CONSIDERATION OF FAILURE LOADS IN THE PRELIMINARY SIZING OF AN AIRCRAFT MOVEABLE AT VIRTUAL PRODUCT HOUSE

28.09.2022, DLRK 2022

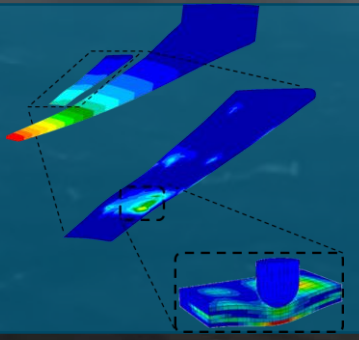|		
M. Rädel & A. Schuster	**DLR-FA**	**Bremen & Braunschweig**
R. W. Hollmann & A. Schäfer	**DLR-FT**	**Bremen & Braunschweig**
M. Alder	**DLR-SL**	**Hamburg**
F. Lange-Schmuckall	**DLR-AS**	**Bremen & Braunschweig**

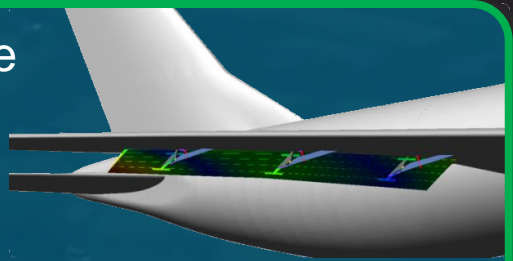DLR

Main structural sizing aspects

Aerodynamic loads & aeroelastics
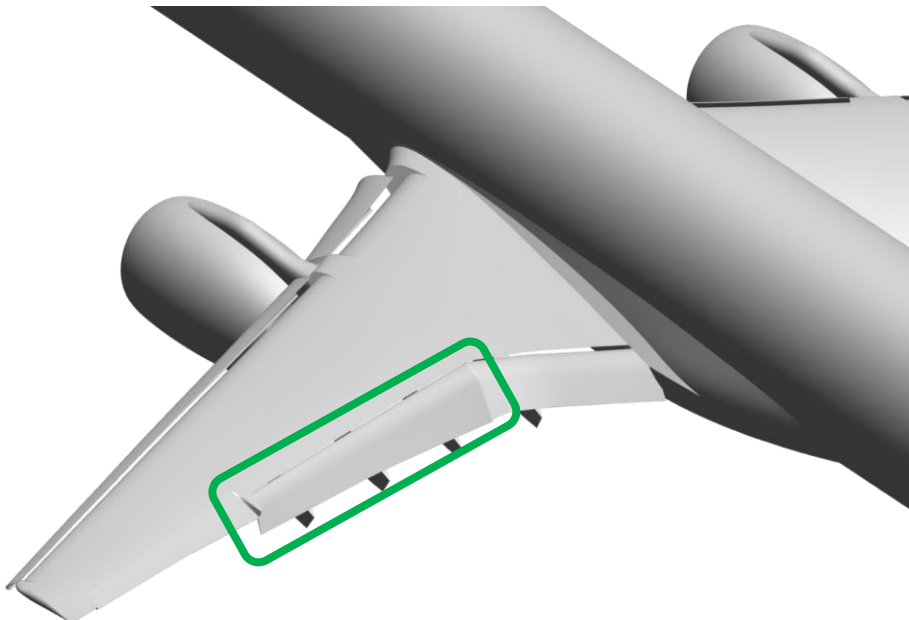
Fatigue & damage tolerance

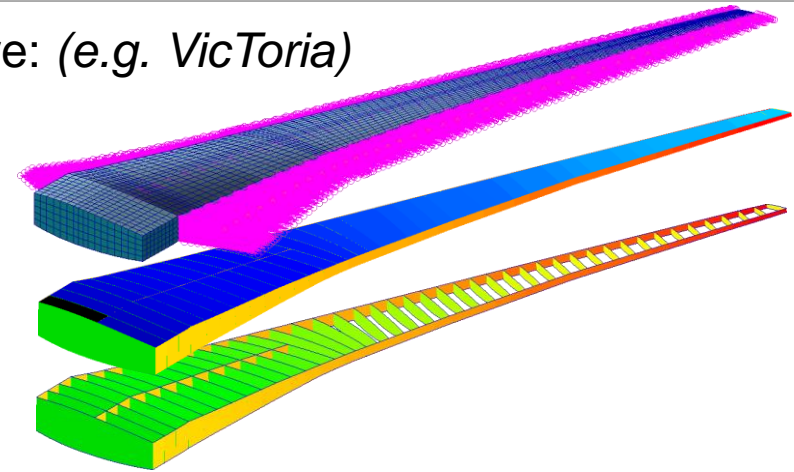System-structure interaction

greysponge66

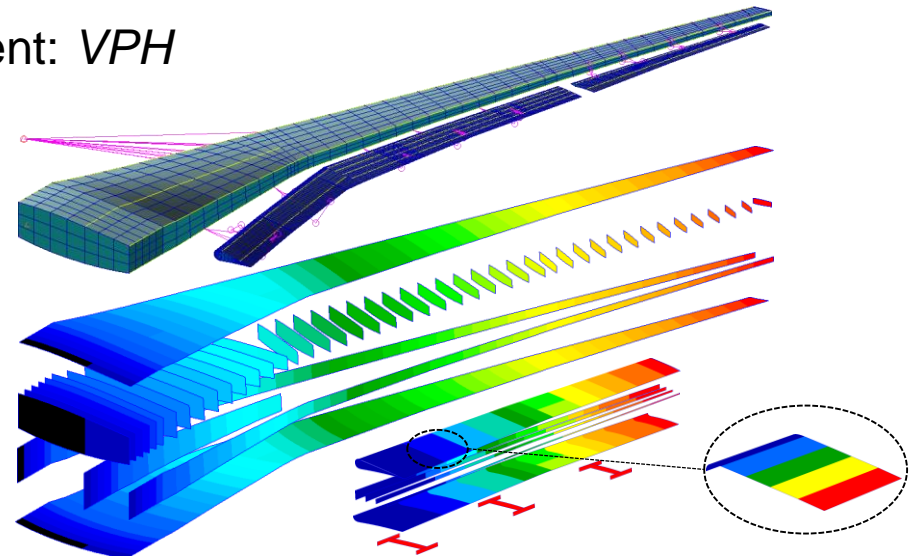# Main structural sizing aspects
Initial state

