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SYSTEM SPECIFICATION
FOR THE
INTERNATIONAL SPACE STATION

Type 1

Contract No. NAS15–10000

CDRL No. MG02

Prepared for
National Aeronautics and Space Administration (NASA)

Prepared by:
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The Space Station shall control attitude rates at any point on the non–articulated portion of the on–orbit Space Station to within +/–0.02 degrees per second per axis with respect to the commanded attitude frame when controlling to LVLH or inertial for propulsive attitude control when not performing translational maneuvers.

The Space Station shall have the capability to control to TEA using propulsive effectors.

The Space Station shall control attitude to a fixed LVLH orientation using propulsive effectors while controlling the nonpropulsive effectors to a commanded momentum state.

The Space Station shall be capable of a maneuver rate of at least 0.10 degrees per second per axis during attitude maneuvers.

The Space Station shall provide dynamic stability to perform mating and demating with the Orbiter at an altitude of 150 nautical miles or above.

The Space Station shall be able to fire or inhibit individual thrusters by direct command from a source independent of the attitude controller.

The Space Station shall be capable of acquiring TEA within 10 orbits, provided that the initial LVLH attitude is within 10 degrees of TEA.

The Space Station shall provide the capability to hold the current LVLH attitude (defined as the LVLH attitude of the Space Station at the time this mode command is received at the GN&C computer).

The Space Station shall provide for the desaturation of nonpropulsive effectors by thruster firings, both automatically upon exceedance of a preset momentum magnitude limit and by direct command from both the crew and ground.

The Space Station shall maintain the on–orbit Space Station docking mechanism interface attitude, rates, and translational (linear) rate changes as defined in Table X when actively controlling the on–orbit Space Station during Orbiter approach/departure and mating/demating operations.

3.2.1.1.3 Mode: Maneuver – habitable.

This mode consists of functionality required to change the Space Station attitude orientation while maintaining a habitable environment and supporting internal and external payload operations. This mode consist of the capabilities as shown in Table V.

3.2.1.1.4 Mode: Microgravity – habitable.

This mode consists of capabilities required for microgravity research by user payloads in a habitable environment. This mode does not include the effects of crew activity, but does include the effects of crew equipment, such as the operation of exercise devices and latched or hinged enclosures. Crew effects will be mitigated to the extent possible. This mode consists of the capabilities as shown in Table V, and the following unique capability.

3.2.1.1.4.1 Capability: Support microgravity experiments.

The purpose of this capability is to establish the required environment for microgravity experiments. The Space Station shall provide the following microgravity acceleration performance for at least 50 percent of the internal payload locations (excluding Nadir window payload location) for 180 days per year in continuous time intervals of at least 30 days:

a. At the centers of the internal payload locations, a quasi–steady (<0.01 Hz) acceleration: (1) magnitude less than or equal to 1 micro–g, and (2) component perpendicular to the orbital average acceleration vector less than or equal to 0.2 micro–g; and

b. At the structural mounting interfaces to the internal payload locations: (1) a vibratory acceleration limit as defined in Figure 4, (2) a transient acceleration limit for individual transient disturbance sources less than or equal to 1000 micro–g per axis, and (3) an integrated transient acceleration limit for individual transient disturbance sources less than or equal to 10 micro–g seconds per axis over any 10 second interval.

