International Space Life Science Working Group

ISLSWG

Space Life Sciences

Flight Experiments Information Package (FEIP)

2014

A Companion Document to
Agency Solicitations in Space Life Science

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Introduction

This supplement is a companion to the 2014 research solicitations released by agency members of the International Space Life Sciences Working Group (ISLSWG): the Italian Agenzia Spaziale Italiana (ASI), the Canadian Space Agency (CSA), France's Centre National d'Etudes Spatiales (CNES), Germany's Deutsches Zentrum für Luft-und Raumfahrt (DLR), the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), and the United States' National Aeronautics and Space Administration (NASA). The various sections of this supplement provide a common basis for proposal preparation and submission by any eligible scientist, regardless of the country of origin.

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Individuals submitting responses to agency solicitations should follow the directions in the appropriate agency solicitation. In general, a Notice of Intent (NOI) to propose, or Step-1 Proposal for NASA, is requested by March 28, 2014, and the final proposal submission deadline for the International Life Sciences Research Announcement 2014 is May 23, 2014. For JAXA, NOIs are requested by March 26, 2014 and final proposals by May 9, 2014. Please see available links to the appropriate agency solicitation for specific directions concerning NOI and proposal submission at http://tinyurl.com/ILSRA2014 or contact the appropriate representative as listed above.

1.0 Anticipated Flight Opportunities for Space Life Sciences

The International Space Station (ISS) US Operating Segment (USOS) assembly is complete with emphasis on the full utilization of the ISS platform. As a result a wide range of facilities and equipment are available with as many as 6-7 crew members (up to four USOS and three Russian crew) operating the ISS. Nevertheless, resources such as crew time, electrical power, and refrigeration/freezing remain limited. Furthermore, transport of experiment related samples and/or hardware to and from the station will be accommodated using a fleet of vehicles with finite transport capacity. It is anticipated that transportation of the crew to and from the ISS will be via the Russian Soyuz vehicle until NASA's Commercial Crew capability becomes available.

Flight experiment opportunities are limited and constrained in a number of ways. Proposals that require resources beyond the capabilities described in this document should not be submitted.

Flight experiment proposals must represent mature studies strongly anchored in previous or current ground-based or flight research. Ground-based research may, and usually must, represent one component of a flight experiment proposal. For a flight experiment proposal, ground-based research should be limited to activities that are essential for the final development of an experiment for flight, such as definition of flight procedures, testing of experiment hardware and control activities for the flight experiment. In this case, only one (flight) proposal needs to be submitted.

Flight experiment proposals must clearly define the actual experiment duration and all requirements and conditions required to successfully complete the experiment. The investigator should allow for flexibility in the selection of the best hardware to be used to accomplish the experimental goals. Descriptions and websites of the functional capabilities of hardware available to support human and nonhuman (biology) experiments are included in Sections 2 and 3 of this document. This information should be used to develop an understanding of the available capabilities. Investigators should use this information as a guide for developing experiment requirements and procedures rather than selecting specific hardware items.

Some experiment proposal requirements may result in the need to develop specialized experiment-unique equipment (EUE) to work in conjunction with the facilities and functional capabilities of existing hardware. Development of (EUE) will require additional funding, and individual agencies will factor this into their overall assessment of the feasibility of a proposal.

Design, construction, and flight of major EUE hardware items or facilities usually require the commitment of large quantities of resources (power, crew time, volume). In the event that such items are proposed, they should be clearly identified.

Flight experiment definition and development generally require one to three years. It is anticipated that flight assignments for experiments selected will occur no earlier than 2016/2017 with planning for the flight experiment occurring in 2015.

It is expected that the experiments selected from proposals in response to this announcement will mainly be performed on the ISS. Pre- and post-mission studies that involve tests of the astronaut crew before launch and upon return from their space flight may also be submitted (see Section 1.2 and 1.3 for specific constraints on pre- and post-flight astronaut participation).

1.1 Flight Experiments

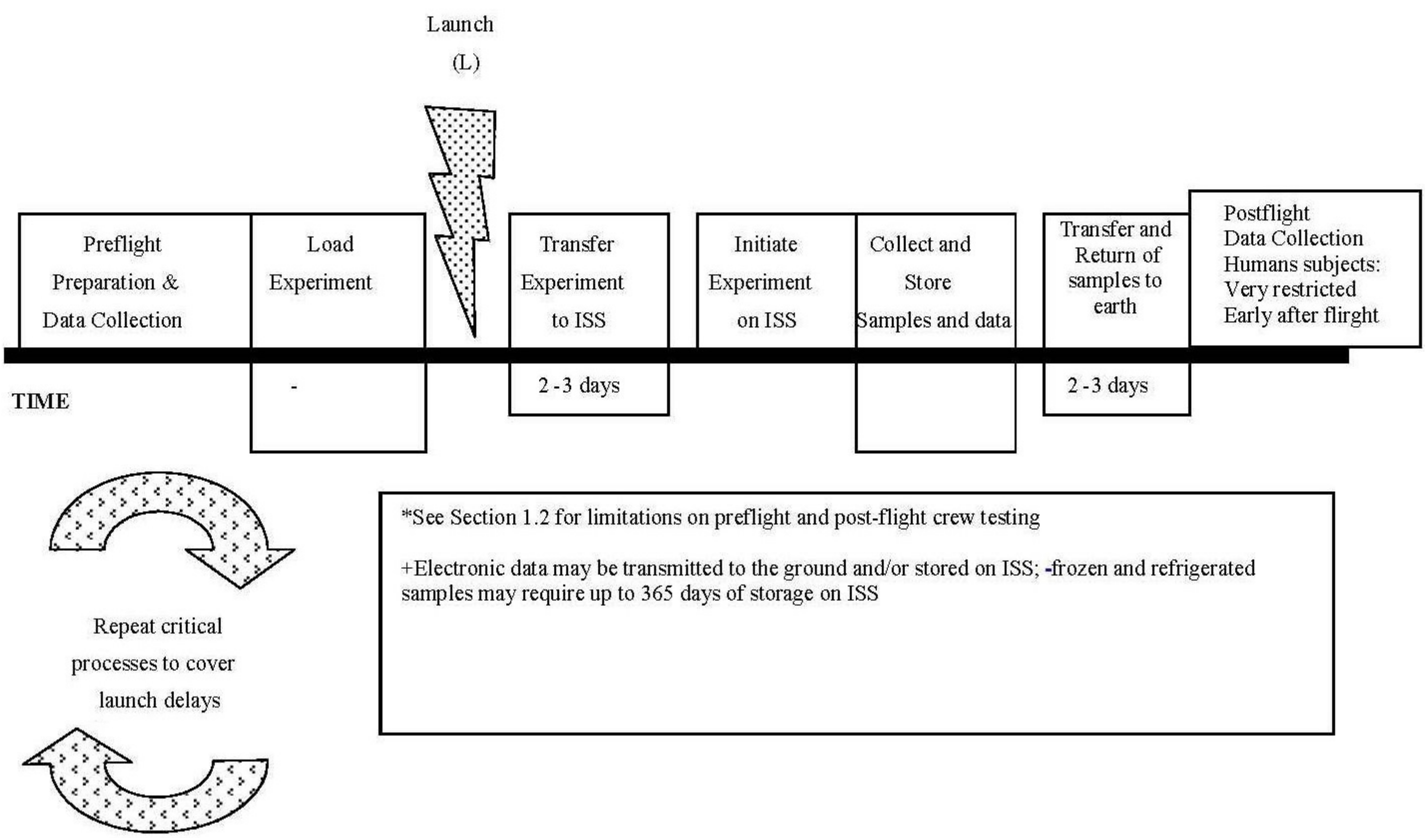
Research activities will be accomplished during ISS operational increments when the ISS crew will act as experiment operators and, if necessary, as subjects. The duration of microgravity exposure can, in theory, be indefinite, with periodic disturbances at intervals caused by U.S., Russian, European and Japanese transportation vehicle docking activities, re-boosting, and some crew activities (e.g. exercise). Flight experiment durations depend on the schedule of launch and return of transport vehicles to/from the ISS. In principle there is no firm upper limit for the maximum duration of an experiment, since ISS is planned to continue to operate continuously at least until 2020.

The primary opportunities to transport scientific equipment, supplies, and samples will be on HTV, Orbital and SpaceX vehicles for launch and on SpaceX for return from ISS. The transport frequency, power during transport, conditioned temperature stowage and mass of transported items are constrained. In addition there may be very limited opportunities for launch and return on Russian transport vehicles (Soyuz and Progress). Refrigerated and frozen transport of samples on Soyuz is not available. There is a minimum delay between handing over an experiment for launch and either starting or storing an experiment onboard ISS, since transfer vehicles must travel to and dock at the ISS (see Figure 1 below). This handover-transportation period typically varies between several hours and several weeks depending on the characteristics of the transport vehicle and operational constraints. The requirements necessary to preserve the integrity of an experiment during these storage periods shall be described on the Space Flight Experiment Requirements Summary).

If sample return to Earth is required, it needs to be scheduled with a return vehicle. Depending upon the duration of the active phase of the experiment, storage of samples for several months must be possible due to the limited frequency and capability of return vehicles. The currently foreseen schedule for SpaceX Dragon missions is approximately one every three to four months. Dragon vehicles are berthed to ISS typically for only 2-4 weeks. While it may be possible to perform some investigations entirely during the docked phase of a Dragon, potentially permitting upload & download on the same vehicle, there are often significant limitations on available resources such as crew time and scheduling of activities during the docked phase. The currently foreseen schedule of Soyuz rotations (subject to change) is 2 and 4 month increments – i.e. the minimum period between upload on Soyuz and download on a Soyuz is between 2-4 months. Therefore, experiments should be designed to survive a minimum of several months inflight. Detailed consideration should be given to both active and passive phases of the proposed experiment (e.g., reagent and specimen storage time and conditions) in order to define adequately the experiment requirements, procedures, and flexibility. Proposers need to understand that they won't be getting their samples back in a matter of hours after landing, and that the current capability does not include live animal return.

The availability of the crew for specifically timed science operations and as subjects of research is also constrained. On average, a total of approximately 70 crew hours per week will be available for all research, of which 50% is allocated to the Russian segment. A subset of this crew time will be available to support life sciences research. However, ISS crewmembers have indicated an interest in science tasks that can be performed on a time-available basis and proposers are strongly encouraged to identify objectives that can be achieved in this manner. Estimates of crew time required to complete the experiment must include the time required for crewmembers to both operate an experiment and serve as subjects. Moreover, crew time for data collection after flight is extremely limited and consideration of current exercise countermeasure protocols is strongly recommended (see Section 2.1.3). There is no assurance that all crewmembers will agree to participate as subjects in experiments. See section 2.1 for more information regarding the use of crewmembers as subjects and the assumptions to be made in planning these types of experiments.

Figure 1: Flight Experiment Implementation Flow



1.2 Pre- and Post-mission Studies with astronauts as subjects

Opportunities will be available to perform experiments, collect samples, and take physiological measurements of the astronaut crew both before their space mission and following their return to Earth. Such proposals are considered flight experiments and should specify the desired activities, and the timeframe in which these activities must be performed prior to and following the mission. There is no assurance that all crewmembers will agree to participate as subjects in experiments. Access to the crew immediately before and upon return is extremely limited (availability of astronauts for research tests on the day of return to Earth, or the day after, may be as little as one hour per day total. See Section 1.4).

1.3 Transportation

Within the timeframe identified in this document, Soyuz launch capabilities for crew transportation will be augmented by additional cargo launch vehicles such as the NASA-provided SpaceX and Orbital vehicles, the JAXA-provided H-II Transfer Vehicle (HTV), and Russia's Progress vehicle. Progress, HTV and Orbital vehicles provide logistics support to the ISS but no return capability. SpaceX provides logistics support to the ISS as well as return capability.

Appropriate transportation for each selected investigation will be arranged as required. Therefore, investigators should take care when anticipating and specifying such requirements as electrical power and temperature constraints during transit from Earth to ISS, and time constraints for pre-launch delivery and post-landing retrieval of experiment equipment and specimens.

1.4 Difficult Experiment Requirements to Implement on the ISS

There are certain experimental procedures that, while not impossible to perform, are difficult to implement during ISS operations. Those requirements that may be difficult to accommodate include:

(a) Human Physiology Experiments

1. Any experiment requiring new flight hardware development / qualification. The extent of how difficult this development will be is dependent on how much design and development is required for custom made equipment and how extensively off-the-shelf equipment will have to be modified.
2. Return of hardware for refurbishment or data retrieval. Down mass resources will be protected for critical science samples; data should be planned to be down linked and hardware will likely be discarded.
3. Requirements for conditioned stowage (i.e. other than ambient temperature) that exceed the capabilities (ie. Temperature ranges, volume) of the equipment identified on the conditioned stowage web site. EUE refrigerators or freezers will not be developed.
4. Studies requiring more than 12 human subjects.
5. Studies requiring overly invasive or complicated procedures that may hinder crew consent.
6. Total pre-flight BDC requirements of more than 10 hours.

7. Single BDC sessions requiring more than 2 hours.
8. More than 2 hours of BDC required within 3 months of launch.
9. BDC testing requirements within two months of launch.
10. In-flight procedures that require a high degree of proficiency and training prior to crewmember launch (e.g. requires more than three, 2 hour sessions for one unique procedure/skill; requires refresher session within 60 days of launch).
11. Two or more hours of testing required within the first three days of landing.
12. More than three hours of total testing in the first week post-flight.
13. Strenuous or provocative sessions on R+0 or R+1. Any activity that could be considered strenuous or provocative for a healthy normal subject may not be feasible for crewmembers in this time frame.
14. Complicated in-flight sessions before the second week in-flight (e.g. requires set-up of multiple pieces of equipment, followed by testing session of more than an hour; sessions that require privatized voice or video)
15. More than five complicated in-flight sessions involving multiple pieces of equipment. (e.g., requires set-up of multiple pieces of equipment, followed by testing of more than 2-3 hours, requires extensive privatized resources).
16. A single session with one crewmember requiring 4 hours in one day.
17. Crew activity that must be performed daily or more than once a week.
18. Very precise/inflexible timing requirements for sessions (e.g., +/- window for testing of less than one week, multiple timed blood draws, sessions that are linked to other crew activities like meals, EVA's, etc.) Note that occasional fasting data collections upon crew wake up are not difficult to implement.
19. Extended, continuous activities over multiple days that could interfere with other operations.

(b) Biology Experiments:

20. Requirements for cold stowage that either exceed the capabilities (ie. Temperature ranges, volume) of the equipment identified on the cold stowage web site or require a significant portion of available cold stowage capability. Experiment unique refrigerators or freezers will not be developed.
21. Snap freezing to -180 is not currently possible.
22. Experiments requiring new dedicated experiment hardware development that has significant complexity and / or low technology readiness for flight implementation.
23. Generally experiments requiring significant crew intervention, especially specialized training will be more challenging to implement. However, for research projects with rodents it is assumed that the crew would perform general animal experiment handling and procedures
24. Experiments requiring a large number of samples and experiment runs
25. Limitations on frozen downmass
26. Environmental controls not available on all vehicles during launch and free flight to ISS.
27. Operations requiring crew intervention that require precise timing, especially with a series of events or activities that require operations outside of the normal crew day.
28. Currently available launch vehicles may offer limited opportunities to load experiments on the spacecraft close to the time of launch
29. The time that astronauts have available after space craft docking with ISS is limited because of space craft tasks that must be performed, and therefore experiments should be designed so

that they can be activated no earlier than 48-72 hours after docking with ISS without negatively impacting the experiment.
30. For the next 1-3 years, routine post-flight return of experimental specimens or samples to investigators after landing may take as anywhere from 48-72 hours to 2 weeks since the present return capsules will land in the ocean and be transported to shore by boat
31. Operations requiring crew intervention that require precise timing, especially with a series of events or activities which require operations outside of the normal crew day.

1.5 International Teams

Due to the limited resources (e.g., crew time, on-orbit experimental supplies, temperature-controlled sample storage) available for the conduct of ISS research, ISLSWG is pursuing the intentional formation of International teams of investigators whose experiments will leverage resources by addressing different facets of the same question. ISLSWG anticipates that such intentional teaming arrangements will result in better utilization of available resources to resolve specific questions. ISLSWG strongly encourages individual investigators submitting applications in response to this solicitation to consider identifying such International collaborations or teams and to identify this pre-coordination in their submissions. Please note that investigators can only receive funding from the agency associated with their country of origin. Therefore, it is required that each member of an International team submit a letter **that acknowledges awareness** from their associated funding agency with their proposal. This is critical because, one of the criteria peer review panels use to evaluate proposals is the expertise and technical capabilities of the proposed investigator team, so the funding agencies need to be sure that all investigators on an international team will be able to participate in the experiment if it is selected.

2.0 Flight Research Capabilities

2.1 Research Involving Human Subjects

The amount of time it takes to complete a study is based on the required number of subjects and crewmember participation. Investigations selected under this solicitation will be flown while there are up to six crew members on board the ISS, and it should be assumed that two Increment (six month periods) crews will be flown every year for a total of 6 potential subjects a year. However, six of these potential subjects are crewmembers in the US Operating Segment (USOS, which includes American, Canadian, Japanese, and European crewmembers), and six are crewmembers in the Russian Operating Segment. Access to Russian OS crew must be negotiated with the Russian Federal Agency (this is not done at the proposal stage). In order to account for variations in subject participation and suitability, it should be assumed that two subjects per Increment will participate, for a total of four subjects per year. Therefore, if an investigation requires a minimum of six crewmember subjects, it will take a minimum of three ISS Increments (1.5 years) to complete the in-flight data collections.

All use of human subjects for research must comply with the national requirements for the ethical treatment of human subjects (see agency-specific announcements for details). Informed consent of human subjects must be obtained before carrying out any study in space, and potential applicants should be aware that obtaining such informed consent will involve a uniform process regardless of the country of origin of the applicants. The availability of consenting subjects may affect the probability of achieving experiment objectives within the expected timeframe.

There are many research tools available to investigators who wish to conduct human physiological research on the ISS. The ISS Human Research Facility (HRF) is a suite of hardware that provides core capabilities to enable research on human subjects. HRF consists of instruments mounted in two racks, as well as separate equipment kept in stowage and brought out as needed.

A complementary set of hardware is provided via the European Physiology Modules Facility (EPM), a multi-user facility supporting human studies. The EPM rack is outfitted with an initial complement of instruments. Due to the modular design, this initial configuration can be easily complemented and/or modified with instruments still under development or to be developed, according to the scientific needs.

HRF 1 and 2 and EPM are located in the Columbus laboratory to allow for combined experiments.

A new platform of integrated medical systems with various equipment is on the Kibo module. This platform supports various medical and biological researches.

A complete list of hardware in the HRF, EPM inventories, and Kibo, and a web site reference for design details is provided in Table 1. General description of HRF and EPM core capabilities is provided below.

In addition to HRF and EPM equipment specifically intended for research, the Health Maintenance System (HMS) is also potentially available to ISS researchers. HMS is a suite of hardware used to maintain and monitor the crew's health onboard the ISS. HMS hardware can be used for research but this must be closely coordinated with the flight surgeons and cannot interfere with planned operational use. A partial list of HMS hardware is included in Table 1 and a general description of HMS capabilities is provided below.

Data collected by Medical Operations, related to maintaining and monitoring of crew health, is in principle also available for scientific use, however again close coordination with crew surgeons is key. The NASA Lifetime Surveillance of Astronaut Health (LSAH) Data Base consists of archived medical data collected previously in a standardized way, and is available to researchers in order to complement flight experiments or to be used in separate studies. How to access this data is described in detail in the URL above.

2.1.1 Human Research Facility (HRF)

Two NASA Human Research Facility (HRF) racks are currently on board ISS. These racks contain a variety of instruments (rack mounted and stowed) available to investigators for human life sciences research. The racks provide power, data, and cooling to components in the rack, and each rack has a dedicated laptop computer to facilitate downlink of experiment data to the ground. HRF racks 1 and 2 are located in the Columbus module on board ISS.

- **Blood Pressure:** The Continuous Blood Pressure Device (CBPD) provides continuous beat-to-beat finger arterial blood pressure measurement of systolic and diastolic measurements between 10 and 300 mm Hg. A basic three-lead electrocardiograph (ECG) is also provided for measurement of ECG data from the subject. The CBPD requires rack power and therefore is not considered an ambulatory device. Data are downloaded to one of the HRF laptop computers for transmission to the ground.

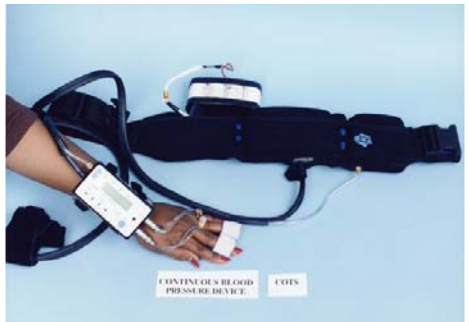


Figure: Continuous Blood Pressure Device

- **Holter Monitor:** The Holter Monitor 2 (HM2) is a modified commercial device, the H12+ from Mortara Instrument Inc. The HM2 is housed in a custom belt, designed to have a fully adjustable waist size suitable for the 90% American male to 10% Japanese female with quick-release buckle providing quick attachment or removal. The HM2 provides ambulatory electrocardiograph (ECG) which accurately and non-invasively measures the electrical activity of the heart over an extended period of time (up to 24 hours continuously). Data is downloaded to one of the HRF laptop computers for transmission to the ground. It is able to support continuous, uninterrupted, non-invasive data collection of the following parameters for an ambulatory subject:
  - Heart rate
  - ECG waveforms
  - Time stamps for each data record
  - Event markers input by the user

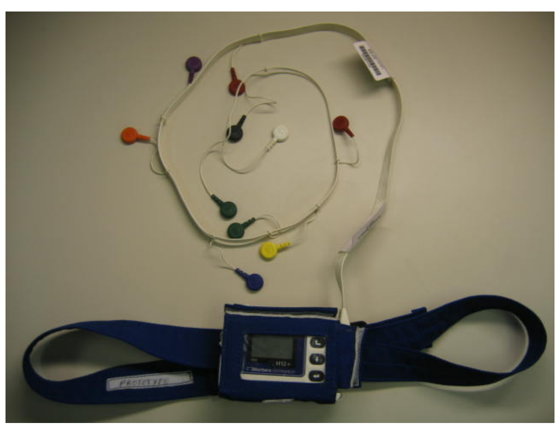


Figure: Holter Monitor 2

- **Pulmonary Function System:** The Pulmonary Function Module/Photoacoustic Analyzer Module (PFM/PAM) consists of a set of photoacoustic analyzers and a laser-based Oxigraf®

oxygen analyzer for the compositional analysis of respiratory gases. The PFM/PAM is a NASA-ESA collaborative piece of hardware consisting of an active 8-panel unit (8PU) Standard Interface Rack (SIR) compatible drawer with front and rear data, power, and gas connections. The PFM/PAM is used in conjunction with the Gas Delivery System (GDS) to measure and analyze inspired and expired breath of subjects. It is currently located in the HRF Rack 1 in the Columbus Module. ESA has developed a portable version of this device, the Portable Pulmonary Function System (PPFS).

Combined with ancillary equipment, including gas supplies for supplying special respiratory gas mixtures, the following measurements are possible:

1. Breath-by-breath measurements of VO_2, VCO_2, and VE
2. Diffusing capacity of the lung for CO
3. Expiratory reserve volume
4. Forced expired spirometry
5. Functional residual capacity
6. Respiratory exchange ratio
7. Residual volume
8. Total lung capacity
9. Tidal volume
10. Alveolar ventilation
11. Vital capacity
12. Volume of pulmonary capillary blood
13. Dead-space ventilation
14. Cardiac output
15. Fractional inspiratory and expiratory volumes, F_{IO2} and F_{EO2}, $F_{ICO2,}$ and F_{ECO2}
16. Numerous other specialized tests of pulmonary function

Figure: Canadian Space Agency astronaut Chris Hadfield using the PFS

- **Ultrasound 2**: The Ultrasound 2 is a modified Commercial Off-The-Shelf (COTS) system that includes the General Electric (GE) Medical Systems Vivid-qTM model ultrasound unit, a Video Power Converter (VPC), probes, and an ECG cable. This system replaces the original HRF Ultrasound (launched in March 2001) and includes additional features that allow for panoramic image construction to estimate muscle volume changes, speckle tracking functions to analyze cardiac stress-strain, and dynamic morphology. The Ultrasound 2 can be used for a variety of experiments for cardiac, muscle, vessel, and blood flow analysis. Each application utilizes either a curved, phased, or linear array probe. The Ultrasound 2 can support real-time downlink of Ultrasound images via the HRF Rack or an EXPRESS rack to facilitate remote guidance from investigator teams.

Figure: The Ultrasound 2 unit on board ISS with US astronaut Mike Fossum as the operator and JAXA astronaut Satoshi Furukawa as the subject.

- **Mass Measurement:** The Space Linear Acceleration Mass Measurement Device (SLAMMD) follows Newton's Second Law of Motion by having two springs generate a known force against a crewmember mounted on an extension arm, the resulting acceleration being used to calculate the subject's mass. The device is accurate to 0.5 pounds over a range from 90 pounds to 240 pounds. This device can measure mass from 95 to 240 pounds (40 to 108 kg) by using the known force generated by two springs located inside of the SLAMMD drawer. The resultant acceleration of the attached crewmember is measured and the mass then calculated.

Figure: US Astronaut Bill McArthur performs a body mass measurement on board the ISS using the SLAMMD

- **Centrifuge:** The Refrigerated Centrifuge (RC), located in the Human Research Facility rack 2 is a device that is used to separate biological substances of varying densities by spinning at a high rate. The RC was designed to provide refrigeration with temperatures that range from ambient ISS temperature to 4 degrees C, but currently, the on-orbit unit is not cooling so this feature is not available to investigators. The six chamber RC rotor chamber can hold samples sized from 2 to 50-ml. The twenty-four chamber RC rotor can hold samples sized from 0.5 to 2.2 ml. The speed can be selected from 500 to 5000 revolutions per minute (rpm) for 1 to 99 minute durations, or it can be set to run continuously.

Figure: US Astronaut Clayton Anderson working with samples in the Refrigerated Centrifuge on board ISS.

Sample Collection and Storage

Blood, urine, and saliva samples may be collected from crew subjects before, during, and after flight. Blood, urine, and saliva collection kits for the collection, preservation, and storage of samples are available. Unique experiment requirements will be discussed with investigators during the definition of the experiment to determine if existing supplies will meet the study requirements. Currently during spaceflight, individual urine voids are collected into urine collection devices (UCD) containing a known concentration of lithium chloride (see photo). The UCD is mixed and a sample taken and returned to Earth. The remainder of the urine is disposed of as trash. Determination of the lithium in the sample is conducted and the volume of the original urine void is calculated by the dilution method.

Figure: Urine Collection Device (w/female adapter) and Frozen Urine Syringes

Activity Monitoring: The Actiwatch Spectrum System is a modified commercial-off-the-shelf (COTS) system consisting of the Actiwatch Spectrum Kit, Actiwatch Spectrum, Actiwatch Spectrum Dock, Actiwatch Spectrum Universal Serial Bus (USB) Cable, and Actiware Software (version 5.52 or later). The Actiwatch Spectrum is a small, battery-powered, limb-worn device that simultaneously detects body movement and light intensity. The unit can be used to investigate a number of activities such as sleep quality, sleep onset, hyperactivity and other daily routines. The Actiwatch Spectrum can be programmed to collect data in a variety of modes including activity, photopic light, red-green-blue (RGB) light or several combinations thereof. Data is sampled by the Actiwatch sensors at a frequency of 32 Hz and may be recorded at a variety of epochs: 15 and 30 seconds and 1, 2 and 5 minutes. Total recording time is limited by the data collection mode and epoch setting. Data from the Actiwatch Spectrum is downloaded to one of the HRF laptop computers for transmission to the ground.

Figure: Actiwatch Spectrum

2.1.2 Exercise

The primary suite of equipment from the HMS inventory available to researchers is the crew exercise equipment. Several exercise devices are/will be available for research including a cycle ergometer, an Advanced Resistive Exercise device (ARED), and two treadmills.

For description, see the following web site:
http://www.nasa.gov/centers/johnson/slsd/about/divisions/hacd/project/exercise-countermeasures.html

Use of this equipment will require coordination with Flight Medicine to ensure appropriate and proper usage. Use of HMS hardware, including exercise devices, must be coordinated and approved by Space Medicine so that impacts to crew health care, standard countermeasures, and exercise prescriptions can be assessed. Under certain circumstances, use of exercise devices for research purposes may replace nominal exercise protocols.

The cycle ergometer provides workload, driven by the hands or feet, that is controlled by manual or computer adjustment. It operates with the subject seated or supine, and provides time-synchronized data compatible with other complementary analyses. The data output consists of work rates in watts and pedal speed (rpm) for use with a data acquisition system.

The Advanced Resistive Exercise Device (ARED) functions to maintain crew health in space. Crew members exercise daily on ARED to maintain their pre-flight muscle and bone strength and endurance. EVA, IVA, re-entry, and emergency egress necessitate the crew members' continued strength and endurance.

The ARED has the capability to exercise all major muscle groups while focusing on the primary resistive exercise: squats, deadlifts and calf raises. It accommodates all crew members, from the 5th percentile female to the 95th percentile male. An informative NASA technical report describing the characteristics of the ARED is at:
http://ston.jsc.nasa.gov/collections/TRS/listfiles.cgi?DOC=TP-2006-213717

The treadmills may be used for walking and running exercise. The devices employ various strategies to simulate, as closely as possible, 1 g skeletal loading during exercise bouts. The treadmill will measure and display the loads exerted on the subject by restraint harnesses before, during, and after the exercise bout. The restraint system provides stabilization of the user and load distribution on the body in a weightless environment. One of the treadmills will also provide foot impact forces, with high accuracy, allowing investigations in the area of locomotion. The treadmill can be motor-driven or passively operated. As with the cycle ergometer, the treadmill provides data compatible with other complementary analyses.

