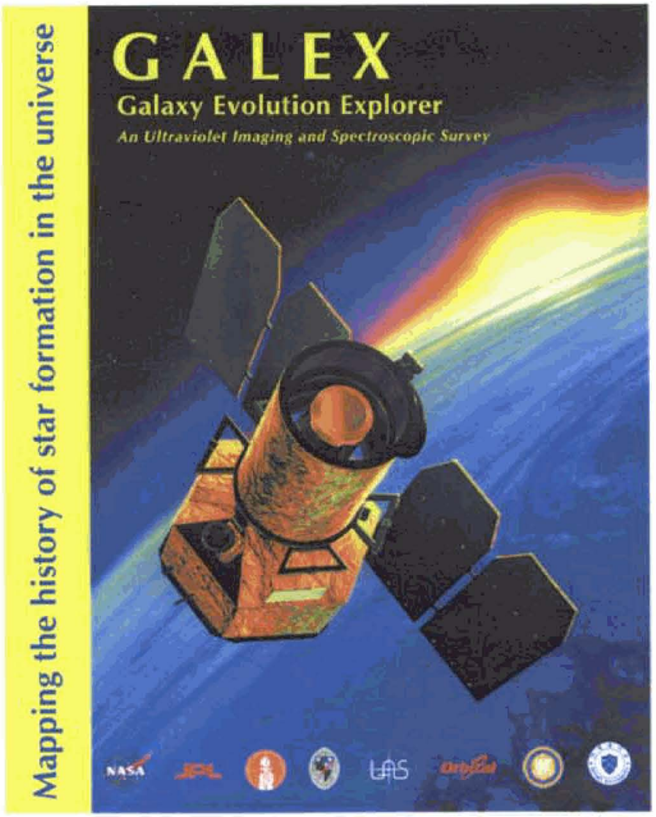

GALEX INSTRUMENT: PEGASUS LAUNCH TEMPERATURE EFFECTS ON A FREQUENCY TUNED DAMPED STRUCTURE

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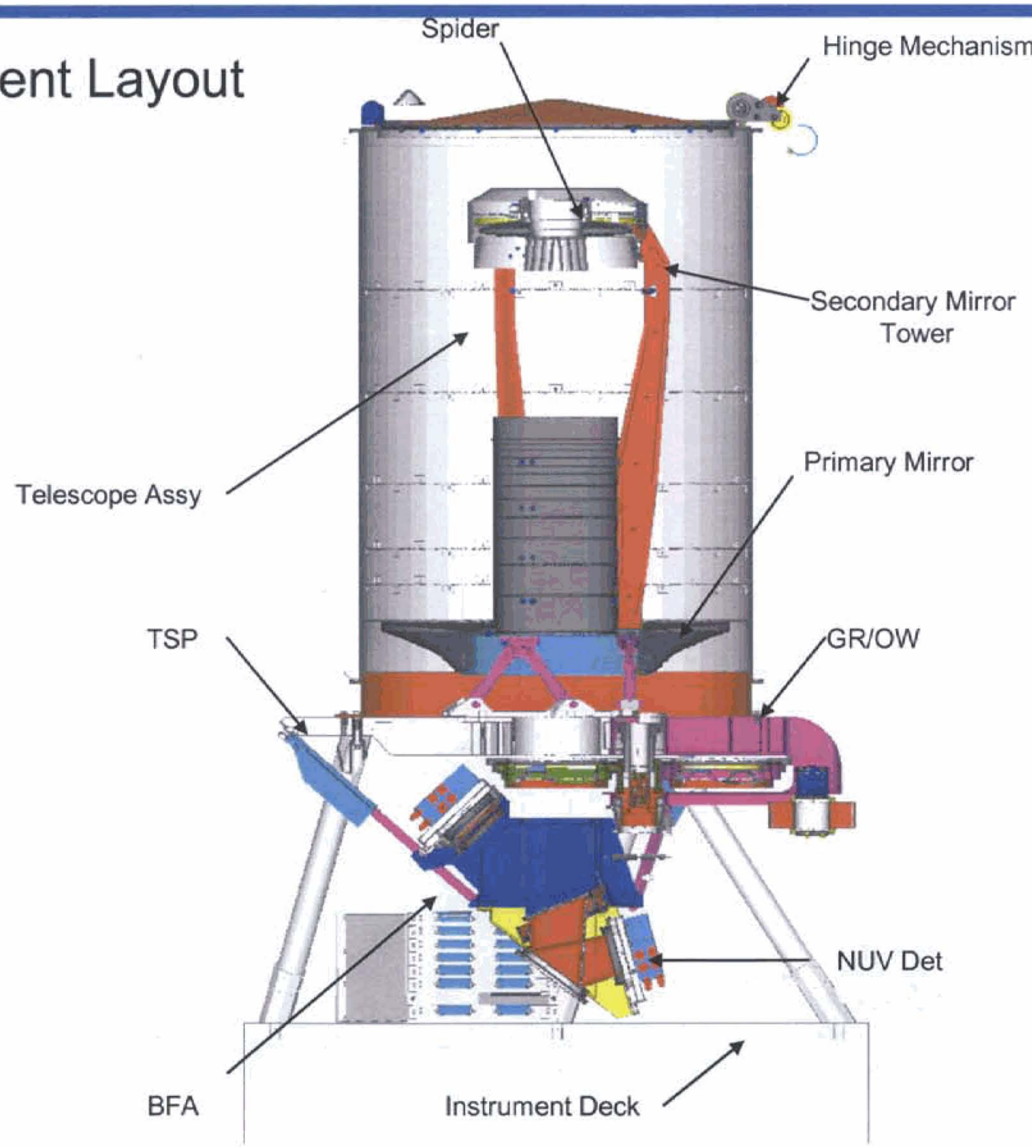
GALEX Instrument

