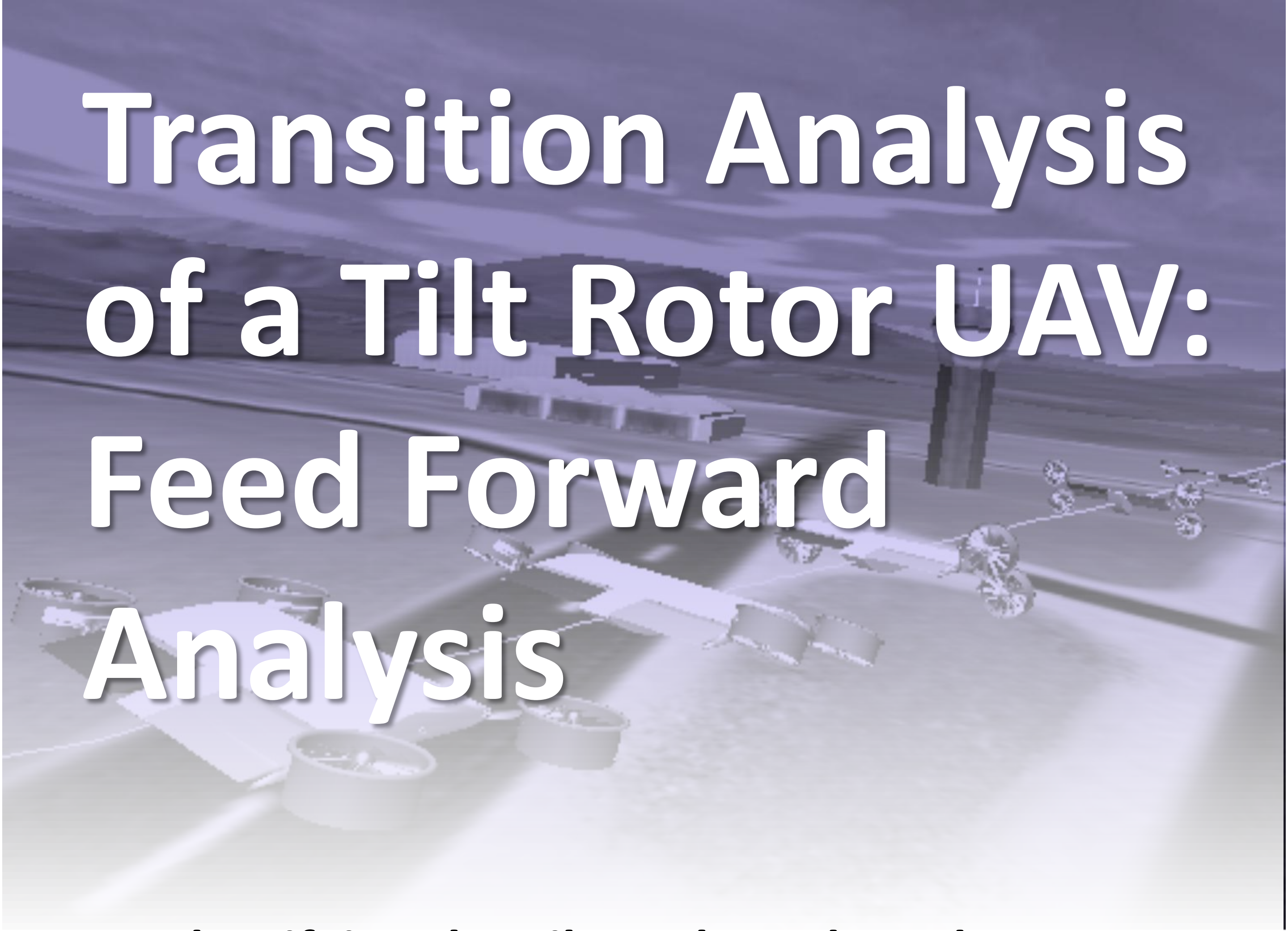
# Transition Analysis of a Tilt Rotor UAV: Feed Forward Analysis



