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LDSD

Pilot Deployment of the LDSD Parachute via a Supersonic Ballute

Chris Tanner

23rd AIAA Aerodynamic Decelerators Systems Technology Conference and Seminar
March 31, 2015

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LDSD Flight Vehicle Overview

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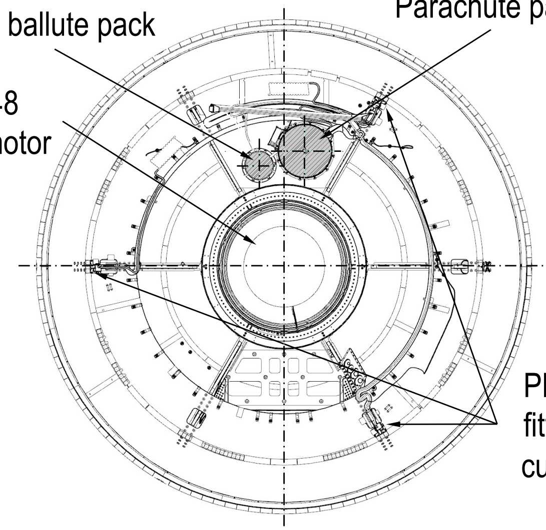
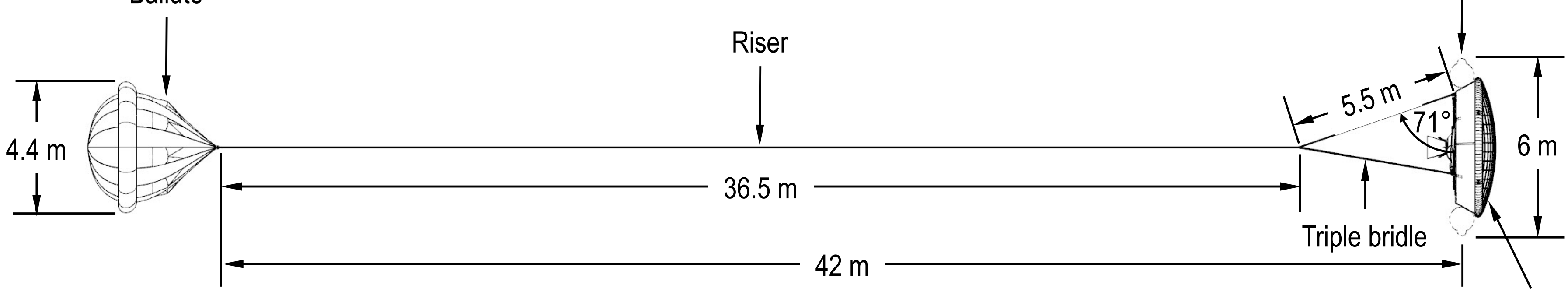
- The Low Density Supersonic Decelerator (LDSD) supersonic flight test vehicle uses a supersonic pilot ballute to deploy its supersonic parachute
  - Referred to as the Parachute Deployment Device (PDD)
  - Mortar deployment of the parachute was infeasible due to tip off moments



- The ballute is mortar deployed to a trailing distance of 137 ft and is attached to the vehicle using a riser and triple bridle

- The ballute is retained for 5 seconds for data acquisition and stabilization, then released to deploy the parachute



