Mapping the history of star formation in the universe

GALEX TELESCOPE VIBRATION RESPONSE REDUCTION

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June 25, 2002

GALEX Telescope
Vibration Response Reduction

- Overview
  - *Telescope Response Problem*
  - *Telescope Response Solution*
  - *Instrument Bipod Design Approach*
    - Stiffness Reduction
    - Damping
  - *Instrument Vibration Test Results*
  - *Spacecraft Vibration Test Results*

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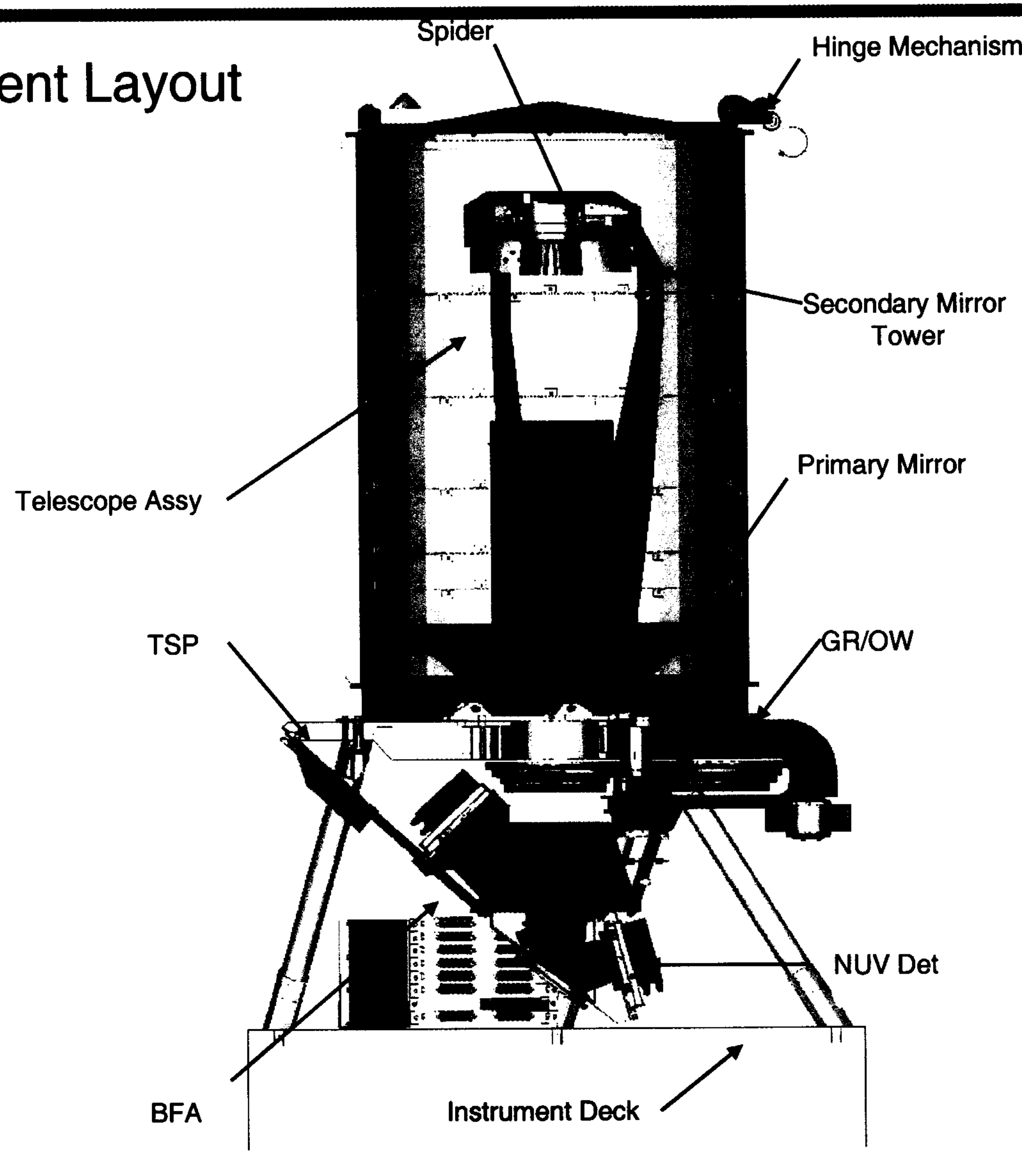
GALEX Telescope Vibration Response Reduction

GALEX The Galaxy Evolution Explorer

- Instrument Layout



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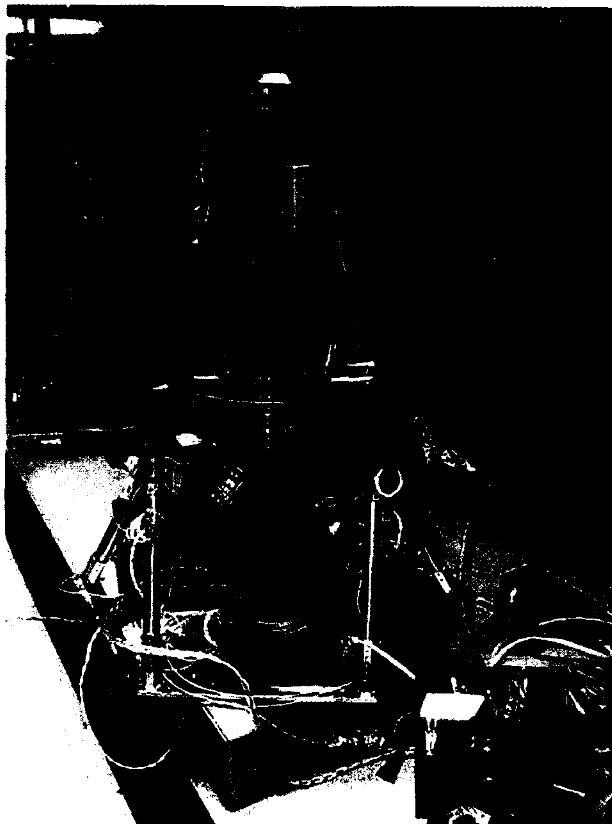
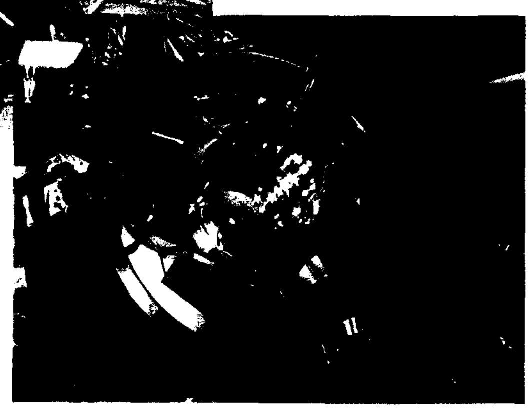
Vibration Response Reduction





