# Digital Aircraft Design Engineering with the j2 Universal Tool-Kit

AIRCRAFT MODELLING AND PERFORMANCE PREDICTION SOFTWARE

## Key Aspects



AIRCRAFT DYNAMICS

*Predicting Performance*

# INTRODUCTION

Since its inception, the j2 Universal Tool-Kit has been focussed on improving aircraft design and the aircraft design process.   This is intended to support the development of aircraft from simple models looking at basic flying qualities through to high fidelity models for pilot training and aircraft certification.  The off-line analytics provide an ability to build-in certification and test manoeuvres into the batch processing analytics and to track all results through the configuration management system means that it is possible to start certifying the aircraft from the very beginning of the design to ensure that there are no surprises later on.

Creating a digital twin and then building multiple variants (delta's), enables differing levels of uncertainty to be tested.  This off-line analysis can also feed directly into the flight test program to ensure the impact of unknowns can be assessed and flight safety decisions made before actual flying starts.  Post flight, the flight test data processing helps to refine the model and reduce the uncertainty at the same time as creating high fidelity digital twin models for use in real-time simulation.  All this activity is easily performed through the Graphical User Interface (GUI) providing smooth workflow and easy to use steps.

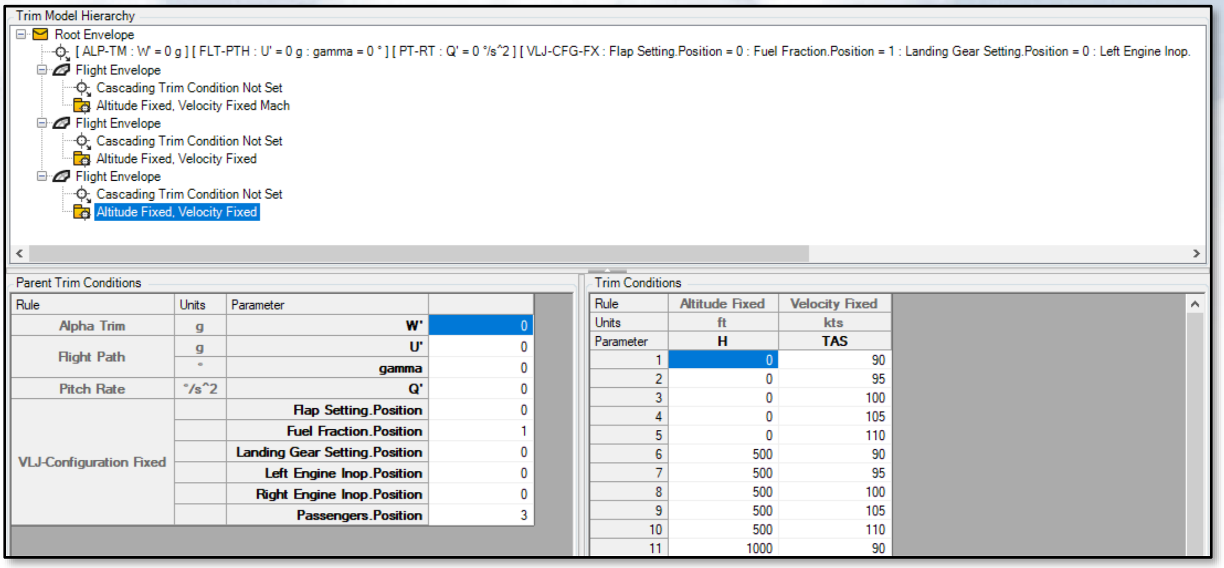
What is sometimes overlooked is the ability for the j2 Universal Tool-Kit to interact with other systems and to run in a remote mode.  Some of these features are becoming more valuable as we move to integrated digital engineering.

# DIGITAL ENGINEERING

## Offline Analysis and Batch Processing

When working with classic flight simulation, all analyses must be performed in real-time. This is very time consuming, especially if looking at multiple conditions.

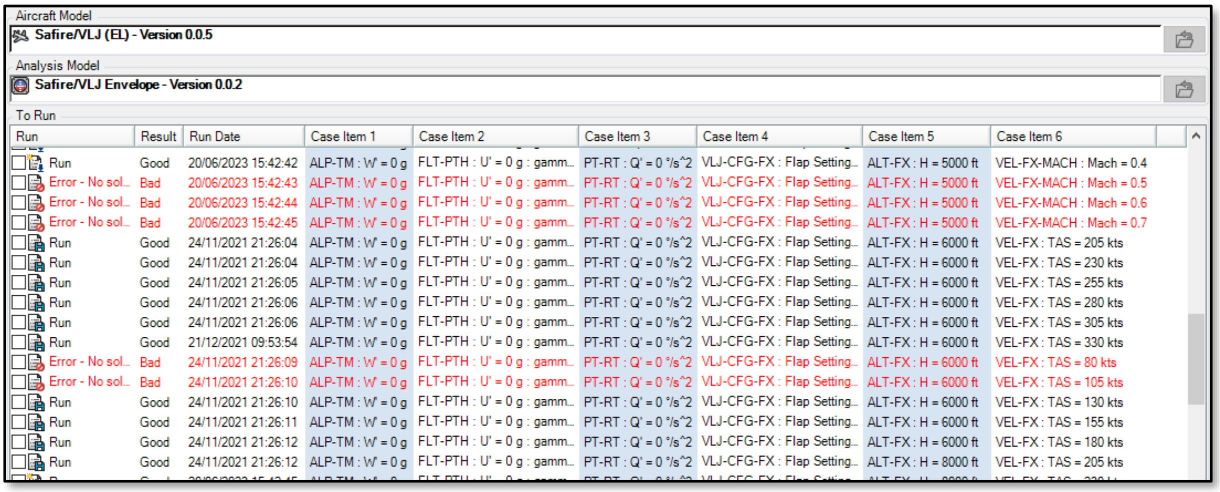
The first thing to consider is the creation/calculation of initial conditions. As aircraft become more complex, so the identification of initial conditions becomes less straight forward. The j2 Universal Tool-Kit has a unique approach to identifying initial conditions. This uses a series of Trim Rules that enable the user to create any pairing of driving and target parameters. Ranges of target parameter values can be defined and the software will automatically calculate all the possible combinations.




