

DEVELOPMENT OF A FULLY AUTOMATED TRANSPORT AIRCRAFT FUSELAGE MODELLING AND SIZING TOOL USING PYTHON

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Wissen für Morgen



Übersicht

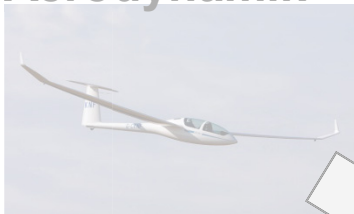
1. **Motivation**
2. **Beispiel** – Flugzeugentwurf am DLR
3. **Austausch** – CPACS Datensatz
4. **Toolumgebung** – Rumpfstruktur Auslegung am DLR-BT
5. **Zusammenfassung**
6. **Ausblick**



1. Warum Tools Entwickeln für den Flugzeugvorentwurf?

Emissionen

Aerodynamik



[1]



[5]

Nutzlast



[2]

Flugleistung



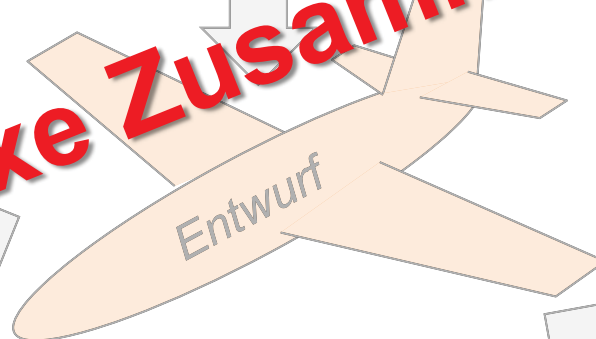
[4]

Struktur



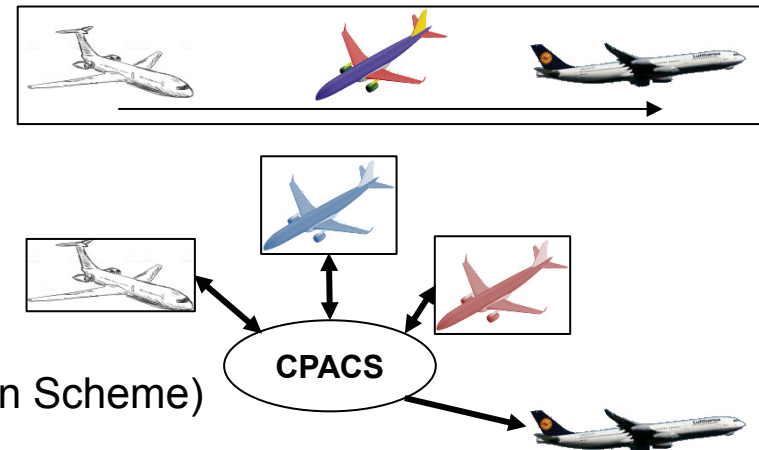
[3]

Komplexe Zusammenhänge

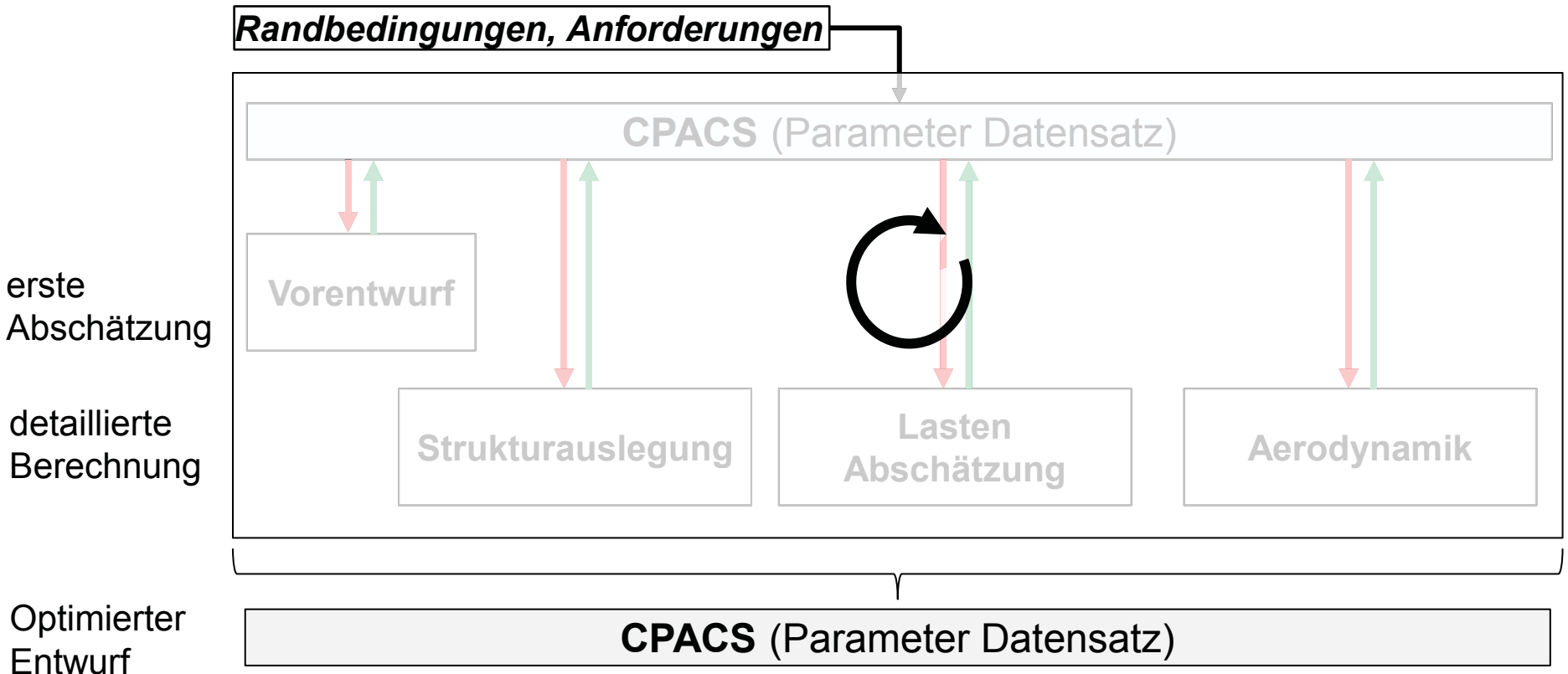


1. Warum Tools Entwickeln für den Flugzeugvorentwurf?

- **Aufwand**
Entwicklungszeit neuer Luftfahrzeuge verkürzen.
- **Effizienz/Emissionen**
Abschätzung z.B. Treibstoffverbrauch im Vorentwurf benötigt:
 - hochgenaue, numerische Methoden
 - komplexe, multidisziplinäre Interaktion
- **Entwicklungsprozess**
 - Bisher: Schrittweiser Entwurfsablauf
 - Zukünftig: individuelle, multidisziplinäre Tools
- **Datenaustausch**
XML-Datensatz als Parameteraustausch
= **CPACS** (Common Parametric Aircraft Configuration Scheme)