**Identifying the Tilt angle and Feed Forward scheduling for Transition between Hover and Forward Flight. Using a Tilt Rotor UAV complete with variations in engine thrust location and centre of gravity and payload using the j2 Universal Tool-Kit**

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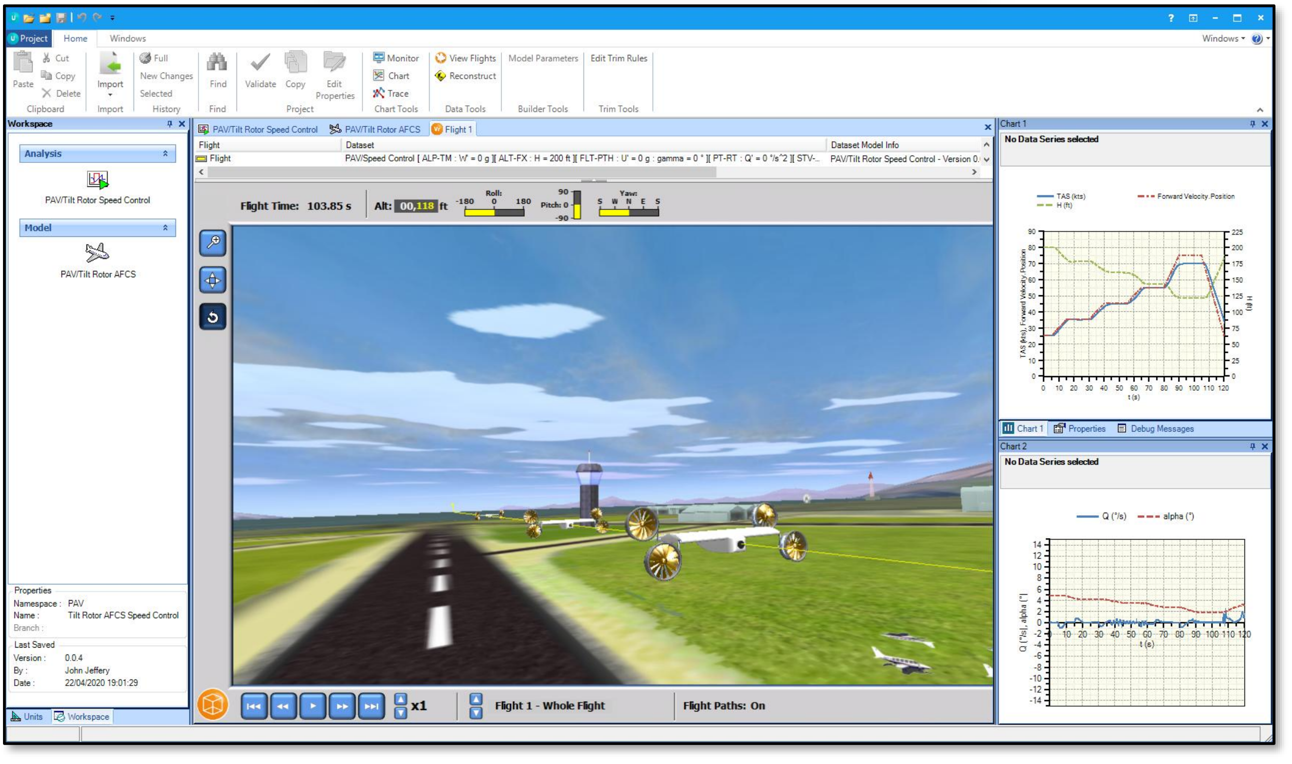
# The Challenges

**When considering PAV's and eVTOL aircraft, there is a critical phase in the flight path as the aircraft transitions from hover/vertical flight into forwards flight.**

Whether this transition is through the tilting of the complete aircraft, or the change in orientation of the engines and the balancing of thrust as in a tilt rotor, it is important to have an understanding of the aircraft behaviour and the blending/balancing of the thrust, thrust orientation, control surfaces, and throttle order to evaluate the response of the aircraft leading to development of the Automatic Flight Control System (AFCS).



