SSD94D0217B

Requirements Report for SSTO Vertical Take-Off/Horizontal Landing Vehicle

Cooperative Agreements NCC1-193, NCC2-9003, and NCC8-39

November 4, 1994

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NASA

Rockwell Aerospace
Space Systems Division

Rockwell Aerospace
North American Aircraft

NORTHROP GRUMMAN

HERCULES

INTRODUCTION

This document describes the detailed design requirements and design criteria to support Structures/TPS Technology development for SSTO winged vehicle configurations that use vertical take-off and horizontal landing and delivers 25, 000 lb payloads to a 220 nm circular orbit at an inclination of 51.6 degrees or 40,000 lb payloads to a 150 nm circular orbit at a 28.5 degree inclination.

This document will be updated on a timely basis as information becomes available throughout the project.

UPDATE MODIFICATIONS

1.Section 0.0 - Replaced existing Section 0.0 with " Design Guidlines for ALT NRA 8-12 Technology Program (Phase D) " dated September 15, 1994 by S. Cook

2. Section 1.0 replaced 300 missions with 100 missions

3. Section 2.0

- Added the configurations of 1A, 3, and 4 - 3 D descriptions, orthographic descriptions, structural arrangement definition, and preliminary weight statement (Modified Table 1W to incorporate reduction in propulsion system weight) - also changed number of Table 2W to be Table 1W1)

- Added the LO and LH main propellant line routings for 2A and 1A

4. Section 3.0

- Removed TBD's wherever appropriate - the term not critical, or not applicable, are used where requirements are not defined but are not expected to be necessary for this projects technology development

- Added Tables of minimum, operating, and maximum pressures for the LO, LH, and RP tanks along with tank geometry and levels of fluid at liftoff, max $q\alpha$, and mas "g'.

- Added Tables of Aeroheating temperatures, heating rates, and heat loads for Reference Space Station and Polar mission with AOA with 1100 nm cross range

- Added the baseline TPS coverage based on the foregoing surface temperatures

- Added the vibration environment for configuration 2A

- Added Table 1 IL -Critical internal loads for Configuration 2A

- Added Table 1 IHM - IHM Requirements

10. Section 4.0 - modified to incorporate comments of J. Sisk titled "Comments on Advanced Launch Technology (ALT) NRA 8-12 Technology Program, Rockwell Requirements Document, SSD94D0217A" Sept 2, 1994

11. New Section 5.0 - Briefing charts describing overall approach to 8 foot diameter tank design

INDEX

Note - The Figures, Tables and drawings that are called out but not currently included will be available on a timely basis:

Section 0.0 SSTO System Requirements and Program Guidelines

0.0 RLV System Level Guidelines

REQUIREMENTS

- Satisfy the National Launch Needs
  - Space Station Missions:
    - -- Deliver and Return Payloads to and from 220 nmi circular/51.6° orbit
    - -- Deliver and Return Station Crews
  - Payload Delivery: Atlas and Delta Class Missions

- Provide High Degree of Reliability and Passenger Safety *Per Flight*
  - Safe Vehicle Return ≥ 0.995
  - Passenger Survivability ≥ 0.999
- Acceptable Cost
- Environmentally Acceptable (EPA std's, etc.)

ASSUMPTIONS

- Launch Vehicle Dry Weight $\leq$ 250,000 lbs
- Capable of Delivering/Returning 25,000 lb to/from Space Station
- Cargo Bay Volume: 15 x 30 ft
- Expendable Upperstage (Delivered to LEO)
- Mission Duration: 7 Days
- Airframe Life: 100 missions/20 years
- OMS Delta V Budget: 1,100 ft/s
- RCS Delta V Budget: 110 ft/s
- Cross Range: 1,100 nmi
- Capable of Withstanding Rainstorm on Launch Pad
- Dry Weight Growth Margin: 15%
- Launch and Landing at Same Site (No downrange aborts or overflight constraints)
- Autonomous Operations (Ground and Flight)
  - Launch System Test and Checkout/Monitoring
  - Launch (e.g., automated umbilicals)
  - On-Board Abort/Contingency Mode Recognition and Execution
  - On-Orbit Maneuvering
- Parallel, Off-Line Processing of Payloads
  - Standardized Interfaces
- No Late Access on Pad (Except passenger ingress and cargo in passenger compartment)
- Off-Line Regularly Scheduled Depot Maintenance
  - Number of Flights Between Depot: 20
  - Only Method for Major Repairs/Inspections and Incorporation of Vehicle Modifications

Section 1.0 Specific SSTO System Requirements

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
1.0 System Requirements - Baseline Winged Body Vehicle - Vertical Take-Off				
1.1 Reference Missions - Space Station Missions - IOC 2006				
1.1.1	Launch & Landing Sites			
	Launch site (day or night)	KSC or Vandenberg		Launch at landing site
		Existing facilities where possible		
		Modify facilities where possible		
		New facilities as required		
		Sustained engineering and logistics support		
	Landing Site (day or night)	KSC or Vandenberg		
		Existing facilities where possible		
		Modify facilities where possible		
		New facilities as required		
1.1.2	Up Payload (in Cannister)			
	Payload up weight	25,000 lbs		
	Orbit height	220 nmi, Circ		
	Orbit Inclination	51.6 degrees		
	Payload envelope dia	up to 15'-0"		
	Payload length	up to 30 feet		
	Payload c.g.	10 to 20 ft		from forward face of cannister
1.1.3	Down Payload (in Cannister)			
	Payload down weight	25,000 lbs		
	Payload envelope dia	up to 15'-0"		
	Payload length	up to 30 ft'-0"		
	Payload c.g.	10 to 20 ft		from forward face of cannister
1.1.4	Payload Attachment to Cannister			
	Standard structural and services interfaces	Yes		
	Z	@ 6, 12, 18 etc inches		from forward face
	Y	@ 6, 12, 18 etc inches		from forward face
	X	@ 6, 12, 18 etc inches		from forward face
	Cannister doors	provides torsion capability		
	Door opening on pad	one g capability without GSE		
	Door opening in OPF	one g capability with GSE		
1.1.5	Cannister Attachment to Payload Bay Structure			
	Standard structural and services interfaces	Yes		
	Forward supports	2 Fz		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Aft supports	2 for both Fz and Fx and one Fy		
1.1.6	Payload Bay Doors	in cannister		
	Door opening on pad	one g capability without GSE		
	Door opening in OPF	one g capability with GSE		
1.1.7	Vehicle Reliability			
	Launch Vehicle	> .98	MSFC	
	Safe vehicle return	> .995	MSFC	Debris Impact may violate this requirement
	Passenger survivability	> .999	MSFC	
1.1.8	Payload Environment			
	No special conditioning			
	Temperature	TBD		
	Pressure	unpressurized - vented to minimize differential pressures		
	Humidity	TBD		
	Cleanliness	TBD		
	Acoustic	145 db		
1.1.9	No. of flights	(100 - TBD) per vehicle		5 per year for 20 years TBD missions as defined in Section 1.2
		60 per engine		
1.1.10	Engine	RD - 704		
	Type (Bell or other)	Bell		
	No. of Engines	8		
	Power head spacing			
	Turbopump attach to structure	Yes or No, if yes turbopump weight		
	Engine weight (lbs)	5,329		includes margin
	Engine S.L. Thrust (lbs)	386,140		
	Engine Vac Thrust (lbs)	441,430		
	Gimbal rates (deg/sec)	3		
	Slew angle (deg/sec)	1.2		
	Actuator loads			
	Engine start sequence order	simultaneous		
	Engine start sequence duration	*Not required		* for this project
	Engine shutdown sequence order	simultaneous		
	Engine shutdown seq duration	*Not required		* for this project
	Max number of engines out	one		
	Engine throttle rate	*Not required		* for this project
	Engine throttle range (%)	100 to 50		
	Engine installation	Per Figure 1 HD		
	Open or closed boattail	closed		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	No of feedline penetrations in thrust structure	8		
	Engine removal time on pad	None		Return to OPF
	Engine removal time OPF	*Not required		* for this project
	Compliance requirememt	TBD		
1.1.11	Flight Rate	(5-TBD) missions per year per vehicle		TBD missions as defined in Section 1.2
1.1.12	Operational Life Cycle	20 years/vehicle		
	Fleet size	5		
	Maximum Flight rate	3 in 2 weeks		
	Max vehicles in flight @ same time	2		
1.1.13	Vehicle Empty Weight Margin	15%		
	Flight performance reserve	1 % of Delta V ideal		
1.1.14	Vehicle Operating Time			
	Pre-launch	24 hours		
	Ascent	0.5 hours		
	On-orbit	3-48 hours nominal		
		168 maximum		
		3 days average		3 x (100-TBD) TBD missions as defined in Section 1.2
		docked to station		
	Re-entry	0.75 hours		
1.1.15	Autonomous Operations			
	Launch system test and check-out monitoring			
	Launch (automated umbilicals and connections)			
	On-board abort/contingency mode recognition/execution			
	On-orbit maneuvering			
1.1.16	Turn Around Time	7 days		
	Shifts	2 shifts/day - 3rd shift for contingencies		
	OPF to end On pad processing	12 hours		
	Maximum Hold Time	12 hours		
	Depot level inspection	20 flights		
	On pad maintenance	vehicle-none		
		payload-none		No access to Payload after rollout to pad
				Vehicle provides safety staus monitoring of payload functions - capability to direct/relay telemetry/command with attached and released payload.

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
				Container independently monitors safety staus of attached payload and is able to shut down and make all p ayload systems safe.
				Standardized power and environment levels supplied by vehicle through standardized interfaces.
	Launch on demand	24 hours		
1.1.17	Fleet Certification	one time		Target
1.1.18	Ferry Capability			
	Land	No		
	Sea	No		
	Air	Yes		
1.1.19	Mission Trajectory	Table 1T		
	Thrust to weight @ lift-off	1.2		
	Delta V On-orbit	1100 fps		
	Max g	3		
1.1.20	All-Envelope Intact Abort Capability			
	Propellant dump	None		
	Propellant consumption	Yes- through engine burn		
1.1.21	Miscellaneous Operations and ground Rules			
	Use of pyrotechnics	None		
	Use of hydraulics	None		
	Use of corrosive fluids	None		
	Use of hypergolics	None		
1.1.22	Spare Parts	Initial procurement shall accommodate attrition		
1.1.23	DDT & E Goal	Minimum		
	Annual Operations cost Goal	Minimum		
1.1.24	Vehicle Weights and c.g.s	Table 1W	SSD	
1.2 Other Missions - 40 K Payload into 150 nm circular orbit - 28.5 degree inclination				
The requirements of this mission are the same as that in Section 1.1 except as delineated in this section				
1.2.2	Up Payload (in Cannister)			
	Payload up weight	40,000 lbs		
	Orbit height	150 nmi, Circ		
	Orbit Inclination	28.5 degrees		
1.2.3	Down Payload in (Cannister)			

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Payload down weight	40,000 lbs		
1.2.14	Vehicle Operating Time			
	Pre-launch	24 hours		
	Ascent	0.5 hours		
	On-orbit	3-48 hours nominal		
		168 maximum		
		3 days average		3 xTBD total days
	Re-entry	0.75 hours		
1.2.20	Mission Trajectory	Not required for goals		
1.2.25	Vehicle Weights and c.g.s	Table 1W but with added 15 k for payload	SSD	Entry and landing designs based on added payload weight
1.3 Other Missions - 16 K Payload into 100 nm circular orbit - 90 degree inclination				
The requirements of this mission are the same as that in Section 1.1 except as delineated in this section				
1.2.2	Up Payload (in Cannister)			
	Payload up weight	16,000 lbs		
	Orbit height	150 nmi, Circ		
	Orbit Inclination	28.5 degrees		
1.2.3	Down Payload in (Cannister)			
	Payload down weight	40,000 lbs		
1.2.14	Vehicle Operating Time			
	Pre-launch	24 hours		
	Ascent	0.5 hours		
	On-orbit	3-48 hours nominal		
		168 maximum		
		3 days average		3 xTBD total days
	Re-entry	0.75 hours		
1.2.20	Mission Trajectory	Not required for goals		
1.2.25	Vehicle Weights and c.g.s	Table 1W but with 9 k less for payload	SSD	Entry and landing designs based on added payload weight

Section 2.0 SSTO Vehicle Descriptions

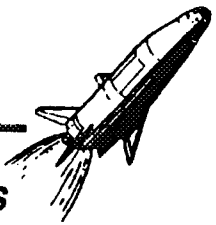
Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
2.0 SSTO Vehicle Configuration Description 2A				
2.1	Configuration 2A Drawings			LO tank forward - integral LO and LH tanks
2.1.1	Vehicle Weight Statement	Tables 1W		
2.1.2	Vehicle Description			
	Ullage volumes (%)	4 % in all tanks		
	Tank materials	Al-Li for LO tank , IM 7/977-2 baseline for LH		
	Feedline materials	Al-Li for LO tank , Composite for LH tank		
	Forward fuselage, Intertank, Wing, and Tail structures materials	Gr/BMI baseline		
	Thrust structure baseline material	IM 7/977-2 baseline		
	TPS	Baseline designs- AFRSI (to 1400 F) , TABI (to 2000 F) , and AETB to (2600 F)		
	RCS propellants	LH and LO		
	OMS propellants	LH and LO		
	Vehicle Management system	CPU Processors/Racks @ 3 MPS 3 Reqd, Remote Processors 8 Reqd, Fiberoptic Bus System, Discrete Wiring, VCntrl Bus Triple Redundant, Mission Dig. Processor 2 Reqd, Mass Storage		
	Navigation and Guidance System	INS/NAV-GPS 3 Reqd, GPS Antennas 3 Reqd, Laser Air Data, Radar Alt System, Navigation Base		
	Communication/NAV AIDS	UHF System, S-Band PCM & Pwr Amp 2 Reqd, S-Band Ant 4 Reqd, S-Band Trmttr, TDRSS		
	Remote Interface Units	Main Engines, Aero Surfaces, RCS, Fuel Cntrl, Doors, Gear Doors		
	Residuals LH and LO tank	0.5%		
	Residuals 0g tanks	3%		
	Engines	RD - 704 (eight)		Data from Pratt and Whitney
				Table 1Eng
2.2	Configuration 1A Drawings			
2.2.1	Vehicle Weight Statement	Table 2W		
2.2.2	Vehicle Description	same as for 2A		