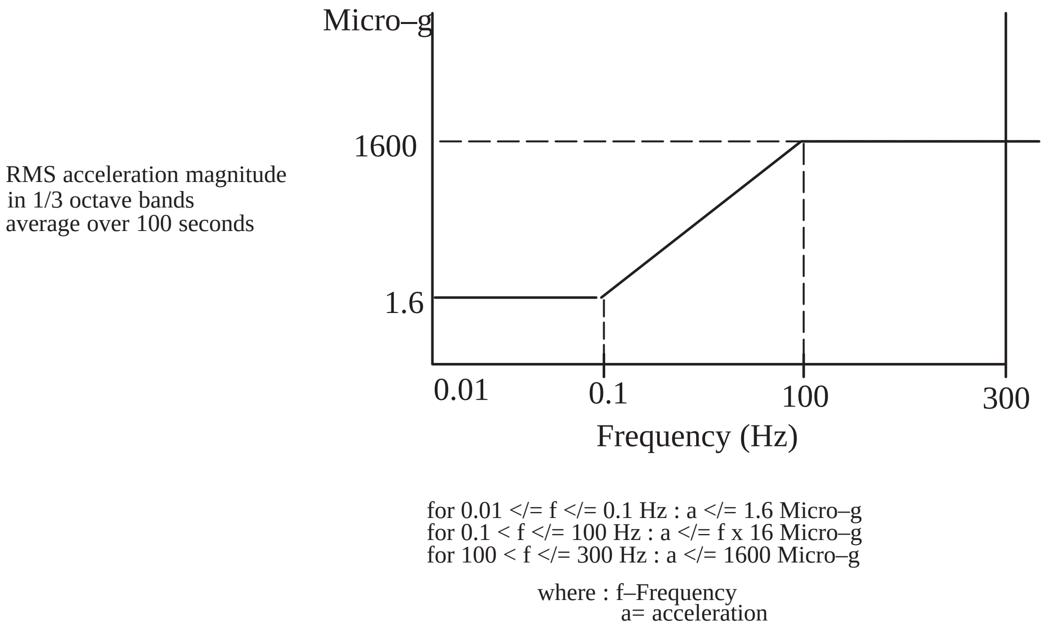


FIGURE 4. On–orbit Space Station vibro–acoustic microgravity acceleration limits

The Space Station shall monitor and record the microgravity environment at selected locations.

3.2.1.1.5 Mode: Survival – habitable.

This mode is initiated upon command or when a warning of imminent threat (e.g. attitude rate/acceleration too high, available power too low, battery charge condition inadequate) is not acknowledged by the on–orbit crew, orbiter crew, or ground. During this mode, the station autonomously attempts to correct the threatening condition and provides keep alive utilities to the Station's crew/core–systems but precludes support or commanding of external or internal payloads. The mode consists of the capabilities as shown in Table V.

3.2.1.1.6 Mode: Proximity – habitable.

This mode provides the capabilities related to supporting safe operations with other vehicles while maintaining a habitable environment and supporting internal and external user payload operations. The vehicle is actively determining and controlling its attitude non–propulsively. This mode consists of the capabilities as shown in Table V.

3.2.1.1.7 Mode: Assured safe crew return.

This mode provides mitigation capability for life threatening illness, unrecoverable loss of station habitability, or extended problem requiring resupply/servicing which is prevented from occurring due to launch problems. This mode consists of the actions/operations/functions necessary to safely populate the Assured Crew Return Vehicle (ACRV), separate and return the ACRV to earth, and egress the ACRV upon recovery on the ground. The mode consists of the capabilities as shown in Table V, and the following unique capability.

3.2.1.1.7.1 Capability: Support assured crew return.

The purpose of this capability is to assure return to earth of the Space Station crew for: (1) medical evacuation mission, (2) unrecoverable loss of Space Station habitability, and (3) unavailability of Space Station resupply or servicing. The Space Station shall return the crew to earth with a 30 km three sigma radial accuracy to targets in more than one landing region for a medical evacuation mission.

The Space Station shall be able to return the entire crew to Earth in the event of unrecoverable loss of station habitability.

The Space Station shall be able to return the entire crew to Earth in the event of unavailability of Space Station resupply of servicing.

3.2.1.1.8 Mode: External operations – habitable.

This mode utilizes functionality related to supporting station based external operations while maintaining a habitable environment and supporting internal and external payload operations. The vehicle is actively determining and controlling its attitude non–propulsively. This mode consists of the capabilities as shown in Table V and the following unique capabilities.

3.2.1.1.8.1 Capability: Support EVA operations.

The purpose of this capability is to support Space Station EVA operations and maintenance. The Space Station shall support the conduct of 52 two–member EVAs per year, egress, voice and data communication, crew tracking, ingress, and illumination of external worksites and translation paths and transfer of hardware and crew.

The Space Station shall support the functions for 2 independent external crewmembers simultaneously for a period of 7 hours from depressurization to repressurization.

3.2.1.1.8.2 Capability: Support external robotic operations.

The purpose of this capability is to support the performance of external robotic operations. The Space Station shall provide external robotic capabilities to support external robotic operations.

The Extravehicular Robotics (EVR) functions shall be controlled by the on–orbit Space Station.

3.2.1.2 State: Perform mission – untended.

A stable condition of the Space Station defined by the provisions of a safe environment for equipment and user payloads to support the accomplishment of mission objectives.

3.2.1.2.1 Mode: Standard – untended.

This mode represents the core operations of the Space Station when it is untended. The vehicle actively determines and controls its attitude non–propulsively. This mode provides a safe environment for the equipment and untended user payloads. Internal and external user payload operations are supported, monitored and controlled. This mode consists of the capabilities as shown in Table V, and the following unique capability.

ISS Microgravity Environment

THE Requirement for the International Space Station

Duration

Quasi-steady

Mode: Microgravity – habitable.

