2.4 Climb-Cruise Engine Matching - An Optimisation Approach

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Abstract (Technical Topics and Desired Outcomes): Aircraft design involves optimising a multi-component system, where each system has sub-components. There are uncertainties in the physical parameters in models of each system, and each system is subject to noise from the environment and from other sub-systems. Many disciplines are involved. There is a large and evolving literature on what is sometimes called, 'bi-level' optimisation, where an optimisation problem involves one or more variables that are optimal for some other optimisation problem that is coupled by one or more variables to the higher-level problem. This Use Case - originally posed at the 2016 Study Group - might be a multi-level version of such bi-level problems generalised by including uncertainty from outside and from within the system [2]. The work at the 2016 Study Group, mainly with surrogates and emulators, could perhaps be usefully combined with ideas on bi-level optimisation.

Objectives: Consider a use case in the context of a 24-hour operation aircraft; a key implication is that aircraft can operate within noise curfews. Then, using a Set-Based Design approach, explore a multitude aircraft configurations with respect to their climb out Noise Levels, the Cruise Performances and Gaseous Emissions, under uncertainty. The basic concept is to generate data for a set of representative single aisle aircraft configurations by combining a multitude of airframes with a multitude of engines. Specific noise measurement criteria in terms of the location of the measurement system and the type of noise level need to be deduced. Then, using coupled analyses 'plug-ins', derive the performance models that enable an architect to explore the sensitivities amongst three exemplar measures of aptness. For this use case these are:

- Noise Levels (lower is better); conversely, Noise Level **Margin** (higher is better)
- Cruise Fuel Consumptions (lower is better)
- Gaseous Emissions (lower is better); conversely Gaseous Emissions **Margin** (higher is better)

Figure 5: Overall Concept of UQ&M in a Set-Based Design Approach

This provides a multi-dimensional challenge for determining, visualising and acting on the uncertainties that propagate through the analyses to these measures of aptness. The main objective is to narrow the set of possible aircraft configurations to a set of feasible ones using uncertain, multi-dimensional decision criteria. The process is then repeated, using analyses models closer to the laws of nature, to narrow the set of feasible aircraft configurations to a set that provides competitive advantages - process shown in Fig. 5.

UQ&M Aspirations: The UQ&M analyses will be used for:

- robust design-making to narrow a set of possible aircraft configurations
- discovering the parameters that strongly contribute to the variations in the measures of aptness
- managing key parameters to drive reliably towards the desired properties and behaviours

Resources Available for this Problem:

- Simulation experts from Airbus
- Data generated through CONGA project to support analysis for a multitude of airframes with a multitude of engines (provided in `.csv` format).
- Access to AirCADia environment - an interactive tool for the composition and exploration of aircraft computational studies at early design stage.

References:

1. Full problem details can be found here: Climb-Cruise Engine Matching. A presentation will be given on the first morning of the Study Group.
2. Final report: Climb-Cruise Engine Matching. Various Authors (2016)