National Aeronautics and Space Administration

A Researcher's Guide to:

INTERNATIONAL SPACE STATION

Human Research

This International Space Station (ISS) Researcher's Guide is published by the National Aeronautics and Space Administration (NASA) ISS Research Integration Office.

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Cover and back cover:

a. Russian Space Agency (RSA) cosmonaut Sergei Volkov assists NASA astronaut Scott Kelly in a Fluid Shifts data collection session using the NASA Ultrasound2 unit and the Russian Chibis hardware during Increment 45.

b. NASA astronaut Peggy Whitson prepares to insert biological samples in the Minus Eighty Laboratory Freezer for ISS (MELFI) for long-term storage prior to return to Earth for analysis during Increment 50.

c. ESA Astronaut Alexander Gerst is pictured after undergoing a generic blood draw during Increment 56 assisted by NASA Astronaut Serena Aunon-Chancellor in the European Laboratory/Columbus Orbital Facility.

The Lab is Open

Orbiting the Earth at almost 5 miles per second, a structure exists that is nearly the size of a football field and weighs almost a million pounds. The International Space Station (ISS) is a testament to international cooperation and significant achievements in engineering, and is critically important to NASA's future exploration missions.

Within the NASA Human Research Program (HRP), the Research Operations and Integration element (ROI) provides flight implementation services to HRP-sponsored research, most of which involves human research subjects, allowing investigators to address the human risks of spaceflight enabling the safe exploration of space. For non-HRP-sponsored studies, ROI supports the overall coordination of the flight studies into efficient science complements for each crew member and the scheduling coordination of pre- and post-flight data collection sessions.

The ISS is a truly unique research platform. The possibilities of what can be discovered by conducting research on the ISS are endless and have the potential to contribute to the greater good of life on Earth and inspire generations of researchers to come.

As we increase utilization of the ISS, now is the time for investigators to propose new research and to make discoveries unveiling novel responses that could not be defined using traditional approaches on Earth.

NASA astronauts Jack Fischer and Peggy Whitson perform a SPRINT session in the Columbus Laboratory of the International Space Station.

Table of Contents

Human Response to Living in Space

The Human Research Program (HRP) uses research findings to develop methods to lessen the effects of the space environment on the health and performance of humans working in that setting. With the goal of traveling to Mars and beyond, the Program is using ground research facilities, the International Space Station, and analog environments to develop these procedures and to further research areas that are unique to Mars.

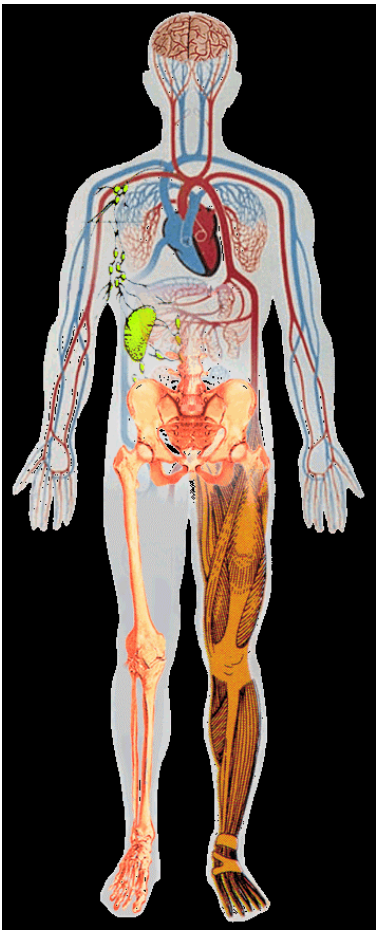

Figure 1. Human research on the ISS allows researchers to investigate the physiological and psychological effects of long duration spaceflight.

HRP-sponsored multi-disciplinary biomedical research currently under way on the ISS include studies addressing behavioral health and performance, bone, muscle, exercise and cardiovascular physiology, nutrition, microbiome, immunology and vision and brain adaptations. These life sciences research studies aim to provide a thorough understanding of the many physiologic adaptations and changes that occur in a microgravity environment. Countermeasures are developed and validated for areas where research has determined that the crew needs additional support in the spaceflight environment.

The research focuses on astronaut health and performance and the development of countermeasures that protect crew members from the space environment during long-duration voyages, evaluate new technologies to meet the needs of future exploration missions and develop and validate operations procedures for long-duration space missions.

Flight Investigations

Following the selection and assignment of a research investigation to an ISS mission, the Research Operations and Integration element (ROI) provides the end-to-end integration, coordination and operational support to meet the science requirements and objectives of the study.

To assist researchers from a variety of disciplines, HRP began the Spaceflight Standard Measures Project during Increment 58. This project collects a set of core measurements, representative of many of the human spaceflight risks, from astronauts before, during, and after ISS missions. The project's main aim is to ensure that an optimized, minimal set of measures are captured consistently from participating ISS crewmembers until the end of the ISS in order to characterize the human in space. These Standard Measures serve as a data repository and are available to other studies under data sharing agreements. The data undergo analysis for trends in the astronaut population.

