



Deployment Testing of the ADEPT Ground Test Article

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ADEPT Background



(Adaptive Deployable Entry and Placement Technology)

ADEPT is an atmospheric entry *architecture* that is Game Changing for missions to most planetary bodies with atmospheres.

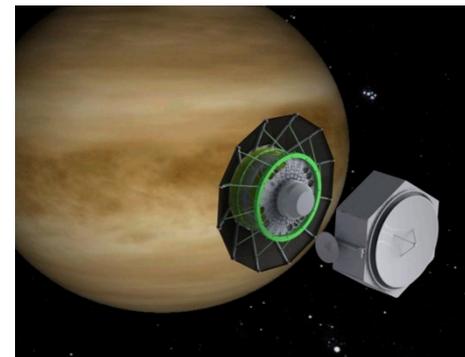
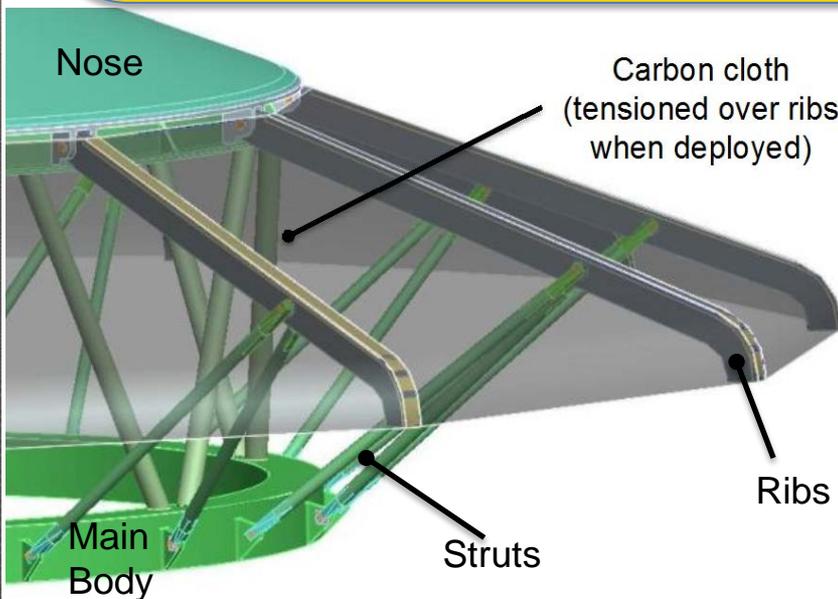
- Stowed inside the launch vehicle shroud and deployed in space prior to entry.
- Provides a benign deceleration and thermal environment to the payload.
- High-temperature ribs support 3D woven carbon fabric to generate drag and withstand high heating.



