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PRIMARY PROPULSION/LARGE SPACE SYSTEMS INTERACTION STUDY

by J. V. Coyner, R. H. Dergance,
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prepared for

NASA Lewis Research Center
Contract NAS3-21955

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16. Abstract

An interaction study was conducted between propulsion systems and large space structures to determine the effect of low-thrust primary propulsion system characteristics on the mass, area, and orbit transfer characteristics of Large Space Systems (LSS). The LSS which were considered would be deployed from the Space Shuttle orbiter bay in low-earth-orbit, then transferred to geosynchronous equatorial orbit by their own propulsion systems. The types of structures studied were the expandable box truss, hoop and colum, and wrap radial rib-each with various surface mesh densities. The impact of the acceleration forces on system sizing was determined and the effects of single-point, multi-point, and transient thrust applications were examined.

Orbit transfer strategies were analyzed to determine the required velocity increment, burn time, trip time, and payload capability over a range of final acceleration levels. Variables considered were number of perigee burns, delivered specific impulse, and constant thrust and constant acceleration modes of propulsion. Propulsion stages were sized for four propellant combinations; oxygen/hydrogen, oxygen/methane, oxygen/kerosene, and nitrogen tetroxide/monomethylhydrazine, for pump-fed and pressure-fed engine systems. Two types of tankage configurations were evaluated-minimum length to maximize available payload volume and maximum performance to maximize available payload mass.

Integration of LSS, orbit transfer strategy, and propulsion analysis results indicated an oxygen/hydrogen propulsion stage with a pump-fed, multiple burn engine operating at a final (stage burnout) thrust level in the range of 3100 to 4200 N delivers the maximum deployed diameter for the LSS structural concepts which were considered.

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FOREWORD

This report was prepared by the Martin Marietta Corporation, Denver Aerospace, under Contract NAS3-21955. The contract was administered by the Lewis Research Center of the National Aeronautics and Space Administration, Cleveland, Ohio. The study was performed from September 1979 to December 1980 and the NASA-LeRC Project Manager was Mr. D. D. Scheer.

The authors wish to acknowledge the contributions of the following individuals to this program: Mr. A. C. Park and Mr. M. K. Umbreit for their LSS analyses; Dr. D. E. Cornick for the mission analyses; and Mr. M. E. Draznin, Mr. K. M. Hamlyn, and Mr. L. R. Redd for their propulsion system analyses.

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SUMMARY

The interactions of a family of propulsion systems, mission parameters, and Large Space Systems (LSS) have determined the allowable acceleration range, orbit transfer requirements, and stage concepts for movement of LSS from low earth orbit (LEO @ 296 km, 28.5° inclination) to geosynchronous earth orbit (GEO @ 35,889 km, 0° inclination) after deployment from the Space Shuttle.

Three generic classes of LSS - rib, truss, and hoop and column - have been statically and dynamically evaluated to determine the effects of steady state engine thrust and start/shutdown transient accelerations on LSS mass and area. These analyses also included the effects of nonstructural surface masses representative of a broad range of potential LSS payloads. Orbit transfer strategies have been analyzed to determine required velocity increment, burn time, trip time, and payload capability for a range of available accelerations. Variables considered were number of perigee burns, delivered specific impulse, and constant thrust and constant acceleration (throttling) engine concepts.

Propulsion stages were sized for 4 propellant combinations; oxygen/hydrogen, oxygen/methane, oxygen/kerosene, and nitrogen tetroxide/monomethylhydrazine, at 3 mixture ratio points for pump-fed and pressure-fed configurations. The range of propellant loads considered in these analyses was consistent with an acceleration range that was compatible with LSS characteristics and orbit transfer strategies. Two generic classes of tankage configurations were evaluated - minimum length to maximize available payload volume and maximum performance to maximize available payload mass.

Integration of LSS, orbit transfer strategy, and propulsion analysis results indicated an oxygen/hydrogen propulsion stage with a pump-fed, multiple burn engine operating at a final (stage burnout) thrust level in the range of 3100 to 4200 N delivers the maximum deployed diameter for the LSS structural concepts which were considered.

I. INTRODUCTION

The availability of the Space Shuttle Transportation System (STS) in the early 1980s will make it feasible to produce on-orbit Large Space Systems (LSS). Studies performed by various agencies of government (NASA, DOD), Martin Marietta, and the remainder of the aerospace industry forecast that large antennas and platforms will be required either in low earth orbit (LEO) or in geosynchronous orbit (GEO).

In general terms, large space structures are classified as either deployable or erectable, depending upon the process used to place them into operational status. With deployable structures, manufacturing and assembly takes place on the ground, and then the completed assembly is flown into space in a high density folded form where it is deployed. The concept of erectable structures refers to assembly in space either by a building crew or by remote manipulation. Propulsion systems required to transfer these general types of structures from LEO to GEO can be either high or low thrust, depending upon the load bearing capability of the structure which depends upon the method and location selected for the final assembly.

The objective of this study program was to determine the effects of low-thrust primary propulsion system characteristics on the mass, area, and orbit transfer characteristics of Large Space Systems, including basic structural elements as well as nonstructural masses (antenna surface, payload subsystem for a phased array, solar array, etc.) The specific objectives of this program are delineated below:

1) Determine the design characteristics of various classes of Large Space Systems which are impacted by the primary propulsion thrust required to effect orbit transfer;

2) Determine the influence of primary propulsion steady state and transient thrust on the mass and area of designated LSS concepts;

3) Determine the effect of selected primary propulsion system characteristics on deliverable payload mass from low earth orbit to high earth orbit;

4) Determine the characteristics of selected pressure-fed and pump-fed stages for orbit transfer of LSS and the effect of these stages and Space Shuttle constraints on mass and volume available for packaged Large Space Systems; and

5) Determine relative merits of selected primary propulsion systems in terms of deliverable LSS mass, area, and/or length available for payload in the Orbiter cargo bay.

The technical effort is divided into five separate tasks which are summarized in the following paragraphs.

Task I - CHARACTERIZATION OF LARGE SPACE SYSTEMS

The objective of this task was to establish and compile those design characteristics of various classes of Large Space Systems (LSS) which affect the mass/area relationship of the system and which were affected by the primary propulsion thrust necessary in the orbit transfer of the system. The generic classes of LSS to be considered in this study included platforms, booms, paraboloids, and hybrids of these three categories. Since there were a variety of structural concepts, both deployable and erectable, within each class and a variety of potential mission requirements were satisfied by these various configurations, this task considered mission-peculiar parameters, such as antenna surface mass and other components, that affect structural response in determining the LSS concepts recommended for further evaluation.

Task II - THRUST AND THRUST TRANSIENT EFFECTS

The objective of this task was to conduct parametric analyses of the recommended concepts from Task I to determine the influence of primary propulsion thrust on LSS mass and area.

The results of this task provided the following data:

1) LSS concept mass as a function of area and thrust-to-mass ratio (T/M) assuming constant thrust and a single point of thrust application;

2) The effects of startup and shutdown thrust transient on the results determined in (1) above. Thrust was assumed to vary linearly with time, and the time interval ranged from instantaneous application or unloading of thrust to a time at which transients do not influence the LSS mass and area;

3) LSS concept mass as a function of area and thrust-to-mass ratio assuming constant thrust and multiple points of thrust application.

Task III - PROPULSION SYSTEM PERFORMANCE

The objective of this task was to parametrically determine the deliverable mass and engine burn times as functions of thrust-to-mass ratio and number of engine burns when transferring the LSS from low earth orbit (LEO) at 296 Km circular at 28.5° inclination to geosynchronous earth orbit (GEO) at 35,889 Km circular at 0° inclination.

Analyses in this task assumed a start burn mass of 27,200 Kg for the expendable stage plus payload and was conducted over the study range of T/M generated in Task II.

Task IV - PROPULSION SYSTEM MASS AND VOLUME

The objective of this task was to determine the characteristics, including mass fraction, length, diameter, and center of gravity, of selected pressure-fed and pump-fed propulsion stages for low-thrust orbit transfer of Large Space Systems and to determine the influence of these stage characteristics and Space Shuttle constraints on the mass and volume available for packaged large space systems.

The range of loaded stage mass for which the parametrics were generated were based on the results of the previous tasks, and, in particular, Task III. The recommended T/M ratio range was based on the results of Task II.

Stage configurations were developed for the following propellant combinations and associated mixture ratios (MR):

1. oxygen/hydrogen (LO_2/LH_2) - MR from 5 to 7;

2. oxygen/methane (LO_2/LCH_4) - MR from 3.4 to 4.0:

3. oxygen/kerosene (LO_2/RP-1) - MR from 2.8 to 3.2; and

4. nitrogen tetroxide/monomethylhydrazine (N_2O_4/MMH) - MR from 1.8 to 2.6.

For each propellant combination shown above, conventional and minimum length tankage configurations were evaluated for pressure-fed and pump-fed engines.

Task V - PROPULSION SYSTEM COMPARISONS

The objective of this task was to determine the relative merit of the various primary propulsion system characteristics studied in Task II, III, and IV for each of the LSS concepts.

The primary factors used in establishing the relative merit of the various primary propulsion characteristics were deliverable LSS mass and area and/or length available for payload in the Orbiter cargo bay.

II. CHARACTERIZATION OF LARGE SPACE SYSTEMS

Characteristics of Large Space Systems (LSS) that are influenced by primary propulsion thrust had to be determined in sufficient detail that representative concepts and variations in design characteristics could be recommended for study in the remainder of the program.

An extensive literature search of 110 documents and subsequent evaluation and characterization of LSS concepts and missions resulted in three generic configurations being selected as most representative of a broad spectrum of requirements. Key variables considered in the evaluation process were:

- o Mission parameters as manifested by:
  - LSS Diameter
  - Operational Altitude
  - Surface Mass Density (Kg/m^2)
  - Thrust-to-Mass Range
- o Structural Configuration:
  - Structural Mass Density, Mass/Deployed Surface Area (Kg/m^2)
  - Stowage Density (Kg/m^3)
  - Deployed Stiffness and Load Paths
  - Point of Thrust Application

A. Mission Parameters

Table II-1 presents the various applications as they relate to diameter, operational altitude, and configuration (dish, boom, or planar system). Typical missions are:

PSCS	- Personal Communication Spacecraft
ODSRS	- Orbiting Deep Space Relay Station
RADIOMETRY	- Earth Resources
SETI	- Search for Extraterrestrial Intelligence
RA	- Radio Astronomy
VLBI	- Very Long Baseline Interferometer
SBR	- Space Based Radar
SPS	- Space Power Satellite Power Generation

From these typical missions for planar and dish systems, a generic set of surface mass densities was derived which encompass the broad spectrum of requirements.

The low RF frequency ($<$ 20 GHZ) antenna surface (mass density = 0.05 Kg/m^2) is of a gold plated, 1.2 mil molybdenum wire, tricot knit mesh with a secondary drawing surface. The high RF frequency ($>$ 20 GHZ) antenna surface mass density of 3.42 Kg/m^2 is typical for a 1.3 cm thick honeycomb sandwich panel with graphite epoxy face sheet and metallized reflective surface. The radar antenna surface mass density of 0.15 Kg/m^2 is typical for a three layer phased array lens which includes the collecting surface, ground plane surface, radiating surface and distributed phase shifting RF modules. The power generating surface (mass density = 0.40 Kg/m^2) represents deployable lightweight solar array technology.

One potential mission that is not a continuous surface on a structure is the space-based geosynchronous platform. This system is typically a

TABLE II-1- LSS MISSION PARAMETERS, OPERATIONAL ALTITUDE AND DIAMETER (REF II-1)

	Applications		Potential Requirements
Dishes	Communications	Earth	30-m LEO, 100-m GEO
		Deep Space	30-m GEO, 200-m GEO
	Earth Observations	Resources	100-m GEO, 300-m GEO
		Recon-Optical	15-m GEO
	Exploration	SETI	30-m LEO, 300-m GEO, 3000-m GEO
		Astronomy	20-m GEO, 100-m GEO
	Power Transmission-Optical		30-m GEO
	Power Generation		1-Mile GEO
Booms	Position Finding		2-Mile GEO
	Communication, Low Freq		1-km LEO
Planar Surfaces	Propulsion Solar Sail		800-m
	Power Transmission		1-km GEO
	Communication/Facscimile Transmission		30-m GEO, 100-m GEO, 300-m GEO
	Power Generation		30-m GEO/LEO
	Power Generation		10-km GEO
	Illumination		1-km GEO
	Space Radar		200-m GEO

1980 1985 1990 1995

truss-type platform with lumped mass payloads at the hard points on a truss. However, this configuration can be represented by the power generation and high frequency surface mass density parameters. For example, by lumping the 0.40 Kg/m^2 surface at the hard points of a box truss with 8.84m member sizes, an equivalent lumped mass platform payload of 31 Kg per node is obtained. By lumping 3.42 Kg/m^2 surface at the hard points of the truss, an equivalent lumped mass platform payload of 267 Kg per node is obtained. Therefore, science or communication platforms with payload lumped masses from 31 Kg to 267 Kg are represented by the selected surface mass densities.

B. Structural Parameters

Fourteen structural configurations were identified from the literature search (see Table II-2). The objective was to select from these concepts three configurations that represent the wide variety of structural and dynamic configurations. The majority of the fourteen concepts can be summarized into three generic classes of structure -- radial rib, hoop and column, and truss. Consequently, a representative structural concept within each generic class was selected.

The wrap radial rib was selected for rib-type structures. This concept has the most efficient stowage density of all the radial rib configurations, is the most mature in design development, is capable of diameters to 200 meters, and is relatively light compared to other radial rib systems.

The wrap-rib antenna consists of a hollow, doughnut-shaped hub to which a series of radial ribs, formed to the shape of a parabola, are attached. A lightweight reflective mesh is stretched between these ribs to form the paraboloidal reflecting surface. The feed system is usually located at the prime focus of the paraboloid by one or more deployable support booms. A sketch of the deployed wrap-rib antenna is shown in Figure II-1. To furl the reflector, the ribs are wrapped around the hollow hub with the mesh folded between them (Figure II-2).

The parabolic surface is formed by a flexible, lightweight reflective mesh supported along each of the radial ribs. The number of ribs or mesh panels used is dependent upon the desired root mean square (rms) surface accuracy, which, in turn, determines the gain of the antenna excluding the losses due to blockage by the feed support structure.

The hollow, doughnut-shaped support hub has mounting pads to interface the antenna system with a spacecraft or the Shuttle. It provides the support points for each radial rib and stowage area for the radial ribs and the reflective mesh. The hub supports the "in space" deployment and refurl mechanism as well as an "in space" surface-contour evaluation and adjustment system if such a system is used.

The flexible ribs are wrapped around a power-driven rotating spool that constrains the stored energy of the wrapped ribs and deploys the reflector surface at a controlled rate. The furling mechanism uses a sliding guide to "wipe" the ribs in a rotating manner back into their stowed configuration. The stowed configuration may be as small as one-fortieth of the deployed diameter of very large antennas. The stowed configuration also lends itself to high load-carrying capability.

TABLE II- 2 - STRUCTURAL CONFIGURATIONS

CONCEPT	ORGANIZATION	DIAMETER* RANGE, M
UMBRELLA RADIAL RIB DOUBLE MESH ANTENNA	HARRIS (REF II-2)	3-25
WRAP RADIAL RIB ANTENNA	LOCKHEED (REF II-3)	30-200
ERECTABLE RADIAL RIB ANTENNA	GENERAL (REF II-4) DYNAMICS	30-200
RADIAL COLUMN RIB ANTENNA	HARRIS (REF II-2)	20-100
ARTICULATED RADIAL RIB ANTENNA	HARRIS (REF II-2)	20-40
MAYPOLE ANTENNA	LOCKHEED (REF II-5)	30-300
HOOP & COLUMN	HARRIS (REF II-2)	30-300
HOOP & COLUMN RADAR	GRUMMAN (REF II-6)	30-200
EXPANDABLE TETRAHEDRAL TRUSS ANTENNA	GENERAL (REF II-3) DYNAMICS	10-175
EXPANDABLE BOX TRUSS ANTENNA	MARTIN (REF II-7) MARIETTA	10-250
SUNFLOWER SOLID PANEL ANTENNA	TRW (REF II-8)	5- 20
EXPANDABLE ASTROCELL MODULE	ASTRO RESEARCH/ LANGLEY	5-100
ELECTROSTATIC MEMBRANE	GRC (REF II-9)	5-200
EXPANDABLE BOX TRUSS PLATFORM	MARTIN (REF II-7) MARIETTA	5-100

Note: Diameter limitations refer to single orbiter packaging with an orbit transfer vehicle.

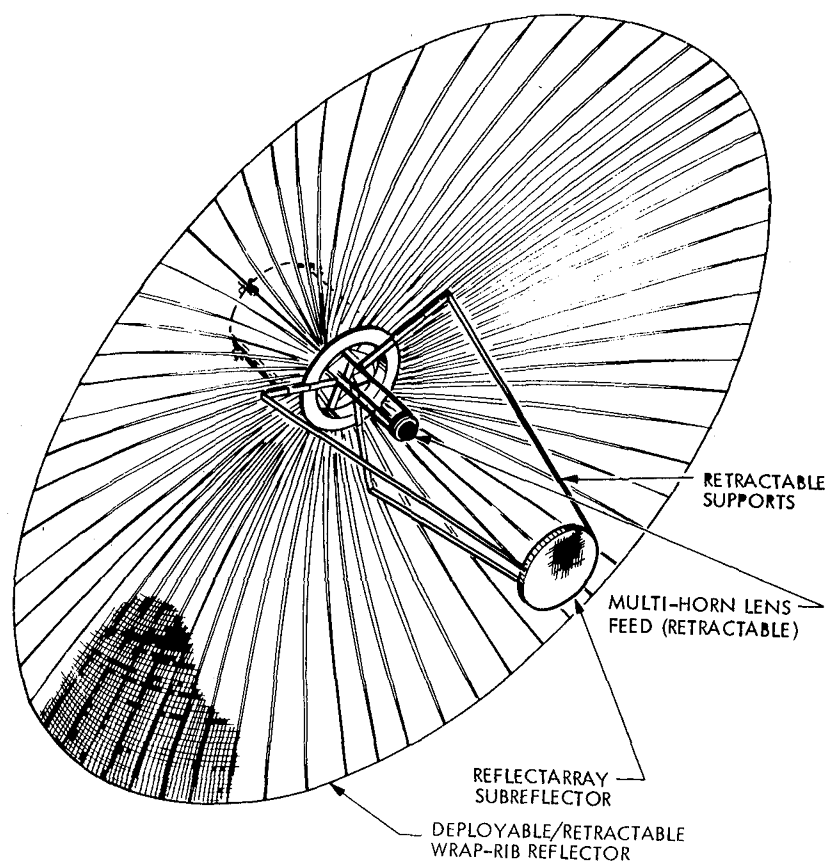


FIGURE II-1-TYPICAL LOCKHEED WRAP-RIB ANTENNA: DEPLOYED CONFIGURATION (REF II-5)

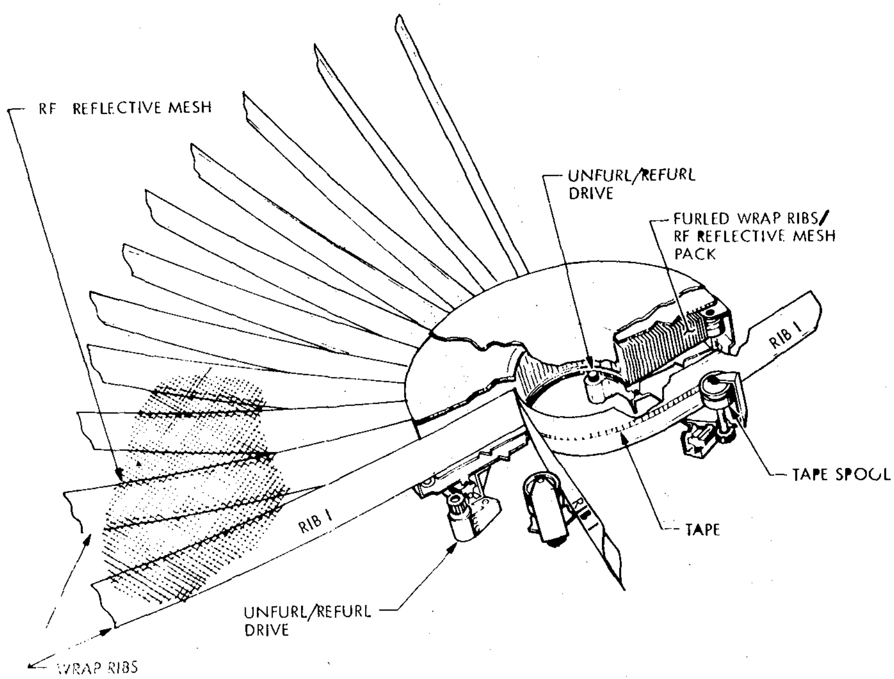


FIGURE II-2 LOCKHEED WRAP-RIB ANTENNA: FURLING MECHANISM (REF II-5)

The feed or feed array used with this concept is dependent upon the reflector size and intended use. It may be a single horn illuminating the total surface; a cluster of horns, each illuminating a portion of the reflector surface, but forming one coherent beam; or a cluster of feeds forming individual spot beams. The cluster of feeds also may be replaced by a phased array used as a feed for either single or multiple beams or to generate specially shaped or steerable beams.

Dependent upon reflector size, the deployable feed support structure could be a simple, powered, folding structural boom; a structurally formed boom that is elastically buckled for storage on powered spools; a modified scissors structural-type boom that is powered for extension and retraction; or some type of telescoping boom. The boom will use conventional thermal control or will be built from materials with low coefficients of thermal expansion to ensure precise positioning of the feeds under varying thermal environments.

The diameter range of the wrap radial rib is 30-200 meters where the actual maximum diameter is limited by the payload and stowage limits in the Orbiter. The primary mission application is a low frequency, large diameter reflector with a surface density of 0.05 Kg/m^2, however the radar surface mass of 0.15 Kg/m^2 was also analyzed. The point of thrust application is at the center of the hub along its longitudinal center line.

For the hoop and column concept, the Grumman planar phased array and the Harris reflector concept were selected. The Grumman approach is typical of planar structure for arrays or solar collectors, and the Harris approach is typical of curved reflector surfaces (Figures II-3 and II-4).

The Grumman space-fed phased-array concept is intended for design up to 200 meters in diameter for operation at L-band or S-band. Grumman developed this concept to the point of a preliminary design for a 60 m diameter antenna and a 1.3 m diameter mechanical model. The mechanical model was used to demonstrate and evaluate the basic mechanical conceptual design. Detailed design of a 200 m antenna was used in a NASTRAN finite element analysis, static and dynamic, to determine the tolerance-holding properties of the design. It was determined that tolerances can be held well under one one-hundreth of a wavelength at L-band.

The Grumman antenna concept is a planar-type array whose basic support structure is a "wire-wheel" type configuration. This concept development was centered around the design of 61 m diameter and 200 m diameter space-fed, phased-array antennas for operation at L-band.

The basic elements of the support structure include the drum, rim assembly, fore and aft stays, and telescoping mast. The phased array itself is composed of 32 to 72 gore panel assemblies and their tensioning devices. The compression rim assembly is located and supported about the drum by the spring-loaded radial stays that extend from the rim to reels located on the drum assembly. This basic configuration is the "wire-wheel". The antenna drum for the 61 m antenna is 7.1 m long and 1.47 m in diameter, and is fabricated principally of aluminum alloy in frame-reinforced, thin-skin cylindrical configuration. Two support rings, external to and supported by the drum, and a multiplicity of antenna gore edge/batten support studs transfer the deployable hardware launch loads to the primary structure. The compression rim assembly is composed of 32 thin-wall graphite/epoxy tubes, 5.96 m long and 10.2 cm in diameter. The radial stays are graphite/epoxy

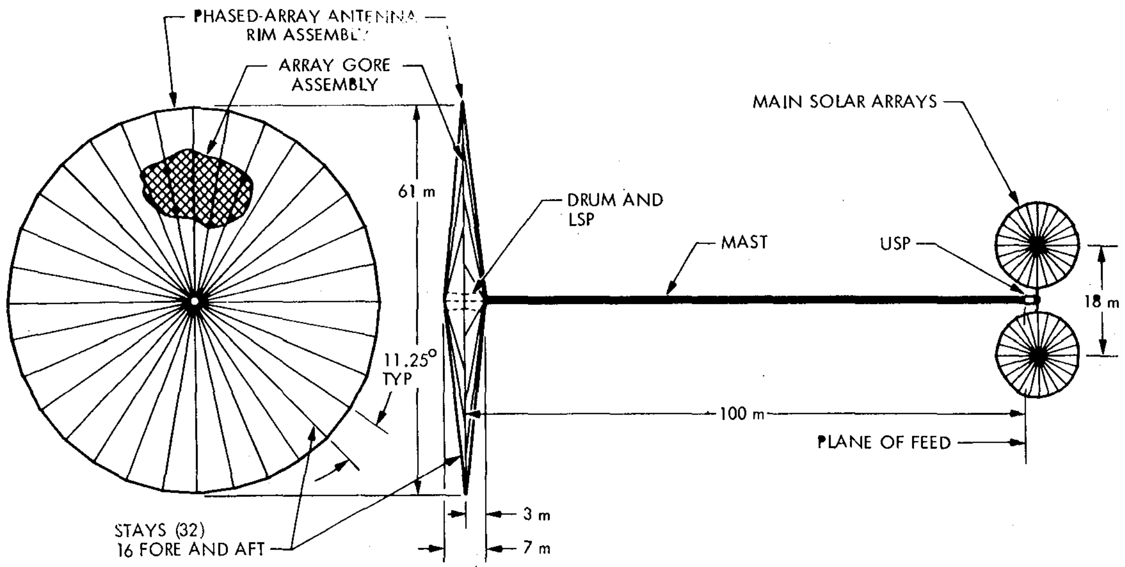


FIGURE II-3 BASIC STRUCTURAL ELEMENTS OF GRUMMAN PHASED-ARRAY CONCEPT (REF II-10)

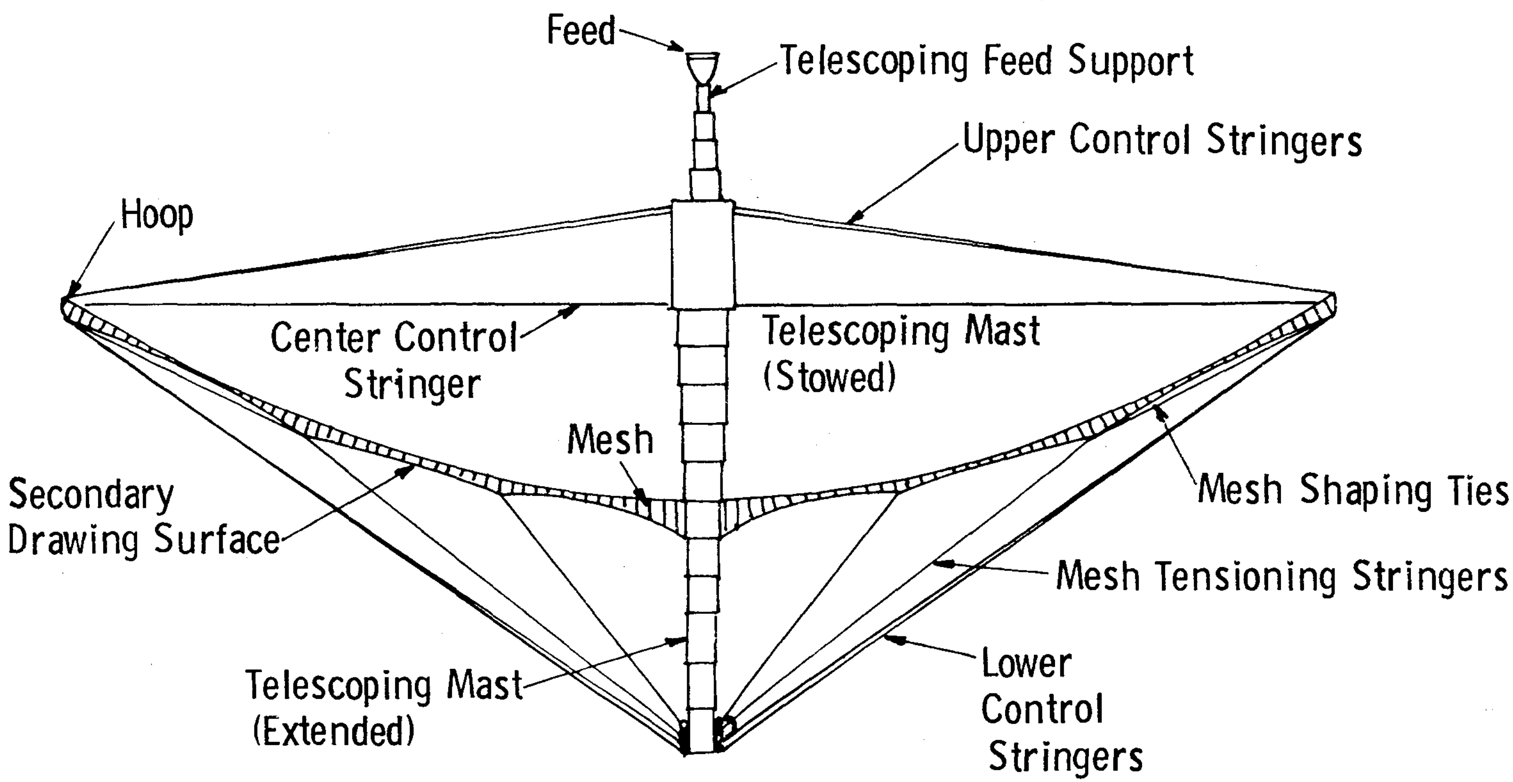


FIGURE II-4 HARRIS HOOP AND COLUMN CONCEPT
(REF II-10)

strips, 0.015 by 2.5 cm. The gore panel assemblies are tensioned between the rim and the drum so that they form a plane. Operation of the antenna at L-band requires a rim assembly radial tolerance of the radiating elements of less than 0.8 cm and axially less than 4.6 cm.

A 91.4 m Astromast locates and supports the antenna feed system and power source which consists of two deployable 14.2 m diameter solar arrays that are based on the same deployable antenna concept. The Astromast canister is located within the drum structure. This concept is also applicable for a large solar cell array power system.

The Harris Corporation hoop and column reflector antenna concept for self-erectable structures is intended for reflector designs up to 100 m in diameter (Figure II-4). This concept has been developed to the point of a preliminary design for sizes up to 45.7 m in diameter and a 1.8 m diameter conceptual demonstration model. This 1.8 m mechanical model was used to verify the basic conceptual design in addition to leading to solutions of the kinematic problems associated with deployment. The preliminary design has been complemented with the development of analytical techniques for prediction of antenna performance for larger size structures.

The fundamental elements of the support structure include the hoop; upper, lower, and center control stringers; and the telescoping mast. The reflector consists of the mesh, mesh shaping ties, secondary drawing surface, and the mesh tensioning stringers. The basic antenna configuration is a type of "may-pole", with a unique technique for contouring the RF reflective mesh.

The hoop's function is to provide a rigid, accurately located structure, to which the reflective surface attaches. It is comprised of 40 rigid sections which articulate at hinges joining adjacent segments. These segments consist of two tubular, graphite fiber members parallel to each other and attached to a long hinge member at each end. These long hinges allow the separation between the tubular members of the hoop segment required by the geometry of the mesh-secondary drawing surface. Torsion springs located in each hinge supply the total energy required to deploy the hoop.

The central column or mast is deployable and contains the microwave components and control mechanisms. It consists of tubular graphite/epoxy shell members that nest inside each other when stowed. Aside from housing various components, the mast provides attachment locations for the reflective surface and the stringers.

Five sets of stringers are used on the hoop and column concept. Three of these sets are used for hoop deployment and its control; the other two sets are used for mesh shaping. The hoop-control stringers are located at the upper end, the center, and the lower end of the extendible mast; they extend radially outward to their attachment positions at the hinges of the hoop. The upper and lower control stringers accurately position the hoop throughout its deployment. The center control stringers are used for rate control during deployment and for moving the hoop joints toward the mast and against their spring forces during the automated stowing sequence. The remaining two sets of stringers (mesh tensioning stringers) are located just above the lower control stringers and are used to shape the reflective surface into the proper contour. All of these stringers are made of stranded quartz cords for high stiffness and thermal stability.

The reflective surface is produced by properly shaping a knitted mesh fabric. The mesh is made of 0.03 mm diameter, gold-plated molybdenum wire. The mechanism that permits shaping of the mesh consists of numerous radial quartz stringers to which the mesh is directly attached (mesh surface stringers) along with a similar set of stringers (secondary drawing surface stringers) positioned beneath them. Short ties (mesh shaping ties) made of Invar wire connect the RF mesh surface stringers to the secondary drawing surface stringers. When the RF mesh tensioning stringers are tensioned, they in turn tension both the secondary drawing surface stringers and the mesh shaping ties to produce an essentially uniform pressure distribution of the mesh. This pressure distribution allows shaping of the mesh to a good approximation of a parabolic curvature. The surface accuracy is affected by the number and spacing of the mesh shaping ties. The greater the number of ties, the greater the surface accuracy.

Two groups of drive mechanisms are used in the hoop and column concept. One group, used to extend the mast, consists of one basic set of mechanisms for each section of the telescoping mast. The second group of drive mechanisms is used to adjust the control stringers and consists of motor-driven spools to which the stringers are attached. There are five sets of spools, one for each group of stringers. The spools are used to retract and discharge the stringers during the deployment and stowing sequence and are positioned around the mast in the locations described for the stringer attachments. A torque motor drives each set of spools independently, as required by the specific position and velocity of the hoop joint being controlled.

The diameter range of the hoop and column is 30-300 meters where the actual maximum diameter is limited by the payload and stowage volume in the Orbiter. The primary mission applications are a low frequency, large diameter reflector, a planar space based radar, and a planar solar array platform (surface mass density range of 0.05-0.15-0.40 Kg/m^2). The point of thrust application is at the lower end of the telescoping mass, perpendicular to the deployed hoop.

For the truss concept, the box truss structure was selected (Figure II-5). This concept has the most efficient stowage density of all the truss concepts, is capable of diameters in excess of 200 meters, and is relatively light compared to other truss concepts.

Figure II-6 illustrates the basic concept's operating principle. Vertical members connect the front and back surfaces of the truss and carry support posts upon which the surface is mounted. Surface tubes, hinged in the middle, connect each vertical member to each adjacent member. Each truss square, composed of surface tubes and vertical members, is stabilized by diagonal tension tapes. For stowage, each surface tube folds about its mid-link hinge and the diagonal tapes telescope.

Structural deployment is accomplished in low earth orbit (LEO) near the Orbiter in a sequence of controlled steps. Following verification that each step has been completed successfully, the next set of rows is deployed. Symmetrical pairs are always deployed simultaneously to balance reaction forces. This preserves the deploying structure's attitude and center of gravity position.

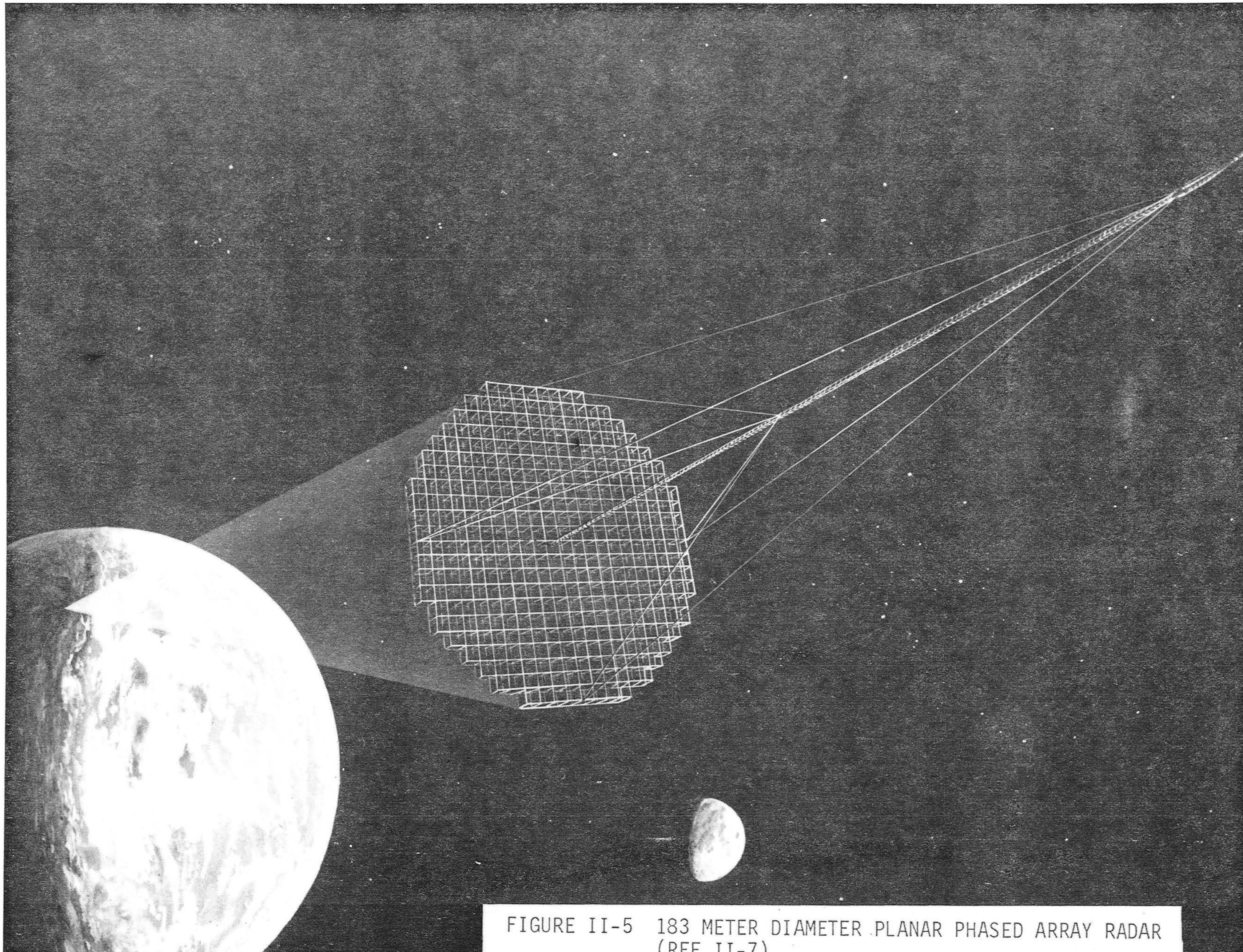


FIGURE II-5 183 METER DIAMETER PLANAR PHASED ARRAY RADAR (REF II-7)

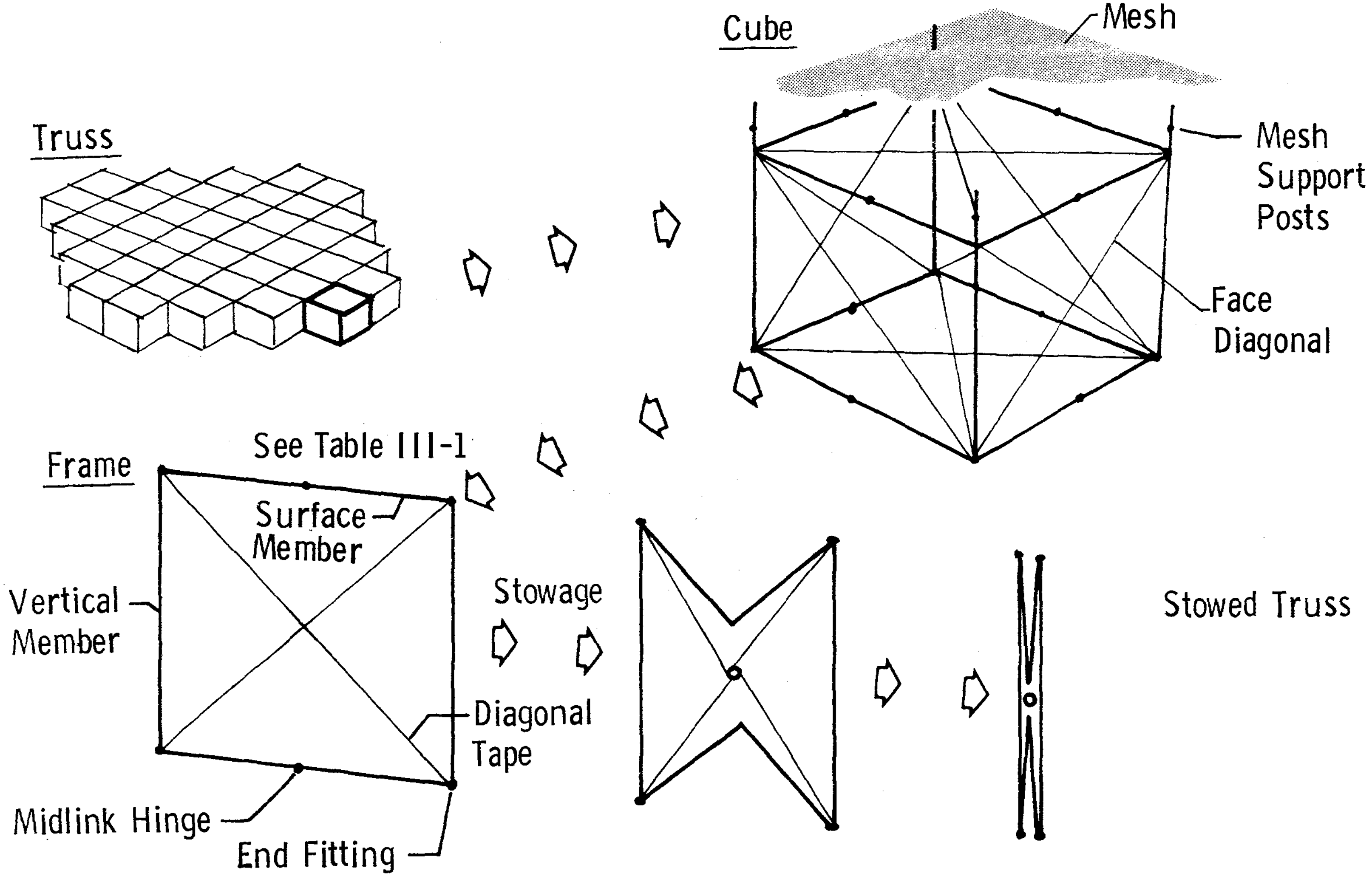


FIGURE II-6-DEPLOYABLE BOX TRUSS STRUCTURE

Prototype designs for all structural members and mechanisms have been defined. Electrically controlled, redundant deployment release latches connect each vertical member's end fitting to the neighboring stowed vertical member's end fittings. These latches provide the desired controlled release sequence. Redundant coil springs in the mid-link hinges drive the deploying structure. As each surface tube swings out to its deployed condition, a spring-loaded latch in the mid-link hinge locks the tube straight and provides the impulse necessary to tension the diagonal tapes and surface.

Deployment dynamics analyses have been made for typical cube faces throughout the deploying truss. Since boundary conditions vary from cube face to cube face, e.g., the outboard mass being accelerated by a given cube face's springs varies, the spring torque profiles are tailored to their locations in the truss. The springs are sized by three requirements: (1) with all springs operating at ten percent over nominal (energy input), the surface tubes are not overstressed; (2) with one spring out of each pair of redundant springs failed, enough energy is still available to deploy each cube face and tension its diagonal tapes and array surface; and (3) with nominal spring performance, all cube faces in a given row or column will deploy at the same rate. Typically, a row or column requires approximately 45 seconds to deploy.

Various types of antenna surfaces have been considered for large aperture spaceborne antennae. These range from simple RF reflective meshes to multi-layer phased arrays that include power distribution and subarray electronic modules. The concept for array surface stowage on the deployable box truss involves double-accordion pleating. One set of pleats is parallel to the truss column direction, and the second set, at ninety degrees to the first, parallels the rows. The small row pleats unfold as the rows are deployed, leaving the larger column pleats still folded. The latter then unfold sequentially as the column deployment steps take place.

This array folding concept, with its orthogonal fold lines, accommodates mesh surfaces easily and, more importantly, allows the surface to contain regularly-spaced, non-foldable objects such as subarray electronic modules. In the case of the planar phased array surface, these modules are located on .76 meter centers throughout the surface. The column fold lines on 1.5 meter centers and the row fold lines on .15 meter centers are located to avoid all of the modules. This concept is also applicable for support of flexible solar arrays.

The diameter range of the box truss is 30-200 meters where the actual maximum diameter is limited by the payload and stowage volume in the Orbiter. The primary mission applications are a low frequency, large diameter reflector, a planar space based radar, a planar solar array platform, and a science or communications platform (surface mass densities 0.05-0.15-0.40-3.42 Kg/m^2). The point of thrust application is at the center of the truss, perpendicular to the deployed plane.

C. Summary of LSS Concepts

Table II-3 summarizes the three LSS concepts which were selected as the baseline configurations for this study. Comparisons of the three classes are presented for diameter range, surface mass densities, point of thrust application, and applicable thrust to mass (acceleration) range.

TABLE II-3- SUMMARY OF LSS CONCEPTS

Concept	Diameter Range (M)	*Surface Mass Density (Kg/M^2)	Point of Thrust Application	T/M (g's)
Wrap Radial Rib	30-200	0.05-0.15	Hub	0.02-1.0
Hoop and Column	30-300	0.05-0.40	Aft end of mast	0.01-1.0
Expandable Box Truss	30-200	0.05-3.42	Center of Structure Normal to Plane	0.02-1.0

*Values are representative of typical missions:

0.05 for low frequency mesh type antennae
0.15 for radar antennae
0.40 for solar cell collectors
3.42 for high frequency antennae (aluminized honeycomb panels)

From these baseline configurations, parametric studies of LSS mass as a function of area and thrust-to-mass ratio were conducted for steady state and transient thrust effects.

III. THRUST AND THRUST TRANSIENT EFFECTS

The objective of this activity was to determine the effects of acceleration (thrust-to-mass) on the area and mass of the previously defined LSS concepts. In order to completely evaluate the interaction of propulsion systems and the LSS, steady-state and transient analyses were performed.

The principal activities were performed for single points of thrust application as described in Section II for the wrap radial rib, hoop and column, and expandable box truss. In addition, the effects of distributed thrust (multiple points of application) were determined for the hoop and column and expandable box truss LSS concepts.

The steady-state analysis (flow chart shown in Figure III-1) begins with the generation of structural finite element models upon which an inertial load (thrust-to-mass ratio) was applied. Structural members were sized to carry their individual loads and the nonstructural mass for mission-related equipment for each LSS concept over a range of mass, area, and thrust-to-mass ratio. To perform the steady state sizing analysis and identify the acceleration level at which the members and mass are impacted by the propulsion system thrust, a minimum member size and mass was determined.

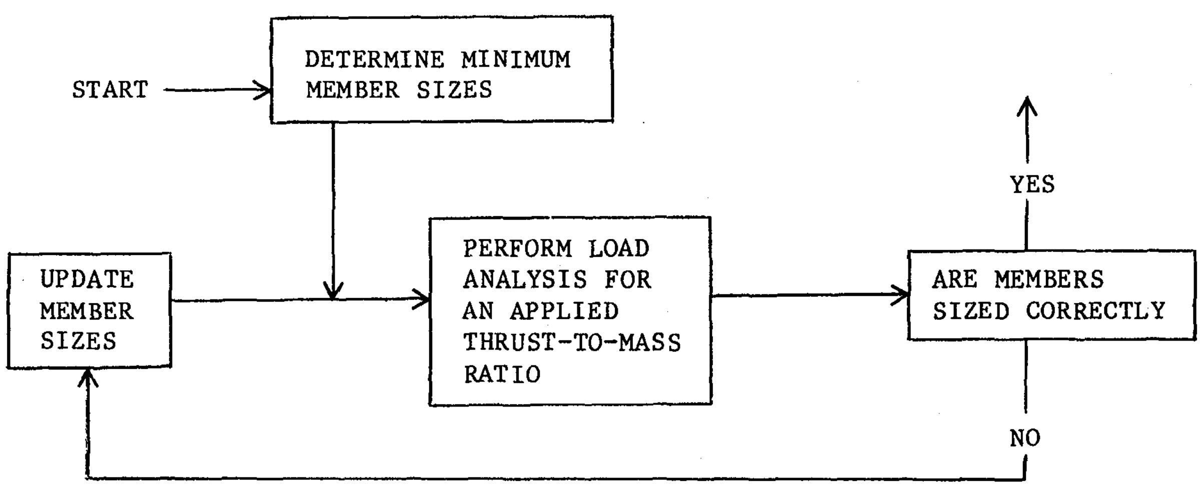


FIGURE III-1 - STEADY STATE ANALYSIS FLOW CHART

Designed as a minimum mass system, structural impacts due to acceleration forces were determined. The output of these analyses were dynamic models used for the transient thrust effects and parametric data which characterize the LSS mass and area as a function of thrust-to-mass ratio. The parametric data generated determined the effect of thrust-to-mass ratio on the LSS mass as a function of area and the effect of LSS diameter on LSS mass as a function of thrust-to-mass ratio.

The engine start and/or shutdown thrust transients on the last orbit transfer (apogee) burn can impose transient loads induced by the propulsion system to the structure, which could be greater than the steady-state loads at the burnout thrust-to-mass ratio. To complete this task, the effect of the engine thrust transients on the LSS was determined from the dynamic models upon which various engine ramp times were imposed. Displayed in Figure III-2 is the flow chart for the thrust transient effects analysis.

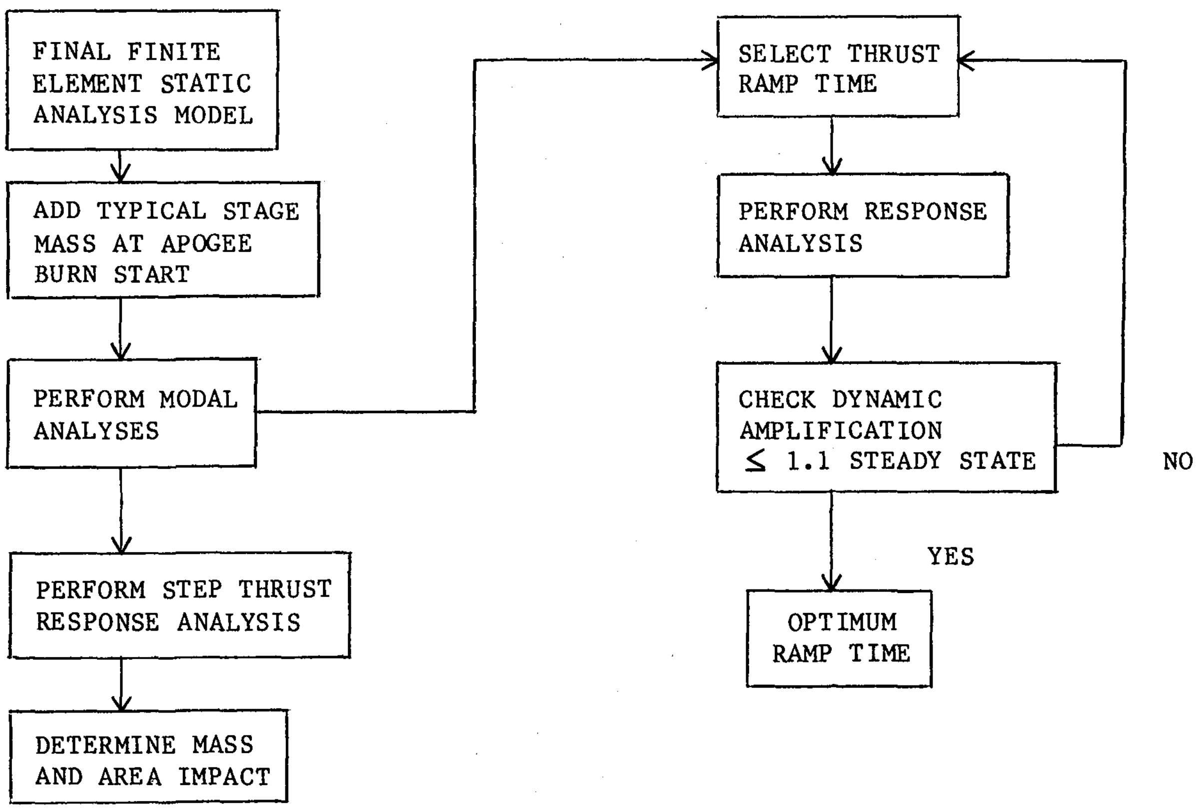


FIGURE III-2 - THRUST TRANSIENT EFFECT ANALYSIS FLOW CHART

This effort was performed under the following guidelines:

1) For single Point-Thrust application thrust assumed to vary linearly with time;
2) Transient time of thrust application variable from instantaneous loading to that time when thrust transients do not influence previous results;
3) Representative configurations were used for three LSS concepts; and
4) Results were extrapolated for the remaining configurations.

Additional results of the thrust transient analysis for multi-point thrust application to assess the effect of dispersed thrust were obtained for the expandable box truss and hoop and column. The wrap radial rib does not have the supportive structure necessary for multi-point thrust applicability. It follows that the wrap radial rib will not be discussed in the multi-point thrust section.

The previous topics will be discussed in the following sections for each Large Space System class.

A. Box Truss Analysis

1. Assumptions and Approach

An automatic model generator was used to create finite element models for both the static parametric analysis and the transient dynamic analysis.

The NASTRAN finite element model consisted of rod elements (one per member) with 3 degrees of freedom per node. A quarter segment of the LSS (Figure III-3) was modeled with symmetric load conditions. The structural mass, nonstructural mass, and fitting mass were lumped at the nodes. A 20% margin was applied to the mass of all structural members.

Fitting mass was constant, consisting of an end fitting mass per node of 1.36 kg and a surface member (see Table III-1) mid-deployment hinge mass of 0.54 kg. From previous studies, a truss depth of 8.84 meters was derived from a representative available payload length in the Orbiter cargo bay. A minimum mass system member was sized to be no smaller than 3.8 cm diameter by 0.044 cm thickness. Strength analysis of the members incorporated minimum material properties (shown in Table III-1) and a 1.5 safety factor. Allowable failure modes of the structure included Euler column and local buckling, and material yield.

The inertial loads were applied to the nodes to simulate orbit transfer. The analysis allowed one set of diagonals to go slack during transfer. It follows that the stiffness characteristics of the slack diagonals were not included in the finite element model but their mass was included. The diagonal members were sized based on a 1/6 effective axial stiffness of surface members in the cube face.

2. Box Truss Steady State Analysis

Listed in Table III-2 are those cases which were subjected to steady-state analysis.

Each finite element model was optimized for the appropriate acceleration level and surface density. The structural optimization for each acceleration level utilized members from Table III-1. Six tubular surface members and their respective six face diagonals were identified. Five cruciform vertical member sizes were identified. The surface diagonals which are on the front and back surfaces of the truss were all 0.084 cm^2 in area.

The results from the steady-state analysis are presented in Figures III-4 through III-7. Figure III-4 illustrates a representative structural

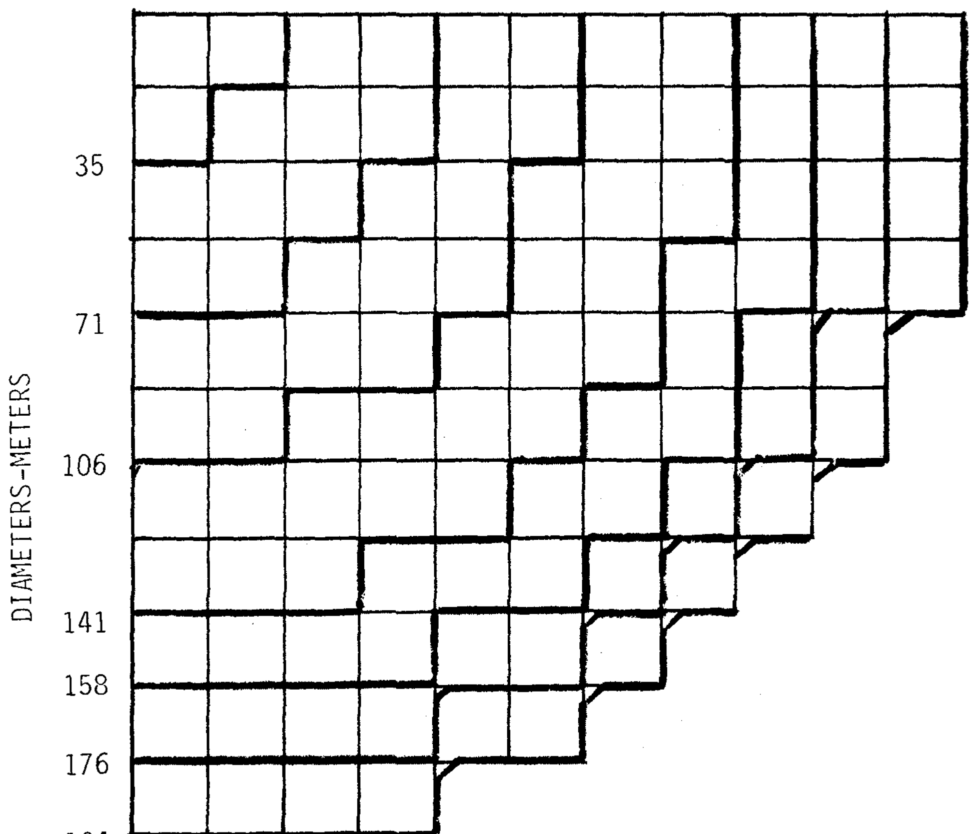
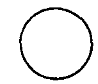
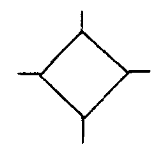


FIGURE III-3 BOX TRUSS QUARTER SEGMENT MODELS

TABLE III-1 MEMBER PROPERTIES (8.84 METER MEMBERS)

MEMBERS	DIMENSIONS (cm)	CROSS SECTION	ALLOWABLE LOADS (N)
<u>SURFACE MEMBERS</u>			
($E = 103 \times 10^9$ N/m^2)			
($\rho = 2000$ Kg/m^3)			
1-	3.81 X 0.044		80
2-	5.08 X 0.044		200
3-	7.11 X 0.044		540
4-	7.11 X 0.112		1370
5-	7.11 X 0.224		2750
6-	7.11 X 0.559		6870
<u>VERTICAL MEMBERS</u>			
($E = 103 \times 10^9$ N/m^2)			
($\rho = 2000$ Kg/m^3)			
	Box Section & Flanges		
A-	3.18 X 0.044 & 0.635 X 0.089		140
B-	3.18 X 0.044 & 1.905 X 0.089		390
C-	3.18 X 0.044 & 3.180 X 0.089		810
D-	3.18 X 0.140 & 3.180 X 0.279		2550
E-	3.18 X 0.351 & 3.180 X 0.701		6370

MEMBERS	AREA (cm^2)	
<u>FACE DIAGONALS</u>		
($E = 138 \times 10^9$ N/m^2)		
($\rho = 2000$ Kg/m^3)		MATERIAL = ALL MEMBERS ARE GRAPHITE EPOXY
1-	0.084	
2-	0.116	
3-	0.115	
4-	0.387	
5-	0.787	
6-	1.968	
<u>SURFACE DIAGONALS</u>		
($E = 138 \times 10^9$ N/m^2)		
($\rho = 2000$ Kg/m^3)		
$A = 0.084$ cm^2)		

TABLE III-2 - EXPANDABLE BOX TRUSS STEADY STATE ANALYSIS DATA POINTS

DIAMETER (m)	SURFACE DENSITY (kg/m^2)	THRUST/MASS (g's)
35	3.42	0.02; 0.05; 0.20
35	0.40	0.20; 0.80
35	0.15	0.20; 0.80
35	0.05	0.20; 0.80
71	3.42	0.02; 0.05
71	0.40	0.02; 0.05; 0.20
71	0.15	0.02; 0.05; 0.20; 0.80
71	0.05	0.02; 0.05; 0.20; 0.80
106	0.40	0.02; 0.05; 0.20; 0.40
106	0.15	0.02; 0.05; 0.20
106	0.05	0.02; 0.05; 0.20; 0.80
141	0.15	0.02; 0.05; 0.20
141	0.05	0.02; 0.05; 0.20; 0.40
158	0.15	0.02; 0.05
158	0.05	0.02; 0.05; 0.10
176	0.05	0.02; 0.05
194	0.05	0.02

mass versus maximum acceleration curve for a 71 m diameter box truss with surface density as a parameter. Structural mass is defined as the mass of structure needed to support itself and the surface payload. All combinations of diameter and surface mass exhibit a common trend-exponential increase in system mass as a function of T/M after the mass is affected by acceleration level causing member size to exceed minimum gage. Figures similar to Figure III-4 were used to derive Figure III-5, structural unit mass versus maximum acceleration. Figure III-5 summarizes the effect of acceleration on the structural mass required relative to the minimum structural system. It is important to realize that each structure type and diameter are unique in terms of minimum mass size. The parametric curves presented in Figure III-5 are mass normalized and are not valid when comparing different diameter mass impacts (this statement also applies to Figures III-14 and III-15 for the wrap radial rib and Figure III-22 for the hoop and column). It can be seen that the larger the diameter and the heavier the surface, the greater the acceleration impact on structural mass. An acceleration of 0.05 g's has minimal effect on structural mass. However, at 0.2 g's, the impact ranges from 20% to 100%. Therefore, based only on impact on box truss structural mass, the optimum T/M varies from 0.05 to 0.20 g's over the range of diameters considered in this study. Shown in Figure III-6 is system mass versus maximum acceleration. System mass is defined as the total mass of the LSS including structure and surface. Above 0.2 g's, drastic increases in system mass exist. Figure III-7 presents system mass versus diameter for variable surface density and acceleration for all box truss systems analyzed.

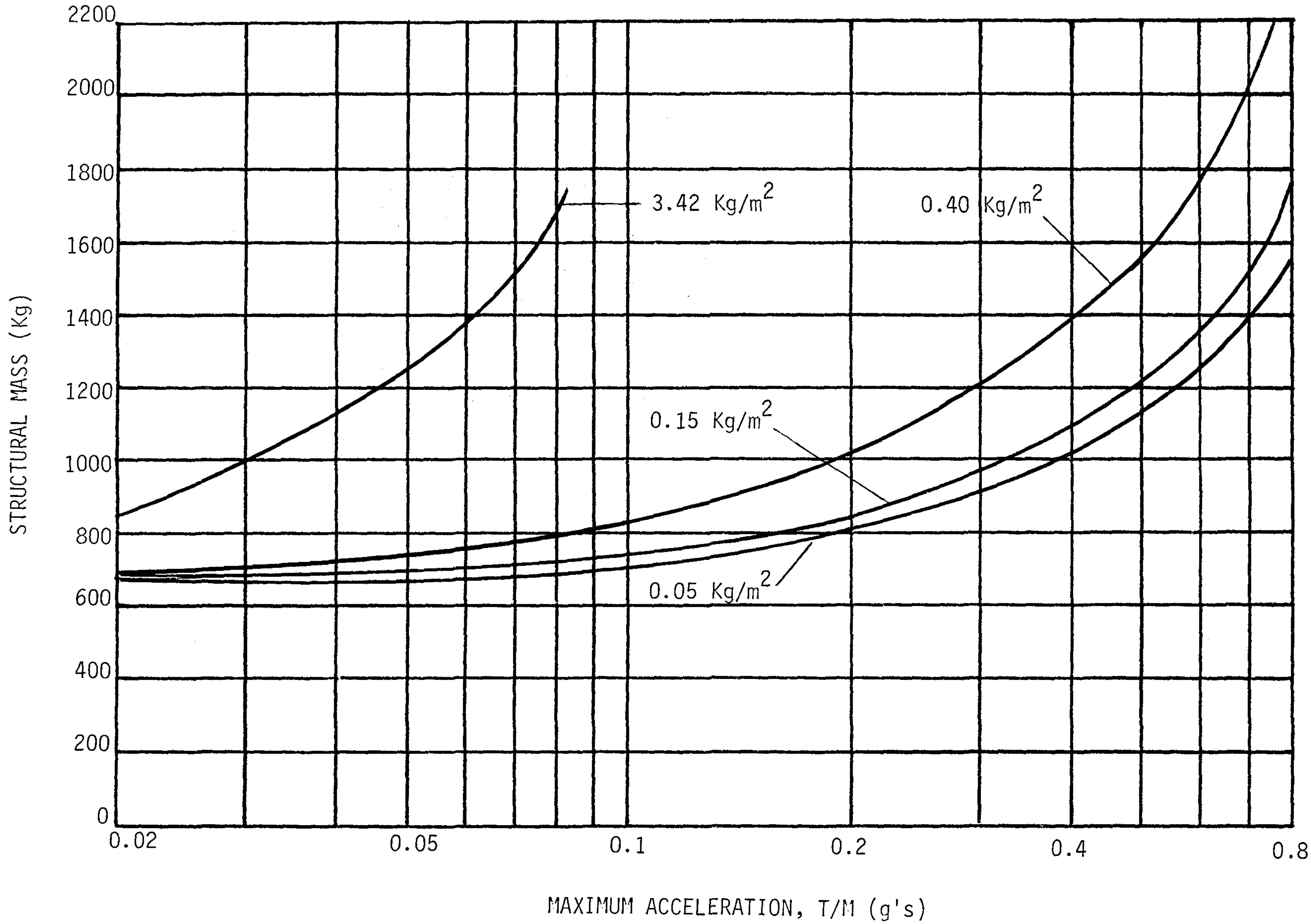


FIGURE III-4 STRUCTURAL MASS IMPACT FOR 71 METER (BOX TRUSS)

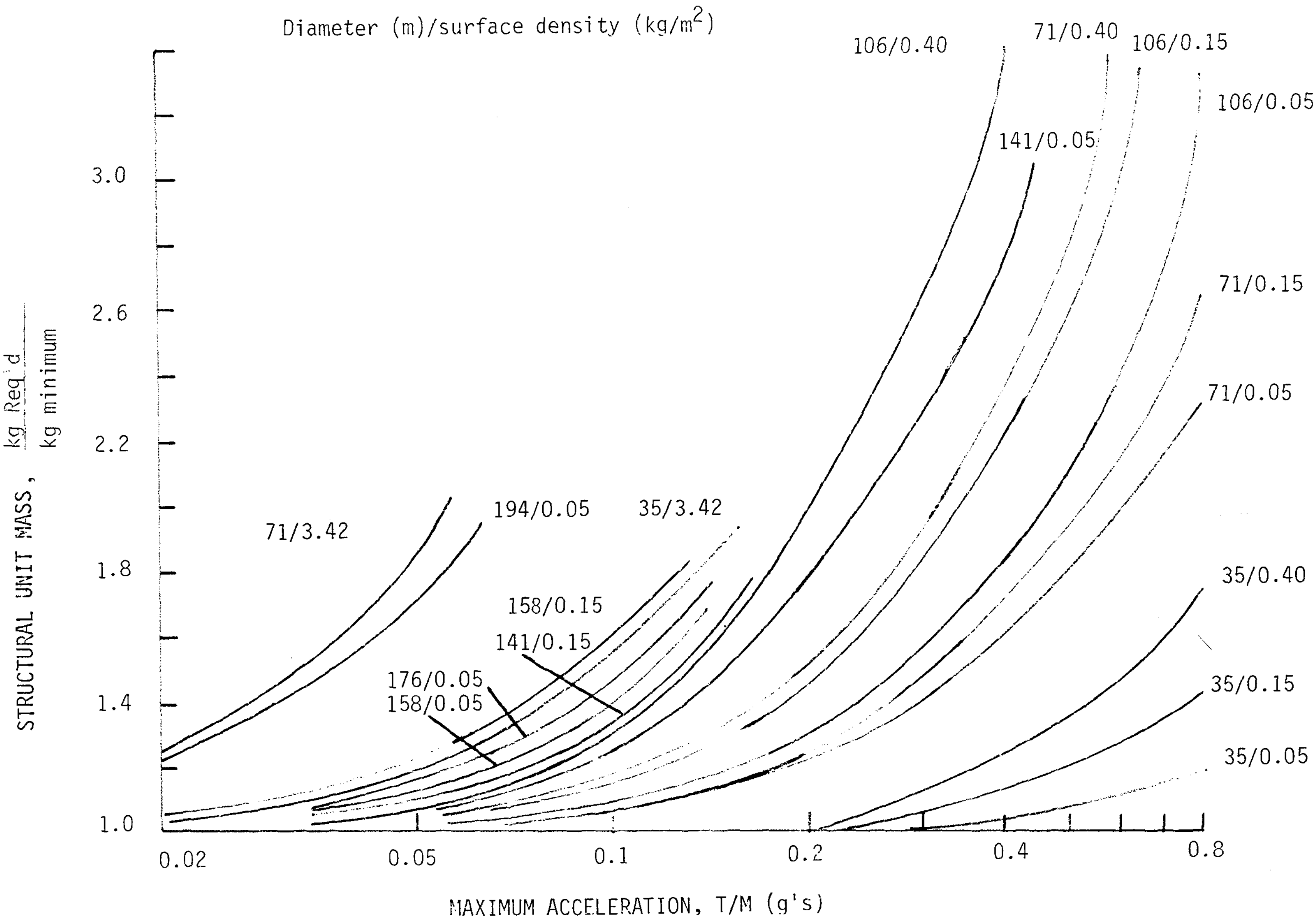


FIGURE III-5- UNIT MASS VERSUS MAXIMUM ACCELERATION (BOX TRUSS)

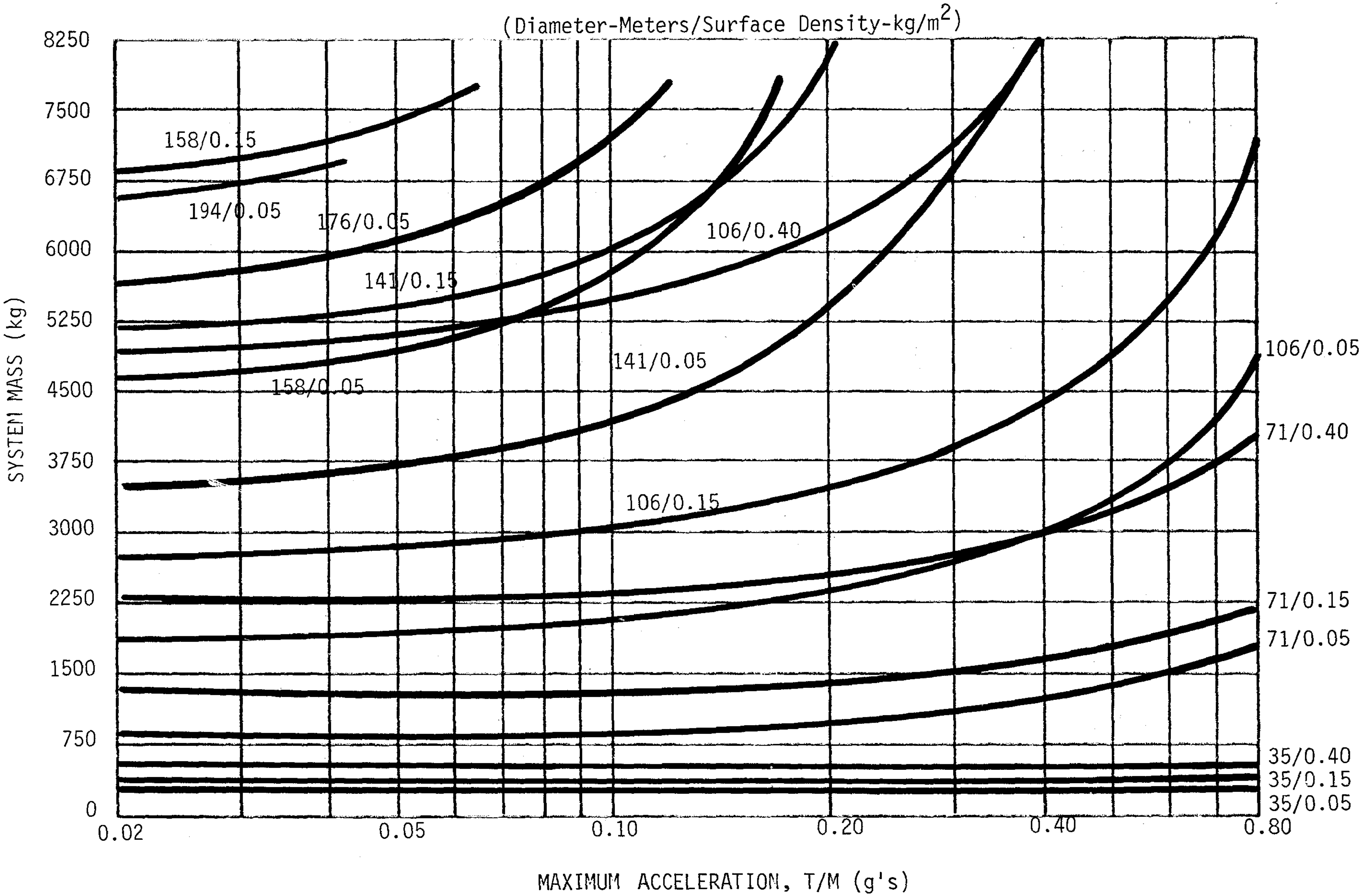


FIGURE III-6- BOX TRUSS SYSTEM MASS VERSUS ACCELERATION

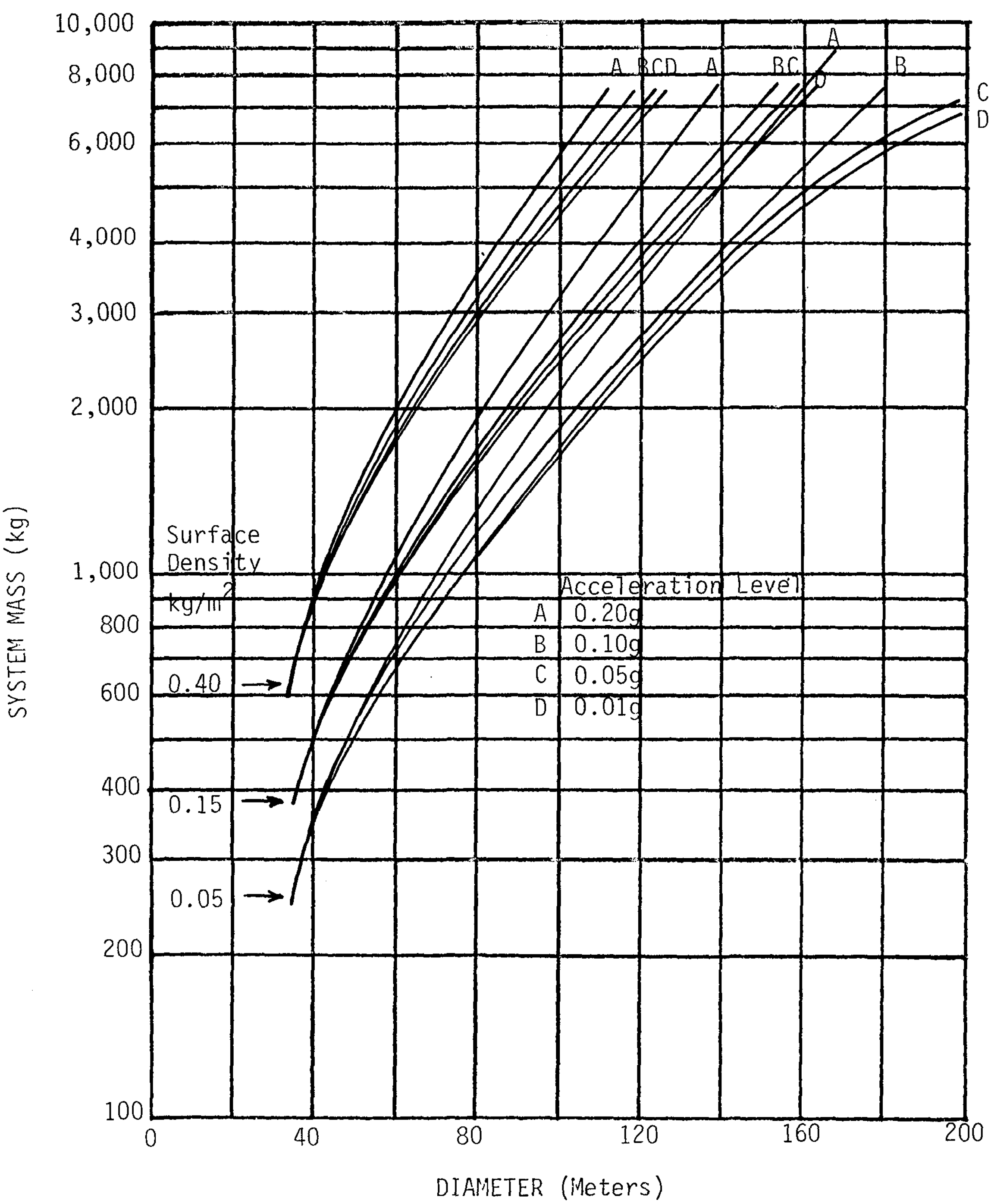


FIGURE III-7- EXPANDABLE BOX TRUSS SYSTEM MASS VERSUS DIAMETER

3. Box Truss Transient Thrust Effect

Transient dynamic finite element analyses were performed on four configurations thought to be representative of the range of designs under consideration. The maximum dynamic amplification factor was obtained for each member in a given design by ratioing the maximum transient load observed in a member during engine startup to the steady state load in the same member obtained from a static (inertial relief) analysis. It was impossible to select a single location of structural member upon which a capable critical design parameter could be based. Therefore, it was not possible to select an explicit design load amplication factor from the data. Instead, a probablistic mean dynamic amplification factor was chosen for each dynamic model at a given ramp time (T_R) and applied to member loads computed from static models. The equivalent static loads thus obtained were used to resize members and assess the effect of dynamic loads on structural mass for the full range of configurations under consideration.

When performing a response analysis, the mode shapes and frequencies of the system being investigated were calculated, and then the desired thrust profile was applied to that modal model. The principal problem arose in defining the realistic modal characteristics of the system. To obtain a realistic dynamic model of the LSS and OTV that are being accelerated by the thrust, the mass of the OTV should be included. Unfortunately, this mass varies depending on the OTV characteristics.

Three sample dynamic cases were run to determine the effect of OTV mass on the modes. Case 1 was free modes with no stage mass. Case 2 was free modes with a typical OTV. Case 3 was fixed modes which is equivalent to an infinite OTV mass. The fundamental frequencies are:

Case 1: 6.44 Hz (no OTV, Free)
Case 2: 4.88 Hz (with OTV)
Case 3: 3.71 Hz (fixed)

As can be seen, the frequencies do vary, and it is necessary that a typical OTV mass be included. Case 2 with an actual OTV mass is the realistic case. However, OTV masses are not known apriori. Therefore, a typical stage mass of 7940 Kg consistent with the Task III results was selected. Using these modes, response analyses were performed to determine the amplification factors for a step response and the optimum thrust for minimum amplification.

The objective is to relate the results of the detailed response analysis to the other cases. To accomplish this, it must be shown that the single degree of freedom relationship $T_R = 1/f$ (f = frequency) applies to the multi-degree of freedom systems. Then the optimum T_R can be defined as a function of the fundamental frequency.

Box truss configurations chosen for transient dynamic analysis are shown in Table III-3. Each of the small trusses were analyzed for $T_R = 0/3f_1$ (STEP), $1/3f_1$, $2/3f_1$, $3/3f_1$, $4/3f_1$ while the larger two trusses were analyzed for $0/3f_1$, $1/3f_1$ and $3/3f_1$ only. The first nine natural frequencies for each design are shown in Table III-4. Typical results of the dynamic analyses are displayed as maximum dynamic amplification factors for the bottom surface horizontal and vertical members of the truss in Figures III-8 and III-9. Note that although the general trend indicates dynamic amplification factors increase with distance from the center of the truss, the

TABLE III-3 -TRANSIENT ANALYSIS CASES FOR BOX TRUSS

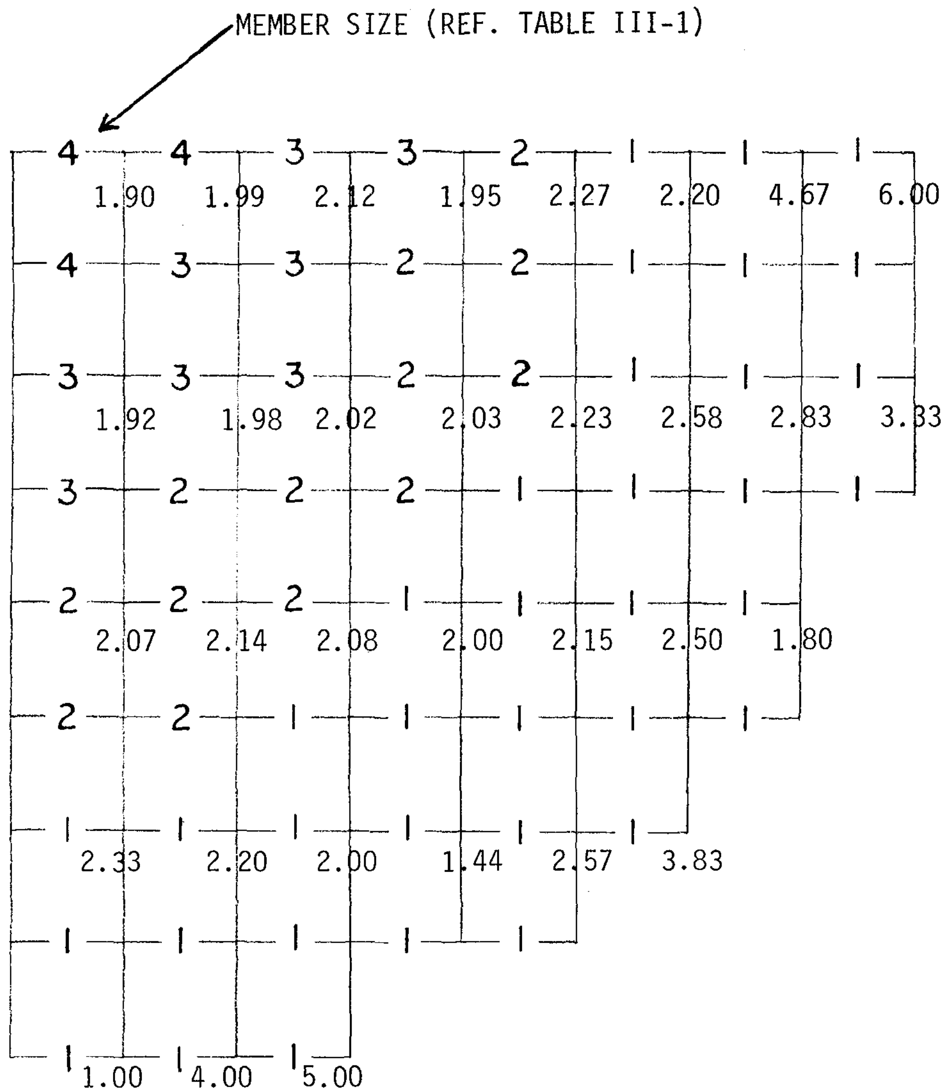
CONFIGURATION NAME	ALLOWABLE STEADY STATE g's	DIAMETER (METERS)	SURFACE DENSITY Kg/m2
BT505	.05	35	3.42
BT507	.60	35	3.42
BT206	.20	141	0.15
BT202B	.05	141	0.15

TABLE III-4 - BOX TRUSS STRUCTURAL FREQUENCIES

CONFIGURATION	NATURAL FREQUENCIES (Hz)								
NAME Mode	1	2	3	4	5	6	7	8	9
BT505	4.55	6.07	8.28	9.46	9.91	12.1	14.2	20.1	20.2
BT507	1.19	2.68	3.90	4.12	4.75	6.21	6.46	6.50	7.42
BT206	1.82	2.39	4.43	4.92	7.47	9.03	9.30	9.97	11.3
BT202B	1.03	1.66	3.45	3.96	6.56	7.64	8.30	9.11	9.90

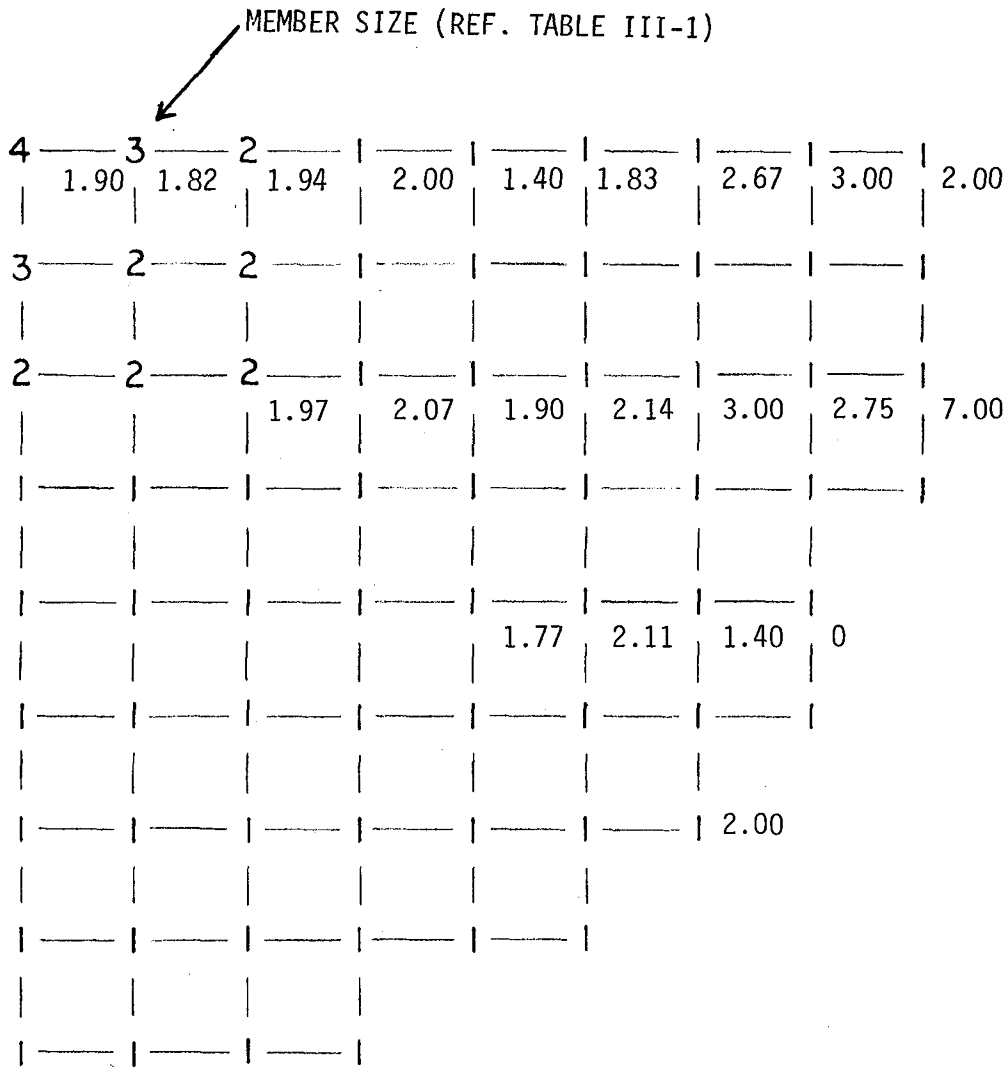
factors for the larger trusses do not increase monotonically. This appears to be due to high accelerations present at the periphery of the structure as illustrated in Figure III-10. Since this "end whip" is dependent upon the superposing of vibratory modes of the structure and, in general, is present to differing degrees in every truss, an attempt to obtain a single representative dynamic amplification was not straightforward.

