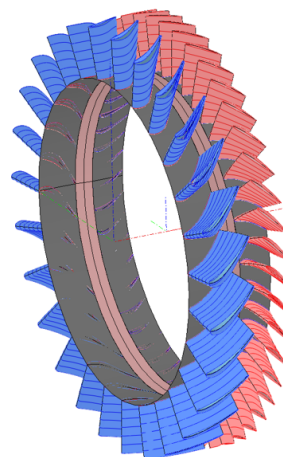
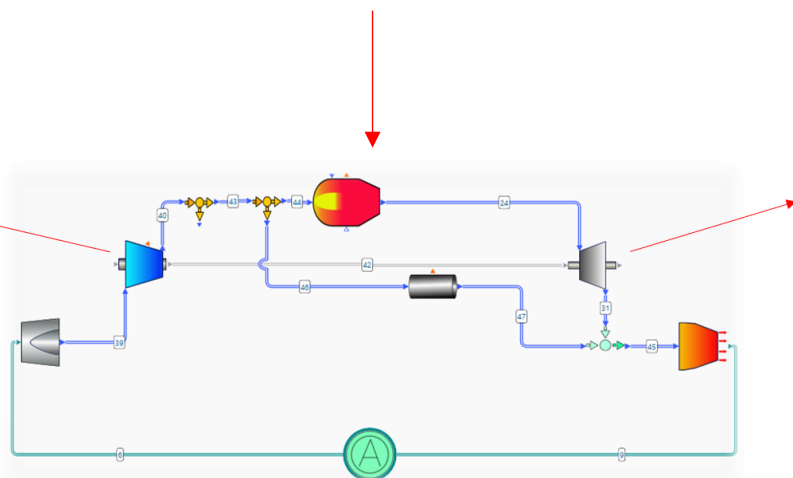
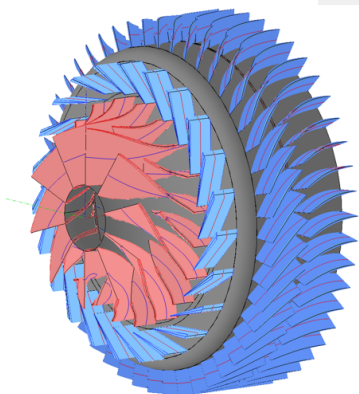
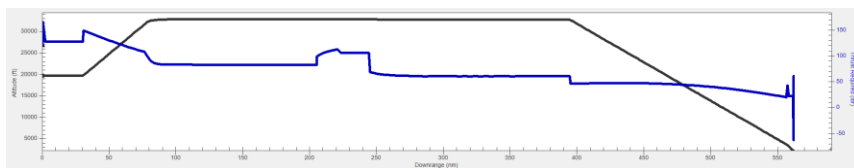




TETS 2026,
Dayton, Ohio,
Aug. 31 - Sept. 03, 2026

Model-based Propulsion System Optimization via Engine-Mission Co-Simulation



Presenter: Clement Joly

Co-Authors: Vladyslav Kotechenkov
Viktor Yevlakhov
Serhii Klindukh
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Affiliation: SoftInWay Inc.

Distribution Statement A: Approved for Public Release: Distribution is Unlimited

SoftInWay: Turbomachinery & Thermofluid System Solutions

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MOTIVATIONS

- Design point selection for a multi-mission engine is not obvious
 - Multi-disciplinary challenge with contradicting trends
 - Engine optimization cannot simply rely on fixed mission segment
 - Integration with mission analysis tool is critical
 - Very inefficient to do it “by hand”
 - Automation required
- Single-point cycle metrics (SFC, specific thrust) do not answer the real question: can the vehicle actually complete its missions and how effectively, under different flight conditions?
- OPR and TIT are the main drivers of thermal efficiency and specific thrust for a turbojet, but they also drive engine mass, dimensions and fuel burn
 - Turbofans have one additional driver – bypass ratio

AGENDA

- Introduction
- Mission Envelope and Engine Requirements
- Mission/Cycle Integration Software Introduction
- Turbojet Engine 0D Design, Off-Design Approach, and Mission Integration
- Results
- Conclusions

Introduction

INTRODUCTION

- Goal: Determine requirements for engine design to optimally support all planned missions for installation on a given drone, accounting for the priority of each mission.
- Real life: No single engine is optimal for every mission
 - One airframe may be assigned very different missions over its life
 - The cycle parameters that win one mission may lose another
 - Environmental integration
 - Future needs
- Solution: Automated process (and some results) for selecting turbojet cycle parameters for an engine digital twin required to complete several different missions.
- Note: unlike civil aviation, expendable and attritable platforms are driven by cost, mass and volume rather than certification and overhaul life, so permissible design margins differ.

TRADITIONAL VS. INTEGRATED APPROACH

Traditional Approach

- Engine sized at one or two design points, then checked against missions one at a time
- Manual iteration between disconnected tools — slow, roughly a month per engine
- Mission-fit problems surface late, once the design is already locked in
- Off-nominal or unplanned cases (hot day, headwind, new mission) are expensive to re-check
- *Trade-off: the integrated workflow needs more upfront tool/data-exchange setup than a single-point manual estimate.*
 - *One-time setup that is reusable*

Integrated Approach (This Work)

- Mission profile (STK) drives engine off-design points (AxSTREAM) automatically
- Quantified trade-offs across the whole mission envelope in hours, not weeks
- Mission fit is checked during sizing, while changes are still cheap
- Off-nominal and unplanned missions can be re-run against the same model at near-zero extra cost

Mission Envelope and Engine Requirements

PRIMARY MISSION DESCRIPTION

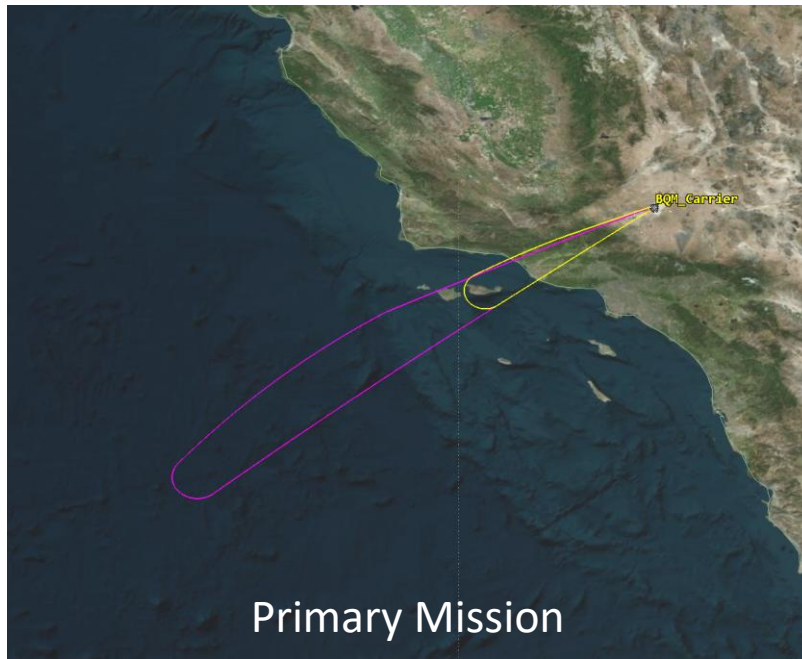
Primary Objective: Long-range rapid interception and persistent surveillance of maritime threats approaching the Western Seaboard.

Engine Design Point Requirements:

Cruise altitude: 10 km

Cruise Speed: 0.8 Mach

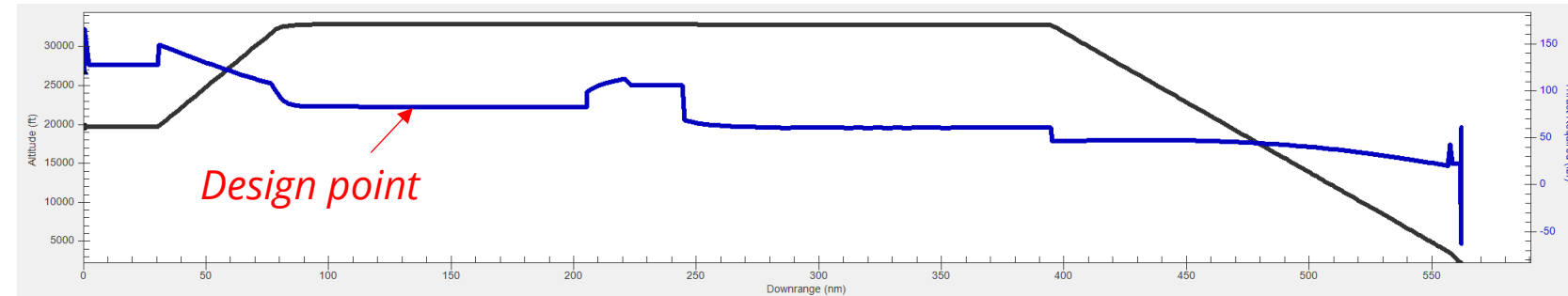
Thrust Required: ~67 lbf



Route 1 – Threat from the Ocean

Flight Phases:

- I. Air Drop: Release from the carrier aircraft at altitude; engine start and stabilization before the transition to powered flight.
- II. Rapid Ingress: High-throttle climb and acceleration to cruise Mach to minimize time-to-intercept.
- III. Transit/Cruise: Sustained flight at 10 km altitude.
- IV. Engagement/Intercept: Brief excursion to 105% power (Maximum Thrust).
- V. Egress/Return: Return to base at optimized long-range cruise speed (LRC).

