

Model-Based Systems Analysis & Engineering for the Sustainable Flight National Partnership

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- Overview
- Digital integration
- Demonstrations
- NASA Research Announcement (NRA)

Sustainable Flight National Partnership

Next-Generation Capability on the Path to Net-Zero Greenhouse Gas Emissions by 2050



Advance engine
efficiency and
emission reduction

Enable integrated
trajectory optimization



Advance airframe
efficiency and
manufacturing rate

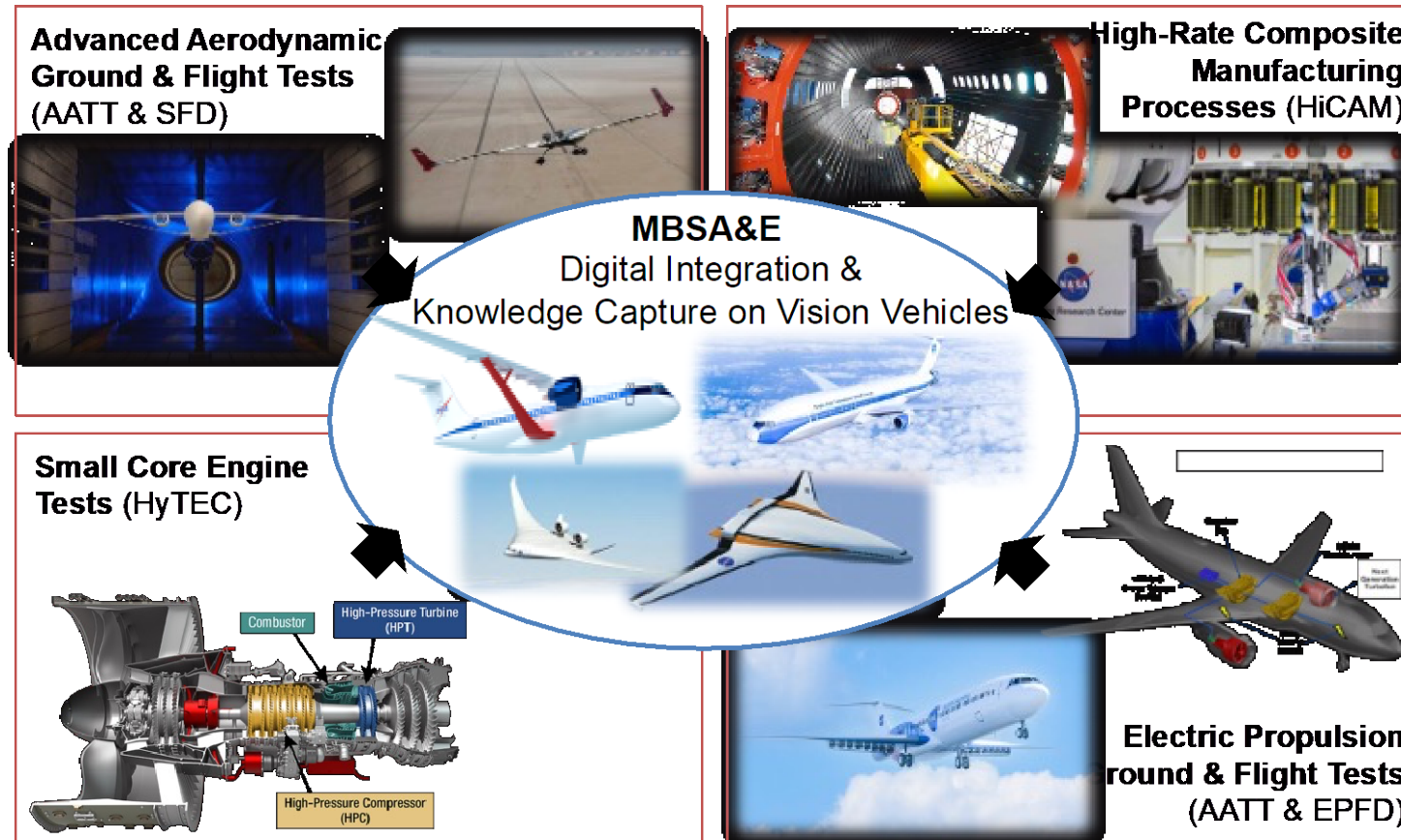
Enable use of 100%
sustainable aviation fuels

Accelerate toward net-zero greenhouse by 2050 through up to 30% energy efficiency improvement in next-generation transports, 100% sustainable aviation fuel, and optimal trajectories.

