Systems Analysis Office

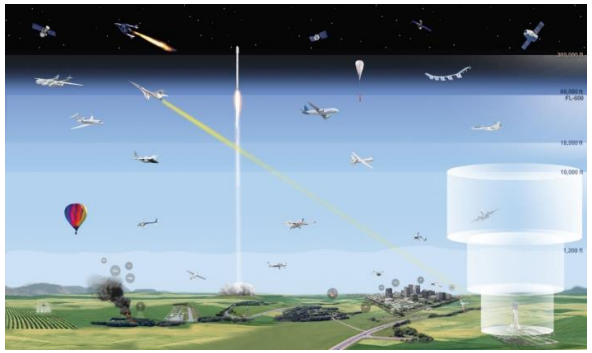
(Code AA)

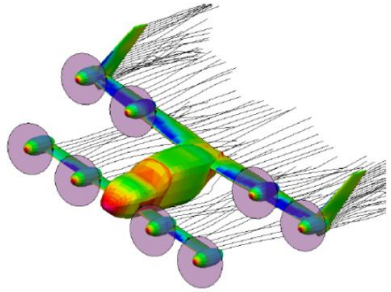
Vehicle and Systems Analysis

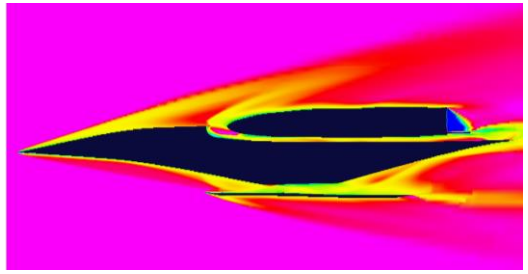
NASA Ames Research Center

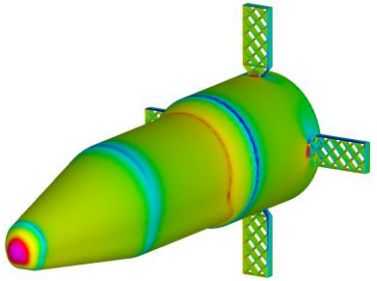
Systems Analysis Office Overview

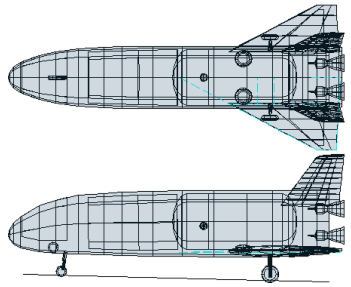
- The Systems Analysis Office (Code AA) is one of six research divisions and offices under the Ames Aeronautics Directorate (Code A)
- Diverse group of early career and senior aerospace engineers
- Office currently composed of 19 civil servants and 5 contractors
- Wide range of aerospace disciplines and capabilities for vehicle and systems analysis
- Long history of supporting NASA, DoD, and commercial projects in various design and testing phases

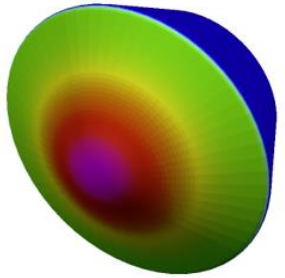








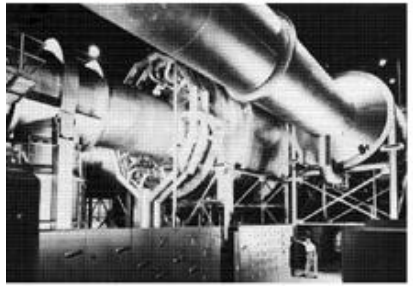


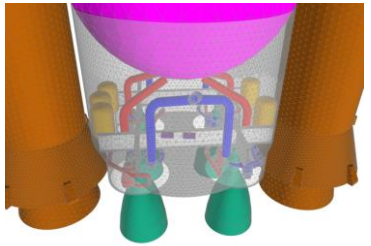


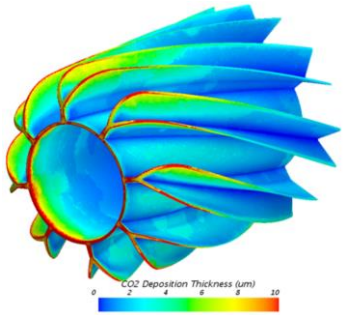
Systems Analysis Office Charter

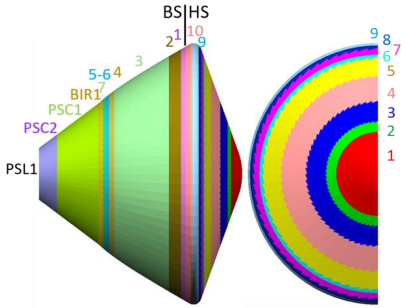
- Code AA provides end-to-end, physics-based, system-integrated, decision-making analyses for aeronautical and aerospace applications to serve next-generation questions
- Supports multiple NASA mission directorates
  - Aeronautics Research Mission Directorate (ARMD)
  - Exploration Systems Development Mission Directorate (ESDMD)
  - Space Technology Mission Directorate (STMD)
  - Science Mission Directorate (SMD)
- Develops process and analysis tool innovations to aid decision-making activities for novel vehicles and systems
  - Rapid-turnaround analyses
  - Conceptual phase to detailed design phase support
    - Trade studies and sensitivity studies
    - Requirements definition and verification
  - Physics-based modeling using engineering-level to high-fidelity tools
  - Using actual design data, heuristics or similarities with existing systems

