



A relocatable lander to explore Titan's prebiotic chemistry and habitability

Simulation of a Subscale Entry Capsule Drop Test for the Dragonfly Mission

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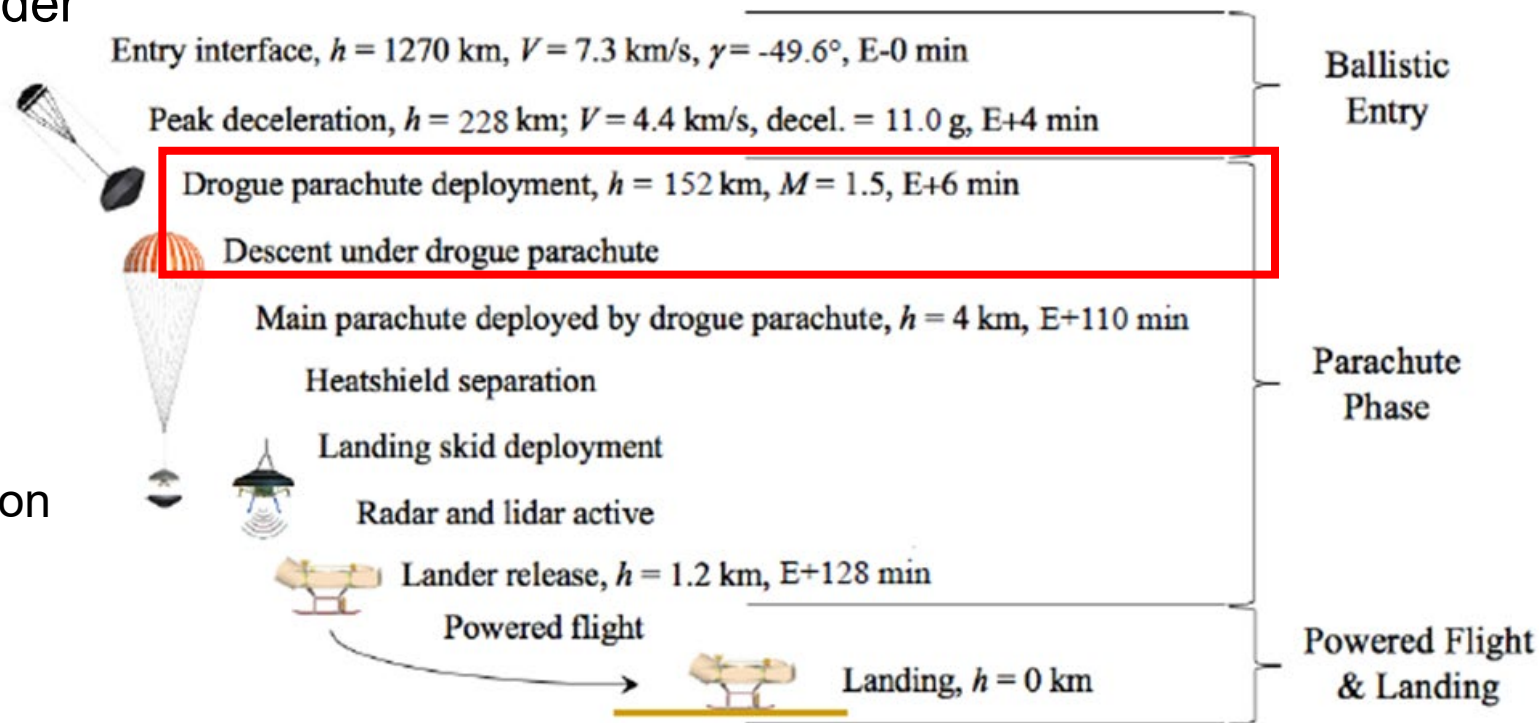
2: NASA Langley Research Center, Atmospheric Flight & Entry Systems Branch



Introduction/Motivation



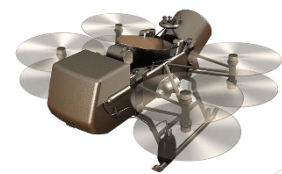
- The Dragonfly trajectory takes ~130 minutes from entry interface to the lander deploy event
 - 104 minutes of this is under the drogue parachute
- The dynamic behavior of the system under the drogue parachute is very important
 - Especially at the drogue-to-main transition
- Subscale drop tests have been performed to assess the vehicle dynamics at low Mach, under drogue