Data collected under the Standard Measures project includes analysis of blood, urine, and saliva, questionnaires, and core measurements from the physiological and psychological domains deemed critical to human spaceflight. This data is intended to provide the following benefits:

- Enable high level monitoring of countermeasure effectiveness
- Enable meaningful interpretation of health and performance outcomes
- Inform and support future hypothesis-driven planetary-mission-enabling research

HRP also leads a multinational complement of integrated protocols for human exploration research designed to investigate the effect of flight duration on the human system. This study is composed of multi-disciplinary science measures that can be integrated into **a single research complement**, and all measures are collected for each participating crew member on missions of varying duration (short, standard, and extended).

Whereas abundant data exists for 6-month durations in space, minimal data exists for durations beyond one year. Additionally, scientific and anecdotal evidence show differences in the effects of spaceflight between crewmembers on 6-month and 12-month missions. It is not known whether 6-month flights are sufficient to indicate that people can be sent on exploration-class missions with a reasonable expectation of maintaining health, safety, and performance.

With this multi-disciplinary experiment, HRP seeks to bridge the gap in knowledge and answer questions about the physiological and psychological adaptations of long-duration spaceflight.

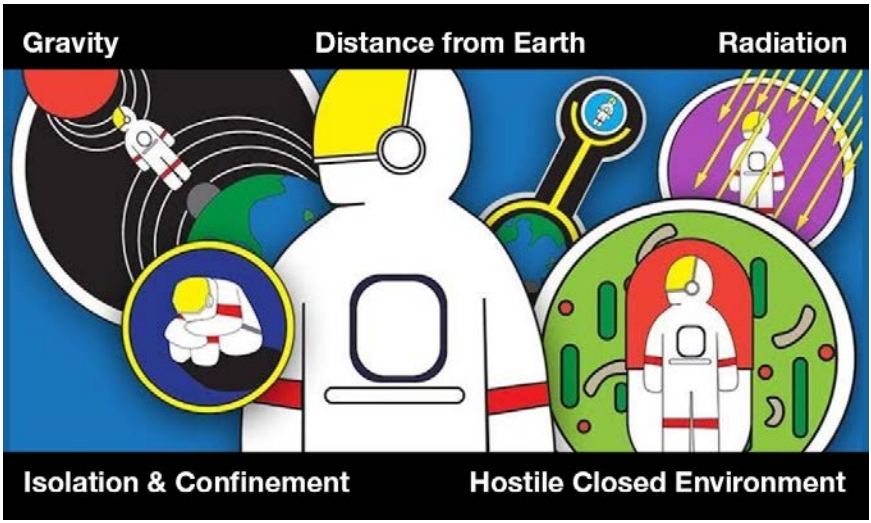

Figure 2. The five categories of human exploration risks relate to the stresses they place on the human body.

The integrated protocol addresses the five hazards of human spaceflight (radiation, isolation, distance from Earth, altered gravity, and hostile/closed environments) by conducting the same research over different mission durations, allowing scientists to extrapolate to multi-year missions. The knowledge gained from this research is used to develop protective countermeasures and safeguard crewmembers for exploration-class missions.

Research Operations and Integration Element Overview

The International Space Station (ISS) provides an exclusive opportunity for advancing research into the effects of the unique spaceflight environment on humans and the development of space resources. Research Operations and Integration (ROI) provides planning, integration, and implementation services for the National Aeronautics and Space Administration (NASA) Human Research Program (HRP).

Figure 3. Fly-around view of the International Space Station taken from STS-132 Space Shuttle Atlantis after separation.

The goals and objectives of ROI are to:

- Maximize the utilization of the ISS to assess the effects of long-duration spaceflight on human systems and to develop and verify strategies to ensure optimal crew performance.
- Enable development and validation of a suite of integrated physical, pharmacologic and/or nutritional countermeasures against the damaging effects of spaceflight that may affect mission success or crew health.
- Support pre-flight, in-flight, and post-flight activities.
- Offer end-to-end, flight-experiment definition, development, documentation, integration, procedure development and validation, and hardware development and certification services.

ROI supports research investigators by defining science protocols as a set of implementable functional requirements, designing operational scenarios and developing as well as certifying hardware and software. Services provided by ROI include developing and validating in-flight crew procedures, providing ISS crew member and ground controller training, monitoring real-time, in-orbit experiment and hardware operations, and facilitating data transfer to the principal investigators (PIs). ROI maintains an expert team of professionals with the knowledge and experience to guide science protocols through the flight-development process.

