Section 20
ISS Design Analysis Cycle & Environment Predictions

Microgravity Environment Interpretation Tutorial
NASA Glenn Research Center
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Presentation Overview

- **Design Analysis Cycle, DAC**
  - **Quasi-Steady Environment**
    - Methods & Tools
    - Results
  - **Vibratory Environment**
    - Methods & Tools
    - Results
- **Verification Analysis Cycle**
- **Non-Isolated Rack Assessment, NIRA**
- **Microgravity Analysis Cycle (MAC)**

Acknowledgements

- **DAC/VAC – Design Analysis Cycle, Verification Analysis Cycle**
  - **JSC Microgravity Team – MIPT (Microgravity Integrated Performance Team)**
    - James Smith, james.p.smith1@jsc.nasa.gov
- **NIRA – Non Isolated Rack Assessment**
  - **NASA GRC, NIRA Team**
    - Bill Hughes, william.o.hughes@nasa.gov
- **MAC – Microgravity Analysis Cycle Tool**
  - **NASA GRC, PIMS**
    - Brad Humphreys, bradley.t.humphreys@grc.nasa.gov

Acronyms

AC : Assembly Complete
APM : Attached Payload Module
ARIS : Active Rack Isolation System
CAM : Centrifuge Accommodations Module
CBM : Common Berthing Mechanism
CDR : Critical Design Review
CEVIS : Cycle Ergometer with Vibration Isolation System
CMG : Control Moment Gyro
COF : Columbus Orbital Facility
DAC : Design Analysis Cycle
EF : Exposed Facility
ELM : Experiment Logistics Module
ESA : European Space Agency
FEA : Finite Element Analysis
GN&C: Guidance, Navigation, and Control
GRC : Glenn Research Center
ISPR : International Standard Payload Rack
I/F : Interface
JAXA : Japanese Exploration Agency
JEM : Japanese Experiment Module
JSC : Johnson Space Center
MAC : Microgravity Analysis Cycle
NASTRAN : NASA Structural Analysis
NASDA : National Space Development Agency of Japan
NIRA : Non Isolated Rack Assessment
PaRIS : Passive Rack Isolation System
PDR : Preliminary Design Review
PIDS : Prime Item Development Specification
PIMS : Principal Investigator Microgravity Services
PM : Pressurized Module
PMA : Pressurized Mating Adapter
RMS : Root Mean Square
RS : Russian Segment
SEA : Statistical Energy Analysis
SM : Service Module
SARJ : Solar Array Rotary Joints
SPP : Science Power Platform
SSMRBS : Space Station Multi Rigid Body Simulation
TRRJ : Thermal Radiator Rotary Joints
TVIS : Treadmill Vibration Isolation System
USOS: United States On-orbit Segment
UF : Utilization Flight
VAC : Verification Analysis Cycle

Design Analysis Cycles

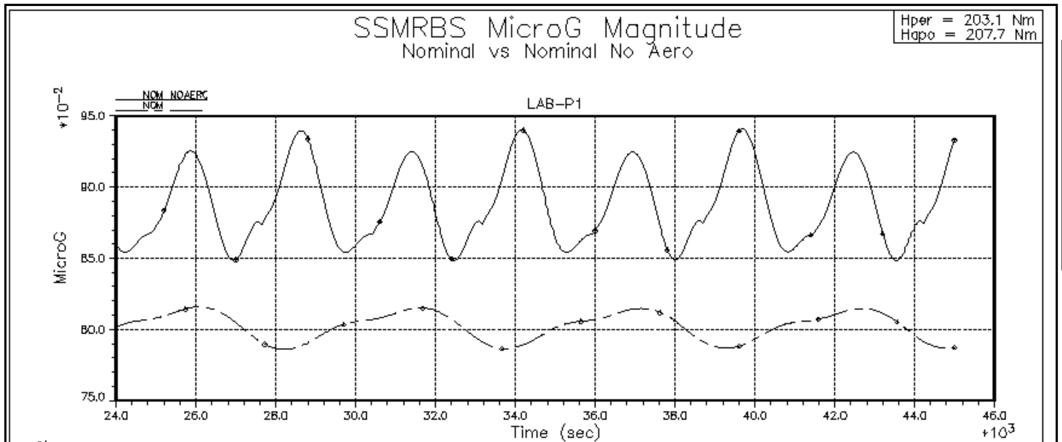
Design Analysis Cycles (DACs) may be viewed as PDR/CDR level analyses or "special" case studies.

- DAC-9 was completed in March 2002.
- DACs capture updated models & disturbance forcing functions.
- System model (several analytical models) developed for Assembly-Complete (AC) configuration when micro-g requirements become applicable.
- System model development is an evolutionary process through Design Analysis Cycles (DAC). Current cycle is DAC-9.
- Each cycle reflects the current assembly sequence and the updated component models. Test-verified (VAC quality) models are available for components that have already flown.

Quasi-steady Analysis
Methods & Tools

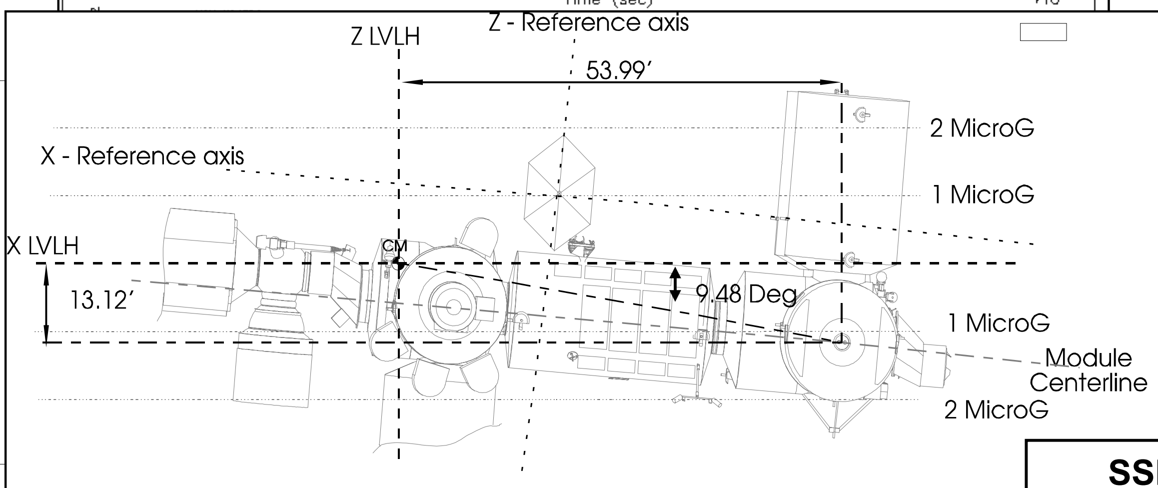
- **Perform integrated analysis to ensure that the microgravity quasi-steady disturbances will not exceed the quasi-steady acceleration limits for the International Space Station at Assembly Complete using the μg control plan inputs.**
- **System Level**
  - **Frequencies < .01 Hz, 1.0 μg Peak and .2 μg perpendicular component**
- **Element level**
  - **Quasi-steady microgravity requirements flow down to the PIDS as an allocation of .02 μg on individual disturbances, excluding the effect of drag and gravity gradient. US LAB and HAB are allocated 0.04 μg each for all combined quasi-steady disturbances**
- **Quasi-steady Individual Disturbance defined as:**
  - **Quasi-steady disturbance is defined as having 95% of its power below 0.01 Hz in any 5400 second period**
    - Any step function greater than 200 seconds
    - Any exponential decay with a time constant greater than 200 seconds
    - Other disturbances analyzed for percentage content below 0.01 Hz
- **Perform studies to compare Orbiter attached, Core complete mass properties, maximum and no aerodynamics runs**

Quasi-steady Analysis
Methods & Tools



Below 0.01 Hz

- **Orbital Mechanic Multi-Rigid Body Closed Loop Attitude Control Analysis**
- **Space Station Multi Rigid Body Simulation**
- **SSMRBS used for GN&C Software Verification**



$$\vec{a} = -\mu\left(\frac{\vec{r}_p}{r_p^3} - \frac{\vec{r}_g}{r_g^3}\right) - \vec{\omega}\times\left(\vec{\omega}\times\vec{r}_{p/g}\right) - \dot{\vec{\omega}}\times\vec{r}_{p/g} + \vec{a}_D$$

Gravity Gradient | Centripetal | Tangential | Aero-Dynamic Drag

SSMRBS Environment Data Validation

verify_gfield (gravity)

ADA Advanced Simulation Development System (ASDS) Gravitational Potential (GOTPOT) model

verify_bfield (magnetic)

Goddard Space Flight Center International Geophysical Reference Field (IGRF) Earth Magnetic model

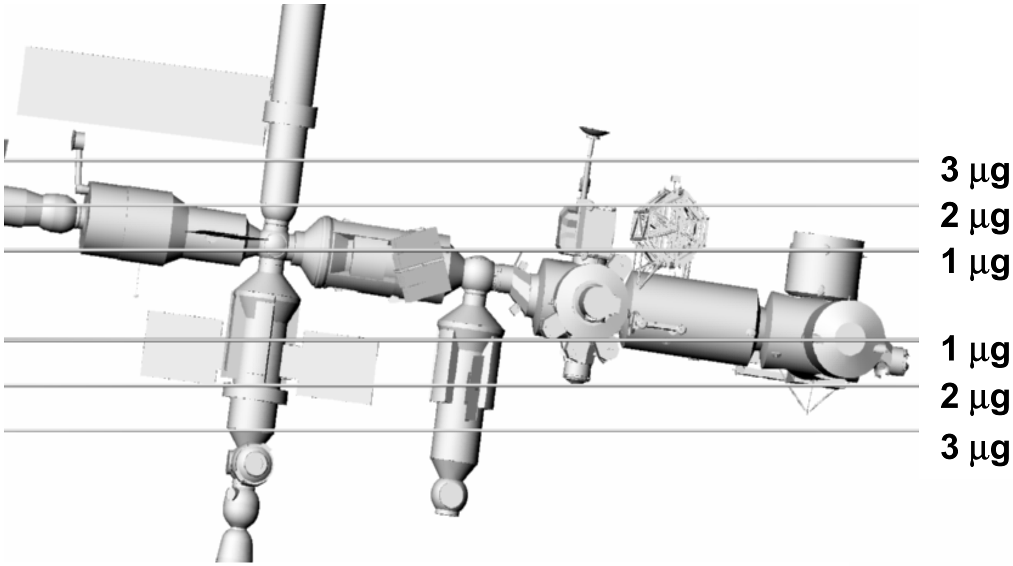
verify_atm_density (density)

Marshall Engineering Thermosphere (MET) Earth Atmospheric Density model

Quasi-steady Analysis
Disturbance Inputs

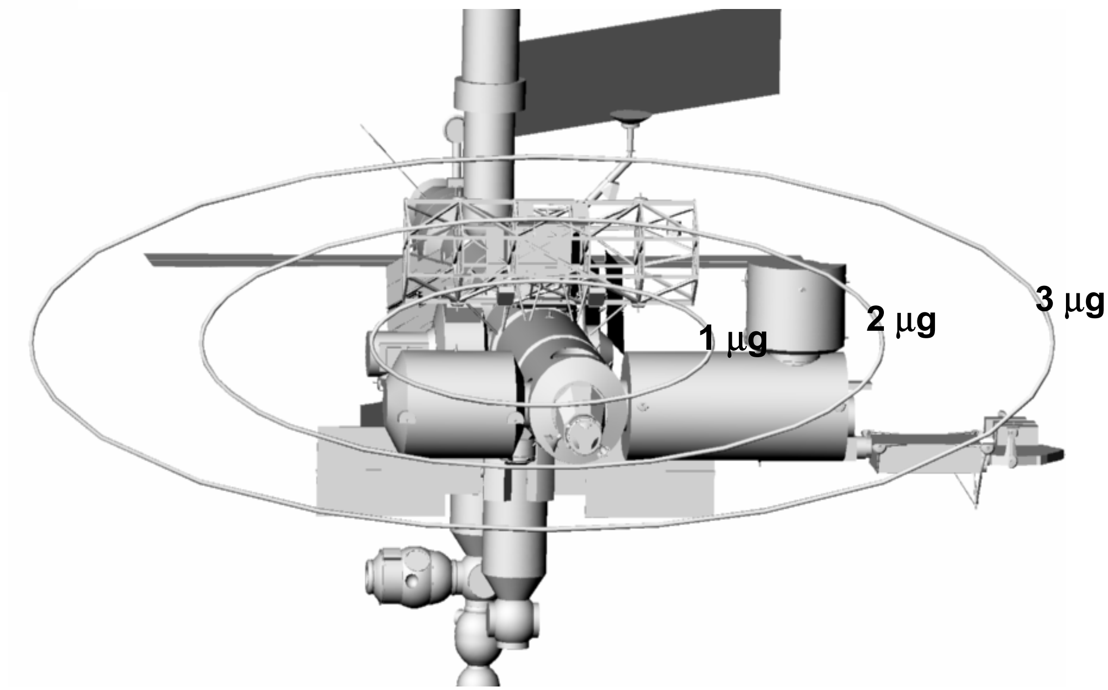
- **Centrifuge startup and shut down**
  - **Spin-up for 120 sec to 236 deg/s, spin for 6.4 hours, spin-down for 120 sec.**
  - **Starts at 17000 sec**
- **TRRJ slew at low betas**
  - **TRRJ 0 beta slew rates - TRRJ Torque Power Spectral Density has 87.7% of its power below 0.01 Hz.**
  - **Not Applicable**
- **Solar Thermal base loads**
  - **Exponential decay for 210 seconds every 2160 seconds (night), 3360 (day), forces combined for eight arrays**
  - **Lighting dependent , continuous**
- **LAB4 Vent**
  - **Force profile, duration of 8700 seconds**
  - **Starts at 6000 seconds**
- **RSA6 Vent**
  - **Exponential decay of 600 seconds every 9000 seconds**
  - **Starts at 10000 seconds**
- **Treadmill Gyro Start-up**
  - **+0.23 ft-lbs. for 10 minutes, 0 ft-lbs. for 60 minutes, -0.23 ft-lbs. for 10 minutes, repeated every 30 minutes.**
  - **Starts at 6000 seconds**

Quasi-steady Results
DAC 9 – Assembly Complete



Quasi-steady Performance:
- 14 of 32 ISPRs < 1.0 μg
- All satisfy stability criteria

