Reference Aircraft

5th Symposium on Collaboration in Aircraft Design, Naples, 13.10.2015
Agenda

- CeRAS – Central Reference Aircraft data System
- The next version of CSR
  - Comparison of CSR-02 to the CSR-01
- Requirements for a long-range version CLR-01
- Conclusion and Outlook
CeRAS – Central Reference Aircraft data System
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**Problem**

- **Limited availability** of consistent reference A/C data for research community
- **Restricted data authorization** from industry
- **Definition process** of a reference for technology integration and evaluation for every single project consumes cost and resources

**Solution: Open Source Reference A/C data System CeRAS**

- Complete and consistent dataset developed by RWTH and validated by Airbus, DLR, BHL and Universities (*incl. standards for cost calculation [TU Berlin] & interface [CPACS DLR]*)
- **Accessibility and extensibility** by a larger research and industrial community
- Especially useful for **SMEs**, who are not able to create own references
- High level of detail
- **Design sensitivities** for masses, aerodynamics and specific fuel consumption for technology evaluation
CeRAS – Central Reference Aircraft data System

Presentation of reference data in the world wide web

- All reference data is stored and distributed by an internal server within the ILR. The server can be reached via:


CeRAS Long Range v1 (CLR-01)

- **Requirements:** today?!
- **Completion:** until the end of 2015
- **Dissemination:** first quarter of 2016 (depends on validation process)

Usage of CeRAS

- CeRAS is used in different projects
- Today we have got 66 members
The next version of CSR
The next version of CSR

Objectives

• Due to new or more sophisticated methods the calculated values of CSR-01 will change from time to time

→ Every year at least a new version of the CSR will be released

• Today a discussion about the „new“ CSR-02 version
  • Explanation of changes in comparison to CSR-01

• The main topics will be:
  • Aerodynamics
  • Masses
  • Systems and Power Off-Takes
  • New Taxi-Fuel values due to a „modified“ engine deck (lower idle rpm)
The next version of CSR

How to handle deviations in reference values?

**FACT:**
- The CSR-01 was placed as a reference, which was validated
- Users are working with this reference

**Question:**
- How to handle deviations in these values due to different methods?

**Solution for CSR-02:**
- Explaining changes in methods
- Calibration of engine (SFC) and fuselage (weight correction) to meet the aerodynamics, operational weight empty and fuel mass

\[
\text{MTOW} = PL_{\text{Design}} + OWE + m_{\text{Fuel}}
\]
The next version of CSR

Aerodynamics

There are several changes in calculating the aerodynamics. With the input of geometry and freestream conditions the lift curves and induced drag coefficients for different angles of attack are calculated with LIFTING_LINE from DLR:

- New grid/panel arrangement
- New transformation of twist distribution to the LIFTING_LINE input file
- Also a compressible lift-distribution is calculated
- New and corrected calculation of moment coefficient
  - Current Centre of Gravity as reference point in every single iteration
    ➔ Higher AoA of Horizontal Stabilizer for trimmed condition
- Corrected methods for calculation of viscous drag for fuselage and nacelles

➔ Small deviations in clean drag polars and small shift of L/D-curves to lower optimum lift coefficients ($C_{L,CSR-02} = 0.526$ compared to $C_{L,CSR-01} = 0.54$)
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Aerodynamics

![Graphs showing Aerodynamics data](image-url)
The next version of CSR

Aerodynamics
The next version of CSR

Masses

FEM method (simple beam theory) was adapted:

- Current lift distribution for the maneuver is read in
- The pull-up maneuver was constituted as the most critical one and is flown at SL, \( v = v_{MO} \), MTOW and max payload
  - Max payload results in least fuel (which is relieving)
- Landing gear and engines are now taken into account as relieving point loads
- Spoiler were added
- Fuel density was reduced
  - Fuel mass (as a relieving mass) was reduced

\[ \rightarrow \text{Results in a lighter wing (Reduction from 8097kg to 7680kg)} \]
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Masses

