Machine Learning Application in Aircraft Engine Conceptual Design (Invited Presentation)

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Outline

- Objectives/Motivation
- Machine learning (ML) models development
- ML models deployment methodologies
  - via a Windows app
  - via an AI chatbot
- Summary & future work
- A demo (time permitting)

Objectives/ Motivation

- To develop a ML-based engine **conceptual** design tool that would:
  - ➢ enable data-informed decision making
  - ➢ enable expeditious assessment (with reasonably good accuracy)

- To develop a digital platform that would:
  - ➢ seamlessly deploy the ML-based conceptual design tool
  - ➢ enhance knowledge sharing among peers (improve org. efficiency)
  - ➢ be simple, intuitive, easy to use (user-centric)

Engine Conceptual Design's Role at NASA

Support Advanced Air Vehicle Program (AAVP) system studies to:

- quantify the benefit of new propulsion technologies for advanced aircraft systems
- identify high payoff technologies worthy of pursuit to decision makers
- provide high-level decision-making information to project managers enabling them to:
    - establish project goals
    - conduct technology down-select process
    - track technology progress

ML Models Development

ML models are big data driven

GE	CFM	P&W		Rolls Royce		IAE
CF6-6D	56-2C1	JT8D-7	certified 1966	RB211-22B		V2500-A1
CF6-80C2A1	56-3B1	JT9D-3A		RB211-524B		V2522-A5
CF6-80C2B1	56-3C1	JT9D-7		RB211-535C		V2524-A5
CF34-10A	56-5A1	2037		Trent 768		V2525-D5
CF34-3A	56-5B1	4052		Trent 553-61		V2527-A5
•	•	•		•		V2528-D5
•	•	•		•		V2530-A5
•	•	•		•		V2533-A5
90-94B	LEAP-1A35	6122A		Trent 970-84		
90-115B	LEAP-1B25	4168-1D		Trent XWB-84		
Genx-1B54	LEAP-1B27	1519G		Trent XWB-97		
Genx-1B70	LEAP-1B28	1527G		Trent 7000-72	certified 2018	

Open-source data (ICAO, Jane's, Company websites…)

Real engine data - minimize ML model uncertainties!

NASA looks to the future

Subsonic Fixed Wing Project (SFW)	Environmentally Responsible Aviation Project (ERA)	Advanced Air Transport Technology Project (AATT)
SA-FPR1.3-GR-HW-2E	Large-DD-2014	N+3
SA-FPR1.4-GR-HW-2E	Large-DD-2015	N3CC-2016
SA-FPR1.5-DD-2D	Large-DD-2015-HWB	N3CC-2017
SA-FPR1.6-DD-2D	Large-Geared-2015	N3CC-2018
SA-FPR1.7-DD-2D	Large-Geared-2015-HWB	Small-Core-Geared
•	•	
•	•	
•	•	
SA-FPR1.3-GR-HW-2D	Medium-Geared-2014	
SA-FPR1.4-GR-HW-2D	Medium-Geared-2015	
SA-FPR1.5-GR-HW-2D	Small-DD-2015	
SA-FPR1.6-GR-HW-2D	Small-Geared-2015	

