11th Overset Grid Symposium,
October 17 2012, Dayton OH

RDECOM

Strategies for OVERFLOW Modularization and Integration into HELIOS

AMRDEC

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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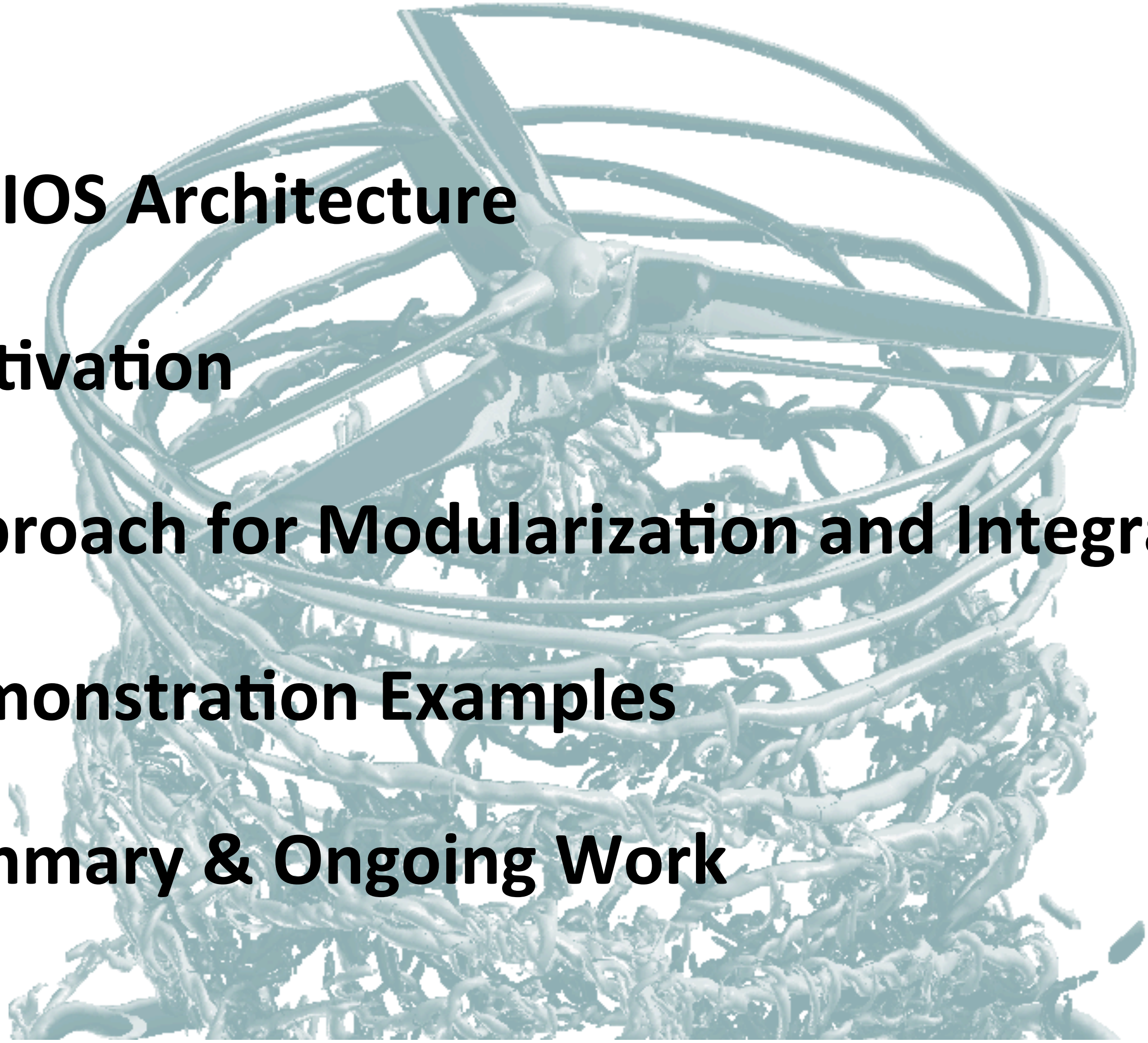
Outline

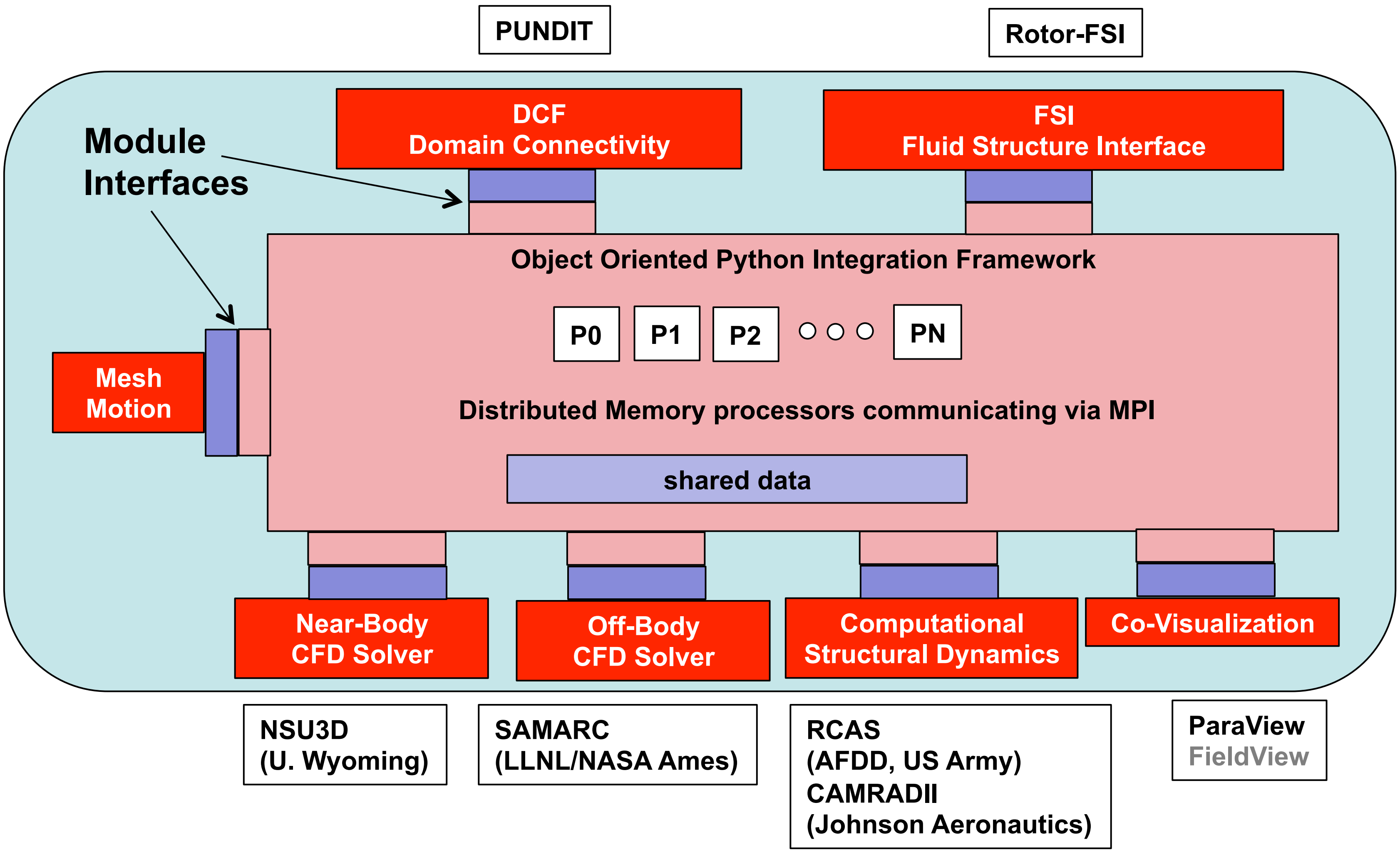
- HELIOS Architecture
- Motivation
- Approach for Modularization and Integration
- Demonstration Examples
- Summary & Ongoing Work



