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MAST FLIGHT SYSTEM BEAM STRUCTURE AND BEAM STRUCTURAL PERFORMANCE

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MAST FLIGHT SYSTEM

The primary MAST Flight System structural component from an experimenter point of view is the beam assembly. The purpose of this paper is to provide an overall understanding of the beam assembly and data with which potential experimenters can begin to conduct analyses relevant to their experiments. The beam structure, along with the deployment and retraction subsystem, is being designed and built by the Astro Aerospace Corporation in California. A scale drawing of the MAST Flight System positioned in the Orbiter cargo bay is shown in figure 1.

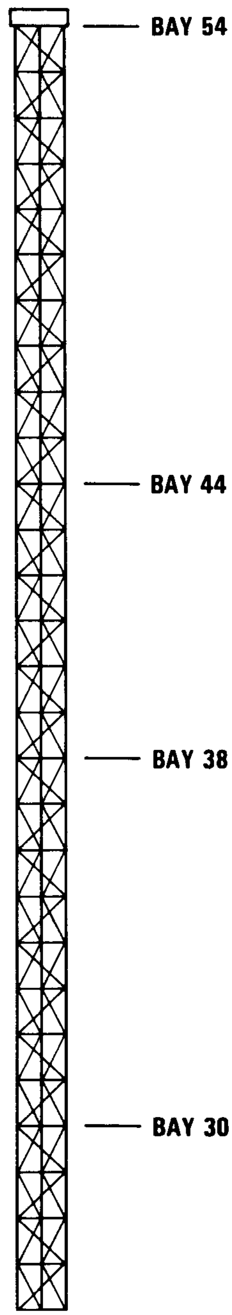


Figure 1.

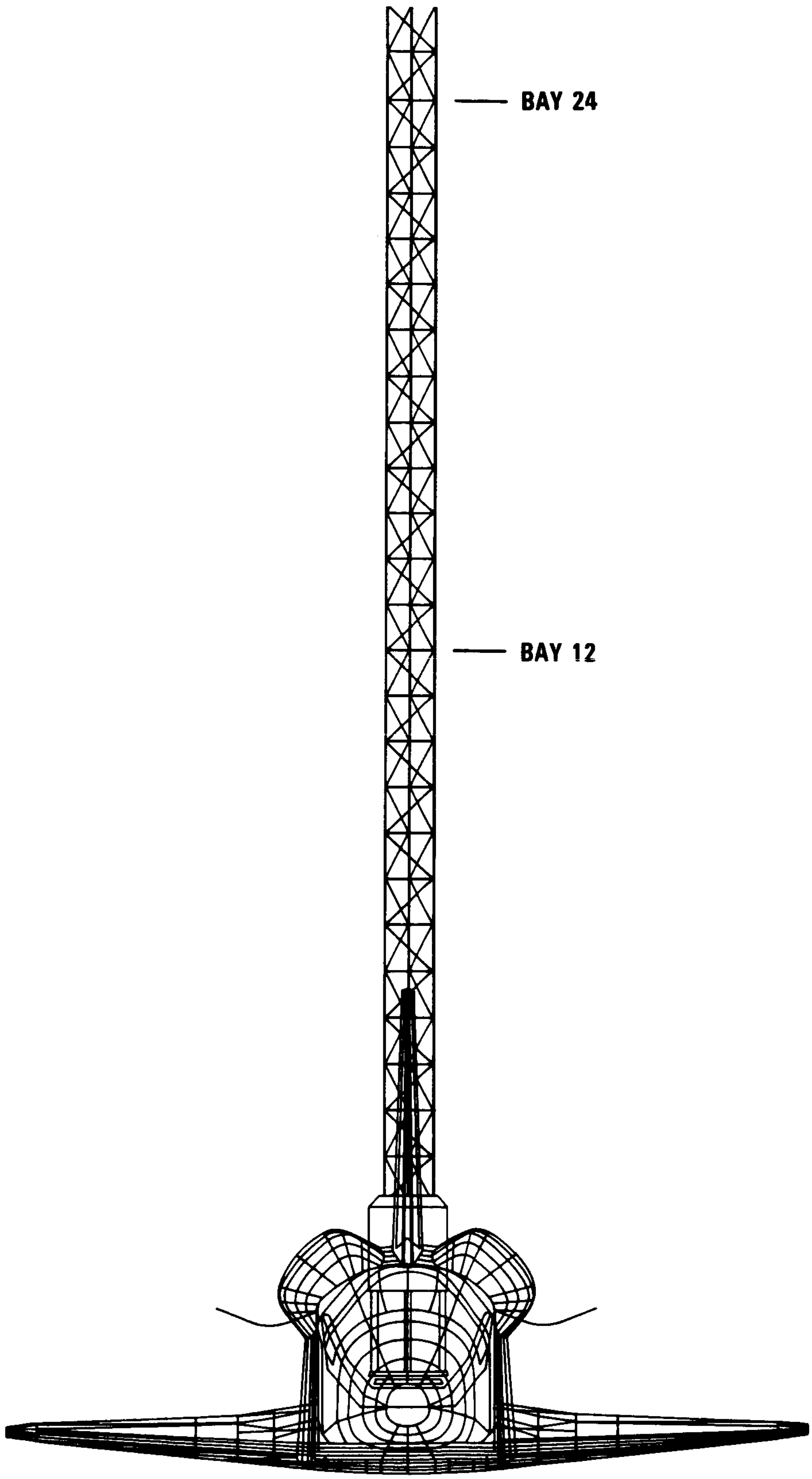


Figure 1. (Concluded)

