Overview of the First Two Flights of the ASPIRE Supersonic Parachute Test Program

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Supersonic Parachute Testing Heritage

- Disk Gap Band (DGB) Parachute developed in 60’s & 70’s for the Viking program
- DGB development included the Planetary Entry Parachute Program (PEPP) which used sounding rockets and high-altitude balloon launched vehicles to test supersonic parachutes in Atmospheric conditions analogous to Mars:

- DGB has been used successfully on 5 Mars Missions (leveraged Viking development)
- The Low-Density Supersonic Decelerators (LDSD) Project saw failures of two supersonic Ringsail parachutes
- LDSD experience showed that stresses seen in subsonic testing may not bound the stresses seen in supersonic testing, at least for some parachutes
- **ASPIRE project was started as a risk reduction activity for the Mars 2020 mission**
The ASPIRE Project

**ASPIRE = Advanced Supersonic Parachute Inflation Research and Experiments**

- **Objective**: Expose two candidate M2020 parachute designs to a supersonic inflation environment and acquire sufficient data to characterize the flight environment, loads, performance of the parachute.

- **Launch Site**: Wallops Flight Facility at Wallops Island, VA
- **Launch Vehicle**: Terrier Black Brant IX Sounding Rocket
- **Launch Provider**: NASA Sounding Rocket Program (NSROC)

Three Flights (nominal)
- Flight 1: MSL Build-to-Print Chute at 35 klbf
- Flight 2: Strengthened Chute at 47 klbf
- Flight 3: Strengthened Chute at 70 klbf
- Flight 4: (optional) Strengthened Chute at 70 klbf

**Test Architecture**
- Rail-launched
- Spin-stabilized at 4 Hz
- Yo-yo de-spin after 2nd stage burnout
- Mortar-deployed full-scale DGB
- Cold gas ACS before mortar fire
- Payload recovered in Atlantic Ocean

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**Timeline**
- 1st stage Terrier burnout: L+5.2 s, Alt: 0.7 km, Mach: 0.8
- 2nd stage Brant Ignition: L+8.0 s, Alt: 1.4 km, Mach: 0.7
- 2nd stage Brant burnout: L+35.5 s, Alt: 16 km, Mach: 3.2
- 1st stage Terrier burnout: L+5.2 s, Alt: 0.7 km, Mach: 0.8
- Payload Sep: L+104 s, Alt: ~50 km, Mach: 1.2
- Mortar Fire (MF): L+160-170 s, Alt: 39-45 km, q∞: 360-820 Pa, Mach: 1.65-1.9
- Line Stretch MF+ ~1 s, Alt: 39-45 km, q∞: 400-930 Pa, Mach: 1.68
- Peak Load MF+ ~2 s, Alt: 39-45 km, q∞: 400-930 Pa, Mach: 1.64
- Nosecone Jettison: L+ ~160 s, Alt: 3 km
- Splashdown: L+ ~30 min

**Launch Site**
- WFF

**Atlantic Ocean**
- ~60 - 100 km
Payload Configuration & Instrumentation

Ballast (jettisoned before splashdown)

Buoyancy Aid (foam) & electronics

Telemetry (sealed)

Attitude Control System

Parachute Experiment Section

Aft transition & separation Hardware

De-spin hardware

**Onboard Instrumentation**

<table>
<thead>
<tr>
<th>Instrument Description</th>
<th>Rate</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLN-MAC IMU</td>
<td>400 Hz</td>
<td>-</td>
</tr>
<tr>
<td>GPS</td>
<td>20 Hz</td>
<td>-</td>
</tr>
<tr>
<td>C-band transponder (radar tracking)</td>
<td>50 Hz</td>
<td>-</td>
</tr>
<tr>
<td>Parachute Triple-Bridle Load Pins</td>
<td>1 kHz</td>
<td>1100 lbf</td>
</tr>
<tr>
<td>High Speed Cameras (x3)</td>
<td>1000 fps</td>
<td>3840x2400</td>
</tr>
<tr>
<td>Situational Video (x3)</td>
<td>120 fps*</td>
<td>1920x1080*</td>
</tr>
</tbody>
</table>

*One Situational Video Camera set to 4K resolution and 30 fps

Meteorological instrumentation:

- 6x meteorological balloons carrying Radiosondes: temperature, density, winds to 37 km
- GEOS Analysis: temperature, density, winds above 37 km

58 ft.
Mars 2020 Supersonic Parachute Test
Flight Test #1
ASPIRE Flight 2 Footage
Payload Recovery

- Payload is recovered from the Atlantic Ocean in order to extract onboard data that is not telemetered during flight.
- Payload recovery was successful for both ASPIRE flights with no recovery-induced damage to the parachute or instrumentation.
ASPIRE Flight 1 & 2 Results

- ASPIRE Flight 1 & 2 were a success
- Both Parachutes survived their flight loads and showed no significant damage from inflation
- See C. O’Farrell et al “Reconstructed disk-gap-band parachute performance during the first two ASPIRE supersonic flight tests” (presentation)

**Flight 1**

Parachute peak load: 32.4 +/- 1.1 klbf

**Flight 2**

Parachute peak load: 55.8 +/- 1.1 klbf
What’s next? Overview of ASPIRE Flight 3

- 21.5 meter Airborne Strengthened DGB parachute
- Target Parachute peak Load of 70,000 lbf
- Launch planned for July/August 2018
Acknowledgements

The success of these two flights is due to the greater ASPIRE Team

Project Manager: Tom Randolph
Project Manager Emeritus: Mark Adler
Principal Investigator: Ian Clark
Parachute CogE: Chris Tanner
Flight Performance (JPL): Mark Ivanov
Flight Performance (LaRC): Eric Queen
Aerosciences: Suman Muppidi
Sounding Rocket Lead: Brian Hall
NSROC Mission Manager: Jay Scott
WFF Range Lead: John Valliant
Recovery Lead: John McCann

And many others from the Jet Propulsion Laboratory, NASA Langley Research Center, NASA Ames Research Center, NASA Wallops Flight Facility, and the Thomas Reed Boat Recovery Crew
Backup
## Overview of ASPIRE Flight 1 and Flight 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Flight 1</th>
<th>Flight 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Date</td>
<td>October 4(^{th}), 2017</td>
<td>March 31(^{st}), 2018</td>
</tr>
<tr>
<td>Launch Time</td>
<td>6:45 am local time</td>
<td>12:19 pm local time</td>
</tr>
<tr>
<td>Parachute</td>
<td>21.3 meter Pioneer MSL Build-to-Print DGB chute</td>
<td>21.5 meter Airborne Strengthened DGB chute</td>
</tr>
<tr>
<td>Parachute Pack Mass</td>
<td>61 kg (134 lbm)</td>
<td>82 kg (181 lbm)</td>
</tr>
<tr>
<td>Mass underneath the Parachute</td>
<td>1,121 kg (2,471 lbm)</td>
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<tr>
<td>Target Peak Parachute Load</td>
<td>35,000 lbf (~156 kN)</td>
<td>47,000 lbf (~209 kN)</td>
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<tr>
<td>Flight Peak Parachute Load</td>
<td>32,400 lbf (~144 kN)</td>
<td>55,800 lbf (~248 kN)</td>
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<tr>
<td>Mach at Full Inflation</td>
<td>1.77</td>
<td>1.97</td>
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