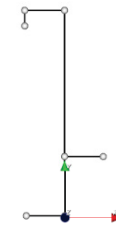
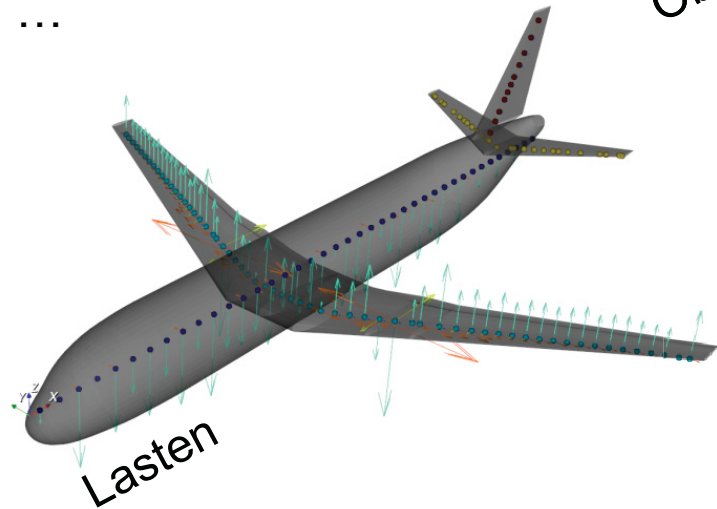
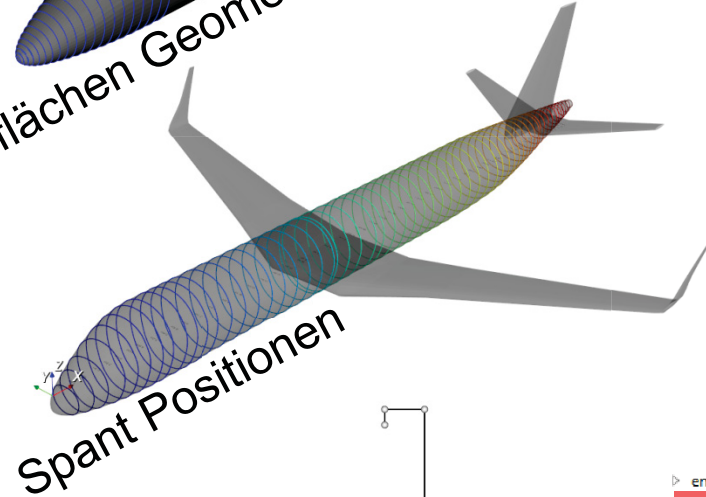
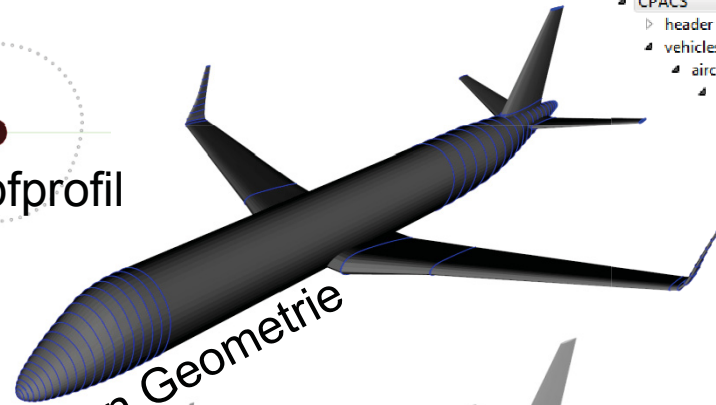
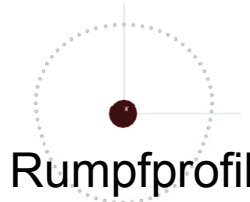
2. Beispiel MDO (Multidisciplinary Design Optimization) im Flugzeugvorentwurf am DLR



3. CPACS (Common Parametric Aircraft Configuration Scheme)

XML-DATENSATZ

- Geometrie (Oberfläche)
- Struktur (Definitionen)
- Profile (z.B. Balkenprofil für Spant)
- Lasten
- Materialien
- ...



```

CPACS
├── header
├── vehicles
│   ├── aircraft
│   │   ├── model
│   │   │   ├── name
│   │   │   ├── description
│   │   │   ├── reference
│   │   │   ├── fuselages
│   │   │   │   ├── fuselage
│   │   │   │   │   ├── name
│   │   │   │   │   ├── description
│   │   │   │   │   ├── transformation
│   │   │   │   │   ├── sections
│   │   │   │   │   ├── positionings
│   │   │   │   │   ├── segments
│   │   │   │   │   ├── structure
│   │   │   │   │   │   ├── frames
│   │   │   │   │   │   ├── stringers
│   │   │   │   │   │   ├── pressureBulkheads
│   │   │   │   │   │   ├── paxCrossBeams
│   │   │   │   │   │   ├── cargoCrossBeams
│   │   │   │   │   │   ├── paxCrossBeamStruts
│   │   │   │   │   │   ├── cargoCrossBeamStruts
│   │   │   │   │   │   ├── longFloorBeams
│   │   │   │   │   │   ├── centerFuselageAreas
│   │   │   │   │   │   ├── tailplaneAttachmentArea
│   │   │   │   │   │   ├── skinSegments
│   │   │   │   │   │   ├── decks
│   │   │   │   │   │   ├── dynamicAircraftModel
│   │   │   │   │   ├── wings
│   │   │   │   │   ├── engines
│   │   │   │   │   ├── global
│   │   │   │   │   ├── analyses
│   │   │   │   │   ├── enginePylons
│   │   │   │   │   ├── landingGear
│   │   │   │   │   ├── engines
│   │   │   │   │   ├── profiles
│   │   │   │   │   │   ├── fuselageProfiles
│   │   │   │   │   │   ├── wingAirfoils
│   │   │   │   │   │   ├── structuralProfiles
│   │   │   │   │   ├── structuralElements
│   │   │   │   │   │   ├── profileBasedStructuralElements
│   │   │   │   │   │   ├── pressureBulkheads
│   │   │   │   │   │   ├── sheetBasedStructuralElements
│   │   │   │   │   │   ├── seatModules
    
```