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The Galaxy Evolution Explorer

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Vibration Response Reduction

- Telescope Response Problem
  - *During Instrument lateral vibration testing (10/00), the input was manually notched -20 dB from 45 to 55 Hz in addition to force limiting due to the TA secondary mirror assembly response above the misalignment g level (22 g) determined by static testing (8/00).*
    - Response at the Telescope secondary mirror showed a Q of 80+

20-30	+9 dB/Oct	20-75	+9 dB/Oct
30-60	0.1 g^2/Hz	75-120	0.1 g^2/Hz
60-80	-10 dB/Oct	120-160	-10 dB/Oct
80-1000	0.04 g^2/Hz	160-1000	0.04 g^2/Hz
1000-2000	-12 dB/Oct	1000-2000	-12 dB/Oct
Overall	7.3 grms	Overall	7.4 grms
duration	75 sec	duration	75 sec

  - *As a result, the Instrument was not qualified in the lateral axes.*

GALEX Telescope
Vibration Response Reduction

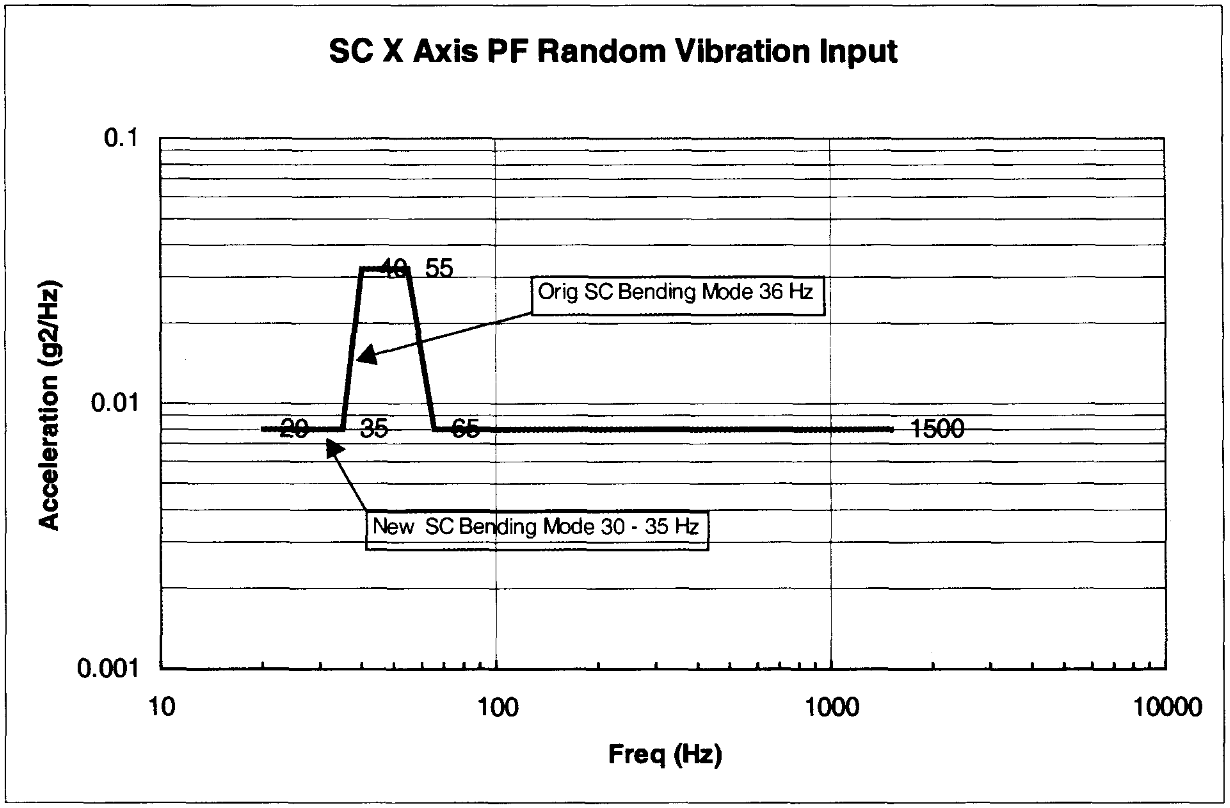
- Telescope Response Solution
  - *Several Paths were investigated*
    - KSC re-analyzed Spacecraft vibration levels based on previous Pegasus flight data
      - *Analysis indicated that a -2 dB reduction in the X axis input acceleration from 0.16 g^2/Hz to 0.10 g^2/Hz was possible*
    - Design modifications to reduce the Telescope Secondary response levels
      - *Options investigated by analysis were*
        - tuned mass damper on Baffle cover
        - dampened spring system between Telescope and Baffle structures
        - Instrument Bipod stiffness reduction with constrained layer damping
        - Instrument vibration isolation system (CSA Engineering)
        - Spacecraft vibration isolation system (CSA Engineering)
      - *Instrument Bipod stiffness reduction was optimal choice (based on schedule and cost) by reducing the TA response to acceptable levels without effecting optical hardware and resulted in 2 benefits*
        - favorable modal combination
        - increased damping