2.1.3 Evaluation of Muscle Strength and Exercise Capacity

A Muscle Atrophy Research and Exercise System (MARES) can also be used to evaluate muscle strength and exercise capacity. The MARES provides active resistance (concentric and eccentric) that can be fully programmed as motion profiles.

MARES supports the following capabilities:

- Measurement of the (bidirectional) torque, position, and velocity generated during programmable tests on the agonist and antagonist muscle groups of the trunk and extremity joints including ankle, knee, hip, wrist, elbow, shoulder, whole leg, and whole arm
- Measurement of these parameters during submaximal and maximal exercises throughout the entire range of motion (except for shoulder) in the isometric, isokinetic (concentric and eccentric), and isotonic (concentric and eccentric) modes
- Simulation of ideal elements: spring, friction and inertia
- Parameter control following predefined pattern: position control, velocity control, torque/force control, power control
- Quick release of free motion
- Complex combinations of the previous modes
- Bilateral torque and angular position/velocity measurements and training on the flexion and extension of the knee, ankle, trunk, hip, shoulder, elbow and wrist, and on the supination/pronation, radial/ulnar deviation of the wrist
- Bilateral force and linear position/velocity measurements and training on the following multi-joint linear movements:
- Arm press (front, overhead and intermediate trajectories)
- Leg press (front, down and intermediate trajectories)
- The displays available to the subject are highly programmable, i.e., display of peak torque vs. joint angles, and average torque at specific joint angles as well as torque-velocity throughout the entire range of motion).
- The motion and experiment profiles are highly programmable (e.g., programming of variable and quantifiable velocities and resistances during training exercises, assessment of fatigue over serial contractions)

Currently, there are already several additional instruments available for:

- Measurement of hand grip strength or pinch strength as a function of time
- Local noninvasive muscle stimulation on human subjects using a high current stimulator that provides trains of pulses up to 0.8 amps, according to pre-programmed protocols. It can be connected to MARES.
- Portable measurement of full range of motion in either 1 or 2 degrees of freedom in selected joints.

2.1.4 Movements

A **Codamotion** system, that tracks body movements is being developed for use on ISS. This system can be combined with a handheld **Manipulandum** that measures pinch force, friction and acceleration. This H/W is developed for an experiment that investigates dexterous manipulation in weightlessness, but would be available for other purposes as well.

ELaboratore Immagini TElevisive for Space, second generation (**ELITE-S2**): Elite-S2 is a system to observe body motor control during long-term exposure to microgravity. Elite-S2 is an EXPRESS Rack drawer-type payload requiring data and video downlink. Video from the cameras is displayed on the EXPRESS Laptop Computer (ELC) for crew quick look in addition to being downlinked.

Four cameras are positioned in the US Lab. Cables are routed from the cameras to the Elite-S2 Interface Management Unit (IMU) located in the EXPRESS Rack. Cables, once installed for each EXPRESS Rack, remain installed until completion of all test objectives.
One crewmember is required for set up, execution of tests, and stow.

During tests, near real-time science data is continuously downlinked through the EXPRESS Ethernet LAN.

Hand Posture Analyser (HPA): A complete HPA system is composed of two sets of instruments which can be used separately to acquire data on the upper limb posture and on the ability to produce isometric grip force. The two subsystems are respectively the Handgrip Dynamometer / Pinch Force Dynamometer (HGD/PFD) for the acquisition of hand and pinch force and the Posture Acquisition Glove (PAG) and Inertial Tracking System (ITS) for the measurement of fingers position and upper limb kinematics.

This system comprises also an Interface Box (IBOX) where instruments connect through dedicated cables. The IBOX is connected to a PCMCIA card of a Laptop PC for data acquisition and a dedicated software application manages the execution of experimental protocols.

2.1.5 European Physiology Modules Facility (EPM)

The initial instrument complement to be accommodated includes:

The MEEMM (**Multi-Electrode EEG Mapping Module**) is designed to support brain and muscle activity studies by measuring EEG/EMG and evoked potentials. The main features of the MEEMM are:

- Supporting acquisition of up to 128 EEG channels (maximum sampling frequency 2.2 kHz, 0.01-580 Hz maximum bandwidth)
- Supporting acquisition of up to 32 EEG channels (maximum sampling frequency 40 kHz, 1.5 Hz-10 kHz maximum bandwidth)
- Supporting acquisition of up to 32 surface EMG channels (64 electrodes) (maximum sampling frequency 40 kHz, 1 Hz-10 kHz maximum bandwidth)
- External triggering digital signal acquisition (8 bit digital interface)

PORTEEM (**Portable EEG**). Modular instrument for ambulatory/sleep EEG measurements. Initial configuration :

- 12 EEG channels (0.3-70 Hz maximum bandwidth)
- 2 EMG channels (1-150 Hz maximum bandwidth)
- 1 ECG channel (1-150 Hz maximum bandwidth)
- 1 strain gauge respiratory signal (0.3-30 Hz maximum bandwidth)

CARDIOLAB. (**Cardiovascular Laboratory**). CARDIOLAB consists of a central data management system providing services to a complement of instruments (sensors and stressors), including :

- CARDIOPRES: Continuous acquisition of blood pressure (finger and arm cuffs), ECG from 1 to 7 leads derivations, thoracic and abdominal breathing patterns
- HLTE: ECG Holter (24 hours ECG full stripes recording)
- HLTA: Arm-cuff blood pressure Holter (Systolic, Diastolic and Mean Blood Pressure measurements)
- PDOP: Portable ultrasound doppler instrument (Main arteries blood velocities measurements up to three channels at a time with 2Mhz, 4Mhz and 8Mhz pulsed wave probes)
- APLT: Air plethysmography, providing limb volume variations against venous occlusion
- LVMD: Limb Volume Measurement Device; reconfigurable for body position determination via spine geometry measurements (continuously up to 48 h)
- HEMO: Hemoglobinometer; measurement of hemoglobin by azide methemoglobine method; control of the status of whole blood
- HEMC: Hematocrit Centrifuge (determination of the whole blood hematocrit by centrifugal separation of blood cells from plasma)
- CMAS: Continous Measurement Ambulatory Device for medium term (up to 8 h) ambulatory acquisition and recording of physiological signals, such as ECG, EMG, EEG, breathing patterns, body movements and activity
- LACS: Leg/arm occlusion cuff system. Application at the level of the limbs of an occlusive stress in a range from 0mm of Hg to 300 mmHg (two different level/profiles of pressure on the arms and on the legs).

In addition to the devices existing on ISS, CNES and DLR as the developers of CARDIOLAB are considering to provide further modules, if required from the scientific community, such as:

- EIT: Electrical Impedance Tomography, providing non-invasive dynamic on-line registration of regional air and fluid distribution in a thoracal cross-section for analysing lung function (ventilation, perfusion, air and fluid distribution); method requires only measurements by 16 normal ECG electrodes attached around the thorax to calculate tomographic images from inside the thorax.
- Portable Echograph : Portable laptop based echocardiograph approx 7 - 9Kg, Battery self powered Device or 28v power Supply, Sector scan probe (3-5MHz) for deep organs and vessels (Cardiac, abdomen, pelvis, etc), Linear probe (5-12Mhz) for superficial structures and vessels: Peripheral vessels, muscle, Ultrasound modes: B mode, Time motion, Pulsed Doppler.

    1) System fully tele-operated from the ground (Gain, depth, Doppler, recording..)

    2) Deliver Radio-frequency (RF= raw ultrasound signal) => Higher accuracy => other parameter (attenuation, propagation velocity…)

    3) Include IMT auto-measurement software (Vessel wall thickness)

    4) PW Doppler output for skin probe (monitoring during LBNP, Ex)

    5) T skin echo probe for superficial Vein/artery monitoring (LBNP, Bracelets, Ex)

- Laser Doppler: Local microcirculation, and particularly vasomotor functions of the arterioles have a real impact on blood pressure regulation. A Laser Doppler instrument will allow the study of microcirculation through the measurement of the skin blood flow. The instrument can use 3 Laser Doppler probes in parallel, with the following characteristics: multifiber laser probes (780nm), room for the probe to receive the drug, application of an electric current (ex. 100µA over 20s) for an application on the skin of the drug by iontophoresis, local skin heating(up to 44°C), measurement of the temperature by a themocouple for the regulation of temperature

SCK (Sample Collection Kit). Stowage of medical and clinical equipment for blood, saliva and urine sample collection and disposal and management of used medical/biohazard items.

2.1.6 Head Mounted Displays (HMD) (ESA)

HMD used for neuro-sensory and cognitive research is available, further developments with more advanced features, like eye- and head-tracking, could be considered if selected experiments require those capabilities.

2.1.7 Eye Movements

A 3-dimensional **Eye Tracking Device** (**ETD**) for the recording of eye movements will be available. This device may be used to measure horizontal, vertical and/or torsional eye positions by means of digital processing of the recorded eye image sequences. Furthermore, head movements will be measured by means of three orthogonally arranged angular rate sensors and three orthogonally arranged linear accelerometers. This encompasses all three degrees of freedom of eye movement (in the head) and all six degrees of freedom of head movement in space. Therefore, gaze can be reconstructed.

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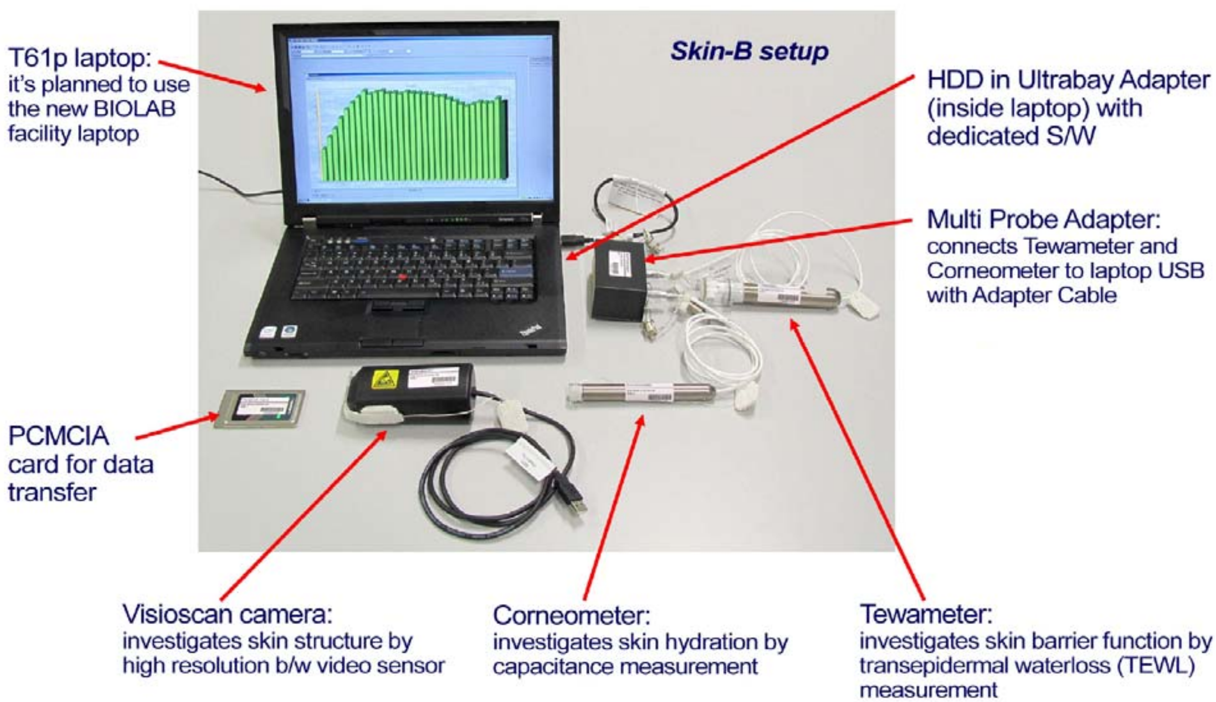
2.1.8 Instruments for investigation of skin physiology (SKIN B H/W Kit):
SKIN B is a system for non-invasive examinations of three skin physiological parameters by using two measurement probes (Corneometer and Tewameter) and a special video camera (Visioscan).
– **Corneometer:** measurement of the hydration grade of the skin
– **Tewameter**: measurement of transepidermal water loss through the skin (TEWL)
– **Visioscan** (UVA-light camera): provision of very sharp and non-glossy images from skin surface → skin structure analysis
A laptop (crew laptop on board ISS) is used for data visualization . The software for Visioscan and both Tewameter and Corneometer is installed on and booted from an external HDD Ultrabay (incl. adapter, part of SKIN B H/W kit), which is inserted in the crew latop.
The Visioscan camera is connected to the laptop directly, while Tewameter and Corneometer are connected to MPA 2 (Multiprobe Adapter 2), an interface and DC-DC converter between laptop and probes. Data are stored on a PCMCIA card and transferred to the downlink station.



2.1.9 Measurements of Core Temperature
The THERMOLAB experiment hardware is used to record astronauts' core temperature changes during exercises and rest with a frequent sampling rate.

A newly developed thermo-sensor (*Double Sensor*, *Draegerwerk AG*) for core temperature is applied. The *Double Sensor* records core temperature by using heat flux recordings. The sensors are placed on the forehead and chest (sternum).

The THERMOLAB Control Unit performs automatically the calculation of the body core temperatures according to the heat flux formula, displays and stores both measured values. Data storage is realized on a flash disk (SD card) which is securely fixed in the *Thermolab Control Unit*. The system is battery buffered and powered by 3 Volt (two AA-batteries). The display of *Thermolab Control Unit* will allow the operator to check the current temperature recordings, battery power, time etc. online. Data download to PFS (Pulmonary Function System or a Laptop) via standard USB data interface.

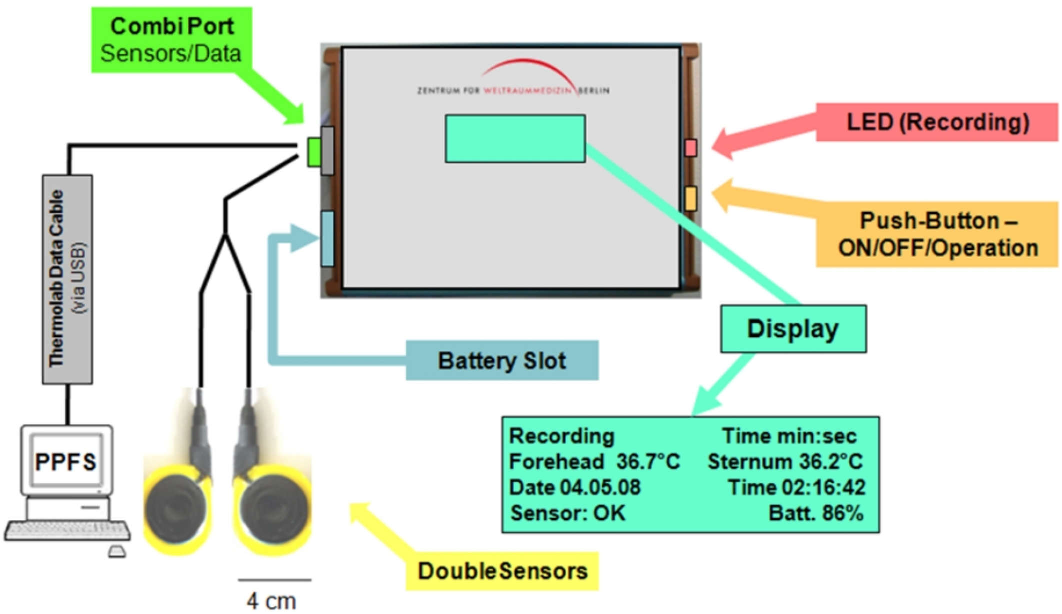


Table 1: Hardware Available to Support Human Subject Research

For further details and other ISS facilities see the below ISS link.
ISS facilities by Hardware Type, grouped by Discipline/Category:
http://www.nasa.gov/mission_pages/station/research/experiments/facilities_hardware.html

Hardware Available to Support Human Subject Research	**Agency**	**Website**
Physiological Monitoring		
Blood Pressure/Electrocardiograph	NASA	Sally Davis, CheCS Hardware, sally.p.davis@nasa.gov
Automatic Blood Pressure Cuff	NASA ESA	Sally Davis, CheCS Hardware, sally.p.davis@nasa.gov http://www.cnes.fr/web/CNES-fr/8781-epm.php
Continuous Blood Pressure Device	NASA ESA	http://www.nasa.gov/mission_pages/station/research/experiments/625.html http://www.cnes.fr/web/CNES-fr/8781-epm.php
Pulmonary Function System	NASA/ESA	http://www.nasa.gov/mission_pages/station/research/experiments/336.html

Hardware Available to Support Human Subject Research	Agency	Website
		http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Pulmonary_Function_System_PFS
Portable Pulmonary Function System	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Pulmonary_Function_System_PFS
ECG Holter Monitor	NASA/ JAXA/ESA	http://www.nasa.gov/mission_pages/station/research/experiments/614.html http://kibo.jaxa.jp/en/experiment/pm/holter/holter.pdf http://www.cnes.fr/web/CNES-fr/8781-epm.php
JAXA Onboard Diagnostic Kit	JAXA	http://www.nasa.gov/mission_pages/station/research/experiments/843.html
Ultrasound 2 Doppler	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/749.html
Thermolab	ESA	http://eea.spaceflight.esa.int/portal/exp/?id=9338
SKIN B H/W Kit	DLR	http://eea.spaceflight.esa.int/portal/exp/?id=9392
Space Linear Acceleration Mass Measurement Device	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/640.html
Sample Collection and Stowage		
Human Sample Collection Kits	NASA	TBD
Refrigerated* Centrifuge *refrigeration function is failed	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/639.html
Exercise		
Cycle Ergometer	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/841.html
Treadmill	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/765.html
Advanced Resistive Exercise Device	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/1001.html
Muscle Strength, Torque, and Joint Angle		
Muscle Atrophy Research and Exercise System	NASA/ESA	http://www.nasa.gov/mission_pages/station/research/experiments/352.html http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Muscle_Atrophy_Research_Exercise_System_MARES http://www.cnes.fr/web/CNES-fr/8783-mares.php
Percutaneous Electrical Muscle Stimulator	NASA/ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Percutaneous_Electrical_Muscle_Stimulator_PEMS
Hand Grip/Pinch Force Dynamometer	NASA/ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Hand_grip
Activity Monitoring		
Actiwatch	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/858.html
Armband monitoring	ESA	http://www.cnes.fr/web/CNES-fr/8914-energy.php

Hardware Available to Support Human Subject Research	Agency	Website
Coordination		
ELITE-S2	ASI	http://www.nasa.gov/mission_pages/station/research/experiments/78.html
Eye Tracking Device (ETD)	DLR	http://eea.spaceflight.esa.int/portal/exp/?id=8225
HPA	ASI	http://www.nasa.gov/mission_pages/station/research/experiments/223.html
European Physiology Modules		
Multi Electrode EEG Mapping Module	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Physiology_Modules http://www.cnes.fr/web/CNES-fr/8781-epm.php
Portable EEG (PORTEEMM)	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Physiology_Modules http://www.cnes.fr/web/CNES-fr/8781-epm.php
Sample Collection Kit (SCK)	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Physiology_Modules http://www.cnes.fr/web/CNES-fr/8781-epm.php
CARDIOLAB	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Physiology_Modules http://www.cnes.fr/web/CNES-fr/8781-epm.php

2.2 Research Involving Non-Human Subjects (Biology and Exobiology)

The ISS now has a full complement of research facilities in the US, European and Japanese laboratory modules. These facilities potentially permit sophisticated experimentation to be performed inflight. However, the scope of any investigation is limited by the resources available to perform the experiment including launch and return capability, condition temperature stowage and crew time limitations. Therefore, experiments designed for use of these facilities will have to fit within limitations of the resource envelope.

A complete list of hardware for biological research and a web site reference for design details is provided in Table 2. A general description of the facilities and capabilities is provided below.

ESA Columbus facilities: The ESA Columbus module has three main facilities for biological research, KUBIK, EMCS and Biolab each of which has different capabilities

2.2.1 KUBIK

Description
KUBIK consists of a small controlled temperature volume, which can function both as an incubator or cooler (+6°C to +38°C temperature range). Additionally, self-contained automatic experiments can be performed using power provided by the facility.

Experiments interface with KUBIK by a variety of removable inserts. A centrifuge insert (CI) permits simultaneous 1g control or intermediate g-level samples to be run in parallel with microgravity samples. Experiments interface with the centrifuge insert via a set of small standardized containers. Therefore experiments need to be designed to fit inside these containers. Alternatively, larger dedicated experiment hardware can be installed via a KUBIK Interface Plate (KIP). Both the CI and KIP inserts can provide limited electrical power to the experiments. In addition a passive insert (PI) can be used for storing standard experiment containers at controlled temperature, while the rack insert (RI) can accommodate sample vials. The PI and RI inserts do not provide electrical power

There are currently no data or command communication possibilities between the experiments and KUBIK, which only provides controlled temperature and electrical power to the experiments. Basic facility data (temperature, operating modes etc) are recorded, which can be retrieved after experiment completion via a datacard. Therefore, the experiment hardware needs to be designed to operate either automatically (with autonomous control at the experiment level). Alternatively, it is possible to use manually operated experiment hardware which the crew removes from the incubator for operations.

A planned enhancement of the KUBIK capability (KUBIK-2) will provide some capability for facility telemetry downlink and the possibility of pre-programmed operation (eg. Incubator temperature change, switch on/off electrical bus). However, it is expected that experiment specific hardware will continue to operate autonomously.

Figure: KUBIK Incubators

Capabilities

- External dimension: 366 mm X 366 mm X 366 mm
- Internal dimension 260 mm X 260 mm X 138 mm
- Temperature settings: +6 ^{o}C to +38 ^{o}C (in increments of 1 ^{o}C)
- Standard cabin atmosphere, no humidity or gas composition control
- Experiment must operate autononmously or be manually opered No data, commanding, or video interfaces to experiment
- Interface to dedicated inserts, including a Centrifuge Insert (CI), KUBIK Interface Plate (KIP), Passive Insert (PI) and Rack Insert
- 12V & 5V DC Electric power to CI and KIP

Centrifuge Insert details

- Accomodation of standardized experiment containers;
  - 16 standard containers or 4 extended containers in static positions
  - 8 standard or extended containers on centrifuge
- Centrifuge Gravity settings: 0.2 g to 2 g (in increments of 0.1 g)
- 5V and 12V D.C. power to experiment containers.
- The CI insert is compatible with a variety of small containers which typically provide 21x40x78mm internal dimensions or 31x40x78mm internal dimensions

More information is available at the following link, including examples of experiment specific experiment containers for KUBIK:
http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Kubik

2.2.2 EMCS

The European Modular Cultivation System (EMCS) is a biology experiment facility which permits more complex operations than is possible with KUBIK. The facility consists of an incubator (18°C – 40°C range), which contains two centrifuge rotors which can provide g-levels in the 0.001g to 2.0g range, as well as microgravity (non-centrifuged). This configuration allows the scientist to simultaneously perform a micro-g or intermediate g-level experiment on one (static) rotor and a 1-g reference experiment on the second rotor.

Experiments interface with the facility by dedicated experiment containers (EC) with a transparent cover (for observation and illumination), 4 containers can be accommodated per rotor. Each EC can provide power and data /command connections to the experiment & the facility can provide a controlled atmosphere (defined O2, CO2, N2 gas composition, humidity, ethylene removal, different gas flow rates etc) as well as water. Additionally white light and infrared illumination of the containers is possible, as well as video observation. Furthermore commands can be sent from the ground to the EMCS facility and experiment containers, data and video downlinked from the experiment. The basic specifications for the EMCS and experiment container, rotor and supply module are shown in Figure 1 below.

Experiment Containers are generic to the EMCS. Although EMCS was primarily designed for long term plant biology experiments, it is also well adapted for small cell biology, biotechnology and small animal (eg. C. elegans, fruit flies, amphibian tadpoles) experiments. One example of ECs with Seed Cassette inserts are shown in Figure 2 below. The experiment containers are 60 mm x 60 mm x 160 mm in dimension, with a growth volume of 0.58 liters.

More information on EMCS is available from the following link:
http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/European_Modular_Cultivation_System_EMCS

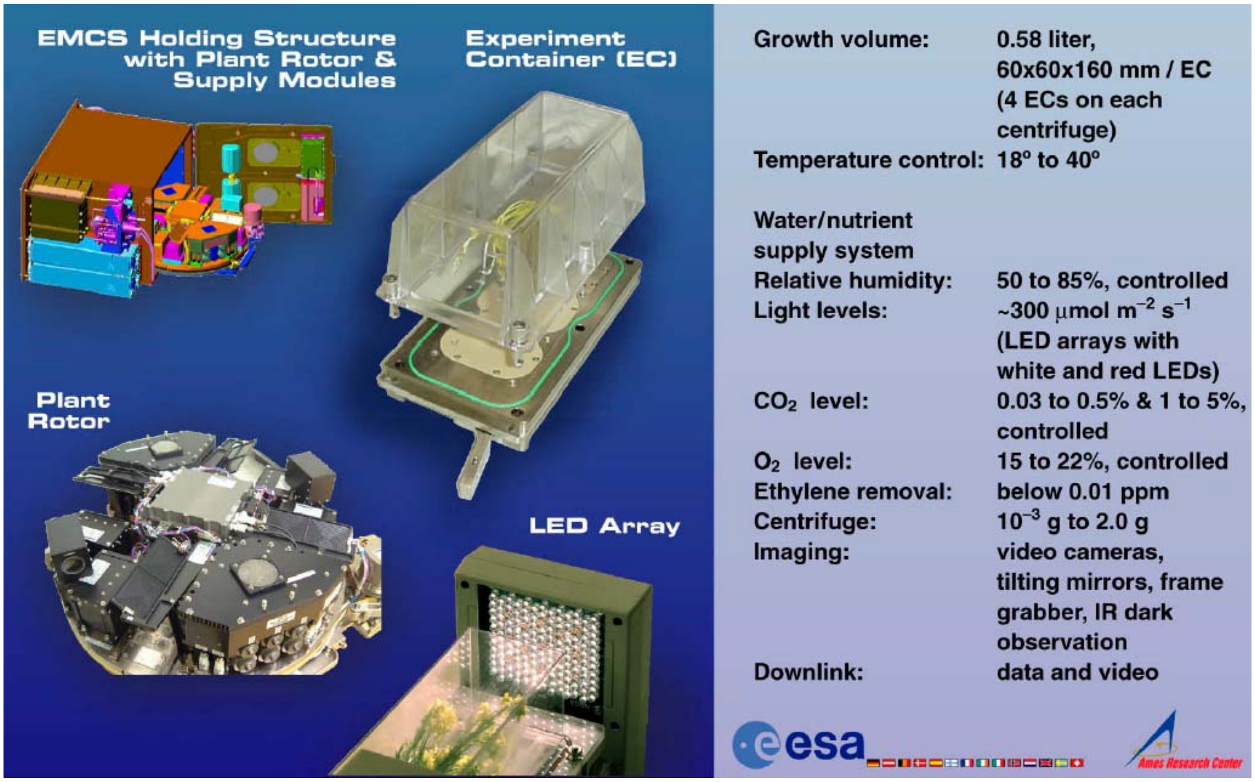


Figure 1: EMCS Hardware Overview and Capabilities

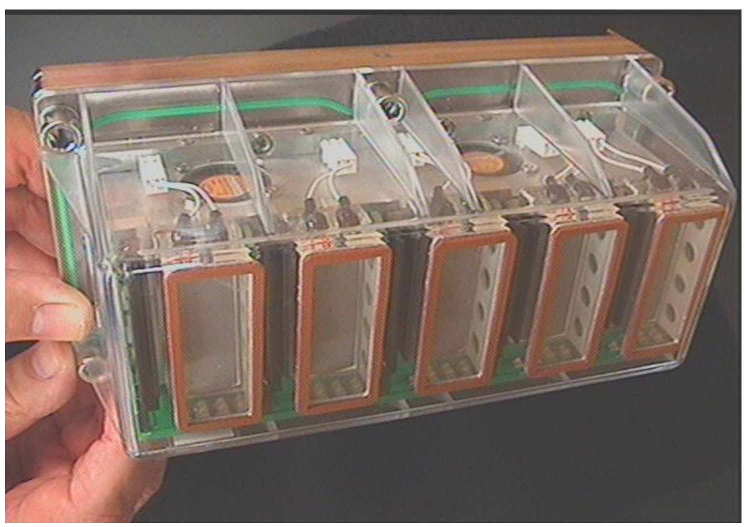


Figure 2: Experiment Container (EC) with Experiment Unique Equipment (EUE) for seedling growth experiment. The EUE contains seed cassettes, a hydration system (pump, bellows), air circulation system (air fan), LED lighting (white, red, blue) and circuit boards to control the fan, lights and pump.

2.2.3 Biolab

Biolab is a self contained, biology experiment facility that provides an incubator, variable g-centrifuges, cooler, freezer and glovebox capabilities for biology experiments. Experiments interface with the facility through dedicated experiment containers and can be placed on the two centrifuge rotors which can provide microgravity (not spinning) or g-levels in the 0.001g to 2g range. Like the EMCS facility it is possible to provide a controlled atmosphere (eg. 0_2, CO_2, set humidity, ethylene removal), as well as video observation and illumination (white light and infrared) of samples. Furthermore, the facility can be operated remotely from the ground with commanding and reception of from the experiment containers. In addition commands can be sent from the Biolab laptop computer.

