The NASA Glenn Acceleration Measurement Projects

Two Decades and Counting of Acceleration Measurement and Support

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CASIS Request for Information

The intent of this RFI is to identify potential implementation partners, service providers and other organizations that can provide support services, which may include project-specific integration and operations support to ISS NL researchers in response to specific requirements as they emerge. **These organizations can**:

- Interface with CASIS and the NASA ISS payloads office on behalf of the researcher. ✓ **YES.**
- Identify and/or design flight-certified hardware to support research objectives. ✓ **YES.**
- Conduct required testing and demonstration of payloads to verify science and hardware requirements. ✓ **YES.**
- Develop and submit documentation as required by CASIS and the NASA payloads office. ✓ **YES.**
- Support NASA bench reviews and crew training. ✓ **YES.**
- Coordinate ground-analog research requirements and post-processing activities. ✓ **YES.**
- Conduct data analysis and/or other support activities per user needs. ✓ **YES.**
- Provide technical support for STEM and outreach activities associated with ISS NL payloads. ✓ **YES.**
- Get Microsoft PowerPoint to line up bulleted lists with check-mark bulleted lists without too much of a hassle. X no**.**

Outline

1. Acronyms
2. Science support/customers
3. Highlights of a microgravity community feedback model
4. Timeline of acceleration system deployment
5. Location of acceleration sensor deployment
6. SAMS mission support
7. How much acceleration data?
8. Characterization of microgravity environment/events
9. Impacts on microgravity science
10. Moving forward

ACRONYM	Definition
ATV	Automated Transfer Vehicle
CIR	Combustion Integrated Rack
DECLIC	DEvice for the study of Critical LIquids and Crystallization
FIR	Fluids Integrated Rack
GRC	Glenn Research Center
HiRAP	High Resolution Accelerometer Package
MAMS	Microgravity Acceleration Measurement System
MEIS	Marangoni Experiment in Space
NASA	National Aeronautics and Space Administration
OARE	Orbital Acceleration Research Experiment
OSS	OARE Sensor Subsystem
PIMS	Principal Investigator Microgravity Services
RTS	Remote Triaxial Sensor
SAMS	Space Acceleration Measurement System
SE	Sensor Enclosure
SODI	Selectable Optical Diagnostics Instrument
SOFBALL	Structure Of Flame Balls At Low Lewis-number
TSH-ES	Triaxial Sensor Head Ethernet Standalone

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Science Support/Customers

NASA's Physical Sciences Research Program conducts fundamental & applied research with experiments in various disciplines such as…

- **Fluid Physics**
- **Combustion Science**
- **Materials Science**
- **Fundamental Physics**

SAMS/MAMS were designed to support these various science disciplines and these instruments along with PIMS play an ongoing role in support of **vehicle/loads monitoring**

collaboration

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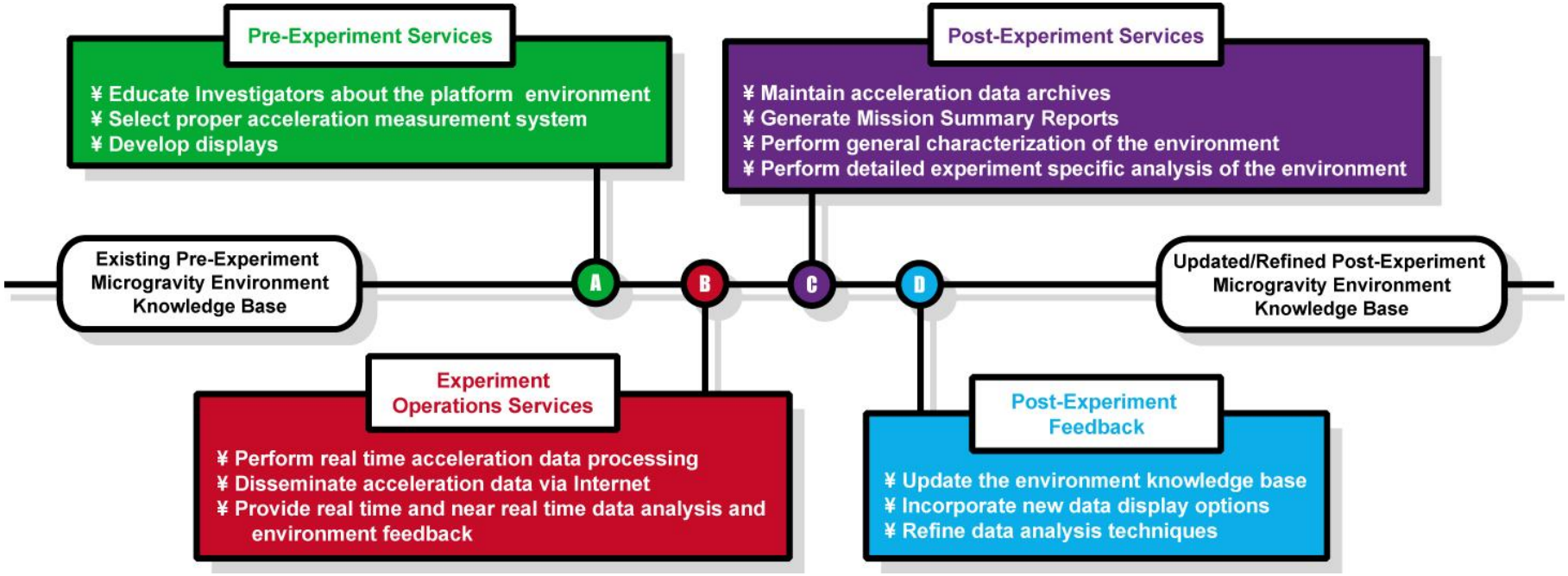
Highlights of Microgravity Community Feedback Model



HIGHLIGHTS

- **Real-Time Displays:** http://pims.grc.nasa.gov/html/PIMS_ISS_plots.html
- **Acceleration Data Archive:** http://pims.grc.nasa.gov/ftp/pad
- **Characterization Handbook:** http://pims.grc.nasa.gov/handbook

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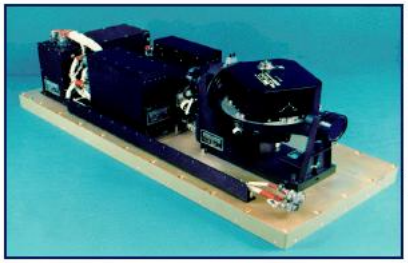
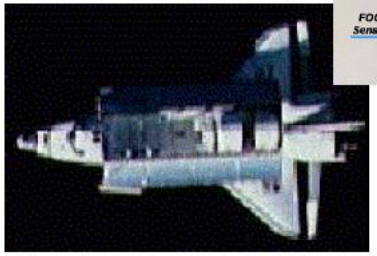
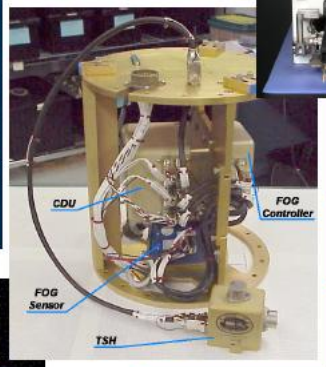
Timeline of NASA GRC System Deployment







SAMS TSH-ES (Compact Ethernet Standalone)
(0.01 to 400 Hz) Station Vibratory

SAMS RTS (Ethernet Distributed)
(0.01 to 400 Hz) Station Vibratory

MAMS HiRAP
(0.01 to 100 Hz) Station Vibratory

MAMS OSS
(DC to 1 Hz) Station Quasi-Steady

RRS (0.1 arc/s)
1 sounding rocket, 1 shuttle

TSH-FF (0.01 to 200 Hz)
3 sounding rocket, 2 shuttle

OARE (DC to 1Hz) - 12 shuttle flights

7 SAMS Units (0.01 to 100 Hz)
21 Shuttle/MIR Flights

SAMS Project Initiated

1986 1991 1994 1997 2000 2003 2006 2009 **2012** 2015 2018

YEAR

SAMS Shuttle Missions

SORTED BY CARRIER		
CARRIER		ACRONYM
Spacelab	Module	SLS-1
		IML-1
		USML-1
		SL-J
		IML-2
		USML-2
		LMS
		MSL-1
	MPESS	USMP-1
		USMP-2
		USMP-3
		USMP-4
SPACEHAB		SH-1
		SH-2
		SH-3
		SH-5
		SH-10
Middeck		STS-43
		ATLAS-3

SORTED BY DATE			
DATE	FLIGHT	ACRONYM	PAYLOAD
June 5-14, 1991	STS-40	SLS-1	1st Spacelab for Life Sciences
August 2-11, 1991	STS-43		TDRS deployment
January 22-30, 1992	STS-42	IML-1	1st International Microgravity Laboratory
June 25 - July 9, 1992	STS-50	USML-1	1st US Microgravity Laboratory
September 12-20, 1992	STS-47	SL-J	Japanese Spacelab
October 22 - November 1, 1992	STS-52	USMP-1	1st US Microgravity Payload
June 21 - July 1, 1993	STS-57	SH-1	1st SPACEHAB
February 3-11, 1994	STS-60	SH-2	2nd SPACEHAB
March 4-18, 1994	STS-62	USMP-2	2nd US Microgravity Payload
July 8-23, 1994	STS-65	IML-2	2nd International Microgravity Laboratory
November 3-14, 1994	STS-66	ATLAS-3	3rd Atmospheric Laboratory for Applications and Sciences
February 3-11, 1995	STS-63	SH-3	3rd SPACEHAB
October 20 - November 5, 1995	STS-73	USML-2	2nd US Microgravity Laboratory
February 22 - March 9, 1996	STS-75	USMP-3	3rd US Microgravity Payload
June 20 - July 7, 1996	STS-78	LMS	Life and Microgravity Spacelab
September 16-26, 1996	STS-79	SH-5	5th SPACEHAB, 4th Mir docking
April 4-8, 1997	STS-83	MSL-1	Microgravity Sciences Laboratory
July 1-17, 1997	STS-94	MSL-1R	Microgravity Sciences Laboratory Reflight
November 19 - December 5, 1997	STS-87	USMP-4	4th US Microgravity Payload
January 22-31, 1998	STS-89	SH-10	10th SPACEHAB, 8th Mir docking

