ADAPTABLE, DEPLOYABLE ENTRY AND PLACEMENT TECHNOLOGY (ADEPT)
FOR FUTURE MARS MISSIONS

IPPW10  Future Mars II Session

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ADEPT Description

Carbon cloth (tensioned over ribs when deployed)

Earth departure

Venus Arrival
ADEPT Technology Maturation and Mission Infusion Timeline

ADEPT is an Entry Architecture that delivers for Game Changing Science and Exploration Missions in the Near, Mid, and Long term.
ADEPT (Adaptable, Deployable, Entry and Placement Technology) is a low ballistic coefficient entry architecture ($m/CdA < 50 \text{ kg/m}^2$) that consists of a series of deployable ribs and struts, connected with flexible 3D woven carbon fabric skin, which when deployed, functions as a semi-rigid aeroshell system to perform entry descent landing (EDL) functions.

ADEPT is an STMD GCD Project started in FY12

**Project Deliverables**

- Characterize thermal and mechanical performance of 3D woven carbon fiber fabric
  - Produce flight like woven fabric skin for ground test article and integrate with breadboard structural/mechanical system
  - *Capable to 250W/cm²*
- Perform mission feasibility study to understand operational requirements/parameters and sizing calculations
- Design, Fabricate and Test sub-scale ground test article (~2m diameter)
  - Fabricate rib/strut/ring/nose structures using COTS type extruded shapes for breadboard structural support system
  - Design and procure COTS hinge/joint/deployment mechanisms to simulate behavior of ADEPT for ground testing

ADEPT was recently approved for Full Scale Demonstrator New Start Project in FY14
<table>
<thead>
<tr>
<th>Challenge Area</th>
<th>Description</th>
<th>Mitigation and Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fabric Thermal Performance</strong></td>
<td>Test at and above anticipated peak heating and heat load anticipated for Venus entry</td>
<td>Arc-jet test series in FY14 to establish performance bounds at and above expected heat rates and integrated heat loads</td>
</tr>
<tr>
<td><strong>Fabric Interfaces</strong></td>
<td>C-fabric to: 1) rib; 2) nose; 3) shoulder/close-out</td>
<td>Arc-jet testing (Sprite-C) and radiant testing will establish performance and failure modes</td>
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<tr>
<td><strong>Deployment</strong></td>
<td>Deployment function and reliability testing on 2 m GTA and fullscale prototype</td>
<td>More relevant flight mission conditions can be replicated on ground for a range of off-nominal states</td>
</tr>
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<td><strong>Thermostructural</strong></td>
<td>Understand thermal design issues- materials selection and performance</td>
<td>Component level radiant tests will validate modeling tools to predict thermal and structural stress</td>
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<td><strong>Aerodynamic Stability</strong></td>
<td>Blunt body entry vehicles in supersonic to transonic regime may be dynamically unstable</td>
<td>Ballistic Range Testing below Mach 3 and analysis will validate free-flight CFD codes</td>
</tr>
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<td><strong>Integrated System</strong></td>
<td>There is no end to end ground test, but the key system test is thermal vac deployment and vibe acoustic of full scale vehicle</td>
<td>Utilize thermal vac and vibracoustic test approaches at full scale with flight materials and relevant payload simulator</td>
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<td><strong>Fluid Structure Interaction</strong></td>
<td>Flutter of cloth could lead to aerodynamic stability issues</td>
<td>Perform component level testing in relevant environment to validate FSI codes</td>
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<td><strong>Manufacturability</strong></td>
<td>Establish manufacturing, assembly and integration at relevant scale</td>
<td>Relevant scale Venus aeroshell manufacturing &amp; assembly processes will be demonstrated</td>
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</table>

![BLAM Test Fixture](image1.png)

![Radiant Test Fixture](image2.png)

![Fabric/Rib Interface](image3.png)

![Mach contours on shoulder](image4.png)

![Deployment Testing](image5.png)

![C-Fabric & Interface Thermal Performance](image6.png)

![Component Thermostructural Testing](image7.png)

![FSI modeling for wind-tunnel model design](image8.png)

![stowed](image9.png)

![deployed](image10.png)
ADEPT is an Entry Architecture that delivers for Game Changing Science and Exploration Missions in the Near, Mid, and Long term.
## Initial Assessments of ADEPT for Future Mars Missions

### Element | % of Entry Mass
--- | ---
**ADEPT:** | 46 %

*Primary Structure (main body, nose cap, lock ring, ribs & bearings, struts & end fittings, joint hardware, carbon cloth)* | 28 %

*TPS (nose, ribs, aft cover)* | 4 %

*Payload Backshell (also contains parachute)* | 2 %

*Mechanisms and Separation (deployment system, stowed/deployed latches, separation ring and guide rails, backshell sep mechanisms, parachute system)* | 12 %

*Avionics and Power (avionics unit, harness, power unit)* | 1 %

### Payload: | 54 %

- ADEPT Conceptual Designs for 5-15m class mission applications
  - Identification of components and mass estimating relationships
  - Preliminary MELs have been generated to support mission studies
Mars Challenges Current EDL Technology