- Overview
  - *Instrument Layout*
  - *Background: Telescope Response*
  - *Instrument Bipod Redesign*
    - Stiffness Reduction
    - Damping
    - Test Results
  - *Temperature effects on Bipod stiffness and damping*
  - *Conclusion*

GALEX Instrument

- Instrument Layout



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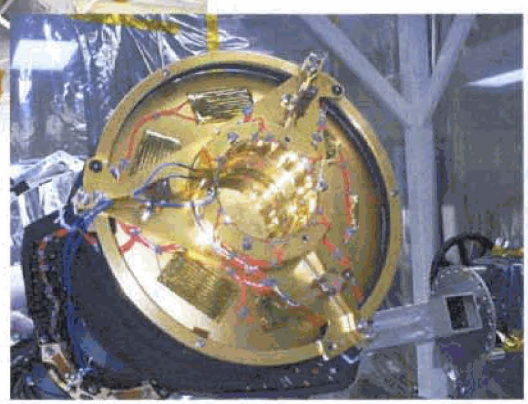

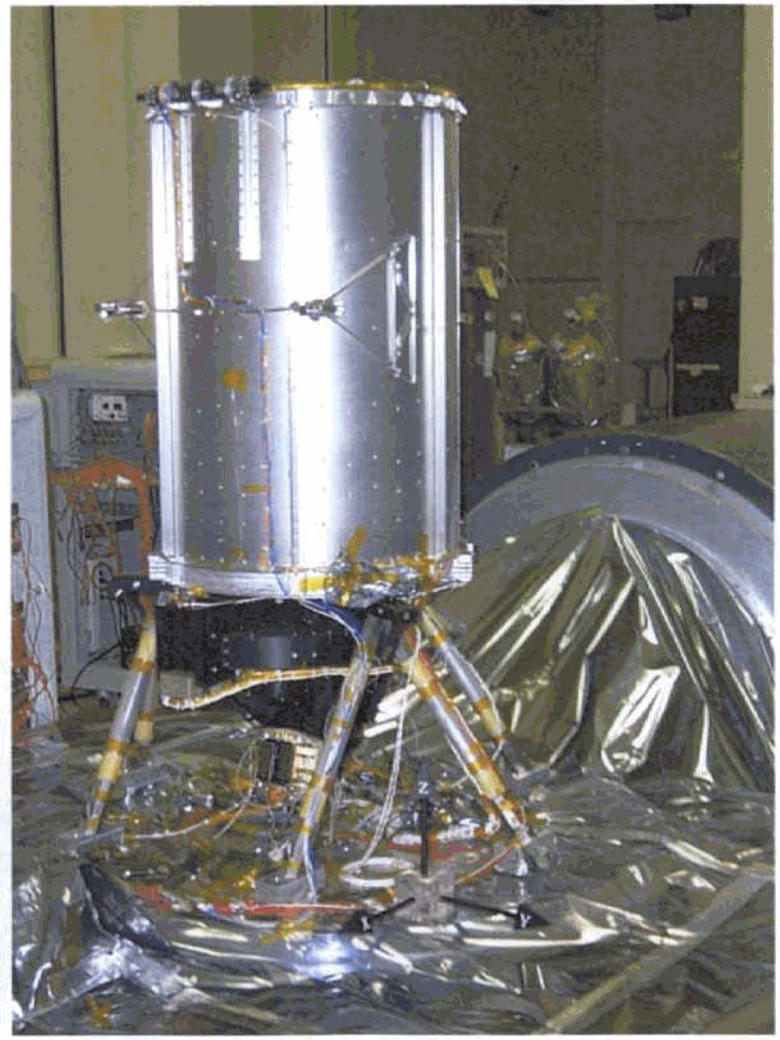

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- Background: Telescope Response
  - *During Instrument lateral vibration testing (10/00), the input was manually notched -20 dB from 45 to 55 Hz in addition to force limiting due to the TA secondary mirror assembly response above the misalignment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

X, Y Axes		Z Axis	
Freq (Hz)	ASD	Freq (Hz)	ASD
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 Instrument

- Background: Telescope Response
