SSD94D0217

SSTO-REQ-1

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

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

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Significant changes to draft copy -

1. Added Section 0.0 SSTO System Requirements and Program Guidelines

2. Added Section 1.2 to Index - Other Missions - 40 k payloads - changed introduction to be compatible

3. Revised Requirements 3.3.6 and 3.3.7 and Section 4.6.3 of Design Criteria

4. Added Tables 2GW, 3GW, and 4GW

5 Added Picture of Option 2A configuration

6. Filled in Configuration 2 Tank pressures

6. Filled in Ascent q and angles of attack

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.

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 SSTO System Requirements and Guidelines

NO.	REQUIREMENT NAME	DESCRIPTION	SOURCE	SOURCE DOCUMENT REFERENCE
0.0 Program Requirements - Operational SSTO				
0.0.1	OPERATIONS COST REDUCTIONS	Option 3 New System to 2030 criteria are safety improvements and operations cost reductions.	C/MSFC	Industry meeting briefing
0.0.2	SAFETY IMPROVEMENTS	Option 3 New System to 2030 criteria are safety improvements and operations cost reductions.	C/MSFC	Industry meeting briefing
0.0.3	ATLAS REPLACEMENT	Atlas class payload flight rate is 8/year.	C/MSFC	Industry meeting
0.0.4	DELTA REPLACEMENT	Delta class payload flight rate is 10/year.	C/MSFC	Industry meeting
0.0.5	DEMO OF KEY OPS TECHNOLOGIES	Key operations oriented technologies are to be demonstrated ahead of SSTO-R development.	C/MSFC	Industry meeting briefing
0.0.6	MODERN TECH FOR IMPROVED OPS	Technology base investment focused on improved operations.	C/MSFC	Industry meeting briefing
0.0.7	OPERATIONALLY AVAILABLE IN 2008	SSTO-R objective is to provide concept definition to replace Shuttle/DeltaAtlas by 2008.	C/MSFC	Industry meeting briefing
0.0.8	P/L USER COMMUNITY	System is to be used by all members of payload user community: NASA, DoD, commercial, etc.	C/MSFC	Industry meeting questions
0.0.9	ATV TO OPERATE WITH INTERIM ELV	Upgrade to ELV's is accomplished along with use of new fully reusable system.	C/Option 3 Team	Option 3 Final Rept V1
0.0.10	TECH MATURITY ASSESSMENTS/PLANS	SSTO-R objective is to define technology maturity & develop maturation plans for concepts.	C/MSFC	Industry meeting briefing
0.0.11	AFFORDABLE	Nonrecurring costs - design, development, test, evaluation, capital investment & production are within affordable envelope.	RI/SE	
0.0.12	LOW RISK SOLUTION	Maximum probability of program success - cost, schedule, performance.	RI/SE	
0.0.13	OPERATIONAL LIFE	Life cycle from 2000 to 2030.	RI/SE	
0.1.0 System Requirements - Operational SSTO				
0.1.1 Safety				
0.1.1.1	INCREASED CREW SAFETY	SSTO-R objective is increased crew safety over existing systems.	C/MSFC	Industry meeting briefing
0.1.1.2	ABORT WITH ENGINE OUT	Abort over full range with fail-safe engine out	C/Option 3	Option 3 Final Rept
0.1.2 Reliability				
0.1.2.1	INCREASED RELIABILITY	SSTO-R objective is increased reliability over existing systems.	C/MSFC	Industry meeting briefing
0.1.2.2	VEHICLE LOSS RELIABILITY	Vehicle survival reliability not less than 0.98 (i.e., lose vehicle less than once per 50 flights).	C/Option 3 Team	Option 3 Final Rept V1
0.1.2.3	ABORT RELIABILITY	Abort reliability of .997 (vehicle survival).	RI/SE	
0.1.2.4	PAYLOAD SURVIVAL	Payload survival reliability of .995.	RI/SE	
0.1.3 Mission Requirements				
0.1.3.1	ALL INCLINATION ACCESS	Vehicle & system capable of all inclination acccess.	RI/SE	
0.1.3.2	NO DOWNRANGE ABORT SITES	Ascent trajectory to allow either RTLS abort or abort to orbit.	C/Option 3 Team	Option 3 Final Rept V1

NO.	REQUIREMENT NAME	DESCRIPTION	SOURCE	SOURCE DOCUMENT REFERENCE
0.1.3.4 Mission Duration				
0.1.3.4.1	MISSION DURATION	Nominal mission duration is 7 days launch to landing.	C/Option 3	Option 3 Final Rept
0.1.3.4.2	MISSION DURATION NOMINAL - SATELLITE	Nominal mission duration for satellite delivery is 2 days, launch- to- landing.	RI/SE	
0.1.3.4.3	MISSION DURATION MAXIMUM	Maximum mission duration is 7 days, launch- to- landing.	RI/SE	
0.1.3.4.4	ON-ORBIT DURATION MAX	Maximum on-orbit duration is 168 hrs (reduced payload).	RI/SE	
0.1.3.4.5	ON-ORBIT DURATION	Nominal on-orbit duration is 48 hrs.	RI/SE	
0.1.3.5 Reference Missions				
0.1.3.5.1 Design Reference Missions				
0.1.3.5.1.1	PRIMARY DRM	Primary Design Reference Mission is 25K# to 220nmi @ 51.6 deg.	C/MSFC	Industry meeting questions
0.1.3.5.2 Operational Reference Missions				
0.1.3.5.2.1	PRIMARY ORM	Primary Operational Reference Mission is space station resupply.	C/MSFC	Industry meeting questions
0.1.3.5.2.1.1	TOTAL SS PMC MISSION	PMC total Space Station resupply flights are 20/year.	C/MSFC	Industry meeting
0.1.3.5.2.1.2	RESERVED			
0.1.3.5.2.1.3 Space Station Cargo Resupply				
0.1.3.5.2.1.3.1	SS DELIVERED MASS	Annual SSF cargo mass delivery is approx. 150,000#/year.	C/Option 3 Team	Option 3 Final Rept V1
0.1.3.5.2.1.3.2	SS RETURNED MASS	Annual SSF cargo mass return is approx. 127,000#/year.	C/Option 3 Team	Option 3 Final Rept V1
0.1.3.5.2.1.3.3	PMC PRESSURIZED	PMC Pressurized Logistics flights are 12/year.	C/MSFC	Industry meeting
0.1.3.5.2.1.3.4	PMC ULC RATE	PMC Unpressurized Logistics flights are 3/year.	C/MSFC	Industry meeting
0.1.3.5.2.1.3.5	STD STATION CARGO MISSIONS UNMANNED	Standard space station cargo resupply missions are unmanned.	RI/SE	
0.1.3.5.2.1.4 Space Station Crew Rotation				
0.1.3.5.2.1.4.1	PMC CREW ROTATION	PMC crew rotation flights are 3/year.	C/MSFC	Industry meeting
0.1.3.5.2.1.4.2	ASSURED CREW RETURN	Assured Crew Return is included in ATS Option 3 Principal Operational Mission description, but is not specifically allocated to the SSTO	C/Option 3 Team	Option 3 Final Rept V1
0.1.3.5.2.1.4.3	CREW CAPABILITY	SSTO-R accommodates 2 flight crew and 4 passengers for rotation missions.	C/Option 3 Team	Option 3 Final Rept V1
0.1.3.5.2.1.4.4	CREW SURVIVAL RELIABILITY	Crew Survival Reliability should not be less than 0.999 (i.e., lose nominal crew less than once per 1,000 flights).	C/Option 3 Team	Option 3 Final Rept V1
0.1.3.5.3. Satellite Deployment				

