Flight Analysis of an Autonomously Navigated Experimental Lander

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Airborne Systems

Autonomously Navigated paraGliding Experimental Lander

ANGEL

NASA GRC Rocket U

Flight Objectives

Increase the reusability of high altitude balloon gondolas after landing			
Goals		**Objectives**	
1.0	Demonstrate a method to reduce damage to the gondola during landing	**1.1**	Launch and land a gondola using damage reduction method
		1.2	Collect and retrieve load data during the operation of the damage reduction method
2.0	Demonstrate a method to increase recoverability of the gondola after landing	**2.1**	Perform a controlled landing of a gondola to a specified target region

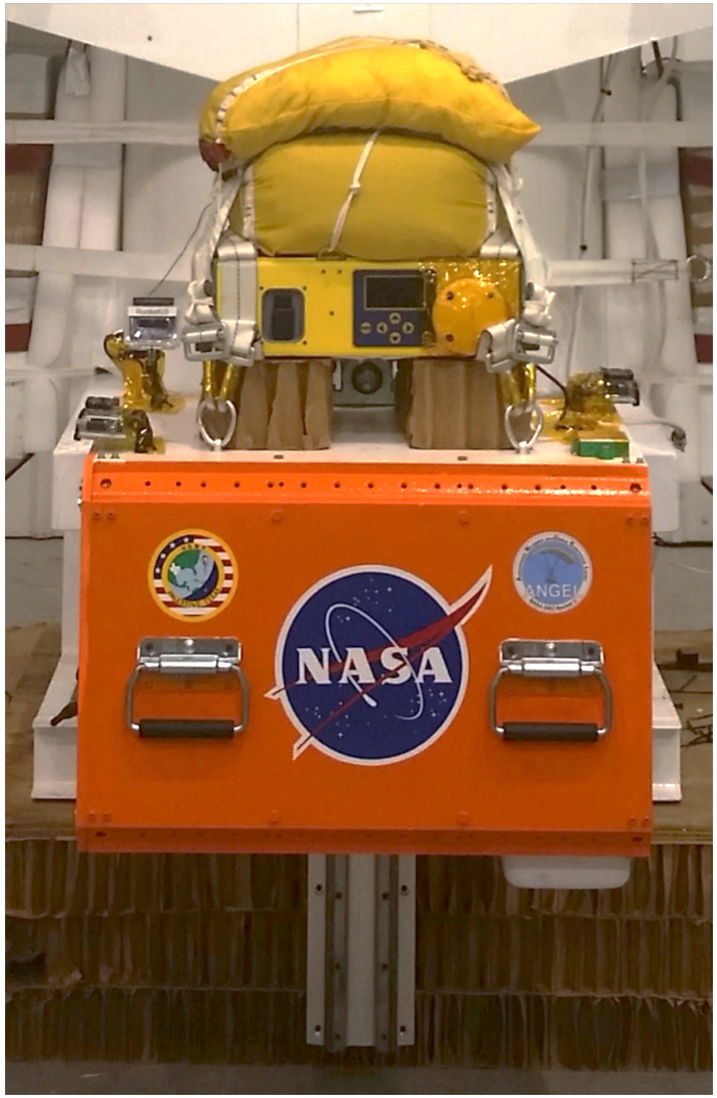
NASAFly System

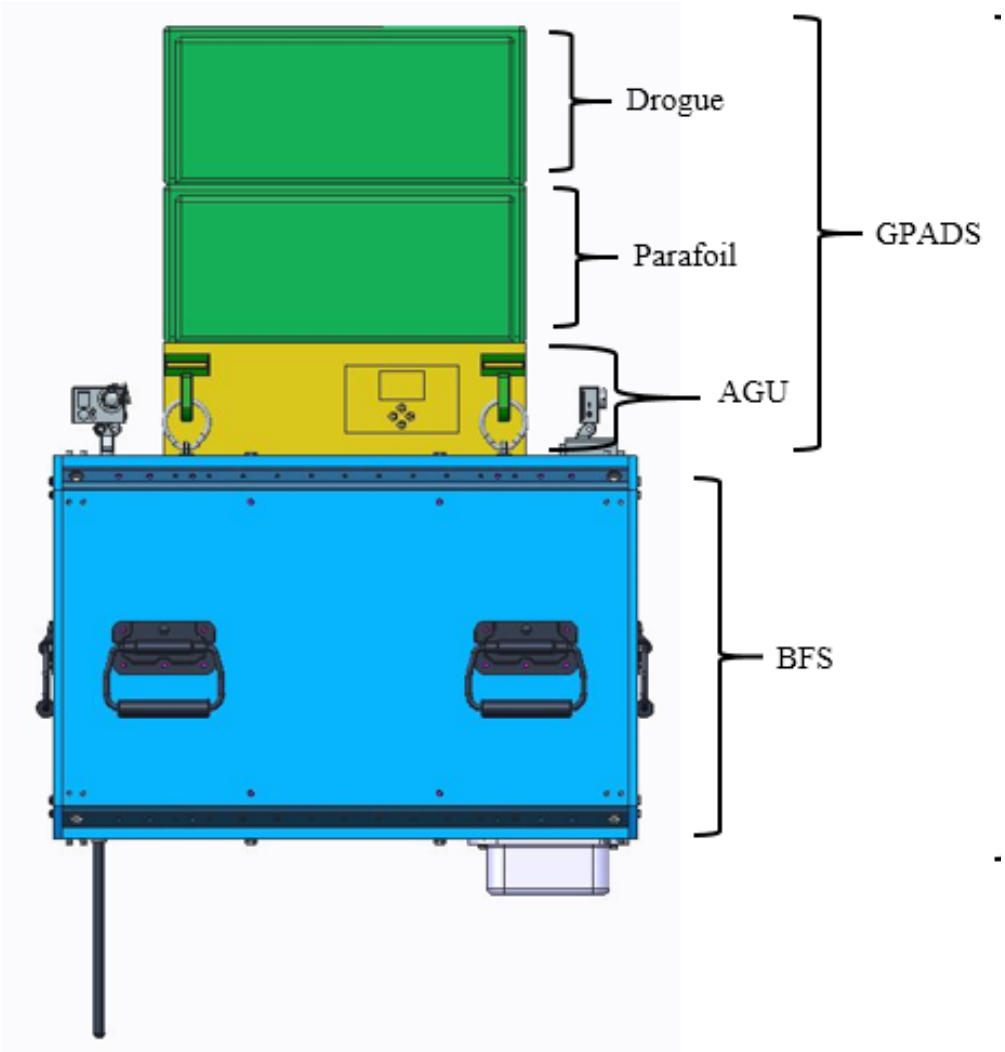
- Developed by Airborne Systems
- Guided Precision Aerial Delivery