Location of NASA GRC ISS Sensor Deployment

Collectively, SAMS & MAMS Sensors Have Been Mounted in 21 Unique Locations

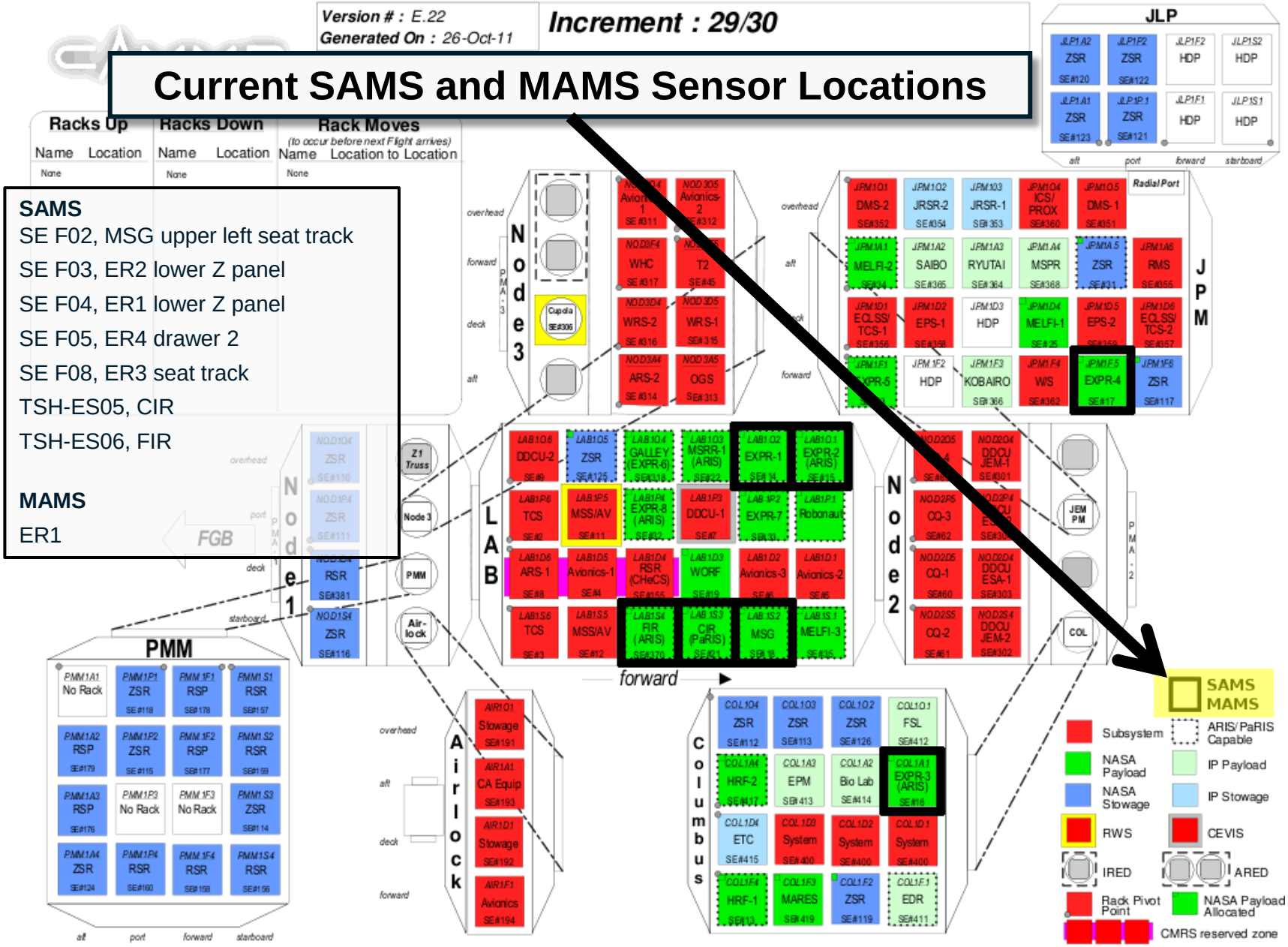
Current

system	coord_name	location_name	r_orient	p_orient	y_orient	x_location	y_location	z_location
MAMS	hirap	LAB1O2, ER1, Lockers 3,4	180	0	0	138.68	-16.18	142.35
MAMS	ossraw	LAB1O2, ER1, Lockers 3,4	90	0	0	135.28	-10.68	132.12
SAMS	121f02	LAB1S2, MSG, Upper Left Seat Track	0	0	90	161.95	40.39	157.64
SAMS	121f03	LAB1O1, ER2, Lower Z Panel	0	30	-90	191.54	-40.54	135.25
SAMS	121f04	LAB1O2, ER1, Lower Z Panel	0	30	-90	149.54	-40.54	135.25
SAMS	121f05	JPM1F5, ER4, Drawer 2	-90	-90	0	466.8	-292.06	214.58
SAMS	121f08	COL1A1, ER3, Seat Track near D1	0	0	180	371.17	193.43	165.75
SAMS	es05	LAB1S3, CIR, Front Panel	180	0	90	116.81	40.39	192.76
SAMS	es06	LAB1S4, FIR,	0	180	0	69.31	40.39	196.41

Previous

system	coord_name	location_name	r_orient	p_orient	y_orient	x_location	y_location	z_location
SAMS	es08	COL1F2, MSG, Ceiling Plate Y1-C3 Y2-D3	0	90	-90	475.71	235.22	160.27
SAMS	121f02	LAB1P3, CEVIS, Frame	0	0	-90	118.45	-38.36	170.57
SAMS	121f02	LAB1O2, ER1, Drawer 1	-90	0	-90	128.73	-23.53	144.15
SAMS	121f02	JPM1F3, TCQ, Lower Panel	180	-45	0	455.55	-227.69	229.07
SAMS	121f02	COL1D3, Forward Foot of FWED	90	-45	-90	395.08	287.99	232.22
SAMS	121f05	LAB1O1, ER2, Upper Z Panel	90	0	90	185.17	38.55	149.93
SAMS	121f08	LAB1S3, MSG, Ceiling Plate A2-A3	-90	90	0	115.21	53.41	160.98
SAMS	121f08	LAB1S3, MSG, Ceiling Plate D3-D2	90	90	0	87.99	55.19	160.98
SAMS	121f08	COL1A1, ER3, B2 Panel	0	180	0	374.17	166.19	157.03
SAMS	121f08	COL1O1, FSL, ODM Seat Track	0	90	0	434.37	183.25	147.01
SAMS	121f08	COL1D3, Seat Track near A3	0	-90	0	378.11	246.46	234.96
SAMS	es08	COL1F2, MSG, Ceiling Plage Y1-B1 Y2-A1	0	90	90	475.63	204.91	159.95

Current SAMS and MAMS Sensor Locations



SAMS Mission Support

Space Acceleration Measurement System

1991	SLS-1
	STS-43
1992	IML-1
	USML-1
	SL-J
	USMP-1
1993	SPACEHAB-1
1994	SPACEHAB-2
	USMP-2
	IML-2
	Mir Space Station
	STS-66
1995	Mir Space Station (SPACEHAB-3)
	USML-2
1996	Mir Space Station
	USMP-3
	LMS
	STS-79/Mir-4
1997	Mir Space Station
	MSL-1
	MSL-1R
	USMP-4
1998	Mir Space Station
	STS-89/Mir-8
	STS-91 (Mir Retrieval)
	STS-95 (HOST)
2001	STS-100 to ISS
2002	ISS
2003	ISS
	STS-107
2004	ISS
2005	ISS
2006	ISS
2007	ISS
2008	ISS
2009	ISS
2010	ISS
2011	ISS
2012	ISS

This slide courtesy of Richard DeLombard

SAMS keeps going and going and going . . . .

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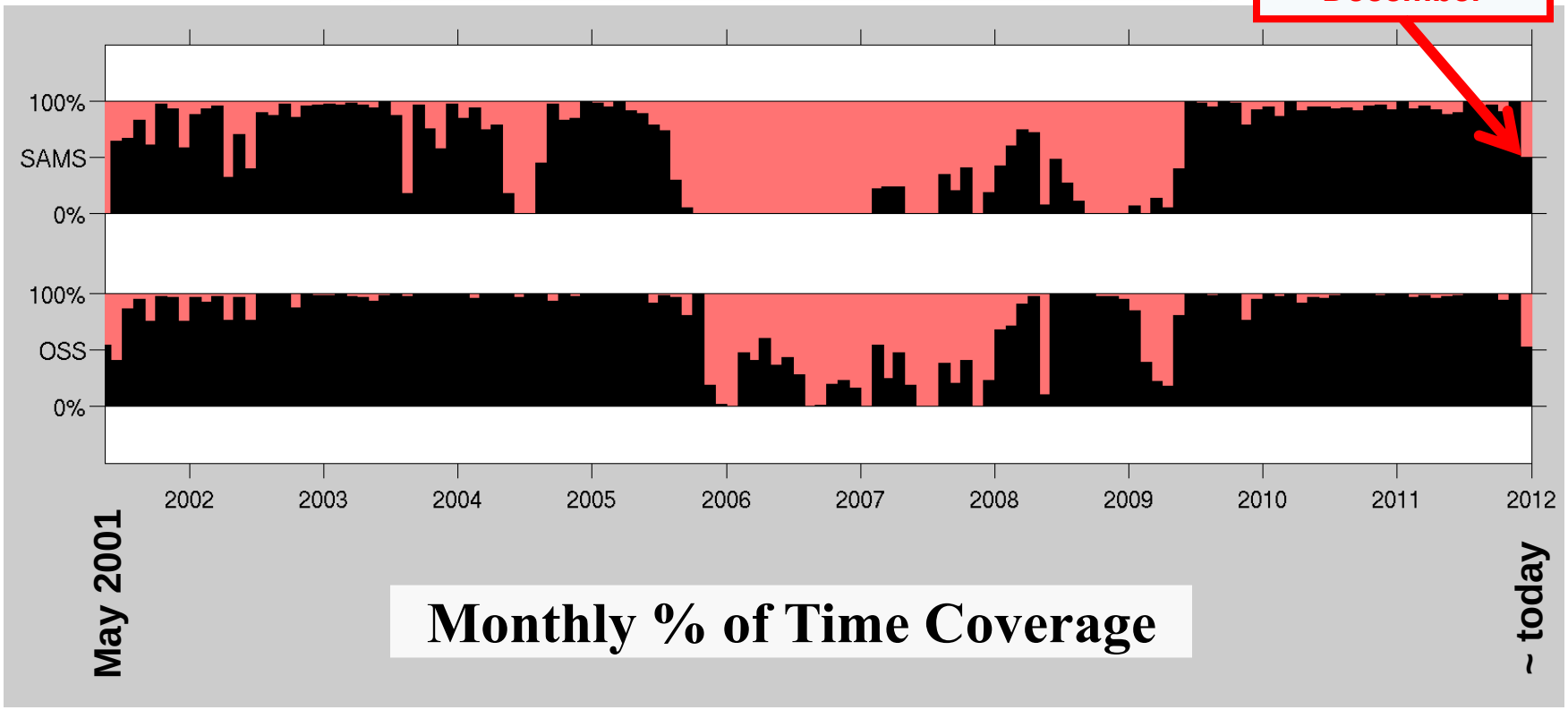
How Much Acceleration Data?