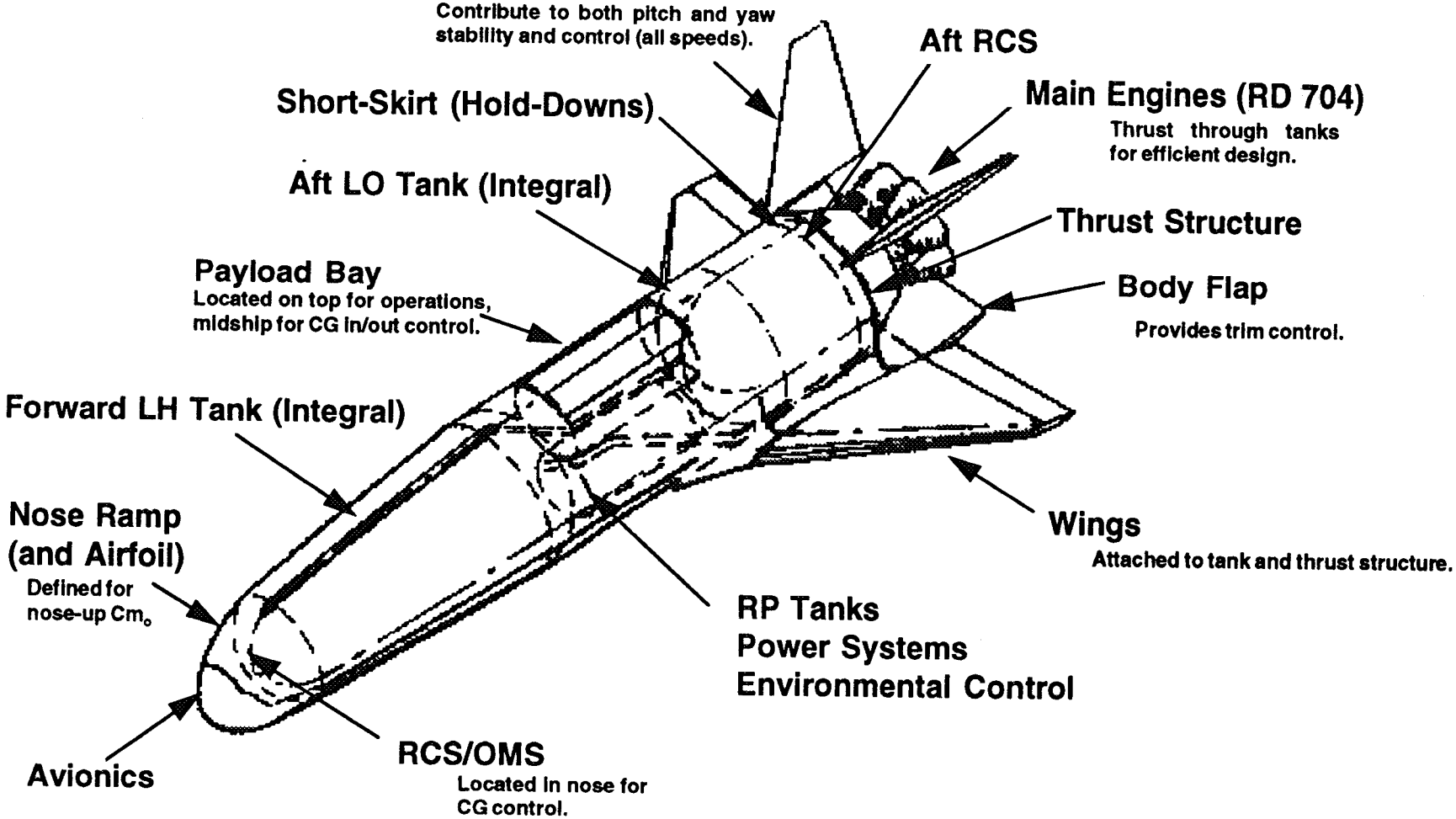
Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
2.3	Configuration 4 Drawings			
2.3.1	Vehicle Weight Statement	Table 3W		
2.3.2	Vehicle Description	same as for 2A - except for common bulkhead which uses Al-Li		
2.4	Configuration 3 Drawings			
2.4.1	Vehicle Weight Statement	Table 4W		
2.4.2	Vehicle Description	same as for 2A - except for common bulkhead which uses Al-Li		

Vehicle Configuration 1A - LO2 Tank Aft



REUSABLE CRYOTANKS



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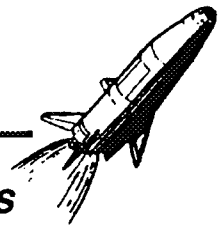
Configuration 1A: Structural Weight Reduction



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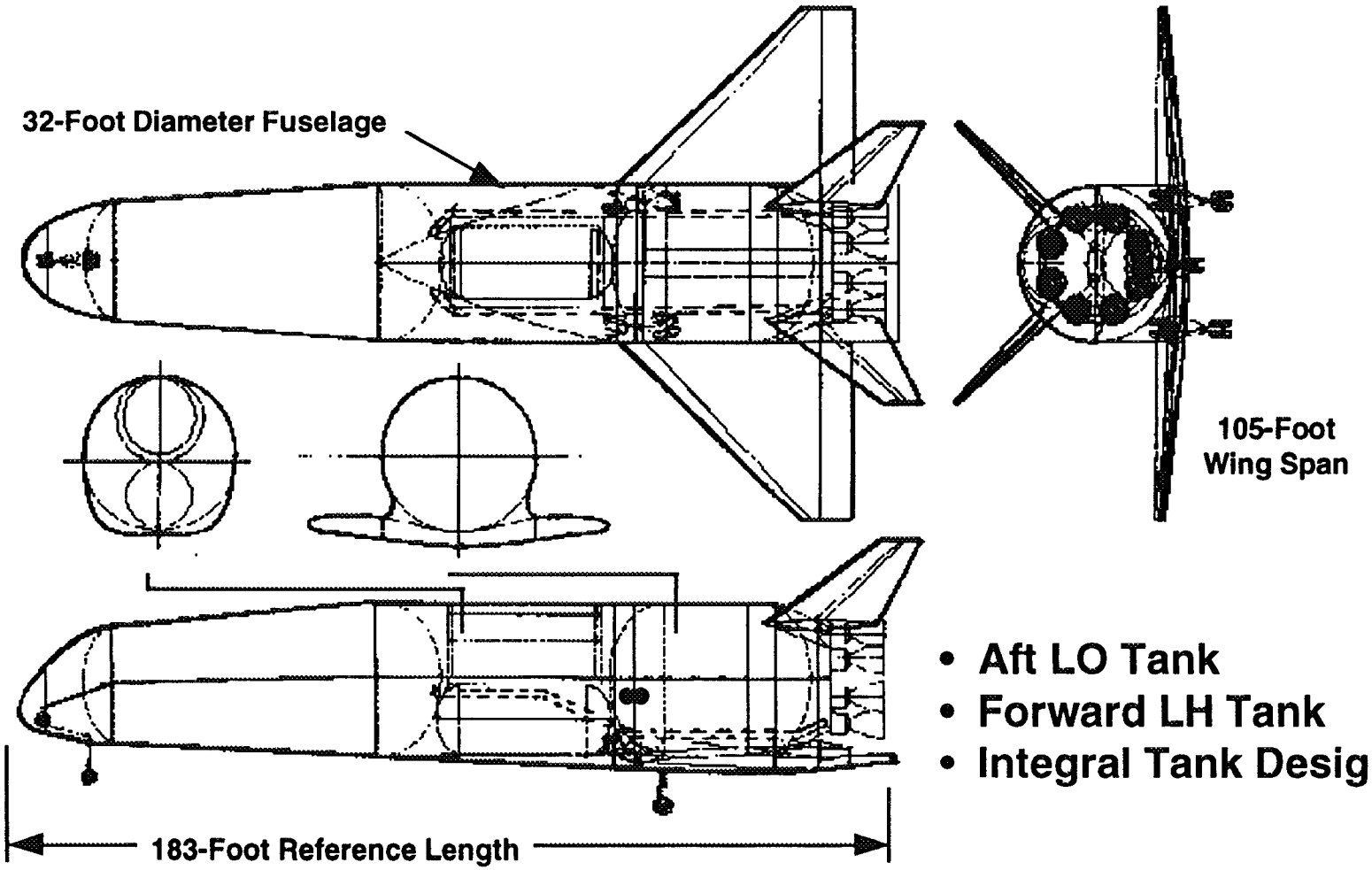

- Aft LO Tank
- Forward LH Tank
- Integral Tank Design

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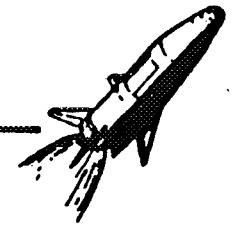
Baseline Configuration 2A Structural Arrangement Highlights



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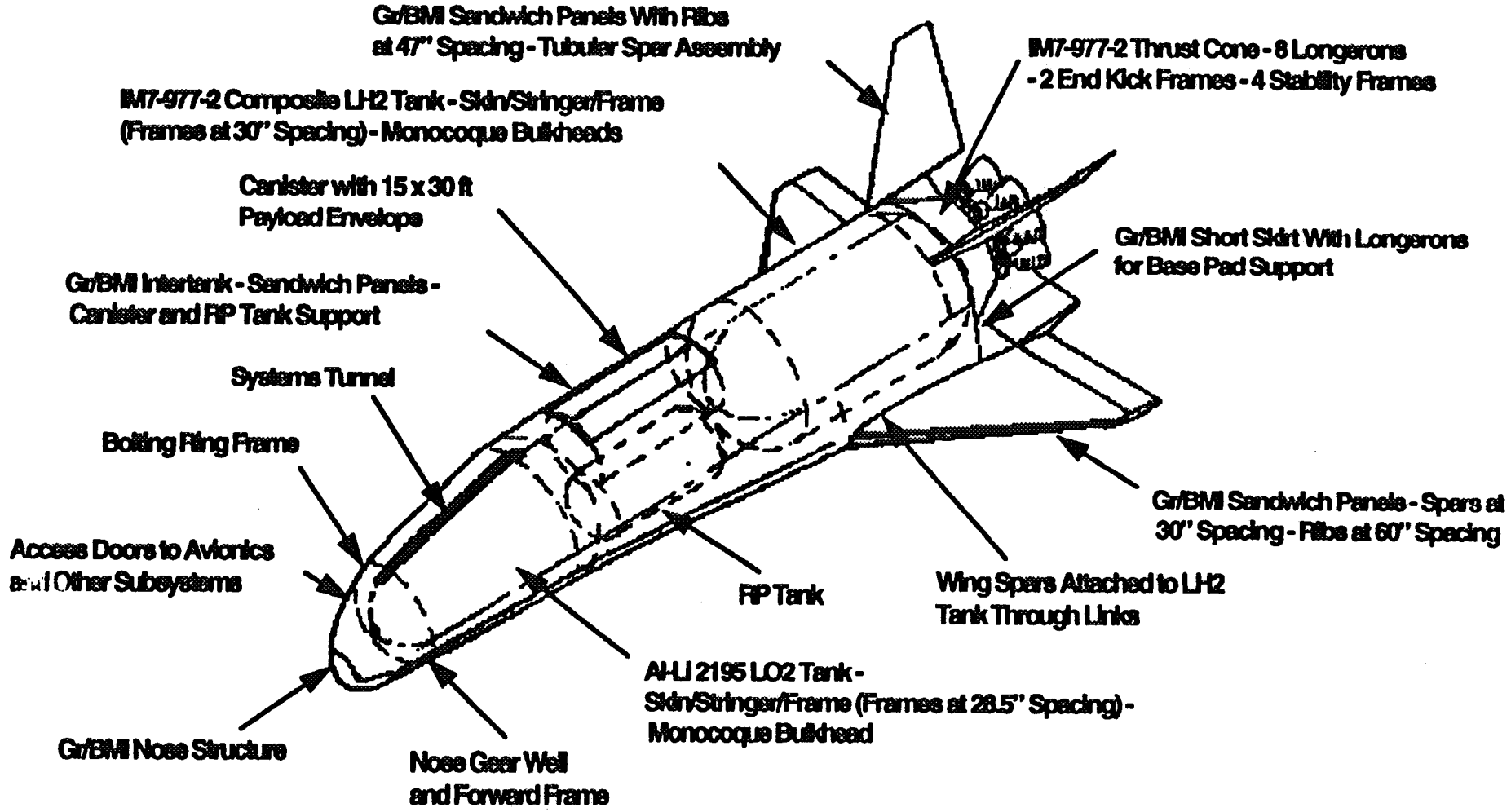

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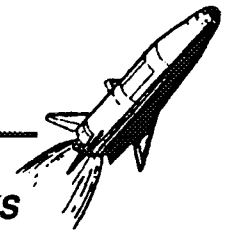
Table 1W
Configuration 2A: Initial Vehicle Mass Properties



REUSABLE CRYOTANKS

SYSTEM	WEIGHT (lb)	X CG (in)	Z CG (in)
STRUCTURE	(116,071)	(1,273)	-(55)
WING & WING CARRY THROUGH	14,243	1,712	-200
BODY FLAP & VERTICAL TAILS	6,751	1,961	118
LANDING GEAR	7,468	1,163	-197
LO2 TANK	9,622	509	-6
RP TANK	1,484	978	-100
LH2 TANK	10,979	1,560	0
NOSE STRUCTURE	2,025	125	-56
INTER TANK, SKIRTS, & FAIRINGS	20,328	1,145	-52
THRUST STRUCTURE	7,392	1,874	0
TPS, TCS, & PURGE & VENT	31,694	1,133	-49
MISC.	4,086	1,149	-1
PROPULSION	(63,712)	(1,849)	-(13)
ENGINES (8 RD-704'S)	42,632	1,967	0
ENGINE ANCILLARY SYSTEMS	3,046	1,978	0
MAIN PROPULSION PLUMBING	14,402	1,711	-31
OMS/RCS/ZERO G TANKS	3,631	910	-114
SUBSYSTEMS	(10,618)	(1,278)	-(78)
AVIONICS	1,277	750	-100
ECLSS	1,485	870	-87
EPD&C	4,320	1,098	-88
SURFACE CONTROL ACTUATION	3,397	1,897	-56
RANGE SAFETY	140	960	0
MARGIN = 17.95%	34,180	1,466	-43
EMPTY WEIGHT	224,582	1,466	-43
PAYLOAD	25,000	978	112
PROPELLENT	2,324,685	627	-16
GLOW	2,574,267	703	-17

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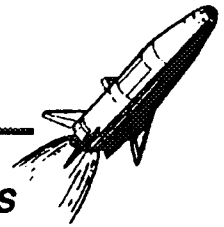
Table 1W1 - Propellant Weight For Specified Load Cases

LOAD CASE NUMBER	LOAD CASE DESCRIPTION	FUEL TANK WEIGHTS		
		LH2 TANK (Lbs)	LOX TANK (Lbs)	RP TANK (Lbs)
2A-3.2.1	Prelaunch - Unfueled - wind from front	0	0	0
2A-3.2.2	Prelaunch - Unfueled - wind from back	0	0	0
2A-3.3.1	Prelaunch - Fueled - wind from front	183456	1900444	221946
2A-3.3.2	Prelaunch - Fueled - wind from back	183456	1900444	221946
2A-3.4.1	Lift-off - wind from front	183456	1900444	221946
2A-3.4.2	Lift-off - wind from back	183456	1900444	221946
2A-3.5.1	Max q Alpha - positive angle of attack (4 Degrees)	143743	1361670	138549
2A-3.5.2	Max q Alpha - negative angle of attack (4 Degrees)	143743	1361670	138549
2A-3.5.3	Max q Beta - positive angle of attack (4 Degrees)	143743	1361670	138549
2A-3.8	Max Thrust - angle of attack is zero	99850	766184	46373
2A-3.11	TAEM Maneuver 2.5 g	917	9502	1110
2A-3.12	Main Gear Landing - Spin-up	917	9502	1110
2A-3.13	Main Gear Landing - Springback	917	9502	1110
2A-3.14	Nose Gear Landing - Slapdown	917	9502	1110

