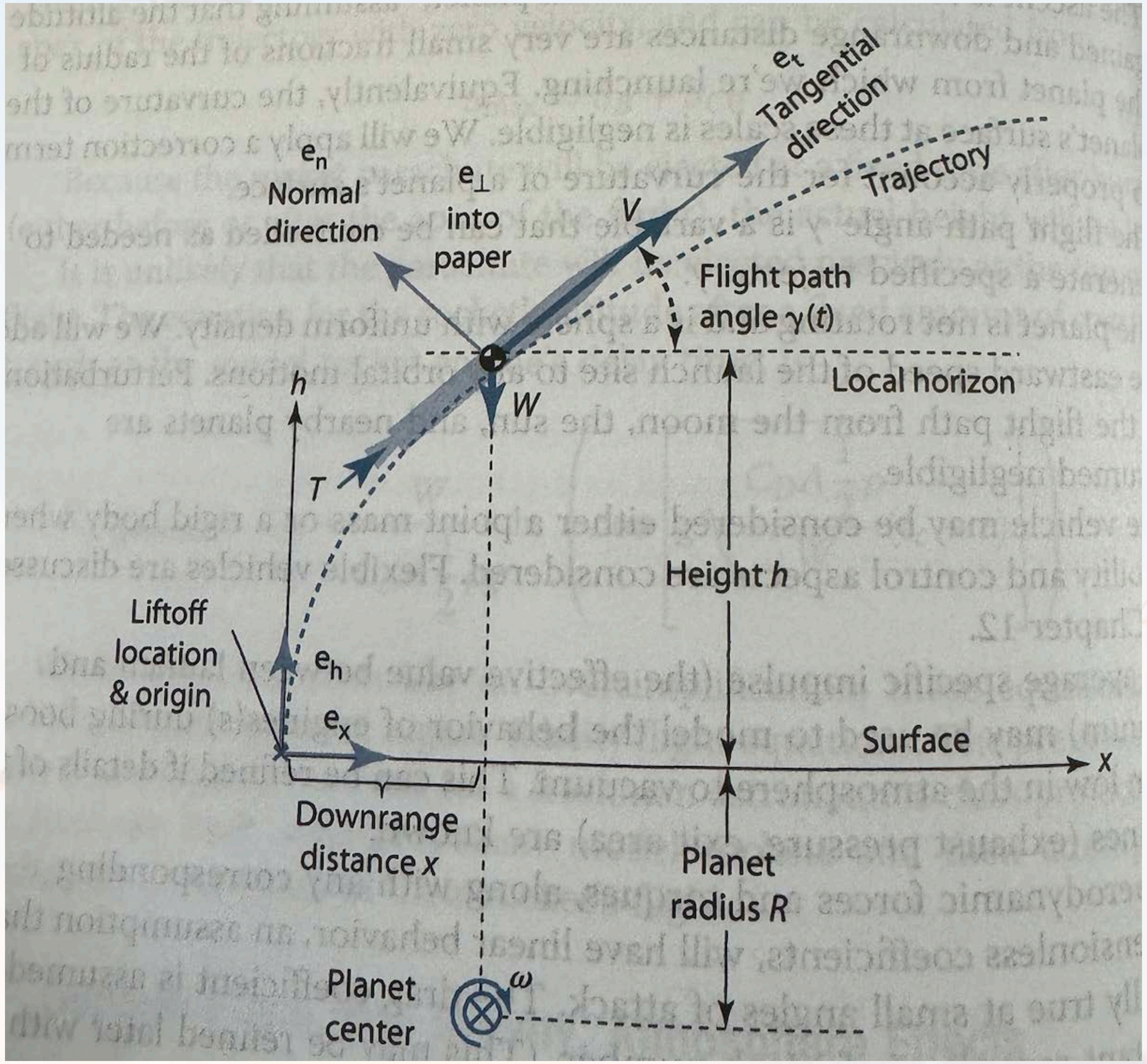
Launch Abort Systems

- First, a word from our sponsor (planar state equations for launch)
- Apollo launch escape system (LES)
- Discussion of requirements (HL-20)
- Shuttle abort modes
- Orion launch abort system (LAS)
- Dragon abort
- New Shepard abort

Coordinate System for Launch Trajectories



from Edberg and Costa, Design of Rockets and Space Launch Vehicles

Planar State Equations for Launch Trajectories

$$\frac{\mathrm{d}v}{\mathrm{d}t} = \frac{T}{m} - \frac{D}{m} - g\sin\gamma$$

$$\frac{\mathrm{d}\gamma}{\mathrm{d}t} = -\left(\frac{g}{v} - \frac{v}{R+h}\right)\cos\gamma$$

$$\frac{\mathrm{d}h}{\mathrm{d}t} = v\sin\gamma$$

$$\frac{\mathrm{d}x}{\mathrm{d}t} = \frac{R_0}{R_0+h}v\cos\gamma$$

Ancillary Equations for Launch Trajectories

$$m(t) = m_0 - \dot{m}t;\ \text{mass flow}\ \dot{m} = \frac{T}{g_0 I_{sp}}$$

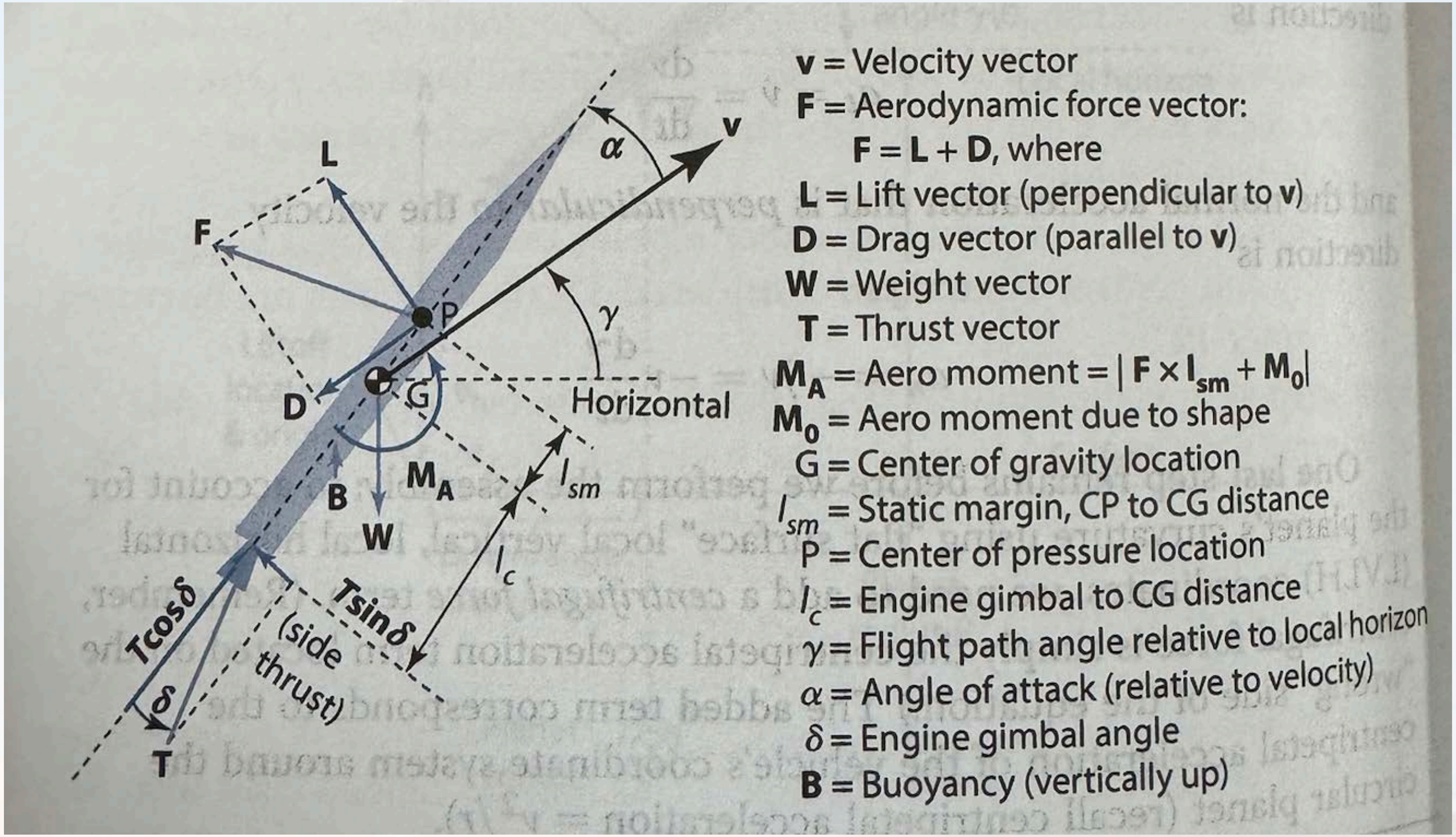
$$D = \frac{1}{2}\rho v^2 c_D S_{ref};\ c_D \text{ is a function of Mach number}$$

$$P_\infty(h) = P_0 e^{-h/h_s}$$

$$\rho(h) = \rho_0 e^{-h/h_s}$$

$$g(h) = \frac{g_0}{\left(1 + h/R_0\right)^2}$$

Free-Body Diagram of Launch Vehicle



from Edberg and Costa, Design of Rockets and Space Launch Vehicles

Dynamic Equations Including Steering

$$ma_t = m\frac{\mathrm{d}v}{\mathrm{d}t} = T\cos(\alpha+\delta) - D - mg\sin\gamma$$

$$ma_n = mv\frac{\mathrm{d}\gamma}{\mathrm{d}t} + \frac{mv^2\cos\gamma}{R_0+h} = L - mg\cos\gamma + T\sin(\alpha+\delta)$$

$$M - l_{CG}T\sin\delta + l_{AC}L\cos\alpha = I_{\text{pitch}}\frac{\partial^2\theta}{\partial t^2}$$

For α, δ small...

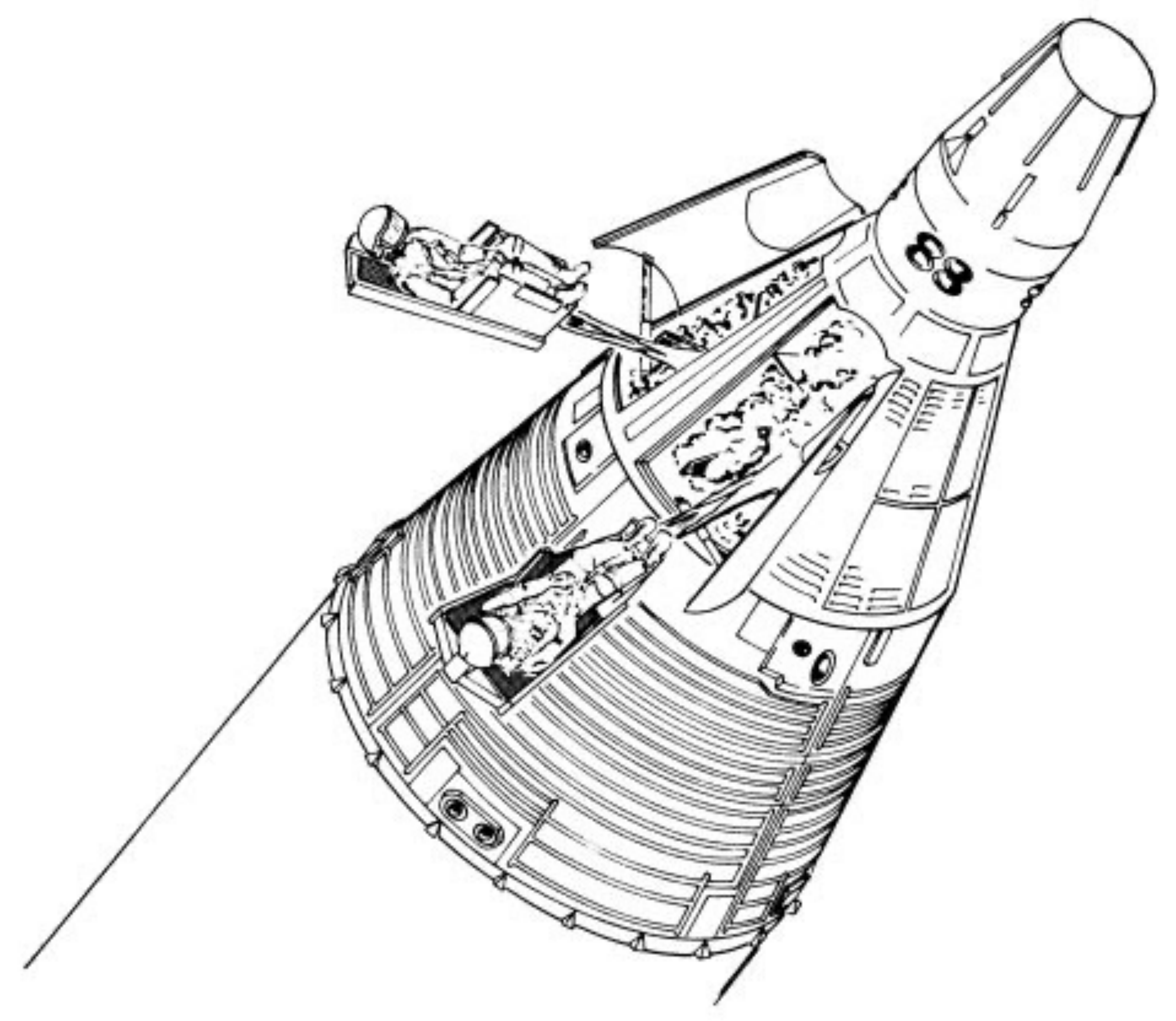
$$ma_t = m\frac{\mathrm{d}v}{\mathrm{d}t} = T - D - mg\sin\gamma$$

$$mv\frac{\mathrm{d}\gamma}{\mathrm{d}t} = L - mg\cos\gamma - \frac{mv^2\cos\gamma}{R_0+h}$$

