Using CPACS for the multidisciplinary design and assessment of future aircraft concepts

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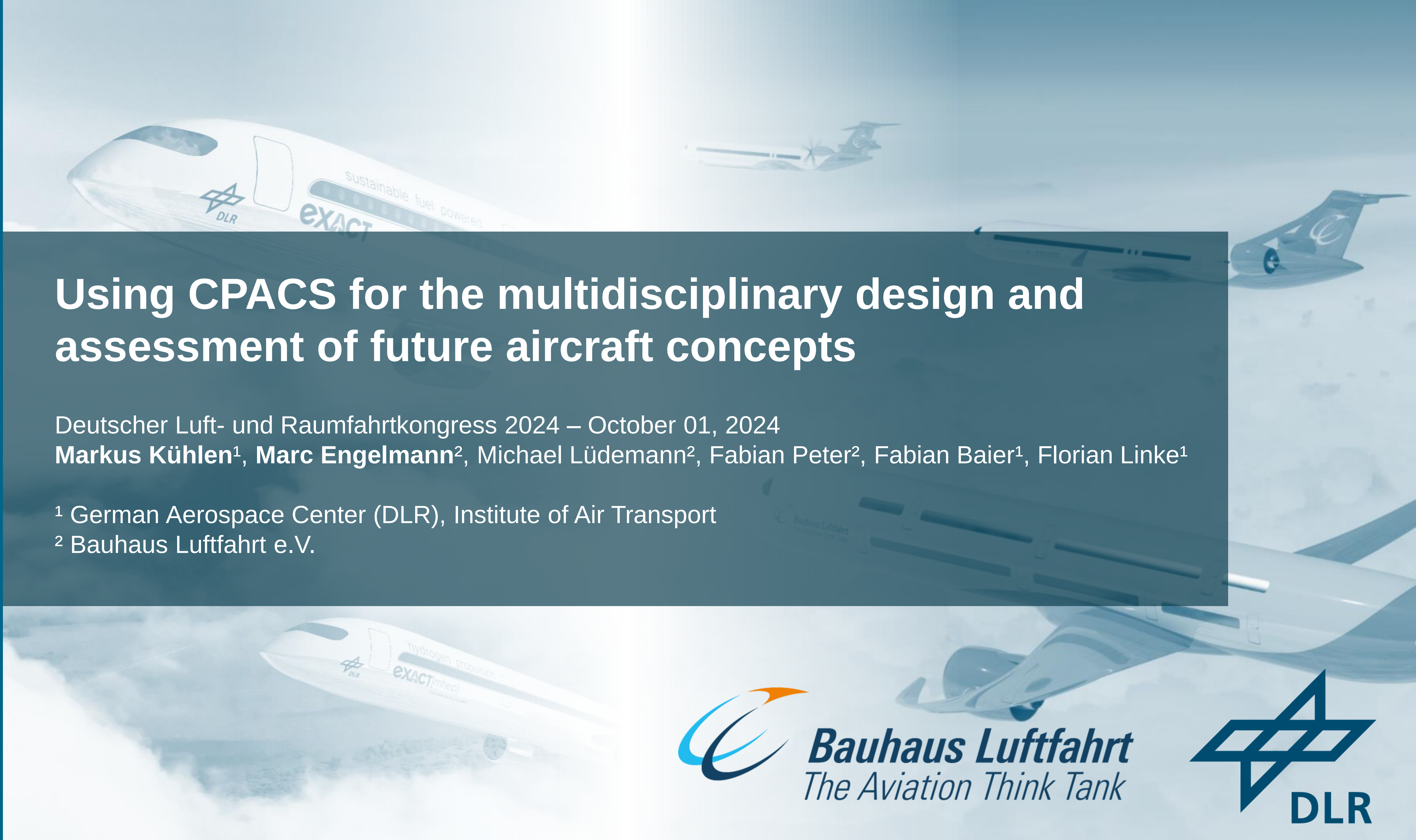

Bauhaus Luftfahrt
The Aviation Think Tank

DLR

Agenda

- Bauhaus Luftfahrt
  - Preliminary aircraft design framework with CPACS[1] at its core
  - Code development and CI/CD[2]
  - CPACS project application cases
- DLR
  - Workflow for assessing future aircraft concepts in different projects
  - Extending the CPACS[1] schema to allow for the multidisciplinary assessment of future aircraft concepts
- Pros, cons and learning

