VMAP-ENABLED MULTI-DISCIPLINARY COLLABORATION ON JET ENGINE DESIGN

Inter- and intra-operability of processes

Oliver Kunc, DLR-BT, 15 Feb 2024

Outline

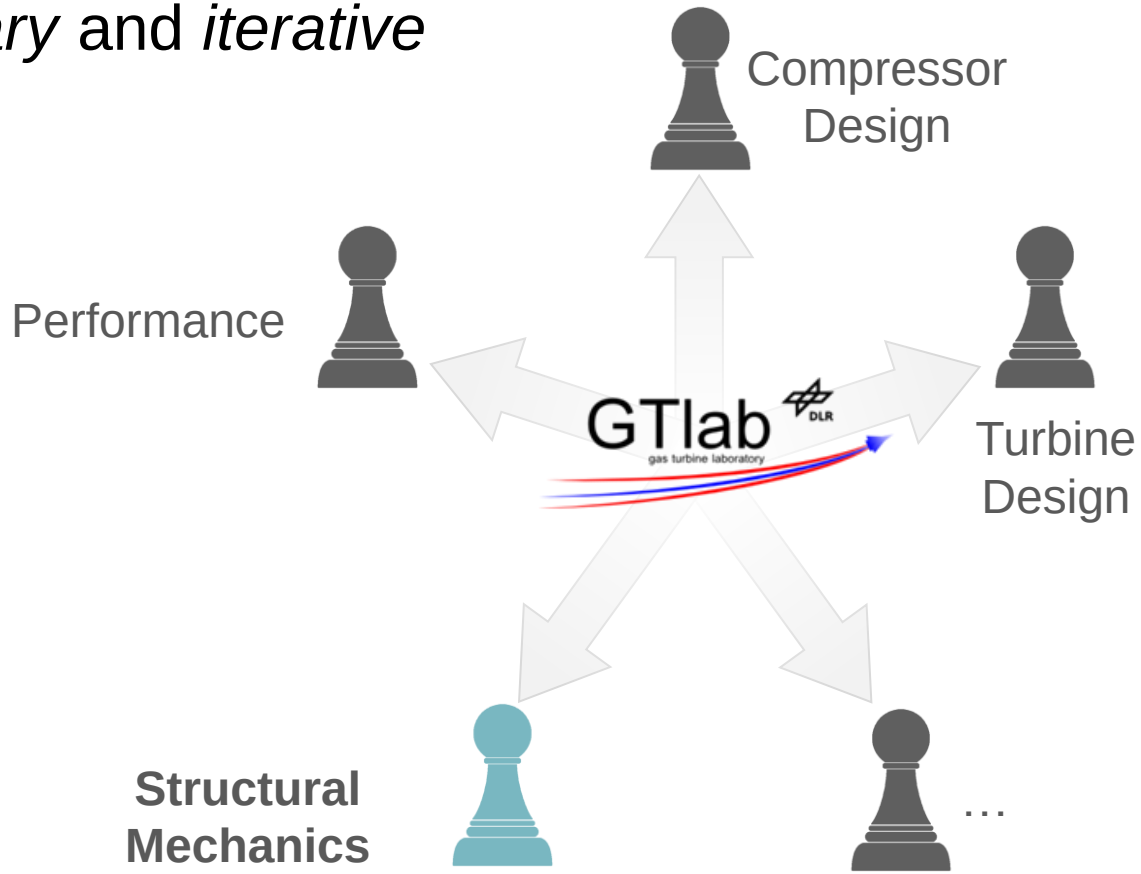
- Brief introduction to jet engine design @ DLR
- Central Data Model (CDM)
- Integration of VMAP into CDM
- Use cases
- Suggested extensions to VMAP → full model storage
- Further challenges

Take home messages:

1. **VMAP adds value to parametric modeling environments**
2. **VMAP needs full model storage – suggestions, requirements?**

Introduction
Aircraft Engine Design

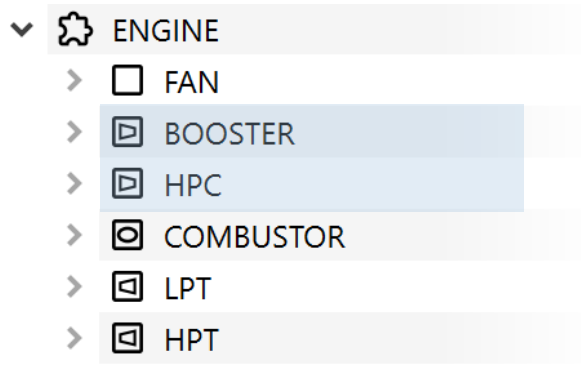
- Aircraft engine design is *multi-disciplinary* and *iterative*
  - Need for collaboration
  - Development of software framework **GTlab** (Gas Turbine Laboratory)
- Modern engines are *highly optimized*
  - Improvements are *incremental*
  - Need for higher-fidelity methods



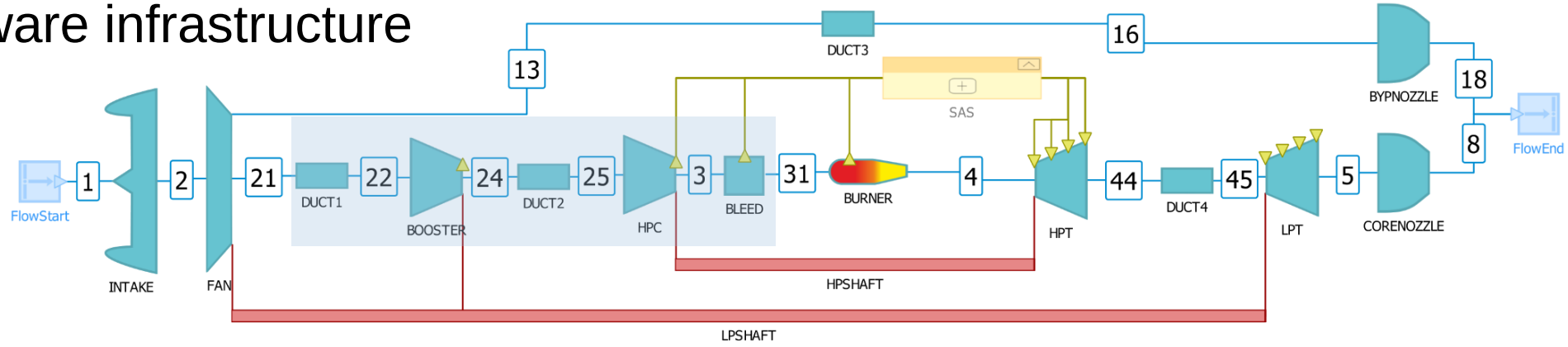
The Gas Turbine Laboratory
Overview

- Framework for collaborative design
  - ✓Coupling of tools
  - ✓Standardized exchange of data
  - ✓Workflow management
  - ✓Support for multi-fidelity data

