Payload Accommodations

- Expendable launch vehicles
- Space shuttle
- Secondary payloads
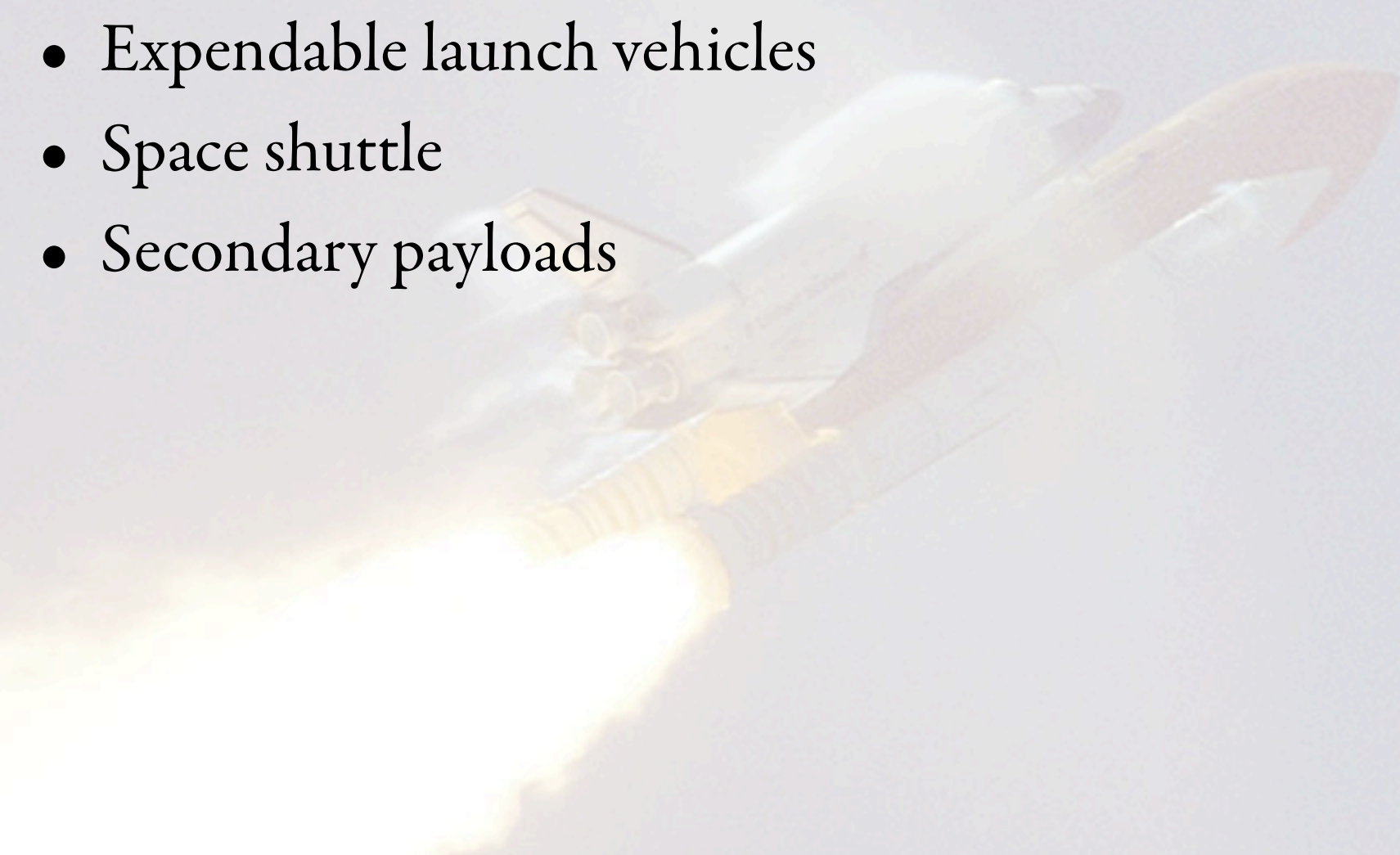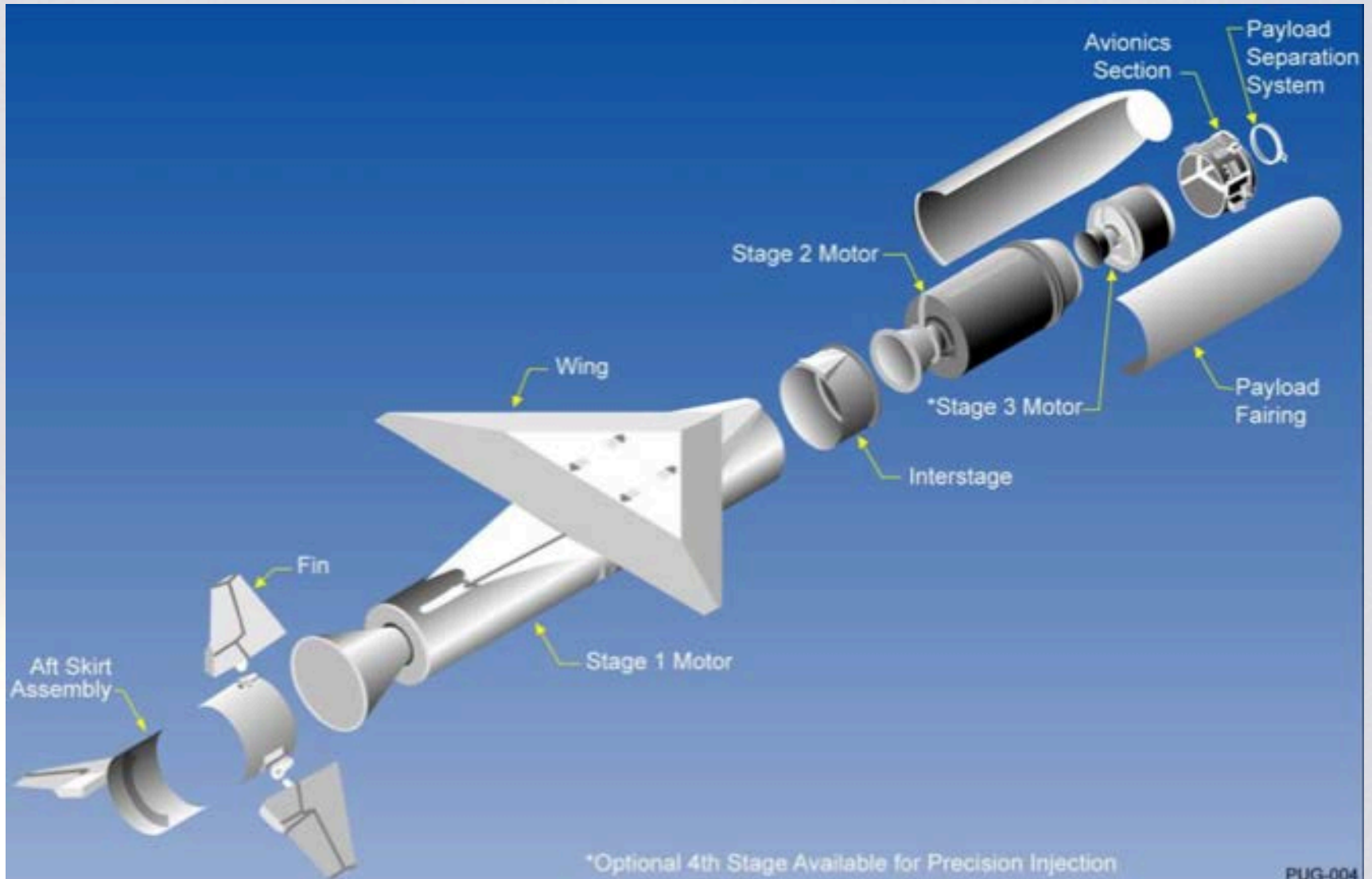
Pegasus XL

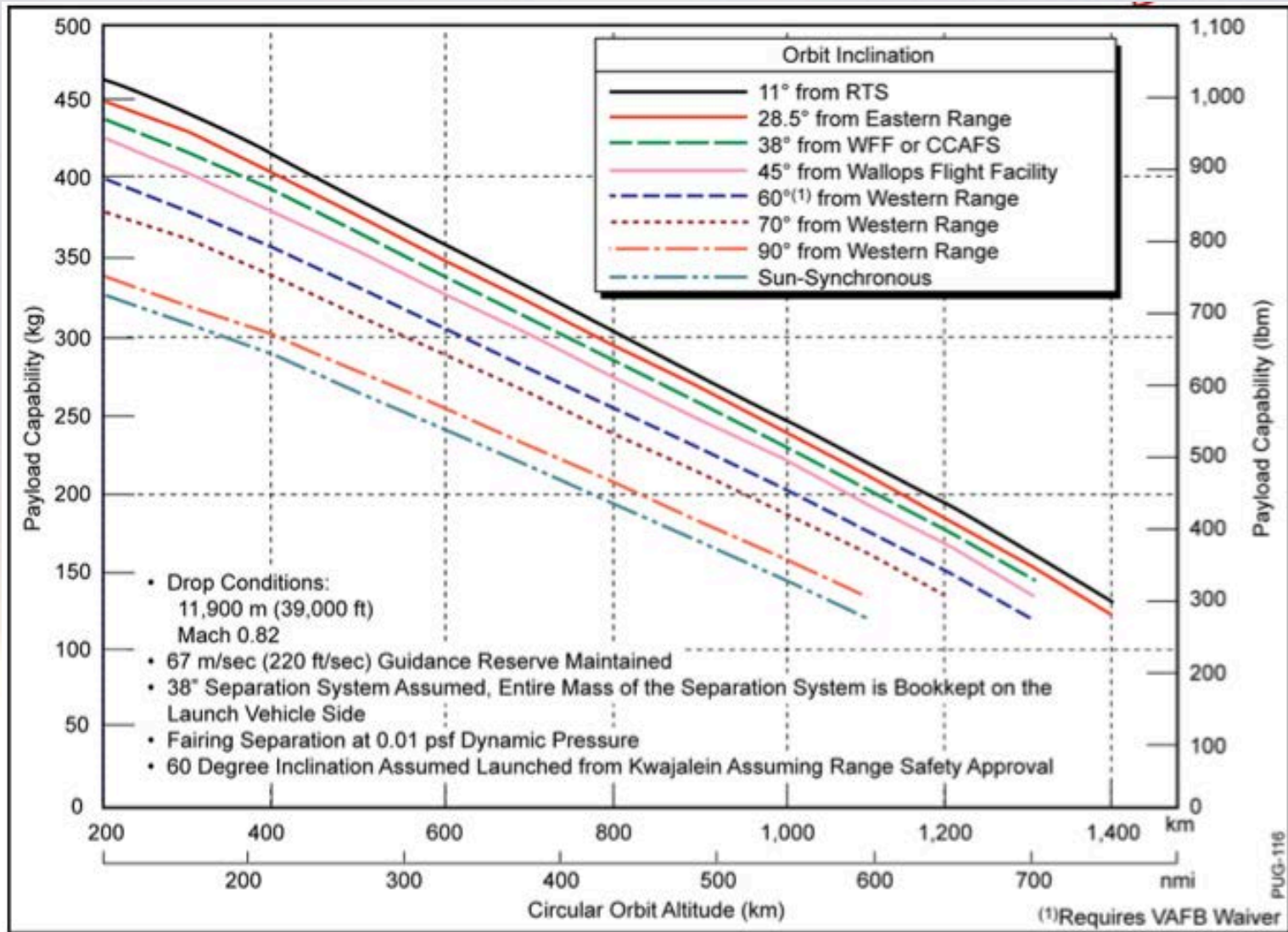*Optional 4th Stage Available for Precision Injection

PUG-004

Pegasus Payload Performance

Falcon 1/1e and Falcon 9

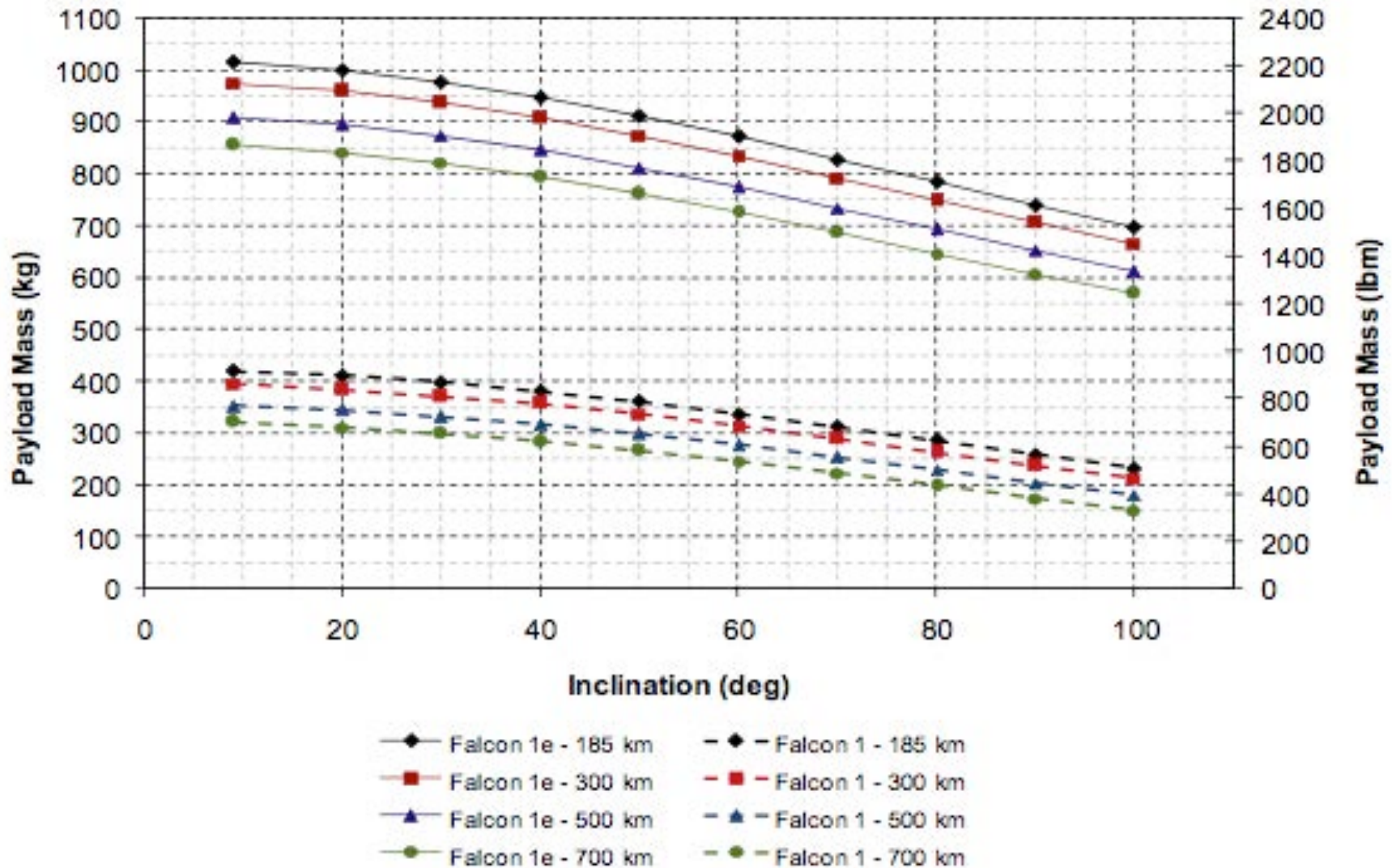- New vehicles developed by Space Exploration Technologies, Inc ("SpaceX")

- "Operate an aerospace company like a dot-com company"

- Cost reduction through modern fabrication techniques, vertical integration

- Falcon 1/1e - $11M/flight
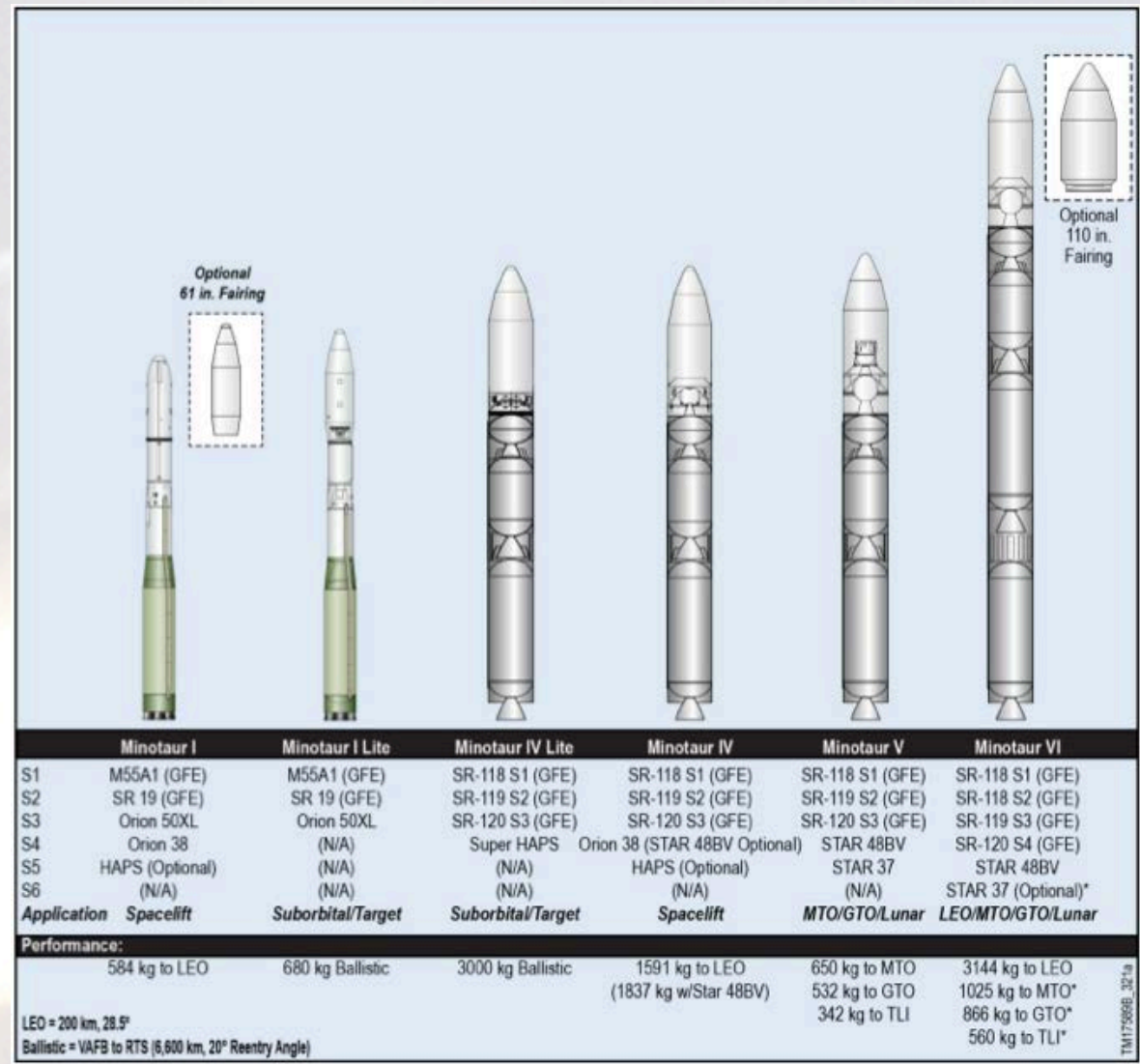
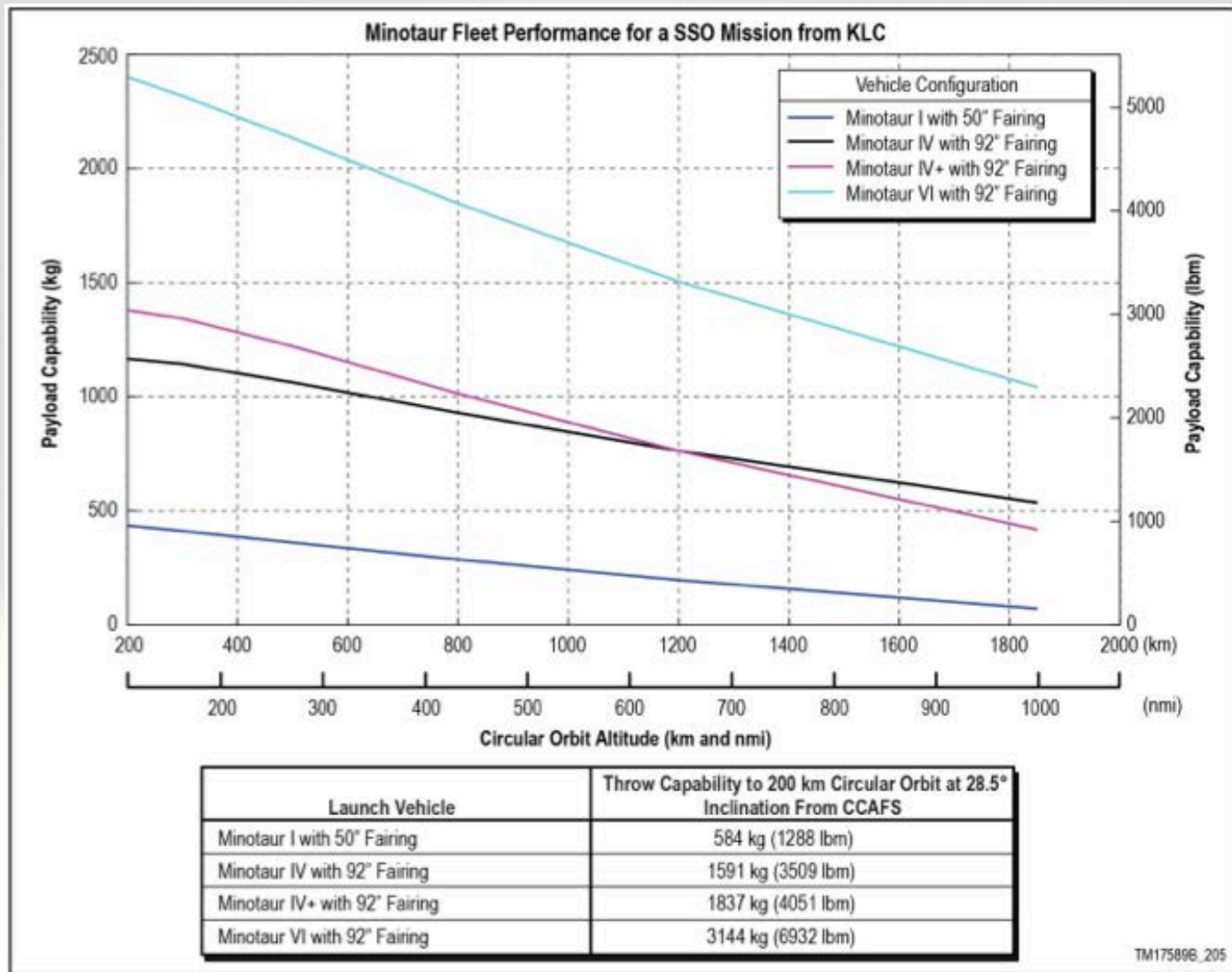- Falcon 9 - $103M/flight

