MISSION PROFILE GENERATION FOR URBAN AIR MOBILITY

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Summary:

A control-and-mission-centric conceptual design tool has been developed in the MATLAB/Simulink environment. The overarching aim was to build a framework for a comprehensive concept design tool to combine different phases of flight into an overall mission, and output control requirements to analyse performance.

KEY ACRONYMS:

eVTOL: electric Vertical Take-off Landing

UTM: Urban Traffic Management

LQR: Linear Quadratic Regulator

UAM: Urban Air Mobility

CHALLENGES IN URBAN AIR MOBILITY

NOVELTY

Hybrid fixed-wing eVTOL designs

High variability

Empirical data is limited

Modelling transition is complex.

COMFORT **SAFETY** **COST**

Comfort, safety (both in certification, and its perception), and cost are all key limitations in the adoption of UAM.

TRAJECTORY

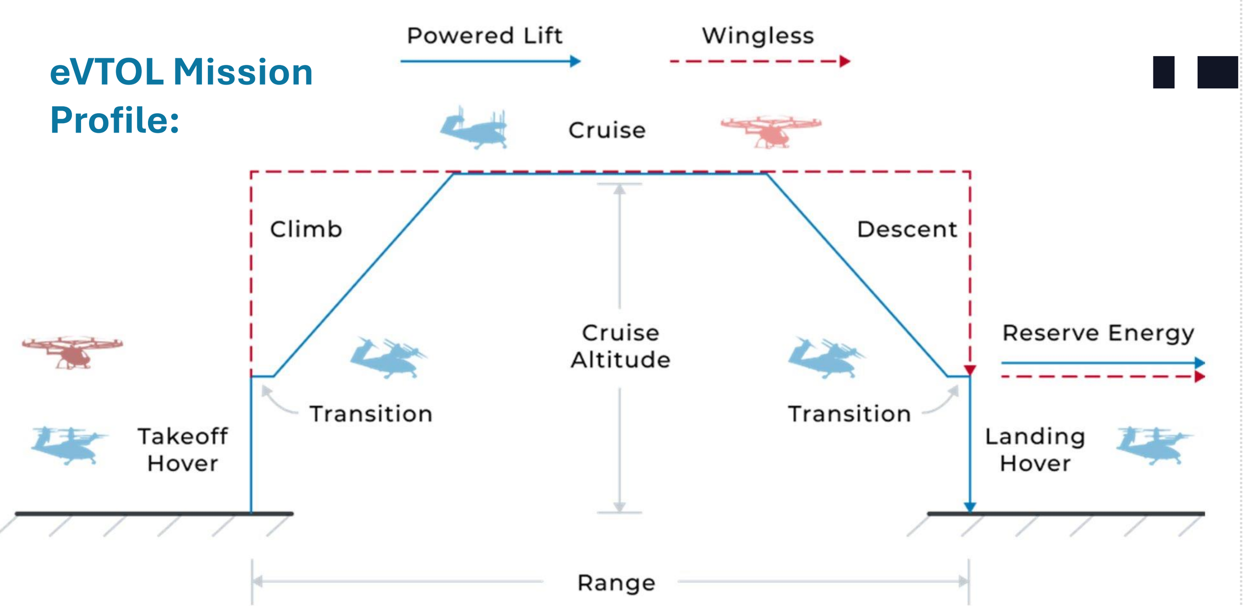
Vital to certification.

Short journeys in urban areas present unique challenges.

UTM/ATM

Significant infrastructure is required around Urban Traffic Management (UTM).

