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J. C. Chen
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F. D. Day III

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National Aeronautics and
Space Administration

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PREFACE

During the Voyager A launch and subsequent staging events, project management suspected that the spacecraft had had a rough ride. Soon after the spacecraft achieved its interplanetary trajectory, it became apparent that the science boom had failed to lock and certain abnormal behavior of the Voyager A was observed. It was speculated at the time that the spacecraft structural system might have been damaged. As required by the project, the flight-measured launch vehicle/spacecraft interface accelerations were to be assessed prior to the launch of the Voyager B. It was during this assessment that the shock spectra from the MECO II event were found to exceed the design envelope. An analysis to estimate the flight loads for all the important structural members was conducted. It was concluded that the structural system was not damaged, although the loads had exceeded the design values for certain members at the MECO II event. Fifteen days after the Voyager A launch, the second spacecraft, Voyager B, was successfully put into space to begin its mission.

The measurements from both flights were used to systematically determine the loads in detail. The estimated flight loads reconfirmed that a correct conclusion was reached immediately after the Voyager A launch. In the present report, the procedures of how that conclusion was arrived at will be described.

The work described in this report was performed by the Applied Mechanics Division of the Jet Propulsion Laboratory.

ACKNOWLEDGEMENT

The authors are indebted to their colleagues who developed the shock spectra/impedance method and subsequently applied the method to the Voyager loads analysis. They are R. Bamford, G. Brownlee, M. Salama and M. Trubert whose cooperation and suggestions during the course of this study have been very helpful. M. Blount programmed the transient solution procedure. Her diligent and timely effort is also acknowledged.

This study was supported by Dr. A. Amos, Materials and Structures Division, Office of Aeronautics and Space Technology, National Aeronautics and Space Administration.

ABSTRACT

Estimates of flight loads for Voyager 1 and Voyager 2 are summarized. These member loads are obtained by using the measured flight accelerations at the launch vehicle/spacecraft interface as forcing functions for the Voyager mathematical model.

The flight loads are compared to the Voyager design loads obtained from the shock spectra/impedance method and to the loads obtained using space vehicle transient loads analysis.

Finally, based on these data, an assessment of the shock spectra/impedance loads method used for Voyager is presented. Also the following conclusions have been reached: (1) the shock spectra approach provided reasonable conservative design loads for Voyager, (2) care has to be executed to insure that all critical events are accounted for in constructing shock spectra envelopes, (3) the selection of critical events is not always obvious, especially for those flight events wherein the spacecraft dynamic characteristics are important, and (4) the success of the method is strongly dependent on the analysts' experience and judgement.

CONTENTS

1. INTRODUCTION

In the late summer of 1977, two spacecrafts, Voyager A and B (later redesignated as Voyager 2 and Voyager 1, respectively) were successfully launched by the Titan-Centaur launch vehicle to begin their journeys to the planets Jupiter and Saturn. The slower Voyager 2, launched first, may be targeted on past Saturn to explore Uranus.

During the powered flight of the Voyager space vehicle, the accelerations at the interface between the spacecraft and the launch vehicle were recorded as a function of time. Applying these interface accelerations to the base of the spacecraft structural model, the member loads can be evaluated. The member loads obtained by this method represent best estimates of the actual loads experienced by the spacecraft during the powered flight. In the context of this report these loads will be referred to as flight loads. The comparison of the flight loads to the design loads is the subject of this report. Such a comparison allows the evaluation of the loads methodology used to design the Voyager spacecraft and should prove valuable for future projects.

The methodology for the establishment of spacecraft loads is strongly influenced by project constraints which include the cost, schedule and allowable weight. The most rigorous approach is the transient loads analysis which requires a composite mathematical model of the spacecraft and launch vehicle. The structural member loads for the entire composite structure are computed by applying the forcing functions, which represent various dynamic environments during the mission, to the composite model. Although this method, which was used to design the Viking Orbiter spacecraft (Refs. 1 and 2), ideally leads to a lightweight design, it is costly and time consuming due to complex interfaces involving many organizations. To reduce complexity and cost a shock spectra/impedance method (Ref. 3) was used to design the Voyager spacecraft structural system. This method utilizes envelopes of shock spectra of launch vehicle accelerations obtained from analysis and flight measurements and introduces the relative impedance of the spacecraft and launch vehicle. Since only limited information on the launch vehicle model is involved in this process the design loads iteration cycle can be rapidly performed within the payload organization as the design evolves. Certain critical assumptions have to be made in this process which is based on previous experiences and judgements in order to simplify the analyses. These assumptions will be examined based on the results of the comparison between the design loads and flight-measured loads.

Analytical evaluations of the shock spectra method regarding the cost savings, the accuracy and degrees of conservatism have been previously reported for one spacecraft, Viking (Ref. 4). The present effort is a comparison of design and flight loads for the first spacecraft structural system specifically designed by this shock spectra/impedance technique. Therefore, the evaluation of the methodology and associated assumptions are important for the subsequent payloads which may be designed by this method.

2. DESCRIPTIONS OF THE DESIGN LOADS ANALYSIS

The Voyager spacecraft weighs approximately 4600 lbs of which about 12% is considered structural weight. The major structural system consists of the high gain antenna truss, the latch truss for the radioisotope thermoelectric generators (RTG), the solid rocket motor ring, the science boom, the scan platform latch truss, the hydrazine tank support truss and the mission module truss. Figure 1 is a picture of the Voyager spacecraft in the launch configuration identifying the major structural systems. Although over 600 structural elements are included in the mathematical model, only the loads of the selected truss members will be used in the present report.

The objectives of the shock spectra method used in the design of the Voyager spacecraft are low-cost analyses within design schedule constraints with high reliability at only a moderate expense of structural weight as compared to a transient analysis design. This approach was chosen after a thorough review of available alternatives for determining spacecraft structural loads during the planning phase of the Voyager project. Since the conventional shock spectra method was considered to be too conservative, a method was developed wherein the shock spectra approach is modified to account for the relative impedance of the spacecraft and launch vehicle, and potential changes in the frequencies of the Voyager spacecraft. A detailed mathematical development has been reported previously (Ref. 3).

Next the dynamic environments which produce the loads were defined. Prior to the Voyager project, a total of four Titan IIIE/Centaur vehicles have flown. The payloads and launch times were as follows: 1) Viking Dynamic Simulator, February 1974, 2) Helios A, December 1974, 3) Viking A, August 1975, 4) Viking B, September 1975. These flights, together with analytical loads data, formed a basis from which the dynamic environments for the Voyager spacecraft were defined. Figure 2 shows a typical launch profile of launch vehicle/payload interface acceleration of the Titan/Centaur vehicle. Although the profile shown in Figure 2 was obtained from the Voyager flight data, similar ones have been measured from the four previous flights. Seven events are marked as the critical dynamic events. They are chronologically: 1) Launch (also referred to as Lift-off and Stage 0 Ignition), 2) Max α_q (Maximum Aerodynamic Pressure). 3) STG I IG (Stage I Ignition), 4) STG I BO (Stage I Burnout), 5) STG II BO (Stage II Burnout), 6) MECO I (First Centaur Main Engine Cutoff), and 7) MECO II (second Centaur Main Engine Cutoff). Clearly, as far as steady state acceleration is concerned, it seems that the STG I BO is the most critical event when the space vehicle undergoes approximately a 4g deceleration in a very short period. Data obtained from earlier Titan launch vehicle systems indicated that launch and STG I BO events produced the highest payload loads. The above mentioned four Titan/Centaur flights confirmed that these two events were indeed critical. Other events such as Max α_q and STG I IG also produced substantial but somewhat lower loads. Based on these observations, it was determined that only the launch and STG I BO events were to be considered for the Voyager design loads analysis by the shock spectra method. An envelope of the ensemble of shock spectra from all the available data including the flight-measured and analytical results from Viking Dynamic Simulator, Helios and Viking Space Vehicle was established and used in the Voyager loads analyses. The loads obtained from this process will be defined as the design loads in the present report.

For the purpose of estimating the conservatism of the shock spectra approach and verifying the final design loads, a number of transient analyses were performed on the launch vehicle/payload composite model. The first transient analysis included a preliminary model for the Voyager spacecraft and the loads were calculated for the launch, Max α_q, STG I BO and MECO II events. Subsequently, the analysis for the launch event was updated. Two significant conclusions were drawn after comparing the loads: 1) the shock spectra approach produced higher loads than that of the transient analysis, and 2) it confirmed that the launch and STG I BO were the critical events for design loads analyses. After the design was finalized, a transient analysis was performed on the final model of the Voyager spacecraft for the launch, STG I BO and Max α_q events. The detailed descriptions of the last transient analysis can be found in a series of "letter reports to NASA" (Refs. 5, 6, and 7) from Martin Marietta Aerospace where the analysis was performed. Briefly, the loads for the launch event were calculated from six separate forcing functions, each representing a different condition such as the axial thrust, lateral overpressure (2), differential thrust from the two solid rocket motors, ground wind force and vehicle/stand misalignment forces. For the Max α_q event, in addition to the axial thrust forcing function, six forcing functions representing the aerodynamic forces at Mach 1.0 due to pitch and yaw angle of attack, buffet loading, gust loading and three dispersion loads in pitch, yaw and axial directions were used to calculate the loads. For the STG I BO event, 17 forcing functions obtained from actual flight measurements of previous Titan flights were used. For each forcing function, a time history solution of the loads was calculated from which the maximum and minimum values were identified as the loads for this particular forcing function. These maximum and minimum values were then combined statistically within each event to obtain the loads for the given event. In the present report, these loads will be defined as transient analysis predicted loads.

Table 1 lists the shock spectra design loads and the transient analysis predicted loads obtained from the final Voyager model.