HELIOS

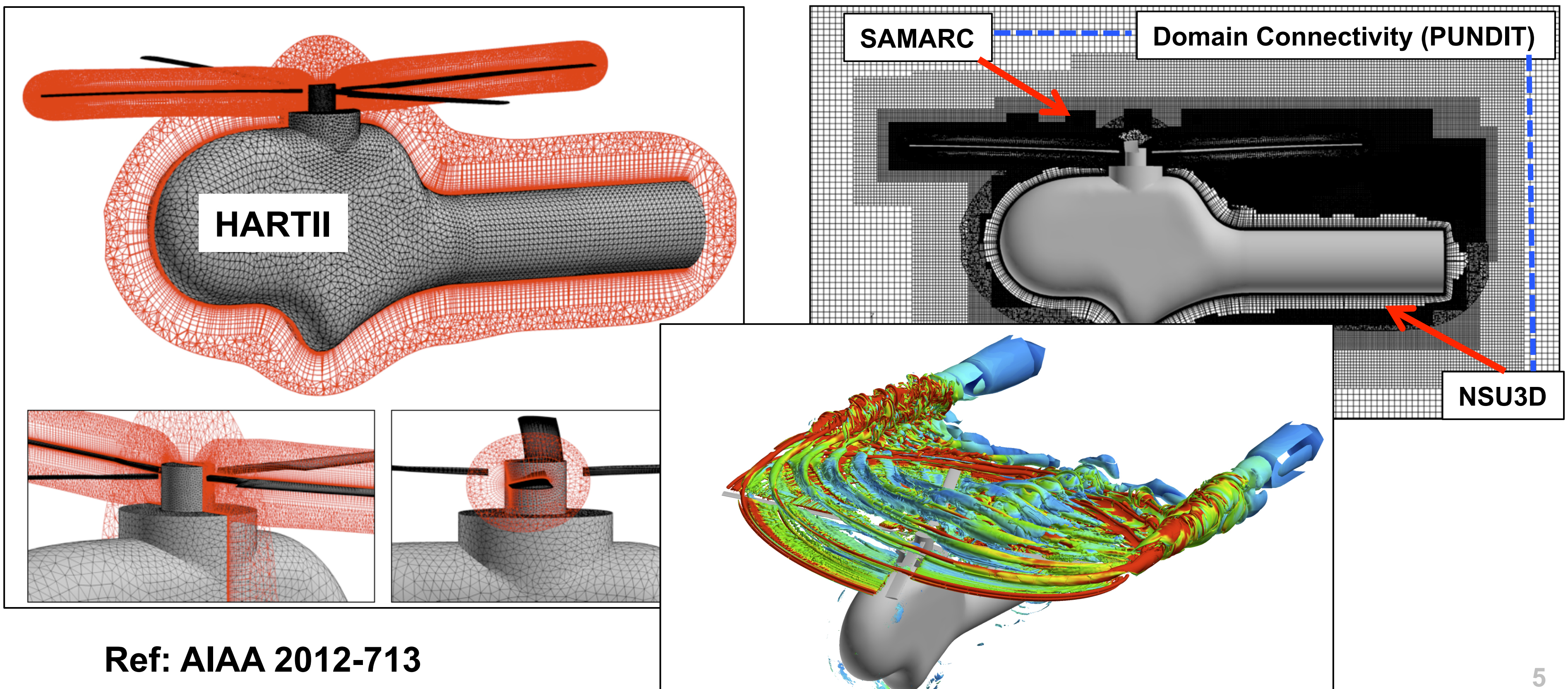
- **High-fidelity, automated software tool for rotorcraft aeromechanics modeling**
- **Sponsored by DoD HPCMO (CREATE-AV) and the US Army**
- **A framework – Flexibility, Extensibility, Modularity**
- **GOALS: Accuracy, Speed, Ease-of-use (automation)**

HELIOS Architecture



HELIOS Dual-mesh Approach

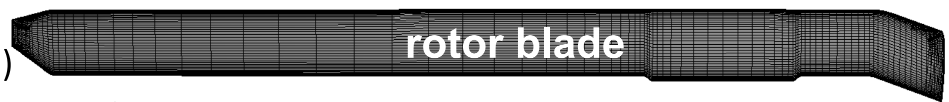
- ✓ **Unstructured** mesh solver for near-body regions
  - Fuselage, hub, blades
  - Direct CAD to CFD mesh generation
- ✓ **Cartesian** adaptive mesh solver for off-body regions



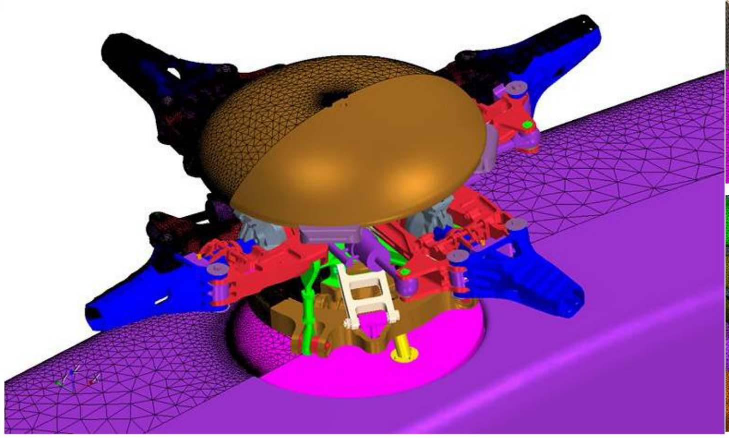
Ref: AIAA 2012-713

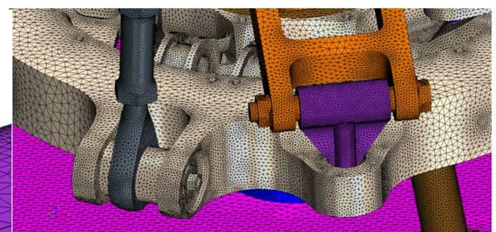
Why have the structured solver option?

