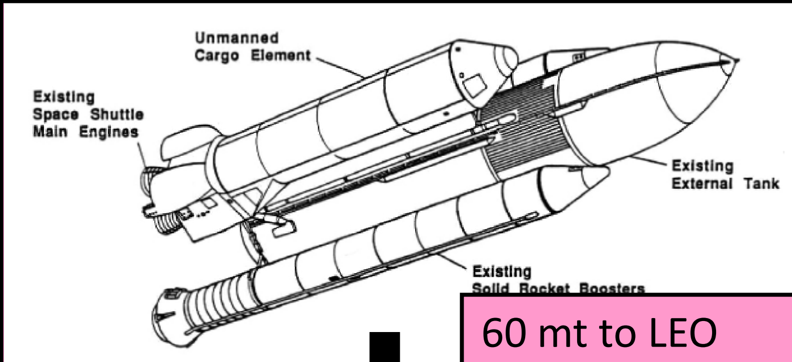
Shuttle-Derived Heavy Lift Launch Vehicle

Presented to the Review of U.S. Human Spaceflight Plans Committee

June 17, 2009

Side-Mount Shuttle Derived Vehicle Concepts Have Matured Via Several Major Design Studies

1990's NASA sponsored Shuttle C

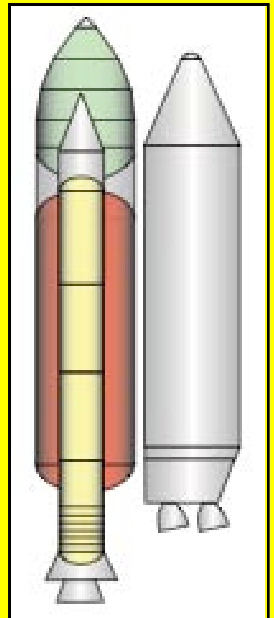


60 mt to LEO

68 mt to LEO

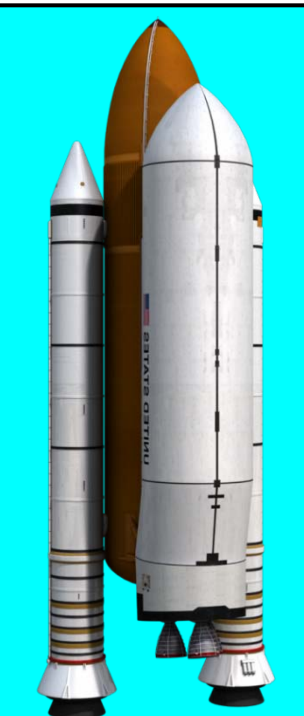
2004 – 2005 Shuttle Derived Launch Vehicle Industry Team Concept B

66 mt to LEO



2005 Exploration Systems Architecture Study (ESAS)

72.1 mt to LEO



2009

HLV Concept

All performance quotes are net payload (consistent 10% performance reserves)

HLV Configuration

- 4,544,684 lb at liftoff
- 647 psf max q
- 3.0 g max

- 7.5-m inner diameter payload carrier
- Modified Shuttle boat tail / Avionics
- Existing 4-segment RSRBs
- Existing ET design

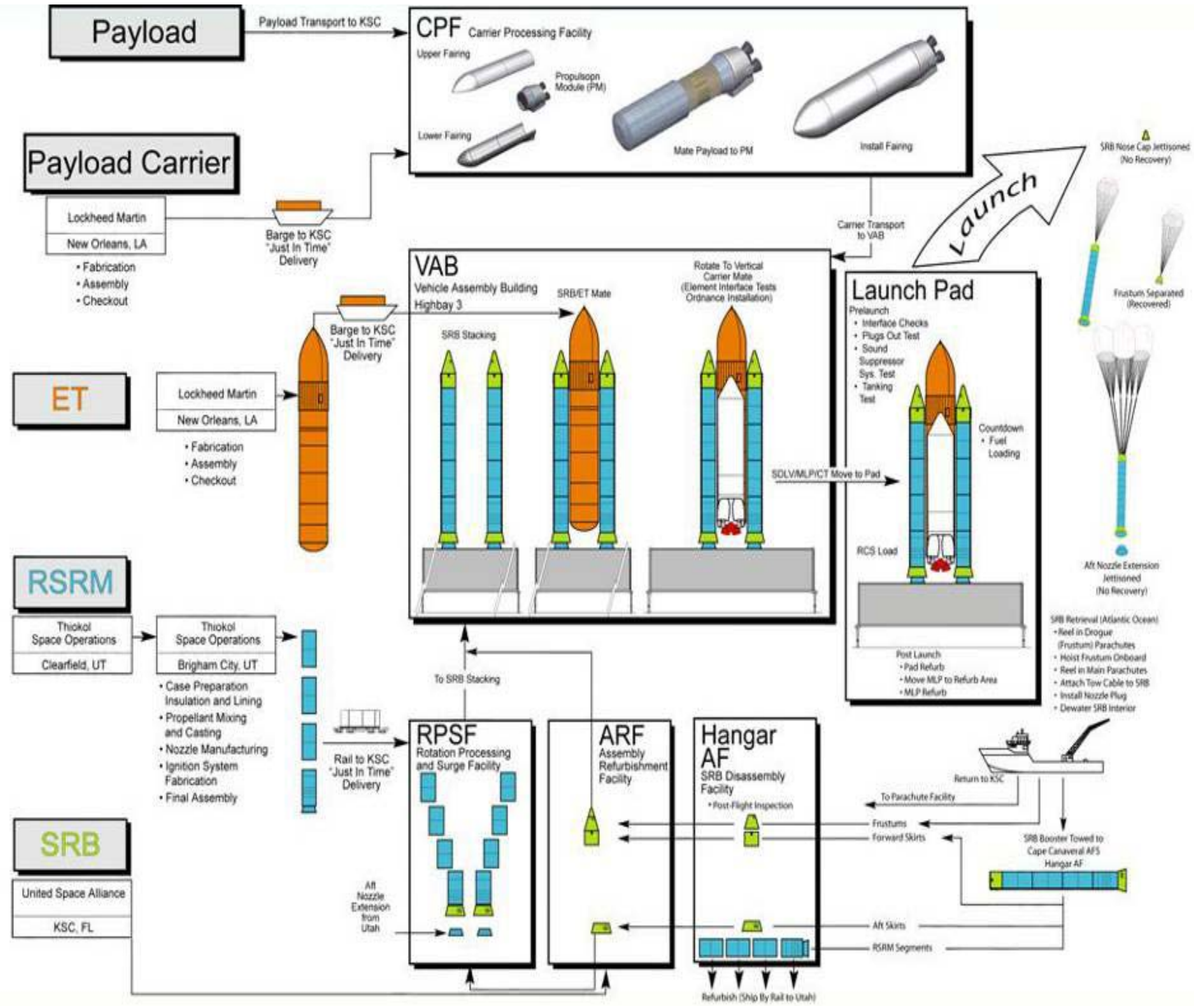
Design Approach

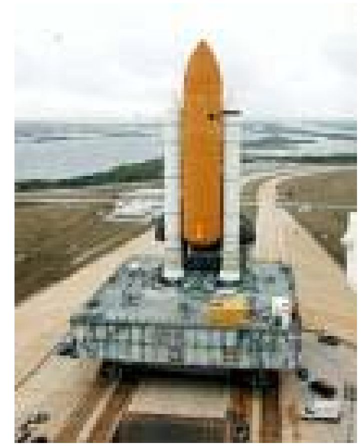
Two block design approach:

- Block I - fly existing Shuttle assets, avionics and software
  - No change to External Tank
  - No change to Solid Rocket Boosters
  - No change to SSMEs
  - Use existing Avionics
  - Use existing Flight Software
  - Use/modify SEI tools (Acoustic, Aerodynamic, Structures, Loads)
  - Existing pad structure
  - Launch and Ground Control software
  - Simplify High-risk aft interface
  - Delete Fuel cells, Cryo, Nitrogen, Cooling systems , OMS, RCS systems