Vehicle Configuration 2A - LO2 Tank Forward



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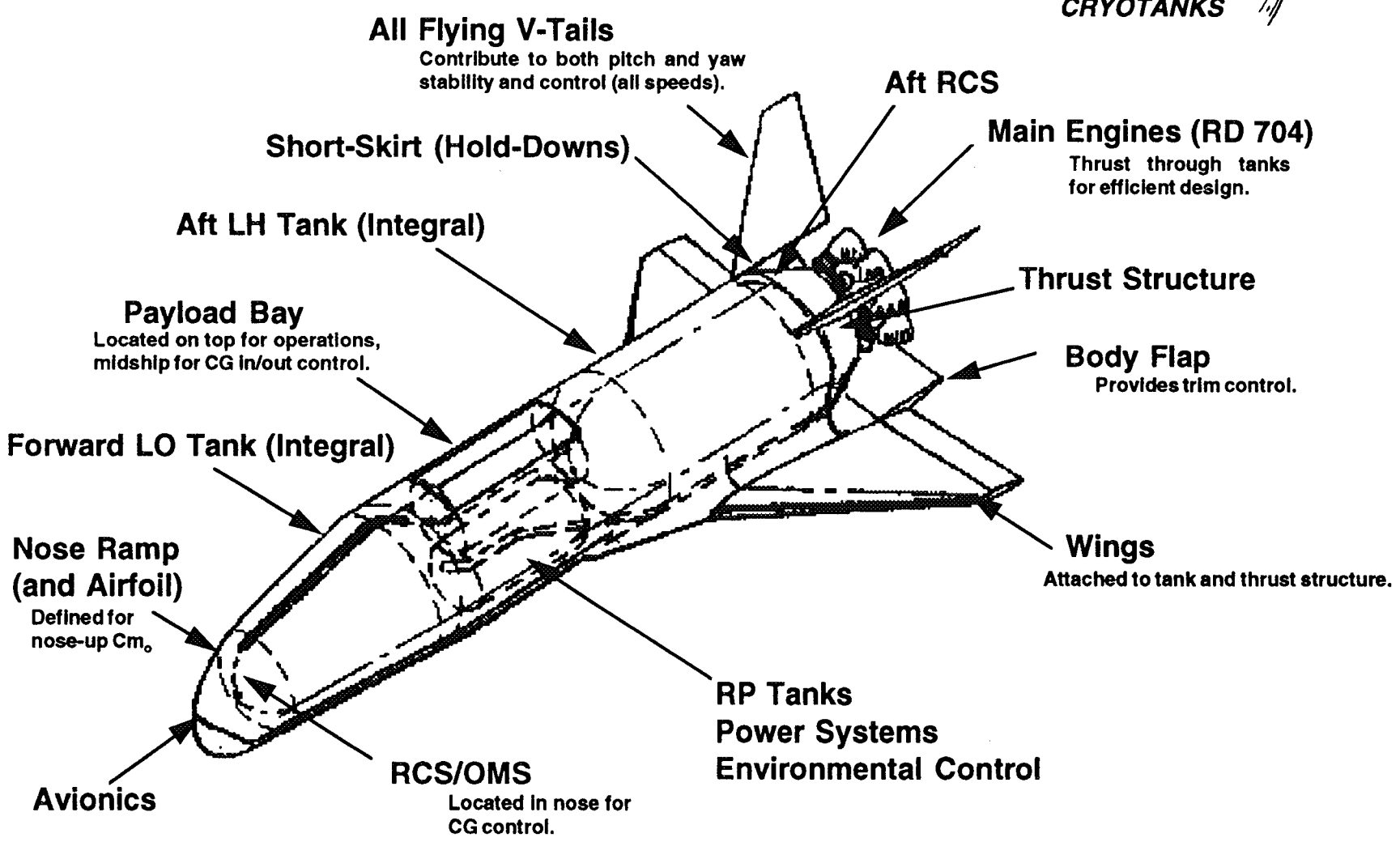

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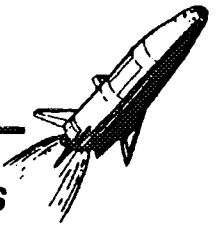
Configuration 2A: Baseline Concept



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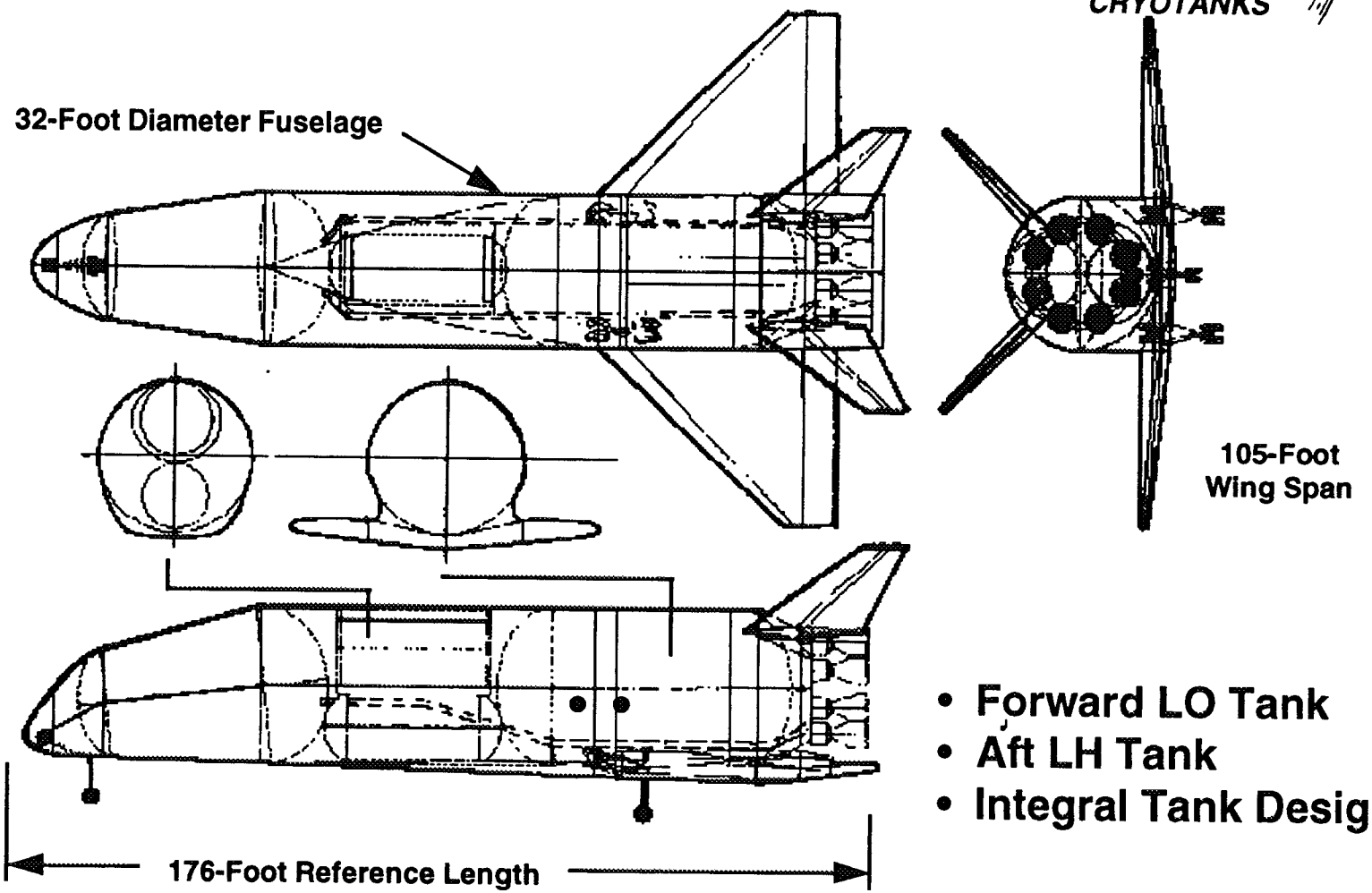

- Forward LO Tank
- Aft LH Tank
- Integral Tank Design

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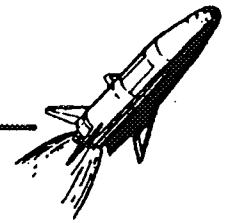
Configuration 1A Structural Arrangement Highlights



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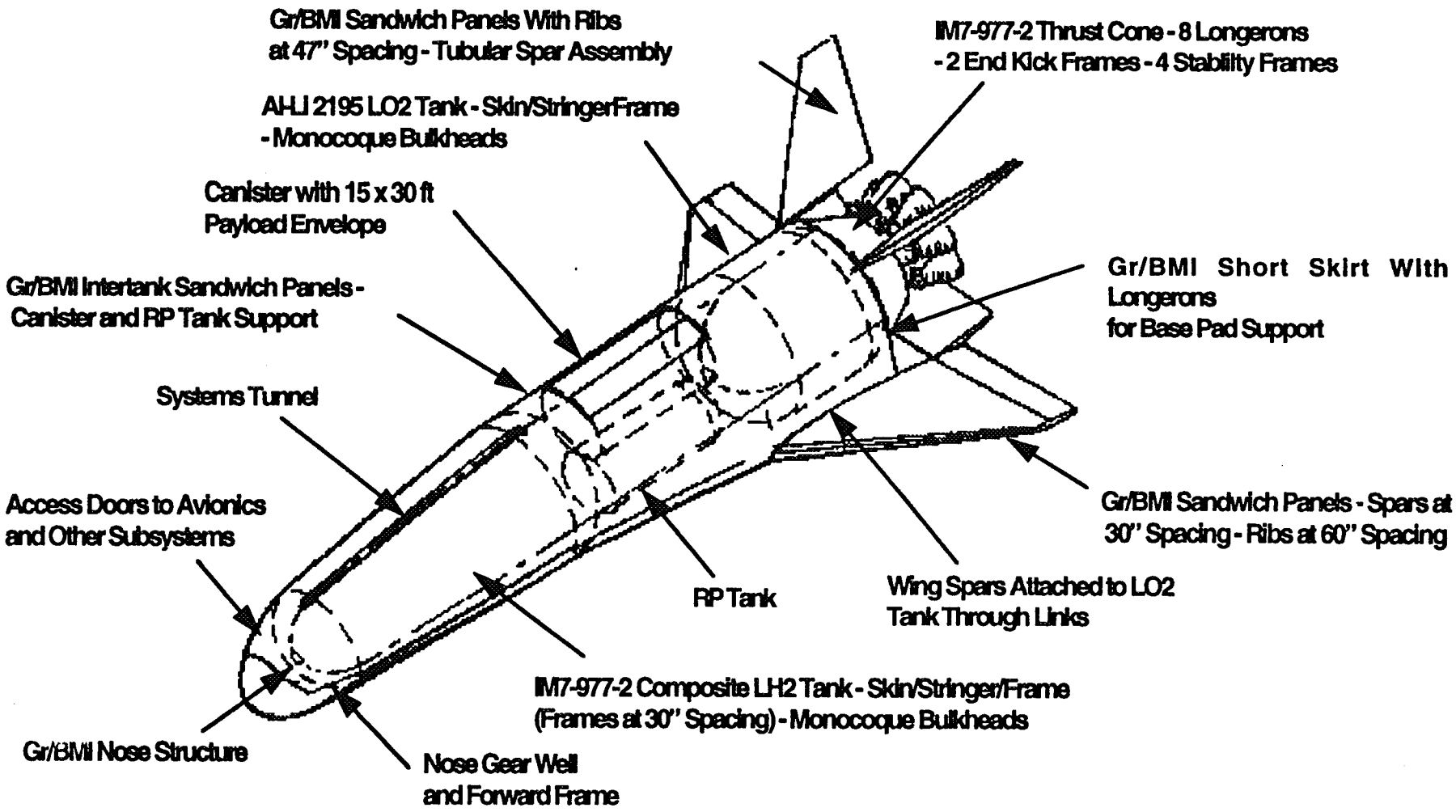

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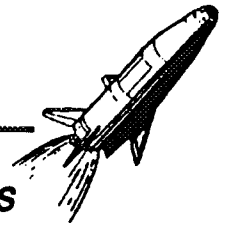
Table 2W
Configuration 1A: Initial Vehicle Mass Properties

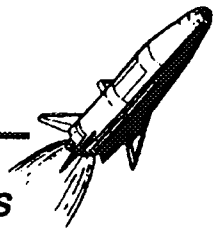


REUSABLE CRYOTANKS

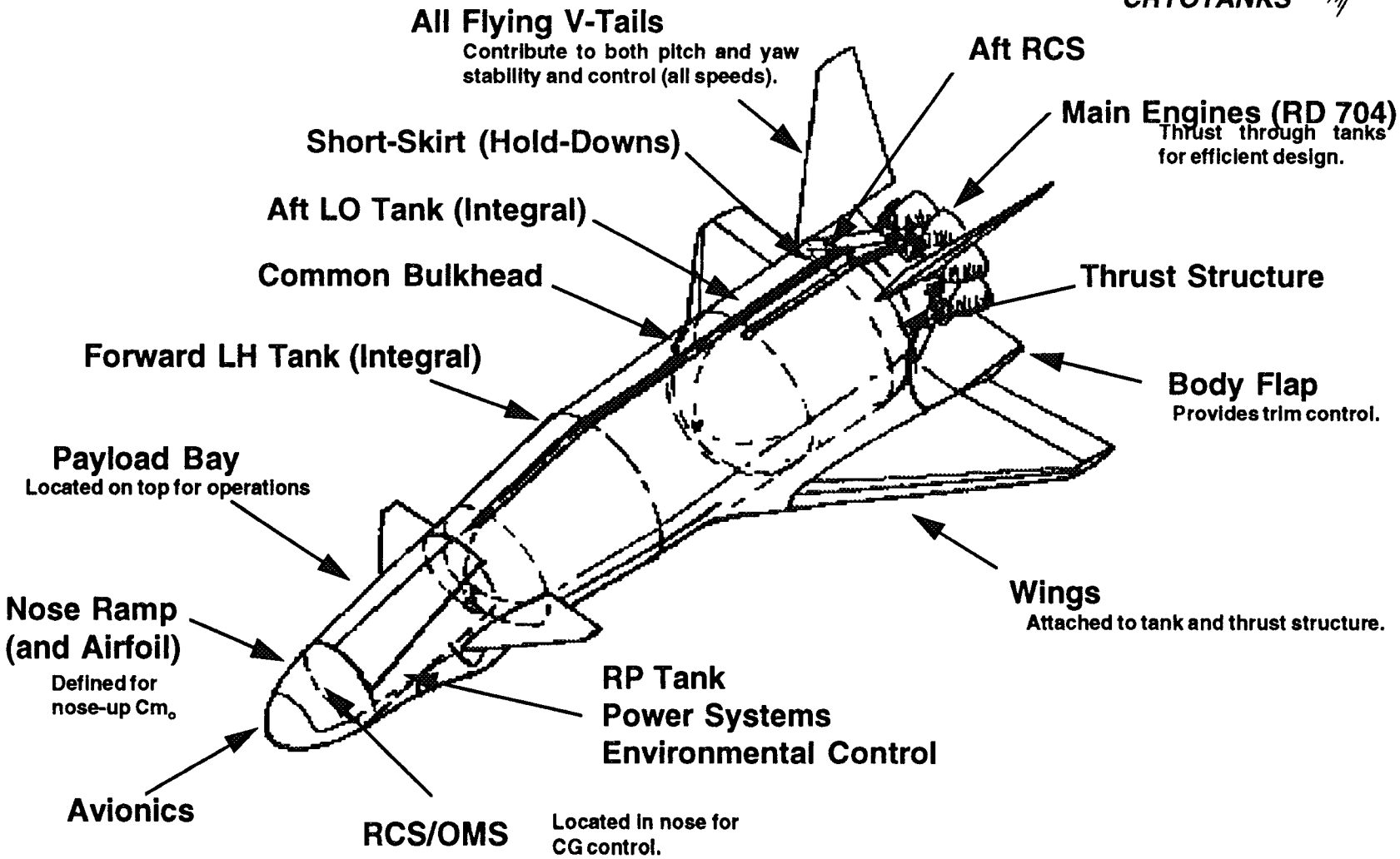
SYSTEM	WEIGHT (lb)	X CG (in)	Z CG (in)
STRUCTURE	(114,138)	(1,383)	-(53)
WING & WING CARRY THROUGH	14,243	1,780	-200
BODY FLAP & VERTICAL TAILS	6,766	2,052	104
LANDING GEAR	7,468	1,201	-161
LO2 TANK	9,380	1,742	0
RP TANK	1,538	1,259	-100
LH2 TANK	11,358	650	-9
NOSE STRUCTURE	2,187	132	-66
INTER TANK, SKIRTS, & FAIRINGS	17,343	1,346	-46
THRUST STRUCTURE	7,784	1,944	0
TPS, TCS, & PURGE & VENT	31,692	1,239	-43
MISC.	4,380	1,356	-16
PROPULSION	(63,837)	(1,930)	-(12)
ENGINES (8 RD-704'S)	42,632	2,047	0
ENGINE ANCILLARY SYSTEMS	3,330	2,057	0
MAIN PROPULSION PLUMBING	14,199	1,778	-23
OMS/RCS/ZERO G TANKS	3,676	1,058	-112
SUBSYSTEMS	(10,753)	(1,465)	-(72)
AVIONICS	1,277	1,050	-100
ECLSS	1,528	1,217	-87
EPD&C	4,370	1,291	-85
SURFACE CONTROL ACTUATION	3,438	1,960	-41
RANGE SAFETY	140	1,200	0
MARGIN = 19.%	35,854	1,573	-40
EMPTY WEIGHT	224,582	1,573	-40
PAYLOAD	25,000	1,250	90
PROPELLENT	2,324,685	1,583	-13
GLOW	2,574,267	1,579	-14

NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Configuration 3 - Canard and Forward Payload

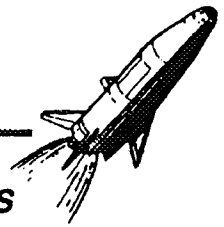


REUSABLE CRYOTANKS

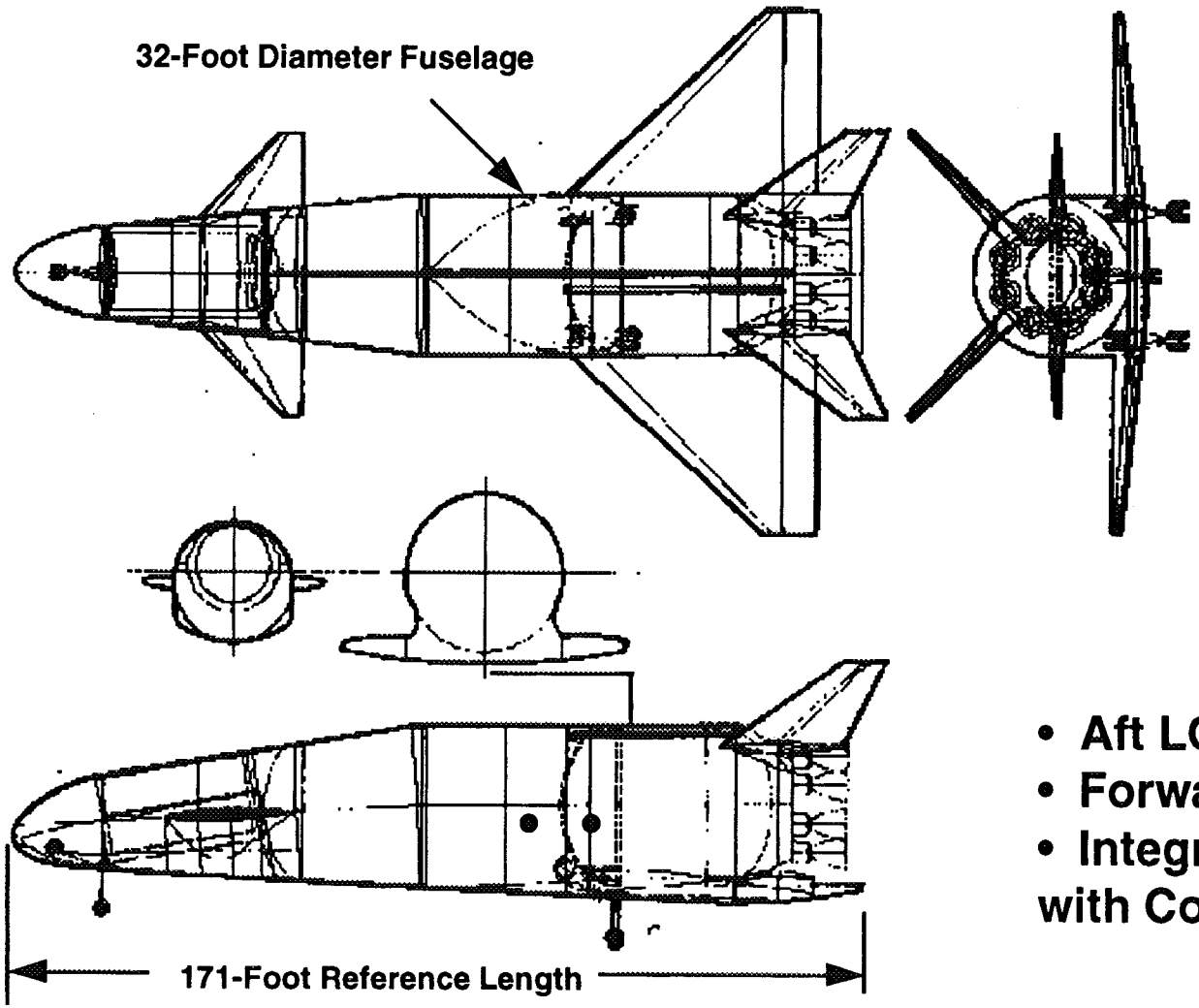


NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Configuration 3: Forward Payload with Canard



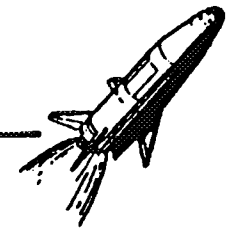
REUSABLE CRYOTANKS



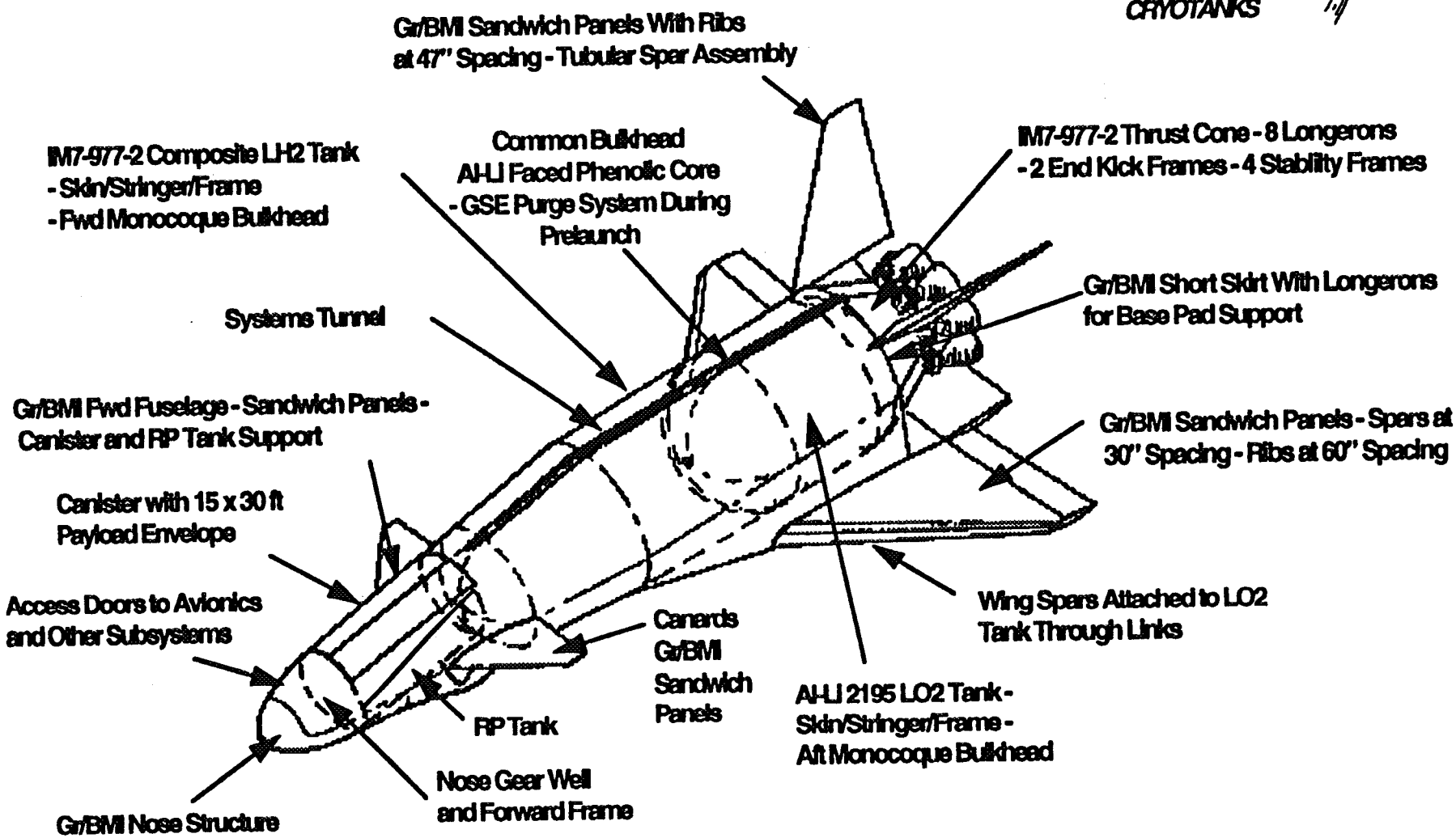
- Aft LO Tank
- Forward LH Tank
- Integral Tank Design with Common Bulkhead

NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Configuration 3 - Canard and Forward Payload

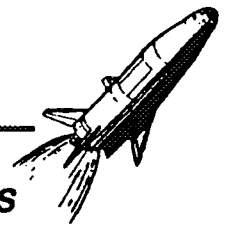


REUSABLE CRYOTANKS



NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Table 3W
Configuration 4: Initial Vehicle Mass Properties

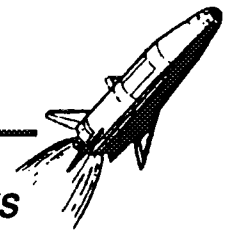


REUSABLE CRYOTANKS

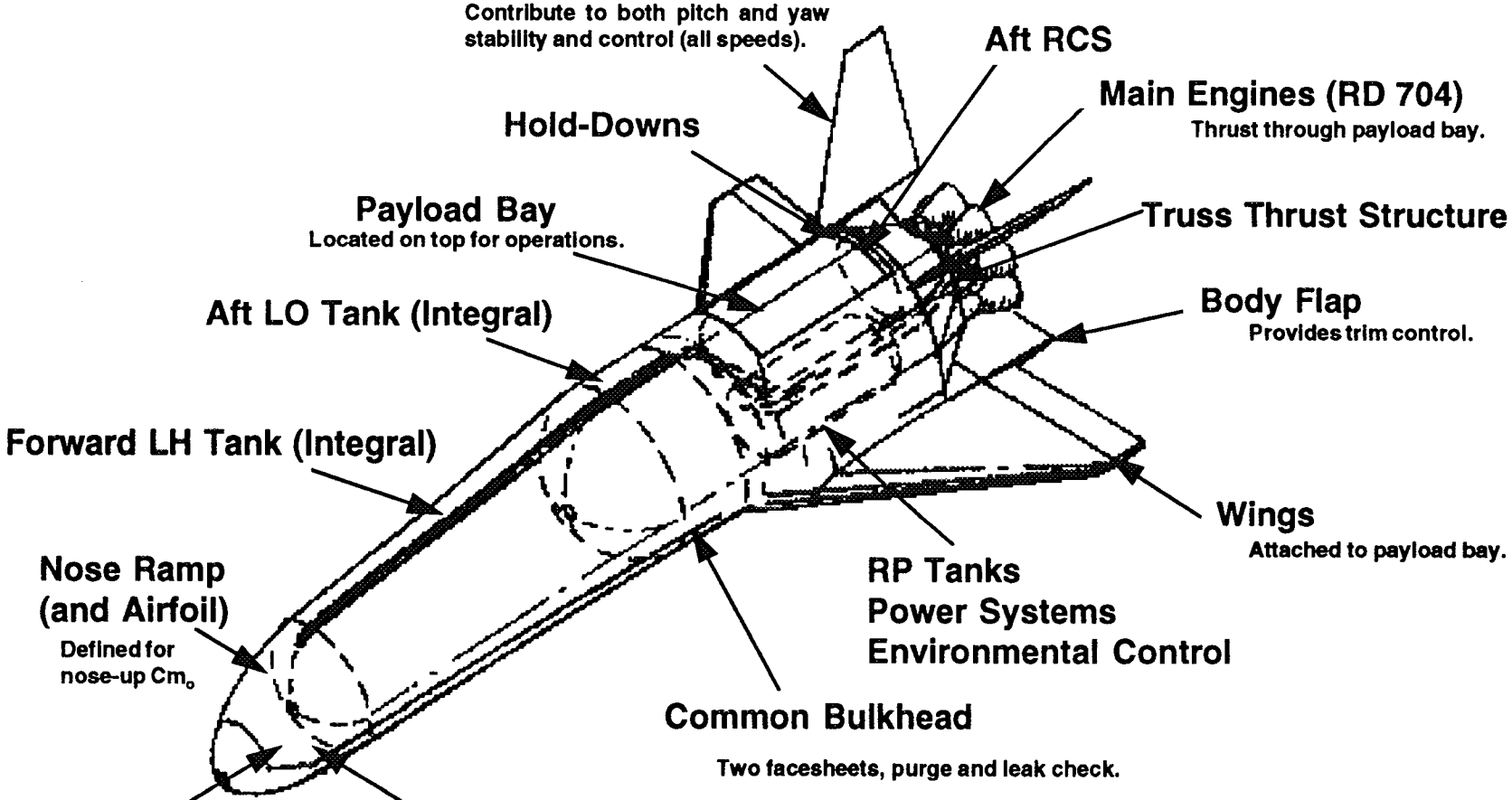
SYSTEM	WEIGHT (lb)	X CG (in)	Z CG (in)
STRUCTURE	(114,106)	(1,384)	-(47)
WING & WING CARRY THROUGH	14,310	1,750	-170
BODY FLAP & VERTICAL TAILS	6,751	2,039	132
LANDING GEAR	7,468	1,262	-179
LO2 TANK	12,535	1,246	0
RP TANK	1,572	1,665	-85
LH2 TANK	11,279	753	-23
NOSE STRUCTURE	2,413	157	-85
INTER TANK, SKIRTS, & FAIRINGS	14,826	1,581	-39
THRUST STRUCTURE	7,200	1,922	0
TPS, TCS, & PURGE & VENT	31,358	1,229	-43
MISC.	4,394	1,551	11
PROPULSION	(65,966)	(1,895)	-(2)
ENGINES (8 RD-704'S)	42,632	2,017	0
ENGINE ANCILLARY SYSTEMS	3,148	2,028	0
MAIN PROPULSION PLUMBING	16,120	1,700	17
OMS/RCS/ZERO G TANKS	4,066	1,282	-102
SUBSYSTEMS	(10,645)	(1,599)	-(72)
AVIONICS	1,277	1,500	-100
ECLSS	1,493	1,262	-87
EPD&C	4,330	1,499	-85
SURFACE CONTROL ACTUATION	3,404	1,946	-40
RANGE SAFETY	140	750	0
MARGIN = 17.8%	33,866	1,573	-33
EMPTY WEIGHT	224,582	1,573	-33
PAYLOAD	25,000	1,658	100
PROPELLENT	2,324,685	1,210	-12
GLOW	2,574,267	1,246	-12

NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Vehicle Configuration 4 - Payload Aft

