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Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

Structural Analysis & Verification

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Presentation Outline

- **Design Requirements**
  - Launch Vehicle
  - Instruments
- **Selected Materials**
- **Design Criteria**
- **Design & Analysis**
  - Spacecraft
    - Launch Configuration
    - Orbit Configuration
  - Instrument Bench
    - Launch Configuration
    - Orbit Configuration
- **Structural Verification**
  - Spacecraft
  - Instruments / Subsystems
- **Mass Properties**

Design Requirements

- **Spacecraft Design & Test**

NASA-STD-5001	Structural Design & Test Factors of Safety for Space Flight Hardware
NASA-STD-5002	Loads Analysis of Spacecraft Payloads
NASA-STD-7001	Payload Vibroacoustic Test Criteria
NASA-STD-7002	Payload Test Requirements
NASA-SP-8077	Transportation and Handling Loads
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems and Components

- **Material Selection**

MSFC-SPEC- 522B	Design Criteria for Controlling Stress Corrosion Cracking
MIL-STD-1568	Corrosion Prevention & Control
MIL-STD- 889B	Protection of Dissimilar Metal Combinations
NASA-RP-1124	Outgassing Data for Spacecraft Materials

- **Material Properties**

MIL- HDBK-5E	Metallic Materials & Elements
MIL- HDBK-17-2C	Polymer Matrix Composites

Launch Vehicle Requirements

Launch Vehicle: ***Delta II 7920-10C (2 stage)***

• **Limit Load Factors:**	Lift-off /Aero	MECO
Thrust: Steady State	-------	7.4
Transient	-------	0.6/-0.6
Combined	2.8/-0.2	8.0/ 6.8
Lateral: Steady State	--------	-----
Transient	--------	0.1/-0.1
Combined	3.0/-3.0	0.1/-0.1

- **Frequency Constraints:**

Thrust Axis	>35.0 Hz.
Lateral Axes	>20.0 Hz.

• **Sinusoidal Vibration**	Frequency (Hz)	Level
Thrust Axis	5.0 - 6.2	0.5 in DA
	6.2 - 100	1.0 g
Lateral Axes	5.0 - 100	0.7 g

Notes: 1. The limit load factors are multiplied by 1.25 to obtain the ultimate loads
2. The vibration levels are applied at the base of the payload attach fitting

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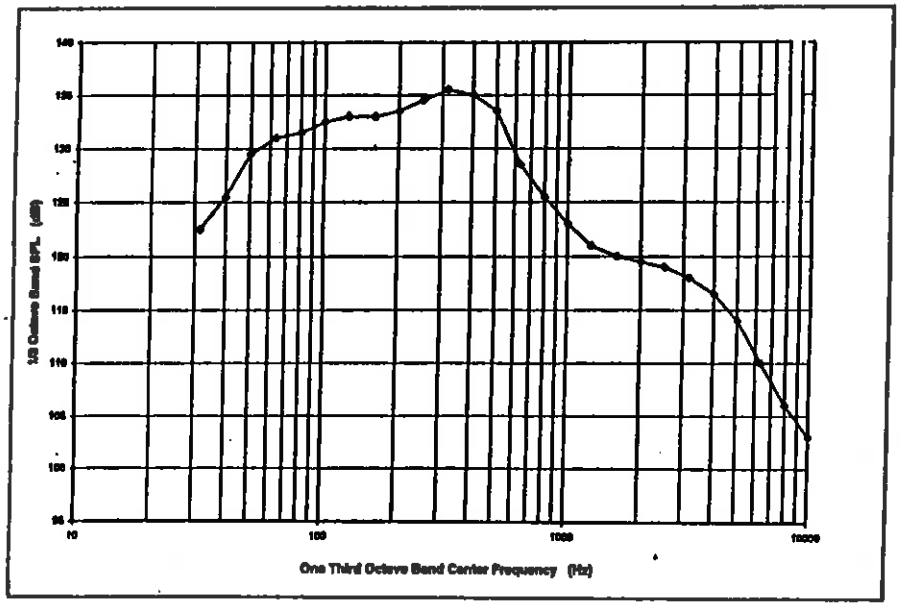
Launch Vehicle Requirement

Max. Expected Flight Level (+3.0 dB.)

Inside the Dual Payload Attach Fitting (DPAF)

10.0 ft. Composite Fairing, with 3.0 in. Acoustic Blanket

Based on a 60% fill factor



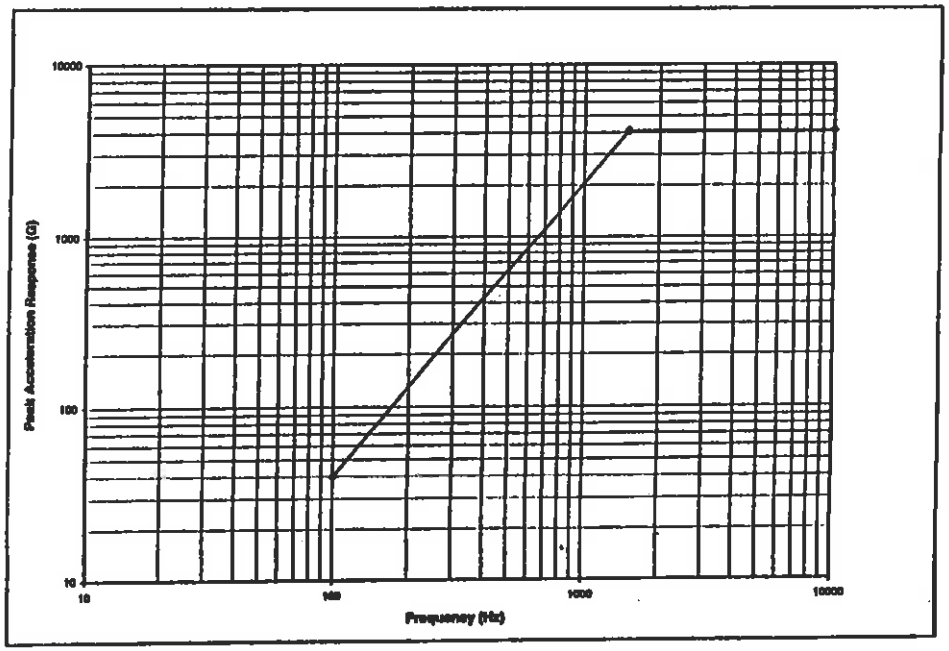
1/3 Octave Band Frequency (Hz.)	Sound Pressure Level (dB.)	1/3 Octave Band Frequency (Hz.)	Sound Pressure Level (dB.)
31.5	122.5	630.0	128.5
40.0	125.5	800.0	125.5
50.0	129.5	1000.0	123.0
63.0	131.0	1250.0	121.0
80.0	131.5	1600.0	120.0
100.0	132.5	2000.0	119.5
125.0	133.0	2500.0	119.0
160.0	133.0	3150.0	118.0
200.0	133.5	4000.0	116.5
250.0	134.5	5000.0	114.0
315.0	135.5	6300.0	110.0
400.0	135.0	8000.0	106.0
500.0	133.5	10000.0	103.0
		OASPL	144.1

dB Reference, 20 micro Pa.

Launch Vehicle Requirement

Shock Response Spectrum

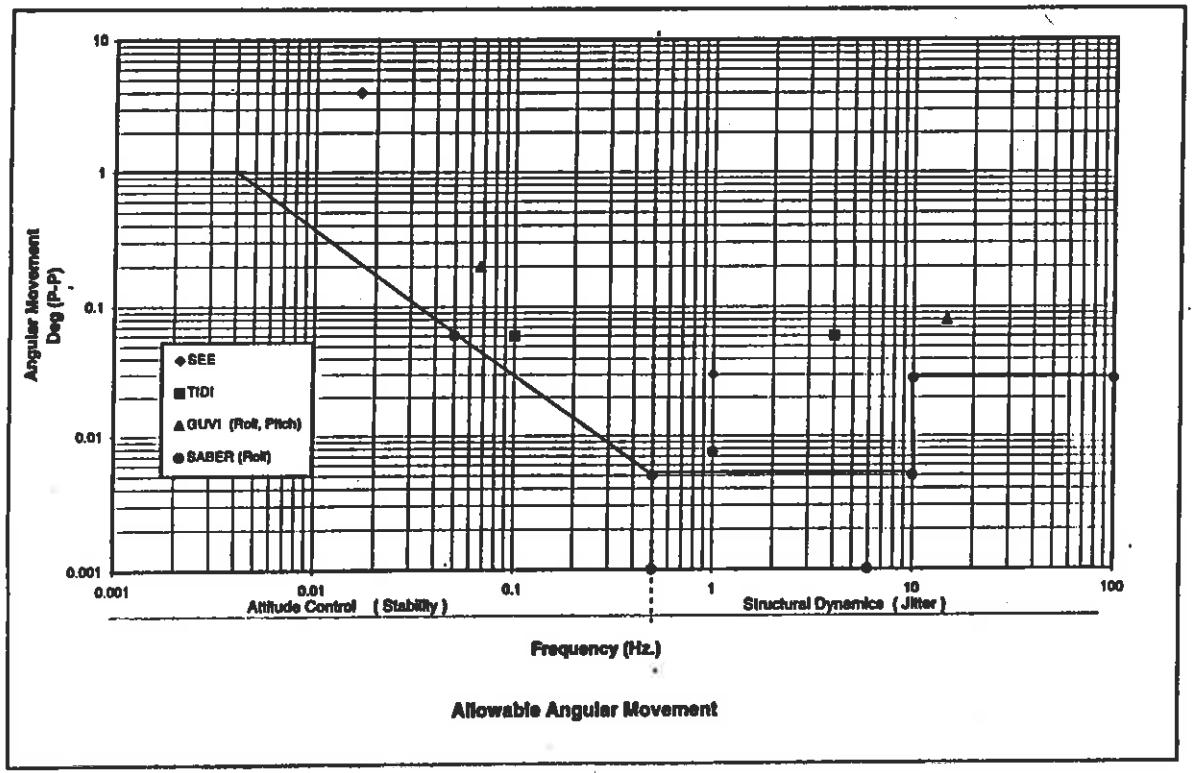
3712C Payload Attach Fitting with Separation Bolt Preload 5700 lbs.



Frequency (Hz.)	Response Acceleration (g's)
100	40
1500	4100
10000	4100

Instrument Requirements

- **Instrument Jitter and Stability**



	Jitter	Stability
GUVI:		
	0.04° / .068 sec. PR	0.1° / 15 sec.
SABER:		
	0.005° p-p / 0.5-10. Hz.	0.0075° p-p /sec.
	0.028° p-p / 10-100. Hz.	0.025° p-p / sec.
SEE:		
	0.03° / sec.	2.0° / 60 sec.
TIDI:		
	0.03° /.25 sec.	.03° / 10 sec.

Selected Materials

Spacecraft Structure

Primary Structure	Machined Aluminum
Aft Deck	6061-T651
Corner Brackets	
Adapter Ring	
Side Panels	Sandwich Panels
Corner Panels	Face sheets: 2024 -T81
Foreward Deck	Core: 1/8 - 5056 - 3.1 lb./Ft^3
Aft Deck	Edge Members: Magnesium ZK60A-T5
	Film Adhesive: FM 73 0.030 lb/ft^2
	Inserts: Magnesium ZK60A-T5
Secondary Structure	Composite System
Instrument Bench	Resin: Cyanate Ester
GPS Antenna Masts	Fiber: Ultra-high Modulus Pitch Fibers
	Inserts: Titanium Ti-6Al-4V
	Film Adhesive: A54 0.015 lb/ft^2

Selected Materials

Structural Attachments / Fasteners

Components	< 5.0 lbs.	Rivnuts
Subsystems	< 30 lbs.	Potted in inserts
Subsystems	> 30 lbs.	Spools

Fasteners:

Primary & Secondary Structure

Material Spec. AMS 4928N

Ti-6Al-4V

Tensile Strength 150000 psi

Socket head cap screws

Size 10-32

Structural Design Criteria

Design and Test Factors of safety:

Protoflight Proof Test Factor of Safety		1.25
Design Factors of Safety:		
Metallic Structures:	Yield design factor	1.4
	Ultimate design factor	1.8
Composite / Bonded Structures:	Ultimate design factor	1.8
Joints:	Ultimate design factor	1.7
Buckling :	Knockdown factor	2.0

Margins of Safety :

$$\text{Margin of safety} = \frac{\text{allowable stress}}{\text{calculated stress} * \text{factor of safety}} - 1$$

Structural Design Criteria

Fastener Design Allowables

- **Potted in inserts, for 10-32 fasteners**

  Face-sheets: 2042 - T81 (t =.015) Core: 1/8 - 5056 - .0007

  Insert: Shur-Lok SL 606-3C Potting Compound : SEL 3010

Tension (lbs.)	385.0
Compression (lbs.)	385.0
Shear (lbs.)	304.0
Torque (in - lbs.)	50.0

  Face-sheets: 5HS _ XN-70A / 996 (t = .040) Core: 1/8 - 5056 - .0007

  Insert: AEP 1035-3CPM565 Potting Compound: EPOCAST 1618-A/B

Tension (lbs.)	289.0
Compression (lbs.)	289.0
Shear (lbs.)	314.0
Torque (in - lbs.)	55.0

Structural Design Criteria

- **Composite Design Allowables**

A test program is currently underway to establish design allowables for the XN 70A Pitch based fibers with a cyanate ester resin system. The following mechanical properties are being evaluated:

Youngs Modulus	(msi)	E_{11} E_{22}
Shear Modulus	(msi)	G_{12}
Poisson Ratio		μ_{12}
Coefficient Thermal Expanaion	(μin/in/°F)	α_{11} α_{22}
Tensile Strength	(ksi)	σ_{11} σ_{22}
Compressive Strength	(ksi)	σ_{11} σ_{22}
Strain To Failure (Tensile)	(%)	ε_{11} ε_{22}
Strain To Failure (Compression)	(%)	ε_{11} ε_{22}
In-plane Shear	(ksi)	τ_{12}
Interlaminar Shear	(ksi)	τ_{13}

The design allowables will be established by taking 80% of the maen value of the sample tests.

- The use of a cyanate siloxane resin system is being investigated because of its advantages over the current cyanate ester systems.

Spacecraft Structure - Launch Configuration

Frequency Constraints:

Thrust Axis > 35.0 Hz.