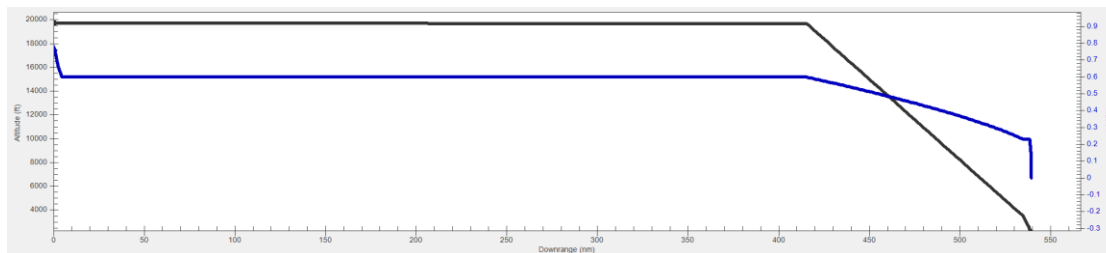


Route 1 Profile in Ansys STK Aviator (altitude in Black; Thrust Required in blue)

ALTERNATIVE MISSIONS



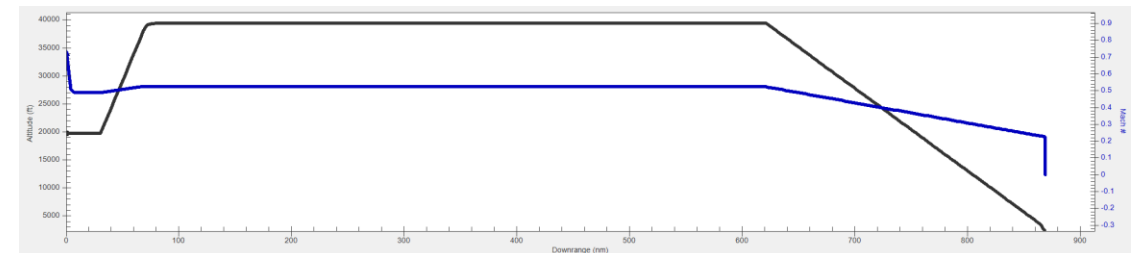
Route 2 – Patrolling Coast



Route 2 Profile in Ansys STK Aviator



Route 3 – Fight readiness



Route 3 Profile in Ansys STK Aviator

DRONE PROTOTYPE

- Drone Prototype: BQM-74 Chukar (Air Launched Configuration)
- Engine Configuration: 1xTurbojet
- Mass:
 - 125 (empty)
 - 250 kg (full fuel tank)
- Range: ~1000 km
- Reference Area: 0.743 m²

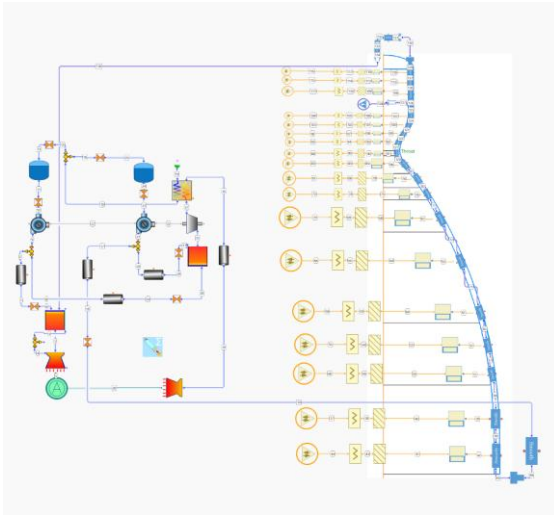
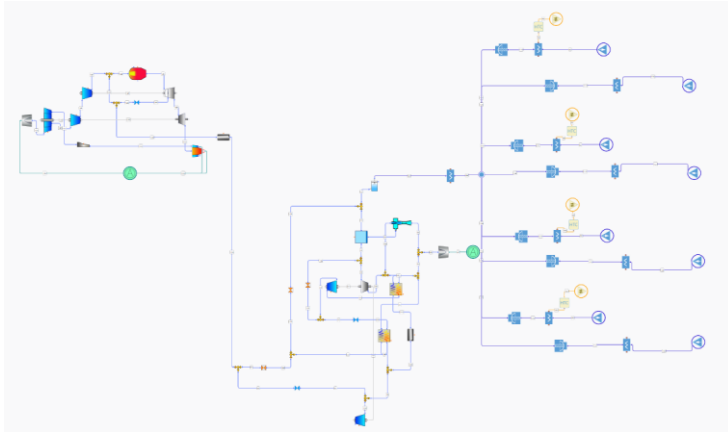


BQM-74F: Northrop Grumman Photo - Source: [Northrop MQM/BQM-74 Chukar](#)

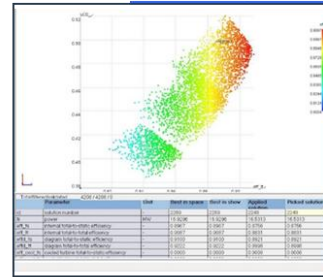
Mission/Cycle Integration Software Introduction

AxSTREAM® - A UNIQUE SOFTWARE PLATFORM!

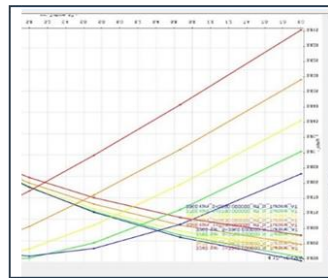
0D-1D Dynamic System Simulation



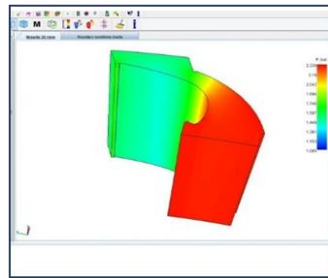
1D-3D Design & Analysis



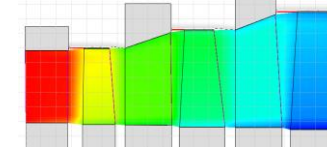
1. New Clean Sheet Design in Preliminary Design solver



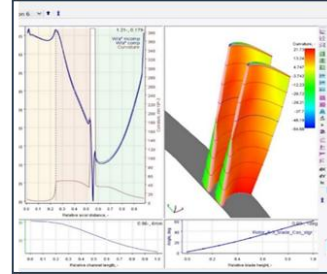
3. Analyze off-design Performance in AxMAP™



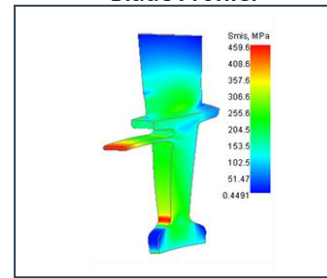
5. 3D Design Optimization in AxCFD™



2. 1D & 2D design in Streamline Solver

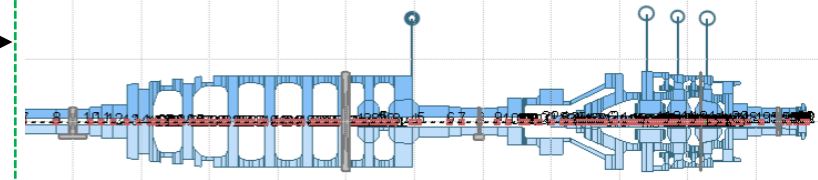


4. Geometry creation in Blade Profiler

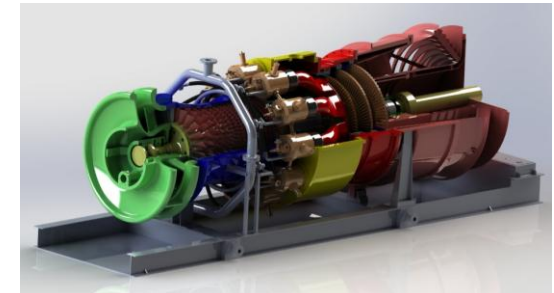


6. Structural and Modeling Analysis in AxSTRESS™

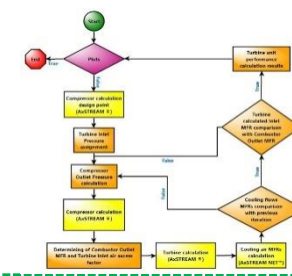
Rotor Dynamics/Bearing Analysis



Complete 3D Design



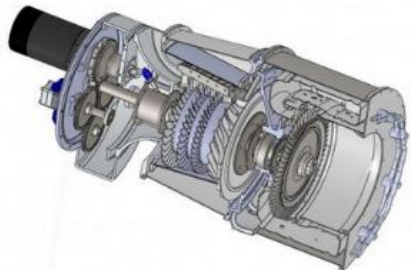
Workflow Automation



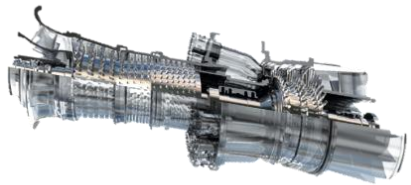
Interact with
CAE/CAD/CAM
software
automatically using
AxSTREAM ION™

ABOUT SOFTINWAY, INC.