MBSA&E Vision for the Sustainable Flight National Partnership



A systems-level, digital integration across Sustainable Flight National Partnership (SFNP) projects which will support the assessment, advancement, and adoption of sustainable technologies for 2030s entry into service subsonic transport aircraft concepts



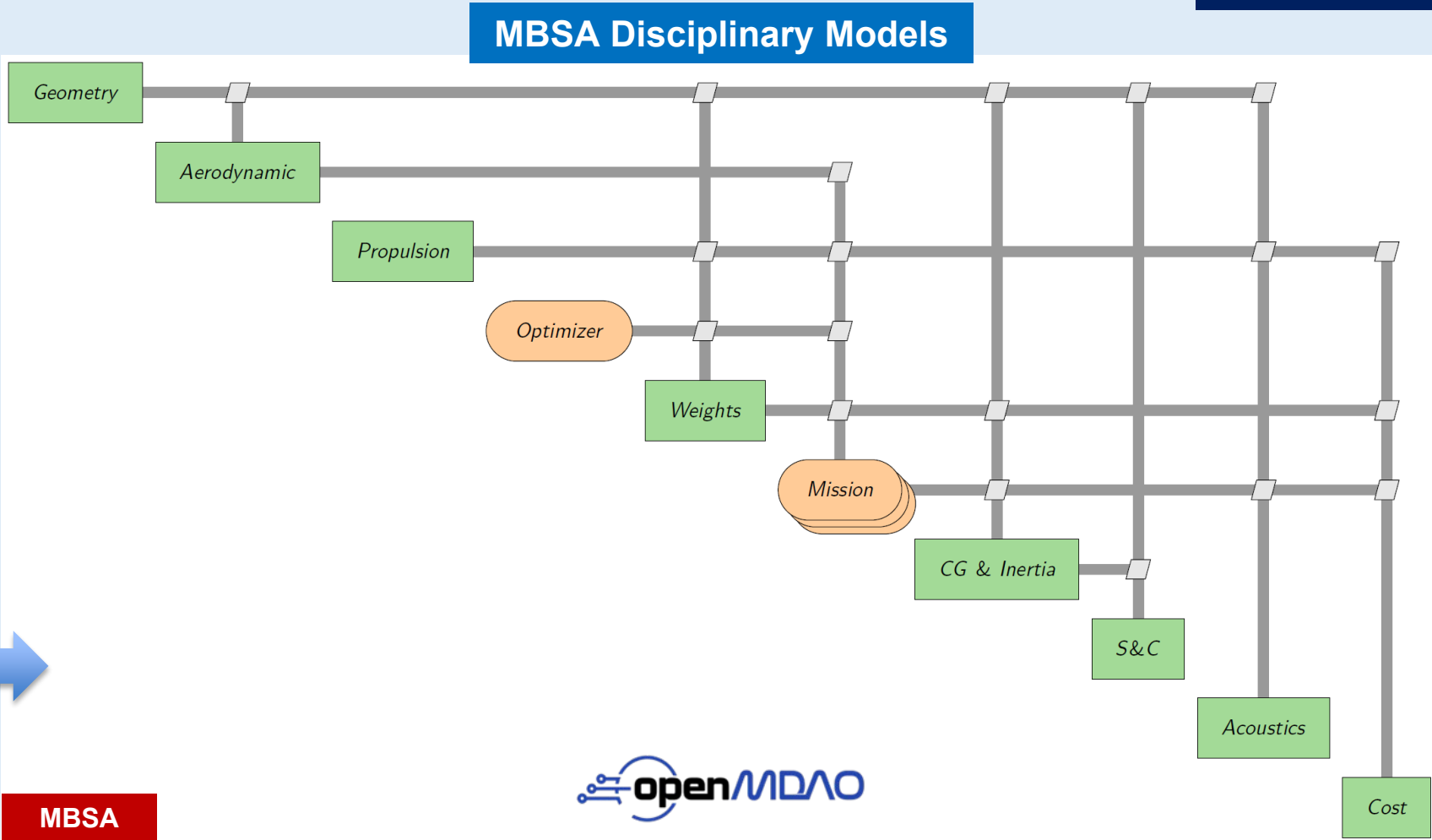
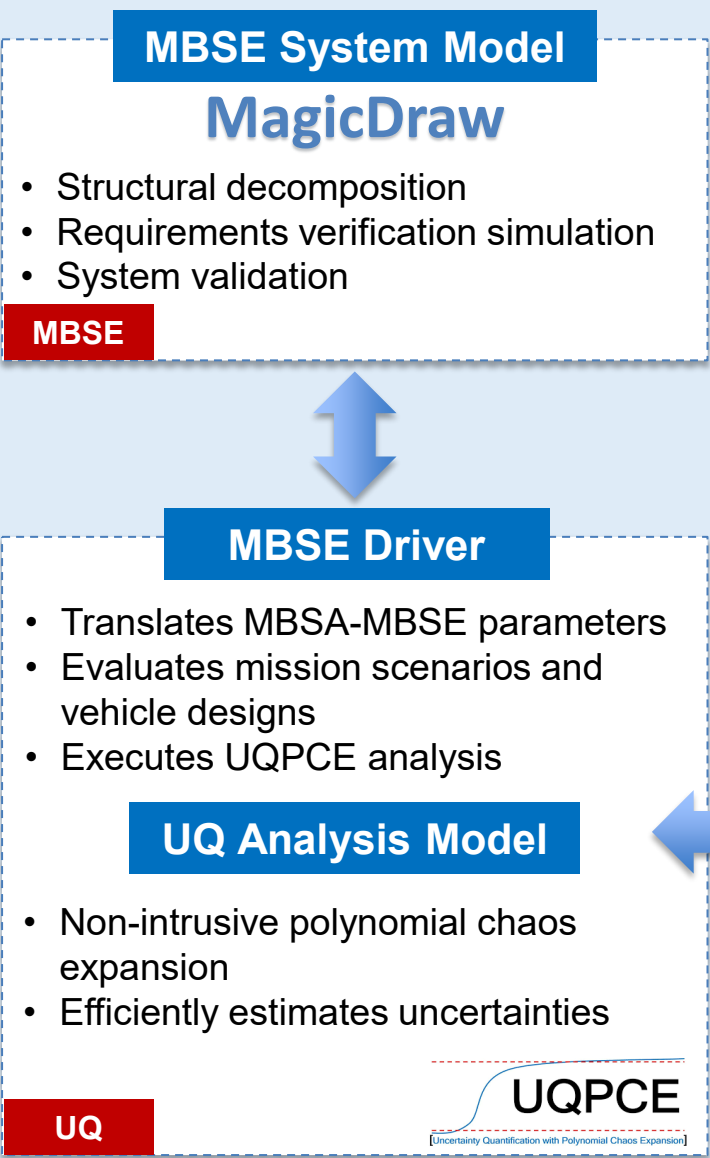