| Rule | Units | Parameter | |
|---|---|---|---|
| Alpha Trim | g | W' | 0 |
| Flight Path | g | U' | 0 |
| | ° | gamma | 0 |
| Pitch Rate | °/s^2 | Q' | 0 |
| VLJ-Configuration Fixed | | Flap Setting.Position | 0 |
| | | Fuel Fraction.Position | 1 |
| | | Landing Gear Setting.Position | 0 |
| | | Left Engine Inop.Position | 0 |
| | | Right Engine Inop.Position | 0 |
| | | Passengers.Position | 3 |

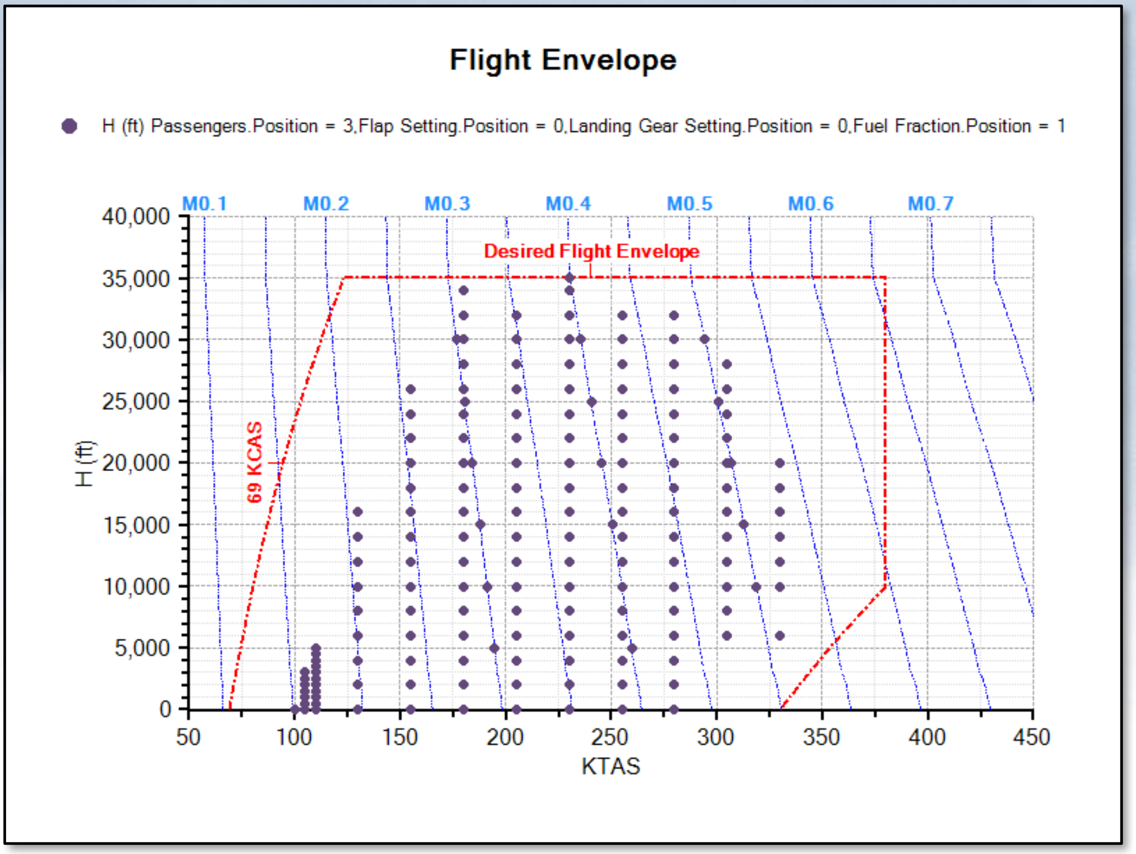
| Rule | Altitude Fixed | Velocity Fixed |
|---|---|---|
| Units | ft | kts |
| Parameter | H | TAS |
| 1 | 0 | 90 |
| 2 | 0 | 95 |
| 3 | 0 | 100 |
| 4 | 0 | 105 |
| 5 | 0 | 110 |
| 6 | 500 | 90 |
| 7 | 500 | 95 |
| 8 | 500 | 100 |
| 9 | 500 | 105 |
| 10 | 500 | 110 |
| 11 | 1000 | 90 |