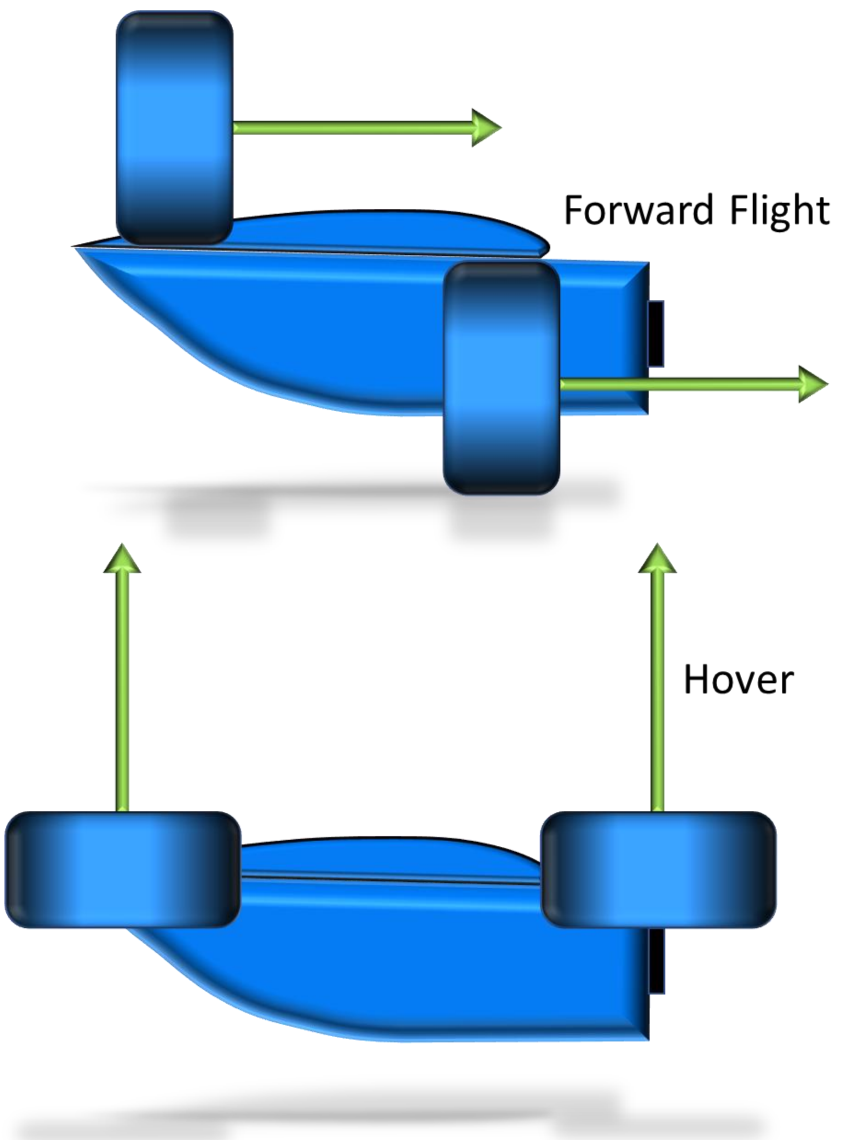

Having used the j2 Universal Tool-Kit to build a complete dynamic model of a tilt rotor UAV the next challenge is to identify the thrust orientation and controls to over the speed range between Hover and Forward Flight.