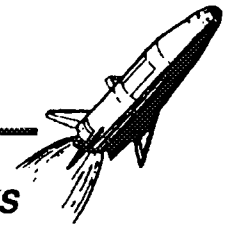


REUSABLE CRYOTANKS

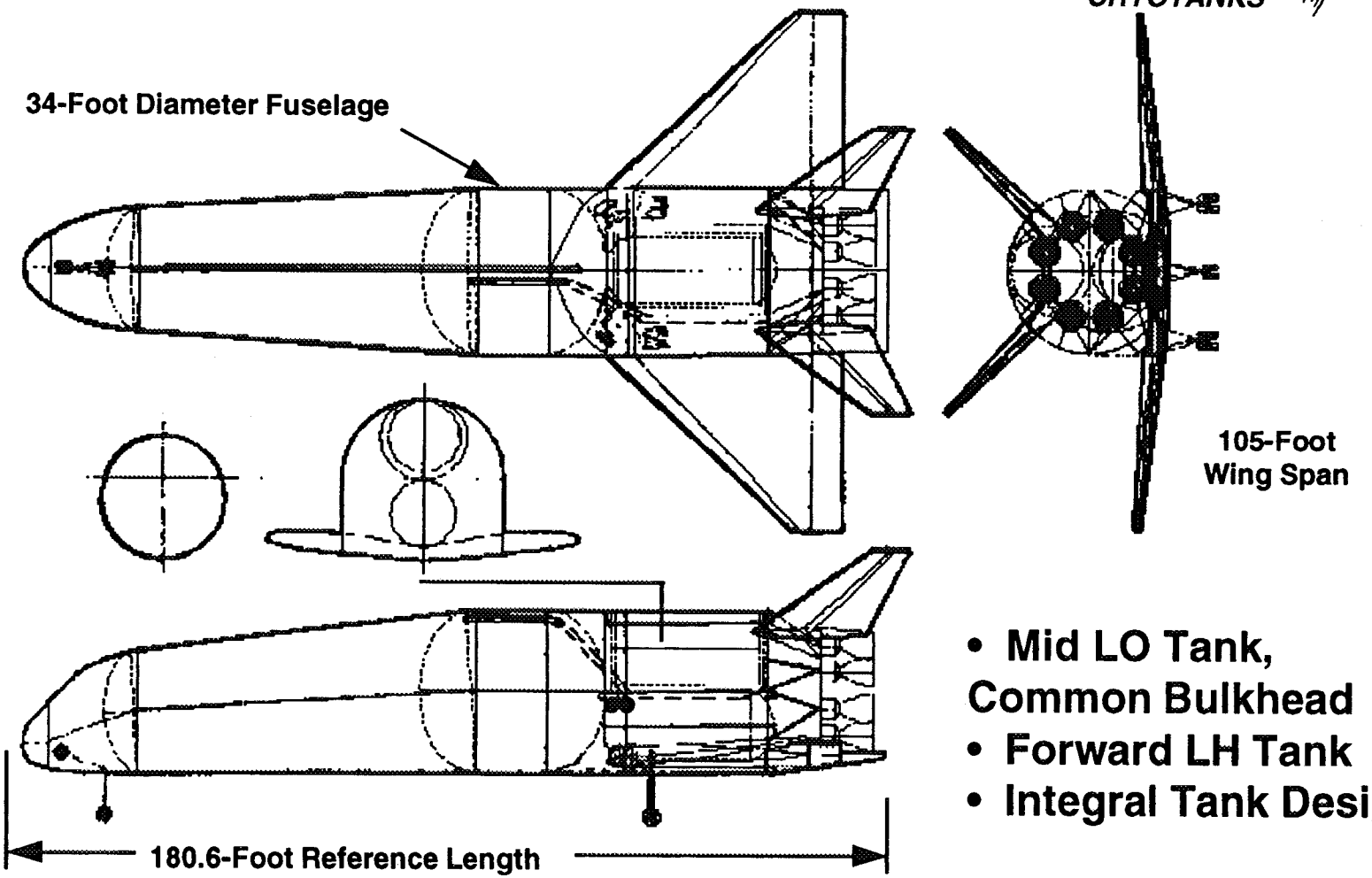


NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Configuration 4 - Truss Thrust Structure



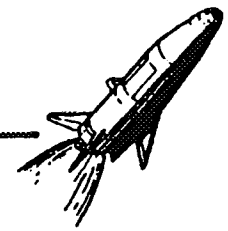
REUSABLE CRYOTANKS



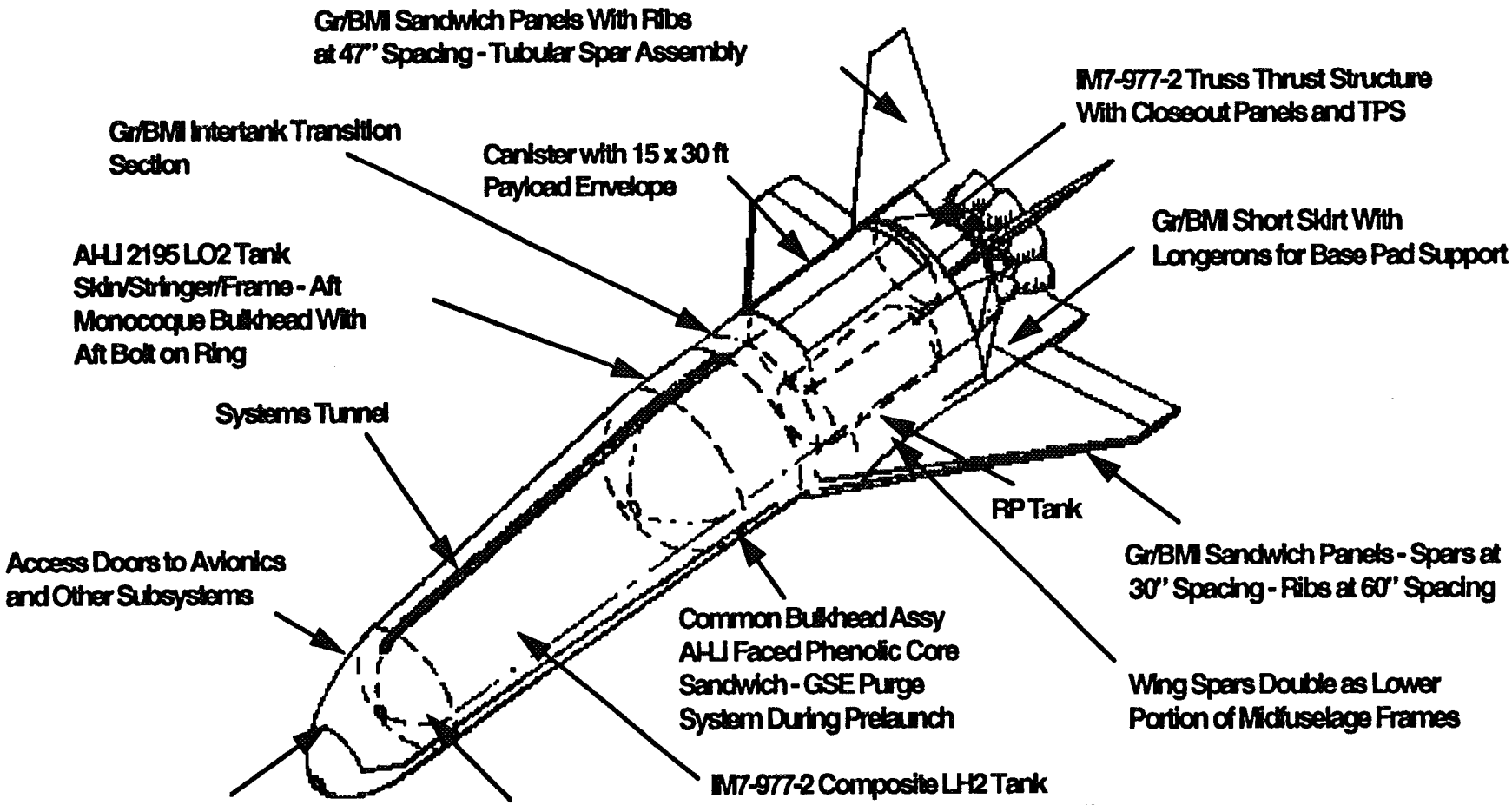
- Mid LO Tank, Common Bulkhead
- Forward LH Tank
- Integral Tank Design

NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Configuration 4 Structural Arrangement Highlights

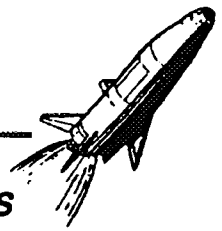


REUSABLE CRYOTANKS



NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Table 4W
Configuration 3: Initial Vehicle Mass Properties

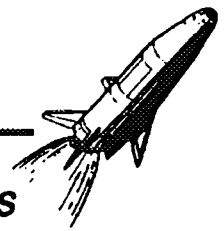


REUSABLE CRYOTANKS

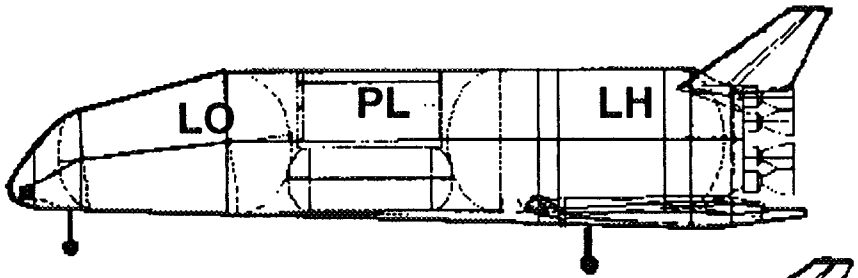
SYSTEM	WEIGHT (lb)	X CG (in)	Z CG (in)
STRUCTURE	(113,535)	(1,298)	-(56)
WING & WING CARRY THROUGH	14,309	1,647	-200
BODY FLAP, VERTICAL TAILS, & CANARD	9,023	1,599	88
LANDING GEAR	7,465	1,151	-163
LO2 TANK	12,760	1,608	0
RP TANK	2,502	492	-100
LH2 TANK	11,050	1,106	-4
NOSE STRUCTURE	646	64	-46
INTER TANK, SKIRTS, & FAIRINGS	14,746	870	-57
THRUST STRUCTURE	7,588	1,821	0
TPS, TCS, & PURGE & VENT	28,662	1,249	-61
MISC.	4,785	904	-39
PROPULSION	(62,607)	(1,773)	-(4)
ENGINES (8 RD-704'S)	42,632	1,917	0
ENGINE ANCILLARY SYSTEMS	3,046	1,928	0
MAIN PROPULSION PLUMBING	13,337	1,692	3
OMS/RCS/ZERO G TANKS	3,592	239	-74
SUBSYSTEMS	(10,941)	(831)	-(31)
AVIONICS	1,277	200	-100
ECLSS	1,448	153	-53
EPD&C	4,278	478	18
SURFACE CONTROL ACTUATION	3,799	1,703	-56
RANGE SAFETY	140	750	0
MARGIN = 20.%	37,499	1,430	-37
EMPTY WEIGHT	224,582	1,430	-37
PAYLOAD	25,000	428	0
PROPELLENT	2,324,685	1,426	-11
GLOW	2,574,267	1,416	-13

NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

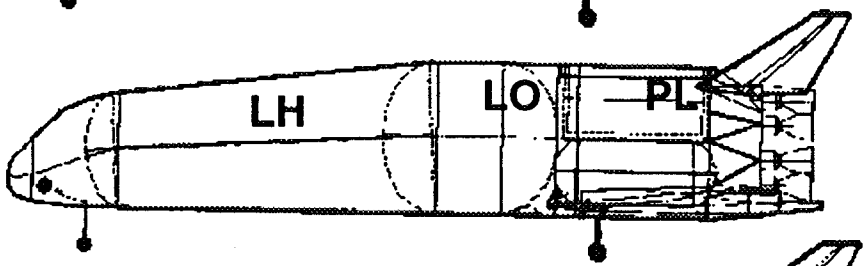
Vehicle Configuration Comparison



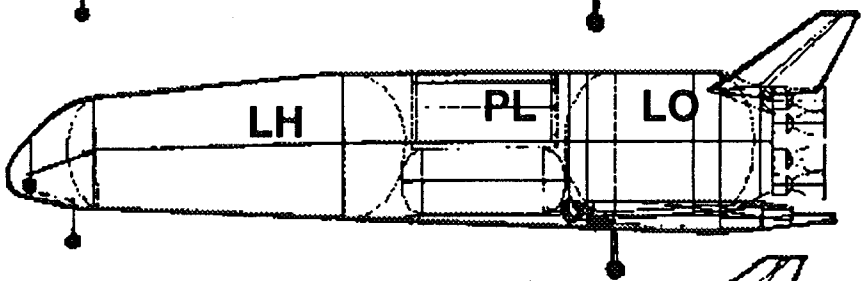
REUSABLE CRYOTANKS



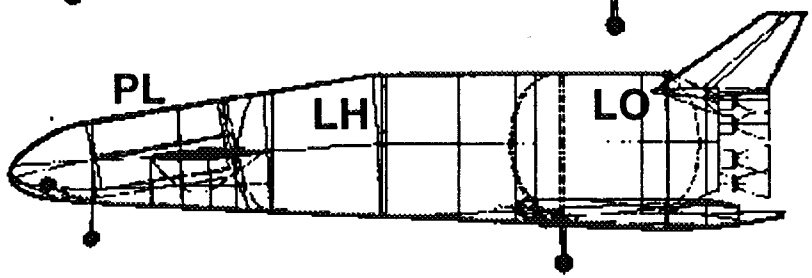
Configuration 2A
Baseline Concept



Configuration 4
Truss Thrust Structure



Configuration 1A
Structural Weight Reduction



Configuration 3
Canard and Forward Payload

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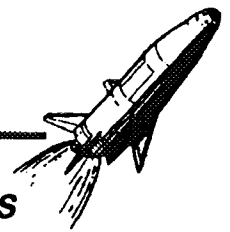
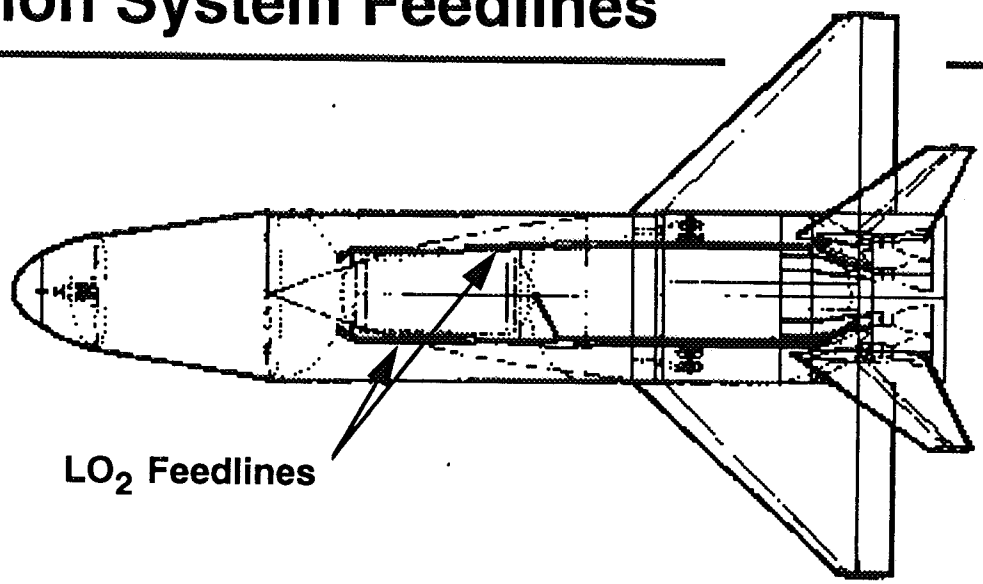
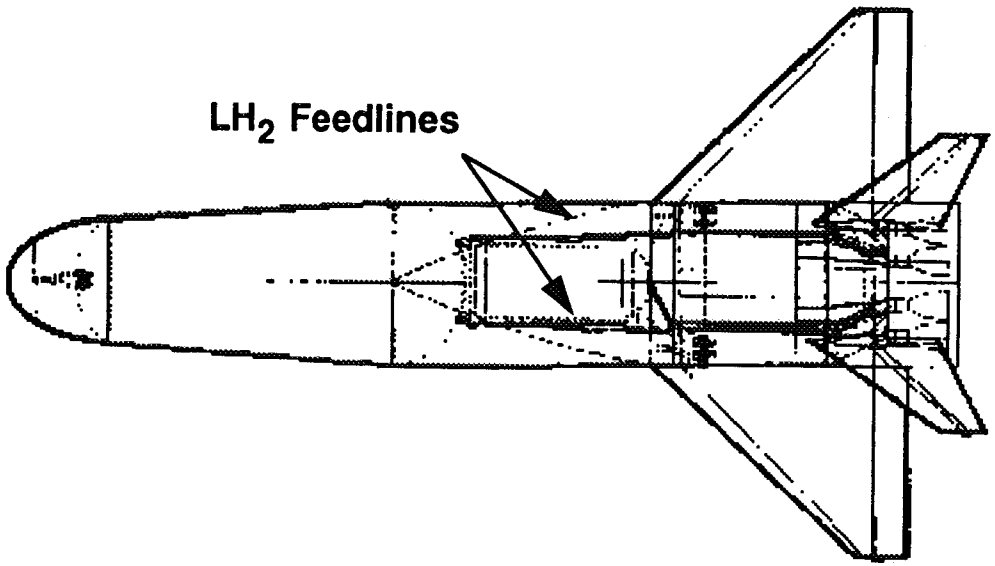
Propulsion System Feedlines