Some elements not shown



Quasi-steady Results
DAC 9 – Assembly Complete

Location	μG Vector		Unit Vector			Cone Angle
	Magnitude (μG)	⊥ Component (μG)	X	Y	Z	Max angle from unit vector (deg)
CG	0.234	0.038	-0.995	-0.090	0.030	20.885
USL-C1	0.298	0.083	-0.630	-0.500	-0.594	18.659
USL-C2	0.266	0.066	-0.751	-0.529	-0.395	22.312
USL-C3	0.244	0.045	-0.854	-0.518	-0.054	22.811
USL-C4	0.237	0.059	-0.830	-0.411	0.378	23.246
USL-C5	0.245	0.085	-0.672	-0.249	0.698	24.359
USL-S1	0.796	0.107	-0.315	0.096	-0.944	7.781
USL-S2	0.743	0.105	-0.330	0.128	-0.935	8.237
USL-S3	0.691	0.104	-0.348	0.165	-0.923	8.739
USL-S4	0.642	0.102	-0.369	0.208	-0.906	9.291
USL-P1	0.811	0.107	-0.247	-0.401	-0.882	7.632
USL-P2	0.754	0.105	-0.259	-0.412	-0.874	8.124
USL-P4	0.641	0.102	-0.288	-0.439	-0.851	9.320
JPM1-A1	1.187	0.111	-0.159	-0.593	-0.789	5.480
JPM2-F1	1.349	0.114	-0.154	-0.556	-0.817	4.959
JPM3-A2	1.266	0.111	-0.135	-0.669	-0.731	5.143
JPM4-F2	1.422	0.114	-0.134	-0.628	-0.766	4.705
JPM5-A3	1.355	0.111	-0.114	-0.730	-0.674	4.809
JPM6-F3	1.506	0.114	-0.115	-0.688	-0.716	4.449
JPM7-A4	1.453	0.111	-0.094	-0.779	-0.620	4.491
JPM8-A5	1.558	0.112	-0.077	-0.817	-0.571	4.197
JPM9-F5	1.696	0.114	-0.081	-0.779	-0.622	3.963
JPM10-F6	1.801	0.115	-0.067	-0.812	-0.579	3.745
APM-CLG1	0.668	0.112	-0.369	0.498	-0.785	9.613
APM-CLG2	0.759	0.113	-0.344	0.631	-0.695	8.593
APM-FWD1	1.246	0.116	-0.263	0.227	-0.938	5.338
APM-FWD2	1.300	0.116	-0.265	0.330	-0.906	5.144
APM-FWD3	1.369	0.117	-0.265	0.422	-0.867	4.919
APM-FWD4	1.449	0.118	-0.262	0.500	-0.826	4.693
APM-AFT1	1.110	0.113	-0.281	0.299	-0.912	5.869
APM-AFT2	1.174	0.114	-0.280	0.407	-0.869	5.595
APM-AFT3	1.254	0.115	-0.276	0.501	-0.820	5.295
APM-AFT4	1.342	0.117	-0.270	0.576	-0.772	5.005

Location	μG Vector		Unit Vector			Cone Angle
	Magnitude (μG)	⊥ Component (μG)	X	Y	Z	Max angle from unit vector (deg)
CAM-MID	1.518	0.111	0.068	-0.104	0.992	4.281
CAM-TOP	2.306	0.111	0.093	-0.060	0.994	2.794
APM-CLG3	0.875	0.116	-0.318	0.711	-0.627	7.587
APM-CLG4	0.990	0.117	-0.296	0.773	-0.561	6.815
JEF1-F1	2.980	0.121	-0.057	-0.749	-0.660	2.388
JEF2-A1	2.682	0.115	-0.049	-0.795	-0.605	2.511
JEF3-F2	3.074	0.122	-0.049	-0.772	-0.633	2.336
JEF4-A2	2.800	0.116	-0.041	-0.814	-0.579	2.431
JEF5-F3	3.181	0.123	-0.042	-0.793	-0.608	2.286
JEF6-A3	2.914	0.117	-0.034	-0.833	-0.552	2.364
JEF7-F4	3.299	0.125	-0.036	-0.809	-0.586	2.238
JEF8-A4	3.022	0.119	-0.026	-0.850	-0.526	2.306
JEF9-O1	3.412	0.127	-0.022	-0.849	-0.528	2.181
JEF10-O2	3.321	0.124	-0.018	-0.862	-0.506	2.198
JEF11-U1	2.599	0.123	0.005	-0.944	-0.330	2.766
JEF12-U2	2.714	0.124	0.015	-0.957	-0.289	2.663
S3LO	3.268	0.163	-0.125	0.982	0.141	2.877
S3LI	2.931	0.155	-0.125	0.978	0.165	3.072
S3UO	3.950	0.152	-0.042	0.830	0.556	2.272
S3UI	3.683	0.145	-0.034	0.797	0.603	2.324
P3LO	3.374	0.122	0.104	-0.958	0.269	2.078
P3UO	4.202	0.113	0.142	-0.764	0.629	1.546
FGB-CG	1.487	0.121	-0.028	0.851	0.525	4.741
SM-CG	1.651	0.106	0.030	0.265	0.964	3.990
USL-CG	0.664	0.103	-0.326	-0.138	-0.935	9.030
JEM-CG	1.560	0.113	-0.083	-0.795	-0.601	4.246
APM-CG	1.267	0.116	-0.272	0.410	-0.871	5.247

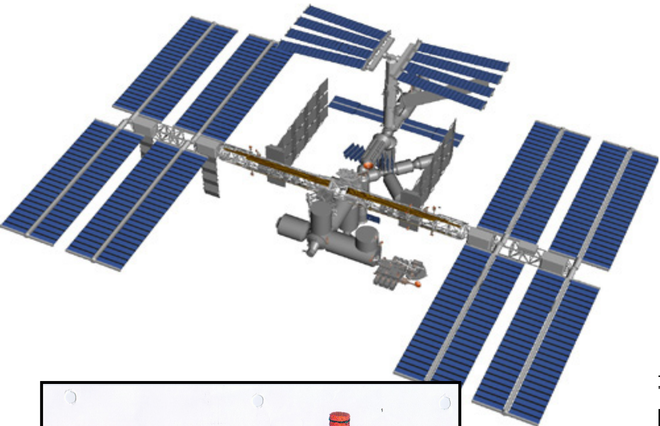
- **Rack count 14 of 32 less than 1 μg**
- **Good stability, all 32 racks below 0.2 μg**

Quasi-steady Results
DAC 9 - Assembly Complete, Comparison

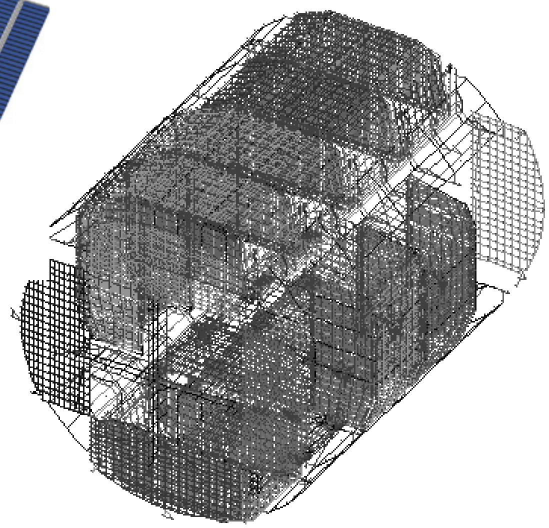
14 of 32 racks less than 1 μg magnitude

Configuration	CG			Principle Axis			Mass	Rack count
	X-ft	Y-ft	Z-ft	Y-deg	P-deg	R-deg	lb.	under 1 μg
7/15/94	-24.77	-0.7	13.55	-5.1	-3.31	0.12	836955	18
3/13/95 (DAC1)	-23.49	-2.26	12.67	-8.15	-4.13	-0.23	896110	16
DAC2	-23.41	-3.02	11.71	-6.17	-4.15	0.08	855301	14
DAC3	-23.07	-1.51	12.9	-1.24	-5.53	0.49	893181	11
DAC4	-21.23	-0.96	15.51	-3.34	-8.28	0.27	893045	14
DAC5	-22.08	-1.19	15.82	-4.05	-9.41	0.1	900412	10
DAC6	-19	-1.18	14.7	-3.26	-7.25	0.37	920170	14
DAC7	-16.21	-0.67	14.74	-5.87	-8.15	-0.16	994969	14
DAC8	-15.34	-1.28	14.87	-8.44	-6.13	0.12	1035473	15
DAC9	-17.66	-1.32	14.8	-6.36	-7.04	0.28	1005479	14
DAC9_CORE	-19.35	-0.59	14.93	-12.55	-10.53	-0.59	947788	10
DAC9_CORE_ADJ	-16.27	-0.63	13.76	-8.78	-9.93	0.14	902738	8
DAC9_ORB	-4.24	-1.09	22.03	8.97	9.49	-1.1	1222209	2
DAC9_CORE_ORB	-4.94	-0.49	22.5	15.4	5.96	-0.76	1164518	3
DAC9_CORE_ORB_ADJ	-1.88	-0.51	21.86	32.12	7.19	-3.68	1119471	4

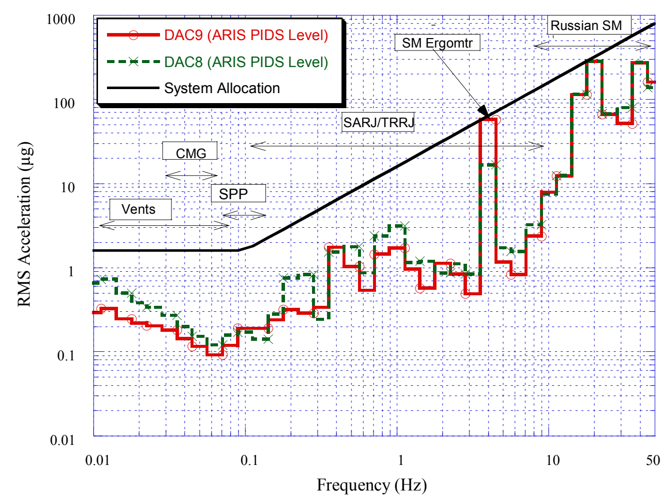
Vibratory Analysis (Structural Dynamic) Methods & Tools



Enhanced COF Model



0.01 to 50 Hz
Structural Dynamic Finite Element Analysis
MSC/NASTRAN "Enhanced" Loads & Dynamics Models

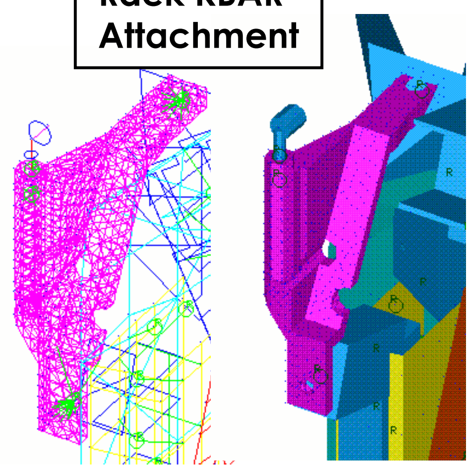


Lower Pivot

Non-isolated Rack I/F

Upper KBAR

Rack KBAR Attachment



Vibratory Analysis
Methods and Assumptions

- "Structural dynamic" micro-gravity assessments (0 to 50 Hz.)
- Frequency domain analysis for steady-state disturbances
  - Analysis frequency vector superposition of 2 frequency sets
    - **8457 system modes resonant frequencies**
    - **2000 supplemental frequencies at constant logarithmic spacing.**
- Time domain simulations for transient disturbances
  - Simulations performed with 0.01 second time step to have Nyquist frequency of 50 hz
  - Simulations performed for 100 seconds provide data down to lower frequency limit of 0.01 hz.
- 0.25% damping for all modes
- ARIS attenuation applied (PIDS level)

Vibratory Analysis
Finite Element Models

- Component models obtained from various sources - element developers, international partners.
- Models usually obtained through Loads & Dynamics AIT
- Some models obtained directly from source
- Models come in various formats: simple stick-beam representations, detailed bulk data, reduced mass/stiffness matrices.
- CONFIGURATION
  - DAC-8 system model represented Rev.C configuration. This was updated to Rev. F configuration for DAC-9, major differences in Russian segment.
  - Node 4 / Propulsion module not included.

- COMPONENT MODELS

COMPONENT MODELS	SOURCE
US Laboratory Module (US Lab)	Boeing Huntsville
Japanese Experiment Module (JEM)	JAXA
ESA Attached Pressurized Module (APM) aka COF	ESA
Centrifuge Accommodation Module (CAM)	JAXA
Node 2 and Node 3	Alenia
Photovoltaic (PV) Arrays	Boeing CP

Vibratory Analysis
Finite Element Model Example – US Lab

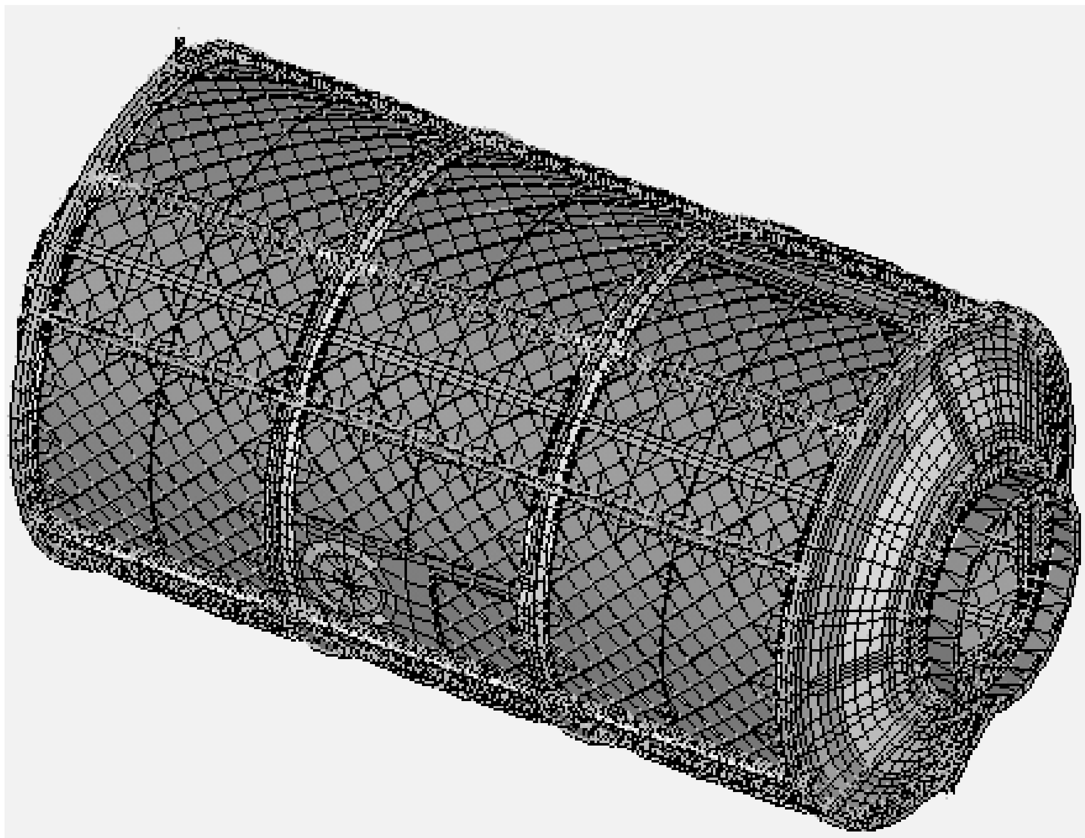
US Lab Finite Element Model (Boeing)

- US Lab model comprised of 32 Superelements: Shell, Forward ESS, Aft ESS, 4 Standoffs, 12 Racks, 12 Isolation Plates
- Includes detailed rack models and attachments - pivot pins, K-bars, knee braces, bayonet fittings. ARIS racks are not included.
- For DAC-9, **unique system rack models were used** rather than a generic rack model used for DAC-8.
- Craig-Bampton reduction performed on all US Lab component models. Modal content to 100 Hz. was retained. Total integrated weight 36325 lb.