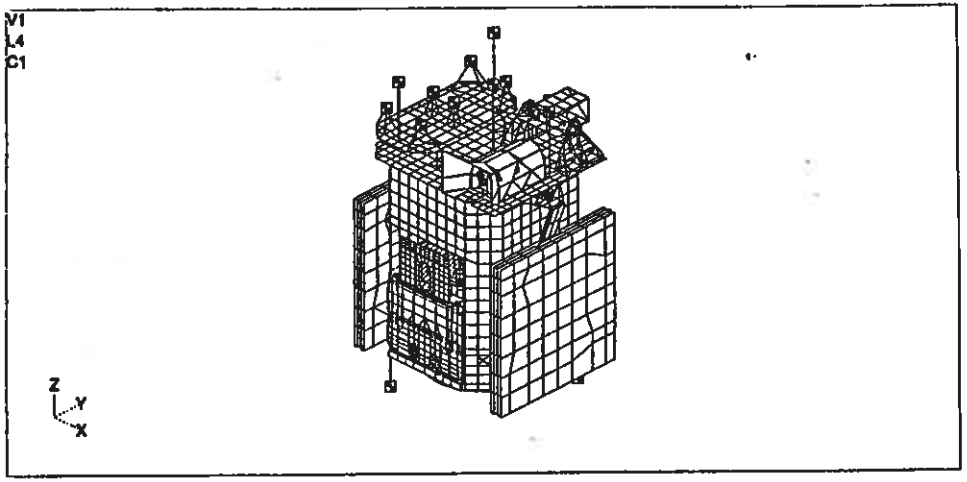
Lateral Axes >20.0 Hz.

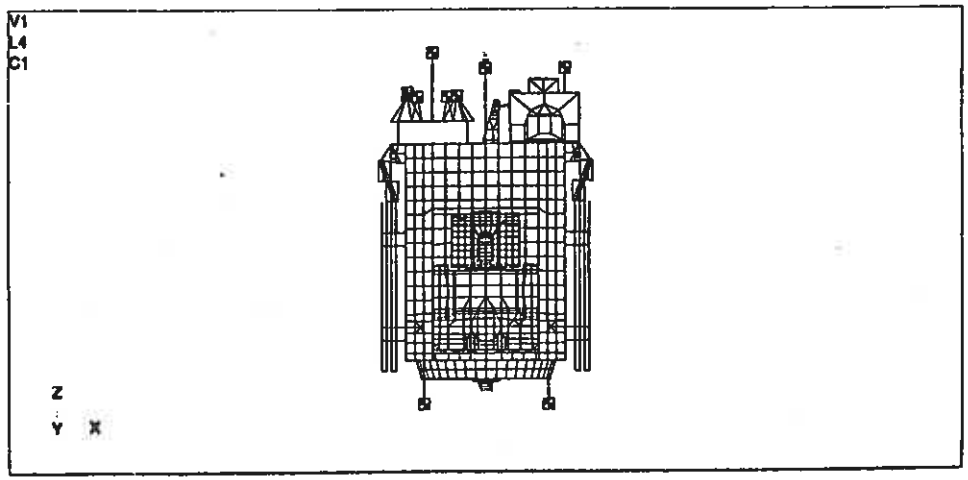
Design Load Cases:

Ultimate Loads (g's)

(Transient plus Steady-State)

Load Cases;	Thrust	Lateral
1. Max. Thrust	10.0	0.5 (x)
2. Max. Thrust	10.0	0.5 (y)
3. Max. Lateral	3.5	3.75 (x)
4. Max. Lateral	3.5	3.75 (y)





Margins of Safety

Structural Component	Load Condition	Failure Mode	Max. Stress (psi)	Margin of Safety Failure Index
Interface Adapter	3	Buckling	4019.	MS 1.7
Bottom Deck Alum.	3	Bending	5769.	MS 3.0
Corner Brackets	3	Bending	4224.	MS 4.5
Vertical Framing Members	2	Bending	8639.	MS 1.7
Bottom Deck Sandwich	2	Bending	4382.	FI 0.101 (1) BFI 0.008
Corner Panels	4	Bending	5416.	FI 0.125 (1) BFI 0.004
Side Panels	2	Bending	18056.	FI 0.453 (1) BFI 0.017
Top Deck	4	Bending	6170.	FI 0.104 (1) BFI 0.007

Notes: MS Margin of Safety FI Failure Index (first ply failure - max. strain criteria) BFI Bond Failure Index
( ) denotes first ply failure

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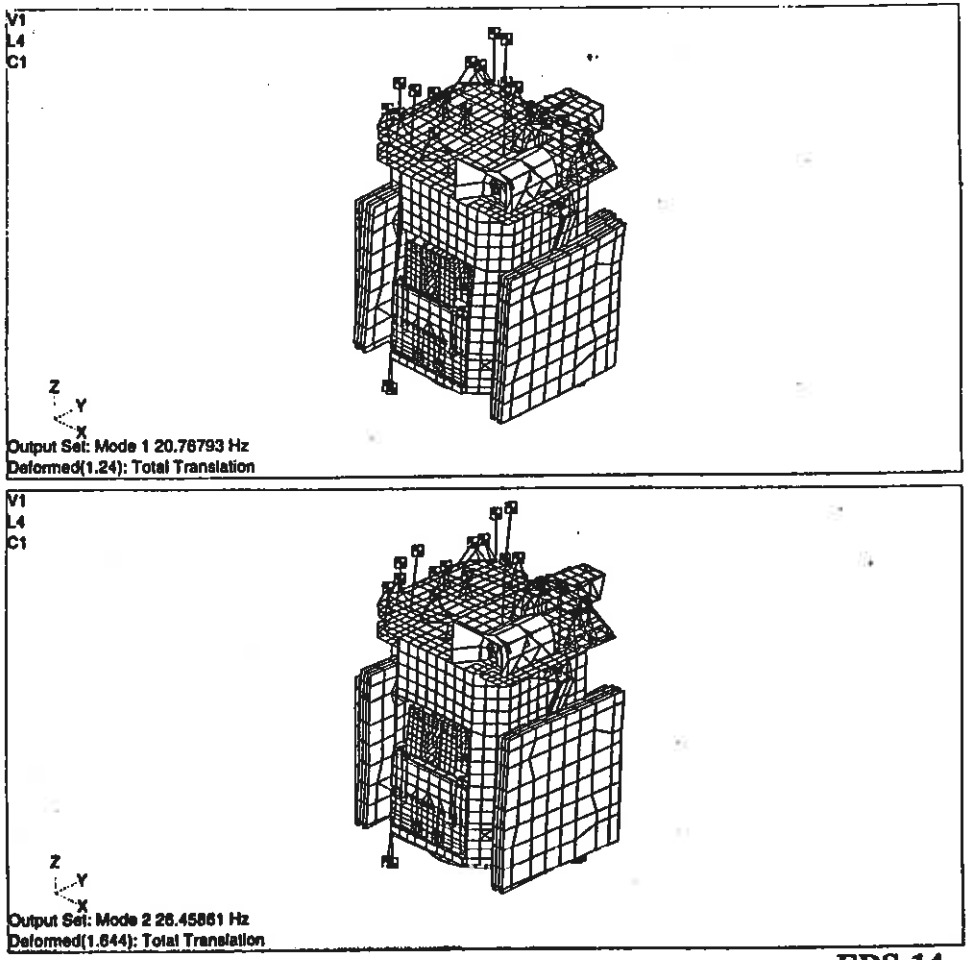
Spacecraft Structure - Launch Configuration

Primary Modes:

Mode No.	Frequency	Mode Shapes
1	20.7 Hz	Lateral Bending (y) axis
2	26.4 Hz	Lateral Bending (x) axis
3	35.1 Hz	SABER Radiator
36	57.0 Hz	Torsion
40	62.3 Hz	Bottom Deck/ Thrust
54	72.2 Hz	Top Deck
79	83.9 Hz	GUVI SIS
91	94.4 Hz	Top Deck



Spacecraft Structure - Launch Environment

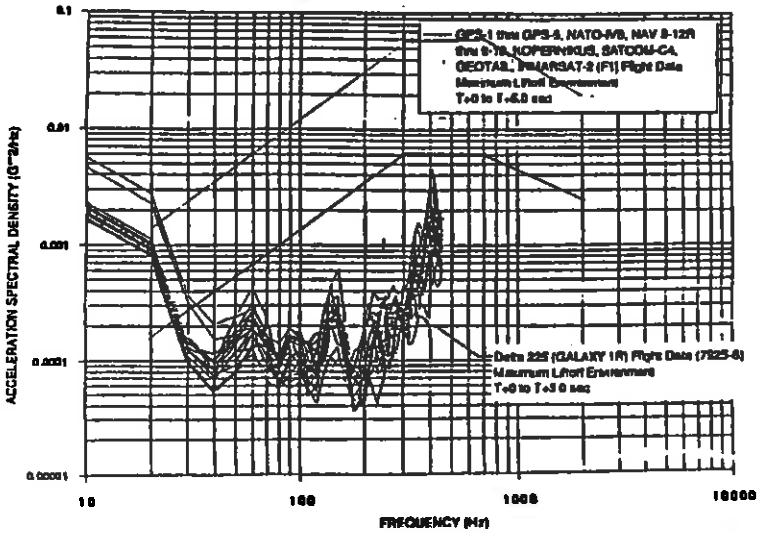
Sinusodal Vibration Test Level - based on the launch vehicle requirements. i.e. maximum flight level +3 dB

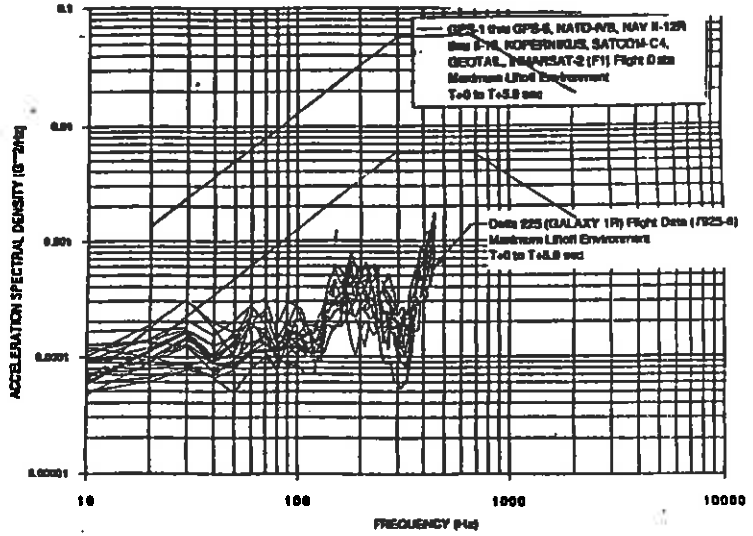
	Frequency (Hz.)	Acceleration (g's)
Thrust Axis	5.0 - 7.4	.5 in DA
	7.4 - 100	1.4
Lateral Axis	5.0 - 6.2	.5 in DA
	6.2 - 100	1.0

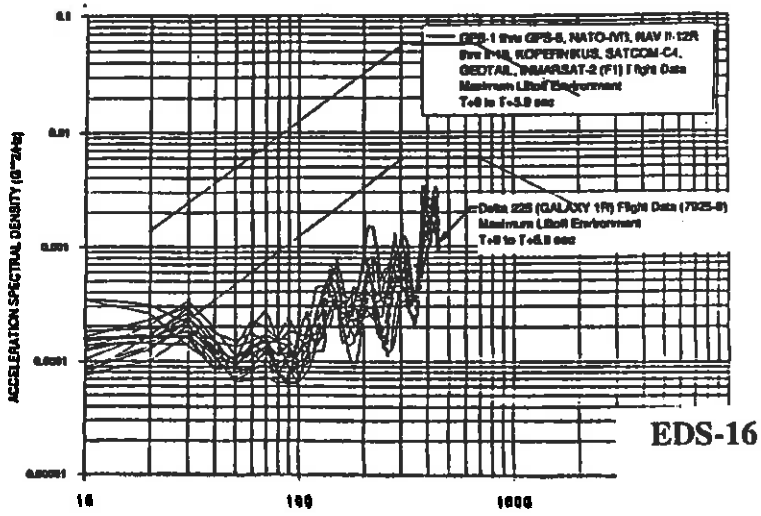
Notes:
1. The acceleration levels shall be applied at the base of the payload attach fitting.
2. The dynamic response of the spacecraft may be limited to the results of the coupled loads analysis.

Spacecraft Structure - Launch Environment

Estimate - Base Excited Random for Delta II
(Test data from Delta II guidance section compared with NASA GEVS recommendation)







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Spacecraft Structure - Launch Environment

Dynamic Response to Base Excited Inputs: Lateral Axis (X)

Instrument	Component	Sinusoidal fn (Hz.)	Sinusoidal Max. (g)	Random fn (Hz.)	Random Max. PSD	Coupled Loads (g's) < 50 Hz.
SABER	Cooler mount	20.7	4.1	190.0	1.2	
	Chopper mount	20.7	5.2	36.5	0.1	
	Ctr. of Scan mirror	36.5	9.1	36.5	0.4	
	Mirror No. 1 & 2	36.5	7.5	36.5	0.3	
	Mirror No. 3	20.7	5.5	36.5	0.14	
	Mirror No. 4	20.7	5.2	36.5	0.8	
	Focal plane COM	20.7	5.0	210.0	0.5	
	Focal plane top	20.7	4.8	210.0	0.35	
	Scan mirror motor	36.5	9.2	36.5	0.4	
TIDI	Profiler (etalron)	20.7	16.0	20.7	0.4	
	Focal plane array	20.7	15.0	20.7	0.5	
	Telescope No.1	20.7	18.0	20.7	0.6	
	Telescope No 2	20.7	18.0	20.7	0.6	
	Telescope No.3	20.7	17.0	20.7	0.5	
	Telescope No.4	20.7	17.0	20.7	0.5	

Based on 4% C/C_o; except GUVI 2.5% C/C_o * Denotes out of plane responses

Spacecraft Structure - Launch Environment

Dynamic Response to Base Excited Inputs: lateral Axis (X)

Instrument	Component	Sinusoidal f_n (Hz.)	Sinusoidal Max. (g)	Random f_n(Hz.)	Random Max. PSD	Coupled Loads (g's) < 50 Hz.
SEE	XUV photometer (XPS)	20.7	17.0	20.7	0.5	
	Grating spectrograph (EGS)	20.7	18.0	20.7	0.5	
	Microcontroller	20.7	17.0	20.7	0.5	
	Power control unit (PCU)	20.7	17.0	20.7	0.5	
	Motor support	20.7	17.0	20.7	0.5	
	Bearing support plate / bkt	20.7	17.0	*410.0	1.8	
GUVI	Focal plane No. 1	83.9	6.0	*460.0	3.5	
	Focal plane No. 2	83.9	5.8	340.0	4.0	
	Grating	*67.0	3.2	550.0	1.8	
	Pop- up mirror	*67.0	3.8	550.0	2.1	
	Slit mechanism	83.9	9.1	83.9	1.4	
	Motor	83.9	13.0	340.0	21.0	
	Mirror No.1	83.9	12.0	340.0	6.5	

