

# Microgravity Environment Interpretation Tutorial

## GLOSSARY

### A

**acceleration**

the rate at which an object's velocity changes with time

**active vibration isolation**

see **vibration isolation - active**

**aliasing**

a computational artifact inherent in all digital signal processing which has been preceded by an analog-to-digital conversion; it occurs when sampling an analog signal at points further apart than  $1/(2B)$ , where B is the bandwidth (in Hertz) of the signal being sampled, resulting in high frequency data content manifesting itself as errors at low frequencies; the only practical way to avoid aliasing errors in digital signal processing is by removing (e.g. by filtering) data with spectral content above the highest frequency of interest prior to the analog-to-digital conversion

**analog signal**

a signal defined over all time with infinite precision; a continuous-time, continuous-amplitude signal

**anti-alias filtering**

lowpass filtering of an analog signal to reduce the effects of aliasing

**ARIS**

Active Rack Isolation System for the International Space Station

**ASTRE**

Accelerometre Spatiale Triaxiale Electrostatique sensor of the Microgravity Measurement Assembly

**atmospheric drag**

deceleration of a vehicle caused by friction (drag) with the atmosphere

**attenuation**

a measure of motion transmitted between two systems defined as the ratio of the isolated system motion to the support structure motion

**attitude maintenance**

a condition of an orbital vehicle in which attitude control is maintained

### B

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### **body coordinate system**

a right-handed, orthogonal coordinate system with the  $+X_b$  axis extending forward (through the Orbiter nose) and the  $+Z_b$  axis extending downward through the Orbiter belly; the  $+Y_b$  axis extends to starboard

## C

### **center of gravity**

the balance point of an object in a steady gravitational (or acceleration) field

### **center of mass**

the centroid of the distributed mass of an article (e.g., a spacecraft)

### **Control Unit (CU)**

the central component of the SAMS-II instrument on the ISS

### **cumulative RMS acceleration vs. frequency**

a plot of the cumulative root-mean-square acceleration versus frequency quantifies the contributions of spectral components at and below a given frequency to the overall root-mean-square acceleration level for the time frame of interest

### **cutoff frequency ( $f_c$ )**

frequency above which filtering is performed; highest frequency of interest

## D

### **DC**

electrical acronym for Direct Current that has been generalized to mean average or steady value

### **deadband**

allowable angular displacement from the desired flight mode, usually between 0.5 and 3 degrees; thruster firings are required for attitude control when the carrier exceeds the deadband

### **digital signal**

a signal defined only at sampling times with finite precision; a discrete-time, discrete-amplitude signal

### **discrete Fourier transform (DFT)**

discrete-time implementation of Fourier transform (see **Fourier transform**)

### **dither**

vibration employed in some mechanical systems to avoid stiction and to ensure smooth motion

### **drop facility**

research facility that creates a microgravity environment by permitting experiments to freefall through an enclosed vertical tube or shaft

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### E

**encoding**

assigning unique (binary) codes to quantized samples

**ergometer**

a bicycle-type device used by crew members to maintain their physical fitness during a mission by means of pedaling

### F

**fast Fourier transform (FFT)**

discrete-time implementation of Fourier transform that speeds computation when an integer power of two number of points is used (see **Fourier transform**)

**flight mode**

attitude of the carrier with respect to the earth; expressed in terms of the Orbiter body axes, local vertical and velocity vector, e.g., -ZLV,+YVV

**Fourier transform**

a mathematical transform which resolves a time series into the sum of a DC (average) component and a series of sinusoids of different amplitude and frequency

**free drift**

a condition of an orbital vehicle in which attitude control is disabled

**free-flyer**

an unmanned orbiting spacecraft

**frequency resolution ( $\Delta f$ )**

spacing in frequency between consecutive data points; limits ability to resolve adjacent spectral peaks (note  $dF=\Delta f$ )

**fundamental frequency**

the lowest (base) frequency of a signal

### G

**g**

an acceleration equal to Earth's gravitational acceleration at sea level (nominally 9.8 m/sec<sup>2</sup>)

**g-jitter**

see **microgravity environment**

**g-LIMIT**

GLovebox Integrated Microgravity Isolation Technology microgravity vibration isolation system for the Microgravity Science Glovebox; developed by McDAC and NASA MSFC

