TRW

A Three Element Viscoelastic Isolator

FAC-1

Presented at : Damping '91
February 13-15, 1991
Catamaran Hotel
San Diego, CA

S. S. Simonian
14 February 1991

AGENDA

- PROBLEM
- STRUCTURE CONFIGURATION
- BASELINE RWA ISOLATOR DESIGN
- ISOLATOR CHARACTERISTICS
- SOME TEST RESULTS

PROBLEM

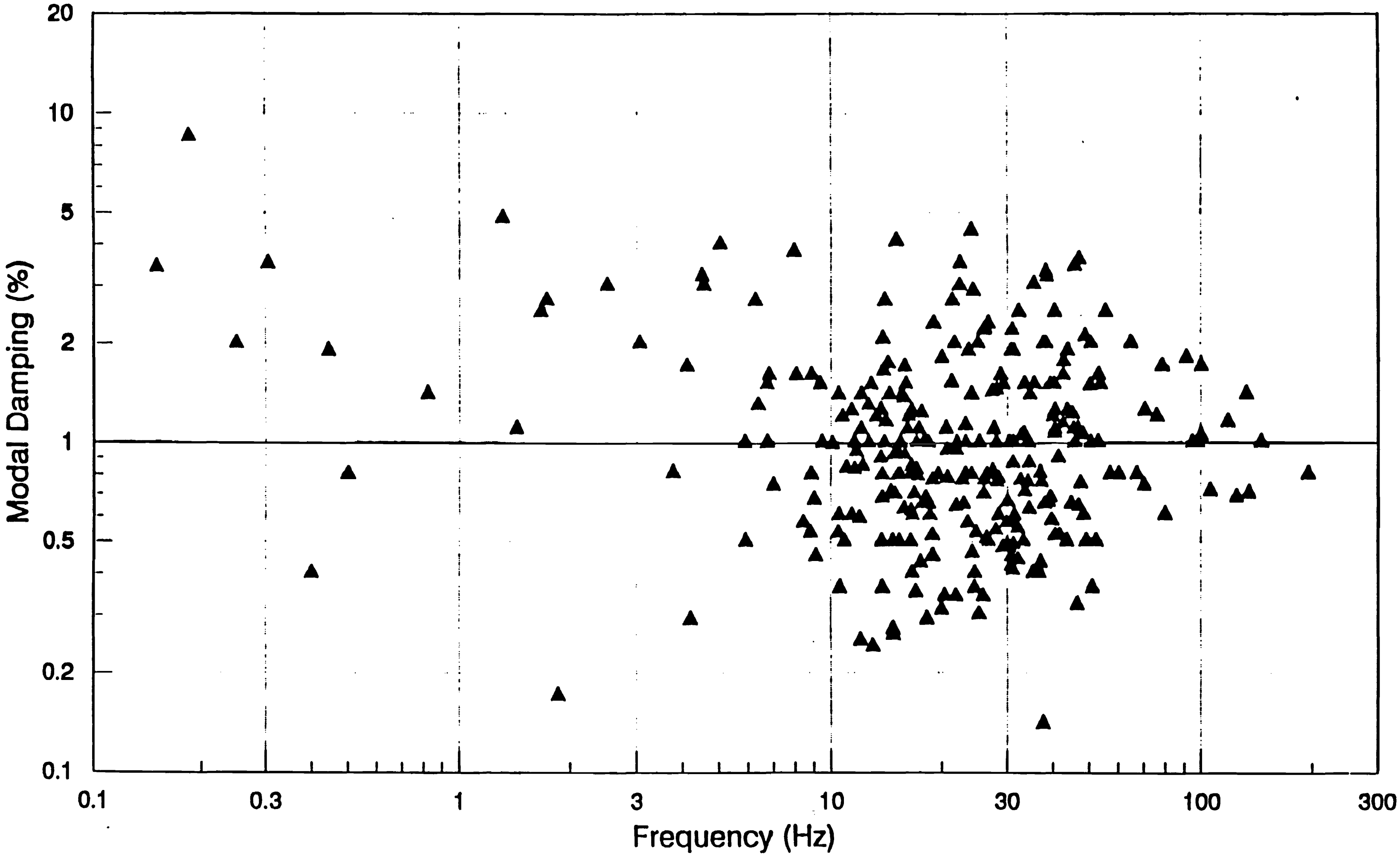
- EXCESSIVE SENSOR LOS DISTURBANCES
- REACTION WHEEL INDUCED DISTURBANCES
    - STATIC UNBALANCE
    - DYNAMIC UNBALANCE
    - BEARING NOISE
- LOW STRUCTURAL DAMPING

SPACECRAFT INHERENT DAMPING

- DATA OBTAINED FROM MEASUREMENTS OF 23 SATELLITES UNDER LOW EXCITATION INPUTS, MOSTLY DURING SINE DWELL MODAL SURVEY TESTS
- A TOTAL OF 290 SAMPLE DATA POINTS
- STRUCTURE FREQUENCY RANGE 0.15 - 195 HERTZ
- FURTHER DETAILS AND STATISTICAL DAMPING MODELS REPORTED IN:

S.S. SIMONIAN, "SURVEY OF SPACECRAFT DAMPING MEASUREMENTS: APPLICATION TO ELECTRO-OPTIC JITTER PROBLEMS", THE ROLE OF DAMPING IN VIBRATION AND NOISE CONTROL, ASME PUBLICATION DE-VOL.5, SEPTEMBER, 1987.