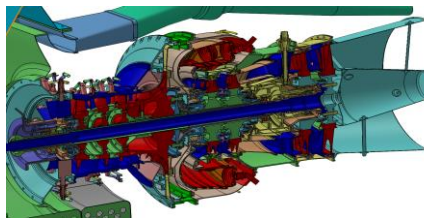
- Leading R&D engineering company specializing in turbomachinery components and thermal fluid system design & solutions through:
 - **In-house developed platform: AxSTREAM**
 - **Consulting services (250+ projects completed)**
 - **Specialized training**
- Global team of 110+ engineers & extensive testing and manufacturing network
- Mission: Enable rapid innovation & development of pioneering turbomachinery and thermo-fluid systems for pilot projects and serialized production.



UAV Gas Turbine



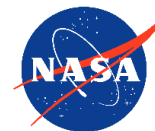
128MW Gas Turbine



Highly Loaded Axial
Compressor and LP
Turbine for Aeroengine

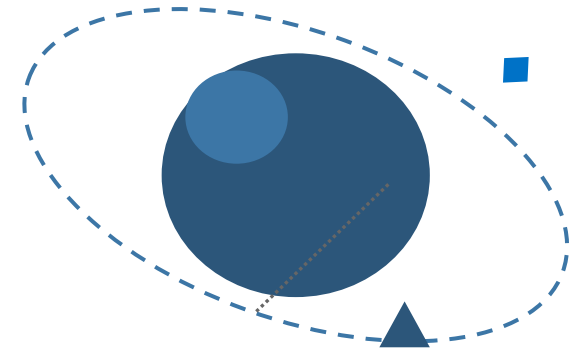


- We support 750+ leading OEMs, innovators, research & government organizations:

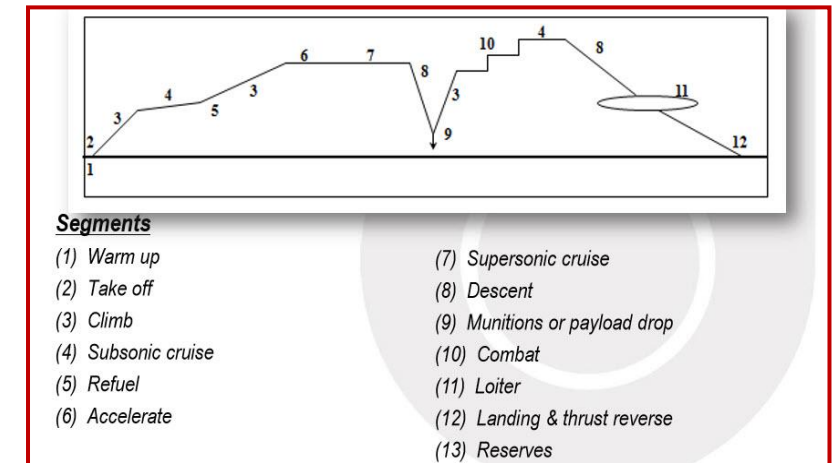


ANSYS STK

- Ansys STK (Systems Tool Kit): physics-based, time-dynamic 3D software for digital mission engineering
- Models platforms — aircraft, spacecraft, ground systems — and their trajectories, sensors, and communication links in a realistic environment
- Aviator module defines complete flight profiles: takeoff, climb, cruise, loiter, engagement, return
- **In this workflow:** STK generates the mission profile that drives AxSTREAM's engine off-design points — mission modeling as part of engine design, not a separate step

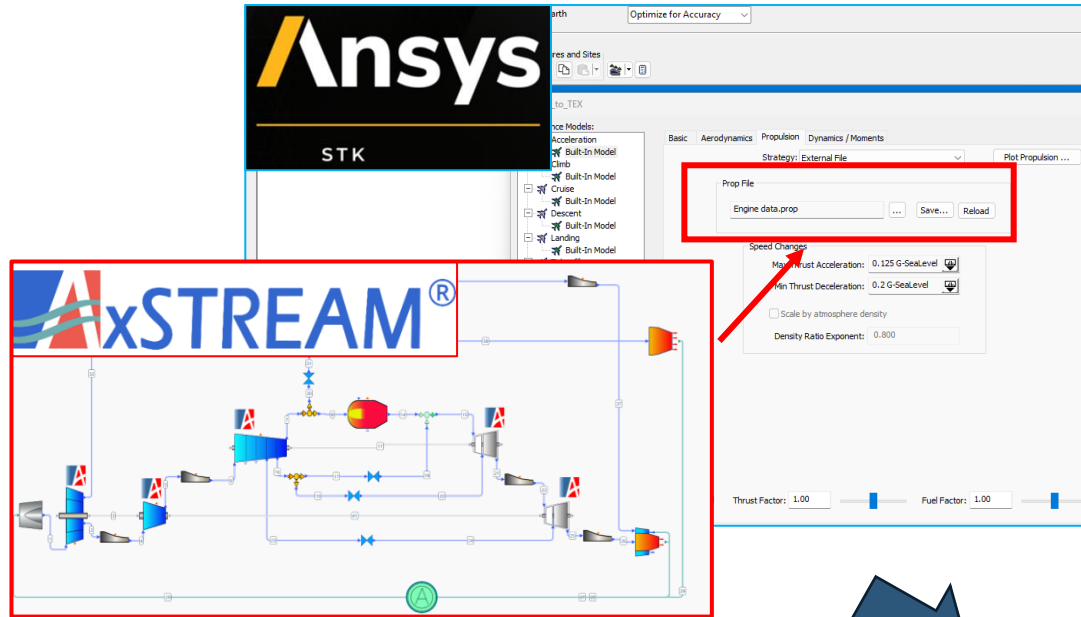


Orbits, trajectories, sensors & comm links in one 3D mission environment

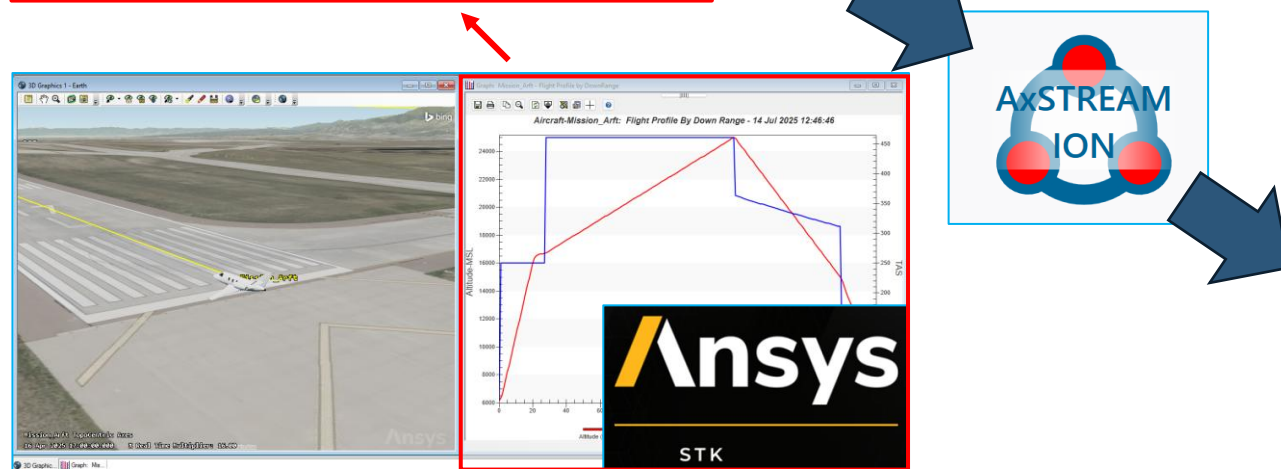


Arbitrary mission profile in literature

AxSTREAM & ANSYS COM-BASED INTEGRATION SOLUTION



- Integration via automation and optimization tools such as AxSTREAM ION enables this study to be efficiently conducted through the following steps:
 1. Missions setup in Ansys STK
 2. Engine Model setup in design and analysis in AxSTREAM System Simulation
 3. Preparation of *.prop file template for engine performance data exchange
 4. Configuration of the fully automated workflow in AxSTREAM ION