[1] CPACS: Common Parametric Aircraft Configuration Schema

[2] CI/CD: Continuous Integration / Continuous Deployment

BLADE - Bauhaus Luftfahrt Aircraft Design Environment

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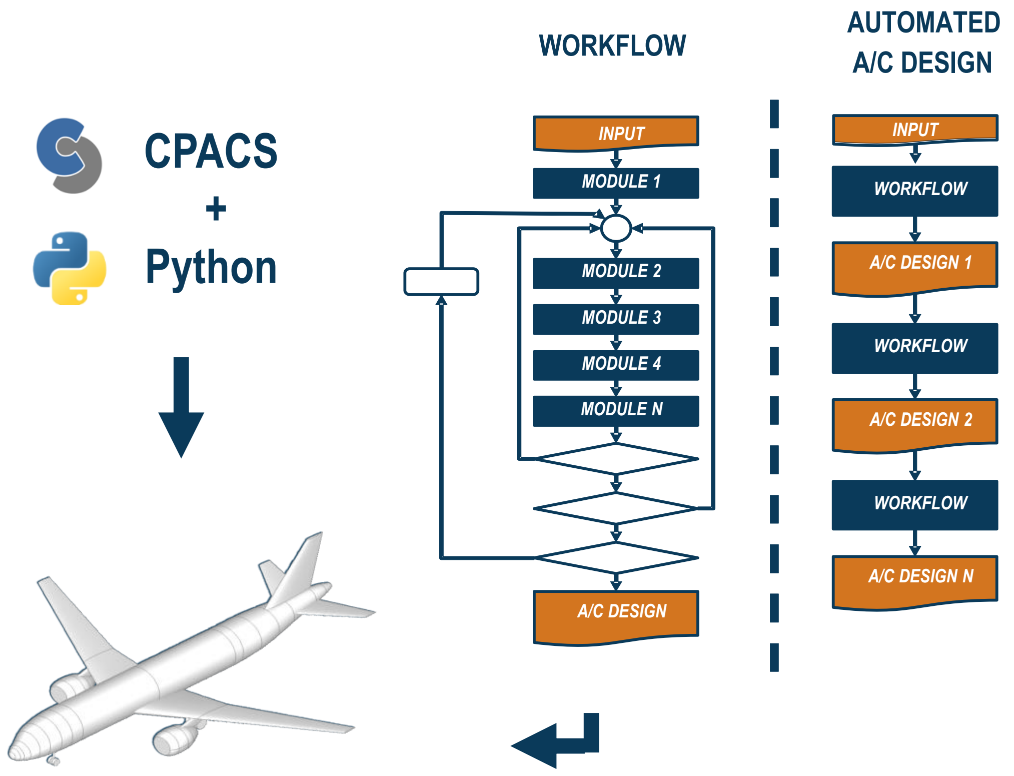
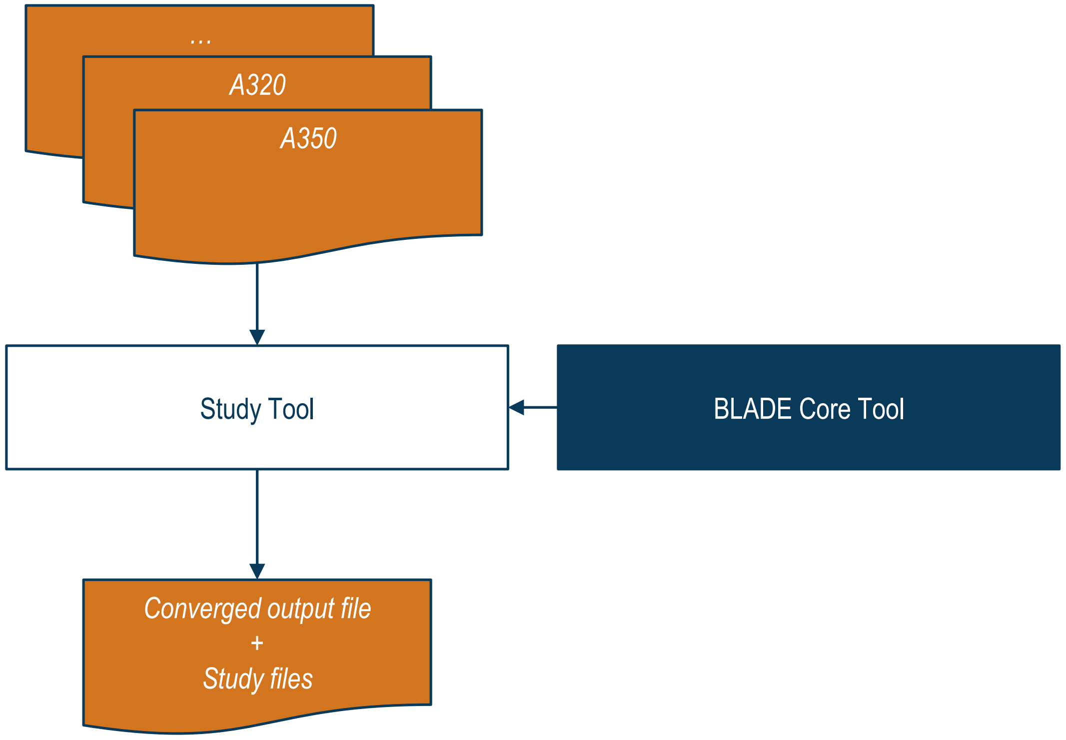
- Preliminary aircraft design framework with **CPACS at its core**
- Key features
  - **Modular**, traceable and **automated**
  - Semi-empirical and analytical sizing methods
  - Detailed table- or neural-net-based engine models
  - Physics-based mission analysis
- Based on CPACS 3.4 and Python 3.12
- Developed with **modern software design** principles using GitLab



