Section 20

ISS Design Analysis Cycle & Environment Predictions

Microgravity Environment Interpretation Tutorial
NASA Glenn Research Center
March 2-4, 2004

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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

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

• System Level
  • Frequencies < .01 Hz, 1.0 $\mu g$ Peak and .2 $\mu g$ perpendicular component

• Element level
  • Quasi-steady microgravity requirements flow down to the PIDS as an allocation of .02 $\mu g$ on individual disturbances, excluding the effect of drag and gravity gradient. US LAB and HAB are allocated 0.04 $\mu g$ 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
ISS Design Analysis Cycle & Environment Predictions

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

\[
\ddot{\mathbf{a}} = -\mu \left( \frac{-\mathbf{r}_p}{r_p^3} - \frac{-\mathbf{r}_g}{r_g^3} \right) - \dot{\mathbf{\omega}} \times \left( \mathbf{\omega} \times \mathbf{r}_p \right) - \mathbf{\omega} \times \mathbf{\omega} \times \mathbf{r}_p + \mathbf{a}_D
\]

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**

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

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#### Rack Count

- **DAC 9**
  - 14 of 32 racks less than 1 µg
  - Good stability, all 32 racks below 0.2 µg

#### Table: Quasi-Steady Results

<table>
<thead>
<tr>
<th>Location</th>
<th>µG Vector</th>
<th>Unit Vector</th>
<th>Cone Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Magnitude (µG)</td>
<td>Component (µG)</td>
<td>X</td>
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<tr>
<td>C6</td>
<td>0.234</td>
<td>0.038</td>
<td>-0.995</td>
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<tr>
<td>USL-C1</td>
<td>0.298</td>
<td>0.083</td>
<td>-0.630</td>
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<tr>
<td>USL-C2</td>
<td>0.266</td>
<td>0.066</td>
<td>-0.751</td>
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<tr>
<td>USL-C3</td>
<td>0.244</td>
<td>0.045</td>
<td>-0.854</td>
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<td>USL-C4</td>
<td>0.237</td>
<td>0.059</td>
<td>-0.830</td>
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<td>USL-C5</td>
<td>0.245</td>
<td>0.085</td>
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<td>USL-S1</td>
<td>0.796</td>
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<td>USL-S2</td>
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<tr>
<td>USL-S3</td>
<td>0.691</td>
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<tr>
<td>USL-S4</td>
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<td>0.102</td>
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<td>USL-P1</td>
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<td>JPM2-F1</td>
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<td>JPM3-A2</td>
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<td>0.111</td>
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<td>JPM4-F2</td>
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<td>JPM5-A3</td>
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<td>JPM6-F3</td>
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<td>JPM7-A4</td>
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<td>JPM8-A5</td>
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<td>JPM9-F5</td>
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<td>JPM10-F6</td>
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<td>APM-FWD2</td>
<td>1.300</td>
<td>0.116</td>
<td>-0.265</td>
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## Quasi-steady Results

### DAC 9 - Assembly Complete, Comparison

14 of 32 racks less than 1 μg magnitude

<table>
<thead>
<tr>
<th>Configuration</th>
<th>CG</th>
<th>Principle Axis</th>
<th>Mass</th>
<th>Rack count under 1 μg</th>
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<tbody>
<tr>
<td></td>
<td>X-ft</td>
<td>Y-ft</td>
<td>Z-ft</td>
<td>Y-deg</td>
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<tr>
<td>7/15/94</td>
<td>-24.77</td>
<td>-0.7</td>
<td>13.55</td>
<td>-5.1</td>
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<tr>
<td>3/13/95 (DAC1)</td>
<td>-23.49</td>
<td>-2.26</td>
<td>12.67</td>
<td>-8.15</td>
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<tr>
<td>DAC2</td>
<td>-23.41</td>
<td>-3.02</td>
<td>11.71</td>
<td>-6.17</td>
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<tr>
<td>DAC3</td>
<td>-23.07</td>
<td>-1.51</td>
<td>12.9</td>
<td>-1.24</td>
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<tr>
<td>DAC4</td>
<td>-21.23</td>
<td>-0.96</td>
<td>15.51</td>
<td>-3.34</td>
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<tr>
<td>DAC5</td>
<td>-22.08</td>
<td>-1.19</td>
<td>15.82</td>
<td>-4.05</td>
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<td>DAC6</td>
<td>-19</td>
<td>-1.18</td>
<td>14.7</td>
<td>-3.26</td>
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<td>DAC7</td>
<td>-16.21</td>
<td>-0.67</td>
<td>14.74</td>
<td>-5.87</td>
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<td>DAC8</td>
<td>-15.34</td>
<td>-1.28</td>
<td>14.87</td>
<td>-8.44</td>
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<td>DAC9</td>
<td>-17.66</td>
<td>-1.32</td>
<td>14.8</td>
<td>-6.36</td>
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<td>DAC9_CORE</td>
<td>-19.35</td>
<td>-0.59</td>
<td>14.93</td>
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<td>DAC9_CORE_ADJ</td>
<td>-16.27</td>
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<td>13.76</td>
<td>-8.78</td>
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<td>DAC9_ORB</td>
<td>-4.24</td>
<td>-1.09</td>
<td>22.03</td>
<td>8.97</td>
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<td>DAC9_ORB_ADJ</td>
<td>-4.94</td>
<td>-0.49</td>
<td>22.5</td>
<td>15.4</td>
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<td>DAC9_CORE_ORB</td>
<td>-1.88</td>
<td>-0.51</td>
<td>21.86</td>
<td>32.12</td>
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</table>
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