New Challenges

- Textile tolerance to radiation exposure
- Operating systems at combined low densities and temperatures
- Safely, reliably, and cleanly separating from the host vehicle and initiating drogue inflation
- Stability during a transonic free-fall
- Use of GPS sensors near their altitude and speed limits
- Mission planning for balloon flights with highly variable trajectories

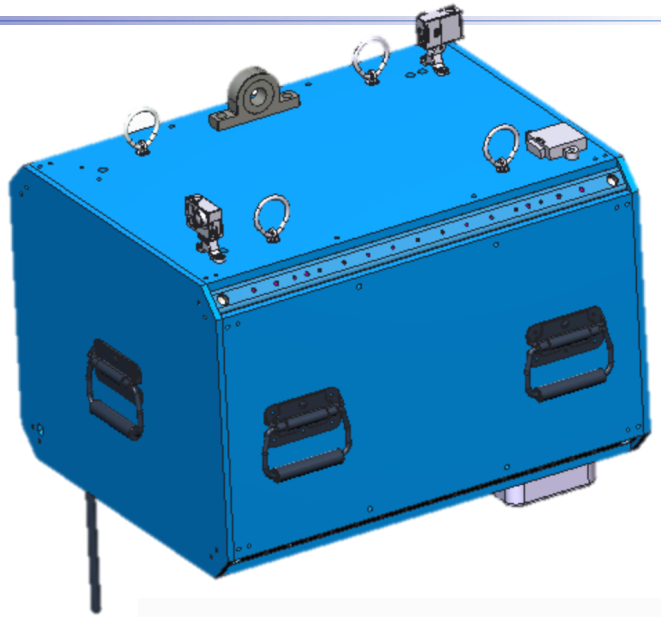
ANGEL Payload

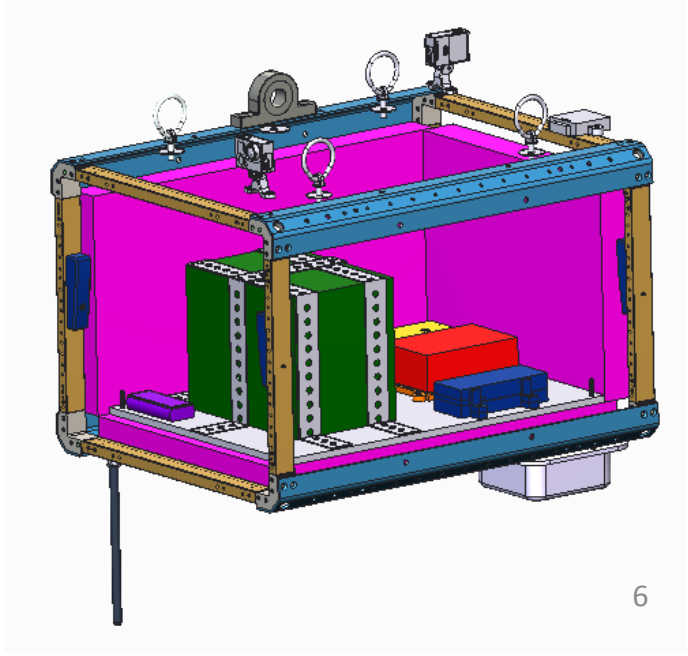




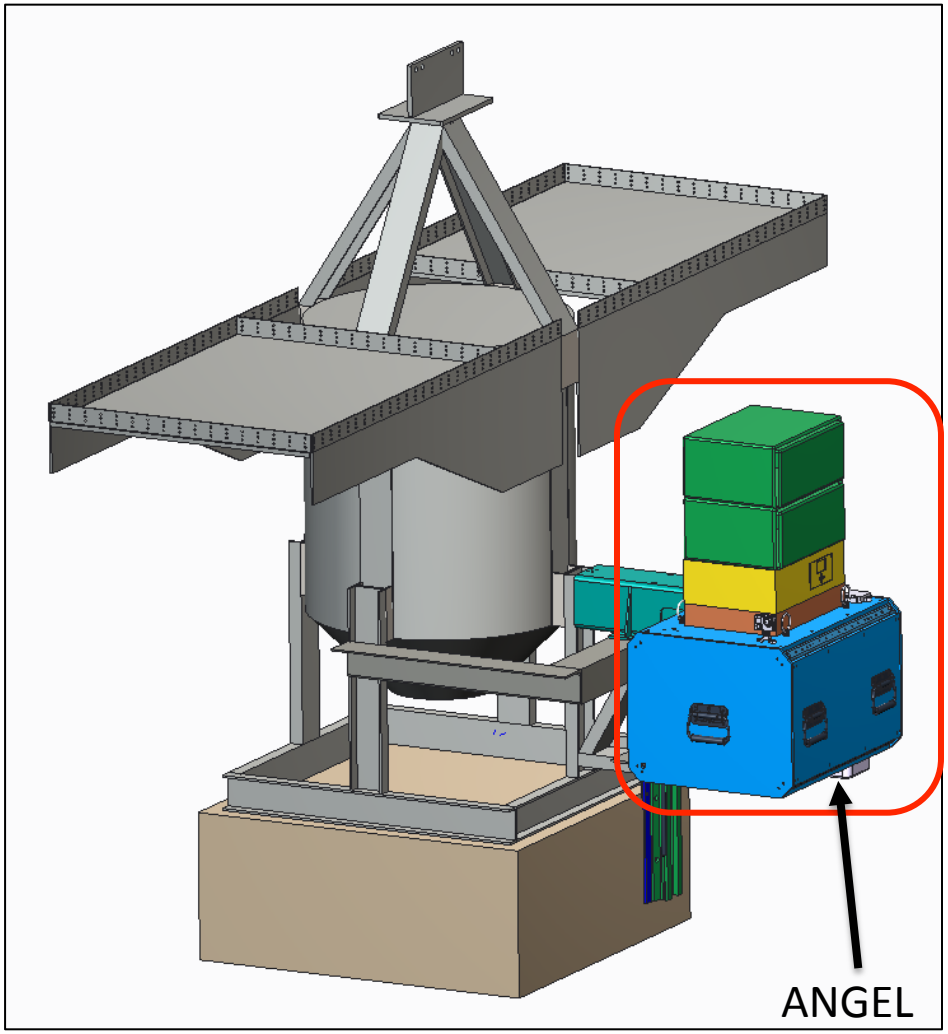
Balloon Flight System (BFS)