BEAM STRUCTURAL CONCEPT

The beam structure is a statically determinate truss. Longitudinal members (longerons) provide bending stiffness and alternating diagonal members (diagonals) provide torsional and shear stiffness. Transverse members (battens) are positioned at regular intervals along the beam to assure longeron stability. The beam cross section is triangular with the longerons located at the vertices of an equilateral triangle. Each leg of the triangle is 1.212 meters long. The truss structure repeats itself in two-bay segments. There are 27 two-bay segments for a total of 54 bays. The battens at either end of a two-bay segment and all of the longerons are continuous members. All of the diagonals and the battens at the midbatten plane of each two-bay segment are hinged near the center to permit retraction. One of the three longerons has been sized slightly stiffer axially in order to provide different system modal characteristics in the x-z and y-z planes. A typical two-bay segment of the beam structure is shown in figure 2. Platforms are positioned along the length of the beam at batten planes 12, 24, 30, 38, 44, and 54 (beam tip). These platforms are used as mounting surfaces for the actuators, sensors, and associated electronics.

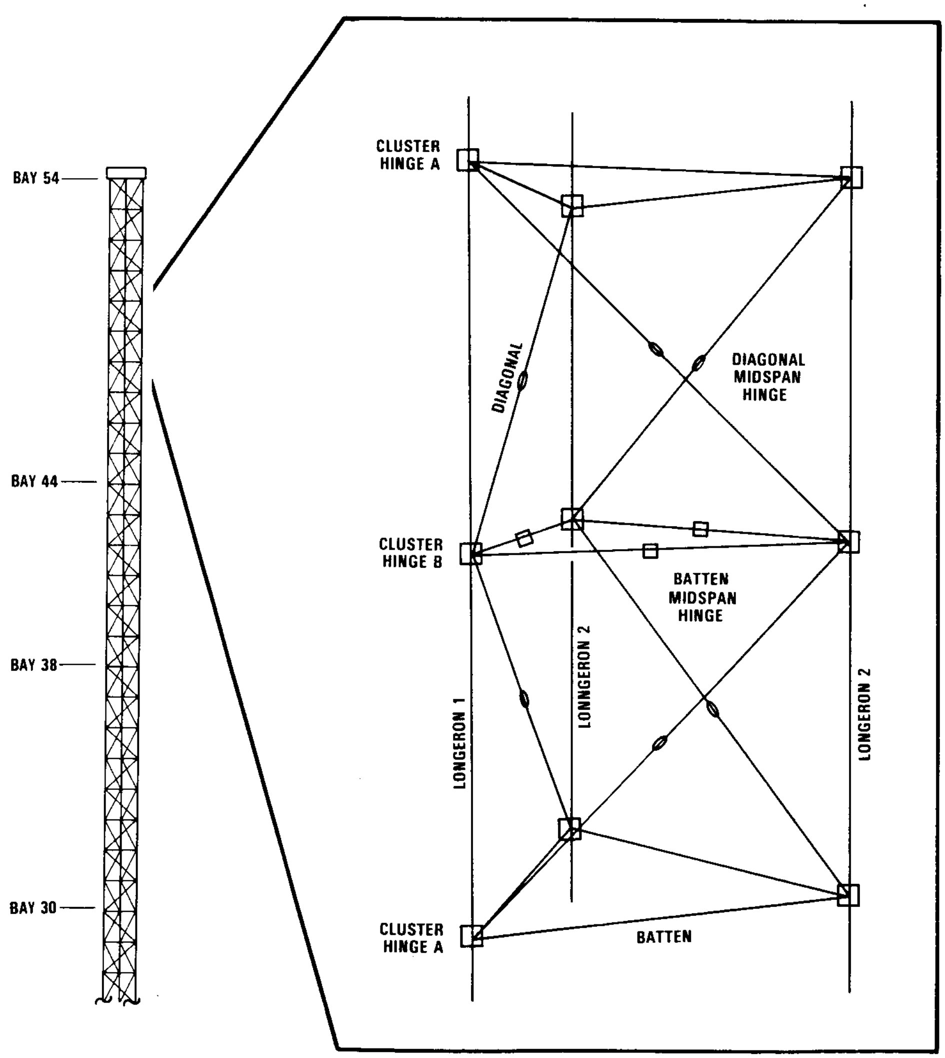


Figure 2.

TIP REMOTE STATION LAYOUT

The tip remote station is distributed on two platforms. The layout of equipment positioned on the upper platform is shown in figure 3. Four Type I Linear DC Motors (LDCM) are provided for actuators. Two of these are aligned with the x-axis and two with the y-axis. The lines of force for each actuator pair are 0.968 meter apart. Two linear accelerometers for measuring motion along the x- and y-axes and a rotational accelerometer for measuring motion about the z-axis (not shown in figure 3) are also located at the tip. Their precise positions are yet to be determined. The parameter modification device (not shown in figure 3) is to be located on the lower platform at the tip remote station.