Digital Integration

Cross-Domain Architecture



MBSA&E



System Modeling Capability in MBSE



- Developed an MBSE system model of a TTBW aircraft concept and identified data interfaces required to couple MBSE and MBSA/MDAO models into an integrated modeling environment (IME)

Approach and Implementation

Developed an architectural framework using SE principles and MBSE tools to generate a system model, and applied it in an integrated design environment for analysis of a concept aircraft

Architecture, Tools and Methods

Used industry and NASA's SE processes, requirements, standards and best practices to develop the system model, interactions and instantiation in a cross-domain architecture

Knowledge Sharing

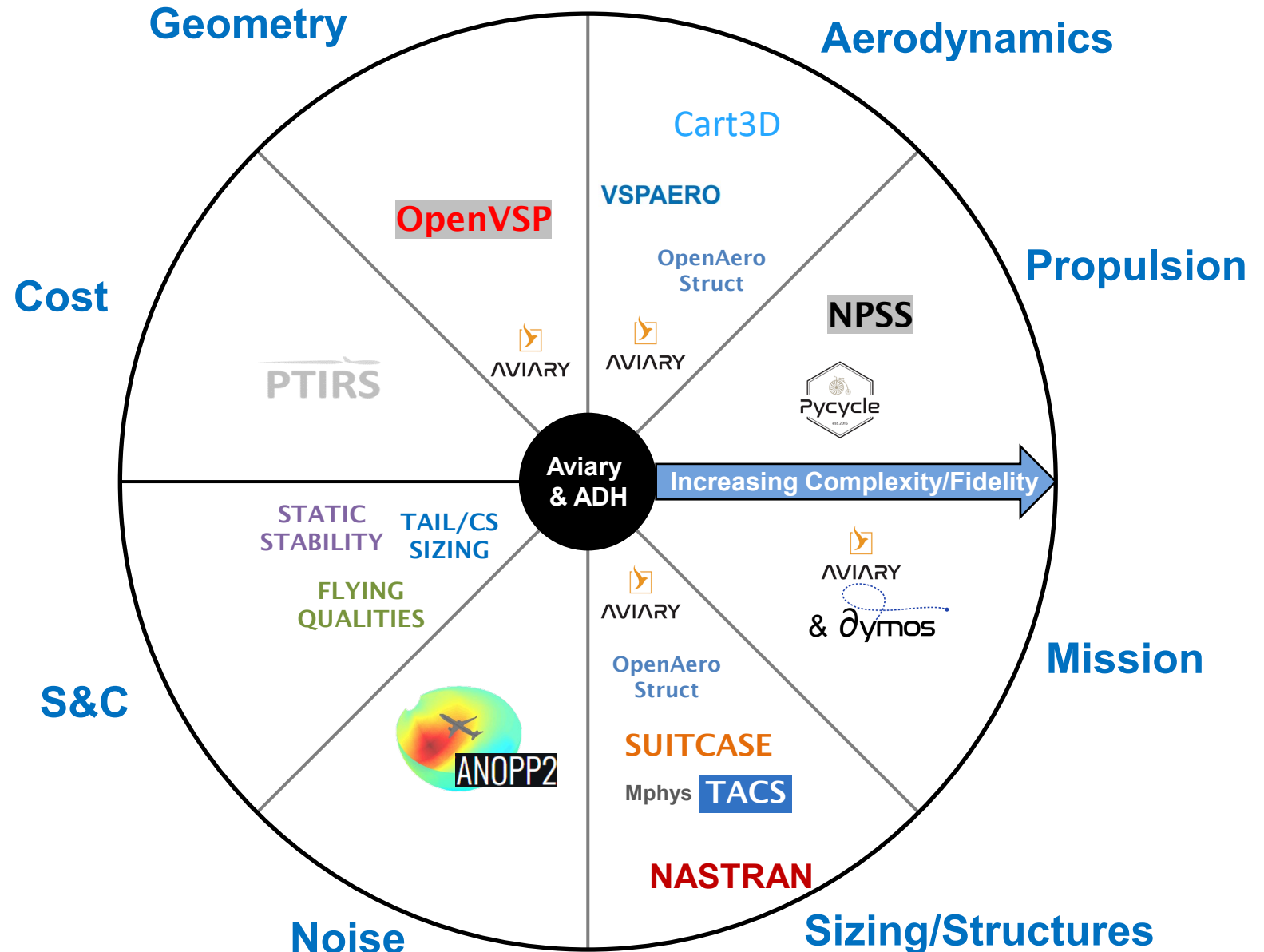
Applied models and methods from NASA's MBSE community of practice, and informed through cross-agency technical interchanges