The probalistic distributions for maximum dynamic amplification factors for configurations BT 505 and BT 507 are shown in Figure III-11. As a first approximation, probablistic mean values were chosen for each configuration at each T_R. These means are plotted as a function of T_R in Figure III-12. From this curve, a value of 2.05 was chosen as an approximate dynamic amplification factor for $T_R = 0/3f_1$ and applied to the results of box truss static analyses to determine the effect of transient thrust on structural mass.



- o Surface Members
- o Diameter = 141m
- o Surface Density = 0.15kg/m^2
- o T/M = 0.05g
- o T_R = Step

FIGURE III-8 TYPICAL DYNAMIC AMPLIFICATION FACTORS FOR SURFACE TUBES



o Symmetric about 45^{o} line
o Vertical Members
o Diameter = 141m
o Surface Density = 0.15kg/m^2
o T/M = 0.05g
o T_R = Step

FIGURE III-9 TYPICAL DYNAMIC AMPLIFICATION FACTORS FOR VERTICAL MEMBERS

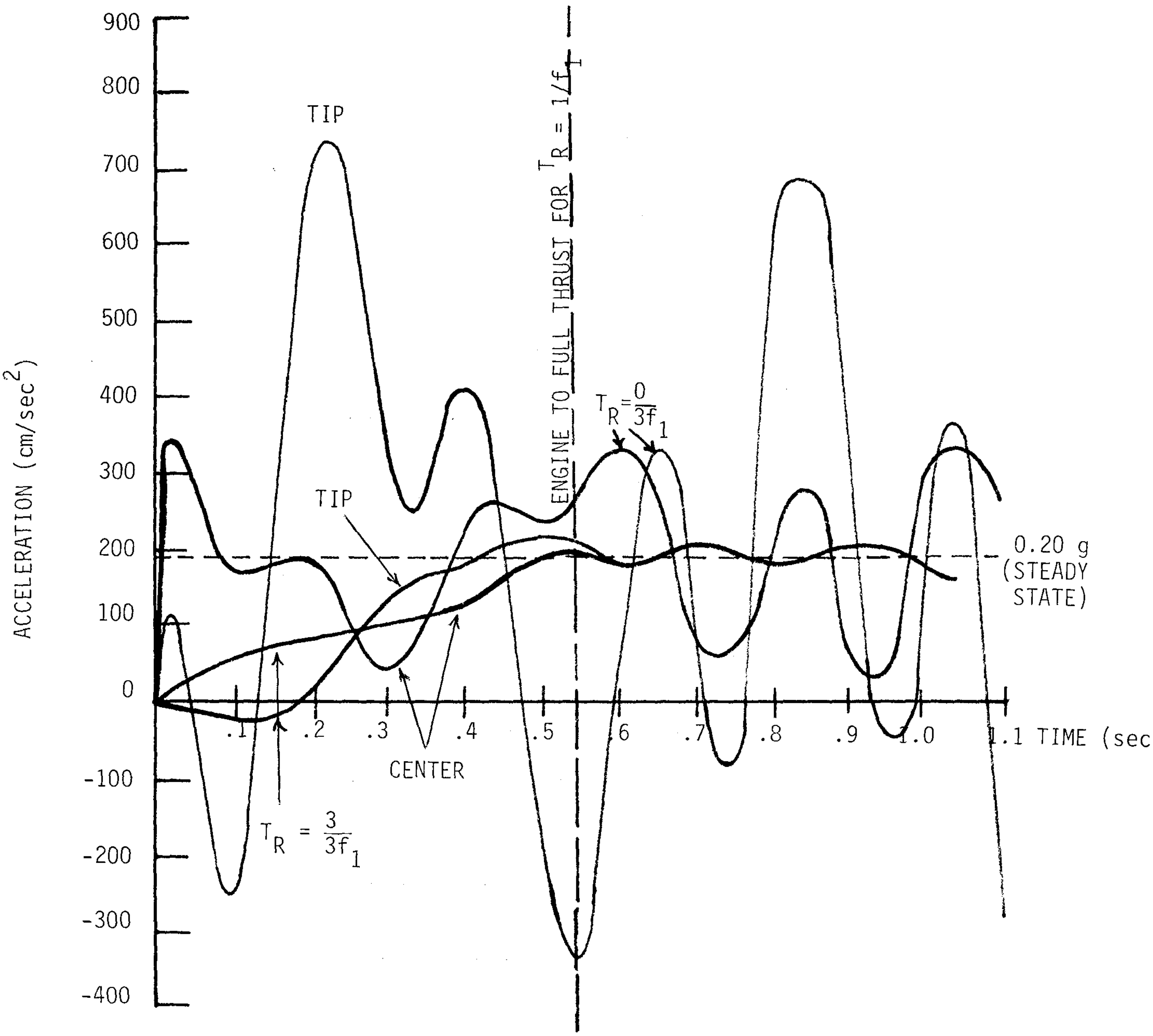
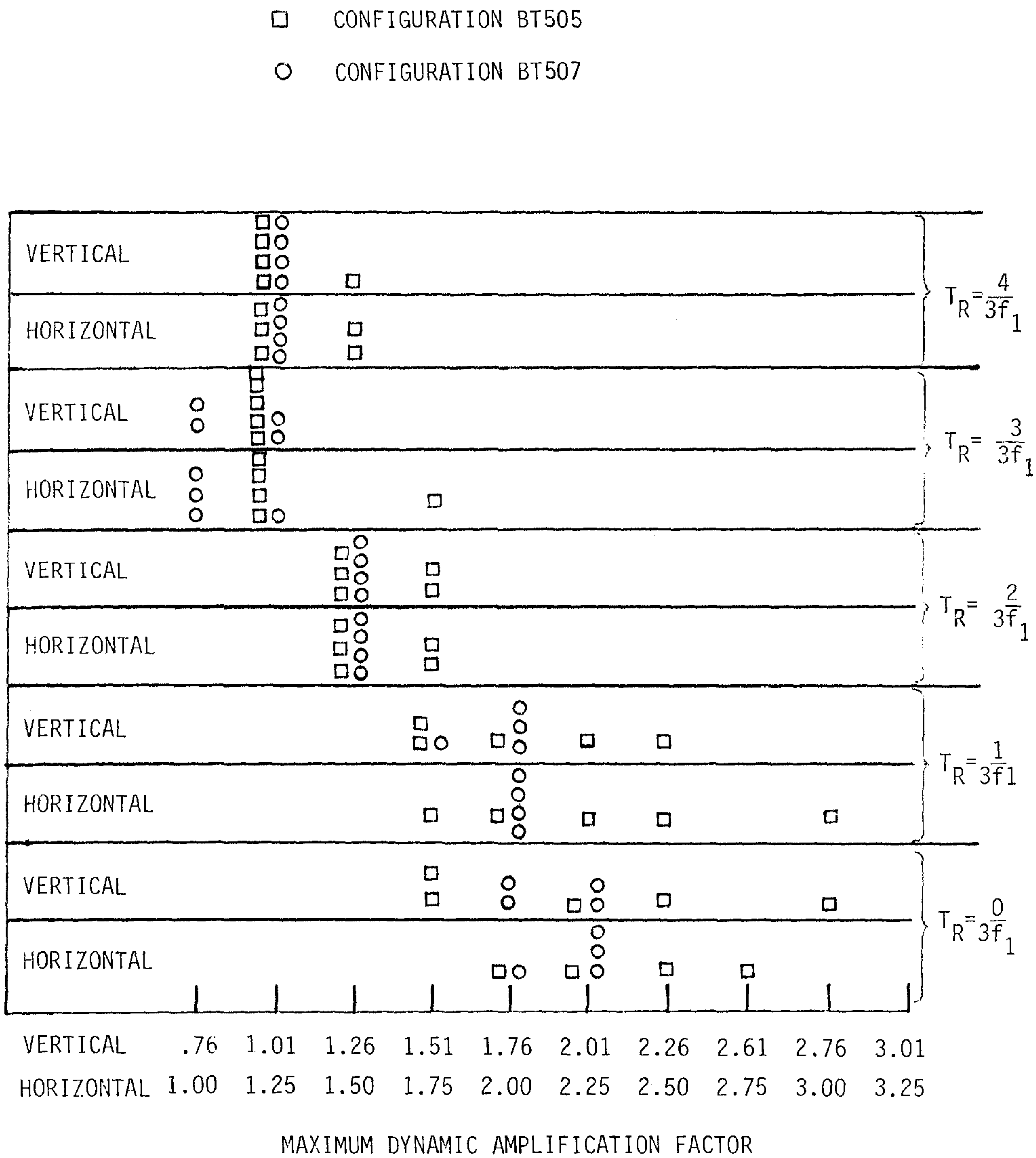


FIGURE III-10 ACCELERATIONS FOR 141m DIAMETER, 0.15 kg/m^2, BOX TRUSS-CENTER AND TIP LOCATIONS FOR $T_R = \frac{0}{3f_1}$, AND $\frac{3}{3f_1}$, (0.20g)

FIGURE III-11 PROBABILITY DISTRIBUTION OF DYNAMIC AMPLIFICATION FOR BOX TRUSS



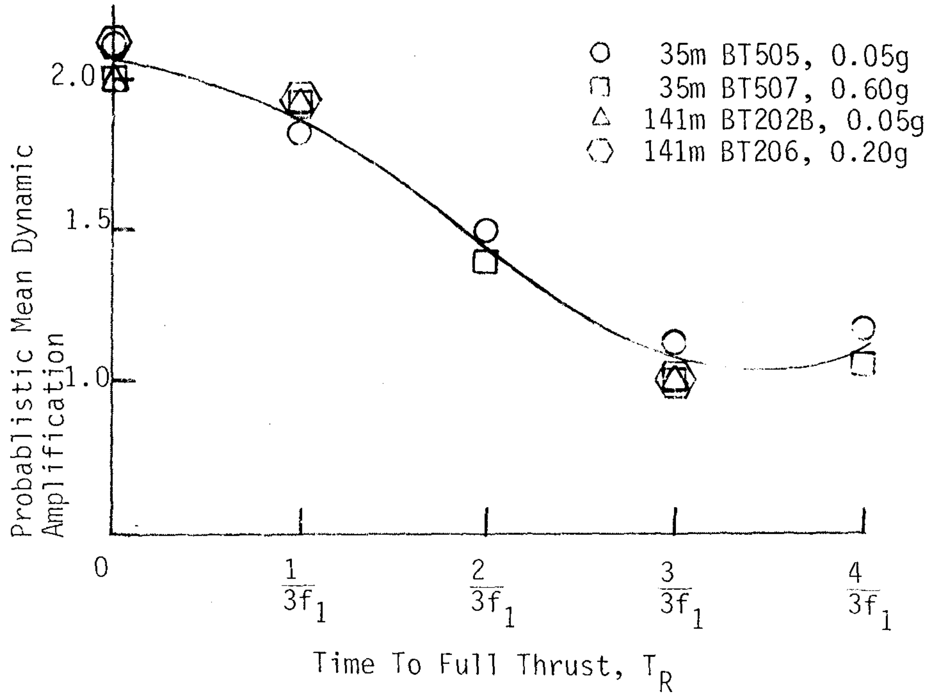


FIGURE III-12 BOX TRUSS MEAN DYNAMIC AMPLIFICATION

To determine the actual design load factors for the structural sizing during a constant thrust burn strategy, the dynamic amplification factors are multiplied by the actual T/M value at the start of the apogee burn. This point of the orbit transfer is the critical dynamic time since the system mass is the lowest of all burn starts. To determine the ratio of T/M at start of apogee burn to T/M at maximum steady-state, typical system masses at start and end of apogee burn were derived from Task III. By ratioing these masses, the ratio of T/M can be derived. Table III-5 presents those results. The T/M derived for the start of apogee burn is multiplied by the dynamic amplification factors and compared to the steady-state design T/M at burnout to determine the maximum design loading factor. Table III-6 presents a summary of the design load calculations for a T/M of 0.05 g's and the transient load impact for the box truss.

The structural analysis approach to the shutdown transient effect used the following thrust/time scenario. At initation of burn, the thrust is linearly increased from zero to a value corresponding to the maximum steady state acceleration in a time interval equal to the fundamental period. The thrust is maintained for an arbitrarily long interval to allow transients to attenuate. Finally, to simulate engine shutdown, the thrust was instantaneously set to zero. The results showed higher accelerations and hence, higher loads at the structure periphery than at the center. Although these loads are higher than those observed at steady state, they are lower than those observed for an abrupt engine start-up. The mass impact for shutdown was less than 2%.

TABLE III-5 - MASS, THRUST, AND T/M FOR TYPICAL STAGE

THRUST (N)	THRUST-TO-MASS T/M APOGEE SHUTDOWN MASS = 9750 kg T/M (MAX)	THRUST-TO-MASS T/M START OF APOGEE BURN MASS = 14500 kg T/M START*
1870	0.02	0.0134
4670	0.05	0.0334
18680	0.20	0.134
37360	0.40	0.268
74730	0.80	0.536

*Assumes ratio of mass at start of apogee burn to mass at apogee burn shutdown remains approximately constant for various thrust values:

$$\frac{M_{shutdown}}{M_{start}} = 0.67$$

From the Task III results, this ratio was constant for initial accelerations from 0.003 to 0.010g for either constant thrust or constant acceleration cases and an Isp of 450 seconds.

TABLE III-6 - BOX TRUSS DESIGN TRANSIENT THRUST IMPACT- CONSTANT THRUST BURN

T_R	DESIGN AMPLIFICATION X 0.034 g's	STEADY STATE DESIGN T/M	DESIGN LOAD FACTOR	ACTUAL DESIGN LOAD AMPLIFICATIONS*	AVERAGE TRANSIENT Kg REQ'D / Kg STEADY STATE
STEP	2.05 X 0.034 = 0.070 g's	0.05 g's	0.070 g's	1.40	1.10
$1/3f_1$	1.85 X 0.034 = 0.063 g's	0.05 g's	0.063 g's	1.26	1.03
$2/3f_1$	1.45 X 0.034 = 0.049 g's	0.05 g's	0.050 g's	1.00	1.0
$3/3f_1$	1.05 X 0.034 = 0.036 g's	0.05 g's	0.050 g's	1.00	1.0
$4/3f_1$	1.15 X 0.034 = 0.039 g's	0.05 g's	0.050 g's	1.00	1.0

*AMPLIFICATION = $\frac{\text{DESIGN LOAD FACTOR}}{\text{STEADY STATE DESIGN T/M,}}$ APPROPRIATE FOR ALL T/M RANGES

NOTE: FOR THE BOX TRUSSES STUDIED, RAMP TIMES OF T_R = 0.2 TO 2 SECONDS @ $T_R = 2/3f_1$ PRODUCE NO STRUCTURAL IMPACT

4. Box Truss Summary and Conclusions

Seventeen typical box truss configurations with diameters ranging from 35 to 194 m and surface densities ranging from 0.05 to 3.42 kg/m^2 were analyzed to determine the effect of steady state thrust on structural mass. At a typical low-thrust T/M ratio of 0.05 g's the structural mass impact was relatively small (20% or less) for fifteen of the seventeen cases. Exceptions were the maximum diameter (194 m/0.05 kg/m^2) and the maximum surface density (71 m/3.42 kg/m^2) cases where the structural mass impacts were 70% and 90% respectively. Each of the configurations exhibited a common trend after the minimum gage structural mass was affected by acceleration, i.e. an exponential increase in structural mass as T/M was increased. For a given diameter and surface density, the mass change is relatively small over a wide rage of T/M and, with the exception of the largest diameter and highest surface density cases noted above, only small reductions in structural mass are realized at T/M ratios below 0.05 g's.

Four typical box truss configurations were analyzed to determine the effect of start and shutdown transients on structural mass. These analyses were conducted for a constant thrust burn strategy. Mean dynamic amplification factors for start transients varied from 2.05 for a step thrust input to 1.05 for a thrust ramp equal in time to the period of the fundamental frequency of the combined LSS-OTV system. For a constant thrust burn strategy. The most critical start condition from a dynamic standpoint is the apogee burn. Anaysis at this condition indicated an average structural mass impact (relative to steady state) of 10% for a step thrust input and negligible mass impact for ramps equal in time to 2/3 of the fundamental frequency. For all configuraitons considered, start times which produced negligible impact ranged from 0.2 seconds to 2.0 seconds. Shutdown transient analyses indicated that the structural mass impact for an instantaneous thrust cutoff at the end of the apogee burn was less than 2%.

C. Wrap Radial Rib

1. Assumptions and Approach

For the wrap radial rib concept, data were received from Lockheed which provided the structural characteristics for their nominal configurations. Parametric data were also provided which related deployed stiffness to mass and packaging efficiency. From these provided data, the steady state thrust effects on system mass were determined.

The baseline design for the wrap radial rib is a Lockheed 100 meter diameter system with 96 ribs. The number of ribs for other diameters was selected to be proportional to $\sqrt{\frac{100m}{\text{diameter}}}$ X 96 ribs. The rib size was selected to maintain a tip deflection for mesh tension that is proportional to diameter ($\delta_{TIP} \propto$ diameter/100 m). This proportionality was based on the general requirements that as the antenna diameter increases, typically the antenna operating frequency decreases and, therefore, surface accuracy requirements are less. The rib properties used in the analysis are shown in Table III-7. The mass values of all systems include a 5% factor for the hub. The oval rib cross section was used instead of the Lockheed flex rib shape, shown in Figure III-13, for ease of analysis.

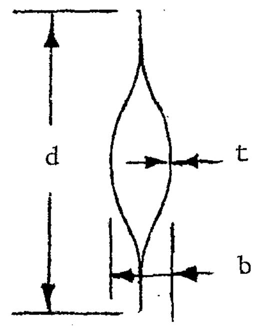
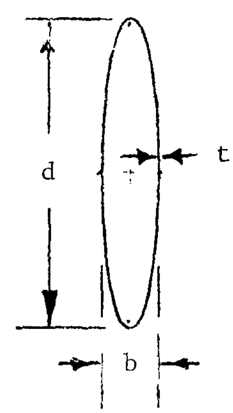


FIGURE III-13 - FLEX RIB CROSS SECTION

TABLE III-7 - RIB PROPERTIES



- GRAPHITE EPOXY MATERIAL
- OVAL RIB CROSS SECTION
- RIB CROSS SECTION d/b = 5
- RIB ROOT TO TIP TAPER = 3/1
- RIB CROSS SECTION d/t = 800
- TIP DEFLECTION $\propto$ (DIAMETER) THEREFORE (d, b, t) $\propto \left(\frac{\text{DIAMETER}}{\text{100M}}\right)^{.75}$
- BASELINE IS 100 METERS @ 96 RIBS
- FAILURE STRESS = 0.6 γ E ($^t/d$) (LOCAL CRIPPLING)

  WHERE γ = KNOCK DOWN FACTOR AND E = MODULUS OF ELASTICITY
- ALLOWABLE STRESS= FAILURE STRESS/1.5 = 3.0×10^7 N/m^2

However, the data are believed to be representative of the actual flex rib cross-section configuration.

2. Wrap Radial Rib Steady State Analysis

Tables III-8 and III-9 present the results of the radial rib analyses. The data presented are for a lens-type and mesh system with surface densities of 0.15 kg/m^2 and 0.05 kg/m^2, respectively. Figures III-14 and III-15 present, in graphical form, the results of the steady-state analysis for 0.05 kg/m^2 and 0.15 kg/m^2 respectively. It can be seen that the rib is highly sensitive to acceleration level. The structural mass increases dramatically when the rib is sized for the inertial loads. The rib is not as efficient as a deep truss for carrying the combined mass of surface and its own structural mass. However, the rib has greater allowable acceleration at large diameters due to stiffness criteria that increases member sizes with diameter. Figure III-16 displays system mass versus diameter for surface densities of 0.15 kg/m^2 and 0.05 kg/m^2, respectively.

3. Wrap Radial Rib Transient Thrust Effect

To obtain the effect on structural mass of varying engine thrust rise times, transient dynamic analyses were performed on four representative LSS configurations. The five ramp times identified for the analysis are T_R = $0/3f_1$, $1/3f_1$, $2/3f_1$, $3/3f_1$, and $4/3f_1$. These analyses were performed for the following cases: diameter = 106 meters and surface = 0.05 kg/m^2; diameter = 106 meters and surface = 0.15 kg/m^2; diameter = 176 meters and surface = 0.05 kg/m^2; diameter = 176 meters and surface = 0.15 kg/m^2. Table III-10 presents the first five modes of the free-free system including a 7940 kg stage mass, which is typical of the start-up for the final apogee burn. Figures III-17 and III-18 show typical accelerations at the root and tip of a radial rib. It can be seen that for $T_R = 3/3f_1$, there is no significant amplification. For a T_R = STEP, there is significant amplification. This amplification is higher at the tip than at the root due to a whipping action that was also observed for the box truss.

From these transient analyses the bending moment distribution and dynamic amplification along the rib were derived. Although the amplification is higher at the tip, the root of the rib is the point of critical stress. Figure III-19 presents the dynamic stress versus the allowable stress along the rib. As can be seen, the dynamic stress is decreasing with radial position along rib and the allowable stress is increasing. Therefore, the root dynamic amplification factor is the design criteria. Table III-11 is a summary of these critical amplification factors for the four cases and five T_R's. Figure III-20 is a plot of the amplification factor for ramp times from T_R = STEP to $T_R = 4/3f_1$. There is a definite minimum of $T_R = 3/3f_1$, which is identical to the single degree of freedom system. However, the final criterion is the effect on structural mass, and that curve will be the factor for determining the optimum T_R.

The effect on structural mass will be determined by the actual design load factor for the structural sizing. Table III-12 presents these results. Figure III-20 is now modified to represent the actual design load amplification factor to be applied to the steady-state structural design for all radial rib cases (Figure III-21). Table III-12 presents a summary of the average structural mass effect for all radial rib configurations.

TABLE III-8 - RADIAL RIB ANALYSIS RESULTS - SURFACE DENSITY = 0.15 Kg/m^2

Case	DIAMETER METERS	No. of Ribs	THRUST/ MASS g's	MINIMUM* RIB SIZE (cm.) d	b	t	LOADED RIB SIZE (cm.) d	b	t	MASS Kg
1	35	168	0.20	22.1	4.4	0.028	22.1	4.4	0.028	670
2	35	168	0.60	22.1	4.4	0.028	36.9	7.4	0.046	1560
3	71	118	0.05	37.6	7.5	0.047	37.6	7.5	0.047	2730
4	71	118	0.17	37.6	7.5	0.047	44.8	9.0	0.056	3510
5	71	118	0.60	37.6	7.5	0.047	98.8	19.7	0.123	15240
6	106	96	0.02	50.8	10.2	0.064	50.8	10.2	0.064	6170
7	106	96	0.05	50.8	10.2	0.064	50.8	10.2	0.064	6170
8	106	96	0.17	50.8	10.2	0.064	74.2	14.8	0.093	11200
9	106	96	0.60	50.8	10.2	0.064	192.1	38.4	0.240	68960
10	141	84	0.02	62.9	12.6	0.079	62.9	12.6	0.079	10820
11	141	84	0.05	62.9	12.6	0.079	62.9	12.6	0.079	10820
12	141	84	0.17	62.9	12.6	0.079	110.0	22.0	0.137	27750
13	158	78	0.02	68.5	13.7	0.086	68.5	13.7	0.086	13490
14	158	78	0.05	68.5	13.7	0.086	68.5	13.7	0.086	13490
15	158	78	0.17	68.5	13.7	0.086	131.1	26.2	0.164	40980
16	176	74	0.02	74.3	14.9	0.093	74.3	14.9	0.093	16730
17	176	74	0.047	74.3	14.9	0.093	74.3	14.9	0.093	16730
18	194	70	0.02	79.9	16.0	0.100	79.9	16.0	0.100	20140

NOTES: *RIB SIZE AT ROOT   b = RIB MINOR AXIS   d = RIB MAJOR AXIS   t = RIB THICKNESS

TABLE III-9 - RADIAL RIB ANALYSIS RESULTS - SURFACE DENSITY = 0.05 Kg/m^2

CASE	DIAMETER METERS	NO. OF RIBS	THRUST/ MASS g's	MINIMUM* RIB SIZE (cm.) d	b	t	LOADED RIB SIZE (cm.) d	b	t	MASS Kg
1	35	168	0.20	22.1	4.4	.028	22.1	4.4	.028	560
2	35	168	0.60	22.1	4.4	.028	28.3	5.7	.035	880
3	71	118	0.05	37.6	7.5	.047	37.6	7.5	.047	2290
4	71	118	0.20	37.6	7.5	.047	37.6	7.5	.047	2290
5	71	118	0.60	37.6	7.5	.047	84.7	16.9	.106	11030
6	106	96	0.02	50.8	10.2	.064	50.8	10.2	.064	5190
7	106	96	0.05	50.8	10.2	.064	50.8	10.2	.064	5190
8	106	96	0.17	50.8	10.2	.064	58.3	11.7	.073	7000
9	106	96	0.60	50.8	10.2	.064	175.6	35.0	.219	57330
10	141	84	0.02	62.9	12.6	.079	62.9	12.6	.079	9110
11	141	84	0.05	62.9	12.6	.079	62.9	12.6	.079	9110
12	141	84	0.17	62.9	12.6	.079	90.4	18.0	.113	18120
13	158	78	0.02	68.5	13.7	.086	68.5	13.7	.086	11340
14	158	78	0.05	68.5	13.7	.086	68.5	13.7	.086	11340
15	158	78	0.17	68.5	13.7	.086	110.1	22.0	.138	27990
16	176	74	0.02	74.3	14.9	.093	74.3	15.0	.093	14050
17	176	74	0.05	74.3	14.9	.093	74.3	15.0	.093	14050
18	194	70	0.02	79.9	16.0	.100	79.9	16.0	.100	16890

NOTES: *RIB SIZE AT ROOT b = RIB MINOR AXIS d = RIB MAJOR AXIS t = RIB THICKNESS

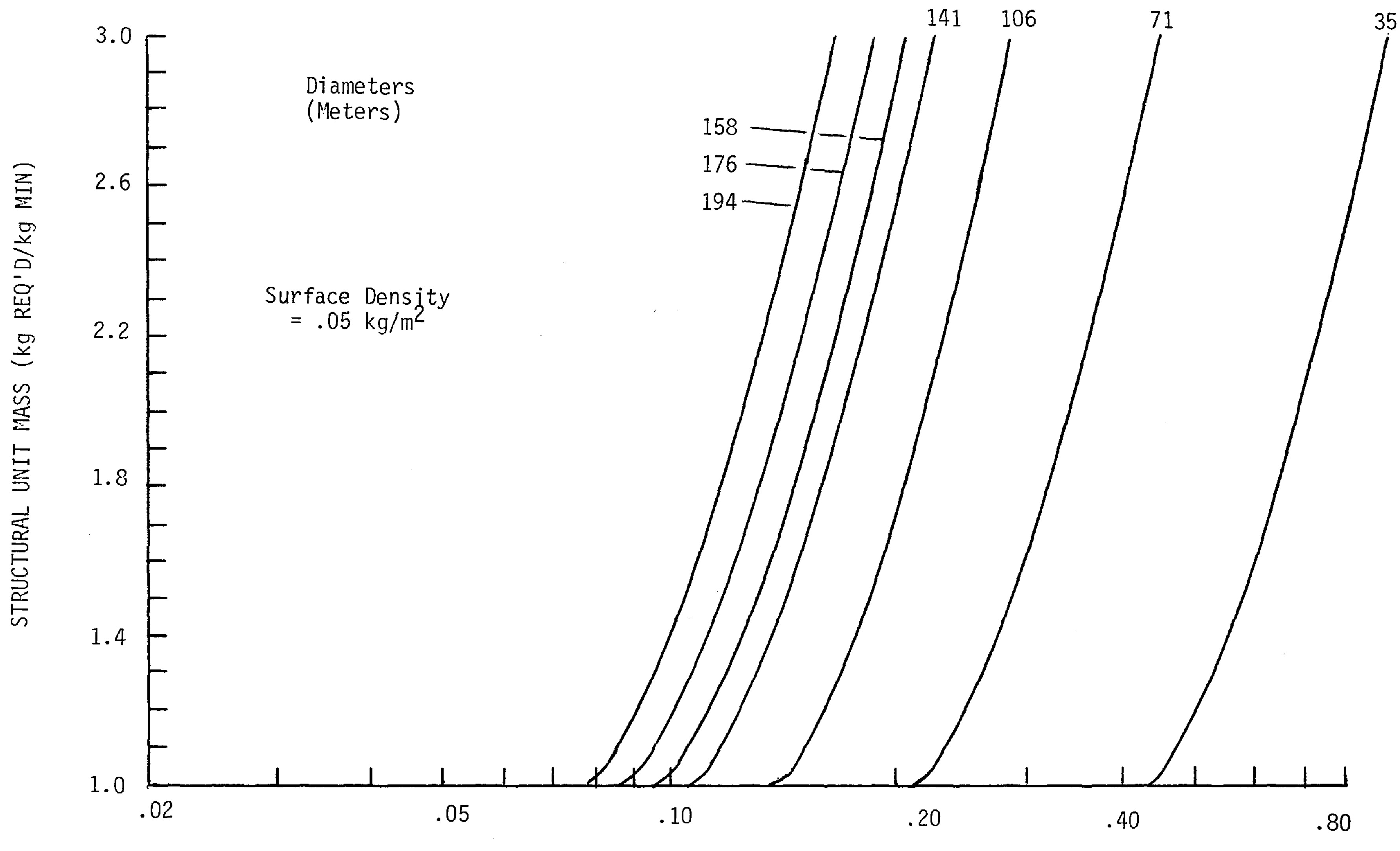


FIGURE III-14 WRAP RADIAL RIB UNIT MASS VERSUS THRUST-TO-MASS FOR SURFACE DENSITY OF 0.05 kg/m^2

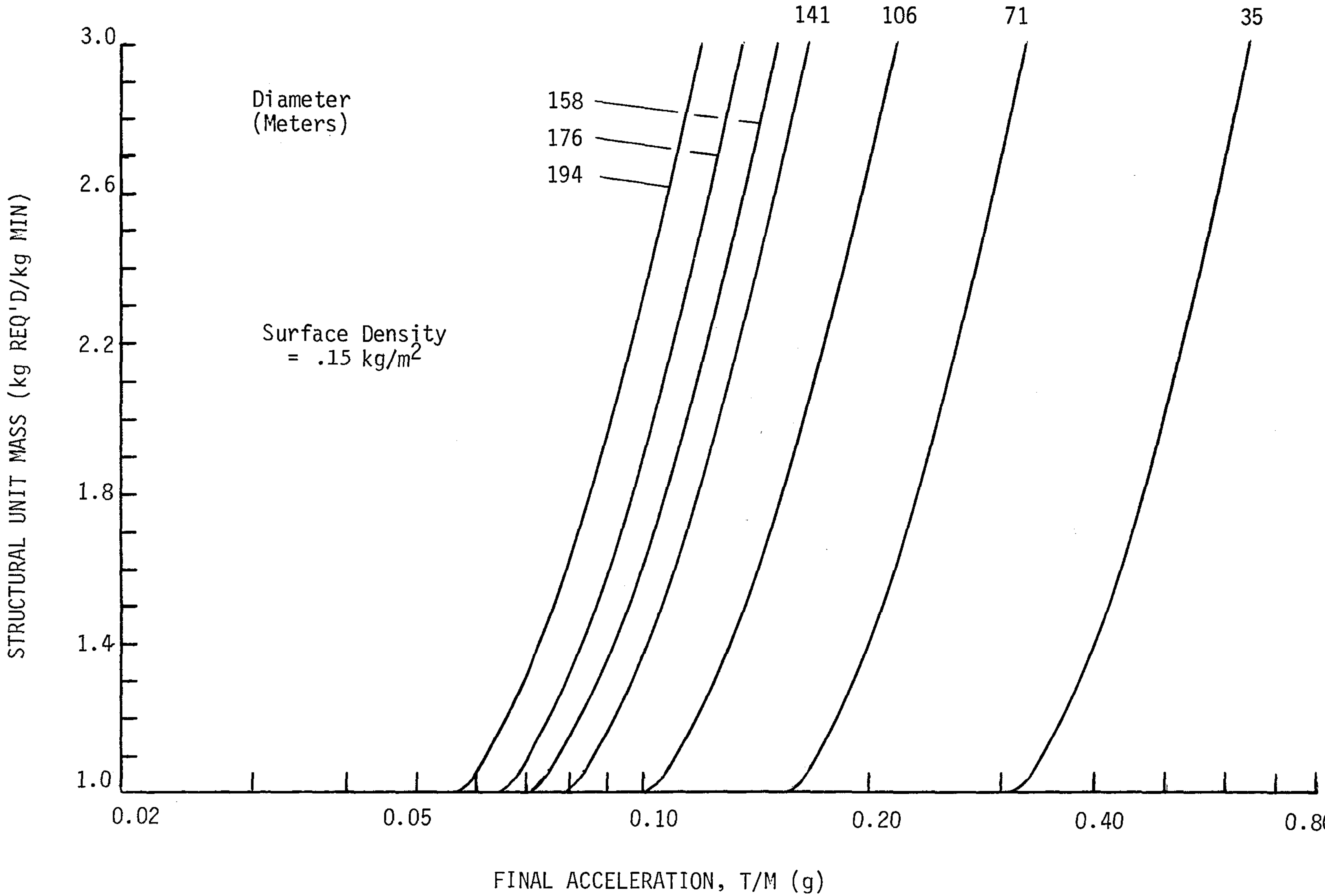


FIGURE III-15 WRAP RADIAL RIB UNIT MASS VERSUS THRUST-TO-MASS FOR SURFACE DENSITY OF 0.15 kg/m^2

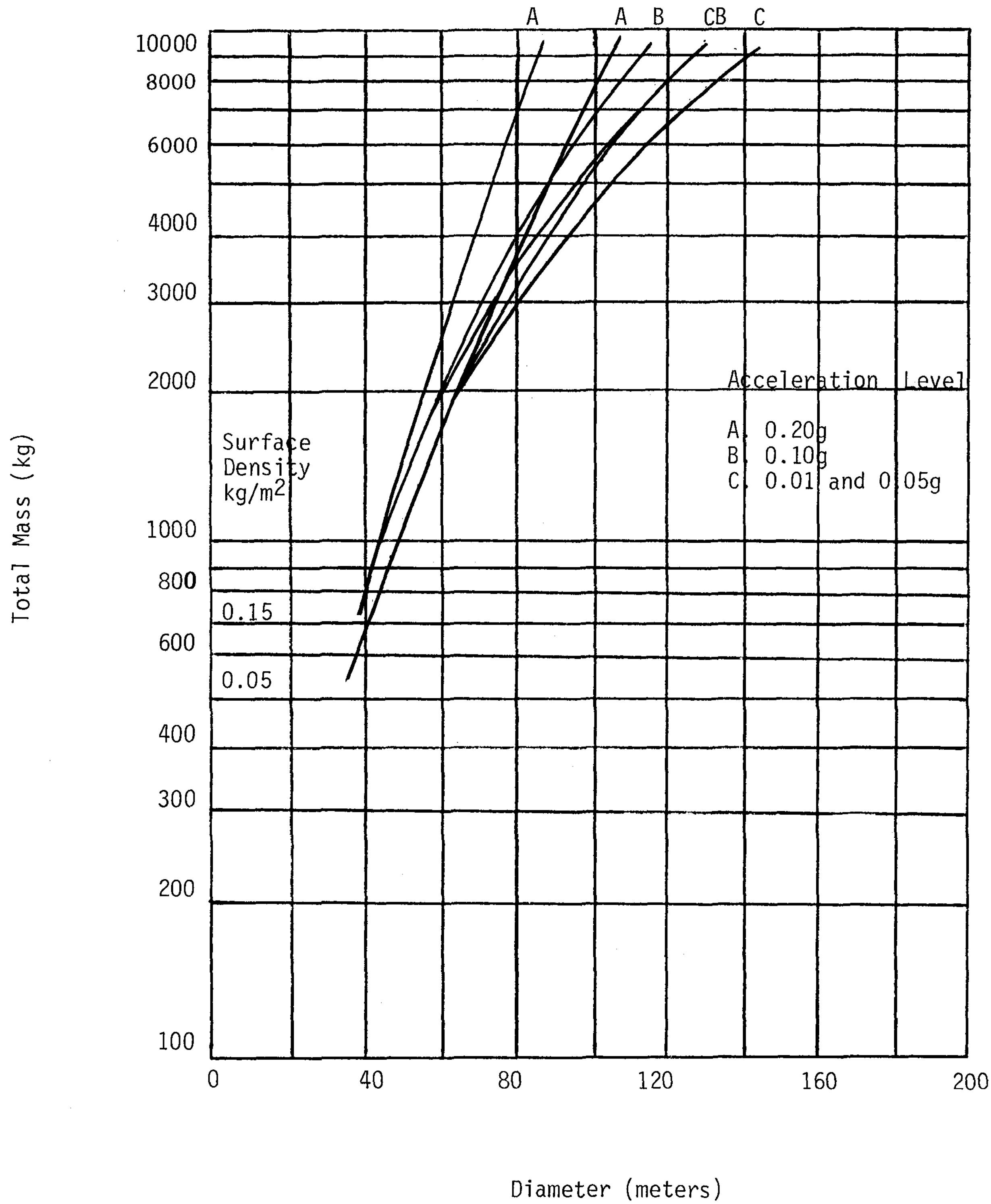


FIGURE III-16 - WRAP RADIAL RIB SYSTEM MASS VERSUS DIAMETER

TABLE III-10 - NATURAL FREQUENCIES FOR RADIAL RIB

	T/M = 0.02 g			
	FREQUENCIES (Hz)			
DIAMETER	106 m		176 m	
SURFACE DENSITY	0.05 kg/m^2	0.15 kg/m^2	0.05 kg/m^2	0.15 kg/m^2
MODE				
1	0.24	0.18	0.12	0.09
2	0.97	0.73	0.51	0.40
3	2.31	1.78	1.22	0.96
4	4.22	3.32	2.23	1.77
5	6.73	5.36	3.57	2.84

TABLE III-11 - ROOT AMPLIFICATION FACTORS

DIAMETER / SURFACE DENSITY	T_R=STEP	$T_R=1/3f_1$	$T_R=2/3f_1$	$T_R=3/3f_1$	$T_R=4/3f_1$
106/0.05	1.71	1.62	1.28	1.01	1.15
106/0.15	1.75	1.63	1.29	1.01	1.16
176/0.05	1.68	1.60	1.26	1.01	1.16
176/0.15	1.70	1.61	1.27	1.01	1.16
AVERAGE	1.71	1.62	1.28	1.01	1.16

The radial rib shutdown transient analysis results are similar to the box truss shutdown transients. The amplification factor is highest at the tip due to "whip lash" effect. However, the rib root is the critical stress location due to the fact that allowable stress increases toward the tip. Therefore, root amplification is the design criterion. A representative case (176 meters diameter, 0.15 kg/m^2 mesh, T/M = 0.05) shows root amplification of 0.76 of the static stress. Therefore, shutdown transients do not impact the structural mass.

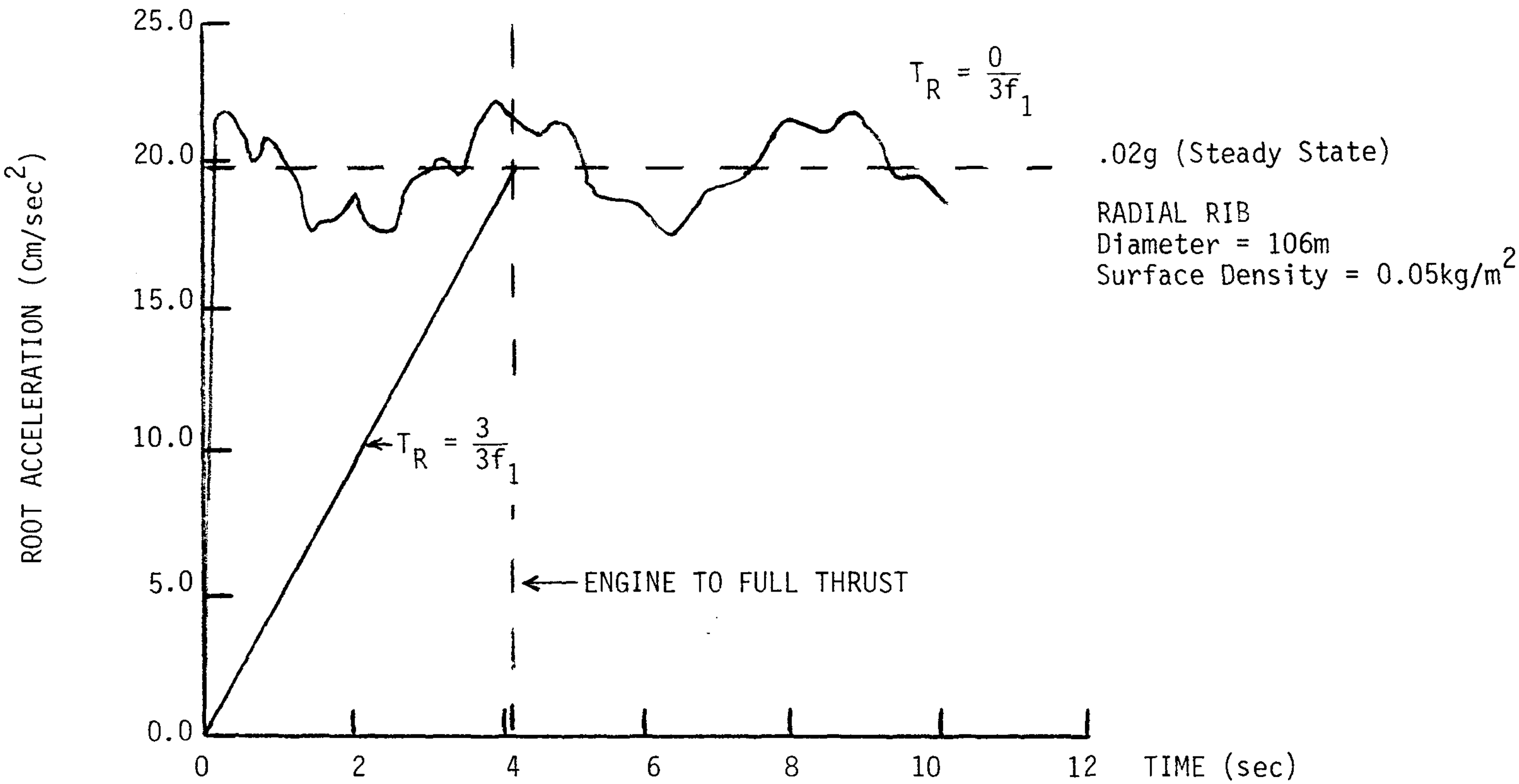


FIGURE III-17 TYPICAL ROOT ACCELERATION FOR STEP AND RAMP INPUT ($T_R = \frac{0}{3f_1}$ AND $T_R = \frac{3}{3f_1}$)

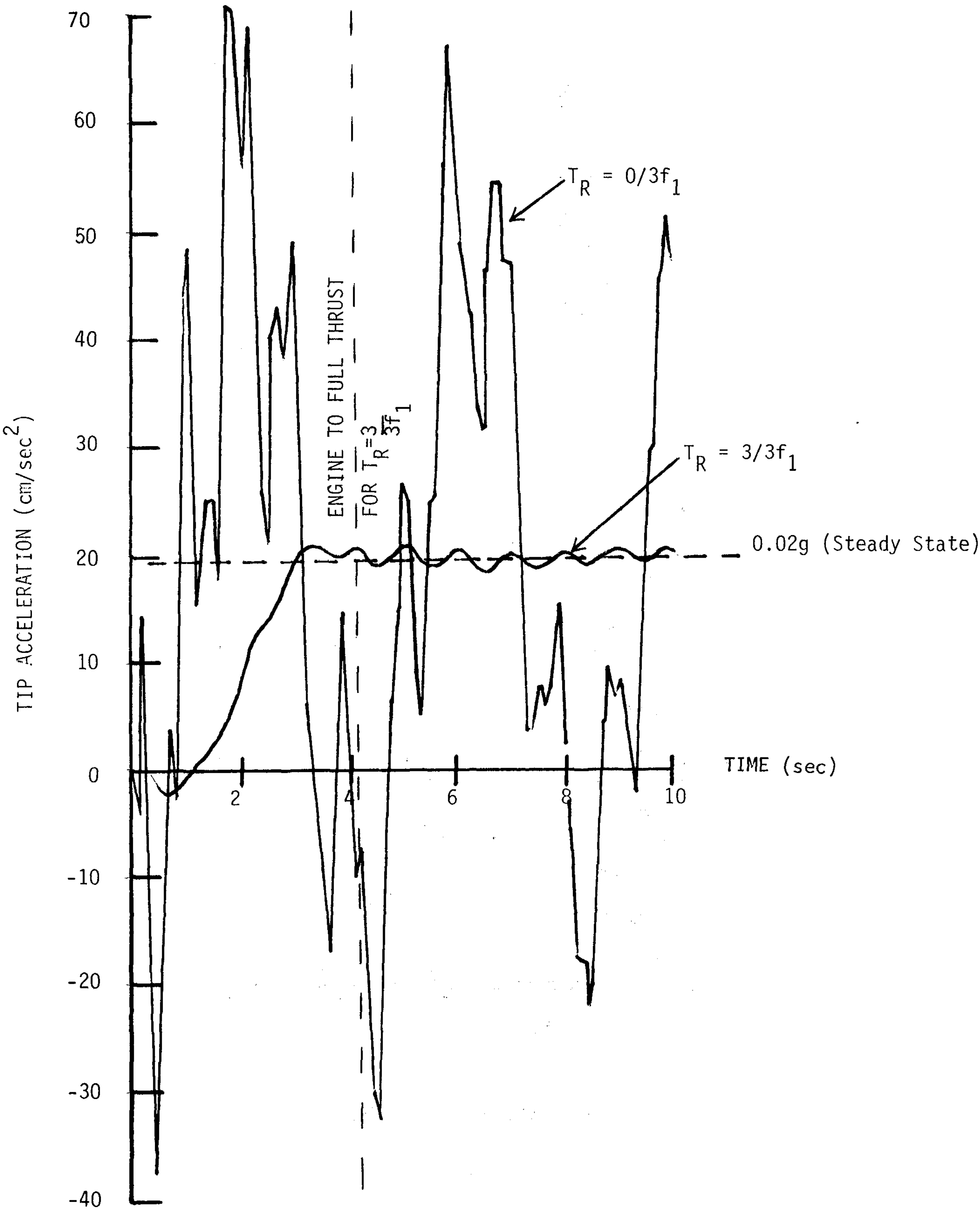


FIGURE III-18- TYPICAL TIP ACCELERATION FOR STEP AND RAMP INPUT (RADIAL RIB, 106m, SURFACE DENSITY = 0.05kg/m^2

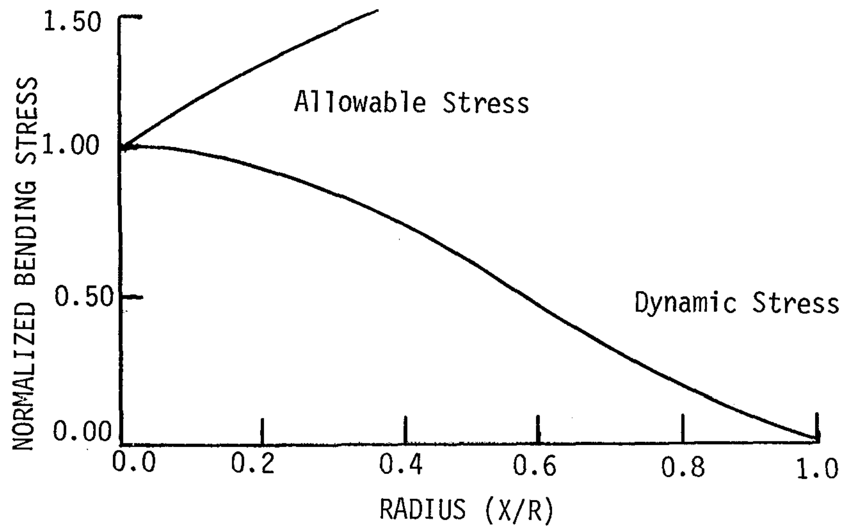


FIGURE III-19 DYNAMIC STRESS VERSUS ALLOWABLE STRESS ALONG RIB (TYPICAL)

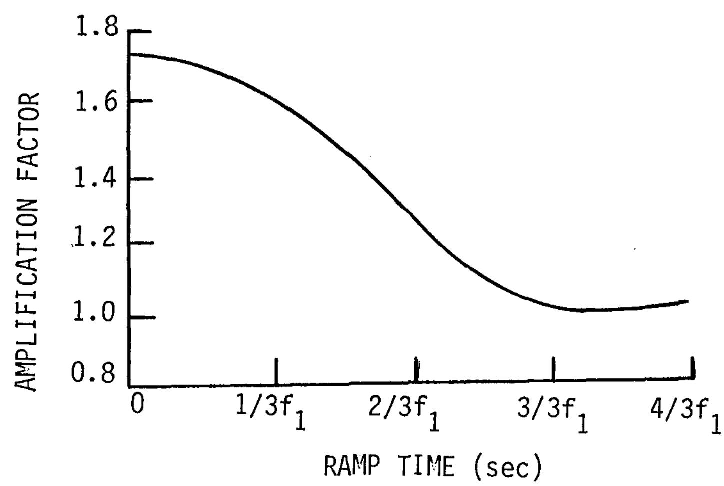


FIGURE III-20 AMPLIFICATION FACTOR FOR VARIOUS RAMP TIMES (RADIAL RIB)

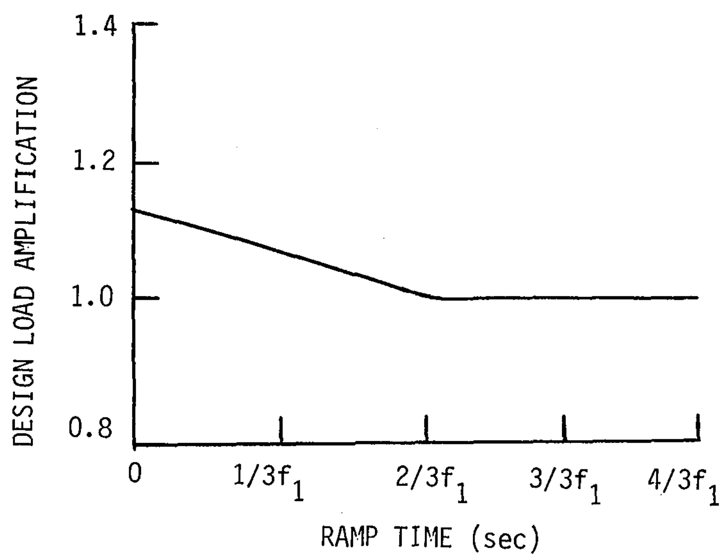


FIGURE III-21 ACTUAL DESIGN LOAD AMPLIFICATION (RADIAL RIB) (CONSTANT THRUST BURN)

TABLE III-12 RADIAL RIB TRANSIENT THRUST IMPACT - CONSTANT THRUST BURN

T_R	DESIGN AMPLIFICATION X 0.034 g's	STEADY STATE DESIGN T/M	DESIGN LOAD FACTOR	ACTUAL DESIGN LOAD AMPLIFICATIONS*	AVERAGE TRANSIENT** Kg REQ'D / Kg STEADY STATE
STEP	1.71 X 0.034 = 0.057 g's	0.05 g's	0.057 g's	1.14	1.10
$1/3f_1$	1.62 X 0.034 = 0.054 g's	0.05 g's	0.054 g's	1.08	1.05
$2/3f_1$	1.28 X 0.034 = 0.043 g's	0.05 g's	0.050 g's	1.00	1.0
$3/3f_1$	1.01 X 0.034 = 0.034 g's	0.05 g's	0.050 g's	1.00	1.0
$4/3f_1$	1.16 X 0.034 = 0.040 g's	0.05 g's	0.050 g's	1.00	1.0

$*\text{AMPLIFICATION} = \frac{\text{DESIGN LOAD FACTOR}}{\text{STEADY STATE DESIGN T/M}}$, APPLICABLE FOR ALL STEADY STATE T/M's BETWEEN 0.01 TO 0.40 g's

**AVERAGE OF ALL RADIAL RIB CASES ANALYZED

NOTE: FOR THE RADIAL RIB STUDIED, RAMP TIMES OF T_R = 0.5 TO 10 SECONDS @ $T_R = 2/3f_1$ PRODUCE NO STRUCTURAL IMPACT

4. Wrap Radial Rib Summary and Conclusions

Fourteen typical radial rib configurations with diameters ranging from 35 to 194m and surface densities ranging from 0.05 to 0.15 kg/m^2 were analyzed to determine the effect of steady state thrust on structural mass. At a typical low-thrust T/M ratio of 0.05 g's there was no structural mass impact on any of the configurations which were analyzed (structural mass impact occurred at a T/M of 0.055 g's on the 194m/0.15 kg/m^2 configuration). The relatively high allowable acceleration at large diameters is due to stiffness criteria which increases the size of cantilevered ribs as diameter increases. Additionally, the radial rib concept was not sized for the higher surface densities of 0.40 and 3.42 kg/m^2. After the minimum size rib structure was affected by acceleration, each of the configurations exhibited a common trend, i.e. an exponential increase in structural mass as T/M was increased. For a given diameter and surface density the structural mass change is very sensitive to T/M and the mass increases are large over a small range of T/M.

Four typical radial rib configurations were analyzed to determine the effect of start and shutdown transients on structural mass. These analyses were conducted for a constant thrust burn strategy. Mean dynamic amplification factors for start transients varied from 1.71 for a step thrust input to 1.01 for a thrust ramp equal in time to the period of the fundamental frequency of the combined LSS-OTV system. For a constant thrust burn strategy, the most critical start condition from a dynamic standpoint is the apogee burn. Analysis at this condition indicated an average structural mass impact (relative to steady state) of 10% for a step thrust input and negligible mass impact for ramps equal in time to 2/3 of the fundamental period. For all configurations considered, start times which produced negligible impact ranged from 0.5 to 10 seconds. Shutdown transient analyses indicated that an instantaneous thrust cutoff at the end of the apogee burn produced root amplification factors of less than 1.0 and did not impact structural mass.

C. Hoop and Column Analysis

1. Assumptions and Approach

The data generator program for a hoop and column configuration (see Figures II-5 and II-6) spacecraft uses a repetitive arrangement. This algorithm provides for automatic data generation for this type of structure in a format suitable for NASTRAN analysis.

Some of the other features of the program are that: 1) it allows for either a convex or concave taper in the central supporting column by simply specifying the diameters at center and the end; 2) it provides pretensioning in the structure that may be necessary which is provided for and simulated by means of a pseudo-temperature field - the degree and extent of which is selected through appropriate input data; 3) any number of radial stays or hoop sections, which are modelled as beams, may be present; and; 4) it provides comprehensive analysis within a reasonable approximation, including the effect of masses concentrated at specific points.

The criteria for the static analysis and methodology used are as follows. It was specified that under inertial loading there are no net compressive stresses (slack) in any of three groups of stay numbers. To provide for this, a pretension load was introduced in the stays to counter the compressive stresses generated by the orbit transfer effect. A minimum residual tension load of approximately 20 N is required in any of the stays.

The other design criterion has the structural member mass being based on a 20% margin with strength analysis of the members incorporating minimum material properties for both stay and rim (E = 11.0 X 10^6 N/cm^2/ ρ = 2000 kg/m^3) and a factor of safety of 1.5. The stay tape allowable limit was 31,700 N/cm^2. Allowable failure modes of the structure considered Euler column and material failure. Nominal sizes for stay and rim are 0.95 cm X 0.013 cm and 10.8 cm diameter X 0.038 cm thick, respectively. The hub, sized by orbiter launch loads, remains constant.

Once the appropriate conditions have been simulated and the necessary data generation completed, the resulting finite element model is analyzed using NASTRAN to obtain the total mass properties and load/stress and displacement data at requisite points of the structure.

2. Hoop and Column Steady State Analysis

Static models of the hoop and column design were used to generate the parametric data necessary to assess the affects of the steady-state thrust-to-mass ratios on structural sizing and resulting system mass. These models were used to generate the loads in each member and then each member was subsequently sized to carry the load. The analysis was then iterated based upon the new member mass and resulting new loads.

Results from 32 cases of 50, 100 and 200 meter diameters over a range of surface densities and T/M ratios are presented in Tables III-13, III-14, and III-15. The key parameter determined by the analysis is the structural mass impact (kg required/kg minimum) of the various diameter, surface density, and T/M combinations. Figure III-22 presents, in graphical form, a summary of the results of the steady-state analysis. The results show that in the T/M range of 0.05 - 0.10 g's, the structural mass impact is small (from 0% to 40%) except for the higher surface densities at a diameter of 200 meters.

System mass versus diameter for the three surface masses with thrust-to-mass as a parameter are presented in Figure III-23.

3. Hoop and Column Transient Thrust Effect

Once the member sizings had been determined based on steady-state thrust loads a finite element model was generated to perform the transient dynamic effects analysis. The transient analysis effects for the step thrust application were determined for the 50, 100 and 200 meter cases as the static analyses. Table III-16 presents the fundamental structural frequencies of the free-free hoop column system with a 7940 Kg stage mass. For this structural system the primary structural frequency is the hoop and mesh mass vibrating in a pogo mode with the stay straps operating as a spring. Because of the single degree of freedom type mode, the amplification factor follows very close to the ideal single degree of freedom system. Table III-17

TABLE III-13 - 50 METER DIAMETER HOOP AND COLUMN STEADY STATE RESULTS

SURFACE DENSITY (kg/m2)	T/M g's	STAY FORCE (NEWTONS)	STAY DELTA MASS (kg)	HOOP COMPRESSION (NEWTONS)	HOOP DELTA MASS (kg)	TOTAL DELTA MASS (kg)	kg REQUIRED / kg MINIMUM
0.05	0.02	30	0	310	0	0	1.0
	0.05	44	0	420	0	0	1.0
	0.20	118	0	990	0	0	1.0
	0.80	412	0	3270	1	1	1.0
0.15	0.02	40	0	400	0	0	1.0
	0.05	72	0	680	0	0	1.0
	0.20	224	0	1990	0	0	1.0
	0.80	838	3	7350	33	36	1.11
0.40	0.02	68	0	660	0	0	0
	0.05	140	0	1310	0	0	0
	0.20	500	1	4570	13	14	1.04
	0.80	1940	12	17570	86	98	1.30

NOTES: MINIMUM STRUCTURE = 322 kg
MAXIMUM RIM DIAMETER = 52 cm (ORBITER PACKAGING CONSTRAINT)

TABLE III-14 - 100 METER DIAMETER HOOP AND COLUMN STEADY STATE RESULTS

SURFACE DENSITY (kg/m2)	T/M g's	STAY FORCE (NEWTONS)	STAY DELTA MASS (kg)	HOOP COMPRESSION (NEWTONS)	HOOP DELTA MASS (kg)	TOTAL DELTA MASS (kg)	kg REQUIRED / kg MINIMUM
0.05	0.02	50	0	550	0	0	1.0
	0.05	94	0	960	0	0	1.0
	0.20	314	0	3010	43	43	1.08
	0.80	1780	28	14970	214	242	1.44
0.15	0.02	92	0	1000	0	0	1.0
	0.05	202	0	2100	21	21	1.04
	0.20	750	7	7590	125	132	1.24
	0.80	3960	72	35742	381	453	1.82
0.40	0.02	198	0	2130	21	21	1.04
	0.05	464	2	4860	81	83	1.15
	0.20	1796	28	18610	249	277	1.50
	0.80	9610	185	89600	655	840	2.52

NOTES: MINIMUM STRUCTURE = 554 kg
MAXIMUM RIM DIAMETER = 38 cm (ORBITER PACKAGING CONSTRAINT)

TABLE III-15 - 200 METER DIAMETER HOOP AND COLUMN STEADY STATE RESULTS

SURFACE DENSITY (kg/m2)	T/M g's	STAY FORCE (NEWTONS)	STAY DELTA MASS (kg)	HOOP COMPRESSION (NEWTONS)	HOOP DELTA MASS (kg)	TOTAL DETLA MASS (kg)	kg REQUIRED / kg MINIMUM
	0.02	126	0	2610	68	68	1.06
0.05	0.05	284	0	5560	186	186	1.17
	0.20	1710	104	29830	1093	1197	2.12
	0.02	294	0	5700	191	191	1.18
0.15	0.05	704	25	13330	392	417	1.39
	0.20	4944	360	85910	3506	3866	4.62
	0.02	722	26	13850	403	429	1.40
0.40	0.05	1776	110	33725	1261	1371	2.29

NOTES: MINIMUM STRUCTURE = 1066 kg
MAXIMUM RIM DIAMETER = 19 cm (ORBITER PACKAGING)

TABLE III-16 Natural Frequencies for Hoop/Column

T/M = 0.02 g's

DIAMETER (METERS)	SURFACE DENSITY (Kg/M2)	FUNDAMENTAL FREQUENCY (HZ)
	0.05	1.83
50	0.15	1.15
	0.40	0.69
	0.05	0.58
100	0.15	0.35
	0.40	0.22
	0.05	0.15
200	0.15	0.09
	0.40	0.06

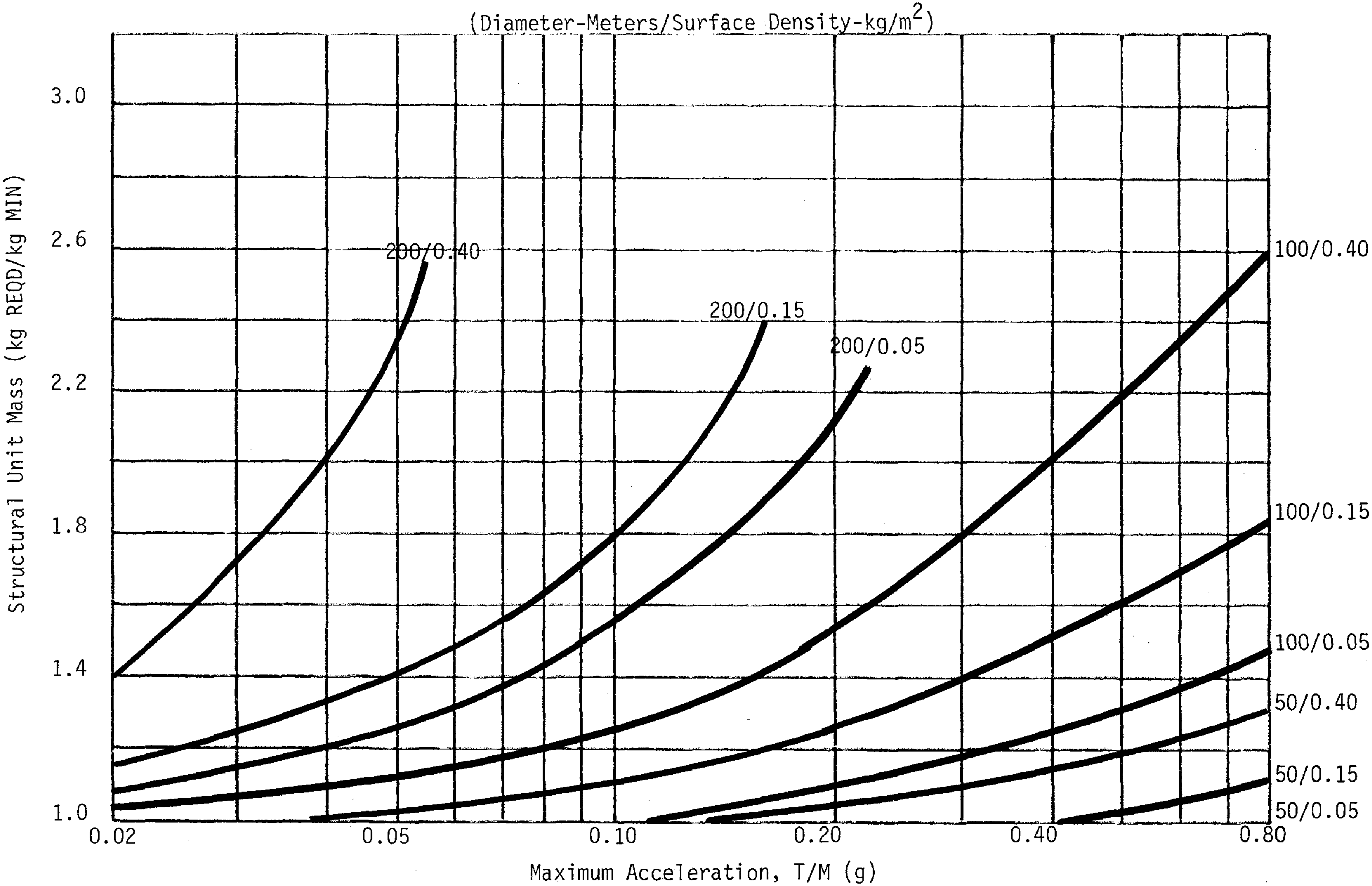


FIGURE III-22- UNIT MASS VERSUS FINAL THRUST TO MASS (HOOP AND COLUMN)

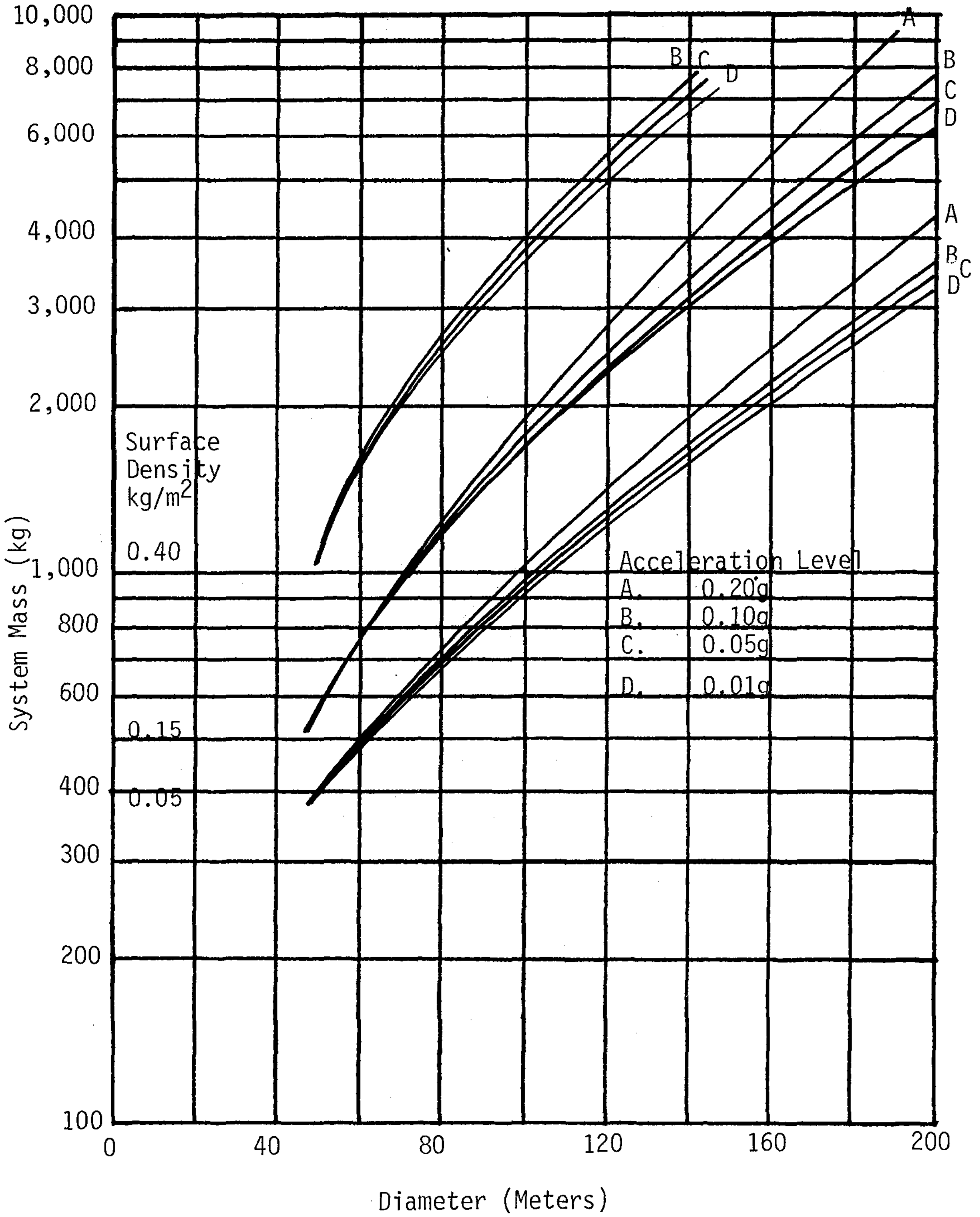


FIGURE III-23- HOOP AND COLUMN SYSTEM MASS VERSUS DIAMETER

TABLE III-17 Typical Dynamic Amplification Factors for the Hoop Pogo Mode

THRUST INPUT	AMPLIFICATION FACTOR
TR = Step	2.0
TR = 1/3f,	1.86
TR = 2/3f,	1.38
TR = 3/3f,	1.01
TR = 4/3f,	1.16

presents typical amplification factors for the hoop and column system. Table III-18 presents the determination of the actual design load amplification factor as applied to the actual steady state acceleration at start of apogee burn. Table III-18 also presents the average structural mass impact for the transient thrust application. The results are similar to the box truss and radial rib with no structural impact at $T_R = 2/3f_1$, and slightly less than 10% impact for a step thrust input.

4. Hoop and Column Summary and Conclusions

Nine typical hoop and column configurations with diameters ranging from 50 to 200 m and surface densities ranging from 0.05 to 0.40 kg/m^2 were analyzed to determine the effect of steady state thrust on structural mass. At a typical low-thrust T/M ratio of 0.05 g's the structural mass impact was relatively small (12% or less) for six of the nine cases. Exceptions were the maximum diameter (200 m) cases with surface densities of 0.05, 0.15, and 0.40 kg/m^2 where the structural mass impacts at 0.05 g's were 23%, 40%, and 134% respectively. Each of the configurations exhibited a common trend after the minimum gage structural mass was affected by acceleration, i.e. an exponential increase in structural mass as T/M was increased. For a given diameter and surface density, the mass change is relatively small over a wide range of T/M and, with the exception of the maximum diameter cases noted above, only small reductions in structural mass are realized at T/M ratios below 0.05 g's.

TABLE III-18 Hoop/Column Design Transient Thrust Impact - Constant Thrust Burn

T_R	Design Amplification x 0.034 g's	Steady State Design T/M	Design Load Factor	Actual Design Load Amplification*	Average Transient** Kg Req'd/Kg Steady State
Step	2.0 x 0.034 = 0.068 g's	0.05 g's	0.068 g's	1.36	1.07
1/3f,	1.86 x 0.034 = 0.063 g's	0.05 g's	0.063 g's	1.26	1.01
2/3f,	1.38 x 0.034 = 0.047 g's	0.05 g's	0.050 g's	1.00	1.00
3/3f,	1.01 x 0.034 = 0.034 g's	0.05 g's	0.050 g's	1.00	1.00
4/3f,	1.16 x 0.034 = 0.039 g's	0.05 g's	0.050 g's	1.00	1.00

*Amplification = $\frac{\text{Design Load Factor}}{\text{Steady State Design T/M}}$, Applicable for all steady state T/M's between 0.01 to 0.40 g's

**Average for all hoop and column cases analyzed.

NOTE: For the Hoop/Columns studied, ramp times of T_R = 0.3 to 11.0 seconds @ T_R = 2/3f, produce no structural impact.

Three typical hoop and column configurations were analyzed to determine the effect of start and shutdown transients on structural mass. Mean dynamic amplificaiton factors for start transients varied from 2.0 for a step input to 1.01 for a thrust ramp equal to the time of the fundamental frequency of the combined LSS-OTV system. For a constant thrust burn strategy at the critical apogee burn, the analysis indicated a 7% structural mass impact for a step thrust input and no impact at a ramp time equal to 2/3 of the structural fundamental period. For all configurations considered start times which produced no structural mass impact ranged from 0.3 to 11 seconds. Shutdown transients produced amplification factors of approximately 1.0 and did not impact the structural mass.

D. Multi-Point Concept Assessment

1. Multi-Point Thrust Approach

The three structural concepts were evaluated to determine their applicability to multi-point thrust application. The box truss, with its large number of hard points for attachment, provides complete flexibility for location of the propulsion system. The hoop and column concept requires that propulsion system locations be limited to the column and the hoop. Although this limits variability of locations, the concept is definitely applicable for multi-point thrust application. The radial rib antenna has only one hard point - the hub. Therefore, multi-point thrust is not applicable to the radial rib concept. The hoop and column and box truss were selected for further study.

2. Box Truss Multi-Point Analysis

Analyses performed in previous sections only addressed loads in the truss caused by thrust from a single engine attached to the geometric center of the LSS. Subsequent analyses entertained the possibility of distributing the same thrust over a larger portion of the truss by virtue of several strategically positioned smaller thrusters.

The idea of reducing the structural mass of the box truss by means of multiple thrust application points is intuitively appealing. A more uniformly distributed thrust results in more uniform acceleration, hence more uniform distributions of internal loads, smaller deformations, and less structural mass are required for a given g-level. Ideally, one might envision a thruster being attached to the base of each vertical member which, when fired with the proper amount of thrust and in phase with all the other thrusters, would result in the perfect uniform acceleration of the truss. Under such conditions each surface member carries only the bending load arising from the acceleration of its own mass and each vertical member carries only the axial load of its mass plus a fraction of the mass with associated surface members and surface mesh.

If a box truss with one thruster per vertical member is considered one extreme of the spectrum, then clearly one centralized thruster is the other. To strike a balance between these extremes and assess sensitivity of structural mass to the number of thrust application points, two multi-point thrust configurations were chosen. A quarter-segment model is illustrated in

Figure III-24 for five-point and nine-point schemes. For each box truss, the stations (verticals) at which the thrusters were located were chosen in an attempt to minimize the effective bending (i.e., compression of bottom surface member, extensions of top) of the truss. Furthermore, for the purposes of analysis it was assumed that the magnitude of the force applied by each thruster would be, by design, that required to keep all thruster stations in a plane perpendicular to the direction of net thrust/acceleration, thereby minimizing gross deformations of the truss.

The multi-point structural analyses were performed on 71, 141 and 194 meter designs. It was felt that these structures were the most representative.

The following approach was taken in the multi-point steady-state analysis for the condition of uniform acceleration achieved during the orbit transfer burn after start-up transients subside.

1. For a given diameter and a given surface density, a finite element model of the truss was developed using the structural properties of the lightest of each of the admissable truss elements (e.g. surface members, vertical members and diagonals).

2. This "minimum gage" configuration was subjected to a baseline steady state g-level of .05 g and internal loads calculated.

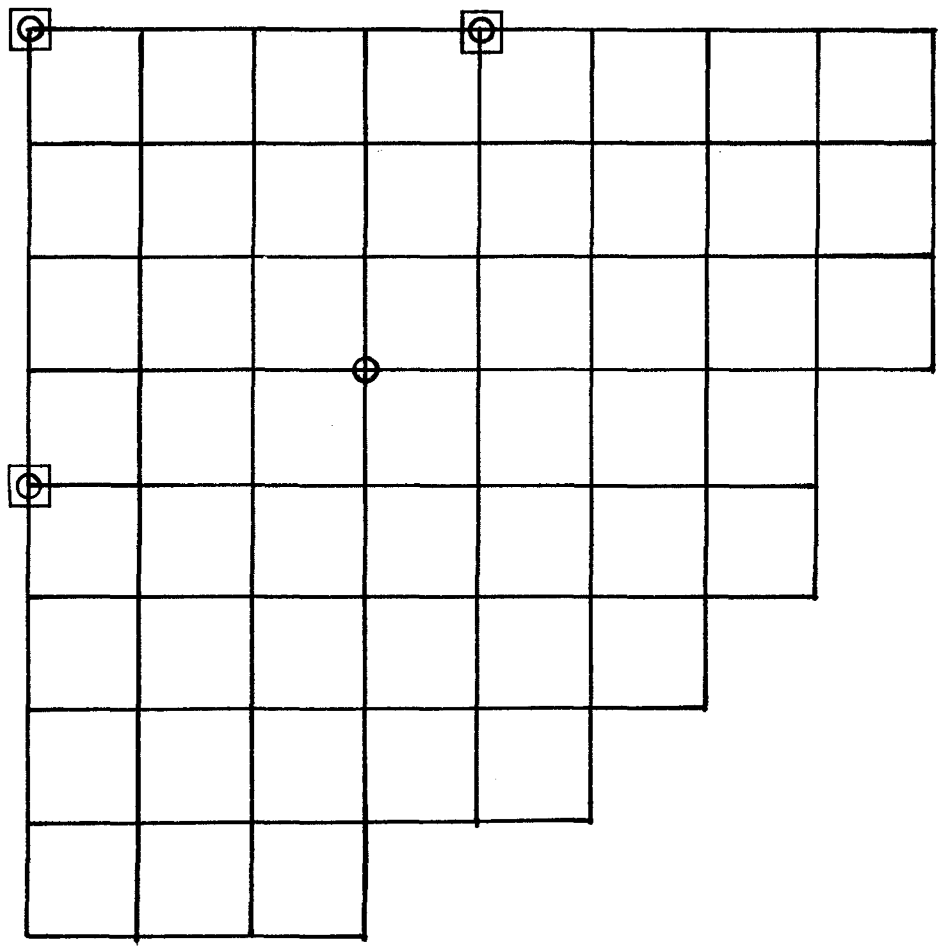
3. Based on these loads, the members of the truss were resized as required for .05, .20 and .40 g loads and the resulting structural mass estimated.

The process is shown in the form of a flow chart in Figure III-25. Note that internal loads for the .20 and .40 g cases were derived by scaling the loads from the .05 g case by a factor of 4 and 8, respectively. Based on these loads the truss members were resized, but the candidate truss was not reanalyzed to ascertain whether the increase in mass and, hence, body force loads was greater than the corresponding increase in strength. The omission of subsequent interactions on the resized truss was justifiable because:

1) Based on experience gained in the single-point analyses, resizing a box truss based strictly on scaled loads generally results in a conservative design (i.e., strength generally increases faster than body force loads); and

2) The effort and expense associated with refining the mass estimates could not be justified in light of the wide range and general nature of the designs under consideration (i.e., subsequent iterations were warranted only for a specific spacecraft and a specific mission).