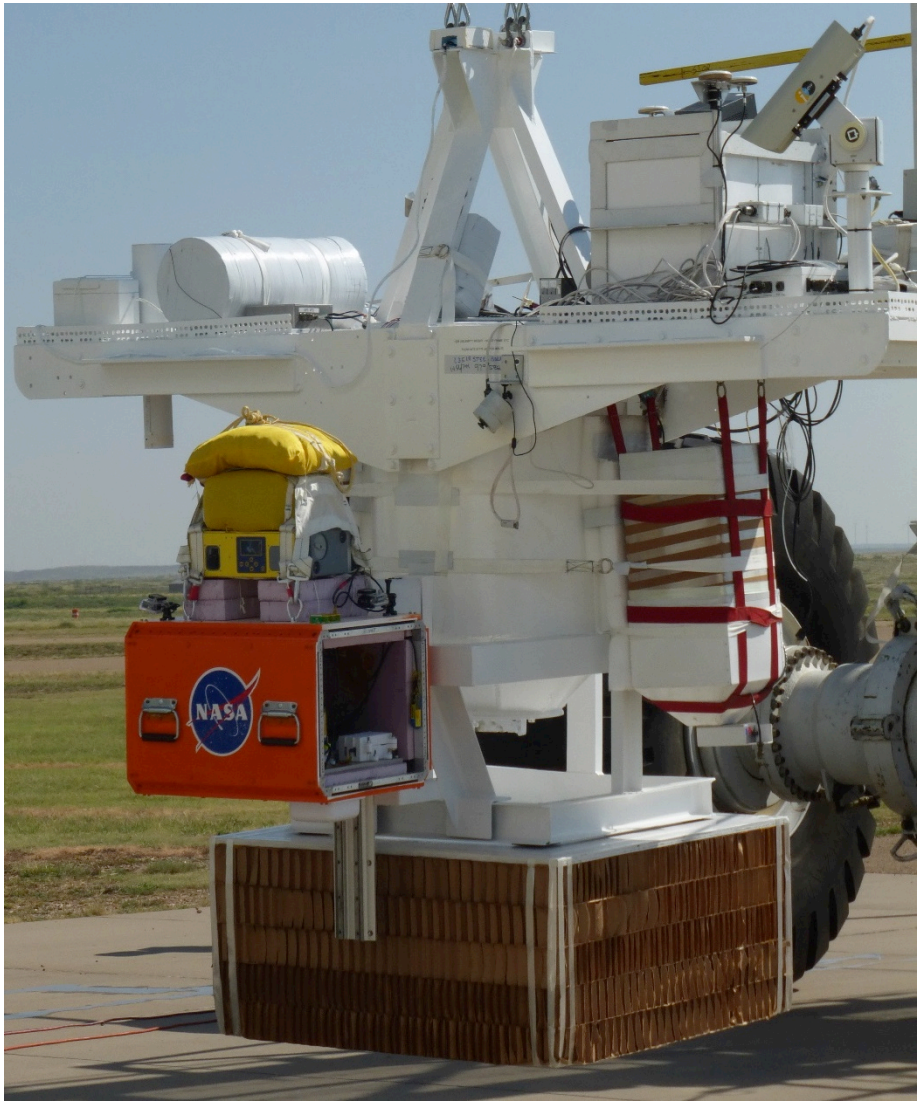
- Monitors flight and landing conditions
- Sensors include:
  - GPS
  - 3-axis Accelerometers
  - 3-axis Gyro
  - 3-axis Magnetometer
  - Thermocouples
  - Barometers
  - Cameras
  - Current/voltage Monitoring
  - Telemetry