LaRC UPWT Facility



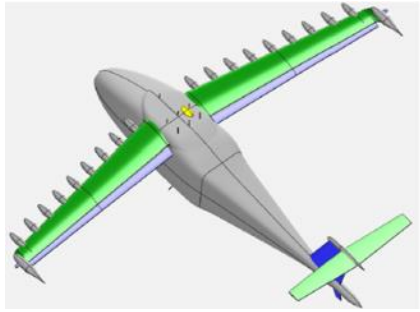


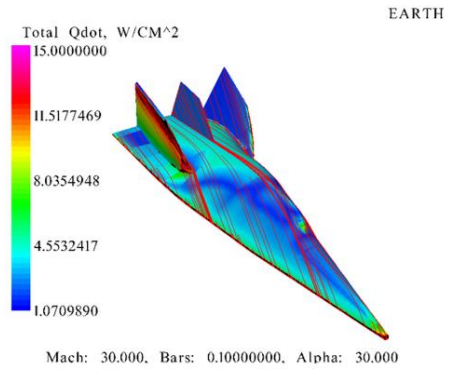


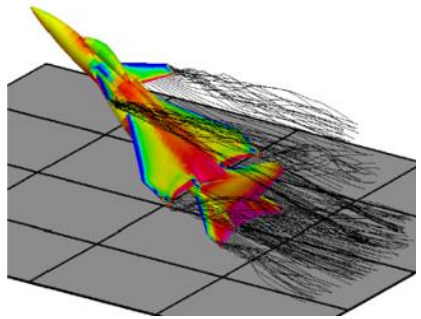


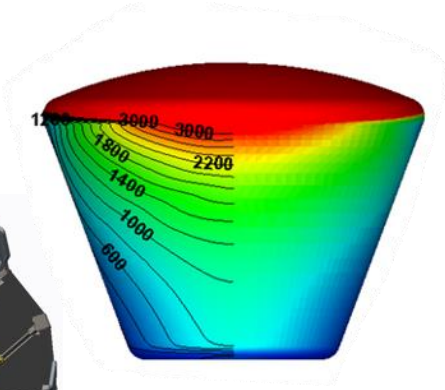
Modeling and Analysis Disciplines

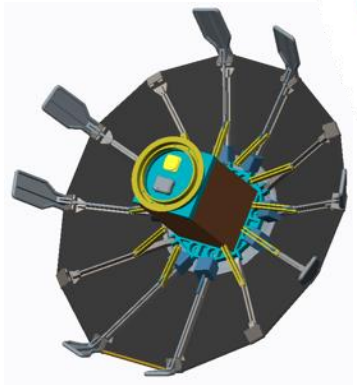
- All Speed Aerodynamics
- Vehicle Closure and Mission Analysis
- Aerodynamic and Aero-Thermodynamic
- Rocket Engine Propulsion System
- Trajectory
- Structures
- Guidance & Control
- Thermal Protection System (TPS) Selection and Sizing
- Multi-Disciplinary Analysis and Optimization (MDAO)
- Risk Assessment and Physics of Failure





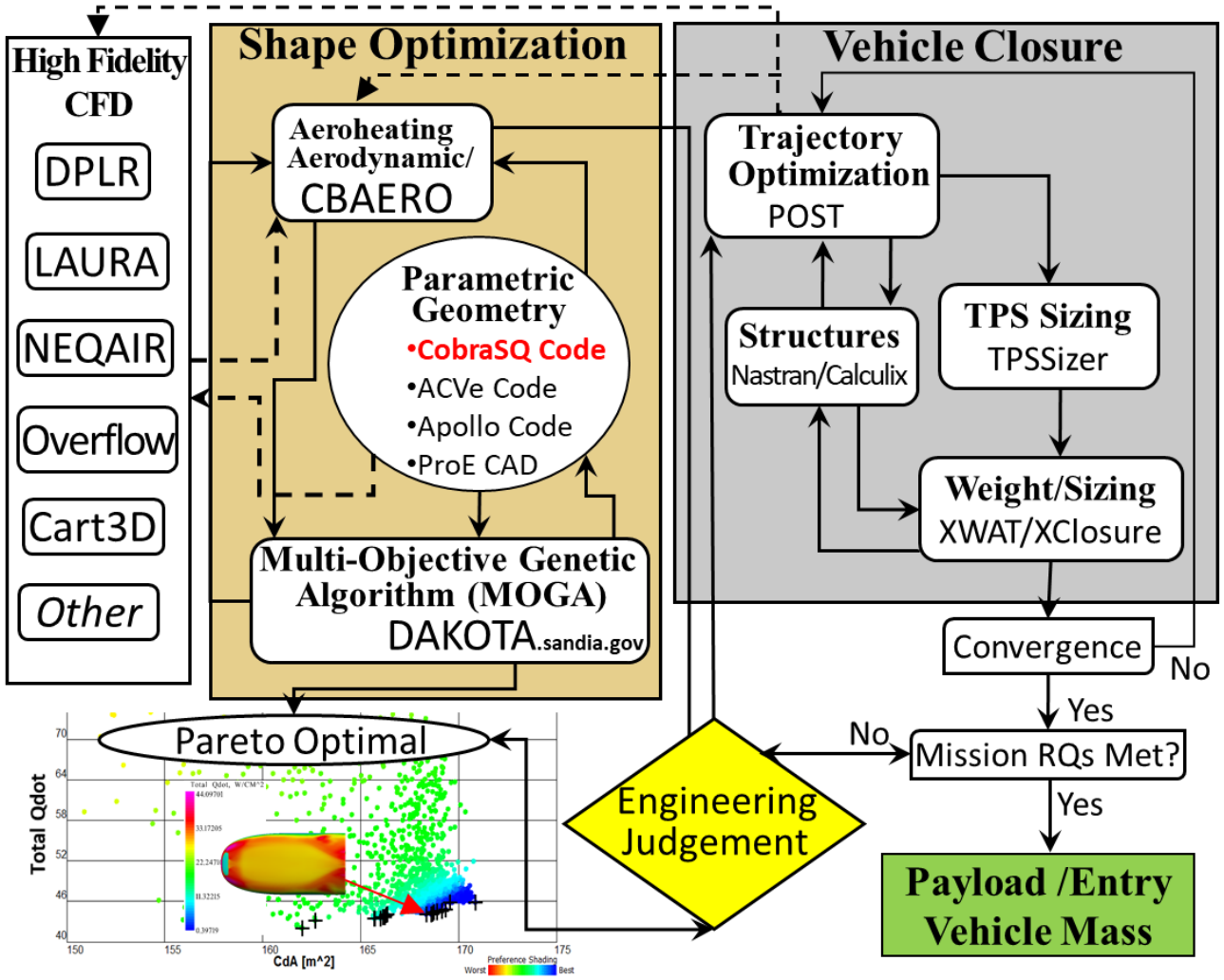






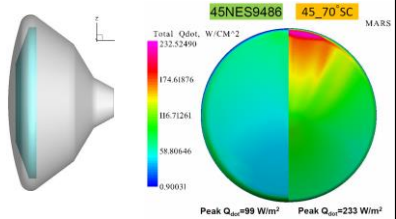
Multi-Disciplinary Analysis and Optimization (MDAO)

MDAO has been successfully used to take CobraMRV from concept to subscale flight test