0.0 SSTO System Requirements and Guidelines

NO.	REQUIREMENT NAME	DESCRIPTION	SOURCE	SOURCE DOCUMENT REFERENCE
0.1.3.5.3..1	TOTAL NON-STATION	Total Non-Station flight rate is 19/year.	C/MSFC	Industry meeting
0.1.3.5.3..2	STD DEPLOYMENT MISSIONS UNMANNED	Standard satellite/payload deployment missions are unmanned.	RI/SE	
0.1.3.5.4 Satellite Servicing				
0.1.3.5.4.1	SATELLITE SERVICING	Satellite servicing flight rate is 1 every 3-1/3 years.	C/MSFC	Industry meeting
0.1.3.5.4.2	STD REPAIR/RETRIEVAL	Standard satellite retrieval/repair missions are	RI/SE	
0.1.4 Operations Requirements				
0.1.4.1 Operating Margins				
0.1.4.1.1	ONE-TIME VEHICLE FLT CERT	Use margins to avoid recertification of the vehicle (e.g., tests and inspections) before each flight.	C/Option 3 Team	Option 3 Final Rept V1
0.1.4.1.2	WIDER WEATHER ENVELOPES	The Vehicle will be designed such that operations will not be as constrained by weather as today's systems.	C/MSFC	Industry meeting briefing
0.1.4.1.3	DEFINITION OF FLIGHT ENVELOPE	Flight design envelope, defined by flight & ground tests, allows use of predetermined models and	C/MSFC	Industry meeting briefing
0.1.4.1.4	DESIGN FOR STD FLT PROFILES	Flight design possesses margin sufficient to standardize ascent, on-orbit & entry profiles.	C/Option 3 Team	Option 3 Final Rept V1
0.1.4.2 Maintenance and Logistics Support				
0.1.4.2.1	LOGISTICS SUPPORT	Logistics support will be resident at the launch site.	C/MSFC	Industry meeting
0.1.4.2.2	INCORPORATION OF MODS/UPDATES	Modifications and/or design updates incorporated only during scheduled depot maintenance.	C/MSFC	Industry meeting briefing
0.1.4.2.3	DEPOT MAINTENANCE SCHEDULE	Scheduled depot maintenance is 3 months maximum time; after initial 10th flight, then each 20th flight of each vehicle.	C/MSFC	Industry meeting briefing
0.1.4.3 Integrated Vehicle Health Management				
0.1.4.3.1	MAX USE OF VHM	Maximum use will be made of Vehicle Health Management for both ground and in-flight	C/MSFC	Industry meeting briefing
0.1.4.3 Ground Operations				
0.1.4.3.1	PRIMARY LANDING SITE	The primary landing site will be at the launch site.	C/MSFC	Industry meeting
0.1.4.3.2	MISSION LANDING SITE	Primary landing site for a mission is a launch site, but not necessarily the one used for the mission flown.	RI/SE	
0.1.4.3.3	DESIGN FOR CALLUP	Design for rapid callup.	C/MSFC	Status Brfg 8/20/93
0.1.4.3.4	FLIGHT DESIGN CYCLE TIME	Flight design process will be accomplished within 21 days prior to T-0.	C/MSFC	Industry meeting briefing
0.1.4.3.5	RAPID TURNAROUND	Design for rapid turnaround.	C/MSFC	Status Brfg 8/20/93
0.1.4.3.6	MINIMIZE SERIAL PROCESSING	Minimize serial processing to reduce ground processing time.	C/Option 3 Team	Option 3 Final Rept V1

0.0 SSTO System Requirements and Guidelines

NO.	REQUIREMENT NAME	DESCRIPTION	SOURCE	SOURCE DOCUMENT REFERENCE
0.1.4.3.7	OFF-LINE P/L PROCESSING	Process the payload separately in order to minimize impacts of Payload on vehicle operations.	C/Option 3 Team	Option 3 Final Rept V1
0.1.4.3.8	APPLICABILITY OF P/L STANDARDIZATION	Standardized payload processing, containerization & interfaces to apply to at least 90% of payloads.	RI/O	
0.1.4.3.9	HORIZONTAL GROUND PROCESSING	Design to maximuze the amount of vehicle processing that can be performed horizontally.	RI/O	
0.1.4.3.10	INDEPENDENCE OF TANKING OPS	Design for independent loading and pressurization of all tanks.	RI/O	
0.1.4.3.11	ROBUST & FLEXIBLE OPERATIONS	System is highly available to fly a wide range of missions under a wide range of conditions.	RI/O	
0.1.4.3.12	MISSION GENERATION	Mission generation in 21 work shifts, through launch.	RI/SE	
0.2.0 Vehicle Requirements - Operational SSTO				
0.2.1 Design Requirements				
0.2.1.1	PAYLOAD BAY SIZE	Payload bay size is 15ft dia. by 30ft length.	C/MSFC	Industry meeting
0.2.1.2	MAXIMUM DESIGN	Maximum design cargo mass is 40k#.	RI/SE	
0.2.1.3	ENTRY CROSSRANGE	Entry crossrange greater than 1100 nmi.	C/Option 3	Option 3 Final Rept
0.2.1.4	MAX AXIAL ACCEL	Maximum axial acceleration of 3 G's	C/Option 3	Option 3 Final Rept
0.2.1.5	MAX TOTAL ACCEL	Maximum total acceleration of 3 G's	C/Option 3	Option 3 Final Rept
2.2 Operations Requirements				
2.2.1	EASE OF ACCESS TO LRU'S	Design of the vehicle will allow ease of access to line replaceable units.	C/MSFC	Industry meeting briefing
2.2.2	VHM CONFIRMS VEHICLE CONDITION	Flight margins, proven in prototype testing, allow Vehicle Health Management to adequately confirm flightworthiness of onboard systems.	C/MSFC	Industry meeting briefing
2.2.3	AUTONOMOUS FLT OPS		C/MSFC	Status Brfg 8/20/93
2.2.4	FULLY REUSABLE	Vehicle is to be fully reusable.	C/MSFC	Status Brfg 8/20/93

Section 1.0 Specific SSTO System Requirements

Requirements Matrix

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"		Figure 1P TBD
	Payload length	up to 30 feet		Figure 1P TBD
	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"		Figure 1P TBD
	Payload length	up to 30 ft'-0"		Figure 1P TBD
	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	TBD		
1.1.5	Cannister Attachment to Payload Bay Structure			
	Standard structural and services interfaces	Yes		
	2 Fwd Z	TBD		
	2 Aft Z with 2 aft X	TBD		
	One Y	TBD		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
1.1.6	Payload Bay Doors	provides torsion capability		
	Door opening on pad	one g capability without GSE		
	Door opening in OPF	one g capability without 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	(300 - TBD) per vehicle		10 per year for 30 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	7		
	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	TBD		
	Engine shutdown sequence order	simultaneous		
	Engine shutdown seq duration	TBD		
	Max number of engines out	one		
	Engine throttle rate	TBD		
	Engine throttle range (%)	100 to 50		
	Engine installation			
	Open or closed boattail	closed		
	No of feedline penetrations in thrust structure	7		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Engine removal time on pad	None		Return to OPF
	Engine removal time OPF			
	Compliance requirememt			
1.1.11	Flight Rate	(10-TBD) missions per year per vehicle		TBD missions as defined in Section 1.2
1.1.12	Operational Life Cycle	30 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 (300-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.

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	TBD		
	Sea	TBD		
	Air	TBD		
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	TBD		
	Annual Operations cost Goal	TBD		
1.1.24	Vehicle Dry weight	Table 1W	SSD	
	Vehicle dry weight w/Payload	Table 2W	SSD	
	Vehicle weight fueled	Table 3W	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		

