X-37 Flight Demonstrator

Orbital Vehicle Technology Development Approach

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FLIGHT DEMONSTRATOR

Phased Approach to Orbital Flight Demonstrations

X-40A Completed Seven Successful Flights in 2001

Approach and Landing Test Vehicle Flies 2004

Orbital Vehicle Flies TBD

Drop Tests

B-52 will carry ALTV up to 40,000 feet

Streamlined Ground Operations

On Orbit

EELV

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Prototype Reusable Spacecraft Benefits/Relevance

- Automated (unmanned) flight demonstration
- High-payoff technology maturation and validation in real-world space and entry environments
- Payload capacity for science, Earth observation, and hardware validation
- Hands-on experience for a new generation of engineers and aerospace professionals
- Long-duration Orbital Vehicle (OV) and return capability to support validation of long-duration vehicle requirements (engineering specifications, natural and induced environments, hardware/technology development, etc.)

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Original Mission Success Criteria

- Flight Demonstration of an Integrated Thermal Protection System
  Level 1 Requirement: Shall provide maturation and validation of TPS
  within the confines of the X-37 reentry heating environments.

    - Leading Edge >2950 °F
    - Acreage TPS at 2400 °F
    - High-temp gap fillers and seals to support Leading Edge (2950 °F) and Acreage TPS (2400 °F)
    - Durability/Re-Usability of TPS better than existing Shuttle - TPS Components are 10X more durable than current tile in windward high temperature environments. New TPS enables adverse weather flight conditions.

- Automated Reentry and Landing
  Level 1 Requirement: Shall provide validation of automated approach and landing technologies.

    - Fault-tolerant operations: single-fault tolerant
    - Cross-wind landing capability: 17 knots
    - Calculated air data system accuracy:
      Angle of Attack (AOA) accuracy <1 degree,
      dynamic pressure >5%,
      and air speed >2%
    - Landing speed capability: >200 knots

- Lightweight System
  Level 1 Requirement: The OV landing weight shall not exceed 7500 lb including payload and residual propellants.

    - Li-Ion batteries – Charge
    - Mean Time Between Failure (MTBF) >100,000 Hrs
    - Gr/BMI Structure
    - Thin Hot Aero Surfaces
    - Lightweight Landing Gear

