On the need for a reference aircraft to support (collaborative) aircraft design

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Chair of Flight Performance and Propulsion

4th CEAS-SCAD - Symposium on Collaboration in Aircraft Design, TOULOUSE 2014
Analysis tool validation

How do we validate our analysis tools?

- For aerodynamics:
  - NACA/NASA reports
  - DLR and NASA reference models from the Drag Prediction Workshops (DLR-F4/F5)
  - Drag polars and coefficients from *Aerodynamic Design of Transport Aircraft*, by E. Obert
  - ...
  - Internal confidential material

http://aaac.larc.nasa.gov/tsab/cfdlarc/aiaa-dpw/Workshop2/DLR-F6-geom.html
http://aaac.larc.nasa.gov/tsab/cfdlarc/aiaa-dpw/Workshop5/DPW5-geom.html

B. Tinling and W. Kolk, *The effects of Mach number and Reynolds number on the aerodynamic characteristics of several 12-percent thick wings having 35 degrees of sweepback and various amounts of camber*, National Advisory Committee for Aeronautics, 1951.
**Analysis tool validation**

*How do we validate our analysis tools?*

- For component **weight estimation**

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### Table 1
Comparative study of some class II & 1/2 weight estimation methods. Wing weight estimation error computed as a percentage of the actual wing weight.

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Error of wing weight estimation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A300-600R</td>
<td>4.7</td>
</tr>
<tr>
<td>A310-300</td>
<td>–7.2</td>
</tr>
<tr>
<td>A320-100</td>
<td>–7.0</td>
</tr>
<tr>
<td>A330-300</td>
<td>0.1</td>
</tr>
<tr>
<td>A340-300</td>
<td>–1.4</td>
</tr>
<tr>
<td>A380-800</td>
<td>22.6</td>
</tr>
<tr>
<td>B737-200</td>
<td>–</td>
</tr>
<tr>
<td>B747-100</td>
<td>–</td>
</tr>
<tr>
<td>B747-200</td>
<td>29.4</td>
</tr>
<tr>
<td>B747-400</td>
<td>53.5</td>
</tr>
<tr>
<td>B777-200</td>
<td>16.2</td>
</tr>
<tr>
<td>DC-8</td>
<td>–</td>
</tr>
<tr>
<td>MD-11</td>
<td>–</td>
</tr>
<tr>
<td>MD-83</td>
<td>–</td>
</tr>
<tr>
<td>L-1011</td>
<td>–</td>
</tr>
<tr>
<td>Fokker 100</td>
<td>–</td>
</tr>
<tr>
<td>Cessna Citation II</td>
<td>–</td>
</tr>
</tbody>
</table>

Available data extremely scarce (dependency on unknown loads, allowables, design criteria, weigh components definition...)

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**Challenge the future**

Delft
University of Technology

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Design tool validation

How do we evaluate our DESIGN tools?

• We can verify them (are they able to synthesize a design?)

Jenkinson’s data collection (Civil Jet Aircraft Design)
http://booksite.elsevier.com/9780340741528/appendices/data/default.htm
Design tool validation

How do we evaluate our DESIGN tools?

• Can we validate them (how well do they do their job)???

• That is not possible without the availability of a reference aircraft*!

• For any fair comparative design study, “the reference” aircraft must be generated by the same design tool

*per category
Need for a reference aircraft

- **TLAR** (including special constraints)
- Detailed **geometry**
  - Airfoils
  - Structural layout
- **Weights**
  - Weight components (wing, tailplanes, systems, etc...)
- Detailed **performance** data
  - $L/D_{\text{max}}$, $L/D_{\text{cruise}}$, $C_{L\text{cruise}}$, $CL_{\text{TO}}$, $CL_{\text{LA}}$, $C_D$, polars (trimmed, flapped, landing gear down)
  - Climb and TO&Landing
  - Stability margins
- **Costs** and Cost model
- ...
- **Design objectives**!!
  - MTOW? Cost? (What cost and what cost model?) Fuel consumption? Other(s)??
What reference aircraft?