Atlas-Agena Launch Failure

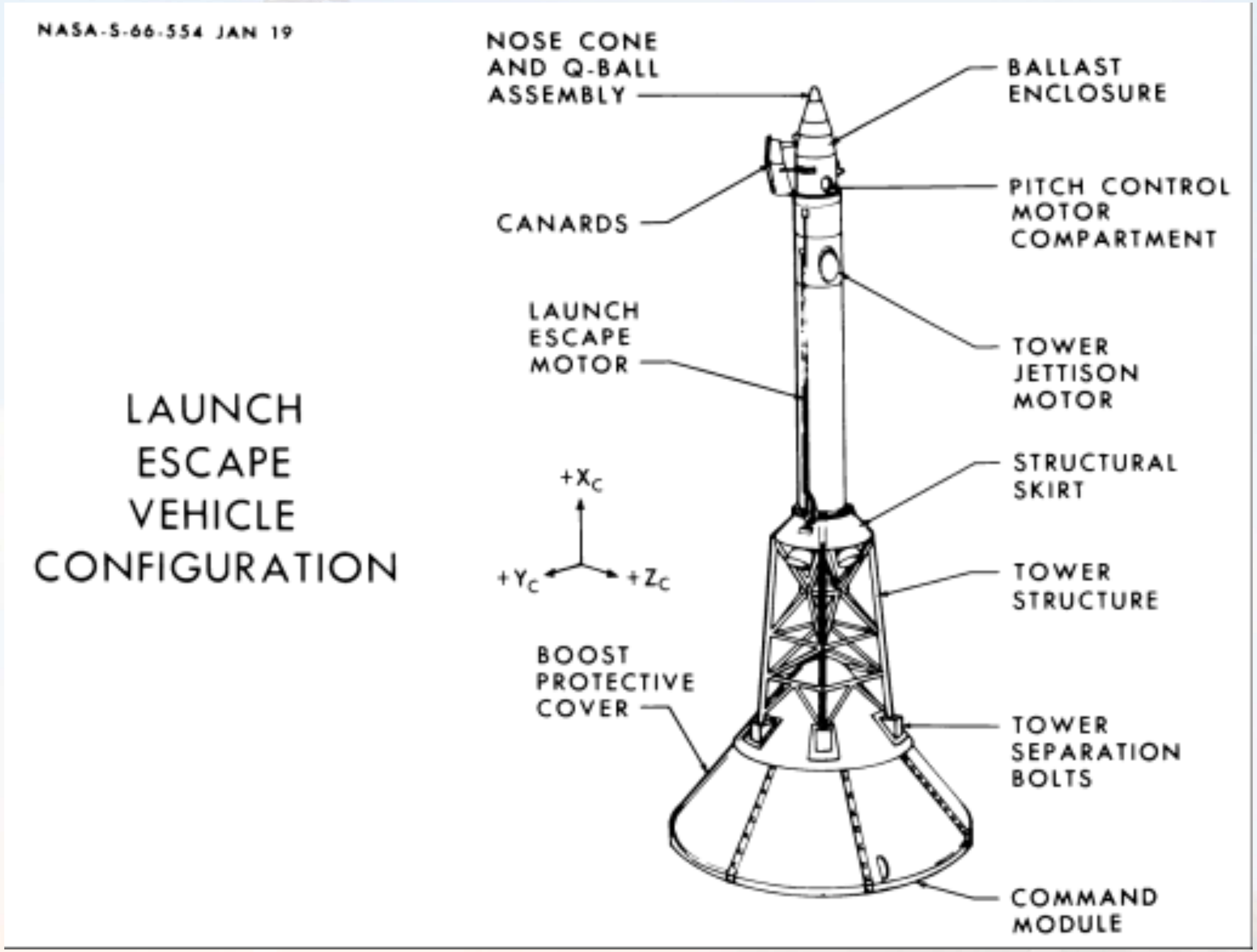
Mercury Pad Abort Test

Gemini Ejection Seats

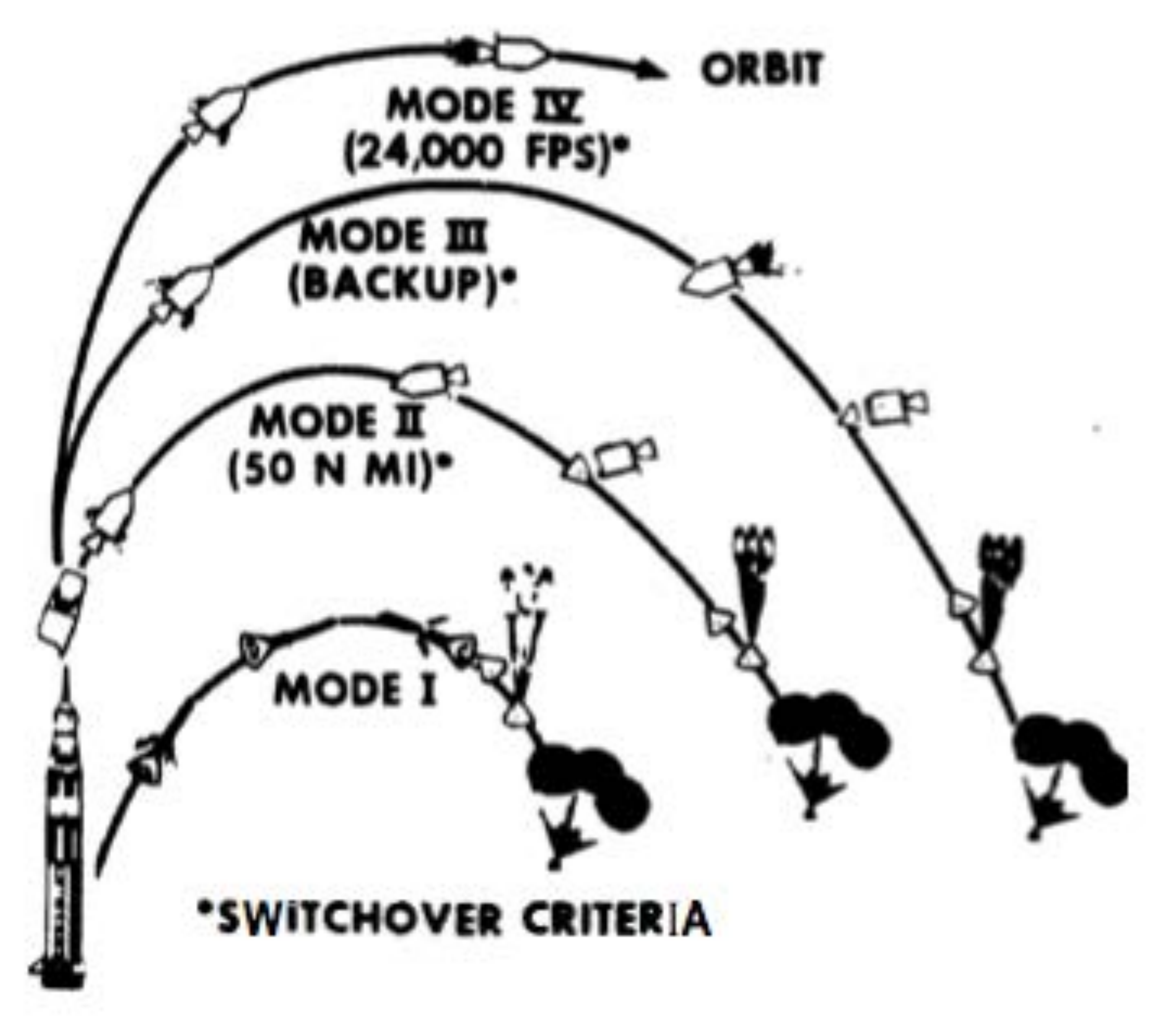


Gemini 6A Pad Abort

Apollo Launch Escape System

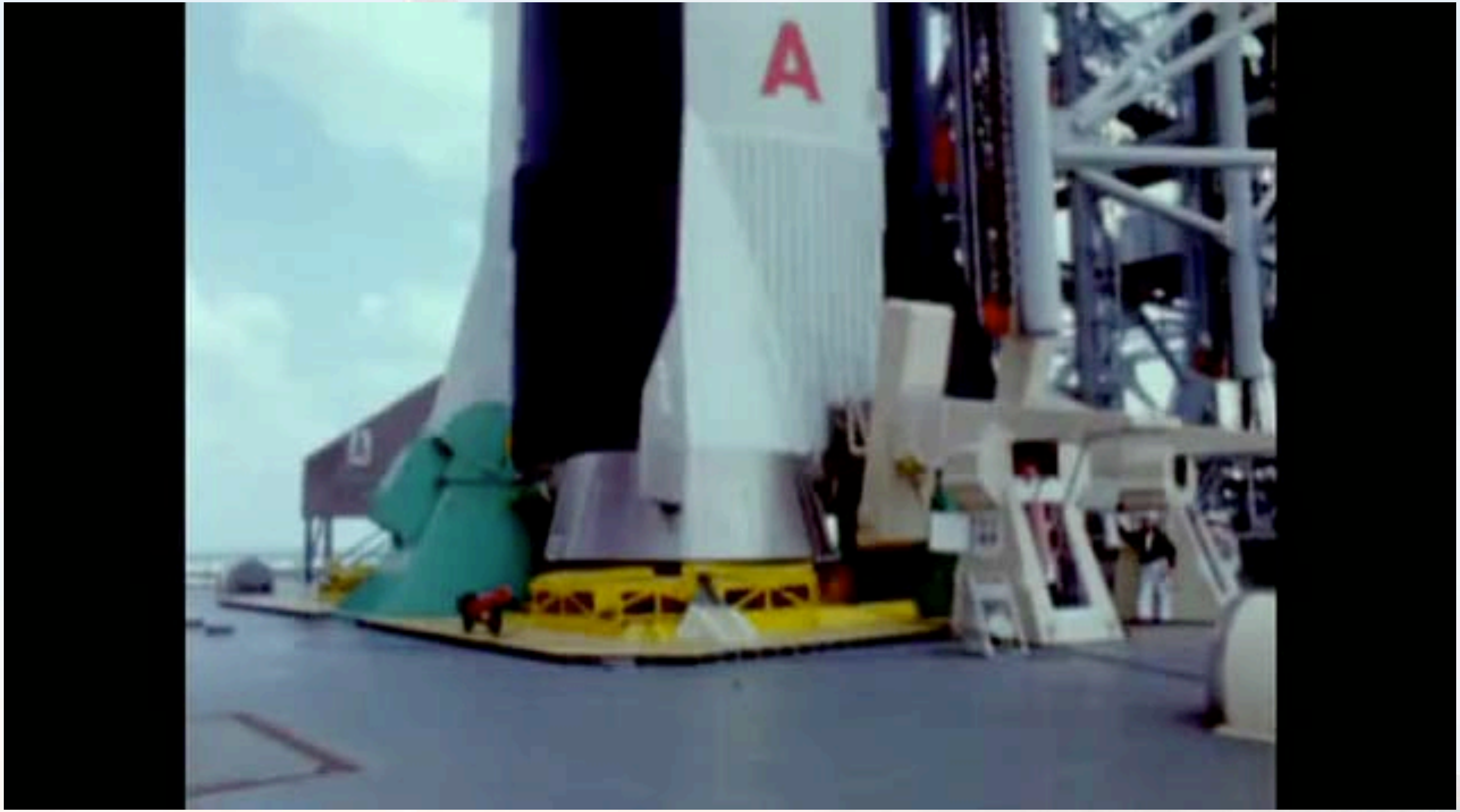


Apollo Abort Modes

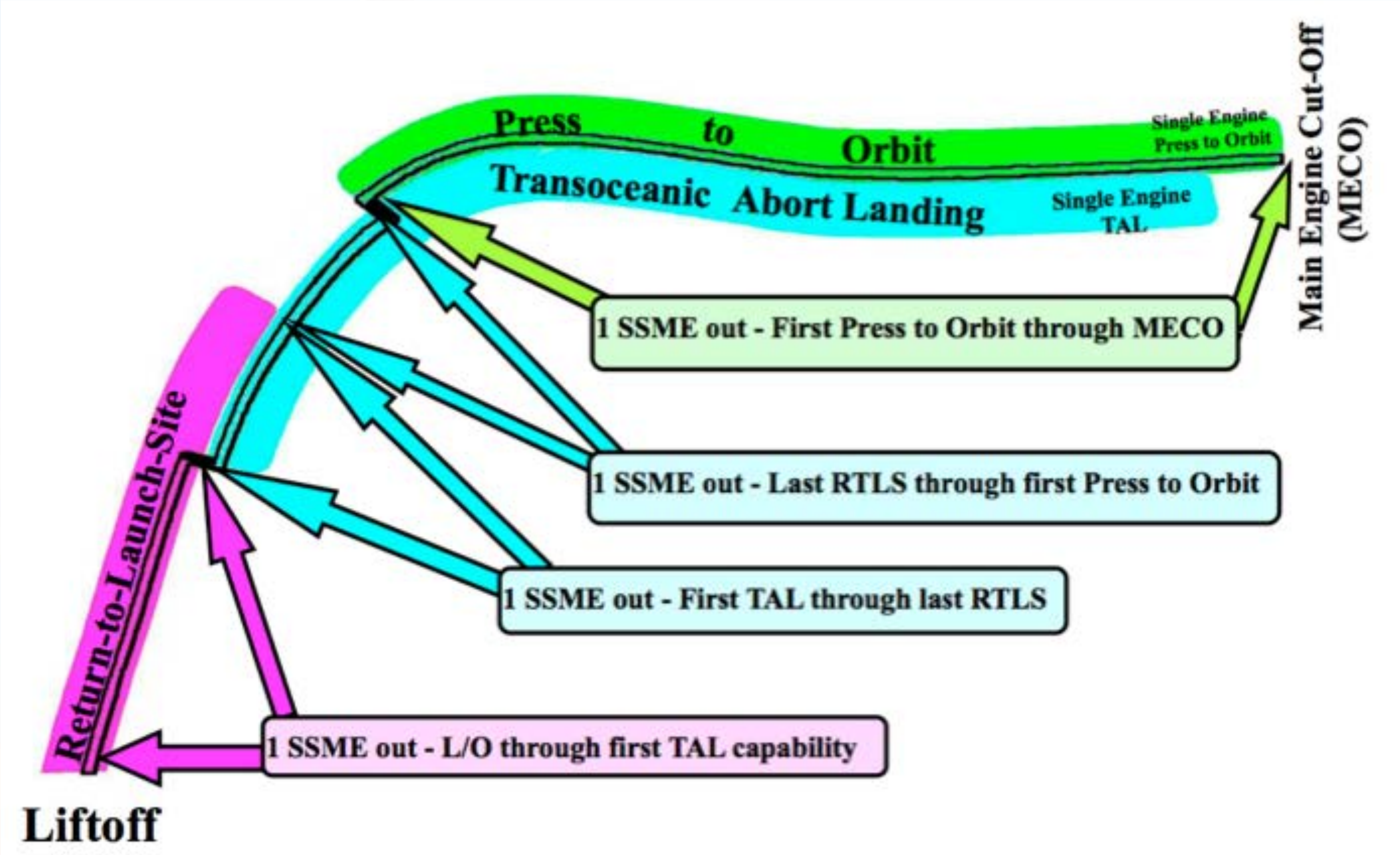


from Hyle et. al., “Abort Planning for Apollo Missions” AIAA 1970-0094

Apollo In-Flight Abort Test