← Stowed for Launch



Earth Departure

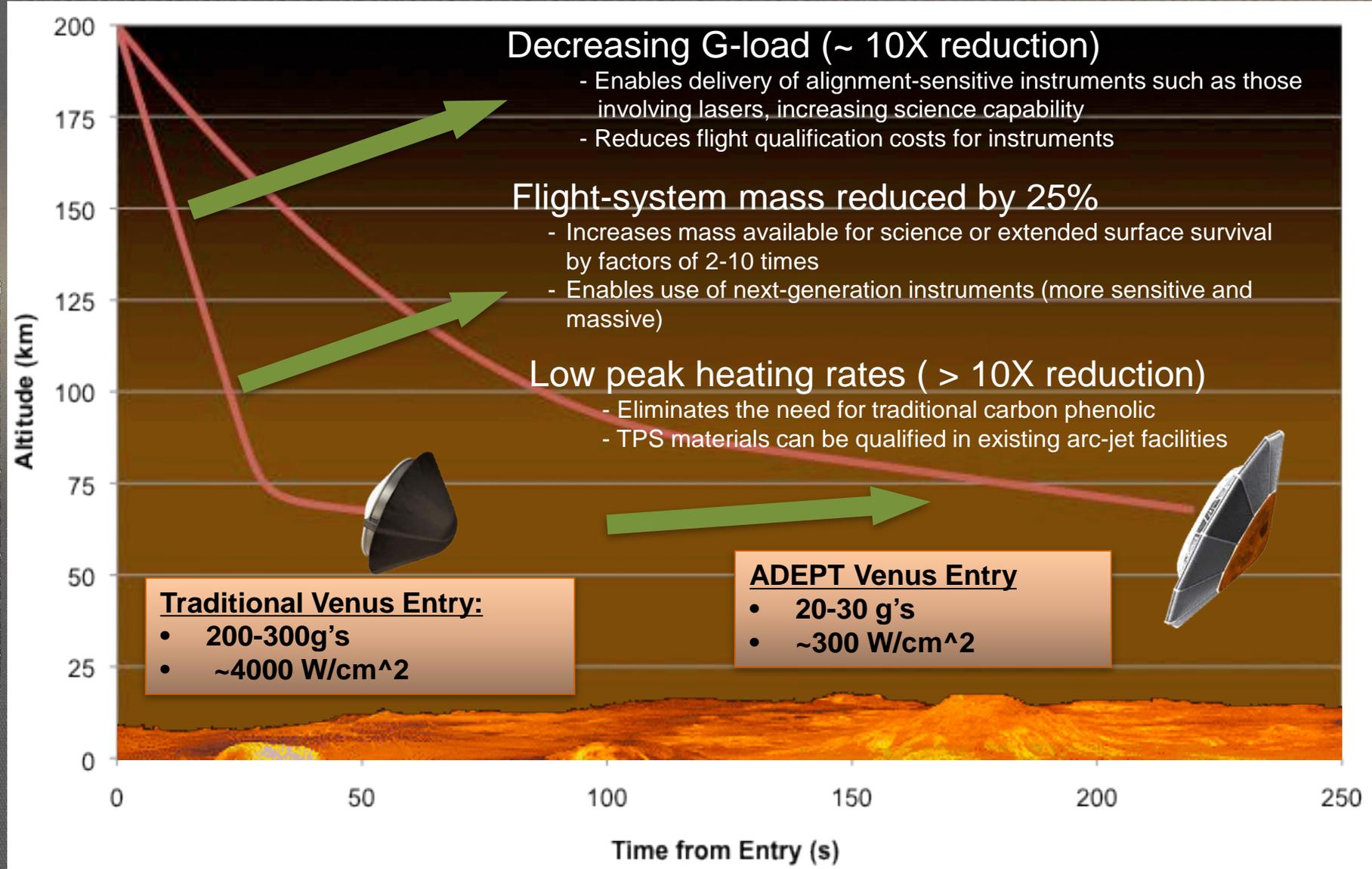


Venus Arrival

ADEPT
Adaptive Deployable Entry Placement Technology

ADEPT Benefits

ADEPT
Adaptable Deployable Entry Placement Technology



GTA: Deployment Test Objectives



The ADEPT Ground Test Article (GTA) is intended to mitigate some of the mechanical risks associated with a large multi-element deployable system by developing, integrating, and testing the configuration at a reduced, yet relevant, scale.

Ground Test Article Objectives

1. Demonstrate feasibility & reliability of the concept
 - Design configuration of mechanisms & actuators
 - Fabric behavior (unfolding, pre-tension, surface characteristics)
 - Control logic
2. Identify proper assembly procedures and tolerances
 - Verify that proposed integration procedure can be performed
 - Does resulting assembly meet requirements?
3. Study system response to off-nominal conditions during deployment
 - Robustness to imperfect conditions = higher probability of success

