Flight Dynamics Analysis with J2 Aircraft Dynamics and the J2 Universal Tool-Kit

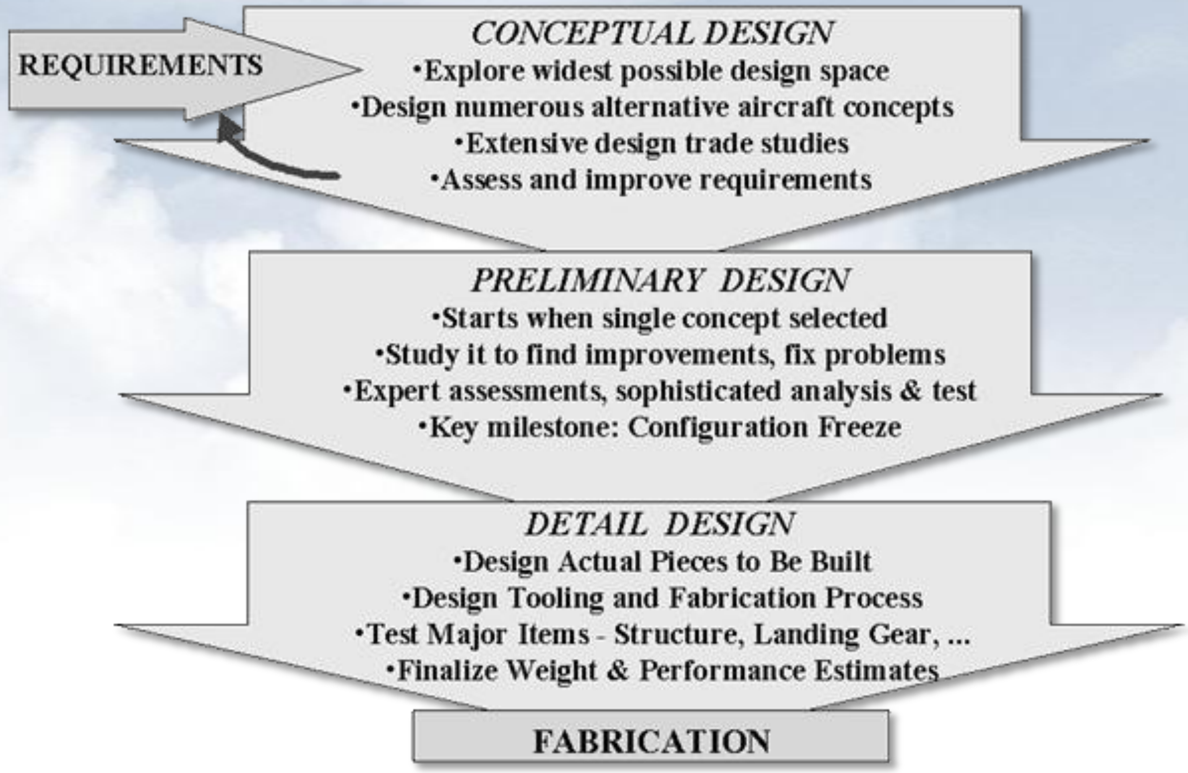
AIRCRAFT MODELLING AND PERFORMANCE PREDICTION SOFTWARE

KEY ASPECTS

- *CONCEPTUAL DESIGN*
  Exploring Possibilities
- *PRELIMINARY DESIGN*
  Refining Ideas
- *DETAILED DESIGN*
  Evaluating Every Condition
- *FLIGHT TEST*
  Getting Certified
- *MID LIFE UPDATES*
  Updating the Original Requirements

AIRCRAFT DYNAMICS
Predicting Performance

This document is intended to give a brief outline of the way in which the J2 Universal Tool-Kit can be used to assess any aircraft at any point in its design cycle from concept to completion and beyond. Each stage has a summary of the data required as well as objectives for each stage and the type of analysis that can be expected.



Three Phases of Aircraft Design

This list is not exhaustive and is primarily for demonstrating how the software can be used rather than a definitive description. From this information, it is believed that it is possible to understand how the software can fit into existing processes to perform the current analysis as well as add additional benefits of speed, a cohesive team environment, and a structure/integrated analysis tool. When considering process development, it is worth understanding how the J2 Universal Tool-Kit can fit into the different design stages and to see the improvements where each discipline is working together, and projects can be passed seamlessly from one stage to another being continually updated as more information is known about the project.