ROI coordinates with the ISS International Partners (IPs) to develop integrated mission-specific science complements for human research investigations and to negotiate inter-agency schedules, usage agreements and international crew member subject participation. Support is provided for the human Institutional Review Board (IRB) approval process and scheduling the Informed Consent

Figure 4. Expedition 56 Flight Engineer Serena Auñón-Chancellor performing a saliva sample collection session in the Columbus Module.

Briefings (ICBs) for potential crew member participation in flight studies. ROI offers investigator logistics support during all phases of the mission and maintains a facility at NASA's Johnson Space Center (JSC) for pre-flight and post-flight collection of medical and scientific data for flight studies.

ROI hardware and software teams provide design, fabrication and testing services for both ground and flight hardware and software systems. The application of unique knowledge of safety controls in human systems enables the reduction of risk in all flight-operational activities. Streamlined operational scenarios and optimized crew procedures for research and facility protocols are used to maximize science return within available resources, including end-to-end testing from experiment systems to data display and transmission in order to verify science data flow. The team provides complete integration support from initial hardware testing to hardware delivery for multiple flight vehicles to the ISS including the Russian Soyuz and Progress vehicles, Japanese H-II Transfer Vehicle (HTV) and commercial launch vehicles.

ROI provides services that result in the successful completion of a wide variety of multidisciplinary, human physiology research studies enabling the safe exploration of space and allowing for the future of exploration class missions.

Preparing for Exploration Class Missions

Figure 5. View of the moon over the Earth horizon taken by the Expedition 23 crew aboard the International Space Station.

NASA's history has proven that humans are able to live safely and work in space. The ISS serves as a platform to extend and sustain human activities in preparation for long-duration, exploration-class missions. NASA uses the ISS for scientific, technological and educational purposes supporting future objectives in human space exploration. These objectives include protecting crews from the space environment, ensuring crew health through countermeasure development, testing research and technology developments, and developing and validating operational procedures for long-duration missions. The ISS is an orbiting research laboratory providing opportunities to address critical medical questions about astronaut health through multidisciplinary research operations to advance our understanding and capabilities for space exploration.

Flight Investigation Activities

Pre-flight Operations

Once assigned to a mission, research investigations proceed through a number of milestones. ROI partners with the investigators to ensure the following: science requirements are met; human institutional review approvals are obtained; crew training is scheduled; flight procedures are developed; and pre-flight baseline data collection (BDC) sessions are completed. Pre-flight data are collected for comparison with subsequent research findings to determine how spaceflight has affected a particular measurement and what effect the return to a 1-g environment may have. ROI also leads the Informed Consent Briefings (ICBs), enabling the participation of ISS crew members in each investigation and coordinates the integration of NASA and International Partner (IP) life sciences research experiments.

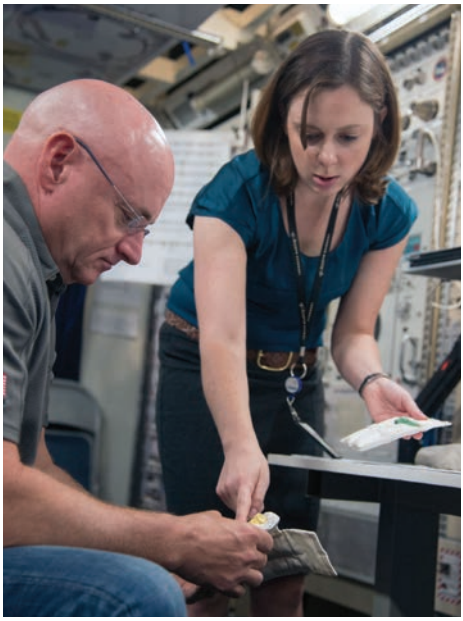

Figure 6. NASA astronaut Scott Kelly participates in a training session in an International Space Station mock-up/trainer in the Space Vehicle Mock-up Facility at NASA's Johnson Space Center (JSC). Photo credit: NASA

The availability of ISS crew members prior to launch for training and BDC is extremely limited because of a heavy training schedule requiring a great deal of international travel to Russia, Europe, and Japan. All U.S. training and BDC (including vehicle and ISS system training as well as all NASA payloads) must be scheduled during the periods of time pre-flight when crew members are at JSC. Some United States Operation Segment (USOS) Crew members launch on Soyuz and depart for Russia approximately two months before launch (L-60 days). While it is possible to perform some simple testing in Russia between L-60 and L-30 (i.e., minimal sampling, simple ambulatory monitoring, questionnaires), such testing is difficult to schedule and will require strong justification for implementation. Also, there are no unique NASA facilities available for performing BDC in Russia; the only resources currently available are a freezer and centrifuge. In the L-60 to L-15

day timeframe, crew members' schedules are very busy with required simulations, vehicle tests, and commissioning activities as well as time with their families, so scheduling research testing of any kind is usually not possible.