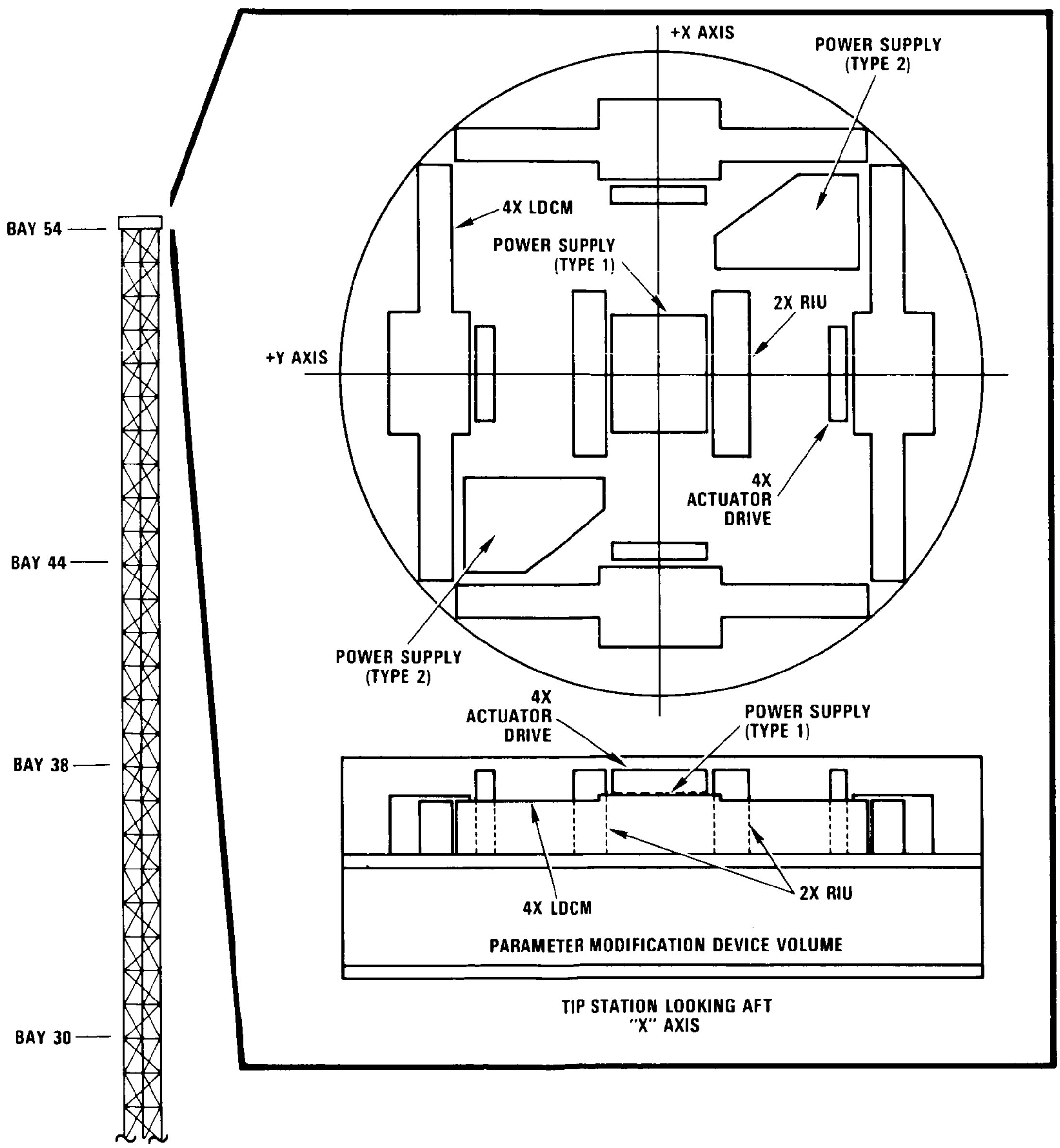


Figure 3.

INTERMEDIATE REMOTE STATION LAYOUT WITH ACTUATORS

The remote station layout for the equipment positioned at batten planes 12, 30, and 44 is shown in figure 4. Two Type II LDCMs are provided for actuators. One of these is aligned with the x-axis and the other aligned with the y-axis. The same accelerometer complement provided at the tip is also provided here (not shown in figure 4). Each linear accelerometer is mounted directly on top of its associated LDCM on the beam z-axis. The angular accelerometer is mounted on the x-axis 0.220 meter from the y-axis.