CONCEPTUAL DESIGN

Exploring Possibilities

What is important to remember at conceptual design is that we are trying to find out major, key, characteristics about our aircraft, and how to change them by modifying the design and looking at different configurations. As such we can start with a lot of estimates; this information can be refined throughout the design process. We can very quickly look at multiple configurations and ideas and eject those that are no good. There is very little information required before we can build a model. Even with this information we can start to investigate FCS design. Also note that at this stage we can start to build manoeuvres that are going to be required for certification, and flight test. If the conceptual designers work with the flight test department to start to look at a flying program at this stage in the design, this can be put into the system and flown.

- **Weights and Balance**
  At this stage in the design, there may be a couple of design weights and inertias of interest, along with the CG information.
- **Geometric Data**
  For the conceptual design we would need to know basic wing geometry, vertical and horizontal tail size, fuselage diameter etc.

  We would also need to have some idea as to configuration and location of different items, although during conceptual design these can change and the J2 Universal Tool-Kit is an excellent tool to assess the impact of these changes and to help finalise a configuration.

  Some idea of control surface sizes and locations is useful.
- **Aerodynamic Data**
  This can be in different formats depending upon the information available. If basic tools have been used, then a series of linear derivatives and steady state conditions may be available (e.g. CLo and CL/alpha) for different points in the envelope. These can be used to create simple models. If using Aerodynamic Strip Theory (AST), then we need to know the Airfoil Section data for each aerodynamic surface. This can be the 2-D or 3-D Lift, Drag and Pitch Characteristics, or we can use other tools to calculate those from airfoil profile information. At this stage, the fuselage data is likely to be a simple constant drag, but this can be refined if necessary. With the aerodynamic data we need to understand where it is acting is it located for the whole aircraft or for each surface.
- **Thrust characteristics**
  In this stage of design we will know very little about our engines, this stage of design we can use the J2 Universal Tool-Kit to see what magnitude of thrust/power we will require. We can build simple engine models and start to evaluate the behaviour. If necessary we can even investigate different types of engines. If there is some basic knowledge available on the engine characteristics, it helps but is not critical.

PRELIMINARY DESIGN

Refining Ideas

By know we should know more information about the aircraft, sizing should be worked out and there should be a core configuration established. The configuration can still change, but these will be smaller changes than Canard or T-Tail options. What can start to go on here is more investigations into CG limits and weight distributions. Some refinement of twist and dihedral and more control surface sizing and balancing. FCS Design may have some idea as to the type of control systems, and could be performing more investigation into gains.

- **Weights and Balance**
  A better understanding of the weights of items should be known here. Whilst we will not have all equipment weights, basic fuselage, wing, tail etc. will be known. We can start to investigate payload characteristics, and fuel fractions to give some idea of the mass/cg profile.
- **Geometric Data**
  As with the conceptual design we would need to know basic wing geometry, vertical and horizontal tail size, fuselage diameter etc.

  A better understanding as to the weight distribution should be known such as Wing CG, Fuselage CG etc. It may still be preferable to consider the aircraft as a single Mass/CG item, but it is possible to break it down into subsystems so any movement of these subsystems their effect on the overall CG will be automatically calculated.

  At this point we could be looking in more detail at control authority and control surfaces so real location of items, will be useful. Surfaces will be more detailed, so we can look at left and right ailerons independently, flaps may now be introduced along with leading edge devices, spoilers etc.

  We may even have a rough estimate of undercarriage now.
- **Aerodynamic Data**
  By now more detailed aerodynamic calculation will have been performed. A better understanding of the fuselage lift drag and pitch characteristics will be known. Vortex Lattice or RANS CFD may have been performed to give steady state look-up tables. This information can be mixed with the AST so with static coefficients, we can look at dynamic characteristics as well. Smaller contributions to aerodynamics can now be considered (e.g. Pylon Drag, Engine Nacelles, and Wing/Body Interference etc.)
- **Thrust characteristics**
  We may still be looking at playing around with engine locations, 2 or 3 engines etc. We should at least know what type of engine is being considered, we may also know the upper limits of the engine to get more information about the achievable envelope. At this stage we could be investigate different tilt and toe characteristics and looking at more detailed manoeuvres for takeoff landing etc.