Two types of experiment containers are available; the IEC container with a 60x60x100mm volume available for experiment unique equipment and the larger AEC with a 125x175x147mm internal volume. 6x IEC and 2x AEC container can be accommodated on each of the centrifuges

A glovebox is included in the facility for manual operations. This can also be reconfigured as a work bench (eg. For performing photography). Additionally a robotic handling mechanism can be used to automatically transfer liquids to/from the experiment containers or actuate experiment hardware in the container by a push/pull/turn tool. A simple light microscope can be used to examine liquid samples transferred via the handling mechanism. Finally, refrigerator and cooler space is provided in separate compartment of the Biolab

http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Biolab

Figure: Astronaut Chris Hadfield inspecting one of the Biolab rotors. Individual IEC experiment containers (transparent) can be seen attached to the outer edge of the rotor.

2.2.4 BIOKON

The BIOKON Container is designed to accommodate a broad variety of Life Science experiments in a “routine” container, limited in size and weight, and easy to accommodate in free volumes of the transportation spacecraft.

The BIOKON provides a dedicated environment for the execution of life science experiments in microgravity. BIOKON complements all types of biological Experiment Units (EU) regardless the fact that they could require electrical power or not. It can operate in a twofold manner:

- as passive container in the case the experiment does not need external power supply (i.e. not powered EU, or EU powered by battery pack inside the BIOKON).
- providing power supply by an external battery pack (e.g. accommodated in another BIOKON) or directly supplied by the spacecraft through an electric interface.

The BIOKON has been initially qualified for hard mounted launch with Soyuz launcher into FOTON capsule, for a 3 kg total mass (1 kg for the BIOKON itself and 2 kg for the internal hardware). This mass limit can be exceeded in case of soft stowed launch. BIOKON could be provided in sealed (max 1 bar differential pressure) or vented version. BIOKON (in both sealed and vented versions) can withstand pressurization/de-pressurization environment specified for Soyuz, Foton, and International Space Station (ISS).

2.2.5 Cell Biology Equipment Facility (CBEF)

The Cell Biology Experiment Facility (CBEF) is integrated in JEM. It has been developed and utilized for various life science experiments such as cell biology, radiation biology, animal biology (nematodes) and plant biology. The CBEF has a microgravity compartment and a centrifuge compartment that provides artificial gravity between 0.2 g and 2.0 g. The CBEF incubator can control temperature, humidity and CO_2 concentration for experiments.

Experiment samples can be accommodated in CBEF special canisters. The canisters are attached to CBEF, 6 in microgravity compartment and 4 in centrifuge compartment. JAXA has developed and utilized 4 kinds of canisters to perform experiments in CBEF. Plant Experiment Unit (PEU) is used to grow plants from seeds to seeds for around 60 days using *Arabidopsis*. Cell Experiment Unit (CEU) is used to culture adherent cells with automated medium exchange for A6 cells (from amphibian). Measurement Experiment Unit (MEU) is used to accommodate various passive bags for floating cells or disposable chambers for adherent cells, nematodes and

plants seedlings. Video Measurement Experiment Unit (V-MEU) is used to grow plant seedlings with video observation for cucumber and *Arabidopsis*. JAXA has also developed disposable cell culture chamber (DCC) with treated cell culture plate and air exchangeable membrane which has septa system for medium exchange and fixation using JAXA solution exchanger. The DCC has 15 cm^2 of culture area with 4.5 ml medium and accommodates adherent cells such as L6 cells (from rat), mice primary cells and A6 cells.
http://iss.jaxa.jp/en/kiboexp/pm/beu/

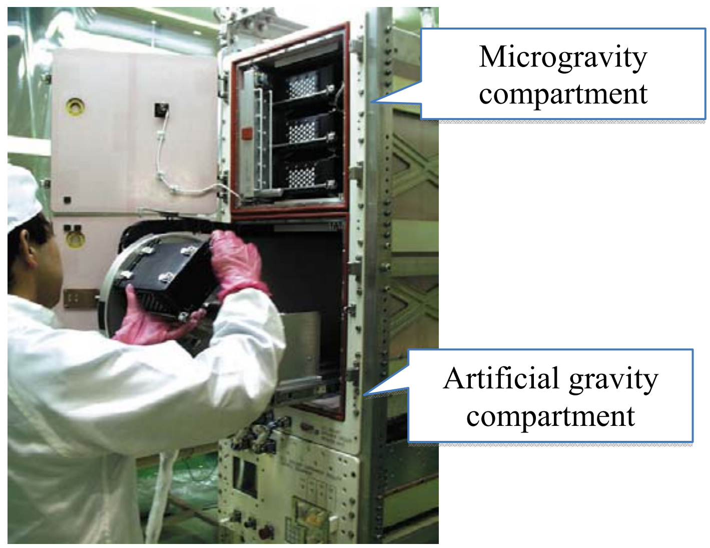


Figure: Astronaut Satoshi Furukawa is installing MEUs (black square boxes) to CBEF centrifugal rotor (artificial gravity compartment) on the ground. MEUs are also installed in the microgravity compartment.

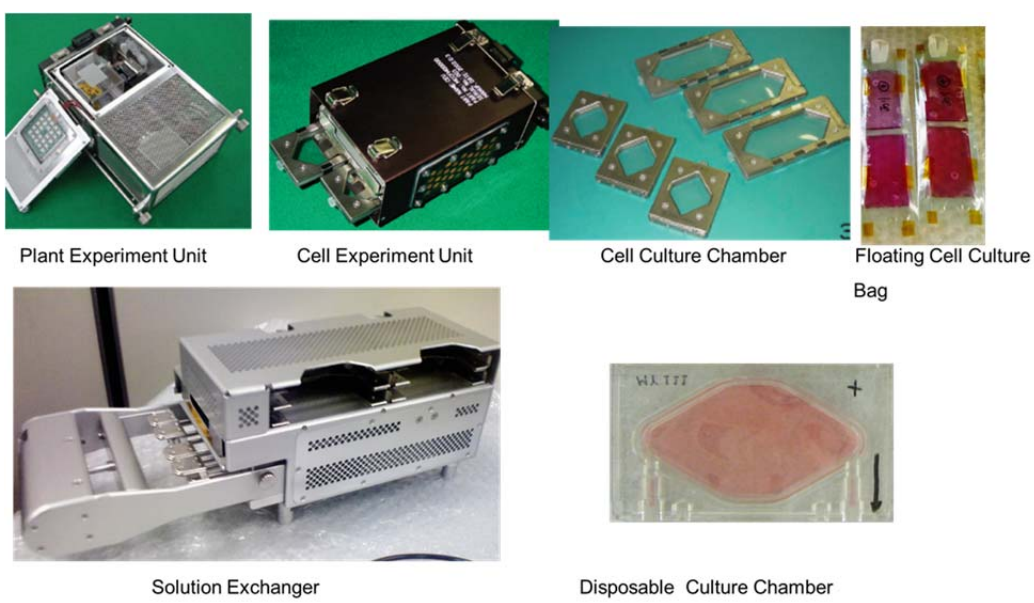
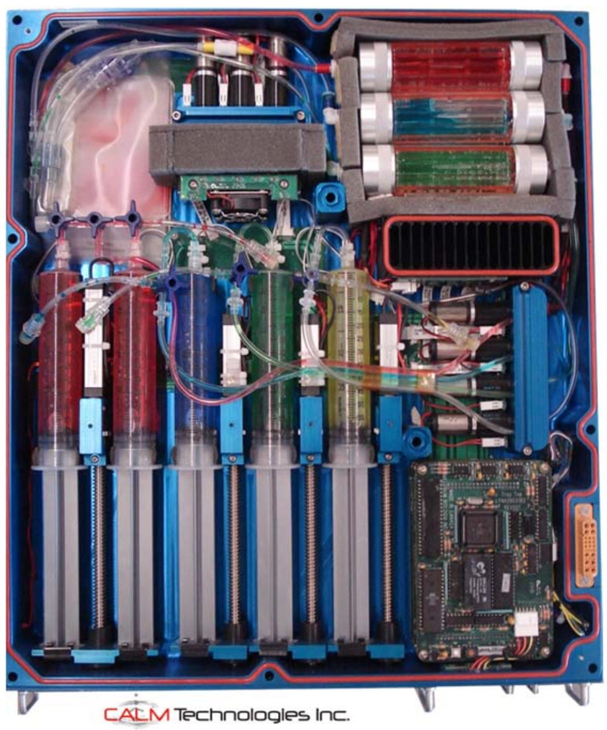


Figure: JAXA experiment tools using with CBEF for Plant biology and Cell biology experiments.

2.2.6 eOSTEO cell culture system

The OSTEO-X system is a space flight payload which represents an upgade of eOSTEO payload (Foton M3) which is now designed to operate on the ISS. The payload is comprised of 3 trays in which bone cells are automatically fed and grown through a network of syringes, pathways and valves. Grown cells are then fixed and analyzed once returned to Earth. It is derived from the first generation OSTEO system, a turnkey cell culture and support system for use in terrestrial and microgravity experiments involving bone cell activity, originally designed for short-term Shuttle experiments and flown on STS-95 and STS-107.

Upgrades required to automate the hardware and produce the eOSTEO system (Figure eOSTEO) includes automated syringe fluid delivery (5x60 mL) through CPU controlled motors, automated fluid valves, through CPU controlled pinch valves, automated sampling of bioreactor waste during the experiment, temperature control of the tray, waste samples and bioreactors as well as cooling of waste samples and bioreactors. Bioreactors can host conventional slides for cell culture or osteogenic slides equipped with a 3D scaffold optimized to grow bone cells. This hardware version supported experiments in the FOTON-M3 satellite and will be qualified for operation on-board the ISS. Summary of previous investigations using eOSTEO can be found using the link below:
http://www.asc-csa.gc.ca/eng/sciences/eosteo.asp



2.2.7 Aquatic Habitat (AQH)

The Aquatic Habitat (AQH) is a sub-rack facility that accommodates small freshwater fish (such as Medaka fish and Zebrafish) installed in Multi-purpose Small Payload Rack (MSPR) inside the Kibo module environment. The facility is designed to accommodate experiments for up to 90 days, making it possible to investigate long-term effects on vertebrate in a microgravity environment. The AQH is composed of two aquariums that contain automatic feeding systems, day/night cycle LED lighting, Charge-coupled device (CCD) cameras and a bacteria based water quality control system.

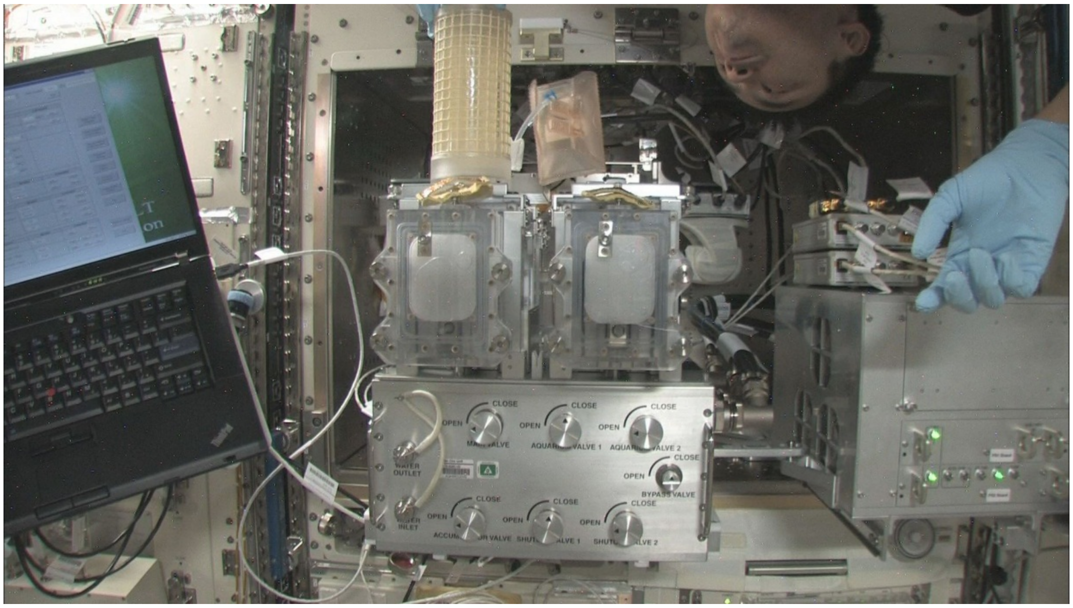


Figure: Astronaut Akihiko Hoshide transferring Medaka fish into the Aquatic Habitat in Multi-purpose Small Payload Rack in Kibo

Figure: Medaka fish in the Aquatic Habitat in the Kibo Module are fed by the automatic feeder. Photo is the 55th day after the experiment starts in space.

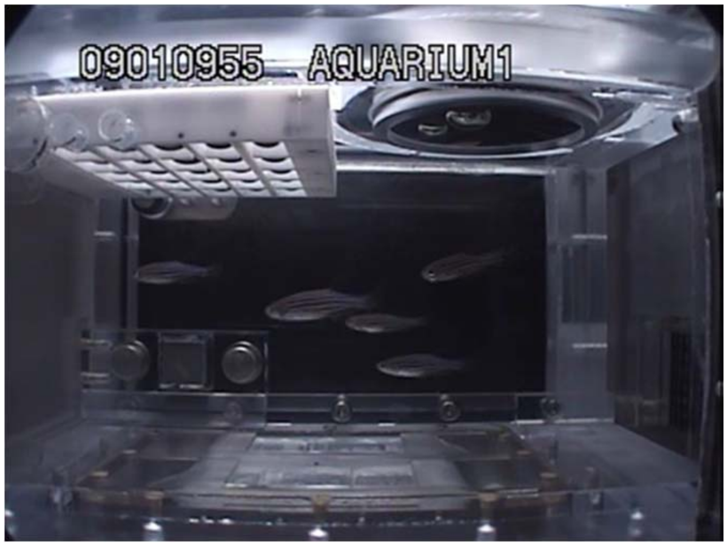
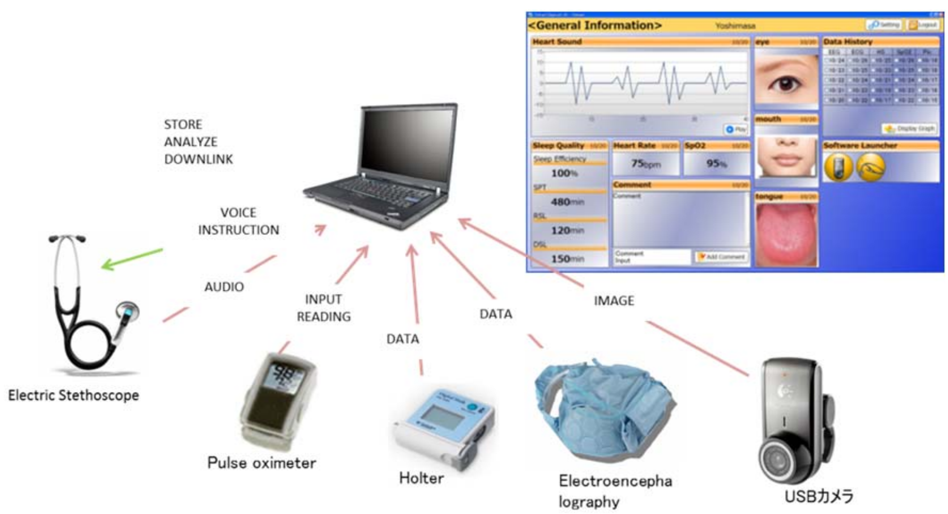


Figure: Zebrafish in AQH Aquarium (ground test)

2.2.8 JAXA Onboard Diagnostic Kit (ODK) is a non-invasive, health-monitoring system capable of measuring, storing, and analyzing crew member medical data while onboard the ISS. The medical data collected onboard can be sent to the ground immediately, whereby doctors can quickly diagnose crewmember health. The ODK contains Digital Holter ECG, Electric Stethoscope, Pulse oximeter, Electroencephalography, USB camera. Laptop, Sphygmomanometer, Thermomete, Myodynamometer and Actiwatch.



2.2.9 BRIC-Petri Dish Fixation Unit (BRIC -PDFU) Hardware

This is a passive payload with no on-orbit power or communications available. Selected investigators will provide biological specimens of their choosing (plated onto/into petri dishes pre-flight), which will be loaded into the selected space flight platform (TBD) and the biological specimens subsequently returned to earth for post-flight processing. Crew members will perform up to two in-flight operations per petri dish to either expose the biology to liquid treatments (to be determined by the selected investigators) and/or chemically fix the tissues on-orbit prior to return (using Glutaraldehyde, RNAlater, Formaldehyde or other options). It is anticipated that there will be a diverse range of investigations undertaken, including but not limited to plant seedlings, callus cultures, *Caenorhabditis elegans*, microbes, and others.

A different version of this hardware flew on STS-87 and STS-107. The unpowered version available for this opportunity has flown on STS-131 and STS-135 and is described below. As mentioned above, biological specimens will be placed either onto (or into) 60 mm petri dishes containing agar-solidified media (although alternative approaches will be considered). Each petri dish will be placed inside its own Petri Dish Fixation Unit (PDFU). The PDFUs will be assembled and loaded with either one or two fluids in the syringe compartment (as specified by the selected investigators). Five PDFUs plus one temperature data logger will be loaded into each BRIC-PDFU canister. A TBD number of BRIC-PDFUs (most likely two per selected PI) will be flown along with actuator equipment that the crew will use for the injections. The PDFU canisters will remain contained within the BRIC-PDFU canisters during all phases of flight operations. Pre-flight turn-over will be between 24 hours and 14 days prior to launch (payload specific). In the event of a launch scrub, the entire assembly can be replaced with an identical back-up unit with freshly loaded specimens.

On-orbit, there will be an opportunity for either one or two crew-facilitated injections into the PDFUs. After landing, the BRIC-PDFU canisters assembly will be handed over to the investigator teams for processing. The delay involved and the site of post-flight processing are TBD (depending upon flight platform and recovery options available).

The baseline utilization plan is to assign two BRIC-PDFU canisters to each selected investigator. This will provide each investigator the option of flying up ten PDFUs, each containing one petri dish. Temperature data loggers will be placed within each BRIC-PDFU (occupying the sixth PDFU location).

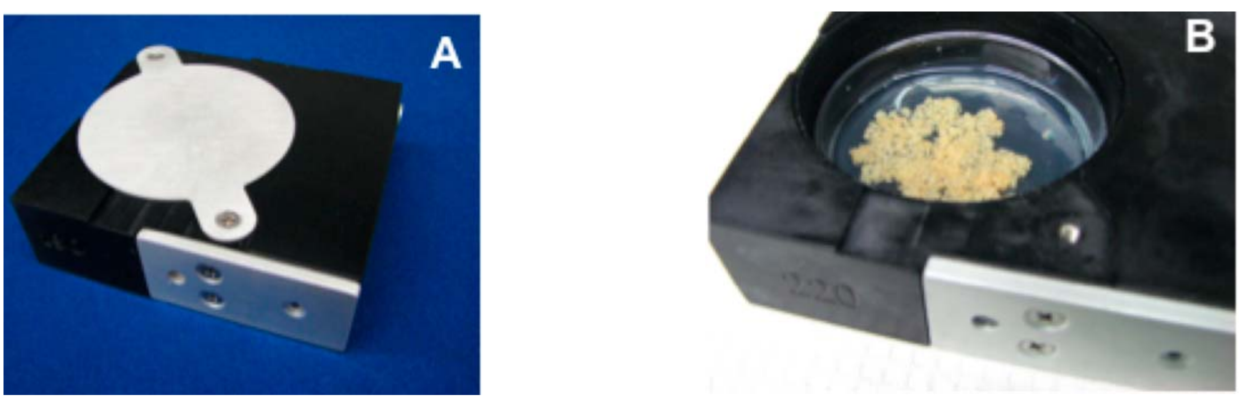


Figure: (A) View of an assembled Petri Dish Fixation Unit (PDFU). (B) Callus culture on petri dish within a PDFU prior to closure (see Paul et. al., 2012).

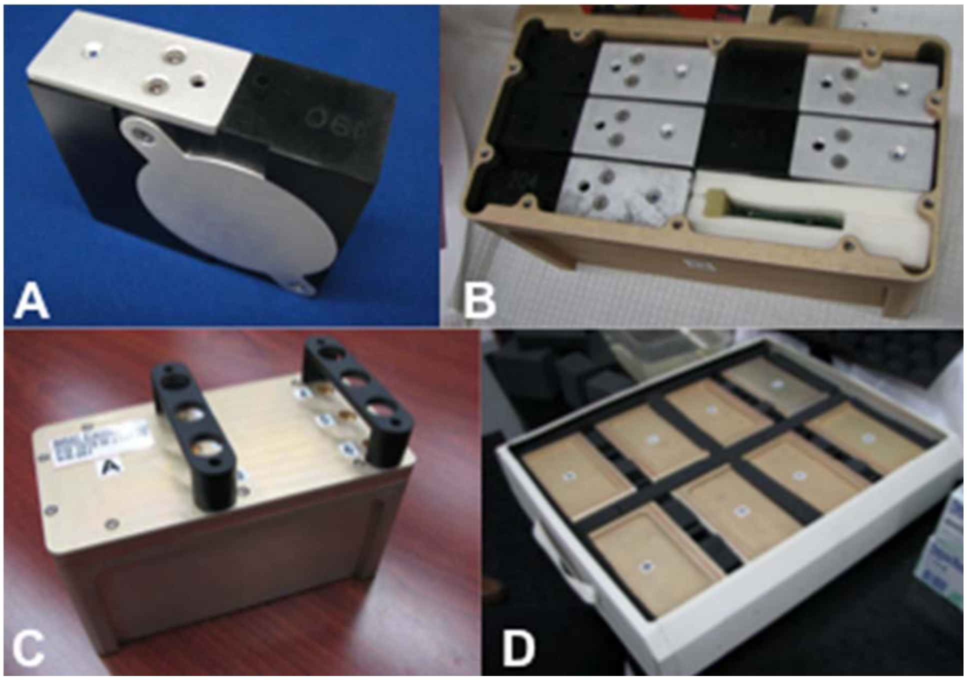


Figure: (A) View of a PDFU on its side (launch position). (B) Five PDFUs plus one temperature logger within

a BRIC-PDFU canister prior to closure. (C) BRIC-PDFU canister with two pin guards attached. (D) Eight BRIC-PDFU canisters stowed within a half middeck locker (as flown on STS-131).

Figure: Tools used for injection of fluids into PDFU petri dishes. (A) Actuator Rod Kit and Actuator Tool. (B) Partially depressed Actuator Tool attached to BRIC-PDFU canister.

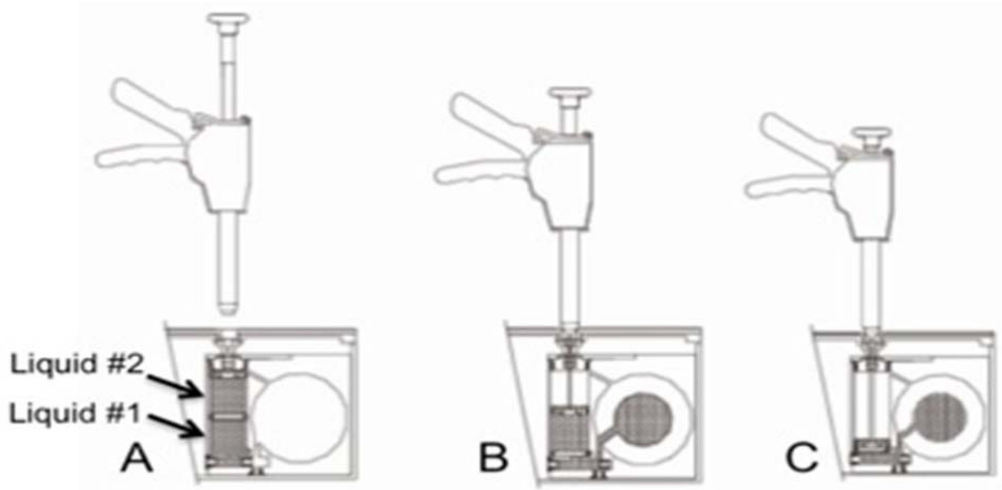


Figure: Injection of fluids into PDFU petri dishes. (A) Actuator Tool prior to attachment to BRIC-PDFU. (B) Actuator partially depressed to deliver Liquid #1. (C) Completion of actuation allows Liquid #2 to be delivered.

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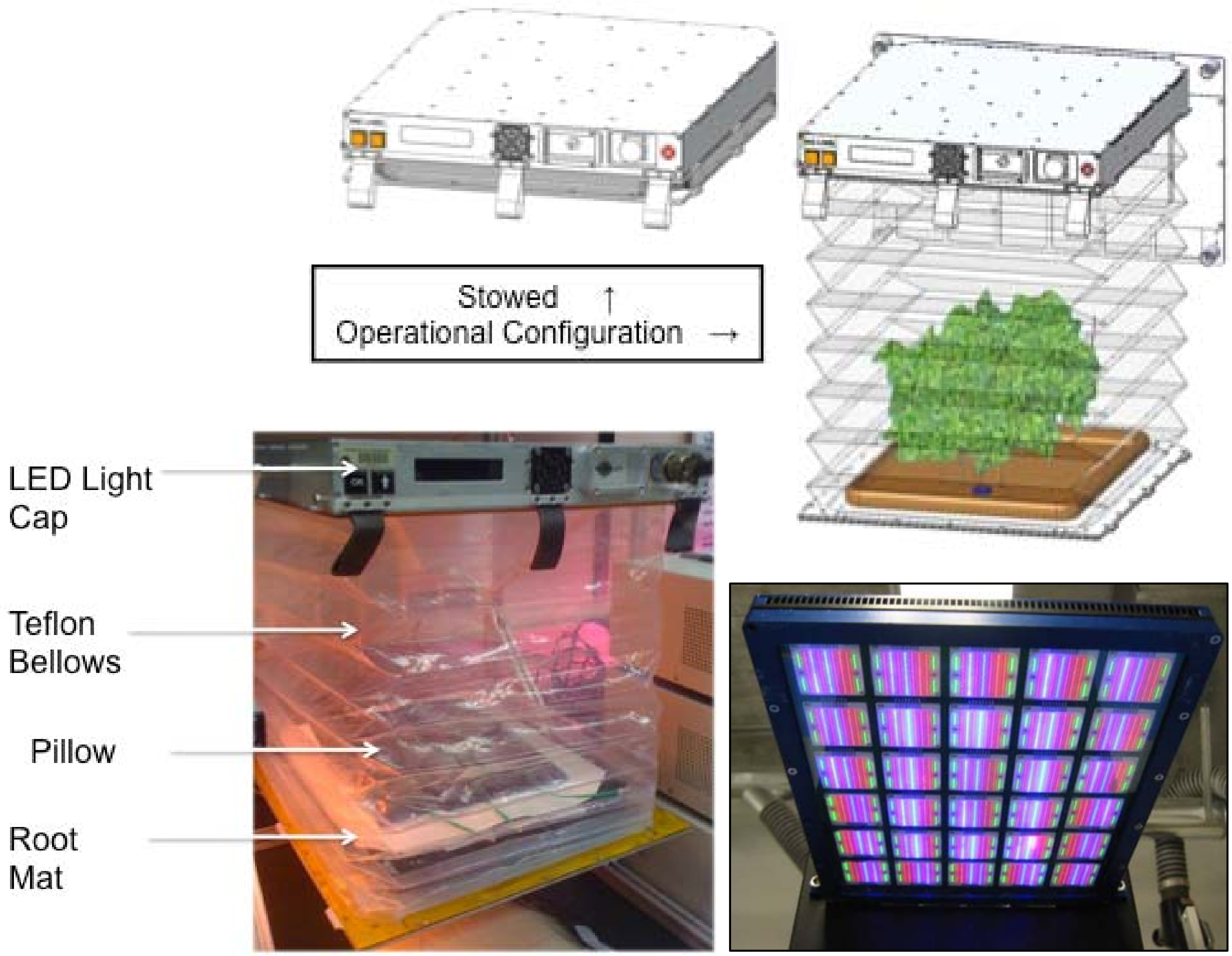
2.2.10 Vegetable Production System (VEGGIE) Hardware

The Vegetable Production Unit (VEGGIE) is an easily stowable, low resource plant growth system designed to produce fresh vegetables on ISS. It will also have near term psychological benefits for the crew as a source of recreation. It provides a relatively large growing area (0.17 m^2), but can be stowed in 10% of its deployed volume. Once on ISS, VEGGIE will remain on-orbit for multiple crop rotations, producing fresh vegetables and offering a source of recreation/aesthetics for the crew. VEGGIE can function as: (1) a plant cultivation device for investigating horticultural variables for vegetable production under microgravity conditions, (2) a test bed for plant surface microflora investigations, and (3) a basis for conducting education/outreach activities on Earth.



The current baseline configuration for VEGGIE is to grow plants on one of 6 independent rooting "pillows" that contains the planting media and fertilizer pellets to support plant growth. Seeds are launched dry either preloaded in the pillows or attached to various substrates that can be inserted into the pillows by the crew. The pillows will be hydrated on orbit by the crew and there will be a replenishment of the water within by passive wicking from the VEGGIE reservoir located below the pillow. The pillows are designed for single use and are to be disposed of after harvest (reducing sanitation requirements).