Integration Objectives:

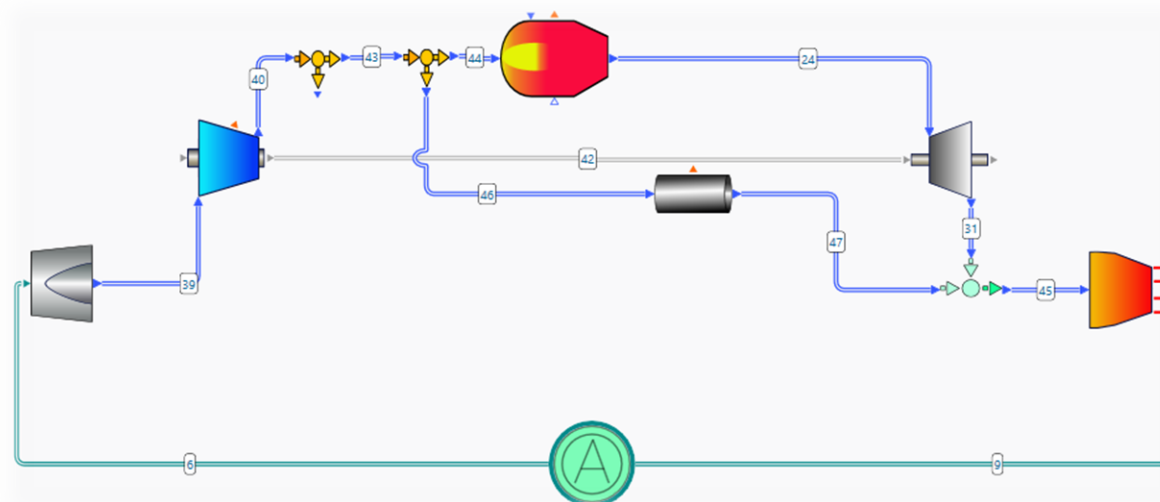
- Much less manual work for *Flying Vehicle and Propulsion* related tasks.
- Faster iteration speed: Loop Automation
- Fully support multi-objective optimization
- Synchronised models: no risk of mismatch or outdated inputs
- **Available now**

Turbojet Engine 0D Design, Off-Design Approach, and Mission Integration

TURBOJET ENGINE DESIGN POINTS

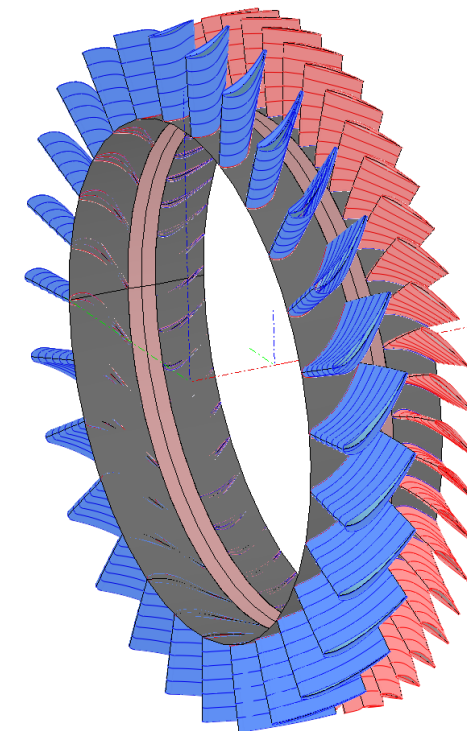
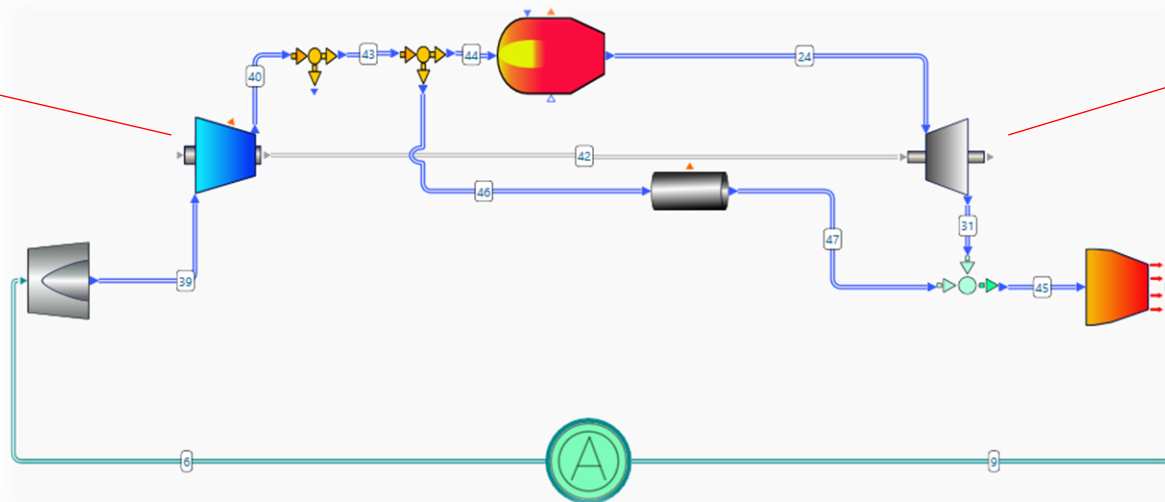
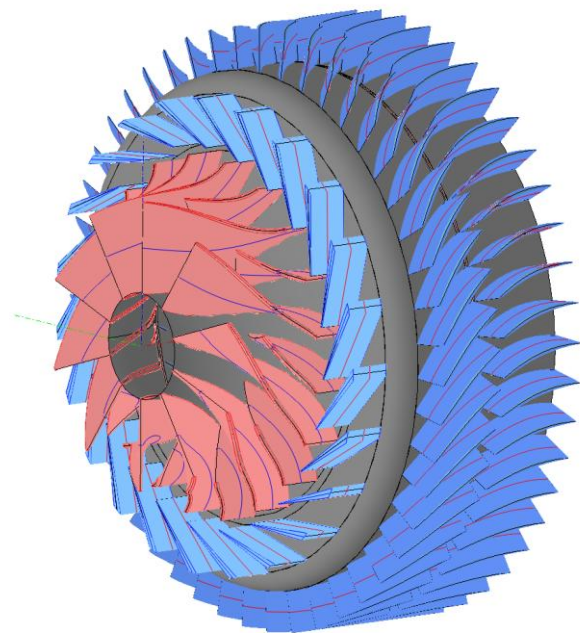
- **16 turbojet engine variations** were sized automatically for different cruise pressure ratios and turbine inlet temperatures for a given thrust to see how each engine with its components performs throughout the **three missions** identified.

	Parameter variation
Design Pressure Ratio	2 – 3 – 4 – 5
Design Turbine Inlet Temperature, °C	650 – 800 – 950 – 1100