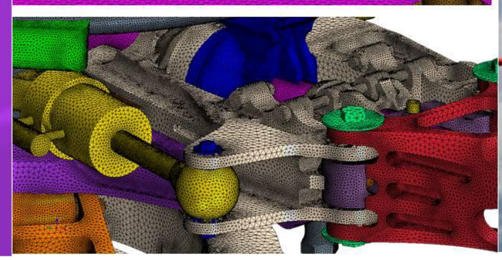
- A near-future solution to an efficient, high-order near-body solver
    - Long term solution – high-order, strand-based solver, DG-based unstructured solvers…
- Use structured solver in combination with unstructured solver
    - ➢ Structured solver for simple geometries/topologies
        - Fast, high-order accurate (5th order)
        - Efficient (storage, domain decomposition)
        - Acceleration methods (line relaxation, multi-grid)
        - Mesh generation easy for simple geometries



- ➢ Unstructured solver for complex geometries – hub, fuselage…



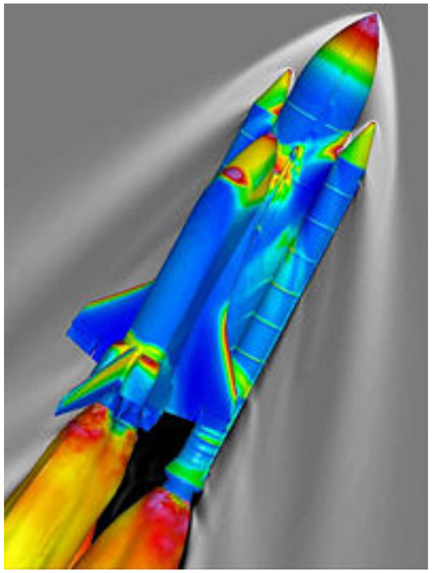




Dombroski et al, AHS Forum 2012

Why OVERFLOW?

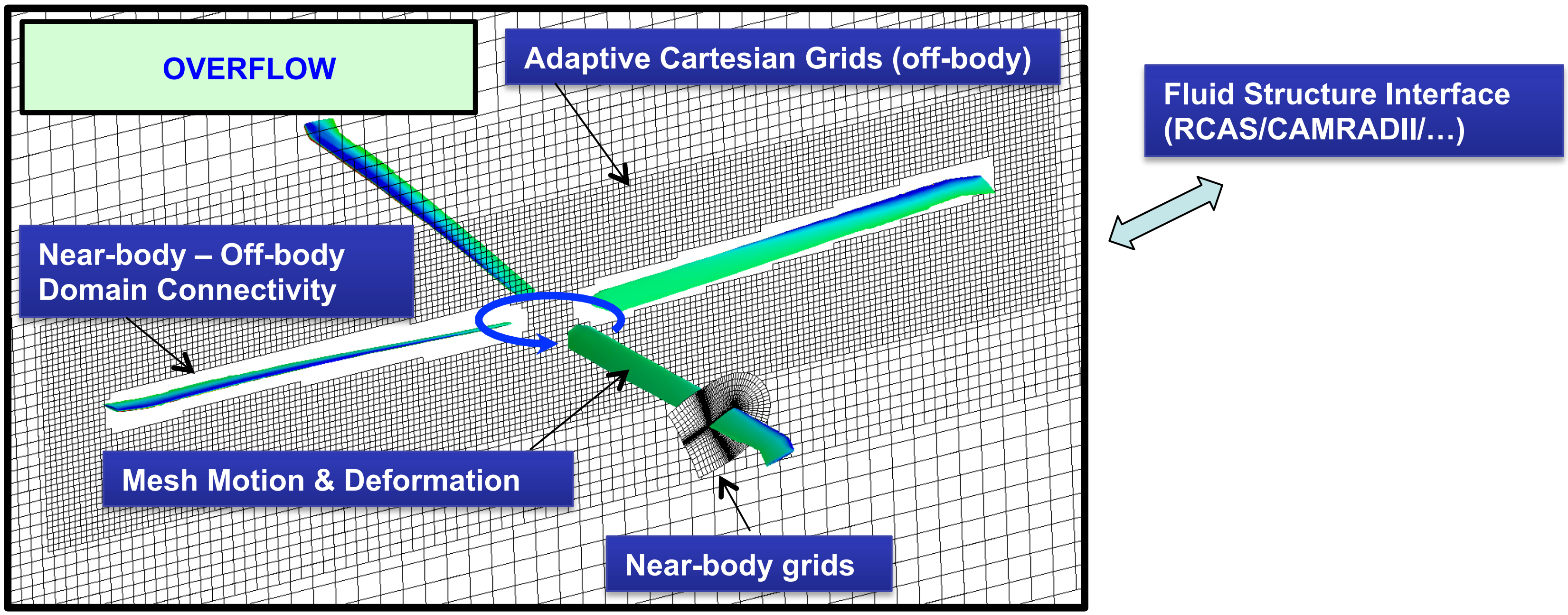
- Overset structured grid solver
- Validated for a wide variety of rotorcraft problems
  - Rotor, fuselage, hub, flaps, coaxial rotor system
  - Coupling with CSD (computational structural dynamics)
  - Steady and maneuver flights
  - Dynamic stall
- Key desirable features
  - High-order schemes
  - Near-body grid adaptation
  - Turbulence and transition modeling



- Industry users are vested
  - Effort spent in mesh generation, validation, developing know-hows…
- Continuously being developed and supported