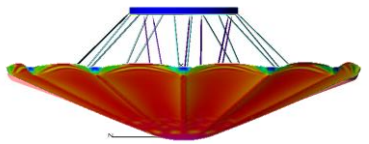


Applications

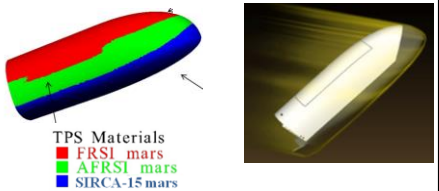
Mars2018

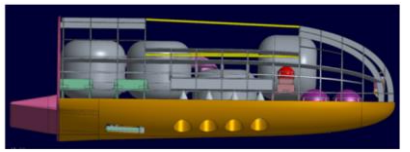


ADEPT



Mars: Mid L/D





Realization

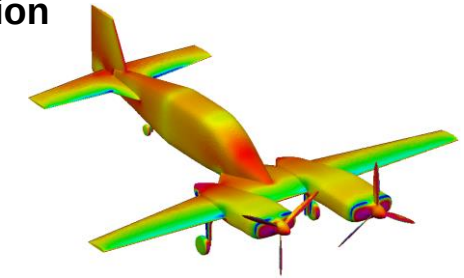
2011 CobraSQ LaRC Mach 6

2017 CobraMRV2908b ARL

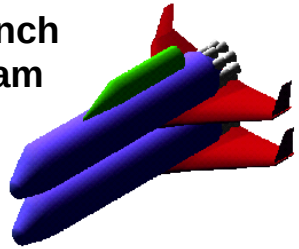
2020 CobraMRV2908g AETC Control Surface Test

Past projects: Aerodynamic & Aerothermodynamic Analyses

Multi-disciplinary Design and Optimization

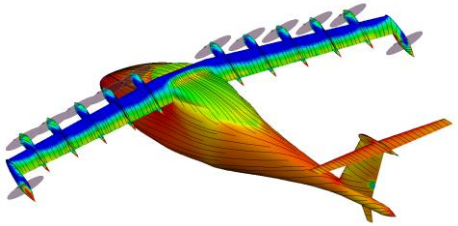


2nd Generation Reusable Launch Vehicle Program



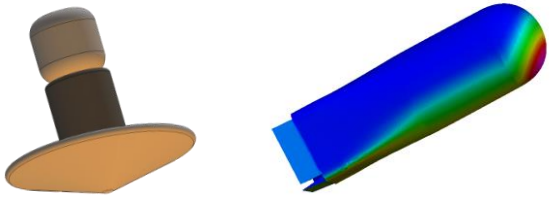
Thermal Protection System Advanced Development Program

Distributed Electric Propulsion Project

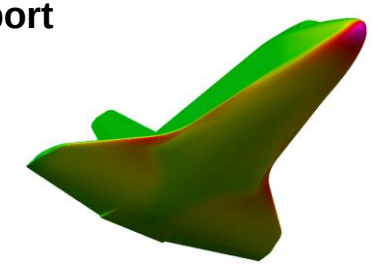


Next Generation Launch Technology Program

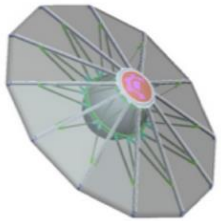
Mars Design Reference Mission 5, Entry Descent and Landing Studies



Columbia Accident Investigation Board Report



Adaptable, Deployable Entry Placement Technology (ADEPT)



Space Launch System (SLS)

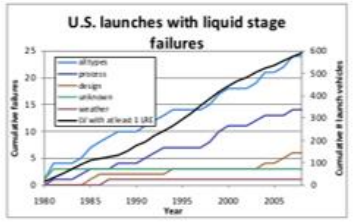
Past projects: Ames Engineering Risk Assessment Examples

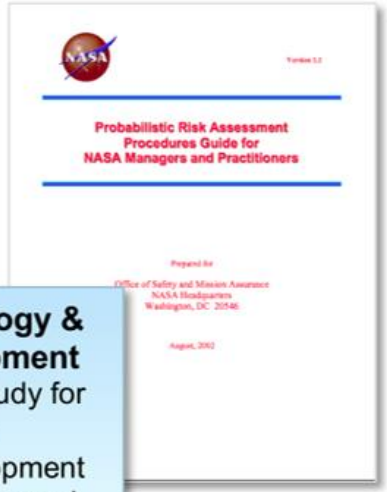
Crew Launch Vehicle Risk Assessment & Risk-Informed Design

- Ares I/V integrated LOM/LOC
- SLS abortability
- SNC Dream Chaser mission risk modeling
- SpaceX DragonRider ascent risk sensitivity

Space Mission, Campaign & System Risk Analyses

- Ares V Mars campaign
- CxAT Lunar Surface Systems
- HEFT II campaign to a NEO
- Aquila II
- SWORDS





Agency Risk Methodology & Requirements Development

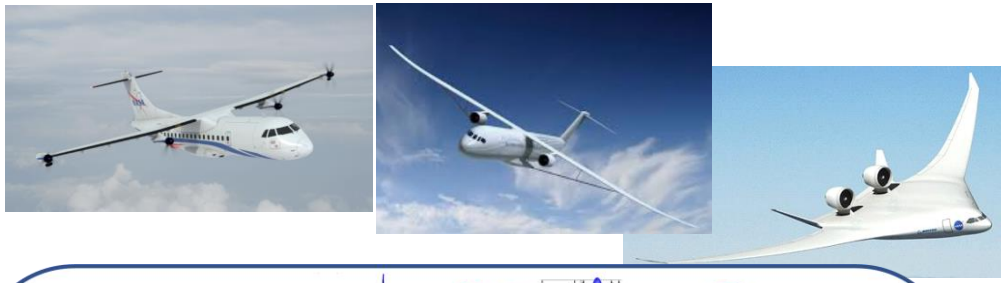
- Liquid/Solid Propellant Study for NASA's Study of Rockets
- CCP requirements development
- OSMA PRA guide chapters and training modules.

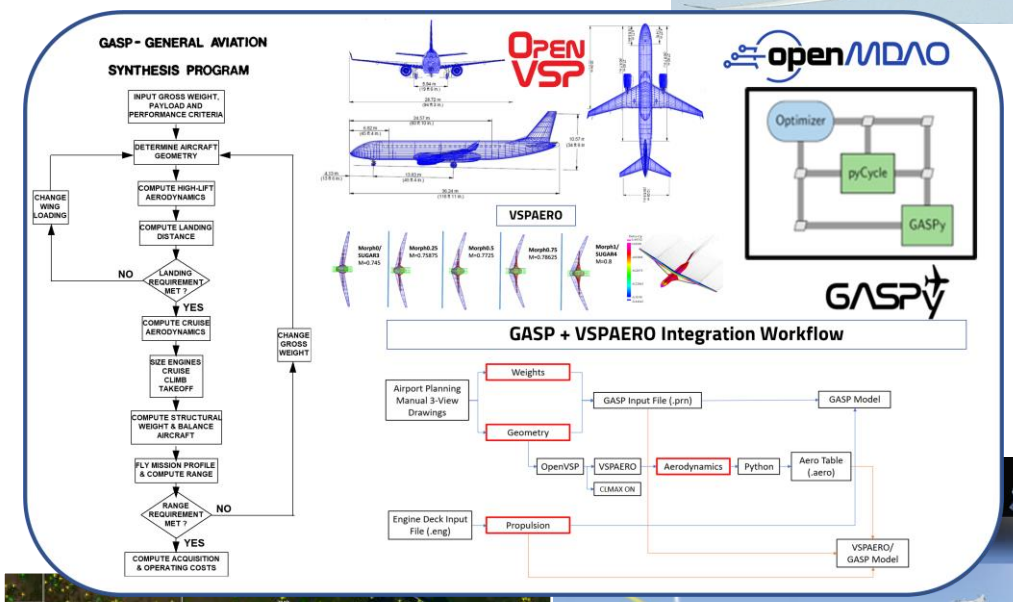
Design Analysis for Flight Demonstrator Projects

