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International Space Station Alpha

Microgravity Environment

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International Space Station Alpha Microgravity Environment

Abstract

One of the main purposes of International Space Station Alpha (ISSA) is to provide a premier microgravity environment for science, technology, and research. To accomplish this, the design requirements for ISSA address the two different categories of quasi-steady-state accelerations and vibratory accelerations, specifying not-to-exceed microgravity levels for frequencies ranging from 0.01 to 300 Hertz (Hz). The basic requirements have remained unchanged since Space Station Freedom days. However, the capability to meet the requirements in the 0.1 to 300 Hz range has long been an issue because many station components, including the crew members themselves, cause high frequency disturbances that exceed allowable microgravity levels.

To meet the design requirements, a new multiprong approach has been developed for the ISSA that includes minimizing disturbances at the source when feasible, a new Active Rack Isolation System, and risk mitigation plans for all identified risk areas. When possible, microgravity disturbers (e.g., pumps, rotating joints) are being attenuated so that the rest of the station does not feel their effects. However, this solution is impractical in many cases (for example, it’s not easy to isolate the crew from the rest of the station!), so the Active Rack Isolation System that is being developed will isolate the payload from the disturbers rather than the other way around. The system will be flown as a flight experiment in 1996. This new development, along with the innovative team process that has been put in place, provides an efficient and cost-effective approach to ensure that the ISSA is a world-class microgravity facility.

Introduction

International Space Station Alpha (ISSA) is committed to providing a premier microgravity environment in space. The microgravity environment is critical for scientists and researchers because it allows them to study fundamental physical, chemical, and biological processes without the masking influence of Earth’s gravity. Microgravity experiments on board the ISSA will cover a diverse range of disciplines: protein crystal growth, cell tissue culture, multiphase heat and flow transfer, and electronic material science research.

To ensure that the science and research goals are achieved, ISSA has very specific requirements that limit any disturbances to the microgravity environment. In fact, the basic requirements have been in place since early in the days of Space Station Freedom and have remained unchanged. However, implementing these design requirements has proven to be a challenge, particularly in the higher frequency range, because many station components (such as pumps and rotary joints) cause vibroacoustic disturbances that exceed the microgravity requirements. The crew itself is a significant disturber of the microgravity environment by the simple acts of closing drawers or pushing away from walls.

To meet ISSA design requirements, an innovative multiprong approach has been developed that addresses all of the requirements and provides an efficient and cost-effective method of design implementation.

ISSA Process

A microgravity analysis integration team (AIIT) was formed when the ISSA program was still in its initial stages. This team is responsible for making sure that the appropriate microgravity requirements are in place in ISSA specifications, that the requirements are adequately implemented
by each subcontractor, and that technically viable implementation plans are in place for all of the
requirements. The AIT is made up of personnel from the NASA program office, the prime
contractor, and each of the major subcontractors as well as representatives of the experimenters.
The team began by ensuring that the correct requirements were in place. Once this was
accomplished, the AIT has concentrated on identifying a design implementation that will efficiently
meet the requirements and on putting in place appropriate control plans to ensure that all
subcontractors have realistic design implementation plans and can meet the requirements.

Microgravity Requirements

The microgravity requirements for ISSA are to ensure that experimenters have extended periods of
time during which the microgravity environment is undisturbed. However, it is not possible to
provide the specified microgravity environment continuously, because events such as station
reboost and Shuttle or Progress dockings (mandatory for station survival) significantly disturb the
microgravity environment. Therefore, the first microgravity requirement—for duration—states that
the microgravity environment must be provided “for at least 180 days per year in continuous time
intervals of at least 30 days.” In addition, all microgravity requirements must be met in at least
50% of the international standard payload rack (ISPR) locations. (ISPRs are the payload
accommodations within the U.S., European, and Japanese laboratories.) Note that there is not a
specific requirement that applies within the Russian laboratories of the ISSA. The Russians do not
currently have any microgravity experiments planned.

The microgravity environment itself is divided into two different categories. The first is called
quasi-steady-state accelerations and covers the microgravity effects due to atmospheric drag, offset
center of gravity and center of pressure, gravity gradient, and angular acceleration and velocity.
This category addresses disturbances at a frequency at or below 0.01 Hz. The two specific
requirements for quasi-steady-state accelerations are that the perpendicular component to the orbital
average quasi-steady-state acceleration vector cannot exceed 0.2 m/s and the microgravity
accelerations must not exceed 1 µg.

The first requirement depends predominantly on orbital altitude, and the entire station meets this
requirement. Fifty-five percent of the station ISPRs meet the second requirement, which is
configuration dependent (remember that 50% is the requirement.). Figures 1a and 1b show which
portions of ISSA are within the 1 µg limit.
TOTAL OF 18 OF 33 ISPRs (55%) LESS THAN 1 μG MAG AND 0.2 μG STAB AT AC

Figure 1a. ISSA assembly complete microgravity contours (front view, velocity vector out of page).

TOTAL OF 18 OF 33 ISPRs (55%) LESS THAN 1 μG MAG AND 0.2 μG STAB AT AC

Figure 1b. ISSA assembly complete microgravity contours (side view, velocity vector toward left of page).
The second category addresses vibratory accelerations at frequencies between 0.01 and 300.0 Hz (expressed graphically in figure 2).