Modularized OVERFLOW

- Is a full-featured software…



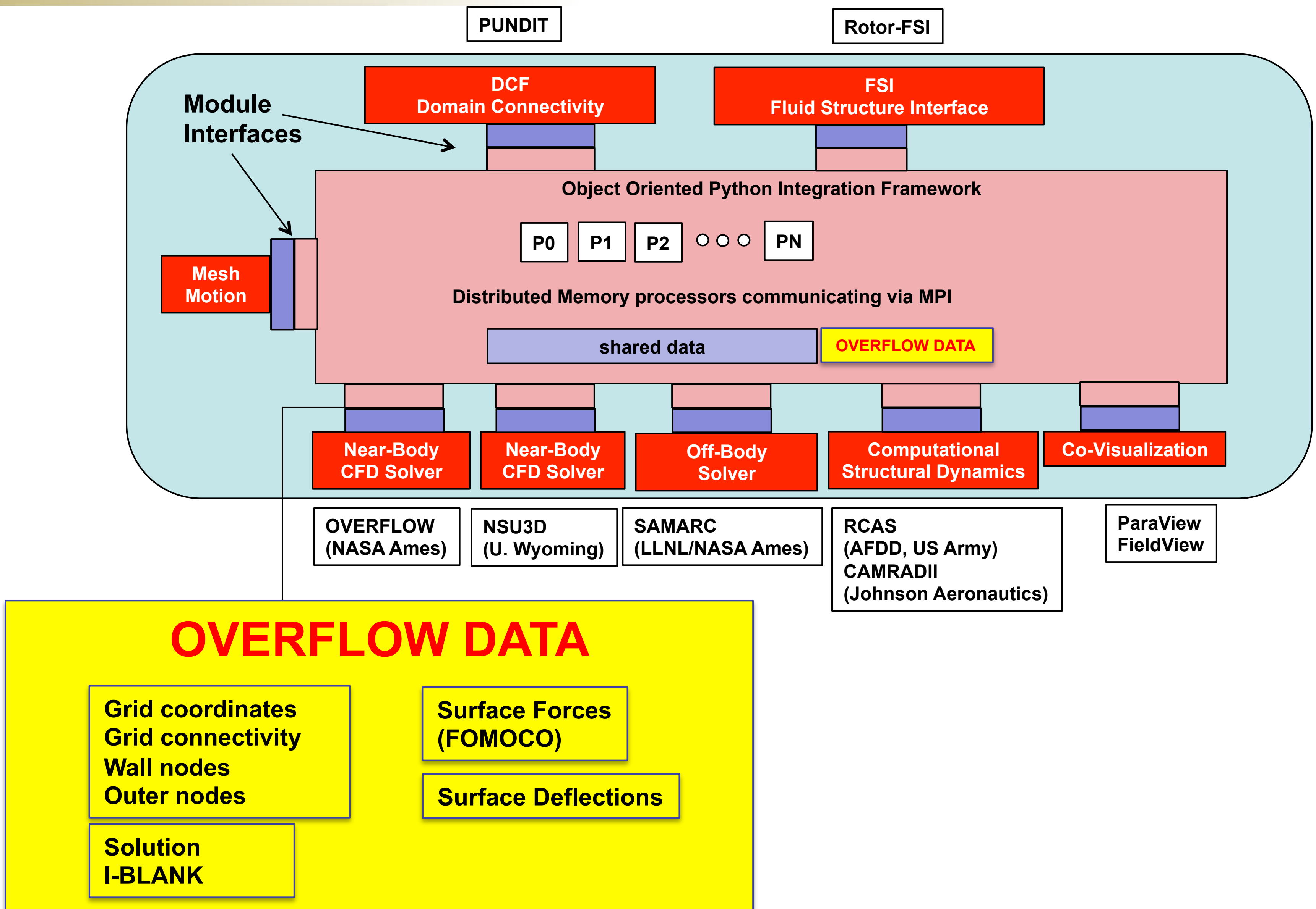
What is retained in the modularized version?

- ✓ **Mesh Motion (GMP/XML) & Mesh Deformation**
- ✓ **Near-body Connectivity (viscous stencil repair)**
- ✓ **FOMOCO**
- ✓ **Parallel grid partitioning**

What is not?

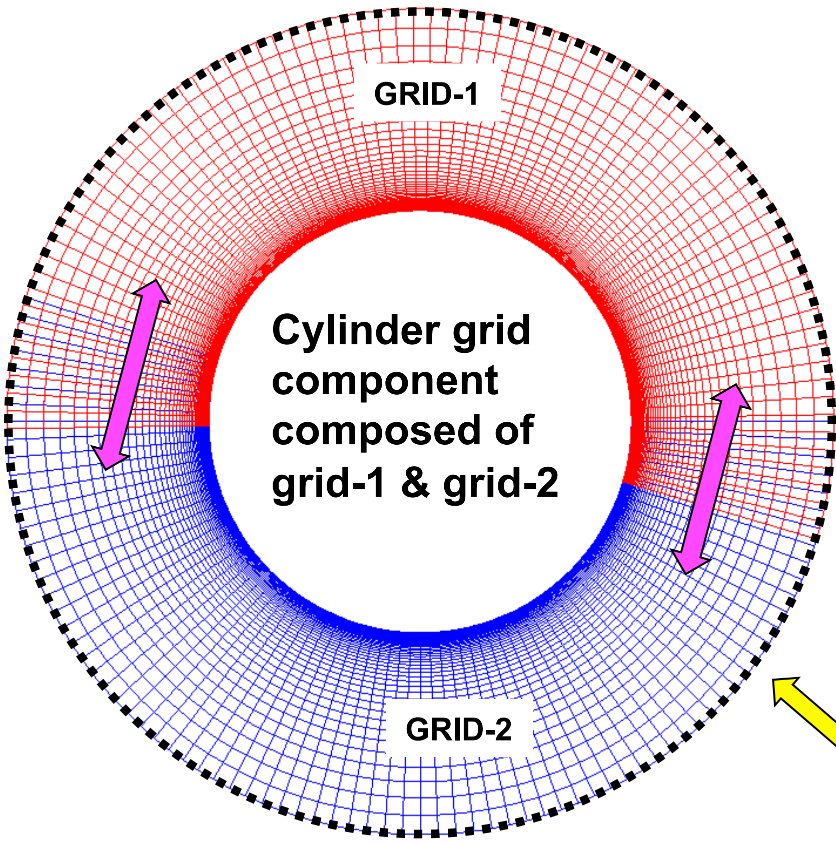
- ✗ Off-body region
- ✗ FSI
- ✗ File-based CFD/ CSD Coupling

Data Interface/Exchange



Near-body Connectivity Strategy

- Group grids into **Components/Bodies** (blade, hub, fuselage…)
  - Use **grid names** in over.namelist



