7.3 Physical Environment

7.3.1 Gravity Levels

Inside the ISS a “microgravity” environment exists in which the acceleration of objects and persons relative to their surroundings is reduced to one-millionth of the value measured on the Earth’s surface (9.81 m/s^2 or 1g). The microgravity environment experienced on the ISS and other orbiting spacecraft is actually due to two principal classes of residual accelerations:

- ☐ Quasi-steady acceleration;
- ☐ Vibratory accelerations.

The levels of both quasi-steady and vibratory accelerations on ISS are of interest to microgravity researchers whose investigations cover the effects of reduced gravity on a large range of physical, chemical and biological phenomena. For this reason, the ISS has been designed, is being assembled, and will be operated to meet a set of requirements for both its quasi-steady and vibratory microgravity environment. The requirements specify not only allowable levels of acceleration, but also where on the ISS and for how long such acceleration limits must be obeyed.

7.3.1.1 Quasi-Steady State Accelerations

Quasi-steady accelerations are accelerations whose magnitude and direction vary relatively slowly, on a timescale greater than 100 seconds (i.e. with a frequency < 0.01 Hz). Accelerations are considered quasi-steady if at least 95 % of their power lies below 0.01 Hz as measured over a 5400-second period (the approximate time of one orbit). Generally these accelerations have a magnitude of approximately 1 µg. Quasi-steady accelerations are caused mainly by two factors:

1. The aerodynamic drag that the ISS experiences due to the residual atmosphere at low Earth orbit. This drag causes the Station to lose altitude, and consequently to accelerate along its orbital velocity vector;
2. Gravity gradient effects: any point not exactly at the ISS centre of mass will tend to want to follow its own orbit. Such points, however, because they are physically part of the ISS are subject to accelerations from the structural forces that keep them attached to the Station as it orbits.

A set of formal design requirements regarding the ISS quasi-steady acceleration environment during the Microgravity Mode (see 7.2.4) at Assembly Complete (AC) have been laid out in the ISS programme, which state that:

“50 % of the International Standard Payload Rack (ISPR) locations within the U.S. Destiny, European Columbus and Japanese Kibo Laboratories must have quasi-steady accelerations less than 1 µg (10^{-6} g) for periods of at least 30 continuous days, on 6 occasions per year.”

NASA has developed several analytical (system) models for the AC configuration when the microgravity design requirements become applicable. This system model development is an evolutionary process called Design Analysis Cycles (DAC), with each cycle reflecting the current assembly sequence and the updated component models. The last cycle was DAC-9, completed in March 2002. The drag, gravity gradient and other secondary effects can be incorporated into calculations that reveal the level of gravity as a function of coordinate position relative to the Station’s centre of mass. These gravity contours are shown in Figure 7-18 and Figure 7-19. The results of the DAC-9 have shown that 14 of the 32 ISPRs analysed (i.e. ~ 44 %) in Destiny, Columbus and Kibo are subject to peak quasi-steady acceleration magnitudes of less than 1µg. This compares favourably with the 50 % figure laid out as a design requirement.

