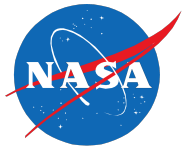
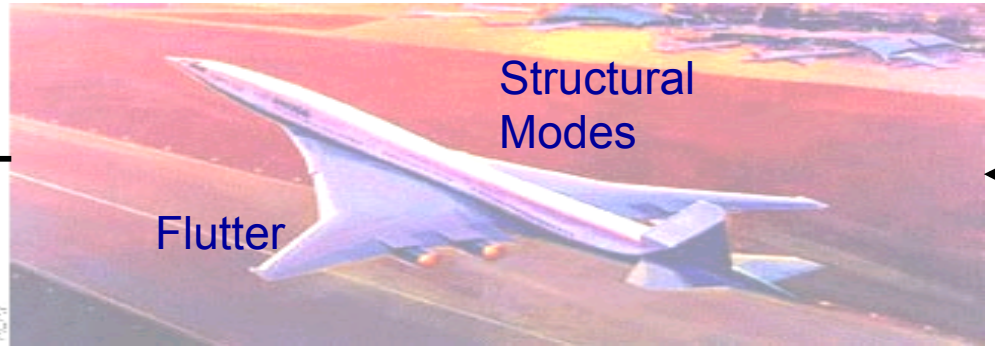
Summary



This presentation was presented at the Fundamental Aeronautics Program Annual Review Meeting held March 15-17 in Cleveland Ohio. This presentation is the second part of a 30 min. presentation entitled “ASE/APSE Overview” by Walter Silva & George Kopasakis, presented at 10:30 AM Wed. March 16 in the Supersonics session. This portion of the presentation covers the propulsion work done under Supersonics Project ASE/APSE task, since the last annual meeting.

Introduction: What is APSE?

Aero-Propulso-Servo-Elasticity



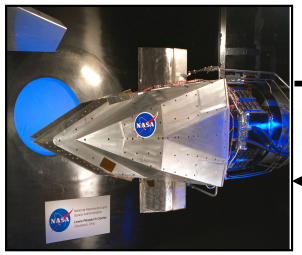
Aero-Servo-Elasticity

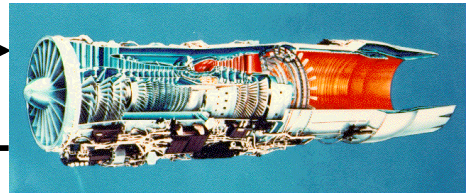
Thrust
Variations

- Integrated Modeling & Controls Design
- Vehicle Stability
- Ride quality

APSE Flow
Disturbances

External Flow
Disturbances





Propulsion

- Cruise Efficiency

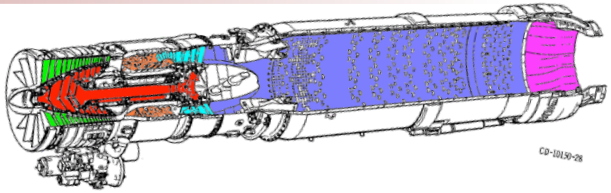
Design and Analysis

Integrated APSE Model

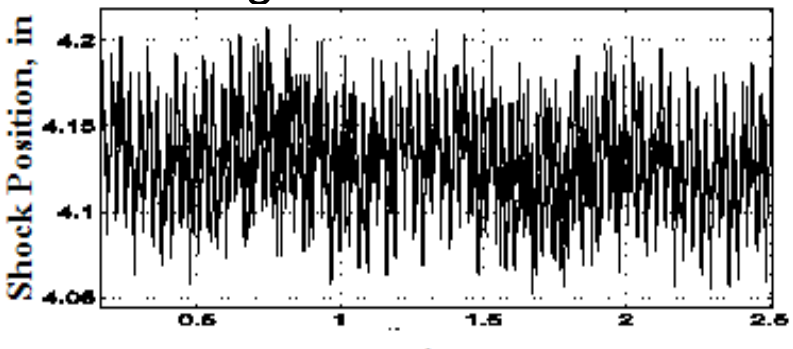
(collaboration with GRC)