Engine Data Record



- Modular software infrastructure

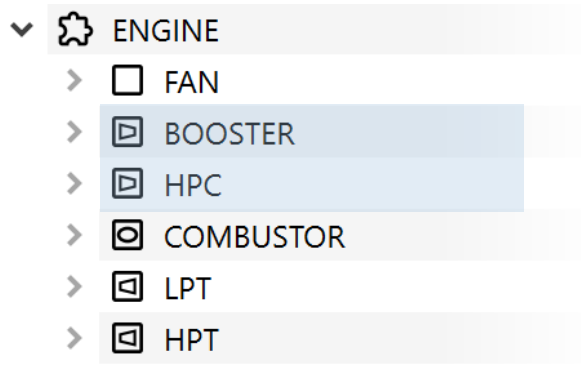


Performance Model

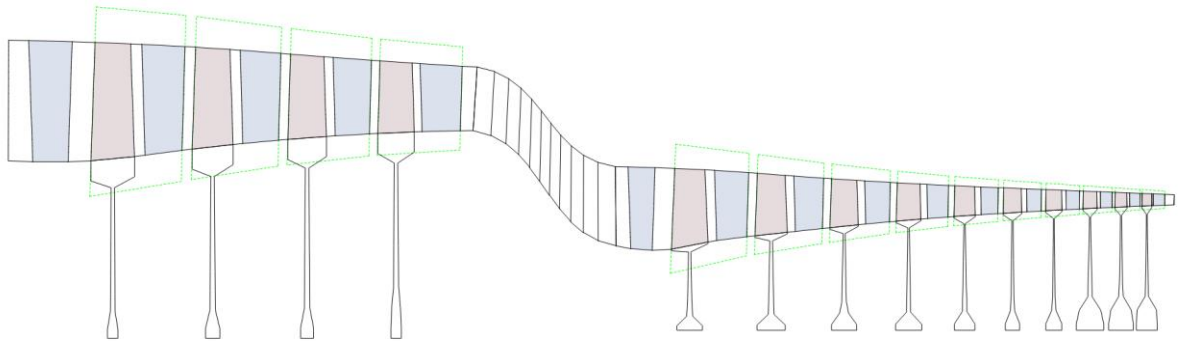
The Gas Turbine Laboratory
Overview

- Framework for collaborative design
  - ✓Coupling of tools
  - ✓Standardized exchange of data
  - ✓Workflow management
  - ✓Support for multi-fidelity data

Engine Data Record



- Modular software infrastructure
  - Performance
  - Sketching
  - 2D Blade design

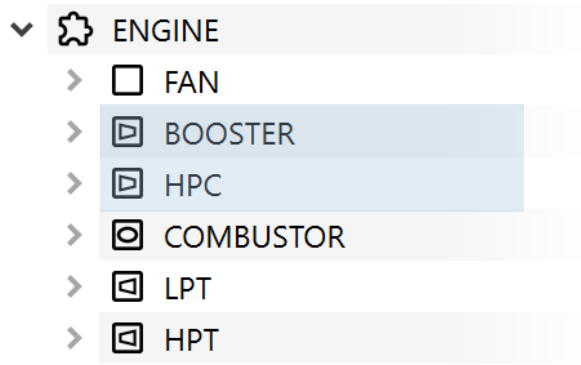


2D Geometry

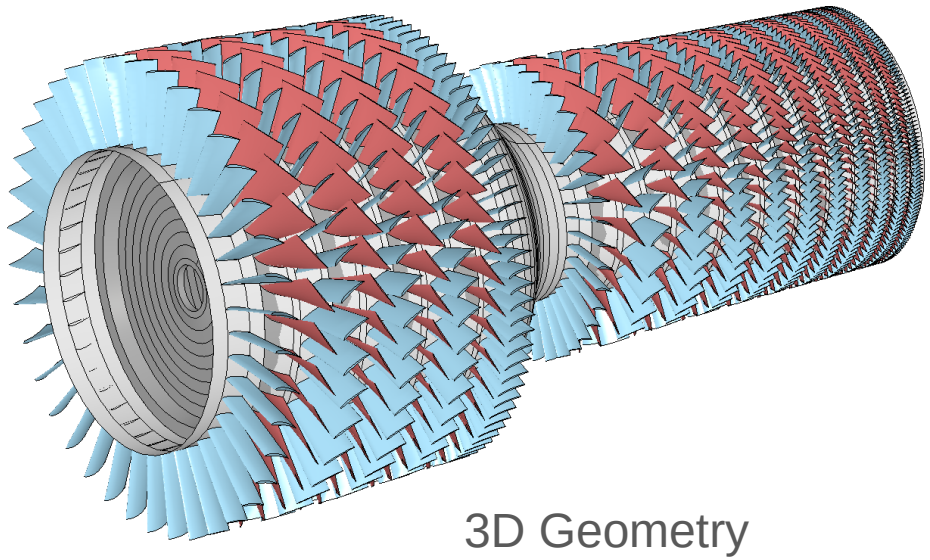
The Gas Turbine Laboratory
Overview

- Framework for collaborative design
  - ✓Coupling of tools
  - ✓Standardized exchange of data
  - ✓Workflow management
  - ✓Support for multi-fidelity data

Engine Data Record



- Modular software infrastructure
  - Performance
  - Sketching
  - 2D + 3D Blade design
  - CAD kernel
  - …



3D Geometry

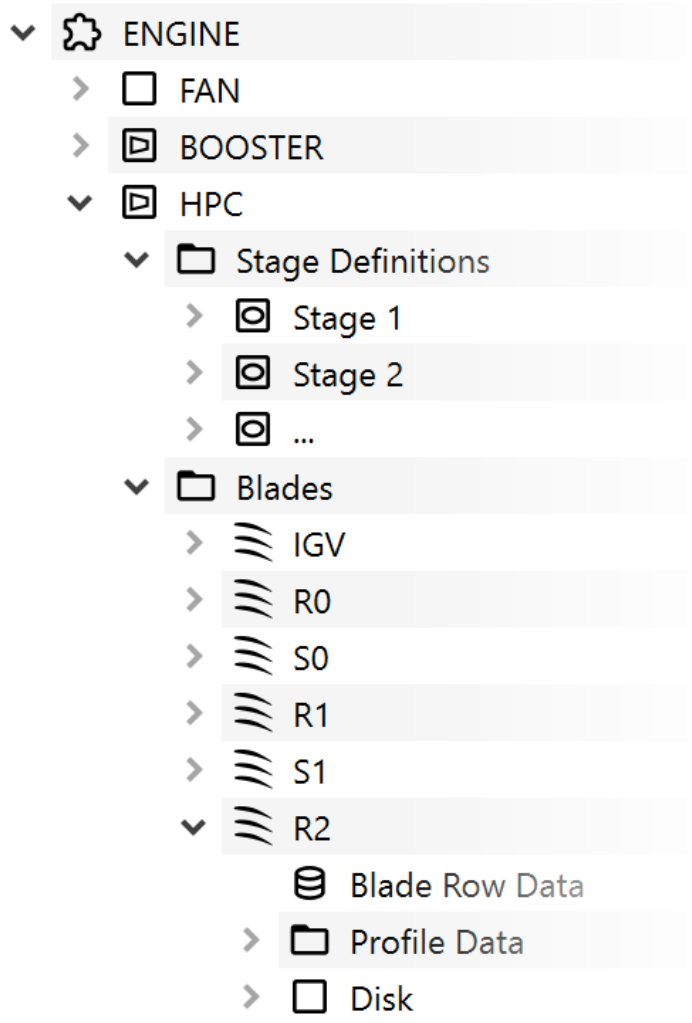
The Gas Turbine Laboratory
Central Data Model

- Parent-child hierarchy

- Multi-fidelity of components
  - ✓Conceptual design
  - ✓Preliminary design
  - ⧖ Higher fidelity information

➢ **How to incorporate CSM?**

1. Choose FE data format 😉
2. Integrate FE data into the data model
3. Develop FE analysis processes

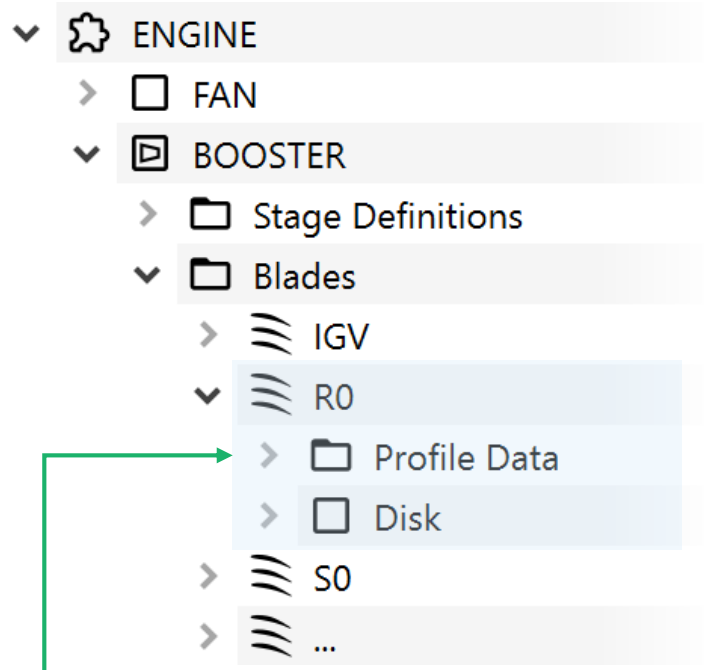


Integration of VMAP data
Idea

- VMAP files contain structural data for blades (and disks)