# The Aircraft

- **Tilt-Rotor UAV**
- **Rectangular Wing with a Fuselage underneath**
- **4 Ducted Propellers located at each corner.**
- **Thrust Vector and Thrust Location Changes during rotation**

The change in engine location enables thrust differential to be used to assist stability e.g. in forward flight the engines thrust lines are located above and below the CG.

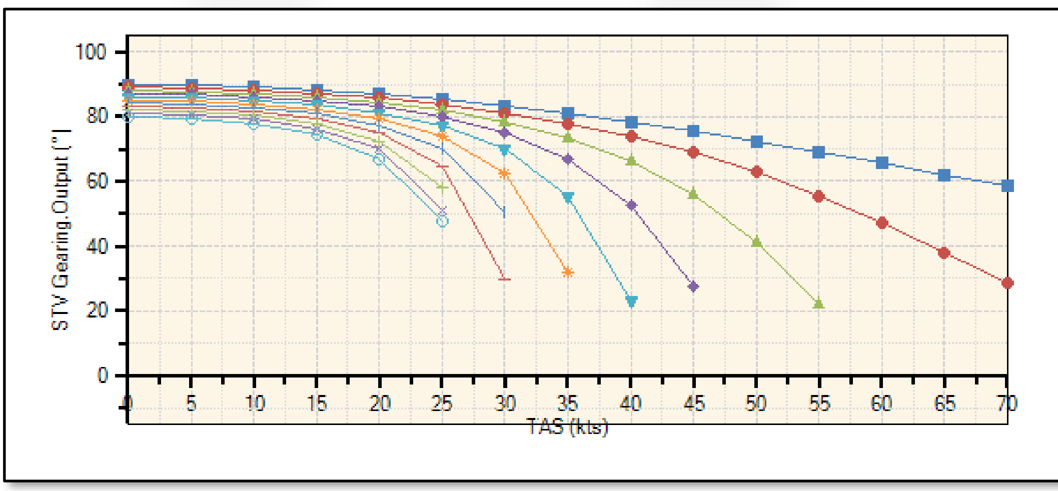
In hover, the engine thrust lines are separated further forward and aft of the cg giving a larger moment arm and a more stable platform.



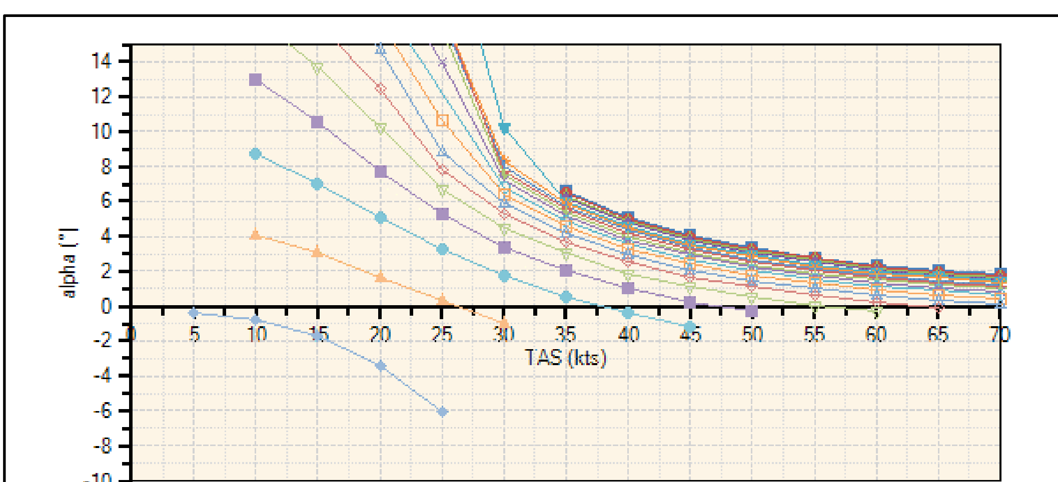
# Baseline Testing

- Unique Rule Based Approach to Defining Conditions
- Define any form Of Control Combinations to Trim
- GUI to Create Test Points
- Automatically Build Combinations and Ranges
- Built In Solver Identifies Complete Set of Controls and States
- NO Coding, NO Script Writing

Using the Trim Rules define a Trim Condition where the Pitch Differential Throttle, Symmetric Throttle and Engine Tilt Angle are used to Trim the aircraft over ranges of Angle of Attack and Forward Velocity. Automatically generate over 150 combinations.