Falcon 1/1e Payload Fairings

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
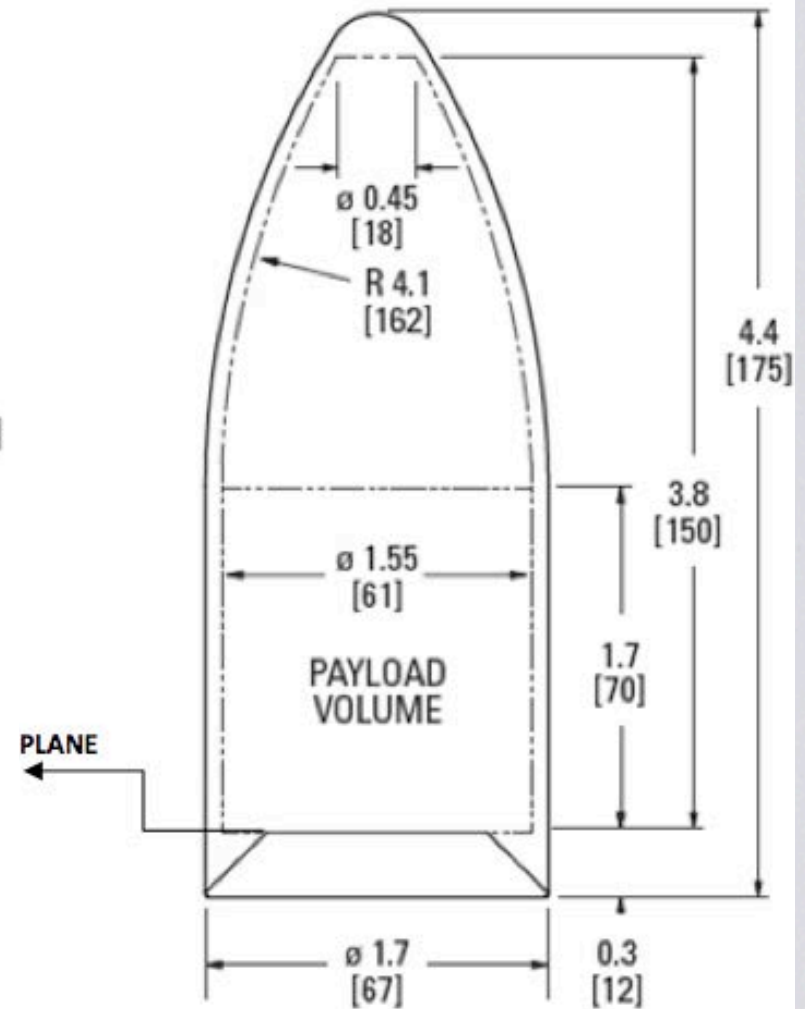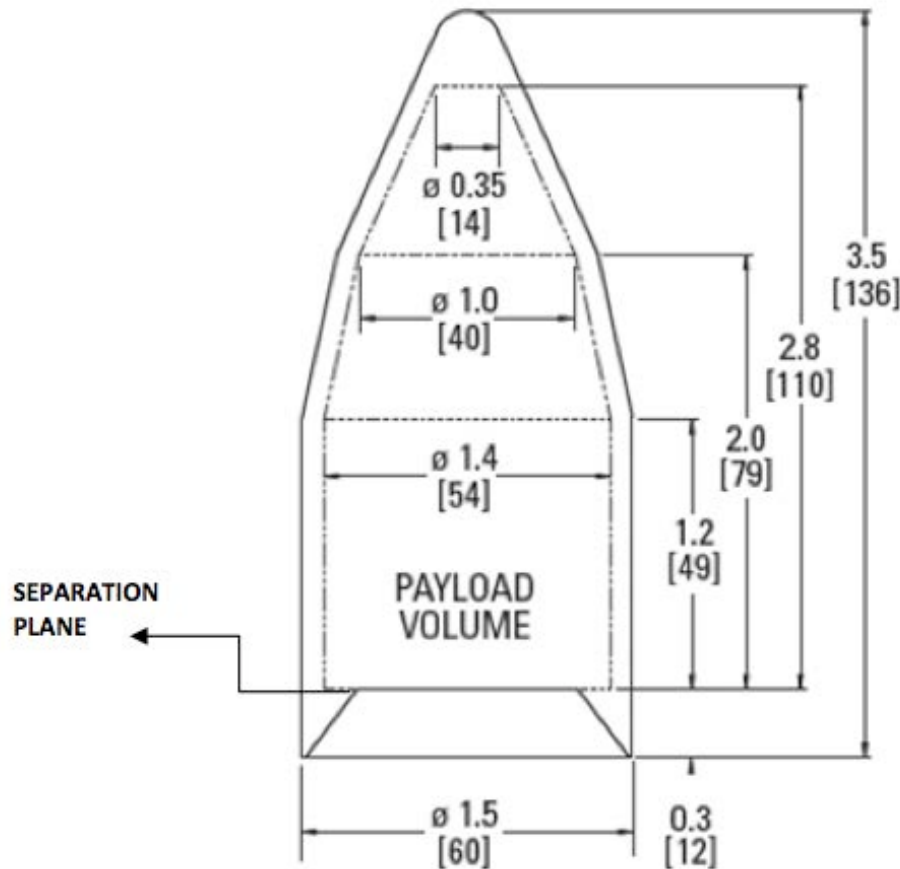
Falcon 1/1e Performance to LEO

Minotaur IV Launch Vehicle Family

	Minotaur I	Minotaur I Lite	Minotaur IV Lite	Minotaur IV	Minotaur V	Minotaur VI
S1	M55A1 (GFE)	M55A1 (GFE)	SR-118 S1 (GFE)	SR-118 S1 (GFE)	SR-118 S1 (GFE)	SR-118 S1 (GFE)
S2	SR 19 (GFE)	SR 19 (GFE)	SR-119 S2 (GFE)	SR-119 S2 (GFE)	SR-119 S2 (GFE)	SR-118 S2 (GFE)
S3	Orion 50XL	Orion 50XL	SR-120 S3 (GFE)	SR-120 S3 (GFE)	SR-120 S3 (GFE)	SR-119 S3 (GFE)
S4	Orion 38	(N/A)	Super HAPS	Orion 38 (STAR 48BV Optional)	STAR 48BV	SR-120 S4 (GFE)
S5	HAPS (Optional)	(N/A)	(N/A)	HAPS (Optional)	STAR 37	STAR 48BV
S6	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	STAR 37 (Optional)*
Application	Spacelift	Suborbital/Target	Suborbital/Target	Spacelift	MTO/GTO/Lunar	LEO/MTO/GTO/Lunar
Performance:						
	584 kg to LEO	680 kg Ballistic	3000 kg Ballistic	1591 kg to LEO (1837 kg w/Star 48BV)	650 kg to MTO 532 kg to GTO 342 kg to TLI	3144 kg to LEO 1025 kg to MTO* 866 kg to GTO* 560 kg to TLI*

LEO = 200 km, 28.5°
Ballistic = VAFB to RTS (6,600 km, 20° Reentry Angle)

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design

Minotaur SSO Payload Performance

Minotaur Fleet Performance for a SSO Mission from KLC

Launch Vehicle	Throw Capability to 200 km Circular Orbit at 28.5° Inclination From CCAFS
Minotaur I with 50" Fairing	584 kg (1288 lbm)
Minotaur IV with 92" Fairing	1591 kg (3509 lbm)
Minotaur IV+ with 92" Fairing	1837 kg (4051 lbm)
Minotaur VI with 92" Fairing	3144 kg (6932 lbm)

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design

Antares

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design

Antares Payload Performance from WFF

Antares 120 from WFF

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
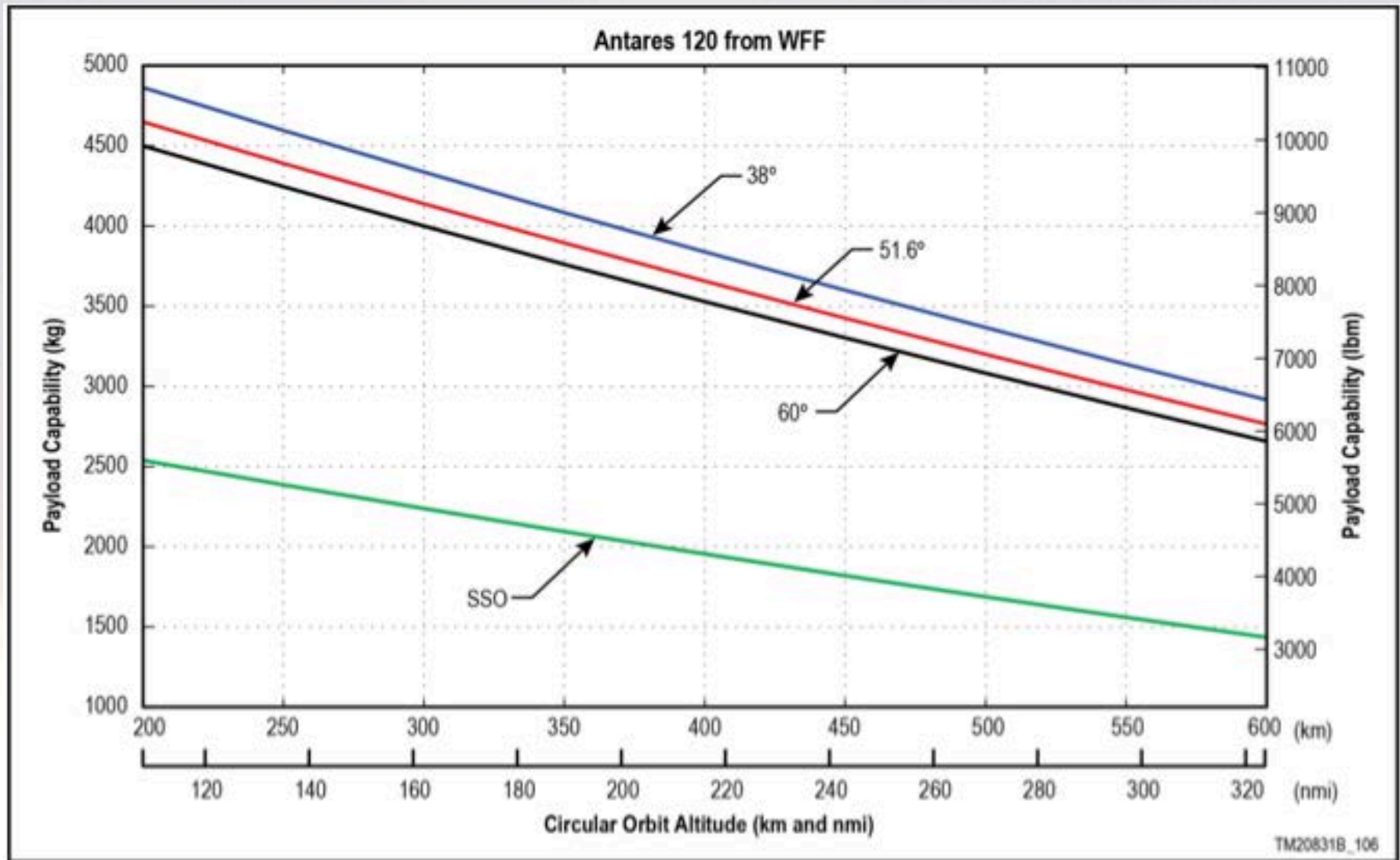
Evolved Expendable Launch Vehicles

Atlas V 400	Atlas V 500					
401	501	511	521	531	541	551
Performance to GTO, kg (lb)						
4,950	3,970	5,270	6,285	7,200	7,980	8,670
(10,913)	(8,752)	(11,618)	(13,856)	(15,873)	(17,593)	(19,114)

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
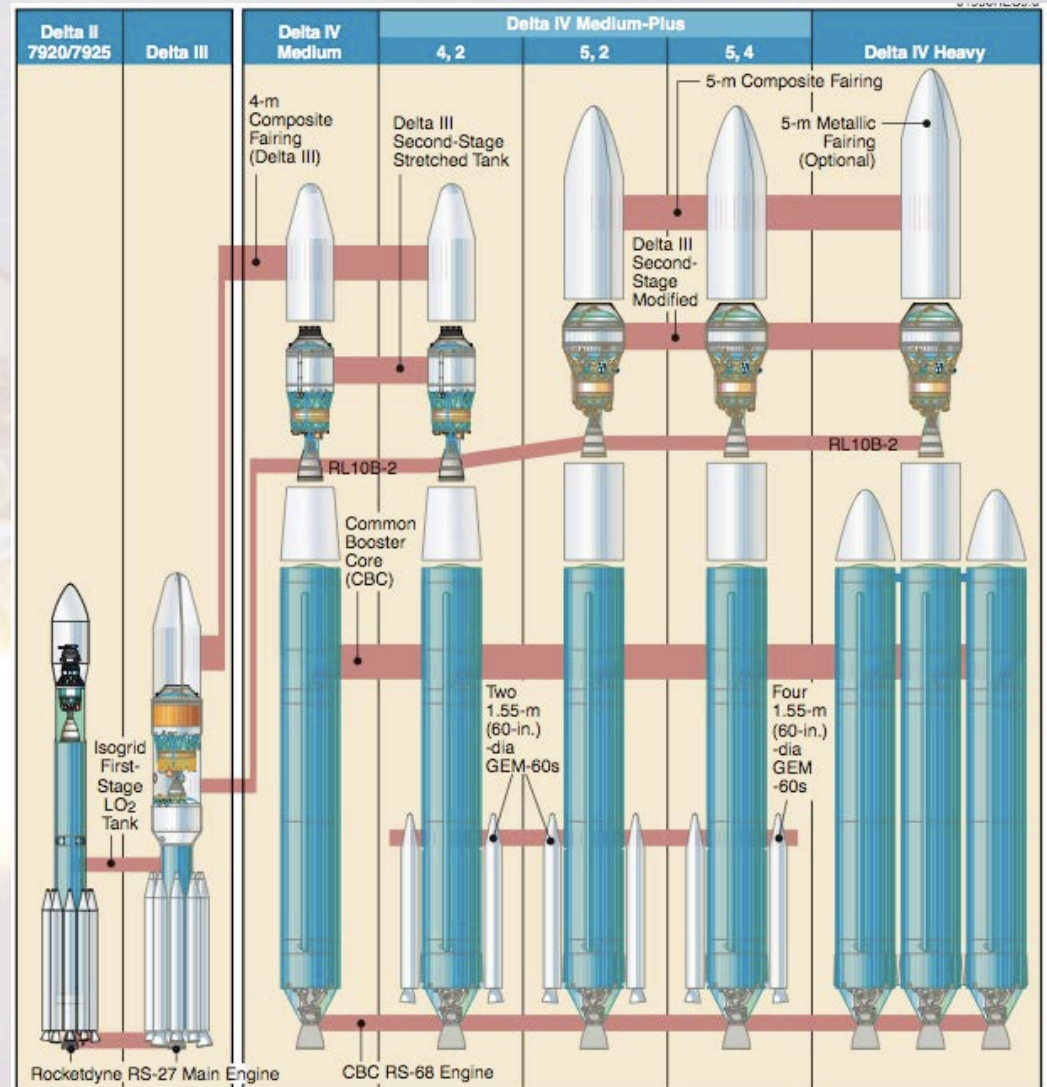
Delta IV Evolution and GTO Capability

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
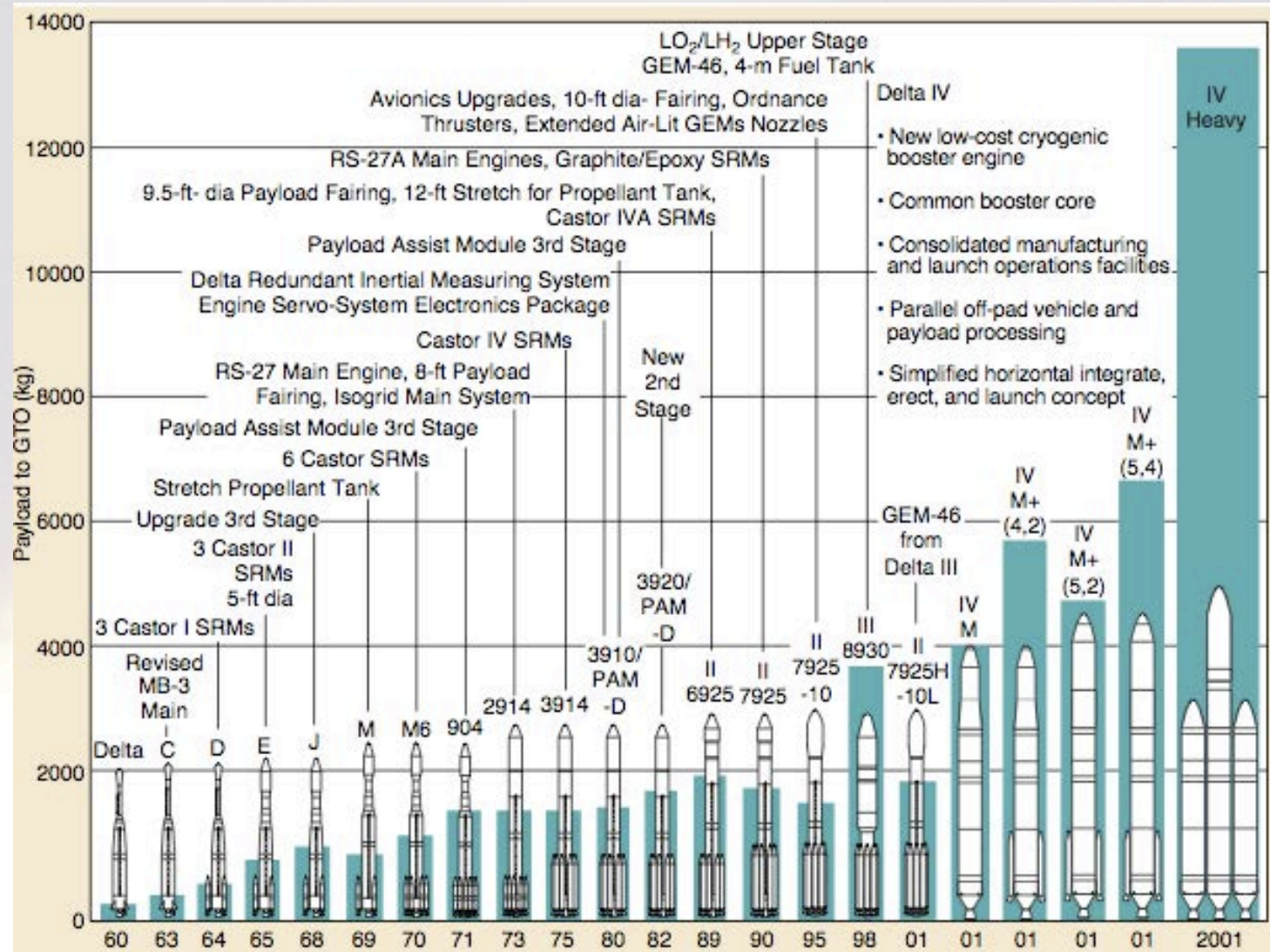
Delta IV RS-68 Engine

- Low-risk simplified LO_2/LH_2 engine improves reliability
- Minimal parts count and low fabrication cost
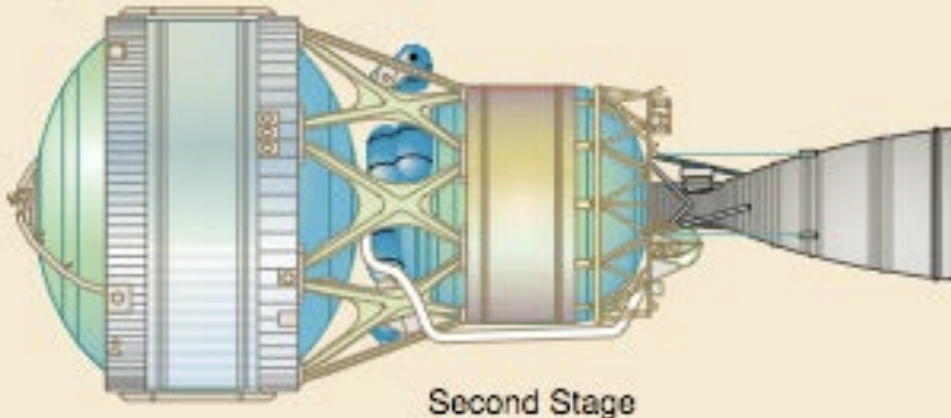- Low to moderate chamber pressure reduces load
- Proven technology
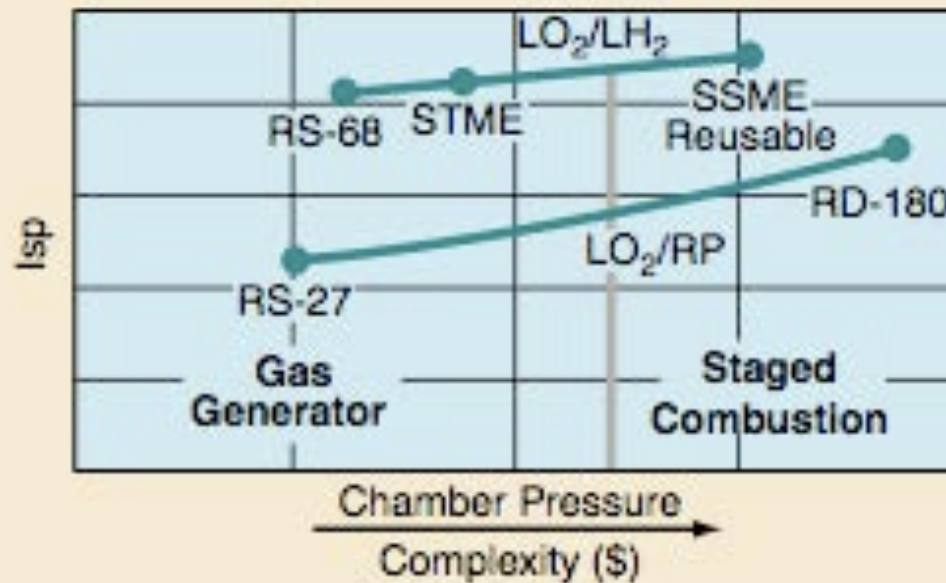
Delta IV Upper Stages

4-m Configuration (Delta IV-M, Delta IV-M+ (4,2))
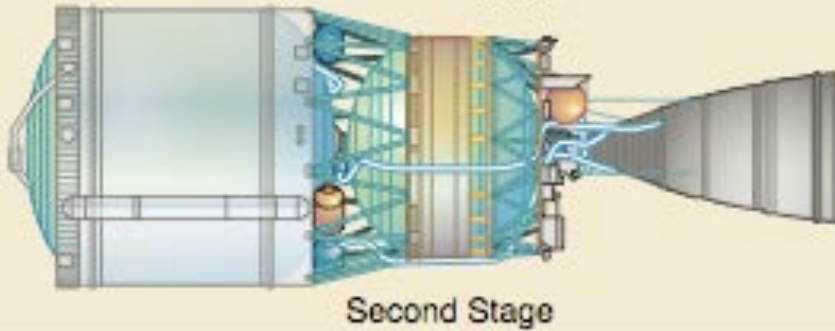
Second Stage