This talk covers the simulation of these tests for the purposes of validating the full-scale simulation



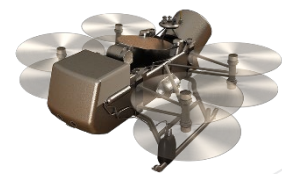
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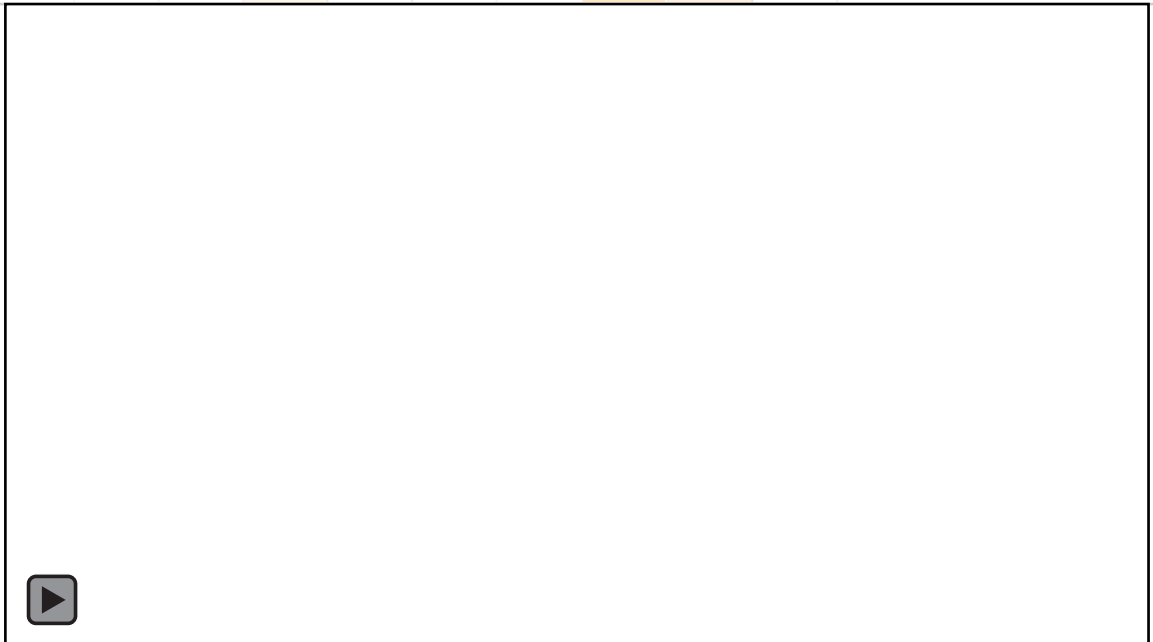
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Dragonfly Subscale Drop Tests



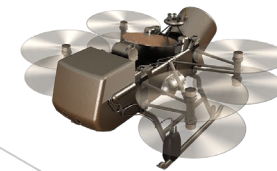
- Twelve subscale drop tests were performed to assess the dynamics of the aeroshell under drogue parachute
- A 16.67% dynamically-scaled model dropped to investigate the dynamics of the aeroshell and parachute
- An onboard accelerometer and gyroscope measured the dynamics of the vehicle as it descended, enabling post-processed estimates of the body angles and rates during descent