The crew travels to the launch site at around L-15 days where there are no BDC facilities available for investigator use. The only feasible activities during this time are those that require passive monitoring (i.e., Actigraphy) or simple computer or pen/paper entries. No freezers or other equipment are available at the launch site. Retrieval of data and equipment must be arranged with crew surgeons (no investigator travel to launch site).

With the majority of future USOS crewmembers launching on commercial crew vehicles, there may be a little more time pre-flight before the crew travel to the Kennedy Space Center (KSC) only a few weeks prior to launch. However, there are also no BDC facilities planned at KSC. Therefore, the only feasible activities during the immediate pre-flight and post-flight timeframe will be limited to simple passive measures or very limited field testing at the landing dock.

Since crew time is constrained during their time at JSC, ROI optimizes the number, length and timing of BDC sessions to maximize research opportunities. Training sessions are limited to skills-based sessions as opposed to lecture-style overview sessions. The ROI team works with HRP investigators to develop an appropriate training plan for each investigation selected for flight.

Figure 7. NASA astronaut Jack Fischer performs a NeuroMapping session on ISS during Increment 51.

In-flight Operations

The Soyuz and the Commercial Crew launch vehicles are space constrained, and it is not feasible to perform in-flight operations before docking with the ISS. After docking with ISS, crew members are busy with handover activities, and crew time for scientific activities is limited for the first two weeks. Crew time is also limited during periods when other vehicles dock or undock because of required preparation activities and around extra vehicular activities (EVAs). Weekends are

protected as time off for crew members, and science is only performed if it is a crew preference.

In-flight crew time constraints require investigators to build flexibility into their scheduling requirements. In addition to the constraints mentioned above, many investigations often have similar in-flight timing requirements, and they cannot all be scheduled during the same week. The ROI team works closely with investigators to document the reasoning for specific timing requirements and define the flexibility (plus or minus number of days) for implementation.

Experiment implementation is more difficult to achieve under the following conditions:

- 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).
- 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 two to three hours, requires extensive privatized resources).
- A single session with one crew member requiring four or more hours in one day.
- Crew activity that must be performed daily or more than once a week.
- Very precise/inflexible timing requirements for sessions (e.g., plus or minus window for testing of less than one week, multiple, timed blood draws, sessions that are linked to other crew activities like meals, EVAs, etc.). Note that occasional fasting data collections upon crew wake up are not difficult to implement.
- Extended, continuous activities over multiple days that could interfere with other operations.

Post-flight Operations

The post-flight priority is to rehabilitate the crew from the flight and return them to safe terrestrial function. Crew members are returned from the ISS via both the Soyuz spacecraft after landing in Kazakhstan and on Commercial Crew vehicles in the USA. In either case, USOS crew members (includes participants from IP agencies of Europe, Canada, and Japan) are returned directly to JSC within approximately 24 hours after landing via a NASA plane. Crew members may have significant circadian disruption. Limited testing is possible during their return flight

Figure 8. NASA Astronaut Jessica Meir smiles for the camera after landing on the Soyuz MS-15 spacecraft in Kazakhstan on April 17, 2020.

to JSC (i.e., Actigraphy, urine and saliva sampling). There is some opportunity for limited passive testing upon immediate crew return to JSC (blood draws, ultrasound scans), but extensive or lengthy testing is not possible. The time from crew landing to crew sleep after return to JSC is considered landing day or "R+0." The start of R+1 begins after crew wake up the day after their return to JSC.

The total amount of time available for science BDC in the first week post-flight (R+0 - R+7) is only 11.5 hours, and this scarce resource must be shared with multiple investigations. Therefore, BDC during this timeframe is prioritized based on study requirements. In addition, scheduling flexibilities for each investigation are used to optimize the post-flight schedule.

ROI integrates all of the implementation constraints for pre-, in-, and post-flight sessions early in the complement development process in order to allow maximize the number of experiments performed simultaneously.

Spaceflight Research

Flight Support Capabilities

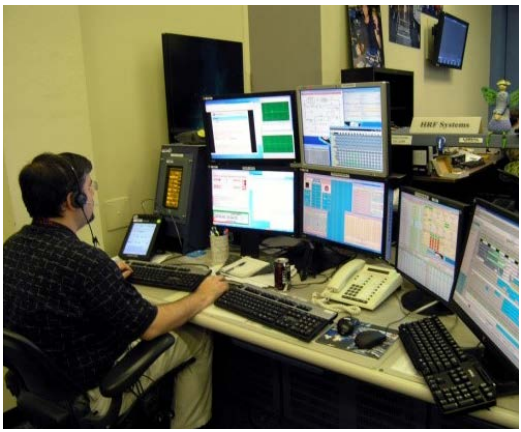

Figure 9. Real-time science monitoring services are provided through the Telescience Support Center.