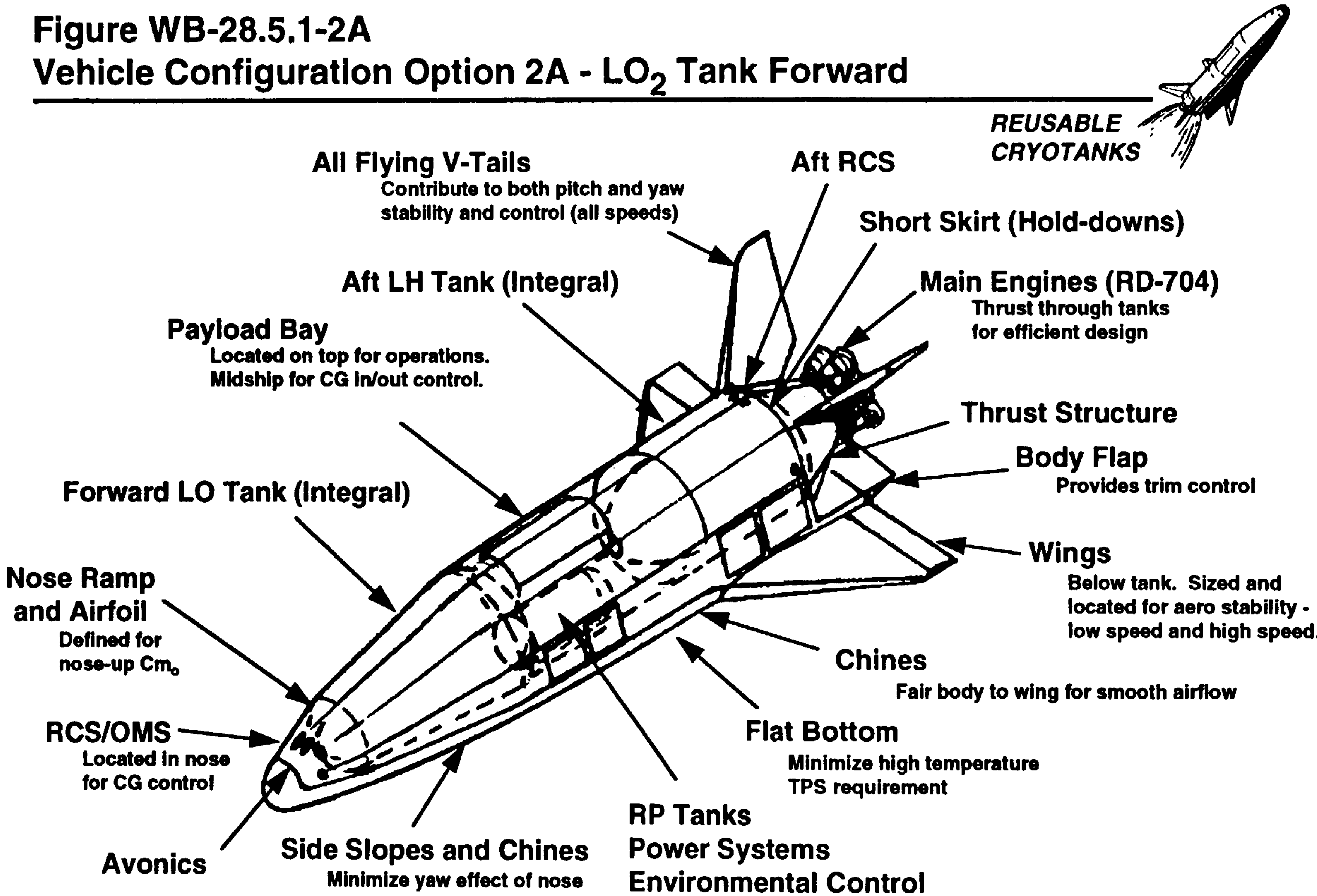
Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
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	Table 2T		
1.2.25	Vehicle Dry weight	Table 1W	SSD	
	Vehicle dry weight w/Payload	Table 2Wa	SSD	
	Vehicle weight fueled	Table 3Wa	SSD	

Section 2.0 SSTO Vehicle Description Option 2A

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
2.0 Baseline SSTO Vehicle configuration Description - Option 1A				
2.1	Configuration 2A Drawing	WB-28.5.1-2A		LO tank forward - integral LH tank
2.2	Vehicle Weight Statement	Tables 1W , 2Wa, and 3Wa		
2.3	Vehicle Description	Section 2.3		
	Ullage volumes (%)	4 % in all tanks		
	Feedline materials			
	RCS propellants			
	OMS propellants			
	Avionics			
	Electrical power			
	Communications			
	Data System			
	Residuals LH and LO tank	0.5%		
	Residuals 0g tanks	3%		
	Engines	TBD RD - 704		

Figure WB-28.5.1-2A
Vehicle Configuration Option 2A - LO_2 Tank Forward



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

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.0 Structure/TPS Requirements - Roll-out to pad to return to OPF				
3.1 Roll-out to Pad				
3.1.1	Vehicle Hold Down at Base	Yes		
	Peak transporter speed	TBD		
	Pad attach concept	TBD		
	Transport acceleration	compatible with vehicle		within capability
3.1.2	Peak Wind Speed	Table 1GW which is same as Table 3W	JSC 07700 Volume X Book 2 Revision L	99 % probability - no exceedance - in one day
	Vortex shedding			
	rainfall	TBD in/hr		TBD Probability
	lightning	TBD volts/meter		TBD Probability
3.1.3	Air Pressures	Table 1AP		
3.2.4	LH & LO Tank Pressure	2.0 psig minimum		
		LO2 Tank- GO2 and He		
		LH2 Tank GH2 and He		
		RP-1 Tank - RP1, GN2, He		
3.1.5	Limit Internal Body Loads	Table 1IL		
3.1.6	IHM Requirements	Table 1IHM		
3.1.7	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.1.8	Vehicle Mass Distribution	Table 2W		
3.2 Prelaunch - Unfueled - Up to 2 Week Duration				
3.2.1	Vehicle Hold Down @ Base	Yes		
	Pad attach concept	TBD		
3.2.2	Peak Wind Speed	Table 2GW	JSC 07700 Volume X Book 2 Revision L	99 % probability - no exceedance- in 2 weeks
	Vortex shedding	Table 2GW		
	Rainfall	TBD in/hour		TBD Probability
	lightening	TBD volts/meter		TBD Probability
3.2.3	Air Pressures	Table 2AP		
3.2.4	LH & LO Tank Pressure	2.0 psig minimum		
		LO2 Tank- GO2 and He		
		LH2 Tank GH2 and He		
		RP-1 Tank - RP1, GN2, He		
3.2.5	Limit Internal Body Loads	Table 2IL		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.2.6	IHM Requirements	Table 2IHM		
3.2.7	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.2.8	Vehicle Mass Distribution	Table 2W		
3.3 Prelaunch - Fueled - Up to one day duration				
3.3.1	Vehicle Hold Down at Base	Yes		
	Pad attach concept	TBD		
	Hold time	12 hours		
3.3.2	Peak Wind Speed	Table 3GW	NSTS 0770 Vol X Rev J June 14, 1990	99 % probability - no exceedance - in one day
	Vortex shedding	Table 3GW		
3.3.3	Air Pressures	Table 3AP		
3.3.4	Pre-Fueling Purge	LO2 - GO2 orHe or GN2		First flight and only after off-line access to tank
		LH2 - He		First flight and only after off-line access to tank
		RP - GN2 or GHe		First flight and only after off-line access to tank
3.3.5	Propellants			
	LO (free boiling)	70.7 pcf and -297 F		
	LH (free boiling)	4.4 pcf and -423 F		
	RP	48 pcf		
3.3.6	Fueling Sequence	LH tank first - LO next		see design criteria - sect 4.6.3
	LO tank fueling rate (gpm)	5,000	Shuttle	
	LH tank fueling rate (gpm)	10,000	Shuttle	
	LO tank drain rate (gpm)	TBD		
	LH tank drain rate (gpm)	TBD		
	RP tank fueling rate (gpm)	TBD		
	RP tank drain rate (gpm)	TBD		
3.3.7	Tank Pressurization			
	Sequence of pressurization	constrained per criteria		see design criteria - sect 4.6.3
	LO tank minimum (psig)	0.3		propulsion requirement only, structure requirement TBD
	LO tank max relief (psig)	20		
	LO peak operating (psig)	15.3		
	LH tank minimum(psig)	0.3		propulsion requirement only, structure requirement TBD
	LH tank max relief (psig)	34		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	LH peak operating (psig)	30.7		
	RP tank minimum (psig)	1		propulsion requirement only,
	RP tank max relief(psig)	20		
	RP peak operating (psig)	10.3		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.3.8	Permissible Leakage			
	LO tank			
	LH tank			
	RP tank			
3.3.9	Maximum Boil-Off Rate			
	LO tank	TBD		
	LH tank	TBD		
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		
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Saltspray			
	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	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Salt spray			
3.3.11	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F		
3.3.12	Limit Internal Body Loads	Table 3IL		
3.3.13	IHM requirements	Table 3IHM		
3.3.14	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.3.15	Vehicle Mass Distribution	Table 3W		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
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
	Vortex shedding	Table 4GW		
3.4.4	Air Pressures	Table 4AP		
3.4.5	Vehicle Hold Down at Base	Drawing No TBD 1		
	Pad attach concept	Drawing No TBD 1		
3.4.6	Load Factors			
	Nx	1.32 inc ampl		
	Ny	TBD		
	Nz	TBD		
3.4.7	Tank Pressurization			
	LO tank minimum (psig)	1		propulsion requirement only, structure requirement TBD
	LO tank max relief (psig)	20		
	LO peak operating (psig)	15.3		
	LH tank minimum(psig)	15.3		propulsion requirement only, structure requirement TBD
	LH tank max relief (psig)	34		
	LH peak operating (psig)	30.7		
	RP tank minimum (psig)	1		propulsion requirement only, structure requirement TBD
	RP tank max relief(psig)	20		
	RP peak operating (psig)	10.3		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		
	GN2 pressuriz Temp	TBD		
3.4.8	Permissible Leakage			
	LO tank			
	LH tank			
	RP tank			
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		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Saltspray			
	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	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Salt spray			
3.4.11	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F		
3.4.12	Limit Internal Body Loads	Table 4IL		
3.4.13	Dynamics			
	Acoustics (db)	Table 1AC		
	Nx amplification Ny Nz	1.1 TBD TBD		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			
	Gimbal angles			
	Actuatator acceleration			
	Actuator rate			
3.4.15	IHM requirements	Table 4IHM		
3.4.16	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.4.17	On Pad Abort			
	Engine shutdown			
	Safing			
	Reinstallation of holddowns			
3.4.18	Vehicle Mass Distribution	Table 3W		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
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	3		
	negative alpha	-3		
	positive beta	3		
	negative beta	-3		
3.5.4	Air Pressure Distribution			Differential pressures based on 1.0 psi
	positive alpha	Table 5AP		
	negative alpha	Table 5AP		
	beta	Table 5AP		
3.5.5	Load factors			
	Nx	1.52		includes amplif
	Ny	TBD		
	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 requirement on, structure requirement TBD
	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		
3.5.7	Permissible Leakage			
	LO tank			
	LH tank			
	RP tank			
3.5.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.5.9	TPS Roughness	Table 1TPS		
	TPS gaps and steps	Table 1TPS		
	TPS curvature	Table 1TPS		
	Catalycity	Table 1TPS		
	Absorptivity	Table 1TPS		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Emissivity	Table 1TPS		
	Aeroheating rates	Table 1AH		
	Base heating	Table 1BH		
	Plume heating	Table 1PH		
3.5.10	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	< 2800 F		
	Gr/BMI	< 375 F		
3.5.11	Limit Internal Body Loads	Table 5IL		
3.5.12	Dynamics			
	Acoustics (db)	Table 2AC		
	Nx amplification	1.05		
	Ny amplification	1.05		
	Nz amplification	1.05		
	POGO			
	Flutter			
	Buffetting			
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			
	Engine actuator loads			
	Engine gimbal angle			
3.5.15	IHM Requirements	Table 5IHM		
3.5.16	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.5.17	Vehicle Environment			
	Coldest temperature	19 F, Mean Min 48 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 89.3, Mean Relative Humidity 13 60.8	not critical	
	Concurrent dew point	Mean dewpoint Temp 50 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Hottest day	98 F Max temp, Mean Max 90 F	not critical	