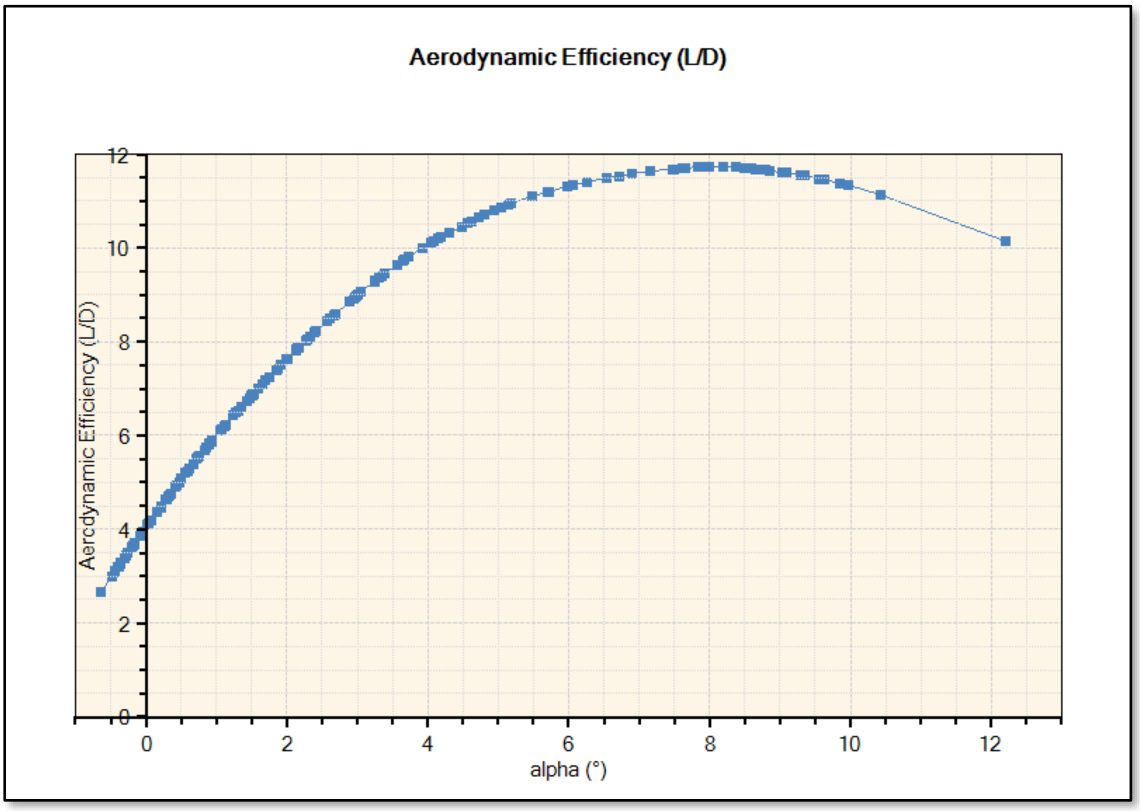
Thus, complete flight envelopes covering multiple configurations can be created in seconds. The full set of flight conditions are then combined with an aircraft model and the complete data set is run as a batch Trim Analysis. The j2 software will find those conditions where the aircraft can achieve the targets and what the corresponding driving parameter values are to achieve them.



