JSC - 23303

Design Mass Properties

Guidelines and Formats for Aerospace Vehicles

Advanced Programs Office
Systems Definition Branch

March 1989

NASA
National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

JSC-23303

DESIGN MASS PROPERTIES

GUIDELINES AND FORMATS
FOR
AEROSPACE VEHICLES

by

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ACKNOWLEDGEMENTS

I would regret not having mentioned, if not by name, by thought of, the many unnamed who have helped to formulate the essence of this report. Your direct involvement, encouragement, and shared concern, will always be appreciated.

In particular, I would like to thank Ann L. Bufkin, Mary P. Cerimele, Shelby J. Lawson, Louis E. Livingston, Wayne L. Peterson, and Kevin C. Templin, all from the Advanced Programs Office; also, Billie E. Johnson, from the Flight Data Office of the Orbiter and GFE Projects Office, and Kelley J. Cyr, from the Cost Analysis Office of the Space Station Project Control Office.

Also, I appreciate the direct and indirect support from the Conceptual Design Section of the Systems Definition Branch, consisting of:

Clarence A. Bell
Ann L. Bufkin
Kriss J. Kennedy
Shelby J. Lawson
Wayne L. Peterson
Michael L. Roberts
James A. Sturm
Kevin C. Templin

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DESIGN MASS PROPERTIES

INTRODUCTION

The guidelines and formats presented in this report are intended to be used for aerospace vehicles from concept design through operational status.

These guidelines and formats have evolved as a result of years of effort to produce a data base of design mass properties for NASA vehicles from Project Mercury through the Space Shuttle. The diverse procedures of recording and reporting design mass properties revealed a significant need for a more consistent procedure.

The following procedure is designed to be flexible enough to apply to essentially all aerospace vehicles but inflexible enough to circumvent excessive scattering of data by a wide range of vehicles and users. As a result, improved estimating relationships can be derived for mass and cost.

BACKGROUND

The guidelines and formats included in this report have been developed during the past several years because of an increasing need to more clearly and consistently record and report the mass properties. This need actually began before the Army-Navy mass statements which were in effect when the Society of Aeronautical Weight Engineers (SAWE) was formed in 1939. These statements have been updated over the years to reflect the latest in aircraft mass recording and reporting in GROUP WEIGHT STATEMENT, AN-9102 (a summary statement), and DETAIL WEIGHT STATEMENT, AN-9103 (a detailed statement).

The space age spawned a new class of vehicles which includes boosters and spacecraft. The need for recording and reporting the mass properties of these vehicles became apparent just as it had years ago for aircraft. In 1964 the NASA-DoD-Industry Committee of the Society of Allied Weight Engineers (SAWE) completed two years of effort in standardization and classification of mass properties requirements for boosters and space vehicles including Functional System Coding. This effort produced a standard, NASA SP-6004, which was superseded by NASA-endorsed military specification, MIL-M-38310 (Reference 1).

As more diverse designs of aerospace vehicles evolved, MIL-M-38310 Functional Coding became too inflexible for effective recording and reporting. This was most evident during Phase A of the Space Shuttle design evolution. As a result, NASA and Study Contractor

Design-Mass Engineers developed a special recording and reporting format and a Functional System Codes procedure to be used during Phase B. This procedure was based on aircraft and spacecraft information and proved to be invaluable during the year-long study effort which involved several contractors. Contractors were required to report monthly on a prescribed format for mass and design data. The design data included items such as design loads as well as dimensional information. The prescribed format was similar to the formats presented in the main body of this report and in appendix A. However, the Space Shuttle Phase B formats were more oriented toward winged vehicles.

With the advent of even later aerospace-vehicle designs such as Mars landers, a new need exists to assure effective, clearly understood, and consistently recorded and reported mass properties and design data. In view of this, two important factors are evident in relation to recording and reporting procedures: (1) a procedure that is too flexible leaves each study group, customer-contractor, or contractor to devise their own procedure, if any, and (2) a procedure that is too inflexible is not easily adaptable to new concepts. The procedure that follows in this report is designed to be flexible enough to apply to essentially all aerospace vehicles but inflexible enough to circumvent excessive scattering of data by a wide range of vehicle designs and users. As a result, two additional benefits of this procedure are a greater accuracy for and adaptability to mass and cost estimating relationships.

Particular emphasis is placed on recording and reporting procedures for mass data and design data in this report. Procedures for recording and reporting centers-of-gravity and mass moments of inertia can logically follow similar formatting within the same guidelines.

The Advanced Programs Office of JSC is developing a computerized data base of mass properties data and design data which is based on this procedure.

DEFINITIONS

This recording and reporting procedure, like previous procedures, uses successive levels of detail to define the functional systems of a spacecraft, module, and so on. Table 1, Guidelines, lists the thirteen first-generation categories, or coded functional systems, into which all components of the vehicle may be placed, together with the types of components that should be included in each system. The first-generation codes are intended to be essentially fixed, that is, no additional codes should be required at this level. Second- and third-generation codes, which reflect successively greater levels of detail within each functional system, are intended to be flexible for adaptation to the needs of the individual case. See appendices A and B for examples that illustrate this procedure.

Table 2, Design Mass Summary, provides a format for recording or reporting a mass summary of the 13 coded systems at the first-generation level. Columns A, B, C, and D could be four modules or stages of a vehicle, for example, which could be identified under the space provided for notes. The remaining space is for a scaled and dimensioned design drawing.

Table 3, Mass Summary, provides a format for second-generation level, functional coding of systems. This level is completely flexible, but data should be provided for the vehicle, module, or stage, to the extent that it is available, commensurate with the status of the design maturity.

Table 4, Mass and Design Details, provides a format for third-generation level or greater level functional coding of systems. Design data that are pertinent to the mass should be entered on the right side of the format page. These data should include items such as design loads, design pressures, design temperatures, factors of safety, maximum dynamic pressure, areas, volumes, materials, derivations, notes, and so on.

Table 1

GUIDELINES

FUNCTIONAL SYSTEM CODES 1. THROUGH 13.
(See References 1 and 2)

1. STRUCTURE

Wing, tail, body, fins, skirts, primary, secondary, pressurized, unpressurized, fuel and oxidizer tanks if integral with the structure, and so on.