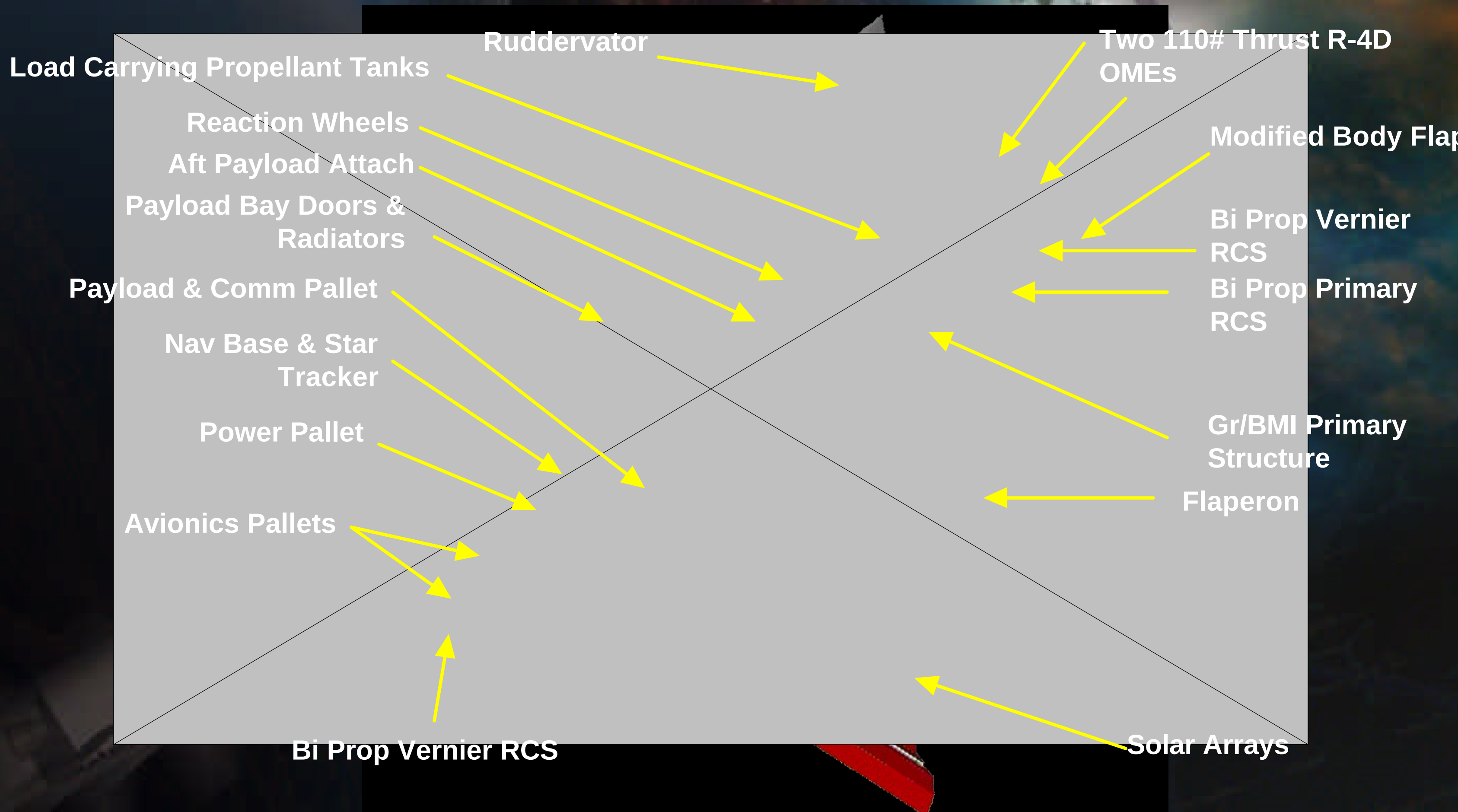
- On-Orbit Stay Time up to 270 Days
  Level 1 Requirement: Shall be capable of performing on-orbit missions with durations ranging from 2 – 270 days without on-orbit servicing.

    - Minimum on-orbit stay: 2 days
    - Maximum on-orbit stay: 270 days

- Demonstration of Low-Cost Operations/Turnaround Capability Level 1 Requirement: Shall be capable of performing 10 missions within 10 years with minimal subsystem maintenance and/or refurbishment or replacement

    - Low-cost operations: Small crew Flight Operations Control Center: <11 personnel (ALTV FOCC)
    - Post-flight Turnaround: 90 days

OV Configuration



Much of X-37 OV will have Heritage Design from Approach & Landing Test Vehicle (ALTV), Cooperative Agreement, & IRAD performed by the Boeing Company

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ALTV & OV Technologies Assessment

Flight Sciences
T-22 High Enthalpy Flight Profile
T-39 Advanced Aero and Aerothermal Analysis

Avionics/Software/Power
T-12 Modular Open Architecture Avionics
T-19 Fault Tolerant Autonomous Ops
T-28 Small Crew FOCC
AFT-1 Solar Arrays
T-35 High-Energy/Density Batteries
T-36 Electrical Actuation for Aerosurfaces
T-37 Power Management and Distribution
T-38 Open Architecture Software

Ground/Flight Operations
T-21 Rapid TPS Waterproofing (Spray Coating)

Structures
T-6 High-Temp Gr/BMI Sandwich Structure
T-8 Thin, Hot Aerosurfaces
T-32 High Temp Gr/PETI-5 Structures

GN&C
T-13 Calculated Air Data System (CADS)
T-17 Windward Adaptive Guidance
T-26 Rapid Mission Data Loading
T-29 Crosswind Landing for Small RSVs

