

Free-Fight Dynamics of an Aeroshell/Drogue Parachute System

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Test Description and Objective

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Dragonfly Mission

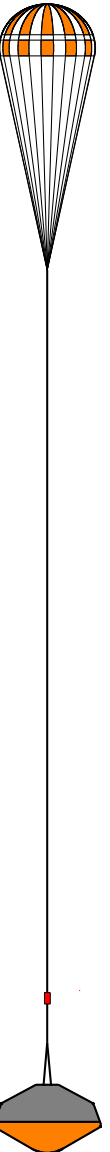
- Place a rotorcraft lander on the surface of Titan (Saturn's largest moon)
- Study prebiotic chemistry and habitability
- Launch June 2027, arrival at Titan by 2034
- Entry, descent, and landing system includes two parachutes: drogue and main

Test Description

- Simulation of the Dragonfly mission drogue parachute descent phase
- Subscale model (6.67% of full-scale) free-flight test
- Aeroshell geometrically scaled
- Dynamically-scaled aeroshell mass properties

Test Objective

- Investigate dynamic behavior of the aeroshell/drogue parachute system
 - Particularly at handoff from drogue to main



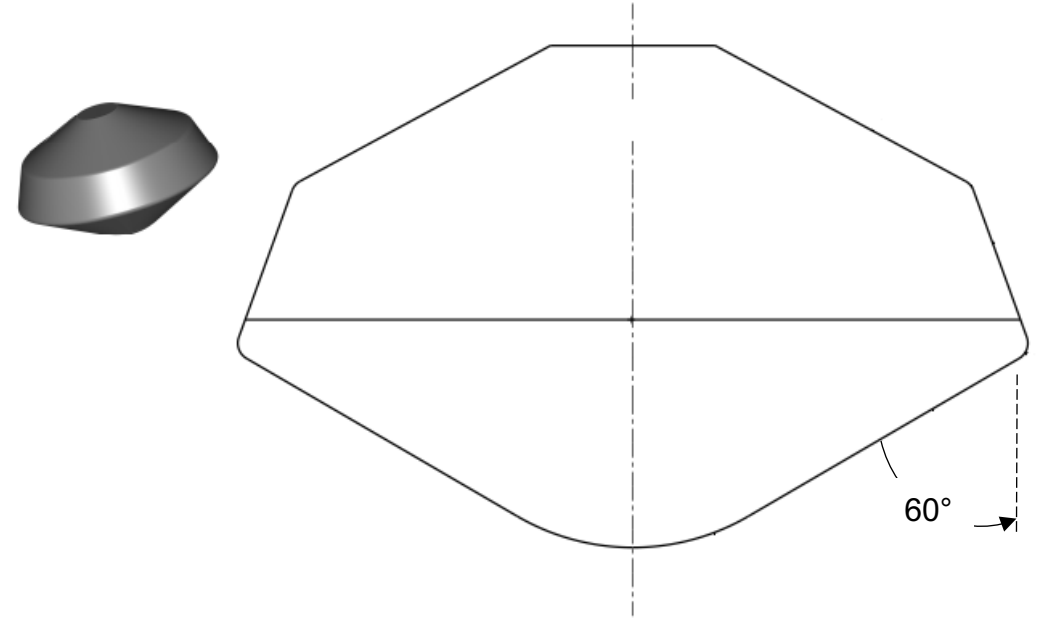
Aeroshell and Parachute Models

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Aeroshell Model

Diameter: 0.300 m
Mass: 249 g



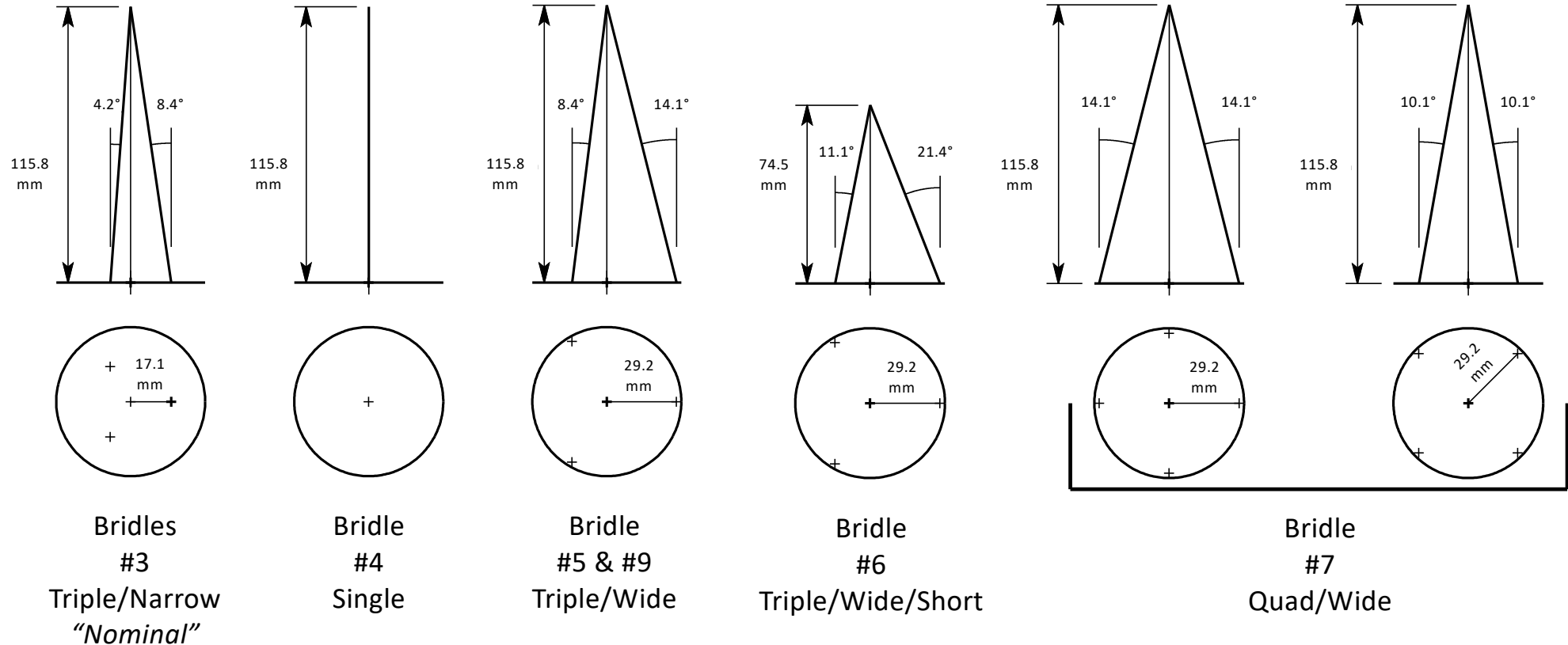
Parachute Models

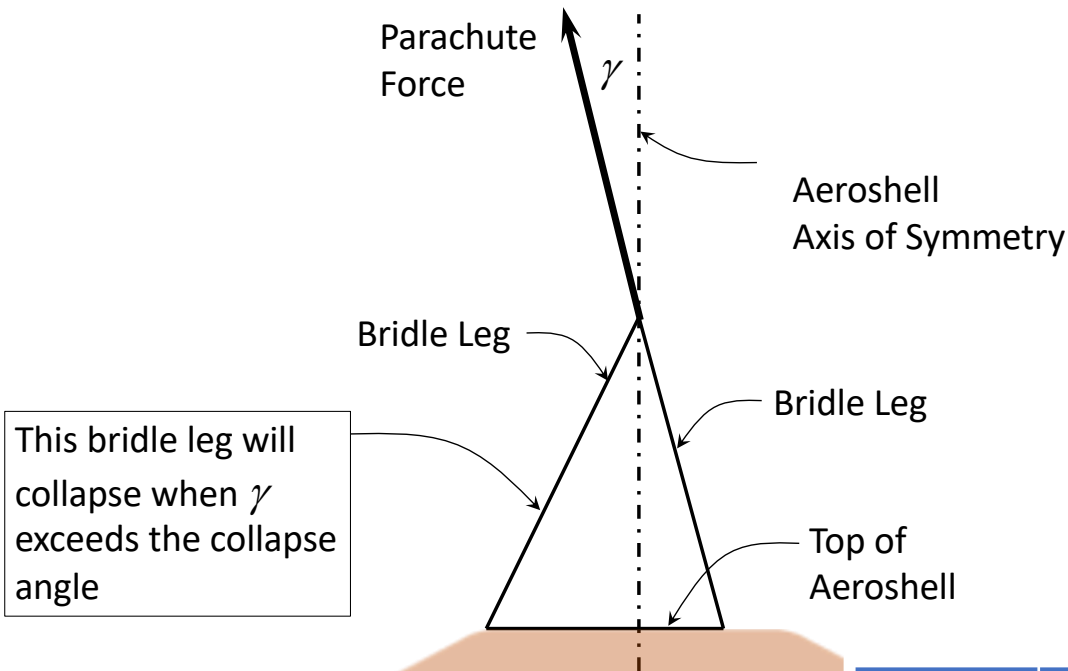
Small: 0.255 m nominal dia.
Nominal: 0.381 m nominal dia.
Large: 0.409 m nominal dia.