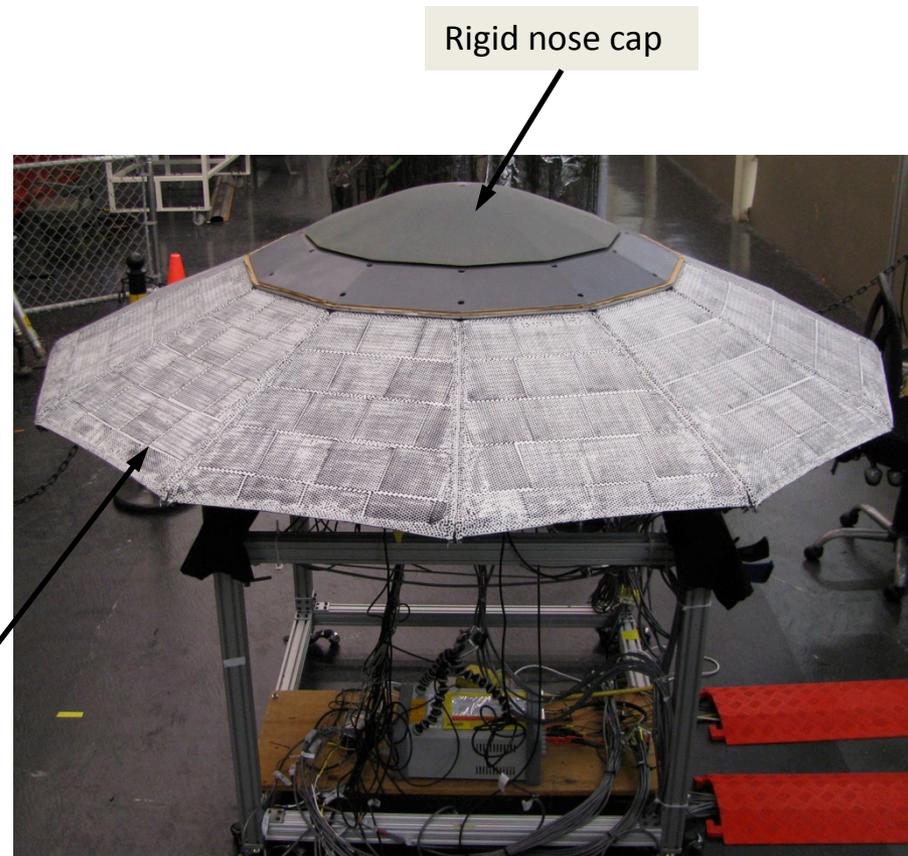


GTA Description



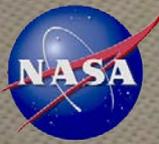
1/3 scale version of 6m ADEPT-VITaL (Venus mission) configuration

- Used scaling laws for structural & kinematic similitude where possible (scaling rigor limited by GTA budget and schedule)
- 2 meter deployed diameter
- 70 degree sphere cone (12 facets)
- 1 meter diameter rigid nose cap
- Four layer 3-D woven carbon fabric manufactured by Bally Ribbon Mills
- COTS parts used extensively for rapid development and cost savings