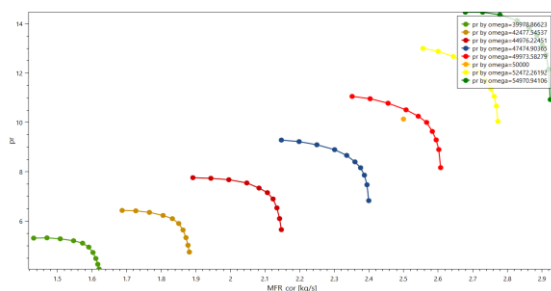


OD turbojet model in AxSTREAM System Simulation

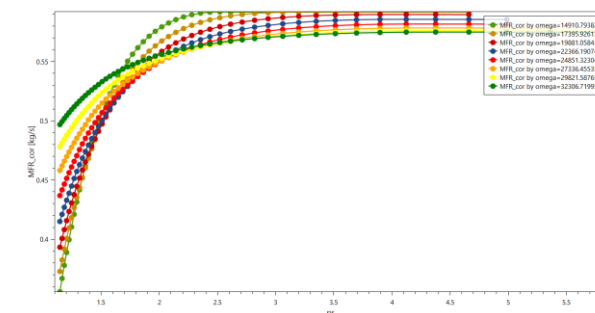
TURBOJET ENGINE ANALYSIS



AxSTREAM System Simulation Turbojet model



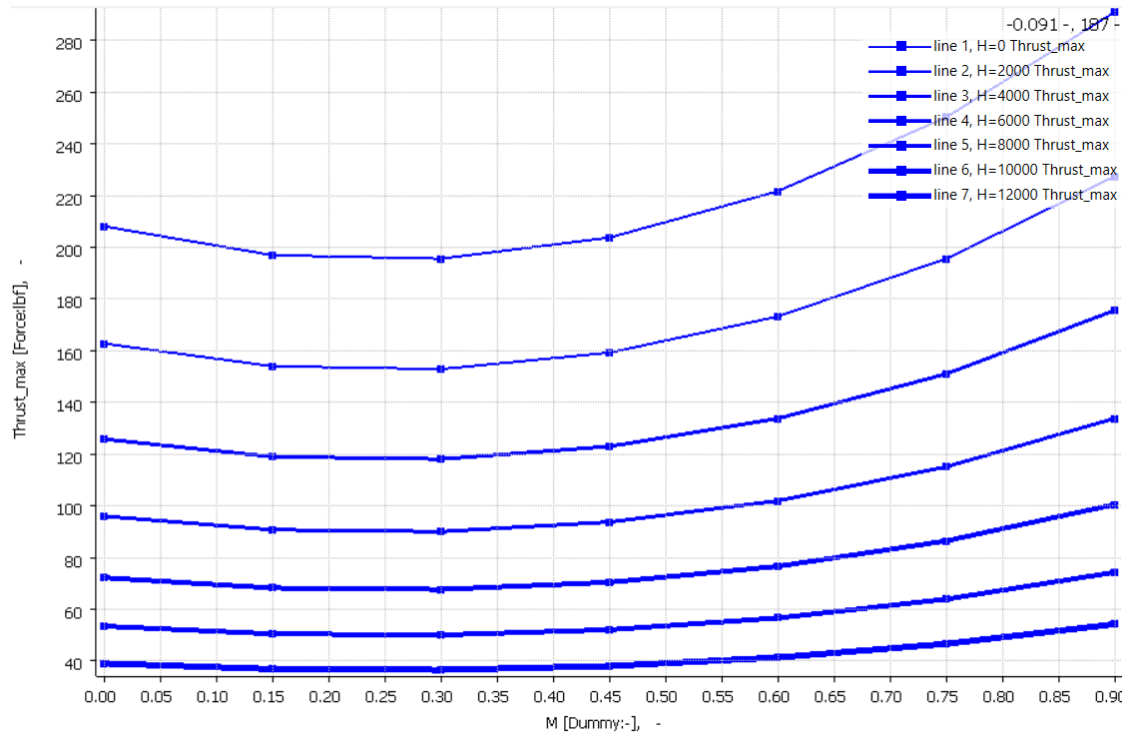
Compressor baseline map



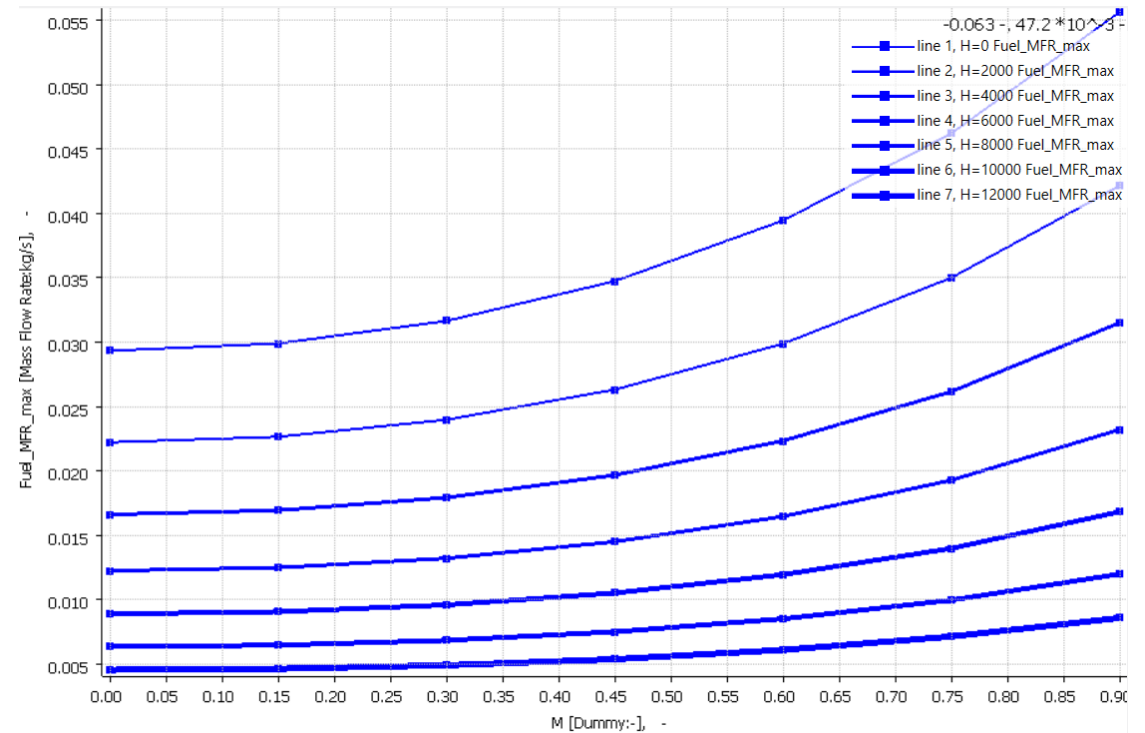
Turbine baseline map

ENGINE MAP GENERATION: PRIMARY RESULTS

Thrust at nominal Ncorr, lbf



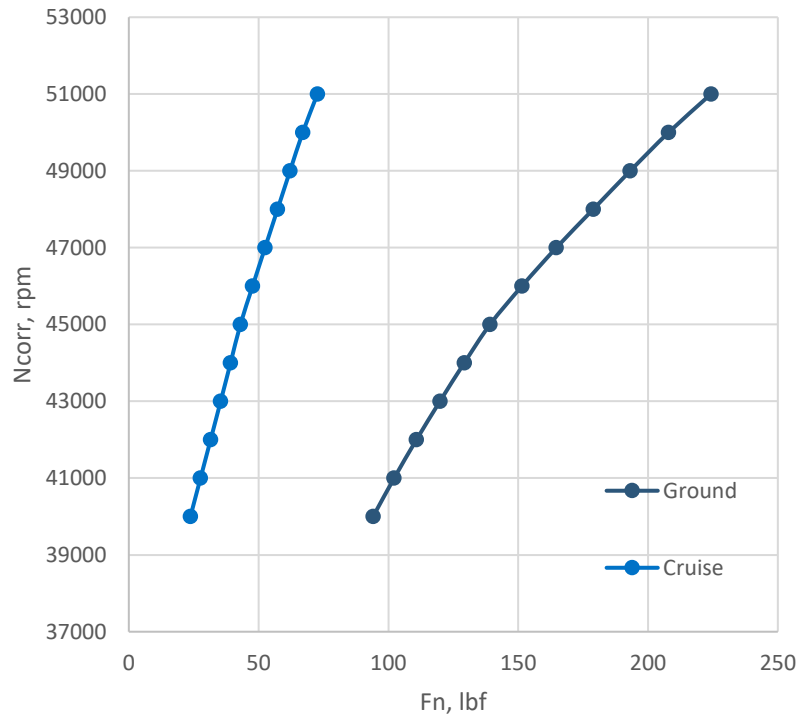
Fuel MFR at nominal Ncorr, kg/s



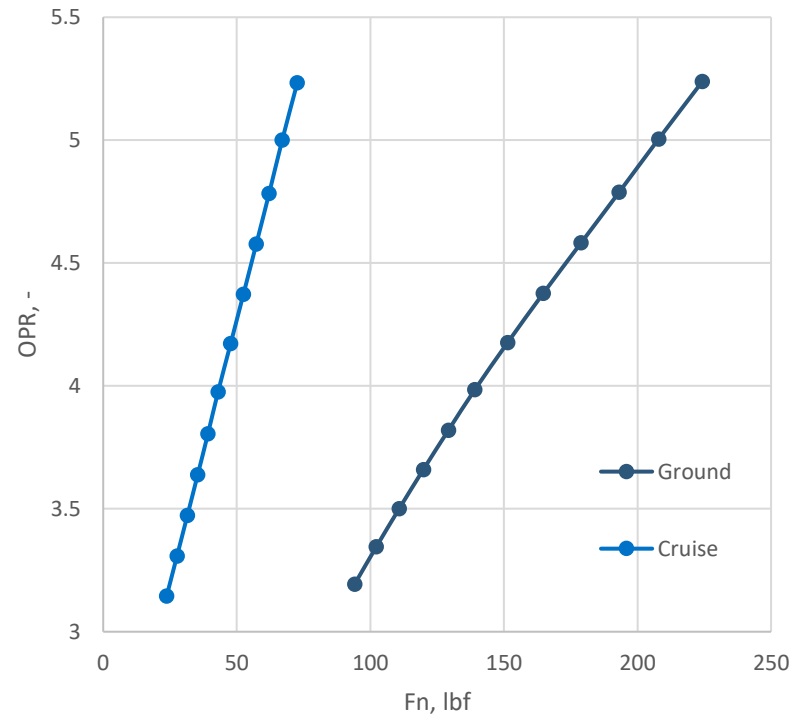
Flight mode	Nominal Thrust, lbf	Fuel flow rate, kg/s	SFC, g/N·s
Cruise (H = 10km, M = 0.8)	67	0.0106	0.0356
At ground (H = 0km, M = 0)	208	0.0295	0.0319

