FUTure PRopulsion and INTegration

towards a hybrid-electric 50-seat regional aircraft

Application of probabilistic principles to Set-Based Design for the optimisation of hybrid-electric propulsion system

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Andrea Spinelli, Luchien Anderson, Hossein Balaghi Enalou, Bahareh Zaghari, Timoleon Kipouros, Panagiotis Laskaridis





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Single-Point Design vs Set-Based Design



Set-Based Design is most suited for *Design Space Exploration* especially of

Innovative Concepts



Hybrid-Electric Propulsion Systems



1 - Georgiades, A., Sharma, S., Kipouros, T., & Savill, M. (2019). ADOPT: An

Previous Work: ADOPT[1] (Set-Based Design & MDO)

Step 1 Filtering



Continuous Design Space



Major Drawback: Previous experience required to avoid combinatorial explosion (Expert Rules)





Probabilistic Set-Based Design with Optimization (P-DOPT)

Solution: Replace Expert rules with a Statistical Model and Probabilistic Evaluation



Test Case: Power Scheduling of Parallel Hybrid Turboprop



Exploration of the degree of hybridisation in cruise and climb under different conditions for an ATR-42 class airplane fitted with a Parallel-Hybrid propulsion system flying a mission of 300 NM.

Objectives: Minimize Take-off Mass and Burned Fuel.

Constraints: Minimum system efficiency of 0.4, Take-Off Mass under MTOM (20000 kg). **Constraints used also as requirements in Step 1 filtering.**

Input Parameter	Range	Levels
Climb Degree of Hybridisation	0.1-0.9	3
Cruise Degree of Hybridisation	0.1-0.9	3
Battery Energy Density	200-500 Wh/Kg	3
Motor Power Density	6000-7000 kW/kg	3





Results from Step 1: Probabilistic Filtering based on Requirements





Results from Step 2: Multi-Objective Optimisation within surviving sets



Out of 81 sets, only 15 were kept from Step 1



Results without Probabilistic Filtering (Unconstrained optimisation in all sets)





	Run with Filtering	Unfiltered Run	Change %
Number of Sets	15	81	-81.48 %
Number of evaluations	20780	107130	-80.60 %
Total Opt. Runtime (s)	12.85	86.22	-85.09 %



Conclusions and Future Work

- Set-Based Design principles are most suited for Design Space Exploration activities
- Previous SBD methodology required expert rules to be effective.
- Data-driven probabilistic models can be used to discard the areas of the design space that can't meet the user requirements, without the need of expertise.

Future Work: Include Uncertainty Quantification on the optimised datapoints in Step 2 for robustness evaluation.



Take-Off Mass [kg] Resulting Pareto Front from the test case





THANK YOU!

Andrea.spinelli@cranfield.ac.uk
www.cranfield.ac.uk
45 College Road, Cranfield, UK