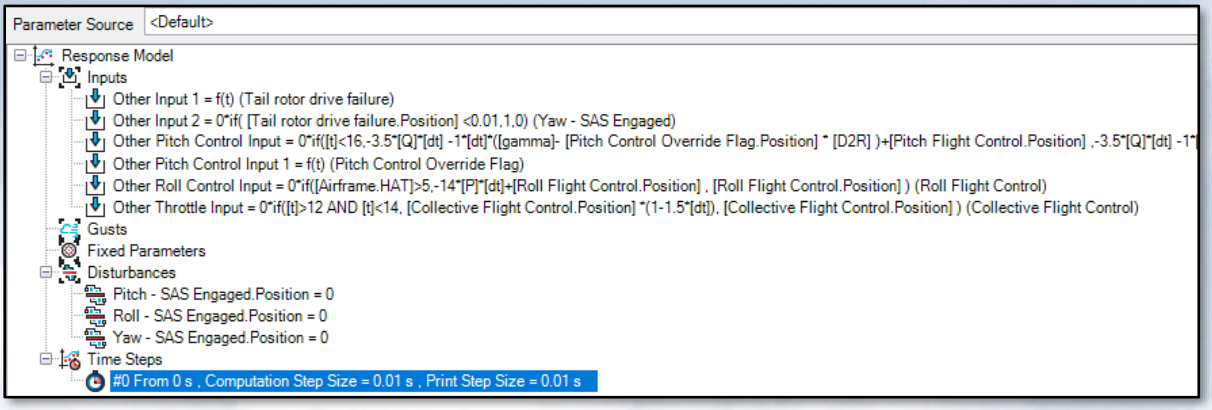

| Run | Result | Run Date | Case Item 1 | Case Item 2 | Case Item 3 | Case Item 4 | Case Item 5 | Case Item 6 |
|---|---|---|---|---|---|---|---|---|
| Run | Good | 20/06/2023 15:42:42 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 5000 ft | VEL-FX-MACH : Mach = 0.4 |
| Error - No sol... | Bad | 20/06/2023 15:42:43 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 5000 ft | VEL-FX-MACH : Mach = 0.5 |
| Error - No sol... | Bad | 20/06/2023 15:42:44 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 5000 ft | VEL-FX-MACH : Mach = 0.6 |
| Error - No sol... | Bad | 20/06/2023 15:42:45 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 5000 ft | VEL-FX-MACH : Mach = 0.7 |
| Run | Good | 24/11/2021 21:26:04 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 205 kts |
| Run | Good | 24/11/2021 21:26:04 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 230 kts |
| Run | Good | 24/11/2021 21:26:05 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 255 kts |
| Run | Good | 24/11/2021 21:26:06 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 280 kts |
| Run | Good | 24/11/2021 21:26:06 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 305 kts |
| Run | Good | 21/12/2021 09:53:54 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 330 kts |
| Error - No sol... | Bad | 24/11/2021 21:26:09 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 80 kts |
| Error - No sol... | Bad | 24/11/2021 21:26:10 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 105 kts |
| Run | Good | 24/11/2021 21:26:10 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 130 kts |
| Run | Good | 24/11/2021 21:26:11 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 155 kts |
| Run | Good | 24/11/2021 21:26:12 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 6000 ft | VEL-FX : TAS = 180 kts |
| Run | Good | 24/11/2021 21:26:12 | ALP-TM : W' = 0 g | FLT-PTH : U' = 0 g : gamm... | PT-RT : Q' = 0 °/s^2 | VLJ-CFG-FX : Flap Setting... | ALT-FX : H = 8000 ft | VEL-FX : TAS = 205 kts |

Templated charts can be used to automatically display the results.

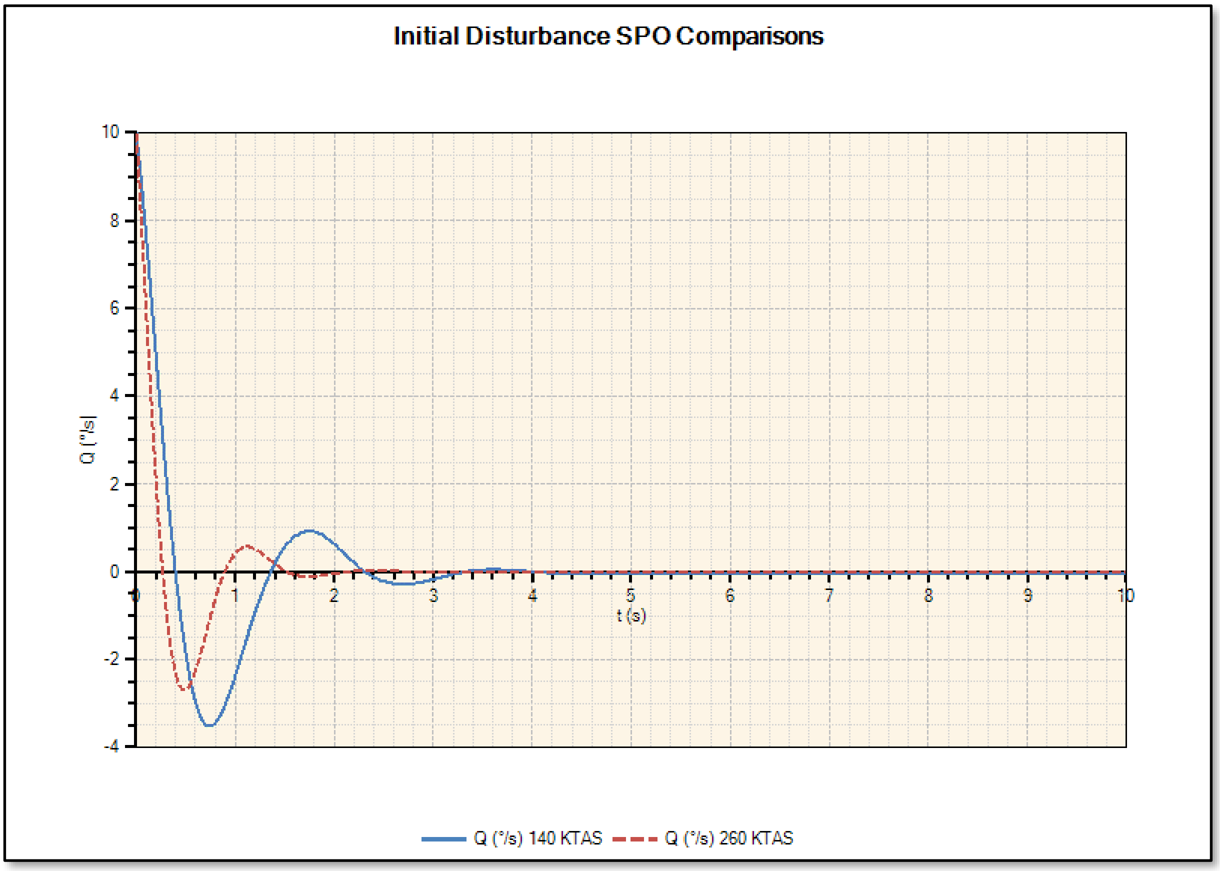


With the j2 Universal Tool-Kit, manoeuvres are created as Response Models that can include any model inputs, initial disturbances, fixed parameters and external gust profiles. These can be combined together using arrays, expressions and constant values to add whatever level of complexity is required, from simple initial disturbances to excite the modes of motion through to certification manoeuvres.