Vegetables successfully grown in VEGGIE at Kennedy Space Center include: Lettuce, Radish, Cherry Tomato, Dwarf Pea, Swiss Chard, Dwarf Chinese Cabbage. Ornamental and model research plants can also be grown.

VEGGIE is currently scheduled to launch in 2014 and a series of plantings will be conducted on this maiden flight to: (1) Assess ease of set-up and operation of the VEGGIE hardware. (2) Assess the capacity for the VEGGIE hardware and pillows to effectively germinate seeds. (3) Assess the capacity for the VEGGIE hardware and pillows to effectively sustain plant growth and adequate media moisture. (4) Compare growth in different media combinations. (5) Demonstrate growth of different types of plants within a single VEGGIE unit. (6) Assess crew handling aspects of VEGGIE (planting, daily maintenance, harvesting, pillow disposal, sanitation) and determine effectiveness of established crew procedures. (7) Assess crew psychological benefits of plant growth and crew acceptance of VEGGIE operations.

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2.2.11 Lada-2 Hardware

Lada is a plant growth chamber originally launched by the Russian Space Agency in 2002 and situated in the Zvezda module on the Russian segment of the International Space Station (ISS). It has been in nearly continuous use since that time. It is a wall-mounted system that provides light and root zone control but relies on the ISS environmental control systems for humidity, gas composition and temperature control. Cabin air is pulled into the plant chamber, flows over the plants and vents back out to the cabin through the light bank to provide both plant gas exchange and light bank cooling. Plants that have been cultivated in Lada include Mizuna, tomatoes, peas, radishes and wheat. The original Lada system included a control module, two independent vegetation modules and two water reservoirs.

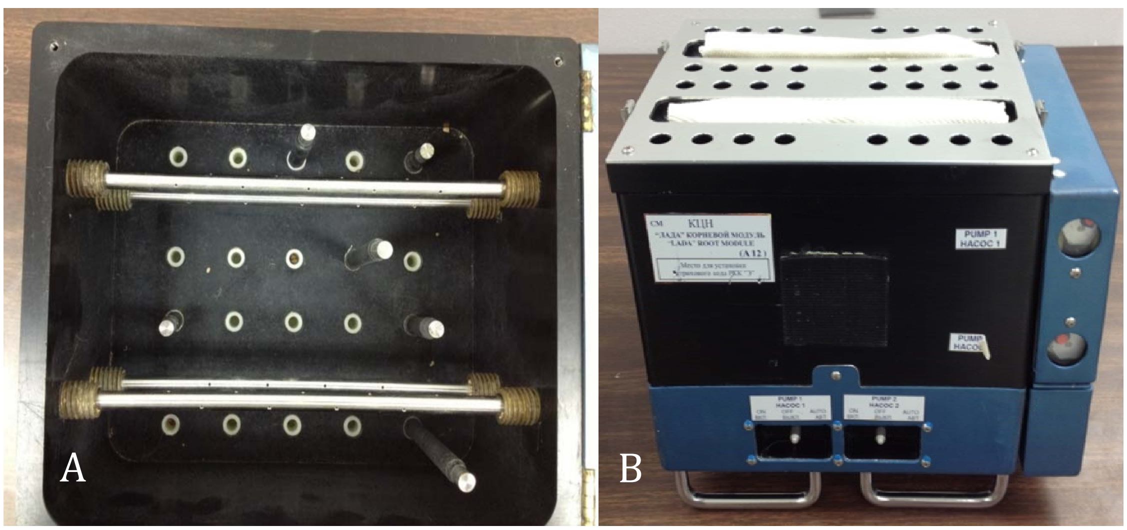

Figure 1. A. Top down view of a Lada-2 root module showing four water injection tubes nominally surrounded by wicking material to increase the substrate wetting area and provide the seed planting area. Sensors for temperature, moisture content (thermal pulse) and matric potential (tensiometers) can be

mounted anywhere in the grid. Three sensor lengths (short, medium, long) are available for profile measurements. B. Side view of a root module completely packed with substrate, wicks and cover. The module contains two pumps, one to control water content, the other to prime the tensiometers. Pump control switches are visible in lower portion of the root module.

Most Lada experiments employ root modules (Figure 1 above) that are typically used for one experiment only. Seeds can be inserted into the root modules on Earth or in space, and the modules launched on Russian Progress rockets and attached to Lada on-orbit. Crew members initiate the experiment by activating computer controlled watering of the seeds and subsequently perform plant maintenance operations. Once experiments are initiated, water is automatically added to the root zone based upon feedback from moisture sensors embedded in the substrate. The crew can harvest plant samples and transfer them to the MELFI ISS freezer or fix them within Kennedy Fixation Tubes (KFTs) for subsequent return and post-flight analysis. They can also package and stow spent root modules (wet and under ambient temperatures) if they are to be returned for study (Figure 2 below).

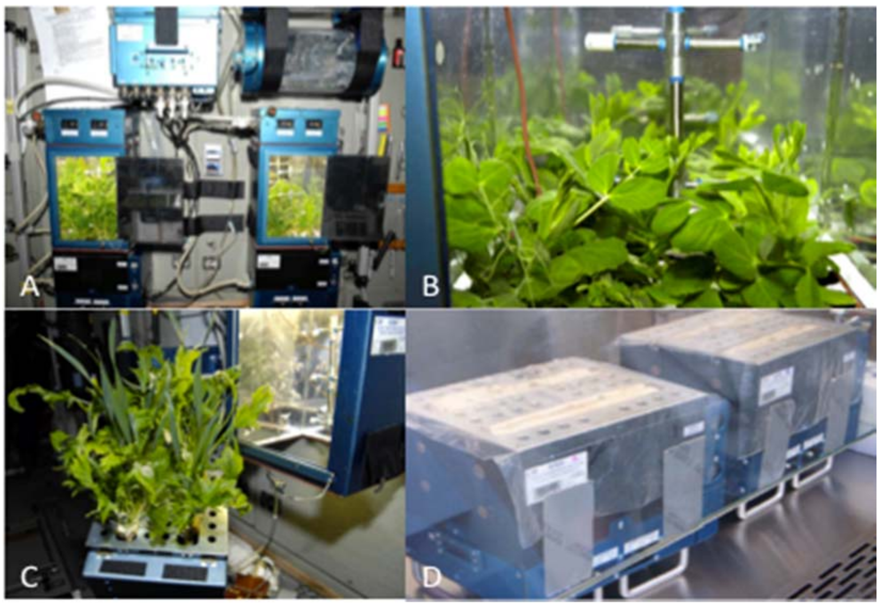

Figure 2. A. Original Lada as deployed on ISS. B. Dwarf Pea plants within Lada chamber. C. Removed root module with Mizuna and Super Dwarf Wheat plants. D. Two root modules packed up for return after a duel chamber on-orbit experiment.

Figure 3: Under Development Lada-2 Design.

Lada-2 is currently under development as an upgrade of the original Lada chamber (Figure 3 above). It contains a new LED light block (LB) that includes a touchscreen controller and an updated power supply. A listing of its specifications is provided below (Figure 4 below).

Neutral White LEDs	
PPF =	310.00
YPF =	273.23
YPF/PPF =	0.88
% UV-A =	0.08
% Blue =	18.0
% Green =	34.2
% Yellow =	10.7
% Red =	32.7
% Far-Red =	4.3
Red/Far-Red =	5.7

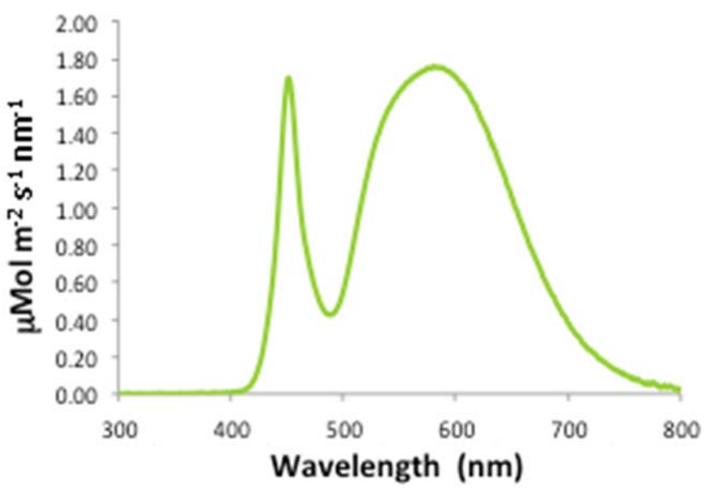

Figure 4. Light spectrum provided by LEDs in Lada-2. Intensity can be adjusted on-orbit. Spectrum is adjustable by replacement of the light module. PPF = Photosynthetic Photon Flux. YPF = Yield Photon Flux. Colors on left show integrated PPF in each spectral band. ***[Note: Photosynthesis is fundamentally driven by photon flux rather than energy flux, but not all absorbed photons yield equal amounts of photosynthesis, resulting in two measures of photosynthetically active radiation: photosynthetic photon flux (PPF), which values all photons from 400 to 700 nm equally, and yield photon flux (YPF), which weights photons in the range from 360 to 760 nm according to plant photosynthetic response (Barnes et. al., 1993)].***

LADA-2 Specifications

Total Growth Area:	550 cubic inches (8 ¾" x 6 ¼" x 10" vegetation chamber)
Maximum Shoot Height:	10"
Root Zone Growth Volume:	140 cubic inches (7" width x 5.75" depth x 3.5" height)
Internal Temperature:	ISS cabin range 18-28° C
Internal Temp Control:	Chamber air vented to the ISS cabin & temperature controlled by ISS life support systems
Internal Rel. Humidity:	ISS cabin range 30-70% (controlled by ISS life support systems)
Internal Light Level:	225 micromoles light at chamber bottom
Internal Light Control:	Programmable daily light cycles. Available channels for automatic light intensity controls.
Internal Light Sensing:	Calibrated silicon photodiode sensor. Downward looking from chamber top to integrate reflected light.
Light Isolation:	Light is contained within a rigid aluminum leaf chamber with reflective inner surfaces
Nutrient Delivery:	Timed release water soluble fertilizer is packed into each root module within the provided substrate
Water Delivery:	Water is pumped from a refillable water tank and injected into the root media through a set of four stainless steel tubes with multiple outlets. Water is then distributed to the substrate by capillary forces using a fabric wick material.
Water Delivery:	Water is pumped using a medical grade peristaltic pump with a revolution counter to meter pump volumes in increments of 0.119 mL. Instantaneous water levels are measured at up to 8 locations within the root media using heat pulsed moisture probes (0-100% saturation levels +/-5% accuracy, 0.5% resolution).
Internal CO_2:	Measured 0-10,000 ppm +/-30 ppm and 10% of measured value.
CO_2 & Ethylene Control:	None. Growth chamber vented to cabin air & dependent on ISS life support systems.
Imaging Capabilities:	A 640 x 480 pixel integrated color camera takes automatic scheduled photos of the leaf chamber from the top center downward.
Image Downlink:	Photos are stored in a compressed format on a removable compact flash card that can be removed and read by a station laptop for in-flight downlink of photos or returned to earth post-experiment for analysis. Max photo rate ~1 per minute.

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2.2.12 Rodent Research Habitat

The Rodent Research (RR) system is being developed to provide the capability to perform animal biology research on the ISS using rodent models including both rats and mice. Early flights of RR will be for mice only and allow for mission durations of 30-60 days. Future flights will have increased duration of up to 180 days and will also include the capability to support rats. For the purposes of this solicitation, only mice should be considered and proposed experiment duration may not exceed 30 days. The RR hardware system is based upon the Animal Enclosure Module (AEM) used aboard Space Shuttle. The RR hardware system consists of a Transporter used to transport animals to ISS on Space-X Dragon supply flights and a Habitat which is used to house animals on the ISS (Figure 1 below). A generic concept of operations for the early animal

flights is shown in Figure 2 below.

Figure 1: Rodent Habitat for ISS

Early flights (2014-2015) for the Rodent Research hardware system will allow for the following:

Preparation and Transportation to ISS

- Laboratories and facilities for receiving animals, housing animals and preparing animals prior to launch from the Kennedy Space Center will be available; but special equipment, procedures or other experiment-unique considerations must be provided by the PI team.
- Animals will be loaded into the Space X Dragon capsule approximately 12 hours prior to launch.

- Transportation of up to 40 total mice (nominally 30g/mouse) to ISS using the Transporter.
- Animals may be divided into two separate Transporter units (maximum of 20 mice per unit); and within each Transporter the animals may be divided into two separate cages (maximum of 10 mice per cage).
- Transportation to ISS is anticipated to take 3-4 days but may take as long as 7 days.
- There will be no video or real-time environmental data available during transportation to ISS; however, recorded environmental data will be available as data for downlink from ISS after animals are delivered.
- Visual assessment of food and water will be available after docking with ISS.
- Once delivered to ISS, the animals will be removed from Transporter units and placed in Habitat units and housed as described below.

Housing Onboard ISS

- A single Habitat unit will house up to 10 mice for early flights. Each Habitat can be divided into two separate cages that can hold up to five animals per cage.
- Although animals may be separated into two cages within one Habitat, the air and waste handling systems are not separated. For fully-separated animals, two Habitat units must be used.
- Temperature and Habitat monitoring will be available but no active thermal control will be provided. The air temperature and the Habitat RH for the animals will correspond with the conditions in the ISS cabin.
- Visual assessment of food & water will be done at regular intervals
- In order to achieve studies with longer durations than the Habitat can support, animals can be transferred to a second Habitat.
- Limited real-time video monitoring for health and status will be available for downlink and scientific analysis. Scheduling of video periods may be done from the ground.
- Light and dark cycles may be scheduled and changed during the mission.
- IR lighting is available for video monitoring during the dark cycle.

Capabilities Onboard ISS

- The Microgravity Sciences Glovebox (MSG) will support dissections and other biological procedures requiring containment..
- Generic kits such as a general dissection kit, an injection kit (with anesthetics for non-terminal procedures and materials to euthanize animals) and an animal health kit to monitor animal health will be available.
- Bone densitometer capability will be available for whole-body measurements
- Experimental procedures will be conducted within the MSG; however, any experimental procedure performed on live animals must take into consideration the limited working environment within the MSG and the challenges and constraints of performing experiments in a microgravity environment.
- Euthanasia and general dissection capabilities will be possible onboard ISS; however, any dissection procedure performed on animals post-euthanasia must take into consideration the limited working environment within the MSG and the challenges and constraints of performing experiments in a microgravity environment.

- Chemical fixation and preservation of tissues after euthanasia will be available onboard ISS.
- Cold stowage resources for frozen tissues will be available onboard ISS.

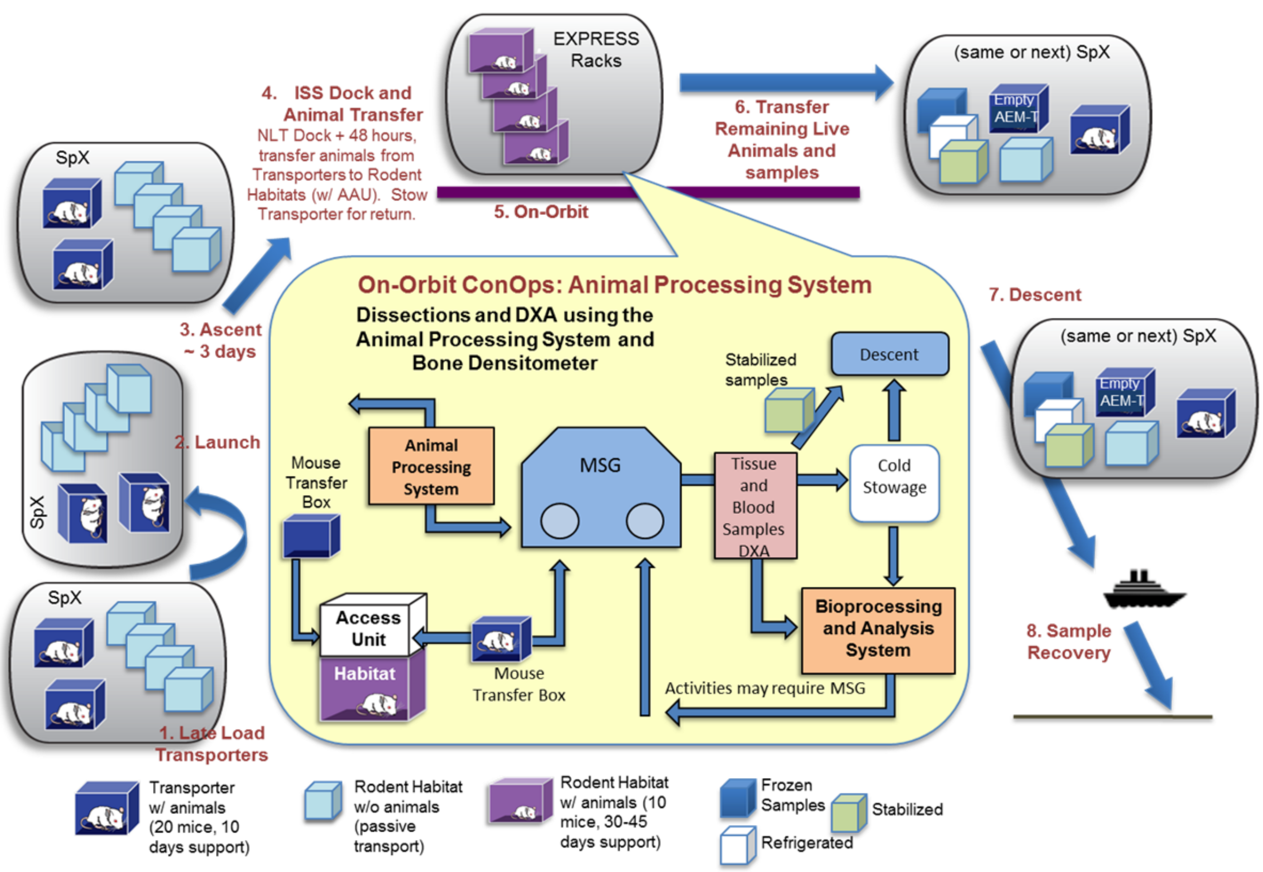
Sample Return

- No live animals will be available for return to Earth from early ISS/Dragon flight experiments. Live animal return capability will be available on later flights which may occur as early as 2016.
- Animal tissues will be returned in frozen or fixed form.
- Animal tissues will nominally be available to the PI as early as 2 days after landing of the Dragon capsule.

Ground Control Experiments

- Synchronous ground control experiments (housed in flight hardware on the ground) will be supported at NASA.
- If appropriate, ground control experiments may be performed on a time delay to allow for temperature and other parameters to be controlled to closely follow actual flight conditions.
- Ground control experiments in normal vivarium conditions will be supported by NASA.

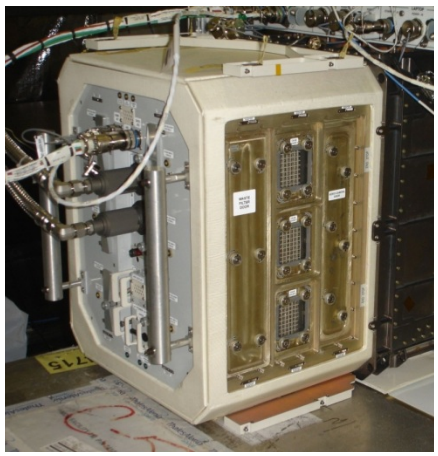
Figure 2: Generic Concept of Operations for Early Rodent Research Aboard ISS



2.2.13 Mice Drawer System

The Mice Drawer System (MDS) is a facility able to support mice onboard the International Space Station during long-duration exploration missions (up to 180 days) by providing living space, food, water, ventilation and lighting.

Mice can be accommodated either individually (maximum 6) or in groups (4 pairs). MDS has been designed to be integrated in the Space Shuttle middeck during transportation (ascent and descent) to the ISS and in an EXPRESS Rack in Destiny, US Laboratory during experiment execution. Modifications are being designed to adapt MDS to the Space-X transportation system.



Onboard the ISS, MDS is relatively self-sufficient; a crewmember will check the health status of the rodents on a daily basis, by assessing them through the viewing window. Water levels will be assessed by the crew daily and refilled as needed. Replacement of the food bars and replacement of the waste filters will be conducted inflight by crewmembers periodically.

Following return of the specimen to Earth, the investigators can perform tissue and molecular analysis on mice after prolonged exposure to microgravity conditions.

MDS has flown on 2009 to ISS for a 91-day mission. Possible re-flights are subject to international co-operations among the ISS IP/Ps.

2.2.14 Bone Densitometer

Quantitative measures of bone and muscle loss in mice during orbital space flight are needed for Space Biology studies as well as for the development of countermeasures for crew members by NASA and for bone-loss syndromes on Earth by commercial entities.

The "gold standard" of bone density measurement is Dual Energy X-ray Absorptiometry (DEXA) in which the absorption of X-rays is quantified at two key

X-ray energies. This method is used to calculate absolute bone density, in g/cm2, in humans, mice and other laboratory animals.

The Bone Densitometer (BD) (Figure 1 below) built by Techshot for NASA to install and use on the ISS measures X-ray absorption by bone and soft tissue and reports bone density in mice. It can also determine soft-tissue density, lean/fat ratio and total animal mass (i.e., weighing mice in space).

Figure 1: Bone Densitometer for ISS

The system is a spaceflight qualified version of GE Medical’s Lunar PIXImus. A small x-ray source exposes the entire animal to a cone shaped beam of both high (80kV) and low (35kV) energy x-rays. A high-resolution digital picture (0.18 x 0.18mm) is taken of an image of the x-rays hitting a luminescent panel. The ratio of attenuation of the high and low energies allows the BD to separate bone from tissue and, from within the tissue samples, the lean and fat. It provides bone mineral and body composition results from total body imaging in approximately three minutes. Fast imaging allows faster access to important data and is safer on animals.

The system allows automated, accurate and precise measurement of bone and tissue for small animals weighing 10-40 g. Bone, fat and lean measurements exhibit excellent correlation to total ashed or chemical extraction weights. The BD uses a lower x-ray energy than that used for peripheral densitometry in humans in order to achieve contrast in the extremely low density bone. Excellent precision of BMD and %Fat makes it ideal for longitudinal studies.

With an image area of 80 mm x 65 mm, the PIXImus can image the entire body of most mice and the subcranial region of large ob\ob mice. Regions of interest (ROIs), such as spine and femur, are manually selectable. The system is compact and provides high-resolution images in addition to quantitative measurements in real time. The user can trace a ROI interactively on the screen. A screen capture depicting output data resulting from a scan is shown in Figure 2 below.

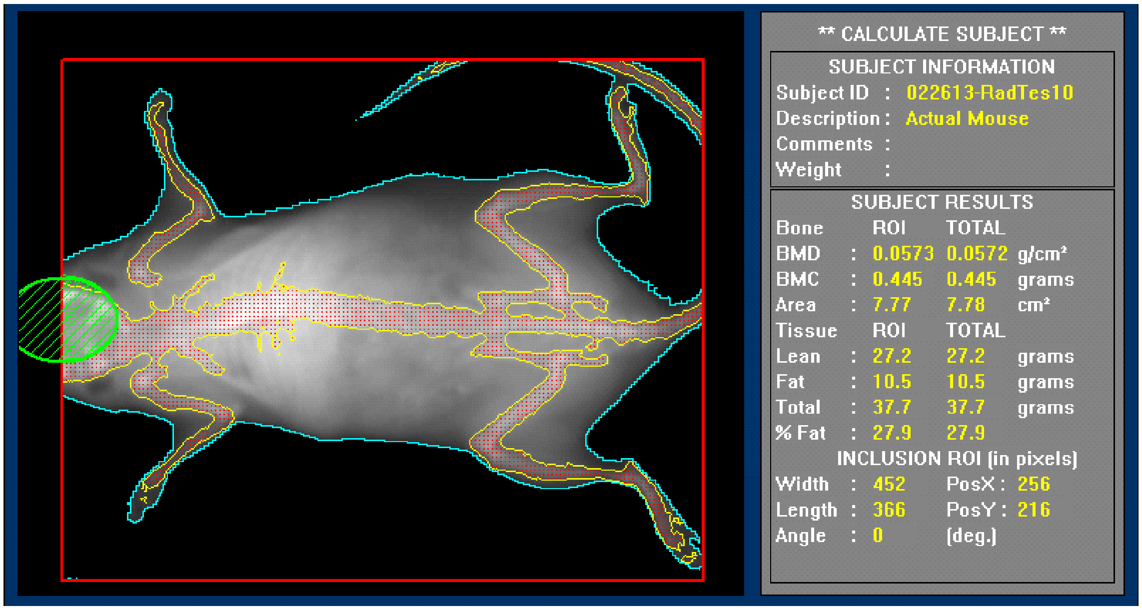


Figure 2: screen capture depicting output data resulting from a scan

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2.2.15 Commercial Generic Bioprocessing Apparatus (CGBA) and Accompanying Hardware Inserts that Support Cell Biology

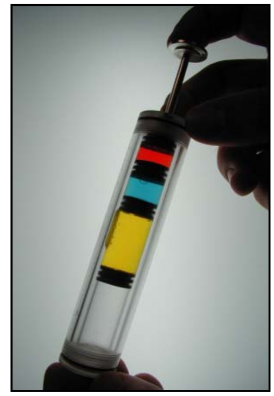
<u>Commercial Generic Bioprocessing Apparatus (CGBA)</u>

CGBA is a temperature-controlled microgravity research platform, developed by BioServe Space Technologies, that has hosted a variety of experiments on numerous Space Shuttle, MIR and International Space Station flights. CGBA provides power, data and video capabilities that enable automated operations of “smart” experiments housed inside the CGBA facilities. An array of automated life sciences experiments have been carried out inside CGBA over the past decade and a half. CGBA’s computer system and custom developed software have enabled remote monitoring and control of experiments on the ISS from BioServe’s Payload Operations and Control Center (POCC).

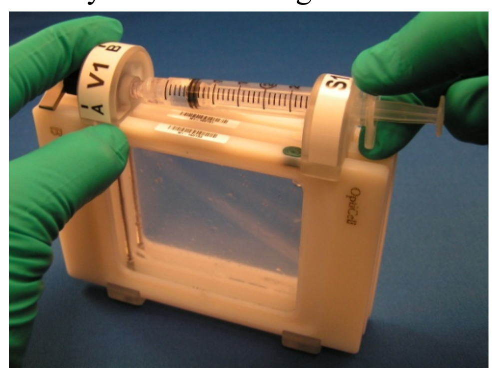
Currently there are two CGBA units available to support life science experiments on board the ISS and additional units available to provide temperature control during transport to and from the station. CGBA has two configurations: the freezer unit which controls temperature from -16°C to +40°C and the refrigeration unit that controls temperature from 4°C to +40°C. The internal volume of the freezer unit is somewhat smaller than the internal volume of the refrigeration unit. All CGBAs offer a high level of autonomous operation, but also allow for remote real-time experiment control as well as real-time data downlink. CGBA also offers HD video capability as well as high resolution image capture of experiments while inside CGBA. CGBA is able to run an entire experiment from cell culture incubation at +37°C to sample fixation and storage at +4°C, all with or without crew interaction.

BioServe has an extensive array of experiment-specific (customizable) hardware (group activation packs (GAPs), Fluids Processing Apparatuses (FPAs), Opticell Processing Modules (OPMs), Cell Culture Habitats (CHabs), and Multi-well plates that are fully compatible with CGBA. All have been used to support a wide variety of biological experiments in space.

Group Activation Pack (GAP) and Fluid Processing Apparatus (FPA)



The FPA is a test tube that allows controlled, sequential mixing of two to four fluids in microgravity while maintaining appropriate levels of containment for safety purposes. A total of 6.5-ml of fluid is contained inside a glass barrel (1.35 cm inner diameter x 11.7 cm). The fluids or cultures are isolated from each other by a rubber septum. A bypass in the glass barrel allows fluid to flow into an adjacent chamber as a plunger mechanism pushes the septum forward. The FPA provides limited gas exchange. However, gas permeable membranes can be utilized with the FPA which increases gas exchange to some degree. The FPA can be flown individually or in sets of eight housed in a single GAP. The FPA and GAP configuration together provides three levels of containment and can support BSL 2 organisms or fluids. If temperature control is required, the CGBA units can hold 9 GAPs in the freezer configuration and up to 16 GAPs in the refrigeration configuration.

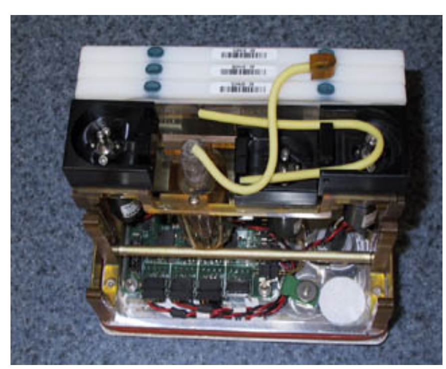


Opticell Processing Module (OPM)

The OPM was designed to safely handle biological fluids in microgravity on board the International Space Station (ISS). The design utilizes three commercially available Opticells™. The Opticell™ is a cell culture format for growing, monitoring, and transporting cells and has two parallel gas-permeable, cell culture treated polystyrene membranes attached to a standard microtiter plate-sized frame. Each side has a growth area of 50 cm², total 100 cm². Two resealing access ports provide closed growth environment with sterile fluid path, thereby reducing risk of contamination. Using the OPM fluids and suspended cells can be passed between the Opticells™ via a 3 way distribution valve and a 3ml syringe. The syringe can be used as a pump to ensure complete fluid mixing, for example during cell inoculation. An OPM experiment can be processed from 4-40ºC. The syringe can be removed, inside a glovebox, so that samples can be transferred from the Opticells™ to a sample vial for refrigeration, freezing or further processing.