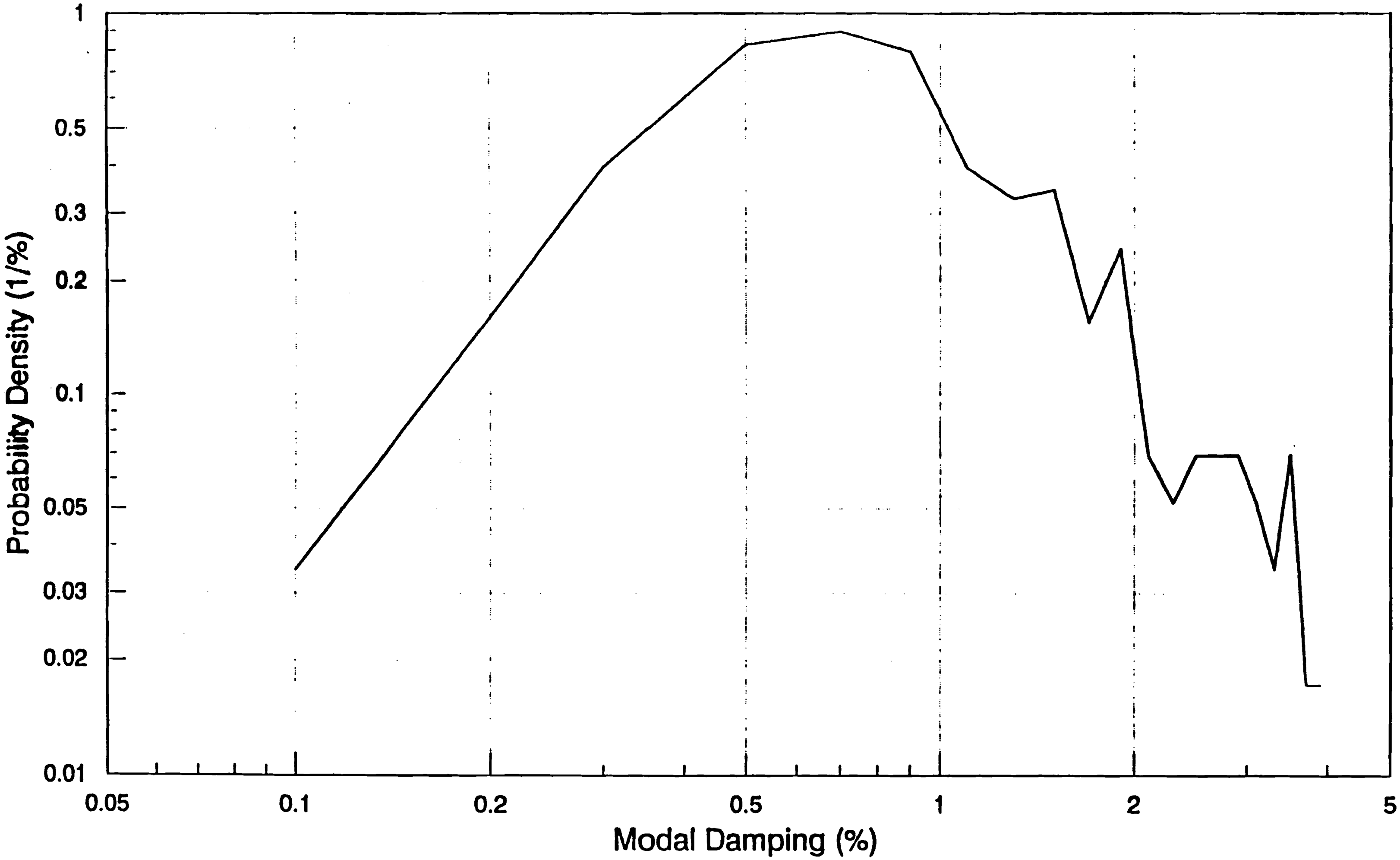
Low Amplitude Modal Damping Database



Data collected by S.S. Simonian
Several spacecraft are represented
DSP data has similar distribution

FAC-6

Low Amplitude Damping - Probability Density



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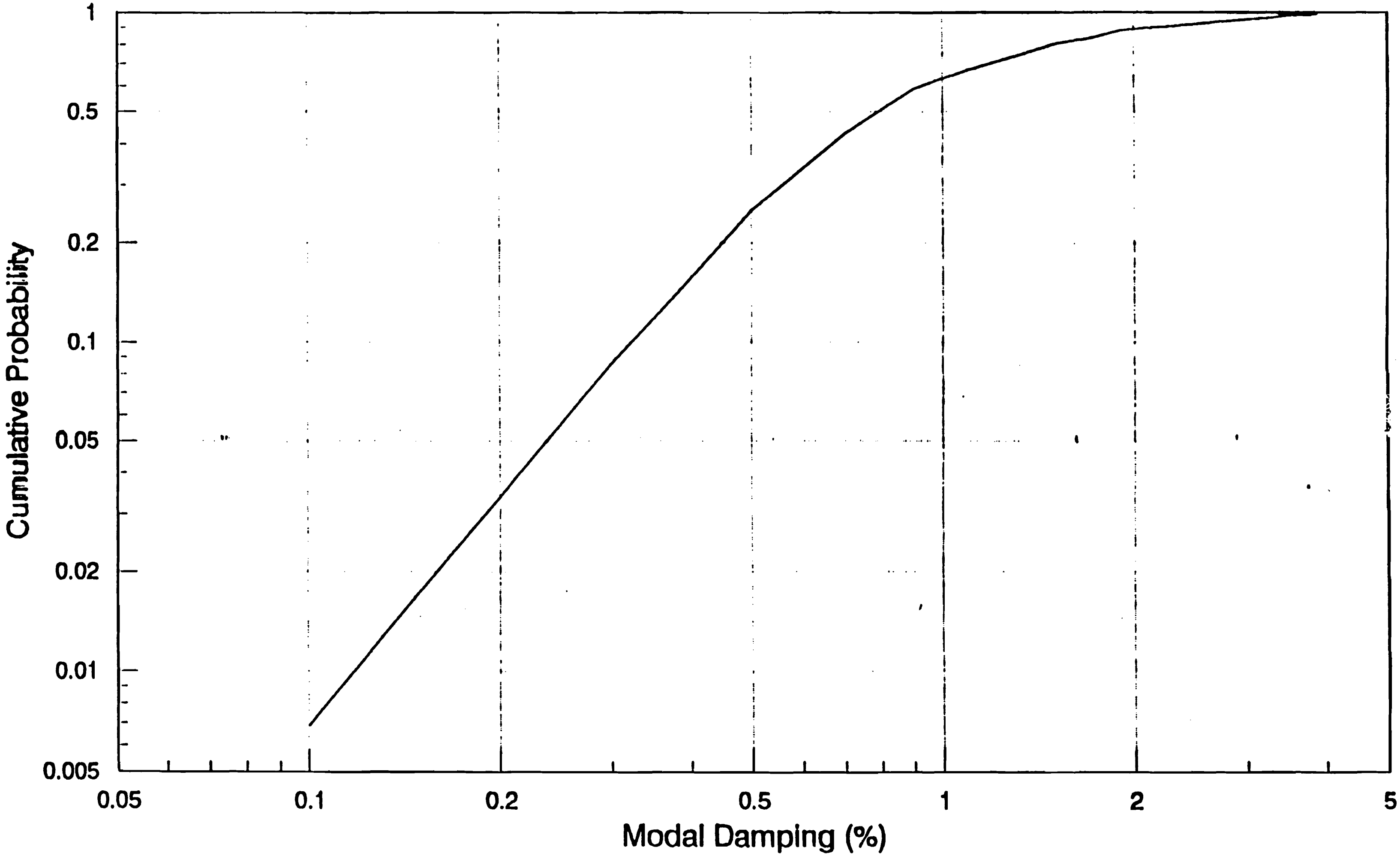
Low Amplitude Damping - Cumulative Probability



Data collected by S.S. Simonian
Several spacecraft are represented
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ROTOR STATIC & DYNAMIC UNBALANCE