The Aircraft Model and Response Model are combined in a Response Analysis. Any of the flight conditions and configurations found from any Trim Analysis can then be used as initial conditions. In a feature unique to j2, the Response Analysis can be run as a batch process. As this is an offline analysis, there is no requirement for the response to run real-time. As such the response will run as fast as possible, with the limiting factors on the speed of the analysis being model complexity, integration step, and processor capability. Once again, the results can be automatically plotted using chart templates.

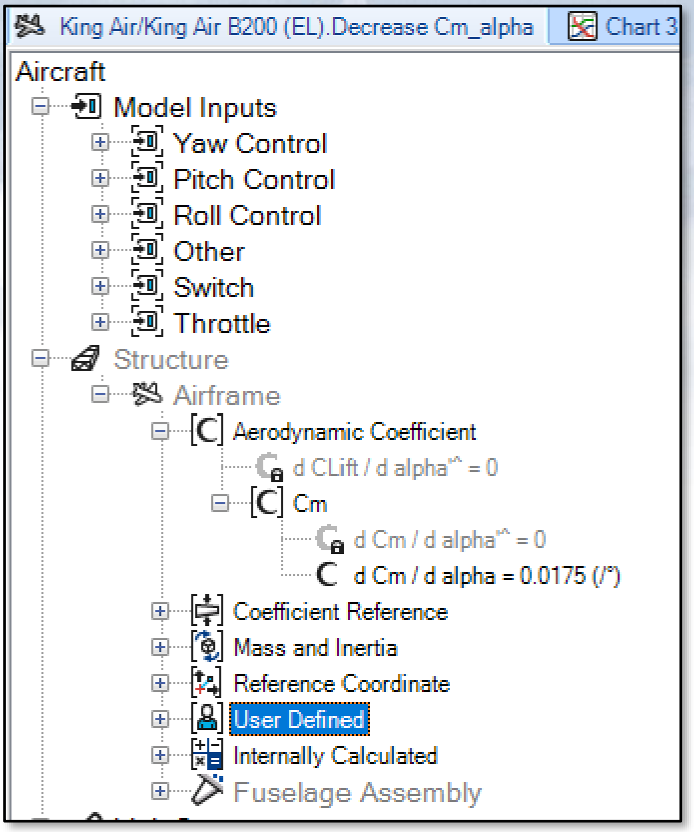



AIRCRAFT DYNAMICS
*Predicting Performance*

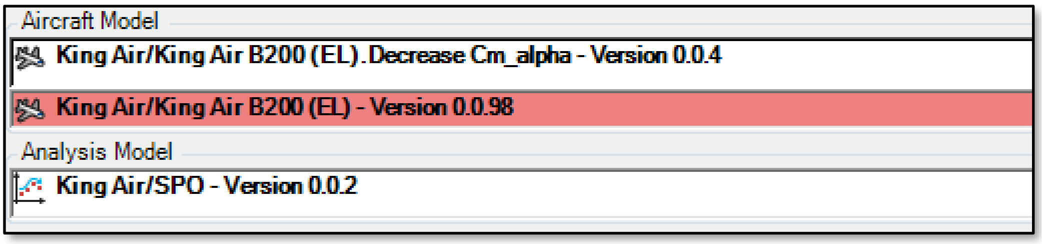
## Multiple Variants

When looking at trade studies and configuration changes, it is not always desirable to create different copies of the model for each variant. J2 Universal Tool-Kit provides two ways to create multiple variants.

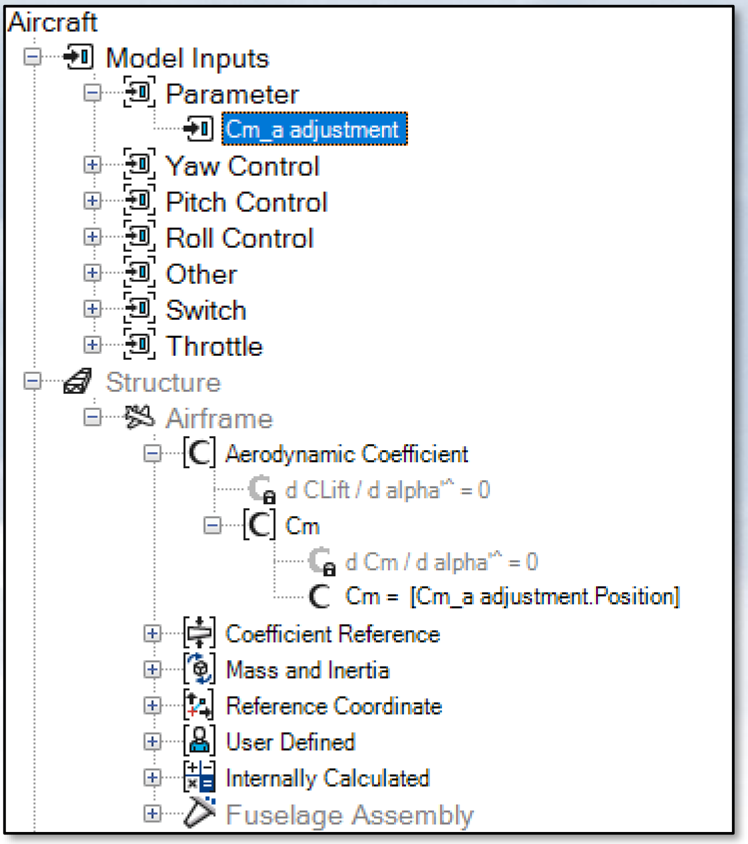
The first approach uses the concept of Delta Models. A Delta Model is always referenced to the Baseline Model and allows changes to be added without compromising the baseline.




