent and non-adherent cell types
- On-orbit initiation of culture from frozen or cold stow vials (automated or Crew tended)
- Controllable CO_2, O_2, temperature and media change out
- 10 independently controllable cartridges
- 5ºC to 45ºc
- Validation Flight SpX 5
- Inflight samples, start new cultures, fix in flight,



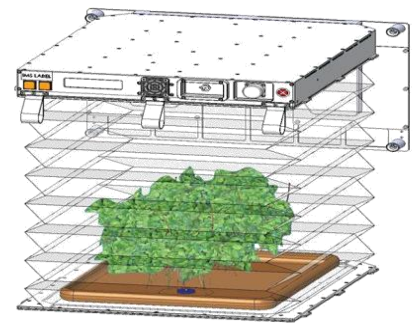


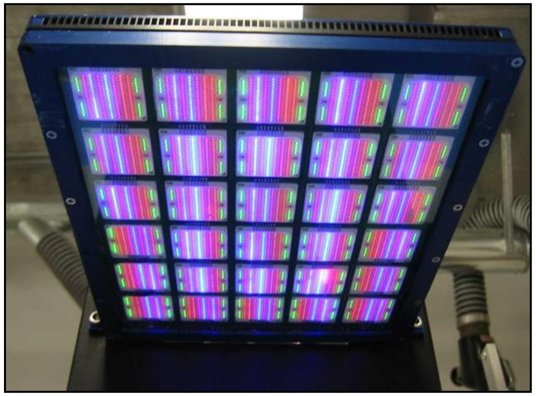
Vegetable Production Plant Unit (VEGGIE)

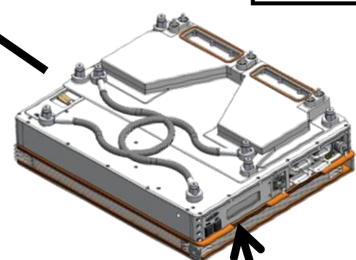
- The Vegetable Production Unit (VEGGIE) has been designed to **produce fresh vegetables on ISS**.
- It will have near term **psychological benefits** for the crew as a source of recreation/aesthetics and long term benefits as a minor food supply for future missions.
- To be used for both **Science and Outreach Activities**.



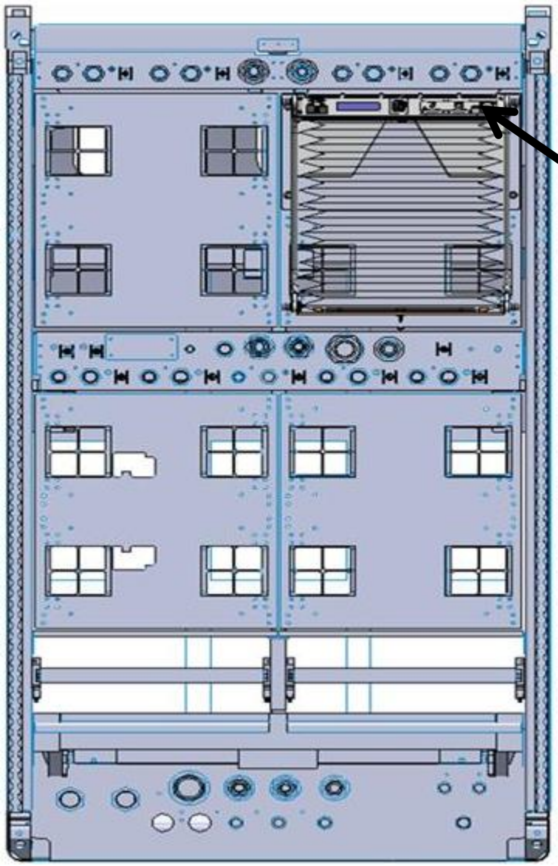
Stowed ↑
Operational Configuration →

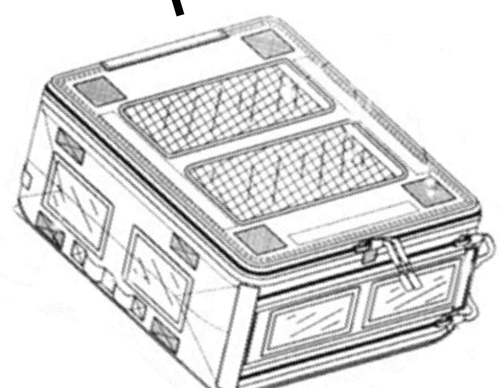






Veggie unit





Express Rack

Cargo Transfer Bag (CTB)

Veg-01 Hardware Validation Payload for the Vegetable Production Unit (VEGGIE)

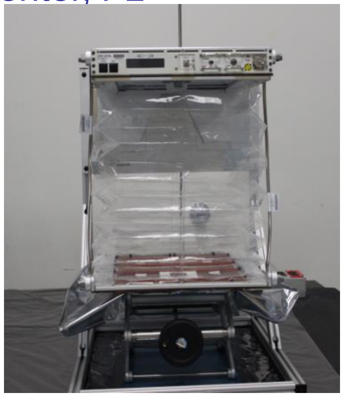
Science Team: Gioia D. Massa, Ph.D., NASA, Kennedy Space Center, FL; Dr. Robert Morrow, ORBITEC, Madison, WI; Raymond M. Wheeler, Ph.D., NASA, Kennedy Space Center, FL

Objective/Background:

•Assess ease of set-up and operation of VEGGIE hardware and science
•Assess capacity for Veggie hardware and pillows to effectively germinate seeds
•Assess capacity for Veggie hardware and pillows to effectively sustain plant growth and adequate media moisture

- Compare growth in different media combinations
- Collect environmental data via data logger (e.g. HOBO)
- Record plant development with photographs

•Assess crew handling aspects of VEGGIE and determine effectiveness of established crew procedures
•Assess crew psychological benefits of plant growth and crew acceptance of VEGGIE operations (questionnaire)
•Analyze microbial status and assess sanitation methods



VEGGIE Facility

Relevance/Impact:

•On the International Space Station, although volume and power constraints limit the size of plant systems, the ISS can still provide a valuable flight setting to test many issues related to crop production. Key among these is:

- The value of adding fresh (perishable) foods on a regular basis to the crew's diet
- The potential for providing a positive effect on the crew's well-being by having plants in their environment. To date, no large scale crop production tests have been conducted in space, hence the need for a functioning flight system with more growing volume than previous experimental systems.

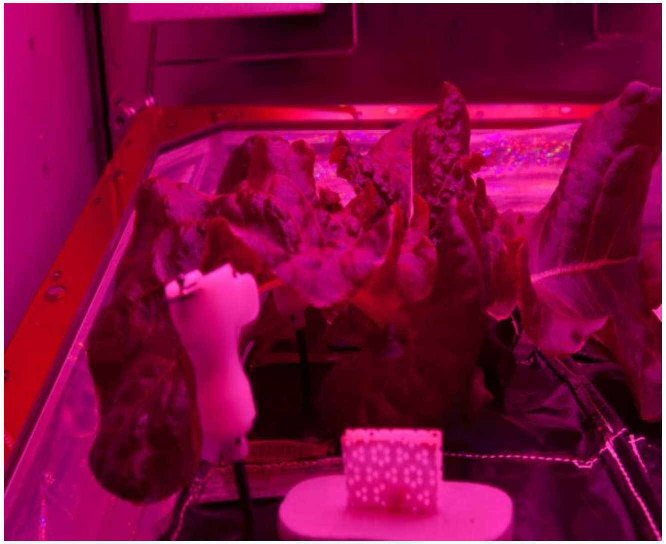
•As with all basic research, an improved understanding of the basic growth and environmental response phenomena of living organisms has important implications for improving growth and biomass production on Earth, thus benefitting the average citizen. Veggie technology might also be readily adaptable to horticultural therapy and recreational activities for elderly or disabled individuals.

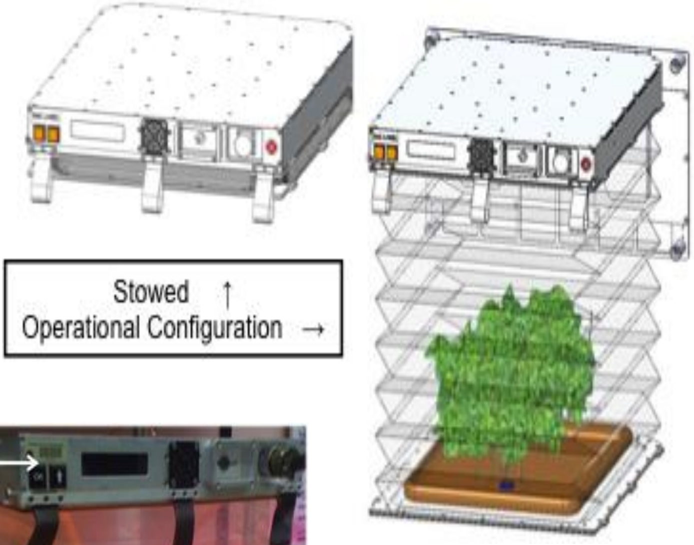
'Outredgeous' red leaf lettuce grown in Veg plant pillow

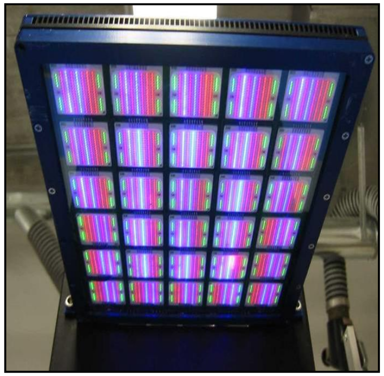
Experimental Approach:

- Flying to ISS on SpaceX-3, Veg-01 assess on-orbit function and performance of the Veggie facility, and focus on the growth and development of 'Outredgeous', 'Lettuce (*Lactuca sativa*) seedlings in the spaceflight environment and the effects of the spaceflight environment on composition of microbial flora on the Veggie-grown plants and the Veggie facility.