3. DESCRIPTIONS OF FLIGHT MEASUREMENTS

The objective of the flight instrumentation was to provide the flight-measured launch vehicle/payload interface accelerations from which the shock spectra would be generated and compared with the shock spectra envelope used in the design. A complete assessment of the Voyager A shock spectra was required before the Voyager B was committed to launch. In the present report these interface acceleration time histories from both flights will be applied analytically to the Voyager structural model at its base. The resulting loads are equivalent to those obtained from the launch vehicle/payload composite model under the corresponding dynamic environments (Refs. 8 and 9). From here on, these resulting loads will be referred to as flight loads.

The main flight instrumentation consisted of six piezoelectric accelerometers placed at three locations on the periphery of the interface between the Centaur and the Voyager. The three locations were 120^{0} from one another and each location had two accelerometers, one in the longitudinal direction and the other in circumferential direction. The six accelerometers completely determined the translational and rotational motion of the interface which was assumed to be rigid, i.e., no elastic deformation within the interface plane. Since structural loads were associated with low frequency dynamics, the cutoff frequency of the six accelerometers was 55 Hz. A seventh accelerometer was mounted on the spacecraft bus to measure longitudinal acceleration environments. It had a higher frequency range, up to 220 Hz. The measurements obtained from the seventh accelerometer are not included in the present report.

In addition to the accelerometers on the spacecraft, an accelerometer was mounted on the Centaur rocket in the longitudinal direction to measure the D.C. signal, i.e., the steady state acceleration. Figure 2 has been constructed using the results of these measurements.

The data transmission from the launch vehicle was pulse code modulated digital data, which was translated into FM analog signals and recorded on tapes for transmittal to JPL. Selected time slices which represent the critical events were digitized. The digitized raw data for each event were then converted into standard time history files which were scaled to provide the appropriate level of acceleration "G". Finally, the data from the six accelerometers at the interface were combined by the transformation matrix to provide the acceleration time histories along the x, y, and z directions, and rotation accelerations about the axes, assuming that the Voyager/Centaur interface remained a plane in the frequency range of interest. These interface accelerations were then applied to the base of the spacecraft for the computation of member loads. The detailed description of the Voyager flight measurements and the data reduction can be found in Refs. 10 and 11. Figure 3 shows a typical time slice of longitudinal interface acceleration for the critical events. Figure 4 shows the member loads calculated from the analytical model due to the interface accelerations shown in Figure 3 for the structure member 71937 of the high gain antenna truss. It should be noted that within each time slice the maximum and minimum amplitude is defined as the flight load for that event. During the calculation of member loads, modal damping, $^{c}/C_{c}$ = 0.01, was assumed for all the spacecraft modes. These same values were used in the transient loads analysis for the design for all the launch vehicle/payload composite modes.

Table 2 and Table 3 list the flight loads for selected structure members for the seven critical events of Voyagers A and B, respectively In the following, these flight loads will be compared with the corresponding shock spectra design loads and the transient analysis predicted loads.

4. COMPARISONS OF DESIGN AND FLIGHT LOADS

The objective of the comparisons between the design and flight loads is to evaluate the design methodology, namely, the shock spectra approach. Specifically two conditions, (1) that the shock spectra approach provides conservative but reasonable loads and (2) that the launch and STG I BO are the critical events for the design loads, must be verified.

Since the interface accelerations play a very prominent role in the shock spectra approach, the flight measurements will be compared with those obtained analytically from the transient analysis. Figure 5 shows this comparison for the launch event. The analytical interface acceleration was obtained by applying the forcing function representing the lateral overpressure condition to the launch vehicle/payload composite model. The amplitude of the analytical interface acceleration is somewhat higher than those of flight-measured values. However due to the different frequency contents, it is not certain that the analytical values will produce higher loads. Similarly, Figure 6 shows the interface acceleration comparisons for the STG I BO event. Here not only the amplitudes of the analytical and flight data are similar but also the frequency contents are characteristically very close. It should be noted that some of the forcing functions used in the transient analysis are synthesized based on the experiences from the previous flights, and certain conservatism has been built into these forcing functions. Yet the resulting analytical interface acceleration is not much greater than those of the flight measurements.

Next, the flight loads will be compared with the corresponding design loads. Since only the launch and STG I BO events were considered in the loads analysis, the comparison will be made by first listing the shock spectra design loads for the two events, then listing the ratio of flight loads to the corresponding design loads as shown in Table 4. Most of the design loads are more than twice the flight loads (the flight to design loads ratio less than

0.5). This confirms the design postulations that the shock spectra approach will provide conservative loads and in view of the uncertainties, the conservatism is reasonable. However it must be emphasized that the comparisons are made for the launch and STG I BO events only. Similar comparisons are made for the transient analysis predicted loads as shown in Table 5. In this comparison, the ratios of flight to predicted loads are much larger than the ones in the previous comparison. In fact, some members have the ratio greater than 1.0 which means that the flight loads are greater than the corresponding transient analysis predicted loads. One may observe that the transient loads analysis indeed does provide more accurate loads prediction than that of the shock spectra approach, of course at a higher cost. It should be noted here that the transient loads analysis for Voyager was performed not for the purpose of obtaining the design loads but rather for the verification of the shock spectra loads. Had the transient loads analysis been used for design purposes, a loads analysis factor would have been used to multiply the resulting loads to provide more conservative design loads.

Finally the maximum value among the flight loads from seven critical events will be examined. This maximum value represents the estimated maximum flight load of the given member during the entire powered flight. Their comparisons to the maximum design loads will indicate the validity of the postulation that the launch and STG I BO are the critical events. From Tables 2 and 3, the maximum flight loads for Voyager A and B, respectively, can be determined. Immediately, an observation can be made that most of the maximum flight loads came from the MECO II event instead of either the launch or the STG I BO event. After the Voyager A launch, the shock spectra obtained from the flight measurements were examined. It was found that the MECO II shock spectra was the only one which exceeded the design envelope. A quick but not too cursory calculation was performed to assess the loads prior to the Voyager B launch. Figure 7 shows the flight loads of two typical structure members for the various events. Clearly, the MECO II event is the most critical event. But the interesting fact is that either the launch cr the STG I BO event would have become the critical event had the MECO II event not been considered. The question of why the importance of the MECO II event was not discovered when the MECO II transient analysis was performed may well be raised. One reason is that a preliminary Voyager model was used in the MECO II transient loads analysis. At the MECO II event, the characteristics of the payload were of primary importance, since the launch vehicle consisted of only the Centaur rocket with depleted propellant. The weight of the launch vehicle, 4800 lbs, was approximately equal to that of the payload, 4570 lbs. Clearly, the responses of the composite model would be highly sensitive to the payload characteristics. Therefore, it is entirely possible that due to the fact that the early Voyager model was not representative of the flight hardware the loads obtained from the MECO II transient analysis were misleading as to the importance of the event. On the other hand, the same preliminary model would not introduce serious errors in the loads from the launch and STG I BO events, since the launch vehicle weighing 1,400,000 lbs and 129,000 lbs, respectively, was the dominant part in the composite model and the responses were less sensitive to the payload characteristics.

From the flight measurements shown in Figure 2 it might be assumed that the STG I BO is a more severe dynamic environment than that of the MECO II. Yet the loads from the MECO II event were considerably higher for most of the structural members. Again the reason is the sensitivity of the composite model to the payload characteristics. Essentially, during both the STG I BO and MECO II events, the launch vehicle/payload composite structure underwent a dynamic environment which can be represented by step functions. Therefore, the interface responses would be basically the decaying periodic motions with the natural frequencies of the composite system. For the STG I BO event the natural frequencies of the composite system would be mainly from the launch vehicle modes. On the other hand, for tne MECO II event the composite frequencies would be dominated by the payload characteristics. Figure 8 shows the flight-measured interface accelerations for the STG I BO and MECO II of the Voyager A. Clearly, the STG I BO event was a more severe dynamic environment than that of the MECO II. However, the MECO II had a periodic motion of 28 Hz as compared to 16 Hz for the launch event. Since one of the natural vibration modes of the Voyager in longitudinal direction was 28 Hz, the loads due to the MECO II will be higher due to the resonance of a lightly damped structure.

With these observations, the maximum flight loads and the maximum design loads are summarized in Table 6 in which the loads obtained by the transient analysis were also listed for reference. The ratios of the maximum design load to the maximum flight load are also tabulated. Among the 47 selected members, 12 members have the flight loads greater than the shock spectra design loads, i.e., the ratio is less than 1.0. But in any case, most of these 12 design loads are close to the flight loads such that the shock spectra design loads should be considered as generally adequate for the design purpose. Also the margins of safety for the selected members are listed in Table 6. The values are calculated based on the structure members limit capabilities which are much higher than the design loads for those members designed by stiffness requirements rather than strength requirements.

5. CONCLUSION

The purpose of the present study was to evaluate the shock spectra loads analysis as used for the design of the Voyager spacecraft. The evaluation will be based on the results of the comparisons of the design and flight loads of the Voyager A and B. The basic conclusion can be summarized as, 1) the shock spectra approach provides reasonable conservative design loads for the dynamic events under consideration, 2) for Voyager neither the launch nor the STG I BO was the most critical event during the powered flight. However, the final design loads seem generally adequate for the design purpose in view of the positive margins of safety, 3) neglecting the MECO II event is a serious omission.

The simplicity of the loads analysis approach using shock spectra is the main driving factor for its application by the projects despite its high probability of a weight penalty. This simplicity is derived from the fact that the launch vehicle/payload composite model is not required thus eliminating the interface activities between various organizations. However, it does require the estimations of dynamic environments at the launch vehicle/payload interface. These environments are most likely estimated from the previous flights of similar launch vehicles. For those events in which the payload characteristics are dominant in the composite system such as the MECO II event, an accurate estimation of the environment can be made only if a substantial number of flights with various or at least similar payload characteristics are available. Obviously, the 4 Titan-Centaur flights prior to the Voyager were not enough for the analysts to realize that the MECO II event was important.