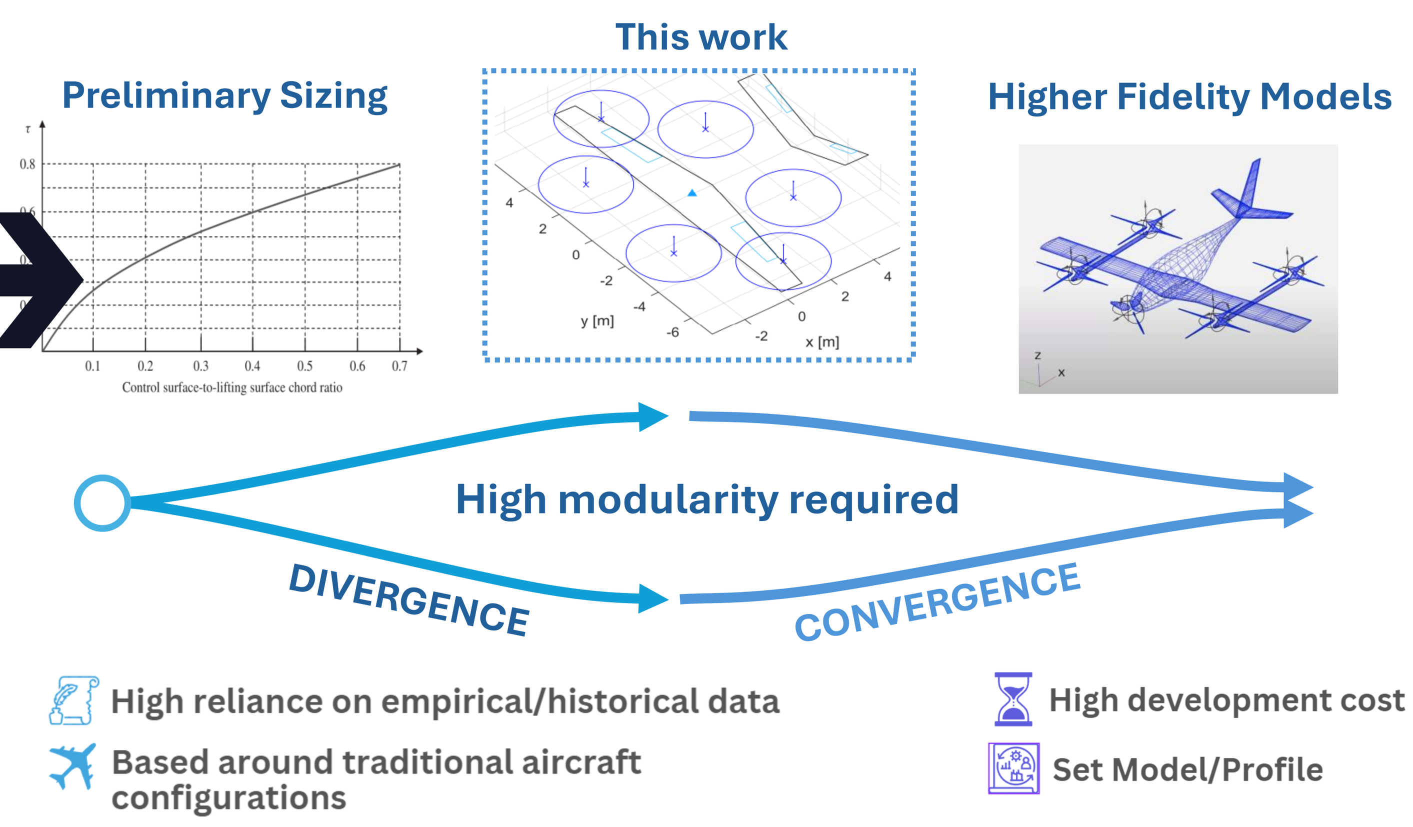
eVTOL Mission Profile:



WHERE DOES THE TOOL FIT IN?

A conceptual design tool has been developed combine different phases of flight into an overall mission, to analyse dynamic performance in 6DoF.

Current tools rely on experimental, semi-empirical, or CFD data.