- VMAP files contain parent-child hierarchy, too

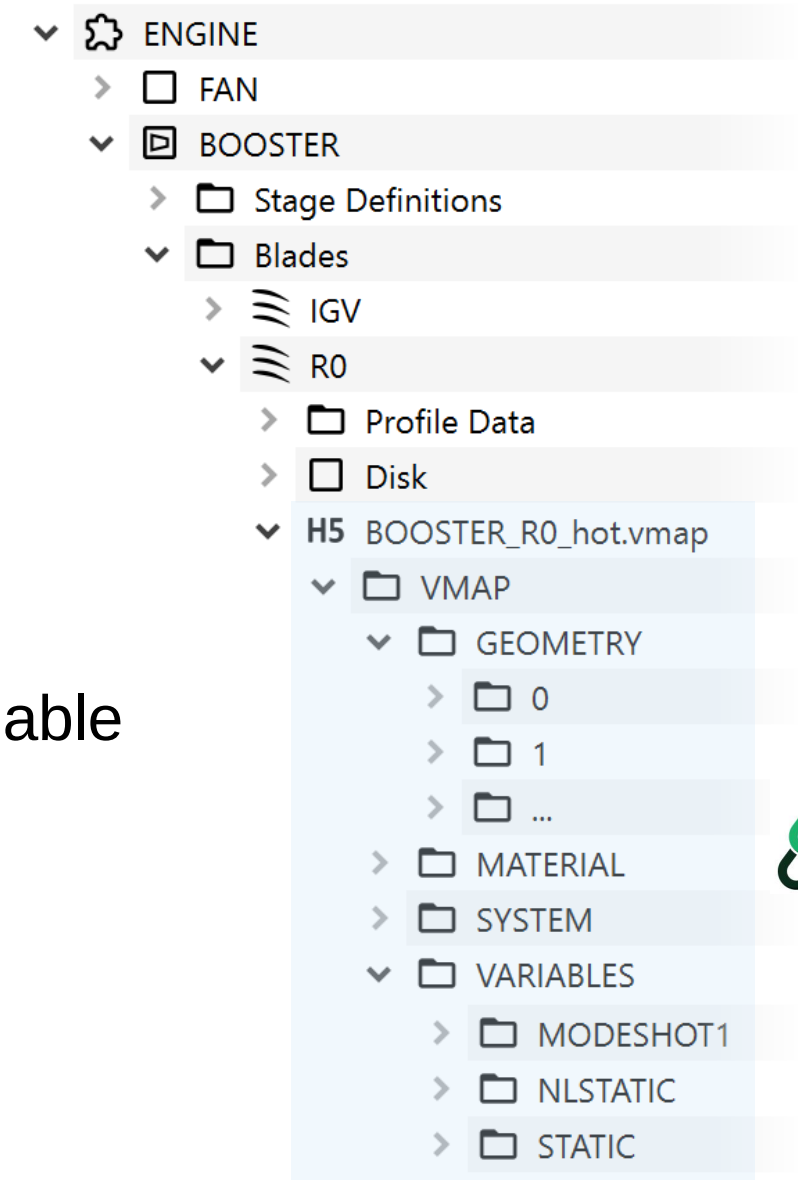
→ Attach VMAP file structure as a child to blade data record



VMAP

Integration of VMAP data
Execution

- Only file structure is appended (Indexing)
  - ✓Expresses data affiliations clearly
- Data remains in VMAP file
  - ✓Lightweight integration
- Individual nodes are made uniquely identifiable
  - ✓Referencing
  - ✓Searching

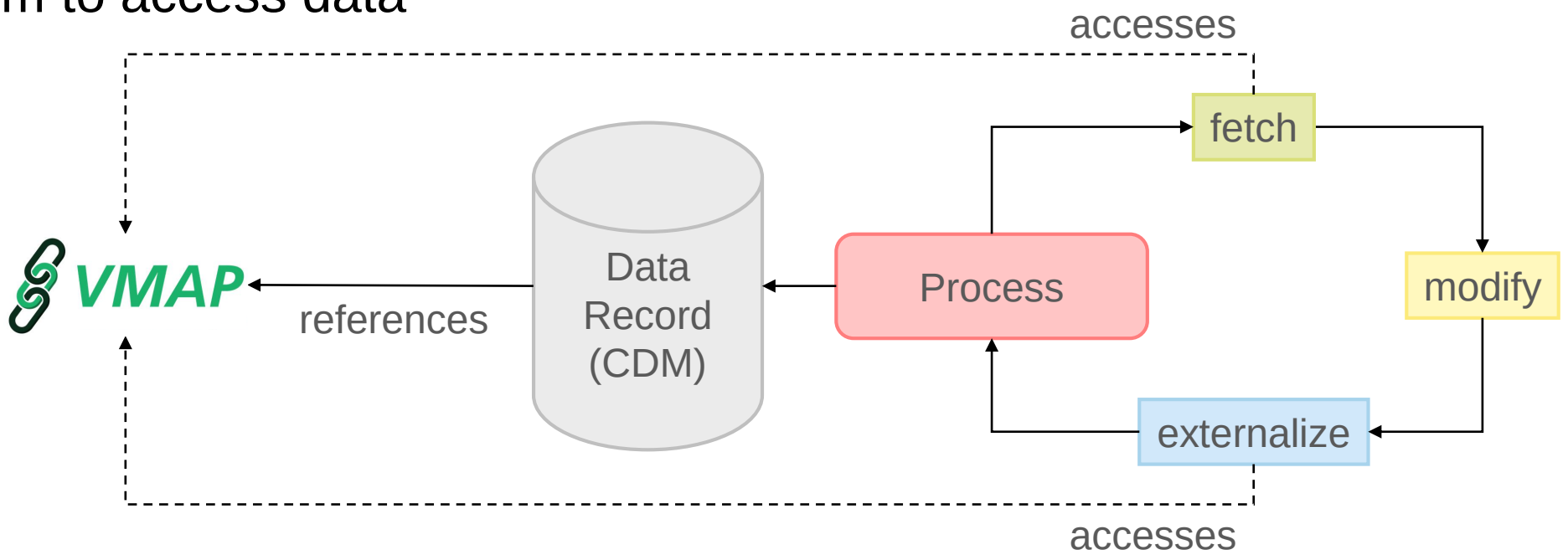


VMAP

Integration of VMAP data
Accessing data automatically

- Workflow execution: data is **not** loaded into the framework

- Dedicated API & reference-counting mechanism to access data



Integration of VMAP data
Accessing data manually

- Manual inspection: data **is** loaded into the framework **on demand**
- Selective, responsive data viewer
- Outperforms official HDF Viewer

H5 HDF5 Viewer (MYELEMENTS)