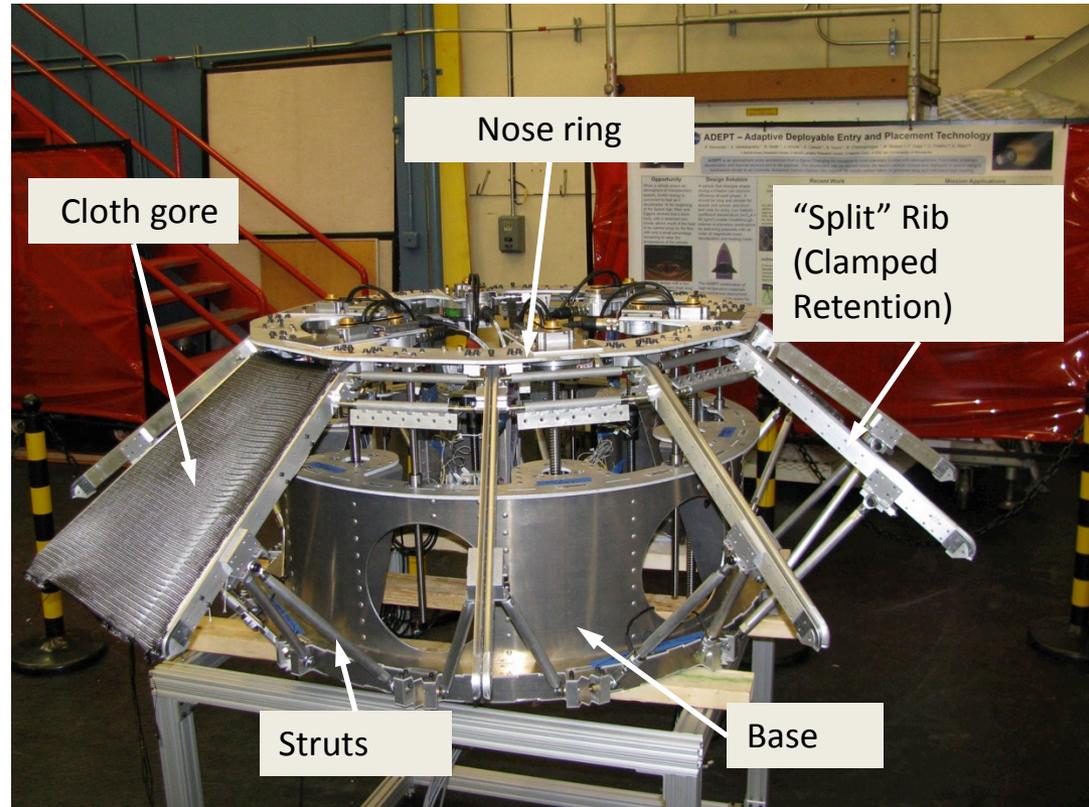


4 Layer carbon fabric
(painted for photogrammetry)

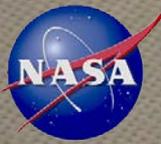
GTA skeleton



- Cylindrical **base** is primary structure and acts as payload bay
- **Nose ring** supports rib pivots and drive system
- 12 **ribs** support cloth “gores”
 - Cloth gores are clamped between “split” rib halves
- 24 **struts** (2 per rib) support the ribs and allow them to articulate from the stowed to deployed position
- 6 synchronized **linear actuators** pull the nose down towards the base to deploy the aeroshell



GTA Deployment Test Series



Series of deployment runs performed in phases to address objectives:

Debug and fabric integration phase:

- Basic mechanism function was evaluated incrementally
- Fabric was installed after deployment of bare “skeleton” checked out

Fabric tensioning and control system adjustments phase:

- Slowly increased deployment angle and deployment speed while evaluating fabric behavior and resulting tension
- Adjusted control system parameters and fabric clamp position
- Verified integrated system function & determined “nominal” conditions

