Reference Aircraft

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

Institute of Aerospace Systems
RWTH AACHEN UNIVERSITY

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

CeRAS – Central Reference Aircraft data System

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

Wing | Mass | Misc | Mission | Cost

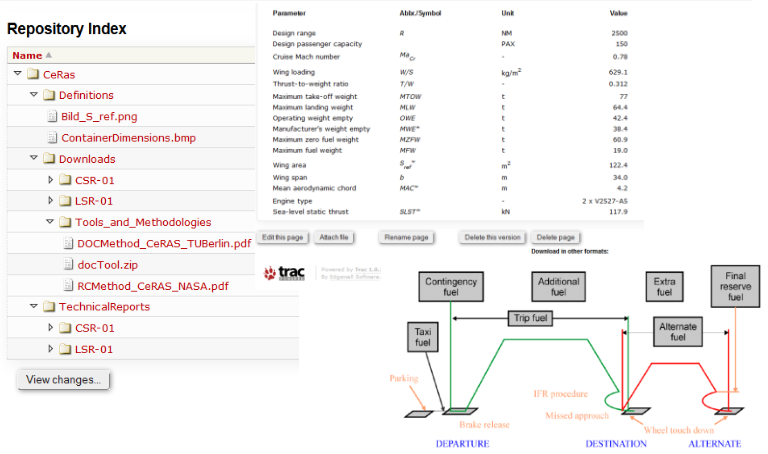
Parameter	Unit	Value	%
RC total	**Mio.$**	**32.39**	**100**
Structure	Mio.$	6.1	18.83%
Wing	Mio.$	1.87	5.77%
Fuselage	Mio.$	2.41	7.44%
Empennage	Mio.$	0.46	1.42%
Landing gear	Mio.$	0.54	1.67%
Pylons	Mio.$	0.83	2.56%
Power unit	Mio.$	12.69	39.18%
Equipped Engines	Mio.$	11.13	34.36%
Nacelles	Mio.$	1.41	4.35%
Bleed Air system	Mio.$	0.09	0.28%
Fuel system	Mio.$	0.05	0.15%
Systems	Mio.$	6.57	20.28%
APU	Mio.$	0.27	0.83%
Hydraulic system	Mio.$	0.19	0.59%
Air conditioning	Mio.$	0.66	2.04%
De-icing	Mio.$	0.04	0.12%
Fire protection	Mio.$	0.04	0.12%
Flight controls	Mio.$	0.63	1.95%
Instruments	Mio.$	0.29	0.9%
Automatic flight systems	Mio.$	0.47	1.45%
Navigation	Mio.$	1.9	5.87%
Communication	Mio.$	0.93	2.87%
Electrical system	Mio.$	1.16	3.58%
Furnishings	Mio.$	1.28	3.95%
Furnishings	Mio.$	0.94	2.9%
Fixed emergency oxygen	Mio.$	0.04	0.12%
Lighting	Mio.$	0.21	0.65%
Water installation	Mio.$	0.09	0.28%
Operators Items	Mio.$	1.54	4.75%
Final Assembly	Mio.$	4.23	13.06%

CeRAS – Central Reference Aircraft data System

Presentation of reference data in the world wide web

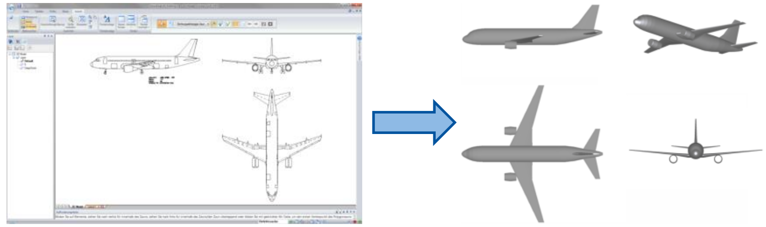
- All reference data is stored and distributed by an internal server within the ILR. The server can be reached via:

http://ceras.ilr.rwth-aachen.de/



Parameter	Abbr./Symbol	Unit	Value
Design range	R	NM	2500
Design passenger capacity		PAX	150
Cruise Mach number	Ma_{Cr}	-	0.78
Wing loading	W/S	kg/m^2	629.1
Thrust-to-weight ratio	T/W	-	0.312
Maximum take-off weight	$MTOW$	t	77
Maximum landing weight	MLW	t	64.4
Operating weight empty	OWE	t	42.4
Manufacturer's weight empty	MWE^*	t	38.4
Maximum zero fuel weight	$MZFW$	t	60.9
Maximum fuel weight	MFW	t	19.0
Wing area	S_{ref}^*	m^2	122.4
Wing span	b	m	34.0
Mean aerodynamic chord	MAC^*	m	4.2
Engine type		-	2 x V2527-A5
Sea-level static thrust	$SLST^*$	kN	117.9

