ADEPT - A Mechanically Deployable Entry System Technology in Development at NASA

Ethiraj Venkatapathy,
Paul Wercinski, Alan Cassell,
Brandon Smith and Bryan Yount
NASA Ames Research Center

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Acknowledgements

- Realizing the dream requires dedication by a large community of people and leadership along the way.
  - EDL experts at NASA Centers (Ames, Langley, Johnson, Goddard), JPL and APL
  - Funding support from NASA HQ and NASA Ames (Center Investment funds).
  - Facilities – Arc-jets and Wind-tunnels at Ames and JSC
  - Technology Partners – Bally Ribbon Mill and Thin Red Line

- ADEPT Project Leadership:
  - Peter Gage, James Arnold, Dinesh Prabhu, Keith Peterson, Ken Hamm and numerous others at Ames and other NASA Centers.
The 21st Century – Will It be as Great as the 20th Century for Human Exploration?

Shuttle Last Flight
July 8, 2011

Asteroid Redirect
~2020?

End of Station
~2025+?

Human Mars Mission ~2035?

MERs
Jan 4, 2004
Jan 25, 2004

Phoenix
May 25, 2008

Curiosity/?
2012/2020

MSR? Precursor to Human?
NASA TODAY
TECHNOLOGY INVESTMENTS FOR THE FUTURE

- Interaction and Collaboration between Mission Directorate
  - Technology Roadmap and Investment Prioritization
  - NRC Decadal Committee Recommended Missions
NASA TODAY: STMD
TECHNOLOGY INVESTMENT OPPORTUNITIES

Space Technology Program

- Technology Demonstration Missions (TDM)
- Small Spacecraft Technologies (SST)
- Flight Opportunities (FO)
- Centennial Challenges (CC)
- Game Changing Development (GCD)

SBIR/STTR
- Center Innovation Fund (CIF)
- NASA Innovative Advanced Concepts (NIAC)
- Space Technology Research Grants (STRG)

Technology Readiness Levels - Technology Maturity

- TDM
- SST
- FO
- GCD
- SBIR
- CIF
- NIAC
- STRG

TRL Ranges of Programs:
- 1
- 2
- 3
- 4
- 5
- 6
- 7

5
HUMAN MISSION TO MARS

Technical challenges - Getting there and coming back, safely.

- Getting to the surface of Mars safely and with precision
  - Humans are fragile – EDL has to be tailored for human survival
  - Human missions require
    - \((20\text{mT} - 40\text{ mT})\) of landed mass per launch
    - MSL landed mass of 899 kg required a launch mass of 531,00 kg

- Getting back to Earth from Mars
  - Orion derived capsule may need upgrade
    - Return velocity likely to be higher

NASA, specifically NASA Ames, is working on both the challenges
  - Mars Entry, Descent and Landing concept development
  - Ablative Thermal Protection System For Earth Return
ENTRY PHYSICS

- Complex and our ability to predict has improved considerably
  - Computational simulations, ground test facilities, and flight data
The mechanically deployable and transformable concept is similar to an umbrella but more complex functionally.

- Deployable thermal protection and aerodynamic load bearing fabric system;
- A deployable structure behind the that reacts to the primary aerodynamic load and provides a simple interface to the delivered payload;
- A self-contained deployment system;
- A primary gimbal design for pivoting of the aeroshell and thereby providing GN&C.
- An ejectable nose heat shield for the retro-propulsion system function;
- A design that transforms the aeroshell into a lander configuration.
ADEPT FOR HUMAN MARS MISSIONS

**Carbon Fabric**
- 8-Layer Super A Carbon Cloth
- 0.10" thick
- Pre-tensioned to ~250 lb/in

**Radial Ribs**
- Advanced carbon-carbon composite hot structure
- Uniform section 6" x 12" x 3/8"

**Struts**
- Titanium
- Sized by buckling
- 8" OD x 0.12"

**Deployment Ring**
- Aluminum
- Sized by FEA
- Tubular section 10" x 15" x 1/4"

**Rigid Nosecap with TPS**
- Hexply 954-6 Cyanate face sheets
- 5 cm honeycomb core
- Composite stringers
- Redux 319 film adhesive

**ADEPT Carriage**
- Reacts loads and provides front-exit transition capability
- Aluminum tubes: 8" OD x 1/4"
- Aluminum rings: 10" x 15" x 1/4"

**Separation System (Not Shown, Same as HIAD)**
- Three Thomson, 500 series, 65mm linear guide rails
- Three pairs of bearing assemblies mounted on HIAD carriage.