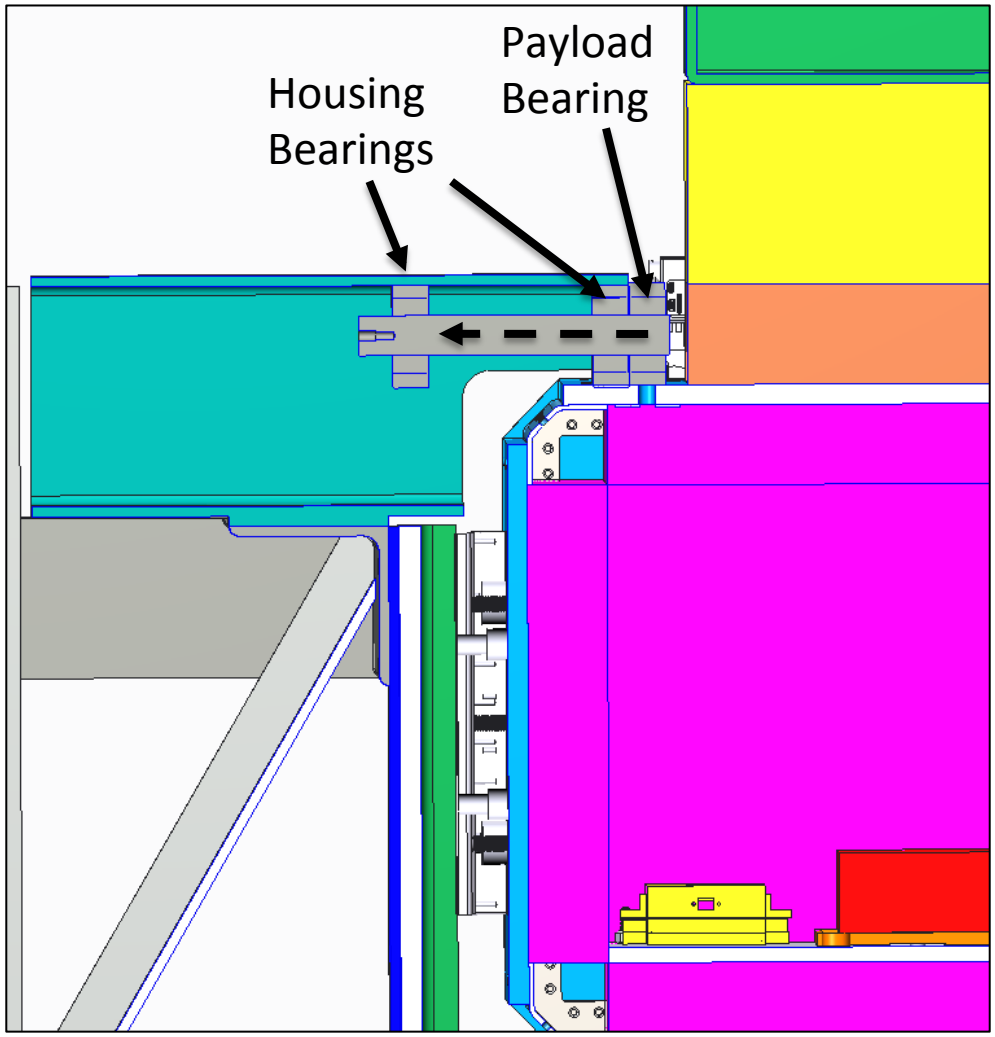


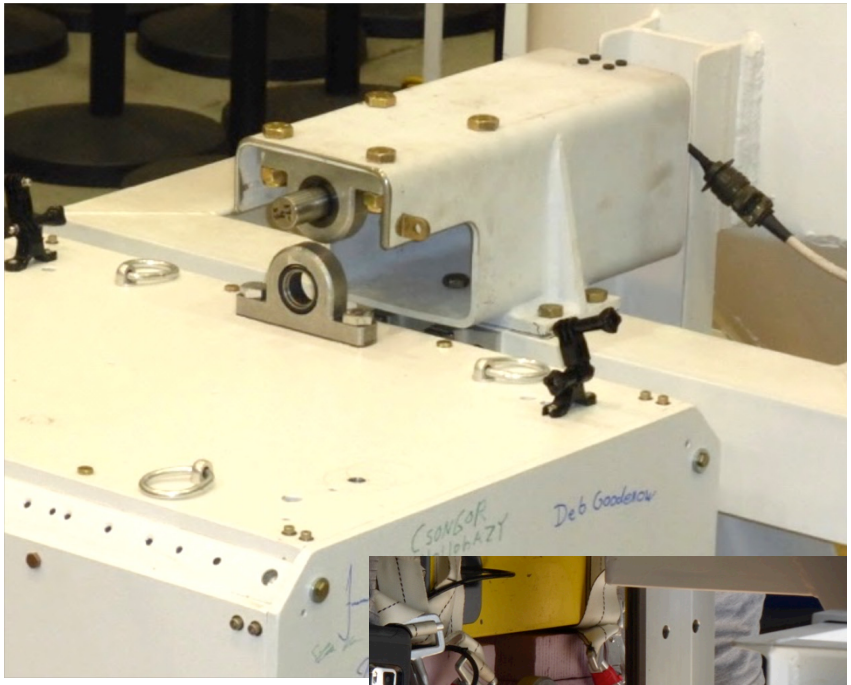
Separation System Design





Separation System – Section View