Source: M. Lüdemann *et al.*, *BLADE: A Modular Environment for Traceable and Automated Aircraft Design*: 13th EASN International Conference on Innovation in Aviation & Space for opening New Horizons, 2023.

BLADE Structure

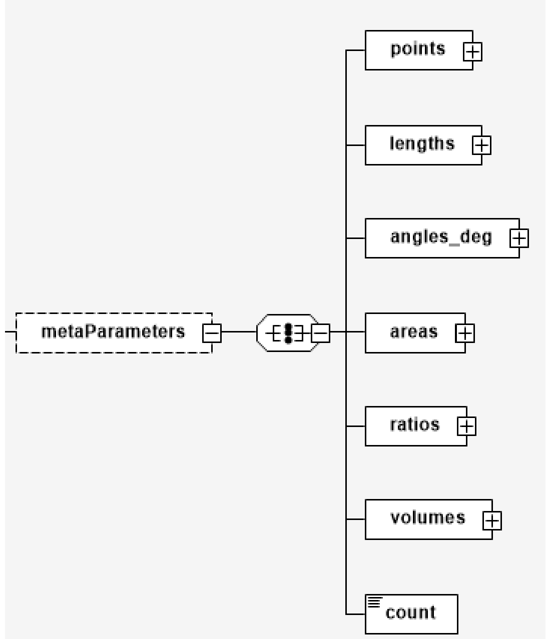
- BLADE structure
  - Core tool, housing design processes
  - CPACS library containing reference aircraft
  - Study tool managing both core and library
- Core tool
  - All component modules are called sequentially
  - Calibration (for references) and sizing (for new concepts) mode for all mass and geometry calculations



BLADE CPACS Integration

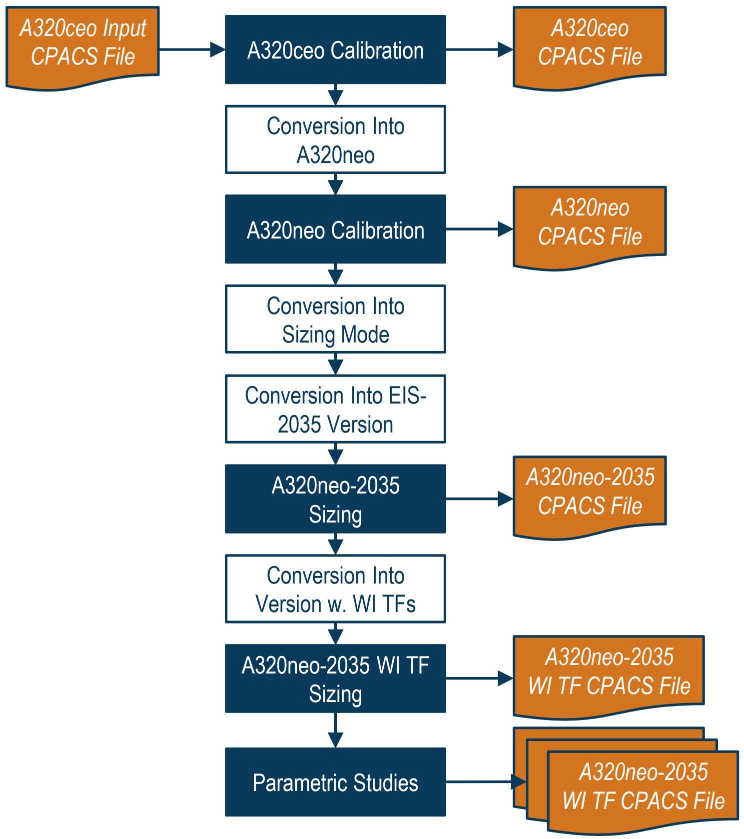
- Common CPACS nodes
  - Contain all relevant aircraft data
  - Central data exchange structure for all modules of BLADE
  - Custom extensions including meta parameters
- Tool-specific nodes

