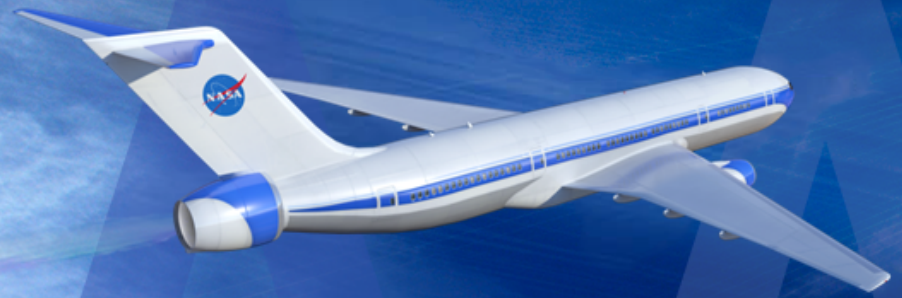
National Aeronautics and Space Administration



Model Based Systems Analysis and Engineering (MBSA&E) Overview

Eric Hendricks & Jesse Quinlan, NASA

Systems Analysis Symposium

November 10, 2021

Subsonic Transport Technology Prioritization

NASA Aeronautics Vision and Strategy Established

Subsonic Concept/Technology Studies
Electrified Aircraft Propulsion, Transonic Truss Braced Wing

Environmentally Responsible Aviation (ERA) Project

Flight Demonstrator Studies

Advanced Composites (ACP)

Next Step

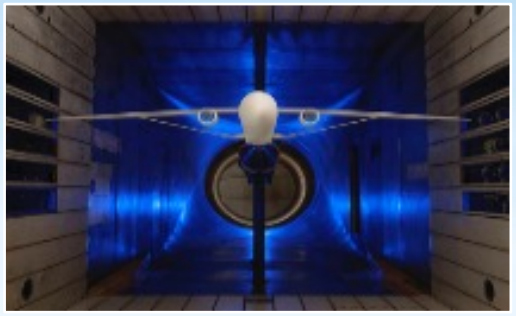
Maturation and Integration of Four Key Technologies that will Create a New "S Curve" for Future Subsonic Transports

FAA CLEEN I | FAA CLEEN II | FAA CLEEN III

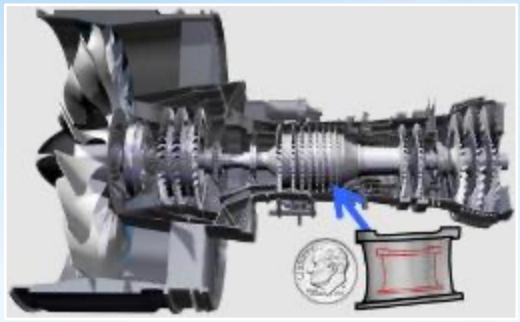
ARMD Subsonic Transport Strategy Based on over a Decade of Research, Concept and Technology Development, and NASA-Industry Partnership

Subsonic Transport Technologies

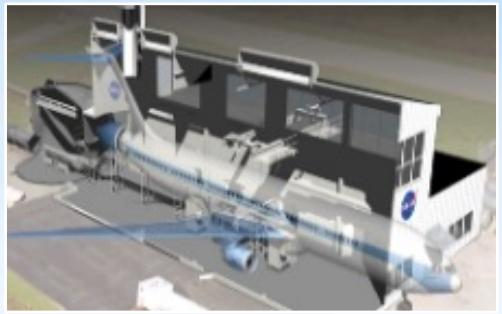
Ensure U.S. industry is the first to establish the new “S Curve” for the next 50 years of transports



Transonic Truss-Braced Wing
5-10% fuel burn benefit



Small Core Gas Turbine
5-10% fuel burn benefit



Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit

High-Rate Composite Manufacturing
4x-6x manufacturing rate increase

Sustainable Flight National Partnership (SFNP)

FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29

Technology Readiness Target

Model Based Systems Analysis & Engineering

Sustainable Flight Demonstrator (SFD)

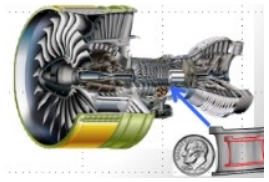
Flight Test

AATT - Transonic Truss Braced Wing

Leverage the Asset – Future Spirals

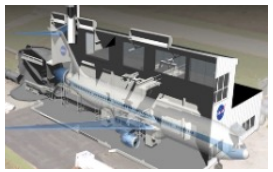
Hi-Rate Composite Aircraft Manufacturing (HiCAM)

Mfg Demo & Structural Test



Hybrid Thermally Efficient Core (HyTEC)

Core Demonstration & Test



Electrified Powertrain Flight Demonstration (EPFD)