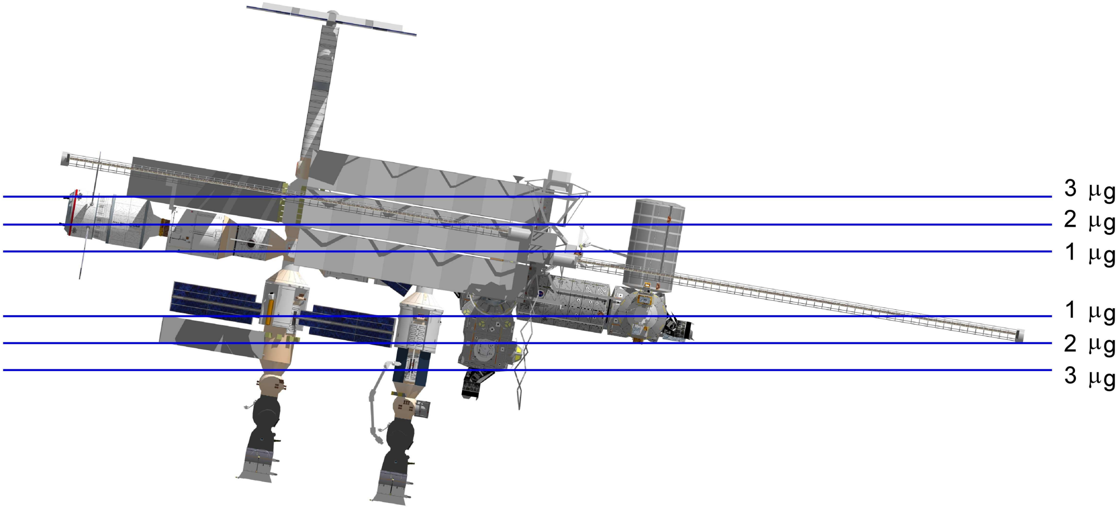


Figure 7-18: ISS "iso-g" contours - XZ plane

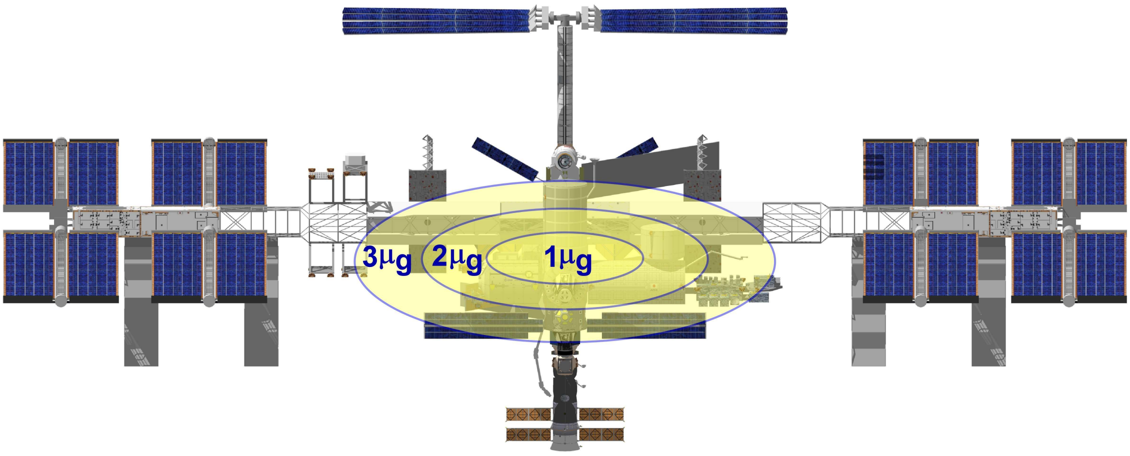


Figure 7-19: ISS "iso-g" contours - YZ plane

7.3.1.2 Vibratory Accelerations

The requirements for the vibratory microgravity environment on ISS are defined in terms of a "spectrum" of allowed root-mean-square (RMS) acceleration as a function of vibrational frequency from 0.01 Hz to 300 Hz. The total vibrational level experienced by the station arises from the combined effects of the payload and vehicle systems. The vibratory microgravity requirements are therefore defined using an RMS acceleration vs. frequency curve for the allowed contribution to the total system vibration by the vehicle alone, with a separate curve for the allowed contribution by the entire complement of payload systems.

In similarity with the quasi-steady state situation, the Microgravity Mode ensures that:

*"the **vibratory acceleration** levels will not be exceeded for 50 % of the International Standard Payload Rack (ISPR) locations within the European Columbus, Destiny and Japanese Kibo laboratories for at least 30 days continuously, on six occasions each year".*

The vibratory acceleration limits (vehicle + payloads) apply at the structural interface between the laboratory module and the ISPRs, and are defined as follows:

- *For frequencies (f) $0.01 \le f \le 0.1$ Hz*: the Root Mean Square microgravity disturbance should be less than 1.8×10^{-6} g;
- *For $0.1 < f \le 100$ Hz:* the disturbance must be less than the product of [1.8×10^{-5} (g) * frequency (Hz)];
- *For $100 < f \le 300$ Hz*: the disturbance should not exceed 1.8×10^{-3} g.

The above limits are represented in the graph in Figure 7-20.

The fact that a payload complement vibratory requirement exists should be noted by any user considering development of a payload for ISS, because the requirement has implications for placing constraints on how much vibration an individual payload can produce.

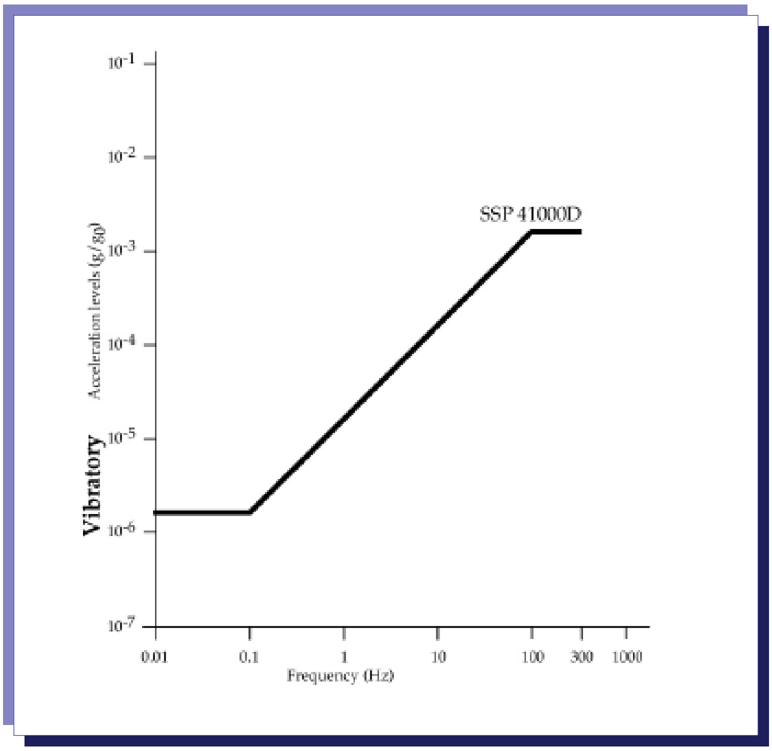


Figure 7-20: Payloads + Vehicle Vibratory Acceleration limits

7.3.1.2.1 Rack Level Isolation Systems

7.3.1.2.1.1 Active Rack Isolation System (ARIS)

In parallel to efforts to further reduce the perturbations by timelining and reduction at the source, NASA has also developed the Active Rack Isolation System (ARIS). The ARIS has been designed to attenuate vibratory disturbances at selected user payload locations in support of United States On–orbit Segment (USOS) requirements for the microgravity environment, such that the on-rack environment will meet the system vibratory specifications. The ARIS is an active electromechanical damping system attached to an International Standard Payload Rack (ISPR – see 7.6.1.1) that imparts a reactive force between the payload rack and module in response to sensed vibratory accelerations, thereby reducing disturbances to user payloads within the rack.