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Mortar Extensibility

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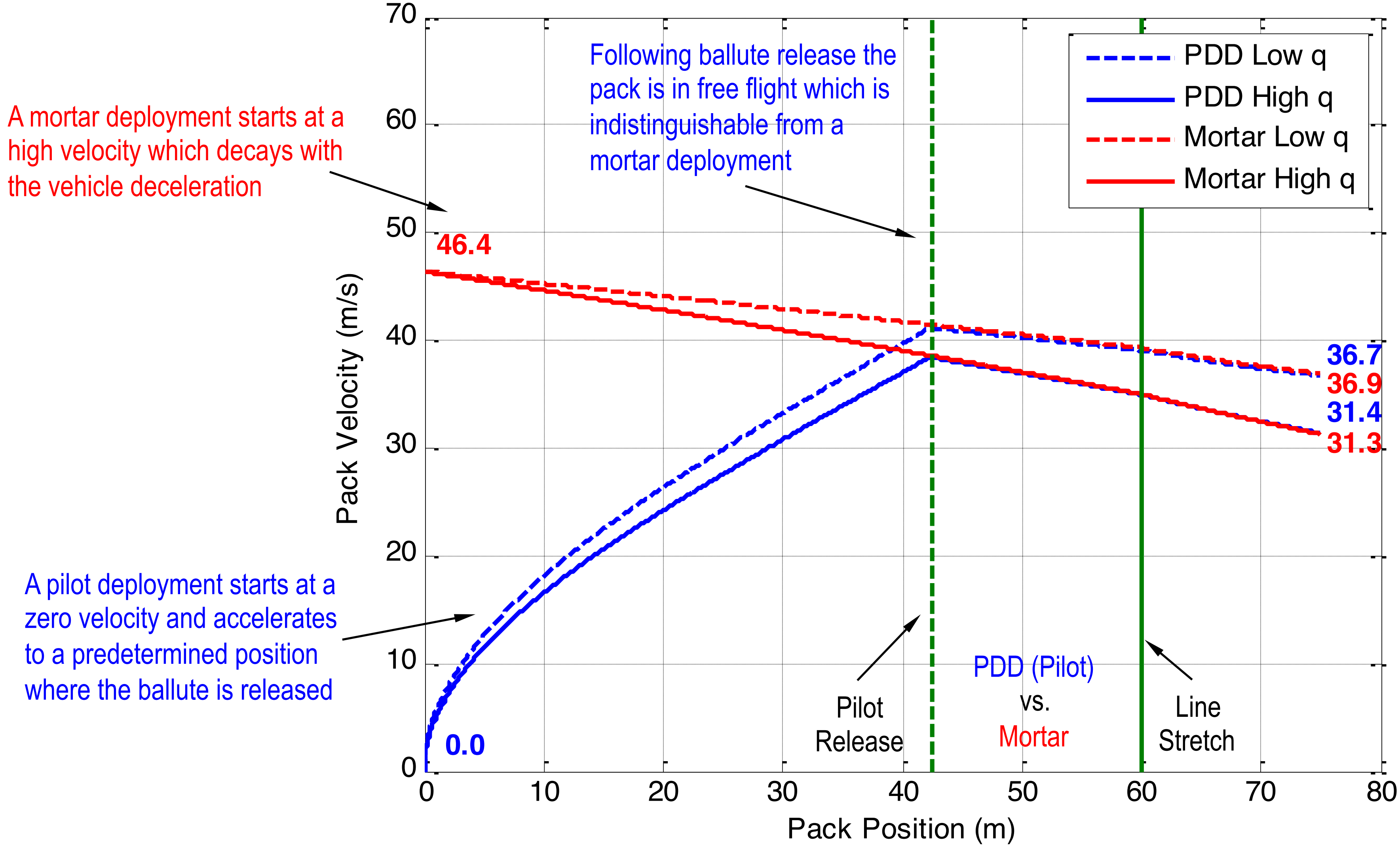