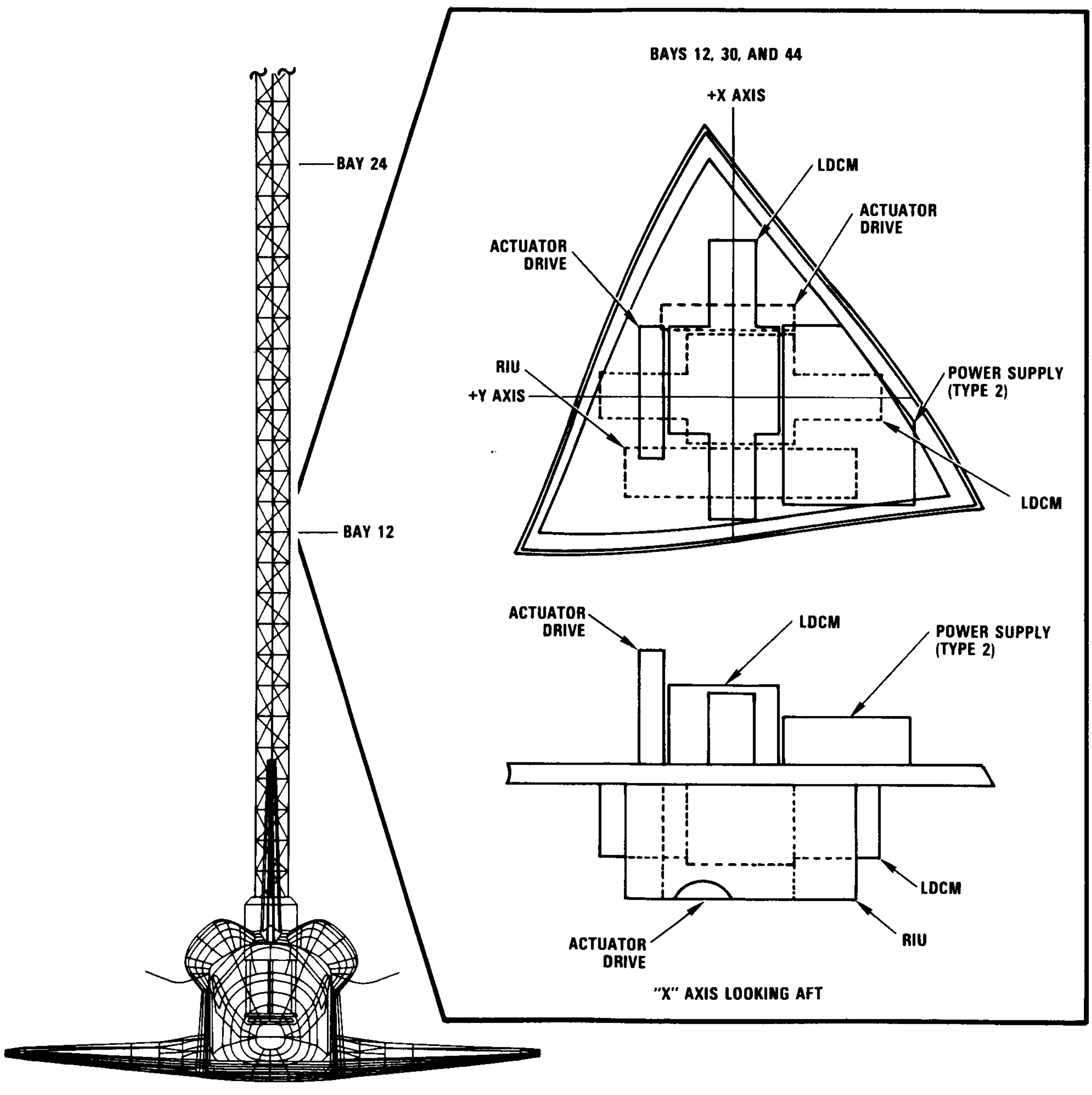


Figure 4.

INTERMEDIATE REMOTE STATION LAYOUT WITHOUT ACTUATORS

The remote station layout for the equipment positioned at batten planes 24 and 38 is shown in figure 5. No actuators are provided at these two stations; however, the same complement of accelerometers with the addition of linear acceleration along the z-axis is provided. The precise location of these accelerometers is yet to be determined.

