UNIVERSITY OF Southampton

Engineering and the Environment

Aeronautics, Astronautics and Computational Engineering

Strategic jet engine system design in light of uncertain fuel and carbon prices

UTC for Computational Engineering

Stephan Langmaak, Prof. James Scanlan and Dr. András Sóbester, Faculty of Engineering and the Environment, and Dr. Stephen Wiseall and John Whurr, Rolls-Royce plc.

1. Background

In 2008, Flightglobal* reported that:

Rolls-Royce is talking up the possibility of a new generation of turboprop-powered aircraft replacing a substantial proportion of today's narrowbody jets.

The manufacturer believes high oil prices are likely to drive airframers to sacrifice cruise speed for economics.

"The TP400 engine [for the Airbus A400M military transport] is a very efficient propulsion system," R-R Director Engineering and Technology, Colin Smith, says. "There is a very sound argument to be made for the majority of the 150-seat market, which flies mostly for less than 1.5h [being turboprop-powered]..."

*Daly, K., "Rolls-Royce Promotes Turboprop Solution for New Civil Airliners," Flightglobal, 2008.

2. Research question

Is there a business case to change the **cruise speed**

and select an **advanced engine system**

that is **financially more robust**

to **uncertain fuel and carbon prices in 2030**

than today's **150-seater turbofan-powered aircraft**

operated within **Europe**?

3. Methodology

In order to find a strategic engine design that is robust with regard to fuel and carbon price uncertainty in 2030, a Surplus Value model (Fig. 1) is being created in MATLAB which will effectively calculate the total profit generated by the aircraft operator, the aircraft and engine manufacturers and their respective supply chains. The model consists of five modules, including an aircraft design, an engine design, a flight profile, a modal shift and a travel demand element.

The flight profile module will simulate typical flights within Europe (Fig. 2) by sampling from the distribution shown in Fig. 3. The cost of these flights will partially be driven by the simulated fuel and carbon prices, as well as the cruise speed's effect on the modal shift (Fig. 4) which assumes that the market share of the plane is dependent on the average speed from door to door. The costs, in turn, will determine the air travel demand (Fig. 5) and hence the size of the aircraft fleet and the Surplus Value generated. In order to maximize the robustness of the Surplus Value, the optimizer will tune the advanced gas turbine system consisting of either a conventional or a geared turbofan, a turboprop or an open rotor engine.