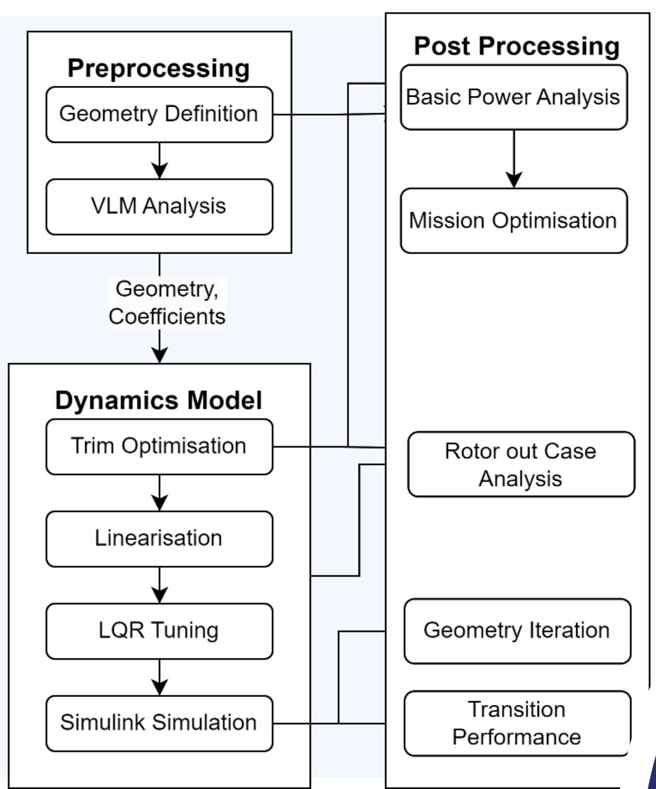


PROPOSED WORKFLOW

APPLICATION

The tool may be iteratively applied to assess:

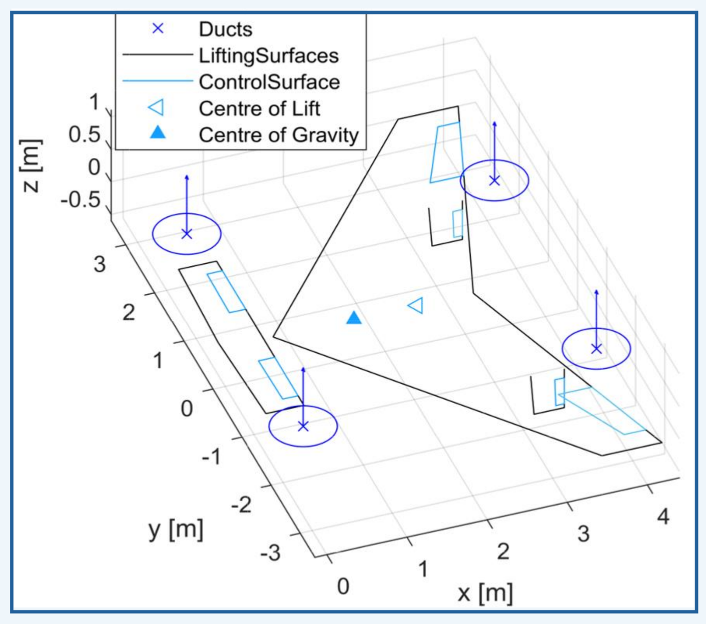
- Mission power requirements
- Transition performance/optimisation
- Safety and redundancy
- Rotor position and number
- Sensitivity analysis of aircraft geometry