  Non-CPACS-defined input and output of the BLADE modules
- Development
  - Using both global as well as per-tool CPACS schema (.xsd) files
  - Derivation of Python classes using modified *generateDS* package
  - Enables fail safe code creation, auto completion etc.



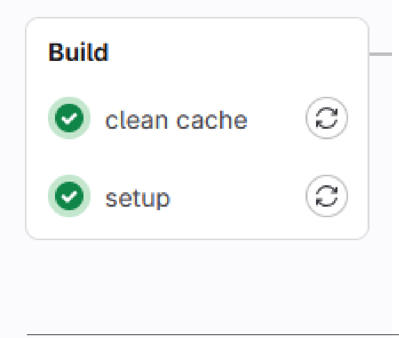
Automation in BLADE within the DINA2030+ Project (LuFo VI-2)

- Aircraft sizing is usually connected to prior calibration
- BLADE allows for various aircraft design automations
- As used in the DINA2030+ project (LuFo VI-2): design and investigation of an Airbus A320neo-class aircraft with water-injection (WI) turbofans (TF)



CI/CD[1] in the Development Process of BLADE

- Automated test pipelines
  - For every commit and merge request
  - Module tests and code assessment
  - Validation of CPACS files using schema validation jobs
  - BLADE integration tests to ensure result consistency of all (10+) reference aircraft
- Merge request process
  - 4-eye principle: No update to the codebase without a review
  - Automatic deployment of new releases using PyPI after successful merge

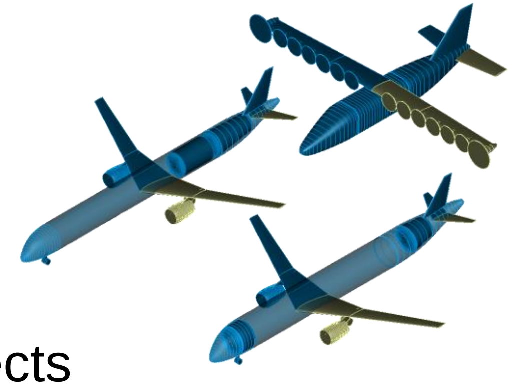


[1] CI/CD: Continuous Integration / Continuous Deployment

CPACS Usage and Application Cases

- Automated cabin visualization using Blender plugin

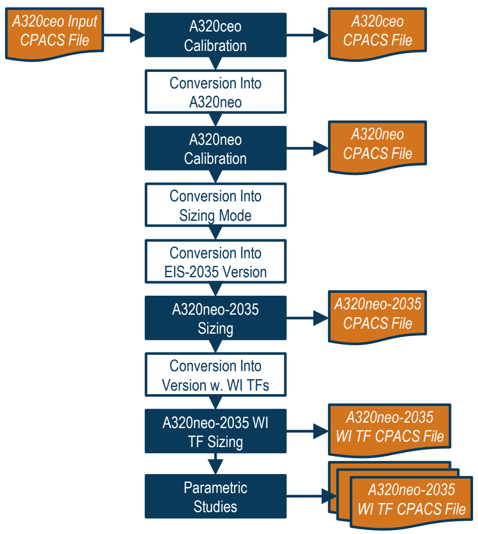
- Contributions to CPACS development (on GitHub etc.)
  - Landing gear definition
  - Cabin definition
  - Mission and fuel definitions
- BLADE/CPACS in research projects
  - IVeKLu
  - Do328-FC
  - HOPE
  - IMOTHEP
  - MINIMAL
  - Partner projects