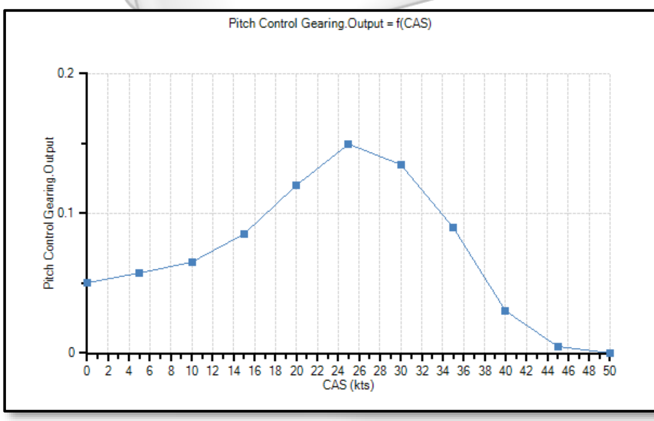

Over the same speed range Define the Tilt Angle and find the Angle of Attack and Elevon Deflection to Trim

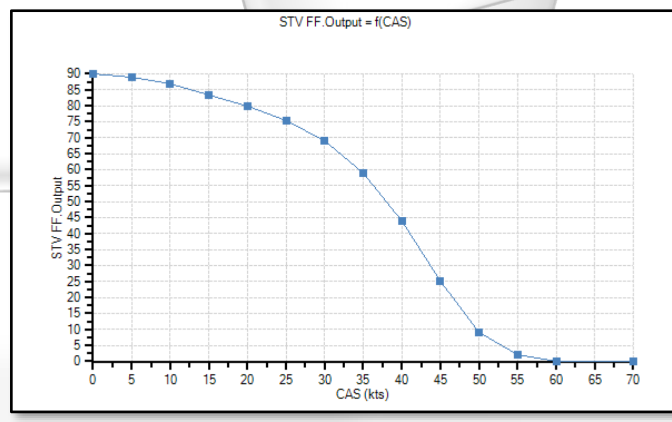


# Identifying Scheduling

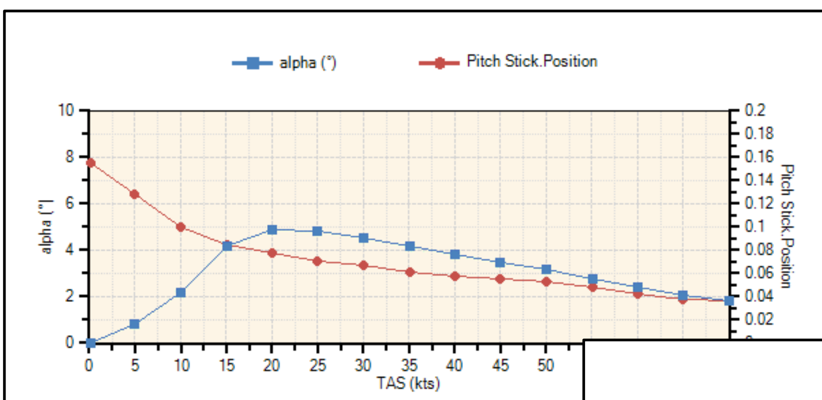
- Blend Different Pitch Control Options
- Define Thrust Angle Schedule
- Run Tests and Adjust
- Built in Version Control and Configuration Management
- Establish Resultant Settings Across Complete Speed Range

Defining an initial schedule for the change from Pitch Differential Thrust to Conventional Pitch Control with airspeed a series of standard trims were run.