Bridles

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- Bridles connect parachute to aeroshell
- Bridles have 1, 3, or 4 legs
- Bridles legs are made of cords, thus they cannot take compressive loads (except Bridle #9)
- Bridle #9 made of piano wire – legs do not collapse





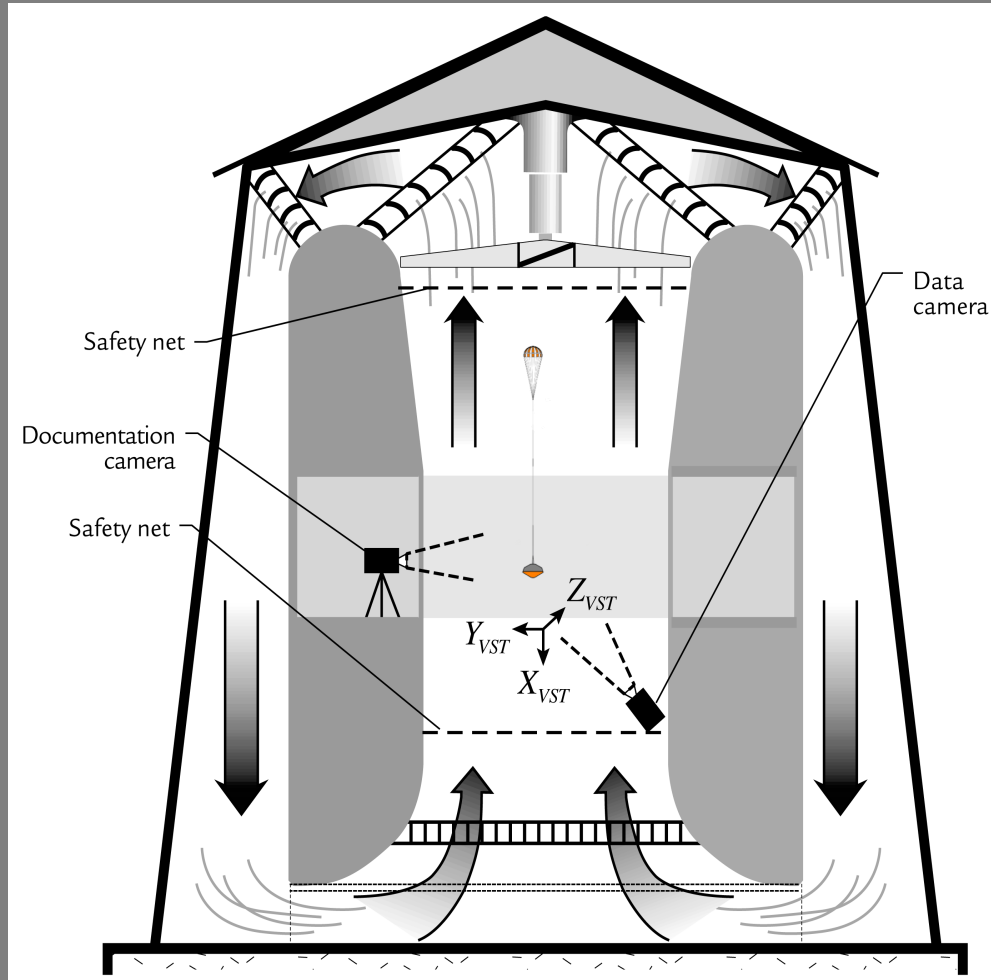
Bridle	Name	Min Collapse Angle	Max Collapse Angle
#3	Triple/Narrow (Nominal)	4.2°	8.4°
#4	Single	Not Applicable	Not Applicable
#5	Triple/Wide	7.2°	14.1°
#6	Triple/Wide/Short	11.1°	21.4°
#7	Quad/Wide	10.1°	14.1°
#9	Triple/Wide/Rigid	Not Applicable	Not Applicable

