



LaRC Structural and Thermal Systems Branch

In Flight Abort Separation Dynamics

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Introduction



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- **Over the next few years many companies will attempt to enter the manned space business**
- **Most of these will include an abort system to escape a launch failure**
- **Much work has been done on demonstrating abort capability**
 - Flight dynamics
 - Stability
 - Aerodynamics
 - Acceleration
- **During aerodynamic flight, especially maximum dynamic pressure, the the abort will be initiated under preloaded strain**
- **Lateral dynamics of separation during max-q have normally been neglected as a point of interest**
- **This presentation examines the lateral separation dynamics for various configurations**





The Vehicles



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- **This study looked at three vehicle concepts**
 - 50 ft, 30 ft, and 20 ft axial length
- **The models are all beam models with cylindrical cross sections**
- **The dimensions of the beams mimic the basic concepts being worked within the Commercial Crew Program at NASA**
 - 50 ft approximates a puller system
 - 30 ft approximates lifting body
 - 20 ft approximates a capsule
- **These models do not represent exact systems, but are used to show the potential responses of such systems**



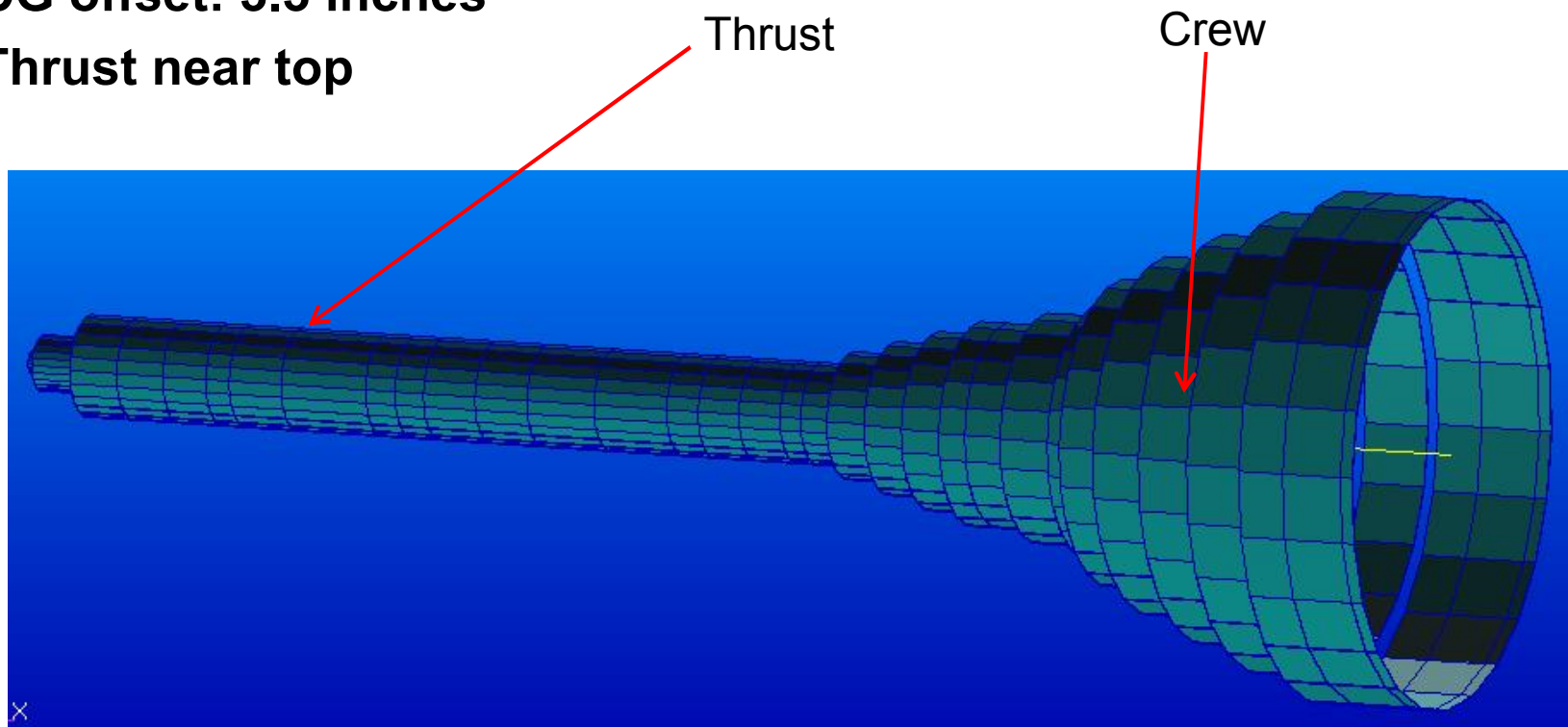


50 ft Vehicle



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- Length: 50 ft
- Weight: 30000 lbs
- Frequency: 7 Hz
- CG offset: 3.3 inches
- Thrust near top



