Hypersonics MDAO Overview

Fundamental Aeronautics Program

2nd Annual Meeting

Atlanta, Georgia

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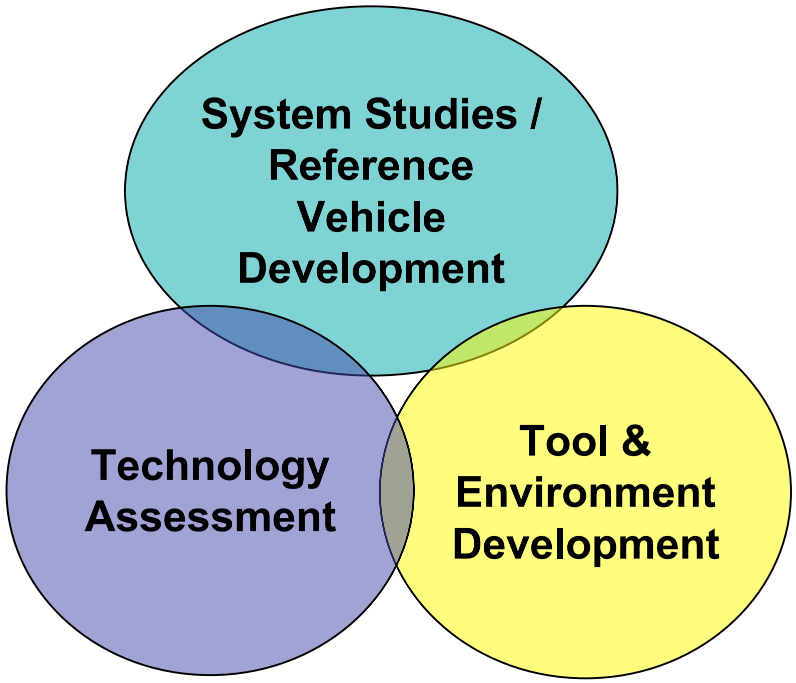
API for Hypersonics MDAO

Outline

- Hypersonics MDAO discipline goals and focus
- Roadmap and milestone summary
- NRA summary
- Major MDAO activities
- FY09 plans
- Summary

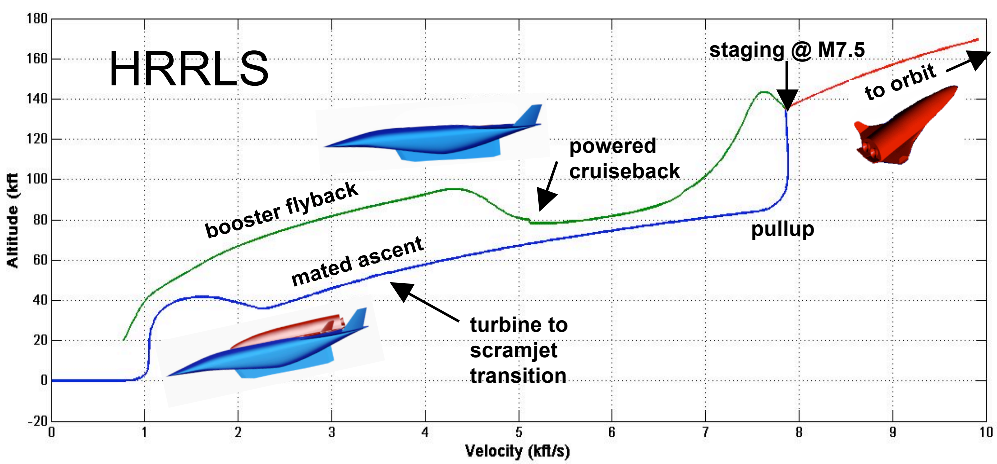
MDAO Goals

- MDAO primary roles within the Hypersonics Project are to:
  1. Develop and analyze reference vehicle concepts to determine potential system capabilities and to establish research and technology goals and requirements.
  2. Advance integrated analysis tools and processes to significantly reduce analysis cycle time.
  3. High fidelity multi-discipline tools and analysis to provide reduced order models and validation for integrated environment analysis.
  4. Assess and prioritize research and technology portfolio supporting the reference missions.