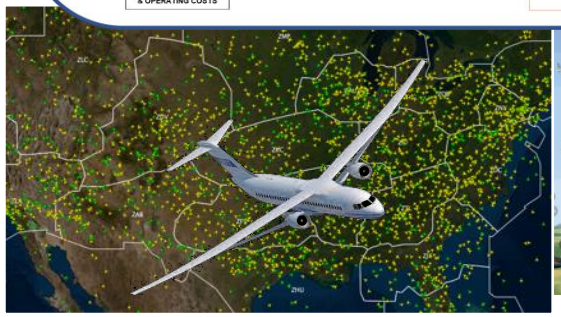
Electrified Powertrain Flight Demonstrator (EPFD) project will conduct ground and flight tests of electrified aircraft propulsion technologies to enable a new generation of electric-powered aircraft.

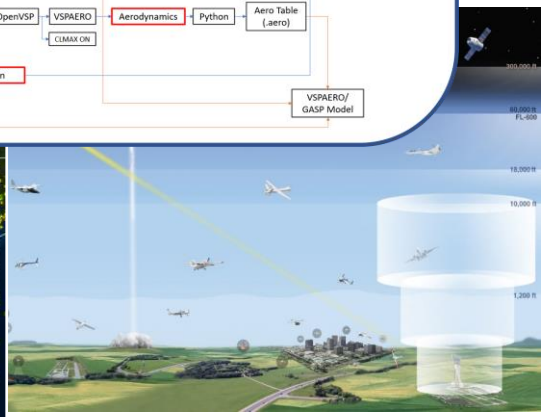
Sustainable Flight Demonstrator (SFD) project will mature key airframe technologies, such as new wing designs, that have a high probability of transition to the next-generation single-aisle seat class airliner.

- EPFD and SFD roles and support in AA
  - Perform conceptual design analyses and trade studies on test and vision vehicles.
  - Evaluate electrified and hybrid-electric concepts.
  - Survey and assess viability of using various alternative fuels.
  - Perform assessments to determine if new concepts will fly, meet the mission requirements, properly integrate into the national airspace system, and achieve project objectives such as emissions, sustainability, and low community noise.
  - Perform system-wide airspace analyses that simulate and evaluate the benefits of introducing new designs into the commercial airliner fleet.
- Code AA's Impact
  - Our team has the breath and depth of expertise that spans Vehicle Synthesis and Mission Analysis to CFD as well as providing NAS-wide benefit assessments.
  - We provide insights to leadership and industry.
  - Our work guides NASA's investment in test programs and in selecting high payoff investment opportunities.