One of the design criteria for the future shuttle payload is the emergency landing in which the unpowered shuttle orbiter will land with its full payload (Ref. 12). In this event, the payload and the orbiter are heavily coupled such that the dynamic environment is very much dependent on the payload characteristics. Therefore, one should be aware that if the dynamic environment cannot be estimated with sufficient accuracy, then a transient loads analysis should be performed.

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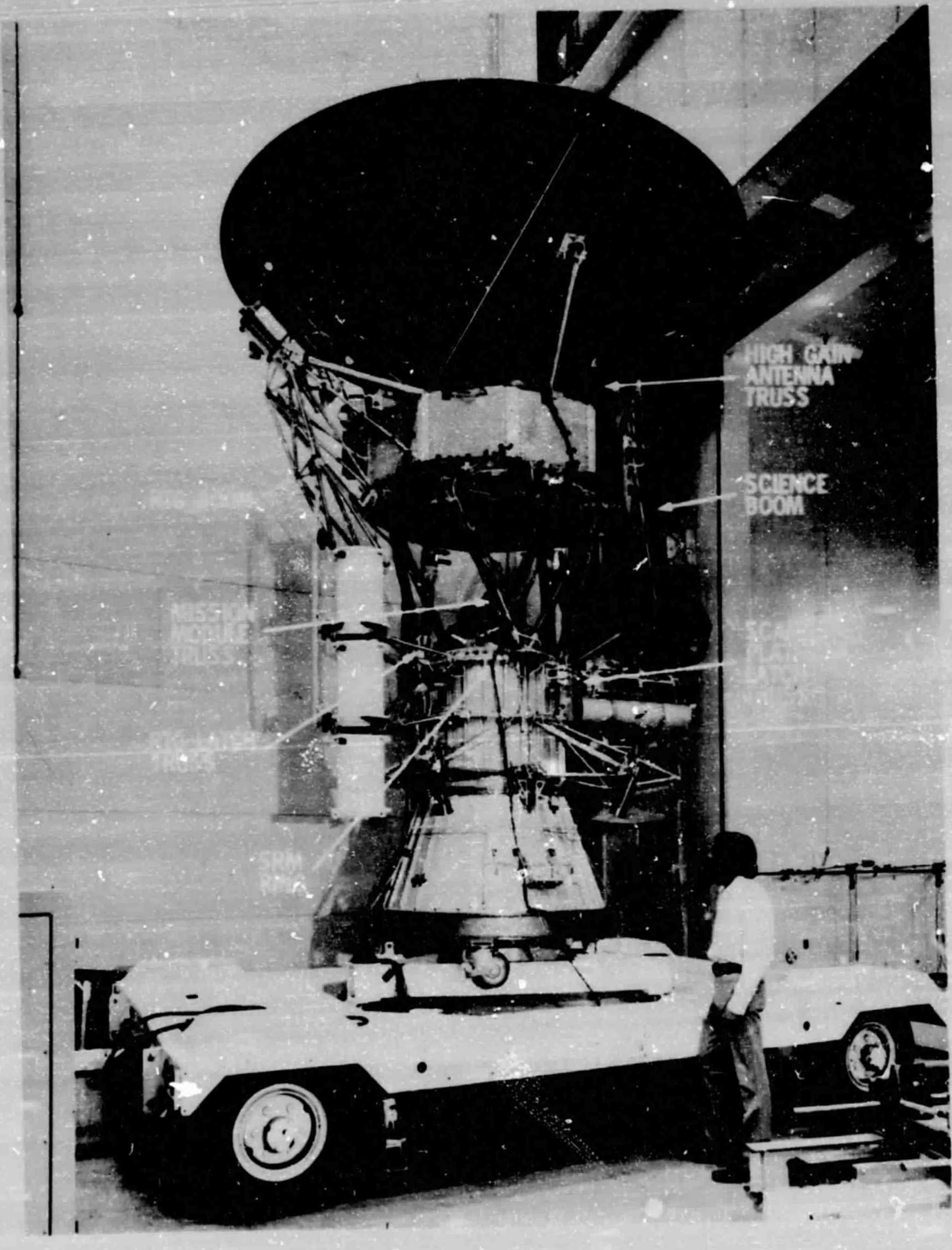

Figure 1. Voyager Spacecraft

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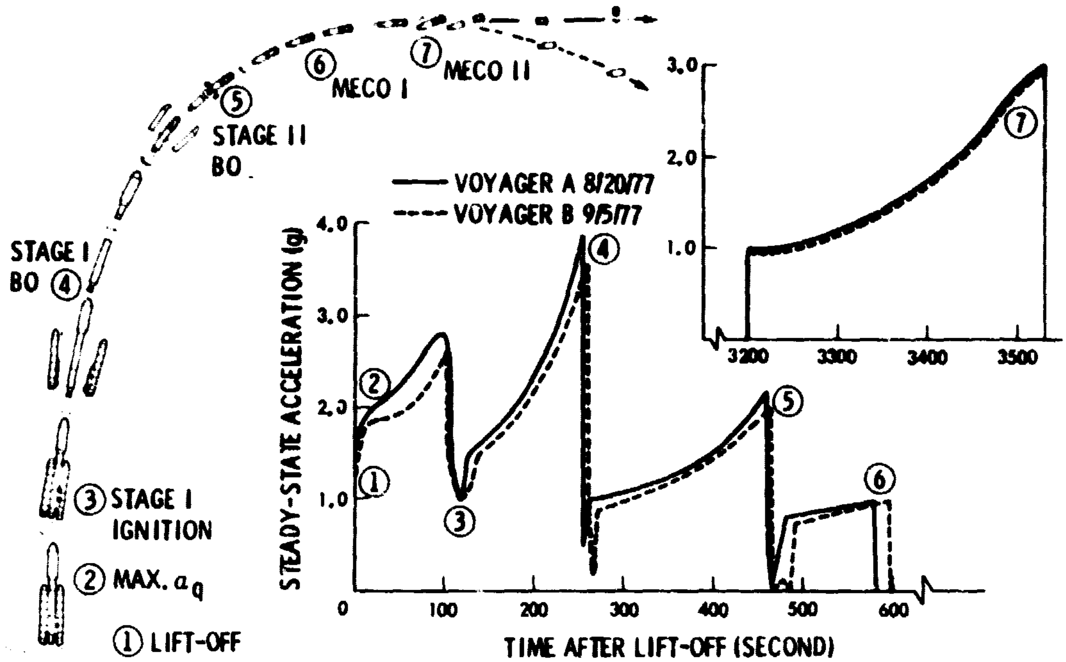

Figure 2. Steady State Acceleration of Launch Vehicle/Voyager Interface

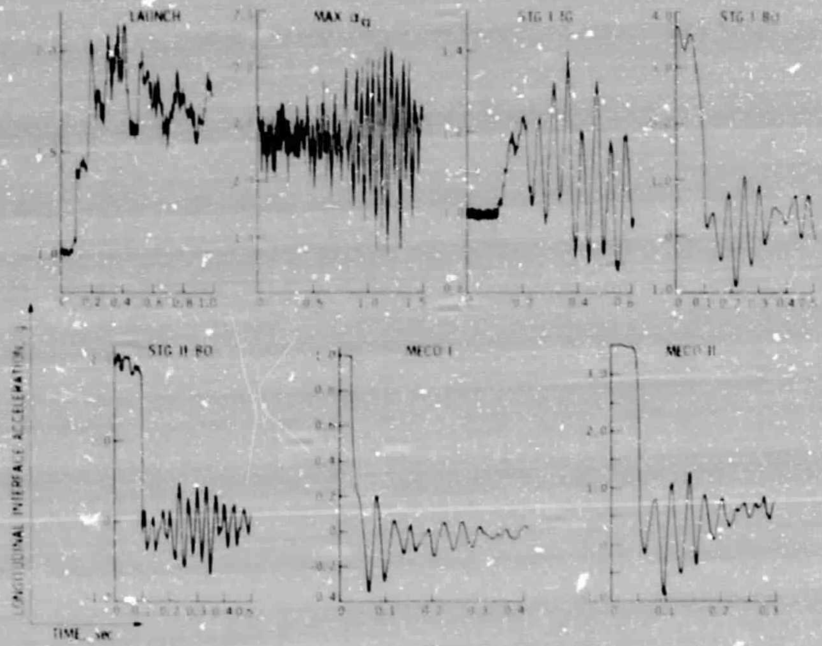

Figure 3. Flight-Measured Voyager Spacecraft Interface Acceleration

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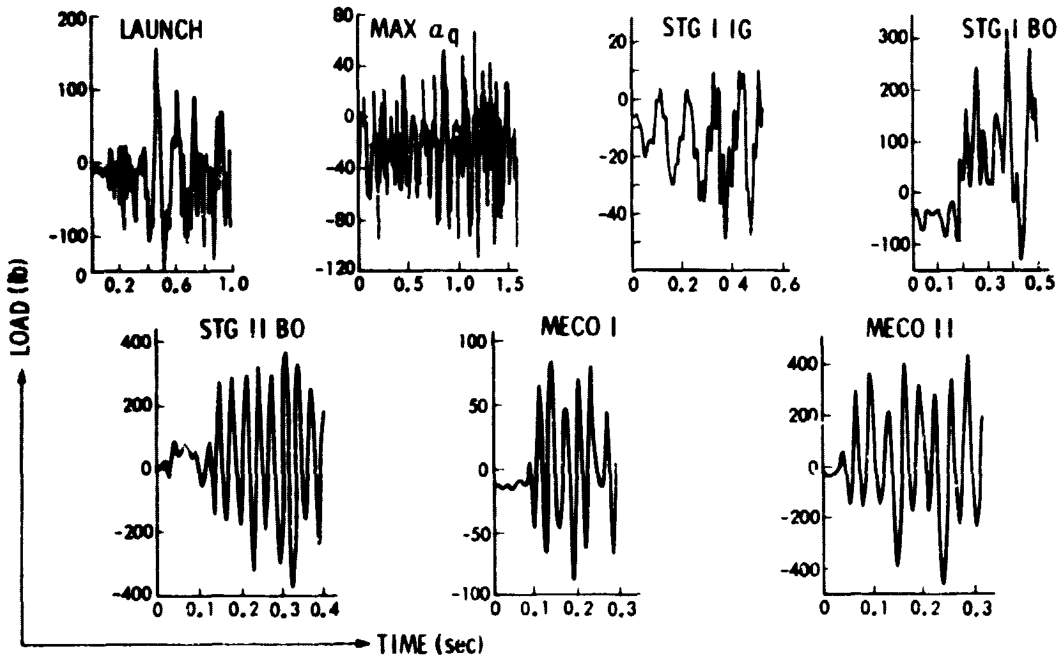