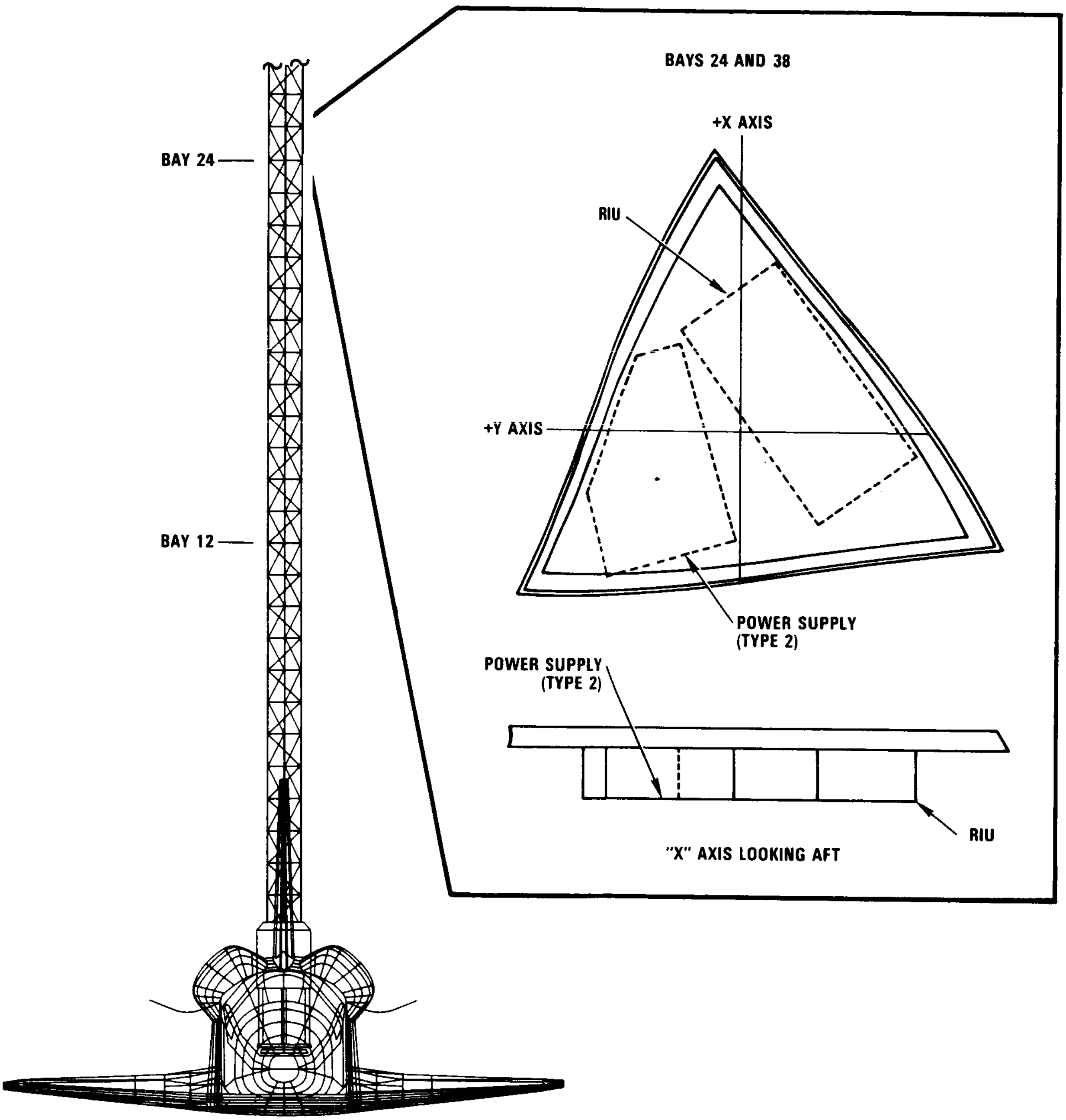


Figure 5.

BEAM ELEMENT MATERIALS

All of the beam structural elements are graphite/epoxy tubes with titanium end fittings. The lengths of the end fittings have been chosen to provide an element coefficient of thermal expansion as near zero as practical.

Longerons	Graphite/Epoxy	P-75/3501-6
Diagonals	Graphite/Epoxy	IM-6/3501-6
Battens	Graphite/Epoxy	HMS-4/3501-6
Hinges	Titanium	6AL-4V
Hinge Pins	Stainless Steel	Type 416

Lay-up details of the graphite/epoxy members are still being determined.

EQUIVALENT BEAM CHARACTERISTICS FOR SIMPLIFIED MODELING

Listed below are characteristics of an equivalent beam intended for simplified initial analyses.

Length	60.693 m
Bay Length	1.124 m
Mass/Length	4.641 kg/m
Moment of Inertia/Length	1.9 kg-m^2/m
EA	124.5×10^6 N
GA	2.11×10^6 N
EIx	28.63×10^6 N-m^2
EIy	32.39×10^6 N-m^2
GK	0.50×10^6 N-m^2

BEAM ELEMENT PROPERTIES

Detail beam element structural data for a finite element type analysis are listed below.

Element	Axial Stiffness	Effective* Axial Stiffness
Longeron 1	72.25×10^6 N	46.63×10^6 N
Longeron 2	55.35×10^6 N	38.95×10^6 N
Diagonal	4.20×10^6 N	3.86×10^6 N
Batten A	8.5×10^6 N	8.23×10^6 N
Batten B	5.1×10^6 N	4.89×10^6 N

* Member stiffness including end fitting and hinge compliance

Element	Pin-to-Pin Length	Mass
Longeron 1	1.090 m	0.372 kg/m
Longeron 2	1.090 m	0.285 kg/m
Diagonal	1.583 m	0.084 kg/m
Batten A	1.158 m	0.076 kg/m
Batten B	1.158 m	0.067 kg/m
Cluster Hinge A (including terminals and pins)		1.374 kg
Cluster Hinge B (including terminals and pins)		0.518 kg
Diagonal Midspan Hinge		0.2 kg
Batten Midspan Hinge		0.1 kg

REMOTE STATION MASS PROPERTIES

Detailed remote station mass properties for a finite element type analysis are listed below.

Bay	Mass*	Center of Gravity** x	y	z	I_z
12	50.1 kg	3 mm	-7 mm	50 mm	2.8 kg-m^2
24	14.4 kg	0 mm	9 mm	-4 mm	1.0 kg-m^2
30	50.1 kg	3 mm	-7 mm	50 mm	2.8 kg-m^2
38	14.4 kg	0 mm	9 mm	-4 mm	1.0 kg-m^2
44	50.1 kg	3 mm	-7 mm	50 mm	2.8 kg-m^2
54***	147.1 kg	0 mm	0 mm	250 mm	21.6 kg-m^2

* Includes the actuator reaction mass. This mass participates in the beam dynamics only when the actuators are locked, or when they are unlocked if motion is perpendicular to the force axis of the actuator. The reaction mass of a Type II actuator at Bay 12, 30, or 44 is 7 kg. The reaction mass of a Type I actuator at Bay 54 is 11.5 kg.

** With respect to the batten midplane and center of the longeron circle.

*** Exclusive of the parameter modification device. The PMD mass is 100 kg. The PMD inertia about the z-axis can be varied from 1.8 kg-m^2 to 33.8 kg-m^2.

MAST FLIGHT SYSTEM MODAL CHARACTERISTICS

Modal data for the first 10 MAST Flight System modes are listed in the following two tables. This data includes the effect of the orbiter and pallet. Mode shapes are shown in figure 6 for reference although the pallet and orbiter have been omitted for clarity.