Based on 4% C/C_o; except GUVI 2.5% C/C_o *Denotes out of plane responses

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Spacecraft Structure - Launch Environment

Dynamic Response to Base Excited Inputs: Lateral Axis (Y)

Instrument	Component	Sinusoidal f_n (Hz.)	Sinusoidal Max. (g)	Random f_n (Hz.)	Random Max. PSD	Coupled Loads (g's) < 50 Hz.
SABER	Cooler mount	26.4	3.0	*205.0	2.30	
	Chopper mount	26.4	6.0	26.4	0.13	
	Ctr. of Scan mirror	26.4	9.8	26.4	0.35	
	Mirror No. 1 & 2	26.4	9.5	*110.0	0.50	
	Mirror No. 3	26.4	6.8	26.4	0.16	
	Mirror No. 4	26.4	6.0	26.4	0.10	
	Focal plane COM	26.4	3.9	*205.0	0.30	
	Focal plane top	26.4	4.0	*205.0	0.25	
	Scan mirror motor	26.4	10.0	26.4	0.30	
TIDI	Profiler (etalron)	26.4	16.0	26.4	0.50	
	Focal plane array	26.4	14.0	220.0	3.5	
	Telescope No.1	26.4	18.5	26.4	1.0	
	Telescope No 2	26.4	18.5	26.4	1.0	
	Telescope No.3	26.4	19.0	26.4	1.0	
	Telescope No.4	26.4	19.0	26.4	1.0	

Based on 4% C/C_o; except GUVI 2.5% C/C_o *Denotes out of plane responses

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Spacecraft Structure - Launch Environment

Dynamic Response to Base Excited Inputs: lateral Axis (Y)

Instrument	Component	Sinusoidal f_n (Hz.)	Sinusoidal Max. (g)	Random f_n (Hz.)	Random Max. PSD	Coupled Loads (g's) < 50 Hz.
SEE	XUV photometer (XPS)	26.4	18.0	26.4	0.80	
	Grating spectrograph (EGS)	26.4	16.0	220.0	0.80	
	Microcontroller	26.4	16.0	26.4	0.55	
	Power control unit (PCU)	26.4	16.0	26.4	0.70	
	Motor support	26.4	16.0	26.4	0.70	
	Bearing support plate / bkt	26.4	16.0	*210.	2.10	
GUVI	Focal plane No. 1	98.2	12.0	98.2	3.0	
	Focal plane No. 2	98.2	12.0	98.2	3.0	
	Grating	98.2	12.0	98.2	3.2	
	Pop- up mirror	98.2	12.0	98.2	2.9	
	Slit mechanism	98.2	12.0	98.2	2.9	
	Motor	98.2	12.0	*205.0	8.1	
	Mirror No.1	98.2	12.0	98.2	2.9	

Based on 4% C/C_o; except GUVI 2.5% C/C_o *Denotes out of plane responses

Spacecraft Structure - Launch Environment

Dynamic Response to Base Excited Inputs: Thrust Axis (Z)

Instrument	Component	Sinusoidal f_n (Hz.)	Sinusoidal Max. (g)	Random f_n (Hz.)	Random Max. PSD	Coupled Loads (g's) < 50 Hz.
SABER	Cooler mount	62.3	6.0	150.	1.0	
	Chopper mount	62.3	19.0	62.3	1.8	
	Ctr. of Scan mirror	62.3	19.0	62.3	2.0	
	Mirror No. 1 & 2	62.3	19.0	62.3	2.0	
	Mirror No. 3	62.3	19.0	62.3	1.8	
	Mirror No. 4	62.3	18.0	62.3	1.8	
	Focal plane COM	62.3	18.0	62.3	1.8	
	Focal plane top	62.3	18.0	62.3	1.8	
	Scan mirror motor	62.2	20.0	62.3	2.1	
TIDI	Profiler (etalron)	*89.2	8.0	*86.0	0.5	
	Focal plane array	95.7	5.7	*130.	1.3	
	Telescope No.1	90.2	9.0	90.2	0.5	
	Telescope No 2	90.2	7.0	90.2	0.5	
	Telescope No.3	93.6	11.0	90.2	1.2	
	Telescope No.4	93.6	10.0	90.2	1.2	

Based on 4% C/C_o; except GUVI 2.5% C/C_o *Denotes out of plane responses

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Spacecraft Structure - Launch Environment

Dynamic Response to Base Excited Inputs: Thrust Axis (Z)

Instrument	Component	Sinusoidal f_n (Hz.)	Sinusoidal Max. (g)	Random f_n (Hz.)	Random Max. PSD	Coupled Loads (g's) < 50 Hz.
SEE	XUV photometer (XPS)	*100.0	12.0	*99.2	1.7	
	Grating spectrograph (EGS)	*48.0	7.0	*150.0	2.0	
	Microcontroller	100.0	7.0	*150.0	1.4	
	Power control unit (PCU)	72.2	10.0	*99.2	0.7	
	Motor support	72.2	10.0	*99.2	0.7	
	Bearing support plate / bkt	*100.0	7.0	*110.0	0.7	
GUVI	Focal plane No. 1	*100.0	19.5	*98.9	4.9	
	Focal plane No. 2	*100.0	19.5	*98.9	4.8	
	Grating	*100.0	19.5	*98.9	4.9	
	Pop- up mirror	*100.0	19.5	*98.9	4.8	
	Slit mechanism	*100.0	19.5	*98.9	4.8	
	Motor	62.3	21.0	*98.9	5.0	
	Mirror No.1	*100.0	19.5	*98.9	4.7	

Based on 4% C/C_o; except GUVI 2.5% C/C_o *Denotes out of plane responses

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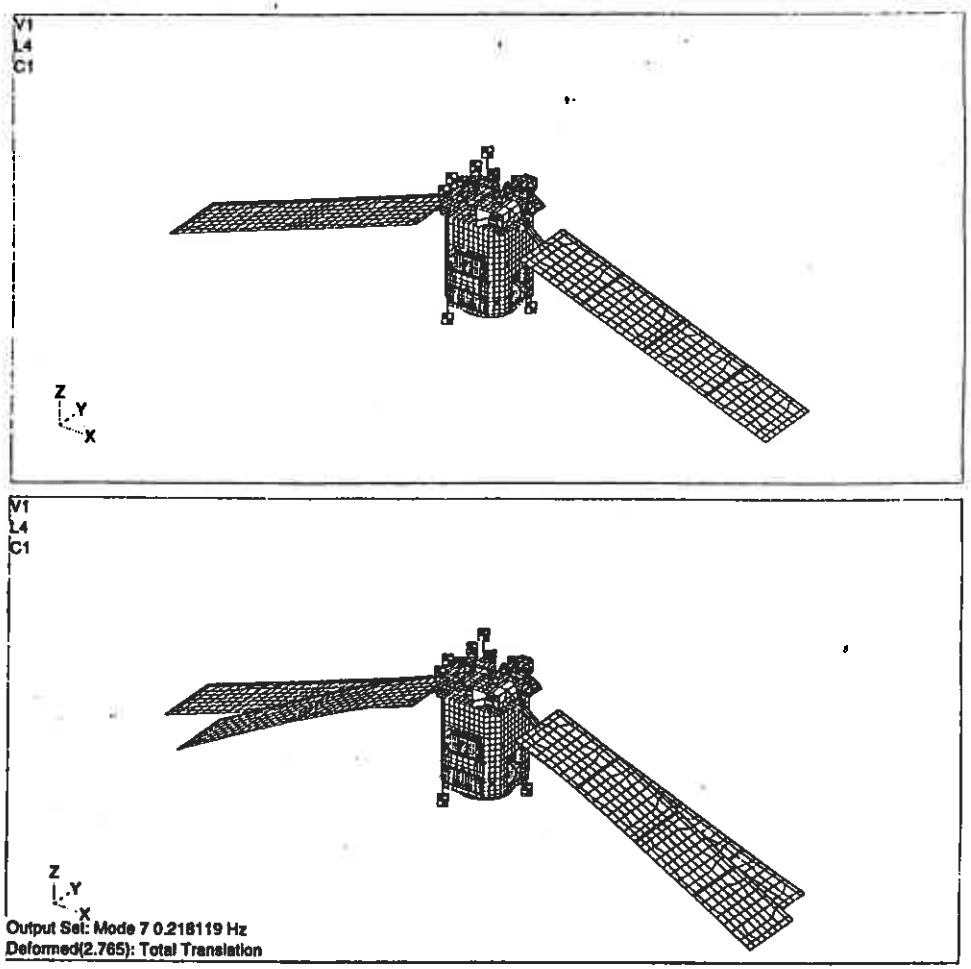
Spacecraft Structure - Orbit Configuration

Primary Modes:

Mode	Frequency	Mode Shape
1	.23 Hz.	Flatwise Bending at Actuator
2	.40 Hz.	Axisymmetric Panel Bending
3	.73 Hz.	Torsion At Actuator
4	1.32 Hz.	First Mode Panel Bending



Dynamic Disturbances - Instruments

- **Jitter** defined, herein, as the line-of-sight disturbance in the optical patch due to transient loads and the mechanical response of the structure.

- **Sources and Forcing Functions:**

Instrument	Jitter Source	Amplitude	Frequency	Axis	Duration
GUVI	Scan mirror (Retrace)	0.80 in - lb	200.0	Ry	2.0 seconds
	Pop-up mirror	0.008 in - lb	10.0	Rz	Infrequent
	Slit mechanism	0.0004 in - lb	10.0	Rz	Infrequent
SABER	Scan mirror	1.56 in - lb	0.5	Rx	141.4 seconds
	Cryo-cooler	0.02 lb	52.0,104	Ty	Continuous
	Chopper	0.002 lb	1000.0	Tx	----------
SEE	SSPP gimbal	0.7 in - lb	2.5,20	Rx	300 seconds
	Filter wheel	0.018 in - lb	2.0	Ry	4 times / cycle
TIDI	Telescope (4)	0.23 in - lb	12.5	Rxy	100 seconds
	Filter wheel	0.34 in - lb	10.0	Ry	4 times / cycle

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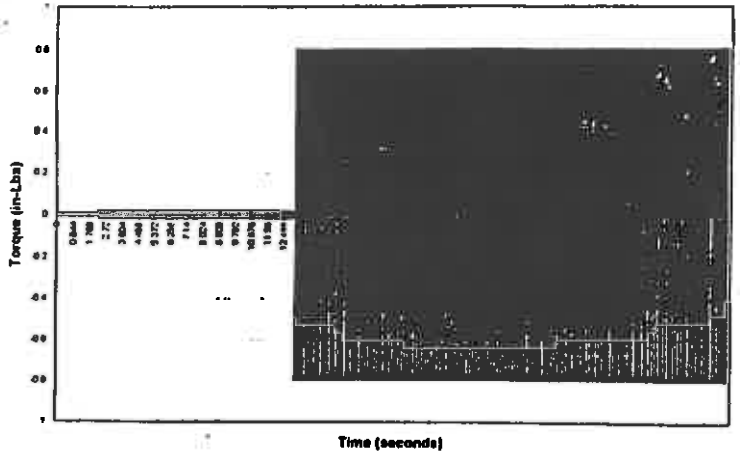
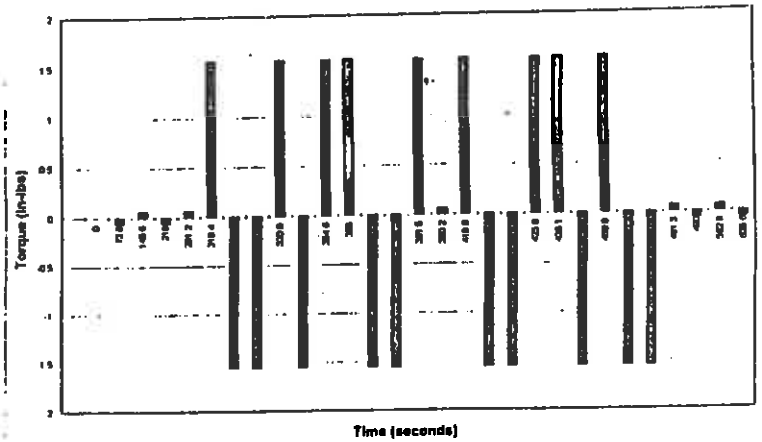
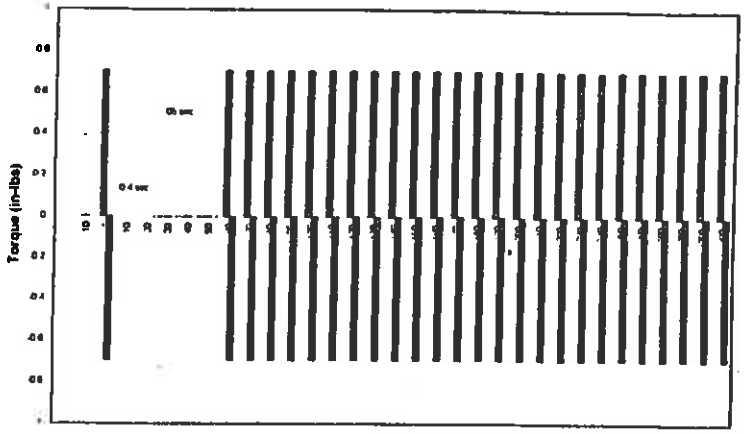
Instrument Disturbance Torques



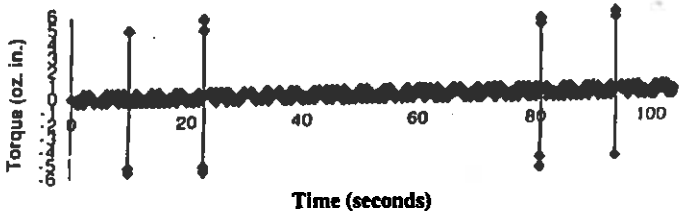
GUVI Torque Disturbances - Scan Mirror (pitch)



SABER Torque Disturbance - Scan Mirror (roll)



SEE Torque Disturbance - SEE Solar Pointing Platform (roll)



TIDI Torque Disturbance - Telescopes with Profiler

Reaction Wheel Disturbances

- Reaction wheel disturbance is not broad band white noise, but sinusoidal, containing many harmonics and some sub-frequencies of the fundamental

- Each reaction wheel produces mechanical noise at specific harmonics of the wheel speed.