- Modified Delta III second stage
- Delta III Pratt & Whitney RL10B-2 engine

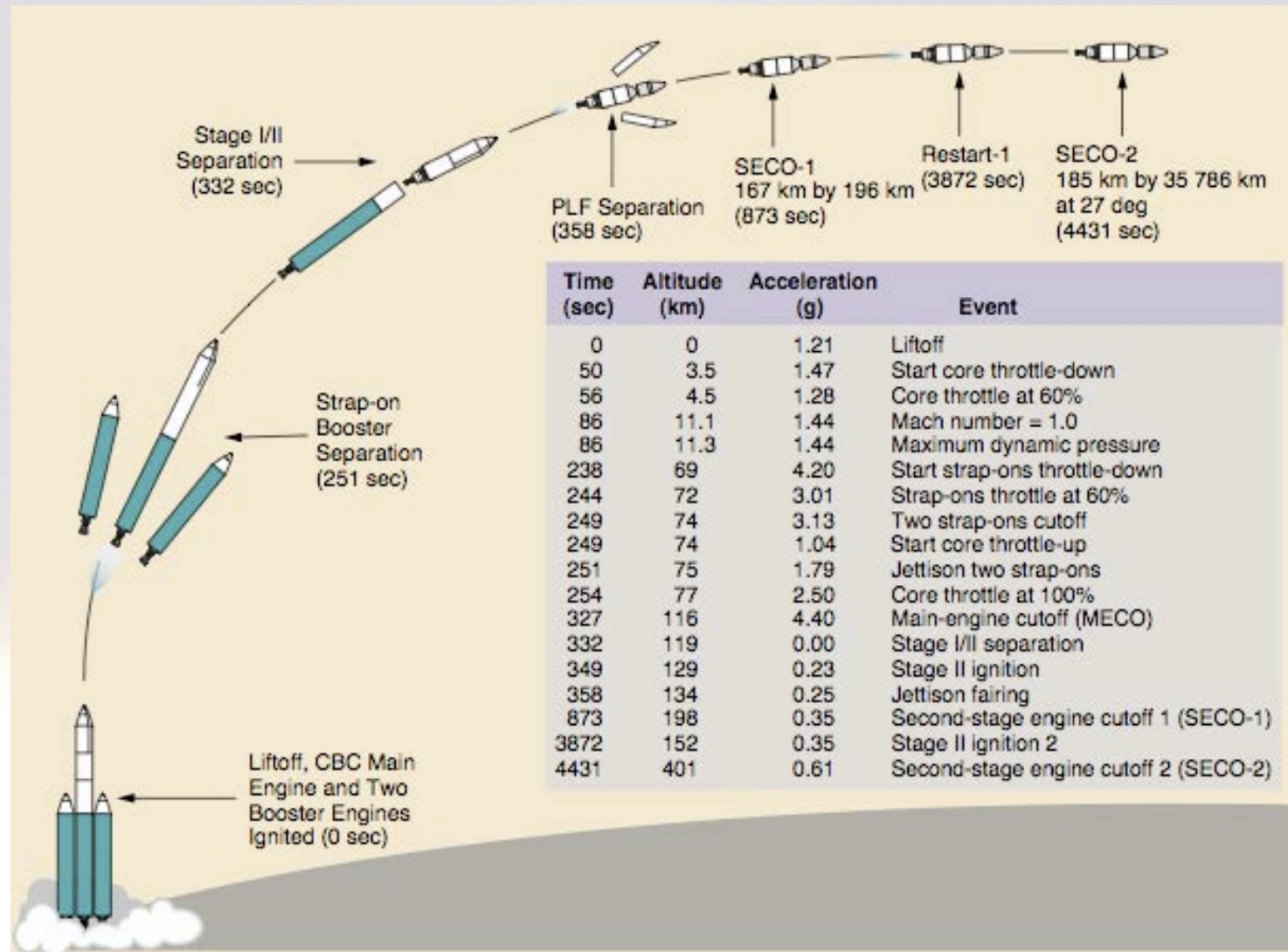**5-m Configuration (Delta IV-M+ (5,2), Delta IV-M+ (5,4), Delta IV-H)**

Second Stage

- 4-m stretched LO_2 tank
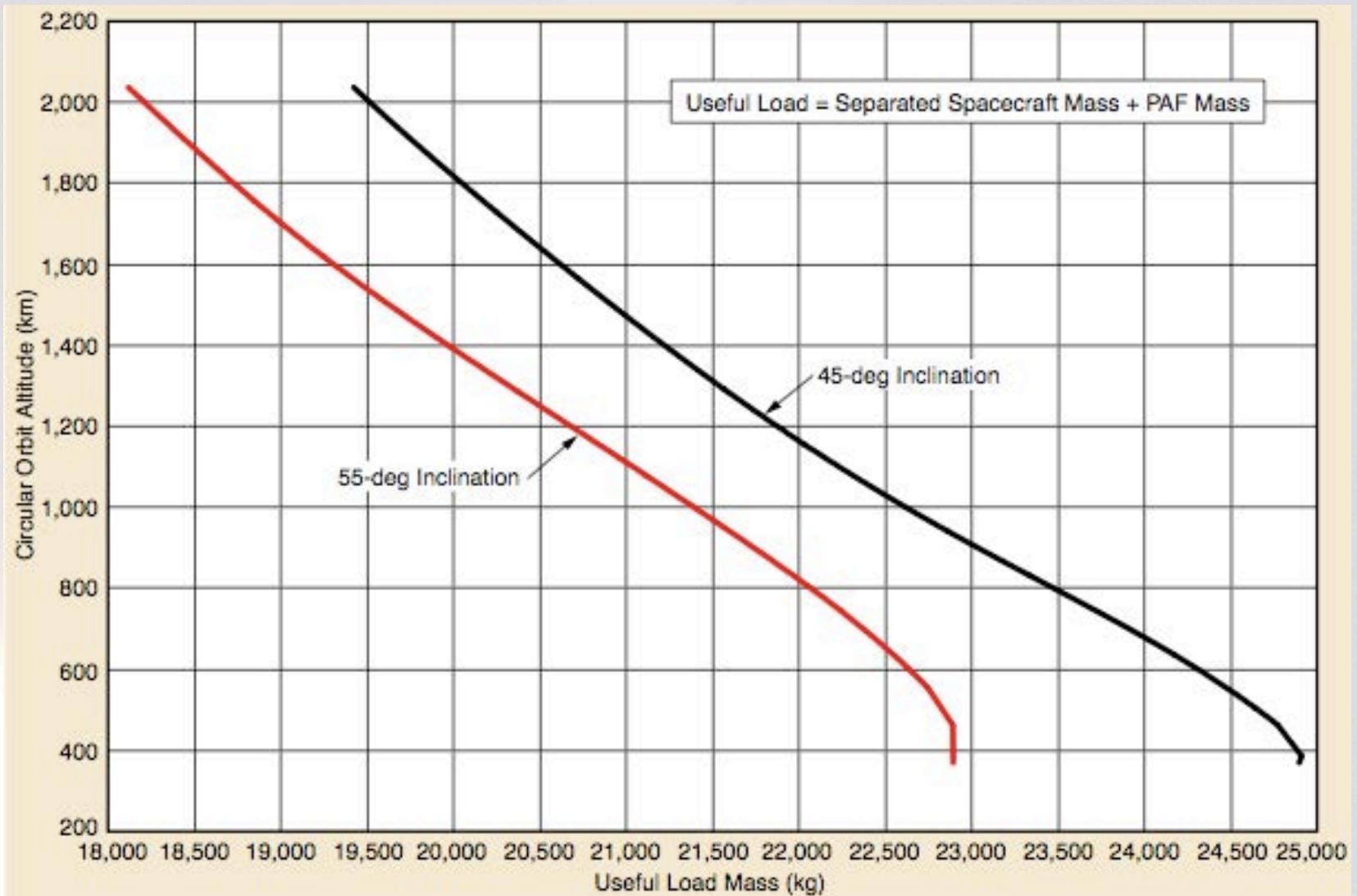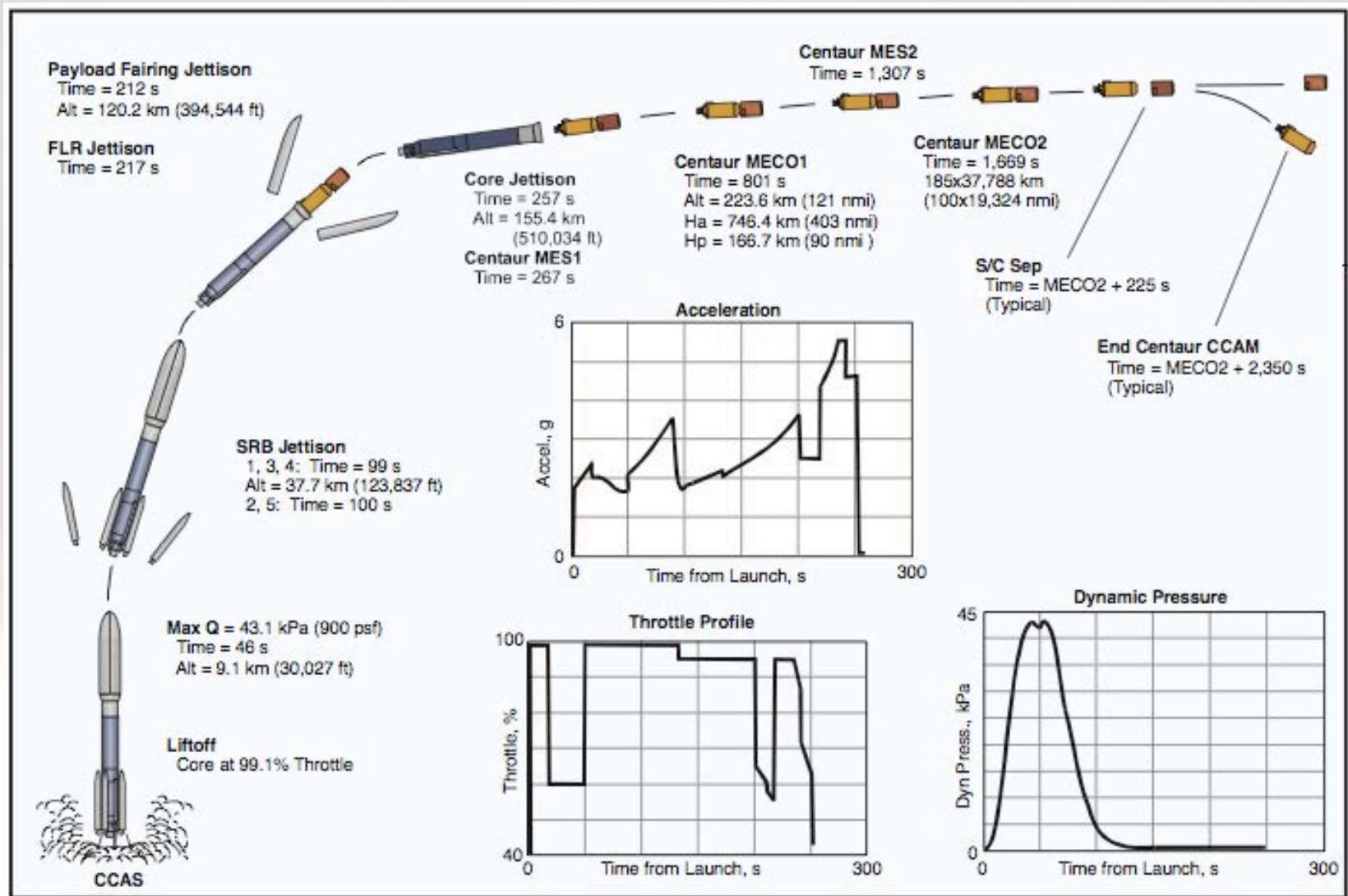- 5-m LH_2 tank
- Delta III Pratt & Whitney RL10B-2 engine

Delta IV Heavy GTO Ascent Profile

Stage I/II Separation (332 sec)

Strap-on Booster Separation (251 sec)

Liftoff, CBC Main Engine and Two Booster Engines Ignited (0 sec)

PLF Separation (358 sec)

SECO-1 167 km by 196 km (873 sec)

Restart-1 (3872 sec)

SECO-2 185 km by 35 786 km at 27 deg (4431 sec)

Time (sec)	Altitude (km)	Acceleration (g)	Event
0	0	1.21	Liftoff
50	3.5	1.47	Start core throttle-down
56	4.5	1.28	Core throttle at 60%
86	11.1	1.44	Mach number = 1.0
86	11.3	1.44	Maximum dynamic pressure
238	69	4.20	Start strap-ons throttle-down
244	72	3.01	Strap-ons throttle at 60%
249	74	3.13	Two strap-ons cutoff
249	74	1.04	Start core throttle-up
251	75	1.79	Jettison two strap-ons
254	77	2.50	Core throttle at 100%
327	116	4.40	Main-engine cutoff (MECO)
332	119	0.00	Stage I/II separation
349	129	0.23	Stage II ignition
358	134	0.25	Jettison fairing
873	198	0.35	Second-stage engine cutoff 1 (SECO-1)
3872	152	0.35	Stage II ignition 2
4431	401	0.61	Second-stage engine cutoff 2 (SECO-2)

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design

Delta IV Heavy Payload to LEO Circular

Useful Load = Separated Spacecraft Mass + PAF Mass

45-deg Inclination

55-deg Inclination

Circular Orbit Altitude (km)

Useful Load Mass (kg)

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design

Atlas V 551 GTO Ascent Profile

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Atlas V 552 LEO Ascent Profile

Falcon 9 Performance to LEO

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
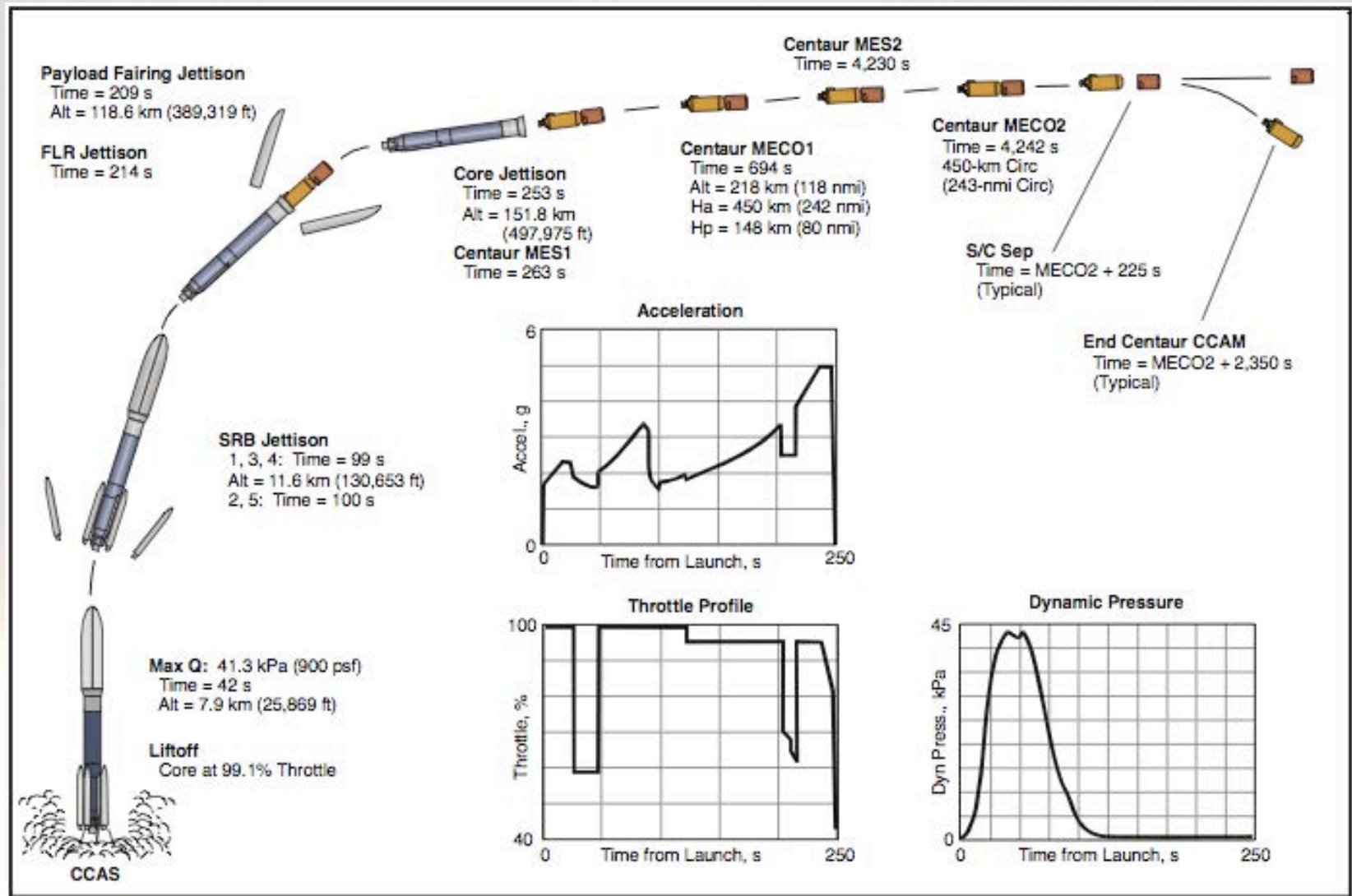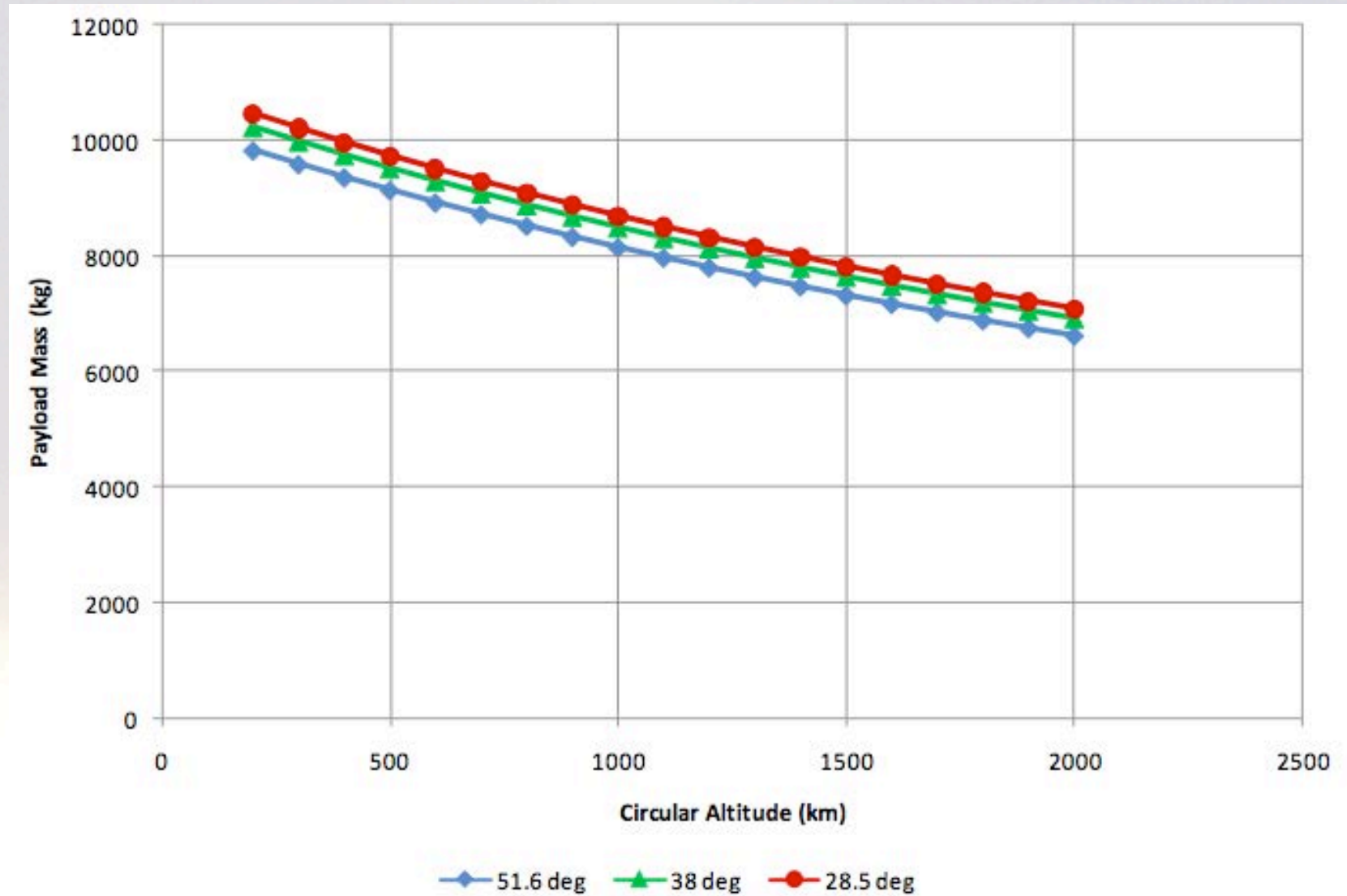
Falcon 9 Payload Fairing
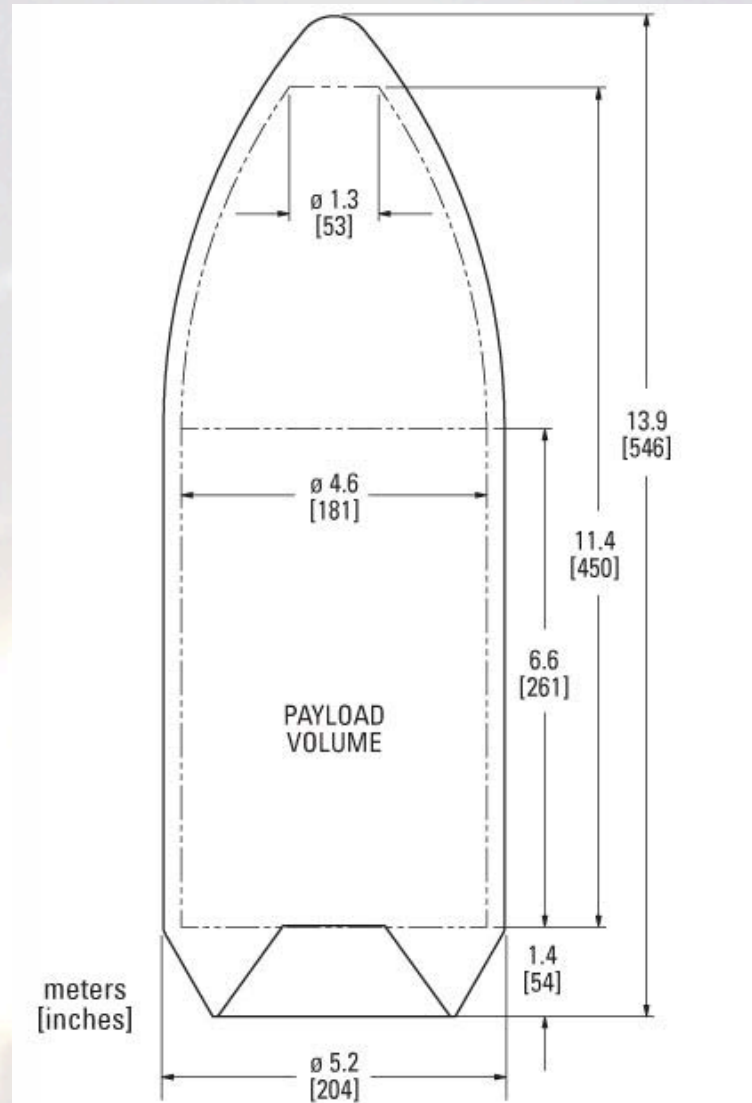
Falcon 9 Performance to Earth Escape
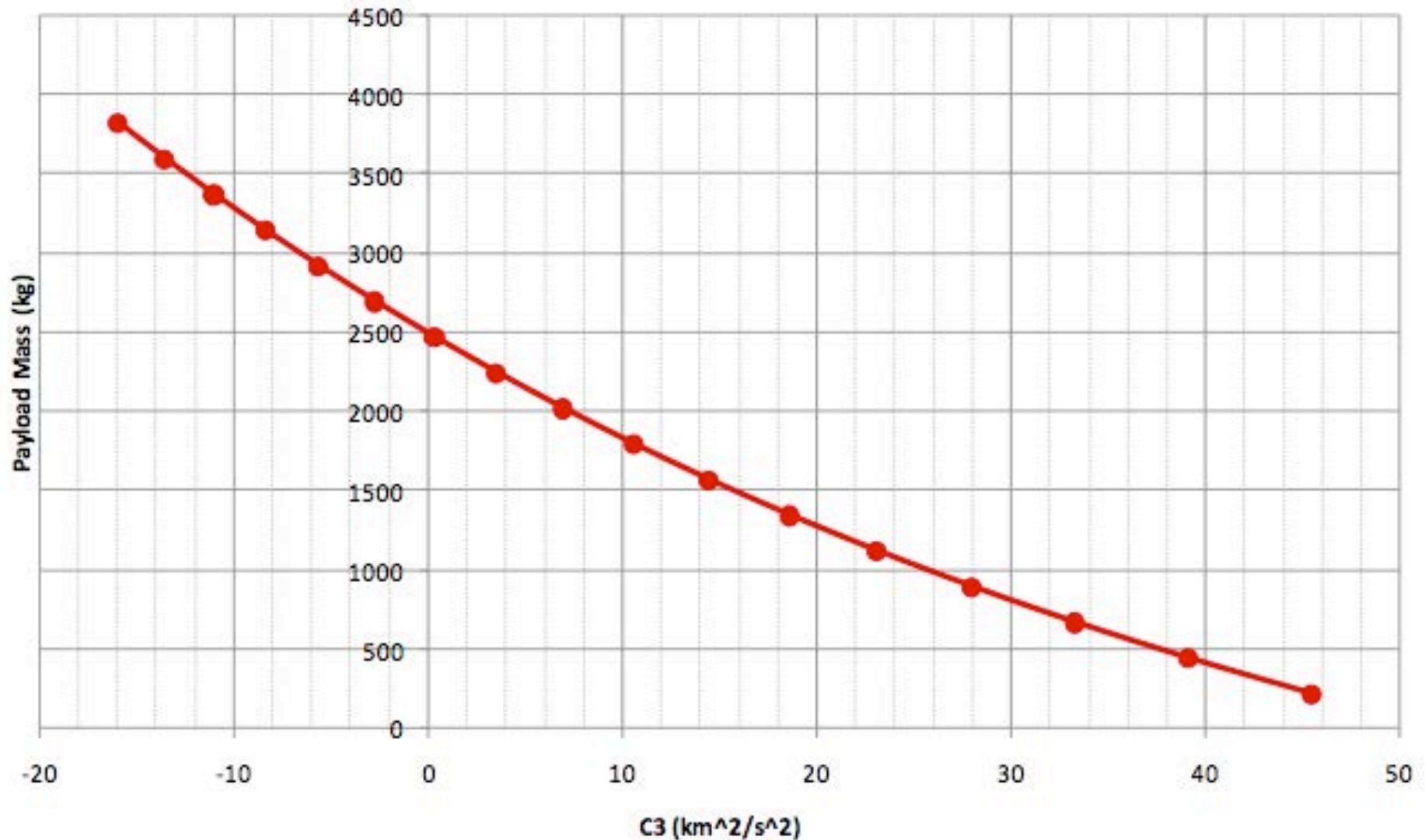
Falcon Heavy (SpaceX)