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

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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)

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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

$$\mathbf{MTOW = PL_{Design} + OWE + m_{Fuel}}$$

The next version of CSR

Aerodynamics

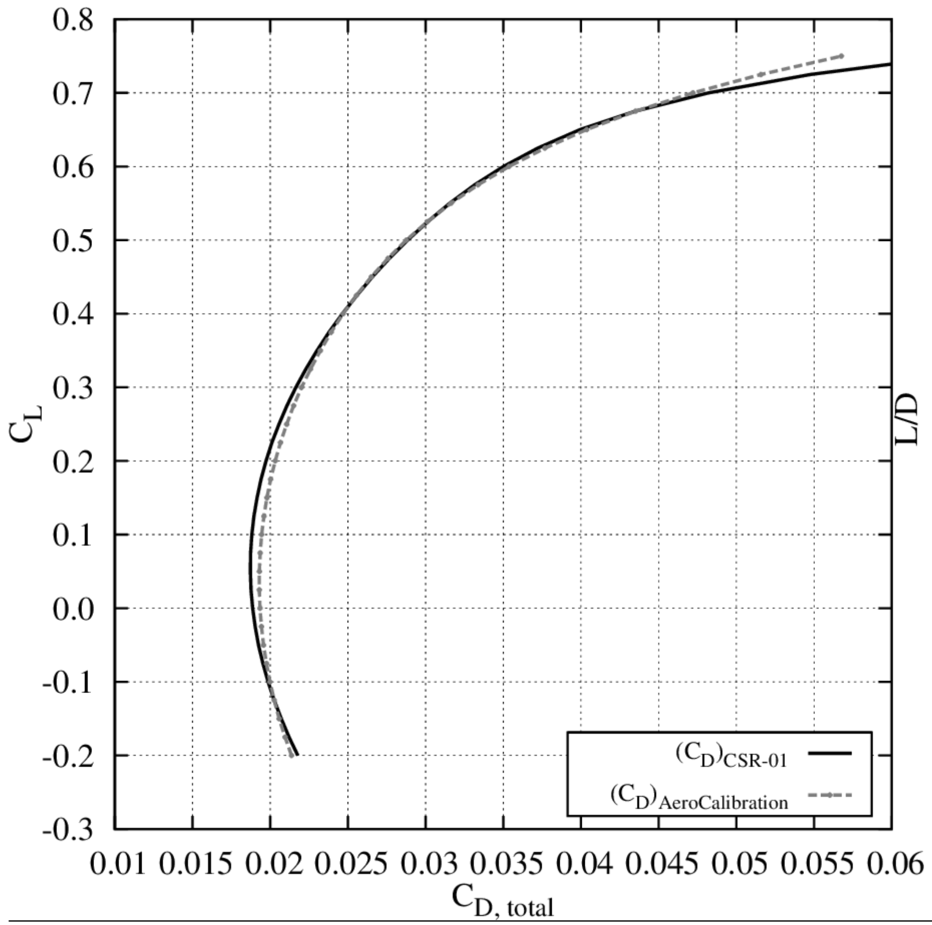
There are several changes in calculating the aerodynamics. With the input of geometry and freestream conditions the lift curves and induced drag coefficients for different angles of attack are calculated with LIFTING_LINE from DLR:

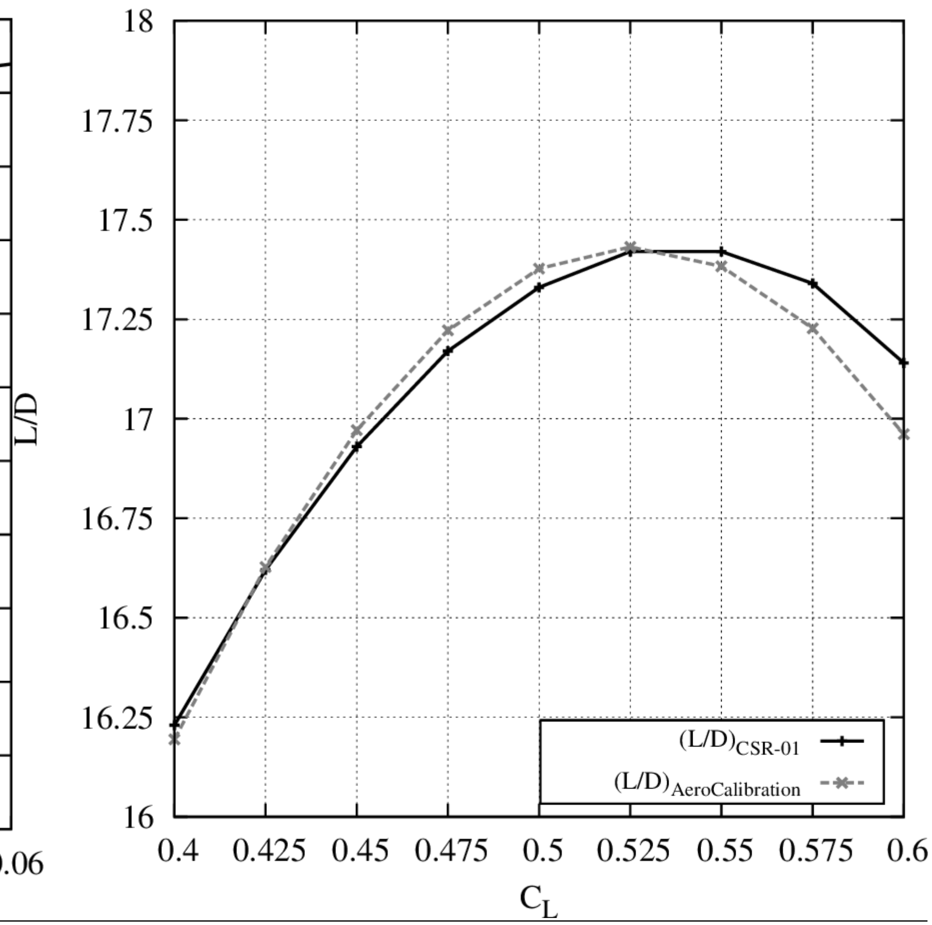
- New grid/panel arrangement
- New transformation of twist distribution to the LIFTING_LINE input file
- Also a compressible lift-distribution is calculated
- New and corrected calculation of moment coefficient
  - Current Centre of Gravity as reference point in every single iteration
  - → Higher AoA of Horizontal Stabalizer 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 ($C_{L,CSR\text{-}02}$ = 0,526 compared to $C_{L,CSR\text{-}01}$ = 0,54)**

