ADEPT Sounding Rocket One (SR-1) Flight Test

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Moffett Field, California
• Background
• Test Description
• Results & Future Work
• Acknowledgements
**Adaptive Deployable Entry and Placement Technology**

- **3D Woven Carbon Fabric**
- **Fabric Weave**
- **Fabric Joint Design**
- **High Density Structural Stitching**

**System Level Aerothermal Testing**


**2 m Deployment Prototype Time Lapse Video**

- Electrically driven actuators achieve high fabric pre-tension

**SR-1 Deployment Test Video**

- Three stage spring-based deployment actuation.
ADEPT Mission Applicability

➢ Science & Exploration Applicability

- (< 2 m) Small Satellite mission designers can utilize ADEPT for direct entry and/or aerocapture.
- (> 10 m) Human Mars exploration class missions require large drag area decelerators capable of precision targeting/landing.
- Guidance and control system integration with ADEPT enables precision targeting and landing. Project Pterodactyl technology development ongoing.

➢ Mission Opportunities

- Investigating robotic sample return capability for cis-Lunar exploration applications.
- Drag-Modulated Aerocapture at Venus, Mars & the Ice Giants.
- Robotic & Human Exploration at Mars. Enhanced hypersonic drag capability and precision targeting.

Drag Modulated Aerocapture

Inner Planet Mission Opportunities
Key Performance Parameters

#1- Exo-atmospheric deployment to an entry configuration of the 1m-class ADEPT.

#2- Aerodynamic stability without active control of the 1m-class ADEPT in a flight configuration.
SR-1 Flight Article Description

- Rib tip to Rib tip diameter: 0.70 m
- Half cone angle (ribs): 70 deg
- Mass: 11.0 kg (24.3 lb)
- $\beta \approx 20 \text{ kg/m}^2$
- $X_{cg}/D = 0.15$

**Instrumentation**

<table>
<thead>
<tr>
<th>Instrumentation</th>
<th>Data/Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVA</td>
<td>Accelerometers, Rate Gyros, Magnetometer, GPS Tracking</td>
</tr>
<tr>
<td>NGIMU</td>
<td>Accelerometers, Rate Gyros, IMU Board Temp Sensors</td>
</tr>
<tr>
<td>LED Indicator Board</td>
<td>System Health Indicator Status</td>
</tr>
<tr>
<td>GoPro Video</td>
<td>1080p, 60 fps video</td>
</tr>
<tr>
<td>C-Band Transponder</td>
<td>WSMR Radar Tracking</td>
</tr>
<tr>
<td>SPOT Trace</td>
<td>GPS Recovery Tracker</td>
</tr>
<tr>
<td>Separation Sensors</td>
<td>Power-on signal for deployment timer, C-Band &amp; GoPro</td>
</tr>
<tr>
<td>Deployment Switch</td>
<td>Indicates full deployment</td>
</tr>
</tbody>
</table>

**Components**

- Four-Layer 3D Woven Carbon Fabric
- Rib Tips
- Ribs
- First-Stage Springs
- Struts
- Second-Stage Springs
- Deployment Latches
- Impact Attenuation Foam
- Push-off Springs
- Rails
- Aft Deck & Late Access Connectors
- Rib Release Deck
- Moving Ring
- Retention Cord Loops
- Stowed Diameter 0.24 m
- SR-1 Stowed in LV

**Additional Notes**

- Power-on signal for deployment timer, C-Band & GoPro
- Indicates full deployment
Launch Vehicle

Launch Rail Cameras
Launch Vehicle Cameras
Nose Section
AFTU Slam Stick LV Avionics
ADEPT
Booster
Launch & On-board Video

UP Aerospace
September 12th, 2018

Required Re-Entry Speed: Mach 2.5
Results - Radar Tracking & Vehicle Recovery

2. RADAR TRACKING - 98 km

1. LAUNCH SITE

4. RECOVERY OPERATIONS

3. IMPACT SITE

NEW MEXICO

WHITE SANDS MISSILE RANGE

Las Cruces
Ciudad Juarez

RADAR TRACK
KPP #1 - Project goal of fully locked deployed configuration achieved.
KPP #2- Project threshold of no tumbling prior to M=0.8 achieved