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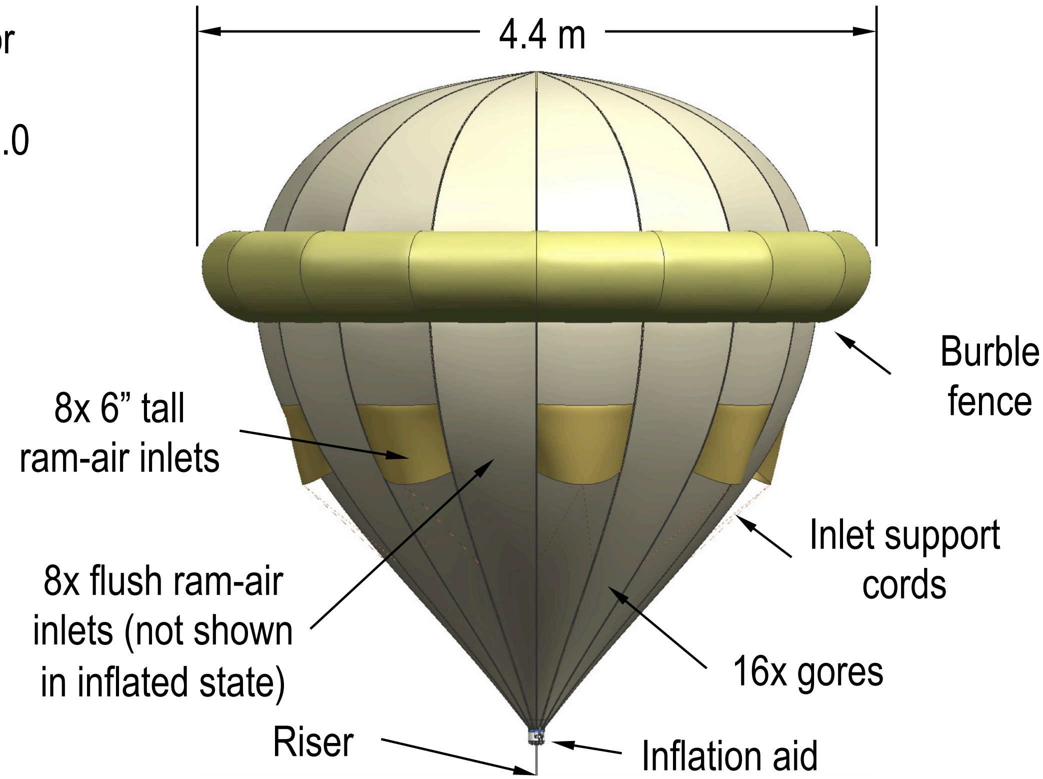
Ballute Overview

- A ballute was selected over a parachute for its higher drag coefficient and stability at the desired deployment Mach number of 3.0
- Ballute was constructed in 16 gores from Kevlar 29 in block orientation
- Two alternating inlet configurations:
  - 8x 6" tall proud inlets for inflation and pressure maintenance in flight
  - 8x flush inlets for inflation only, closed off when ballute is fully inflated
- Proud inlets are supported with Kevlar cords in a V-shape to prevent collapse



- A gas generator is at the nose of the ballute to provide initial pressurization
- Riser is attached to the ballute through the inflation aid

Inflation Aid Overview

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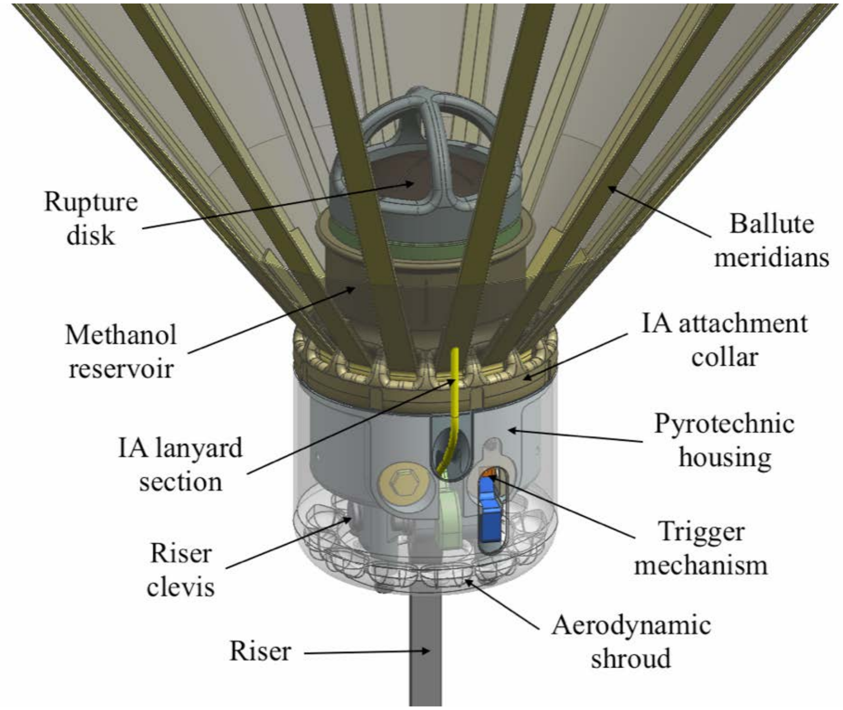