FORCE OR MOMENT

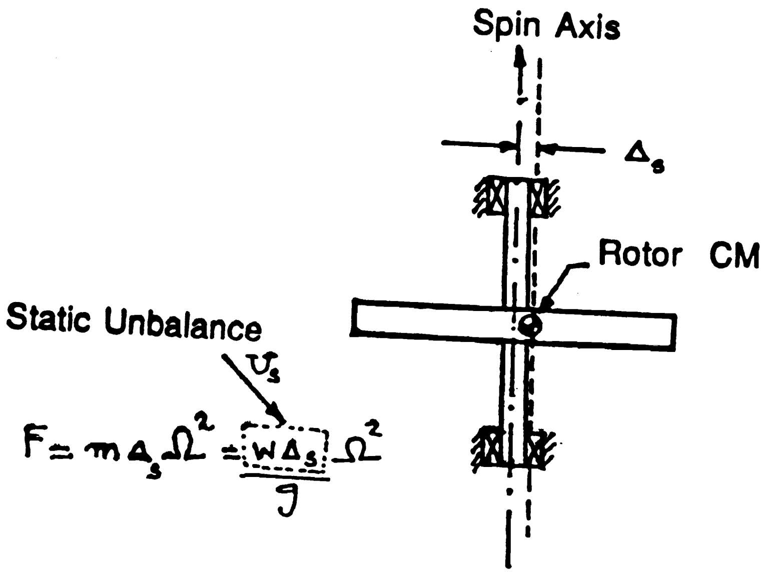
$F = \delta . M . \Omega^2$

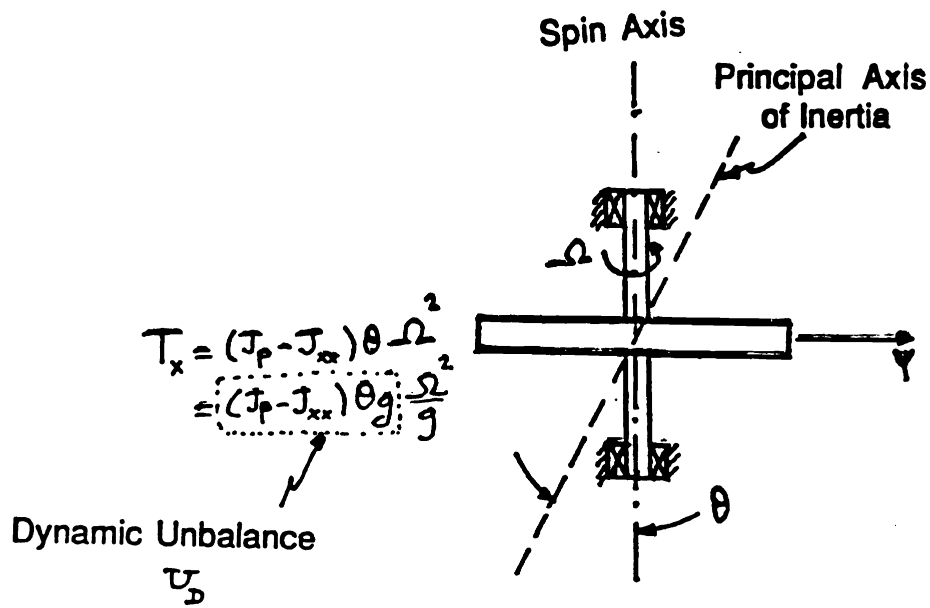
F = FORCE OR MOMENT (LB OR IN-LB)

M = ROTOR MASS (LB-SEC^2/IN)

Ω = WHEEL SPEED (RAD/SEC)

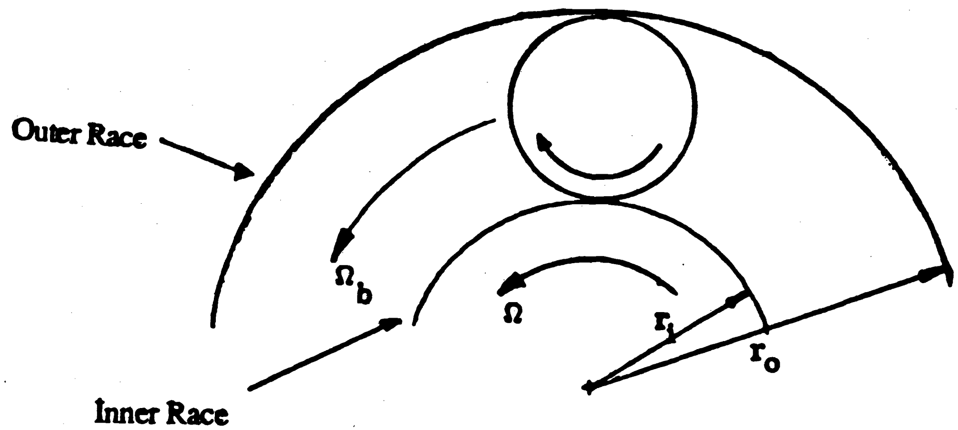
δ = CONSTANT OF PROPORTIONALITY (TABULATED)





BALL BEARING DISTURBANCES

BALL BEARING GEOMETRY



$$\frac{\Omega_b}{\Omega} = \frac{r_i}{r_i + r_o}$$

COMPONENT	SPEED
ROTOR/OUTER RACE	$N \times \Omega$
ROTOR/BALL GROUP	$N \times (\Omega - \Omega_b)$
BALL GROUP/OUTER RACE	$N \times \Omega_b$
BALLS/OUTER RACE	$N \times N_b \times \Omega_b$
ROTOR/BALLS	$N \times N_b \times (\Omega - \Omega_b)$

N_b = Number of balls

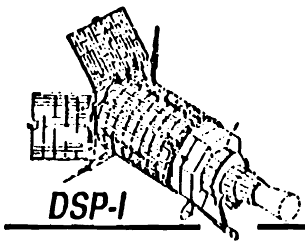
N = Harmonics of rotor speed, N = 1, 2, 3, . . .

MEASURED REACTION WHEEL DISTURBANCE MODELS

- **PROPORTIONALITY CONSTANTS FOR TWO TRW REACTION WHEELS**

Disturbance	Harmonic	Axial Force	Lateral Force (Y)	Lateral Force (Z)	Radial Force (avg)	Lateral Moment (Y)	Lateral Moment (Z)	Radial Moment (avg)
		(in · 10^{-6})	(in · 10^{-6})	(in · 10^{-6})	(in · 10^{-6})	(in^2 · 10^{-6})	(in^2 · 10^{-6})	(in^2 · 10^{-6})
Ball Group / Outer Race	1	0.061	0.150	0.200	0.175	6.0	5.0	5.5
(0.418 x Wheel Speed)	2	0.081	0.040	0.040	0.040	1.5	5.0	3.3
	3	0.098	0.040	0.080	0.060	3.0	3.0	3.0
	4	0.175	0.150	0.200	0.175	1.5	3.0	2.3
Ball Group / Inner Race	1	0.051	0.030	0.020	0.025	2.0	2.0	2.0
(0.582 x Wheel Speed)	2	0.177	0.020	0.090	0.055	2.0	4.0	3.0
	3	0.179	0.200	0.200	0.200	4.0	4.0	4.0
Inner / Outer Race	1	13.500	1.300	1.800	1.550	550.0	500.0	530.0
(1.000 x Wheel Speed)	2	1.180	0.800	1.500	1.150	20.0	20.0	20.0

Disturbance	Harmonic	Axial Force	Lateral Force (Y)	Lateral Force (Z)	Radial Force (avg)	Lateral Moment (Y)	Lateral Moment (Z)	Radial Moment (avg)
		(in · 10^{-6})	(in · 10^{-6})	(in · 10^{-6})	(in · 10^{-6})	(in^2 · 10^{-6})	(in^2 · 10^{-6})	(in^2 · 10^{-6})
Ball Group / Outer Race	1	0.015	0.500	0.500	0.500	6.0	6.0	6.0
(0.418 x Wheel Speed)	2	0.010	0.030	0.070	0.050	3.0	0.7	1.9
	3	0.091	0.090	0.110	0.100	2.0	6.0	4.0
	4	0.371	0.200	0.110	0.155	2.0	1.5	1.8
Ball Group / Inner Race	1	0.026	0.020	0.020	0.020	3.0	3.0	3.0
(0.582 x Wheel Speed)	2	0.382	0.040	0.050	0.045	4.0	4.0	4.0
	3	0.383	0.200	0.100	0.150	7.0	7.0	7.0
Inner / Outer Race	1	1.230	3.000	2.500	2.750	400.0	400.0	400.0
(1.000 x Wheel Speed)	2	1.450	0.500	0.700	0.600	10.0	10.0	10.0