- Stick models

- MDO/A experience, focus cruise, e.g.
  - Digital-X
  -

Before: *(e.g. VicToria)*

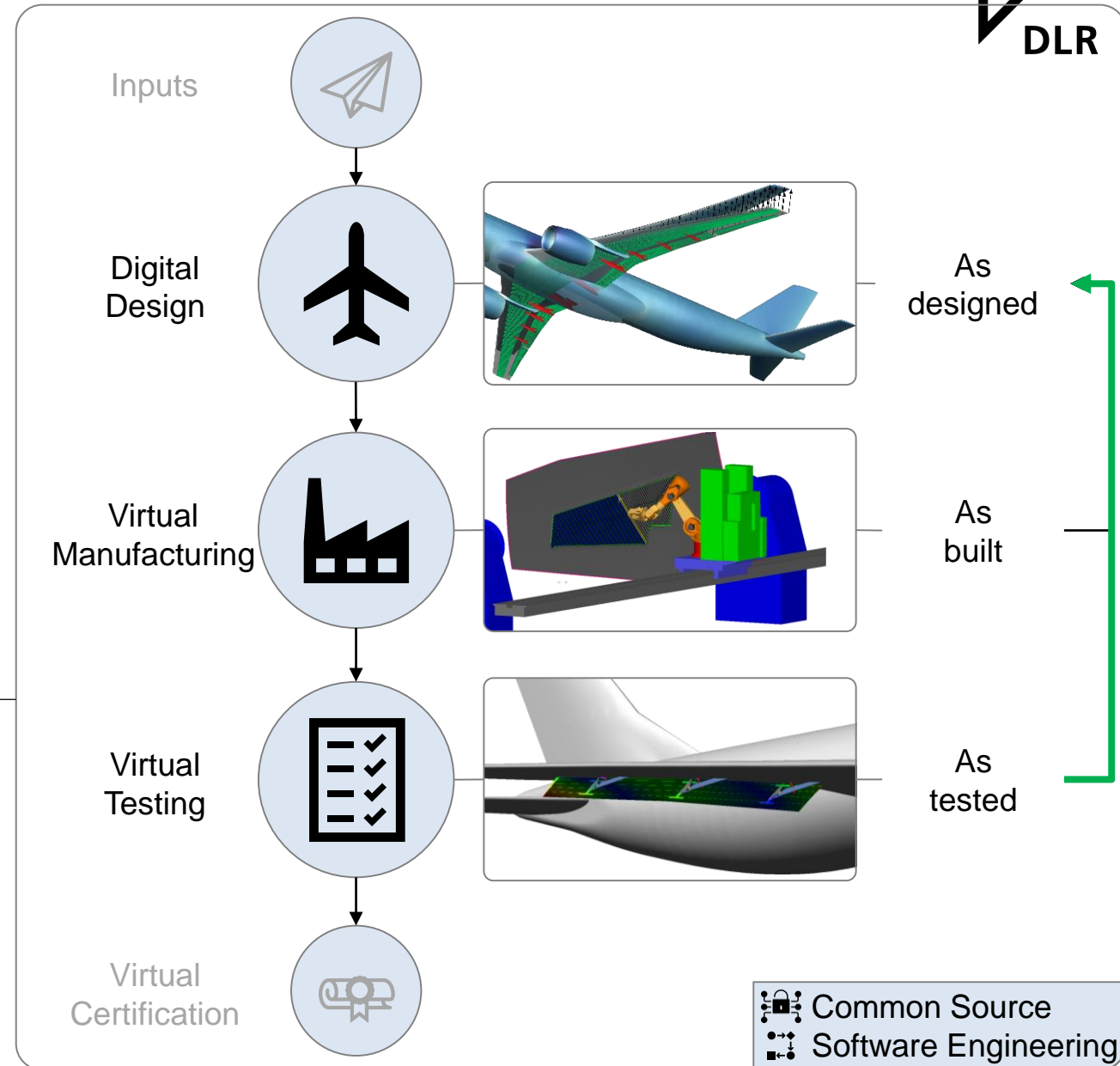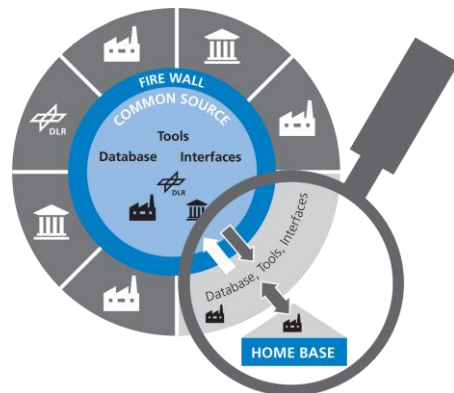Current: *VPH*

Context

Modeling

Simulation

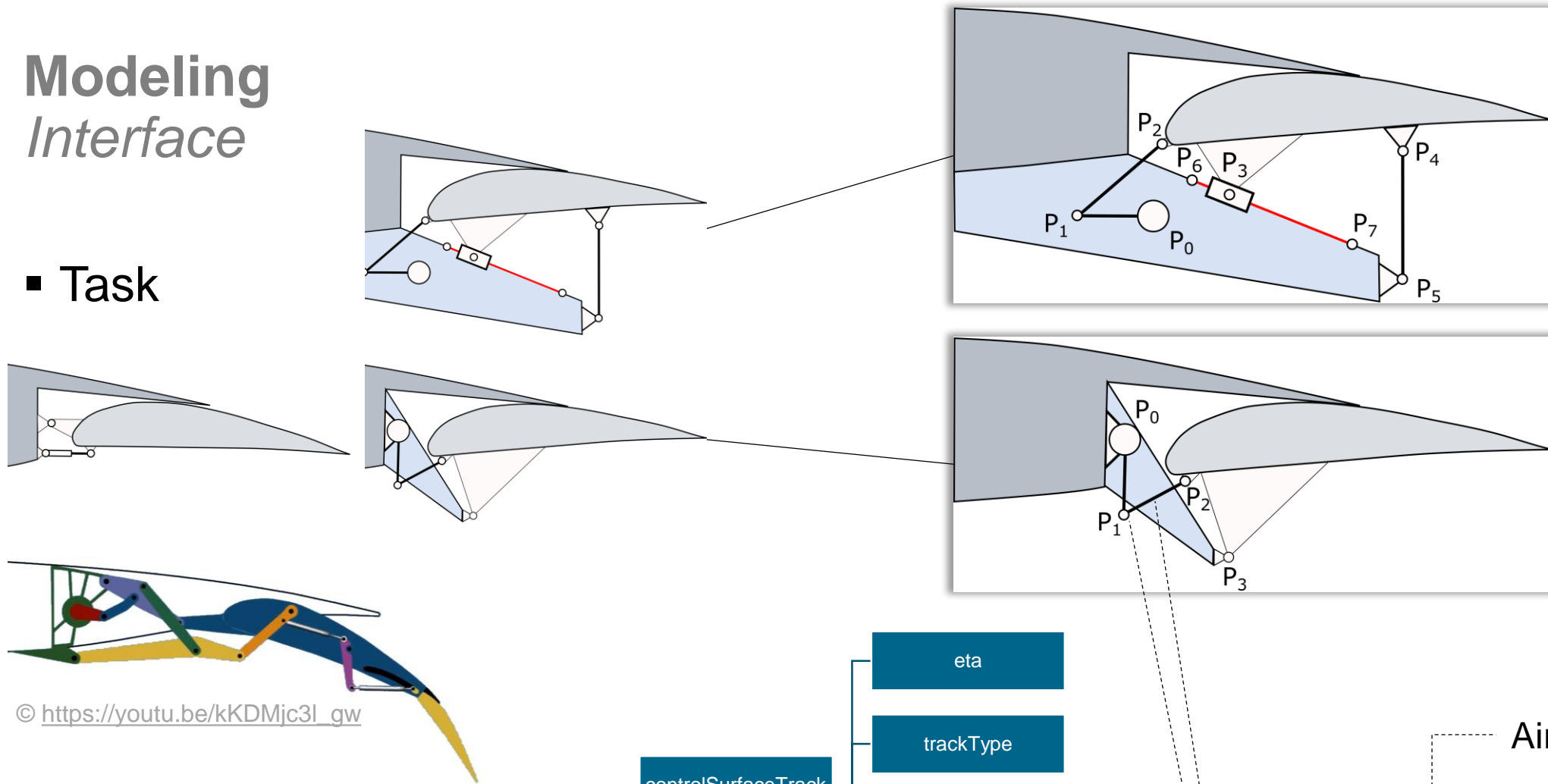Feedback

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Context
VPH

- Task
  - Integration & test center
  - For virtual simulation & certification components & technologies
  - Integration in overall aircraft