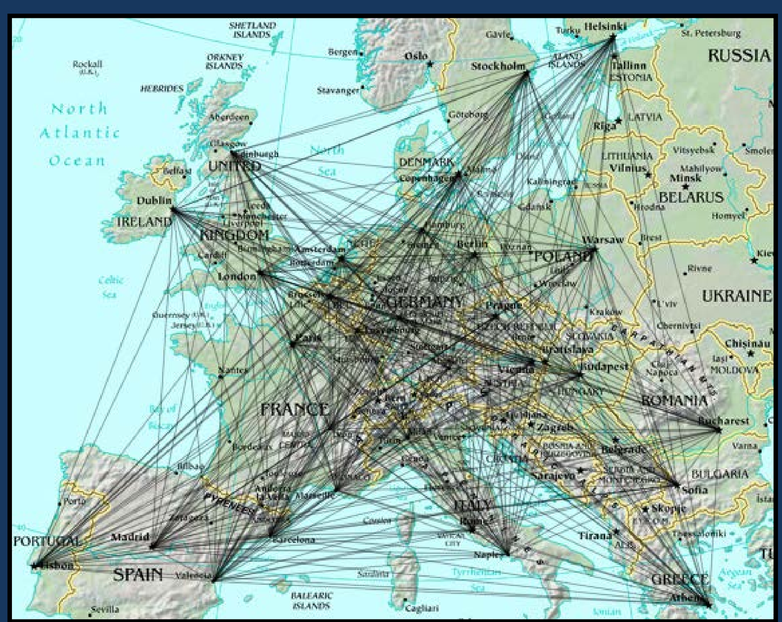

Figure 2: Simulated flight network

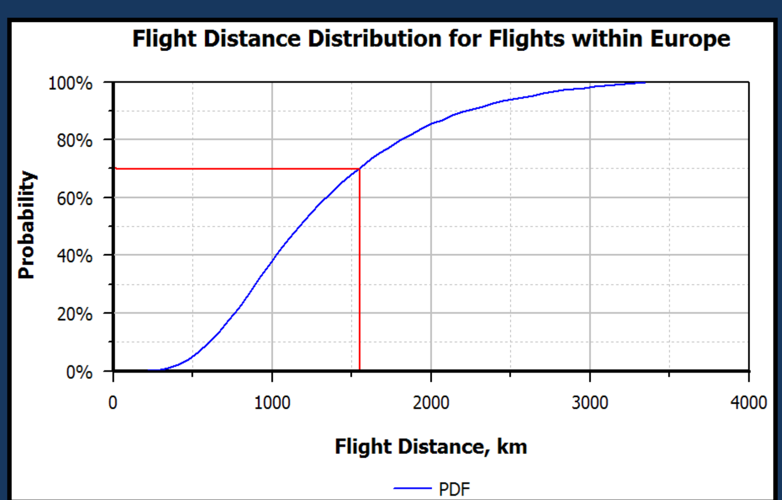

Figure 3: Flight distance distribution

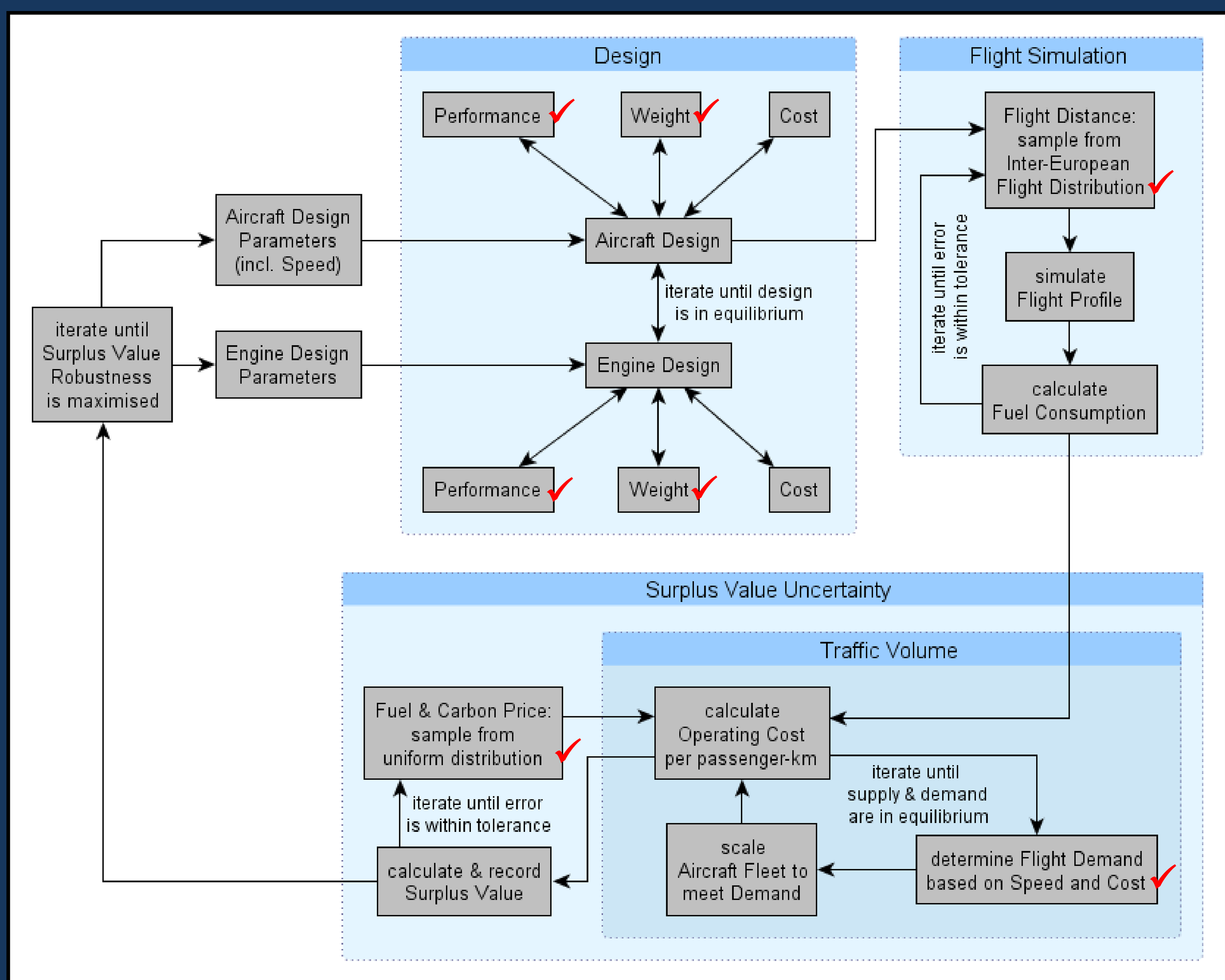

Figure 1: Model schematic

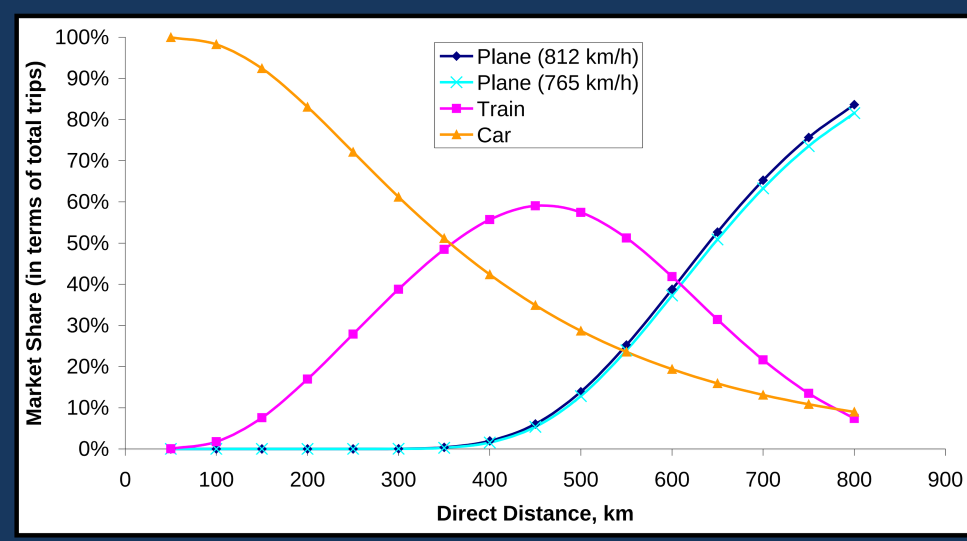

Figure 4: Modal shift

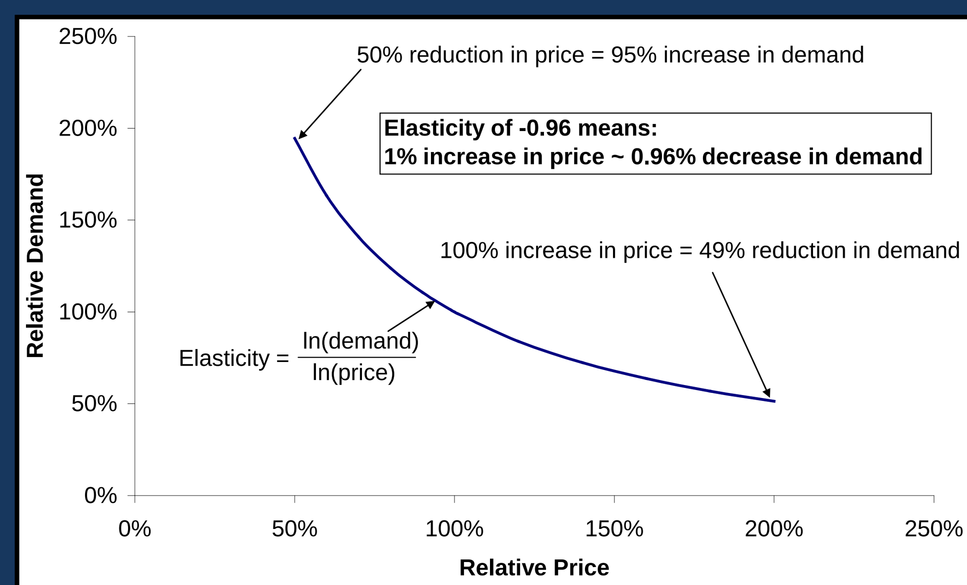

Figure 5: European air travel demand elasticity

4. Preliminary results

Fig. 6 and 7 show the 5 engine design options available, drawn to scale. The 2-shaft turbofan is