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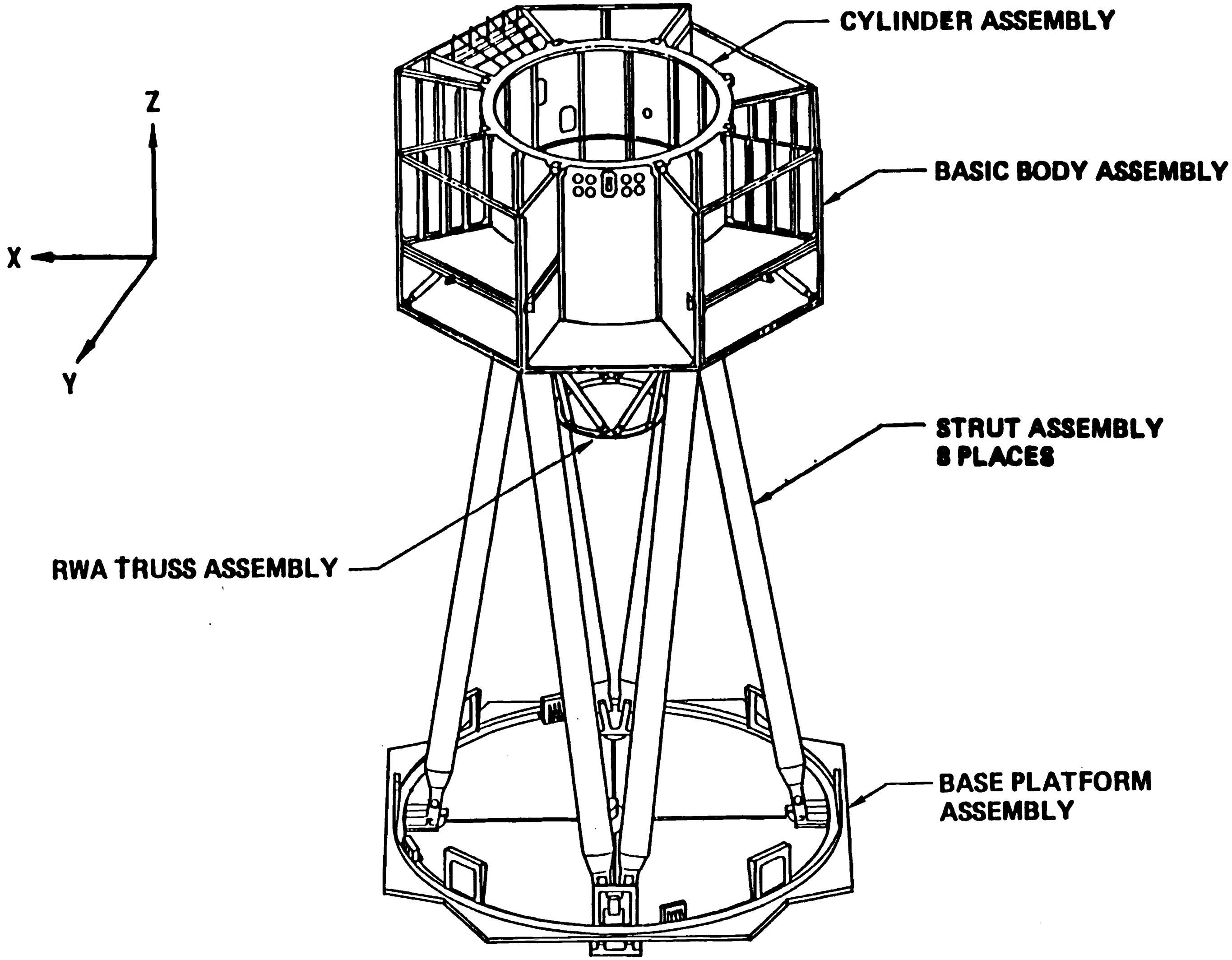
DSP Basic Structure Assembly



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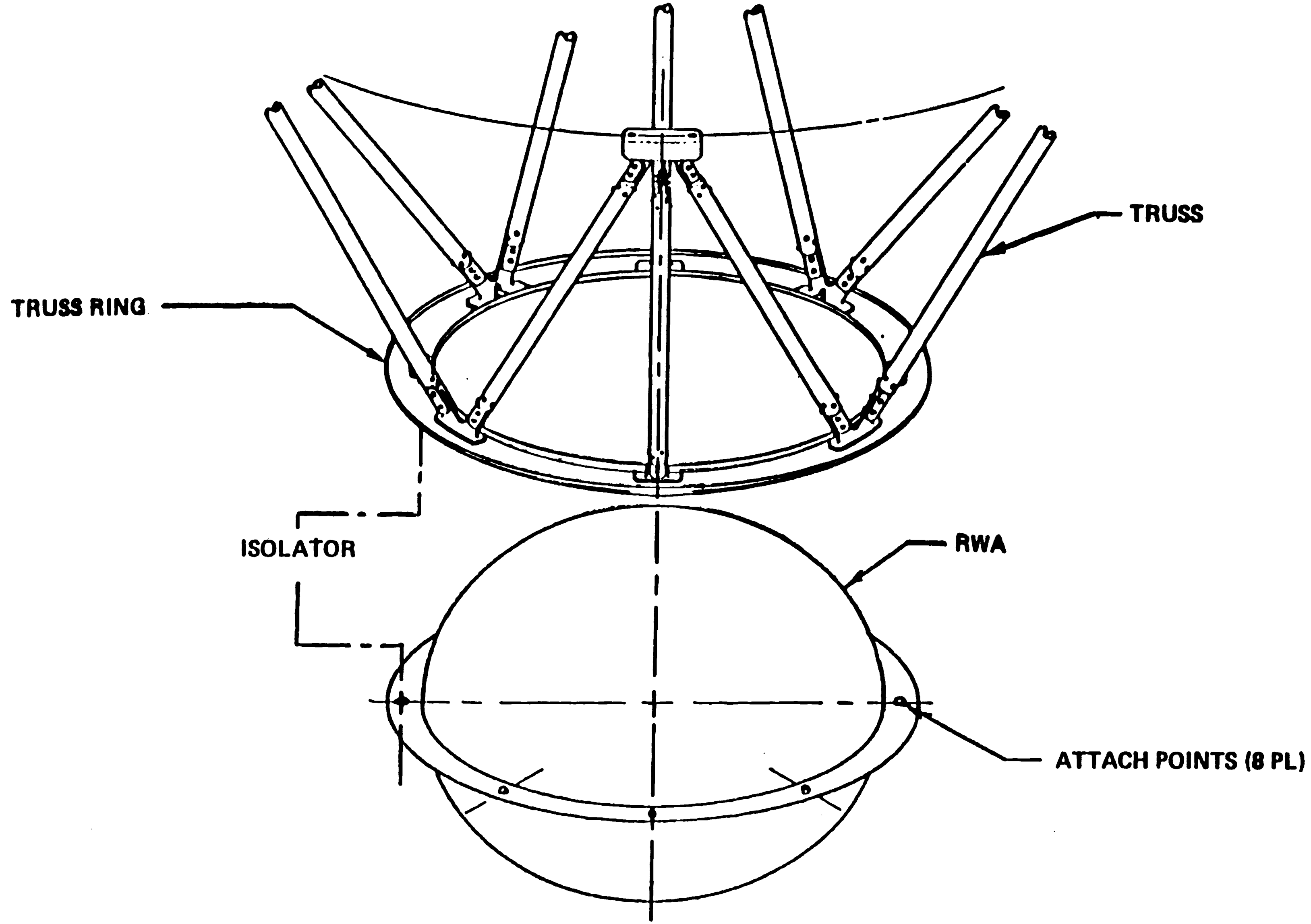
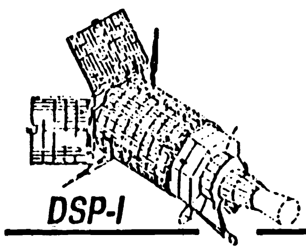
RWA and Truss Assembly