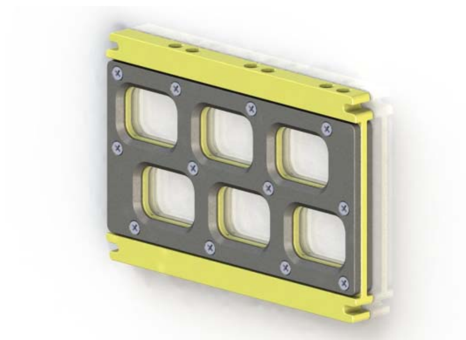
Culture Habitat (CHAB)

The CHAB can hold up to six Opticell™ culture chambers which can be inoculated sequentially for an extended growth period or concurrently to increase replication of experiment samples. The CHAB can



utilize one or two syringes for sample activation or fixation through the use of up to 3 dual-tube peristaltic pumps. Passive gas exchange occurs utilizing ISS cabin air. The unit contains temperature, pH and experiment specific sensors for environmental monitoring. The unit provides up to 3 levels of containment yet has windows for microscopy, still and video imaging. Microscopy is attainable in up to four of the six Opticells™. While macro-video imaging can be attained in up to two of the Opticells™. The CHAB offers automated, configurable experiment control.

Multi-well Plate



The Multi-well Plate is being designed to fly in 2013 and utilize the plate reader now on board the ISS. The multi-well plate will utilize FEP (fluorinated ethylene propylene) clear Teflon film to form wells within the plate frame. BioServe has developed methods to seal this film to a custom frame in a micro-plate format. FEP Teflon has a number of advantages for this design, including supporting high levels of O_2 and CO_2 gas exchange yet having a relatively low water vapor loss. In addition, FEP Teflon can be autoclaved for sterilization procedures. Finally, the film has light transmission properties consistent with the needs of investigators who might require imaging, spectroscopy or fluorescence-based assays from the cell cultures. The Multi-well Plate has a septum seal that enables injections through dual ports into each of the six wells. This design, currently being developed for a custom payload application, will be further developed into a stand-alone format that can be loaded with reagents or inoculated with cells on orbit, processed inside CGBA for temperature control and imaging, if required, or placed in the ISS plate reader to enable a wide variety of assays.

More information and specifications regarding BioServe's CGBA and associated hardware can be found at the following links:

http://www.nasa.gov/mission_pages/station/research/experiments/GAP-FPA.html
http://www.colorado.edu/engineering/BioServe/

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2.2.16 Bioculture System (BIOS) Hardware Description

The NASA Bioculture System is an advanced space bioscience culturing system capable of supporting variable duration and long duration experiments on ISS. Based on its technological heritage to the Space Shuttle-era Cell Culture Module (CCM), the Bioculture System is capable of supporting a variety of primary and established mammalian and non-mammalian cells and cell lines, respectively, including 3D tissue cultures and microbiological cultures. In addition experiments that require co-culturing of different specimen types (e.g. cell and cell or cell and microbe) can be conducted in this system. The Bioculture System is designed to conduct a wide range of experiments to investigate the fundamental and biomedical impacts of microgravity and the space flight environment on cellular, tissue, and microbial specimens and systems. Furthermore, the Bioculture System provides capabilities for biopharmaceutical investigations for discovery biology, drug discovery, and pharmaceutics testing. The Bioculture System provides ten independent incubation chambers (Cassettes) that allows the scientist the capability to pre-program environmental set points, and automated sampling and injection timelines while providing Crew access for manual operations, such as on-orbit culture initiation and subculturing. The Bioculture System is compatible technology for delivering medium perfusion to cultures using with hollow fiber technology, which eliminates exposure of the cells to mechanical and fluid shear forces.

The Bioculture System supports both academic and biotechnology/pharmaceutical company goals and objectives for utilizing the unique space flight environment provided by ISS. The Systems supports cell biology studies such as the following:

- Cell physiology
- Omics studies
- Cell cycle
- Cell differentiation
- 3D tissue culture
- Tissue biology
- Host-pathogen (bacteria and virus) interaction via co-culture
- Cell to Cell interactions via co-culture
- Immune cell function
- Latent virus activation
- Cancer-related, radiation, biotech/ commercial pharmaceutical discovery biology, drug discovery, and drug compound and countermeasure analyses and testing.

Microbiology studies supported such as the following:

- Basic microbe physiology and molecular analyses
- Omics studies
- Microbial pathogenesis
- Long duration growth for genetics and evolution
- Biofilm research.
- Biotech / commercial pharmaceutical discovery biology, drug discovery, and drug compound and countermeasure analyses and testing.

The Bioculture System supports on-orbit experiment design flexibility and automated and manual capabilities to conduct the study:

- Conduct variable duration and long duration experiments up to 60 days using nominal supplies; longer duration experiments are possible but will require resupply of consumables
- Incubation of biological samples
- On-orbit initiation of cultures and subculture
- Cold chamber for containing heat labile media, additive solutions, preservatives and fixative solutions, and samples
- Media circulation for perfused feeding of the cultures; amenable to use with hollow fiber media delivery systems to protect cells from media flow forces
- Programmable automated specimen sampling from the biochamber
- Programmable automated solution injection
- Manual Crew activities for on-orbit initiation of cultures, subculturing, sampling and injections, and removal/change-out of bags and biochamber
- Manual change out of Cassettes and flow path assemblies for initiation of new experiments on-orbit
- Near-real time data downlink
- Change pre-programmed set points or automated activity timelines, per Cassette, by commanding from the ground
- Resupply Cassette consumable supplies, including the Gas Supply Assembly

- Crew operations can be performed in the Microgravity Glovebox or ISS Disposable Glovebag

Bioculture System Specifications:

- The Bioculture System is made up of two components: 1) docking station and 2) 10
- Docking Station
    - Removable Gas Supply Assembly – PI selected gas mixture
    - Power Module
    - Power and gas supply connectors for the ten Cassettes
- Cassette assemblies
    - Support the simultaneous but independent operations of ten Cassettes
    - ISS ExPRESS Locker equivalent in size
    - Weight 61lbs without ISS Locker
    - Weight 72 lbs when hosed in the ISS ExPRESS Locker
    - Operating Power: 140W to 150W
- Per Each Cassette Assembly - Base, cover, and Disposable flow path assembly
    - Cassette Base
        - Carries cold chamber, incubation chamber, and PC controller board
        - Two independent O-rings for 2 levels of containment for fluid and particles when the cover is attached
    - Cassette Cover
        - Gorefilter, which provides air exchange blocks fluids and particles; safety considered infinite level of containment
    - Disposable Flow Path Assembly
        - Media bag
        - Up to 16 accessory solution bags for additives, fixatives, preservatives, and samples
        - Fluidics tubing
        - Oxygenation system
        - Media warming system
        - Biochamber (Compatible with hollow fiber bioreactor technology)
        - Media pump
        - Up to 16 solenoid valves for automated sampling and fluid injection
        - Provides one level of additional containment
- Each Cassette provides experiment selectable temperature settings and flow rate control that is independent of the other Cassettes
    - Cold Chamber: temperature set point selection from ambient to +5 ^{o}C
    - Incubated Chamber: temperature set point selection from ambient to +42 ^{o}C
    - Pump: selectable rate and mode (intermittent, pulsed, or continuous)
    - Environmental gas supply is shared between all of the Cassettes

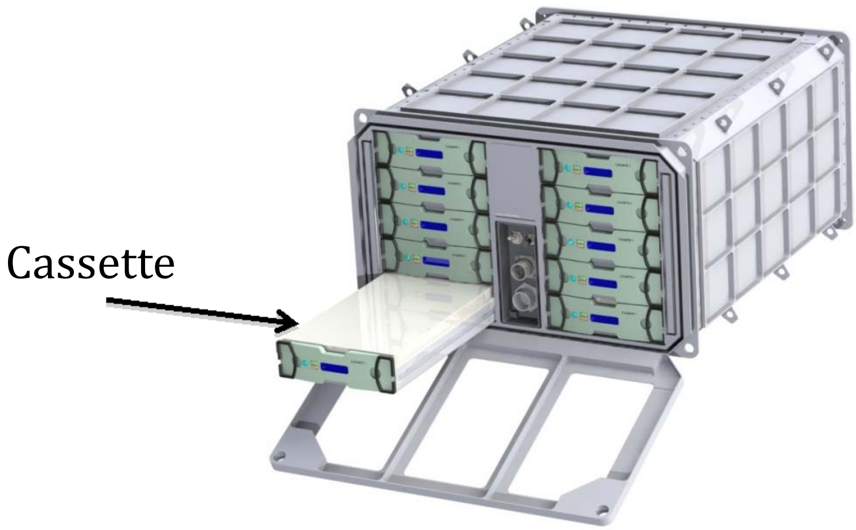


Figure: Bioculture System in an EXPRESS Locker

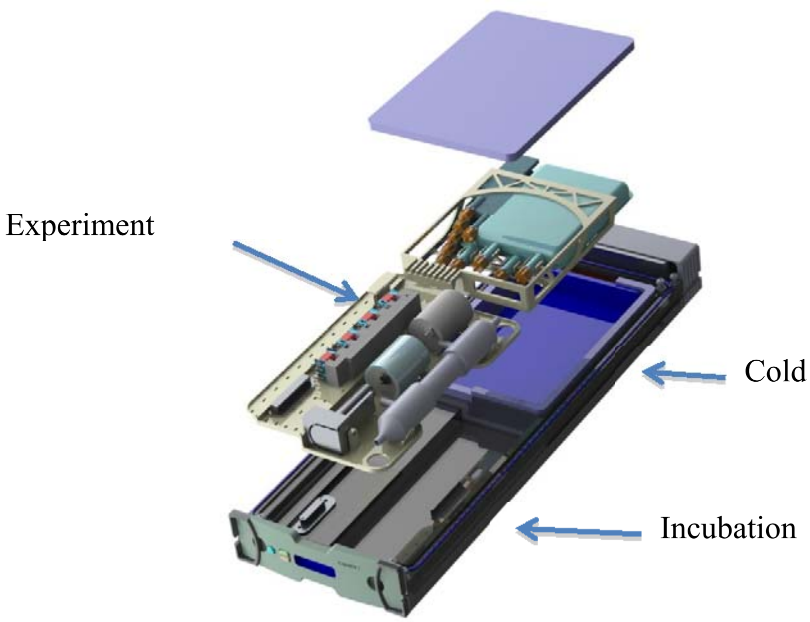


Figure: Cassette Assembly. The Experiment Insert carries the biochamber, solenoids, pump, and controllers (section over the incubation zone) and the solution bags (section over the cold zone). The flow path tubing between the bags and the other subsystems are not shown.

2.2.17 JAXA microbial monitoring tools

JAXA has developed small tools to sampling for microbial monitoring such as wet wipe, microbial detection sheet (for fungi), sampling sheet (dry sampling) and a particle counter using laser detector. The particle counter is modified from COTS product (Rion Co. Ldt. KR-12A: http://www.rion.co.jp/dbcon/pdf/KR-12A-E.PDF) to measure particle from 0.5 µm to 10µm.

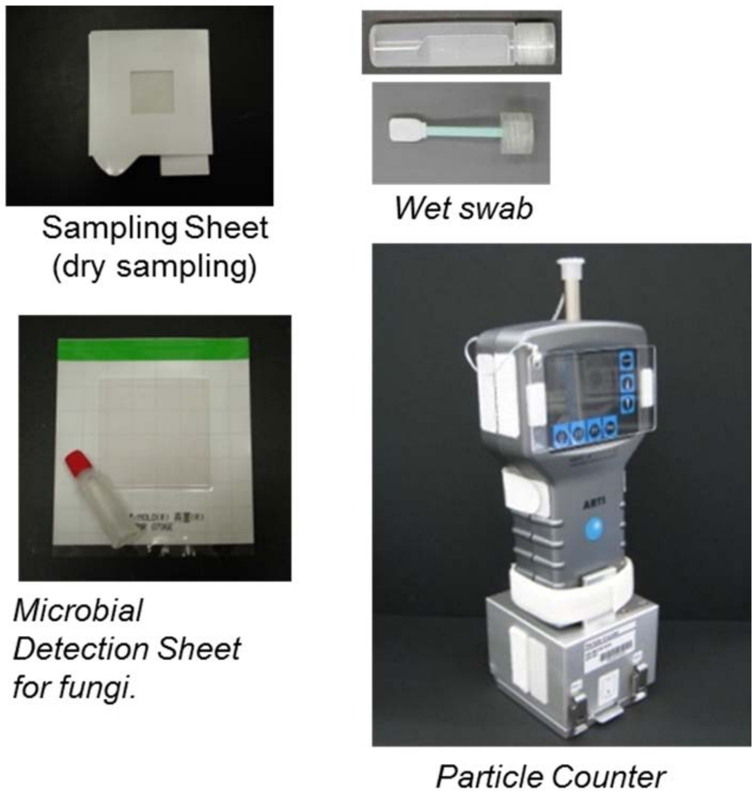
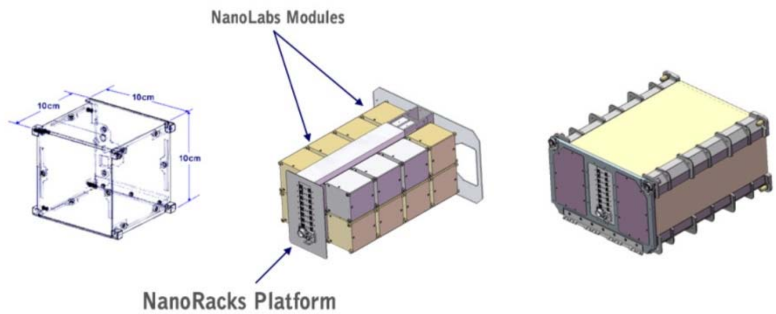


Figure: FJAXA microbial sampling tools and particle counter

2.2.18 NanoLabs

NanoLab is a box in the CubeSat form factor, measuring 10 cm by 10 cm by 10 cm. Every NanoLab has a circuit board that activates the experiment, turns it off and can be functioned for other activities. Customers have also deployed video cameras and a wide range of sensors inside NanoLabs.

NanoLabs are plugged into the NanoRack research platforms via a normal USB port, allowing data and power to flow. A single NanoLab is 1U in size; we can also handle 2U, or 4U or 2 by 4U for example–and we charge by the size of the NanoLab.



Included in the management of NanoLabs payloads is full experiment development from transportation to data retrieval.

- 10cm cube modules
- Power from ISS (5V dc)
- Standard USB connection
- Easy data downloads
- Repeatable missions
- Returnable payloads

NanoRacks offers complete in-house capabilities for payload integration, payload design and development and interfacing with NASA and foreign space agencies. NR Research Platforms 1 and 2 hold the basic NanoLab. NR Research Platform-3 holds our SuperLab, which is 4U in size and allows for more sophisticated payloads with more power and capabilities. For more information about NanoLabs capabilities please visit the NanoRacks website; http://nanoracks.com/products/nanolabs/

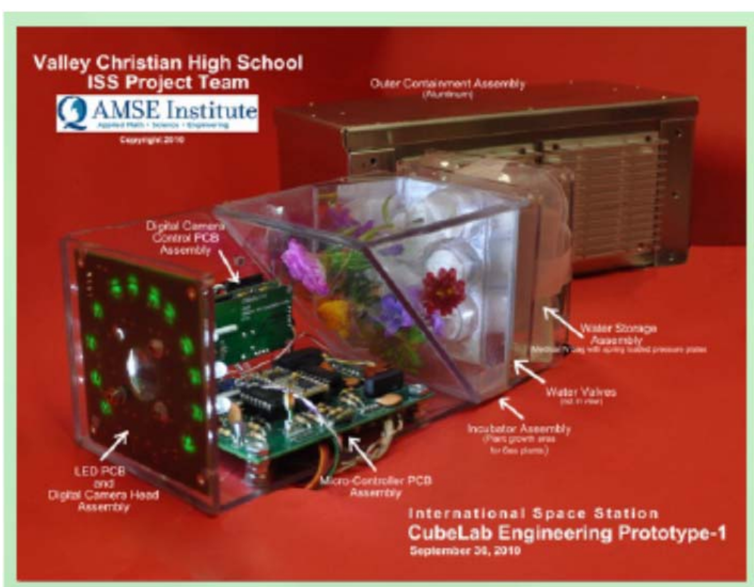


Figure: Example of NanoLab CubeLab built by Valley Christian High School for life sciences research.

2.2.19 Nanoracks Facilities

NanoRacks provides microgravity research facilities aboard ISS allowing small standardized payloads to be plugged into any of the NanoRack platforms, providing interface with the International Space Station power and data capabilities. The Nanoracks U.S. National Lab facilities provide turnkey opportunities to conduct experiments and currently includes two NanoLab Platforms, NanoRacks Plate Reader, NanoRacks Microscope and NanoRacks MixStix, providing repeatable microgravity research opportunities onboard the ISS. A passive centrifuge facility is available and may be used to provide variable-gravity environments for a variety of research applications. The facilities are described briefly below with links to the NanoRacks website for more information.

Overview of NanoRacks Laboratory Inside International Space Station

- Three research platforms in CubeSat form factor with USB standard interface
- Two microscopes;
- Centrifuge (With Astrium)
- Spectrophotometer microplate Reader (Molecular Devices Spectra Max M5e) allowing sophisticated on-orbit analysis:
- UV-Visible Absorbance
- Fluorescence Intensity
- Time-Resolved Fluorescence including CisBio HTRF
- Fluorescence Polarization
- Glow LuminescenceHardware for biological research
- Data returns to customer
- Power
- Return of payloads possible

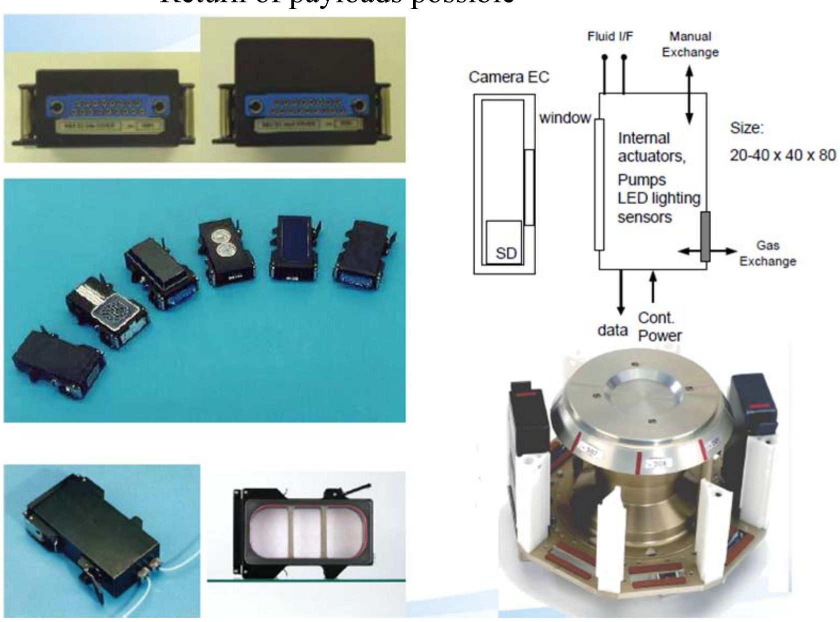


Figure 1: Centrifuge and Modified Type I containers

Two NanoRacks Platforms are now permanently housed on the ISS U.S. National Lab, allowing for 32 payload slots of NanoRacks research modules, known as NanoLabs (1U = 4 inches by 4 inches by 4 inches) or any combination, such as 2U or 3U x 8U and so on. Everything necessary for a mission is taken care of by the NanoRacks team. Through NanoRacks partners and via their own facilities, NanoRacks offers complete in-house capabilities for payload integration, payload design and development and interfacing with NASA and foreign space agencies http://nanoracks.com/facilities/nanolabs/.

The NanoRacks optical microscopes allow on-the-ground researchers to undertake in-situ microgravity analysis. The USB Microscope plugs into any ISS laptop allowing crewmembers to adjust the position of the samples on the slide and focus the microscope as well as choose the magnification from the 5X, 10X or 20X objectives. When the desired images are captured, the crewmember will copy them from the USB Video Device to the destination file for later downlink to your team on the ground http://nanoracks.com/facilities/microscope/.

The NanoRacks' MD Plate Reader-1 holds 96 samples allowing veteran space researchers and those new to space to perform the same state of the art analysis now done in laboratories on the Earth. The Plate Reader is derived from an off the shelf Molecular Devices M5E (http://nanoracks.com/facilities/plate-reader/).

The NanoRacks Centrifuge was developed in collaboration with Astrium. It is a passive facility that is maintained in the ISS cabin and has no independent temperature, humidity or atmospheric control. The facility can hold up to 6 ESA Type 1 containers (each one measuring 20 mm x 40 mm x 80 mm).. Hardware for biological research is available for Nanoracks research. ESA Type I Experiment containers are available for supporting plant growth, small aquatic organisms and drosophila. A variety of modified Type I containers and the centrifuge system are shown in Figure 1 above. Other modifications to Type 1 containers are possible and being considered.

Microgravity Microplates/Cuvettes

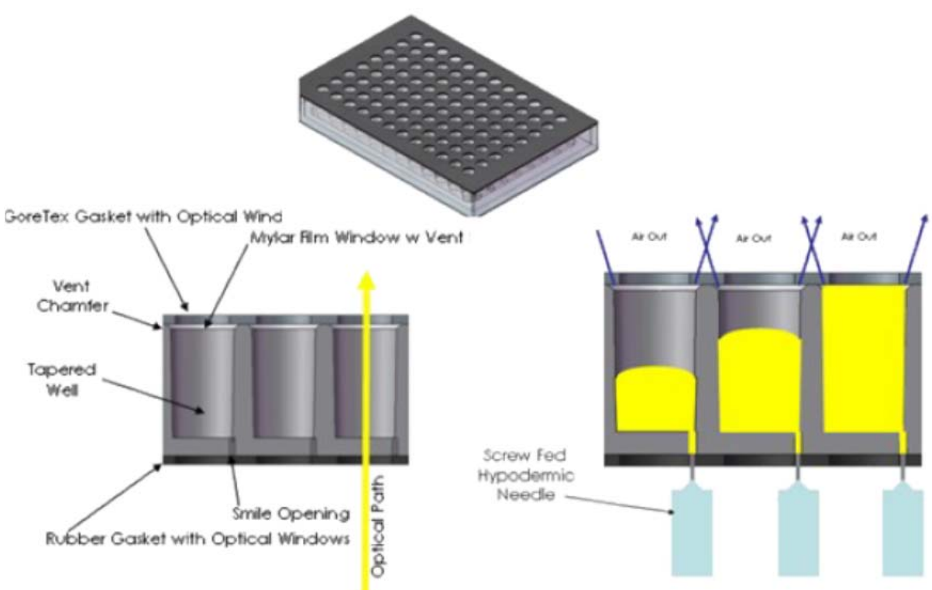


Figure 2. NanoRacks Vented Microplate

NanoRacks is modifying off-the-shelf microplate and cuvette designs to accommodate fluids in the microgravity environment for use in the Plate Reader. The following designs are currently under development.Vented Microplate The Vented Microplate is essentially a standard microplate with a Mylar seal over the wells including Gore-Tex gas permeable membranes. Filling of the Vented Microplate is accomplished on-orbit by injecting a liquid sample into each well using a hypodermic syringe through a rubber seal.

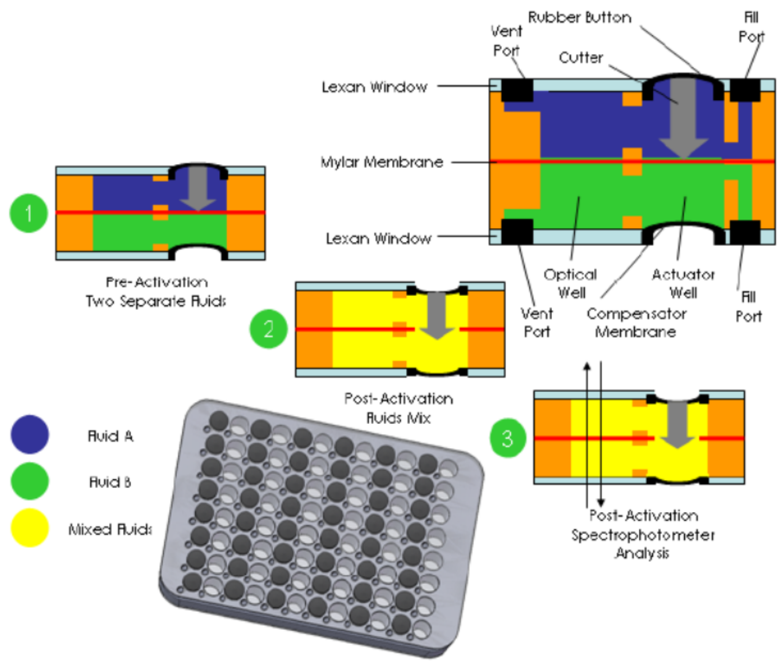


Figure 3. NanoRacks Reactor Microplate

Reactor Microplate
The Reactor Microplate is a modified microplate that contains liquid sample storage cells that contain pierceable membranes for mixing the fluids and thus activating experimental operations. The Reactor Microplate is loaded on the ground and activated by crew on-orbit. Analysis by the Plate Reader is unaffected.

Cuvette System
The Plate Reader has a top port for use with single cuvette samples or experimenters can use CuvettePlate™ by Perfector Scientific, which is an off the shelf microplate cuvette adaptor that can hold up to 8 screw cap sealed cuvettes in an adapter tray that is read in the Plate Reader. This permits experimenters to design and utilize a wide variety of cuvettes for use in microgravity including reactor cuvettes and miniature flow cytometry systems. Analysis by the Plate Reader is unaffected.

Transmission Microscope
NanoRacks flew a miniature Celestron Model 44330 USB transmission microscope to the ISS on HTV-2. The system was recently tested by astronaut Mike Fossum and this system is ready for use by experimenters. It utilizes standard plastic microscope slides and is operated with a laptop computer. It has a maximum magnification of approximately 1880X. The ISS crew takes snapshots with the laptop and downlinks the images which are distributed to experimenters from a NanoRacks website.

Figure 4. Cuvette System (courtesy Perfector Scientific)

Figure 5. **NanoRacks Transmission Microscope**

Reflective Microscope
NanoRacks flew a miniature Celestron Model 44306 USB reflection microscope to the ISS on Progress 45. It takes images directly off of sample surfaces and is operated with a laptop computer. It has a maximum magnification of approximately 200X. The ISS crew takes snapshots with the laptop and downlinks the images which are distributed to experimenters from a NanoRacks website.

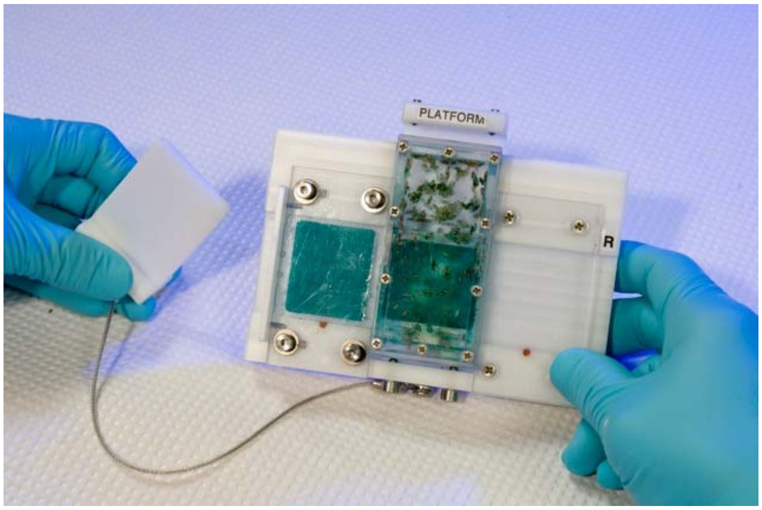
External Platform:
NanoRacks is also in the process of designing an external platform that will have access to open space via the JEM Experiment Airlock. This facility will provide experimenters with the convenience of crew tended maintenance/replacement of hardware while providing exposure to outer space conditions using robotic manipulation. In particular, this system will be useful for exobiology experiments.

Figure 6. **NanoRacks Reflection Microscope (example images inset)**

2.2.20 Fruit Fly Lab

Fruit fly spaceflight experiments have contributed significantly to our understanding of the effects of microgravity on biological processes that are directly relevant to humans in space. The Fruit Fly Lab provides a research platform aboard the International Space Station for long-duration fruit fly (*Drosophila melanogaster*) experiments in space. Such experiments will examine how microgravity and other aspects of the space environment affect these insects, providing information relevant to long-term human spaceflight.

NASA's Ames Research Center developed the Fruit Fly Lab to enable fruit fly research aboard the space station. This hardware development project leverages the experience gained from prior flight experiments with fruit flies using a space shuttle-based system. Advanced capabilities of the new Fruit Fly Lab include providing environmental and behavioral monitoring for long duration studies that the previous system lacked. The hardware also supports safe transport of fruit flies on the commercial resupply service vehicle SpaceX Dragon.