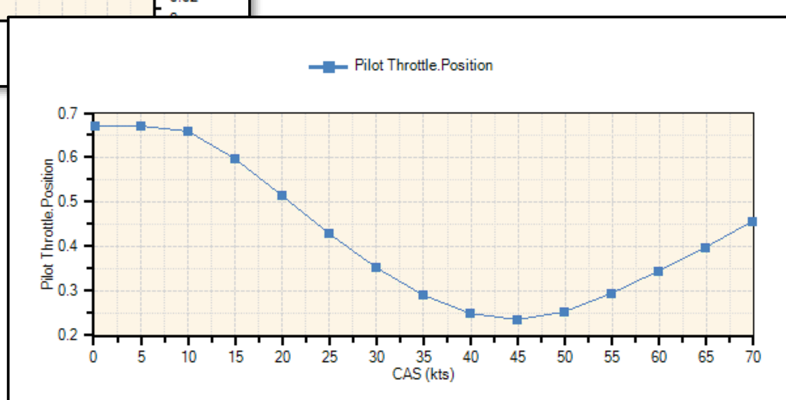



Response is evaluated and the scheduling adjusted to get the target behaviour. Due to the built in configuration management and version control the cases are re-run and the results assigned to a version number.




From the test cases it was possible to establish the angle of attack, Pitch Stick and throttle required over the range of airspeeds.

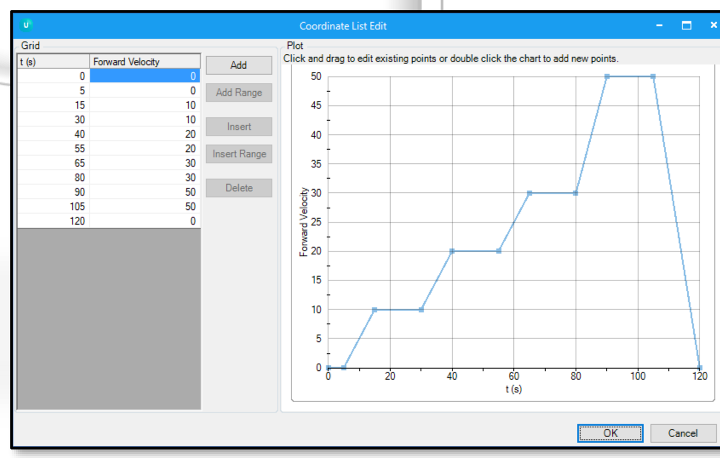



These can now be used for Feed Forward Scheduling of Controls.