- System masses get heavier due to higher power consumption
  - APU: $\Delta = -12\text{kg}$ (new method with regard to Electrical Power Consumption)
  - Hydraulics: $\Delta = +85\text{kg}$ (due to spoiler hydraulic power consumption)
  - Air Conditioning: $\Delta = -8\text{kg}$ (less heat load due to no personnel IFEs)
  - Flight Controls: $\Delta = -76\text{kg}$ (new method and spoiler actuators)
  - Electrics: $\Delta = +18\text{kg}$ (more electrical power consumption)

→ Total change of $+8\text{kg}$

- Furnishing mass increases due to new and higher toilet masses ($+70 \text{ kg}$)
- Operator Items mass increases due to new seat masses ($+123 \text{ kg}$)

→ In summation of structures, systems, furnishings and operator items there is a mass delta of $\Delta = -231 \text{ kg}$ which will be compensate with fuselage mass
The next version of CSR

Systems

Some sequences of power consumption of several ATA chapters had some deviations to „reality“:
- ATA-21: Conventional ECS (Air Conditioning)

• Electrical Load is scaled with cabin volume; old method was unknown

→ Results in a $\Delta = + 8.5$ kW over the mission
The next version of CSR

Systems

Some sequences of power consumption of several ATA chapters had some deviations to „reality“:

- **ATA-25**: Conventional Furnishing
  - **ATA-25 - conventional Furnishing**
  - Power of galleys adapted; no personnel IFEs (1kW permanent load now for IFE)
  - Results in a $\Delta = -16$ kW over the mission
The next version of CSR

Systems

Some sequences of power consumption of several ATA chapters had some deviations to „reality“:

- ATA-27: Flight Controls

• Summation of peak load corrected; geometric calculation improved (physic based)

→ Results in a $\Delta = +1.5 \text{ kW}$ over the mission
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Mission - Functionality

- The whole mission is divided into infinitesimal mission steps
- In every step the equations of motion are solved to determine the needed thrust. Input are:
  - Current aircraft mass
  - Aerodynamic polars of full aircraft
  - Freestream conditions
  - Atmosphere
- The power off-takes in every single mission step are considered to catch the effects to the engine performance which is then working in off-design conditions → higher fuel consumption
The next version of CSR

Modified Engine Deck - Functionality

• The used engine performance model based on full thermodynamic engine cycle analysis using software GasTurb\(^1\)

• Export of engine performance decks, containing thrust, fuel flow, cycle parameters, emissions etc. as function of Mach number and flight altitude

• Model provides available thrust, fuel flow and other parameters according to limits, engine rating and off-takes

→ For the CSR-02 the decks are converged to lower idle rpm (27.5% of N1 instead of 50%).

The next version of CSR

Modified Engine Deck – Influence on Taxi Fuel

- „Idle mode“ of V2527-A5 at 0,5 N1
- „Idle mode“ of V2527-A5 at 0,275 N1

<table>
<thead>
<tr>
<th>Mission simulation results</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Take-off weight</td>
<td>$TOW = OWE + PL + MF - TXF_{out}$</td>
</tr>
<tr>
<td>Mission (loaded) fuel</td>
<td>$MF = BF + RF$</td>
</tr>
<tr>
<td>Block fuel</td>
<td>$BF = TF + TXF_{out} + TXF_{in}$</td>
</tr>
<tr>
<td>Trip fuel</td>
<td>$TF$</td>
</tr>
<tr>
<td>Reserve fuel</td>
<td>$RF$</td>
</tr>
<tr>
<td>Taxi-out fuel</td>
<td>$TXF_{out}$</td>
</tr>
<tr>
<td>Taxi-in fuel</td>
<td>$TXF_{in}$</td>
</tr>
</tbody>
</table>

$\rightarrow$ The modification results in less and more realistic taxi fuel
The next version of CSR