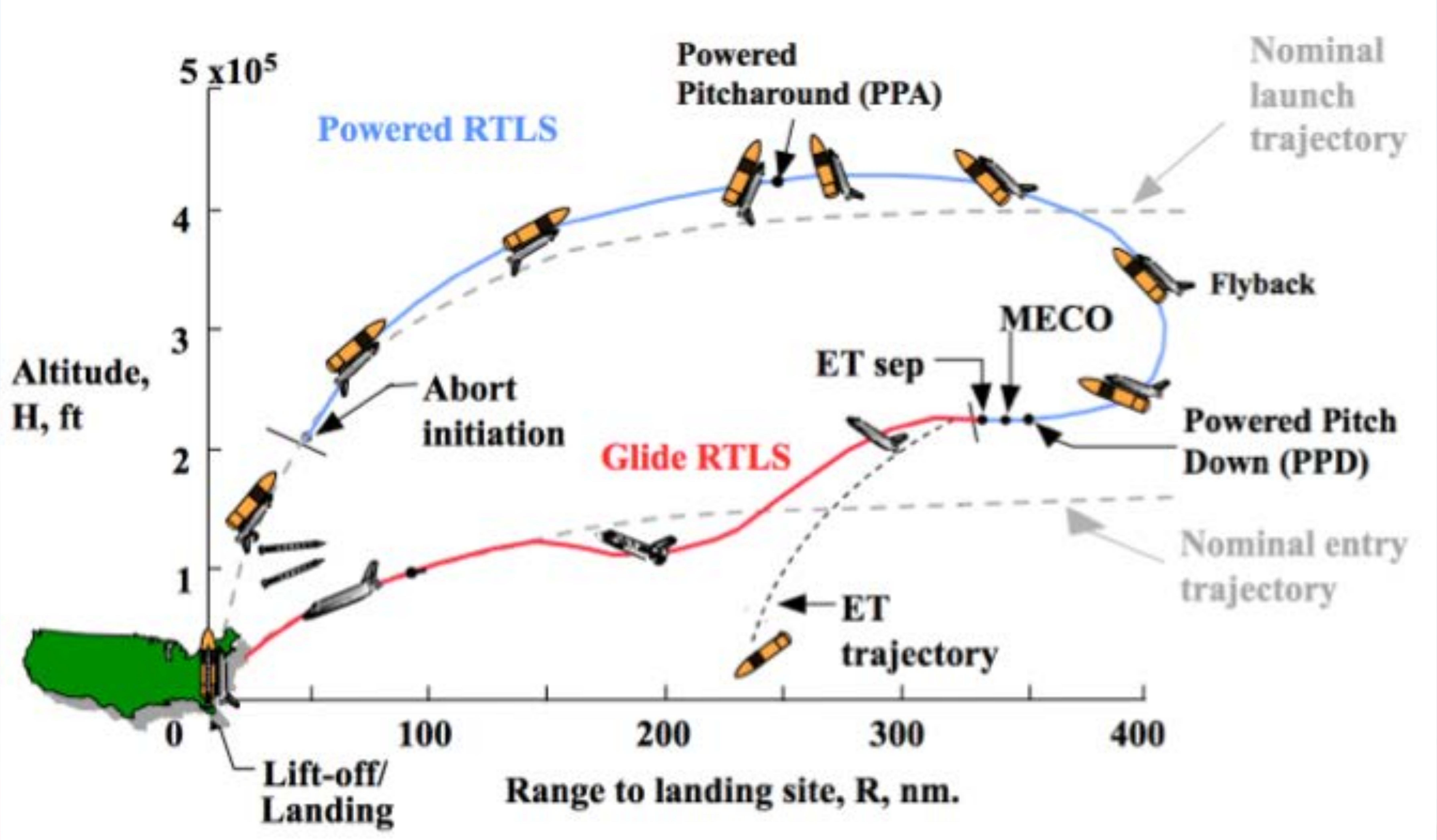


Shuttle Ascent Abort Profile



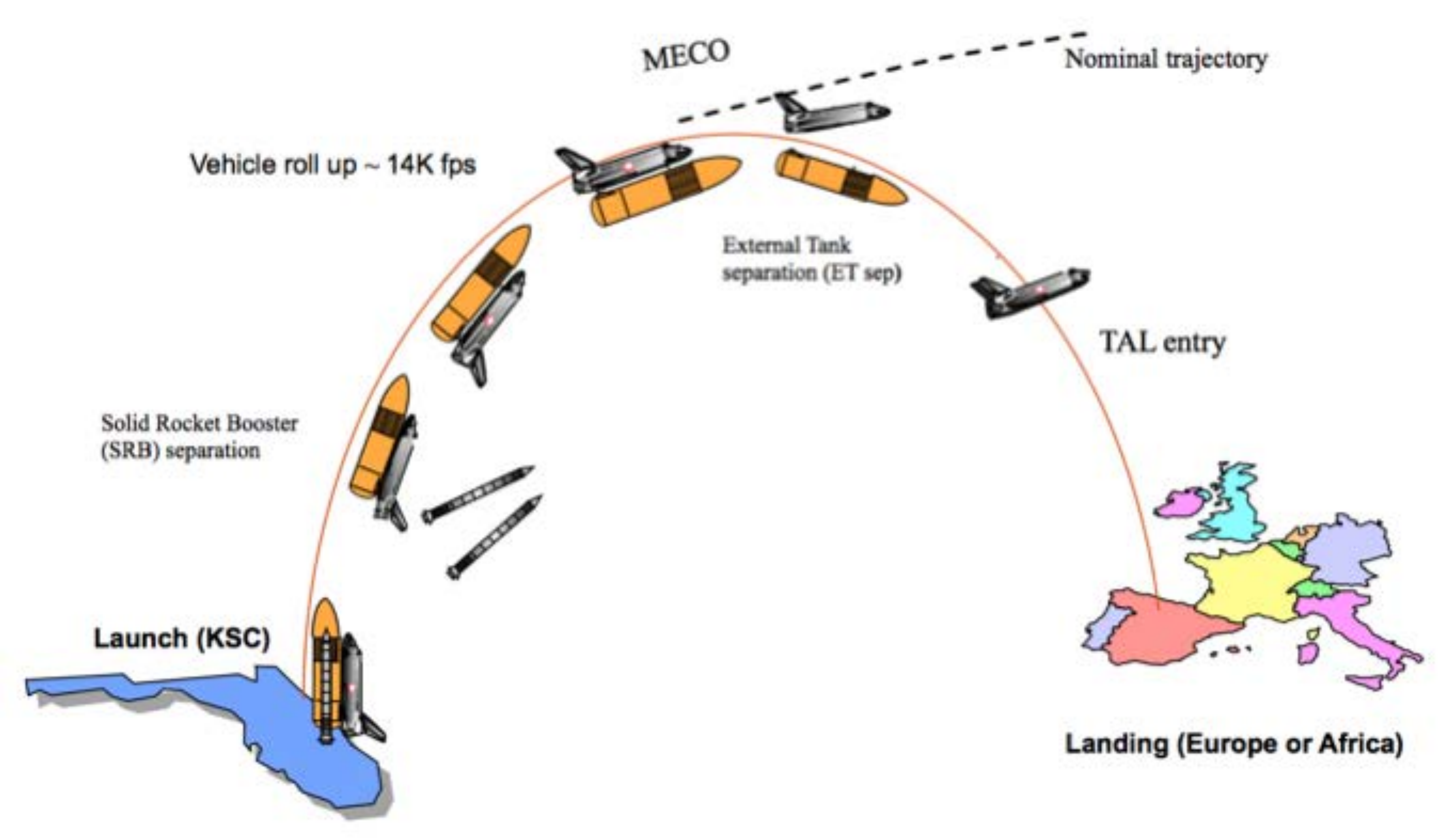
from Henderson and Nguyen, "Space Shuttle Abort Evolution" AIAA 2011-7245

Shuttle Return to Launch Site (RTLS)



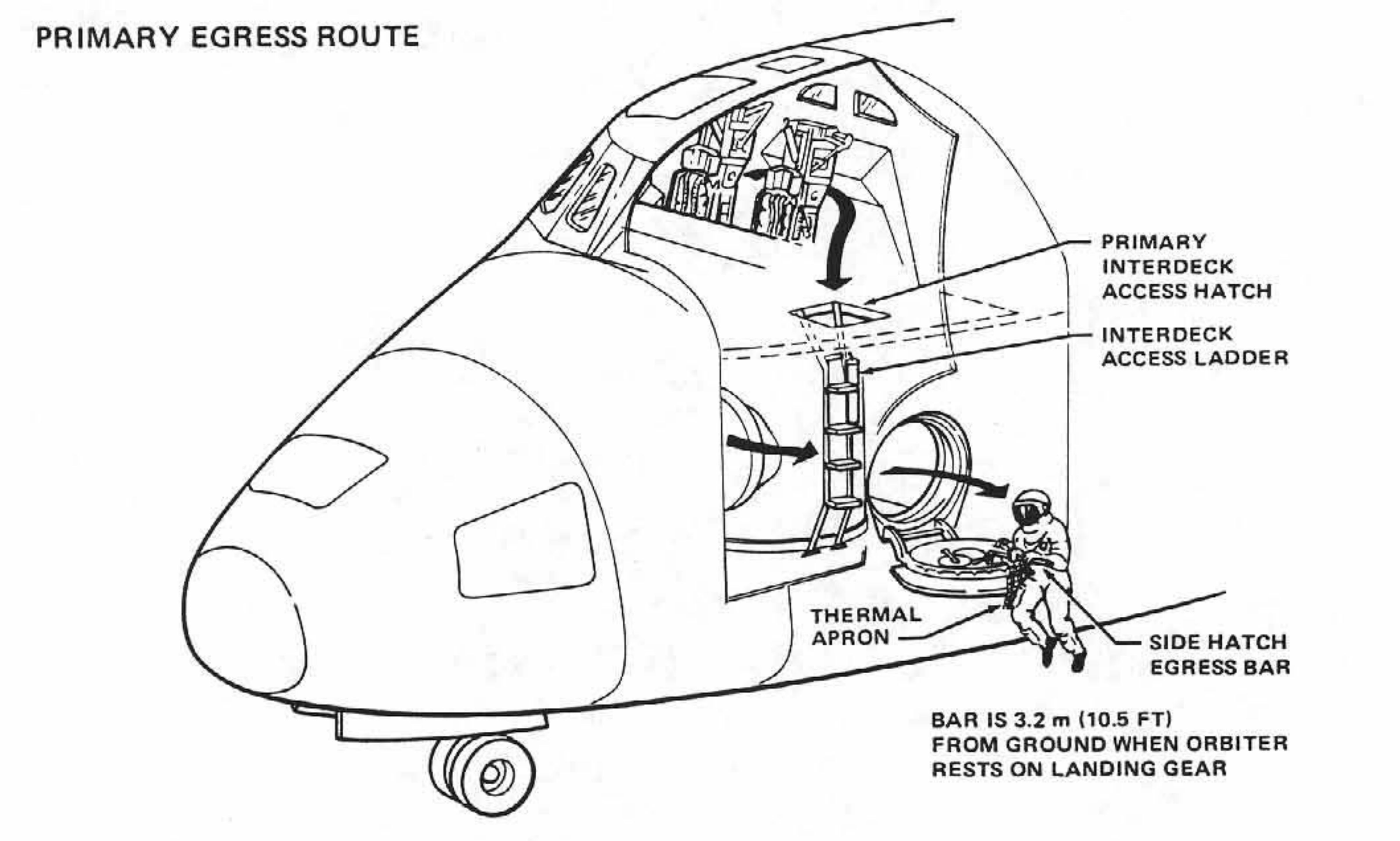
from Henderson and Nguyen, “Space Shuttle Abort Evolution” AIAA 2011-7245

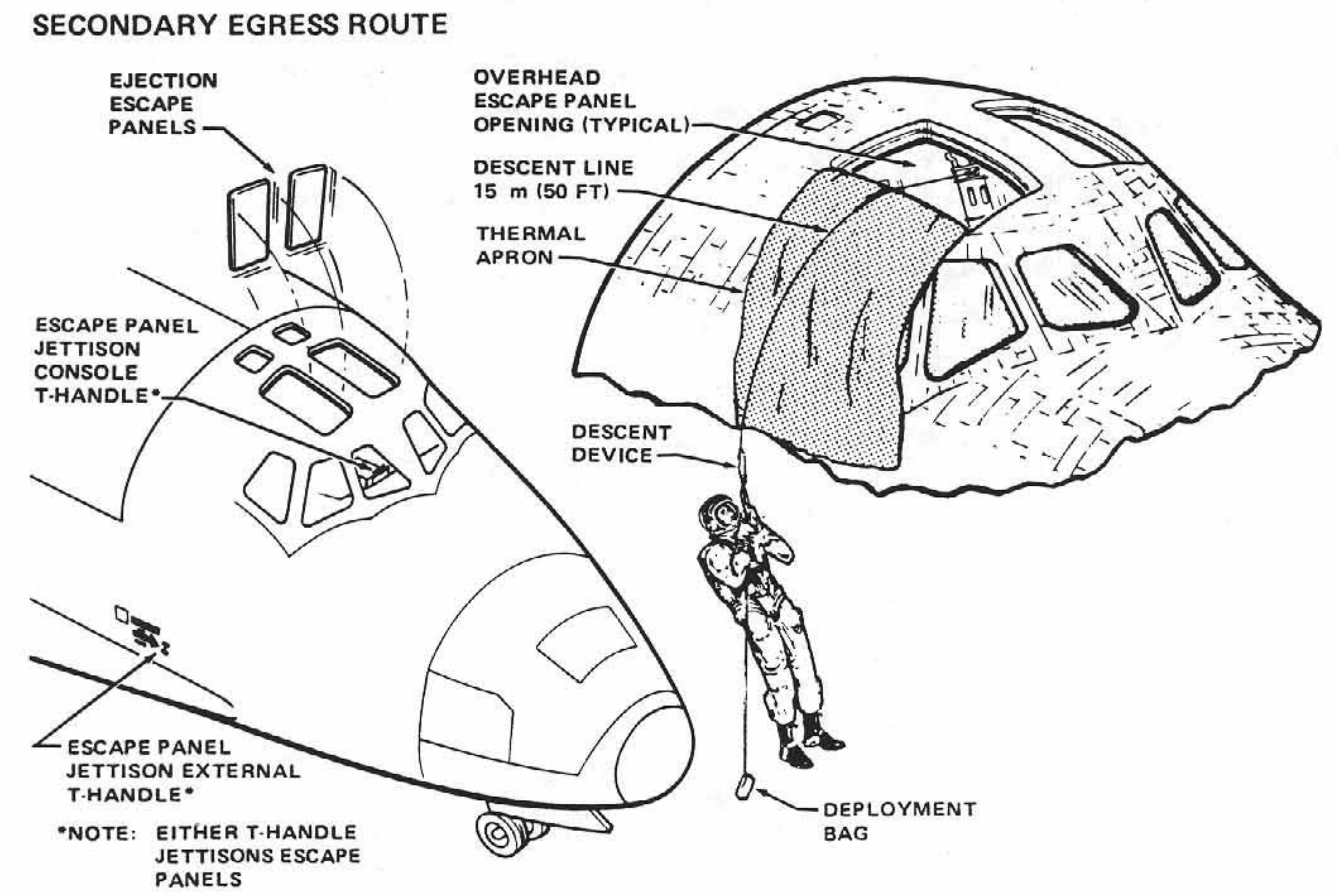
Shuttle Transatlantic Abort Landing (TAL)



