iAircraft™

Overview

iAircraft is an aircraft simulation modeling package designed specifically for use in aircraft lab test facilities such as “iron bird” simulators and simulation-based avionics integration test facilities. iAircraft has been developed for the simulation of commercial aircraft and can also be parameterized to represent a wide range of fixed-wing aircraft. iAircraft is made up of a collection of Simulink models that may be run within the Simulink simulation software or on Applied Dynamics real-time simulation computer systems (rtX, rtX-V, RTS). iAircraft has been developed with an architecture that allows the aircraft simulation to get up and running quickly in pure simulation mode but also makes it easy to connect real aircraft LRU for performing aircraft hardware-in-the-loop testing, integration, and avionics verification activities.

The iAircraft simulation modeling methodology is based on commercial aircraft industry-leading research and development for several decades.

Flight Dynamics Model

The iAircraft flight dynamics model is a high-fidelity 6-degree-of-freedom aircraft model with a rotating spherical earth. The flight dynamics model is based on the work of Robert M. Howe discussed in his paper entitled “Airframe Equations of Motion and Transfer Operators”.

This flight dynamics model includes wind velocities, power plant forces and moments, aerodynamic forces and moments, earth axis forces, translational equations, rotational equations, and quaternion equations. This flight dynamics model is of a fidelity and detail sufficient for the design of aircraft flight control systems and for use within high-fidelity engineering flight simulators such as iron bird simulators and simulation-based integration test facilities.
Aircraft Simulation Trim

Aircraft simulation model “trim” is a term that refers to the initialization of the aircraft simulation model. In order for an aircraft simulation model to be efficiently utilized in a simulation-based lab testing facility for aircraft system integration and verification, the aircraft model must enable simulated flight to be initialized to any reasonable state. This capability eliminates the need to go through a take-off sequence in order to get to a desired flight condition. For example, if the purpose of a simulation test case is to test aircraft landing scenarios then it would be desired to initialize the aircraft at a steady-state flight condition immediately prior to the landing procedure. The alternative approach is to start with the aircraft stationary on the runway, take-off, fly to the desired waypoints, then begin the landing procedure. Without a trim capability the time required to perform each test case will be significantly higher. A comprehensive trim capability requires that the correct model inputs (ex: throttle, pilot controls, etc.) be solved to obtain near-zero derivatives for many of the states of the aircraft model. This is achieved using a sophisticated algorithm and an iterative approach that takes each simulation block through several solver steps before switching to standard simulation mode of operation. iAircraft includes an industry-leading trim capability that is made up of a Simulink trim block and input and outputs to and from each of the aircraft system blocks that require trim-solving to reach steady-state flight conditions.

Landing Gear Model - iAircraft+ Landing Gear

The iAircraft landing gear model is based on the combined work of The Boeing Company and NASA Ames Research Center [ref: Henke]. The landing gear model includes nose gear, main left gear, and main right gear. The main left gear and main right gear are calculated using an “equivalent landing gear” that enables most standard main gear configurations to be grouped and represented with sufficient accuracy for high-fidelity engineering aircraft simulator applications such as iron bird simulators and simulation-based integration test facilities.

Features of the landing gear model include:

- Braking capability is included on the equivalent main gear
- Nose wheel steering is included as a function of rudder pedal travel and as a function of the tiller
- Small angle approximations are used for computing landing gear compression, compression rate, and body axes force and moment resolution using oleo strut compression equations
- Tire normal force, side force, and drag force are computed for each individual oleo strut and resolved into body axes
- Forces exerted on the aircraft through the oleo strut are obtained by summing the partial body axes forces
- Body axes moments are computed from the partial body axes forces and the distance from the center of gravity to the runway
Avionics

iAircraft includes simulation model blocks to provide the avionics capability required to apply the model to a wide range of simulation, aircraft integration, and verification testing activities. Avionics blocks are divided into two categories:

- Autopilot Modules
- Other Avionics System Modules

Autopilot Modules

A powerful set of capabilities included with iAircraft are the autopilot modules. iAircraft includes a complete set of autopilot blocks. The autopilot blocks provide full support for auto takeoff and autoland.

- Pitch Angle Hold
  - Given a pitch angle demand, the Angle Hold autopilot determines the elevator command. When enabled, the Flight Path Angle Hold autopilot overrides the Pitch Angle Hold autopilot elevator control.

- Flight Path Angle Hold
  - Given a glide slope demand, the Flight Path Angle Hold autopilot controls the elevator to achieve the desired value. When enabled, the Flight Path Angle Hold overrides the Pitch Angle Hold control.