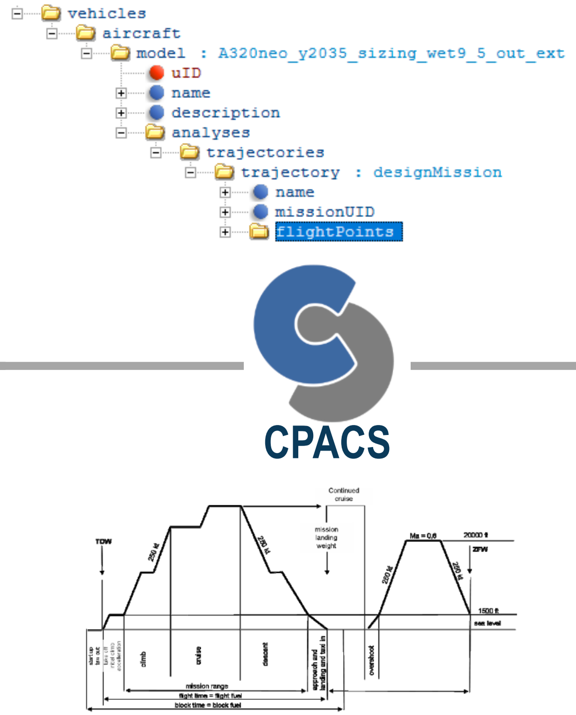


Source: Engelmann, M.; Drust, D.; Hornung, M. (2020): Automated 3D cabin generation with PAXelerate and Blender using the CPACS file format. Deutsche Gesellschaft für Luft- und Raumfahrt - Lilienthal-Oberth e.V.. https://doi.org/10.25967/530014

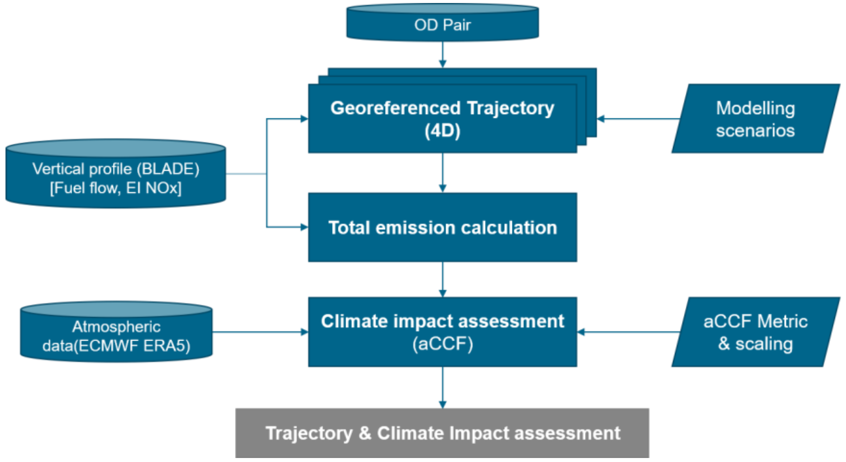
Collaboration using CPACS within the DINA2030+ Project (LuFo VI-2)

Aircraft design workflow





Assessment workflow



- Assessment of NOx-/CO2-induced climate impact with algorithmic climate change functions (aCCFs)
  - Using real 4D Trajectories with publicly available weather data from ECMWF
  - Based on BLADE trajectories and associated emission calculations
- CPACS enables fast and easy inter-organizational data exchange

Collaboration using CPACS within any aircraft design and assessment project

Aircraft design workflow

Black box

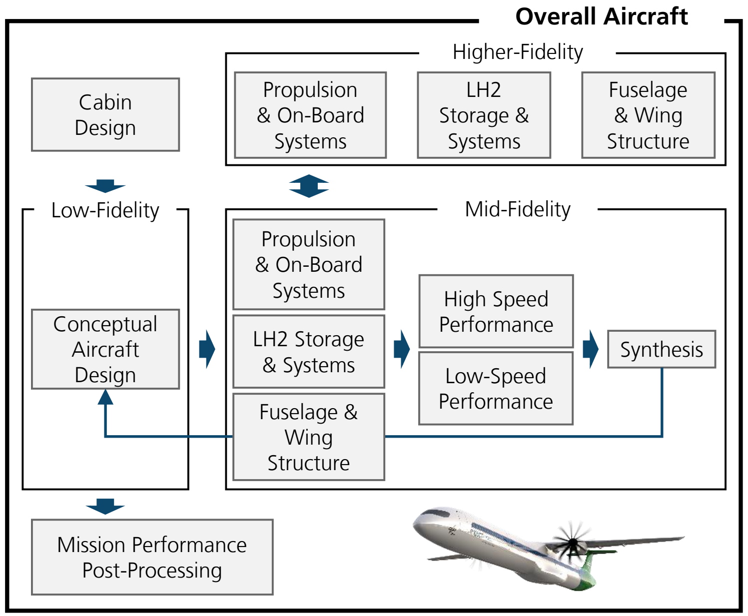
CPACS

Assessment workflow

Black box

Collaboration using CPACS within the EXACT project (DLR-internal)