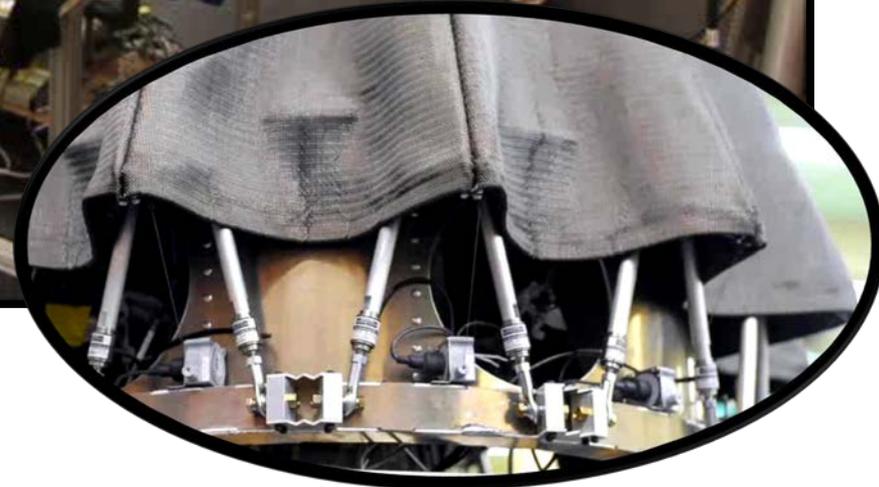
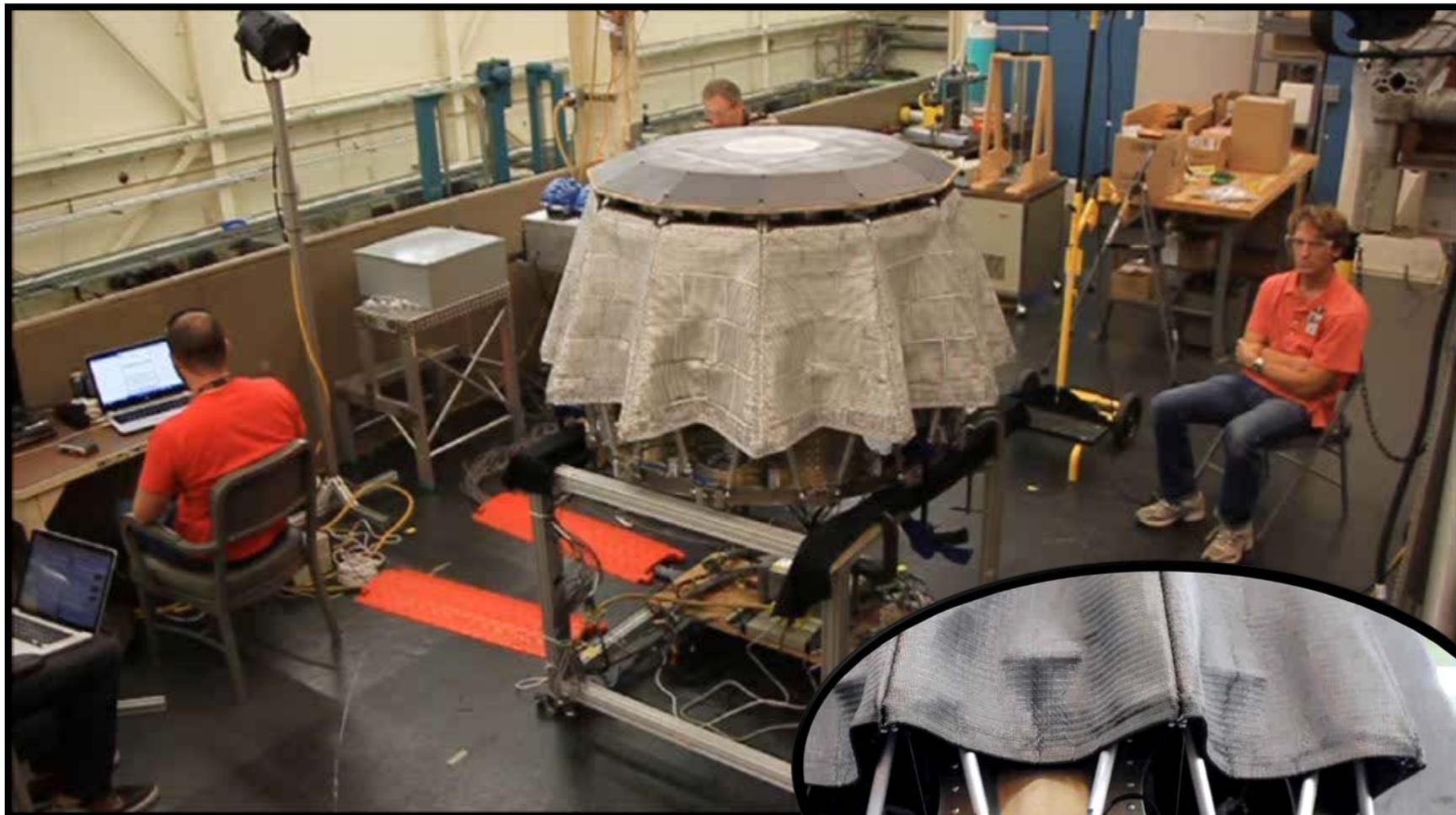
Nominal testing phase:

- Performed multiple deployment runs (15+) to the nominal condition to observe repeatability & reliability
- Resulting aero shell shape & fabric tension distribution assessed

Off-nominal testing phase:

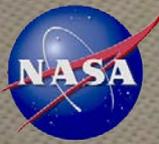
- Under-deployed one rib to create uneven fabric tension
- Mismatched strut lengths to cause improper joint loading
- Deployed with a simulated actuator failure (stopped 1 of 6 actuators)
- Installed pin joints (in place of ball joints) at strut ends to evaluate DOF

Time Lapse Deployment Video



ADAPT
Adaptable Deployable Entry Placement Technology

Instrumentation

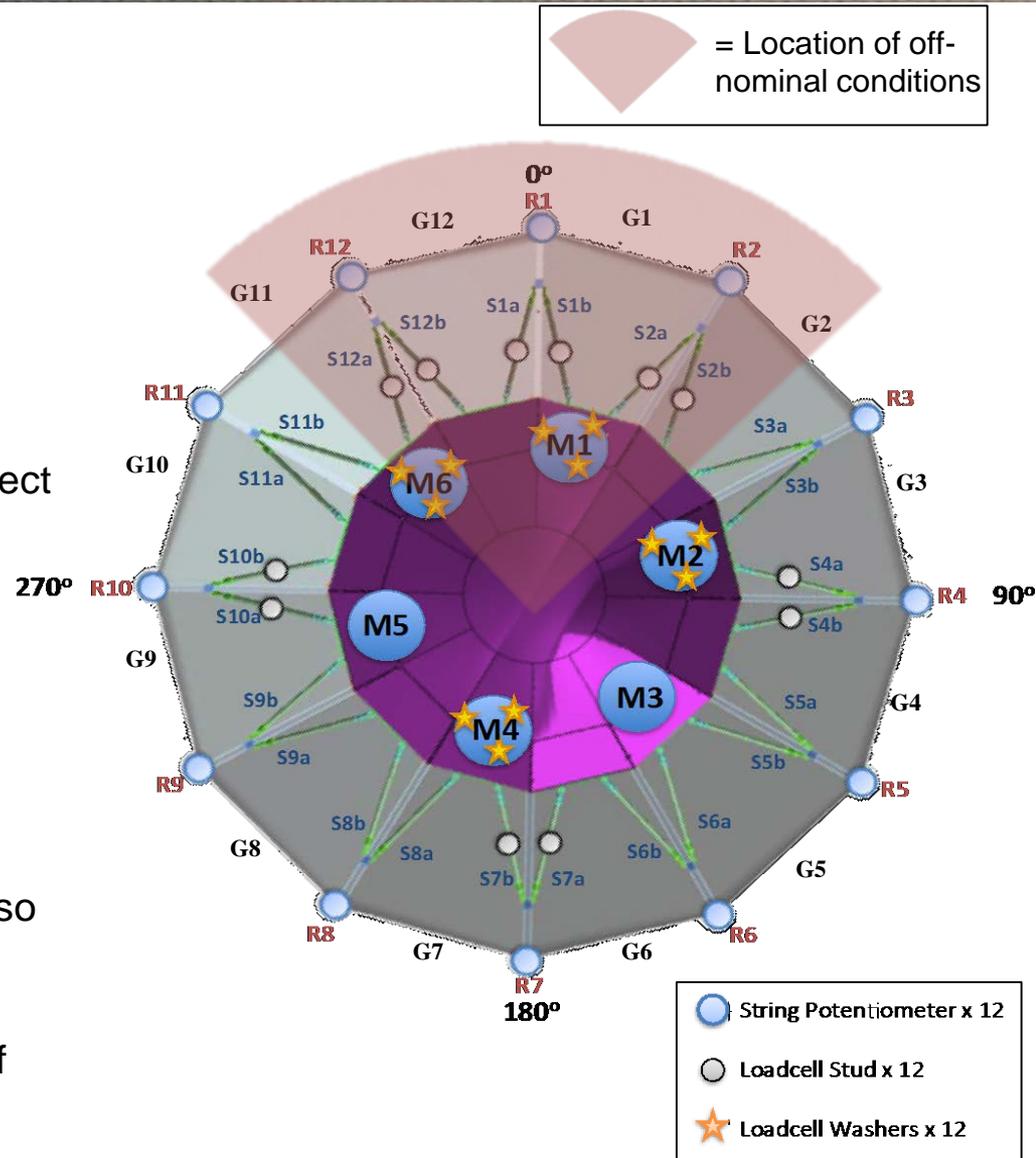


Measurement Methods & Locations:

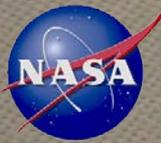
- Rib angle (string pots: all 12 ribs)
- Strut loads (load studs: 12 of 24 struts)
- Actuator loads (load washers: 4 of 6 actuators)
- Actuator position (rotary encoders: all 6 motors)
- Photogrammetry (image top surface)
- Fabric tension (custom deflection tool: select locations)

Density of Measurements:

- Only one quadrant of the model was fully instrumented due to budget limitations (symmetry was expected)
- Load distribution was somewhat uneven, so missing instrumentation did not allow complete load mapping
- Off-nominal conditions applied in region of highest instrumentation

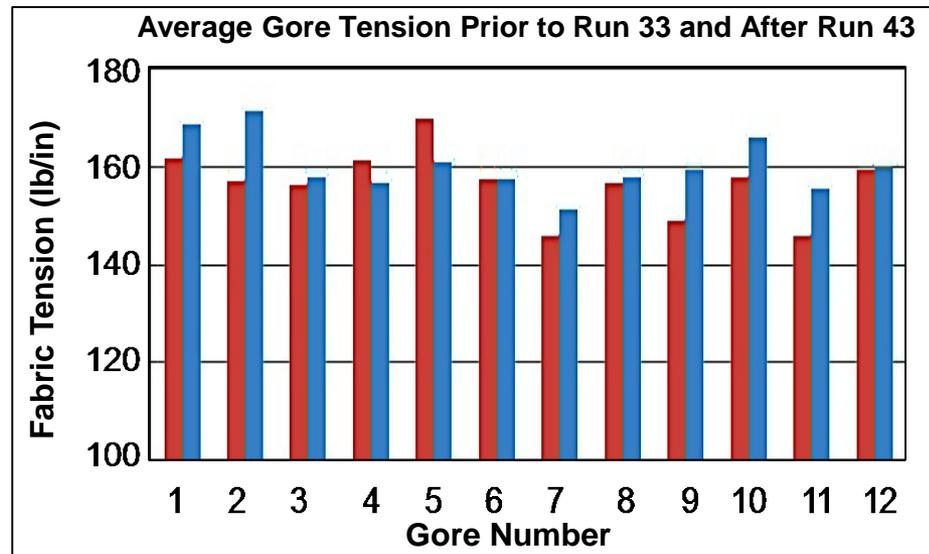


Results Summary



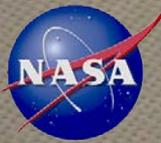
Deployment Feasibility & Reliability

- After the debug and adjustment runs were complete, all nominal and off nominal runs deployed successfully: (over 40 full deployment runs)
 - ✓ All primary mechanisms and actuators performed as expected
 - ✓ Fabric unfolded/deployed without problems
 - No hang-ups or snags, no significant wear or fiber breakage
 - Required fabric tension levels were achieved and maintained over multiple runs
 - ✓ Control system maintained synchronization between actuators and deployed the aeroshell to the set rib angle within tolerance
- Missions will only require one deployment, but repeated successful deployments in varying conditions provides confidence in the ADEPT system
- 10 consecutive, uninterrupted nominal runs were conducted (Runs 33-43) to assess repeatability and reliability