presented in Fig. 6a. Its design and performance are very similar to the V2533-A5 engine which powers the current Airbus A321. It has a Sea Level Static Thrust of 147kN and an Overall Pressure Ratio of 33.4. The 3-shaft and the geared 2-shaft turbofan are illustrated in Fig. 6b and Fig. 6c, respectively. Although they obviously have different design layouts in comparison to Fig. 6a, they have identical thrust levels and overall pressure ratios. The 3-shaft turboprop displayed in Fig. 7a is based on the TP400-D6 engine that is found on the Airbus A400M. With an Overall Pressure Ratio of 25, it has a Sea Level Static Thrust of 103kN. Although the geared 3-shaft open rotor in Fig. 7b has the same core as Fig. 7a, its rotor layout is based on the open rotor configuration developed by Snecma as part of the DREAM* project.

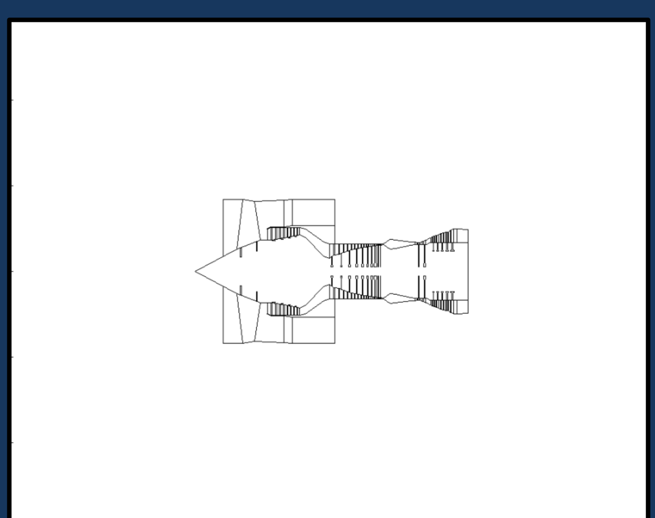

Figure 6a: 2-shaft turbofan (similar to V2500 engine)

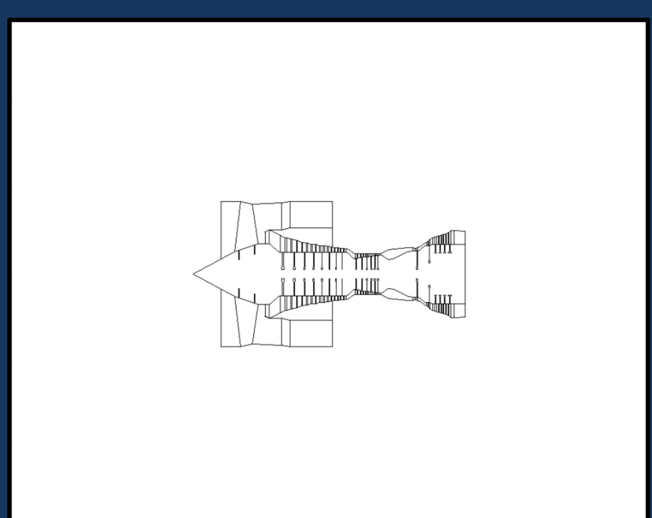

Figure 6b: 3-shaft turbofan (with V2500 performance)