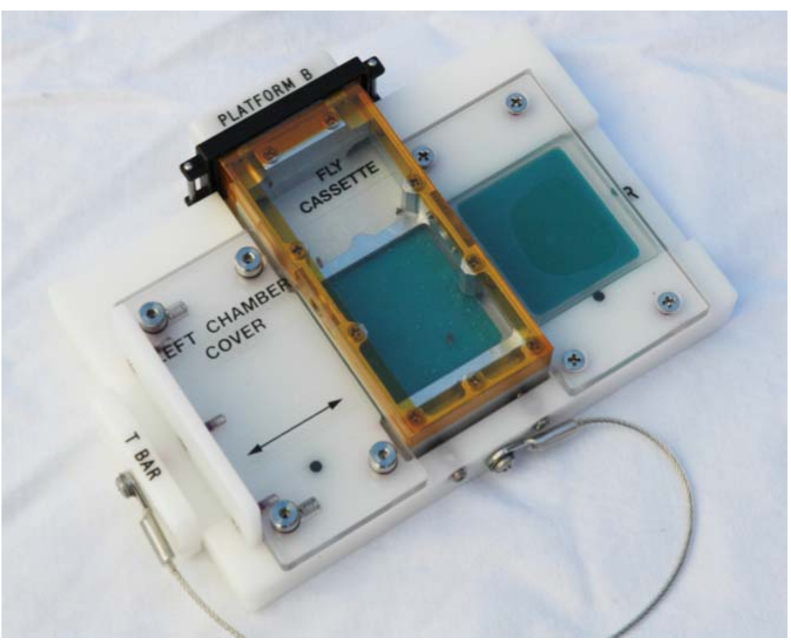


Housing Aboard the ISS

The new system has three major components. The first is the **Cassette** that will safely transport fruit flies to the space station. The second is the **Food Change out Platform** that will be used to change the fruit fly food without breaching containment, and allow extraction of the fruit fly larvae for preservation. [The third is the **Observation System** that will be used to record videos of the flies in orbit. –The Fruit Fly Lab will provide long-term housing for fruit flies aboard the station at microgravity and a controlled 1g inside an on-orbit centrifuge.

Capabilities Aboard ISS

The Fruit Fly Lab hardware operates in ambient conditions of the ISS atmosphere - no environmental controls or monitoring are available. There may be opportunities for crew to make manual changes to the experiment while aboard ISS. Crew will be able to provide observation data during flight.



Sample Return

Fruit Fly samples can be returned frozen, refrigerated, or ambient. An inflight fixation method is currently under development, but is not likely to be available for the first experimental runs.

References

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2.2.21 Microbial Cryogenic Canister Assemblies

The Microbial Cryogenic Canisters provide containment for three 8 ml Cryovials that can be used for microbial growth. The Cryovials are inserted into aluminum vial jackets to provide efficient thermal transfer from the canister to the specimens. The canisters containing the Cryovials can be stored in temperature controlled environments during ascent, on-orbit, and descent.

2.2.22 Advance Plant Habitat Hardware (Under Development)

In 2010 NASA's Fundamental Space Biology Science Plan, developed to guide research efforts through 2020 (http://www.nasa.gov/exploration/library/esmd_documents.html), strongly recommended that an Advanced Plant Habitat (APH) be developed to facilitate multi-generational studies with large plants under well-controlled environmental conditions on the International Space Station (ISS). A Science Requirements Envelope Document (SRED) was developed to establish the science requirements to conduct plant biology research with a variety of plants using the APH and associated hardware. Early on the decision was made to target a quad-locker sized facility with an adjoining ISIS drawer (Figure 1 below) containing one large "Specimen Chamber" (Figure 2 below) to provide the science community with the largest plant growth environment ever provided for microgravity experiments. It will be mounted in a standard EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack in the U.S. Laboratory (Figure 3 below).

When completed in 2016, APH will provide a large, enclosed, environmentally controlled chamber designed to support commercial and fundamental plant research onboard ISS. It will incorporate proven microgravity plant growth technologies with newly developed fault tolerance and recovery technology to increase overall efficiency, reliability, and robustness. The design is based on an open architecture concept to allow critical subsystems to be removed and replaced onboard the ISS. Key requirements for its design are presented below.

<u>Selected Key Requirements:</u>

- Total Shoot Growth Area: 2,290 cm^2
- Total Root Growth Area: 2,052 cm^2
- Maximum Shoot Height: 43 cm
- Root Module Height: 5 cm
- Growth Volume: 109,933 cm^3

- Growth Chamber Relative Humidity Range: 50%-86% RH; Set-point definable in 2% RH increments; maintained within ± 5% RH
- Growth Chamber Humidity Condensate Volume: quantified with an accuracy of ±10% (for the calculation of evapotransporation)
- Growth Chamber Leak Rate: ≤10% by volume/day
- Growth Chamber Air Velocity: 0.3-0.7 m/s in 0.1 m/s increments (at chamber center)
- Growth Chamber Air Flow Direction: in the vertical direction from bottom to top
- Growth Chamber Air Velocity Uniformity: uniform over the entire plant growing area to ± 5% of the set-point
- Growth Chamber Internal CO_2 Levels: 400–5,000 ppm (set-point in 25 ppm increments & maintained within ± 5%)
- Growth Chamber CO_2 Measurements: measured to a tolerance of ± 10%
- Growth Chamber Air Circulation System: filters out air contaminants ≥ 0.5 μm
- Growth Chamber Internal Ethylene Levels: ≤ 25 ppb
- 3 unique cameras for different types of viewing/perspectives
- Lighting Control (both intensity and spectrum) up to 1,000 $\mu mol/m^2s$
- Lighting Wavelengths: Red, Blue, Green, Far Red, White, and IR
- Remote monitoring and control

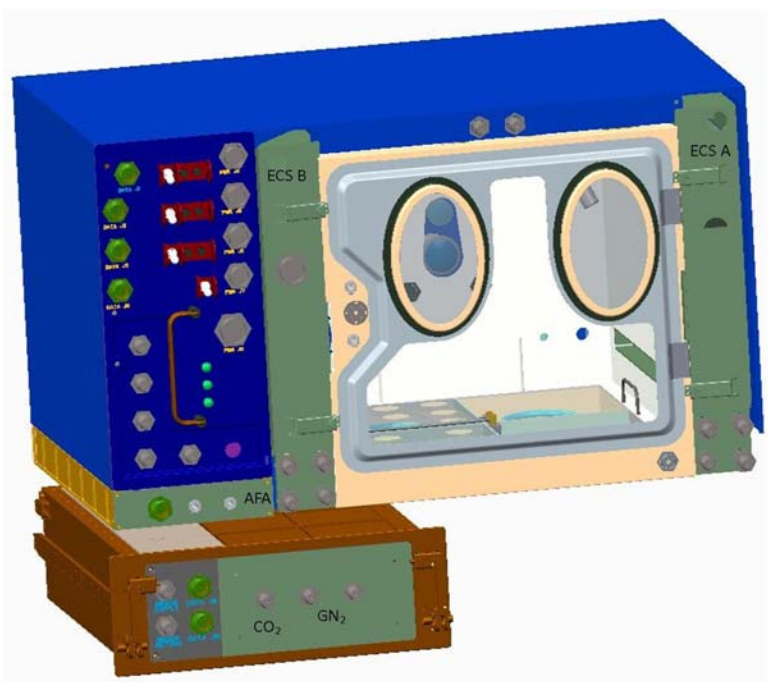


Figure 1. Diagrammatic representation of APH showing the Speciment Chamber on right side (see Figure 2 for details), two Environmental Control System (ECS) modules, the Air Filtration Assembly (AFA), and the ISIS Drawer containing CO_2 & GN_2 components. All are replaceable on-orbit.

The Science Carrier (Figure 4 below) consists of a structural element, a water delivery mechanism, and a standard interface plate that will provide instrumentation support as part of the basic APH capabilities. The Science Carrier will also provide 28 VDC power, additional instrumentation channels, and video and imaging interface to allow Principal Investigators (PIs) to extend the APH basic capabilities. It will contain a structural element to separate the root zone from the shoot zone, as well as imaging, light, O_2, temperature, and moisture sensor interfaces on the structure's side walls. The water delivery input is located at the top of the Science Carrier at each quadrant for simple access and manipulation. Power and data outputs will include integration with the Specimen Chamber and plug into the back of the Carrier.

Baseline Concept of Operations

It is assumed that most experiments will be initiated using seeds launched dry within a "Science Carrier" (Figure 4 below) that will be inserted into the base of the APH Specimen Chamber (Figure 2 below). This does not preclude other more challenging approaches that may be proposed at a later time (e.g. launching pre-initiated seedlings, cuttings, etc. from Earth). Once the Science Carrier is installed, APH will be activated, and proper operation validated. Water will then be delivered to the Science Carrier's root zone (initially baselined as being composed of 0.5-2.0 mm arcillite with slow release Osmocote fertilizer pellets distributed within) and seed imbibition initiated. The capability for command of the environmental control parameter set points will be provided both on-orbit and from the ground. Operating conditions during the seed germination phase will generally utilize lower light intensities and higher relative humidity set-points than will be used once the seedlings are established. It is anticipated that in most instances, light intensities will ramp up as the plants increase in size, reaching a maximum as canopy closure approaches. The crew will be able to obtain specimen samples at any point within an experiment (e.g. for pollination, chemical preservation, cold storage, etc.) using the sleeved access ports (Figure 2 below). They will also be able to *manually* obtain water samples both from APH's internal reservoir and root zone, and gas samples from both the shoot and root zones. Plant growth, water usage and other physiological parameters will be gauged from non-invasive measurements of chamber CO_2, O_2, canopy temperature and root zone moisture content. Direct observation of the plants will be possible at any time via a transparent front panel (nominally blocked by a light-tight cover), and indirect viewing will be possible (both on-orbit and on the ground) via the imaging capabilities of APH (enabling assessments of plant growth, leaf area development, etc.).

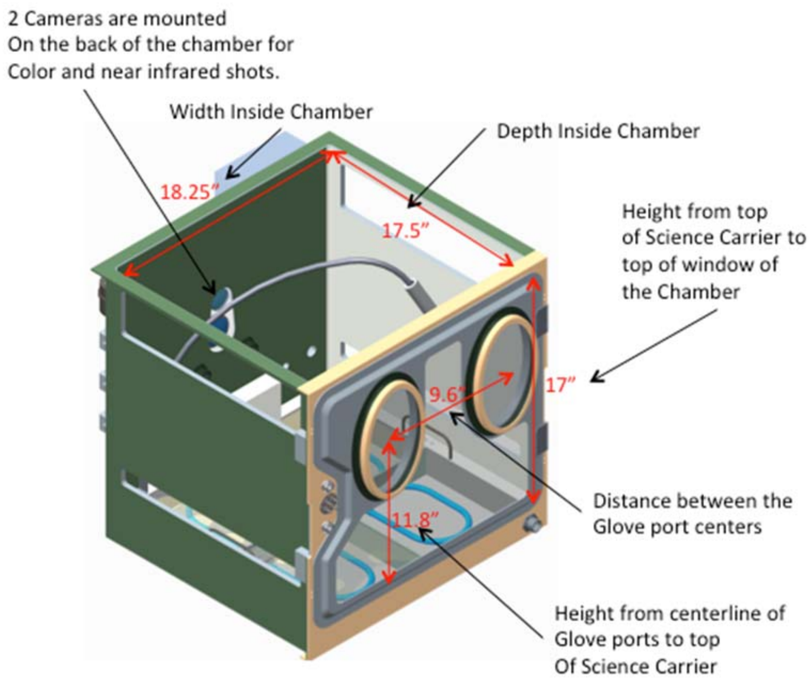


Figure 2. Specimen Chamber: Two glove ports are present to permit access to the chamber's interior during experiments. The Science Carrier (see Figure 4 for details) can be seen on the bottom. Under normal operating conditions a light-tight cover blocks light entry from the cabin environment.

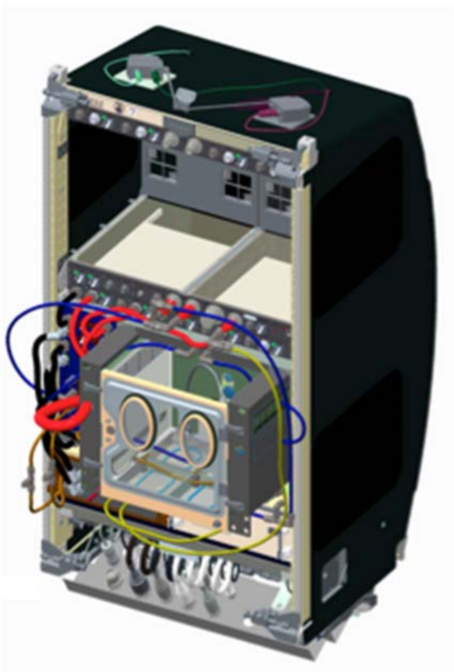


Figure 3. APH mounted in a standard EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack. As shown, the Specimen Chamber slides out 25 cm from the main unit for viewing through the top window during glove port operations.

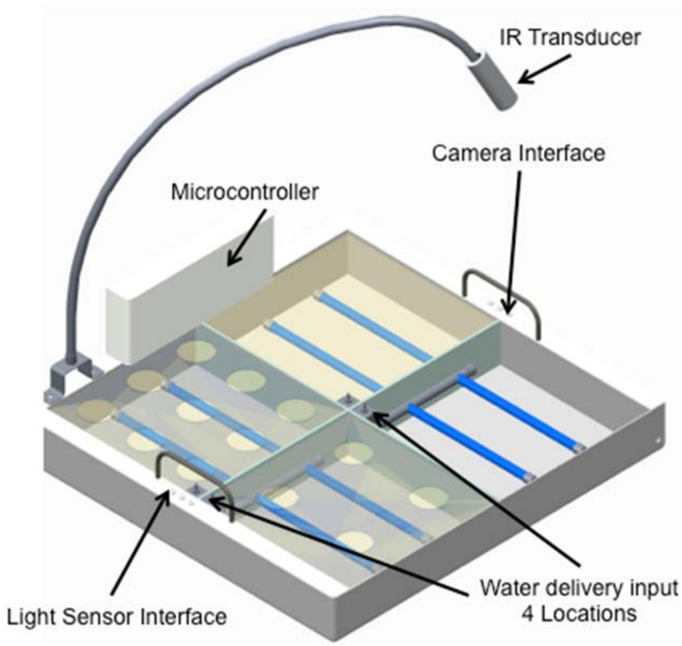


Figure 4. Science Carrier: The four substrate quadrants can be independently controlled to different wetness level setpoints. Two moisture sensors will be located within each quadrant for real-time measurements of substrate moisture content.

Future Operation Plan

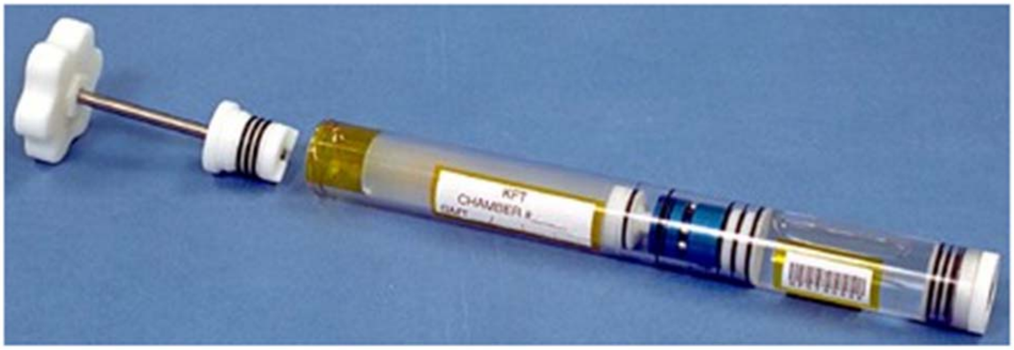
Subject to funding availability, NASA anticipates selecting PIs for APH no earlier than 2015. Current funding profiles project 1-2 long-duration tests each year through the life of the ISS. A minimum of two APHs will be fabricated, one for installation within an ISS Express Rack on ISS, and one ground control unit to be maintained at Kennedy Space Center. A third lower fidelity unit will be produced for PI operations and for crew training. APH will be capable of supporting fully powered experiments up to 135 days without disruption, except for replenishment of planned expendable commodities. If merited by PI requirements, additional Science Carriers may be developed with alternative capabilities.

2.2.23 Plant Growth Experiment Containers (EC) for the EMCS

The Plant Growth Experiment Containers (EC's) work with the European Modular Cultivation System (EMCS). Each EC has an internal volume of 60 x 60 x 160 mm with a transparent cover and up to 8 of these EC's can be integrated into the EMCS. The EC's work with the EMCS to provide lighting, water, environmental control and monitoring, video, and digitial still image capture.

2.2.24 Kennedy Space Center Fixation Tube (KFT)

The Kennedy Space Center Fixation Tube (KFT) is a system designed to contain small biological samples during flight and chemically fix and/or stain the tissue samples. Because chemical fixatives are extremely hazardous to humans, the device is designed to contain its fixative solution within a triply-redundantly sealed environment.



The KFT is comprised of the following elements: a polycarbonate main tube where fixative is loaded preflight, the sample tube which is used to keep the plant or other specimen in place during operations, the expansion plug, top plug, base plug, and the plunger. The KFT contains approximately 35 ml of fixative solution and provides a usable sample volume of either 25 or 41 ml depending on which of the current two configurations is employed. KFTs have proven to provide very robust containment. The KFT has been demonstrated to maintain its containment at ambient temperatures, +4 degrees C refrigeration, and -99 degrees C freezing.

The KFT has been shown to be compatible with many fixative reagents. Some of the tested reagents are: 100% RNAlater; 0.4% Formaldehyde; 5% formalin, 5% acetic acid, 50% ethanol; 0.5% Glutaraldehyde, 2% Paraformaldehyde. In flight, in order to perform fixation of the samples, the KFT system is removed from a storage bag that is inspected prior to opening to ensure there have been no leaks. After a specimen has been placed into the sample tube, a plunger is locked into place at the top of the tube and the fully assembled KFT is actuated by turning the plunger handle several turns to release an internal expansion plug, forcing the fixative through openings located in the bottom of the sample tube. The fired KFT is then replaced in the plastic bag and restowed in a locker or transferred to MELFI or other conditioned stowage as required.

Results Publications

Ferl RJ, Zupanska AK, Spinale A, Reed DW, Manning-Roach S, Guerra G, Cox DR, Paul A. The performance of KSC Fixation Tubes with RNALater for orbital experiments: A case study in ISS operations for molecular biology. Advances in Space Research. 2011; 48(1): 199-206.

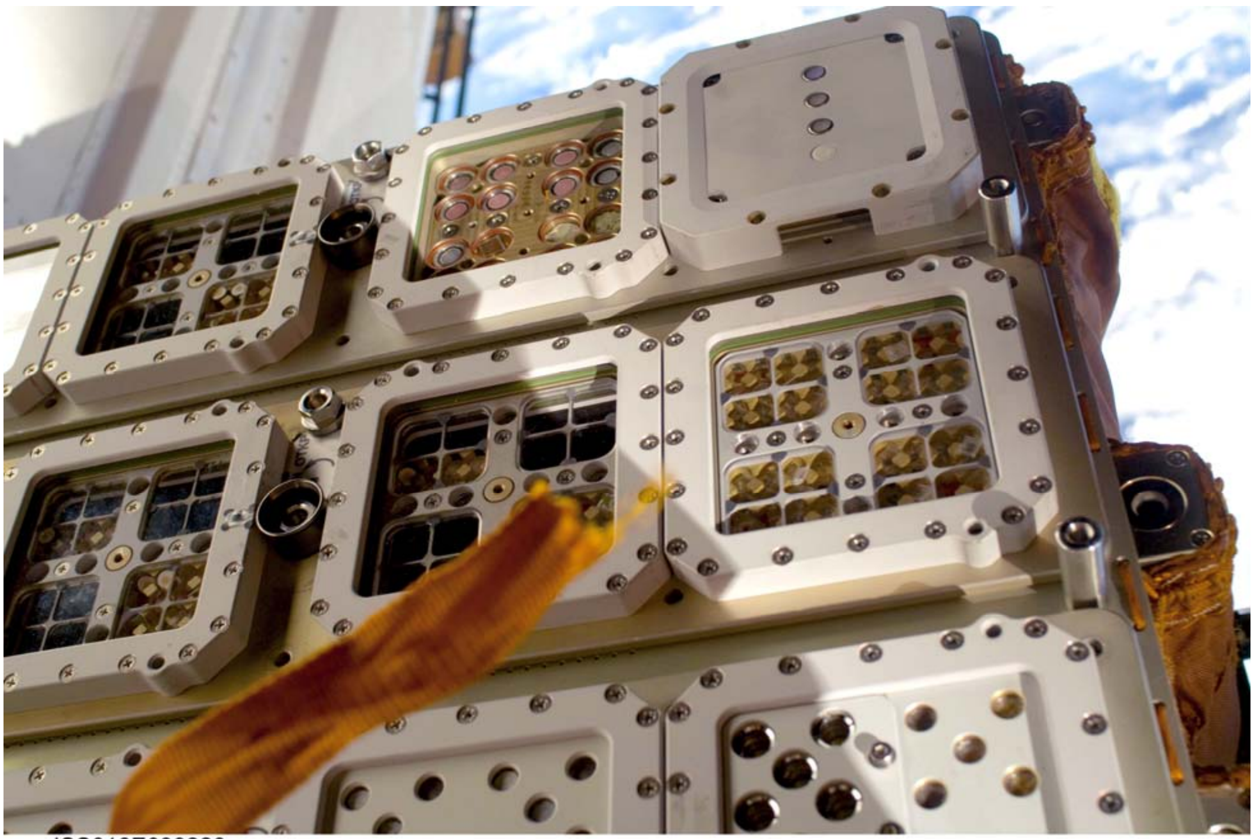
http://www.nasa.gov/mission_pages/station/research/experiments/724.html

2.2.25 Passive Dosimeter System (PDS)

The Passive Dosimeter System (PDS) hardware consists of two kinds of radiation dosimeters and an electronic "reader." The dosimeters can be placed anywhere in the ISS to provide an accurate point measurement of the radiation at their locations. One of the radiation dosimeters is a thermoluminescent detector, or TLD. These detectors are used to measure incident ionizing radiation (protons, neutrons, electrons, heavy charged particles, gamma and x-rays.) The other type of dosimeter is a set of Plastic Nuclear Track Detectors (PNTDs). The PNTDs are used to measure heavy charged ions radiation. This information is used to improve the accuracy of the radiation dose the TLDs have recorded and to improve the estimate of the biological effects of the radiation.

2.2.26 EXPOSE

The EXPOSE facility permit exposure of biological and chemical samples to the direct space environment (incl. vacuum, solar UV, ionizing radiation). Samples are contained in small wells in a variety of different sample carriers, under a small window. The windows are either made of MgF_2 glass which permits exposure to solar UV radiation down to 110nm or quartz, which only passes UV longer than 200nm wavelength simulating the Martian UV environment. The sample wells can be vented to the space vacuum or sealed with an argon or simulated planetary atmosphere (eg. Mars CO_2 atmosphere). Samples can be exposed to the space environment for over 1 year. A typical EXPOSE experiment passively undergoes its mission in orbit: there are no telecommanding or telemetry capabilities provided, neither can the experiments be manipulated by the crew. However, active and passive dosimeters on the facility can record the cosmic and solar UV radiation flux



ISS018E039226

2.2.27 ExHAM

The Exposed experiment Handrail Attachment (ExHAM) can deploy small sized samples on the Exposed area of Kibo. 10cm x 10 cm or 10cm x 20 cm size samples are attached to the ExHAM inside the ISS. Then the ExHAM with samples is transferred to the exposed area through the JEM airlock and installed to the handrail on JEM exterior by the JEMRMS Small Fine Arm.

ExHAM provide easier and more frequent opportunities for small sized technical demonstrations or experiments such as biological/chemical sample exposure, capture of space debris/aerosols and small device test.

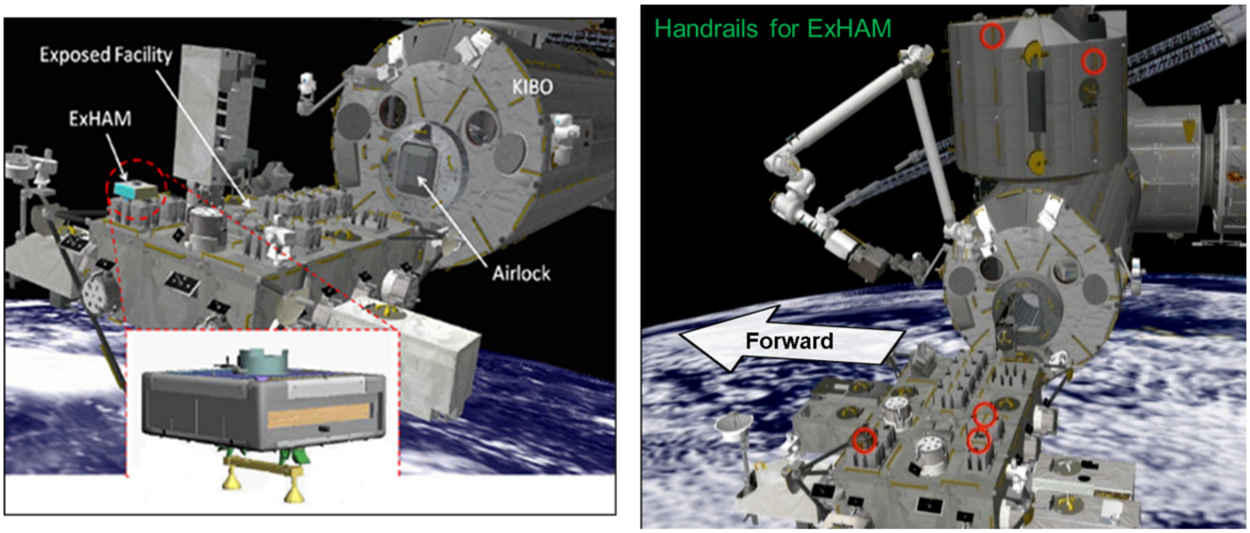


Figure: ExHAM

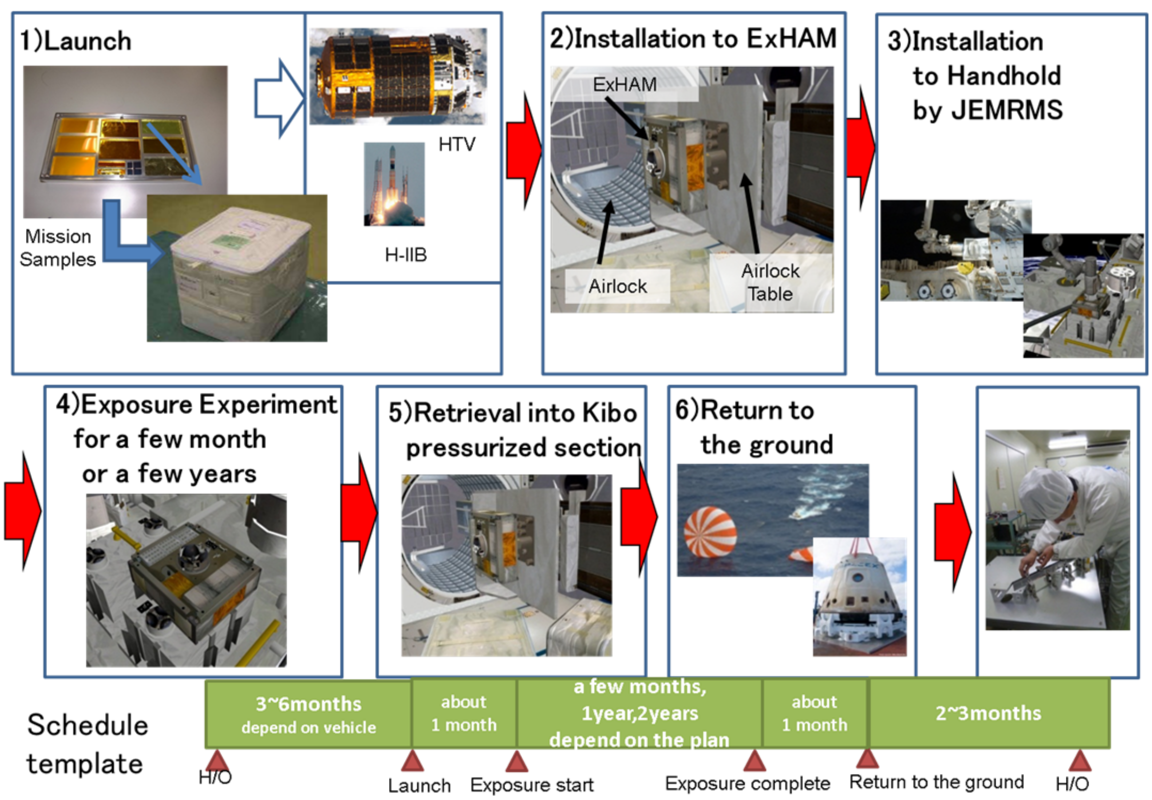


Figure: Mission Steps for the ExHAM mission

Table 2: Hardware Available to Support Biology & Exobiology Research

For further details and other ISS facilities see the below ISS link.
ISS facilities by Hardware Type, grouped by Discipline/Category:
http://www.nasa.gov/mission_pages/station/research/experiments/facilities_hardware.html

Hardware Available to Support Biology & Exobiology Research	Agency	Website
Biology		
KUBIK	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Kubik
EMCS	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/European_Modular_Cultivation_System_EMCS
BIOLAB	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Biolab
CBEF	JAXA	http://kibo.jaxa.jp/en/experiment/pm/cbef/
AQH	JAXA	http://kibo.jaxa.jp/en/experiment/pm/aqh/
BRIC- PDFU	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/708.html
VEGGIE	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/Veggie.html
Lada-2	NASA	http://www.nasa.gov/missions/science/f_lada.html
Rodent Research Habitat	NASA	Under Development
Bone Densitometer	NASA	http://www.techshot.com/documents/BD.pdf
CGBA	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/CGBA.html
BIOS	NASA	http://spacebiosciences.arc.nasa.gov/mission/bioculture-system-spacex-5
NanoLabs	NASA	http://nanoracks.com/products/nanolabs
NanoRacks facilities	NASA	http://nanoracks.com/
Advanced Plant Habitat	NASA	Under Development
Fruit Fly Lab	NASA	http://spacebiosciences.arc.nasa.gov/mission/fruit-fly-lab-ffl-01-spacex-5
Microbial Cryogenic Canister Assemblies	NASA	http://spacebiosciences.arc.nasa.gov/microbial-cryogenic-canister-assemblies
JAXA microbiology kit	JAXA	
EC	NASA	http://spacebiosciences.arc.nasa.gov/plant-growth-experiment-unique-containers-ec-european-modular-cultivation-system-emcs
PDS	NASA	http://spacebiosciences.arc.nasa.gov/passive-dosimeter-system-pds
Exobiology		
EXPOSE	ESA	http://www.esa.int/Our_Activities/Human_S

Hardware Available to Support Biology & Exobiology Research	Agency	Website
		paceflight/Human_Spaceflight_Research/Expose
ExHAM	JAXA	

2.2.28 Biology Experiment Mission Scenarios

Most biology experiments typically require launch and upload of experiment samples & reagents in a dormant or quiescent state, followed by activation and cultivation of the experiment onboard ISS. Inflight activities possibly include sampling, real time measurements/ recordings, fixation then storage of the samples. Data recorded inflight can be downlinked and samples are returned for postflight analysis. The feasibility of performing an experiment onboard ISS is therefore driven by the available resources for transport of the experiment to/from the station, conditioned temperature stowage, crewtime and experiment and/or facility constraints.