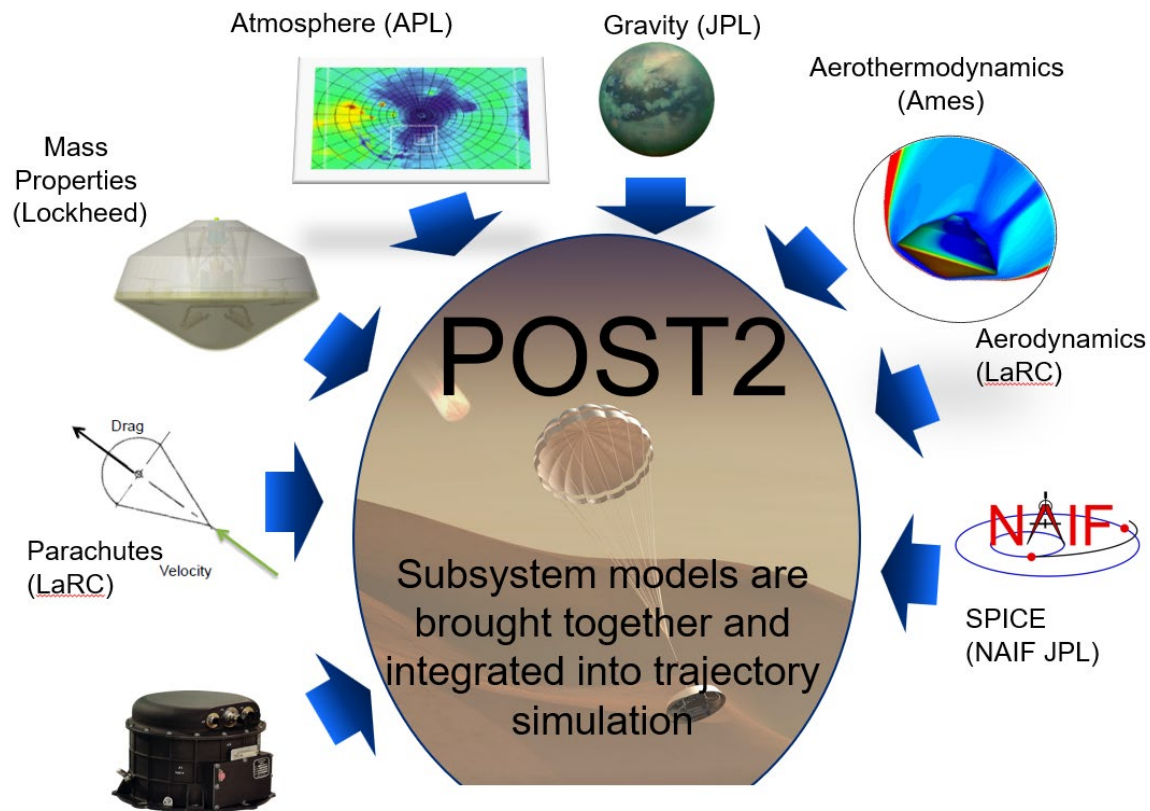
Parameter	Value
Aeroshell Mass, kg	3.038
Parachute Type	Disk-Gap-Band
Parachute Diameter, m	0.90
Drop Altitude (AGL), m	350
Titan Equivalent Altitude, m	4000



Dragonfly Flight Mechanics Simulation



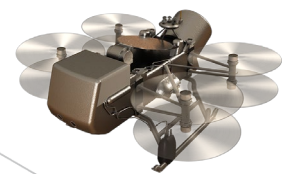
- The Program to Optimize Simulated Trajectories II (POST2) is used to simulate the full-scale entry, descent, and landing (EDL) segment of the Dragonfly mission
- POST2 is a six degree-of-freedom flight dynamics simulation that can simulate trajectories with multiple bodies
- **This enables modeling of the aeroshell and parachute as separate bodies which can move with respect to each other**



Model sources for the full-scale simulation

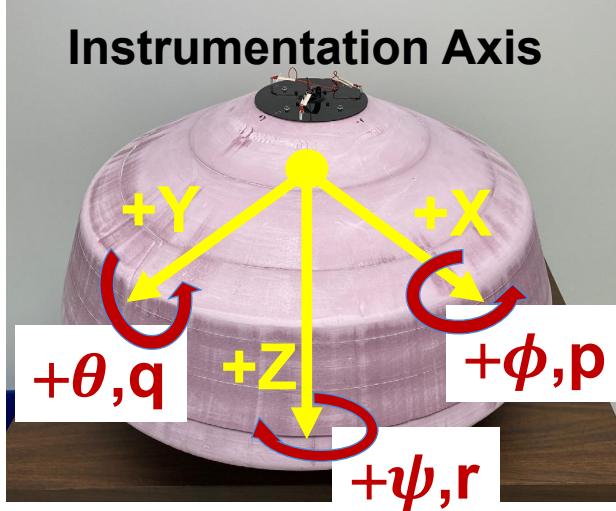


Simulated Drop Test



- POST2 planet, gravity, and atmosphere models were changed as necessary
- 100 drops were simulated and used to calculate statistics