Propulsion
T-2 RCS

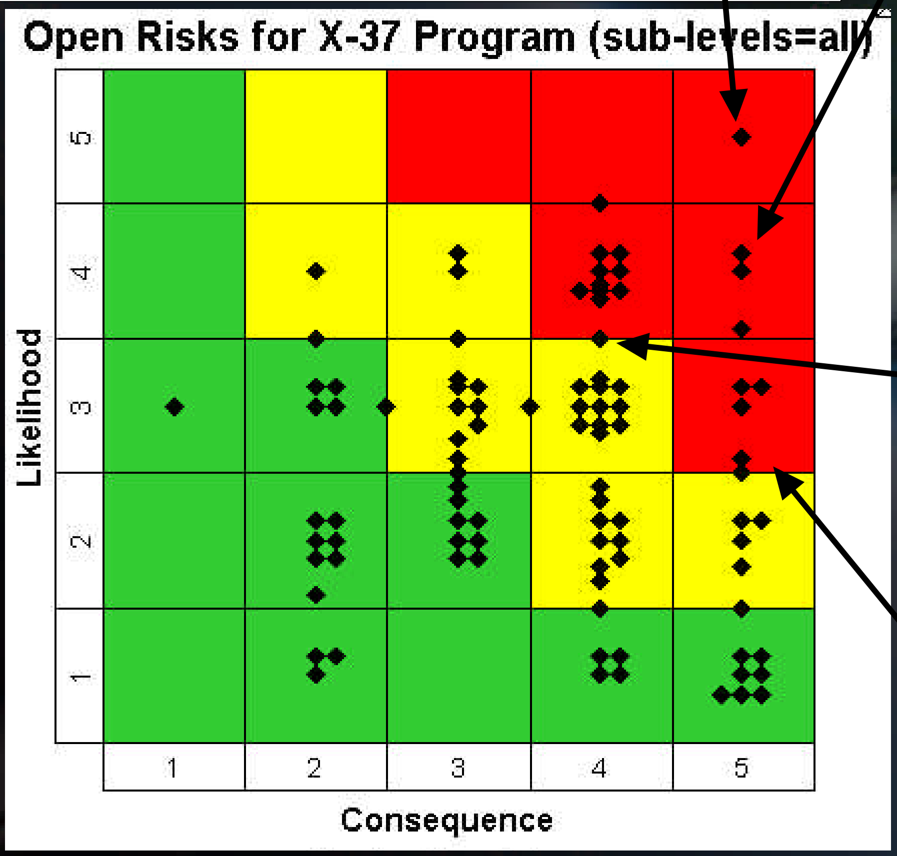
Mechanical Systems
T-10 Lightweight Landing Gear
T-31 Phase Change Brakes

Thermal Systems
T-3 High-Temp Windward TPS
T-4 High-Temp Upper/Side TPS
T-7 High-Temp Aerothermal Pressure /Seals
T-9 Loop Heat Pipe TCS
T-40 Durable, Low Conductivity/Density Tile
T-41 Durable Acreage Leeward Quilted Blankets
T-42 Durable Acreage Leeward Felted Blankets
T-43 Metallic TPS Experiment Panel
T-44 DurAFRSI TPS Experiment Panel
T-45 Failsafe Screening Surface TPS Test Panels
T-46 Ames Wing Leading Edge Tile

Technologies Key:
ALTV & OV
OV only

OV Risks Identified & Managed

164 ALTV – Success-Oriented Flight Test Schedule
341 X-37 OV Long-Lead Propulsion Items



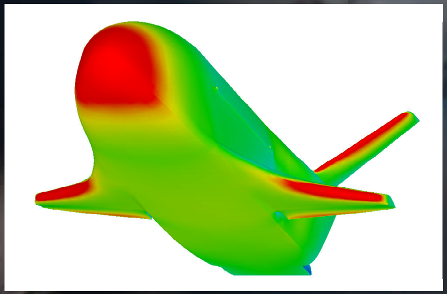
356 Increase in Payload power
344 Long Lead Procurement
300 Wing Leading-Edge TPS Capability

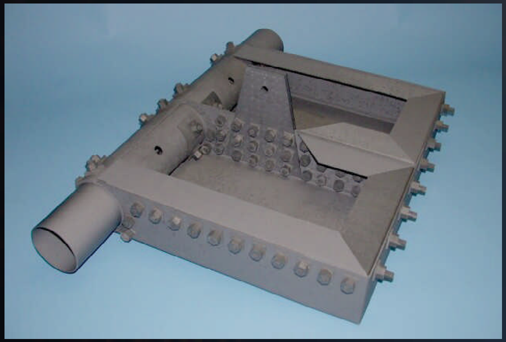
365 SIGI Performance Untested for Re-Entry
362 Stability – Time to Double (TTD)
357 Next Generation photo voltaic cells
346 High Voltage Battery Recharge
364 Modal Test Data Validity
303 Hot Structure Control Surface Performance
358 ALTV Supplier Follow-on Support
187 Short ALTV Integration Schedule
287 OV Hypersonic Aero Uncertainties
350 High Voltage Battery Cell Divergence