- Intercept & Track
  - Given a waypoint, the Intercept & Track autopilot determines the heading command which is fed to the Heading Hold autopilot. The Intercept & Track continuously adjusts the desired heading in order to reach the desired waypoint.

- Speed Hold
  - Given a speed demand, the Speed Hold autopilot provides “autothrottle” control of the throttle to achieve the desired value.

- Damper Control
  - The Damper Control autopilot generates a rudder command based on the yaw rate to provide damping of “dutch roll” mode effects.

- Bank Angle Hold
  - Given a bank angle demand, the Angle Hold autopilot controls the ailerons to achieve the desired bank angle value.

- Heading Hold
  - Given a heading demand, the Heading Hold autopilot determines the bank angle command which is fed to the Bank Angle autopilot. When the Intercept & Track autopilot is enabled it overrides the Heading Hold control.

Figure 9 - iAircraft Autolanding Concept and Autolanding Phases

Position | Phase Commences
---------|------------------
A        | Automatic Approach - Track
B        | Automatic Approach - Glide
C        | Automatic Land - Flare
Other Avionics System Modules

In addition to the autopilot modules, Applied Dynamics is offering a complete set of aircraft avionics modules specific to the C919 class of aircraft. These modules provide avionics system interfacing capability and basic avionics system dynamics as required for simulation-based lab test facilities such as iron bird simulators and simulation-based integration test facilities. Avionics system modules include:

- Air Data Computer
- Aircraft Maintenance System
- Flight Management System Interface
- Inertial Navigation System
- Meteorological Radar Interface
- Radio Navigation System Interface
- Radio Communications System Interface
- Warning System Interface

The avionics modules interface with the flight dynamics, engine, landing gear, hydraulics, and electrical system models to provide closed loop dynamics for system verification purposes. The initial version of the avionics model is currently in the definition and design phase. Contact ADI for the latest available information.

Flight Controls

iAircraft flight controls simulation includes the complete set of systems from pilot controls, to the Flight Control Computer, linkage with the autopilots, to flight control actuators, to the flight control surfaces. Flight control surfaces are modeled within the aerodynamics model. Pilot control dynamics are aircraft-specific. Therefore a pilot control model that includes the effects of control stick and wheel position on the flight control actuator position demands is currently in the definition phase. Contact ADI for the latest information.

Engine Model

iAircraft offers two gas turbine engine models as follows:

- Low Fidelity Engine – Engine pressure ratio and thrust simulation
- High Fidelity Engine – Piecewise linear model with each stage of the engine modeled individually

Low Fidelity Engine Model

The low fidelity engine model provides a reasonably accurate model for use in many flight simulation tasks and allows the iAircraft model to be flown without the need to obtain detailed engine stage data.

Figure 11 - iAircraft Low Fidelity Engine Model Block

The low fidelity model calculates engine pressure ratio, and thrust as a function of pilot lever throttle input, aircraft Mach number, aircraft altitude, and ambient pressure. Reverse thrust is included in the low fidelity engine model. The low fidelity model provides limited transient detail and fidelity. This low-fidelity engine model was developed based on flight simulator work performed by Boeing and NASA.

High Fidelity Engine Model

The high fidelity model provides a mean value gas turbine engine model for the purpose of enabling a real FADEC (EEC) to be connected to the iAircraft simulation and for integrating a real FADEC into a lab test facility such as an iron bird or a simulation-based integration test facility.
The high fidelity engine model represents each component of the core gas engine including inlet, compressor, volume, duct, turbine, rotor, bleed, variable stator vane, and nozzle stages, as appropriate. Calculated values include moment, temperature, pressure, mass, fuel, fuel-to-air ratio, enthalpy, specific heat, and thrust. Additional dynamics include:

- Fuel metering unit
- Thrust reverser door dynamics
- Starter motor and generator torque load on the HP spool
- Variable stator vane actuation

This engine model was developed based on the original work by Y. Matsuda, the original work by N. Sugiyama, and research internal to Applied Dynamics which carried forward this earlier work.
Hydraulics Model - iAircraft+ Hydraulics

Applied Dynamics is offering an aircraft hydraulics model developed for the C919 class of aircraft. This model will be developed in cooperation with COMAC and will provide hydraulic system dynamics and avionics interfacing capability as required for simulation-based lab test facilities such as iron bird simulators and simulation-based integration test facilities. This hydraulics model is not appropriate for aircraft hydraulic system design tasks such as performance evaluation.

The hydraulic model will interface with the flight dynamics, engine, landing gear, avionics, and electrical system models to provide closed loop dynamics for system verification purposes. The initial version of the hydraulics model is currently in the definition and design phase. Contact ADI for the latest available information.