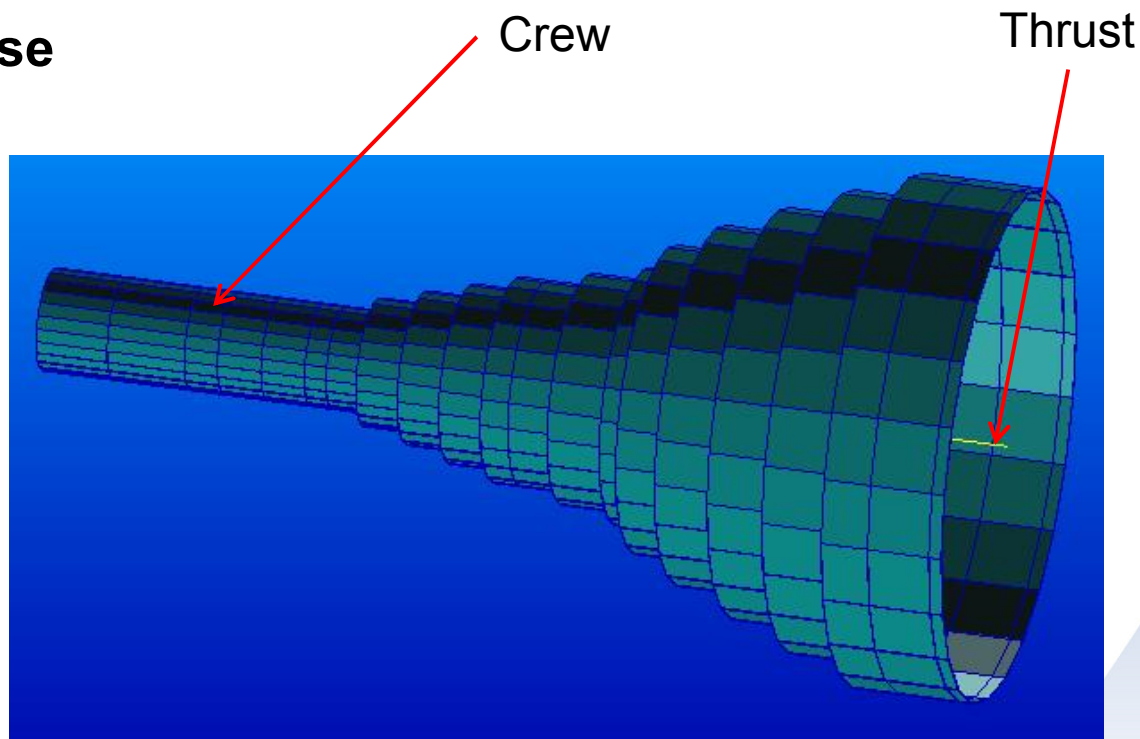


30 ft Vehicle



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- Length: 30 ft
- Weight: 25000 lbs
- Frequency: 23 Hz
- CG offset: 3.8 inches
- Thrust at base



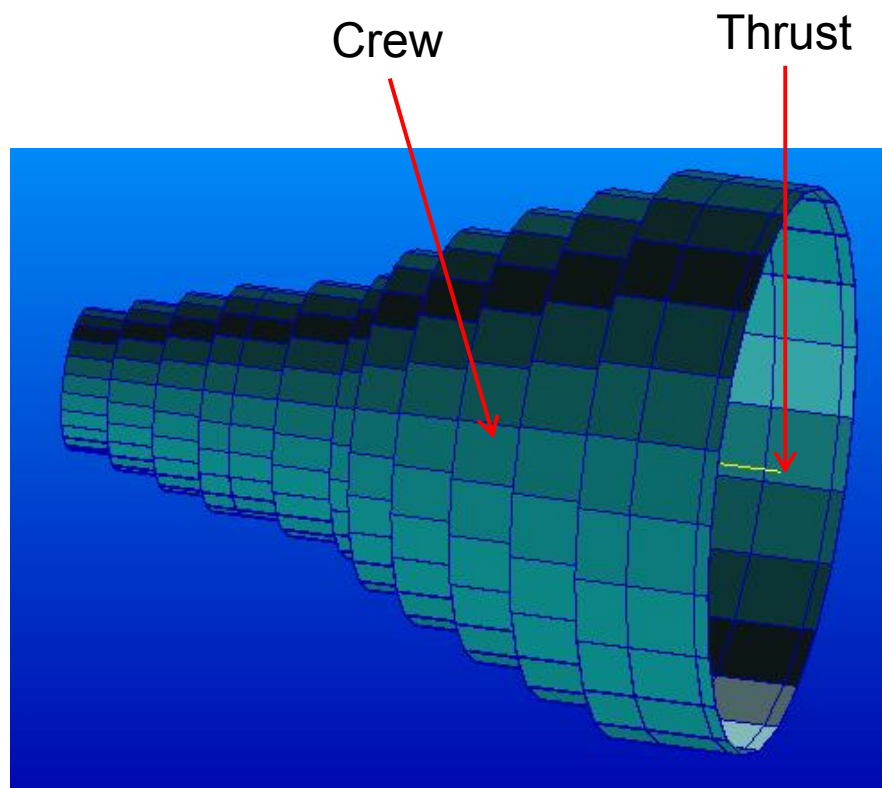


20 ft Vehicle



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- **Length: 20 ft**
- **Weight: 20000 lbs**
- **Frequency: 90 Hz**
- **CG offset: 4.5 inches**
- **Thrust at base**