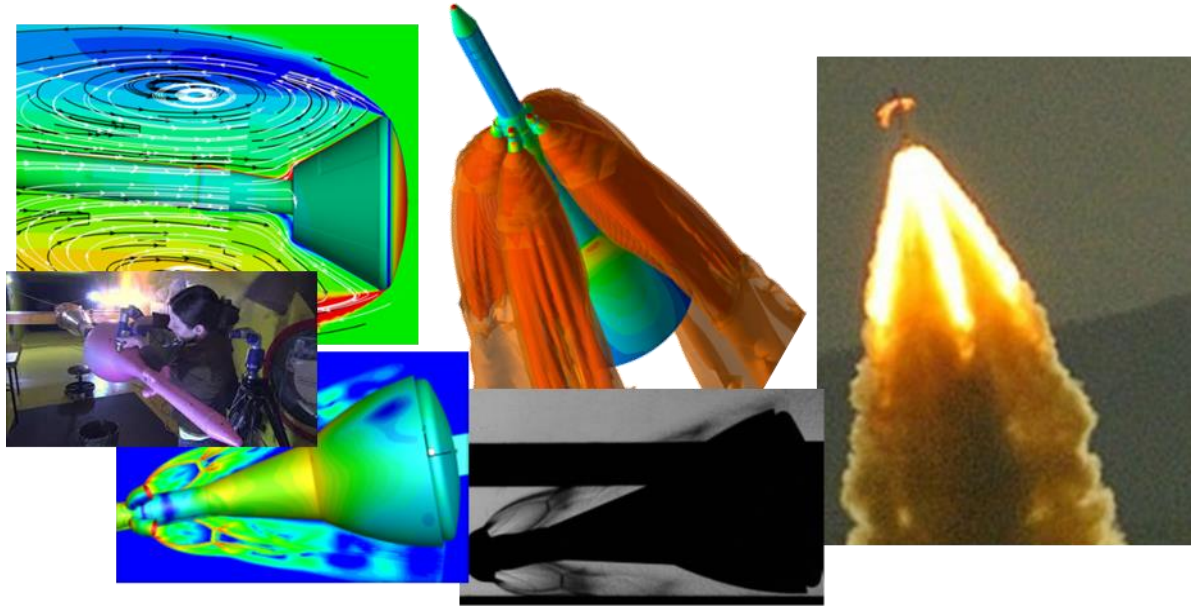


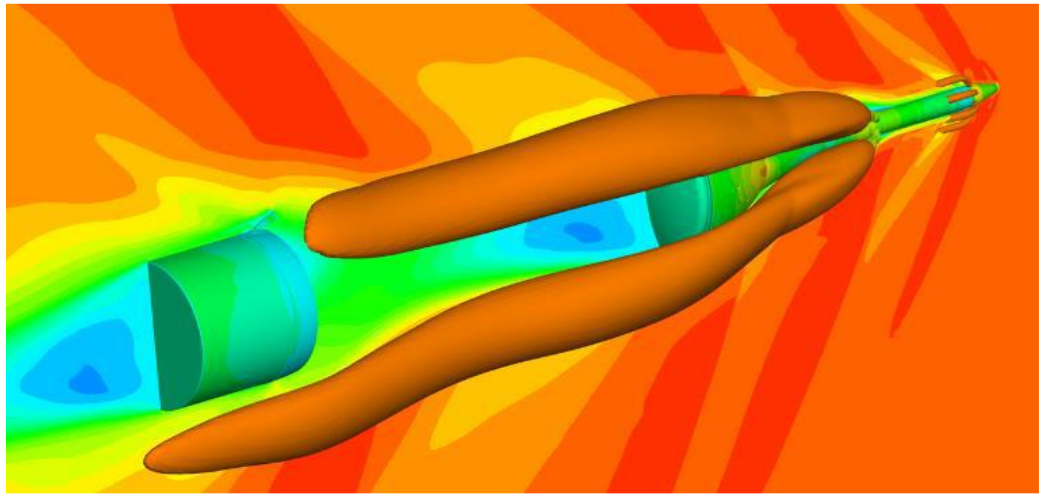
Aerodynamic Analyses for Orion Vehicle

The Orion Aerosciences Project is responsible for the development of both the Crew Module (CM) and Launch Abort Vehicle (LAV) aerodynamic databases using both wind tunnel testing and Computational Fluid Dynamic (CFD) in support of the Artemis Program.

- Orion Aerosciences Project roles and support in AA
  - Coordinate aerodynamic analyses at Ames in the development of Overflow CFD simulation guidelines for the overall project, led out of Johnson Space Center (JSC).
  - Support CFD simulations for the creation of the vehicle aerodynamic databases including extrapolation of wind tunnel data to flight for both CM and LAV.

- Code AA's Impact
  - Supported Aerodynamic database development in the following key flight test and post flight analyses:
    - Orion's Pad Abort -1 (PA-1) flight test
    - Orion's Ascent Abort-2 (AA-2) flight test
    - Exploration Mission-1 (EM-1) flight test



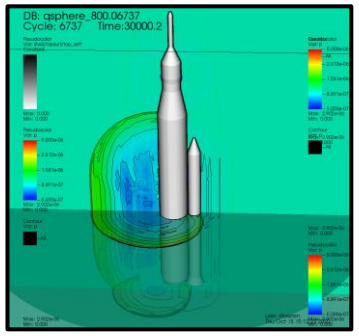


Space System Risk Assessments

Space Launch System

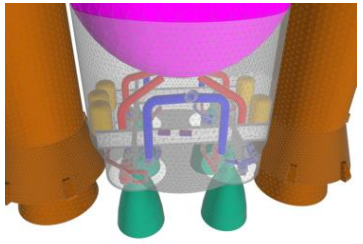
Ames Engineering Risk Assessment Team provides launch abort risk analyses for the Space Launch System (SLS) Probabilistic Risk Assessment, Loss-of-Crew risk assessments, and abort environments teams

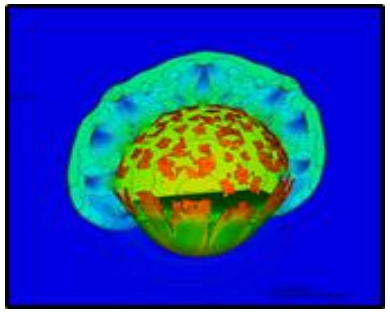
- Code AA provides abortability data for the assessment SLS Loss-of-Crew probabilities against requirements.
- This information is also used in performing trade studies for design and operational decisions.
- In order to provide this information, Code AA has developed physics-based tools and processes for estimating the potential for failure propagation as well as characterizing risks associated with explosion events.



Pressure Field from Single Booster Burst w/ Stack Geometry (ALE3D Simulations)

Engine Section Component Triangulations for Use in the Failure Propagation Simulation



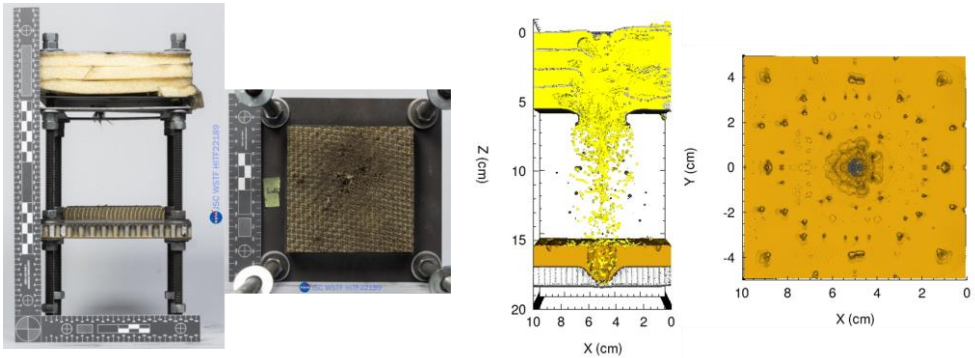


ALE3D simulations of spherical tank experiencing internal overpressure event

Mars Sample Return (MSR): Earth Entry Vehicle (EEV)

Ames Engineering Risk Assessment Team supports risk analysis of MMOD impact damage to the TPS and structure of the MSR EEV

- MMOD impact damage on candidate EEV TPS and structure designs are assessed using ALE3D and CTH hydrocodes.
- Available hypervelocity impact test data are used to tune and validate the hydrocode material models.
- Results inform development of ballistic energy equations used in BUMPER to determine penetration risk during the EEV return phase.



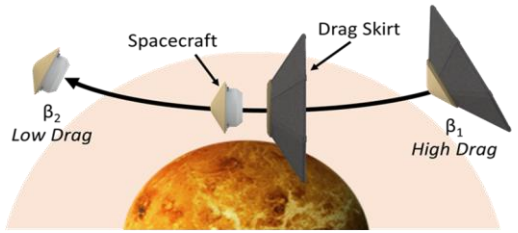
A medium mass impact test of the shield and penetration into the TPS layer positioned below the shield (left). A CTH solution at the same impact conditions showed the same level of damage to the shield and TPS layer (right).