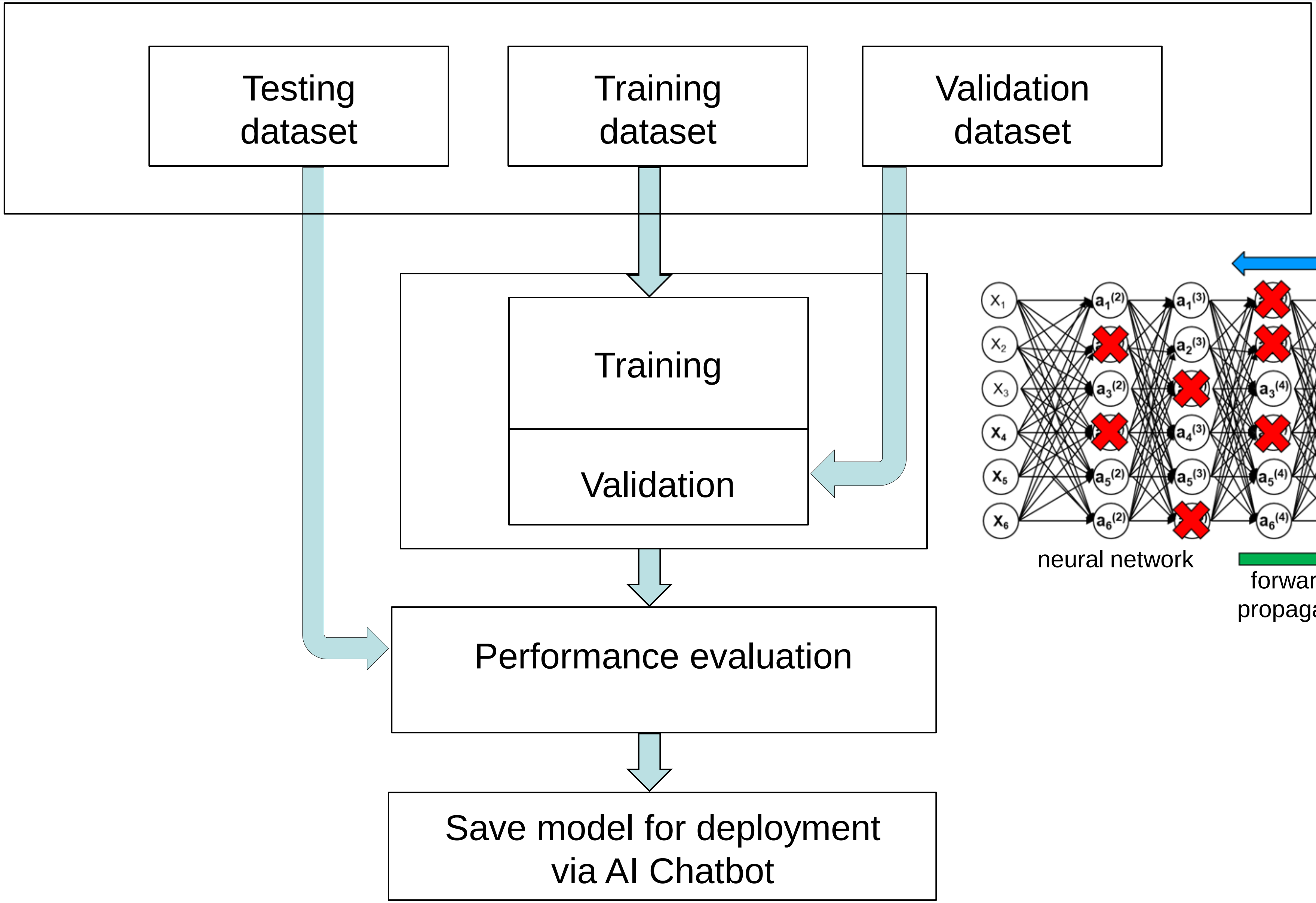
Expand database by data augmentation

Engine	No. of engines
Commercial	290
NASA	122

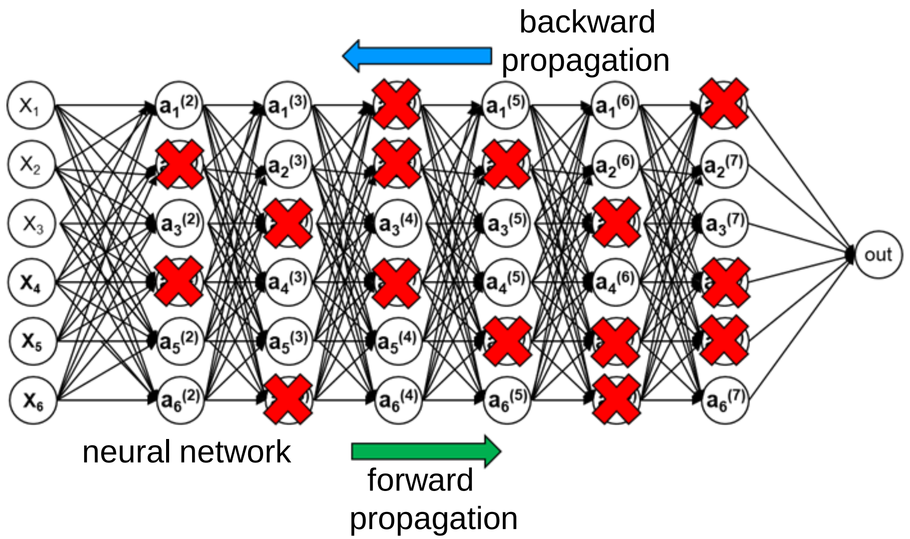
<u>Data augmentation - example</u>

BPR	OPR	SLS Thrust (lbs)	Mach	Alt. (ft)	TSFC (lb/hr/lb)	Weight (lbs)
8.44	38.37	79377	0.85	35000	.5526	18949
8.44	38.37	87315	0.85	35000	.5526	20844