Methodology



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- **Multi-body approach (Henkel-Mar)**
- **Abort vehicle attached to “stay behind vehicle” rigidly in 6-dof**
- **Launch vehicle engines accelerating stack**
- **Aerodynamic forces applied axially and laterally**
- **Control force applied to aft end of LV to stabilize system**
- **At abort:**
 - LV engines keep firing
 - Aerodynamic forces remain constant
 - Connections allowed to separate (don't actually separate until abort vehicle $T/W > 1$)
 - Abort motor starts and rises in about 200 ms
 - No abort vehicle control forces are applied
- **Nominal Case (from which sensitivity is established):**
 - $Q\text{-alpha} = 2000$ psf, thrust angle = 0, no shear pins



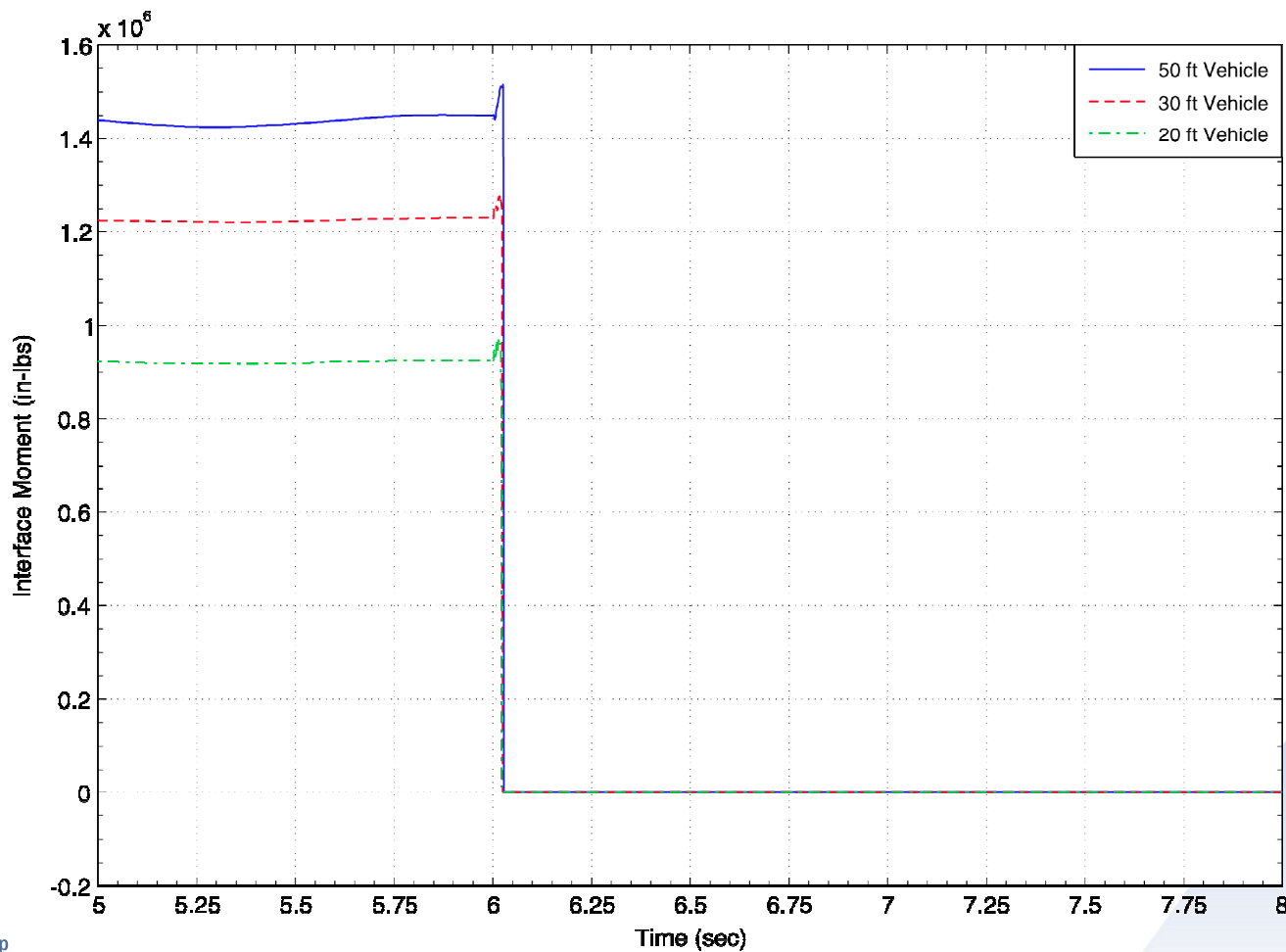


Separation Transient



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- Interface force drops to zero in 20 ms as $T/W > 1$