- Initial use case: moveable

- Approach: Digital end2end process
  - Technical
  - IT, collaboration & data

Inputs

Digital Design — As designed

Virtual Manufacturing — As built

Virtual Testing — As tested

Virtual Certification
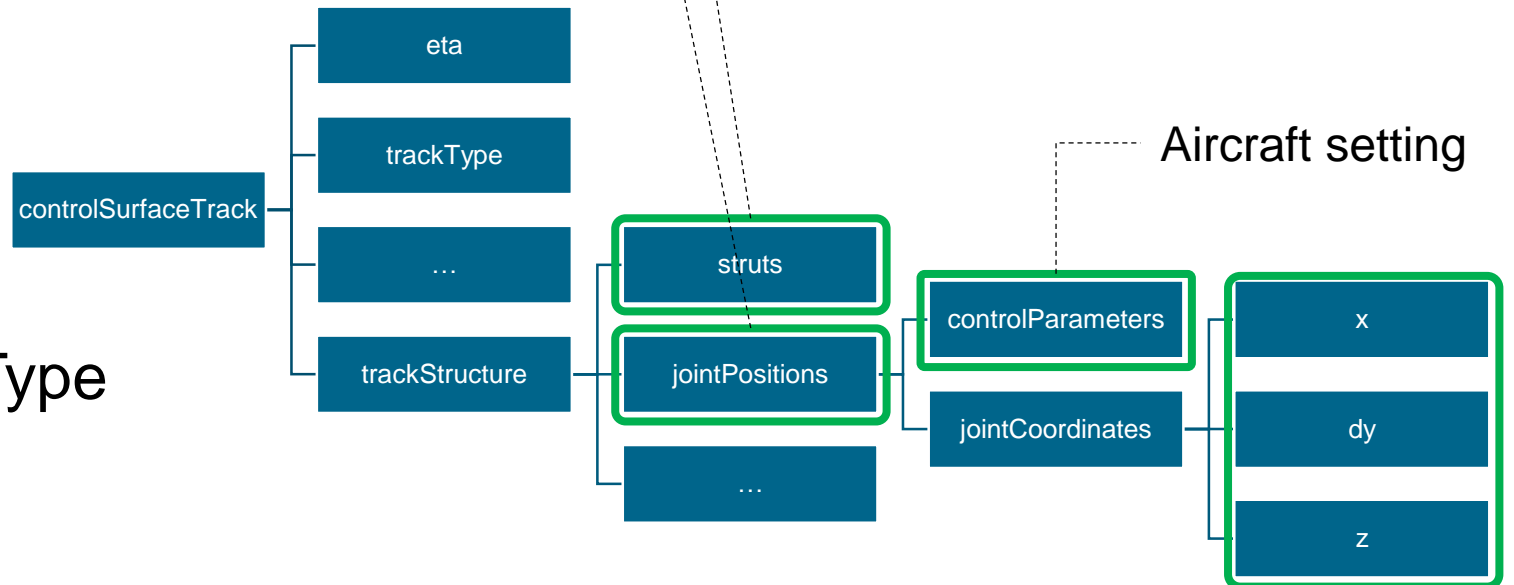
Common Source
Software Engineering

Modeling
Interface

- Task

© https://youtu.be/kKDMjc3I_gw

- CPACS (1)
- ControlSurfaceTrackTypeType
  #605

Aircraft setting

controlSurfaceTrack
- eta
- trackType
- …
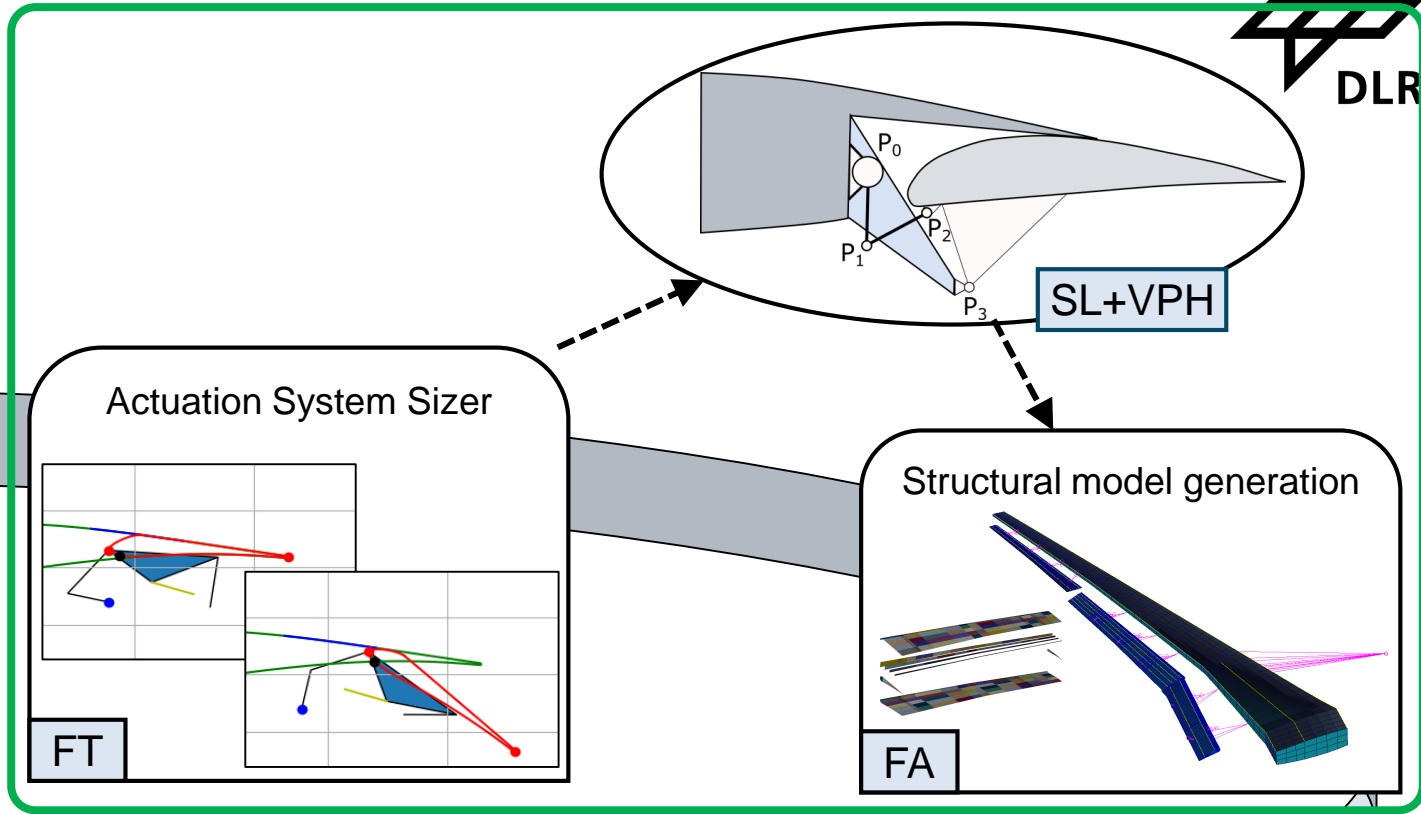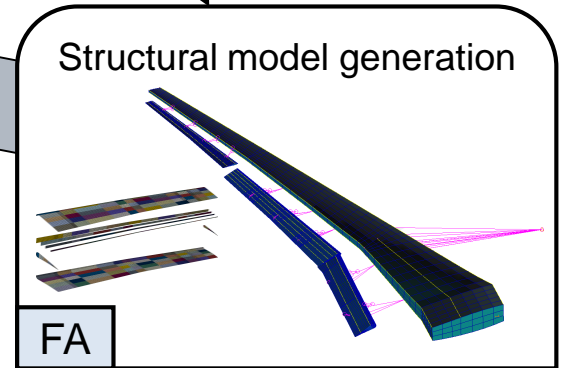- trackStructure
  - struts
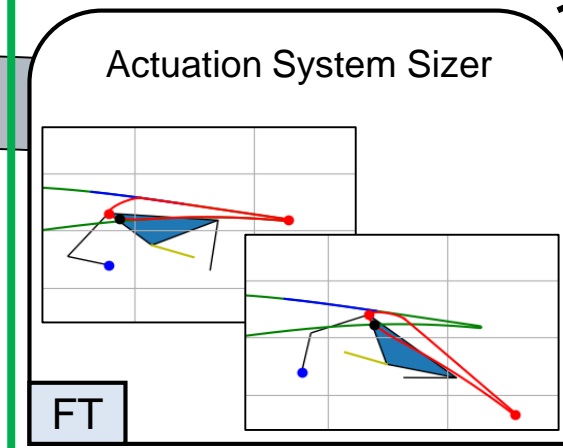 - jointPositions
  - …