- Growth version of Falcon 9
- 53,000 kg of payload to LEO (28.5°)
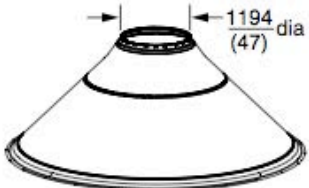- 21,200 kg of payload to GTO
- First flight early 2015
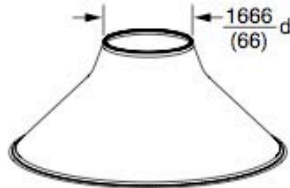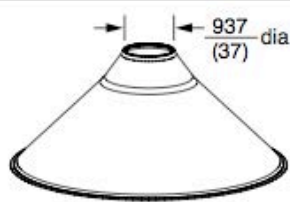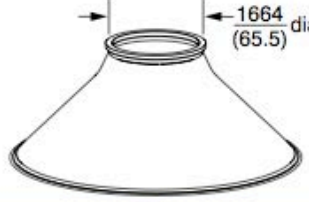
Delta IV Heavy Coordinate System
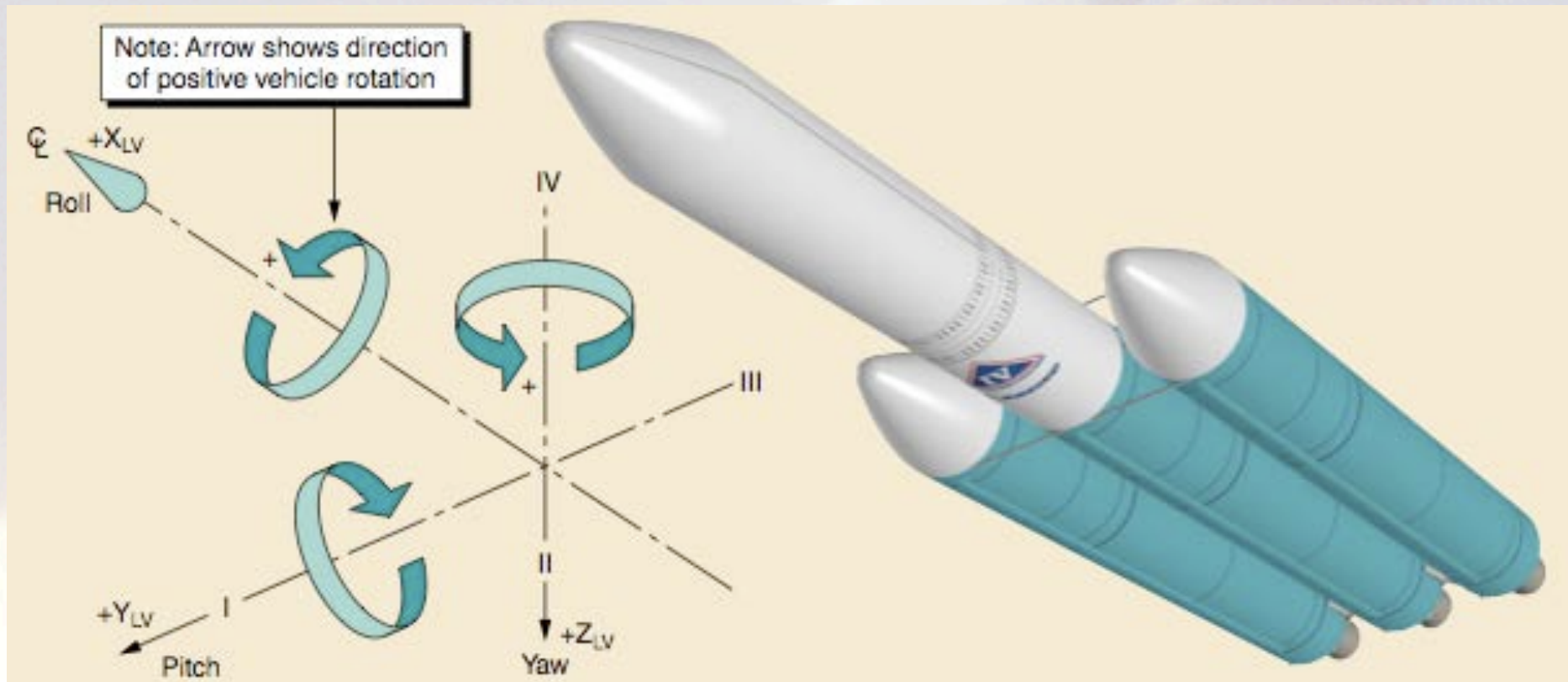
Delta Standard Payload Attach Fittings

Delta IV 1666-4 PAF	$\frac{1666}{(66)}$ dia	$\frac{1666}{(66)}$ dia clampband
Delta IV 1194-4 PAF	$\frac{1194}{(47)}$ dia	$\frac{1194}{(47)}$ dia clampband
Delta IV 937-4 PAF	$\frac{937}{(37)}$ dia	$\frac{937}{(37)}$ dia clampband
Delta IV 1664-4 PAF	$\frac{1664}{(65.5)}$ dia	Four separation bolts in a $\frac{1664}{(65.5)}$ dia bolt circle
Delta IV 1575-4 PAF	$\frac{1575}{(62)}$ dia	121 bolts in a $\frac{1575}{(62)}$ dia bolt circle

Delta IV 1666-5 PAF	$\frac{1666}{(66)}$ dia	$\frac{1666}{(66)}$ dia clampband
Delta IV 1194-5 PAF	$\frac{1194}{(47)}$ dia	$\frac{1194}{(47)}$ dia clampband
Delta IV 937-5 PAF	$\frac{937}{(37)}$ dia	$\frac{937}{(37)}$ dia clampband
Delta IV 1664-5 PAF	$\frac{1664}{(65.5)}$ dia	Four separation bolts $\frac{1664}{(65.5)}$ dia bolt circle
Delta IV 4394-5 PAF	$\frac{4394}{(173)}$ dia	72 bolts in a $\frac{4394}{(173)}$ dia bolt circle

Marmon Band/Separation Springs
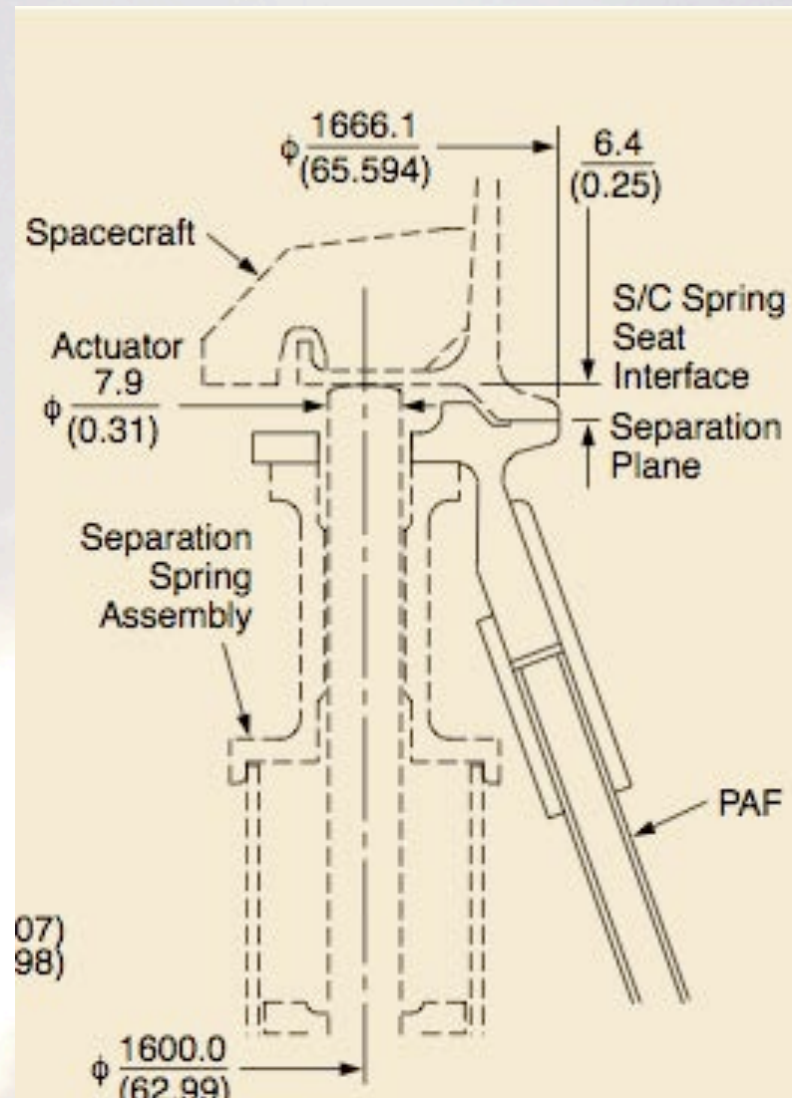
Marmon Band/Separation Springs
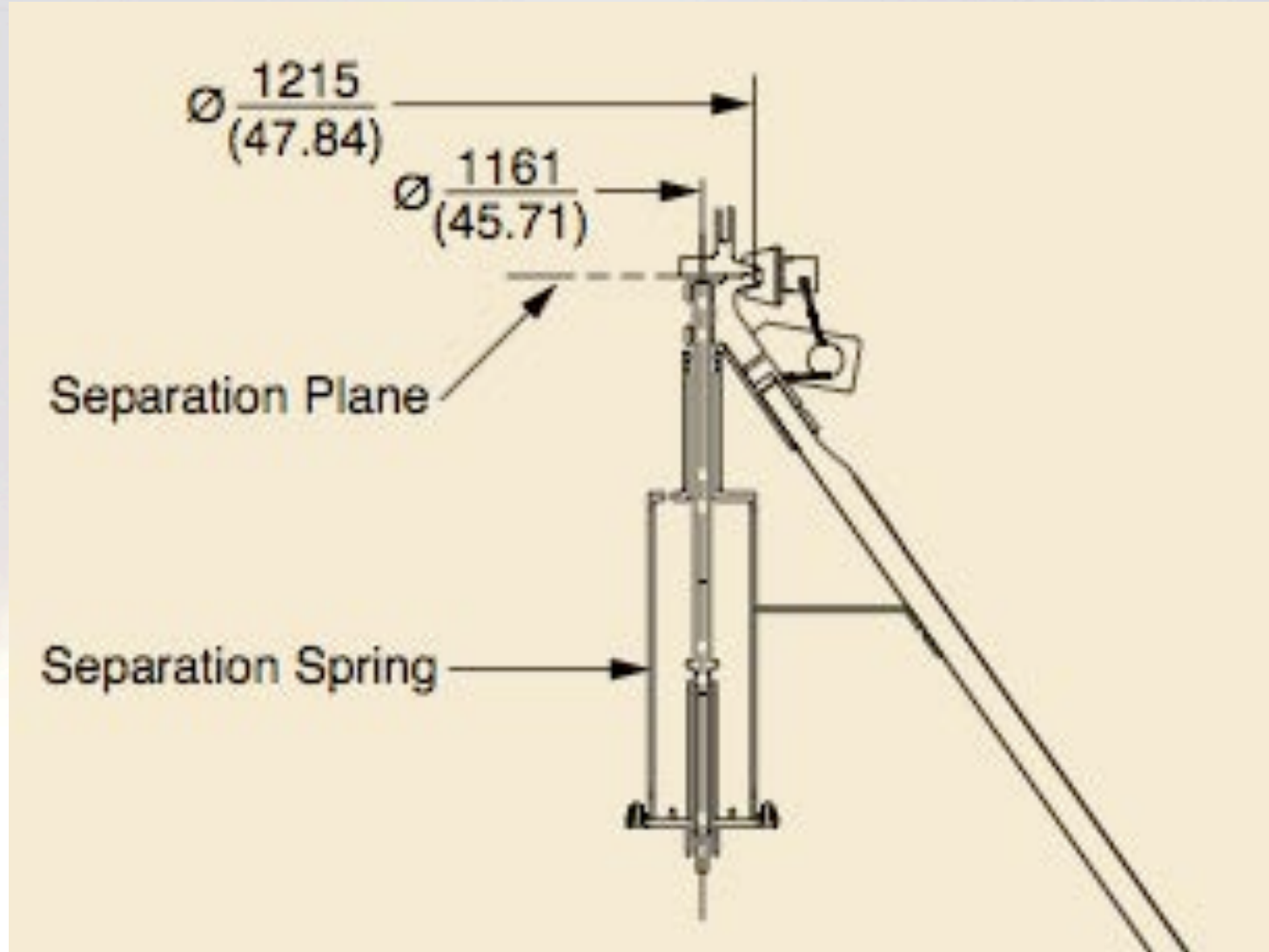
Delta 1575-4 Bolted Payload Interface

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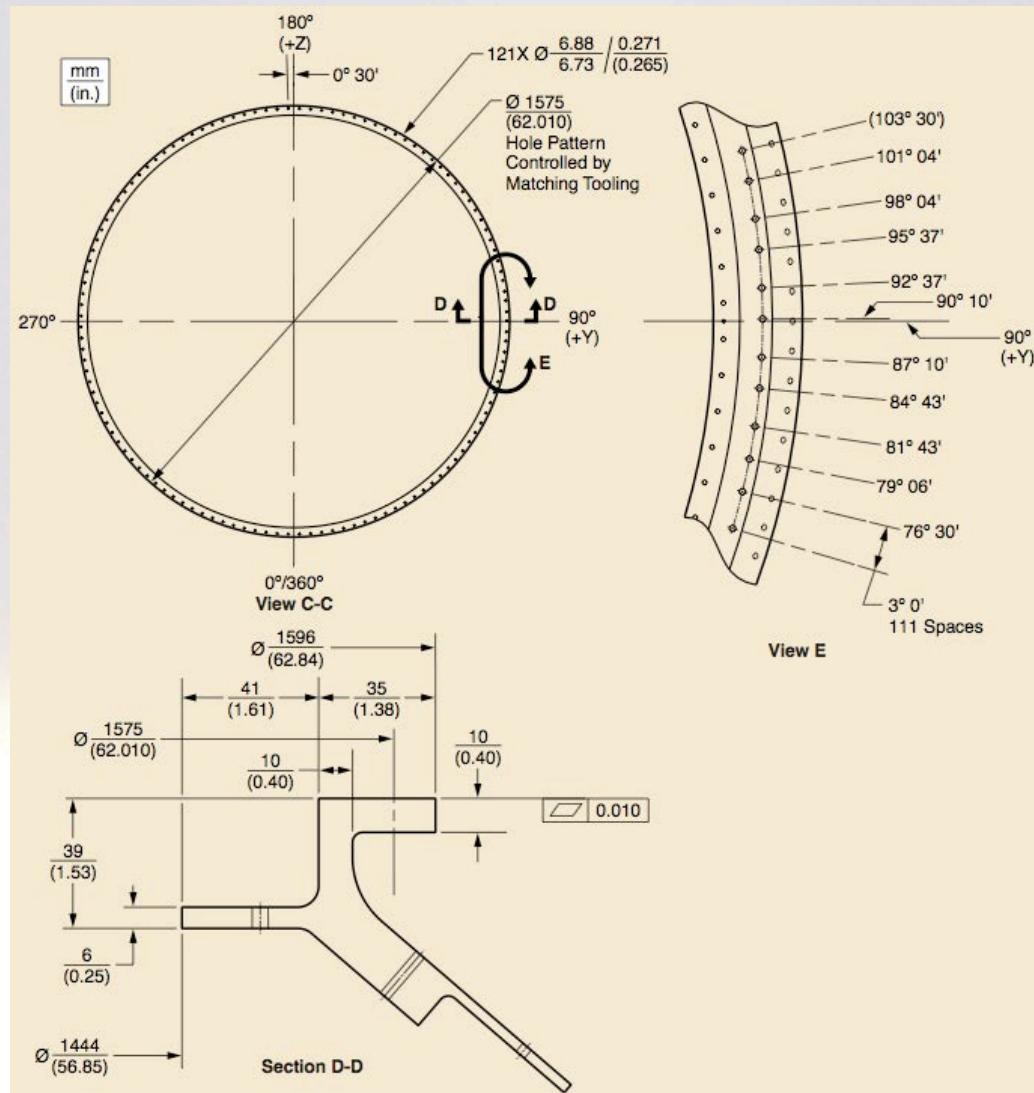
Delta 4394-5 Bolted Interface

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
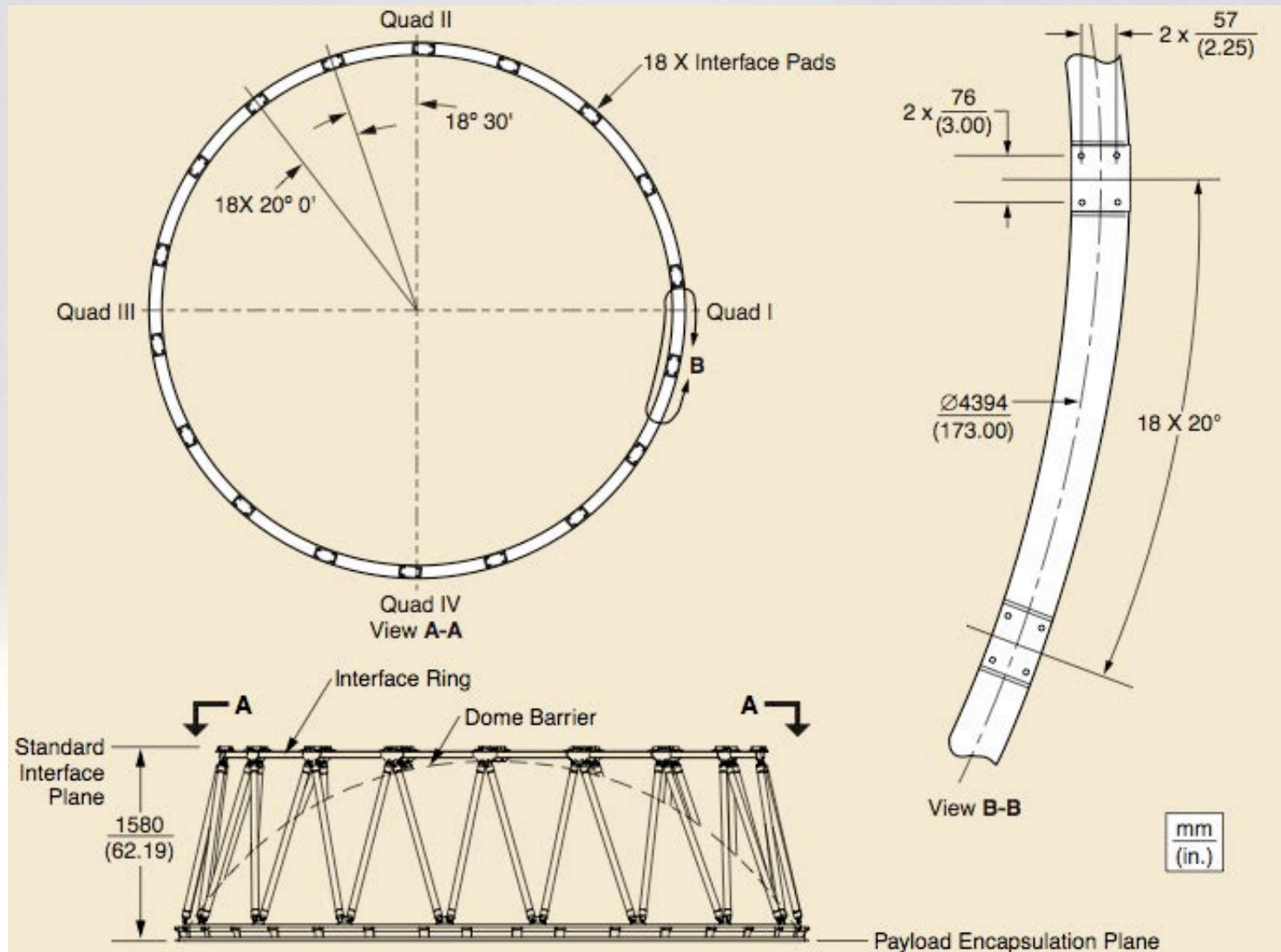
Atlas V Bolted 173 inch PAF