ROI services include the management, maintenance, operations, and use of the Telescience Support Center (TSC) located at JSC, providing a focal point for real-time ROI operations and a distribution point for remote investigators to monitor their experiments and acquire telemetry data for HRP sponsored experiments. The TSC interfaces with the Payload Operations Integration Center (POIC) at NASA's Marshall Space Flight Center (MSFC). The TSC provides investigators and ground teams with ISS Space-to-Ground audio capabilities allowing the relaying of commands and software uplinks to the ROI facility systems. This facility serves as a gateway to distribute ISS digital data and video over virtual private networks to support the ROI science and engineering communities. Real-time system and experiment data displays are available over a secure network between the ISS and remote investigator data facilities.

On-Orbit Research Hardware

ROI provides the Human Research Facility (HRF), which is comprised of a suite of hardware that provides core capabilities to enable research on human subjects. These research tools are available to HRP-sponsored investigators who wish to conduct human physiological research on the ISS. Most flight hardware must be specially built or modified to suit the space environment. ROI provides flight hardware development processes designed to meet rigorous requirements for safety, mass, operation, human factors, electrical power usage, computer interfaces, and thermal properties. All flight hardware must be tested to verify that it can withstand the mechanical and acoustic vibrations encountered during launch, the acceleration forces during ascent into orbit, and the microgravity conditions in orbit.

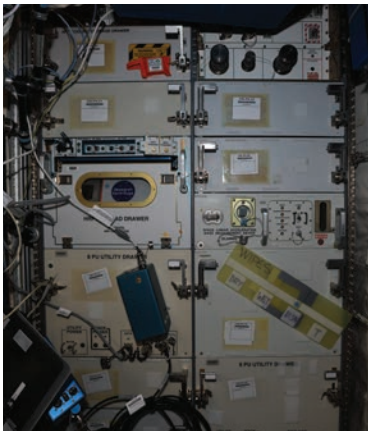

Figure 10. Human Research Facility 1 (HRF1) on ISS in the Columbus Module.

The HRF consists of items mounted on two racks located in the Columbus module, as well as separate portable equipment kept in stowage locations and brought out as needed. The HRF enables human life science researchers to study and evaluate the physiological, behavioral, and biochemical changes induced by long-duration spaceflight. The two HRP racks contain a clinical ultrasound, 2 centrifuges (one for rodent and one for human samples), Radio Frequency Identification (RFID) drawer, HRF consumable supplies and the Space Linear Acceleration Mass Measurement Device (SLAMMD) for measuring in-orbit crew member mass. The HRF Racks are regularly used for data collection and downlink of experiment data.

Supplies for collection of human biological samples, including blood, urine and saliva are available for investigators who require them. Standardization of this type of hardware reduces costs and provides a familiar interface for crew members regardless of which investigation(s) they may be performing.

More information on the HRF hardware is available at:

https://www.nasa.gov/hrp/elements/roi/facilities/rack

https://www.nasa.gov/hrp/elements/roi/facilities/portable

Investigators should not assume that hardware previously flown but not listed on this website is available for their use. Potential investigators should check with the appropriate facility managers for current hardware functionality and availability.

International partner agencies have also launched several hardware facilities designed for use in human life sciences experiments. Information about these facilities can be found at: https://www.nasa.gov/mission_pages/station/research/experiments/explorer/search.html?#q=&i=&p=&c=&g=Facility&s=. Filter on Category: Human Research and then by Partner. Investigators should be aware that while these facilities will be aboard the ISS, use of them by NASA investigators must be negotiated.

Hardware is available aboard the ISS for investigations that require conditioned storage of samples. Information about these facilities can be found at: https://www.nasa.gov/mission_pages/station/research/experiments/explorer/search.html?#q=&i=&p=&c=&g=Facility&s=. Search on "Refrigerator or Freezer."

Information on all ISS facilities can be found at: https://www.nasa.gov/mission_pages/station/research/experiments/explorer/search.html?#q=&i=&p=&c=&g=Facility.

Executing flight experiments necessitates different constraints than are usually found in ground-based research. All hardware is launched to ISS using an International Partner resupply vehicle or a U.S. commercial vehicle. Return of hardware and samples from the ISS is only possible using U.S. commercial vehicles, with a very limited capability on the Soyuz.

Experiment-Unique Equipment

Some investigators may need to develop their own experiment hardware to work in conjunction with the facilities and functional capabilities of existing hardware. Development of Experiment-Unique Equipment (EUE) can be costly and extend the preparation time for an experiment to design, build, and test the hardware to meet spaceflight requirements. Commercially-available hardware is often more feasible to prepare for flight than custom-made hardware, but it still requires additional resources and certification in order to meet the requirements levied on all hardware flying to the ISS. It should not be assumed that any device can fly "as is" off the shelf.

Figure 11. HRP Fecal Sample Collection Kit.

ROI assesses experiment-required hardware during the definition phase of the study as part of the overall feasibility assessment. The following questions are used during the ROI hardware assessment:

- Is new flight hardware required? The level of difficulty of development depends on how much design and development is required for custom-made equipment and how much any off-the-shelf equipment must be modified. Resources such as up-mass and volume could constrain launch opportunities.