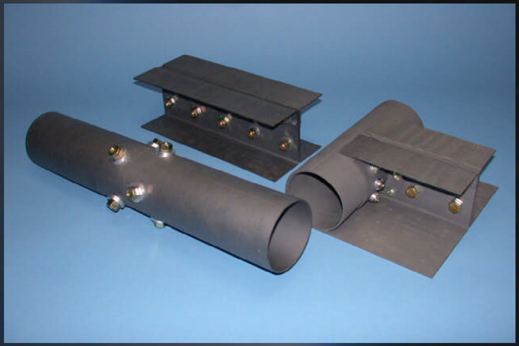
288 OV Aeroheating Damage to Critical Components
347 Battery Qualification Risk
268 Micro-Meteoroid/Orbital Debris Assessment
340 X-37 OV Propulsion Verification Approach

OV Key Technical Issues

- **Critical technology development through qualification**
  - Thermal Protection Systems
  - Hot Structures
  - Lithium-Ion Batteries
  - Other Activities
    - Aeroheating & Aerodynamics Database development







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Thermal Protection System (TPS) Description/Goals

- TPS developed to withstand reentry environments:
  - Surface temperatures as high as 2950 °F for up to 10 minutes during peak heating

- Effort focuses on Wing Leading Edge (WLE) material reproducibility and system qualification

- Arc Jet test testing includes Nose Cap and Flaperon Seal elements.
  - Includes High-temperature gap fillers

- WLE TPS system is the TUFROC system being developed by NASA Ames Research Center

  - BRI-20 Substrate
  - ROCCI Top Cap
  - HETC Coating

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Wing Leading Edge TPS Accomplishments/Future Work

Completed

- NASA Ames tested WLE materials 2003
- Down selected to TUFROC material 2003

Future Work

- BRI-20 process qualification
- HETC on BRI-20 process reproducibility at NASA Ames
- Nose cap arc jet testing at Ames
- 10x10x6 inch BRI-20 arc jet test article production
- WLE Swept configuration arc jet test at NASA Ames
- ROCCI process reproducibility at NASA Ames
- HETC on ROCCI process reproducibility at NASA Ames
- Process reproducibility of TUFROC System
- WLE component part certification and arc jet test
- WLE TPS qualification and certification complete

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Hot Structures Description/Goals

- The objective is to qualify high-temperature, high performance Hot Structure Control Surfaces that are lightweight and meet stringent performance requirements in a Shuttle-type environment with peak temperatures of approximately 2800 °F

- Hot Structures Components include Control Surface (Flaperon and Rudervator) joints/spindle and hinge-pin interfaces

- To reduce technical and schedule risk to the project, both C/C and C/SiC will be developed, tested, and fabricated in parallel

- Dual-path development is being pursued through initial sub-component testing, downselect, and performance of qualification unit testing of selected material system for one mission cycle

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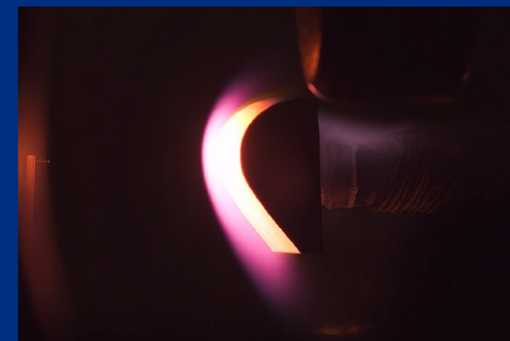
Hot Structures Accomplishments/Future Work