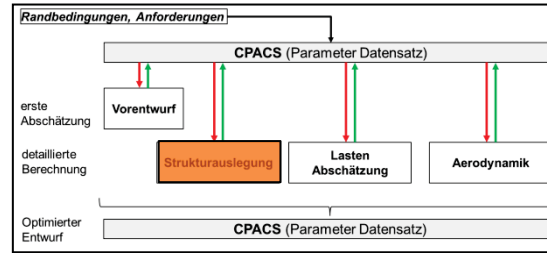


4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

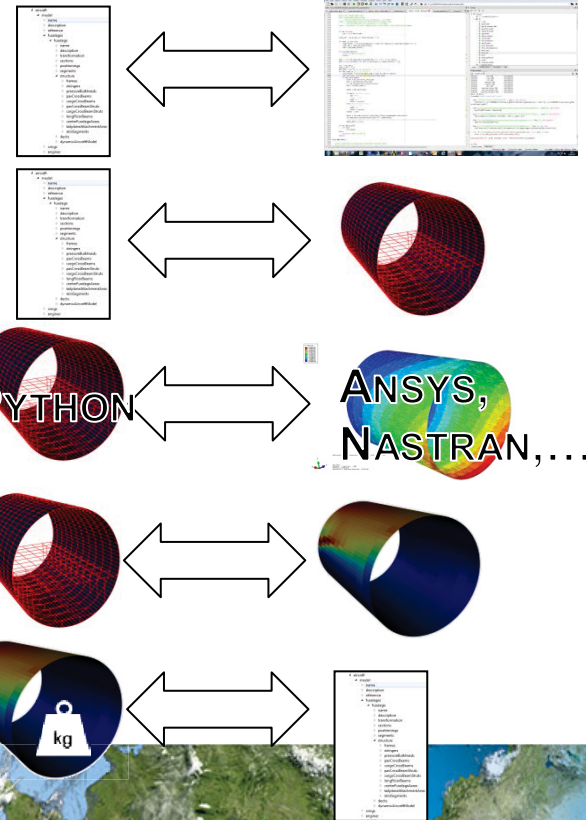
PRIMÄRES ENTWICKLUNGSZIEL (DLR-BT)

- **Massenabschätzung** Rumpfstruktur



ENTWICKLUNGSSCHRITTE

- Schnittstellen zu CPACS aufbauen/vereinfachen
- Automatisierte/parametrisierte Finite Elemente (FE) Modell Generierung
- Schnittstelle zu FE-Lösern herstellen
- Dimensionierung der FE-Struktur anhand von Lastfällen
- Strukturmasse/Hautdicken auswerten



4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

WARUM NEUE TOOLUMGEBUNG?

Tool TRAFUMO existiert bereits [1]

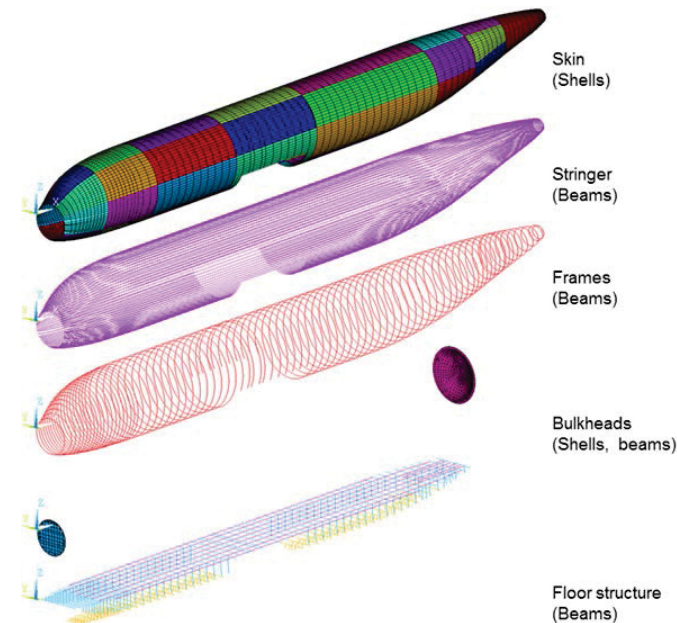
- ANSYS APDL basiert → eingeschränkt, langsam
- Austausch (andere Formate) erschwert
- Umständlich programmiert (durch APDL)

Langsam & Umständlich

FAZIT: NEUENTWICKLUNG PANDORA

- Python Programmierung
- Open source (Numpy, OCC, VTK, lxml,...)
- Unabhängig von kommerzieller Software
- beliebige FE-Lösungen integrierbar
- GUI zur erleichterten Nutzung
- Modular – weitere Einsatzmöglichkeiten
- *In Entwicklung ca. seit 2016...*

Schnell & Offen



Basis Strukturkomponenten TRAFUMO [1]

4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Basispakete

cpacs_data

visualization_tools

math_functions

geometry_core

cpacs_geometry

fe_pyprep

- XML Daten verwalten (Nutzung von lxml Paket)
- Objektorientierter Aufbau

XML-ASCII File

```
<profiles>
  <fuselageProfiles>
    <fuselageProfile uID="fuselageCircleProfileuID">
      <name>Circle</name>
      <description>Profile build up from set of Points on Circle where may Dimensions are
        1..-1</description>
      <pointList>
        <x mapType="vector">0.0;0.1;0.2;0.3;0.4;0.3;0.2;0.1;0.0</x>
```

Python usage

```
obj = root.VEHICLES.PROFILES.FUSELAGEPROFILES[0]
obj.get.uid

'fuselageCircleProfileuID'

obj.POINTLIST.X.get.data

array([ 0. ,  0.1,  0.2,  0.3,  0.4,  0.3,  0.2,  0.1,  0. ])
```