Baseline RWA Isolator Design

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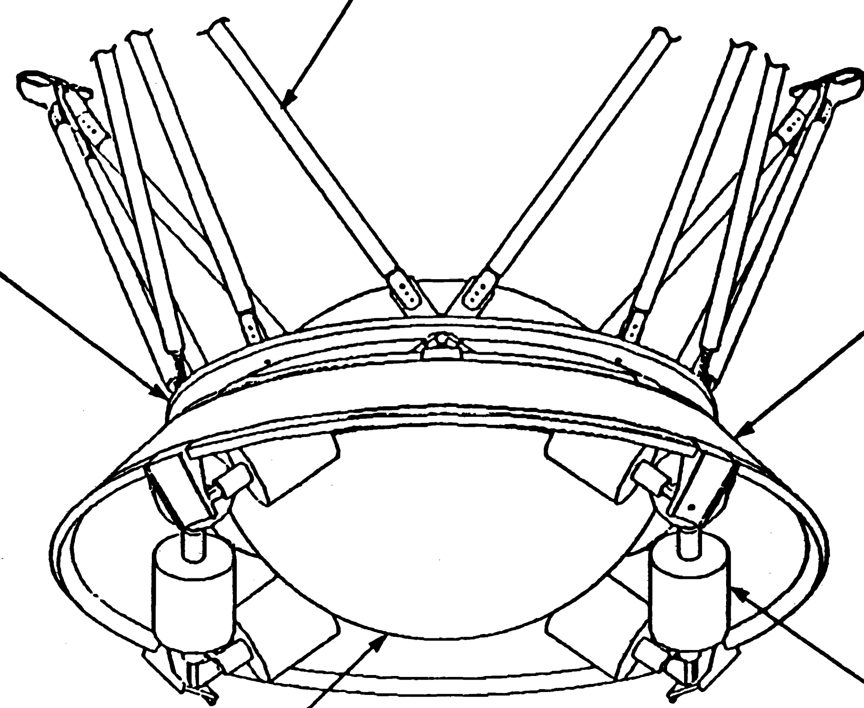

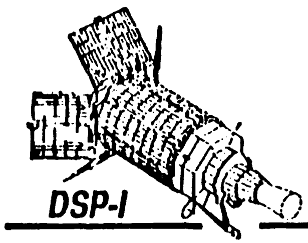

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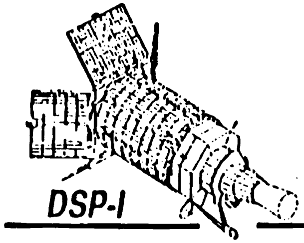
Isolator Unit Section View

- All parts are screwed together and lockwired
- Elastomer is injection molded to central cylinder and piston
- Cap has thin wall (0.043 in.) for "oil can" motion
- All parts are fabricated using standard machining practices
- 3 engineering demonstration units completed in one month



