Plans for Plant Research Opportunities on ISS

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Research Advisor

NASA's Translation To It's Mission and Vision

Vision:

To reach for new heights and reveal the unknown

so that what we do and learn will benefit all humankind.

Mission:

Drive advances in science, technology, and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of the Earth

Goal 1: Extend and sustain human activities across the solar system.

Goal 2: Expand scientific understanding of the Earth and the universe in which we live.

Goal 3: Create the innovative new space technologies for our exploration, science, and economic future

Goal 4 Aeronautics

Goal 5 Program and institutional capabilities

Goal 6 Share NASA with public, educators, and students

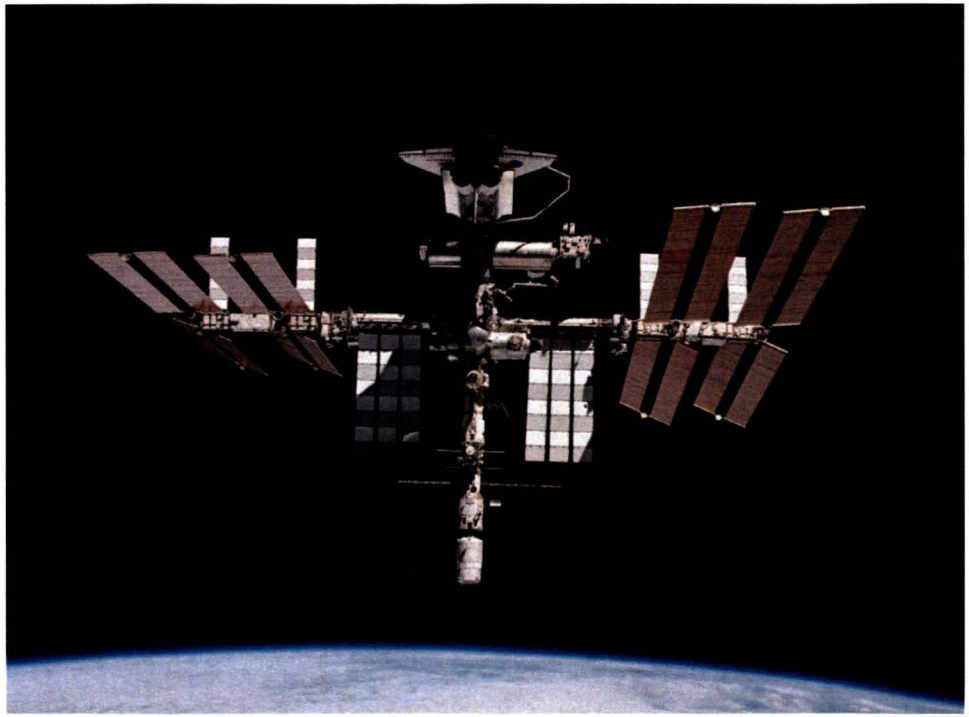
Choosing one to follow

- Fundamental Space Biology Science Plan 11/2010
  - Cell, Microbial and Molecular Biology
  - Organismal and Comparative Biology
  - Developmental Biology
- 2011 National Academies recommendation for NASA research in Life and Physical Science
  - P1 Establish a microbial observatory program on ISS to conduct long term multigenerational studies of microbial population dynamics
  - P2 Establish a robust spaceflight program of research analyzing plant and microbial growth and physiological responses to the multiple stimuli encountered in spaceflight environments
  - P3 Develop a research program aimed at demonstrating the roles of microbial-plant systems in long term life support systems.

The International Space Station

International Space Station Size & Mass

- Module Length: 167.3 feet (51 meters)
- Truss Length: 357.5 feet (109 meters)
- Solar Array Length: 239.4 feet (73 meters)
- Mass: 861,804 lb (390,908 kilograms)
- Habitable Volume: 13,696 cubic feet (388 cubic meters)
- Pressurized Volume: 32,333 cubic feet (916 cubic meters)
- Power Generation: 8 solar arrays = 84 kilowatts
- Lines of Computer Code: approximately 2.3 million

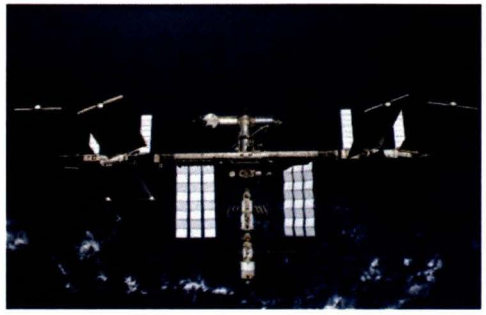


Flight Processing

John F. Kennedy Space Center
ISS & Spacecraft Processing Directorate

Customer I/F & Reqm't Dev → Pre-Launch Experiment Preparation → Launch → On-Orbit Operations → Landing → Post-Landing Payload Processing

- Principal Investigators
  - Receive/Inspect
  - Post Delivery Checkout
- NASA
  - Primary customer interface
  - Payload testing)
  - Turnover for stowage
- CAPPS/TOSC
  - Technician support to NASA
  - Infrastructure support



