SECTION A2

LOADS

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A2 SPACE VEHICLE LOADS.

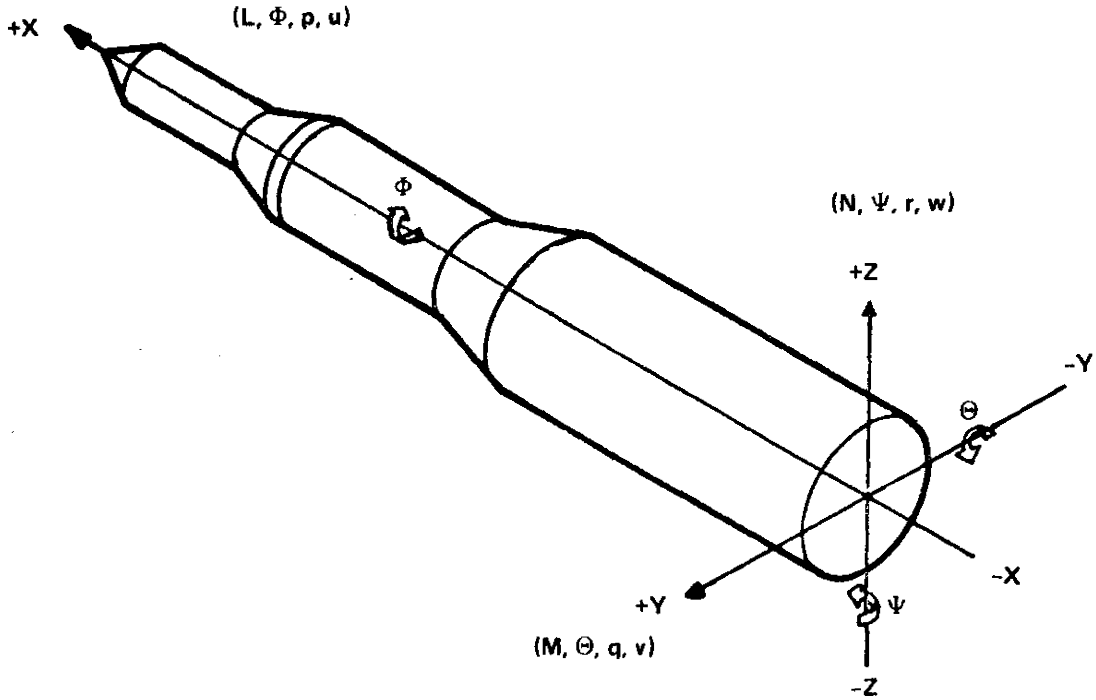
A.2.1 COORDINATE SYSTEMS.

The standard coordinate axes which have been used for rockets, missiles, and launch vehicles are shown in Figure A2.1-1. The longitudinal X axis is taken as positive in the flight direction. The Y and Z axes are taken in appropriate directions to form a right-handed system. Moments are positive as determined by the right-hand rule.

For aircraft analysis the sign conventions used are shown in Figure A2.1-2. In this figure externally applied loads acting at the airplane center of gravity are defined as positive when directed aft in the X direction, outboard to the left in the Y direction, and upward in the Z direction. Externally applied moments about the airplane center of gravity are defined as positive when acting as shown in Figure A2.1-2 (left-hand rule). At any section under positive shear the rear, left outboard, or upper part tends to move aft, left, or up; the right outboard, or upper part, tends to move aft, right, or up. Any section under positive torsion tends to rotate clockwise when viewed from the rear, left, or above. Positive bending moments produce compression in the rear, left, and upper fibers. Positive axial load produces tension across any section.

The external loads which may act on a space vehicle are categorized as follows:

1. Flight Loads
2. Launch Pad Loads



AXIS	FORCE SYMBOL	MOMENT SYMBOL	LINEAR VELOCITY
LONGITUDINAL	X	L	u
LATERAL	Y	M	v
YAW	Z	N	w

ANGLE	SYMBOL	POSITIVE DIRECTION	ANGULAR VELOCITY
ROLL	Φ	Y to Z	p
PITCH	Θ	Z to X	q
YAW	Ψ	X to Y	r

NOTE: Sign convention follows right-hand rule.

Figure A2.1-1. Coordinate axes and symbols for a space vehicle.