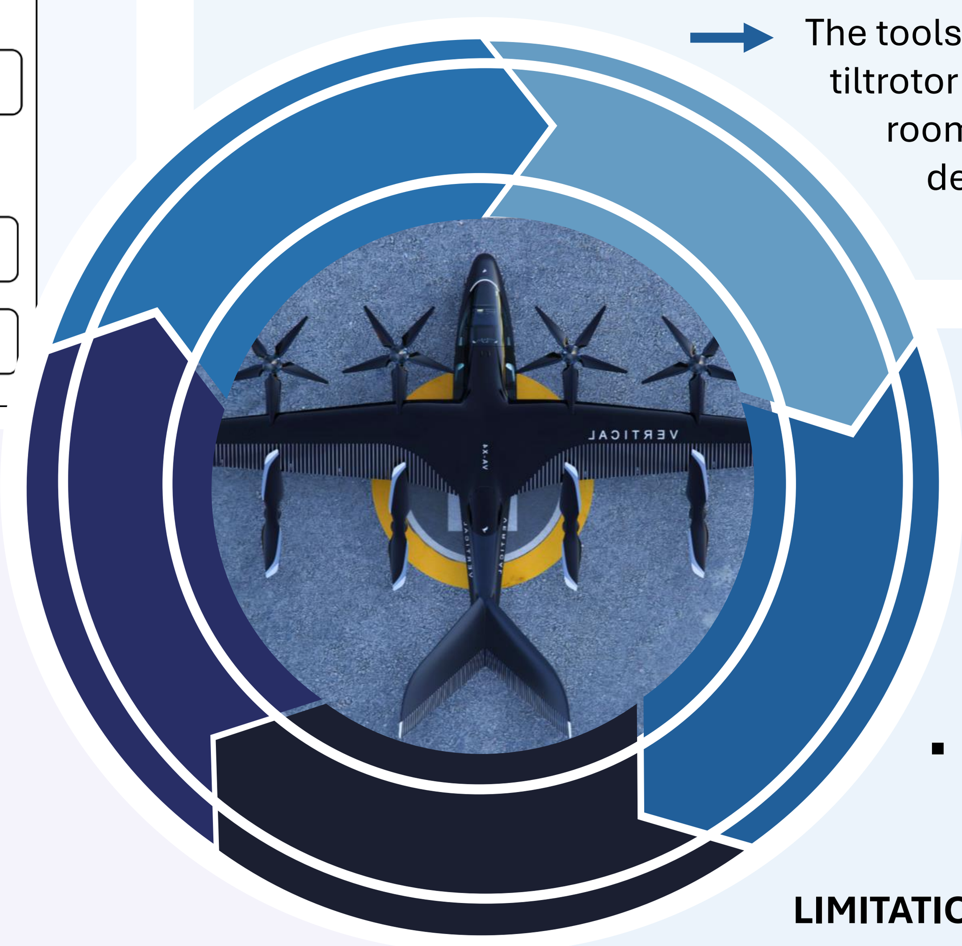


THE IMPORTANCE OF GENERALISED MODELS

An object-oriented approach is taken to allow for a high level of flexibility and modularity.

The tools can be applied to any tiltrotor configuration, with room for further development





CHARACTERISING AERODYNAMICS

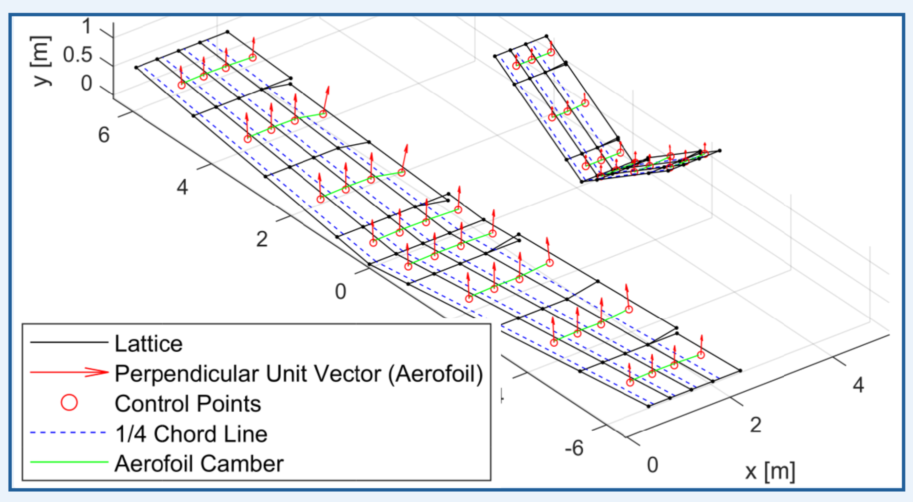
A 'Vortex Lattice Method (VLM)' module is developed to characterise aerodynamic behaviour by linear derivatives.