Since May of 2001 on the ISS, SAMS and MAMS have collected

*over **179,283 sensor-hours***

*more than **7 terabytes***

~50% in Dec. of 2011 b/c this slide was made about mid-December



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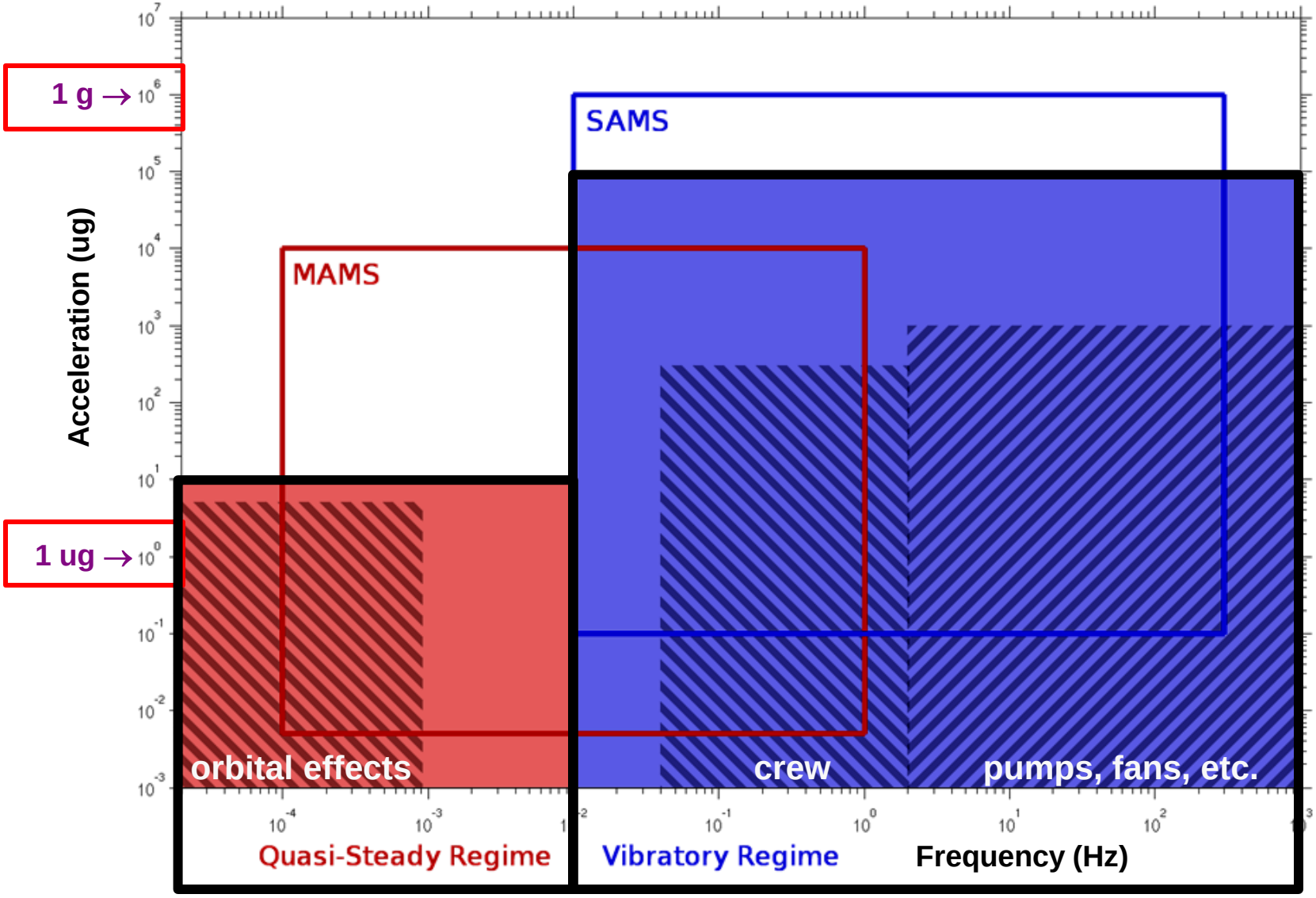
ZIN Technologies

General Characterization
Components of Microgravity Environment



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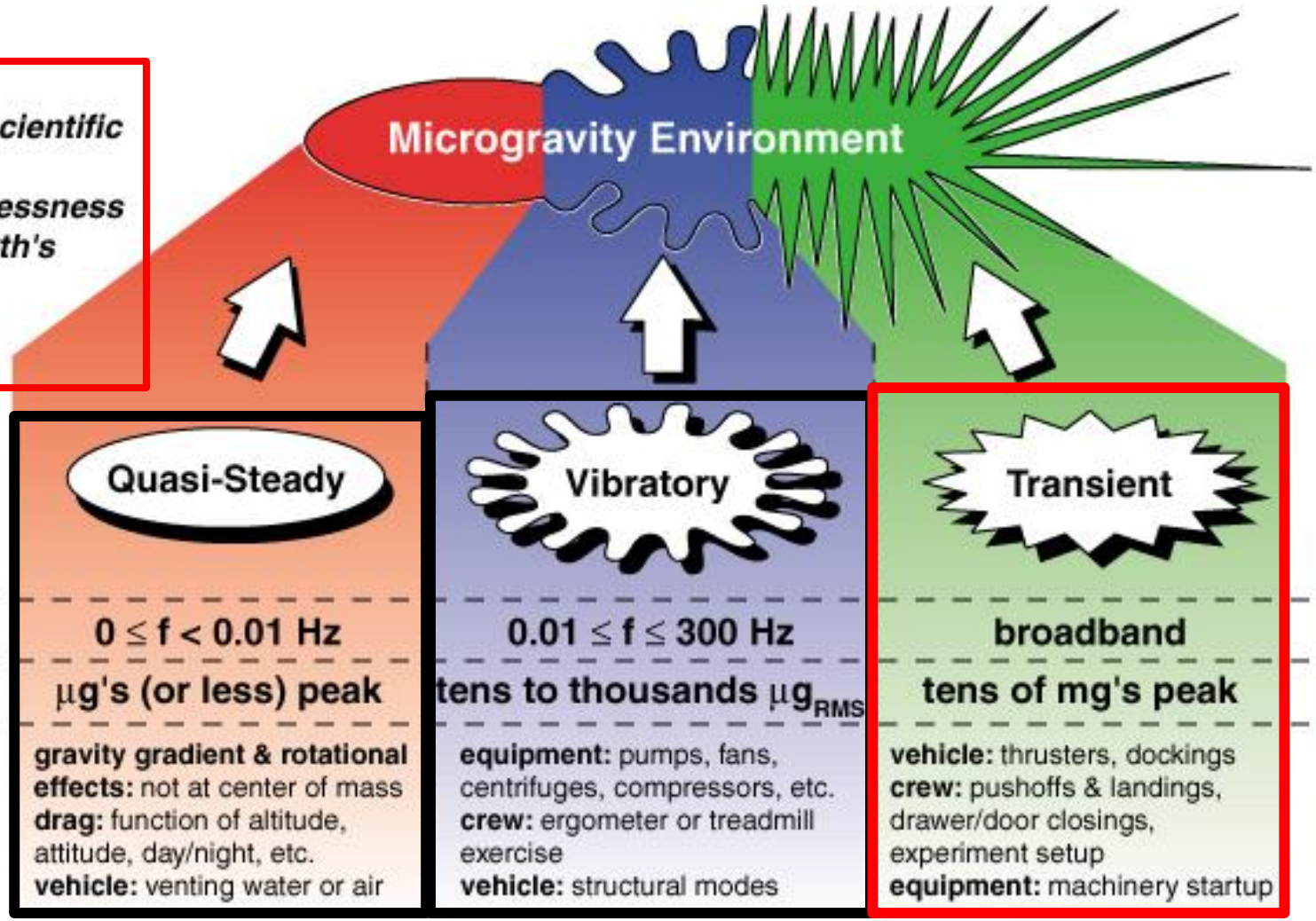
General Characterization
Components of Microgravity Environment

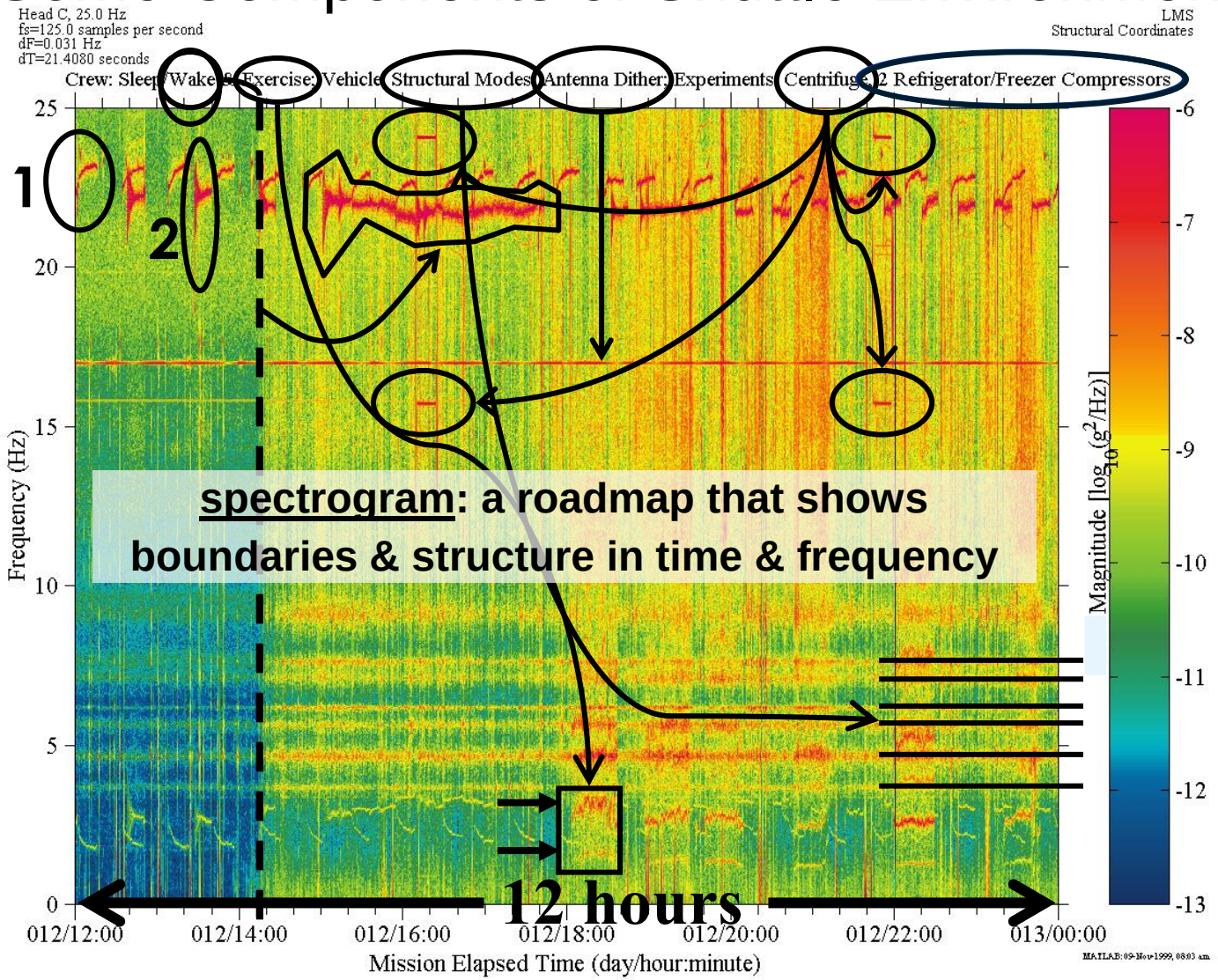
Microgravity is:
- ***a general label for scientific investigations that exploit near-weightlessness***
- ***one-millionth of Earth's normal gravity***
- ***a reduced gravity environment***