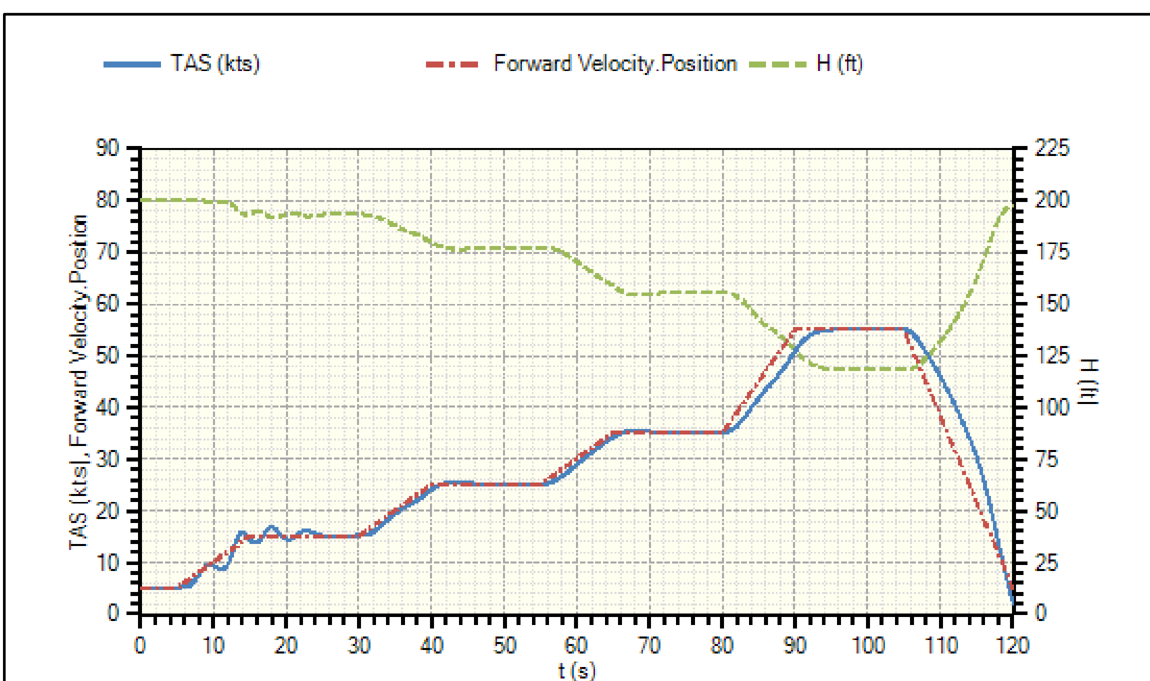
# Feed Forward Assessment

- Add Feed Forward Tables for Throttle, Pitch and Tilt
- Graphically Create Target Velocity Manoeuvre
- Evaluate Dynamic Response
- Select Multiple Start Points
- Use Chart Templates to View Results Quickly
- Integrated 3-D Visualisation gives Complete Understanding of Response

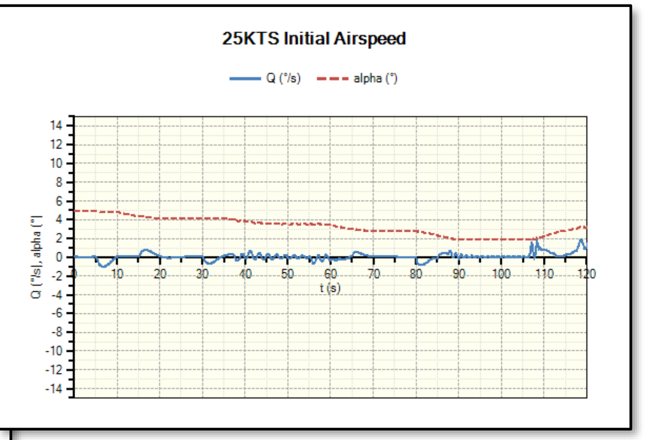
A Target Velocity Profile was created that stepped up to 50kts above the initial trim speed. This would cover the full range of Thrust Angle.

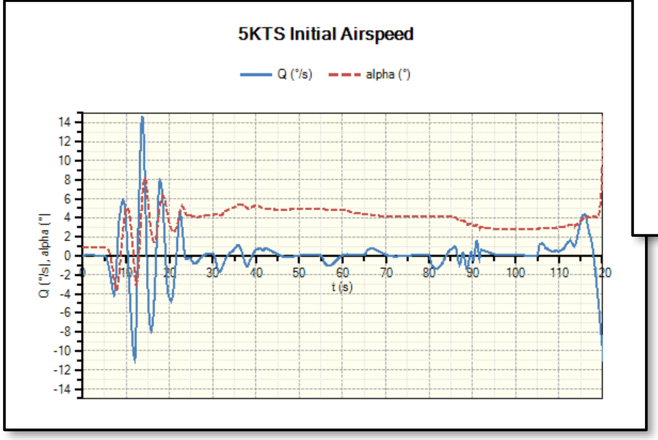



Dynamic Responses were run using **j2 Freedom** from trim point of 5KTS and 25KTS going through transition to conventional flight and starting in transition to high speed flight. Results plotted with **j2 Visualize**.