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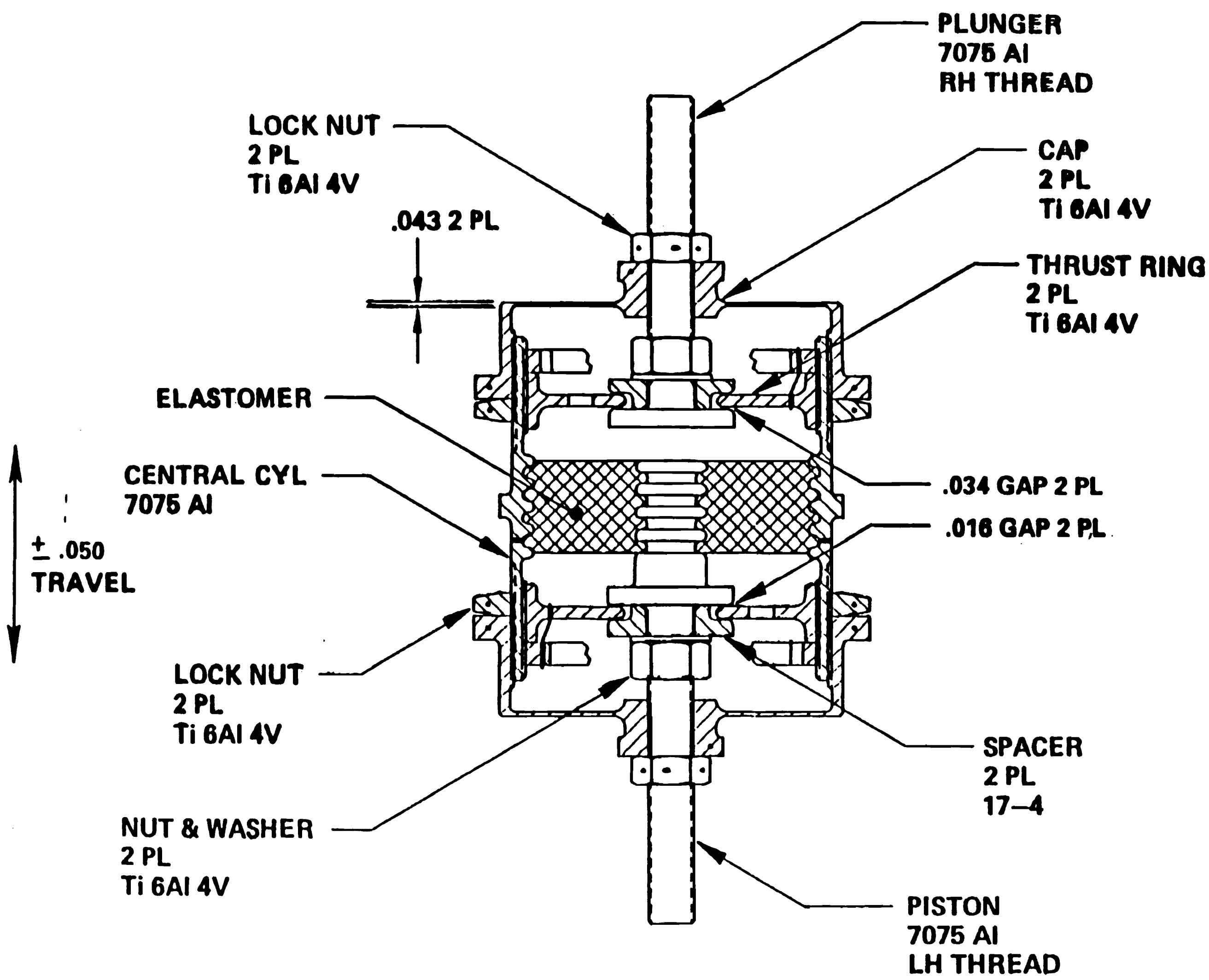
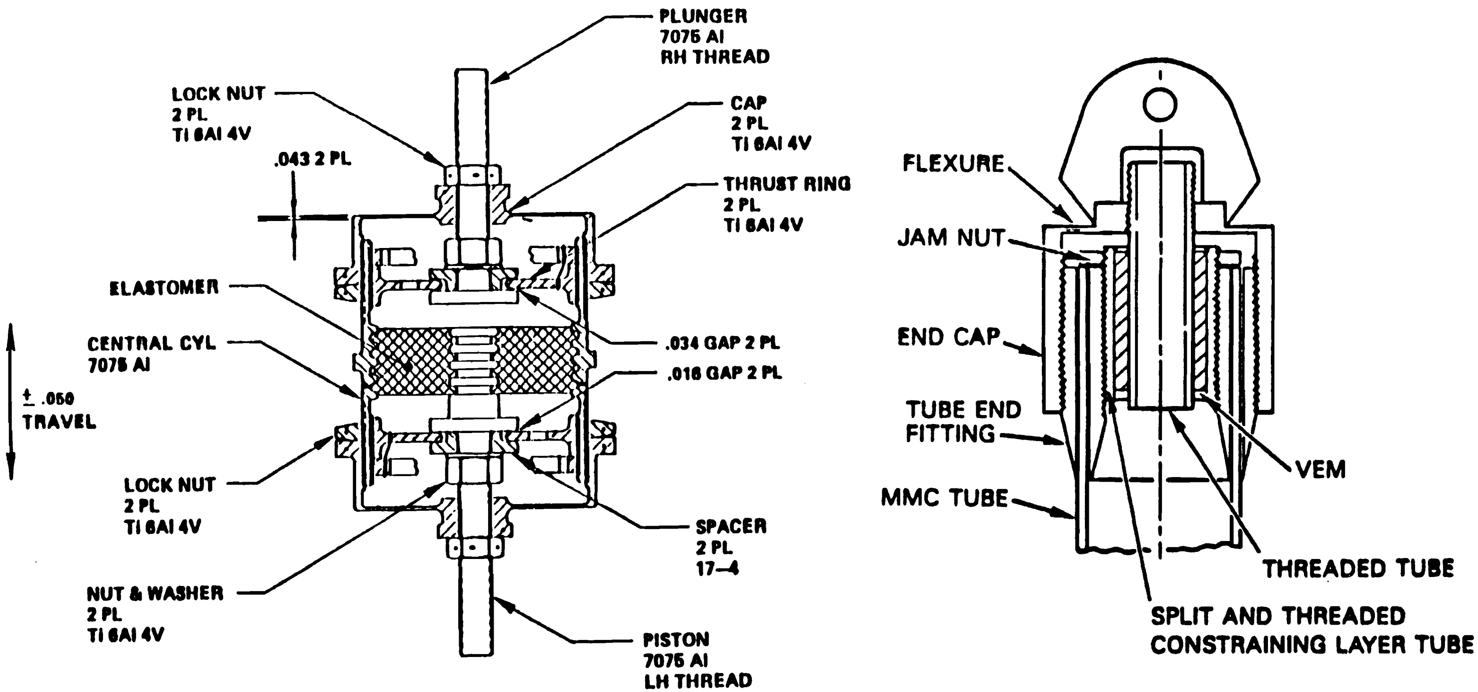
Isolator Unit Section View

TRW



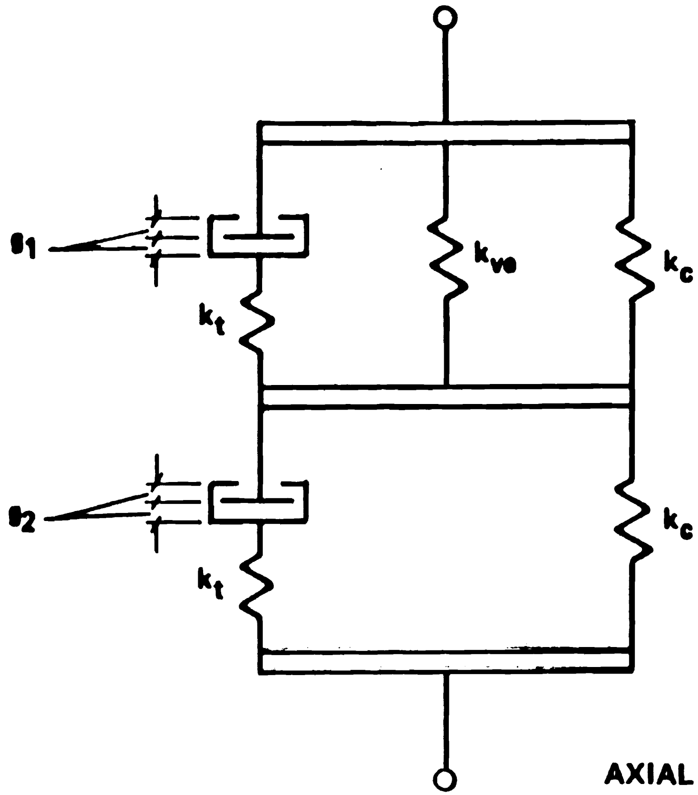


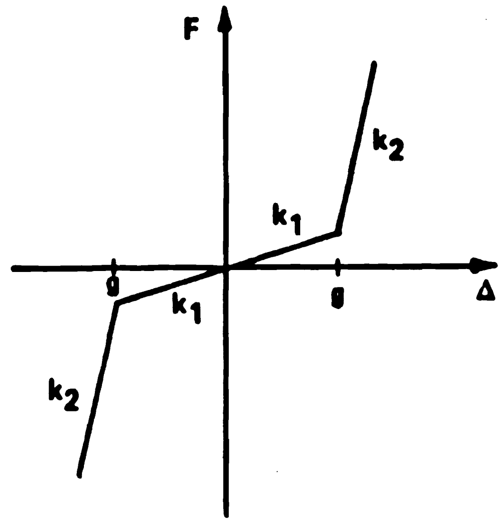
(A)

(B)

Figure 2: Comparison of A) DSP Proposed Isolator, and B) DAMMPS JOINT Concept

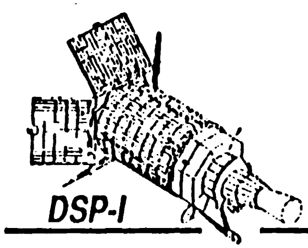
Isolator Mechanical Model
(Schematic)





AXIAL ISOLATOR STIFFNESS MODEL:

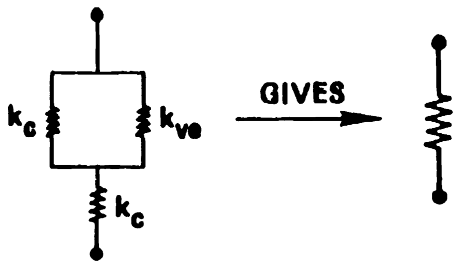
k_c = ISOLATOR CAP STIFFNESS
k_{ve} = VISCOELASTIC SPRING STIFFNESS
k_t = THRUST RING STIFFNESS
g_1, g_2 = GAPS



Temperature Insensitive Design

- Performance of isolator is only slightly effected by extreme changes in temperature. Operating temperature is fairly constant at about 80°F.