MYELEMENTS - /VMAP/GEOMETRY/3/ELEMENTS/

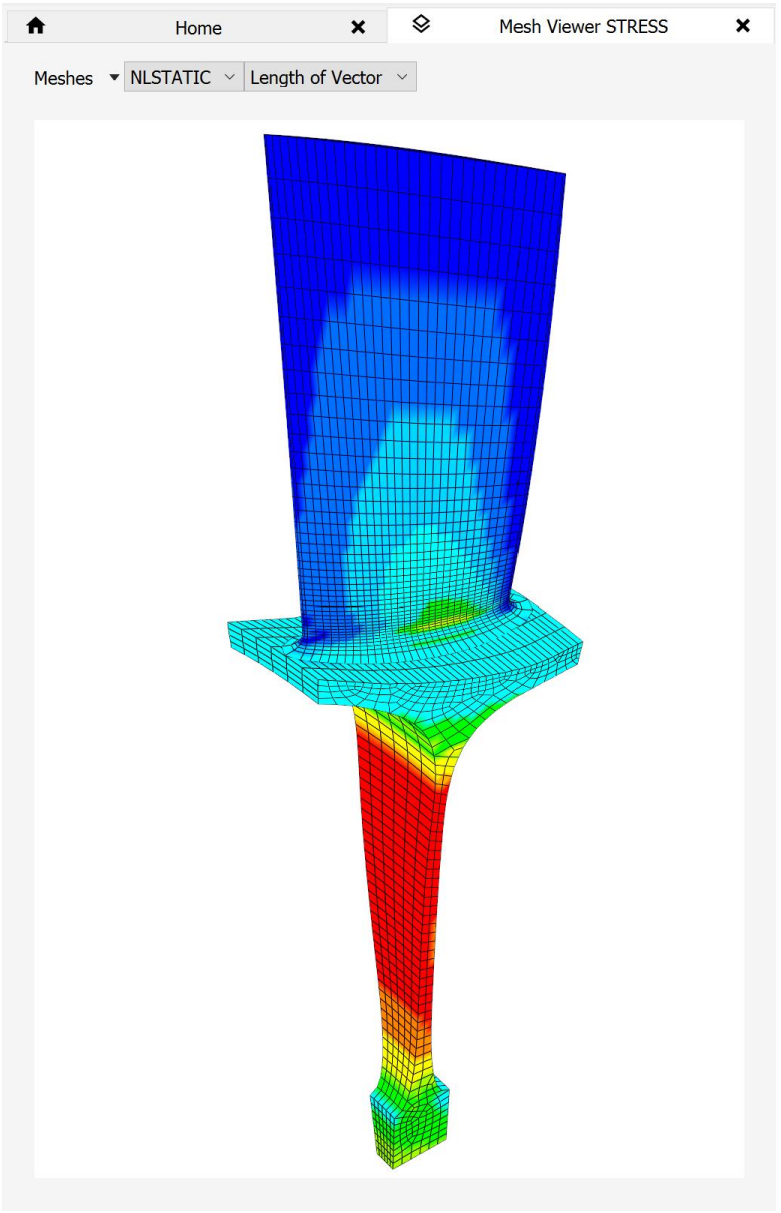
	myIdentifier	myElementType	myCoordinateSystem	myMaterialType	mySectionType	myConnectivity
0	316066	2	1	0	0	(4082, 3231, 1431, 1581, 4084, 1347, 1346, 1345, 1344, 1343)
1	316067	2	1	0	0	(7927, 8094, 1829, 1583, 8093, 1342, 1341, 1340, 1339, 1338)
2	316068	2	1	0	0	(7929, 8094, 7927, 1583, 8198, 8093, 7928, 1337, 1339, 1340)
3	316069	2	1	0	0	(3867, 4010, 1829, 1583, 4009, 1336, 1335, 1334, 1333, 1338)
4	316070	2	1	0	0	(4010, 3867, 3869, 1583, 4009, 3868, 5746, 1333, 1334, 1332)
5	316071	2	1	0	0	(3905, 3889, 8040, 1580, 3908, 1331, 1330, 1329, 1328, 1327)
6	316072	2	1	0	0	(1643, 1348, 2209, 1351, 1326, 1325, 1324, 1323, 1322, 1321)
7	316073	2	1	0	0	(1803, 4010, 1832, 1583, 1320, 1319, 1318, 1317, 1333, 1316)
8	316074	2	1	0	0	(8094, 8106, 1440, 1583, 8108, 1315, 1314, 1339, 1313, 1312)
9	316075	2	1	0	0	(8094, 7929, 8106, 1583, 8198, 8107, 8108, 1339, 1337, 1313)
...	**<fetch more>**	**<fetch more>**	**<fetch more>**	**<fetch more>**	**<fetch more>**	**<fetch more>**
7731	323797	2	1	0	0	(1554, 3120, 1370, 3021, 636, 10702, 10703, 564, 3141, 11256)
7732	323798	2	1	0	0	(1723, 2705, 1785, 2885, 13361, 11198, 12471, 12354, 2928, 12763)
7733	323799	2	1	0	0	(1736, 1747, 8080, 1826, 11304, 11483, 11482, 13315, 12011, 9789)
7734	323800	2	1	0	0	(1382, 1828, 1372, 3023, 11692, 290, 11693, 12115, 10924, 11056)
7735	323801	2	1	0	0	(1484, 3917, 3920, 1438, 12416, 3919, 9331, 9332, 10334, 9159)
7736	323802	2	1	0	0	(1382, 1830, 1424, 1372, 9546, 9545, 9547, 11693, 293, 13124)
7737	323803	2	1	0	0	(1382, 3025, 1424, 1390, 13895, 10399, 9547, 9550, 13096, 9548)
7738	323804	2	1	0	0	(1424, 3025, 1382, 1372, 10399, 13895, 9547, 13124, 13794, 11693)
7739	323805	2	1	0	0	(1424, 4043, 3863, 4052, 13666, 5733, 10484, 10477, 4053, 4054)
7740	323806	2	1	0	0	(2577, 1788, 2575, 2707, 10492, 10491, 2576, 2746, 13064, 2809)

Selection mode: Front and back Block size: 10 Block count: 1 Refresh

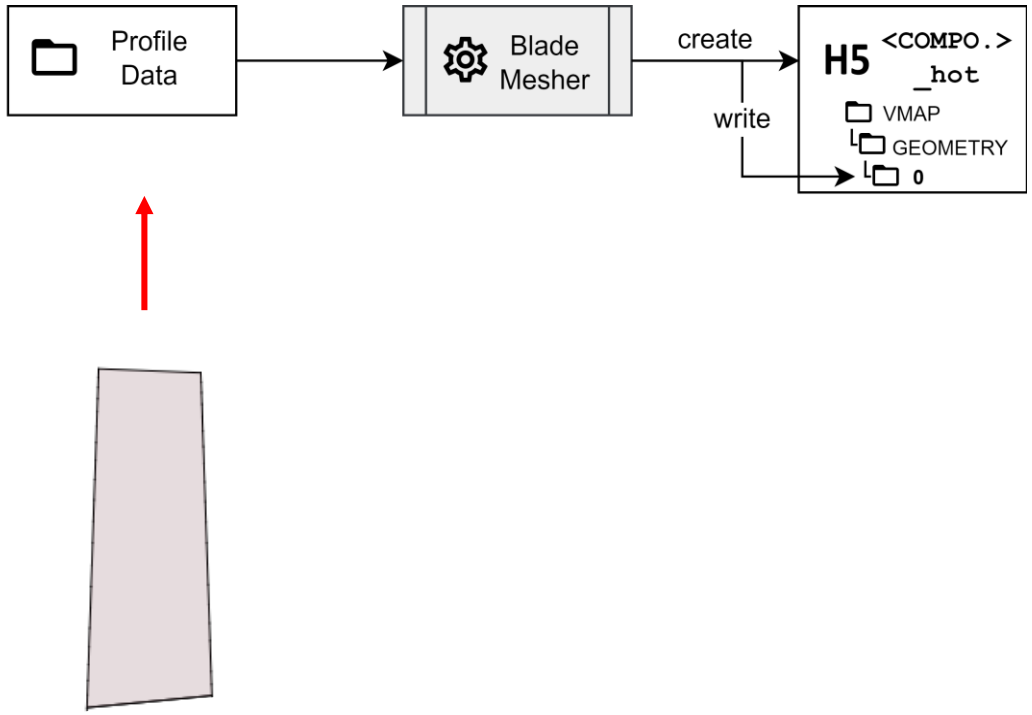
Integration of VMAP data
Accessing data visually