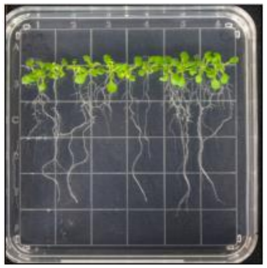
Veggie





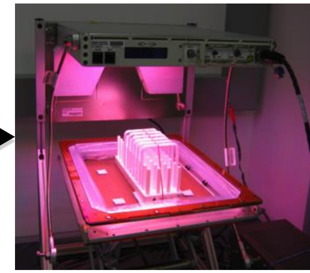


APEX Science Investigations in VEGGIE

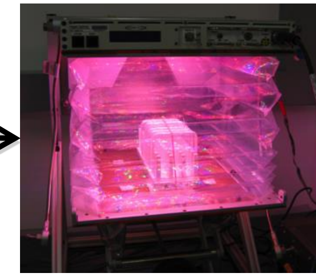


Arabidopsis seedlings on petri plate.

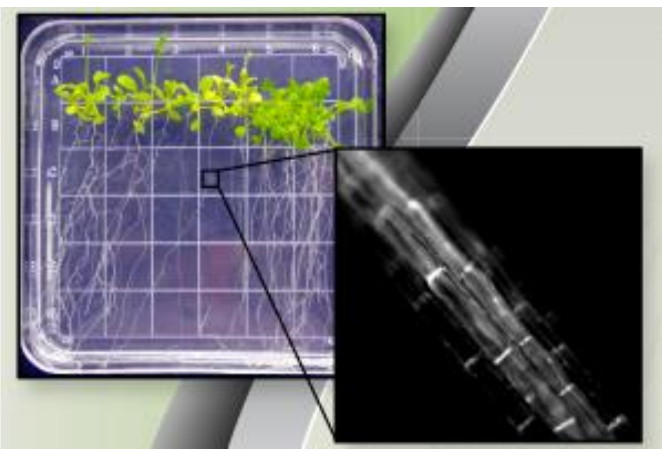
COTs Arabidopsis plate holder for VEGGIE concept.



COTS petri plate holder in Veggie baseplate with bellows lowered.



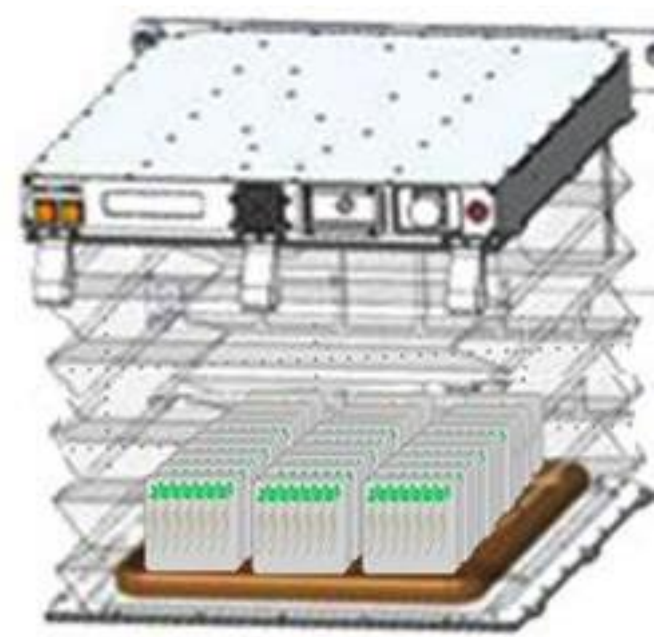
Petri plate holder in VEGGIE with bellows closed.



Fluorescent image of Arabidopsis root taken in LMM.

LMM Photography

Crew Photography



Arabidopsis plates in VEGGIE concept.

Kennedy Fixation Tube (KFT).

Space Experiments Provide Insight into Molecular Biological Responses to Extraterrestrial Environments: Advanced Plant Experiment (APEX) – 03

PI: Dr. Robert Ferl, University of Florida
Co-PI: Dr. Anna-Lisa Paul, University of Florida

Objective/Background:

•Plants experiencing spaceflight are quite normal in appearance but can exhibit growth habits distinctly different from plants on earth. This research specifically addresses growth and molecular changes that occur in *Arabidopsis thaliana* plants during spaceflight. By using molecular and genetic tools, fundamental questions regarding root structure, growth and cell wall remodeling may be answered.

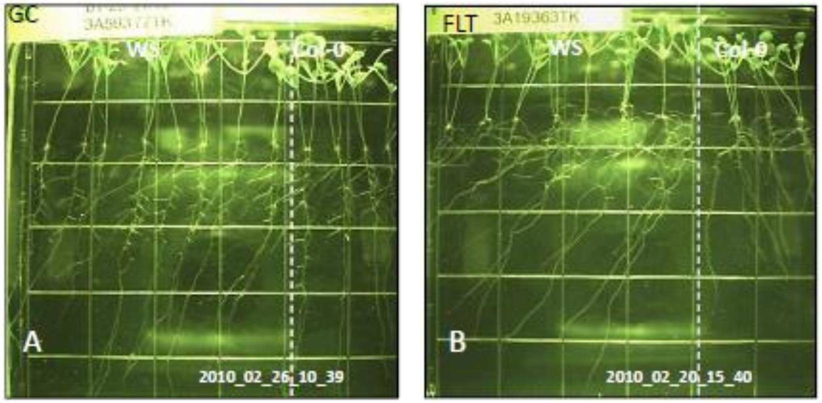
Relevance/Impact:

- **Benefit:** This investigation will advance the fundamental understanding of the molecular biological responses to extraterrestrial environments. This understanding helps to further define the impacts of spaceflight on biological systems to better enable NASA's future space exploration goals.
- **Significance:** An improved understanding of the basic growth and environmental response phenomena of living organisms has important implications for improving growth and biomass production on Earth, thus benefitting the average citizen.

Experimental Approach:

•Scheduled to Launch on SpX-4 during Inc 39/40.

•APEX-03 will utilize the Advanced Biological Research System (ABRS) facility and the Green Fluorescent Protein (GFP) imaging system currently on ISS. Specimens will be harvested on-orbit, preserved with a chemical fixative, and returned to the ground for post-flight evaluation.