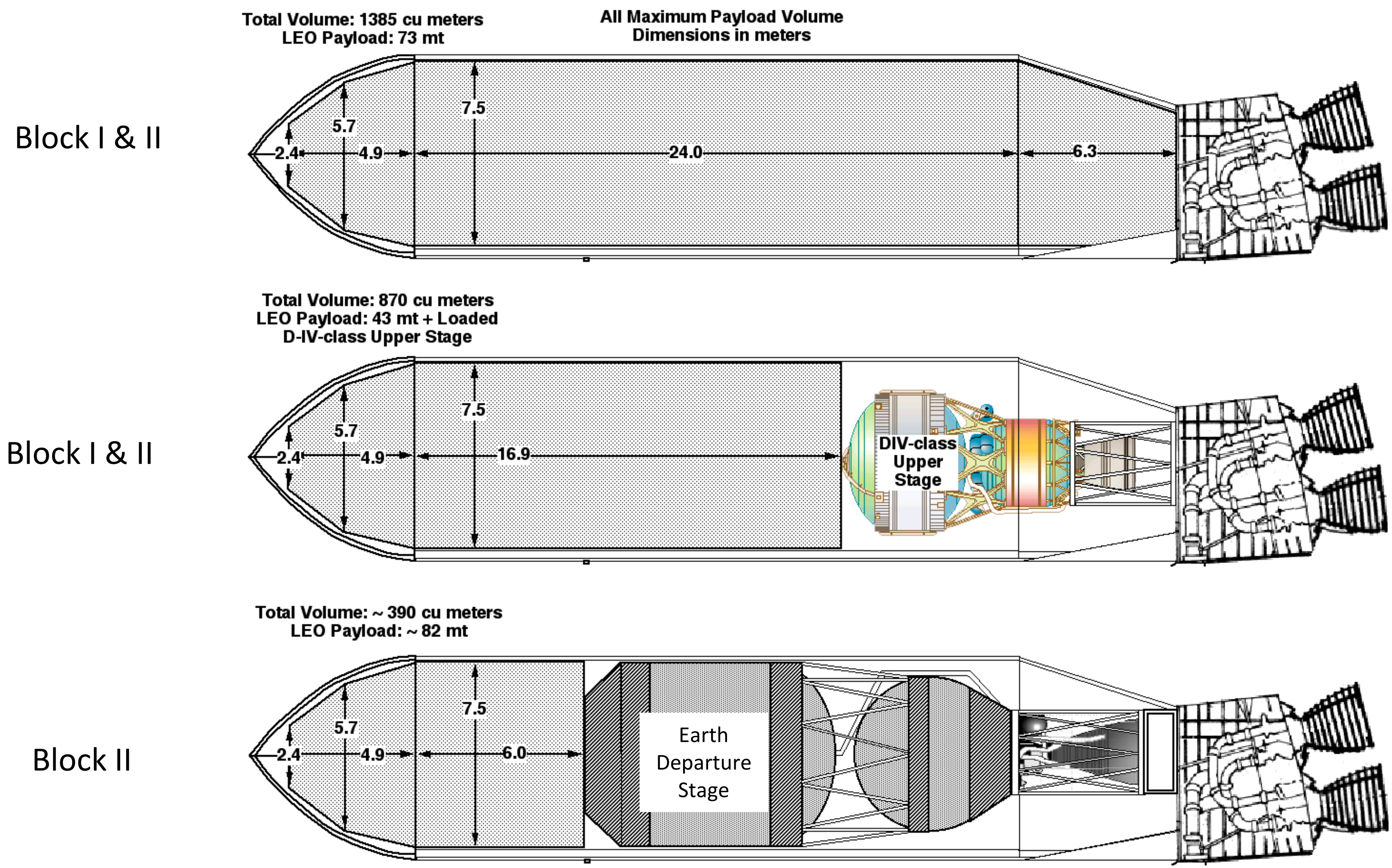
- Block II - Block I upgrade to fly new capabilities as Shuttle spares run out

Use Existing Space Shuttle Infrastructure/Facilities





Block I & Block II HLV Carrier Design Payload Envelopes



Systems Architecture Phasing Strategy

One Fault Tolerant	GNC	DPS HW	DPS SW	C&T	Instru-mentation	EPD&C	APU/HYD	ECLSS/ATCS	MPS
Block I	**IMU, RGA, AA, ATVC**	**GPC MDM EIU DBIA**	**Latest OI FSW revision with minor updates to deliver a new OI release.**	**NSP COMSEC S-band HW**	**MTU PCMMU DSC**	**GCIL EMEC/AMEC AC Inverters PDA Control Assy. New Primary batteries.**	**APU APU controller Fuel tank & HW Exhaust ducts Hyd Hose & vlvs Servoactuator Accumulator**	**Manifold & Duct assy**	**Feedlines Replenish lines FCV Ghe Tank Valves PSE Level sensors Umbilical Assy Manifold Assy**
Block I 4-6 flights	**Same s Block I**	**New DBIA *EIU**	**New Minor FSW updates to accommodate Hardware I/F changes.**	**New NSP COMSEC. Replace S-band HW with OTS S-band equipment.**	**Replace MTU with IRIG generator. Develop New/Alt PCMMU.**	***Delete AC inverters. Replace PDA and Control Assy**	**Need to turn on manufacturing of Hyd Hose & vlvs, and servoactuator.**	**Turn on NSLD production of duct assy's.**	**NEW MPS HW to support new SSME's. New/Alt PSE and level sensors. Turn on production of O2/H2 manifold assy's.**
Block II	**New RGA ATVC**	**New GPC MDM**	**New Minor FSW updates to accommodate hardware I/F changes and new GPS look-a-like HW.**	**Use Block I+ hardware**	**Upgrade DSC's and combine with new MDM's.**	**Incorporate GCIL function in new MDM/DSC. Upgrade EMEC/AMEC.**	***Replace hydrazine APU and hyd with electro-mechanical system.**	**Use Block I+ hardware where required.**	**Use Block I+ hardware.**

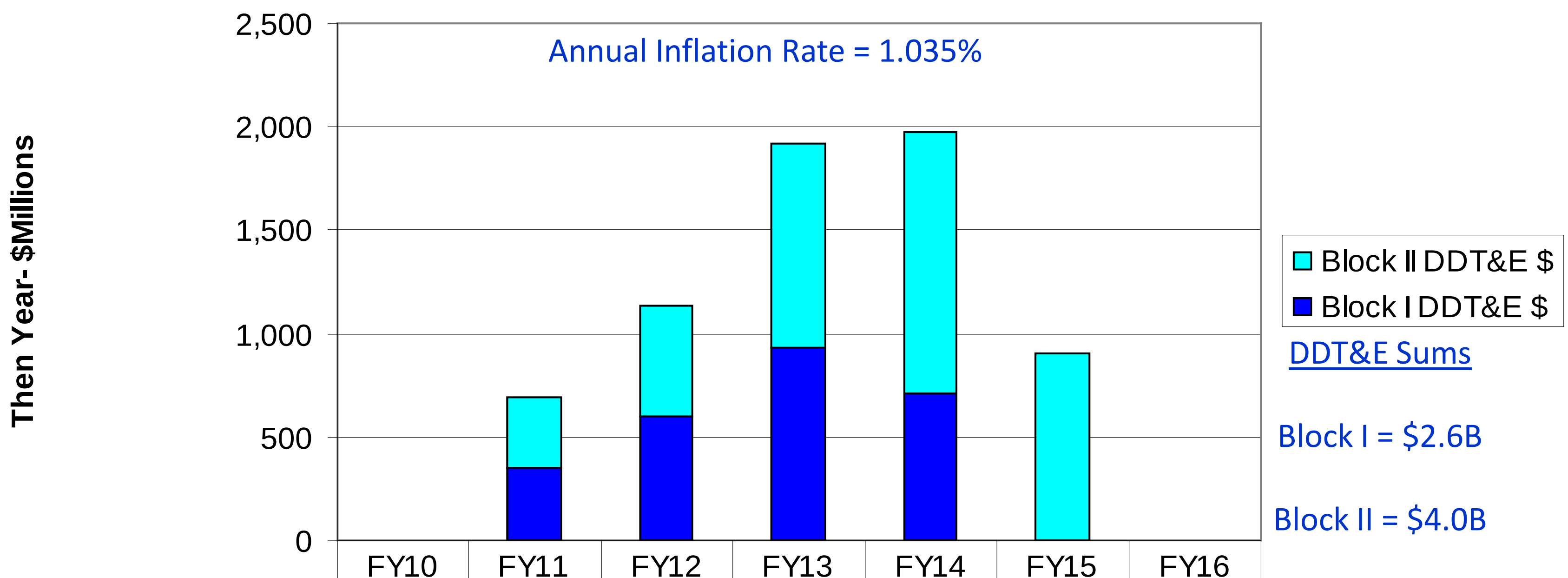
* Jointly delete AC and hydraulic requirements from new SSME controllers