- Isolator axial model:



$$k_{eq} = \frac{k_c\,(k_c + k_{ve})}{2k_c + k_{ve}}$$

k_c = Isolator End - Cap Stiffness

k_{ve} = Viscoelastic Material Stiffness (Acts Both as a Spring and Damper)

k_{eq} = Equivalent Spring Stiffness

- **Robust Stiffness K_{eq}:**

If $k_{ve} \rightarrow 0,\ k_{eq} \rightarrow \frac{k_c}{2}$

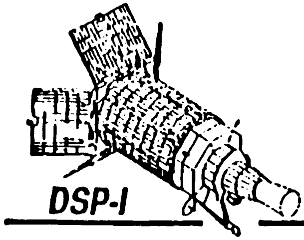
If $k_{ve} \rightarrow \infty,\ k_{eq} \rightarrow k_c$

$$\frac{k_c}{2} \leqslant k_{eq} \leqslant k_c$$

Extreme Bounds

- Variations due to manufacturing, radiation, and fatigue are also bounded by using this analytical method

FAC–18



Isolator Stiffness

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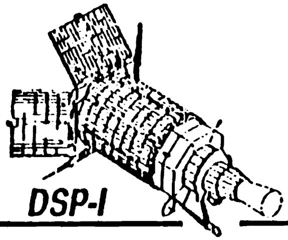
- Nominal 13 Hz Isolator
- Single isolator axial stiffness (total of 8 per module):

	Temp (°F)	K_c (lb/in)	K_{ve} (lb/in)	K_{eq} (lb/in)	Freq. (Hz)
Lower limit :	20	2000	135,000	1970	16
Operating :	80	2000	2000	1330	13.3
Upper limit :	185	2000	300	1070	11.8

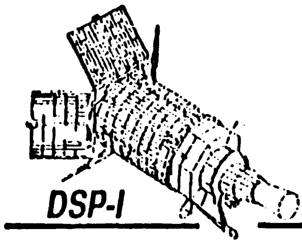


Low Outgassing Viscoelastic Material

- Specification : NASA JSC SP - R - 0022

	Requirement
— Total mass loss (%) *	≤ 1.0
— Collected volatile condensible material (%) (CVCM)	≤ 0.1

* Vendor data indicates TML of .46% for E.A. R. 's HD Isoloss and .067% for Isodamp C1002 (Tested per ASTM-E-595 modified)



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Compressive Creep

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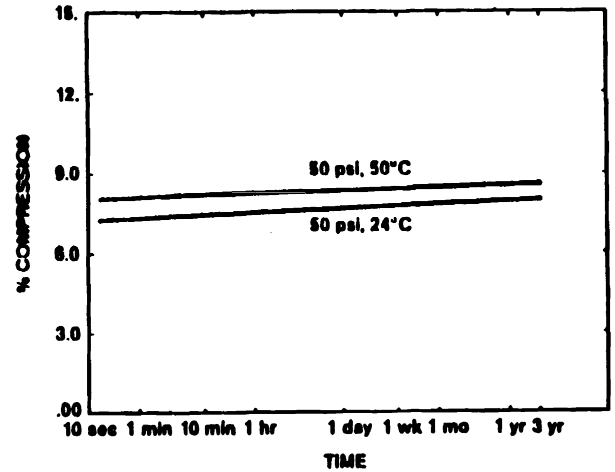
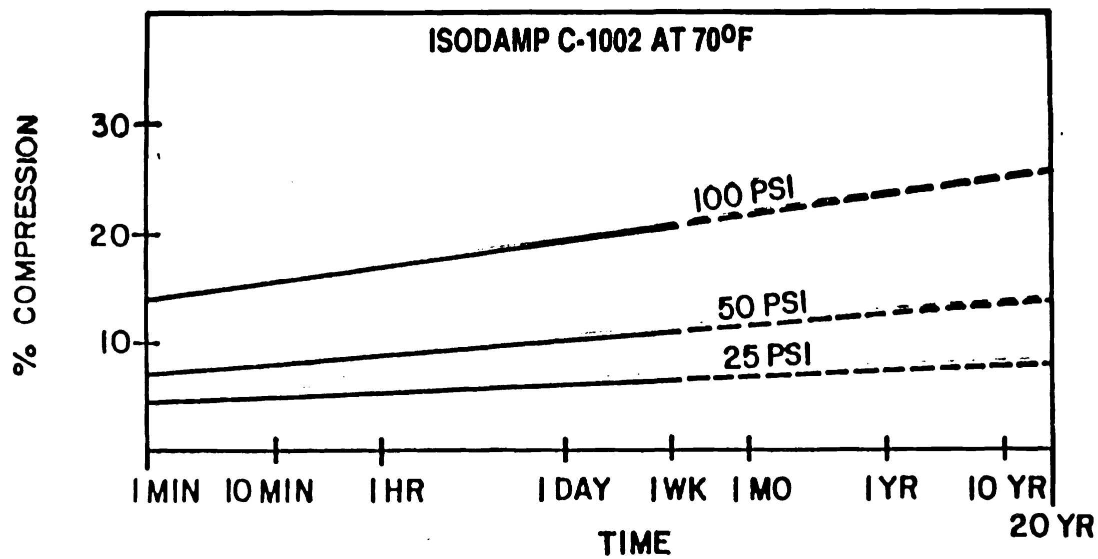
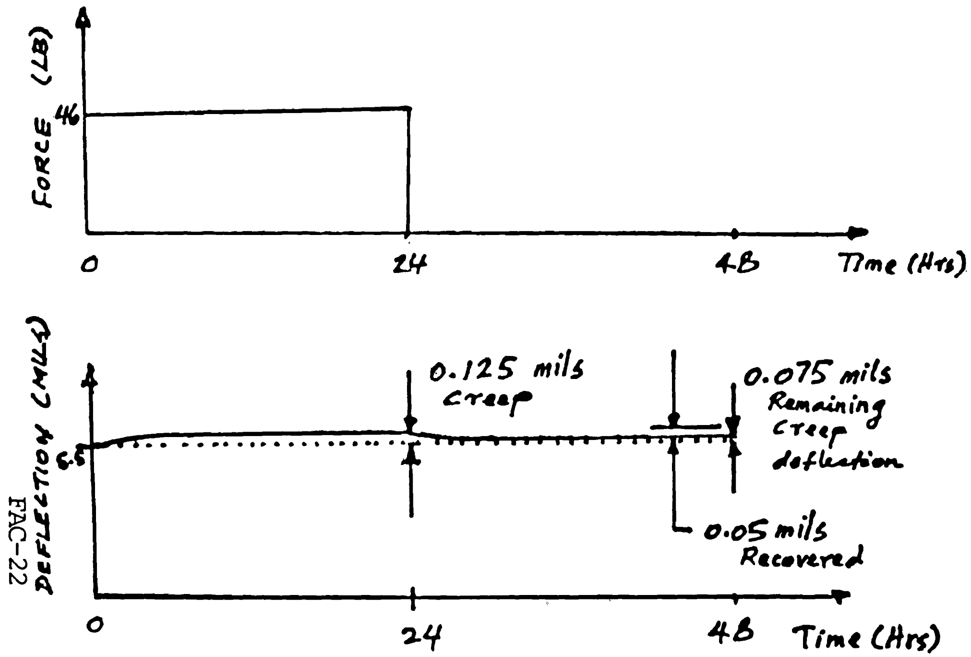
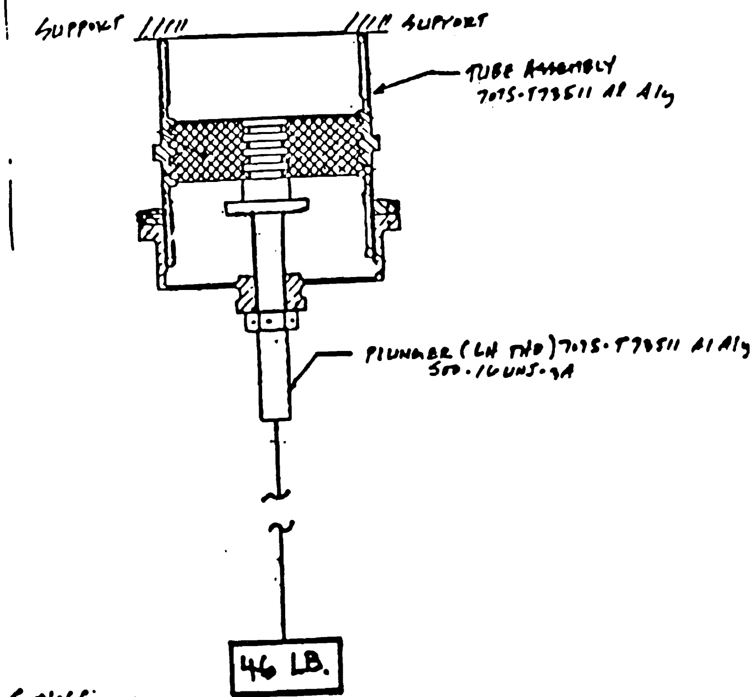
HD ISOLOSS