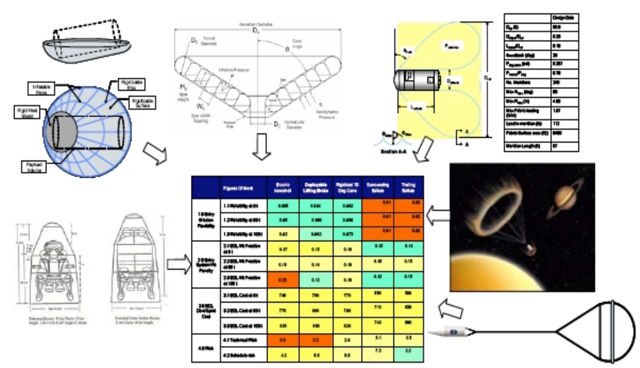


MDAO Reference Missions

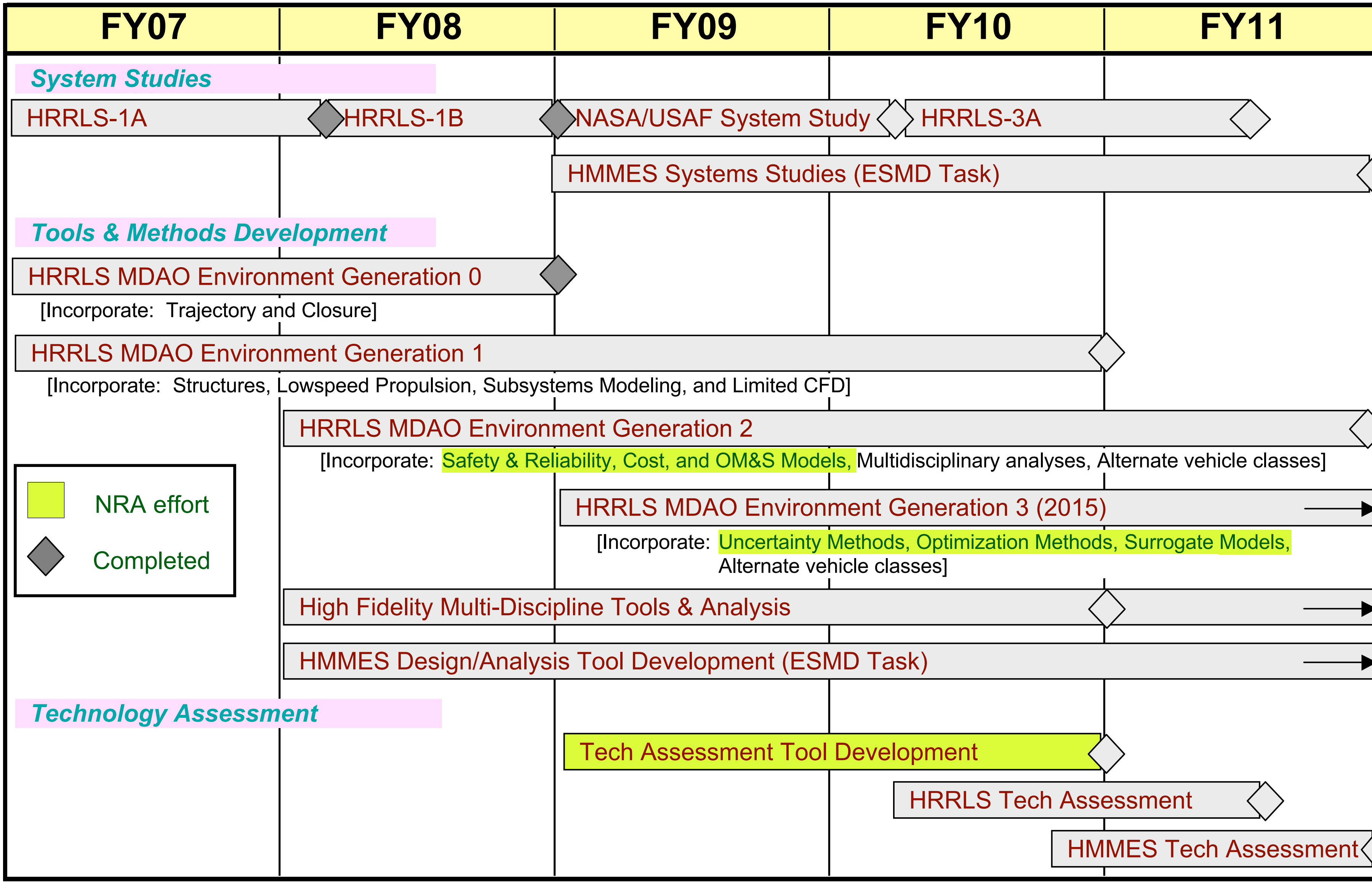
- MDAO is focused on two primary reference missions including Highly Reliable Reusable Launch Systems (HRRLS) and High Mass Mars Entry Systems (HMMES.)
- HRRLS is an ARMD mission and application where system studies and tool development are being performed within Hypersonics Project.
- HMMES is ESMD mission where system studies and design/analysis tool development are being performed by ESMD.
- MDAO will assess both missions/systems against the Hypersonics Project Research and Technology (R&T) portfolio.