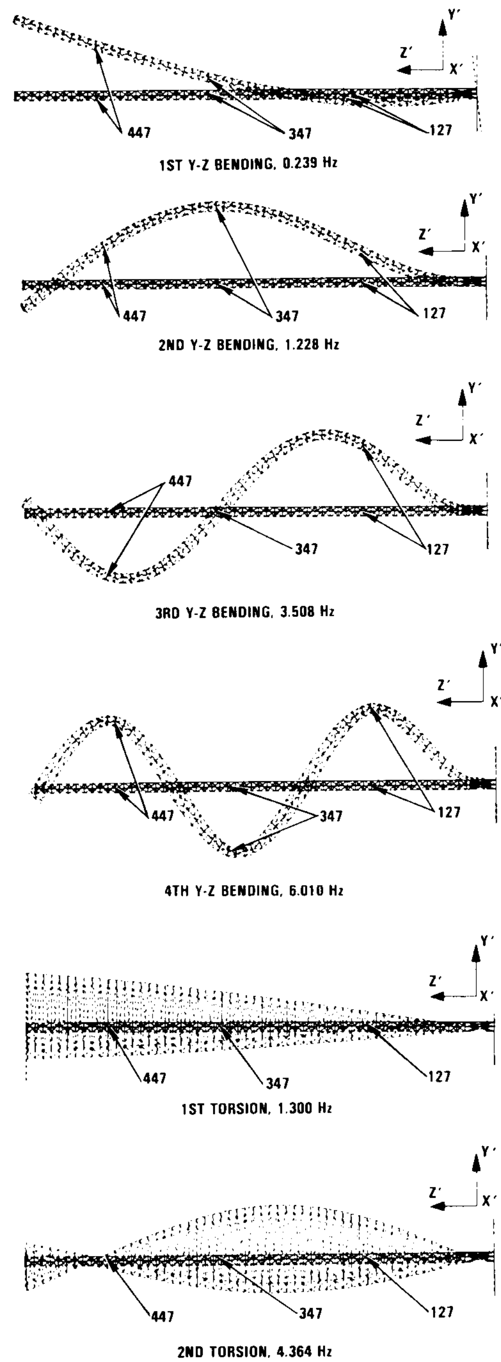


Figure 6.

MAST Flight System Modal Data (Includes Orbiter)
Beam Length 54 Bays, Maximum PMD Inertia, LDCMs Locked

BAY	COMP.	1 1st x-z	2 1st y-z	3 2nd y-z	4 2nd x-z	5 1st Torsion	6 3rd y-z	7 3rd x-z	8 2nd Torsion	9 4th y-z	10 4th x-z
12	X	.0344	.0001	.0044	.4196	.0083	.0059	.9047	.0014	-.0004	.9968
	Y	-.0007	-.1431	.3939	-.0027	-.0152	.8858	-.0052	-.0106	.9892	-.0006
	θz	.0002	.0000	.0197	-.0124	.2686	.0190	-.0070	.7243	.0155	-.0053
24	X	.2189	-.0008	.0086	.9158	.0191	.0032	.6197	.0024	-.0006	-.5821
	Y	-.0006	.0125	.8948	-.0063	-.0355	.6240	-.0044	-.0126	-.5645	-.0006
	θz	-.0003	.0000	.0375	-.0231	.5229	.0203	-.0064	1.0000	-.0091	.0043
30	X	.3486	-.0014	.0090	.9830	.0207	-.0006	-.0095	.0008	.0000	-.8769
	Y	-.0004	.1600	.9682	-.0075	-.0387	.0004	-.0006	-.0072	-.8642	.0000
	θz	-.0003	.0000	.0454	-.0280	.6401	.0153	-.0046	.9090	-.0170	.0074
38	X	.5481	-.0024	.0070	.7800	.0166	-.0045	-.7236	-.0019	.0003	.2165
	Y	-.0001	.4072	.7745	-.0061	-.0316	-.7157	.0043	.0023	.2060	.0003
	θz	-.0004	.0000	.0545	-.0338	.7810	.0617	-.0015	.5473	-.0120	.0058
44	X	.7111	-.0033	.0037	.4335	.0094	-.0044	-.7747	-.0025	.0002	.8883
	Y	.0002	.6133	.4337	-.0035	-.0187	-.7702	.0049	.0050	.8701	.0002
	θz	-.0004	.0000	.0604	-.0376	.8743	.0003	.0008	.1687	-.0045	.0025
54	X	.9997	-.0047	-.0038	-.3883	.0080	.0016	.2212	.0006	-.0003	-.1605
	Y	.0008	1.0000	-.3807	.0031	.0120	.2187	-.0015	-.0011	-.1572	.0002
	θz	-.0004	-.0001	.0680	-.0426	1.0000	-.0063	.0036	-.4967	.0004	-.0023
f*		0.1813	0.2387	1.2276	1.2773	1.3004	3.5079	3.6584	4.3637	6.0100	6.2370
$\bar{M}$**		470.46	802.76	260.71	264.12	130.76	223.43	227.79	82.97	266.61	273.68

* Natural Frequency, Hz
** Generalized Mass, kg or kg-m^2 as appropriate

MAST Flight System Modal Data (Includes Orbiter)
Beam Length 46 Bays, PMD Adjusted to Match 2nd x-z Bending, LDCMs Locked