- **Existing EDL Technology**
  - Limits Landed Payload Mass (~ 1 mT)
  - Requires use of Supersonic Parachutes
  - Access to Mars Surface Limited by ~ 0 MOLA altitude limit
ADEPT Enables Global Mars Access

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<tr>
<th>Entry mass kg</th>
<th>θ_e deg</th>
<th>β=22 kg/m²</th>
<th>β=44 kg/m²</th>
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<td>1000</td>
<td></td>
<td>5.8</td>
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Example:
70° sphere-cone ADEPT
- Diameter = 6.5 m
- Entry Ballistic Coefficient = 44 kg/m²
- Entry mass = 2500 kg
- Aeroshell Mass = ~ 870 kg
- Descent/Payload = ~ 1630 kg
ADEPT Enables Global Mars Access

• Ballistic entry with ADEPT can eliminate risky EDL events for Robotic Mars
• High altitude deceleration results in benign aerothermal environment and g-load’s
• ADEPT architecture allows steeper FPA reducing landing dispersion footprint
• ADEPT can enable subsonic parachute deployment at high altitudes
  • Does not require either Supersonic Retropropulsion (SRP) or Supersonic Parachute
• With ADEPT, landing site elevations is not an issue – Access any site on Mars

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ADEPT Technology Maturation and Mission Infusion Timeline

### ADEPT Project
- TRL Maturation
- GCD Project
  - FY’12 – FY’13

### ADEPT Full-Scale Demonstrator Project
- FY’2014-16

### Human/Heavy Mass Mars Mission and Design Studies
- FY’11

### Ballistic Robotic Venus
- VISE Lander (~2017)

### ADEPT Lifting
- (FY’16 – FY’18)

### Large Scale Lifting Concept Flight Demos
- (> FY’2026)

### Venus Lifting (2018+)
- - Aerocapture-Balloon with ASRG

### Mars Robotic Lifting (2020+)

### Human Mars (~2035)

### Total Global surface access
- No supersonic chutes

ADEPT is an Entry Architecture that delivers for Game Changing Science and Exploration Missions in the Near, Mid, and Long term.
Scaling ADEPT for Mars Large Payload Missions

- Road-Mapping and Systems Analysis Assessments are beginning to Plan EDL Development Path for Future Human Mars Exploration

LV Static Payload Envelope - Maximum ADEPT Size

- **ADEPT 36 m**
- **ADEPT 20 m**
- **ADEPT 13 m**
- **SLS-Block-II-Cargo**
- **Delta-IV-H Long**
- **Delta-IV-H Short**

Dimensions:
- 9.1 m
- 27 m
- 15 m
- 11 m
- 4.6 m
Considerations for Mars 2026 Sub-Scale Demo

• Demonstration Challenges for Sub-Scale Precursor Mission
  - ADEPT performs aerocapture and entry from orbit
  - Accommodation of SRP (assumed for terminal descent)
  - ADEPT Aeroshell transforms to landing system during terminal descent
  - Potential re-stowage of aeroshell after Aerocapture, prior to entry

• ADEPT considered a potential EDL implementation path for HEOMD Mars Missions
  - Project will support Tech Development Road Mapping activities

Potential Low – $\beta$ EDL Architectures

ADEPT generates lift with Gimbaled Payload
ADEPT Technology Maturation and Mission Infusion Timeline

ADEPT is an Entry Architecture that delivers for Game Changing Science and Exploration Missions in the Near, Mid, and Long term

- ADEPT Full-Scale Demonstrator Project (FY’14–FY’16)
- Venus Lifting (2018+)
- Ballistic Robotic Venus Lander (~2017)
- Human/Heavy Mass Mars Mission and Design Studies (FY’11)
- ADEPT Project TRL Maturation GCD Project (FY’12–FY’13)
- Large Scale Lifting Concept Flight Demos (> FY’2026)
- Human Mars (~2035)
- Venus Lifting (2018+ - Aerocapture-Balloon with ASRG)
- Mars Robotic Lifting (2020+)
- Ballistic Robotic Mars (2020+)
- Total Global surface access
- No supersonic chutes
ADEPT Scaled-Up (Way Up!) for Human Mars Missions

- Ribs, struts and mechanisms allow deployment and gimballing of the frontal surface for lift vectoring during aerocapture, entry and descent.
- During landing, an invert maneuver allows the Aeroshell to be a landing attenuation system.
- Analysis, design, testing as well as mission design have been performed to prove viability of the mass competitive concept (Venkatapathy et al, AIAA 2011-2068)
Conclusion

• Low Ballistic Coefficient ADEPT Architecture:
  – Developed to address the grand EDL challenges of Human Mars mission
  – A simpler, non-lifting, ballistic entry architecture potentially capable of
    • Achieving subsonic parachute deployment at higher altitude compared to rigid aeroshell without lifting entry nor supersonic parachute
    • Also, enabler for Venus robotic in-situ science missions
  • STMD GCD is investing in ADEPT Technology Maturation Project

ADEPT is a Game Changer for Mid- and Long-term Robotic and Human Mars missions