Flight Test

AATT - Electrified Aircraft Propulsion

Planned

Notional

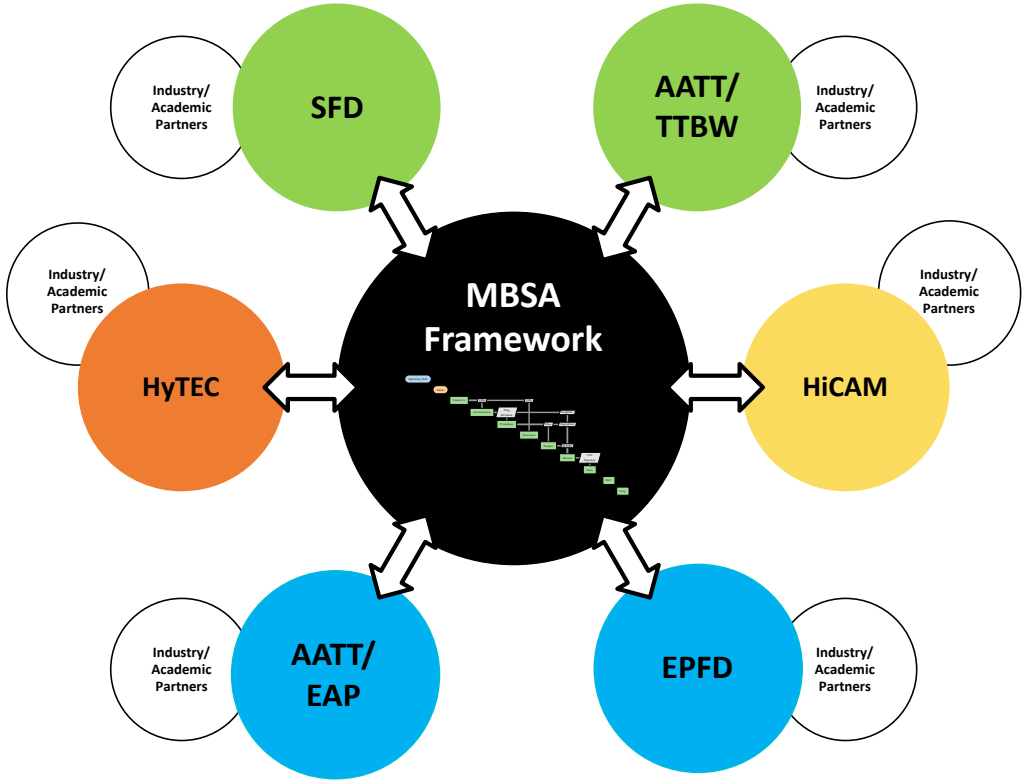
Achieve TRL 6 in time for Industry Product Decision-Making

The Vision

A systems-level, digital integration across SFNP projects

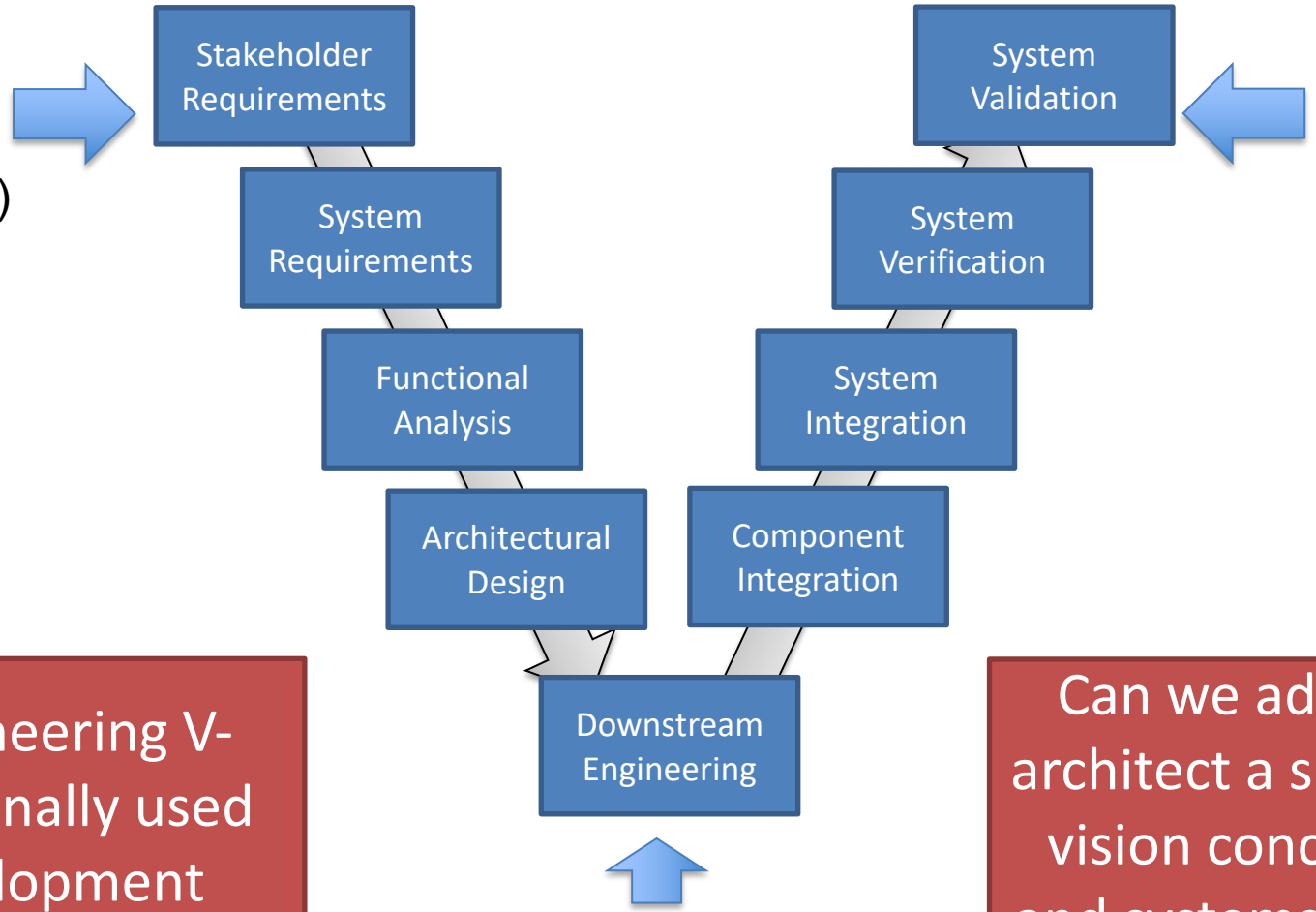
- Open, cross-project/program/external-capable MBSA ecosystem building off ARMD investments and capabilities across AAVP/IASP/TACP in support of the SFNP

- Coordinated, integrated systems analysis studies in support of SFNP
  - Common, open, reference vehicle models
  - Common, open, vision vehicle models
  - Technology benefit assessments and sensitivity studies informed by the SFNP demos



Classic Systems Engineering V-Model

Left Side:
specification of the system properties (requirements, architecture, interfaces, etc.)