When the Baseline Model is updated the Delta Models automatically reference the new version without the need to make multiple changes across multiple models. All analyses track the version numbers of the Baseline and the Delta Models.




The second option is to parameterise the model. The model can have any number of inputs that in turn can be linked to any value. These inputs can be adjusted as the model is being analysed or initialised via the Trim Rules. Thus, ranges of model parameters can be evaluated in a single batch run.



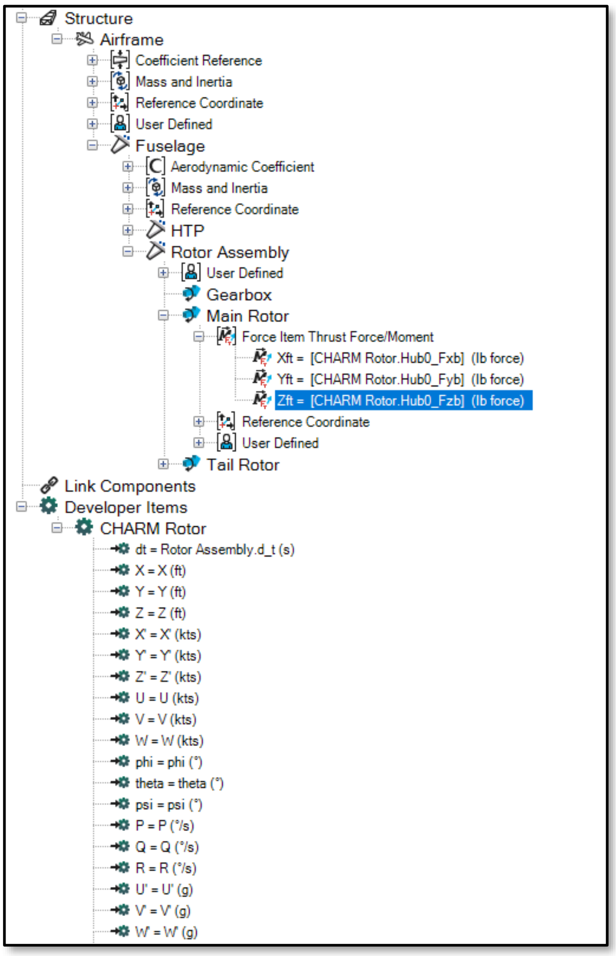

## Integrating External Systems Into the Model

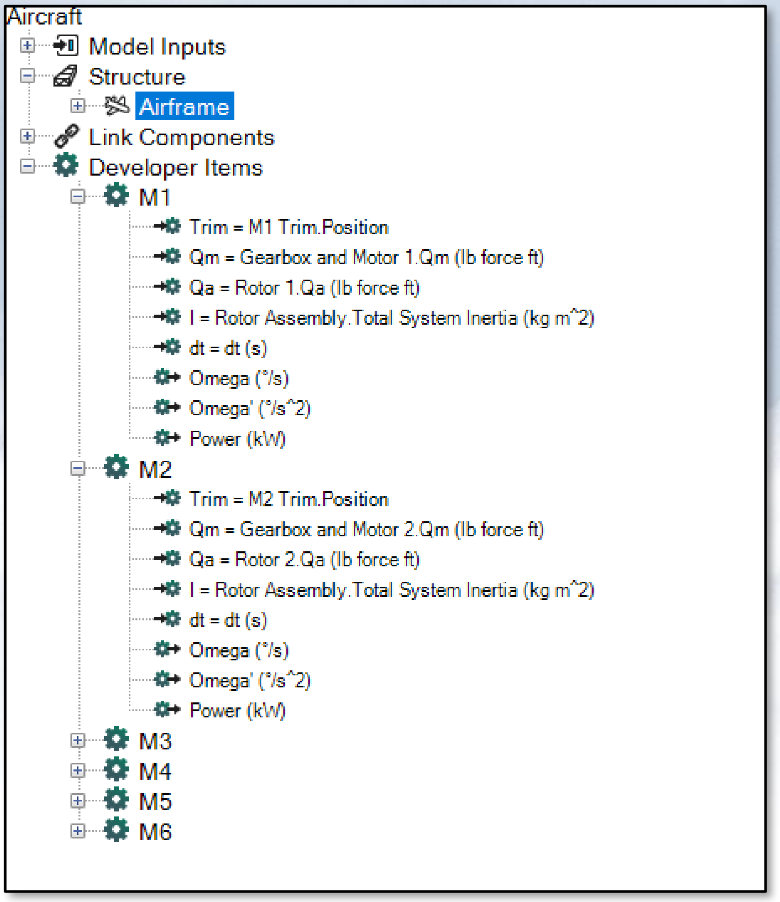
There are two powerful API's built into the j2 Universal Tool-Kit that enable multiple systems to be integrated with the model or the model integrated with external analytical engines.

'J2 Developer' Items allow any external code to be integrated into the model. This code can be direct calculations linked into the model, middleware running external analytical tools or middleware driving Hardware in the Loop (HiL). Outputs from the j2 Developer Item are then placed back onto the model. When the model performs a calculation, the external code is also called and the results then returned to the model.

Multiple developer items can be added to the model to represent anything. The code only needs building once and can be re-used as multiple instances.