Experimental Validation

- Modal Survey Test performed by Boeing Huntsville
- Launch configuration - Common Module with one standoff, one rack, CBM's, Mass Simulators for PMA.
- Frequency range for Model Correlation, 0 to 50 Hz.
- Deflection data from static testing and transfer function correlation studies to further validate on-orbit model.

Vibratory Analysis
Finite Element Model Example – US Lab



Vibratory Analysis
Example Forcing Functions - Exercise Devices

Treadmill

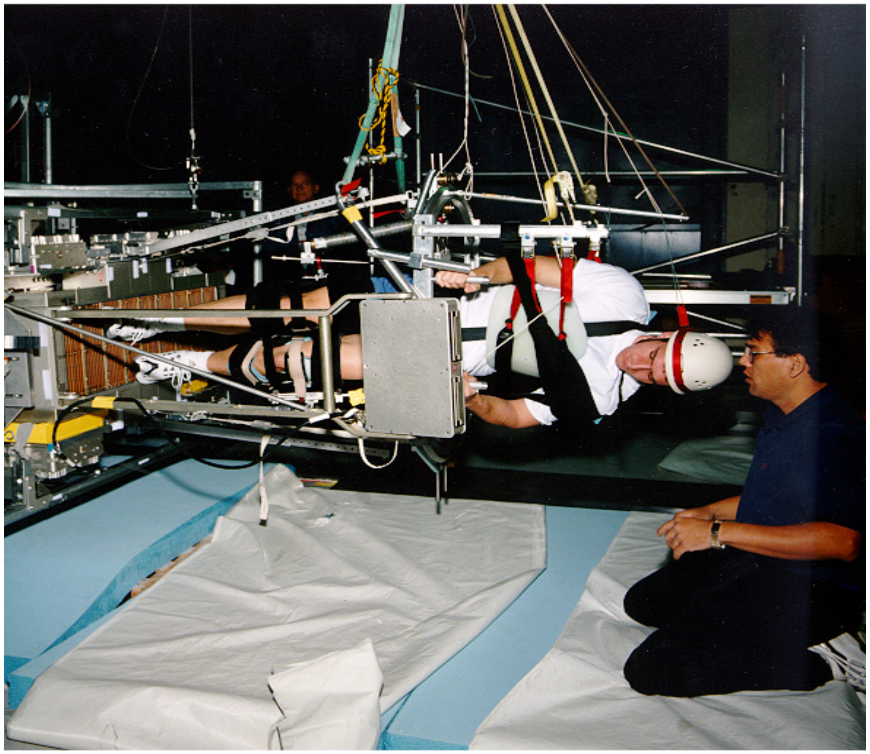
- The Service Module (SM) treadmill disturbance definition is based on horizontal test measurements for TVIS certification.
- Measurements include source isolation effects
- Force measurements from 3 cases were used as inputs for transient analysis.
  - speed 1.9, 4.2, and 8.1 mph

Cycle Ergometer

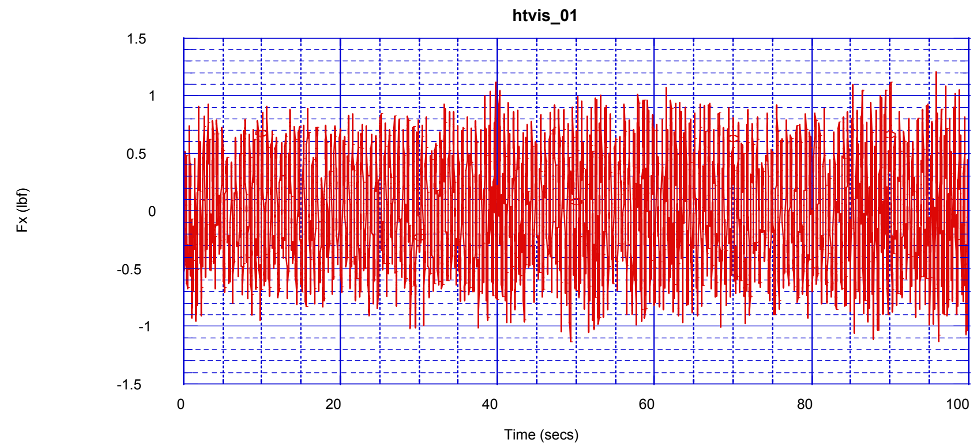
- The US Lab ergometer disturbance definition is based on test measurements for CEVIS certification.
- Measurements include source isolation effects
- Force measurements from 4 cases were used as inputs for the transient analysis.
  - 190 lb. crew member cycling 60, 75, 90, and 105 rpm
- Ergometer mounted on rack seat-tracks in US Lab. Possible relocation to Node 1 in the future.

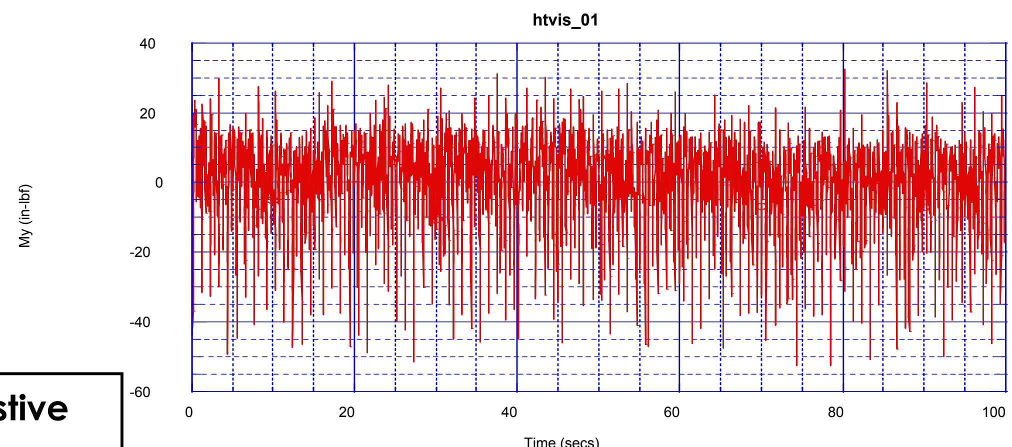
Vibratory Analysis
Example Forcing Functions - Exercise Devices

TVIS Certification Test



6 DOF Transient Force/Moment For Various Subjects

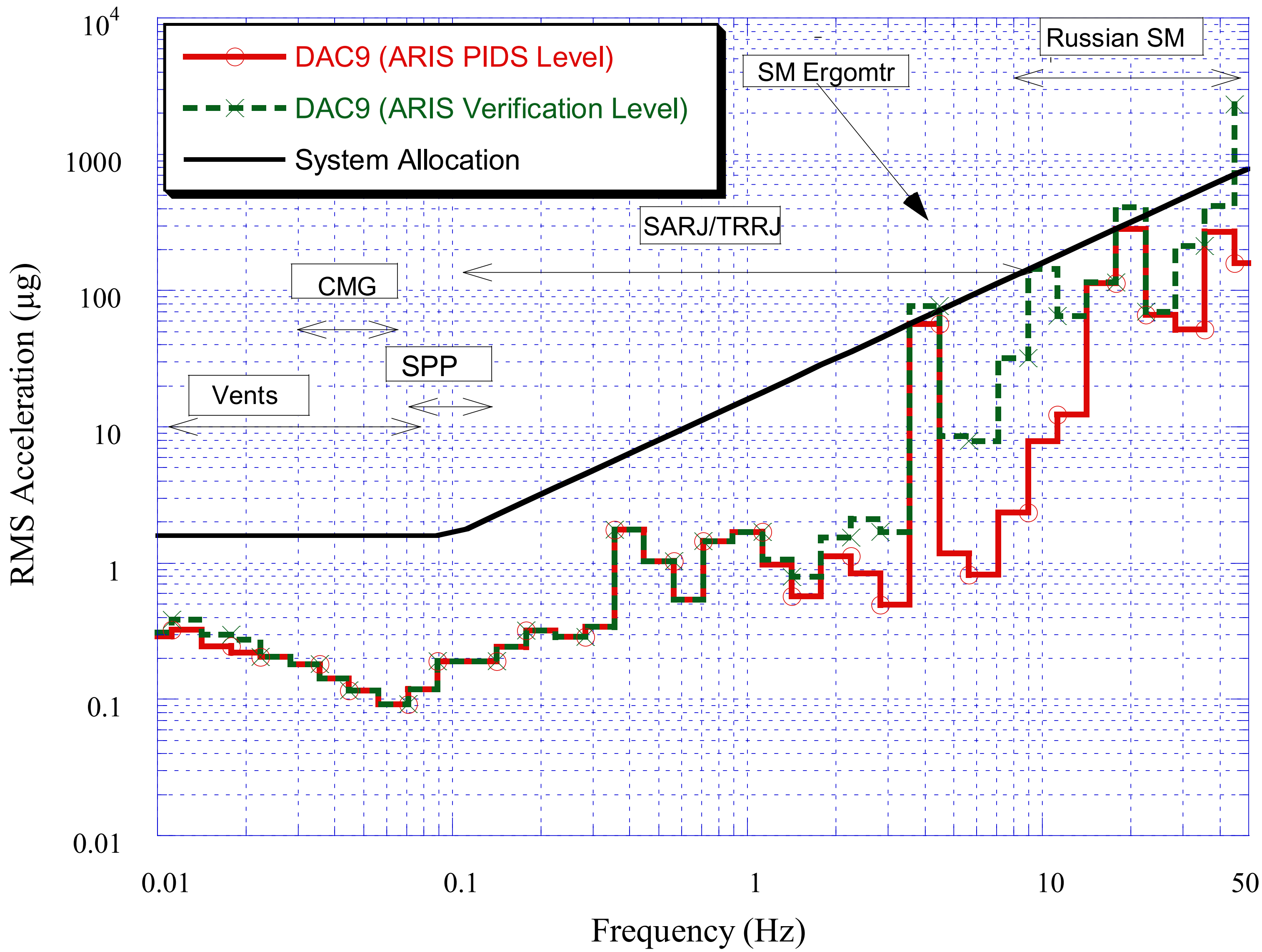




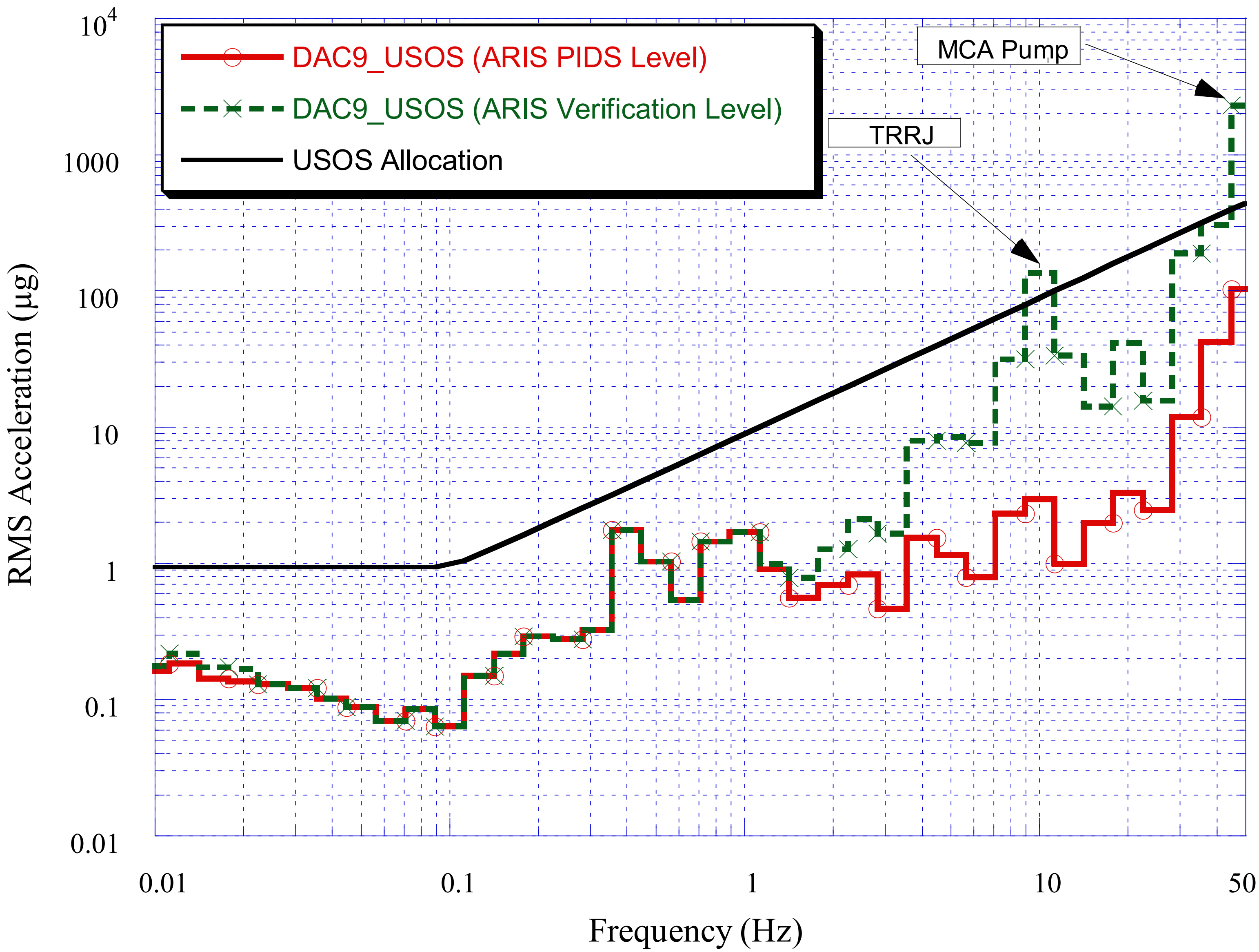
<u>Crew Exercise Equipment:</u> **Treadmill, Ergometer, Resistive Exercise Device (Isolated/Non-isolated)**

<u>InterVehicular Activity:</u> **Translation, Station Keeping, Console Operations, … Scheduled Maintenance.**