In addition to attenuation, the ARIS measures vibratory disturbances within the ISPR. The ARIS reports ISPR acceleration measurements to a payload controller for evaluation of ISS microgravity performance, analysis of microgravity effects on payloads, and analysis of disturbance–related anomalies. The ARIS is designed for compatibility with the EXPRESS (EXpedite the PRocessing of Experiments to Space Station) and non–EXPRESS payload racks. Both configurations are based on the ISPR.

More information regarding the ARIS can be found in the document SSP 57006 Rev. A, “Active Rack Isolation System (ARIS) User’s Handbook”, November 2002.

7.3.1.2.1.2 Passive Rack Isolation System (PaRIS)

The PaRIS is a passive rack vibration isolation system intended for use in the United States Laboratory “Destiny” and Centrifuge Accommodation Module (CAM), with some capability within the Japanese Experiment Module “Kibo” and the Columbus Lab Module. By suspending the integrated payload rack from the ISS module structure using passive dampers, it will attenuate vibratory accelerations above 1 Hz to the user payloads.

The combination of integrated rack and PaRIS provides vibration isolation in both dynamic load path directions (i.e., attenuating vibrations imposed on the rack by the ISS vehicle as well as attenuating vibrations induced on the ISS vehicle by the rack) without consuming any ISS power, thermal, or data/command system resources.

For more information users can consult the following document: SSP 57058 “Passive Rack Isolation System (PaRIS) to International Standard Payload Rack (ISPR) Interface Control Document (ICD)”, January 2002.

7.3.1.2.2 Sub-Rack Isolation Systems

7.3.1.2.2.1 Microgravity Isolation Mount (MIM)

This facility was developed by the Canadian Space Agency (CSA) to help isolate experiments from the g-jitter present on all spacecraft. The MIM provides a significant improvement in the acceleration environment for critical experiments that are extremely sensitive to vibrations. The MIM is also capable of imparting vibrations of known frequency and amplitude to an attached experiment.

The MIM consists of a magnetically levitating plate called the Flotor upon which small experiments can be mounted. Sensors inside the MIM detect incoming vibrations and then cancel them out with equal and opposite vibrations to the Flotor. Vibration levels on the Flotor are attenuated by a factor of 10 or more. The MIM can also create known vibrations of up to 100 Hz for experiments mounted to the Flotor. This is most useful for studying the free-surface response of fluids to a known input. Fluids are extremely sensitive to vibrations at or near their natural frequency and typically respond by visible agitation.

An isolation system derived from the MIM technology, known as the Microgravity Vibration Isolation Subsystem (MVIS) has been developed by the CSA for ESA’s Fluid Science Laboratory (FSL), in exchange for 5 % of the utilisation rights of the FSL. Its purpose is to isolate an Experiment Container together with the optical bench in which it is accommodated from the support systems of the laboratory. This approach has the advantage of necessitating minimum mass, volume and power for the isolation system. MVIS is the third generation of the MIM technology.

7.3.1.3 Measuring the ISS Microgravity Environment & Accessing Data

As discussed previously, the ISS microgravity acceleration environment consists of two regimes: the quasi-steady environment and the vibratory environment. Currently, the measurement of the microgravity acceleration environment is accomplished by two NASA accelerometer systems, through its Principal Investigator Microgravity Services (PIMS) project at the Glenn Research Center. These 2 systems on-board of the ISS are:

- ☐ *The Space Acceleration Measurement System-II (SAMS-II):* The vibratory environment covering the frequency range 0.01 – 400 Hz, is measured by the SAMS-II. Due to the localised nature of these vibrations, this frequency range requires measurement of the environment near the experiment hardware of interest. SAMS-II provides this distributed measurement system through the use of Remote Triaxial Sensor systems (RTS);

- *The Microgravity Acceleration Measurement System (MAMS)*: The MAMS will record the quasi-steady microgravity environment (f < 0.01 Hz), including the influences of aerodynamic drag, vehicle rotation, and venting effects.

The data obtained from the above systems is managed, processed and archived by the PIMS, which has set up an ISS operations website (http://pims.grc.nasa.gov/pims_iss_index.html) that allows researchers and payload developers to:

- *View the current locations of accelerometers* – this allows users to view the current location of accelerometer hardware. Figure 7-21 shows an example for stage 11A (http://pims.grc.nasa.gov/html/CURRENT_LOCATIONS.htm);
- *View real time plots* – users can view real-time plots of data coming from the accelerometers. This information can be viewed directly from a menu on the PIMS ISS operations page, or by clicking on the rack location of interest (see Figure 7-21). The various display formats and data analysis techniques are summarised in Table 7-8;
- *Request archived data* – users can, via an on-line form, request archived data.

