Mary Poppin’s Approach to Human Mars Mission Entry, Descent and Landing

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ACKNOWLEDGEMENTS

- Efforts that are focused towards addressing long term challenges require a whole community of people.
  - EDL experts at NASA Centers (Ames, Langley, Johnson, Goddard), JPL and APL
  - Funding for large effort needs NASA HQ. STMD, SMD and HEOMD.
  - Facilities – Arc-jets and Wind-tunnels at Ames and JSC
  - Technology Partners – Bally Ribbon Mills and Thin Red Line

- ADEPT Project Leadership:
  - Paul Wercinski, Peter Gage, James Arnold, Dinesh Prabhu, Keith Peterson, Ken Hamm, Bryan Yount, Brandon Smith, Alan Cassell and numerous others at Ames.
HUMAN EXPLORATION
VISION AND PURPOSE
ARTICULATED
REALIZING THE VISION ARTICULATED BY NASA LEADERSHIP

Expanding human presence in space and human Exploration of Mars

- Faces considerable challenges:
  - Political, programmatic (budgetary included) and Technical.

- Technical Challenges:
  - Multitude of areas such as Launch, interplanetary travel and the danger of space radiation to Astronauts, EDL, survival at the surface and safe Return to planet Earth.
  - One critical area is:
    - Getting the human travelers safely through the atmosphere while slowing the vehicle and landing safely, either on to the surface of Mars or Earth.

The Entry, Descent and Landing (EDL) for Human missions to Mars requires new and innovative technologies.
ENTRY, DESCENT AND LANDING

- We have perfected EDL on Earth
  - Apollo Capsule (1960’s)
    - Basis for Orion or Multi Purpose Crew Vehicle (MPCV)
  - Space Shuttle Orbiter (1980’s)
    - Lifting and guided entry

- U.S. is the only nation that has successfully landed on Mars
  - Multiple times
  - Currently exploring the surface of Mars – the only nation

Credit: DPLR Video on YouTube
https://www.youtube.com/watch?v=3_gnLGLnTE4
HUMAN MISSION TO MARS

Two big 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 will require
    - ~40 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
    - Return velocity will be much higher than Lunar return
    - Thermal protection system for extreme entry

NASA, specifically NASA Ames, is working on both the challenges
- Mars Entry, Descent and Landing concept development
- Ablative thermal protection system for earth return
HIGH-LEVEL DESIREMENTS

- Mass efficiency
  - A mass efficient EDL system for reduced cost and complexity of Launch
- Large drag EDL system
  - Mars requires large drag surface to slow down
- Pin-point landing
  - Precision in GN&C in all phases of EDL
- Operational Considerations
  - Aero-capture
  - Transitions – from Aerocapture to Entry to Descent and Landing
  - Heat-shield/aeroshell – Retain or Dispose?
- Risk Posture
  - Humans as cargo requires robustness
- Scale-ability
AEROCAPTURE - AN EXTENSION OF EDL MISSION SEGMENT

1. Hyperbolic approach trajectory
2. Enter Atmosphere
3. Begin Bank Angle Modulation, Equilibrium Glide Phase (g-load trigger)
4. Peak heat rate, g-load
5. Periapsis
6. Begin Exit Phase (velocity trigger)
7. End Bank Angle Modulation (g-load trigger)
8. Exit Atmosphere
9. Periapsis Raise Maneuver
10. Orbit Adjust Maneuver

Target Orbit

From: EDL-SA NASA TM-2010-216720
ENTRY PHYSICS

- Complex and our ability to predict has improved considerably
  - Computational simulations, ground test facilities, and flight data – needed and have played a role in our ability to design

Credit: Brett Cruden
ADAPTIVE DEPLOYABLE ENTRY AND PLACEMENT TECHNOLOGY (ADEPT)

The mechanically deployable and transformable concept is similar to an umbrella but more complex functionally.

- A self-contained deployment system;
  - Deployable thermal protection and aerodynamic load bearing fabric system;
  - Deployable structure behind the that reacts to the primary aerodynamic load and provides a simple interface to the delivered payload;

- An **ejectable** nose heat shield for the retro-propulsion system function;

- A design that transforms the aeroshell into a lander configuration.
ADAPTIVE DEPLOYABLE ENTRY AND PLACEMENT TECHNOLOGY (ADEPT): DESIGNED TRANSFORMATIONS
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
CARBON FABRIC TESTING AT VENUS RELEVANT CONDITIONS
ADEPT
Adaptable, Deployable Entry and Placement Technology
Rigid nose cap

4 Layer carbon fabric (painted for photogrammetry)
23 m (HUMAN MARS) - 6m VENUS TO - 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
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
C-PICA Nose, 6 Layer, Phenolic Resin joint
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
Dual heat pulse – 7.5 kJ/cm² total stagnation point heat load
1. Launch of SpaceLoft XL
From White Sands, NM

2. Ye-Ye Deployment

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 = ~30 m/sec

7. Chuteless Recovery in WSMR

CONOPS

Predicted Trajectory
Deployment
(Prototype with carbon fabric skirt – Slo-mo)
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
WHAT’S MARY POPPINS GOT TO DO WITH HUMAN MARS MISSION?

Frosty white water-ice clouds and swirling orange dust storms above a vivid rusty landscape reveal Mars as a dynamic planet.

Credit: NASA and Hubble Heritage Team (STScI/AURA)
Thank you very much for your time and attention

Ready to answer questions.