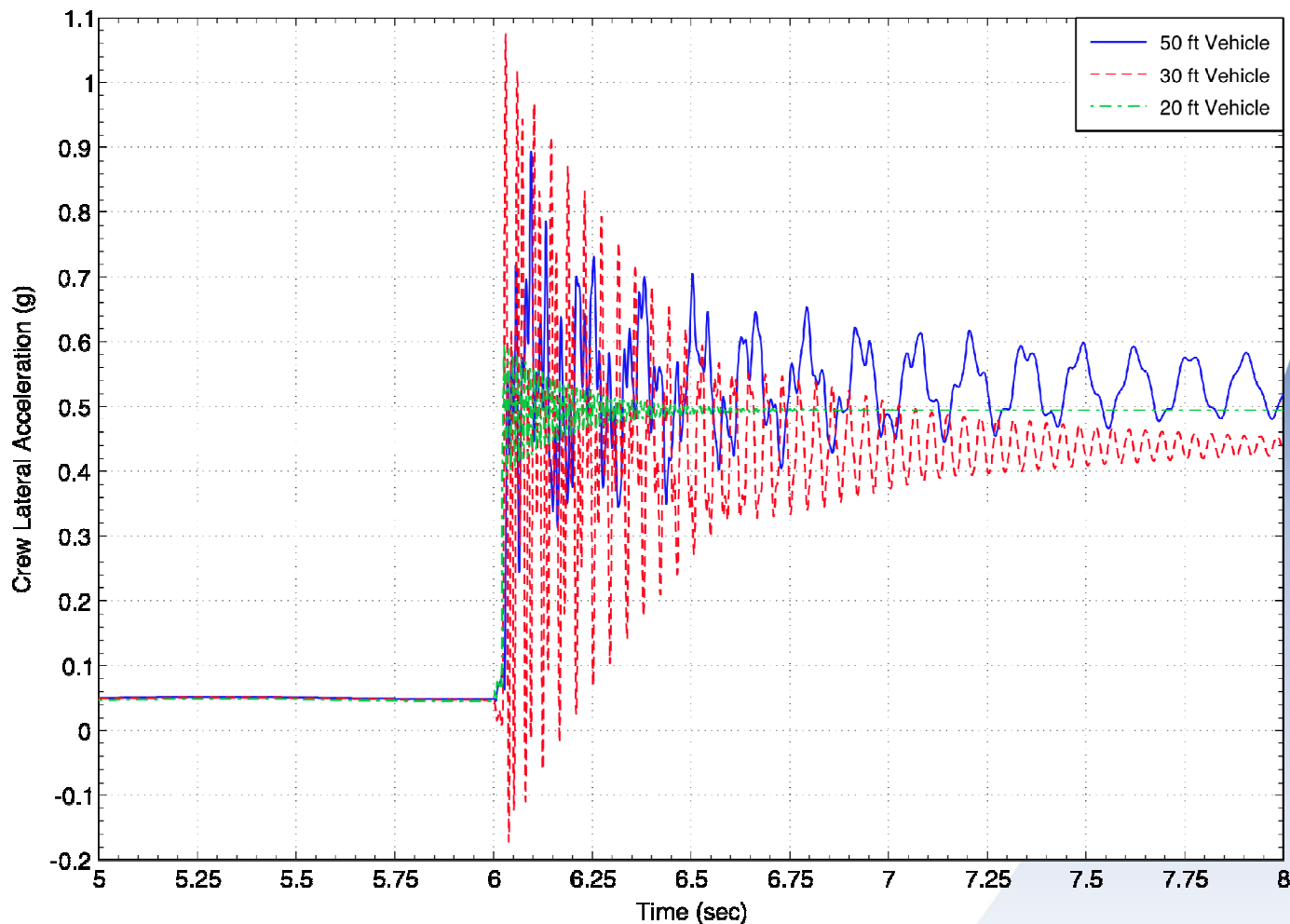
Separation Transient (Twang)



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- 50 ft vehicle has lower frequency, higher initial strain
- 20 ft vehicle has low initial strain
- 30 ft vehicle has crew forward and away from cg.