A) Ground control root growth from APEX-01
B) Flight root growth from APEX-01

BMC Plant Biology 2012, 12:232

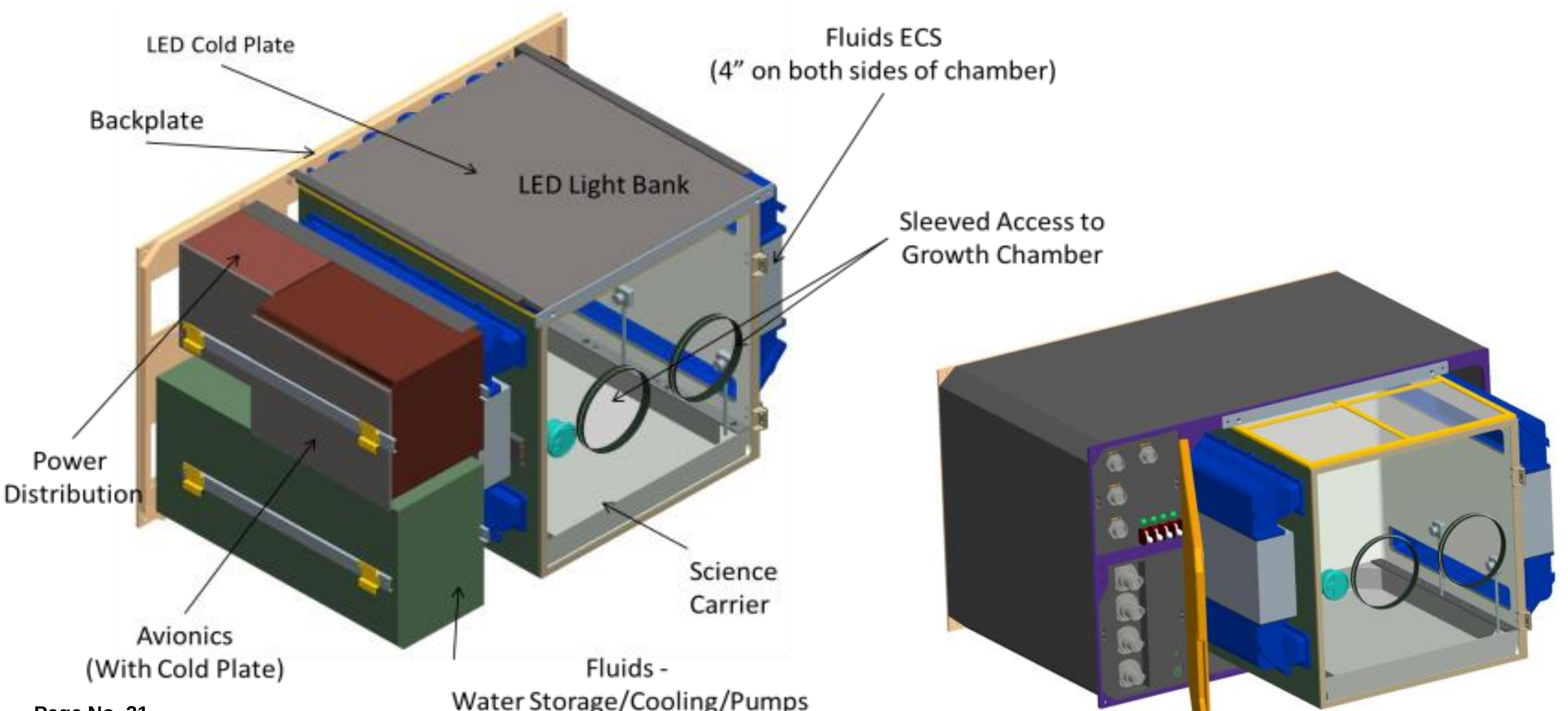
ABRS GFP Imager with Petri Plates Installed

Advanced Plant Habitat (under development)

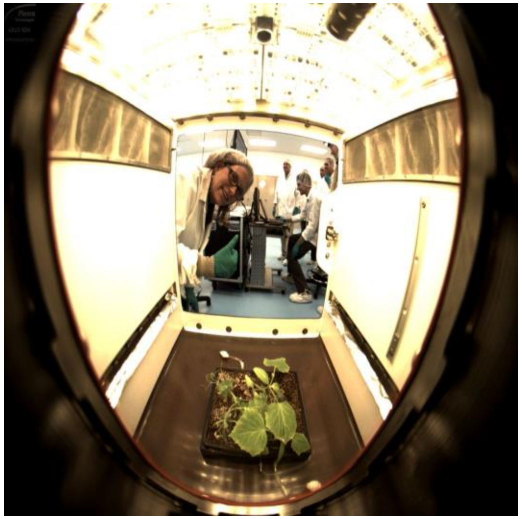
Objective: Develop a **large volume** plant habitat for **multi-generational studies** in which **environmental variables** (e.g., Temperature, Relative Humidity, Carbon Dioxide Level, Light Intensity and Spectral Quality) can be **tracked and controlled** in support of whole plant physiological testing and Bioregenerative Life Support System investigations.

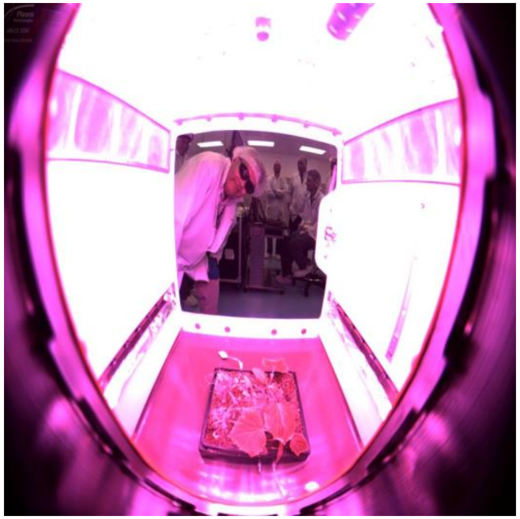
Open architecture concept to allow critical subsystems to be removed and replaced.

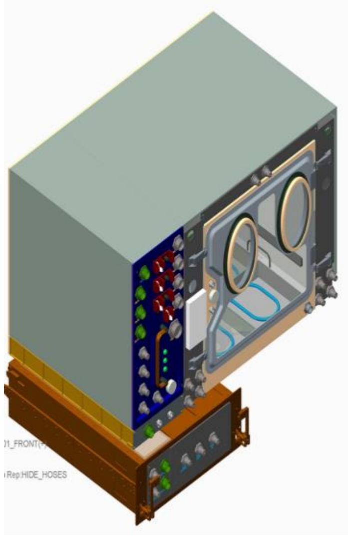
Specs: Max. Shoot Height: 45 cm; Root Zone Height: 5 cm, Growth Area: 2,500 cm2; Growth Volume: 112,500 cm3; Light Intensity: >600 µmol/m2/s; Temp: 18-30 C; Relative Humidity: 50-86%



Advanced Plant Habitat
(under development)



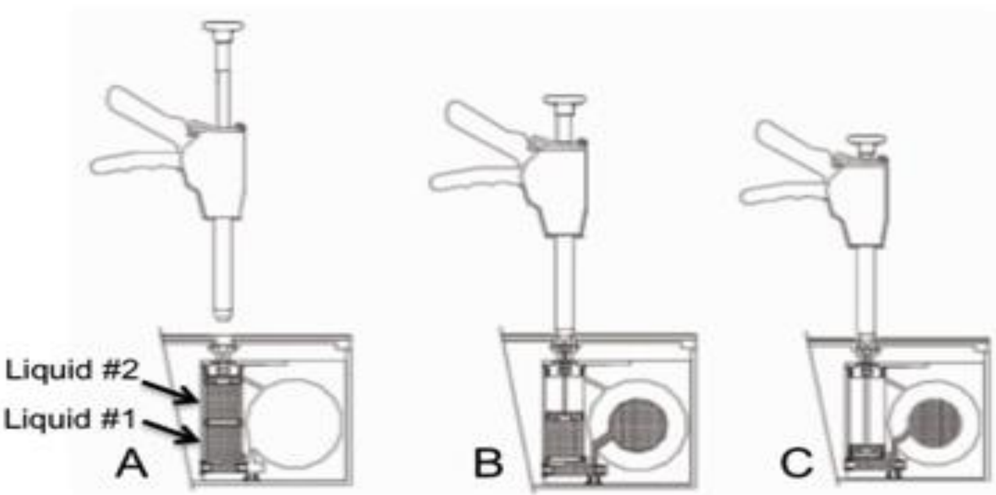




Biological Research in Canisters (BRIC) Petri Dish Fixation Unit (PDFU)

- The BRIC-PDFU hardware facilitates Rapid Turn-Around payloads involving in-flight fixation & multiple NRA-selected PIs.
- Provides shorter period of time for PI to obtain flight opportunity and ultimately flight data for analysis and publication.

A. Petri Dish Fixation Unit (PDFU). B. Callus culture on petri dish within a PDFU. C. 5 PDFUs plus 1 temperature logger within a BRIC-PDFU Canister. D. BRIC-PDFU Canister with two pin guards attached. E. Actuator Rod Kit & Actuator Tool. F. Actuator Tool attached to BRIC- PDFU canister.



Injection of fluids into PDFU petri dishes:
A. Actuator Tool prior to attachment to BRIC-PDFU.
B. Actuator partially depressed to Liquid 1.
C. Completion of actuation allows Liquid 2 to be delivered.

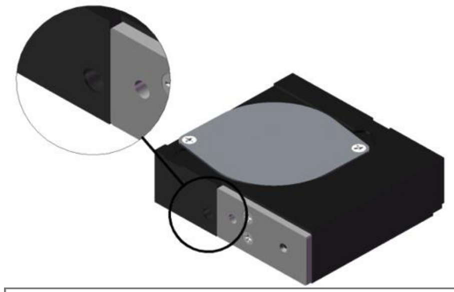
BRIC-PDFU Hardware Upgrades

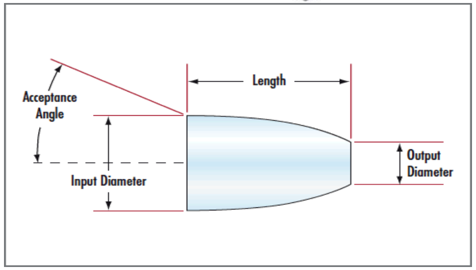
Background:

- This effort is to **expand the capability of the BRIC-PDFU hardware** series for rapid turn-around NRA space flight experiments for the space biology community.
- This new hardware configuration will enable better use of the ISS platform and significantly **expand the PI base of investigators**.