Note: Reference 1 defines aerodynamic surfaces structure (wing, tail, and so on) as the basic and secondary load-carrying members for all primary lifting and aerodynamic control surfaces, both fixed and movable, exclusive of the non-structural panels used for induced environmental protection systems. Body structure is the basic and secondary load-carrying members, exclusive of the non-structural panels used for induced environmental protection systems.

2. PROTECTION

Heat, micrometeoroid, radiation, noise, corrosion, and so on.

Note: Reference 1 defines induced environmental protection as the devices which in themselves, or in combination, protect the vehicle structure from the detrimental effects of heat, noise, micrometeorites, and radiation.

3. PROPULSION

Main, maneuver, reaction control, attitude control, tanks if not integral with the structure, structural supports, circuitry, and so on.

Note: Reference 1 defines main propulsion as propulsive items that provide flight path thrust and acceleration and include rocket engines, nuclear engines, propulsive devices, and related equipment, such as fuel systems, oxidizer systems, and pressurizing systems. Secondary propulsion systems, such as maneuver, reaction control, and attitude control, are defined as control units, exclusive of navigation and guidance, which provide relatively small amounts of thrust or force compared to the main propulsion system, usually for purposes such as velocity control, attitude control, rendezvous, and docking.

4. POWER

Electrical source, hydraulic source, pneumatic source, conversion and distribution, structural supports, and so on.

Note: Reference 1 defines prime power source as systems used to generate power for purposes other than propulsion, including the source of initial power. However, once the power has been generated, any additional conversion equipment is listed under the Power Conversion and Distribution group (that is, hydraulic, pneumatic, or electrical). Power conversion and distribution is defined as the systems used to distribute electrical, hydraulic, or pneumatic power. The source of initial power is included in the Prime Power Source group.

5. CONTROL

Surface controls, thrust vector controls, structural supports, circuitry, and so on.

Note: Surface controls are normally associated with winged vehicles and are the systems, generally exclusive of the integrated avionics, that move the control surfaces of aerodynamic surfaces, such as elevons, rudders, speed brakes, body flaps, and so on. This includes actuators, plumbing, fluid within the systems, cockpit controls such as rudder pedals, and so on. Thrust vector controls are normally associated with booster vehicles and are the systems, generally exclusive of the integrated avionics, that move the main engines. This includes actuators, plumbing, fluid within the systems, structural, and so on.

6. AVIONICS

Guidance, navigation, communications, instrumentation, tracking, data processing, structural supports, circuitry, and so on.

Note: Reference 1 defines guidance and navigation as a group divided into the following major subgroups:

a. Guidance Source; receives a sensor signal.
b. Guidance Evaluation; evaluates signals, determines navigation requirements and informs the output systems.
c. Output; activates the control systems.

Communications is defined as the equipment required for all means of communication within, emanating from, and received by the missile or space vehicle. This includes such items as transmitters, receivers, antennas, power amplifiers, television cameras, and spares. Instrumentation is defined as measuring, signal conditioning, recording, and programming systems for data sampling and recording, including the sensors, circuitry, signal converters, and recording media from the measurement source to a point of telemetry or permanent storage. (Note: the Shuttle Orbiter also lists tracking and data processing under Avionics.)

7. ENVIRONMENT

Environmental control system, personnel provisions, crew station controls, panels, pressurized volume, unpressurized volume, structural supports, circuitry, and so on.

Note: Reference 1 defines environmental control as the system that controls internal environmental conditions such as temperature, pressure, humidity, atmospheric constituents, and odor for personnel and equipment. Personnel provisions are defined as items within the crew cabin, such as accommodations, fixed life support equipment, cargo handling, furnishings, and built-in emergency equipment. Crew station controls and panels are defined as items consisting of crew station controls, pedestals, stands, and display panels for all systems.

8. OTHER

Landing gear, parachute system, docking system, manipulator, structural supports, circuitry, and so on.

Note: Reference 1 defines launch, recovery, and docking as the items that provide the vehicle with the capability to be launched from or brought to rest with respect to a mass.

9. GROWTH

Percentage of DRY MASS, and so on.

Note: Reference 1 defines mass growth allowance as the mass allowance to account for changes due to development and manufacturing problems, changes in design requirements, and other in-scope causes that are not identifiable at this time. Also, Reference 1 states, "The contractor shall develop and substantiate appropriate weight growth allowances consistent with prior experience."

10. NON-CARGO

Unusable propellant, unusable service items (fluids, gases), reserve propellant, personnel, structural supports, circuitry, and so on.

Note: Reference 1 defines unusable propellant as residual propellant and service items, remaining in an item, which are not usable. Also, reserve propellant and service items are the propellant and service items carried by a propulsion stage or module in excess of that required to perform a mission with a nominal vehicle. Personnel is the crew required to perform a particular mission, including the nonfixed items required to support the crew both inside and outside of the spacecraft, such as personal gear, life support items, and crew accessories.

11. CARGO

Payload, payload support equipment, structural supports, circuitry, and so on.

Note: Reference 1 defines cargo as items stored aboard the spacecraft that will be required to perform certain functions during the mission. These items include scientific instruments and equipment to perform experiments, passengers, and associated equipment.

12. NON-PROPELLANT

Usable food, usable water, usable fluids, usable gases, structural supports, circuitry, and so on.

13. PROPELLANT

A. Usable propellant (full thrust propellant); main (delta v), maneuver (delta v), and so on.

Note: Reference 1 defines full thrust propellant as propellant consumed during the burning period from the specified value of thrust following ignition, or from lift-off from the launch pad, to the specified value of thrust following the cutoff signal.

B. Unusable propellant and fluid losses

Note: Separate totals should be supplied for A and B, and if data for B are not available, notes of estimates should be supplied for a, b, c, and d, either separately, or as a group. Reference 1 defines unusable propellant and fluid losses as:

a. Inflight losses; propellant losses associated with the use of auxiliary propulsion systems. These include losses for roll and attitude control, venting losses from pressurization gases, and boil-off losses.

b. Thrust-decay propellant; propellant consumed from the specified value of thrust, following the engine cutoff signal, to stage or module separation, or to zero value of thrust.

c. Thrust-buildup propellant; propellant consumed from ignition to the specified value of thrust, or consumed prior to lift-off from the launch pad.

d. Pre-ignition losses; fluid losses associated with starting the primary propulsion system of a stage or module which occur prior to the ignition signal.