REUSABLE CRYOTANKS



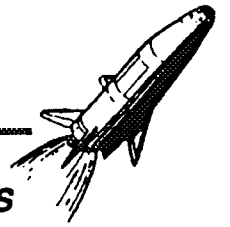
2A Installation



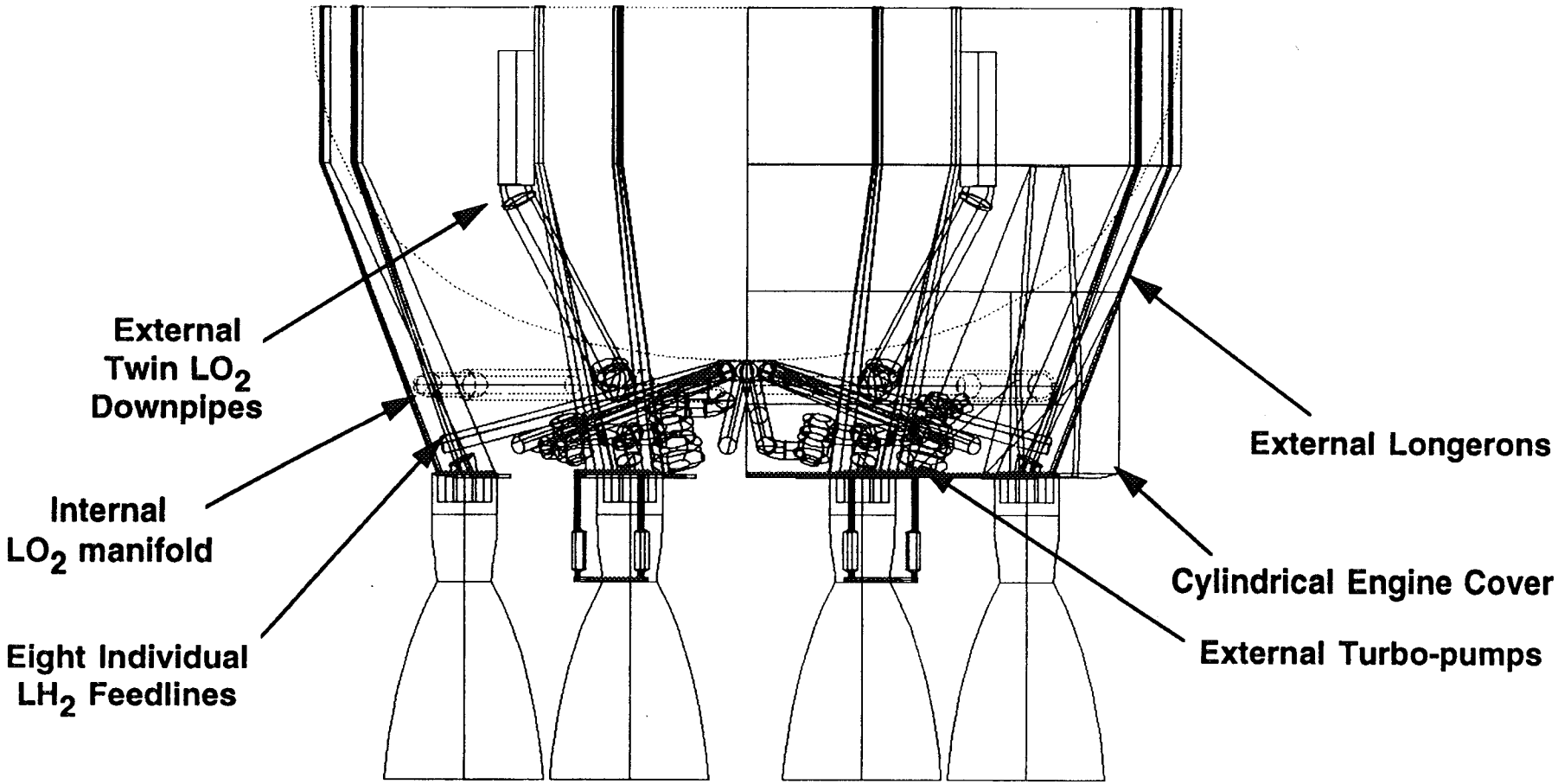
1A Installation

NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Propulsion installation maximizes accessibility

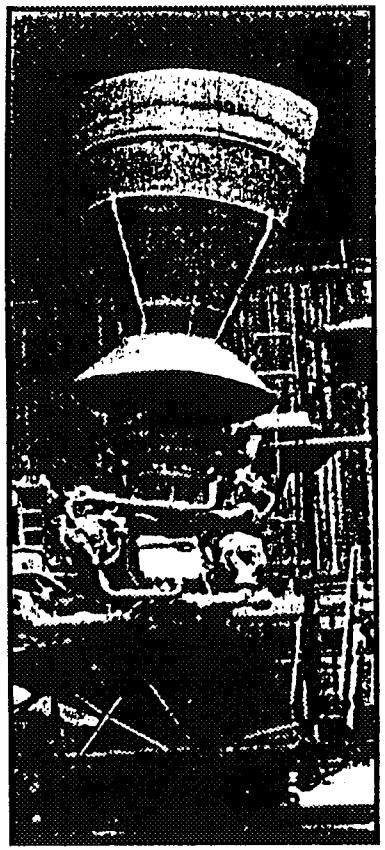


(2A Baseline Configuration shown)



NASA - ROCKWELL/SSD - ROCKWELL/NAAD/TULSA - HERCULES

Table 1 ENG
RD-704 CHARACTERISTICS



Mode			1	2
Propellants			LO_2/LH_2/RP-1	LO_2/LH_2
Thrust (lbs)	S.L.		386,140	N/A
	Vac		441,430	175,560
Impulse (sec)		S.L.	356/351	N/A
(Nominal worst case)		Vac	407/401	452/450
Weight (lbs)			5,329*	
Mixture ratio (O/F)			4.38	6.0
Chamber pressure (psia)			4,266	1,762
Area ratio			74	
Dimensions (in.)		Dia.	70.1	
(Single bell)		Length	151	

*MSFC/P&W worst case prediction. Excludes sensors, gimbal actuators, and heat shield

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Section 3.0 Structure/TPS Requirements - Roll Out to Pad to return to OPF

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.3.6	Fueling Sequence	LH tank first - LO next		see design criteria - sect 4.6.3
	LO tank fueling rate (gpm)	10,000		
	LH tank fueling rate (gpm)	15,000		
	LO tank drain rate (gpm)	3000		Allows Loading
	LH tank drain rate (gpm)	5000		In Reasonable Time
	RP tank fueling rate (gpm)	2000		
	RP tank drain rate (gpm)	500		
3.3.7	Tank Pressurization			
	Sequence of pressurization	constrained per criteria		see design criteria - sect 4.6.3
	LO tank minimum (psig)	>0		propulsion requirements only - see Table 1 TP for
	LO tank max relief (psig)	20		
	LO peak operating (psig)	18		
	LH tank minimum(psig)	>0		propulsion requirements only - see Table 1 TP for
	LH tank max relief (psig)	34		
	LH peak operating (psig)	32		
	RP tank minimum (psig)	>0		propulsion requirements only - see Table 1 TP for
	RP tank max relief(psig)	20		
	RP peak operating (psig)	10.3		
	GH2 pressuriz Temp (Max °F)	160		
	GO2 pressuriz Temp (Max °F)	160		
	GHe pressurization Temp (Max °F)	160		
3.3.8	Permissible Leakage	0		
	LO tank	0		
	LH tank	0		
	RP tank			
3.3.9	Maximum Boil-Off Rate			
	LO tank (lb/sec)	2		Max Allowable During
	LH tank (lb/sec)	1		Replenish Operation
3.3.10	Pad Environment			
	Coldest temperature	19 F, Mean Min 48 F		
	Concurrent humidity	Mean Real Humidity 07 89.3, Mean Relative Humidity 13 60.8		
	Concurrent dew point	Mean dewpoint Temp 50 F		
	Hottest day	98 F Max temp, Mean Max 90 F		
	Concurrent humidity	Mean Real Humidity 07 88.4, Mean Relative Humidity 13 63.9		
	Concurrent dew point	Mean dewpoint temp 77 F		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Rainfall	2.5 to 5.5 in/hr - no wind 5.7 to 11.7 in/hr - 4.4 to 8.4 knots wind 17 to 25 in/hr - 35 to 55 knots wind		TBD Probability
	lightening	Not applicable		Lightening arresters assumed on pad
	Water deluge	Yes		after scrubbed launch
	Salt spray	Yes		
	Bird droppings	Yes		
	Debris Impact	90 Degree impact - 0.125 and 2.0 inch radius - 1 to 5 ft lbs		
3.3.11	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F		
3.3.12	Limit Critical Body Loads	Table 1 IL		
3.3.13	IHM requirements	Table 1IHM		
3.3.14	Payload Environment			
	Temperature	not critical		
	Pressure	not required		
	Humidity	not required		
	Cleanliness	not required		
3.3.15	Vehicle Mass Distribution	Defined in finite element model		
3.4 Lift- off				
3.4.1	Thrust to Weight	1.2		
3.4.2	Dynamic Amplification	1.1		
3.4.3	Peak Wind Speed	Table 4GW	JSC 07700 Volume X Book 2 Revision L	95 % probability of exceedance in 1 hour
3.4.4	Air Pressures	Defined in finite element model		
3.4.5	Vehicle Hold Down at Base	Figure 1 HD		
	Pad attach concept	Figure 1 HD		
3.4.6	Load Factors			
	Nx	1.32 inc ampl		
	Ny	0		
	Nz	0.013		
3.4.7	Tank Pressurization			

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	LO tank minimum (psig)	1		propulsion requirements only - see Table 1 TP for
	LO tank max relief (psig)	20		
	LO peak operating (psig)	15.3		
	LH tank minimum(psig)	15.3		propulsion requirements only - see Table 1 TP for
	LH tank max relief (psig)	34		
	LH peak operating (psig)	32		
	RP tank minimum (psig)	1		propulsion requirements only - see Table 1 TP for
	RP tank max relief(psig)	20		
	RP peak operating (psig)	10.3		
	GH2 pressuriz Temp (Max °F)	160		
	GO2 pressuriz Temp (Max ° F)	450		
	GHe pressurization Temp (Max ° F)	160		
3.4.8	Permissible Leakage			
	LO tank	TBD		
	LH tank	TBD		
	RP tank	TBD		
3.4.9	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.4.10	Pad Environment			
	Coldest temperature	19 F, Mean Min 48 F		
	Concurrent humidity	Mean Real Humidity 07 89.3, Mean Relative Humidity 13 60.8		
	Concurrent dew point	Mean dewpoint Temp 50 F		
	Hottest day	98 F Max temp, Mean Max 90 F		
	Concurrent humidity	Mean Real Humidity 07 88.4, Mean Relative Humidity 13 63.9		
	Concurrent dew point	Mean dewpoint temp 77 F		
	Rainfall	2.5 to 5.5 in/hr - no wind 5.7 to 11.7 in/hr - 4.4 to 8.4 knots wind 17 to 25 in/hr - 35 to 55 knots wind		TBD Probability
	lightening	50 kiloamperes		TBD Probability
	Water deluge	Yes		after scrubbed launch
	Salt spray	Yes		
	Bird droppings	Yes		
	Debris impact	No		
3.4.11	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.4.12	Limit Critical Body Loads	Table 1 IL		
3.4.13	Dynamics			
	Acoustics (db)	Table 1 and 2 AC		
	Nx amplification Ny Nz	1.1 1.05 1.05		Engine gimbal transients, and unsteady engine flow transients
	Ignition over pressure	TBD		
	POGO	TBD		
3.4.14	Guidance and Control			
	Elevons	Fixed orientation at TBD		
	Body Flap	Fixed orientation at 0 deg		
	Tail			
	Main engine			
	Actuator loads	TBD		
	Gimbal angles	TBD		
	Actuatator acceleration	TBD		
	Actuator rate	TBD		
3.4.15	IHM requirements	Table 1IHM		
3.4.16	Payload Environment			
	Temperature	not required		
	Pressure	not required		
	Humidity	not required		
	Cleanliness	not required		
3.4.17	On Pad Abort			
	Engine shutdown	TBD		
	Safing	TBD		
	Reinstallation of holddowns	TBD		
3.4.18	Vehicle Mass Distribution	Defined in finite element model		
3.5 Ascent - Max qa - at T=76 secs				
3.5.1	Thrust to Weight	1.78		
3.5.2	Dynamic Pressure	560		500 nominal + 60 dispersed
3.5.3	Angles of Attack			
	positive alpha	4		
	negative alpha	-4		
	positive beta	4		
	negative beta	-4		
3.5.4	Air Pressure Distribution			Differential pressures based on 1.0 psi

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	positive alpha	Defined in finite element model - Maximums in Table 1 AP		
	negative alpha	Defined in finite element model - Maximums in Table 1 AP		
	beta	Defined in finite element model - Maximums in Table 1 AP		
3.5.5	Load factors			
	Nx	1.52		includes amplification
	Ny	0		
	Nz	TBD		
3.5.6	Tank Pressurization	no constraints		
	LO tank minimum (psia)	17		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	TBD		
	LH tank minimum(psia)	30		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	TBD		
	RP tank minimum (psia)	1		propulsion requirements only - see Table 1 TP for
	RP tank max relief(psig)	20		
	RP peak operating (psig)	TBD		
	GH2 pressuriz Temp (Max °F)	160		
	GO2 pressuriz Temp (Max °F)	TBD		
	GHe pressurization Temp (Max ° F)	TBD		
3.5.7	Permissible Leakage			
	LO tank	TBD		
	LH tank	TBD		
	RP tank	TBD		
3.5.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.5.9	Aeroheating			
	TPS Data Points	Figure 1 TPS, Table 1 TPS		
	TPS gaps and steps	Table 2TPS		
	TPS waviness	Table 3TPS		
	Catalycity			
	Absorptivity/emissivity	1		
	Equilibrium temperatures, heating rates and total heat loads	Table 1AH		
3.5.10	Temperature Constraints			

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	TPS/insulation bondline	no less than - 160 F and no more than 400 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	leading edges	< 3000 F		
	Gr/BMI	< 350 F		
3.5.11	Limit Critical Body Loads	Table 1IL		
3.5.12	Dynamics			
	Acoustics (db)	Table 1 and 2AC		
	Nx amplification	1.05		
	Ny amplification	1.05		
	Nz amplification	1.05		
	POGO	TBD		
	Flutter	TBD		
	Buffetting	TBD		
3.5.13	Moisture in Sructures	TBD		
3.5.14	Guidance and Control			
	Elevons	Fixed orientation at TBD		
	Body Flap	Fixed orientation at 0 deg		
	Tail	TBD		
	Engine actuator loads	TBD		
	Engine gimbal angle	TBD		
3.5.15	IHM Requirements	Table 1IHM		
3.5.16	Payload Environment			
	Temperature	less than 300 F		
	Pressure	not required		
	Humidity	TBD		
	Cleanliness	TBD		
3.5.17	Vehicle Environment			
	Coldest temperature	not applicable	not critical	
	Concurrent humidity	not applicable	not critical	
	Concurrent dew point	not applicable	not critical	
	Hottest day	not applicable	not critical	
	Concurrent humidity	not applicable	not critical	
	Concurrent dew point	not applicable	not critical	
	Rainfall	2 mm drops - at 870 fps @ 30 degree inclnation	Test conditions in TA 3 project	TBD Probability
	Lightning	50 kiloamperes		TBD Probability
3.5.18	Vehicle Mass Distribution	Defined in finite element model		
3.5a Ascent - Max qa - at T=76 secs with any one engine out				