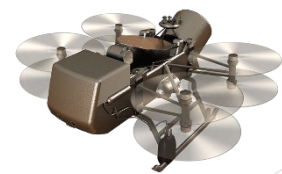
Modeling Parameter	Modelling Choice
Mass Properties	As in Test
Vehicle Geometry	As in Test
Aerodynamics	As in Full-scale
Initial Altitude, m	1000



Uncertainty Parameter	Choice
Aerodynamic Uncertainties	As in Full-scale
Atmosphere Dispersions	EarthGRAM defaults + Patchy atmosphere

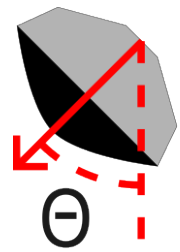
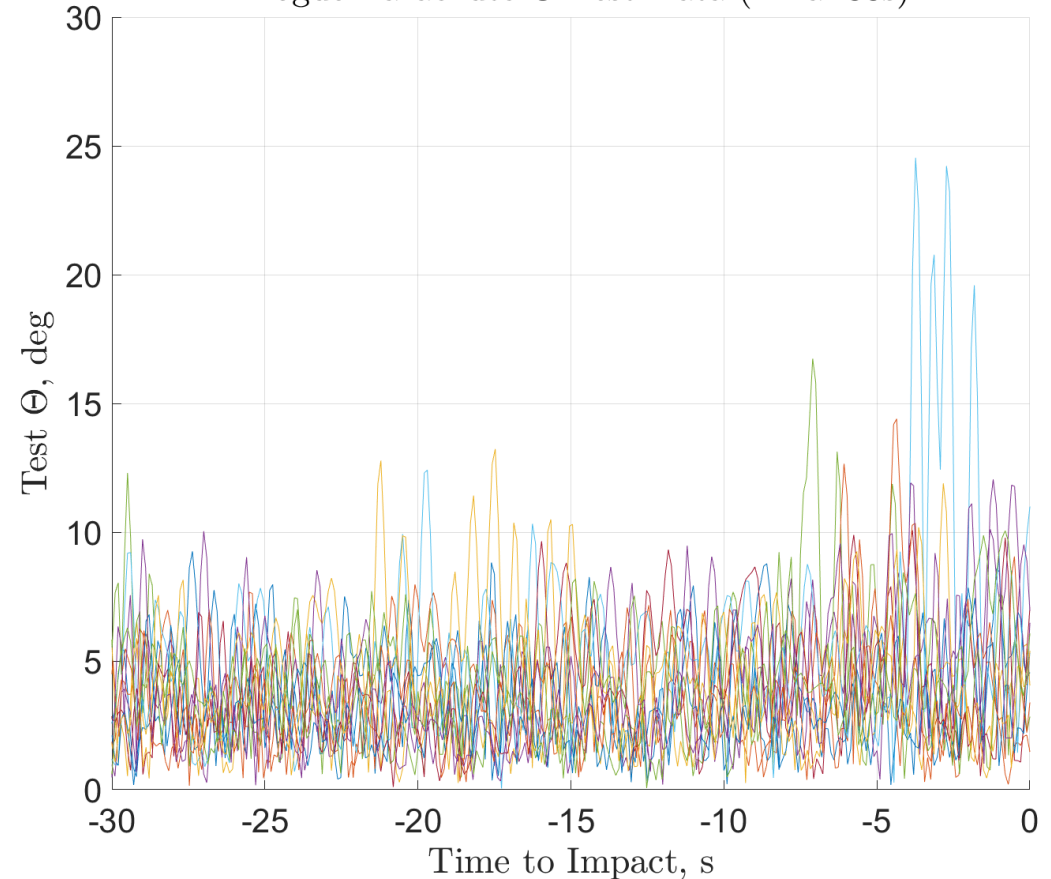