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## GLOSSARY

### **g vs. time plot**

a two-dimensional graph, which shows acceleration magnitude versus time

### **gravity gradient effects**

the residual acceleration imposed by an off-center of mass location on an orbiting vehicle

## H

### **harmonic**

a frequency which is an integer multiple of the fundamental frequency

### **HiRAP**

High Resolution Accelerometer Package, an accelerometer managed by NASA JSC for use on the International Space Station as a component of MAMS

## I

### **Interim Control Unit (ICU)**

an initial central component of the SAMS-II instrument on the ISS

### **International Space Station (ISS) Program**

a cooperative venture between international partners to build a large orbiting laboratory in space

### **interval average**

a calculation method which averages a time interval of data points and produces one average value for the time interval

## J

### **Japanese Experiment Module (JEM)**

a module to be provided by NASDA for the ISS

## K

### **Ku band antenna**

a communication antenna attached to the forward wall of the Shuttle cargo bay; this antenna typically operates with a 17 Hz dither vibration

## L

### **life support systems**

collection of pumps, valves, fans, etc. to provide circulation of vital materials (e.g. air, water) to the crew and other living organisms in an orbital spacecraft

**LV / LH / VV**

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local vertical, local horizontal, velocity vector; these may be used in specifying the attitude of an orbital vehicle

## M

### **MAMS**

Microgravity Acceleration Measurement System, an accelerometer managed by NASA JSC for use on the International Space Station

### **mg (milli-g)**

an acceleration equal to one-thousandth of Earth's gravitational acceleration at sea level

### **µg (micro-g)**

an acceleration equal to one-millionth of Earth's gravitational acceleration at sea level

### **microgravity environment**

an environment in which the effects of gravity are small compared to those experienced on Earth; a complex combination of accelerations typically present on an orbiting spacecraft or ground-based carrier (such as drop facility, parabolic flight aircraft, or sounding rocket); comprised of quasi-steady, oscillatory, and transient accelerations; historically referred to as g-jitter and residual acceleration; also not zero-gravity

### **middeck**

center deck of the Shuttle crew compartment which provides crew accommodations and contains three avionics equipment bays; small payloads may be accommodated in the middeck

### **MIM**

Microgravity Isolation Mount vibration isolation system developed by the Canadian Space Agency

### **Mir Space Station**

Russia's space station launched February 20, 1986; its name means peace or world in Russian; it is a manned, modular, permanent, and multi-mission station

### **mission elapsed time (MET)**

time basis for Shuttle missions; MET begins at zero days, zero hours, zero minutes, zero seconds at the time of Shuttle lift-off at launch

### **MMA**

Microgravity Measurement Assembly, an accelerometer managed by ESTEC/ESA for use on the Shuttle

### **MMD**

Microgravity Measuring Device, an accelerometer managed by NASA JSC for use on the Shuttle

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## GLOSSARY

### **MPSS**

Mission Peculiar Equipment Support Structure; experiment carrier mounted in the Shuttle cargo bay

## N

### **NASDA**

National Space Development Agency of Japan; Japan's space agency

### **Nyquist criteria**

sampling rate must be at least twice that of the highest frequency contained in the signal of interest

### **Nyquist frequency ( $f_N$ )**

highest resolvable frequency; half the sampling rate ( $f_N = f_s/2$ )

## O

### **OARE**

Orbital Acceleration Research Experiment, a low-frequency accelerometer managed by NASA Glenn for use on Shuttle

### **one third octave band RMS acceleration vs. frequency**

a plot of one third octave band root-mean-square acceleration versus frequency that quantifies the spectral content in proportional bandwidth frequency bands for a given time interval of interest (100 seconds for ISS vibratory requirements)

### **Orbital Acceleration Research Experiment (OARE)**

an accelerometer managed by NASA Glenn for use on Shuttle; measures acceleration in the quasi-steady regime

### **Orbital Maneuvering System (OMS)**

provides the thrust for orbit insertion, orbit circularization, orbit transfer, rendezvous, de-orbit, launch abort to orbit and launch abort once around