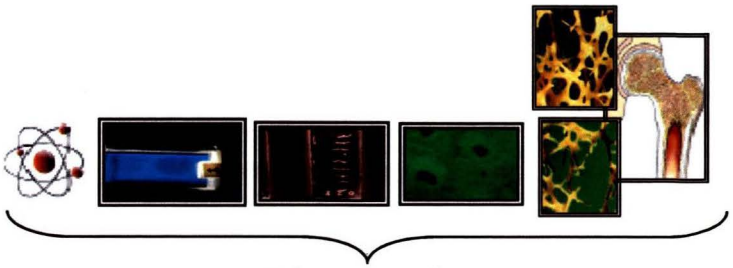
RACKS/ SUB-RACKS

SUB-RACKS/ SAMPLES

Space X Dragon

Space X Dragon

- NASA
  - Retrieve payloads/samples
  - Turnover payloads/samples to customer
- Principal Investigators
  - Post-flight experiment processing
  - Prepare for shipment

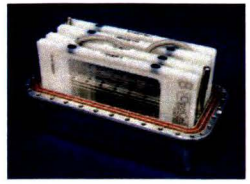


Science samples

Plant Flight Hardware

- **Hardware**

- Biological Research in a Canister (BRIC)
  - Status – Currently in use for ISS mission and currently being redesigned to optimize ISS utilization
- Advanced Biological research System (ABRS)
  - Status – Currently on station waiting for the next user and additional unique equipment is being proposed
- Kennedy Fixation Tubes (KFT)
  - Status - Operational
- Open Plant Growth System (VEGGIE)
  - Status – In final Stage Development
- Advance Plant Habitat (APH)
  - Status - In early development
- Magnetic Field Apparatus (BioTube)
  - Status – Final testing for flight
- FastRack for Parabolic, Suborbital & Orbital Use
  - Status - Operational

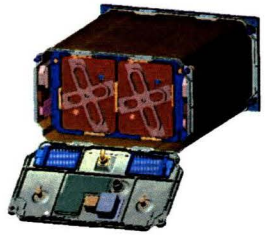


BRIC Opti

BRIC PDFU

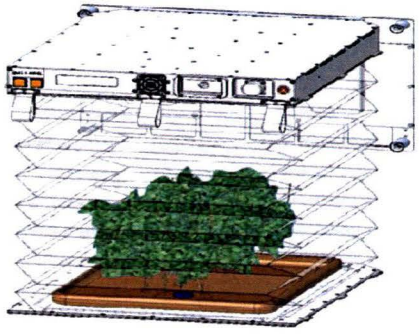
BRIC 100's

FastRack

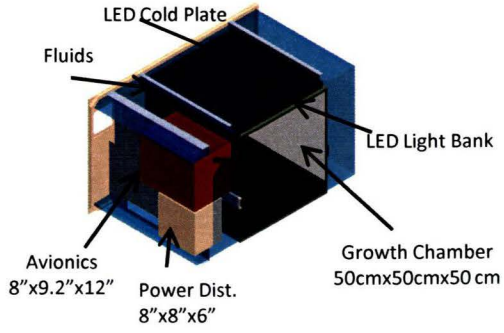


Advanced Biological Research System (ABRS)