HLV SSME Utilization

- The Current Space Shuttle Main Engine (SSME) [also Known as RS 25] has a well established engineering History
  - More than 100 flight engines with over 1million seconds of hot fire time
  - Well known reliability in all modes of operation, i.e. start , run @ 100% run @ 104.5%, 106%, 109% , Engine Shutdown
  - Established knowledge base for manufacturing, test and integration into flight vehicle
- Hardware is readily available for Block I and Test Flights
  - Currently 14 flight engines supporting the SSP
  - Existing inventory of hardware to support HLV
  - Hot fire test stands exist to support HLV use of SSME
  - KSC infrastructure exists to support HLV use of SSME
- RS 25E (Expendable) has been extensively studied
  - Channel Wall Nozzle, Non-refurbished turbopumps, Reduced Inspection

HLV $ROM Cost Estimates DDT&E

HLV $ROM Cost Estimate
Block I + Block II DDT&E
ISS Mission (without Transfer Stage $)



	FY10	FY11	FY12	FY13	FY14	FY15	FY16
Block II DDT&E $	0	343	533	984	1,265	903	0
Block I DDT&E $	0	347	600	930	712	0	0

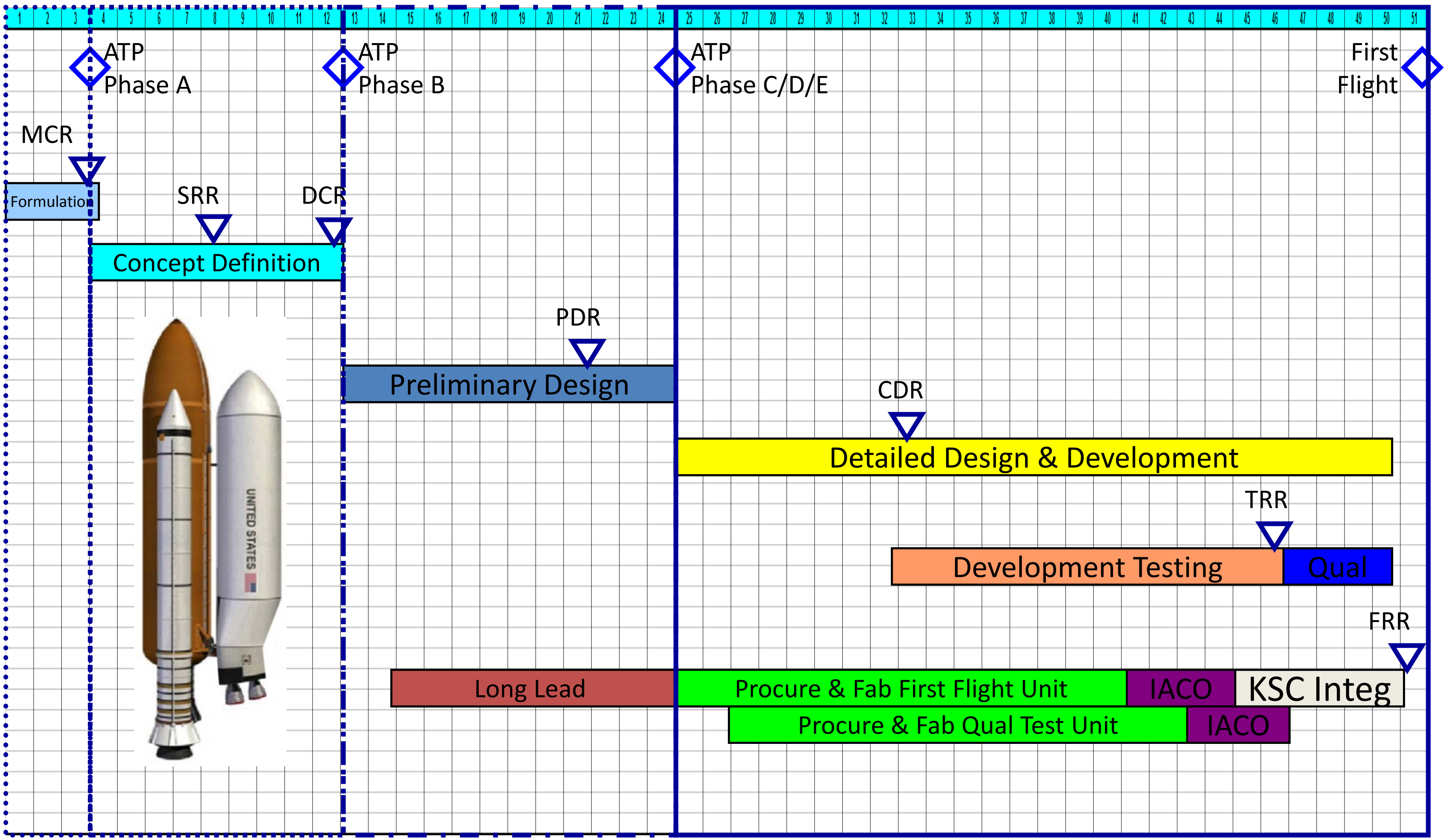
DDT&E Sums

Block I = $2.6B

Block II = $4.0B

Total = $6.6B

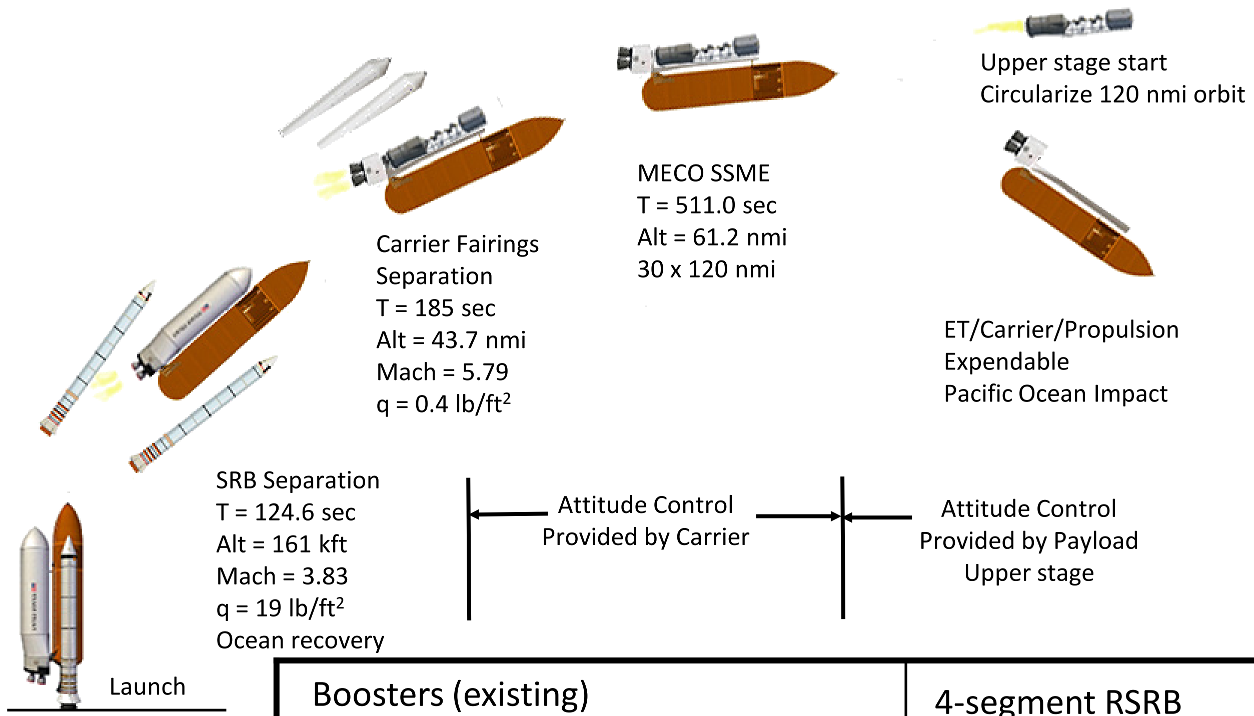
HLV Development Schedule



Initial ISS Logistics Design Reference Mission

- Use available Shuttle assets:
  - -SSME, RSRM, ET-122 (139, 140, 141, 94)
  - -Flight Software, Avionics
  - -APU's, TVC, MPS
- Fly Shuttle Launch Profile
- New 7.5m Payload Carrier (PLC)
- Payload
  - - Barge/Pallets
  - - MPLM (expend) + Unpressurized logistics
- Barge delivers ISS payloads and then deorbits expendable payloads