Figure 4. Flight Load History of Member 71937

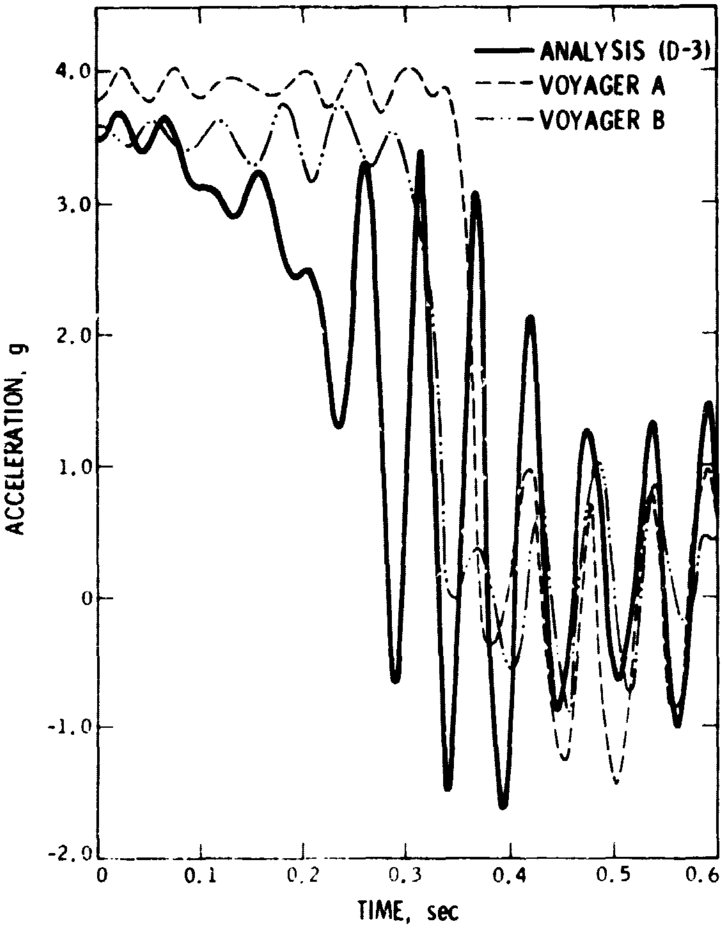

Figure 5. Interface Accelerations for Launch

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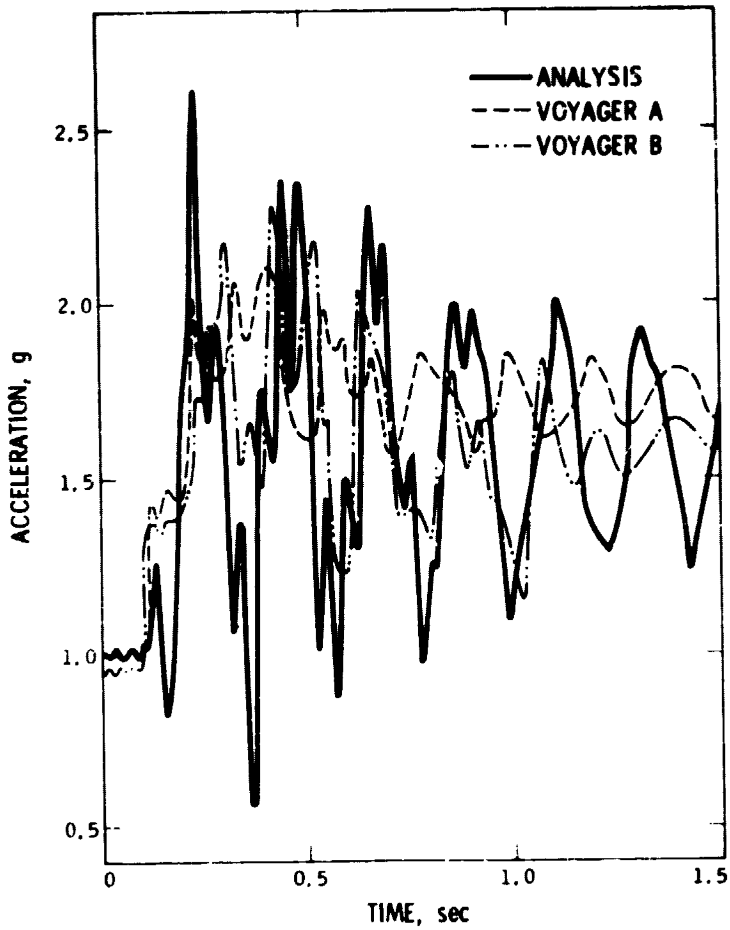

Figure 6. Interface Accelerations for Stage I Burnout

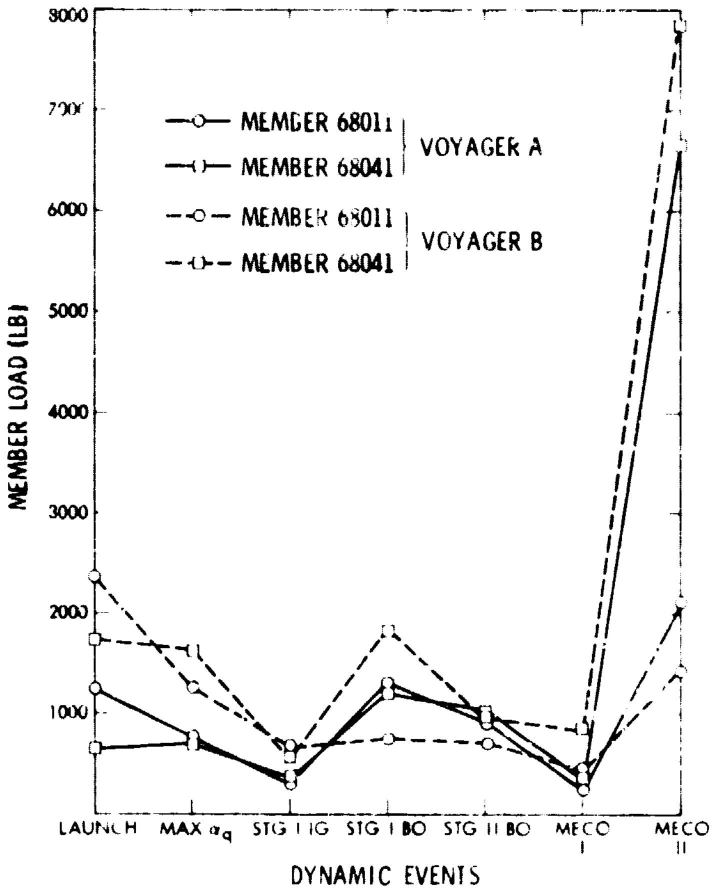

Figure 7. Maximum Member Load for Various Events

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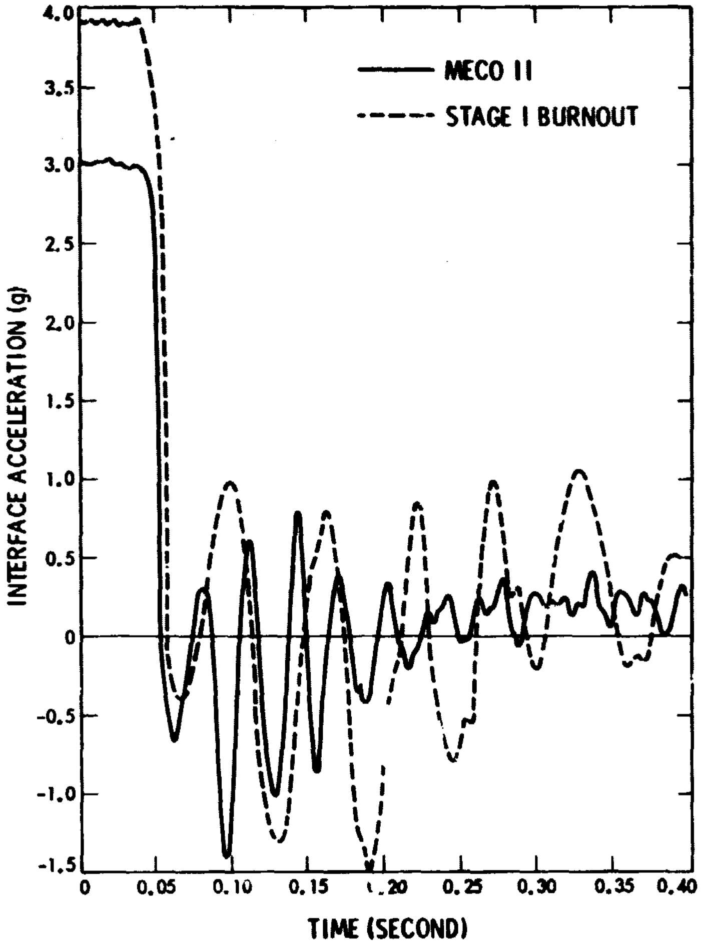