An aircraft...

- Whose complete data set is available (in any form)
- For which designers and discipline specialists are still available (chief designers, aerodynamics, weight specialists, ...)
- For which there are disclosure possibilities (e.g., aircraft no more operational, out of production, ...)

• FOKKER 100???
The Fokker 100

**FOKKER 100 REGIONAL JET**

The Fokker 100 is a regional jet in service with over 40 operators worldwide. The Fokker 100 was manufactured during 1993 through to 1996 and a total of 278 were built.

Prevailing market conditions have made a number of Fokker 100 aircraft available at affordable prices or monthly lease rentals. Favorable operating expenses and substantial revenue potential combine to make the economics of the Fokker 100 very compelling. The Fokker 100 is the natural successor of the F-28 Fellowship and is formally certified as the F-28 Mk0100.

Go directly to the Fokker 100 specifications:

- Basics
- Interior
- Performance
- Environment
- Avionics
- Operation
- Continued airworthiness
- Availability

http://www.flyfokker.com/Fokker-100
The Fokker 100

http://www.flyfokker.com/Fokker-100
The Fokker 100

Dimensions and areas

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value (m)</th>
<th>Value (ft)</th>
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</thead>
<tbody>
<tr>
<td>Overall length</td>
<td>35.53</td>
<td>116.7</td>
</tr>
<tr>
<td>Overall height</td>
<td>8.51</td>
<td>27.1</td>
</tr>
<tr>
<td>Fuselage length</td>
<td>32.50</td>
<td>106.8</td>
</tr>
<tr>
<td>Fuselage external diameter</td>
<td>3.30</td>
<td>10.10</td>
</tr>
<tr>
<td>Wing area</td>
<td>93.50</td>
<td>1006.46</td>
</tr>
<tr>
<td>Wing span</td>
<td>28.08</td>
<td>92.1</td>
</tr>
<tr>
<td>Gear track</td>
<td>5.04</td>
<td>16.6</td>
</tr>
</tbody>
</table>

Weights

<table>
<thead>
<tr>
<th>Category</th>
<th>MTOW (kg)</th>
<th>MTOW (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTOW</td>
<td>45,810</td>
<td>101,000</td>
</tr>
<tr>
<td>MLW</td>
<td>44,450</td>
<td>98,000</td>
</tr>
<tr>
<td>MLW</td>
<td>39,915</td>
<td>88,000</td>
</tr>
<tr>
<td>MZFW</td>
<td>36,740</td>
<td>81,000</td>
</tr>
<tr>
<td>Fuel capacity</td>
<td>10,731</td>
<td>23,660</td>
</tr>
<tr>
<td>Fuel capacity</td>
<td>10,293</td>
<td>22,690</td>
</tr>
</tbody>
</table>

Assumptions:
- ISA
- Zero Wind
- Long Range Cruise
- EU-OPE 1.225 Reserves:
- 100 NM alternate
- RR Tay 850 engines

http://www.flyfokker.com/Fokker-100
What’s in for the CEAS/TCAD community?

- A reference aircraft to validate our aircraft design tools
- A baseline to evaluate the impact of MDO studies
- A baseline to evaluate the impact of new technologies (e.g., relaxed stability, new materials, new structure design & manufacturing approaches, flow control devices...)
- ...

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What’s in for FOKKER?

- Opportunity to evaluate the impact of MDO studies
- Opportunity to evaluate the impact of new technologies (relaxed stability, new materials, new structure design & manufacturing approaches, flow control devices...)
- Opportunity to benchmark design tools
- Opportunity to benchmark design teams
- Eased accessibility to design and optimization tools?
- A community to submit “request for proposals”, design cases and contests...
How to proceed?

- A preliminary request has been sent to Fokker by TUD
- Should we let TUD and NLR proceed with the first phases of the request?
- Should we approach Fokker as CEAS/TCAD?
- ...

...
What else is out there?

• Any Airbus-like design?
• Any ATR-like design?

...and what about these?
Let’s think this together!