BAY	COMP.	1 1st x-z	2 1st y-z	3 1st Torsion	4 2nd x-z	5 2nd y-z	6 3rd x-z	7 3rd y-z	8 2nd Torsion	9 4th x-z	10 4th y-z
12	X	-.0115	-.0009	-.0044	.1049	-.0083	.2996	-.1573	-.0009	.6784	-.1494
	Y	-.0005	-.0830	.0176	.0096	.0891	.1595	.2880	-.0026	.1565	.6308
	θz	-.0003	-.0020	.1075	.0038	-.0404	.0048	.0226	.3104	-.0044	.0622
24	X	.1347	-.0007	-.0284	.7427	-.0637	.9781	-.5174	.0029	.3816	-.0350
	Y	-.0022	.0212	.1294	.0735	.6851	.5284	.9539	-.0202	.0902	.3645
	θz	-.0004	-.0020	.4231	.0183	-.1621	.0167	.0505	.9547	.0009	.0482
30	X	.2663	.0000	-.0364	.9595	-.0827	.5305	-.2807	.0024	-.5588	.1236
	Y	-.0034	.1570	.1678	.0953	.8907	.2873	.5187	-.0160	-.1311	-.5255
	θz	-.0004	-.0020	.5693	.0250	-.2188	.0155	.0463	.9874	.0003	-.0222
33	X	.4836	.0015	-.0336	.8903	-.0770	-.5914	.3134	-.0015	-.2425	.0533
	Y	-.0053	.3955	.1558	.0887	.8302	-.3191	-.5766	.0041	-.0579	-.2306
	θz	-.0005	-.0020	.7434	.0330	-.2870	.0079	.0244	.6606	.0016	-.0785
44	X	.6678	.0028	-.0213	.5658	-.0491	-.9478	.5019	-.0031	.4562	-.1015
	Y	-.0063	.6106	.0985	.0565	.5294	-.5123	-.9251	.0123	.1066	.4301
	θz	-.0005	-.0020	.8561	.0381	-.3316	.0017	.0048	.2344	.0026	-.0640
54	X	.9986	.0053	.0132	-.3471	.0298	.2116	-.1119	.0006	-.0680	.0151
	Y	-.0095	.9986	-.0635	-.0344	-.3210	.1138	.2065	-.0024	-.0156	-.0640
	θz	-.0005	-.0020	1.0000	.0446	-.3891	-.0050	-.0210	-.5518	-.0016	.0257
f*		.2162	.2618	1.585	1.594	1.606	4.606	4.613	5.191	8.555	8.577
$\bar{M}$**		422.8	584.4	111.0	234.8	219.1	283.0	270.2	70.96	143.1	127.8

* Natural Frequency, Hz
** Generalized Mass, kg or kg-m^2 as appropriate

ALLOWABLE STRUCTURAL DEFLECTIONS

The allowable structural deflections for single mode excitation are shown in figures 7 and 8. The deflection shown is the maximum deflection of each mode. Also depicted are lines of constant signal-to-noise ratio for reference. Well over a 100-to-1 signal-to-noise ratio is available for each mode. A decrease in allowable beam second bending and first torsion structural capability has been shown when these modes are coupled to account for unexpected energy transfer between the coupled modes.