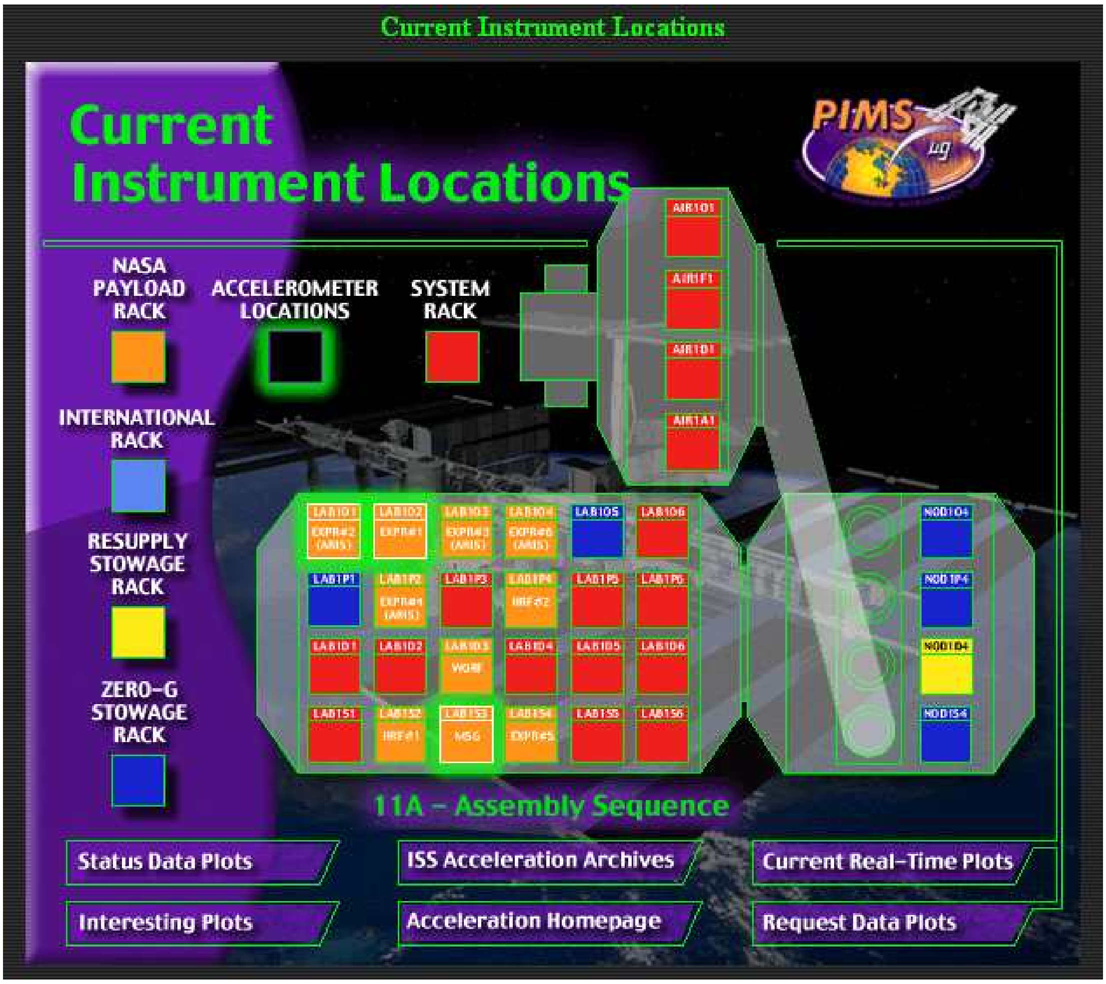


Figure 7-21: Accelerometer locations for stage 11A of the assembly sequence (Image: NASA)