Figure 8. Voyager A Interface Accelerations for Stage I Burnout and MECO II

TABLE 1 VOYAGER DESIGN LOADS (LB)

MEMBER		LAUNCH			MAX αq		STAGE I BURNOUT		
		TRANSIENT		SHOCK SPECTRA	TRANSIENT		TRANSIENT		SHOCK SPECTRA
		MAX	MIN		MAX	MIN	MAX	MIN	
RTG LATCH TRUSS	30007	401.6	-1021.0	1750.0	60.9	694.2	459.2	-897.4	2400.0
	30017	351.4	-940.3	1850.0	22.6	-673.3	478.6	-925.5	2540.0
	30027	35.8	-56.1	570.0	54.8	-52.6	22.6	-21.1	140.0
	30047	1321.0	-537.0	1910.0	928.2	-98.3	1080.0	-44.3	2650.0
	30057	1005.0	-283.0	1900.0	890.9	-48.4	1088.3	-446.3	2600.0
	30067	592.2	-475.0	1310.0	536.9	-553.7	488.8	-506.3	980.0
	30077	648.8	-770.0	1320.0	564.5	-556.3	470.3	-456.0	1050.0
	30087	124.9	-91.2	450.0	106.4	-104.2	83.8	-80.3	200.0
H.G. ANT. TRUSS	71917	213.4	-347.6	1000.0	253.0	-344.0	183.7	-212.3	820.0
	71927	413.6	-401.8	980.0	278.4	-316.5	248.0	-306.7	770.0
	71937	543.4	-563.2	1020.0	320.7	-360.9	396.4	-423.3	850.0
	71947	472.6	-565.5	1020.0	294.2	-396.3	352.1	-450.9	990.0
	71957	392.9	-492.6	730.0	196.4	-316.6	278.8	-354.5	810.0
	71967	172.6	-313.4	710.0	149.2	-269.5	63.0	-144.0	630.0
SCIENCE BOOM	40501	66.3	-38.8	150.0	59.0	-21.2	212.6	-204.3	500.0
	40511	240.8	-184.5	450.0	196.4	-60.5	230.2	-159.3	750.0
	40521	268.9	-181.0	530.0	220.6	-53.1	305.2	-224.7	830.0
	40611	164.0	-341.4	630.0	-29.4	-255.1	201.9	-373.4	1100.0
	40621	217.3	-448.5	860.0	-5.5	-361.2	278.2	-505.0	1430.0
	42851	151.1	-187.3	660.0	97.2	-91.1	394.4	-388.1	1250.0
	42861	201.0	-162.0	390.0	97.8	-104.3	416.4	-423.1	1340.0
	42881	173.4	-178.2	390.0	128.4	-122.5	434.0	-431.8	1280.0
SRM RING	80016	192.6	-134.6	450.0	164.2	-147.6	161.9	-169.9	760.0
	80017	493.7	-246.3	790.0	450.6	-83.5	489.2	-248.7	620.0
	80106	180.2	-257.4	410.0	292.6	-350.1	139.7	-176.7	460.0
	80107	454.4	-71.0	700.0	344.4	-127.6	610.2	-256.5	900.0
	80176	446.7	-297.3	550.0	441.4	-400.9	324.0	-287.2	530.0
	80177	343.0	37.6	670.0	315.9	-140.4	582.2	-177.9	740.0
SCAN LATCH TRUSS	48027	291.7	-97.4	620.0	215.4	22.5	585.5	-517.2	1190.0
	48037	183.2	-23.9	650.0	153.8	41.3	231.7	-112.7	1130.0
	48047	514.8	-11.1	1040.0	403.6	177.0	771.6	-388.9	1610.0
	48057	342.3	-54.8	570.0	233.5	96.8	450.6	-218.9	1260.0
	48067	307.9	-734.9	950.0	37.0	-587.5	542.6	-852.2	2580.0
	48077	71.2	-253.8	830.0	66.3	-253.5	141.3	-258.0	1420.0
	48087	95.9	-366.1	580.0	35.1	-305.0	750.4	-775.3	1870.0

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TABLE 1 (continued)

MEMBER		LAUNCH			MAX α_q		STAGE I BURNOUT		
		TRANSIENT		SHOCK SPECTRA	TRANSIENT		TRANSIENT		SHOCK SPECTRA
		MAX	MIN		MAX	MIN	MAX	MIN	
TANK SUPPORT	50007	20.5	-338.7	490.0	-66.4	-286.5	124.8	-439.9	600.0
	50027	217.0	-487.1	990.0	75.1	-408.2	238.2	-435.4	760.0
	50057	115.5	-488.9	1040.0	38.3	-407.0	167.8	-467.1	760.0
	50077	-22.9	-259.1	400.0	-82.7	-233.2	108.6	-395.0	530.0
MISSION MODULE TRUSS	68011	2366.0	-3234.0	5900.0	2144.0	-2632.0	2667.1	-2784.8	4320.0
	68021	3174.0	-3753.0	7060.0	2521.0	-3248.0	2702.0	-3432.7	4910.0
	68031	1676.0	-2507.0	7120.0	2376.0	-2922.0	1381.6	-1543.0	4520.0
	68041	1733.0	-2143.0	6870.0	2098.0	-2798.0	1034.2	-1393.0	5040.0
	68051	3149.0	-3398.0	6770.0	2397.0	-3087.0	2797.1	-3321.9	4880.0
	68061	3287.0	-3774.0	7110.0	2647.0	-3188.0	3021.9	-3434.0	4320.0
	68071	1872.0	-2056.0	6990.0	2292.0	-2944.0	736.0	-864.3	4890.0
	68081	1390.0	-2038.0	5800.0	1857.0	-2335.0	1020.5	-1320.0	4320.0

TABLE 2 VOYAGER A FLIGHT LOADS (LB)

	MEMBER	LAUNCH	MAX α_q	STG I IG	STG I BO	STG II BO	MECO I	MECO II
HIGH GAIN ANTENNA TRUSS	71917	25.5	8.1	2.7	46.5	177.7	67.4	985.5
		-119.7	-146.4	-68.2	-156.7	-242.2	-48.4	-1118.9
	71927	79.5	71.6	24.5	182.3	412.4	95.6	621.9
		-109.5	103.0	-43.4	-115.8	-327.3	-110.6	-659.0
	71937	160.0	66.7	29.1	259.5	375.1	88.4	508.3
		-146.2	-117.8	-49.9	-136.5	-383.1	-90.1	-547.5
	71947	75.2	38.0	6.1	161.2	226.5	65.7	871.7
		-225.7	-159.4	-73.8	-223.6	-288.3	-77.4	-879.7
	71957	11.6	-14.5	-9.9	102.7	224.7	65.1	592.6
		-194.4	-137.2	-72.3	-201.7	-251.8	-72.6	-654.7
	71967	-17.1	-35.0	-19.9	77.5	196.4	56.1	705.7
		-130.8	-152.9	-69.6	-172.6	-229.0	-67.0	-697.7
SOLID ROCKET MOTOR RING	80017	266.7	296.0	147.4	474.2	327.8	108.1	760.1
		92.0	129.8	72.4	-198.0	-277.0	-77.0	-715.6
	80016	86.2	67.7	32.7	91.4	155.7	68.6	340.8
		-87.6	-69.4	-22.2	-129.0	-125.5	-81.2	-358.2
	80106	49.0	13.4	-2.9	15.2	65.7	37.2	300.2
		-121.6	-78.5	45.3	-170.9	-143.6	-51.6	-380.2
	80107	327.4	335.8	189.9	572.8	338.4	137.4	547.1
		121.7	193.4	96.2	-238.8	-213.1	-85.6	-364.9
	80177	323.4	342.1	208.5	548.8	343.5	133.0	533.0
		122.6	196.2	86.6	-283.4	-320.2	-78.4	-475.2
	80176	152.3	106.4	32.2	103.0	112.9	73.4	409.1
		-92.0	-43.0	-4.5	-162.0	-125.5	-54.3	-510.5

TABLE 2 (continued)