The next version of CSR

Aerodynamics





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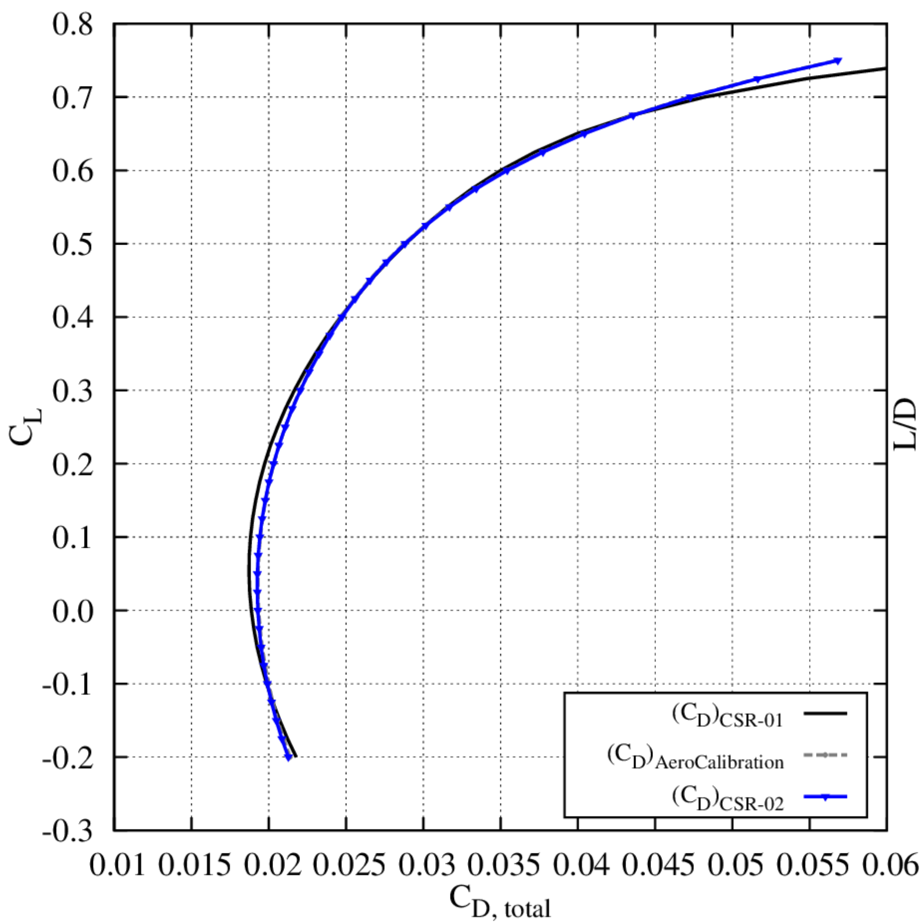
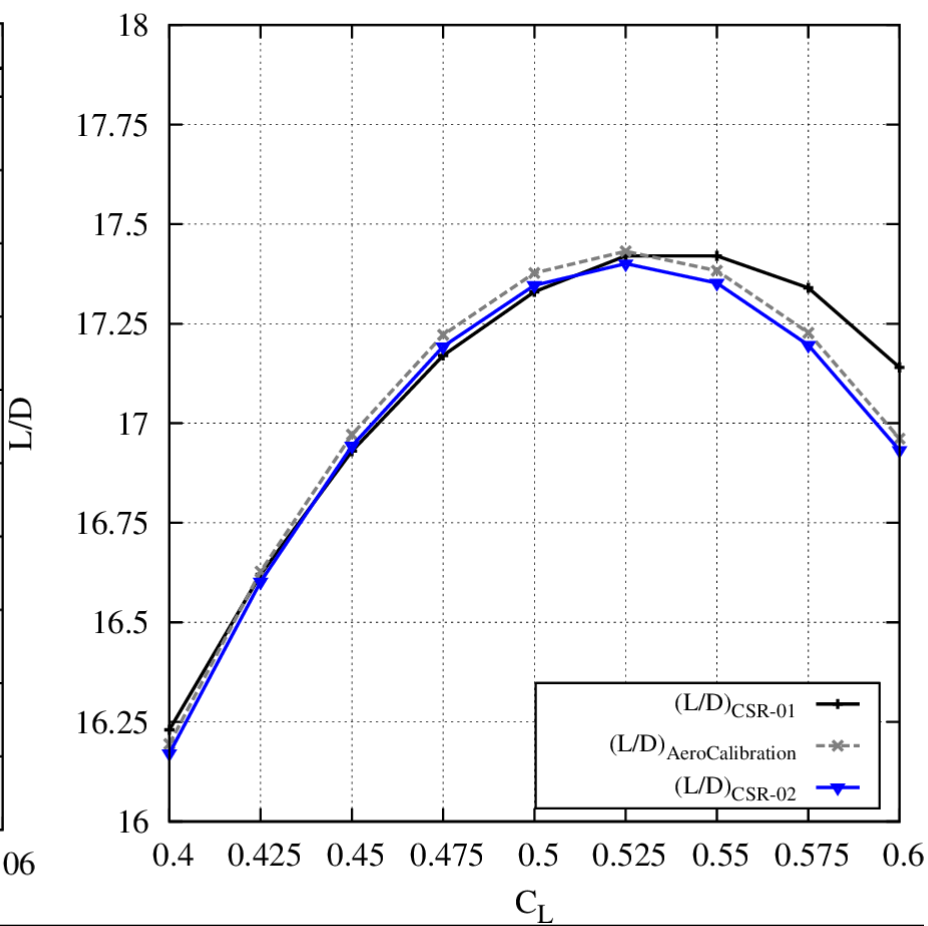
Aerodynamics