ZIN Technologies

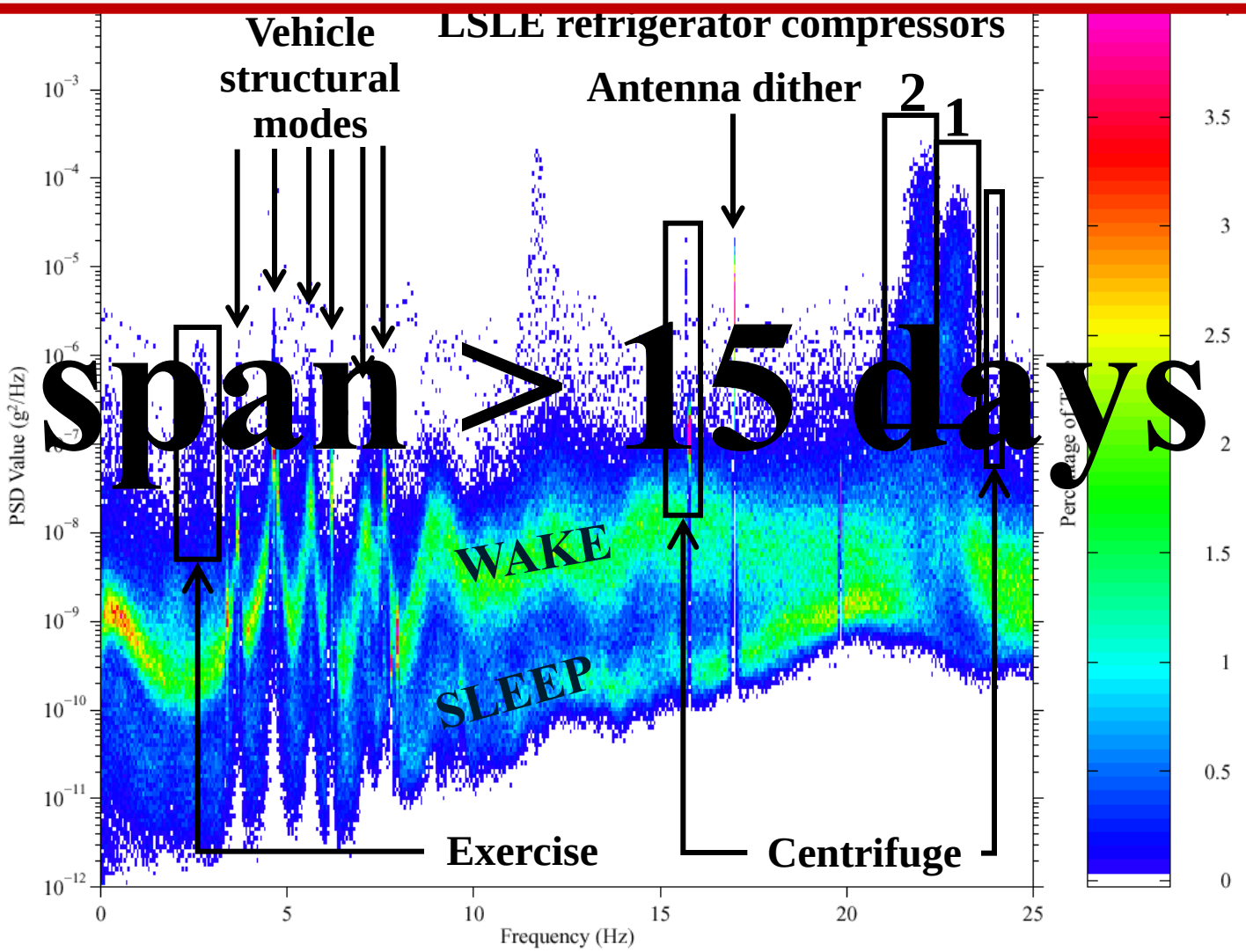
Basic Characterization
Some Components of Shuttle Environment

spectrogram: a roadmap that shows boundaries & structure in time & frequency



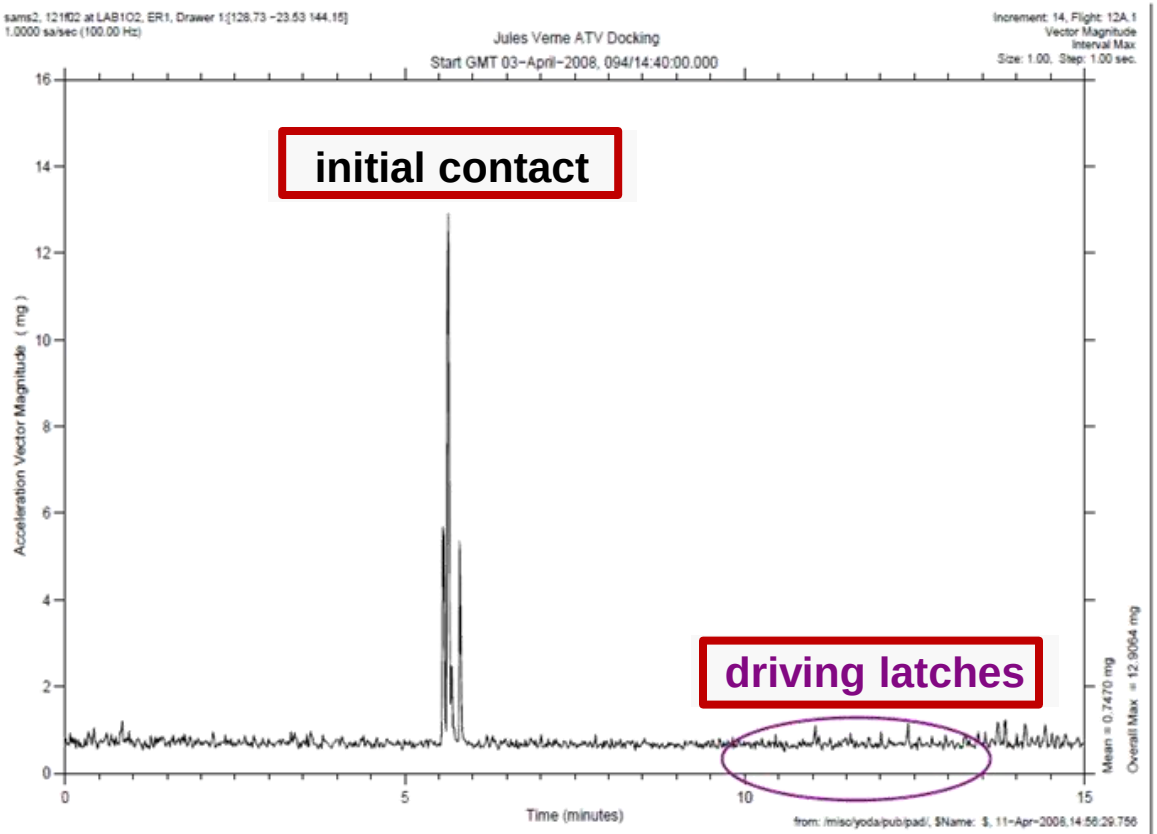
Summary Characterization

Principal Component Spectral Analysis serves to summarize acceleration spectrum



Detail Characterization ISS

Jules Verne ATV Docking
QUANTIFY



Microgravity Science Division

Glenn Research Center

PIMS ISS Acceleration Handbook
Date last modified 4/18/08

Description	
Sensor	121f02 250.0 sa/sec (100.00 Hz)
Location	LAB1O2, ER1, Drawer 1
Inc/Flight	Increment: 16, Flight: S15
Plot Type	spectrogram

NOTES:

- The ATV's initial contact with ISS occurs at approximately 6 minutes into the interval max plot.
- Peak magnitude of initial contact as measured by 121f02 was12.9 mg.
- Unlike shuttle dockings, the driving of the latches is not readily apparent in these plots. The oval calls out the time period where the driving of the latches occurred.

ATV Docking (Image from ESA Website)

Regime:	Vibratory
Category:	Vehicle
Source:	ATV Docking

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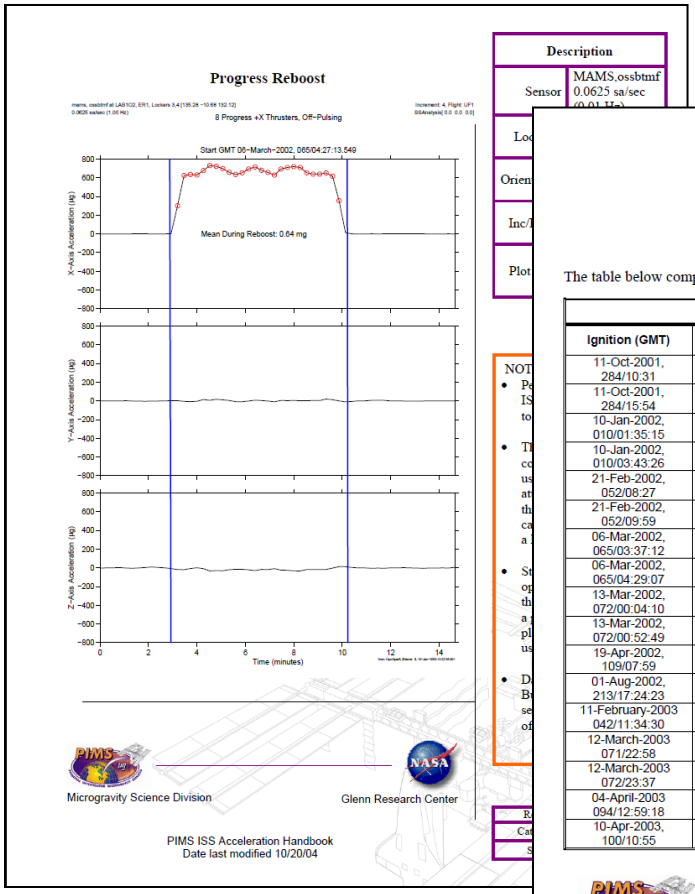
Detail Characterization ISS