Figures III-26, III-27, and III-28 present the box truss, steady state multi-point thrust application structural mass impact. The results are summarized below:

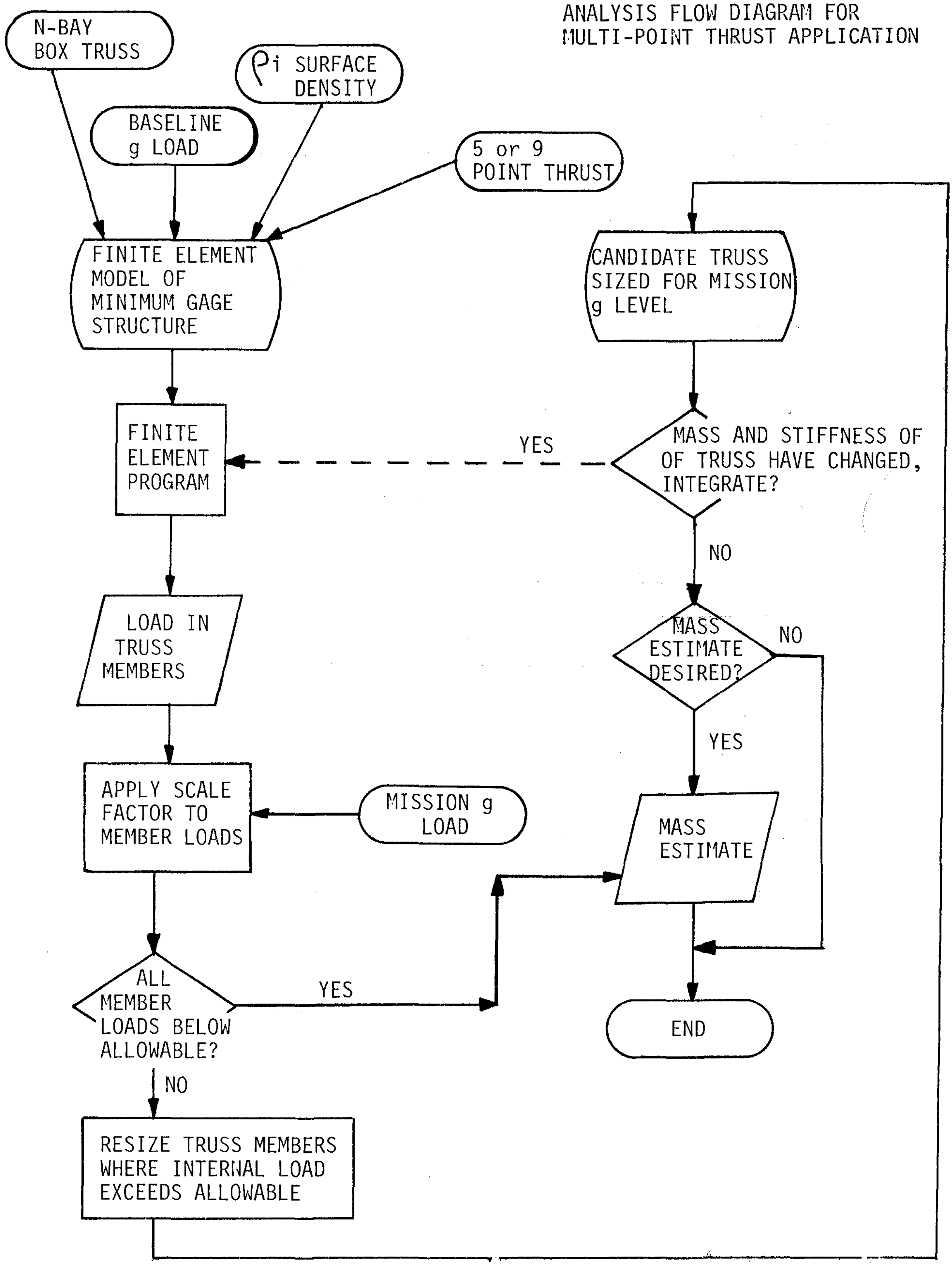


□ MULTI-POINT (5 POINT) THURST LOCATIONS

O MULTI-POINT (9 POINT) THRUST LOCATIONS

FIGURE III-24-BOX TRUSS MULTI-POINT THRUST LOCATIONS

FIGURE III-25
ANALYSIS FLOW DIAGRAM FOR
MULTI-POINT THRUST APPLICATION



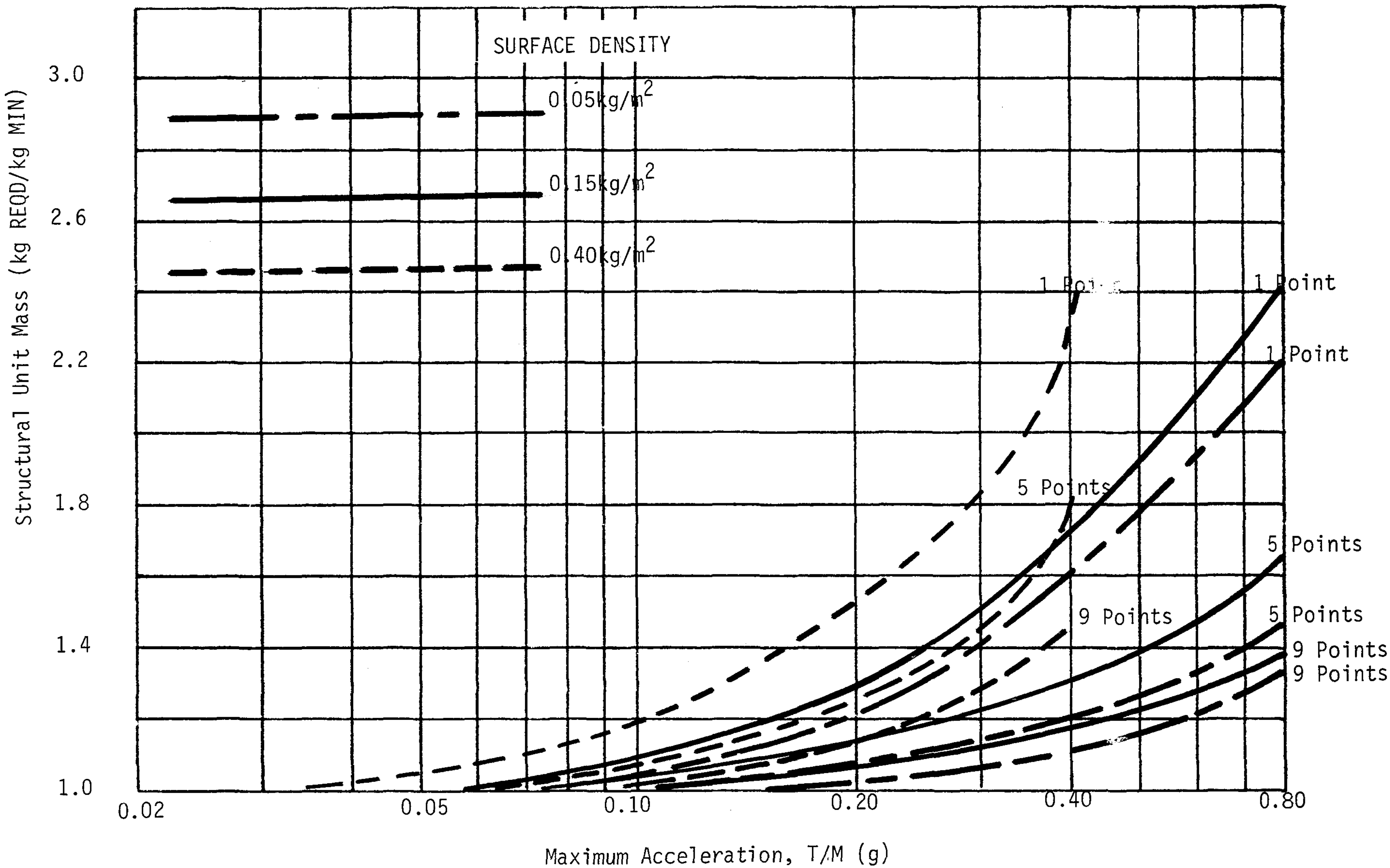


FIGURE III-26- 1, 5, AND 9 POINT THRUST IMPACT FOR 71 METER (BOX TRUSS)

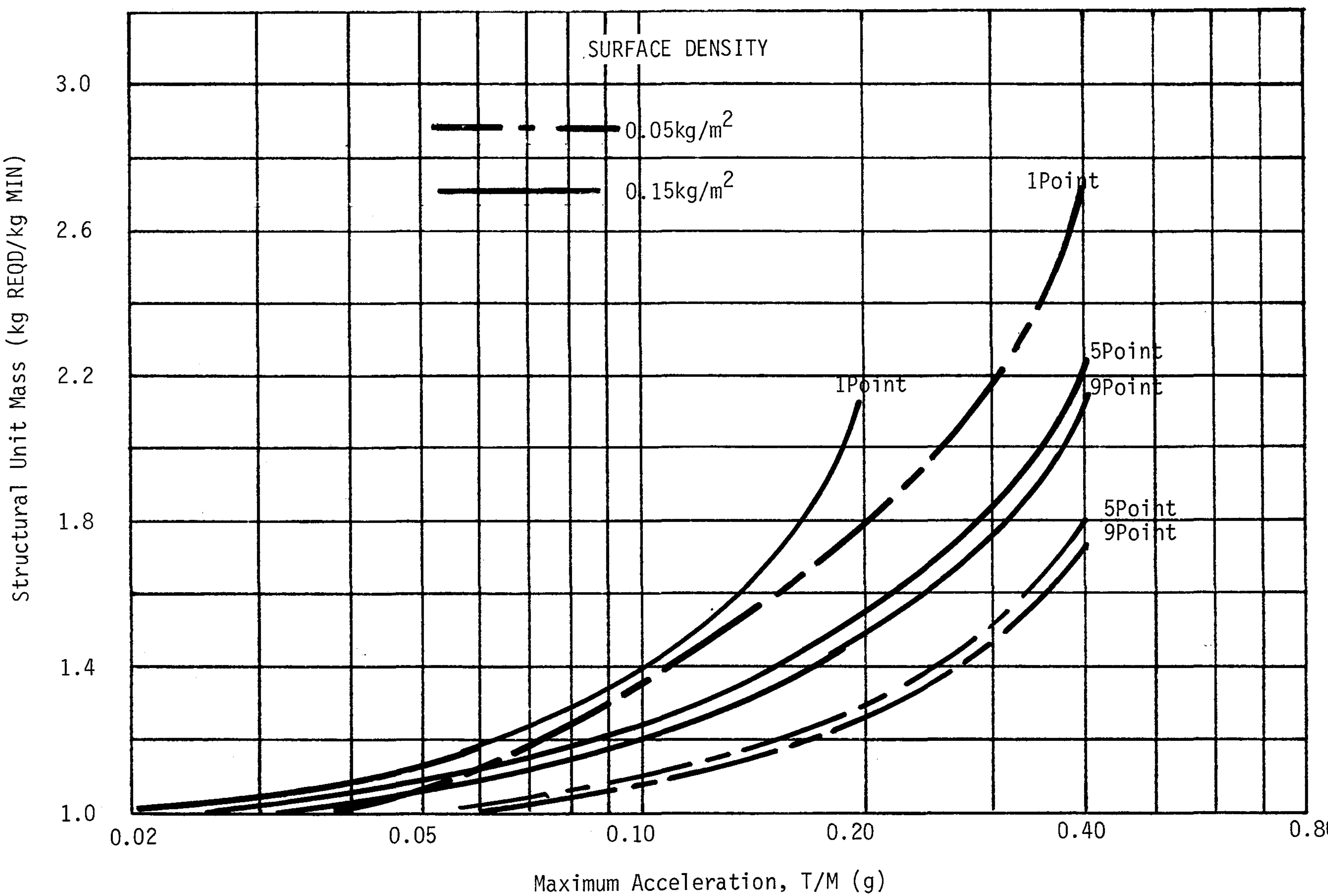


FIGURE III-27- 1, 5, AND 9 POINT THRUST IMPACT FOR 141 METER (BOX TRUSS)

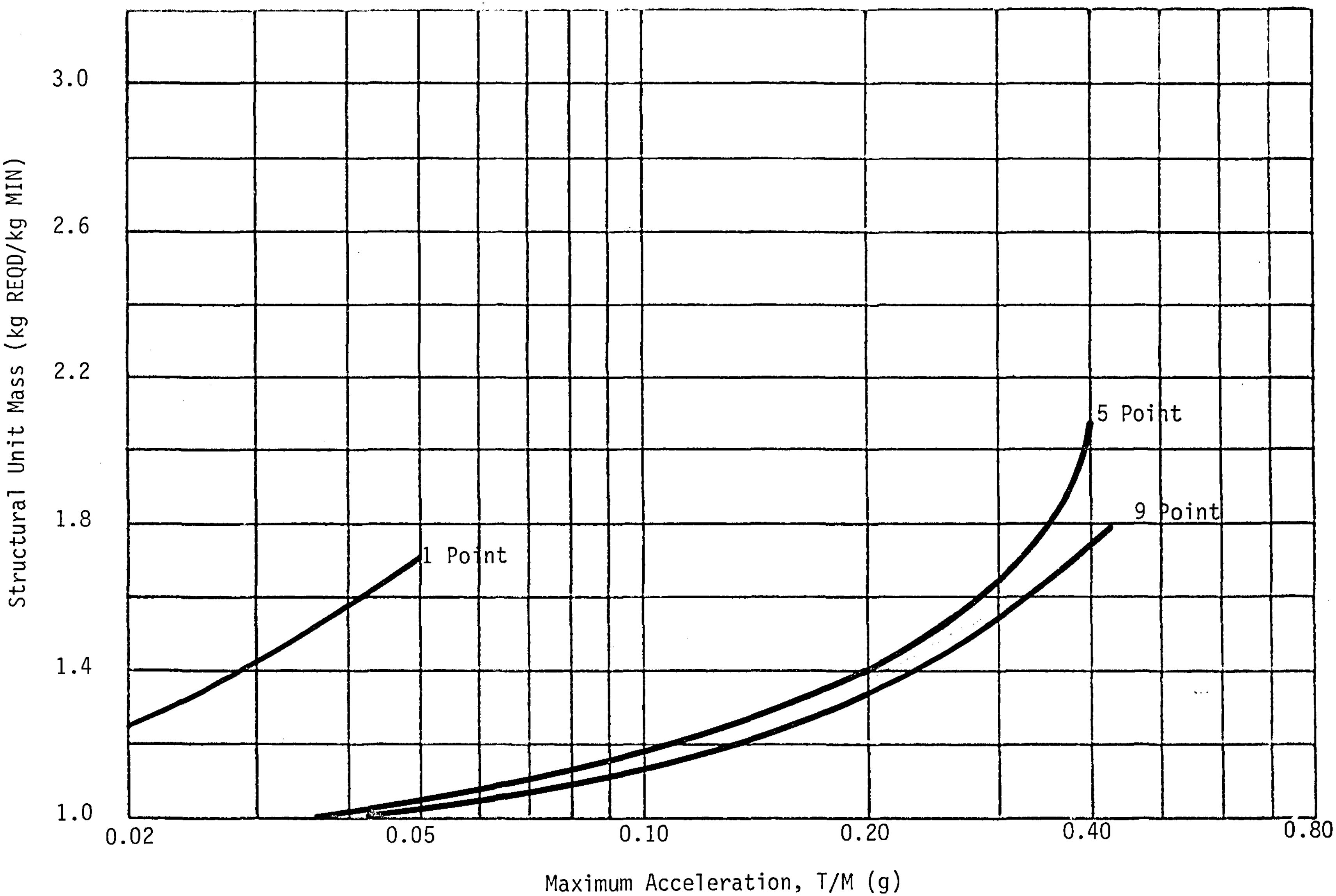


FIGURE III-28- 1, 5, AND 9 POINT THRUST IMPACT FOR 194 METER AND 0.05kg/m^2 (BOX TRUSS)

1. By utilizing a 5 point thrust application, a factor of $\approx$ 2 increase in thrust can be allowed without a change in structural mass impact.

2. By going from a 5 point to a 9 point thrust application, less than a 50% increase in thrust can be realized for no change in structural mass impact

The results indicate that for these size ranges, multi-point thrust does not provide enough of a performance enhancement to warrant the added stage complexity. This is principally based on the small changes in payload mass as f(T/M) over the range of accelerations considered herein (See Sections IV & V).

Although analysis was not performed to determine the effect of engine phasing errors, there will be a negative impact reducing the allowable thrust levels that were determined. In addition, the required phasing of thrusters may be too complex to implement within current projected capabilities of the guidance and propulsion subsystems.

The biggest obstacle in the path of an analytical approach to the structural response of the box truss during dynamic events such as engine startup and shutdown is the non-linear response of the structure. This phenomenon made finite element analysis of the multi-point thrust schemes relatively more complex than analysis of single-point. Consequently conclusions regarding multi-point shutdown were based on the following reasoning rather than explicit results.

Since the deflections and loads obtained in the multi-point analysis for a given steady-state g-load were considerably less than those obtained in the single-point it follows that the structural response of the multi-point box truss would be less than the single-point thrust, given ideal phasing in engine firing. Dynamic amplification factors from the single-point analyses maximizing at 2.05 for a step thrust input, resulted in a 1.4 design load amplification factor. Given that most of the response of the truss was in the first mode, and for multi-point thrust the tendency to excite the first mode will be substantially less, it would appear conservative to assume an average dynamic amplification of 2.0 for the worst case of multi-point dynamics. This results in a 1.36 design load amplification factor. Since the increase in required structural mass for a given increase in steady-state g-load is considerably less for the multi-point case than the single point, it follows that if the average dynamic amplification of 2.0 is used to obtain an "equivalent" steady state g-level, the corresponding increase in required mass will be even less significant in the multi-point case than the single-point case. Table III-19 presents the results of the 1, 5 and 9 point thrust application for the box truss. As can be seen, the thrust transient impacts are slightly lower for the multi-points. The 10% average structural mass impact for the single-point is reduced to 5% for the 5 point.

3. Hoop and Column Multi-Point Analysis

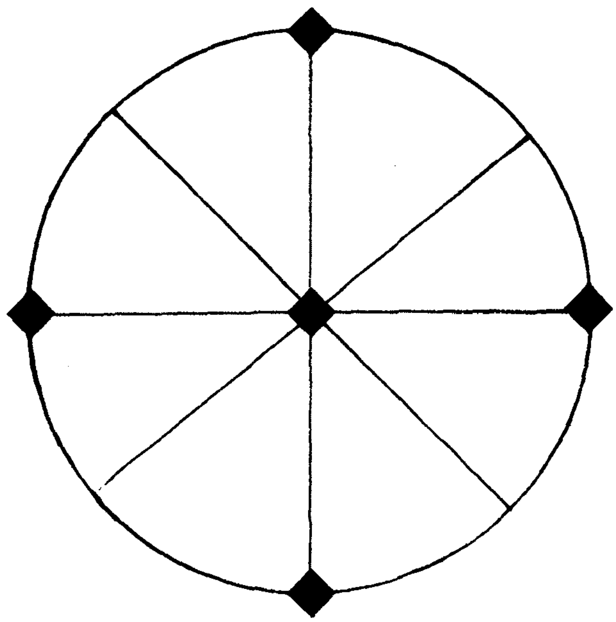
The hoop and column design allows for placement of one thruster on the column and the remaining 4 or 8 thrusters equally spaced on the hoop (Figure III-29). By thrusting on the hoop a reduction in the hoop compression load is achieved. However, there is no decrease in the loads produced by the

TABLE III-19 - BOX TRUSS STRUCTURAL MASS IMPACT FOR STEP INPUT

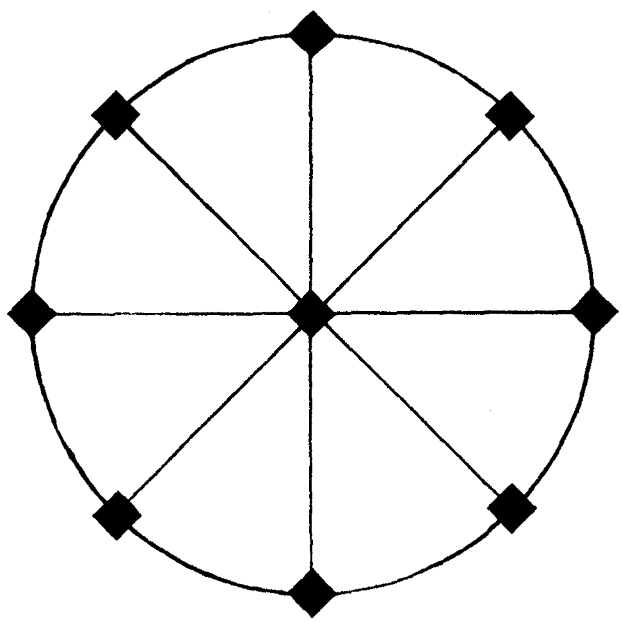
DIAMETER METERS	T/M g's	SURFACE DENSITY (kg/m²) 0.05	0.15	0.40
194	.02	1.03/1.02/1.00(1)(2)		
	.05	---/1.10/1.08		
141	.02	1.21/1.00/1.00	1.02/1.00/1.00	
	.05	1.03/1.00/1.00	1.11/1.08/1.07	
	.20	1.18/1.14/1.10	1.22/1.16/1.12	
71	.02	1.00/1.00/1.00	1.01/1.00/1.00	1.03/1.00/1.00
	.05	1.01/1.00/1.00	1.03/1.00/1.00	1.12/1.08/1.06
	.20	1.00/1.00/1.00	1.11/1.07/1.06	1.38/1.25/1.21

(1) kg REQUIRED/kg STEADY STATE
(2) SINGLE POINT/5 POINT/9 POINT

FIGURE III-29-HOOP AND COLUMN MULTI-POINT THRUST POINTS OF APPLICATION



5-Point Application



9-Point Application

suspended surface. Therefore, the overall reduction in loads are not as dramatic. Figures III-30, III-31, and III-32 present the hoop and column, steady-state multi-point thrust application, structural mass impact. The results show that by utilizing a 5 point thrust application, less than a factor of two increase in thrust can be allowed without a change in structural mass impact. The 9 point thrust application shows only a small improvement over the 5 point.

Like the box truss, the results indicate that for these size ranges, multi-point thrust does not provide enough of a performance enhancement to warrant the added stage complexity.

The hoop and column transient analysis assumed a dynamic amplification factor of 2.0 resulting in a design load factor of 1.36. The results are summarized in Table III-20. Again, the results show a small decrease in the structural mass impact.

TABLE III-20 - HOOP AND COLUMN STRUCTURAL MASS IMPACT FOR STEP INPUT

DIAMETER METERS	T/M g's	SURFACE DENSITY (kg/m^2) 0.05	0.15	0.40
50	0.02	1.00/1.00/1.00(1)(2)	1.00/1.00/1.00	1.00/1.00/1.00
	0.05	1.00/1.00/1.00	1.00/1.00/1.00	1.00/1.00/1.00
	0.20	1.00/1.00/1.00	1.00/1.00/1.00	1.00/1.00/1.00
	0.80	1.03/1.00/1.00	1.05/1.00/1.00	1.06/1.02/1.00
100	0.02	1.00/1.00/1.00	1.00/1.00/1.00	1.02/1.00/1.00
	0.05	1.00/1.00/1.00	1.02/1.00/1.00	1.06/1.02/1.00
	0.20	1.04/1.00/1.00	1.05/1.01/1.00	1.07/1.03/1.01
	0.80	1.07/1.03/1.01	1.10/1.06/1.04	1.13/1.09/1.07
200	0.02	1.02/1.00/1 00	1.04/1.00/1.00	1.17/1.13/1.11
	0.05	1.04/1.00/1.00	1.16/1.12/1.10	1.53/1.40/1.32
	0.20	1.20/1.15/1.13	1.28/1.20/1.15	

(1) kg REQUIRED/kg STEADY STATE
(2) SINGLE POINT/5 POINT/9 POINT

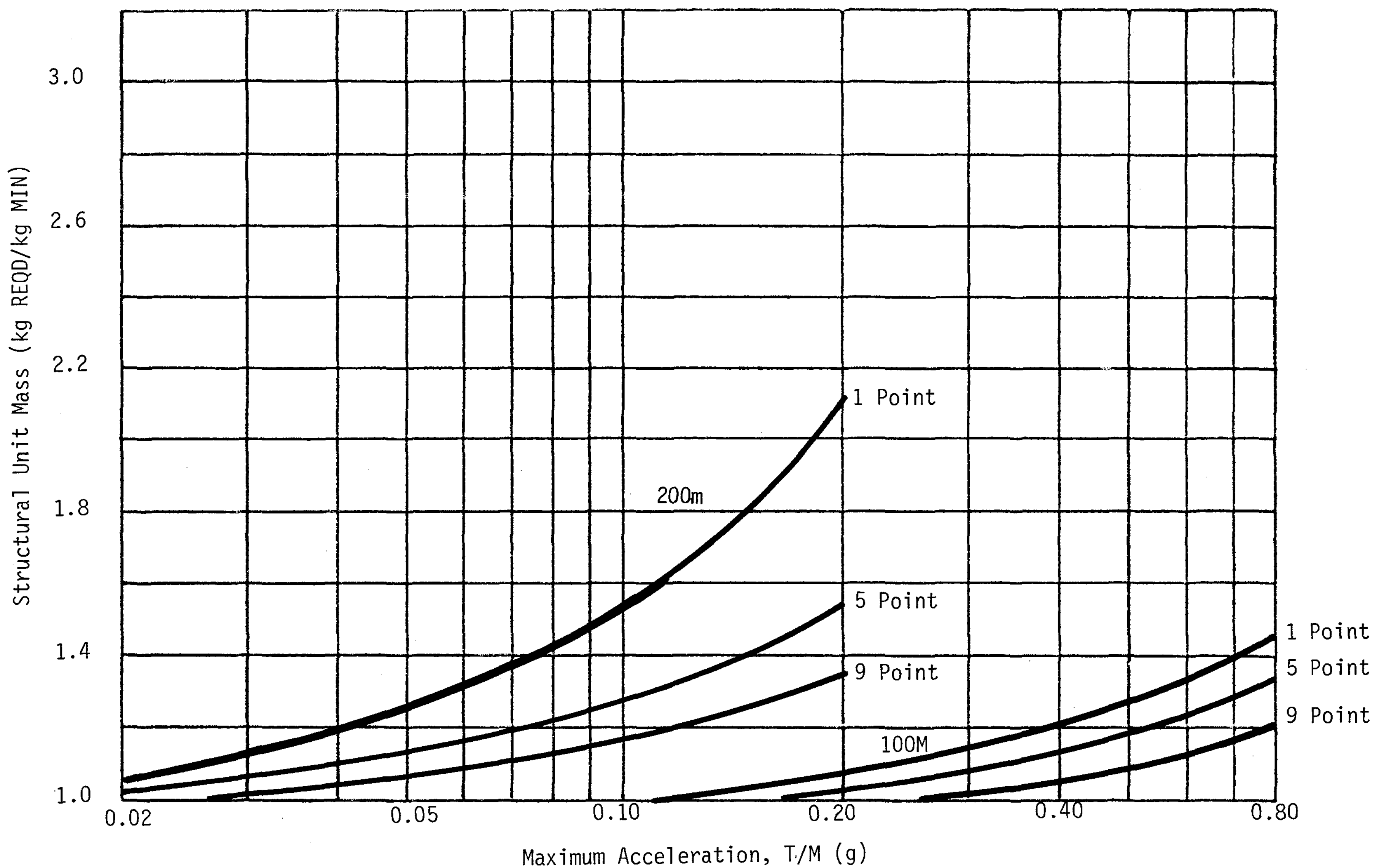


FIGURE III-30- 1, 5, AND 9 POINT THRUST IMPACT FOR 0.05kg/m^2 SURFACE DENSITY (HOOP AND COLUMN)

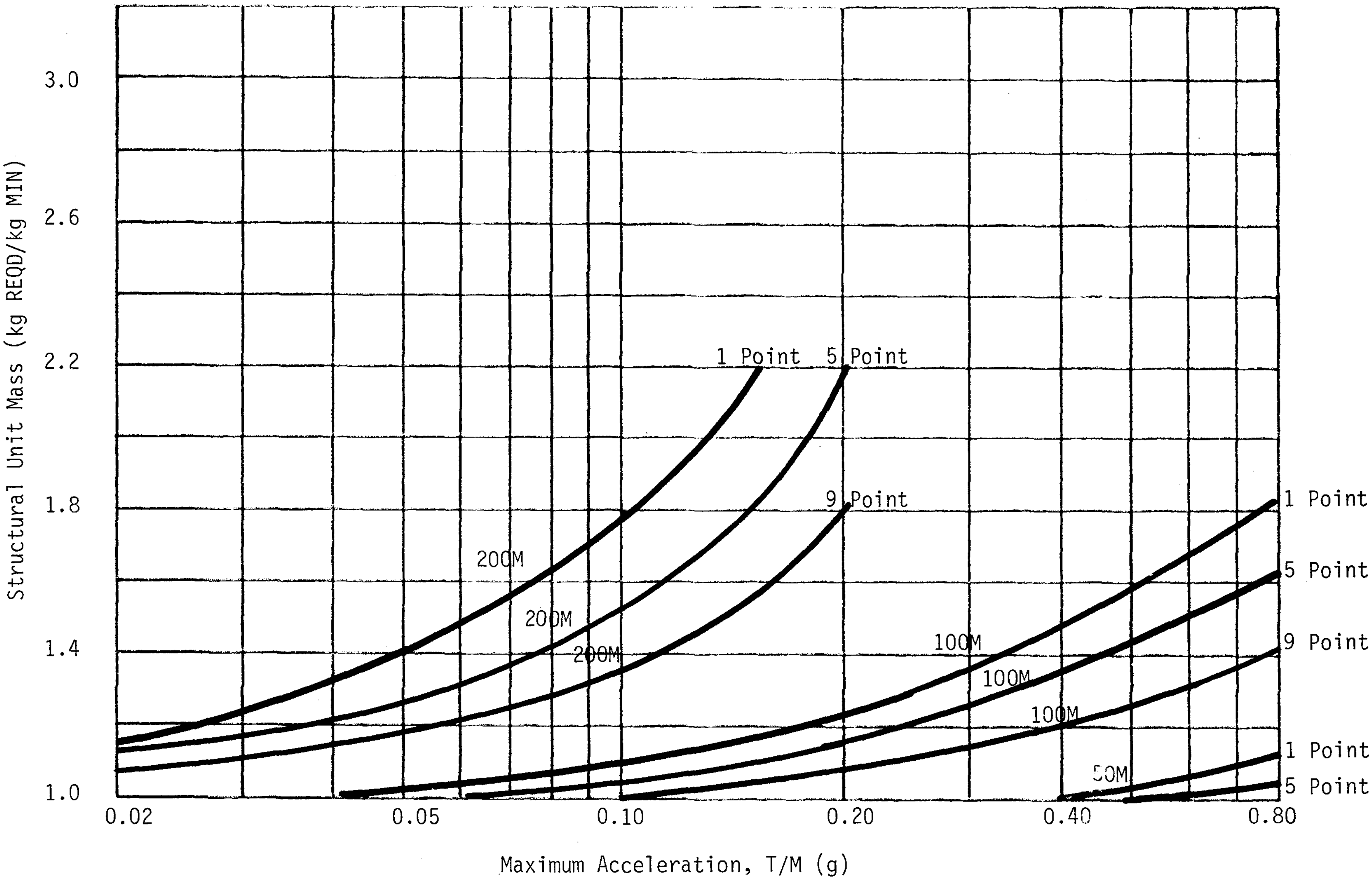


FIGURE III-31- 1, 5, AND 9 POINT THRUST IMPACT FOR 0.15kg/m^2 SURFACE DENSITY (HOOP AND COLUMN)

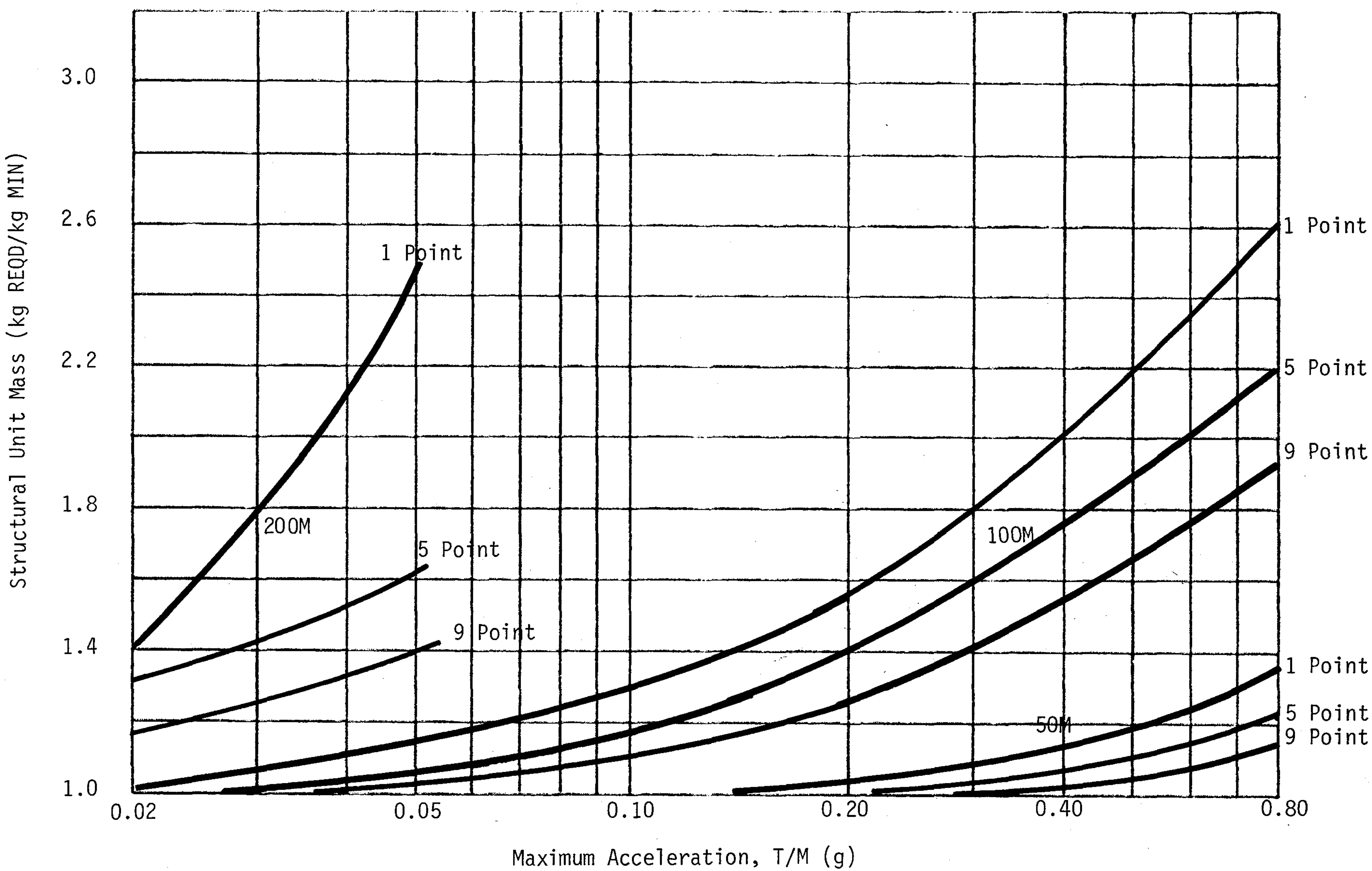


FIGURE III-32- 1, 5, AND 9 Point THRUST IMPACT FOR 0.40kg/m^2 SURFACE DENSITY (HOOP AND COLUMN)

IV. PROPULSION SYSTEM PERFORMANCE

A. Approach

In this task parametric analyses were performed to determine deliverable payload mass and engine burn times as a function of T/M, propulsion system performance, and number of perigee burns for transfer from low earth orbit (LEO) to geosynchronous earth orbit (GEO). This analysis was conducted within certain groundrules. The orbit transfer is from LEO (296 km circular orbit at 28.5° inclination) to GEO (35,900 km circular orbit at 0° inclination). The 28.5° plane change will occur at apogee. An initial startburn mass of 27,200 kg was assumed consistent with the STS capability with 2270.0 Kg for ASE. Other parameters considered are a specific impulse range of 300 to 450 seconds, a final thrust to mass ratio range of 0.01 to 1.0, and number of perigee burns ranging from 1 to 8.

A three-degree of freedom trajectory targeting and optimization program (GMAP) in which the entire trajectory can be simulated was used to develop the ideal velocity requirements. Certain options were taken into consideration to develop the trajectory strategy. The thrust segments were numerically integrated; with the coast segments propagated using Keplerian equations. Gravity turn steering was used during all perigee burns with constant yaw and pitch angles used at apogee to change the plane and circularize the orbit.

B. Results

Three thrust models; impulsive, constant thrust, and constant acceleration with ISP, number of burns, and T/M as parameters were studied as possible trajectory strategies. The cases studied are summarized in Table IV-1. Several conclusions can be drawn from the data associated with the trajectories identified in Table IV-1. First, multiple perigee burns can significantly reduce the ideal ΔV requirement for geosynchronous missions. This is illustrated in Figure IV-1. Utilization of mutiple burns lowers the required ideal velocity increment by reducing the gravity losses accumulated during the thrusting segments. Reduction of the gravity loss is a direct result of the negative to positive change in the flight path angle (FPA) over all but the first perigee burn (see Figure IV-2). Since the flight path angle is negative at the start of all multiple burns, the gravitational acceleration has a component that is in the same direction as the thrust vector. This effect causes the gravity losses to decrease prior to the osculating perigee passage. After perigee passage, the FPA becomes positive, and the gravitational acceleration causes a velocity loss in the normal sense of the term. However, the net loss is reduced by the counter-balancing contribution of favorable gravitational acceleration prior to perigee. This balancing effect is illustrated in Figure IV-2 by comparing the area above and below the zero FPA condition.

The second conclusion that can be drawn is that the constant acceleration propulsion mode offers advantages in ideal velocity requirements at certain T/M values over constant thrust cases for both 1 and 8 perigee burn transfers as illustrated in Figure IV-3. Constant thrust requires a 2% ΔV increase at low T/M using one burn and an 11% ΔV increase at low T/M using eight burns. In addition these data indicate that there is only minor ΔV variation between these propulsion modes at high T/M. This implies that for medium to high

TABLE IV-1 TRAJECTORY DATA SUMMARY

TYPE OF PROPULSION MODE	NUMBER OF PERIGEE BURNS	I_{sp} (SEC)	INITIAL T/M	FINAL T/M	ΔV* (M/S)	BURN TIME (HRS)	TRIP TIME (HRS)	PAYLOAD MASS (Kg) λ = .75	λ = .85	λ = .95
IMPULSIVE	1	450	∞	∞	4232	0	5.3	4836	7469	9547
CONSTANT THRUST	1	450	0.10	0.2732	4435	0.8	5.6	4211	6918	9055
	1	450	0.06	0.174	4698	1.4	5.7	3441	6238	8446
	1	450	0.01	0.0337	5357	8.8	13.6	1706	4706	7076
	1	450	0.003	0.0108	5768	30.1	36.1	987	4073	6509
	2	450	0.01	0.032	5206	8.7	14.5	2082	503	7374
	4	450	0.01	0.033	4933	8.4	18.0	2795	5668	7936
	8	450	0.01	0.0281	4557	8.05	30.3	3849	6598	8768
	8	450	0.003	0.0101	5343	29.3	51.0	1740	4737	7103
	1	300	0.003	0.019	5562	23.6	29.6	3593	32	2893
	8	300	0.01	0.046	4501	6.5	30.3	1214	2130	4770
	8	300	0.003	0.0166	5046	22.8	46.8	2533	967	3729
	1	375	0.003	0.014	5621	27.2	33.2	1202	2140	4780
	4	450	0.136	0.0427	4756	5.9	17.1	3289	6104	8326
CONSTANT ACCEL.	1	450	0.1	0.1	4537	1.3	5.9	3908	6650	8815
	1	450	0.017	0.017	5457	8.9	13.3	1466	4496	6887
	1	450	0.01	0.01	5647	16.0	19.2	1021	4103	6536
	8	450	0.1	0.1	4287	1.2	29.1	4664	7317	9412
	8	450	0.03	0.03	4350	4.1	29.3	4469	7145	9258
	8	450	0.01	0.01	4817	13.5	30.9	3108	5945	8184

λ = MASS FRACTION

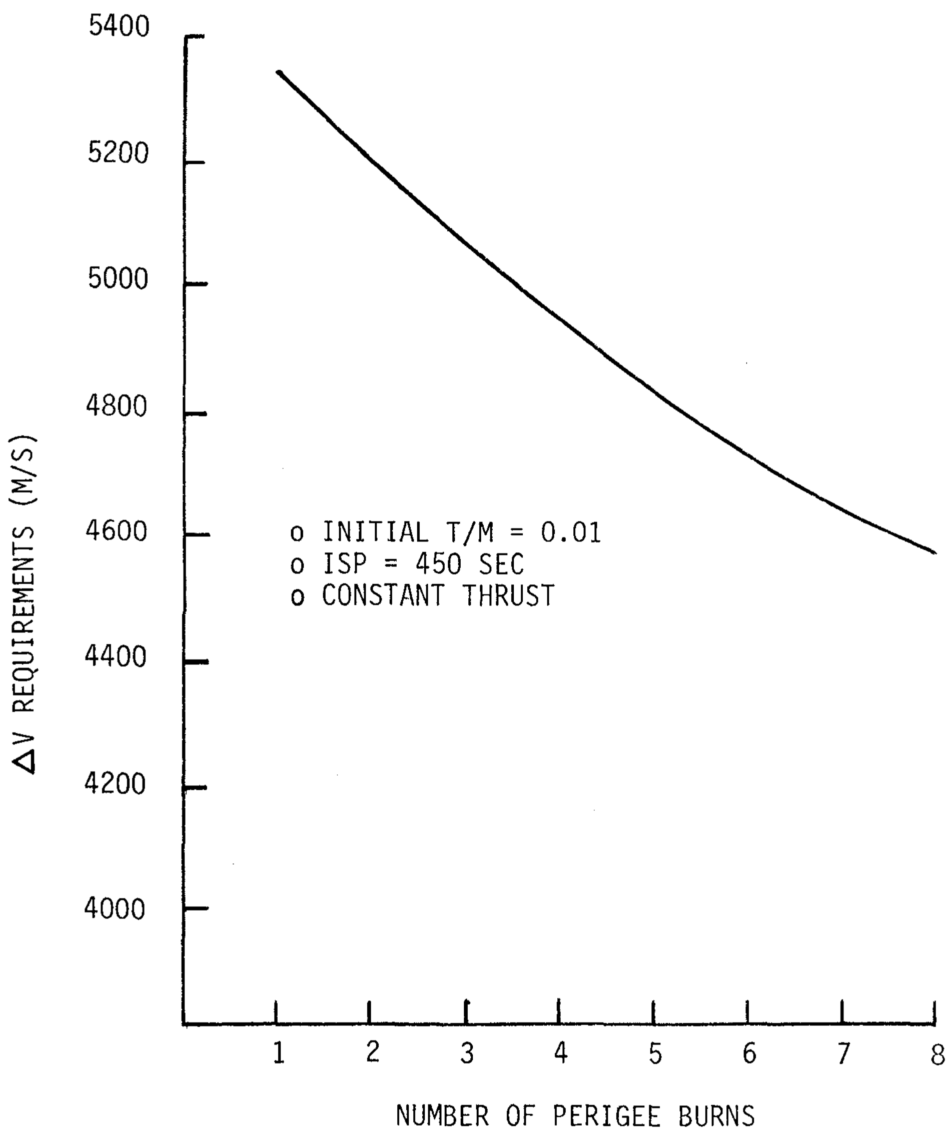


FIGURE IV-1 - VARIATION IN IDEAL VELOCITY REQUIREMENTS AS A FUNCTION OF THE NUMBER OF PERIGEE BURNS

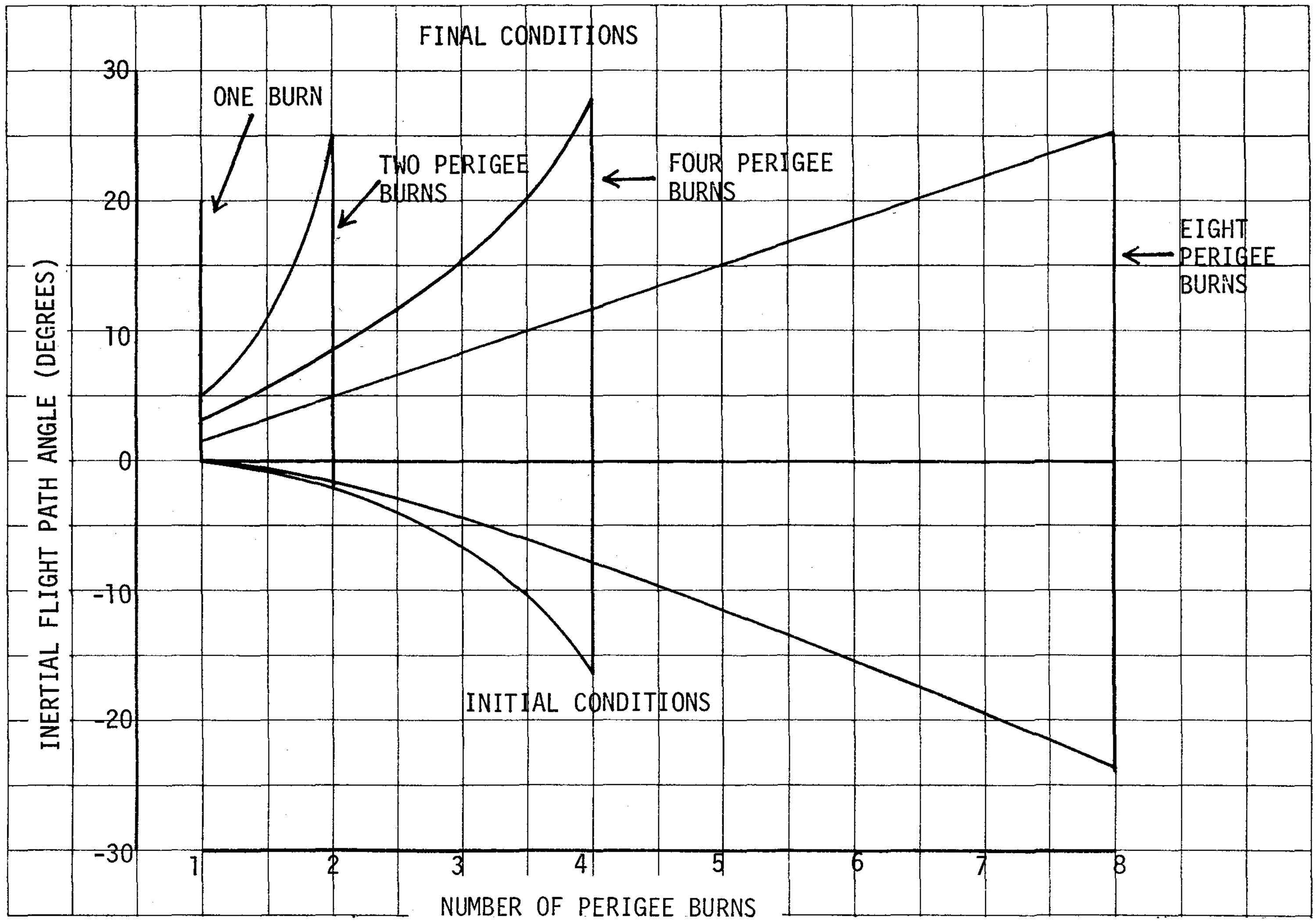


FIGURE IV-2 - APPROXIMATE FLIGHT PATH ANGLE ENVELOPES FOR THRUST SEGMENTS

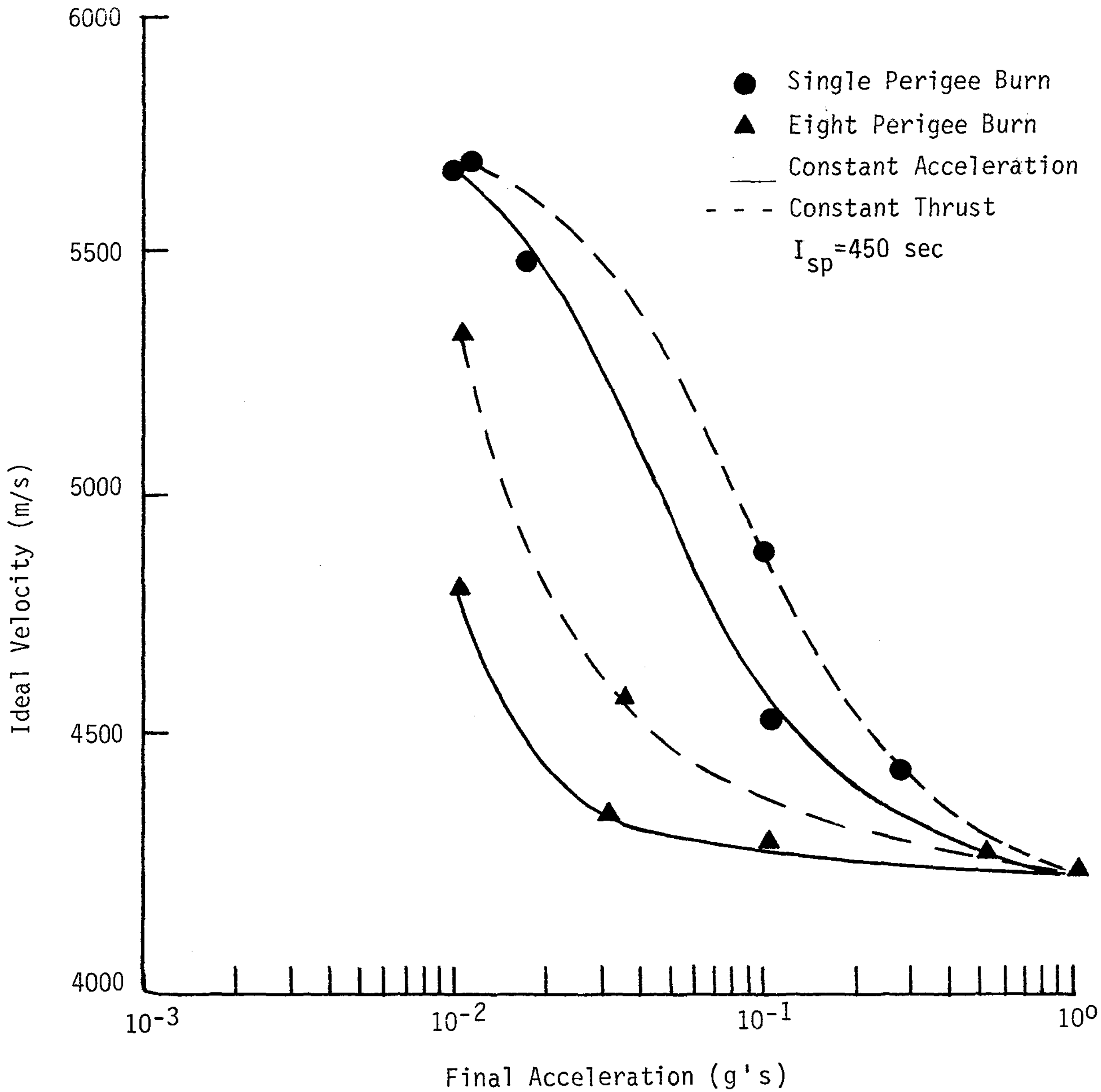


FIGURE IV-3- Ideal Velocity Requirements thrust or extremely low thrust level applications, simplicity of the constant thrust propulsion mode would most likely offset the advantages of ΔV savings offered by the constant acceleration option. Figure IV-4 illustrates the comparisons of burn time as a function of thrust to mass for the constant thrust, constant acceleration modes for 1 and 8 burn transfer strategies. There are minimal differences between single and multiple burns burn time for both constant thrust and constant acceleration. However, constant thrust requires a 115% increase in burn times relative to constant acceleration at low T/M.

Figure IV-5 illustrates the comparisons of trip time for the two propulsion modes and the two perigee burn strategies. As shown by the curves constant thrust increases trip time by 65-88%, depending upon the number of perigee burns. With the use of high thrust multiple burns, coast time dominates burn time, however with the use of low thrust, burn time dominates. Therefore, trip time increases with the number of perigee burns due to the domination of coast time between burns. Also, multiple burn trip times for constant acceleration are nearly invariant to T/M.

Payload capabilities as a function of T/M with constant acceleration and constant thrust, 1 and 8 perigee burns and mass fraction as parameters are shown in Figure IV-6. Payload mass is essentially invariable at $T/M > 0.1$ g for eight perigee burns across the range of mass fractions from 0.75 to 0.95. For both 1 and 8 burn strategies payload mass does not equilibrate until $T/M \geq 1.0$ g for all mass fractions. Constant acceleration increases payload by 3-15% over constant thrust depending upon the number of perigee burns employed.

The numerical results obtained also indicated that required velocity increment (ΔV req) is relatively insensitive to the propulsion system Isp. The magnitude of this sensitivity for a final thrust to mass ratio of approximately 0.01 is presented in Figure IV-7. These data show that for a given final acceleration increased specific impulse results in a increased ΔV requirement. This trend is caused by the differences in mass consumption and burning times which cause gravitational losses, at least during the initial phases of the transfer, to be higher for the higher Isp systems. Comparison of the data in Figure IV-7 with the required ΔV shown in Figure IV-3 clearly demonstrates that Isp is not a major factor in the estimation of the mission ΔV requirements. In fact, analysis can show that Isp does not enter into the ΔV requirements for the constant acceleration mode. This is because in the constant acceleration case, Isp can be eliminated from the equations of motion. The impact of Isp only changes the vehicle weight time history; hence, deliverable payload; and not the ΔV requirement.

In summary, it is clear from these sensitivities that the T/M ratio is by far the principal driver in the trajectory design for low thrust systems with mass fraction as the second most important variable. The number of perigee burns has a significant impact on ΔV requirement, trip time, and delivered payload. The least important parameter appears to be Isp. However, changes in Isp still impact payload mass.

An intermediate orbit for an eight burn transfer is illustrated in Figure IV-8. Intermediate orbits one through eight represent the results of the perigee burns. The eighth orbit is the transfer orbit that delivers the payload to geosynchronous orbit. The thrusting areas are not shown so that

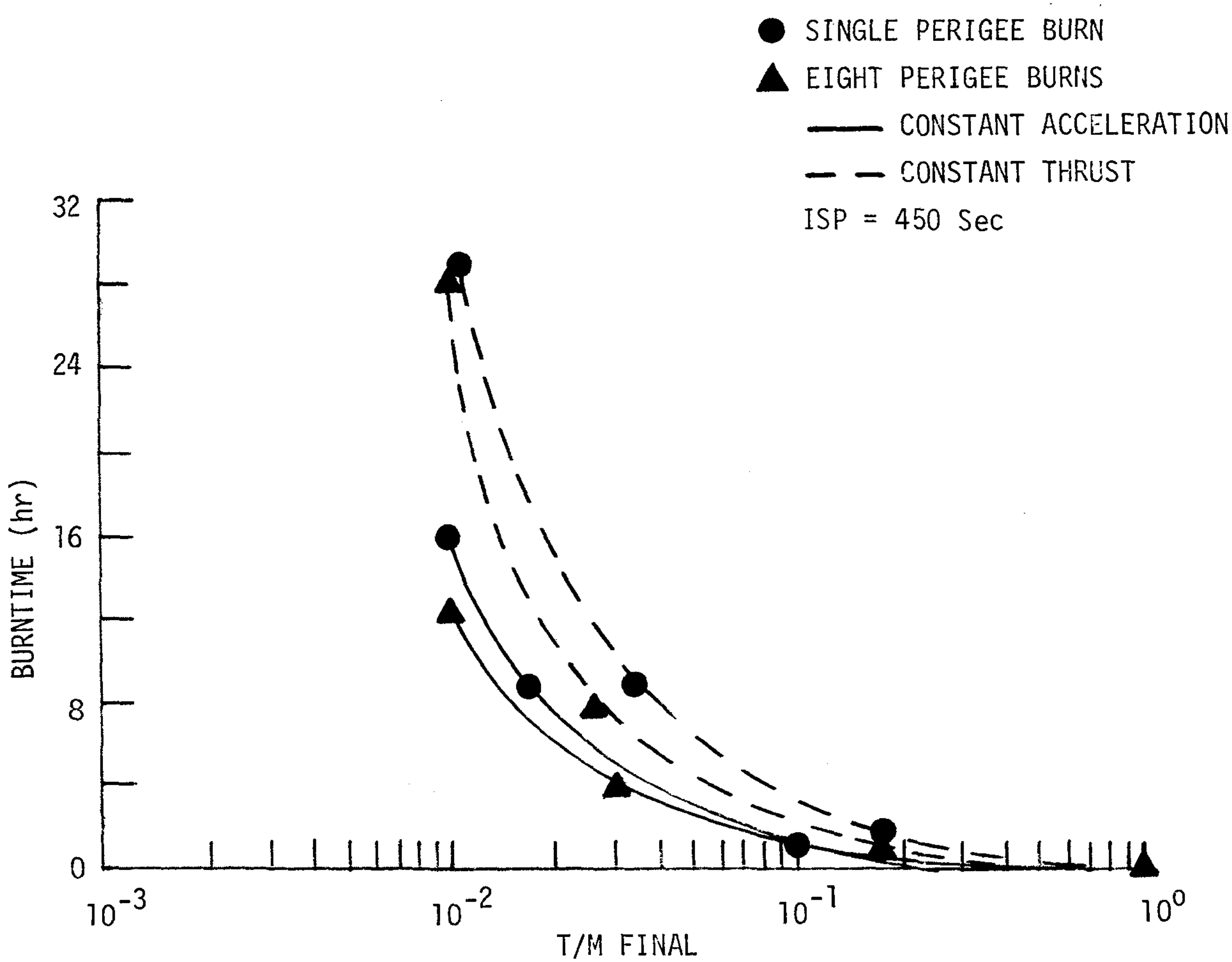


FIGURE IV-4 - BURNTIME REQUIREMENTS

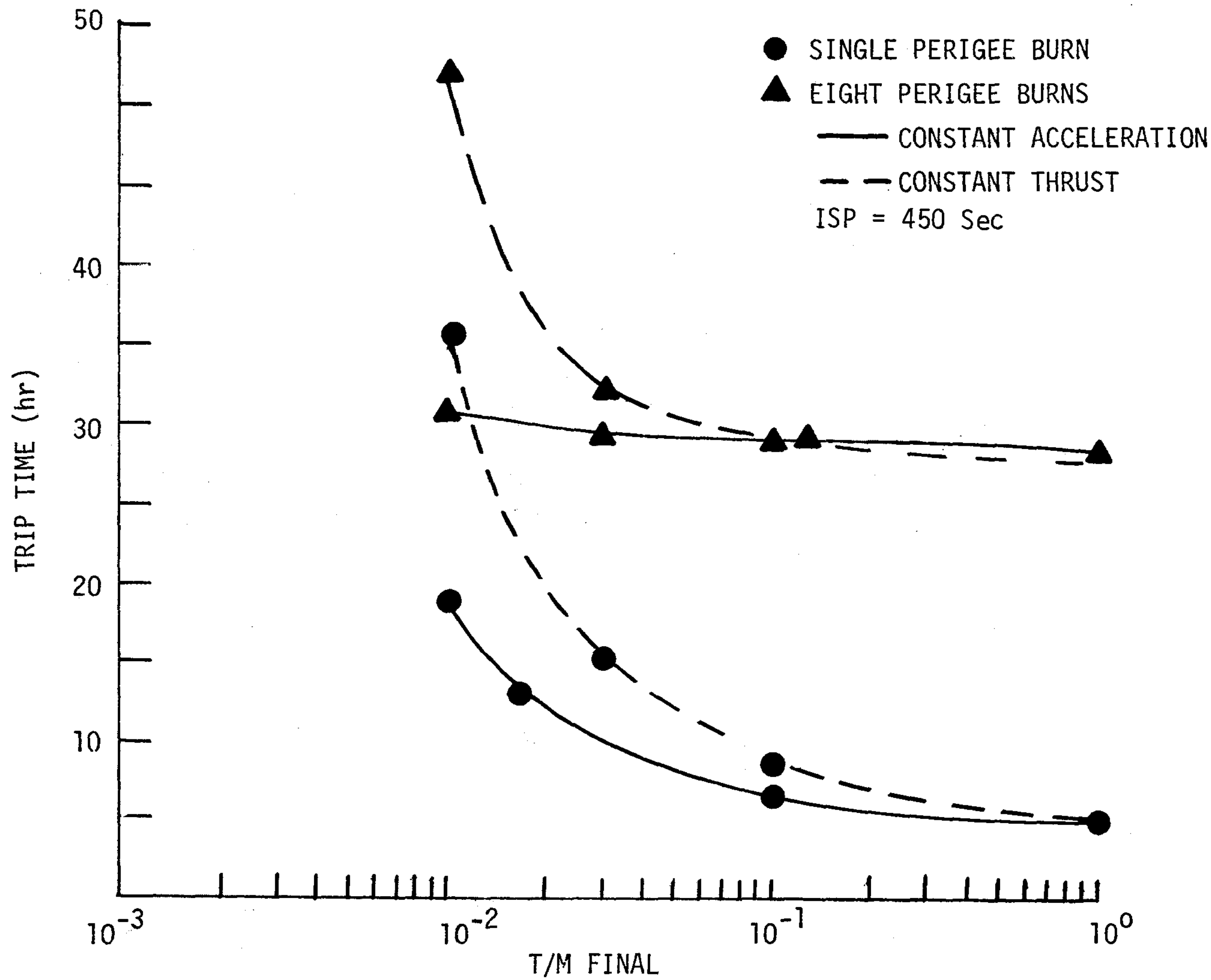


FIGURE IV-5 - TRIP TIME REQUIREMENTS

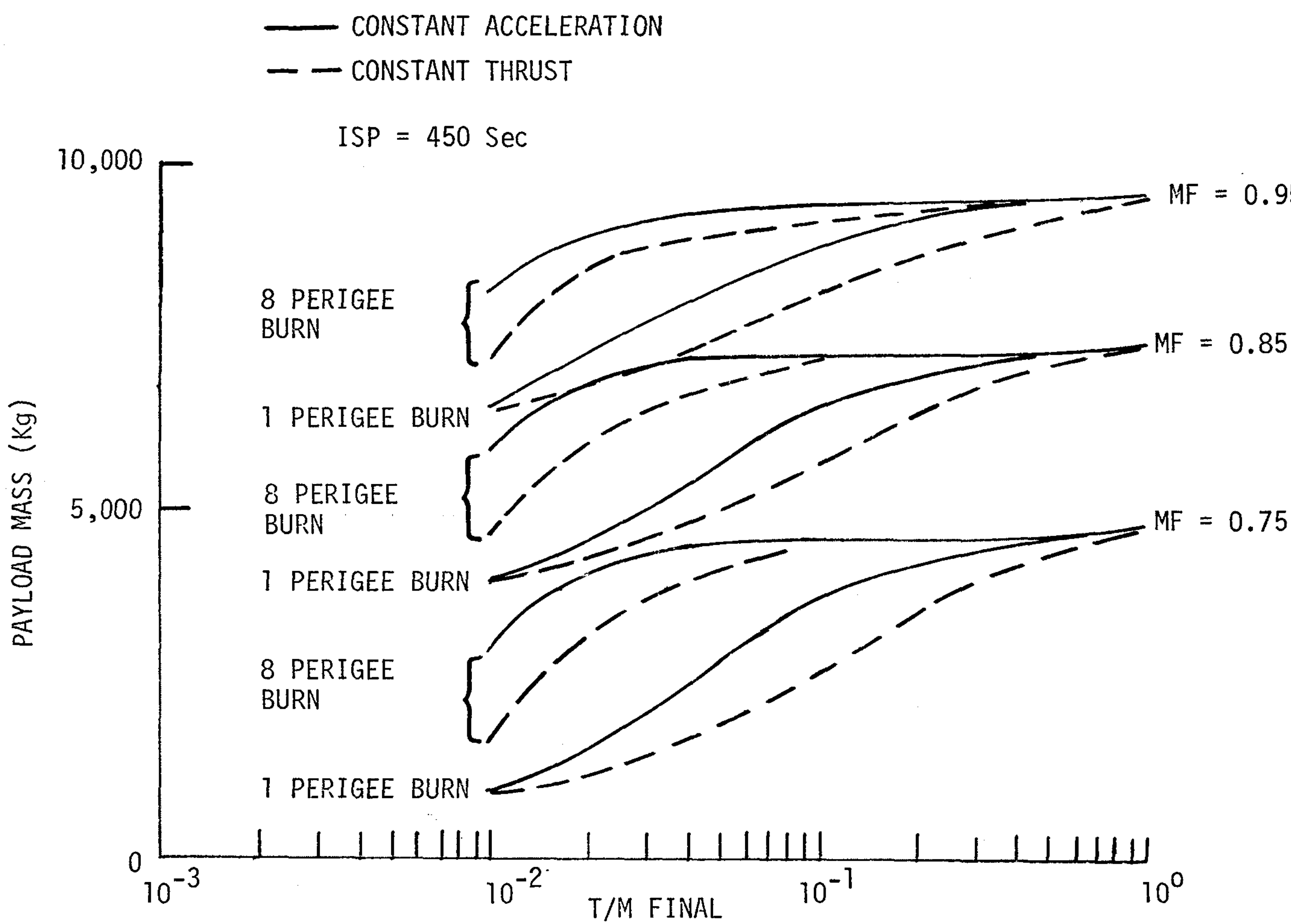


FIGURE IV-6 - PAYLOAD CAPABILITIES

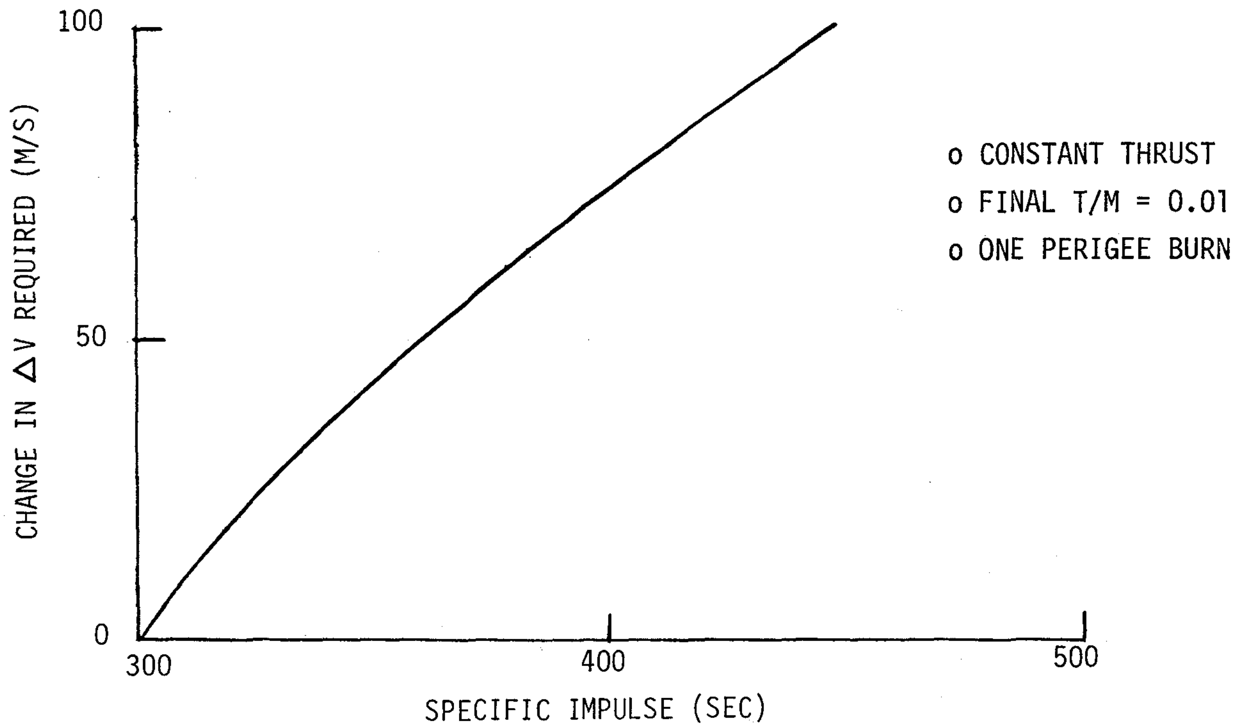


FIGURE IV-7 TYPICAL VARIATION IN ΔV REQUIRED AS A FUNCTION OF PROPULSION SYSTEM SPECIFIC IMPULSE

Initial Thrust to Mass = 0.01	Perigee Altitude, km	Apogee Altitude, km
Initial Orbit	296	296
Orbit After Burn 1	570	1269
2	796	2537
3	982	4699
4	1130	6425
5	1252	9477
6	1348	13875
7	1430	20674
8	1545	35128
Final Orbit	35862	35862

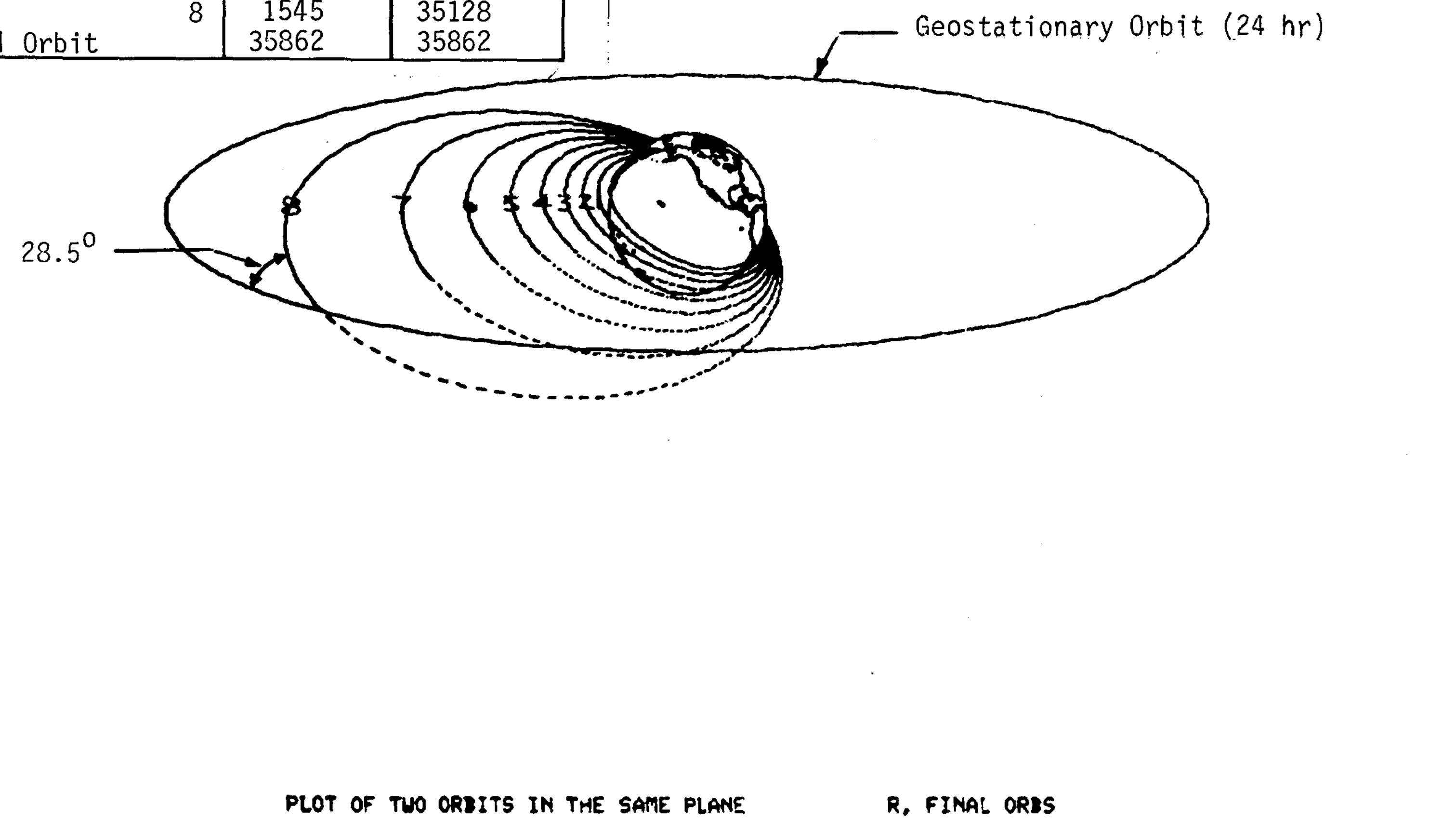


Figure IV-8 Sequence of Orbits for an Eight Burn Transfer Strategy
Viewpoint = 15°N, 135°W, $T/M_{Initial}$ = 0.01

one can see the relative orbital growth as a function of the number of perigee burns. The sequence of apogee and perigee altitudes for these orbits are tabulated in the upper corner of Figure IV-8.

V. PROPULSION SYSTEM MASS AND VOLUME

A. Task Description

The objective of this task was to provide the characteristics of several primary propulsion stages that are packaged in the Orbiter cargo bay which are used to deliver LSS from low earth orbit (LEO) to geosynchronous earth orbit (GEO). Characteristics determined include mass fraction, length, diameter, and center of gravity position. The characteristics were determined parametrically as a function of thrust-to-mass ratio for four propellant combinations and three propellant masses over a selected mixture ratio range for both pump-and pressure-fed engines.

The loaded stage mass for which the parametrics were generated was based on the efforts of the previous tasks and in particular Section IV, Propulsion System Performance. This study was groundruled to begin with a Shuttle Payload Capability of 29486 Kg, of which 2270 Kg is depleted by the MMU (450 Kg) and ASE (1820 Kg). Thus the loaded stage mass plus payload delivery capability to geosynchronous orbit was based on 27,215 Kg total mass. Since stage delivery capability varies with mass fraction, specific impulse, thrust level, and number of perigee burns, the loaded stage mass must cover the range of stage delivery capability necessary to total 27,215 Kg. The thrust-to-mass ratio range, based on the results shown in Section III, Thrust and Thrust Transient Effects, is 0.01 g to 0.1 g. The three loaded stage mass values generated encompass the thrust-to-mass range which allowed the development of parametric plots of mass fractions, length, maximum diameter, and center of gravity versus final acceleration level. Mass statements were developed in sufficient detail so a realistic center of gravity and mass fractions were determined in consonance with the stage tankage configurations.

B. Stage Configuration Development

Stage configurations were developed for: oxygen/hydrogen, LO_2/LH_2; oxygen/methane, LO_2/LCH_4; oxygen/kerosene, LO_2/RP-1; and nitrogen tetroxide/monomethylhydrazine, N_2O_4/MMH. For each of the propellant combinations listed above, a maximum performance design and a minimum length design, each with pump-fed and pressure-fed engines, were evaluated.

Eight stage concepts (four propellants each with two tankage configurations) were developed for both engine types. Three mass statements corresponding to three propellant loads were developed for each configuration at three mixture ratios over the specified range, shown in Table V-1, for a total of 144 for each transfer strategy. The pump-fed and pressure-fed engine characteristics for the study were supplied by the LeRC project manager before the start of the task for all propellant combinations (see Appendix A).

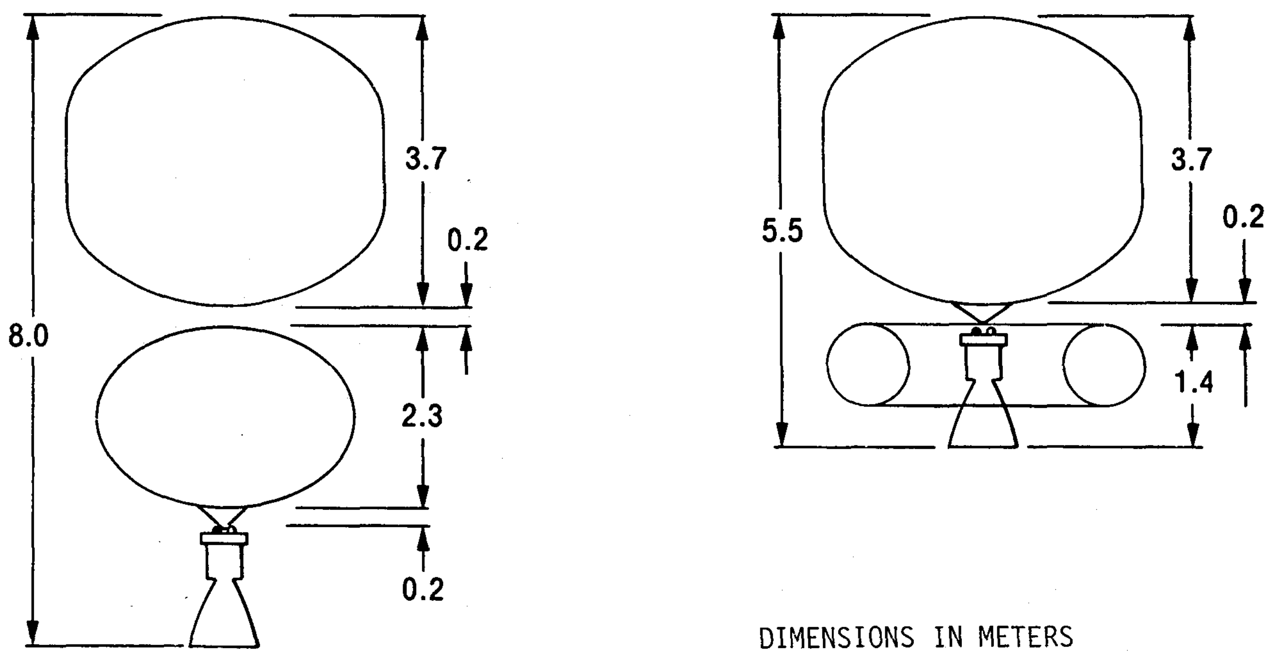
1. Tankage Configuration

Maximum performance stage concepts were configured of cylindrical barrels with $\sqrt{2}$ dome ellipsoidal tank shapes for each of the four propellant combinations. The maximum performance configurations and selected tank shapes, Figure V-1, were based on study activities conducted in Low Thrust Chemical Orbit Propulsion System Propellant Management Study (NASA CR-165293); thus, maximum performance is consistent with Shuttle requirements and current tankage technology. The concept of maximum performance is designed around maximum delivery of payload mass to GEO. The maximum length available for

FIGURE V-I-TANKAGE CONFIGURATIONS

MAXIMUM PERFORMANCE

MINIMUM LENGTH



DIMENSIONS IN METERS
MAXIMUM OUTSIDE DIAMETER = 4.3 m
DIMENSIONS ARE TYPICAL

TABLE V-1 - PARAMETRIC RANGE OF MIXTURE RATIO

Propellant Combination	Mixture Ratio Min.	Int.	Max.	Comments
LO_2/LH_2	5.0	6.0	7.0	
LO_2/LCH_4	3.4	3.7	4.0	These mixture ratios are associated with all tankage configurations and pump-fed pressure-fed engine concepts.
LO_2/RP-1	2.8	3.0	3.2	
N_2O_4/MMH	1.8	2.2	2.6	

maximum performance tankage and payload ranges from 16.22 to 16.46 meters, dependent upon propellant combination, was determined from Orbiter restraints presented in Figure V-2.

Minimum length configuration, also presented in Figure V-1, while providing for larger payload volume, requires more tankage mass and, therefore, limits the overall deliverable payload mass. The increased tankage mass is attributed to the use of a toroidal tank which weighs approximately 30 to 35% more than an ellipsoidal tank in the 13,600 to 15,870 Kg oxidizer propellant load range. For all minimum length cases analyzed, the oxidizer, is located in the toroidal tank. The advantage of the toroidal tank is the increased available orbit transfer vehicle payload length due to the shorter toroidal tank and embedding the engine within the toroid. The maximum available length for a minimum length tankage and payload is 15.24 meters as shown in Figure V-2.

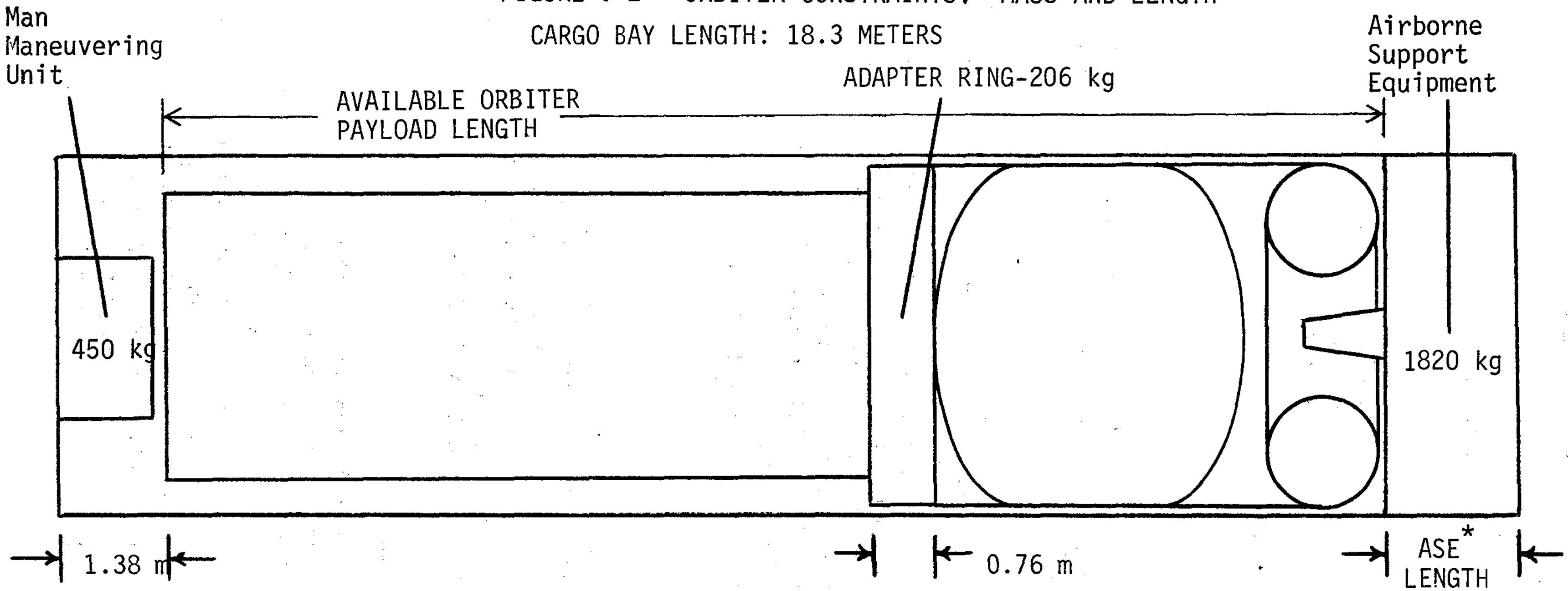
2. Maximum Diameter

Starting with the maximum cargo bay diameter of 4.57 m, an allowable stage diameter of 4.42 m was determined from inputs of DOD/STS Payload Integration Contract (F04701-77-00183). With a shell thickness of 1.32 cm, a clearance between the shell and insulation of 2.54 cm, and a maximum insulation thickness of 3.56 cm, the maximum inside diameter of the tank is limited to 4.26 meters. The tank material is aluminum 2219-T87.

3. Lift-Off Propellant Densities

Propellant conditions at lift-off and during the no vent period of Shuttle ascent (T + 90 seconds) have been derived under Contract NAS3-21954, Low Thrust Chemical Orbit to Orbit Propulsion System Propellant Management Study (NASA CR-165293). The analysis performed accounted for changes in cryogenic propellant densities due to boiling of the propellant during launch. For the initial tank sizing in Section V-B, the propellants were considered to be at saturation conditions. Since the heat leak to the propulsion system during the ground hold time and launch is large enough to produce boiling in the cryogens, the decrease in density must be integrated into the system sizing. These analyses apply to the LO_2/LH_2, LO_2/LCH_4, and LO_2/RP-1 propellant combinations.

FIGURE V-2 - ORBITER CONSTRAINTS: MASS AND LENGTH



*ASE LENGTH FOR 75° DEPLOYMENT OF ORBITER PAYLOAD

MAXIMUM PERFORMANCE: LO_2/RP-1 -0.46 m
TANKAGE
LO_2/LCH_4 -0.61 m
LO_2/LH_2 -0.70 m
N_2O_4/MMH -0.70 m

MINIMUM LENGTH: ALL PROPELLANT COMBINATIONS -1.67 m
TANKAGE

These densities and the associated tank pressure (124 KN/M^2 nominal, 165 KN/M^2 maximum) and time line (top to T-4 minutes, no venting until T + 90 seconds) were applied to the systems for this program. The results are summarized below:

	DENSITY
LH_2	67.1 Kg/M^3
LO_2	1106.5 Kg/M^3
LCH_4	411.0 Kg/M^3

For RP-1, N_2O_4, and MMH, densities consistent with 21°C propellant temperature were used:

RP-1	805.8 Kg/M^3
N_2O_4	1433.9 Kg/M^3
MMH	870.2 Kg/M^3

4. Insulation Systems

Multilayer (MLI) and spray-on foam insulation (SOFI) systems have been evaluated for cryogenic propellants (LO_2, LH_2, LCH_4) in NASA CR-165293. The results show that for all cases ranging from 445.0 N thrust (0.005g) to 4448.0 N (0.05g), the MLI system are lighter than comparable SOFI systems. Therefore, MLI was used as the baseline insulation system for this program.

C. Stage Mass Statements

Mass statements for each stage concept were generated at minimum intermediate, and maximum mixture ratios for a minimum of three propellant loads. The stage masses were based on an iterative scheme utilizing the ideal velocity equation and the engine data supplied by LeRC. The details of the mass statements are presented in Table V-2 through V-4, where Table V-2 shows the fixed masses for all propulsion systems. The remaining tables represent masses which were assigned specifically for cryogenics or storable propellants with either maximum performance or minimum length stages. Where masses are variable with stage mass, a range of masses is given. A 10% contingency factor was applied to all stage mass results. However, this percentage is not included in the values presented in Tables V-2, V-3, and V-4. Many of the mass items are self-explanatory, but the following ground rules for some of the components had to be set forth to provide uniform values:

Propellant Load:

Usable - calculated from ideal velocity equation;
Performance Reserve - 2% of usable based on previous Centaur data;
Start/Shutdown Losses - 1 to 2.3 Kg loss per burn, dependent upon engine thrust, at ignition (for cryogens) including chilldown and engine tailoff losses;
Boiloff - conservative estimate of losses from propellant evaporation due to thermal energy leaks (calculated for each transfer strategy);
Trapped Propellants - consists of the amount of propellant necessary to fill the feed lines and engine;
Expulsion Efficiency - 98%, the efficiency associated with draining the propellant from the tank; and
Loading Accuracy - 0.5%, percentage assigned to accuracy of loading equipment.

TABLE V-2 - COMMON MASSES FOR ALL VEHICLES (Ref. V-1)

ITEM	MASS (Kg)	Remarks
Avionics		
Data Management and Instrumentation	71.7	
Guidance and Navigation	69.8	
Communications	32.8	
Power (Fuel Cells)	181.4	
Propulsion		
ACS Engine (Bipropellant)	68.0	16 @ 445 N
ACS Support	152.7	4 modules @ 11 kg-sec each estimate
ACS Booms and Controls	45.3	
Nonusable Propellant		
Trapped Propellant - ACS	12.7	trapped and outage
Propellant Reserves - ACS	17.2	10% of usable
Propellant Fluids Loaded		
Attitude Control	186.8	
Shuttle Interface Accomodation	1820.0	
ACS	174.1	
Spacecraft Interface Equipment		
Retaining Ring	205.9	
Airborne Support Equipment		
Shuttle Interface Accomodation	1820.0	
MMU	450.0	

TABLE V-3 - CRYOGENIC PROPELLANTS MASS STATEMENTS (Ref. V-2)

ITEM	MASS (Kg) MAXIMUM PERFORMANCE	MIN LENGTH	
Stuctures			
Body structure	353-376	328-345	
Thrust structure	11	20-23	
Equipment mounting	41	41	
Umbilical	15	15	
Shuttle I/F equipment	48	48	
Thermal Control			
Purge System	67	67	
Thermal Control	57	57	
Propulsion			
Fill vent & drain	244	270	
Trapped propellant-main	32	64	
Trapped gas (vapor)	92-103	92-103	
Propellant outage (max)	49-55	47-56	0.25% of usuable

TABLE V-4 - STORABLE PROPELLANT MASS STATEMENTS (Ref. V-3)

ITEM	MASS (Kg) MAXIMUM PERFORMANCE	MIN LENGTH	
Structures			
Body structure	191-388	349-513	
Thrust structure	11-13	11-30	
Equipment mounting	29	29	
Umbilical	4	4	
Shuttle I/F equipment	26	26	
Thermal control	33-124	49-124	
Propulsion			
Fill vent & drain	70	91	
Trapped propellant main	7	20	
Trapped gas (vapor)	103-116	103-116	
Propellant outage(max)	48-55	48-55	0.25% of usuable

Structures:

Fuel and Oxidizer Tanks - the primary metal enclosure in which propellant is contained excluding thermal protection, support structure and transmission lines.
Body Structures - the basic lattice structure of the stage which acts as the primary support for the stage;
Thrust Structure - the structural support used to attach the engine to the body structure including engine gimbaling assemblies;
Equipment Mountings - the devices used to mount stage equipment i.e. Avionics, fuel cells, batteries, etc. to the body structures;
Umbilicals - all connection cables or lines that detach from the vehicle before operation but that are payload chargeable weight;
Shuttle I/F (Interface) Equipment - all fittings connectors and other equipment (excluding umbilical and ASE) that the stage requires to interface properly with shuttle and are not deployable after use; and
Payload Separation Module - the equipment used to separate the payload from the stage after it is positioned.

Insulation:

Fuel and Oxidizer - the primary blanketing material that covers the tanks and feedlines (MLI) as applicable.

Purge Systems:

The helium storage and delivery system used to purge the insulation of air to prevent liquid air pumping during the prelaunch period.

Thermal Control:

The active system used for control of propellant temperature that uses vented propellant, or other propellant conditioning methods.

Avionics:

Data management and instrumentation includes the on-board digital logic-service functions of on-board checkout, redundancy control, data transfer, command decoding/distribution, data sampling/conditioning/ accumulating/storage, caution and warning, timing, interbox/vehicle data transfer, coding/decoding, and computer services.

