FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Clean-sheet supersonic engine design and performance

Project 47

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Introduction

Increasing interest in civil supersonic transport in the private sector

- 50 years ago: The first test flight of the Concorde!
- Existing environmental regulations based on the Concorde (e.g. FAA 14 CFR Part 34, CFR Title 14 Part 36.301 Noise limits: Concorde)
- Need to understand the environmental footprint of modern SSTs

Challenges posed by the SSTs:

- Engine and aircraft operating conditions are significantly different
- Propulsion systems built around existing engine cores
- No clean-sheet engine development programs

Introduction

Introduction

Project description

RESEARCH QUESTION:
What are the noise and emissions characteristics of clean-sheet and derivative engines designed for future civil supersonic transport aircraft?

Identify operating requirements for propulsion system

Build engine cycle model to explore the design space

Quantify fuel burn, noise and emission characteristics

Compare clean-sheet design to a repurposed engine core

Objectives

Understand the environmental impact of the unique operating conditions of civil supersonic aircraft

- Increased environmental sensitivity (to NO_x) at higher altitude
- Noise challenges due to higher jet velocity

Understand the challenges of supersonic aircraft engine technology

- Repurposing an existing engine core versus a clean-sheet engine design
- Increased challenge of designing for both cruise (high specific thrust – high FPR) and take-off condition (low specific thrust – low FPR)

Expected outcomes

Develop a technological basis for environmental regulations of SST

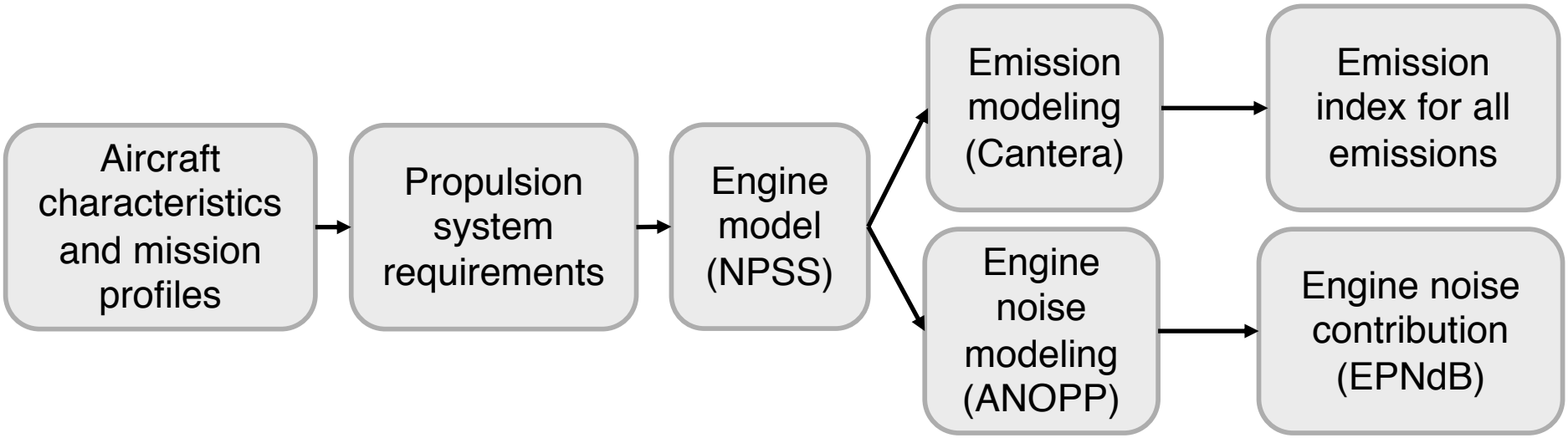
- Supersonic regulations based on the Concorde
- Lack of sufficient understanding to set meaningful regulations

Identify what new technologies are needed to mitigate the environmental impact of supersonic aircraft engines

- Prioritize components and technologies needed
- Develop a research roadmap for engine architectures

Approach

1. Develop a model to assess the noise and emissions footprint of supersonic transport aircraft



Approach

1. Develop a model to assess the noise and emissions performance of supersonic transport aircraft

2. Compute sensitivities and uncertainties associated with the environmental performance of engine technology and aircraft operating parameters