Reboost



Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (0.01 Hz)
Loc	
Orien	
Inc/I	
Plot	

Progress Reboost

The table below compares average acceleration from vehicle data to the average acceleration calculated from MAMS

Reboost Information					Calculations from MAMS OSS data		
Ignition (GMT)	Comments	Δ V (m/sec)	Duration (sec)	ΔV/T (mg)	Duration (sec)	ΔV (m/sec)	X-Axis Mean (mg)
11-Oct-2001, 284/10:31	4 Progress +X Thrusters	4.7	1560	0.31	1,629.30	4.63	0.29
11-Oct-2001, 284/15:54	4 Progress +X Thrusters	4.5	1560	0.29	1,623.78	4.46	0.28
10-Jan-2002, 010/01:35:15	4 Progress +X Thrusters	5.4	1877	0.29	1,863.90	5.3	0.29
10-Jan-2002, 010/03:43:26	4 Progress +X Thrusters	4.8	1654	0.30	1,643.00	4.67	0.29
21-Feb-2002, 052/08:27	8 Progress +X Thrusters, Off-Pulsing	1.35	239	0.58	237.40	1.21	0.52
21-Feb-2002, 052/09:59	8 Progress +X Thrusters, Off-Pulsing	1.35	243	0.57	238.50	1.24	0.53
06-Mar-2002, 065/03:37:12	8 Progress +X Thrusters, Off-Pulsing	1.0	158.2	0.65	157.70	0.93	0.60*
06-Mar-2002, 065/04:29:07	8 Progress +X Thrusters, Off-Pulsing	2.5	395.1	0.65	398.80	2.5	0.64*
13-Mar-2002, 072/00:04:10	8 Progress +X Thrusters, Off-Pulsing	2.2	319	0.70	300.30	1.8	0.61*
13-Mar-2002, 072/00:52:49	8 Progress +X Thrusters, Off-Pulsing	4.0	636.1	0.64	609.70	3.94	0.66*
19-Apr-2002, 109/07:59	8 Progress +X Thrusters, Off-Pulsing	0.73	118	0.63	142.70	0.6	0.43
01-Aug-2002, 213/17:24:23	8 Progress +X Thrusters, Off-Pulsing	4.3	760	0.58	761.10	4.18	0.56
11-February-2003 042/11:34:30	8 Progress +X Thrusters, Off-Pulsing	5.1	~1200	0.43	1168	4.01	0.35
12-March-2003 071/22:58	Progress Manifold 1 4 Progress +X Thrusters	1.38	597	0.24	634	1.3	0.21
12-March-2003 072/23:37	Progress Manifold 2 4 Progress +X Thrusters	0.37	198	0.19	219	0.3	0.14
04-April-2003 094/12:59:18	8 Progress +X Thrusters Off-Pulsing	1.8	N/A	N/A	835	1.83	0.23
10-Apr-2003, 100/10:55	8 Progress +X Thrusters Off-Pulsing	1.48	661	0.23	672	1.43	0.22

Description	
Sensor	MAMS,ossbtmf 0.0625 sa/sec (1 Hz)
Location	LAB1O2, ER1, Lockers 3,4
Orientation	Space Station Analysis (SSA)
Inc/Flight	Increments: 3-9 Flights: Various
Plot Type	Time Series

NOTES:

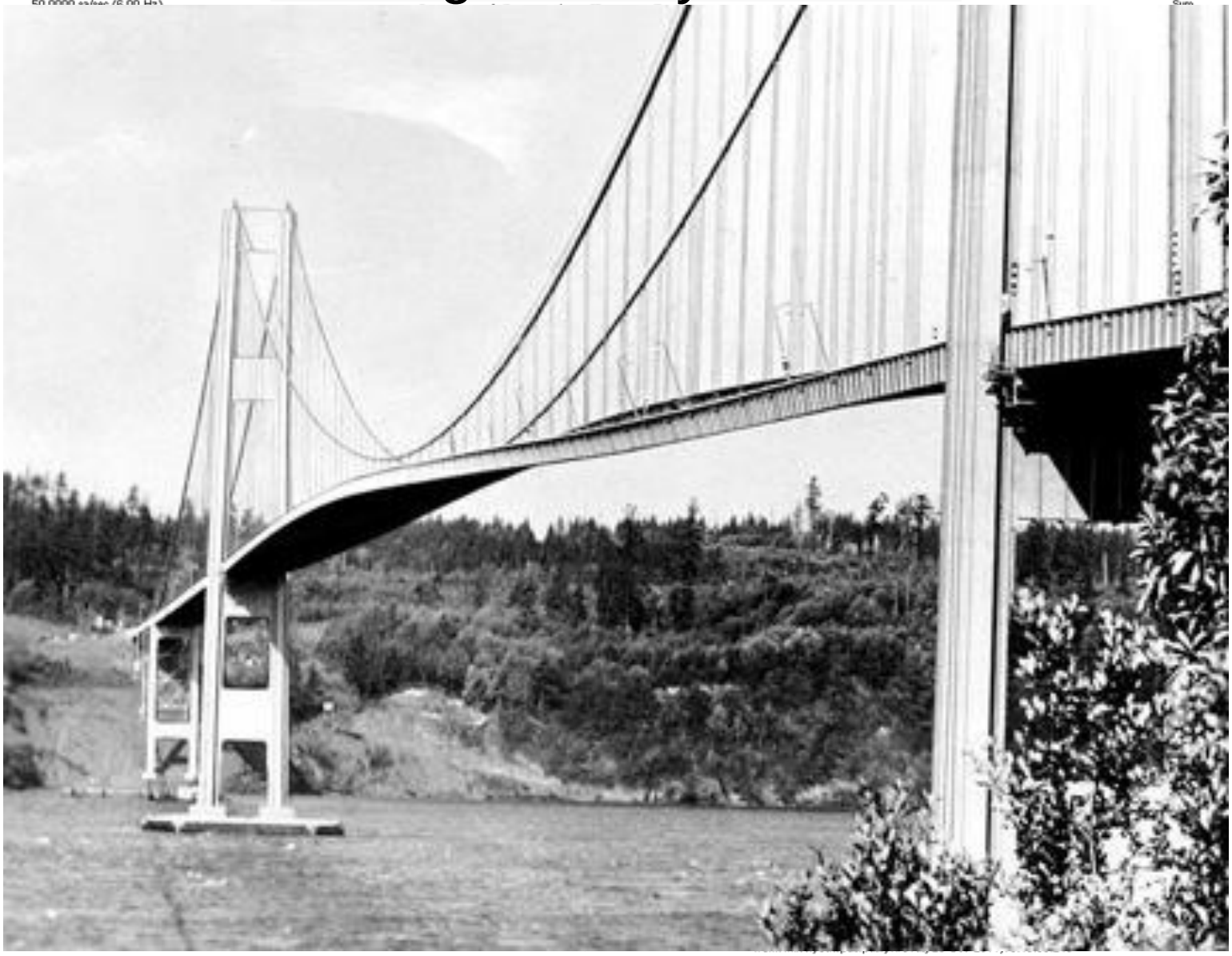
- Reboost Information column contains estimates. This information was obtained from Rex Delventhal, GNC Daily Reports and/or On-Orbit Summaries.
- Values marked with an asterisk may be off by as much as 14 ug due to lack of bias compensation for OSS A-range data.

Regime:	Quasi-steady
Category:	Vehicle
Source:	Progress Thrusters

	duration(sec)	deltaV(m/s)	xMean(mg)
MEAN	686	2.36	0.39
STD	517	1.49	0.15

statistics for 24 reboost events

Fatigue Analysis ISS



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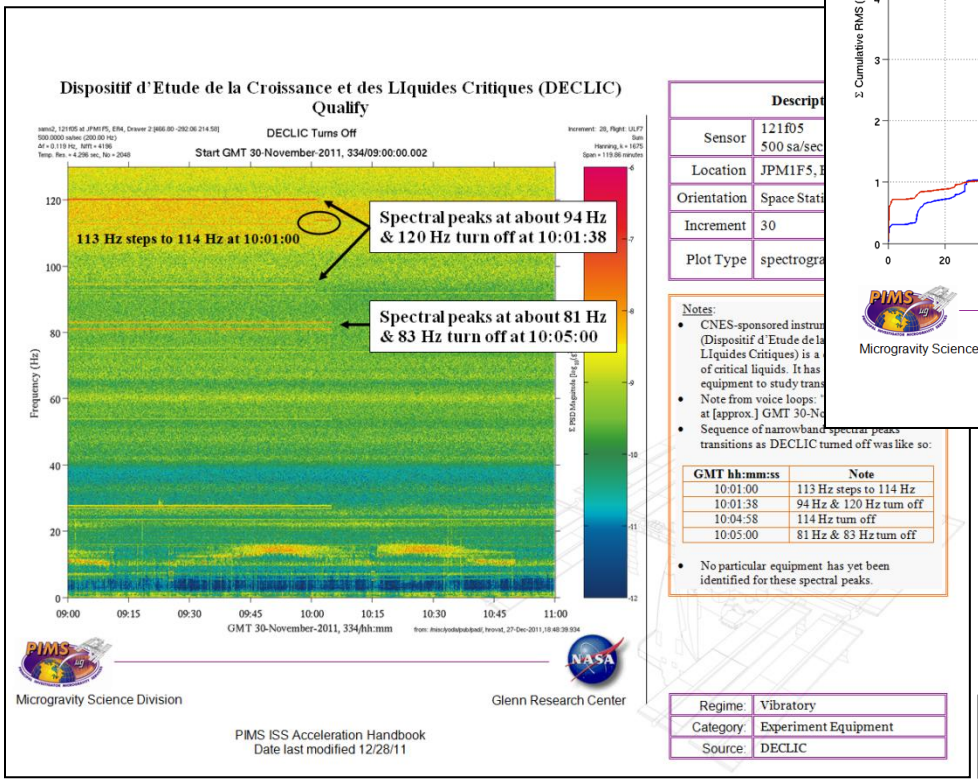
Fatigue Analysis ISS

…nics info …Boeing)

…odes

DEvice for the study of Critical LIquids and Crystallization (DECLIC) ISS

Captured recent voice loop call regarding DECLIC turn off time, which resulted in the following handbook pages…



Description	
Sensor	121f05 500 sa/sec
Location	JPM1F5, E
Orientation	Space Stati
Increment	30
Plot Type	spectrogra

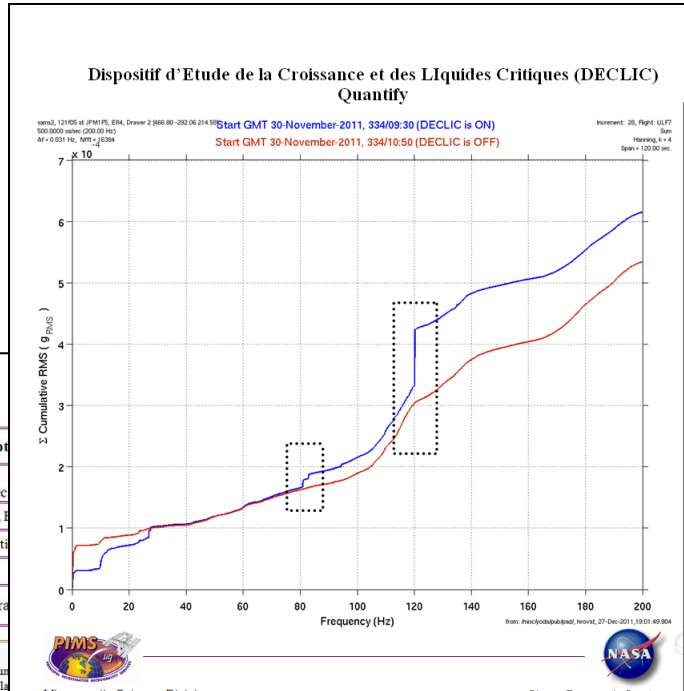
Notes:
- CNES-sponsored instru
(Dispositif d'Etude de la
LIquides Critiques) is a
of critical liquids. It has
equipment to study trans
- Note from voice loops:
at [approx.] GMT 30-No
- Sequence of narrowband spectral peaks transitions as DECLIC turned off was like so:

GMT hh:mm:ss	Note
10:01:00	113 Hz steps to 114 Hz
10:01:38	94 Hz & 120 Hz turn off
10:04:58	114 Hz turn off
10:05:00	81 Hz & 83 Hz turn off

- No particular equipment has yet been identified for these spectral peaks.