Crew Response to Separation: Twang Axis



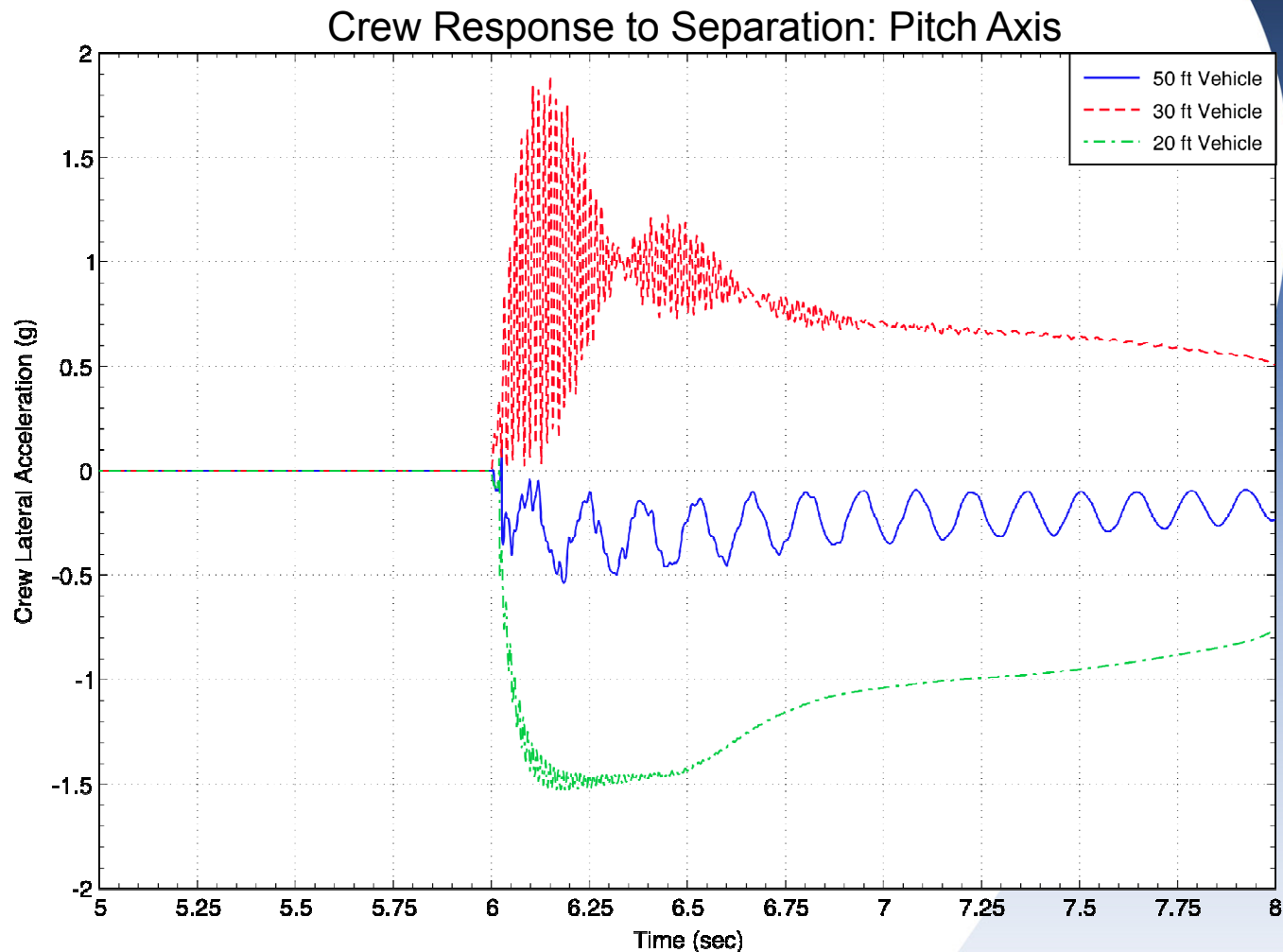


Separation Transient (Pitch Axis)



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- Thrust angle is more important for larger c.g. offset in 20 ft and 30 ft vehicles
- Dynamics is higher in forward crew