  - *Several Paths were investigated to reduce the Telescope Secondary response levels*
    - Instrument Bipod stiffness reduction was optimal choice (based on schedule and cost) by reducing the TA secondary mirror response to acceptable levels without effecting existing Instrument configuration and resulted in 2 benefits
      - *favorable modal combination*
      - *increased damping*

GALEX Instrument

- Instrument Bipod Redesign - 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 was varied from current 262,000 lb/in to 46,500 lb/in minimum
      - *Titanium (1.5" OD, 0.084" thick) to Astroquartz II with a ±45 layup (1.5" OD , 0.070"thick)*
  - *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 due to increased effective mass*

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GALEX Instrument

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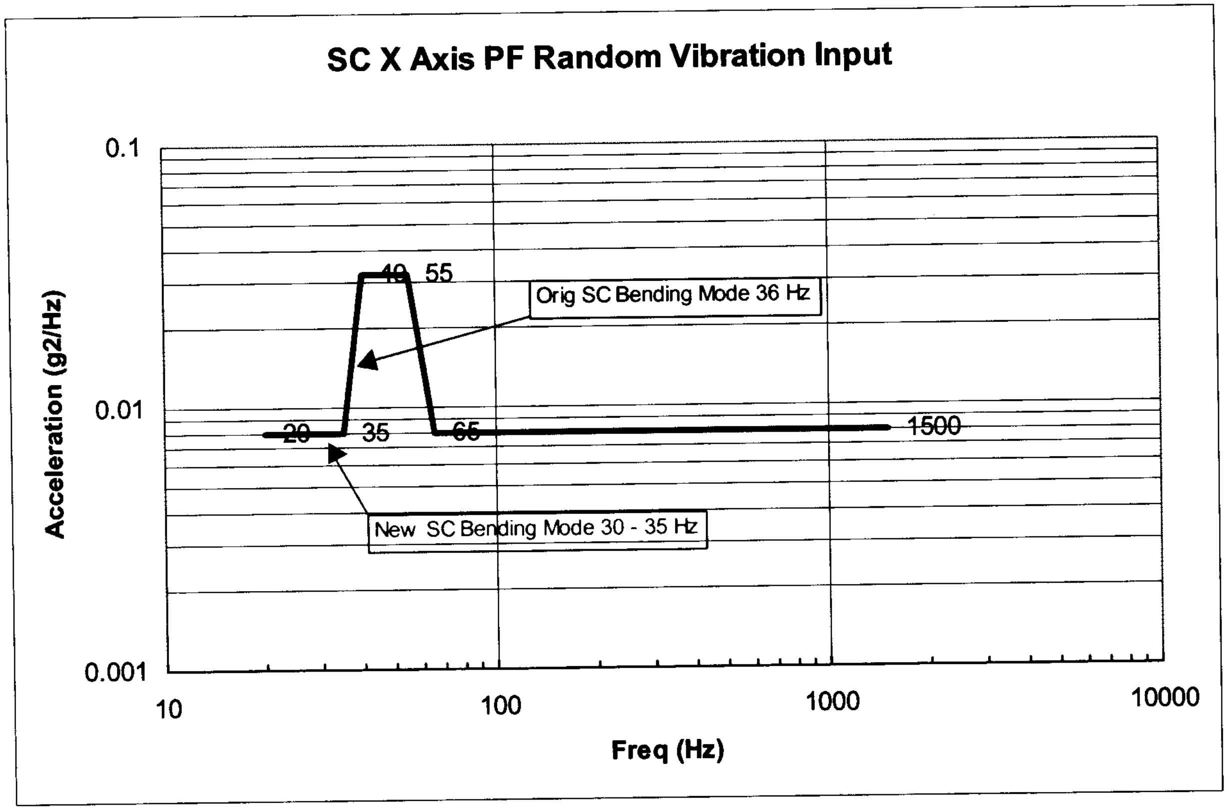
- Instrument Bipod Design - Stiffness Reduction