HMMES



MDAO Top-Level Roadmap



NRA Integration Strategy for HRRLS

Reference System Designs & System Sensitivities

NRA

- Life Cycle Analysis Supporting NASA/USAF TSTO Joint System Study

NASA

- NASA/USAF TSTO Joint System Study
- Alternate TSTO System Concepts
- Sensitivity Studies

System Studies

Integrated Analysis Process & Tools to Reduce Cycle Time

NRA

- Discrete Event Simulation (DES) of Operations
- Uncertainty Sources & Propagation in System Analysis
- Aero Data Integration & Uncertainty Assessment
- Optimization in Presence of Uncertainty

NASA

- Traditional Discipline Analysis Tool Integration

Integrated Environment Development

Reduced Models and/or Validation for Integrated Analysis Environment

NRA

- Coupled Fluid-Thermal Structural Analysis for HRRLS
- Optimization in Presence of Uncertainty
- Full-Vehicle Airframe/TPS Sizing

NASA

High Fidelity Multi-Discipline Tools & Analysis

Research & Technology Impact on System & Portfolio Prioritization

NRA

NASA

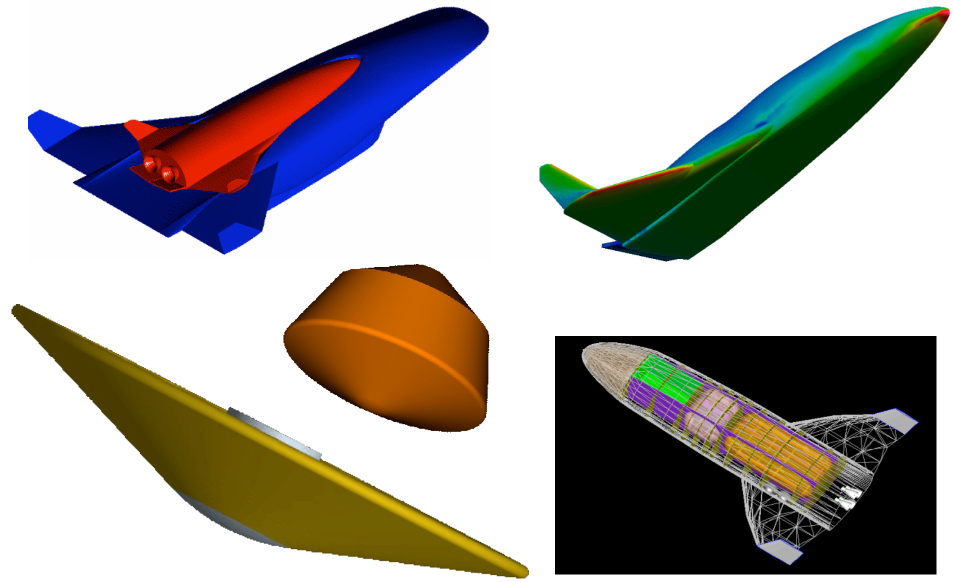
- Limited Technology Trades

Technology Assessment

System Studies

<u>Objectives:</u>

- Perform system studies for the HRRLS and HMMES missions, providing:
  - Reference concepts for project disciplines to analyze / exercise tools and apply technologies
  - A means to exercise and evaluate MDAO tool development progress
  - Reference concepts to perform technology assessment, providing technology investment guidance