- A pre-inflation system was deemed necessary after evidence of a ballute inflation failure when an inflation aid was not present
- The Inflation Aid interfaces with the nose of the ballute and serves as the attachment point for the riser
- The Inflation Aid is a custom-developed gas generator that uses the evaporation of liquid methanol to pressurize the ballute
  - Methanol is relatively safe to handle at ambient temperature and pressure
  - Methanol will vaporize quickly due to a sudden drop in pressure
- The methanol is pyrotechnically ejected through a rupture disk into the ballute
  - The mechanism is mechanically actuated near the end of bag strip by a pair of lanyards
- Methanol-based gas generators were used in early ballute development in the 1960's

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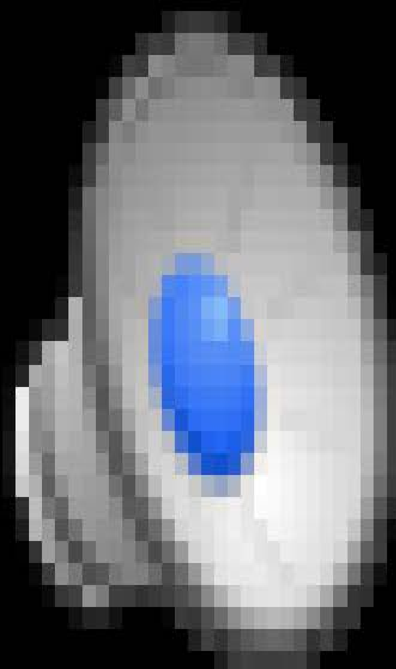
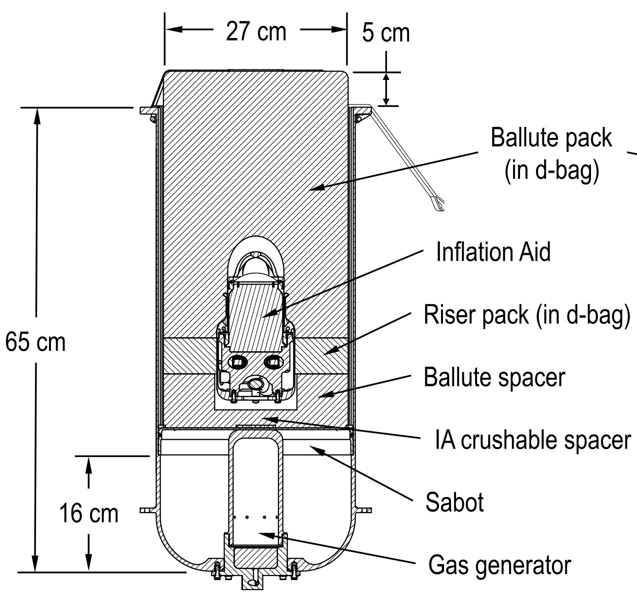
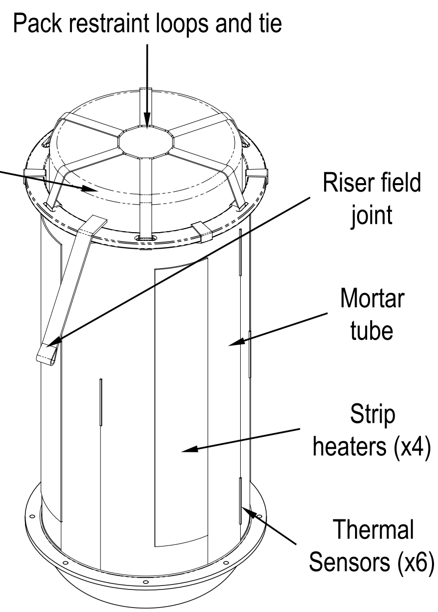
5.5 m Ballute without Inflation Aid



Mortar System Overview

- Mortar nominally provides a muzzle velocity of approximately 59 m/s and an impulse of 1080 N-s
  - Mortar performance was “maxed out” to ensure that the ballute had sufficient velocity relative to the decelerating vehicle
- The presence of the inflation aid required the use of a system of spacers between the sabot and ballute to transfer energy to the ballute and prevent damage to the inflation aid