Regime:	Vibratory
Category:	Experiment Equipment
Source:	DECLIC

Qualify



Description	
Sensor	121f05 500 sa/sec (200 Hz)
Location	JPM1F5, ER4, Drawer 2
Orientation	Space Station Analysis (SSA)
Increment	30
Plot Type	cumulative RMS

Notes:
- The spectral peak at 120 Hz was the primary vibratory contributor while DECLIC was on giving rise to the ~100ug$_{RMS}$ step above the "off" condition at that frequency. The other narrowband contributors were analyzed also to give the following table:

Frequency (Hz)	ug$_{RMS}$
81	11
83	6
114	10
120	92

Regime:	Vibratory
Category:	Experiment Equipment
Source:	DECLIC

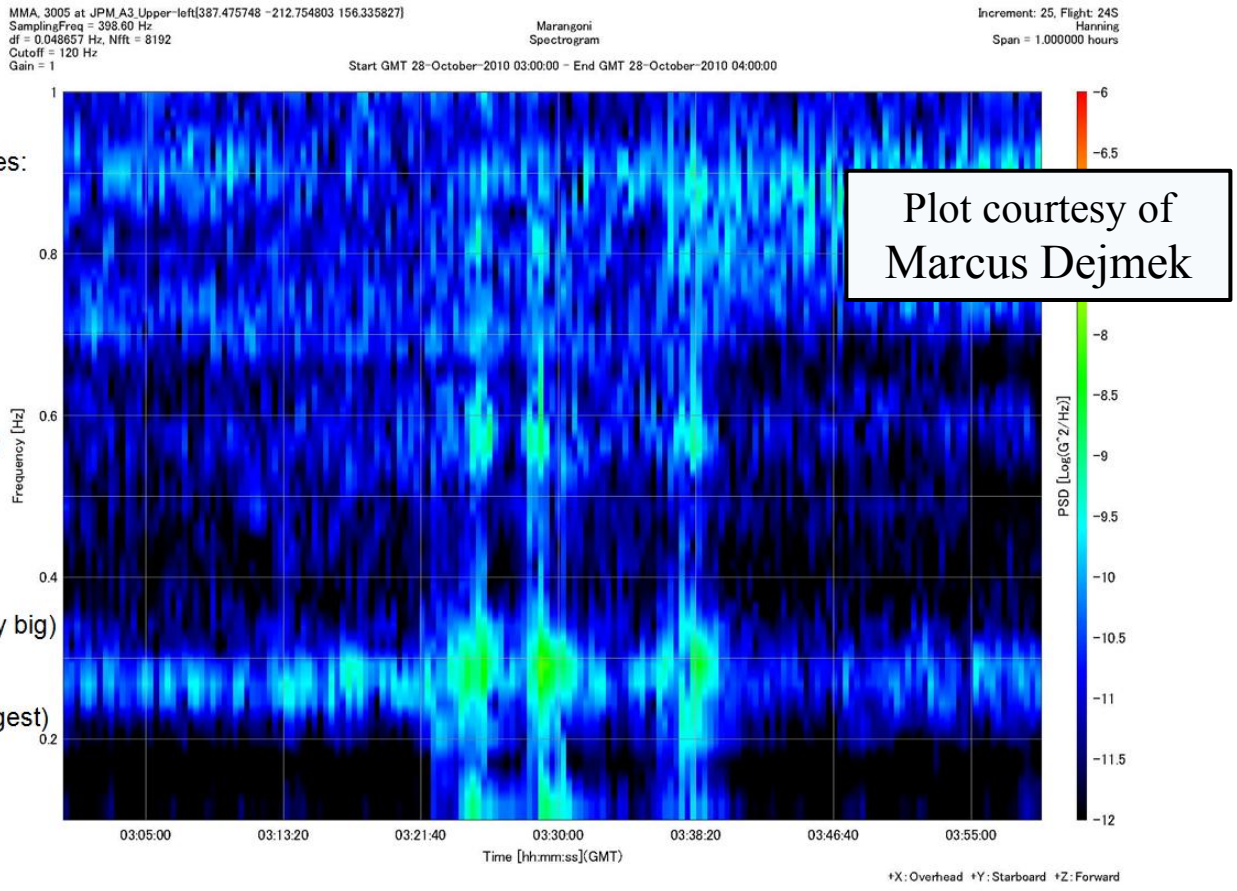
Quantify

ZIN Technologies

Marangoni Experiment in Space (MEIS) ISS

JAXA Colour Spectrogram

Recorded Disturbances:
22:18(very small)
22:29(very small)
22:33(small)
22:35(small)
23:40(big)
23:41(big)
00:06(big)
00:09(big)
00:14(remarkably big)
01:34(middle)
01:37(big)
01:46(big)
02:47(big)
03:11(middle)
03:17～18(remarkably big)
03:20(big)
03:25(big)
03:33(remarkably biggest)
04:46(big)



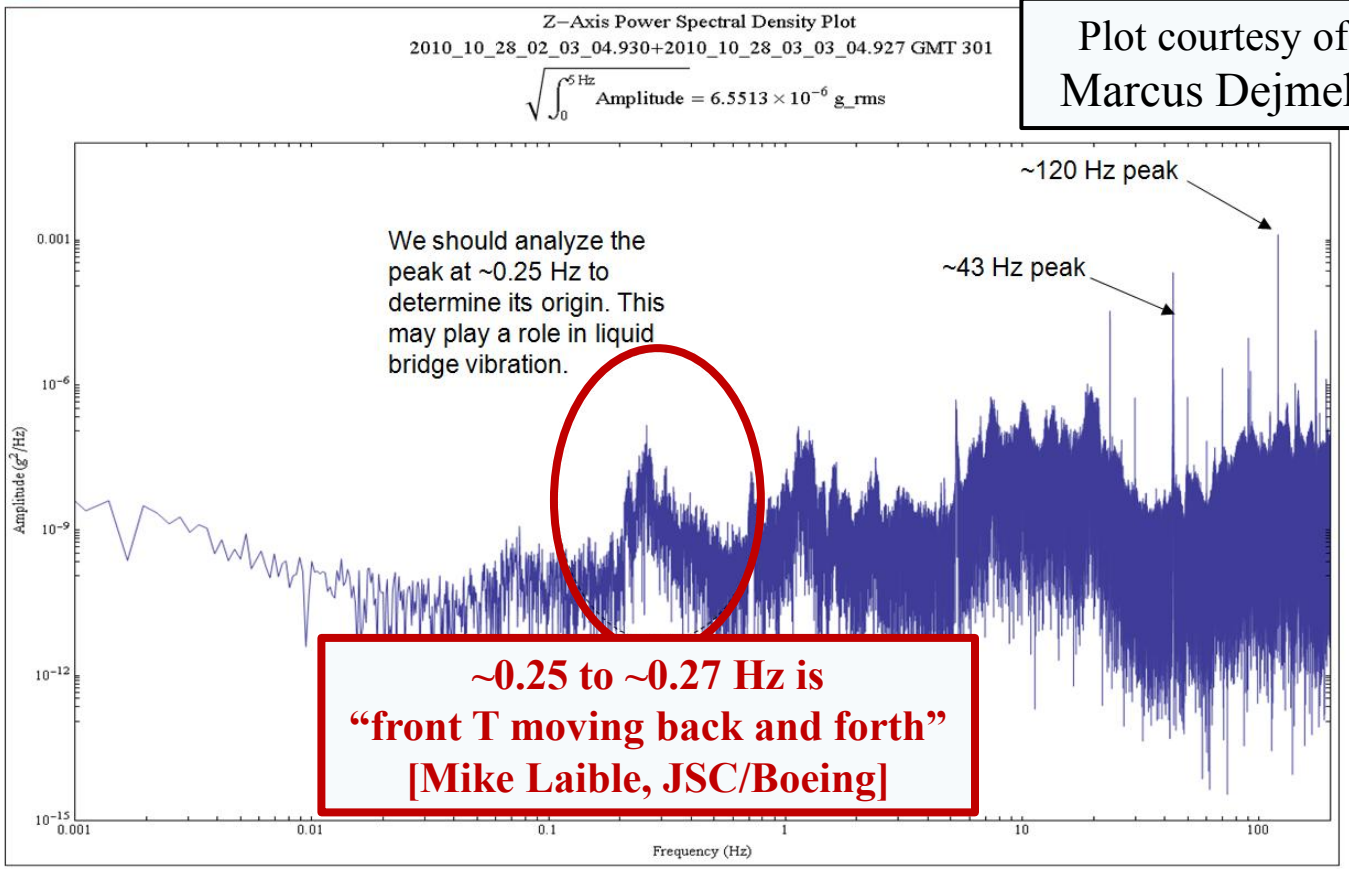
Plot courtesy of Marcus Dejmek

ZIN Technologies

Marangoni Experiment in Space (MEIS) ISS

Example Z Axis PSD
02:03 GMT301 to 03:03 GMT301

Plot courtesy of Marcus Dejmek



Japan Aerospace Exploration Agency

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1. Acronyms
2. Science support/customers
3. Highlights of a microgravity community feedback model
4. Timeline of acceleration system deployment
5. Location of acceleration sensor deployment
6. SAMS mission support
7. How much acceleration data?
8. Characterization of microgravity environment/events
9. Impacts on microgravity science
10. Moving forward

