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

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Outline

• ADEPT Technology Overview
• ADEPT SR-1 Flight Experiment
  – Overview and Test Objectives
  – Description and Status
• Summary
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

1m Nano-ADEPT (Mars)
16m Lifting ADEPT Human Mars Exploration

6m ADEPT-VITaL (Venus)

Deployed

Stowed Atlas V Shroud
ADEPT Development Focus

1m ‘Nano’ Technology Maturation Strategy

- Deployment Prototypes
- Interface with primary payload
- Component Structural Loads
- Fabric edge buzz/flutter (Dynamic FSI)
- Shape Knowledge

Deployment reliability
- Ejection from primary spacecraft
- Pre-Entry orientation
- Supersonic Aerostability
- Exo-atmospheric Deploy
- Fabric system

Tech Maturation for Mission Infusion
- Achievable fabric pre-tension
- Tension maintenance under load
- Gore Deflection (Static FSI)
- Thermo-structural loads
- Peak heat rate
- Shear pressure

System-Level Arc-Jet (SPRITE-C)

SR-1 Sounding Rocket Flight Test (FY17-18)

- Tip-off rates
- Fabric System Stowage
- Pre-Entry orientation

SR-1 Sounding Rocket Flight Test

- Exo-atmospheric Deploy
- Mission end-to-end Demo

Deployment Prototype Demonstrator (FY15-16)

- ADEPT Development Focus
  - 1m ‘Nano’ Technology Maturation Strategy

7x10 Wind-tunnel Aeroloads test (FY15)

SPRITE C System level Arc-jet testing (FY15)

- System Level testing in relevant environments: TAYF -> FAYT

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**SR-1 Flight Experiment Overview**

**Launch**
- UP Aerospace SR
  - T = 0.0min

**Ascent**
- High spin rate

**Stowed ADEPT Separates from Rocket**

**Yo-Yo De-spin**
- Lowers spin rate

**ADEPT Deployment**
- Altitude ~ 100 km
  - T = 1.6 min

**Peak Mach Number**
- Mach 3 (~70 km)

**White Sands Missile Range, NM**

**Ground Impact**
- Impact speed: 25 m/s
- No parachute
  - T = 15 min
- On-board data stored on SD card

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

**Key Performance Parameter 2:** Demonstrate Aerodynamic stability without active control

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SR-1 Animation movie
SR-1 Layout and Subsystems

Deployment mechanism

Ribs

Struts

Carbon fabric “skirt”

Late access connectors

Electronics Carriage:
- Avionics
- C-band Transponder
- Battery Pack
- GoPro Camera

Spot Trace

GPS patch antenna

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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

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

Video: UP Aerospace Launch and Ascent Environments RISK: Component Failure

SR-1 Flight Experiment Development Tests driven by Risks
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

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

Video: UP Aerospace Launch and Ascent Environments
Risk: Component Failure On-Board Flight Data Collection
Risk: Data not obtained and stored (no telemetry)
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)
SR-1 Flight Experiment
Development Tests driven by Risks

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

Launch and Ascent Environments
RISK: Component Failure

Separation Risk:
Excessive Tip off and no Damage

ADEPT Deployment
RISK: Improper flight attitude at atmosphere entry

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On-Board Flight Data Collection
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Ground Impact and Data Retrieval
RISK: Impact loads damage SD Cards and/or cause battery thermal event
Vehicle Length Limitation

- 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
Preliminary VST Test Results

- 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
• **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