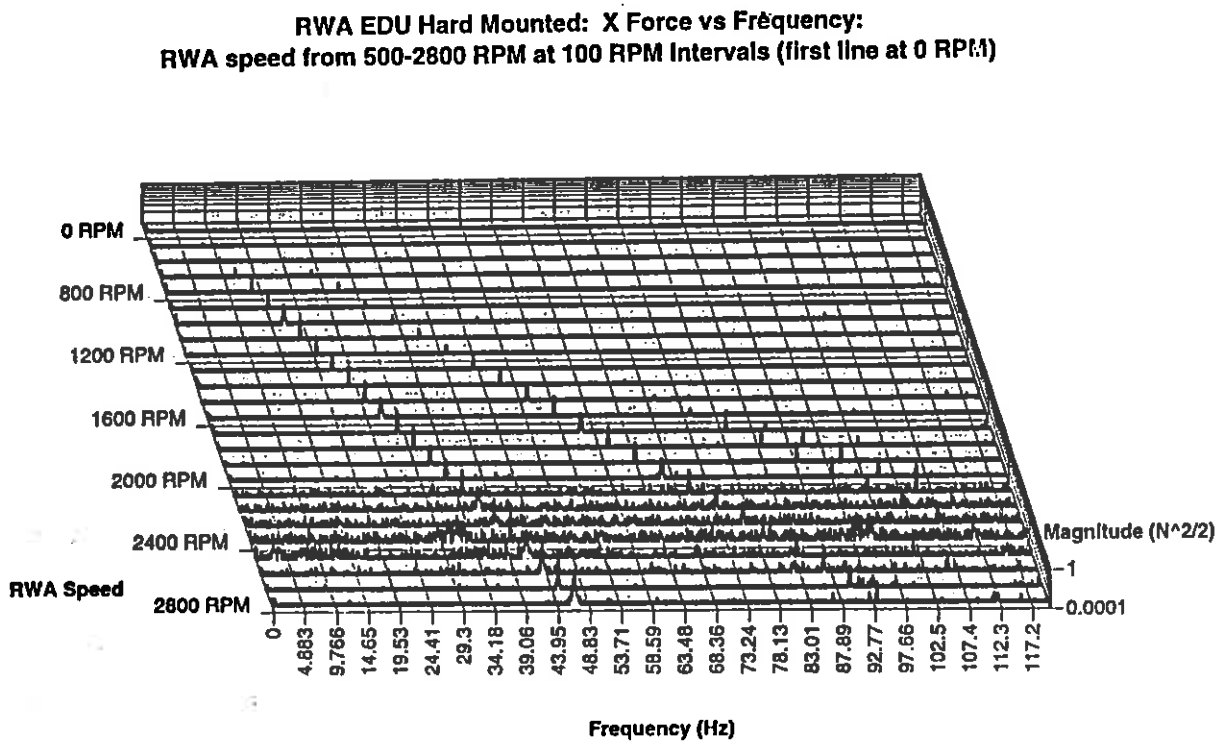
- The primary harmonics are as follows:

Harmonic Multiple	Harmonic Source
0.34	Ball bearing retainer
1.0	Rotor mass imbalance
1.39	Bearing race-to-race misalignment
2.0	Rotor mass imbalance
2.74	Defects in outer race
3.0	Rotor mass imbalance
5.26	Defects in the inner race
144.0	Motor torque ripple

Reaction Wheel Disturbances

Critical Wheel Frequencies:

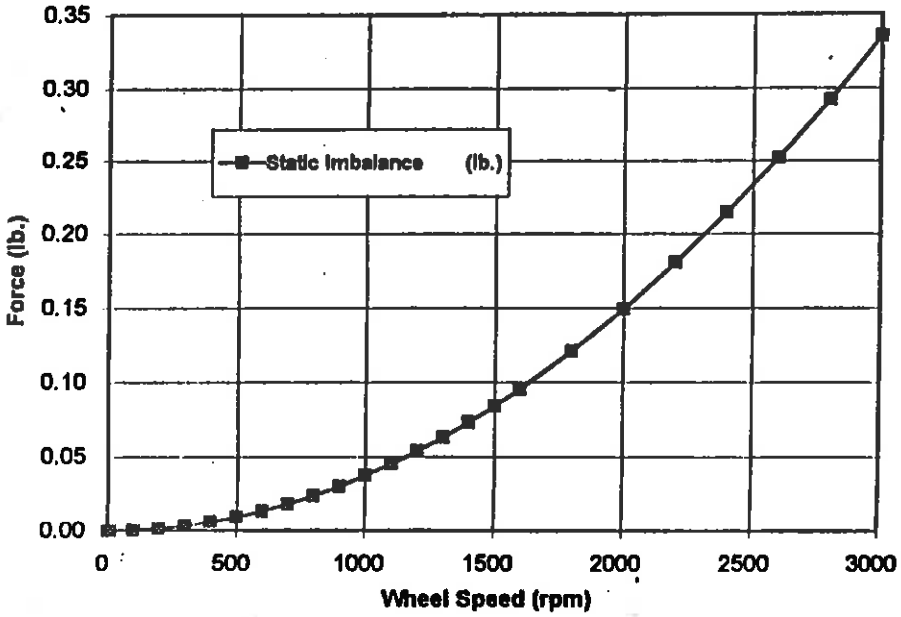
Mode	Critical Frequency (RPM)
Axial Translation	3900
Rocking	5100
Radial Translation	12000



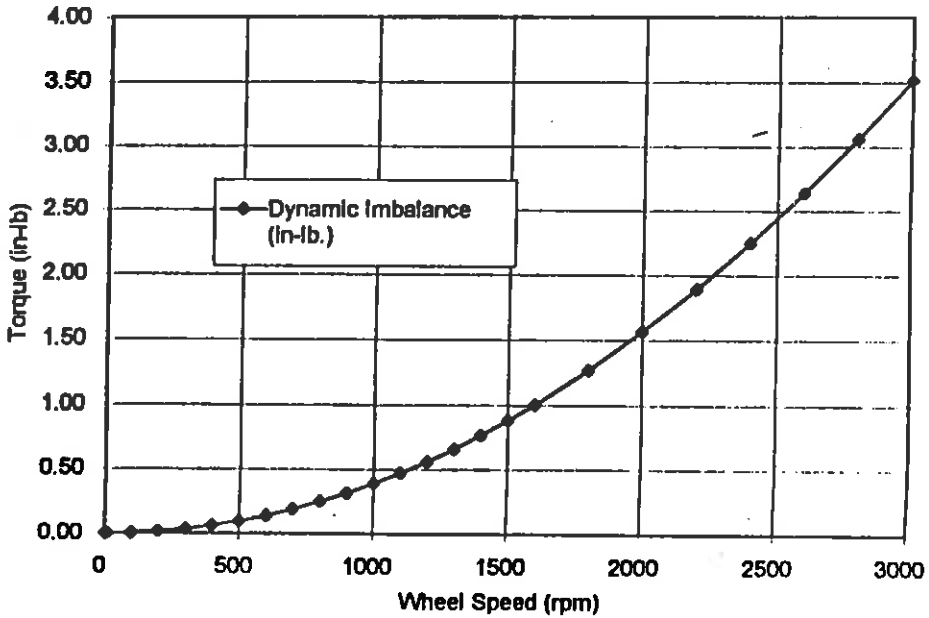
Reaction Wheel Disturbances

Static & Dynamic Imbalance (rss)

Typical Wheel Speeds 100 - 500 RPM



Static Imbalance



Dynamic Imbalance

Jitter Analysis

Model Parameters:

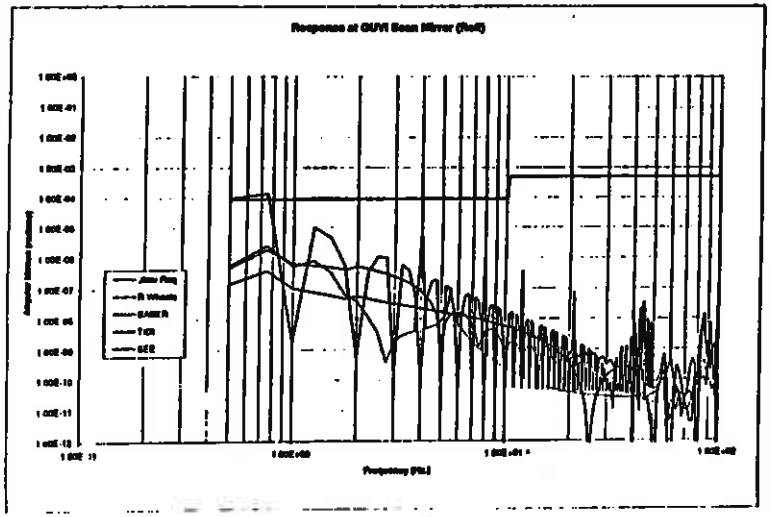
- The jitter frequency range is defined herein as 0.50 to 50.0 Hz. (30 to 3000 rpm)
- With the exception of the reaction wheels,the disturbances are randomly phased to combine in a root-sum-square (rss) manner.
- Percent critical damping 0.5%

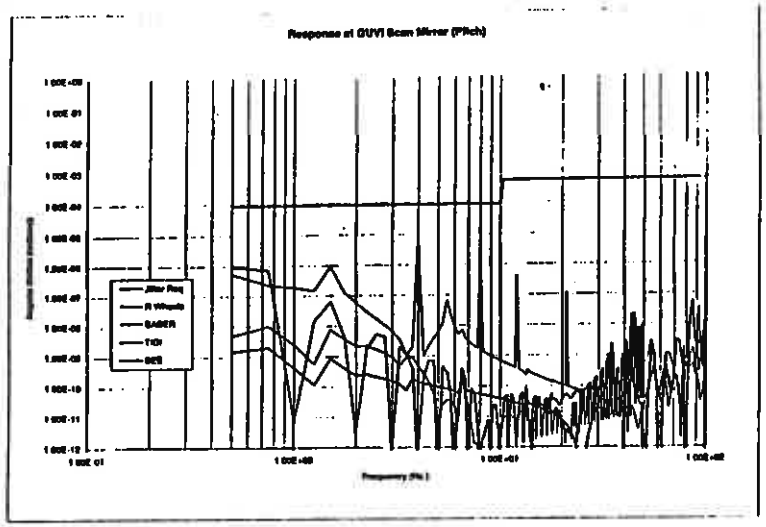
Dynamic Load Cases	1	2	3	4	5
Reaction Wheels	O	O	O	O	O
GUVI	R	R	O	O	O
SABER	R	O	R	O	O
SEE	R	O	O	R	O
TIDI	R	O	O	O	R

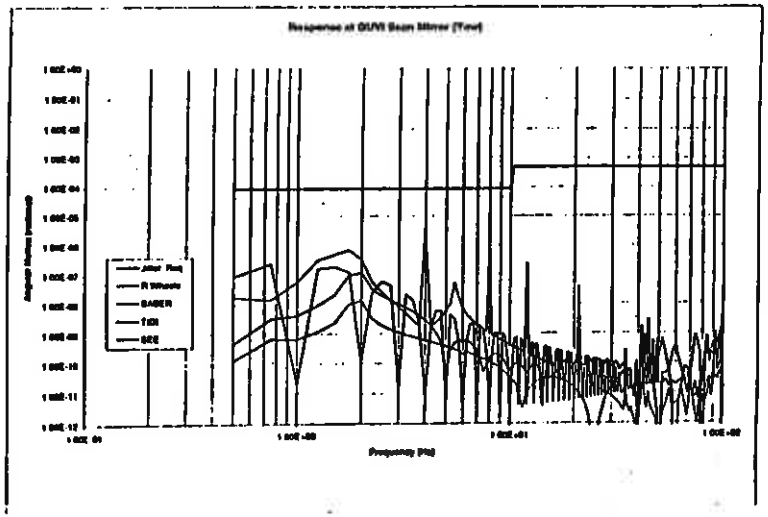
Note: (O) Equipment or Instrument Operating (R) Response Measurement

Jitter Analysis

- **Operating Environment for GUVI**
  - Typical reaction wheel speed: 240 RPM
  - All other instruments operating
  - Response location : Scan mirror







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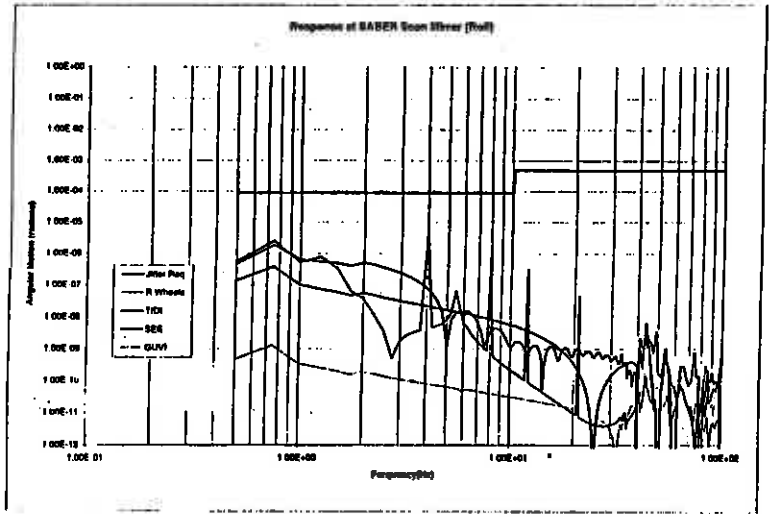
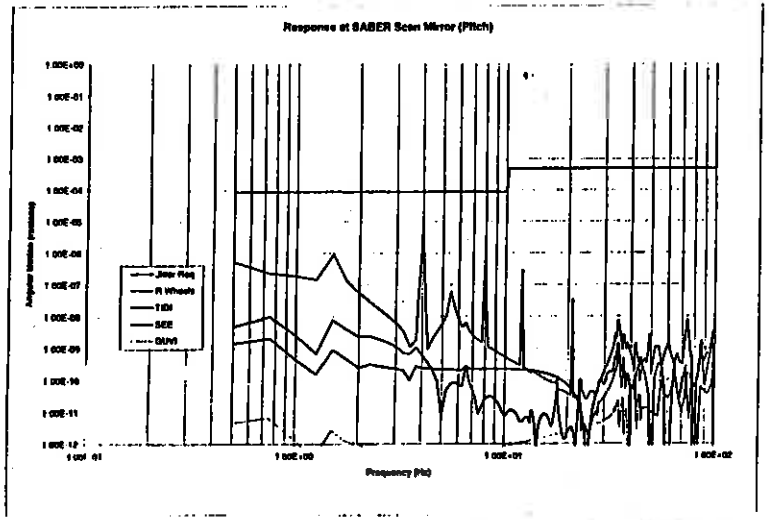
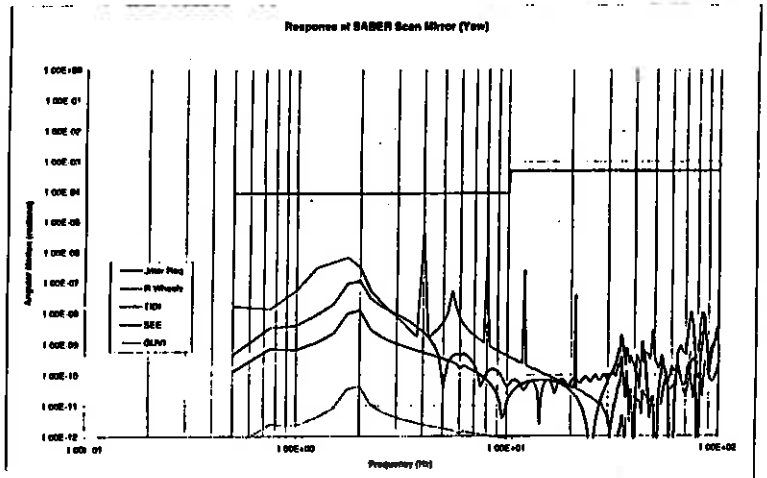
Jitter Analysis