This proposed effort will:

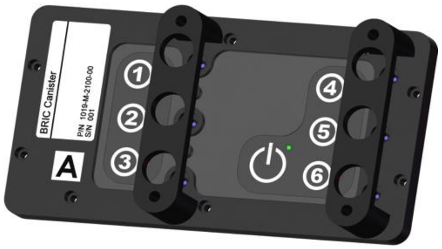
- Include a **light provision capability** in the BRIC-PDFU hardware (expanding the diversity of experiments it can support).
- **Upgrade BRIC lid control electronics** to be **capacitance touch-based and include temperature sensors** (replacing the need to fly HOBOs for temperature data) providing for an **additional PDFU/canister**.
- Design & build an **ExPRESS Rack Drawer tray** (capable of holding 8 BRIC canisters) that will interface to ISS via the **ExPRESS Rack** and provide power to the individual BRICs. This will provide the **capability for external/remote control for experiment activation and fixation** (without crew assistance).
- The addition of an **active temperature control** system for more precise maintenance of internal PDFU temperatures (existing temperature control is totally passive).





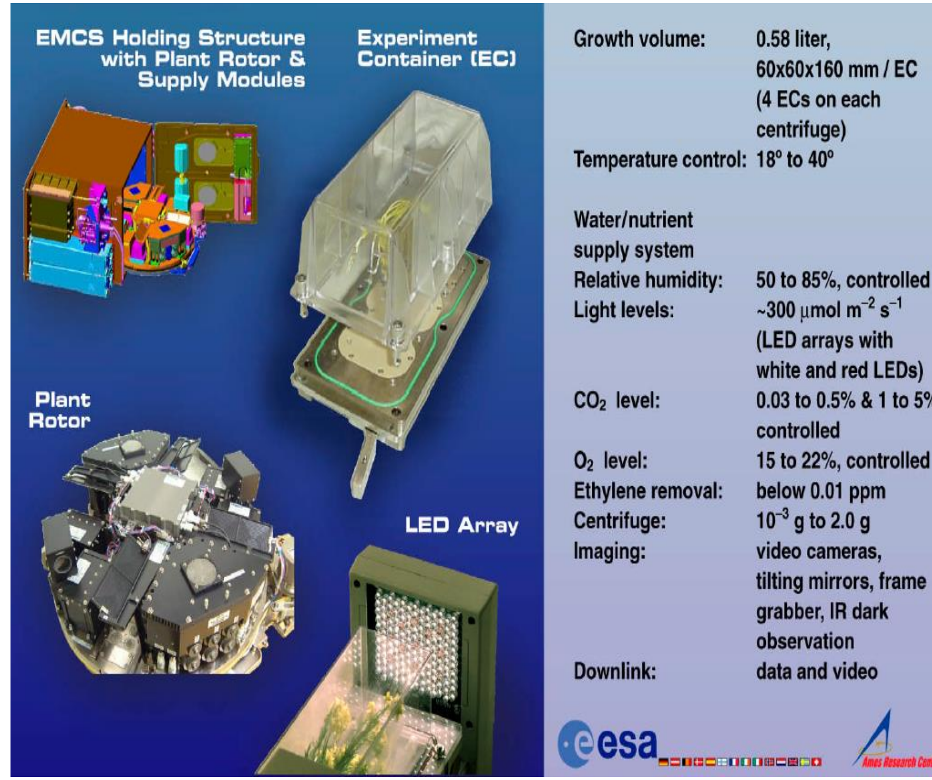
Top: Location of Light guide installation into PDFU. Bottom: Light Collimeter design.

Locker half tray containing eight BRIC-PDFUs.



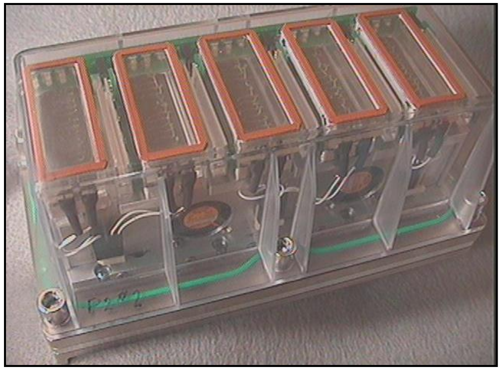
Capacitance Touch-Based Lid design.

European Modular Cultivation System (EMCS)



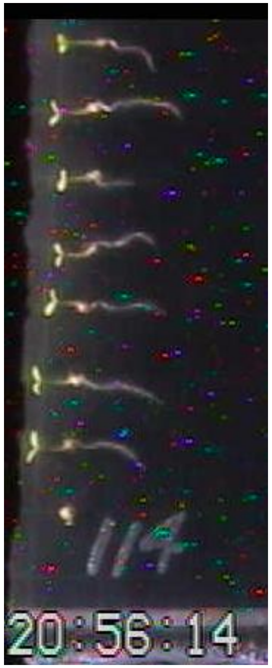
Seedling Growth

Space Biology Project Accomplishments
Seedling Growth



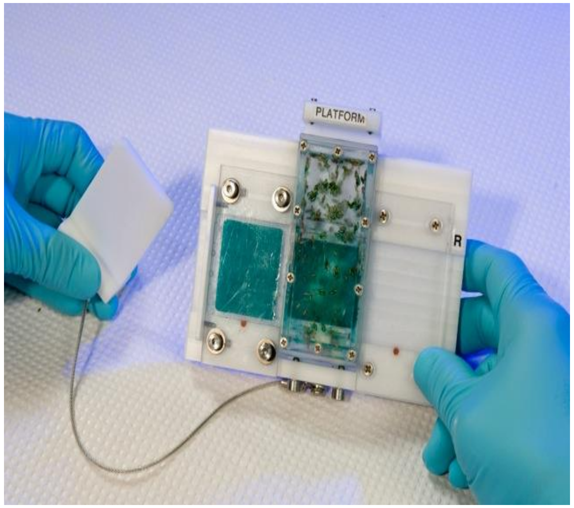
- **Seedling Growth-1 (PI: John Kiss, Javier Medina)**
  - The CoFR was signed for return of the samples and hardware from SpaceX-3.
  - LRODs and PrePack lists are checked and updated.
  - ERM 2 schedules are being updated and tested for the Ground Control Test in Feb.
  - Successfully completed the OVT at the N-USOC with excellent germination and growth there and at ARC. Lessons learned will be fed into flight operations.
  - Completed a set of CO2 calibration and adjustments of the ERM-2, in the EMCS lab at ARC to mimic concentrations on orbit.

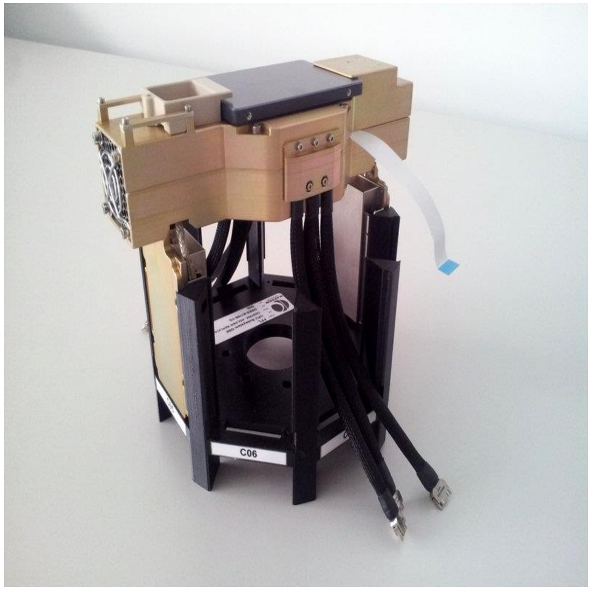
- **Seedling Growth-2 (PI: John Kiss, Javier Medina)**
  - Successfully completed the OVT at the N-USOC with excellent germination and growth there and at ARC. Lessons learned will be fed into flight operations.
  - The SG-2 Science team completed the ARC SG-2 OVT Report draft. Currently, the draft is under internal review.
  - The Launch/Return/On-orbit Data Set (LRODS) top-level documentation of the Seedling Growth/EMCS hardware is under review. After the transition to eLRODS, the data is being reviewed for validation.