MBSE and MBSA coupling enables the integration of research results from all projects to ensure system level aircraft design and mission requirements are satisfied

Multi-Fidelity Analysis Capability



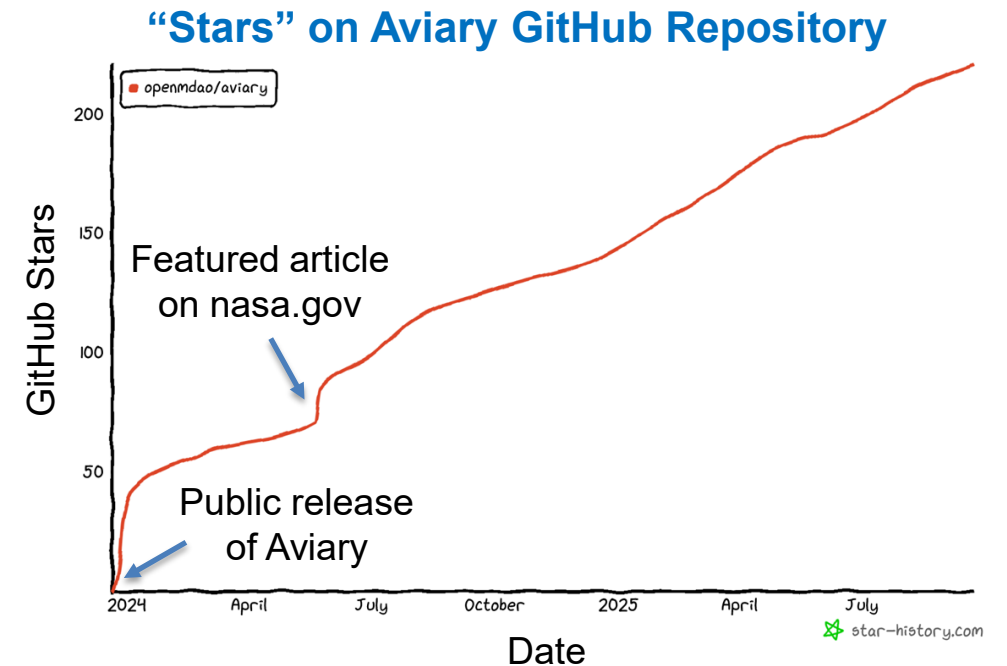
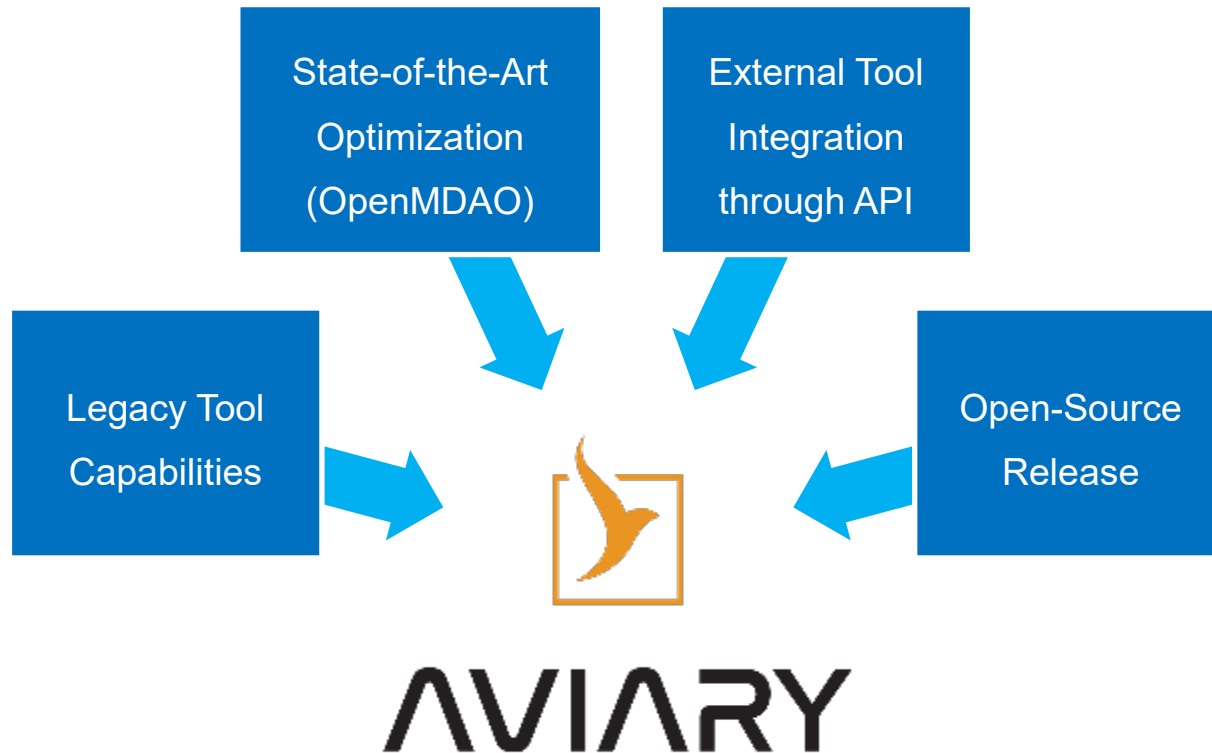
- **Aviary external subsystem API** used to integrate disciplinary components and extend analysis capability for non-conventional concepts for which historical empirical data is not available
- **Common variable hierarchy and metadata** organized using physical decomposition is accessible by all disciplinary components to avoid variable duplication and ensures consistency across disciplines
- **AIMEE - Aircraft Modeling and dEscriptive Environment**, an abstraction layer that allows automated construction and execution of a framework, provides a common, unified, and descriptive input file, and decouples the problem definition from the architecture/assembly development