OVERFLOW COMMUNICATION

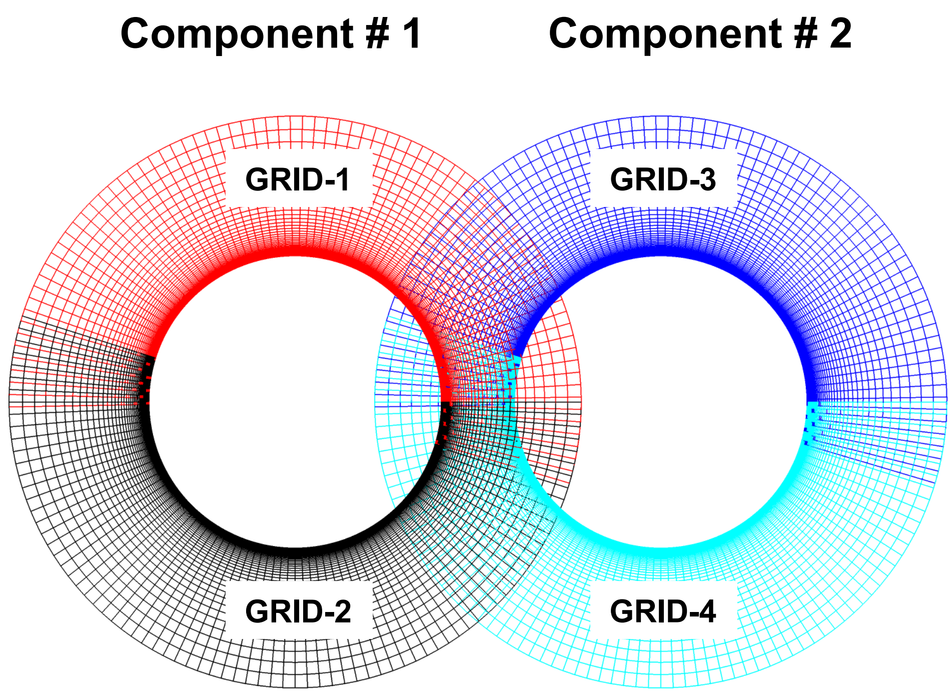
- Intra-component grid connectivity & communication (viscous stencil repair)

HELIOS COMMUNICATION

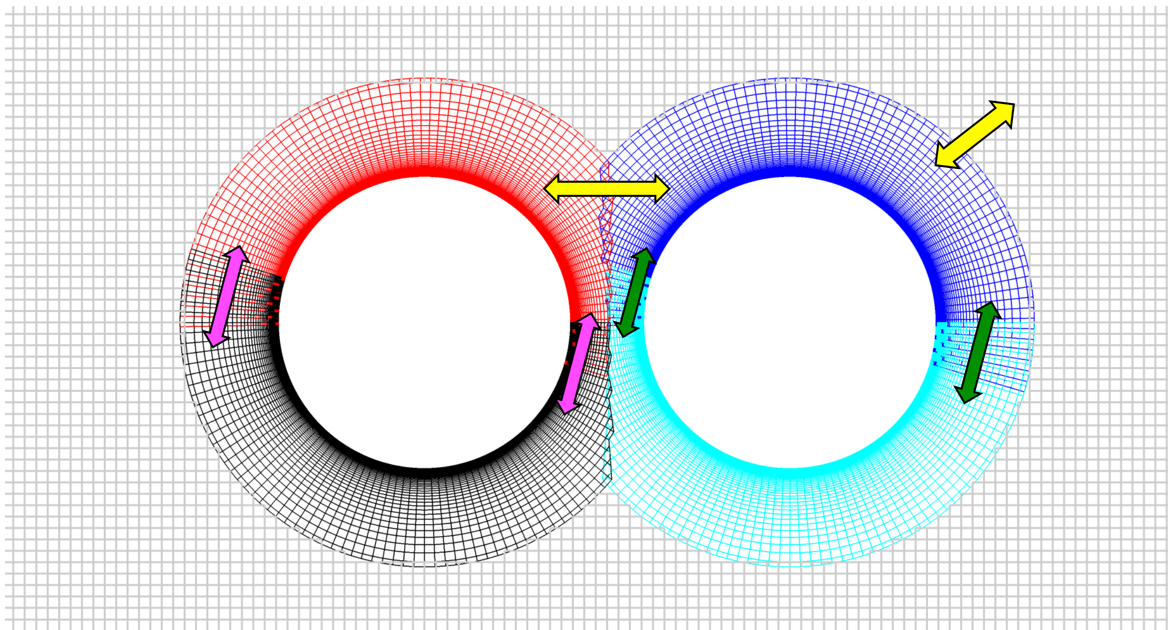
- Inter-component grid connectivity & communication
- Components (near-body) to off-body communcation

Other components or off-body grids

Near-body Connectivity Strategy



Near-body Connectivity Strategy



OVERFLOW COMMUNICATION

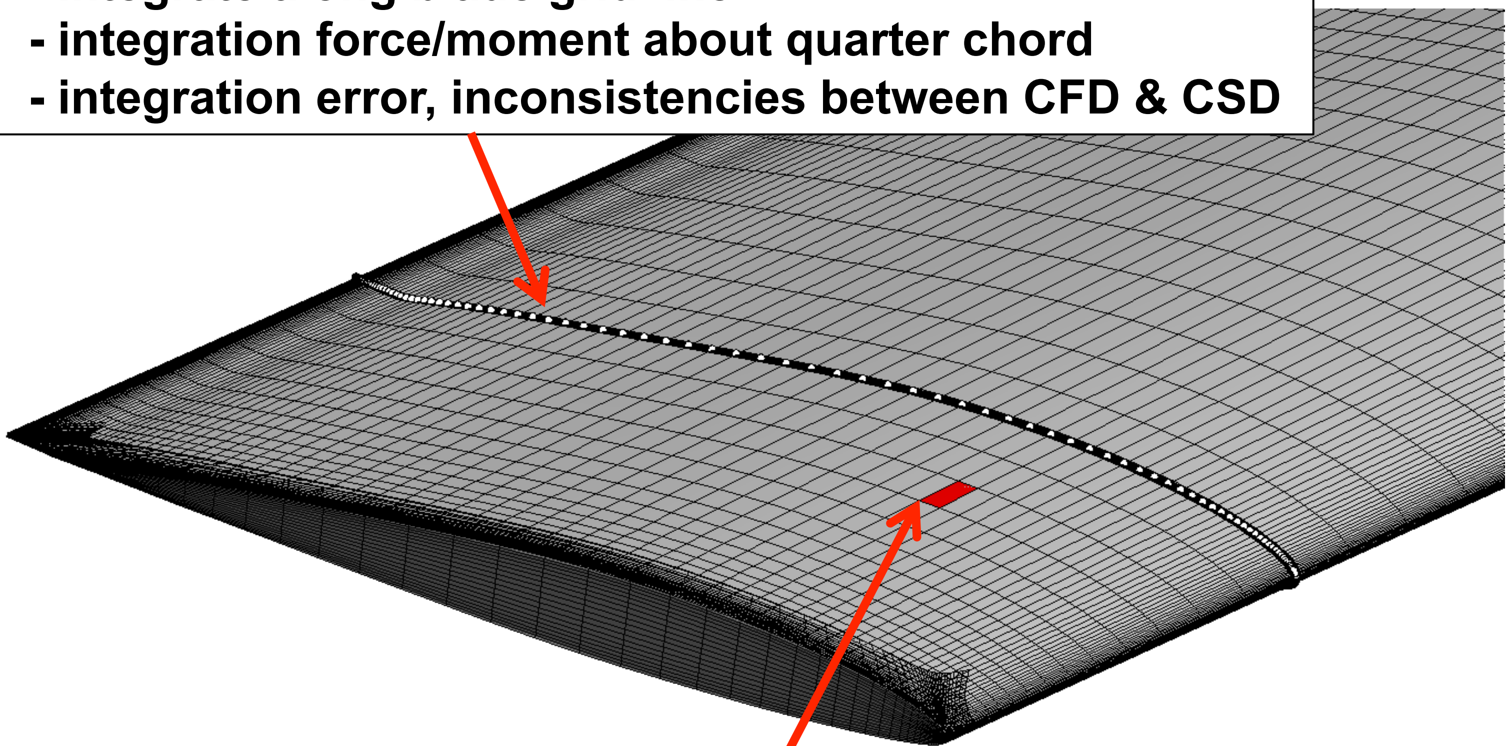
- Intra-component grid connectivity & communication