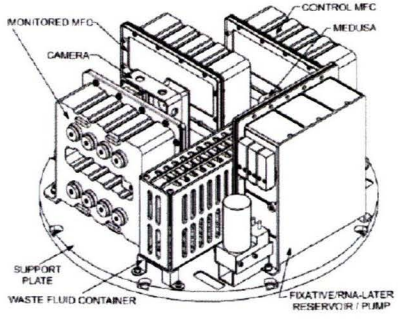
Fixation tube



VEGGIE

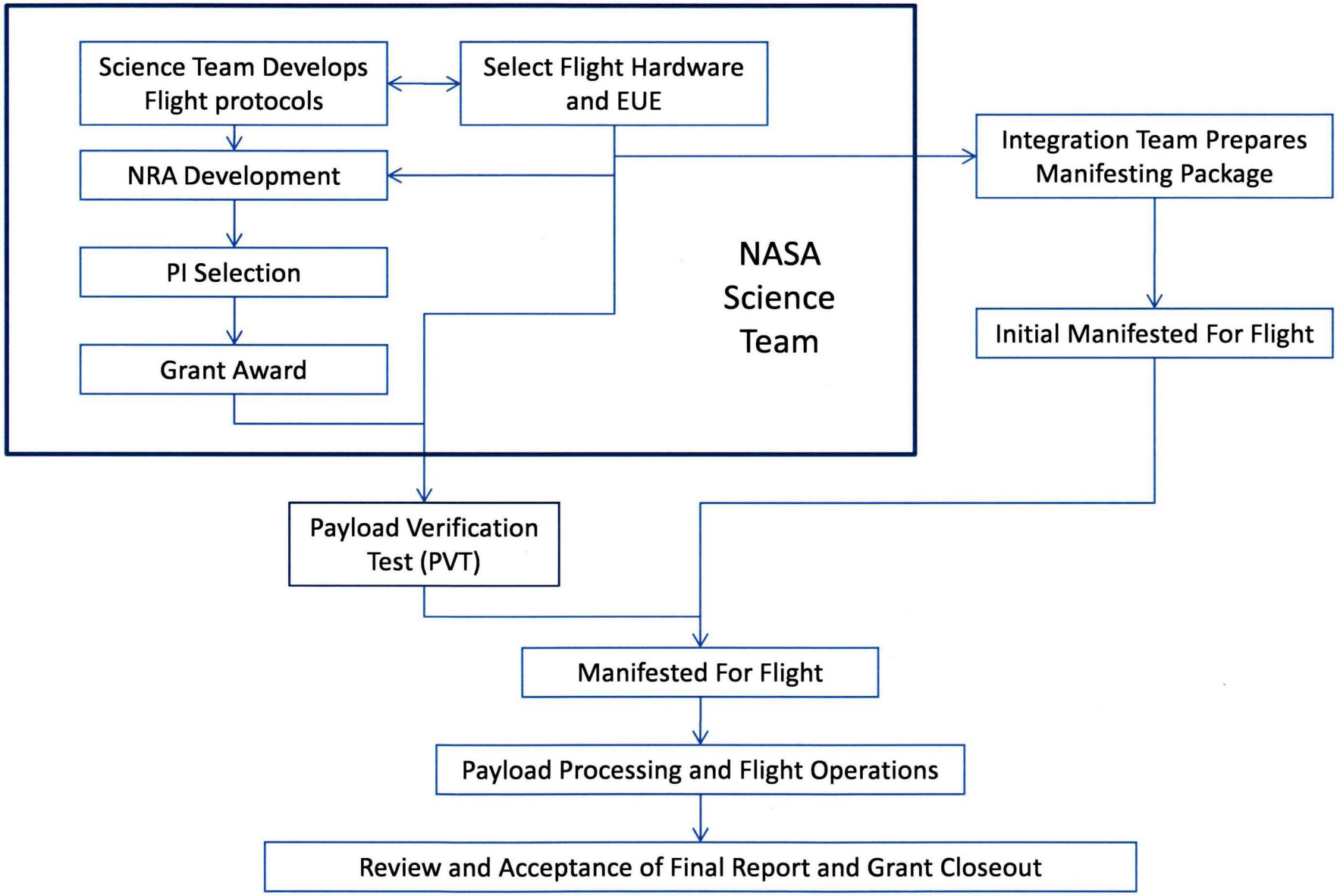


Advanced Plant Habitat

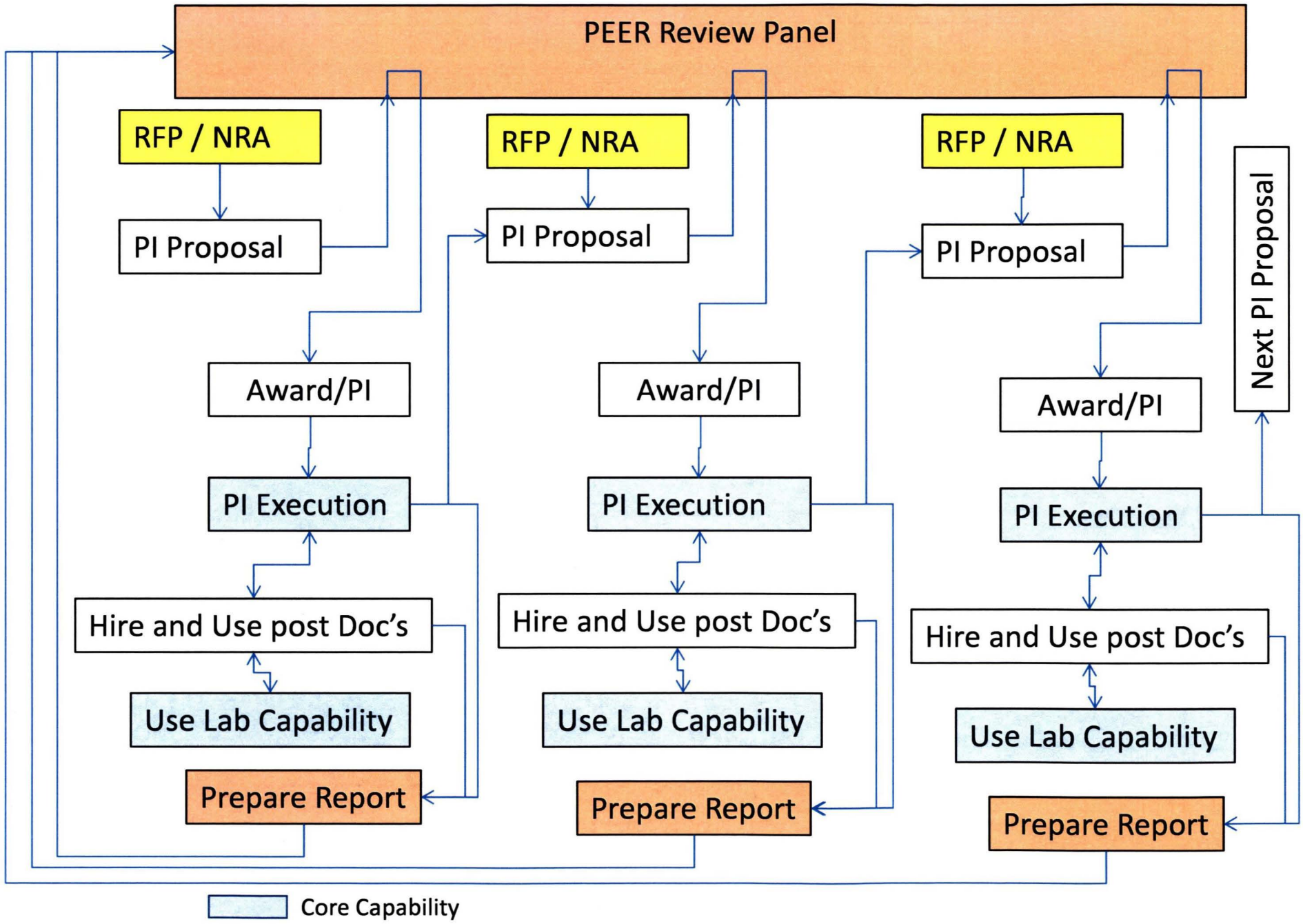


Biotube MFC hardware

Fast Track Science Deployment Process



Peer Reviewed Science



Science Payload Planning

Current Plan

	2012		2013		2014		2015		2016		2017		2018		2019		2020		Total PIs
	29/30	31/32	33/34	35/36	37/38	39/40	41/42	43/44	45/46	47/48	49/50	51/52	53/54	55/56	57/58	59/60	61/62	63/64	
KSC Payloads																			
Biotube Micro				X(1)															1
BRIC- PDFU			X(2)	X(2)		X(4)		X(4)		X(4)		X(4)		X(4)		X(4)		X(4)	32
ABRS Experiment Kits				X(2)		X(2)		X(2)		X(2)		X(2)		X(2)		X(2)		X(2)	16
VEGGIE Experiment Kits				X(1)		X(1)		X(1)		X(1)		X(1)		X(1)		X(1)		X(1)	8
APH Experiment Kits								X(1)		X(1)		X(1)		X(1)		X(1)		X(1)	6
																		Total	63

Potential Plan

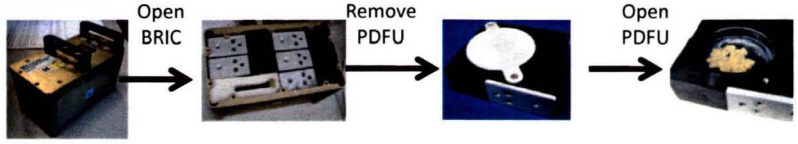
	2012		2013		2014		2015		2016		2017		2018		2019		2020		Total PIs
	29/30	31/32	33/34	35/36	37/38	39/40	41/42	43/44	45/46	47/48	49/50	51/52	53/54	55/56	57/58	59/60	61/62	63/64	
KSC Payloads																			
Biotube Micro				X(1)		X(1)		X(1)		X(1)		X(1)		X(1)		X(1)		X(1)	8
BRIC- PDFU			X(2)	X(2)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	X(4)	60
ABRS Experiment Kits				X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	X(2)	30
VEGGIE Science Experiment Kits				X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	15
APH Experiment Kits								X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	11
STEM VEGGIE / BRIC Science Education Kits				X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	X(1)	15
Real Time DNA				X(1)		X(1)		X(1)		X(1)		X(1)		X(1)		X(1)		X(1)	8
																		Total	147

BRIC Series Experiments
BRIC Hardware Upgrades Converting from Shuttle Configuration for ISS Use

Description and Objectives:

- Theme: P2 and AH16 Establish a program of research analyzing plant, microbial, and animal growth and physiological responses to the in spaceflight environments
- Technical Description: Science is performed in a petri dish
- Physical Description: See graphic
- Objectives: convert hardware for best use on ISS and a rapid turn-around flight series for flying multiple peer-reviewed science investigations sharing the BRIC-PDFU hardware. Specific PI objectives to be determined in proposals.