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

→ **Results in a lighter wing (Reduction from 8097kg to 7680kg)**

The next version of CSR

Masses

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

  → **Total change of +8kg**

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

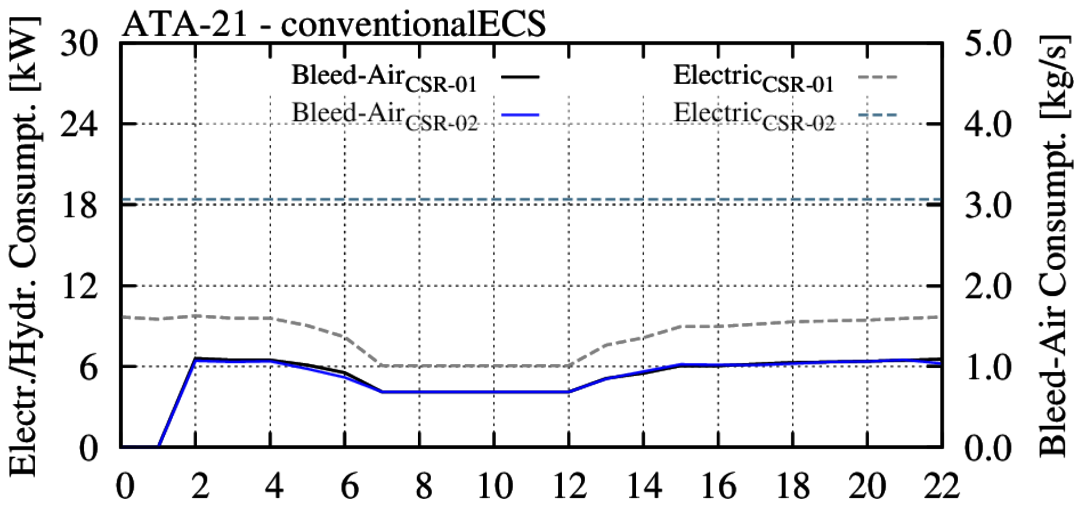
→ **In summation of structures, systems, furnishings and operator items there is a mass delta of Δ = - 231 kg which will be compensate with fuselage mass**

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

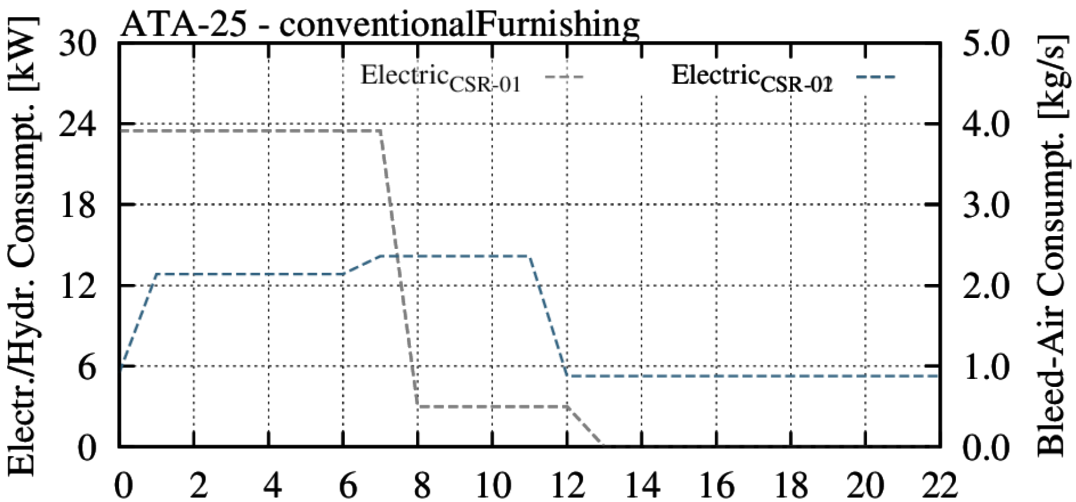
→ **Results in a Δ = + 8,5 kW over the mission**

The next version of CSR

Systems

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

- ATA-25: Conventional Furnishing



- Power of galleys adapted; no personnel IFEs (1kW permanent load now for IFE)