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Concurrent humidity	Mean Real Humidity 07 88.4, Mean Relative Humidity 13 63.9	not critical	
	Concurrent dew point	Mean dewpoint temp 77 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
3.5.18	Vehicle Mass Distribution	Table 4W		
3.5a Ascent - Max qa - at T=76 secs with any one engine out				
3.5a.1	Thrust to Weight	1.48		
3.5a.2	Dynamic Pressure	TBD		
3.5a.3	Angles of Attack			
	Positive alpha	TBD		
	Negative alpha	TBD		
	Positive beta	TBD		
	Negative beta	TBD		
3.5a.4	Air Pressure Distribution			Differential pressures based on 1.0 psi
	Positive alpha	Table 6AP		
	Negative alpha	Table 6AP		
	Beta	Table 6AP		
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 requirement on, structure requirement TBD
	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			
	LH tank			
	RP tank			

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.5a.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.5a.9	TPS Roughness	Table 1TPS		
	TPS gaps and steps	Table 1TPS		
	Curvature	Table 1TPS		
	Catalycity	Table 1TPS		
	Absorptivity	Table 1TPS		
	Emissivity	Table 1TPS		
	Aeroheating rates	Table 2AH		
	Base heating	Table 2BH		
	Plume heating	Table 2PH		
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	< 2800 F		
	Gr/BMI	< 375 F		
3.5a.11	Limit Internal Body Loads	Table 6IL		
3.5.a.12	Dynamics			
	Acoustics (db)	Table 3AC		
	Nx amplification			
	Ny amplification			
	Nz amplification			
	POGO			
	Flutter			
	Buffeting			
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			
	Engine actuator loads			
	Engine gimbal angle			
3.5a.15	IHM Requirements	Table 6IHM		
3.5a.16	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.5a.17	Vehicle Environment			

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Coldest temperature	19 F, Mean Min 48 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 89.3, Mean Relative Humidity 13 60.8	not critical	
	Concurrent dew point	Mean dewpoint Temp 50 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Hottest day	98 F Max temp, Mean Max 90 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 88.4, Mean Relative Humidity 13 63.9	not critical	
	Concurrent dew point	Mean dewpoint temp 77 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
3.5a.18	Vehicle Mass Distribution	Table 5W		
3.6 Ascent - Max q - at T= 76 secs				
3.6.1	Thrust to Weight	1.78		
3.6.2	Dynamic Pressure	560		500 nominal + 60 dispersed
3.6.3	Angles of Attack			
	Positive alpha	3		
	Negative alpha	-3		
	Positive beta	3		
	Negative beta	-3		
3.6.4	Air Pressure Distribution			Differential pressures based on 1.0 psi
	Positive alpha	Table 7AP		
	Negative alpha	Table 7AP		
	Beta	Table 7AP		
3.6.5	Load Factors			
	Nx	1.52		includes amplif
	Ny	TBD		
	Nz	TBD		
3.6.6	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 requirement on, structure requirement TBD
	RP tank max relief(psig)	20		
	RP peak operating (psig)	TBD		
	GH2 pressuriz Temp	TBD		
	GO2 pressuriz Temp	TBD		
	GHe pressurization Temp	TBD		

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	GN2 pressuriz Temp	TBD		
3.6.7	Permissible Leakage			
	LO tank			
	LH tank			
	RP tank			
3.6.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.6.9	TPS Roughness	Table 1TPS		
	TPS gaps and steps	Table 1TPS		
	curvature	Table 1TPS		
	catalycity	Table 1TPS		
	absorptivity	Table 1TPS		
	emissivity	Table 1TPS		
	Aeroheating rates	Table 3AH		
	Base heating	Table 3BH		
	Plume heating	Table 3PH		
3.6.10	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	< 2800 F		
	Gr/BMI	< 375 F		
3.6.11	Limit Internal Body Loads	Table 7IL		
3.6.12	Dynamics			
	Acoustics (db)	Table 4AC		
	Nx amplification	1.05		
	Ny amplification			
	Nz amplification			
	POGO			
	Flutter			
	Buffeting			
3.6.13	Moisture in Structures	TBD		
3.6.14	Guidance and Control			
	Elevons	fixed TBD orientation		
	Body flap	fixed orientation @ 0 deg		
	Tail			
	Engine actuator loads			
	Engine gimbal angle			
3.6.15	IHM requirements	Table 7 IHM		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.6.16	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.6.17	Vehicle Environment			
	Coldest temperature	19 F, Mean Min 48 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 89.3, Mean Relative Humidity 13 60.8	not critical	
	Concurrent dew point	Mean dewpoint Temp 50 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Hottest day	98 F Max temp, Mean Max 90 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 88.4, Mean Relative Humidity 13 63.9	not critical	
	Concurrent dew point	Mean dewpoint temp 77 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
3.6.18	Vehicle Mass Distribution	Table 6W		
3.7 Ascent - Max g - at T= 164secs				
3.7.1	Thrust to Weight	3		continuous
3.7.2	Dynamic Pressure (psf)	60 to 0		
3.7.3	Angles of Attack			
	Positive alpha	TBD		
	Negative alpha	TBD		
	Positive beta	TBD		
	Negative beta	TBD		
3.7.4	Air Pressure Distribution			Differential pressures based on 1.0 psi
	Positive alpha	Table 8AP		
	Negative alpha	Table 8AP		
	Beta	Table 8AP		
3.7.5	Load Factors			
	Nx	3.15		includes amplif
	Ny	TBD		
	Nz	TBD		
3.7.6	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		