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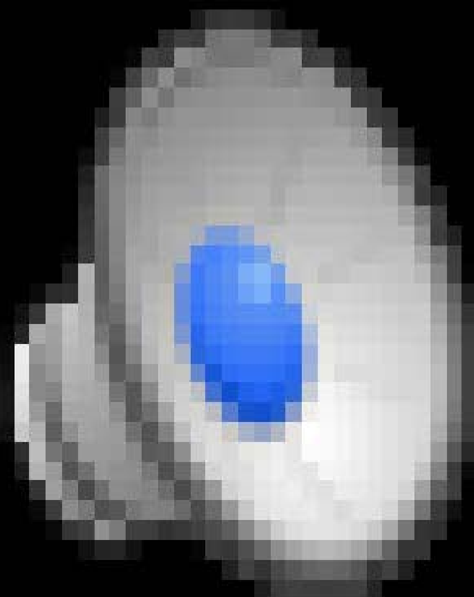
Mortar V&V Testing



Inflation Aid and Deployment V&V Testing

Low Density Supersonic Decelerator Project
Pneumatic Mortar Testing
March 05, 2014
Pioneer Aerospace, South Windsor, CT

Jet Propulsion Laboratory, California Institute of Technology

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V&V Testing and Analysis Montage

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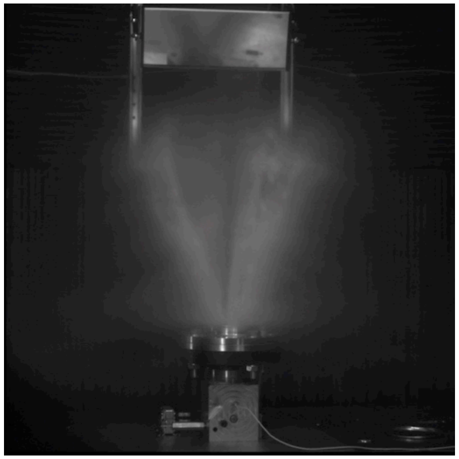