4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Basispakete

cpacs_data

visualization_tools

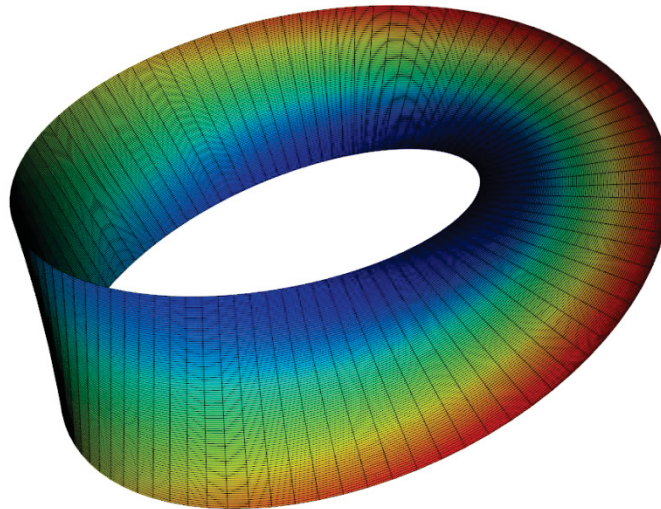
math_functions

geometry_core

cpacs_geometry

fe_pyprep

- 3D Visualisierung (Nutzung von VTK, PyQt)



VTK

VISUALIZATION TOOLKIT

4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Basispakete

cpacs_data

visualization_tools

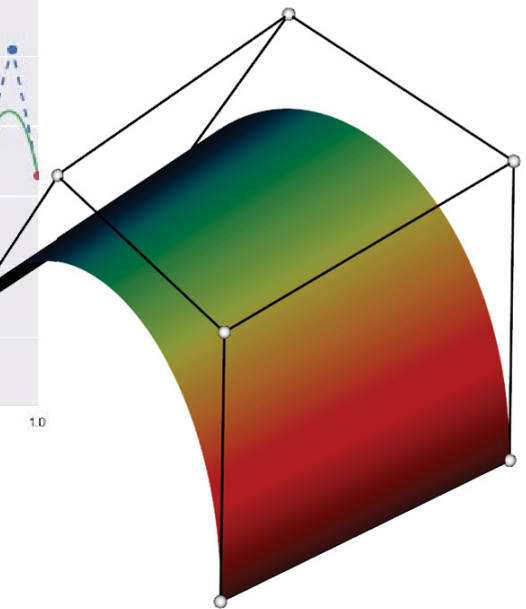
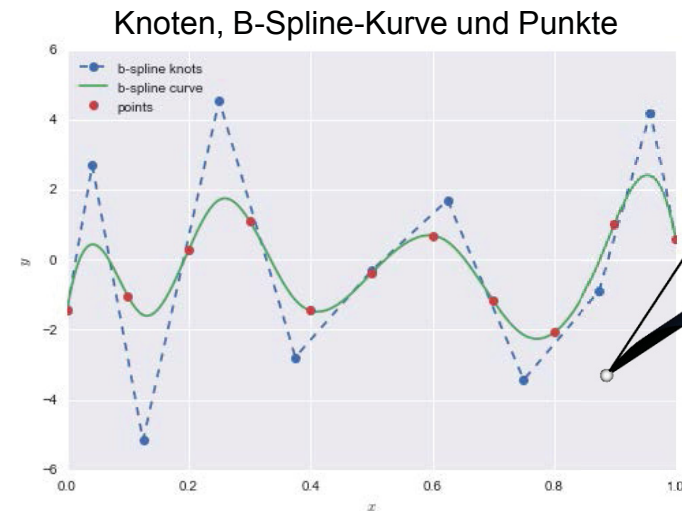
math_functions

geometry_core

cpacs_geometry

fe_pyprep

- Koordinaten Transformationen
- Interpolationen z.B. B-Spline Kurve/Oberfläche



4. Toolumgebung PANDORA

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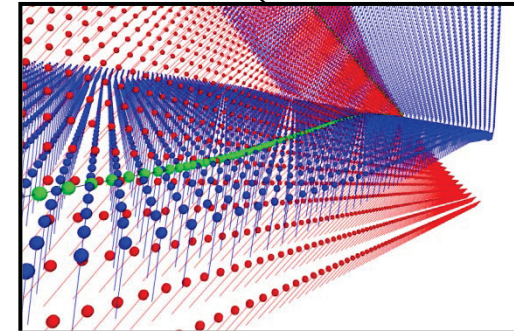
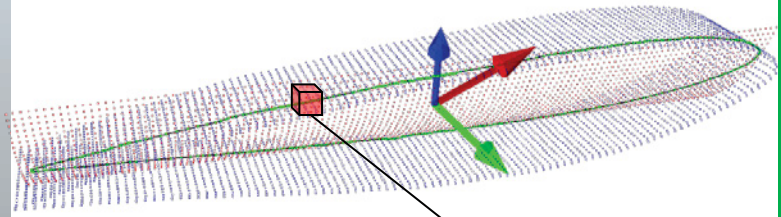
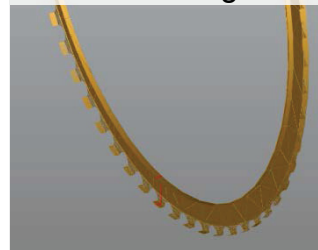
cpacs_geometry

fe_pyprep

- Basis Funktionalitäten zur Geometrie Nutzung
 - OCC (Open Cascade) Hilfsfunktionen
 - Meshbasierte Geometriealgorithmen