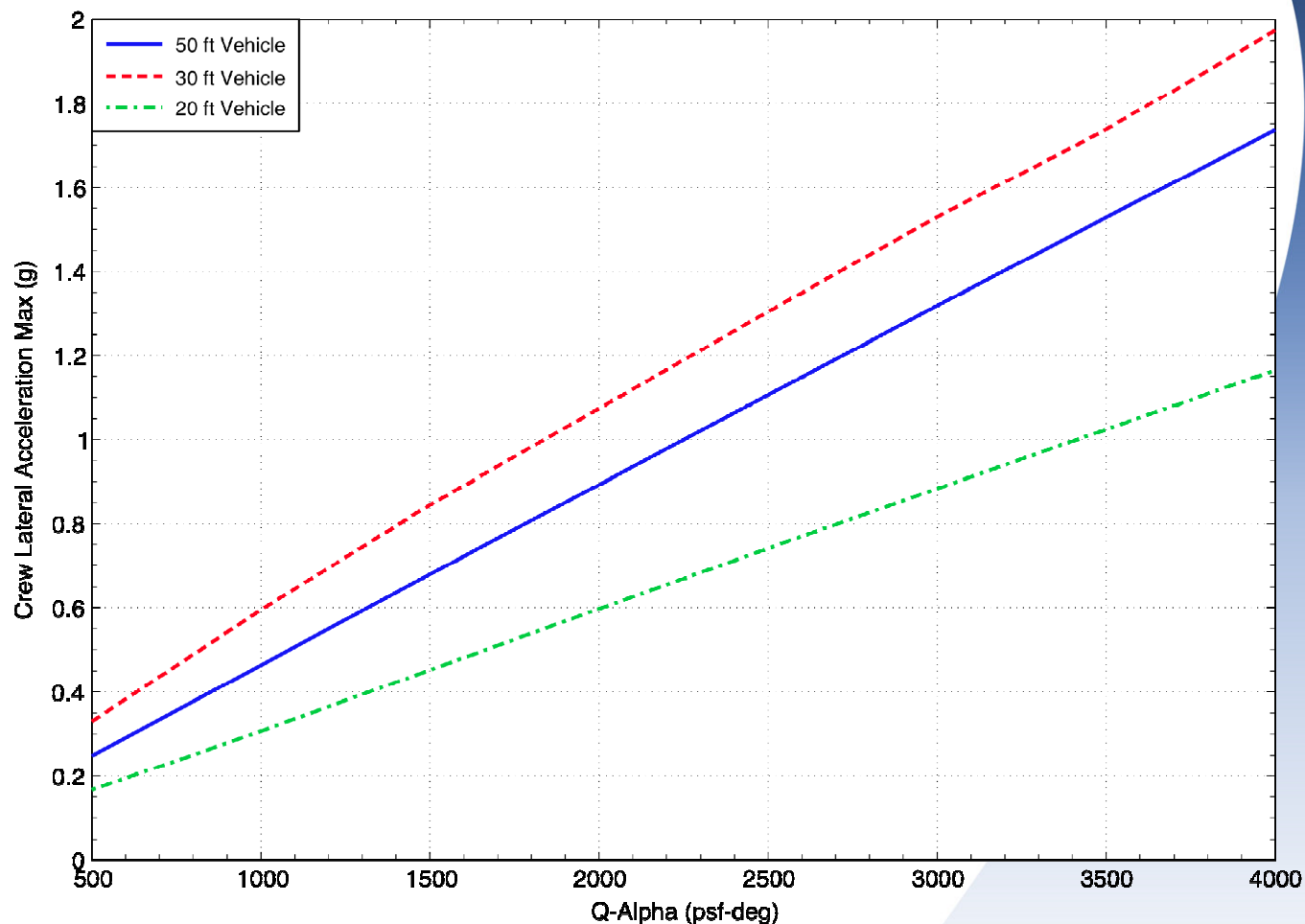
Q-Alpha Sensitivity



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- All vehicles sensitive to q -alpha due to correlation of q -alpha to strain