Test Facility and Test Procedure

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NASA-LaRC

Vertical Spin Tunnel



Test Section:
25 ft high by 20 ft wide

Speed:
Up to 85 ft/s

Test Procedure

Unperturbed Launch

Aeroshell released in airstream upright with minimal pitch/yaw angles and rates.

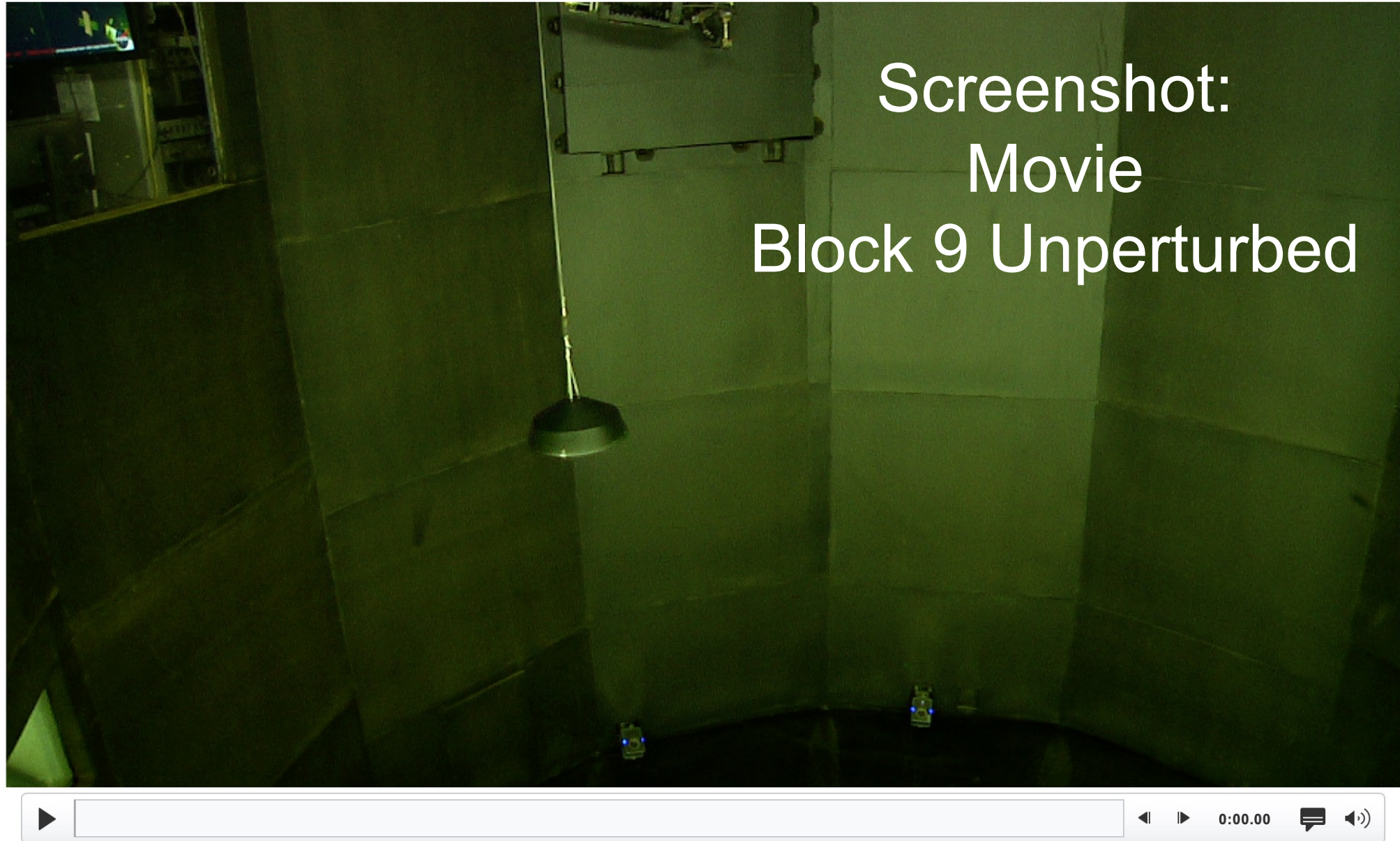
Perturbed Launch

Aeroshell released inverted with large pitch/yaw angles and rates.