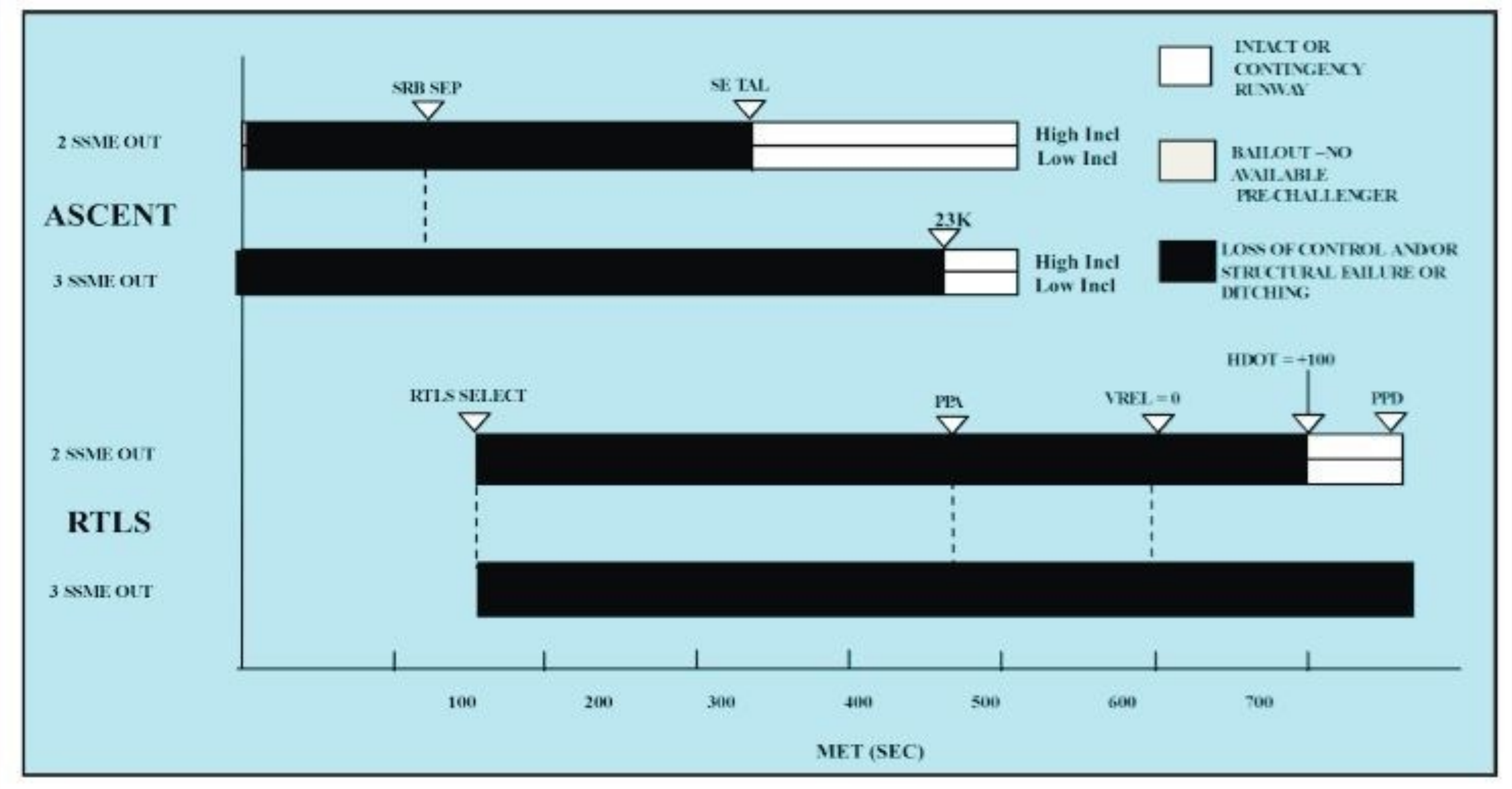
from Henderson and Nguyen, “Space Shuttle Abort Evolution” AIAA 2011-7245