<u>Status:</u>

- HRRLS system studies
  - HRRLS-1A: RP/LOX both stages, SOA technologies
  - HRRLS-1B: RP/LOX both stages, near-term technologies
  - HRRLS-1X: USAF ORS mission, RP/LOX both stages, 2016 technology freeze date
- HMMES system studies
  - Mars EDL architecture studies

<u>Key Deliverables and Milestones:</u>

- HRRLS-1A complete 04/08
- HRRLS-1B complete 10/08
- HRRLS-1X due 02/10
- HMMES EDL architecture study end of FY11

Motivation for Mars EDL System Study

- NASA lacks the technology to land large masses on Mars. MSL represents the limit of current Viking derived EDL technology.
  - Current EDL capabilities based on 1960's and '70's NASA research and technology investment
  - Recent investments have focused on extending current capabilities or on specific areas (e. g., TPS), but were not integrated as a system solution
  - Robotic missions exceeding MSL's landed mass (2 - 5 metric tons) will need alternative technology solutions
  - Exploration class missions anticipated to be in the 20 to 50 metric tons range -- current technologies are infeasible
  - To date, successful missions consisted of < 600 kg Landed useful mass, < -1km MOLA elevation & large position uncertainty
- Effect of EDL
  - EDL system drives the mission architecture for missions with atmospheric flight elements
  - Fundamental physics due to atmospheric flight define the majority of the EDL system risk

Previous Mars EDL System Studies

- Previous high-mass EDL studies focused on existing or nearer-term technologies
- Lower TRL elements considered, but not baselined
- Previous studies provide excellent point of departure for detailed assessments

Year	Name	Description
2002	MIAS	Large robotic and crewed
2002	MPSET	Large robotic with mid L/D
2005	2x MSL	Large robotic
2007	CEMMENT	Large robotic (MSR)
2007	MAWG - DRM 5	Exploration-crewed & cargo

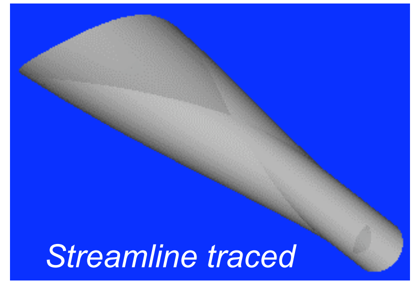
Mars Architecture Working Group (MAWG) — DRM 5 Update

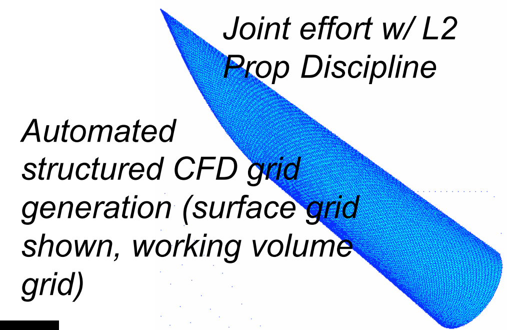
- Focused effort identified limitations at Exploration scale. Limited effort on alternate technologies and capabilities due to low TRL (I.e. inflatables.)
- Defined an EDL architecture. Only assessed nominal performance with no margin. Unlikely robust to reasonable dispersions.
- Detailed follow-on EDL architecture studies recommended.
- Observed increased potential for successful landing by reducing ballistic coefficient and increasing L/D

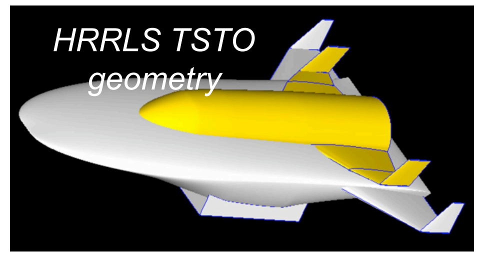
Tool & Method Development

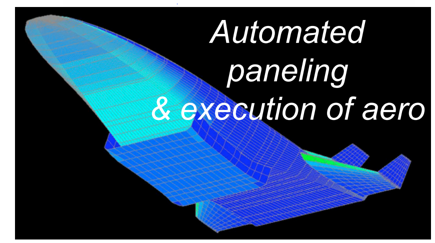
Objectives:

- Develop a geometry centric integrated design, analysis & optimization environment
  - Support multi-fidelity analysis
  - Rapid uncertainty analysis / assessment
  - Flexible and robust
  - Incorporate existing discipline tools
- Improve and/or streamline individual discipline tools, such as “life cycle” analysis models for hypersonic systems
- Identify and fill gaps in tool suite









Status:

- HRRLS environment: currently integrating trajectory, aero, geometry, packaging, and sizing for upper stage; structures, packaging, propulsion and sizing for first stage
- Also working automated structured CFD grid generation, STI inlets for HRRLS
- HMMES design/analysis tool development being performed under ESMD task with support from NRAs

Key Deliverables and Milestones:

- HRRLS Integrated Environment Generation 0 complete 9/08
- HRRLS Integrated Environment Generation 1, due 9/10
  - Generation 1 will be for 2-D class of vehicle
- NRAs to provide improved life cycle analysis tools and models for HRRLS, and uncertainty quantification and related tools
- NRAs to provide HMMES design technology advancement

Multi-Disciplinary Modeling and Analysis

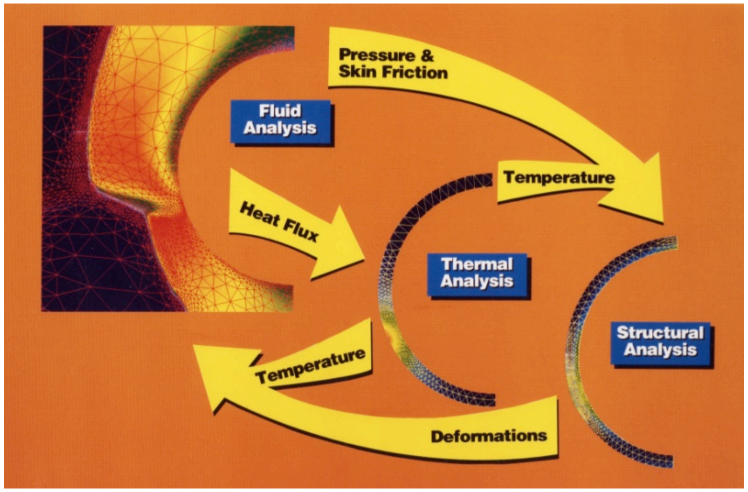
Objective: Develop and validate multidisciplinary, highly-integrated design, modeling, and predictive capabilities for HRRLS and HMMES Missions

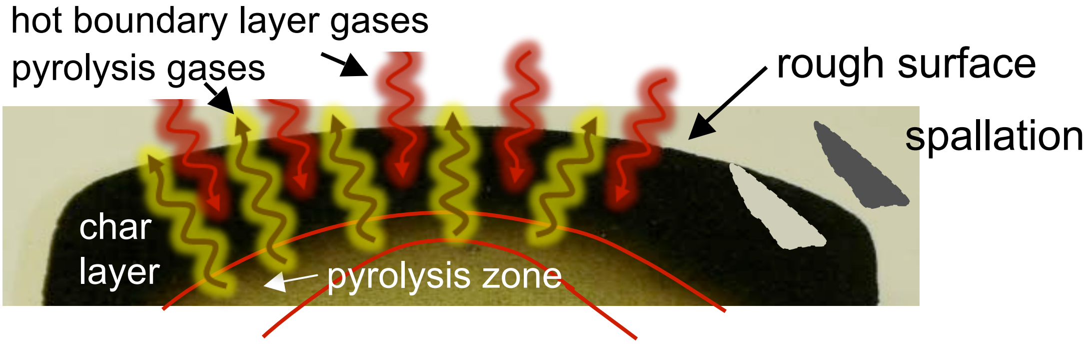
Technical Challenges (Top 3):

1. High-Fidelity Multidisciplinary Analysis Methods for tightly-coupled physics associated with Hypersonic "Vehicles"

2. Bridging the Gap: Methods to enable use of high-fidelity analysis from Level 2 disciplines for PB-MDAO and systems analysis at Level 4