Where external code is trusted but is no longer under development, this can be integrated into the model





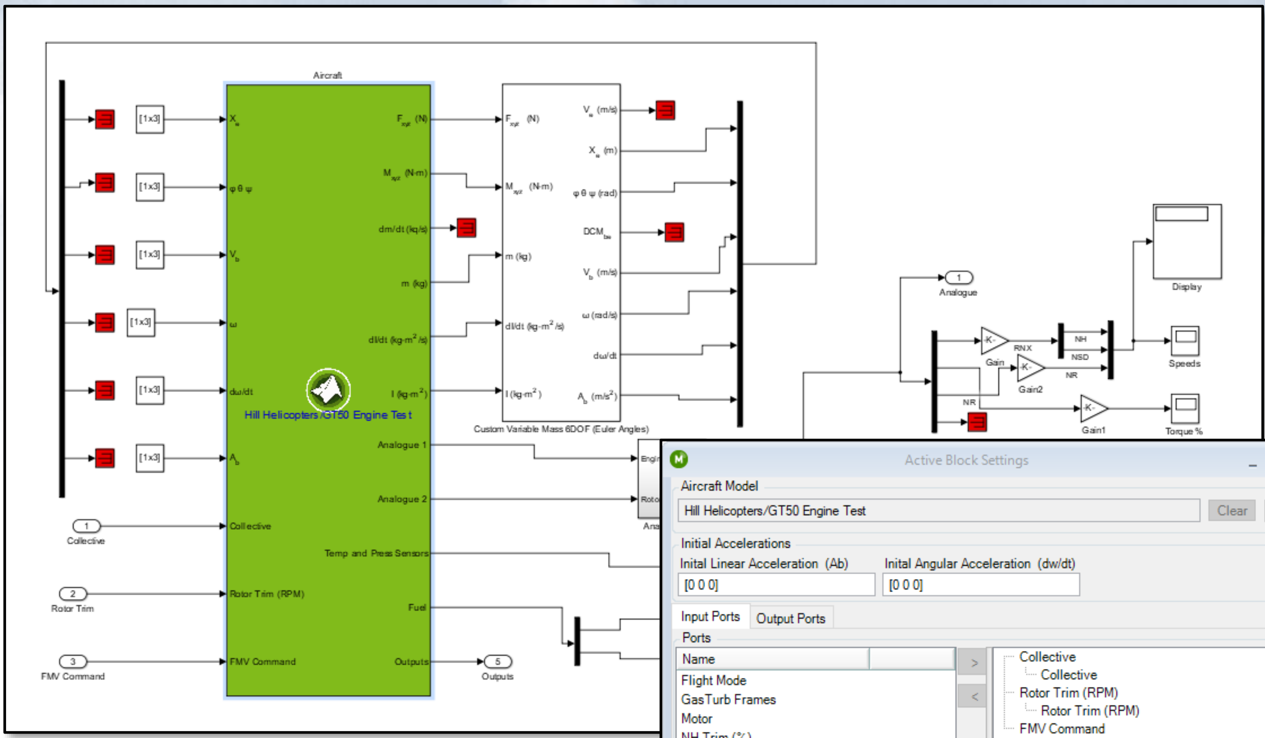

through the j2 Developer API and any future changes can be added on top through the j2 Universal Tool-Kit.

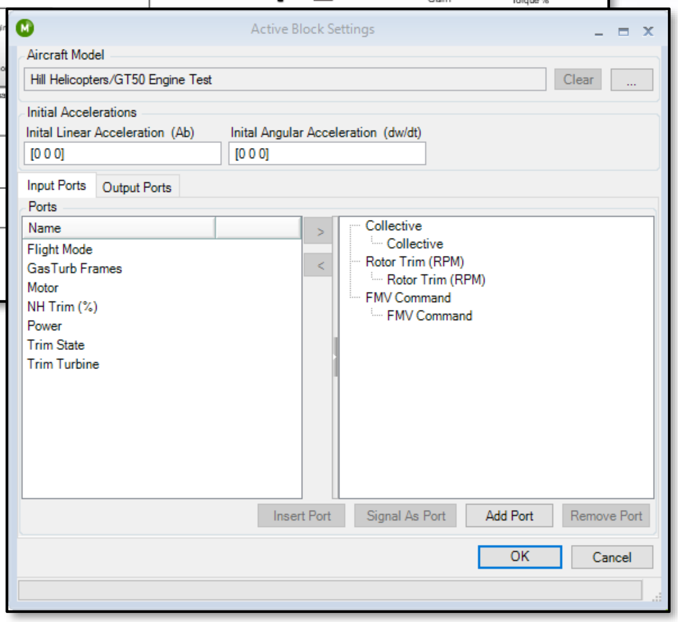
This helps to ringfence and protect any existing code whilst enabling models to progress.

## Integrating with External Systems

In addition to j2 Developer, the j2 Active plug-in provides another API that enables external code to call the calculation engine of the model. This API can be called from any number of programs and languages.

J2 already use the j2 Active API with the j2 Matlab Toolbox plugin to enable Matlab/Simulink to integrate with the model and with the j2 Pilot plug-in that enables the models to be flown in real-time. With the j2 Matlab Toolbox, a j2 Block is placed into a Simulink model.