ADVANTAGE

- Widely applicable

LIMITATIONS

- Does not represent viscous effects, such as stall
- Underestimation of drag



AUTOMATED CONTROL LAW DESIGN

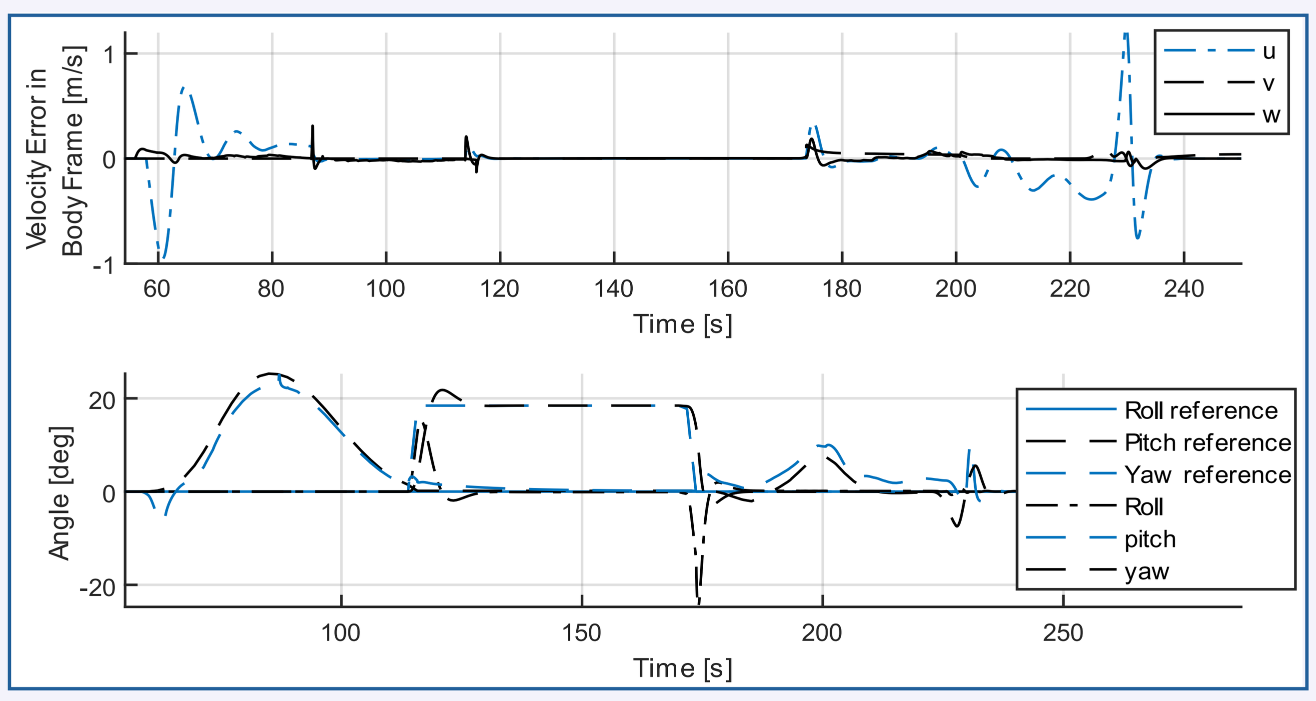
To provide insight into controllability, transition performance, and passenger comfort, an automated control design methodology is created.

Linear Quadratic Regulator (LQR) control, an optimal controller has been tuned automatically by particle swarm optimisation.

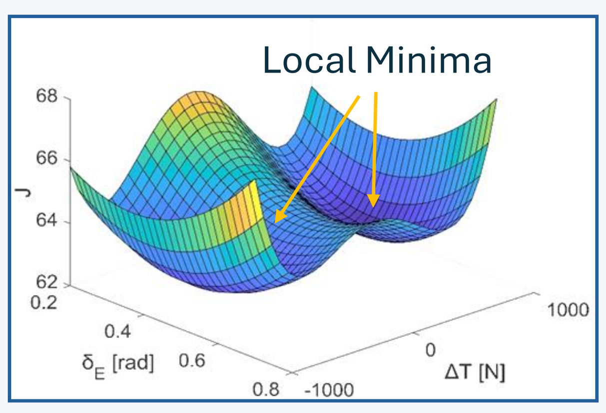
LQR minimises the error (J) by balancing:

Reduction of State Error **Controller Effort**

$$J = \int_0^\infty (\tilde{x}^T \boldsymbol{Q} \tilde{x} + \tilde{u}^T \boldsymbol{R} \tilde{u})\, dt$$



TRIM OPTIMISATION



*The combination of rotorcraft controls and aerodynamic cruise controls (aileron, rudder etc.) results in an **over-actuated** system with several local minima.*

To obtain control for trim:

- ❑ The presence of local minima requires a gradient-free global algorithm
- ❑ A highly exploratory particle swarm algorithm was employed