Table 2

DESIGN MASS SUMMARY

FUNCTIONAL SYSTEM CODE	A	B	C	D
1. STRUCTURE				
2. PROTECTION				
3. PROPULSION				
4. POWER				
5. CONTROL				
6. AVIONICS				
7. ENVIRONMENT				
8. OTHER				
9. GROWTH				
DRY MASS				
10. NON-CARGO				
11. CARGO				
INERT MASS				
12. NON-PROPELLANT				
13. PROPELLANT				
GROSS MASS				

NOTE:

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Table 3

MASS SUMMARY

1. STRUCTURE ( )	4. POWER ( )	8. OTHER ( )
		9. GROWTH ( )
		DRY MASS
	5. CONTROL ( )	10. NON-CARGO ( )
2. PROTECTION ( )	6. AVIONICS ( )	11. CARGO ( )
		INERT MASS
		12. NON-PROPELLANT ( )
3. PROPULSION ( )		
	7. ENVIRONMENT ( )	13. PROPELLANT ( )
		GROSS MASS

Table 4

MASS AND DESIGN DETAILS				
MASS			DESIGN	

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REFERENCES

1. Military Specification, MASS PROPERTIES CONTROL REQUIREMENTS FOR MISSILE AND SPACE VEHICLES, MIL-M-38310B(USAF), Amendment 2, 15 January 1976.

2. GUIDELINES FOR MASS PROPERTIES CONTROL ON INTERNATIONAL SPACE AND MISSILE SYSTEMS, issued by INTERNATIONAL SOCIETY OF ALLIED WEIGHT ENGINEERS, INC., Recommended Practice Number 2, April 1, 1985.

3. ORBITER DETAIL WEIGHT STATEMENT, SD75-SH-0116-155, CONTRACT NAS9-14000, IRD # SE-484EA, WBS 23.3.4, Shuttle Orbiter Division, Rockwell International, July 2, 1988.

4. Status Report, SHUTTLE SYSTEMS WEIGHT AND PERFORMANCE, NASA, Lyndon B. Johnson Space Center, Houston, Texas, June, 21, 1988.

5. Shuttle Operational Data Book, Volume II, Mission Mass Properties, Revision B, August 1980, Amendment 163, Appendix STS 26, November 16, 1988.

6. Orbiter Load Sheet, Nominal MPS Propellant Inventory, STS 037, Revision A, TDDP: SPLA73E, Table A6, Page A7, NASA, Lyndon B. Johnson Space Center, Houston, Texas, July 5, 1988.

7. Shuttle Operational Data Book, Volume II, Mission Mass Properties, Revision B, August 1980, Amendment 167, OMS and RCS Propellant Systems, Tables 4.1-1 through 4.2-2, December 21, 1988.

APPENDIX A

EXAMPLES USING FORMS OF TABLES 2, 3, AND 4

It is important to point out that the primary procedure for recording and reporting, as presented in the main body of this report, is to record and report directly on the forms, Tables 2, 3, and 4. Main advantages of using these forms, especially for conceptual designs, are:

1. Consistency between designers and analysts
2. Consistency of study results, presentations, and documentation
3. Consistent comparability between competing vehicle designs
4. Consistent assessment of stand-alone and competing vehicle designs

The forms may be used directly as illustrated by the examples in this appendix. This is the format that is being used for the mass properties data and design data assembled into a computerized data base by the Advanced Programs Office of JSC. It is also being used for recording and reporting the mass properties data and design data of the various studies by the Advanced Programs Office.

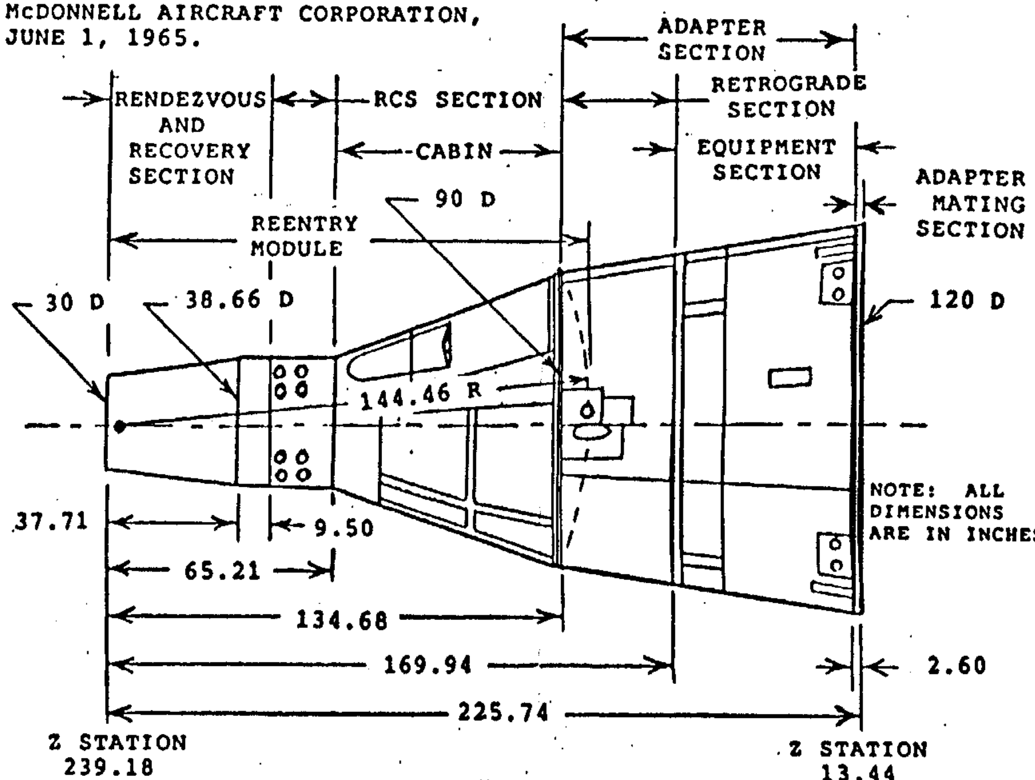
Table A-1

DESIGN MASS SUMMARY

GEMINI SPACECRAFT (JUN 1, 1965)

FUNCTIONAL SYSTEM CODE	A	B	C	D
1. STRUCTURE	1074	407		
2. PROTECTION	729	11		
3. PROPULSION	144	407		
4. POWER	263	472		
5. CONTROL	---	---		
6. AVIONICS	558	138		
7. ENVIRONMENT	1035	305		
8. OTHER	353	368		
9. GROWTH	---	---		
DRY MASS	4156	2108		
10. NON-CARGO	569	---		
11. CARGO	27	12		
INERT MASS	4752	2120		
12. NON-PROPELLANT	37	88		
13. PROPELLANT	72	689		
GROSS MASS	4861	2897		

REFERENCE: PROJECT GEMINI WEIGHT DATA, McDONNELL AIRCRAFT CORPORATION, JUNE 1, 1965.