Prior Progress

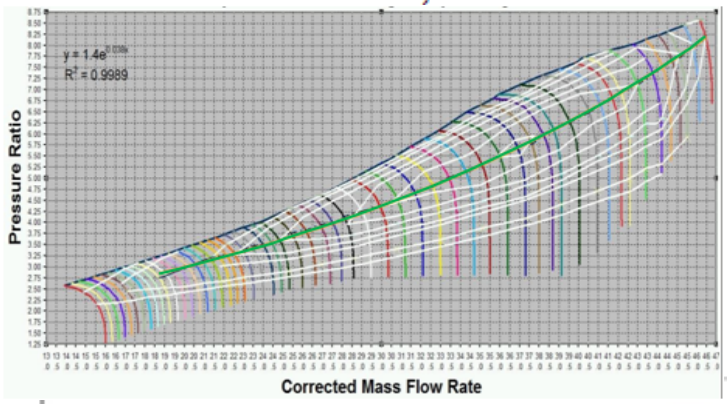
- Developed unsteady turbojet & turbofan engine models (J85-13) – Gas volume dynamics



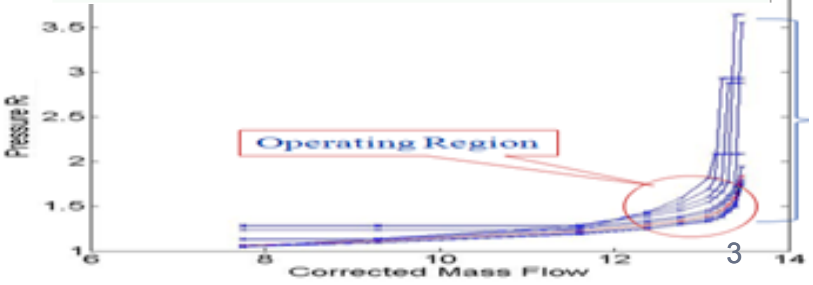
- Developed new feedback controls design approach – Taking actuators hardware into account to maximize performance



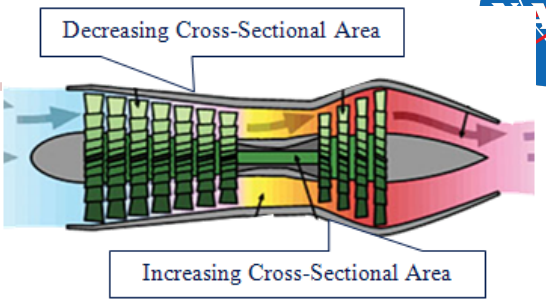
- Developed shock position controls design for internal compression inlets
- Developed compressor schedules – operate compressor over speed regime



- Developed fuel controls, scaled generic maps & manipulate geometries to develop engine simulation
- Developed stage-by-stage compressor & turbine models & Methodology



Recent Accomplishments



- Finished developing Atmospheric Turbulence Model
- Finished developing Parallel Compressor Model for Flow Distortion and Stall
- Developed preliminary Integrated APSE model
- Developed Quasi 1D CFD model of Internal Compression Inlets
- Developed approach for 1D CFD modeling of External Compression Inlets
- In the process of finishing developing Exit Nozzle Area Schedule and approach
- Started developing N+3 engine model

