Hochschule für Angewandte Wissenschaften Hamburg
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AERO – AIRCRAFT DESIGN AND SYSTEMS GROUP

Flight Dynamics Analysis of a Medium Range Box Wing Aircraft

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Airport2030 – Work Package 4.1:

Aircraft Configurations for Scenario 2015

Contents

- Introduction to 'Airport 2030' and Box Wing Aircraft
- Stability and Control Derivatives
- Flight Dynamics Model (FDM) – JSBSim
- Integration of FDM in Flight Simulator – Flight Gear
- Analysis of Eigenmodes and Handling Qualities
- Conclusions

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Introduction to Airport 2030 and Box Wing Aircraft

Flightpath 2050

"In 2050 technologies and procedures available allow a 75% reduction in CO_2 emissions per passenger kilometer ... these are relative to the capabilities of typical new aircraft in 2000."

EU 2011

- Without **unconventional** configurations, stated Flightpath 2050 goals will not be reached!

Airport2030

AIRPORT 2030

- Joint project of several German research institutes and aeronautical companies
- HAW Hamburg participates with Aero research group
- The task is to design aircraft configurations for efficient ground handling.

Box Wing configuration

- A conventional wing is split along the wing span into two wings
- Reduction of induced drag

Fuel savings because of the wing configuration

Current version

- Based on Airbus A320 (same design mission)
- 9% fuel savings
- Twin aisle layout

Advantages with regard to 'Airport 2030'

- Less emissions during landing and take off (induced drag = 80-90 % of the total drag)

- More efficient ground handling because of undivided cargo compartment (usually the center wing box divides the cargo compartment) and the twin aisle layout

Introduction to Airport 2030 and Box Wing Aircraft

1) **Conceptual design** (Schiktanz 2011) ✔

Next step:

2) **Flight Dynamics Analysis**

- An accurate description of the flight-dynamics of the aircraft is necessary to decide whether its design is feasible (especially for unconventional configurations).
- Need to increase the knowledge about stability and control (S&C) as early as possible in the aircraft development process in order to be first-time-right with the FCS design architecture, in later stages of design.

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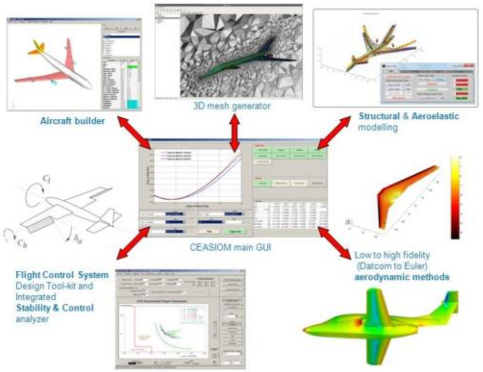
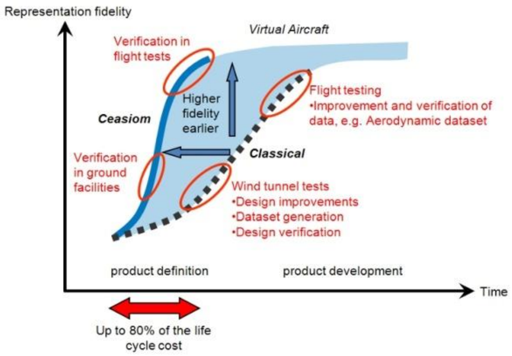
Computerised Environment for Aircraft Synthesis and Integrated Optimisation Methods (CEASIOM)

- Recalibrated handbook methods (from experience and previous designs) are not reliable enough for aircraft conceptual design of unconventional configurations.

- CEASIOM: integrated design and decision making environment where all necessary predictive computations can take place during the early conceptual design phase.