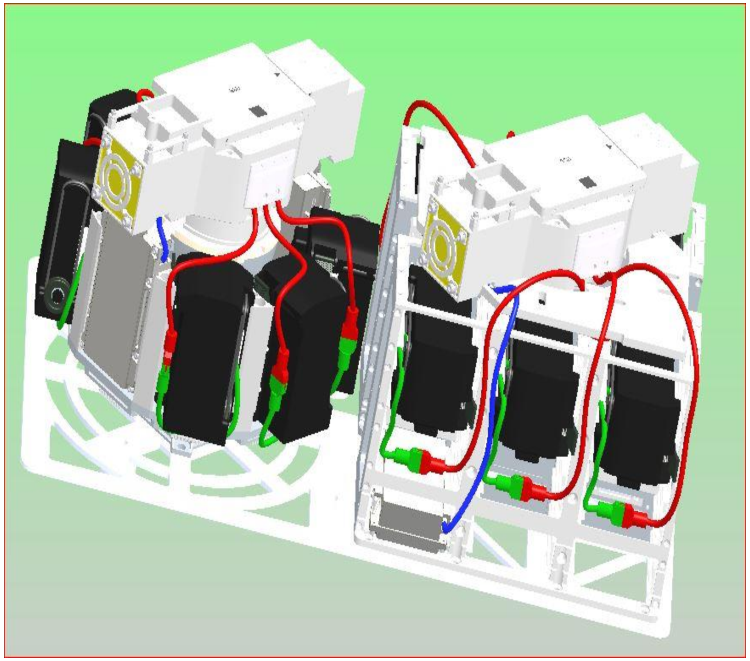


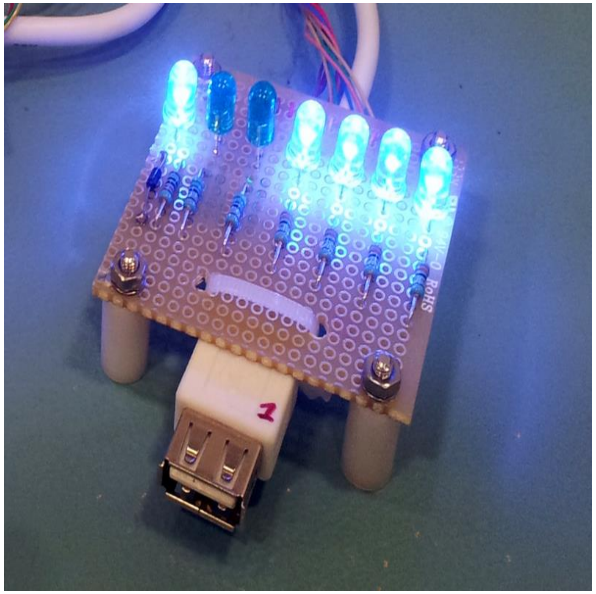
- **Seedling Growth-3 (PI: John Kiss, Javier Medina)**
  - Status: In July 2013, ESA de-manifested the payload from SpaceX-3.
  - ESA FixBox is being redesigned, and it will not be ready for testing until Dec. 2014. Since ESA requires six months of ground testing before flight certification, it cannot be ready for SpaceX-6. ESA will not manifest for INC 43/44 on SpaceX-7 or on -8.
  - ARC team will support development of new schedule and budget plan when a new flight manifest is determined.

Fruit Fly Lab







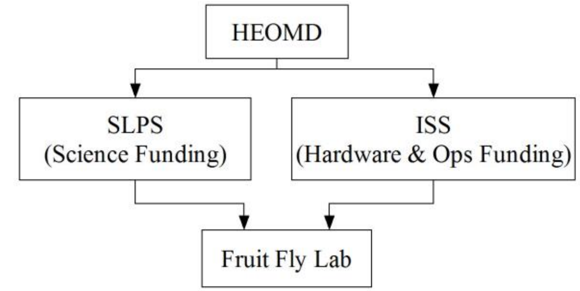


Science Capability of Drosophila Lab

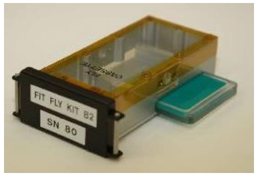
Description and Objectives:

- **Theme**: (Decadal Survey Area): AH14, AH16, CC2, CC8, CC10
- **Description**: To support multi-generational experiments with Drosophila melanogaster (fruit flies) at various gravity levels (0 to 2 g).
- **Implementation**: Two phase approach to provide an immediate capability using existing hardware, and then to develop new fly hardware that meets the full requirements.
  - Phase I – Use FIT Fly cassettes in the Nanorack Centrifuge
  - Phase II – Develop Fly EUE for either the EMCS, TechShot Multi-specimen Variable-g Facility (MVF), or other vendor facility with environmental control, added containment, and fixation.
- **Schedule**:

  Tech Demo FFL-1 Fall 2014, FFL-2 Spring 2015, FFL-3 Fall 2015

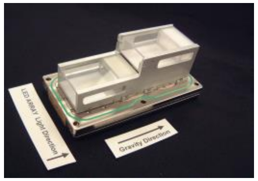


Phase 1 HW



Drosophila melanogaster
(fruit fly)

Possible Phase 2 HW



Approach:

A small diameter centrifuge onboard ISS will provide the capability to study the flies in partial-g and 1-g. The NanoRacks BioRack Centrifuge and μg-Rack will accommodate FIT fly cassettes inside an Observation System enclosure enabling video capture. It does not currently provide full environmental control. This will be addressed with Phase 2 hardware.

Justification:

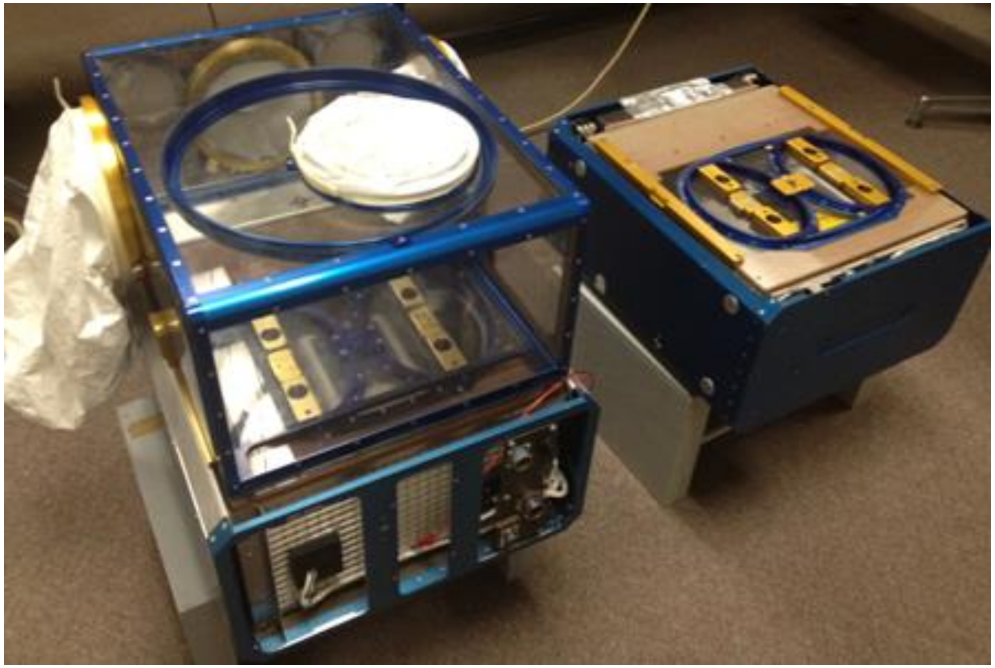
- Value to Agency (Space Benefit)
  This system enables studies of genetic responses to micro- and fractional-gravity and effects on reproduction in a complex organism that has been extensively used in labs around the world for such studies. This is a capability that is lacking, but desired, by all of the international partners for on-orbit space biology research.

- Value to Public (Earth Benefit)
  Microgravity exposure has unmasked genetic mechanisms in simpler organisms, and needs to be studied in more complex organisms. Strong potential for education outreach paired with the science

Rodent Research (RR): suite of hardware developed by ARC

Rodent Habitat – provides on-orbit housing for rodents in an EXPRESS rack
Transporter – provides housing for rodents during ascent on Dragon
Animal Access Unit (AAU) – Interfaces with both the Habitat and Transporter for transfer of the animals between the units and access to the animals for science operations

- Validation Flight SpX 4



ISS Manifested Mouse Experiments

Impact of Spaceflight on Primary and Secondary Antibody Responses

- Primary PI: Michael Pecaut, PhD, Loma Linda University
- Research Sponsor: NASA Space Life and Physical Sciences (SLPS)

  - **SLPS Specific Aim #1:** Determine the impact of the spaceflight environment on primary antibody responses.

  - **SLPS Specific Aim #2:** Establish that adjuvants that function through TLR-9 receptors are effective during spaceflight.

Effects of Microgravity on Cerebral Arterial, Venous and Lymphatic Function: Implications for Elevated Intracranial Pressure

- Primary PI: Michael Delp, Florida State University
- Research Sponsor: NASA SLPS

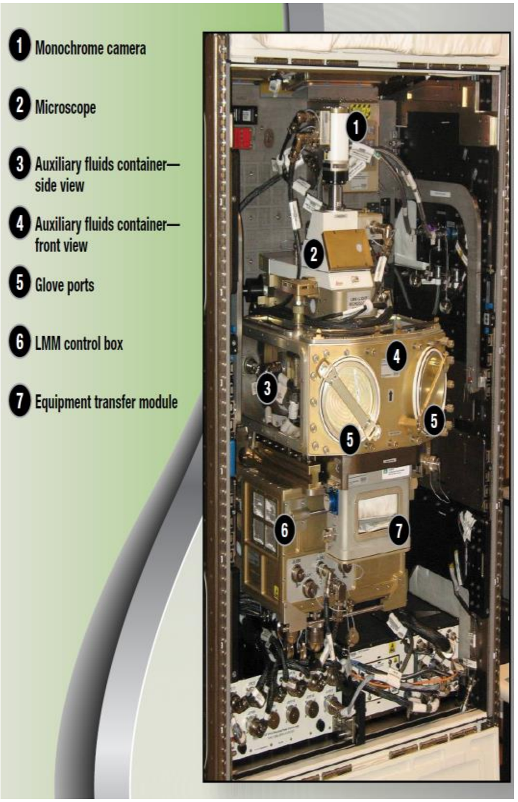
  - **SLPS Specific Aim #3:** Investigate whether spaceflight on the ISS alters the blood-brain barrier in rodents, as indicated by ultrastructural examination of the junctional complex of the cerebral capillary endothelium, which ultimately results in impaired vision.