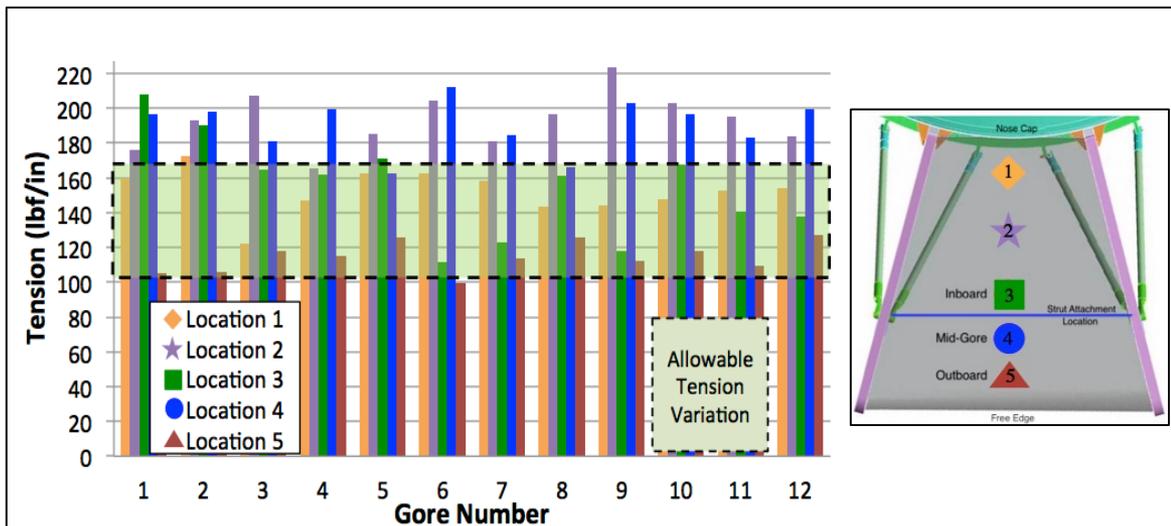
Note: Run 43 deployed 0.1° more than Run 33

Results Summary (2)

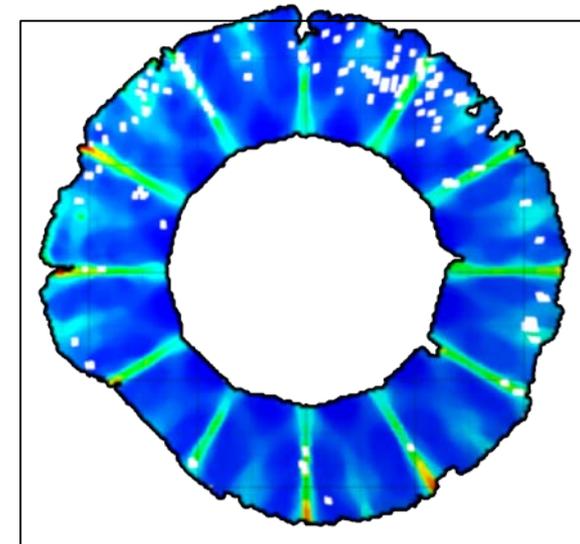


• Assembly procedure and tolerances

- Assembly procedure was satisfactory from an operations standpoint
 - ✓ The GTA was assembled without significant difficulty and operated mostly as planned
- Deployment requirements were partially met via assembly procedure & tolerances
 - ✓ Able to generate and maintain tension at required levels
 - Deployment stopped 0.7° short of target deployment angle (tension achieved prior to target)
 - Tension distribution within the gores was not as consistent as desired
 - Photogrammetry of the 3-D woven carbon fabric did not provide reliable strain data (possibly due to the varying through-thickness construction of the fabric)



Fabric Tension at Five Measurement Locations (Run 43).



Photogrammetry Strain Plot – Run 43

Observations / Conclusions



Key Observations:

- ***The high in-plane stiffness of the fabric makes integration tolerances critical to achieving the desired fabric tension and uniformity***
 - Fabric tension is very sensitive to deployed rib angle (small angle change → large change in loads)
 - Clamped rib-fabric interface not conducive to load redistribution
- Fabric wear, wrinkling and fiber breakage not a problem
- First attempt at outboard shoulder shape generation was inadequate and needs improvement

The GTA test series was successful and informative:

Test Objectives Addressed:

1. The ADEPT configuration was shown to be feasible and reliable
 - Deployed reliably / no primary mechanism or fabric problems
2. Assembly procedure was successful → functional system
 - Better fabric tension uniformity desired via improved integration methods and/or tolerances
3. System was robust to the off-nominal conditions applied