Crew Response to Variations in Q-alpha: Twang Axis





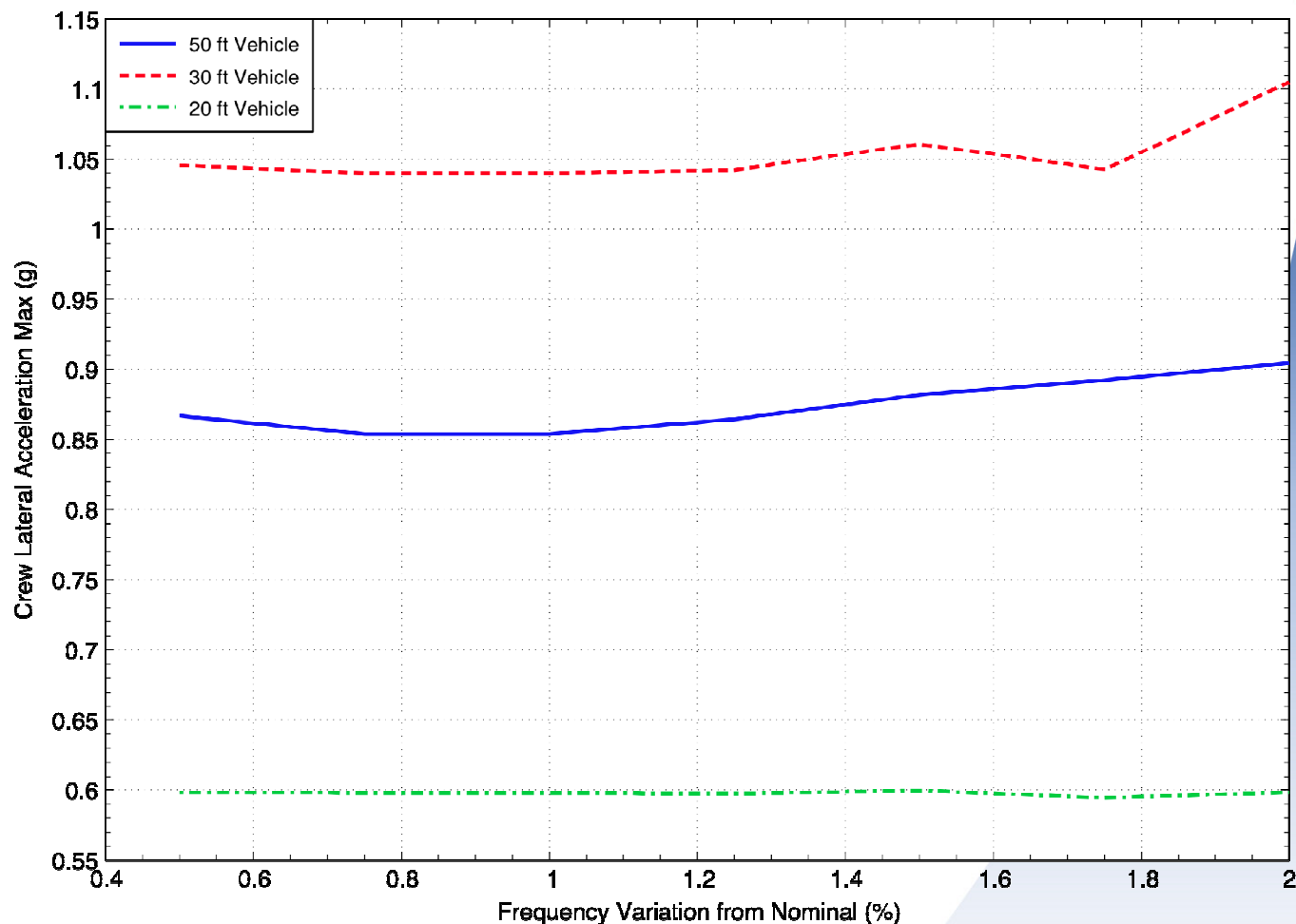
Vehicle Frequency Sensitivity



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- Vehicle responses insensitive to changes in vehicle frequency
- Twang excites any frequency

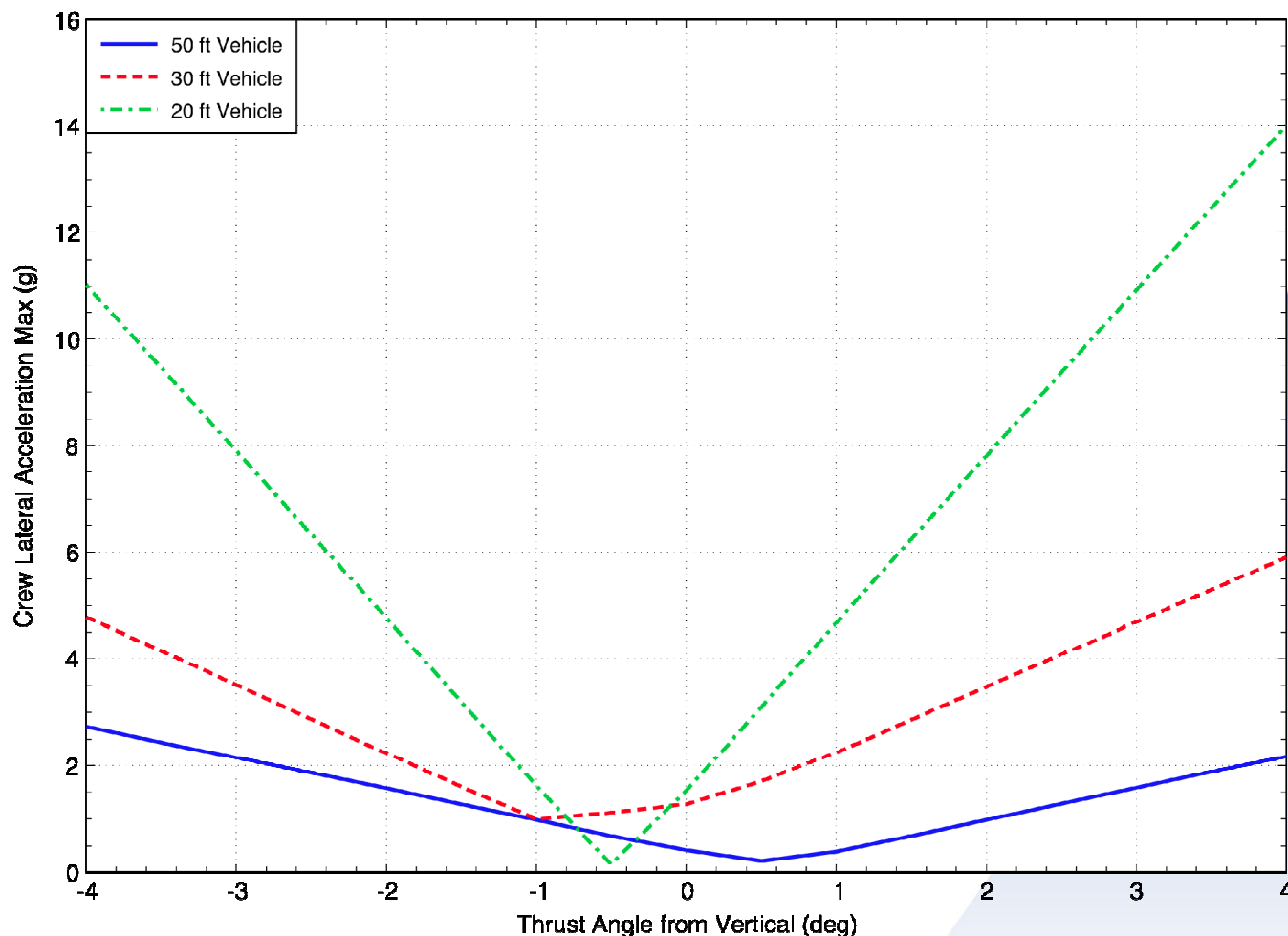
Crew Response to Variations in Vehicle Frequency: Twang Axis