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
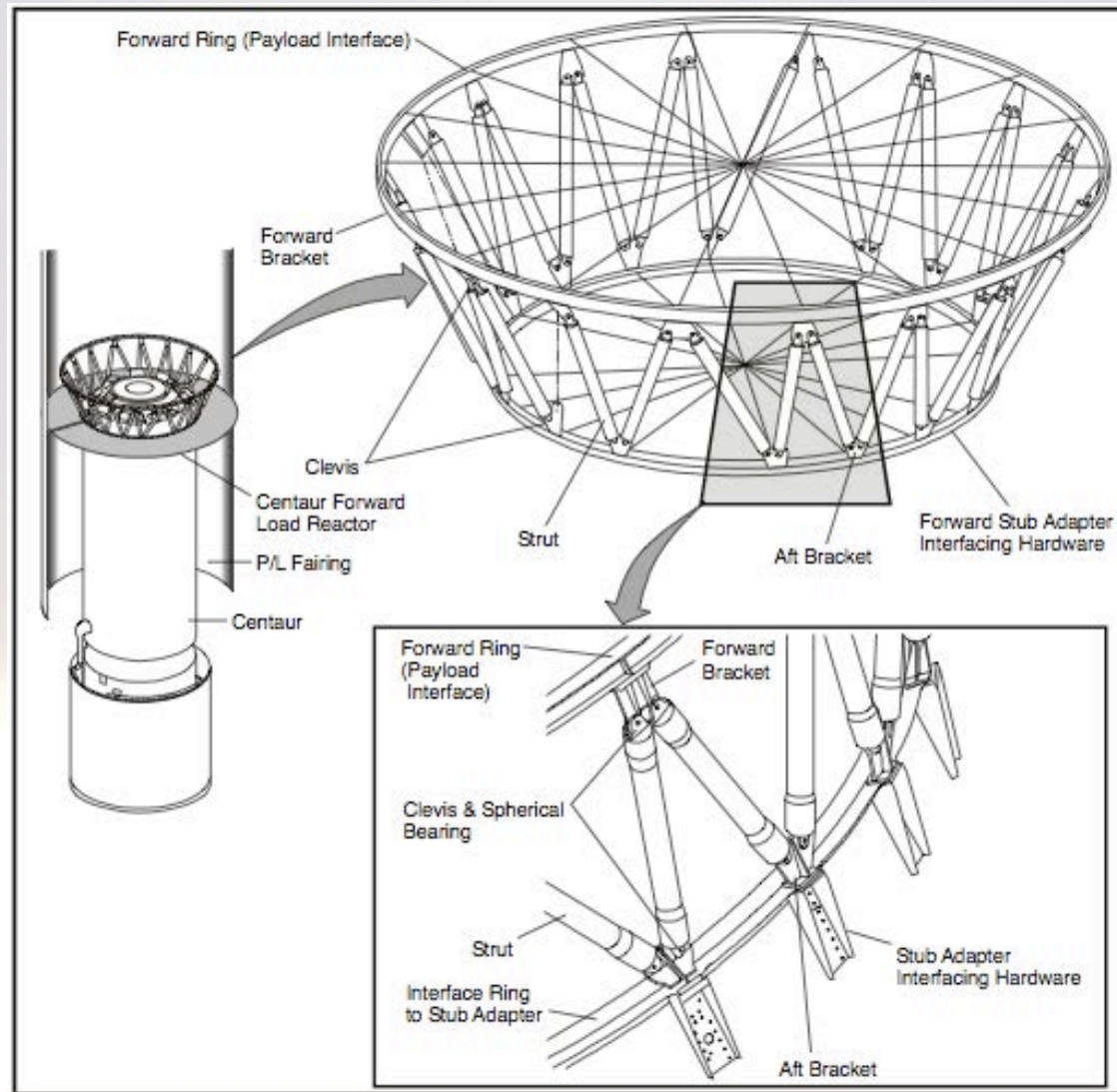
Atlas V 400 Allowable CG Locations

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design

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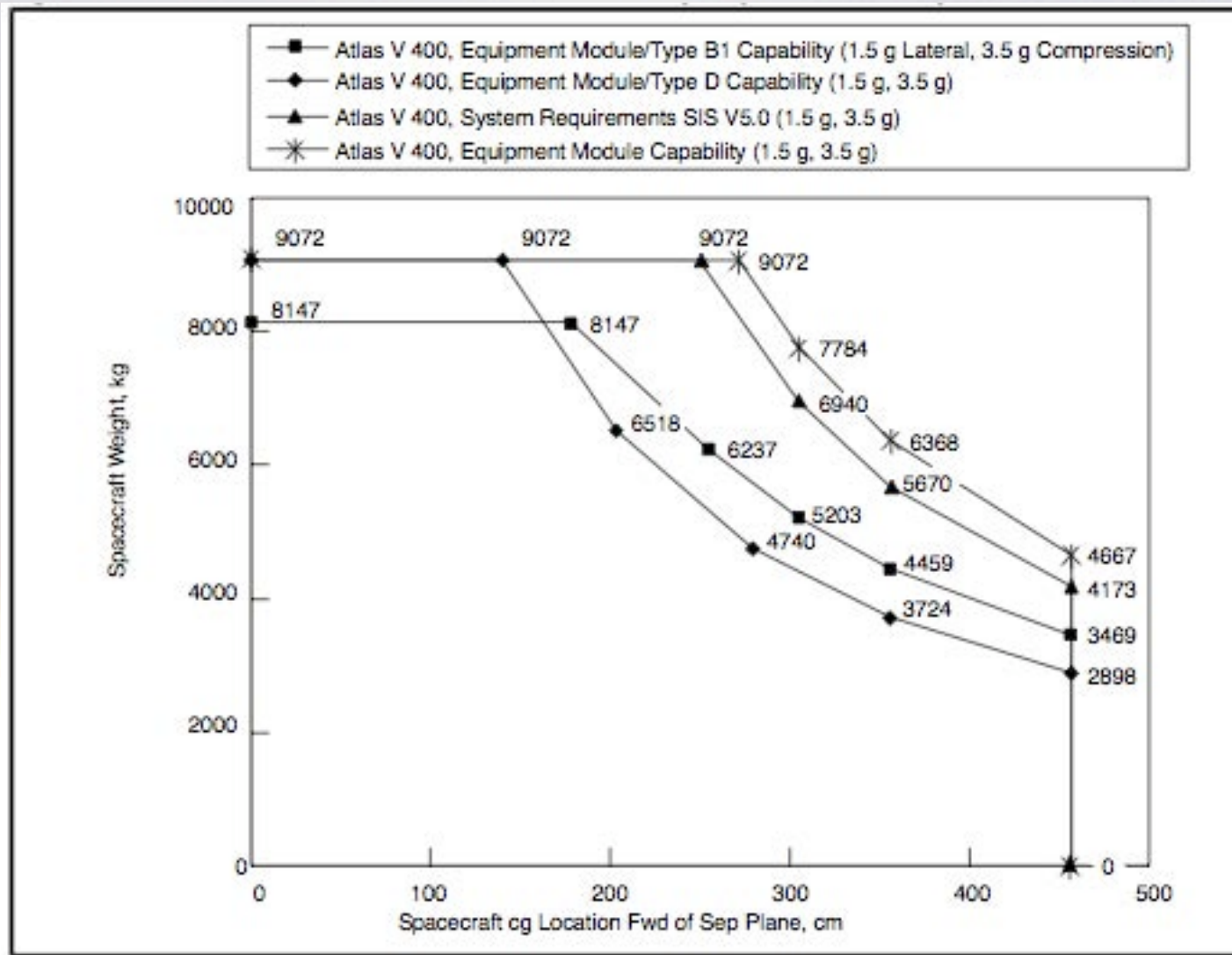
Delta Payload Fairings
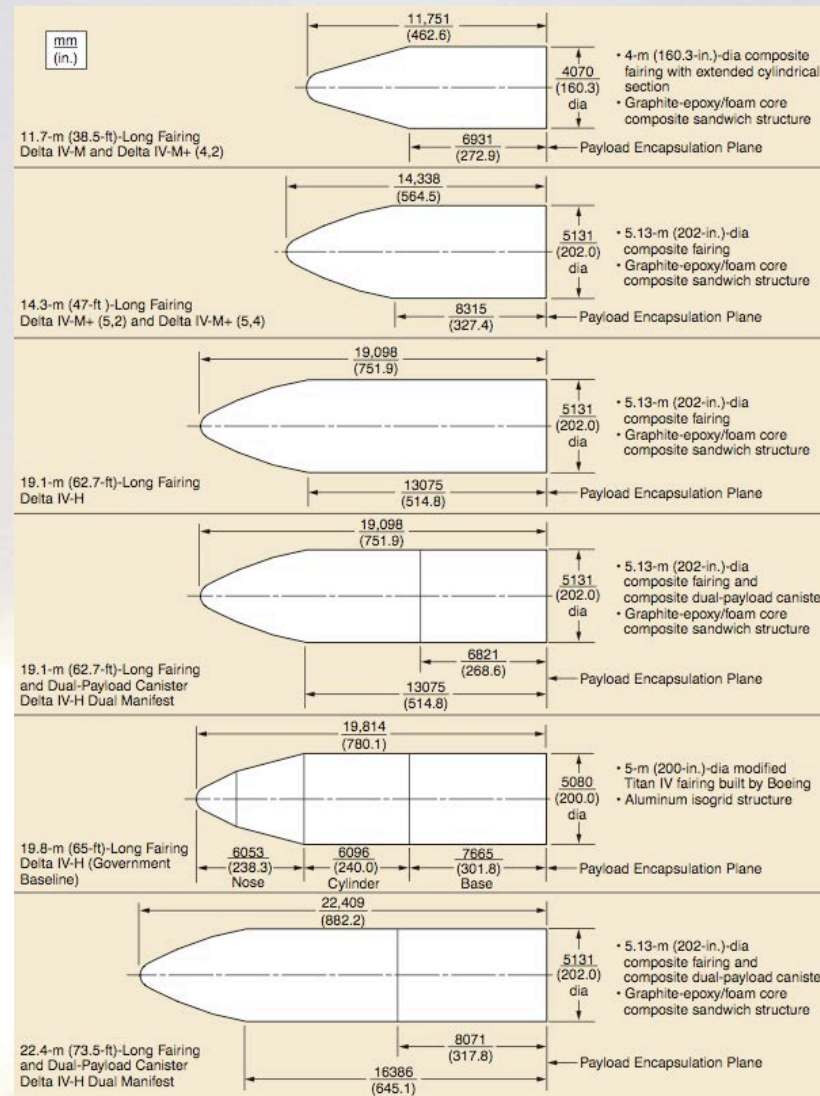
Delta Metallic Fairing Temperatures
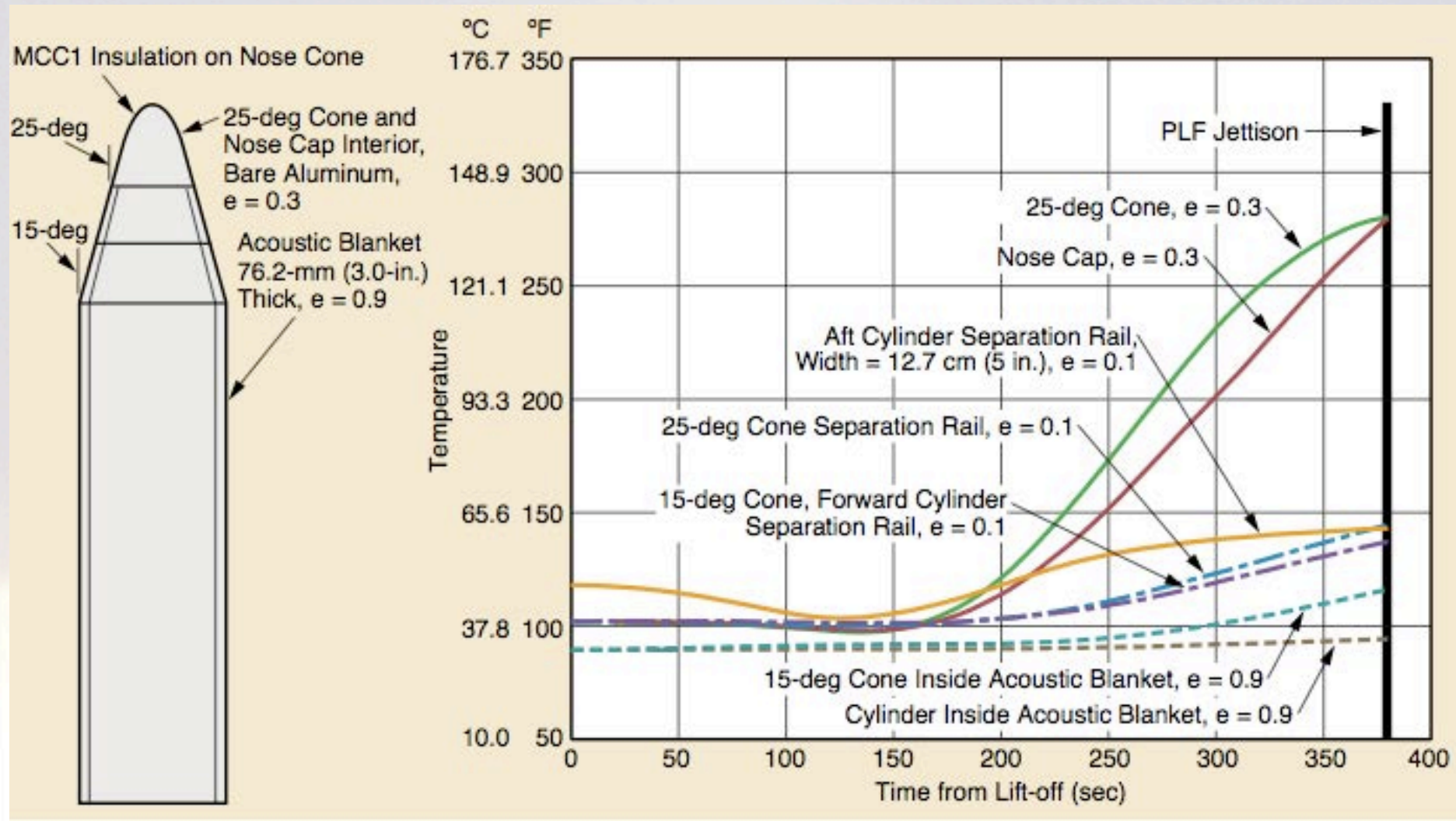
Delta Composite Fairing Temperatures
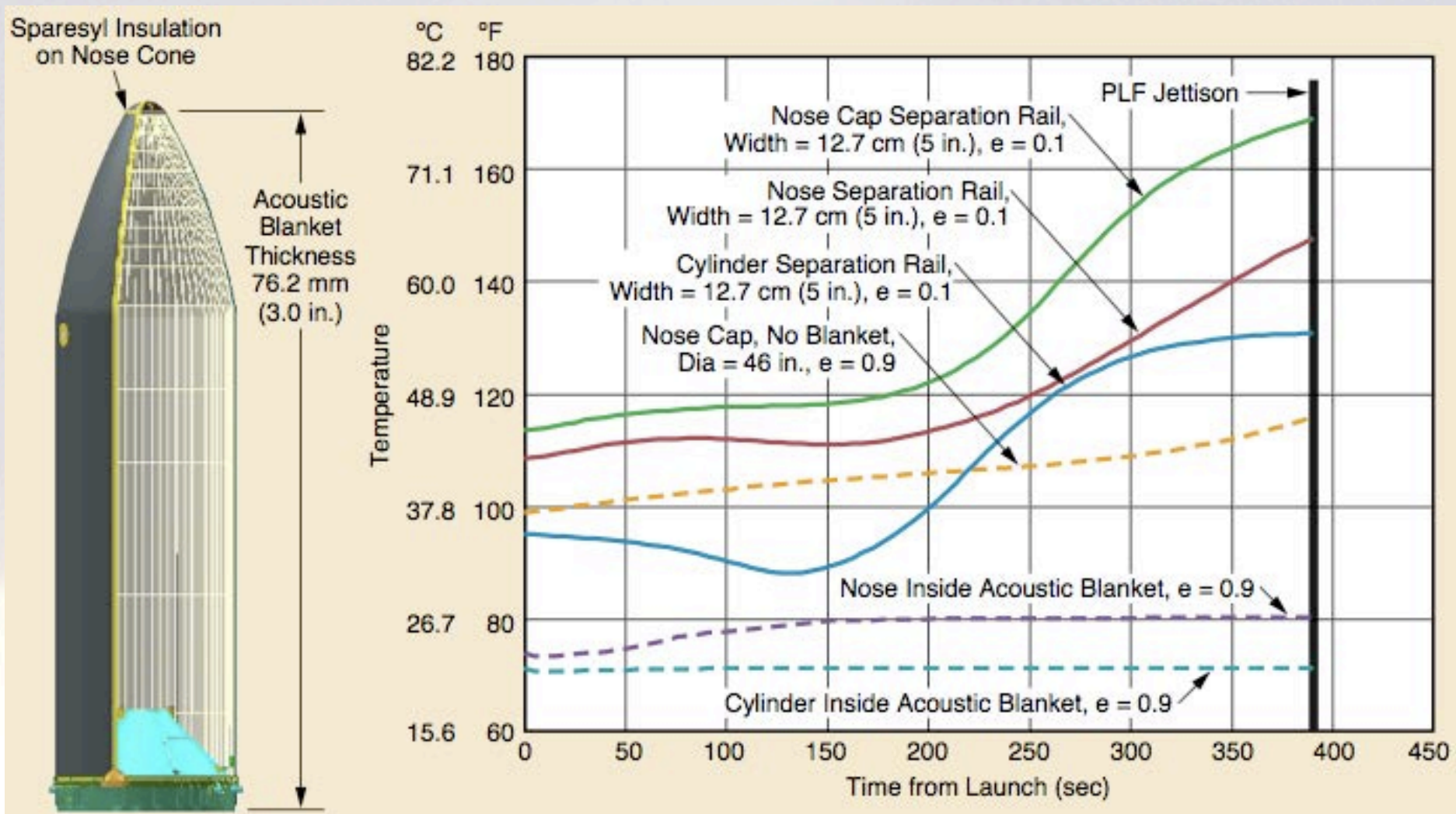
Delta IV Heavy Payload Venting

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
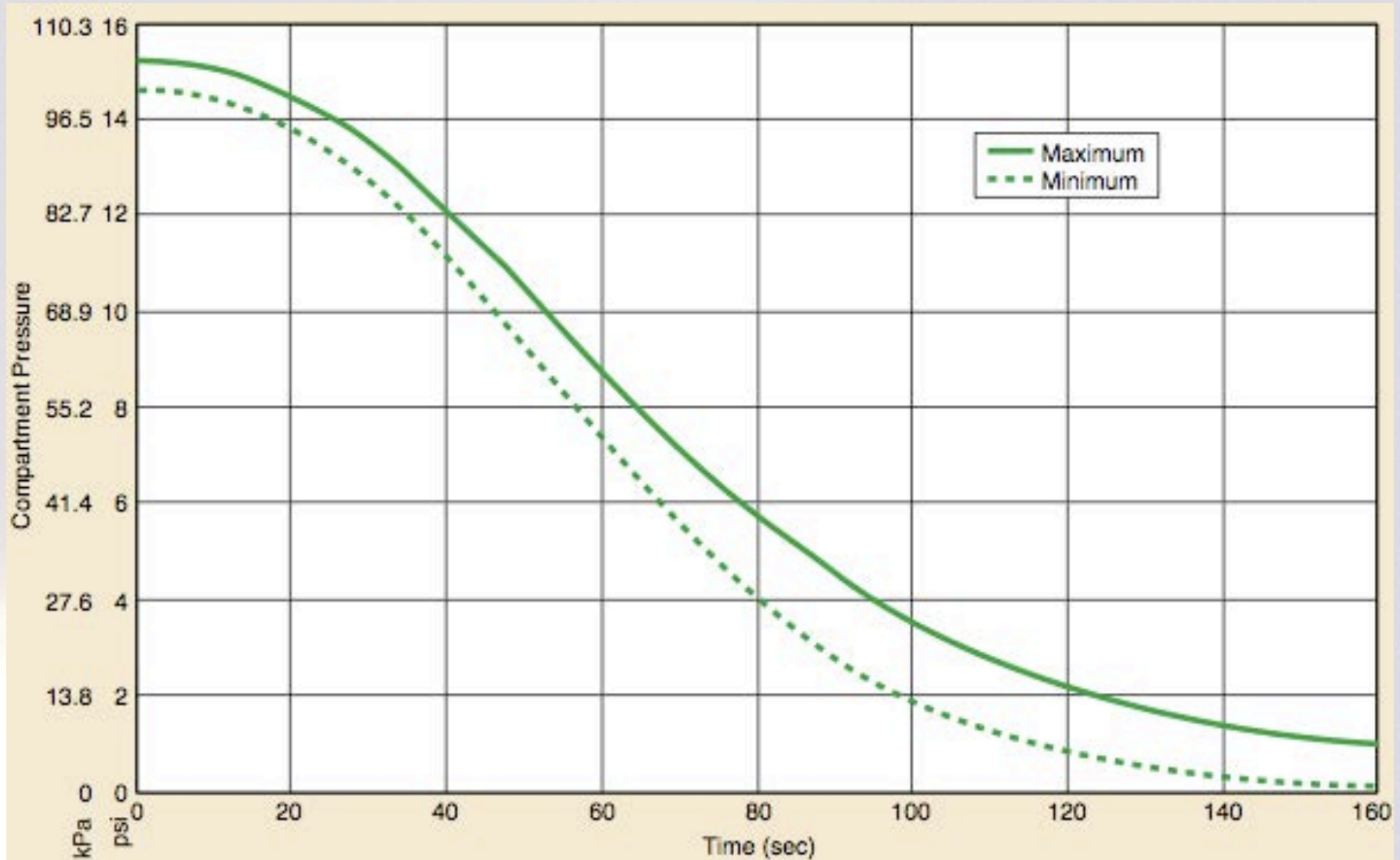
Delta IV Heavy Acoustic Environment