ML models development process



Periodic monitoring & updating



ML models development - references

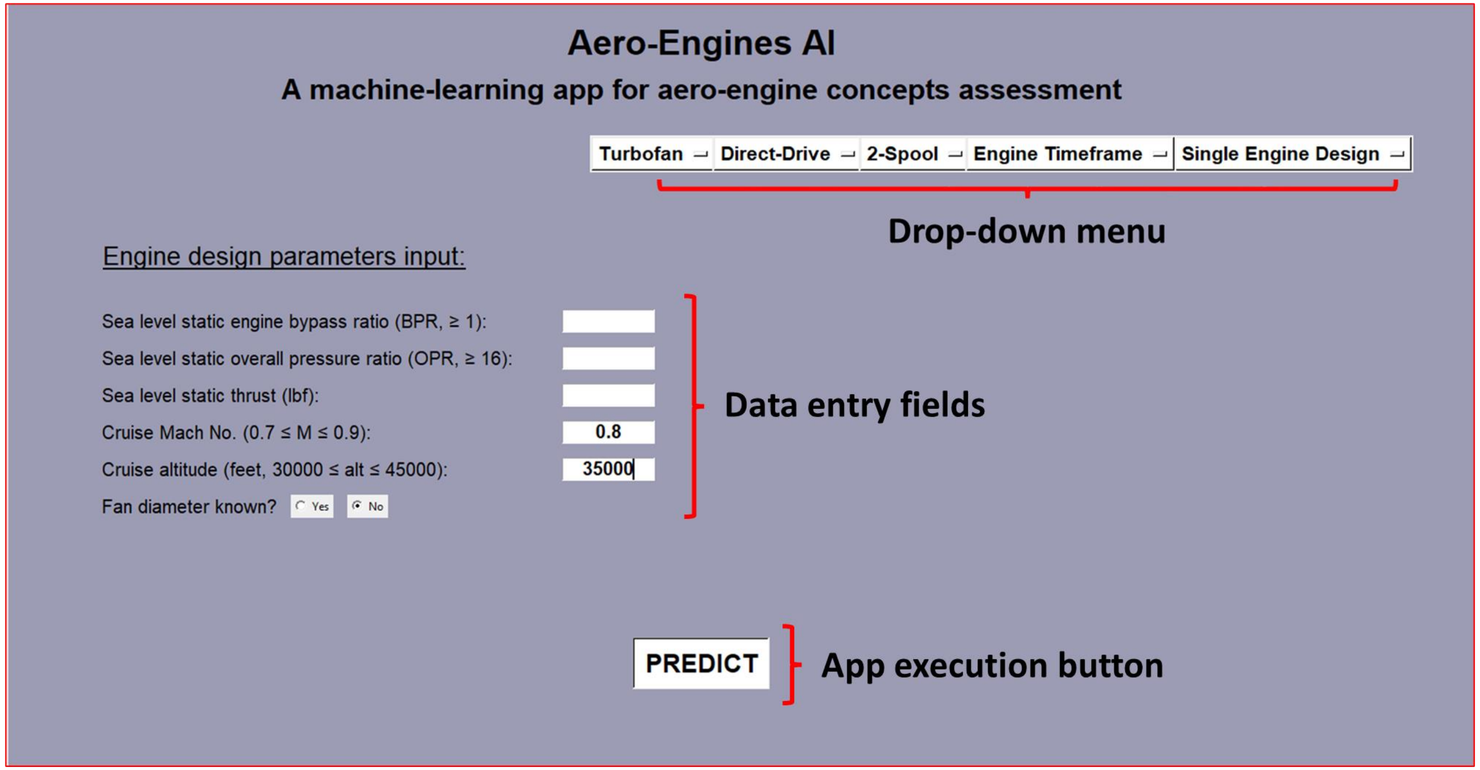
Tong, M. T., “Using Machine Learning to Predict Core Sizes of High-Efficiency Turbofan Engines,” GTP-19-1338, ASME Journal of Engineering for Gas Turbines and Power, Volume 141, Issue 11, November 2019.