Crew Egress Following Emergency Landing

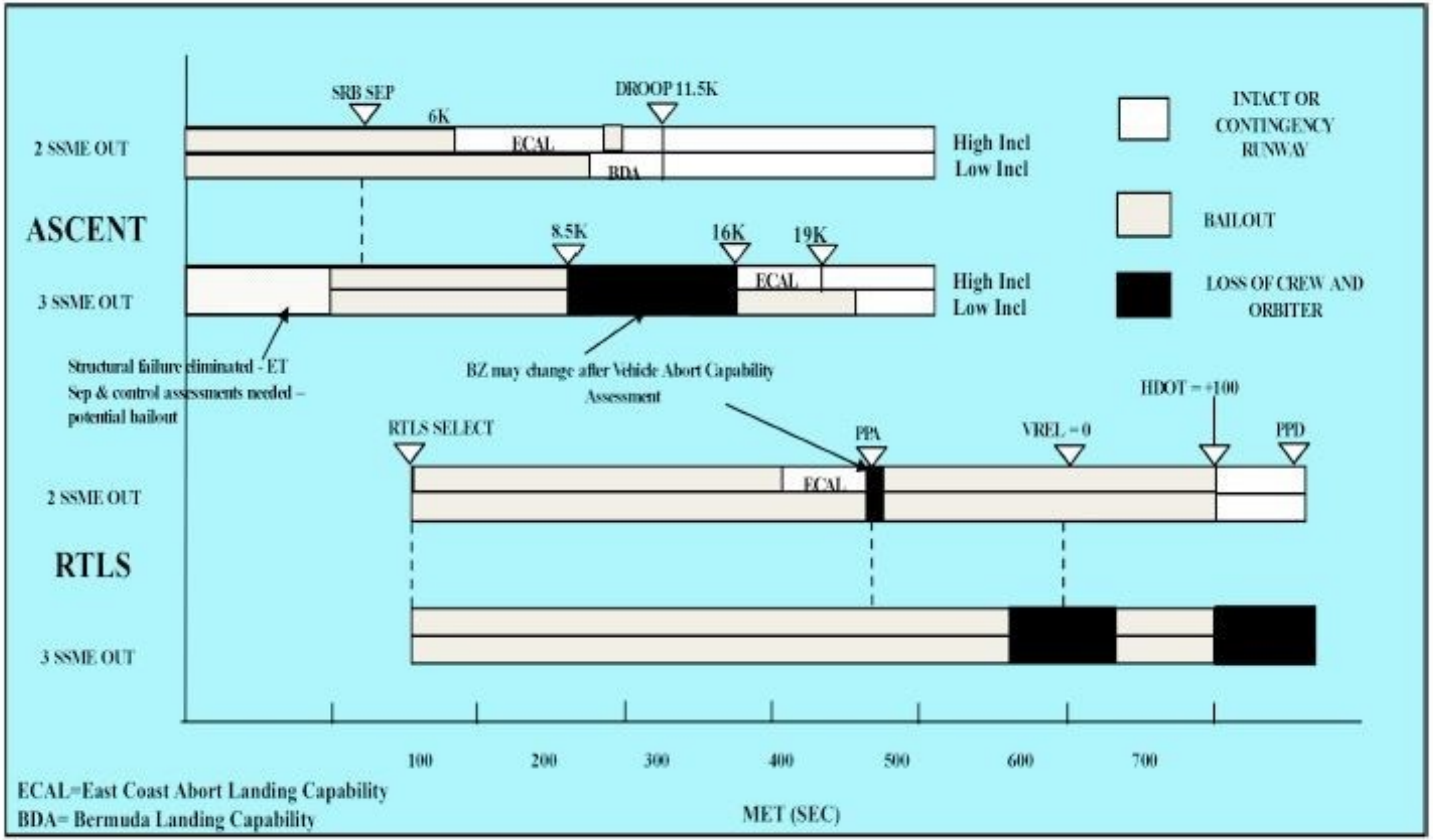




STS Abort Prior to 51-L

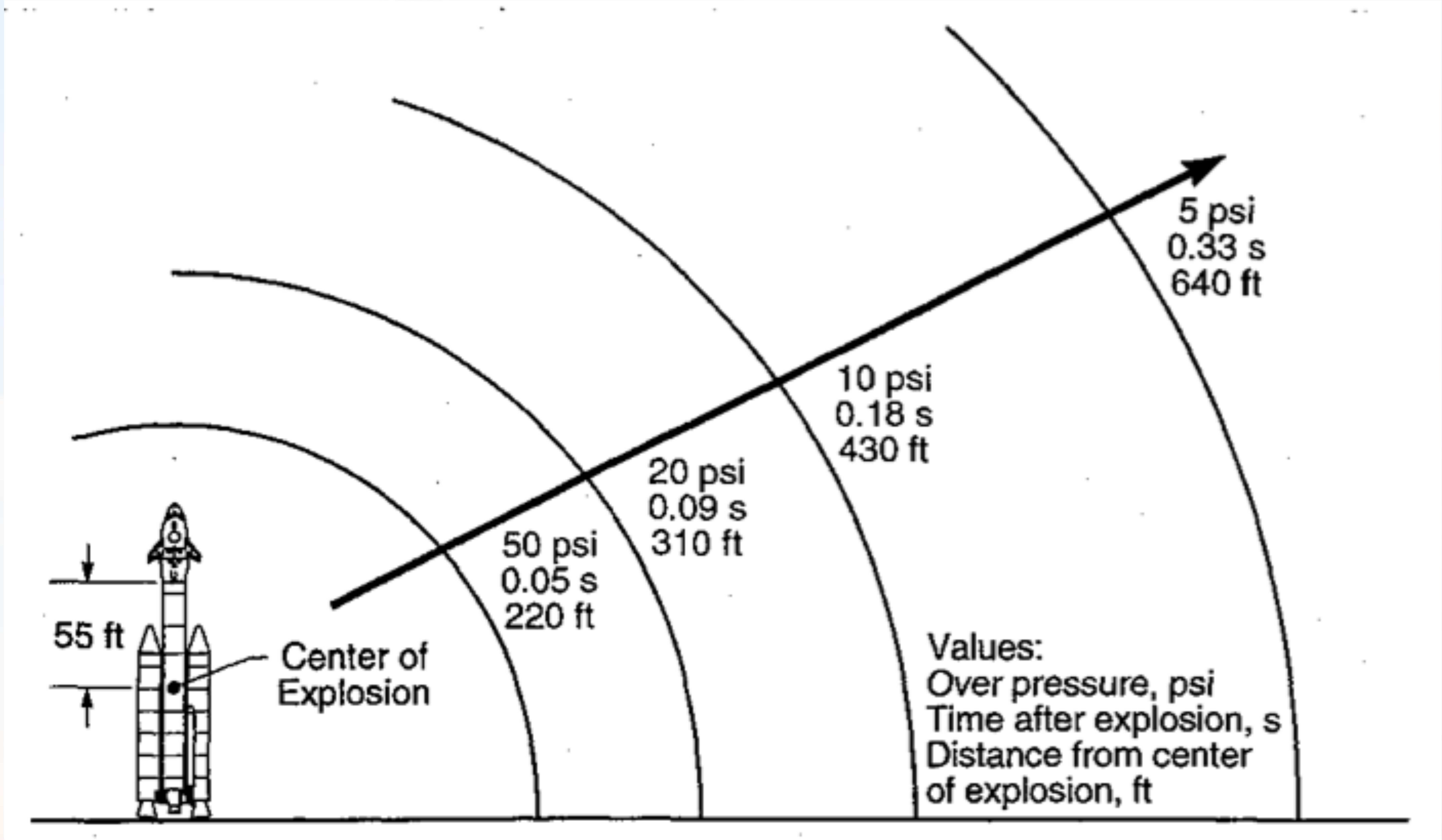


Shuttle Abort Post-2000



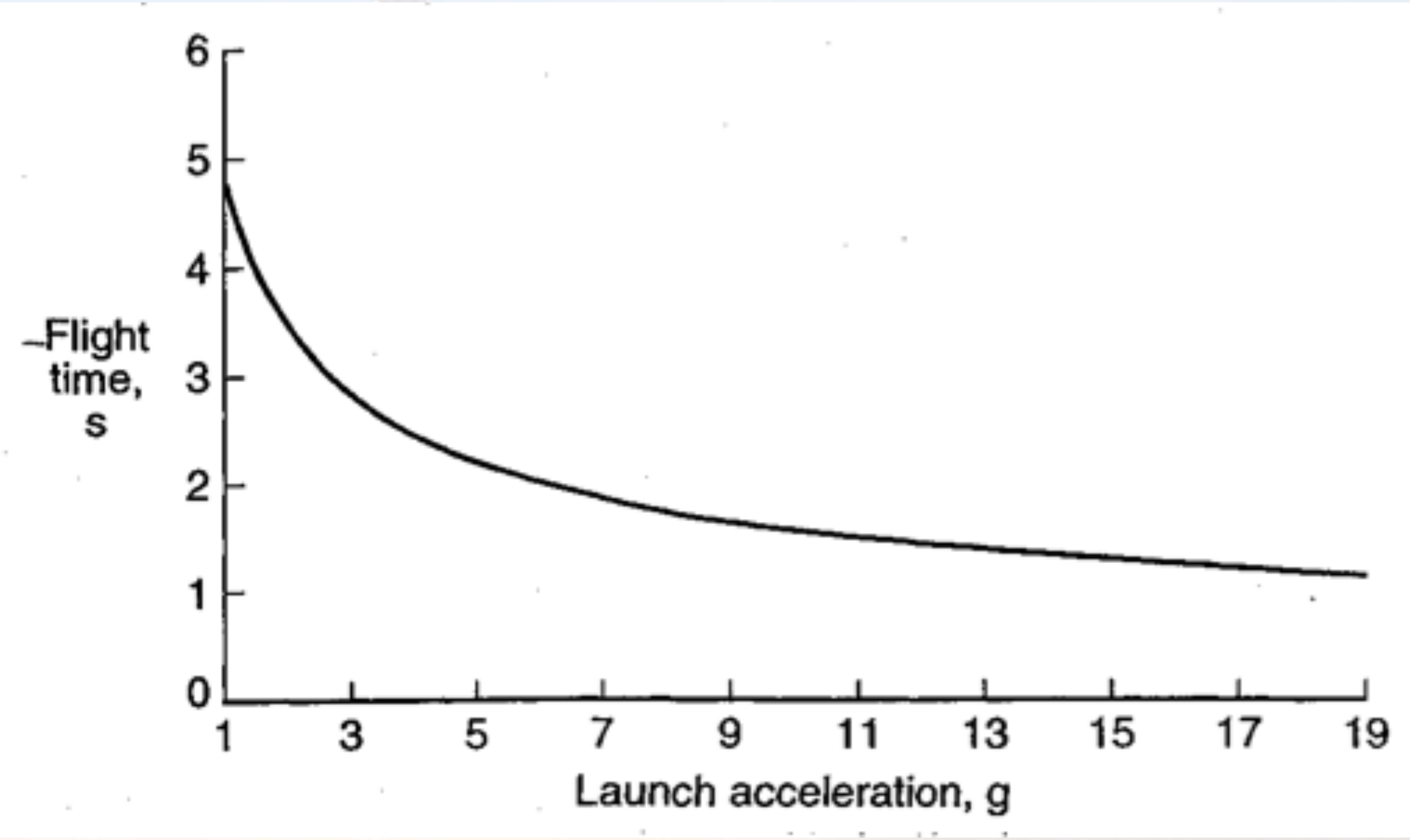
Shuttle Bail-out Certification Tests

Titan IIIC Blast Pressures



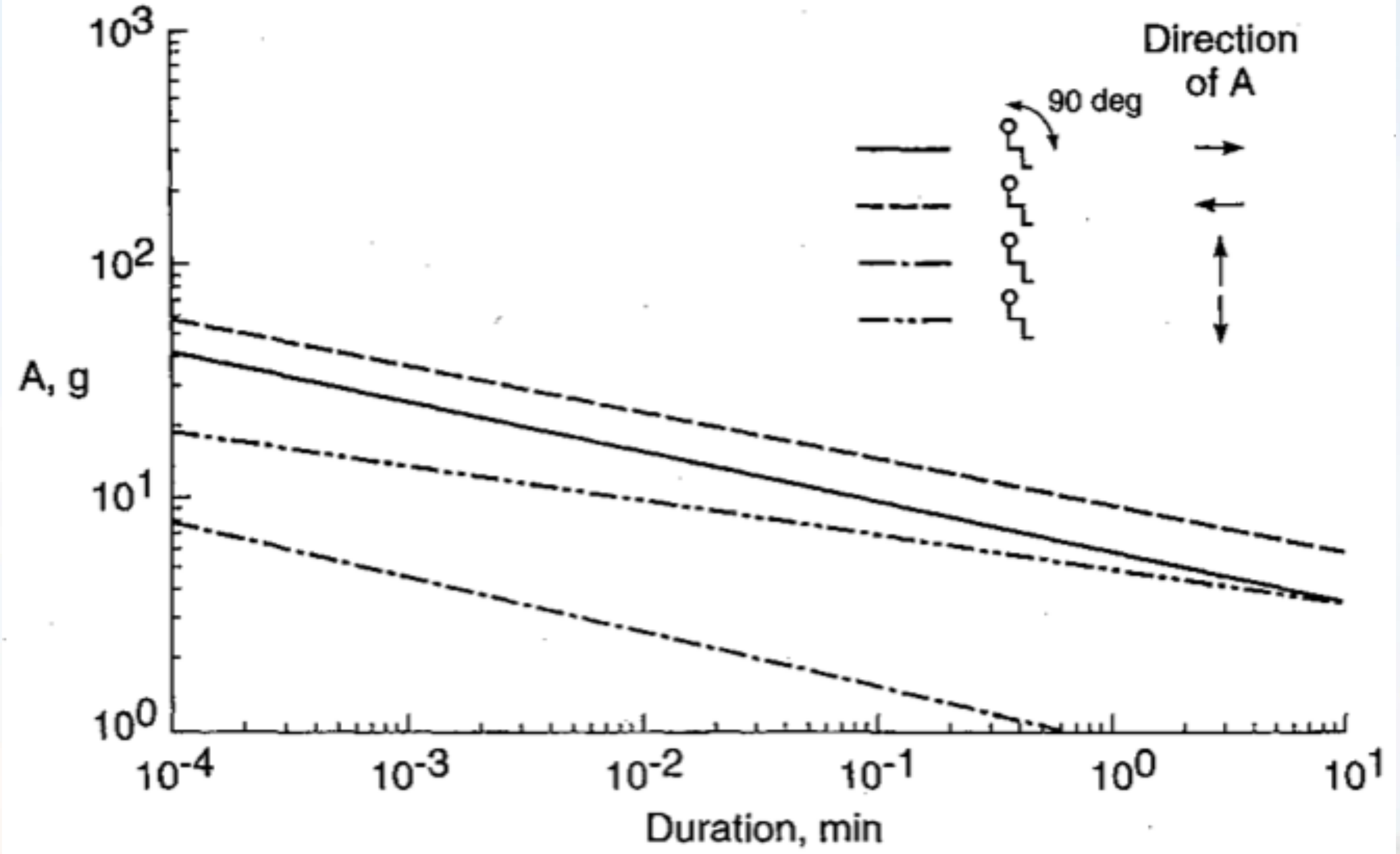
from Naftel and Talay, "Ascent Abort Capability for the HL-20" JSR v30 n5, Sept-Oct 1993

Flight Time to 10psi Overpressure Limit



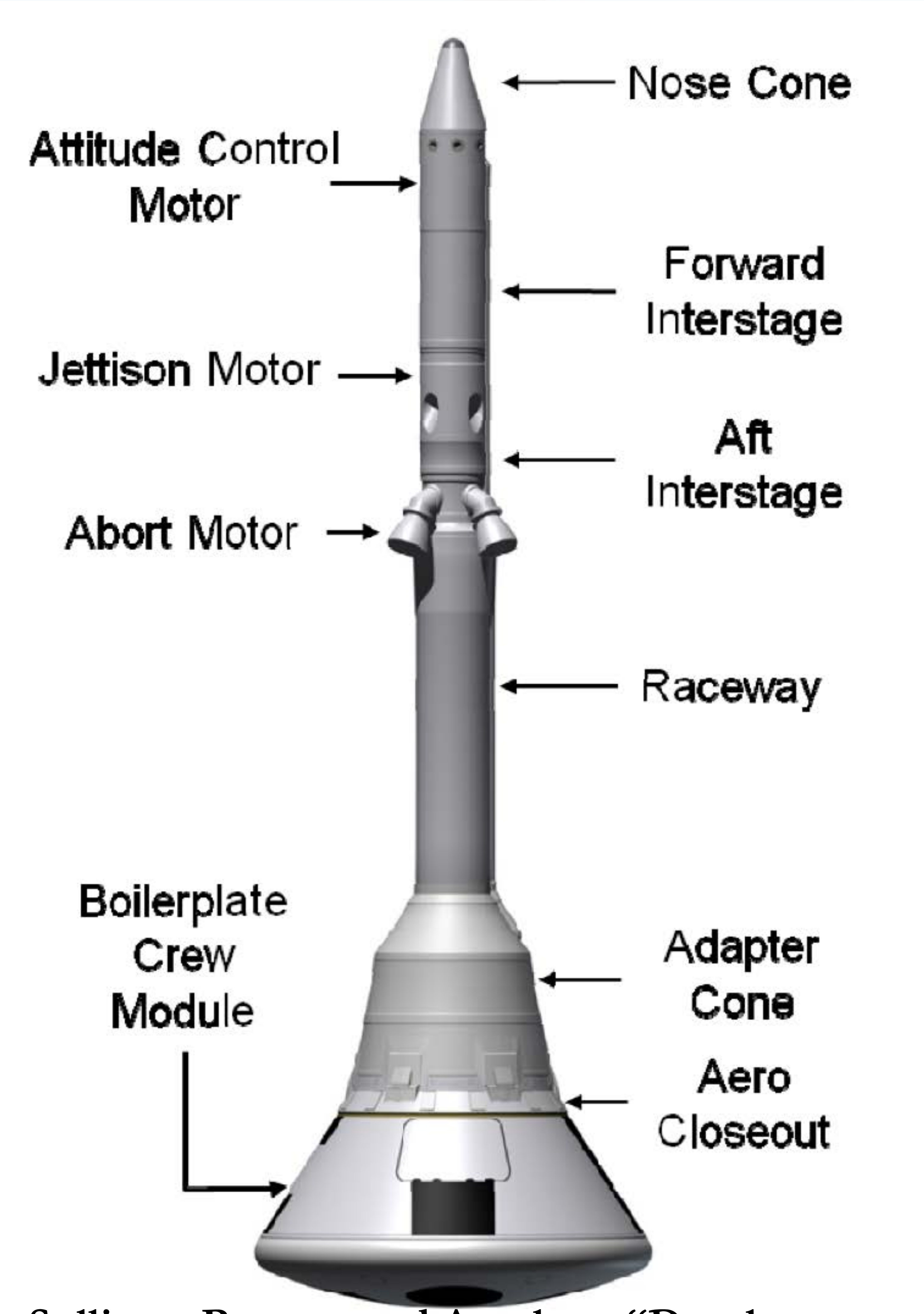
from Naftel and Talay, "Ascent Abort Capability for the HL-20" JSR v30 n5, Sept-Oct 1993

Human Acceleration Limits



from Naftel and Talay, "Ascent Abort Capability for the HL-20" JSR v30 n5, Sept-Oct 1993

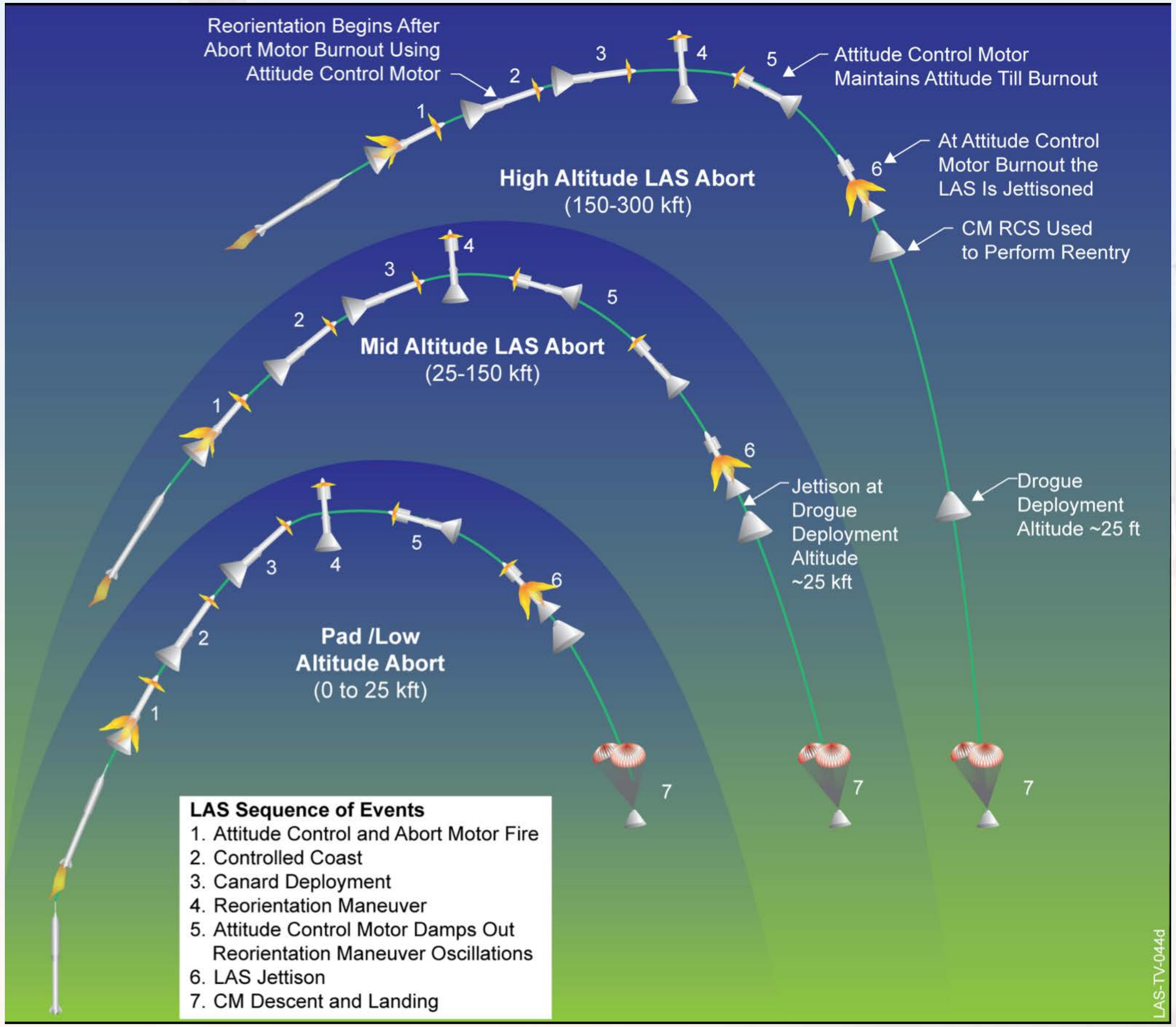
Orion Launch Abort System



from Sullivan, Bocam, and Ascalera, "Development of the Orion PA-1 Launch Abort System" AIAA 2011-7129

Orion Pad Abort Test 1

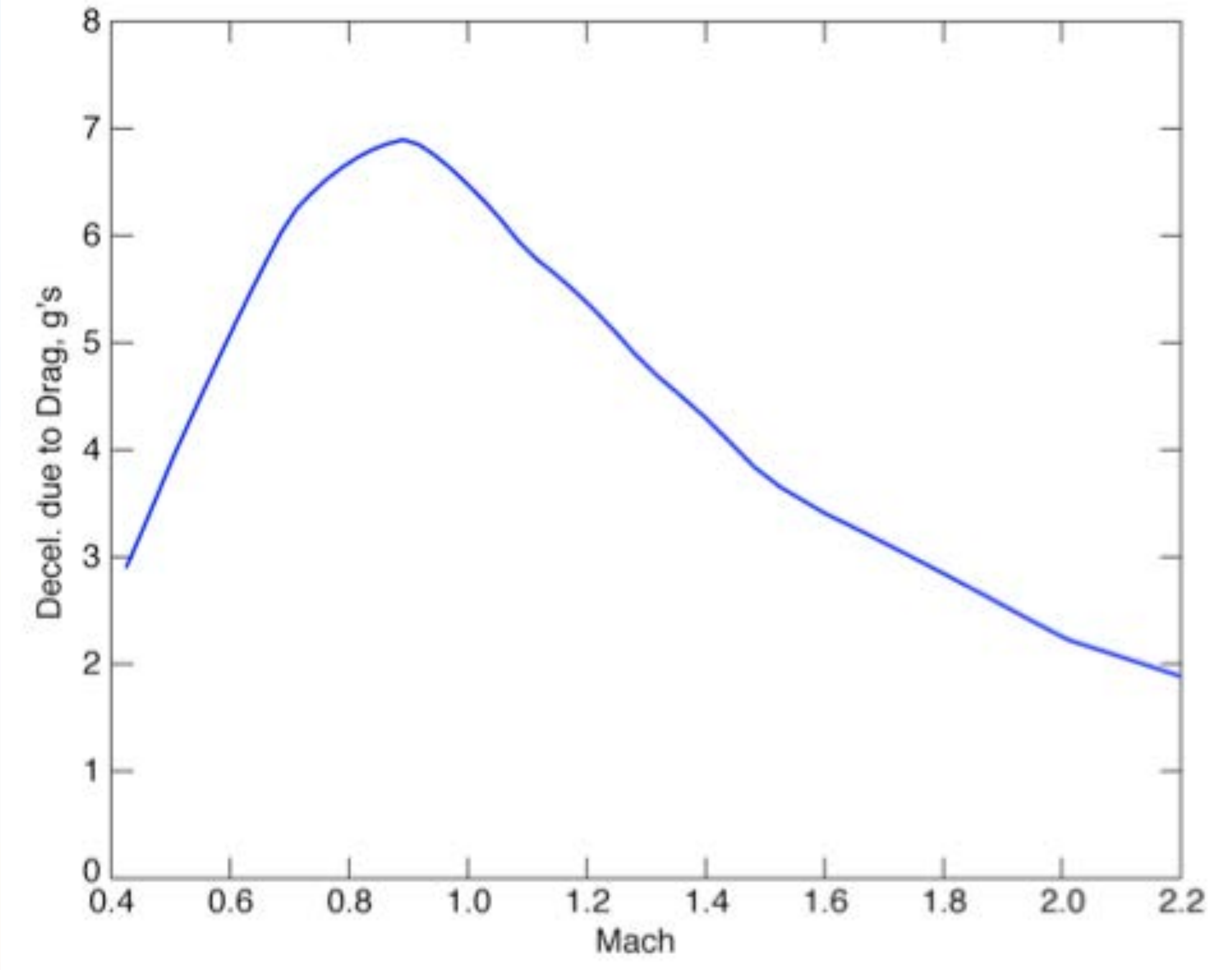
Orion Abort Modes



from Sullivan, Bocam, and Ascalera, "Development of the Orion PA-1 Launch Abort System" AIAA 2011-7129