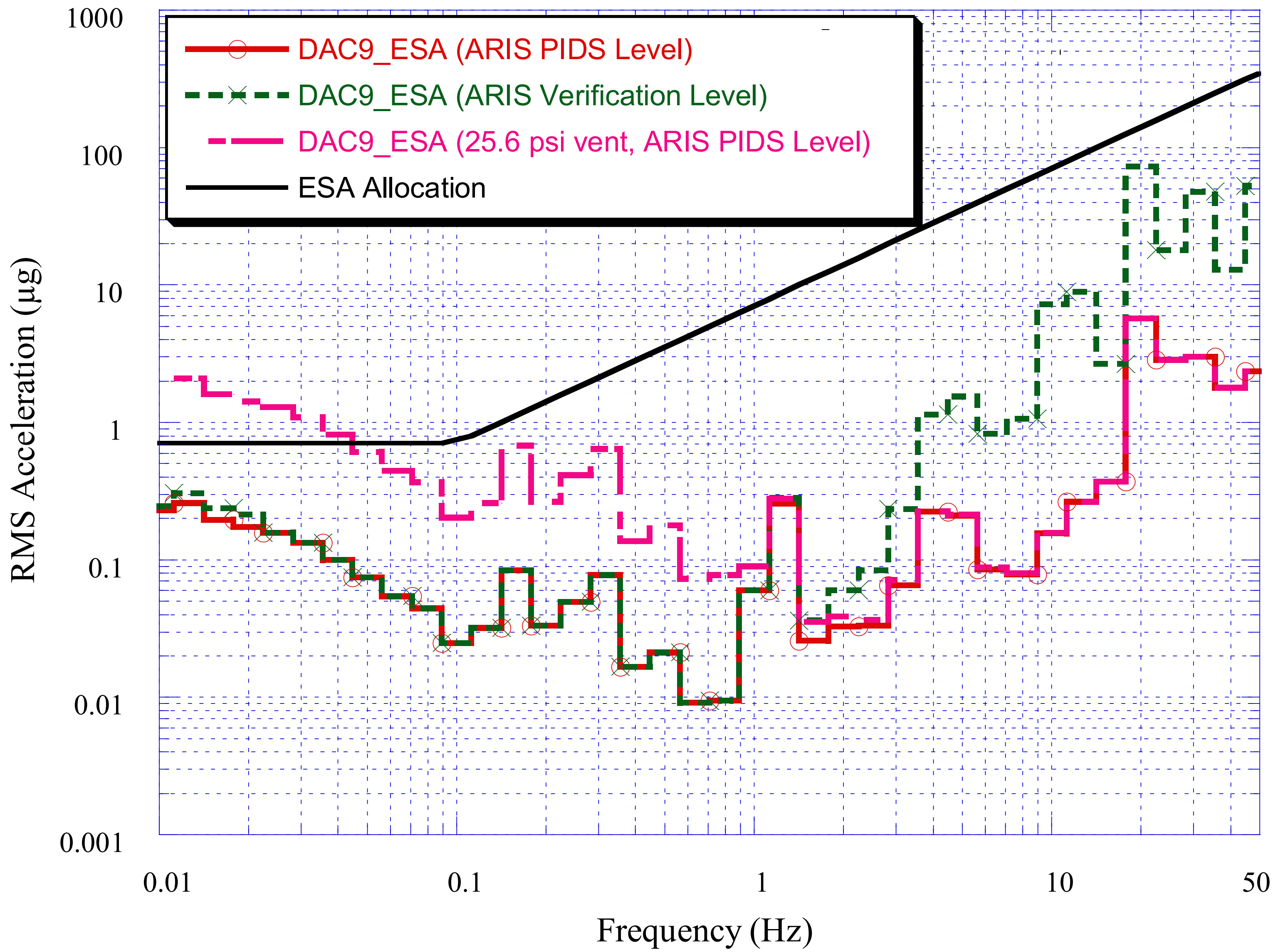
Vibratory Results
DAC 9 - Composite



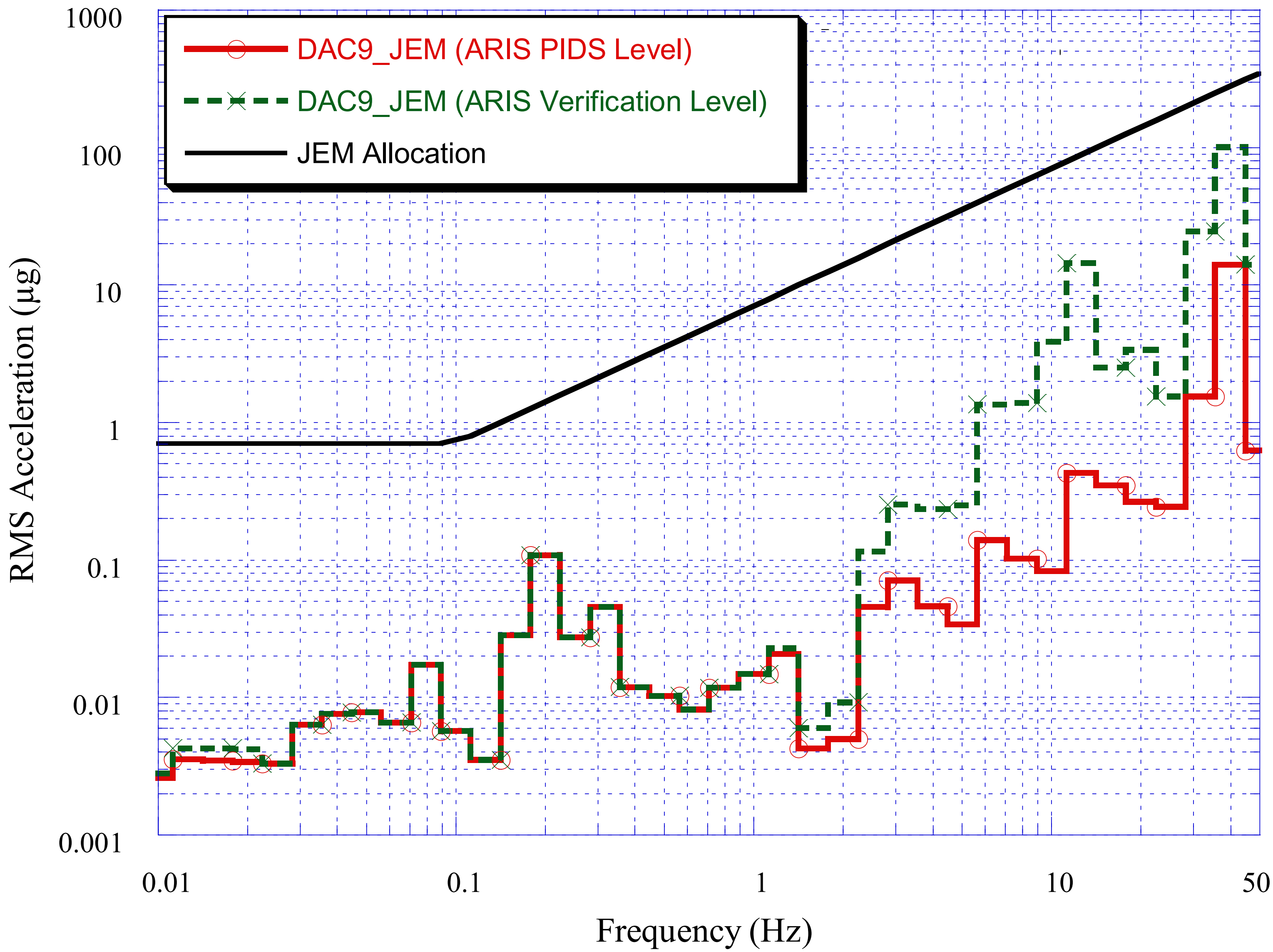
Vibratory Results
DAC 9 – USLAB



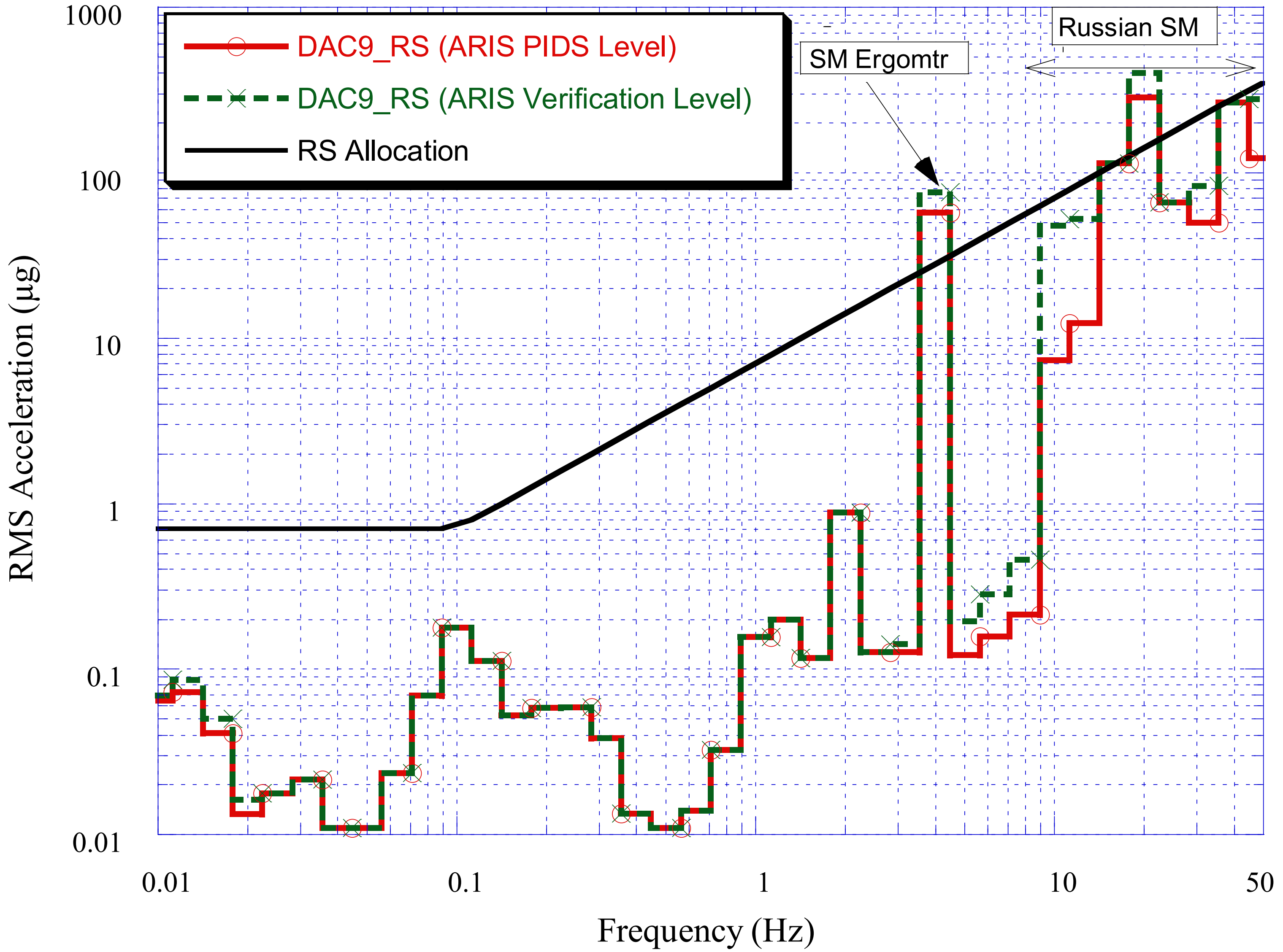
Vibratory Results
DAC 9 – COF/CAM



Vibratory Results
DAC 9 – JEM



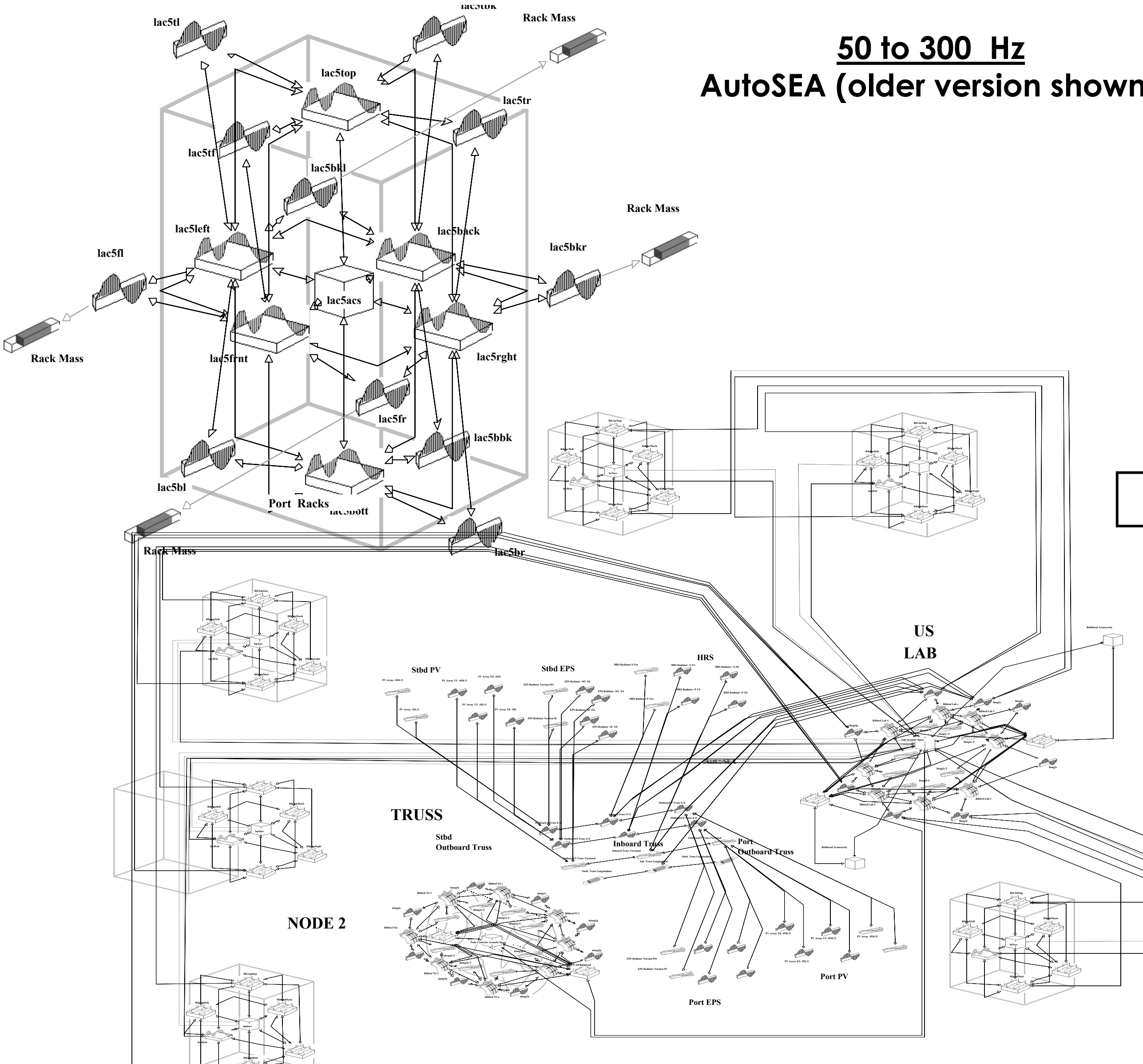
Vibratory Results
DAC 9 – Russian Segment (RS)