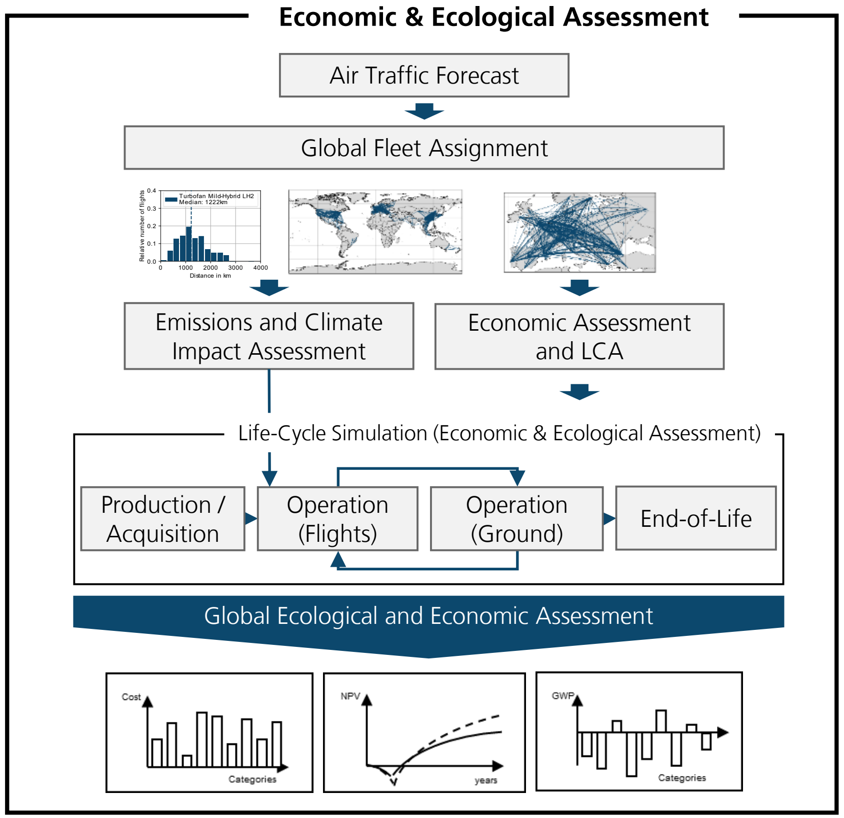
Aircraft design workflow



CPACS

Fully Described Aircraft Concepts

Assessment workflow

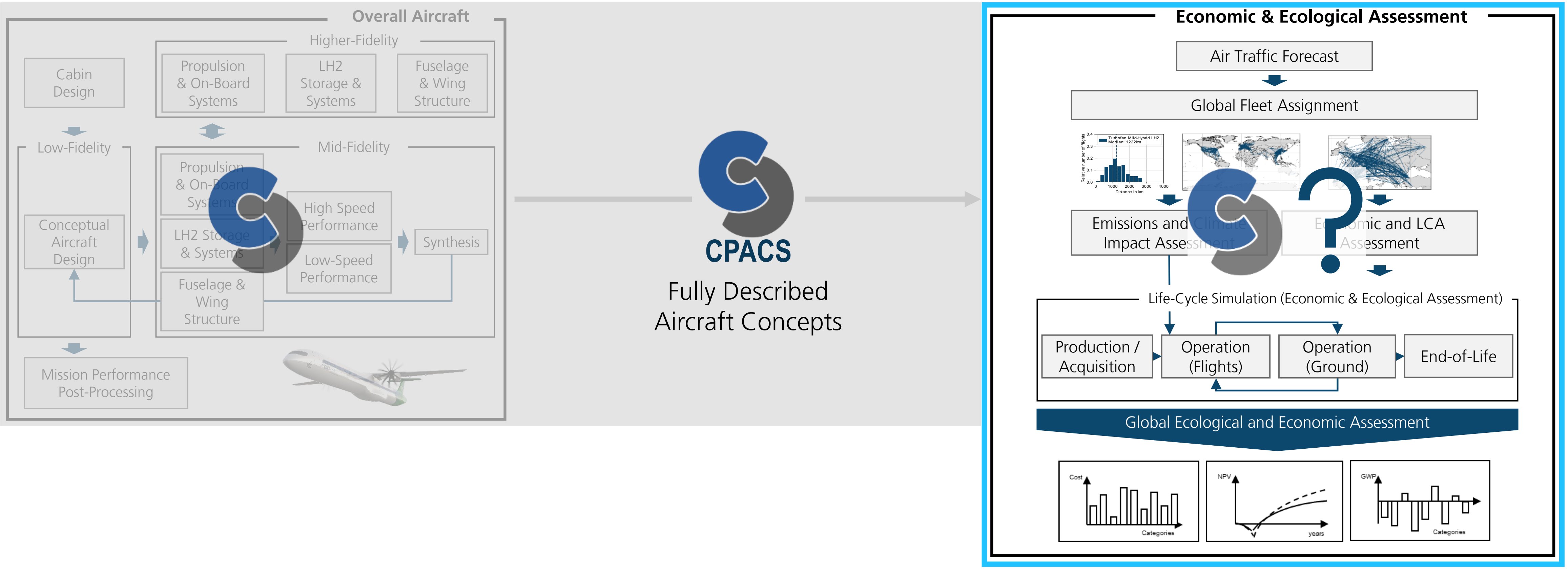


- Evaluate which aircraft concepts have the potential to drastically reduce aviation’s climate impact while being economically viable?
- EXACT1 (2020-2023): regional and short-range aircraft;
  EXACT2 (2024-2026): short-, medium- and long-range aircraft

How to formalize the tool interfaces for a multi-disciplinary assessment workflow using CPACS?