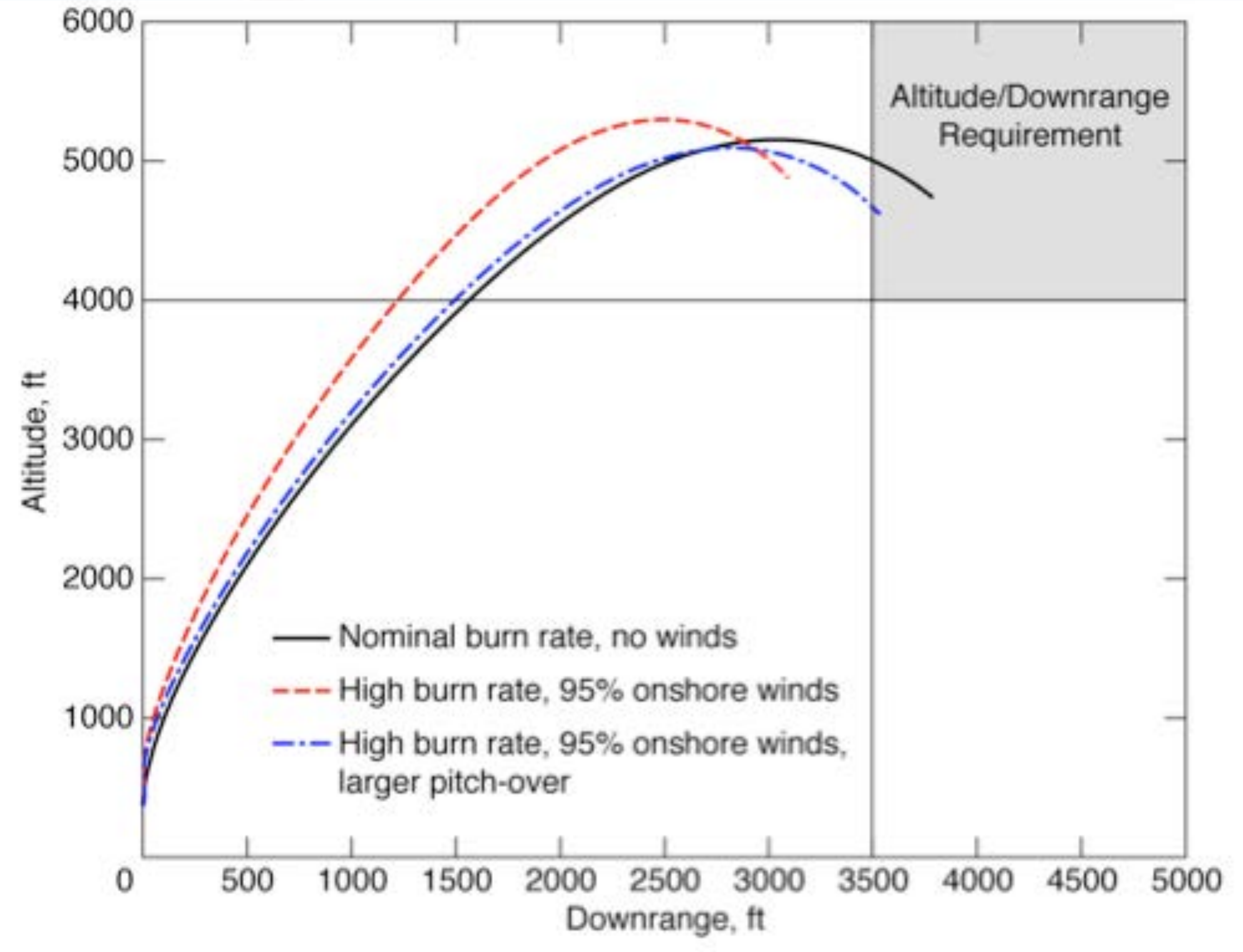
Orion Flight Abort Test

Base Drag Effects at Separation



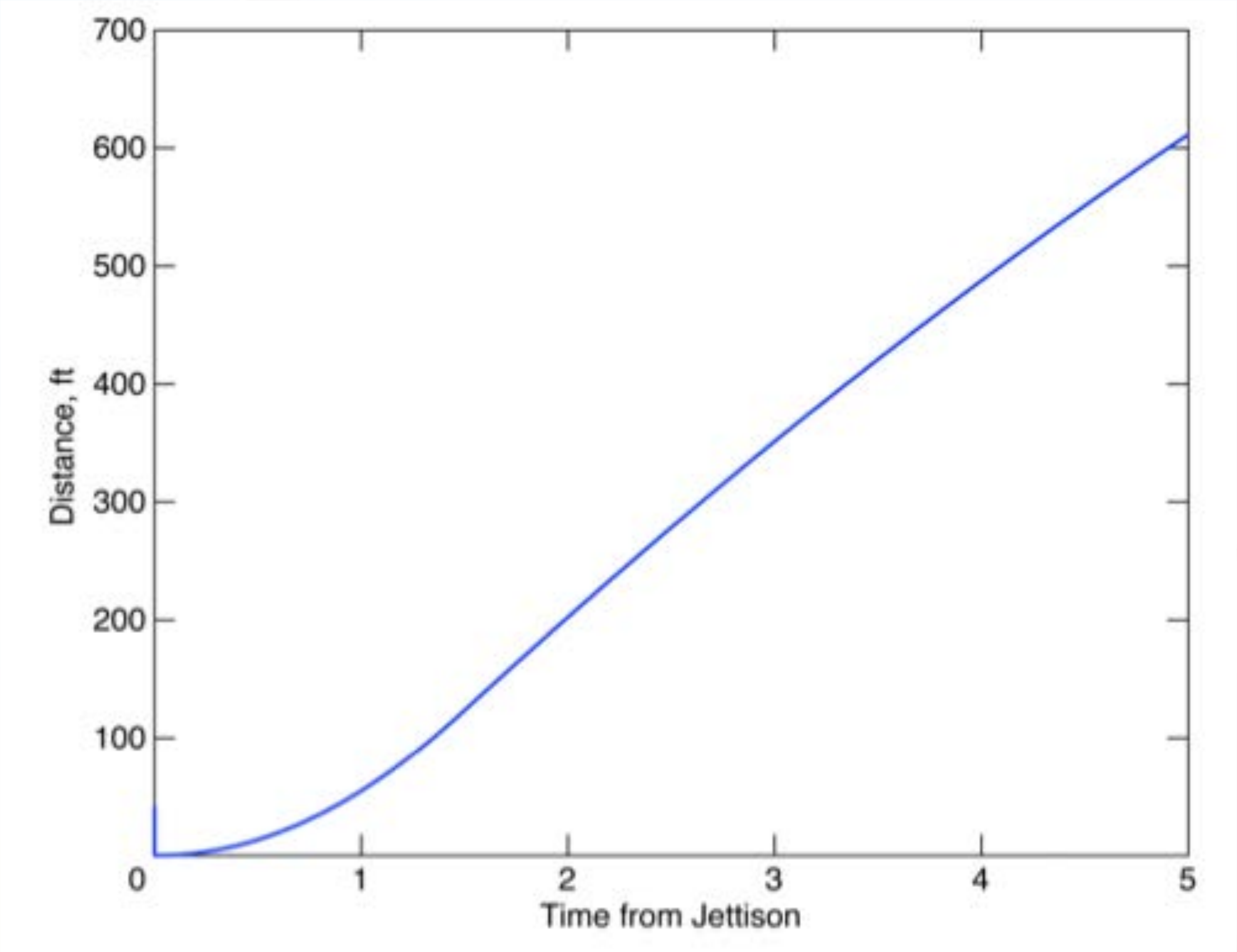
from Tartabini, “Integrated Flight Performance of a Launch Abort System Concept”AIAA 2007-6622

Orion Pad Abort Trajectory Performance



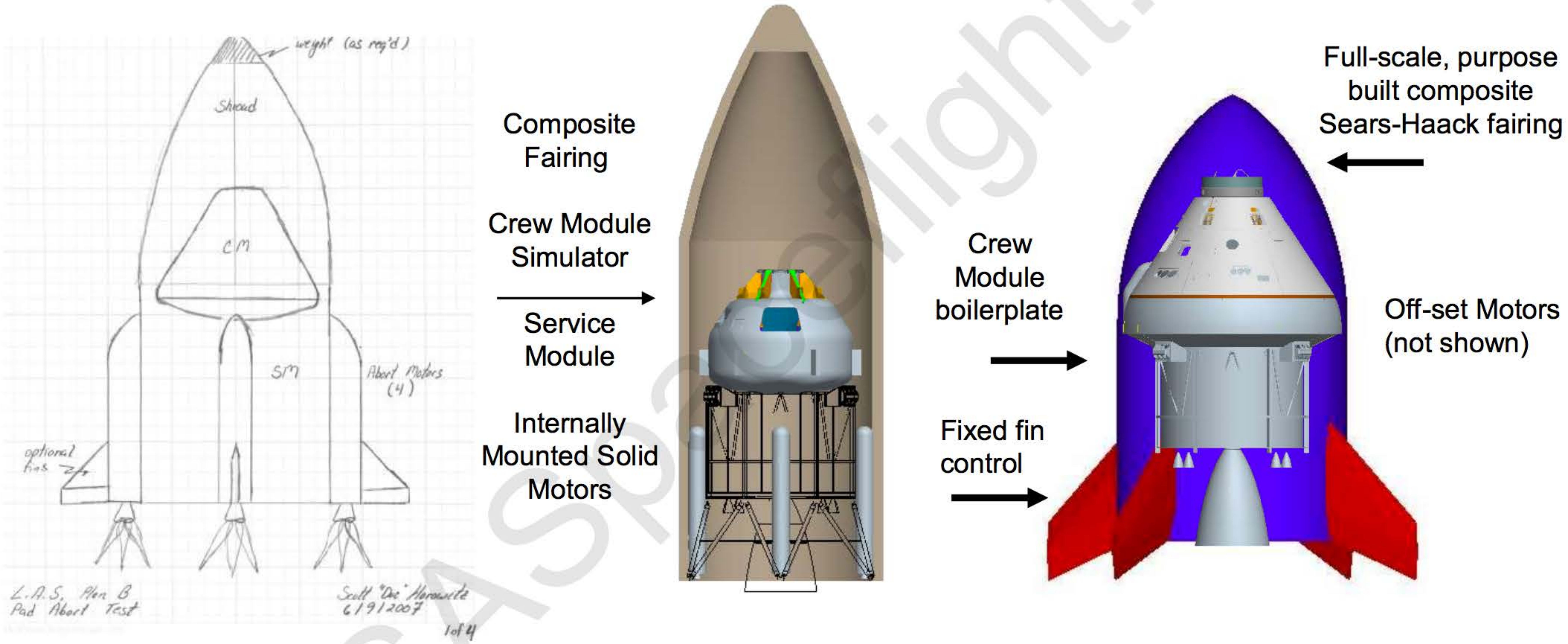
from Tartabini, "Integrated Flight Performance of a Launch Abort System Concept" AIAA 2007-6622

Orion Separation Distance for Pad Abort



from Tartabini, "Integrated Flight Performance of a Launch Abort System Concept" AIAA 2007-6622

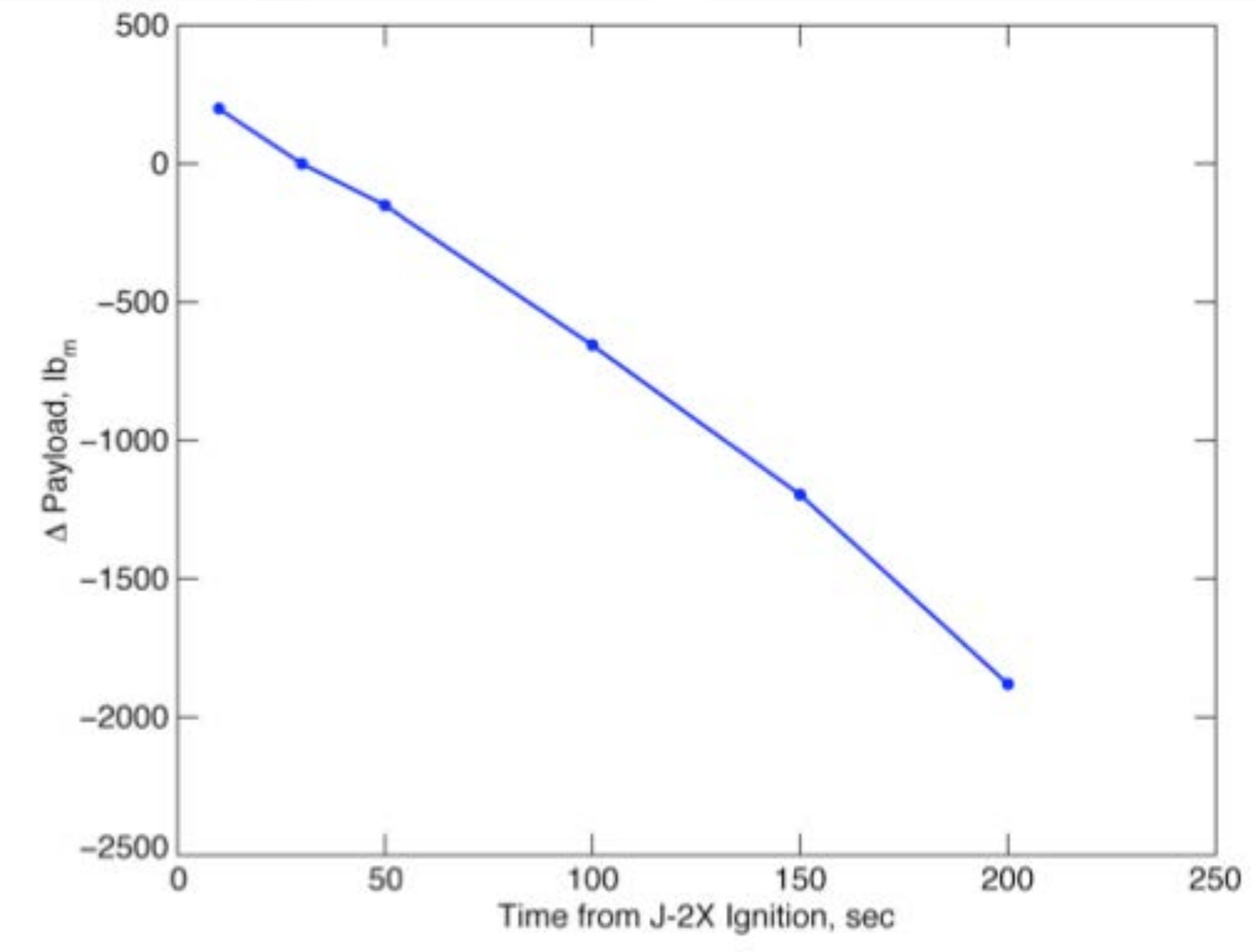
MLAS Concept



Horowitz Design **Early MLAS Concept** **Current MLAS Concept**

Max Launch Abort System Test

Effect of LAS Jettison on Payload

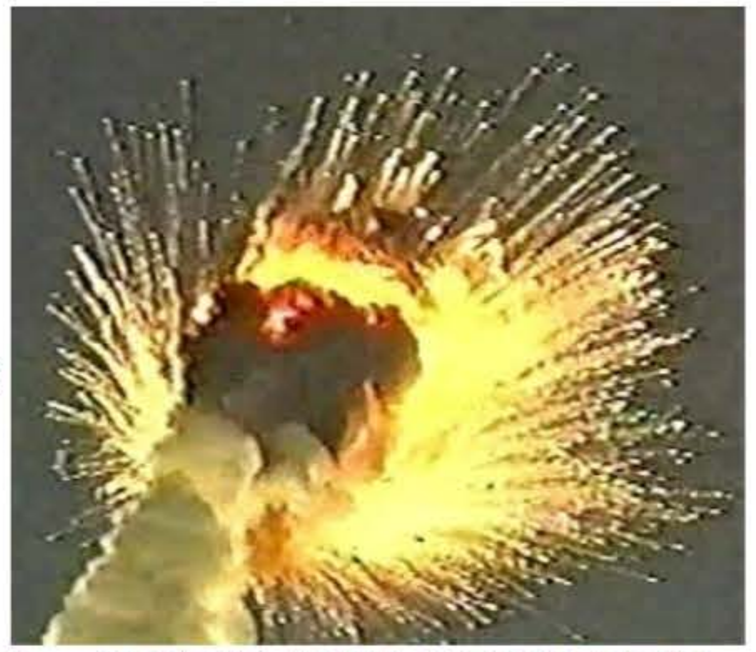


from Tartabini, "Integrated Flight Performance of a Launch Abort System Concept"AIAA 2007-6622