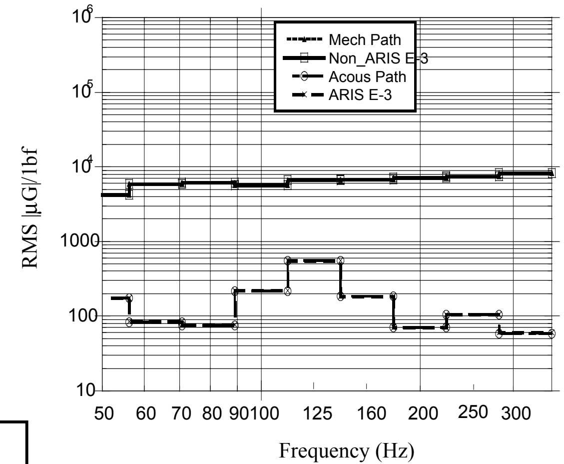
VibroAcoustic Analysis Methods & Tools

50 to 300 Hz

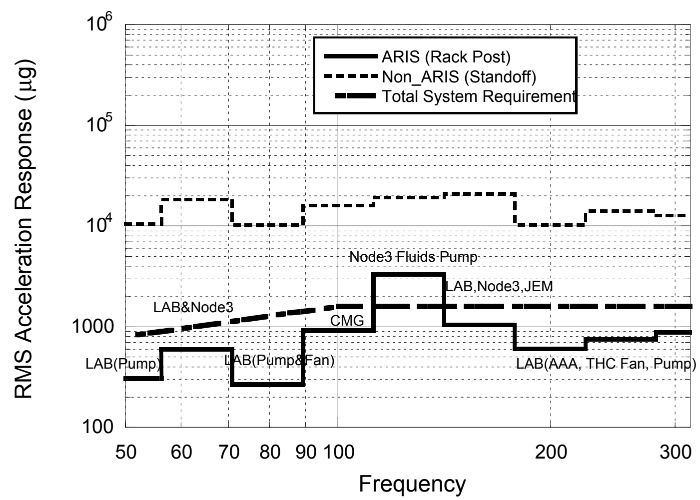
AutoSEA (older version shown)



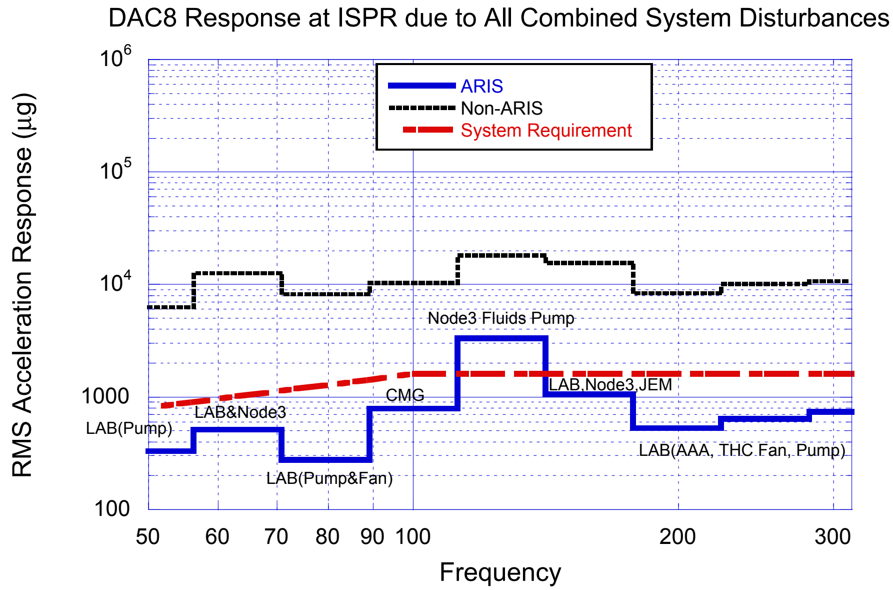
SEA Transfer Function E-3
Input: Lab longeron Output: ISPR

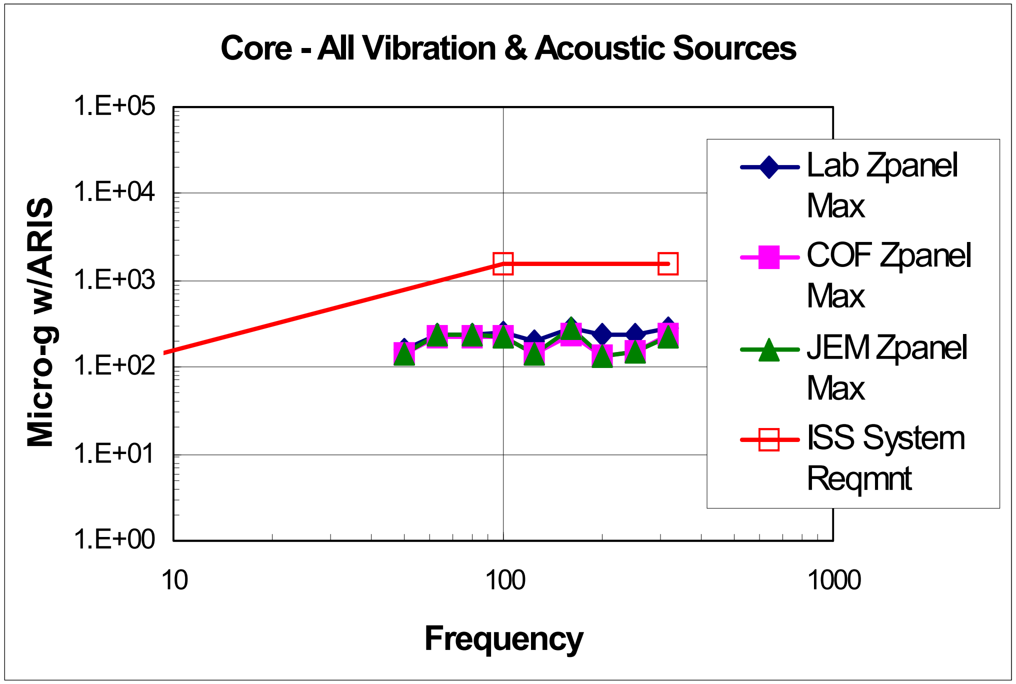


Overall DAC-8 ARIS Off-board
Vibroacustic Environment Predictions



VibroAcoustic Results





Verification Analysis Cycles

Verification Analysis Cycles (VACs) are in process and are conducted on an increment by increment basis.

- Verify that the hardware launched complies with Assembly Complete microgravity requirements.
- Priority tasks necessary for Certification of Flight Readiness.
- Example: ISS Stage 6A Quasi-steady environment (as measured by MAMS) and SSMRBS was correlated (using actual Solar Flux Data, actual array configuration, and vehicle attitude). Model to environment deviation was only 3-4%.

Microgravity sustaining engineering efforts underway (JSC)

- Use of on-orbit measurements for issue resolution, uncertainty reduction, analytical model correlation.
- Support anomaly resolution and operations.

Non Isolated Rack Analysis

Non–Isolated Rack Assessment (NIRA)

- **Uses the DAC models**
- **Previous Version completed in 1999**
- **Latest Version completed December 2003***
  - **Vibratory range (0.01-50 Hz)**
  - **VibroAcoutic range (50-300 Hz) in work**
  - **Updates to disturbers**
  - **Some changes in methodology**
- **Reports μg at rack interfaces on a per element (US LAB, JEM, etc.) basis**
- **Assumptions/Limitations**
  - **Station in μg mode**
  - ***Includes payload and crew disturbances***
  - ***Does not include active (ARIS) or passive isolation at the crew interface***
- **Data used by payload developers**
  - **More conservative since payload disturbances are included**
  - **Developer simulates lab to rack isolation technique based on their specific rack configuration**

* Contact William Hughes, NASA GRC (william.o.hughes@grc.nasa.gov)

DAC/NIRA Comparison

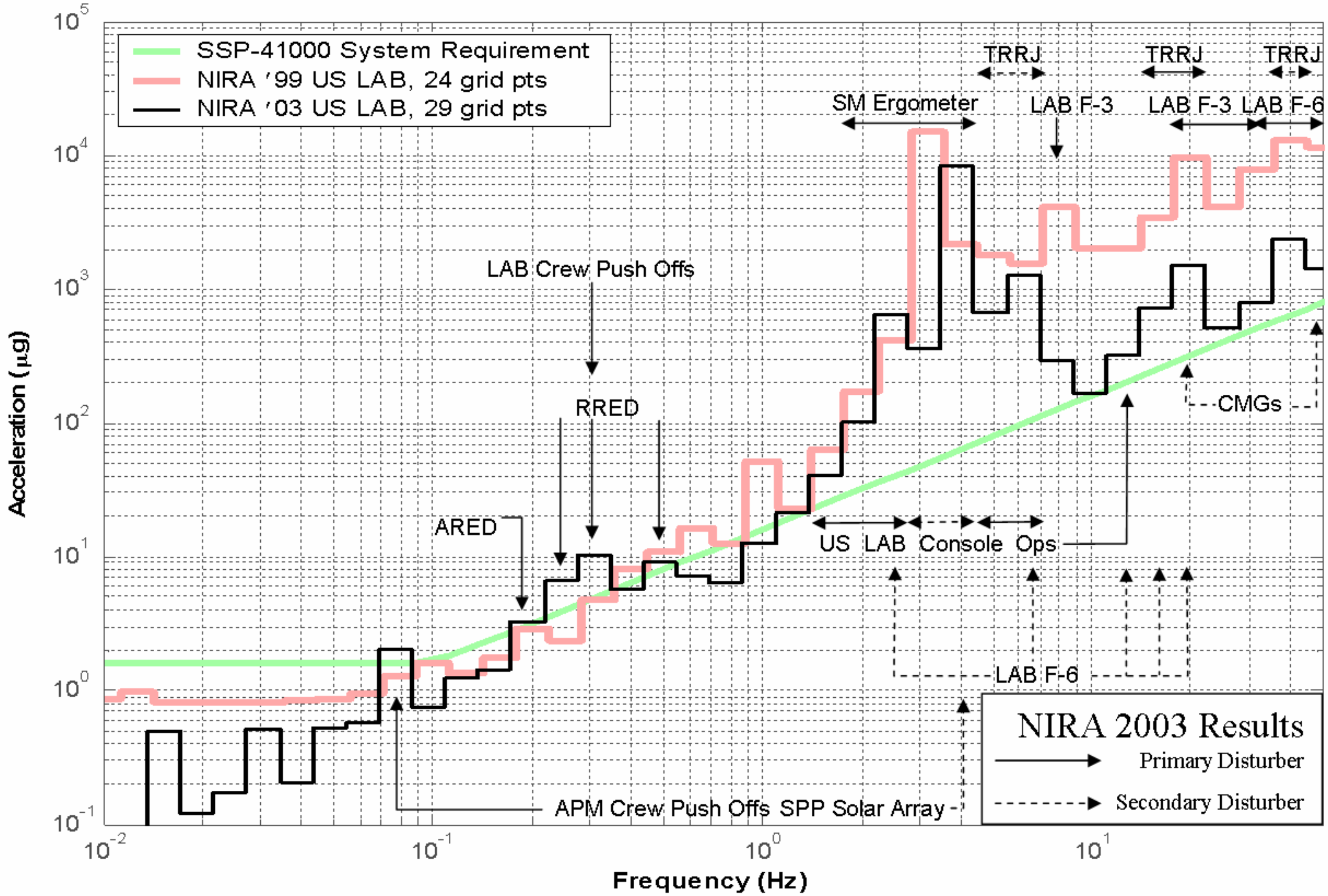
DAC

- Vehicle Disturbers/Response
- Does not include Payload Disturbers
- Includes Active Rack Isolation System (ARIS)
- Used by vehicle to show compliance to μg specification requirements
- Damping = 0.25%

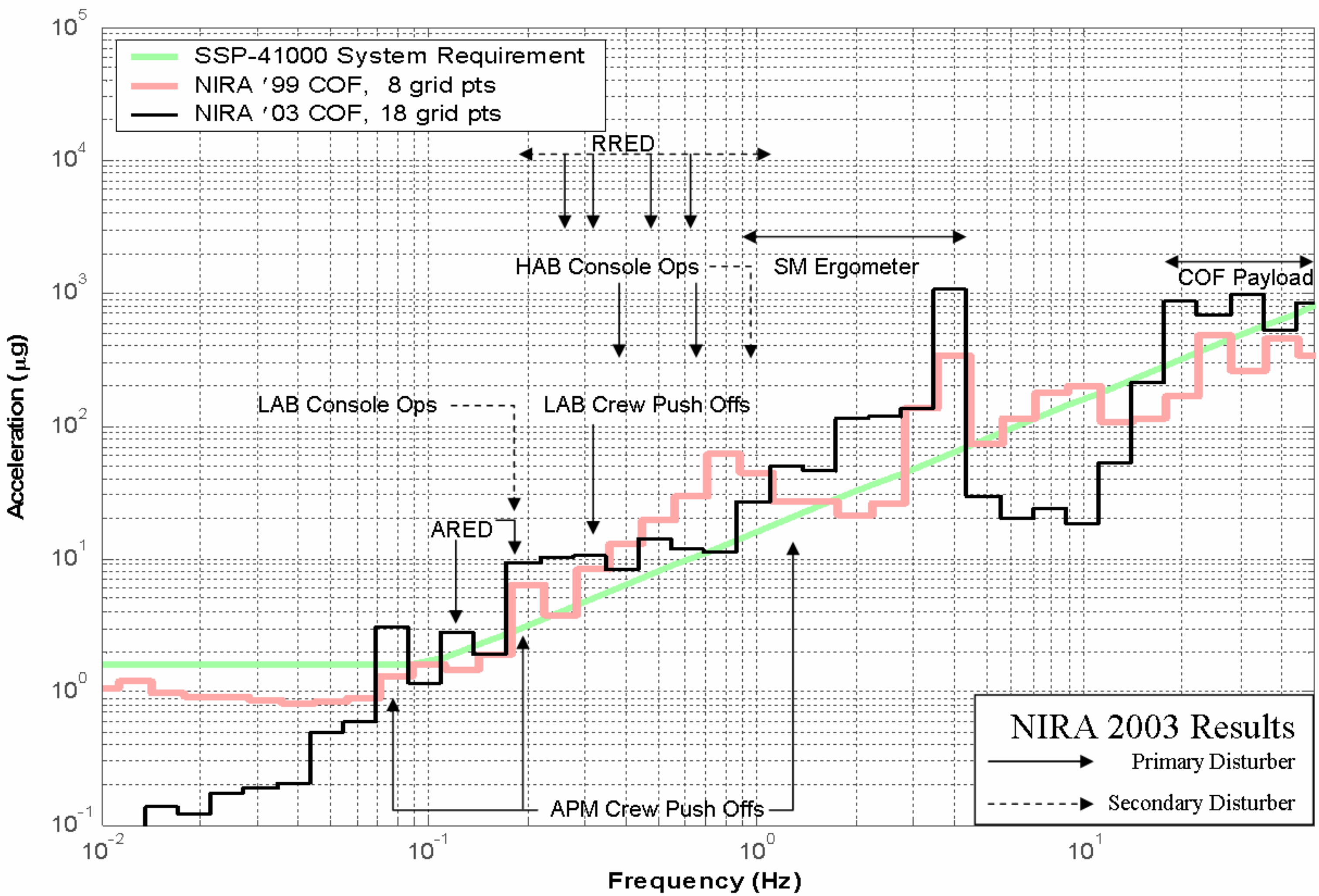
NIRA

- Vehicle Disturbers/Response
- Includes Payload Disturbers (Based on Allocations)
- Does not include rack isolation (Isolation determined by Payload Developer)
- Used by payloads to predict μg levels at rack interfaces
- Damping = 1.0%