**Deployment System**
- 8 motors with gearboxes
- 8 Thomson precision ball screws, 1.5" x 0.473 lead
Project Background

- **ADEPT FY12-FY13**
  - STMD Game Changing Development Program
  - Focus on 6m Venus DRM (Delivery of 1000kg lander with peak decel < 30 g’s)
  - Carbon fabric arc-jet tested 100-240 W/cm².
  - Successful demonstration of 2m Ground Test Article

- **ADEPT FY14**
  - Demonstration carbon-fabric stitched joint
  - Project re-plan to 1m scale
    - Potential for ‘cubesat class’ secondary payload mission infusion
    - Cost effective approach for key system-level demonstrations

- **ADEPT FY15/FY16**
  - Focus on 0.7m aero-loads wind tunnel test & 0.35m SPRITE pathfinder arcjet test
  - Development efforts - 0.7m sounding rocket flight
CARBON FABRIC TESTING AT VENUS RELEVANT CONDITIONS
2m GROUND TEST ARTICLE DESIGN, BUILD AND TESTING

Rigid nose cap

4 Layer carbon fabric (painted for photogrammetry)
Each test campaign provides system knowledge in more than one system attribute, and many system attributes are explored by more than one test.
VIDEO HIGHLIGHTS FROM 7X10 TEST

Yaw Sweep 100 psf (4.8 kPa)
SPRITE-C Pathfinder Test Article #2
Test Video (1st Pulse 40s duration)

IHF 301
21" Nozzle

East Sting: SPRITE-C #1

Overhead Sting: Slug_Cal_102mm_Hemi_OH

West Sting: SPRITE-C #2

Run: 001
Date: 09/28/2015
Test Article C1 IR Video
Dual heat pulse – 7.5 kJ/cm² total stagnation point heat load
**SUB 1m NANO-ADEPT**

- Ribs tension fabric with pockets at tips (like an umbrella)
- 3D woven carbon fabric sized for mission
- Stitched and resin-infused seams
- Shoulder stitching treatments
- Two phase spring-deployment system (1- high displacement, 2- high tension)
- Payload area (2U shown for example)
- Avionics unit (IMU, GPS, solid memory, power)
- Struts
- Conformal TPS Nosecap

*Other mission-specific hardware not shown: antennae, parachute*
SOUNDING ROCKET FLIGHT TEST (CY'15)

1. Launch of SpaceLoft XL From White Sands, NM

2. Yo-Yo De-spin

3. Separate Nose Cone

4. ADEPT Ejection

5. Deployment

6. Re-entry
   Mach ~3.1
   Peak Decel. = ~4 g
   Peak Dyn. Pressure = ~0.8 kPa
   Impact Velocity ~ 20 m/sec

7. Chuteless Recovery in WSMR

Predicted Trajectory

CONOPS
Deployment

Prototype with carbon fabric skirt – Slo-mo
1m ADEPT Mission Pull (Discovery class)

**Venus**
- Science Pull:
  - Delivery of In-situ atmosphere science instruments.
  - Achieve low deceleration loads for sensitive instruments.

**Mars**
- Science Pull:
  - Global distribution, low cost
  - Numerous landers
- Dandelander (Malin SSS):
  Cubesat distributed surface network concept

**Earth**
- LEO Return: Secondary on Upper Stage, ISS Downmass or free-flyer on Super Strypi class LV
- De-orbit Capability
- 22 N thruster incorporated with green propellant
- 6 ea, 3U slots for subsystems or payloads

**Titan**
- Lifting ADEPT configuration allows aerocapture at Titan, effective thermal control with open-back configuration
A SCALABLE ADEPT EDL ARCHITECTURE
MISSION INFUSION OPPORTUNITIES

Nano-ADEPT (< 1m & 5 kg)
Small Science Payload
(Earth, Mars, Venus)

ADEPT Project
TRL Maturation
FY’12 – FY’13

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

Ballistic –Venus, 6m
VISE Lander (~2017)

Ballistic Robotic Mars, 10m
(2020+)
Total Global surface access
No supersonic chutes

ADEPT Full-Scale Demonstrator Project
FY’2014-17

ADEPT Lifting (FY’16 – FY’18)

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

Human Mars (> 2035)
(15m – 23m)

Venus Lifting (2018+)
-Aerocapture
Mars Robotic Lifting Precursor (2020+)

(6m – 15 m)

Ballistic –Venus, 6m
VISE Lander (~2017)
SUMMARY REMARKS

- Mars has been and continues to be both an exciting and a challenging place to explore
  - We have reached the limit of EDL technology with MSL
  - Landing large payloads and human at Mars is a grand challenge
    - Combination of innovation and new technologies needed

- Mechanically deployable entry system, ADEPT, is a game changing concept that has the potential
  - Within 5 years, retrieving small-satellites from around earth orbit and send small payload to Mars and Venus.
  - Within a decade, enable cost effective, in-situ missions to robotic science exploration
  - In the longer term, the concept and the robotic experiences at earth, Venus and Mars can enable Human Mars missions
Thank you

Questions?