→ **Results in a Δ = - 16 kW over the mission**

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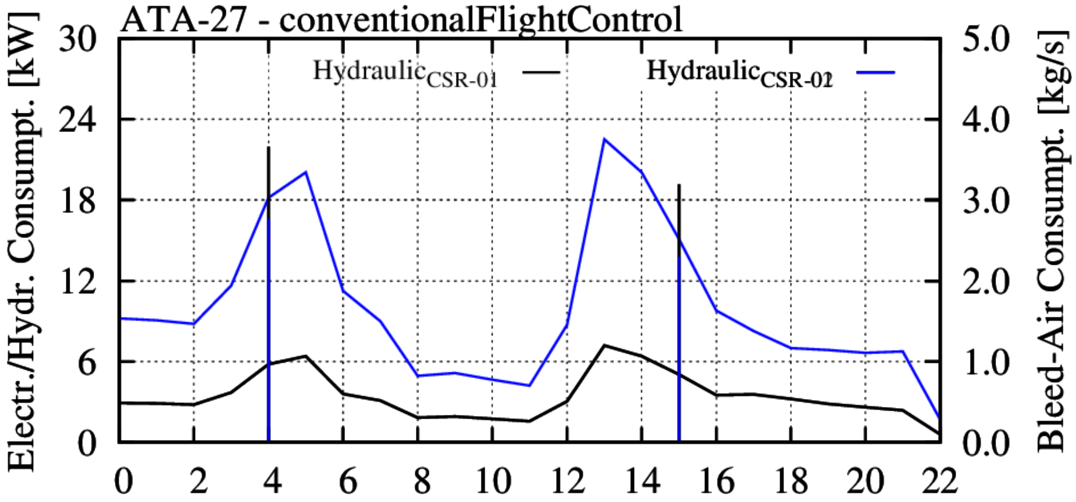
Systems