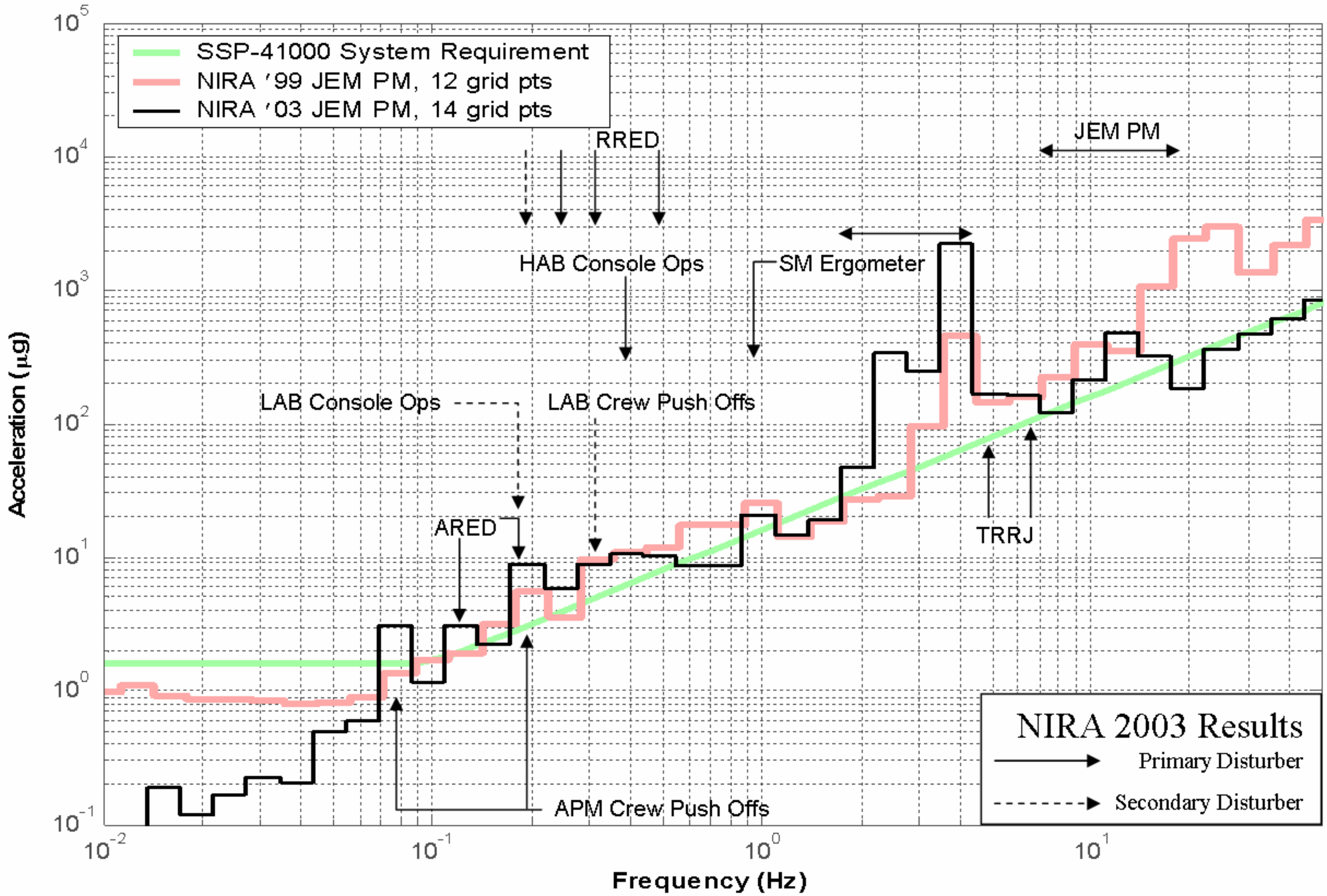
NIRA03 - US Lab



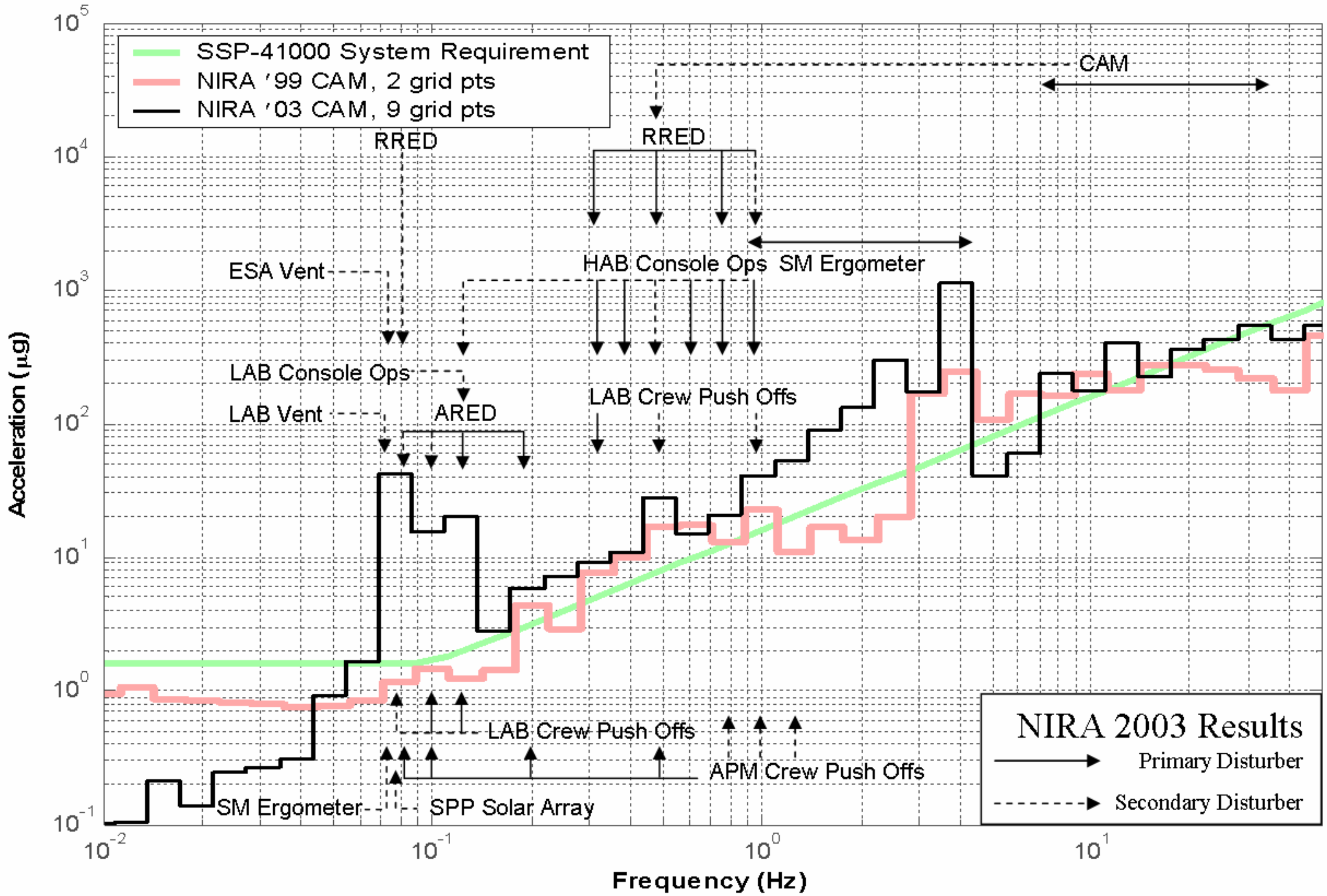
NIRA03 – COF


SSP-41000 System Requirement
NIRA '99 COF, 8 grid pts
NIRA '03 COF, 18 grid pts
RRED
HAB Console Ops
SM Ergometer
COF Payload
LAB Console Ops
LAB Crew Push Offs
ARED
APM Crew Push Offs
NIRA 2003 Results
Primary Disturber
Secondary Disturber
Acceleration (μg)
Frequency (Hz)
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-1}
10^{0}
10^{1}

NIRA03 – JEM PM (Pressurized Module)



NIRA03 - CAM


SSP-41000 System Requirement
NIRA '99 CAM, 2 grid pts
NIRA '03 CAM, 9 grid pts
CAM
RRED
RRED
ESA Vent
HAB Console Ops
SM Ergometer
LAB Console Ops
LAB Vent
ARED
LAB Crew Push Offs
LAB Crew Push Offs
APM Crew Push Offs
SM Ergometer
SPP Solar Array
NIRA 2003 Results
Primary Disturber
Secondary Disturber
Acceleration (μg)
Frequency (Hz)
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-1}
10^{0}
10^{1}

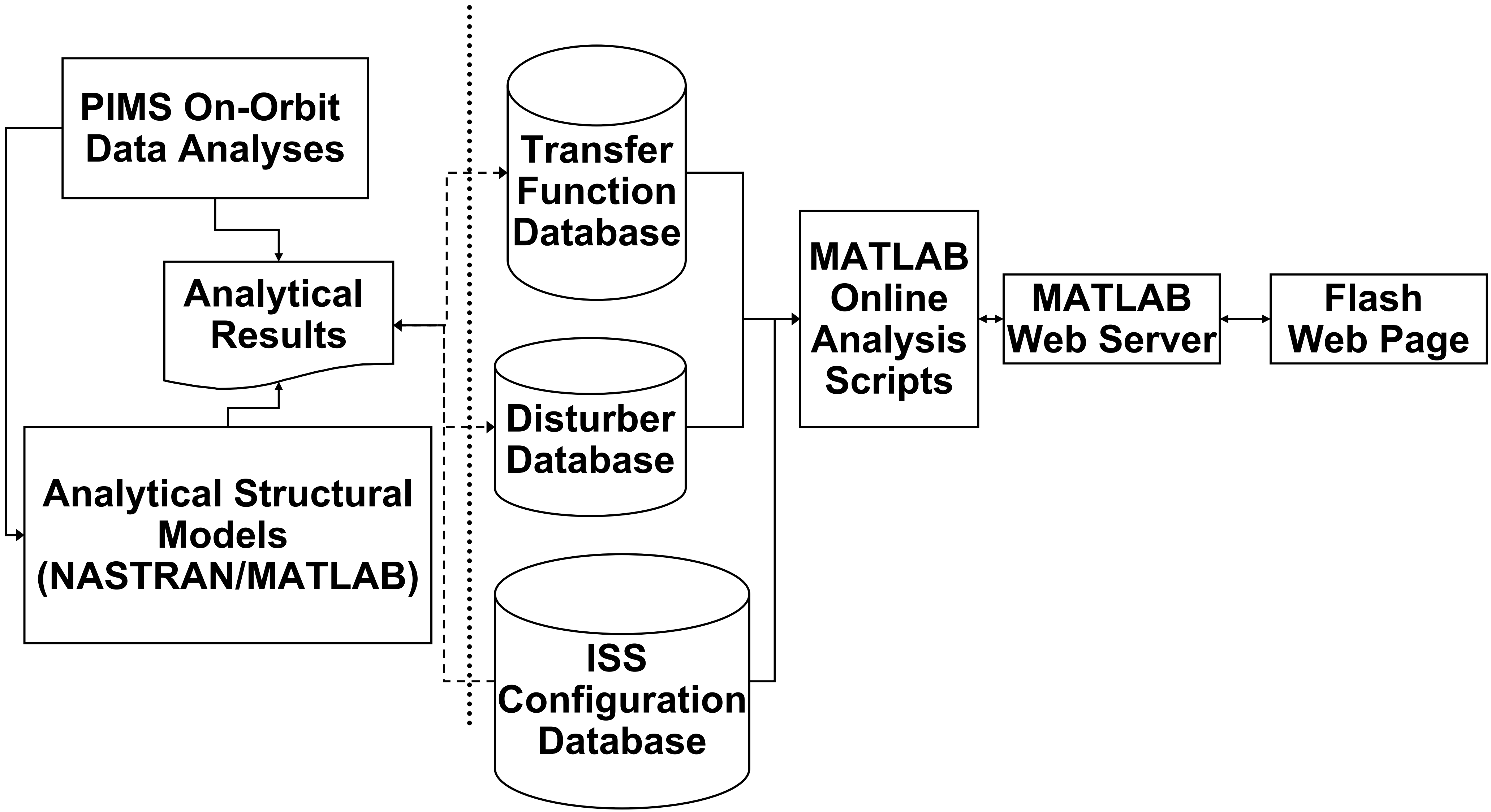
NIRA03

- "Skylines" also available for
  - COF Exposed Payload Facility
  - JEM Exposed Facility
  - JEM Experiment Logistics Module
  - Node 1
  - Node 2
  - Node 3
  - S3 and P3 Trusses