HELIOS COMMUNICATION

- Inter-component grid connectivity & communication
- Components (near-body) to off-body communication

Fluid Structure Interface

Traditional approach:
- integrate along blade grid line
- integration force/moment about quarter chord
- integration error, inconsistencies between CFD & CSD

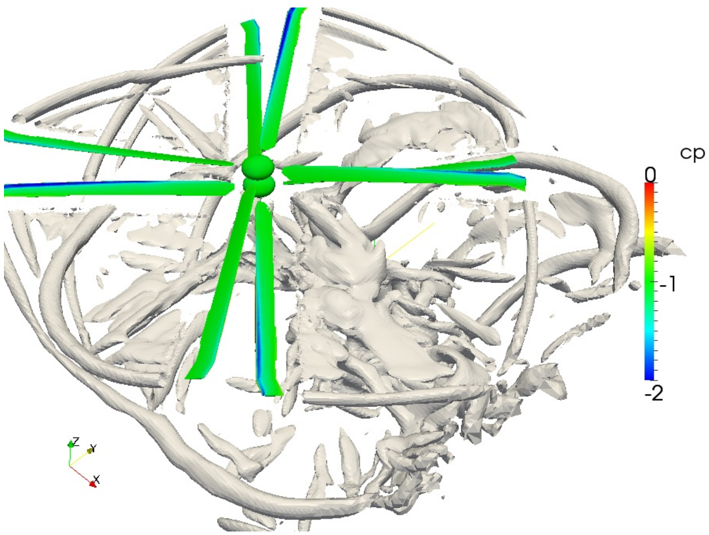


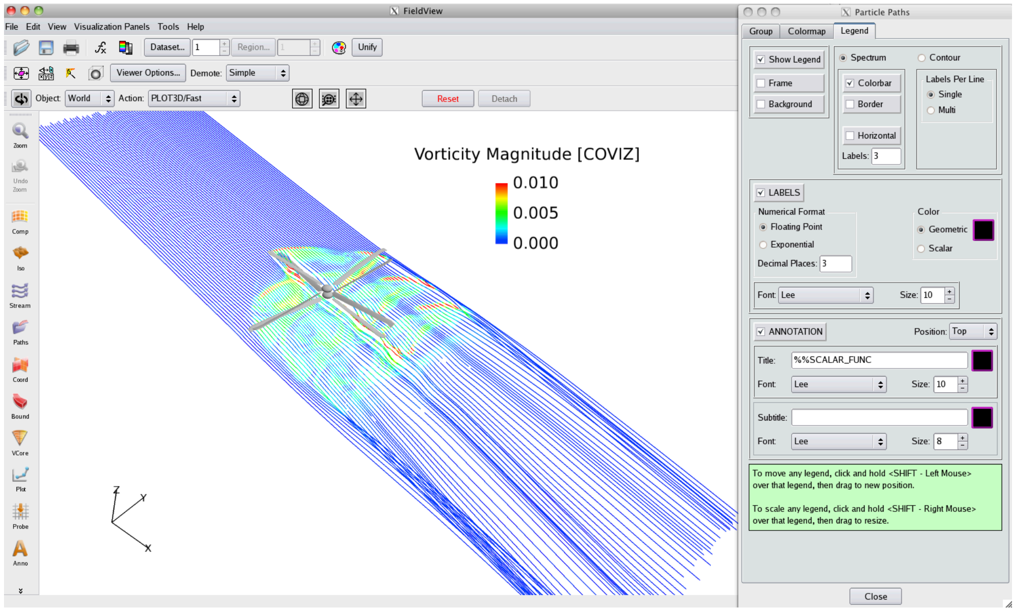
New approach inherited from the **HELIOS FSI** module:
- integrate **face-by-face** on stitched FOMOCO surface
- convert to 1-D beam forcing based on principle of virtual work
- accurate, conservative
- applicable to large surface deformation and flapped rotor cases

Co-Visualization

- On-the-fly, parallel co-visualization
- Typically handy for large dataset simulation on remote clusters

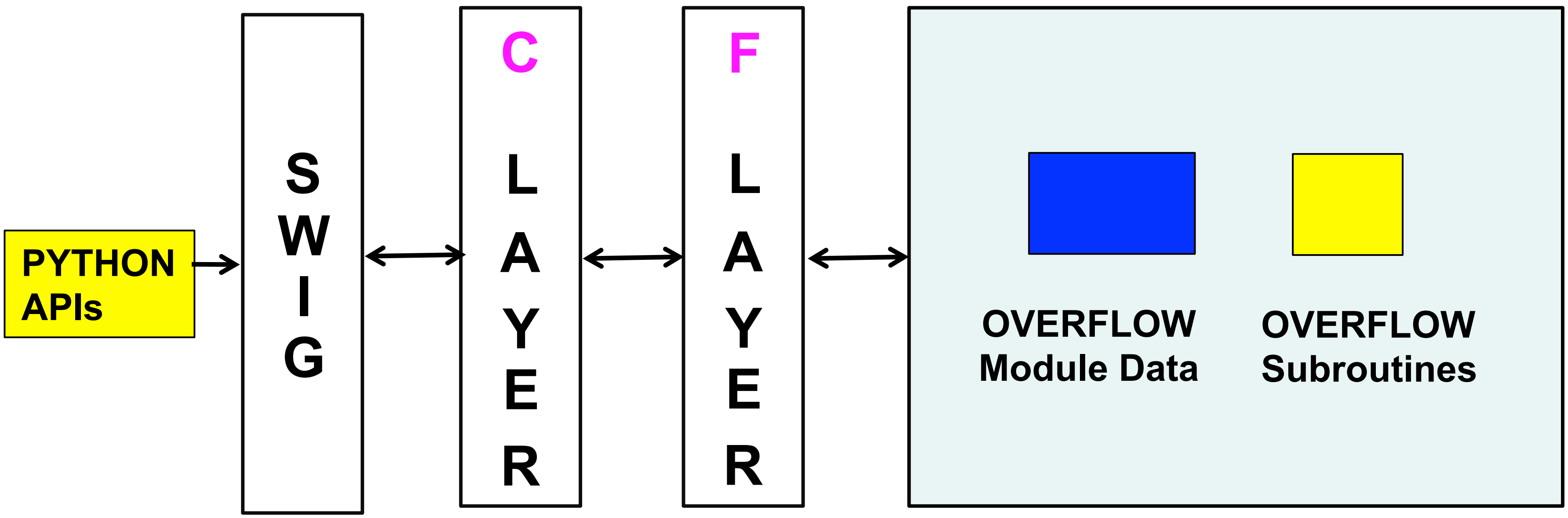
- Slices, iso-surface, streamlines, point/line/surf probes
- User defined types