	MEMBER	LAUNCH	MAX αq	STG I IG	STG I BO	STG II BO	MECO I	MECO II
RTG LATCH TRUSS	30007	-131.3 -544.7	-222.6 -552.3	-88.2 -342.0	566.1 -857.3	765.9 -844.8	423.4 -438.3	992.3 -802.3
	30017	-133.3 -568.7	-205.7 -597.2	-108.6 -334.7	614.4 -886.2	803.2 -760.5	427.0 -452.2	1065.3 -815.5
	30027	66.2 -64.8	80.5 -76.4	26.7 -24.8	28.5 -38.6	83.1 -78.7	17.0 -21.1	279.9 -280.1
	30047	646.7 145.6	583.6 287.6	344.9 147.1	980.7 -628.6	730.6 -688.7	412.1 -402.0	799.4 -597.5
	30057	549.4 201.1	635.7 329.1	369.3 119.4	972.1 -627.3	780.8 -647.9	407.5 -397.9	1624.2 -1762.9
	30067	117.9 -116.1	143.3 -87.0	53.3 -38.8	247.9 -183.3	246.8 -165.7	99.5 -90.2	1566.6 -1727.4
	30077	247.8 -120.0	171.1 -118.0	77.2 -31.1	318.4 -277.0	287.0 -341.8	149.6 -115.9	1225.2 -1212.6
	30087	51.9 -52.1	71.9 -64.4	21.6 -21.2	56.4 -49.3	87.3 -68.7	17.2 -16.7	248.6 -258.1
SCIENCE BOOM	40501	33.0 -5.6	33.8 3.3	18.0 .2	60.7 -65.3	53.3 -70.6	31.4 -32.8	205.6 -163.0
	40511	118.5 9.1	112.4 48.5	70.8 15.3	187.6 -184.6	127.8 -123.6	86.8 -93.8	223.6 -258.8
	40521	139.9 32.5	137.4 58.9	89.0 18.9	231.6 -221.4	159.1 -159.9	103.7 -94.4	291.8 -353.4
	40611	-58.6 -208.1	-106.3 -212.3	-36.4 -128.8	306.0 -343.2	235.4 -242.7	146.9 -147.1	377.4 -333.9
	40621	-78.0 -269.6	-131.9 -274.9	-42.9 -168.4	408.5 -446.6	319.5 -331.1	177.0 -200.0	568.8 -521.4
	42851	81.1 -73.9	62.4 -38.5	31.1 -19.1	140.2 -155.8	211.5 -211.2	64.5 -64.4	495.5 -473.1
	42861	79.3 -87.0	41.3 -67.0	20.5 -33.4	167.1 -150.4	226.5 -227.0	69.1 -69.2	507.5 -531.6
	42881	66.5 -69.9	61.3 -41.4	28.1 -14.6	115.2 -151.8	172.5 -155.8	65.2 -45.4	547.0 -530.8

TABLE 2 (continued)

	MEMBER	LAUNCH	MAX α_q	STG I IG	STG I BO	STG II BO	MECO I	MECO II
SCAN PLATFORM LATCH TRUSS	48027	166.6	176.0	103.5	261.7	428.1	182.9	521.6
		35.7	51.2	23.2	-239.0	-439.4	-179.4	-717.2
	48037	121.2	133.9	82.7	213.8	196.7	114.8	337.5
		26.5	55.9	22.7	-221.7	-176.2	-117.0	-396.7
	48047	368.6	430.0	254.3	677.1	347.3	184.3	626.5
		147.8	208.7	98.5	-512.8	-329.3	-210.4	-743.5
	48057	212.2	227.0	149.9	400.6	281.8	156.0	394.5
		84.1	132.0	53.8	-319.1	-300.8	-162.5	-414.7
	48067	-82.6	-157.4	-48.2	707.8	640.5	326.0	1202.7
		-393.5	-441.5	-266.7	-735.6	-685.7	-319.5	-1305.8
	48077	-37.9	-54.6	-28.4	219.8	237.6	87.4	306.0
		-160.2	-181.4	-92.8	-252.5	-284.0	-93.8	-230.9
	48087	-56.1	-103.0	-44.7	212.0	203.2	111.7	650.1
		-206.1	-213.3	-128.2	-337.2	-212.7	-118.5	-774.5
HYDRAZINE TANK SUPPORT	50007	-55.0	-154.6	-70.5	290.1	481.9	203.0	423.1
		-319.8	-285.8	-161.9	-501.4	-504.3	-144.4	-357.0
	50027	-51.3	-103.1	-57.3	284.4	444.0	197.9	728.6
		-302.7	-294.4	-148.4	-490.0	-480.3	-140.4	-802.7
	50057	-42.5	-114.4	-62.8	217.7	380.2	204.0	733.8
		-333.1	-311.3	-167.2	-518.2	-537.1	-160.4	-908.6
	50077	-42.6	-142.6	-68.2	275.7	468.9	195.4	456.7
		-293.3	-265.7	-144.2	-466.5	-494.9	-141.1	-359.8
MISSION MODULE TRUSS	68011	412.9	120.1	-24.8	523.9	560.7	190.1	1828.1
		-1230.7	-762.6	-296.8	-1316.0	-921.8	-232.3	-2109.1
	68021	919.4	279.3	61.1	1179.4	690.0	263.6	5312.1
		-1104.2	-881.8	-377.5	-1039.8	-718.2	-189.6	-5020.9
	68031	61.5	29.9	-45.7	132.6	220.0	112.8	7355.7
		-633.2	-887.1	-313.0	-1312.0	-840.3	-293.3	-8500.7
	68041	111.0	173.5	-25.9	1237.4	1031.1	332.5	6564.7
		-643.9	-721.8	-361.0	-802.3	-376.5	-164.9	-6654.9
	68051	959.8	149.6	30.3	1571.3	643.3	242.4	3540.9
		-1145.8	-830.6	-363.3	-904.2	-809.5	-205.6	-3024.6
	68061	638.0	155.2	75.1	775.2	752.3	288.8	5118.6
		-1494.2	-778.6	-390.4	-1597.2	-741.1	-185.5	-5611.8
	68071	221.9	258.9	-15.5	1263.1	951.0	229.2	8184.9
		-580.8	-687.4	-351.6	-754.6	-418.0	-171.7	-7793.1
	68081	181.3	52.1	-31.0	167.5	402.2	224.0	4358.1
		-724.3	-821.2	-821.2	-288.2	-902.9	-257.3	-5172.0

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TABLE 3 VOYAGER B FLIGHT LOADS (LB)

	MEMBER	LAUNCH	MAX $q\alpha$	STG I IG	STG I BO	STG II BO	MECO I	MECO II
HIGH GAIN ANTENNA TRUSS	71917	163.9	152.8	43.9	122.1	173.1	125.2	1136.9
		-200.8	-241.9	-108.0	-214.1	-186.4	-161.9	-316.9
	71927	233.7	191.7	91.3	220.9	333.1	188.4	441.7
		-310.8	-214.6	-82.7	-159.6	-263.8	-138.8	-994.8
	71937	357.8	176.8	65.4	193.2	326.0	185.9	504.9
		-359.5	-221.1	-87.5	-133.6	-391.4	-132.4	-547.6
	71947	245.5	73.0	32.9	184.2	229.9	97.7	223.6
		-446.3	-283.2	-136.1	-163.7	-243.1	-123.8	-633.2
	71957	176.7	18.8	-.1	110.4	211.4	130.6	312.5
		-311.6	-234.7	-114.1	-174.1	-263.7	-114.6	-443.7
	71967	48.6	69.6	30.6	107.4	154.5	110.8	897.0
		-221.1	-217.9	-101.8	-174.8	-227.4	-128.9	-320.6
SOLID ROCKET MOTOR RING	80017	386.7	363.5	175.9	415.0	247.6	144.5	766.2
		-29.5	57.7	37.7	-239.1	-213.5	-118.7	-229.9
	80016	325.1	129.2	59.5	182.7	185.9	227.6	521.6
		-266.3	-121.8	-59.0	-119.8	-216.6	-203.5	-374.2
	80106	162.1	58.3	16.9	15.3	41.1	92.6	420.7
		-171.8	-140.0	-79.6	-181.8	-109.3	-132.6	-228.6
	80107	429.4	384.2	229.1	517.1	306.0	193.4	347.1
		-99.8	125.9	73.1	-240.7	-220.8	-170.0	-362.4
	80177	410.8	381.3	221.0	510.6	302.4	168.4	534.2
		38.7	98.7	59.8	-240.5	-212.9	-134.1	-230.0
	80176	346.0	97.0	30.5	111.7	115.5	89.3	204.0
		-320.5	-116.7	-59.2	-77.2	-160.5	-99.5	-576.3
RTG LATCH TRUSS	30007	299.4	-87.1	-99.7	397.3	667.1	900.9	1985.1
		-1122.2	-759.2	-415.5	-816.6	-903.4	-986.7	-970.2
	30017	167.9	-18.2	-51.2	417.2	835.5	871.5	2317.8
		-905.9	-788.9	-431.7	-853.5	-815.2	-1017.4	-1011.2
	30027	121.3	137.0	38.0	35.5	118.0	56.4	190.0
		-106.7	-135.4	-41.4	-46.9	-125.7	-48.0	-56.3
	30047	1157.1	825.9	441.6	936.7	706.2	949.0	1200.7
		-215.8	155.8	115.1	-510.4	-691.2	-844.9	-1378.0
	30057	877.7	814.3	446.4	933.3	787.7	873.3	978.4
		-210.5	82.3	88.8	-375.7	-567.6	-756.0	-2656.8
	30067	321.4	247.5	111.8	386.0	321.6	284.6	327.6
		-451.3	-336.4	-102.6	-237.8	-179.4	-214.9	-1966.2
	30077	610.6	396.5	138.6	235.1	283.5	339.8	1555.4
		-284.5	-266.7	-53.9	-258.8	-376.0	-400.7	-455.7
	30087	81.3	138.8	33.0	83.2	94.0	62.0	85.2
		-123.1	-151.3	-47.6	-20.5	-80.0	-57.1	-279.3

TABLE 3. (continued)