GALEX Telescope Vibration Response Reduction

- Instrument Bipod Design Approach - Stiffness Reduction
  - *Favorable modal combinations*
    - *200 lb Instrument on a 200 lb Spacecraft bus*
    - *Critical local Telescope mode not susceptible to force limiting due to low effective mass*
  - *Vibration Analysis Assumptions*
    - Spacecraft FEM with 1.5% modal damping for all modes
    - Stiffness of the bipods were varied from current 262,000 lb/in to 46,500 lb/in min
  - *Method relies on changing the Instrument modal character*
    - Instrument bending mode combines with the Telescope bending mode and drives the overall Spacecraft bending mode from 36 Hz to 30 Hz.
    - Reduced SC bending mode occurs at a frequency which is at the lower acceleration input level than previous SC bending frequency
      - *Force limiting at the base further reduces input acceleration*
    - Telescope secondary response decreased from 11.1 grms to 5.6 grms without force limiting and 8.5 grms to 4.2 grms with force limiting

GALEX Telescope Vibration Response Reduction

- Instrument Bipod Design Approach - Stiffness Reduction



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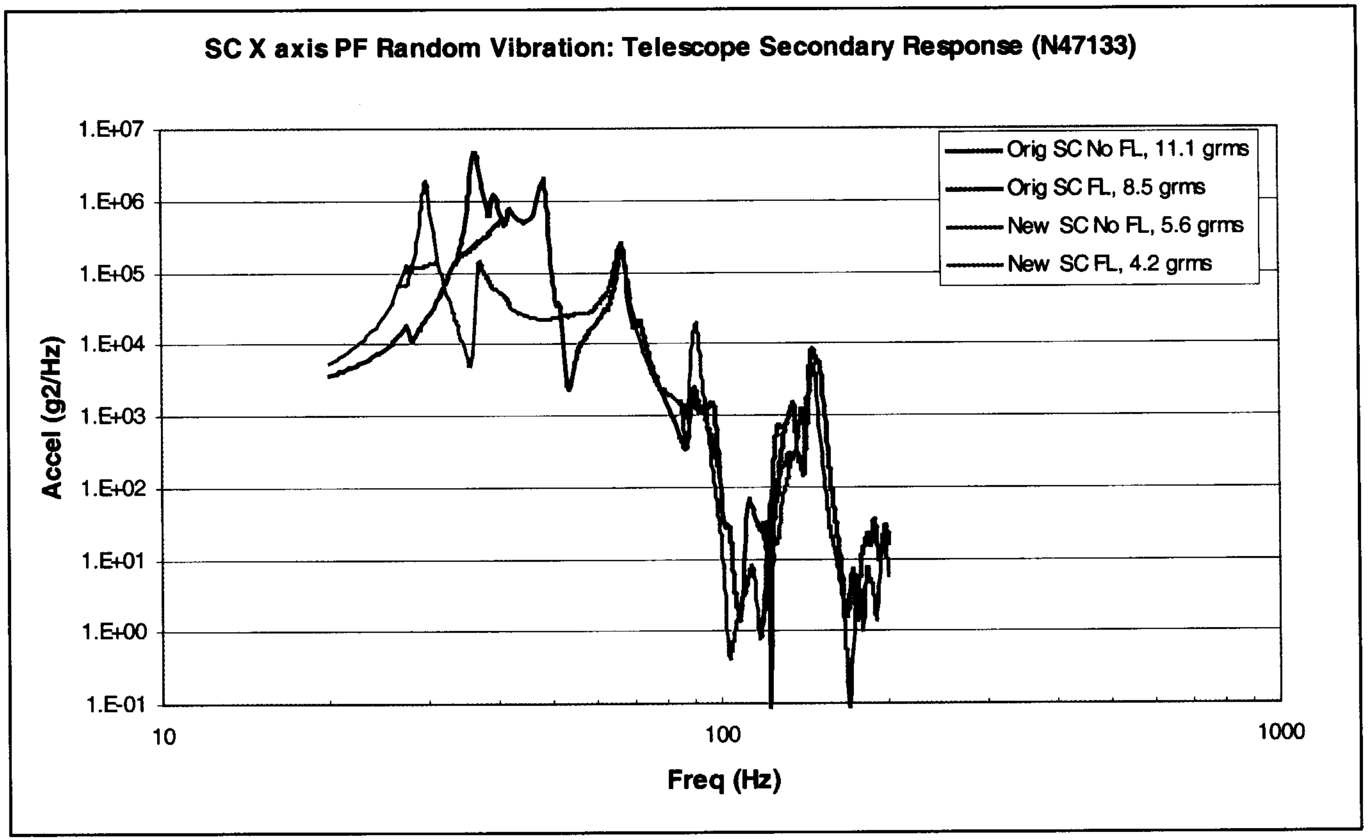
Vibration Response Reduction

- Instrument Bipod Design Approach - Stiffness Reduction



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Vibration Response Reduction