NOTE:

A REENTRY MODULE

B ADAPTER SECTION

ALL MASS IS IN POUNDS

Table A-2

MASS SUMMARY

GEMINI REENTRY MODULE (JUN 1, 1965)

NOTE: ALL MASS IS IN POUNDS

1. STRUCTURE	(1074)
PRESSURIZED BODY	131
LARGE BULKHEAD	79
SMALL BULKHEAD	16
CREW HATCH	339
NON-PRESSURIZED STR	86
MAIN LDG GEAR FTGS	32
SHEAR PANELS	68
DOORS	79
MISCL	71
RCS SECTION	78
RENDEZ AND RECOV SECT	95
2. PROTECTION	(729)
HATCH SHING AND INSUL	50
CABIN SHING AND INSUL	149
RCS SEC SHING AND INSUL	62
RR SEC SHING AND INSUL	123
ABLATOR MATL	187
ABLATOR INSUL	158
3. PROPULSION	(144)
RCS ENGINES (16)	38
RCS ENG MOUNTING	4
RCS PRESS SYS	28
RCS FUEL SYS	14
RCS OXIDIZER SYS	14
RCS SYS INSTL	24
RCS SYS HEATERS	4
RCS SYS CIRCUITRY	18
4. POWER	(263)
BATT (4 MAIN, 3 SQUIB)	102
CONTROL	106
LIGHTS	2
SEPARATION CIRCUITRY	31
BATT MOUNTING	13
MISCL	9
5. CONTROL	(---)
6. AVIONICS	(558)
INSTRUMENTATION	188
COMMUNICATION	60
ATT CONTR ELECTRONICS	38
INERTIAL GUIDANCE	195
HORIZON SENSORS	22
MTG 11, CIRCUITRY 44	55
7. ENVIRONMENT	(1035)
CREW SYSTEMS	605
BREATHING SYS	46
AIR RENOVATING SYS	92
COOLING SYS	103
SECONDARY OXYGEN SYS	46
CIRCUITRY	14
DISPLAYS	129
8. OTHER	(353)
RETROGRADE CIRCUITRY	7
LANDING SYS (CHUTE)	209
RECOVERY SYS	29
RENDEZVOUS SYS	115
ACTUAL WEIGHT ADJUST	-7
9. GROWTH	(---)
DRY MASS	4156
10. NON-CARGO	(569)
CREW (2 IN SUITS)	416
CREW EQUIP STOWAGE	5
BALLAST (CG OFFSET)	148
UNUSABLE FLUIDS AND GASES (NONE REPORTED)	---
11. CARGO	(27)
EXPERIMENTS	27
INERT MASS	4752
12. NON-PROPELLANT	(37)
FOOD	5
WATER (CREW)	15
OXYGEN (CREW SECONDARY)	14
NITROGEN GAS (RCS)	3
13. PROPELLANT	(72)
RCS FUEL	32
RCS OXIDIZER	40
UNUSABLE PROPELLANT (NONE REPORTED)	---
GROSS MASS	4861

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Table A-3

NOTE: ALL MASS IS IN POUNDS

MASS AND DESIGN DETAILS

GEMINI REENTRY MODULE (JUN 1, 1965)

MASS		DESIGN	
1. STRUCTURE	(1074.29)	1. STRUCTURE	
PRESSURIZED BODY STRUCTURE	(131.12)	SURFACE AREA LESS HEAT SHIELD	157.85
SIDE PANELS	44.47	SPHERICAL SEGMENT, SQ FT	
		DESIGN PRESSURE, PSI	12
ECS BAY	37.67	ECS BAY AREA, SQ FT	55
MISCL PANELS	8.67		
ECS DOOR	26.77	ECS DOOR AREA, SQ FT	5.4
EQUIP SUPPORTS, SIDE PANELS	8.54		
SEALANT	5.00		
LARGE BULKHEAD	(78.72)	LARGE BULKHEAD AREA, SQ FT	25.44
PANELS	18.14		
STIFFENERS	44.41		
INSTALLATION	16.17		
SMALL BULKHEAD	(15.70)	SMALL BULKHEAD AREA, SQ FT	7.95
PANELS	12.56		
STIFFENERS	3.14		
CREW HATCH	(338.72)	CREW HATCH AREA, SQ FT	22.65
FIXED STRUCTURE, SILLS	57.84		
ACTUATOR	44.30		
MOVABLE STRUCTURE			
HINGE FTG, DRIVE BEAM	37.00		
BASIC SKIN	29.30		
STRUCTURE DETAILS	81.46		
WINDOW	25.74		
HATCH MECHANISM	44.69		
FLIPPER DOORS	10.86		
FLOTATION CURTAINS	2.90		
HATCH ATTACH BOLTS	4.63		
NON-PRESSURIZED STRUCTURE	(86.47)		
SKIN PANELS, FWD SMALL BHD	14.96		
PANEL, SMALL BHD	7.96		
PANELS OUTBD OF HATCHES	4.19		
STRINGERS	27.50		
STIFFENERS	2.25		