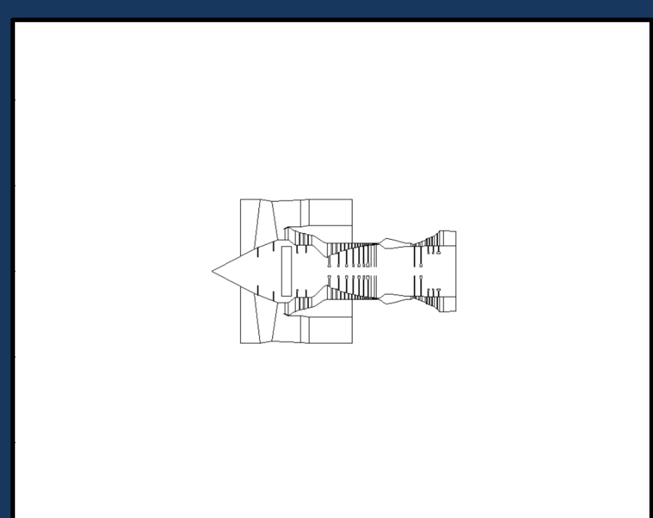

Figure 6c: 2-shaft geared turbofan (with V2500 performance)

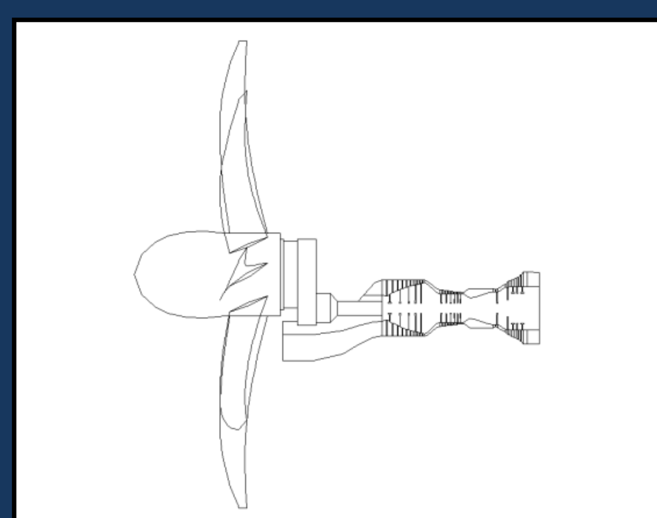

Figure 7a: 3-shaft turboprop (similar to TP400 engine)

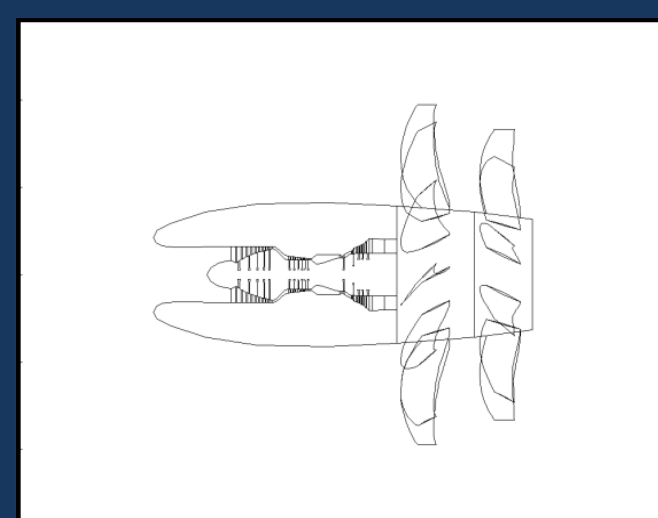

Figure 7b: 3-shaft geared open rotor (with TP400 performance)

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* **DREAM** = vali**D**ation of **R**adical **E**ngine **A**rchitecture syste**M**s

http://www.soton.ac.uk/engineering/research/groups/CED/posters.page | email: s.langmaak@soton.ac.uk
Computational Engineering & Design Group, University of Southampton, SO17 1BJ, U.K.