- Instrument Bipod Design Approach - Stiffness Reduction
  - *Based upon acceptable TA secondary response from random vibration analysis, bipod stiffness variations were determined*
    - 46500 lb/in minimum
    - 66400 lb/in maximum
  - *Bipod material and wall thickness were determined using 46500 lb/in*
    - 1.5" OD drove the tube material to Fiberglass for acceptable wall thickness of 0.050" for handling and positive buckling margins
      - *Composite codes showed that Astroquartz II with ±45 layup produced an acceptable Young's Modulus*
        - coupon plate test results (±45 & 0, 90, ±45 layups) showed Young's Modulus lower than composite code predictions
        - Tube (t=0.040" & 0.060") test for Young's Modulus (less than predicted) and tensile failure
        - Tube thickness was increased to 0.070", tested for Young's modulus and sent to CSA Engineering
    - Bipod fittings were changed from AL 7075 to Ti 6Al 4V for thermal compatibility with new fiberglass tubes and 8 mil bond line of 9394 epoxy
  - *Structural Integrity maintained*

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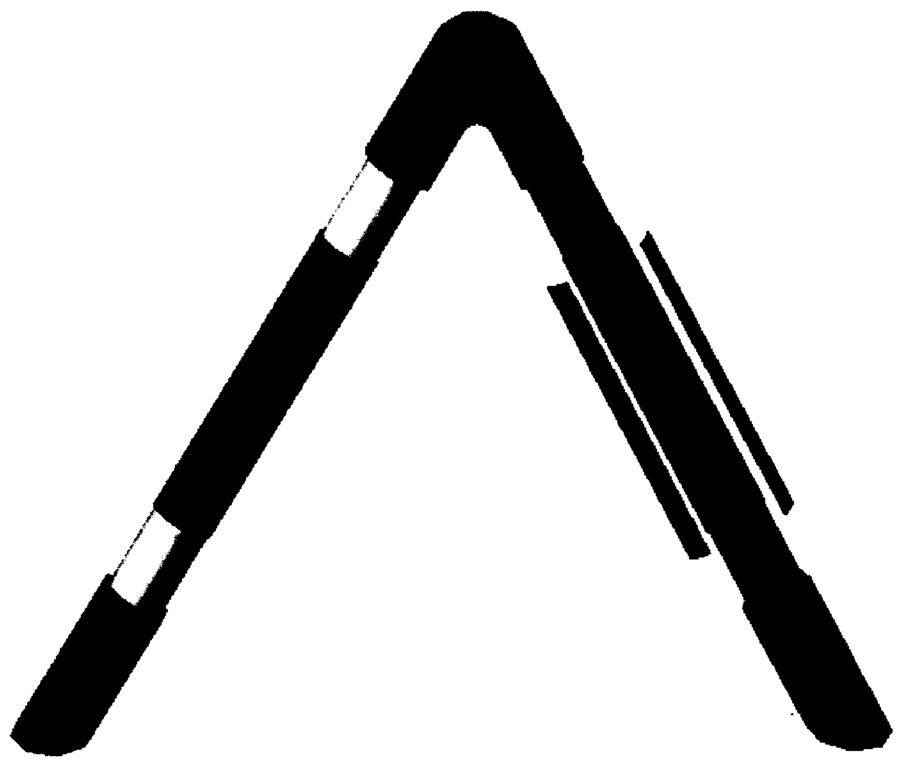
Vibration Response Reduction

- Instrument Bipod Design Approach - Damping
  - *In order to achieve 1.5% modal damping, CSA Engineering designed a constrained layer damping treatment*
    - Eight Alum 0.050" thick staves, 0.010" thick 3M9473 2" at both ends of strut



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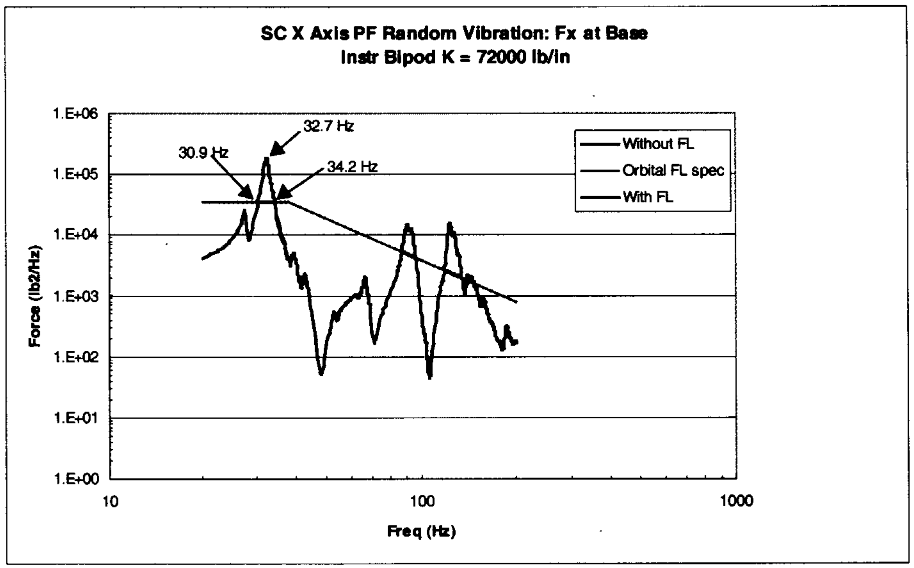
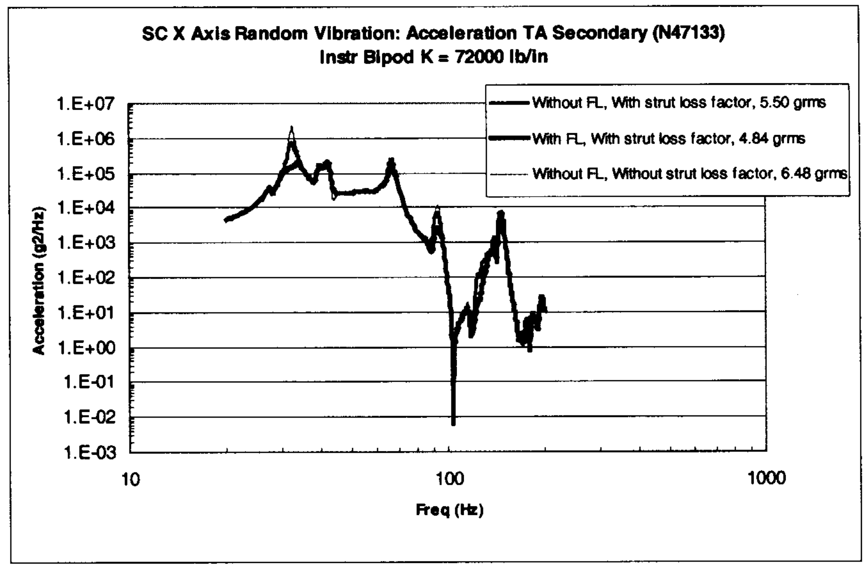
Vibration Response Reduction