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
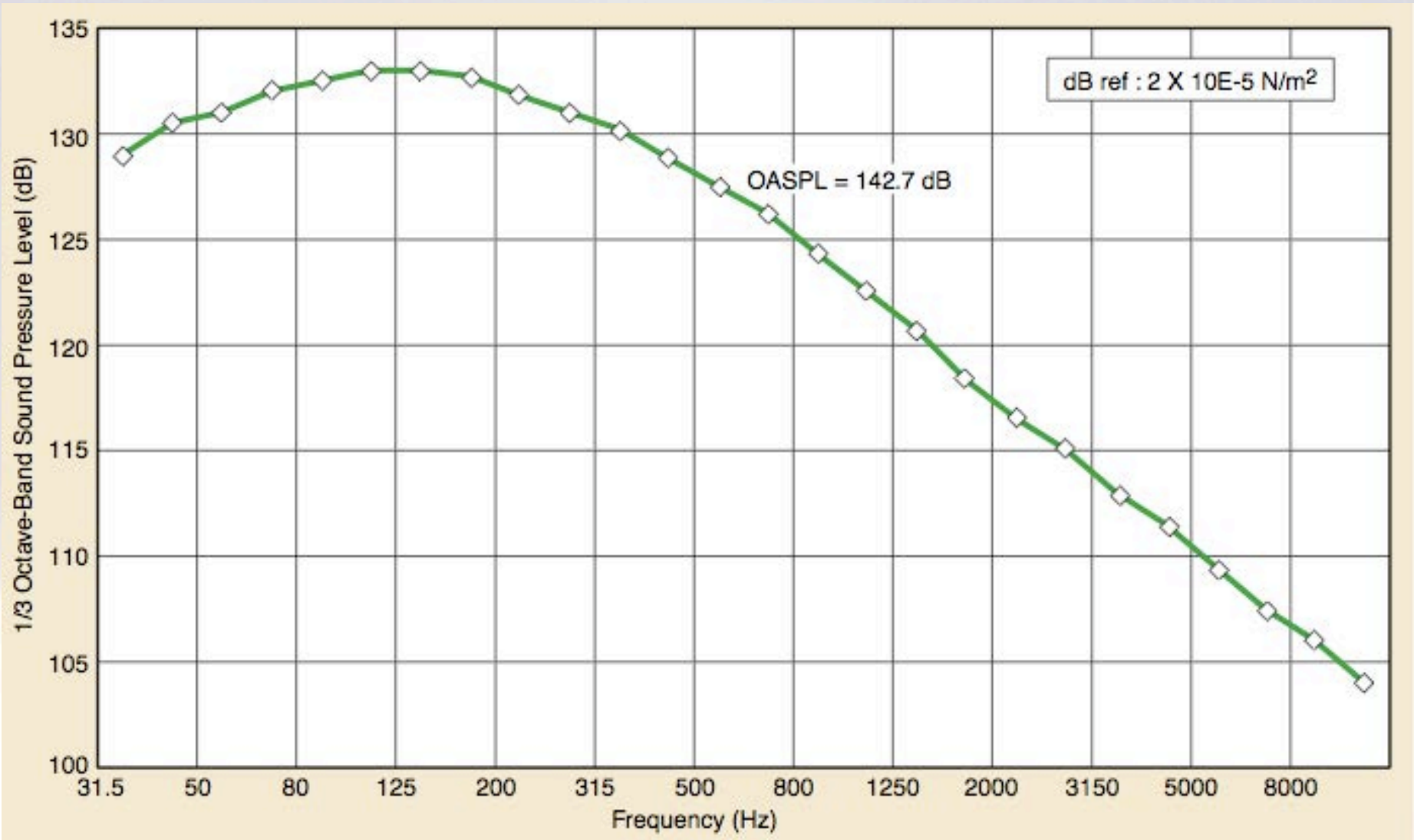
Delta IV Heavy Dynamic Loads
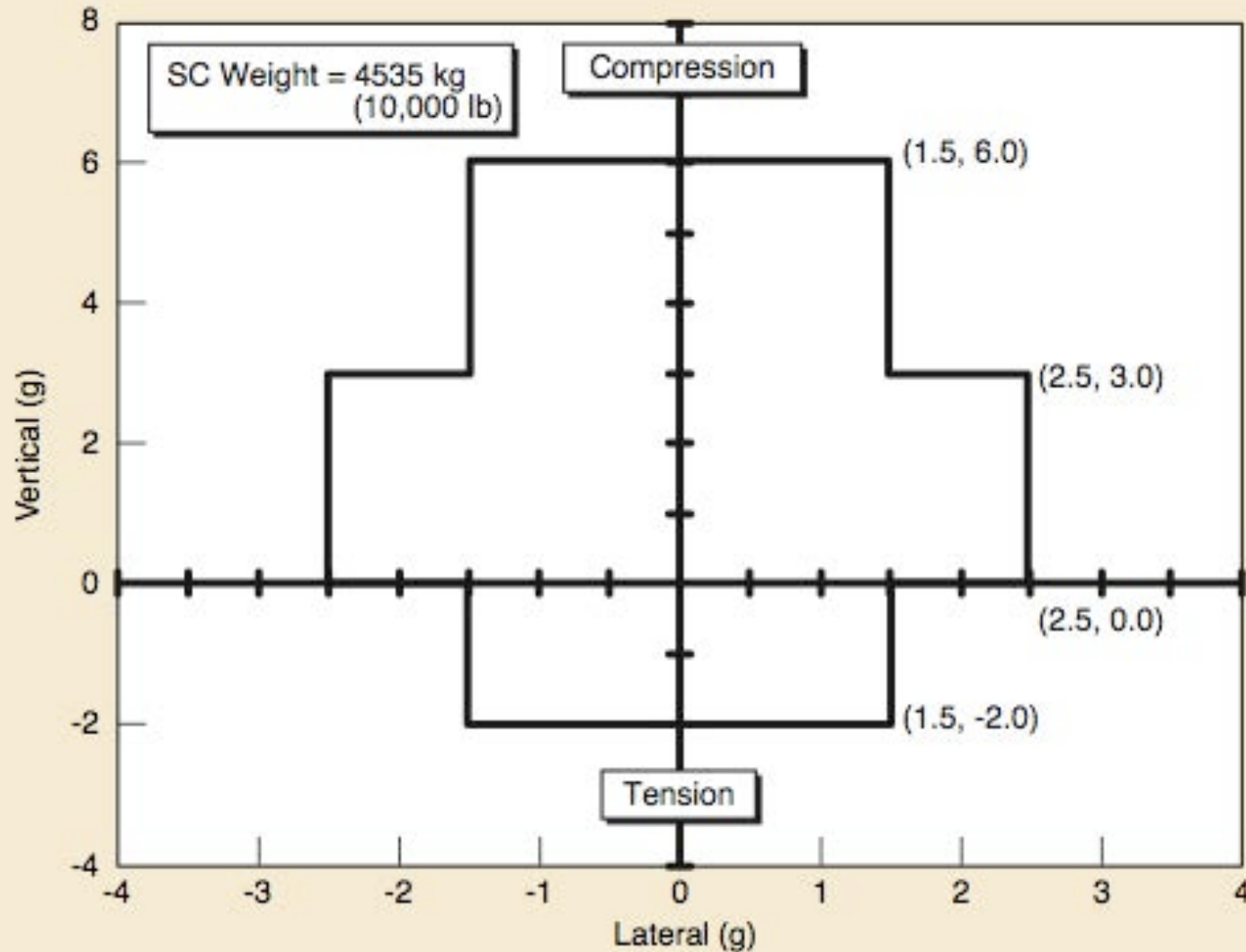
Shuttle Mission Profile

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
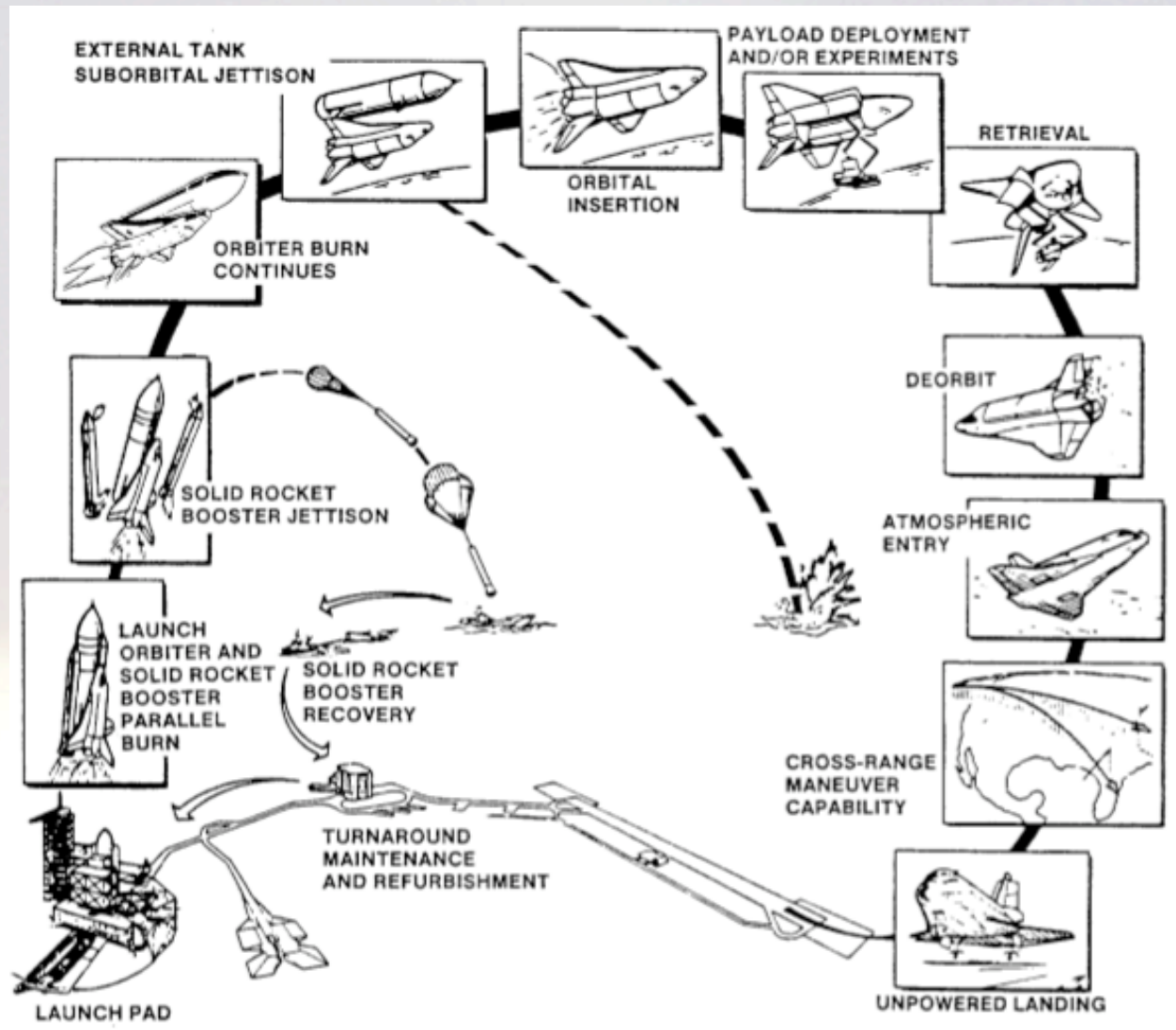
Orbiter Coordinate System

DIMENSIONS ARE IN INCHES.

236

400
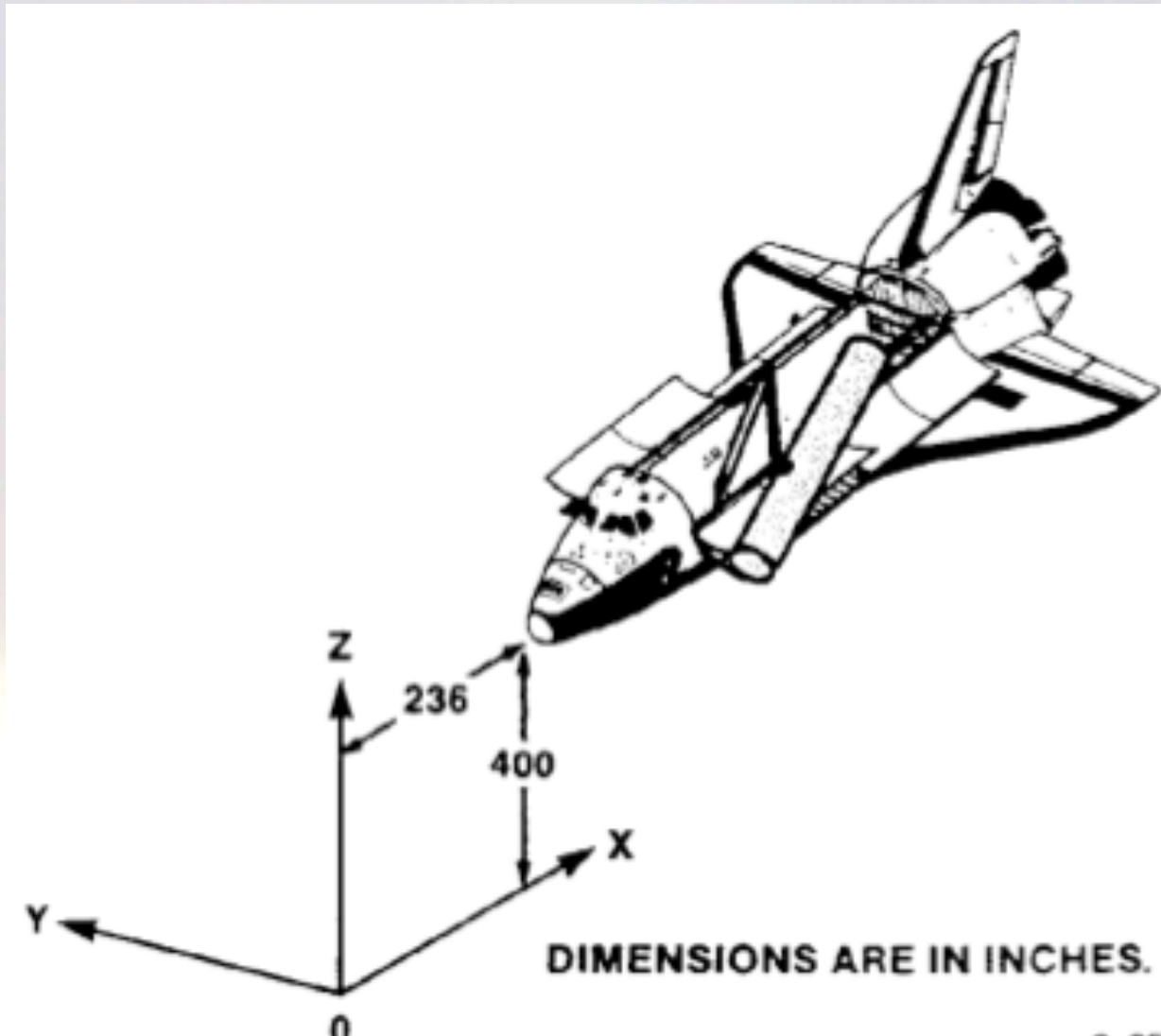
Orbiter Payload Bay Envelope

X_o 1302

X_o 582   60 FT (18.3 m)

Z_o 400

CENTERLINE OF PAYLOAD BAY

15 FT (4.6 m) DIA

X_o 0

Z_o

Y_o   X_o

PAYLOAD BAY ENVELOPE
15 FT (4.6 m) DIAMETER,
BY 60 FT (18.3 m) LENGTH

MID-FUSELAGE VIEW LOOKING AFT

Y_o 90   Y_o 0   Y_o -90

MAXIMUM PAYLOAD ENVELOPE

Z_o 490

90 IN. (229 cm)

Z_o 400

LONGERON

Z_o 310

KEEL

NOTE:
CENTER OF 90 IN. ENVELOPE @ Z_o 400
LONGERON ATTACH @ Z_o 414

app4g2
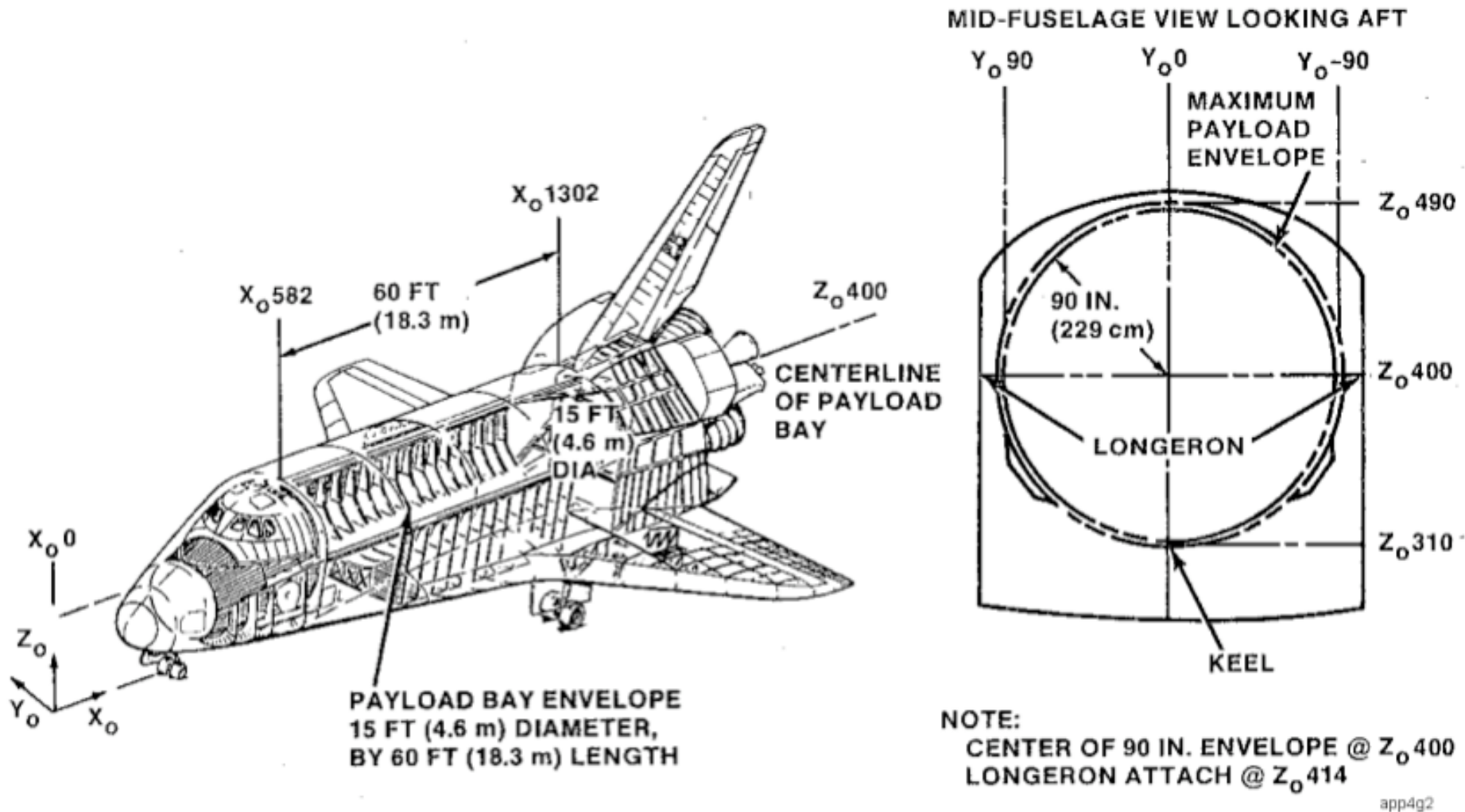
Orbiter Longeron Bridge Fittings

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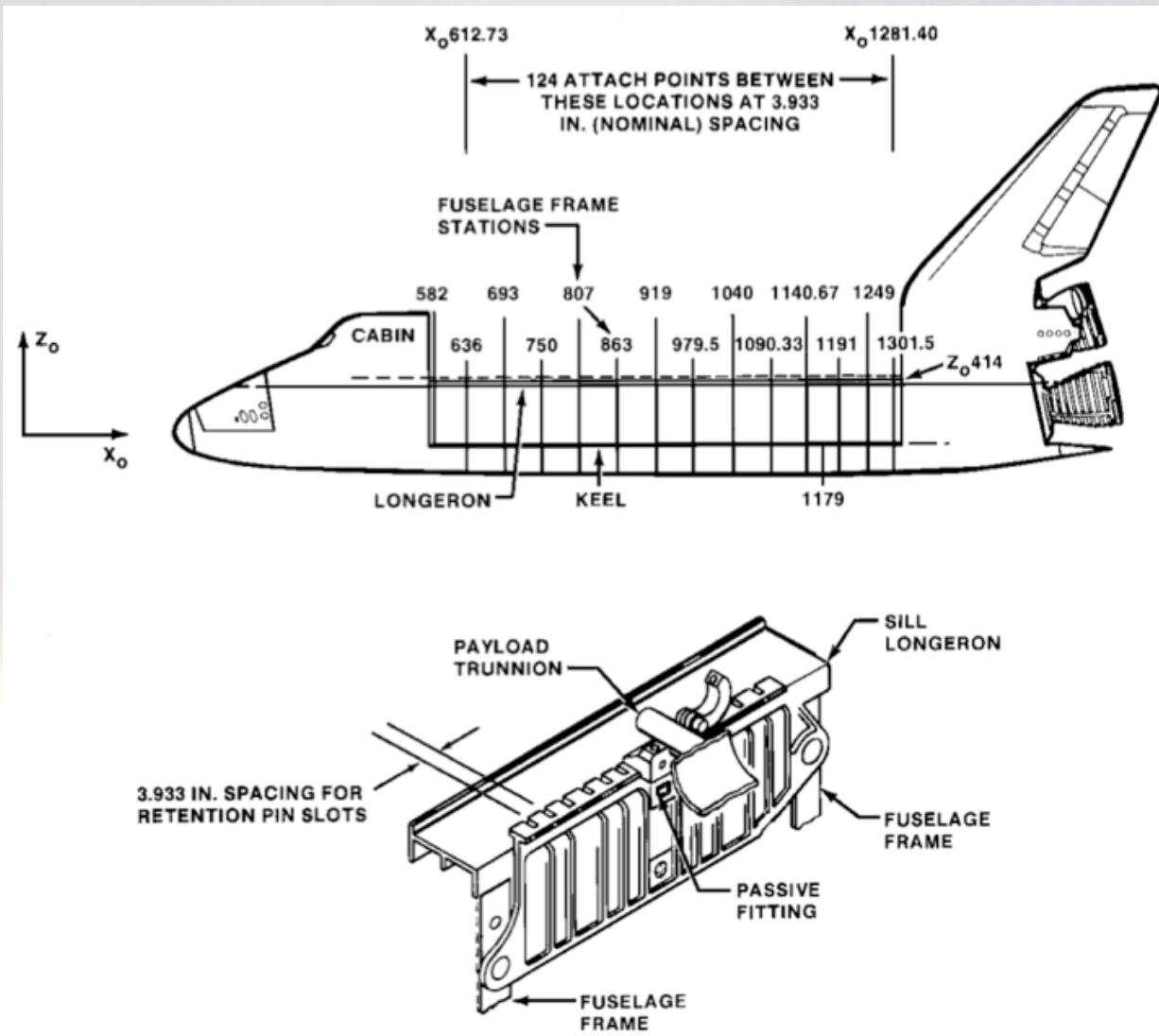
Orbiter Five-Point Attach System
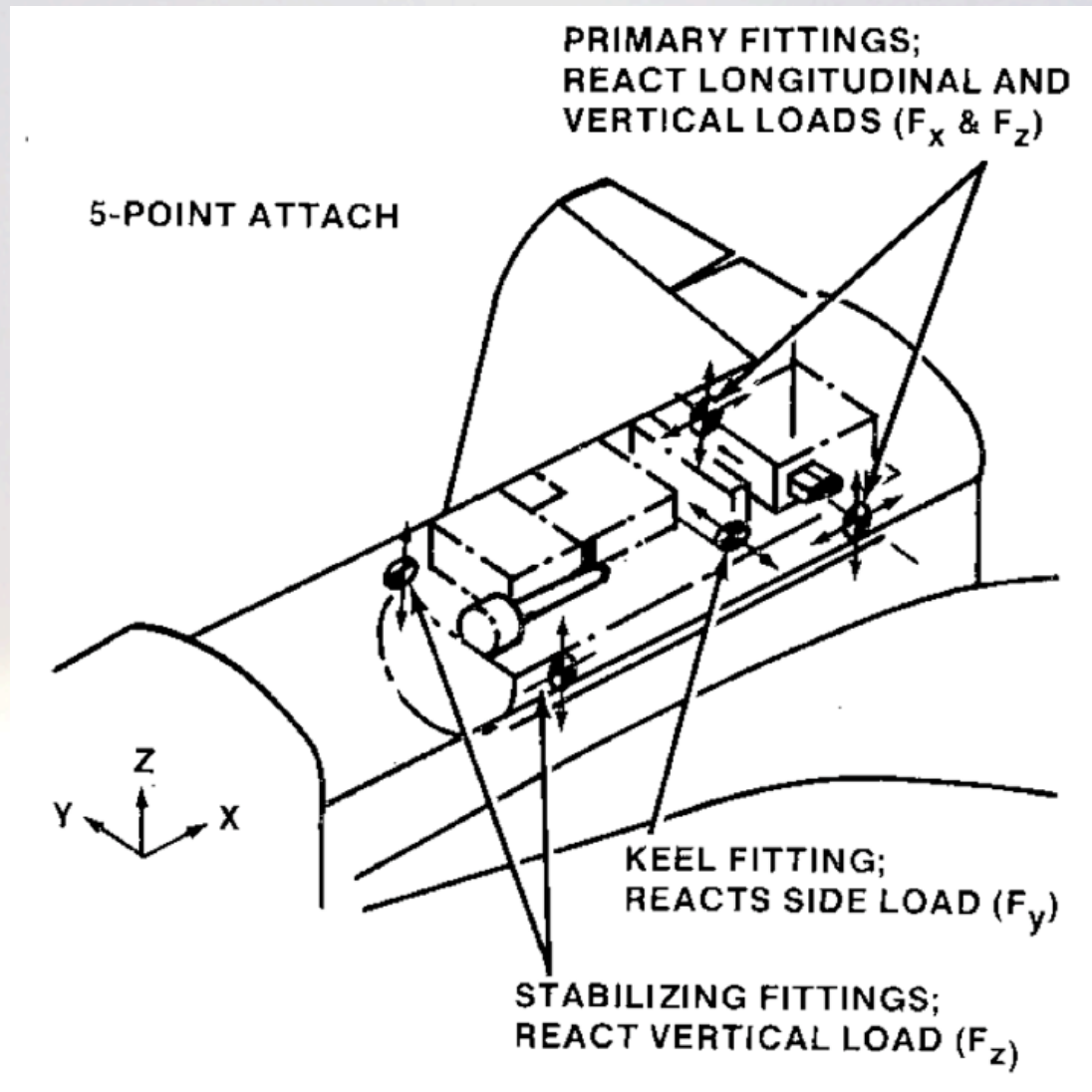
Orbiter Three-Point Attach System