### **Orbiter**

a component of the National Space Transportation System (NSTS); individual vehicles are known by their Orbiter Vehicle (OV) numbers (e.g. OV-105); commonly referred to as the Shuttle (see **Space Shuttle**)

### **oscillatory**

a signal that varies above and below a mean value; acceleration components which are periodic in nature; for microgravity applications, accelerations with a frequency greater than 0.01 Hz; sources of oscillatory accelerations include: structural resonance, machinery operation, and crew activity

## P

### **parabolic flight aircraft**

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## GLOSSARY

research aircraft which creates microgravity conditions by flying a parabolic trajectory; about 40 periods of 15 to 20 seconds of microgravity can be flown during a single flight

### **Parseval's theorem**

equivalence between the root-mean-square value computed from the time domain signal to that computed from the frequency domain by taking the square root of the integral of the power spectral density

### **passive vibration isolation**

see **vibration isolation - passive**

### **performance**

a measure of how well a system achieves specified goals

### **power spectral density (PSD)**

a function that quantifies the distribution of power in a signal with respect to frequency

### **Primary Reaction Control System (PRCS)**

the RCS normally used for Shuttle maneuvers; PRCS jets provide 870 pounds of vacuum thrust each

### **Principal Component Spectral Analysis (PCSA)**

a variation of spectral averaging and spectrogram analyses, which employs a peak detection algorithm to accumulate magnitude and frequency values of dominant or persistent spectral contributors and display them via a 2-D histogram

### **Principal Investigator Microgravity Services (PIMS)**

a project at NASA Glenn which analyzes microgravity environment data to support Principal Investigators and to characterize the microgravity environment of microgravity carriers

## Q

### **QSAM**

Quasi-Steady Acceleration Measurement, an accelerometer managed by DLR for use on the Shuttle and FOTON free flyer

### **quantization**

digitization; converting discrete-time, continuous-amplitude signal to discrete-time, discrete-amplitude signal

### **quasi-steady**

acceleration components which are unchanging or change very slowly; for microgravity applications, typical variations occurs on the order of an orbital period or more (approximately 90 minutes); sources of quasi-steady accelerations include aerodynamic drag, gravity gradient effects, and rotational effects

### **Quasi-steady Three-dimensional Histogram (QTH)**

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a histogram technique which shows the variation of three dimensional accelerations in three two-dimensional plots

## R

### **rack level isolation**

the application of isolation to an entire rack structure; this is the standard design approach for the International Space Station

### **Reaction Control System (RCS)**

provides the thrust for Shuttle attitude (rotational) maneuvers (pitch, yaw and roll) and for small velocity changes along the orbiter axis (translation maneuvers)

### **reference frame**

a location against which an object's changes in position are observed; a set of lines or surfaces used for defining coordinates that define positions, directions, velocities, etc.

### **residual acceleration**

see **microgravity environment**

### **RTS-EE**

remote triaxial sensor head - electronics enclosure (SAMS-II)

### **RTS-SE**

remote triaxial sensor head - sensor enclosure (SAMS-II)

## S

### **sample rate ( $f_s$ )**

rate at which analog signal is sampled (samples per second)

### **sampling**

discretization; converting an analog signal to a discrete-time, continuous-amplitude signal

### **SAMS**

Space Acceleration Measurement System, an accelerometer managed by NASA Glenn for use on Shuttle, Mir, and KC-135

### **SAMS-FF**

SAMS for Free Flyers, an accelerometer managed by NASA Glenn for use on sounding rockets, Shuttle, and KC-135

### **SAMS-II**

a second generation SAMS, an accelerometer managed by NASA Glenn for use on the ISS

### **SIMO water dump**



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## GLOSSARY

an action taken by the Shuttle when waste water and supply water are simultaneously vented out the port side of the fuselage

### **smearing**

an obscuring of the exact nature of frequency domain data, that results from the spectral averaging of non-stationary data

### **sounding rocket**

rocket which follows suborbital, parabolic path; used by microgravity researchers to achieve several minutes of reduced gravity conditions

### **Space Shuttle**

also known as the National Space Transportation System (NSTS) and Space Transportation System (STS); this system is composed of the Orbiter vehicles, the external tank, and the solid rocket boosters