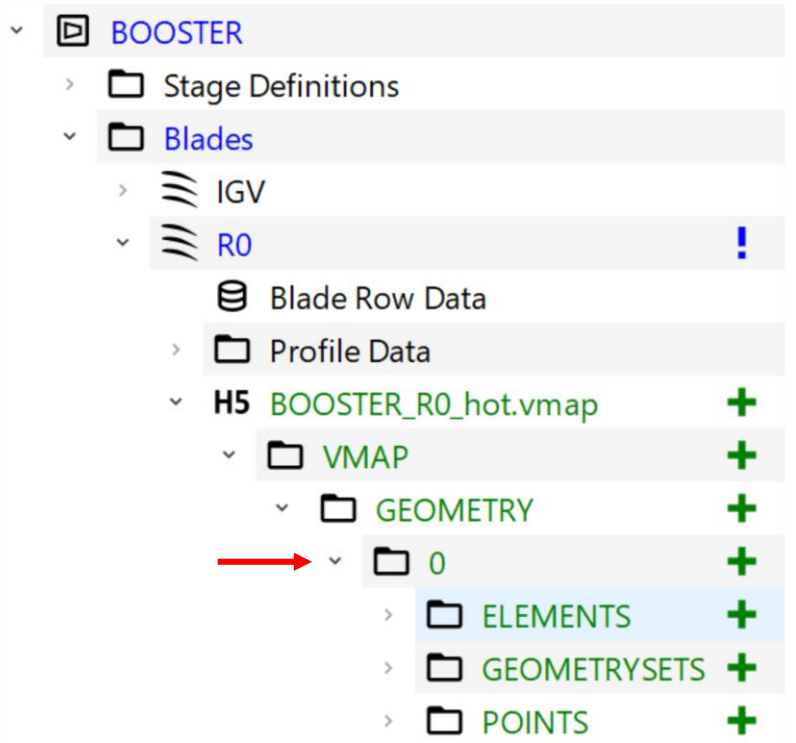
- Visual inspection: prototype

- Customized implementation based on VTK

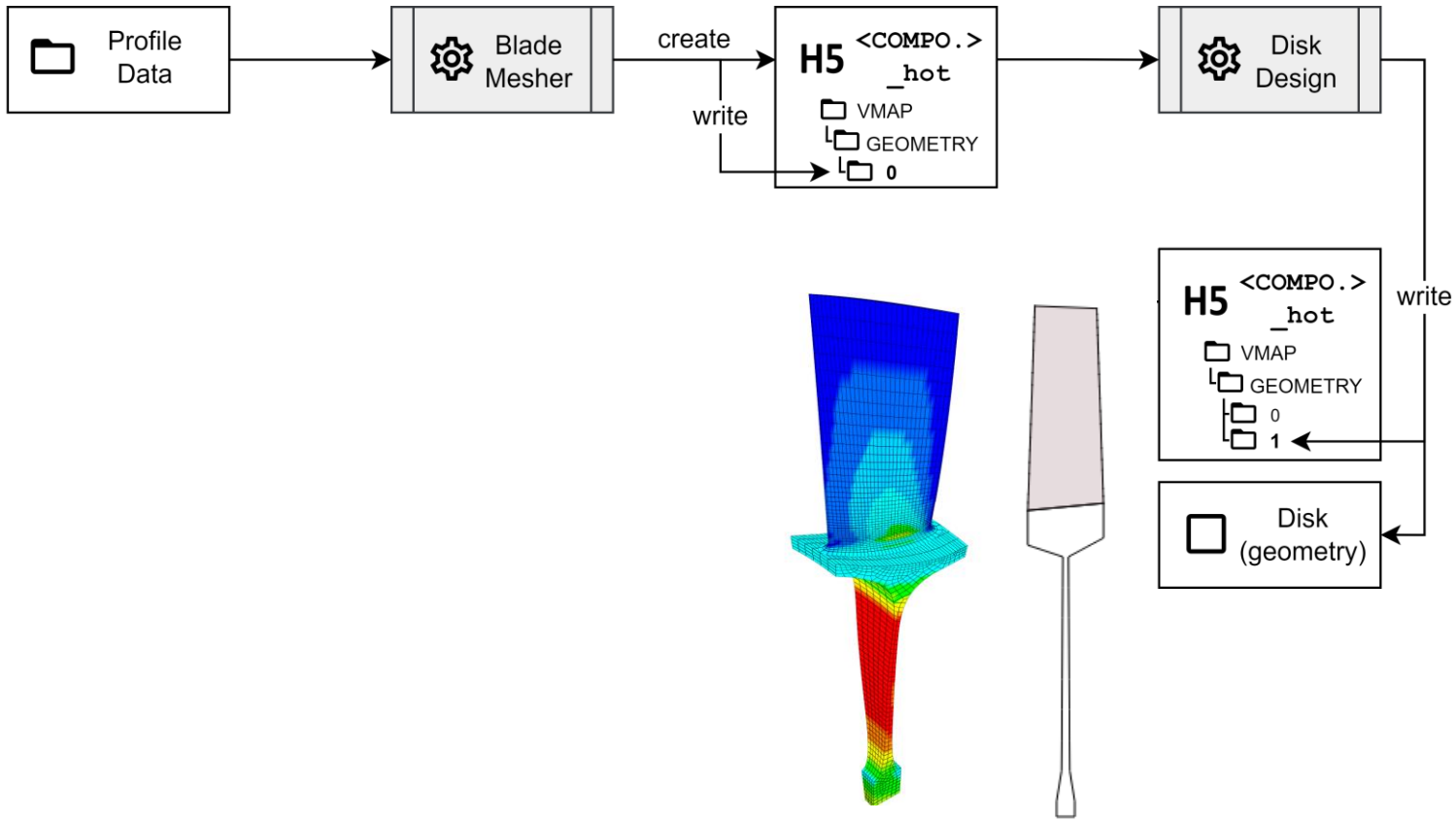


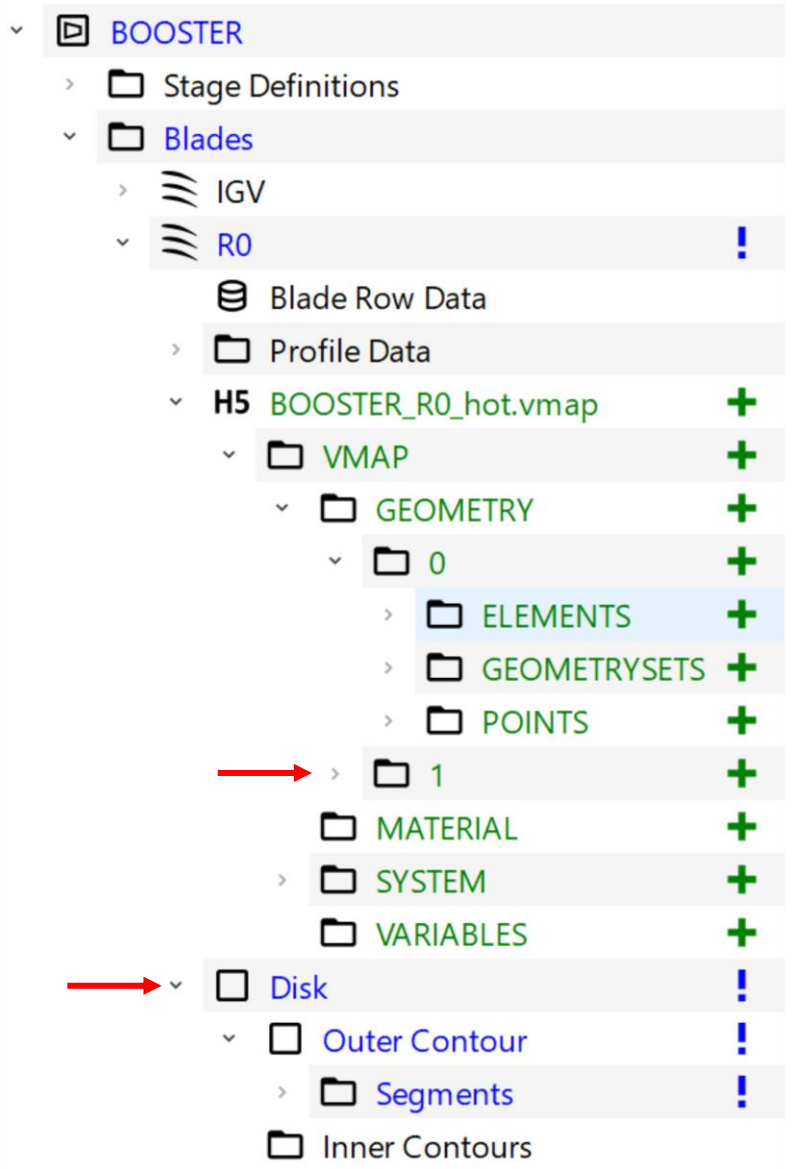