Right Side:
verification of the system against the specifications

The Systems Engineering V-Model is conventionally used for product development

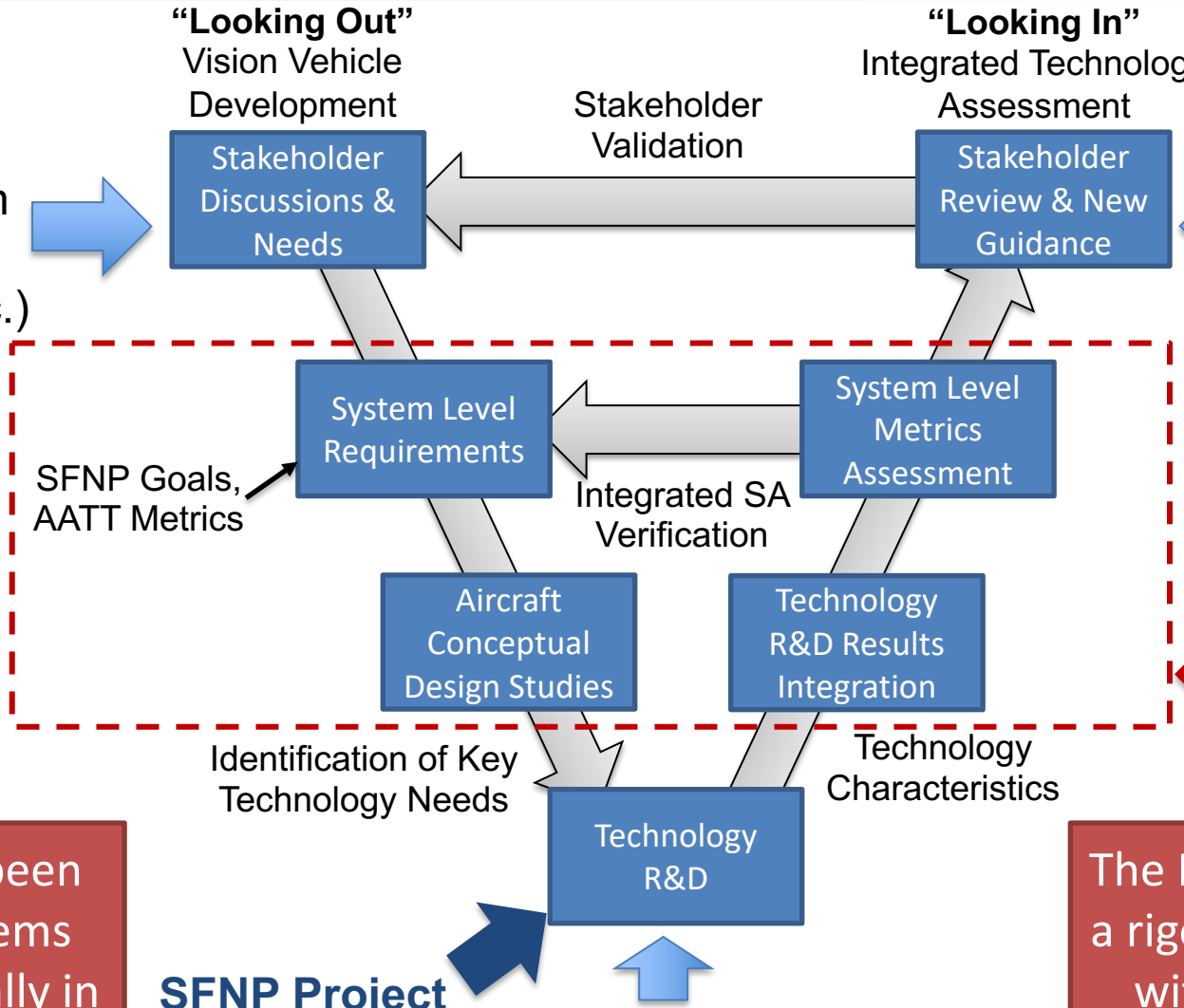
Bottom:
discipline-specific engineering and design work

Can we adapt this model to architect a similar construct for vision concept development and systems analysis for SFNP?

*Based on **Agile Model-Based Systems Engineering Cookbook** by Bruce Powel Douglass

SFNP Systems Analysis and Engineering V-Model

Left Side:
specification of the system properties (requirements, architecture, interfaces, etc.)



Right Side:
verification of the system against the specifications

New MBSA&E Framework

SFNP Project Engagement

Bottom:
discipline-specific engineering and design work

Both legs of this V have been done historically by systems analysis teams but generally in an ad-hoc manner

The MBSA Framework will provide a rigorous and traceable approach with improved interfaces with internal/external tech R&D efforts