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.5a.1	Thrust to Weight	1.48		
3.5a.2	Dynamic Pressure	TBD		
3.5a.3	Angles of Attack			
	Positive alpha	5		
	Negative alpha	-5		
	Positive beta	5		
	Negative beta	-5		
3.5a.4	Air Pressure Distribution			Differential pressures based on 1.0 psi
	Positive alpha	Defined in finite element model - Maximums in Table 1 AP		
	Negative alpha	Defined in finite element model - Maximums in Table 1 AP		
	Beta	Defined in finite element model - Maximums in Table 1 AP		
3.5a.5	Load Factors			includes amplif
	Nx	TBD		
	Ny	TBD		
	Nz	TBD		
3.5a.6	Tank Pressurization			
	LO tank minimum (psia)	17		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	TBD		
	LH tank minimum(psia)	30		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	TBD		
	RP tank minimum (psia)	1		propulsion requirements only - see Table 1 TP for
	RP tank max relief(psig)	20		
	RP peak operating (psig)	TBD		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.5a.7	Permissible Leakage			
	LO tank	TBD		
	LH tank	TBD		
	RP tank	TBD		
3.5a.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.5a.9	Aeroheating			
	TPS Data Points	Figure 1 TPS, Table 1 TPS		
	TPS gaps and steps	Table 2TPS		
	TPS waviness	Table 3TPS		
	Catalycity			
	Absorptivity/emissivity	1		
	Equilibrium temperatures, heating rates and total heat loads	Table 1AH		
3.5a.10	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F and no more than 400 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	leading edges	< 3000 F		
	Gr/BMI	< 350 F		
3.5a.11	Limit Critical Body Loads	Table 1 IL		
3.5.a.12	Dynamics			
	Acoustics (db)	Table 1 and 2 AC		
	Nx amplification	TBD		
	Ny amplification	TBD		
	Nz amplification	TBD		
	POGO	TBD		
	Flutter	TBD		
	Buffeting	TBD		
3.5a.13	Moisture in Structures	TBD		
3.5a.14	Guidance and Control			
	Elevons	fixed TBD orientation		
	Body flap	fixed orientation at 0 deg		
	Tail	TBD		
	Engine actuator loads	TBD		
	Engine gimbal angle	TBD		
3.5a.15	IHM Requirements	Table 1IHM		
3.5a.16	Payload Environment			
	Temperature	not critical		
	Pressure	not critical		
	Humidity	not critical		
	Cleanliness	not critical		
3.5a.17	Vehicle Environment			
	Coldest temperature	not applicable	not critical	
	Concurrent humidity	not applicable	not critical	
	Concurrent dew point	not applicable	not critical	
	Hottest day	not applicable	not critical	

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Concurrent humidity	not applicable	not critical	
	Concurrent dew point	not applicable	not critical	
	Rainfall	2 mm drops - at 870 fps @ 30 degree inclnation	Test conditions in TA 3 project	TBD Probability
	Lightning	50 kiloamperes		TBD Probability
3.5a.18	Vehicle Mass Distribution	Defined in fined element model		
3.6 Ascent - Max q - at T= 76 secs				
	This condition is regarded as the same as 3.5 Max qa - consistent with project goals			
3.7 Ascent - Max g - starts at T= 164 secs				
	This condition is regarded as the same as 3.8 Max Thrust - consistent with project goals			
3.8 Max Thrust @ T = 164 secs				
3.8.1	Thrust to Weight	3		
3.8.2	Dynamic Pressure	60		
3.8.3	Angles of Attack			
	Positive alpha	Not significant to goals		
	Negative alpha	Not significant to goals		
	Positive beta	Not significant to goals		
	Negative beta	Not significant to goals		
3.8.4	Air pressure distribution			Differential pressures based on 1.0 psi
	Positive alpha	Not significant to goals		
	Negative alpha	Not significant to goals		
	Beta	Not significant to goals		
3.8.5	Load factors			
	Nx	3.15		includes amplif
	Ny	0		
	Nz	0		
3.8.6	Tank Pressurization			
	LO tank minimum (psia)	17		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	TBD		
	LH tank minimum(psia)	30		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	TBD		
	RP tank minimum (psia)	1		propulsion requirements only - see Table 1 TP for
	RP tank max relief(psig)	20		
	RP peak operating (psig)	TBD		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.8.7	Permissible Leakage			
	LO tank	TBD		
	LH tank	TBD		
	RP tank	TBD		
3.8.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.8.9	Aeroheating			
	TPS Data Points	Figure 1 TPS, Table 1 TPS		
	TPS gaps and steps	Table 2TPS		
	TPS waviness	Table 3TPS		
	Catalycity			
	Absorptivity/emissivity	1		
	Equilibrium temperatures, heating rates and total heat loads	Table 1AH		
3.8.10	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F or greater than 400 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	Leading edges	< 3000 F		
	Gr/BMI	< 350 F		
3.8.11	Limit Critical Body Loads	Table 1 IL		
3.8.12	Dynamics			
	Acoustics (db)	Not significant to goals		
	Nx amplification	1.05		
	Ny amplification	1		
	Nz amplification	1		
	POGO			
	Flutter	Not applicable		
	Buffetting	Not applicable		
3.8.13	Moisture in Structures	TBD		
3.8.14	Guidance and Control			
	Elevons	TBD		
	Body flap	TBD		
	Tail	TBD		
	Engine actuator load	TBD		
	Engine gimbal angle	TBD		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.8.15	IHM Requirements	Table 1IHM		
3.8.16	Payload Environment			
	Temperature	not critical		
	Pressure	not critical		
	Humidity	not critical		
	Cleanliness	not critical		
3.8.17	Vehicle Environment			
	Coldest temperature	not applicable	not critical	
	Concurrent humidity	not applicable	not critical	
	Concurrent dew point	not applicable	not critical	
	Hottest day	not applicable	not critical	
	Concurrent humidity	not applicable	not critical	
	Concurrent dew point	not applicable	not critical	
	Rainfall	not applicable	Test conditions in TA 3 project	TBD Probability
	Lightning	50 kiloamperes		TBD Probability
3.8.18	Vehicle mass distribution	Defined in finite element model		
3.8a Ascent - Max Thrust - at T= more than 164 secs - with any one engine out				
3.8a.1	Thrust to Weight	3		
3.8a.2	Dynamic Pressure	60		
3.8a.3	Angles of Attack			
	Positive alpha	Not significant to goals		
	Negative alpha	Not significant to goals		
	Positive beta	Not significant to goals		
	Negative beta	Not significant to goals		
3.8a.4	Air pressure distribution			Differential pressures based on 1.0 psi
	Positive alpha	Not significant to goals		
	Negative alpha	Not significant to goals		
	Beta	Not significant to goals		
3.8a.5	Load factors			
	Nx	3.15		includes amplif
	Ny	0		
	Nz	0		
3.8a.6	Tank Pressurization			
	LO tank minimum (psia)	17		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	TBD		
	LH tank minimum(psia)	30		note: absolute pressure
	LH tank max relief (psig)	34		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	LH peak operating (psig)	TBD		
	RP tank minimum (psia)	1		propulsion requirements only - see Table 1 TP for
	RP tank max relief(psig)	20		
	RP peak operating (psig)	TBD		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.8a.7	Permissible Leakage			
	LO tank	TBD		
	LH tank	TBD		
	RP tank	TBD		
3.8a.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.8a.9	Aeroheating			
	TPS Data Points	Not significant to goals		
	TPS gaps and steps	Not significant to goals		
	TPS waviness	Not significant to goals		
	Catalycity	Not significant to goals		
	Absorptivity/emissivity	Not significant to goals		
	Equilibrium temperatures, heating rates and total heat loads	Not significant to goals		
3.8a.10	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 For greater than 400 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	Leading edges	< 3000 F		
	Gr/BMI	< 350 F		
3.8a.11	Limit Internal Body Loads	Table 1 IL		
3.8a.12	Dynamics			
	Acoustics (db)	Not significant to goals		
	Nx amplification	1.05		
	Ny amplification	1		
	Nz amplification	1		
	POGO			
	Flutter	Not applicable		
	Buffetting	Not applicable		
3.8a.13	Moisture in Structures	TBD		
3.8a.14	Guidance and Control			

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Elevons	TBD		
	Body flap	TBD		
	Tail	TBD		
	Engine actuator load	TBD		
	Engine gimbal angle	TBD		
3.8a.15	IHM Requirements	Table 1IHM		
3.8a.16	Payload Environment			
	Temperature	TBD		
	Pressure	TBD		
	Humidity	TBD		
	Cleanliness	TBD		
3.8a.17	Vehicle Environment			
	Coldest temperature	not applicable	not critical	
	Concurrent humidity	not applicable	not critical	
	Concurrent dew point	not applicable	not critical	
	Hottest day	not applicable	not critical	
	Concurrent humidity	not applicable	not critical	
	Concurrent dew point	not applicable	not critical	
	Rainfall	not applicable	Test conditions in TA 3 project	TBD Probability
	Lightning	50 kiloamperes		TBD Probability
3.8a.18	Vehicle mass distribution	Defined in finite element model		
3.9 Orbit Insertion to De-Orbit				
3.9.1	Vehicle Orientation	Docked to station		
3.9.2	Docking			
	Approach velocities	Table 1DO		
	Docking loads	Table 1DO		
3.9.3	Tank Pressurization			
	LO tank minimum (psia)	16.7		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	Not applicable		
	LH tank minimum(psia)	16.7		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	Not applicable		
	RP tank minimum (psia)	16.7		
	RP tank max relief(psig)	20		
	RP peak operating (psig)	Not applicable		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.9.4	Permissible Leakage			

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	LO tank	TBD		
	LH tank	TBD		
	RP tank	TBD		
3.9.5	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F or greater thna 400 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	Leading edges	< 3000 F		
	Gr/BMI	< 375 F		
3.9.6	Environment			
	Micrometeoroid	NASA TM-4527 June 94		Probability TBD
	Debris	NASA TM-4527 June 94		Probability TBD
	Ultra violet Radiation	EUVS = 5 days		
	Vacuum	TBD		
	Atomic oxygen	1 x 10 exp 21 atoms/sq cm		
3.9.7	Thermal environment	Table 1TH		
3.9.8	IHM requirements	Table 1IHM		
3.9.9	Payload Environment			
	Temperature	not critical		
	Pressure	not critical		
	Humidity	not critical		
	Cleanliness	not critical		
3.10 Entry Heating				
3.10.1	Cross Range	1100 nm		
3.10.2	Vehicle L/D	> 1.5 Hypersonic flight > 4 at landing		
3.10.3	Aeroheating			
	TPS Data Points	Figure 1 TPS, Table 1 TPS		
	TPS gaps and steps	Table 2TPS		
	TPS waviness	Table 3TPS		
	Catalycity			
	Absorptivity/emissivity	1		
	Equilibrium temperatures, heating rates and total heat loads	Table 1AH		
3.10.4	Structural Temperatures	Table 1TE		
3.10.5	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F or greater thna 400 F		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	Leading edges	< 3000 F		
	Gr/BMI	< 350 F		
3.10.6	IHM requirements	Table 11IHM		
3.10.7	Tank Pressurization			
	LO tank minimum (psia)	16.7		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	Not applicable		
	LH tank minimum(psia)	16.7		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	Not applicable		
	RP tank minimum (psia)	16.7		
	RP tank max relief(psig)	20		
	RP peak operating (psig)	Not applicable		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.10.8	Payload Environment			
	Temperature	TBD		
	Pressure	TBD		
	Humidity	TBD		
	Cleanliness	TBD		
3.10.9	Vehicle mass distribution	Defined in finite element model		
3.11 TAEM Maneuver				
3.11.1	Payload In - Aerodynamic Stability	Stable vehicle- full control authority		
3.11.2	Payload Out - Aerodynamic Stability	Stable vehicle - full control authority		May accept - 2% static margin (based on length)
3.11.3	Environment			
	Rainfall	2.5 to 5.5 in/hr - no wind 5.7 to 11.7 in/hr - 4.4 to 8.4 knots wind 17 to 25 in/hr - 35 to 55 knots wind		TBD Probability
	Lightning	50 kiloamperes		TBD Probability
	Water deluge	Yes		after scrubbed launch
	Salt spray	Yes		
	Bird droppings	Yes		
	Debris Impact	No		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.11.4	Load Factors			
	Nx	TBD		includes amplif
	Ny	0		
	Nz	Neg 1.0 to 2.5	MIL SPEC	
3.11.5	Air Pressure Distribution	Defined in finite element model - Maximums in Table 1 AP		Differential pressures based on neg1.0 psi
3.11.6	Tank Pressurization			
	LO tank minimum (psia)	16.7		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	Not applicable		
	LH tank minimum(psia)	16.7		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	Not applicable		
	RP tank minimum (psia)	16.7		
	RP tank max relief(psig)	20		
	RP peak operating (psig)	Not applicable		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.11.7	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	leading edges	< 3000 F		
	Gr/BMI	< 350 F		
3.11.8	Structural Temperatures	Table 2TE		
3.11.9	Limit Internal Body Loads	Table 1 IL		
3.11.10	Dynamics			
	Nx amplification	TBD		
	Ny amplification	TBD		
	Nz amplification	TBD		
	Flutter	TBD		
	Buffetting	TBD		
3.11.11	Moisture in Structures	TBD		
3.11.12	Guidance and Control			
	Elevons	Deflection limits - TBD		
	Body Flaps	Deflection limits - TBD		
	Tail	Deflection limits - TBD		
	Engine actuators	Not required		
	Maximum roll angle	60 deg	MIL SPEC	
	Maximum roll rate	20 deg/sec		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.11.13	IHM requirements	Table IHM 1		
3.11.14	Payload Environment			
	Temperature	less than 300 F		
	Pressure	not critical		
	Humidity	not critical		
	Cleanliness	not critical		
3.11.15	Vehicle Mass Distribution	Defined in finite element		
3.12 Main Gear Landing - Spin Up - Both wheels concurrent				
3.12.1	On Concrete Surface with Propellant Residuals			
3.12.2	Sink Speed-Max Weight	10 ft/sec	MIL/SPEC	
	Sink speed intact abort	6 ft/sec	MIL SPEC	
	Maximum touchdown speed	190 knots		
	Minimum touchdown speed	170 knots		
	Max cross wind	20 knots	MIL SPEC	
	Main Gear stroke	TBD		
	Main Gear Max Z load	TBD		
	Side gear load	TBD		
	Crosswind	15 knots	Shuttle	Tire capability on landing
	Lightning	50 kiloamperes		TBD Probability
3.12.3	Load Factors			
	Rotational accel abt y	TBD		
	Ny	0		
	Nx	TBD		
	Nz	TBD		
3.12.4	Tank Pressurization			
	LO tank minimum (psia)	16.7		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	Not applicable		
	LH tank minimum(psia)	16.7		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	Not applicable		
	RP tank minimum (psia)	16.7		
	RP tank max relief(psig)	20		
	RP peak operating (psig)	Not applicable		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.12.5	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	LO tank wall	< 250 F		
	leading edges	< 3000 F		
	Gr/BMI	< 350 F		
3.12.6	Limit Critical Internal Body Loads	Table 1 IL		
3.12.7	Structural Temperatures	Table 3TE		
3.12.8	Dynamics			
	Nx amplification	TBD		
	Ny amplification	TBD		
	Nz amplification	TBD		
	Flutter	TBD		
	Buffetting	TBD		
3.12.9	Moisture in Structures	TBD		
3.12.10	Guidance and Control			
	Elevons	Deflection limits - TBD		
	Body flap	Deflection limits - TBD		
	Tail	Deflection limits - TBD		
	Engine actuators	Not required		
3.12.11	IHM requirements	Table 1IHM		
3.12.12	Payload Environment			
	Temperature	less than 300 F		
	Pressure	not critical		
	Humidity	not critical		
	Cleanliness	not critical		
3.12.13	Air pressure distribution	Defined in finite element model		Differential pressures based on neg1.0 psi
3.12.14	Vehicle mass distribution			
	w/payload in	Defined in finite element		
	w/payload out	Defined in finite element		
3.13 Main Gear Landing - Spring Back - Both wheels concurrent				
3.13.1	On Concrete Surface with Propellant Residuals			
3.13.2	Sink Speed-Max Weight	10 ft/sec	MIL/SPEC	
	Sink speed intact abort	6 ft/sec	MIL SPEC	
	Maximum touchdown speed	190 knots		
	Minimum touchdown speed	170 knots		
	Max cross wind	20 knots	MIL SPEC	
	Main Gear stroke	TBD		
	Main Gear Max Z load	TBD		
	Side gear load	TBD		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Crosswind	15 knots	Shuttle	Tire capability on landing
	Lightning	50 kiloamperes		TBD Probability
3.13.3	Load Factors			
	Rotational accel abt y	TBD		
	Ny	0		
	Nx	TBD		
	Nz	TBD		
3.13.4	Tank Pressurization			
	LO tank minimum (psia)	16.7		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	Not applicable		
	LH tank minimum(psia)	16.7		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	Not applicable		
	RP tank minimum (psia)	16.7		
	RP tank max relief(psig)	20		
	RP peak operating (psig)	Not applicable		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.13.5	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	leading edges	< 3000 F		
	Gr/BMI	< 350 F		
3.13.6	Limit Internal Body Loads	Table 1 IL		
3.13.7	Structural Temperatures	Table 3TE		
3.13.8	Dynamics			
	Nx amplification	TBD		
	Ny amplification	0		
	Nz amplification	TBD		
	Flutter	TBD		
	Buffetting	TBD		
3.13.9	Moisture in Structures	TBD		
3.13.10	Guidance and Control			
	Elevons	Deflection limits - TBD		
	Body Flaps	Deflection limits - TBD		
	Tail	Deflection limits - TBD		
	Engine actuators	not required		
3.13.11	IHM requirements	Table 1IHM		