- Instrument Bipod Design Approach - Damping
  - *CSA test tube results (1.35" ID, 14 plies Astroquartz II ±45 layup)*
    - undamped - tube stiffness 59400 lb/in, loss factor of 0.45%
    - damped - VEM (t=0.010") is temperature and frequency dependent
      - *@70F and 30Hz*
        - tube stiffness 64000 lb/in, loss factor 9.6%
      - *@74.5F and 30 Hz*
        - tube stiffness 62700 lb/in, loss factor 8.7%
  - *A tube stiffness of 72000 lb/in was used in the analysis to account for colder temperature and additional margin*

GALEX Telescope Vibration Response Reduction

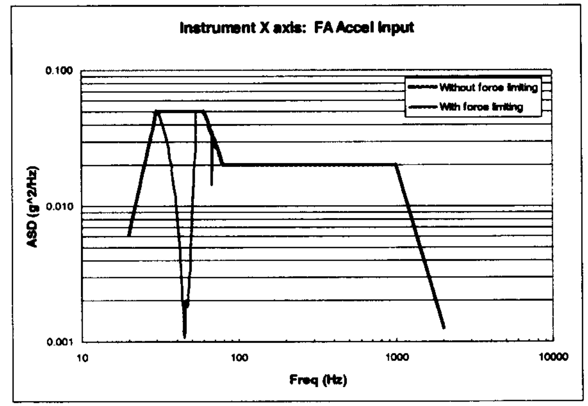
- Instrument Bipod Design Approach - Damping
  - *SC vibration analysis for 72000 lb/in strut with a loss factor of 0.11 resulted in a SC bending mode of 32.7 Hz and TA secondary response of 5.5 grms without force limiting and 4.8 grms with force limiting*

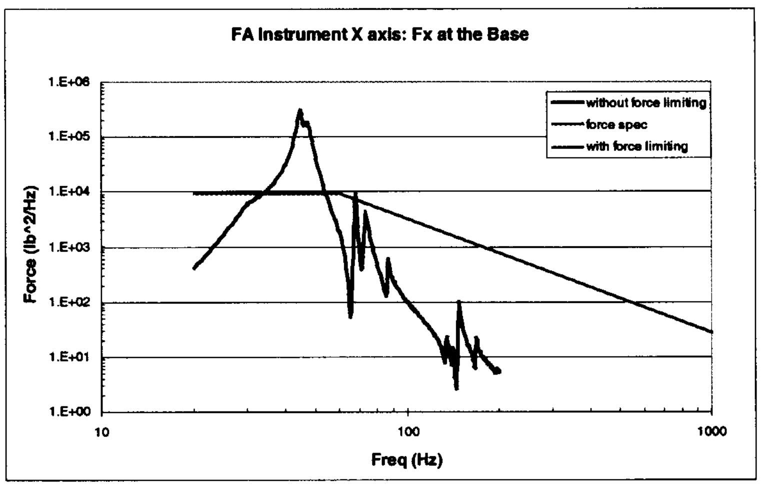


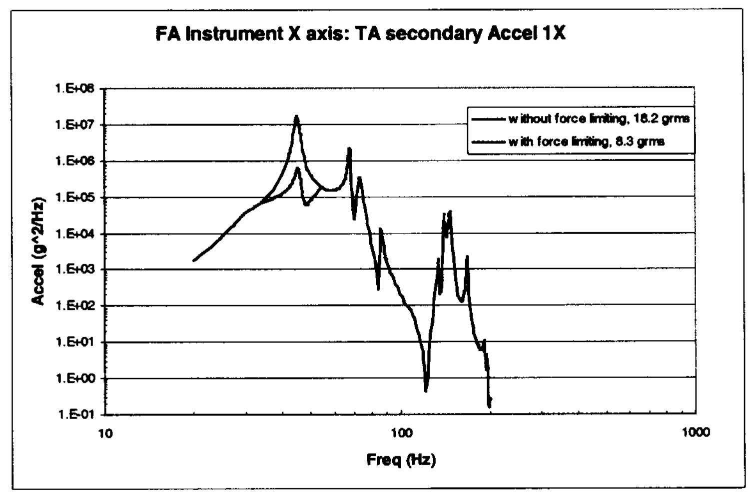


GALEX Telescope
Vibration Response Reduction

- Instrument Random Vibration Test, June 2001 - Predictions
  - *Analysis predicted a single mode at 45 Hz with enough effective mass for force limiting to reduce input and Telescope response*