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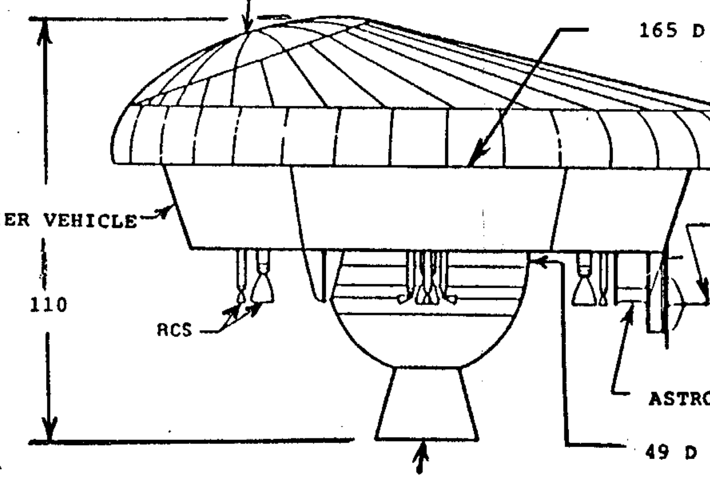
Table A-4

DESIGN MASS SUMMARY

AEROASSIST FLIGHT EXPERIMENT (MAY 27, 1986)

FUNCTIONAL SYSTEM CODE	A	B	C	D
1. STRUCTURE	809			
2. PROTECTION	259			
3. PROPULSION	463			
4. POWER	273			
5. CONTROL	---			
6. AVIONICS	462			
7. ENVIRONMENT	---			
8. OTHER	---			
9. GROWTH	239			
DRY MASS	2505			
10. NON-CARGO	103			
11. CARGO	---			
INERT MASS	2608			
12. NON-PROPELLANT	---			
13. PROPELLANT	4981			
GROSS MASS (11837)	7589	4248		

Reference: Aeroassist Flight Experiment, Preliminary Design Document, NASA, George C. Marshall Space Flight Center, Coordinated by Program Development/Preliminary Design Office; Marshall Space Flight Center, Langley Research Center, Ames Research Center, Johnson Space Center, May 27, 1986.



NOTE: ALL DIMENSIONS ARE IN INCHES

PRELIMINARY DRAWING (DRAWING IS NOT TO SCALE)

NOTE:

A AEROBRAKE AND CARRIER VEHICLE
B AIRBORNE SUPPORT EQUIPMENT (ASSIGNED TO SHUTTLE ORBITER)
1 165"D IS NOT A TRUE DIAMETER
2 SOME DIMENSIONS ARE APPROXIMATE

ALL MASS IS IN POUNDS

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Table A-5

NOTE: ALL MASS IS IN POUNDS

MASS SUMMARY
AEROASSIST FLIGHT EXPERIMENT (MAY 27, 1986)

1. STRUCTURE	(809)	4. POWER	(273)	8. OTHER	(---)
AEROBRAKE(AB) STRUCT	234	ELECTRICAL POWER	273		
CARRIER VEHICLE(CV)					
PRIMARY STRUCT	451				
SECONDARY STRUCT	124				
				9. GROWTH	(239)
				DRY MASS	2505
		5. CONTROL	(---)	10. NON-CARGO	(103)
				RESIDUALS, RESERVES	12
				PROPELLANT RESERVES	91
2. PROTECTION	(259)	6. AVIONICS	(462)	11. CARGO	(---)
THERMAL PROT ON AB	204	INSTRUMENTATION (AB)	227		
INSULATION ON CV	40	COMMUNICATION AND DH	131	**INERT MASS**	2608
HEATERS ON CV	15	GUID, NAV, AND CONTR	104		
				12. NON-PROPELLANT	(---)
3. PROPULSION	(463)				
MAIN AT BURN-OUT	272				
RCS SYSTEM	191				
		7. ENVIRONMENT	(---)	13. PROPELLANT	(4981)
				RCS(POST ATMOS EXIT)	126
				MAIN (STAR 48A) SRM	4829
				RCS (TRIM BURN)	26
				UNUSABLE	0
				GROSS MASS	7589

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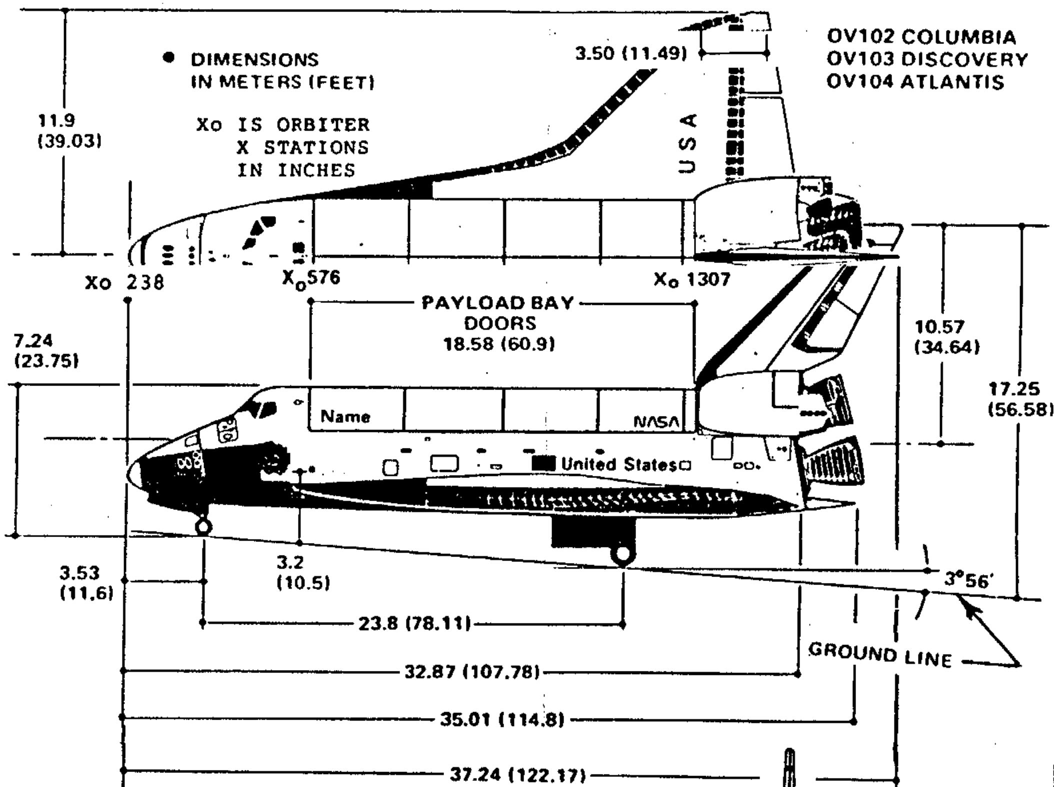
Table A-6