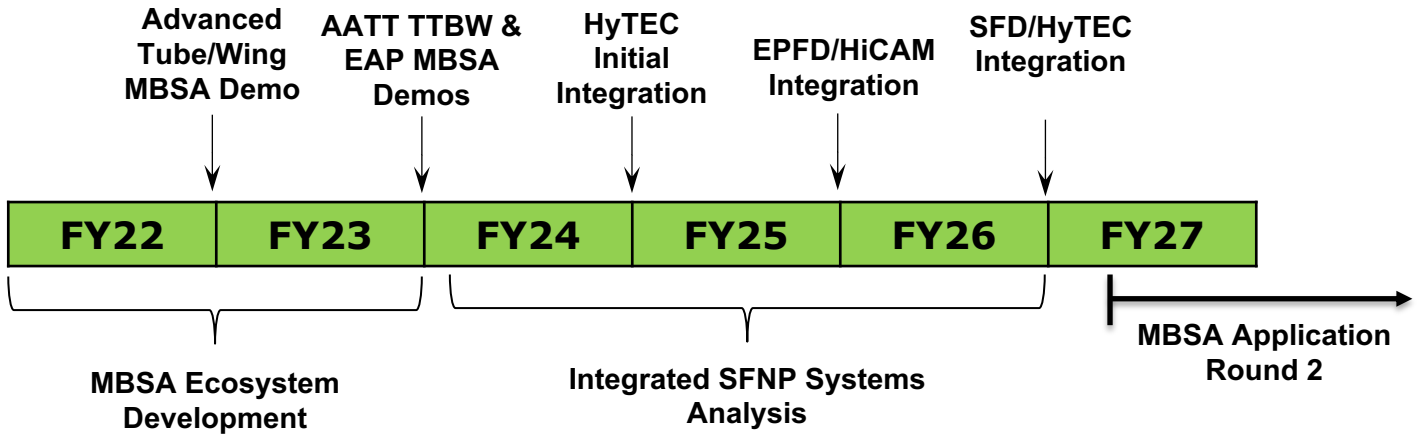
Phased MBSA&E - Key Points of Progress

Phase I - Develop common MBSA&E Framework/Ecosystem

- Create building blocks needed for key disciplinary analyses where lacking
- Integrate building blocks to form coupled MBSA&E framework – leveraging cross-project collaboration (e.g. TTT)
- Evaluate and test the MBSA&E framework with several use cases (conventional aircraft, TTBW, EAP)

Phase II - Coordinate cross-project integrated model development and systems analysis studies

- Development of open, common SFNP reference and vision vehicle concepts and models
- Regular, frequent tech interchange meetings across SFNP systems analysis teams, including external project partners
- Integrated systems analysis studies to incrementally 'roll-up' SFNP findings into a consolidated understanding of vision vehicle benefits and trades

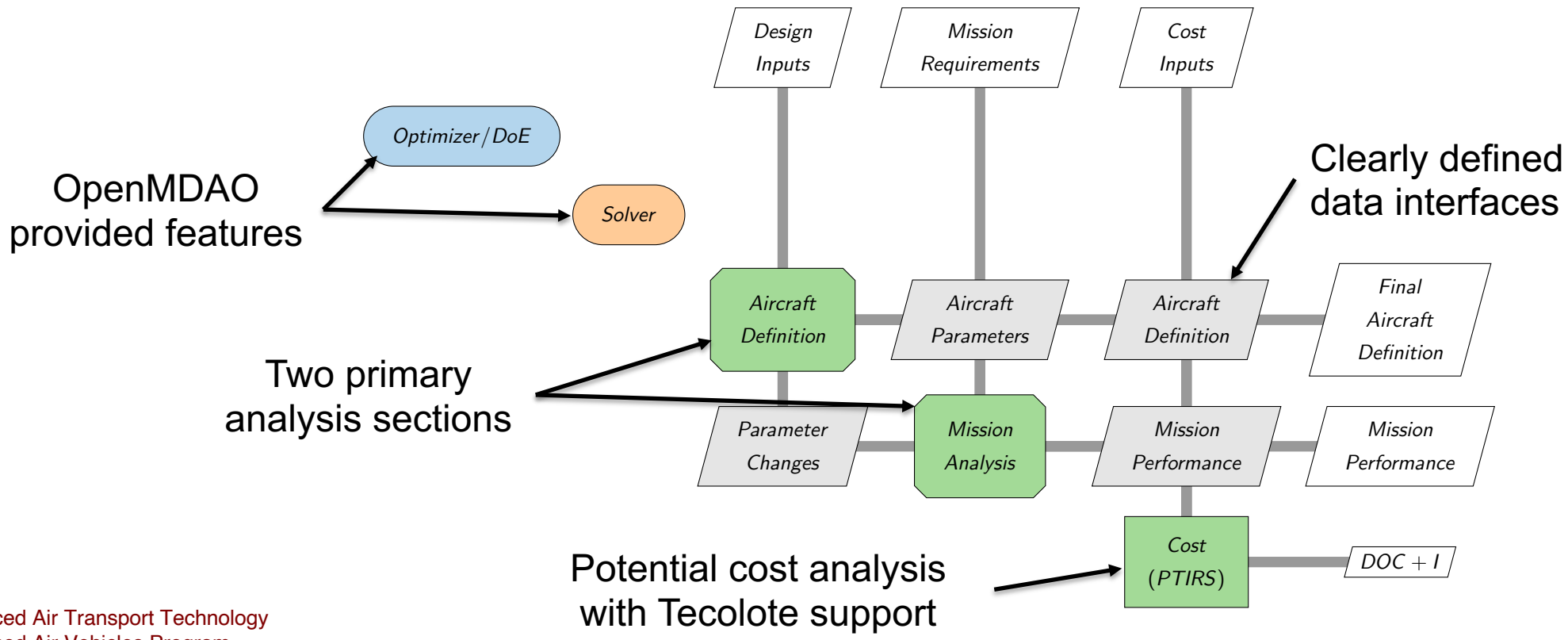


MBSA&E: Phase I

MBSA Framework – Top Level

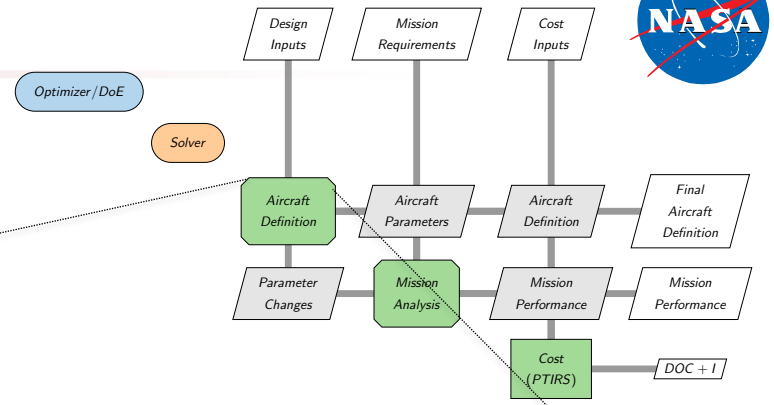
- Provides a rigorous and traceable systems analysis approach with improved interfaces with internal/external tech R&D efforts