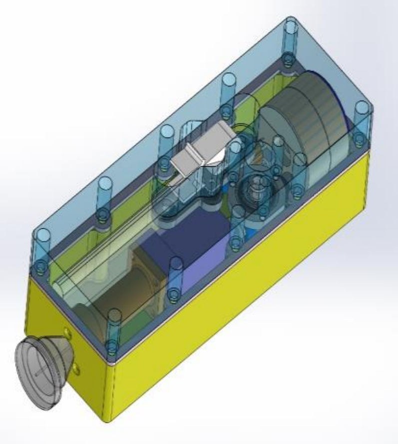
Rodent Experiments selected for Definition from Flight NRA NNH14ZTT001N

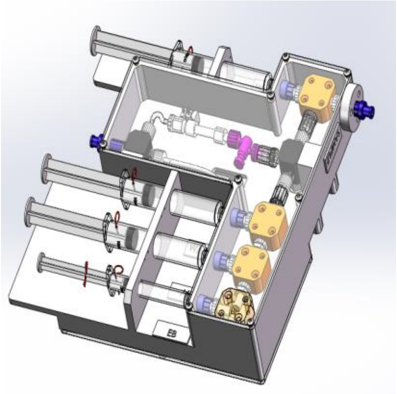
1. Mao – Loma Linda - Space flight environment induces remodeling of vascular network and glia-vascular communication mouse retina
2. Globus – Ames Research Center - Free radical theory of aging in space
3. Tash – University of Kansas - Female reproductive health: spaceflight induced ovarian and estrogen signalling dysfunction, adaptation, and recovery
4. Almeida – Ames Research Center - The role of p21/CDKN1a in microgravity-induced bone tissue regenerative arrest: a spacelfight study of transgenic p21/CDKN1a null mice in microgravity.
5. Robbins - Texas Medical Center Houston- Vascular health in space
6. Willey – Wake Forest - Exercise countermeasures for knee and hip degradation during spaceflight
7. Pluth – Lawrence Berkeley Laboratories - Space adaptation effects on the immune system impacts reproductive function and mammary development across generations
8. Zawieja –Texas A&M – Tissue Sharing - Effects of microgravity on lymphatic proliferation and transport efficiency in the gut of C57Bl6 mice AND Effects of microgravity adaptations on cephalic lymphatic function and associated edema development and immune dysfunction
9. Chapes – Kansas State Univesity – Tissue Sharing - Collection of immune/stress-related tissues from mice flown on the ISS
10. Delp – Florida State University – Tissue Sharing - Effects of space flight on ocular oxidative stress and the blood-retinal barrier

Advanced Technologies for ISS

LMM

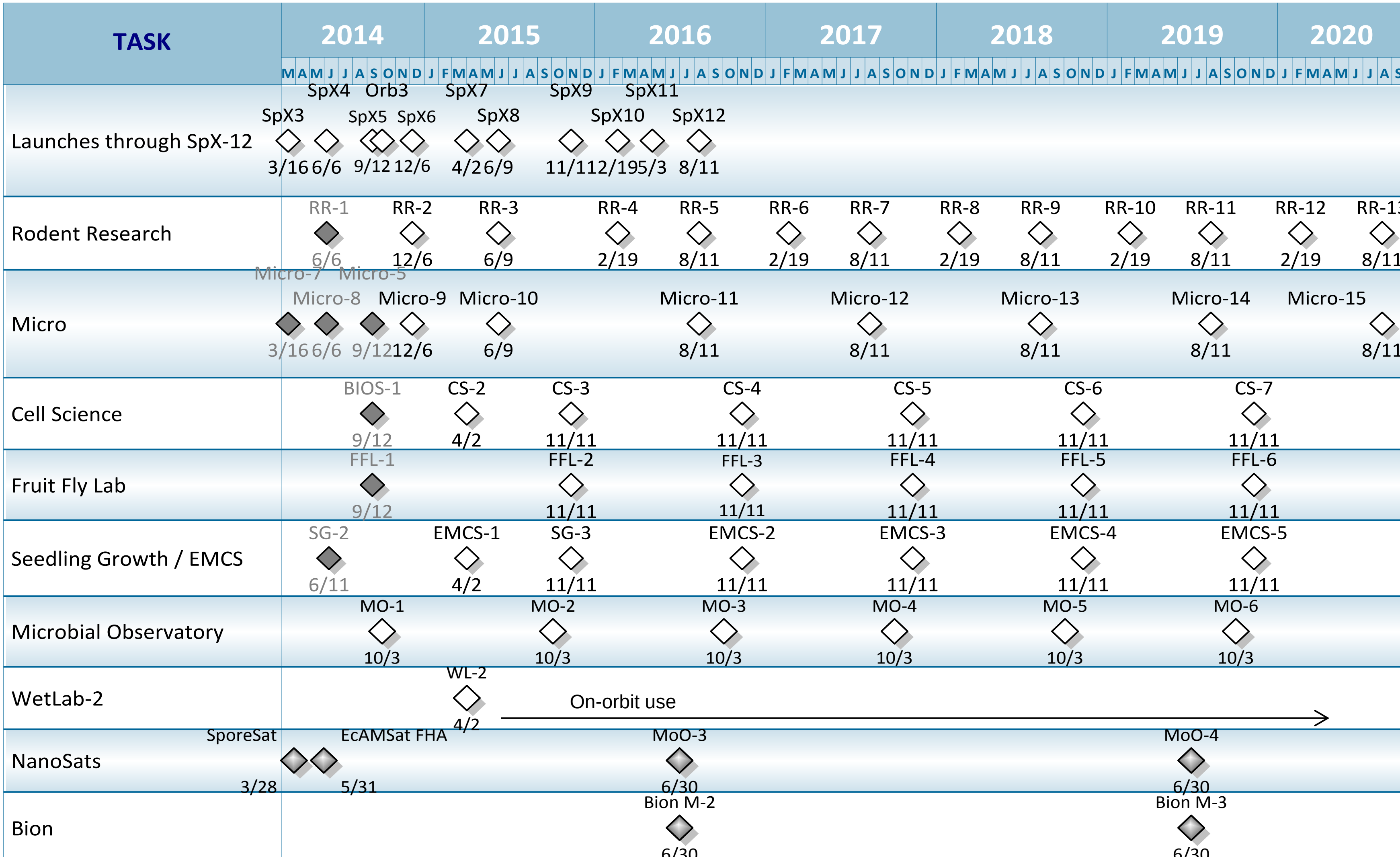






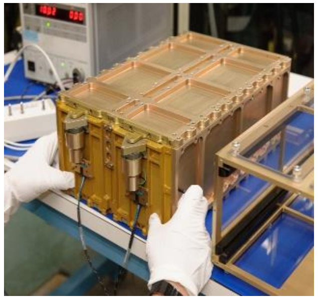
WetLab2-
qRT-PCR
and Tissue
Homogenizer

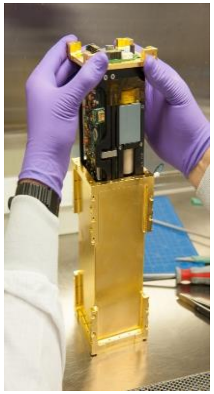
ARC Traffic Model for Flight Projects
48 Flight Missions/Projects FY15-FY20

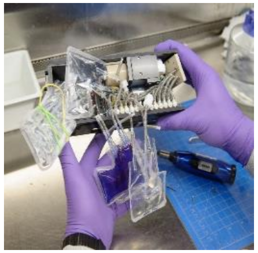


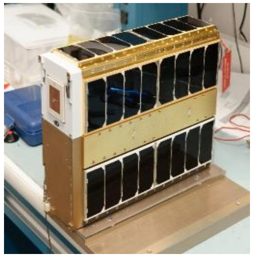
ISS Missions may serve multiple PIs and multiple customers including NASA, CASIS and geneLAB