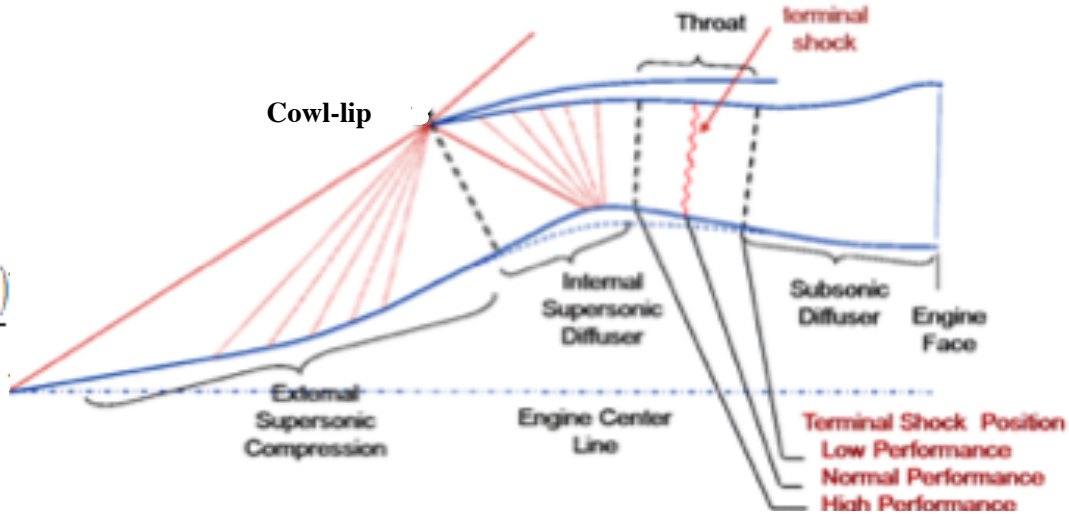
Quasi 1D CFD Modeling of Mixed Compression Inlets

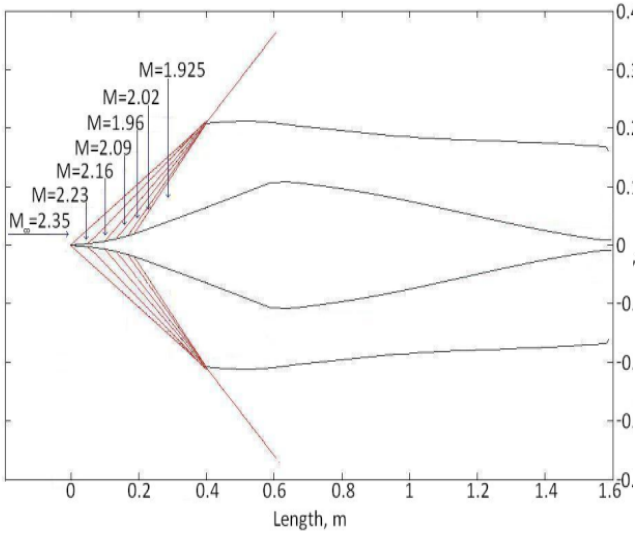
1) Modeled external compression using compressible flow relations

2) Modeled internal compression using 1D CFD w/ central difference, w/ artificial viscosity & variable geometry

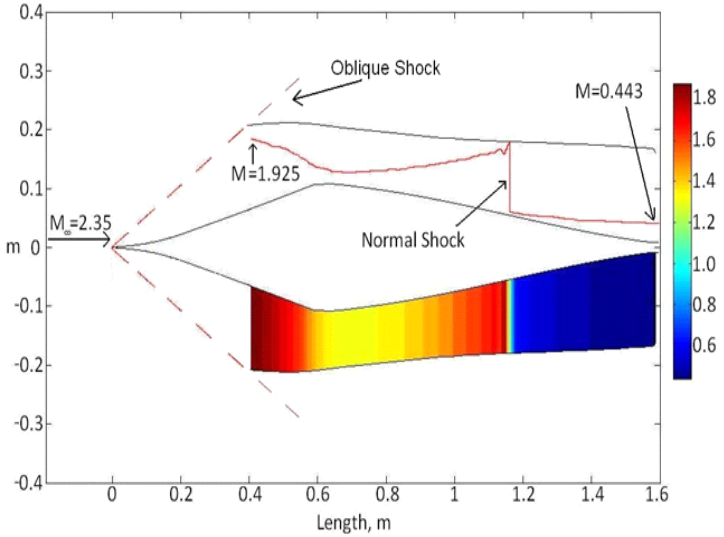
$$\frac{\partial}{\partial t}(W_{j,n}) = -\left(\frac{A_{n+1}F_{j,n+1} - A_{n-1}F_{j,n-1}}{2\Delta x A_n}\right) + \frac{S_{j,n}}{A_n} +$$