- **Operating Environment for SABER**
  - Typical reaction wheel speed: 240 RPM
  - All other instruments operating
  - Response location : Scan mirror

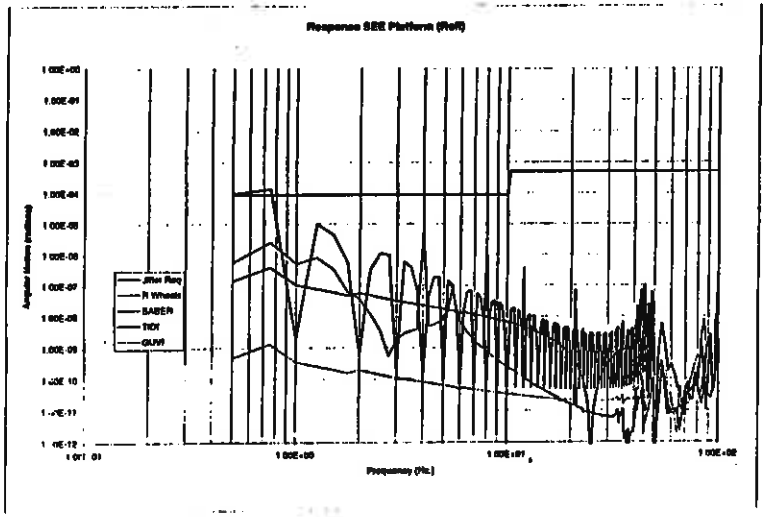


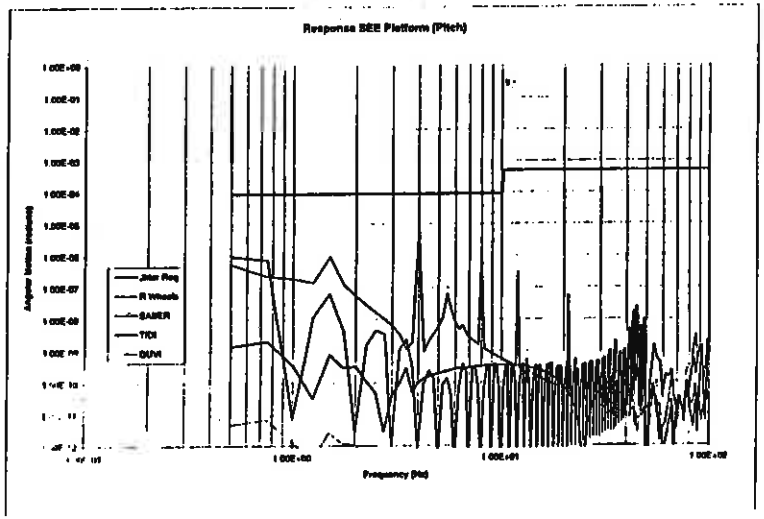


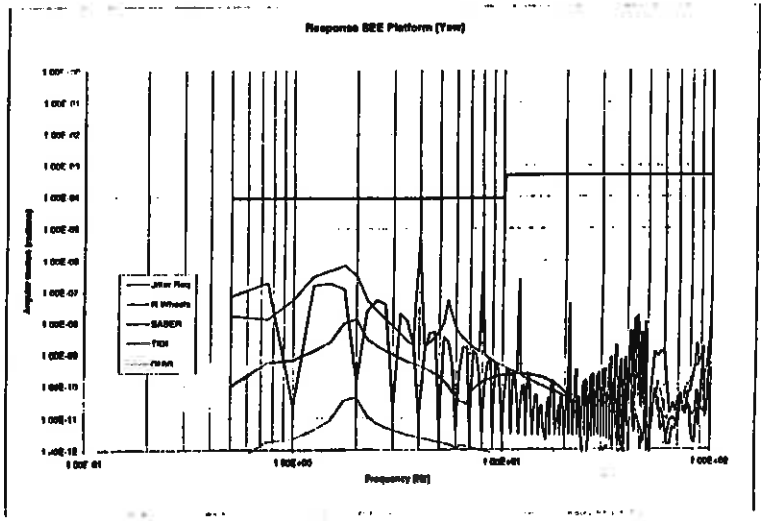


Jitter Analysis

- **Operating Environment for SEE**
  - Typical reaction wheel speed: 240 RPM
  - All other instruments operating
  - Response location : Solar Pointing Platform

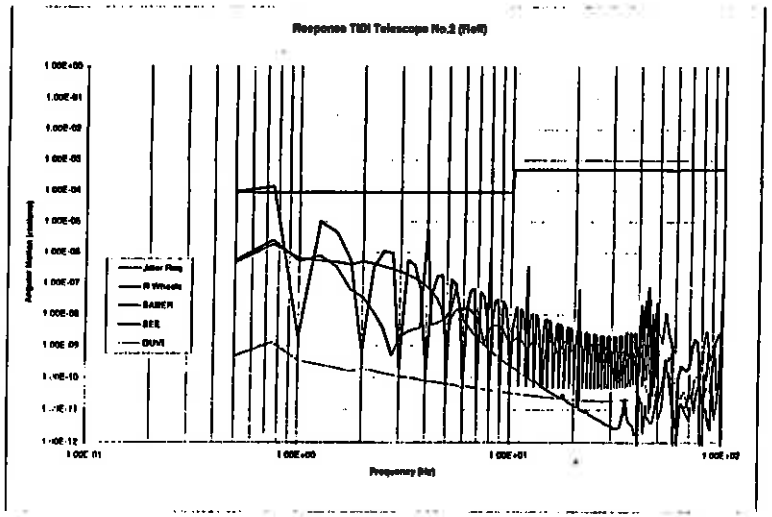


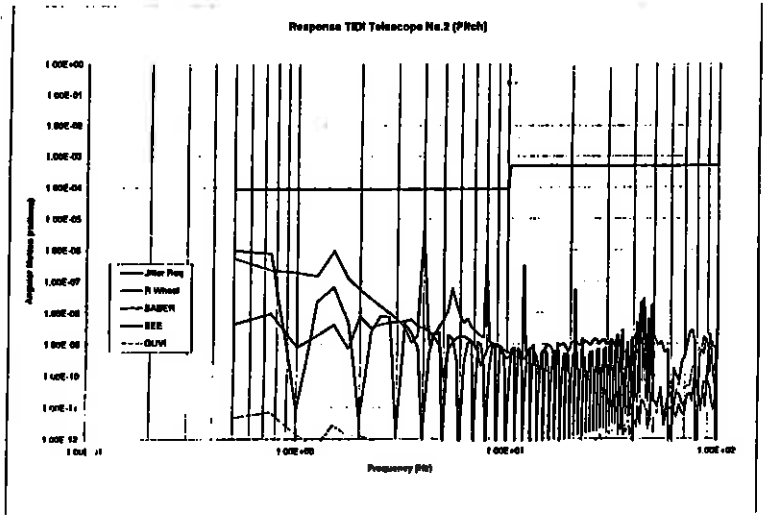


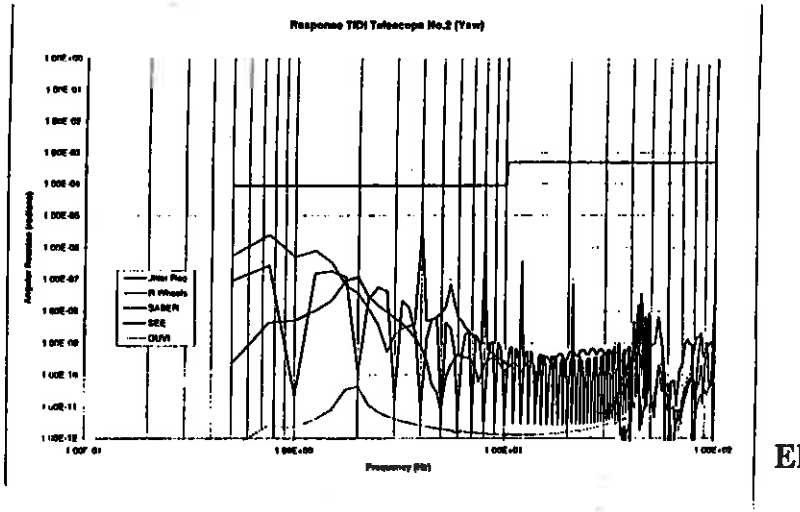


Jitter Analysis

- **Operating Environment for TIDI**
  - Typical reaction wheel speed: 240 RPM
  - All other instruments operating
  - Response location : Telescope No. 1







Instrument Bench Requirements / Criteria

- **Frequency Constraint:** Thrust > 50.0 Hz.
  Lateral > 30.0 Hz.

- **Quasi-static Loading :** 30 g's Applied independently, each axes

- **Thermal, Max Operating:** (includes 10 deg. C margin) -15 to 35 deg. C

- **Distortion Angular:** Defined herein as the relative angular rotation between a point on the bench adjacent to the base of each TIDI telescope with respect to a point representing the bore sight axis of each star tracker.

  Static Distortion: Due to the 1.0 g effect

  Thermal, Operating: (β) angles 0 & 88 deg. Cold
  (β) angles 0 & 88 deg. Hot

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Instrument Bench

Bench Structure

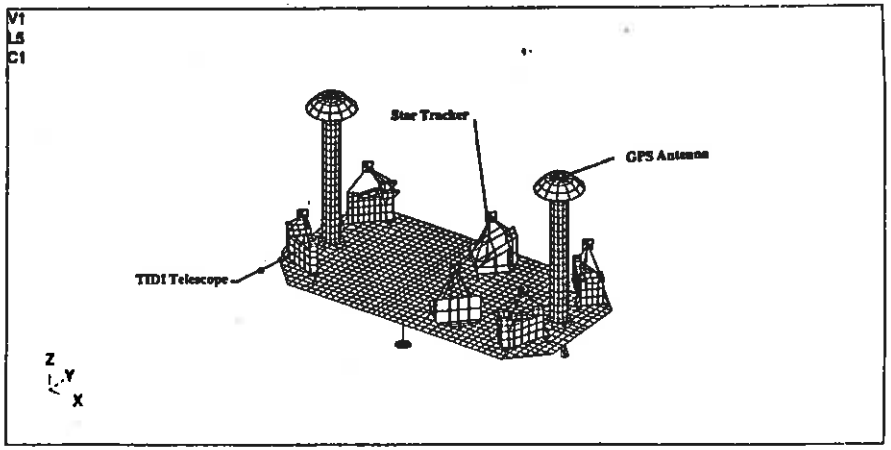
Composite System: Pitch Fibers / Cyanate Ester

Sandwich Panel: t =1.83in.

Face Sheets: 5HS XN-70A / EX-1515

Core: 1/8 - 5056 - 0.0007 - 3.1Lb/Ft^3

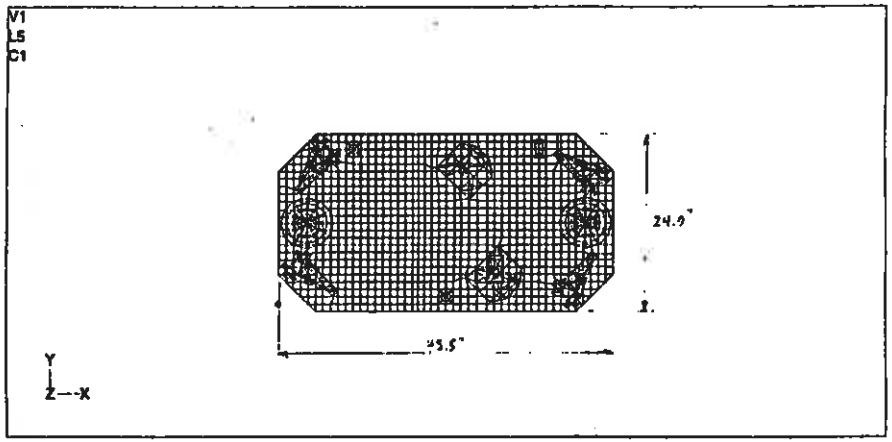
Lay-up: $\{[(-45)(0)(45)(90)]_s$/ core /$[(90)(45)(0)(-45)]_s\}$



Mounting System

Kinematic support system

Launch locks with (2) Pyro-release



Weight Estimate

Bench Structure	4.7 kg.
Inserts	1.8 kg.
Mounting System	1.8 kg.
Total	8.3 kg.