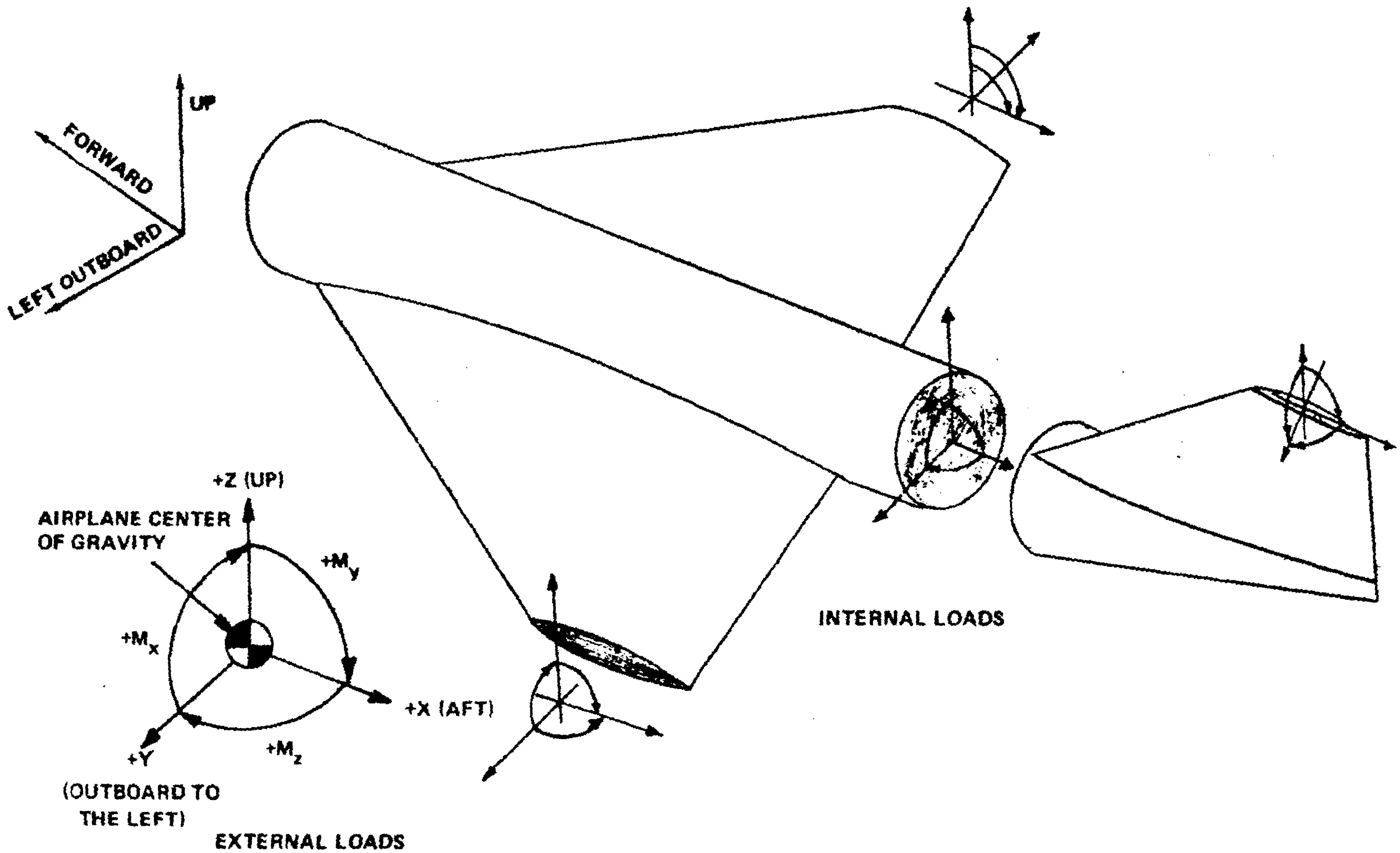


Figure A2.1-2. Positive sense of internal shear, torsion and bending moment and positive designation and sign convention of external applied loads and moments for an airplane.

3. Transportation and Handling Loads

4. Static Test Loads

5. Recovery Loads.

Since it is universal practice in the airframe industry for the stress analyst to obtain the magnitudes of external loads for the space vehicle from the cognizant "Loads Group" in his organization, the methods of calculating these quantities will not be presented in this manual. Rather, it will be assumed that these loads are furnished to the stress analyst so that only their qualitative description is required. These loads are generally resolved along the coordinate axes for stress and aerodynamic analysis.

A2.2.0 Loading Curves

The loads are usually presented in the form of load versus vehicle station curves, where locations along the longitudinal coordinate are referred to as vehicle stations. These curves are plotted for various times during the flight of the vehicle. At each of these times, the longitudinal force, the shear and the bending moment are plotted as a function of the vehicle station. Typical curves showing the bending moment and longitudinal force distribution along a vehicle can be seen in Figure A2.2.0-1.