Result

• This approach results in a dataset:
  • which is consistent
  • with similar aerodynamic behaviour
  • same key characteristics
  • where former failures are eliminated

• Another approach is to relax the key parameters and allow changes in aerodynamic values for example
  • this leads also to a consistent dataset, but different to a former reference
Requirements for a long-range version CLR-01
## Requirements for a long-range version CLR-01

### Requirements for CLR-01

<table>
<thead>
<tr>
<th>Requirement</th>
<th>A330-200</th>
<th>B777</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTOW</td>
<td>230.000 kg</td>
<td>299.370 kg</td>
</tr>
<tr>
<td>OWE</td>
<td>124.500 kg</td>
<td>160.120 kg</td>
</tr>
<tr>
<td>Payload</td>
<td>30.000 kg</td>
<td>35.000 kg</td>
</tr>
<tr>
<td>Maximum Payload</td>
<td>48.000 kg</td>
<td>64.960 kg</td>
</tr>
<tr>
<td>PAX</td>
<td>246 (2-class layout)</td>
<td>368 (3-class layout)</td>
</tr>
<tr>
<td>Range</td>
<td>6100 NM</td>
<td>5900 NM</td>
</tr>
<tr>
<td>Cruise Mach Number</td>
<td>0.82</td>
<td>0.84</td>
</tr>
<tr>
<td>Cruise Altitude</td>
<td>37000 ft</td>
<td>40000 ft</td>
</tr>
<tr>
<td>BFL</td>
<td>2515 m</td>
<td>3353 m</td>
</tr>
<tr>
<td>Landing Distance</td>
<td>1753 m</td>
<td>1860 m</td>
</tr>
</tbody>
</table>
Requirements for a long-range version CLR-01

Requirements for CLR-01 - Ideas

• Put a form on the homepage to request for requirements from all users
  • Maybe you need your own reference

• Using a Boeing aircraft as reference keeping in mind that industry (e.g. AIRBUS) is not restricted with these data
  • Providing that AIRBUS has got some data of Boeing aircraft

• Using a conventional configuration with a technology standard of the year …
Conclusion and Outlook
Conclusion and Outlook

Conclusion

- Design of a second version of the CSR-Reference Aircraft
- Keeping Aerodynamic, Operating Weight Empty and MTOW constant
- Notice of deviations to CSR-01
- Given explanations for the deviations

→ Complete and full consistent dataset with
  - corrected aerodynamic calculations
  - corrected power offtakes of aircraft systems
  - corrected and more realistic taxi fuel values
  - comparable to CSR-01

- The data are also stored in the newest CPACS data standard
Conclusion and Outlook

Outlook

- Setting up the requirements for a CLR-01 version
- Acceptance of CSR-02 data in design community
- Upload CSR-02 to server

- Using CSR-02 for application of your tools on a reference aircraft
  - Either for validation of your own tools or to expand the level of detail
- Creation of a „list of experts“ (maybe the TCAD activity map can be used?!)

My suggestion:

LET’S TALK CPACS
Outlook

Remaining Questions

• **Usage and Calibration of CeRAS?**
  – When I calibrate my tools against CeRAS data: How much deviations in which parameters are allowed? \(\rightarrow\) definition of quality standards
  – If a “better” method leads to changed values, e.g. in wing mass \(\rightarrow\) redesign?

• **When is a user allowed to download files?**
  – What are the requirements?
  – Is a contribution needed first?

• **In which way can a user contribute to the contents of the CeRAS homepage?**
  – Create new areas?
  – Create an area where all new data is stored first until it is validated by the community?

• **Who is in charge for the continuation of the project?**
  – To delegate means that there are people in the background
Thank you for your attention

Florian Schültke, M.Sc.
Institute of Aerospace Systems
RWTH Aachen University
Wuellnerstrasse 7
52062 Aachen
Tel +49 241-8096800
Fax +49 241-8092233