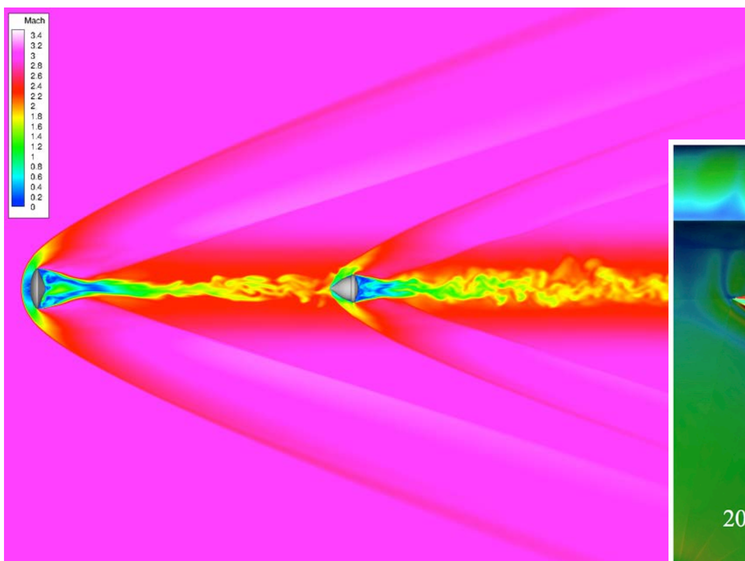

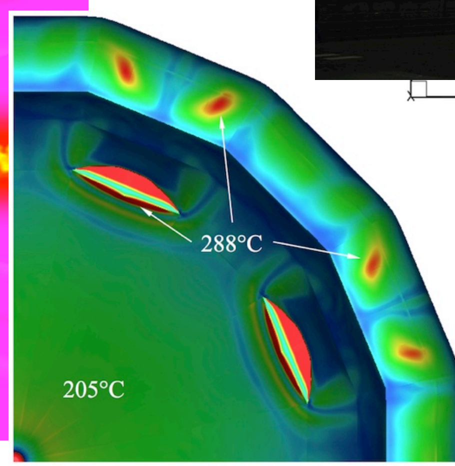

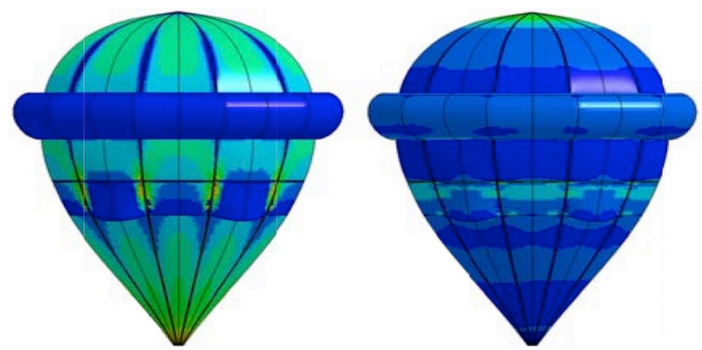

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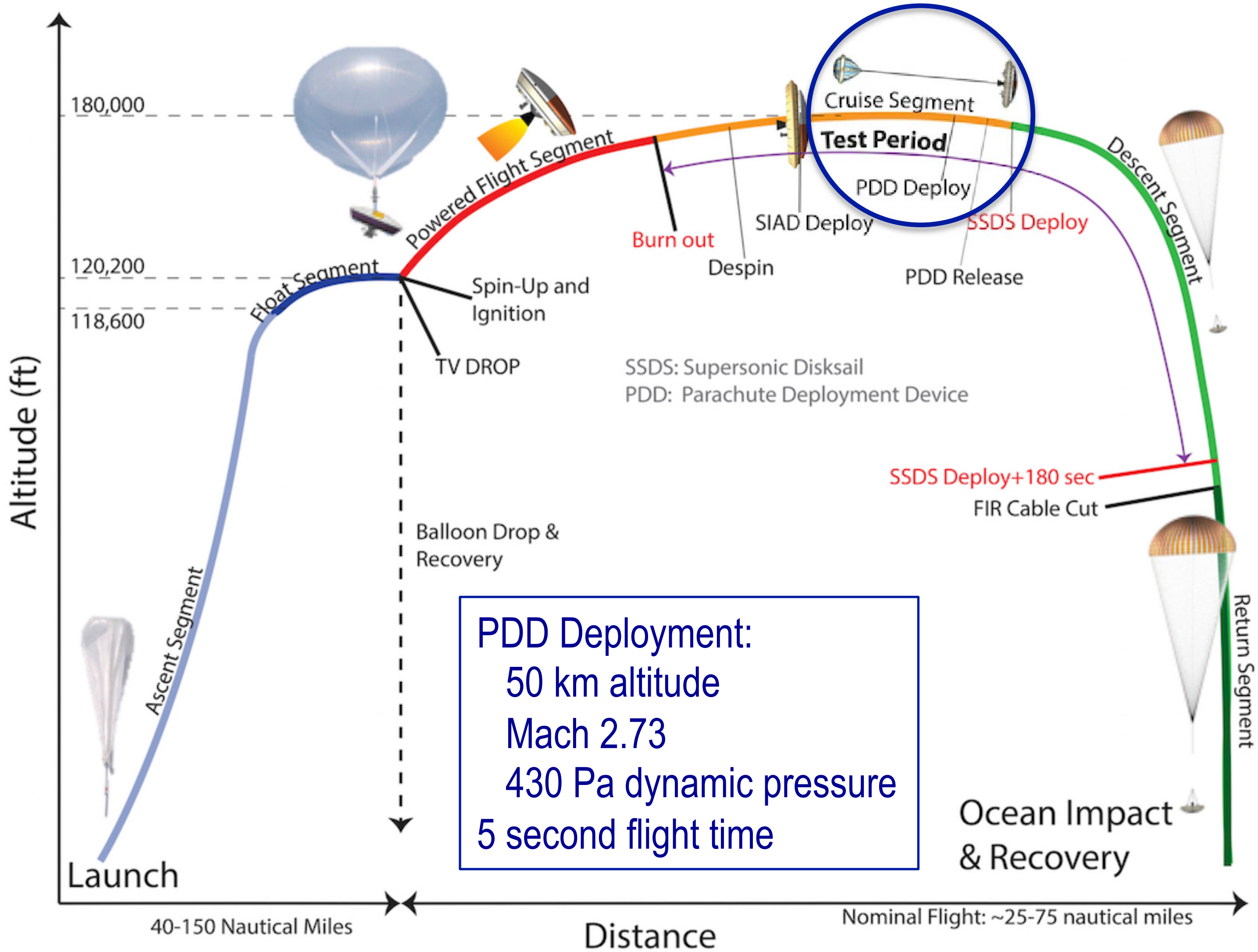
Supersonic Flight Dynamics Test