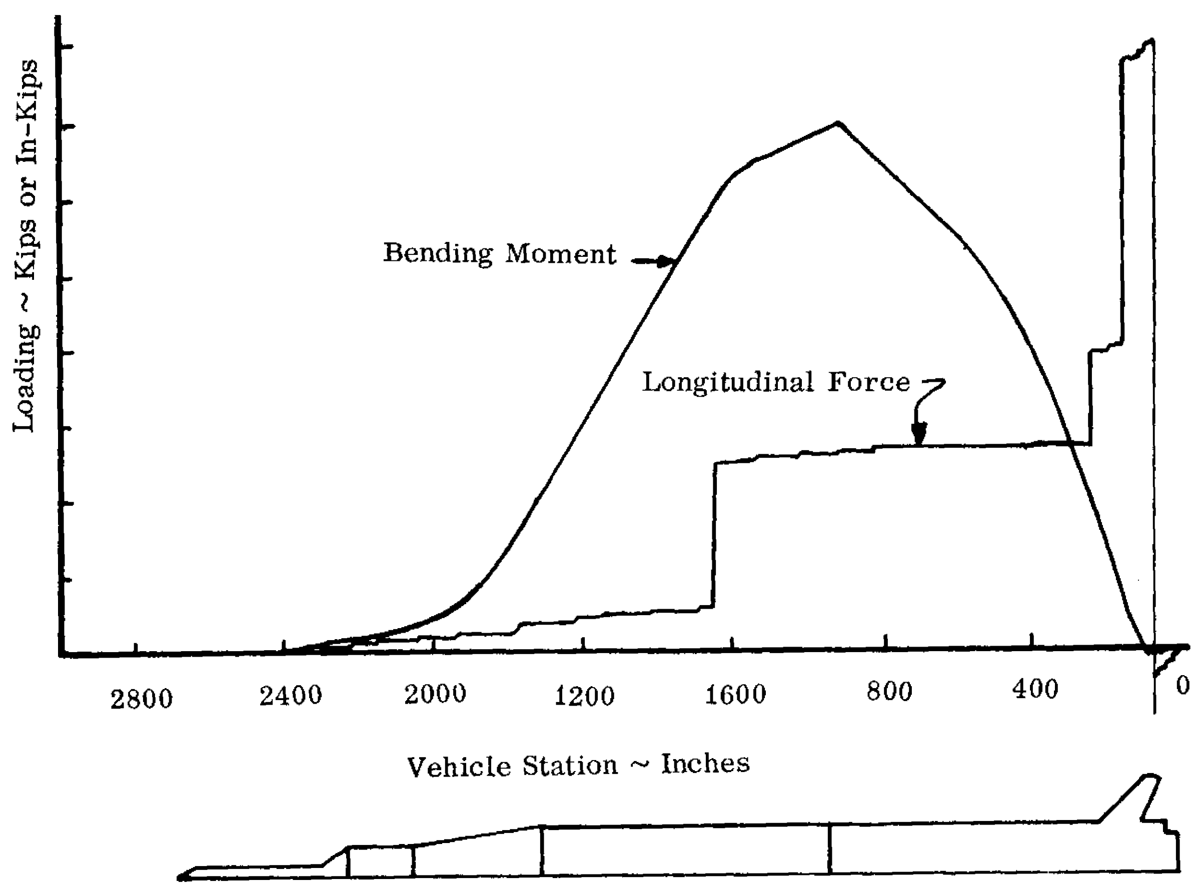


Fig. A2.2.0-1 Typical Bending Moment and Longitudinal Force Distribution Curves.

A2.2.0 Loading Curves (Cont'd)

It is necessary to know the circumferential pressure distribution along the vehicle at times of critical loading. This circumferential pressure is applied to the structure along with the critical loads during strength analysis of the vehicle. Typical distribution of this circumferential pressure at a particular vehicle station may appear as in Figure A2.2.0-2.

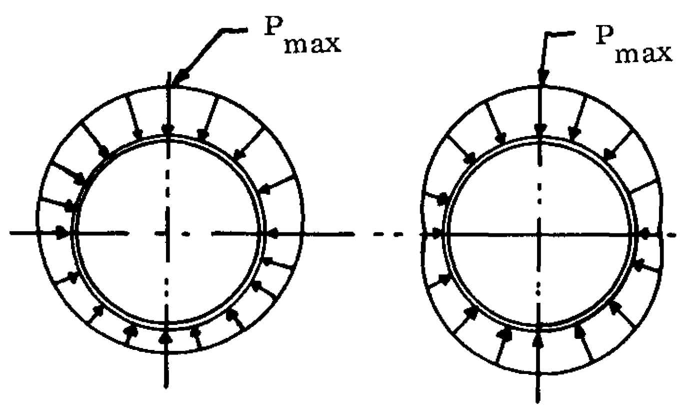


Figure A2.2.0-2 Typical Circumferential Pressure Distribution Curves at a Vehicle Station

A2.3.0 Flight Loads

A2.3.1 General

A space vehicle is subjected to flight loads of varying magnitudes during its flight. These flight loads must be investigated to determine the critical loads on the vehicle. Although it is not possible to know when these critical loads will occur without considering the entire flight history, there are certain times during the flight where conditions exist which are favorable for the build-up of critical loads. These times and the loads which occur may be summarized as follows:

1. Liftoff - As the vehicle lifts off the launch pad there is a sudden application and redistribution of loads on the vehicle. This causes dynamic loads which may be critical.