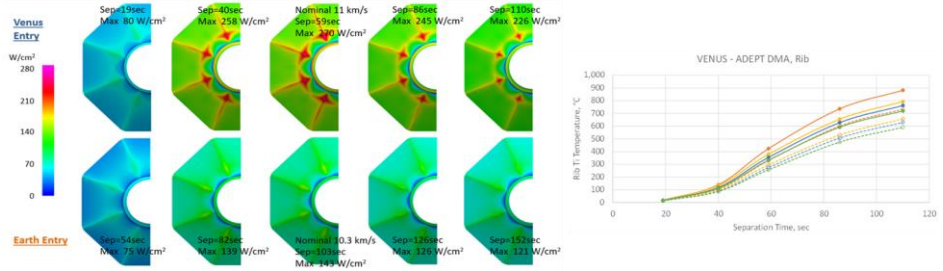
Aerothermal and TPS Sizing for Entry Systems

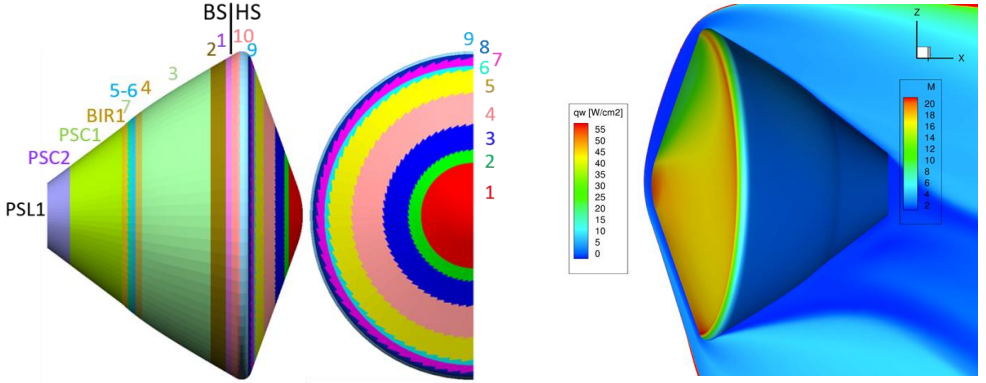
ADEPT Drag-Modulated Aerocapture (DMA)

The Adaptable, Deployable Entry and Placement Technology (ADEPT) DMA is a mechanically deployable low-ballistic coefficient aeroshell entry system for a broad range of planetary destinations

- Code AA supports the computational aerothermal modeling and simulation of hypersonic, low-density flows for the project.
- We support development of the aerothermal database and TPS analysis at both destination planet(s) and Earth demonstration.
- We perform sensitivity studies and development (with rationale) of a margin policy.
- Hypersonic analysis tools and capabilities demonstrated to JPL and DMA Mission Management.







Mars Sample Return Lander (SRL)

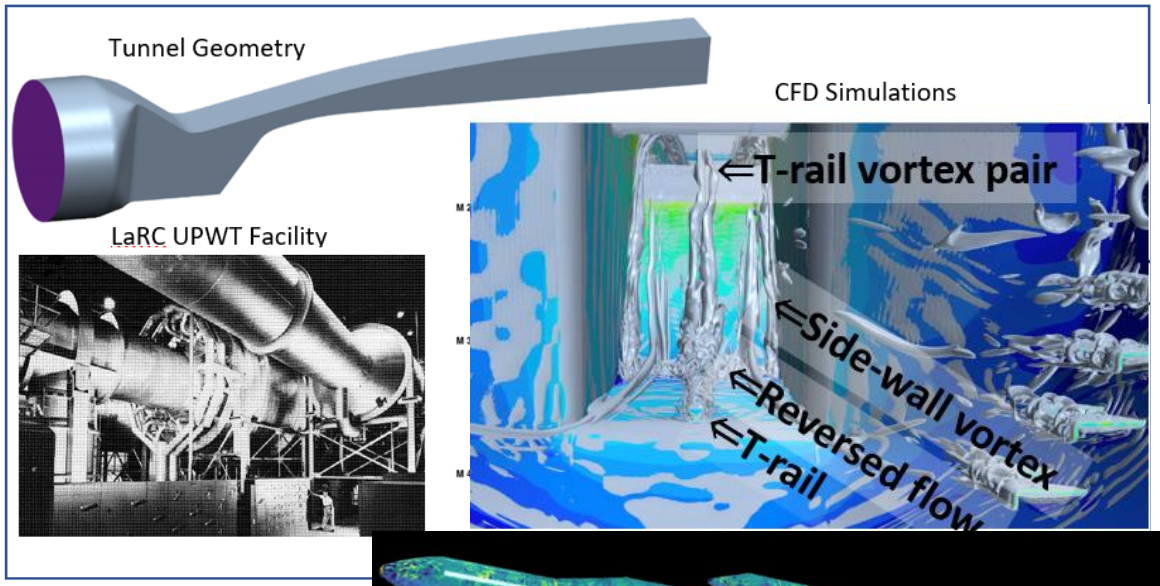
Mission is a heavy vehicle (SRL) that delivers a sample retrieval system and a sample return launcher to surface of Mars

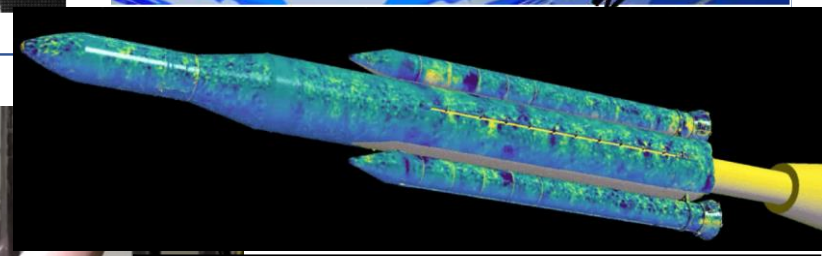
- Code AA performs aerothermal and TPS sizing analysis for the SRL
  - Analysis supporting multiple geometric design iterations
  - Cases run for several trajectory alternatives
  - Trade studies of TPS options, structural design constraints and TPS lay-out possibilities
- Ongoing contribution of Code AA's analysis informs design trades to aid the passing of the design activities from JPL to the Prime Contractor
- Code AA's products have impacted the project
  - Identification of TPS mass threats and opportunities
  - Our analysis results aid with JPL's and Lockheed Martin's design decisions such as vehicle shape, structural materials, tile layout and TPS alternatives
  - Trade studies inform possible trajectory and mission options
  - Margin management plan implementation

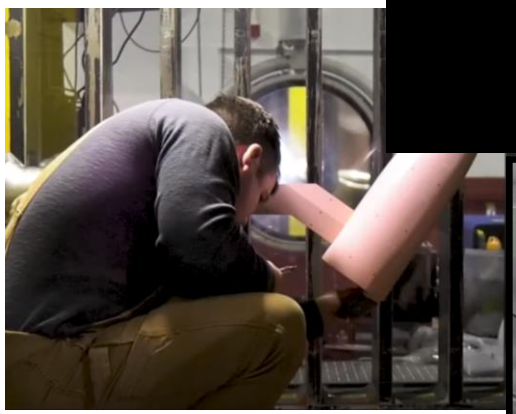
Analysis Applications: Wind Tunnel Studies