This mode consists of capabilities required for microgravity research by user payloads in a habitable environment. This mode does not include the effects of crew activity, but does include the effects of crew equipment, such as the operation of exercise devices and latched or hinged enclosures. Crew effects will be mitigated to the extent possible. This mode consists of the capabilities described in SSP 41000 and the following unique capability.

Capability: Support microgravity experiments.

The purpose of this capability is to establish the required environment for microgravity experiments. The Space Station shall provide the following microgravity acceleration performance for at least 50 percent of the internal payload locations (excluding Nadir window payload location) for 180 days per year in continuous time intervals of at least 30 days:

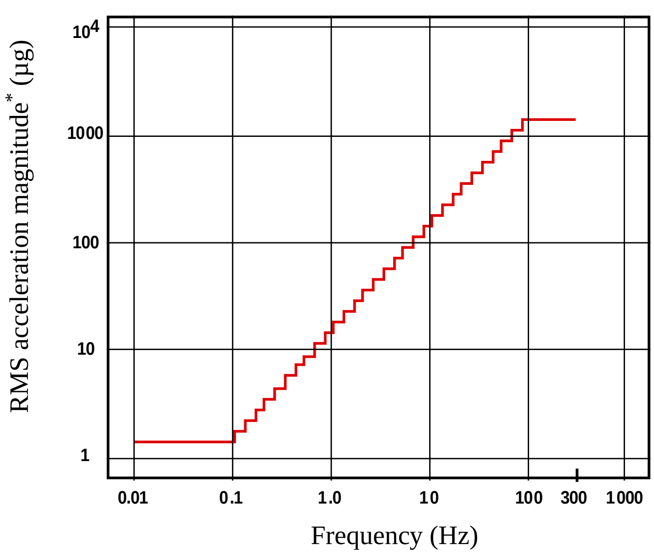
a. At the centers of the internal payload locations, a quasi–steady (<0.01 Hz) acceleration:
   (1) magnitude less than or equal to 1 micro–g, and
   (2) component perpendicular to the orbital average acceleration vector less than or equal to 0.2 micro–g; and

b. At the structural mounting interfaces to the internal payload locations:
   (1) a vibratory acceleration limit as defined in the figure below,
   (2) a transient acceleration limit for individual transient disturbance sources less than or equal to 1000 micro–g per axis, and
   (3) an integrated transient acceleration limit for individual transient disturbance sources less than or equal to 10 micro–g seconds per axis over any 10 second interval.

The Space Station shall monitor and record the microgravity environment at selected locations.

Vibratory

Transient



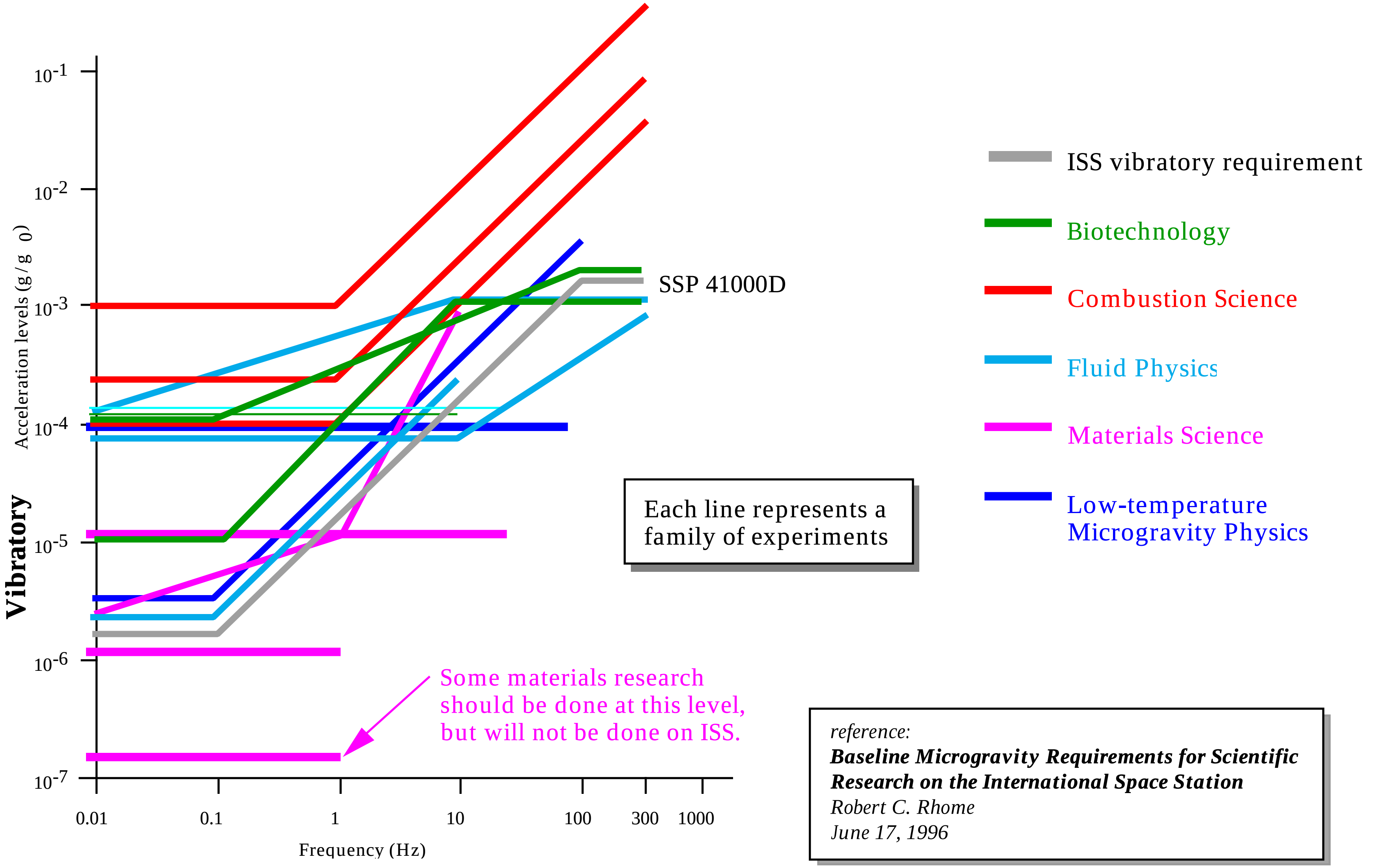
for $0.01 \le f \le 0.1$ Hz : $a \le 1.6$ µg
for $0.1 < f \le 100$ Hz : $a \le f \times 16$ µg
for $100 < f \le 300$ Hz : $a \le 1600$ µg
where : f = frequency
a = acceleration