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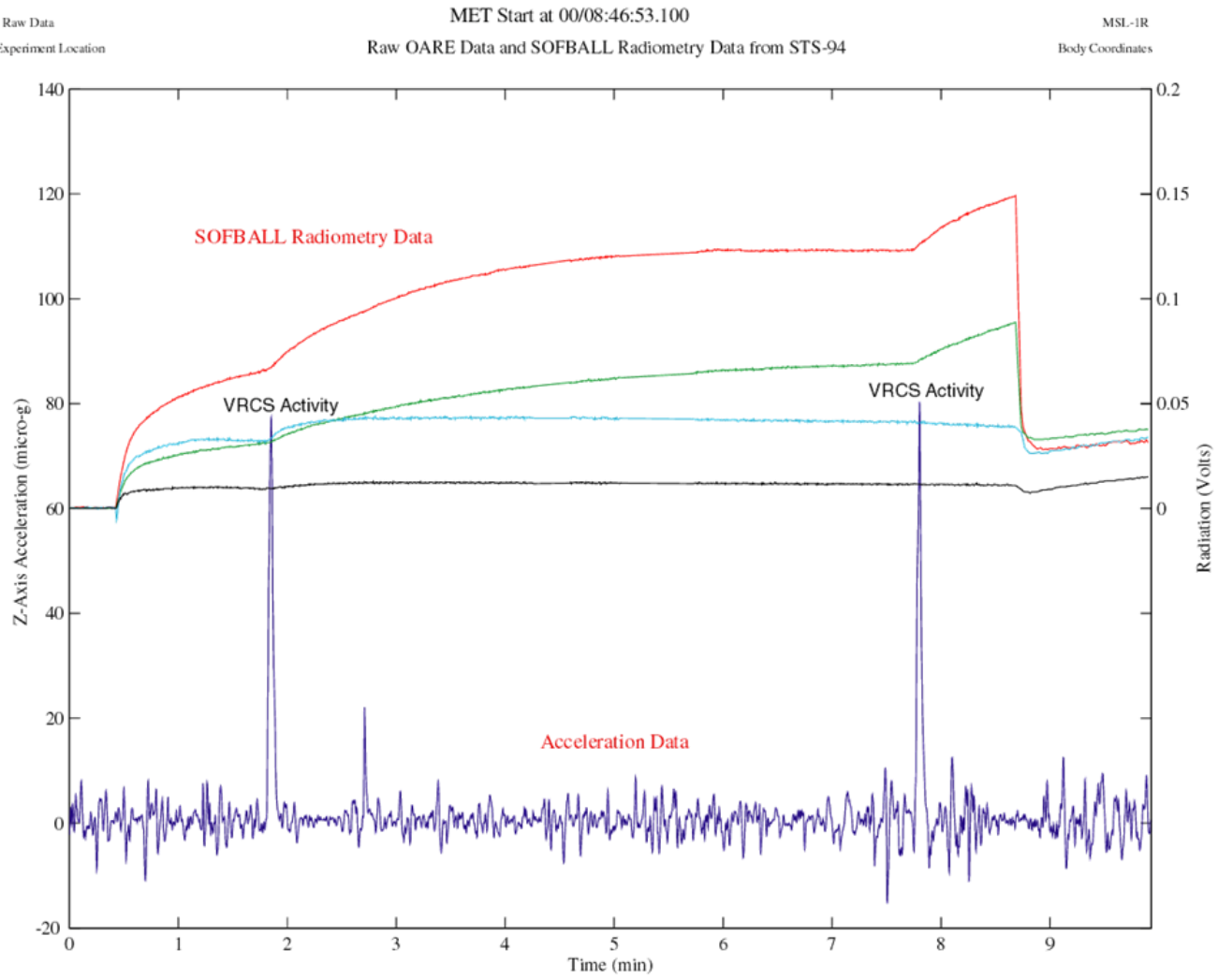
Impacts on Shuttle Microgravity Science



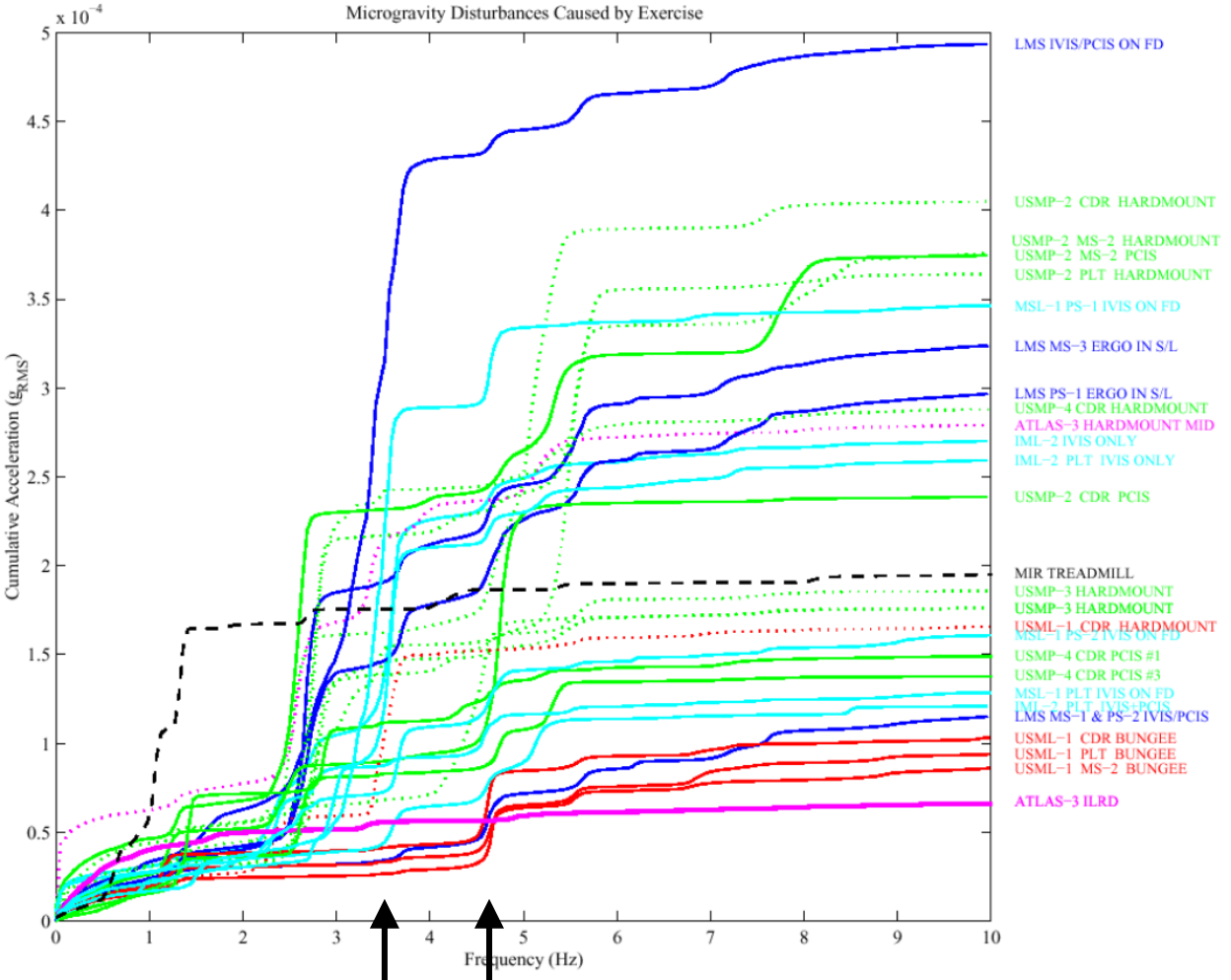
Near real-time support to investigators…

Example:
SOFBALL experiment sensitive to impulsive disturbances during execution of test points.

PIMS:
Correlate OARE data with SOFBALL science data.

Results:
SOFBALL team had justification needed to request periods of STS "free drift" (no thrusters) in order to conduct their experiment.

Impacts/Crew Exercise: Shuttle



2 spectral peaks arise from shoulder sway & pedaling rate with excitation of Shuttle structural modes @ 3.5 and 4.8 Hz

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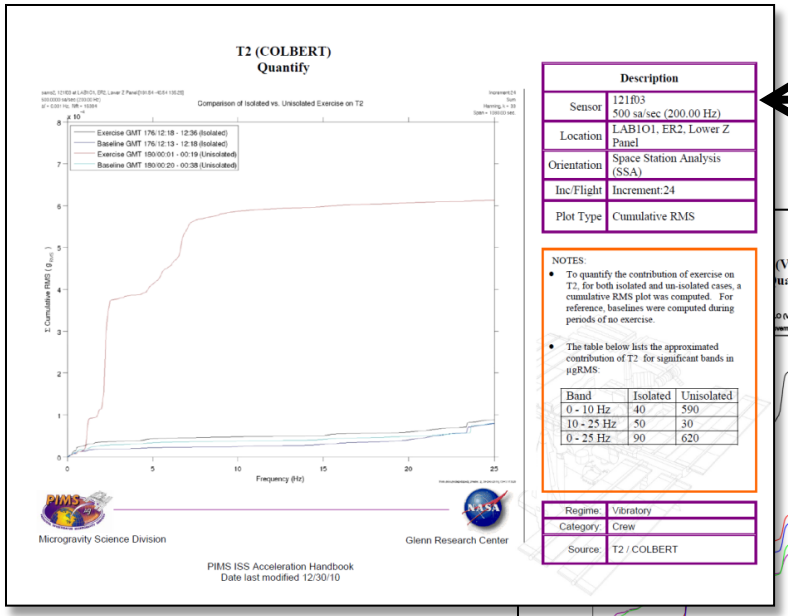
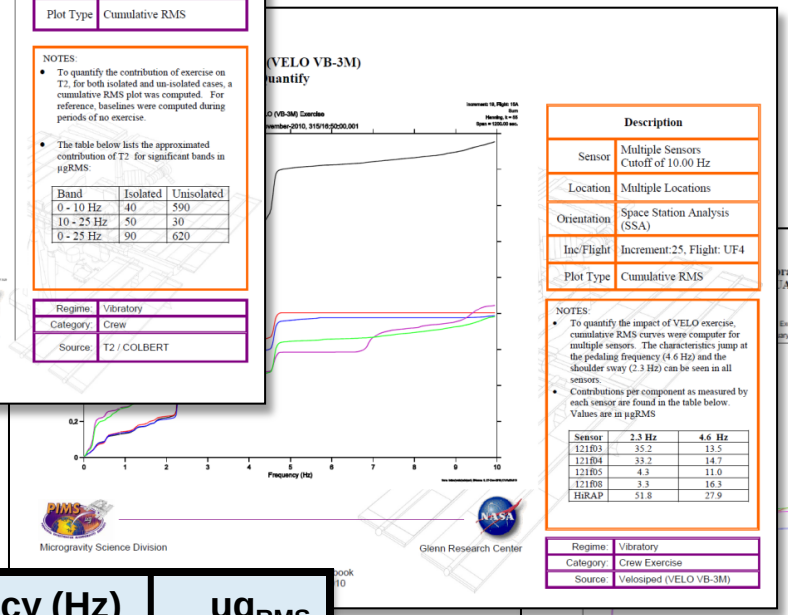
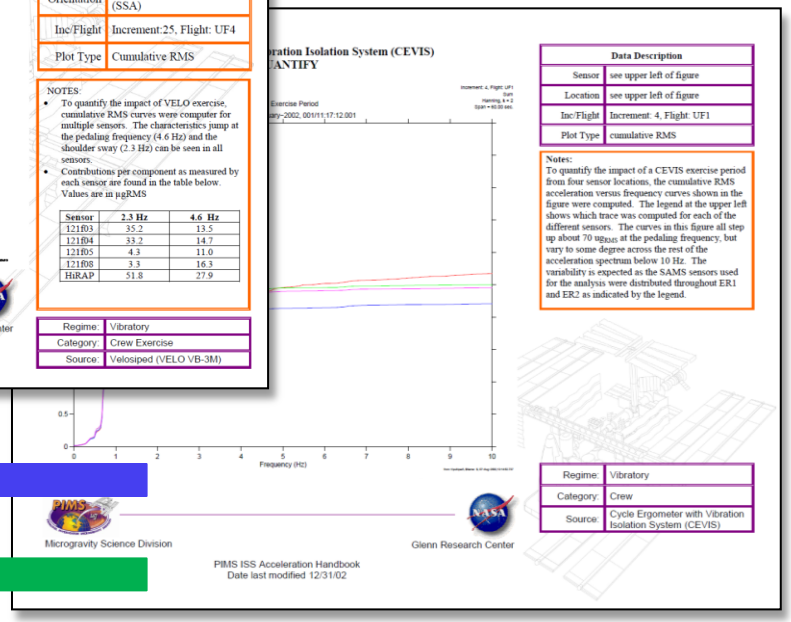
Impacts/Crew Exercise: ISS