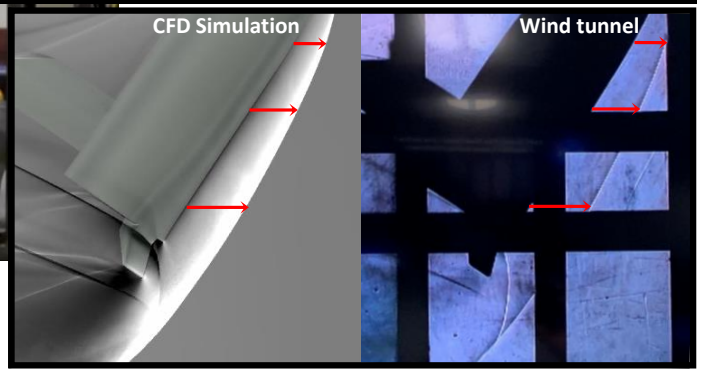
The Aerosciences Evaluation and Test Capabilities (AETC) Portfolio Office executes strategic efforts to preserve and enhance research and test capabilities for NASA's world-class portfolio of National Wind Tunnel facilities.

- AETC Project roles and support in AA
  - Support the generation of the wind tunnel facility CAD for use in all CFD tools being used across the project.
  - Use state-of-the-art CFD tools to predict high-speed aerodynamic flows and compare them with experimental data obtained from NASA Langley's high-speed Unitary Plan Wind Tunnel (UPWT).
  - Perform Overflow and Kestrel CFD as a few of the tools to compare to the measured wind tunnel data and troubleshoot differences between them.
  - Provide wind tunnel CFD support for the development of measurement apparatus, such as the rake probe design as well as various wind tunnel model entries.
  - Support development of backend tools for digital signal processing and embedded systems for the Unsteady Pressure Sensitive Paint wind tunnel experimental measurement techniques.



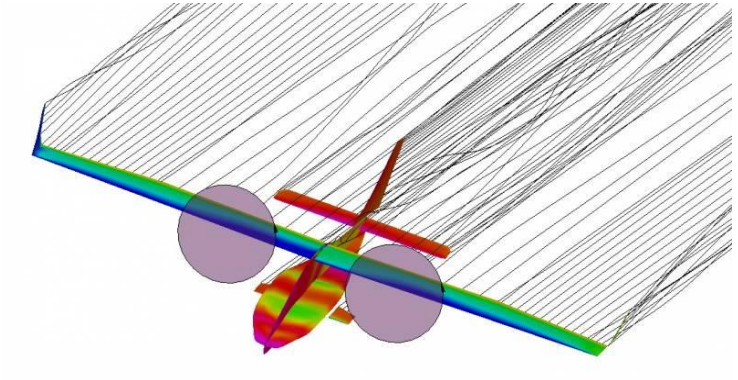


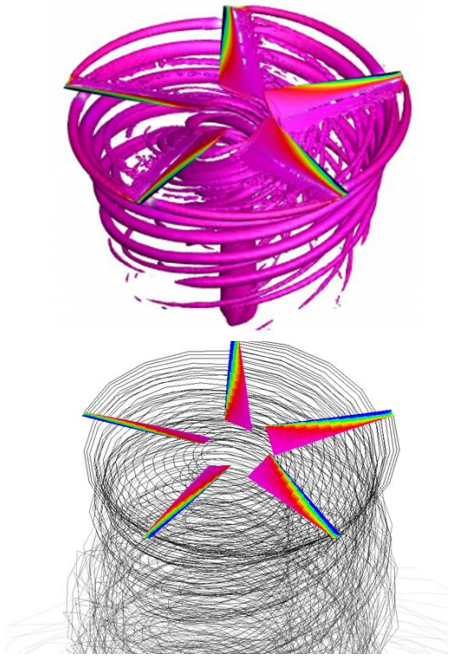




https://www.youtube.com/watch?v=1cxkxZ6jlJU

Engineering-Level Analysis Tools

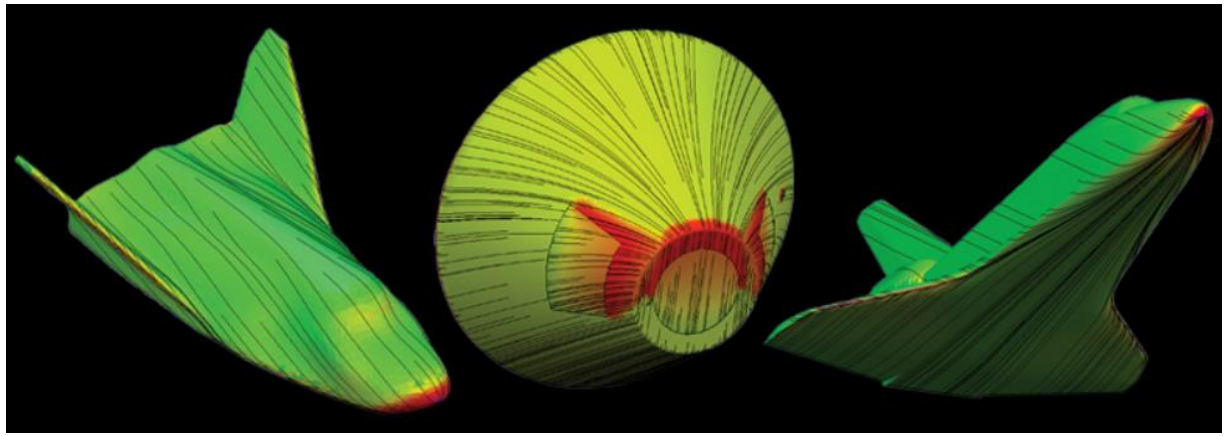




VSPAERO

VSPAERO is a fast, linear, vortex lattice solver which integrates actuator disks that can be accurately and easily described for aero-propulsive analysis. Discrete vortices are applied to each panel generated in the OpenVSP degenerate geometry file and then evaluated over the entire surface to obtain a pressure distribution, and thus force. This information can be used to find lift, drag, slip, and (x,y,z) forces and moments.