Guidance and Navigation control consists of a skewed redundant strapped-down inertial measurement unit, star tracker, horizontal sensor, portions of the data management subsystem, integrated hydraulic actuators, and attitude-control valves and nozzles.

Communications include a S-band communications system which utilizes the airborne electronically steerable microwave phased array. The general purpose television camera, command decoder and command distribution and driver are additional components.

Power includes two fuel cells (2.0 kw avg. - 3.5 kw peak), one auxiliary battery (25 amp-hr), 28 V. Power system, dual electrical power and distribution system, conventional power distribution with data bus control, solid state power control, fuel cells to be started after release from orbiter, emergency shutdown capability from orbiter, monitoring capability from orbiter, dedicated reactant tanks, and fail operate/fail safe.

Sufficient detail is provided in the mass statements so that realistic assessments of mass fractions are derived from stage propulsion data.

D. Stage Parametric Analysis

To help generate stage propulsion data, a propulsion sizing computer program, PROP was used. The discrete elements contained in the program are shown in Figure V-3 and are briefly described in the following paragraphs.

Internal calculations in the program include:

1) Pressurant mass, regulated or blowdown system,
2) Propellant mass, from required ΔV,
3) Propellant tank mass and size,
4) Mass of the structure.

Inputs to the program are: engine performance and mass data; tankage details such as shape, single, dual or multiple tanks; ΔV; mission time line, propellant properties; insulation properties; pressurization system type; performance; etc.

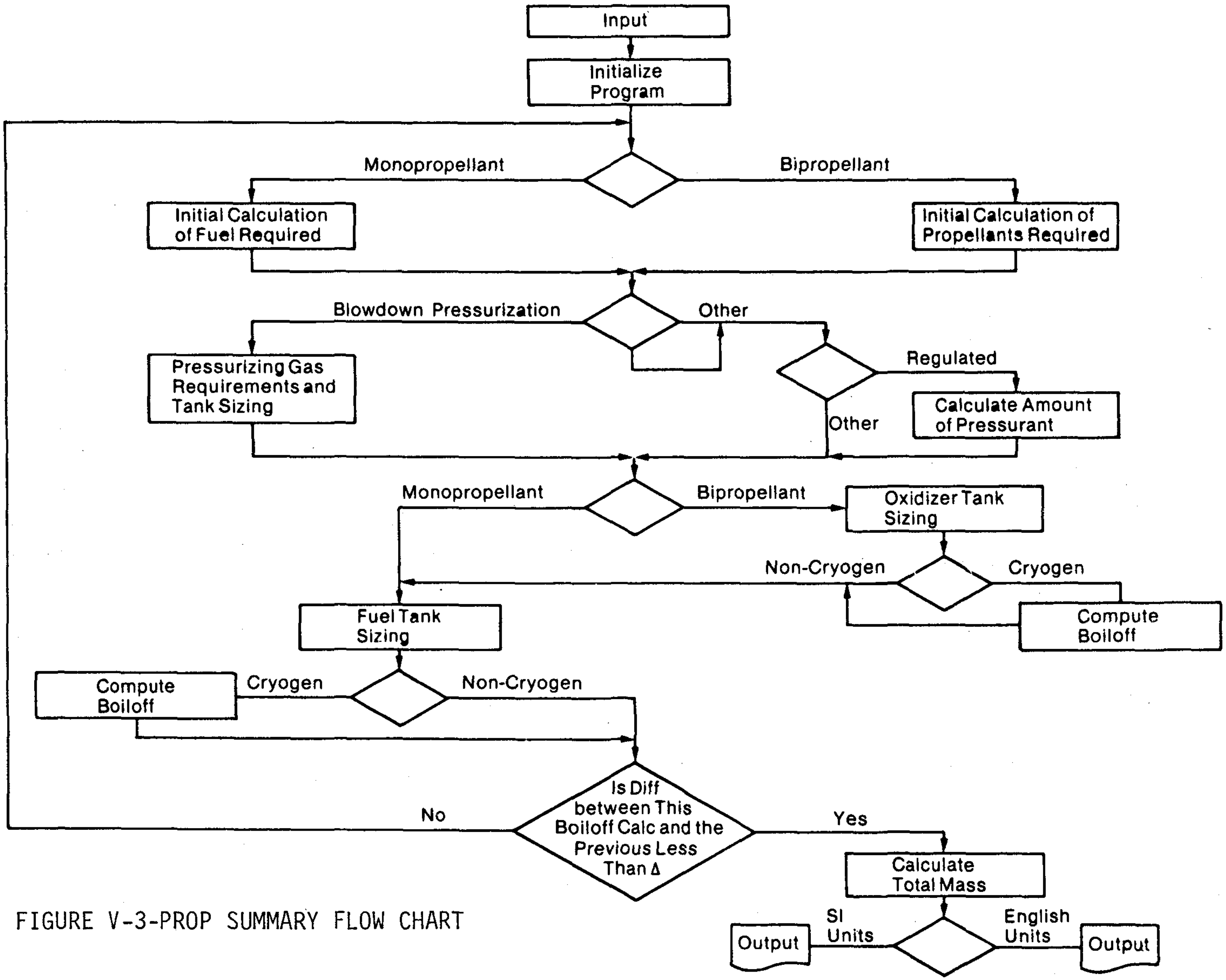


FIGURE V-3-PROP SUMMARY FLOW CHART

A sample output of PROP is shown in Figure V-4. The output sheets for the remaining cases are shown in Appendix B. The total mass of a number of items listed in Tables V-2, V-3, and V-4 are output by the prop program under the heading of (1) components and lines and (2) engine mounts and supports. A breakout of these items is shown in Table V-5 for this sample case. The values for trapped propellants consider propellant in the feed line, a 98% expulsion efficiency, and a loading accuracy of 0.5%. The parameters extracted from the mass statements are the total stage wet system mass, mass fraction, and stage length.

The stage length was determined for maximum performance and minimum length tankage configurations. The equation for stage length of maximum performance is: Stage Length = Fuel Tank Length + Oxidizer Tank Length + 30.4 cm Clearance + Engine Length.

The equation for minimum stage length is: Stage Length = Fuel Tank + 15.2 cm Clearance + Oxidizer (Torodial) Tank Height + the length of the engine that exceeds the Oxidizer Tank Height (Embedded Engine)

The engine lengths were determined from the supplied LeRC engine data in Appendix A at the corresponding thrust level of the stage being considered.

With lengths and masses of the individual components available, center of gravity calculations were completed with the nose of the Orbiter as the reference.

Based on the stage mass statements and stage design details, parametric data were generated for stage length, mass fraction, stage mass, and center of gravity versus propellant mass and thrust-to-mass for both pressure-fed and pump-fed engines.

E. Stage Parametrics Versus Thrust-To-Mass:

Stage parametric data are shown as a function of final thrust-to-mass ration in Figures V-5 through V-16. The figures are arranged as follows:

Figure V-5 through V-8: Stage Mass
Figures V-9 and V-10: Mass Fraction
Figures V-11 and V-14: Stage Length
Figure V-15 and V-16: Center of Gravity

It can be observed from the Figures that the total matrix of variables was not duplicated for all permutations since the basic trends and resultant conclusions can be derived from the primary set of propulsion system data.

F. Stage Parametrics Results

1. Mixture Ratio

Review of stage characteristics data for an 8 perigee burn, constant acceleration transfer exposed mixture ratio as an ineffective parameter for LO_2/LCH_4, LO_2/RP-1, and N_2O_4/MMH. Variation of stage length, mass fraction and stage mass with mixture ratio was less than 3% from the nominal mixture ratio for all configurations. Thus, stage characteristics for the above propellants are plotted versus thrust/mass at their corresponding

FIGURE V-4-SAMPLE OUTPUT OF PROP

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
    LH2/LO2  MIN LENGTH  PUMP FED                 MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4432.4 N-S/KG

TOTAL PROPELLANT                          18208.04 KG
  USABLE FUEL                     2450.90
  USABLE OXIDIZER                14705.41
  FUEL TRAPPED                      97.70
  OXID TRAPPED                     571.27
  FUEL START-S/D LOSSES              7.26
  OXID START-S/D LOSSES              7.26
  FUEL BOILOFF                     148.65
  OXIDIZER BOILOFF                 219.58

OXIDIZER TANKS (NO.= 1)                     104.79
 (TOROIDAL)
  INNER DIA=     1.449 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.409 M
  VOLUME   =    13.999 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         156.50
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.784 M
  VOLUME  =   39.735 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  15.886

PRESSURANT TANKS (NO.= 1)                   85.16
  DIA=     .8985 M
  VOL=      .380 M3
  THK=    .00758 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                        99.67
OXIDIZER TANK INSULATION                    58.22

ENGINES (NO.= 1)                            40.82

COMPONENTS AND LINES                       589.67
ENG. MOUNTS,SUPPORTS                      1293.65

TOTAL WET SYSTEM MASS                     20652.4
TOTAL BURNOUT MASS                         3113.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                .831
TOTAL IMPULSE                      76047159.3 N-S

             PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
```

Table V-5 - Sample Breakout of Components and Lines, and Engine Mounts and Supports

- LO_2/LH_2, minimum length, pump-fed, T/M = 0.015, MR = 6.0
- 8 perigee burn, constant acceleration

	kg
Fill Vent and Drain	270.0
ACS Engine (Bipropellant)	68.0
ACS Support	152.7
ACS Booms and Controls	45.3
Subtotal	536.0
10% Contingency	53.6
Components and Lines	589.6
Body Structure	333.4
Thrust Structure	21.3
Retaining Ring	205.9
Equipment Mounting	41.0
Umbilical	15.0
Shuttle I/F Equipment	48.0
Thermal Control	
Purge System	67.0
Control	57.0
Avionics	
Data Mgnt. and Instrumentation	71.7
Guidance and Navigation	69.8
Communications	32.8
Power (Fuel Cells)	181.4
Nonusable Propellant	
Trapped Propellant (ACS)	12.7
Trapped Helium (Main and ACS)	1.8
Propellant Reserves (ACS)	17.2
Subtotal	1176.0
10% Contingency	117.6
Eng. Mounts, Supports Total	1293.6

FIGURE V-5 STAGE MASS VERSUS THRUST-TO-MASS

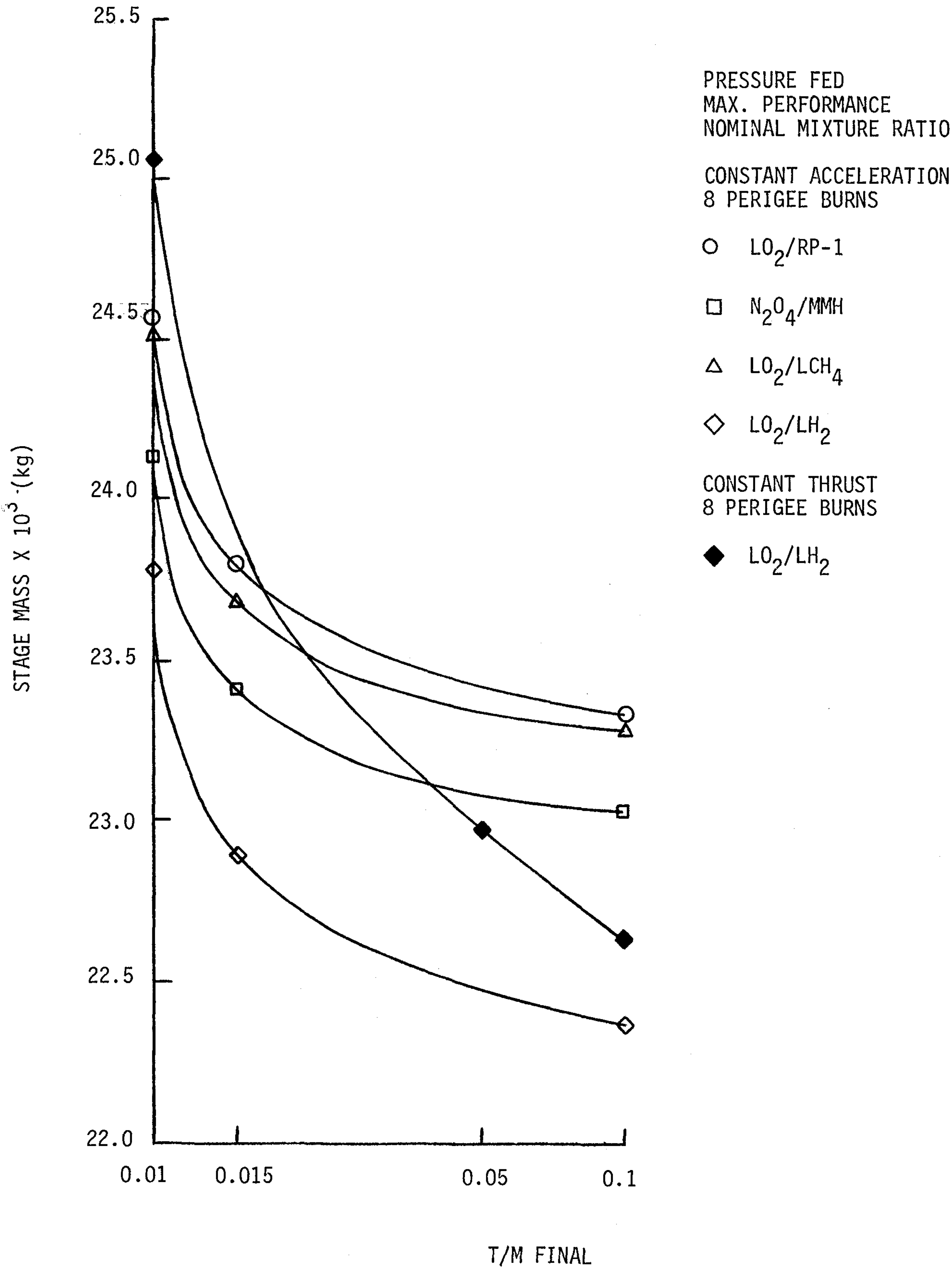


FIGURE V-6 STAGE MASS VERSUS THRUST-TO-MASS

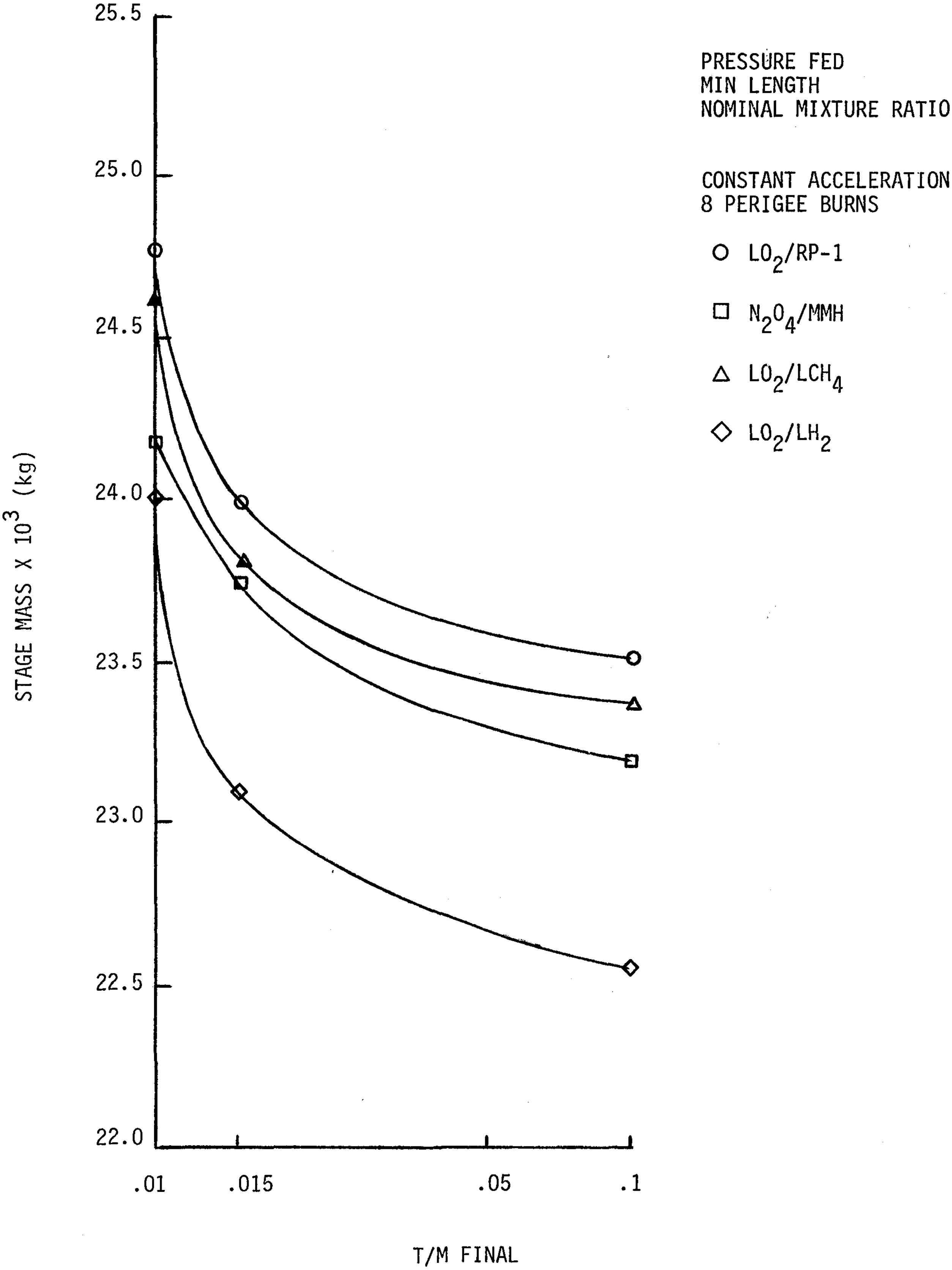


FIGURE V-7 - STAGE MASS VERSUS THRUST-TO-MASS

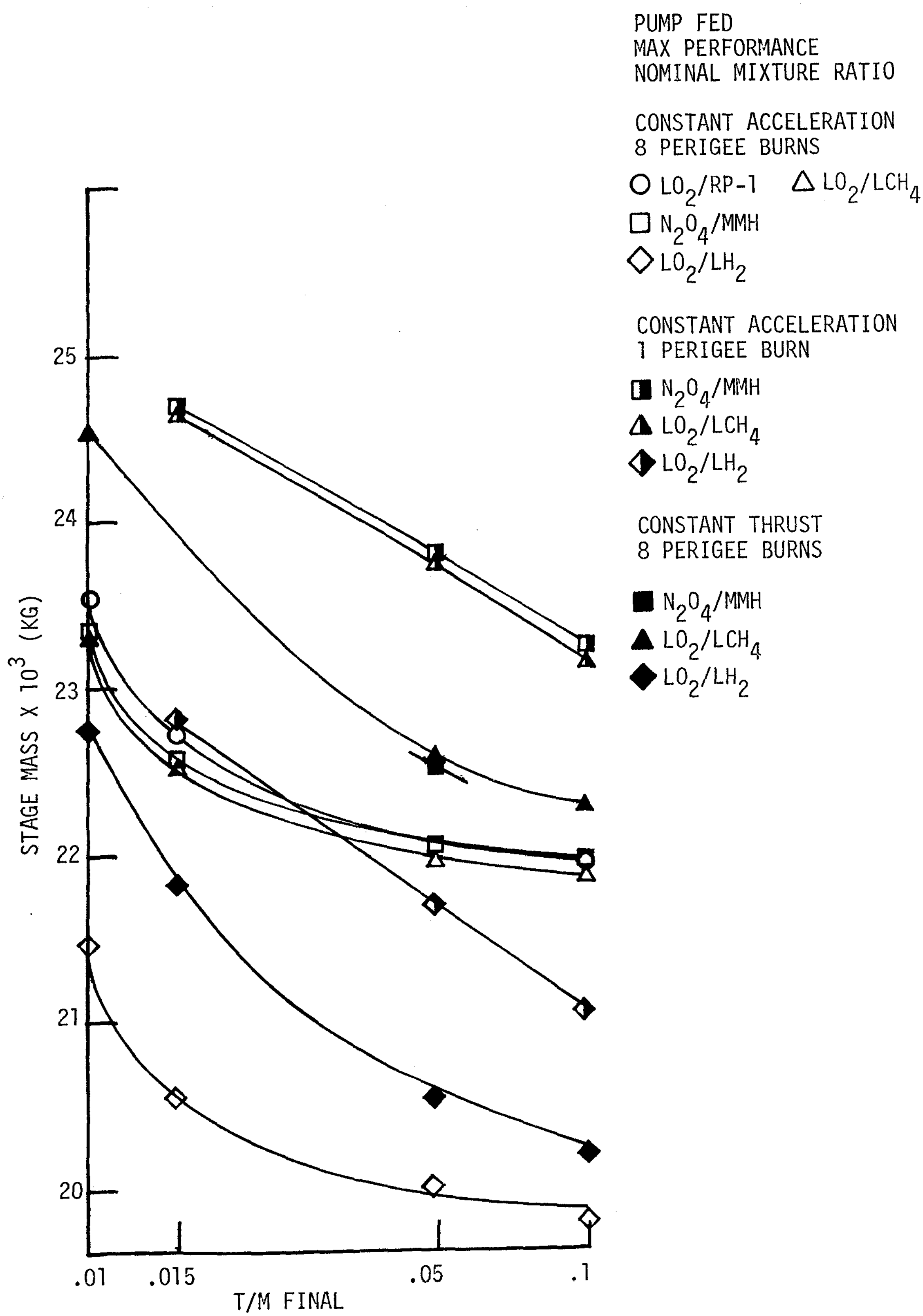


FIGURE V-8 - STAGE MASS VERSUS THRUST-TO- MASS

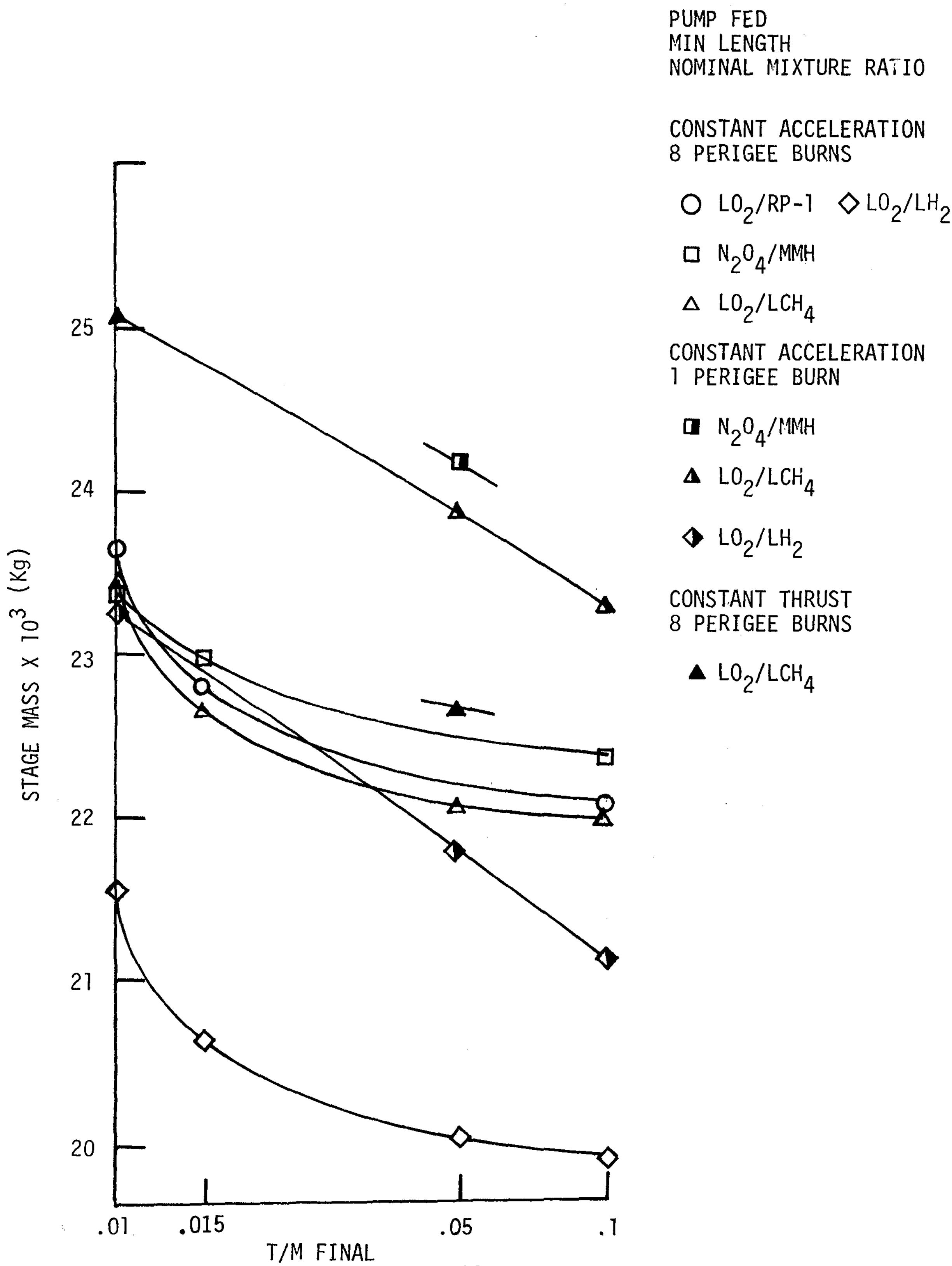


FIGURE V-9 - MASS FRACTION VERSUS THRUST-TO-MASS

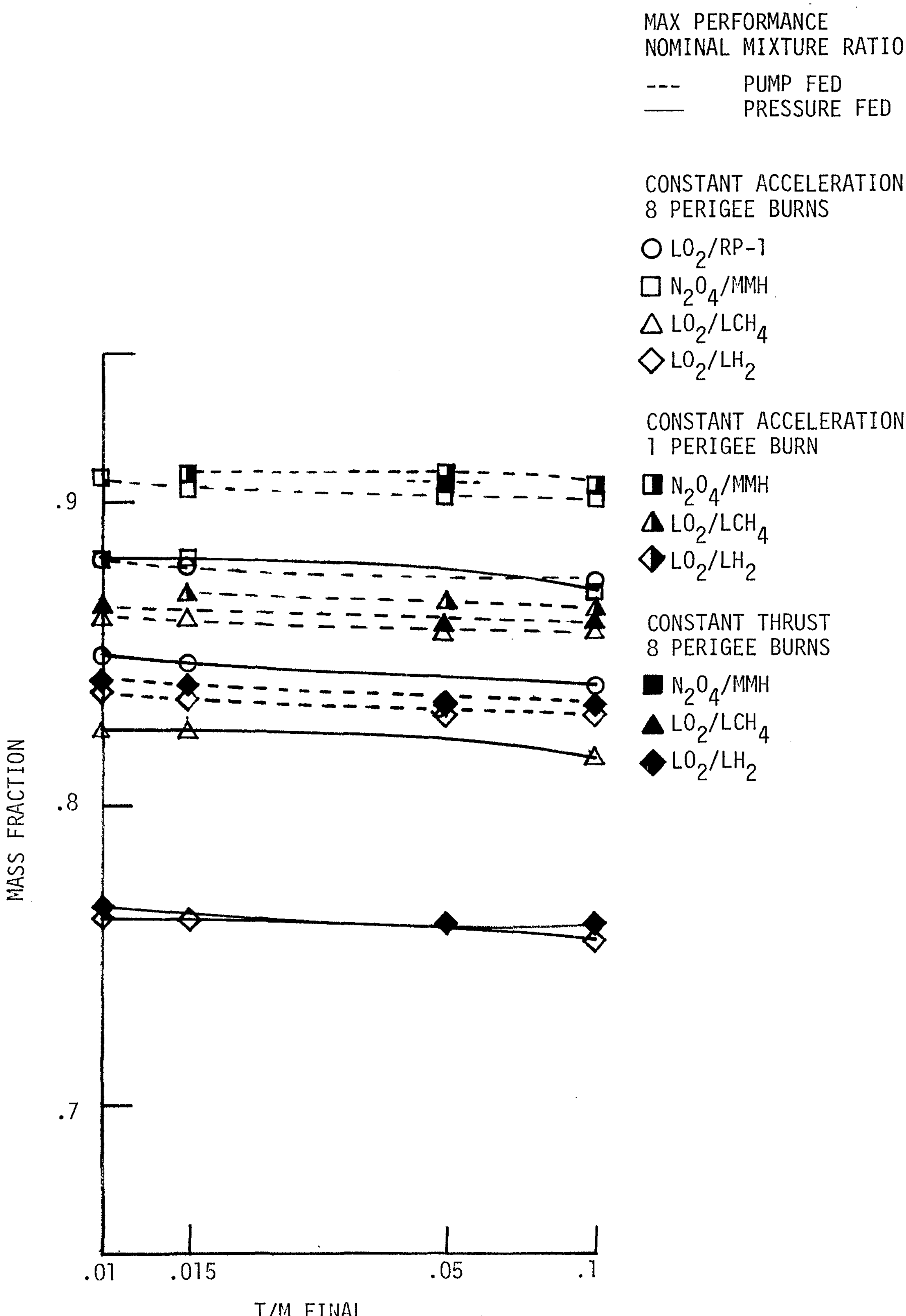


FIGURE V-10 - MASS FRACTION VERSUS THRUST-TO-MASS

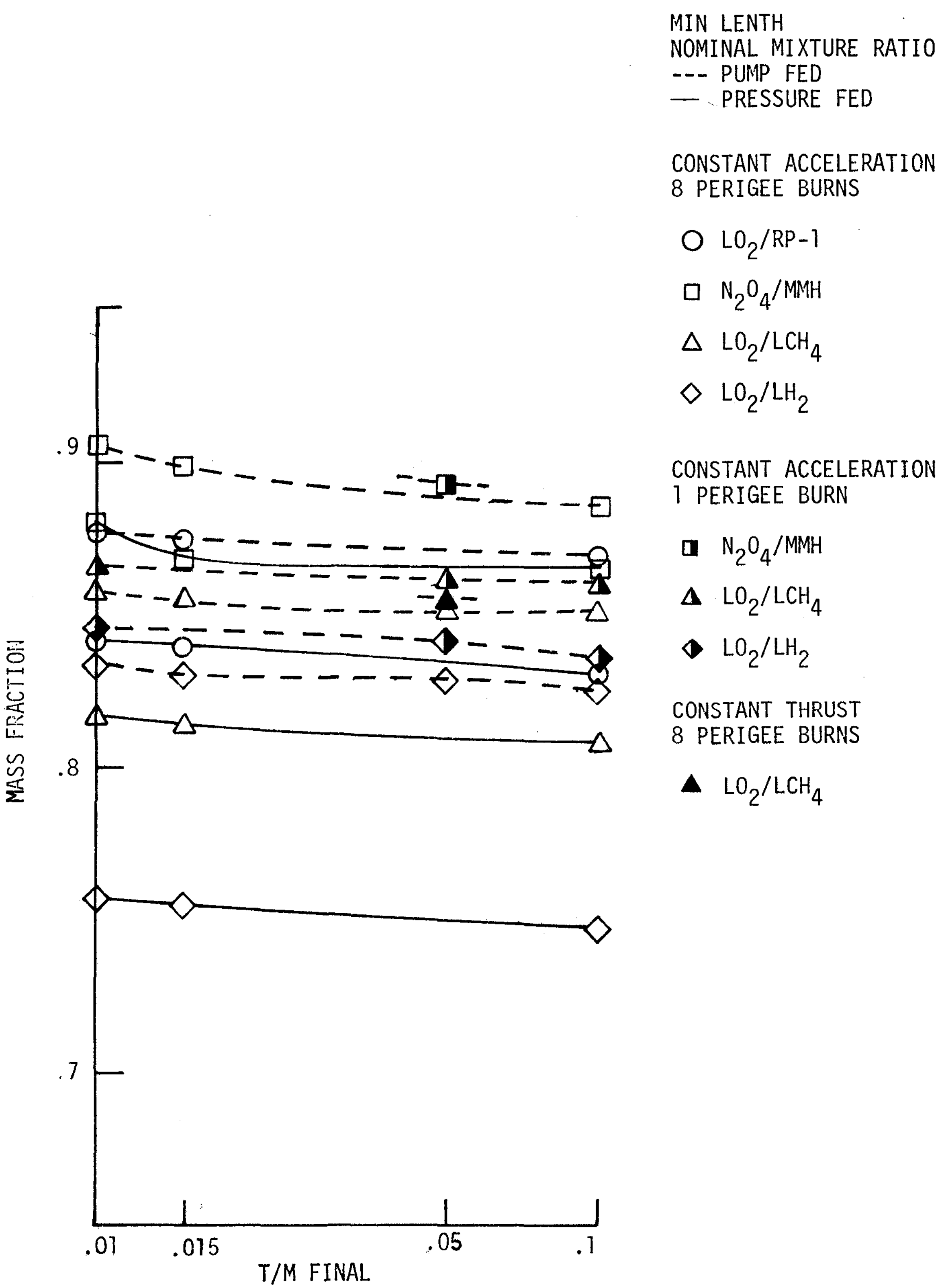


FIGURE V-11 - STAGE LENGTH VERSUS THRUST-TO-MASS

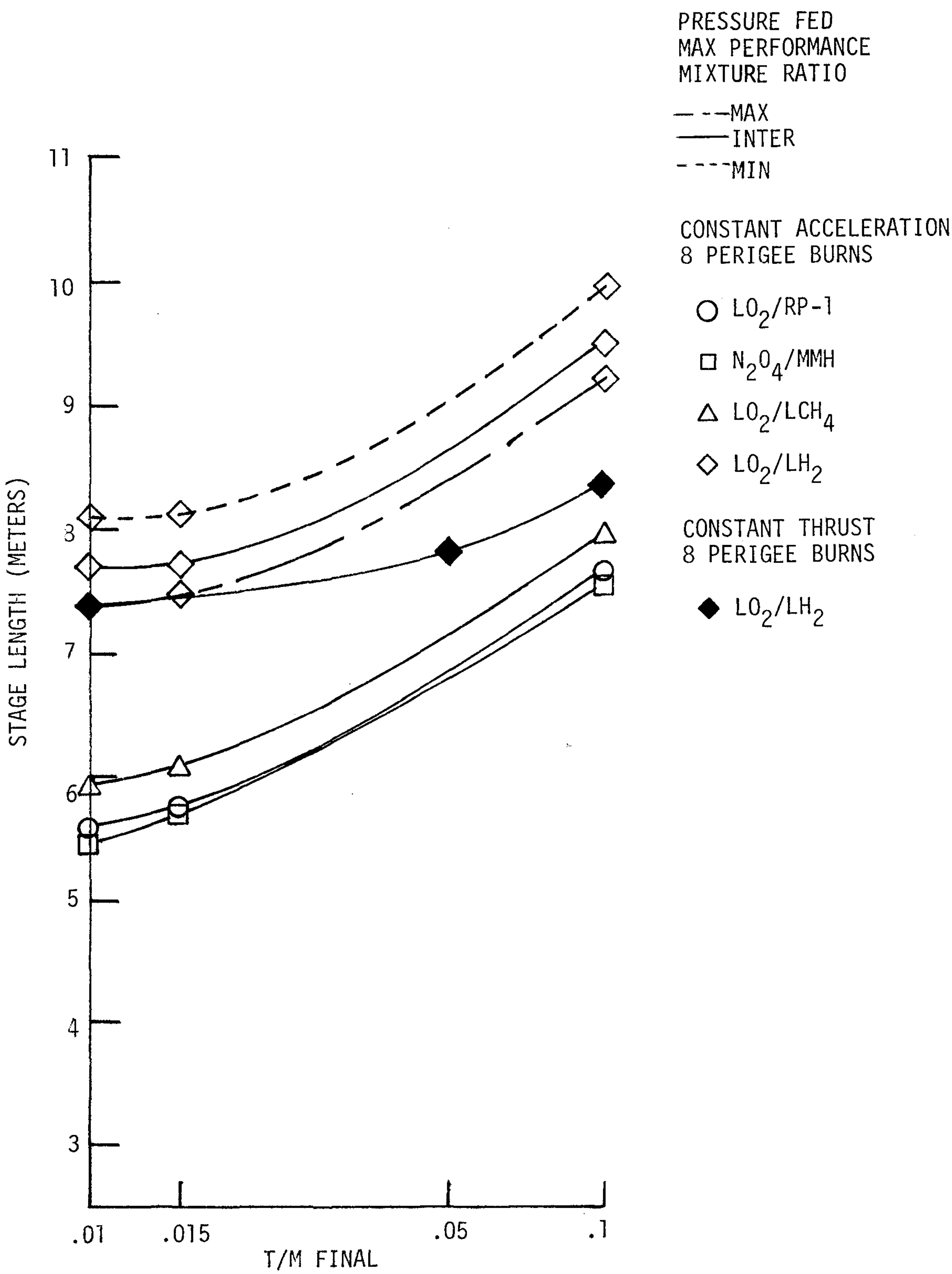


FIGURE V-12 - STAGE LENGTH VERSUS THRUST-TO-MASS

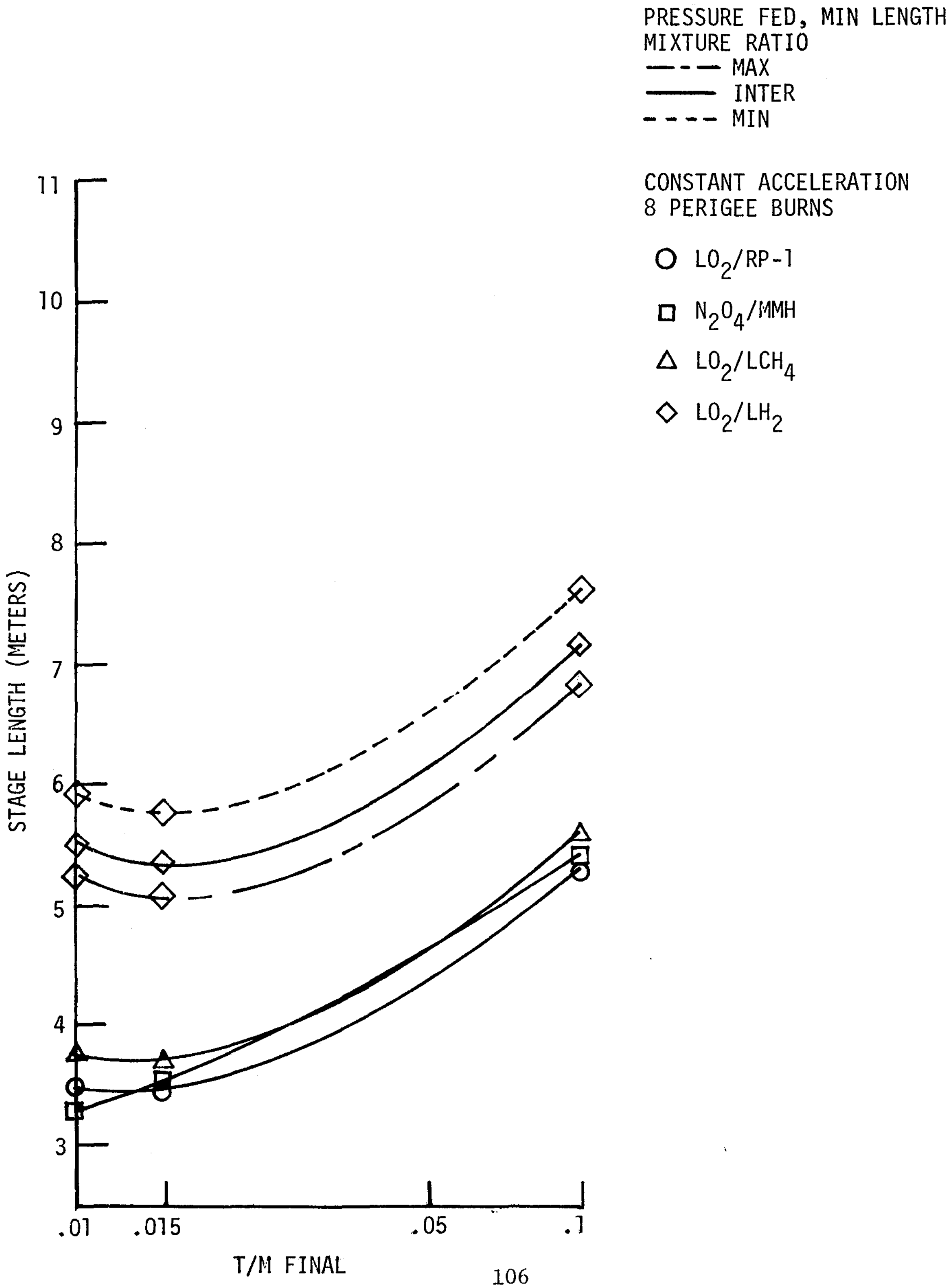


FIGURE V-13 STAGE LENGTH VERSUS THRUST-TO-MASS

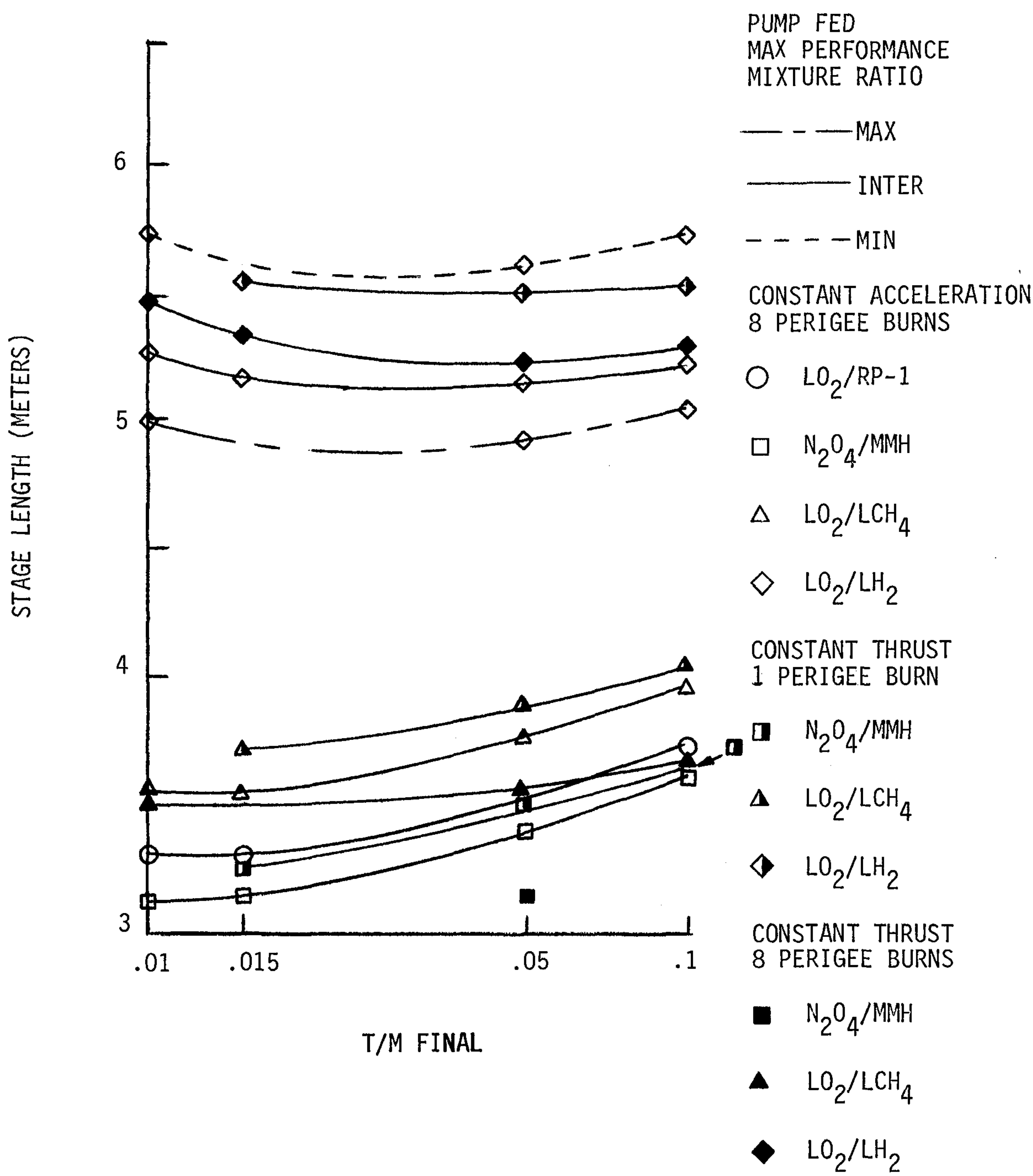
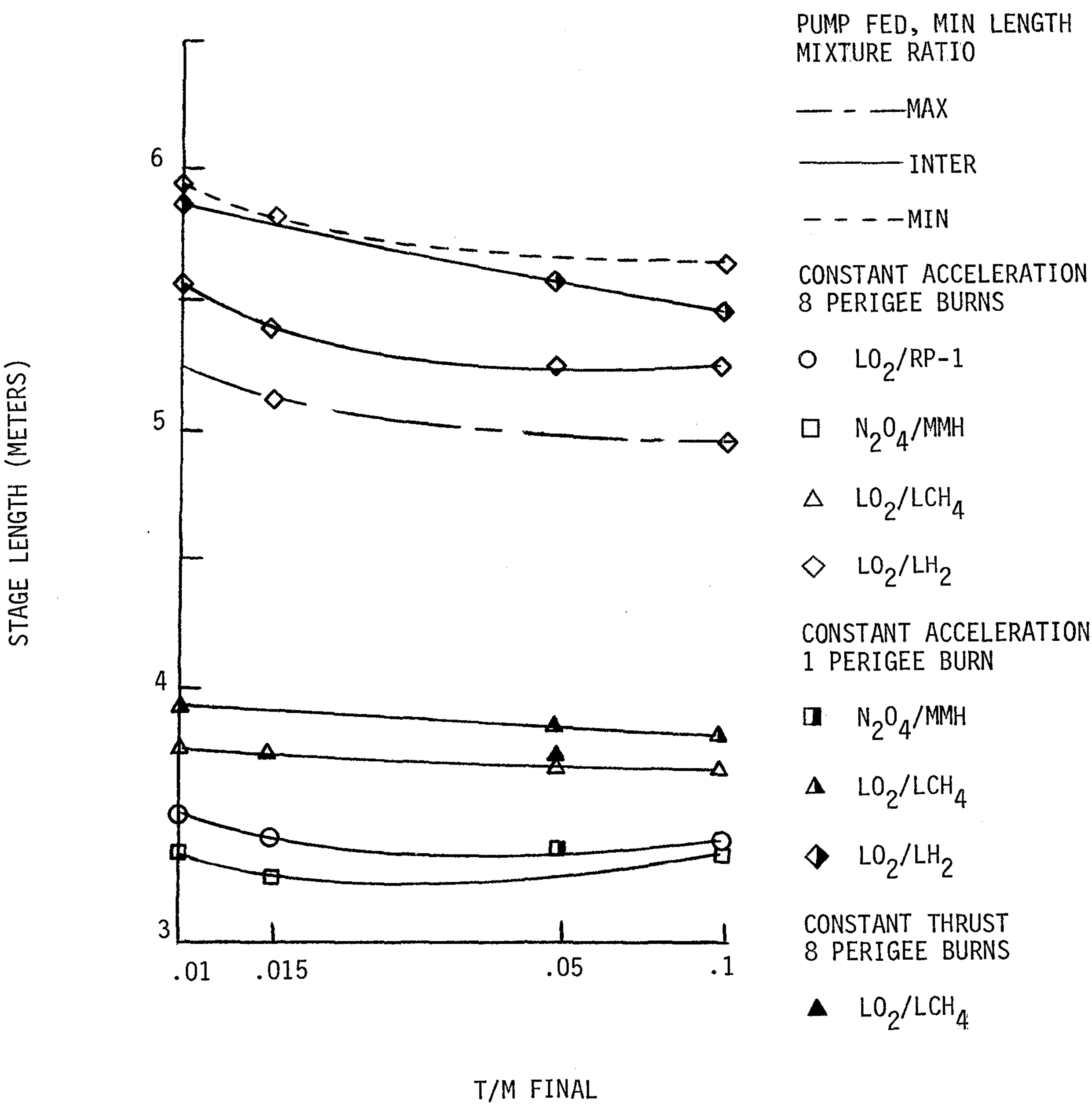


FIGURE V-14 STAGE LENGTH VERSUS THRUST-TO-MASS



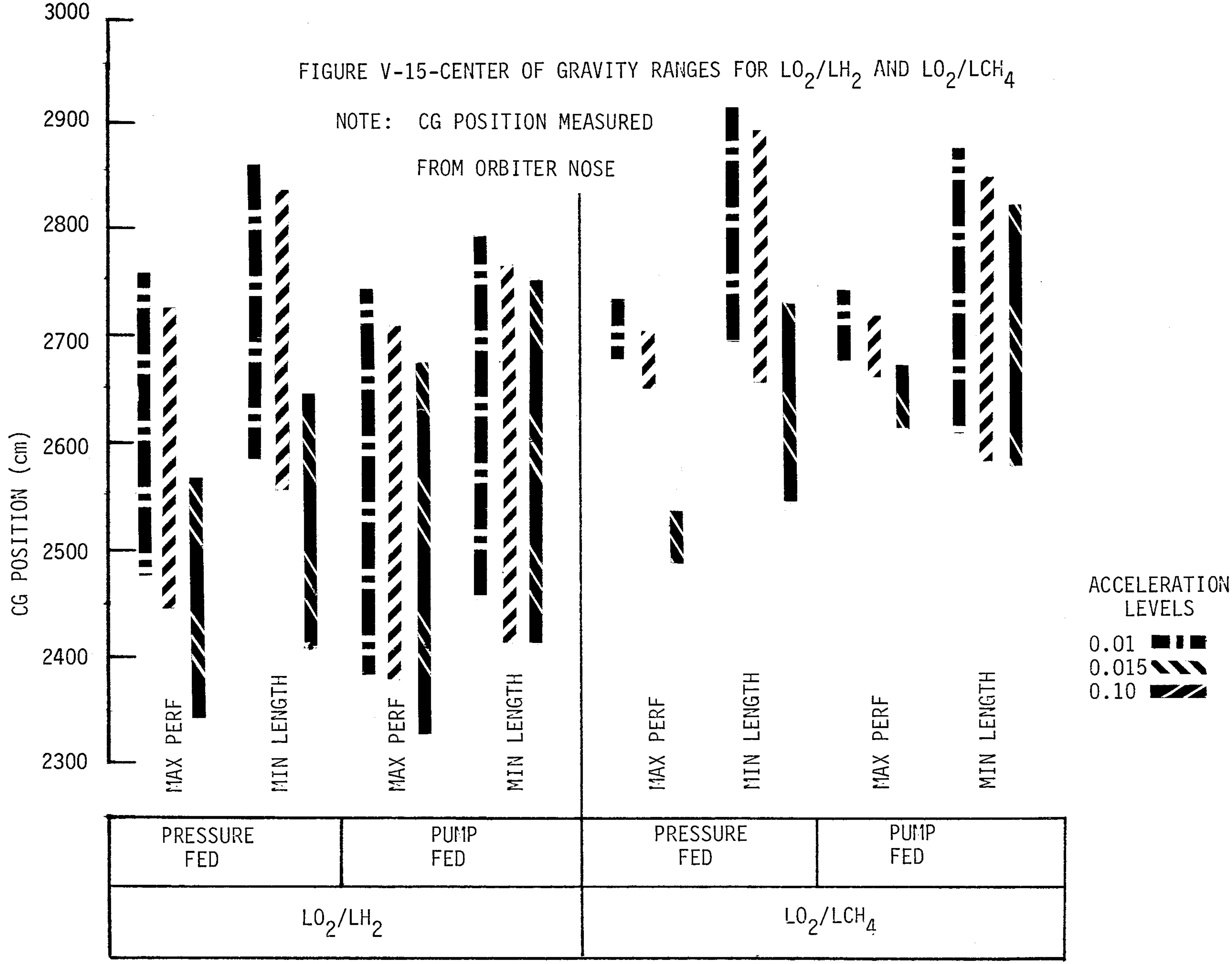


FIGURE V-15-CENTER OF GRAVITY RANGES FOR LO_2/LH_2 AND LO_2/LCH_4

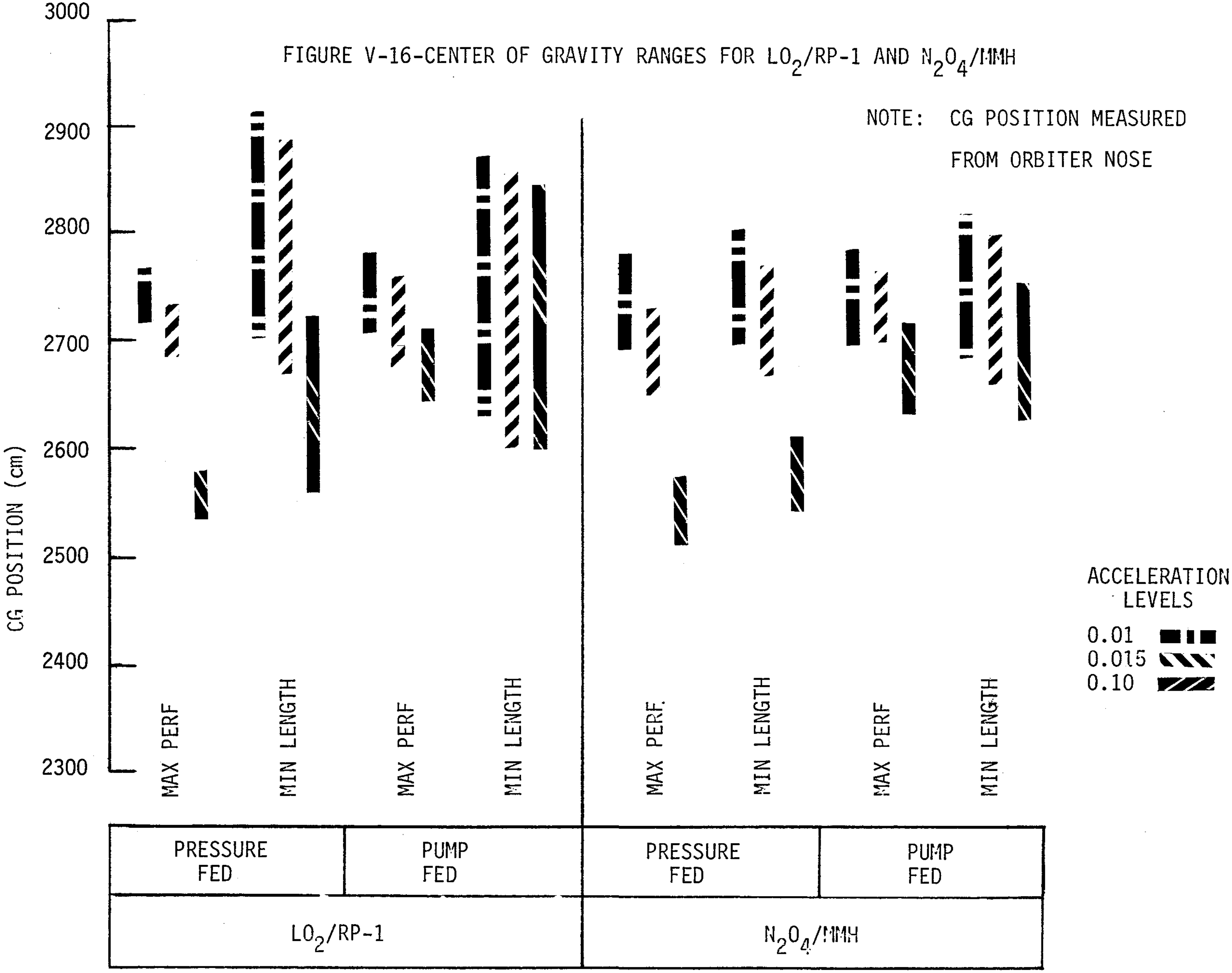


FIGURE V-16-CENTER OF GRAVITY RANGES FOR LO_2/RP-1 AND N_2O_4/MMH nominal mixture ratio. The variation of mass fraction and stage mass was less than 3% for LO_2/LH_2 also. However, stage length variation for LO_2/LH_2 was 11% for the mixture ratio range as indicated in Figure V-11 through V-14.

2. Constant Acceleration - Constant Thrust Comparison

To compare the constant acceleration transfer method with the constant thrust transfer method, certain system parameters are held constant while final thrust/mass ratio varies. The constant parameters consist of an 8 perigee burn orbit transfer strategy, maximum performance stage configuration, and nominal mixture ratio. Table V-6 shows the comparison of stage mass and stage length associated with various propellant combinations for the two transfer methods. These values of length and mass are typical and representative of their respective families.

The results from Table V-6 indicate the constant acceleration approach delivers 478 to 574 Kg more payload mass at 0.05 g and 278 to 422 Kg more payload mass at 0.1 g than the constant thrust approach. However, the constant thrust method is capable of greater payload length delivery of 2 to 78 cm at 0.5 g and 5 to 115 cm at 0.1 g.

The constant acceleration method, which implies a throttling engine, requires less propellant due to reduced delta velocity requirements compared to the constant thrust method. This decrease in propellant mass yields higher payload mass. However, the payload length increase is primarily driven by engine length, and the constant thrust approach has a lower initial thrust level of the two transfer methods, resulting in a shorter engine length. Therefore, available payload length is greater for constant thrust than constant acceleration, for a fixed final thrust/mass ratio. The payload length increase (i.e engine length effect) is more pronounced for pressure-fed systems than pressure-fed systems since chamber and nozzle sizes for pressure-fed engines are larger.

The conclusions drawn from Table V-6 depend upon whether the payload is mass or length constrained. If increased payload mass is the primary consideration, a constant acceleration approach is suggested. Conversely, if payload length is more critical than mass, a constant thrust transfer method is preferred.

3. 1 Burn - 8 Burn Comparison (Perigee)

Table V-7 displays the contrast of stage mass and stage length between a 1 perigee burn and an 8 perigee burn orbit transfer strategy with final thrust/mass ratio as a parameter. Other system parameters, such as constant acceleration, pump-fed engines, and nominal mixture ratio, are set for this comparison. The propellant combinations and stage configuration are representative samples.

TABLE V-6 - CONSTANT THRUST VERSUS CONSTANT ACCELERATION COMPARISON
(EIGHT PERIGEE BURN, MAXIMUM PERFORMANCE)

THRUST MASS	0.05 g		0.1 g	
	CONSTANT THRUST	CONSTANT ACCELERATION	CONSTANT THRUST	CONSTANT ACCELERATION
Pump Fed				
N_2O_4/MMH				
Stage Mass (Kg)	22570	22090	NA	22010
Stage Length (cm)	508	530	NA	551
LO_2/LH_2				
Stage Mass (Kg)	20550	20020	20240	19840
Stage Length (cm)	709	711	716	721
LO_2/LCH_4				
Stage Mass (Kg)	22580	22000	22320	21900
Stage Length (cm)	548	566	559	584
Pressure Fed				
LO_2/LH_2				
Stage Mass (Kg)	22960	22410*	22620	22340
Stage Length (cm)	785	863**	838	953

* THIS DATA POINT DERIVED BY INTERPOLATION FROM FIGURE V-5
** THIS DATA POINT DERIVED BY INTERPOLATION FROM FIGURE V-11

In all cases considered, the 8 burn strategy provides a minimum increase in payload mass of 1220 Kg and a minimum increase in available payload length of 8 cm over the respective values of the 1 burn strategy.

4. Pressure Fed - Pump Fed Comparison

Table V-8 presents data obtained from a constant acceleration, 8 perigee burn orbit transfer strategy with maximum performance stage configuration and nominal mixture ratio for all propellant combinations. The values in Table V- 8 display stage mass and stage length at a thrust/mass ratio of 0.1 g. Each of the four propellant combinations compare the pressure-fed systems parameters with pump-fed systems parameters.

TABLE V-7 - 1 PERIGEE BURN - 8 PERIGEE BURNS COMPARISON
(CONSTANT ACCELERATION, PUMP-FED)

THRUST/MASS	0.05 g		0.1 g	
NUMBER OF BURNS	1	8	1	8
N_2O_4/MMH				
Maximum Performance				
Stage Mass (Kg)	23840	22090	23270	22010
Stage Length (cm)	544	531	559	511
Minimum Length				
Stage Mass (Kg)	24220	22500*	N/A	22390
Stage Length (cm)	338	330**	N/A	335
LO_2/LCH_4				
Maximum Performance				
Stage Mass (Kg)	23785	22000	23210	21900
Stage Length (cm)	579	566	594	584
Minimum Length				
Stage Mass (Kg)	23900	22140	23310	22030
Stage Length (cm)	386	371	381	368
LO_2/LH_2				
Maximum Performance				
Stage Mass (Kg)	21710	20020	21080	19840
Stage Length (cm)	741	711	742	721
Minimum Length				
Stage Mass (Kg)	21810	20060	21160	19940
Stage Length (cm)	554	523	541	521

* DERIVED BY INTERPOLATION FROM FIGURE V-8
** DERIVED BY INTERPOLATION FROM FIGURE V-14

TABLE V-8 - PRESSURE FED AND PUMP FED MASS/LENGTH COMPARISONS FOR 0.1 g
(CONSTANT ACCELERATION, EIGHT PERIGEE BURNS)

PROPELLANT COMBINATION	PRESSURE-FED	PUMP-FED
N_2O_4/MMH		
Stage Mass (Kg)	23020	22010
Stage Length (cm)	757	511
LO_2/RP-1		
Stage Mass (Kg)	23320	22000
Stage Length (cm)	770	561
LO_2/LH_2		
Stage Mass (Kg)	22340	19840
Stage Length (cm)	953	721
LO_2/LCH_4		
Stage Mass (Kg)	23280	21900
Stage Length (cm)	800	584

As shown in Table V-8, when pump-fed systems are utilized, a minimum additional 1010 Kg of payload mass and 209 cm of payload length are available.

The pressure-fed systems are mass-penalized for the engine mass and tank mass which are linked to their higher operating pressures. The 178 cm stage length penalty is primarily due to the engine length, even in the minimum length stage configuration. Similar payload parameter results are found upon inspection of the minimum length configuration. However, the positive point for pressure-fed systems is that they eliminate the complex, expensive rotating machinery characteristic of pump-fed systems. The conclusion of this comparison is that pump-fed engines are preferred from the total systems viewpoint.

From the previous discussion, the 8 perigee burn, constant acceleration, pump-fed parametric data is the suggested stage configuration selected as the baseline to develop the relative merit of the various concepts.

VI. PROPULSION SYSTEMS COMPARISONS

A. Approach

Propulsion system comparisons were performed to provide insight as to how the primary propulsion system charactersistics, orbit transfer techniques, LSS mass and area, Shuttle cargo bay packaging, and engine technology are interactive. The relative merit of the various primary propulsion system characteristics was established by consideration of two factors - deliverable LSS mass and area.

A method, shown in Figure VI-1, was necessary to compare the various propellant combinations and tankage configurations with the Large Space Systems. This method incorporated available payload mass or available volume in the cargo bay, as a driver, in such a manner as to result in the maximum LSS diameter deliverable to GEO. The established procedure was to maximize the LSS diameter by utilizing 100% of either available payload mass or available payload volume without exceeding the other. The procedure begins with determining the diameter of a specific LSS class with a selected surface density by entering the appropriate system mass versus diameter curve (Figure III-7, III-16, and III-23) at a mass value equal to available payload mass. This yields a maximum deployed LSS diameter based on available payload mass.

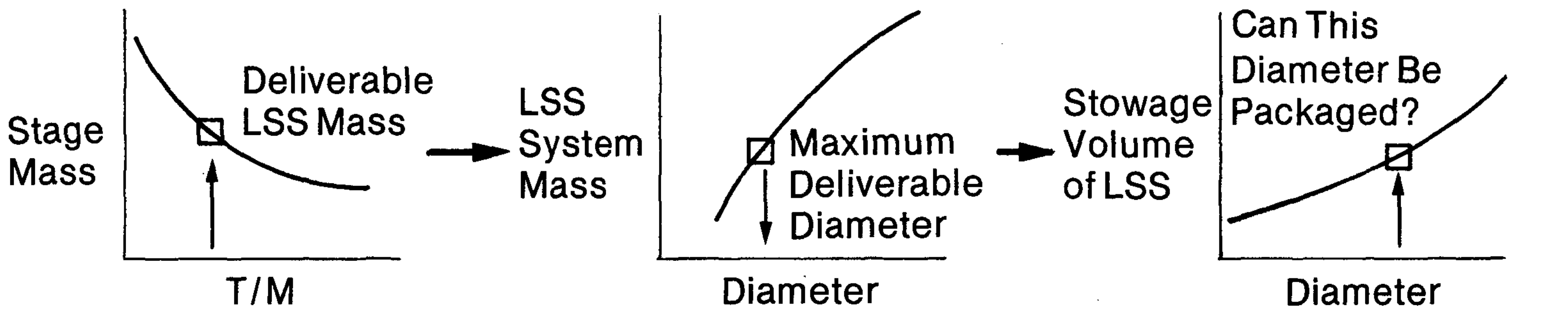
The question arises as to whether or not the packaged "maximum" LSS diameter exceeds the available payload volume. To answer this question a LSS storage volume analysis was conducted from which the results are presented in Figure VI-2 as stowage volume versus diameter. The baseline for Figure VI-2 is for a T/M range of 0.05 to 0.10 g's with available payload volume based upon a 4.1 meter stowed payload diameter. There are some minor volume increases at 0.10 g with the higher surface densities and larger diameters, but the change is less than 10%, which is well within the accuracy of the data. Only one volume curve is required for the hoop and column since the surface is stowed within the ring and and does not impact the overall length and volume. These data should not be taken as exact, especially with respect to the wrap radial rib. All curves were generated utilizing the best data available and engineering judgement. Figure VI-2 is now used to extract the stowage volume of the LSS corresponding to the maximum diameter. If the stowage volume is less than the payload volume, then the LSS is mass constrained. However, if the stowage volume is greater than the available payload volume, the LSS is volume constrained. If this is the case, the problem is worked in reverse starting with the available payload volume and ending with system total mass. This technique permitted determination of maximum LSS diameter for a given T/M which was compatible with propulsion system performance.

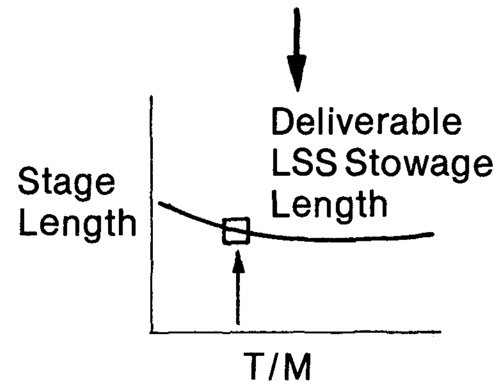
This procedure was followed for three transfer strategies (8 perigee burns, constant acceleration; 8 perigee burns, constant thrust; and 1 perigee burn, constant acceleration) with the eight possible combinations of LSS type and surface density as parameters.

Use 100% of Payload Mass or Volume

Select Propellant Combination, Tankage Configuration, Propellant Fed (Pump or Pressure), Orbit Transfer Strategy, Acceleration Level, LSS Class, and LSS Surface Density

Maximum LSS Diameter Not To Exceed 200 meters





— If diameter can be packaged, LSS is mass constrained.

— Diameter cannot be packaged, then proceed in reverse with maximum deliverable diameter to determine if mass-LSS is volume constrained.

FIGURE VI-1 INTERACTION METHODOLOGY

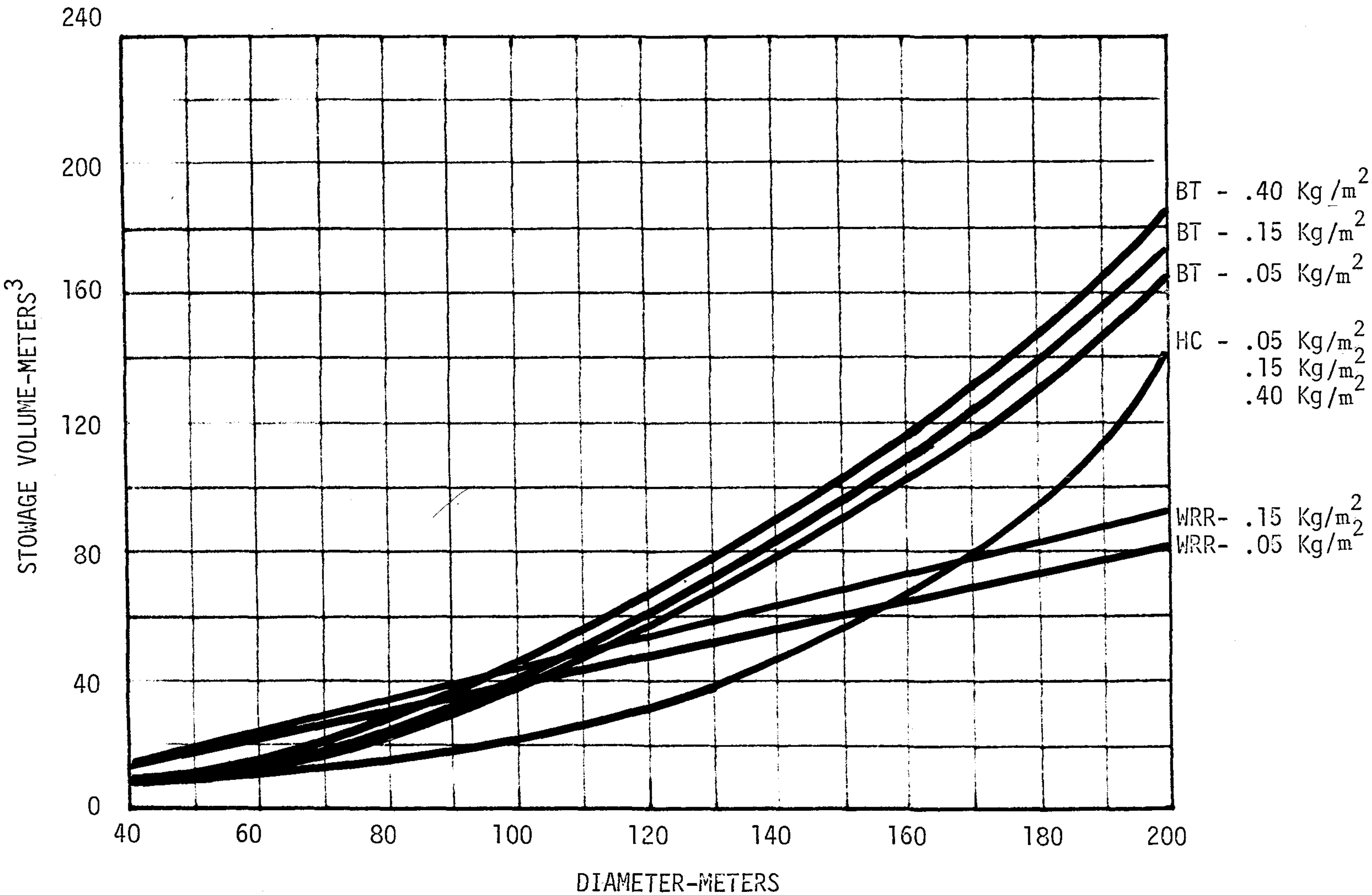


FIGURE VI-2-STOWAGE VOLUME FOR THE BOX TRUSS (BT), HOOP AND COLUMN (HC), AND WRAP RADIAL RIB (WRR) FOR 0.05-0.15-0.40 Kg/m^2 SURFACE DENSITY (T/M BETWEEN 0.05 AND 0.10 g's)

B. Results and Conclusions

There were a few situations where the available payoad mass and available payload volume exceeded the applicable range of the LSS data. In these cases, a maximum diameter, 200 meters, was chosen from the upper allowable limits of the payload.

Once the diameters have been tabulated, an equally weighted numerical average of the maximum diameters for each propellant combination and tankage configuration was calculated to determine propulsion system/LSS interaction trends. An average maximum diameter was used since future LSS characterisitics, i.e., structure class and surface density, have yet to be defined.

Table VI-1 correlates the interaction data with the table number for each interaction combination considered. Table VI-2 through Table VI-11 present the maximum LSS diameter in relation to tankage configuration and propellant combination.

TABLE VI - 1 - INTERACTION DATA CORRELATION

		g LEVEL	LO_2/RP-1	N_2O_4/MMH	LO_2/LCH_4	LO_2/LH_2
8 PERIGEE BURNS	CONSTANT ACCELERATION	0.01	2*	2	3	3
		0.05	4	4	5	5
		0.10	8	8	9	9
	CONSTANT THRUST	0.05	--	7	7	7
		0.10	--	--	11	11
1 PERIGEE BURN	CONSTANT ACCELERATION	0.05	--	6	6	6
		0.10	--	10	10	10

* INDICATES TABLE NUMBER

TABLE VI-2 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.01 g 8 PERIGEE BURNS PUMP FED
CONSTANT ACCELERATION NOMINAL MIXTURE RATIO

LSS CONFIGURATION \ PROPULSION CONFIGURATION	LO_2/RP-1 MAX. PERF. $(\frac{x}{y})$	LO_2/RP-1 MIN. LENGTH $(\frac{x}{y})$	N_2O_4/MMH MAX. PERF. $(\frac{x}{y})$	N_2O_4/MMH MIN. LENGTH $(\frac{x}{y})$
BOX TRUSS				
0.05 kg/m^2	144 $(\frac{82}{139})$	142 $(\frac{66}{146})$	148 $(\frac{52}{138})$	147 $(\frac{62}{148})$
0.15 kg/m^2	124 $(\frac{75}{139})$	122 $(\frac{84}{146})$	128 $(\frac{69}{138})$	127 $(\frac{80}{148})$
0.40 kg/m^2	92 $(\frac{101}{139})$	90 $(\frac{109}{146})$	94 $(\frac{98}{138})$	93 $(\frac{109}{148})$
HOOP AND COLUMN				
0.05 kg/m^2	199* $(\frac{404}{3654})$***	200**	199* $(\frac{712}{3862})$***	200**
0.15 kg/m^2	157 $(\frac{75}{139})$	155 $(\frac{83}{146})$	161 $(\frac{70}{138})$	160 $(\frac{81}{148})$
0.40 kg/m^2	99 $(\frac{118}{139})$	98 $(\frac{125}{146})$	104 $(\frac{115}{138})$	103 $(\frac{125}{148})$
WRAP RADIAL RIB				
0.05 kg/m^2	89 $(\frac{105}{139})$	88 $(\frac{112}{146})$	92 $(\frac{102}{138})$	91 $(\frac{113}{148})$
0.15 kg/m^2	81 $(\frac{104}{139})$	80 $(\frac{112}{146})$	84 $(\frac{102}{138})$	83 $(\frac{113}{148})$
AVERAGE	123	122	126	126

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS.

$(\frac{x}{y})$ X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-3 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.01 g 8 PERIGEE BURN PUMP FED
CONSTANT ACCELERATION NOMINAL MIXTURE RATIO

LSS CONFIGURATION \ PROPULSION CONFIGURATION	LO_2/LCH_4 MAX. PERF. $(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH $(\frac{x}{y})$	LO_2/LH_2 MAX. PERF. $(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH $(\frac{x}{y})$
BOX TRUSS				
0.05 kg/m^2	149 $(\frac{45}{133})$	146 $(\frac{58}{142})$	165* $(\frac{818}{5718})$***	172* $(\frac{335}{5635})$***
0.15 kg/m^2	127 $(\frac{65}{133})$	125 $(\frac{77}{142})$	148 $(\frac{16}{109})$	146 $(\frac{28}{119})$
0.40 kg/m^2	93 $(\frac{94}{133})$	92 $(\frac{104}{142})$	113 $(\frac{49}{109})$	112 $(\frac{61}{119})$
HOOP AND COLUMN				
0.05 kg/m^2	198* $(\frac{720}{3870})$***	200**	188* $(\frac{2918}{5718})$***	192* $(\frac{2685}{5635})$***
0.15 kg/m^2	162 $(\frac{64}{133})$	160 $(\frac{75}{142})$	188* $(\frac{318}{5718})$***	191 $(\frac{1}{119})$
0.40 kg/m^2	104 $(\frac{110}{133})$	103 $(\frac{119}{142})$	130 $(\frac{86}{109})$	129 $(\frac{82}{119})$
WRAP RADIAL RIB				
0.05 kg/m^2	92 $(\frac{98}{133})$	91 $(\frac{107}{142})$	116 $(\frac{64}{109})$	112 $(\frac{75}{119})$
0.15 kg/m^2	84 $(\frac{97}{133})$	82 $(\frac{107}{142})$	102 $(\frac{64}{109})$	100 $(\frac{75}{119})$
AVERAGE	126	125	144	144

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS.

$(\frac{x}{y})$ X IS THE REMAININT VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-4 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.05 g 8 PERIGEE BURN CONSTANT ACCELERATION — PUMP FED NOMINAL MIXTURE RATIO

Propulsion Configuration / LSS Configuration	$LO_2/RP-1$ MAX. PERF.	$(\frac{x}{y})$	$LO_2/RP-1$ MIN. LENGTH	$(\frac{x}{y})$	N_2O_4/MMH MAX. PERF.	$(\frac{x}{y})$	N_2O_4/MMH MIN. LENGTH	$(\frac{x}{y})$
<u>BOX TRUSS</u>								
0.05 Kg/M^2	162	$(\frac{35}{137})$	158	$(\frac{50}{150})$	162	$(\frac{34}{138})$	156	$(\frac{52}{148})$
0.15 Kg/M^2	138	$(\frac{55}{137})$	136	$(\frac{70}{150})$	138	$(\frac{56}{138})$	135	$(\frac{70}{148})$
0.40 Kg/M^2	106	$(\frac{85}{137})$	104	$(\frac{100}{150})$	105	$(\frac{86}{138})$	102	$(\frac{100}{148})$
<u>HOOP/COLUMN</u>								
0.05 Kg/M^2	198*	$(\frac{1728}{5100})$***	200**		199*	$(\frac{1730}{5130})$***	200**	
0.15 Kg/M^2	178	$(\frac{45}{137})$	176	$(\frac{60}{150})$	178	$(\frac{46}{138})$	172	$(\frac{66}{148})$
0.40 Kg/M^2	120	$(\frac{106}{137})$	118	$(\frac{120}{150})$	120	$(\frac{107}{138})$	115	$(\frac{120}{148})$
<u>WRAP RADIAL RIB</u>								
0.05 Kg/M^2	106	$(\frac{95}{137})$	105	$(\frac{109}{150})$	106	$(\frac{96}{138})$	102	$(\frac{108}{148})$
0.15 Kg/M^2	97	$(\frac{95}{137})$	96	$(\frac{108}{150})$	97	$(\frac{96}{138})$	93	$(\frac{108}{148})$
AVERAGE	138		137		138		135	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) or MASS (kg) NOT OCCUPIED BY THIS LSS, Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS

TABLE VI-5 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.05 g 8 PERIGEE BURN CONSTANT ACCELERATION — PUMP FED NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	LO_2/LCH_4 MAX. PERF.	$(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH	$(\frac{x}{y})$	LO_2/LH_2 MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS								
0.05 Kg/M^2	164	$(\frac{15}{131})$	164	$(\frac{29}{145})$	166*	$(\frac{1470}{7170})$***	172*	$(\frac{1360}{7160})$***
0.15 Kg/M^2	139	$(\frac{49}{131})$	138	$(\frac{63}{145})$	154	$(\frac{9}{111})$	154	$(\frac{24}{126})$
0.40 Kg/M^2	106	$(\frac{79}{131})$	105	$(\frac{93}{145})$	122	$(\frac{43}{111})$	121	$(\frac{59}{126})$
HOOP/COLUMN								
0.05 Kg/M^2	196*	$(\frac{1970}{5218})$***	200**		189*	$(\frac{4170}{7170})$***	195*	$(\frac{3910}{7160})$***
0.15 Kg/M^2	173	$(\frac{48}{131})$	172	$(\frac{63}{145})$	189*	$(\frac{1170}{7170})$***	195*	$(\frac{650}{7160})$***
0.40 Kg/M^2	121	$(\frac{99}{131})$	120	$(\frac{114}{145})$	142	$(\frac{64}{111})$	142	$(\frac{79}{126})$
WRAP RADIAL RIB								
0.05 Kg/M^2	107	$(\frac{89}{131})$	106	$(\frac{104}{145})$	124	$(\frac{62}{111})$	124	$(\frac{77}{126})$
0.15 Kg/M^2	96	$(\frac{89}{131})$	96	$(\frac{103}{145})$	115	$(\frac{60}{111})$	115	$(\frac{75}{126})$
AVERAGE	138		138		150		152	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-6 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.05 g 1 PERIGEE BURN PUMP FED
CONSTANT ACCELERATION NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	N_2O_4/MMH MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH	$(\frac{x}{y})$	LO_2/LCH_4 MAX. PERF.	$(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS										
0.05 Kg/M^2	136	$(\frac{60}{136})$	164*	$(\frac{400}{5500})$***	167	$(\frac{21}{132})$	137	$(\frac{53}{130})$	136	$(\frac{65}{141})$
0.15 Kg/M^2	117	$(\frac{76}{136})$	142	$(\frac{20}{107})$	141	$(\frac{47}{132})$	118	$(\frac{69}{130})$	113	$(\frac{85}{141})$
0.40 Kg/M^2	85	$(\frac{105}{136})$	109	$(\frac{55}{107})$	108	$(\frac{81}{132})$	86	$(\frac{98}{130})$	84	$(\frac{111}{141})$
HOOP/COLUMN										
C.05 Kg/M^2	198*	$(\frac{30}{3380})$***	186*	$(\frac{2700}{5500})$***	197*	$(\frac{2100}{5400})$***	196*	$(\frac{180}{3400})$***	198	$(\frac{5}{141})$
0.15 Kg/M^2	148	$(\frac{84}{136})$	183	$(\frac{7}{107})$	182	$(\frac{34}{132})$	149	$(\frac{77}{130})$	147	$(\frac{90}{141})$
0.40 Kg/M^2	93	$(\frac{117}{136})$	124	$(\frac{73}{107})$	123	$(\frac{99}{132})$	95	$(\frac{110}{130})$	93	$(\frac{122}{141})$
WRAP RADIAL RIB										
0.05 Kg/M^2	86	$(\frac{103}{136})$	110	$(\frac{64}{107})$	109	$(\frac{89}{132})$	87	$(\frac{96}{130})$	85	$(\frac{108}{141})$
0.15 Kg/M^2	79	$(\frac{103}{136})$	100	$(\frac{63}{107})$	99	$(\frac{89}{132})$	79	$(\frac{97}{130})$	77	$(\frac{109}{141})$
AVERAGE	118		140		141		118		117	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-7 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.05g 8 PERIGEE BURNS CONSTANT THRUST PUMP FED NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Config.	N_2O_4/MMH Max Perf.	$(\frac{x}{y})$	LO_2/LH_2 Max Perf.	$(\frac{x}{y})$	LO_2/LH_2 MIN Length	$(\frac{x}{y})$	LO_2/LCH_4 Max Perf.	$(\frac{x}{y})$	LO_2/LCH_4 Min Length	$(\frac{x}{y})$
BOX TRUSS										
0.05 Kg/M^2	157	$(\frac{42}{141})$	166*	$(\frac{1370}{6670})$***	182	$(\frac{2}{134})$	157	$(\frac{35}{134})$	155	$(\frac{47}{133})$
0.15 Kg/M^2	134	$(\frac{64}{141})$	151	$(\frac{3}{110})$	149	$(\frac{39}{134})$	134	$(\frac{57}{134})$	133	$(\frac{67}{143})$
0.40 Kg/M^2	101	$(\frac{96}{141})$	118	$(\frac{49}{110})$	117	$(\frac{70}{134})$	101	$(\frac{89}{134})$	100	$(\frac{99}{143})$
HOOP/ COLUMN										
0.05 Kg/M^2	199*	$(\frac{1250}{4650})$***	188*	$(\frac{3670}{6670})$***	197*	$(\frac{3050}{6420})$***	198*	$(\frac{1280}{4630})$***	200*	$(\frac{1070}{4520})$***
0.15 Kg/M^2	170	$(\frac{62}{141})$	188*	$(\frac{765}{6670})$***	193	$(\frac{13}{134})$	170	$(\frac{55}{134})$	168	$(\frac{67}{143})$
0.40 Kg/M^2	113	$(\frac{119}{141})$	137	$(\frac{67}{110})$	134	$(\frac{93}{134})$	113	$(\frac{106}{134})$	112	$(\frac{116}{143})$
WRAP RADIAL RIB										
0.05 Kg/M^2	100	$(\frac{101}{141})$	120	$(\frac{62}{110})$	119	$(\frac{88}{134})$	100	$(\frac{94}{134})$	98	$(\frac{105}{143})$
0.15 Kg/M^2	91	$(\frac{101}{141})$	111	$(\frac{60}{110})$	108	$(\frac{85}{134})$	91	$(\frac{94}{134})$	89	$(\frac{105}{143})$
AVERAGE	133		147		150		133		132	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS.

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS,
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-8 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.1 g   8 PERIGEE BURN   PUMP FED
CONSTANT ACCELERATION   NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	LO_2/RP-1 MAX. PERF.	(x/y)	LO_2/RP-1 MIN. LENGTH	(x/y)	N_2O_4/MMH MAX. PERF.	(x/y)	N_2O_4/MMH MIN. LENGTH	(x/y)
BOX TRUSS								
0.05 Kg/M^2	154	(38/134)	153	(55/150)	154	(40/136)	150	(48/138)
0.15 Kg/M^2	136	(56/134)	136	(70/150)	136	(56/136)	133	(62/138)
0.40 Kg/M^2	103	(86/134)	102	(102/150)	103	(88/136)	100	(92/138)
HOOP/COLUMN								
0.05 Kg/M^2	197*	(1170/5220)***	200**		198*	(1050/5200)***	199*	(650/4830)***
0.15 Kg/M^2	172	(60/134)	170	(72/150)	172	(54/136)	166	(64/138)
0.40 Kg/M^2	118	(112/134)	117	(121/150)	118	(106/136)	114	(111/138)
WRAP RADIAL RIB								
0.05 Kg/M^2	100	(95/134)	98	(112/150)	100	(97/136)	95	(101/138)
0.15 Kg/M^2	89	(96/134)	88	(112/150)	89	(98/136)	85	(101/138)
AVERAGE	134		133		134		130	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ X IS THE VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS.
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

TABLE VI-9 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.1 g 8 PERIGEE BURN, CONSTANT ACCELERATION — PUMP FED, NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	LO_2/LCH_4 MAX. PERF.	(x/y)	LO_2/LCH_4 MIN. LENGTH	(x/y)	LO_2/LH_2 MAX. PERF.	(x/y)	LO_2/LH_2 MIN. LENGTH	(x/y)
<u>BOX TRUSS</u>								
0.05 Kg/M^2	154	(33/129)	153	(50/145)	165*	(1580/7380)***	172*	(280/7280)***
0.15 Kg/M^2	133	(54/129)	132	(71/145)	152	(12/110)	151	(29/126)
0.40 Kg/M^2	104	(79/129)	102	(97/145)	117	(36/110)	116	(48/126)
<u>HOOP/COLUMN</u>								
0.05 Kg/M^2	196*	(2120/5320)***	200**		188*	(2870/7380)***	195*	(3830/7280)***
0.15 Kg/M^2	174	(45/129)	172	(63/145)	188*	(479/7380)***	193	(4/126)
0.40 Kg/M^2	118	(99/129)	116	(119/145)	138	(66/110)	137	(83/126)
<u>WRAP RADIAL RIB</u>								
0.05 Kg/M^2	101	(90/129)	100	(106/145)	115	(65/110)	114	(/126)
0.15 Kg/M^2	89	(90/129)	88	(107/145)	104	(65/110)	103	(81/126)
AVERAGE	134		133		145		148	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

*** MASS RATIO-ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

(x/y) WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS

TABLE VI-10 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.1 g 1 PERIGEE BURN CONSTANT ACCELERATION PUMP FED NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	N_2O_4/MMH MAX. PERF.	(x/y)	LO_2/LH_2 MAX. PERF.	(x/y)	LO_2/LH_2 MIN. LENGTH	(x/y)	LO_2/LCH_4 MAX. PERF.	(x/y)	LO_2/LCH_4 MIN. LENGTH	(x/y)
BOX TRUSS										
0.05 Kg/M^2	138	(56/134)	164	(+)	163	(28/133)	139	(49/128)	138	(64/142)
0.15 Kg/M^2	123	(69/134)	143	(19/107)	142	(46/133)	124	(62/128)	122	(78/142)
0.40 Kg/M^2	91	(97/134)	110	(54/107)	109	(81/133)	92	(91/128)	90	(107/142)
HOOP/COLUMN										
0.05 Kg/M^2	197*	(1440/3900)***	186*	(3190/6130)***	197*	(2550/6050)***	195*	(550/4000)***	200*	(200/3900)***
0.15 Kg/M^2	152	(77/134)	184	(5/107)	183	(33/133)	153	(70/128)	151	(86/142)
0.40 Kg/M^2	101	(112/134)	128	(70/107)	126	(98/133)	103	(105/128)	101	(120/142)
WRAP RADIAL RIB										
0.05 Kg/M^5	89	(99/134)	107	(65/107)	106	(91/133)	89	(93/128)	88	(107/142)
0.15 Kg/M^2	79	(100/134)	96	(65/107)	95	(91/133)	80	(94/128)	78	(109/142)
AVERAGE	121		140		140		122		121	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED.

*** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS.

(x/y) WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (kg) NOT OCCUPIED BY THIS LSS. Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

\+ BOTH PAYLOAD MASS AND PAYLOAD VOLUME CONSTRAINTS ARE MET SIMULTANEOUSLY.

TABLE VI-11 MAXIMUM LSS DIAMETERS (METERS)

T/M = 0.1 g — 8 PERIGEE BURNS, CONSTANT THRUST — PUMP FED, NOMINAL MIXTURE RATIO

LSS Configuration \ Propulsion Configuration	LO_2/LH_2 MAX. PERF.	$(\frac{x}{y})$	LO_2/LH_2 MIN. LENGTH	$(\frac{x}{y})$	LO_2/LCH_4 MAX. PERF.	$(\frac{x}{y})$	LO_2/LCH_4 MIN. LENGTH	$(\frac{x}{y})$
BOX TRUSS								
0.05 Kg/M^2	166*	$(\frac{780}{6980})$***	170	$(\frac{20}{135})$	151	$(\frac{41}{133})$	145	$(\frac{71}{156})$
0.15 Kg/M^2	149	$(\frac{15}{110})$	147	$(\frac{20}{135})$	133	$(\frac{57}{133})$	129	$(\frac{66}{156})$
0.40 Kg/M^2	116	$(\frac{52}{110})$	113	$(\frac{75}{135})$	100	$(\frac{89}{133})$	95	$(\frac{166}{156})$
HOOP/COLUMN								
0.05 Kg/M^2	188*	$(\frac{3880}{6980})$***	198*	$(\frac{3050}{6700})$***	197*	$(\frac{1390}{4890})$***	200**	
0.15 Kg/M^2	188*	$(\frac{380}{6980})$***	188	$(\frac{25}{135})$	167	$(\frac{58}{133})$	160	$(\frac{90}{156})$
0.40 Kg/M^2	136	$(\frac{68}{110})$	132	$(\frac{95}{135})$	114	$(\frac{105}{133})$	108	$(\frac{130}{156})$
WRAP RADIAL RIB								
0.05 Kg/M^2	112	$(\frac{66}{110})$	111	$(\frac{92}{135})$	95	$(\frac{96}{133})$	92	$(\frac{120}{156})$
0.15 Kg/M^2	102	$(\frac{66}{110})$	99	$(\frac{92}{135})$	88	$(\frac{94}{133})$	84	$(\frac{120}{156})$
AVERAGE	145		145		131		127	

* VOLUME CONSTRAINED, OTHERWISE MASS CONSTRAINED *** MASS RATIO - ALL OTHERS ARE DIAMETER (VOLUME) RATIOS

$(\frac{x}{y})$ WHERE: X IS THE REMAINING VOLUME (M^3) OR MASS (Kg) NOT OCCUPIED BY THIS LSS.
Y IS THE AVAILABLE PAYLOAD VOLUME OR AVAILABLE PAYLOAD MASS.

** THESE DIAMETERS ARE NOT BASED ON MAXIMIZED PAYLOAD VOLUME OR PAYLOAD MASS DUE TO LIMITATIONS IMPOSED UPON LSS DATA.

From the maximum average LSS diameter comparisons, several conclusions can be drawn:

1) As expected, the greater the surface density of the three LSS concepts, the lower the maximum LSS diameter.
2) A T/M of 0.05 g provides for maximum LSS diameters for constant acceleration and constant thrust, each with 8 perigee burns.
3) A T/M of 0.1 g provides for maximum LSS diameters for constant acceleration, 1 perigee burn transfers.
4) Maximum LSS diameters for an 8 perigee burn are generally greater than a 1 perigee burn strategy.
5) Constant acceleration provides for a greater maximum LSS diameter than constant thrust for the same T/M.
6) Maximum LSS diameters for maximum performance and minimum length propulsion configurations are within four percent of which maximum performance is higher.
7) The LO_2/LH_2 propellant combination provides the highest average LSS diameters for both tankage configurations, propulsion mode, burn strategy, and T/M range.

With the OTV burnout mass and LSS mass known, a final burnout thrust was calculated from the corresponding acceleration. This allowed LSS deployed diameter curves to be developed as a function of thrust level for each combination of vehicle and LSS.

Propulsion system sizing results indicated a LO_2/LH_2 maximum performance vehicle and a N_2O_4/MMH minimum length vehicle are the best and worst performers, respectively, based on a deliverable payload mass. Presented in Figure VI-3 is LSS diameter versus thrust level for LO_2/LH_2, maximum performance vehicle with parametric LSS. Inspection of Figure VI-3 reveals two types of trends for LSS diameters which result from the 100% utilization of payload volume or payload mass. The top two curves (HC-0.15 and BT-0.05) represent volume limited LSS in the Orbiter cargo bay. The deliverable diameter of volume limited LSS are relativity insensitive to thrust level. This insensitivity occured because of the small change in stage length for pump-fed vehicles as shown in Figures V-13 and V-14. As stage length changes only slightly over the thrust range, so does that available payload volume. Only small diameter changes ($<$ 2M) were determined when developing maximum LSS diameter points over the thrust range of interest. The second LSS diameter trend is shown in the remaining five curves. All of these LSS were mass limited in the cargo bay. Below thrust levels of 2225 N, dramatic decreases in LSS deployed diameter were seen because of the vehicle increased delta velocity requirements below the acceleration level (0.015 g's). LSS deployed diameter decreased above thrust levels of 4450 N due to the acceleration mass impacts on the LSS. The resultant optimum thrust level

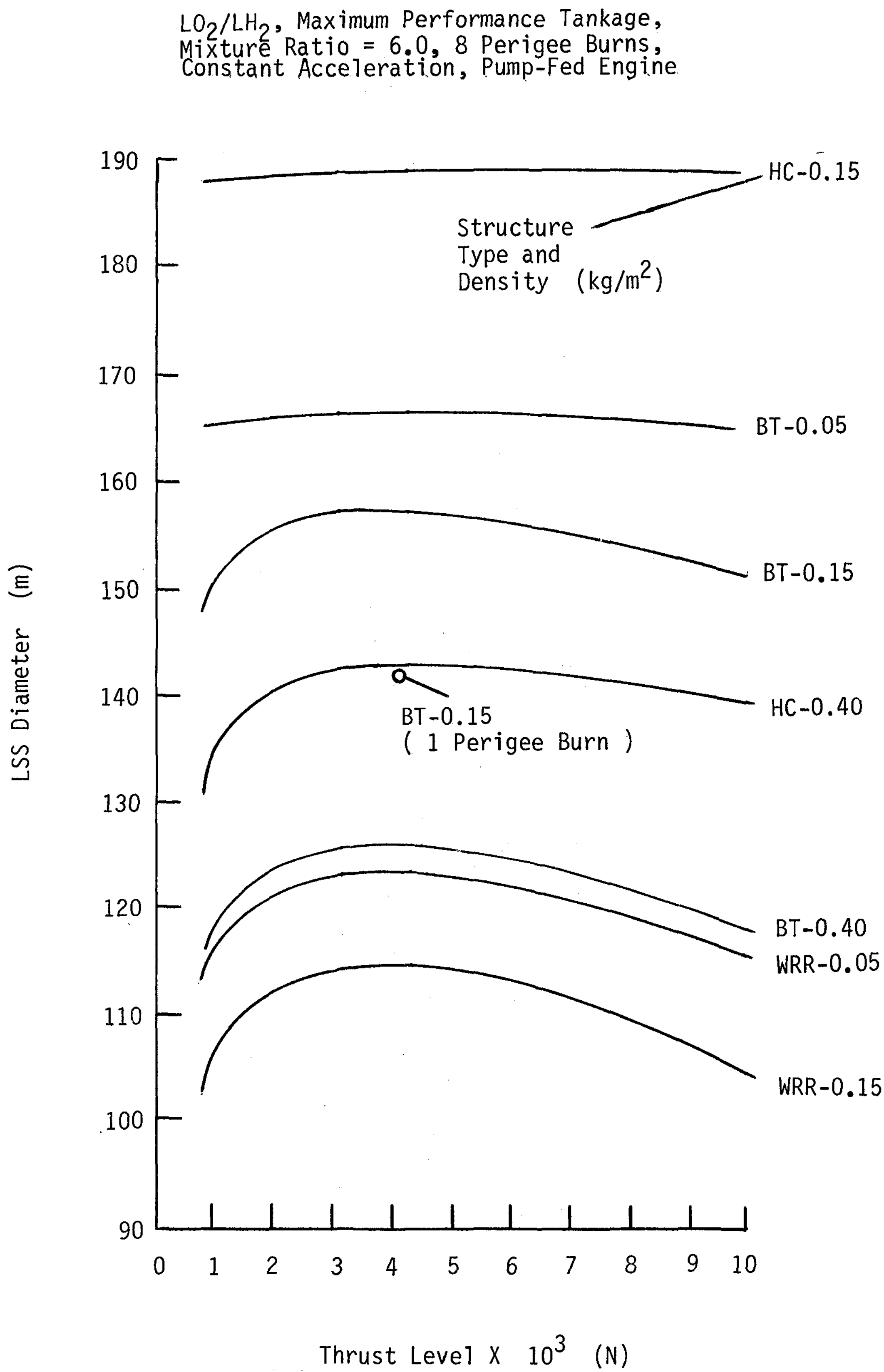


FIGURE VI - 3 - Effect of Thrust Level on LSS Diameter for LO_2/LH_2 OTV range for all structures is between 3100 to 4200N. Included in Figure VI-3 is a comparison point of a 1 perigee burn, constant acceleration, pump-fed, minimum length, LO_2/LH_2 vehicle. As shown, the 8 burn transfer strategy delivered approximately a 10% greater LSS diameter than a 1 burn strategy at a thrust level of 4450 N. On the other end of the performance spectrum is a minmum length, N_2O_4/MMH OTV. This vehicle's delivery capability is shown in Figure VI-4 for the various LSS. Similar to the LO_2/LH_2 vehicle, the N_2O_4/MMH vehicle has an optimum thrust level range of 3100 to 4200 N for all structures.

To demonstrate the independence of propellant combination and tankage configuration on optimum thrust level, Figure VI-5 presents LSS diameter versus thrust level for the expandable box truss with 0.05 Kg/M^2 surface density. The top two curves in Figure VI-5 represent volume-limited structures where as the remaining curves are mass-limited structures. All the mass-limited curves have an optimum thrust level of 3100 to 4200N independent of propellent combination and tankage configuration.

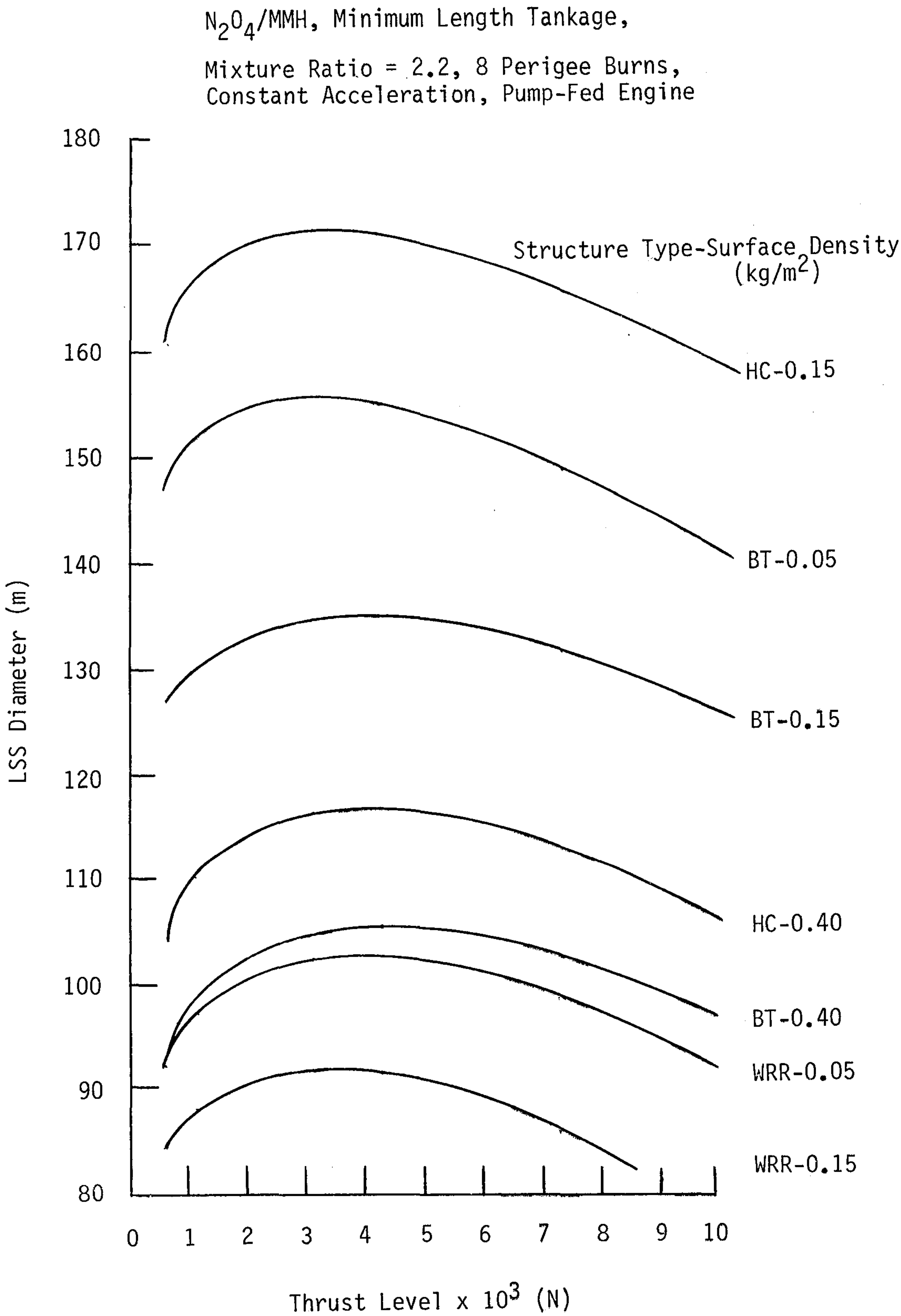


FIGURE VI - 4 - Effect of Thrust Level on LSS Diameter for N_2O_4/MMH OTV.

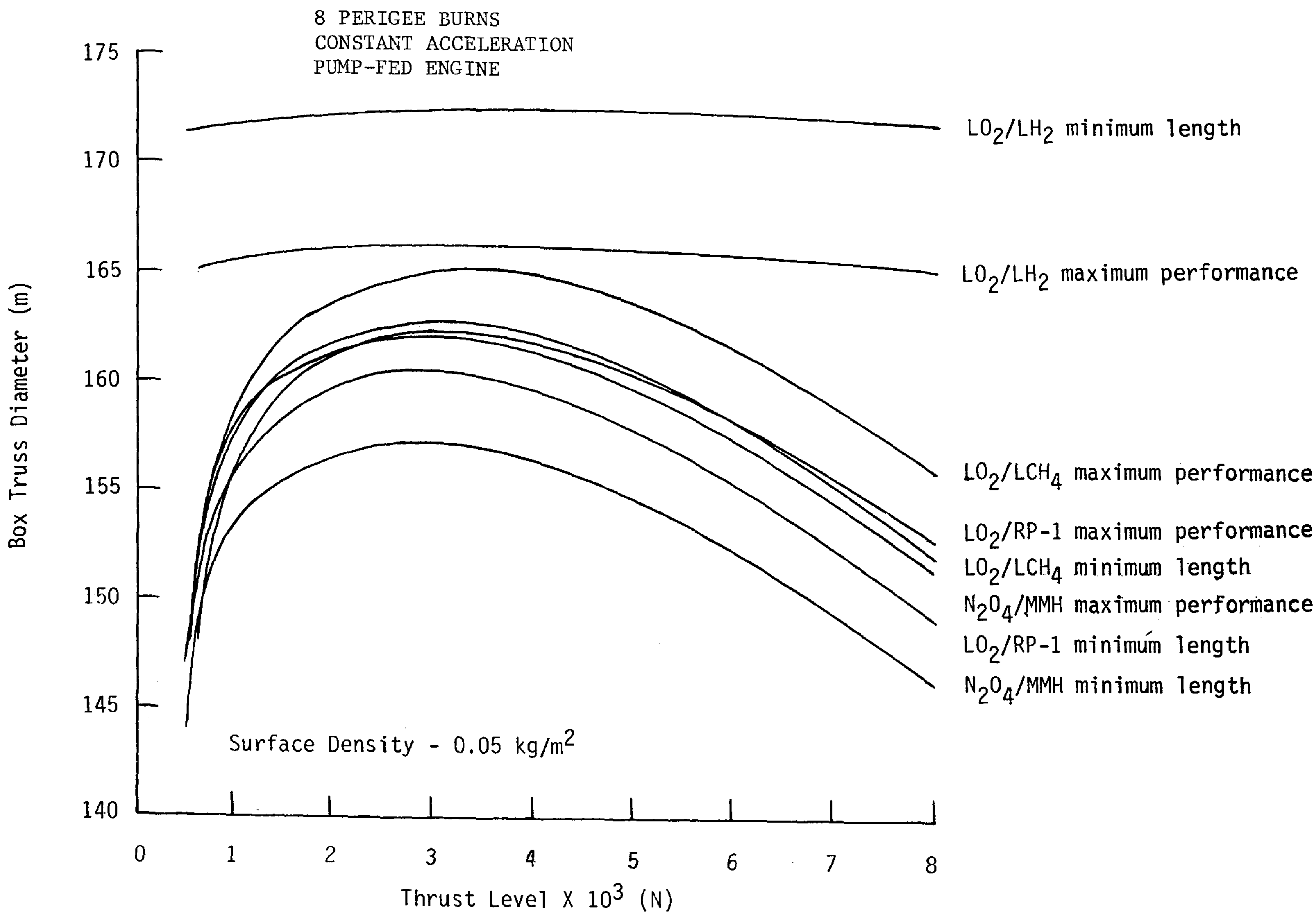


FIGURE VI - 5 - Effect of Thrust Level on Box Truss Diameter for Various Propellant Combinations and Tankage Configurations

VII. SUMMARY OF RESULTS & CONCLUSIONS

This study has investigated the interactions of large space systems and primary propulsion. Three LSS concepts with a broad range of diameters, surface densities and acceleration rates were compared to 175 primary propulsion systems in order to identify propulsion system characteristic which maximize deployed LSS diameter. The three LSS concepts which baselined this study are wrap radial rib, hoop and column, and expandable box truss.

For these baseline configurations, parametric studies of LSS mass as a function of area and thrust-to-mass ratio were conducted to determine the effect of steady state and transient thrust on structural mass.

Seventeen typical box truss configurations with diameters ranging from 35 to 194 m and surface densities ranging from 0.05 to 3.42 kg/m^2 were analyzed. At a typical low-thrust T/M ratio of 0.05 g's the structural mass impact (i.e., the additional mass above that associated with minimum gage structural elements) was relatively small (20% or less) for fifteen of the seventeen cases. Exceptions were the maximum diameter (194 m/0.05 kg/m^2) and the maximum surface density (71 m/3.42 kg/m^2) cases where the structural mass impacts were 70% and 90% respectively.

Fourteen typical radial rib configurations with diameters ranging from 35 to 194 m and surface densities ranging from 0.05 to 0.15 kg/m^2 were analyzed. At a typical low-thrust T/M ratio of 0.05 g's there was no structural mass impact on any of the configurations which were analyzed (structural mass impact occurred at a T/M of 0.055 g's on the 194m/0.15 kg/m^2 configuration). The relatively high allowable acceleration at large diameters is due to stiffness criteria which increases the size of cantilevered ribs as diameter increases. Additionally, the radial rib concept was not sized for the higher surface densities of 0.40 and 3.42 kg/m^2.

Nine typical hoop and column configurations with diameters ranging from 50 to 200 m and surface densities ranging from 0.05 to 0.40 kg/m^2 were analyzed. At a typical low-thrust T/M ratio of 0.05 g's the structural mass impact was relatively small (12% or less) for six of the nine cases. Exceptions were the maximum diameter (200 m) cases with surface densities of 0.05, 0.15, and 0.40 kg/m^2 where the structural mass impacts at 0.05 g's were 23%, 40%, and 134% respectively.

All of the LSS configurations exhibited a common trend after the minimum gage structural mass was affected by acceleration, i.e., an exponential increase in structural mass as T/M was increased. For a given diameter and surface density the mass change is relatively small for the box truss and the hoop and column over a wide range of T/M and, with the exception of the maximum diameter and/or surface density cases noted above, only small reductions in structural mass are realized at T/M ratios below 0.05 g's. For the wrap radial rib, the structural mass change is very sensitive to T/M and the mass increases are large over a small range of T/M.

Typical box truss, radial rib, and hoop and column configurations were analyzed to determine the effect of start and shutdown transients on structural mass. These analyses were conducted for a constant thrust burn strategy. For this strategy the most critical start condition from a dynamic standpoint is the apogee burn. Results of the analyses indicated an average structural mass impact (relative to steady state) of 10% for a step thrust input and negligible mass impact for ramps equal in time to 2/3 of the fundamental period of the combined LSS-OTV. For the LSS configurations considered, start times which produced negligible impact ranged from 0.2 to 10 seconds. Shutdown transient analyses indicated that an instantaneous thrust cutoff at the end of the apogee burn (critical condition) produced negligible structural mass impact.

The three structural concepts were evaluated to determine their applicability to multi-point thrust application. The box truss, with its large number of hard points for attachment, provides complete flexibility for location of the propulsion system. The hoop and column concept requires that propulsion system locations be limited to the column and the hoop. The radial rib antenna has only one hard point - the hub. Therefore, multi-point thrust is not applicable to the radial rib concept.

The box truss, structural mass impact results for steady state multi-point thrust application are summarized as follows. By utilizing a 5 point thrust application, a factor of ≈ 2 increase in thrust can be allowed without a change in structural mass impact. By going from a 5 point to a 9 point thrust application, less than a 50% increase in thrust can be realized for no change in structural mass impact. The hoop and column, steady state multi-point thrust application results show that by utilizing a 5 point thrust application, less than a factor of two increase in thrust can be allowed without a change in structural mass impact. The 9 point thrust application shows only a small improvement over the 5 point. Like the box truss, the results indicate that for these size ranges, multi-point thrust does not provide enough of a performance enhancement to warrant the added stage complexity.

Parametric analyses were performed to determine deliverable payload mass and engine burn times as a function of T/M, propulsion system performance, and number of perigee burns for transfer from low earth orbit (LEO) to geosynchronous earth orbit (GEO). Three thrust models; impulsive, constant thrust, and constant acceleration with ISP, number of burns, and T/M as parameters were studied as possible trajectory strategies. Several conclusions were drawn from the various trajectory strategies. First, multiple perigee burns can significantly reduce the ideal Δ V requirement for geosynchronous missions. Utilization of multiple burns lowers the required ideal velocity increment by reducing the gravity losses accumulated during the thrusting segments. Reduction of the gravity loss is a direct result of the negative to positive change in the flight path angle (FPA) over all but the first perigee burn. The second conclusion that can be drawn is that the constant acceleration propulsion mode offers advantages in ideal velocity requirements at certain T/M values over constant thrust cases for both 1 and 8 perigee burn transfers. It is clear from the trajectory parameter sensitivities that the T/M ratio is by far the principal driver in the trajectory design for low thrust systems with mass fraction as the second most important variable. The number of perigee burns has a significant impact on V requirement, trip time, and delivered payload. The least important Δ parameter appears to be Isp. However, change in Isp still impact payload mass.

The characteristics of several primary propulsion stages that are packaged in the Orbiter cargo bay and are used to deliver LSS from low earth orbit (LEO) to geosynchronous earth orbit (GEO) were determined. The characteristics include mass fraction, stage length, stage mass, and center of gravity position. Stage characteristics were generated parametrically as a function of thrust-to-mass ratio for oxygen/hydrogen, oxygen/methane, oxygen/kerosene, and nitrogen tetroxide/monomethylhydrazine over a selected acceleration range compatible with the LSS data, for both pump-fed and pressure-fed engines. The conclusion from the stage characteristic data suggest an 8 perigee burn, constant acceleration, pump-fed engine, primary propulsion system will maximize LSS deployed diameter.

Propulsion system comparisons were performed to provide insight as to how the primary propulsion system characteristics, orbit transfer techniques, LSS mass and area, Shuttle cargo bay packaging, and engine technology are interactive. The relative merit of the various primary propulsion system characteristics were established at T/M ratios of 0.01, 0.05 and 0.10 g's.

From these comparisons, several conclusions can be drawn:

1) As expected, the greater the surface density of the three LSS concepts, the lower the maximum LSS diameter;
2) A T/M of 0.05 g provides for maximum LSS diameters for constant acceleration and constant thrust, each with 8 perigee burns;
3) A T/M of 0.1 g provides for maximum LSS diameters for constant acceleration, 1 perigee burn transfers
4) Maximum LSS diameters for an 8 perigee burn are generally greater than a 1 perigee burn strategy;
5) Constant acceleration provides for a greater maximum LSS diameter than constant thrust for the same T/M;
6) Maximum LSS diameters for maximum performance and minimum length propulsion configurations are within four percent of which maximum performance is higher; and
7) The LO_2/LH_2 propellant combination provides the highest average maximum LSS diameter for both tankage configurations, propulsion mode, burn strategy, and T/M range.

Analyses were conducted to determine deployed LSS diameter as a function of thrust level for various combinations of OTV and LSS. Results indicated that, based on a single Shuttle flight with a LEO to GEO orbit transfer, the optimum OTV final thrust level range to maximize delivered LSS diameter (if payload mass limited) is between 3100 to 4200N and the maximum performance tankage configuration delivers the maximum deployed LSS diameter. This range is relatively independent of the following:

1) Propellant Combination;
2) Tankage Configuration;
3) Mixture Ratio;
4) Type of LSS; and
5) Type of LSS nonstructural surface.

However, if the spacecraft is volume limited in the Orbiter cargo bay then the maximum LSS diameter is relatively insensitive to thrust level over the range studied and the minimum length tankage configuration delivers the maximum deployed LSS diameter.

The following stage characteristics are reemphasized which deliver the maximum LSS diameter based on the results of this study. These characteristics are:

1) LO_2/LH_2 propellant combination
2) Pump-fed single engine, and
3) Constant acceleration, 8 perigee burn orbit transfer strategy

APPENDIX A

ENGINE DATA

Pressure-fed and pump-fed engine data for each of the propellant combinations at six thrust levels over the thrust range of interest were supplied by NASA-LeRC. Engine cycle and chamber pressure assumptions used in generating the data were as follows:

Pressure-Fed Engines: Chamber Pressure = 69 N/cm^2 for all propellant combinations and thrust levels.

Pump-Fed Engines:

N_2O_4/MMH: Gas Generator Cycle

LO_2/RP-1: Gas Generator Cycle

LO_2/LH_2: Expander Cycle

LO_2/LCH_4: Expander Cycle

THRUST LEVEL (N)	CHAMBER PRESSURE (N/cm^2)			
	N_2O_4/MMH	LO_2/RP-1	LO_2/LH_2	LO_2/LCH_4
445	69	69	69	69
1334	186	186	221	209
2224	269	269	345	303
4448	448	448	638	517
13344	607	607	965	724
31136	827	827	1379	1034

ENGINE DATA (Continued)

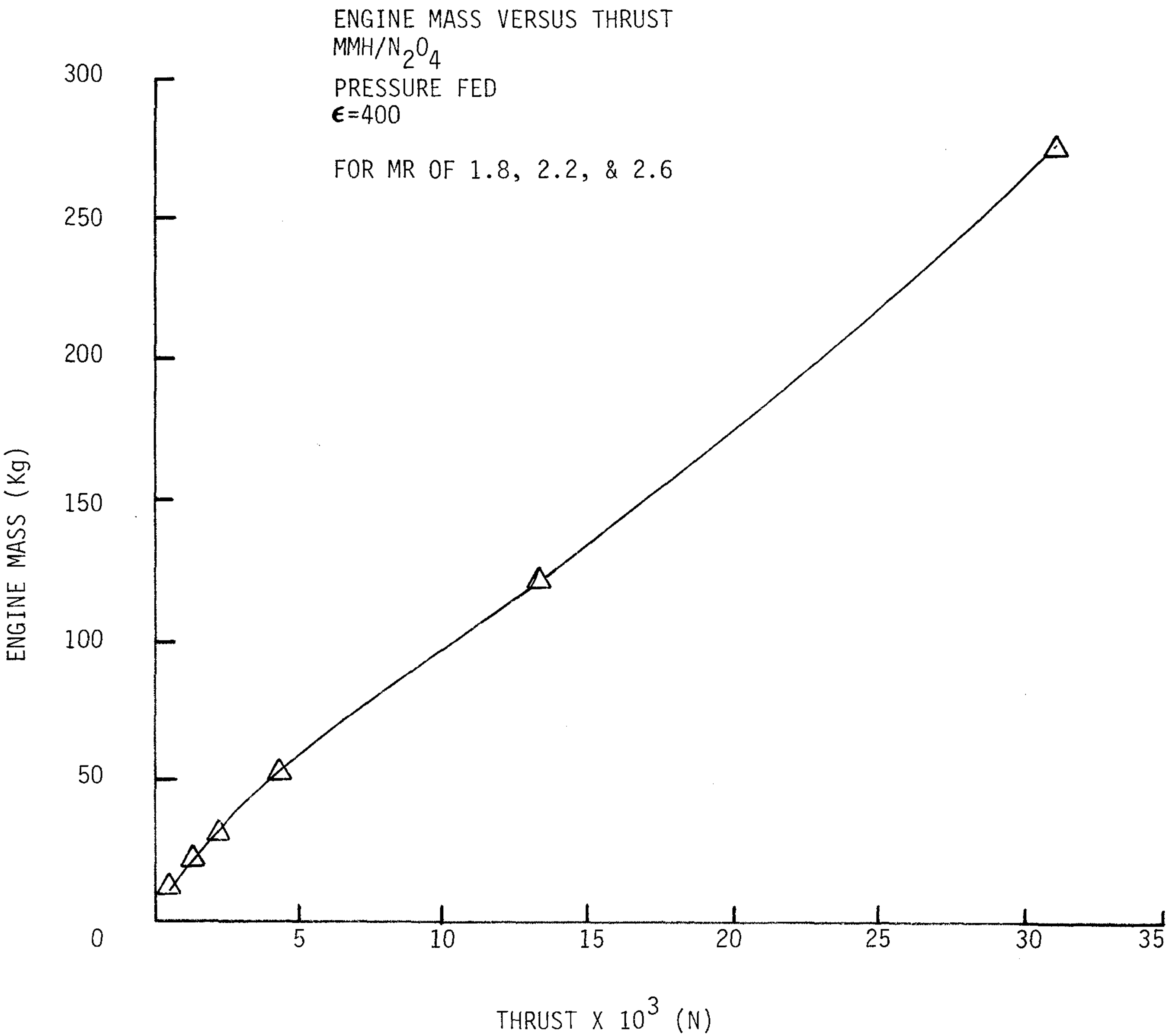
The engine data has been plotted for ease of use in the Section V parametric analysis. Engine mass, length with nozzle retracted, and vacuum specific impulse are plotted versus thrust level. The parametrics for the engine data figures are the four propellant combinations each with three mixture ratios, see Table V-1, for pump-fed and pressure-fed engines. In some instances, a maximum of 3% engine data variation with mixture ratio occurs at 31,150 N; therefore, the mixture ratio is an insignificant parameter and the data is expressed by a single (intermediate mixture ratio) curve.

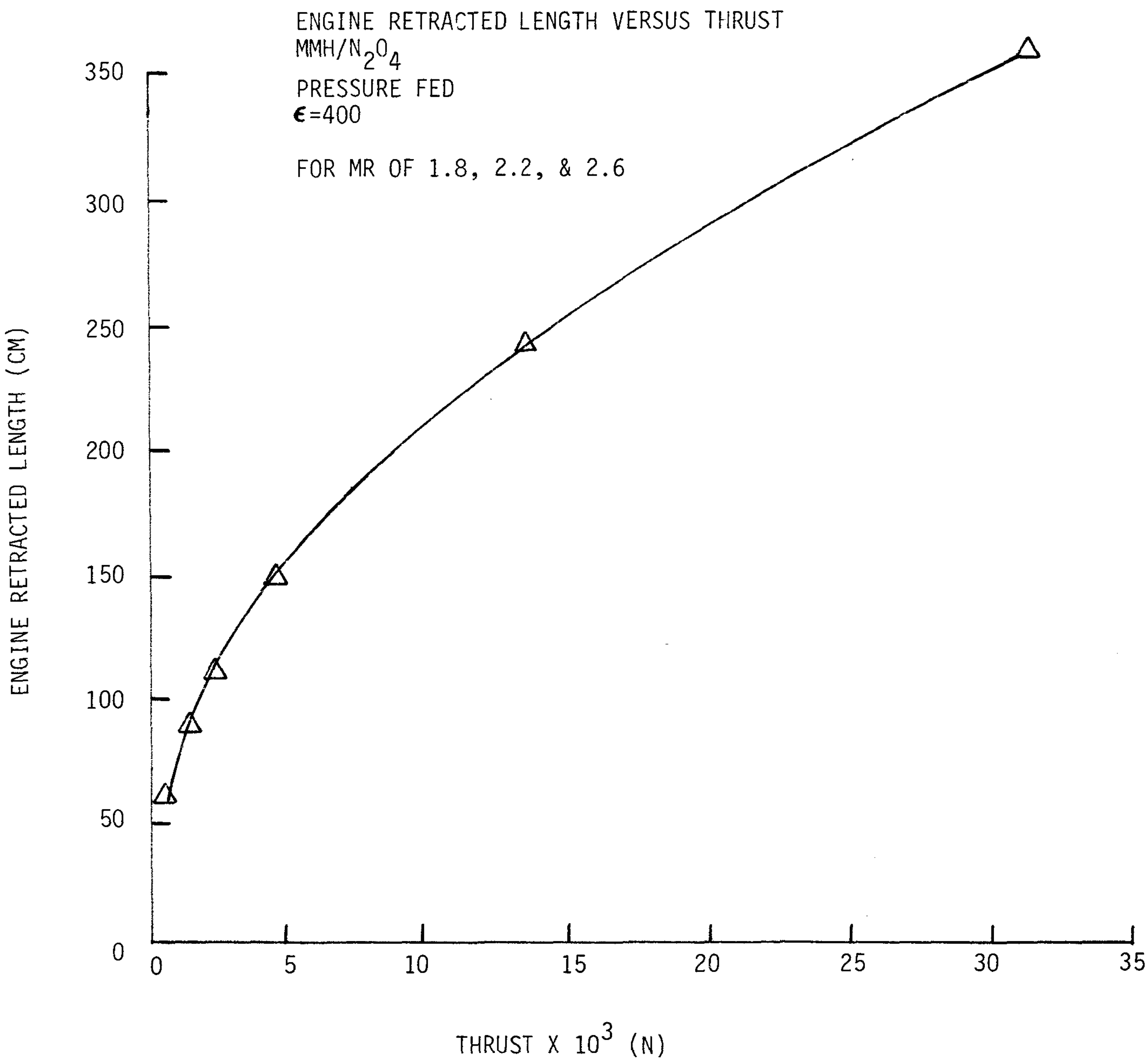
The order in which the figures are arranged for each propellant combination is displayed below in a generic outline. The figures are subdivided into the four propellant combinations which are arranged as follows: nitrogen tetroxide/monomethylhydrazine, N_2O_4/MMH; oxygen/kerosene, LO_2/RP-1; oxygen/hydrogen, LO_2/LH_2; and oxygen/methane, LO_2/LCH_4.

Engine Mass versus Thrust
Pressure-Fed, Pump-Fed

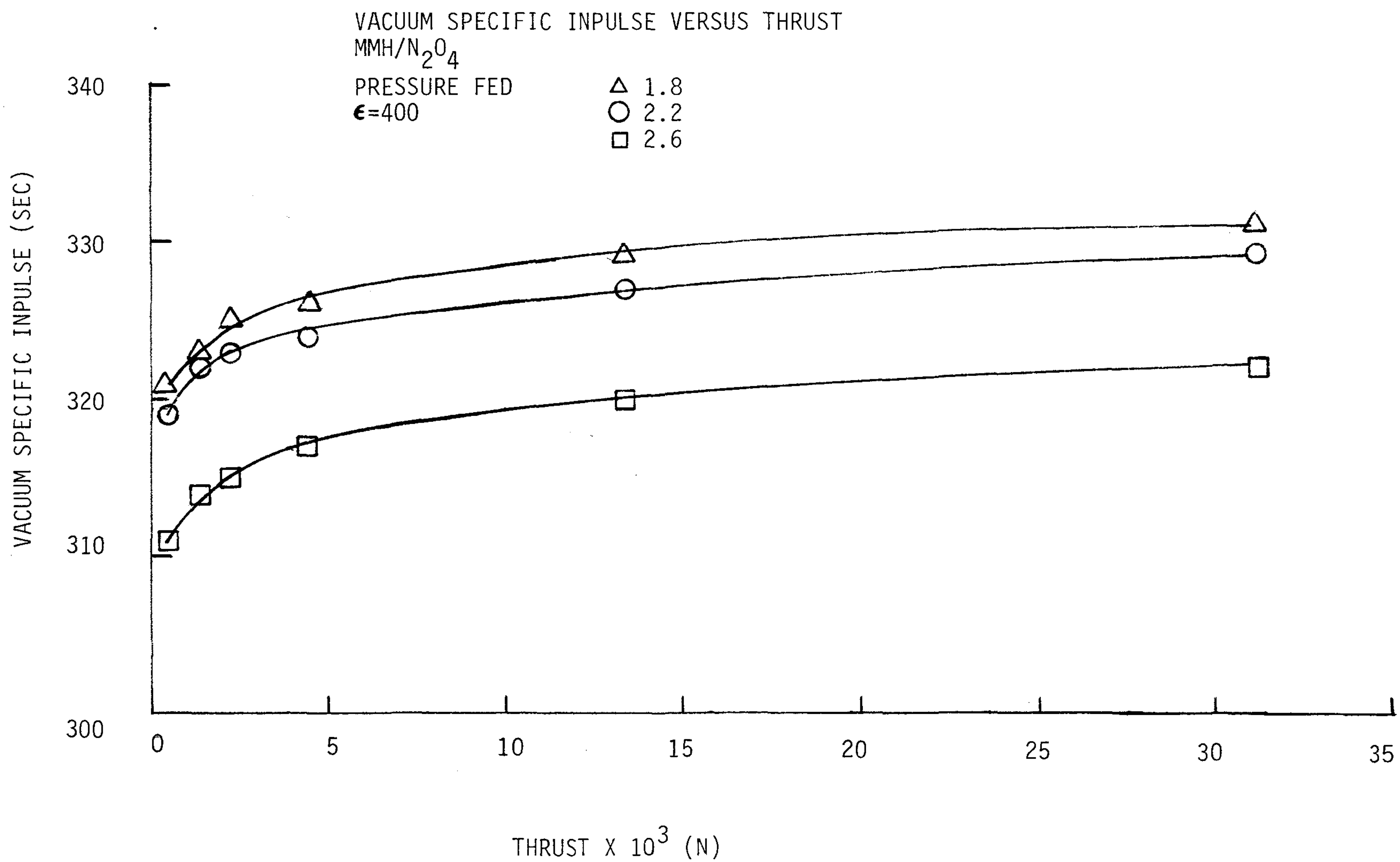
Engine Retracted Length versus Thrust
Pressure-Fed, Pump-Fed

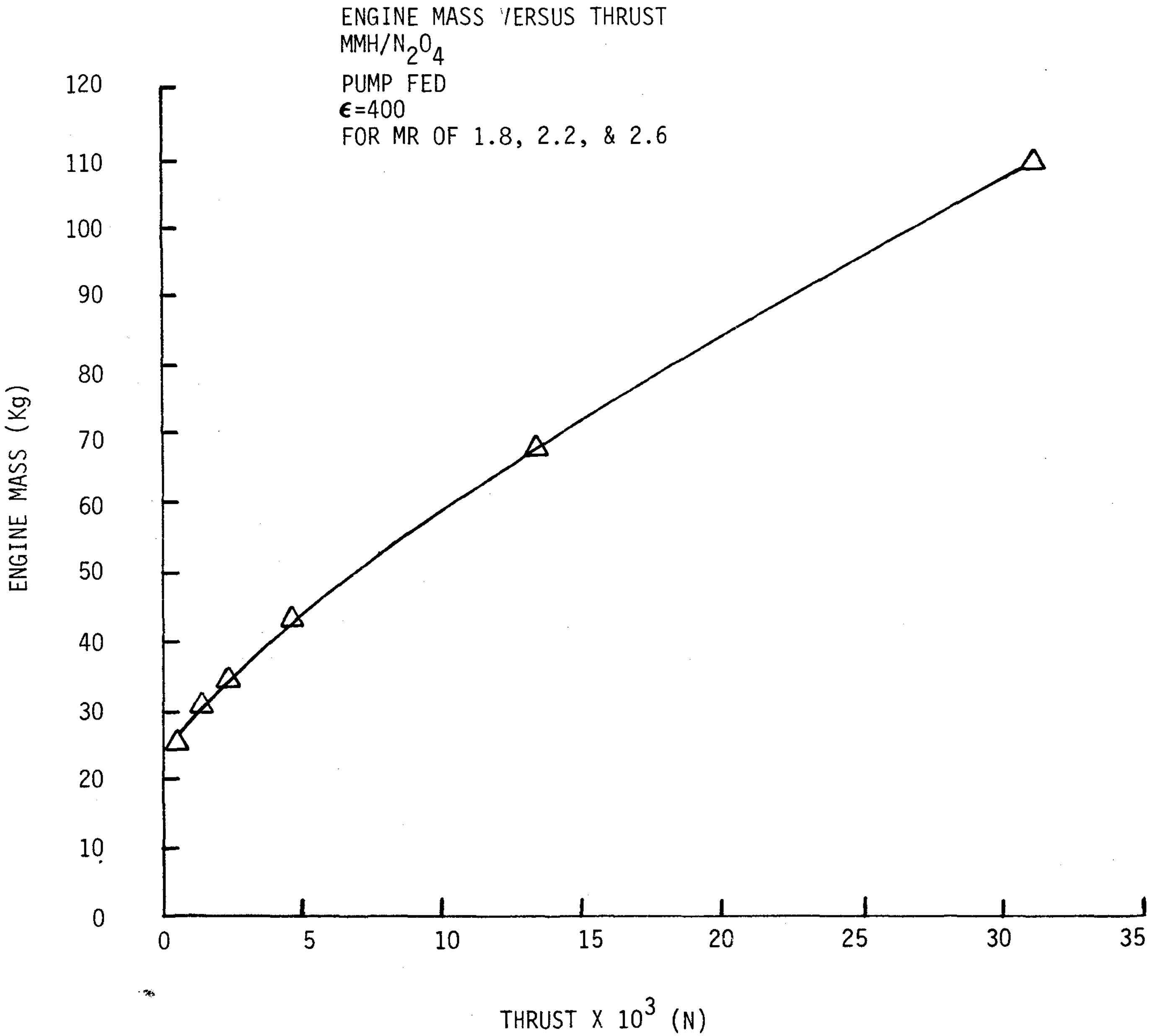
Vacuum Specific Impulse versus Thrust
Pressure-Fed, Pump-Fed

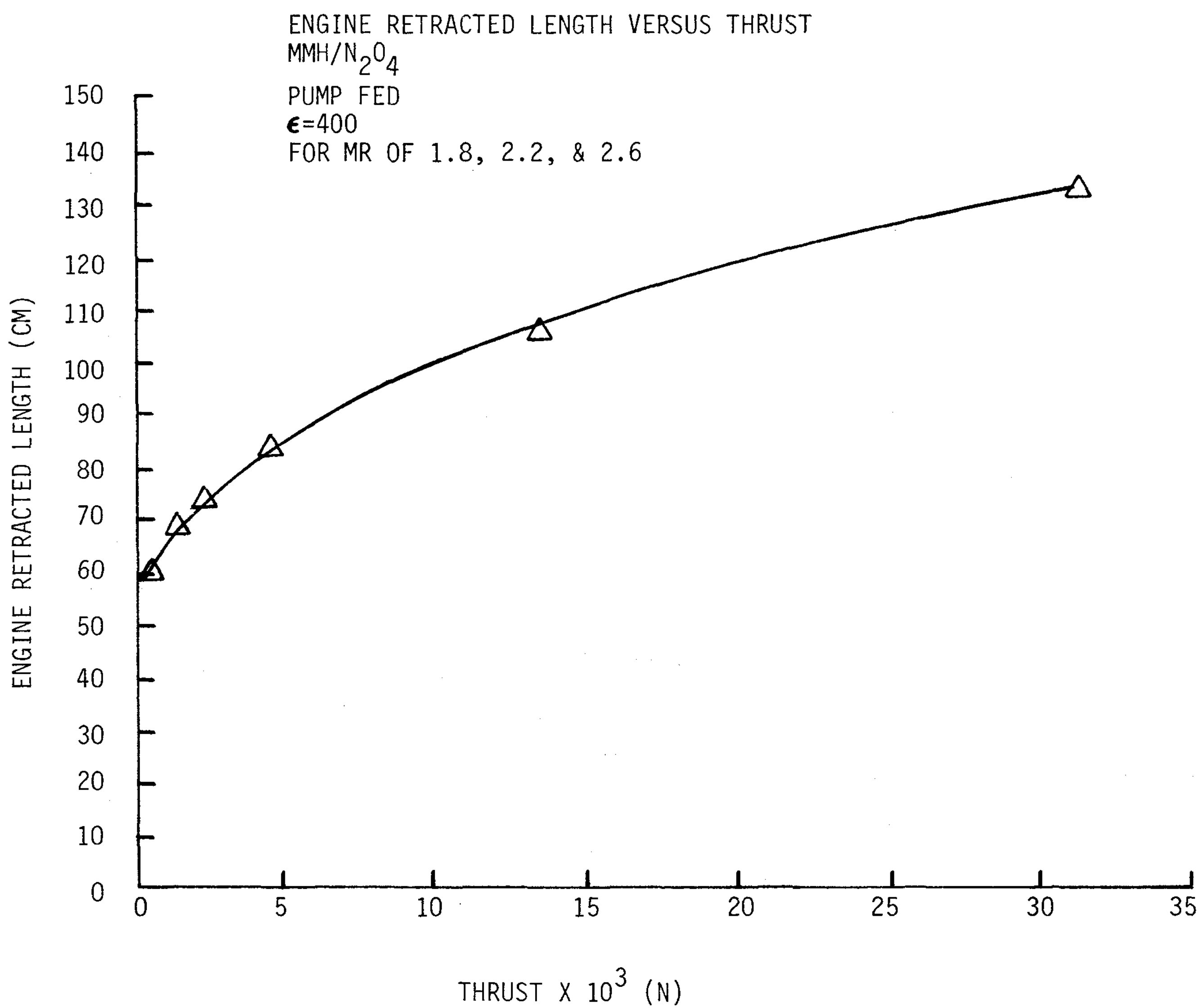

ENGINE MASS VERSUS THRUST
MMH/N_2O_4
PRESSURE FED
ϵ=400
FOR MR OF 1.8, 2.2, & 2.6
ENGINE MASS (Kg)
0
50
100
150
200
250
300
5
10
15
20
25
30
35
THRUST X 10^3 (N)

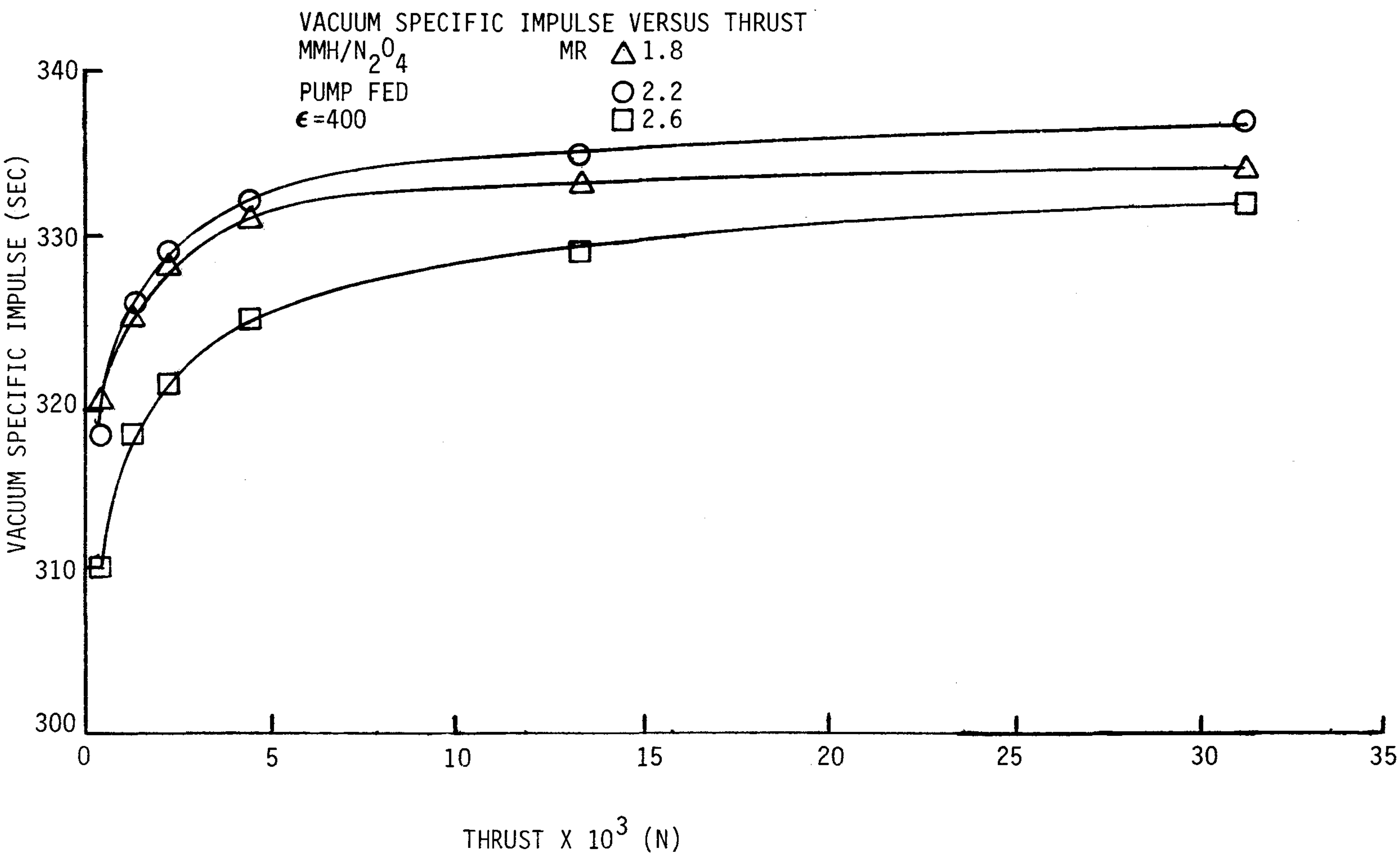


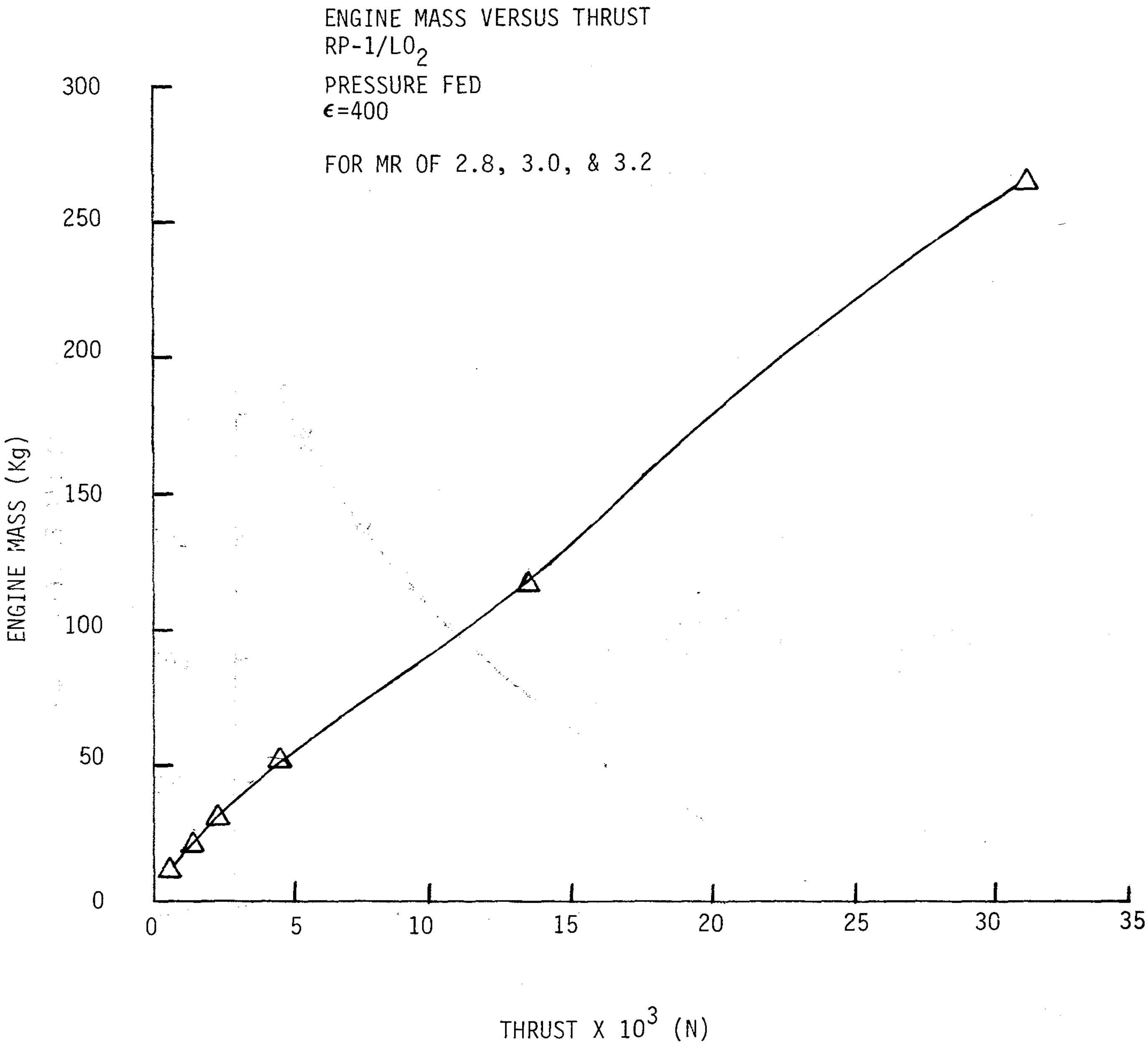
ENGINE RETRACTED LENGTH VERSUS THRUST
MMH/N_2O_4
PRESSURE FED
ϵ=400
FOR MR OF 1.8, 2.2, & 2.6
ENGINE RETRACTED LENGTH (CM)
0
50
100
150
200
250
300
350
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

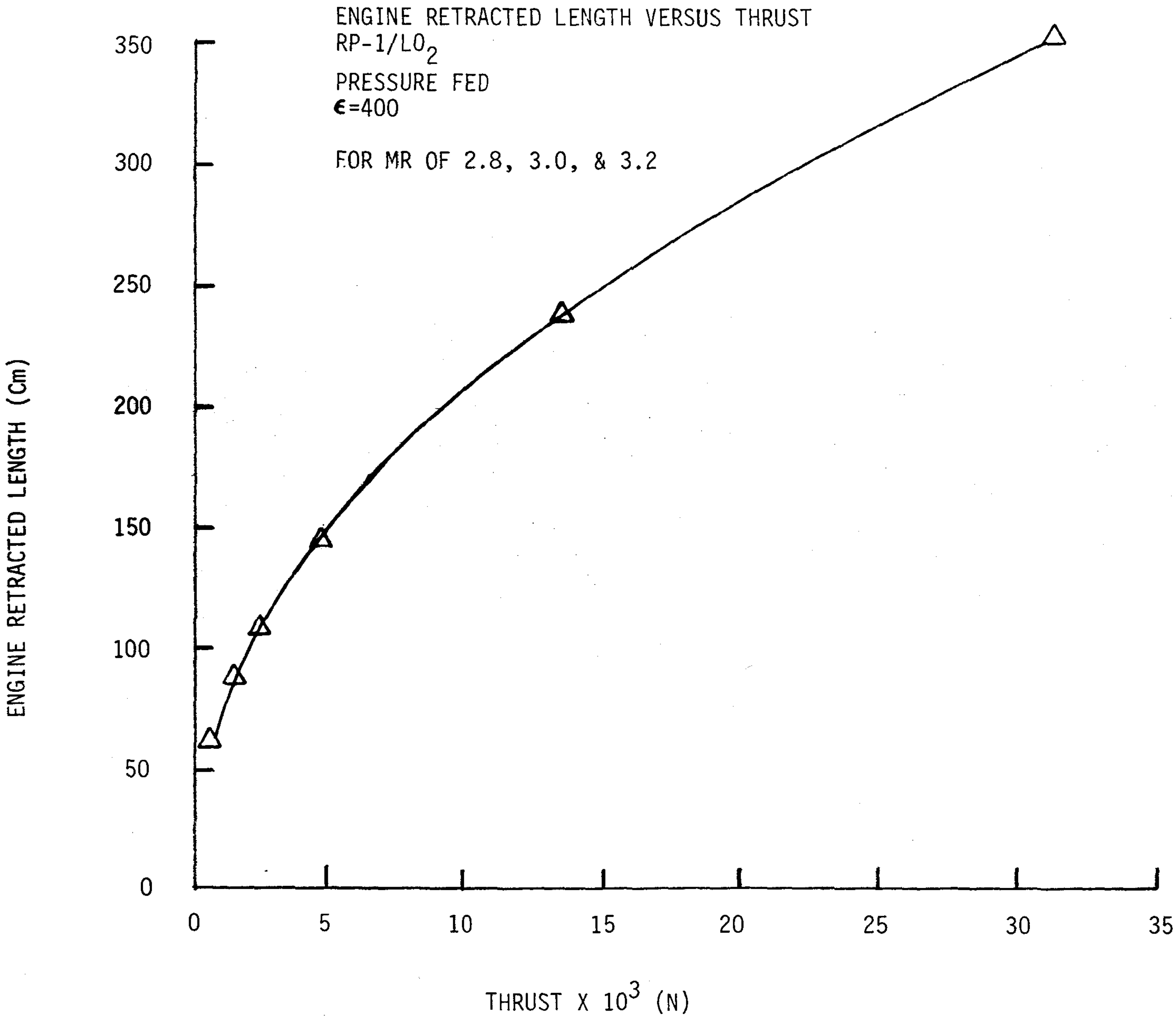

VACUUM SPECIFIC INPULSE VERSUS THRUST
MMH/N_2O_4
PRESSURE FED
ϵ=400
△ 1.8
○ 2.2
□ 2.6
VACUUM SPECIFIC INPULSE (SEC)
340
330
320
310
300
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

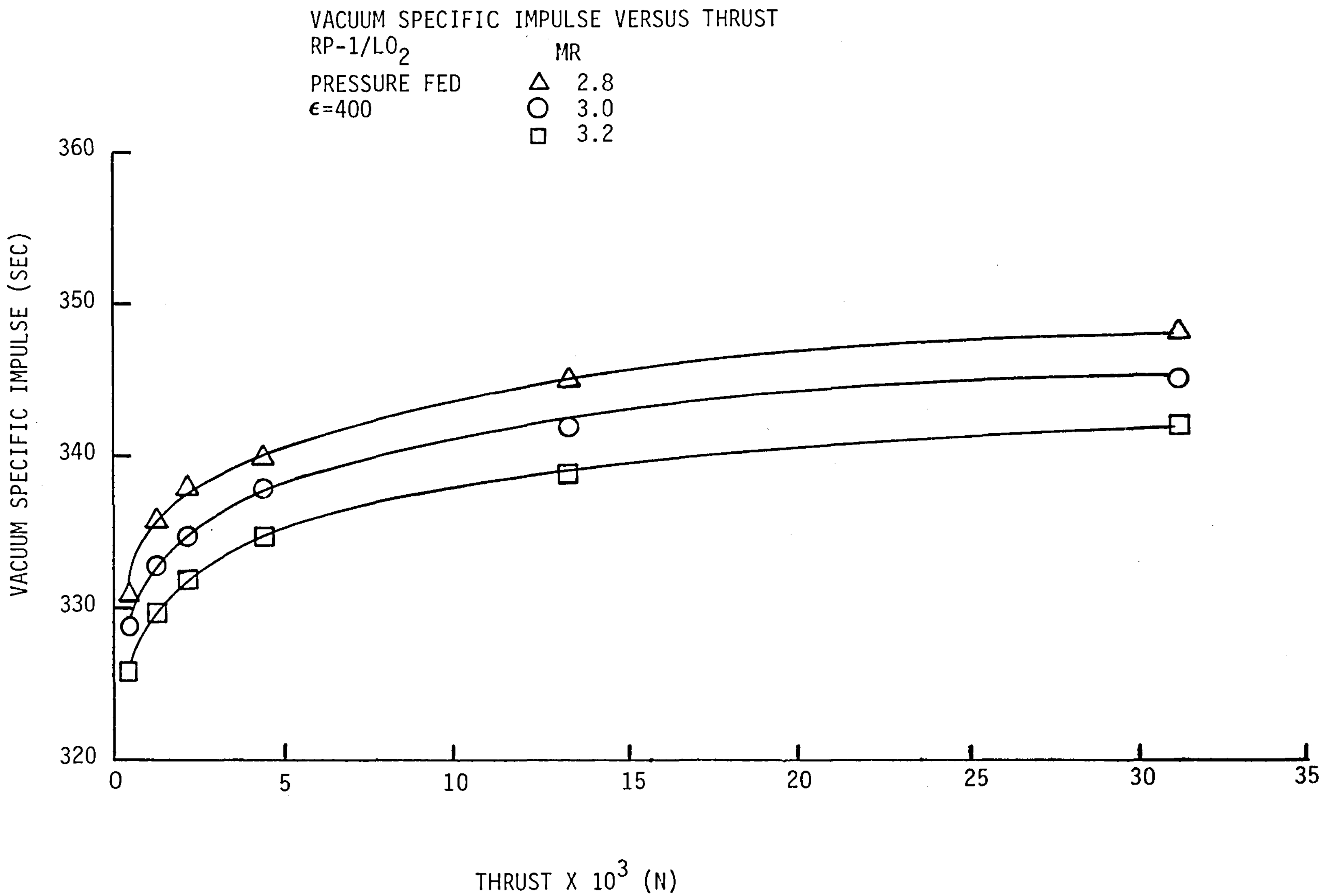

ENGINE MASS VERSUS THRUST
MMH/N2O4
PUMP FED
ε=400
FOR MR OF 1.8, 2.2, & 2.6
ENGINE MASS (Kg)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

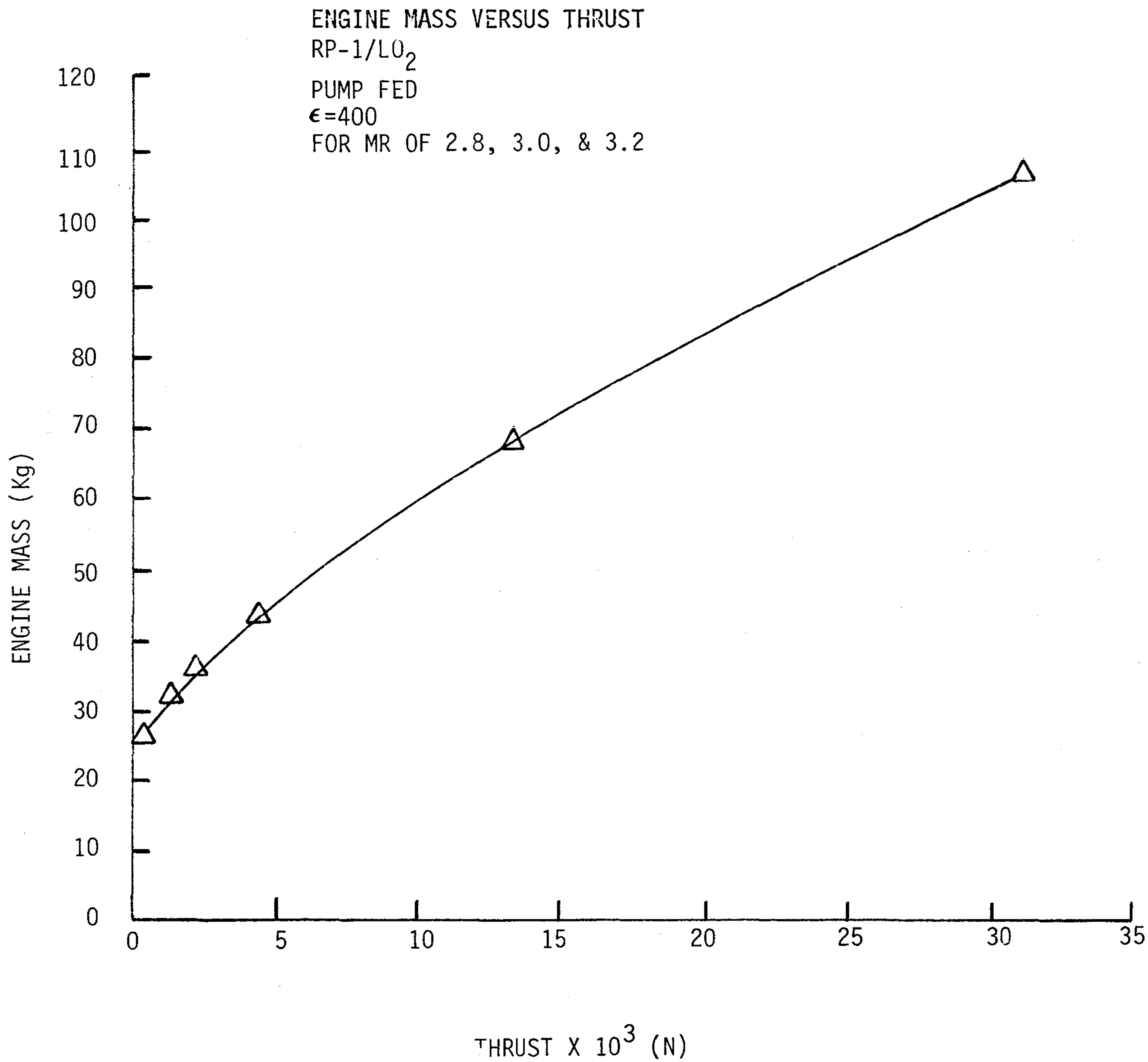

ENGINE RETRACTED LENGTH VERSUS THRUST
MMH/N_2O_4
PUMP FED
ϵ=400
FOR MR OF 1.8, 2.2, & 2.6
ENGINE RETRACTED LENGTH (CM)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

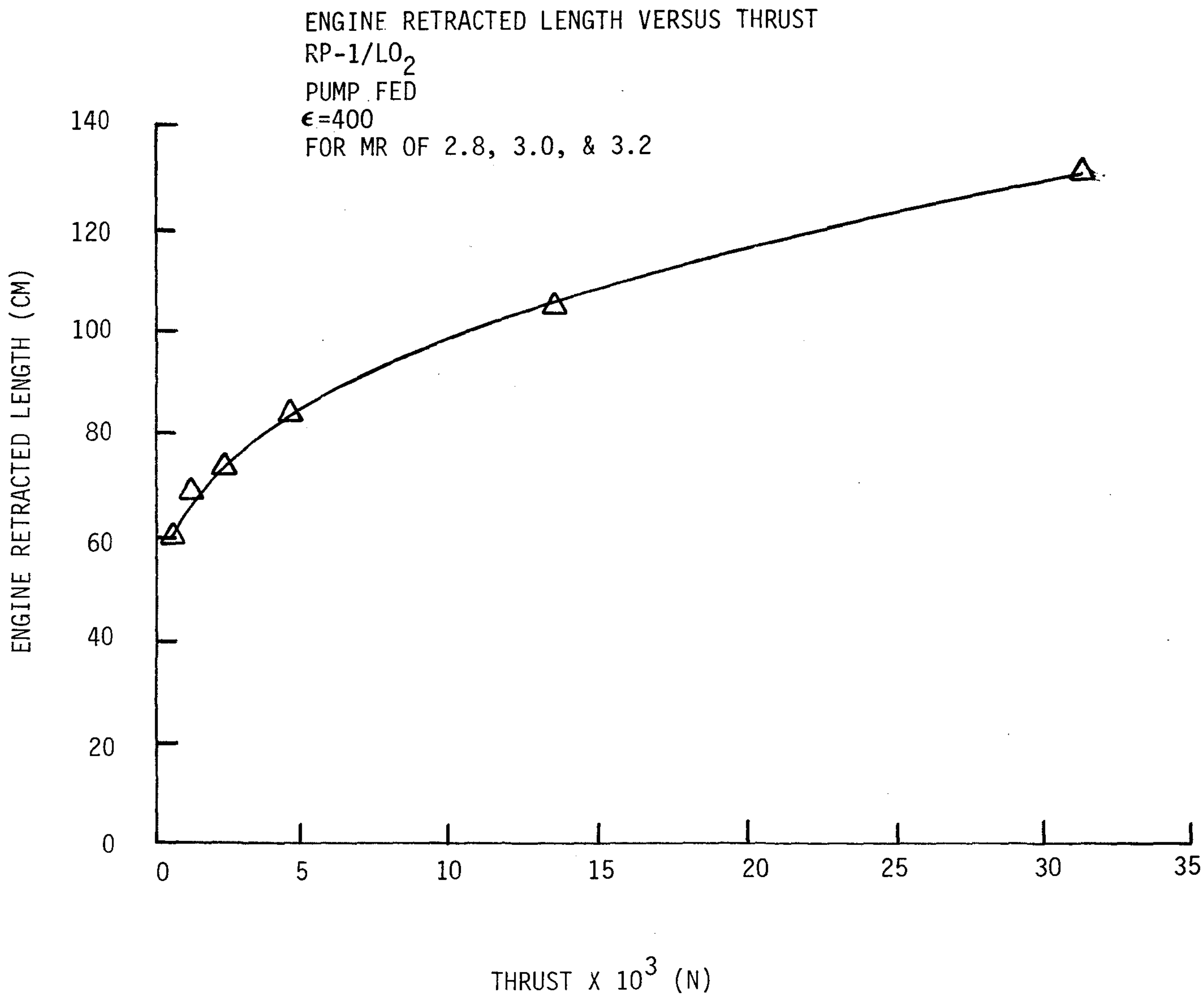

VACUUM SPECIFIC IMPULSE VERSUS THRUST
MMH/N2O4
PUMP FED
ε=400
MR △ 1.8
○ 2.2
□ 2.6
VACUUM SPECIFIC IMPULSE (SEC)
340
330
320
310
300
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

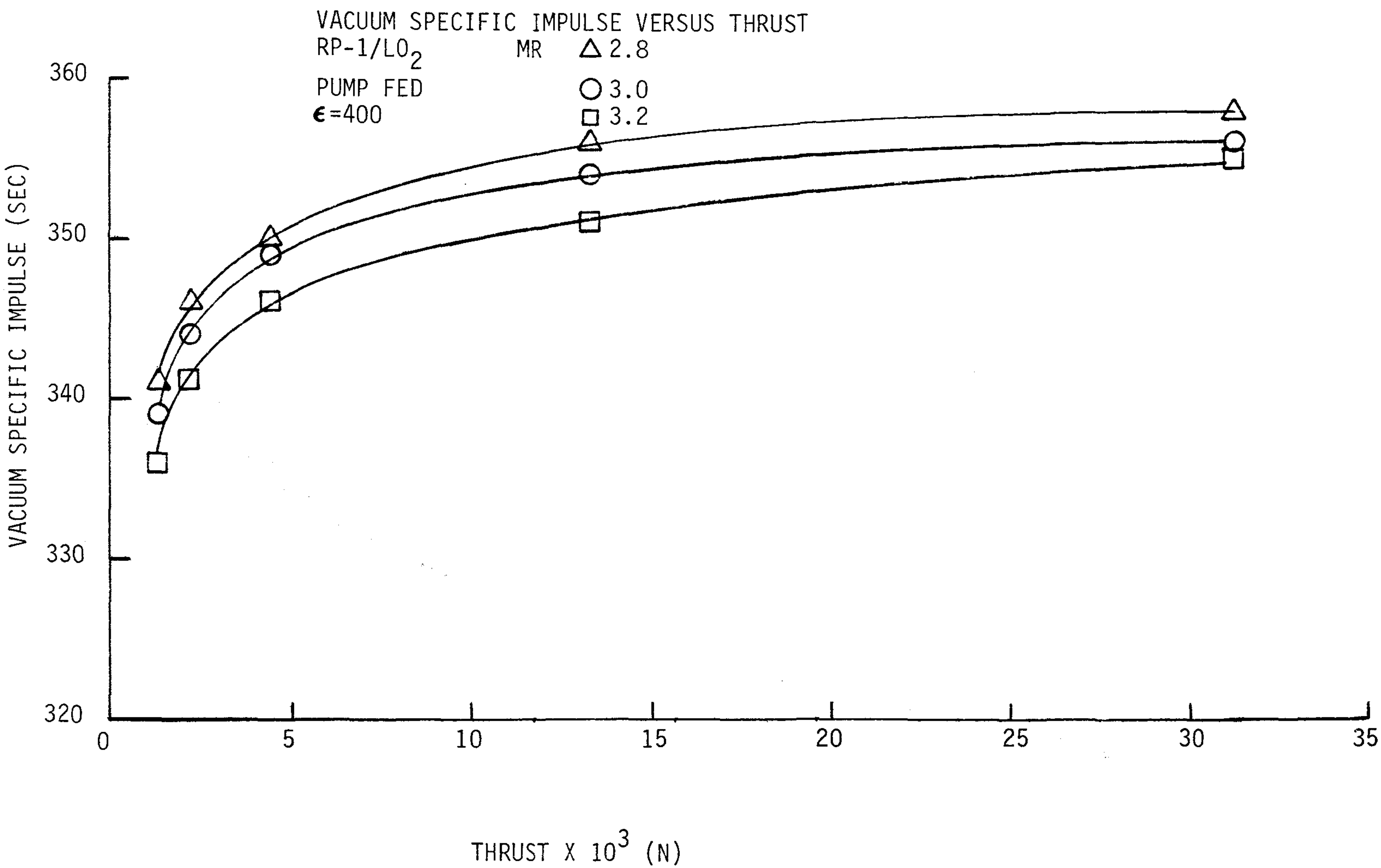

ENGINE MASS VERSUS THRUST
RP-1/LO2
PRESSURE FED
ϵ=400
FOR MR OF 2.8, 3.0, & 3.2
ENGINE MASS (Kg)
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
THRUST X 10³ (N)

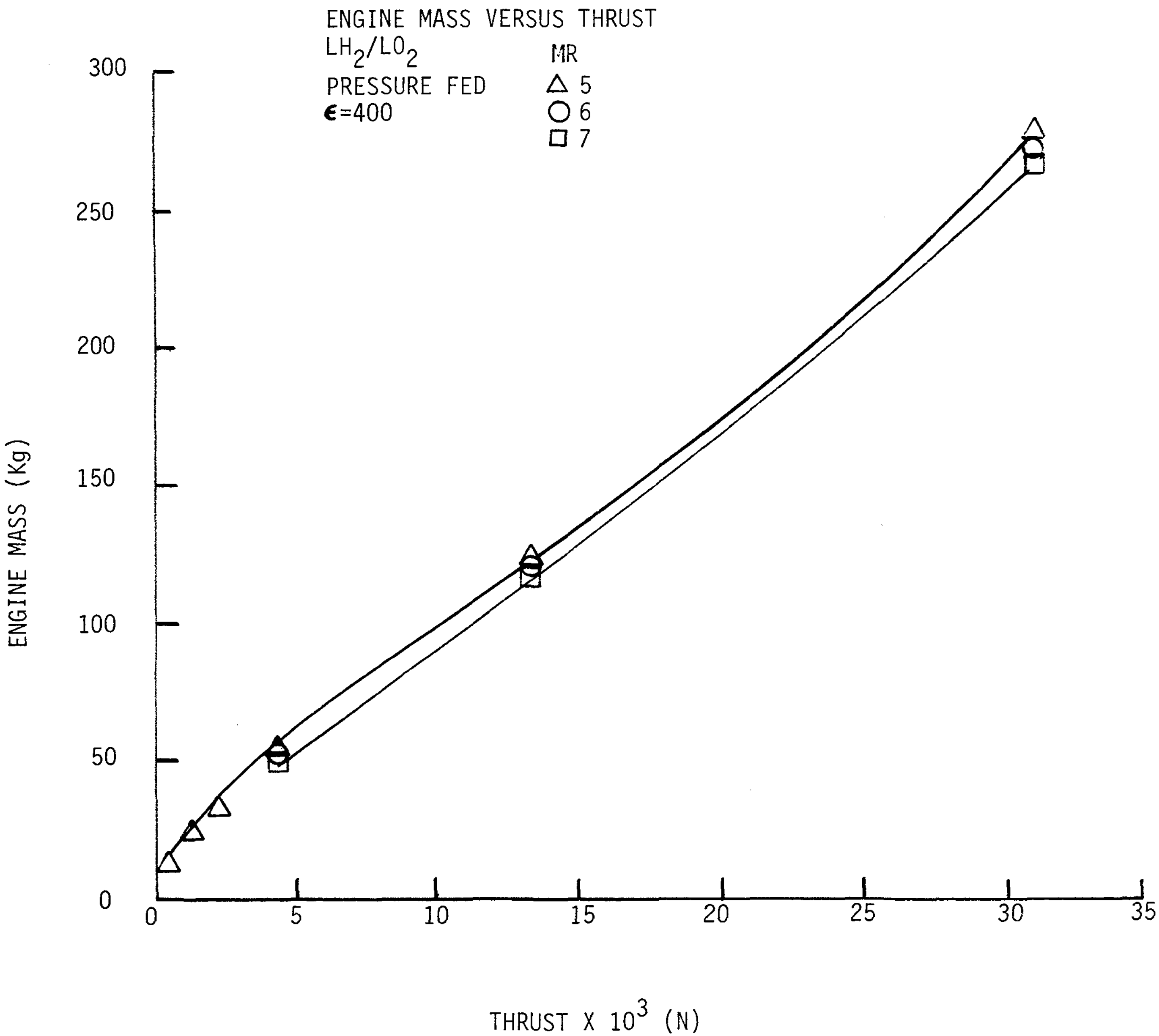

ENGINE RETRACTED LENGTH VERSUS THRUST
RP-1/LO2
PRESSURE FED
ε=400
FOR MR OF 2.8, 3.0, & 3.2
ENGINE RETRACTED LENGTH (Cm)
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

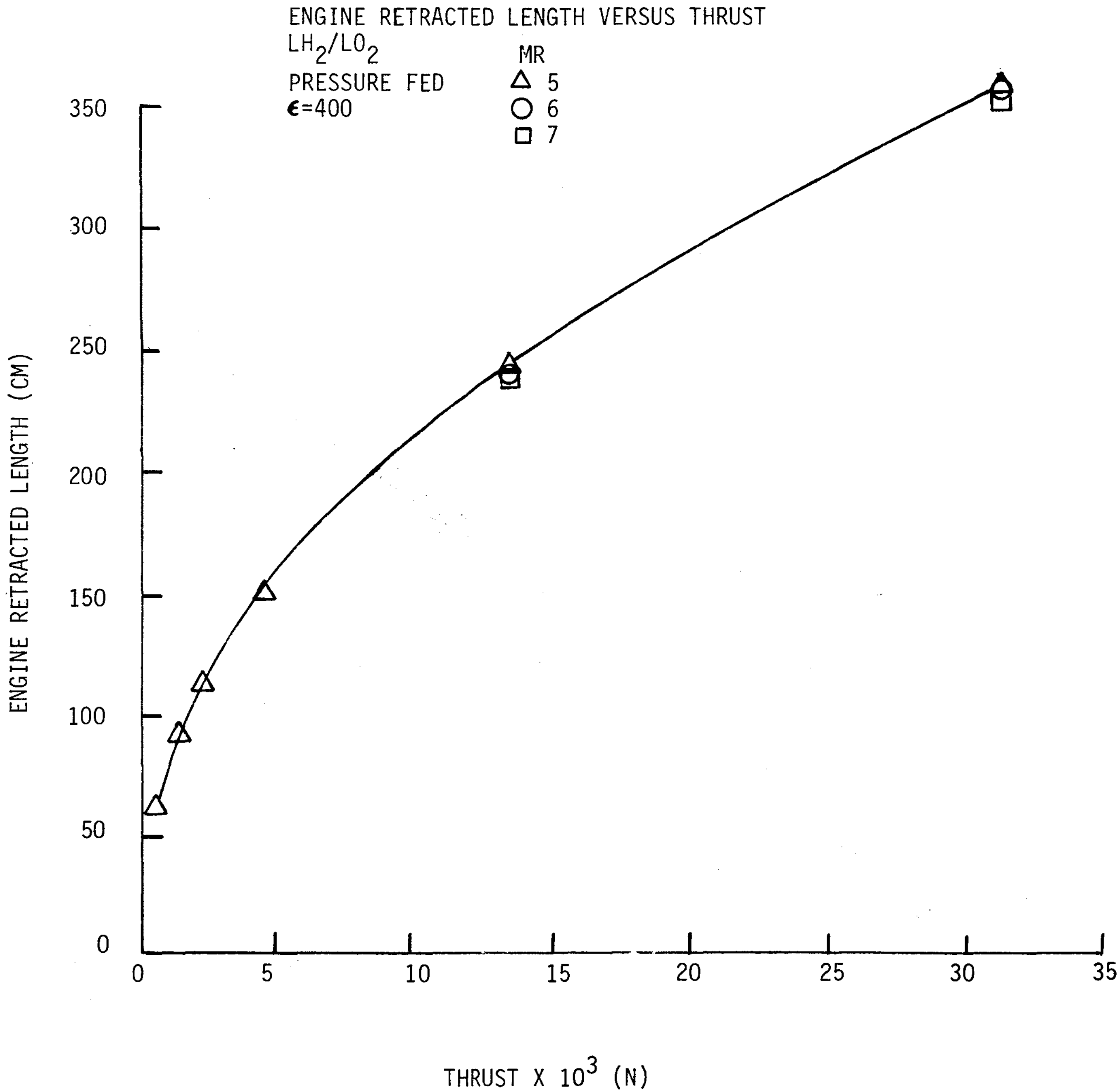

VACUUM SPECIFIC IMPULSE VERSUS THRUST
$RP\text{-}1/LO_2$
PRESSURE FED
$\epsilon=400$
MR
2.8
3.0
3.2
VACUUM SPECIFIC IMPULSE (SEC)
360
350
340
330
320
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

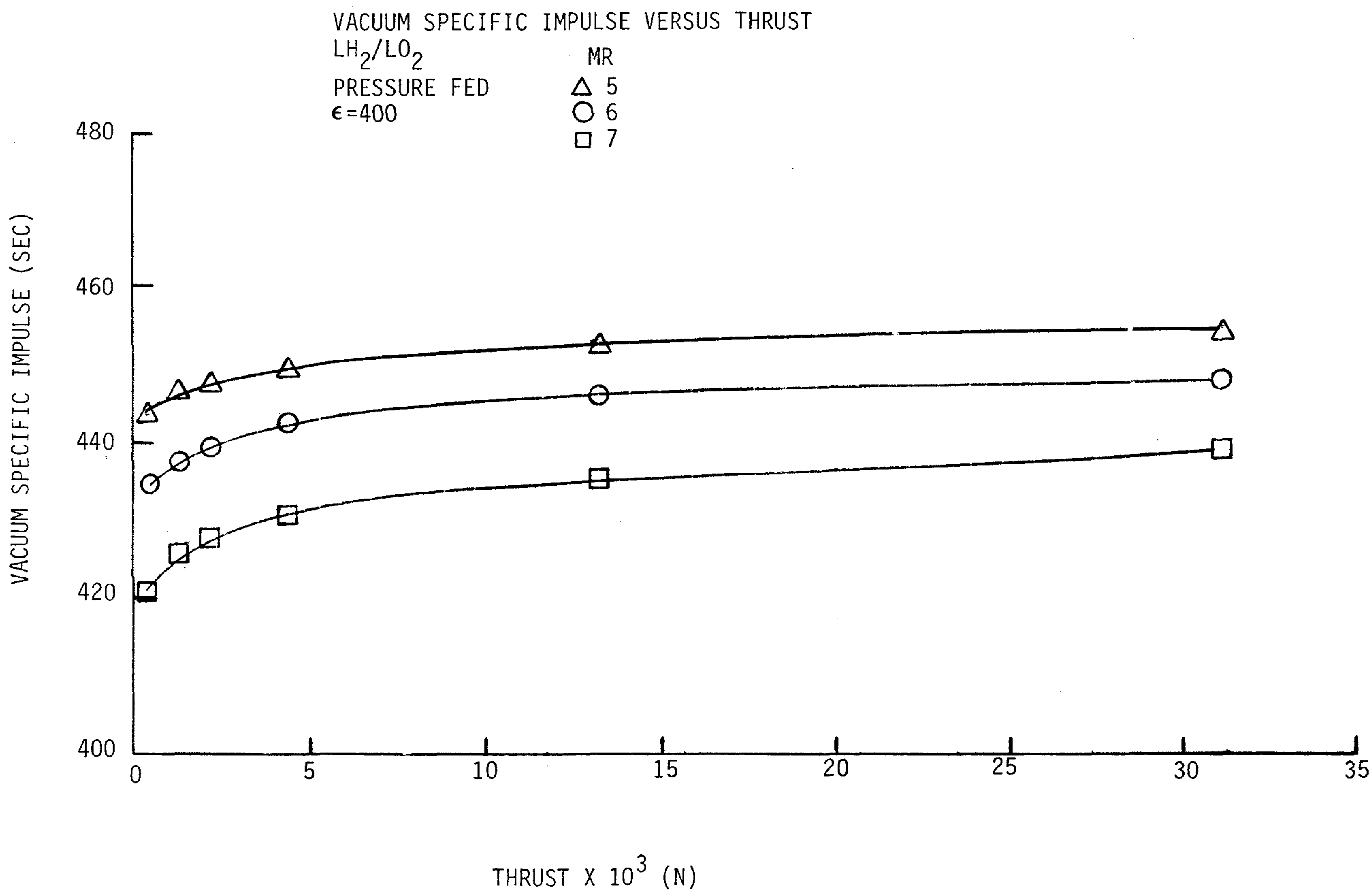

ENGINE MASS VERSUS THRUST
RP-1/LO2
PUMP FED
ϵ=400
FOR MR OF 2.8, 3.0, & 3.2
ENGINE MASS (Kg)
THRUST X 10^3 (N)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
5
10
15
20
25
30
35


ENGINE RETRACTED LENGTH VERSUS THRUST
RP-1/LO2
PUMP FED
ϵ=400
FOR MR OF 2.8, 3.0, & 3.2
ENGINE RETRACTED LENGTH (CM)
0
20
40
60
80
100
120
140
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

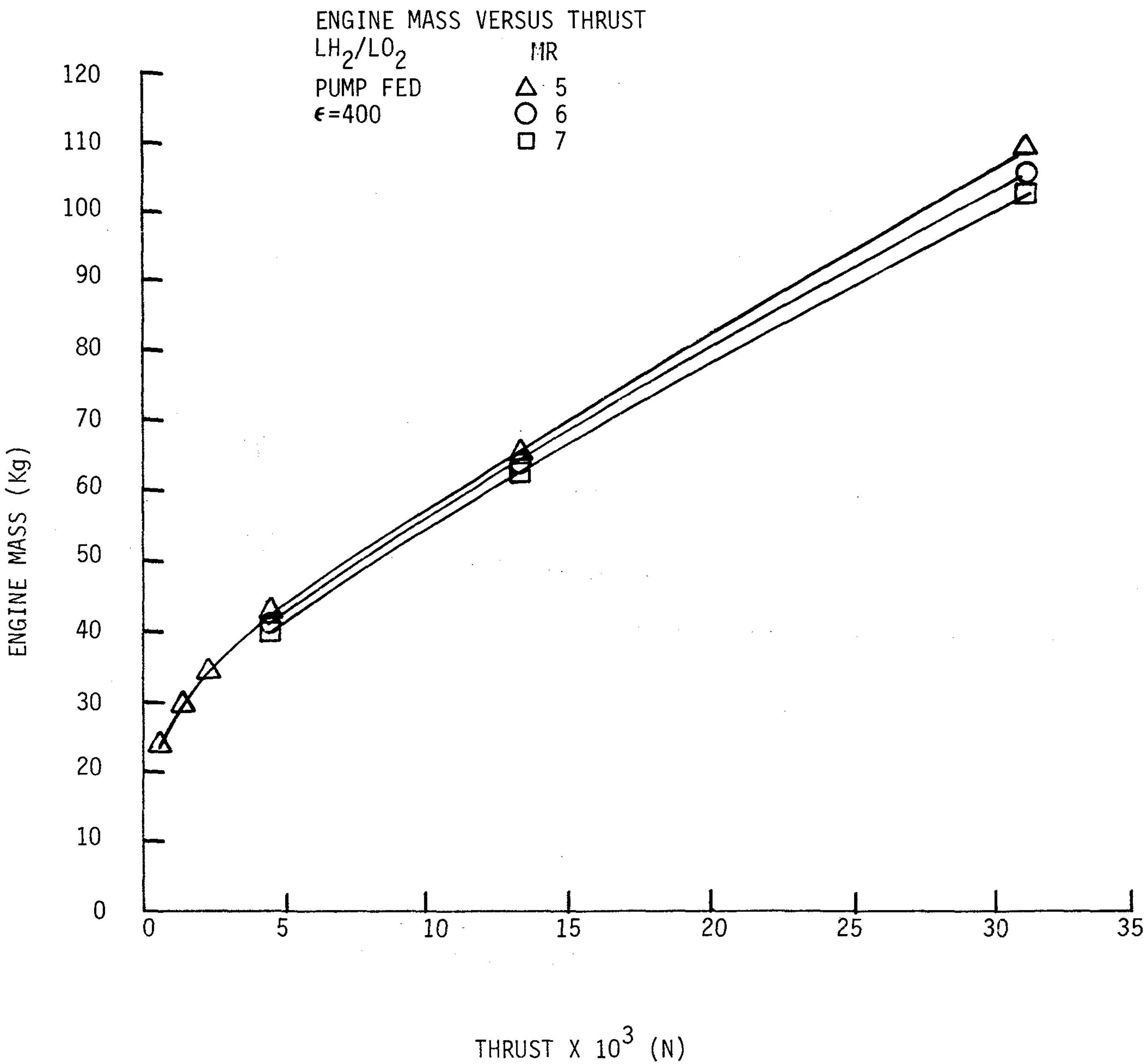

VACUUM SPECIFIC IMPULSE VERSUS THRUST
RP-1/LO2
PUMP FED
ϵ=400
MR
2.8
3.0
3.2
VACUUM SPECIFIC IMPULSE (SEC)
360
350
340
330
320
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

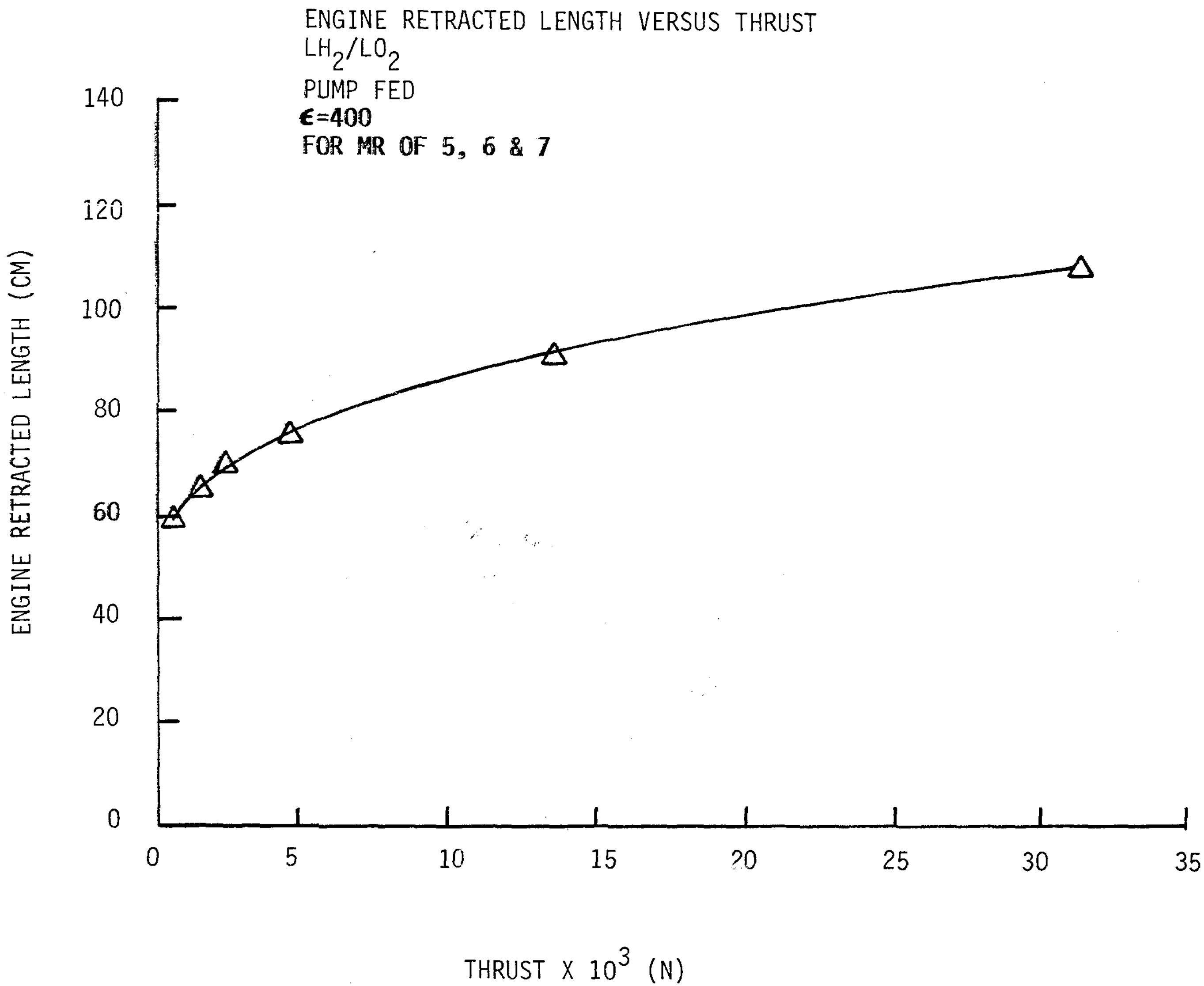

ENGINE MASS VERSUS THRUST
LH_2/LO_2
PRESSURE FED
ϵ=400
MR
△ 5
○ 6
□ 7
ENGINE MASS (Kg)
0
50
100
150
200
250
300
THRUST X 10^3 (N)
0
5
10
15
20
25
30
35

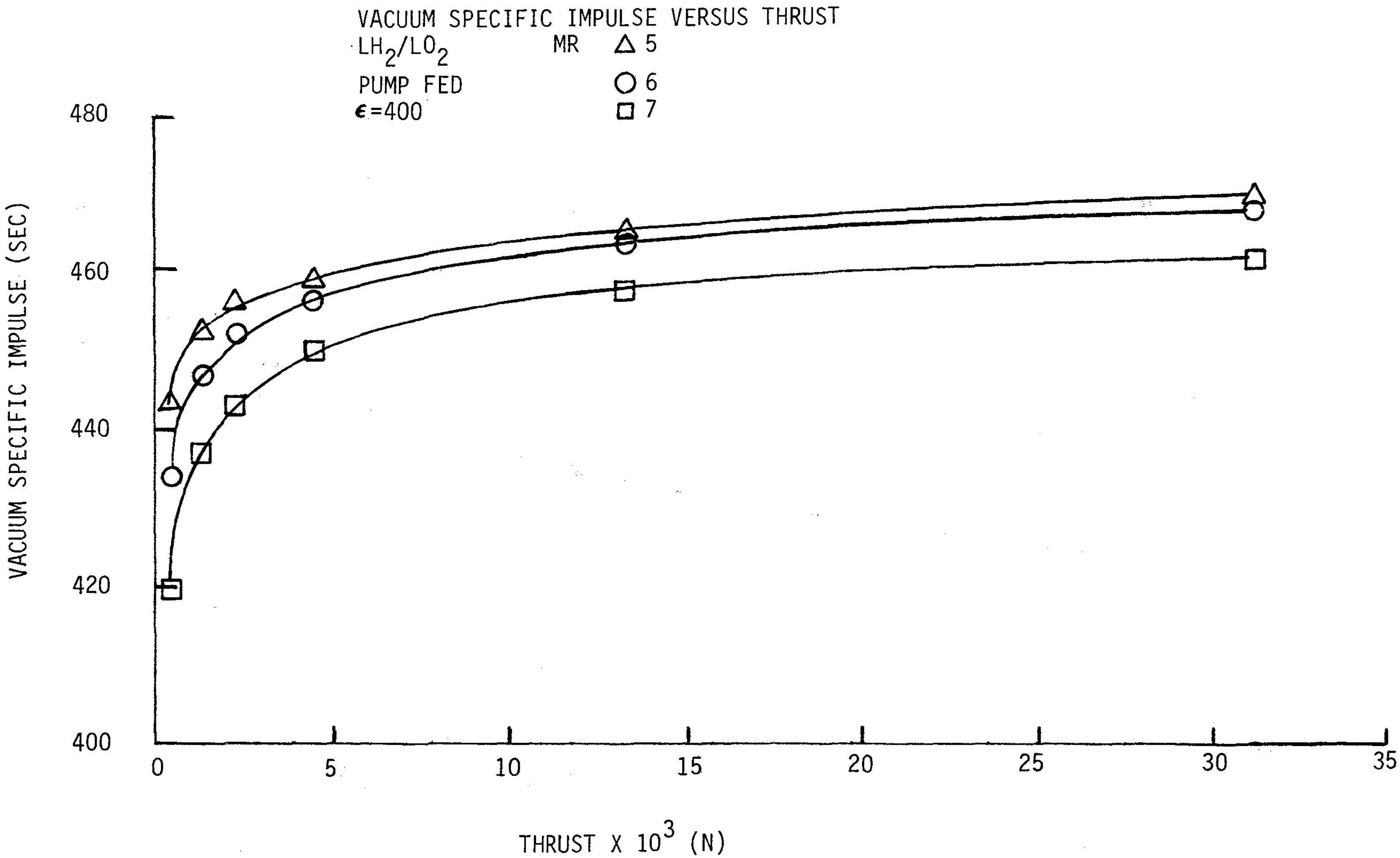

ENGINE RETRACTED LENGTH VERSUS THRUST
LH_2/LO_2
PRESSURE FED
ϵ=400
MR
△ 5
○ 6
□ 7
ENGINE RETRACTED LENGTH (CM)
0
50
100
150
200
250
300
350
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

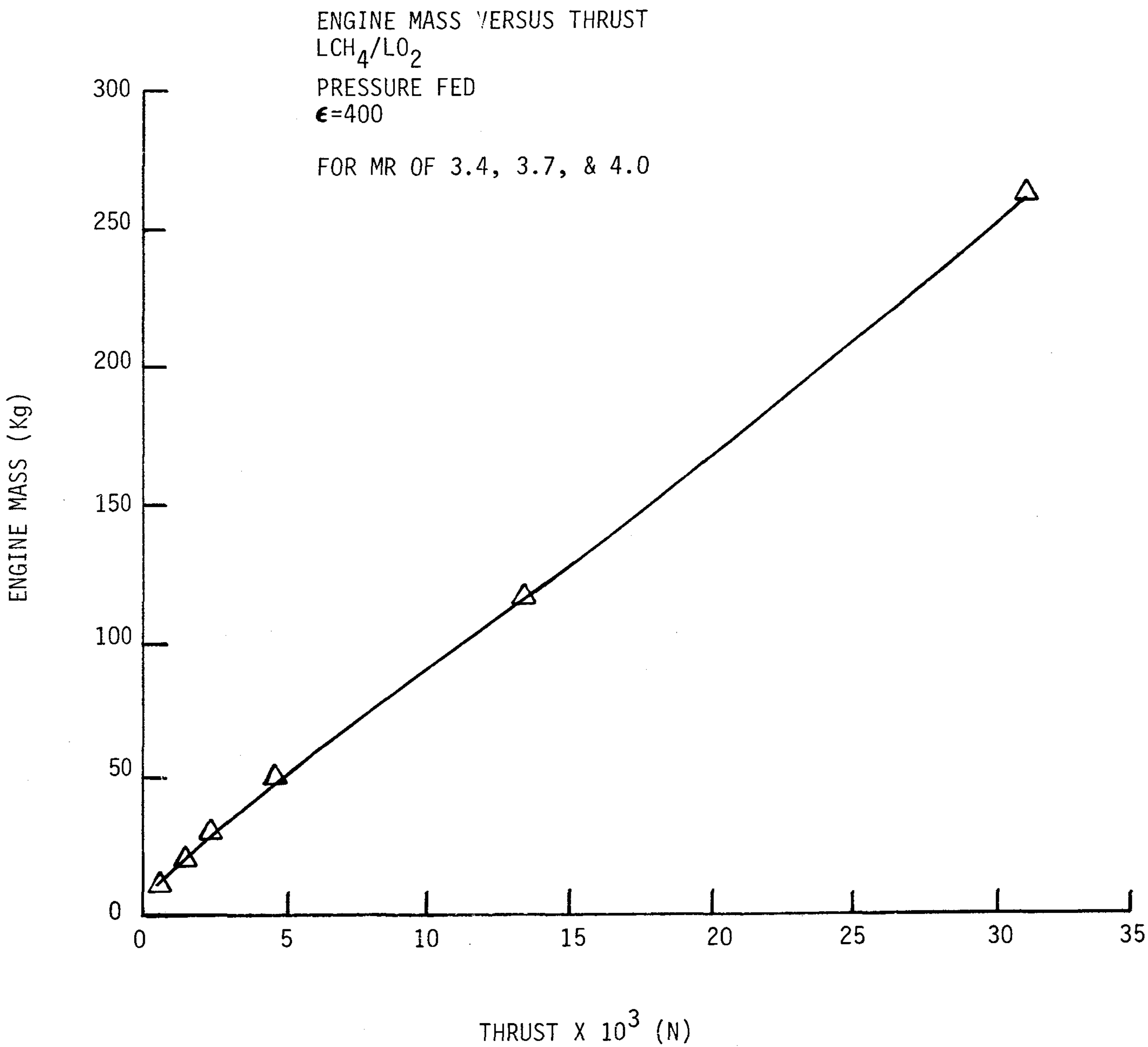


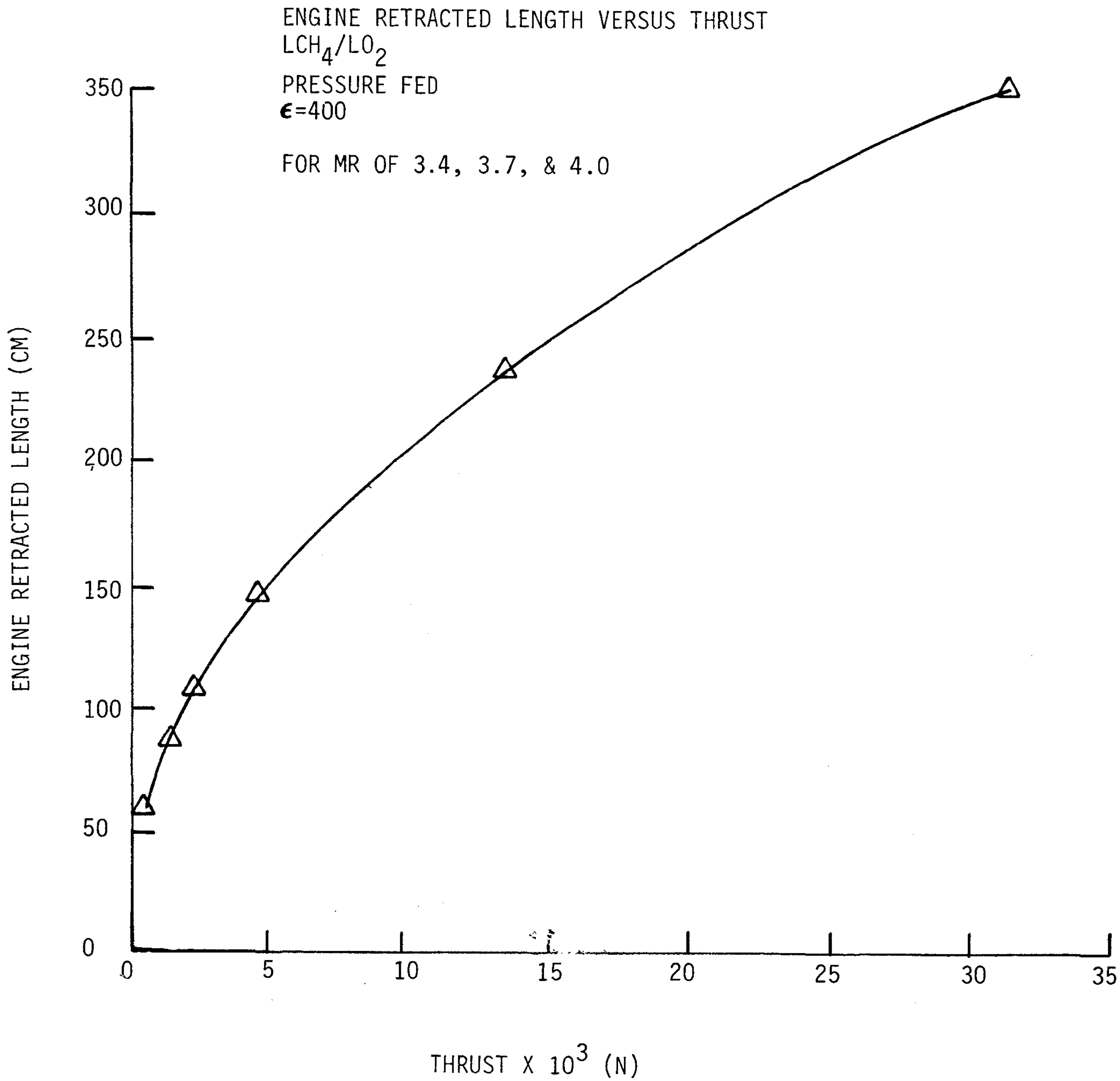
VACUUM SPECIFIC IMPULSE VERSUS THRUST
LH2/LO2
PRESSURE FED
ε=400
MR
5
6
7
480
460
440
420
400
VACUUM SPECIFIC IMPULSE (SEC)
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

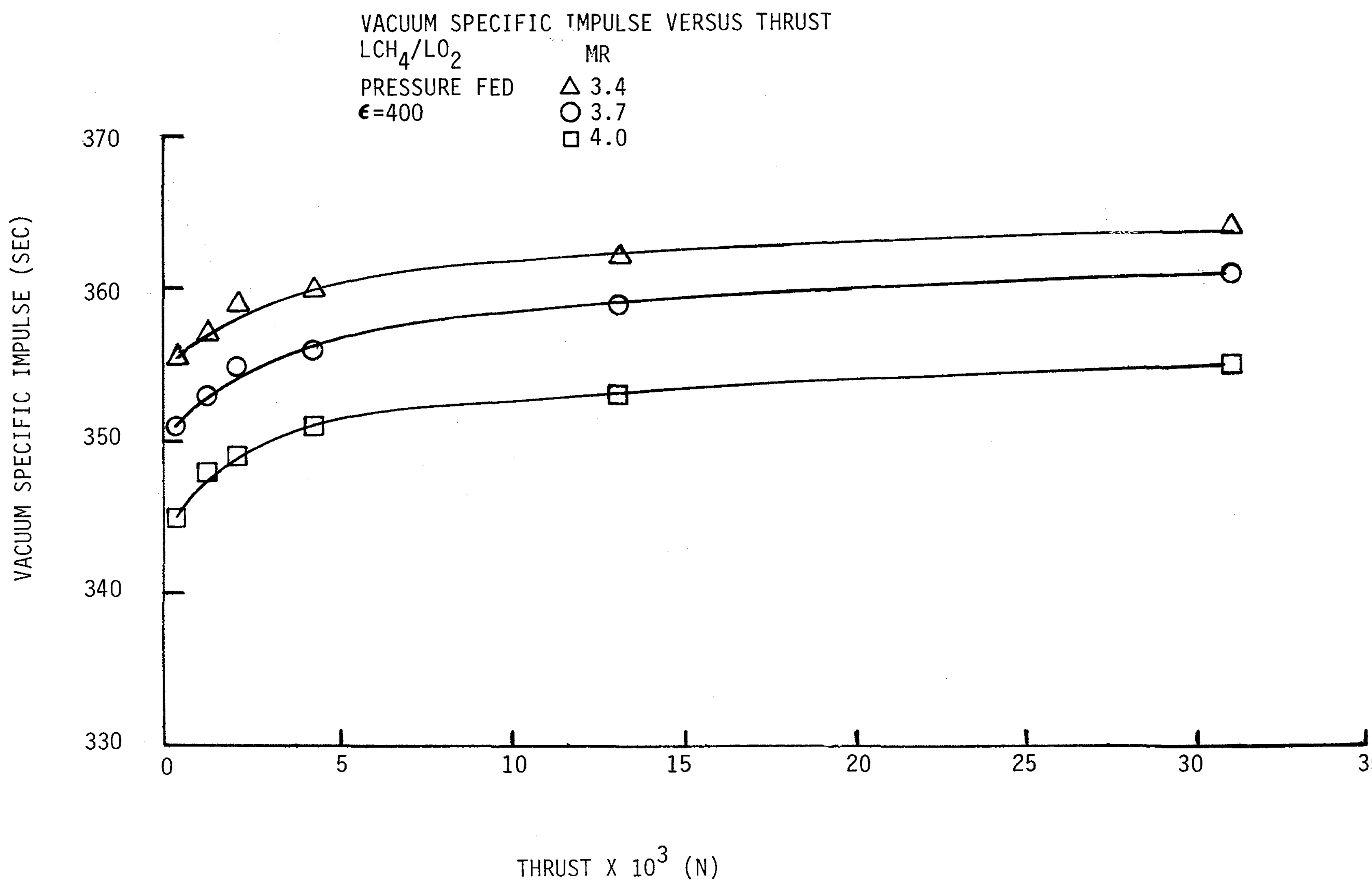

ENGINE MASS VERSUS THRUST
LH_2/LO_2
PUMP FED
ϵ=400
MR
5
6
7
ENGINE MASS (Kg)
0
10
20
30
40
50
60
70
80
90
100
110
120
THRUST X 10^3 (N)
0
5
10
15
20
25
30
35


ENGINE RETRACTED LENGTH VERSUS THRUST
LH_2/LO_2
PUMP FED
ϵ=400
FOR MR OF 5, 6 & 7
ENGINE RETRACTED LENGTH (CM)
0
20
40
60
80
100
120
140
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

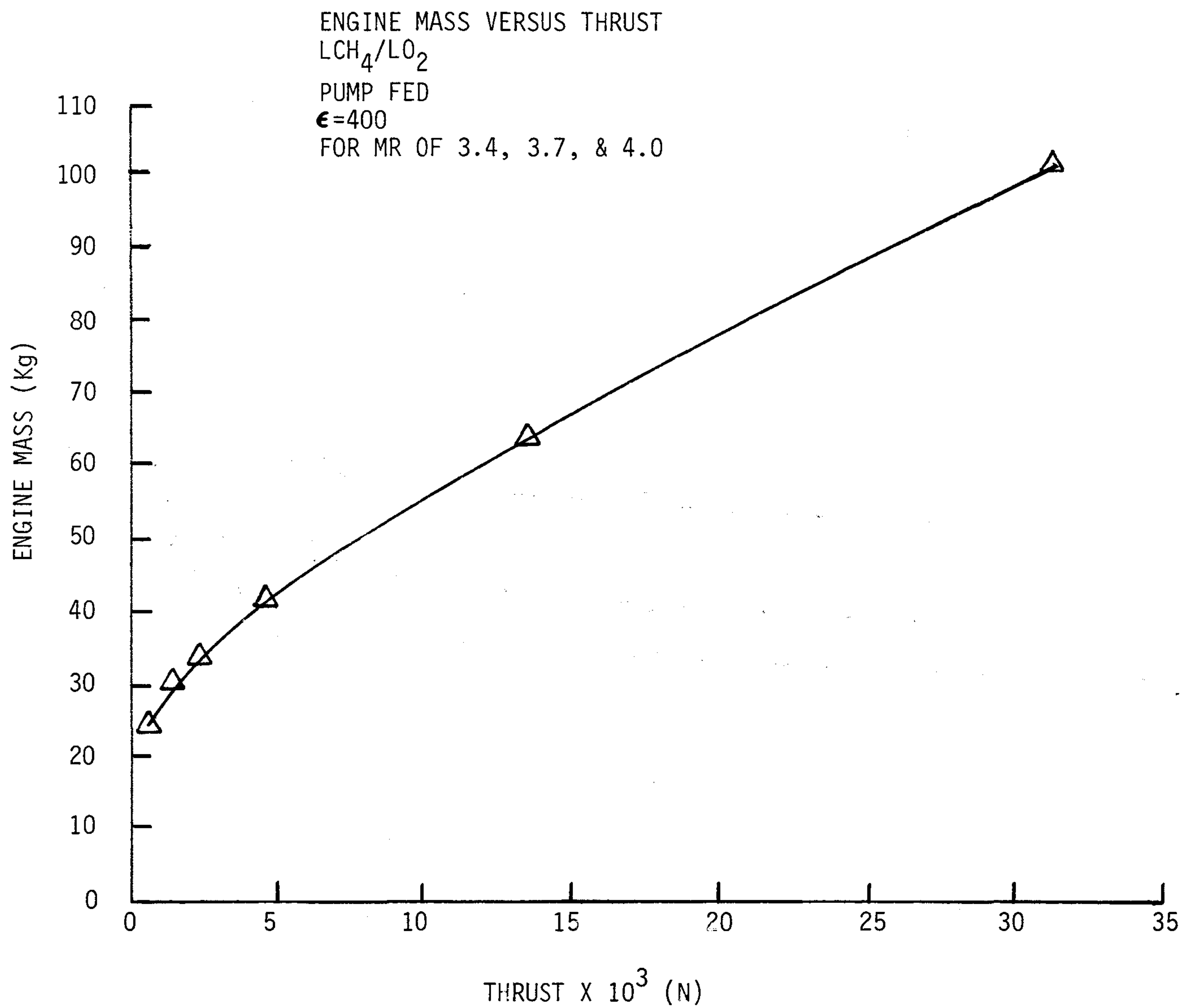

VACUUM SPECIFIC IMPULSE VERSUS THRUST
LH_2/LO_2
PUMP FED
ϵ=400
MR
△ 5
○ 6
□ 7
VACUUM SPECIFIC IMPULSE (SEC)
480
460
440
420
400
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)


ENGINE MASS VERSUS THRUST
LCH4/LO2
PRESSURE FED
ε=400
FOR MR OF 3.4, 3.7, & 4.0
ENGINE MASS (Kg)
0
50
100
150
200
250
300
THRUST X 10^3 (N)
0
5
10
15
20
25
30
35

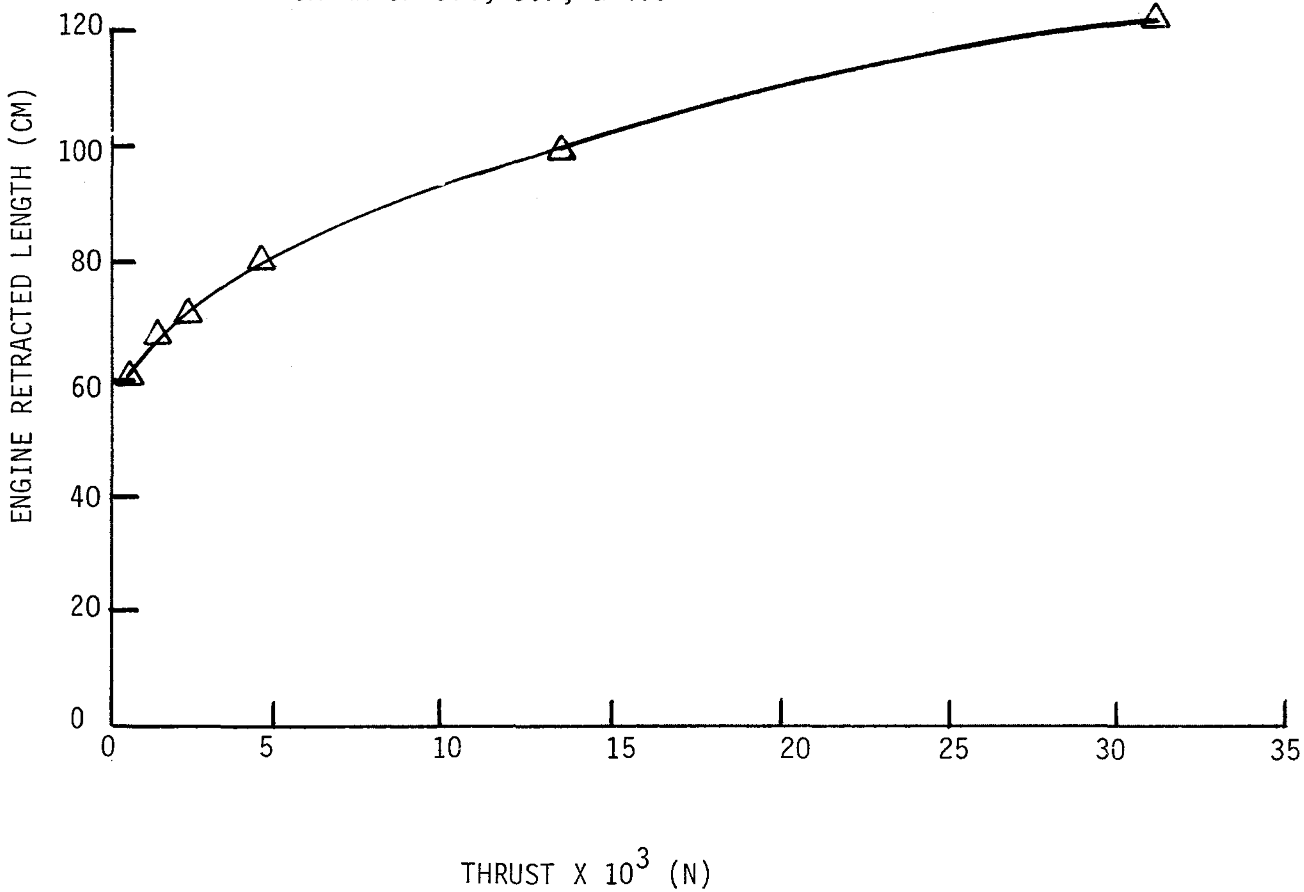

ENGINE RETRACTED LENGTH VERSUS THRUST
LCH4/LO2
PRESSURE FED
ε=400
FOR MR OF 3.4, 3.7, & 4.0
ENGINE RETRACTED LENGTH (CM)
0
50
100
150
200
250
300
350
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

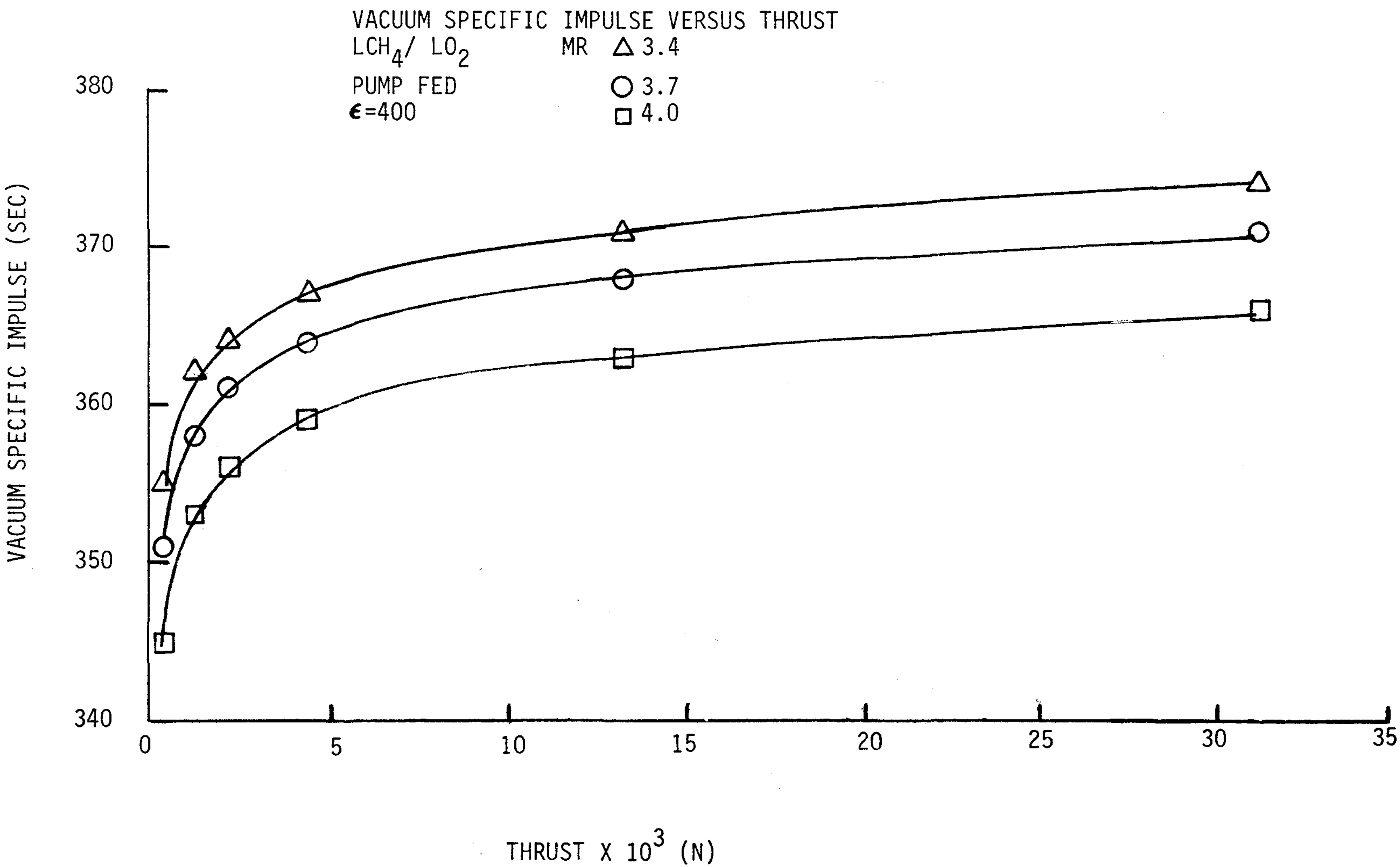


VACUUM SPECIFIC IMPULSE VERSUS THRUST
LCH4/LO2
PRESSURE FED
ϵ=400
MR
3.4
3.7
4.0
VACUUM SPECIFIC IMPULSE (SEC)
370
360
350
340
330
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)


ENGINE MASS VERSUS THRUST
LCH4/LO2
PUMP FED
ε=400
FOR MR OF 3.4, 3.7, & 4.0
ENGINE MASS (Kg)
0
10
20
30
40
50
60
70
80
90
100
110
0
5
10
15
20
25
30
35
THRUST X 10^3 (N)

ENGINE RETRACTED LENGTH VERSUS THRUST
LCH_4/LO_2
PUMP FED
ϵ=400
FOR MR OF 3.4, 3.7, & 4.0




VACUUM SPECIFIC IMPULSE VERSUS THRUST
LCH4/ LO2
MR △ 3.4
PUMP FED
○ 3.7
ε=400
□ 4.0
VACUUM SPECIFIC IMPULSE (SEC)
380
370
360
350
340
0
5
10
15
20
25
30
35
THRUST X 10³ (N)

APPENDIX B

MASS STATEMENTS (PROP OUTPUT SHEETS)

The mass statements for the various propulsion system configurations, analyzed in Section V, are displayed in the following pages. These statements were used to determine available payload mass and length, and center of gravity. The statements are arranged by orbit transfer strategy in the order of 8 perigee burn - constant acceleration; 1 perigee burn - constant acceleration; and 8 perigee burn - constant thrust. Each orbit transfer strategy section is further divided into the four propellant combinations: N_2O_4/MMH, LO_2/RP-1, LO_2/LCH_4, and LO_2/LH_2. The structure of each propellant combination section, if applicable*, is shown below.

Propellant Combination "A"

- Pressure Fed Engine
  - Maximum Performance Configuration
    - Thrust-To-Mass Ratio
      - Mixture Ratio
  - Minimum Length Configuration
    - Thrust-To-Mass Ratio
      - Mixture Ratio
- Pump Fed Engine
  - Maximum Performance Configuration
    - Thrust-To-Mass Ratio
      - Mixture Ratio
  - Minimum Length Configuration
    - Thrust-To-Mass Ratio
      - Mixture Ratio

*Thrust-to-mass ratios of 0.01, 0.015, 0.05 and 0.10 were not analyzed for all cases.

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PRESSURE FED,   MR = 1.8

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3167.4 N-S/KG