What is Aviary?



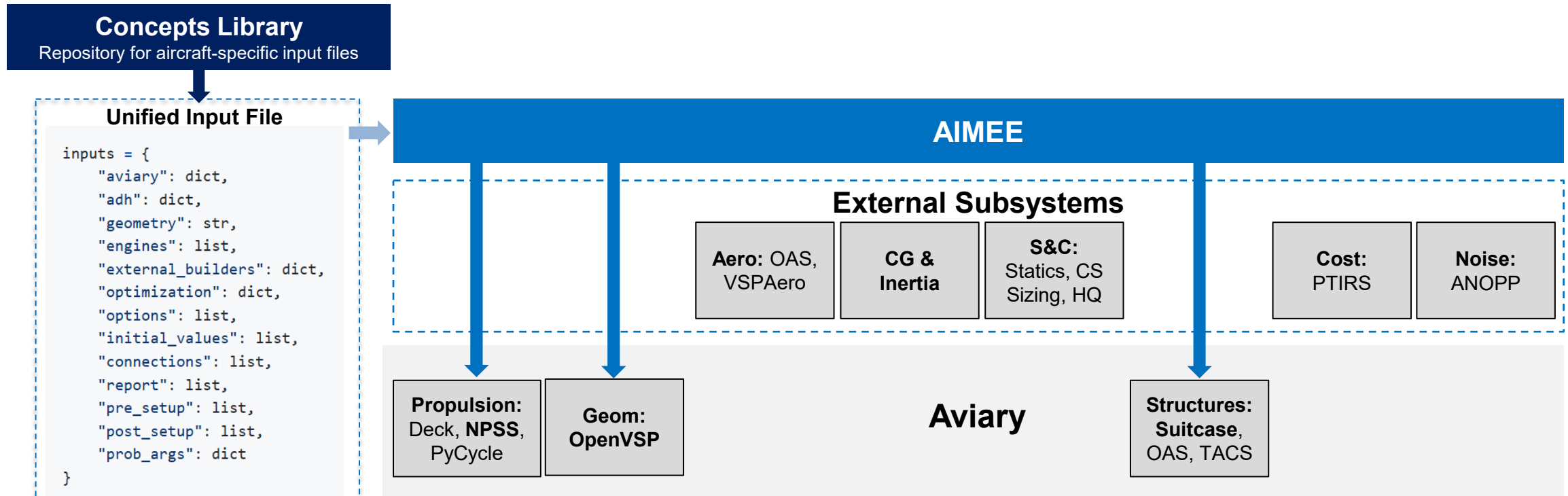
- Aviary is NASA's next-gen conceptual aircraft design tool
- Developed as a partnership between AATT, TTT, and EPFD