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	LH peak operating (psig)	TBD		
	RP tank minimum (psia)	1		propulsion requirement on, structure requirement TBD
	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		
3.7.7	Permissible Leakage			
	LO tank			
	LH tank			
	RP tank			
3.7.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.7.9	TPS Roughness	Table TPS1		
	TPS gaps and steps	Table TPS1		
	curvature	Table TPS1		
	catalycity	Table TPS1		
	absorptivity	Table TPS1		
	emissivity	Table TPS1		
	Aeroheating rates	Table 4AH		
	Base heating	Table 4BH		
	Plume heating	Table 4PH		
3.7.10	Temperature Constraints			
	TPS/insulation bondline	no less than - 160 F or grater than 400 F		
	TPS	Table 1TR		
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	Leading edges	< 2800 F		
	Gr/BMI	< 375 F		
3.7.11	Limit Internal Body Loads	Table 8IL		
3.7.12	Dynamics			
	Acoustics (db)	Table 5AC		
	Nx amplification	1.05		
	Ny amplification			
	Nz amplification			
	POGO			
	Flutter			
	Buffetting			
3.7.13	Moisture in Structures	TBD		
3.7.14	Guidance and Control			

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Elevons	fixed TBD orientation		
	Body flap	fixed orientation @ 0 deg		
	Tail			
	Engine actuator loads			
	Engine gimbal angle			
3.7.15	IHM Requirements	Table 8 IHM		
3.7.16	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.7.17	Vehicle Environment			
	Coldest temperature	19 F, Mean Min 48 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 89.3, Mean Relative Humidity 13 60.8	not critical	
	Concurrent dew point	Mean dewpoint Temp 50 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Hottest day	98 F Max temp, Mean Max 90 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 88.4, Mean Relative Humidity 13 63.9	not critical	
	Concurrent dew point	Mean dewpoint temp 77 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
3.7.18	Vehicle mass distribution	Table 7W		
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	TBD		
	Negative alpha	TBD		
	Positive beta	TBD		
	Negative beta	TBD		
3.8.4	Air pressure distribution			Differential pressures based on 1.0 psi
	Positive alpha	Table 9AP		
	Negative alpha	Table 9AP		
	Beta	Table 9AP		
3.8.5	Load factors			
	Nx	3.15		includes amplif

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Ny	TBD		
	Nz	TBD		
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 requirement on, structure requirement TBD
	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		
3.8.7	Permissible Leakage			
	LO tank			
	LH tank			
	RP tank			
3.8.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.8.9	TPS Roughness	Table TPS 1		
	TPS gaps and steps	Table TPS 1		
	Curvature	Table TPS 1		
	Catalycity	Table TPS 1		
	Absorptivity	Table TPS 1		
	Emissivity	Table TPS 1		
	Aeroheating rates	Table 5AH		
	Base aeroheating	Table 5BH		
	Plume heating	Table 5PH		
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	< 2800 F		
	Gr/BMI	< 375 F		
3.8.11	Limit Internal Body Loads	Table 9IL		
3.8.12	Dynamics			
	Acoustics (db)	Table 6AC		
	Nx amplification	1.05		

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Ny amplification			
	Nz amplification			
	POGO			
	Flutter			
	Buffetting			
3.8.13	Moisture in Structures	TBD		
3.8.14	Guidance and Control			
	Elevons			
	Body flap			
	Tail			
	Engine actuator load			
	Engine gimbal angle			
3.8.15	IHM Requirements	Table 9 IHM		
3.8.16	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.8.17	Vehicle Environment			
	Coldest temperature	19 F, Mean Min 48 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 89.3, Mean Relative Humidity 13 60.8	not critical	
	Concurrent dew point	Mean dewpoint Temp 50 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Hottest day	98 F Max temp, Mean Max 90 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 88.4, Mean Relative Humidity 13 63.9	not critical	
	Concurrent dew point	Mean dewpoint temp 77 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
3.8.18	Vehicle mass distribution	Table 8W		
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	TBD		
	Negative alpha	TBD		
	Positive beta	TBD		
	Negative beta	TBD		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.8a.4	Air pressure distribution			Differential pressures based on 1.0 psi
	Positive alpha	Table 9AP		
	Negative alpha	Table 9AP		
	Beta	Table 9AP		
3.8a.5	Load factors			
	Nx	3.15		includes amplif
	Ny	TBD		
	Nz	TBD		
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		
	LH peak operating (psig)	TBD		
	RP tank minimum (psia)	1		propulsion requirement on, structure requirement TBD
	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			
	LH tank			
	RP tank			
3.8a.8	Maximum Boil-Off Rate			
	LO tank	0		
	LH tank	0		
3.8a.9	TPS Roughness	Table TPS 1		
	TPS gaps and steps	Table TPS 1		
	Curvature	Table TPS 1		
	Catalycity	Table TPS 1		
	Absorptivity	Table TPS 1		
	Emissivity	Table TPS 1		
	Aeroheating rates	Table 5AH		
	Base aeroheating	Table 5BH		
	Plume heating	Table 5PH		
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		

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	LO tank wall	< 250 F		
	Leading edges	< 2800 F		
	Gr/BMI	< 375 F		
3.8a.11	Limit Internal Body Loads	Table 9IL		
3.8a.12	Dynamics			
	Acoustics (db)	Table 6AC		
	Nx amplification	1.05		
	Ny amplification			
	Nz amplification			
	POGO			
	Flutter			
	Buffetting			
3.8a.13	Moisture in Structures	TBD		
3.8a.14	Guidance and Control			
	Elevons			
	Body flap			
	Tail			
	Engine actuator load			
	Engine gimbal angle			
3.8a.15	IHM Requirements	Table 9 IHM		
3.8a.16	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.8a.17	Vehicle Environment			
	Coldest temperature	19 F, Mean Min 48 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 89.3, Mean Relative Humidity 13 60.8	not critical	
	Concurrent dew point	Mean dewpoint Temp 50 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
	Hottest day	98 F Max temp, Mean Max 90 F	not critical	
	Concurrent humidity	Mean Real Humidity 07 88.4, Mean Relative Humidity 13 63.9	not critical	
	Concurrent dew point	Mean dewpoint temp 77 F	not critical	
	Rainfall	TBD in/hour		TBD Probability
	Lightning	TBD Volts/meter		TBD Probability
3.8a.18	Vehicle mass distribution	Table 8W		
3.9 Orbit Insertion to De-Orbit				

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
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			
	LO tank			
	LH tank			
	RP tank			
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	< 2800 F		
	Gr/BMI	< 375 F		
3.9.6	Environment			
	Micrometeoroid	per SSP 30425 Rev A		
	Debris	per SSP 30425 Rev A		
	Radiation	TBD		
	Vacuum	TBD		
	Atomic oxygen	TBD		
3.9.7	Thermal environment	Table 1TH		
3.9.8	IHM requirements	Table 10 IHM		
3.9.9	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
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	TPS Roughness	Table 2TPS		
	TPS gaps and steps	Table 2TPS		
	TPS curvature	Table 2TPS		
	Catalycity	Table 2TPS		
	Absorptivity	Table 2TPS		
	Emissivity	Table 2TPS		
3.10.4	Aeroheating Rates	Table 6AH		
	Base aeroheating	Table 6BH		
3.10.5	Structural Temperatures	Table 1TE		
3.10.6	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	< 2800 F		
	Gr/BMI	< 375 F		
3.10.7	IHM requirements	Table 11IHM		
3.10.8	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		
3.10.9	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.10.10	*Vehicle mass distribution*	Table 9W		