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.13.12	Payload Environment			
	Temperature	less than 300 F		
	Pressure	not critical		
	Humidity	not critical		
	Cleanliness	not critical		
3.13.13	Vehicle Mass Distribution			
	W/payload in	Defined in finite element		
	W/payload out	Defined in finite element		
3.14 Nose Gear Slapdown Landing				
3.14.1	On Concrete Surface with Propellant Residuals			
3.14.2	Minimum Speed for Pitchover	TBD		
	Maximum pitchover rate	TBD		
	Maximum speed for pitchover	TBD		
	Nose attitude at slapdown	TBD		
	Fwd Gear stroke	TBD		
	Fwd Gear Max Z load	TBD		
	Fwd Side gear load	TBD		
	Lightning	50 kiloamperes		TBD Probability
3.14.3	Load Factors			
	Ny	0		
	Nx	TBD		
	Nz	TBD		
3.14.4	Tank Pressurization			
	LO tank minimum (psia)	16.7		note: absolute pressure
	LO tank max relief (psig)	20		
	LO peak operating (psig)	Not applicable		
	LH tank minimum(psia)	16.7		note: absolute pressure
	LH tank max relief (psig)	34		
	LH peak operating (psig)	Not applicable		
	RP tank minimum (psia)	16.7		
	RP tank max relief(psig)	20		
	RP peak operating (psig)	Not applicable		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.14.5	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	leading edges	< 3000 F		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Gr/BMI	< 350 F		
3.14.6	Limit Internal Body Loads	Table 1 IL		
3.14.7	Structural Temperatures	Table 3TE		
3.14.8	Dynamics			
	Nx amplification	TBD		
	Ny amplification	0		
	Nz amplification	TBD		
	Flutter	TBD		
	Buffetting	TBD		
3.14.9	Moisture in Structures	TBD		
3.14.10	Guidance and Control			
	Elevons	Deflection limits - TBD		
	Body Flaps	Deflection limits - TBD		
	Tail	Deflection limits - TBD		
	Engine actuators	not required		
3.14.11	IHM Requirements	Table 1IHM		
3.14.12	Payload Environment			
	Temperature	less than 300 F		
	Pressure	not critical		
	Humidity	not critical		
	Cleanliness	not critical		
3.14.13	Vehicle Mass Distribution			
	W/payload in	Defined in finite element		
	W/payload out	Defined in finite element		
3.15 Return to OPF and In OPF				
3.15.1	Towing Load Factors			
	Nz	*not critical		* except for local fitting
	Nx	*not critical		* except for local fitting
	Ny	*not critical		* except for local fitting
3.15.2	Taxi Load Factors			
	Nz	2.0		
	Nx	*not critical		* except for local fitting
	Ny	*not critical		* except for local fitting
3.15.3	Jacking/Hoisting			
	Nz	*not critical		* except for local fitting
	Nx	*not critical		* except for local fitting
	Ny	*not critical		* except for local fitting
3.15.4	LO, LH, and RP tank pressures	2.0 minumum		

Reqments Matrix for Nov 4

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.15.5	IHM Requirements			
3.15.6	Payload Environment			
	Temperature	not required		
	Pressure	not required		
	Humidity	not required		
	Cleanliness	not required		
3.15.7	Vehicle Safing			
	Purge	TBD		
	Unload payload	TBD		
3.15.8	Vehicle Mass Distribution			
	W/payload in	Defined in finite element		
	W/payload out	Defined in finite element		
3.15.9	Waterproofing			
	TABI	TBD		
	CFBI	TBD		
	AETB	TBD		
	Others	TBD		
3.15.10	Install Payload			
3.1.5.11	Payloads Processed in Parallel, Off-Line			
3.16 Loading Spectrums				
3.16.1	LO Tank Pressures	proof test - one cycle 300 missions -1 added cycle every 10th flight- see Table 3.16.1		
3.16.2	LH Tank Pressures	proof test - one cycle 300 missions -1 added cycle every 10th flight- see Table 3.16.1		
3.16.3	Fuselage Body Loads	Table LS-1		
3.16.4	Wing Loads	Table LS-2		
3.16.5	Tail Loads	Table LS-3		
3.16.6	Thrust Structure	Table LS-4		
	See criteria document for safety factors, damage tolerance, etc.			

TABLE 2 GW

DESIGN PEAK WIND SPEED PROFILE FOR A 1% RISK OF EXCEEDING THE 18.3 METER REFERENCE LEVEL PEAK WIND SPEED FOR THE WINDIEST TWO–WEEK EXPOSURE PERIOD

HEIGHT		PEAK WIND SPEED			
		KSC		VAFB	
(m)	(ft)	(m/sec)	(knots)	(m/sec)	(knots)
18.3	60	31.1	60.4	25.0	48.6
30.5	100	33.1	64.3	26.9	52.3
61.0	200	36.0	69.9	29.7	57.7
91.4	300	37.8	73.5	31.5	61.2
121.9	400	39.1	76.0	32.8	63.8
152.4	500	40.2	78.1	33.9	65.9

TEN–MINUTE STEADY STATE WIND SPEED PROFILE ASSOCIATED WITH 1% RISK PEAK WIND SPEED PROFILE FOR THE WINDIEST TWO–WEEK EXPOSURE PERIOD

HEIGHT		MEAN WIND SPEED			
		KSC		VAFB	
(m)	(ft)	(m/sec)	(knots)	(m/sec)	(knots)
18.3	60	20.6	40.1	19.1	37.1
30.5	100	23.0	44.7	21.3	41.3
61.0	200	26.5	51.4	24.6	47.7
91.4	300	28.6	55.6	26.6	51.6
121.9	400	30.2	58.6	28.1	54.5
152.4	500	31.4	61.1	29.3	56.8

Table 3 GW

DESIGN PEAK WIND SPEED PROFILE FOR A 1% RISK OF EXCEEDING THE 18.3 METER REFERENCE LEVEL PEAK WIND SPEED FOR THE WINDIEST 1–DAY EXPOSURE PERIOD

HEIGHT		MEAN WIND SPEED			
		KSC		VAFB	
(m)	(ft)	(m/sec)	(knots)	(m/sec)	(knots)
18.3	60	24.2	47.0	23.2	45.2
30.5	100	26.1	50.6	25.0	48.5
61.0	200	28.9	56.1	27.7	53.7
91.4	300	30.6	59.5	29.4	57.0
121.9	400	31.9	62.0	30.6	59.4
152.4	500	33.0	64.1	31.7	61.5

DESIGN MEAN WIND SPEED PROFILE FOR A 1% RISK OF EXCEEDING THE 18.3 METER REFERENCE LEVEL PEAK WIND SPEED FOR THE WINDIEST 1–DAY EXPOSURE PERIOD

HEIGHT		MEAN WIND SPEED			
		KSC		VAFB	
(m)	(ft)	(m/sec)	(knots)	(m/sec)	(knots)
18.3	60	16.0	31.1	15.6	30.3
30.5	100	18.1	35.2	17.7	34.3
61.0	200	21.2	41.2	20.8	40.4
91.4	300	23.1	44.9	22.7	44.0
121.9	400	24.5	47.7	24.2	46.9
152.4	500	25.8	50.0	25.4	49.3

Table 4 GW

DESIGN LAUNCH PEAK WIND SPEED PROFILES FOR THE 18.3 METER REFERENCE LEVEL PEAK WIND SPEED FOR THE WINDIEST 1-HOUR EXPOSURE PERIOD

(a) All Azimuths Considered (For a 5% risk of exceeding)

HEIGHT		PEAK WIND SPEED			
		KSC		VAFB	
(m)	(ft)	(m/s)	(k)	(m/s)	(k)
10	33	15.8	30.8	15.8	30.8
18.3	60	17.7	34.4	17.7	34.4
30.5	100	19.5	37.9	19.5	37.9
61.0	200	22.1	43.0	22.1	43.0
91.4	300	23.9	46.4	23.9	46.4
121.9	400	25.2	48.9	25.2	48.9
152.4	500	26.2	51.0	26.2	51.0

(b) Limited Azimuth Considered (For wind from South [180°] at KSC and for 60° arc centered on West and East at VAFB)

HEIGHT KSC FROM DUE SOUTH		PEAK WIND SPEED VAFB					
		WEST				EAST	
(m)	(ft)	(m/s)	(k)	(m/s)	(k)	(m/s)	(k)
10	33	10.7	20.7	10.7	20.7	12.6	24.6
18.3	60	12.3	24.0	12.3	24.0	14.4	28.0
30.5	100	14.0	27.2	14.0	27.2	16.0	31.3
61.0	200	16.5	32.1	16.5	32.1	18.7	36.3
91.4	300	18.2	35.4	18.2	35.4	20.4	39.6
121.9	400	19.6	38.0	19.6	38.0	21.7	42.2
152.4	500	20.7	40.1	20.7	40.1	22.8	44.3

NOTE: For KSC wind directions, $\ominus$ between 134° and 226° compute the peak wind speed at the 18.3 m level by: $U_{18.3} = \frac{12.3 \text{ m/s}}{-\cos \ominus}$ and then use Equation 1, Section 4.1.2.1.1 to obtain peak wind versus height. For all other wind directions use Table $4.2.1_{(a)}$.

Table 1 TP - Design Tank Pressures

		Configuration 2A Limit Tank Pressures					
			all pressures (psig)				
No.	Mission Phase	LH Tank minimum	LH Tank operating	LH Tank maximum	LO tank minimum	LO tank operating	LO tank maximum
1	Prelaunch unfueled	0.0	3.0	34.0	0.0	3.0	20.0
2	LH fueling	0.0	3.0	34.0	0.0	3.0	20.0
3	End LH pressurization	20 to 0	21.3 to 3	34.0	0.0	3.0	20.0
4	LO fueling	20 to 0	21.3 to 3	34.0	0.0	3.0	20.0
5	End LO pressurization	20 to 0	21.3 to 3	34.0	0.0	18.0	20.0
6	Liftoff	30.0	31.3	34.0	2.0	18.0	20.0
7	MECO	30.0	31.3	34.0	16.7	18.0	20.0
8	On orbit	16.7	18.0	20.0	16.7	18.0	20.0
9	Start of Entry	16.7	18.0	20.0	16.7	18.0	20.0
10	TAEM maneuvers	2.0	3.3	5.3	2.0	3.3	5.3
11	Landing	2.0	3.3	5.3	2.0	3.3	5.3
		Phases 3 to 5 pressures vary to support trade off analysis					
		Configuration 4 Limit Tank Pressures					
			all pressures (psig)				
No.	Mission Phase	LH Tank minimum	LH Tank operating	LH Tank maximum	LO tank minimum	LO tank operating	LO tank maximum
1	Prelaunch unfueled	0.0	3.0	5.3	0.0	3.0	20.0
2	LO fueling	0.0	3.0	5.3	0.0	3.0	20.0
3	End LO pressurization	0.0	3.3	5.3	16.7	18.0	20.0
4	LH fueling	0.0	3.3	5.3	16.7	18.0	20.0
5	End LH pressurization	30.0	31.3	34.0	16.7	18.0	20.0
6	Liftoff	30.0	31.3	34.0	16.7	18.0	20.0
7	MECO	30.0	31.3	34.0	16.7	18.0	20.0
8	On orbit	16.7	18.0	20.0	16.7	18.0	20.0
9	Start of Entry	16.7	18.0	20.0	16.7	18.0	20.0
10	TAEM maneuvers	2.0	3.3	5.3	2.0	3.3	5.3
11	Landing	2.0	3.3	5.3	2.0	3.3	5.3

Table 1 TP - Design Tank Pressures (cont'd)

		Configuration 1A Limit Tank Pressures					
			all pressures (psig)				
No.	Mission Phase	LH Tank minimum	LH Tank operating	LH Tank maximum	LO tank minimum	LO tank operating	LO tank maximum
1	Prelaunch unfueled	0.0	3.0	34.0	0.0	3.0	25.0
2	LH fueling	0.0	3.0	34.0	0.0	3.0	25.0
3	End LH pressurization	0.0	3.0	34.0	0.0	3.0	25.0
4	LO fueling	0.0	3.0	34.0	0.0	3.0	25.0
5	End LO pressurization	0.0	3.0	34.0	18.0	22.3	25.0
6	Liftoff	30.0	31.3	34.0	18.0	22.3	25.0
7	MECO	30.0	31.3	34.0	21.0	22.3	25.0
8	On orbit	16.7	18.0	20.0	16.7	18.0	20.0
9	Start of Entry	16.7	18.0	20.0	16.7	18.0	20.0
10	TAEM maneuvers	2.0	3.3	5.3	2.0	3.3	5.3
11	Landing	2.0	3.3	5.3	2.0	3.3	5.3
		Configuration 3 Limit Tank Pressures					
			all pressures (psig)				
No.	Mission Phase	LH Tank minimum	LH Tank operating	LH Tank maximum	LO tank minimum	LO tank operating	LO tank maximum
1	Prelaunch unfueled	0.0	3.0	5.3	0.0	3.0	25.0
2	LO fueling	0.0	3.0	5.3	0.0	3.0	25.0
3	End LO pressurization	0.0	3.3	5.3	0.0	3.0	25.0
4	LH fueling	0.0	3.3	5.3	0.0	3.0	25.0
5	End LH pressurization	30.0	31.3	34.0	18.0	22.3	25.0
6	Liftoff	30.0	31.3	34.0	18.0	22.3	25.0
7	MECO	30.0	31.3	34.0	21.0	22.3	25.0
8	On orbit	16.7	18.0	20.0	16.7	18.0	20.0
9	Start of Entry	16.7	18.0	20.0	16.7	18.0	20.0
10	TAEM maneuvers	2.0	3.3	5.3	2.0	3.3	5.3
11	Landing	2.0	3.3	5.3	2.0	3.3	5.3

Table 1 TP - Design Tank Pressures (cont'd)

		All Configurations RP Tank Pressures					
			all pressures (psig)				
No.	Mission Phase	RP Tank	RP Tank	RP Tank			
		minimum	operating	maximum			
1	Prelaunch unfueled	0.0	3.0	20.0			
2	RP fueling	0.0	3.0	20.0			
3	End RP fueling	3.3	17.3	20.0			
4							
5							
6	Liftoff	3.3	17.3	20.0			
7	End of Mode 1	16.7	18.0	20.0			
8	On orbit	16.7	18.0	20.0			
9	Start of Entry	16.7	18.0	20.0			
10	TAEM maneuvers	2.0	3.3	5.3			
11	Landing	2.0	3.3	5.3			