Nadir Angle Time Histories

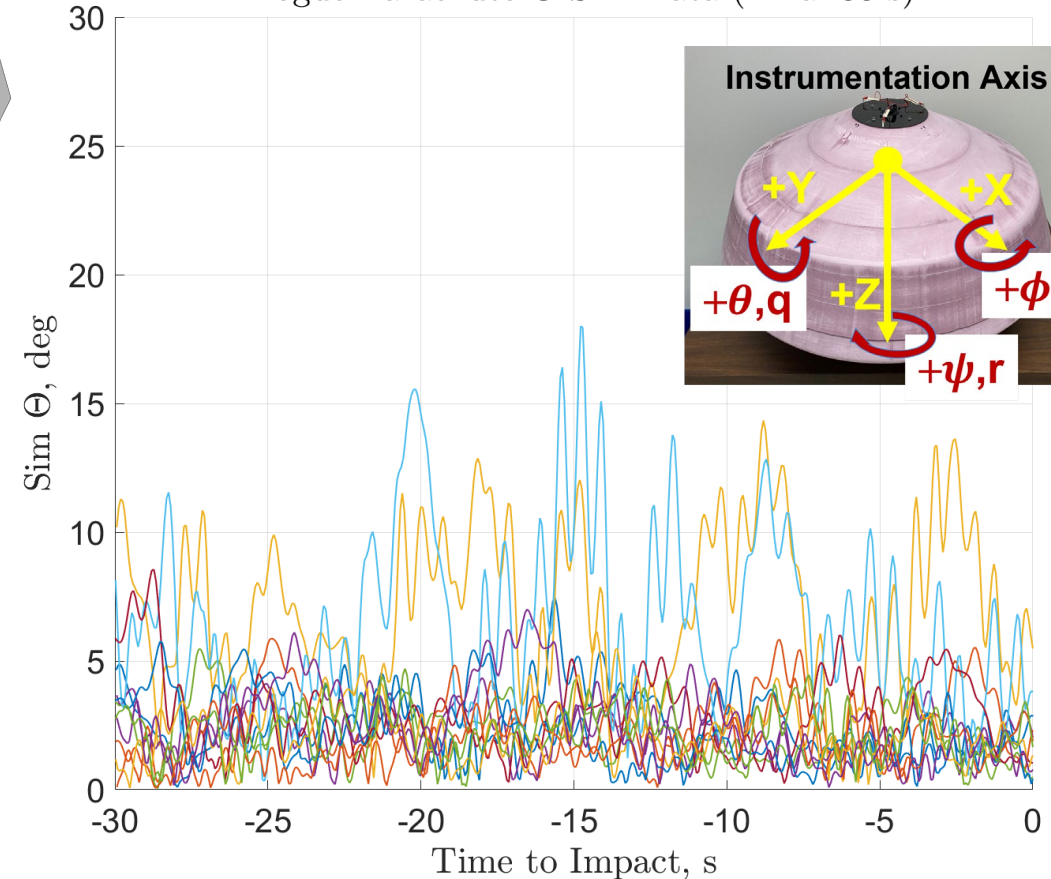


$$\Theta = \text{acos}(\cos(\theta) \cos(\phi))$$

Drogue Parachute Θ Test Data (Final 30s)



Drogue Parachute Θ Sim Data (Final 30 s)



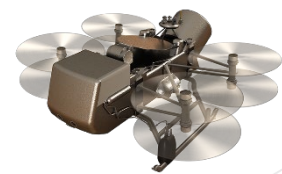
Simulation dynamics are in-family with test data