Exemplary Workflow 1
Blade mesh



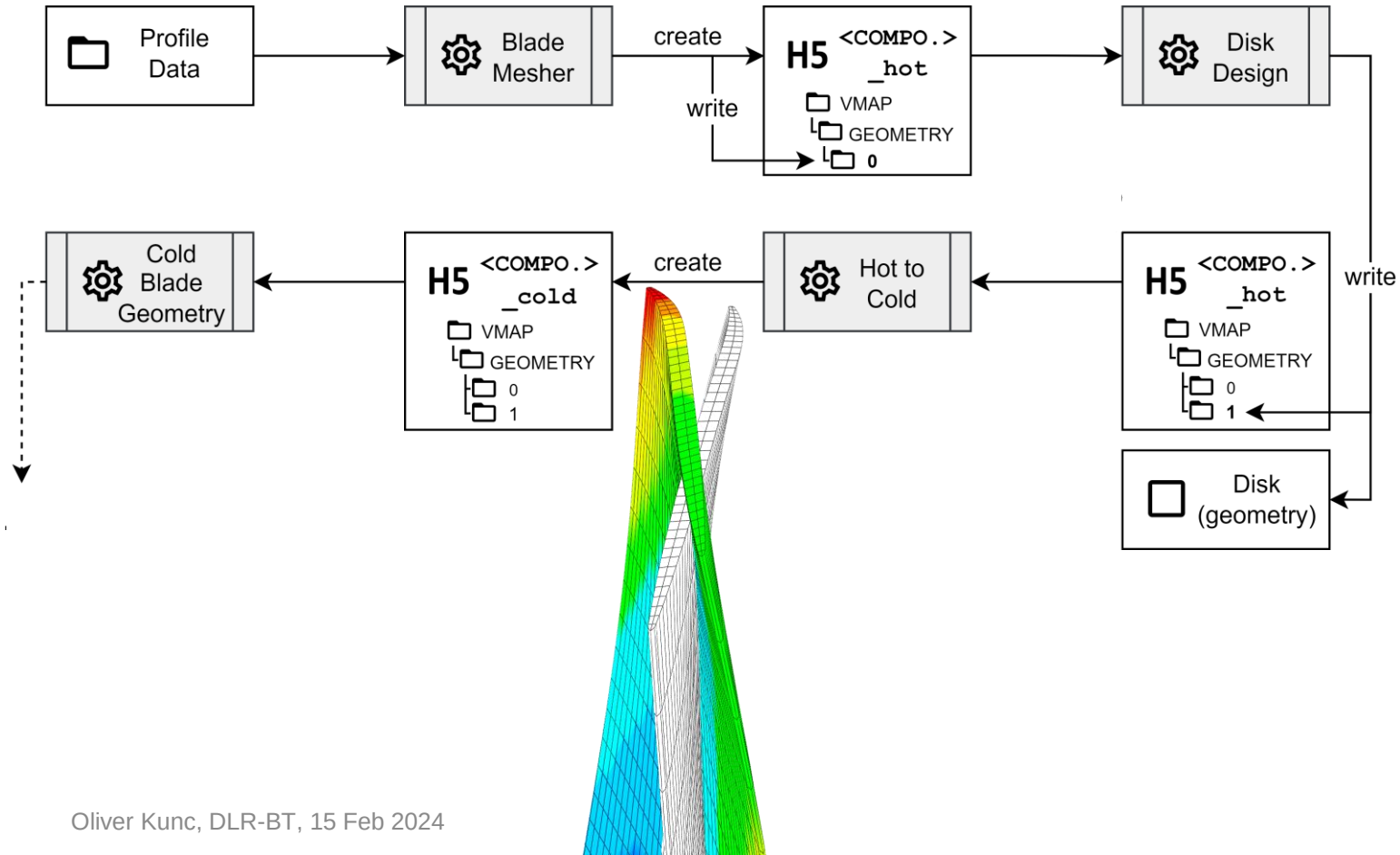


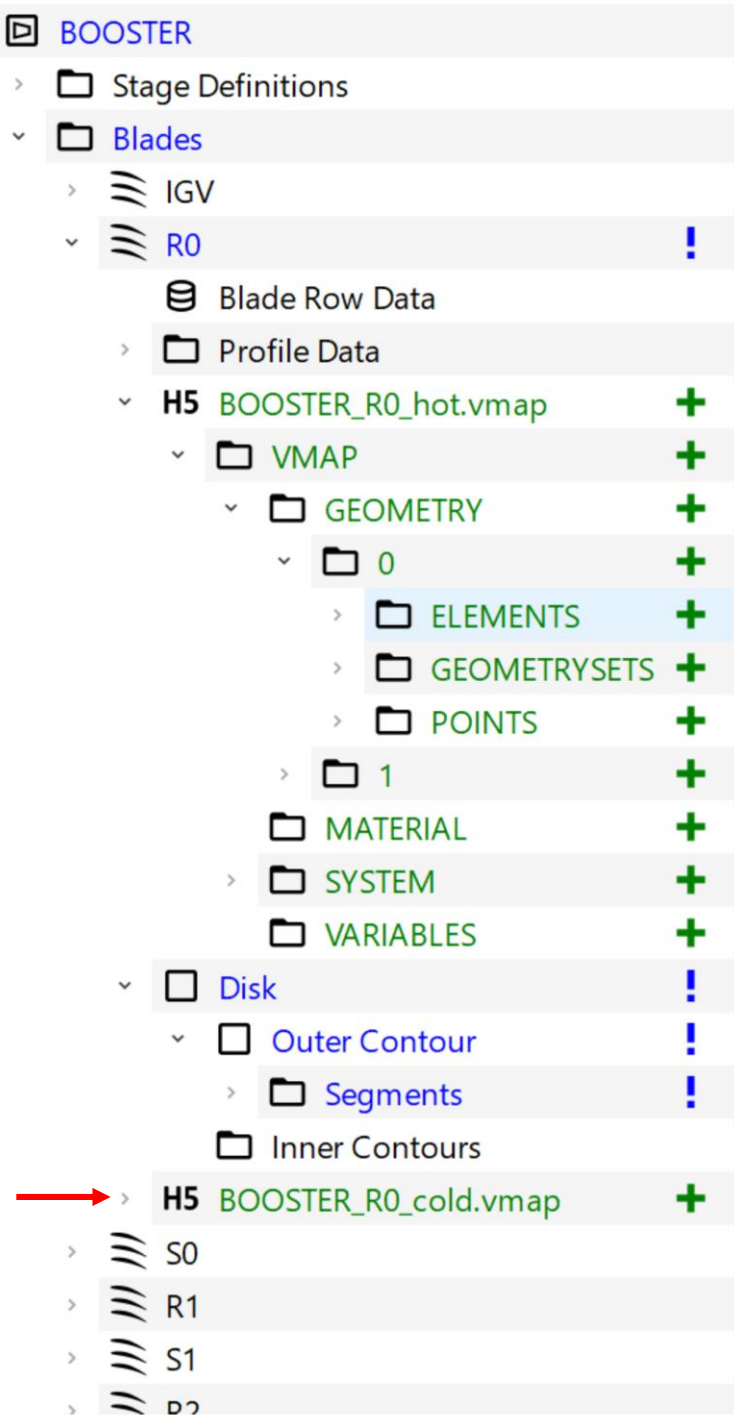
Exemplary Workflow 1
Blade mesh, disk design