HLV Flight Profile for ISS DRM

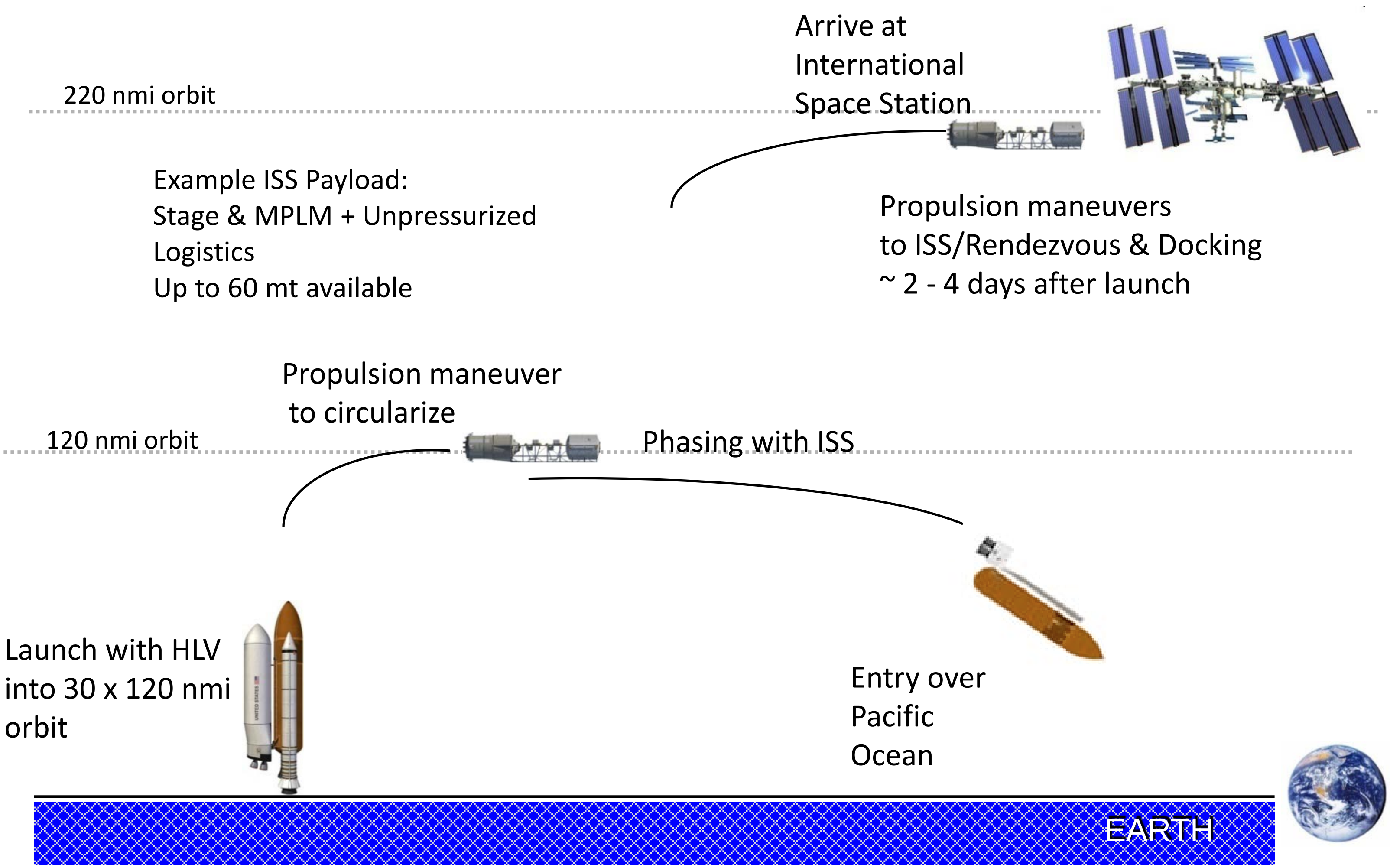


Max q = 650 psf
Max g = 3.00

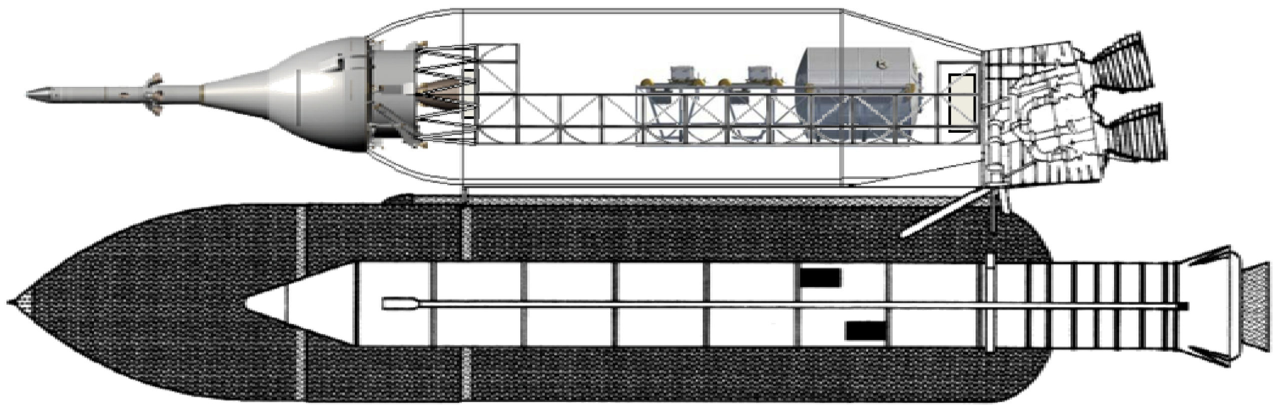
Gross mass = 4,533,029 lb
Net Payload = 72 mt to
30 x 120 nmi 51.6 deg orbit from KSC

Boosters (existing)	4-segment RSRB
ET-94 LWT/Propulsion Module/Carrier	3 SSME @ 104.5%
Existing or Modified Upper Stage	ISS Mission Dependent
Payload Volume	7.5 m x 30 m
LEO payload to 51.6 deg inclination)	72 mT