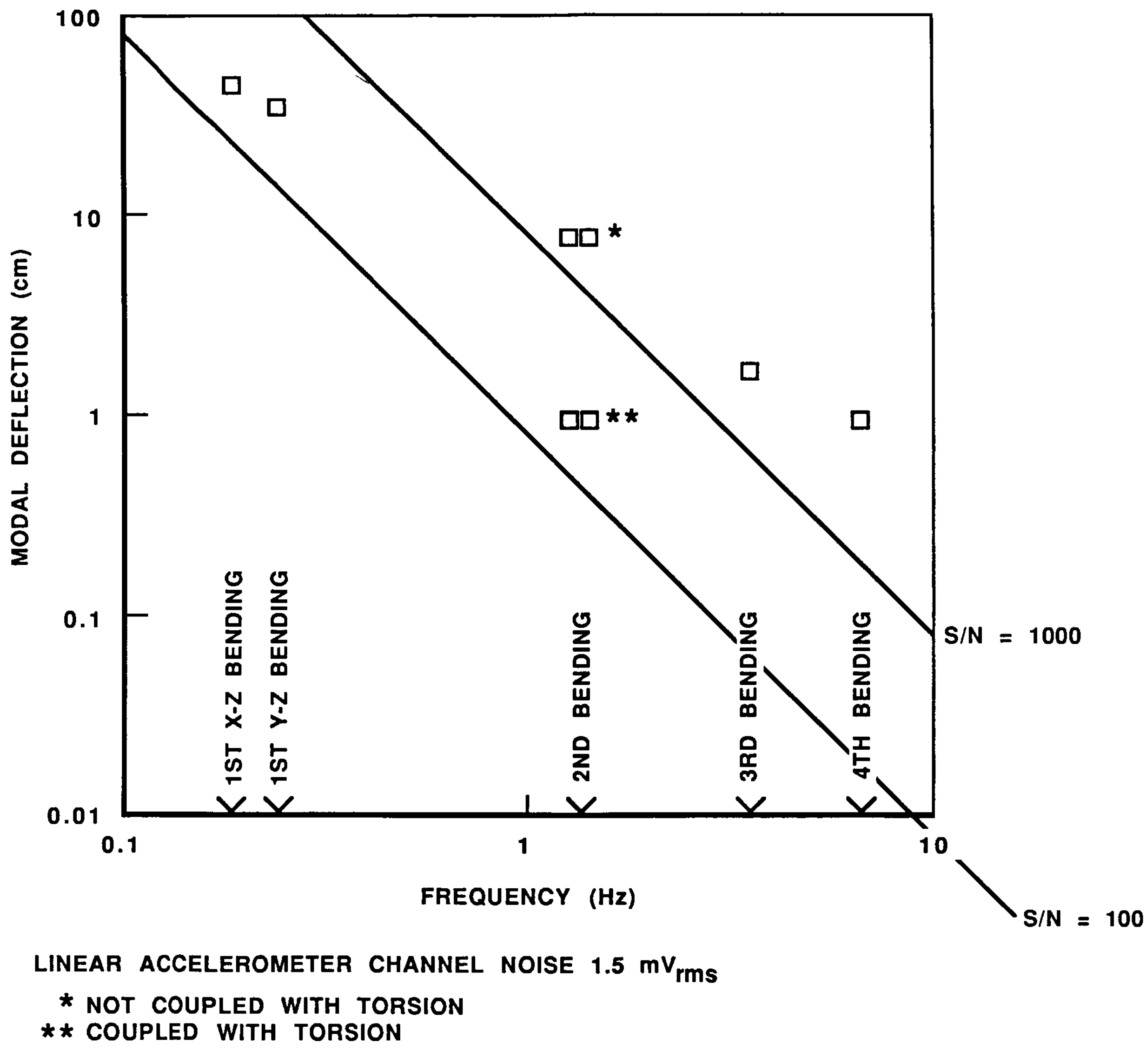
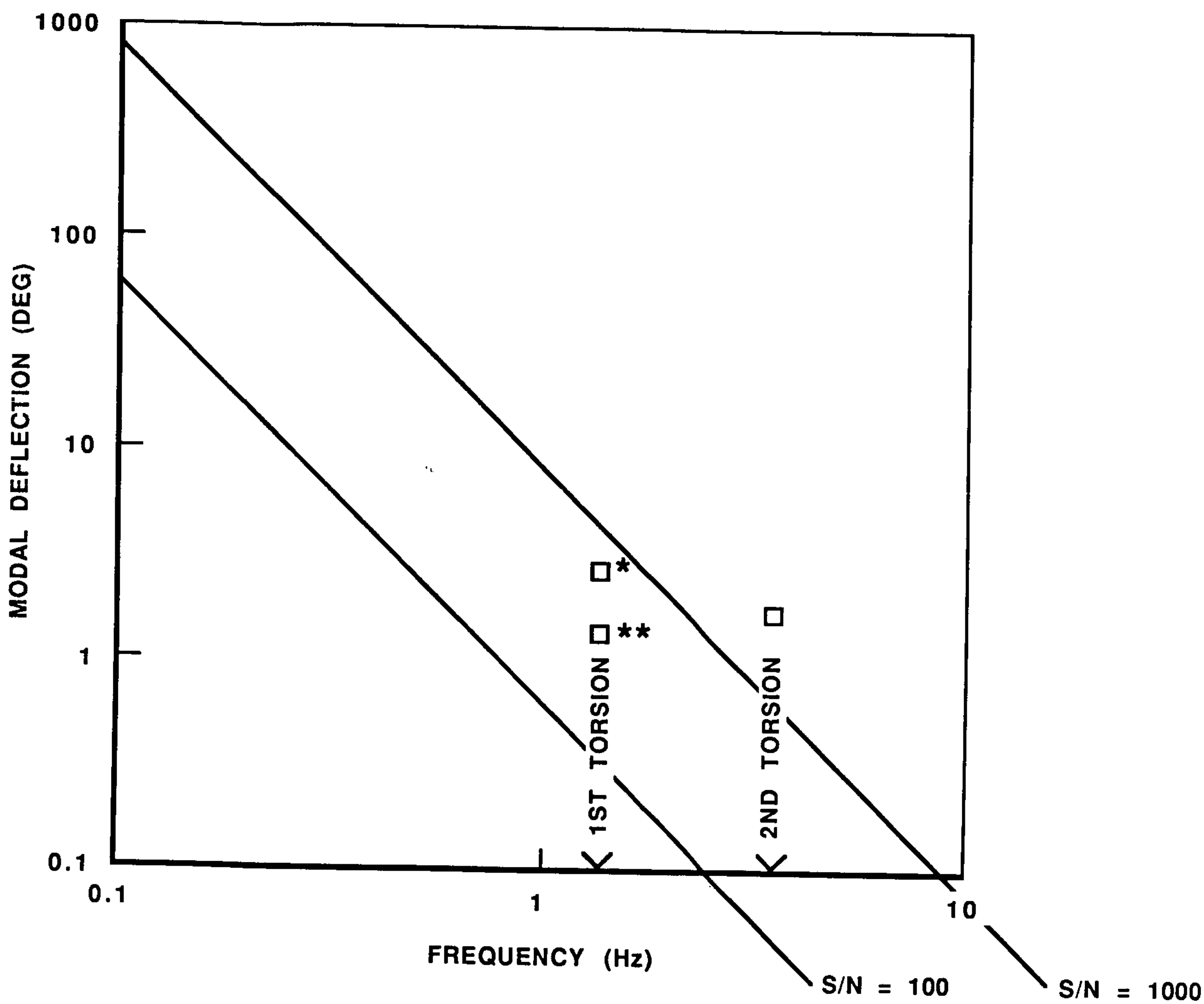


Figure 7.



ANGULAR ACCELEROMETER CHANNEL NOISE 2.0 mV_{rms}

* NOT COUPLED WITH 2ND BENDING
** COUPLED WITH 2ND BENDING

Figure 8.

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