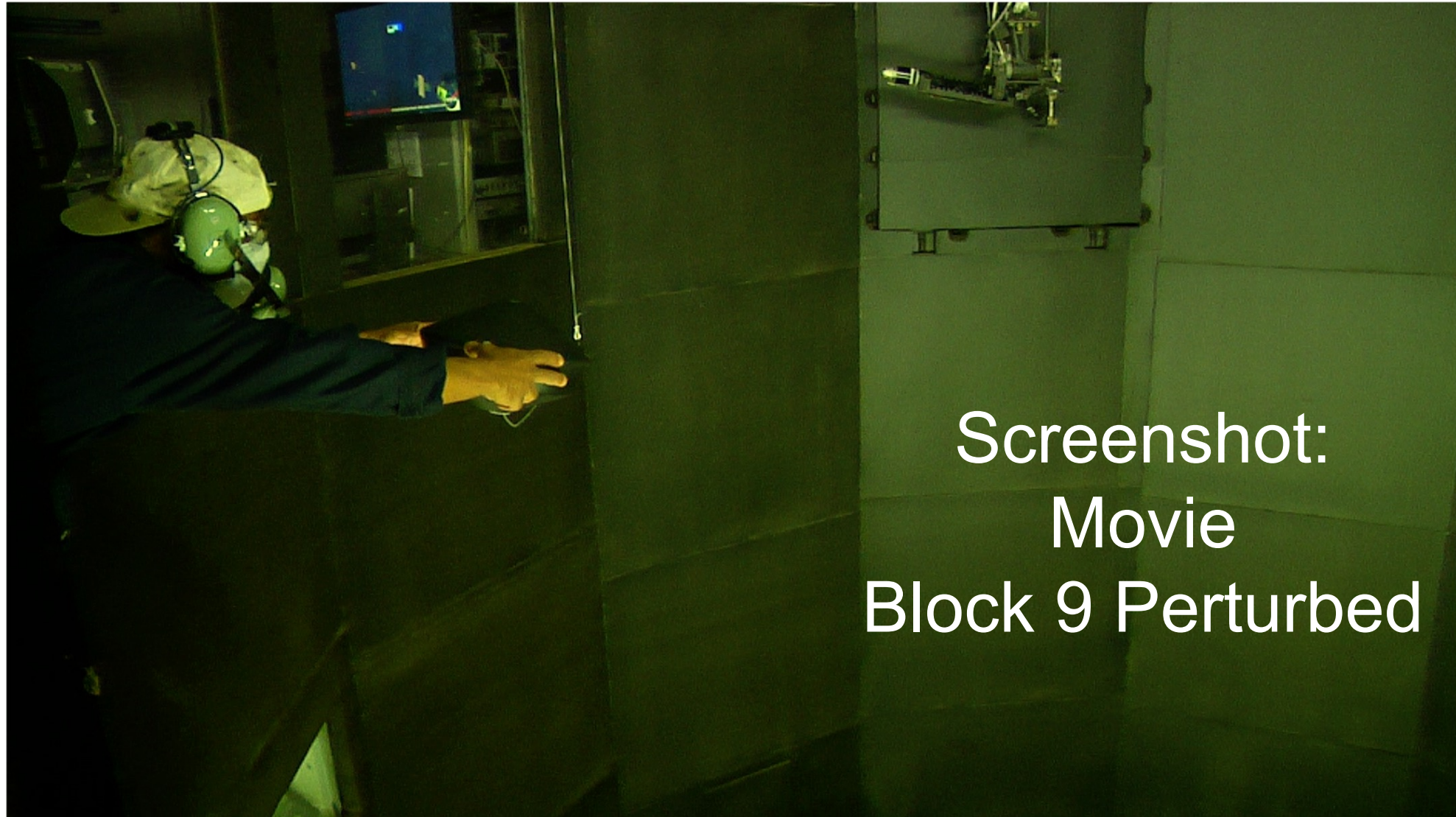


Results – Small Angles Oscillation

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