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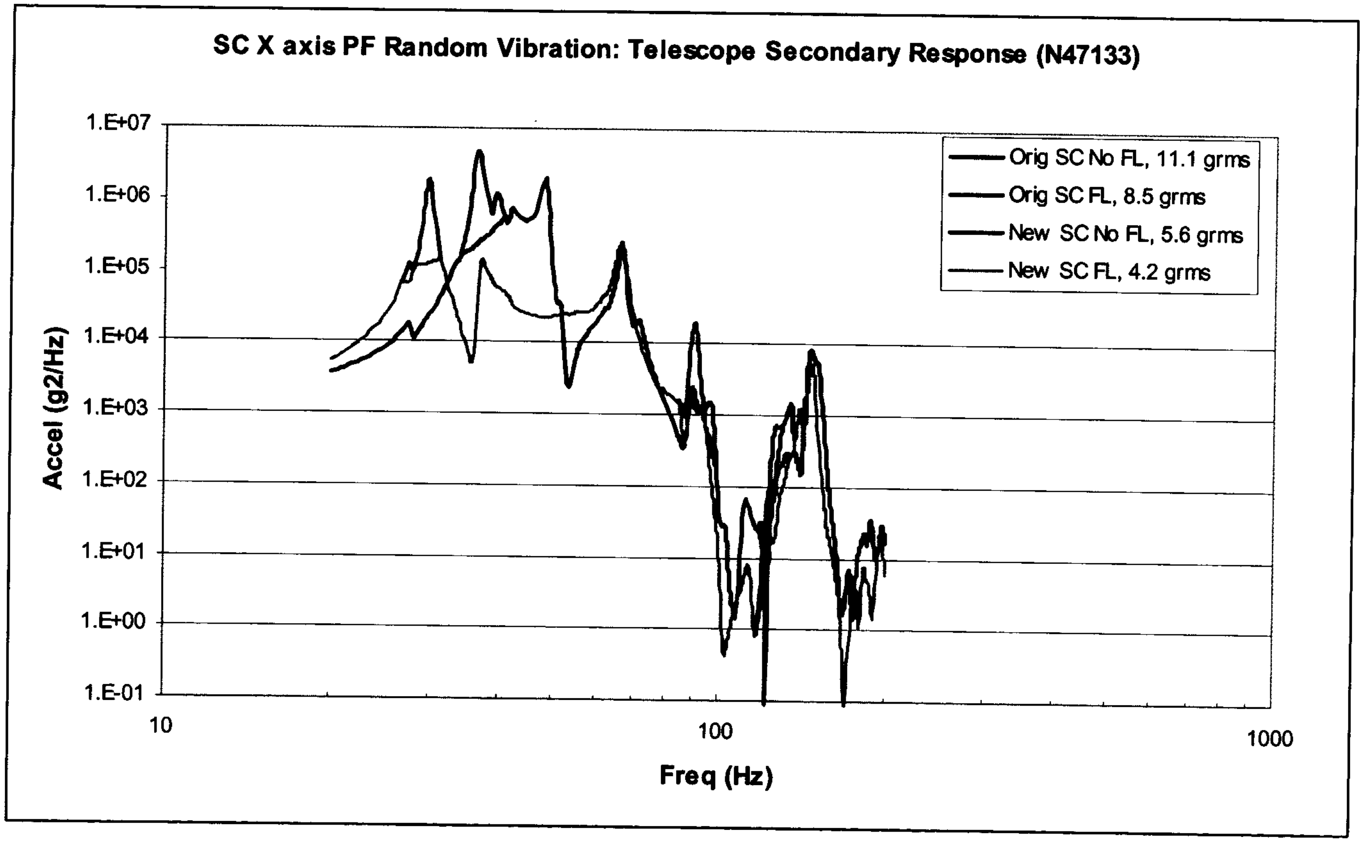
- Instrument Bipod Redesign - Stiffness Reduction
  - *Telescope secondary response decreased from 11.1 grms to 5.6 grms without force limiting and 8.5 grms to 4.2 grms with force limiting*