*NOTE: Root-mean-square acceleration magnitude in $^1/_3$ octave bands averaged over 100 seconds.

Vibro–acoustic microgravity acceleration limits for the International Space Station vehicle

Derived from SSP41000E, July 3, 1996
(RD 12/16/99)

Science Discipline Microgravity Vibration Requirements



reference:
Baseline Microgravity Requirements for Scientific Research on the International Space Station
Robert C. Rhome
June 17, 1996

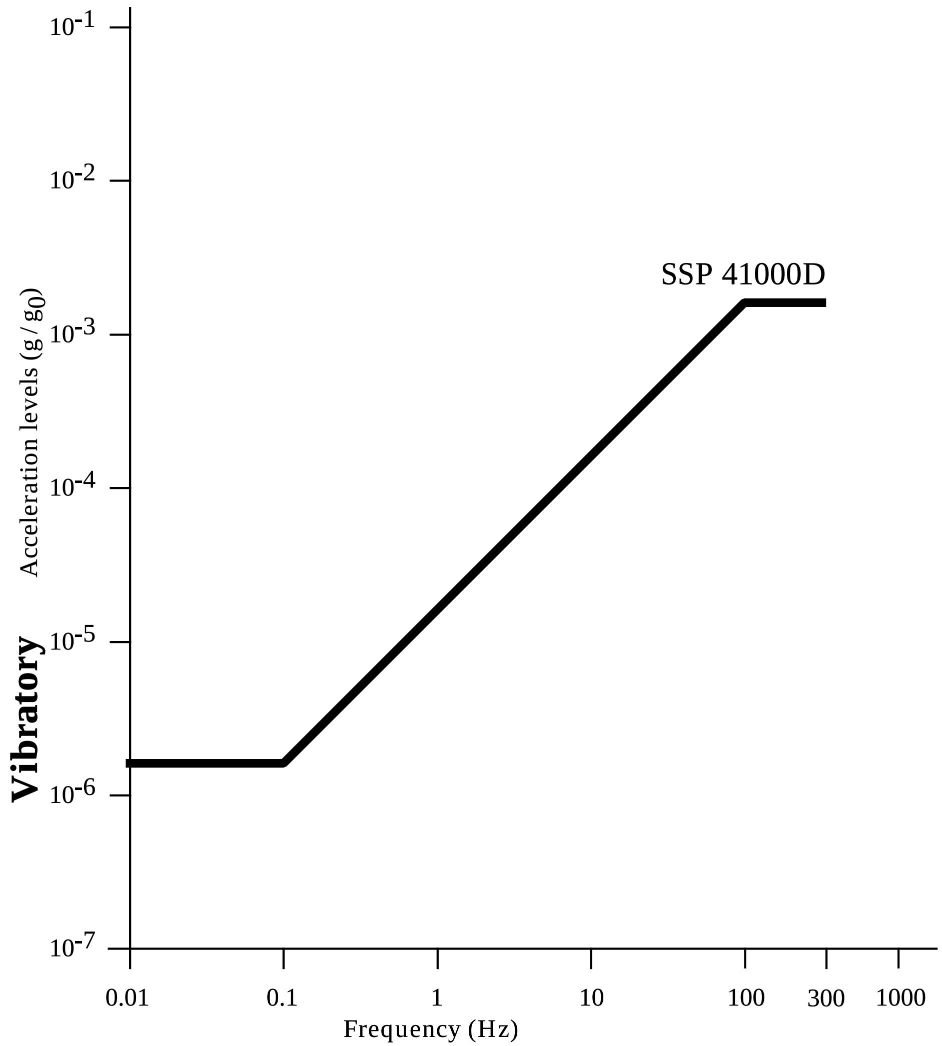
ISS Microgravity Requirements

Summary