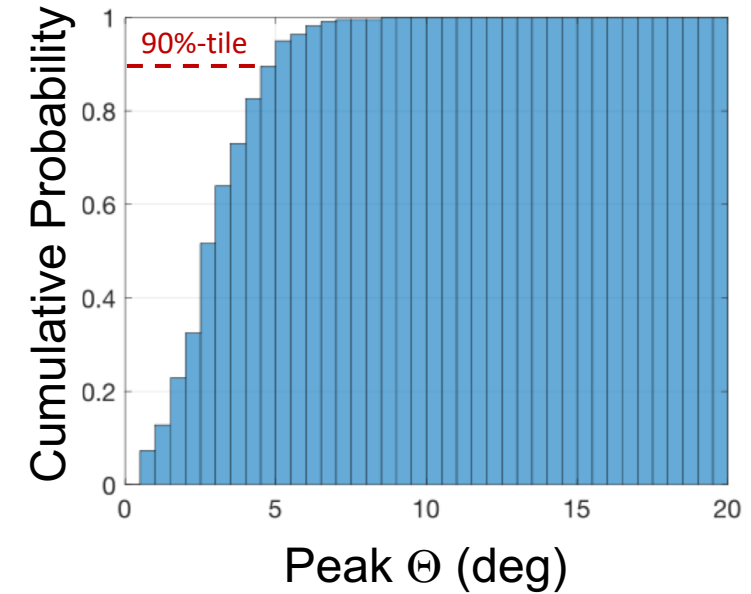
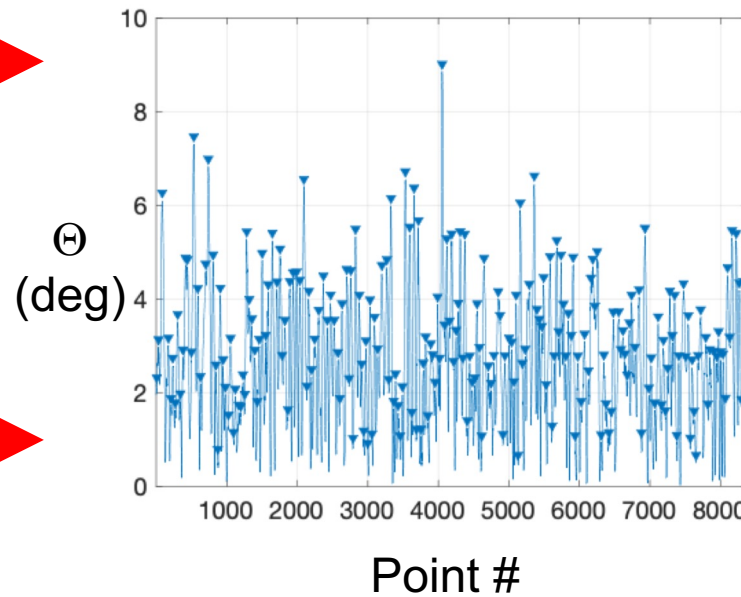
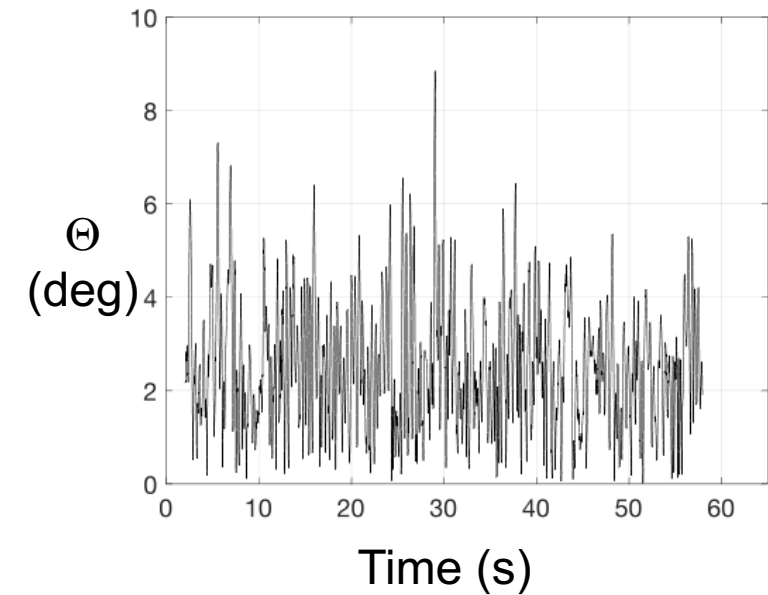
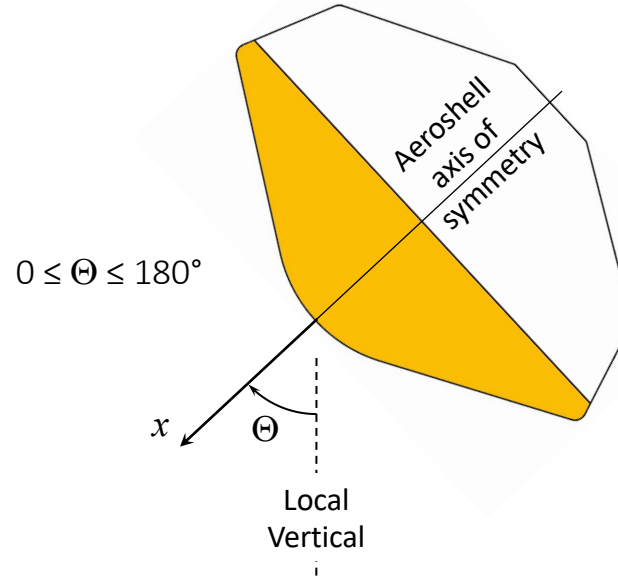