2. Maximum Dynamic Pressure (Maximum q) - At this time the combination of vehicle velocity and air density is such that the maximum airloads result.

3. Maximum $q\alpha$ - At this time the combination of vehicle velocity, air density and vehicle angle of attack is such that high bending moments due to airloads and vehicle acceleration result.

4. Engine Cutoff - Engine thrust and longitudinal inertia loads are maximum just before cutoff. During cutoff, high dynamic loads may result because of the redistribution of these loads.

A2.3.2 Dynamic and Acoustic Loads

Dynamic loads are loads which are characterized by an intensity that varies with time. These loads may be analyzed by one of two methods. One method is to replace the dynamic load by an equivalent static load, and it is the preferred method for most cases. The other method is a fatigue analysis and it is justified only in those cases where the confidence in the load time-history is good and the design is felt to be marginal.

Acoustic loads are loads induced by pressure fluctuations resulting from extraneous disturbances such as engine noise. The effects of these loads are determined by using an equivalent static pressure load. This equivalent static pressure acts in both the positive and negative directions, since the pressure fluctuates about a zero mean value. This pressure should be combined with the design inflight pressure to obtain the total pressure, and should be considered only in shell or panel stress analysis, not in the analysis of primary or supporting structure.

A2.3.3 Other Flight Loads

Other flight loads, which are caused by pressure and temperature differentials, must be considered in the stress analysis. In addition to the

A2. 3. 3 Other Flight Loads (Cont'd)

longitudinal loads presented in the loading diagrams in Section A2. 1. 1, there is a longitudinal load resulting from the difference between the ambient external pressure and the vehicle internal pressure at any time during flight. The ambient external pressure is a function of the vehicle's altitude only, while the vehicle internal pressure depends on vehicle trajectory and venting effects. These pressures in combination usually produce positive net internal pressures which either increases the tensile or decreases the compressive longitudinal load in the vehicle.

In order to determine the hoop loads at a particular vehicle station, the difference between the local external pressure and the vehicle internal pressure must be known at the desired time. The local external pressure is a function of the angle of attack, dynamic pressure and ambient pressure. The pressure difference may be positive or negative depending on the circumferential and longitudinal location of the point in question and on the range of values used in the aerodynamic analysis. This range of values results in a maximum and a minimum design curve.

Temperature magnitudes and temperature differentials caused by aerodynamic heating, retro or ullage rocket heating and cryogenic propellants result in additional vehicle loads which must be considered. The effects of these temperatures on material properties must also be investigated.

A2. 4. 0 Launch Pad Loads

The vehicle may be subjected to various loads while it is on the launch pad. These loads are referred to as launch pad loads and are generally categorized as follows:

1. Holddown Loads - The vehicle is usually held onto the launch pad by a holddown mechanism during engine ignition. The loads on the vehicle during this time are referred to as the holddown loads.

2. Rebound Loads - During engine ignition it may be necessary to shut down the engines due to some malfunction. The loads on the vehicle as it settles back onto the launch pad are referred to as rebound loads.

A2.4.0 Launch Pad Loads (Cont'd)

3. Surface Wind Loads - While the vehicle is freestanding on the launch pad, i.e., unsupported except for the holddown mechanism, it is exposed to surface wind loads. The magnitude of these loads will depend on the geographical location and should be specified in the design specifications.

4. Air-blast Loads - The vehicle may be subjected to an air-blast load from an accidental explosion at an adjacent vehicle launch site. The potential effect of this air-blast on the vehicle must be determined.

A2.5.0 Static Test Loads

The static test loads are the loads on the vehicle during static testing of the vehicle. These loads are summarized as follows:

1. Engine gimbaling loads

2. Longitudinal loads due to various propellant loadings during the holddown and rebound conditions

3. Wind loads

The dynamic and acoustic loads for static firing tests should also be investigated since they are higher during static test than in flight, in many cases.

A2.6.0 Transportation and Handling Loads

The transportation and handling loads are the loads which occur during transportation and handling of the space vehicle. In the design of the vehicle, these loads are required primarily for the design of tiedown and handling attachments.

A2.7.0 Recovery Loads

The recovery loads are the loads which occur during the recovery of a particular structural component or stage of the vehicle. These recovery loads also include the loads which may occur during descent and impact.