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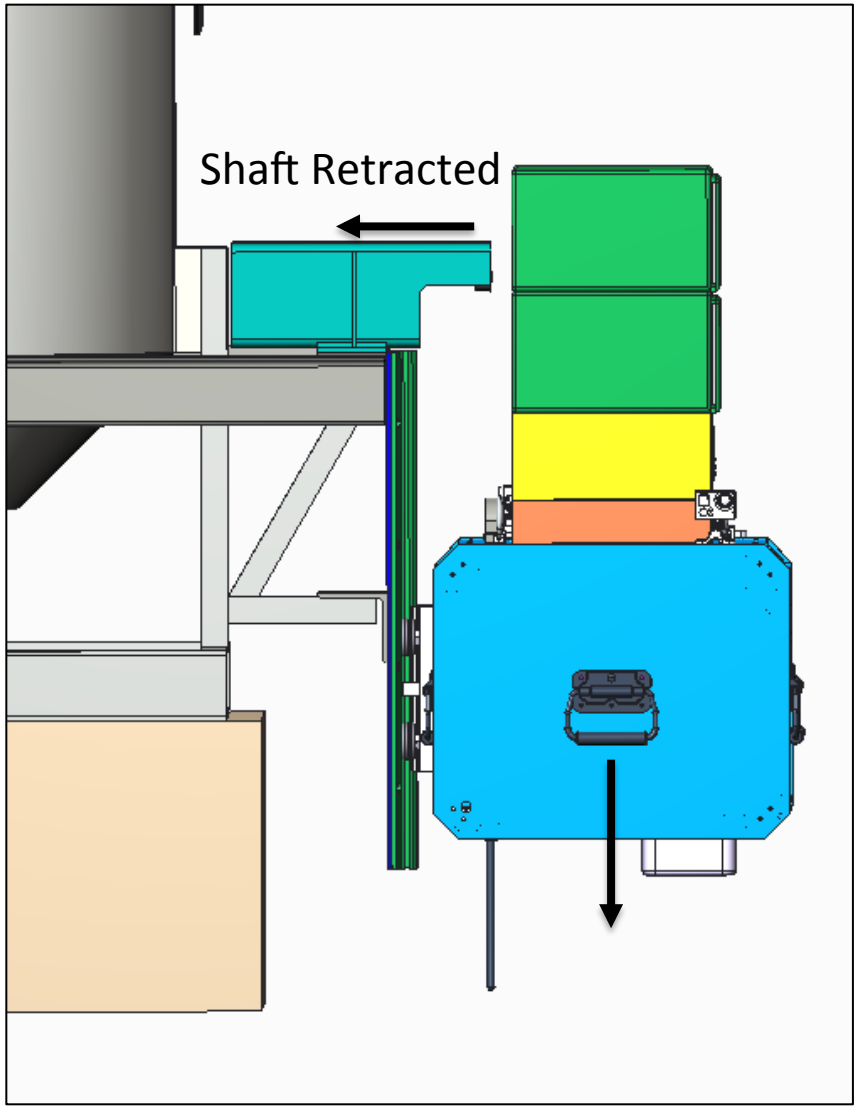
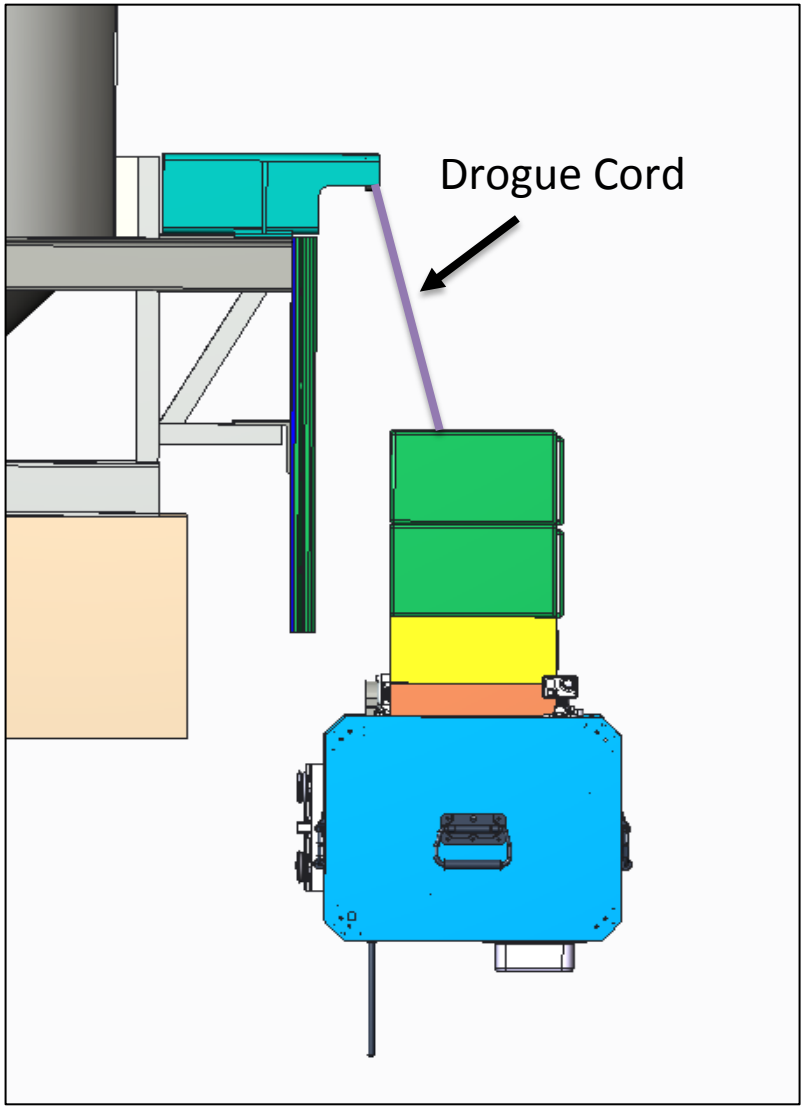
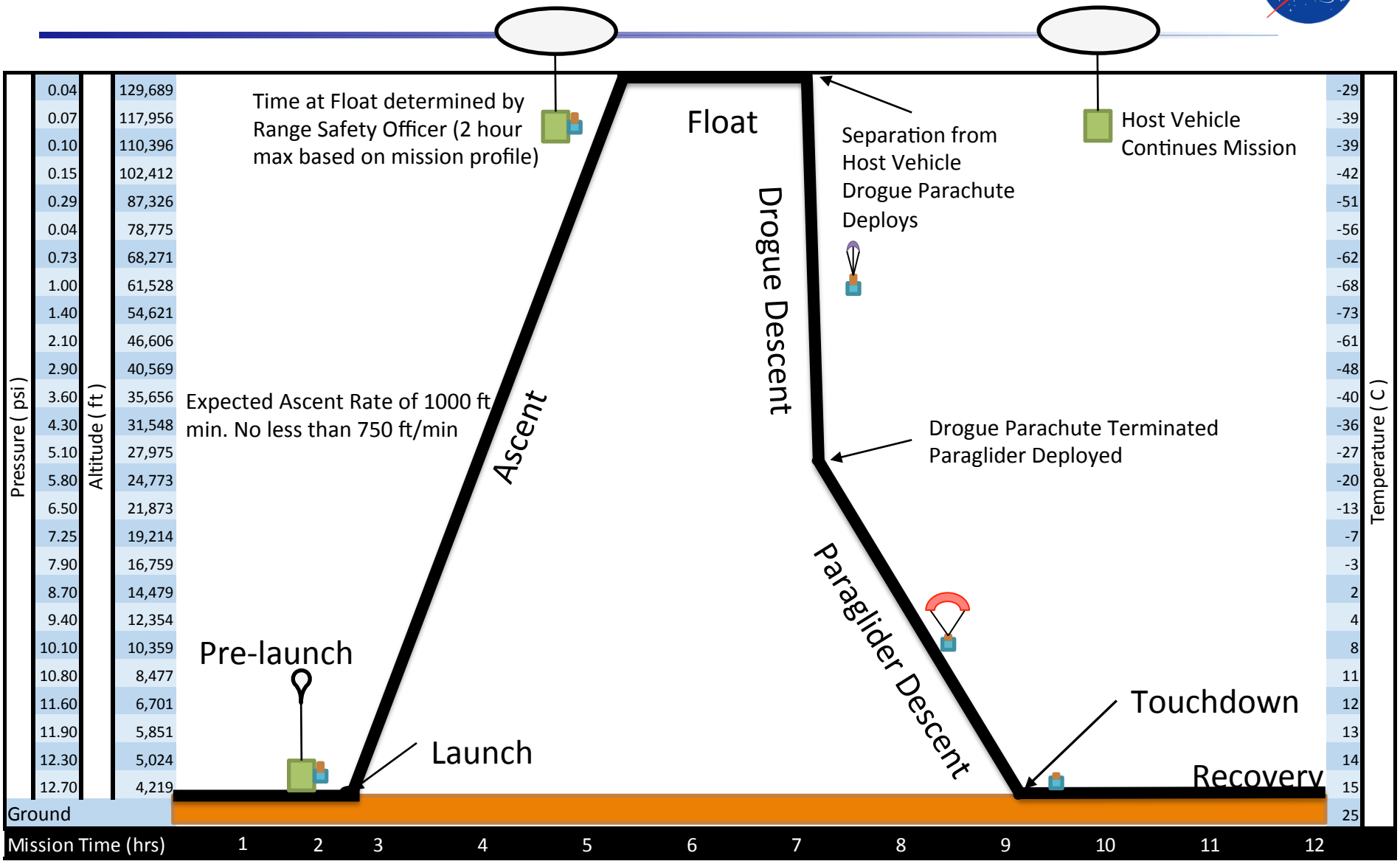