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- Instrument Bipod Redesign - 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 3M 9473 2" at both ends of strut
    - Strut test results
      - *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 (16°C/60°F) and additional margin

GALEX Instrument

- Instrument Bipod Redesign - Test Results
  - *Instrument Random Vibration Test, June 2001*
    - Secondary Mirror time histories: 29.1 g peak X axis, 21.4 g peak Y axis
    - Post-test optical misalignment showed acceptable
    - FEM model was correlated to test results
  - *Spacecraft Random Vibration Test, January 2002*
    - Frequency and Telescope response predictions correct
      - *Spacecraft / Instrument/ Telescope mode at ~33 Hz*
      - *Telescope response rms prediction*
    - Spacecraft provided additional damping
    - Secondary Mirror time histories: 17.4 g on leg extrapolated to 19.6 g peak at spider in X axis
    - Spacecraft successfully completed random vibration testing with minimal force limiting

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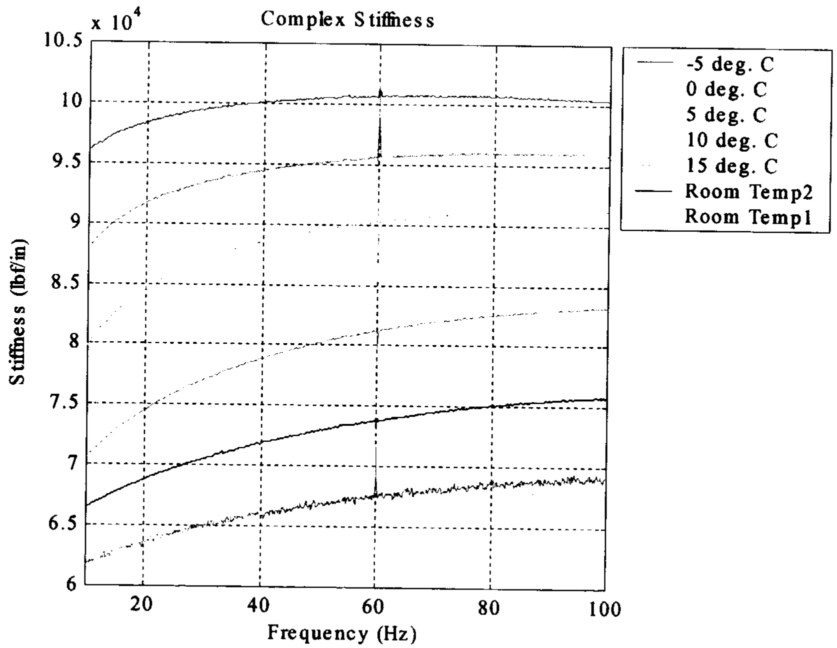