PDD Deployment:

- 50 km altitude
- Mach 2.73
- 430 Pa dynamic pressure

5 second flight time

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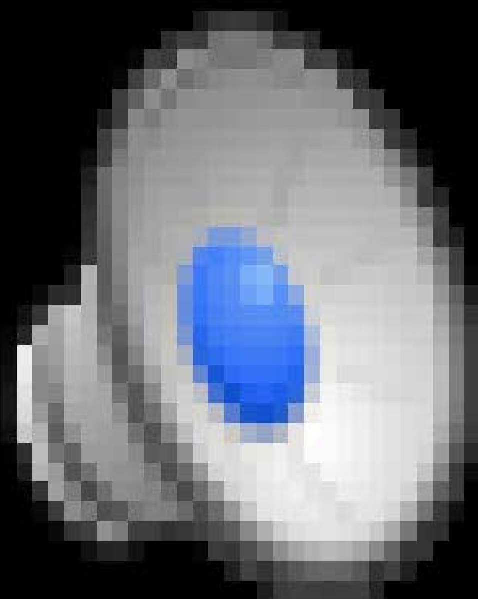
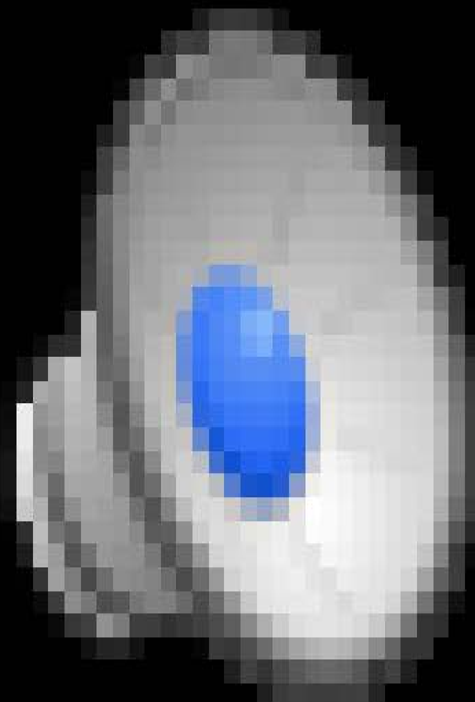
SFDT-1 Situational Video