PYTHON WRAPPNG

- Need access to FORTRAN-90 derived data types in OVERFLOW



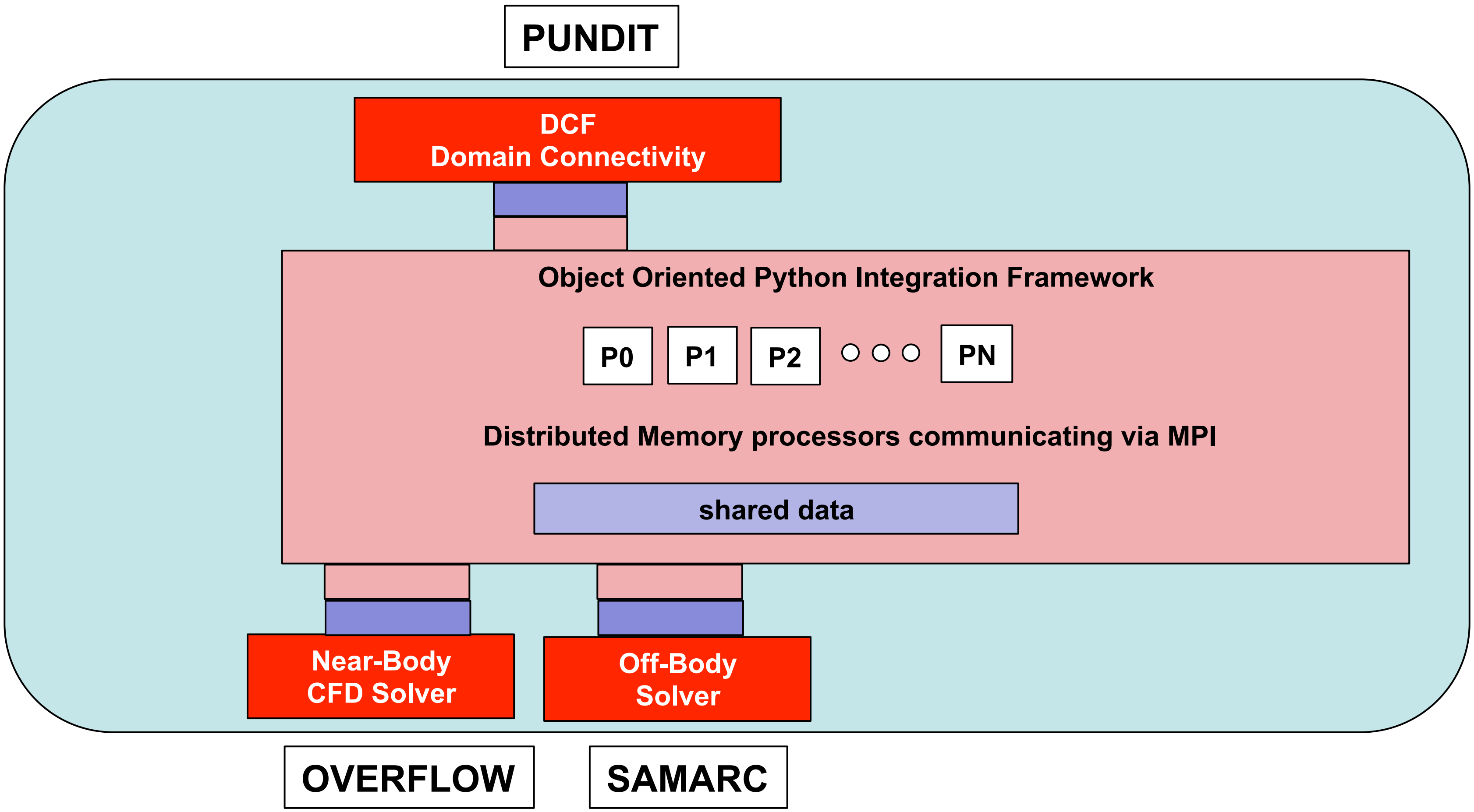
Code Management

- **OVERFLOW**
  - **A single, common source code repository**
    - *make* – compiles standalone executable
    - *make library* – compiles the python version
    - preprocessor directives (#ifdef PYTHON)
    - all python-related code contained in a separate python subdirectory
- **HELIOS**
  - **Common python interface for NSU3D and OVERFLOW**

Examples

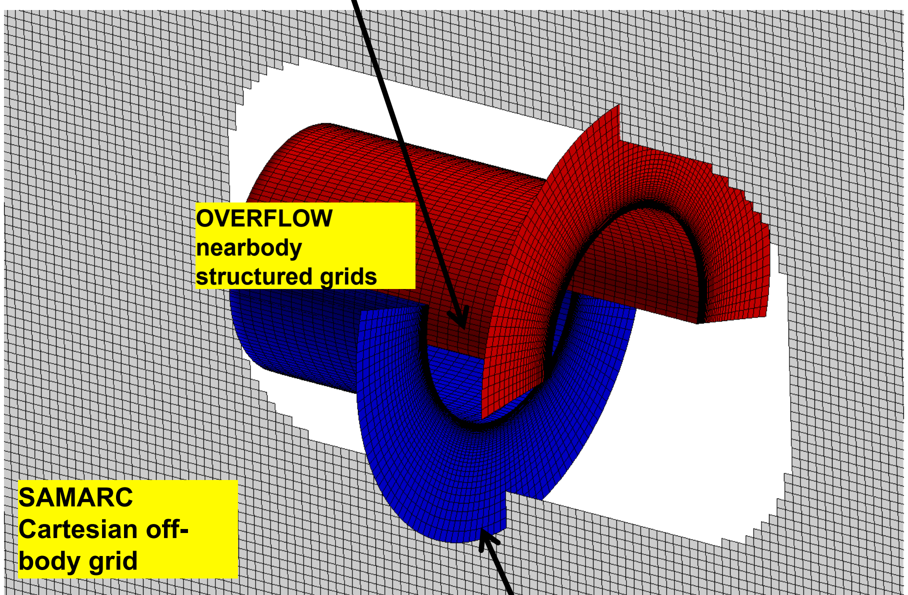
- Flow over a cylinder
- Isolated rotor
- Multiple rotor
- Rotor-hub-fuselage
- Multiple rotor + fuselage