controlParameters

jointCoordinates
- x
- dy
- z

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Modeling
Initial sizing approach

- Digital design

Overall Aircraft Design KPIs — AS

Actuation System Sizer — FT

SL+VPH

Structural model generation — FA

Aero – Structural Sizing — AS+FA

SkinFrictionX
0.004
0.003
0.002
0.001
0
-0.001

State: *As designed* — VPH

Modeling
Kinematics

Requirements

Mechanism: ASySi

Types

Synthesis

Kinematic analysis

Kinetostatic analysis

Sizing

Structure: DELiS

Mechanism loads vs. drive angle (Flap 1)

ASySi by O. Bertram et al. (2)

DELiS by S. Freund et al. (3)

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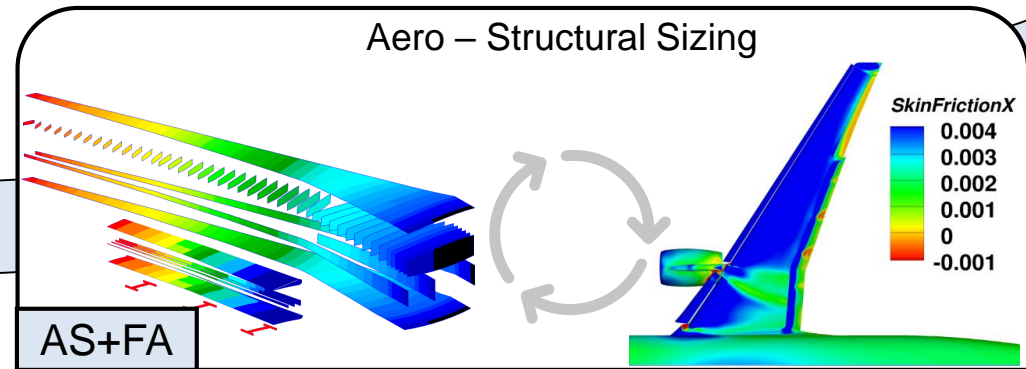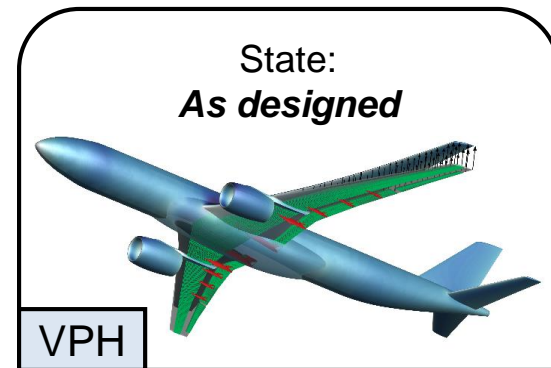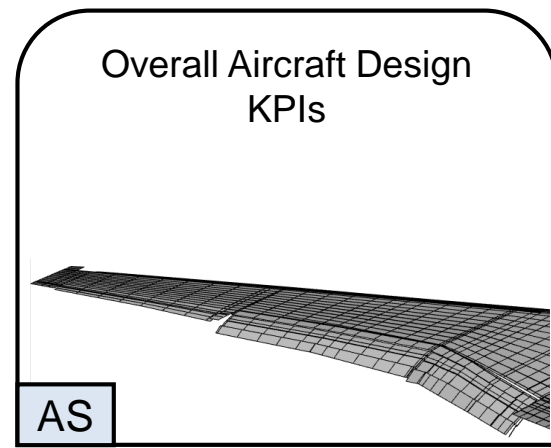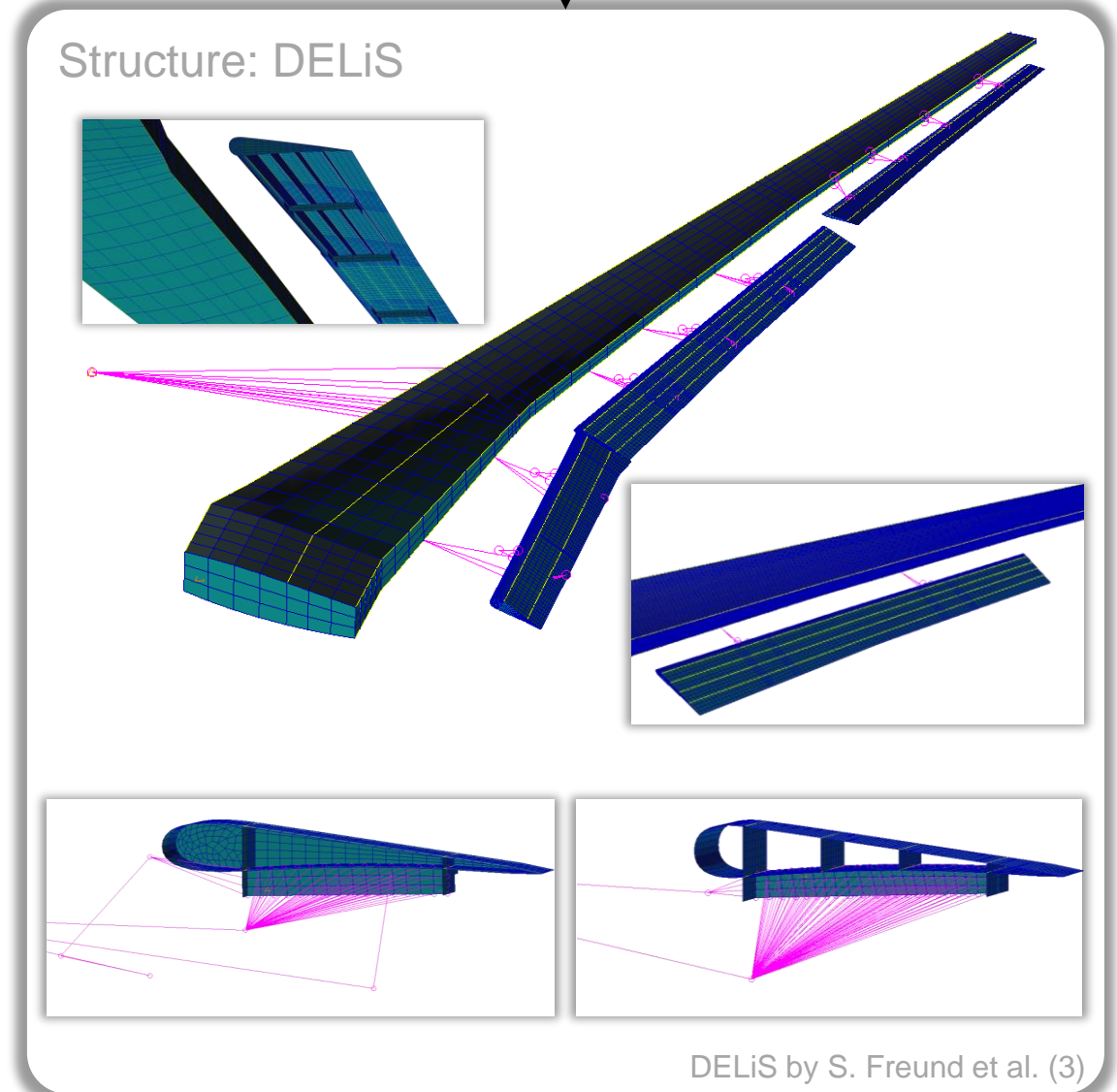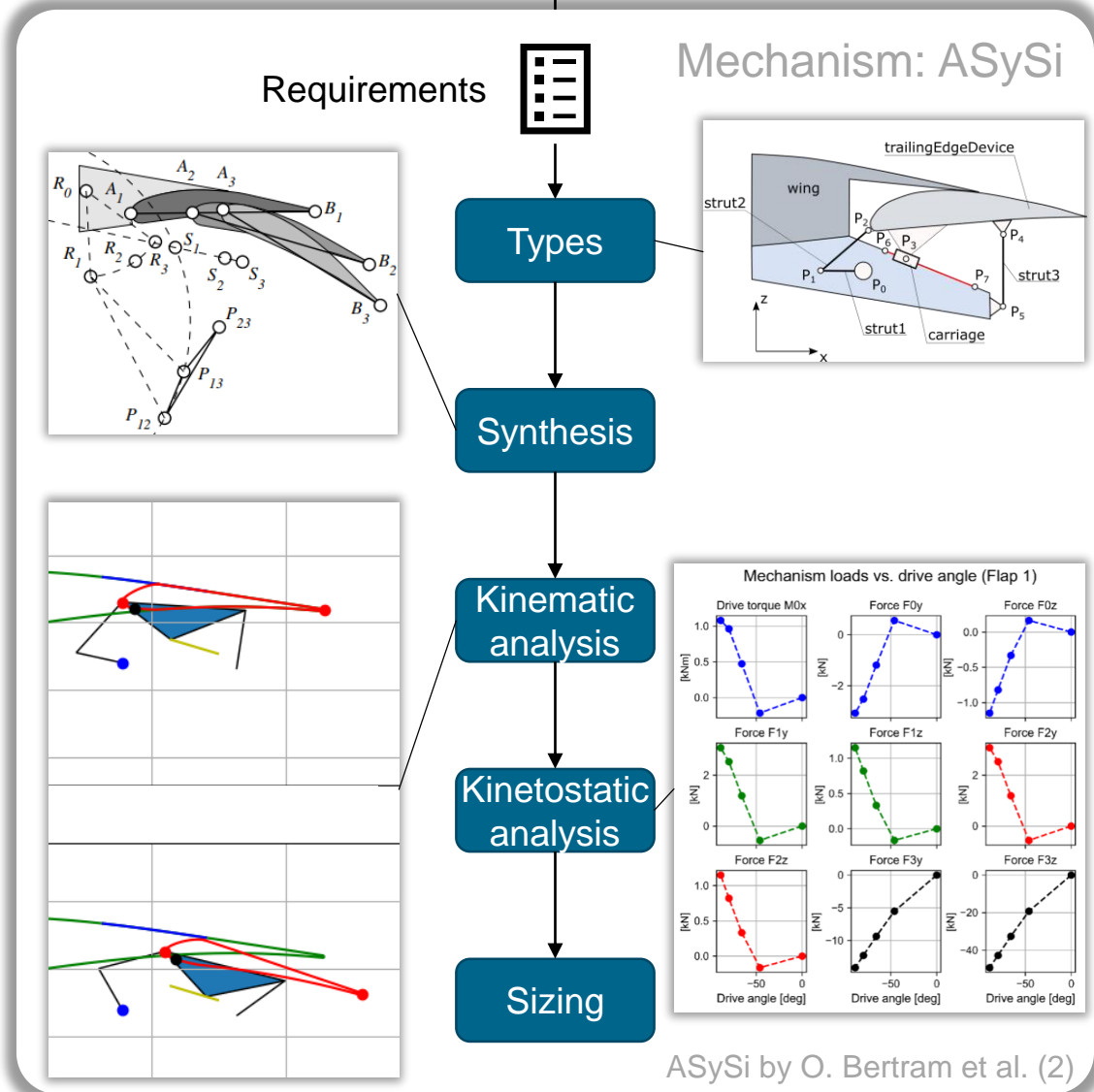
Modeling
Initial sizing results