```
TOTAL PROPELLANT                          21916.91 KG
  USABLE FUEL                   7594.78
  USABLE OXIDIZER              13670.61
  FUEL TRAPPED                   228.20
  OXID TRAPPED                   409.72
  FUEL START-S/D LOSSES            6.80
  OXID START-S/D LOSSES            6.80

OXIDIZER TANKS (NO.= 1)                     289.23
 (ELLIPSOIDAL)
  DIAMETER=    3.032 M
  LENGTH  =    2.144 M
  VOLUME  =   10.315 M3
  AVG THK =   .00343 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                         299.12
 (ELLIPSOIDAL)
  DIAMETER=    2.944 M
  LENGTH  =    2.082 M
  VOLUME  =    9.448 M3
  AVG THK =   .00376 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   44.225

PRESSURANT TANKS (NO.= 1)                   234.63
  DIA=    1.2596 M
  VOL=     1.047 M3
  THK=    .01063 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                             37.19

COMPONENTS AND LINES                        363.33
ENG. MOUNTS,SUPPORTS                        949.37

TOTAL WET SYSTEM MASS                     24134.0
TOTAL BURNOUT MASS                         2855.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .881
TOTAL IMPULSE                        67359105.6 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =  .1207E+07   FINAL FU SYS PRESSURE    =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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N2O4/MMH, MAX. PERF., PRESSURE FED,                MR = 2.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3153.7 N-S/KG

TOTAL PROPELLANT                              21955.52 KG
  USABLE FUEL                     6657.70
  USABLE OXIDIZER                14646.94
  FUEL TRAPPED                     200.31
  OXID TRAPPED                     436.96
  FUEL START-S/D LOSSES              6.80
  OXID START-S/D LOSSES              6.80

OXIDIZER TANKS (NO.= 1)                         309.84
 (ELLIPSOIDAL)
  DIAMETER=     3.102 M
  LENGTH  =     2.193 M
  VOLUME  =    11.050 M3
  AVG THK =    .00351 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             262.25
 (ELLIPSOIDAL)
  DIAMETER=     2.818 M
  LENGTH  =     1.993 M
  VOLUME  =     8.284 M3
  AVG THK =    .00360 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      43.266

PRESSURANT TANKS (NO.= 1)                       229.61
  DIA=    1.2506 M
  VOL=     1.024 M3
  THK=    .01055 M
  FS = 1.50,  FNOP= 1.10

ENGINES (NO.= 1)                                 37.19

COMPONENTS AND LINES                            363.33
ENG. MOUNTS,SUPPORTS                            949.37

TOTAL WET SYSTEM MASS                          24150.4
TOTAL BURNOUT MASS                              2832.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .882
TOTAL IMPULSE                             67190937.9 N-S

             PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =    .1207E+07   FINAL FU SYS PRESSURE    =  .1207E+07
```

9 BURNS, CONSTANT ACCELERATION,T/M=0.01

N2O4/MMH, MAX. PERF., PRESSURE FED,   MR = 2.6

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3075.2 N-S/KG

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TOTAL PROPELLANT                          22188.08 KG
  USABLE FUEL                   5980.68
  USABLE OXIDIZER              15549.78
  FUEL TRAPPED                   178.91
  OXID TRAPPED                   465.09
  FUEL START-S/D LOSSES            6.80
  OXID START-S/D LOSSES            6.80

OXIDIZER TANKS (NO.= 1)                     328.95
 (ELLIPSOIDAL)
  DIAMETER=     3.164 M
  LENGTH  =     2.238 M
  VOLUME  =    11.732 M3
  AVG THK =    .00358 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                         235.57
 (ELLIPSOIDAL)
  DIAMETER=     2.719 M
  LENGTH  =     1.923 M
  VOLUME  =     7.441 M3
  AVG THK =    .00347 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                  42.907

PRESSURANT TANKS (NO.= 1)                   227.75
  DIA=    1.2472 M
  VOL=     1.016 M3
  THK=    .01052 M
  FS = 1.50,   FNOP= 1.10

ENGINES (NO.= 1)                             37.19

COMPONENTS AND LINES                        363.33
ENG. MOUNTS,SUPPORTS                        949.37

TOTAL WET SYSTEM MASS                      24373.2
TOTAL BURNOUT MASS                          2829.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .883
TOTAL IMPULSE                         66214016.7 N-S

             PRESSURE SCHEDULE(N/M2 )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1069E+07   FINAL OX SYS PRESSURE    = .1069E+07
INITIAL FU SYS PRESSURE   =  .1207E+07   FINAL FU SYS PRESSURE    = .1207E+07
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3176.2 N-S/KG

TOTAL PROPELLANT		21195.03 KG
USABLE FUEL	7348.21	
USABLE OXIDIZER	13226.77	
FUEL TRAPPED	216.52	
OXID TRAPPED	389.01	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		279.71
DIAMETER= 2.998 M		
LENGTH = 2.120 M		
VOLUME = 9.975 M3		
AVG THK = .00339 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		289.27
DIAMETER= 2.911 M		
LENGTH = 2.059 M		
VOLUME = 9.137 M3		
AVG THK = .00372 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		42.790
PRESSURANT TANKS (NO.= 1)		227.03
DIA= 1.2459 M		
VOL= 1.013 M3		
THK= .01051 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		944.83
TOTAL WET SYSTEM MASS		23391.9
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2802.4
MASS FRACTION		.880
TOTAL IMPULSE		65353809.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N204/MMH, MAX. PERF., PRESSURE FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3162.5 N-S/KG

TOTAL PROPELLANT		21237.22 KG
USABLE FUEL	6442.35	
USABLE OXIDIZER	14173.17	
FUEL TRAPPED	190.32	
OXID TRAPPED	416.87	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		299.71
(ELLIPSOIDAL)		
DIAMETER= 3.068 M		
LENGTH = 2.169 M		
VOLUME = 10.689 M3		
AVG THK = .00347 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		253.66
(ELLIPSOIDAL)		
DIAMETER= 2.787 M		
LENGTH = 1.971 M		
VOLUME = 8.013 M3		
AVG THK = .00356 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		41.868
PRESSURANT TANKS (NO.= 1)		222.19
DIA= 1.2370 M		
VOL= .991 M3		
THK= .01044 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		944.83
TOTAL WET SYSTEM MASS		23412.7
TOTAL BURNOUT MASS		2782.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.881
TOTAL IMPULSE		65199540.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3088.0 N-S/KG

TOTAL PROPELLANT		21464.80 KG
USABLE FUEL	5788.16	
USABLE OXIDIZER	15049.21	
FUEL TRAPPED	170.86	
OXID TRAPPED	442.05	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		318.21
(ELLIPSOIDAL)		
DIAMETER= 3.130 M		
LENGTH = 2.213 M		
VOLUME = 11.348 M3		
AVG THK = .00354 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		227.93
(ELLIPSOIDAL)		
DIAMETER= 2.689 M		
LENGTH = 1.901 M		
VOLUME = 7.200 M3		
AVG THK = .00344 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		41.527
PRESSURANT TANKS (NO.= 1)		220.43
DIA= 1.2337 M		
VOL= .983 M3		
THK= .01041 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		4[illegible].90
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		944.83
TOTAL WET SYSTEM MASS		23631.0
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2779.1
MASS FRACTION		.882
TOTAL IMPULSE		64348162.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3229.2 N-S/KG

TOTAL PROPELLANT		20628.18 KG
USABLE FUEL	7146.44	
USABLE OXIDIZER	12863.59	
FUEL TRAPPED	210.11	
OXID TRAPPED	377.20	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		272.17
(ELLIPSOIDAL)		
DIAMETER= 2.971 M		
LENGTH = 2.101 M		
VOLUME = 9.707 M3		
AVG THK = .00336 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		281.63
(ELLIPSOIDAL)		
DIAMETER= 2.886 M		
LENGTH = 2.040 M		
VOLUME = 8.896 M3		
AVG THK = .00369 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		41.642
PRESSURANT TANKS (NO.= 1)		220.93
DIA= 1.2346 M		
VOL= .985 M3		
THK= .01042 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		232.24
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		941.66
TOTAL WET SYSTEM MASS		22981.8
TOTAL BURNOUT MASS		2940.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.871
TOTAL IMPULSE		64618954.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 2.2

VEHICLE MASS =27215.5 KG   DELTA V= 4291.6 M/S   AVE. ISP=3208.6 N-S/KG

TOTAL PROPELLANT		20691.10 KG
USABLE FUEL	6272.26	
USABLE OXIDIZER	13798.97	
FUEL TRAPPED	184.70	
OXID TRAPPED	404.33	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		291.94
(ELLIPSOIDAL)		
DIAMETER= 3.041 M		
LENGTH = 2.150 M		
VOLUME = 10.411 M3		
AVG THK = .00344 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		247.26
(ELLIPSOIDAL)		
DIAMETER= 2.763 M		
LENGTH = 1.954 M		
VOLUME = 7.810 M3		
AVG THK = .00353 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		40.790
PRESSURANT TANKS (NO.= 1)		216.47
DIA= 1.2263 M		
VOL= .965 M3		
THK= .01035 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		232.24
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		941.66
TOTAL WET SYSTEM MASS		23024.8
TOTAL BURNOUT MASS		2922.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.872
TOTAL IMPULSE		64403232.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/W=0.1

N2O4/MMH, MAX. PERF., PRESSURE FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3140.9 N-S/KG

TOTAL PROPELLANT		20899.25 KG
USABLE FUEL	5631.70	
USABLE OXIDIZER	14642.43	
FUEL TRAPPED	165.58	
OXID TRAPPED	428.69	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		309.75
(ELLIPSOIDAL)		
DIAMETER= 3.102 M		
LENGTH = 2.193 M		
VOLUME = 11.047 M3		
AVG THK = .00351 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		222.06
(ELLIPSOIDAL)		
DIAMETER= 2.666 M		
LENGTH = 1.885 M		
VOLUME = 7.014 M3		
AVG THK = .00341 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		40.432
PRESSURANT TANKS (NO.= 1)		214.61
DIA= 1.2227 M		
VOL= .957 M3		
THK= .01032 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		232.24
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		941.66
TOTAL WET SYSTEM MASS		23223.3
TOTAL BURNOUT MASS		2918.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.873
TOTAL IMPULSE		63682438.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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N2O4/MMH, MIN. LENGTH, PRESSURE FED,                 MR = 1.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3167.4 N-S/KG

TOTAL PROPELLANT                               21921.02 KG
  USABLE FUEL                          7594.78
  USABLE OXIDIZER                     13670.61
  FUEL TRAPPED                          229.56
  OXID TRAPPED                          412.46
  FUEL START-S/D LOSSES                   6.80
  OXID START-S/D LOSSES                   6.80

OXIDIZER TANKS (NO.= 1)                          300.98
 (TOROIDAL)
  INNER DIA=     1.947 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.160 M
  VOLUME   =    10.317 M3
  AVG THK  =    .00235 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              299.17
 (ELLIPSOIDAL)
  DIAMETER=     2.944 M
  LENGTH  =     2.082 M
  VOLUME  =     9.450 M3
  AVG THK =    .00376 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        44.225

PRESSURANT TANKS (NO.= 1)                        234.63
  DIA=    1.2596 M
  VOL=     1.047 M3
  THK=    .01063 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                  37.19

COMPONENTS AND LINES                             386.01
ENG. MOUNTS,SUPPORTS                             949.37

TOTAL WET SYSTEM MASS                           24172.6
TOTAL BURNOUT MASS                               2893.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .880
TOTAL IMPULSE                               67359105.6 N-S

            PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1069E+07   FINAL OX SYS PRESSURE   =  .1069E+07
INITIAL FU SYS PRESSURE   =  .1207E+07   FINAL FU SYS PRESSURE   =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
 N2O4/MMH, MIN. LENGTH, PRESSURE FED,              MR = 2.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3153.7 N-S/KG

TOTAL PROPELLANT                          21961.44 KG
  USABLE FUEL                     6657.70
  USABLE OXIDIZER                14646.94
  FUEL TRAPPED                     201.67
  OXID TRAPPED                     441.52
  FUEL START-S/D LOSSES              6.80
  OXID START-S/D LOSSES              6.80

OXIDIZER TANKS (NO.= 1)                     326.05
 (TOROIDAL)
  INNER DIA=     1.846 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.211 M
  VOLUME   =    11.053 M3
  AVG THK  =    .00248 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                         262.31
 (ELLIPSOIDAL)
  DIAMETER=     2.818 M
  LENGTH  =     1.993 M
  VOLUME  =     8.286 M3
  AVG THK =    .00360 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  43.267

PRESSURANT TANKS (NO.= 1)                   229.61
  DIA=    1.2506 M
  VOL=     1.024 M3
  THK=    .01055 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                             37.19

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                        949.37

TOTAL WET SYSTEM MASS                      24195.2
TOTAL BURNOUT MASS                          2877.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .881
TOTAL IMPULSE                         67190937.9 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07    FINAL FU SYS PRESSURE    =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MIN. LENGTH, PRESSURE FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3075.2 N-S/KG

TOTAL PROPELLANT		22193.09 KG
USABLE FUEL	5980.68	
USABLE OXIDIZER	15549.78	
FUEL TRAPPED	181.19	
OXID TRAPPED	467.83	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER TANKS (NO.= 1)		350.09
(TOROIDAL)		
INNER DIA= 1.753 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.257 M		
VOLUME = 11.734 M3		
AVG THK = .00261 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		235.66
(ELLIPSOIDAL)		
DIAMETER= 2.719 M		
LENGTH = 1.923 M		
VOLUME = 7.444 M3		
AVG THK = .00347 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		42.908
PRESSURANT TANKS (NO.= 1)		227.75
DIA= 1.2472 M		
VOL= 1.016 M3		
THK= .01052 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		37.19
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		949.37
TOTAL WET SYSTEM MASS		24422.1
TOTAL BURNOUT MASS		2878.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.882
TOTAL IMPULSE		66214016.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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   N2O4/MMH, MIN. LENGTH, PRESSURE FED,                    MR = 1.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3176.2 N-S/KG

TOTAL PROPELLANT                             21209.16 KG
  USABLE FUEL                       7348.21
  USABLE OXIDIZER                  13226.77
  FUEL TRAPPED                       221.53
  OXID TRAPPED                       398.13
  FUEL START-S/D LOSSES                7.26
  OXID START-S/D LOSSES                7.26

OXIDIZER TANKS (NO.= 1)                        289.85
 (TOROIDAL)
  INNER DIA=     1.994  M
  OUTER DIA=     4.267  M
  HEIGHT   =     1.137  M
  VOLUME   =     9.982  M3
  AVG THK  =    .00229  M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                            289.46
 (ELLIPSOIDAL)
  DIAMETER=     2.912  M
  LENGTH  =     2.059  M
  VOLUME  =     9.143  M3
  AVG THK =    .00372  M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                     42.791

PRESSURANT TANKS (NO.= 1)                      227.03
  DIA=    1.2459  M
  VOL=     1.013  M3
  THK=    .01051  M
  FS = 1.50,   FNOP= 1.10


ENGINES (NO.= 1)                                 4.54

COMPONENTS AND LINES                           386.01
ENG. MOUNTS,SUPPORTS                          1289.11

TOTAL WET SYSTEM MASS                         23737.9
TOTAL BURNOUT MASS                             3148.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .867
TOTAL IMPULSE                            65353809.2 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =O.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE     =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07    FINAL FU SYS PRESSURE     =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
N2O4/MMH, MIN. LENGTH, PRESSURE FED,                 MR = 2.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3162.5 N-S/KG

TOTAL PROPELLANT                              21250.90 KG
  USABLE FUEL                      6442.35
  USABLE OXIDIZER                 14173.17
  FUEL TRAPPED                      194.42
  OXID TRAPPED                      426.44
  FUEL START-S/D LOSSES               7.26
  OXID START-S/D LOSSES               7.26

OXIDIZER TANKS (NO.= 1)                          313.76
 (TOROIDAL)
  INNER DIA=     1.895 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.186 M
  VOLUME   =    10.696 M3
  AVG THK  =    .00242 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                              253.82
 (ELLIPSOIDAL)
  DIAMETER=     2.787 M
  LENGTH   =    1.971 M
  VOLUME   =    8.018 M3
  AVG THK =    .00356 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                       41.869

PRESSURANT TANKS (NO.= 1)                        222.19
  DIA=     1.2370 M
  VOL=       .991 M3
  THK=     .01044 M
  FS = 1.50,   FNOP= 1.10


ENGINES (NO.= 1)                                   4.54

COMPONENTS AND LINES                             386.01
ENG. MOUNTS,SUPPORTS                            1289.11

TOTAL WET SYSTEM MASS                           23762.2
TOTAL BURNOUT MASS                               3132.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .868
TOTAL IMPULSE                              65199540.1 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =    .1207E+07    FINAL FU SYS PRESSURE    =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MIN. LENGTH, PRESSURE FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3088.0 N-S/KG

TOTAL PROPELLANT		21478.47 KG
USABLE FUEL	5788.16	
USABLE OXIDIZER	15049.21	
FUEL TRAPPED	174.96	
OXID TRAPPED	451.62	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		336.62
(TOROIDAL)		
INNER DIA= 1.805 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.231 M		
VOLUME = 11.355 M3		
AVG THK = .00254 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		228.09
(ELLIPSOIDAL)		
DIAMETER= 2.690 M		
LENGTH = 1.902 M		
VOLUME = 7.205 M3		
AVG THK = .00344 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		41.529
PRESSURANT TANKS (NO.= 1)		220.43
DIA= 1.2337 M		
VOL= .983 M3		
THK= .01041 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		4.54
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1289.11
TOTAL WET SYSTEM MASS		23984.8
TOTAL BURNOUT MASS		3132.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.869
TOTAL IMPULSE		64348162.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1207E+07	FINAL FU SYS PRESSURE =	.1207E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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N204/MMH, MIN. LENGTH, PRESSURE FED,                 MR = 1.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3229.2 N-S/KG

TOTAL PROPELLANT                            20639.13 KG
  USABLE FUEL                      7146.44
  USABLE OXIDIZER                 12863.59
  FUEL TRAPPED                      215.13
  OXID TRAPPED                      383.13
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42

OXIDIZER TANKS (NO.= 1)                       280.97
 (TOROIDAL)
  INNER DIA=     2.031 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.118 M
  VOLUME    =    9.711 M3
  AVG THK   =   .00225 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                           281.82
 (ELLIPSOIDAL)
  DIAMETER=     2.886 M
  LENGTH  =     2.041 M
  VOLUME  =     8.902 M3
  AVG THK =    .00369 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    41.643

PRESSURANT TANKS (NO.= 1)                     220.94
  DIA=    1.2346 M
  VOL=      .985 M3
  THK=    .01042 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                5.44

COMPONENTS AND LINES                          386.01
ENG. MOUNTS,SUPPORTS                         1275.05

TOTAL WET SYSTEM MASS                        23131.0
TOTAL BURNOUT MASS                            3090.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .865
TOTAL IMPULSE                            64618954.6 N-S

            PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07   FINAL FU SYS PRESSURE    =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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    N2O4/MMH, MIN. LENGTH, PRESSURE FED,              MR = 2.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3208.6 N-S/KG

TOTAL PROPELLANT                              20704.77 KG
  USABLE FUEL                        6272.26
  USABLE OXIDIZER                   13798.97
  FUEL TRAPPED                        188.81
  OXID TRAPPED                        413.90
  FUEL START-S/D LOSSES                15.42
  OXID START-S/D LOSSES                15.42

OXIDIZER TANKS (NO.= 1)                         304.38
 (TOROIDAL)
  INNER DIA=     1.933 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.167 M
  VOLUME   =    10.418 M3
  AVG THK  =    .00237 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             247.42
 (ELLIPSOIDAL)
  DIAMETER=     2.764 M
  LENGTH  =     1.954 M
  VOLUME  =     7.815 M3
  AVG THK =    .00353 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      40.791

PRESSURANT TANKS (NO.= 1)                       216.47
  DIA=    1.2263 M
  VOL=      .965 M3
  THK=    .01035 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                  5.44

COMPONENTS AND LINES                            386.01
ENG. MOUNTS,SUPPORTS                           1275.05

TOTAL WET SYSTEM MASS                          23180.3
TOTAL BURNOUT MASS                              3078.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .866
TOTAL IMPULSE                             64403232.0 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07    FINAL FU SYS PRESSURE    =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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 N2O4/MMH, MIN. LENGTH, PRESSURE FED,              MR = 2.6

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3140.9 N-S/KG

TOTAL PROPELLANT                           20912.92 KG
  USABLE FUEL                      5631.70
  USABLE OXIDIZER                 14642.43
  FUEL TRAPPED                      169.69
  OXID TRAPPED                      438.26
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42

OXIDIZER TANKS (NO.= 1)                      326.08
 (TOROIDAL)
  INNER DIA=     1.846 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.211 M
  VOLUME   =    11.054 M3
  AVG THK  =    .00248 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          222.22
 (ELLIPSOIDAL)
  DIAMETER=     2.666 M
  LENGTH  =     1.885 M
  VOLUME  =     7.019 M3
  AVG THK =    .00341 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    40.433

PRESSURANT TANKS (NO.= 1)                    214.61
  DIA=    1.2227 M
  VOL=      .957 M3
  THK=    .01032 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                               5.44

COMPONENTS AND LINES                         386.01
ENG. MOUNTS,SUPPORTS                        1275.05

TOTAL WET SYSTEM MASS                       23382.8
TOTAL BURNOUT MASS                           3077.8
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .867
TOTAL IMPULSE                         63682438.5 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1207E+07    FINAL FU SYS PRESSURE    =  .1207E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PUMP FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3185.1 N-S/KG

TOTAL PROPELLANT		21855.73 KG
USABLE FUEL	7576.80	
USABLE OXIDIZER	13638.24	
FUEL TRAPPED	224.55	
OXID TRAPPED	402.53	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		93.04
DIAMETER= 3.029 M		
LENGTH = 2.142 M		
VOLUME = 10.286 M3		
AVG THK = .00111 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		50.40
DIAMETER= 2.941 M		
LENGTH = 2.080 M		
VOLUME = 9.422 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.606
PRESSURANT TANKS (NO.= 1)		18.89
DIA= .5439 M		
VOL= .084 M3		
THK= .00459 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		37.19
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		949.37
TOTAL WET SYSTEM MASS		23371.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2142.9
MASS FRACTION		.908
TOTAL IMPULSE		67574119.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/m=0.01

N204/MMH, MAX. PERF., PUMP FED, MR = 2.2

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VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3191.9 N-S/KG

TOTAL PROPELLANT                             21835.88 KG
  USABLE FUEL                        6623.59
  USABLE OXIDIZER                   14571.91
  FUEL TRAPPED                        196.26
  OXID TRAPPED                        430.52
  FUEL START-S/D LOSSES                 6.80
  OXID START-S/D LOSSES                 6.80

OXIDIZER TANKS (NO.= 1)                         99.41
 (ELLIPSOIDAL)
  DIAMETER=     3.096 M
  LENGTH  =     2.189 M
  VOLUME  =    10.990 M3
  AVG THK =    .00113 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             46.08
 (ELLIPSOIDAL)
  DIAMETER=     2.813 M
  LENGTH  =     1.989 M
  VOLUME  =     8.238 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      3.518

PRESSURANT TANKS (NO.= 1)                       18.42
  DIA=      .5393 M
  VOL=       .082 M3
  THK=     .00455 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                37.19

COMPONENTS AND LINES                           363.33
ENG. MOUNTS,SUPPORTS                           949.37

TOTAL WET SYSTEM MASS                         23353.2
TOTAL BURNOUT MASS                             2144.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .908
TOTAL IMPULSE                            67657372.7 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =    .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3111.5 N-S/KG

TOTAL PROPELLANT		22072.02 KG
USABLE FUEL	5951.58	
USABLE OXIDIZER	15474.12	
FUEL TRAPPED	176.36	
OXID TRAPPED	456.36	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER TANKS (NO.= 1)		105.56
(ELLIPSOIDAL)		
DIAMETER= 3.159 M		
LENGTH = 2.234 M		
VOLUME = 11.670 M3		
AVG THK = .00115 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		42.91
(ELLIPSOIDAL)		
DIAMETER= 2.714 M		
LENGTH = 1.919 M		
VOLUME = 7.403 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.490
PRESSURANT TANKS (NO.= 1)		18.26
DIA= .5378 M		
VOL= .081 M3		
THK= .00454 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		37.19
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		949.37
TOTAL WET SYSTEM MASS		23592.1
TOTAL BURNOUT MASS		2152.8
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.908
TOTAL IMPULSE		66669249.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MAX. PERF., PUMP FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3209.6 N-S/KG

TOTAL PROPELLANT		21095.00 KG
USABLE FUEL	7313.20	
USABLE OXIDIZER	13163.76	
FUEL TRAPPED	216.09	
OXID TRAPPED	387.43	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1)		89.80
(ELLIPSOIDAL)		
DIAMETER= 2.993 M		
LENGTH = 2.116 M		
VOLUME = 9.928 M3		
AVG THK = .00109 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		49.22
(ELLIPSOIDAL)		
DIAMETER= 2.907 M		
LENGTH = 2.056 M		
VOLUME = 9.095 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.478
PRESSURANT TANKS (NO.= 1)		18.23
DIA= .5375 M		
VOL= .081 M3		
THK= .00454 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		42.18
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		944.83
TOTAL WET SYSTEM MASS		22606.1
TOTAL BURNOUT MASS		2114.6
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.906
TOTAL IMPULSE		65725208.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.2

VEHICLE MASS =27215.5 KG   DELTA V= 4480.6 M/S   AVE. ISP=3216.4 N-S/KG

TOTAL PROPELLANT		21074.57 KG
USABLE FUEL	6392.77	
USABLE OXIDIZER	14064.09	
FUEL TRAPPED	189.07	
OXID TRAPPED	414.13	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		95.94
DIAMETER= 3.060 M		
LENGTH = 2.164 M		
VOLUME = 10.607 M3		
AVG THK = .00112 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		45.01
DIAMETER= 2.780 M		
LENGTH = 1.965 M		
VOLUME = 7.951 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3,393
PRESSURANT TANKS (NO.= 1)		17.77
DIA= .5330 M		
VOL= .079 M3		
THK= .00450 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		42.18
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		944.83
TOTAL WET SYSTEM MASS		22587.0
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2115.7
MASS FRACTION		.906
TOTAL IMPULSE		65801106.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.6

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3141.9 N-S/KG

TOTAL PROPELLANT		21299.90 KG
USABLE FUEL	5743.48	
USABLE OXIDIZER	14933.04	
FUEL TRAPPED	169.73	
OXID TRAPPED	439.13	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 3.122 M, LENGTH = 2.207 M, VOLUME = 11.261 M3, AVG THK = .00114 M, FS = 1.50, FNOP= 1.30		101.86
FUEL TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 2.682 M, LENGTH = 1.897 M, VOLUME = 7.144 M3, AVG THK = .00064 M, FS = 1.50, FNOP= 1.30		41.91
PRESSURANT		3.366
PRESSURANT TANKS (NO.= 1) DIA= .5314 M, VOL= .079 M3, THK= .00448 M, FS = 1.50, FNOP= 1.10		17.62
ENGINES (NO.= 1)		42.18
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		944.83
TOTAL WET SYSTEM MASS		22815.0
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2124.0
MASS FRACTION		.906
TOTAL IMPULSE		64966654.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.05

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4303.8 M/S AVE. ISP=3265.5 N-S/KG

TOTAL PROPELLANT		20561.01 KG
USABLE FUEL	6228.15	
USABLE OXIDIZER	13701.94	
FUEL TRAPPED	190.86	
OXID TRAPPED	418.28	
FUEL START-S/D LOSSES	10.89	
OXID START-S/D LOSSES	10.89	
OXIDIZER TANKS (NO.= 1)		93.59
(ELLIPSOIDAL)		
DIAMETER= 3.035 M		
LENGTH = 2.146 M		
VOLUME = 10.347 M3		
AVG THK = .00111 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		44.28
(ELLIPSOIDAL)		
DIAMETER= 2.757 M		
LENGTH = 1.950 M		
VOLUME = 7.759 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.307
PRESSURANT TANKS (NO.= 1)		17.32
DIA= .5284 M		
VOL= .077 M3		
THK= .00446 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		68.04
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		940.75
TOTAL WET SYSTEM MASS		22091.6
TOTAL BURNOUT MASS		2139.8
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.902
TOTAL IMPULSE		65083972.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N204/MMH, MAX. PERF., PUMP FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3266.4 N-S/KG

TOTAL PROPELLANT		20515.35 KG
USABLE FUEL	7107.13	
USABLE OXIDIZER	12792.83	
FUEL TRAPPED	209.12	
OXID TRAPPED	375.42	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		87.32
DIAMETER= 2.965 M		
LENGTH = 2.097 M		
VOLUME = 9.653 M3		
AVG THK = .00108 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		48.33
DIAMETER= 2.880 M		
LENGTH = 2.037 M		
VOLUME = 8.847 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.385
PRESSURANT TANKS (NO.= 1)		17.73
DIA= .5326 M		
VOL= .079 M3		
THK= .00449 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		100.24
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		941.66
TOTAL WET SYSTEM MASS		22077.3
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2146.5
MASS FRACTION		.901
TOTAL IMPULSE		65005073.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MAX. PERF., PUMP FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3288.0 N-S/KG

TOTAL PROPELLANT		20450.60 KG
USABLE FUEL	6198.94	
USABLE OXIDIZER	13637.68	
FUEL TRAPPED	182.85	
OXID TRAPPED	400.28	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		93.08
DIAMETER= 3.029 M		
LENGTH = 2.142 M		
VOLUME = 10.290 M3		
AVG THK = .00111 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		44.13
DIAMETER= 2.752 M		
LENGTH = 1.946 M		
VOLUME = 7.720 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.295
PRESSURANT TANKS (NO.= 1)		17.25
DIA= .5277 M		
VOL= .077 M3		
THK= .00445 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		100.24
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		941.66
TOTAL WET SYSTEM MASS		22013.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2146.1
MASS FRACTION		.901
TOTAL IMPULSE		65226155.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, $T/\dot{M}=0.1$

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   N2O4/MMH, MAX. PERF., PUMP FED,              MR = 2.6

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3230.2 N-S/KG

TOTAL PROPELLANT                            20625.07 KG
  USABLE FUEL                     5557.53
  USABLE OXIDIZER                14449.59
  FUEL TRAPPED                     163.71
  OXID TRAPPED                     423.39
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42

OXIDIZER TANKS (NO.= 1)                        98.61
 (ELLIPSOIDAL)
  DIAMETER=     3.088 M
  LENGTH  =     2.184 M
  VOLUME  =    10.902 M3
  AVG THK =    .00113 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                            41.04
 (ELLIPSOIDAL)
  DIAMETER=     2.654 M
  LENGTH  =     1.877 M
  VOLUME  =     6.923 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     3.261

PRESSURANT TANKS (NO.= 1)                      17.06
  DIA=     .5257 M
  VOL=      .076 M3
  THK=    .00444 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                              100.24

COMPONENTS AND LINES                          363.33
ENG. MOUNTS,SUPPORTS                          941.66

TOTAL WET SYSTEM MASS                       22190.3
TOTAL BURNOUT MASS                           2152.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .902
TOTAL IMPULSE                          64629185.2 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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 N2O4/MMH, MIN. LENGTH, PUMP FED,                MR = 1.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3185.1 N-S/KG

TOTAL PROPELLANT                             21869.40 KG
  USABLE FUEL                    7576.80
  USABLE OXIDIZER               13638.24
  FUEL TRAPPED                    229.11
  OXID TRAPPED                    411.64
  FUEL START-S/D LOSSES             6.80
  OXID START-S/D LOSSES             6.80

OXIDIZER TANKS (NO.= 1)                         98.71
 (TOROIDAL)
  INNER DIA=     1.950 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.158 M
  VOLUME   =    10.293 M3
  AVG THK  =    .00077 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                             50.42
 (ELLIPSOIDAL)
  DIAMETER=     2.942 M
  LENGTH  =     2.080 M
  VOLUME  =     9.428 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      3.606

PRESSURANT TANKS (NO.= 1)                       18.89
  DIA=      .5439 M
  VOL=       .084 M3
  THK=     .00459 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                37.19

COMPONENTS AND LINES                           386.01
ENG. MOUNTS,SUPPORTS                           949.37

TOTAL WET SYSTEM MASS                         23413.6
TOTAL BURNOUT MASS                             2185.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .906
TOTAL IMPULSE                            67574119.3 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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  N2O4/MMH, MIN. LENGTH, PUMP FED,              MR = 2.2

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=3191.9 N-S/KG

TOTAL PROPELLANT                          21849.56 KG
  USABLE FUEL                   6623.59
  USABLE OXIDIZER              14571.91
  FUEL TRAPPED                   200.81
  OXID TRAPPED                   439.64
  FUEL START-S/D LOSSES            6.80
  OXID START-S/D LOSSES            6.80

OXIDIZER TANKS (NO.= 1)                      105.09
 (TOROIDAL)
  INNER DIA=     1.854 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.207 M
  VOLUME   =    10.997 M3
  AVG THK  =    .00080 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                           46.10
 (ELLIPSOIDAL)
  DIAMETER=     2.813 M
  LENGTH  =     1.989 M
  VOLUME  =     8.243 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     3.518

PRESSURANT TANKS (NO.= 1)                     18.42
  DIA=     .5393 M
  VOL=      .082 M3
  THK=    .00455 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                              37.19

COMPONENTS AND LINES                         386.01
ENG. MOUNTS,SUPPORTS                         949.37

TOTAL WET SYSTEM MASS                      23395.3
TOTAL BURNOUT MASS                          2186.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .906
TOTAL IMPULSE                          67657372.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

N2O4/MMH, MIN. LENGTH, PUMP FED   MR = 2.6

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3111.5 N-S/KG

TOTAL PROPELLANT		22085.70 KG
USABLE FUEL	5951.58	
USABLE OXIDIZER	15474.12	
FUEL TRAPPED	180.46	
OXID TRAPPED	465.93	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER TANKS (NO.= 1)		112.27
(TOROIDAL)		
INNER DIA= 1.761 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.253 M		
VOLUME = 11.677 M3		
AVG THK = .00084 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		42.93
(ELLIPSOIDAL)		
DIAMETER= 2.715 M		
LENGTH = 1.920 M		
VOLUME = 7.408 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.490
PRESSURANT TANKS (NO.= 1)		18.26
DIA= .5378 M		
VOL= .081 M3		
THK= .00454 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		37.19
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		949.37
TOTAL WET SYSTEM MASS		23635.2
TOTAL BURNOUT MASS		2195.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.907
TOTAL IMPULSE		66669249.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MIN. LENGTH, PUMP FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3209.6 N-S/KG

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TOTAL PROPELLANT                           21108.67 KG
  USABLE FUEL                   7313.20
  USABLE OXIDIZER              13163.76
  FUEL TRAPPED                   220.65
  OXID TRAPPED                   396.55
  FUEL START-S/D LOSSES            7.26
  OXID START-S/D LOSSES            7.26

OXIDIZER TANKS (NO.= 1)                       95.55
 (TOROIDAL)
  INNER DIA=    2.000 M
  OUTER DIA=    4.267 M
  HEIGHT   =    1.134 M
  VOLUME   =    9.935 M3
  AVG THK  =   .00076 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                           49.24
 (ELLIPSOIDAL)
  DIAMETER=    2.908 M
  LENGTH  =    2.056 M
  VOLUME  =    9.100 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     3.478

PRESSURANT TANKS (NO.= 1)                     18.23
  DIA=    .5375 M
  VOL=     .081 M3
  THK=   .00454 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                              42.18

COMPONENTS AND LINES                         386.01
ENG. MOUNTS,SUPPORTS                        1289.11

TOTAL WET SYSTEM MASS                       22992.5
TOTAL BURNOUT MASS                           2501.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .891
TOTAL IMPULSE                          65725208.9 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =  .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
```

9 BURNS,CONSTANT ACCELERATION, T/M=0.015

N2O4/MMH, MIN. LENGTH, PUMP FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3216.4 N-S/KG

TOTAL PROPELLANT		21088.25 KG
USABLE FUEL	6392.77	
USABLE OXIDIZER	14064.09	
FUEL TRAPPED	193.17	
OXID TRAPPED	423.70	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	

OXIDIZER TANKS (NO.= 1) 101.59
(TOROIDAL)
INNER DIA= 1.906 M
OUTER DIA= 4.267 M
HEIGHT = 1.181 M
VOLUME = 10.614 M3
AVG THK = .00079 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 45.03
(ELLIPSOIDAL)
DIAMETER= 2.780 M
LENGTH = 1.966 M
VOLUME = 7.956 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT 3.393

PRESSURANT TANKS (NO.= 1) 17.77
DIA= .5330 M
VOL= .079 M3
THK= .00450 M
FS = 1.50, FNOP= 1.10

ENGINES (NO.= 1) 42.18

COMPONENTS AND LINES 386.01
ENG. MOUNTS,SUPPORTS 1289.11

TOTAL WET SYSTEM MASS 22973.3
TOTAL BURNOUT MASS 2502.0
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .890
TOTAL IMPULSE 65801106.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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  N2O4/MMH, MIN. LENGTH, PUMP FED,                 MR = 2.6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3141.9 N-S/KG

TOTAL PROPELLANT                          21313.58 KG
  USABLE FUEL                    5743.48
  USABLE OXIDIZER               14933.04
  FUEL TRAPPED                    173.84
  OXID TRAPPED                    448.71
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26

OXIDIZER TANKS (NO.= 1)                     107.62
 (TOROIDAL)
  INNER DIA=     1.817 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.225 M
  VOLUME   =    11.268 M3
  AVG THK  =    .00081 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          41.93
 (ELLIPSOIDAL)
  DIAMETER=    2.683 M
  LENGTH  =    1.897 M
  VOLUME  =    7.149 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    3.366

PRESSURANT TANKS (NO.= 1)                    17.62
  DIA=     .5314 M
  VOL=      .079 M3
  THK=    .00448 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                             42.18

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                       1289.11

TOTAL WET SYSTEM MASS                      23201.4
TOTAL BURNOUT MASS                          2510.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .891
TOTAL IMPULSE                          64966654.5 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06    FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N204/MMH, MIN. LENGTH, PUMP FED, MR = 1.8

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3266.4 N-S/KG

TOTAL PROPELLANT		20526.29 KG
USABLE FUEL	7107.13	
USABLE OXIDIZER	12792.83	
FUEL TRAPPED	214.14	
OXID TRAPPED	381.35	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		93.14
(TOROIDAL)		
INNER DIA= 2.039 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.114 M		
VOLUME = 9.658 M3		
AVG THK = .00075 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		48.35
(ELLIPSOIDAL)		
DIAMETER= 2.881 M		
LENGTH = 2.037 M		
VOLUME = 8.853 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.385
PRESSURANT TANKS (NO.= 1)		17.73
DIA= .5326 M		
VOL= .079 M3		
THK= .00449 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		100.24
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1275.05
TOTAL WET SYSTEM MASS		22450.2
TOTAL BURNOUT MASS		2519.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.886
TOTAL IMPULSE		65005073.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MIN. LENGTH, PUMP FED, MR = 2.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3288.0 N-S/KG

TOTAL PROPELLANT		20464.27 KG
USABLE FUEL	6198.94	
USABLE OXIDIZER	13637.68	
FUEL TRAPPED	186.96	
OXID TRAPPED	409.85	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER TANKS (NO.= 1)		98.75
(TOROIDAL)		
INNER DIA= 1.950 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.159 M		
VOLUME = 10.297 M3		
AVG THK = .00077 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		44.15
(ELLIPSOIDAL)		
DIAMETER= 2.753 M		
LENGTH = 1.947 M		
VOLUME = 7.725 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.295
PRESSURANT TANKS (NO.= 1)		17.25
DIA= .5277 M		
VOL= .077 M3		
THK= .00445 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		100.24
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1275.05
TOTAL WET SYSTEM MASS		22389.0
TOTAL BURNOUT MASS		2521.6
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.886
TOTAL IMPULSE		65226155.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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N2O4/MMH, MIN. LENGTH, PUMP FED,                MR = 2.6

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3230.2 N-S/KG

TOTAL PROPELLANT                          20639.20 KG
  USABLE FUEL                  5557.53
  USABLE OXIDIZER             14449.59
  FUEL TRAPPED                  167.81
  OXID TRAPPED                  433.42
  FUEL START-S/D LOSSES          15.42
  OXID START-S/D LOSSES          15.42

OXIDIZER TANKS (NO.= 1)                     104.29
 (TOROIDAL)
  INNER DIA=     1.866 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.201 M
  VOLUME   =    10.909 M3
  AVG THK  =    .00080 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          41.06
 (ELLIPSOIDAL)
  DIAMETER=     2.655 M
  LENGTH  =     1.877 M
  VOLUME  =     6.928 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   3.261

PRESSURANT TANKS (NO.= 1)                    17.06
  DIA=     .5257 M
  VOL=      .076 M3
  THK=    .00444 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                            100.24

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                       1275.05

TOTAL WET SYSTEM MASS                     22566.2
TOTAL BURNOUT MASS                         2528.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                .887
TOTAL IMPULSE                         64629185.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3292.9 N-S/KG

TOTAL PROPELLANT		21747.51 KG
USABLE FUEL	5476.39	
USABLE OXIDIZER	15333.90	
FUEL TRAPPED	190.20	
OXID TRAPPED	529.08	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	204.34	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		419.54
DIAMETER= 3.432 M		
LENGTH = 2.427 M		
VOLUME = 14.962 M3		
AVG THK = .00388 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		240.70
DIAMETER= 2.713 M		
LENGTH = 1.918 M		
VOLUME = 7.392 M3		
AVG THK = .00357 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		62.763
PRESSURANT TANKS (NO.= 1)		338.79
DIA= 1.4237 M		
VOL= 1.511 M3		
THK= .01201 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		43.98
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1257.81
TOTAL WET SYSTEM MASS		24510.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3482.5
MASS FRACTION		.849
TOTAL IMPULSE		68529765.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3265.5 N-S/KG