The Combined Operational Load Bearing External Resistance Treadmill (**COLBERT**), technically named the Treadmill 2 (**T2**) derived from the Treadmill with Vibration Isolation Stabilization System (**TVIS**)

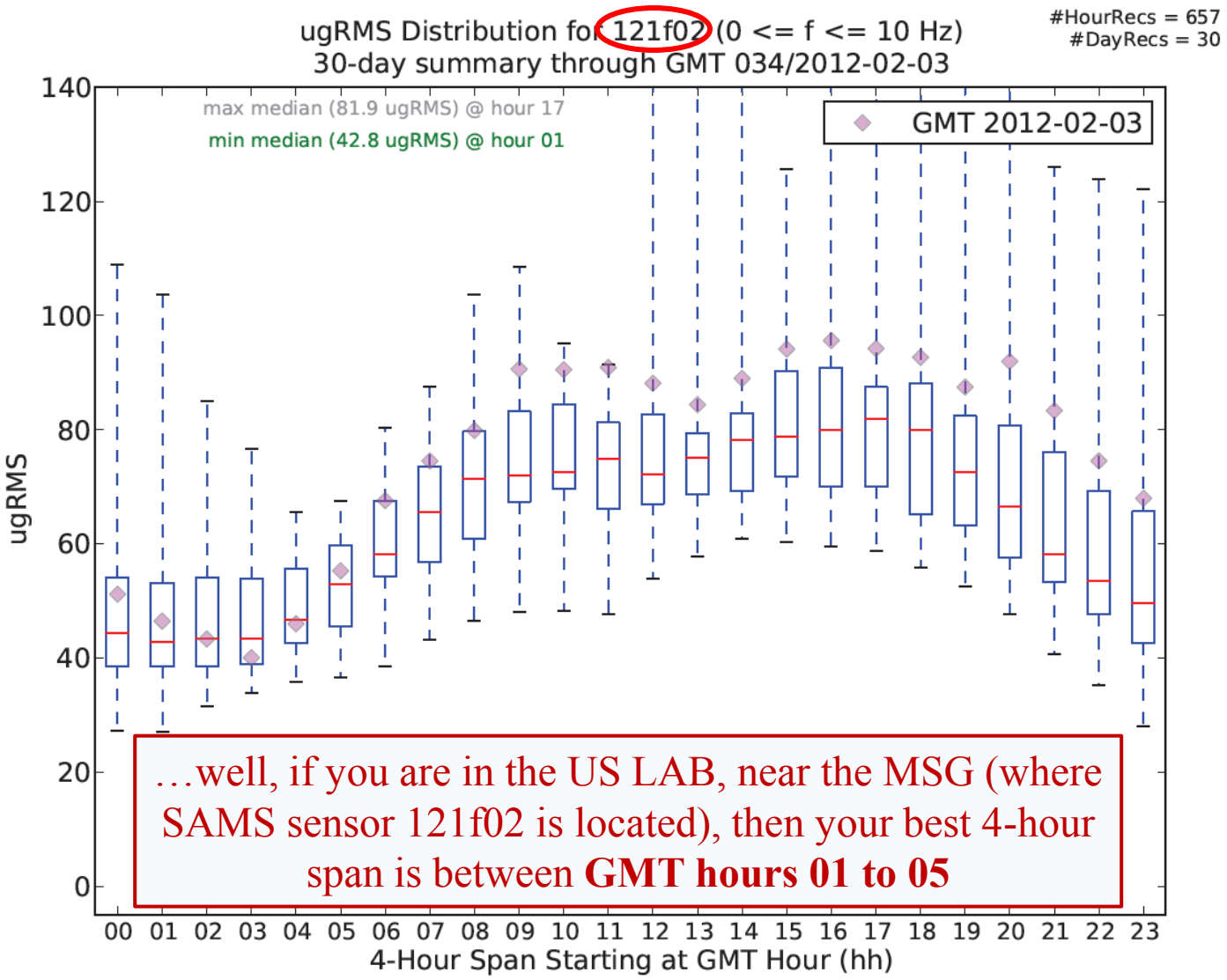






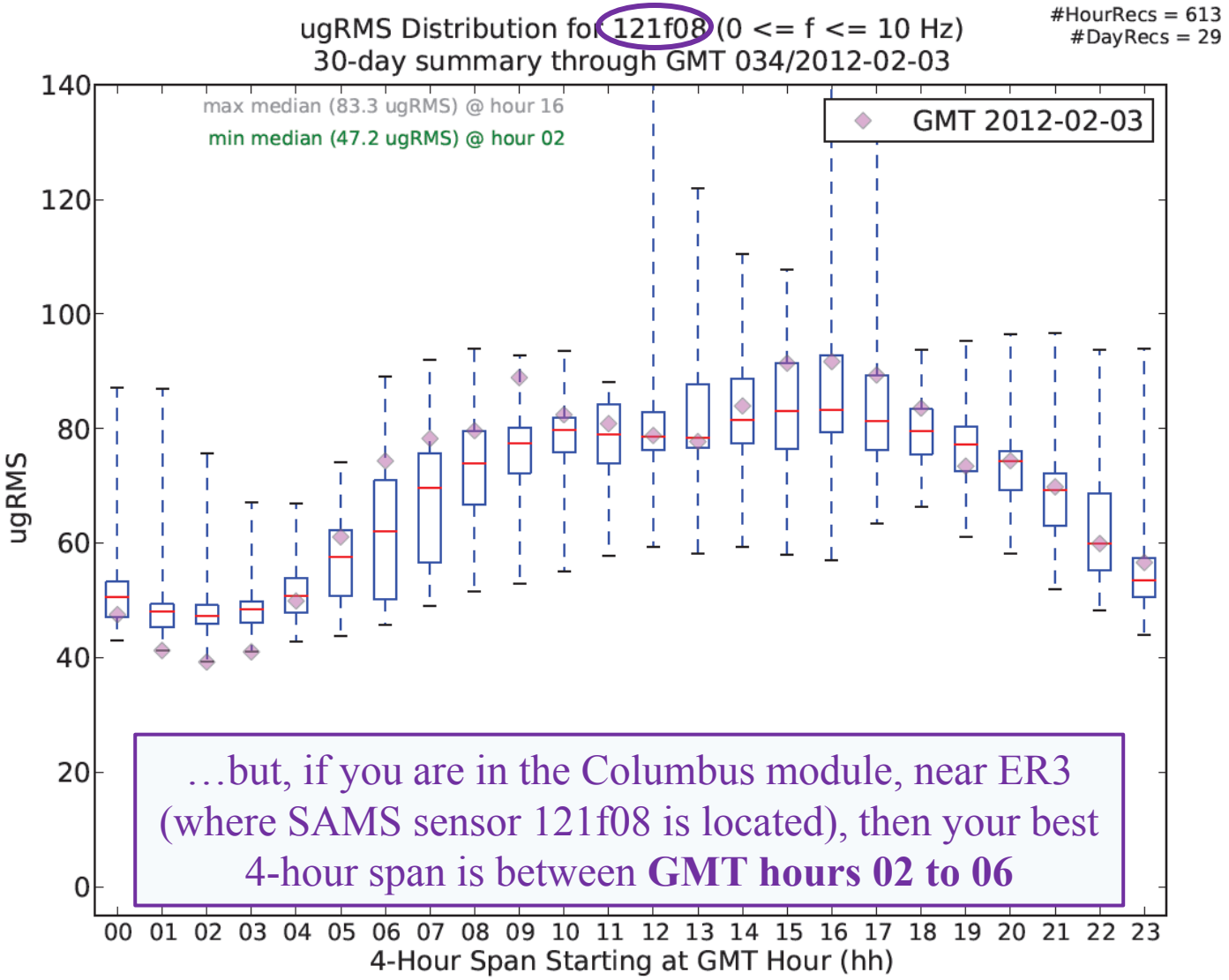
Equipment	Frequency (Hz)	ug_{RMS}
CEVIS	2.6	70
Velo	4.6	14
T2 (isolated)	<10	40
T2 (non-isolated)	<10	590

When Should I Run My Experiment?



…well, if you are in the US LAB, near the MSG (where SAMS sensor 121f02 is located), then your best 4-hour span is between **GMT hours 01 to 05**

When Should I Run My Experiment?



…but, if you are in the Columbus module, near ER3 (where SAMS sensor 121f08 is located), then your best 4-hour span is between **GMT hours 02 to 06**

Moving Forward

- Ongoing microgravity acceleration services are available for principal investigators, structural studies, sustaining engineering plus microgravity community at-large (JAXA, ESA, CSA, etc.)
- SAMS has the ability to instrument and measure in all 3 laboratories (LAB, JPM, COL) for the vibratory regime
- MAMS has the ability to measure quasi-steady acceleration and map to arbitrary locations on the ISS (rigid body assumed).

That sure was a lot to take in…

…is probably what you're thinking, what with 20 years of acceleration data measurement and all, but try not to sweat it…there's more to come.