Table 7-8: PIMS acceleration data analysis techniques

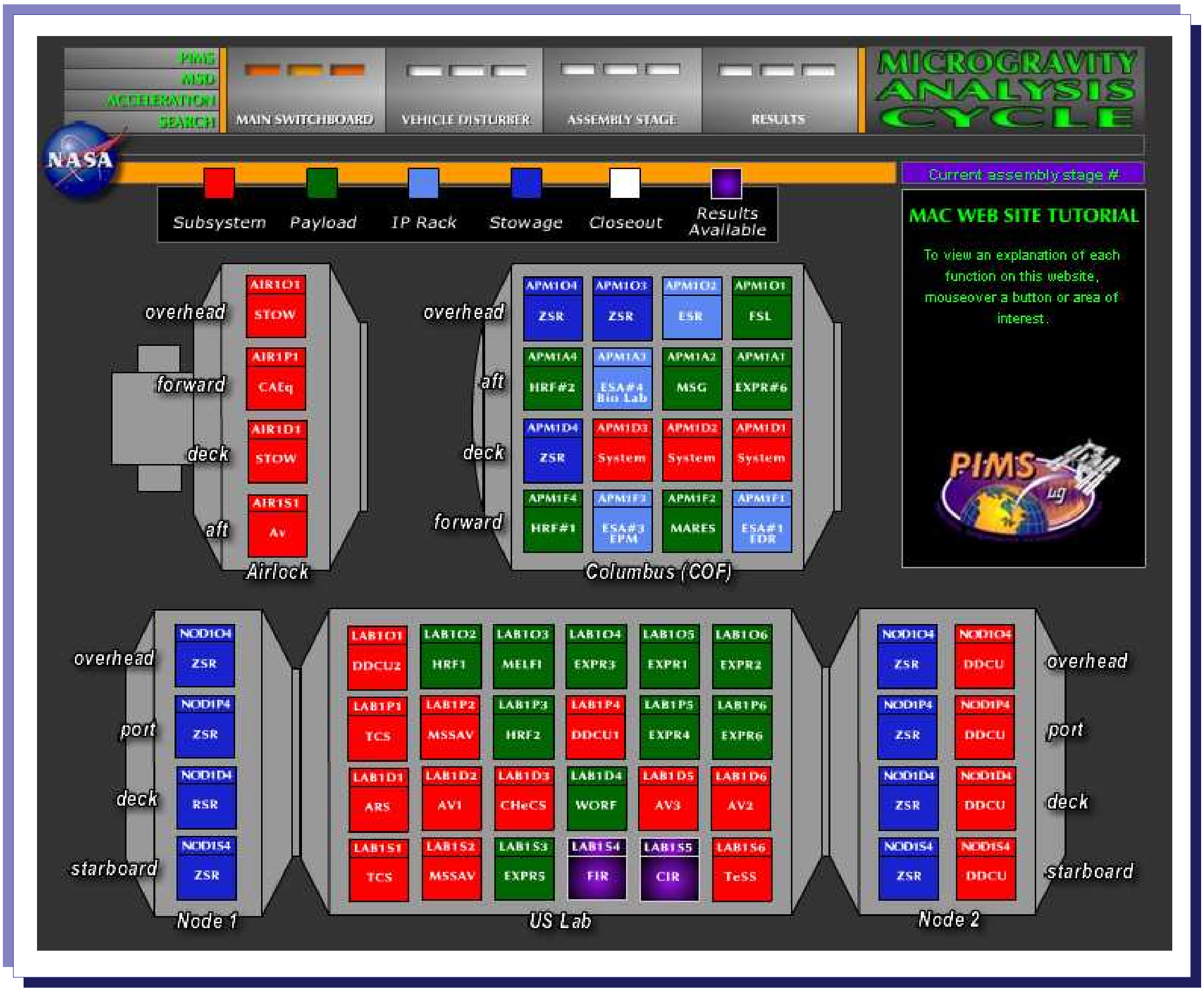
DISPLAY FORMAT	REGIME (S)	NOTES
Acceleration vs. Time	Quasi-steady, Vibratory	❑ Precise accounting of measured data w.r.t. time ❑ Best temporal resolution
Interval Min/Max Acceleration vs. Time	Quasi-steady, Vibratory	❑ Displays upper and lower bounds of peak-to-peak excursions of measured data ❑ Good display approximation for time histories on output devices with resolution insufficient to display all data in time frame of interest
Interval Average Acceleration vs. Time	Quasi-steady, Vibratory	❑ Provides a measure of net acceleration of duration greater than or equal to interval parameter
Interval Root Mean Square (RMS) Acceleration vs. Time	Vibratory	❑ Provides a measure of peak amplitude
Trimmed Mean Filtered Acceleration vs. Time	Quasi-steady	❑ Removes infrequent, large amplitude outlier data
Quasi-Steady Mapped Acceleration vs. Time	Quasi-steady	❑ Use rigid body assumption & vehicle rates and angles to compute acceleration at any point in the vehicle
Quasi-Steady 3D Histogram (QTH)	Quasi-steady	❑ Summarise acceleration magnitude and direction for a long period of time ❑ Indication of acceleration "centre-of-time" via projections onto three orthogonal planes
Power Spectral Density (PSD) vs. Frequency	Vibratory	❑ Displays distribution of power w.r.t. frequency
Spectrogram (PSD vs. Frequency vs. Time)	Vibratory	❑ Displays power spectral density variations with time ❑ Identify structure & boundaries in time and frequency
Cumulative RMS Acceleration vs. Frequency	Vibratory	❑ Quantifies RMS contribution at and below a given frequency ❑ Quantitatively highlights key spectral contributors
Frequency Band(s) RMS Acceleration vs. Time	Vibratory	❑ Quantify RMS contribution over selected frequency band(s) as a function of time
RMS Acceleration vs. One-Third Frequency Bands	Vibratory	❑ Quantify RMS contribution over proportional frequency bands ❑ Compare measured data to ISS vibratory requirements
Principal Component Spectral Analysis (PCSA)	Vibratory	❑ Summarise magnitude and frequency excursions for key spectral contributors over a long period of time ❑ Results typically have finer frequency resolution and high PSD magnitude resolution relative to a spectrogram at the expense of poor temporal resolution

From the above data, a general characterisation of the ISS microgravity environment can be obtained that affords scientists and hardware developers the pre-flight ability to anticipate the acceleration environment available for experimentation. A handbook of acceleration disturbance sources for the ISS can also be viewed at the PIMS web site, which provides a concise visualisation of the ISS disturbance sources.

The Glenn Research Center is also currently developing a Microgravity Analysis Cycle (MAC) interactive web page, which aims to:

- ❑ Provide data that can be utilised to make operational decisions based on the predicted microgravity environment for specific payloads. This would allow payload operational decisions to be made based on planned ISS operations;
- ❑ Better predict the microgravity environment for science payloads;
- ❑ Merge analytical predictions with on-orbit experience/data.