- Iterative structural sizing
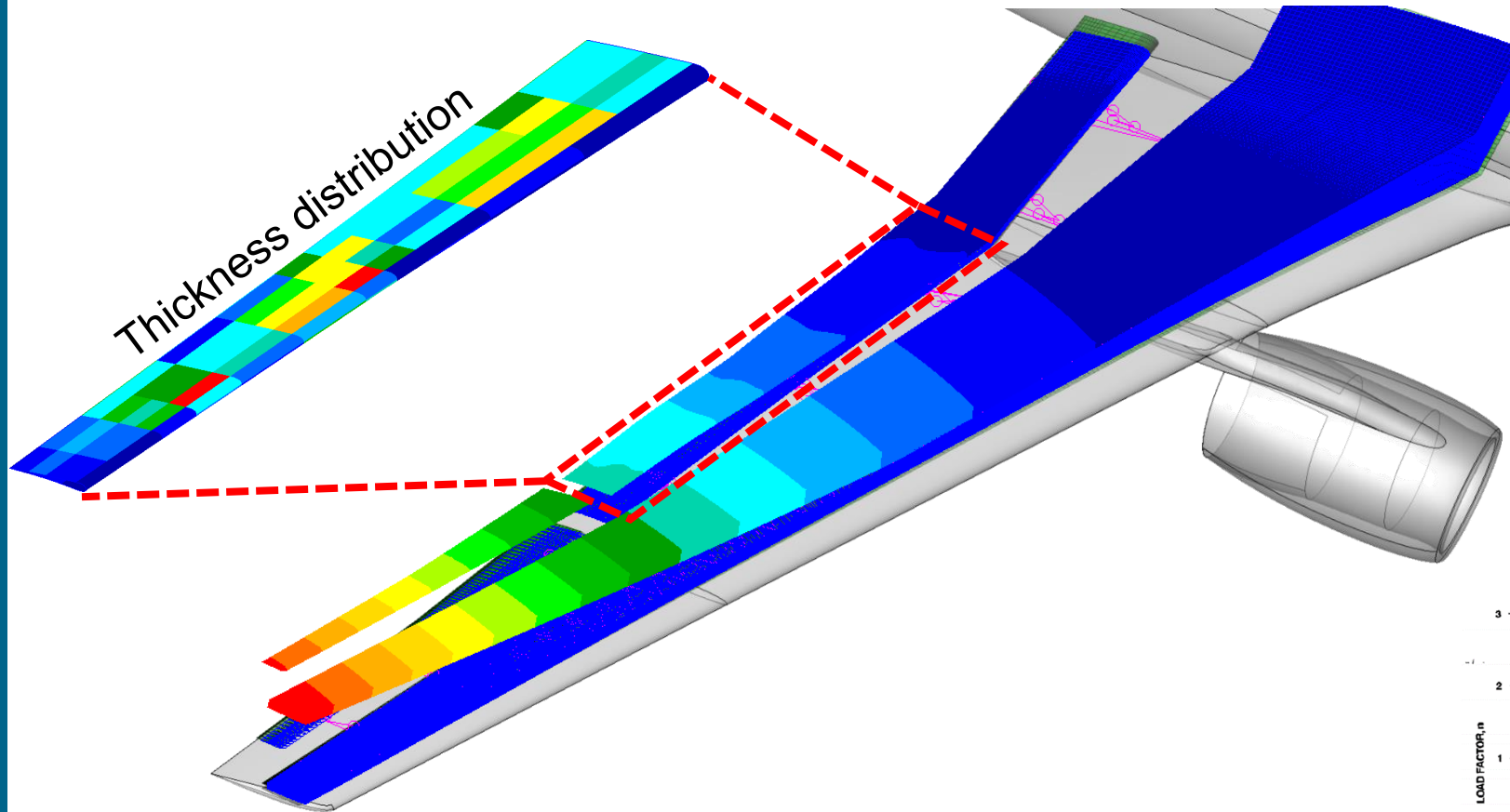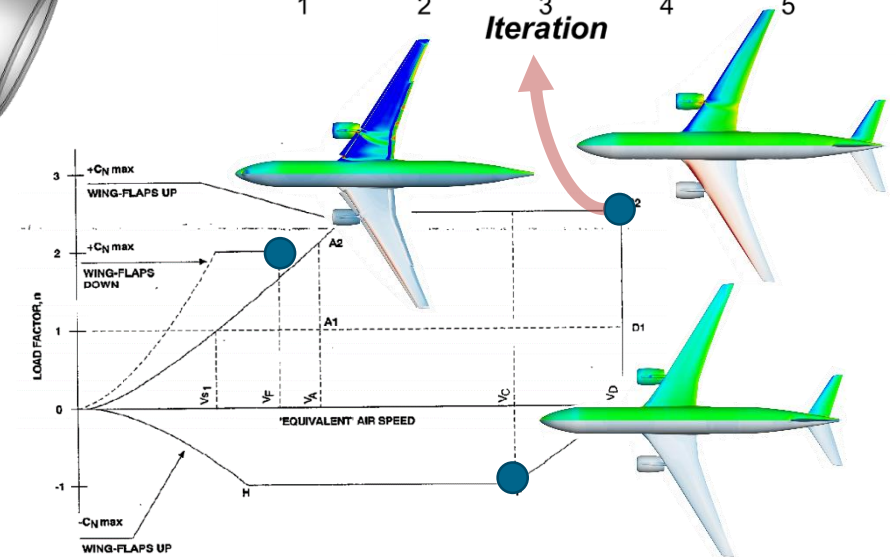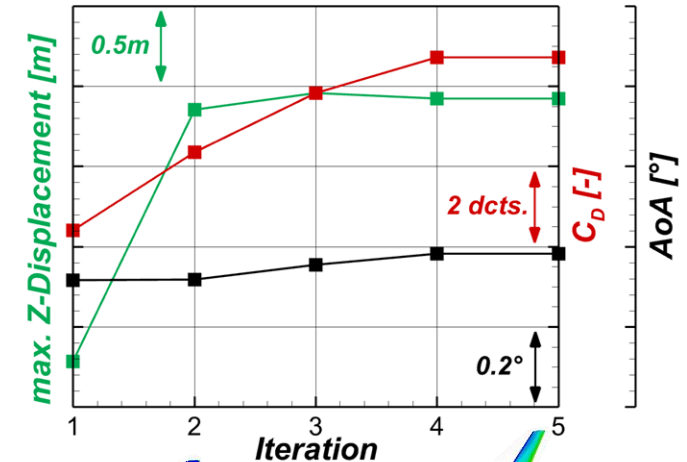- Parallel investigation of flight load cases
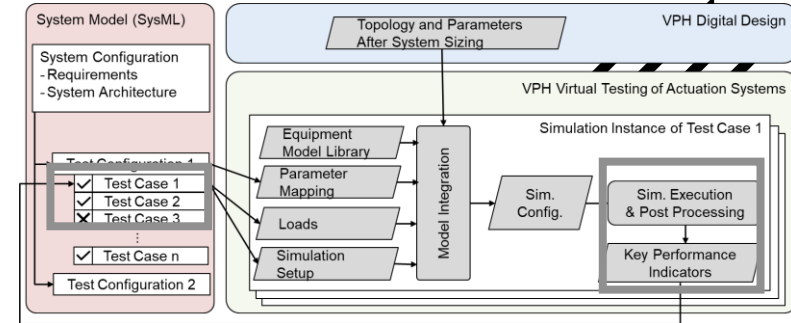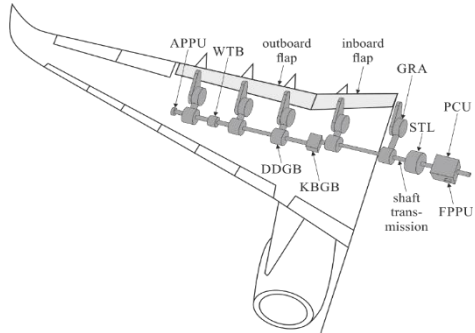- Structural sizing based on high speed cases