ENGINE ANALYSIS: THROTTLING

Rotational Speed vs Net Thrust



OPR vs Net Thrust



➤ *Analysis control parameter:
Corrected Rotational Speed
Ncorr*

➤ *Maximum Thrust: Ncorr =
102% (~105% Thrust)*

➤ *Take-off/contingency
rating; provides peak
thrust while
maintaining structural
and thermal limits*

➤ *Minimum Thrust: Ncorr =
80% (~39% Thrust)*

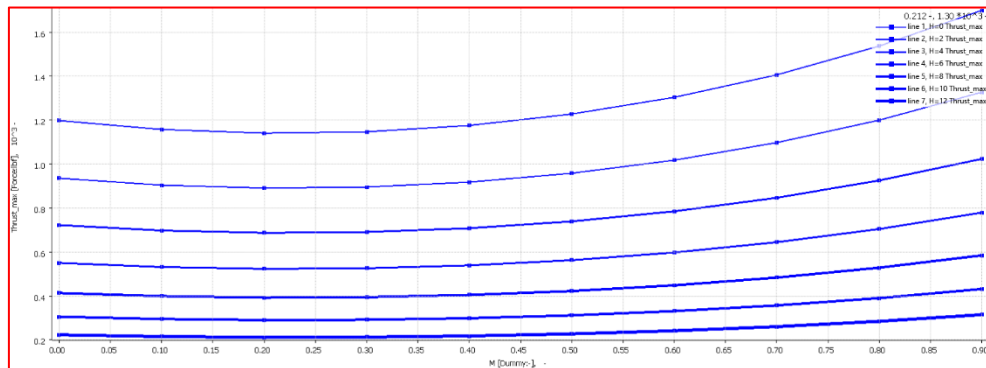
➤ *Flight idle threshold;
ensures compressor
stability (surge margin)*

DATA EXCHANGE

Data Exchange

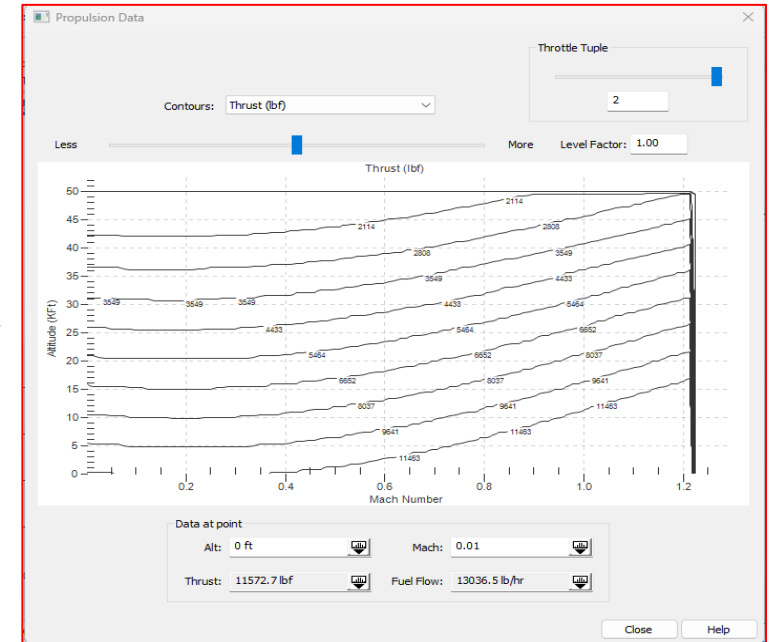
From AxSTREAM → to STK:

- Export Engine Map (thrust/fuel rate vs. altitude and Mach number) using *.prop file format (as an example)
- Import into STK using External Data



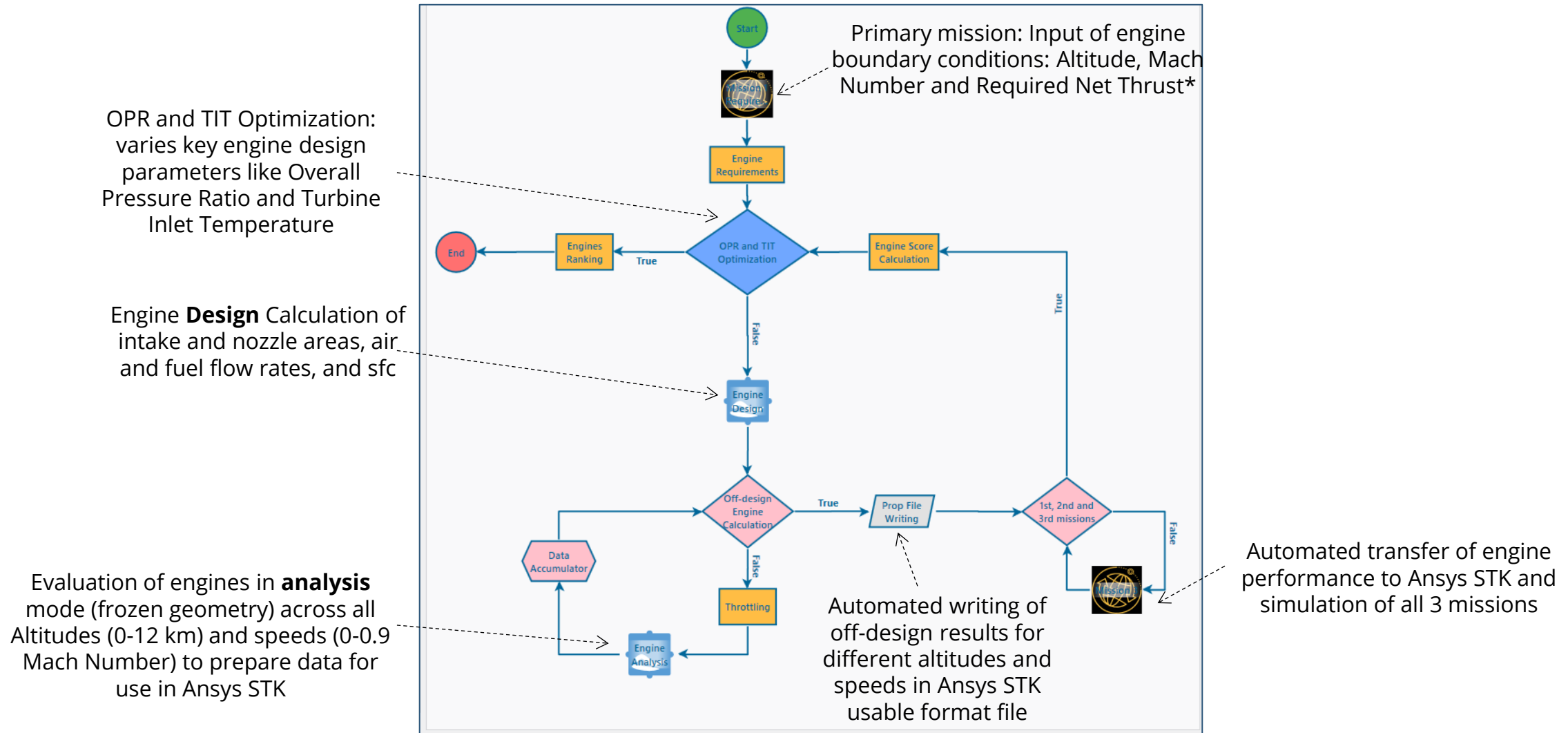
Propulsion for Aviator Format (*.prop) Example

```
# version is required - this feature debuted at 9.0
Version: 9.0
# the following Accel/Decel/Density items are optional. If not specified, the user may
Acceleration: 0.125
Deceleration: 0.2
DensityExponent: 0.8
DensityScale: 1
NormalizeThrottle: 1
# NThrottleTuples is required and must be >= 2
NThrottleTuples: 2
# a throttle tuple consists of pairs of thrust and fuel flow values
# alt mach minThrustN minFuelFlowKg5 maxThrustN maxFuelFlowKg5
0.000000 0.000000 515.936100 0.164159 51593.610000 1.641588
0.000000 0.100000 504.308200 0.165141 50430.820000 1.651412
0.000000 0.200000 500.267900 0.168109 50026.790000 1.681088
0.000000 0.300000 503.275100 0.173122 50327.510000 1.731224
0.000000 0.400000 513.264500 0.180283 51326.450000 1.802833
0.000000 0.500000 530.263000 0.189733 53026.300000 1.897330
0.000000 0.600000 554.440500 0.201652 55444.050000 2.016523
0.000000 0.700000 586.087700 0.216259 58608.770000 2.162586
0.000000 0.800000 625.592900 0.233804 62559.290000 2.338044
0.000000 0.900000 673.412200 0.254571 67341.220000 2.545712
0.000000 1.000000 730.030200 0.278863 73003.020000 2.788627
0.000000 1.100000 792.593000 0.305965 79259.300000 3.059645
0.000000 1.200000 862.172500 0.336375 86217.250000 3.363749
0.000000 1.300000 939.218100 0.370433 93921.810000 3.704334
0.000000 1.400000 1023.405000 0.408272 102340.500000 4.082723
0.000000 1.500000 1113.870000 0.449892 111387.000000 4.498922
0.000000 1.600000 1209.095000 0.495135 120909.500000 4.951355
0.000000 1.700000 1306.743000 0.543637 130674.300000 5.436367
```