- Does the hardware need to be returned to the ground for refurbishment or data retrieval? Down mass resources are protected for critical science samples; data should be planned to be downlinked, and hardware no longer being used will likely be discarded.
- Is conditioned stowage required in orbit or for return? The ISS has freezers and refrigerators aboard the ISS, but conditioned down-mass volume is limited.

Data and Sample Sharing

Some experiments plan to collect identical or similar data as standard medical tests or other concurrently scheduled investigations. Duplication may be avoided via data sharing. A Data Sharing Plan (DSP) is implemented for each mission to minimize crew time and inconvenience. The plan also allows individual investigators to enhance their studies through interpretation of their data within the context of the many physiologic adjustments provoked by spaceflight. The correlation and comparison of all experiment results will, in turn, produce a more coherent and comprehensive understanding of human physiologic adaptation to spaceflight.

In addition, data produced from NASA-funded life sciences research must be archived in the Life Sciences Data Archive (LSDA) for the benefit of the greater research and operational spaceflight community. Archival data products may include but are not limited to low-level (raw) data, high-level (processed) data, and data products such as calibration data, documentation, related software, and other tools or parameters that are necessary to interpret the data. To protect the right of first publication, funded investigator(s) are generally allowed a period of one year after final data collection before making the data available to other investigators through release from the LSDA. This archive, as well as other NASA data repositories, allows investigators to implement research by enabling analysis of existing astronaut experiment, medical, and/or performance data.

ROI works with the investigative teams to determine if sample sharing may be available, depending on the type and quantity of sample requested. Similar to the DSPs, sample sharing minimizes valuable crew time and inconvenience and decreases up and down mass.

Research Involving Human Subjects

Prior to 2020, the maximum number of crew members aboard the ISS at any given time was six; this nominally included three Russian and three USOS crew members. With the success of commercial crew, the maximum number of crewmembers on ISS will increase by one USOS crewmember to seven. On-orbit durations are typically about six months, and the crew rotations are staggered, so there may be periods when only three crew members are living on ISS. Currently, NASA-sponsored investigations may only seek participation from USOS crew members; therefore, the maximum number of subjects available per year for any one experiment is eight. For planning purposes, four to six subjects per year should be assumed for any experiment since other constraints and crew consent may limit participation.

All flight investigations involving USOS crew members must receive approval by the NASA/JSC Institutional Review Board (IRB) and the Human Research Multilateral Review Board (HRMRB). Approval by the ESA Medical Board (MB) and Japanese Aerospace Exploration Agency (JAXA) IRB are also needed if participation of crew members representing those agencies will be recruited. Crew members are given an informed consent briefing (ICB) that describes each human research study proposed for their mission at approximately one year before launch. A large number of human life sciences investigations are typically being performed concurrently such that it is not possible for one crew member to participate in all of them, even if that crew member is willing. This constraint is due to resource limitations described in this document as well as science conflicts between investigations. Based on crew members' interests and program priorities, a specific complement of research is developed that can be performed within the flight resource constraints.

With a small subject pool and a large number of investigations requiring human subjects, the number of subjects required to complete an investigation becomes an important aspect of technical feasibility for all flight proposals. In addition to taking a long time to complete, studies that require large subject numbers limit the throughput for overall human spaceflight research. An investigation that has multiple constraints that effectively reduces the number of other investigations in which a subject can participate will be more difficult to implement. It is important to note that one crew member can participate in up to 20 human life sciences investigations, depending on complexity, across all USOS partners.

Pathway to Flight Investigations

A proposal can be submitted for consideration to the Human Research Program in many different ways including, among others, in response to a NASA Research Announcement (NRA), NASA Space Act Agreement (SAA), NASA HRP-Directed Task, and through an International Announcement of Opportunity (AO). ISS investigators may receive funding from NASA and many other sources. These sources determine the sponsorship for access to the orbiting laboratory. Studies that involve only pre-flight and post-flight testing of crew members before launch and upon return from their spaceflight may also be performed. Additional information for prospective investigators can be found at: https://www.nasa.gov/mission_pages/station/research/research_information.html.

Following submittal to HRP, a research proposal undergoes a peer-review process to evaluate the relevance of the study to NASA's goals and objectives and the scientific merit of the proposed investigation. The outcome of this review may lead to a refinement of the study followed by selection as a flight investigation. After selection of a research proposal is made by the sponsoring organization, the process formally begins to define the overall research requirements, objectives, and probable costs. Critical to conducting a successful study is obtaining agreement on a set of realistic mission objectives, including establishing the technical, functional, and performance requirements to satisfy the objectives.