DESIGN MASS SUMMARY

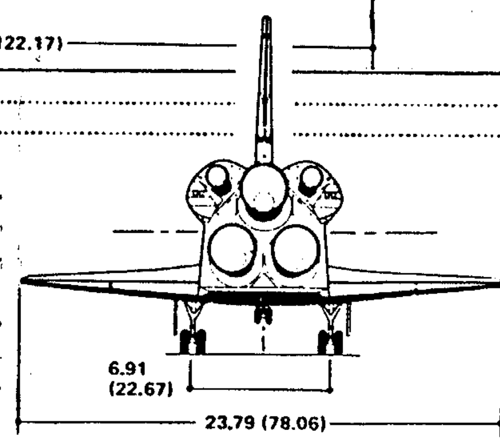
SHUTTLE ORBITER OV-103 (REFERENCES 3, 4, 5, AND 6)

FUNCTIONAL SYSTEM CODE	A	B	C	D
1. STRUCTURE	62777			
2. PROTECTION	27722			
3. PROPULSION	37422			
4. POWER	16387			
5. CONTROL	2785			
6. AVIONICS	6505			
7. ENVIRONMENT	7131			
8. OTHER	9314			
9. GROWTH	-320			
DRY MASS	169723			
10. NON-CARGO	11368			
11. CARGO	44645			
INERT MASS	225736			
12. NON-PROPELLANT	5225			
13. PROPELLANT	20556			
GROSS MASS	251517			



NOTE:

A SHUTTLE ORBITER



ALL MASS IS IN POUNDS

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Table A-7

NOTE: ALL MASS IS IN POUNDS

MASS SUMMARY

SHUTTLE ORBITER OV-103 (REFERENCES 3, 4, 5, AND 6)

Item	Mass
1. STRUCTURE	62777
1.1 WING GROUP	15929
1.2 TAIL GROUP	2609
1.3 BODY GROUP	44239
2. PROTECTION	27722
2.1 INDUCED ENVIRON PROTECT SYSTEM (THERMAL PROT SYSTEM)	27722
3. PROPULSION	37422
3.1 ASCENT PROPUL (MAIN ENGINES AND SYSTEMS)	31238
3.2 REACTION CONTR SYSTEM (RCS)	3142
3.3 ORBIT MANEUVER SYSTEM (OMS)	3042

Item	Mass
4. POWER	16387
4.1 ELECTRICAL POWER	14522
4.2 HYDRAULIC POWER	1865
5. CONTROL	2785
5.1 SURFACE CONTROLS	2785
6. AVIONICS	6505
6.1 GUIDANCE, NAV, AND CONTROL	919
6.2 COMMUNICATION AND TRACKING	1507
6.3 DISPLAYS AND CONTROLS	2102
6.4 INSTRUMENTATION	658
6.5 DATA PROCESSING AND SOFTWARE	1319
7. ENVIRONMENT	7131
7.1 ENVIRONMENTAL CONTROL	5298
7.2 PERSONNEL PROVISIONS	1833

Item	Mass
8. OTHER	9314
8.1 LANDING GEAR	6315
8.2 AUXILIARY SYSTEMS	2229
8.3 PAYLOAD PROVISIONS	770
9. GROWTH	-320
DRY MASS	169723
10. NON-CARGO	11368
10.1 STS OPERATOR	1095
10.2 CREW OF FIVE	4698
10.3 THROUGH 10.7 SEE PAGE B-2	2793
10.8 USABLE FPR PROPEL	2782
11. CARGO	44645
11.1 PAYLOAD	44645
INERT MASS	225736
12. NON-PROPELLANT	5225
12.1 CONSUMABLES	5225
13. PROPELLANT	20556
13.1 RCS (USABLE)	6556
13.2 OMS (USABLE)	14000
13.3 UNUSABLE	0
GROSS MASS	251517

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APPENDIX B

EXAMPLES USING FORMAT BASED ON GUIDELINES AND FUNCTIONAL SYSTEM CODING

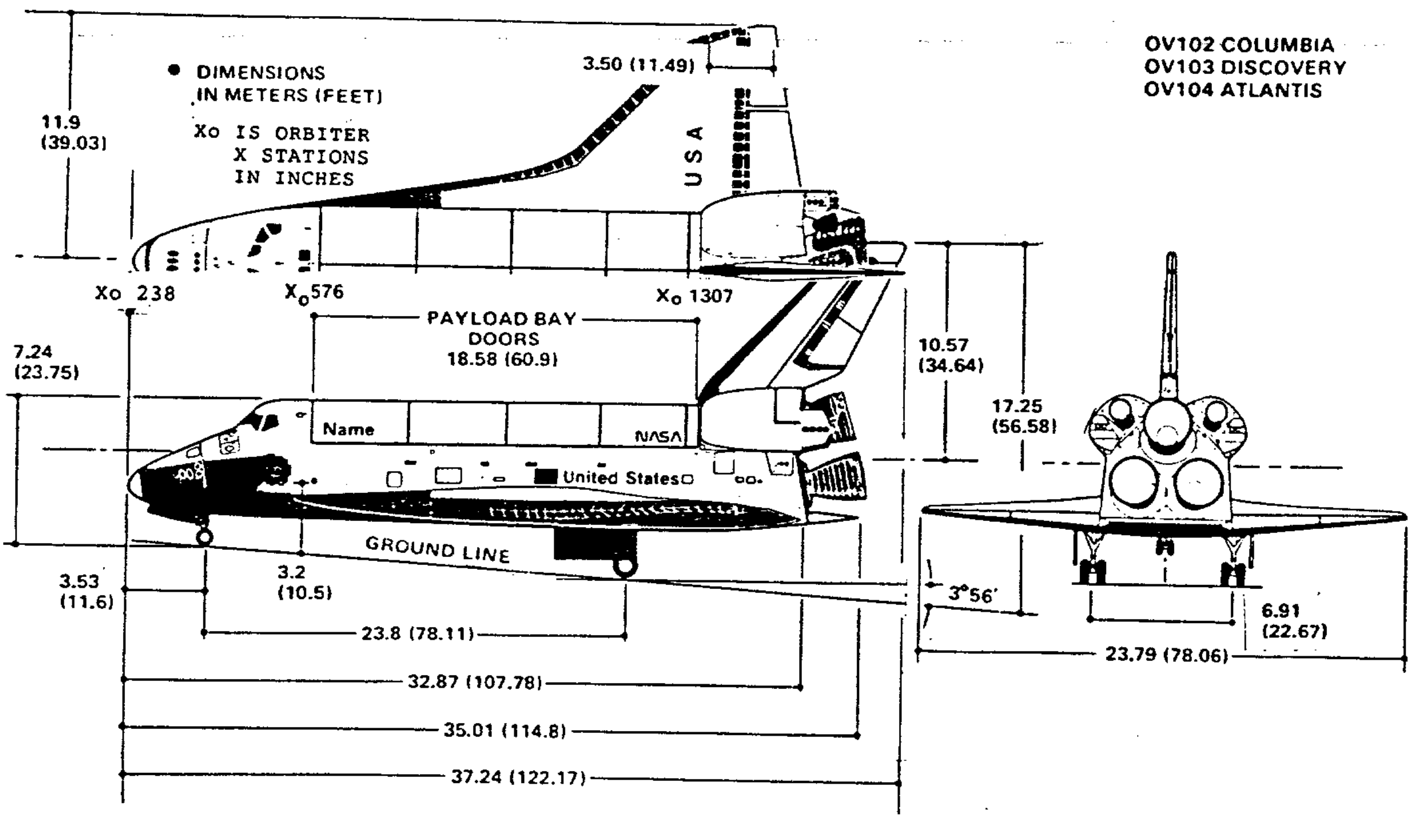
It is important to point out that the primary procedure for recording and reporting, as presented in the main body of this report, is to record and report directly on the forms, Tables 2, 3, and 4 (also, see appendix A). If this is not possible, or highly undesireable, a format may be developed that conforms to the presented guidelines as well as the coded functional systems. However, the advantages (see appendix A) of using the forms of appendix A, outweigh newly developed formats, and formats such as shown in appendix B, should not be used as a general rule.