	MEMBER	LAUNCH	MAX αq	STG I IG	STG I BO	STG II BO	MECO I	MECO II
SCIENCE BOOM	40501	73.9	54.5	22.3	51.6	67.9	67.4	199.6
		-43.1	-18.4	-14.5	-65.8	-79.6	-80.2	-96.0
	40511	210.1	150.9	69.7	174.7	123.9	185.3	255.1
		-93.1	-41.8	-7.7	-136.5	-141.4	-166.5	-258.3
	40521	212.5	180.7	88.8	215.2	164.4	195.1	361.3
		-88.0	-35.2	-.5	-158.5	-164.7	-195.5	-304.8
	40611	63.6	0.8	021.4	232.5	229.6	252.8	357.2
		-305.3	-254.9	-128.5	-324.7	-226.5	-275.2	-440.7
	40621	101.6	-5.0	-26.2	302.3	310.0	347.2	510.2
		-407.3	-336.2	-167.2	-424.8	-320.8	-333.2	-710.2
	42851	201.7	106.5	57.7	133.4	207.0	171.4	246.5
		-185.1	-85.1	-51.6	-111.5	-189.2	-160.9	-367.6
	42861	198.6	91.4	54.7	119.6	203.1	172.6	394.5
		-216.4	-114.3	-61.9	-143.1	-222.2	-183.9	-264.6
	42881	194.6	108.8	55.8	184.2	143.5	149.5	176.1
		-202.2	-98.0	-46.0	-126.9	-152.7	-114.3	-502.0
SCAN PLATFORM LATCH TRUSS	48027	277.2	208.9	115.6	254.8	348.3	367.0	621.6
		-130.3	-4.6	9.8	-256.3	-452.8	-334.5	-708.1
	48037	203.9	146.9	82.3	195.2	196.7	237.1	389.1
		-57.7	17.6	11.4	-222.6	-213.9	-217.2	-326.4
	48047	575.3	452.3	264.7	634.0	361.2	392.5	683.8
		-17.3	123.9	68.5	-362.7	-345.8	-403.8	-520.6
	48057	386.9	260.9	151.2	371.3	227.8	334.5	363.7
		-75.8	74.6	36.5	-204.9	-259.1	-322.8	-524.5
	48067	221.0	-58.3	-33.4	665.4	512.6	706.6	574.6
		-822.6	-539.8	-254.0	-691.0	-551.8	-680.0	-1676.4
	48077	66.2	6.8	-5.2	189.2	167.6	179.1	392.1
		-238.2	-195.8	-101.1	-253.2	-241.9	-199.3	-324.2
	48087	187.5	-5.6	-20.0	184.7	181.0	198.0	830.8
		-433.5	-274.2	-174.5	-296.7	-220.9	-277.3	-261.7

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TABLE 3 (continued)

	MEMBER	LAUNCH	MAX α_q	STG I IG	STG I BO	STG II BO	MECO I	MECO II
HYDRAZINE TANK SUPPORT	50007	7.2 -344.6	-74.9 -308.4	-50.0 -165.0	401.7 -416.8	467.4 -426.6	159.4 -217.9	470.0 -329.2
	50027	56.8 -463.3	-3.1 -413.5	-31.6 -182.6	350.4 -392.9	476.1 -485.9	146.0 -230.7	219.7 -931.8
	50057	67.3 -403.5	-2.5 -384.6	-32.9 -198.9	321.4 -430.9	442.0 -479.4	178.6 -190.6	1145.4 -277.3
	50077	-6.9 -310.6	-63.5 -289.6	-45.6 -156.3	378.1 -376.9	464.6 -438.5	151.3 -204.2	329.1 -451.9
MISSION MODULE TRUSS	68011	1604.5 -2376.1	248.0 -1288.0	60.0 -685.6	282.7 -761.1	449.1 -724.2	412.0 -447.8	971.0 -1436.6
	68021	2864.3 -2102.2	856.6 -950.5	440.9 -541.6	612.5 -827.1	701.9 -436.1	594.2 -566.2	5145.3 -489.4
	68031	1095.7 -1279.4	1078.0 -1592.4	260.9 -613.9	735.3 -1631.5	436.8 -702.6	533.4 -885.2	9446.1 -1714.2
	68041	788.2 -1720.3	1035.4 -1631.4	311.7 -577.7	1850.9 -753.0	991.5 -410.6	820.8 -674.9	1738.5 -7828.2
	68051	2737.4 -2611.7	806.2 -925.4	388.9 -513.6	580.5 -710.5	827.6 -461.0	598.6 -461.6	3667.5 -909.1
	68061	2057.0 -3597.9	387.9 -1425.3	175.7 -741.6	1036.2 -823.9	500.4 -620.0	603.0 -759.1	620.3 -5651.8
	68071	790.4 -1493.1	1026.7 -1650.9	356.2 -649.2	1725.0 -591.8	827.0 -326.8	1003.7 -717.1	1731.2 -8526.7
	68081	1044.3 -1204.5	787.2 -1330.1	253.2 -570.0	493.5 -1474.6	387.6 -787.7	284.9 -667.0	5902.1 -1408.8

TABLE 4

COMPARISON OF MAXIMUM FLIGHT AND SHOCK SPECTRA DESIGN LOADS

	MEMBER	LAUNCH DESIGN (lb)	LAUNCH FLIGHT/DESIGN A	LAUNCH FLIGHT/DESIGN B	STAGE I BURNOUT DESIGN (lb)	STAGE I BURNOUT FLIGHT/DESIGN A	STAGE I BURNOUT FLIGHT/DESIGN B
HIGH GAIN ANTENNA TRUSS	71917	1000.0	0.12	0.20	820.0	0.19	0.26
	71927	980.0	0.11	0.32	770.0	0.24	0.29
	71937	1020.0	0.16	0.35	850.0	0.31	0.23
	71947	1020.0	0.22	0.44	990.0	0.23	0.19
	71957	730.0	0.27	0.43	810.0	0.25	0.22
	71967	710.0	0.18	0.31	630.0	0.27	0.28
SOLID ROCKET MOTOR RING	80017	790.0	0.34	0.49	620.0	0.77	0.67
	80016	450.0	0.20	0.72	760.0	0.17	0.24
	80106	410.0	0.30	0.42	460.0	0.37	0.40
	80107	700.0	0.47	0.61	900.0	0.64	0.58
	80177	670.0	0.48	0.61	740.0	0.74	0.69
	80176	550.0	0.28	0.63	530.0	0.31	0.21
RTG LATCH TRUSS	30007	1750.0	0.31	0.64	2400.0	0.36	0.34
	30017	1850.0	0.31	0.49	2540.0	0.35	0.34
	30027	570.0	0.12	0.21	140.0	0.28	0.34
	30047	1910.0	0.34	0.61	2650.0	0.37	0.35
	30057	1900.0	0.29	0.46	2600.0	0.37	0.36
	30067	1310.0	0.09	0.34	980.0	0.25	0.39
	30077	1320.0	0.19	0.46	1050.0	0.30	0.25
	30087	450.0	0.12	0.27	200.0	0.28	0.42

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TABLE 4
(continued)

MEMBER		LAUNCH			STAGE I BURNOUT		
		DESIGN	FLIGHT/DESIGN		DESIGN	FLIGHT/DESIGN	
		(lb)	A	B	(lb)	A	B
SCIENCE BOOM	40501	150.0	0.22	0.50	500.0	0.13	0.13
	40511	450.0	0.26	0.47	750.0	0.25	0.23
	40521	530.0	0.27	0.40	830.0	0.28	0.26
	40611	630.0	0.33	0.48	1100.0	0.31	0.29
	40621	860.0	0.31	0.48	1430.0	0.31	0.30
	42851	360.0	0.23	0.56	1250.0	0.13	0.11
	42861	390.0	0.22	0.56	1340.0	0.13	0.11
	42881	390.0	0.18	0.52	1280.0	0.12	0.14
SCAN PLATFORM LATCH TRUSS	48027	620.0	0.27	0.45	1190.0	0.20	0.22
	48037	650.0	0.19	0.31	1130.0	0.20	0.20
	48047	1040.0	0.35	0.55	1610.0	0.42	0.39
	48057	570.0	0.37	0.68	1260.0	0.32	0.30
	48067	950.0	0.41	0.87	2580.0	0.29	0.27
	48077	830.0	0.19	0.29	1420.0	0.18	0.18
	48087	580.0	0.36	0.75	1870.0	0.18	0.16
HYDRAZINE TANK SUPPORT	50007	490.0	0.65	0.70	600.0	0.84	0.70
	50027	990.0	0.31	0.47	760.0	0.65	0.52
	50057	1040.0	0.32	0.39	760.0	0.68	0.57
	50077	400.0	0.73	0.78	530.0	0.88	0.71
MISSION MODULE TRUSS	68011	5900.0	0.21	0.40	4320.0	0.31	0.18
	68021	7060.0	0.16	0.40	4910.0	0.24	0.17
	68031	7120.0	0.09	0.18	4520.0	0.29	0.36
	68041	6870.0	0.09	0.25	5040.0	0.25	0.37
	68051	6770.0	0.17	0.40	4880.0	0.32	0.15
	68061	7110.0	0.21	0.51	4320.0	0.37	0.24
	68071	6990.0	0.08	0.21	4890.0	0.26	0.35
	68081	5800.0	0.13	0.21	4320.0	0.32	0.34