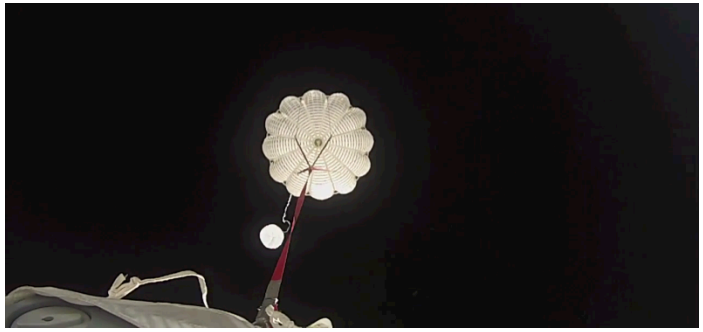


Flight Profile



Separation and Descent

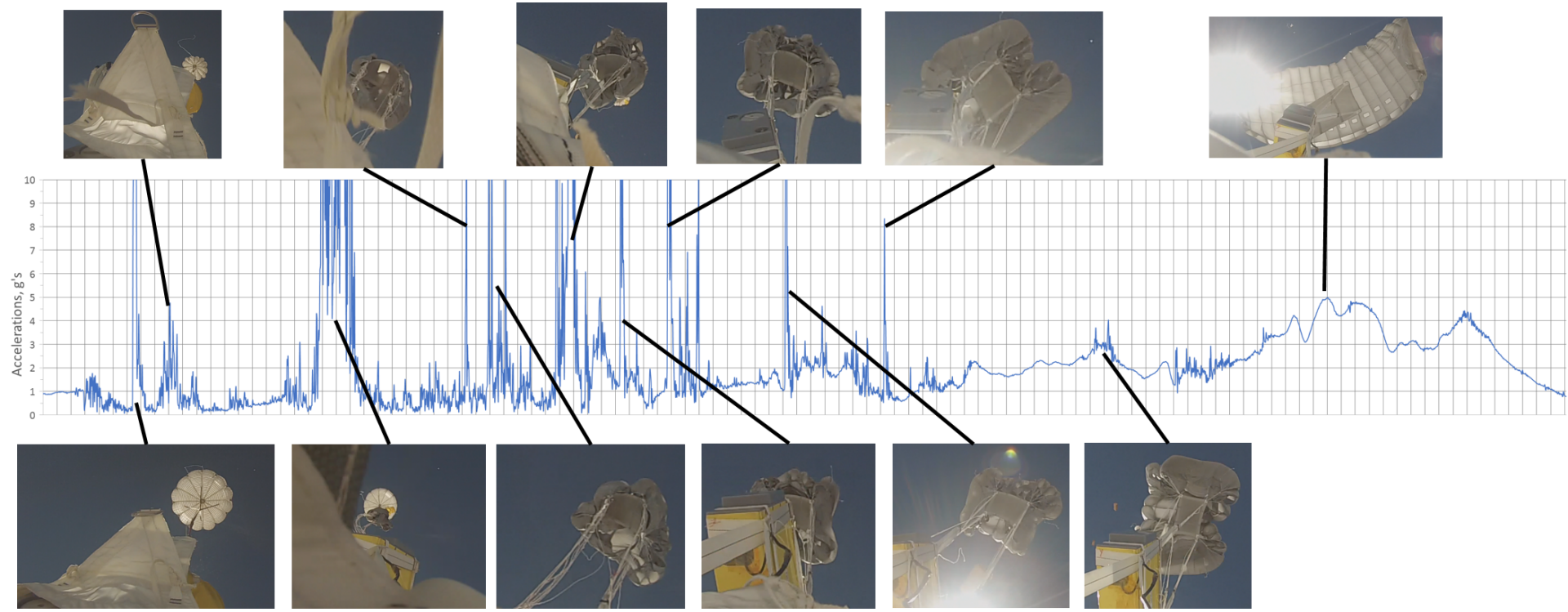
41.5 minute descent from 108,000 ft.
360 mph max speed during drogue fall



Successfully maintained:

- ✓ Temperature above 10 Celsius
- ✓ 7-10 satellite GPS lock
- ✓ Clean separation and drogue
- ✓ Stable Subsonic Fall
- ✓ Telemetry though out descent