The mission phases of a typical biology experiment are the following:

Preflight preparation: There are several scenarios for preflight preparation. If the preparation of the biological material is not time critical, the experiment can be prepared in the investigators home laboratory or a user support operation center (USOC). Alternatively, if the experiment samples have a limited lifetime (eg. live cell cultures) then it may be necessary to perform the preparation at or near the launch site. In either case the requirements of shipment of the experiment, samples, reagents and equipment need to be considered (eg. time of transport, temperature requirements etc). At the launch site a laboratory facility may be required for experiment preparation, however it is difficult to provide the same level of facilities as in the investigators laboratory. For example at Baikonur and at Kennedy Space Center laboratory facilities are available, with tissue culture capabilities (eg. laminar flow hood, incubator, centrifuge, microscope), but all consumables and specialized equipment needs to be brought to the site by the investigator. Therefore, the preparation activities should be simplified as much as possible to minimize the laboratory requirements.

Preflight installation, launch and transfer to ISS (upload phase): The timeline of this phase of the mission and the conditions available for the experiment vary depending on the launch vehicle. It is assumed that the baseline upload transport vehicle for transport of time / temperature critical experiment samples will be the SpaceX Dragon vehicles. The Dragon capsule provides the possibility for frozen and refrigerated sample transport (see 3.1.2. for details of temperature ranges). Cargo is exposed to temperature environments similar to vehicles with crew during the freeflight phase of the mission. If a finer temperature tolerance is required than the ambient capsule temperature it is possible to package the experiment samples in phase change gels. In this way temperatures of 23-30°C can be ensured for transport of live cell cultures. Experiments / samples can be loaded into the Dragon capsule between 24h to 3 days before launch (depending on the temperature conditioning) and the time from launch to hatch opening at ISS takes between 1 and 5 days. For some small experiments a Soyuz vehicle could be potentially used. For this, the experiment can be loaded as late as 14h prior to launch if required and typically the flight time from launch until transfer to the ISS is in the order of 55-60h. During this time the experiment is exposed to ambient cabin environment (typically in the range of 15-30°Cunless buffered with a passive phase change materials). Other vehicles without a crew such as Progress, and HTV typically have late access times of several days before launch and may take several days more to reach station. Furthermore, the experiment may be subject to wider temperature extremes than in the Soyuz.

Operations onboard ISS: Following docking of the transport vehicle, the experiment is transferred to ISS. If the start of the experiment is not time critical, then the experiment equipment and samples will be transferred to stowage. Conditioned temperature stowage can be provided for some samples, including refrigerated (+4°C) and frozen stowage (-80°C). In case the experiment samples have a limited lifetime, the experiment will need to start shortly after arrival at ISS. However, it is very difficult to perform complex activities on the day the transport vehicle arrives at ISS, therefore realistically the first major experiment operations usually can only start the day after docking. The preference is to perform experiment operations with as much automation as possible (eg. automated experiment hardware, automatic facility operations controlled from the ground), although manual experiment operations (eg. Glovebox operations) are also possible. Even with automatic experiment operation some crew activity is required, for example to transfer experiment containers. It is important to have some flexibility in the timing of experiment activities requiring the crew, to facilitate fitting the experiment within the general crew schedule. The current scenario for Soyuz crew rotations foresees a period of 2-4 months between the upload of experiments and download. Therefore, the experiment must be able to survive this period of time on orbit including pre-experiment storage, operations and post-experiment storage.

Return from ISS and early retrieval: The current baseline method for sample retrieval is download in a returning Space X vehicle. Typically the time from transfer of samples to the vehicle until sample retrieval is 4-5 days. Frozen, refrigerated and ambient stowage is available during this period as described in section 3.1.2. In the case of Soyuz samples are transferred to Soyuz 24-36h prior to landing and maintained at ambient temperature (15-30°C). Some limited passive conditioned temperature stowage (e.g. phase change gels) may be available for small samples. Following a nominal landing, samples can typically be transferred to conditioned transport containers within 2-3h and handed over to investigators in Moscow approximately 12-18h after landing.

2.2.29 Exobiology experiment mission scenarios

The mission scenarios for exobiology experiments are similar to those for biology experiments, in terms of preflight preparation, upload and download. Deployment of the samples on orbit will usually require an EVA and a separate EVA to retrieve the samples. Therefore, the external exposure time will be less than the total flight time onboard ISS due to the constraints associated with EVA scheduling.

3.0 General Support Capabilities

3.1 Temperature-Controlled Storage

3.1.1. Temperature controlled storage onboard ISS

There are a number of hardware systems and methods for the maintenance of specific temperatures for specimens or preserved samples onboard ISS:

- Ambient Storage (approximately +18°C to +28°C)
- Refrigeration (+4°C)
- Freezing (-20°C to -80°C)

Storage at temperatures outside these ranges can be done, but only for a limited amount of time (few days) (passive temperature control)
Experiment operational requirements, hardware availability, and sample volumes dictate which system or combination of systems is used to accommodate specific experiment objectives. It should be noted that in all cases that the cold stowage volume available for anyone experiment is limited, as this is a shared resource.

The Minus Eighty-degree Laboratory Freezer for ISS (MELFI) is a cold storage unit that maintains experiment samples at ultra-cold temperatures on ISS. Each MELFI rack contains four dewars. Each dewar includes four trays that can be extracted without disturbing the samples in the other locations. Furthermore, each tray contains a combination of one-quarter size box modules and one one-half size box modules to hold science samples. Standard accommodation hardware is provided for the insertion of samples of different sizes and shapes. Although MELFI is technically capable of operation at any setpoint between 10 degrees C and -99 degrees C, there are three standard operating modes; -95 degrees C, -35 degrees C and +2 degrees C. The dewar temperature is continuously monitored and recorded realtime.

The General Laboratory Active Cryogenic International Space Station (ISS) Experiment Refrigerator (GLACIER) is a rear-breathing or water-cooled cryogenic freezer that provides cryogenic transportation and preservation of samples requiring temperatures between +4 °C (39 °F) and -160 °C (-301 °F). The cold volume of the unit has a generic design that allows multiple types of science samples requiring cryogenic thermal storage to use the GLACIER. The GLACIER is a double-locker-equivalent unit that can be operated in an EXpedite the PRocessing of Experiments to Space Station (EXPRESS) rack. The GLACIER incorporates a cold volume sample storage area of 23.1 cm (10.75 in.) x 27.94 cm (11.00 in.) x 41.91 cm (16.5 in.). It is capable of supporting 10 kg (22 lb) of experiment samples and has an internal cold volume of 20 L. The GLACIER can maintain a temperature of -160 °C (-256 °F) for 6 to 8 hours without power if it has been operating at -160 °C (-301 °F) prior to the power outage.

JAXA has developed Freezer-Refrigerator of Stirling Cycle (FROST). FROST is a stirling cooler that is able to keep up to -70 deg C and to keep cold even in case of power outage for more than 10 hours. The FROST was launched by HTV-4 and placed in JEM. Volume of FROST for samples is 33.1 x 25.5 x 15cm (12.2L).

Table 3: Hardware Available for Temperature-Controlled Storage

Facility	Temperature Ranges & Tolerances	Agency	Website
Minus Eighty Degree Life Sciences Freezer (MELFI)	3 set points: +4°C (+0.5°C to +6°C) -26°C (-37°C to -23°C) -80°C (below -68°C)	NASA/ESA	http://www.nasa.gov/mission_pages/station/research/experiments/58.html http://www.spaceflight.esa.int/users/index.cfm?act=default.page&level=11&page=1725
GLACIER	-160°C to +4°C (in ExPRESS rack on ISS)	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/351.html
BIOLAB TCU	-20°C to +10°C (1°C increments, +/-1°C)	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Biolab
KUBIK	+6°C to +15°C	ESA	
FROST	-70°C to Room temp	JAXA	

3.1.2. Temperature controlled storage during upload and download

A variety of active and passive systems are available for transporting samples to/from ISS, providing frozen, refrigerated and buffered "room temperature" conditioning. The characteristics of these systems are described below.

JAXA has developed ISS Cryogenic Experiment Storage Box (ICE Box) and launched it by HTV-4. The ICE Box is a cool box for delivery made to keep the container cool for 10 days without the electrical power. Volume of the ICE Box for sample is 31.9 x 26.6 x 8.8cm (7.3L).

The GLACIER freezer provides conditioned storage during transportation to and from ISS as well as on ISS. See previous section for a description of GLACIER. However with the limited power and cooling resources provided within the SpaceX Dragon, GLACIER is capable of providing thermal control between -95° C and + 4° C.

Polar is a Cold Stowage managed facility that provides transport and storage of science samples at cryogenic temperatures (-80°C) to and from ISS. Polar operates on 75 W supplied power and uses air cooling as its heat rejection method. Polar is the size of one middeck locker equivalent (MLE) can accommodate up to 12.75 liters of sample volume and 20 lbm including sample support equipment. Polar provides active transport of samples to / from the ISS via the SpaceX Dragon and to the ISS via Orbital Cygnus, and passive transport of samples to the ISS via the Dragon, Cygnus, ATV, HTV and Progress vehicles.

Facility	Temperature Ranges & Tolerances	Agency	Website
Double Cold Bag	-32°C, -26°C, +4°C	NASA	
GLACIER	-95°C to +4°C (in SpaceX, to and from ISS)	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/351.html
Polar	-32°C	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/1205.html

ECCO	+2°C to +10°C -15°C	ESA	
Phase change packs in soft pouch	+23°C to +30°C	ESA	
ICE Box	+2°C to +6°C for 10days	JAXA	

3.2 Chemical Fixation

Several options are available to chemically preserve specimens prior to return to Earth for analysis. Fixation cocktails would need to be tested in the specific hardware for biocompatibility. Previous flights have allowed chemical fixation with glutaraldehyde- and formaldehyde-based cocktails, and stabilization with "RNAlater". The investigator is encouraged to suggest less toxic chemical fixatives to decrease the use of hazardous materials.

The EMCS Fixbox has been developed to perform formaladehyde or RNAlater fixation of plant samples in TROPI Experiment hardware culture cassettes. Other types of samples can be fixed in either the TROPI culture cassettes or other containers which have the same dimensions (17 x 51 x 18 mm)

JAXA has developed a Chemical Fixation Bag to fix plant sample using RNAlater® or low toxic fixatives.

Table 4: Hardware Available for Chemical Fixation

	Agency	Website
KSC Fixation Tube (KFT)	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/724.html
EMCS Fixbox	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/European_Modular_Cultivation_System_EMCS
Chemical Fixation Bag	JAXA	

3.3 Mass Measurement

The ISS will have the capability to measure the mass of the human body.

Table 5: Hardware Available to Measure Mass

	Agency	Website
Body Mass Measurement Device (human) (SLAMMD)	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/640.html

3.4 Computers

Laptop computers outfitted with mass storage devices, communication adapters, power supplies and cables, and custom-built software are available for use. These laptops support software compatible with a Microsoft Windows operating system.

3.5 Radiation Monitoring

A **passive** dosimeter system will be available on the ISS to determine the space radiation dose for payloads. It uses thermoluminescent detectors (TLDs) in combination with plastic nuclear track detectors (PNTDs). The TLDs will be co-located with the PNTDs, and will be distributed throughout the ISS. Typically, neither the TLDs nor the PNTDs can be read-out on board; they have to be returned to the ground to be processed and analyzed in a laboratory. The passive detectors will provide the total radiation dose as absorbed during their stay onboard, as well as the average linear energy transfer (LET) spectrum. The passive detector can accumulate data for periods spanning as long as one year.

JAXA has developed a passive dosimeter package, PADLES as the device for monitoring radiation dose in ISS. The PADLES package consists of two types of passive and integrating dosimeters, a CR-39 Plastic Nuclear Track Detector (PNTD) and Thermo Luminescence Dosimeter (TLD). The PADLES is small and light weight; 25 mm square x 4 mm height and 5 g.

Complementing the passive detectors, a number of **active** dosimeter systems will be available on the ISS. Featuring time resolution, the active dosimeters can provide the history of irradiation by cosmic particles. Some active dosimeters deliver real-time or near-real time information. Examples are a tissue equivalent proportional counter (TEPC), and two charged particle directional spectrometers (CPDSs). The TEPC will be moved around the pressurized volume of ISS. The CPDSs have limited real-time data collection capability. One will be housed inside the Habitation Module, and the other, a triple CPDS with 3-axis sensitivity, is located outside on the S0 truss. The intravehicular CPDS is moved from module to module to conduct surveys. Initially, the instruments' first priority will be to support operational measurements, including contingencies. Eventually, the data is expected to become available for payload users.

Table 6: Radiation Monitoring Tools

	Agency	Website
Tissue Equivalent Proportional Counter (TEPC)	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/630.html
Charged Particle Directional Spectrometer (CPDS)	NASA	
Passive Dosimeter System (RAMs)	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/236.html
Passive Dosimeter System (PADLES)	JAXA	http://kibo.jaxa.jp/en/experiment/pm/padles/
Passive Dosimeter System (CRDP)	ESA	

3.6 Video Imaging

Activities may be documented using video and still cameras. Most habitats for nonhuman specimens provide both data and video downlink.

Various image data taken by video or digital cameras inside of experiment hardware will be accepted by the Image Processing Unit (IPU) through the ISS data network. IPU will encode or edit the image data. NTSC video image inputs will be digitized into MPEG2. Still images will be compressed to TIFF/LZW format and downlinked. The IPU also has capability to store images in removable hard disks.

Table 7: Video Imaging

	Agency	Website
Cameras	Various	
Image Processing Unit	JAXA	http://kibo.jaxa.jp/en/experiment/pm/ipu/ http://www.nasa.gov/mission_pages/station/research/experiments/340.html

3.7 Centrifuges

In addition to the centrifuges that are built into various habitats and facilities and the EPM hematocrit centrifuge, a refrigerated centrifuge will be available for processing of biological samples such as blood and saliva.

Table 8: Centrifuges

	Agency	Website
HRF Centrifuge	NASA	http://www.nasa.gov/mission_pages/station/research/experiments/639.html

3.8 Gloveboxes and Specimen Manipulation

Gloveboxes provide an enclosed environment to conduct manipulations of specimen, chambers, other materials, and the science support equipment necessary to conduct experiments in orbit. These gloveboxes have been designed to isolate the crew from potentially hazardous materials used during experiment operations (such as fixations, injections, waste removal, and dissections) while maintaining an internal environment suitable for specimen manipulation. There are also a large number of tools, surgical instruments, and kits designed for a wide range of applications in support of on-orbit biomedical and fundamental biology investigations.

Ancillary Hardware and Support Items for Rodent Research Aboard ISS

Rodent research in space requires a variety of operational support hardware that can be used by crew to perform various scientific operations. Support equipment is designed to be used in the space environment and allow astronaut crews to perform a wide variety of research tasks common to rodent science investigations. The support equipment available allows for replenishment of food and water, general animal husbandry and for procedures such as injection, euthanasia and dissection/preservation of specific tissues. Not all operations for rodent research that can be done easily on the ground are readily translatable to the space environment. The list of ancillary hardware and kits currently available for rodent research aboard ISS are shown below. Specialized hardware and kits may be developed or assembled by modification of the existing systems, or by development of completely new systems. In order to design a spaceflight experiment that can be performed in space, it is important to understand what procedures are available with the existing kits and only require new on-orbit operations and capabilities if they are absolutely necessary to achieve the scientific objectives of a specific investigation.

Mouse Transfer Box

The Mouse Transfer Boxes is used to hold the rodents during transfer operations. (see Figure) The Mouse Transfer Boxes is placed inside the AAU, and then the AAU is attached to a Rodent Habitat or Transporter. When the rodents are removed from either the Rodent Habitat or Transporter they are placed in the Mouse Transfer Box for transfer to the MSG or another Rodent Habitat.

Fixative Kit

Fixative kits consist of vials containing RNALater, a fixative solution for preserving tissue samples. The kit provides the required 2 levels of containment to safely contain the fixative. RNALater is a Toxicity Hazard Level 1 chemical and must have 2 levels of containment. Dissection canisters that were flown on Neurolab can provide one level of containment, O-ring vials provide another level, and a third level can be provided using Ziploc bags. Vials with fixative is flown in dissection canisters. (see Figure)

Cold Block

An aluminum block with holes for cryovials is used in conjunction with JSC's Mini-cold Bag and Ice Bricks to provide a freezing capability in the MSG.

Cryo Box

The Cryo Box is modified COTS hardware. Cryo Boxes are used to contain mouse carcasses after dissection and will be placed in either the glacier or MELFI. The aluminum containers are modified with Velcro riveted to the lid and base as a means of securing the two items.

Dissection Kit

Dissection kits provide the specialized surgical tools necessary for the tissue dissections. The kit is a Nomex roll-up pouch with Kevlar sewn in for sharps protection. The kit contains tools such as hemostat clamps, bone rongeurs, iris scissors, scalpel handle and blades, forceps, dissection scissors, a bulldog clamp, dental picks, and a spatula in appropriate sizes (see Figure). This kit is stowed in a locker during launch and landing procedures and are stowed in-flight until it is transferred to the MSG for animal operations. The safety concern with the dissection pouches is the number of sharp surgical tools contained in the pouch. The pockets in the pouch have three layers of Kevlar fabric sewn in for each tool to be inserted sharp end first so the tool does not puncture the pouch. This stowed configuration protects the crew from inadvertent exposure to sharp edges.

Injection Kit

The Injection Kit contains anesthetics and tools to anesthetize animals for injections or other non-terminal activities. The kit also contains materials to euthanize animals for dissections or to euthanize any animals that the NASA Vet has determined distressed and should be euthanized. The Injection Kit provides 3 levels of containment. The first level is the syringe with a locking pin on the plunger and a silicon rubber stopper over the needle. The second level of containment is the individual Ziploc bag around each syringe. The syringes will be in a hard Lexan protective case. The case will be in the third level of containment, a Ziploc bag. (see Figures)

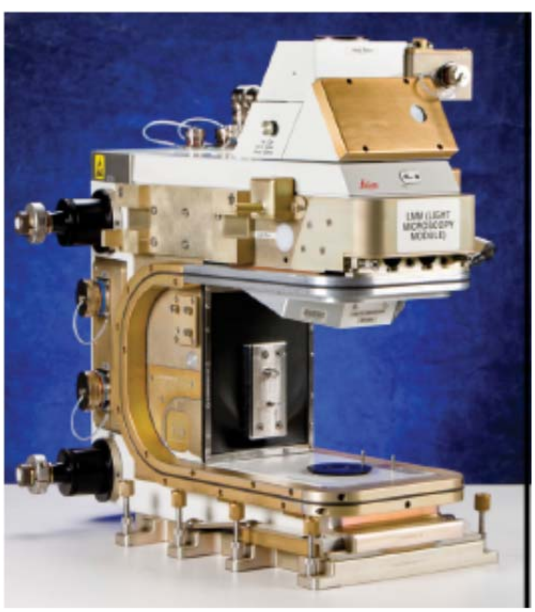
Table 9: Gloveboxes and Specimen Manipulation

	Agency	Website
Microgravity Science Glovebox	NASA/ESA	http://www.nasa.gov/mission_pages/station/research/experiments/350.html
BIOLAB Glovebox	ESA	http://www.esa.int/Our_Activities/Human_Spaceflight/Human_Spaceflight_Research/Biolab_BioGlovebox
JAXA Clean Bench	JAXA	http://kibo.jaxa.jp/en/experiment/pm/cb/

3.9 Microscopes

3.9.1 NASA Light Microscopy Module (LMM)

Engineers at NASA Glenn Research Center modified a Leica RXA laboratory-grade microscope by adding 23 micromotors to permit remote control by scientists on the ground and to meet the demands of space flight and crew-tended operations. As such, it contains all of the necessary optical components for use as a fully functional microscope. The microscope can house many different lenses corresponding to magnifications of 2.5X, 4X, 10X, 20X, 40X, 50X, 63X (air), 63X and 100X oil-coupled objectives. Present capabilities include brightfield and epi-illumination microscopy. Two cameras can be mounted on the headpiece of the microscope; one coaxially with the viewing axis of the microscope and one mounted at an angle on the confocal tube assembly. The two cameras employed are identical Q-Imaging Retiga 1300 units. In addition to these two cameras, there is a small surveillance camera that can be mounted inside the AFC (shown on the next image). The surveillance camera has a fixed window size of 640X 480 pixels/frame. The Q-Imaging 1300 cooled monochrome camera (6.7X6.7 μm) has a maximum window size of 1280X 1024 pixels/frame. A camera upgrade has been initiated for 2015. The LMM is a remotely controllable, automated microscope that gives scientists the ability to study the effects of the space environment on physics and biology in real time.



Specimens can be studied without the need to return the samples to Earth. The LMM flight unit features a modified commercial laboratory Leica RXA microscope configured to operate in an automated mode with interaction from the ground support staff. Its core capabilities include a level of containment, white light imaging (available now), fluorescence, confocal microscopy (available in 2016 to 2017), and an imaging capability from a Q-Imaging Retiga 1300 camera. The LMM operates in the Fluids Integrated Rack (FIR), which is located in the U.S. Destiny Laboratory of the ISS. The FIR provides the LMM with the laboratory infrastructure common to most investigations, including an optics bench, temperature control, power control, illumination, imaging and frame capture, data processing, and other resources.

The FIR also provides isolation from vibrations on the station to allow for a more stable environment to obtain high-resolution images. The LMM, in conjunction with the FIR, will help fulfill the vision of a true laboratory in space, which is ideal for low-cost payload development. A stage and condenser upgrade is planned for 2015 to provide transillumination and in-situ mixing and standard features such as darkfield and phase contrast microscopy. In-situ mixing allows for the observation of samples shortly after mixing, and for samples to be reinitialized at any time without intervention by the ISS crew. This will be implemented using a commercial off-the-shelf Leica condenser that will be modified

for the LMM.

3.9.2 JAXA Microscope

The JAXA Microscope is a remotely controllable microscope system to perform light field, phase contrast, and fluorescent observations for various biological experiments. The system is assembled in Multi-purpose Small Payload Rack (MSPR) inside the Kibo module. Crew will set a specimen on the microscope stage and remote observation operations will be carried out by the commanding from the ground.

The JAXA Microscope is modified from a commercial fluorescence inverted microscope, Leica DMI6000B. Objective lenses include 5X(NA 0.12), 10X (NA 0.25), 20X (NA 0.35), 20X (NA 0.70), 40X (NA 0.50), 40X (NA 0.75). On the microscope stage, Leica micro-titer plate holder (No. 11531434) is set as a standard specimen holder. The maximum size of the specimen vessel including frame or holder is micro-titer plate size (83x127mm).

4.0 Flight Proposal Evaluation Process

This section describes the evaluation and selection process that will be used for flight experiment proposals submitted to any member agency of the International Space Life Sciences Working Group (ISLSWG) in reply to the coordinated 2014 Space Life Sciences Research Announcements.

In the event that any instruction to proposers in this section about content or preparation of a proposal differs from the instruction in the solicitation of the proposer's country, that solicitation is the instruction that should be followed.

NASA is not soliciting, nor will it fund, any U.S. investigator, either as principal investigator or as a co-investigator in the areas of astrobiology or exobiology that are submitted in response to any ISS partner agency's research announcement associated with this ILSRA 2014.

Each research proposal must be a complete response to the appropriate individual space agency's official solicitation. In that solicitation, an agency may define a number of critical constraints that proposals must satisfy to be considered for selection. For example, an agency may not accept proposals for work in certain discipline areas. Proposals to these agencies to carry out work that is not responsive to their solicitation will be returned without further review. Please note that investigators can only receive funding from the agency associated with their country of origin. **Therefore, it is required that each member of an International team submit a letter that acknowledges awareness from their associated funding agency with their proposal.** This is critical because, one of the criteria peer review panels use to evaluate proposals is the expertise and technical capabilities of the proposed investigator team, so the funding agencies need to be sure that all investigators on an international team will be able to participate in the experiment if it is selected.
Compliant proposals submitted in response to the Space Life Sciences Research Announcements will undergo an intrinsic scientific merit review. Proposals that receive a passing score in this review will then undergo additional review(s) as follows:

- Flight feasibility review
- Relevance to the programs of the soliciting agencies (Completed by NASA prior to scientific merit – Step 1 proposal review)
- Cost (applicable to proposals submitted to NASA, JAXA, and CSA only)

Proposals will undergo the following three-tiered review process to assess these factors.

4.1 Scientific Merit Review

The merit review will be conducted by a panel of international scientific or technical experts. The number and diversity of experts required will be determined by the response to this research announcement and by the variety of disciplines represented in the proposals. The merit review panel will assign **a score from 0 to 100** or a designation of "not recommended for further consideration" based upon the intrinsic scientific or technical merit of the proposal. This score will reflect the consensus of the panel.

The score assigned by this panel ***will not be affected by the cost of the proposed work, nor will it reflect the programmatic relevance of the proposed work***. However, the panel will have the opportunity to include in their critique of each proposal any comments they may have concerning the proposal's budget and relevance.

The following will be used to determine the merit score:

- **Significance:** Does this study address an important problem? If the aims of the application are achieved, how will scientific knowledge or technology be advanced? What will be the effect of these studies on the concepts, methods, or products that drive this field?
- **Approach:** Are the conceptual framework, design, methods, and analyses adequately developed, well integrated, and appropriate to the aims of the project? Does a flight proposal build upon a successful foundation of ground studies? Is the proposed approach likely to yield the desired results? Does the applicant acknowledge potential problem areas and consider alternative tactics?
- **Investigator:** Is the investigator appropriately trained and well suited to carry out this work? Is the work proposed appropriate to the experience level of the Principal Investigator and any Co-investigators? Is the evidence of the investigator's productivity satisfactory?
- **Environment:** Does the scientific environment in which the work will be performed contribute to the probability of success? Do the proposed experiments take advantage of unique features of the scientific environment or employ useful collaborative arrangements? Is there evidence of institutional support?

4.2 Flight Feasibility Review

A second review will be an evaluation of the feasibility of the proposed work using available facilities on a space platform. The flight feasibility review will be conducted for each flight experiment proposal that receives a scientific merit score greater than a threshold score agreed upon by the ISLSWG Steering Committee. An international team of engineers and scientists experienced in the development, integration and operation of space flight experiments will conduct this review. For this reason, experimental requirements and procedures should be clearly and succinctly explained in terms that a layperson can understand.

In addition to the actual proposal, the information requested in the Space Flight Experiment Requirements Summary form is essential to the flight feasibility review. Flight experiment proposals submitted without the information requested will not be evaluated.

Of particular concern regarding the feasibility of a proposal is the identification of risk factors which could affect the implementation of an otherwise meritorious proposal. Therefore, the feasibility of implementing the proposal and associated risks will be evaluated using the following technical criteria:

- **Functional Requirements:** Will the planned flight and ground hardware meet the requirements of the experiment? What experiment-unique hardware will be required, and can it be developed in time for projected flight opportunities? Are the number of subjects or specimens required attainable within a reasonable period of time (1-2 years for non-humans, 2-3 years for human subjects) considering projected flight opportunities and other competition for those flight opportunities?
- **Operational Feasibility:** How complex are the experimental procedures? Will the crew have sufficient time to be trained to perform the experiment? Will they have sufficient time in their schedule to perform the experiment? Are the requirements for launch vehicle loading and unloading of the experiment specimens compatible with the capabilities of these vehicles? Can requirements for data collection on human subjects be accommodated in the preflight and postflight schedules for the astronauts? Has the experimental protocol taken into account the unavoidable period of time between the launch of an experiment and the actual initiation of the experiment? Will the experiment requirements for crew time, experiment volume, mass, power, or other features of on-orbit operations (such as temperature-controlled storage) affect the completion of this or other experiments? What other impacts will the experiment have on activities or experiments planned for the same mission?
- **Environmental Health and Safety:** Are there elements of the proposed ground or flight activities that pose concerns for the health and safety of personnel and/or the environment? For experiments that utilize the crew as research subjects, could the implementation of these experiments, even if considered safe, lead to an impact on their performance with respect to their other crew duties? Is it possible that specific restrictions on the human subjects (such as diet, exercise, etc.) will interfere with their other activities?