QUICK SUMMARY of RESULTS:

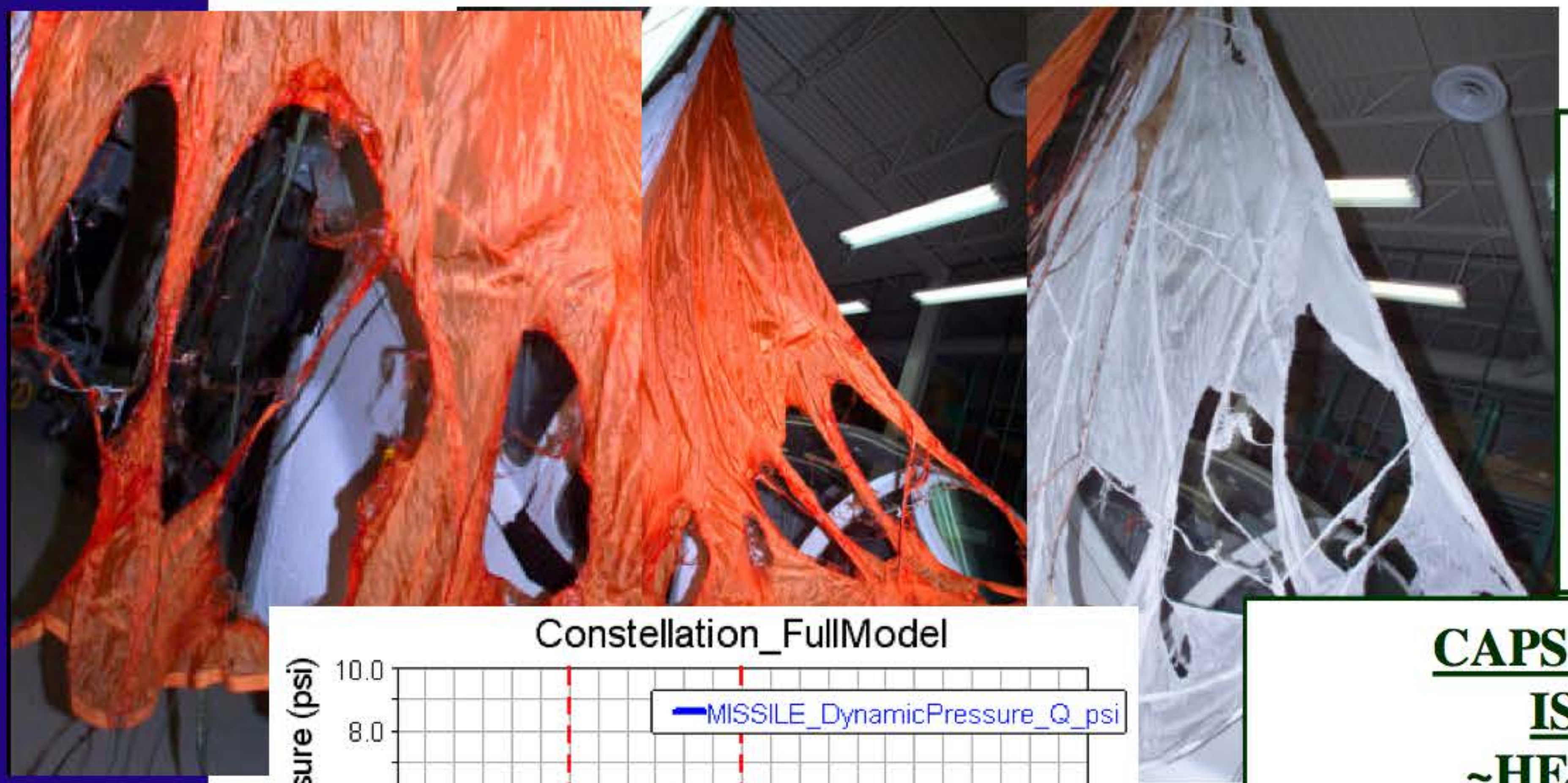
A) FRAG VELOCITY DISTRIBUTION. Propellant fragments expand…

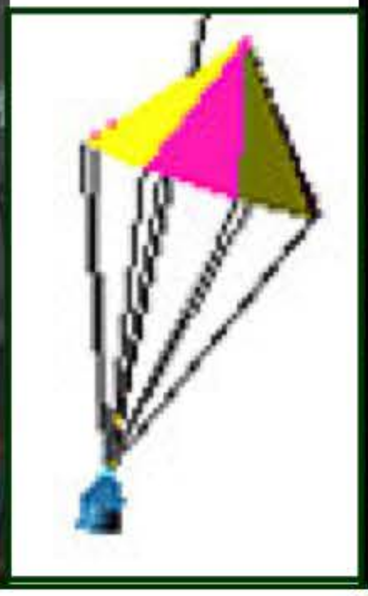
- as a spherical "shell" (i.e. of comparable velocity magnitudes – leaving little distribution of propellant fragments within, or beyond, the "shell")
- At fairly "tight" ranges, from approximately 300-500 fps (some outliers, each side), with betas from ~20-700 lbm/sqft.
- Mass and count distributions comparable to the "FRAG" program, generated from studies such as the joint NASA/DOE/INSRP Explosion Working Group on the Titan 34D-9 and Challenger 51L.

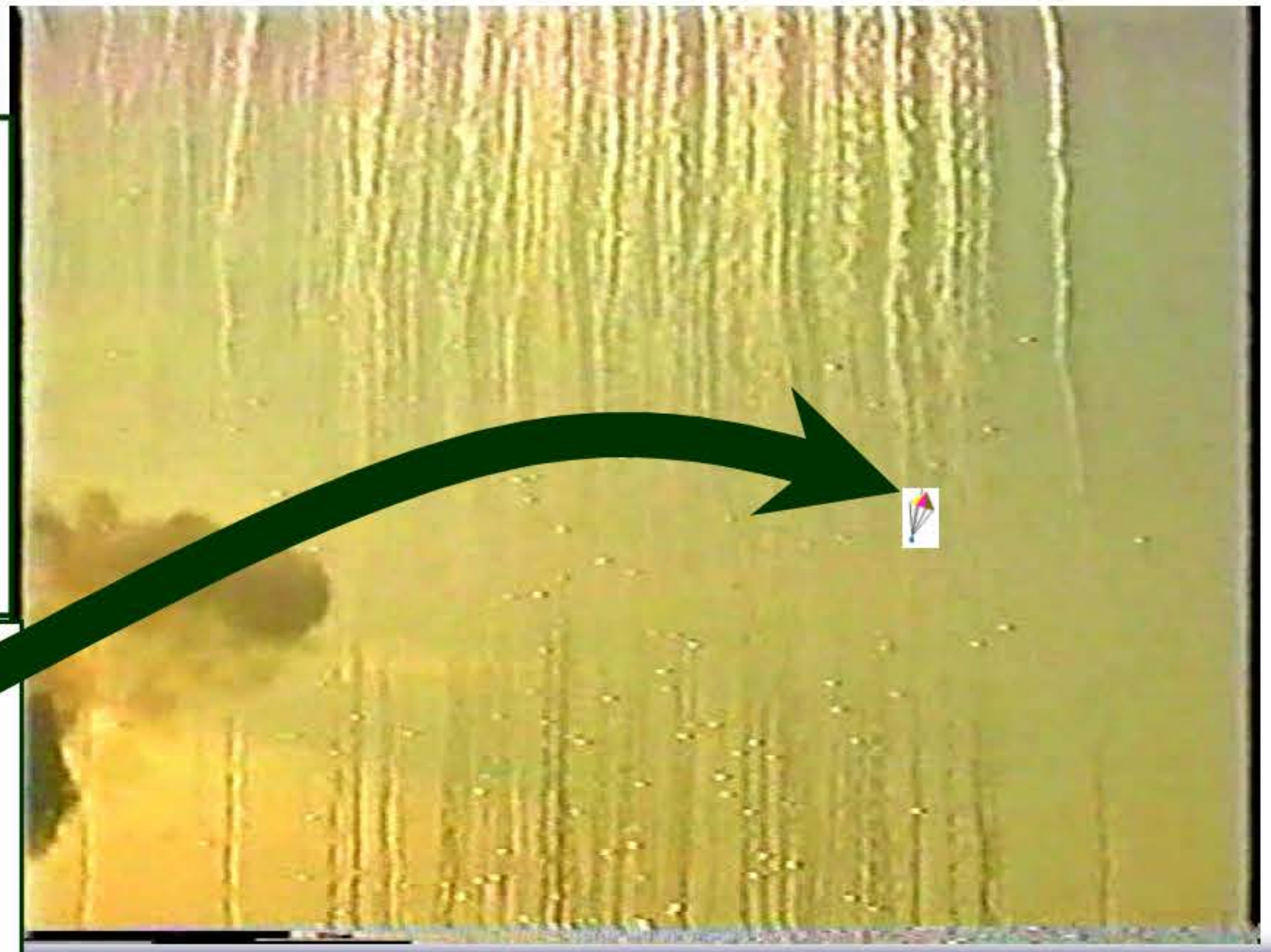


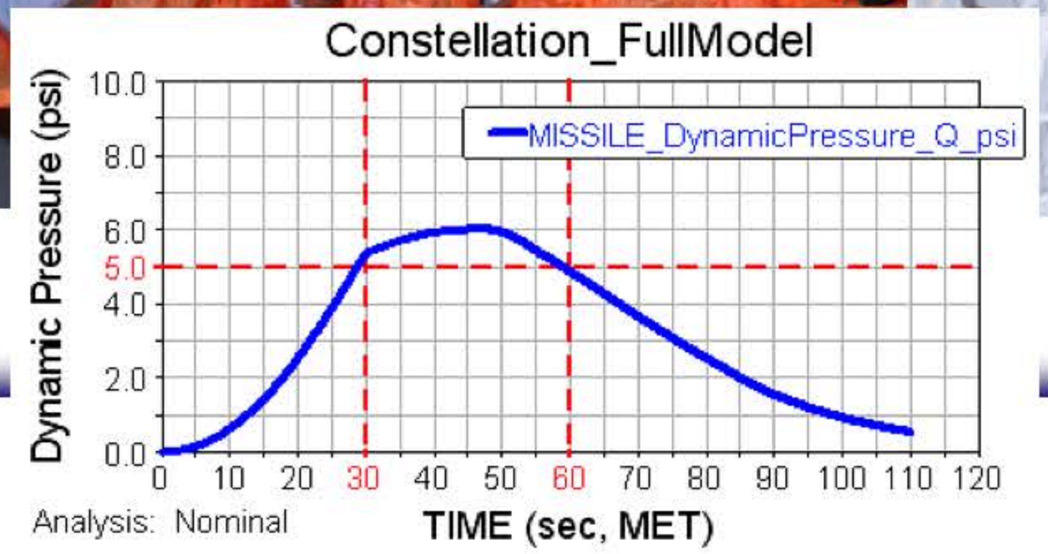
B) CAPSULE ~100% FRATRICIDE by SECONDARY RADIATIVE WILTING of NYLON CHUTES

The capsule will not survive an abort between MET's of ~30 and 60 seconds – as the capsule is engulfed until water-impact by solid propellant fragments radiating heat from 4,000F toward the nylon parachute material (with a melt-temperature of ~400F).