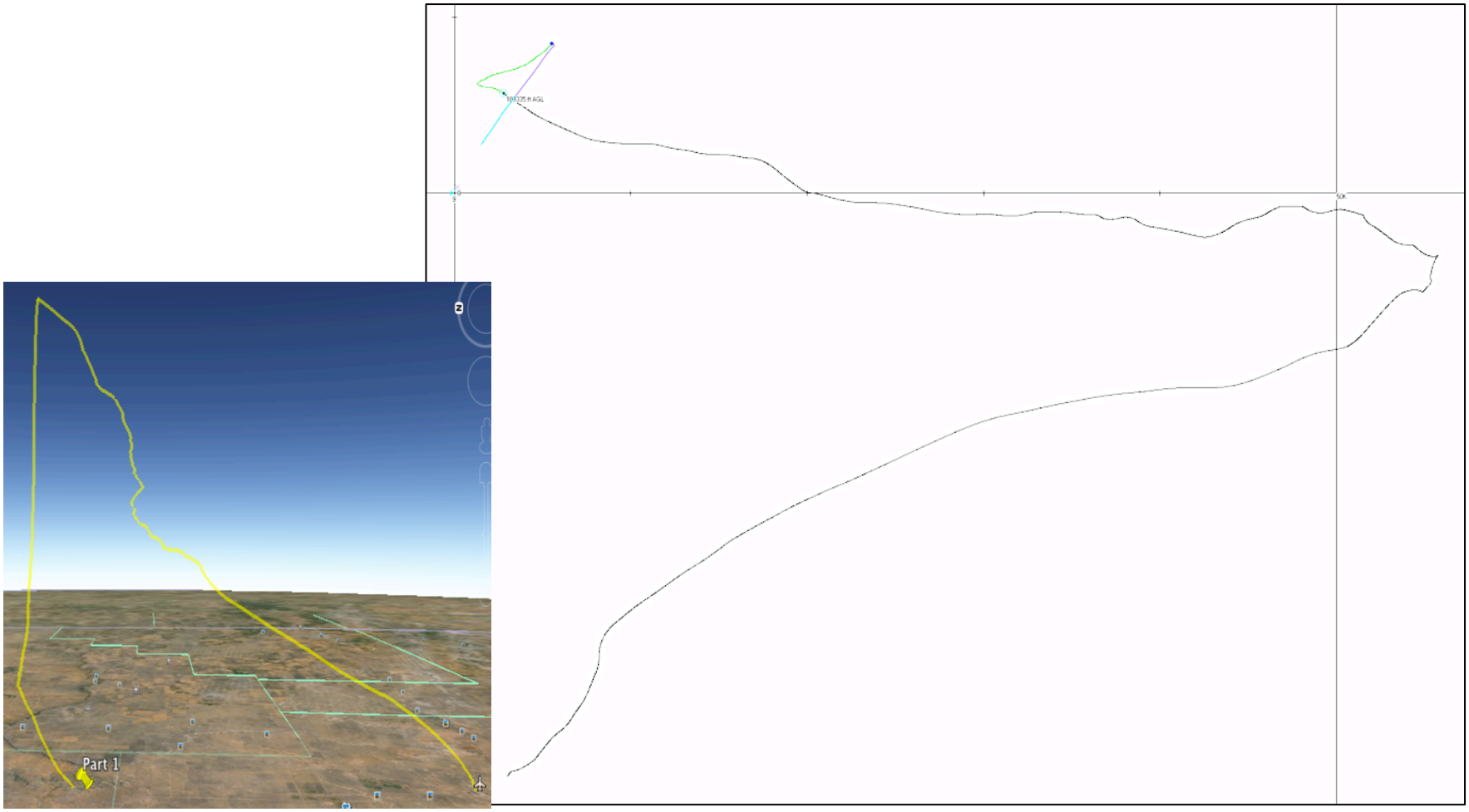
Deployment Loads



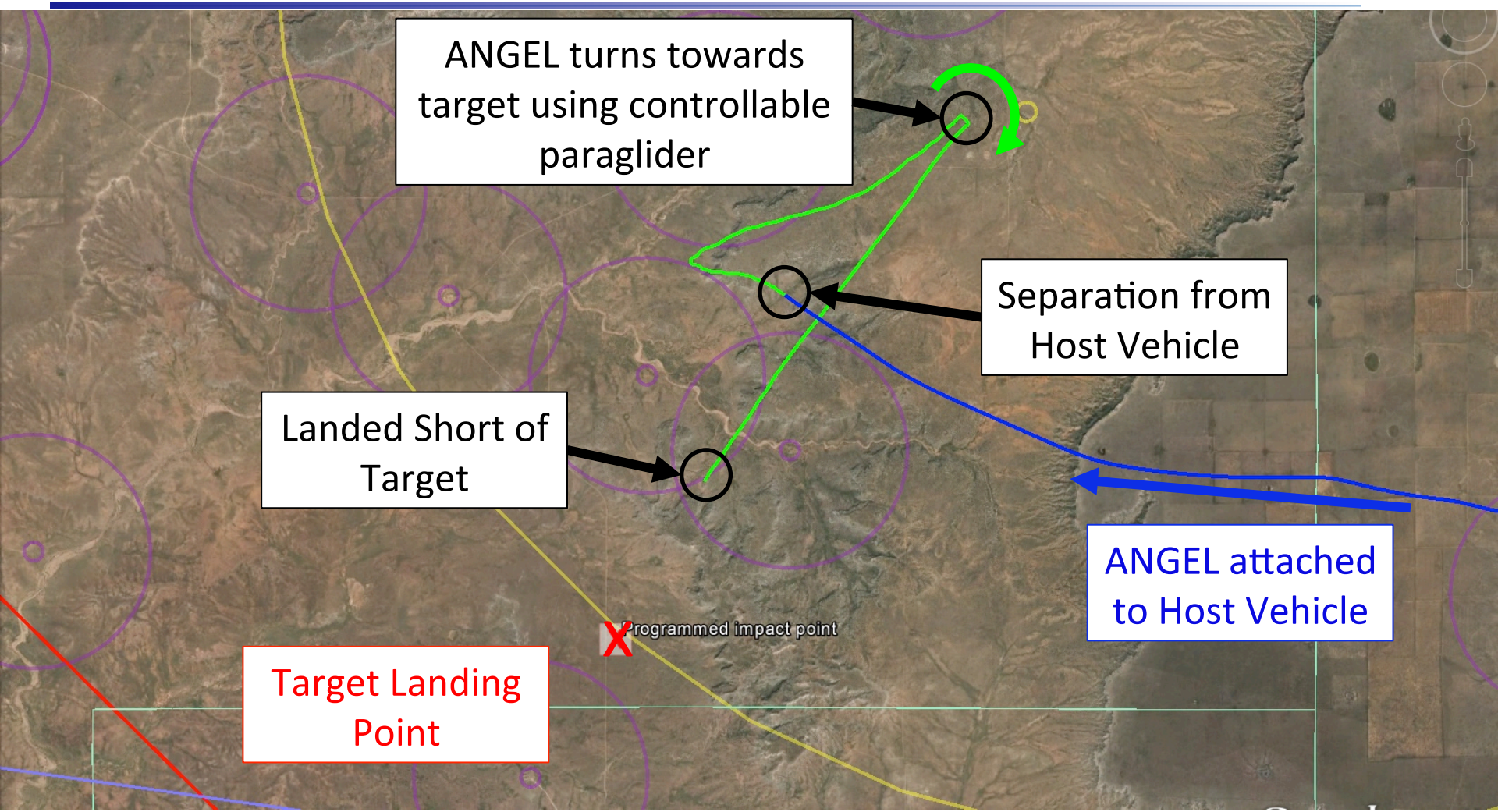
Acceleration, g's

	Snatch	Inflation
Raw	20.93	4.99
0.025s Average	13.33	4.87
0.05 Dwell	9.26	4.45

Flight Path



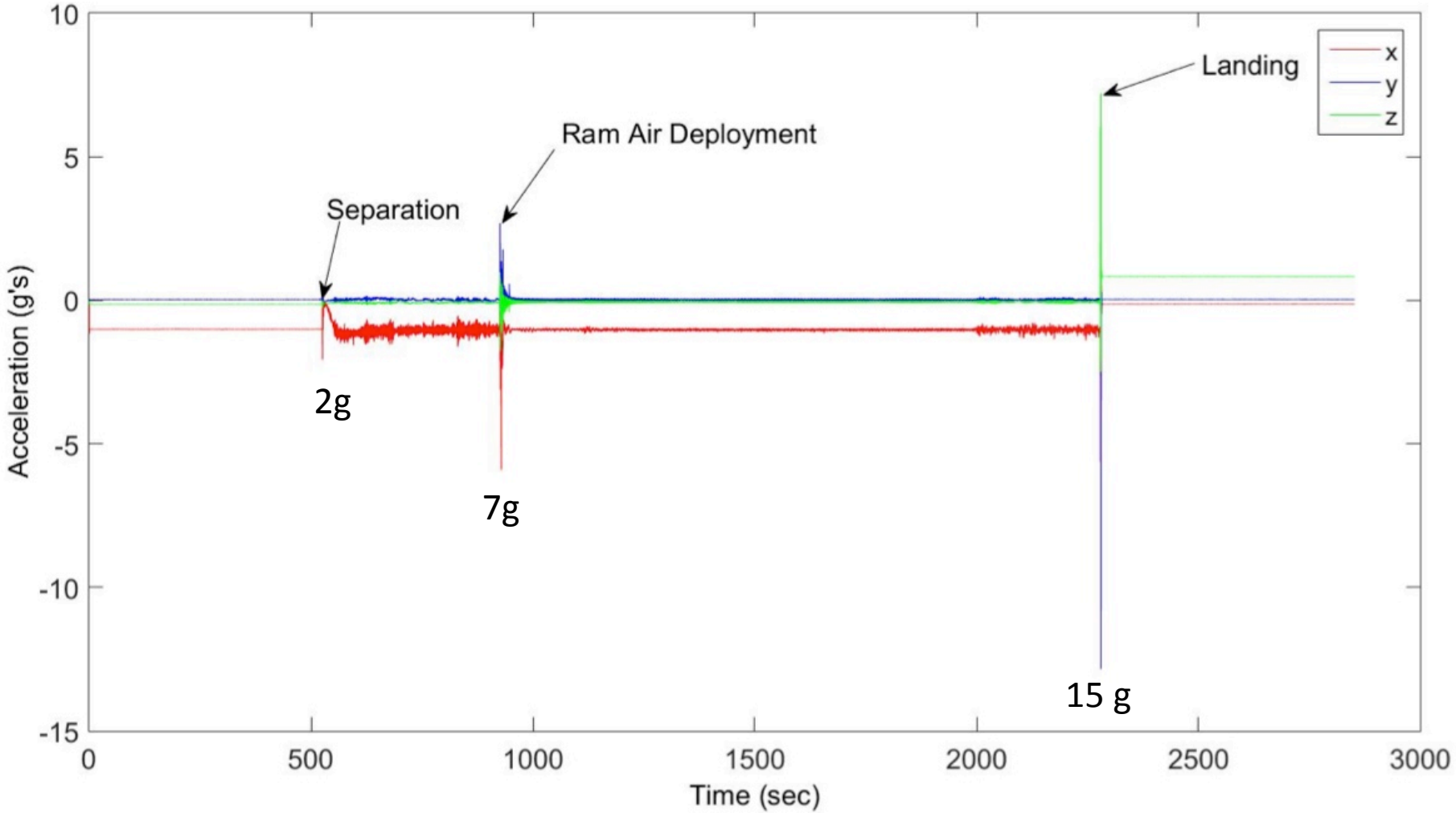
Final Flight Path

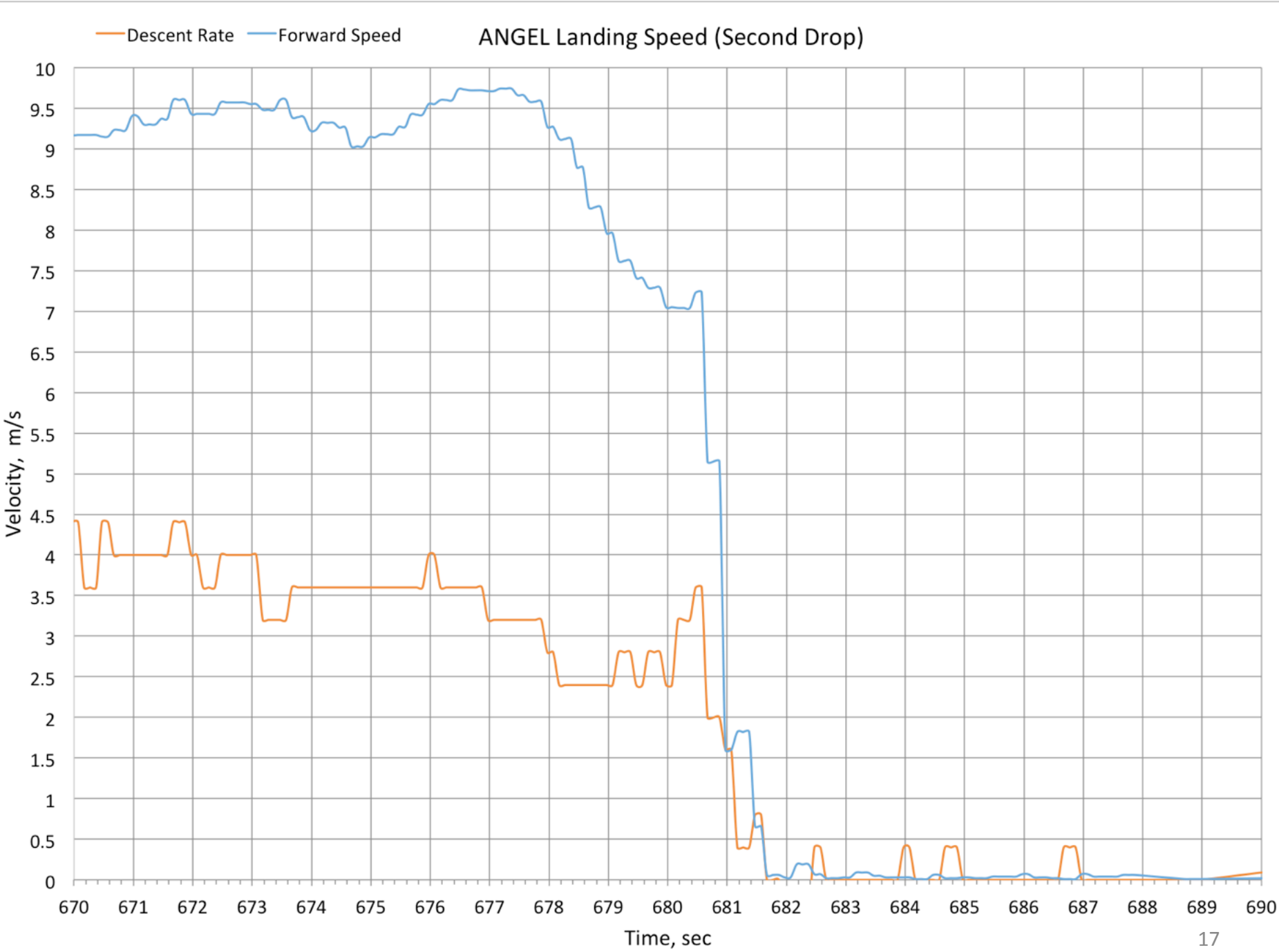


ANGEL landed 3,113 meters from the Impact Point (~1.93 miles)

Impact

Impact Loads




Descent Rate
Forward Speed
ANGEL Landing Speed (Second Drop)
Velocity, m/s
Time, sec
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
670
671
672
673
674
675
676
677
678
679
680
681
682
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690

Lessons Learned

- Use low elastic material, such as Kevlar, as attenuation against drogue rebound and lengthen as far as necessary, consider adding a cutter after drogue apex
- Sew stiffener material into the drogue bridle to help it remain straight during initial separation transient
- Minimize loose linkages along the parachute load path to minimize deployment shock, incorporate a confluence to reduce coupling between payload and canopy yaw
- Pre-program numerous acceptable impact points to protect against highly variable flight trajectory
- Make deployment altitude autonomously adjustable to compensate for wind and trajectory drift
- Incorporate a range finder to supplement altitude information for off-nominal landing flaring operation

Thank you!

Questions?