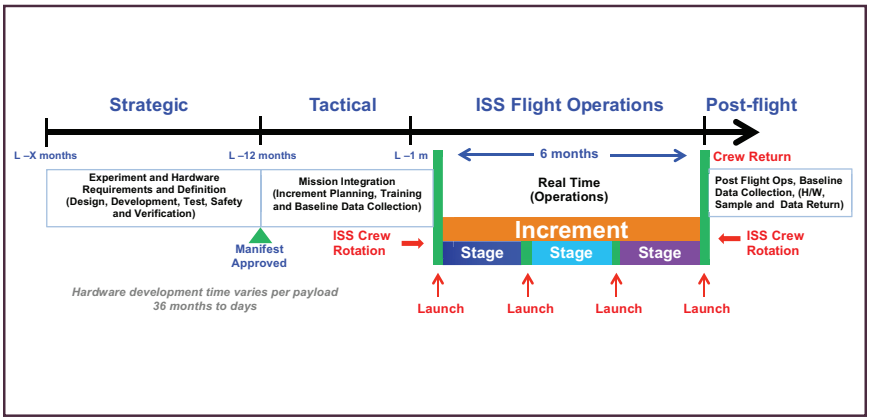

Figure 12. Example pathway following select-for-flight for a research investigation.

After the peer review, ROI will conduct a feasibility assessment of the investigation focusing on the functional requirements, including the use of any experiment-unique hardware and development time and the requested number of subjects. Ground-based requirements for conducting the pre-flight and post-flight operations necessary for performing the flight experiment must also be defined. Included in the feasibility assessment is a determination of the complexity of the experiment, the crew time requirements, and the testing schedule.

The ROI team plays a critical role in conducting HRP human life sciences investigations on the ISS and provides an experienced team to each investigation to assist each investigator in defining their experiment hardware, software, and operational requirements.

Funding Opportunities

What Should Principal Investigators Know About Conducting Research on ISS?

Supporting research in science and technology is an important part of NASA's overall mission. NASA solicits research through the release of NASA Research Announcements (NRAs), which cover a wide range of scientific disciplines. All NRA solicitations are facilitated through the Web-based NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES), http://nspires.nasaprs.com/external/. Registering with NSPIRES allows investigators to stay informed of newly-released NRAs and enables submission of proposals. NSPIRES supports the entire lifecycle of NASA research solicitations and awards, from the release of new research calls through the peer review and selection process.

In planning the scope of their proposals, investigators should be aware of available resources and the general direction guiding NASA research selection. The Human Research Roadmap (https://humanresearchroadmap.nasa.gov/) identifies the approach and research activities planned to address the highest risks to human health and performance in spaceflight. In addition, principal investigators should be aware that spaceflight experiments may be limited by a combination of power, crew time, or volume constraints. Launch and/or landing scrubs are not uncommon, and alternative implementation scenarios should be considered in order to reduce the risk from these scrubs. Preliminary investigations using ground-based simulators may be necessary to optimize procedures before spaceflight.

To understand previous spaceflight studies, prospective PIs should become familiar with the Space Station Research Explorer (SSRE) database on nasa.gov, found at www.nasa.gov/stationexperiments. This searchable system describes research previously conducted on the ISS, including that of the International Partners. In addition, a detailed catalog of previous, current, and proposed experiments, facilities, and results, including investigator information, research summaries, operations, hardware information, and related publications, is available through the NASA Research and Technology website's pages at https://www.nasa.gov/iss-science.

Additionally, details pertaining to research previously supported by the Biological and Physical Sciences (BPS) Division of NASA's Human Exploration and Operations Mission Directorate can be located in the Space Life & Physical Sciences Research and Applications Division Task Book in a searchable online database format at: https://taskbook.nasaprs.com/Publication/welcome.cfm.

NASA generally uses Broad Agency Announcements (BAA) to solicit proposals for research and technology investigations. Such BAAs may take the form of Announcements of Opportunity (AO), NRAs or, less frequently, Cooperative Agreement Notices (CAN). In addition, for specific, well-defined research end points or tests, NASA may elect to use Requests for Proposals.

NASA solicits this research through the release of various research announcements in a wide range of science and technology disciplines. NASA uses a peer review process to evaluate and select research proposals submitted in response to these research announcements.

The AO is used to solicit and competitively select research investigations characterized as having a well-defined purpose and end product; for example, science investigations with hardware responsibility for a unique spaceflight mission, a program of flight missions or unique but large-cost, non-flight programs.

The NRA solicits research characterized as being a part of the HRP's ongoing approved research program under the budgetary discretion of the HRP program manager. HRP's standard times for issuing NRAs are July, November, and March. Flagship solicitations contain specific research emphases that proposers must address in order to be considered responsive to the solicitation. Example Flagship topics include Evaluation of the Neurobehavioral Effects of a Dynamic Lighting System on the ISS and Effects of Spaceflight Durations up to One Year in Low Earth Orbit on Cardiovascular Structure and Function in Astronauts. In addition to Flagship solicitations, HRP issues Omnibus solicitations that request investigations lasting no more than one year that provide innovative approaches to any of the risks and gaps contained in the Integrated Research Plan of the Human Research Program.