![ISSA System Microgravity Requirement (SSP 41000)](image)

**Figure 2. Vibratory accelerations.**

These requirements address the microgravity effects due to induced vibration frequencies. There are many sources of induced frequencies, including station components such as fans, pumps, rotary joints, and the crew themselves. Figure 2 shows that as the induced disturbance frequency increases, the acceptable level of acceleration (expressed in µgs) increases. This occurs until a maximum level of 1000 µgs is reached at a disturbance frequency of 100 Hz. At that point the curve levels out.

**Performance vs Requirements**

As shown in figures 1a and 1b, ISSA design meets the quasi-steady-state microgravity requirements, with a total of 18 out of 33 ISPRs (55%) within requirements.

The vibroacoustic requirements, however, have long been at issue because of the many station components, including the crew, that cause disturbances exceeding allowable microgravity levels. The smaller dashed line in figure 3 shows what the microgravity environment would have been if no additional steps were taken to isolate either the sources of the disturbance or the payloads themselves. As can be seen in figure 3, the requirement is consistently violated between the frequencies of 0.01 Hz to 300 Hz.

One way to solve this problem would be to try to isolate the source of the disturbance. However, this is not practical due to the large number of disturbers as well as the fact that the crew is one of the primary disturbance sources. Since basic crew movements (such as shutting drawers or moving through the modules) can cause disturbances that exceed the requirements, it was necessary to find another design approach. The approach selected includes three parts.
• Minimize the disturbance "tall poles" at the source.
• Use passive isolation where feasible.
• Provide active isolation of payloads.

The two main rotary joints on the station are an example of the "tall poles" that are minimized at the source. As can be seen in Figure 3, both the thermal radiator rotary joint and the solar array rotary joint are two large disturbers of the microgravity environment. Consequently, both of these joints have undergone electrical and mechanical design modifications to reduce disturbance levels. However, as noted previously, this is not practical for the large majority of ISSA components.

Passive isolation has proven to be feasible only in rare cases, due to volume and mass limitations as well as overall effectiveness. One disturber that may be passively isolated is the treadmill used by the astronauts to exercise. Although still in the development phase, one concept has the treadmill installed on a water-filled container that will serve as a passive isolator.

Active isolation of payloads is a new approach for the space station. By isolating the payloads from the disturbers, it is no longer necessary to worry about how to isolate the crew or how to make sure that the designers have either significantly reduced the disturbance frequency on all pumps, fans, rotary joints, etc, or effectively isolated all of the contributors. Also, since there are 33 ISPRs on board ISSA and only 50% of these have to meet the microgravity requirements, only a maximum of 17 ISPRs would have to be isolated instead of the many sources that would have to
be minimized or isolated. This is a much more cost-effective design implementation, as well as a much more technically feasible one. The system being designed to isolate the experiments is called the Active Rack Isolation System (ARIS). The solid line in figure 3 shows the estimated performance of the ARIS, and it can be seen that this brings the performance well within ISSA requirements.

Overview of ARIS

The ARIS concept is shown in figure 4. The equipment is located to avoid impact to the volume available to the experimenters, and is being designed for minimal power usage and mass (specification levels are 100 watts average and 120 lbs, respectively). It is a new engineering implementation, but the concept is not complicated. Basically, the ISPR is floated with a rattle space to move in and actuators to push the ARIS in one direction or another. Accelerometers sense the acceleration caused by a disturber and the precision actuators push the ARIS in the opposite direction, so that the net force on the payload is zero. One of the biggest challenges is to implement the system with all the umbilicals and connections that a standard ISPR has (in order to provide power, cooling, data transmission, and other utilities).

Figure 4. Active rack isolation system sensor assembly
A laboratory demonstration unit of ARIS has been designed by the Boeing Company. Figure 5 shows how the simulation of ARIS performance compares with the lab test results from the demonstration unit (with 3 degrees of freedom and a 160 lb payload).

**Risk Mitigation**

ARIS is critical to ISSA for meeting the objectives of the science, technology, and research community. Although a laboratory test unit has demonstrated outstanding performance consistent with estimated performance, it was felt that additional risk mitigation was appropriate. Therefore, ISSA is developing a flight experiment that will fly on one of the Shuttle flights to the Russian space station Mir. The experiment will be a near-production configuration with 6 degrees of freedom and built for a full size ISPR. It will be flown on Mir 4 in mid-1996. Since the ARIS will not be needed until payloads begin arriving at ISSA in early 1999, this allows sufficient time to implement any modifications that are proven necessary by the flight experiment. The ARIS flight experiment will be launched in the Shuttle and used in the Space Hab. The primary purpose will be to run extensive tests on the unit. If an appropriate microgravity experiment can be made ready in time, an actual microgravity payload will be included in the tests.
Conclusions

The ISSA program has well-defined and well-understood requirements for the on-orbit microgravity environment. More significantly, it now has a cost-effective approach to meet its microgravity design requirements. The approach includes minimizing extreme disturbers at the source, passive isolation where feasible, and the ARIS—which actively isolates the experiments themselves at the payload racks. It is the first time that an implementation plan has been put in place that takes into account all disturbers of the microgravity environment—including the crew. Since ARIS is critical to the success of this approach, a full flight test is being developed to further validate the laboratory demonstration results. The entire process will ensure that ISSA can provide a premier microgravity environment for innovative science and research.

References