Design Reference Mission



HLV-CEV Option 2 - ISS Crew & Logistics

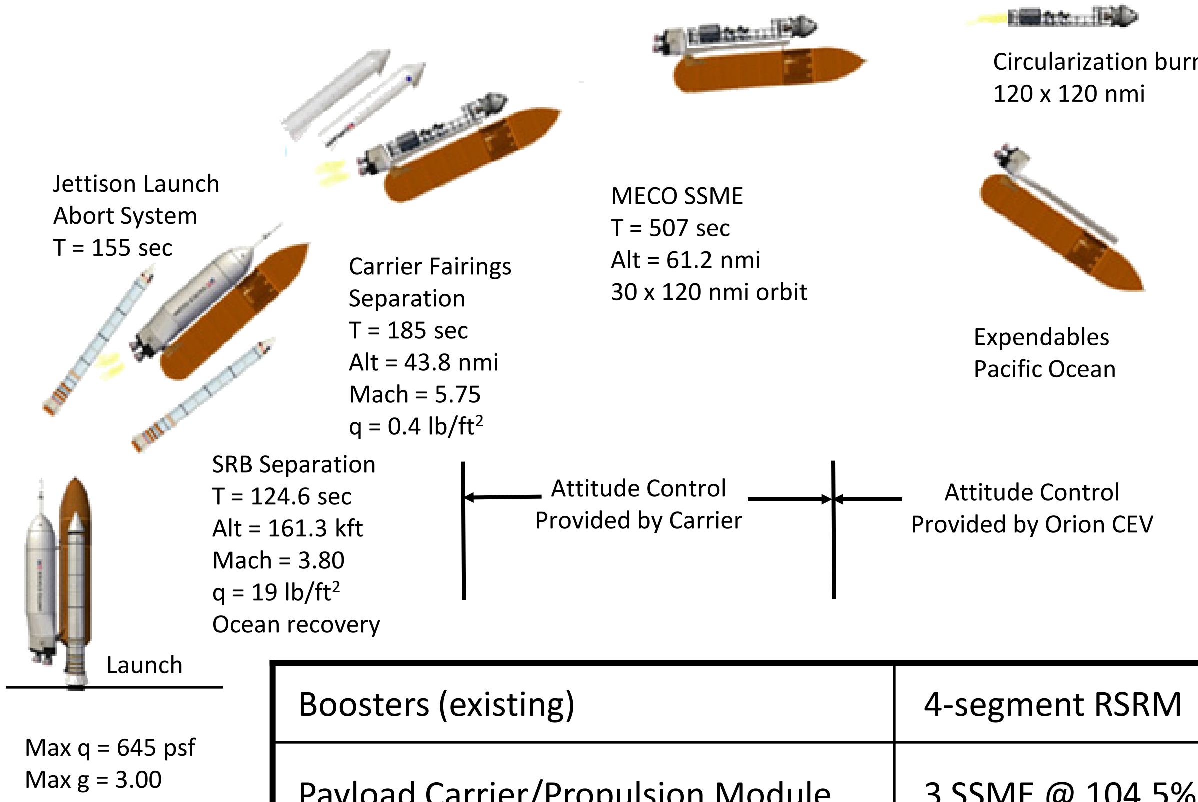


HLV to 51.6 deg MECO: 72 mt

- Orion w/o LAS: 21.2 mt (full propellant load)
- ASE Structure w/docking adapter: 16 mt (estimated)
- 120 nmi circularization propulsion: 1.6 mt
- MPLM: 13.2 mt
- Available: 11.3 mt (unpressurized logistics w/carriers)

- Aft mounted propulsion conducts 160 ft/sec circularization burn (GNC by Orion)
- Orion separates from logistics carrier - docks with forward adapter on ASE frame
- Orion propulsion used for all subsequent orbit maneuvers to and from ISS
    - Sufficient propellants in lunar version Orion Service Module for maneuvers

Block II HLV
ISS Crew & Logistics Launch



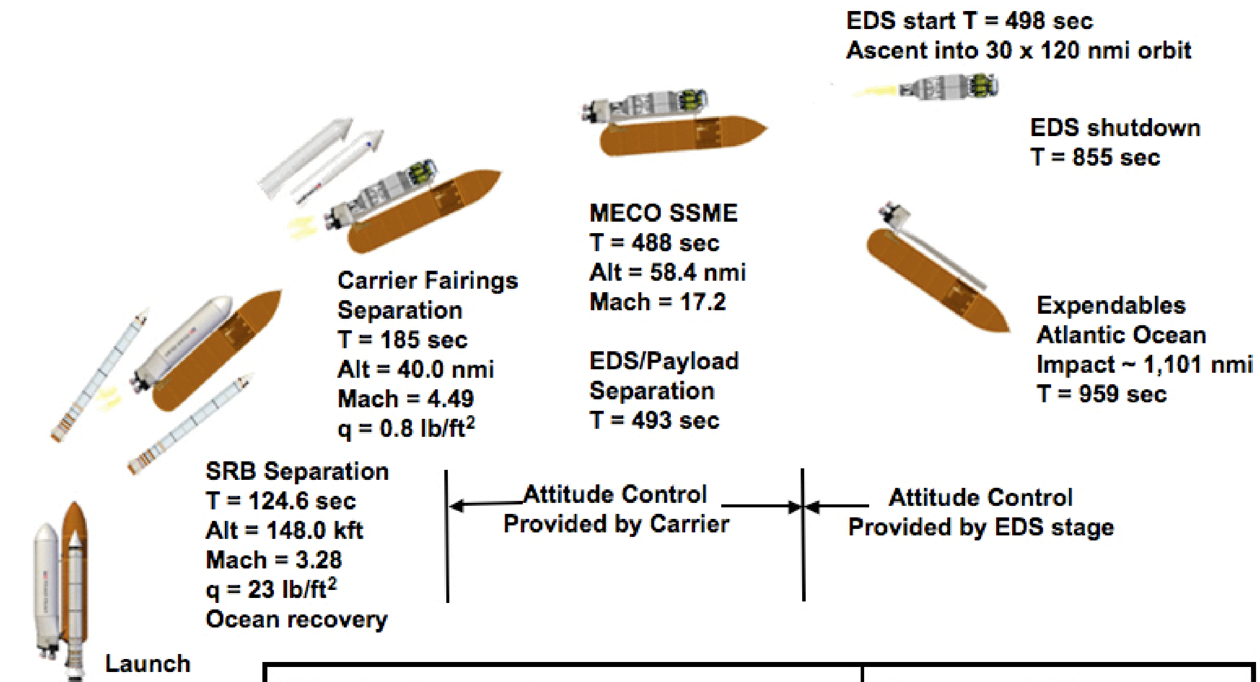
Gross liftoff mass = 4,541,316 lb

Payload = 21 mt CEV + 25 mt Logistics

120 nmi east orbit from KSC

Boosters (existing)	4-segment RSRM
Payload Carrier/Propulsion Module	3 SSME @ 104.5%
Logistics carrier w/docking adapter	Circularization stage
Payload Volume	7.5 m x 25 m
Net LEO payload	72 mt

Block II HLV Heavy-lift Flight Profile –Lunar Lander

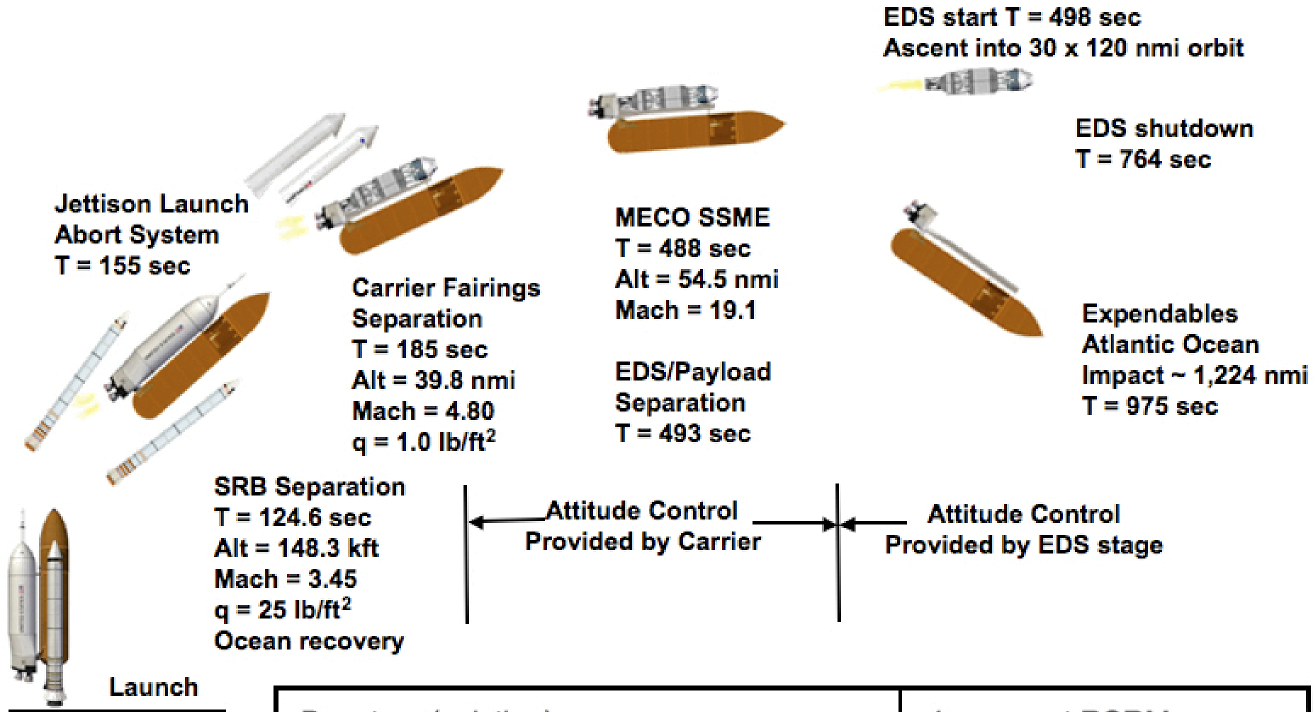


Max q = 615 psf
Max g = 2.29

Gross liftoff mass = 4,847,644 lb
Payload = 45 mt LSAM + EDS Stage
120 nmi east orbit from KSC