Overview of CEASIOM



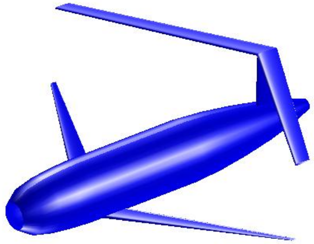
Up to 80 % of the lifecycle cost of an aircraft is a direct result of decisions made in the conceptual design phase: **mistakes must be avoided**

Check if problem could arise from Box Wing configuration (the second wing)

Use of the **stand-alone** versions of some modules of CEASIOM

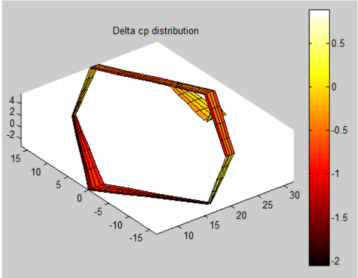
Stability and Control Derivatives

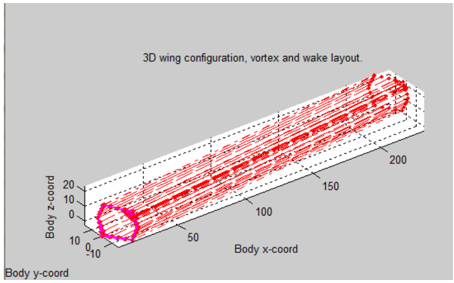
- Definition of stability and control derivatives necessary for the flight dynamics analysis
- Modeling of aircraft geometric model and derivatives calculation:
  - **USAF Digital Datcom**: problems with geometry, winglets cannot be modeled



Aircraft geometric model obtained with Digital Datcom (no possibility of winglets)

  - **Tornado**: - Vortex Lattice Method (VLM) for linear aerodynamic wing design applications, implemented in MATLAB
    - Aircraft is built up by multiple wings which can have a full 3D orientation (no fuselage)





Screenshots of Tornado calculations

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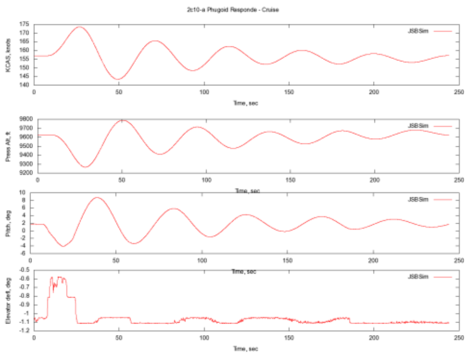
Flight Dynamics Model (FDM) - JSBSim

FDM: Physics/math model that defines the movement of an aircraft under the forces and moments applied to it using the various control mechanisms and from the forces of nature

JSBSim: open source FDM compiled in C++

- Fully configurable flight control system, aerodynamics, propulsion, landing gear arrangement, etc. through XML-based text file format.
- It can be run as a stand-alone program, taking input from a script file and various vehicle configuration files or incorporated into a flight simulator (real time) with a visual system.
- JSBSim also allows to perform flight tests (ie. FAA-style tests) and evaluate the behavior of the aircraft from graphic plots: Flap change dynamics, Phugoid dynamics…



Results of the Phugoid response for a business-class turbojet aircraft

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Integration of FDM in Flight Simulator – FlightGear

FLIGHT GEAR: Open-source flight simulator, mostly written in C++

- Intended to use in research or academic environments, pilot training, as an industry engineering tool, etc.
- Currently supports several FDM's: **JSBSim** (default since 2000), YASim (the only FDM providing simulation for rotorcraft), UIUC.

Screenshot of FlightGear (www.flightgear.org)

- Once implemented in FlighGear, it will be possible to observe the behaviour of the Box Wing aircraft from a more subjective point of view (that of a pilot), and find out whether it "handles nicely" (**Cooper-Harper-Rating-Scale**).

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Analysis of Eigenmodes and Handling Qualities

- Once the stability derivatives are determined it is possible to set up the equations of motion of the aircraft
- The equations of motion can be evaluated and the eigenmodes (Phugoid, Short-period oscillation…) determined by means of JSBSim.
- The flying and handling qualities based on the derivatives could also be examined with the SDSA module of CEASIOM
- The integration of the FDM into FlightGear allows for a subjective evaluation of the handling qualities of the aircraft.

IS THE BOX WING AIRCRAFT ALSO DYNAMICALLY A VALID DESIGN?

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Conclusions

- The flight dynamics analysis of an aircraft within the conceptual design stage is necessary to decide as soon as possible whether its design is feasible (the aircraft will behave properly).
- An automatic workflow for analysing aircraft with multiple wings is not possible within CEASIOM. Hence use of the aerodynamic modules as standalone applications (Digital Datcom, Tornado…)
- Once the derivatives are known the flying and handling qualities of the aircraft can be examined, and a decision about the validity of the design can be made.

Thank you very much for for your attention!

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Backup

Cooper-Harper Rating Scale