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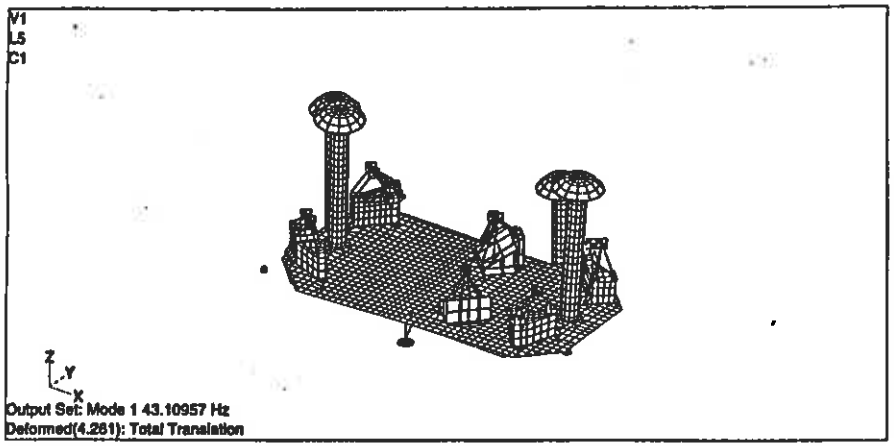
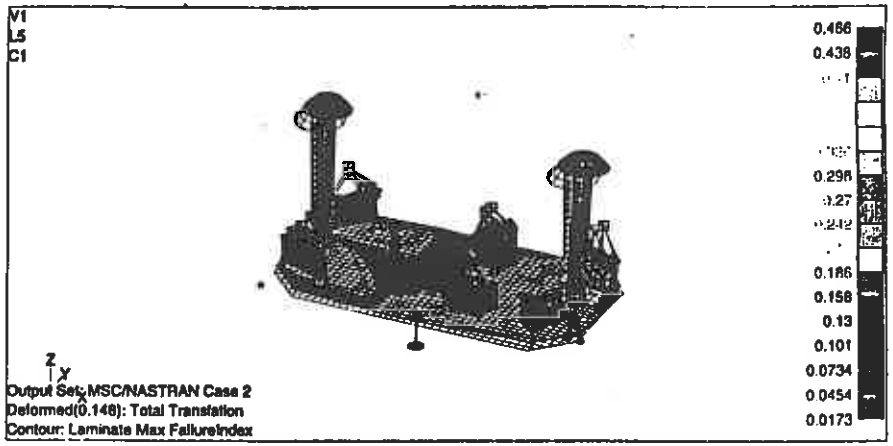
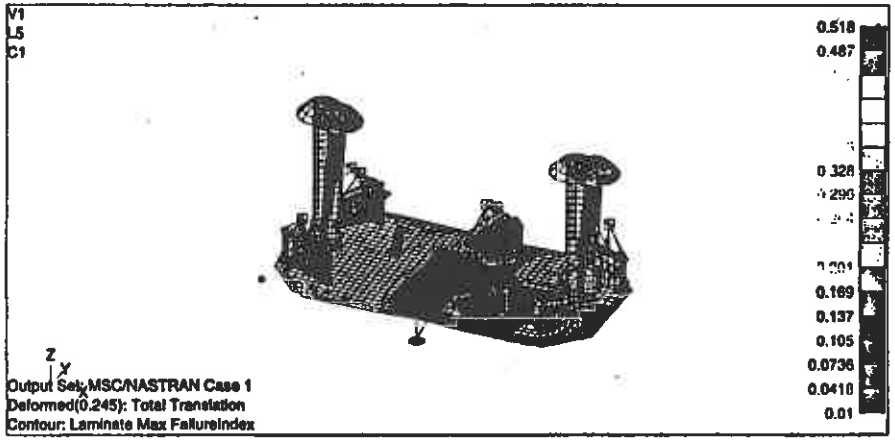
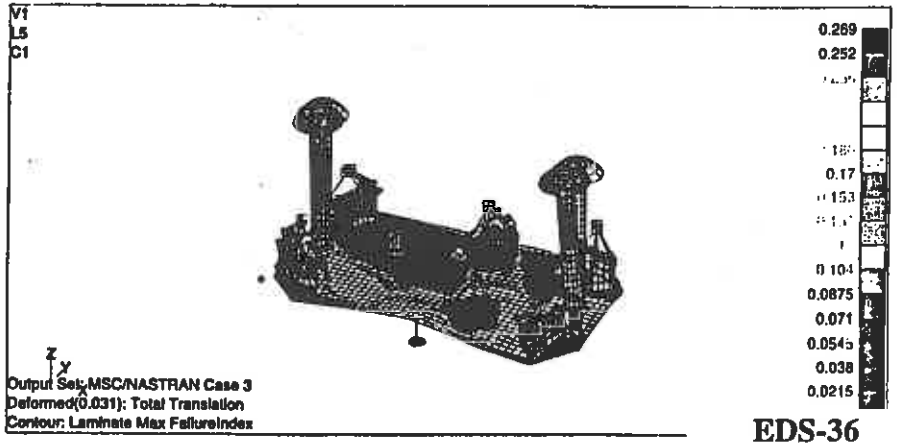
Instrument Bench Launch Configuration









GPS Antenna Mast

Mast Structure

Composite System

Prepreg: XN-70A / EX-1515

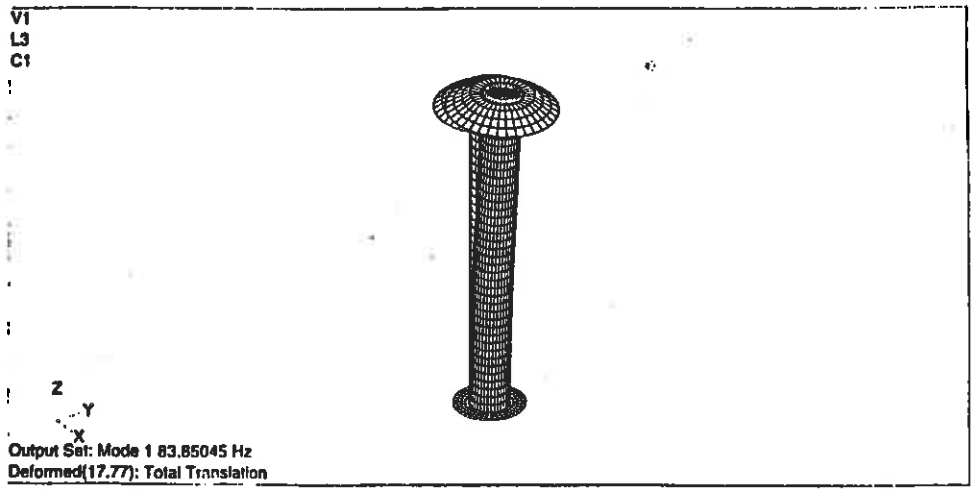
Layup: $(0/60/0/-60)_s$

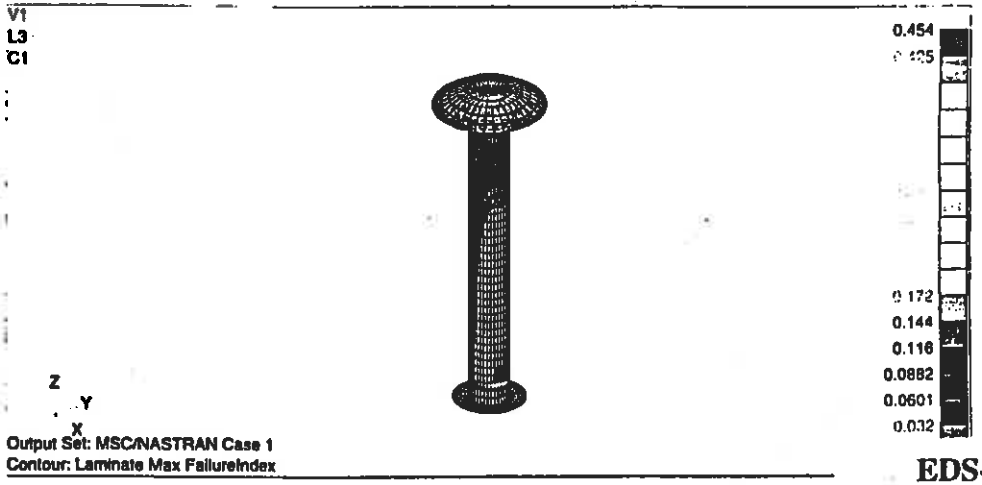
Wall Thickness: 0.040 in.

Mast Height: 21.5 in.

Weight Estimate

Mast structure	.52 kg.
Ground plane& Antenna	.30 kg.
Coaxial cable	.27 kg.
ML insulation	.17 kg.
Total	1.26 kg.





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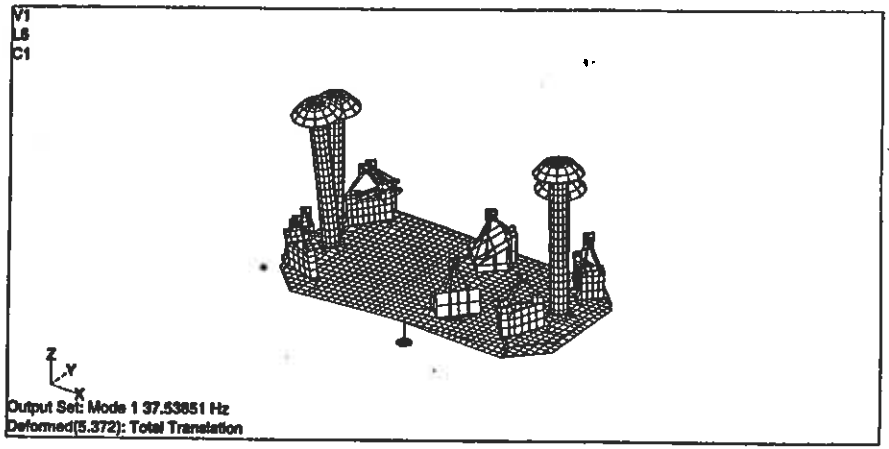
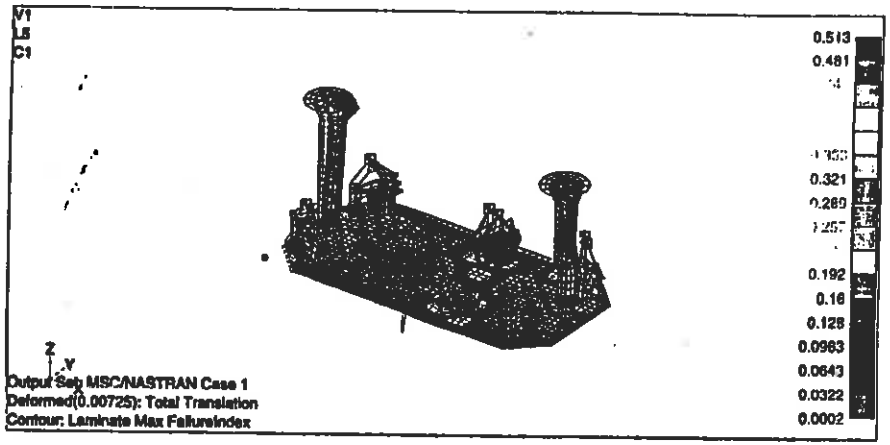
Instrument Bench Orbit Configuration

Angular Distortion (arcseconds)

Error Type	Roll	Pitch	Yaw
1 g effect	27.4	25.6	2.2
Thermal			
Cold ($\beta = 88^0$)	34.3	39.2	4.7
Cold ($\beta = 0^0$)	34.6	38.6	5.2
Hot ($\beta = 88^0$)	35.9	36.7	7.3
Hot ($\beta = 0^0$)	36.1	36.3	7.8





Structural Verification

Protoflight test program serves the purpose of both prototype and flight acceptance tests.

- Structural Verification will be performed at the component, the assembly/ subsystem and at the system level. A bottoms up approach is used to screen out design flaws and infant mortality.

- **Subsystem Level Tests**
  - Mechanical Functional
  - Sine Vibration
  - Random Vibration
  - Pyro-releases
  - Solar Panel Deployment
  - Static Load Test

- **Spacecraft Dynamic Tests**
  - Modal Survey
  - Sine Vibration
  - Acoustic
  - Pyro-shock clampband & release mechanisms

Structural Verification - Spacecraft

- **Structural Verification** - A static load test will be performed on the primary structure.
  (Draft of static load test procedure complete)

- **Modal Survey** - Experimental verification of the spacecraft's significant modes will be measured and correlated to the mathematical model

- **Vibration Test** - A sinusoidal test will be performed in accordance with the launch vehicle requirements
  A test duration of 4.0 octaves per minute, with a tolerance of +/- 10% on the amplitude.
  (No notching currently requested by spacecraft or instruments)

- **Acoustic Test** - Broad band reverberant field test, using the maximum expected flight level plus 3 dB. The test duration is 60 seconds. A tolerance of +/-1.0 dB. on the overall sound pressure level, with +/- 3.0 dB. from 50 to 3000 Hz. Below 50 Hz and above 3000 Hz is based on capability of the test facility.

- **Pyrotechnic Shock** - Two live firings per device.

Instrument / Subsystem Design Criteria

- **Load Factor:** Based on Instrument/Subsystem weight, the load will be applied individually along each of the three orthogonal axes of the subsystem at its center of gravity.

Subsystem Weight (lbs)	Load Factor
< 10	30
10 - 100	25
> 100	16

- **Frequency Constraints:**

	SABER	All other Instruments & Subsystems
Thrust axis	> 35 Hz	> 50 Hz.
Lateral axes	> 20 Hz.	> 30 Hz.

- **Pyro Shock: Requires Testing,**
  Near field < 1.0 in, no pyro sensitive hardware should be mounted in this region
  Mid field 1.0 to 6.0 in. requires two pyrotechnic firings

- **Min. Factors of Safety :** Same as spacecraft structure

Instrument / Subsystem Dynamic Tests

Sinusoidal Vibration:

Test duration: 4.0 Octave / minutes

Test tolerance: +/- 10 % Amplitude, +/- 2% Frequency

	SABER		All other Instruments & Subsystems	
	f_n (Hz.)	Acceleration (g's)	f_n (Hz.)	Acceleration (g's)
Thrust Axis	5 - 9	0.50 in (DA)	5 - 24	.50 in (DA)
	9 - 100	2.0	24 - 80	15.5
			80 - 100	2.0
Lateral Axes	5 - 7.7	0.50 in (DA)	5 - 18	.50 in DA
	7.7 - 100	1.5	18 - 30	8.5
			30 - 100	1.4

* An alternative approach Sine Burst

Instrument / Subsystem Dynamic Tests

Random Vibration:

Test duration : 1.0 min / axis

Test tolerance: +/- 3 dB. PSD, +/- 10% g_{rms}.

	Frequency (Hz.)	PSD Level (G^2/Hz.)
< 100 lbs.	20	.026
	50 - 800	.160
	2000	.026
	Overall Level 14.1 g_{rms}	
> 100 lbs.	20	.013
	50 - 800	.080
	2000	.013
	Overall Level 10.0 g_{rms}	

* An alternative approach force limiting

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Summary of Mass Properties

Item	Launch		On-Orbit	
Mass	**lb**	**kg**		
	1322.8	599.9		
Center of Gravity	**in.**	**cm.**	**in.**	**cm.**
CGx	.51	1.31	.51	1.31
CGy	1.95	4.95	1.95	4.95
CGz	39.4	100.2	38.4	97.4
Moment of Inertia	**slug-ft^2**	**kg-m^2**	**slug-ft^2**	**kg-m^2**
Ixx	225.9	306.3	243.9	330.7
Iyy	264.4	358.4	1155.3	1566.2
Izz	132.2	179.2	1011.4	1371.1
Product of Inertia	**slug-ft^2**	**kg-m^2**	**slug-ft^2**	**kg-m^2**
Pxy	1.28	1.74	1.28	1.74
Pxz	0.32	0.43	0.16	0.22
Pyz	1.07	1.45	0.47	0.63

*Properties about the spacecraft CG

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Weight Estimate (kg.)