- Implementation: Eng thru Engineer contractor, Science selection through the NRA / PEER review process
- Schedule: FY13: Perform Phase I mod work
  FY14: one flight planned with 4 PI's and Phase II upgrade
  FY15: one flight planned with 4 PI's potentially more

Graphic



New on orbit activities

Microscopy	Manipulation	Fixation	Cold Stowage	Photography	Analysis

New Express Rack Drawer

New removable lid with temp sensor and LEDs

Approach:

- This highly successful system needs to be adapted for optimum use on ISS
  - Initiate and terminate experiments on ISS
  - More experiments in each canisters by moving the temp logger to the lid
  - Conduct longer experiments by adding lighting options using express rack sys
  - Option of opening the canister and performing manipulation on the specimens
  - Control some BRIC activities from the ground
- Plans are made for a specific BRIC configuration
- Based on these plans a NRA is released and PI's are selected
- PI's are expected to Fly with six months of authority to proceed
- Initial science report is due one month after post flight ground control complete
- UpMass 29kg
- Down Mass 29kg

Collaborators/Roles:

- This hardware would be usable by NASA, National Lab and international partners
- The PI's are selected through the NRA process
- The hardware is designed and managed by NASA KSC
- The flight processing activities conducted by NASA KSC and its contractors

Justification:

- The overall goal is to attract quality science investigations to the ISS facility by increasing the opportunities, adapt the equipment for use on ISS and improve investigation equipment
- Value to Agency - This new hardware configuration will enable better use of the ISS platform and significantly expand the PI base of investigators. Observations and discoveries made using this hardware will define research directions within our more complex research systems
- Value to Public - These investigations performed in this hardware will be looking at fundamental biological science without the gravity component. This type of investigations reveal secondary effect which have always been masked due to the gravity effect. The more investigators proposing to perform research the greater the potential for great discovery and ROI