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

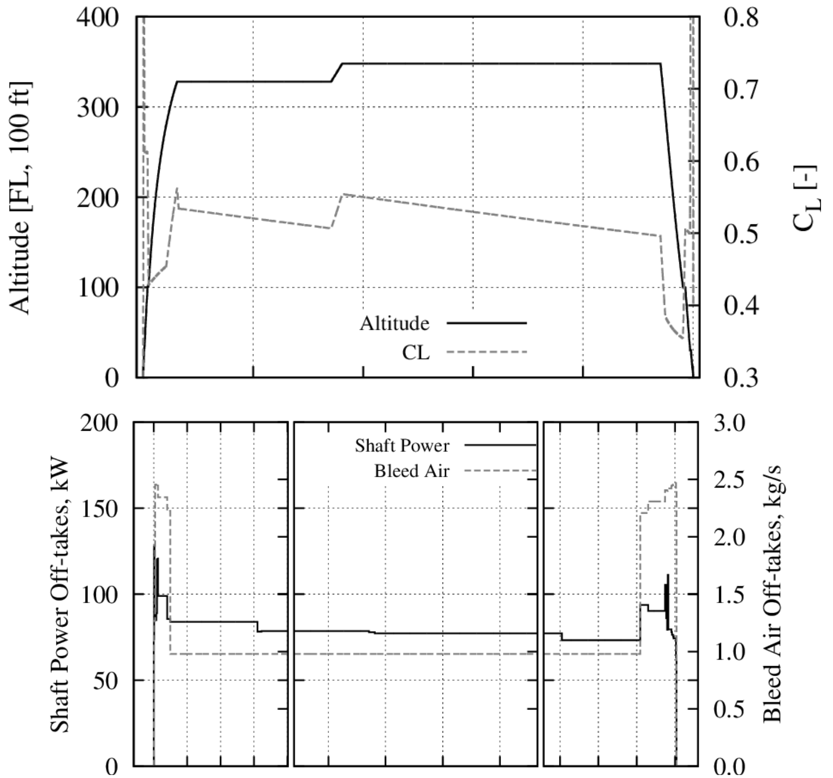
- ATA-27: Flight Controls



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

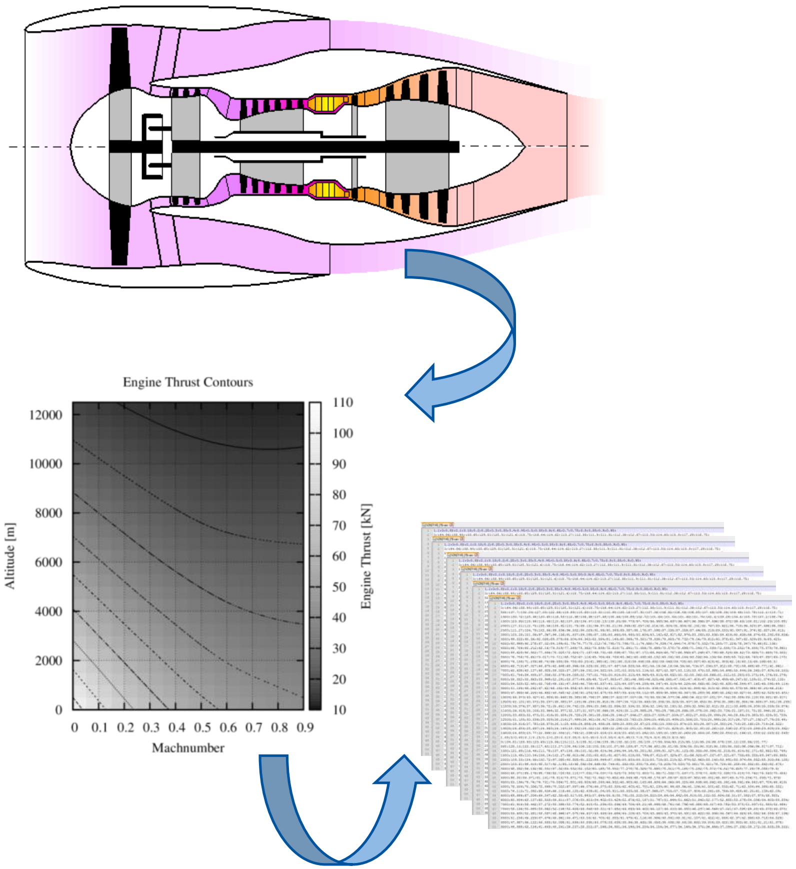
→ **Results in a Δ = + 1,5 kW over the mission**

Mission - Functionality



- The whole mission is devided into infenitesimal 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 offtakes in every single mission step are considered to catch the effects to the engine performance which is then working in offdesign conditions → higher fuel consumption

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%)**

1 Kurzke, J., Gas Turb 11 - Design and Off-Design Performance of Gas Turbines, 2007.

Modified Engine Deck – Influence on Taxi Fuel

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

Mission simulation results

Take-off weight	$TOW = OWE + PL + MF - TXF_{out}$	kg	76999
Mission (loaded) fuel	$MF = BF + RF$	kg	18183
Block fuel	$BF = TF + TXF_{out} + TXF_{in}$	kg	14789
Trip fuel	TF	kg	14360
Reserve fuel	RF	kg	3394
Taxi-out fuel	TXF_{out}	kg	276
Taxi-in fuel	TXF_{in}	kg	153

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

Mission simulation results

Take-off weight	$TOW = OWE + PL + MF - TXF_{out}$	kg	77004
Mission (loaded) fuel	$MF = BF + RF$	kg	18021
Block fuel	$BF = TF + TXF_{out} + TXF_{in}$	kg	14507
Trip fuel	TF	kg	14324
Reserve fuel	RF	kg	3514
Taxi-out fuel	TXF_{out}	kg	118
Taxi-in fuel	TXF_{in}	kg	65

→ **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

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Requirements for a long-range version CLR-01

Requirements for CLR-01

Requirement	A330-200	B777
MTOW	**230.000 kg**	**299.370 kg**
OWE	**124.500 kg**	**160.120 kg**
Payload	**30.000 kg**	**35.000 kg**
Maximum Payload	**48.000 kg**	**64.960 kg**
PAX	**246 (2-class layout)**	**368 (3-class layout)**
Range	**6100 NM**	**5900 NM**
Cruise Mach Number	**0,82**	**0,84**
Cruise Altitude	**37000 ft**	**40000 ft**
BFL	**2515 m**	**3353 m**
Landing Distance	**1753 m**	**1860 m**

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

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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

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Outlook

Remaining Questions

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

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