	CoDR	PDR	CDR
Instruments	111.9	141.3	**151.0**
Power Subsystem	164.4	172.8	**186.0**
R F	8.2	4.3	**4.2**
Navigation	----	0.4	**2.1**
Attitude	36.3	55.6	**60.4**
IEM	24.0	26.8	**27.7**
Thermal	26.5	21.1	**16.9**
Harness	15.2	45.1	**36.3**
Primary Structure	154.7	84.4	**88.9**
Sec. Structure	--	29.8	**26.7**
Total	541.2	581.6	**600.2**
Margin %	21.9	13.4	**10.0**

11/05/97

TIMED LAUNCH CONFIGURATION WEIGHT AND MASS PROPERTIES SUMMARY

S/C ASSEMBLY		WT (LBS.)	*WT (KG.)	% CONT.	WT. WITH CONT. (KG.)	NTE WT (KG.)	Xcg (IN.)	Ycg (IN.)	Zcg (IN.)	Ix (IN.)	Iy (IN.)	Iz (IN.)	Wt*Xcg	Wt*Ycg	Wt*Zcg	TOTAL COMPONENT INERTIA ABOUT S/C COORDINATE AXES hx	Iyy
1.0 INSTRUMENTS		333.22	161.12		163.81	163.80	1.12	-6.09	46.70				374.46	-1697.66	16227.18	1137482.95	1106313.43
1.1 TIDI TELESCOPE #1	A-300	10.14	4.60	10	5.06	4.83	-6.50	-18.50	82.00	0.00	0.00	0.00	-65.91	-187.59	831.46	71651.78	68609.78
1.2 TIDI TELESCOPE #2	A-301	10.14	4.60	10	5.06	4.83	-22.50	-18.50	82.00	0.00	0.00	0.00	-228.16	-187.59	831.46	71651.78	73314.74
1.3 TIDI TELESCOPE #3	A-302	10.14	4.60	10	5.06	4.83	-22.50	18.50	82.00	0.00	0.00	0.00	-228.16	187.59	831.46	71651.78	73314.74
1.4 TIDI TELESCOPE #4	A-303	10.14	4.60	10	5.06	4.83	-6.50	18.50	82.00	0.00	0.00	0.00	-65.91	187.59	831.46	71651.78	68609.78
1.5 TIDI PROFILER	A-325	34.61	15.70	10	17.27	14.81	17.00	-8.00	77.00	0.00	0.00	0.00	588.37	-276.88	2664.97	207417.73	215204.98
1.6 TIDI ELECTRONICS	A-320	13.00	5.90	10	6.49	5.78	0.00	8.00	64.50	0.00	0.00	0.00	0.00	104.00	838.50	54916.25	54083.25
1.7 TIDI HARNESS		4.41	2.00	10	2.20	1.05	-10.00	11.00	75.00	0.00	0.00	0.00	-44.10	48.51	330.75	25339.86	25247.25
1.8 SEE	A-400	53.50	24.26		24.26	27.90	13.00	13.50	81.00	0.00	0.00	0.00	696.50	722.25	4333.50	360763.88	360055.00
1.9 GUVI SIS (BLANKET & HARNESS)	A-600	20.73	9.40	10	10.34	9.87	0.00	-2.50	0.00	0.00	0.00	0.00	0.00	-51.83	0.00	129.56	0.00
1.10 GUVI SIS ELEC.	A-605	2.27	1.03	10	1.13	1.06	0.00	-7.00	4.00	0.00	0.00	0.00	0.00	-15.89	9.08	147.56	36.32
1.11 GUVI FPE #1	A-610	1.65	0.75	10	0.82	0.78	-3.50	14.50	3.50	0.00	0.00	0.00	-5.78	23.93	5.78	367.13	40.43
1.12 GUVI FPE #2	A-612	1.65	0.75	10	0.82	0.78	5.50	3.50	3.50	0.00	0.00	0.00	9.08	5.78	5.78	40.43	70.13
1.13 GUVI HVPS #1	A-620	1.00	0.45	10	0.50	0.47	-6.00	1.00	4.50	0.00	0.00	0.00	-6.00	1.00	4.50	21.25	56.25
1.14 GUVI HVPS#2	A-622	1.00	0.45	10	0.50	0.47	-6.00	1.00	4.50	0.00	0.00	0.00	-6.00	1.00	4.50	21.25	56.25
1.15 GUVI ECU	A-626	14.13	6.41	10	7.05	6.73	-19.00	6.00	40.00	0.00	0.00	0.00	-268.47	84.78	565.20	23116.68	27708.93
1.16 SABER	A-500	144.71	65.63	10	72.19	64.76	0.00	-16.20	28.60	12.40	12.20	8.76	0.00	-2344.30	4138.71	178595.29	139905.63
2.0 POWER SUBSYSTEM		409.90	185.90		204.26		2.01	1.38	29.66				822.50	564.40	12167.05	511721.95	709204.87
2.1 +X SOLAR ARRAY WING	A-064	99.30	45.03	10	49.54		29.00	0.00	28.00	20.43	15.09	13.94	2879.70	0.00	2780.40	119297.62	183973.91
2.2 -X SOLAR ARRAY WING	A-065	99.30	45.03	10	49.54		-29.00	0.00	28.00	20.43	15.09	13.94	-2879.70	0.00	2780.40	119297.62	183973.91
2.3 +X ARRAY DR. MOTOR	A-062	3.80	1.72	5	1.81		27.00	0.00	64.00	0.00	0.00	0.00	102.60	0.00	243.20	15564.80	16335.00
2.4 -X ARRAY DR .MOTOR	A-063	3.80	1.72	5	1.81		-27.00	0.00	64.00	0.00	0.00	0.00	-102.60	0.00	243.20	15564.80	16335.00
2.5 SOLAR ARRAY CONTROLLER	A-060	4.20	1.90	5	2.00		-10.00	7.00	55.50	0.00	0.00	0.00	-42.00	29.40	233.10	13142.85	13357.05
2.6 BATTERY #1	A-050	62.00	28.12	10	30.93		-18.00	2.00	19.00	9.20	7.75	7.00	-1116.00	124.00	1178.00	27877.68	46193.88
2.7 BATTERY #2	A-051	62.00	28.12	10	30.93		18.00	2.00	19.00	9.20	7.75	7.00	1116.00	124.00	1178.00	27877.68	46193.88
2.8 PSE/DPU.	A-052	45.50	20.63	10	22.70		19.00	2.00	40.50	6.80	6.80	6.00	864.50	91.00	1842.75	76917.30	93160.80
2.9 PPTCM #1	A-054	14.00	6.35	10	6.98		-19.25	7.00	55.50	5.40	2.70	5.10	-269.50	98.00	777.00	44217.74	48413.44
2.10 PPTCM #2	A-055	14.00	6.35	10	6.98		19.25	7.00	55.50	5.40	2.70	5.10	269.50	98.00	777.00	44217.74	48413.44
2.11 S/A FUSE	A-067	1.00	0.45	15	0.52		24.00	0.00	62.00	5.40	2.70	5.10	24.00	0.00	62.00	3873.16	4427.29
2.12 S/A FUSE	A-069	1.00	0.45	15	0.52		-24.00	0.00	62.00	5.40	2.70	5.10	-24.00	0.00	62.00	3873.16	4427.29
3.0 RF COMMUNICATIONS		9.11	4.13		4.54		10.05	0.61	55.30				91.58	5.60	503.76	35602.16	39961.70
3.1 DIPLEXER #1	A-134	0.90	0.41	10	0.45		13.00	-4.00	66.00	0.00	0.00	0.00	11.70	-3.60	59.40	3934.80	4072.50
3.2 DIPLEXER #2	A-136	0.90	0.41	10	0.45		13.00	-4.00	66.00	0.00	0.00	0.00	11.70	-3.60	59.40	3934.80	4072.50
3.3 RF SWITCH / SPLITTER #1	A-130/133	0.60	0.27	10	0.30		13.00	5.00	66.00	0.00	0.00	0.00	7.80	3.00	39.60	2628.60	2715.00
3.4 RF SWITCH / SPLITTER #2	A-132/137	0.60	0.27	10	0.30		13.00	5.00	66.00	0.00	0.00	0.00	7.80	3.00	39.60	2628.60	2715.00
3.5 S BAND & CABLES ZENITH # 1	A-140	0.85	0.39	10	0.42		0.00	4.00	91.00	0.00	0.00	0.00	0.00	3.40	77.35	7052.45	7038.85
3.6 S BAND & CABLES ZENITH # 2	A-141	0.85	0.39	10	0.42		25.00	4.00	91.00	0.00	0.00	0.00	21.25	3.40	77.35	7052.45	7570.10
3.7 S BAND & CABLES NADIR # 1	A-145	1.00	0.45	10	0.50		-20.50	20.50	-4.00	0.00	0.00	0.00	-20.50	20.50	-4.00	436.25	436.25
3.8 S BAND & CABLES NADIR # 2	A-146	1.00	0.45	10	0.50		20.50	-20.50	-4.00	0.00	0.00	0.00	20.50	-20.50	-4.00	436.25	436.25
3.9 COAX CABLES		2.41	1.09	10	1.20		13.00	0.00	66.00	0.00	0.00	0.00	31.33	0.00	159.06	10497.96	10906.25
4.0 NAVIGATION SUBSYSTEM		4.50	2.04		2.24		-14.60	0.00	90.39				-66.25	0.00	406.75	38670.23	37816.35
4.1 LOW LOSS CABLES # 1		1.00	0.45	10	0.50		-14.60	-20.00	85.00	0.00	0.00	0.00	-14.60	-20.00	85.00	7625.00	7435.25
4.2 LOW LOSS CABLES # 2		1.00	0.45	10	0.50		-14.60	20.00	85.00	0.00	0.00	0.00	-14.60	20.00	85.00	7625.00	7435.25
4.3 GPS ANTENNA /GROUND PLANE # 1	A-160	1.25	0.57	10	0.62		-14.50	-20.00	94.70	0.00	0.00	0.00	-18.13	-25.00	118.38	11710.11	11472.93
4.4 GPS ANTENNA /GROUND PLANE # 2	A-161	1.25	0.57	10	0.62		-14.50	20.00	94.70	0.00	0.00	0.00	-18.13	25.00	118.38	11710.11	11472.93
5.0 ATTITUDE DETECTION & CONTROL		133.22	60.42		62.46		-1.60	2.74	42.29				-213.67	364.73	6633.96	345622.88	349686.78
5.1 STAR CAMERA # 1	A-220	10.80	4.90	5	5.14		-21.00	-5.00	82.50	0.00	0.00	0.00	-226.80	-54.00	891.00	73777.50	78270.30
5.2 STAR CAMERA # 2	A-222	10.80	4.90	5	5.14		-7.50	-1.00	82.50	0.00	0.00	0.00	-81.00	-10.80	891.00	73518.30	74115.00
5.3 REACT. WHEEL # 1	A-241	12.89	5.85	0	5.85		6.00	4.00	14.00	0.00	0.00	0.00	77.34	61.56	180.46	2732.68	2990.48
5.4 REACT. WHEEL # 2	A-243	12.89	5.85	0	5.85		-6.00	4.00	14.00	0.00	0.00	0.00	-77.34	61.56	180.46	2732.68	2990.48
5.5 REACT. WHEEL # 3	A-245	12.89	5.85	0	5.85		-6.00	18.50	14.00	0.00	0.00	0.00	-77.34	238.47	180.46	6938.04	2990.48
5.6 REACT. WHEEL # 4	A-247	12.89	5.85	0	5.85		6.00	18.50	14.00	0.00	0.00	0.00	77.34	238.47	180.46	6938.04	2990.48
5.7 Z-AXIS TORQUE ROD (+X)	A-232	4.65	2.11	0	2.11		19.00	19.00	45.00	0.00	0.00	0.00	88.35	88.35	209.25	11094.90	11094.90
5.8 Y-AXIS TORQUE ROD	A-231	4.65	2.11	0	2.11		16.00	0.00	32.00	0.00	0.00	0.00	74.40	0.00	148.80	4761.60	6962.00
5.9 X-AXIS TORQUE ROD	A-230	4.65	2.11	0	2.11		0.00	16.00	36.00	0.00	0.00	0.00	0.00	74.40	176.70	7905.00	6714.60
5.10 IRU (GYRO'S)	A-210/212	18.10	8.21	5	8.62		-6.00	-6.00	62.00	0.00	0.00	0.00	-108.60	-90.60	1122.20	70028.90	70228.00
5.11 AIU	A-200	14.18	6.43	5	6.75		19.00	-10.00	66.00	0.00	0.00	0.00	269.42	-141.80	794.08	45886.48	49587.46