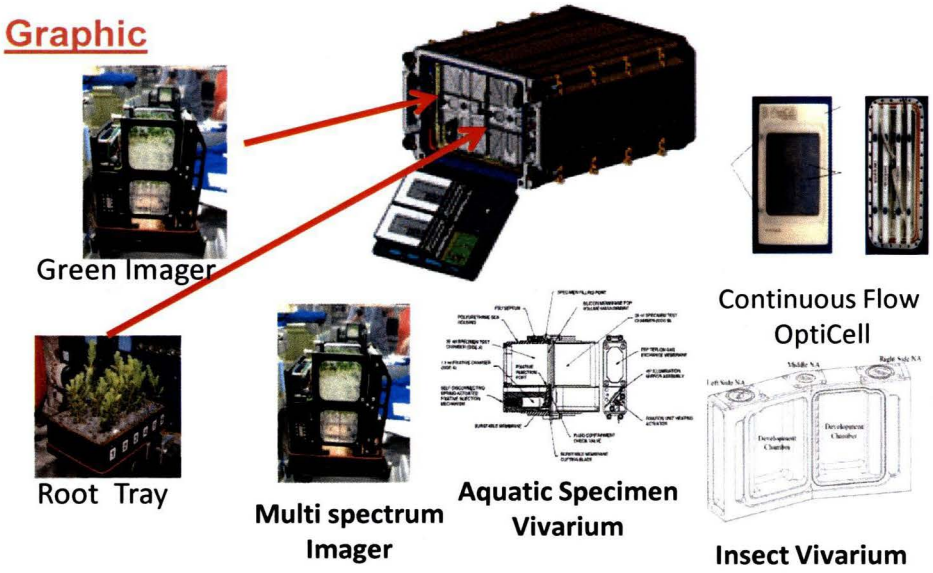
Point of Contact: Jose Camacho 321-867-5880

APEX Series Experiments, ABRS System Upgrades, and EUE Development to Attract More Investigators

Description and Objectives:

- Theme: P2 and AH16 Establish a program of research analyzing plant, microbial, and animal growth and physiological responses to the in spaceflight environments
- Technical Description: These experiments use the ABRS which can control temp, lighting, and humidity and scrub some trace gases
- Physical Description: see graphic plus an microbial, aquatic and insect insert units are in planning
- Objectives: To permit scaled up science in a controlled system
- Implementation: selection through the NRA / PEER review process
- Schedule: FY13: Upgrade system and add insect vivarium
  FY14: one flight with 2 PI's and add aquatic vivarium and Multi spectrum imager
  FY15: one flight with 2 PI's and add continuous flow OptiCell

Graphic



Approach:

- Plans are made for a specific flight opportunity but the insert selection is left up to the selected PI
- An NRA is released and PI's are selected
- PI's select the flight insert for the selected investigation
- PI's are expected to Fly with one year of authority to proceed
- Initial science report is due one month after ground control and flight testing is complete
- UpMass 29kg
- Down Mass 29kg

Collaborators/Roles:

- This hardware would be usable by NASA, National Lab and international partners
- The PI's are selected through the NRA process
- The hardware is designed and managed by NASA KSC
- The flight processing activities conducted by NASA KSC and its contractors

Justification:

- The overall goal is to attract quality science investigations to the ISS facility by increasing the opportunities and the investigation equipment
- Value to Agency - This operating model is specifically targeted at doing more detailed investigation in a tightly controlled environment on small model organisms. Observations and discoveries made during these investigations will provide high quality science and add to the body of knowledge necessary for long duration space flight within a tightly closed system. It will define research directions within our larger research systems
- Value to Public - These investigations are looking at fundamental biological science without the gravity component. This type of investigations reveal secondary effect which have always been masked due to the gravity effect. The knowledge gained on how biological systems perform under stress conditions will have important implications as we manage energy and materials on earth.

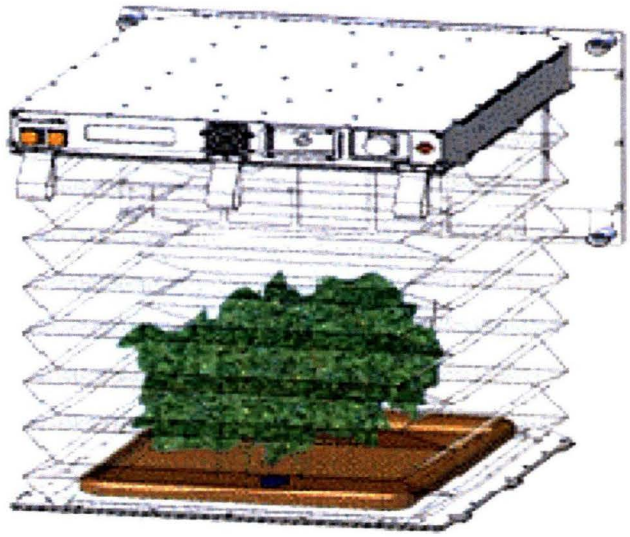
Point of Contact: Brian Onate 321-867-5151

VEGGIE Series Experiments

Description and Objectives:

- Theme: P3 - Develop a research program aimed at demonstrating the roles of microbial-plant systems in long-term life support systems.
- Technical Description: This is a highly controllable light cap and a growth media base within an expandable volume.
- Physical Description: See graphic
- Objectives: Provide the capability to understand the issues associated with growing large plants in the space flight environment
- Implementation: Select directed research PI's
- Schedule: FY13: Deploy to ISS and begin demonstration period
  FY14: Conduct science investigation and education demo
  FY15: Conduct science investigation and education demo