Quasi-steady
- Steady state < f < 0.01 Hz
- $g \leq 1\ \mu g_{rms}$
- Stability: perpendicular $g \leq 0.2\ \mu g_{rms}$

Vibratory
- Levels in figure at structural mounting interfaces
- RMS acceleration magnitude in one-third octave averaged over 100 seconds
- Does not include crew disturbances

Transient
- $g \leq 1000\ \mu g$ per axis
- $g \leq 10\ \mu g$-sec per axis (integrated over 10 sec)



RD 2/5/97

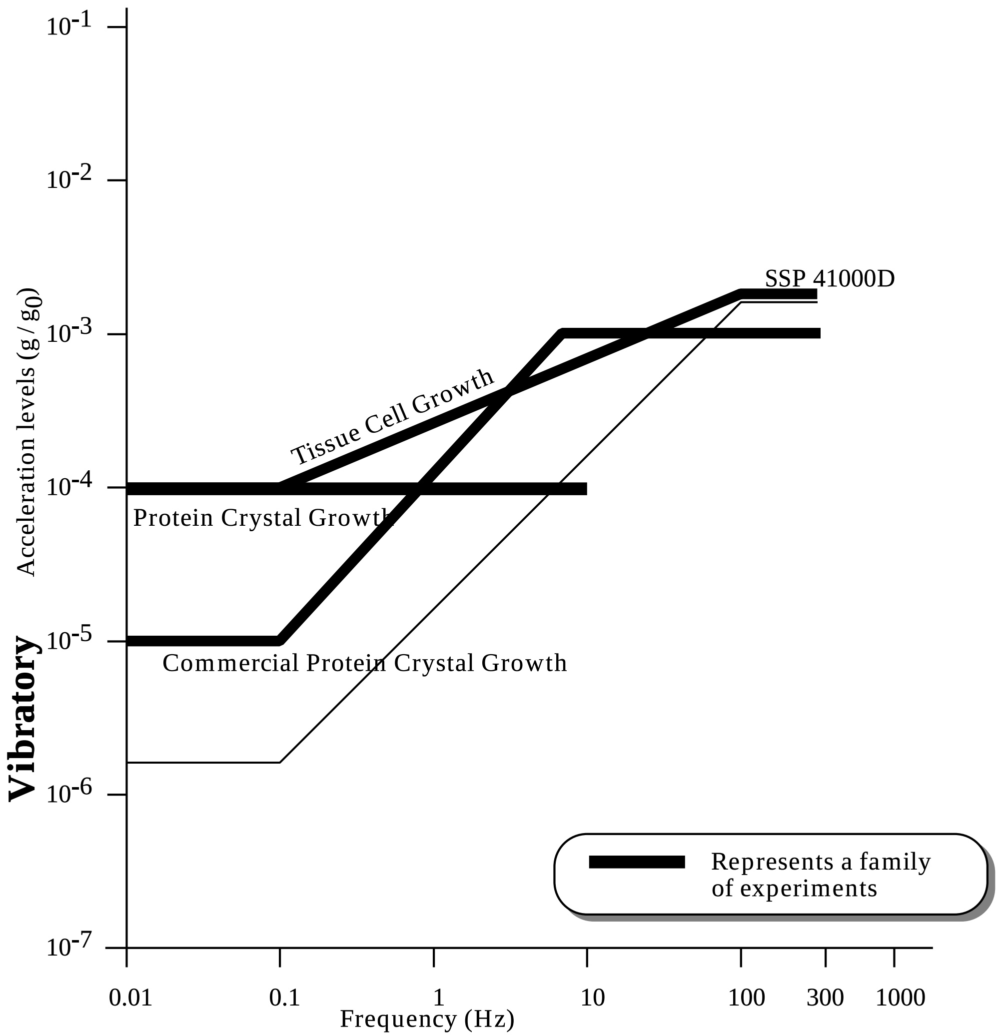
Biotechnology

Quasi-steady
- Not a major concern (10^{-3} to 10^{-4} g_o)