CREEP / RECOVERY TEST
(DSP ISOLATOR STUDY)





- Total Deflection (24 Hrs) = Elastic Defl. + Creep Defl. (Stiffness $\simeq$ 8360 lb/in)

  = 0.0055 in. + 0.000125 in.

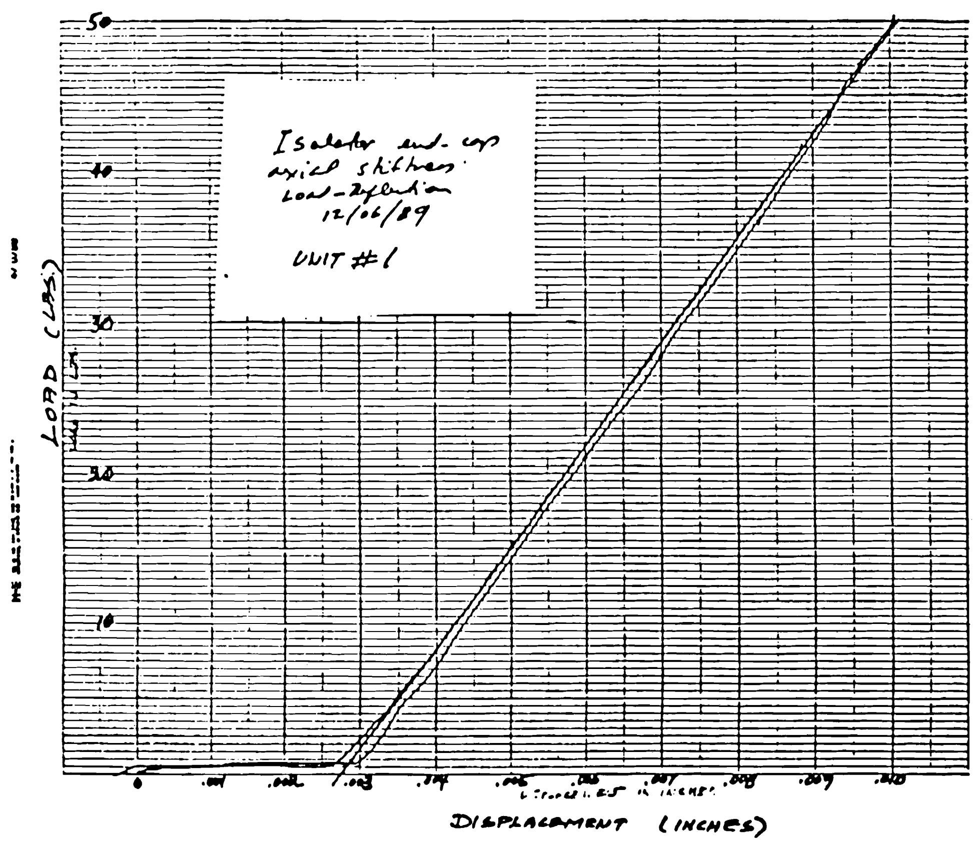
  δ_{Total} = 0.005625 in.

- Recovered Deflection (creep part after 24 Hrs) = 0.00005 in.

- 40% of creep deflection recovered after 24 Hrs.

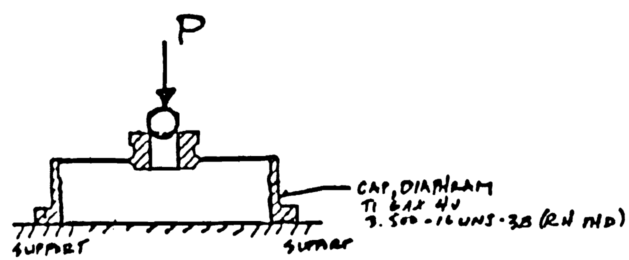
- COMPARISONS (ISOLOSS HD)
  - COMPRESSIVE CREEP (24 Hrs) : $(\delta_{creep} / \delta_{elastic})_c = 0.056$
  - SHEAR CREEP (24 Hrs) : $(\delta_{creep} / \delta_{elastic})_s = 0.0227$

CAP FLEXURE STIFFNESS TESTS
(DSP ISOLATOR STUDY)



$$k \simeq \frac{50-0.7}{.010-.00275} = \frac{49.3}{.00725} = 6800\ lb/in$$

$$k \simeq \frac{50}{.0101-.00275} = 6803\ lb/in\ \text{ok}$$



- UNIT NO. 1 STIFFNESS $\cong$ 6800 lb/in
- UNIT NO. 2 STIFFNESS $\simeq$ 6430 lb/in

} Difference within 5.4%

- FLEXURE THICKNESS MEASUREMENTS : 0.043", 0.044", 0.044"

(SPOT CHECKS)

SPECS : $0.043'' {}^{+0.001''}_{-0.000''}$