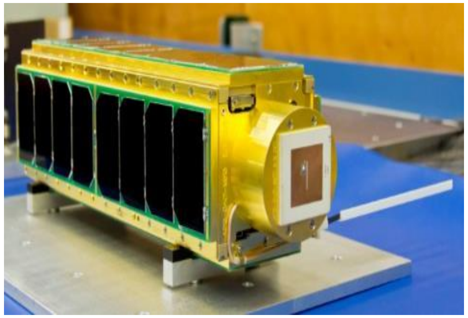
Free Flyers









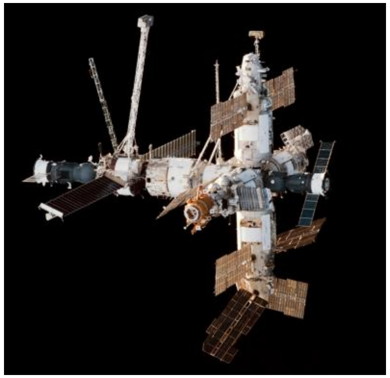


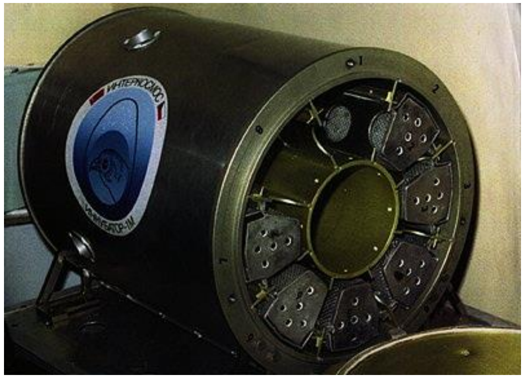
SporeSat

ECamSAT

Free Flyers - U.S./Russian Space Biology Cooperation

- 40-yr history facilitated by the U.S./Russian Joint Working Group For Biomedicine and Space Biology Research
- Space Biology Cooperation on Cosmos-782, 936, 1129, 1514, 1667, 1887, 2044, 2229, and Bion 11 (approx. every 2 years) 1975-1997
- SLS-1 and SLS-2 Spacelab 1991-1993
- Quail Reproduction and Plant Research on MIR 1990-1999; Lada Plant Research on ISS 2000-2004
- Foton-M3 and Foton-M3 2005 and 2007; Bion-M1 2013
- Enables leveraging of resources and crew time sharing for research



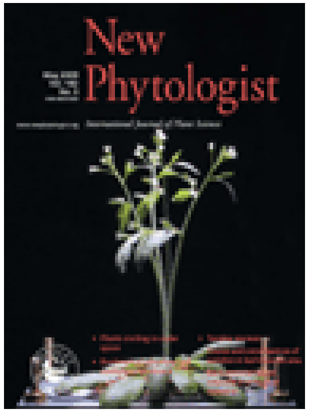


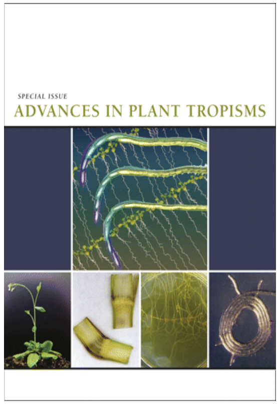

Free Flyers - Space Biology U.S./Russian Bion-M1 Mission

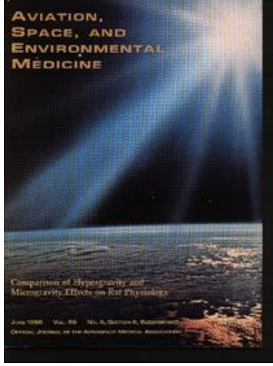
- 19 April 2013 – 18 May 2013 Launched from Baikonur, Kazakhstan
- Cooperation for rodent research while U.S. capability for long duration rodent research was still under development
- Male mice, all Shuttle studies are based on female mice studies
- Specimens: Mice, gerbils, geckos, snails, fish, plants, microbes

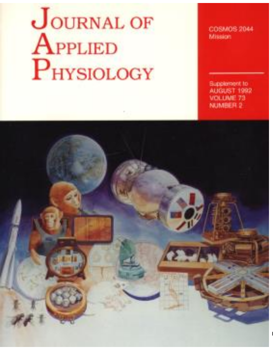
- U.S. Science Program:
- U.S. side received mouse tissues to meet their primary science goals – 45 mice total launched on the mission
- U.S. side will also receive video recordings of Mongolian gerbils for analysis of in flight behavior
- U.S. involvement limited to post flight sample collection and video analysis

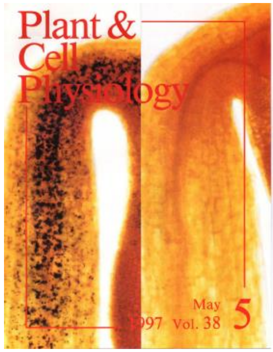
NASA Biology Research Flight Publications 1975-2014