Tong, M. T., “Machine Learning-Based Predictive Analytics for Aircraft Engine Conceptual Design,” NASA TM-20205007448, October 2020.

Tong, M. T., “Aero-Engines AI - A Machine-Learning App for Aircraft Engine Concepts Assessment,” NASA TM-20230012237, September 2023.

ML Models Deployment

Deployment via a point-and-click app



Reference: Tong, M. T., “Aero-Engines AI - A Machine-Learning App for Aircraft Engine Concepts Assessment,” NASA TM-20230012237, September 2023.

Point-and-Click App Design for ML Models Deployment

- Created using *Tkinter*, a Python GUI.
- Converted to a MS Windows executable using ***pyinstaller*** (Python library)
    - ➢ easy access for users (Python installation not needed)
- Focused on user experience
    - ➢ simple, intuitive, easy to use (hard work done behind the scene)
    - ➢ effective & efficient usability (instruction manual not needed)

User-centric deployment is as important as ML model development!

Deployment via an AI chatbot

Develop AI/ML Models

<u>Deployment</u>

Aero-Engines Chatbot

A digital assistant/platform for:

- Sharing knowledge among department members*
- Aero-Engines AI deployment

Deploy

<u>Development</u>

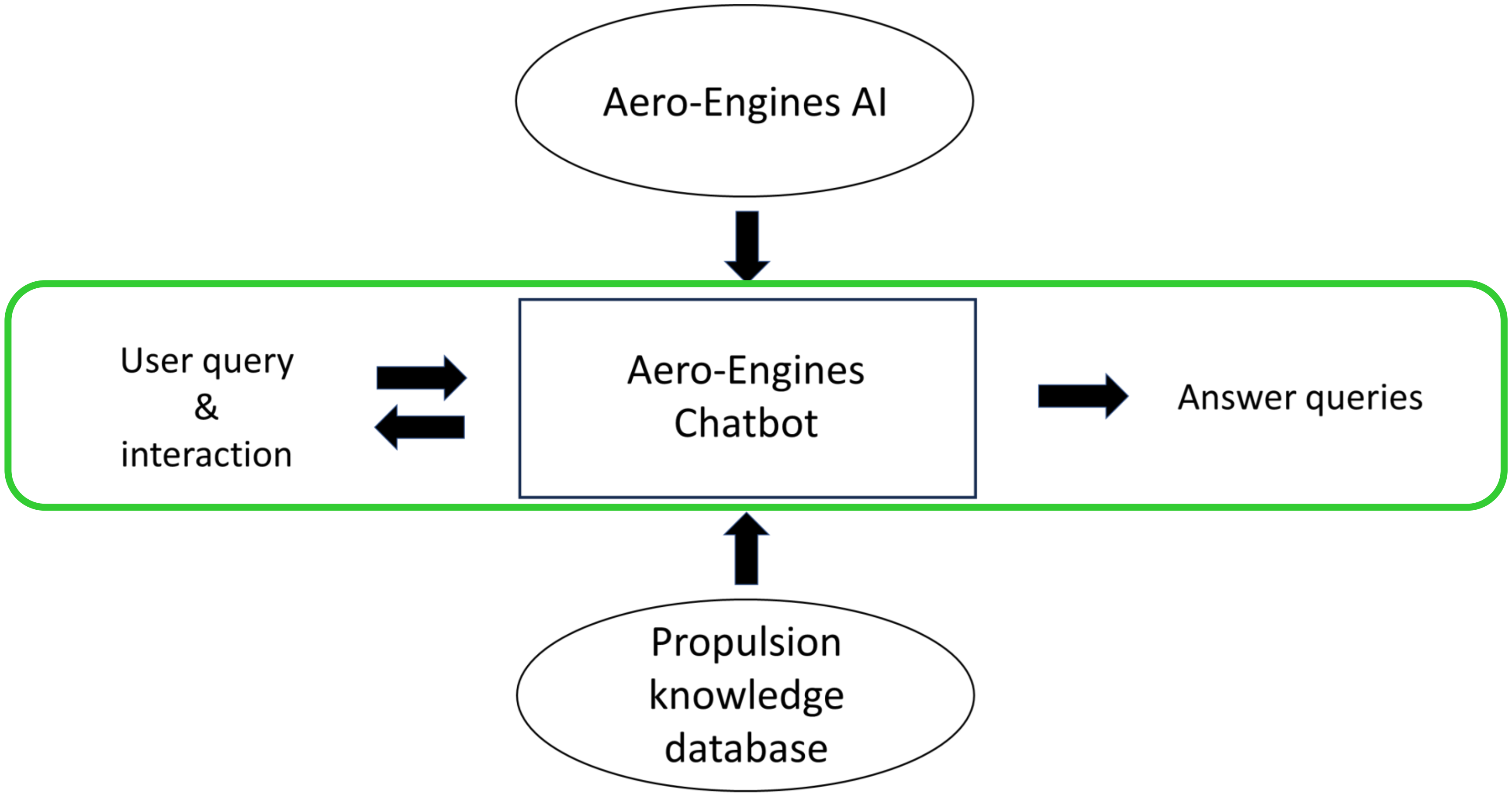
Aero-Engines AI

ML-based analytics for engine conceptual study & assessment:

- TSFC
- Engine weight & dimensions
- Turbomachinery stage counts
- Core size
- ……….

**to preserve dept. knowledge amid personnel retirements and job transitions*

Structure of Aero-Engines Chatbot



Aero-Engines Chatbot development process

- Choose a natural language processing (NLP) framework
  - python Natural Language Toolkit (NLTK)

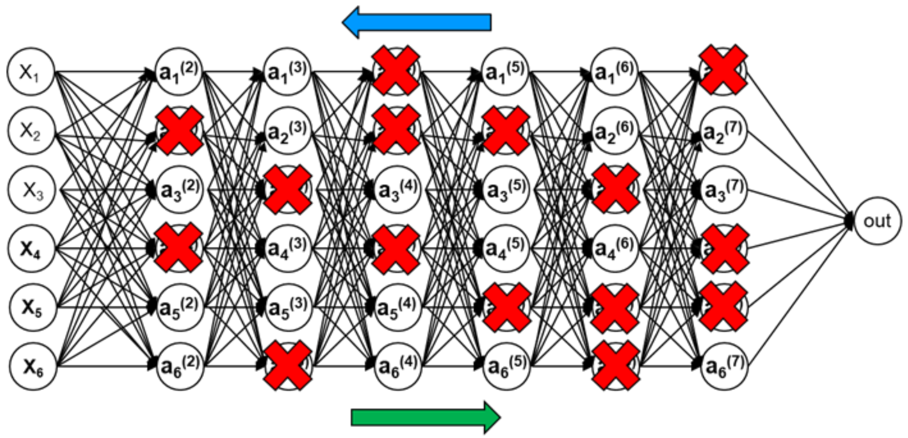
- Data (knowledge) collection and preprocessing
  - tokenization (splitting text into words or phrases)
  - lemmatization (reducing words to their root form)

- Feature extraction
  - convert text data into numerical vector (facilitate training)

- ML model building
  - construct deep-learning neural networks

- ML model training with knowledge data
  - training algorithms - use python & Google AI libraries