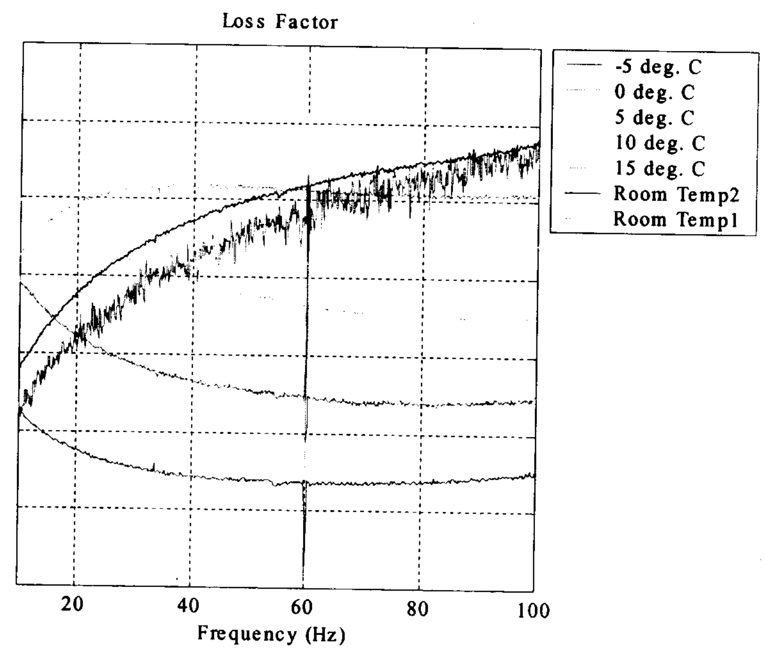
GALEX Instrument

- Temperature Effects on Bipod Stiffness and Damping
  - *Pegasus launch fairing temperature variations during takeoff, captive carry, and drop events*
    - Not a concern with typical launch vehicles
  - *Pretest thermal analysis predicted Instrument bipod temperatures of 6°C to 25°C for the drop event*
  - *Composite bipod and damping material sensitive to temperature*
    - At cold temperatures, the bipod stiffness increases and damping decreases
      - *Problem for frequency tuned structure on overall optical alignment*
    - Analysis performed to determine the maximum allowable bipod stiffness to maintain a spacecraft first bending mode less than 35 Hz.
      - *Maximum stiffness = 100,000 lb/in*
      - *Damping secondary effect*

GALEX Instrument

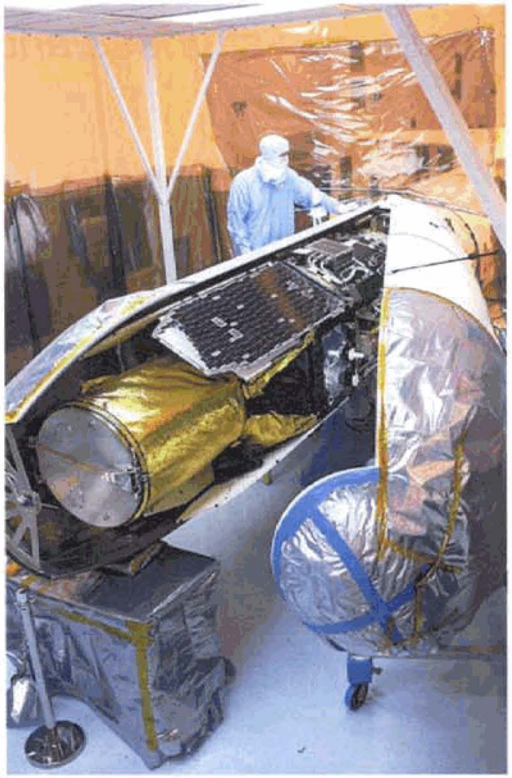
- GALEX Strut Stiffness and Loss Factor vs. temperature
  - *Sample strut tested by CSA Engineering*
  - *5°C determined as minimum bipod temperature based on stiffness and damping*





