"The Adaptable, Deployable Entry and Placement Technology (ADEPT)"

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16 June 2017
Outline

• ADEPT Technology Overview
• ADEPT SR-1 Flight Experiment
  – Overview and Test Objectives
  – Description and Status
• Summary
Adaptable, Deployable Entry and Placement Technology (ADEPT) Overview

- ADEPT is an atmospheric entry architecture for missions to different planetary bodies with atmospheres.
  - Enables missions where entry vehicle stowed volume on spacecraft is a constraint
  - ’Open back’ (no backshell) expected to be dynamically stable in transonic flight, no supersonic chute @ Mars
  - Robust system can be deployed for long durations prior to entry
  - Low ballistic coefficient entry vehicle with low L/D enables large payload (20 mT) delivery to Mars surface
ADEPT Development Focus
1m ‘Nano’ Technology Maturation Strategy

- System Level testing in relevant environments: TAYF -> FAYT
SR-1 Flight Experiment Overview

Key Performance Parameter 1: *Exo-atmospheric deployment to an entry configuration*

Key Performance Parameter 2: *Demonstrate Aerodynamic stability without active control*
SR-1 Animation movie
SR-1 Flight Experiment
Development Tests driven by Risks

Pre Launch Integration
RISK: SR-1 not powered and operational

Separation
Risk: Excessive Tip off and no Damage

Launch and Ascent Environments
RISK: Component Failure

ADEPT Deployment
RISK: Improper flight attitude at atmosphere entry

Supersonic Aero Stability
RISK: Instability causes tumbling

Ground Impact and Data Retrieval
RISK: Impact loads damage SD Cards and/or cause battery thermal event

On-Board Flight Data Collection
RISK: Data not obtained and stored (no telemetry)

Video: UP Aerospace Launch and Ascent Environments

Component Failure On-Board Flight Data Collection
RISK: Data not obtained and stored (no telemetry)
SR-1 Flight Experiment
Development Tests driven by Risks

- Pre Launch Integration Risk: SR-1 not powered and operational
- ADEPT Deployment Risk: Improper flight attitude at atmosphere entry
  - Supersonic Aero Stability Risk: Instability causes tumbling
  - On-Board Flight Data Collection Risk: Data not obtained and stored (no telemetry)
  - Ground Impact and Data Retrieval Risk: Impact loads damage SD Cards and/or cause battery thermal event
- Launch and Ascent Environments Risk: Component Failure
- Video: UP Aerospace Launch and Ascent Environments

5/16/2017
Deployment System (Rib release)
Test results

- Vectran cable **retains** rib tips in stowed state
- A separation sensor in the nose cap detects when ADEPT is ejected from the payload module.
- Sensor activates Ni-Chrome burn wire, which cuts through Vectran cable.
- SR-1 spring-actuated deployment occurs immediately after Vectran cable has been cut.
- Burn wire tested in vacuum chamber equivalent to 100K ft altitude.
- Cut time was repeatable 4.5 seconds at 1.6 amps. (Temperature was 66°F)
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Risk: Component Failure

ADEPT Deployment
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Risk: Component Failure

5/16/2017
The maximum vehicle length is constrained by the need to avoid impingement with the high-speed flow as it expands in the wake
  - Aerodynamic interaction with shear layer could cause unpredictable flight dynamics
  - No “payload heating” concerns with SR-1, but need to avoid any impingement for DRM traceability

This need puts severe limitations on the volume available for instrumentation
  - Most volume is already consumed by crushable mass, C-Band transponder, and AVA

Current vehicle length: 0.32 m (nose tip to aft end)
  - Payload configuration is getting close to the shear layer at this angle of attack and is feeling some effects from the higher velocity flow
  - Magnitude of induced forces are an order of magnitude lower than forebody
  - Recommendation to limit vehicle length to 0.32 m
Preliminary Ballistic Range Test Results

- 15 total shots were performed
  - 11 calibration shots
  - 4 “for credit” shots
- Mach at mid-range of ”for credit” shots: 1.225, 1.208, 1.493, 2.245
- Preliminary results:
  - The vehicle is dynamically unstable at low angle of attack (typical of blunt body entry vehicles)
  - Limit cycle oscillation amplitude is ~25º at Mach 2.2
  - SR-1 Flight Design CG set to x/D=0.15 based on test observations

Mach 1.50, -13.7º angle of attack

Mach 2.58, 19.2º angle of attack
The models flew near the expected airspeed.

The 50% model was statically and dynamically stable at a wide range of CoM locations.

Unperturbed pitch/yaw oscillations were relatively small in amplitude.

Inverted, the model is statically stable and dynamically unstable: it eventually tumbles.

For the 15% model (high altitude), with the CoM in a near nominal location, the model was statically and dynamically stable for the most part.

Once either model tumbles, they tend to glide (move laterally). The models give no indication that they will recover from a tumble if it occurs.
Bringing the Data Home
Avionics and Power Subsystems

Aft Deck:
- GPS Antenna
- Spot Trace
- Late Access Connectors

Electronics Carriage:
- Avionics
- C-Band Transponder
- Power System (EPS)
- Camera

ADEPT SR-1 Data Sources (On-board and Ground Tracking)
- Confirm full and locked deployment
- Trajectory reconstruction for dynamic stability assessment
- Locate SR-1 after ground impact
ADEPT SR-1 Flight Hardware Integration Underway!

Carbon Fabric Skirt – Integration Fit Checks

Hardware Assembly, Integration and Test Progressing Well!
SL-12 Launch scheduled for Sept 18, 2017
Summary

- **ADEPT SR-1**
  - “First step” flight experiment demonstrating ADEPT flight and operations

- **Looking beyond SR-1…**
  - Small spacecraft mission using an ADEPT EDL to overcome volume limits
  - Secondary payloads to Venus, Mars, and LEO return are feasible near-term applications. Potential Discovery and New Frontiers pathways.
  - Nano-ADEPT provides technology development extensible to large ADEPT applications

1m ADEPT Mars Lander Malin SSS Concept (2014)

2m-3m Lifting ADEPT LEO Flight Test Concept NASA Ames & JHU-APL Study (2016)

8m Lifting ADEPT Mars Precursor Human Exploration