$$S_v\left[\frac{\left(|v_n| + a_n\right)\left(A_{n+1}W_{j,n+1} - A_n W_{j,n}\right) - \left(|v_{n-1}| + a_{n-1}\right)\left(A_n W_{j,n} - A_{n-1}W_{j,n-1}\right)}{\Delta x A_n}\right.$$

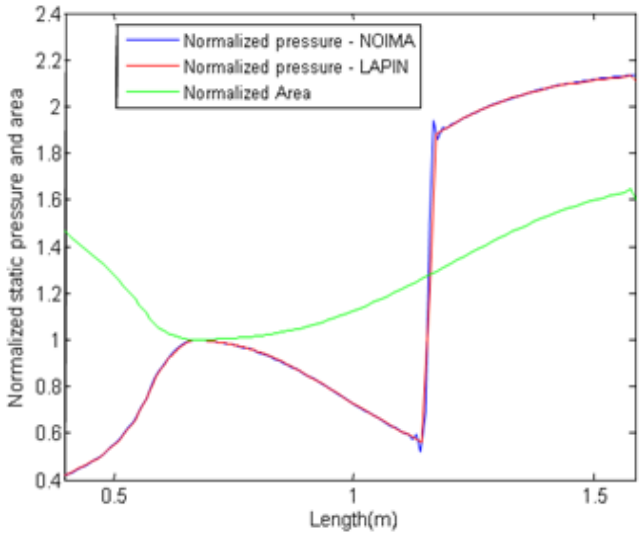




External Compression with Multiple Oblique Shocks



Single Oblique Shock & Mach Number Distribution



Normalized Inlet Steady-State Pressure & Area

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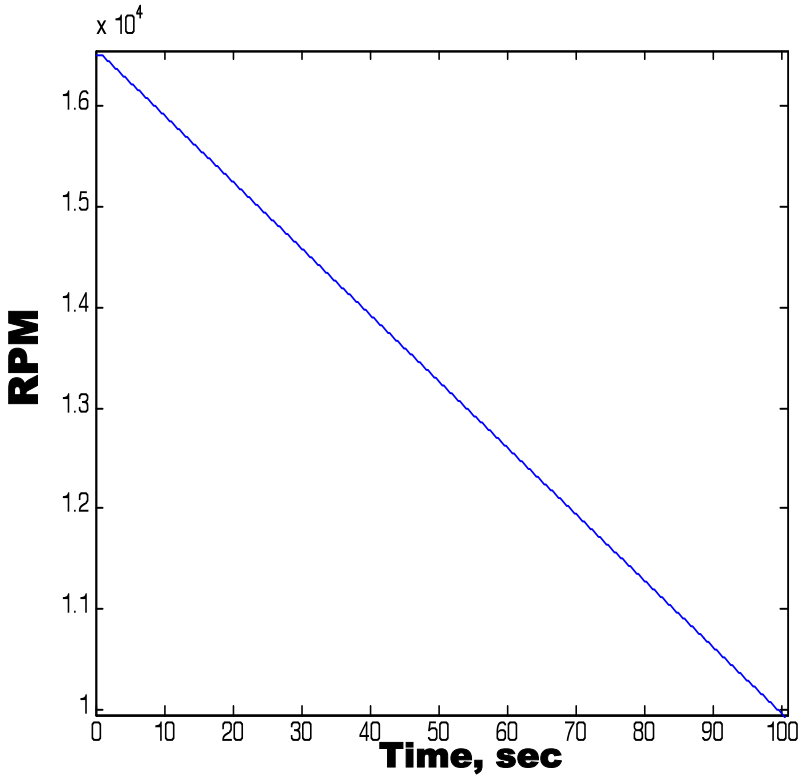
Exit Nozzle Schedule