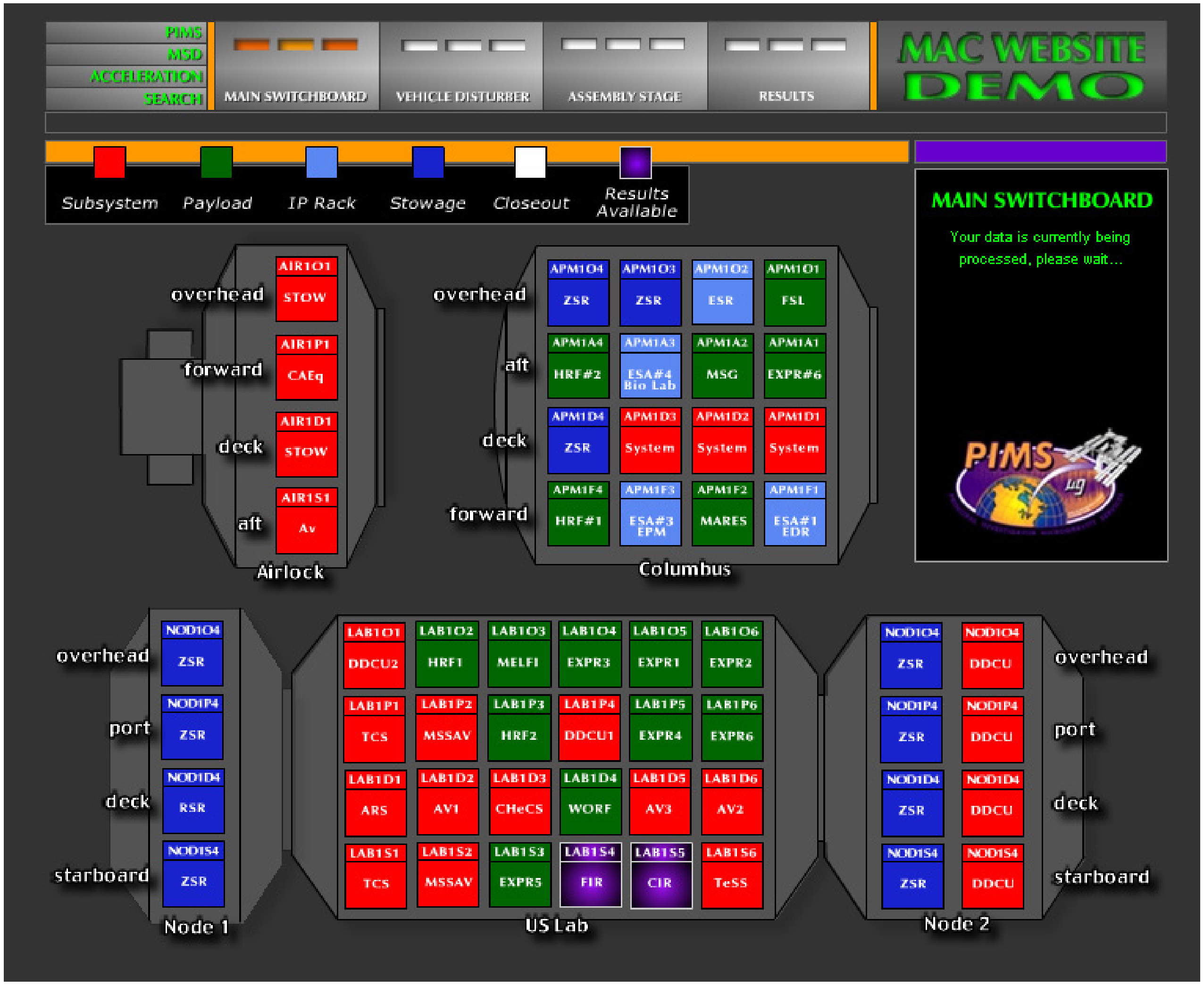
MAC – Microgravity Analysis Cycle

- **Microgravity Analysis Cycle**
  - **Goals:**
    - ***Provide data that can be utilized 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.
    - Further leverage the PIMS group's expertise and extensive knowledge base of the ISS microgravity environment and operations ***to better predict the microgravity environment for science payloads***
    - Merge analytical predictions with on-orbit experience/data
  - **Users: payload developers, science community, payload operations planners, PIMS, etc.**
  - **Differs from "Requirements" based analyses, e.g. NIRA & DAC**
    - Requirements based analyses are conservative (for a good reason)
      - methodology uses maximum enveloping of disturbers
      - Multiple operation scenarios applied simultaneously (high and low speed modes of a disturber applied simultaneously for μg envelope)
      - Useful for payload design and requirement analysis; provides overly conservative results for determining operational cases
      - Currently, pre-assembly complete stages are treated as special runs
- **http://microgravity.grc.nasa.gov/mac_website/**

MAC – Microgravity Analysis Cycle Tool

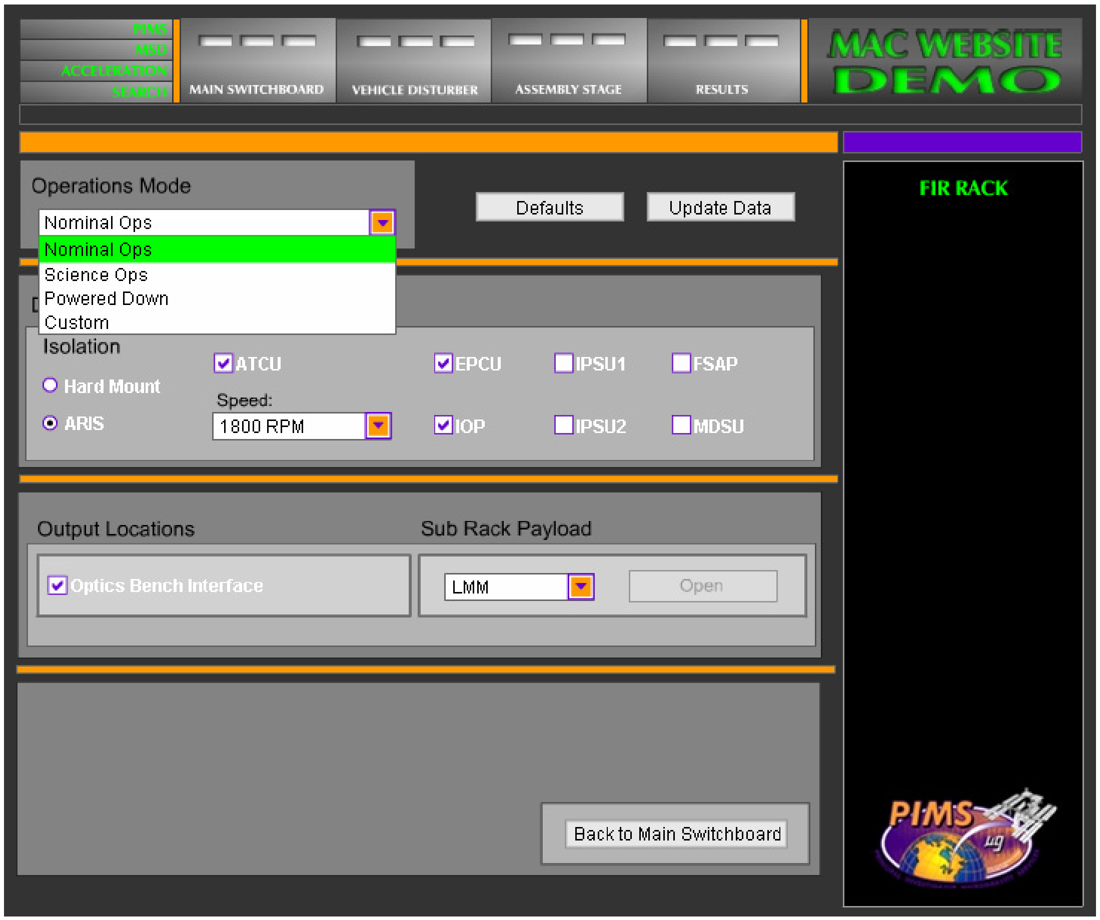


MAC Webpage – Main Page



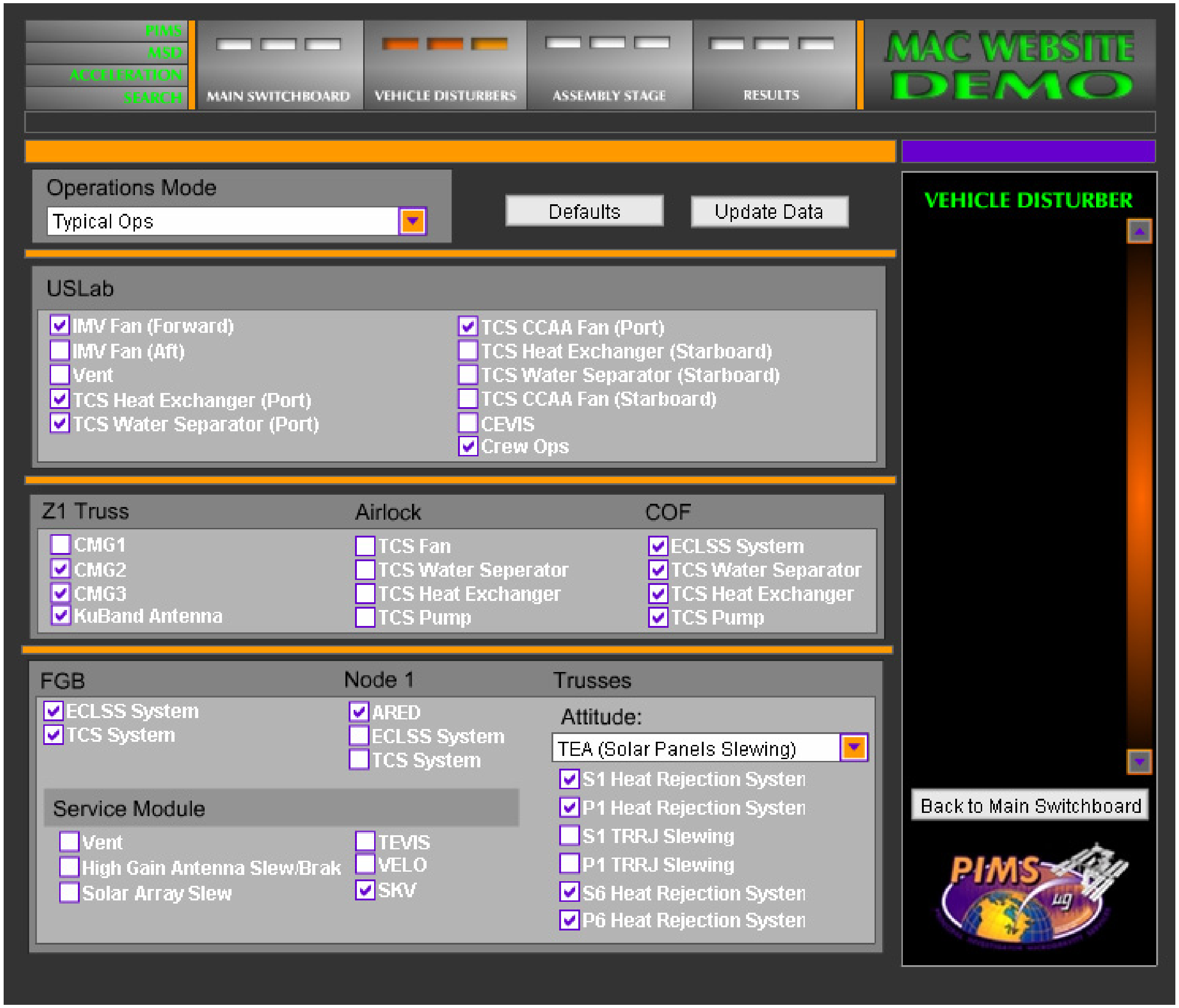
- User can select from different ISS configurations
  - Currently limited to ISS Configuration: UF5
- Racks in "purple" have:
  - Recovery Locations (Results)
  - Configurable Disturbers
- User can select "Vehicle Disturber"

MAC Web Page – Example Rack Page (FIR- Fluids Integrated Rack)



- **User can select among:**
  - **Nominal operations mode**
  - **Predefined modes**
    - "Nominal Ops"
    - "Science Ops"
    - "Powered Down"
  - **Custom mode**
    - User selects desired disturbers
- **User selects requested output (recovery) location by checking check box**

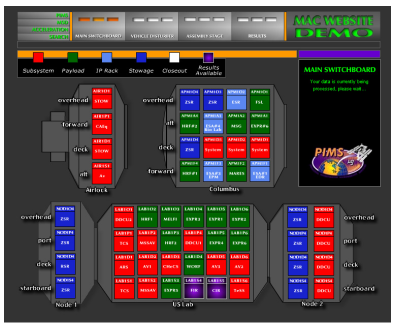
MAC Web Page – Vehicle Disturbers

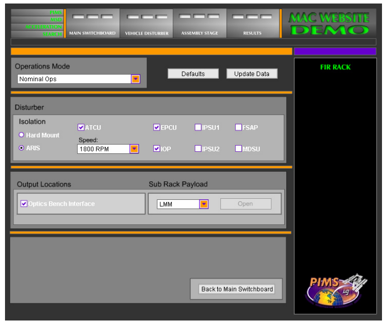


- User can select amongst:
  - Typical operations mode
    - Active disturbers chosen based on PIMS experience for “typical” operations
  - Analytical Predictions (NIRA)
    - NIRA levels are applied at rack interfaces in place of station disturbers
  - Custom mode
    - User selects desired disturbers

MAC Web Page – Results

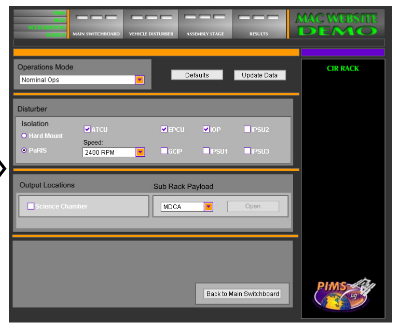
Main Switchboard





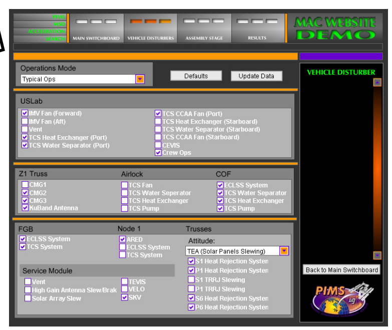
FIR Rack Page

- Choose "Nominal Ops"
  - ATCU, EPCU, IOP, ARIS become active
- *Choose "Optics Bench" for results*