AIMEE - Aircraft Modeling and dEscriptive Environment



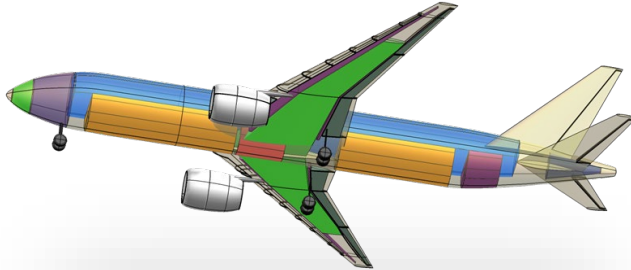
A **builder and abstraction layer** that allows the **automated construction and execution** of aeronautics framework problems based on Aviary level 2 user interface and external physics-based analysis tools.



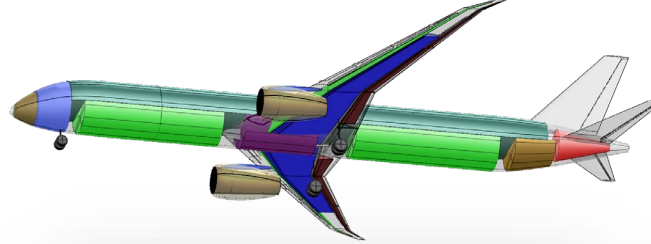
Aircraft Models



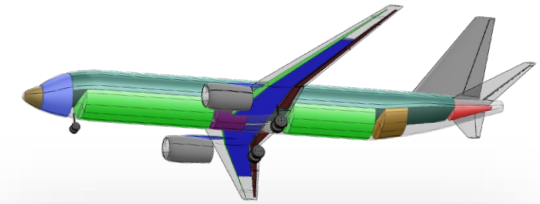
Present
Day
Technology



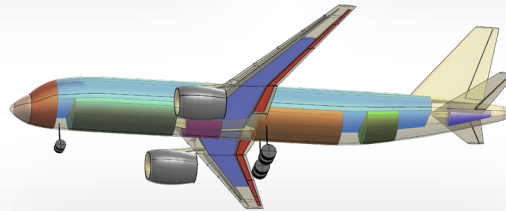
BOEING 777-200ER "LIKE"
GE90 ENGINE



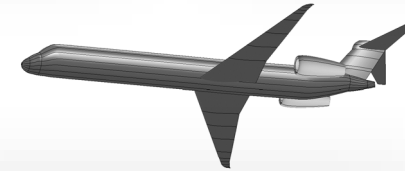
BOEING 787-10 "LIKE"
GenX/RR Trent 100 ENGINE