http://openvsp.org/wiki/doku.php?id=vspaerotutorial

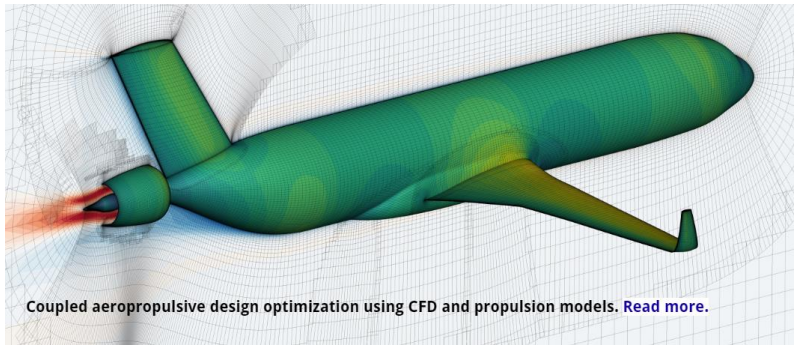


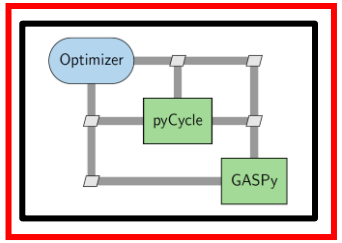
CBAERO

The Configuration-Based Aerodynamics (CBAERO) software created at NASA Ames Research Center is the first to predict both the aerodynamics and temperatures of spacecraft atmospheric entries and allow models to be imported directly from computer-aided design programs. CBAERO is now widely used by commercial space companies, the Department of Defense, and various defense contractors.

https://software.nasa.gov/software/ARC-15819-1

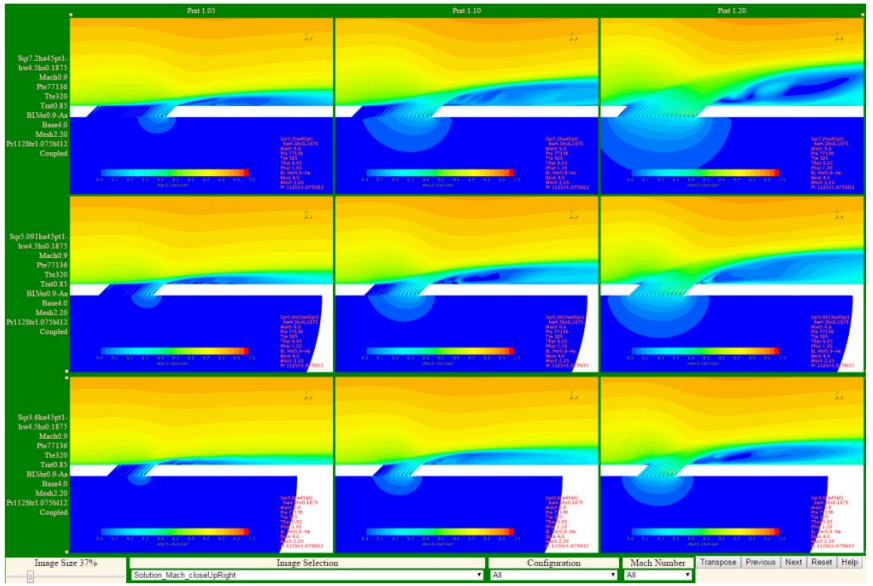
Multi-Disciplinary Analysis Optimization (MDAO) and Visualization Tools





The General Aviation Synthesis Program in Python (GASPy) is a vehicle synthesis code that is being ported into NASA's OpenMDAO framework. GASPy is based on the legacy GASP software developed at NASA Ames Research Center in the late 1970s. This analysis framework enables coupled physics-based propulsion airframe optimization and mission analysis for unconventional airframe and hybrid-electric aircraft studies.

https://openmdao.org/



MiniWall

The MiniWall software is a browser-based software that is used to analyze and understand large and small computationally and experimentally generated data sets. The MiniWall software presents a matrix view of plots and other visualization images and provides a responsive and productive way to investigate the data and extract knowledge and understanding from it. Since it is browser based, it runs on any computer or device that can display a web page.

https://software.nasa.gov/software/ARC-18270-1

Trajectory, Guidance, Navigation, Control, and Optimization Analysis Tools

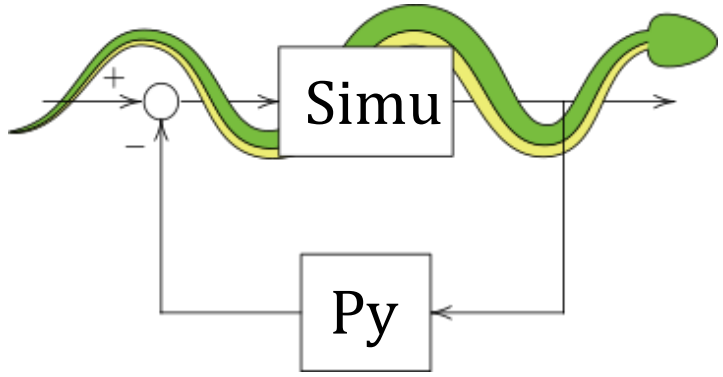
Modular planet models:
- Planetodetics
- Atmosphere
- Gravity
- Wind

Modular vehicle model:
- Aerodynamics
- Propulsion Model
- Inertia properties

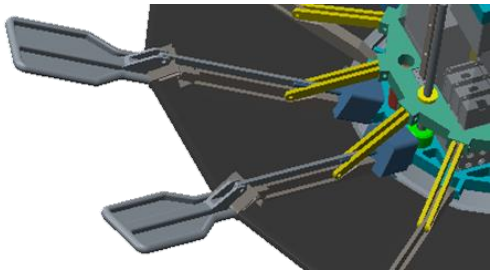
Flight Vehicle Toolkit

6DOF equations of motion validated against NESC test cases

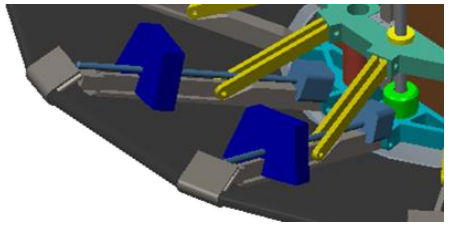
Open-source python-based alternative to Simulink



Flap Control System



Moving Mass Control System



SimuPy Flight Vehicle Toolkit

Simupy-FVT is a NASA open-source software that provides a modular framework for rapid implementation of simulations for novel flight vehicle concepts leveraging open-source software from the scientific Python community.
https://software.nasa.gov/software/ARC-18618-1

Novel GNC algorithms have been developed for emerging vehicle types including deployable entry vehicles and electric vertical take-off and landing vehicles.
https://technology.nasa.gov/patent/TOP2-303

Summary

- Code AA supports multiple NASA mission directorates and external government and commercial partners
- Multi-disciplinary vehicle and system analysis
  - Aircraft synthesis, mission analysis and aerodynamic database development for subsonic vehicles
  - Aero and aerothermal analysis and thermal protection system sizing for hypersonic vehicles and entry systems
  - Physics-based risk assessments for space launch systems and vehicles
  - Wind tunnel CFD support that informs future upgrades and modifications