To illustrate how a newly developed format may be developed, Shuttle Orbiter data is formatted in appendix B. Note that the guidelines and coded functional systems agree with those presented in the main body of this report and appendix A. Also, note that Shuttle Orbiter data is formatted in appendix A.

Table B-1

DESIGN MASS SUMMARY

SHUTTLE ORBITER OV-103 (References 3, 4, 5, and 6)
Note: All Mass is in Pounds



1. STRUCTURE........	62777
2. PROTECTION.......	27722
3. PROPULSION.......	37422
4. POWER............	16387
5. CONTROL..........	2785
6. AVIONICS.........	6505
7. ENVIRONMENT......	7131
8. OTHER............	9314
9. GROWTH...........	-320
DRY MASS	169723

10. NON-CARGO........	11368
11. CARGO............	44645
INERT MASS	225736
12. NON-PROPELLANT...	5225
13. PROPELLANT.......	20556
GROSS MASS	251517

Table B-2

MASS SUMMARY

SHUTTLE ORBITER OV-103 (References 3, 4, 5, and 6)

Note: All Mass is in Pounds

1. STRUCTURE..........(	62777)
1.1 Wing Group.....	15929
1.2 Tail Group.....	2609
1.3 Body Group.....	44239
2. PROTECTION.........(	27722)
2.1 Induced Environ Protect System (Thermal Prot System)........	27722
3. PROPULSION.........(	37422)
3.1 Ascent Propul (Main Engines and Systems)...	31238
3.2 Reaction Contr System (RCS)...	3142
3.3 Orbit Maneuver System (OMS)...	3042
4. POWER..............(	16387)
4.1 Electrical Pwr.	14522
4.2 Hydraulic Pwr..	1865
5. CONTROL............(	2785)
5.1 Surface Control	2785
6. AVIONICS...........(	6505)
6.1 Guidance, Nav, and Control....	919
6.2 Communication and Tracking...	1507
6.3 Displays and Controls.......	2102
6.4 Instrumentation	658
6.5 Data Processing and Software...	1319
7. ENVIRONMENT........(	7131)
7.1 Environmental Control........	5298
7.2 Personnel Provisions.....	1833
8. OTHER..............(	9314)
8.1 Landing Gear...	6315
8.2 Auxiliary Systs	2229
8.3 Payload Provis.	770
9. GROWTH.............(	-320)
9.1 Margin.........	-320
DRY MASS	169723
10. NON-CARGO..........(	11368)
10.1 STS Operator..	1095
10.2 Crew of Five for Four Days.	4698
10.3 Unusable RCS Propellant....	255
10.4 Unusable OMS Propellant....	154
10.5 Unusable MPS Propellant, Orbiter Lines.	771
10.6 Unusable MPS Propellant, SSME X 3......	1383
10.7 Unusable MPS Propellant, ET to SSME X 3	230
10.8 Usable FPR Propellant....	2782
11. CARGO..............(	44645)
11.1 Payload.......	44645
INERT MASS	225736
12. NON-PROPELLANT.....(	5225)
12.1 Consumables...	5225
13. PROPELLANT.........(	20556)
13.1 RCS (Usable)..	6556
13.2 OMS (Usable)..	14000
13.3 Unusable......	0
GROSS MASS	251517

Table B-3

MASS AND DESIGN DETAILS
Shuttle Orbiter Dry Mass (Reference 3)
Note: All Mass is in Pounds

MASS		DESIGN
1. STRUCTURE----------------------(	62777.0)	(Data such as design loads, design pressures, design temperatures, factors of safety, maximum dynamic pressure, areas, volumes, materials, derivations, notes, and so on.)
1.1 Wing Group-----------------(	15929.0)	
1.1.1 Basic Structure--------	10022.7	
1.1.2 Secondary Structure----	3075.9	
1.1.3 Control Surfaces-------	2830.4	
1.2 Tail Group-----------------(	2609.0)	
1.2.1 Basic Structure, Vertical Fin-----------	1782.9	
1.2.2 Secondary Structure Doors, and so on-------	154.2	
1.2.3 Control Surfaces-------	671.9	
1.3 Body Group-----------------(	44239.0)	
1.3.1 Basic Structure--------	30221.0	
1.3.2 Secondary Structure----	14018.0	
2. PROTECTION---------------------(	27722.0)	
2.1 Induced Environmental Protection-----------------(	27722.0)	
2.1.1 TPS (external) Wing----	11347.8	
2.1.2 TPS (external) Tail----	1161.6	
2.1.3 TPS (external) Body----	10379.9	
2.1.4 Thermal Control System (internal)-------------	3164.4	
2.1.5 Purge and Vent System--	1480.1	
2.1.6 Drain, Window Conditioning, and so on	188.2	