*First 12 sim samples shown for clarity 7

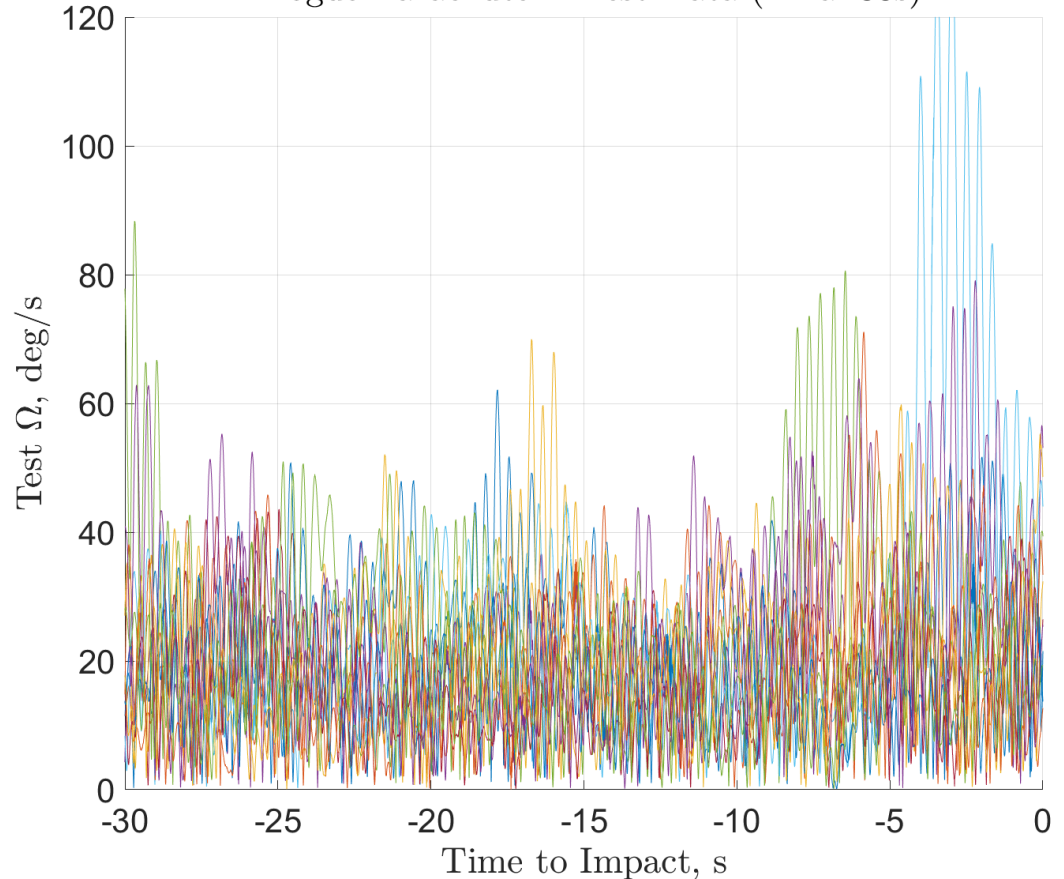


Lateral Attitude Rate Time Histories

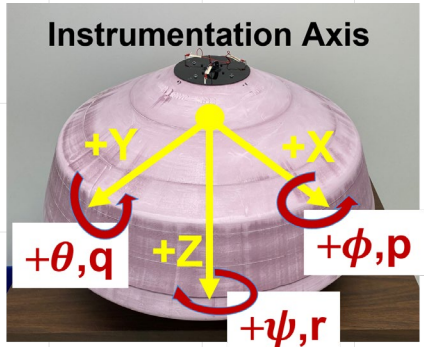
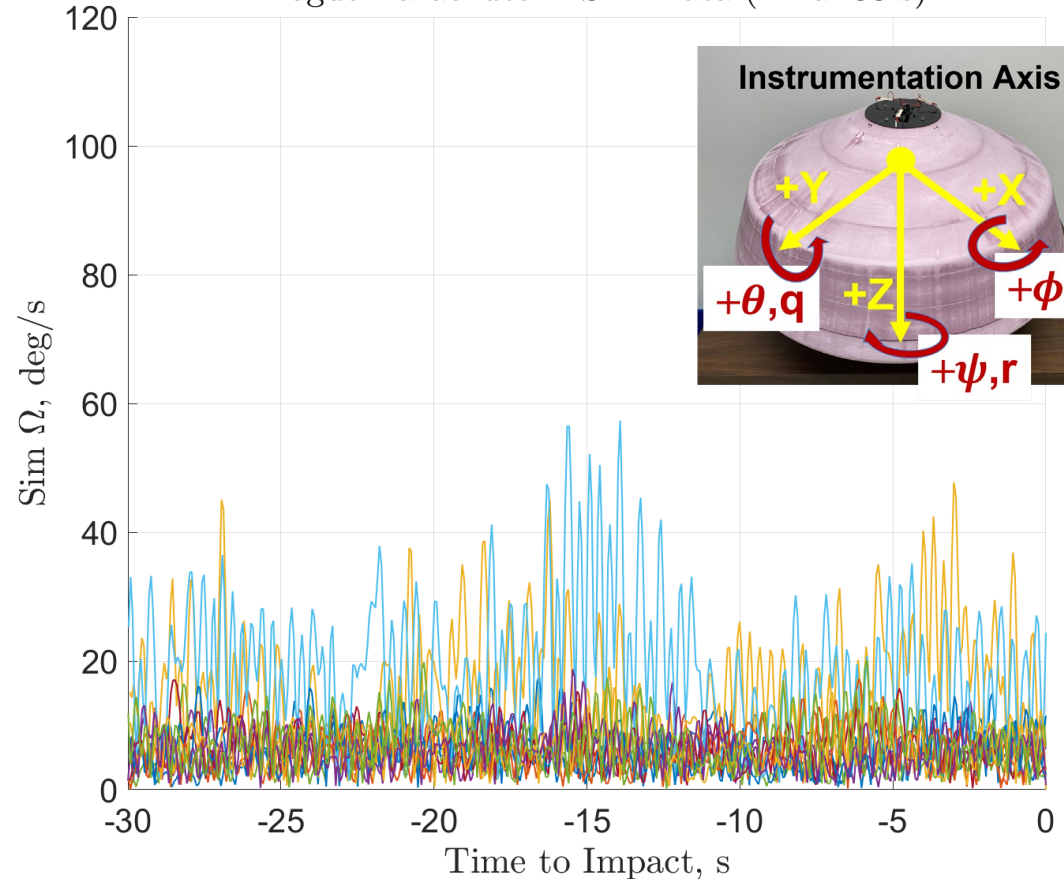