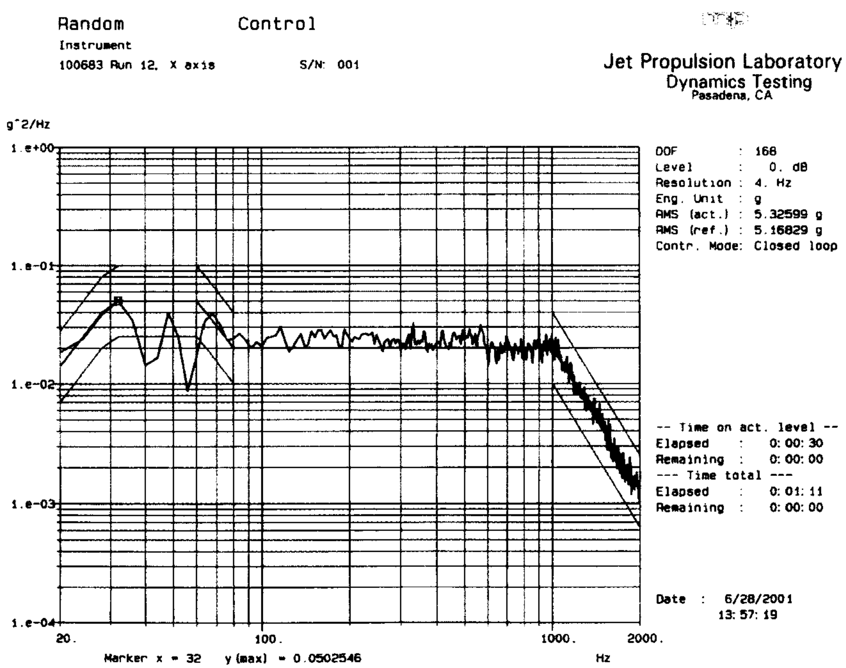




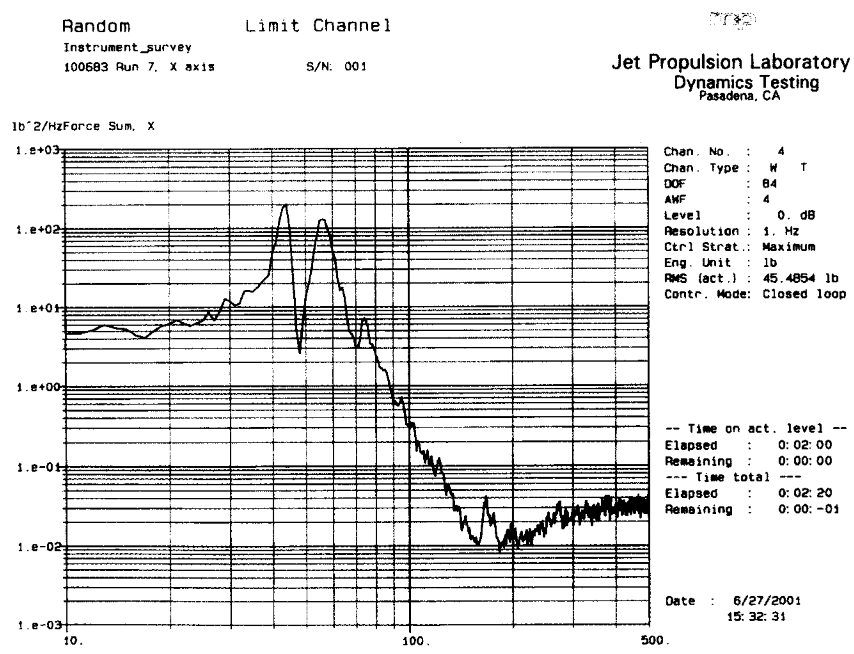
GALEX Telescope
Vibration Response Reduction

- Instrument Random Vibration Test, June 2001 - Results
  - *Two modes at 45 and 55 Hz with large effective mass for force limiting to reduce input by 6 dB.*