Boosters (existing)	4-segment RSRM
Payload Carrier/Propulsion Module	3 SSME @ 104.5%
Earth Departure Stage	J-2X
Payload Volume	7.5 m x 30 m
Net LEO payload (90% of gross payload per ESAS groundrules); ASE in carrier	**81.1 mt (Inert EDS not included)**

Block II HLV Heavy-lift Flight Profile - Orion

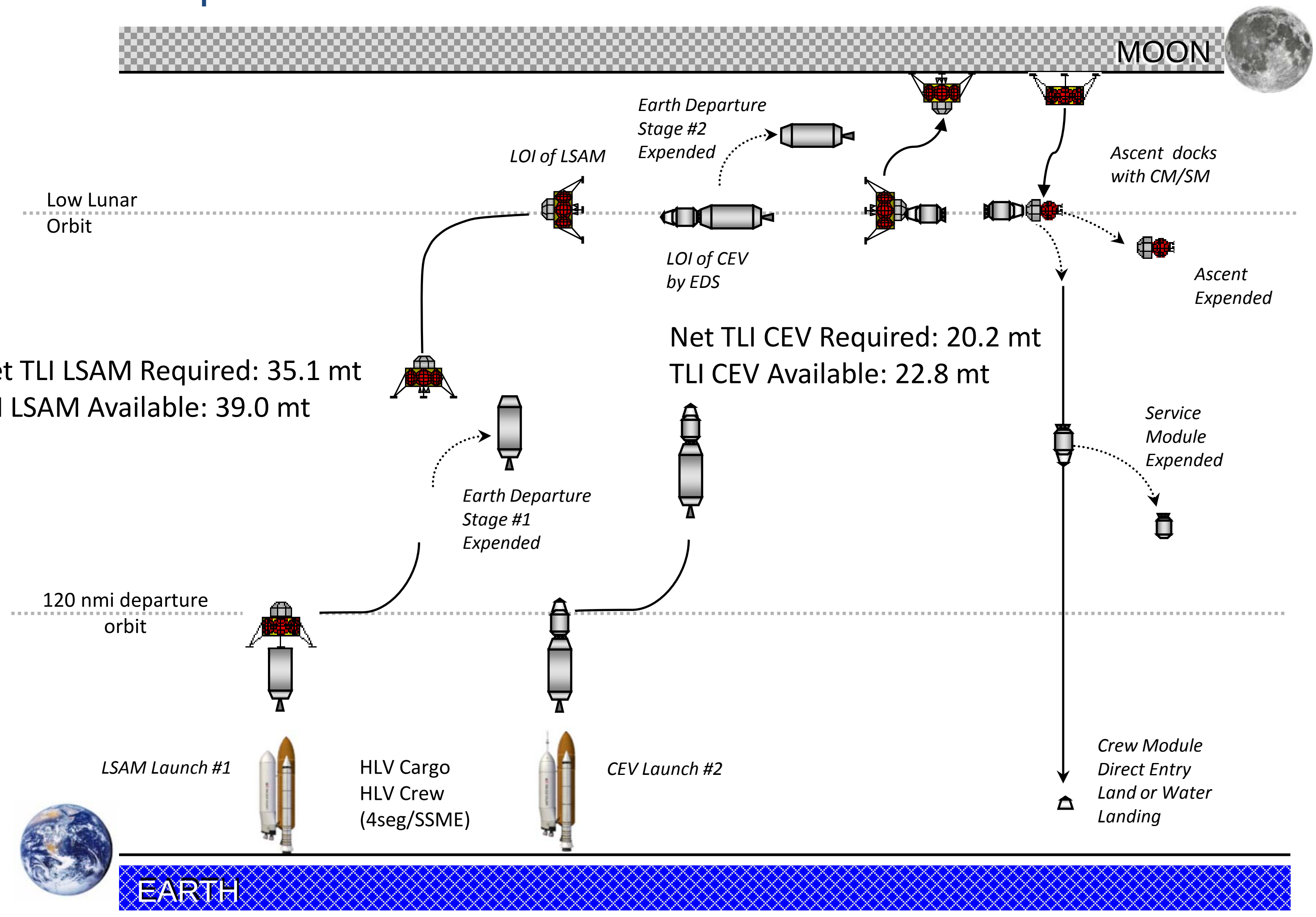


Max q = 639 psf
Max g = 2.56

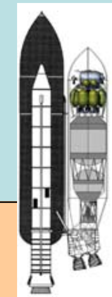
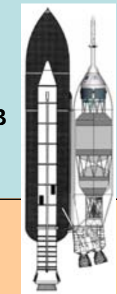
Gross liftoff mass = 4,793,359 lb
Payload = 20.2 mt CEV + EDS Stage
120 nmi east orbit from KSC

Boosters (existing)	4-segment RSRM
Payload Carrier/Propulsion Module	3 SSME @ 104.5%
Earth Departure Stage	J-2X
Payload Volume	7.5 m x 30 m
Net LEO payload (90% of gross payload per ESAS groundrules); ASE in carrier	**82.9 mt (Inert EDS not included)**

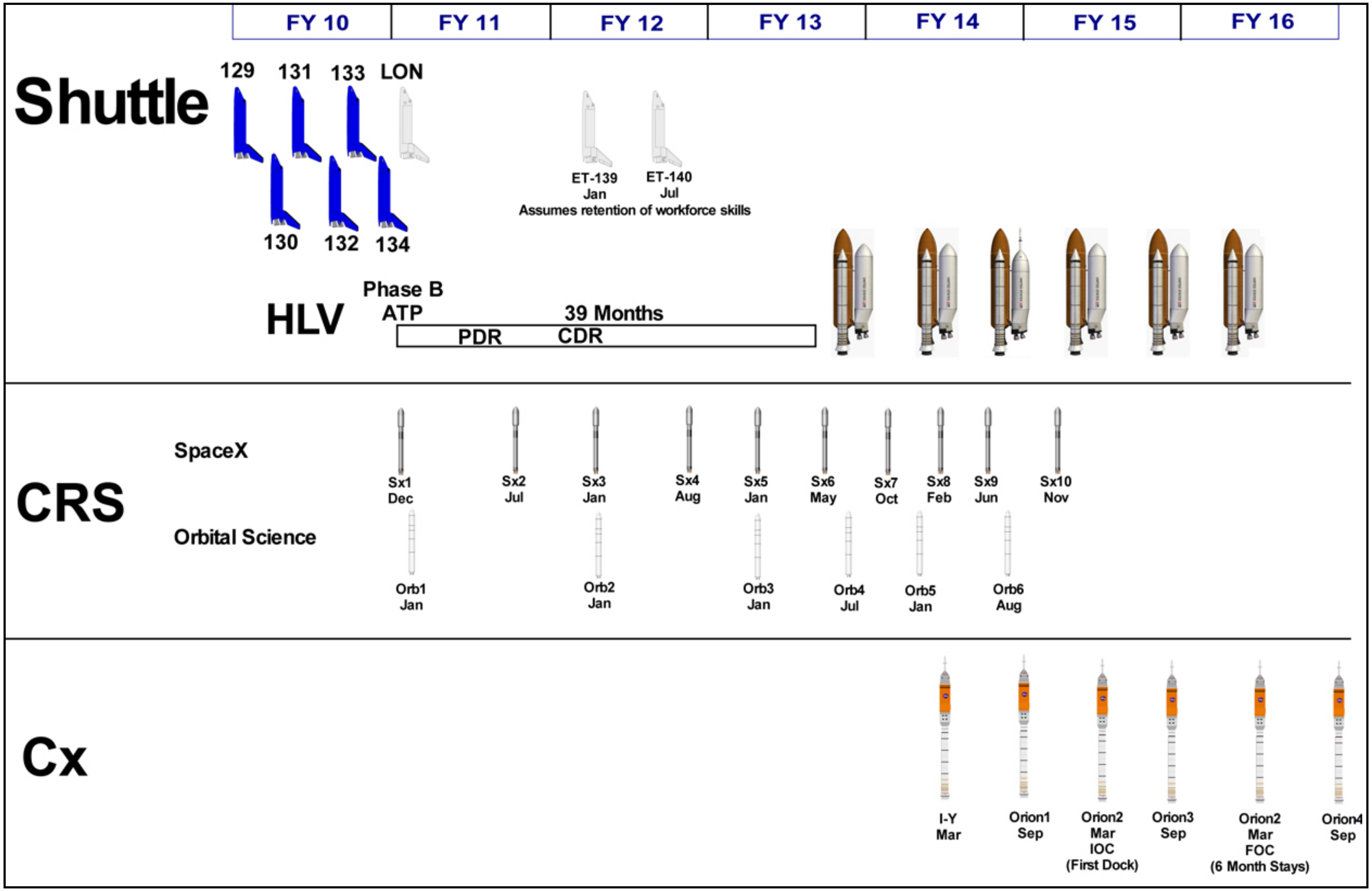
Block II HLV
Split Mission LOR Human Lunar Scenario