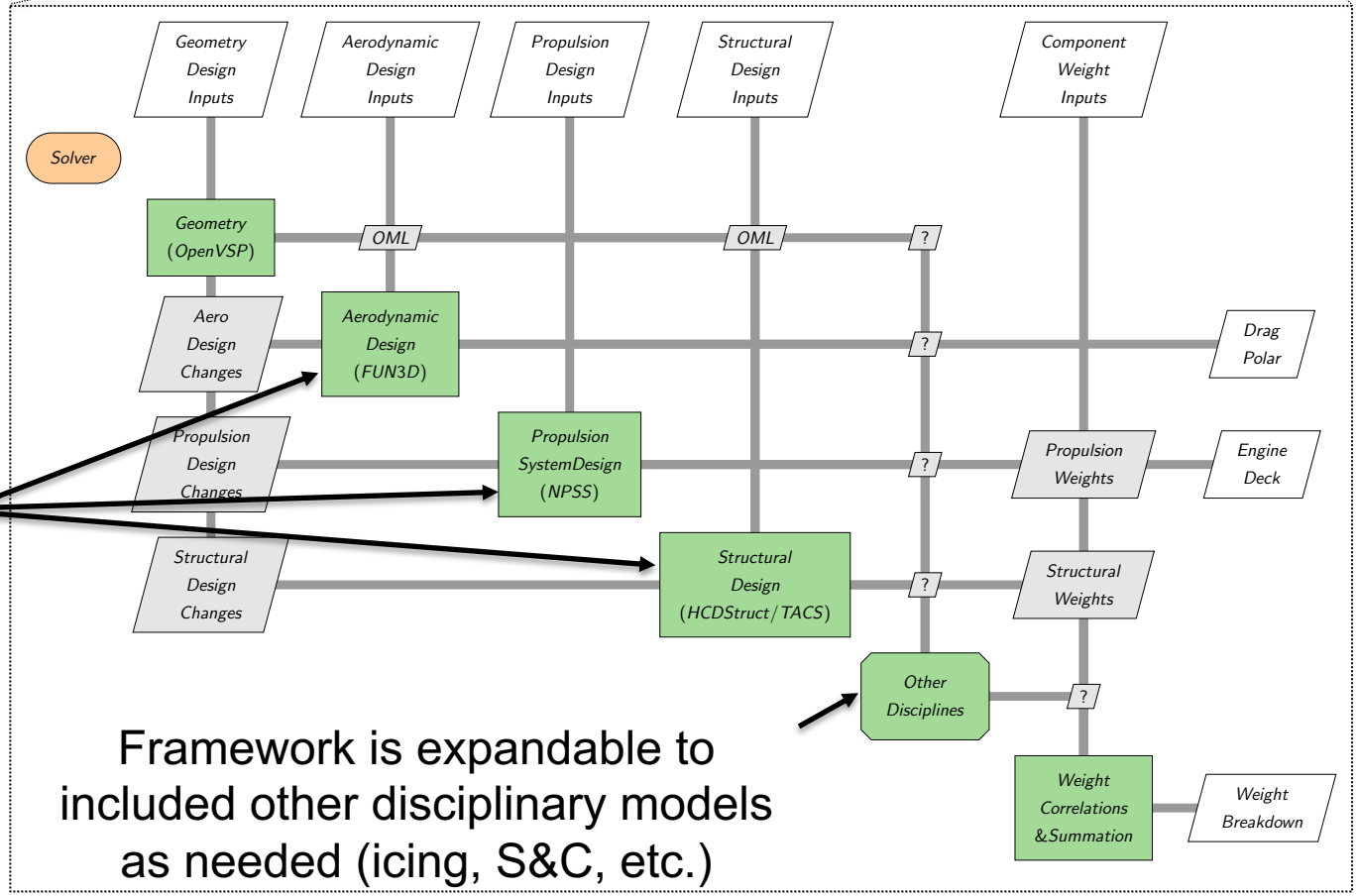
- Framework will be created in OpenMDAO (TTT leading development) which will provide advanced capabilities for coupling existing tools and producing optimized, converged solutions



MBSA Framework – Aircraft Definition Section

- Analysis section focuses on defining the aircraft configuration and size in a single integrated model
- Develops the aerodynamic, propulsion system, structural and other disciplinary designs





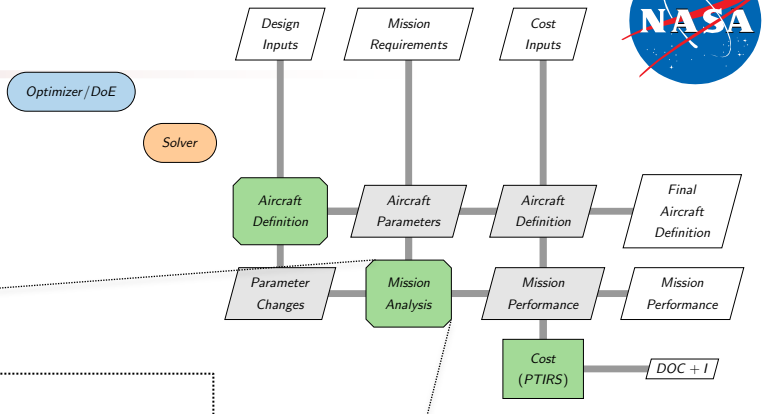
Disciplinary models are points of engagement with internal/ external tech R&D efforts:

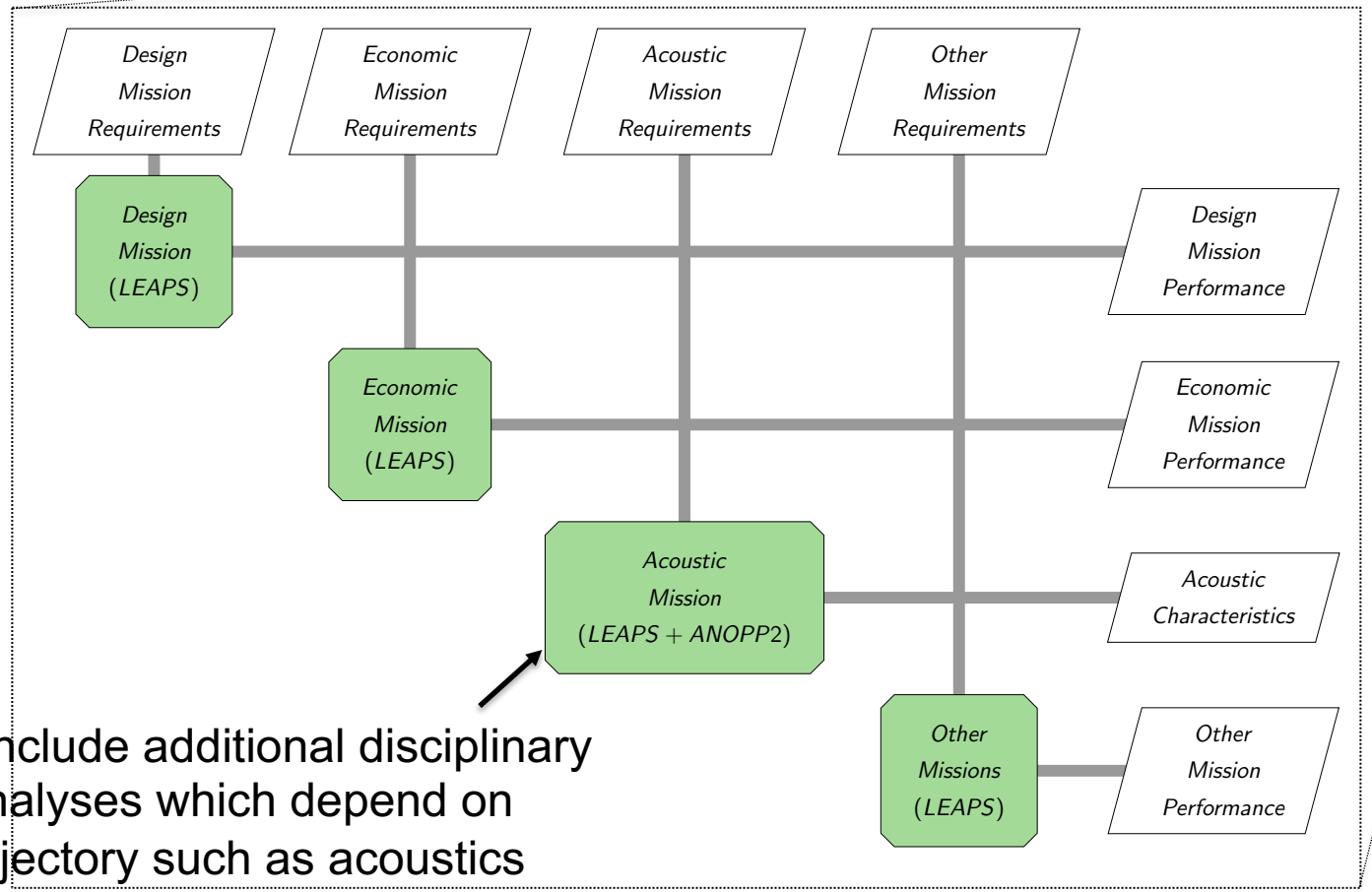
- Modifying inputs and assumptions to traditional systems analysis tools
- Integrating high fidelity models

Framework is expandable to included other disciplinary models as needed (icing, S&C, etc.)

MBSA Framework – Mission Analysis Section

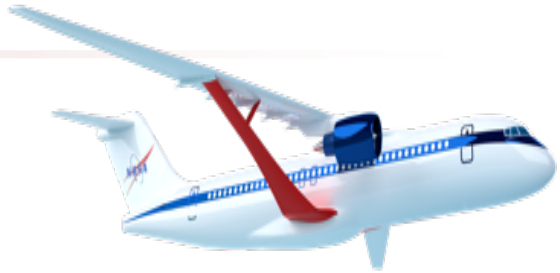
- Evaluates the defined aircraft over any number of missions to determine the aircraft performance characteristics