- Evaluating and testing



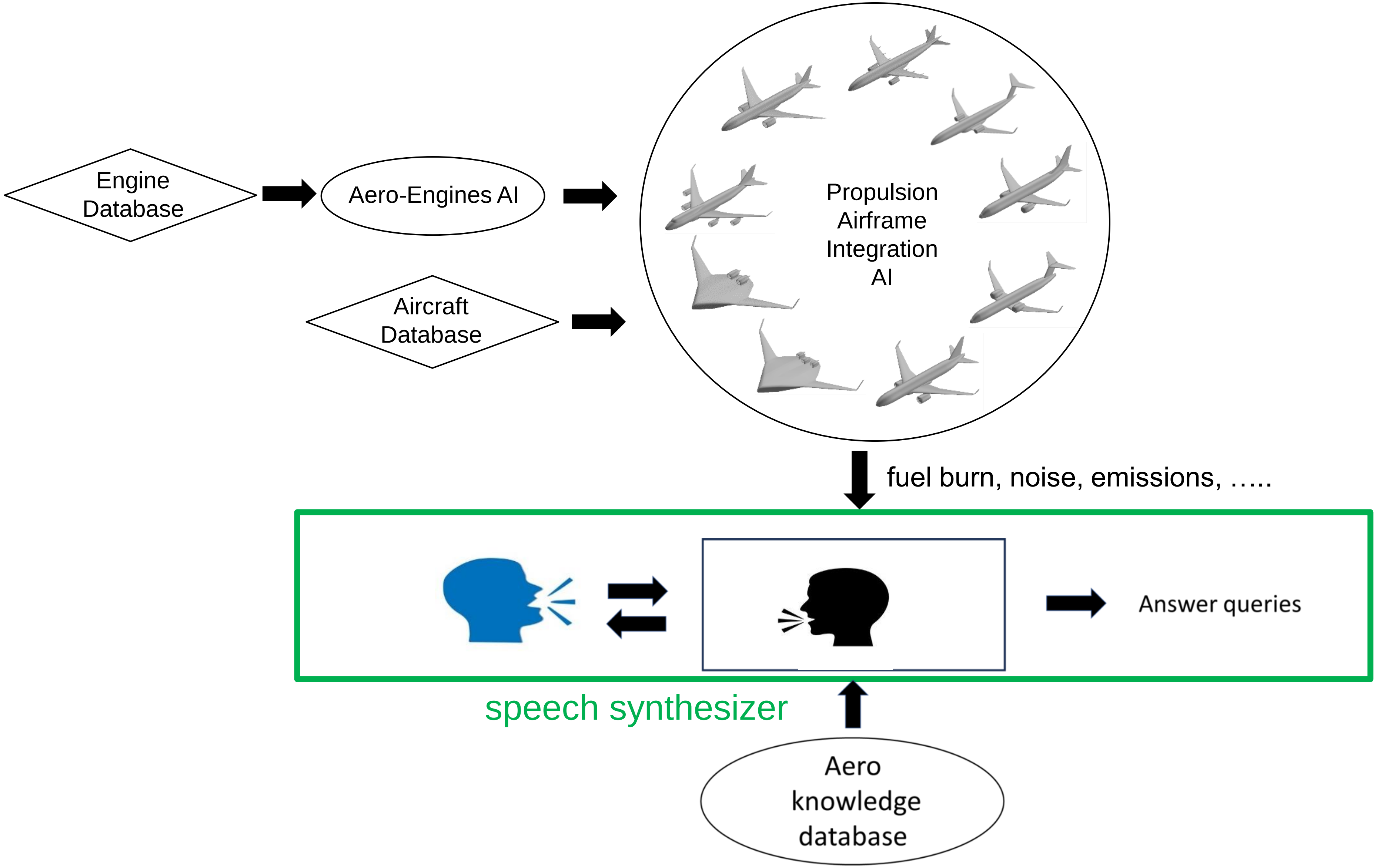
Summary

- *Aero-Engines AI* created for turbofan conceptual design study
- An app built for *Aero-Engines AI* deployment
- *Aero-Engines Chatbot* built for:
  - *Aero-Engines AI* deployment
  - propulsion knowledge sharing & management

What's next?

- *Aero-Engines AI*
  - monitor & update database to improve accuracy
  - collect data & develop ML models for other engine architectures (hybrid-electric, turboshaft, …)
- *Aero-Engines Chatbot* – expand knowledge database

An Aero AI Conceptual Design Tool – A Vision



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A demo