RMS Acceleration (µg)

Frequency (Hz)

Non-isolated Rack I/F

Upper KBAR

Lower Pivot

Rack KBAR Attachment

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DAC9 (ARIS PIDS Level)
DAC8 (ARIS PIDS Level)
System Allocation

SPP
SM Ergomtr
Russian SM

SARJ/TRRJ
CMG

MEIT-2004 / Section 20 / Page 12
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

  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

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

InterVehicular Activity: Translation, Station Keeping, Console Operations, ... Scheduled Maintenance.

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Vibratory Results
DAC 9 - Composite

![Graph showing RMS acceleration versus frequency for different systems and components.]

- DAC9 (ARIS PIDS Level)
- DAC9 (ARIS Verification Level)
- System Allocation

Key Components:
- CMG
- SPP
- Russian SM
- SM Ergomtr
- SARJ/TRRJ
- Vents
Vibratory Results
DAC 9 – USLAB

RMS Acceleration (µg)

Frequency (Hz)

DAC9_USOS (ARIS PIDS Level)
DAC9_USOS (ARIS Verification Level)
USOS Allocation

MCA Pump
TRRJ

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Vibratory Results
DAC 9 – COF/CAM

RMS Acceleration (µg) vs Frequency (Hz)

- DAC9_ESA (ARIS PIDS Level)
- DAC9_ESA (ARIS Verification Level)
- DAC9_ESA (25.6 psi vent, ARIS PIDS Level)
- ESA Allocation

March 2-4, 2004
Vibratory Results

DAC 9 – JEM

RMS Acceleration (μg)

Frequency (Hz)

DAC9_JEM (ARIS PIDS Level)

DAC9_JEM (ARIS Verification Level)

JEM Allocation
Vibratory Results

DAC 9 – Russian Segment (RS)

RMS Acceleration (µg) vs Frequency (Hz)

- DAC9_RS (ARIS PIDS Level)
- DAC9_RS (ARIS Verification Level)
- RS Allocation

SM Ergomtr

Russian SM
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
Vibroacoustic Environment Predictions
VibroAcoustic Results

DAC8 Response at ISPR due to All Combined System Disturbances

Core - All Vibration & Acoustic Sources

RMS Acceleration Response (µg)

Frequency

Micro-g w/ARIS

Frequency
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)
  - VibroAcoustic range (50-300 Hz) in work
  - Updates to disturbers
  - Some changes in methodology
- Reports $\mu g$ at rack interfaces on a per element (US LAB, JEM, etc.) basis
- Assumptions/Limitations
  - Station in $\mu g$ 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

<table>
<thead>
<tr>
<th>DAC</th>
<th>NIRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Vehicle Disturbers/Response</td>
<td>• Vehicle Disturbers/Response</td>
</tr>
<tr>
<td>• Does not include Payload Disturbers</td>
<td>• Includes Payload Disturbers (Based on Allocations)</td>
</tr>
<tr>
<td>• Includes Active Rack Isolation System (ARIS)</td>
<td>• Does not include rack isolation (Isolation determined by Payload Developer)</td>
</tr>
<tr>
<td>• Used by vehicle to show compliance to $\mu g$ specification requirements</td>
<td>• Used by payloads to predict $\mu g$ levels at rack interfaces</td>
</tr>
<tr>
<td>• Damping = 0.25%</td>
<td>• Damping = 1.0%</td>
</tr>
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</table>
ISS Design Analysis Cycle & Environment Predictions

NIRA03 - US Lab

![Graph showing acceleration vs. frequency for different events.](image)

- SSP-41000 System Requirement
- NIRA '99 US LAB, 24 grid pts
- NIRA '03 US LAB, 29 grid pts

NIRA 2003 Results
- Primary Disturber
- Secondary Disturber

- LAB Crew Push Offs
- ARED
- RRED
- US LAB Console Ops
- LAB F-6
- SM Ergometer
- TRRJ

March 2-4, 2004
NIRA03 – JEM PM (Pressurized Module)
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

- PIMS On-Orbit Data Analyses
- Analytical Results
- Analytical Structural Models (NASTRAN/MATLAB)
- ISS Configuration Database
- Transfer Function Database
- Disturber Database
- MATLAB Online Analysis Scripts
- MATLAB Web Server
- Flash Web Page
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
The 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
ISS Design Analysis Cycle & Environment Predictions

MAC Web Page – Results

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

March 2-4, 2004
What is the $\mu g$ environment at the selected output location?

**Output Location**

**$\mu g$ 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)
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

Frequency
• In One Third Octave Bands (OTOB)

Response at FIR Optics Bench due to each Disturber

RMS Acceleration (µg)

µg Level

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