GALEX Instrument

- GALEX is successfully launched on April 28, 2003



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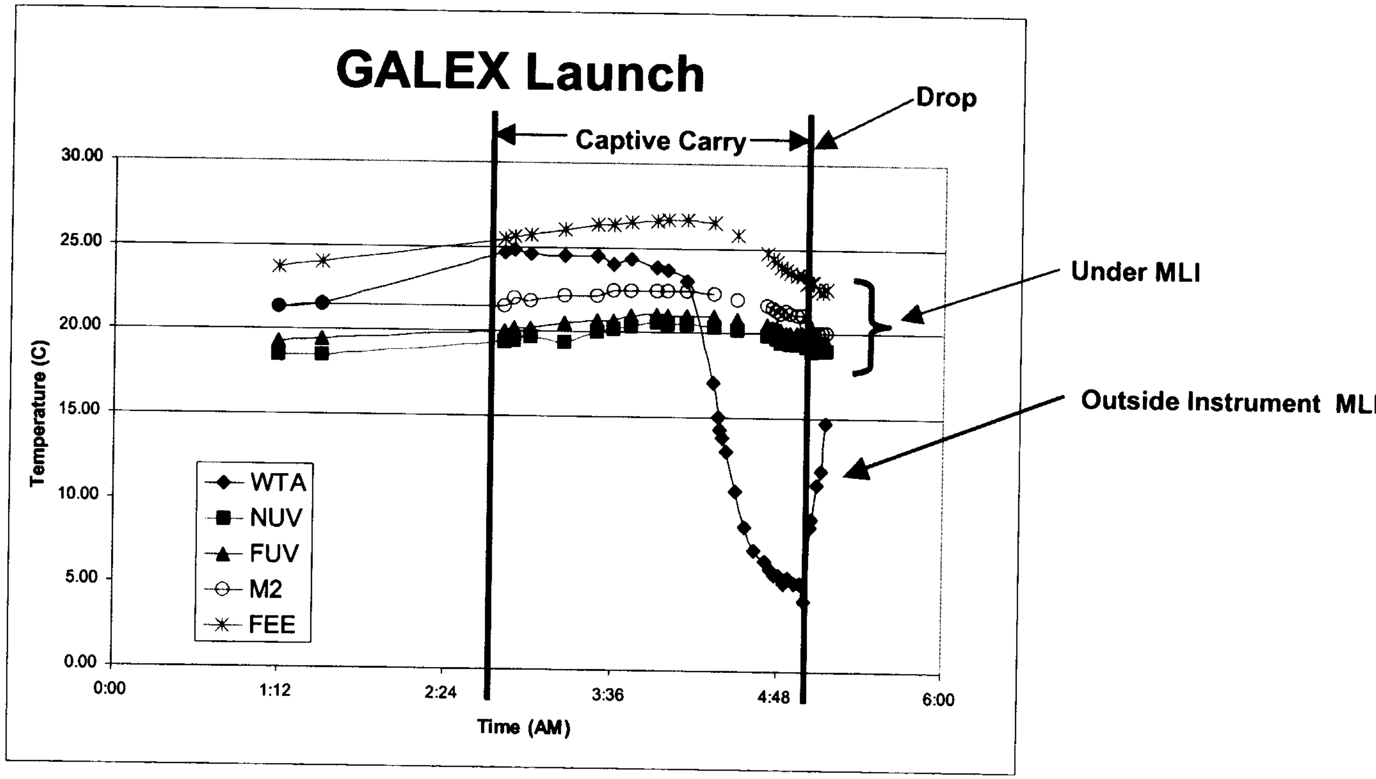
- GALEX Component Launch Temperatures
  - *Instrument bipod temperatures similar to FUV and NUV detector data*



  - *Post launch data reviewed and found to be within specifications*

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- Conclusion
  - *Pegasus launch fairing temperature variations during takeoff, captive carry, and drop events is a concern not common with typical launch vehicles*
  - *A tuned damped structure can reduce component responses*
  - *Temperature effects on a tuned system with composite and damping materials must be considered*

GALEX Instrument

- GALEX 'First Light' is successful!