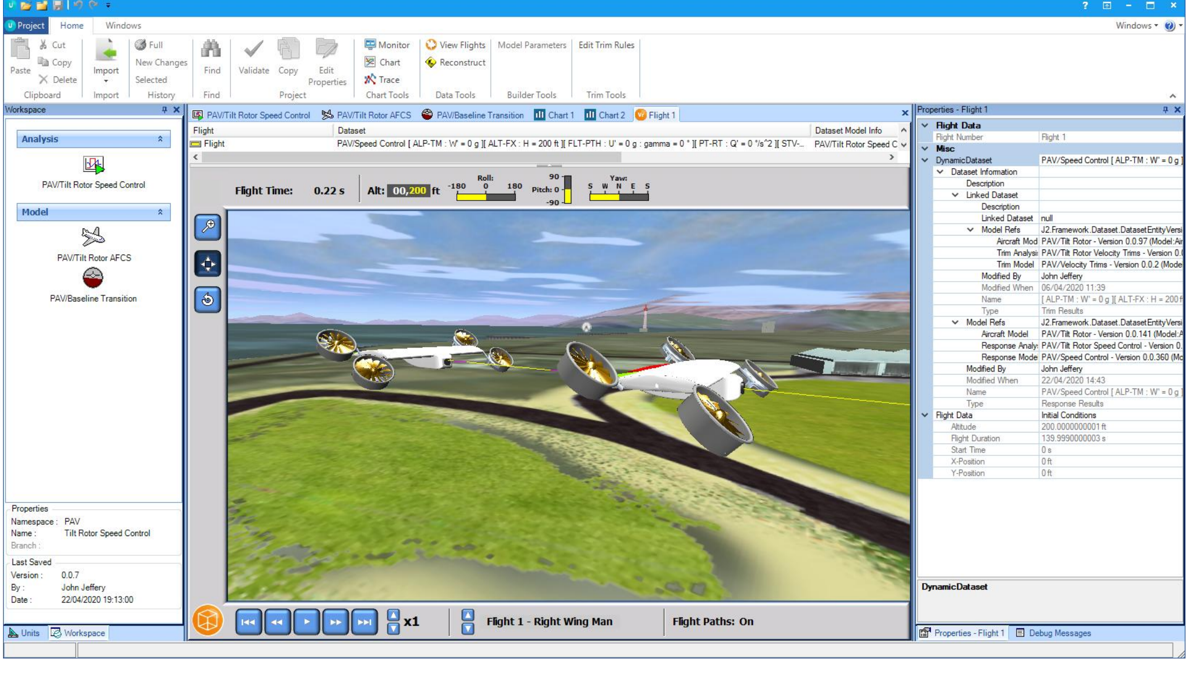


The response shows that using the target velocity to schedule the Pitch Control, Throttle, and Thrust Angle so the speed can be changed and the aircraft maintains stable flight.




Any parameter can be plotted so when looking a the Angle of Attack (alpha) and Pitch Rate (Q) so there is some oscillation at low speed but at the higher speeds the aircraft is very stable.




The results can be viewed in a 3-D Real Time Interactive Playback using **j2 Virtual.** Multiple test points can be put into the same playback for comparison.

The Aircraft is now ready for AFCS Development.

| The j2 Universal Tool-Kit | |
|---|---|
| j2 Universal Framework | Management System |
| j2 Builder | Graphical Model Building |
| j2 Elements | Integrated Aerodynamics |
| j2 Developer | External API |
| j2 Rotary | Integrated BERM |
| j2 Freedom | Static and Dynamic Analysis |
| j2 Flight | Flight Data Processing & Matching |
| j2 Classical | Classical Linear Analysis |
| j2 Pilot | Real-Time Flight Simulation |
| j2 Visualize | Charting and Templates |
| j2 Virtual | 3-D Playback |

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