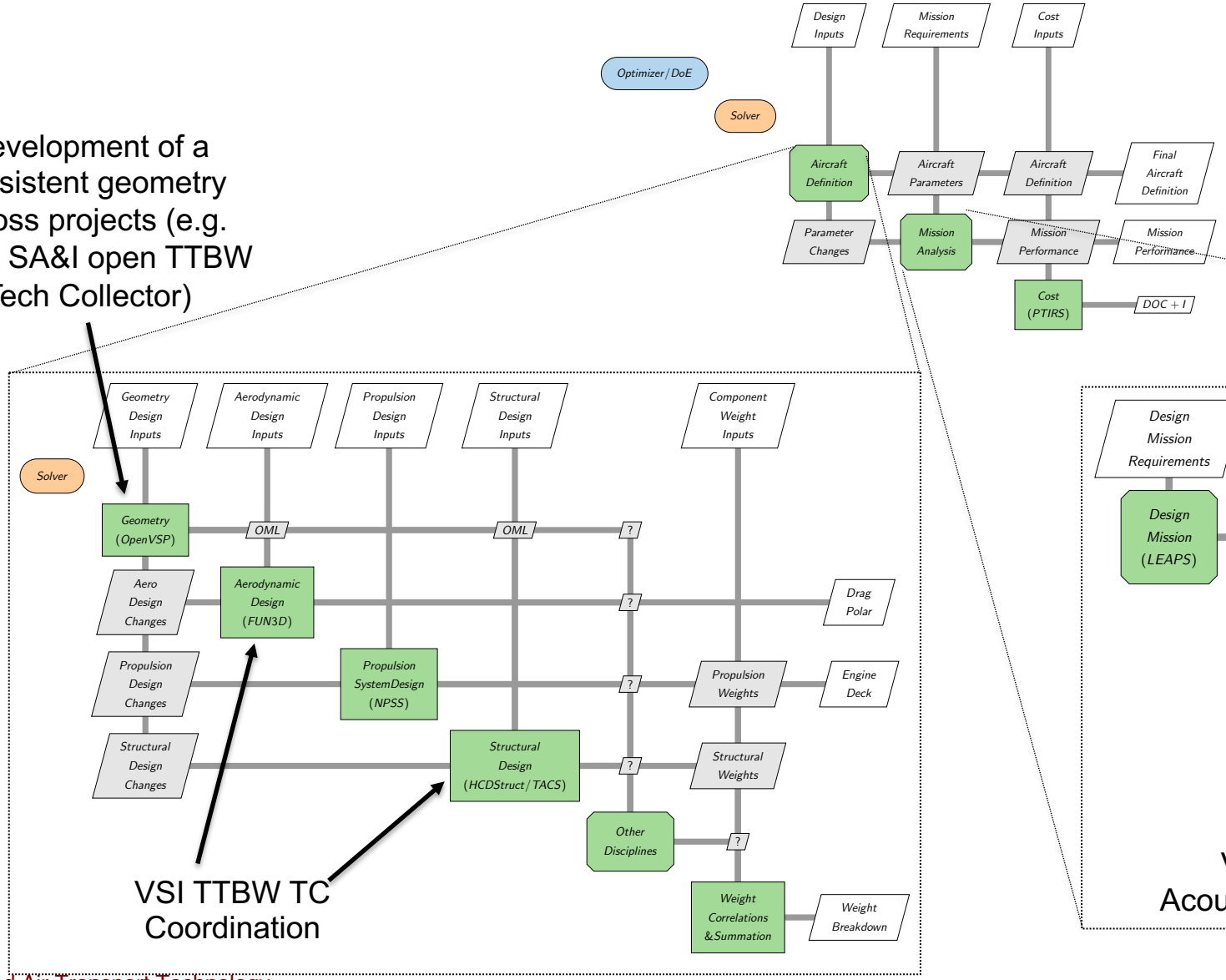


May include additional disciplinary analyses which depend on trajectory such as acoustics

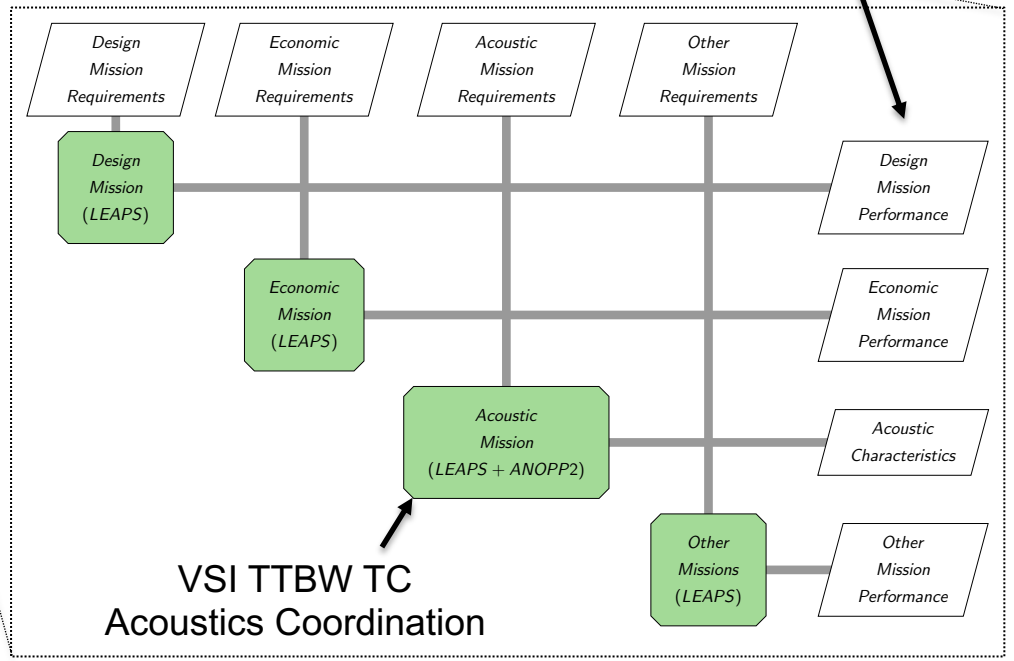
Notional TTBW Example



Development of a consistent geometry across projects (e.g. AATT SA&I open TTBW Tech Collector)