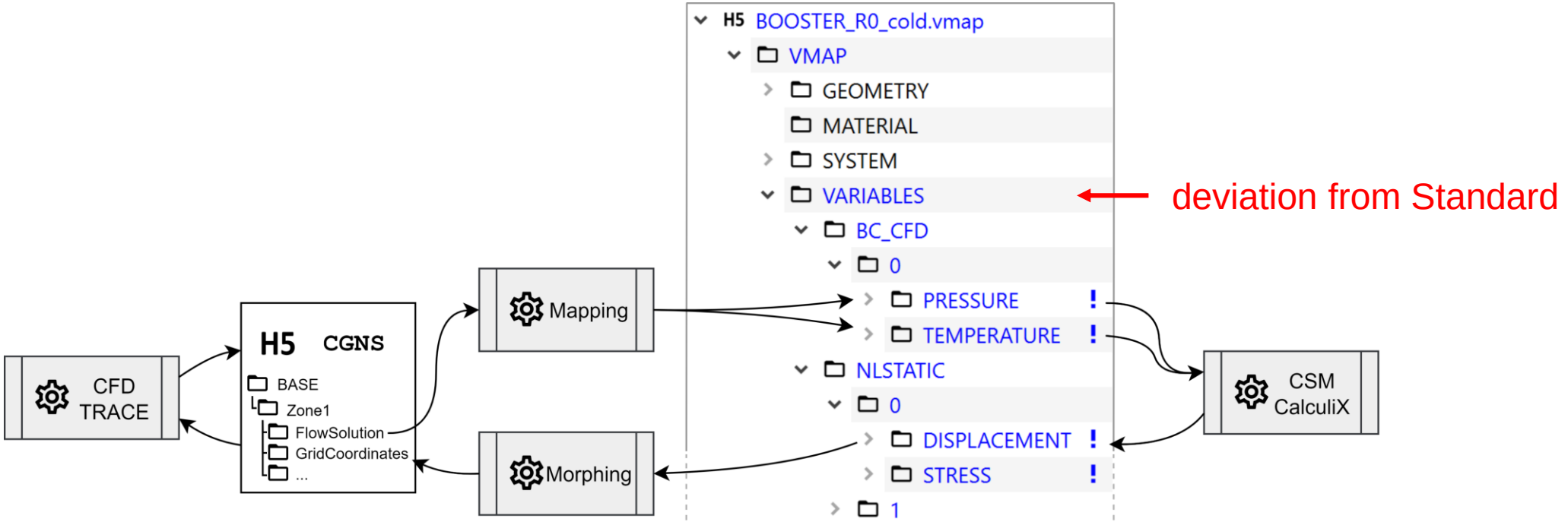


Exemplary Workflow 1
Blade mesh, disk design, hot-to-cold

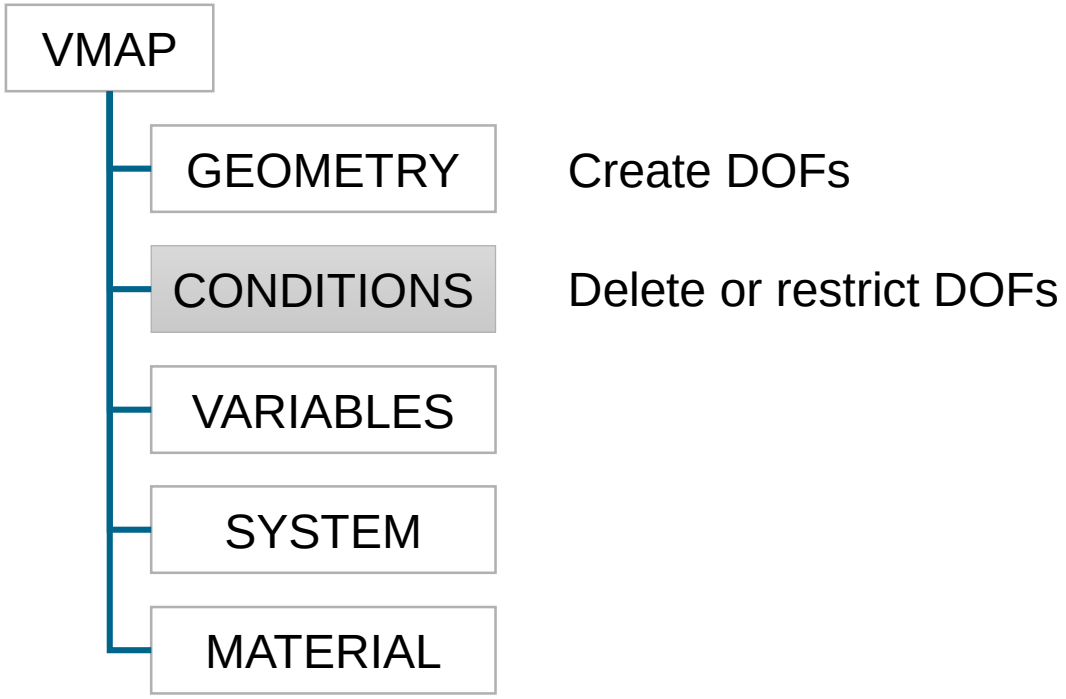




Exemplary Workflow 2
Static FSI



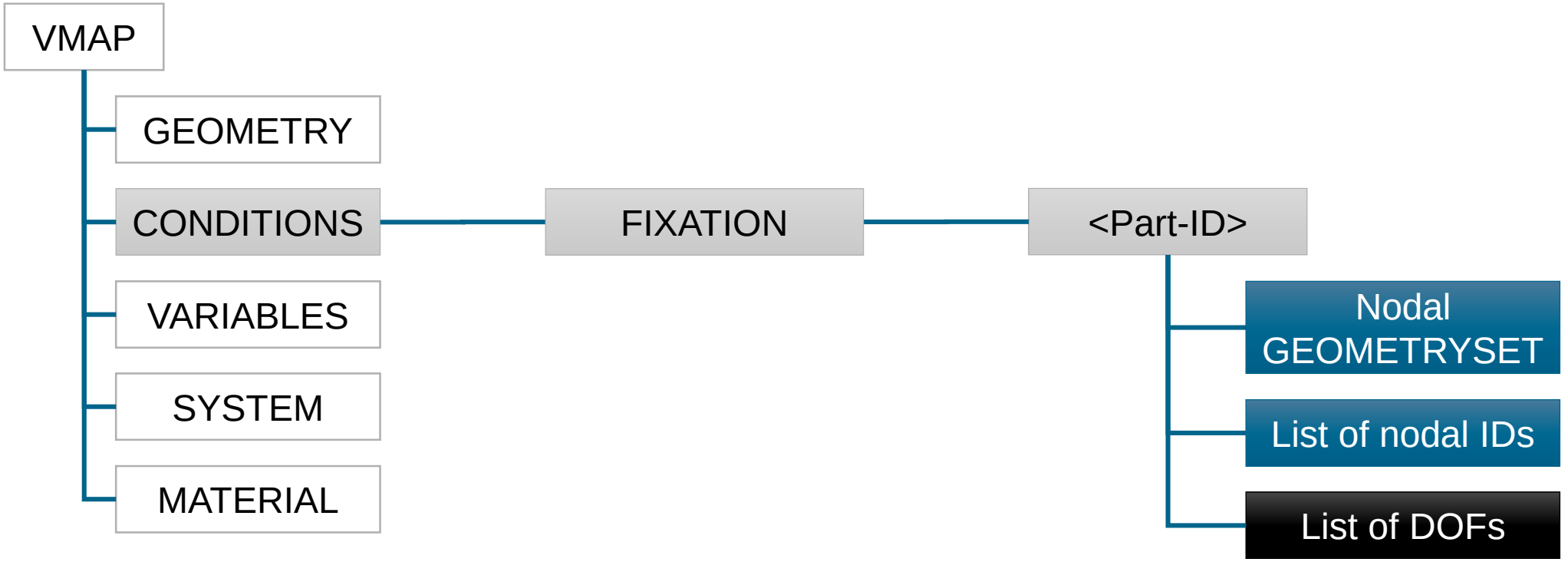
Suggested Extension to VMAP: CONDITIONS
Principle



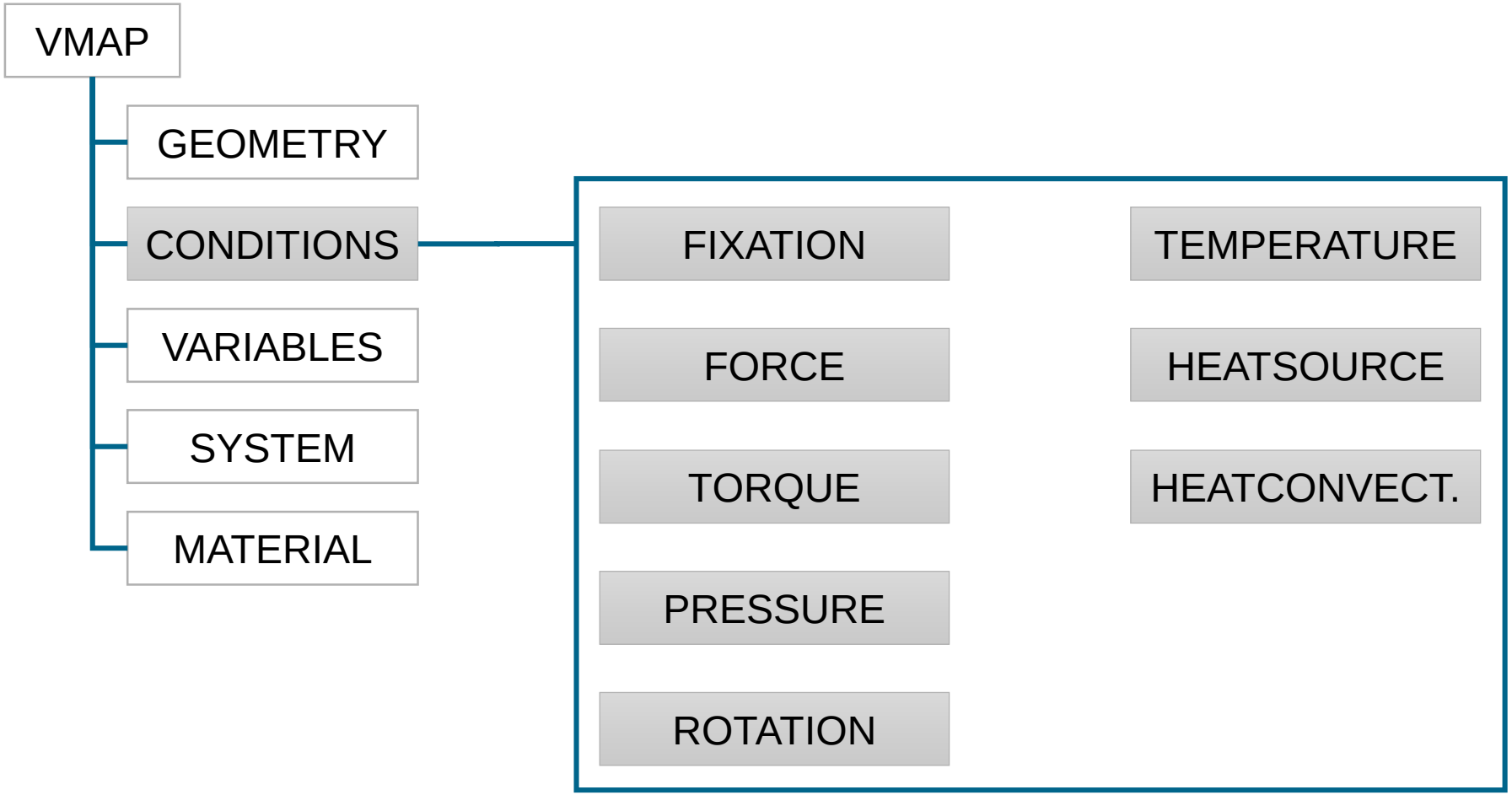
Create DOFs

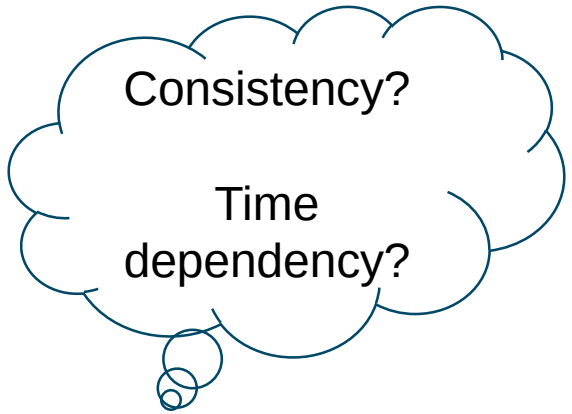
Delete or restrict DOFs

Suggested Extension to VMAP: CONDITIONS
Detailed Example



Suggested Extension to VMAP: CONDITIONS List





Suggested Extension to VMAP: CONDITIONS
Goal

- Complete storage of model + results for **elementary** CSM problems, e.g.:

- Cantilever beam
- Truss system
- Plate with hole
- Brick heatflow: source, conduction, convection

- Static thermo-mechanics
- Transient thermo-mechanics
- Modal mechanics

Further challenges

- Intra-process challenges:
  - VMAP full model storage
  - VMAP converters to/from different formats
    (Permas-VMAP converter: `github.com/BT-DLR/PermasVmap`)
- Inter-process challenges:
  - VMAP & CGNS: standardized fluid structure interface?
- Data management:
  - Versioning of HDF5 data
  - Cloud, remote processing
  - ➢ Data Management System, future HDF5 features

References

- GTlab:
  - Architecture and Methodology: Reitenbach et al, *AIAA 2020-0867*
  - Data Provenance Models: Reitenbach et al, *J. Eng. Gas Turbines Power, 2020*
  - Open source release: coming soon

- Integration of VMAP/HDF5 in GTlab:
  - Part A, Implementation: Bröcker et al, *AIAA 2024-0482*
  - Part B, 8 detailed Use Cases: Kunc et al, *AIAA 2024-0383*

SCITECH FORUM

AIAA SCITECH 2024 Forum

8-12 January 2024

Orlando, FL

Take home messages:

1. **VMAP adds value to parametric modeling environments**
2. **VMAP needs full model storage – suggestions, requirements?**