Vibratory
- Impact at higher frequencies of the desired operating level

Transient
- Primary concern is for large scale accelerations, such as Orbital Maneuvering System engines and crew disturbances

Rationale
- Large disturbances cause nucleations to occur in multiple sites destroying single crystal formation



Combustion Science

Quasi-steady

- Not a major concern (10^{-4} g_o)

Vibratory

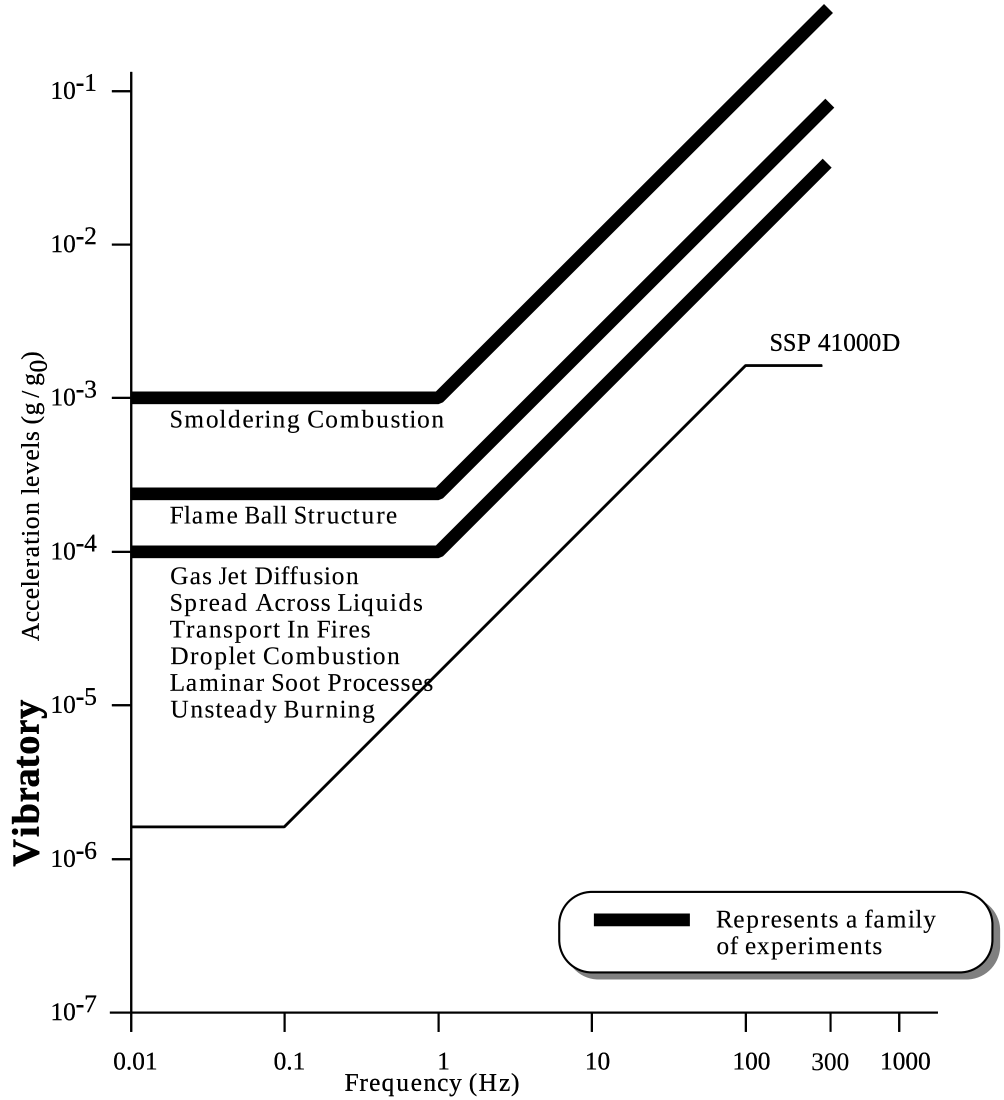
- Typically low acceleration levels at low frequencies (< 1 Hz) disturb experiments
- Most experiments are above the ISS requirement curve but some are below the expected environment
- Low frequency g-jitter has been observed repeatedly to affect the combustion characteristics of a variety of flames, e.g., candle, gas jet, flame balls, etc.
  ref: Dr. H. Ross / NASA LeRC