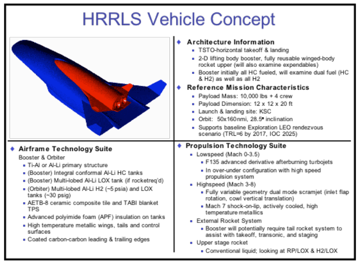
3. Validation



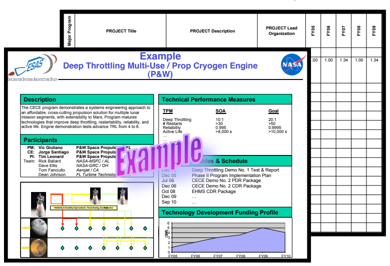


Technology Assessment

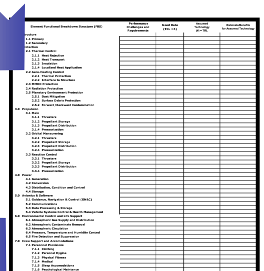
Proposed Process Enables R&T Assessment and Prioritization Against Reference Mission Concept



Mission Needs Mapped to System Taxonomy

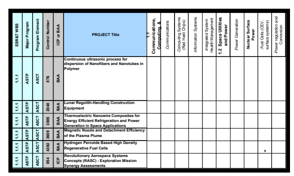


Existing R&T Mapped to Taxonomy



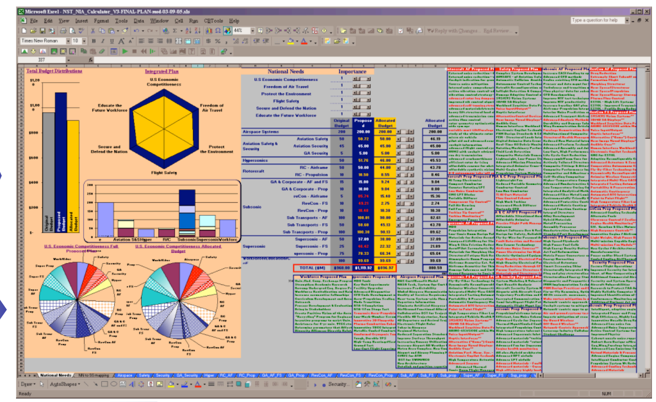
R&T Needs Taxonomy

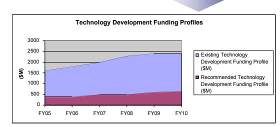
R&T Needs FOM Impact Scored

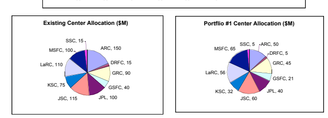


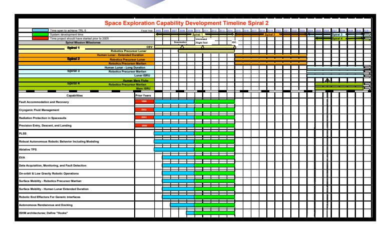
Existing R&T Benefit Scored

Information Integrated into "Portfolio Calculator"