### **SPACEHAB module**

a commercial pressurized laboratory module carried in the Shuttle cargo bay with shirt-sleeve working conditions for the crew

### **Spacelab module**

pressurized laboratory module carried in the Shuttle cargo bay with shirt-sleeve working conditions for the crew

### **spectral averaging**

averaging of power spectral densities (Welch's method) as a means of noise suppression

### **spectral leakage**

a by-product of convolution that limits ability to resolve closely-spaced spectral peaks

### **spectrogram plot**

a two-dimensional graph, which shows power spectral density magnitude (as color) versus frequency versus time; In other words, it displays how the power spectrum varies with time

### **stability margin**

a measure of how much uncertainty or variation can be tolerated with system stability maintained

### **STABLE**

Suppression of Transient Accelerations By LEvitation microgravity vibration isolation system developed by McDAC

### **station keeping**

see **attitude maintenance**

### **structural coordinate system**

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a right-handed, orthogonal coordinate system with the  $+X_0$  axis extending aft (through the Orbiter tail) and the  $+Z_0$  axis extending upward out of the Orbiter payload bay; the  $+Y_0$  axis extends to starboard

**structural (natural) frequency**

the lowest resonant frequency of a mechanical system

**sub-rack level isolation**

the application of isolation to a specific payload within a rack or some other configuration

**supply water dump**

an action taken by the Shuttle when supply water is vented out the port side of the fuselage

## T

**Telescience Support Center (TSC)**

a user's operation center remote from but connected to a primary operations center; full voice communication and mission video and data are available in a TSC

**temporal resolution (dT)**

spacing in time between consecutive PSDs on a spectrogram; limits ability to resolve temporal changes (note dT does not equal  $\Delta t$ )

**tolerance criterion**

least stringent environment specification which will allow a successful experiment to take place; in this context, it is given in terms of the level of acceleration, including its maximum and/or minimum magnitude, orientation, frequency, duration, etc.

**transient**

acceleration disturbances which are impulsive (short duration, high amplitude) in nature; sources of transient accelerations include: thruster firings, crew activity, and docking

**transmissibility function**

the transfer function that relates the magnitude of the acceleration (or position) response of a system to the acceleration (or position) of the support structure

**treadmill**

an exercise device used by crew members to maintain their physical fitness during a mission by means of walking and running

**trim mean filter (a.k.a. trimmean filter, trimmed mean filter)**

a filtering technique typically applied to low frequency data which is intended to mitigate the effects of higher amplitude, higher frequency accelerations

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## GLOSSARY

### U

#### **Utilization Flight (UF)**

a Shuttle mission to the ISS which carries re-supply material and/or experiment apparatus

### V

#### **Vernier Reaction Control System (VRCS)**

the RCS are normally used for finite maneuvers and station keeping (long-time attitude hold); VRCS jets provide 24 pounds of vacuum thrust each

#### **vibration isolation**

the reduction of vibration transmitted to/from an object from/to the surrounding structure

#### **vibration isolation - active**

the use of active mechanical devices such as motors, actuators, and sensors, to reduce the transmission of vibrations by applying forces to cancel the measured motion

#### **vibration isolation - passive**

the use of passive mechanical devices such as springs and dampers to reduce the transmission of vibrations

### W

#### **waste water dump**

an action taken by the Shuttle when waste water is vented out the port side of the fuselage

### X

#### **X<sub>b</sub>, Y<sub>b</sub>, Z<sub>b</sub>**

components of the Orbiter body coordinate system (see **body coordinate system**)

#### **X<sub>0</sub>, Y<sub>0</sub>, Z<sub>0</sub>**

components of the Orbiter structural coordinate system (see **structural coordinate system**)

### Y

### Z

**zero-gravity or zero-g**

# **Microgravity Environment Interpretation Tutorial**

## **GLOSSARY**

term historically used to describe the effect of the severely reduced gravity environment in a microgravity carrier, such as an orbiting spacecraft or a drop tower (see **microgravity environment**)

### ***NUMERIC***

#### **3-DMA**

Three Dimensional Microgravity Accelerometer, an accelerometer managed by the University of Alabama in Huntsville for use on the Shuttle and sounding rockets