Transient

- Tolerable for most experiments with time and magnitude restrictions on the disturbance

Rationale

- Microgravity conditions allow:
  - isolation of gravity-driven mechanisms;
  - influence of transport phenomena
  - creation of symmetry and / or boundary & initial conditions
  - new diagnostic probing or testing of similitude
- Microgravity environment has attracted widespread external peer advocacy for combustion science in space



Fluid Physics

Quasi-steady

- Quasi-steady accelerations disturb most fluid experiments (2X10^{-6} g_o)

Vibratory

- Mid-range frequencies of expected environment will disturb fluid free surface experiments
- Some experiments require environment at lower levels than the ISS requirements curve

  e.g. Thin Film Fluid Flows at Menisci
- Surface Tension Driven Convection Experiment experienced surface distortion due to g-jitter frequently throughout the USML-2 mission

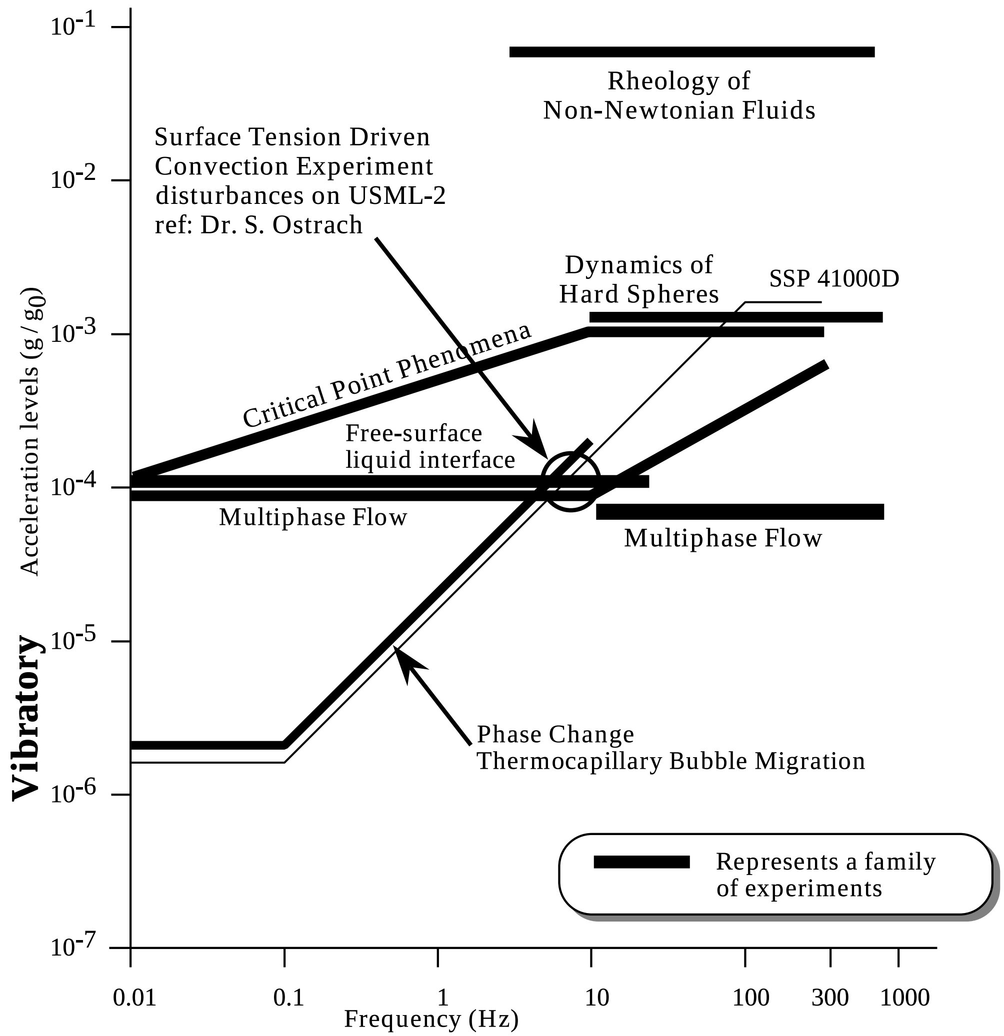
  ref: Dr. S. Ostrach / CWRU

Transient

- Transients disturb fluid experiments with lower viscosity fluids

Rationale

- Accelerations above a threshold cause interface instability, density settling, and density-driven convection & mixing