Graphic



Approach:

- Plans are being made to deploy VEGGIE to ISS in FY13 as a DTO and perform a system checkout of flight procedures
- An opportunity will be released for flight in FY 14 and beyond and investigators will be selected.
- Investigators are expected to Fly with six months of authority to proceed
- Initial report is due one month after ground control and flight testing is complete
- UpMass 10kg
- Down Mass 10kg

Collaborators/Roles:

This is a ISS-R funded activity but has collaboration potential with advanced habitats and education

- The investigators are selected through internal processes
- The hardware is designed Orbitec and managed by NASA KSC
- The flight processing activities conducted by NASA KSC and its contractors

Justification:

- Value to Agency - This operating model is specifically targeted at doing investigations associated with growing plants In a large volume in space. Observations and discoveries made during these investigations will provide direction for high quality science in our APH chamber stating in FY17.

- Value to Public - These investigations in addition to providing knowledge for space exploration it will enable school participation at the high school level across the country. The system we are developing for the NASA investigation may have significant commercial application for people wanting to grow herbs and vegetables in their homes all year round.

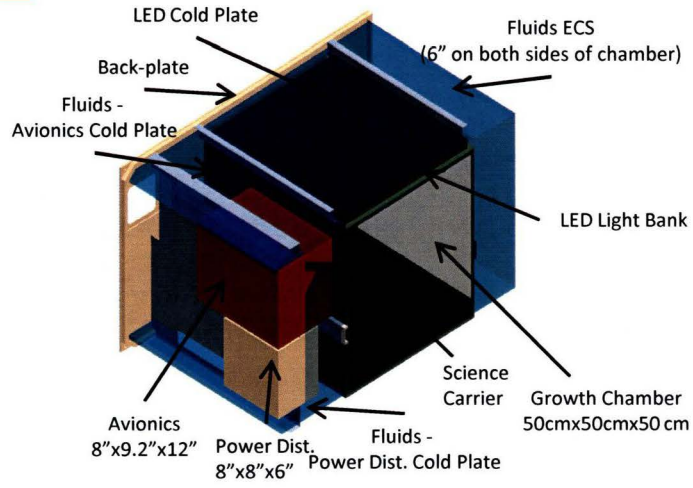
Point of Contact: Bryan Onate 321.867.5151

Advanced Plant Habitat Series Experiments

Description and Objectives:

- Theme: P2 and AH16 Establish a program of research analyzing plant, microbial, and animal growth and physiological responses to the in spaceflight environments
- Technical Description: This chamber with .25 M^2 growing area will control temp, lighting, and humidity and scrub some trace gases
- Physical Description: see graphic First use on ISS is in FY17
- Objectives: To permit scaled up science in a controlled system
- Implementation: selection through the NRA / PEER review process
- Schedule: FY13: Completion of the system design
  FY14: Hardware development
  FY15: hardware development and test

Graphic



Approach:

- Plans are made for a specific flight opportunity and insert selection and development is left up to the selected PI
- An NRA is released and PI's are selected
- PI's select the flight insert for the selected investigation
- PI's are expected to Fly with two year of authority to proceed
- Initial science report is due one month after ground control and flight testing is complete
- Upmass Initial deployment 2016 200kg
- UpMass After initial deployment 29kg
- Down Mass 29kg

Collaborators/Roles:

This is a ISS-R funded activity
- The PI's are selected through the NRA process
- The hardware is designed by NASA and managed by NASA KSC
- The flight processing activities conducted by NASA KSC and its contractors

Justification:

- Value to Agency - This operating model is specifically targeted at doing more detailed investigation in a tightly controlled environments. Observations and discoveries made during these investigations will provide high quality science and add to the body of knowledge necessary for long duration space flight within a tightly closed system. It will define research directions.

- Value to Public - These investigations are looking at fundamental biological science without the gravity component. This type of investigations reveal secondary effect which have always been masked due to the gravity effect. The knowledge gained on how biological systems perform under stress conditions will have important implications as we manage energy and materials on earth.

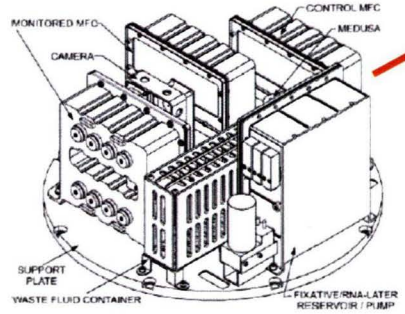
Point of Contact: Bryan Onate 321-867- 5151

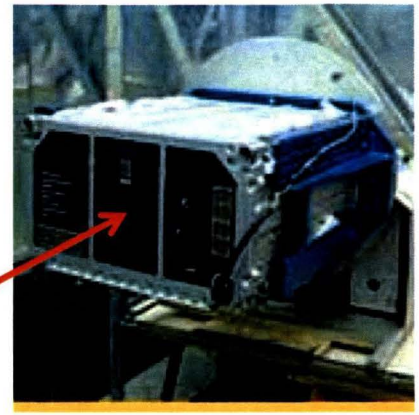
BioTube Series Experiments

Description and Objectives:

- Theme: P2 Establish a program of research analyzing plant and microbial growth and physiological responses to the in spaceflight environments
- Technical Description: This is a MDL size self contained experiment unit. It provides three level of containment to support the use of hazardous liquids
- Physical Description: See graphic
- Objectives: To support selected research
- Implementation: : selection through the NRA / PEER review process
- Schedule: FY13: Fly on Space X3
  FY14: no planned use
  FY15 : no planned use

Graphic





Approach:

- Plans are made for this specific flight opportunity
- More investigator are needed through the NRA process
- PI's select and build the experiment unique equipment going inside the containment system for the selected investigation
- Initial science report is due one month after ground control and flight testing is complete
- UpMass 29kg
- Down Mass 29kg

Collaborators/Roles:

This is a ISS-R funded activity

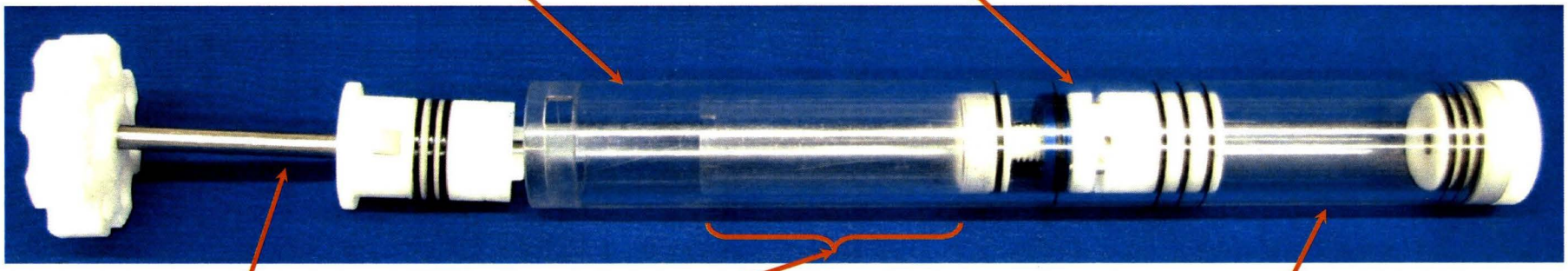
- The PI's are selected through the NRA process
- The hardware is designed and managed by NASA KSC
- The flight processing activities conducted by NASA KSC and its contractors

Justification:

- The overall goal is to attract quality science investigations to the ISS facility by increasing the opportunities investigator unique equipment
- Value to Agency - This operating model is specifically targeted at doing more detailed investigation in a tightly controlled environment. Observations and discoveries made during these investigations will provide high quality science and add to the body of knowledge necessary for long duration space flight within a tightly closed system. It will define research directions.
- Value to Public - These investigations are looking at fundamental biological science without the gravity component. This type of investigations reveal secondary effect which have always been masked due to the gravity effect. The knowledge gained on how biological systems perform under stress conditions will have important implications as we manage energy and materials on earth.

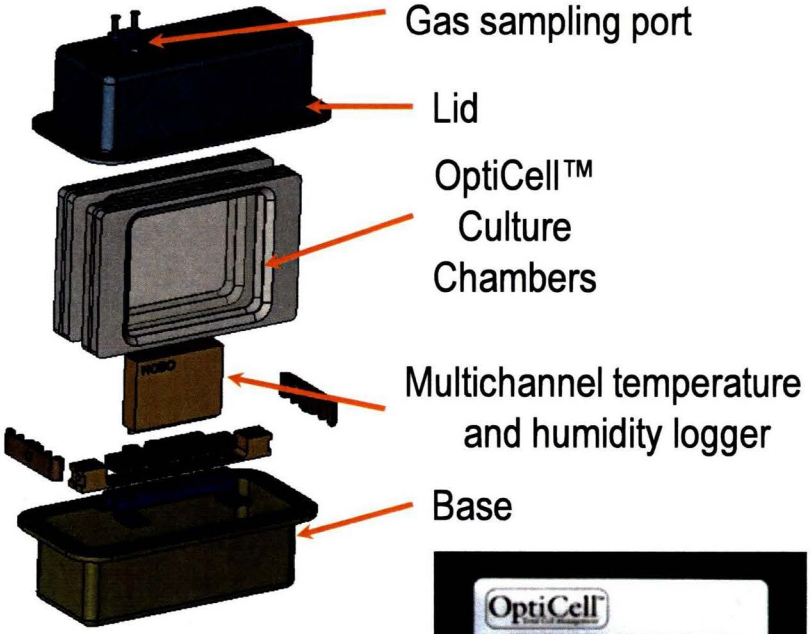
Point of Contact: Ralph Fritsche 321-867-6120

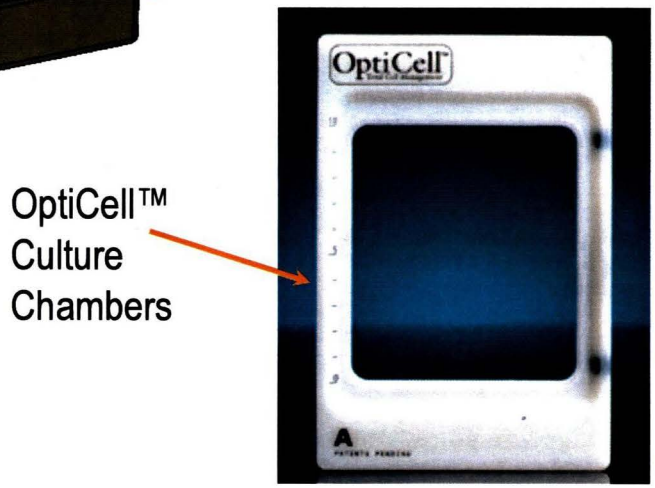
Kennedy Space Center Fixation Tube (KFT)