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
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			
	Hail			
	Lightening			
3.11.4	Load Factors			
	Nx	TBD		includes amplif
	Ny	TBD		
	Nz	Neg 1.0 to 2.5	MIL SPEC	
3.11.5	Air Pressure Distribution	Table 3.10.5		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	< 2800 F		
	Gr/BMI	< 375 F		
3.11.8	Structural Temperatures	Table 2TE		
3.11.9	Limit Internal Body Loads	Table 10IL		
3.11.10	Dynamics			
	Nx amplification			
	Ny amplification			
	Nz amplification			
	Flutter			

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Buffetting			
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		
3.11.13	IHM requirements	Table 3.10.13		
3.11.14	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.11.15	Vehicle Mass Distribution	Table 10W		
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			
	Main Gear Max Z load			
	Side gear load			
	Crosswind	15 knots	Shuttle	Tire capability on landing
3.12.3	Load Factors			
	Rotational accel abt y	TBD		
	Ny			
	Nx			
	Nz			
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		

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	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		
	LO tank wall	< 250 F		
	leading edges	< 2800 F		
	Gr/BMI	< 375 F		
3.12.6	Limit Internal Body Loads	Table 11IL		
3.12.7	Structural Temperatures	Table 3TE		
3.12.8	Dynamics			
	Nx amplification			
	Ny amplification			
	Nz amplification			
	Flutter			
	Buffetting			
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 12IHM		
3.12.12	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.12.13	Air pressure distribution	Table 11AP		Differential pressures based on neg1.0 psi
3.12.14	Vehicle mass distribution			
	w/payload in	Table 10W		
	w/payload out	Table 11W		
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	

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	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			
	Main Gear Max Z load			
	Side gear load			
	Crosswind	15 knots	Shuttle	Tire capability on landing
3.13.3	Load Factors			
	Rotational accel abt y	TBD		
	Ny			
	Nx			
	Nz			
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	< 2800 F		
	Gr/BMI	< 375 F		
3.13.6	Limit Internal Body Loads	Table 12IL		
3.13.7	Structural Temperatures	Table 3TE		
3.13.8	Dynamics			
	Nx amplification			
	Ny amplification			
	Nz amplification			
	Flutter			
	Buffetting			
3.13.9	Moisture in Structures	TBD		
3.13.10	Guidance and Control			

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	Elevons	Deflection limits - TBD		
	Body Flaps	Deflection limits - TBD		
	Tail	Deflection limits - TBD		
	Engine actuators	not required		
3.13.11	IHM requirements	Table 12IHM		
3.13.12	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.13.13	Vehicle Mass Distribution			
	W/payload in	Table 10W		
	W/payload out	Table 11W		
3.14 Nose Gear Slapdown Landing				
3.14.1	On Concrete Surface with Propellant Residuals			
3.14.2	Minimum Speed for Pitchover			
	Maximum pitchover rate			
	Maximum speed for pitchover			
	Nose attitude at slapdown			
	Fwd Gear stroke			
	Fwd Gear Max Z load			
	Fwd Side gear load			
3.14.3	Load Factors			
	Ny			
	Nx			
	Nz			
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		

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
	LH tank wall	< 250 F		
	LO tank wall	< 250 F		
	leading edges	< 2800 F		
	Gr/BMI	< 375 F		
3.14.6	Limit Internal Body Loads	Table 13IL		
3.14.7	Structural Temperatures	Table 3TE		
3.14.8	Dynamics			
	Nx amplification			
	Ny amplification			
	Nz amplification			
	Flutter			
	Buffetting			
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 13 IHM		
3.14.12	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.14.13	Vehicle Mass Distribution			
	W/payload in	Table 10W		
	W/payload out	Table 11W		
3.15 Return to OPF and in OPF				
3.15.1	Towing Load Factors			
	Nz			
	Nx			
	Ny			
3.15.2	Taxi Load Factors			
	Nz	2.0		
	Nx			
	Ny			
3.15.3	Jacking/Hoisting			
	Nz			
	Nx			
	Ny			

Requirements Matrix

NO.	PARAMETER	QUANTIFICATION	SOURCE	CLARIFICATION
3.15.4	LO, LH, and RP tank pressures	2.0 minumum		
3.15.5	IHM Requirements			
3.15.6	Payload Environment			
	Temperature			
	Pressure			
	Humidity			
	Cleanliness			
3.15.7	Vehicle Safing			
	Purge			
	Unload payload			
3.15.8	Vehicle Mass Distribution			
	W/payload in	Table 3.13.13		
	W/payload out	Table 3.13.13		
3.15.9	Waterproofing			
	TABI			
	CFBI			
	AETB			
	Others			
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	Table LS-1		proof test - one cycle 300 missions -1 added cycle every 10th flight- see Table 3.16.1
3.16.2	LH Tank Pressures	Table LS-2		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-3		
3.16.4	Wing Loads	Table LS-4		
3.16.5	Tail Loads	Table LS-5		
3.16.6	Thrust Structure	Table LS-6		
	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 W

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 W

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

Section 4.0 Design Criteria

4.0 DESIGN CRITERIA

The design criteria delineated herein will be updated on a timely basis as further insight is obtained and through continuing discussions with all three NASA agencies concerned personnel.

4.1. Design Factors

4.1.1 LH Composite tank design factors and material allowables

4.1.1.1 Ultimate safety factor applied to maximum relief valve pressure - 1.4

4.1.1.2 Proof test pressure- applied to peak operating pressure -1.1

4.1.1.3 Ultimate safety factor applied to mechanically induced body loads-1.4

4.1.1.4 Margins of Safety - 0.0 for regions in which 100% of the stress is due to membrane behavior - 0.10 for discontinuity regions with more than 50 % of the stress due to discontinuity induced bending.

4.1.1.5 Fittings factors - Fittings analysis will apply an appropriate TBD fitting factor to the ultimate safety factor.

4.1.1.6 Material allowables - For analysis, "B" basis strength allowable shall be used when available. If the material data base is insufficient to generate true "B" basis values, then preliminary design allowables shall be specified which represent 80% of the average strength as measured by coupon tests. For stiffness properties, average test values shall be used in analysis.

4.1.2. LO Metallic Tank design factors

4.1.2.1 Ultimate safety factor applied to maximum relief valve pressure - 1.4

4.1.2.2 Proof test pressure - applied to peak operating pressure -1.1

4.1.2.3 Ultimate safety factor applied to mechanically induced body loads-1.4

4.1.2.4 Margins of Safety - 0.0 for regions in which 100% of the of the stress is due to membrane behavior - 0.10 for discontinuity regions with 50 % or more of the stress due to discontinuity induced bending.

4.1.2.5 Fittings factors - Fittings analysis will apply an appropriate TBD fitting factor to the ultimate safety factor.

4.1.2.6 Material allowables - For analysis, "B" basis strength allowable shall be used when available. If the material data base is insufficient to generate true "B" basis values, then preliminary design allowables shall be specified which represent 80% of the average strength as measured by coupon tests. For stiffness properties, average test values shall be used in analysis.

4.1.3 Unpressurized Composite Structures

4.1.3.1 Ultimate Safety factor applied to limit mechanical load-1.4

4.1.3.2 Ultimate safety factor applied to limit thermally load-1.0

4.1.3.3 Ultimate safety factor applied to combined mechanical and thermally induced load- 1.4 for mechanical and 1.0 for thermal when thermal is additive - 1.4 for mechanical and 0.0 for thermal when thermal is relieving

4.1.3.4 Margins of Safety - 0.0

4.1.3.5 Fittings factors - Fittings analysis will apply an appropriate TBD fitting factor above the the ultimate safety factor

4.1.2.6 Material allowables - For analysis, "B" basis strength allowable shall be used when available. If the material data base is insufficient to generate true "B" basis values, then preliminary design allowables shall be specified which represent 80% of the average strength as measured by coupon tests. For stiffness properties, average test values shall be used in analysis.

4.2 Loads Determination Criteria

4.2.1 Load factors will include estimated dynamic amplification factors for lift-off, max $q\alpha$, max q, max g, and landing The load factors will be delineated in the requirements document.