Input



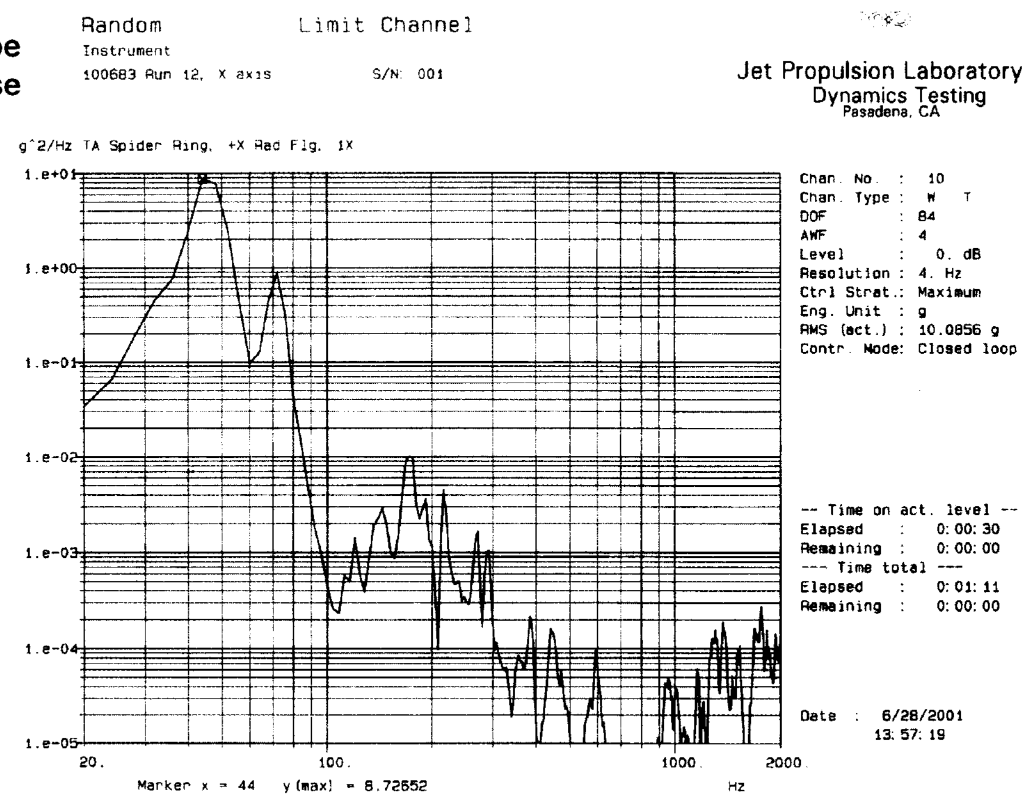
X Force at Base



GALEX Telescope
Vibration Response Reduction

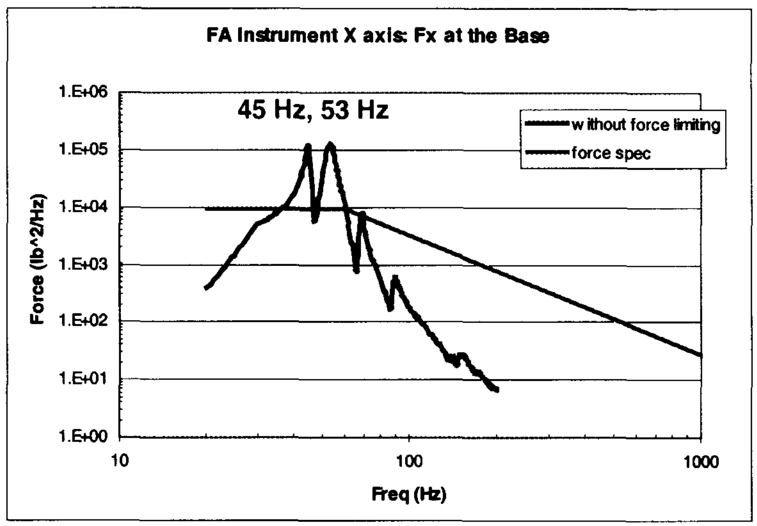
- Instrument Random Vibration Test, June 2001 - Results
  - *Time histories: 29.1 g peak X axis, 21.4 g peak Y axis*
  - *Post-test misalignment showed acceptable*

Telescope Response



GALEX Telescope
Vibration Response Reduction

- Instrument Random Vibration Test, June 2001 - Results
  - *Correlation of vibe test results with Instrument finite element model*
    - calculated effective mass from test
    - single mode to two modes
  - *Adjusted bipod properties to obtain results similar to test*



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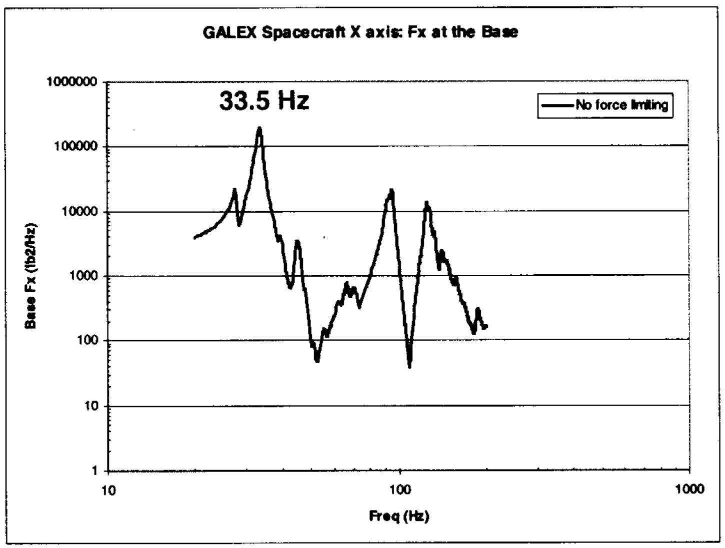
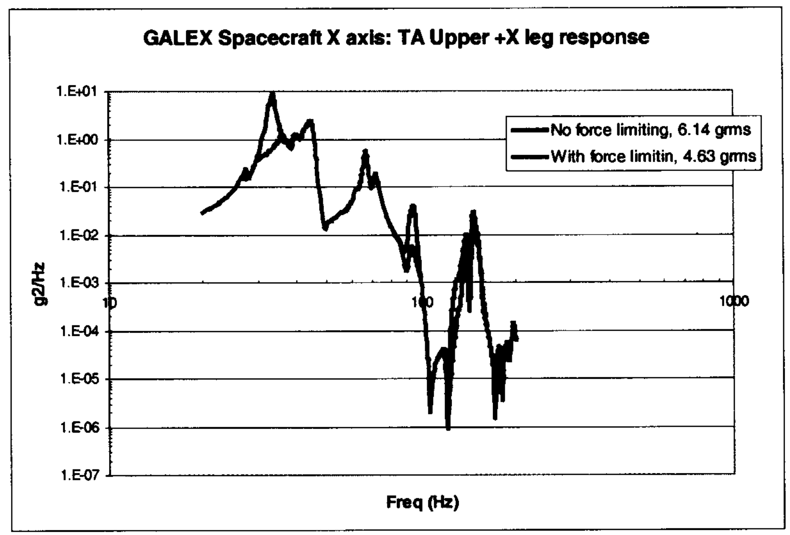
Vibration Response Reduction

- Spacecraft Random Vibration Test, January 2002 - Predictions
  - *Re-analyzed Spacecraft random analysis with updated Instrument FEM*