.prop file created by AxSTREAM and imported into Ansys STK

AUTOMATED WORKFLOW PROCESS IN AxSTREAM ION



ANSYS & STK FOR MISSILE PROPULSION DEVELOPMENT



[Watch Video](#)

Results

AxSTREAM & ANSYS STK CO-SIMULATION RESULTS

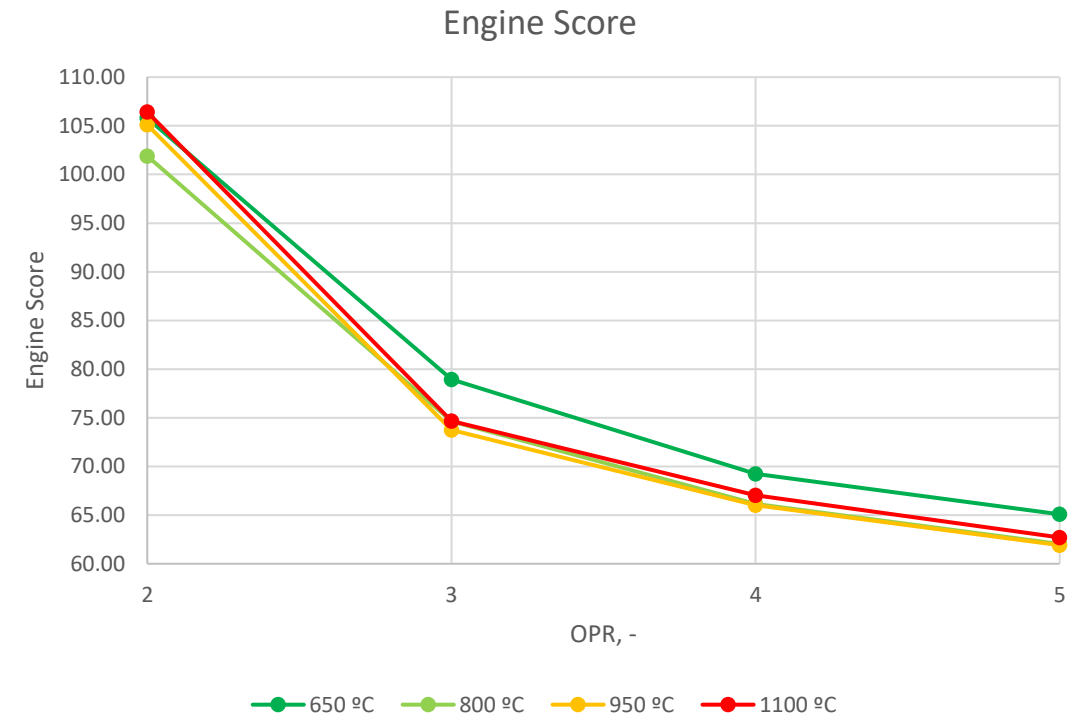
- **Success metric:** Engine Score which reflects fuel required for each weighted mission.
 - A lower value indicates better performance.

$$\text{Engine Score} = \text{Engine Mass Penalty} * \sum \left(\frac{\text{Mission Weight} * \text{Fuel Used}}{\text{Coefficient of Completion}} \right)$$

Rank	Engine		Engine Score	Engine Mass, kg	Mission Completion		
	Pr	TIT, °C			Route 1	Route 2	Route 3
1	5	950	61.91	19.44	100%	100%	100%
2	5	800	62.03	19.96	100%	100%	100%
3	5	1100	62.71	19.05	100%	100%	100%
4	5	650	65.08	20.73	100%	100%	100%
5	4	950	66.02	19.09	100%	100%	100%
6	4	800	66.16	19.59	100%	100%	100%
7	4	1100	67.04	18.71	100%	100%	100%
8	4	650	69.24	20.45	100%	100%	100%
9	3	950	73.75	18.5	100%	100%	95%
10	3	800	74.65	19.15	100%	100%	97%
11	3	1100	74.68	18.12	100%	100%	92%
12	3	650	78.92	20.39	100%	100%	97%
13	2	800	101.90	19.92	91%	84%	75%
14	2	650	105.79	21.55	85%	85%	81%
15	2	950	105.10	18.87	86%	81%	67%
16	2	1100	106.42	18.14	86%	77%	64%