Test: Extrudiertes Spantprofil mit Ausschnitte für Stringer in OCC



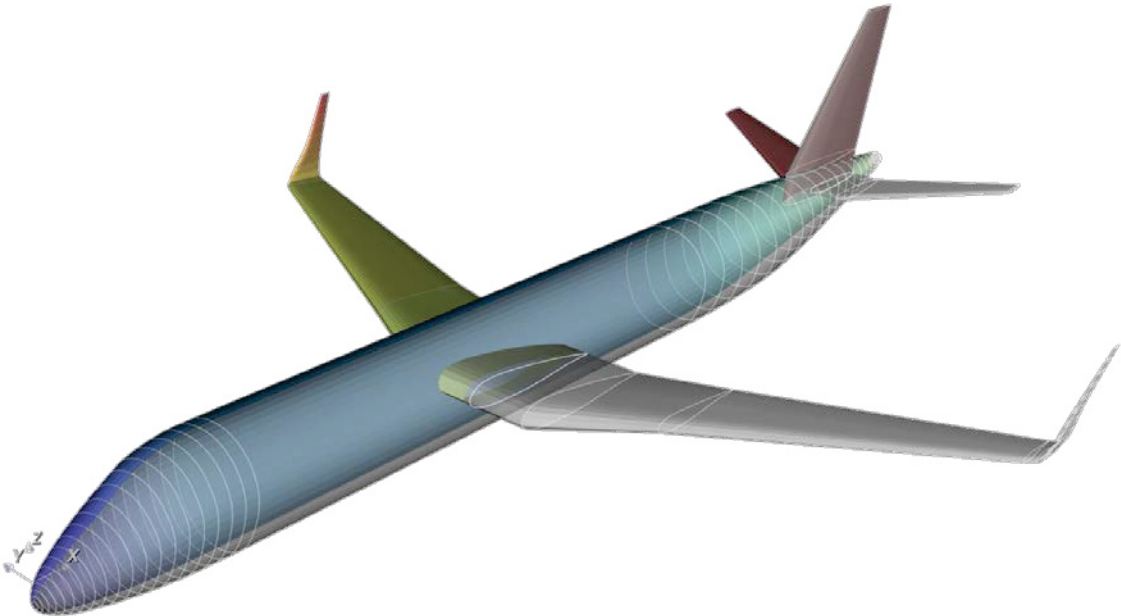
Test: Netzbasierter Verschneidungsalgorithmus

4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Basispakete

cpacs_data	<ul style="list-style-type: none">• Geometriedaten aus CPACS extrahieren<ul style="list-style-type: none">• Profile, Schnitte, Segmente  A 3D wireframe model of an aircraft fuselage, showing the internal structure and external shape. The model is rendered in a light blue color with a grid of lines. It is positioned in the center of the slide, with a green border around it. The aircraft is shown from a perspective view, facing towards the left.
visualization_tools	
math_functions	
geometry_core	
cpacs_geometry	
fe_pyprep	

4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Basispakete

cpacs_data

visualization_tools

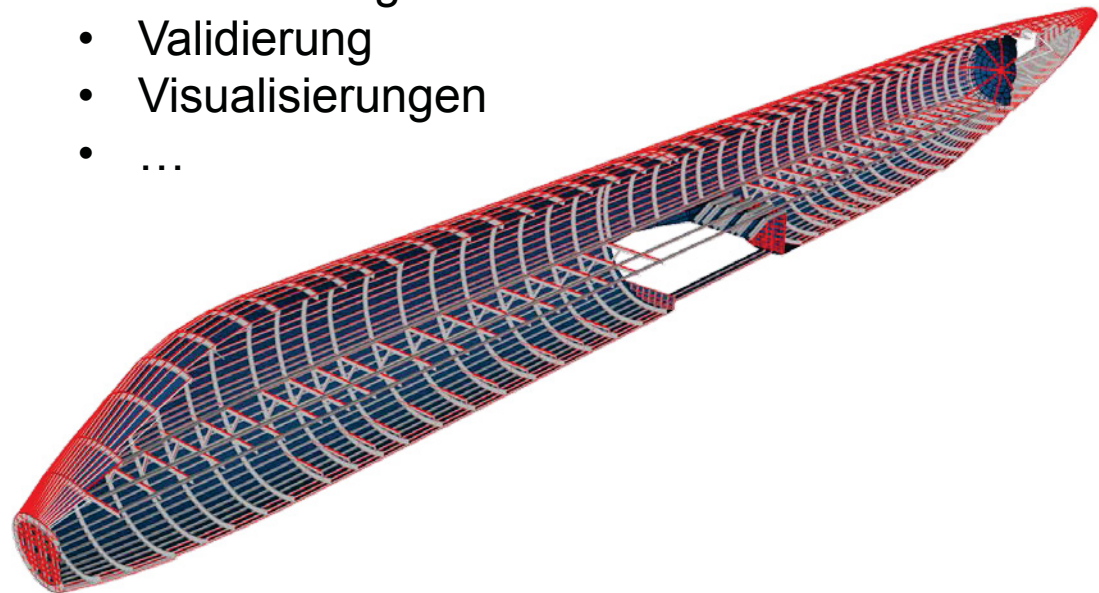
math_functions

geometry_core

cpacs_geometry

fe_pyprep

- FE (Finite Elemente) Daten verwalten
 - Balken, Schalen,... erstellen
 - Ausschnitte
 - Orientierungen
 - Validierung
 - Visualisierungen
 - ...



4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Spezifische Pakete

cpacs_predesign

fe_converter

fe_sizer

cpacs_gfem

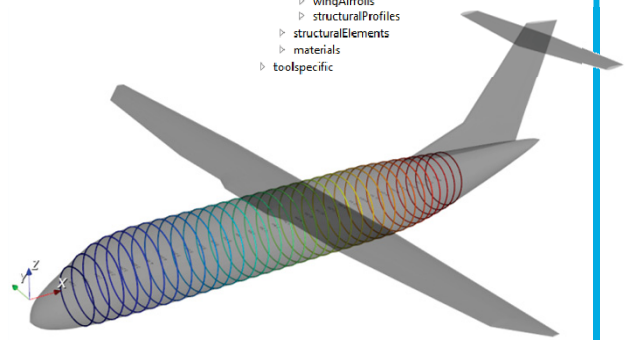
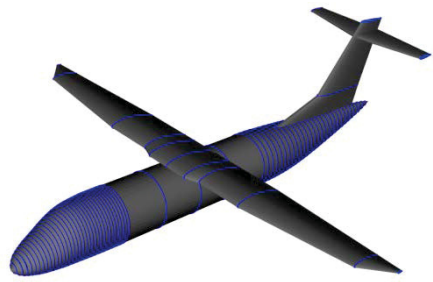
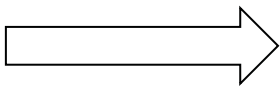
- Vollständige CPACS Daten aus Inputparametern Extrapolieren

```

CPACS
├── header
├── vehicles
│   └── aircraft
│       └── model
│           ├── name
│           ├── description
│           ├── reference
│           └── fuselages
│               └── fuselage
│                   ├── name
│                   ├── description
│                   ├── transformation
│                   ├── sections
│                   ├── positionings
│                   └── segments
├── wings
├── profiles
└── toolsspecific
    
```

```

CPACS
├── header
├── vehicles
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│       └── model
│           ├── name
│           ├── description
│           ├── reference
│           └── fuselages
│               └── fuselage
│                   ├── name
│                   ├── description
│                   ├── transformation
│                   ├── sections
│                   ├── positionings
│                   └── segments
│                       └── structure
│                           ├── frames
│                           ├── stringers
│                           └── pressureBulkheads
│                               ├── pressureBulkhead
│                               ├── pressureBulkhead
│                               ├── cargoCrossBeams
│                               └── skinSegments
├── wings
├── profiles
├── fuselageProfiles
├── wingAirfoils
├── structuralProfiles
├── structuralElements
├── materials
└── toolsspecific
    
```