Results – Large Angles Oscillation



Screenshot:
Movie
Block 9 Perturbed

Results – Quantitative Data Analysis



Results – Quantitative Data Analysis

Block	Parachute	Bridle	90%-tile Small Θ (deg)	90%-tile Large Θ (deg)	Comments
9	Nominal	#3, Triple/Narrow (Nominal)	5.0	53.5	Baseline configuration. 100% of perturbed launches yielded sustained large Θ oscillations (14/14).
10	Large	#3, Triple/Narrow (Nominal)	5.4	53.2	100% of perturbed launches yielded sustained large Θ oscillations (9/9).
11	Small	#3, Triple/Narrow (Nominal)	5.9	82.3	100% of perturbed launches yielded sustained large Θ oscillations (6/6).
12	Nominal	#4, Single	5.3	59.6	100% of perturbed launches yielded sustained large Θ oscillations (8/8).
13	Nominal	#5, Triple/Wide	5.2	49.5	18% of perturbed launches yielded sustained large Θ oscillations (2/11).
14	Nominal	#6, Triple/Wide/Short	4.8	52.8	75% of perturbed launches yielded sustained large Θ oscillations (6/8).
15	Nominal	#7, Quad/Wide	4.9	48.0	31% of perturbed launches yielded sustained large Θ oscillations (4/13).
17	Nominal	#9, Triple/Wide/Rigid	5.3	None	0% of perturbed launches yielded sustained large Θ oscillations (0/29).

Conclusions

- 1) Most test configurations exhibit bimodal oscillatory behavior: small Θ and large Θ . Which mode is excited depends on launch conditions.
- 2) Large Θ oscillations seem to be driven by the aeroshell aerodynamics.
- 3) Bridle legs collapse is an enabling factor for large Θ oscillations. If bridle is rigid sustained large Θ oscillations are not possible.
- 4) Wider bridle attachment footprints make it more difficult for large Θ oscillations to occur.
- 5) Configuration with small parachute has a large Θ mode of significantly higher magnitude than those using nominal or large parachute.