Thickness distribution

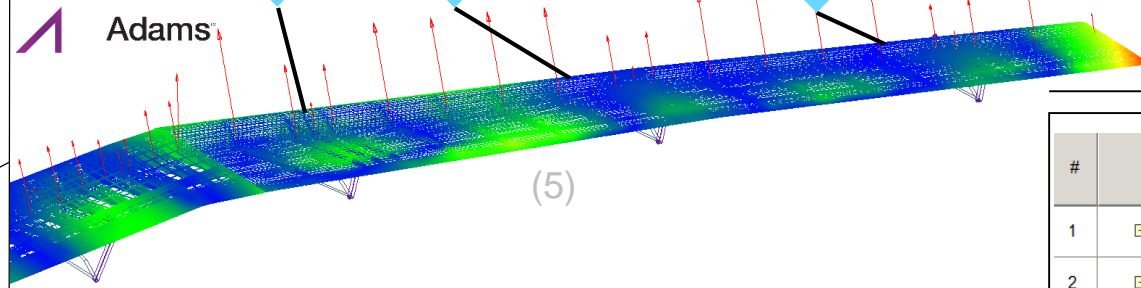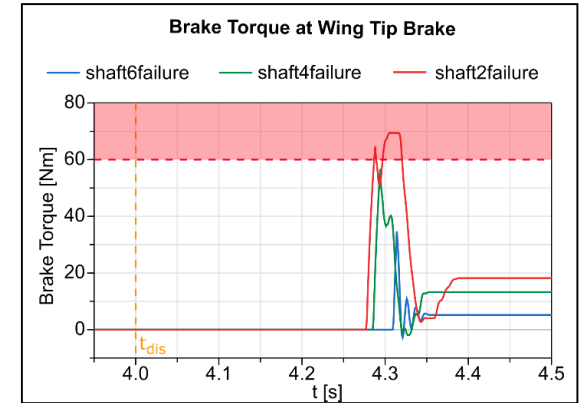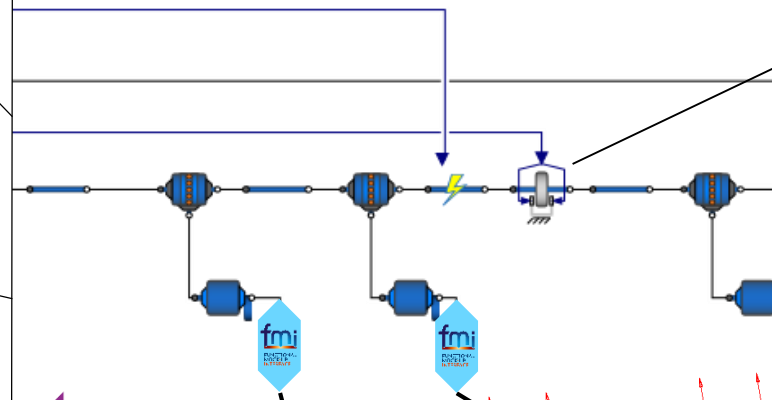*Example history for one load case*

- Consideration system-structure interaction in sizing?
- E.g. with respect to failure cases

Simulation
Virtual Testing

System Model (SysML)

System Configuration
- Requirements
- System Architecture

Test Configuration 1
- ☑ Test Case 1
- ☑ Test Case 2
- ☒ Test Case 3
- ☑ Test Case n

Test Configuration 2

VPH Digital Design

Topology and Parameters
After System Sizing

VPH Virtual Testing of Actuation Systems

Equipment Model Library
Parameter Mapping
Loads
Simulation Setup

Model Integration

Simulation Instance of Test Case 1

Sim. Config.

Sim. Execution & Post Processing

Key Performance Indicators

APPU WTB outboard flap inboard flap GRA PCU STL DDGB KBGB FPPU shaft transmission

Dymola

Down drive gearbox with torque limiter

Differential gearbox

Gearbox   (4)

Geared rotary actuator

Integrated geared rotary actuator

Adams

(5)

Brake Torque at Wing Tip Brake

— shaft6failure   — shaft4failure   — shaft2failure

Brake Torque [Nm] vs t [s]

t_{dis}

#	△ Name	MaxAsymConst : Maximum Asymmetry	WTBTorqueConst : Maximum Torque of WTB after failure
1	shaft2failure	pass	fail
2	shaft4failure	pass	pass
3	shaft6failure	pass	pass

→ Evaluation & verification of system functions
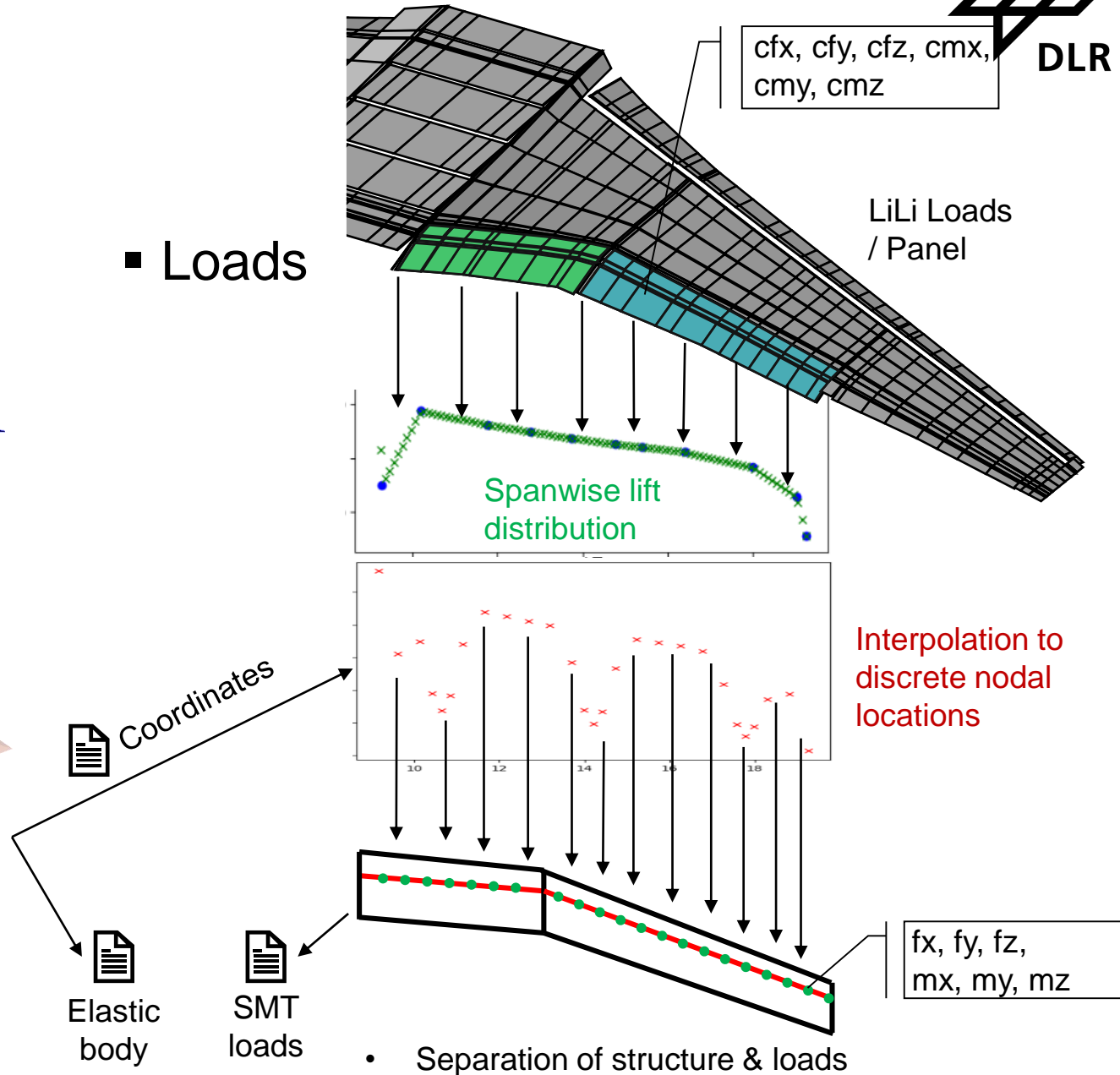→ Determination of interface loads

Simulation
Virtual Testing

DLR

▪ **Structure**

▪ **Loads**

cfx, cfy, cfz, cmx, cmy, cmz

LiLi Loads / Panel

Spanwise lift distribution

- Reduction to elastic body Craig-Bampton-method
- ASETs at interfaces

Coordinates

Interpolation to discrete nodal locations

- Faster alternative to RANS-based CFD loads
- Load reference axis along l/4-line