Aircraft design workflow

Assessment workflow



Two DLR projects to extend and apply a CPACS schema for assessing aircraft, airports and the air transportation system

Project

ALICIA

exACT

Objectives regarding CPACS adoption

ALICIA:

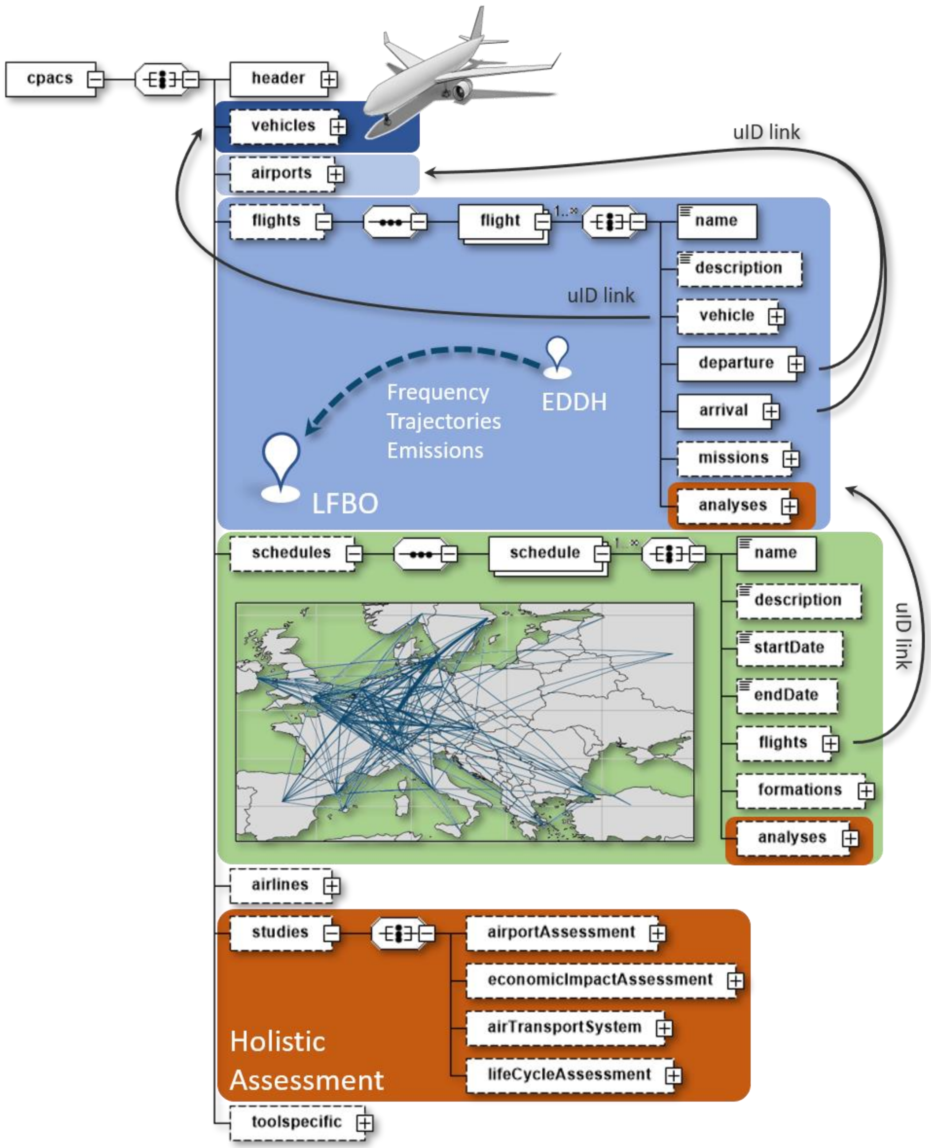
- Formalize tool interfaces for multidisciplinary assessment workflow
- Agree on extended CPACS schema for assessment workflow
- Demonstrate exemplary use-cases