TOTAL PROPELLANT		21825.99 KG
USABLE FUEL	5221.62	
USABLE OXIDIZER	15664.87	
FUEL TRAPPED	181.10	
OXID TRAPPED	539.67	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	205.12	
OXIDIZER TANKS (NO.= 1)		428.47
(ELLIPSOIDAL)		
DIAMETER= 3.456 M		
LENGTH = 2.444 M		
VOLUME = 15.281 M3		
AVG THK = .00391 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		229.51
(ELLIPSOIDAL)		
DIAMETER= 2.670 M		
LENGTH = 1.888 M		
VOLUME = 7.048 M3		
AVG THK = .00351 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		63.518
PRESSURANT TANKS (NO.= 1)		343.06
DIA= 1.4297 M		
VOL= 1.530 M3		
THK= .01206 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		44.60
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1257.81
TOTAL WET SYSTEM MASS		24592.6
TOTAL BURNOUT MASS		3487.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.849
TOTAL IMPULSE		68207207.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3234.1 N-S/KG

TOTAL PROPELLANT		21916.55 KG
USABLE FUEL	4993.83	
USABLE OXIDIZER	15980.26	
FUEL TRAPPED	173.13	
OXID TRAPPED	549.87	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	205.85	
OXIDIZER TANKS (NO.= 1)		436.99
(ELLIPSOIDAL)		
DIAMETER= 3.479 M		
LENGTH = 2.460 M		
VOLUME = 15.584 M3		
AVG THK = .00394 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		219.50
(ELLIPSOIDAL)		
DIAMETER= 2.631 M		
LENGTH = 1.860 M		
VOLUME = 6.741 M3		
AVG THK = .00346 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		64.261
PRESSURANT TANKS (NO.= 1)		347.25
DIA= 1.4355 M		
VOL= 1.549 M3		
THK= .01211 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		45.19
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1257.81
TOTAL WET SYSTEM MASS		24687.2
TOTAL BURNOUT MASS		3493.6
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.850
TOTAL IMPULSE		67835082.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3309.6 N-S/KG

TOTAL PROPELLANT		21000.81 KG
USABLE FUEL	5287.03	
USABLE OXIDIZER	14803.69	
FUEL TRAPPED	183.11	
OXID TRAPPED	509.38	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	203.08	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 3.392 M; LENGTH = 2.399 M; VOLUME = 14.449 M3; AVG THK = .00384 M; FS = 1.50, FNOP= 1.30		405.16
FUEL TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 2.681 M; LENGTH = 1.896 M; VOLUME = 7.137 M3; AVG THK = .00352 M; FS = 1.50, FNOP= 1.30		232.39
PRESSURANT		60.611
PRESSURANT TANKS (NO.= 1) DIA= 1.4073 M; VOL= 1.459 M3; THK= .01187 M; FS = 1.50, FNOP= 1.10		327.18
OXIDIZER TANK INSULATION		42.97
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1250.55
TOTAL WET SYSTEM MASS		23732.9
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3424.6
MASS FRACTION		.847
TOTAL IMPULSE		66495127.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3284.1 N-S/KG

TOTAL PROPELLANT		21076.56 KG
USABLE FUEL	5040.85	
USABLE OXIDIZER	15122.55	
FUEL TRAPPED	174.68	
OXID TRAPPED	520.12	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	203.84	
OXIDIZER TANKS (NO.= 1)		413.79
(ELLIPSOIDAL)		
DIAMETER= 3.416 M		
LENGTH = 2.415 M		
VOLUME = 14.757 M3		
AVG THK = .00387 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		221.58
(ELLIPSOIDAL)		
DIAMETER= 2.639 M		
LENGTH = 1.866 M		
VOLUME = 6.805 M3		
AVG THK = .00347 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		61.337
PRESSURANT TANKS (NO.= 1)		331.28
DIA= 1.4131 M		
VOL= 1.478 M3		
THK= .01192 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		43.58
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1250.55
TOTAL WET SYSTEM MASS		23811.9
TOTAL BURNOUT MASS		3430.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.847
TOTAL IMPULSE		66221580.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3253.7 N-S/KG

TOTAL PROPELLANT		21166.75 KG
USABLE FUEL	4821.58	
USABLE OXIDIZER	15429.06	
FUEL TRAPPED	166.93	
OXID TRAPPED	530.10	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	204.56	

OXIDIZER TANKS (NO.= 1) 422.07
(ELLIPSOIDAL)
DIAMETER= 3.439 M
LENGTH = 2.431 M
VOLUME = 15.052 M3
AVG THK = .00389 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 211.95
(ELLIPSOIDAL)
DIAMETER= 2.600 M
LENGTH = 1.839 M
VOLUME = 6.509 M3
AVG THK = .00342 M
FS = 1.50, FNOP= 1.30

PRESSURANT 62.062

PRESSURANT TANKS (NO.= 1) 335.37
DIA= 1.4189 M
VOL= 1.496 M3
THK= .01197 M
FS = 1.50, FNOP= 1.10

OXIDIZER TANK INSULATION 44.16

ENGINES (NO.= 1) 49.90

COMPONENTS AND LINES 363.33
ENG. MOUNTS,SUPPORTS 1250.55

TOTAL WET SYSTEM MASS 23906.1
TOTAL BURNOUT MASS 3436.4
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .847
TOTAL IMPULSE 65892462.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PRESSURE FED,　　　　MR = 2.8

VEHICLE MASS =27215.5 KG　　DELTA V= 4291.6 M/S　　AVE. ISP=3384.1 N-S/KG

TOTAL PROPELLANT		20364.02 KG
USABLE FUEL	5122.57	
USABLE OXIDIZER	14343.19	
FUEL TRAPPED	175.78	
OXID TRAPPED	489.65	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	201.99	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		392.81
DIAMETER= 3.357 M		
LENGTH = 2.374 M		
VOLUME = 14.009 M3		
AVG THK = .00380 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		225.44
DIAMETER= 2.654 M		
LENGTH = 1.877 M		
VOLUME = 6.923 M3		
AVG THK = .00349 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		58.771
PRESSURANT TANKS (NO.= 1)		317.24
DIA= 1.3929 M		
VOL= 1.415 M3		
THK= .01175 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		42.09
ENGINES (NO.= 1)		235.87
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1241.94
TOTAL WET SYSTEM MASS		23241.5
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3542.9
MASS FRACTION		.838
TOTAL IMPULSE		65877441.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3357.6 N-S/KG

TOTAL PROPELLANT		20442.55 KG
USABLE FUEL	4885.29	
USABLE OXIDIZER	14655.86	
FUEL TRAPPED	168.03	
OXID TRAPPED	499.78	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	202.74	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		401.26
DIAMETER= 3.381 M		
LENGTH = 2.391 M		
VOLUME = 14.310 M3		
AVG THK = .00383 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		215.05
DIAMETER= 2.613 M		
LENGTH = 1.848 M		
VOLUME = 6.604 M3		
AVG THK = .00343 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		59.490
PRESSURANT TANKS (NO.= 1)		321.30
DIA= 1.3988 M		
VOL= 1.433 M3		
THK= .01180 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		42.69
ENGINES (NO.= 1)		235.87
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1241.94
TOTAL WET SYSTEM MASS		23323.5
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3548.7
MASS FRACTION		.838
TOTAL IMPULSE		65615194.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3327.2 N-S/KG

TOTAL PROPELLANT		20532.20 KG
USABLE FUEL	4673.41	
USABLE OXIDIZER	14954.92	
FUEL TRAPPED	160.46	
OXID TRAPPED	509.12	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	203.45	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		409.33
DIAMETER= 3.404 M		
LENGTH = 2.407 M		
VOLUME = 14.598 M3		
AVG THK = .00385 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		205.74
DIAMETER= 2.575 M		
LENGTH = 1.820 M		
VOLUME = 6.318 M3		
AVG THK = .00338 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		60.200
PRESSURANT TANKS (NO.= 1)		325.30
DIA= 1.4046 M		
VOL= 1.451 M3		
THK= .01185 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		43.26
ENGINES (NO.= 1)		235.87
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1241.94
TOTAL WET SYSTEM MASS		23417.2
TOTAL BURNOUT MASS (INCL. NON-USABLE PROP. AND GAS)		3554.5
MASS FRACTION		.838
TOTAL IMPULSE		65311223.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3292.9 N-S/KG

TOTAL PROPELLANT		21769.83 KG
USABLE FUEL	5473.24	
USABLE OXIDIZER	15325.07	
FUEL TRAPPED	194.30	
OXID TRAPPED	539.89	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	223.72	
OXIDIZER TANKS (NO.= 1)		556.71
(TOROIDAL)		
INNER DIA= 1.318 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.475 M		
VOLUME = 14.982 M3		
AVG THK = .00330 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		240.74
(ELLIPSOIDAL)		
DIAMETER= 2.713 M		
LENGTH = 1.918 M		
VOLUME = 7.393 M3		
AVG THK = .00357 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		62.780
PRESSURANT TANKS (NO.= 1)		338.88
DIA= 1.4239 M		
VOL= 1.511 M3		
THK= .01201 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.53
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1253.28
TOTAL WET SYSTEM MASS		24704.0
TOTAL BURNOUT MASS		3668.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.842
TOTAL IMPULSE		68490307.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3265.5 N-S/KG

TOTAL PROPELLANT		21848.61 KG
USABLE FUEL	5218.66	
USABLE OXIDIZER	15655.98	
FUEL TRAPPED	185.20	
OXID TRAPPED	550.94	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	224.22	
OXIDIZER TANKS (NO.= 1)		574.40
(TOROIDAL)		
INNER DIA= 1.275 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.496 M		
VOLUME = 15.301 M3		
AVG THK = .00338 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		229.55
(ELLIPSOIDAL)		
DIAMETER= 2.670 M		
LENGTH = 1.888 M		
VOLUME = 7.050 M3		
AVG THK = .00351 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		63.534
PRESSURANT TANKS (NO.= 1)		343.14
DIA= 1.4298 M		
VOL= 1.530 M3		
THK= .01206 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.93
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1253.28
TOTAL WET SYSTEM MASS		24794.7
TOTAL BURNOUT MASS		3682.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.842
TOTAL IMPULSE		68168496.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3234.1 N-S/KG

TOTAL PROPELLANT		21939.02 KG
USABLE FUEL	4991.04	
USABLE OXIDIZER	15971.32	
FUEL TRAPPED	176.78	
OXID TRAPPED	561.59	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	224.68	
OXIDIZER TANKS (NO.= 1)		591.93
(TOROIDAL)		
INNER DIA= 1.235 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.516 M		
VOLUME = 15.605 M3		
AVG THK = .00346 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		219.54
(ELLIPSOIDAL)		
DIAMETER= 2.631 M		
LENGTH = 1.860 M		
VOLUME = 6.742 M3		
AVG THK = .00346 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		64.276
PRESSURANT TANKS (NO.= 1)		347.33
DIA= 1.4356 M		
VOL= 1.549 M3		
THK= .01211 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		60.30
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1253.28
TOTAL WET SYSTEM MASS		24898.0
TOTAL BURNOUT MASS		3697.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.842
TOTAL IMPULSE		67797133.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	O.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3309.6 N-S/KG

TOTAL PROPELLANT		21024.17 KG
USABLE FUEL	5283.92	
USABLE OXIDIZER	14794.98	
FUEL TRAPPED	187.21	
OXID TRAPPED	520.66	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	222.89	

OXIDIZER TANKS (NO.= 1)	529.60
(TOROIDAL)	
INNER DIA= 1.387 M	
OUTER DIA= 4.267 M	
HEIGHT = 1.440 M	
VOLUME = 14.470 M3	
AVG THK = .00317 M	
FS = 1.50, FNOP= 1.50	
FUEL TANKS (NO.= 1)	232.43
(ELLIPSOIDAL)	
DIAMETER= 2.681 M	
LENGTH = 1.896 M	
VOLUME = 7.138 M3	
AVG THK = .00352 M	
FS = 1.50, FNOP= 1.30	
PRESSURANT	60.629
PRESSURANT TANKS (NO.= 1)	327.27
DIA= 1.4074 M	
VOL= 1.460 M3	
THK= .01188 M	
FS = 1.50, FNOP= 1.10	
OXIDIZER TANK INSULATION	58.86
ENGINES (NO.= 1)	49.90
COMPONENTS AND LINES	386.01
ENG. MOUNTS,SUPPORTS	1243.30
TOTAL WET SYSTEM MASS	23912.2
TOTAL BURNOUT MASS	3595.9
(INCL.NON-USABLE PROP. AND GAS)	
MASS FRACTION	.840
TOTAL IMPULSE	66456000.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2. MIN. LENGTH. PRESSURE FED. MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3284.1 N-S/KG

TOTAL PROPELLANT		21099.33 KG
USABLE FUEL	5037.92	
USABLE OXIDIZER	15113.77	
FUEL TRAPPED	178.33	
OXID TRAPPED	531.40	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	223.39	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		545.69
INNER DIA= 1.345 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.461 M		
VOLUME = 14.777 M3		
AVG THK = .00325 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		221.61
DIAMETER= 2.639 M		
LENGTH = 1.866 M		
VOLUME = 6.806 M3		
AVG THK = .00347 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		61.354
PRESSURANT TANKS (NO.= 1)		331.37
DIA= 1.4133 M		
VOL= 1.478 M3		
THK= .01192 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.27
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1243.30
TOTAL WET SYSTEM MASS		23997.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3608.2
MASS FRACTION		.840
TOTAL IMPULSE		66183109.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3253.7 N-S/KG

TOTAL PROPELLANT		21189.36 KG
USABLE FUEL	4818.82	
USABLE OXIDIZER	15420.21	
FUEL TRAPPED	170.57	
OXID TRAPPED	541.37	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	223.86	
OXIDIZER TANKS (NO.= 1)		561.66
(TOROIDAL)		
INNER DIA= 1.306 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.481 M		
VOLUME = 15.072 M3		
AVG THK = .00332 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		211.99
(ELLIPSOIDAL)		
DIAMETER= 2.600 M		
LENGTH = 1.839 M		
VOLUME = 6.510 M3		
AVG THK = .00342 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		62.079
PRESSURANT TANKS (NO.= 1)		335.45
DIA= 1.4190 M		
VOL= 1.496 M3		
THK= .01197 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.64
ENGINES (NO.= 1)		49.90
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1243.30
TOTAL WET SYSTEM MASS		24099.4
TOTAL BURNOUT MASS		3622.0
(INCL. NON-USABLE PROP. AND GAS)		
MASS FRACTION		.840
TOTAL IMPULSE		65854673.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3384.1 N-S/KG

TOTAL PROPELLANT		20407.51 KG
USABLE FUEL	5119.50	
USABLE OXIDIZER	14334.59	
FUEL TRAPPED	185.35	
OXID TRAPPED	515.07	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	222.16	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		508.07
INNER DIA= 1.444 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.412 M		
VOLUME = 14.043 M3		
AVG THK = .00308 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		225.72
DIAMETER= 2.655 M		
LENGTH = 1.878 M		
VOLUME = 6.932 M3		
AVG THK = .00349 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		58.793
PRESSURANT TANKS (NO.= 1)		317.35
DIA= 1.3930 M		
VOL= 1.415 M3		
THK= .01175 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		58.28
ENGINES (NO.= 1)		235.87
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1231.50
TOTAL WET SYSTEM MASS		23429.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3722.0
MASS FRACTION		.830
TOTAL IMPULSE		65837960.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3357.6 N-S/KG

.TOTAL PROPELLANT		20485.89 KG
USABLE FUEL	4882.39	
USABLE OXIDIZER	14647.18	
FUEL TRAPPED	176.69	
OXID TRAPPED	526.11	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	222.68	
OXIDIZER TANKS (NO.= 1)		523.20
(TOROIDAL)		
INNER DIA= 1.403 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.432 M		
VOLUME = 14.345 M3		
AVG THK = .00314 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		215.29
(ELLIPSOIDAL)		
DIAMETER= 2.614 M		
LENGTH = 1.848 M		
VOLUME = 6.612 M3		
AVG THK = .00344 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		59.510
PRESSURANT TANKS (NO.= 1)		321.40
DIA= 1.3989 M		
VOL= 1.434 M3		
THK= .01180 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		58.69
ENGINES (NO.= 1)		235.87
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1231.50
TOTAL WET SYSTEM MASS		23517.4
TOTAL BURNOUT MASS		3734.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.830
TOTAL IMPULSE		65576323.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MIN. LENGTH, PRESSURE FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3327.2 N-S/KG

TOTAL PROPELLANT		20575.40 KG
USABLE FUEL	4670.68	
USABLE OXIDIZER	14946.17	
FUEL TRAPPED	168.66	
OXID TRAPPED	535.89	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	223.16	
OXIDIZER TANKS (NO.= 1)		538.06
(TOROIDAL)		
INNER DIA= 1.365 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.451 M		
VOLUME = 14.633 M3		
AVG THK = .00321 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		205.97
(ELLIPSOIDAL)		
DIAMETER= 2.576 M		
LENGTH = 1.821 M		
VOLUME = 6.325 M3		
AVG THK = .00338 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		60.221
PRESSURANT TANKS (NO.= 1)		325.40
DIA= 1.4047 M		
VOL= 1.451 M3		
THK= .01185 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.08
ENGINES (NO.= 1)		235.87
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1231.50
TOTAL WET SYSTEM MASS		23617.5
TOTAL BURNOUT MASS		3746.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.831
TOTAL IMPULSE		65272981.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1241E+07	FINAL FU SYS PRESSURE =	.1241E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PUMP FED, MR = 2.8

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3334.1 N-S/KG

TOTAL PROPELLANT		21630.17 KG
USABLE FUEL	5446.32	
USABLE OXIDIZER	15249.70	
FUEL TRAPPED	189.43	
OXID TRAPPED	526.96	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	204.14	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		68.35
DIAMETER= 3.425 M		
LENGTH = 2.422 M		
VOLUME = 14.882 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		42.72
DIAMETER= 2.708 M		
LENGTH = 1.915 M		
VOLUME = 7.352 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.926
PRESSURANT TANKS (NO.= 1)		26.31
DIA= .6074 M		
VOL= .117 M3		
THK= .00513 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		43.82
ENGINES (NO.= 1)		37.65
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		1260.08
TOTAL WET SYSTEM MASS		23477.3
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2563.6
MASS FRACTION		.882
TOTAL IMPULSE		69005898.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3304.7 N-S/KG

TOTAL PROPELLANT		21713.71 KG
USABLE FUEL	5194.29	
USABLE OXIDIZER	15582.87	
FUEL TRAPPED	180.41	
OXID TRAPPED	537.61	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	204.92	
OXIDIZER TANKS (NO.= 1)		69.33
(ELLIPSOIDAL)		
DIAMETER= 3.450 M		
LENGTH = 2.439 M		
VOLUME = 15.202 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		41.39
(ELLIPSOIDAL)		
DIAMETER= 2.665 M		
LENGTH = 1.885 M		
VOLUME = 7.012 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.986
PRESSURANT TANKS (NO.= 1)		26.64
DIA= .6100 M		
VOL= .119 M3		
THK= .00515 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		44.45
ENGINES (NO.= 1)		37.65
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1260.08
TOTAL WET SYSTEM MASS		23561.6
TOTAL BURNOUT MASS		2565.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.882
TOTAL IMPULSE		68665193.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3285.1 N-S/KG

TOTAL PROPELLANT		21770.00 KG
USABLE FUEL	4959.85	
USABLE OXIDIZER	15871.53	
FUEL TRAPPED	172.27	
OXID TRAPPED	547.14	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	205.60	
OXIDIZER TANKS (NO.= 1)		70.18
(ELLIPSOIDAL)		
DIAMETER= 3.471 M		
LENGTH = 2.454 M		
VOLUME = 15.480 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		40.13
(ELLIPSOIDAL)		
DIAMETER= 2.625 M		
LENGTH = 1.856 M		
VOLUME = 6.696 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		5.036
PRESSURANT TANKS (NO.= 1)		26.92
DIA= .6121 M		
VOL= .120 M3		
THK= .00516 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		44.99
ENGINES (NO.= 1)		37.65
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1260.08
TOTAL WET SYSTEM MASS		23618.3
TOTAL BURNOUT MASS		2567.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.882
TOTAL IMPULSE		68435810.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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RP-1/LO2, MAX. PERF., PUMP FED,                 MR = 2.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3368.4 N-S/KG

TOTAL PROPELLANT                          20829.09 KG
  USABLE FUEL                    5243.03
  USABLE OXIDIZER               14680.48
  FUEL TRAPPED                    181.99
  OXID TRAPPED                    506.29
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26
  OXIDIZER BOILOFF                202.79

OXIDIZER TANKS (NO.= 1)                      66.66
 (ELLIPSOIDAL)
  DIAMETER=     3.383 M
  LENGTH  =     2.392 M
  VOLUME  =    14.332 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                          41.65
 (ELLIPSOIDAL)
  DIAMETER=     2.674 M
  LENGTH  =     1.891 M
  VOLUME  =     7.078 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   4.744

PRESSURANT TANKS (NO.= 1)                    25.34
  DIA=     .5998 M
  VOL=      .113 M3
  THK=    .00506 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                     42.73

ENGINES (NO.= 1)                             39.46

COMPONENTS AND LINES                        363.33
ENG. MOUNTS,SUPPORTS                       1250.55

TOTAL WET SYSTEM MASS                      22663.6
TOTAL BURNOUT MASS                          2522.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .879
TOTAL IMPULSE                          67113974.8 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3348.8 N-S/KG

TOTAL PROPELLANT		20886.83 KG
USABLE FUEL	4994.66	
USABLE OXIDIZER	14983.99	
FUEL TRAPPED	173.50	
OXID TRAPPED	516.65	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	203.51	

OXIDIZER TANKS (NO.= 1) 67.56
(ELLIPSOIDAL)
DIAMETER= 3.406 M
LENGTH = 2.408 M
VOLUME = 14.624 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 40.32
(ELLIPSOIDAL)
DIAMETER= 2.631 M
LENGTH = 1.860 M
VOLUME = 6.743 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT 4.796

PRESSURANT TANKS (NO.= 1) 25.63
DIA= .6021 M
VOL= .114 M3
THK= .00508 M
FS = 1.50, FNOP= 1.10

OXIDIZER TANK INSULATION 43.31

ENGINES (NO.= 1) 39.46

COMPONENTS AND LINES 363.33
ENG. MOUNTS,SUPPORTS 1250.55

TOTAL WET SYSTEM MASS 22721.8
TOTAL BURNOUT MASS 2525.1
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .879
TOTAL IMPULSE 66907913.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3319.4 N-S/KG

TOTAL PROPELLANT		20973.02 KG
USABLE FUEL	4776.67	
USABLE OXIDIZER	15285.34	
FUEL TRAPPED	165.78	
OXID TRAPPED	526.49	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	204.22	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 3.428 M LENGTH = 2.424 M VOLUME = . 14.915 M3 AVG THK = .00064 M FS = 1.50, FNOP= 1.30		68.46
FUEL TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 2.592 M LENGTH = 1.833 M VOLUME = 6.449 M3 AVG THK = .00064 M FS = 1.50, FNOP= 1.30		39.14
PRESSURANT		4.852
PRESSURANT TANKS (NO.= 1) DIA= .6045 M VOL= .116 M3 THK= .00510 M FS = 1.50, FNOP= 1.10		25.94
OXIDIZER TANK INSULATION		43.89
ENGINES (NO.= 1)		39.46
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1250.55
TOTAL WET SYSTEM MASS		22808.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2527.9
MASS FRACTION		.880
TOTAL IMPULSE		66596829.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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    RP-1/LO2, MAX. PERF., PUMP FED,               MR = 2.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3487.1 N-S/KG

TOTAL PROPELLANT                            20065.69 KG
  USABLE FUEL                      5046.12
  USABLE OXIDIZER                 14129.14
  FUEL TRAPPED                      173.83
  OXID TRAPPED                      484.28
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42
  OXIDIZER BOILOFF                  201.47

OXIDIZER TANKS (NO.= 1)                        65.01
 (ELLIPSOIDAL)
  DIAMETER=     3.341 M
  LENGTH  =     2.362 M
  VOLUME  =    13.804 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                            40.64
 (ELLIPSOIDAL)
  DIAMETER=     2.641 M
  LENGTH  =     1.868 M
  VOLUME  =     6.821 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                     4.570

PRESSURANT TANKS (NO.= 1)                      24.41
  DIA=     .5924 M
  VOL=      .109 M3
  THK=    .00500 M
  FS = 1.50,   FNOP= 1.10

OXIDIZER TANK INSULATION                       41.68

ENGINES (NO.= 1)                               97.98

COMPONENTS AND LINES                          363.33
ENG. MOUNTS,SUPPORTS                         1241.94

TOTAL WET SYSTEM MASS                        21945.2
TOTAL BURNOUT MASS                            2537.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .874
TOTAL IMPULSE                          66868804.8 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3469.4 N-S/KG

TOTAL PROPELLANT		20117.09 KG
USABLE FUEL	4806.06	
USABLE OXIDIZER	14418.19	
FUEL TRAPPED	166.01	
OXID TRAPPED	493.82	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	202.17	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		65.89
DIAMETER= 3.363 M		
LENGTH = 2.378 M		
VOLUME = 14.083 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		39.34
DIAMETER= 2.599 M		
LENGTH = 1.838 M		
VOLUME = 6.498 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.619
PRESSURANT TANKS (NO.= 1)		24.68
DIA= .5946 M		
VOL= .110 M3		
THK= .00502 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		42.24
ENGINES (NO.= 1)		97.98
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1241.94
TOTAL WET SYSTEM MASS		21997.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2539.8
MASS FRACTION		.874
TOTAL IMPULSE		66700289.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

RP-1/LO2, MAX. PERF., PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3450.8 N-S/KG

TOTAL PROPELLANT		20170.58 KG
USABLE FUEL	4589.58	
USABLE OXIDIZER	14686.64	
FUEL TRAPPED	158.32	
OXID TRAPPED	502.38	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	202.81	
OXIDIZER TANKS (NO.= 1)		66.69
(ELLIPSOIDAL)		
DIAMETER= 3.384 M		
LENGTH = 2.393 M		
VOLUME = 14.341 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		38.15
(ELLIPSOIDAL)		
DIAMETER= 2.559 M		
LENGTH = 1.810 M		
VOLUME = 6.206 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.666
PRESSURANT TANKS (NO.= 1)		24.95
DIA= .5967 M		
VOL= .111 M3		
THK= .00503 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		42.75
ENGINES (NO.= 1)		97.98
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		1241.94
TOTAL WET SYSTEM MASS		22051.0
TOTAL BURNOUT MASS		2541.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.874
TOTAL IMPULSE		66521431.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3334.1 N-S/KG

TOTAL PROPELLANT		21652.58 KG
USABLE FUEL	5443.17	
USABLE OXIDIZER	15240.89	
FUEL TRAPPED	193.54	
OXID TRAPPED	537.78	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	223.59	

OXIDIZER TANKS (NO.= 1) 106.97
(TOROIDAL)
INNER DIA= 1.329 M
OUTER DIA= 4.267 M
HEIGHT = 1.469 M
VOLUME = 14.901 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 42.72
(ELLIPSOIDAL)
DIAMETER= 2.708 M
LENGTH = 1.915 M
VOLUME = 7.353 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT 4.928

PRESSURANT TANKS (NO.= 1) 26.32
DIA= .6075 M
VOL= .117 M3
THK= .00513 M
FS = 1.50, FNOP= 1.10

OXIDIZER TANK INSULATION 59.43

ENGINES (NO.= 1) 37.65

COMPONENTS AND LINES 386.01
ENG. MOUNTS, SUPPORTS 1253.73

TOTAL WET SYSTEM MASS 23570.3
TOTAL BURNOUT MASS 2649.1
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .878
TOTAL IMPULSE 68966026.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3304.7 N-S/KG

TOTAL PROPELLANT		21736.42 KG
USABLE FUEL	5191.33	
USABLE OXIDIZER	15574.00	
FUEL TRAPPED	184.51	
OXID TRAPPED	548.88	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	224.10	
OXIDIZER TANKS (NO.= 1) (TOROIDAL) INNER DIA= 1.286 M, OUTER DIA= 4.267 M, HEIGHT = 1.491 M, VOLUME = 15.222 M3, AVG THK = .00064 M, FS = 1.50, FNOP= 1.50		107.70
FUEL TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 2.666 M, LENGTH = 1.885 M, VOLUME = 7.013 M3, AVG THK = .00064 M, FS = 1.50, FNOP= 1.30		41.39
PRESSURANT		4.988
PRESSURANT TANKS (NO.= 1) DIA= .6100 M, VOL= .119 M3, THK= .00515 M, FS = 1.50, FNOP= 1.10		26.65
OXIDIZER TANK INSULATION		59.83
ENGINES (NO.= 1)		37.65
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1253.73
TOTAL WET SYSTEM MASS		23654.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2651.3
MASS FRACTION		.878
TOTAL IMPULSE		68626081.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3285.1 N-S/KG

TOTAL PROPELLANT		21792.58 KG
USABLE FUEL	4957.06	
USABLE OXIDIZER	15862.61	
FUEL TRAPPED	175.91	
OXID TRAPPED	558.86	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
OXIDIZER BOILOFF	224.52	
OXIDIZER TANKS (NO.= 1)		109.11
(TOROIDAL)		
INNER DIA= 1.249 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.509 M		
VOLUME = 15.501 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		40.14
(ELLIPSOIDAL)		
DIAMETER= 2.625 M		
LENGTH = 1.856 M		
VOLUME = 6.697 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		5.038
PRESSURANT TANKS (NO.= 1)		26.93
DIA= .6122 M		
VOL= .120 M3		
THK= .00517 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		60.17
ENGINES (NO.= 1)		37.65
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1253.73
TOTAL WET SYSTEM MASS		23711.4
TOTAL BURNOUT MASS		2653.6
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.878
TOTAL IMPULSE		68397332.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 2.8

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3368.4 N-S/KG

TOTAL PROPELLANT		20852.59 KG
USABLE FUEL	5239.93	
USABLE OXIDIZER	14671.80	
FUEL TRAPPED	186.09	
OXID TRAPPED	517.57	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	222.69	
OXIDIZER TANKS (NO.= 1)		105.66
(TOROIDAL)		
INNER DIA= 1.402 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.432 M		
VOLUME = 14.353 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		41.65
(ELLIPSOIDAL)		
DIAMETER= 2.674 M		
LENGTH = 1.891 M		
VOLUME = 7.079 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.746
PRESSURANT TANKS (NO.= 1)		25.35
DIA= .5999 M		
VOL= .113 M3		
THK= .00506 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		58.70
ENGINES (NO.= 1)		39.46
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1243.75
TOTAL WET SYSTEM MASS		22757.9
TOTAL BURNOUT MASS		2609.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.875
TOTAL IMPULSE		67074296.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3348.8 N-S/KG

TOTAL PROPELLANT		20909.75 KG
USABLE FUEL	4991.75	
USABLE OXIDIZER	14975.24	
FUEL TRAPPED	177.15	
OXID TRAPPED	527.92	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	223.18	
OXIDIZER TANKS (NO.= 1)		106.37
(TOROIDAL)		
INNER DIA= 1.363 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.452 M		
VOLUME = 14.645 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		40.33
(ELLIPSOIDAL)		
DIAMETER= 2.631 M		
LENGTH = 1.861 M		
VOLUME = 6.744 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.798
PRESSURANT TANKS (NO.= 1)		25.64
DIA= .6022 M		
VOL= .114 M3		
THK= .00508 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.09
ENGINES (NO.= 1)		39.46
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1243.75
TOTAL WET SYSTEM MASS		22815.2
TOTAL BURNOUT MASS		2610.5
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.875
TOTAL IMPULSE		66868825.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3319.4 N-S/KG

TOTAL PROPELLANT		20995.79 KG
USABLE FUEL	4773.91	
USABLE OXIDIZER	15276.52	
FUEL TRAPPED	169.43	
OXID TRAPPED	537.76	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
OXIDIZER BOILOFF	223.65	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		107.05
INNER DIA= 1.324 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.471 M		
VOLUME = 14.935 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		39.15
DIAMETER= 2.592 M		
LENGTH = 1.833 M		
VOLUME = 6.450 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.854
PRESSURANT TANKS (NO.= 1)		25.95
DIA= .6046 M		
VOL= .116 M3		
THK= .00510 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		59.47
ENGINES (NO.= 1)		39.46
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1243.75
TOTAL WET SYSTEM MASS		22901.5
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2612.9
MASS FRACTION		.876
TOTAL IMPULSE		66558404.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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     RP-1/LO2, MIN. LENGTH, PUMP FED.                , MR = 2.8

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3487.1 N-S/KG

TOTAL PROPELLANT                          20109.43 KG
  USABLE FUEL                    5043.07
  USABLE OXIDIZER               14120.61
  FUEL TRAPPED                    183.40
  OXID TRAPPED                    509.69
  FUEL START-S/D LOSSES            15.42
  OXID START-S/D LOSSES            15.42
  OXIDIZER BOILOFF                221.80

OXIDIZER TANKS (NO.= 1)                     104.38
 (TOROIDAL)
  INNER DIA=    1.471 M
  OUTER DIA=    4.267 M
  HEIGHT   =    1.398 M
  VOLUME   =   13.839 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          40.67
 (ELLIPSOIDAL)
  DIAMETER=    2.642 M
  LENGTH  =    1.868 M
  VOLUME  =    6.830 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   4.572

PRESSURANT TANKS (NO.= 1)                    24.42
  DIA=    .5925 M
  VOL=     .109 M3
  THK=   .00500 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                     57.99

ENGINES (NO.= 1)                             97.98

COMPONENTS AND LINES                        386.01
ENG. MOUNTS,SUPPORTS                       1231.96

TOTAL WET SYSTEM MASS                      22057.4
TOTAL BURNOUT MASS                          2641.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .869
TOTAL IMPULSE                           66828425.1 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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     RP-1/LO2, MIN. LENGTH, PUMP FED,             MR = 3.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=3469.4 N-S/KG

TOTAL PROPELLANT                              20160.71 KG
  USABLE FUEL                        4803.19
  USABLE OXIDIZER                   14409.57
  FUEL TRAPPED                        174.67
  OXID TRAPPED                        520.14
  FUEL START-S/D LOSSES                15.42
  OXID START-S/D LOSSES                15.42
  OXIDIZER BOILOFF                    222.29

OXIDIZER TANKS (NO.= 1)                          105.09
 (TOROIDAL)
  INNER DIA=     1.434 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.417 M
  VOLUME    =   14.118 M3
  AVG THK   =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                               39.37
 (ELLIPSOIDAL)
  DIAMETER=     2.600 M
  LENGTH   =    1.838 M
  VOLUME   =    6.506 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        4.622

PRESSURANT TANKS (NO.= 1)                         24.70
  DIA=     .5947 M
  VOL=      .110 M3
  THK=    .00502 M
  FS = 1.50,  FNOP= 1.10

OXIDIZER TANK INSULATION                          58.38

ENGINES (NO.= 1)                                  97.98

COMPONENTS AND LINES                             386.01
ENG. MOUNTS,SUPPORTS                            1231.96

TOTAL WET SYSTEM MASS                           22108.8
TOTAL BURNOUT MASS                               2642.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .869
TOTAL IMPULSE                              66660424.7 N-S

             PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1034E+06    FINAL FU SYS PRESSURE    =  .1034E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

RP-1/LO2, MIN. LENGTH, PUMP FED, MR = 3.2

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3450.8 N-S/KG

TOTAL PROPELLANT		20214.07 KG
USABLE FUEL	4586.86	
USABLE OXIDIZER	14677.95	
FUEL TRAPPED	166.53	
OXID TRAPPED	529.16	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
OXIDIZER BOILOFF	222.73	
OXIDIZER TANKS (NO.= 1)		105.72
(TOROIDAL)		
INNER DIA= 1.399 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.434 M		
VOLUME = 14.377 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		38.18
(ELLIPSOIDAL)		
DIAMETER= 2.560 M		
LENGTH = 1.810 M		
VOLUME = 6.213 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		4.668
PRESSURANT TANKS (NO.= 1)		24.96
DIA= .5968 M		
VOL= .111 M3		
THK= .00504 M		
FS = 1.50, FNOP= 1.10		
OXIDIZER TANK INSULATION		58.74
ENGINES (NO.= 1)		97.98
COMPONENTS AND LINES		386.01
ENG. MOUNTS, SUPPORTS		1231.96
TOTAL WET SYSTEM MASS		22162.3
TOTAL BURNOUT MASS		2643.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.869
TOTAL IMPULSE		66482071.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3510.6 N-S/KG

TOTAL PROPELLANT		21211.34 KG
USABLE FUEL	4585.51	
USABLE OXIDIZER	15590.73	
FUEL TRAPPED	153.31	
OXID TRAPPED	567.02	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	80.01	
OXIDIZER BOILOFF	203.91	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		414.66
DIAMETER= 3.418 M		
LENGTH = 2.417 M		
VOLUME = 14.788 M3		
AVG THK = .00387 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		362.66
DIAMETER= 3.170 M		
LENGTH = 2.241 M		
VOLUME = 11.792 M3		
AVG THK = .00393 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		71.067
PRESSURANT TANKS (NO.= 1)		385.06
DIA= 1.4858 M		
VOL= 1.717 M3		
THK= .01254 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		26.27
OXIDIZER TANK INSULATION		43.64
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		24425.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3934.7
MASS FRACTION		.826
TOTAL IMPULSE		70834325.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		21346.55 KG
USABLE FUEL	4320.90	
USABLE OXIDIZER	15987.33	
FUEL TRAPPED	141.61	
OXID TRAPPED	581.99	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	79.05	
OXIDIZER BOILOFF	204.82	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		425.10
DIAMETER= 3.447 M		
LENGTH = ' 2.437 M		
VOLUME = 15.161 M3		
AVG THK = .00390 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		341.86
DIAMETER= 3.108 M		
LENGTH = 2.198 M		
VOLUME = 11.116 M3		
AVG THK = .00386 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		70.565
PRESSURANT TANKS (NO.= 1)		382.38
DIA= 1.4824 M		
VOL= 1.706 M3		
THK= .01251 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.25
OXIDIZER TANK INSULATION		44.37
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		554.74
ENG. MOUNTS, SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		24547.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3924.1
MASS FRACTION		.827
TOTAL IMPULSE		70301918.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PRESS FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3402.8 N-S/KG

TOTAL PROPELLANT		21510.40 KG
USABLE FUEL	4093.61	
USABLE OXIDIZER	16374.44	
FUEL TRAPPED	132.22	
OXID TRAPPED	595.36	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	78.21	
OXIDIZER BOILOFF	205.70	
OXIDIZER TANKS (NO.= 1)		435.27
(ELLIPSOIDAL)		
DIAMETER= 3.474 M		
LENGTH = 2.456 M		
VOLUME = 15.523 M3		
AVG THK = .00393 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		324.04
(ELLIPSOIDAL)		
DIAMETER= 3.053 M		
LENGTH = 2.159 M		
VOLUME = 10.537 M3		
AVG THK = .00379 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		70.261
PRESSURANT TANKS (NO.= 1)		380.78
DIA= 1.4803 M		
VOL= 1.698 M3		
THK= .01249 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.37
OXIDIZER TANK INSULATION		45.07
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		24701.2
TOTAL BURNOUT MASS		3918.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.829
TOTAL IMPULSE		69650868.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

```
   LCH4/LO2  MAX PERF  PRESS FED               MR=3.4

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3520.4 N-S/KG

TOTAL PROPELLANT                               20430.01 KG
  USABLE FUEL                         4423.48
  USABLE OXIDIZER                    15039.83
  FUEL TRAPPED                         144.07
  OXID TRAPPED                         529.43
  FUEL START-S/D LOSSES                  7.26
  OXID START-S/D LOSSES                  7.26
  FUEL BOILOFF                          78.48
  OXIDIZER BOILOFF                     200.20

OXIDIZER TANKS (NO.= 1)                          399.46
 (ELLIPSOIDAL)
  DIAMETER=     3.376 M
  LENGTH  =     2.387 M
  VOLUME  =    14.246 M3
  AVG THK =    .00382 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              349.08
 (ELLIPSOIDAL)
  DIAMETER=     3.130 M
  LENGTH  =     2.213 M
  VOLUME  =    11.351 M3
  AVG THK =    .00388 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       68.517

PRESSURANT TANKS (NO.= 1)                        371.25
  DIA=   1.4678 M
  VOL=    1.656 M3
  THK=   .01238 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              25.61
OXIDIZER TANK INSULATION                          42.56

ENGINES (NO.= 1)                                  47.63

COMPONENTS AND LINES                             554.74
ENG. MOUNTS,SUPPORTS                            1307.25

TOTAL WET SYSTEM MASS                           23596.1
TOTAL BURNOUT MASS                               3839.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .825
TOTAL IMPULSE                               68522264.7 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1172E+07    FINAL FU SYS PRESSURE    =  .1172E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3481.2 N-S/KG

TOTAL PROPELLANT		20540.44 KG
USABLE FUEL	4164.08	
USABLE OXIDIZER	15407.10	
FUEL TRAPPED	133.41	
OXID TRAPPED	542.75	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.53	
OXIDIZER BOILOFF	201.04	
OXIDIZER TANKS (NO.= 1)		409.12
(ELLIPSOIDAL)		
DIAMETER= 3.403 M		
LENGTH = 2.406 M		
VOLUME = 14.590 M3		
AVG THK = .00385 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		328.75
(ELLIPSOIDAL)		
DIAMETER= 3.068 M		
LENGTH = 2.169 M		
VOLUME = 10.690 M3		
AVG THK = .00381 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		67.965
PRESSURANT TANKS (NO.= 1)		368.31
DIA= 1.4639 M		
VOL= 1.643 M3		
THK= .01235 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.60
OXIDIZER TANK INSULATION		43.25
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		23692.1
TOTAL BURNOUT MASS		3827.8
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.826
TOTAL IMPULSE		68134308.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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LCH4/LO2  MAX PERF  PRESS FED              MR=4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3422.4 N-S/KG

TOTAL PROPELLANT                          20707.88 KG
  USABLE FUEL                    3946.90
  USABLE OXIDIZER               15787.59
  FUEL TRAPPED                    124.74
  OXID TRAPPED                    555.50
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26
  FUEL BOILOFF                     76.73
  OXIDIZER BOILOFF                201.91

OXIDIZER TANKS (NO.= 1)                     419.09
 (ELLIPSOIDAL)
  DIAMETER=     3.430 M
  LENGTH  =     2.426 M
  VOLUME  =    14.946 M3
  AVG THK =    .00388 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                         311.75
 (ELLIPSOIDAL)
  DIAMETER=     3.014 M
  LENGTH  =     2.131 M
  VOLUME  =    10.137 M3
  AVG THK =    .00374 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  67.704

PRESSURANT TANKS (NO.= 1)                   366.93
  DIA=    1.4621 M
  VOL=     1.637 M3
  THK=    .01234 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         23.75
OXIDIZER TANK INSULATION                     43.95

ENGINES (NO.= 1)                             47.63

COMPONENTS AND LINES                        554.74
ENG. MOUNTS,SUPPORTS                       1307.25

TOTAL WET SYSTEM MASS                      23850.7
TOTAL BURNOUT MASS                          3823.0
   (INCL.NON-USABLE PROP  AND GAS)

MASS FRACTION                                 .827
TOTAL IMPULSE                          67541666.5 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1172E+07    FINAL FU SYS PRESSURE    =  .1172E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT		19878.14 KG
USABLE FUEL	4304.20	
USABLE OXIDIZER	14634.29	
FUEL TRAPPED	139.63	
OXID TRAPPED	512.39	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	77.14	
OXIDIZER BOILOFF	196.87	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		388.66
DIAMETER= 3.345 M		
LENGTH = 2.365 M		
VOLUME = 13.861 M3		
AVG THK = .00379 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		339.67
DIAMETER= 3.101 M		
LENGTH = 2.193 M		
VOLUME = 11.045 M3		
AVG THK = .00385 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		66.675
PRESSURANT TANKS (NO.= 1)		361.27
DIA= 1.4545 M		
VOL= 1.611 M3		
THK= .01227 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.15
OXIDIZER TANK INSULATION		41.79
ENGINES (NO.= 1)		222.26
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1302.26
TOTAL WET SYSTEM MASS		23180.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3954.5
MASS FRACTION		.817
TOTAL IMPULSE		67417498.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3530.2 N-S/KG

TOTAL PROPELLANT		19961.97 KG
USABLE FUEL	4046.43	
USABLE OXIDIZER	14971.80	
FUEL TRAPPED	129.01	
OXID TRAPPED	524.98	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.20	
OXIDIZER BOILOFF	199.93	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		397.61
DIAMETER= 3.371 M		
LENGTH = 2.383 M		
VOLUME = 14.180 M3		
AVG THK = .00381 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		319.46
DIAMETER= 3.039 M		
LENGTH = 2.149 M		
VOLUME = 10.388 M3		
AVG THK = .00377 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		70.488
PRESSURANT TANKS (NO.= 1)		382.46
DIA= 1.4824 M		
VOL= 1.706 M3		
THK= .01251 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.14
OXIDIZER TANK INSULATION		42.43
ENGINES (NO.= 1)		222.26
COMPONENTS AND LINES		554.74
ENG. MOUNTS, SUPPORTS		1302.26
TOTAL WET SYSTEM MASS		23277.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3969.8
MASS FRACTION		.817
TOTAL IMPULSE		67141817.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PRESS FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		20164.09 KG
USABLE FUEL	3842.08	
USABLE OXIDIZER	15368.31	
FUEL TRAPPED	127.95	
OXID TRAPPED	538.12	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	75.46	
OXIDIZER BOILOFF	198.56	

OXIDIZER TANKS (NO.= 1) 407.94
(ELLIPSOIDAL)
DIAMETER= 3.400 M
LENGTH = 2.404 M
VOLUME = 14.549 M3
AVG THK = .00385 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 304.00
(ELLIPSOIDAL)
DIAMETER= 2.989 M
LENGTH = 2.113 M
VOLUME = 9.885 M3
AVG THK = .00371 M
FS = 1.50, FNOP= 1.30

PRESSURANT 65.913

PRESSURANT TANKS (NO.= 1) 357.22
DIA= 1.4491 M
VOL= 1.593 M3
THK= .01223 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	23.35
OXIDIZER TANK INSULATION	43.16
ENGINES (NO.= 1)	222.26
COMPONENTS AND LINES	554.74
ENG. MOUNTS, SUPPORTS	1302.26
TOTAL WET SYSTEM MASS	23444.9
TOTAL BURNOUT MASS	3946.9
(INCL.NON-USABLE PROP. AND GAS)	
MASS FRACTION	.819
TOTAL IMPULSE	66501476.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3510.6 N-S/KG

TOTAL PROPELLANT		21255.04 KG
USABLE FUEL	4582.84	
USABLE OXIDIZER	15581.65	
FUEL TRAPPED	159.24	
OXID TRAPPED	596.98	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	80.02	
OXIDIZER BOILOFF	223.47	
OXIDIZER TANKS (NO.= 1)		548.21
(TOROIDAL)		
INNER DIA= 1.339 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.464 M		
VOLUME = 14.825 M3		
AVG THK = .00326 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		362.90
(ELLIPSOIDAL)		
DIAMETER= 3.171 M		
LENGTH = 2.242 M		
VOLUME = 11.800 M3		
AVG THK = .00394 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		71.070
PRESSURANT TANKS (NO.= 1)		385.06
DIA= 1.4858 M		
VOL= 1.717 M3		
THK= .01254 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		26.28
OXIDIZER TANK INSULATION		59.33
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1305.44
TOTAL WET SYSTEM MASS		24637.0
TOTAL BURNOUT MASS		4138.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.818
TOTAL IMPULSE		70793072.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2   MIN LENGTH   PRESS FED   MR=3.7

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		21390.04 KG
USABLE FUEL	4318.42	
USABLE OXIDIZER	15978.17	
FUEL TRAPPED	146.62	
OXID TRAPPED	612.86	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	79.06	
OXIDIZER BOILOFF	224.06	
OXIDIZER TANKS (NO.= 1)		568.60
(TOROIDAL)		
INNER DIA= 1.289 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.489 M		
VOLUME = 15.197 M3		
AVG THK = .00335 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		342.05
(ELLIPSOIDAL)		
DIAMETER= 3.109 M		
LENGTH = 2.198 M		
VOLUME = 11.122 M3		
AVG THK = .00386 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		70.568
PRESSURANT TANKS (NO.= 1)		382.39
DIA= 1.4824 M		
VOL= 1.706 M3		
THK= .01251 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.26
OXIDIZER TANK INSULATION		59.80
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1305.44
TOTAL WET SYSTEM MASS		24767.8
TOTAL BURNOUT MASS		4137.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.819
TOTAL IMPULSE		70261647.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2   MIN LENGTH   PRESS FED   MR=4.0

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=3402.8 N-S/KG

TOTAL PROPELLANT		21553.67 KG
USABLE FUEL	4091.31	
USABLE OXIDIZER	16365.22	
FUEL TRAPPED	136.33	
OXID TRAPPED	627.13	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	78.22	
OXIDIZER BOILOFF	224.61	

OXIDIZER TANKS (NO.= 1) 589.34
(TOROIDAL)
INNER DIA= 1.241 M
OUTER DIA= 4.267 M
HEIGHT = 1.513 M
VOLUME = 15.560 M3
AVG THK = .00345 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 324.18
(ELLIPSOIDAL)
DIAMETER= 3.054 M
LENGTH = 2.159 M
VOLUME = 10.541 M3
AVG THK = .00379 M
FS = 1.50, FNOP= 1.30

PRESSURANT 70.264

PRESSURANT TANKS (NO.= 1) 380.79
DIA= 1.4803 M
VOL= 1.698 M3
THK= .01249 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	24.37
OXIDIZER TANK INSULATION	60.25
ENGINES (NO.= 1)	34.02
COMPONENTS AND LINES	589.67
ENG. MOUNTS, SUPPORTS	1305.44
TOTAL WET SYSTEM MASS	24932.0
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	4141.8
MASS FRACTION	.820
TOTAL IMPULSE	69611646.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3520.4 N-S/KG

TOTAL PROPELLANT		20491.98 KG
USABLE FUEL	4420.84	
USABLE OXIDIZER	15030.86	
FUEL TRAPPED	153.19	
OXID TRAPPED	573.98	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	78.50	
OXIDIZER BOILOFF	220.09	
OXIDIZER TANKS (NO.= 1)		520.70
(TOROIDAL)		
INNER DIA= 1.410 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.429 M		
VOLUME = 14.296 M3		
AVG THK = .00313 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		349.57
(ELLIPSOIDAL)		
DIAMETER= 3.131 M		
LENGTH = 2.214 M		
VOLUME = 11.367 M3		
AVG THK = .00389 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		68.522
PRESSURANT TANKS (NO.= 1)		371.26
DIA= 1.4678 M		
VOL= 1.656 M3		
THK= .01238 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.63
OXIDIZER TANK INSULATION		58.63
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		23817.2
TOTAL BURNOUT MASS		4052.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.817
TOTAL IMPULSE		68481392.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3481.2 N-S/KG

TOTAL PROPELLANT		20602.23 KG
USABLE FUEL	4161.63	
USABLE OXIDIZER	15398.04	
FUEL TRAPPED	141.16	
OXID TRAPPED	588.66	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.55	
OXIDIZER BOILOFF	220.66	
OXIDIZER TANKS (NO.= 1)		538.50
(TOROIDAL)		
INNER DIA= 1.364 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.452 M		
VOLUME = 14.641 M3		
AVG THK = .00322 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		329.15
(ELLIPSOIDAL)		
DIAMETER= 3.069 M		
LENGTH = 2.170 M		
VOLUME = 10.703 M3		
AVG THK = .00381 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		67.971
PRESSURANT TANKS (NO.= 1)		368.32
DIA= 1.4639 M		
VOL= 1.643 M3		
THK= .01235 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.62
OXIDIZER TANK INSULATION		59.09
ENGINES (NO.= 1)		47.63
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		23920.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		4048.4
MASS FRACTION		.818
TOTAL IMPULSE		68094234.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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LCH4/LO2  MIN LENGTH  PRESS FED                MR=4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3422.4 N-S/KG

TOTAL PROPELLANT                            20768.99 KG
  USABLE FUEL                      3944.61
  USABLE OXIDIZER                 15778.45
  FUEL TRAPPED                      131.12
  OXID TRAPPED                      602.32
  FUEL START-S/D LOSSES               7.26
  OXID START-S/D LOSSES               7.26
  FUEL BOILOFF                       76.74
  OXIDIZER BOILOFF                  221.23

OXIDIZER TANKS (NO.= 1)                         557.57
 (TOROIDAL)
  INNER DIA=     1.316 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.476 M
  VOLUME   =    14.998 M3
  AVG THK  =    .00330 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                             312.06
 (ELLIPSOIDAL)
  DIAMETER=     3.015 M
  LENGTH  =     2.132 M
  VOLUME  =    10.147 M3
  AVG THK =    .00374 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      67.710

PRESSURANT TANKS (NO.= 1)                       366.95
  DIA=    1.4621 M
  VOL=     1.637 M3
  THK=    .01234 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             23.76
OXIDIZER TANK INSULATION                         59.55

ENGINES (NO.= 1)                                 47.63

COMPONENTS AND LINES                            589.67
ENG. MOUNTS,SUPPORTS                           1293.65

TOTAL WET SYSTEM MASS                          24087.5
TOTAL BURNOUT MASS                              4052.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .819
TOTAL IMPULSE                              67502547.5 N-S

             PRESSURE SCHEDULE(N/M2   )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1172E+07   FINAL FU SYS PRESSURE    =  .1172E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PRESS FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT		19937.23 KG
USABLE FUEL	4301.60	
USABLE OXIDIZER	14625.44	
FUEL TRAPPED	148.29	
OXID TRAPPED	554.21	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	77.16	
OXIDIZER BOILOFF	216.93	
OXIDIZER TANKS (NO.= 1)		501.46
(TOROIDAL)		
INNER DIA= 1.461 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.403 M		
VOLUME = 13.909 M3		
AVG THK = .00305 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		340.12
(ELLIPSOIDAL)		
DIAMETER= 3.103 M		
LENGTH = 2.194 M		
VOLUME = 11.060 M3		
AVG THK = .00385 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		66.681
PRESSURANT TANKS (NO.= 1)		361.29
DIA= 1.4546 M		
VOL= 1.611 M3		
THK= .01227 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.17
OXIDIZER TANK INSULATION		58.09
ENGINES (NO.= 1)		222.26
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1283.67
TOTAL WET SYSTEM MASS		23385.6
TOTAL BURNOUT MASS		4150.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.809
TOTAL IMPULSE		67376704.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PRESS FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3530.2 N-S/KG

TOTAL PROPELLANT		20019.95 KG
USABLE FUEL	4044.29	
USABLE OXIDIZER	14963.88	
FUEL TRAPPED	136.31	
OXID TRAPPED	568.18	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.22	
OXIDIZER BOILOFF	217.47	
OXIDIZER TANKS (NO.= 1)		517.25
(TOROIDAL)		
INNER DIA= 1.419 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.424 M		
VOLUME = 14.228 M3		
AVG THK = .00312 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		319.85
(ELLIPSOIDAL)		
DIAMETER= 3.040 M		
LENGTH = 2.150 M		
VOLUME = 10.400 M3		
AVG THK = .00377 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		66.063
PRESSURANT TANKS (NO.= 1)		357.98
DIA= 1.4501 M		
VOL= 1.597 M3		
THK= .01224 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.16
OXIDIZER TANK INSULATION		58.53
ENGINES (NO.= 1)		222.26
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1283.67
TOTAL WET SYSTEM MASS		23459.4
TOTAL BURNOUT MASS		4143.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.810
TOTAL IMPULSE		67106288.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =0.	
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PRESS FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		20213.66 KG
USABLE FUEL	3839.82	
USABLE OXIDIZER	15359.27	
FUEL TRAPPED	127.04	
OXID TRAPPED	580.38	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	75.45	
OXIDIZER BOILOFF	218.08	

OXIDIZER TANKS (NO.= 1) 536.13
(TOROIDAL)
INNER DIA= 1.370 M
OUTER DIA= 4.267 M
HEIGHT = 1.449 M
VOLUME = 14.596 M3
AVG THK = .00320 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 303.76
(ELLIPSOIDAL)
DIAMETER= 2.988 M
LENGTH = 2.113 M
VOLUME = 9.877 M3
AVG THK = .00371 M
FS = 1.50, FNOP= 1.30

PRESSURANT 65.918

PRESSURANT TANKS (NO.= 1) 357.24
DIA= 1.4491 M
VOL= 1.593 M3
THK= .01223 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 23.34
OXIDIZER TANK INSULATION 59.03

ENGINES (NO.= 1) 222.26

COMPONENTS AND LINES 589.67
ENG. MOUNTS, SUPPORTS 1283.67

TOTAL WET SYSTEM MASS 23654.7
TOTAL BURNOUT MASS 4148.4
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .812
TOTAL IMPULSE 66462367.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1172E+07	FINAL FU SYS PRESSURE =	.1172E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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  LCH4/LO2  MAX PERF  PUMP FED             MR=3.4

VEHICLE MASS  =27215.5 KG ,  DELTA V=  4815.8 M/S   AVE. ISP=3549.8 N-S/KG

TOTAL PROPELLANT                               21103.85 KG
  USABLE FUEL                        4561.74
  USABLE OXIDIZER                   15509.92
  FUEL TRAPPED                        152.70
  OXID TRAPPED                        564.99
  FUEL START-S/D LOSSES                15.42
  OXID START-S/D LOSSES                15.42
  FUEL BOILOFF                         79.93
  OXIDIZER BOILOFF                    203.73

OXIDIZER TANKS (NO.= 1)                           67.84
 (ELLIPSOIDAL)
  DIAMETER=     3.413 M
  LENGTH  =     2.413 M
  VOLUME  =    14.713 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                               58.33
 (ELLIPSOIDAL)
  DIAMETER=     3.164 M
  LENGTH  =     2.238 M
  VOLUME  =    11.733 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        8.755

PRESSURANT TANKS (NO.= 1)                         47.34
  DIA=     .7388 M
  VOL=      .211 M3
  THK=    .00623 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              26.18
OXIDIZER TANK INSULATION                          43.49

ENGINES (NO.= 1)                                  35.38

COMPONENTS AND LINES                             554.29
ENG. MOUNTS,SUPPORTS                            1322.22

TOTAL WET SYSTEM MASS                           23267.7
TOTAL BURNOUT MASS                               2881.5
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .863
TOTAL IMPULSE                              71254532.0 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3520.4 N-S/KG

TOTAL PROPELLANT		21184.19 KG
USABLE FUEL	4287.29	
USABLE OXIDIZER	15862.97	
FUEL TRAPPED	140.74	
OXID TRAPPED	578.87	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	78.93	
OXIDIZER BOILOFF	204.54	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		68.85
DIAMETER= 3.438 M		
LENGTH = 2.431 M		
VOLUME = 15.045 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		55.99
DIAMETER= 3.100 M		
LENGTH = 2.192 M		
VOLUME = 11.032 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.670
PRESSURANT TANKS (NO.= 1)		46.89
DIA= .7364 M		
VOL= .209 M3		
THK= .00621 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.13
OXIDIZER TANK INSULATION		44.14
ENGINES (NO.= 1)		35.38
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		23345.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2881.2
MASS FRACTION		.863
TOTAL IMPULSE		70940717.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MAX PERF PUMP FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3471.4 N-S/KG

TOTAL PROPELLANT		21319.18 KG
USABLE FUEL	4056.40	
USABLE OXIDIZER	16225.60	
FUEL TRAPPED	131.26	
OXID TRAPPED	591.62	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	78.07	
OXIDIZER BOILOFF	205.37	
OXIDIZER TANKS (NO.= 1)		69.89
(ELLIPSOIDAL)		
DIAMETER= 3.464 M		
LENGTH = 2.449 M		
VOLUME = 15.385 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		53.98
(ELLIPSOIDAL)		
DIAMETER= 3.044 M		
LENGTH = 2.152 M		
VOLUME = 10.443 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.622
PRESSURANT TANKS (NO.= 1)		46.63
DIA= .7351 M		
VOL= .208 M3		
THK= .00620 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.22
OXIDIZER TANK INSULATION		44.80
ENGINES (NO.= 1)		35.38
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		23479.2
TOTAL BURNOUT MASS		2882.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.864
TOTAL IMPULSE		70410040.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PUMP FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT		20320.25 KG
USABLE FUEL	4399.21	
USABLE OXIDIZER	14957.32	
FUEL TRAPPED	143.45	
OXID TRAPPED	527.35	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	78.39	
OXIDIZER BOILOFF	200.01	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 3.370 M, LENGTH = 2.383 M, VOLUME = 14.169 M3, AVG THK = .00064 M, FS = 1.50, FNOP= 1.30		66.16
FUEL TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 3.124 M, LENGTH = 2.209 M, VOLUME = 11.290 M3, AVG THK = .00064 M, FS = 1.50, FNOP= 1.30		56.86
PRESSURANT		8.437
PRESSURANT TANKS (NO.= 1) DIA= .7298 M, VOL= .203 M3, THK= .00616 M, FS = 1.50, FNOP= 1.10		45.62
FUEL TANK INSULATION		25.52
OXIDIZER TANK INSULATION		42.41
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		22467.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2818.2
MASS FRACTION		.862
TOTAL IMPULSE		68905628.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3540.0 N-S/KG

TOTAL PROPELLANT		20374.81 KG
USABLE FUEL	4129.79	
USABLE OXIDIZER	15280.24	
FUEL TRAPPED	132.53	
OXID TRAPPED	539.57	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.41	
OXIDIZER BOILOFF	200.76	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		67.10
DIAMETER= 3.394 M		
LENGTH = 2.400 M		
VOLUME = 14.473 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		54.53
DIAMETER= 3.060 M		
LENGTH = 2.163 M		
VOLUME = 10.604 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.346
PRESSURANT TANKS (NO.= 1)		45.14
DIA= .7272 M		
VOL= .201 M3		
THK= .00614 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.47
OXIDIZER TANK INSULATION		43.01
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		22519.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2817.1
MASS FRACTION		.862
TOTAL IMPULSE		68715377.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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    LCH4/LO2   MAX PERF   PUMP FED                    MR=4.0

VEHICLE MASS   =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=3491.0 N-S/KG

TOTAL PROPELLANT                               20512.50 KG
  USABLE FUEL                       3908.88
  USABLE OXIDIZER                  15635.51
  FUEL TRAPPED                       123.76
  OXID TRAPPED                       551.68
  FUEL START-S/D LOSSES                7.26
  OXID START-S/D LOSSES                7.26
  FUEL BOILOFF                        76.59
  OXIDIZER BOILOFF                   201.57

OXIDIZER TANKS (NO.= 1)                           68.12
 (ELLIPSOIDAL)
  DIAMETER=     3.420 M
  LENGTH  =     2.418 M
  VOLUME  =    14.805 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                               52.59
 (ELLIPSOIDAL)
  DIAMETER=     3.004 M
  LENGTH  =     2.124 M
  VOLUME  =    10.041 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        8.303

PRESSURANT TANKS (NO.= 1)                         44.90
  DIA=     .7259 M
  VOL=      .200 M3
  THK=    .00612 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              23.60
OXIDIZER TANK INSULATION                          43.67

ENGINES (NO.= 1)                                  40.82

COMPONENTS AND LINES                             554.29
ENG. MOUNTS,SUPPORTS                            1307.25

TOTAL WET SYSTEM MASS                          22656.1
TOTAL BURNOUT MASS                              2819.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .863
TOTAL IMPULSE                               68232717.0 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.05

LCH4/LO2 MAX PERF PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4303.8 M/S AVE. ISP=3608.7 N-S/KG

TOTAL PROPELLANT		19816.36 KG
USABLE FUEL	4006.98	
USABLE OXIDIZER	14825.83	
FUEL TRAPPED	148.50	
OXID TRAPPED	540.48	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.93	
OXIDIZER BOILOFF	202.12	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		75.96
DIAMETER= 3.362 M		
LENGTH = 2.377 M		
VOLUME = 14.064 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		53.64
DIAMETER= 3.034 M		
LENGTH = 2.146 M		
VOLUME = 10.344 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.103
PRESSURANT TANKS (NO.= 1)		43.82
DIA= .7200 M		
VOL= .195 M3		
THK= .00608 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.07
OXIDIZER TANK INSULATION		42.20
ENGINES (NO.= 1)		64.41
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1318.59
TOTAL WET SYSTEM MASS		22001.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2874.1
MASS FRACTION		.856
TOTAL IMPULSE		67964694.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PUMP FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3647.9 N-S/KG

TOTAL PROPELLANT		19632.15 KG
USABLE FUEL	4249.81	
USABLE OXIDIZER	14449.36	
FUEL TRAPPED	138.22	
OXID TRAPPED	507.75	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.95	
OXIDIZER BOILOFF	196.45	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		64.65
DIAMETER= 3.331 M		
LENGTH = 2.356 M		
VOLUME = 13.689 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		55.57
DIAMETER= 3.089 M		
LENGTH = 2.184 M		
VOLUME = 10.908 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.152
PRESSURANT TANKS (NO.= 1)		44.08
DIA= .7215 M		
VOL= .197 M3		
THK= .00609 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.94
OXIDIZER TANK INSULATION		41.45
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1301.81
TOTAL WET SYSTEM MASS		21820.5
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2834.4
MASS FRACTION		.857
TOTAL IMPULSE		68215933.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3618.5 N-S/KG

TOTAL PROPELLANT		19713.39 KG
USABLE FUEL	3995.45	
USABLE OXIDIZER	14783.17	
FUEL TRAPPED	127.69	
OXID TRAPPED	520.23	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.01	
OXIDIZER BOILOFF	197.22	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		65.64
DIAMETER= 3.357 M		
LENGTH = 2.374 M		
VOLUME = 14.003 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		53.34
DIAMETER= 3.026 M		
LENGTH = 2.140 M		
VOLUME = 10.260 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.076
PRESSURANT TANKS (NO.= 1)		43.68
DIA= .7192 M		
VOL= .195 M3		
THK= .00607 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.94
OXIDIZER TANK INSULATION		42.08
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1301.81
TOTAL WET SYSTEM MASS		21899.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2834.2
MASS FRACTION		.857
TOTAL IMPULSE		67953323.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MAX PERF PUMP FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3569.5 N-S/KG

TOTAL PROPELLANT		19850.16 KG
USABLE FUEL	3782.41	
USABLE OXIDIZER	15129.66	
FUEL TRAPPED	119.12	
OXID TRAPPED	532.12	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	75.22	
OXIDIZER BOILOFF	198.02	
OXIDIZER TANKS (NO.= 1)		66.65
(ELLIPSOIDAL)		
DIAMETER= 3.382 M		
LENGTH = 2.392 M		
VOLUME = 14.327 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		51.45
(ELLIPSOIDAL)		
DIAMETER= 2.972 M		
LENGTH = 2.101 M		
VOLUME = 9.717 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.035
PRESSURANT TANKS (NO.= 1)		43.46
DIA= .7180 M		
VOL= .194 M3		
THK= .00606 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.09
OXIDIZER TANK INSULATION		42.73
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1301.81
TOTAL WET SYSTEM MASS		22035.1
TOTAL BURNOUT MASS		2836.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.858
TOTAL IMPULSE		67508902.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PUMP FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3549.8 N-S/KG

TOTAL PROPELLANT		21147.64	KG
USABLE FUEL	4559.08		
USABLE OXIDIZER	15500.86		
FUEL TRAPPED	158.62		
OXID TRAPPED	594.95		
FUEL START-S/D LOSSES	15.42		
OXID START-S/D LOSSES	15.42		
FUEL BOILOFF	79.94		
OXIDIZER BOILOFF	223.35		
OXIDIZER TANKS (NO.= 1)		106.61	
(TOROIDAL)			
INNER DIA= 1.349 M			
OUTER DIA= 4.267 M			
HEIGHT = 1.459 M			
VOLUME = 14.750 M3			
AVG THK = .00064 M			
FS = 1.50, FNOP= 1.50			
FUEL TANKS (NO.= 1)		58.36	
(ELLIPSOIDAL)			
DIAMETER= 3.165 M			
LENGTH = 2.238 M			
VOLUME = 11.741 M3			
AVG THK = .00064 M			
FS = 1.50, FNOP= 1.30			
PRESSURANT		8.756	
PRESSURANT TANKS (NO.= 1)		47.34	
DIA= .7388 M			
VOL= .211 M3			
THK= .00623 M			
FS = 1.50, FNOP= 1.10			
FUEL TANK INSULATION		26.19	
OXIDIZER TANK INSULATION		59.23	
ENGINES (NO.= 1)		35.38	
COMPONENTS AND LINES		589.67	
ENG. MOUNTS, SUPPORTS		1304.99	
TOTAL WET SYSTEM MASS		23384.2	
TOTAL BURNOUT MASS		2990.1	
(INCL.NON-USABLE PROP. AND GAS)			
MASS FRACTION		.858	
TOTAL IMPULSE		71212900.9	N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=3520.4 N-S/KG

TOTAL PROPELLANT		21227.81 KG
USABLE FUEL	4284.82	
USABLE OXIDIZER	15853.84	
FUEL TRAPPED	145.76	
OXID TRAPPED	609.74	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	78.94	
OXIDIZER BOILOFF	223.88	
OXIDIZER TANKS (NO.= 1)		107.38
(TOROIDAL)		
INNER DIA= 1.305 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.481 M		
VOLUME = 15.082 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		56.01
(ELLIPSOIDAL)		
DIAMETER= 3.101 M		
LENGTH = 2.193 M		
VOLUME = 11.038 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.671
PRESSURANT TANKS (NO.= 1)		46.89
DIA= .7365 M		
VOL= .209 M3		
THK= .00621 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.13
OXIDIZER TANK INSULATION		59.66
ENGINES (NO.= 1)		35.38
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1304.99
TOTAL WET SYSTEM MASS		23461.6
TOTAL BURNOUT MASS		2989.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.858
TOTAL IMPULSE		70899867.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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    LCH4/LO2  MIN LENGTH  PUMP FED              MR4.0

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S    AVE. ISP=3471.4 N-S/KG

TOTAL PROPELLANT                               21362.60 KG
  USABLE FUEL                        4054.10
  USABLE OXIDIZER                   16216.40
  FUEL TRAPPED                        135.36
  OXID TRAPPED                        623.40
  FUEL START-S/D LOSSES                15.42
  OXID START-S/D LOSSES                15.42
  FUEL BOILOFF                         78.08
  OXIDIZER BOILOFF                    224.41

OXIDIZER TANKS (NO.= 1)                          108.51
 (TOROIDAL)
  INNER DIA=     1.259 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.504 M
  VOLUME   =.   15.422 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                               53.99
 (ELLIPSOIDAL)
  DIAMETER=     3.044 M
  LENGTH  =     2.153 M
  VOLUME  =    10.448 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        8.623

PRESSURANT TANKS (NO.= 1)                        46.63
  DIA=     .7351 M
  VOL=      .208 M3
  THK=    .00620 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             24.23
OXIDIZER TANK INSULATION                         60.08

ENGINES (NO.= 1)                                 35.38

COMPONENTS AND LINES                            589.67
ENG. MOUNTS,SUPPORTS                           1304.99

TOTAL WET SYSTEM MASS                          23594.7
TOTAL BURNOUT MASS                              2990.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .859
TOTAL IMPULSE                              70370128.5 N-S

             PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PUMP FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3559.7 N-S/KG

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TOTAL PROPELLANT                              20382.31 KG
  USABLE FUEL                      4396.58
  USABLE OXIDIZER                 14948.37
  FUEL TRAPPED                      152.57
  OXID TRAPPED                      571.90
  FUEL START-S/D LOSSES               7.26
  OXID START-S/D LOSSES               7.26
  FUEL BOILOFF                       78.41
  OXIDIZER BOILOFF                  219.96

OXIDIZER TANKS (NO.= 1)                          105.34
 (TOROIDAL)
  INNER DIA=     1.420 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.424 M
  VOLUME    =   14.220 M3
  AVG THK   =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                               56.91
 (ELLIPSOIDAL)
  DIAMETER=     3.126 M
  LENGTH   =    2.210 M
  VOLUME   =   11.306 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                         8.439

PRESSURANT TANKS (NO.= 1)                         45.63
  DIA=     .7298 M
  VOL=      .204 M3
  THK=    .00616 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              25.54
OXIDIZER TANK INSULATION                          58.52

ENGINES (NO.= 1)                                  40.82

COMPONENTS AND LINES                             589.67
ENG. MOUNTS,SUPPORTS                            1293.65

TOTAL WET SYSTEM MASS                          22606.8
TOTAL BURNOUT MASS                              2949.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .856
TOTAL IMPULSE                               68864404.4 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3540.0 N-S/KG

TOTAL PROPELLANT		20436.73 KG
USABLE FUEL	4127.35	
USABLE OXIDIZER	15271.21	
FUEL TRAPPED	140.28	
OXID TRAPPED	585.48	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	77.43	
OXIDIZER BOILOFF	220.47	
OXIDIZER TANKS (NO.= 1)		106.08
(TOROIDAL)		
INNER DIA= 1.379 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.444 M		
VOLUME = 14.524 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		54.57
(ELLIPSOIDAL)		
DIAMETER= 3.061 M		
LENGTH = 2.164 M		
VOLUME = 10.617 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.348
PRESSURANT TANKS (NO.= 1)		45.14
DIA= .7272 M		
VOL= .201 M3		
THK= .00614 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.49
OXIDIZER TANK INSULATION		58.93
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		22658.4
TOTAL BURNOUT MASS		2947.5
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.856
TOTAL IMPULSE		68674765.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.05

LCH4/LO2 MIN LENGTH PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4303.8 M/S AVE. ISP=3608.7 N-S/KG

TOTAL PROPELLANT		19831.45 KG
USABLE FUEL	4004.58	
USABLE OXIDIZER	14816.96	
FUEL TRAPPED	138.52	
OXID TRAPPED	540.39	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	77.92	
OXIDIZER BOILOFF	222.23	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		105.00
INNER DIA= 1.438 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.414 M		
VOLUME = 14.082 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		53.60
DIAMETER= 3.033 M		
LENGTH = 2.145 M		
VOLUME = 10.334 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.112
PRESSURANT TANKS (NO.= 1)		43.87
DIA= .7203 M		
VOL= .196 M3		
THK= .00608 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.05
OXIDIZER TANK INSULATION		58.33
ENGINES (NO.= 1)		64.41
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1356.24
TOTAL WET SYSTEM MASS		22134.7
TOTAL BURNOUT MASS (INCL. NON-USABLE PROP. AND GAS)		2982.2
MASS FRACTION		.850
TOTAL IMPULSE		67924062.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MIN LENGTH PUMP FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=3491.0 N-S/KG

TOTAL PROPELLANT		20573.78 KG
USABLE FUEL	3906.60	
USABLE OXIDIZER	15626.40	
FUEL TRAPPED	130.14	
OXID TRAPPED	598.50	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	76.60	
OXIDIZER BOILOFF	221.01	
OXIDIZER TANKS (NO.= 1)		106.86
(TOROIDAL)		
INNER DIA= 1.335 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.466 M		
VOLUME = 14.857 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		52.62
(ELLIPSOIDAL)		
DIAMETER= 3.005 M		
LENGTH = 2.125 M		
VOLUME = 10.052 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.304
PRESSURANT TANKS (NO.= 1)		44.91
DIA= .7259 M		
VOL= .200 M3		
THK= .00613 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.61
OXIDIZER TANK INSULATION		59.37
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		22793.6
TOTAL BURNOUT MASS		2948.5
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.857
TOTAL IMPULSE		68192954.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PUMP FED MR=3.4

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3647.9 N-S/KG

TOTAL PROPELLANT		19691.90 KG
USABLE FUEL	4247.22	
USABLE OXIDIZER	14440.56	
FUEL TRAPPED	146.89	
OXID TRAPPED	550.02	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.97	
OXIDIZER BOILOFF	216.63	
OXIDIZER TANKS (NO.= 1)		104.12
(TOROIDAL)		
INNER DIA= 1.484 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.391 M		
VOLUME = 13.738 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		55.62
(ELLIPSOIDAL)		
DIAMETER= 3.090 M		
LENGTH = 2.185 M		
VOLUME = 10.923 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.154
PRESSURANT TANKS (NO.= 1)		44.09
DIA= .7215 M		
VOL= .197 M3		
THK= .00609 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.96
OXIDIZER TANK INSULATION		57.85
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1284.12
TOTAL WET SYSTEM MASS		21953.9
TOTAL BURNOUT MASS		2958.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.851
TOTAL IMPULSE		68174398.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PUMP FED MR=3.7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3618.5 N-S/KG

TOTAL PROPELLANT		19772.99 KG
USABLE FUEL	3993.05	
USABLE OXIDIZER	14774.28	
FUEL TRAPPED	134.98	
OXID TRAPPED	563.87	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	76.03	
OXIDIZER BOILOFF	217.17	
OXIDIZER TANKS (NO.= 1) (TOROIDAL) INNER DIA= 1.442 M; OUTER DIA= 4.267 M; HEIGHT = 1.412 M; VOLUME = 14.052 M3; AVG THK = .00064 M; FS = 1.50, FNOP= 1.50		104.92
FUEL TANKS (NO.= 1) (ELLIPSOIDAL) DIAMETER= 3.027 M; LENGTH = 2.141 M; VOLUME = 10.272 M3; AVG THK = .00064 M; FS = 1.50, FNOP= 1.30		53.39
PRESSURANT		8.078
PRESSURANT TANKS (NO.= 1) DIA= .7193 M; VOL= .195 M3; THK= .00607 M; FS = 1.50, FNOP= 1.10		43.68
FUEL TANK INSULATION		23.96
OXIDIZER TANK INSULATION		58.29
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1284.12
TOTAL WET SYSTEM MASS		22032.5
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2958.4
MASS FRACTION		.852
TOTAL IMPULSE		67912424.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PUMP FED MR=4.0

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=3569.5 N-S/KG

TOTAL PROPELLANT		19907.29 KG
USABLE FUEL	3780.17	
USABLE OXIDIZER	15120.67	
FUEL TRAPPED	125.50	
OXID TRAPPED	574.39	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	75.23	
OXIDIZER BOILOFF	217.72	
OXIDIZER TANKS (NO.= 1)		105.72
(TOROIDAL)		
INNER DIA= 1.399 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.434 M		
VOLUME = 14.375 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		51.48
(ELLIPSOIDAL)		
DIAMETER= 2.973 M		
LENGTH = 2.102 M		
VOLUME = 9.727 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.037
PRESSURANT TANKS (NO.= 1)		43.47
DIA= .7181 M		
VOL= .194 M3		
THK= .00606 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		23.10
OXIDIZER TANK INSULATION		58.73
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1284.12
TOTAL WET SYSTEM MASS		22165.1
TOTAL BURNOUT MASS		2957.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.853
TOTAL IMPULSE		67468788.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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   LH2/LO2  MAX PERF  PRESS FED              MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4373.6 N-S/KG

TOTAL PROPELLANT                            19066.74 KG
  USABLE FUEL                     3001.63
  USABLE OXIDIZER                15008.13
  FUEL TRAPPED                     113.14
  OXID TRAPPED                     552.39
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42
  FUEL BOILOFF                     158.02
  OXIDIZER BOILOFF                 202.58

OXIDIZER TANKS (NO.= 1)                       399.50
 (ELLIPSOIDAL)
  DIAMETER=     3.376 M
  LENGTH  =     2.387 M
  VOLUME  =    14.248 M3
  AVG THK =    .00382 M
  FS = 1.50,   FNOP= 1.30

FUEL TANKS (NO.= 1)                          1420.13
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     4.384 M
  VOLUME  =    48.311 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,   FNOP= 1.30

PRESSURANT                                    148.780

PRESSURANT TANKS (NO.= 1)                     799.34
  DIA=    1.8954 M
  VOL=     3.565 M3
  THK=    .01599 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                          113.80
OXIDIZER TANK INSULATION                       42.57

ENGINES (NO.= 1)                               36.29

COMPONENTS AND LINES                          554.74
ENG. MOUNTS,SUPPORTS                         1322.22

TOTAL WET SYSTEM MASS                        23904.1
TOTAL BURNOUT MASS                            5502.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .753
TOTAL IMPULSE                            78770443.8 N-S

             PRESSURE SCHEDULE(N/M2   )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =    .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =    .1069E+07    FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =    .1138E+07    FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MAX PERF PRESS FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4295.1 N-S/KG

TOTAL PROPELLANT		19247.87 KG
USABLE FUEL	2598.67	
USABLE OXIDIZER	15592.03	
FUEL TRAPPED	97.91	
OXID TRAPPED	572.07	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	152.42	
OXIDIZER BOILOFF	203.93	

OXIDIZER TANKS (NO.= 1) 414.82
(ELLIPSOIDAL)
DIAMETER= 3.419 M
LENGTH = 2.417 M
VOLUME = 14.794 M3
AVG THK = .00387 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 1241.25
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.948 M
VOLUME = 42.085 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 131.183

PRESSURANT TANKS (NO.= 1) 704.37
DIA= 1.8171 M
VOL= 3.142 M3
THK= .01533 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	103.54
OXIDIZER TANK INSULATION	43.65
ENGINES (NO.= 1)	34.02
COMPONENTS AND LINES	554.74
ENG. MOUNTS,SUPPORTS	1322.22
TOTAL WET SYSTEM MASS	23797.7
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	5219.8
MASS FRACTION	.764
TOTAL IMPULSE	78134701.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MAX PERF PRESS FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4177.4 N-S/KG

TOTAL PROPELLANT		19526.89 KG
USABLE FUEL	2308.20	
USABLE OXIDIZER	16157.42	
FUEL TRAPPED	86.92	
OXID TRAPPED	589.91	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	148.38	
OXIDIZER BOILOFF	205.21	
OXIDIZER TANKS (NO.= 1)		429.62
(ELLIPSOIDAL)		
DIAMETER= 3.459 M		
LENGTH = 2.446 M		
VOLUME = 15.322 M3		
AVG THK = .00391 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		1112.30
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.635 M		
VOLUME = 37.596 M3		
DOME THK= .00514 M		
CYL THK = .00852 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		118.596
PRESSURANT TANKS (NO.= 1)		636.42
DIA= 1.7567 M		
VOL= 2.839 M3		
THK= .01482 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		96.15
OXIDIZER TANK INSULATION		44.68
ENGINES (NO.= 1)		31.75
COMPONENTS AND LINES		554.74
ENG. MOUNTS,SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		23873.4
TOTAL BURNOUT MASS		5023.3
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.773
TOTAL IMPULSE		77142541.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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   LH2/LO2   MAX PERF   PRESS FED              MR=5

 VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4383.4 N-S/KG

 TOTAL PROPELLANT                             18260.31 KG
   USABLE FUEL                       2879.08
   USABLE OXIDIZER                  14395.41
   FUEL TRAPPED                       104.90
   OXID TRAPPED                       513.24
   FUEL START-S/D LOSSES                7.26
   OXID START-S/D LOSSES                7.26
   FUEL BOILOFF                       154.45
   OXIDIZER BOILOFF                   198.71

 OXIDIZER TANKS (NO.= 1)                         382.69
  (ELLIPSOIDAL)
   DIAMETER=     3.328 M
   LENGTH  =     2.353 M
   VOLUME  =    13.648 M3
   AVG THK =    .00377 M
   FS = 1.50,   FNOP= 1.30

 FUEL TANKS (NO.= 1)                            1359.97
  (CYLINDRICAL/SQRT(2) ELLIPTICAL)
   DIAMETER=     4.267 M
   LENGTH  =     4.237 M
   VOLUME  =    46.217 M3
   DOME THK=    .00514 M
   CYL THK =    .00852 M
   FS = 1.50,   FNOP= 1.30

 PRESSURANT                                      142.526

 PRESSURANT TANKS (NO.= 1)                       765.76
   DIA=    1.8685 M
   VOL=     3.415 M3
   THK=    .01577 M
   FS = 1.50,   FNOP= 1.10

 FUEL TANK INSULATION                            110.35
 OXIDIZER TANK INSULATION                         41.36

 ENGINES (NO.= 1)                                 54.43

 COMPONENTS AND LINES                            554.74
 ENG. MOUNTS,SUPPORTS                           1307.25

 TOTAL WET SYSTEM MASS                          22979.4
 TOTAL BURNOUT MASS                              5337.2
    (INCL.NON-USABLE PROP. AND GAS)

 MASS FRACTION                                      .752
 TOTAL IMPULSE                             75723939.4 N-S

              PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

 GAS TANK LOCK-UP PRESSURE =    .2482E+08   INITIAL CHAMBER PRESSURE =0.
 INITIAL OX SYS PRESSURE   =    .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
 INITIAL FU SYS PRESSURE   =    .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MAX PERF PRESS FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4304.9 N-S/KG

TOTAL PROPELLANT		18442.05 KG
USABLE FUEL	2493.68	
USABLE OXIDIZER	14962.09	
FUEL TRAPPED	91.03	
OXID TRAPPED	531.58	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	149.13	
OXIDIZER BOILOFF	200.03	

OXIDIZER TANKS (NO.= 1) 397.54
(ELLIPSOIDAL)
DIAMETER= 3.371 M
LENGTH = 2.383 M
VOLUME = 14.178 M3
AVG THK = .00381 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 1189.20
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.822 M
VOLUME = 40.273 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 125.702

PRESSURANT TANKS (NO.= 1) 674.96
DIA= 1.7915 M
VOL= 3.010 M3
THK= .01512 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	100.56
OXIDIZER TANK INSULATION	42.43
ENGINES (NO.= 1)	49.90
COMPONENTS AND LINES	554.74
ENG. MOUNTS,SUPPORTS	1307.25
TOTAL WET SYSTEM MASS	22884.3
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	5064.9
MASS FRACTION	.763
TOTAL IMPULSE	75149127.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MAX PERF PRESS FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4187.2 N-S/KG

TOTAL PROPELLANT		18722.49 KG
USABLE FUEL	2216.48	
USABLE OXIDIZER	15515.39	
FUEL TRAPPED	80.83	
OXID TRAPPED	548.66	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	145.31	
OXIDIZER BOILOFF	201.30	
OXIDIZER TANKS (NO.= 1)		412.01
(ELLIPSOIDAL)		
DIAMETER= 3.411 M		
LENGTH = 2.412 M		
VOLUME = 14.694 M3		
AVG THK = .00386 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		1066.27
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.523 M		
VOLUME = 35.994 M3		
DOME THK= .00514 M		
CYL THK = .00852 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		113.699
PRESSURANT TANKS (NO.= 1)		610.16
DIA= 1.7322 M		
VOL= 2.721 M3		
THK= .01462 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		93.51
OXIDIZER TANK INSULATION		43.45
ENGINES (NO.= 1)		45.36
COMPONENTS AND LINES		554.74
ENG. MOUNTS, SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		22969.0
TOTAL BURNOUT MASS		4876.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.772
TOTAL IMPULSE		74251127.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MAX PERF PRESS FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4442.2 N-S/KG

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TOTAL PROPELLANT                             17671.76 KG
  USABLE FUEL                  2785.94
  USABLE OXIDIZER             13929.71
  FUEL TRAPPED                  101.10
  OXID TRAPPED                  494.70
  FUEL START-S/D LOSSES           6.80
  OXID START-S/D LOSSES           6.80
  FUEL BOILOFF                  151.45
  OXIDIZER BOILOFF              195.24

OXIDIZER TANKS (NO.= 1)                        370.33
 (ELLIPSOIDAL)
  DIAMETER=    3.292 M
  LENGTH  =    2.328 M
  VOLUME  =   13.207 M3
  AVG THK =   .00373 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                           1317.60
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    4.134 M
  VOLUME  =   44.742 M3
  DOME THK=   .00514 M
  CYL THK =   .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     137.982

PRESSURANT TANKS (NO.= 1)                      741.35
  DIA=   1.8484 M
  VOL=    3.307 M3
  THK=   .01560 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                           107.92
OXIDIZER TANK INSULATION                        40.47

ENGINES (NO.= 1)                               238.14

COMPONENTS AND LINES                           554.74
ENG. MOUNTS,SUPPORTS                          1301.81

TOTAL WET SYSTEM MASS                         22482.1
TOTAL BURNOUT MASS                             5406.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .744
TOTAL IMPULSE                             74257814.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =  .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   LH2/LO2  MAX PERF  PRESS FED             MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=4383.4 N-S/KG

TOTAL PROPELLANT                           17805.40 KG
  USABLE FUEL                      2407.14
  USABLE OXIDIZER                 14442.87
  FUEL TRAPPED                       87.40
  OXID TRAPPED                      511.69
  FUEL START-S/D LOSSES               6.80
  OXID START-S/D LOSSES               6.80
  FUEL BOILOFF                      146.26
  OXIDIZER BOILOFF                  196.44

OXIDIZER TANKS (NO.= 1)                      383.79
 (ELLIPSOIDAL)
  DIAMETER=     3.331 M
  LENGTH  =     2.356 M
  VOLUME  =    13.687 M3
  AVG THK =    .00377 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                         1149.73
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.726 M
  VOLUME  =    38.899 M3
  DOME THK=    .00514 M
  CYL THK =    .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   121.419

PRESSURANT TANKS (NO.= 1)                    651.97
  DIA=    1.7709 M
  VOL=     2.908 M3
  THK=    .01494 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                          98.30
OXIDIZER TANK INSULATION                      41.44

ENGINES (NO.= 1)                             233.60

COMPONENTS AND LINES                         554.74
ENG. MOUNTS,SUPPORTS                        1301.81

TOTAL WET SYSTEM MASS                       22342.2
TOTAL BURNOUT MASS                           5135.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .754
TOTAL IMPULSE                           73863206.1 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2   MAX PERF   PRESS FED   MR=7

VEHICLE MASS =27215.5 KG   DELTA V= 4291.6 M/S   AVE. ISP=4285.3 N-S/KG

TOTAL PROPELLANT		18034.39 KG
USABLE FUEL	2134.50	
USABLE OXIDIZER	14941.48	
FUEL TRAPPED	77.31	
OXID TRAPPED	527.40	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	142.52	
OXIDIZER BOILOFF	197.59	

OXIDIZER TANKS (NO.= 1)	396.84
(ELLIPSOIDAL)	
DIAMETER= 3.369 M	
LENGTH = 2.382 M	
VOLUME = 14.153 M3	
AVG THK = .00381 M	
FS = 1.50, FNOP= 1.30	
FUEL TANKS (NO.= 1)	1028.81
(CYLINDRICAL/SQRT(2) ELLIPTICAL)	
DIAMETER= 4.267 M	
LENGTH = 3.431 M	
VOLUME = 34.690 M3	
DOME THK= .00514 M	
CYL THK = .00852 M	
FS = 1.50, FNOP= 1.30	
PRESSURANT	109.585
PRESSURANT TANKS (NO.= 1)	588.09
DIA= 1.7111 M	
VOL= 2.623 M3	
THK= .01444 M	
FS = 1.50, FNOP= 1.10	
FUEL TANK INSULATION	91.36
OXIDIZER TANK INSULATION	42.38
ENGINES (NO.= 1)	226.80
COMPONENTS AND LINES	554.74
ENG. MOUNTS, SUPPORTS	1301.81
TOTAL WET SYSTEM MASS	22374.8
TOTAL BURNOUT MASS	4945.1
(INCL.NON-USABLE PROP. AND GAS)	
MASS FRACTION	.763
TOTAL IMPULSE	73179157.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MIN LENGTH PRESS FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4373.6 N-S/KG

TOTAL PROPELLANT		19111.91 KG
USABLE FUEL	2999.83	
USABLE OXIDIZER	14999.16	
FUEL TRAPPED	119.07	
OXID TRAPPED	582.35	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	158.08	
OXIDIZER BOILOFF	222.58	
OXIDIZER TANKS (NO.= 1)		520.13
(TOROIDAL)		
INNER DIA= 1.411 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.428 M		
VOLUME = 14.285 M3		
AVG THK = .00313 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		1421.90
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 4.388 M		
VOLUME = 48.373 M3		
DOME THK= .00514 M		
CYL THK = .00852 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		148.717
PRESSURANT TANKS (NO.= 1)		798.95
DIA= 1.8951 M		
VOL= 3.564 M3		
THK= .01599 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		113.90
OXIDIZER TANK INSULATION		58.61
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1305.44
TOTAL WET SYSTEM MASS		24105.5
TOTAL BURNOUT MASS		5695.0
(INCL. NON-USABLE PROP. AND GAS)		
MASS FRACTION		.747
TOTAL IMPULSE		78723341.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MIN LENGTH PRESS FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4295.1 N-S/KG

TOTAL PROPELLANT		19292.72 KG
USABLE FUEL	2597.15	
USABLE OXIDIZER	15582.91	
FUEL TRAPPED	102.93	
OXID TRAPPED	602.93	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	152.47	
OXIDIZER BOILOFF	223.48	
OXIDIZER TANKS (NO.= 1)		548.56
(TOROIDAL)		
INNER DIA= 1.338 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.464 M		
VOLUME = 14.831 M3		
AVG THK = .00326 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		1242.75
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.952 M		
VOLUME = 42.137 M3		
DOME THK= .00514 M		
CYL THK = .00852 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		131.130
PRESSURANT TANKS (NO.= 1)		704.05
DIA= 1.8168 M		
VOL= 3.140 M3		
THK= .01533 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		103.63
OXIDIZER TANK INSULATION		59.34
ENGINES (NO.= 1)		34.02
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1305.44
TOTAL WET SYSTEM MASS		24011.3
TOTAL BURNOUT MASS		5424.4
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.757
TOTAL IMPULSE		78089037.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MIN LENGTH PRESS FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4177.4 N-S/KG

TOTAL PROPELLANT		19571.36 KG
USABLE FUEL	2306.89	
USABLE OXIDIZER	16148.20	
FUEL TRAPPED	91.02	
OXID TRAPPED	621.68	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	148.42	
OXIDIZER BOILOFF	224.31	
OXIDIZER TANKS (NO.= 1)		577.73
(TOROIDAL)		
INNER DIA= 1.268 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.500 M		
VOLUME = 15.359 M3		
AVG THK = .00340 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		1113.50
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.637 M		
VOLUME = 37.638 M3		
DOME THK= .00514 M		
CYL THK = .00852 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		118.551
PRESSURANT TANKS (NO.= 1)		636.14
DIA= 1.7564 M		
VOL= 2.837 M3		
THK= .01482 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		96.22
OXIDIZER TANK INSULATION		60.00
ENGINES (NO.= 1)		31.75
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1305.44
TOTAL WET SYSTEM MASS		24100.4
TOTAL BURNOUT MASS		5241.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.766
TOTAL IMPULSE		77098534.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/ṁ=0.015

LH2/LO2 MIN LENGTH PRESS FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4383.4 N-S/KG

TOTAL PROPELLANT		18323.82 KG
USABLE FUEL	2877.32	
USABLE OXIDIZER	14386.58	
FUEL TRAPPED	114.01	
OXID TRAPPED	557.80	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	154.55	
OXIDIZER BOILOFF	219.05	
OXIDIZER TANKS (NO.= 1) (TOROIDAL) INNER DIA= 1.490 M; OUTER DIA= 4.267 M; HEIGHT = 1.389 M; VOLUME = 13.699 M3; AVG THK = .00300 M; FS = 1.50, FNOP= 1.50		491.30
FUEL TANKS (NO.= 1) (CYLINDRICAL/SQRT(2) ELLIPTICAL) DIAMETER= 4.267 M; LENGTH = 4.245 M; VOLUME = 46.327 M3; DOME THK= .00514 M; CYL THK = .00852 M; FS = 1.50, FNOP= 1.30		1363.12
PRESSURANT		142.471
PRESSURANT TANKS (NO.= 1) DIA= 1.8682 M; VOL= 3.414 M3; THK= .01576 M; FS = 1.50, FNOP= 1.10		765.40
FUEL TANK INSULATION		110.53
OXIDIZER TANK INSULATION		57.79
ENGINES (NO.= 1)		54.43
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		23192.2
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		5540.2
MASS FRACTION		.744
TOTAL IMPULSE		75677490.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MIN LENGTH PRESS FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4304.9 N-S/KG

TOTAL PROPELLANT		18505.25 KG
USABLE FUEL	2492.18	
USABLE OXIDIZER	14953.09	
FUEL TRAPPED	98.78	
OXID TRAPPED	577.49	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	149.22	
OXIDIZER BOILOFF	219.98	

OXIDIZER TANKS (NO.= 1) 517.32
(TOROIDAL)
INNER DIA= 1.419 M
OUTER DIA= 4.267 M
HEIGHT = 1.424 M
VOLUME = 14.229 M3
AVG THK = .00312 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 1191.87
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.828 M
VOLUME = 40.366 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 125.656

PRESSURANT TANKS (NO.= 1) 674.66
DIA= 1.7912 M
VOL= 3.009 M3
THK= .01511 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 100.71
OXIDIZER TANK INSULATION 58.53

ENGINES (NO.= 1) 49.90

COMPONENTS AND LINES 589.67
ENG. MOUNTS,SUPPORTS 1293.65

TOTAL WET SYSTEM MASS 23107.2
TOTAL BURNOUT MASS 5278.2
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .755
TOTAL IMPULSE 75103960.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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    LH2/LO2  MIN LENGTH  PRESS FED              MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4187.2 N-S/KG

TOTAL PROPELLANT                            18785.32 KG
  USABLE FUEL                     2215.18
  USABLE OXIDIZER                15506.26
  FUEL TRAPPED                      87.67
  OXID TRAPPED                     595.48
  FUEL START-S/D LOSSES              7.26
  OXID START-S/D LOSSES              7.26
  FUEL BOILOFF                     145.38
  OXIDIZER BOILOFF                 220.83

OXIDIZER TANKS (NO.= 1)                       543.99
 (TOROIDAL)
  INNER DIA=     1.350 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.459 M
  VOLUME    =   14.745 M3
  AVG THK   =   .00324 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          1068.64
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.528 M
  VOLUME  =   36.077 M3
  DOME THK=   .00514 M
  CYL THK =   .00852 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    113.660

PRESSURANT TANKS (NO.= 1)                     609.90
  DIA=    1.7320 M
  VOL=     2.720 M3
  THK=    .01461 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                           93.64
OXIDIZER TANK INSULATION                       59.22

ENGINES (NO.= 1)                               45.36

COMPONENTS AND LINES                          589.67
ENG. MOUNTS,SUPPORTS                         1293.65

TOTAL WET SYSTEM MASS                        23203.1
TOTAL BURNOUT MASS                            5100.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .764
TOTAL IMPULSE                             74207444.3 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =O.
INITIAL OX SYS PRESSURE   =   .1069E+07   FINAL OX SYS PRESSURE    =  .1069E+07
INITIAL FU SYS PRESSURE   =   .1138E+07   FINAL FU SYS PRESSURE    =  .1138E+07
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PRESS FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4442.2 N-S/KG

TOTAL PROPELLANT		17732.90 KG
USABLE FUEL	2784.21	
USABLE OXIDIZER	13921.05	
FUEL TRAPPED	109.76	
OXID TRAPPED	536.98	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	151.54	
OXIDIZER BOILOFF	215.76	
OXIDIZER TANKS (NO.= 1)		470.50
(TOROIDAL)		
INNER DIA= 1.549 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.359 M		
VOLUME = 13.256 M3		
AVG THK = .00290 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		1320.56
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 4.141 M		
VOLUME = 44.845 M3		
DOME THK= .00514 M		
CYL THK = .00852 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		137.927
PRESSURANT TANKS (NO.= 1)		741.00
DIA= 1.8481 M		
VOL= 3.305 M3		
THK= .01559 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		108.09
OXIDIZER TANK INSULATION		57.14
ENGINES (NO.= 1)		238.14
COMPONENTS AND LINES		589.67
ENG. MOUNTS, SUPPORTS		1284.12
TOTAL WET SYSTEM MASS		22680.0
TOTAL BURNOUT MASS		5593.9
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.737
TOTAL IMPULSE		74211602.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PRESS FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4383.4 N-S/KG

TOTAL PROPELLANT		17865.83 KG
USABLE FUEL	2405.67	
USABLE OXIDIZER	14434.03	
FUEL TRAPPED	94.69	
OXID TRAPPED	554.87	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	146.33	
OXIDIZER BOILOFF	216.62	

OXIDIZER TANKS (NO.= 1) 493.10
(TOROIDAL)
INNER DIA= 1.485 M
OUTER DIA= 4.267 M
HEIGHT = 1.391 M
VOLUME = 13.736 M3
AVG THK = .00301 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 1152.22
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.732 M
VOLUME = 38.986 M3
DOME THK= .00514 M
CYL THK = .00852 M
FS = 1.50, FNOP= 1.30

PRESSURANT 121.374

PRESSURANT TANKS (NO.= 1) 651.67
DIA= 1.7706 M
VOL= 2.907 M3
THK= .01494 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 98.44
OXIDIZER TANK INSULATION 57.84

ENGINES (NO.= 1) 233.60

COMPONENTS AND LINES 589.67
ENG. MOUNTS,SUPPORTS 1284.12

TOTAL WET SYSTEM MASS 22547.9
TOTAL BURNOUT MASS 5331.6
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .747
TOTAL IMPULSE 73818020.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE = .2482E+08 INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE = .1069E+07 FINAL OX SYS PRESSURE = .1069E+07
INITIAL FU SYS PRESSURE = .1138E+07 FINAL FU SYS PRESSURE = .1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PRESS FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4285.3 N-S/KG

TOTAL PROPELLANT		18092.69 KG
USABLE FUEL	2133.21	
USABLE OXIDIZER	14932.50	
FUEL TRAPPED	83.69	
OXID TRAPPED	569.67	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	142.58	
OXIDIZER BOILOFF	217.42	
OXIDIZER TANKS (NO.= 1)		515.89
(TOROIDAL)		
INNER DIA= 1.423 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.422 M		
VOLUME = 14.201 M3		
AVG THK = .00311 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		1030.99
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.437 M		
VOLUME = 34.766 M3		
DOME THK= .00514 M		
CYL THK = .00852 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		109.547
PRESSURANT TANKS (NO.= 1)		587.83
DIA= 1.7108 M		
VOL= 2.622 M3		
THK= .01443 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		91.49
OXIDIZER TANK INSULATION		58.50
ENGINES (NO.= 1)		226.80
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1284.12
TOTAL WET SYSTEM MASS		22587.5
TOTAL BURNOUT MASS		5148.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.756
TOTAL IMPULSE		73135184.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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   LH2/LO2  MAX PERF  PUMP FED                MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4442.2 N-S/KG

TOTAL PROPELLANT                             18908.60 KG
  USABLE FUEL                      2976.03
  USABLE OXIDIZER                 14880.13
  FUEL TRAPPED                      112.47
  OXID TRAPPED                      549.17
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42
  FUEL BOILOFF                      157.67
  OXIDIZER BOILOFF                  202.29

OXIDIZER TANKS (NO.= 1)                          76.19
 (ELLIPSOIDAL)
  DIAMETER=     3.367 M
  LENGTH   =    2.381 M
  VOLUME   =   14.129 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                             216.75
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    4.356 M
  VOLUME   =   47.920 M3
  DOME THK=    .00069 M
  CYL THK  =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                       18.947

PRESSURANT TANKS (NO.= 1)                       101.65
  DIA=     .9531 M
  VOL=      .453 M3
  THK=    .00804 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                            113.16
OXIDIZER TANK INSULATION                         42.33

ENGINES (NO.= 1)                                 37.19

COMPONENTS AND LINES                            554.29
ENG. MOUNTS,SUPPORTS                           1322.22

TOTAL WET SYSTEM MASS                          21391.3
TOTAL BURNOUT MASS                              3144.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .835
TOTAL IMPULSE                              79324355.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =O.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MAX PERF PUMP FED MR=6

VEHICLE MASS =27215.5 KG   DELTA V= 4815.8 M/S   AVE. ISP=4373.6 N-S/KG

TOTAL PROPELLANT		19064.40 KG
USABLE FUEL	2573.20	
USABLE OXIDIZER	15439.22	
FUEL TRAPPED	97.25	
OXID TRAPPED	568.23	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	152.07	
OXIDIZER BOILOFF	203.58	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		78.06
DIAMETER= 3.408 M		
LENGTH = 2.410 M		
VOLUME = 14.652 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (CYLINDRICAL/SQRT(2) ELLIPTICAL)		189.24
DIAMETER= 4.267 M		
LENGTH = 3.921 M		
VOLUME = 41.696 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.50		
PRESSURANT		16.696
PRESSURANT TANKS (NO.= 1)		89.51
DIA= .9136 M		
VOL= .399 M3		
THK= .00771 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		102.90
OXIDIZER TANK INSULATION		43.37
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		21497.0
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3098.1
MASS FRACTION		.838
TOTAL IMPULSE		78782087.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MAX PERF PUMP FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4815.8 M/S AVE. ISP=4285.3 N-S/KG

TOTAL PROPELLANT		19269.25 KG
USABLE FUEL	2276.90	
USABLE OXIDIZER	15938.33	
FUEL TRAPPED	86.10	
OXID TRAPPED	584.41	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	147.95	
OXIDIZER BOILOFF	204.72	

OXIDIZER TANKS (NO.= 1) 79.70
(ELLIPSOIDAL)
DIAMETER= 3.444 M
LENGTH = 2.435 M
VOLUME = 15.118 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 169.01
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.601 M
VOLUME = 37.118 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.50

PRESSURANT 15.049

PRESSURANT TANKS (NO.= 1) 80.63
DIA= .8823 M
VOL= .360 M3
THK= .00744 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	95.36
OXIDIZER TANK INSULATION	44.28
ENGINES (NO.= 1)	35.38
COMPONENTS AND LINES	554.29
ENG. MOUNTS,SUPPORTS	1322.22
TOTAL WET SYSTEM MASS	21665.2
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3066.4
MASS FRACTION	.841
TOTAL IMPULSE	78061442.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MAX PERF PUMP FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4471.6 N-S/KG

TOTAL PROPELLANT		18057.04 KG
USABLE FUEL	2846.17	
USABLE OXIDIZER	14230.87	
FUEL TRAPPED	104.04	
OXID TRAPPED	509.11	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	154.00	
OXIDIZER BOILOFF	198.33	
OXIDIZER TANKS (NO.= 1)		73.89
(ELLIPSOIDAL)		
DIAMETER= 3.316 M		
LENGTH = 2.345 M		
VOLUME = 13.495 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		207.00
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 4.202 M		
VOLUME = 45.714 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.50		
PRESSURANT		18.096
PRESSURANT TANKS (NO.= 1)		97.09
DIA= .9387 M		
VOL= .433 M3		
THK= .00792 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		109.52
OXIDIZER TANK INSULATION		41.06
ENGINES (NO.= 1)		41.73
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		20507.0
TOTAL BURNOUT MASS		3063.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.833
TOTAL IMPULSE		76365658.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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   LH2/LO2  MAX PERF  PUMP FED                  MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4432.4 N-S/KG

TOTAL PROPELLANT                          18144.12 KG
  USABLE FUEL                   2452.39
  USABLE OXIDIZER              14714.34
  FUEL TRAPPED                    89.49
  OXID TRAPPED                   525.36
  FUEL START-S/D LOSSES            7.26
  OXID START-S/D LOSSES            7.26
  FUEL BOILOFF                   148.56
  OXIDIZER BOILOFF               199.46

OXIDIZER TANKS (NO.= 1)                      75.53
 (ELLIPSOIDAL)
  DIAMETER=    3.352 M
  LENGTH  =    2.370 M
  VOLUME  =   13.948 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         180.14
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.777 M
  VOLUME  =   39.635 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                   15.891

PRESSURANT TANKS (NO.= 1)                    85.20
  DIA=     .8987 M
  VOL=      .380 M3
  THK=    .00758 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         99.51
OXIDIZER TANK INSULATION                     41.97

ENGINES (NO.= 1)                             40.82

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1307.25

TOTAL WET SYSTEM MASS                      20544.7
TOTAL BURNOUT MASS                          3015.5
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .836
TOTAL IMPULSE                         76093308.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =  .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MAX PERF PUMP FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4344.1 N-S/KG

TOTAL PROPELLANT		18347.88 KG
USABLE FUEL	2170.98	
USABLE OXIDIZER	15196.83	
FUEL TRAPPED	79.64	
OXID TRAPPED	540.66	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	144.69	
OXIDIZER BOILOFF	200.57	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		77.15
DIAMETER= 3.388 M		
LENGTH = 2.396 M		
VOLUME = 14.398 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (CYLINDRICAL/SQRT(2) ELLIPTICAL)		160.97
DIAMETER= 4.267 M		
LENGTH = 3.474 M		
VOLUME = 35.299 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.50		
PRESSURANT		14.327
PRESSURANT TANKS (NO.= 1)		76.76
DIA= .8680 M		
VOL= .342 M3		
THK= .00732 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		92.36
OXIDIZER TANK INSULATION		42.87
ENGINES (NO.= 1)		39.01
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1307.25
TOTAL WET SYSTEM MASS		20712.9
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2985.3
MASS FRACTION		.839
TOTAL IMPULSE		75451734.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.05

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    LH2/LO2  MAX PERF  PUMP FED                MR=6

VEHICLE MASS  =27215.5 KG     DELTA V=  4303.8 M/S    AVE. ISP=4491.2 N-S/KG

TOTAL PROPELLANT                             17612.48 KG
  USABLE FUEL                      2376.75
  USABLE OXIDIZER                 14260.52
  FUEL TRAPPED                       89.80
  OXID TRAPPED                      524.90
  FUEL START-S/D LOSSES               7.26
  OXID START-S/D LOSSES               7.26
  FUEL BOILOFF                      147.56
  OXIDIZER BOILOFF                  198.43

OXIDIZER TANKS (NO.= 1)                         74.04
 (ELLIPSOIDAL)
  DIAMETER=     3.319 M
  LENGTH  =     2.347 M
  VOLUME  =    13.537 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.50

FUEL TANKS (NO.= 1)                            175.18
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.699 M
  VOLUME  =    38.514 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,   FNOP= 1.50

PRESSURANT                                      15.423

PRESSURANT TANKS (NO.= 1)                       82.68
  DIA=     .8897 M
  VOL=      .369 M3
  THK=    .00751 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                            97.66
OXIDIZER TANK INSULATION                        41.14

ENGINES (NO.= 1)                                64.41

COMPONENTS AND LINES                           554.29
ENG. MOUNTS,SUPPORTS                          1303.62

TOTAL WET SYSTEM MASS                         20020.9
TOTAL BURNOUT MASS                             3023.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                    .831
TOTAL IMPULSE                             74725372.2 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MAX PERF PUMP FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4579.5 N-S/KG

TOTAL PROPELLANT		17361.72 KG
USABLE FUEL	2735.75	
USABLE OXIDIZER	13678.75	
FUEL TRAPPED	99.79	
OXID TRAPPED	488.40	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	150.77	
OXIDIZER BOILOFF	194.65	

OXIDIZER TANKS (NO.= 1) 71.98
(ELLIPSOIDAL)
DIAMETER= 3.272 M
LENGTH = 2.314 M
VOLUME = 12.974 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 199.32
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 4.081 M
VOLUME = 43.976 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.50

PRESSURANT 17.408

PRESSURANT TANKS (NO.= 1) 93.40
DIA= .9266 M
VOL= .417 M3
THK= .00782 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	106.66
OXIDIZER TANK INSULATION	39.99
ENGINES (NO.= 1)	99.79
COMPONENTS AND LINES	554.29
ENG. MOUNTS,SUPPORTS	1302.26
TOTAL WET SYSTEM MASS	19846.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3073.3
MASS FRACTION	.827
TOTAL IMPULSE	75173527.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   LH2/LO2  MAX PERF  PUMP FED              MR=6

VEHICLE MASS  =27215.5 KG   DELTA V=  4291.6 M/S   AVE. ISP=4559.9 N-S/KG

TOTAL PROPELLANT                          17403.12 KG
  USABLE FUEL                    2351.31
  USABLE OXIDIZER               14107.83
  FUEL TRAPPED                     85.94
  OXID TRAPPED                    503.27
  FUEL START-S/D LOSSES             6.80
  OXID START-S/D LOSSES             6.80
  FUEL BOILOFF                    145.50
  OXIDIZER BOILOFF                195.67

OXIDIZER TANKS (NO.= 1)                      73.46
 (ELLIPSOIDAL)
  DIAMETER=     3.306 M
  LENGTH  =     2.338 M
  VOLUME  =    13.376 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.50

FUEL TANKS (NO.= 1)                         173.11
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.666 M
  VOLUME  =    38.046 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,   FNOP= 1.50

PRESSURANT                                   15.252

PRESSURANT TANKS (NO.= 1)                    81.77
  DIA=     .8865 M
  VOL=      .365 M3
  THK=    .00748 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                         96.89
OXIDIZER TANK INSULATION                     40.81

ENGINES (NO.= 1)                             96.16

COMPONENTS AND LINES                        554.29
ENG. MOUNTS,SUPPORTS                       1302.26

TOTAL WET SYSTEM MASS                      19837.1
TOTAL BURNOUT MASS                          3023.2
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .830
TOTAL IMPULSE                           75055167.5 N-S

             PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MAX PERF PUMP FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4510.9 N-S/KG

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TOTAL PROPELLANT                                17511.50 KG
  USABLE FUEL                     2070.97
  USABLE OXIDIZER                14496.82
  FUEL TRAPPED                      75.64
  OXID TRAPPED                     516.23
  FUEL START-S/D LOSSES              6.80
  OXID START-S/D LOSSES              6.80
  FUEL BOILOFF                     141.65
  OXIDIZER BOILOFF                 196.57

OXIDIZER TANKS (NO.= 1)                            74.78
 (ELLIPSOIDAL)
  DIAMETER=     3.336 M
  LENGTH   =    2.359 M
  VOLUME   =   13.740 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                               153.99
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    3.364 M
  VOLUME   =   33.720 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                         13.687

PRESSURANT TANKS (NO.= 1)                          73.33
  DIA=     .8548 M
  VOL=      .327 M3
  THK=    .00721 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                               89.76
OXIDIZER TANK INSULATION                           41.55

ENGINES (NO.= 1)                                   93.44

COMPONENTS AND LINES                              554.29
ENG. MOUNTS,SUPPORTS                             1302.26

TOTAL WET SYSTEM MASS                           19908.6
TOTAL BURNOUT MASS                               2989.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                       .832
TOTAL IMPULSE                               74738265.9 N-S

            PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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   LH2/LO2  MIN LENGTH  PUMP FED              MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4442.2 N-S/KG

TOTAL PROPELLANT                            18953.91 KG
  USABLE FUEL                      2974.24
  USABLE OXIDIZER                 14871.19
  FUEL TRAPPED                      118.40
  OXID TRAPPED                      579.14
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42
  FUEL BOILOFF                      157.73
  OXIDIZER BOILOFF                  222.37

OXIDIZER TANKS (NO.= 1)                       105.21
 (TOROIDAL)
  INNER DIA=     1.427 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.420 M
  VOLUME   =    14.166 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                           188.09
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     4.361 M
  VOLUME  =    47.982 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    18.939

PRESSURANT TANKS (NO.= 1)                     101.60
  DIA=     .9530 M
  VOL=      .453 M3
  THK=    .00804 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                          113.26
OXIDIZER TANK INSULATION                       58.45

ENGINES (NO.= 1)                               37.19

COMPONENTS AND LINES                          589.67
ENG. MOUNTS,SUPPORTS                         1305.44

TOTAL WET SYSTEM MASS                        21471.8
TOTAL BURNOUT MASS                            3215.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .831
TOTAL IMPULSE                           79276703.6 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  :1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

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   LH2/LO2  MIN LENGTH  PUMP FED              MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4373.6 N-S/KG

TOTAL PROPELLANT                            19109.41 KG
  USABLE FUEL                      2571.69
  USABLE OXIDIZER                 15430.14
  FUEL TRAPPED                      102.26
  OXID TRAPPED                      599.10
  FUEL START-S/D LOSSES              15.42
  OXID START-S/D LOSSES              15.42
  FUEL BOILOFF                      152.12
  OXIDIZER BOILOFF                  223.25

OXIDIZER TANKS (NO.= 1)                       106.47
 (TOROIDAL)
  INNER DIA=     1.357 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.455 M
  VOLUME    =   14.689 M3
  AVG THK   =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                           164.21
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.925 M
  VOLUME  =    41.748 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    16.690

PRESSURANT TANKS (NO.= 1)                      89.47
  DIA=     .9134 M
  VOL=      .399 M3
  THK=    .00771 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                          102.99
OXIDIZER TANK INSULATION                       59.15

ENGINES (NO.= 1)                               36.29

COMPONENTS AND LINES                          589.67
ENG. MOUNTS,SUPPORTS                         1305.44

TOTAL WET SYSTEM MASS                        21579.8
TOTAL BURNOUT MASS                            3171.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .834
TOTAL IMPULSE                           78735768.6 N-S

             PRESSURE SCHEDULE(N/M2   )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.01