CIR Rack Page

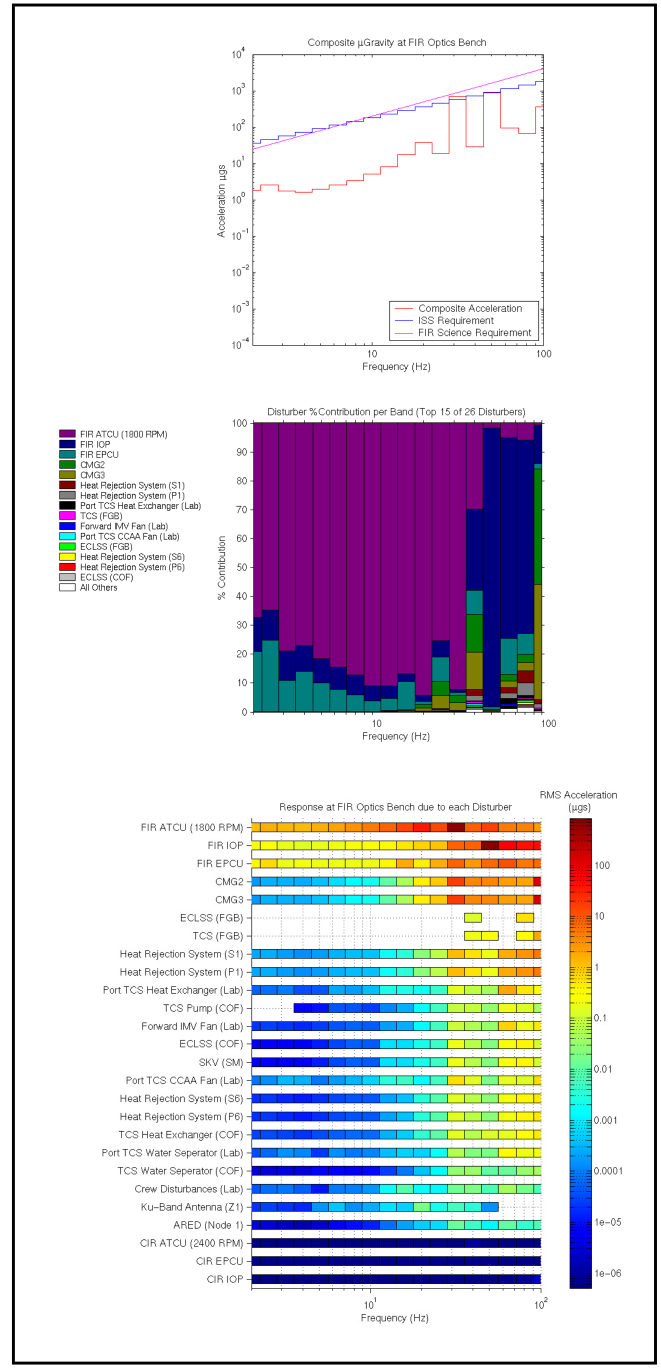
- Choose "Nominal Ops"
  - ATCU, EPCU, IOP, PaRIS become active



Vehicle Disturbers Page

- Choose "Typical Ops"
  - US Lab IMV Fan, TCS Components, CMG 2 & 3, etc. become active

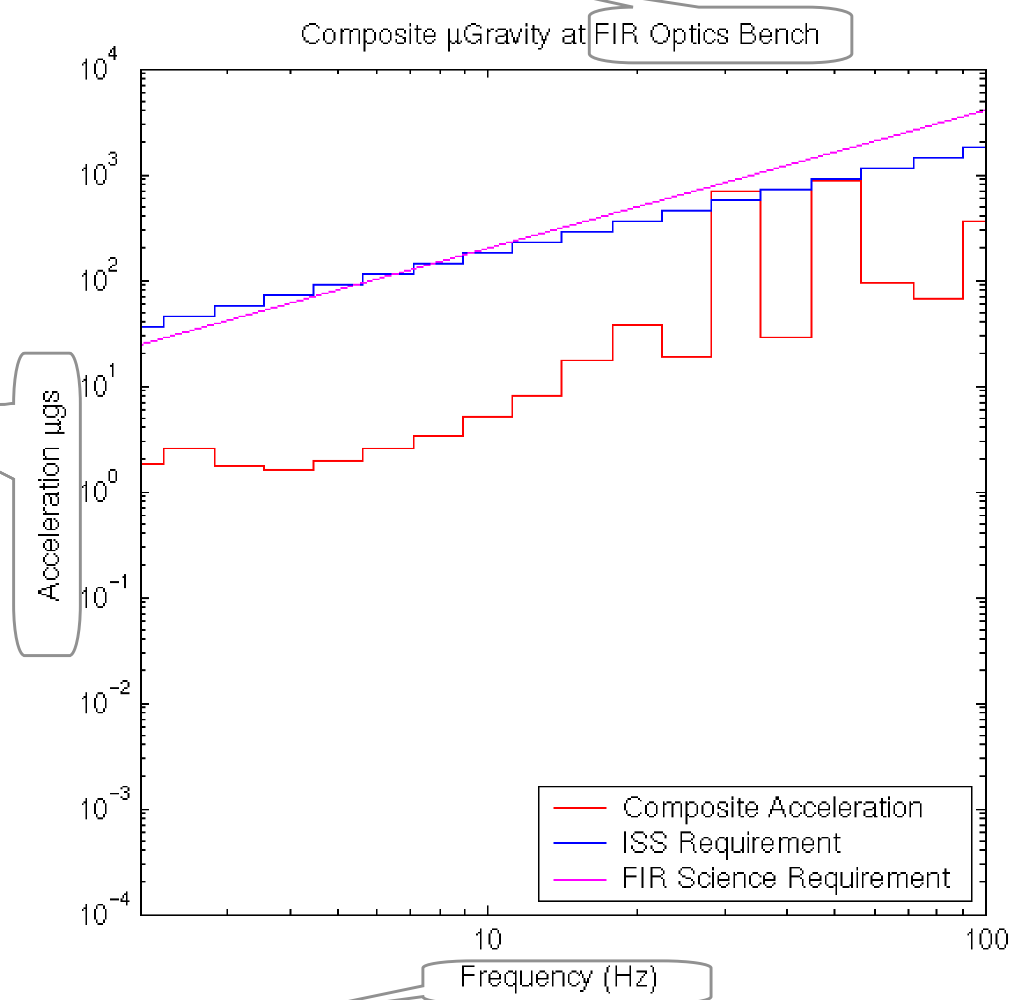
Results Page



Results – Figure 1

What is the μg environment at the selected output location?

Output Location



μg Level
- **Composite Level**
- **Requirements (as applicable)**

Frequency
- **In One Third Octave Bands**

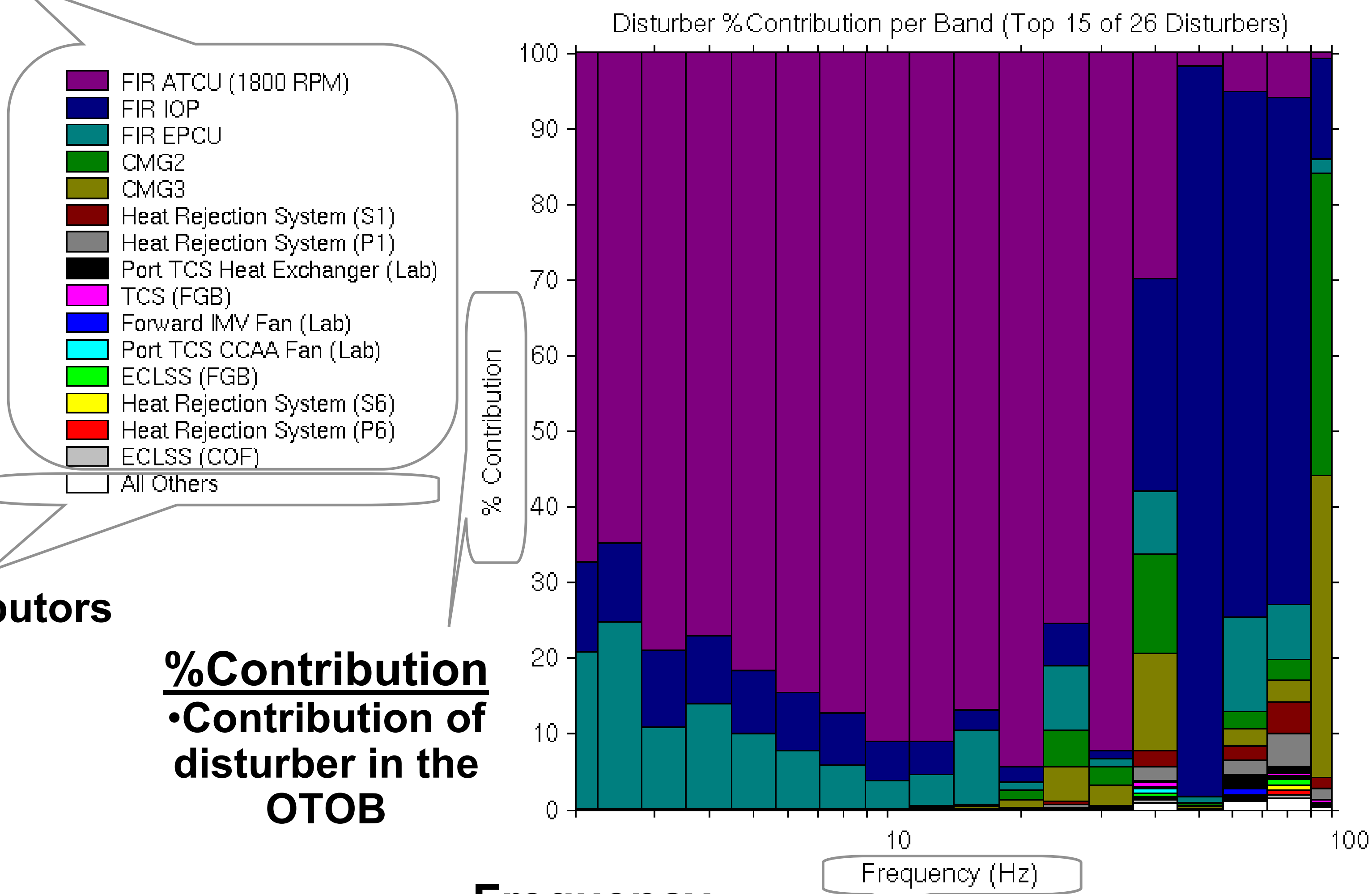
Results – Figure 2

What disturbers are significantly contributing to the μg environment at the selected output location?

Top 15 Contributors

Most (across the spectrum)

Least



All Other Contributors Combined

%Contribution

- **Contribution of disturber in the OTOB**

Frequency

- **In One Third Octave Bands (OTOB)**

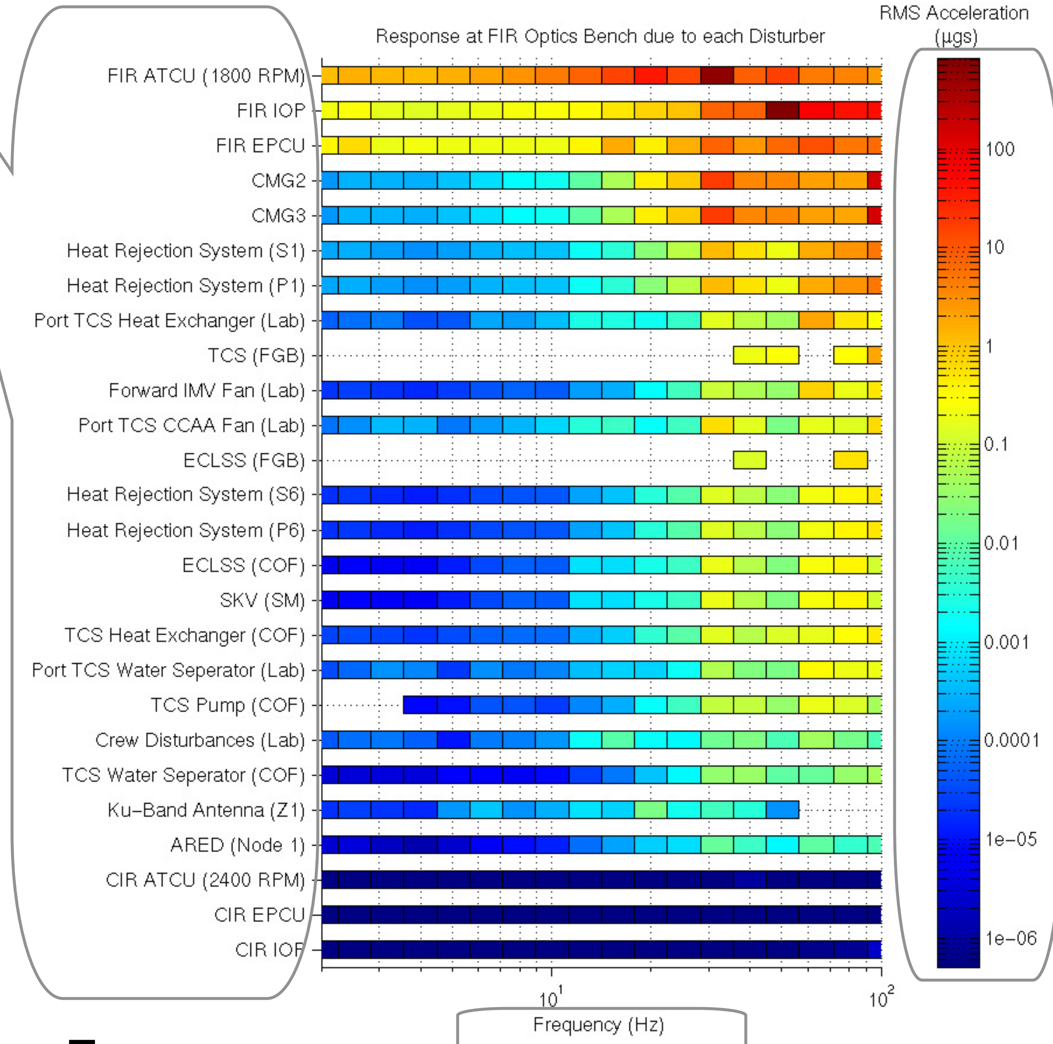
Results - Figure 3

What are the RMS acceleration levels from each disturber at the selected output location?

Each Disturber
- **Horizontal Bar**

Most Contribution (across the spectrum)

Least Contribution



µg Level

Frequency
- **In One Third Octave Bands (OTOB)**

MAC Development Status

- **Frequency Range**
  - **Example above shows 2-100 Hz**
  - **Will increase to 0.01 to 100 Hz for periodic disturbers**
  - **Will increase to 0.01 to 50 Hz for transients**

- **ISS Assembly Configurations**
  - **Currently completing UF2 and UF5**
    - *Results on preceding pages are not actual predicted values*
  - **Will expand to all other assembly stages**

- **Web Page**
  - **Adding Help Pages**
    - Tutorial
    - Plain English description of payload and vehicle disturbers
    - Links to PIMS handbook pages
  - **Report Page**
    - Summary of user inputs
    - Summary of model configuration (configuration management)
  - **Methodology Page**
    - Details describing methodology in generating analytical results

Summary

- **Quasi-steady Environment – SSMRBS**
- **Vibratory from 0.01 to 50 Hz – FEA**
- **Vibratory from 50 Hz to 360 Hz - SEA**
- **Design Analysis Cycle**
  - **DAC predictions to show vehicle compliance to requirements**
- **Non-Isolated Rack Assessment**
  - **NIRA used by payload developers in conjunction with Isolation (ARIS, PaRIS, None) to assess environment**
- **Design Analysis Cycle**
  - **http://microgravity.grc.nasa.gov/mac_website**
  - **In development**
  - **Provide data that can be utilized to make operational decisions based on the predicted microgravity environment for specific payloads**