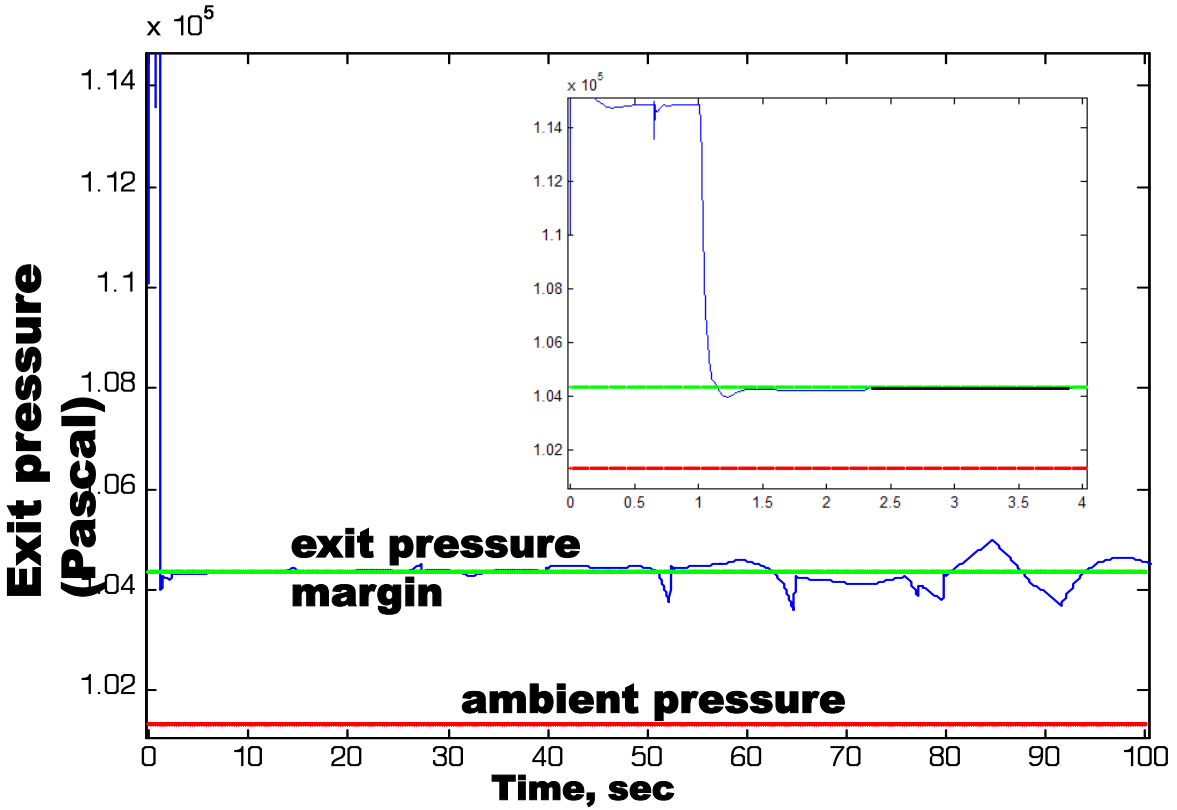
- Started developing exit nozzle area schedule approach to fully expand the flow

-- Approach based on PR vs Cd (discharge coefficient) schedule w/ area limit vs speed