4.2.2 Ascent loads will be based on fixed elevon orientation and body flap at 0 degrees

4.2.3 Ascent and Entry loads will be based on rigid body analysis

4.2.4 Payload bay doors - Door and Latch designs will provide torsional capability to the payload bay structure andwill be capable of opening in the vertical orientation on the pad without GSE. The capability to open without GSE in the horizontal attitude is TBD

4.3 Structure Loading spectrums

4.3.1 Cryogenic Tankage - The spectrum of pressurization cycles to be sustained is one proof test + 1.1 x the number of specified missions of peak operating pressure- The spectrum for wing attachment loads is the same as that of the wing, and for intertank to tank Nx and q loadings is that of the intertank as specified below.

4.3.2 Intertank, Wing, Tail and Thrust structure loading spectrums are as follows:

4.3.2.1 Intertank - Peak limit load for W times number of missions, 90 % of peak limit load for X times number of missions, 80 % of peak limit load for Y times number of missions, 70 % of peak load for Z times number of missions

4.3.2.2 Wing - Peak limit load for W times number of missions, 90 % of peak limit load for X times number of missions, 80 % of peak limit load for Y times number of missions, 70 % of peak load for Z times number of missions

4.3.2.3 Tail - Peak limit load for W times number of missions, 90 % of peak limit load for X times number of missions, 80 % of peak limit load for Y times number of missions, 70 % of peak load for Z times number of missions

4.3.2.4 Thrust Structure - Any one engine out condition, three shutdowns at 80 % thrust, plus one cycle each for the number of missions

4.4 Danage Tolerance for Metallic Tank -

4.4.1 NASGRO computer program as developed by NASA on STS Orbiter program will be used as required to predice flaw growth. The analysis will be based on the largest initial flaw undetected by inspection. (The analysis properties published for Al-Li 2195 will be assumed to be still valid assuming resolution of the recent material problems). A scatter afctor of 2 is used.

4.5 Damage Tolerance for Composte Structures

4.5.1 Fracture/Damage tolerance - The structural design shall account for the susceptibility of materials to brittle fracture. Fracture analyses shall be performed to determine critical flaw sizes, allowable initial flaw sizes, and possible fracture modes for structural materials.

4.6. Miscellaneous Criteria for Tank Design

4.6.1 Cryogenic tanks will be purged prior to fueling to eliminate any moisture and negate or minimize thermal shock

4.6.2 LO and LH positive pressure- During roll-out to the pad, prelaunch prior to fueling, and return to Operations facility a positive pressure differential of 2.0 psig is to be maintained by GSE

4.6.3 During prelaunch the LO and LH tank shall be capable of sustaining loads due to weight and applied wind loads for any combination of fueling and pressurization except for configuration option 2A- For this design fueling and pressurization of the LH_2 tank first will be considered. The weight savings realized and percent of minimum pressure to be used for compression load relief will be determined to ascertain if this criteria is appropriate.

4.6.4 For a common bulkhead design, such as in configurations 3 and 4, GSE shall be capable of limiting the peak differential, across the bulkhead, to the largest of (1) the difference between the LH maximum relief and LO minimum pressure (2) the difference between the LO maximum relief and LH minimum pressure.

4.6.5 LO and LH pressure Load relief - Longitudinal load relief shall be based upon the limit minimum pressure only if the vehicle can not be returned safely in the event that tank pressure is below minimum pressure

4.6.6 Upon entry to orbit - LH and LO tank pressures are to be reduced to lowest pressures compatible with maintenance of positive pressure of no less than 2.0 psig during entry to landing. Until quantified on the basis of data obtained by early impact tests it is assumed that the probability of a puncture, from debris impact that is large enough to lose positive pressure, has an acceptable low level of probability.

4.6.7 Residual fluids - The SSTO is designed to retain any LO, RP, and LH residuals during on-orbit, entry, and landing. There will be no provisions for ejection of the residuals

4.6.8 Entry , Pull-up maneuver, and landing loads critical Nx compression loads will be determined assuming no relief from net internal differential pressure.

4.6.9 Intact abort landing - It is assumed that the LO, LH, and RP propellants are consumed by operation of the engines before landing is attempted.

4.6.10 The tank structure must be capable of repair, in a timely manner, in the event damage is incurred due to debris or any other foreign object impact.

4.6.11 Tank structures with Ceramic tile direct bonded to cryogenic insulation - Direct bonding of the ceramic tiles to the cryogenic insulation must be compatible with the curvatures due to either tank pillowing and/or tank wall strain. Use of SIP may be possible here too if a significant weight penalty overrides the benefit of the direct bonded design.

4.6.12 Tank insulation materials will be resistant to damage or degradation from repeated freezing and thawing.

4.6.13 Surfaces in contact with fuel components will be resistant to damage or degradation from solvents used in maintenance or repair.

4.6.14 Composites Ply Drop-off - A minimum spacing of TBD shall be maintained between any adjacent ply edges. Ply drop-offs shall be a minimum of 20 to 1.

4.6.15 Buckling and Crippling- Buckling is not permitted below 1.1 x limit load. Buckling shall not cause components that are subject to instability to collapse when ultimate loads are applied, nor shall buckling deformation at 1.15 x limit load degrade the functioning of any system or produce changes in loading that are not accounted for.

4.6.16 Fatigue/Durability - Safe life design based on 300 mission cycles shall be adopted for all primary load carrying structure. Structural integrity shall be demonstrated by analysis or test for two (2) times the load spectra associated with the total mission cycles expected in service.

4.6.17 Creep - Materials shall not exhibit cumulative creep strain leading to rupture, detrimental or creep buckling of compression members during their service life.

4.6.18 Composite Material Failure Criteria - An acceptable failure criterion such as the Maximum Strain Theory shall be used to determine structural integrity. Linear elastic lamination theory at the macro-mechanics level is deemed acceptable for point stress analysis of the graphite epoxy materials used in the LH2 tank. Standard computer codes are available to perform the necessary calculations. Lamina properties are to be used as basic input. It should be recognized that linear lamination theory is often sufficient for engineering analysis, but is never exact. Hence, very complex lay-ups or complex load cases may require confirmatory testing prior to use of a given laminate in the LH2 tank.

4.6.19 Degradation Philosophy -No arbitrary knockdown factors on material properties, etc. are used for environmental effects or for impact damage. Only those influences actually characterized by test or historical data base shall be included.

4.6.20 Temperature Constraint - Composite materials shall not be subjected to temperatures in excess of the saturated Tg of the resin matrix

4.6.21 Material properties shall account for liquid hydrogen effects and statistical influences. Some basic thermal and mechanical cycling tests have been completed, and no degradation effects have been noted. During the course of development, additional work will be accomplished in identifying and characterizing environmental effects on material properties.

4.6.22 All materials used in the construction of the tanks will be capable of withstanding 300 thermal cycles over the range of cryogenic (-423F for LH2 and -320F for LOX) to 250F, without degradation or damage leading to potential failure of critical components.

4.6.23 Fail safe requirements - All composite stiffeners will be capable of tanking limit loads with one adjacent stiffener assumed to be delaminated between frames.

4.6.24 Hydrogen embrittlement - No materials shall be used in the LH tank systems or internal construction, which are susceptible to hydrogen embrittlement.

4.7 Miscellaneous Criteria for Composite Unpressurized Structures Design

4.7.1 Composite structures with ceramic tiles that are direct bonded will be limited to in-plane strain, curvature, and torsional twist compatible with the appropriate ceramic tile. TA -3 testing will establish these criteria. However structure sizing analyses prior to test results will use the limitations, determined by analysis, of the tile capability. Further, skin-stringer designs will be sized such that no skin buckling is permitted below 1.15 x limit load.

4.7.2 Composite structures with ceramic tiles with SIP - This design is applicable only if a significant weight penalty is associated with the direct bonded design.

4.7.3 Wing and tail panels will be designed to be flutter free.

4.7.4 Compartment differential pressures will be based on the assumption that vents are located where the external surface pressure is near ambient. In this case it is assumed that the vents will limit the positive differential pressure during ascent and the negative differential pressure during descent to 1.0 psig.

4.7.5 The unpressurized structures designs must be suitable for the worst case of local differential pressures based on the determined aerodynamic pressures and the associated compartment vent pressures.