SFDT-1 High Speed Video



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PDD Performance

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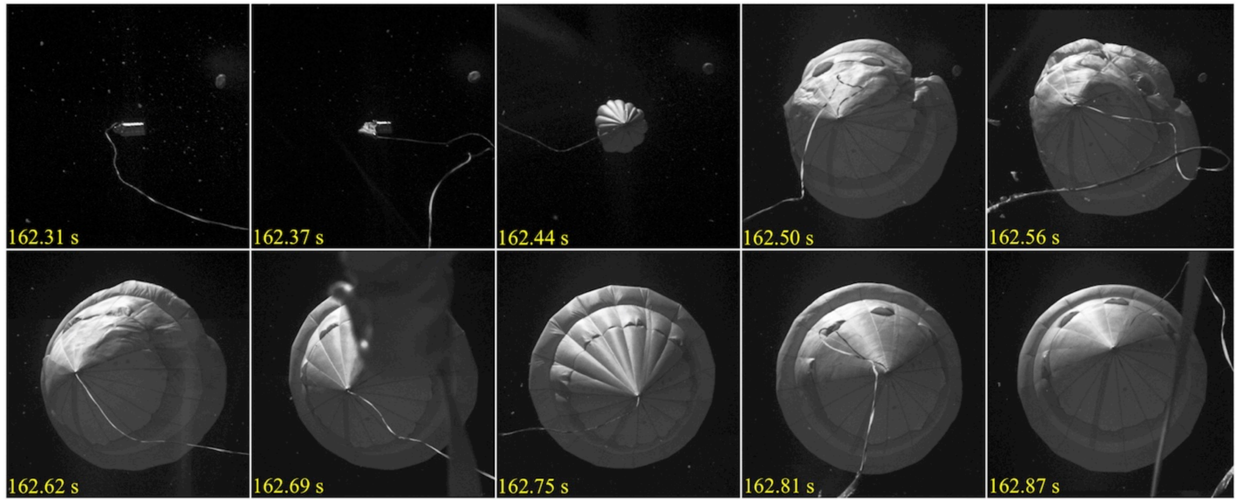
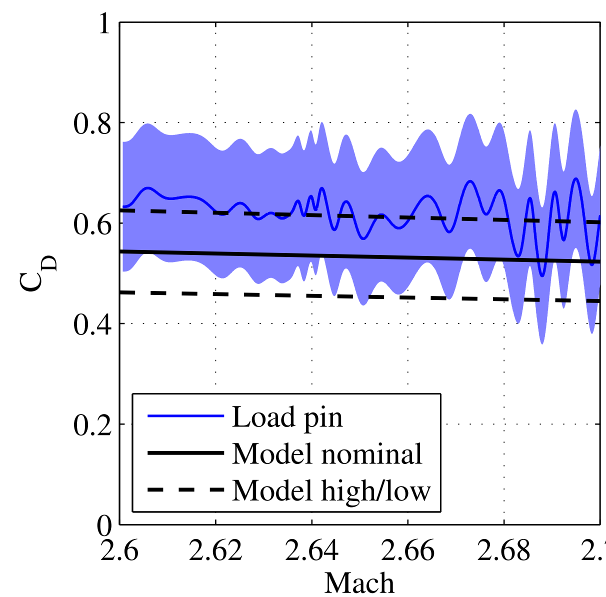


- Mortar muzzle velocity estimated at 60 m/s
- Line stretch velocity estimated at 52 m/s
- Ballute inflation occurred in approximately 0.3 seconds
- Pre-flight drag coefficient estimates were nominally 0.5 with a ±20% dispersion (approximately)
  - Assumed ballute in the core of the vehicle wake
  - Drag coefficient obtained from both historical data and CFD
- Flight data showed that the drag coefficient, on average, was around 0.6
  - Why was drag performance on the high end of pre-test predictions?



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SFDT-1 Reconstructed Ballute Position

Low Density Supersonic Decelerator Project
PDD Flight Animation for SFDT-1

Animation created by Deepak Bose, NASA ARC

JPL

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Ballute Recovery

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- Recovery of the ballute was not expected
  - Recovery priority was with the vehicle and the data
  - No location H/W on the ballute and unknown trajectory after release
- Recovery boats serendipitously encountered the ballute while en route to the test vehicle
- Ballute was damaged during the recovery effort:
  - The envelope had to be cut open to relieve water
  - Abrasion against the boat deck caused some minor damage
- Recovery and inspection yielded a lot of information:
  - No visible evidence of structural damage or thermal damage to any surface due to the flight conditions
  - Inflation aid appeared to have fired as designed

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Summary and Onward

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- This flight represents the first successful deployment and supersonic flight of a ballute of this size ever by a NASA organization
  - Potentially pioneers a path for a supersonic pilot deployment system for a future US flight mission to Mars

- No changes to the ballute or rigging are planned for future flights

- The Project is planning on recovery of the next two flights
  - Initial trajectory analyses indicate that the landing footprint of the ballute is within the footprint of the vehicle

- Acknowledgements:
  - Pioneer Aerospace Corporation for the design and fabrication of the ballute
  - Systima Technologies, Inc. for the design and fabrication of the mortar system
  - NASA ARC and LaRC for CFD analyses of the ballute

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