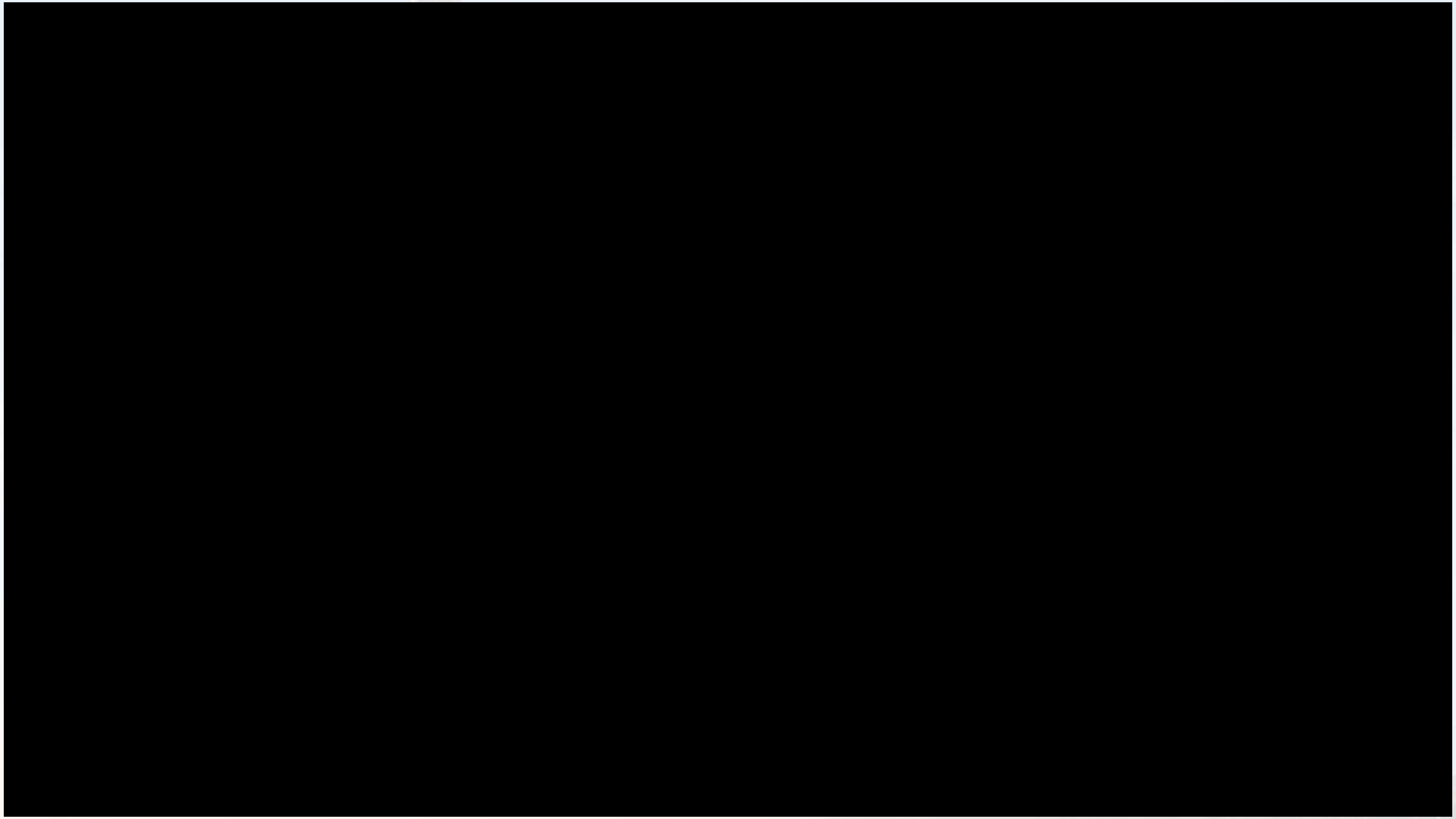




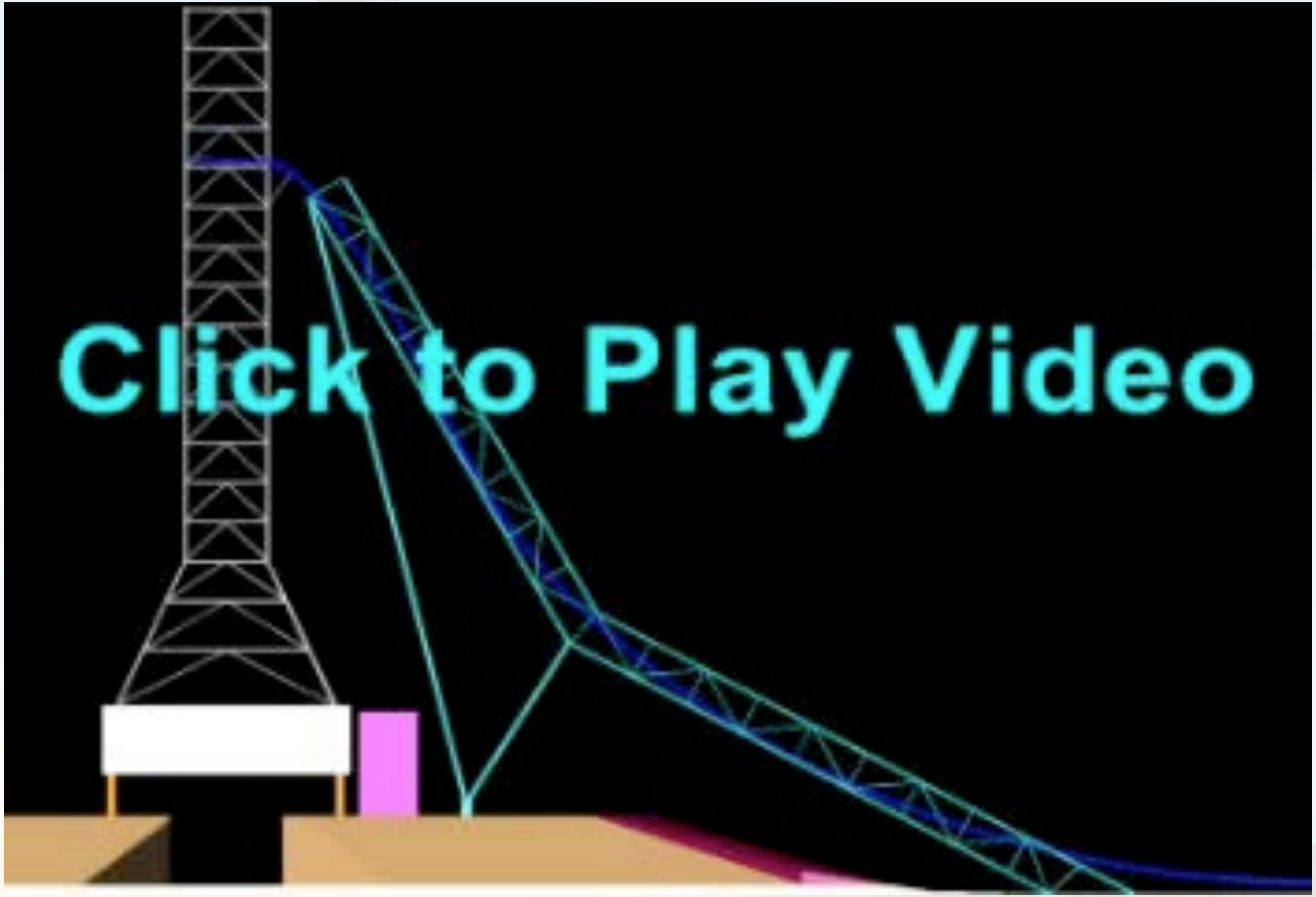


CAPSULE IS ~HERE
(surrounded throughout descent, for aborts MET's ~30-60 sec)

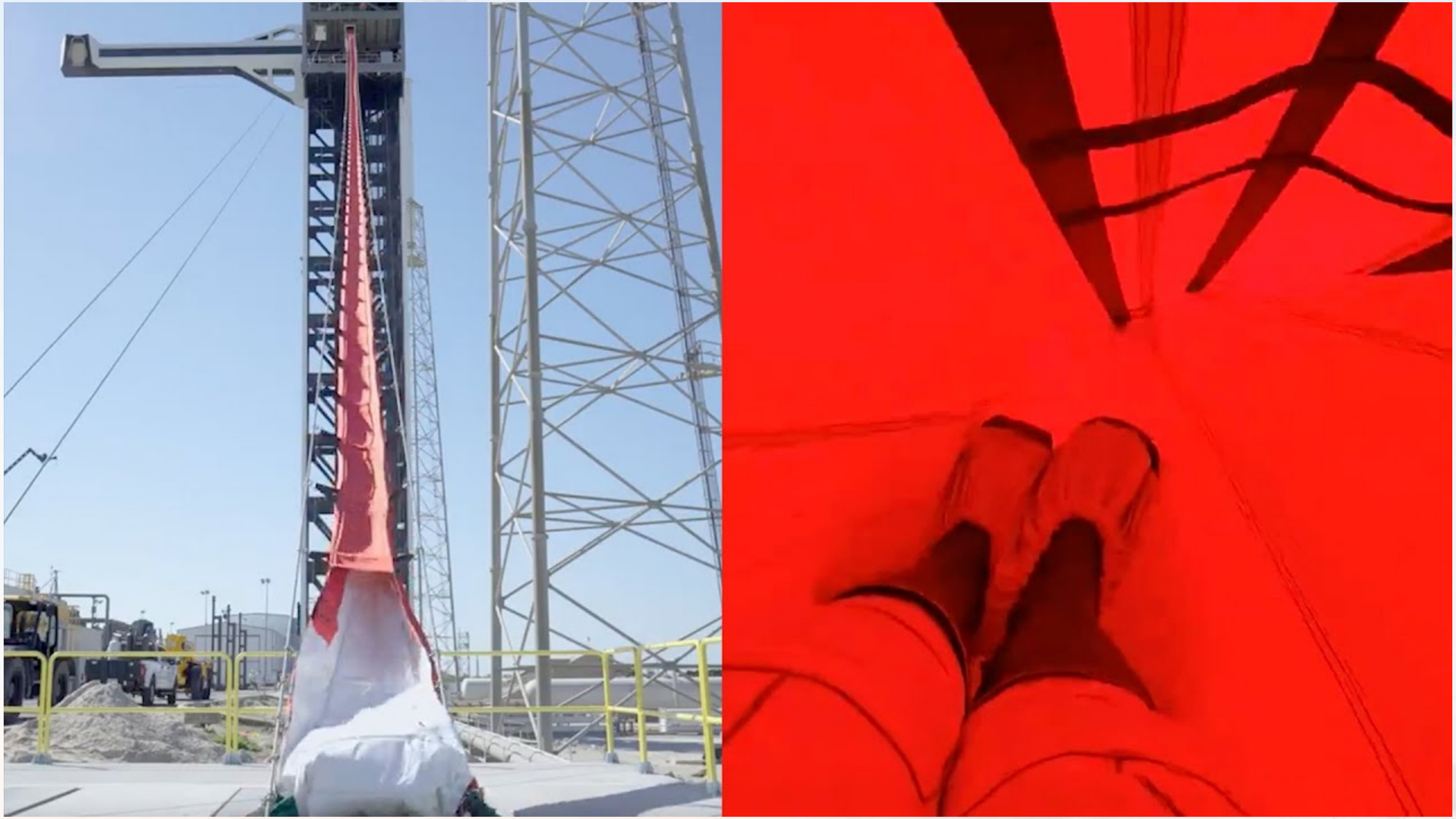
Boeing Starliner Pad Escape System



Original Orion Pad Escape System

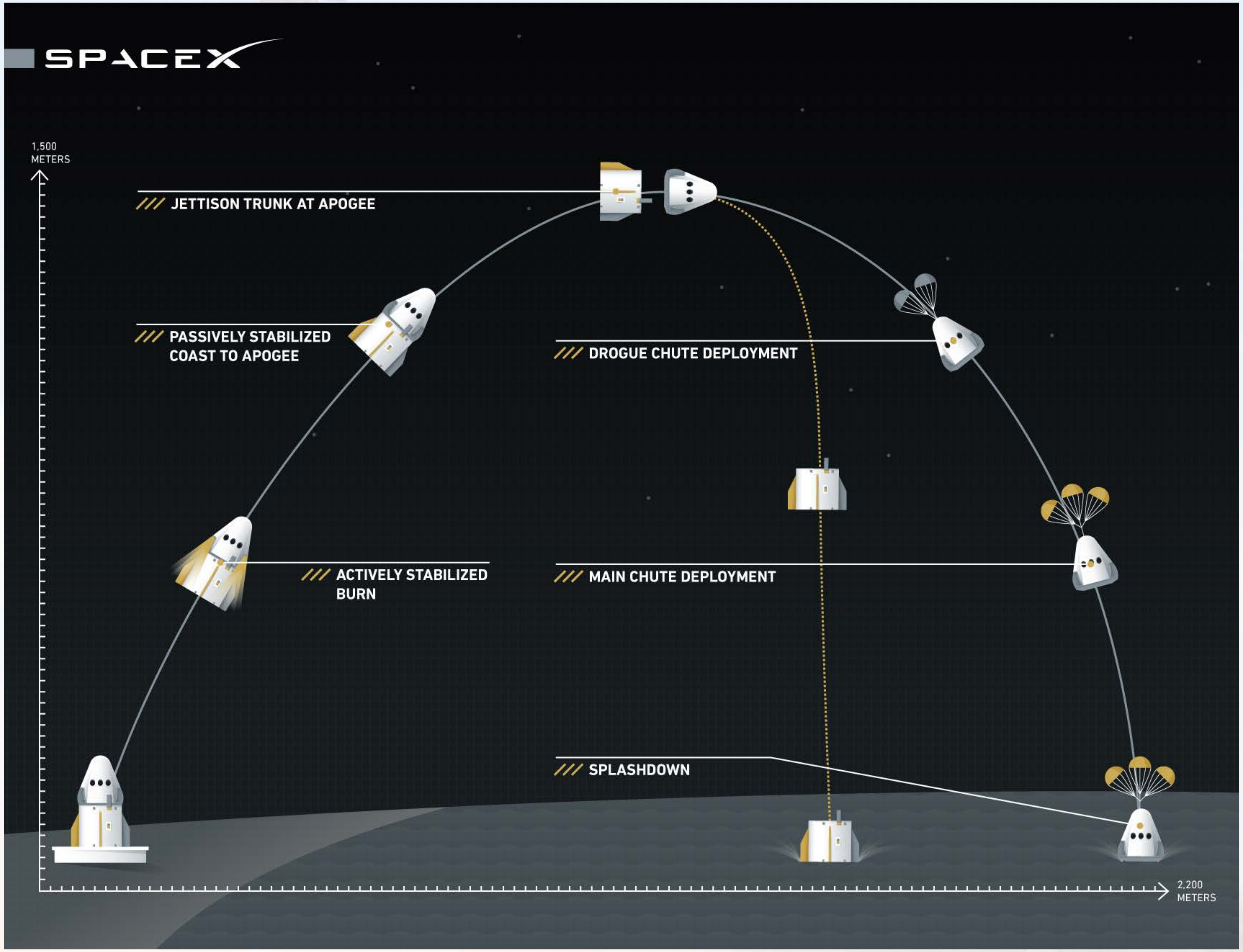


SpaceX LC40 Pad Escape System



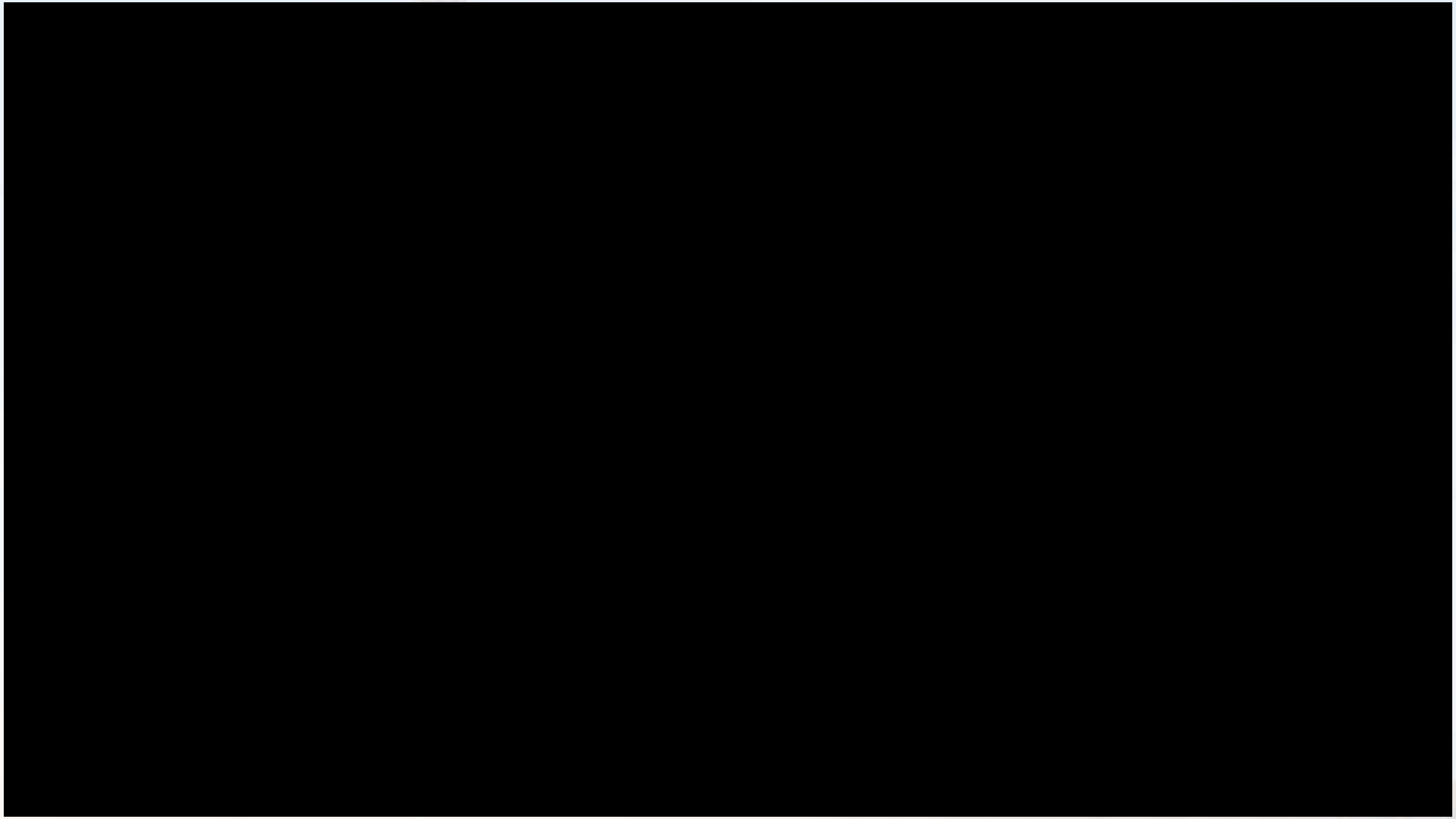
SpaceX Dragon Pad Abort Test

Dragon Abort Profile



SpaceX Dragon Pad Abort Test

Dragon Pad Abort POV



Boeing Starliner Pad Abort Test

New Shepard In-Flight Abort Test