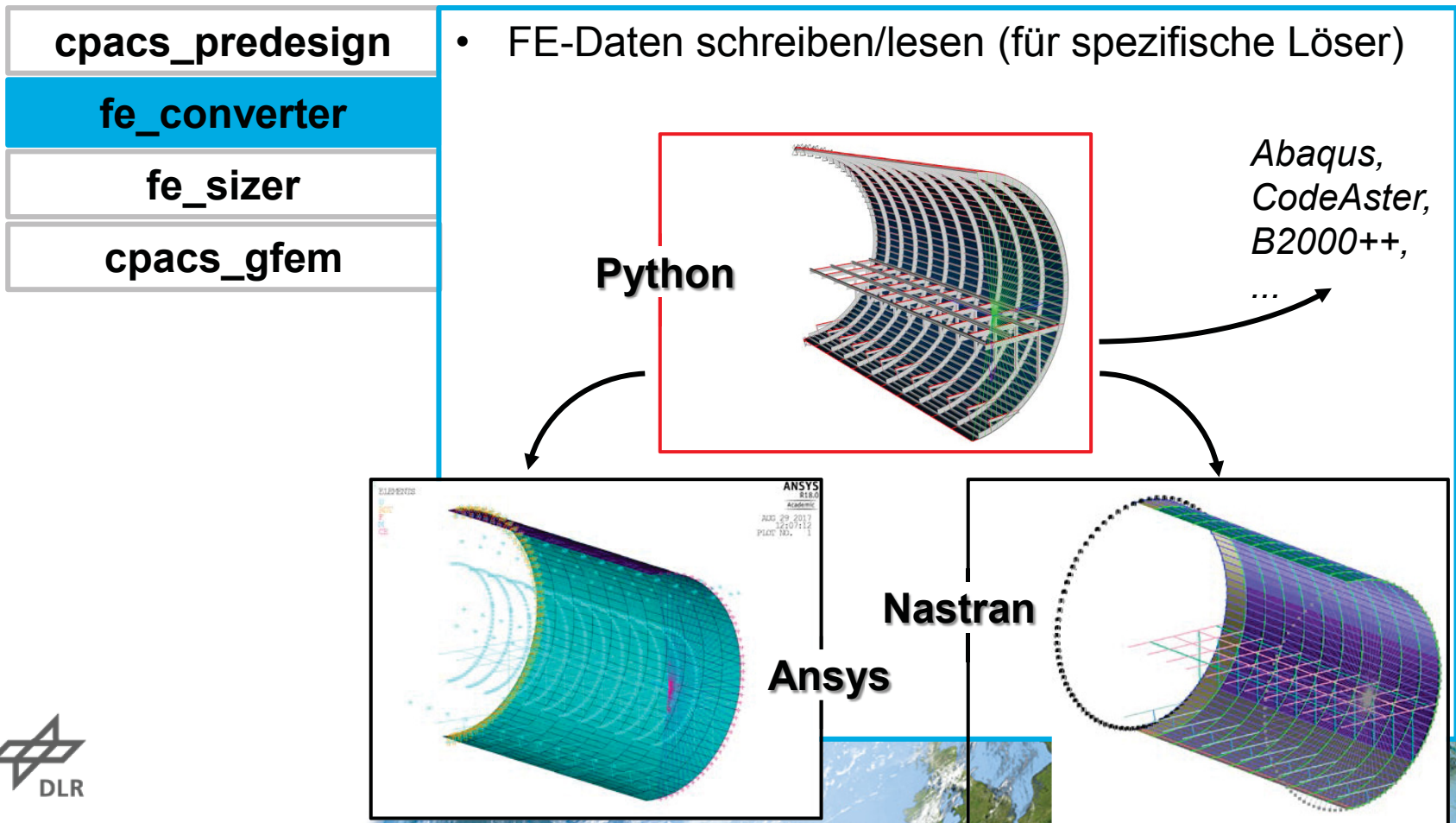


4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Spezifische Pakete



4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Spezifische Pakete

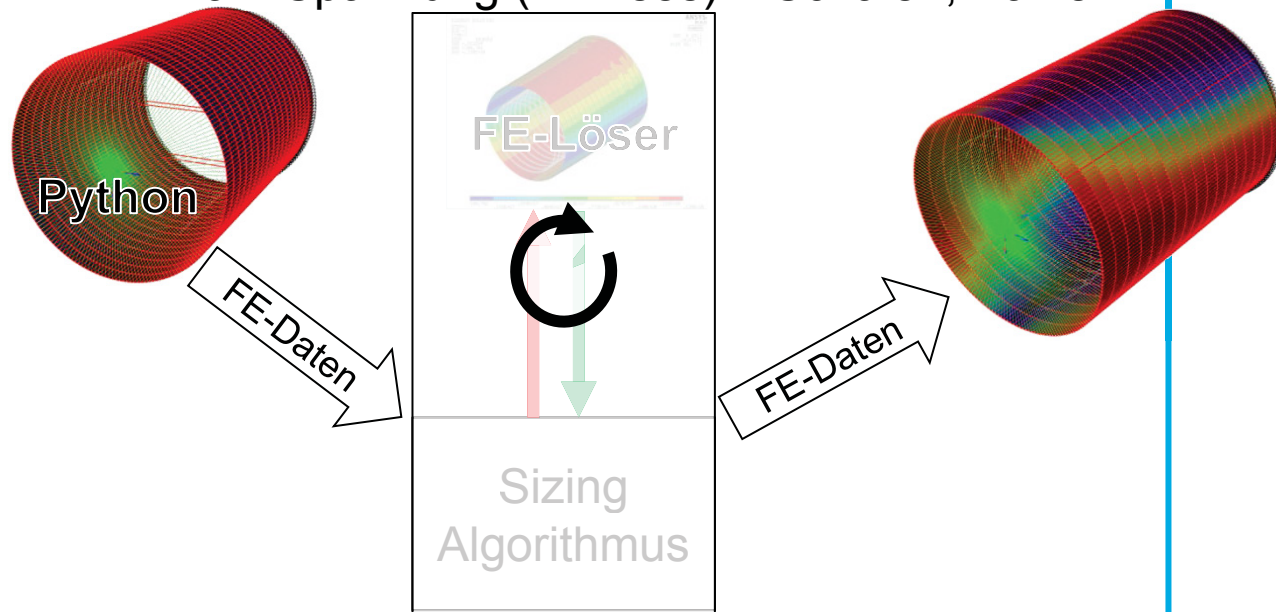
cpacs_predesign

fe_converter

fe_sizer

cpacs_gfem

- FE-Struktur Dimensionierungs Algorithmus
Kriterien bisher:
 - Hautfeld-Beulen (Bruhn) – Schalen
 - max. Spannung (v. Mises) – Schalen, Balken



4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Spezifische Pakete

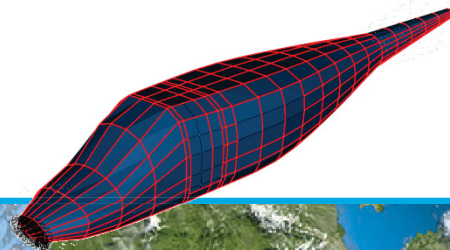