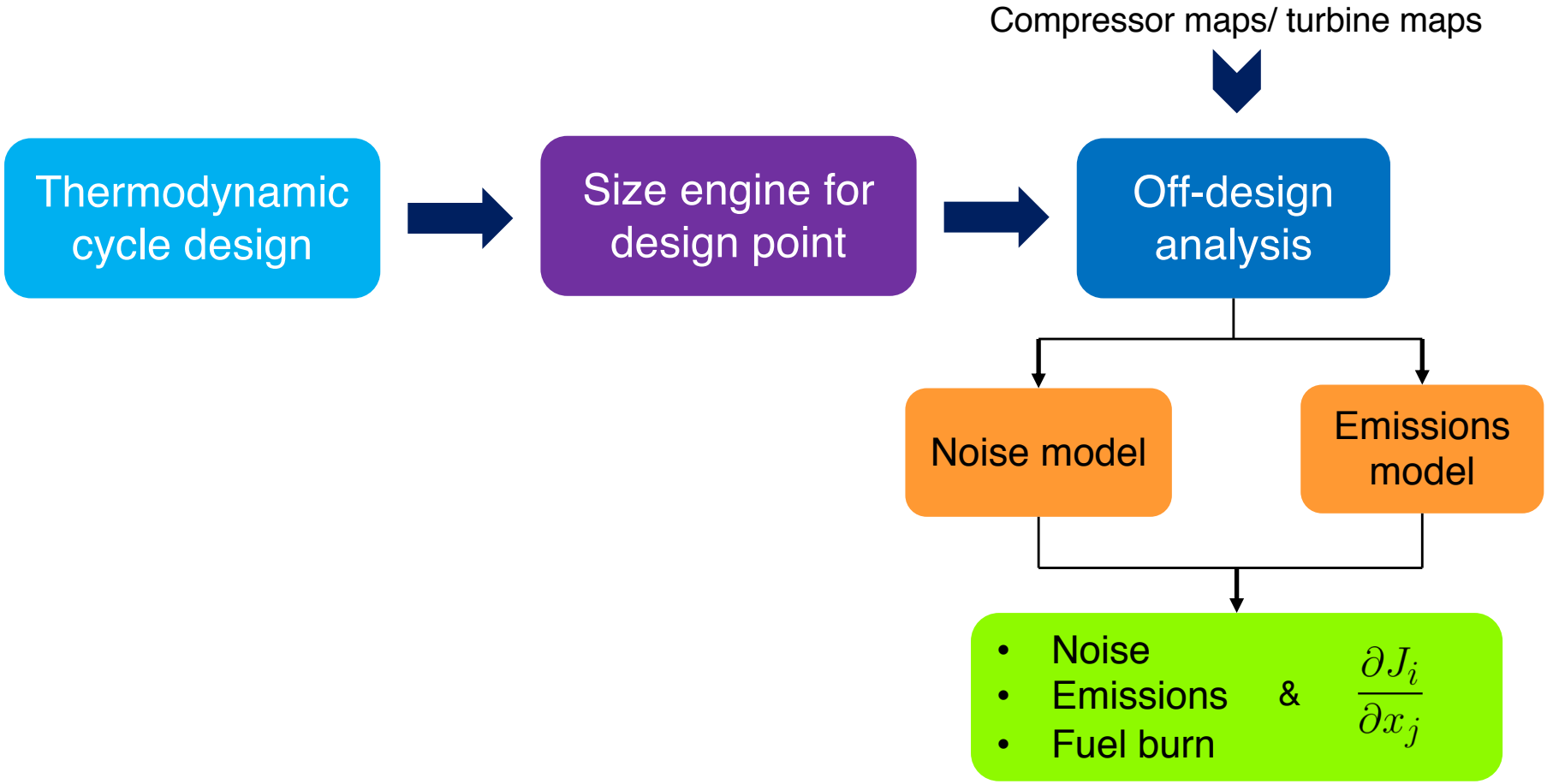
3. Compare clean-sheet engine design with a repurposed core

4. Identify key technological innovations and improvements to mitigate environmental impacts of commercial SSTs

Mission analysis

- Preliminary mission analysis using SUAVE (Stanford University Aero-Vehicle Environment)
- Considering multiple flight Mach numbers and aircraft sizes
- Collaboration with ASCENT 10: Aircraft Technology Modeling and Assessment