HLV Characteristics

Vehicle Characteristics	Block I HLV - Cargo	Block II HLV - Cargo	Block II HLV - Crew
First Stage Boosters			
Gross Mass	2,596,932 lbm	2,596,932 lbm	2,596,932 lbm
Burnout Mass	385,227 lbm	385,227 lbm	385,277 lbm
Useable Propellant	2,211,705 lbm	2,211,705 lbm	2,211,705 lbm
# of Engines/ Type	2 x 4-segment SRB	2 x 4-segment SRB	2 x 4-segment SRB
Engine Thrust (each)	2.94 Mlbf @ SL	2.94 Mlbf @ SL	2.94 Mlbf @ SL
Stage Engine Isp	267 s @ Vac	267 s @ Vac	267 s @ Vac
External Tank			
Gross Mass	1,662,895 lbm	1,664,095 lbm	1,664,095 lbm
Burnout Mass	73,111 lbm	74,311 lbm	74,311 lbm
Usable Propellant	1,589,784 lbm	1,589,784 lbm	1,589,784 lbm
Propulsion/Carrier			
Main Propulsion Gross Mass	57,398 lbm	57,398 lbm	57,398 lbm
# of Engines/ Type	3 x SSME	3 x SSME	3 x SSME
Engine Thrust (each @ 104.5%)	396,569 lbf SL; 490,847 lbf Vac	396,569 lbf SL; 490,847 lbf Vac	396,569 lbf SL; 490,847 lbf Vac
Stage Engine Isp	452.19 s	452.19 s	452.19 s
7.5-m internal dia Carrier Mass	50,994 lbm (includes ASE)	53,980 lbm (includes ASE)	48,060 lbm (includes ASE)
Upper Stage	Stage at MECO (59.6 nmi)	Stage at Mach 17.2, 59.7 nmi	Stage at Mach 19.1, 55.3 nmi
Gross Mass	30 x 120 nmi orbit	364,988 lbm	363,621 lbm
Burnout Mass	(Upper stages determined	37,942 lbm	36,575 lbm
Usable Propellant	by mission types)	327,046 lbm	327,046 lbm
# of Engines/ Type		1 x J-2x	1 x J2-X
Engine Thrust		293,750 lbf Vac	293,750 lbf Vac
Stage Engine Isp		448.0 s	448.0 s
Total LV			
Gross Liftoff Mass	4,544,684 lbm	4,847,644 lbm	4,793,559 lbm
Gross Delivery (120 x 120 nmi)	174,454 lb (79.1 mt)	198,735 lbm (90.1 mt)	203,049 lbm (92.1 mt)
Net payload (@28.5 deg)	157,008 lb (71.2 mt)	178,862 lbm (81.1 mt)	182,744 lbm (82.9 mt)
Net payload = gross delivery	reduced by 10%	(Orbited EDS not included)	(Orbited EDS not included)
Flight Conditions			Jettison 14 Klb LAS at 155 sec
Max dynamic pressure	647 psf	616 psf	639 psf
Max acceleration	3.00 gs	2.31 gs	2.56 gs
Liftoff Thrust/Weight	1.57	1.47	1.48
Jettison upper carrier fairings	22,883 lb @ 185 sec	22,883 lb @ 185 sec	18,306 lb @ 185 sec

Manifest



FY 10
FY 11
FY 12
FY 13
FY 14
FY 15
FY 16
Shuttle
129
131
133
LON
130
132
134
ET-139
Jan
ET-140
Jul
Assumes retention of workforce skills
HLV
Phase B
ATP
39 Months
PDR
CDR
CRS
SpaceX
Sx1 Dec
Sx2 Jul
Sx3 Jan
Sx4 Aug
Sx5 Jan
Sx6 May
Sx7 Oct
Sx8 Feb
Sx9 Jun
Sx10 Nov
Orbital Science
Orb1 Jan
Orb2 Jan
Orb3 Jan
Orb4 Jul
Orb5 Jan
Orb6 Aug
Cx
I-Y Mar
Orion1 Sep
Orion2 Mar IOC (First Dock)
Orion3 Sep
Orion2 Mar FOC (6 Month Stays)
Orion4 Sep

HLV Growth Options

The HLV has growth potential up to 91.9 mt (net payload) as shown in the following examples:

Lunar Reference Vehicle with Suborbital Staging (4-seg SRB, 104.5% SSME, J-2X EDS)	**81.1 mt**
SSME at 109%	**+ 2.5 mt**
5-segment SRBs	**+ 7.3 mt**
SSME EDS	**+ 1.0 mt**
Total Potential Lift	**91.9 mt**

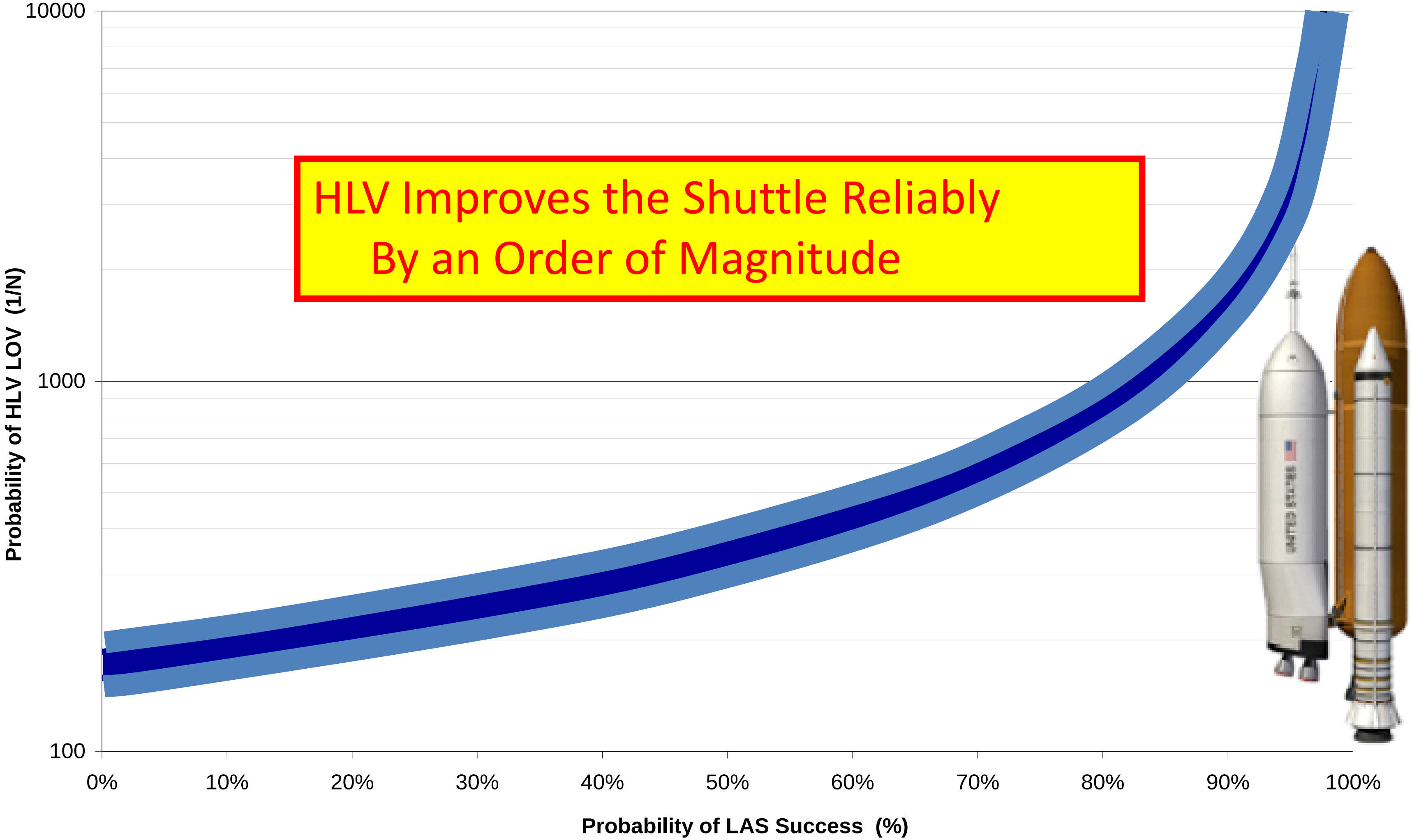
HLV Reliability from the Shuttle PRA

Contributor	High Reliability Scenario	Low Reliability Scenario
SSME	1 in 300	1 in 250
RSRM	1 in 1550	1 in 1550
SRB only	1 in 2104	1 in 2104
Total SRB	1 in 893	1 in 893
External Tank	1 in 4762	1 in 4762
Subtotal (Shuttle Systems Only)	~1 in 214	~1 in 188
Payload Carrier	~1 in 1400	~1 in 1000
Total HLV LOV	**~1 in 186**	**~1 in 158**