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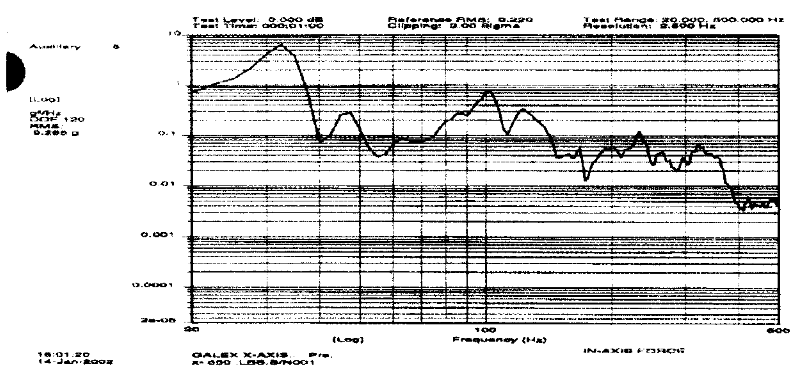
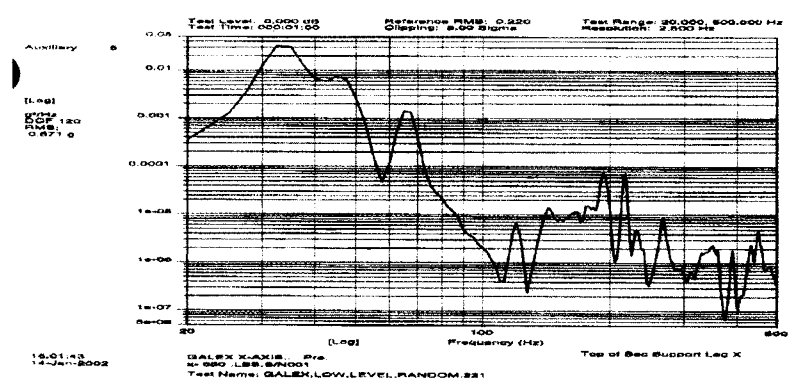
Vibration Response Reduction

- Spacecraft Random Vibration Test, January 2002 - Results
  - *Frequency and Telescope response predictions correct*
    - Spacecraft / Instrument/ Telescope mode at ~33 Hz
    - Telescope response rms prediction
  - *Spacecraft provided additional damping*

Low level run: X Force at Base



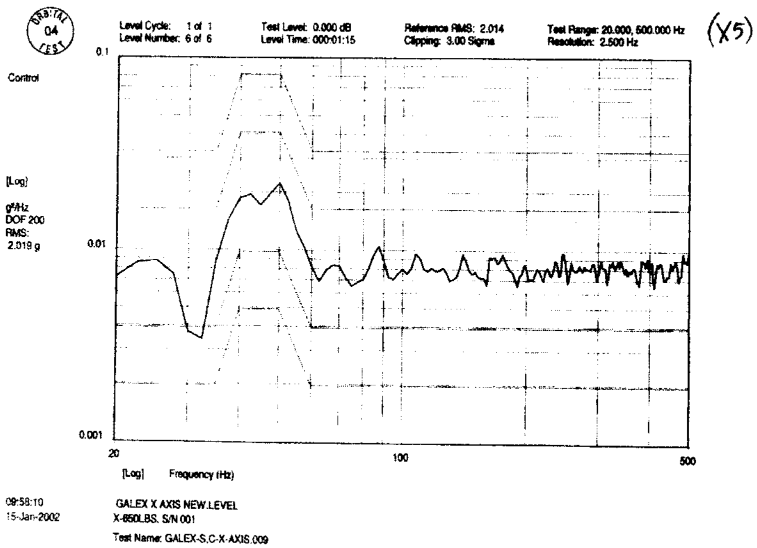
Low level run: Telescope Response



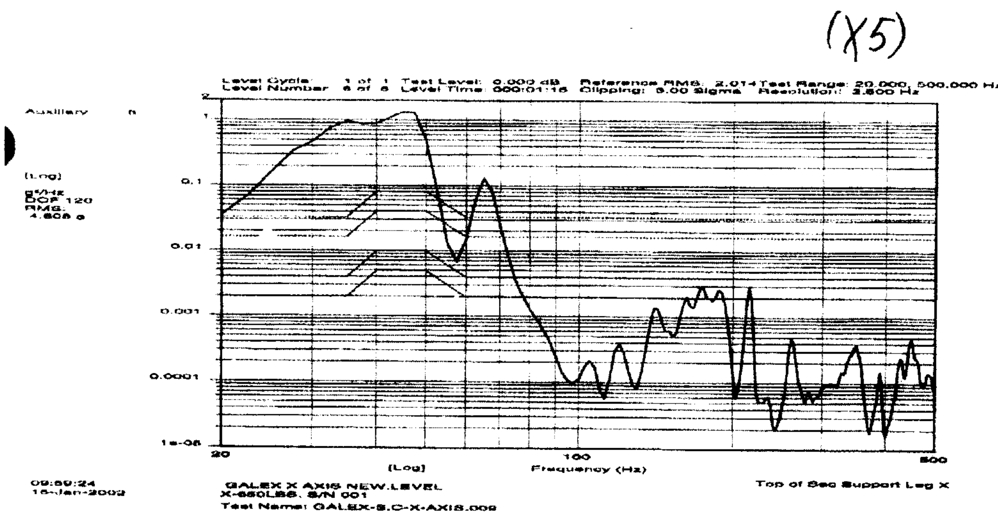
GALEX Telescope
Vibration Response Reduction

- Spacecraft Random Vibration Test, January 2002 - Results
  - *Time Histories: 17.4 g on leg extrapolated to 19.6 g peak at spider in X axis*

Full level run: X Force at Base



Full level run: Telescope Secondary leg Response



  - *Spacecraft successfully completed random vibration testing with minimal force limiting*