Detailed Design

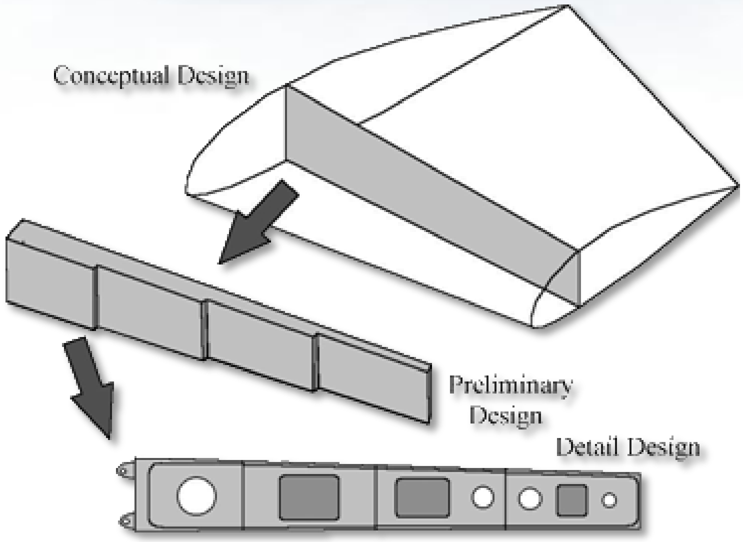
Evaluating Every Condition

Hopefully the configuration is fixed at this point. Detailed CFD work will have been performed and maybe even wind tunnel data. Systems design and internal equipment is the focus of this stage, large amounts of analysis (1,000s of test points) investigating the complete flight envelope may be taking place. FCS Design could be focussing on robustness across the complete envelope and gain scheduling to cover transition between different phases. The other aspect of design that can be investigated now is tolerances and small variations. This if the aerodynamics change, what is the impact, fuel flow, failure analysis (fuel pump stops working and all the fuel is on one side, engine out etc.)

- **Weights and Balance**
  We should be looking at individual equipment weights and subsystems. The model will have expanded in terms of the number of structural items each contributing to the mass/cg.

- **Geometric Data**
  Whilst more information will be known, less will be required. At this stage it is assumed a lot of the aerodynamic information has been consolidated to the whole aircraft rather than individual items. The focus here is on where items are located for the CG calculations.

  Better understanding of the undercarriage locations and dynamics may be known so we can look at takeoff and landing.



Wing Spar as Defined in Conceptual, Preliminary, and Detail Design

- **Aerodynamic Data**
  Full CFD Models or even Wind Tunnel data may be available now. This can be entered as look-up tables. This information will typically be for the complete aircraft + surface contributions. As such the reference location for the complete aero data needs to be known. Downwash etc. will already be included now in the aero data so will no longer be required in the model. Running different analyses with different aerodynamic tolerances is important here, looking at the case where the calculations are in error, and what impact do those errors have on the overall dynamics.

- **Thrust characteristics**
  By now we should know the engine characteristics in detail. We should understand their locations and orientation. Detailed characteristics of thrust or power with respect to altitude, speed, engine RPM, throttle etc. along with propeller characteristics if applicable. What can be investigated here is the engine out scenarios, and failure modes.

FLIGHT TEST

Getting Certified

Even at Flight Test, the J2 Universal Tool-Kit has major uses. Having built a prototype or even production version, it is best to "fly" the flight before anyone steps into the cockpit or picks up the controls. From the flying schedule, the manoeuvres are performed to give the pilot some idea as to what can be expected when flying. When the aircraft has landed the information from the flight test recorder can be plotted and compared to the original estimate. The flight recorder data can be used to create visualisations so that the engineer on the ground can see what happened in the air from many angles rather than just watching a video or looking at graphs.. Further analysis can then take place to use the flight recorded information as a manoeuvre input so that the actual flight can be run through the model. Flight comparison can be performed and the aerodynamic model refined for more accuracy. With the flight matching, driving the control surfaces directly helps to eliminate and FCS effects, however the inputs can be moved so once the aerodynamics are correct, investigations into the FCS can take place.

Flight Testing a UAV at Dawn

- **Weights and Balance**
  At this stage we are using the mass, inertia and cg information from the real aircraft measured before/during the flight.
- **Geometric Data**
  Reference area and information is all that is required here
- **Aerodynamic Data**
  As with the Detailed design stage. Now additional factors can be added in to account for the flight matching.
- **Thrust characteristics**
  As for detailed design, we could even be using manufactures engine details linked via DLLs. If required, the engines can be removed entirely and the true thrust characteristics recorded from flight test can be used. Thus we are just comparing the aerodynamics in the flight matching and eliminating all other unknowns.