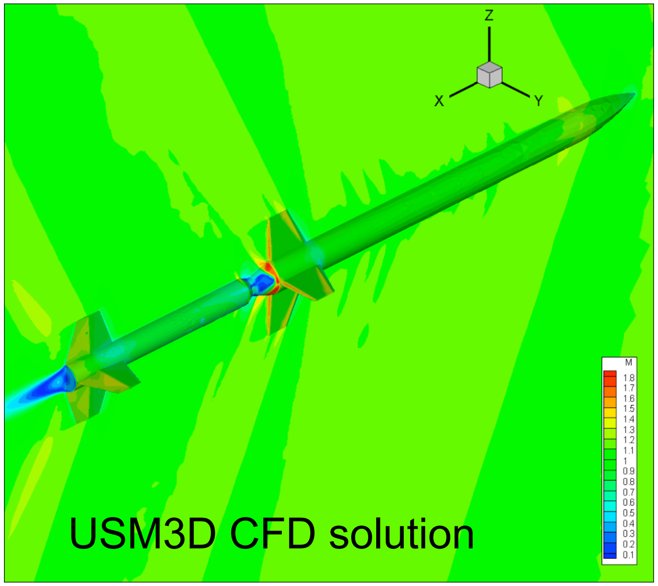


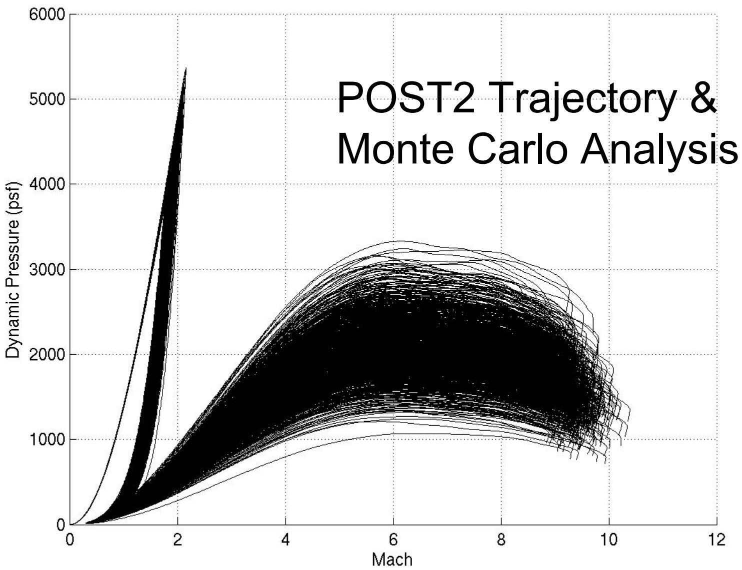


R&T Investment Recommendations

HIFIRE Special Project Support

- MDAO supports the HIFIRE flight test series with aerodynamic database development and trajectory analysis
- Aero database generation with Missile DATCOM, USM3D, SHABP
- Trajectory & Monte Carlo analysis performed using POST2
- Also worked to improve design and analysis tools
  - Rapid missile geometry generation
  - Automated execution of Missile DATCOM
  - Automated generation of paneled surfaces for APAS/SHABP, tetrahedral grids for CFD, and IGES surfaces
  - Automated execution of Monte Carlo trajectory runs





HRRLS FY09 Plans and Priorities

- NASA/USAF joint system study
  - Assessment of NASA and USAF TSTO concepts against Operationally Responsive Spacelift (ORS) mission objectives
  - Both NASA and USAF will evaluate each other's concepts and compare results to understand differences
  - NASA HRRLS concept design will be modified to align with ORS mission and technology freeze date of 2016
  - Assessment FOMs will include turn-around time, system reliability, operations cost, and development cost
- Tool and environment development
  - Complete vehicle level structural sizing & analysis capability (automated loads generation, FEM synthesis, and element sizing loop)
  - Improve subsystem modeling and complete vehicle closure algorithm for Gen 0 environment release
  - Continue development of automated structured gridding tools
  - Work low speed propulsion (M<3) modeling and integration

HMMES EDL Systems Study Plans

- Ad hoc Charter: Develop a plan for NASA to be able to successfully land large payloads at Mars for both robotic and Exploration scale missions
- EDL Systems Analysis study sponsored by NASA Office of Chief Engineer
- 3 year high fidelity Systems Analysis Study
  - Assess integrated EDL architectures to enable precise delivery of landed masses (useful mass) in the 2 to 5 metric ton range for large robotic missions and 20 to 50 metric ton range for Exploration class missions
  - Develop detailed technology development roadmaps and associated development costs
  - Identify nearer term technologies which could benefit from immediate focused technology development (leveraging the previous study results)
  - Perform low fidelity viability demonstration testing for selected technologies
  - Consider lower TRL technologies with potential for high payoffs, but need to be consistent with assumed mission need dates
  - Document results via Peer Reviews and written reports.

Summary

- MDAO tasks in three major areas: system studies, tool & method development, and technology assessment
- Focus on two primary mission classes: Highly Reliable Reusable Launch Systems (HRRLS) and High Mass Mars Entry Systems (HMMES)
- NASA/USAF Joint System Study will be major HRRLS FY09 focus
- Strong complement of supporting NRAs for both HRRLS and HMMES missions although some gaps remain
- Progress being made with HRRLS design/analysis environment and tool development
- Technology assessment tools need development