Assumptions for SSMEs

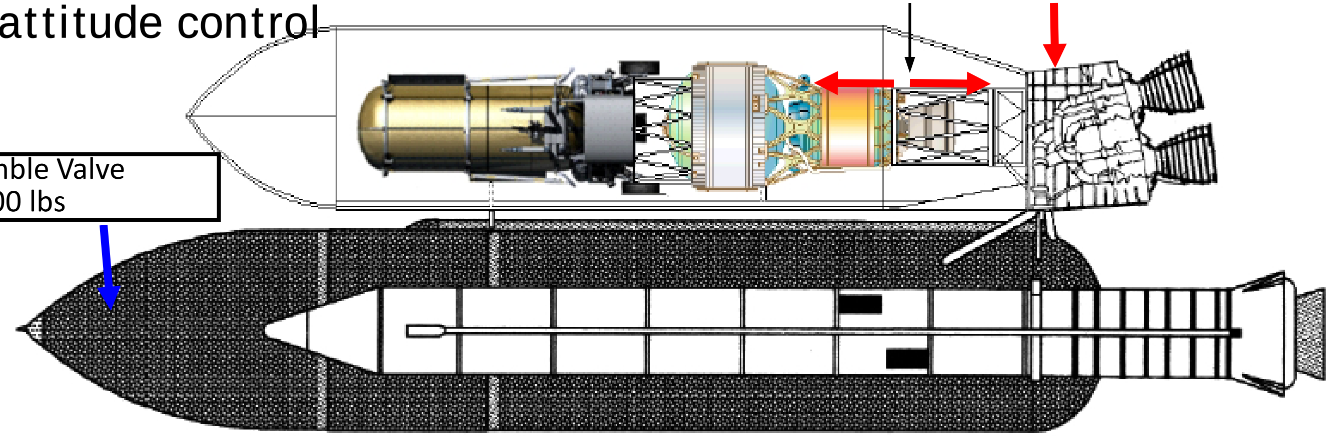
- 3 SSMEs
- 104% Power Level
- 540 sec. Duration
- No Engine Out Capability
- TBD Carrier Subsystems

Probability of HLV LOC with LAS



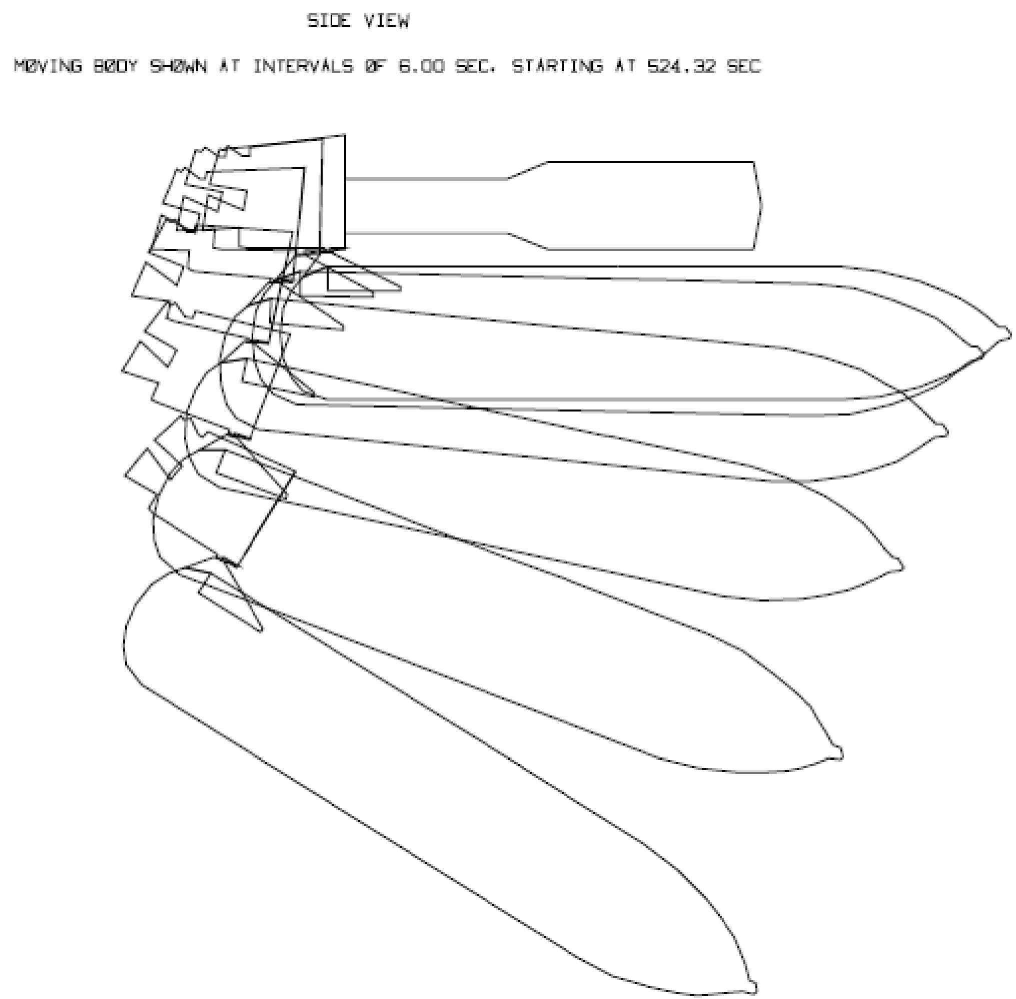
Payload Separation Design

- Spring loaded separation actuator along Payload centerline
  - 20,000 lbs spring rate with a 6 inch stroke (10K lb on each body)
- ET vent forces are used in assist mode
  - ET Tumble Valve put back into the ET and activated
  - 40s and 800 lb vent forces
- SSP worst-on-worst staging ICs
  - No Active attitude control



No major Separation issues identified

Near Field Payload Separation –Max Body Rates



Body Rates at Separation
P = -0.38 deg/sec
Q = -0.62 deg/sec
R = -0.30 deg/sec

Conclusions

- HLV Design is less capable than the current baseline
- A significant amount of study of this concept is required by the broader community
- Some benefits:
  - HLV makes maximum use of Shuttle assets
  - HLV retains essential contractor and civil servant skills
- Potential support for ISS for both crew and cargo
- Foundational Heavy Lift capability to support a variety of architectures

Backup

Only One Unique New Start for HLV

Element	HLV	Ares 1	Ares 5	Direct
New Core stage			x	x
New Tank			x	x
New Boat Tail	x		x	x
New Prop Feed Lines			x	x
New Software		x	x	x
New RCS		x	x	x
New Interstage		x	x	x
New Upper Stage	x	x	x	x
New Upper Stage Engine	x	x	x	x
New 5 or 5.5 segment SRB		x	x	
New Parachutes		x	x	
New Cargo Carrier	x			
New Fairing	x	x	x	x
New Main Propulsion			x	x
New Launch Abort Systems	x	x		x
Harden Crawler Roadway			x	
Modify MLP		x		x
New MLP			x	
New Launch Tower		x	x	x
Certify Engine (Human Rating)		x	x	x
New Payload Processing	x	x	x	x
New Flame Trench			x	
New Pad Escape		x		x
Mods to VAB	x	x	x	x
New starts	8	15	20	18
Total new system starts	8		35	18

Ares 1, Ares 5, Direct Unique New Starts

HLV Unique New start