$$\Omega = \sqrt{q^2 + p^2}$$

Drogue Parachute Ω Test Data (Final 30s)



Drogue Parachute Ω Sim Data (Final 30 s)



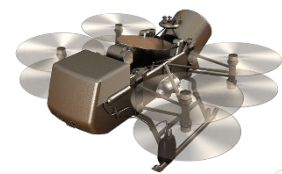
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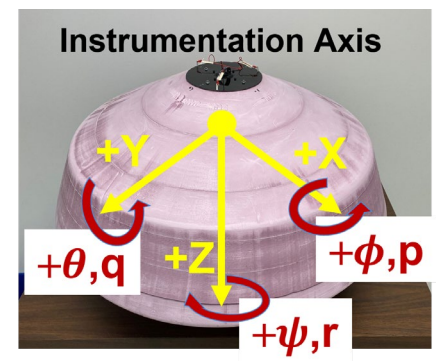


Statistical Comparisons



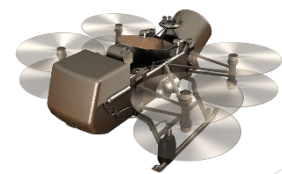
99 %-tile Statistic	Symbol	Test	Sim	Δ (Sim – Test)
Absolute Roll Angle, deg	$ \phi $	9.39	12.11	2.72
Absolute Pitch Angle, deg	$ \theta $	9.34	12.17	2.83
Nadir Angle, deg	Θ	11.41	14.89	3.48
Absolute Roll Rate, deg/s	$ r $	45.76	37.12	-8.64
Absolute Pitch Rate, deg/s	$ p $	50.90	33.30	-17.60
Lateral Attitude Rate, deg/s	Ω	61.00	45.57	-15.43

- Model-scale differences in Euler angles are within 4 degrees
- Model-scale differences in rates are within 20 deg/s
 - Titan-scale rates are smaller by a factor of 6.604, so differences are within 3 deg/s