Elastic body

SMT loads

fx, fy, fz, mx, my, mz

- Separation of structure & loads
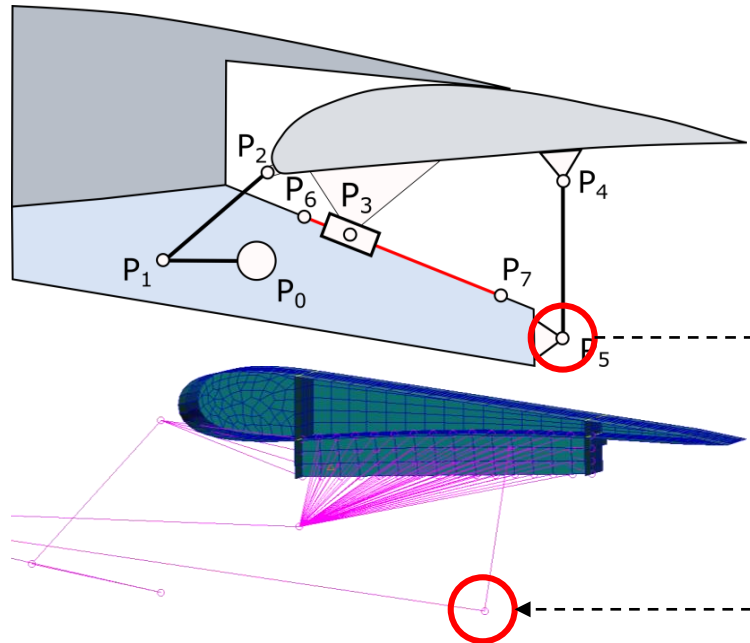
Simulation
Virtual Testing

- Co-simulation actuation system & structure
  - Example: Drive-shaft failure

- Interface loads mechanism ↔ moveable

- Critical state?
  - Single transient state (worst case)
  - Min/Max
  - Equidistant transient states

- Additional loads for structural sizing
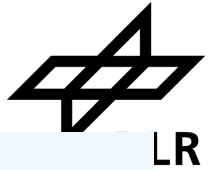 - W.r.t. static aerodynamic loads flight state

Co-simulation

f_x [N]

| 3_P2 | 4_P2 | 5_P2 |
| 3_P4 | 4_P4 | 5_P4 |

f_z [N]

Time [s]
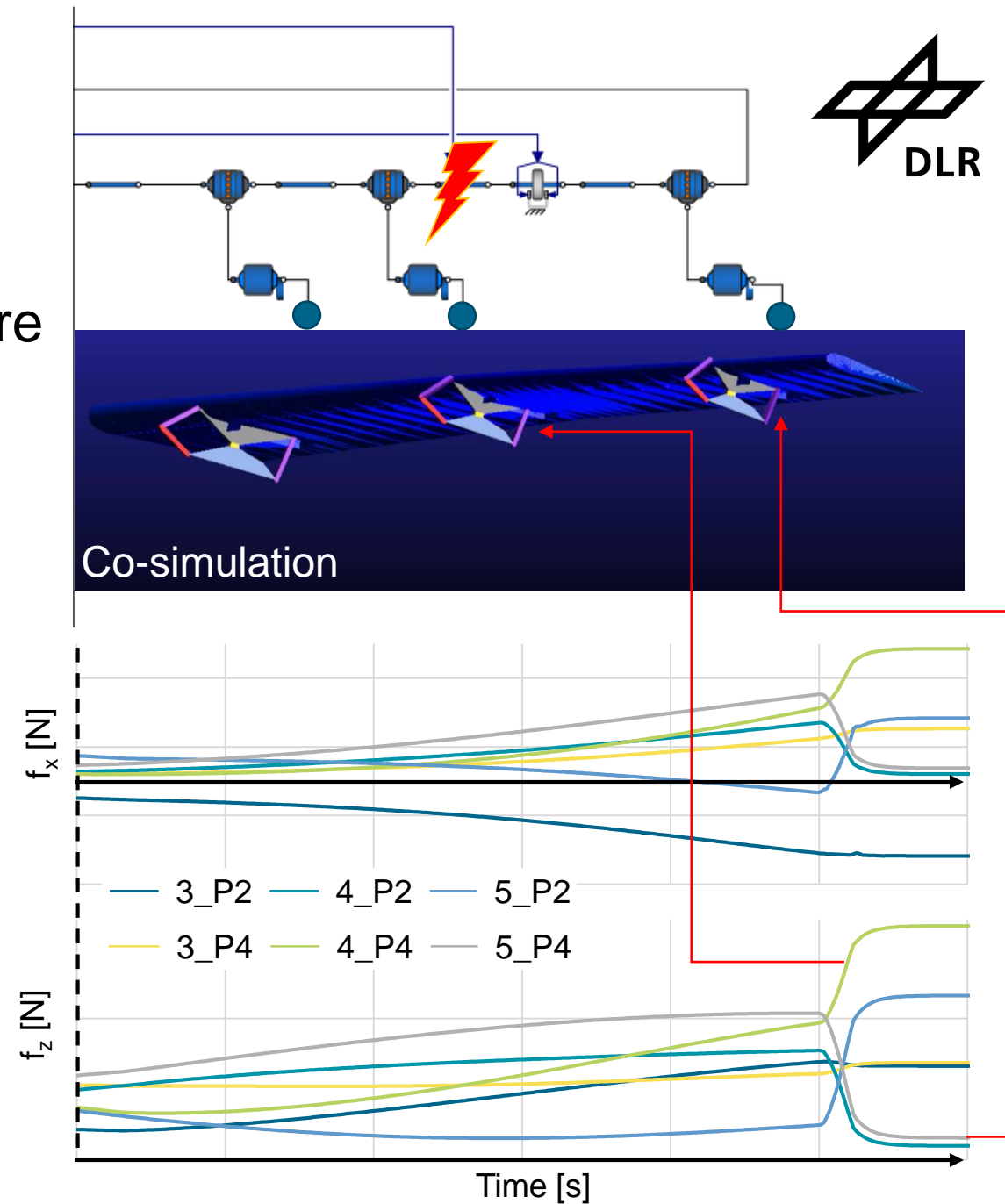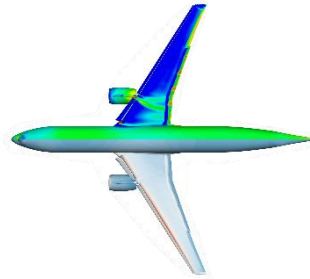
Feedback

- Failure case at flight state, #623

- E.g.: jointDisconnect

Release of MPC

- Feedback to next sizing run

- Effects: VPH2.0

THANK YOU FOR YOUR ATTENTION

Contact

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Literature

(1) M. Alder, E. Moerland, J. Epsen, B. Nagel: Recent Advances in Establishing a Common Language for Aircraft Design with CPACS; https://elib.dlr.de/134341/

(2) O. Bertram: Interdisciplinary Design Method for Actuation Load Determination of Aircraft High-Lift Systems; DOI: 10.1109/SYSCON.2016.7490562

(3) T. Führer, C. Willberg, S. Freund, F. Heinecke: Automated model generation and sizing of aircraft structures; DOI: 10.1108/AEAT-02-2015-0054.R1

(4) A. Schäfer, R. W. Hollmann, O. Bertram: Modeling and simulation of a multi-functional high-lift actuation system based on key performance data; DOI: 10.11128/arep.59

(5) R. W. Hollmann, A. Schäfer, O. Bertram, M. Rädel: Virtual testing of multifunctional moveable actuation systems, DOI: 10.1007/s13272-022-00602-5

Impressum

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