Engines performance summary

	Route 1	Route 2	Route 3
Weight (Priority)	0.5	0.3	0.2

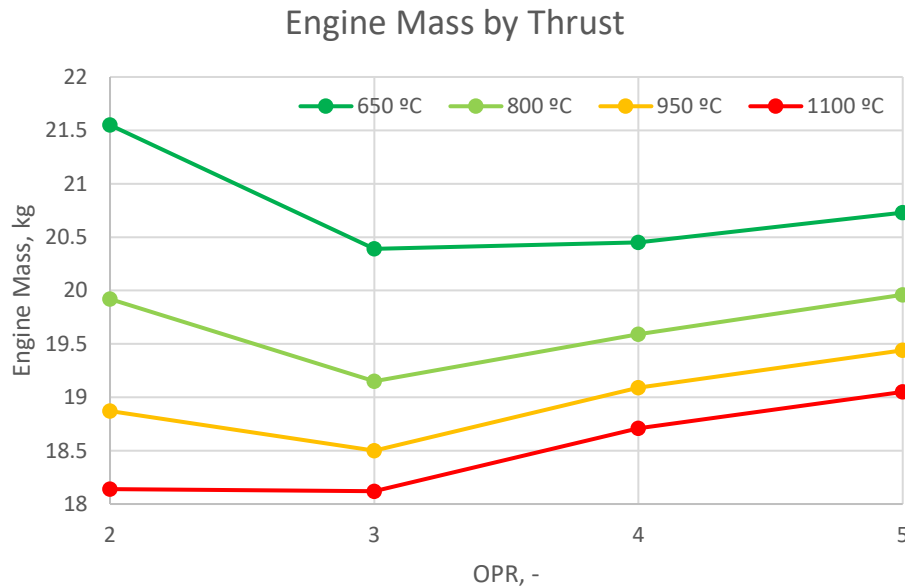


Engine score across all engine configurations

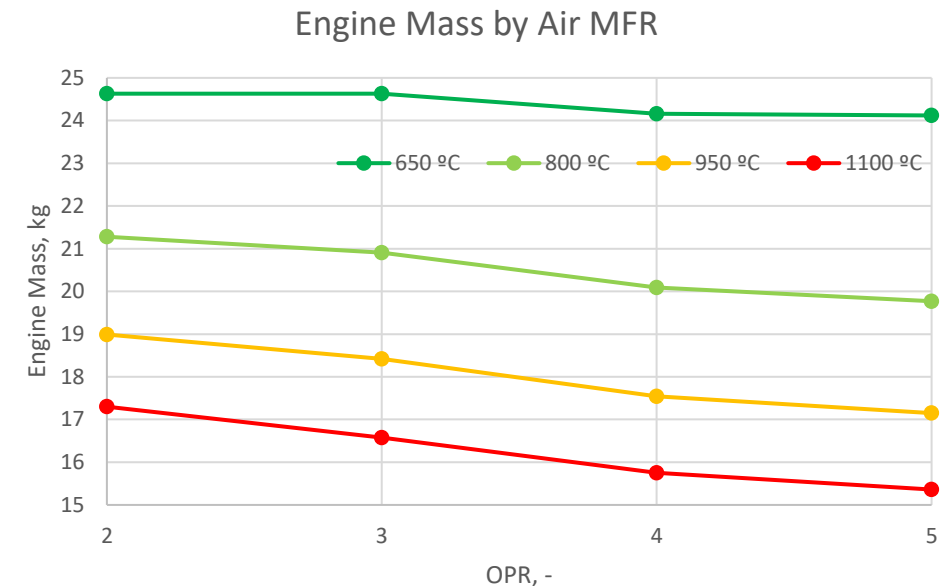
ENGINE MASS ESTIMATION

➤ Two statistical methods were used to preliminary estimate the mass of engines

$$M_{eng} = 21.55 * Thrust_{take-off}^{0.98}$$



$$M_{eng} = 14.7 * MFR_{air}^{0.818}$$



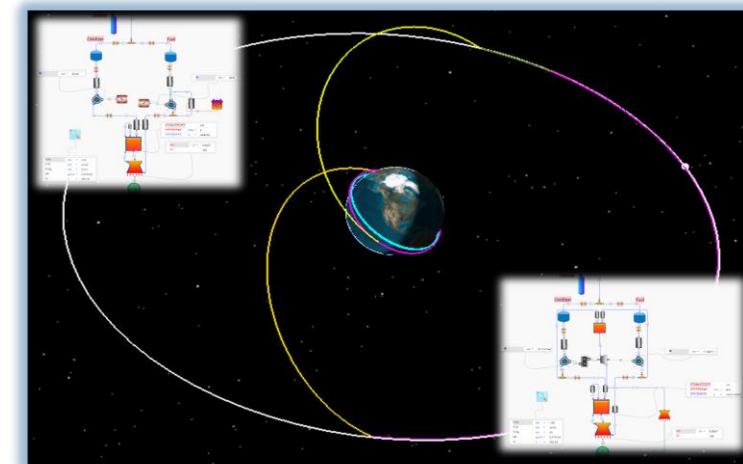
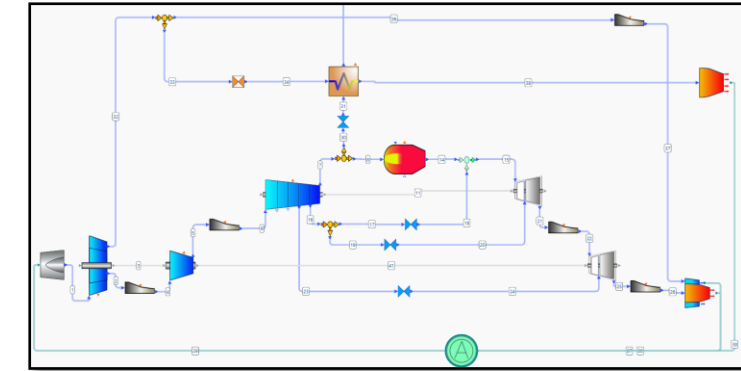
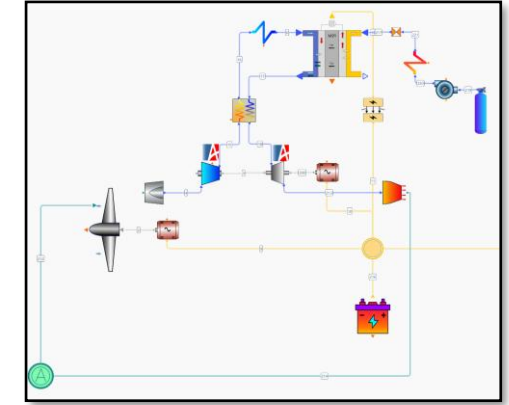
$$Engine\ Mass\ Penalty = \left(\frac{Engine\ Mass}{Lightest\ Engine\ Mass} \right)^n$$

Where n – mass penalty exponent

Conclusions

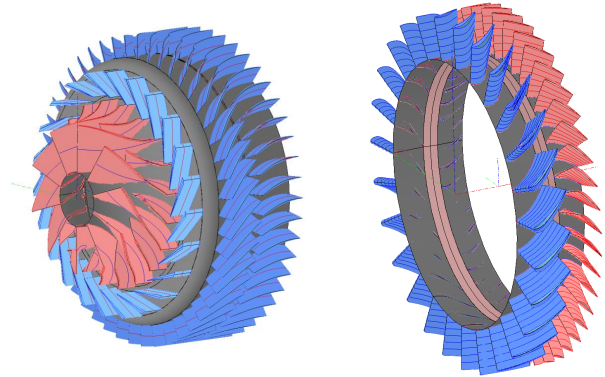
CONCLUSIONS

- **1 month → 16 hours.** Automated engine-mission co-simulation cuts evaluation time by ~45x, turning a month-long bottleneck into a same-day answer.
- **Right the first time.** Mission performance is validated during sizing, not discovered after the design is locked — catching costly mismatches before they're expensive to fix.
- **One platform, every mission.** AxSTREAM + Ansys STK covers turbojets, turboprops, turbofans, satellites, and rockets — the same automated workflow scales from a single drone engine to a full mission trade study.
- **Confidence, not guesswork.** PTR = 4–5 met every mission tested; PTR = 3 came close — giving you a data-backed answer on where the real design margin is, not an estimate.
 - A future trade-off study weighing mass and cost during turbomachinery conceptual design will determine whether higher pressure ratio is a net win.

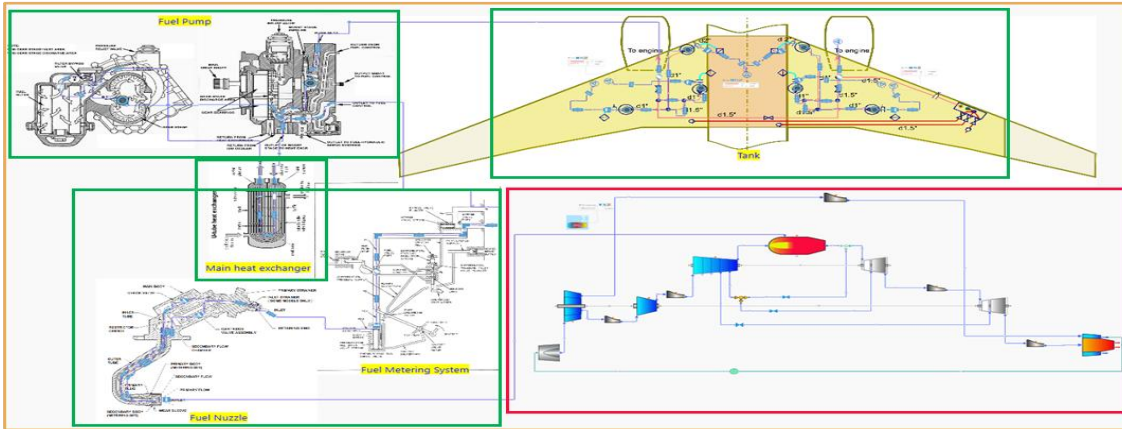


FURTHER WORK

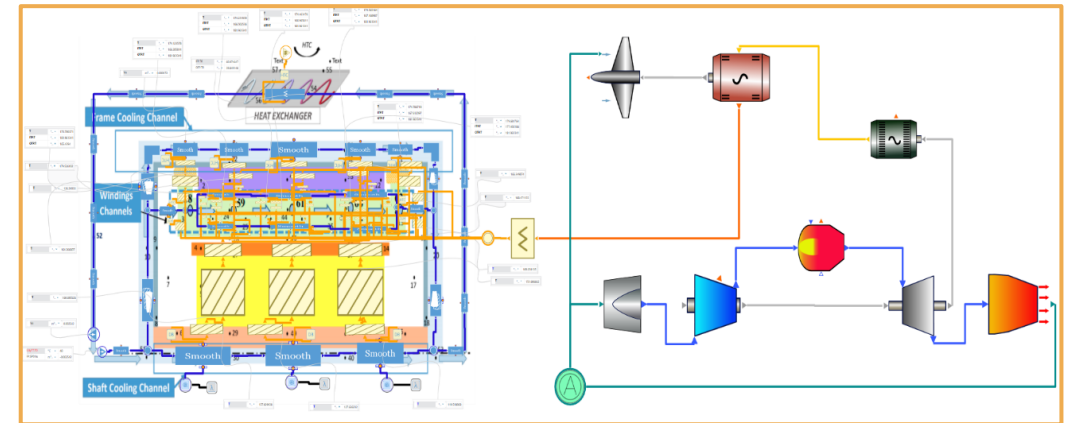
- Adopting a holistic approach by replacing traditional map scaling with automated turbomachinery design generation in AxSTREAM - followed by off-design modelling - will improve fidelity.
 - Directly coupled to the system model
 - Improved performance prediction accuracy
 - Accounts for leakage and feed-system effects
 - Includes combustion-product composition effects for turbines



Turbomachinery design



Fuel supply system coupled to engine



Coupled electro-motor thermal management system

EXAMPLES OF MISSION/CYCLE INTEGRATION POTENTIAL

- Enables rapid convergence on feasible engine architectures instead of iterating between disconnected tools.
- Allows early detection of requirement conflicts — SFC vs. thrust vs. thermal margin — while they are still cheap to resolve.
- Provides quantified trade-offs across performance, mass and cost, resolved at mission level rather than at a single operating point.
- Accounts for off-nominal conditions — hot day, headwind, angle of attack, etc. — in the assessment of mission completion.
- Delivers confidence that the selected engine can complete every assigned mission, not only the one it was sized for — and, using real engine performance, extends the same assessment to unplanned missions to determine Go/No-Go and optimize the flight.
- Establishes a traceable, repeatable process that supports design reviews and independent verification.

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