Electrical Model - iAircraft+ Electrical

Applied Dynamics is offering an aircraft electrical system model developed for the C919 class of aircraft. This model will be developed in cooperation with COMAC and will provide electrical system interfacing capability and basic electrical system dynamics as required for simulation-based lab test facilities such as iron bird simulators and simulation-based integration test facilities. This electrical model is not appropriate for aircraft electrical system design tasks such as performance evaluation.

The electrical model will interface with the flight dynamics, engine, landing gear, avionics, and hydraulics system models to provide closed loop dynamics for system verification purposes. The initial version of the electrical model is currently in the definition and design phase. Contact ADI for the latest available information.

Aircraft Visuals

Available for the iAircraft model is a comprehensive 3D aircraft visual display. The iAircraft 3D visual display is run on a separate PC and communicates with the iAircraft integrated simulation model across a UDP Ethernet interface. The iAircraft 3D visual display provides out-the-window visual display, 3D cockpit display, aircraft chase-and-follow viewing, and other modes that allow comprehensive flight simulation visuals to be added to the aircraft simulation lab.

Cockpit Displays

The iAircraft 3D visual display optionally includes 3D cockpit displays and glass cockpit displays. iAircraft 3D cockpit displays allow a 3D representation of the C919 cockpit to be assembled and animated during real-time simulation runs. Cockpit display values may be linked and animated with values from the iAircraft simulation model, from values on the ARINC 429 databus, from values on the ARINC 664/AFDX databus, or from emulated sensor signals all available from within the ADvantageVI run-time interface.

The iAircraft 3D Glass Cockpit display provides a virtual glass cockpit display for your iAircraft simulations that may be configured with thousands of display options. The iAircraft 3D Glass Cockpit is ideally suited for when running non-real-time aircraft simulations for model validation and test script development.
iAircraft Support Services

For more than two decades Applied Dynamics has been working with leading aircraft manufacturers and suppliers to assist with aircraft simulation needs. Our expertise in the simulation of aircraft components and the simulation of the complete, integrated aircraft leads the industry. Our simulation-related customers include Airbus, Boeing, BAE Systems, Gulfstream, Goodrich, Honeywell, NASA, General Atomics, Messier, Crane Aerospace, Meggitt, and many more.

The Integrated Aircraft Simulation Model

A high-fidelity, real-time integrated aircraft simulation model is a critical component for any advanced commercial aircraft program. The aircraft simulation model should evolve over the course of the aircraft program in alignment with the aircraft design. The early-stage aircraft simulation model provides generalized simulation of the complete aircraft. As aircraft design details are firmed, the fidelity and detail of the aircraft simulation model is increased and firmed. A simulation model in alignment with the aircraft design allows the model to act as an asset for communicating the aircraft design. The aircraft simulation becomes an “executable specification” for the aircraft which means engineers are able to experiment with the simulation model to examine time-based behavior and performance characteristics.

The integrated aircraft model acts as an important tool for many tasks within the aircraft program including:
- Communication of the design specification
- Software-in-the-loop simulation
- Avionics development and verification
- Flight controls development and verification
- Landing system development and verification
- Hydraulic system development and verification
- Electrical system development and verification
- Integrated Mechanical and Electrical system development and verification
- Full aircraft integration and verification

Supporting Your Simulation Needs

In addition to supplying the iAircraft real-time and non-real-time model software, Applied Dynamics is offering the following support services:
- Model parameterization to a specific aircraft
- Development of “specific-subsystem” simulation modules
- Model validation against aircraft performance data
- iAircraft user training
- Simulation model development training

iAircraft Specific-Subsystem Modules

The design of many of the subsystems within a given aircraft vary widely from aircraft to aircraft. As a result of the unique, aircraft-specific designs for these subsystems a generalized simulation module is not appropriate for iAircraft. Rather, specific-subsystem modules must be developed which exactly match the design of those subsystems for the aircraft. Aircraft subsystems that fall under the category of “specific-subsystem modules” include:
- hydraulic power
- electrical system
- detailed avionics
- environmental control system (ECS)

Applied Dynamics is offering to work with your departments to develop “specific-subsystem modules” as required and integrate these simulation modules into the iAircraft software.

Program-Wide Agreements

In a typical commercial aircraft program there are multiple groups with demand for iAircraft as the integrated aircraft simulation modeling solution of choice. Applied Dynamics is willing to offer significant quantity discounts should a program select iAircraft as the program-wide aircraft simulation solution.