BOEING 737 MAX 8 "LIKE"
LEAP 1B ENGINE

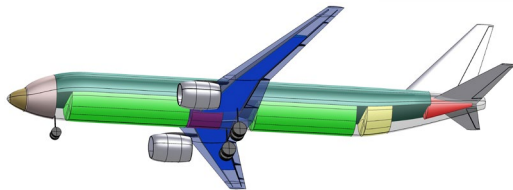


AIRBUS A320 Neo "LIKE"
PW1100 GTF / LEAP-1A ENGINE

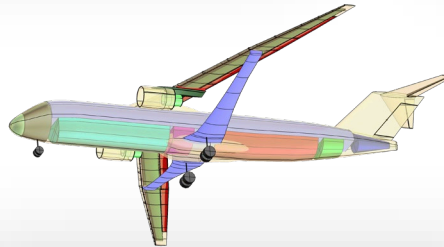


MD 90-30 "LIKE"
IAE V2500 ENGINE

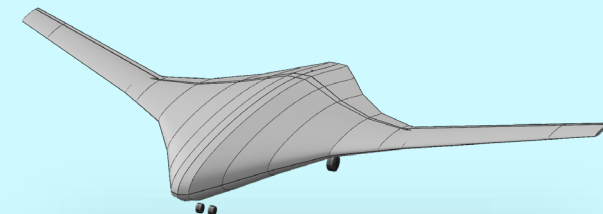
2035
Entry-into-
Service



N3CC CONCEPT
gFAN+ ENGINE



TTBW "LIKE" CONCEPT
gFAN+ / N+3 ENGINE



ADVANCED CONCEPTS

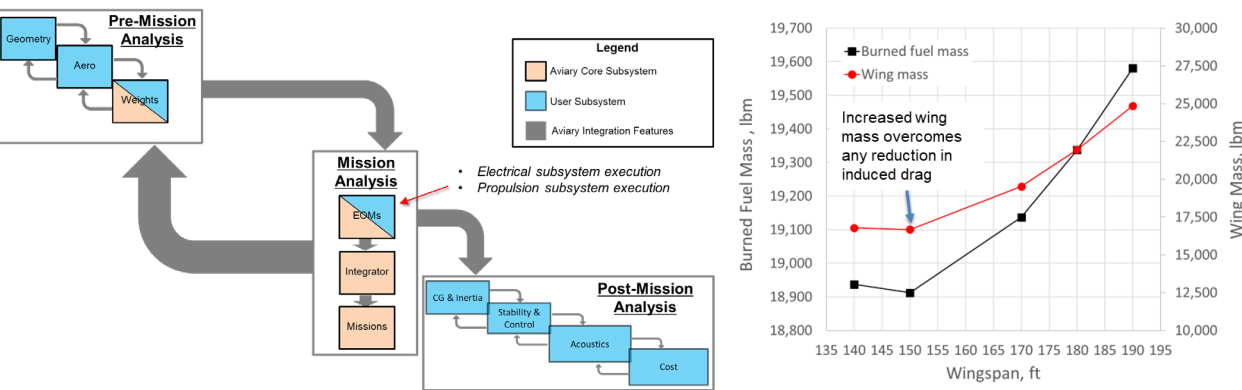
Future
Technology

Demonstrations



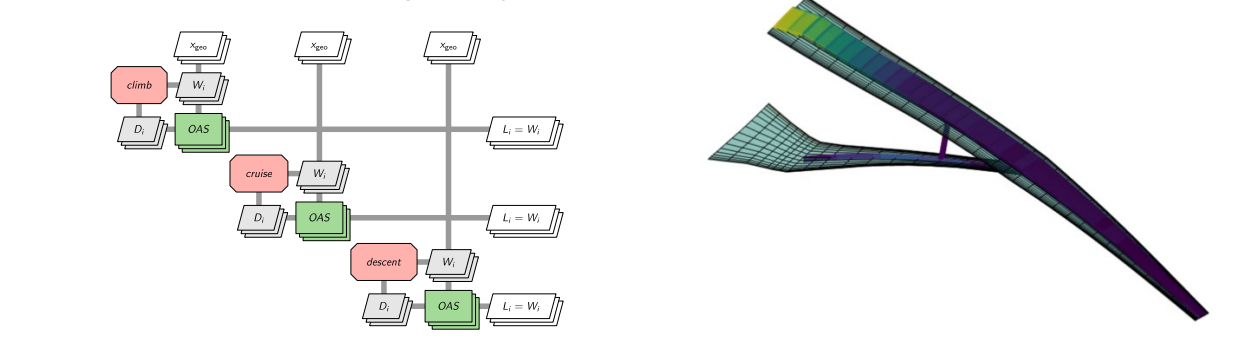
System Level Optimization of Hybrid Electric Aircraft Concept

- Minimize fuel burn
- Design variables include gross mass, engine mass flow, battery current and capacity, electrical motor max power, and trajectory
- Constraints placed on mass residual, state of charge, and trajectory



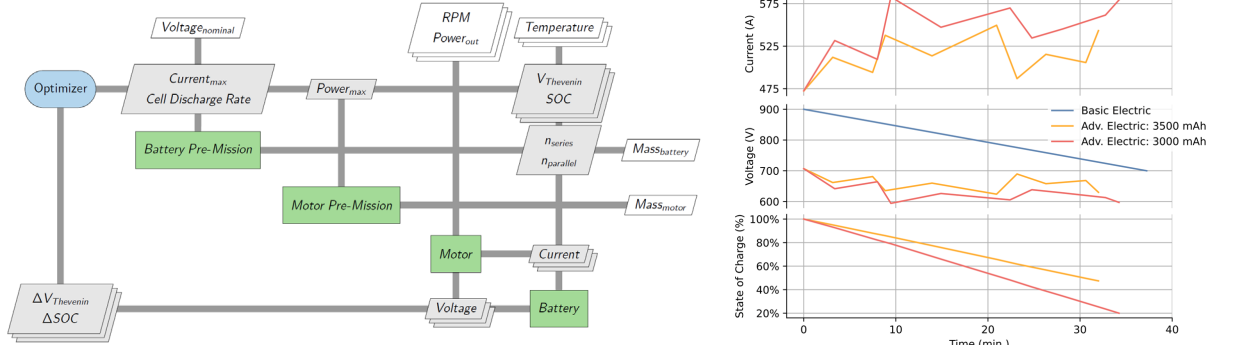
Aerostructural Optimization (AIAA Aviation 2025)

- Minimize fuel burn
- Design variables include wing twist, span, gross mass, structural sizing, and trajectory
- Constraints placed on mass residual, structural strength, lift, pitching moment trim, and trajectory