-- Creates Feedback w/ instabilities – Designed Notch filters to resolve



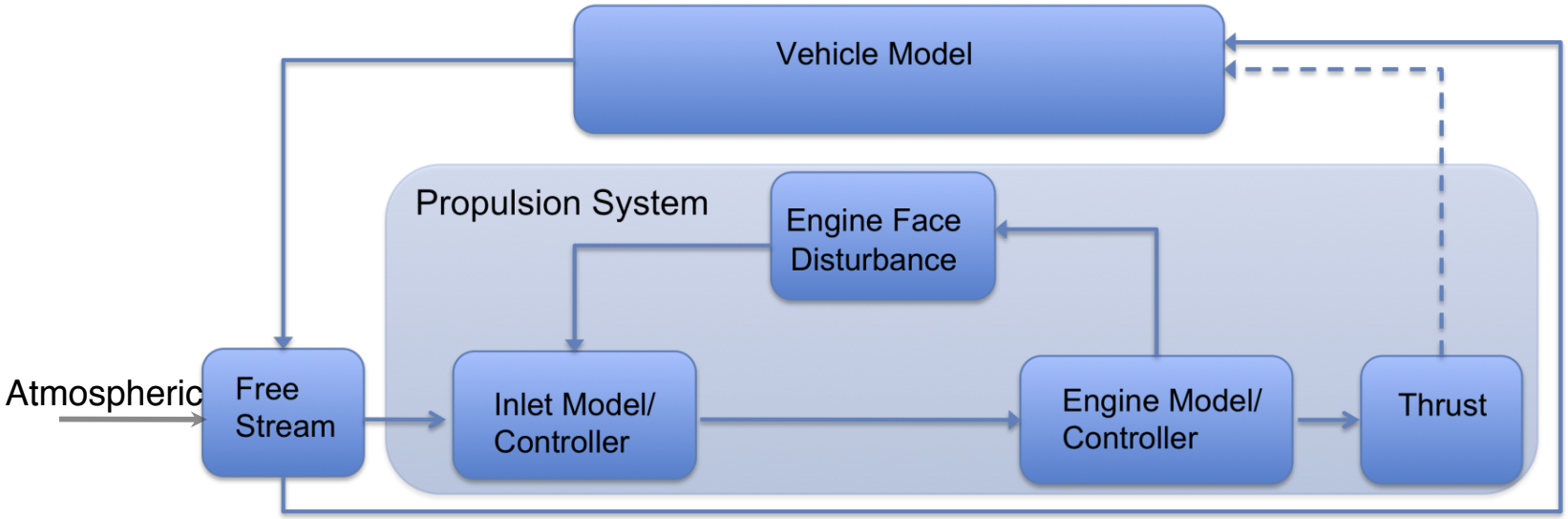
Engine Speed (100% to 60%)