- Provides three levels of containment during all phases
- No glovebox required
- Samples may be transferred from other growth facilities
- Maintains robust containment down to -100 ° C

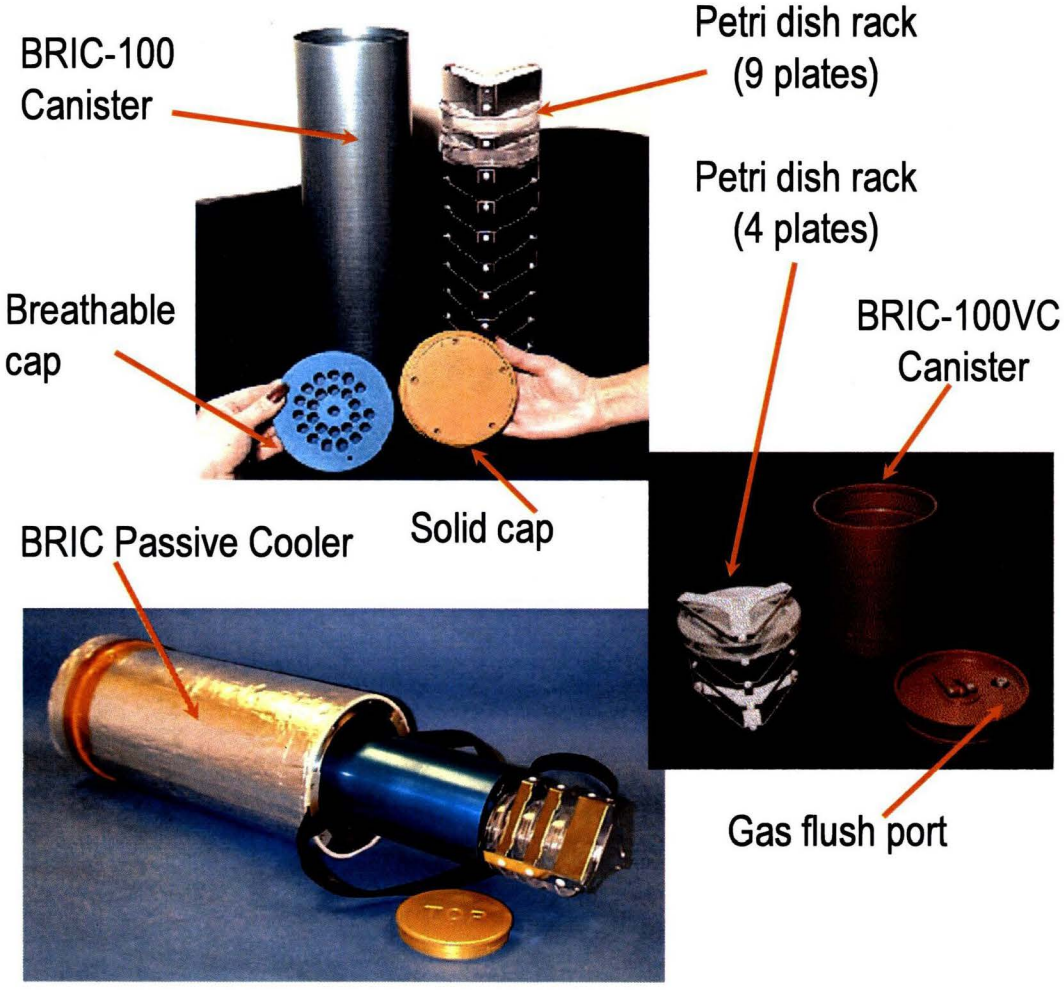
Biological Research in Canisters
BRIC-Opti





- 2 sealed levels of containment
- Gas sampling capable
- Passive
- Can be frozen (-100 ° C)
- Contains up to 4 OptiCell™ culture chambers
- Autonomous environmental data logging

Biological Research in Canisters
BRIC-100 series



- Sealed or vented passive containers
- BRIC-100 holds 9 100mm Petri dishes
- Can be used in conjunction with BRIC passive cooler (+4 ° C)
- BRIC-100 VC is sealed
- BRIC-100VC holds four 100mm Petri Dishes & two data loggers
- Gas flushing capability

Relating Hardware to Science Objectives

	KFT	BRIC	ABRS	VEGGIE	APH	BIOTUBE
Cell, Microbial and Molecular Biology	X	X	X	X	X	X
Organismal and Comparative Biology	X		X	X	X	
Developmental Biology			X	X	X	
P1 Microbial Observatory	X			X		
P2 Establish a robust spaceflight program of research analyzing plant and microbial growth and physiological responses to the multiple stimuli	X	X	X	X	X	X
P3 Develop a research program aimed at demonstrating the roles of microbial-plant systems in long term life support systems	X	X	X	X		X

Acknowledgements

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