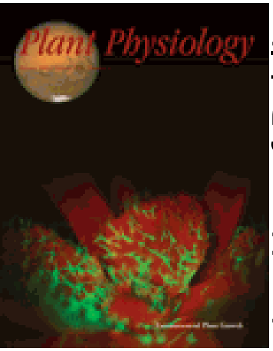


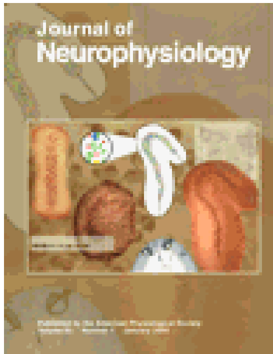


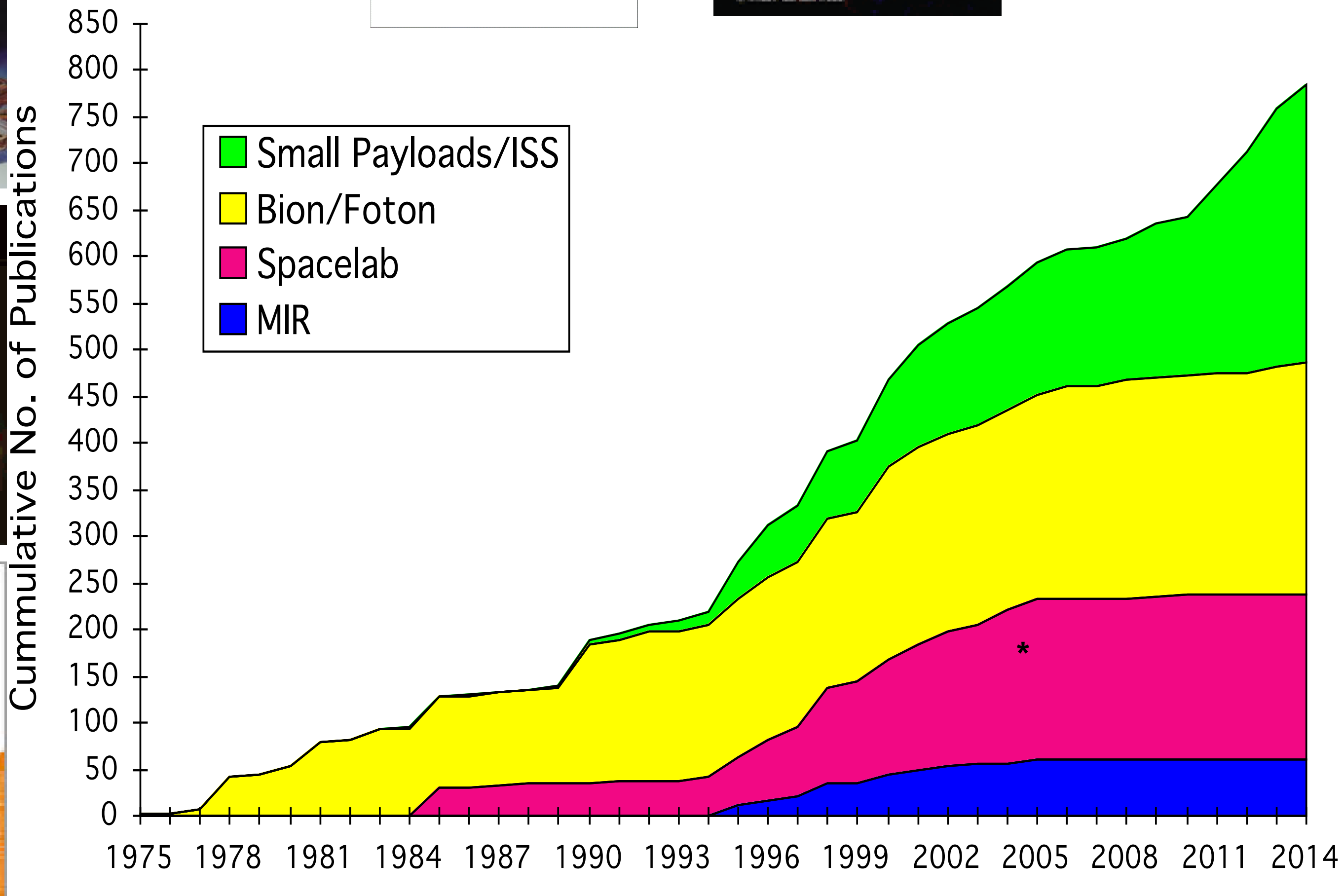




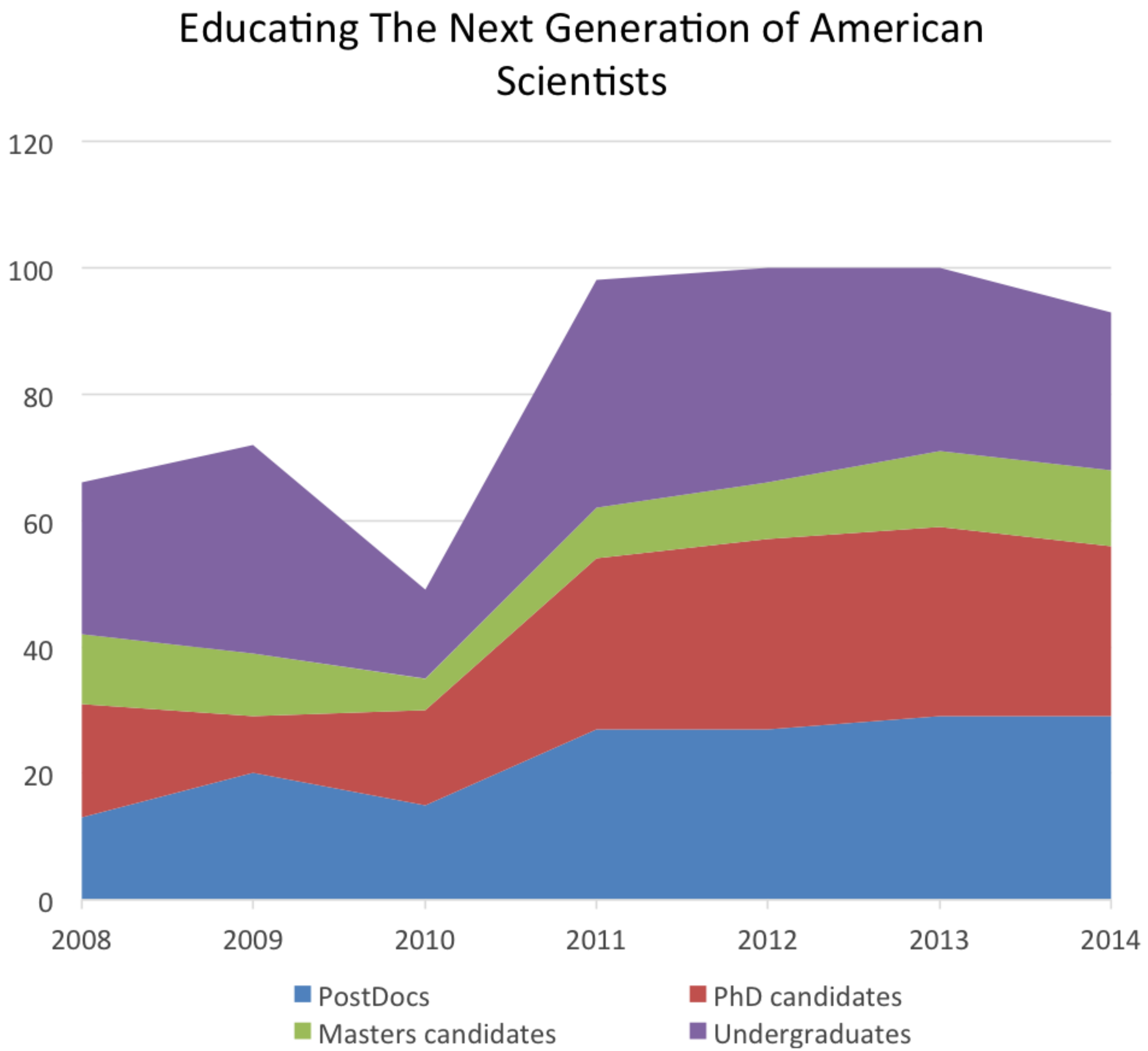








Students Supported by Space Biology Grants



(currently funded SB students and post docs working on an ISS payload)

Students Supported by Space Biology Grants (Flight Projects Only)

		2008	2009	2010	2011	2012	2013	2014	Total
ISS Small Payloads	PostDocs	13	20	15	27	27	29	29	160
	PhD candidates	18	9	15	27	30	30	27	156
	Masters candidates	11	10	5	8	9	12	12	67
	Undergraduates	24	33	14	36	34	29	25	195
	Total	*66*	*72*	*49*	*98*	*100*	*100*	*93*	*578*
BION-FOTON	PostDocs	1	4	2	4	8	9	8	36
	PhD candidates	1	0	0	1	15	13	13	43
	Masters candidates	1	1	0	0	2	3	3	10
	Undergraduates	4	10	0	4	8	7	8	41
	Total	*7*	*15*	*2*	*9*	*33*	*32*	*32*	*130*

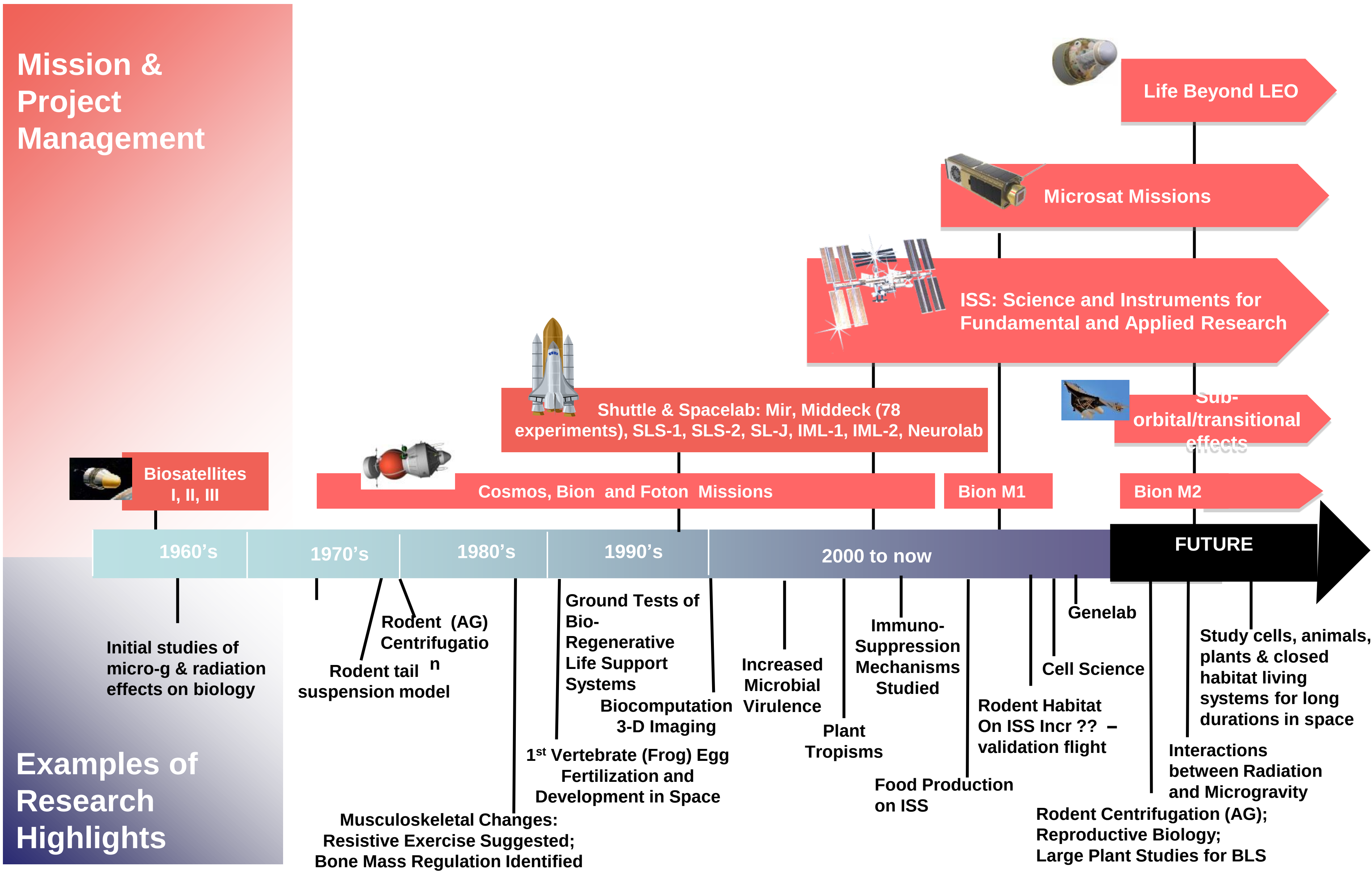
Source of Data: NASA Task Book; Data as reported by PIs as of 10/2/2014

Outreach to Professional Societies

Outreach includes Space Biology exhibit – banner, staff, and hardware, special session, symposium or workshop when possible

- Experiment Biology Meeting – April 2014 San Diego
- American Society for Microbiology – May 2014 Boston
- ASGSR – October 2014
- American Society for Cell Biology – December 2014 Philadelphia
- World Stem Cell Summit – December 2014 San Antonio
- Experimental Biology Meeting – March 2015 Boston
- American Society for Microbiology – May 2015 New Orleans
- American Society for Plant Biologists – July 2015 Minneapolis

Six Decades of Space Biology Research




National Aeronautics and Space Administration
NASA
Questions?