Users will be able to view predicted data based on different selected ISS configurations and modes.
Figure 7-22 shows the current MAC demo page (http://microgravity.grc.nasa.gov/mac_website/tutorial.html) for the ISS UF5 configuration, in which the Combustion Integrated Rack (CIR) and Fluids Integrated Rack (FIR) are active.



To view an explanation of each function on this website, mouseover a button or area of interest.

Figure 7-22: NASA MAC demo page for ISS UF5 configuration (Image: NASA)

7.3.2 Internal Environment

7.3.2.1 Cabin Atmosphere

The characteristics of the ISS cabin atmosphere are summarised in the following table (Table 7-9).

Table 7-9: Characteristics of internal cabin atmosphere

PARAMETER	OPERATIONAL VALUE
Normal Total Cabin Pressure Range	97.9 – 102.7 kPa
Contingency Total Cabin Pressure Range	95.8 – 97.9 kPa
Normal Composition of Atmosphere	21 % Oxygen; 78 % Nitrogen
Maximum Allowable % Oxygen in Atmosphere	24.1 %
Maximum N_2 Partial Pressure	80 kPa
O_2 Partial Pressure Range	19.5 – 23.1 kPa
CO_2 Levels	The medical operations requirement, and the ISS specification, for CO_2 level is a 24-hour average of 0.7 % or less, although a 24-hour average exposure as high as 1 % is allowable during crew exchanges. The ISS programme has agreed to maintain the cabin CO_2 level to 0.37 % (with the goal of reaching 0.3 %) for two 90-day periods each year. Modelling has shown that with two U.S.- and one Russian-segment CO_2 scrubbers a level closer to 0.2 % can be expected.
Average CO_2 Partial Pressure during normal operations	0.71 kPa
Air Temperature	17 – 28 °C
Dew Point	4.4 – 15.6 °C
Relative humidity	25 – 75 %
Ventilation velocity	0.076 – 0.203 m/s
Airborne microbial growth	≤ 1000 Colony Forming Units (CFU)/m^3
Atmosphere Particulate level	Class 100 000 (i.e. less than 100 000 particles/ft^3, for particles less than 0.5 microns in size)

7.3.2.2 Illumination

The internal lighting of the ISS consists of:

- ❑ *General illumination*: Produced by a number of Module Lighting Units distributed throughout the station, which may be controlled either remotely or locally (i.e., a manually-operated switch on each unit). The general illumination of the Space Station in the aisle will be a minimum of 108 lux (10–foot candles) of white light. This illumination will be sufficient for ordinary payload operations performed in the aisle (e.g., examining dials or panels, reading procedures, transcription, tabulation, etc.);

- ☐ *Portable lighting*: A number of portable lighting units are available for temporary crew use (e.g., to increase the local illumination in particularly inaccessible areas);
- ☐ *Emergency lighting*: An emergency lighting system is common throughout all pressurised modules of the ISS.

Additional illumination for payload tasks must be taken into account following the set of requirements listed in Table 7-10.

Table 7-10: Payload required illumination levels

TYPE OF TASK	REQUIRED LUX (FOOT-CANDLES)*
Medium payload operations (not performed in the aisle) (e.g., payload change-out and maintenance)	325 (30)
Fine payload operations (e.g., instrument repair)	1075 (100)
Medium glovebox operations (e.g., general operations, experiment set-up)	975 (90)
Fine glovebox operations (e.g., detailed operations, protein crystal growth, surgery/dissection, spot illumination)	1450 (135)

* As measured at the task site

7.3.2.3 Interior Colour

A common interior colour scheme is used throughout all pressurised modules (excluding those in the Russian segment) to ensure a consistent environment for the crew. Depending on the type of hardware, the principal surface colours and finishes adopted are:

Table 7-11: Interior hardware colours and finishes

COLOURS	FINISHES
White	Lustreless
Black	Semi gloss
Off-white	Gloss
Nickel plate	
Medium grey	
Tan	

Label colours will include red (emergency use items only), yellow (Caution & Warning items only), green, blue and orange. No more than 9 colours, including black and white, should be used in a coding system.

7.3.2.4 Internal Contamination

The control of contamination within the pressurised modules is crucial to maintain an efficient working environment for the crew, equipment and user payloads. Contamination can affect the health of the crew, reduce the operational lifetime of equipment, and increase required maintenance activities. Typical sources of contamination are the crew, equipment, materials, experiment processes – all of which combine to produce trace gases, carbon dioxide, particulates and microbial contaminants. The microbial growth and particulate level within the living and working environment of the ISS will be monitored and controlled according to the limits specified in Table 7-9.

7.3.2.5 Noise

The ISS interior will be subject to various noise levels caused by pumps, fans and other operating systems and subsystems. Stringent limits have been set regarding noise in the interior of the ISS. The maximum allowable continuous broadband sound pressure levels (SPLs) produced by the summation of all the individual SPLs from all operating systems and subsystems considered at a given time shall not exceed the values shown in Figure 7-23 for work periods and sleep compartments, respectively. Noise of constant sound levels of 85.0 dB and greater are considered hazardous regardless of the duration of exposure. Hearing protection devices are provided for crew to use during exposure to noise levels of 85.0 dB or greater.