5.12 FLIGHT COMPUTER	A-206/207	10.26	4.66	15	5.36	-19.00	-8.00	65.00	0.00	0.00	0.00	-194.76	-82.00	663.75	31662.26	34706.60
5.13 MAGNETOMETER	A-235	0.99	0.45	0	0.45	-18.00	18.00	16.50	0.00	0.00	0.00	-17.86	17.86	16.37	691.48	691.48
5.14 MAGNETOMETER	A-237	0.99	0.45	0	0.45	-17.00	-17.00	3.00	0.00	0.00	0.00	-16.83	-16.83	2.97	295.02	295.02
5.15 SUN SENSOR	A-260	0.40	0.18	15	0.21	16.00	25.00	60.00	0.00	0.00	0.00	6.40	10.00	24.00	1690.00	1642.40
5.16 SUN SENSOR	A-262	0.40	0.18	15	0.21	-16.00	25.00	60.00	0.00	0.00	0.00	-6.40	10.00	24.00	1690.00	1642.40
5.17 SUN SENSOR	A-264	0.40	0.18	15	0.21	16.00	-25.00	60.00	0.00	0.00	0.00	6.40	-10.00	24.00	1690.00	1642.40
5.18 SUN SENSOR	A-266	0.40	0.18	15	0.21	-16.00	-25.00	60.00	0.00	0.00	0.00	-6.40	-10.00	24.00	1690.00	1642.40
6.0 INTEGRATED ELECTRONICS MOD.		61.00	27.66		31.59	-0.88	-16.56	57.96				-53.50	-948.90	3535.50	229229.77	214654.00
6.1 IEM #1 (9 cards + chassis)	A-100	27.00	12.24	15	14.08	6.80	-18.35	59.50	4.00	4.90	4.00	183.60	-496.45	1606.50	106110.26	97483.60
6.2 IEM #2 (9 cards + chassis)	A-102	27.00	12.24	15	14.08	-6.80	-18.35	59.50	4.00	4.90	4.00	-183.60	-496.45	1606.50	106110.26	97483.60
6.3 RIU (-X,+Y CORNER)	A-110/A-120	2.00	0.91	16	1.04	-16.50	16.50	46.00	0.00	0.00	0.00	-33.00	33.00	92.00	4776.50	4776.50
6.4 RIU (-X)	A-111/A-121	1.00	0.45	5	0.48	-19.00	-9.00	40.00	0.00	0.00	0.00	-19.00	-9.00	40.00	1681.00	1961.00
6.5 RIU (BD)	A-112/A-122	1.00	0.45	6	0.48	-12.50	1.50	4.00	0.00	0.00	0.00	-12.50	1.50	4.00	18.25	172.25
6.6 RIU. (+X)	A-113/A-123	1.00	0.45	5	0.48	20.00	10.00	41.00	0.00	0.00	0.00	20.00	10.00	41.00	1781.00	2081.00
6.7 RIU. (TD)	A-114/A-124	1.00	0.45	5	0.48	-10.00	11.50	75.00	0.00	0.00	0.00	-10.00	11.50	75.00	6767.25	5725.00
6.8 RIU. (INST BENCH)	A-116/A-126	1.00	0.45	5	0.48	1.00	-5.00	70.50	0.00	0.00	0.00	1.00	-5.00	70.50	4995.25	4971.25
7.0 THERMAL		37.30	16.92		18.61	-1.13	-2.87	37.34				-42.00	-106.90	1392.90	74864.40	75573.45
7.1 TOP DECK BLANKET		5.60	2.49	10	2.74	0.00	0.00	70.00	0.00	0.00	0.00	0.00	0.00	385.00	26950.00	26950.00
7.2 BTM. DECK BLANKET		6.20	2.81	10	3.09	0.00	0.00	2.50	0.00	0.00	0.00	0.00	0.00	15.50	38.75	38.75
7.3 +X PANEL BLANKET		3.00	1.36	10	1.50	23.50	0.00	38.00	0.00	0.00	0.00	70.50	0.00	114.00	4332.00	5988.75
7.4 - X PANEL BLANKET		3.00	1.36	10	1.50	-23.50	0.00	38.00	0.00	0.00	0.00	-70.50	0.00	114.00	4332.00	5988.75
7.5 +Y PANEL BLANKET		1.00	0.45	10	0.50	0.00	23.50	38.00	0.00	0.00	0.00	0.00	23.50	38.00	1996.25	1444.00
7.6 - Y PANEL BLANKET		4.00	1.81	10	2.00	0.00	-23.50	38.00	0.00	0.00	0.00	0.00	-94.00	152.00	7985.00	5776.00
7.7 +X/+Y PANEL BLANKET		1.00	0.45	10	0.50	21.00	21.00	38.00	0.00	0.00	0.00	21.00	21.00	38.00	1885.00	1885.00
7.8 - X/+Y PANEL BLANKET		1.00	0.45	10	0.50	-21.00	21.00	38.00	0.00	0.00	0.00	-21.00	21.00	38.00	1885.00	1885.00
7.9 - X/- Y PANEL BLANKET		1.00	0.45	10	0.50	-21.00	-21.00	38.00	0.00	0.00	0.00	-21.00	-21.00	38.00	1885.00	1885.00
7.10 +X/-Y PANEL BLANKET		1.00	0.45	10	0.50	21.00	-21.00	38.00	0.00	0.00	0.00	21.00	-21.00	38.00	1885.00	1885.00
7.11 MLI BLKT SUPT BRKTS		1.00	0.45	10	0.50	0.00	0.00	38.00	0.00	0.00	0.00	0.00	0.00	38.00	1444.00	1444.00
7.12 HEATERS & WIRE		1.60	0.73	10	0.80	0.00	0.00	38.00	0.00	0.00	0.00	0.00	0.00	60.80	2310.40	2310.40
7.13 THERMOSTATS		1.30	0.59	10	0.65	0.00	0.00	38.00	0.00	0.00	0.00	0.00	0.00	49.40	1877.20	1877.20
7.14 SURFACE COATINGS		1.90	0.86	10	0.96	0.00	0.00	38.00	0.00	0.00	0.00	0.00	0.00	72.20	2743.60	2743.60
7.15 DOUBLER- IMU (16*23*.08)		2.80	1.27	10	1.40	-15.00	-13.00	67.50	0.00	0.00	0.00	-42.00	-36.40	189.00	13230.70	13387.60
7.16 HEAT PIPES (4)		2.00	0.91	10	1.00	0.00	0.00	6.50	0.00	0.00	0.00	0.00	0.00	13.00	84.50	84.50
8.0 SPACECRAFT HARNESS		80.00	36.28		39.91	0.00	-6.00	42.11				0.00	-480.00	3368.50	181284.25	186676.25
8.1 +X,-Y PANEL		16.00	6.80	10	7.48	16.00	-16.00	38.00	0.00	0.00	0.00	240.00	-240.00	570.00	25500.00	25500.00
8.2 -X,-Y PANEL		16.00	6.80	10	7.48	-16.00	-16.00	38.00	0.00	0.00	0.00	-240.00	-240.00	570.00	25500.00	25500.00
8.3 + X PANEL		6.00	2.72	10	2.99	21.00	0.00	38.00	0.00	0.00	0.00	126.00	0.00	228.00	8664.00	11310.00
8.4 - X PANEL		6.00	2.72	10	2.99	-21.00	0.00	38.00	0.00	0.00	0.00	-126.00	0.00	228.00	8664.00	11310.00
8.5 TOP DECK		25.00	11.34	10	12.47	0.00	0.00	67.00	0.00	0.00	0.00	0.00	0.00	1675.00	112225.00	112225.00
8.6 BTM DECK		13.00	6.90	10	6.49	0.00	0.00	7.50	0.00	0.00	0.00	0.00	0.00	97.50	731.25	731.25
9.0 PRIMARY STRUCTURE		196.99	88.88		98.76	0.00	-1.72	30.53				0.30	-337.83	5983.62	363027.16	352081.06
9.1 TOP DECK & FRAMING	A-001	28.65	12.99	15	14.94	0.00	0.00	68.60	13.30	13.30	18.80	0.00	0.00	1962.53	139500.86	139500.86
9.2 BTM HONEYCOMB DECK	A-001	12.40	5.62	15	6.47	0.00	0.00	6.60	13.30	13.30	18.80	0.00	0.00	80.60	2717.34	2717.34
9.3 BTM ALUM. DECK	A-001	32.70	14.83	10	16.31	0.00	0.00	6.60	19.90	17.30	9.80	0.00	0.00	212.66	14331.10	11168.36
9.4 +X PANEL	A-001	13.60	6.12	10	6.73	22.50	0.00	37.60	13.30	13.30	18.80	303.75	0.00	506.26	21372.39	28206.77
9.5 - X PANEL	A-001	13.60	6.12	10	6.73	-22.50	0.00	37.50	19.90	17.30	9.80	-303.75	0.00	506.26	24330.61	29859.17
9.6 +Y PANEL	A-001	7.60	3.45	10	3.79	0.00	22.50	37.50	17.30	19.90	9.80	0.00	171.00	286.00	16809.60	13697.18
9.7 - Y PANEL	A-001	16.00	6.80	10	7.48	0.00	-22.50	37.50	17.30	19.90	9.80	0.00	-337.50	562.50	33176.85	27033.90
9.8 +X/+Y PANEL $ LONG.	A-001	9.00	4.08	10	4.49	20.00	20.00	37.50	17.40	17.30	2.05	180.00	180.00	337.50	18981.09	18949.86
9.9 - X/+Y PANEL $ LONG.	A-001	9.00	4.08	10	4.49	-20.00	20.00	37.50	17.40	17.30	2.05	-180.00	180.00	337.50	18981.09	18949.86
9.10 - X /-Y PANEL & LONG.(SABER)	A-001	12.30	5.58	10	6.14	-20.00	-20.00	37.50	17.30	17.40	2.05	-246.00	-246.00	461.25	25898.14	25940.82
9.11 +X /-Y PANEL & LONG.(SABER)	A-001	12.30	5.58	10	6.14	20.00	-20.00	37.50	17.30	17.40	2.05	246.00	-246.00	461.25	25898.14	25940.82
9.12 +X/+Y CORNER BKTS	A-001	3.00	1.36	10	1.50	15.60	15.60	12.00	0.00	0.00	0.00	46.80	46.80	36.00	1162.08	1162.08
9.13 - X/+Y CORNER BKTS	A-001	3.00	1.36	10	1.50	-15.60	15.60	12.00	0.00	0.00	0.00	-46.80	46.80	36.00	1162.08	1162.75
9.14 - X/- Y CORNER BKTS	A-001	3.00	1.36	10	1.50	-15.60	-15.60	12.00	0.00	0.00	0.00	-46.80	-46.80	36.00	1162.08	1162.08
9.15 + X/- Y CORNER BKTS	A-001	3.00	1.36	10	1.50	15.60	-15.60	12.00	0.00	0.00	0.00	46.80	-46.80	36.00	1162.08	1162.08
9.16 PAYLOAD ADAPTER	A-002	13.95	6.32	10	6.96	0.00	0.00	2.75	9.80	9.80	13.70	0.00	0.00	38.31	1443.18	1443.18
9.17 SEP.SPRING & BKT(4)	A-015	2.00	0.91	15	1.04	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	4.00	8.00	8.00
9.18 SEP.SWITCH & BKT(2)	A-030	0.40	0.18	15	0.21	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	1.20	3.60	3.60
9.19 BEAM Y-PANEL	A-001	1.71	0.78	10	0.85	0.00	-23.00	48.50	0.00	0.00	0.00	0.00	-39.33	82.94	4926.94	4022.36
10. SECONDARY STRUCTURE		58.55	26.55		29.82	-4.00	1.03	60.74				-234.25	60.13	2970.90	199635.26	211652.18
10.1 GPS ANTF ST #1	A-012	1.15	0.52	10	0.57	-14.60	-20.00	1.50	0.00	0.00	0.00	-16.68	-23.00	97.18	8671.7	8453.08
10.2 GPS ANT. ST #2	A-014	1.15	0.52	10	0.57	-14.60	20.00	.50	0.00	0.00	0.00	-16.68	23.00	97.18	8671.	8453.08

10.5 ZENITH ANT. MAST #1	A-010	1.30	0.89	10	0.66	0.00	4.00	79.60	0.00	0.00	0.00	0.00	5.20	103.36	8237.13	8216.33
10.4 ZENITH ANT. MAST #2	A-011	1.30	0.89	10	0.66	25.00	4.00	79.60	0.00	0.00	0.00	32.50	5.20	103.36	8237.13	9028.83
10.5 NADIR ANT. MAST #1	A-008	1.60	0.68	18	0.78	-20.60	20.60	4.00	0.00	0.00	0.00	-30.76	30.76	6.00	654.38	654.38
10.6 NADIR ANT. MAST #2	A-009	1.60	0.68	18	0.78	20.60	-20.60	4.00	0.00	0.00	0.00	30.75	-30.75	6.00	654.38	654.38
10.7 UMBICAL CONN & BKT (Z)	A-024	1.20	0.64	16	0.63	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	2.40	4.80	4.80
10.8 INSTRUMENT BENCH	A-013	18.30	8.30	10	9.13	-14.60	0.00	76.00	0.00	0.00	0.00	-266.36	0.00	1372.50	102937.50	106785.08
10.9 STAR CAMERA BKT. #1	A-017	1.30	0.69	10	0.65	-21.00	0.00	80.00	0.00	0.00	0.00	-27.30	0.00	104.00	8320.00	8893.30
10.10 STAR CAMERA BKT. #2	A-018	1.30	0.59	10	0.68	-7.60	0.00	80.00	0.00	0.00	0.00	-9.76	0.00	104.00	8320.00	8393.13
10.11 ARMING CONN.	A-022	1.15	0.62	15	0.60	-20.00	-18.60	59.00	0.00	0.00	0.00	-23.00	-21.28	67.85	4396.74	4463.15
10.12 TEST PT. CONN.	A-026	1.00	0.45	15	0.52	20.00	-19.00	57.50	0.00	0.00	0.00	20.00	-19.00	57.50	3667.25	3706.25
10.14 R W BKT #1	A-004	2.00	0.91	15	1.04	6.00	4.00	12.00	0.00	0.00	0.00	12.00	8.00	24.00	320.00	360.00
10.15 R W BKT #2	A-005	2.00	0.91	15	1.04	-6.00	4.00	12.00	0.00	0.00	0.00	-12.00	8.00	24.00	320.00	360.00
10.16 R W BKT #3	A-006	2.00	0.91	15	1.04	-6.00	18.50	12.00	0.00	0.00	0.00	-12.00	37.00	24.00	972.50	360.00
10.17 R W BKT #4	A-007	2.00	0.91	15	1.04	6.00	18.50	12.00	0.00	0.00	0.00	12.00	37.00	24.00	972.50	360.00
10.18 MISC. HARDWARE		5.00	2.27	15	2.61	0.00	0.00	38.00	0.00	0.00	0.00	0.00	0.00	190.00	7220.00	7220.00
10.19 SOLAR PNL. MOTOR BKT (+X)	A-028	2.20	1.00	15	1.15	26.00	0.00	64.00	0.00	0.00	0.00	65.00	0.00	140.80	9011.20	10386.20
10.20 SOLAR PNL. MOTOR BKT (-X)	A-029	2.20	1.00	15	1.15	-25.00	0.00	64.00	0.00	0.00	0.00	-65.00	0.00	140.80	9011.20	10386.20
10.21 SOLAR PNL. HOLD-DOWN BKTS (X)		3.00	1.36	10	1.50	26.00	0.00	28.00	0.00	0.00	0.00	76.00	0.00	84.00	2362.00	4227.00
10.22 SOLAR PNL. HOLD-DOWN BKTS (-X)		3.00	1.36	10	1.50	-26.00	0.00	28.00	0.00	0.00	0.00	-76.00	0.00	84.00	2362.00	4227.00
10.23 PURGE SYSTEM		3.00	1.36	15	1.66	24.00	0.00	38.00	0.00	0.00	0.00	72.00	0.00	114.00	4332.00	6060.00
WT SUBTOTALS		1322.79	599.91		655.98							680.19	-2676.44	62180.11	3110140.99	3283620.03

TIMED MASS PROPERTIES (ABOUT S/C CG, WITHOUT CONTINGENCIES)
MAXIMUM LAUNCH WEIGHT 1455.0 (lbs.) 660 (KG.)
CURRENT WEIGHT MARGIN = 10.02 %
WEIGHT (W/O CONTINGENCY) = 1322.79 LBS.

CGX =	0.61 in.	0.04 ft.	1.31 cm.	
CGY =	-1.96 in.	-0.16 ft.	-4.96 cm.	
CGZ =	39.45 in.	3.29 ft.	100.20 cm.	
IXX =	1046776.49 lb-in**2	226.96 sls.	306.33 kg-m**2	
IYY =	1224823.96 lb-in**2	264.40 sls.	358.43 kg-m**2	
IZZ =	612207.43 lb-in**2	132.16 sls.	179.16 kg-m**2	
PXY =	5929.46 lb-in**2	1.28 sls.	1.74 kg-m**2	
PXZ =	-1475.74 lb-in**2	-0.32 sls.	-0.43 kg-m**2	
PYZ =	4968.89 lb-in**2	1.07 sls.	1.45 kg-m**2	