MID LIFE UPDATES

Updating the Original Requirements

Once the system has been fully designed, tested and is operational, there is no reason to stop gaining benefits from the J2 Universal Tool-Kit. At this point, the impacts of modifications to the system are being assessed. This can include such aspects as adding a radome, or simple cargo conversions or stretch versions. In this instance we build on the existing real data and add as much information as is known about the modification being made as is possible.

- **Weights and Balance**
  At this stage we can use the mass, inertia and cg information from the real aircraft measured before/during the flight. Or the approved mass/cg envelope from certification. The change in mass can be put in as a "delta" (positive or negative) from the baseline aircraft, and the location of this delta will help determine revised cg positions.
- **Geometric Data**
  Reference area and information is all that is required here for the baseline aircraft with the additional locations, and reference data for whatever changes are being made.
- **Aerodynamic Data**
  With the system flight matched, it is now a question of what data is available for the modification. This can be simple Aerodynamic Strip Theory being superimposed on top of the baseline, or more complex CFD or Wind Tunnel data, contributions.
- **Thrust characteristics**
  If new engines are being used, we can simply remove the old ones and add the new thrust and response characteristics, or reverse engineer the change in thrust required to support the modification.

IT TOOK J2 AIRCRAFT DYNAMICS' AEROSPACE ENGINEERING AND AIRCRAFT DESIGN SPECIALISTS OVER 10 YEARS TO BUILD THE 'CODE' THAT ENABLES THE UNIVERSAL TOOL –KIT TO INVESTIGATE ALL ASPECTS OF AIRCRAFT HANDLING AND PERFORMANCE.

WE HAVE DONE ALL THIS SO THAT YOU DON'T HAVE TO.

This state-of-the-art, but easy-to-use software suite gives you unprecedented power to design and 'fly' multiple configurations of the complete flight envelope in a 3-D virtual environment – all at the click of a mouse! When using the J2 Universal Tool Kit, you can save hundreds of thousands of dollars by streamlining your process, maximizing your analysis capability and reduce the risk of serious project flaws.

At the heart of J2's software is the **J2 Universal Framework**, a cutting-edge configuration control and data management platform that hosts all steps of the design process. Everything we offer begins and interacts with this key framework.

Now it's time to investigate our range of plug-ins. 'Mix and match' their additional design and analysis capabilities using floating licenses. Take control of a bespoke package that perfectly fits your requirements. This way, you get the right functionality and maximise the return on your investment.

ARE YOU READY TO RETHINK THE WAY YOU DEVELOP YOUR AIRCRAFT?

To find out more about **J2 Aircraft Dynamics**, our software and our consultancy services, visit **www.j2aircraft.com**

PLUG-INS

J2 Builder
An easy-to-use graphical interface that rapidly develops aircraft models and builds multiple variants for comparison.

J2 Elements
Enables automatic calculation of total aerodynamic coefficients and derivatives through integrated strip theory.

J2 Developer
A Software Development Kit (SDK) for all users to write their own components and libraries and then an interface into J2 Aircraft Models into which these libraries can be plugged in.

J2 Freedom
Provides flight dynamics simulation of aircraft data models, allowing you to evaluate the complete flight envelope.

J2 Active
An open COM interface that instantly integrates your existing design packages with the power of the J2 Universal Tool-kit.

J2 Matlab Toolbox
Allows the full capability of the J2 Universal Tool-Kit with Simulink Model files. Manoeuvres developed from within J2 can also be flown on Simulink Models. it is possible to run analyses from within J2 using J2 Matlab Response and J2 Matlab Trim analyses.

J2 Visualize
Instant understanding and evaluation of aircraft behaviour through data visualization and graphic displays.

J2 Virtual
View any results in a virtual 3-D real-world, to understand what exactly happens during unexplained/complex manoeuvres

J2 AIRCRAFT DYNAMICS
Predicting Performance

Microsoft CERTIFIED Partner

MathWorks Partner

Use the power of the **J2 Universal Tool-kit** to optimise your aircraft design from first concept through to final flight trials, slash development costs and fast-forward your time to market. Our **industry-leading software suite** allows you to fly your design in a realistic virtual environment, to predict its performance and behaviour, stability and control with unprecedented accuracy. Design changes can be made quickly and cheaply, all at the click of a mouse.

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