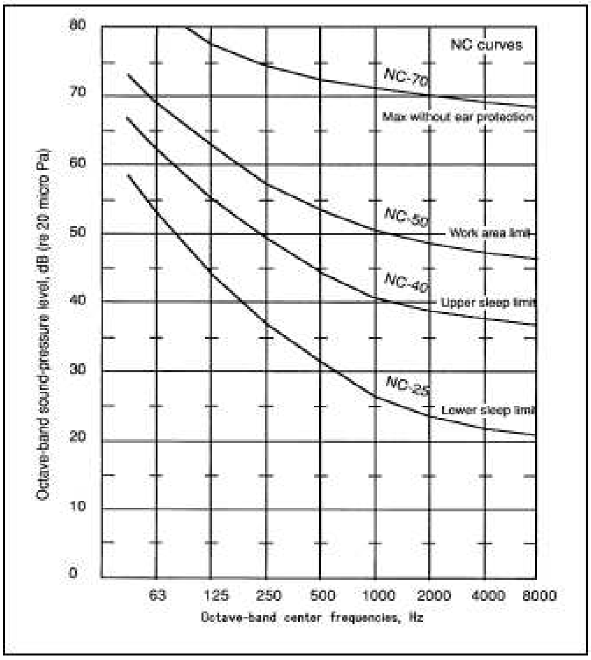


Figure 7-23: ISS Interior Noise Criteria Curves

7.3.2.6 Touch Temperatures

In order to avoid endangering the crew or damaging sensitive equipment, exposed surfaces within the habitable areas of the ISS are subject to requirements regarding minimum and maximum temperatures:

- Surfaces that are subject to *continuous* contact with a crewmember's bare skin and whose temperature exceeds 45 °C, are required to be provided with guards or insulation to prevent crewmember contact;
- Surfaces which are subject to *incidental* or *momentary* contact (30 seconds or less), with a crewmember's bare skin and whose temperatures are between 45 and 50 °C, are required to have warning labels that will alert crewmembers of the temperature levels;

- ☐ Surfaces that are subject to *incidental* or *momentary* contact (30 seconds or less), with a crewmember's bare skin and whose temperatures exceed 50 °C, are required to have guards or insulation;
- ☐ Surfaces which are subject to *continuous* or *incidental* contact with a crewmember's bare skin and whose temperatures are below 4 °C, must provide crew with protective equipment and warning labels must be provided at the surface site.

7.3.3 External Environment

Users should be aware of the ISS external environment for two reasons:

1. It may affect the design and operations of external payloads; and
2. It may be the object of investigation for external experiments.

The ISS external environment consists of:

- ☐ *The Induced External Environment* – this is the space environment that exists as a consequence of the presence of the ISS and its related operations;
- ☐ *The Natural External Environment* – this is the space environment that exists even if the ISS were not in orbit. This includes neutral atmosphere, plasma, charged particle radiation, electromagnetic radiation, meteoroids, space debris, magnetic field, and gravitational field.

7.3.3.1 Induced External Environment

7.3.3.1.1 Quiescent Periods

The ISS Programme specifications have imposed the following regarding the induced external environment during quiescent periods, i.e. Standard and Microgravity modes.

7.3.3.1.1.1 Molecular Column Density

The contribution to the molecular column density created by the presence of the ISS contamination sources along any unobstructed line of sight will not exceed 1×10^{14} molecules/cm^2 for individual released species. This includes contributions from outgassing, venting, leakage, and other ISS contamination sources but does not include ram–wake effects.

7.3.3.1.1.2 Particulate Background

The release of particulates from the ISS is limited to one particle, 100 microns or larger, per orbit per 1×10^{-5} steradian field of view as seen by a 1 metre diameter aperture telescope. This includes contributions of particulates originating from external ISS surfaces, compartments vented to space, movable joints, vents (of solids, liquids and gases) and other ISS particulate sources but excludes particulates in the natural environment and their effect on ISS hardware (e.g., their impact on ISS surfaces).
Attached payloads must limit any active venting release of particulates to less than 100 microns in size.

7.3.3.1.1.3 Molecular Deposition

The flux of molecules emanating from the ISS is limited such that the 300K mass deposition rate on sampling surfaces is limited to 1×10^{-14}g/cm^2/sec (daily average). The sampling surfaces are typically located at the solar arrays, thermal radiators, observation windows, truss attached payloads, and the JEM Exposed Facility.
Contamination requirements directed specifically at effects on attached payloads and the ISS vehicle by other attached payloads specify that an attached payload shall not deposit material at a rate greater than 1×10^{-14} g/cm^2/sec on other attached payloads and 1×10^{-15} g/cm^2/sec on ISS vehicle elements.

7.3.3.1.2 Non-Quiescent Periods

7.3.3.1.2.1 Molecular Deposition

Total deposition at 300K on the sampling surfaces will not exceed 1×10^{-6} g/cm^2/yr.

7.3.3.2 Natural External Environment

7.3.3.2.1 Pressure

A natural high-quality vacuum exists outside of the ISS, providing numerous experimental possibilities for a number of research fields. The ISS external on-orbit minimum pressure environment is 3.6×10^{-11} kPa.

7.3.3.2.2 Thermal Environment

ISS external elements and payloads will be exposed to:

- ☐ Thermal solar constants, albedo, and Earth Outgoing Long-wave Radiation (OLR) environments as defined in Table 7-12;
- ☐ A space sink temperature of 3 K;
- ☐ The induced thruster plume environment and induced thermal environments from vehicle(s) docking and docked with the ISS;
- ☐ Thermal interactions with other on-orbit segments.