exACT:

- Apply CPACS interfaces to assess how new aircraft designs could mitigate aviation's climate impact
- Leverage higher workflow automation to gain new research insights

[1] ATS: Air Transportation System

Extending the CPACS schema for assessments of airports and the air transportation system



- Airports can include geographic (lat, lon, elevation) and operational characteristics (e.g., runway & airspace layout)

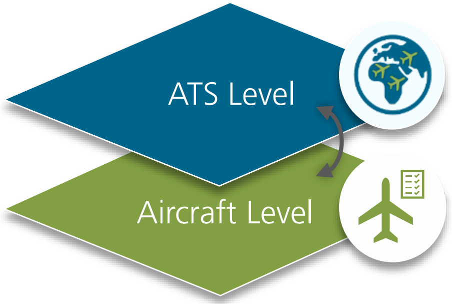
- Flights can use uIDs links to vehicles and airports
- Flights are defined by origin and destination airports
- Additional information can be used to specify, among others, trajectories, flight frequencies, ticket prices, emissions and climate impact

- Schedules use uID links to flights
- Additional information can be used to specify, among others, schedule start and end dates, formation flights and aggregated emissions

- Studies can use uID links to flights (e.g., life cycle assessment) or schedules (economic impact assessment)

Use cases for extended CPACS schema in DLR-projects ALICIA and EXACT

Project	ALICIA	EXACT®
Use cases	• Aircraft level: Life cycle assessment of short-range aircraft with SAF, LH2 and plug-in hybrid propulsion architectures • Airport level: Noise assessment of innovative approach procedures and vehicle technologies • ATS Level: Assess aviation's emissions and climate impact given a global air traffic forecast	• Which aircraft concepts have the potential to drastically reduce aviation's climate impact while being economically viable? • Economically and ecologically assess different short-, medium- and long-range aircraft configurations with SAF, LH2 and plug-in hybrid propulsion architectures • Quantify assessment uncertainties by using a range of different assumptions, e.g., for technology development, economics and regulations



Pros, Cons and Learnings from using CPACS

- ✓ Formalized tool interfaces ease establishment of **inter-organizational data exchange** and workflows
- ✓ Excellent starting point for parametrization
- ✓ **Active user community**
- ✓ Ongoing development

- – **Extensive file size** for tabulated data (e.g., polars)
- – No open-source CPACS Python package to access/visualize/analyze data ➔ initial effort
- – Balance of conceptual and detailed design ➔ redundant information
- – **CPACS hangar** and further development of CPACS creator desired (see OpenVSP)
- – TiGL (viewer) version lacks behind CPACS releases

- schedule ≠ schedule
  - Devil is in the details (schedule for whole year or single day; schedule for global fleet or single aircraft; schedule for global ATS or one airport; …)
  - Getting a mutual understanding of what different disciplines mean with the identical wording is important and a communication-intensive process
- Breaking the existing way of working for a greater cause
  - Using CPACS should not be a self purpose, but actually contribute to additional capabilities
  - Adopting tools and existing workflows to CPACS creates upfront work, which is only worth it if everyone is on the same page

Summary and Conclusion

- CPACS is essential for BLADE
  - Established language within BHL and for collaboration with partners
  - Powerful help in code development and CI/CD

- New CPACS schema for the nodes “flights”, “schedules” and “studies” enables integration of more aircraft assessment disciplines
  - Two DLR-internal projects to revise new schema and apply it to different use cases

Thank you for your attention!

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