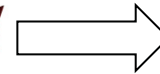
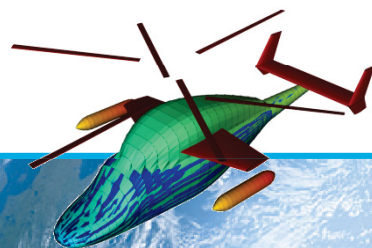
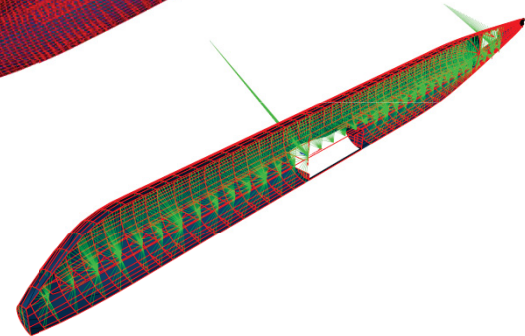
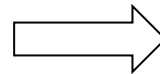
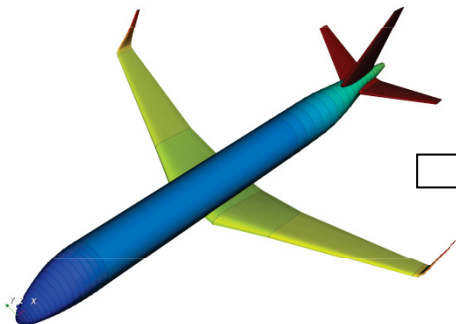
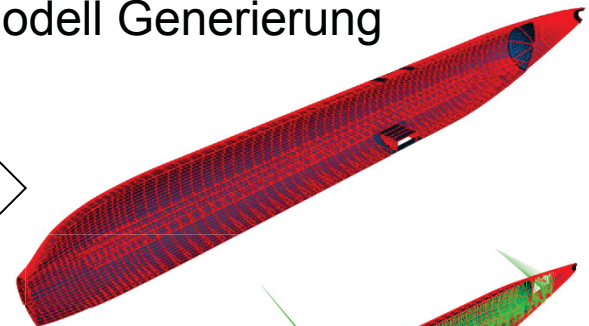
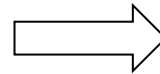
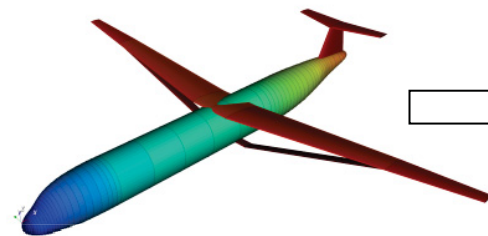
cpacs_predesign

fe_converter

fe_sizer

cpacs_gfem

- CPACS basierte FE-Modell Generierung



4. Toolumgebung PANDORA

(Parametric Numerical Design and Optimization Routines for Aircraft)

Pakete der Toolumgebung:

Anwendung

main

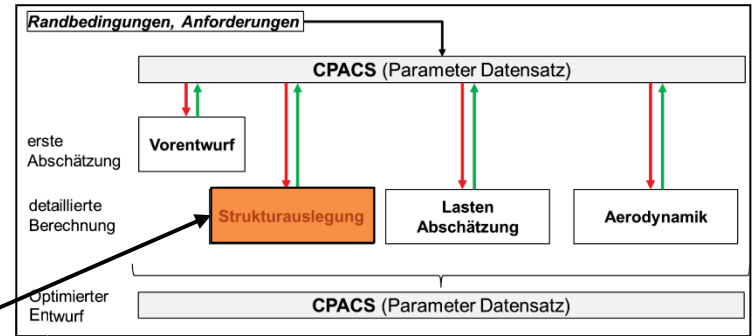
- GUI, Prozess-Steuerung



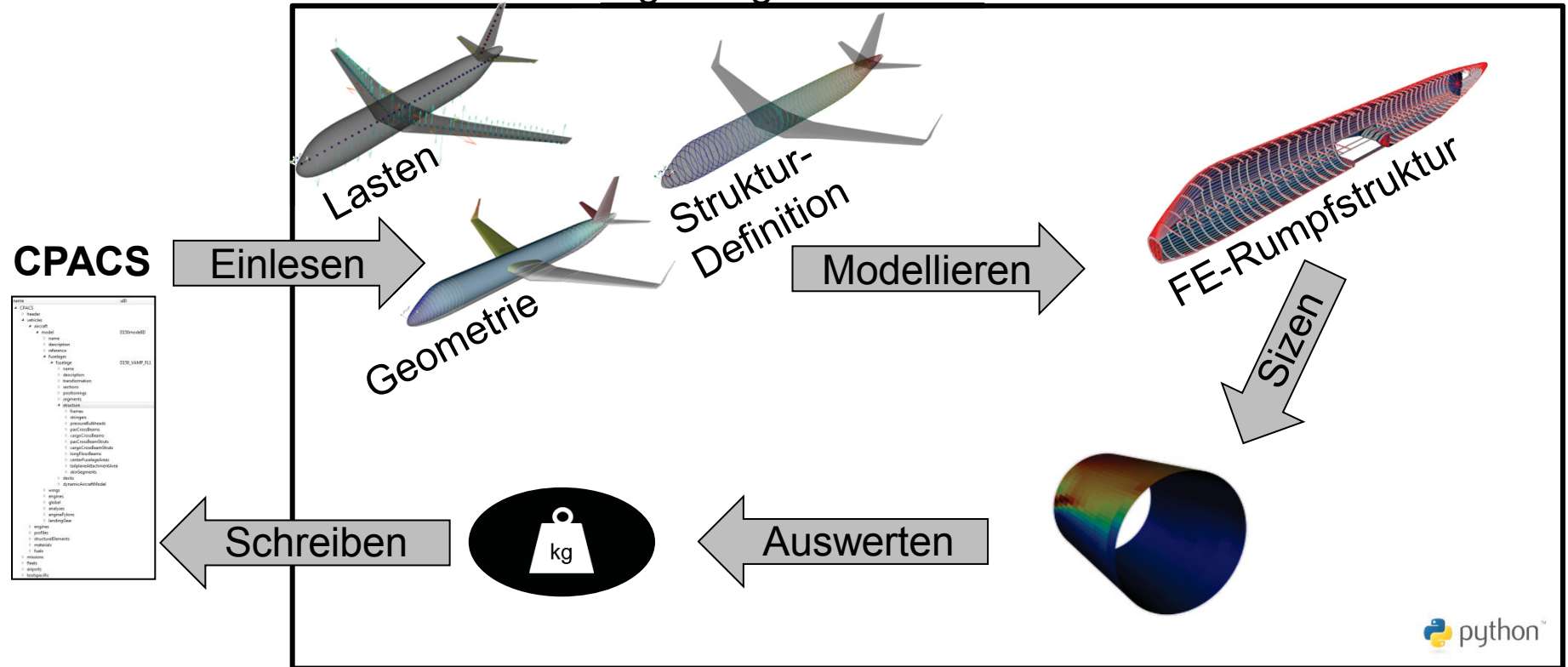
The screenshot displays the PANDORA software interface. On the left, a console window shows a series of log messages, including 'get_AskUser of 28 nodes', '412 element orientations reversed of 420', and '114 element orientations reversed of 213'. Below the console is a tree view of the model structure, showing 'CPACS' as the root, with sub-entities like 'aircraft' and 'fuselage'. The main area features a 3D visualization of an aircraft fuselage structure, rendered in green and brown. A context menu is open over the 3D model, listing various actions such as 'mesh', 'add', 'check', 'get_edges_by_nodes', and 'show_mesh_edges'. On the right side, a 'FE raw data' window displays a table with columns for 'ED', 'G1', 'G2', 'G3', 'G4', 'MAJORANT', and 'P1'. The table contains numerical data for various element IDs.

ED	G1	G2	G3	G4	MAJORANT	P1
type ind4	float64	float64	float64	float64	float64	float64
name	0.0%	0.0%	0.0%	0.0%	41.1%	100.0%
4102	15873	12017.0	12035.0	12057.0	12044.0	nan
4103	15874	12075.0	12057.0	12056.0	nan	103.0
4104	15875	12056.0	12043.0	12067.0	12073.0	nan
4105	15876	12076.0	12067.0	12045.0	12059.0	nan
4106	15877	12076.0	12059.0	12058.0	nan	103.0
4107	15878	12058.0	12046.0	12068.0	12076.0	nan
4108	15879	12068.0	12046.0	12061.0	nan	103.0
4109	15880	12077.0	12068.0	12061.0	12060.0	nan
4110	15881	12060.0	12047.0	12069.0	12077.0	nan
4111	15882	12070.0	12069.0	12047.0	12048.0	nan
4112	15883	12048.0	12040.0	12062.0	12070.0	nan
4113	15884	12040.0	12049.0	12071.0	12062.0	nan
4114	15885	12049.0	12041.0	12063.0	12071.0	nan

5. Zusammenfassung



PANDORA Toolumgebung*



* In Entwicklung bei DLR-BT ca. seit 2016

6. Ausblick

PRIMÄRES ENTWICKLUNGSZIEL

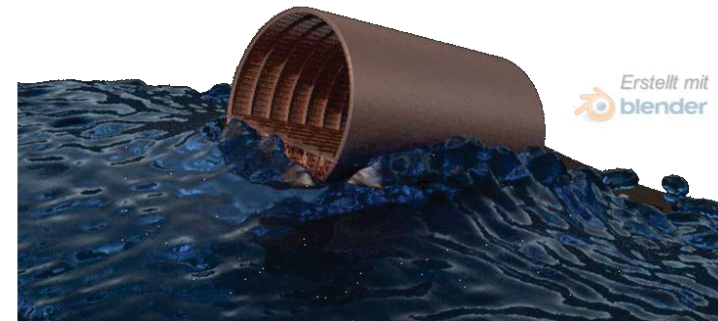
- Massenabschätzung Rumpfstruktur

ENTWICKLUNGSSCHRITTE

- Schnittstellen zu CPACS vereinfachen
- Automatisierte FE Modell Generierung
- Schnittstelle zu FE-Lösern
- Dimensionierung der FE-Struktur

ZUKÜNFTIGES ENTWICKLUNGSPOTENTIAL

- Detaillierte Crash/Ditching Modelle
- Weitere Dimensionierungs-Kriterien
- Optimierung der Struktur
- Ausbau der GUI



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DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT (DLR)

INSTITUT FÜR BAUWEISEN UND STRUKTURTECHNOLOGIE (BT)

PFÄFFENWALDRING 38-40 | 70569 STUTTGART

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Fragen?

Vielen Dank für Ihre Aufmerksamkeit!