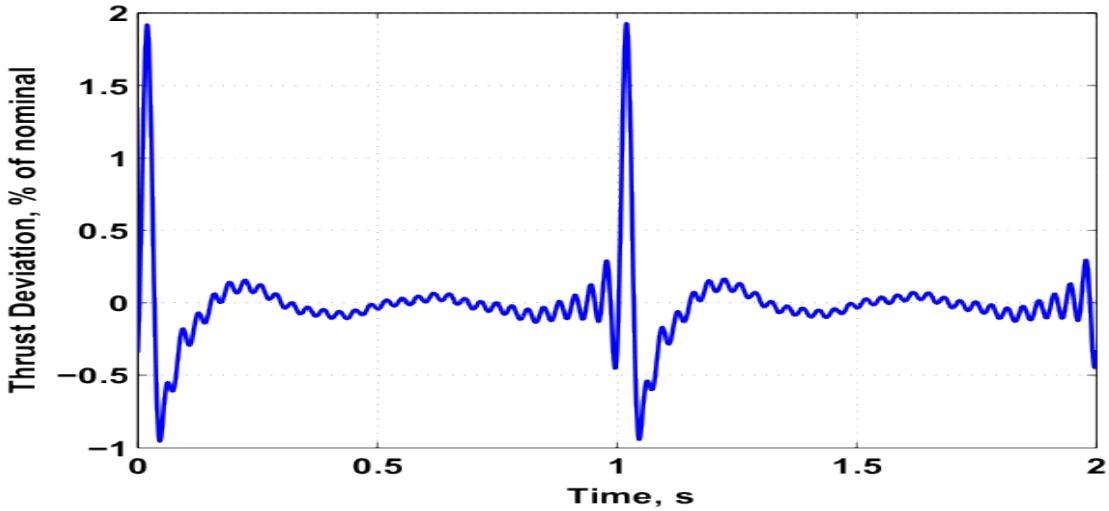


Exit Nozzle Pressure as Speed Decreases Starting from 100%

Integrated APSE Modeling

- Preliminary Linear Integrated APSE model developed





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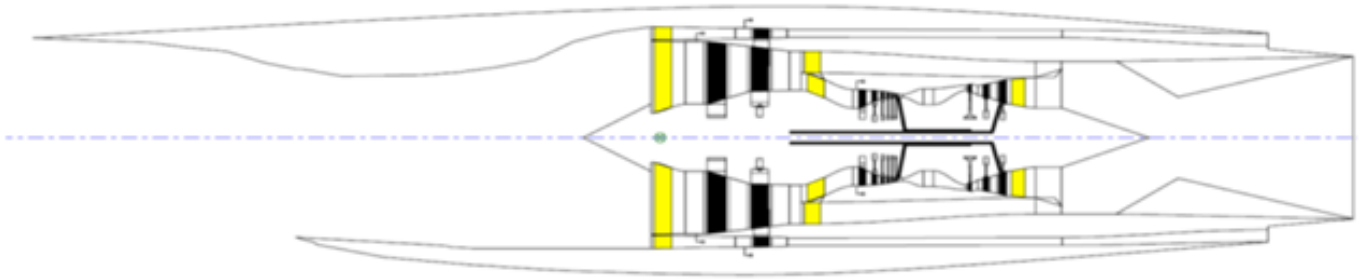
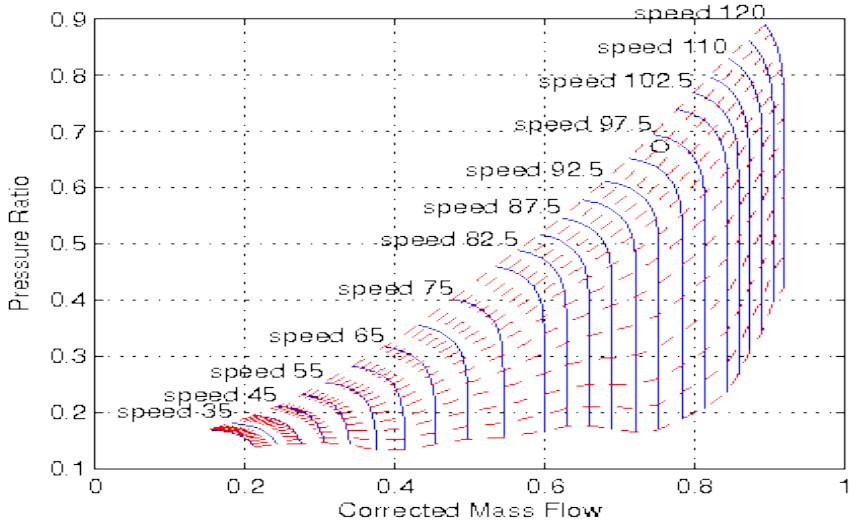
N+3 Engine Modeling

- N+3 dynamic engine model is being developed & validated based on steady-state data provided by NPSS model developers

  -- Engine has multiple flow paths – So far completed 4 out of 10 major components besides ducts and mixers



Variable Cycle N+3 Engine Diagram

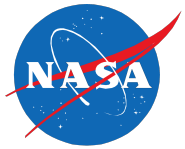


Normalized Compressor Map for Certain IGV angle

% error between dynamic model & NPSS

Design Point	P_T	T_T	W
Fan	0.1%	0.14%	0.2%
Fan VCE	0.2%	0.06%	3.7%
Compressor	4.8%	0.4%	0.07%
Combustor	2.01%	0.6%	2.97%

Future Plans



- Continue developing models (inlets, N+3 engine, parallel flow paths/distortion)
- Integrate Propulsion and AeroServoElastic models and control design
- Support Advanced Flight Simulator (AFS) Development