4.7.6. Moisture in laminates - Materials will be resistant to damage or degradation from repeated freezing and thawing. Composite structures shall not be subjected to temperatures in excess of the saturated Tg of the resin matrix.

4.7.7 Any exposed composite structures shall be suitable for coastal salt spray for 300 missions. Exposure per Mil Std TBD per ASTM B 117 salt spray.

4.7.8 Any exposed composite materials shall be suitable for LEO UV radiation environments for 300 missions. Exposure per specification No. TBD

4.7.9 Composites Ply Drop-off - A minimum spacing of TBD shall be maintained between any adjacent ply edges. Ply drop-offs shall be a minimum of 20 to one.

4.7.10 Composites Fastener Bearing - Composites requiring attachment using mechanical fasteners shall have minimum bearing strength of TBD.

4.7.11 Buckling and Crippling- Buckling is not permitted below 1.1 x limit load. Buckling shall not cause components that are subject to instability to collapse when ultimate loads are applied, nor shall buckling deformation at 1.15 x limit load degrade the functioning of any system or produce changes in loading that are not accounted for.

4.7.12 Fatigue/Durability - Safe life design based on 300 mission cycles shall be adopted for all primary load carrying structure. Structural integrity shall be demonstrated by analysis or test for two (2) times the load spectra associated with the total mission cycles expected in service.

4.7.13 Creep - Materials shall not exhibit cumulative creep strain leading to rupture, detrimental or creep buckling of compression members during their service life.

4.7.14 Composite Material Failure Criteria - Linear elastic lamination theory at the macro-mechanics level is deemed acceptable for point stress analysis of the graphite epoxy materials used in the LH2 tank. Standard computer codes are available to perform the necessary calculations. Lamina properties are to be used as basic input. It should be recognized that linear lamination theory is often sufficient for engineering analysis, but is never exact. Hence, very complex lay-ups or complex load cases may require confirmatory testing prior to use of a given laminate in the LH2 tank.

4.7.15 Degradation Philosophy -No arbitrary knockdown factors on material properties, etc. are used for environmental effects or for impact damage. Only those influences actually characterized by test shall be included.

4.7.16 Temperature Constraint - Composite materials shall not be subjected to temperatures in excess of the saturated Tg of the resin matrix

4.8. Operations Related Criteria

4.8.1 The analysis will assume on-pad hold down will be provided until thrust = 90 to 100 % of gross vehicle weight is achieved. This is based on IHM of the engine thrust build-up phase. Capability to restore on pad hold down in the event of engine shutdown is to be provided.

4.8.2 The analysis will assume that no operations will be performed to eliminate or reduce moisture in the composite structures

4.8.3 Structural and operations analysis will assume that after landing, active cooling methods will not be used to maintain TPS and tank structure temperatures within required limits.

4.8.4 Allowable boil-off rate is based upon on pad capability to resupply TBD gallons per minute of LH and TBD gallons per minute of LO.

4.9 TPS Criteria for analysis and design

4.9.1 TPS, cryoinsulation, and tank wall temperature limits are summarized in the requirements document. Temperature limits will be updated as timely based on the results of TA 1, TA 2, and TA 3 developments.

4.9.2 TPS and cryogenic insulation temperature margins - The temperature limits used for the thermal analysis will include the temperature margin s stated in Table TBD.

4.9.3 Ascent - The ascent heating timeline will begin at ignition (prior to launch) and terminate at orbit insertion. Prelaunch and ascent plume heating, plume impingement, and aeroheating are included. The analysis will include relaminarization, surface roughness and TBD surface catalycity as appropriate.

4.9.4 On-orbit - Orbital TPS and tank soak-back heating effects will be defined from orbit insertion until de-orbit burn. TPS surface $\alpha_S / \varepsilon = 1.0$ will be assumed and updated as TA 3 data becomes available.

4.9.5 Entry - Entry heating will be defined from de-orbit through TAEM. The heating analysis will include surface emmisivity, curvature, roughness, surface catalycity, and transition to turbulent flow.

4.9.6 The allowable pillowing or curvature during aeroheating is as shown in Figure TBD

4.9.7 On-Orbit thermal analysis will be based on the SSTO docked to the Space Station

4.9.8 The average time on orbit is 3 days . The maximum time on orbit is 8 days.

4.9.9 The TPS design will be sufficiently durable in the presence of TBD wind/rain, TBD ice, TBD hail, TBD temperature extremes without loss of performance and life duration

4.9.10 TPS repair - The TPS, and for tankage the TPS/crogenic insulation must be capable of either repair and or replacement , in a timely manner, such that no performance degradation is realized

4.9.11 TPS Waterproofing - Waterproofing will be required in TPS such as PBI, TABI, CFBI, AETB and batting insulations.

4.9.12 Rewaterproofing - Rewaterproofing of TABI, CFBI, AETB and batting insulation will not be required for radiation equilibrium temperatures below 1100 F. In the event the value of this temperature is increased due to developments in TA-3 the value will accordingly be increased.

4.9.13 Frost -TBD

4.9.14 TPS materials shall be suitable for coastal salt spray for 300 missions

4.9.15 TPS materials shall be suitable for LEO UV radiation environments for 300 missions.

4.10. NDE/NDI/IHM -

4.10.1 Operations will require on no offline vehicle NDE/NDI inspections more frequently than every 20 flights unless IHM indicates inspection is warrented. The value of 20 will be updated based on the technology development during TA 1, TA 2, TA 3

4.10.2 IHM will provide TBD % of continuous critical fault monitoring and TBD % of periodic fault coverage (non-critical) to identify maintenance options.

4.10.2 Acess - All the designs must provide for access to the interior of the tank in the event visual inspection is required.

4.11 Aerodynamic pressure analysis criteria-TBD

4.12 Aerodynamic Stability Criteria

4.12.1 Stability Requirements

4.12.1.1 Minimum longitudinal static margin shall be zero.

4.12.1.2 Subsonic flight: The minimum longitudinal static margin (rigid body) shall be -2% of body length at 10 deg angle of attack (OVEI spec).

4.12.2 Lift to Drag Performance

4.12.2.1 Hypersonic flight: Peak L/d at entry speeds shall be no lower than 1.5 to meet cross-range performance.

4.12.2.2 Subsonic flight: Peak value of L/D (gear up at zero deg speed brake setting shall not be less than 4.0 (OVEI spec).

4.12.3 Control Requirements

4.12.3.1 The vehicle shall be capable of controlled flight with Nz max of 2.5 g to 0 g above Mach 3 and 2.5 g to -1.0 g below Mach 3 (OVEI spec).

4.12.3.2 The vehicle shall have adequate response and lateral/directional and longitudinal control capability to maintain attitude control and provide maneuvering performance identified above.

4.12.3.3 The longitudinal control effectiveness shall be such that all positive values of L/D between zero and the maximum value can be obtained within the permissible speed and load limits.

4.12.4 Landing Performance

4.12.4.1 The vehicle shall have a maximum landing speed below 200 knots when landing without a return payload or with a 25,000 lb payload.

4.12.4.2 Landing will be based on a runway length of TBD.feet

4.13 Trajectory Criteria-TBD

4.14. On Orbit Micrometeoroid/Debris Impact upon Cryogenic Tankage -

4.14.1 Ballistic efficiency will be determined, for combinations of integrated TPS/insulation/composite tank walls, from early impact tests at NASA/MSFC and refined by subsequent tests.

4.14.2 Probability of no catastrophic explosion resulting from on-obit debris impact shall be .99

4.15 Miscellaneous Environmental Criteria

4.15.1 Lightning Strikes- The TBD electricity phenomena occurring separately shall not degrade, damage, or cause to fail critical components of the SSTO vehicle when airborne such that safe, continued, and controlled flight is in question and, additionally, shall not cause injury to support personnel servicing or maintaining the air vehicle:

4.15.1 Lightning Protection - The vehicle shall be capable of withstanding lightning strikes. The lightning environment to be considered shall be TBD.

4.15.2 Electrostatic Charge Control -The vehicle shall be capable of adequately controlling and dissipating the buildup of electrostatic charges for internal and external portions of the vehicle, in particular those components exposed to air flow or personnel contact.