RD 2/5/97

Fundamental Physics

Quasi-steady
- A large quasi-steady level will destroy sample uniformity of critical fluid

Vibratory
- Primary concern is vibratory heating of sample and destruction of sample uniformity

Transient
- Primary concern is vibratory heating of sample and destruction of sample uniformity

Rationale
- Low temperature physics experiments rely on establishment of highly uniform sample in microgravity

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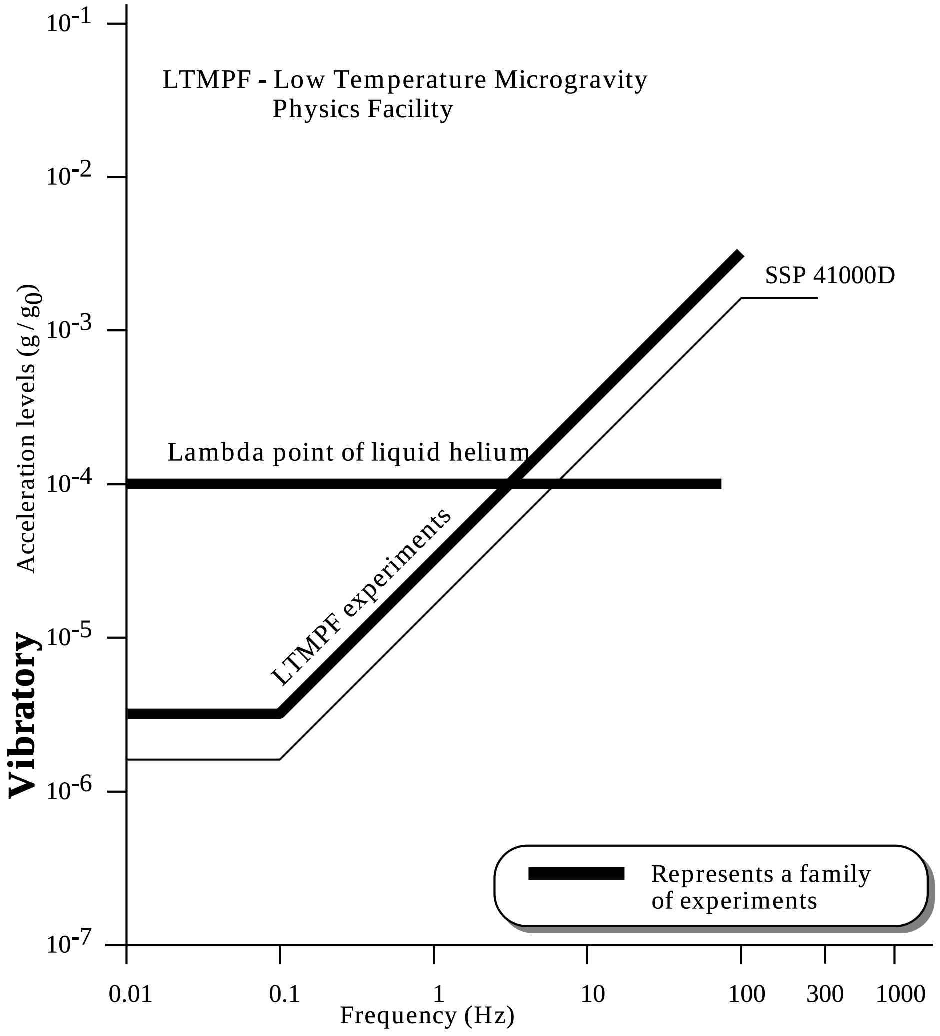
- NOTE: Many of these experiments are expected to be operated on the JEM-EF



RD 2/5/97

Materials Science

Quasi-steady

- Some samples and processes require very low quasi-steady acceleration levels (a < 0.1 micro-g)
  e.g., Stoke's settling, Bridgman growth, Float zone
- Residual acceleration direction and stability are important factors for crystallization processes
- A Crystal Growth Furnace sample was withdrawn from USML-2 due to a change in Orbiter attitude just before launch
  ref: Dr. S. Lehoczky / NASA MSFC

Vibratory

- Disturbances in various frequency ranges disturb experiments involving molten samples, suspended samples, etc.

Transient

- Some processes are very susceptible to transients such as thruster firings
- MEPHISTO (USMP-1 & USMP-3) experienced effects which lasted minutes from single thruster firings (0.01 g for 10 - 25 seconds)

Rationale

- Accelerations above a threshold cause thermo-solutal convection and interface instability