<table>
<thead>
<tr>
<th>EVENT #</th>
<th>DESCRIPTION</th>
<th>PREDICTED TIME (SEC)</th>
<th>ACTUAL TIME (SEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>APOGEE 110 km</td>
<td>161</td>
<td>156</td>
</tr>
<tr>
<td>2</td>
<td>ADEPT RE-ENTRY 85 km</td>
<td>244</td>
<td>229</td>
</tr>
<tr>
<td>3</td>
<td>PEAK MACH 3.2</td>
<td>270</td>
<td>254</td>
</tr>
<tr>
<td>4</td>
<td>PEAK DYNAMIC PRESSURE 822 Pa</td>
<td>294</td>
<td>282</td>
</tr>
<tr>
<td>5</td>
<td>MACH 0.8</td>
<td>318</td>
<td>307</td>
</tr>
<tr>
<td>6</td>
<td>MACH 0.4</td>
<td>363</td>
<td>352</td>
</tr>
<tr>
<td>7</td>
<td>TUMBLING OCCURED</td>
<td>-</td>
<td>407</td>
</tr>
<tr>
<td>8</td>
<td>IMPACT (~25 m/sec)</td>
<td>879</td>
<td>856</td>
</tr>
</tbody>
</table>

- Half cone angle (ribs)- 70 deg
- Mass- 11.0 kg (24.3 lb)
- $\beta\sim 20$ kg/m²
- $X_{cg}/D= 0.15$
- $X_{cg} = 0.1074$ m
- $Y_{cg} = 0.0005$ m
- $Z_{cg} = 0.0002$ m
Results - Trajectory Reconstruction

- Trajectory reconstruction simulated at 100 Hz using LV IMU, AVA IMU, AVA Magnetometer, radar tracking and atmospheric models using an Extended Kalman Filter-Smoother code call NewSTEP. For more details see "Reconstruction of the ADEPT Sounding Rocket One Flight Test" AIAA Aviation 2019

- Total angle of attack remains below stability threshold of 20 degrees through M=0.4.

- The spin rate increase through supersonic deceleration was unexpected. Post flight analysis is ongoing to determine cause.

- For details on the flight mechanics modeling, see: “Flight Mechanics Modeling and Post-Flight Analysis of ADEPT SR-1” AIAA Aviation 2019
Summary

SR-1 Key Performance Parameters

<table>
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<tr>
<th>Performance Parameter</th>
<th>Threshold Value</th>
<th>Project Goal</th>
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<tbody>
<tr>
<td>#1- Exo-atmospheric deployment to an entry configuration of the 1m-class ADEPT.</td>
<td>Less than fully locked condition resulting in shape with less than 70-degree fore body cone angle.</td>
<td>Full, locked deployment before reaching 80 km altitude on descent, to 70-degree fore body cone angle achieving 6x greater drag area.</td>
</tr>
<tr>
<td>#2- Aerodynamic stability without active control of the 1m-class ADEPT in a flight configuration.</td>
<td>Does not tumble prior to M=0.8 while decelerating from peak Mach # (when Mach number is decreasing after passing through peak Mach number).</td>
<td>ADEPT does not tumble* before ground impact; Sign of pitch damping coefficient (Cmq) is determined; FF-CFD simulation tool is validated</td>
</tr>
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Mission Success Criteria

A. ADEPT separates from the sounding rocket prior to apogee- SUCCESSFUL
B. ADEPT does not re-contact any part of the launch vehicle after separation- SUCCESSFUL
C. ADEPT reaches an apogee greater than 100 km- SUCCESSFUL
D. ADEPT achieves fully deployed configuration prior to reaching 80 km altitude on descent- SUCCESSFUL
E. Obtain on-board video of deployed ADEPT to observe fabric response during entry- SUCCESSFUL
F. Obtain data necessary to reconstruct ADEPT 6-DOF descent trajectory- SUCCESSFUL
Acknowledgements

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Space Technology Mission Directorate:
- Game Changing Development Program
- Flight Opportunities Program

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Bally Ribbon Mills
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References