3-POINT ATTACH

PRIMARY FITTINGS;
REACT LONGITUDINAL AND
VERTICAL LOADS (F_x & F_z)

KEEL FITTING;
REACTS SIDE AND LONGITUDINAL
LOADS (F_y & F_x)
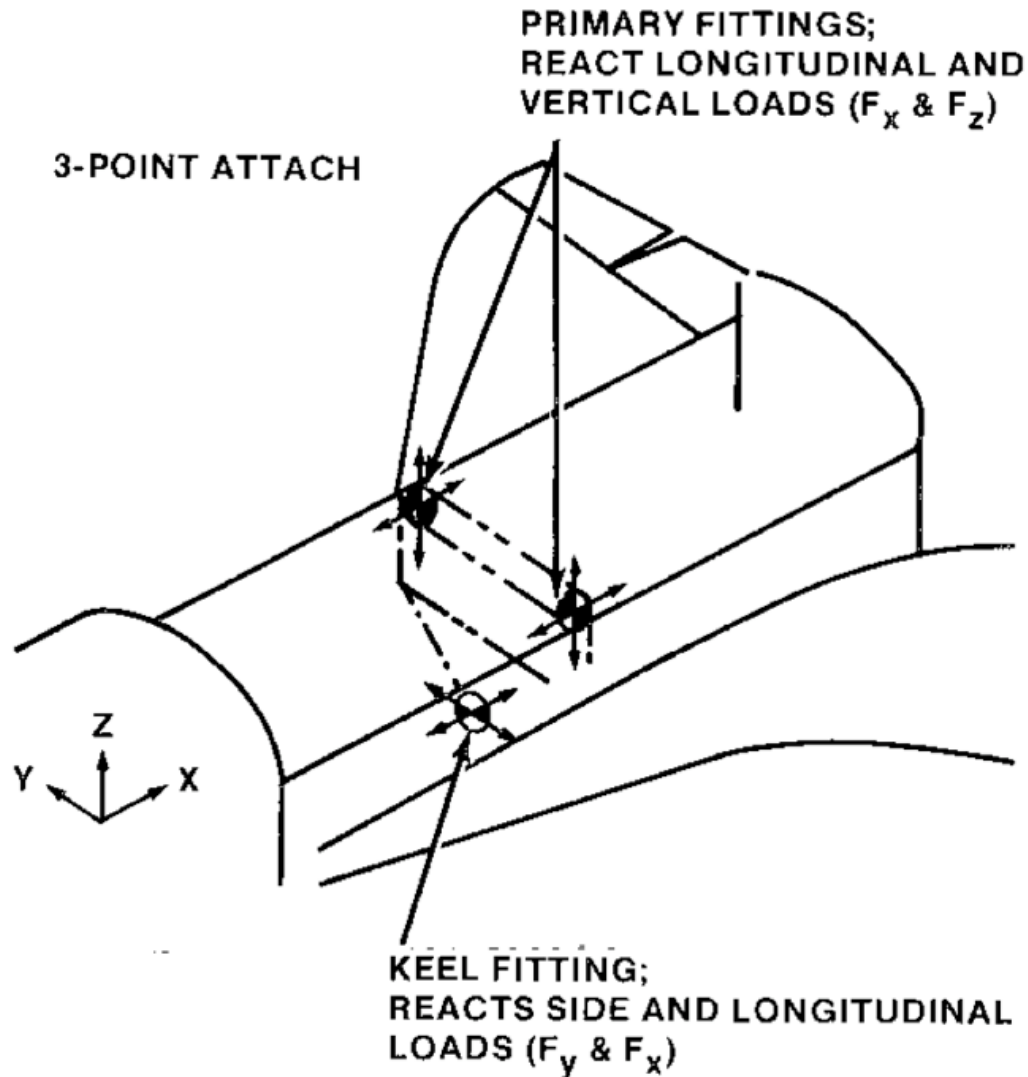
Orbiter Payload Attach Fittings

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
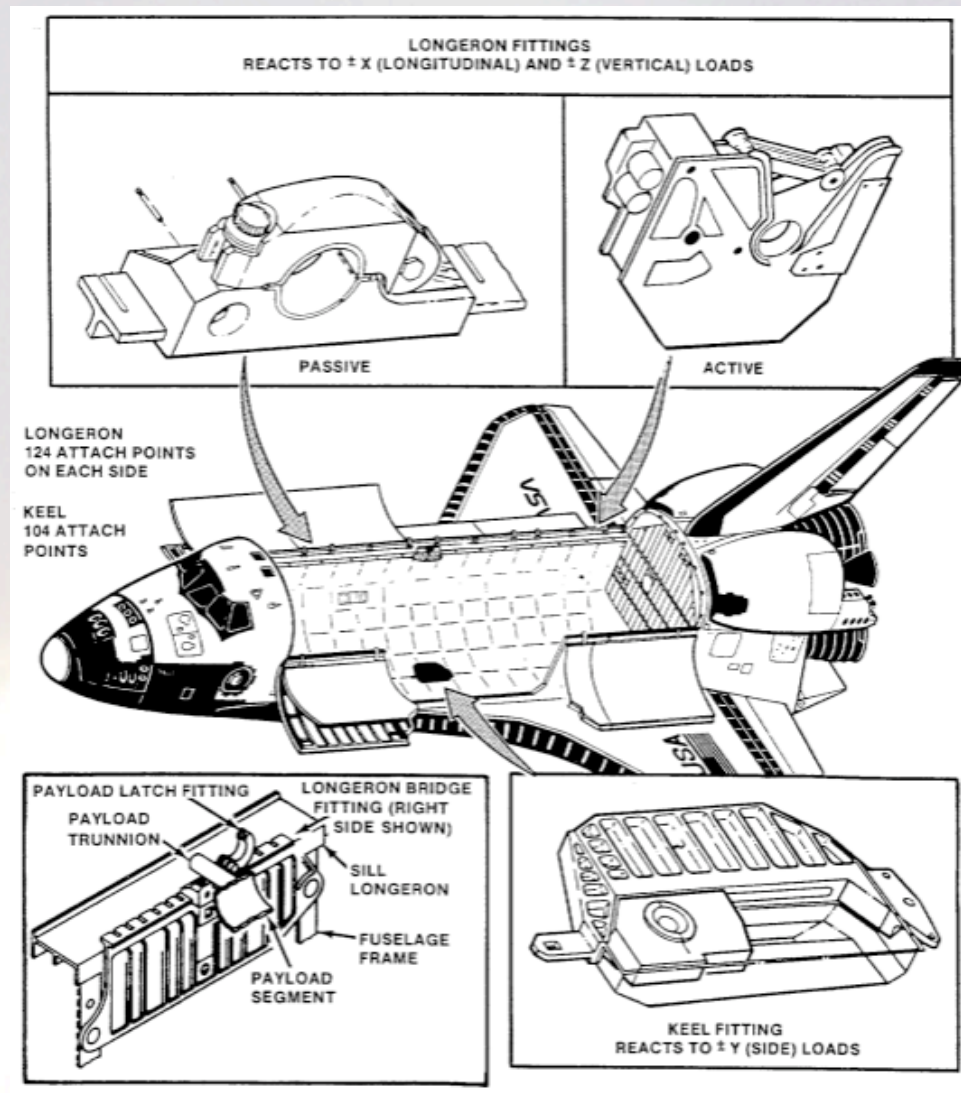
Shuttle Payload Bay Temperatures

Orbiter ROEU

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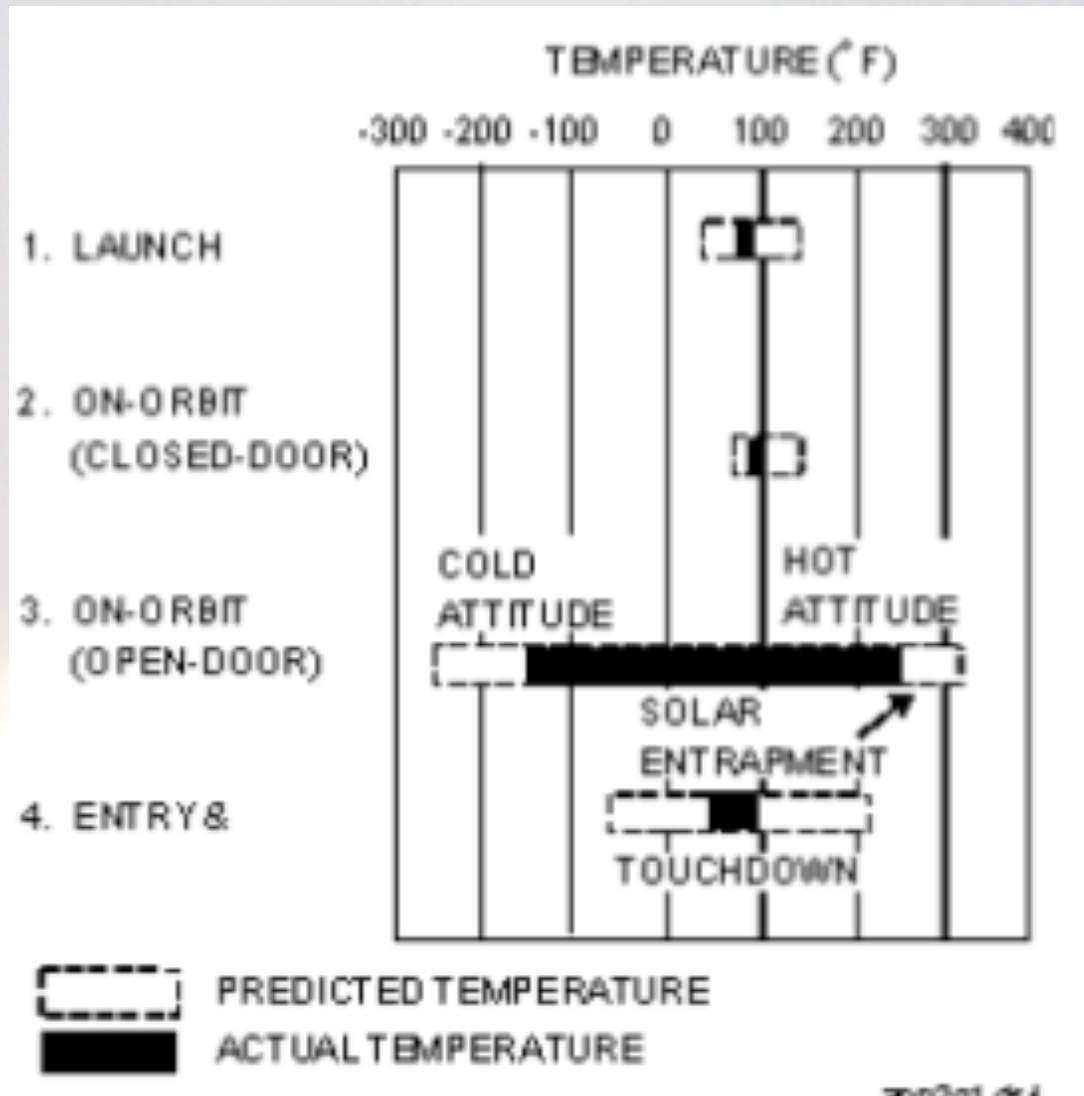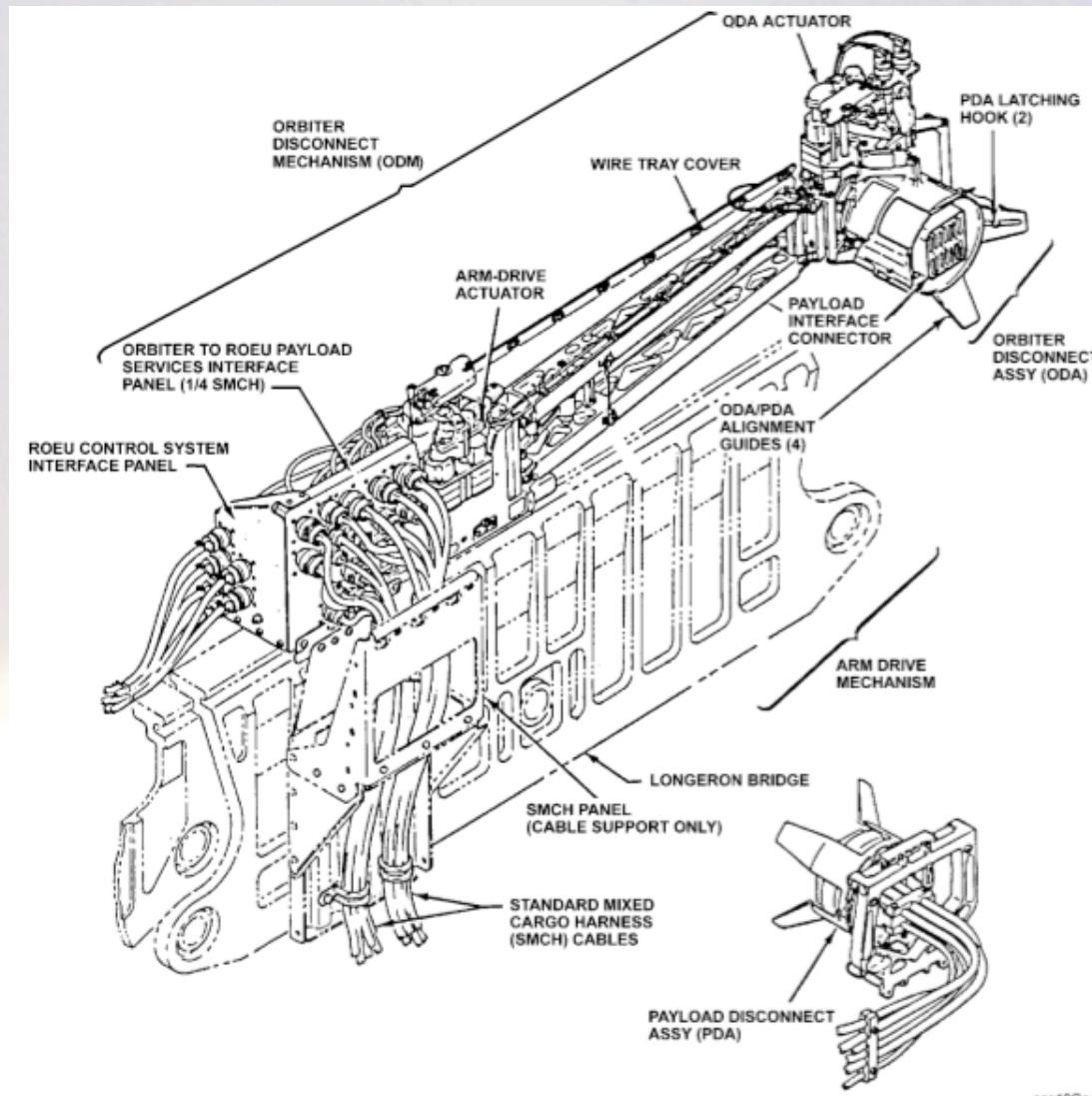
Payload Qualification Testing

- Structural load testing (flight x 1.25)

- Acoustic load testing (flight + 3 dB)

- Sinusoidal vibration testing (flight + 3 dB at 2 octaves/min sweep rate)

- Shock testing (actuation of pyrotechnics)

Delta IV Heavy Launch Processing Flow

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design
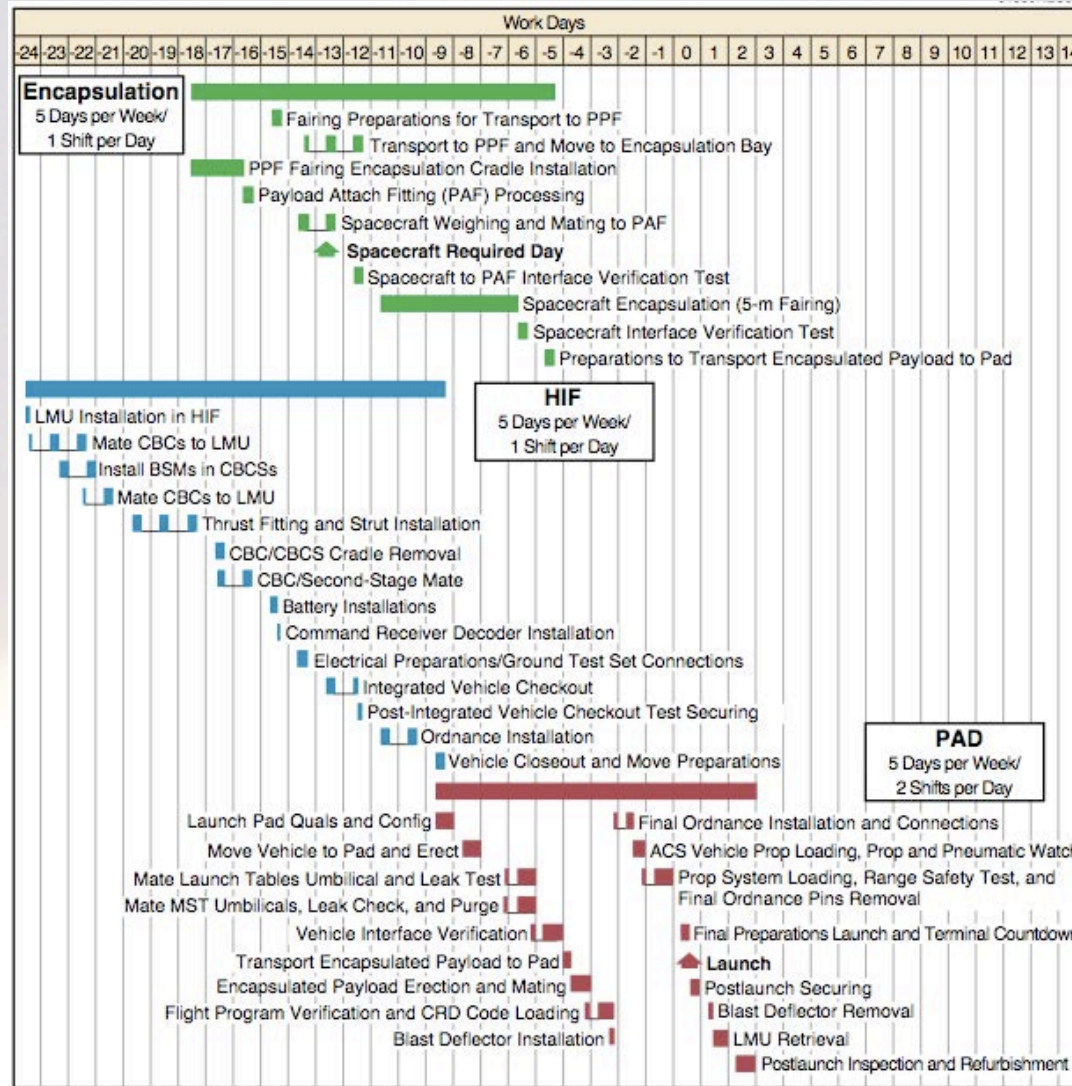
Delta IV Horizontal Integration Facility

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Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design

Integration Documentation (part 1)

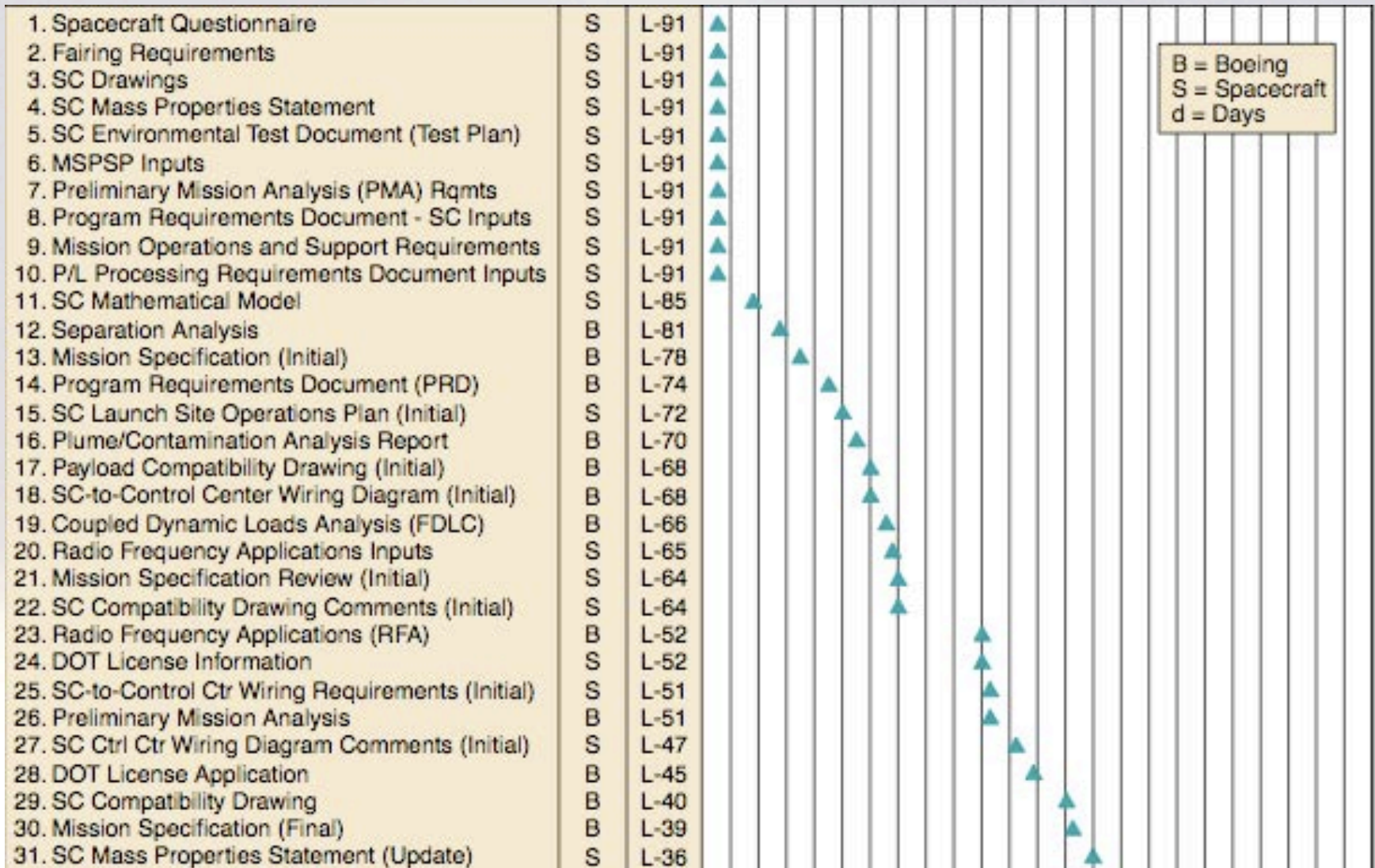|			
1. Spacecraft Questionnaire	S	L-91	
2. Fairing Requirements	S	L-91	
3. SC Drawings	S	L-91	
4. SC Mass Properties Statement	S	L-91	
5. SC Environmental Test Document (Test Plan)	S	L-91	
6. MSPSP Inputs	S	L-91	
7. Preliminary Mission Analysis (PMA) Rqmts	S	L-91	
8. Program Requirements Document - SC Inputs	S	L-91	
9. Mission Operations and Support Requirements	S	L-91	
10. P/L Processing Requirements Document Inputs	S	L-91	
11. SC Mathematical Model	S	L-85	
12. Separation Analysis	B	L-81	
13. Mission Specification (Initial)	B	L-78	
14. Program Requirements Document (PRD)	B	L-74	
15. SC Launch Site Operations Plan (Initial)	S	L-72	
16. Plume/Contamination Analysis Report	B	L-70	
17. Payload Compatibility Drawing (Initial)	B	L-68	
18. SC-to-Control Center Wiring Diagram (Initial)	B	L-68	
19. Coupled Dynamic Loads Analysis (FDLC)	B	L-66	
20. Radio Frequency Applications Inputs	S	L-65	
21. Mission Specification Review (Initial)	S	L-64	
22. SC Compatibility Drawing Comments (Initial)	S	L-64	
23. Radio Frequency Applications (RFA)	B	L-52	
24. DOT License Information	S	L-52	
25. SC-to-Control Ctr Wiring Requirements (Initial)	S	L-51	
26. Preliminary Mission Analysis	B	L-51	
27. SC Ctrl Ctr Wiring Diagram Comments (Initial)	S	L-47	
28. DOT License Application	B	L-45	
29. SC Compatibility Drawing	B	L-40	
30. Mission Specification (Final)	B	L-39	
31. SC Mass Properties Statement (Update)	S	L-36	