Abort Motor Angle Sensitivity

- All vehicles sensitive to angle
- Minimum value is when thrust is directed towards offset c.g.
- Sensitivity increases with c.g. offset

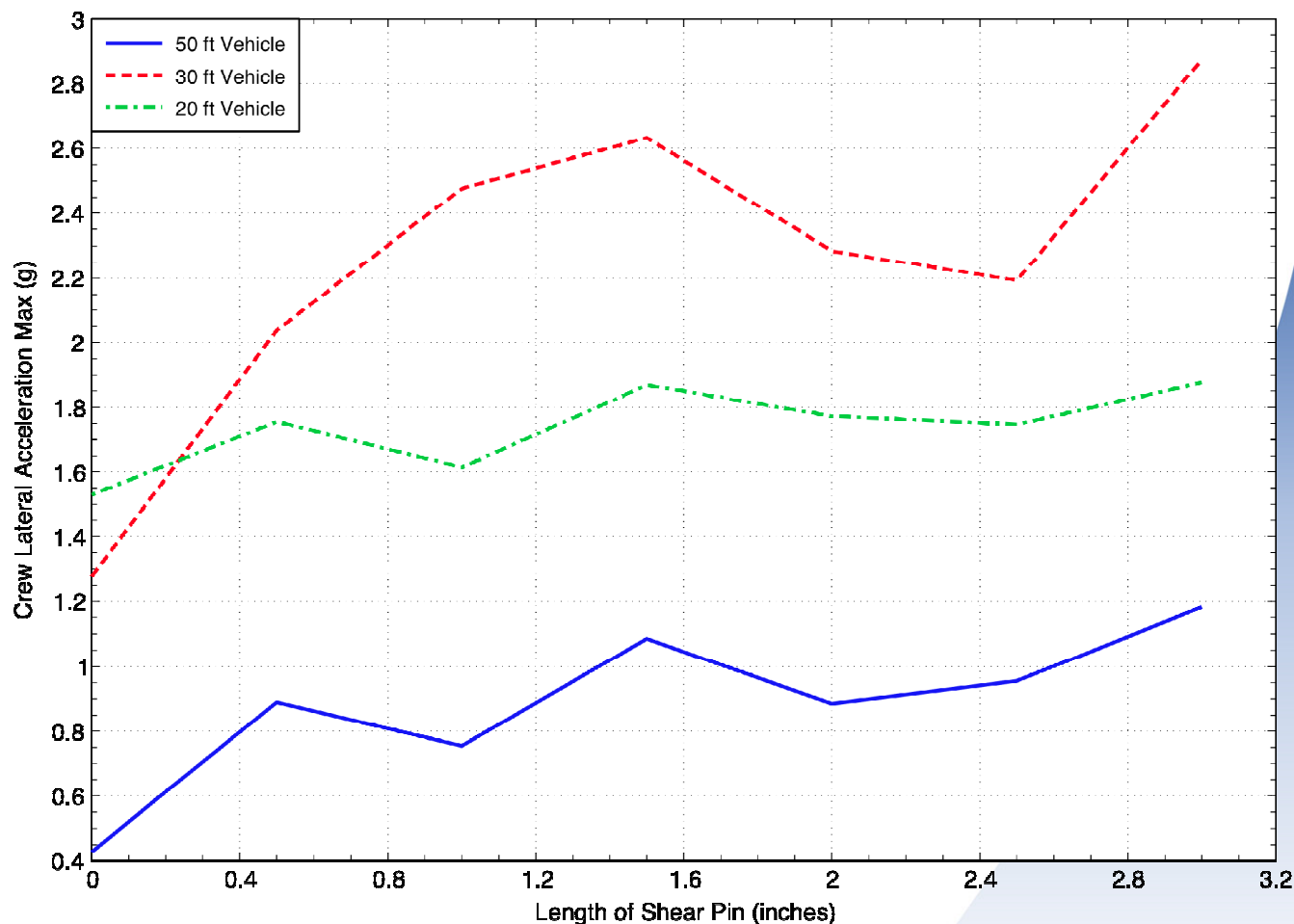
Crew Response to Variations in Abort Motor Angle: Pitch Axis



Shear Pin Length Sensitivity

- **Slight sensitivity as thrust builds up while still attached**

Crew Response to Variations in Shear Pin Length: Pitch Axis





Conclusions



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- **With a built-in c.g. offset, motor angle is the most important parameter for controlling abort accelerations**
 - Consistent with Armand presentation SCLV 2011
- **Separation twang will occur and cannot be neglected**
 - Twang responses are minimized by placing the crew near the c.g.
 - Twang responses are reduced by reducing q -alpha