TABLE 5

COMPARISON OF MAXIMUM FLIGHT AND TRANSIENT PREDICTED LOADS

MEMBER		LAUNCH			MAX αq			STAGE I BURNOUT		
		Predicted (LB)	Flight/Predicted A	Flight/Predicted B	Predicted (LB)	Flight/Predicted A	Flight/Predicted B	Predicted (LB)	Flight/Predicted A	Flight/Predicted B
HIGH GAIN ANTENNA TRUSS	71917	347.6	0.35	0.58	344.0	0.43	0.70	212.3	0.73	1.00
	71927	413.6	0.26	0.76	316.5	0.33	0.68	306.7	0.60	0.73
	71937	563.2	0.29	0.63	360.9	0.33	0.61	423.3	0.62	0.46
	71947	565.5	0.40	0.79	396.3	0.40	0.72	450.9	0.51	0.38
	71957	492.6	0.40	0.64	316.6	0.43	0.74	354.5	0.57	0.50
	71967	313.4	0.41	0.70	269.5	0.57	0.81	144.0	1.18	1.23
SOLID ROCKET MOTOR RING	80017	493.7	0.54	0.78	450.6	0.66	0.81	489.2	0.98	0.85
	80016	192.6	0.47	1.68	164.2	0.53	0.79	169.9	0.76	1.08
	80106	257.4	0.48	0.67	350.1	0.22	0.40	176.7	0.96	1.04
	80107	454.4	0.72	0.94	344.4	0.98	1.12	610.2	0.94	0.86
	80177	343.0	0.94	1.19	315.9	1.08	1.21	582.2	0.94	0.88
	80176	446.7	0.35	0.78	441.4	0.24	0.26	324.0	0.51	0.34
RTG LATCH TRUSS	30007	1021.0	0.54	1.10	694.2	0.80	1.09	897.4	0.96	0.91
	30017	940.3	0.61	0.96	673.3	0.89	1.17	925.5	0.96	0.93
	30027	56.1	1.18	2.16	54.8	1.47	2.50	22.6	1.74	2.11
	30047	1321.0	0.49	0.88	928.2	0.63	0.89	1080.0	0.91	0.86
	30057	1005.0	0.54	0.87	890.9	0.71	0.91	1088.3	0.88	0.86
	30067	592.2	0.20	0.76	553.7	0.26	0.61	506.3	0.48	0.76
	30077	770.0	0.32	0.79	564.5	0.30	0.70	470.3	0.67	0.56
	30087	124.9	0.42	0.99	106.4	0.68	1.42	83.8	0.67	1.00

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TABLE 5

(continued)

MEMBER		LAUNCH Predicted (LB)	LAUNCH Flight/Predicted A	LAUNCH Flight/Predicted B	MAX αq Predicted (LB)	MAX αq Flight/Predicted A	MAX αq Flight/Predicted B	STAGE I BURNOUT Predicted (LB)	STAGE I BURNOUT Flight/Predicted A	STAGE I BURNOUT Flight/Predicted B
SCIENCE BOOM	40501	66.3	0.50	1.13	59.0	0.57	0.92	212.6	0.30	0.30
	40511	240.8	0.49	0.88	196.4	0.57	0.77	230.2	0.82	0.75
	40521	268.9	0.53	0.79	2[illegible]0.6	0.62	0.82	305.2	0.76	0.71
	40611	341.4	0.61	0.89	255.1	0.83	1.00	373.4	0.91	0.85
	40621	448.5	0.59	0.92	361.2	0.69	0.93	505.0	0.88	0.85
	42851	187.3	0.44	1.08	97.2	0.64	0.93	394.4	0.41	0.35
	42861	201.0	0.43	1.09	104.3	0.64	1.10	423.1	0.41	0.35
	42881	178.2	0.39	1.14	128.4	0.48	0.85	434.0	0.35	0.41
SCAN PLATFORM LATCH TRUSS	48027	291.7	0.57	0.96	215.4	0.82	0.97	585.5	0.41	0.45
	48037	183.2	0.67	1.10	153.8	0.87	0.96	231.7	0.98	0.98
	48047	514.8	0.71	1.11	403.6	1.07	1.12	711.6	0.95	0.88
	48057	342.3	0.62	1.13	233.5	0.97	1.12	450.6	0.90	0.84
	48067	734.9	0.53	1.13	587.5	0.75	0.92	852.2	0.88	0.82
	48077	253.8	0.62	0.95	253.5	0.72	0.77	258.0	0.99	0.99
	48087	366.1	0.57	1.19	305.0	0.70	0.90	775.3	0.43	0.39
HYDRAZINE TANK SUPPORT	50007	338.7	0.94	1.01	286.5	1.00	1.08	439.9	1.15	0.96
	50027	487.1	0.63	0.96	408.2	0.72	1.01	435.4	1.14	0.91
	50057	488.9	0.68	0.83	407.0	0.77	0.95	467.1	1.11	0.93
	50077	259.1	1.13	1.20	233.2	1.14	1.24	395.0	1.18	0.95

TABLE 5

(continued)

MEMBER		LAUNCH			MAX. αq			STAGE I BURNOUT		
		Predicted (LB)	Flight / Predicted		Predicted (LB)	Flight / Predicted		Predicted (LB)	Flight / Predicted	
			A	B		A	B		A	B
MISSION MODULE TRUSS	68011	3234.0	0.38	0.73	2632.0	0.29	0.49	2784.8	0.48	0.28
	68021	3753.0	0.30	0.75	3248.0	0.27	0.29	3432.7	0.34	0.24
	68031	2507.0	0.26	0.51	2922.0	0.30	0.55	1543.0	0.85	1.05
	68041	2143.0	0.29	0.80	2798.0	0.26	0.58	1393.0	0.90	1.34
	68051	3398.0	0.34	0.80	3087.0	0.27	0.30	3321.9	0.47	0.22
	68061	3774.0	0.40	0.96	3188.0	0.24	0.45	3434.0	0.47	0.30
	68071	2056.0	0.27	0.71	2944.0	0.23	0.56	864.3	1.47	1.98
	68081	2038.0	0.37	0.60	2335.0	0.35	0.57	1320.0	1.05	1.11

TABLE 6

COMPARISON OF OVERALL MAXIMUM LOADS AND MARGIN OF SAFETY

	Member	Max. Flight Load (lb)[1]	Max. Design Load (lb)[2] Transient	Max. Design Load (lb)[2] Shock Spectra	S.S. Design / Max. Flight	Limit Capabilities (lb)	Margin of Safety[3]
HIGH GAIN ANTENNA TRUSS	71917	1136.9	347.6	1000.0	0.88	3870.0	2.40
	71927	994.8	413.6	980.0	0.99	2500.0	1.51
	71937	547.6	662.3	1020.0	1.86	2500.0	3.57
	71947	879.7	565.5	1020.0	1.16	3870.0	3.40
	71957	654.7	492.6	810.0*	1.24	1550.0	1.37
	71967	897.0	313.4	710.0	0.79	1550.0	0.73
SOLID ROCKET MOTOR RING	80017	760.2	493.7	790.0	1.04	900.0	0.18
	80016	521.6	192.6	760.0*	1.46	710.0	0.36
	80106	420.7	350.1**	460.0*	1.09	710.0	0.69
	80107	547.1	610.2*	900.0*	1.65	900.0	0.65
	80177	548.8	582.2*	740.0*	1.35	900.0	0.64
	80176	576.3	446.7	550.0	0.95	710.0	0.23
HYDRAZINE TANK SUP.	50007	504.3	439.9*	600.0*	1.19	1110.0	1.20
	50027	931.8	487.1	990.0	1.06	1110.0	0.19
	50057	1145.4	488.9	1040.0	0.91	1110.0	-0.03
	50077	468.9	395.0*	530.0*	1.13	1110.0	1.37
RTG LATCH TRUSS	30007	1985.1	1021.0	2400.0*	1.21	7400.0	2.73
	30017	2317.8	940.3	2540.0*	1.10	7400.0	2.19
	30027	280.1	56.1	570.0	2.04	1410.0	4.03
	30047	1378.0	1321.0	2650.0*	1.92	5360.0	2.89
	30057	2656.8	1088.3*	2600.0*	0.98	5360.0	1.02
	30067	1966.2	592.2	1310.0	0.67	7400.0	2.76
	30077	1555.4	770.0	1320.0	0.85	7400.0	3.76
	30087	279.3	124.9	450.0	1.61	1290.0	3.62

TABLE 6

(continued)

Member		Max. Flight Load (lb)[1]	Max. Design Load (lb)[2]		S.S. Design	Limit Capabilities (lb)	Margin of Safety[3]
			Transient	Shock Spectra	Max. Flight		
SCIENCE BOOM	40501	199.6	212.6*	500.0*	2.51	1380.0	5.91
	40511	258.8	240.8	750.0*	2.90	1860.0	6.19
	40521	361.3	305.2*	830.0*	2.30	1860.0	4.15
	40611	440.7	373.4*	1100.0*	2.50	2680.0	5.08
	40621	710.2	505.0*	1430.0*	2.01	2680.0	2.77
	42851	495.5	394.4*	1250.0*	2.52	2080.0	3.20
	42861	531.6	423.1*	1340.0*	2.52	2030.0	2.82
	42881	547.0	434.0*	1280.0*	2.34	1930.0	2.53
MISSION MODULE TRUSS	68011	2370.1	3234.0	5900.0	2.49	1370.0	4.78
	68021	5312.1	3753.0	7670.0	1.44	12500.0	1.35
	68031	9446.1	3922.0**	7120.0	0.75	12000.0	0.27
	68041	7828.2	2790.0**	6870.0	0.88	13600.0	0.74
	68051	3667.5	3398.0	6770.0	1.85	13600.0	2.71
	68061	5651.8	3774.0	7110.0	1.26	12000.0	1.12
	68071	8526.7	2944.0**	6990.0	0.82	12500.0	0.47
	68081	5902.1	2335.0**	5800.0	0.98	13700.0	1.32
SCAN PLATFORM LATCH TRUSS	48027	717.2	585.5*	1190,0*	1.66	3270.0	3.56
	48037	396.7	231.7*	1130.0*	2.85	3200.0	7.07
	48047	743.5	711.6*	1610.0*	2.17	2660.0	2.58
	48057	524.5	450.6*	1260.0*	2.17	2660.0	2.58
	48067	1676.4	852.2*	2580.0*	1.54	3270.0	0.95
	48077	392.1	258.0*	1420.0*	3.62	3200.0	7.16
	48087	830.8	775.3*	1870.0*	2.25	2480.0	1.99

1. All max flight loads are from MECO II event except 80177 from STG I BO, 50007 and 50077 from STG II BO, and 68011 from launch.

2. Max design loads are from the launch event except those with * are from STG I BO and ** from Max α_q.

3. Margin of Safety $= \left(\dfrac{\text{Limit Capability}}{\text{Max Flight Load}} \right) - 1$