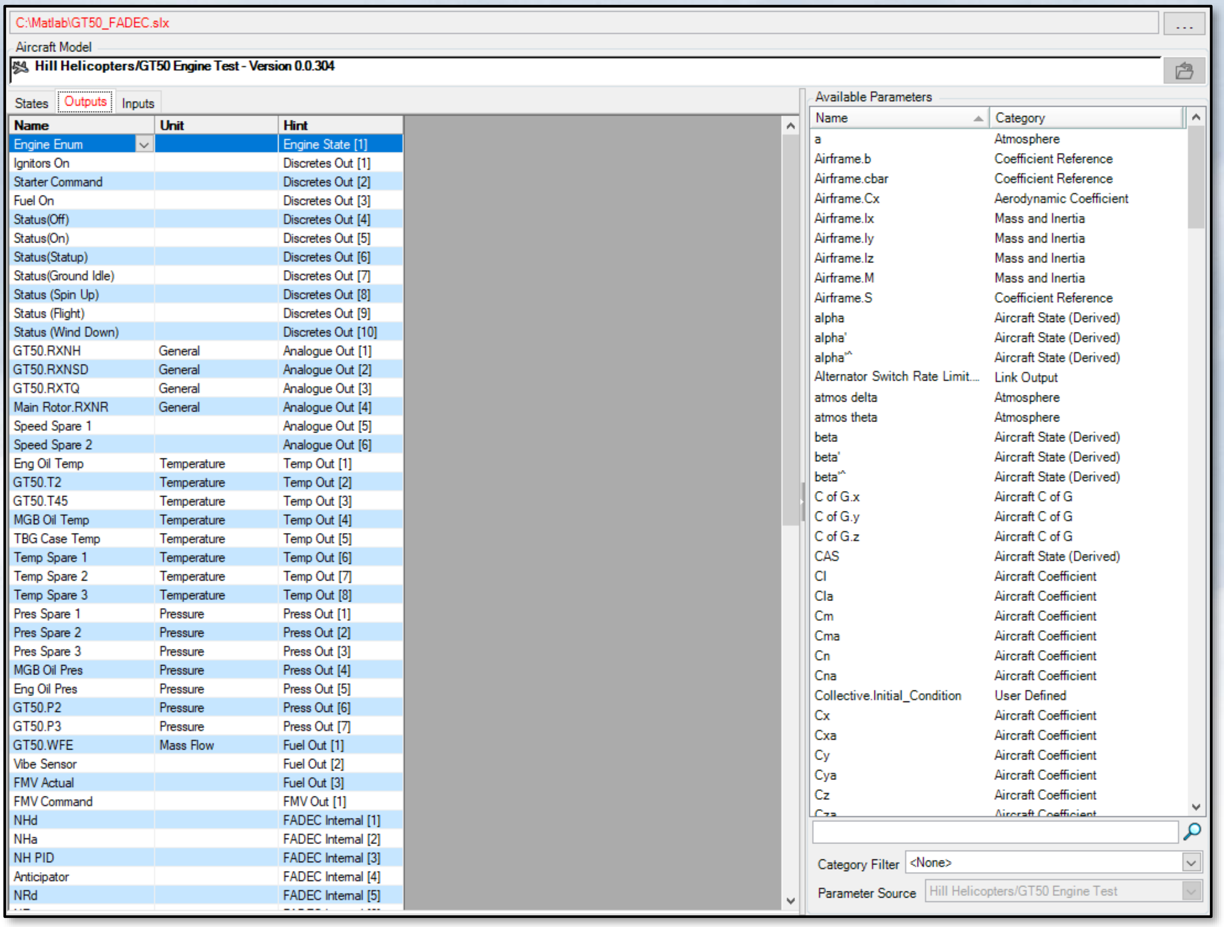




The desired model can be selected from the database and the input and output ports selected from the model inputs and any model parameter respectively.

Any additional system models or control systems can then be connected up to the aircraft model.

The Simulink model can now be run as normal and tested with Matlab using the j2 Active API to call into the j2 model directly.

To ease the design and test of control systems further, the Simulink model can then be loaded back into the j2 Universal Tool-Kit using a j2 Matlab Aircraft Model. This connects the complete Simulink system back into the j2 environment so that all analyses can now be run through j2.




This also enables the Simulink model to be tracked through the j2 configuration control system.

Other tools can be connected into the j2 models in the same way that Matlab can, using the j2 Active API to provide further integration.

## Automation

The final stage is to be able to automate the analytics from other tools to run optimisation tasks or as part of a larger design cycle process. To this end, the j2 Universal Tool-Kit provides multiple command line functions that can be used in scripts or batch files to run analyses without loading the Graphical User Interface (GUI).

This can be used for processing large sets of cases over extended periods of time or for running a parametrised model with inputs defined through external tools and then reviewing the results before performing additional analyses. In this way, optimisation routines can be used to investigate complicated models over a range of test cases without any operator interaction required.

## Conclusions

The j2 Universal Tool-Kit can be integrated with multiple external tools and languages into the aircraft model, including HiL and can then be used to run multiple offline analyses at whatever rate the user chooses. These analyses can be run on a single model or across multiple variants and the results compared. The whole system includes version control and configuration management, keeping track of all results and what version of the models were used to create them.

External tools can be integrated with the j2 Aircraft models for additional analyses using a built in API. Further offline analyses can be performed using the command line system to support the integration of the analyses into optimisation routines and process management systems.

Further work is also in progress for expanding the j2 Developer API and to allow variants to be combined as well as integration with tools such as Siemens Teamcenter and Simcenter as overarching full project management systems.