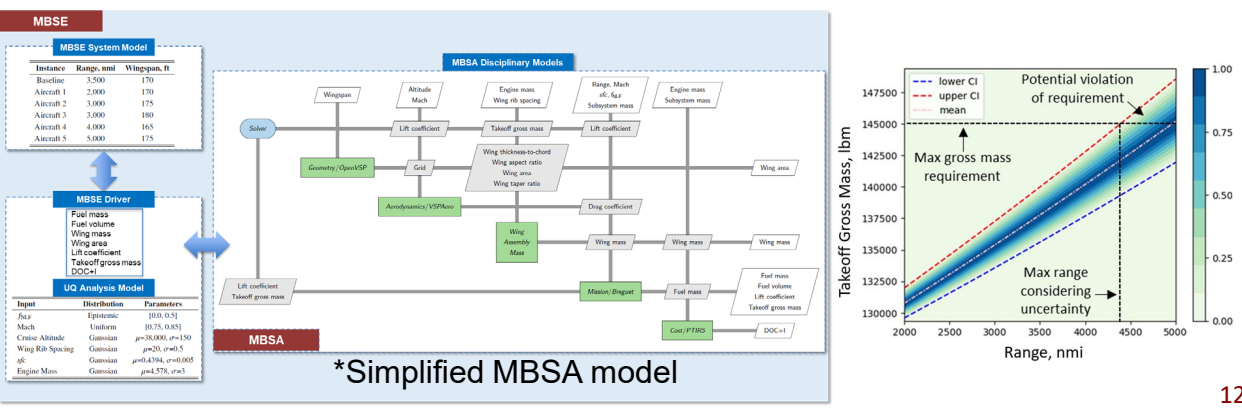
Hybrid-Electric Propulsion System Development (AIAA Aviation 2024)

- Minimize fuel burn
- Design variables include gross mass, trajectory, engine mass flow, max power and current, battery cell discharge rate and total energy capacity
- Constraints placed on mass residual, trajectory, throttle, Thevenin voltage, min state of charge, and max power and current



MBSA&E and UQ Integration (AIAA Aviation 2024)

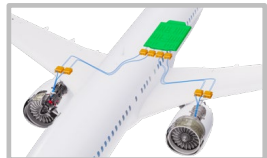
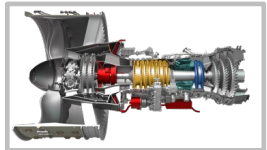
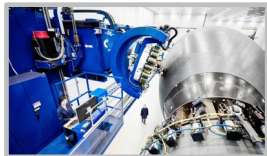
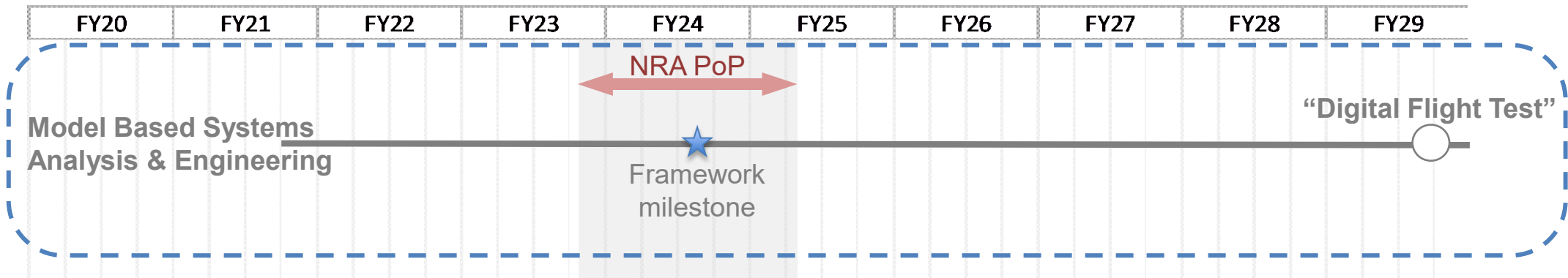
Enables engineers to assess and mitigate uncertainties associated with a system model, design parameters, and constraint inputs, leading to more complete design studies and better-informed decision-making processes





NRA Overview

NRA Objectives



A key element of the SFNP was the development of an MBSA&E framework to **facilitate technology integration and assessment at the system level** and **enable collaboration through data exchange and model integration** between numerous NASA Aeronautics projects and industry partners.

Industry partnership in the development of the MBSA&E framework was needed to:

- **Develop and incorporate consistent, state-of-the-art methods** for systems analysis and systems engineering across all SFNP partners
- **Establish best practices** within the MBSA&E framework **for data exchange and model sharing between industry and government**
- **Develop system-level models of SFNP technologies** which will be incorporated into the MBSA&E framework for technology evaluation

1. Aircraft Data Hierarchy/Definition
2. Standard Interface Definition Between Disciplinary Models/Tools
3. Systems Analysis and Systems Engineering Integration
4. Comprehensive Model Sharing and Collaboration Approaches
5. Narrow Model Sharing and Collaboration Approaches
6. Aircraft and Component/Subsystem Models
7. Disciplinary Analysis Tool Integration with OpenMDAO
8. Disciplinary Analysis Tool Development with OpenMDAO

Boeing

Boeing

Boeing

Boeing

Boeing

Boeing, Northrop Grumman

M4 Engineering

Georgia Tech

Publications and Reports



Questions?