The CAN is used to solicit and competitively select proposals to support NASA program interests that require a high degree of cooperation between NASA and the selected institution. The scope of activities solicited by a CAN may be as modest as those for an NRA or as complex as those through an AO. The cooperative agreements awarded as a result of a CAN are similar to grants except that both NASA and the selected institution are required to provide resources, and both are involved in decisions related to the activities carried out by the selected institution.

NASA issues annual program solicitations that set forth a substantial number of research topics in areas consistent with stated agency needs or missions. Both the list of topics and the description of the topics and subtopics are sufficiently comprehensive to provide a wide range of opportunity for Small Business Concerns

to participate in NASA research programs. Topics and subtopics emphasize the need for proposals with advanced concepts to meet specific agency needs.

Congress established the Small Business Innovation Research (SBIR) Program in 1982 to provide increased opportunities for small businesses to participate in research and development, to increase employment, and to improve U.S. competitiveness. The program's specific objectives are to stimulate U.S. technologic innovation, use small businesses to meet federal research and development needs, increase private-sector commercialization of innovations, and foster and encourage participation by socially disadvantaged businesses. Legislation enacted in 2000 extended and strengthened the SBIR program and increased its emphasis on pursuing commercial applications of SBIR project results.

The Small Business Technology Transfer (STTR) Program awards contracts to small business concerns for cooperative research and development with a non-profit research institution such as a university. Congress's goal in establishing the STTR program is to facilitate the transfer of technology developed through the entrepreneurship of a small business and is modeled after the SBIR Program with the same basic requirements and phased funding structure. STTR is nevertheless separate from the SBIR Program and is funded separately. It differs from SBIR in several important aspects including existing as a smaller program. The small company must take the research and intellectual property of the research institution and convert it into a useful product. Additional information and a current list of solicitations are available at: http://sbir.gsfc.nasa.gov.

Points of Contact

ROI provides planning, integration, and implementation services for HRP, enabling the research communities as well as NASA's International Partners requiring access to space. For more information regarding ROI, please visit: https://www.nasa.gov/hrp/elements/roi.

Future Directions

The ISS is a test bed to continue validation of countermeasures, assess autonomous operations, and evaluate new technologies to acquire the knowledge, skills and capabilities to venture beyond low-Earth orbit. With a growing portfolio of laboratory facilities and capabilities onboard, scientific research is a top priority for ISS utilization. ROI is uniquely positioned to support life science investigations to produce a biomedical research portfolio to mitigate space human health risks and to extend and sustain human activities for future human space exploration.

Figure 13. The ISS is the only facility allowing researchers to evaluate the capabilities needed in preparation for missions to the moon and Mars. ((Image Credit: NASA)

Acronyms

AO	Announcements of Opportunity
BAA	Broad Agency Announcements
BDC	Baseline data collection
CAN	Cooperative Agreement Notices
DSP	Data Sharing Plan
ESA	European Space Agency
EUE	Experiment Unique Equipment
EVA	Extra vehicular activities
HTV	H-II Transfer Vehicle
HRF	Human Research Facility
HRF 1	HRF Rack 1
HRF 2	HRF Rack 2
HRMRB	Human Research Multilateral Review Board
HRP	Human Research Program
ICB	Informed Consent Briefing
IP	International Partner
IRB	Institutional Review Board
ISS	International Space Station
JAXA	Japanese Exploration Agency
JSC	NASA's Johnson Space Center
KSC	Kennedy Space Center
L-	Launch Minus (days before launch)
LSDA	Life Sciences Data Archive
MB	Medical Board
MELFI	Minus Eighty Laboratory Freezer for ISS
MSFC	Marshall Spaceflight Center
NASA	National Aeronautics and Space Administration
NRA	NASA Research Announcement
NRC	National Research Council
NSPIRES	NASA Solicitation and Proposal Integrated Review and Evaluation System
PI	Principal Investigator
POIC	Payload Operations & Integration Center
R+	Return Plus (days after landing)

RFID	Radio Frequency Identification
ROI	Research Operations & Integration
RSA	Russian Space Agency
SAA	Space Act Agreement
SBIR	Small Business Innovation Research
SLAMMD	Space Linear Acceleration Mass Measurement Device
STTR	Small Business Technology Transfer
TSC	Telescience Support Center
US	United States
USOS	United States Operation Segment

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For more information...

Space Station Science
http://www.nasa.gov/iss-science

Station Research Facilities/Capabilities
http://go.nasa.gov/researchexplorer

Station Research Opportunities
http://www.nasa.gov/stationopportunities

Station Research Experiments/Results
http://go.nasa.gov/researchexplorer

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