Engine modeling in NPSS

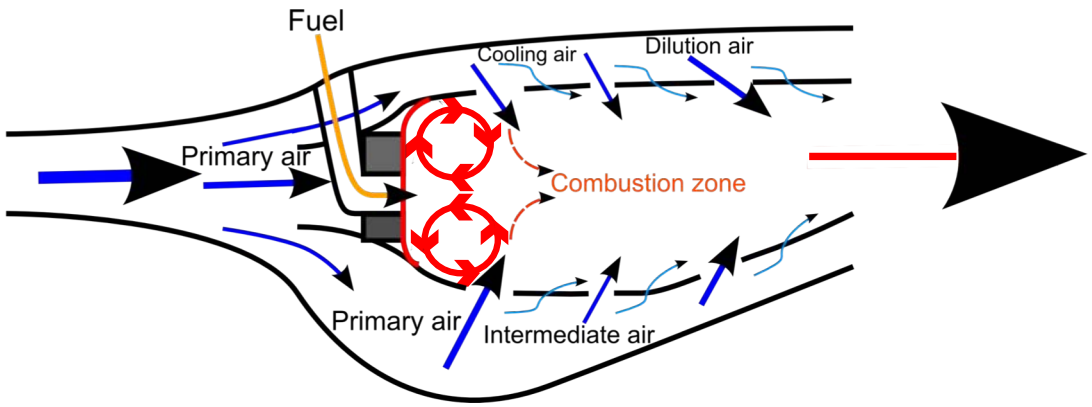


Combustor modeling Cantera

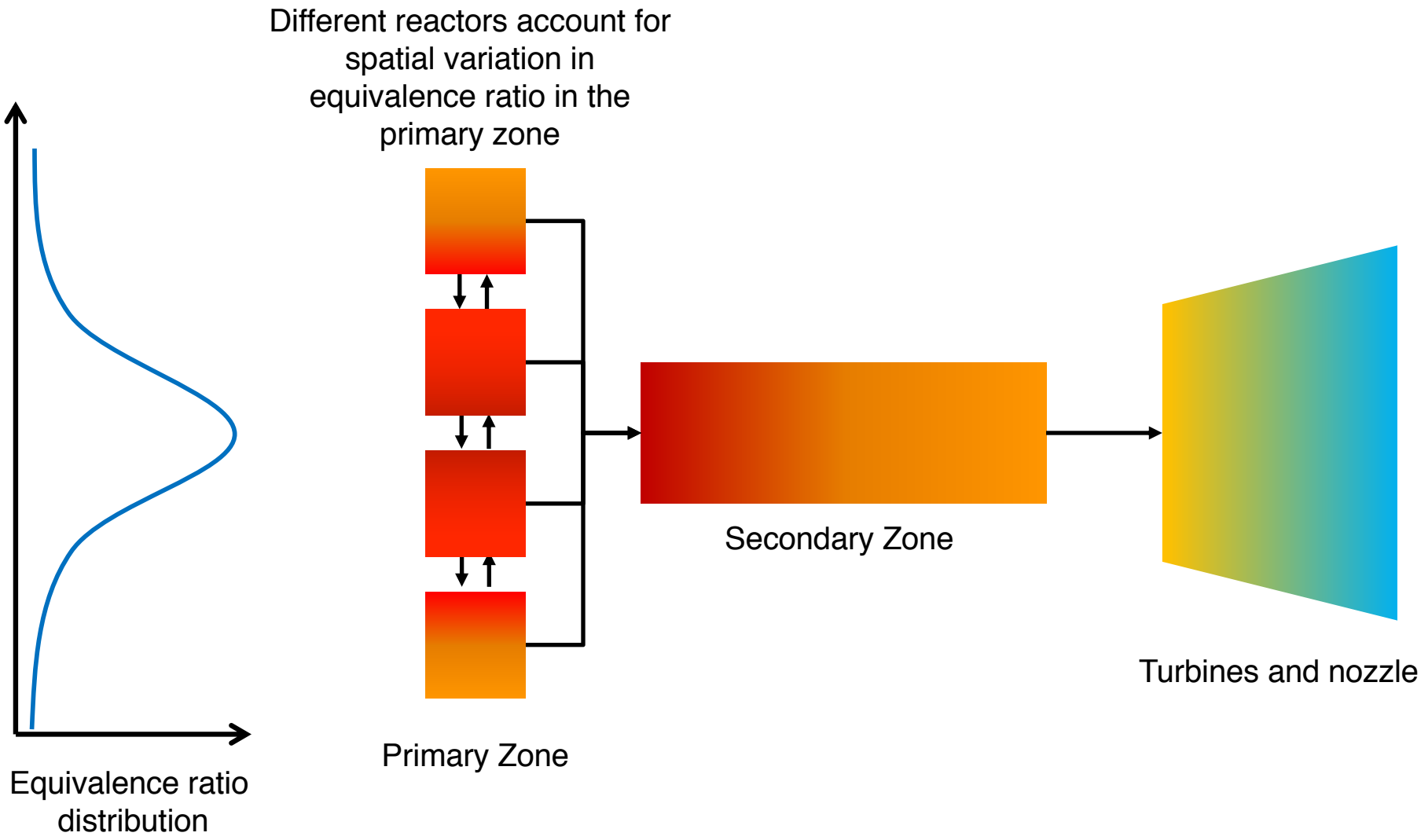
Combustor emissions impacted by flow physics as well as chemistry

Modeling approach

- Model the flow physics with a distribution of local equivalence ratios in a reactor network
- Quantify NO_x, CO and soot at design point and LTO cycle using Cantera



Approach for combustor modeling



Summary

Flight speed and altitude for SSTs affect their thermodynamic cycle and the noise/emissions performance of the propulsion system

- Combustor pressure and temperature will be different due to changes in ambient conditions as well as flight speed
- Use of existing engine core may not preserve their emissions performance
- Higher jet velocity necessary for high speed flight presents noise challenges

A first-principles based approach to provide rational basis for regulations and identifying new technologies to improve the environmental footprint

- Use industry standard models for engine performance, combustion chemistry and noise assessment
- Evaluate the design space of clean-sheet and derivative engines for SSTs and determine the resulting environmental performance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