B = Boeing
S = Spacecraft
d = Days

Payload Accommodations
ENAE 791 - Launch and Entry Vehicle Design

Integration Documentation (part 2)

#	Document	S/B	Time
32.	Real-Time Tracking Data Requirements	S	L-36
33.	SC-to-Control Ctr Wiring Diagram Comm (Final)	B	L-36
34.	Mission Specification Review (Review)	S	L-36
35.	SC Clearance Drawing	S	L-36
36.	SC-to-Control Center Wiring Diagram (Final)	B	L-35
37.	Launch Vehicle Insignia	S	L-35
38.	Final Mission Analysis (FMA) Requirements	S	L-35
39.	Launch Window (Initial)	S	L-35
40.	Spacecraft Thermal Model	S	L-29
41.	Coupled Dynamic Loads Analysis (LVC)	B	L-28
42.	Delta IV/SC Combined Ops Reqmts Doc (OR)	B	L-26
43.	SC Integrated Test Procedure	S	L-26
44.	SC Launch Site Procedures	S	L-26
45.	Final Mission Analysis (FMA)	B	L-25
46.	Thermal Analysis Report	S	L-22
47.	SC/Fairing Clearance Analysis (Initial)	B	L-16
48.	MSPSP (Final)	B	L-10
49.	Launch Window (Final)	S	L-08
50.	SC Mass Properties Statement (Final)	S	L-08
51.	Launch Site Procedures	B	L-06
52.	SC Launch Site Operations Plan (Final)	S	L-06
53.	Launch Operations Plan (LOP)	B	L-05
54.	Best-Estimate Trajectory	B	L-04
55.	Vehicle Information Memorandum (VIM) Data	B	L-04
56.	SC/Fairing Clearance Analysis	B	L-03
57.	RF Compatibility Analysis Report	B	L-01
58.	Vehicle Information Memorandum (VIM)	B	L-4d
59.	Launch Readiness Review Data Package	B	L-1d
60.	Launch	B	L-0
61.	Post-Launch Report	S	L+2hr
62.	Post-Launch Orbit Confirmation Data	B	L+7d

# Spacecraft Contractor Data Requirements

Spacecraft Questionnaire	2	L-91
Fairing Requirements	8	L-91
SC Drawings	18	L-91
SC Mathematical Model	3	L-91
Preliminary Mission Analysis (PMA) Inputs	11	L-91
Missile System Prelaunch Safety Package SC Inputs	9	L-91
SC Mass Properties Statement (Initial/Update)	22	L-91/L-36
SC Environmental Test Documents	5	L-85
Mission Specification Comments	4	L-64
SC Compatibility Drawing Comments	18	L-64
SC-to-LCC Wiring Diagram Review	28	L-64
Mission Operational and Support Requirements	12, 13	L-52
Payload Processing Requirements Document	14	L-52
FAA License Information	2	L-52
Radio Frequency Applications Inputs	10	L-52
Electrical Wiring Requirements	7	L-51
Launch Vehicle Insignia	15	L-35
Final Mission Analysis (FMA) Inputs	17	L-35
SC Integrated Test Procedure	21	L-26
SC Launch-Site Procedures	20	L-26
Launch Window (Initial/Final)	16	L-08
Postlaunch Orbit Confirmation Data	27	L+2 hr

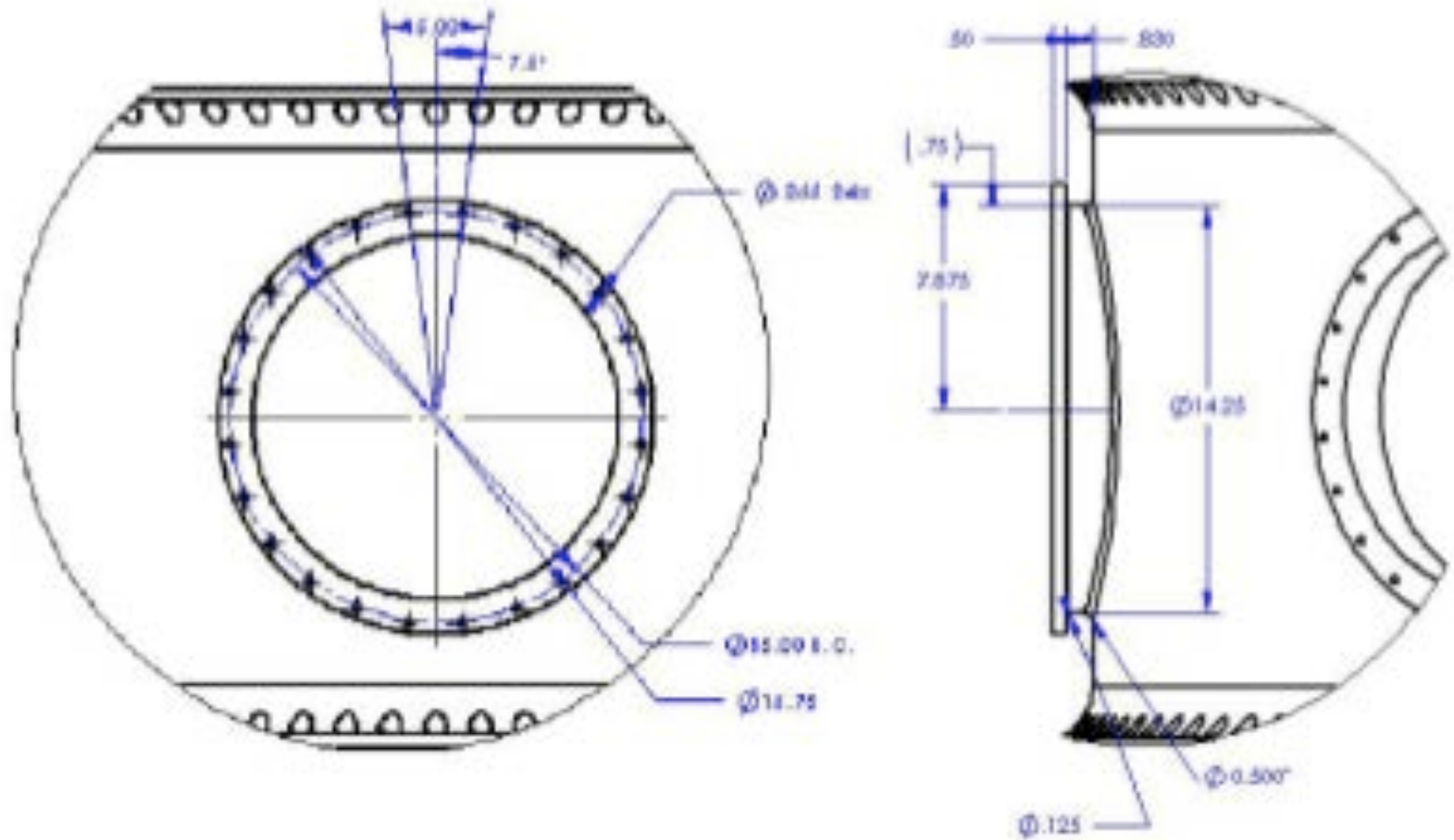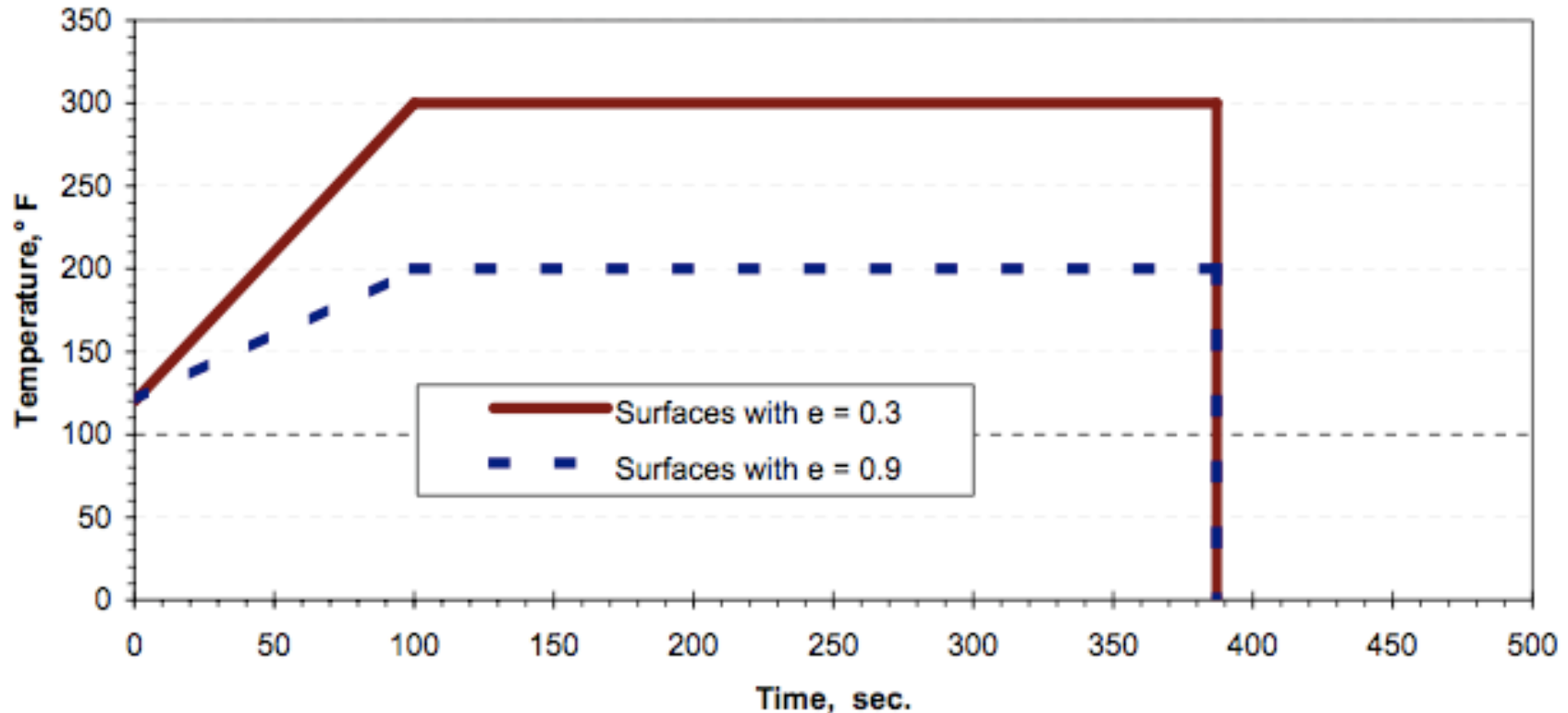# EELV Secondary Payload Adapter (ESPA)

Primary Payload / Satellite

ESPA structure

Secondary Payloads

EELV Cone Adapter
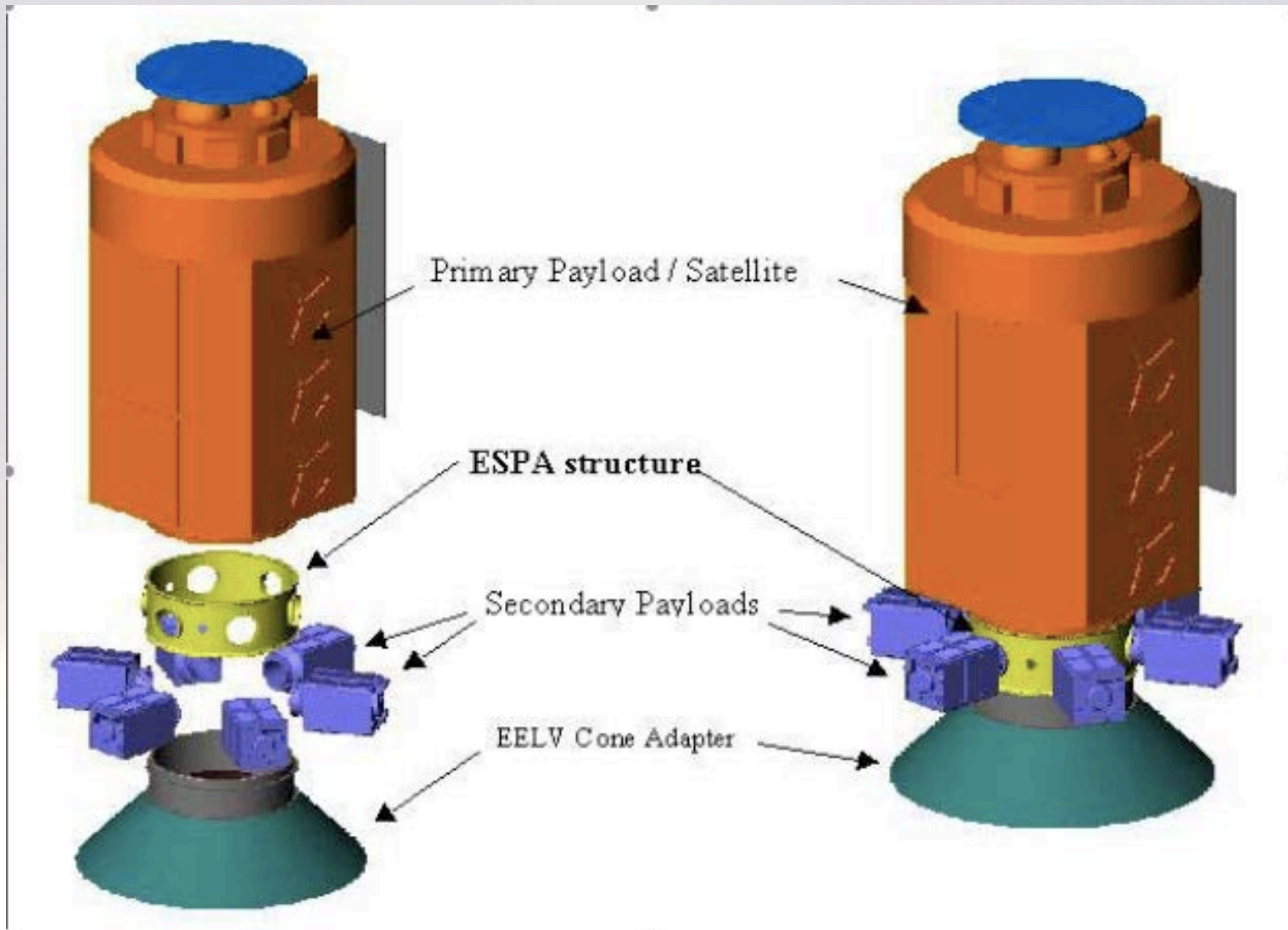
ESPA Mass/CG Limitations
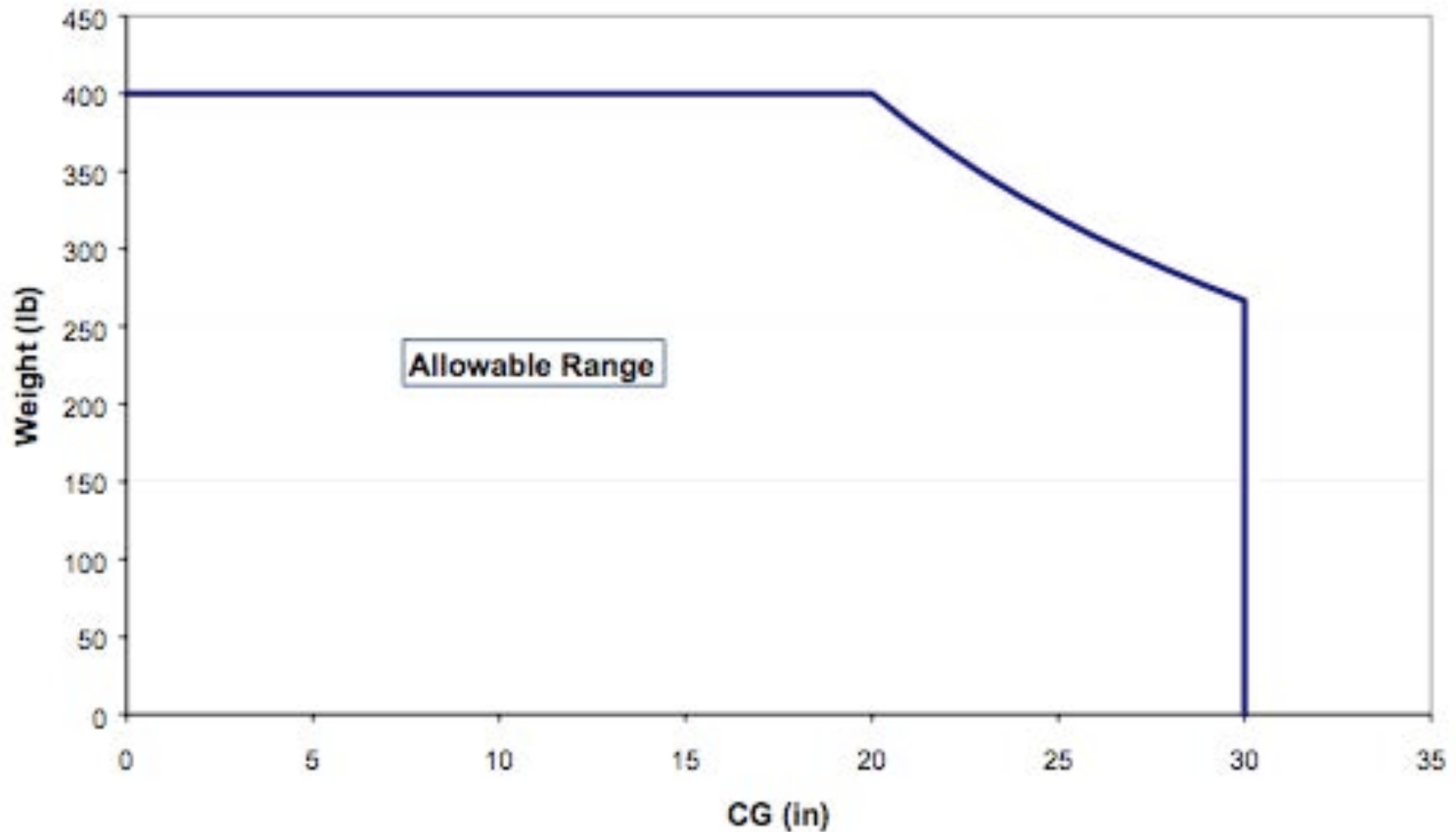
ESPA Mechanical Interface

UNIVERSITY OF
MARYLAND

ESPA Surface Temperature Profiles

ESPA Shock Environment

UNIVERSITY OF
MARYLAND
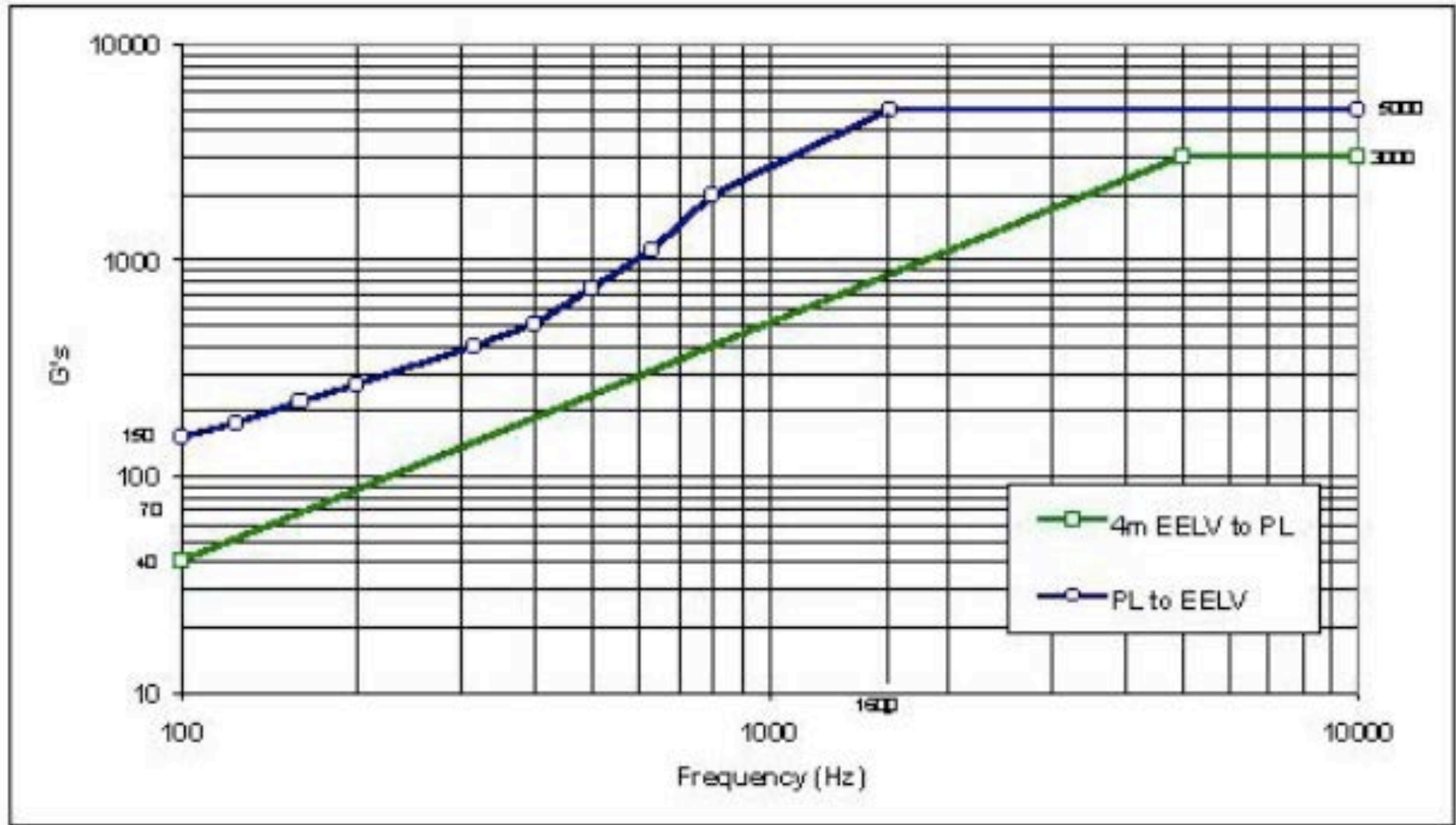
Final Thoughts about Payloads

- Payload development details are specific to the launch vehicle

- Integration processes are unique to the individual launch site

- Every launch is a custom operation

- Payload documentation for launch is comparable to complexity of payload itself

- But there's nothing like seeing your payload heading to orbit!!!