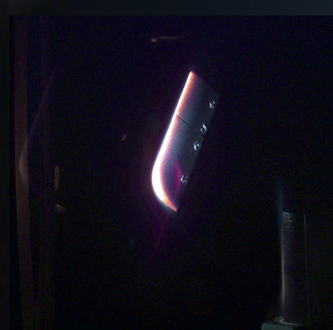


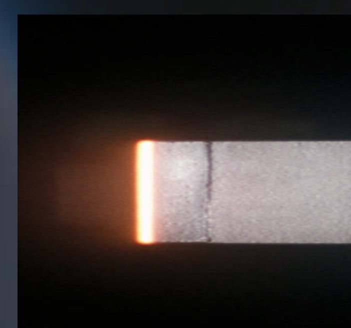
Completed

- Hot Structures PDR - Jan 2004

Future Work

- Ruddervator subcomponent delivery
- Hot Structures CDR
- Flaperon sub-component delivery
- Qual unit fabrication
- Ruddervator sub-component testing
- Flaperon sub-component testing
- Flaperon/Ruddervator EDU fabrication/inspection
- Flaperon/Ruddervator Qual unit fabrication
- Flaperon/Ruddervator Qual Unit testing





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Li-Ion Batteries Description/Goals

- Provide space qualified Lithium-Ion High- and Low- Voltage Battery Qualification Units. Including cell charge equalization electronics at the battery level
- 50% Weight Savings
- 50% Volume Savings
- Greater Safety Margins
- Better Depth of Discharge Performance

Lithium-Ion Batteries Accomplishments/Future Needs

Completed

- Low Voltage Cells (Phase 1) Dec, 12, 2003
- PDR Kickoff Meeting January 29, 2004

Future Needs

- Battery Spec and ICD complete
- High voltage Cell material procurement
- Special Test Equipment complete and delivered to Yardney
- Battery CDR
- 270 day cell life cycle testing
- Qual units built and ready for qualification testing
- Environmental Qual testing
- Full Qual complete
- Complete 270 day cell life cycle testing

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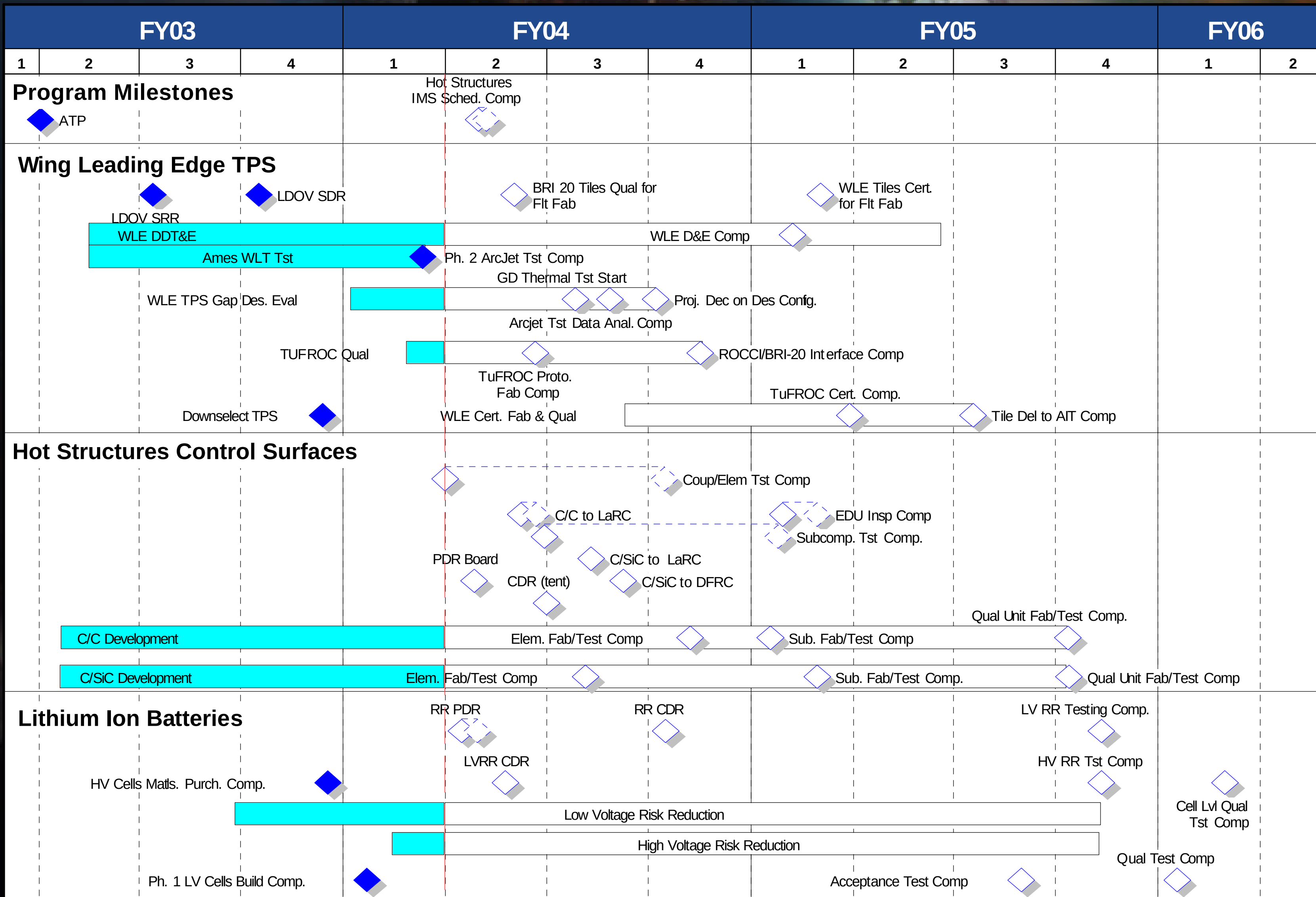
Other Activities
Aerothermal/Aerodynamic Database Development