```
   LH2/LO2  MIN LENGTH  PUMP FED              MR=7

VEHICLE MASS  =27215.5 KG    DELTA V=  4815.8 M/S   AVE. ISP=4285.3 N-S/KG

TOTAL PROPELLANT                           19313.96 KG
  USABLE FUEL                    2275.59
  USABLE OXIDIZER               15929.15
  FUEL TRAPPED                     90.20
  OXID TRAPPED                    616.18
  FUEL START-S/D LOSSES            15.42
  OXID START-S/D LOSSES            15.42
  FUEL BOILOFF                    147.99
  OXIDIZER BOILOFF                224.00

OXIDIZER TANKS (NO.= 1)                      107.55
 (TOROIDAL)
  INNER DIA=     1.295 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.486 M
  VOLUME   =    15.156 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          146.63
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.604 M
  VOLUME  =    37.160 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   15.043

PRESSURANT TANKS (NO.= 1)                     80.59
  DIA=     .8822 M
  VOL=      .359 M3
  THK=    .00744 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                          95.43
OXIDIZER TANK INSULATION                      59.75

ENGINES (NO.= 1)                              35.38

COMPONENTS AND LINES                         589.67
ENG. MOUNTS,SUPPORTS                        1305.44

TOTAL WET SYSTEM MASS                       21749.4
TOTAL BURNOUT MASS                           3141.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .837
TOTAL IMPULSE                           78016494.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    = .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    = .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MIN LENGTH PUMP FED MR=5

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4471.6 N-S/KG

TOTAL PROPELLANT		18120.74 KG
USABLE FUEL	2844.42	
USABLE OXIDIZER	14222.10	
FUEL TRAPPED	113.16	
OXID TRAPPED	553.67	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	154.10	
OXIDIZER BOILOFF	218.78	
OXIDIZER TANKS (NO.= 1)		103.62
(TOROIDAL)		
INNER DIA= 1.510 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.379 M		
VOLUME = 13.546 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		179.82
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 4.210 M		
VOLUME = 45.824 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		18.090
PRESSURANT TANKS (NO.= 1)		97.04
DIA= .9385 M		
VOL= .433 M3		
THK= .00792 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		109.70
OXIDIZER TANK INSULATION		57.57
ENGINES (NO.= 1)		41.73
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		20611.6
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3157.7
MASS FRACTION		.828
TOTAL IMPULSE		76318566.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.015

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   LH2/LO2  MIN LENGTH  PUMP FED                   MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4480.6 M/S   AVE. ISP=4432.4 N-S/KG

TOTAL PROPELLANT                              18208.04 KG
  USABLE FUEL                    2450.90
  USABLE OXIDIZER               14705.41
  FUEL TRAPPED                     97.70
  OXID TRAPPED                    571.27
  FUEL START-S/D LOSSES             7.26
  OXID START-S/D LOSSES             7.26
  FUEL BOILOFF                    148.65
  OXIDIZER BOILOFF                219.58

OXIDIZER TANKS (NO.= 1)                         104.79
 (TOROIDAL)
  INNER DIA=     1.449 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.409 M
  VOLUME   =    13.999 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                             156.50
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.784 M
  VOLUME  =   39.735 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                      15.886

PRESSURANT TANKS (NO.= 1)                        85.16
  DIA=     .8985 M
  VOL=       .380 M3
  THK=    .00758 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             99.67
OXIDIZER TANK INSULATION                         58.22

ENGINES (NO.= 1)                                 40.82

COMPONENTS AND LINES                            589.67
ENG. MOUNTS,SUPPORTS                           1293.65

TOTAL WET SYSTEM MASS                          20652.4
TOTAL BURNOUT MASS                              3113.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .831
TOTAL IMPULSE                               76047159.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MIN LENGTH PUMP FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4480.6 M/S AVE. ISP=4344.1 N-S/KG

TOTAL PROPELLANT		18411.05 KG
USABLE FUEL	2169.68	
USABLE OXIDIZER	15187.78	
FUEL TRAPPED	86.02	
OXID TRAPPED	587.94	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	144.75	
OXIDIZER BOILOFF	220.35	

OXIDIZER TANKS (NO.= 1) 105.90
(TOROIDAL)
INNER DIA= 1.389 M
OUTER DIA= 4.267 M
HEIGHT = 1.439 M
VOLUME = 14.451 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 139.80
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.479 M
VOLUME = 35.375 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.30

PRESSURANT 14.323

PRESSURANT TANKS (NO.= 1) 76.73
DIA= .8678 M
VOL= .342 M3
THK= .00732 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 92.49
OXIDIZER TANK INSULATION 58.83

ENGINES (NO.= 1) 39.01

COMPONENTS AND LINES 589.67
ENG. MOUNTS, SUPPORTS 1293.65

TOTAL WET SYSTEM MASS 20821.4
TOTAL BURNOUT MASS 3084.4
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .834
TOTAL IMPULSE 75406814.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE = .2482E+08 INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE = .1517E+06 FINAL OX SYS PRESSURE = .1517E+06
INITIAL FU SYS PRESSURE = .1517E+06 FINAL FU SYS PRESSURE = .1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.05

```
   LH2/LO2  MIN LENGTH  PUMP FED               MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4303.8 M/S   AVE. ISP=4491.2 N-S/KG

TOTAL PROPELLANT                            17649.58 KG
  USABLE FUEL                     2375.29
  USABLE OXIDIZER                14251.75
  FUEL TRAPPED                      90.75
  OXID TRAPPED                     530.31
  FUEL START-S/D LOSSES             15.42
  OXID START-S/D LOSSES             15.42
  FUEL BOILOFF                     149.33
  OXIDIZER BOILOFF                 221.31

OXIDIZER TANKS (NO.= 1)                        103.66
 (TOROIDAL)
  INNER DIA=     1.508 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.380 M
  VOLUME   =    13.562 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                            152.35
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    3.708 M
  VOLUME  =   38.652 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                     15.470

PRESSURANT TANKS (NO.= 1)                      82.94
  DIA=     .8906 M
  VOL=      .370 M3
  THK=    .00751 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                           97.89
OXIDIZER TANK INSULATION                       57.59

ENGINES (NO.= 1)                               64.41

COMPONENTS AND LINES                          554.29
ENG. MOUNTS,SUPPORTS                         1282.31

TOTAL WET SYSTEM MASS                        20060.5
TOTAL BURNOUT MASS                            3032.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                   .829
TOTAL IMPULSE                            74679413.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =O.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT ACCELERATION, T/M=0.1

```
   LH2/LO2  MIN LENGTH  PUMP FED                MR=5

VEHICLE MASS  =27215.5 KG    DELTA V=  4291.6 M/S   AVE. ISP=4579.5 N-S/KG

TOTAL PROPELLANT                               17423.13 KG
  USABLE FUEL                        2734.03
  USABLE OXIDIZER                   13670.17
  FUEL TRAPPED                        108.46
  OXID TRAPPED                        530.68
  FUEL START-S/D LOSSES                 6.80
  OXID START-S/D LOSSES                 6.80
  FUEL BOILOFF                        150.86
  OXIDIZER BOILOFF                    215.32

OXIDIZER TANKS (NO.= 1)                          102.22
 (TOROIDAL)
  INNER DIA=     1.580 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.344 M
  VOLUME   =    13.024 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                              173.14
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    4.088 M
  VOLUME  =   44.079 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                        17.402

PRESSURANT TANKS (NO.= 1)                         93.35
  DIA=     .9265 M
  VOL=      .416 M3
  THK=    .00782 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             106.83
OXIDIZER TANK INSULATION                          56.79

ENGINES (NO.= 1)                                  99.79

COMPONENTS AND LINES                             589.67
ENG. MOUNTS,SUPPORTS                            1284.12

TOTAL WET SYSTEM MASS                           19946.4
TOTAL BURNOUT MASS                               3162.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                      .822
TOTAL IMPULSE                              75126398.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
```

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4559.9 N-S/KG

TOTAL PROPELLANT		17463.91 KG
USABLE FUEL	2349.85	
USABLE OXIDIZER	14099.11	
FUEL TRAPPED	93.23	
OXID TRAPPED	546.46	
FUEL START-S/D LOSSES	6.80	
OXID START-S/D LOSSES	6.80	
FUEL BOILOFF	145.58	
OXIDIZER BOILOFF	216.07	
OXIDIZER TANKS (NO.= 1)		103.31
(TOROIDAL)		
INNER DIA= 1.526 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.371 M		
VOLUME = 13.426 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		150.36
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.672 M		
VOLUME = 38.133 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		15.247
PRESSURANT TANKS (NO.= 1)		81.74
DIA= .8863 M		
VOL= .365 M3		
THK= .00748 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		97.03
OXIDIZER TANK INSULATION		57.39
ENGINES (NO.= 1)		96.16
COMPONENTS AND LINES		589.67
ENG. MOUNTS,SUPPORTS		1284.12
TOTAL WET SYSTEM MASS		19938.9
TOTAL BURNOUT MASS		3114.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.825
TOTAL IMPULSE		75008757.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED MR=7

VEHICLE MASS =27215.5 KG DELTA V= 4291.6 M/S AVE. ISP=4510.9 N-S/KG

```
TOTAL PROPELLANT                          17570.26 KG
  USABLE FUEL                   2069.71
  USABLE OXIDIZER              14487.97
  FUEL TRAPPED                    82.03
  OXID TRAPPED                   558.51
  FUEL START-S/D LOSSES            6.80
  OXID START-S/D LOSSES            6.80
  FUEL BOILOFF                   141.72
  OXIDIZER BOILOFF               216.71

OXIDIZER TANKS (NO.= 1)                     104.25
 (TOROIDAL)
  INNER DIA=     1.478 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.395 M
  VOLUME    =   13.788 M3
  AVG THK   =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                         133.75
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.369 M
  VOLUME  =    33.796 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                  13.682

PRESSURANT TANKS (NO.= 1)                    73.30
  DIA=     .8547 M
  VOL=      .327 M3
  THK=    .00721 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         89.89
OXIDIZER TANK INSULATION                     57.92

ENGINES (NO.= 1)                             93.44

COMPONENTS AND LINES                        589.67
ENG. MOUNTS,SUPPORTS                       1284.12

TOTAL WET SYSTEM MASS                      20010.3
TOTAL BURNOUT MASS                          3080.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .827
TOTAL IMPULSE                          74692662.4 N-S

              PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =  .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
```

2 BURNS, CONSTANT ACCELERATION, T/M=0.01

N204/MMH, MAX. PERF., PUMP FED,

VEHICLE MASS =27215.5 KG DELTA V= 5516.9 M/S AVE. ISP=3157.6 N-S/KG

```
TOTAL PROPELLANT                          23159.80 KG
  USABLE FUEL                   7022.64
  USABLE OXIDIZER              15449.81
  FUEL TRAPPED                   214.05
  OXID TRAPPED                   468.94
  FUEL START-S/D LOSSES            2.18
  OXID START-S/D LOSSES            2.18

OXIDIZER TANKS (NO.= 1)                      105.45
 (ELLIPSOIDAL)
  DIAMETER=     3.158 M
  LENGTH  =     2.233 M
  VOLUME  =    11.658 M3
  AVG THK =    .00115 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                           47.92
 (ELLIPSOIDAL)
  DIAMETER=     2.868 M
  LENGTH  =     2.028 M
  VOLUME  =     8.735 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    3.726

PRESSURANT TANKS (NO.= 1)                     19.52
  DIA=     .5499 M
  VOL=       .087 M3
  THK=    .00464 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                              41.73

COMPONENTS AND LINES                         363.33
ENG. MOUNTS,SUPPORTS                         958.89

TOTAL WET SYSTEM MASS                       24700.4
TOTAL BURNOUT MASS                           2223.6
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .910
TOTAL IMPULSE                         70962166.6 N-S

            PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1379E+06   FINAL OX SYS PRESSURE    = .1379E+06
INITIAL FU SYS PRESSURE   =  .1034E+06   FINAL FU SYS PRESSURE    = .1034E+06
```

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

```
   N2O4/MMH, MAX. PERF., PUMP FED,

VEHICLE MASS   =27215.6 KG    DELTA V=  5120.6 M/S    AVE. ISP=3236.0 N-S/KG

TOTAL PROPELLANT                             22283.79 KG
  USABLE FUEL                      6757.10
  USABLE OXIDIZER                 14865.63
  FUEL TRAPPED                      205.98
  OXID TRAPPED                      451.09
  FUEL START-S/D LOSSES               2.00
  OXID START-S/D LOSSES               2.00

OXIDIZER TANKS (NO.= 1)                         101.46
 (ELLIPSOIDAL)
  DIAMETER=     3.117 M
  LENGTH  =     2.204 M
  VOLUME  =    11.217 M3
  AVG THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              46.70
 (ELLIPSOIDAL)
  DIAMETER=     2.832 M
  LENGTH  =     2.002 M
  VOLUME  =     8.405 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       3.588

PRESSURANT TANKS (NO.= 1)                        18.78
  DIA=     .5429 M
  VOL=      .084 M3
  THK=    .00458 M
  FS = 1.50,  FNOP= 1.10


ENGINES (NO.= 1)                                 68.04

COMPONENTS AND LINES                            363.33
ENG. MOUNTS,SUPPORTS                            949.37

TOTAL WET SYSTEM MASS                          23835.1
TOTAL BURNOUT MASS                              2208.3
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .907
TOTAL IMPULSE                             69975322.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1379E+06   FINAL OX SYS PRESSURE    =  .1379E+06
INITIAL FU SYS PRESSURE   =   .1034E+06   FINAL FU SYS PRESSURE    =  .1034E+06
```

2 BURNS, CONSTANT ACCELERATION, T/M=0.1

N2O4/MMH, MAX. PERF., PUMP FED.

VEHICLE MASS =27215.5 KG   DELTA V= 4846.3 M/S   AVE. ISP=3265.5 N-S/KG

TOTAL PROPELLANT		21693.20 KG
USABLE FUEL	6576.65	
USABLE OXIDIZER	14468.63	
FUEL TRAPPED	200.98	
OXID TRAPPED	440.22	
FUEL START-S/D LOSSES	3.36	
OXID START-S/D LOSSES	3.36	
OXIDIZER TANKS (NO.= 1)		98.77
(ELLIPSOIDAL)		
DIAMETER= 3.090 M		
LENGTH = 2.185 M		
VOLUME = 10.919 M3		
AVG THK = .00113 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		45.88
(ELLIPSOIDAL)		
DIAMETER= 2.806 M		
LENGTH = 1.984 M		
VOLUME = 8.183 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.493
PRESSURANT TANKS (NO.= 1)		18.28
DIA= .5380 M		
VOL= .082 M3		
THK= .00454 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		99.79
COMPONENTS AND LINES		363.33
ENG. MOUNTS,SUPPORTS		949.37
TOTAL WET SYSTEM MASS		23272.1
TOTAL BURNOUT MASS		2220.1
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.904
TOTAL IMPULSE		68725760.2 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

N204/MMH, MIN. LENGTH, PUMP FED,

VEHICLE MASS =27215.5 KG   DELTA V= 5120.6 M/S   AVE. ISP=3236.0 N-S/KG

TOTAL PROPELLANT		22298.38 KG
USABLE FUEL	6757.10	
USABLE OXIDIZER	14865.63	
FUEL TRAPPED	210.54	
OXID TRAPPED	461.12	
FUEL START-S/D LOSSES	2.00	
OXID START-S/D LOSSES	2.00	
OXIDIZER TANKS (NO.= 1)		107.21
(TOROIDAL)		
INNER DIA= 1.823 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.222 M		
VOLUME = 11.224 M3		
AVG THK = .00081 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		46.72
(ELLIPSOIDAL)		
DIAMETER= 2.832 M		
LENGTH = 2.003 M		
VOLUME = 8.410 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.585
PRESSURANT TANKS (NO.= 1)		18.78
DIA= .5429 M		
VOL= .084 M3		
THK= .00458 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		65.77
COMPONENTS AND LINES		386.01
ENG. MOUNTS,SUPPORTS		1289.11
TOTAL WET SYSTEM MASS		24215.6
TOTAL BURNOUT MASS		2588.8
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.893
TOTAL IMPULSE		69975322.3 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.015

LCH4/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5516.9 M/S AVE. ISP=3491.0 N-S/KG

TOTAL PROPELLANT		22480.56 KG
USABLE FUEL	4567.05	
USABLE OXIDIZER	16898.09	
FUEL TRAPPED	168.42	
OXID TRAPPED	612.34	
FUEL START-S/D LOSSES	2.18	
OXID START-S/D LOSSES	2.18	
FUEL BOILOFF	64.43	
OXIDIZER BOILOFF	165.87	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		71.63
DIAMETER= 3.507 M		
LENGTH = 2.479 M		
VOLUME = 15.963 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		58.27
DIAMETER= 3.163 M		
LENGTH = 2.236 M		
VOLUME = 11.714 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		2.299
PRESSURANT TANKS (NO.= 1)		11.60
DIA= .4624 M		
VOL= .052 M3		
THK= .00390 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		26.15
OXIDIZER TANK INSULATION		45.92
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1343.54
TOTAL WET SYSTEM MASS		24635.1
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2935.3
MASS FRACTION		.871
TOTAL IMPULSE		74938390.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

LCH4/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5120.6 M/S AVE. ISP=3559.7 N-S/KG

```
TOTAL PROPELLANT                              21582.48 KG
  USABLE FUEL                      4386.93
  USABLE OXIDIZER                 16231.64
  FUEL TRAPPED                      161.94
  OXID TRAPPED                      587.79
  FUEL START-S/D LOSSES               2.00
  OXID START-S/D LOSSES               2.00
  FUEL BOILOFF                       58.85
  OXIDIZER BOILOFF                  151.33

OXIDIZER TANKS (NO.= 1)                          69.71
 (ELLIPSOIDAL)
  DIAMETER=     3.459 M
  LENGTH  =     2.446 M
  VOLUME  =    15.326 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              56.71
 (ELLIPSOIDAL)
  DIAMETER=     3.120 M
  LENGTH  =     2.206 M
  VOLUME  =    11.245 M3
  AVG THK =    .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       8.829

PRESSURANT TANKS (NO.= 1)                        47.75
  DIA=     .7409 M
  VOL=      .213 M3
  THK=    .00625 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             25.45
OXIDIZER TANK INSULATION                         44.69

ENGINES (NO.= 1)                                 63.50

COMPONENTS AND LINES                            554.29
ENG. MOUNTS,SUPPORTS                           1331.29

TOTAL WET SYSTEM MASS                          23784.7
TOTAL BURNOUT MASS                              2951.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .867
TOTAL IMPULSE                             73398260.4 N-S

            PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =  .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.1

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   LCH4/LO2  MAX PERF  PUMP FED

VEHICLE MASS  =27215.5 KG    DELTA V=  4846.3 M/S   AVE. ISP=3579.3 N-S/KG

TOTAL PROPELLANT                               20990.64 KG
  USABLE FUEL                       4266.74
  USABLE OXIDIZER                  15786.95
  FUEL TRAPPED                       153.37
  OXID TRAPPED                       573.42
  FUEL START-S/D LOSSES                3.08
  OXID START-S/D LOSSES                3.08
  FUEL BOILOFF                        57.11
  OXIDIZER BOILOFF                   146.87

OXIDIZER TANKS (NO.= 1)                          68.44
 (ELLIPSOIDAL)
  DIAMETER=     3.428 M
  LENGTH   =    2.424 M
  VOLUME   =   14.908 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                              55.64
 (ELLIPSOIDAL)
  DIAMETER=     3.091 M
  LENGTH   =    2.185 M
  VOLUME   =   10.929 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                       8.588

PRESSURANT TANKS (NO.= 1)                        46.44
  DIA=     .7341 M
  VOL=      .207 M3
  THK=    .00619 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                             24.97
OXIDIZER TANK INSULATION                         43.87

ENGINES (NO.= 1)                                 93.44

COMPONENTS AND LINES                            554.29
ENG. MOUNTS,SUPPORTS                           1322.22

TOTAL WET SYSTEM MASS                          23208.5
TOTAL BURNOUT MASS                              2944.7
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .864
TOTAL IMPULSE                             71780720.3 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =O.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.01

LCH4/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5638.8 M/S AVE. ISP=3461.6 N-S/KG

TOTAL PROPELLANT		22809.24 KG
USABLE FUEL	4620.68	
USABLE OXIDIZER	17096.50	
FUEL TRAPPED	177.61	
OXID TRAPPED	647.10	
FUEL START-S/D LOSSES	1.45	
OXID START-S/D LOSSES	1.45	
FUEL BOILOFF	69.19	
OXIDIZER BOILOFF	195.26	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		114.81
INNER DIA= 1.155 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.556 M		
VOLUME = 16.200 M3		
AVG THK = .00066 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		58.81
DIAMETER= 3.177 M		
LENGTH = 2.247 M		
VOLUME = 11.877 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		9.314
PRESSURANT TANKS (NO.= 1)		50.37
DIA= .7542 M		
VOL= .225 M3		
THK= .00636 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		26.39
OXIDIZER TANK INSULATION		60.99
ENGINES (NO.= 1)		36.29
COMPONENTS AND LINES		584.23
ENG. MOUNTS, SUPPORTS		1340.82
TOTAL WET SYSTEM MASS		25091.3
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3106.7
MASS FRACTION		.866
TOTAL IMPULSE		75179337.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

LCH4/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG   DELTA V= 5120.6 M/S   AVE. ISP=3559.7 N-S/KG

TOTAL PROPELLANT		21623.47 KG
USABLE FUEL	4384.44	
USABLE OXIDIZER	16222.42	
FUEL TRAPPED	169.23	
OXID TRAPPED	616.82	
FUEL START-S/D LOSSES	2.00	
OXID START-S/D LOSSES	2.00	
FUEL BOILOFF	58.87	
OXIDIZER BOILOFF	167.71	
OXIDIZER TANKS (NO.= 1)		108.02
(TOROIDAL)		
INNER DIA= 1.268 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.500 M		
VOLUME = 15.359 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		56.75
(ELLIPSOIDAL)		
DIAMETER= 3.121 M		
LENGTH = 2.207 M		
VOLUME = 11.256 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.829
PRESSURANT TANKS (NO.= 1)		47.74
DIA= .7409 M		
VOL= .213 M3		
THK= .00625 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		25.47
OXIDIZER TANK INSULATION		60.00
ENGINES (NO.= 1)		64.41
COMPONENTS AND LINES		584.23
ENG. MOUNTS,SUPPORTS		1322.68
TOTAL WET SYSTEM MASS		23901.6
TOTAL BURNOUT MASS		3064.2
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.862
TOTAL IMPULSE		73356531.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE	=0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.1

LCH4/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 4846.3 M/S AVE. ISP=3579.3 N-S/KG

TOTAL PROPELLANT		21011.80 KG
USABLE FUEL	4264.28	
USABLE OXIDIZER	15777.82	
FUEL TRAPPED	160.21	
OXID TRAPPED	582.85	
FUEL START-S/D LOSSES	3.08	
OXID START-S/D LOSSES	3.08	
FUEL BOILOFF	57.12	
OXIDIZER BOILOFF	163.36	
OXIDIZER TANKS (NO.= 1)		107.02
(TOROIDAL)		
INNER DIA= 1.326 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.471 M		
VOLUME = 14.924 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		55.68
(ELLIPSOIDAL)		
DIAMETER= 3.092 M		
LENGTH = 2.186 M		
VOLUME = 10.940 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.588
PRESSURANT TANKS (NO.= 1)		46.44
DIA= .7341 M		
VOL= .207 M3		
THK= .00619 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.99
OXIDIZER TANK INSULATION		59.45
ENGINES (NO.= 1)		93.44
COMPONENTS AND LINES		584.23
ENG. MOUNTS, SUPPORTS		1322.68
TOTAL WET SYSTEM MASS		23314.3
TOTAL BURNOUT MASS		3045.6
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.860
TOTAL IMPULSE		71739197.4 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.015

LH2/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5516.9 M/S AVE. ISP=4354.0 N-S/KG

TOTAL PROPELLANT		20365.10 KG
USABLE FUEL	2768.85	
USABLE OXIDIZER	16613.10	
FUEL TRAPPED	100.47	
OXID TRAPPED	587.41	
FUEL START-S/D LOSSES	2.18	
OXID START-S/D LOSSES	2.18	
FUEL BOILOFF	125.65	
OXIDIZER BOILOFF	165.27	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		81.68
DIAMETER= 3.486 M		
LENGTH = 2.465 M		
VOLUME = 15.683 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (CYLINDRICAL/SQRT(2) ELLIPTICAL)		199.58
DIAMETER= 4.267 M		
LENGTH = 4.085 M		
VOLUME = 44.035 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.50		
PRESSURANT		17.680
PRESSURANT TANKS (NO.= 1)		94.79
DIA= .9312 M		
VOL= .423 M3		
THK= .00786 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		106.76
OXIDIZER TANK INSULATION		45.38
ENGINES (NO.= 1)		40.82
COMPONENTS AND LINES		554.29
ENG. MOUNTS, SUPPORTS		1326.30
TOTAL WET SYSTEM MASS		22832.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3155.2
MASS FRACTION		.849
TOTAL IMPULSE		84391911.1 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

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    LH2/LO2   MAX PERF   PUMP FED

VEHICLE MASS   =27215.5 KG    DELTA V=  5120.6 M/S    AVE. ISP=4481.4 N-S/KG

TOTAL PROPELLANT                                19312.29 KG
  USABLE FUEL                       2625.28
  USABLE OXIDIZER                  15751.66
  FUEL TRAPPED                        97.63
  OXID TRAPPED                       569.81
  FUEL START-S/D LOSSES                1.45
  OXID START-S/D LOSSES                1.45
  FUEL BOILOFF                       114.62
  OXIDIZER BOILOFF                   150.39

OXIDIZER TANKS (NO.= 1)                            78.85
 (ELLIPSOIDAL)
  DIAMETER=     3.425 M
  LENGTH   =    2.422 M
  VOLUME   =   14.875 M3
  AVG THK  =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                               189.31
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    3.922 M
  VOLUME   =   41.711 M3
  DOME THK=    .00069 M
  CYL THK  =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                         16.736

PRESSURANT TANKS (NO.= 1)                          89.72
  DIA=     .9143 M
  VOL=      .400 M3
  THK=    .00771 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                              102.93
OXIDIZER TANK INSULATION                           43.81

ENGINES (NO.= 1)                                   41.73

COMPONENTS AND LINES                              554.29
ENG. MOUNTS,SUPPORTS                             1284.12

TOTAL WET SYSTEM MASS                            21713.8
TOTAL BURNOUT MASS                                3068.9
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                       .846
TOTAL IMPULSE                               82358782.8 N-S

             PRESSURE SCHEDULE(N/M2  )    AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.1

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    LH2/LO2  MAX PERF  PUMP FED

VEHICLE MASS  =27215.5 KG    DELTA V=  4846.3 M/S   AVE. ISP=4520.7 N-S/KG

TOTAL PROPELLANT                                    18661.00 KG
  USABLE FUEL                        2535.52
  USABLE OXIDIZER                   15213.12
  FUEL TRAPPED                         95.28
  OXID TRAPPED                        556.27
  FUEL START-S/D LOSSES                 2.00
  OXID START-S/D LOSSES                 2.00
  FUEL BOILOFF                        111.06
  OXIDIZER BOILOFF                    145.76

OXIDIZER TANKS (NO.= 1)                                77.06
 (ELLIPSOIDAL)
  DIAMETER=     3.386 M
  LENGTH  =     2.394 M
  VOLUME  =    14.373 M3
  AVG THK =    .00064 M
  FS = 1.50,   FNOP= 1.50

FUEL TANKS (NO.= 1)                                   183.13
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.825 M
  VOLUME  =    40.313 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,   FNOP= 1.50

PRESSURANT                                             16.169

PRESSURANT TANKS (NO.= 1)                              86.68
  DIA=     .9039 M
  VOL=      .387 M3
  THK=    .00763 M
  FS = 1.50,   FNOP= 1.10

FUEL TANK INSULATION                                  100.63
OXIDIZER TANK INSULATION                               42.82

ENGINES (NO.= 1)                                       53.52

COMPONENTS AND LINES                                  554.29
ENG. MOUNTS,SUPPORTS                                 1307.25

TOTAL WET SYSTEM MASS                                21082.6
TOTAL BURNOUT MASS                                    3073.1
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                           .842
TOTAL IMPULSE                                   80239156.2 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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2 BURNS, CONSTANT ACCELERATION, T/M=0.01

LH2/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG   DELTA V= 5638.8 M/S   AVE. ISP=4295.1 N-S/KG

TOTAL PROPELLANT		20796.48 KG
USABLE FUEL	2815.71	
USABLE OXIDIZER	16894.24	
FUEL TRAPPED	109.94	
OXID TRAPPED	643.84	
FUEL START-S/D LOSSES	1.45	
OXID START-S/D LOSSES	1.45	
FUEL BOILOFF	134.83	
OXIDIZER BOILOFF	195.02	

OXIDIZER TANKS (NO.= 1)   113.24
(TOROIDAL)
INNER DIA= 1.180 M
OUTER DIA= 4.267 M
HEIGHT = 1.544 M
VOLUME = 16.014 M3
AVG THK = .00066 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1)   176.62
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 4.151 M
VOLUME = 44.987 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.30

PRESSURANT   18.016

PRESSURANT TANKS (NO.= 1)   96.58
DIA= .9370 M
VOL= .431 M3
THK= .00791 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	108.33
OXIDIZER TANK INSULATION	60.78
ENGINES (NO.= 1)	26.31
COMPONENTS AND LINES	584.23
ENG. MOUNTS,SUPPORTS	1317.23
TOTAL WET SYSTEM MASS	23297.8
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	3255.1
MASS FRACTION	.846
TOTAL IMPULSE	84660346.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.05

LH2/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5120.6 M/S AVE. ISP=4481.4 N-S/KG

TOTAL PROPELLANT		19353.76 KG
USABLE FUEL	2623.75	
USABLE OXIDIZER	15742.49	
FUEL TRAPPED	102.64	
OXID TRAPPED	600.20	
FUEL START-S/D LOSSES	1.45	
OXID START-S/D LOSSES	1.45	
FUEL BOILOFF	114.66	
OXIDIZER BOILOFF	167.10	
OXIDIZER TANKS (NO.= 1) (TOROIDAL)		106.99
INNER DIA= 1.328 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.470 M		
VOLUME = 14.909 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1) (CYLINDRICAL/SQRT(2) ELLIPTICAL)		164.27
DIAMETER= 4.267 M		
LENGTH = 3.926 M		
VOLUME = 41.763 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		16.729
PRESSURANT TANKS (NO.= 1)		89.68
DIA= .9142 M		
VOL= .400 M3		
THK= .00771 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		103.01
OXIDIZER TANK INSULATION		59.44
ENGINES (NO.= 1)		41.73
COMPONENTS AND LINES		584.23
ENG. MOUNTS,SUPPORTS		1293.65
TOTAL WET SYSTEM MASS		21813.5
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		3162.6
MASS FRACTION		.842
TOTAL IMPULSE		82310830.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

2 BURNS, CONSTANT ACCELERATION, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED

VEHICLE MASS =27215.5 KG   DELTA V= 4846.3 M/S   AVE. ISP=4520.7 N-S/KG

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TOTAL PROPELLANT                          18702.78 KG
  USABLE FUEL                   2534.01
  USABLE OXIDIZER              15204.07
  FUEL TRAPPED                   100.30
  OXID TRAPPED                   586.67
  FUEL START-S/D LOSSES            2.00
  OXID START-S/D LOSSES            2.00
  FUEL BOILOFF                   111.10
  OXIDIZER BOILOFF               162.64

OXIDIZER TANKS (NO.= 1)                      105.80
 (TOROIDAL)
  INNER DIA=     1.395 M
  OUTER DIA=     4.267 M
  HEIGHT   =     1.436 M
  VOLUME   =    14.407 M3
  AVG THK  =    .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                          158.91
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH  =     3.828 M
  VOLUME  =    40.366 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                    16.163

PRESSURANT TANKS (NO.= 1)                     86.64
  DIA=     .9037 M
  VOL=      .386 M3
  THK=    .00763 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         100.71
OXIDIZER TANK INSULATION                      58.78

ENGINES (NO.= 1)                              53.52

COMPONENTS AND LINES                         584.23
ENG. MOUNTS,SUPPORTS                        1293.65

TOTAL WET SYSTEM MASS                       21161.2
TOTAL BURNOUT MASS                           3145.4
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                  .838
TOTAL IMPULSE                          80191452.1 N-S

            PRESSURE SCHEDULE(N/M2  )  AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =  .2482E+08   INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =  .1517E+06   FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =  .1517E+06   FINAL FU SYS PRESSURE    =  .1517E+06
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9 BURNS, CONSTANT THRUST, T/M=0.05

N2O4/MMH, MAX. PERF., PUMP FED,

VEHICLE MASS =27215.5 KG   DELTA V= 4511.0 M/S   AVE. ISP=3245.9 N-S/KG

TOTAL PROPELLANT		21062.15 KG
USABLE FUEL	6385.92	
USABLE OXIDIZER	14049.03	
FUEL TRAPPED	191.63	
OXID TRAPPED	420.14	
FUEL START-S/D LOSSES	7.71	
OXID START-S/D LOSSES	7.71	
OXIDIZER TANKS (NO.= 1) (ELLIPSOIDAL)		95.88
DIAMETER= 3.059 M		
LENGTH = 2.163 M		
VOLUME = 10.600 M3		
AVG THK = .00112 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1) (ELLIPSOIDAL)		44.99
DIAMETER= 2.779 M		
LENGTH = 1.965 M		
VOLUME = 7.947 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		3.390
PRESSURANT TANKS (NO.= 1)		17.76
DIA= .5328 M		
VOL= .079 M3		
THK= .00450 M		
FS = 1.50, FNOP= 1.10		
ENGINES (NO.= 1)		39.92
COMPONENTS AND LINES		363.33
ENG. MOUNTS, SUPPORTS		943.02
TOTAL WET SYSTEM MASS		22570.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)		2120.1
MASS FRACTION		.905
TOTAL IMPULSE		66331859.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1379E+06	FINAL OX SYS PRESSURE =	.1379E+06
INITIAL FU SYS PRESSURE =	.1034E+06	FINAL FU SYS PRESSURE =	.1034E+06

9 BURNS, CONSTANT THRUST, T/M=0.01

LCH4/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5334.0 M/S AVE. ISP=3466.5 N-S/KG

TOTAL PROPELLANT		22372.51 KG
USABLE FUEL	4516.80	
USABLE OXIDIZER	16712.17	
FUEL TRAPPED	166.69	
OXID TRAPPED	606.33	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	98.96	
OXIDIZER BOILOFF	257.03	

OXIDIZER TANKS (NO.= 1) 71.37
(ELLIPSOIDAL)
DIAMETER= 3.500 M
LENGTH = 2.475 M
VOLUME = 15.877 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1) 58.17
(ELLIPSOIDAL)
DIAMETER= 3.160 M
LENGTH = 2.235 M
VOLUME = 11.684 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT 9.149

PRESSURANT TANKS (NO.= 1) 49.47
DIA= .7497 M
VOL= .221 M3
THK= .00633 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION	26.11
OXIDIZER TANK INSULATION	45.75
ENGINES (NO.= 1)	25.40
COMPONENTS AND LINES	554.29
ENG. MOUNTS,SUPPORTS	1342.18
TOTAL WET SYSTEM MASS	24554.4
TOTAL BURNOUT MASS (INCL.NON-USABLE PROP. AND GAS)	2954.9
MASS FRACTION	.865
TOTAL IMPULSE	73593423.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	O.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT THRUST, T/M=0.05

LCH4/LO2 MAX PERF PUMP FED

VEHICLE MASS =27215.5 KG   DELTA V= 4511.0 M/S   AVE. ISP=3564.6 N-S/KG

TOTAL PROPELLANT		20420.16 KG
USABLE FUEL	4129.53	
USABLE OXIDIZER	15279.25	
FUEL TRAPPED	153.51	
OXID TRAPPED	559.61	
FUEL START-S/D LOSSES	9.98	
OXID START-S/D LOSSES	9.98	
FUEL BOILOFF	77.49	
OXIDIZER BOILOFF	200.80	
OXIDIZER TANKS (NO.= 1)		67.16
(ELLIPSOIDAL)		
DIAMETER= 3.395 M		
LENGTH = 2.401 M		
VOLUME = 14.492 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		54.73
(ELLIPSOIDAL)		
DIAMETER= 3.065 M		
LENGTH = 2.167 M		
VOLUME = 10.661 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		8.349
PRESSURANT TANKS (NO.= 1)		45.15
DIA= .7272 M		
VOL= .201 M3		
THK= .00614 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		24.56
OXIDIZER TANK INSULATION		43.05
ENGINES (NO.= 1)		39.92
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1327.21
TOTAL WET SYSTEM MASS		22584.6
TOTAL BURNOUT MASS		2877.5
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.859
TOTAL IMPULSE		69186788.7 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT THRUST, T/M=0.1

LCH4/LO2   MAX PERF   PUMP FED

VEHICLE MASS =27215.5 KG   DELTA V= 4419.6 M/S   AVE. ISP=3584.2 N-S/KG

TOTAL PROPELLANT		20153.78 KG
USABLE FUEL	4076.11	
USABLE OXIDIZER	15081.61	
FUEL TRAPPED	150.76	
OXID TRAPPED	549.17	
FUEL START-S/D LOSSES	10.89	
OXID START-S/D LOSSES	10.89	
FUEL BOILOFF	76.39	
OXIDIZER BOILOFF	197.96	

OXIDIZER TANKS (NO.= 1)   66.57
(ELLIPSOIDAL)
DIAMETER= 3.380 M
LENGTH = 2.390 M
VOLUME = 14.303 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

FUEL TANKS (NO.= 1)   54.26
(ELLIPSOIDAL)
DIAMETER= 3.052 M
LENGTH = 2.158 M
VOLUME = 10.524 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.30

PRESSURANT   8.242

PRESSURANT TANKS (NO.= 1)   44.57
DIA= .7241 M
VOL= .199 M3
THK= .00611 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION   24.35
OXIDIZER TANK INSULATION   42.68

ENGINES (NO.= 1)   50.80

COMPONENTS AND LINES   554.29
ENG. MOUNTS,SUPPORTS   1322.22

TOTAL WET SYSTEM MASS   22321.8
TOTAL BURNOUT MASS   2867.9
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION   .858
TOTAL IMPULSE   68667578.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 BURNS, CONSTANT THRUST, T/M=0.01

LH2/LO2 MAX PERF PRESS FED

VEHICLE MASS =27215.5 KG DELTA V= 5334.0 M/S AVE. ISP=4270.6 N-S/KG

TOTAL PROPELLANT		20403.46 KG
USABLE FUEL	2748.98	
USABLE OXIDIZER	16493.86	
FUEL TRAPPED	101.80	
OXID TRAPPED	597.66	
FUEL START-S/D LOSSES	7.26	
OXID START-S/D LOSSES	7.26	
FUEL BOILOFF	190.18	
OXIDIZER BOILOFF	256.47	
OXIDIZER TANKS (NO.= 1)		439.43
(ELLIPSOIDAL)		
DIAMETER= 3.485 M		
LENGTH = 2.464 M		
VOLUME = 15.671 M3		
AVG THK = .00394 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		1318.83
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 4.137 M		
VOLUME = 44.785 M3		
DOME THK= .00514 M		
CYL THK = .00852 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		139.534
PRESSURANT TANKS (NO.= 1)		749.22
DIA= 1.8549 M		
VOL= 3.342 M3		
THK= .01565 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		107.99
OXIDIZER TANK INSULATION		45.36
ENGINES (NO.= 1)		15.88
COMPONENTS AND LINES		554.74
ENG. MOUNTS, SUPPORTS		1322.22
TOTAL WET SYSTEM MASS		25096.7
TOTAL BURNOUT MASS		5392.7
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.767
TOTAL IMPULSE		82182199.9 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =0.	
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT THRUST, T/M=0.05

LH2/LO2 MAX PERF PRESS FED

VEHICLE MASS =27215.5 KG DELTA V= 4511.0 M/S AVE. ISP=4334.3 N-S/KG

TOTAL PROPELLANT		18465.23 KG
USABLE FUEL	2493.63	
USABLE OXIDIZER	14961.78	
FUEL TRAPPED	93.77	
OXID TRAPPED	548.45	
FUEL START-S/D LOSSES	8.16	
OXID START-S/D LOSSES	8.16	
FUEL BOILOFF	150.02	
OXIDIZER BOILOFF	201.26	

OXIDIZER TANKS (NO.= 1)	398.01
(ELLIPSOIDAL)	
DIAMETER= 3.372 M	
LENGTH = 2.384 M	
VOLUME = 14.194 M3	
AVG THK = .00382 M	
FS = 1.50, FNOP= 1.30	
FUEL TANKS (NO.= 1)	1191.09
(CYLINDRICAL/SQRT(2) ELLIPTICAL)	
DIAMETER= 4.267 M	
LENGTH = 3.826 M	
VOLUME = 40.339 M3	
DOME THK= .00514 M	
CYL THK = .00852 M	
FS = 1.50, FNOP= 1.30	
PRESSURANT	125.772
PRESSURANT TANKS (NO.= 1)	675.32
DIA= 1.7918 M	
VOL= 3.012 M3	
THK= .01512 M	
FS = 1.50, FNOP= 1.10	
FUEL TANK INSULATION	100.67
OXIDIZER TANK INSULATION	42.46
ENGINES (NO.= 1)	52.16
COMPONENTS AND LINES	554.74
ENG. MOUNTS,SUPPORTS	1352.61
TOTAL WET SYSTEM MASS	22958.1
TOTAL BURNOUT MASS	5135.1
(INCL.NON-USABLE PROP. AND GAS)	
MASS FRACTION	.760
TOTAL IMPULSE	75661123.6 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1069E+07	FINAL OX SYS PRESSURE =	.1069E+07
INITIAL FU SYS PRESSURE =	.1138E+07	FINAL FU SYS PRESSURE =	.1138E+07

9 BURNS, CONSTANT THRUST, T/M=0.01

LH2/LO2 MAX PEF. PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 5334.0 M/S AVE. ISP=4314.7 N-S/KG

TOTAL PROPELLANT		20310.04 KG
USABLE FUEL	2734.79	
USABLE OXIDIZER	16408.75	
FUEL TRAPPED	102.36	
OXID TRAPPED	598.27	
FUEL START-S/D LOSSES	9.80	
OXID START-S/D LOSSES	9.80	
FUEL BOILOFF	190.01	
OXIDIZER BOILOFF	256.27	

```
OXIDIZER TANKS (NO.= 1)                          81.38
 (ELLIPSOIDAL)
  DIAMETER=    3.480 M
  LENGTH  =    2.460 M
  VOLUME  =   15.597 M3
  AVG THK =   .00064 M
  FS = 1.50,  FNOP= 1.50

FUEL TANKS (NO.= 1)                             202.17
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=    4.267 M
  LENGTH  =    4.126 M
  VOLUME  =   44.620 M3
  DOME THK=   .00069 M
  CYL THK =   .00114 M
  FS = 1.50,  FNOP= 1.50

PRESSURANT                                      17.865

PRESSURANT TANKS (NO.= 1)                        95.78
  DIA=     .9344 M
  VOL=      .427 M3
  THK=    .00788 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                            107.72
OXIDIZER TANK INSULATION                         45.21

ENGINES (NO.= 1)                                 35.38

COMPONENTS AND LINES                            554.29
ENG. MOUNTS,SUPPORTS                           1323.58

TOTAL WET SYSTEM MASS                          22773.4
TOTAL BURNOUT MASS                              3164.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                     .841
TOTAL IMPULSE                              82602947.6 N-S
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PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE	= .2482E+08	INITIAL CHAMBER PRESSURE	=0.		
INITIAL OX SYS PRESSURE	= .1517E+06	FINAL OX SYS PRESSURE	= .1517E+06		
INITIAL FU SYS PRESSURE	= .1517E+06	FINAL FU SYS PRESSURE	= .1517E+06		

9 BURNS, CONSTANT THRUST, T/M=0.015

LH2/LO2 MAX PEF. PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 4968.2 M/S AVE. ISP=4363.8 N-S/KG

TOTAL PROPELLANT		19419.85 KG
USABLE FUEL	2620.15	
USABLE OXIDIZER	15720.88	
FUEL TRAPPED	97.54	
OXID TRAPPED	572.18	
FUEL START-S/D LOSSES	9.80	
OXID START-S/D LOSSES	9.80	
FUEL BOILOFF	166.16	
OXIDIZER BOILOFF	223.36	

OXIDIZER TANKS (NO.= 1) 79.02
(ELLIPSOIDAL)
DIAMETER= 3.429 M
LENGTH = 2.424 M
VOLUME = 14.923 M3
AVG THK = .00064 M
FS = 1.50, FNOP= 1.50

FUEL TANKS (NO.= 1) 192.86
(CYLINDRICAL/SQRT(2) ELLIPTICAL)
DIAMETER= 4.267 M
LENGTH = 3.978 M
VOLUME = 42.514 M3
DOME THK= .00069 M
CYL THK = .00114 M
FS = 1.50, FNOP= 1.50

PRESSURANT 17.031

PRESSURANT TANKS (NO.= 1) 91.31
DIA= .9196 M
VOL= .407 M3
THK= .00776 M
FS = 1.50, FNOP= 1.10

FUEL TANK INSULATION 104.25
OXIDIZER TANK INSULATION 43.90

ENGINES (NO.= 1) 39.92

COMPONENTS AND LINES 554.29
ENG. MOUNTS, SUPPORTS 1313.60

TOTAL WET SYSTEM MASS 21856.0
TOTAL BURNOUT MASS 3105.9
(INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION .839
TOTAL IMPULSE 80039443.0 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE = .2482E+08 INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE = .1517E+06 FINAL OX SYS PRESSURE = .1517E+06
INITIAL FU SYS PRESSURE = .1517E+06 FINAL FU SYS PRESSURE = .1517E+06

9 BURNS, CONSTANT THRUST, T/M=0.1

LH2/LO2 MAX PEF. PUMP FED

VEHICLE MASS =27215.5 KG DELTA V= 4419.6 M/S AVE. ISP=4530.5 N-S/KG

TOTAL PROPELLANT		17795.61 KG
USABLE FUEL	2402.02	
USABLE OXIDIZER	14412.13	
FUEL TRAPPED	90.47	
OXID TRAPPED	528.71	
FUEL START-S/D LOSSES	9.80	
OXID START-S/D LOSSES	9.80	
FUEL BOILOFF	146.27	
OXIDIZER BOILOFF	196.42	
OXIDIZER TANKS (NO.= 1)		74.56
(ELLIPSOIDAL)		
DIAMETER= 3.330 M		
LENGTH = 2.355 M		
VOLUME = 13.677 M3		
AVG THK = .00064 M		
FS = 1.50, FNOP= 1.50		
FUEL TANKS (NO.= 1)		176.94
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.727 M		
VOLUME = 38.913 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.50		
PRESSURANT		15.584
PRESSURANT TANKS (NO.= 1)		83.55
DIA= .8928 M		
VOL= .373 M3		
THK= .00753 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		98.32
OXIDIZER TANK INSULATION		41.42
ENGINES (NO.= 1)		96.16
COMPONENTS AND LINES		554.29
ENG. MOUNTS,SUPPORTS		1303.62
TOTAL WET SYSTEM MASS		20240.1
TOTAL BURNOUT MASS		3063.6
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.831
TOTAL IMPULSE		76179378.5 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

9 PERIGEE BURNS, CONSTANT THRUST, T/M=0.05

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LH2/LO2  MIN LENGTH  PUMP FED  MR=6

VEHICLE MASS  =27215.5 KG    DELTA V=  4526.3 M/S   AVE. ISP=4481.4 N-S/KG

TOTAL PROPELLANT                          18159.37 KG
  USABLE FUEL                    2449.71
  USABLE OXIDIZER               14698.25
  FUEL TRAPPED                     89.48
  OXID TRAPPED                    524.64
  FUEL START-S/D LOSSES            10.43
  OXID START-S/D LOSSES            10.43
  FUEL BOILOFF                    151.92
  OXIDIZER BOILOFF                224.51

OXIDIZER TANKS (NO.= 1)                     436.68
 (TOROIDAL)
  INNER DIA=     1.455 M
  OUTER DIA=     4.267 M
  HEIGHT    =    1.406 M
  VOLUME    =   13.958 M3
  AVG THK   =   .00306 M
  FS = 1.50,  FNOP= 1.30

FUEL TANKS (NO.= 1)                         156.33
 (CYLINDRICAL/SQRT(2) ELLIPTICAL)
  DIAMETER=     4.267 M
  LENGTH   =    3.781 M
  VOLUME   =   39.692 M3
  DOME THK=    .00069 M
  CYL THK =    .00114 M
  FS = 1.50,  FNOP= 1.30

PRESSURANT                                   15.912

PRESSURANT TANKS (NO.= 1)                    85.31
  DIA=     .8991 M
  VOL=      .381 M3
  THK=    .00759 M
  FS = 1.50,  FNOP= 1.10

FUEL TANK INSULATION                         99.60
OXIDIZER TANK INSULATION                     58.16

ENGINES (NO.= 1)                             64.41

COMPONENTS AND LINES                        584.23
ENG. MOUNTS,SUPPORTS                       1131.26

TOTAL WET SYSTEM MASS                      20791.3
TOTAL BURNOUT MASS                          3246.0
   (INCL.NON-USABLE PROP. AND GAS)

MASS FRACTION                                 .825
TOTAL IMPULSE                          76850900.7 N-S

             PRESSURE SCHEDULE(N/M2  )   AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =   .2482E+08    INITIAL CHAMBER PRESSURE =0.
INITIAL OX SYS PRESSURE   =   .1517E+06    FINAL OX SYS PRESSURE    =  .1517E+06
INITIAL FU SYS PRESSURE   =   .1517E+06    FINAL FU SYS PRESSURE    =  .1517E+06
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9 PERIGEE BURNS, CONSTANT THRUST, T/M=0.1

LH2/LO2 MIN LENGTH PUMP FED MR=6

VEHICLE MASS =27215.5 KG DELTA V= 4446.4 M/S AVE. ISP=4530.5 N-S/KG

TOTAL PROPELLANT		17868.84 KG
USABLE FUEL	2409.12	
USABLE OXIDIZER	14454.72	
FUEL TRAPPED	88.44	
OXID TRAPPED	518.52	
FUEL START-S/D LOSSES	15.42	
OXID START-S/D LOSSES	15.42	
FUEL BOILOFF	148.08	
OXIDIZER BOILOFF	219.11	
OXIDIZER TANKS (NO.= 1)		427.19
(TOROIDAL)		
INNER DIA= 1.485 M		
OUTER DIA= 4.267 M		
HEIGHT = 1.391 M		
VOLUME = 13.732 M3		
AVG THK = .00301 M		
FS = 1.50, FNOP= 1.30		
FUEL TANKS (NO.= 1)		154.06
(CYLINDRICAL/SQRT(2) ELLIPTICAL)		
DIAMETER= 4.267 M		
LENGTH = 3.740 M		
VOLUME = 39.097 M3		
DOME THK= .00069 M		
CYL THK = .00114 M		
FS = 1.50, FNOP= 1.30		
PRESSURANT		15.670
PRESSURANT TANKS (NO.= 1)		84.01
DIA= .8945 M		
VOL= .375 M3		
THK= .00755 M		
FS = 1.50, FNOP= 1.10		
FUEL TANK INSULATION		98.62
OXIDIZER TANK INSULATION		57.84
ENGINES (NO.= 1)		96.16
COMPONENTS AND LINES		584.23
ENG. MOUNTS,SUPPORTS		1131.26
TOTAL WET SYSTEM MASS		20517.9
TOTAL BURNOUT MASS		3256.0
(INCL.NON-USABLE PROP. AND GAS)		
MASS FRACTION		.822
TOTAL IMPULSE		76404490.8 N-S

PRESSURE SCHEDULE(N/M2) AT T=294.4 K

GAS TANK LOCK-UP PRESSURE =	.2482E+08	INITIAL CHAMBER PRESSURE =	0.
INITIAL OX SYS PRESSURE =	.1517E+06	FINAL OX SYS PRESSURE =	.1517E+06
INITIAL FU SYS PRESSURE =	.1517E+06	FINAL FU SYS PRESSURE =	.1517E+06

APPENDIX C

SYMBOLS

A	Area
ACS	Altitude Control System
ASE.	Airborne Support Equipment
b	Wrap Radial Rib Minor Axis Diameter
BT	Box Truss
cm	Centimeter
d	Wrap Radial Rib Major Axis Diameter
E	Modulus of Elasticity
f	Frequency
FPA	Flight Path Angle
g	Acceleration
GEO	Geosynchronous Earth Orbit
HC	Hoop and Column
hr	Hour
HZ	Hertz
I	Moment of Inertia
I/F	Interface
Kg	Kilogram
km	Kilometer
kN	Kilonewton
kW	Kilowatt
LCH_4	Liquid Methane
LEO	Low Earch Orbit
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LSS	Large Space Systems
LTPS	Low Thrust Propulsion System
m	Meters
MLI	Multilayer Insulation
mm	Millimeter
MMH	Monomethylhydrazine
mps	Meters Per Second
MR	Mixture Ratio
N	Newtons
N_2O_4	Nitrogen Tetroxide
ODSRS	Orbiting Deep Space Relay Station
OTV	Orbit Transfer Vehicle
P	Load
PSCS	Personal Communication Spacecraft
r	Radius
RA	Radio Astronomy
RF	Radio Frequency
rms	Root Mean Square
RP-1	Kerosene
SBR	Space Based Radar
sec	Seconds
SETI	Search for Extraterrestrial Intelligence
SOFI	Spray on Foam Insulation
SPS	Space Power Satellite

APPENDIX C

SYMBOLS (Continued)

STS	Space Transportation System
t	Wrap Radial Rib Thickness
T	Temperature
ΔT	Change in Temperature
T_R	Ramp Time
T/M	Thrust-to-Mass
v	Volts
ΔV	Change in velocity
VLBI	Very Long Based Interferometer
WRR	Wrap Radial Rib
α	Coefficient of Thermal Expansion
δ	Deflection
ϵ	Ratio of Engine Exit Diameter to Throat Diameter
γ	Knock Down Factor
λ	Mass Fraction
ρ	Density
σ	Stress

APPENDIX D

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