Using the risk factors identified in the evaluation, a score will be assigned to indicate this level of uncertainty. The risk assessment score categories are:

Low Risk: minimal risk to the successful achievement of objectives

Medium Risk: moderate risk to the successful achievement of objectives

High Risk: extreme risk to the successful achievement of objectives

The Principal Investigators will not be provided the risk assessment score, but in cases where the decision to not select a proposal is based in part on the technical evaluation, a description of the identified risk factors will be provided.

4.3 Evaluation of Programmatic Relevance and Cost

A third review will evaluate the programmatic relevance and cost of proposals that meet scientific/technical merit and flight feasibility criteria. Please note, NASA evaluates programmatic relevance based on a short (5-page) Step-1 proposal. Only those found to be relevant to the NASA needs will be invited to submit a complete scientific proposal that includes all information required for the scientific merit, cost and feasibility reviews. This review will be conducted independently by program scientists and managers from each soliciting agency for proposals submitted to their specific solicitations. Programmatic relevance is determined by the contribution of the proposed work to the balance of scientific and technical issues identified by agencies in their research announcements. Review of cost is applicable to proposals submitted to only CSA and NASA. Evaluation of cost will also be performed for proposals submitted to other agencies that include a component requiring only CSA or NASA funding. Evaluation of the cost of a proposed effort will include consideration of the realism and reasonableness of the proposed cost and the relationship of the proposed cost to available funds.

Please note that Canadian applicants (PI or Co-I) must submit a Notice of Intent to CSA prior to submitting Full Proposals to NRESS. This NOI has different structure, content, and due date as compared to the NASA NOI. The CSA will review the CSA NOI for programmatic relevance and impact, and will provide a Letter of Support to proposals that pass this CSA review. The Letter of Support must be included in the Full Proposal submitted to NRESS.

4.4 Recommendation for Selection for Further Definition

The results of the three levels of review will be used to prepare a recommendation for selection for further definition developed by each of the soliciting agencies. This recommendation will be based on:

1. The numerical merit score from the peer review panel
2. The results of the flight feasibility review
3. The programmatic relevance
4. Cost (applicable as described in Section 5.9)

A high merit score does not guarantee selection. A proposal must also be feasible to implement, have programmatic relevance, and have reasonable projected costs to be selected. The members of the ISLSWG will meet to ensure appropriate coordination of all their selections to optimize science return and resource utilization. For example, the composite selection will not greatly exceed the projected flight opportunities. In addition, it may be more efficient or effective to form international teams of researchers requiring similar resources to address overlapping questions than to have individuals competing for the use of the same specimens or test subjects. Such teams are best formed at the time of selection and early in the experiment definition period, rather than later during the flight experiment development process.

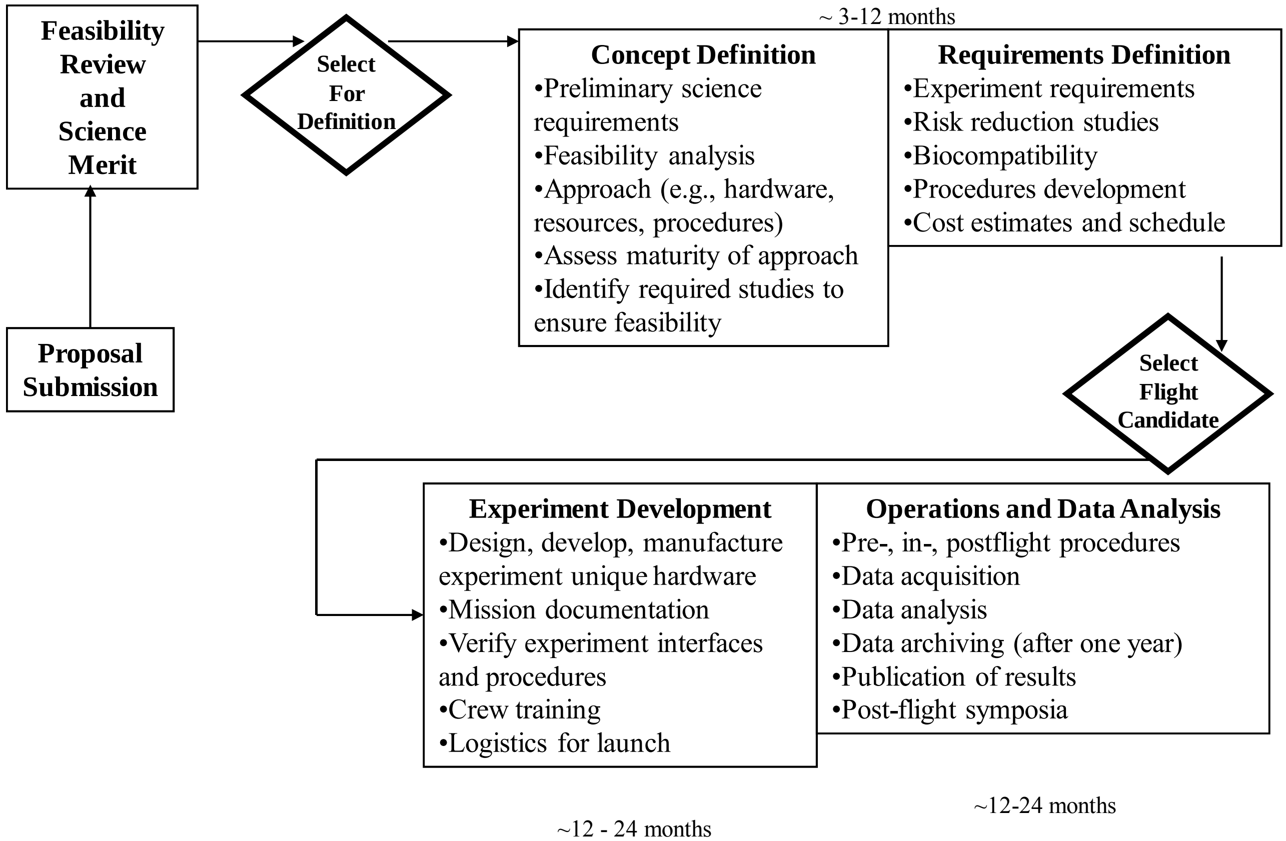
Following this coordination meeting of the ISLSWG, each agency will finalize and announce its own selections.

4.5 Flight Experiment Implementation

Applicants should be aware that flight experiment implementation is a multi-step process (Figure 2 below). Following the complete review of flight proposals, successful investigators will receive a letter informing them that their experiment has been selected for entry into a definition period. During the definition period, the agency with management responsibility for the experiment will interact with the investigator to determine specific hardware and operational requirements needed to achieve the proposed objectives. Identification of issues that will affect implementation of the space flight experiment and refinement of the funding requirements are key components of the definition period. After successful completion of the definition period, the experiment will be selected for flight and will enter a development period, leading eventually to implementation on a space mission. Detailed budgets will be refined or negotiated for each flight experiment during each period. The flight experiments selected will be reviewed every year and may be deselected based on the policy of each agency for deselection. One or more of the following conditions may warrant deselection:

1. Definition activities have indicated that the experiment is technically infeasible or so high risk that successful completion is unlikely.
2. Ground-based studies conducted as part of the definition period, or related research in the field, produce results that demonstrate the hypothesis of the flight experiment to be flawed.
3. The projected costs of the experiment, as determined during definition, are significantly greater than anticipated funding levels will support.
4. The investigator does not maintain a reasonable publication record in peer-reviewed journals in the specific research area to which the flight experiment is directed or with the results from previous flight experiments.
5. The experiment has been in the definition period for three or more years, due to either the lack of flight opportunities or the failure on the part of the investigator to complete definition activities.
6. Weaknesses identified in the scientific evaluation of the original proposal were not addressed during the definition period.
7. Funding limitations require reduction in the flight program. In such cases, the original proposal and critiques, the cost of the investigation, the ongoing publication record, and the length of time the investigator has been in definition will be considered in determining which experiments will be deselected.

Figure 2: Experiment Definition and Selection for Flight Process



5.0 International Application Forms and Instructions for Proposal Preparation

This section contains the general instructions for submission of a Notice of Intent, proposal preparation, and the specific forms required to agency solicitations for flight experiments in the Space Life Sciences for 2014. ***Applicants are referred to Agency specific Announcements for further instructions.***

5.1 Notice of Intent (non-US proposers) and Step-1 proposals (US proposers only)

5.1.a Notice of Intent for non-US applicants

A Notice of Intent (NOI, also referred to as a letter of intent) to submit a proposal is requested for all non-US applicants by **March 28, 2014**. NOIs should be submitted online either through NASA's Proposal System NSPIRES (http://nspires.nasaprs.com/), or directly to the soliciting agency (see agency-specific instructions for NOI submission). ***Applicants from Japan should submit NOI to JAXA, not NSPIRES, by March 26th, 2014.***

To register with the NSPIRES system:

1) Go to http://nspires.nasaprs.com and click on the "Registration Information" link in the Member Login Box on the right side of the page.
2) Click on the yellow "Begin Registration" button on the Registration Information page and complete the requested information to obtain an account. You are not required to affiliate with an organization for NOI submission. You will be required to affiliate with an organization for full proposal submission (see instruction 5.2 below).
3) Activate your account by responding to the instructions provided in an automatic email sent by the NSPIRES system.

NOIs will be completed and submitted by the Science Team Coordinator / Lead PI. No document uploads are required for completion of the NOI.

To create an NOI:

1. Log in to NSPIRES
2. Select the "Proposals/NOIs" link
3. Select the "Create NOI" button;
4. Select Research Solicitation "Flight Opportunities for Space Life Sciences (non-US proposers only)"
5. Follow the online instructions to complete your NOI.

Please refer to the NSPIRES tutorial at http://nspires.nasaprs.com/tutorials/index.html for on-line help. All information entered will remain private until the electronic submission is completed.

NOIs must include the following information:

1) Science Team Coordinator / Lead PI contact details and institution
2) Science Team Members' contact details and institutions (each team member must also register for an NSPIRES account in order to be added to the NOI)

3) Project Title
4) Project Summary

For non-US proposers only: The NSPIRES system will by default ask you to provide responses to business data questions pertaining to international collaboration, environmental impact, and US Civil Servant applicants. Please answer "no" to any business data question posed with a yes/no response. These questions only pertain to US investigators.

5.1.b Step-1 proposal for US applicants only

U.S. applicants must submit a Step-1 proposal by **March 28, 2014**. Step-1 proposals may be submitted through NASA's Proposal System NSPIRES (http://nspires.nasaprs.com/) or through Grants.gov.

Step-1 proposals submitted to NASA will include Cover Page elements and a Proposal PDF upload. Cover Page elements will be collected online through the Step-1 create proposal process via NSPIRES and include 1) Science Team Coordinator / Lead PI contact details and institution; 2) Science Team Members' contact details and institutions; 3) Project Title; and 4) Project Summary (100-300 words). The Proposal PDF upload will include 1) A clear description of the research product(s); 2) The type of investigation (ground-based, analog definition, or flight definition); 3) The specific aims of the proposal; and 4) An outline of the plan to accomplish the specific aims. The proposal PDF cannot exceed 5 total pages.

To create NASA Step-1 proposal:

1. Log in to NSPIRES;
2. Select the "Proposals/NOIs" link;
3. Select the "Create Proposal" button;
4. Choose Solicitation as the source;
5. Select one of two applicable research solicitations:
    a. "Research Opportunities for Flight Experiments in Space Biology," NRA NNH14ZTT002N for Space Biology emphasis area proposals
    b. "International Life Sciences Research Announcement (ILSRA)," NRA NNJ13ZSA002N-ILSRA for Human Research Program emphasis area proposal
6. You must submit separate proposals if you are submitting research in response to emphases under both the Space Biology and the Human Research Program announcements.

5.2 General Instructions for Proposal Preparation and submission via the NASA NSPIRES system

The information contained in these instructions summarizes the specific guidance provided in agency specific announcements. ***Applicants are referred to Agency specific Announcements for further instructions.***

Proposals must be submitted online through the NASA NSPIRES web site (http://nspires.nasaprs.com/) by **May 23, 2014.** ***Applicants from Japan must submit proposals to JAXA, not NSPIRES, by May 9th, 2014.***

The online submission process includes several steps, during which proposers will be asked to fill in the proposal title, acronym, abstract and science team contact details (proposers will be asked to fill in online the names and full contact details of the Science Team Coordinator / Lead PI and all Science Team Members, specifying the members' institutional affiliations). A signature version of this form will not be requested.

The information submitted will then be compiled by the system. Proposers will then be required to upload their proposal, established following participating agencies' guidelines, as a single PDF document. The compiled information and the uploaded proposal will then be automatically merged and forwarded to proposers. This document, stored in the NSPIRES database, will represent the reference document for future queries.

US proposers must register in the NSPIRES system and affiliate with their submitting US institution.

Non-US proposers must register in NSPIRES using the NSPIRES International Office as their affiliate. Below are the instructions on how to complete this.

1. Step 1: ONLY if you do not already have an NSPIRES account:
    1) To register, go to http://nspires.nasaprs.com and click on the "Registration Information" link in the Member Login Box on the right side of the page
    2) Click on the yellow "Begin Registration" button on the Registration Information page and complete the requested information to obtain an account
    3) Activate your account by responding to the instructions provided in an automatic email sent by the NSPIRES system
2. Step 2: Linking with the NSPIRES International Office organization (Affiliation**). It is your responsibility** to request this affiliation at least two weeks in advance of the proposal due date in order to guarantee an approved affiliation for proposal submission. Affiliations will be approved by the NSPIRES International Office during regular business hours: Monday through Friday from 8AM – 6PM US Eastern Time.
    1) International proposer logs into NSPIRES (http://nspires.nasaprs.com)
    2) Select the "Account Management" link on the NSPIRES Welcome page
    3) Select "Affiliations" on the Account Management page
    4) Click on the "Add Affiliations" on the Current Affiliations page
    5) Type in "NSPIRES International Office" and click "Search"
    6) Select the radio button for "NSPIRES International Office" under the search results and click the "Select" button
    7) Verify that you have selected NSPIRES International Office and click "Continue"
    8) Complete the Affiliation Address Book Data.
    9) Click "Continue"
    10) Click "OK" on the Affiliations page
    11) Return to the Affiliations page in the Account Management section of NSPIRES to confirm that your affiliation request has been approved. Affiliations will be approved by the NSPIRES International Office, Monday through Friday, 8AM-6PM Eastern Time. A status of "confirmed" allows you to link your application to the NSPIRES International Office.

To create a Proposal:

1. Log in to NSPIRES
2. Select the "Proposals/NOIs" link
3. Select the "Create Proposal" link
4. Select "NOI" as your source to carry over the information you have previously provided in an NOI
5. If you wish to begin a new proposal or did not submit an NOI via NSPIRES, select "Solicitation" as your source and then choose solicitation "Flight Opportunities for Space Life Sciences (non-US proposers only)."

Please refer to the NSPIRES tutorial at http://nspires.nasaprs.com/tutorials/index.html for on-line help. All information entered will remain private until the electronic submission is completed.

All proposals must be contained in one single and non-protected PDF document, and include the following material, in this order:

1) Project Description (see § 5.4)
2) Management Approach (see § 5.5)
3) Biographical Sketches (see § 5.6)
4) Special Matters: specific information on human subjects protocol approval required, and/or the use of vertebrate animals, if applicable (see § 5.7)
5) Appendices, if any; reviewers are not required to consider information presented in appendices (see § 5.9)
6) Space Flight Experiment Information Summary (see § 5.10)

Additional information may be requested by certain agencies. Applicants are referred to Agency specific Announcements for further instructions.

5.3 Online submission forms

Proposers will be asked to fill in online the names and full contact details of the Science Team Coordinator/Lead PI and all Science Team Members, specifying the members' institutional affiliations. Mandatory fields are specified in the forms. A signature version of this form will not be requested. Furthermore proposers must provide an abstract and proposal acronym, and specify relevant keywords and research areas. The information requested in this part of the form is essential to the review of the proposal.

For non-US proposers only: The NSPIRES system may by default ask you to provide responses to business data questions pertaining to international collaboration, environmental impact, and US Civil Servant applicants. Please answer "no" to any business data question posed with a yes/no response. These questions only pertain to US investigators.

5.4 Project Description

The length of the Project Description section of the proposal shall not exceed twenty (20) pages using regular (12 point) type. The proposal should contain sufficient detail to enable a reviewer to make informed judgments about the overall merit of the proposed research and the probability that the investigators will be able to accomplish their stated objectives. The proposal should clearly indicate the relationship between the proposed work and the research emphases defined in the agency-specific solicitations. The development of a clear hypothesis, along with the available data evidence, should be emphasized in this section. In addition, the proposal should provide evidence of completed or planned ground research to justify the flight experiment. In particular Science Team Coordinators/Lead PIs should refer to agency-specific solicitations for instructions regarding additional information that should be included in the proposal.

5.5 Management Approach

Each proposal must specify a single Science Team Coordinator/Lead PI who is responsible for carrying out the proposed project and coordinating the work of other personnel involved in the project. In proposals that designate several senior professionals as key participants in the research project, the management approach section should define the roles and responsibilities of each participant and note the proportion of each individual's time to be devoted to the proposed research activity. The proposal must clearly and unambiguously state whether these key personnel have reviewed the proposal and endorsed their participation.

5.6 Personnel/Biographical Sketches

The Science Team Coordinator/Lead PI is responsible for direct supervision of the work and must participate in the conduct of the research regardless of whether or not compensation is received under the award. A short biographical sketch of the Science Team Coordinator/Lead PI, including his or her current position title, educational background, a list of major publications, and a description of any exceptional qualifications, must be included. In chronological order (concluding with present position), list previous employment, experience, and honors. Include present membership on any government public advisory committees. List in chronological order the titles, authors, and complete references to all publications pertinent to this application. If the list of publications exceeds two pages, select the most pertinent and recent publications. Do not exceed two pages. Omit personal information that does not merit consideration in evaluation of the proposal. Complete this part of the application for other senior professional personnel who will be directly associated with the project. Provide the names and titles of any other scientists and technical personnel associated substantially with the project in an advisory capacity. Universities should list the approximate number of students or other assistants, together with information as to their level of academic attainment. Any special industry-university cooperative arrangements should be described.

5.7 Special Matters

The Special Matters section must contain appropriate statements regarding human subject provisions and/or the use of vertebrate animals. Investigators should refer to agency-specific solicitations for instructions on this section.

5.8 Letters of Collaboration/Support

Include letters of support from collaborators. Please refer to the individual agency's Space Life Sciences Research Announcement about including a Letter of Assurance of Foreign Support.

5.9 Appendices

Appendices may be included, but investigators should be aware that reviewers are not required to consider information presented in appendices.

5.10 Space Flight Experiment Requirements Summary

All applicants proposing space flight research must provide the information requested on this form. The information on this form is essential for the technical evaluation of the feasibility of the proposed study. In addition, it should be used by the investigator to determine all required components of the flight experiment, from preflight preparation and data collection to tests and data/specimen processing. Before filling out this form, applicants should read Sections 1 and 2 of this document carefully to make certain that they understand the constraints that are associated with flight experiments. This form is used primarily by a team of technical experts which does not necessarily have expertise in every area of science. Be sure to clearly and succinctly explain all experiment requirements, from trivial to grand, in terms that an intelligent non-scientist can understand. The Science Team Coordinator/Lead PI should contact the appropriate Agency Point of Contact for questions or clarification before submitting a proposal.

SPACE FLIGHT EXPERIMENT REQUIREMENTS SUMMARY

In addition to the actual proposal, this part of the proposal is required for the Flight Feasibility Review. This form has been designed for a description of all pre-flight, in-flight and post-flight components of the flight experiment. It consists of two sections:

- A section to be completed only for experiments that require human subjects, and
- A section to be completed only for experiments that require non-human specimens i.e. biology and/or exobiology experiments.

If an experiment requires both human and non-human specimens, both forms must be completed. If no specimens are required (e.g., radiation dosimetry), complete applicable hardware and procedures questions as required. If the proposal consists of distinct segments with different requirements, fill out multiple forms to fully describe all segments. **This form is mandatory for flight experiments.** Flight experiment proposals submitted without this completed form will not be evaluated.

Please read the questions carefully and keep answers brief but thorough, ensuring that all requested information has been provided. Expand tables/response space as needed.

Part I: Research Involving Crewmembers as Subjects

1. Principal Investigator: ____________________________________

2. Investigation/Activity Title: ____________________________________

3. Type of Study (check one). Also indicate the minimum number of days on-orbit required:

		On-orbit Duration Required (minimum)
☐	Long Duration: Pre/Post-flight only	
☐	Long Duration: Pre/In/Post-flight only	
☐	Long Duration: In-flight only	

4. How many subjects are required?
   a. Long Duration: _______________
   b. Ground Duration: _______________

5. Provide a pre- and post-flight testing schedule for baseline data collection (BDC). Include the name of the test/activity, dates required (L-X days preflight, R+X days post-flight, R+0 indicating landing day), and estimated crew time requirements in the table below. Crew time estimates should reflect the time required for testing of one subject. *NOTE: Training sessions should not be included unless they are considered part of the data set.*

Preflight Test/Activity	**Schedule**	**Crew Time (min)**		**Post-flight Test/Activity**	**Schedule**	**Crew Time (min)**	
		per session	**total**			**per session**	**total**
E.g., DEXA	***L-180 and L-45***	***60***	***120***	***DEXA***	***R+6 and R+180***	***60***	***120***
TOTAL PREFLIGHT BDC (per subject)				**TOTAL POSTFLIGHT BDC (per subject)**			

6. Launches and landings of long-duration crewmembers will occur in Russia (via Soyuz) until an alternate U.S. crew transportation vehicle is available. Crewmembers typically depart the US in the L-60-45 day timeframe (in addition, some crewmembers also take vacation time or visit their home country prior to going to Russia) and current plans are to nominally return USOS crewmembers to JSC within 24 hours of landing. Please address the following:

   a. If preflight BDC is required within 45-60 days of launch, please explain why it cannot be moved earlier so it can be performed at JSC prior to the crew departing for Russia, and explain what equipment, facilities, and personnel are required to conduct the test.

b. Do you have any unique facility requirements for conducing BDC and/or performing analysis of data at JSC? If so, please describe below.

7. Due to current logistical limitations, it is very difficult to gain immediate access to crewmembers returning via Soyuz on landing day. Currently all USOS crewmembers are directly returned to JSC within 24 hours of landing. There is some time available after the crew returns to JSC for minimal testing, which is still considered "R+0". If you have an R+0 requirement, please describe the nature of the testing and state whether or not this is a firm requirement; i.e., what are the science impacts of delaying the session to R+1 and, if this occurs, are the objectives of the experiment compromised.

8. The amount of time available for BDC in the first week of post-flight is extremely limited. If you have additional requirements in the R+0 to R+7 day timeframe that are not addressed in #7 above, for each session please explain any flexibilities in the schedule and provide the impact if the session cannot be scheduled by R+7 days.

9. Provide an in-flight testing schedule in the table below. Include the name of the test/activity, dates required (Flight Day (FD) X days in-flight), and estimated crew time requirements. Crew time estimates should reflect the time required for testing of one subject; however, if an operator is

required for an in-flight activity, their time should be included as well. Activities that are performed once regardless of the number of participants (e.g., set-up and stow) should be listed separately. Please assume a six-month mission in calculating the crew time estimates.

Test/Activity	**Schedule**	**Crew time (min)**	
		per session	**total**
E.g., Experiment Protocol (per subject)	*FD 30 and monthly thereafter*	*60*	*360*
TOTAL IN-FLIGHT CREW TIME (per subject)			

a. Is real-time data transmittal to the ground either required or highly desirable*? (NOTE: "Required" means that the experiment cannot be performed if downlink is not available; "highly desired" means that the experiment data will be transmitted if the downlink is available.)*

b. How critical is the timing of the in-flight sessions? Please explain any flexibility in the schedule provided in the table above. Examples of in-flight timing requirements that may be difficult to implement are: early in-flight (especially during the first 10 days and through the 3rd or 4th week), late in-flight, any activity that must be performed daily or weekly, and any activity requiring precisely timed operations.

10. Please list all of the flight hardware required for in-flight data collection along with the quantity required (indicate if item is for one subject, one increment, etc.) and the estimated total mass and volume for the given quantity (N/A for equipment already on board ISS). In the comments, provide additional explanatory information such as development status, past flight history, assumptions made when calculating quantities required, etc. If new flight hardware is required, indicate in the

comments if it is Commercial-Off-The-Shelf (COTS) or if it will be experiment unique equipment.

Hardware Item	**Qty.**	**Mass (kg)**	**Volume (m^3)**	**New, Previously Flown, or On-Orbit (specify)**	**Comments**
E.g., Urine Collection Kit	*5 kits/ 3 subj.*	*10*	*0.045*	*Previously Flown*	*Flown on ISS Increments 3-6, 8, & 11-12; five kits provide supplies for three 24 hr urine collections with three subjects*

11. If flight software is required, please answer the following:
    a. Is the software equipment-unique or commercial off-the-shelf?

    b. If it is experiment-unique, what is the status of development and who is the developer?

12. Storage of equipment and samples (for all flight experiments):

Is temperature control of equipment/supplies needed:	Yes	No	Not Known	Temperature (ºC)	Estimated Volume (cm^3 or *x* number of *y* ml vials)
-- for launch?					
-- in flight?					
-- for return?					

13. Can all of your flight hardware and supplies be stowed for launch at L-2 months?
    ☐ Yes ☐ No
    If "No", list each item that must be late-loaded along with the L-requirement (indicate if units are in hours or days):

14. Do any flight hardware or supply items expire in two years or less? ☐ Yes ☐ No
    If "Yes", list each item along with estimated shelf life (indicate if units are in days or months):

15. Return of hardware and samples are limited after Space Shuttle retirement. Does your experiment require timely return of hardware or samples? ☐ Yes ☐ No

If "Yes", explain the nature of the requirement and the impacts if it cannot be met. Also indicate if early retrieval of items is required.

Part II: Research: Biology & Exobiology

Science Team Coordinator name:____
Proposal title: ____

____

Use the table below to list the requirements for non-human specimens. *Add more rows if necessary.*

Biological sample / Specimen type (eg. species, strain, age etc)	Treatments / conditions (eg. activators, drugs, tracers, fixatives)	Required g-levels	Number of samples required for each g-level / condition

General description of experiment protocol: *Describe in general terms the types of procedures required for the experiment from preparation of the experiment in the lab until postflight handover of the sample to the investigator.*

- Parameters measured: *Describe the type of parameters measured inflight, such as realtime / recorded measurements (eg. temperature, with accuracy & time resolution, timing of experiment steps) and parameters measured in postflight analysis*
  -
  - *Inflight parameters measured;*
  -
  - *Postflight parameters measured*

- Imagery requirements: *List any requirements for photography or video observation / recording of samples*
  - Photography:
  - Video

- Requirements on telemetry / data downlink / storage: *List any potential requirements for telemetry downlink (e.g. fluorescence measurements, facility housekeeping data, downlink of photo's)*

- Requirements on commands uplink: *List any potential need for remote command of the experiment & whether this is dependant on downlink of telemetry from the experiment (eg. modification of experiment timeline based on results of video observation)*

Ground reference experiment(s): *Indicated whether a ground control reference experiment*

Pre-launch late access: Specify the maximum and preferred period in hours that can be accepted between hand-over of the experiment and transfer to either ISS stowage or activation on orbit

Early retrieval: Specify the maximum and preferred time in hours between landing & hand-over of the experiment samples that can be accepted.

Describe the method for delaying experiment activation until it is installed on the ISS (eg. dry unactivated seeds or cultures, freezing).

Describe the method for preserving samples after the experiment run for up to 365 days, or longer, on the ISS (eg. chemicals, freezing temperature, refrigeration temperature, dessication).

Hazardous materials and controlled/radioactive substances used in experiment

What is the preferred sample layout for the experiment? (Number of samples per condition) What is the minimal sample layout?

What is the estimated mass and volume of each sample?

Experiment Steps: Use the table below to list the experiment steps from prelaunch experiment hand-over until postflight retrieval, with the required environmental parameters & allowable range for each parameter. Add rows as necessary:

Experiment Step description	Duration (preferred, min & maximum) *1	Temperature (preferred, min & maximum) *2	Gravity requirements (eg. micro-g or 1.g control) *3	Humidity & gas composition requirements (eg. CO2, ethylene) *4	Light requirements *5	Data, imagery or other requirements *6

*1 - Specify duration of experiment step, including margins (i.e preferred time, minimum & maximum acceptable times if known)
*2 - Specify required temperature of experiment step, including margins (i.e. preferred temperature, minimum & maximum temperature if known)
*3 - Specify required g-levels (ie. Microgravity, 1.g reference control, intermediate g-level & any requirements on quality of g-level)
*4 – Specify any requirements for humidity control, (including preferred, maximum and minimum rh if known), gas composition, including oxygen and CO2 concentrations / pressure. Also indicate if there are any requirements concerning maximum allowable trace gas concentrations (eg. Ethylene)
*5 – Specify light requirements, flux, quality / spectrum, light dark cycles as applicable. For exobiology experiments include the solar UV wavelength ranges desired (eg. >110nm, or >200nm to simulate Martian conditions)
*6 – Specify data recording requirements, such as temperature logging , imagery requirements, eg. Photo / video, frequency of imaging, and any additional requirements not covered by the other columns in the table