- The wing leading edge size and expected high temperature requires new TPS material
- Computational Fluid Dynamic (CFD) analysis established a 25% uncertainty level
  - TPS material capability
  - Analytical methodologies
  - Operational methods to meet requirements (trajectory shaping, etc.)

- Provide an independent assessment of aerothermal database for high altitude and high Mach numbers
- Establish reentry aerodynamic heating database for the OV using current Outer Mold Line (OML) design
- Perform CFD analysis to support aerodynamic database

OV Technologies Draft Schedule



Summary

- Orbital Vehicle design & development complete to PDR; on hold pending funding/policy decisions
- OV High-Priority Technologies development is in progress

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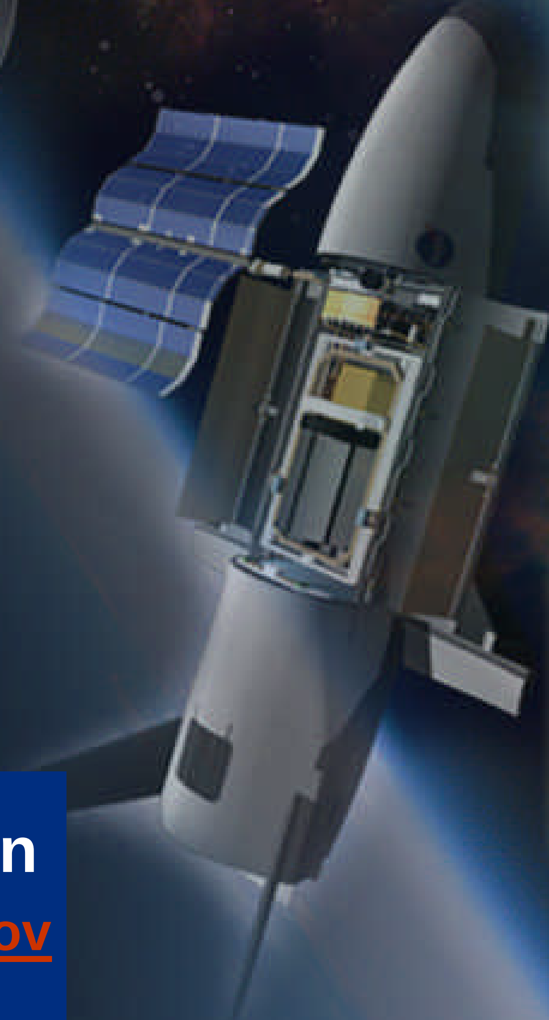
Technology Leadership for Space Transportation



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