3. PROPULSION	(37422.0)
3.1 Ascent Propulsion	(31238.0)
3.1.1 Ancillary Systems	5331.0
3.1.2 Propellant Feed Systems	5023.0
3.1.3 Engine, Space Shuttle Main Engine	20884.0
3.2 Reaction Control System (RCS)	(3142.0)
3.2.1 Forward	1514.0
3.2.2 Aft	1628.0
3.3 Orbit Maneuver System (OMS)	(3042.0)
3.3.1 Engine Installation	608.6
3.3.2 Pressurization System	759.0
3.3.3 OMS Fuel System	832.0
3.3.4 OMS Oxidizer System	842.4
4. POWER	(16387.0)
4.1 Electrical Power	(14522.0)
4.1.1 Auxiliary Power System (APS)	912.1
4.1.2 Electrical Power System (EPS)	2981.9
4.1.3 EPS Conversion and Distribution	10628.0
4.2 Hydraulic Power	(1865.0)
4.2.1 Supply Equipment	201.0
4.2.2 Distribution and Control	1064.2
4.2.3 Temperature Control System	599.8

5. CONTROL	(2785.0)
5.1 Surface Controls	(2785.0)
5.1.1 Cockpit Controls	70.4
5.1.2 Body Flap Actuation	360.4
5.1.3 Elevon Actuation	1097.6
5.1.4 Rudder Speed Brake Actuation	1256.6
6. AVIONICS	(6505.0)
6.1 Guidance, Navigation, and Control	(918.9)
6.1.1 Units	768.9
6.1.2 Installation	150.0
6.2 Communication and Tracking	(1507.0)
6.2.1 Units	846.8
6.2.2 Circuitry	172.1
6.2.3 Antenna	342.5
6.2.4 Installation	145.6
6.3 Displays and Controls	(2102.5)
6.3.1 Units	1671.2
6.3.2 Installation	431.3
6.4 Instrumentation	(657.5)
6.4.1 Units	618.2
6.4.2 Installation	39.3
6.5 Data Processing and Software	(1319.1)
6.5.1 Units	1319.1)
7. ENVIRONMENT	(7131.0)
7.1 Environmental Control	(5298.0)
7.1.1 Cabin and Personnel System	2123.7
7.1.2 Equipment Environment and Heat Transport	3145.2
7.1.3 Airlock Support	29.1

7.2 Personnel Provision-------(	1833.0)
7.2.1 Fixed Life Support System----------------	717.8
7.2.2 Personnel Accommodations--------	512.0
7.2.3 Furnishings and Equipment-------------	603.2
8. OTHER--------------------------(	9314.0)
8.1 Landing Gear--------------(	6315.5)
8.1.1 Landing Gear Structure	5477.8
8.1.2 Landing Gear Controls-	837.7
8.2 Auxiliary Systems---------(	2228.5)
8.3 Payload Provisions--------(	770.0)
8.3.1 Fixed Scar Items------	95.0
8.3.2 Removable Payload Provisions------------	675.0
9. GROWTH-------------------------(	-320.0)
9.1 Margin--------------------(	-320.0
DRY MASS (Note 1)	169723.0
10. NON-CARGO----------------------(	11368.0)
10.1 Space Transportation System (STS) Operator (Reference 4)------------	1095.0
10.2 Crew of Five for Four Days (Reference 4)------------	4698.0
10.3 Unusable RCS Propellant (Reference 5)------------	255.0
10.4 Unusable OMS Propellant (Reference 5)------------	154.0

10.5 Unusable Main Propulsion System (MPS) Propellant, Orbiter Lines, Nominally Dumped, (Reference 6)----	771.0
10.6 Unusable MPS Propellant, SSME X 3, Nominally Dumped, (Reference 6)----	1383.0
10.7 Unusable MPS Propellant, Transferred from External Tank (ET) to SSME X 3, Nominally Dumped, (Reference 6)------------	230.0
10.8 Usable Flight Performance Reserves (FPR), MPS, Orbiter Lines, Nominally Dumped, (Reference 6)------------	2782.0
11. CARGO (Reference 4)------------(	44645.0)
11.1 Payload (Zero Manager's Reserve)-----------------	44645.0)
INERT MASS (Note 2)	225736.0
12. NON-PROPELLANT (Reference 4)---(	5225.0)
12.1 Non-Propellant Consumables--------------	5225.0
13. PROPELLANT Reference 4)--------(	20556.0)
13.1 RCS (Usable)-------------	6556.0
13.2 OMS (Usable)-------------	14000.0
13.3 Unusable (See code 10.)--	0.0
GROSS MASS (Note 3)	251517.0

Dumped Main Propellant	- 5166.0
GROSS MASS (Notes 3 and 4)	246351.0
GROSS MASS (Note 5)	285172.0

NOTES:

1. The Dry Mass represented by Codes 1. through 9. reflects the nomenclature and values found in Reference 3. The nomenclature and values for Codes 10. through 13. are taken from References 4, 5, and 6.

2. The Inert Mass includes Code 10.6, Usable Flight Performance Reserve (FPR) Propellants which are nominally dumped before landing.

3. The Gross Mass is based on the mass that is assigned to the Orbiter only and may not agree with totals that may include External Tank (ET) assigned mass.

4. The usable, maximum propellant for the RCS System is 6756 pounds and for the OMS System is 24266 pounds (Reference 7). These values should be used for reference only since each flight mission is subject to loading and flight limitations.

5. The design, maximum payload is 65000 pounds. If this payload and 6756 pounds of usable, maximum RCS propellant and 24266 pounds of usable, maximum OMS propellant are substituted for the table values, the GROSS MASS would be 285172 pounds without observing limitations, such as for centers-of-gravity, structural and aerodynamic loads, and so on.