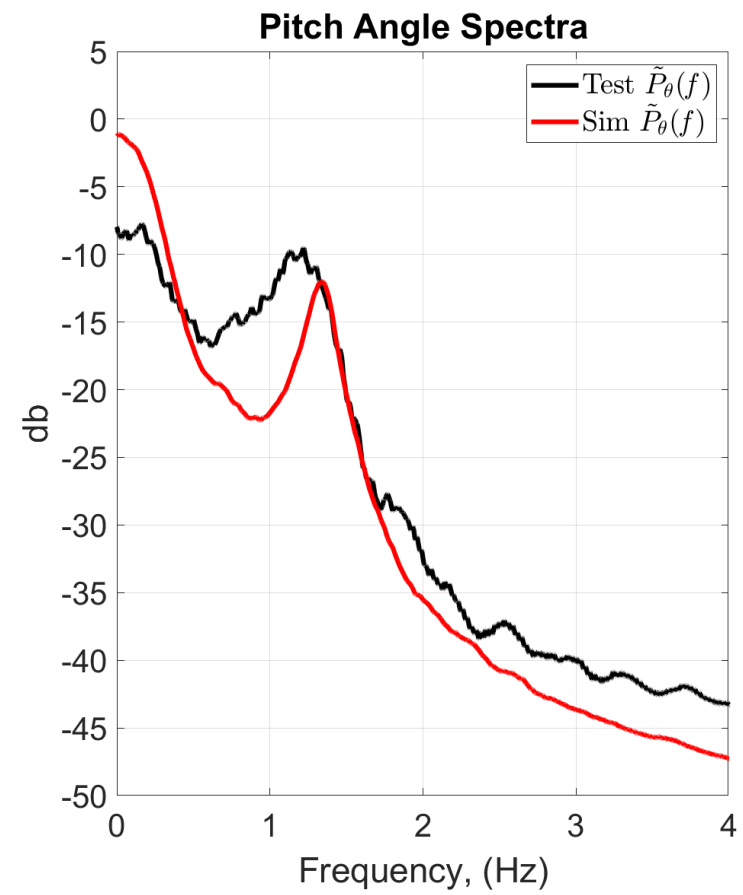
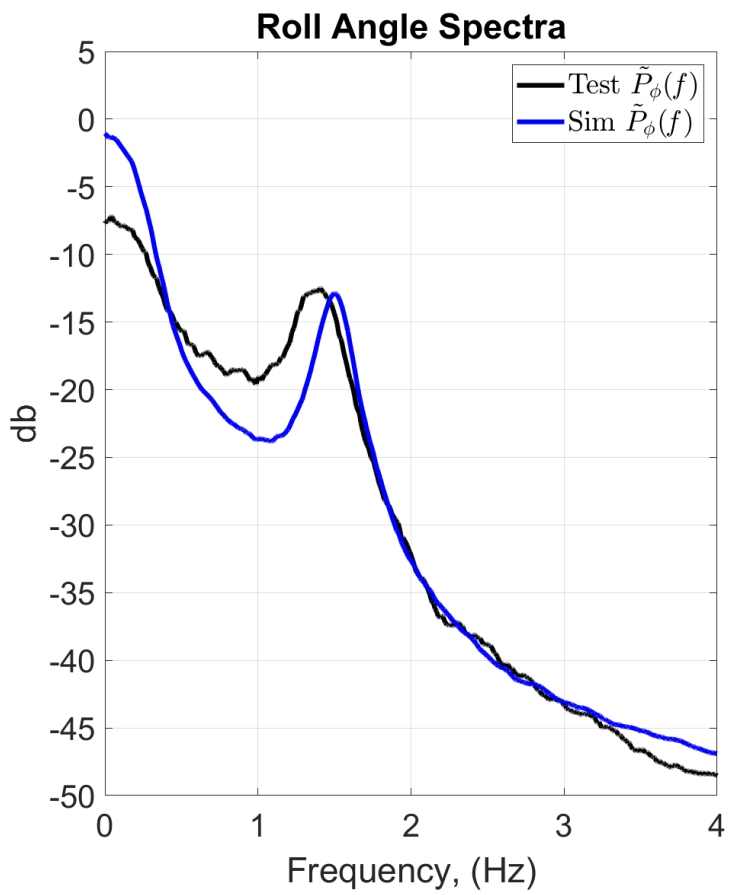




Response Power Spectra Analysis



Power spectra analysis shows close agreement between the test and sim data





Conclusions & Future Work



Conclusions

- This analysis was focused on simulating a subscale drop test of the Dragonfly drogue parachute
- The simulation results appear to be in-family with the test data

The results of this study contribute to the validation of the full-scale POST2 simulation of the Dragonfly entry trajectory

Future Work

- Drop tests for the main parachute have been completed and are being analyzed & simulated
- Plans are underway for additional drop tests with the posed lander