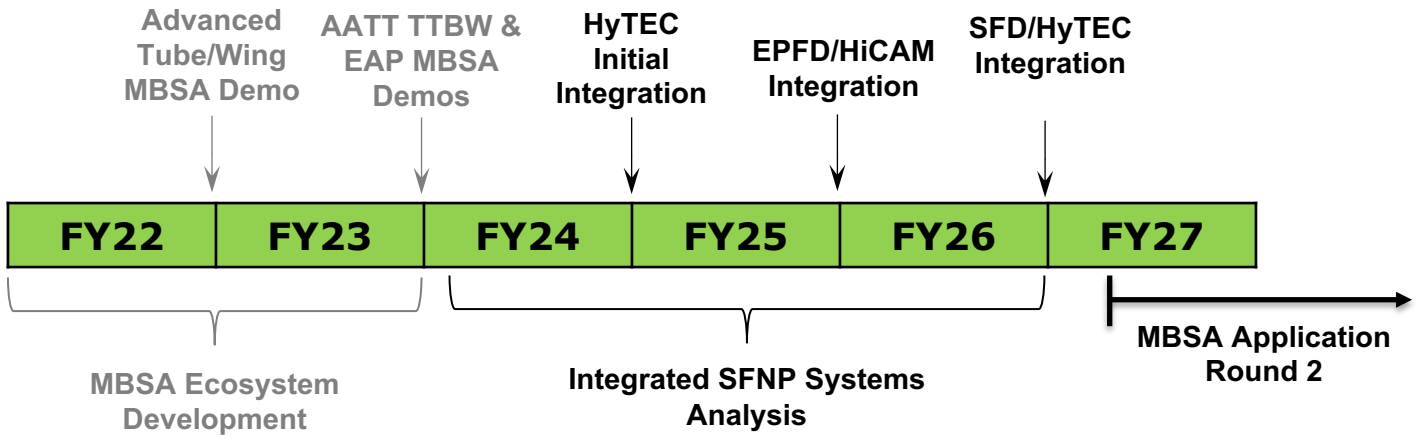
Assessment of system-level benefits through comparison with equivalent tube and wing model outputs



MBSA&E: Phase II

Overview of Phase II

- Phase II will focus on the coordination of integrated systems analysis studies for the broader SFNP
- Key elements of Phase II will include:
  - Formulation of integrated systems analysis needs for the SFNP with an emphasis on development and assessment of vision vehicle concepts associated with the flight demo concepts
  - Project-specific technical interchange activities informed by the key project decision points and deliverables
  - Integration of experimental data, flight test data, and SME input into the integrated vision vehicle models for the purposes of technology benefit assessments for the SFNP
  - Regular cross-project reviews of the integrated, system-level vehicle models and associated systems analysis results to inform project plans and objectives early and frequently
  - Close coordination with the contract partners involved with each of the SFNP projects



MBSA&E – Phase II – FY24-26

FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29

Technology Readiness Target

Model Based Systems Analysis & Engineering

MBSA MDAO Framework Dev

Integrated Vision Vehicle Assessment

Sustainable Flight Demonstrator (SFD)

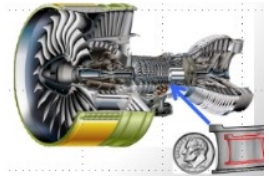
Flight Test

AATT - Transonic Truss Braced Wing

Leverage the Asset – Future Spirals

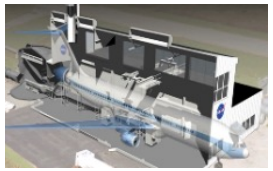
Hi-Rate Composite Aircraft Manufacturing (HiCAM)

Mfg Demo & Structural Test



Hybrid Thermally Efficient Core (HyTEC)

Core Demonstration & Test



Electrified Powertrain Flight Demonstration (EPFD)

Flight Test

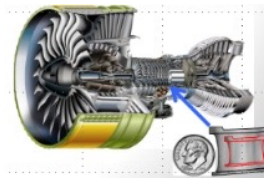
AATT - Electrified Aircraft Propulsion

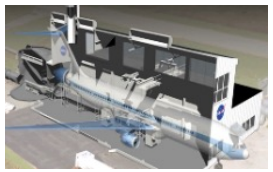
Planned

Notional

Achieve TRL 6 in time for Industry Product Decision-Making

MBSA&E – Phase II – FY24-26 :: Notional Integration





FY20 | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29

Technology Readiness Target

Model Based Systems Analysis & Engineering

MBSA MDAO Framework Dev

Integrated Vision Vehicle Assessments

Sustainable Flight Demonstrator (SFD)

Flight Test

AATT - Transonic Truss Braced Wing

Hi-Rate Composite Aircraft Manufacturing (HiCAM)

Mfg Demo & Structural Test

Hybrid Thermally Efficient Core (HyTEC)

Core Demonstration & Test

Potential Points of Engagement/Integration

Electrified Powertrain Flight Demonstration (EPFD)

Flight Test

AATT - Electrified Aircraft Propulsion

Leverage the Asset – Future Spirals

Planned

Notional

Achieve TRL 6 in time for Industry Product Decision-Making

Final SFNP MBSA&E 'Deliverables'

- Common, open, MBSA&E framework/ecosystem
  - Built in OpenMDAO with support for core SFNP systems analysis and vehicle modeling tools
  - Framework architecture and component data interfaces informed by cross-project systems analysis teams and external SFNP partners
  - Library of open NASA plug-ins and SFNP data
  - MBSE attributes where possible (requirements tracking, common interfaces, etc)
- Common, open, systems-level SFNP reference vehicle models
- Common, open, systems-level SFNP vision vehicle models
- Integrated system-level benefit assessments of the SFNP vision vehicle concepts informed by SME elicitation and ground/flight demos across the SFNP

A systems-level, digital integration across SFNP projects