Table 7-12: Hot and Cold Natural Thermal Environments

CASE	SOLAR CONSTANT (W/M^2)	EARTH ALBEDO	EARTH OLR (W/M^2)
Cold	1321	0.2	206
Hot	1423	0.4	286

The thermal environment results in maximum and minimum external surface temperatures of ~ +120 °C and –120 °C, respectively.

7.3.3.2.3 Humidity

ISS external elements and payloads will be exposed to an external environment of 0 % relative humidity during on–orbit operations.

7.3.3.2.4 Atomic Oxygen

At Low Earth Orbit altitude, the ISS will encounter the Earth’s low-density residual atmosphere, which at this altitude is primarily composed of oxygen in an atomic state (molecular bonds being broken by the solar Ultra Violet rays). Although the particle density is low, the flux (i.e., combined product of density, relative velocity and surface area) is high. The incidence of this neutral oxygen flux can result in significant erosion of certain surfaces depending on their nature. External surfaces may be exposed to fluxes of up to 4.4×10^{19} atoms/cm^2/day.

7.3.3.2.5 Electromagnetic Radiation

Important sources of electromagnetic noise exist over the entire frequency spectrum from direct current (dc) to X–ray at the ISS orbit altitudes. These noise sources broadly separate into four categories:

- ☐ Galactic;
- ☐ Solar;
- ☐ Near–Earth natural plasma;
- ☐ Man–made radio noise.

The highest power densities expected to be irradiating the ISS are from the solar radiation in the ultraviolet and visible portions of the electromagnetic spectrum. The ultraviolet radiation can damage materials exposed to it. Other effects of electromagnetic radiation to be considered include radio noise and the effects of field strengths from the natural sources at the ISS. Field strengths produced from quasi–static field structures in the plasma have typical values around 25 mV/m, but can be larger. These values generally occur at latitudes greater than 50°.

7.3.3.2.6 Plasma

Plasma is a quasi–neutral gas consisting of neutral and charged particles that exhibit collective behaviour. From approximately 80 km altitude to about 1000 km altitude, a plasma environment about the Earth is designated as the ionosphere. A plasma environment extends further from the Earth into a region designated as the magnetosphere and still further into the solar wind. A primary interaction of plasma with a spacecraft is the accumulation of an electrical charge by the spacecraft until electrical equilibrium is reached between the spacecraft and the local plasma environment. Because electrons have greater thermal velocities than do ions at similar temperatures, a spacecraft tends to reach equilibrium potential at a few volts negative with respect to the plasma at ISS altitudes. However, active components and their associated structure (such as solar arrays) may accumulate sufficient negative potential to produce arcing to other elements of the spacecraft.

7.3.3.2.7 Ionising Radiation

The ionising radiation environment results from the natural radiation in Low Earth Orbit (LEO) due to trapped electrons, trapped protons, and solar, anomalous, and galactic cosmic rays. The contribution of other LEO environmental constituents such as neutrons and x–rays are negligible and are not considered by the ISS Programme. The ionising radiation environment interacts with devices and materials to produce radiation dose effects and single event effects (SEE).

7.3.3.2.7.1 Radiation Dose Environment

Dose effects are ionising radiation–induced changes in devices and materials resulting from exposure to the trapped proton and electron environment during the orbital lifetime. Dose effects are usually manifested as degradation of electronic device and material performance and are cumulative with exposure to the ionising radiation environment.

7.3.3.2.7.2 Single Event Radiation Dose Environment

SEE are ionising radiation–induced effects produced when single, ionised particles interact with electronic devices to change the electrical states or characteristics of the devices. These effects include single event upset, transients, latchup, burnout, and gate rupture. The ionising radiation environment for SEE is divided into a nominal environment and an extreme environment

- ☐ *Nominal SEE* – The nominal SEE design environment is the environment, which the Space Station will typically experience, and consists of trapped protons and cosmic rays. The SEE trapped proton environment represents daily average proton fluxes. The trapped proton flux is a maximum during passes through the South Atlantic Anomaly (SAA), where fluxes are more severe than the daily average environment. The ISS will pass through the SAA on 50 % of its orbits and will spend 5–10 minutes of these orbits in the SAA. Cosmic ray particles originate from outside the solar system and although the fluxes are low, they include heavy energetic ions for which it is difficult to shield against. Cosmic rays are known to result in Single Event Upset and “latchup” in electronic components and an uncertain radiobiological effect on biological organisms;

- ☐ *Extreme SEE* – The extreme SEE environment consists of protons and heavy ions emitted during the most intense solar flares in a solar cycle. The extreme environment occurs once over an 11 year solar cycle period, and lasts for approximately 24 hours. Three different aspects of this environment are defined:
    - peak proton flux,
    - peak heavy ion flux,
    - orbit–averaged heavy ion fluency for the worst-case flare event.

7.3.3.2.8 Plume Impingement

External payloads and exposed secondary structures (e.g. Multi-Layer Insulation – MLI – blankets) will be exposed to the maximum effective normal pressure of 0.16 kPa and shear plume impingement pressure of 0.038 kPa.

7.3.3.2.9 Meteoroids and Orbital Debris

In orbit, the ISS will encounter meteoroids and orbital debris. Either type of object can pose a serious threat of damage or decompression to the ISS upon impact. Meteoroids are natural in origin, and debris is the result of man–made material remaining in Earth orbit.