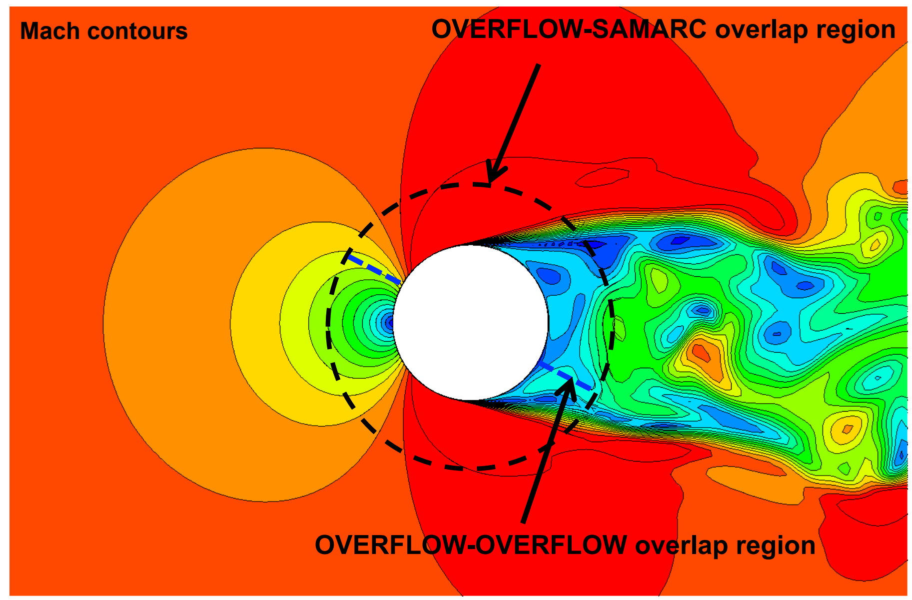
Flow Over a Cylinder



Flow Over a Cylinder

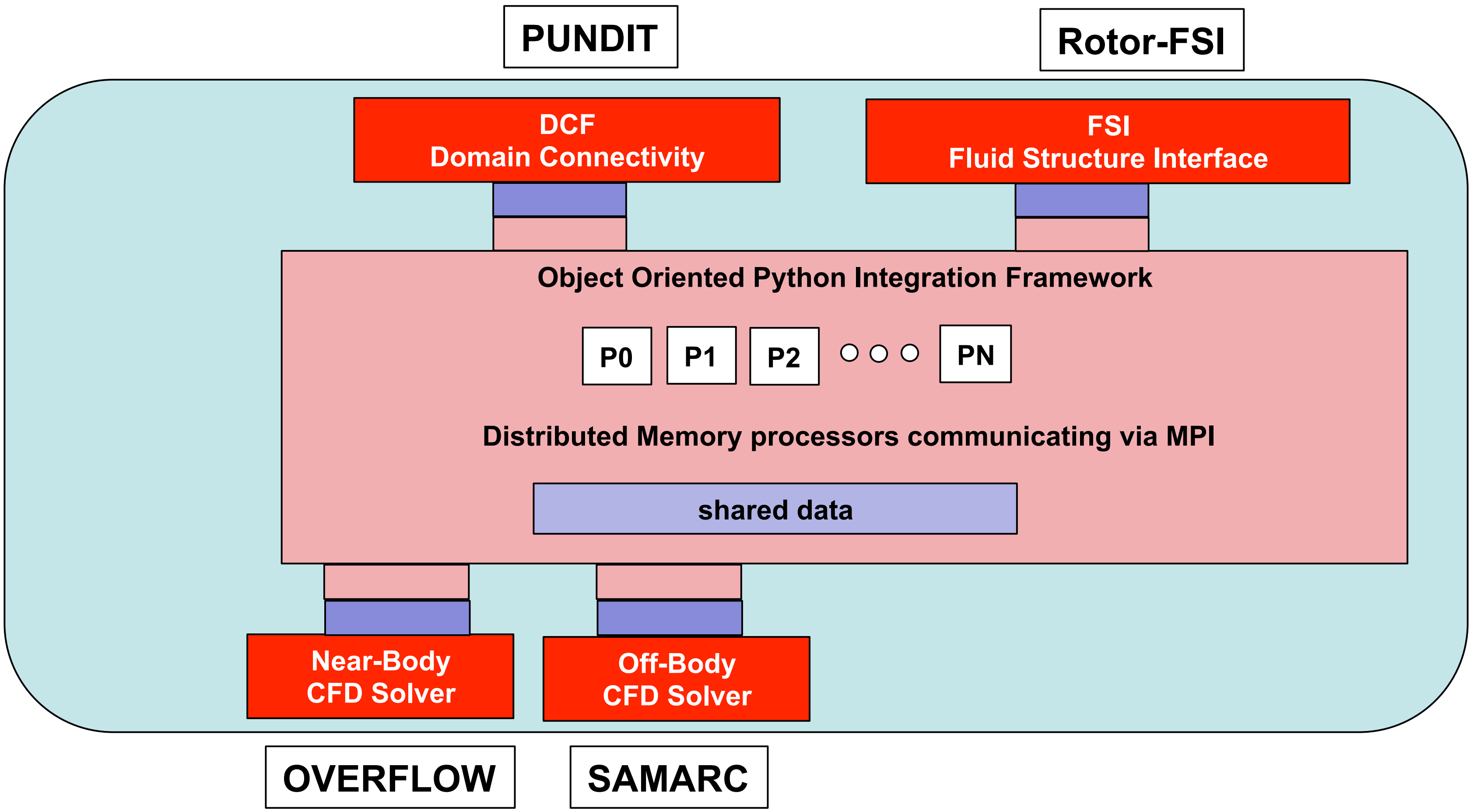
WALL-WALL/Nearbody-Nearbody overlap region overset communication and parallel partioning handled by OVERFLOW





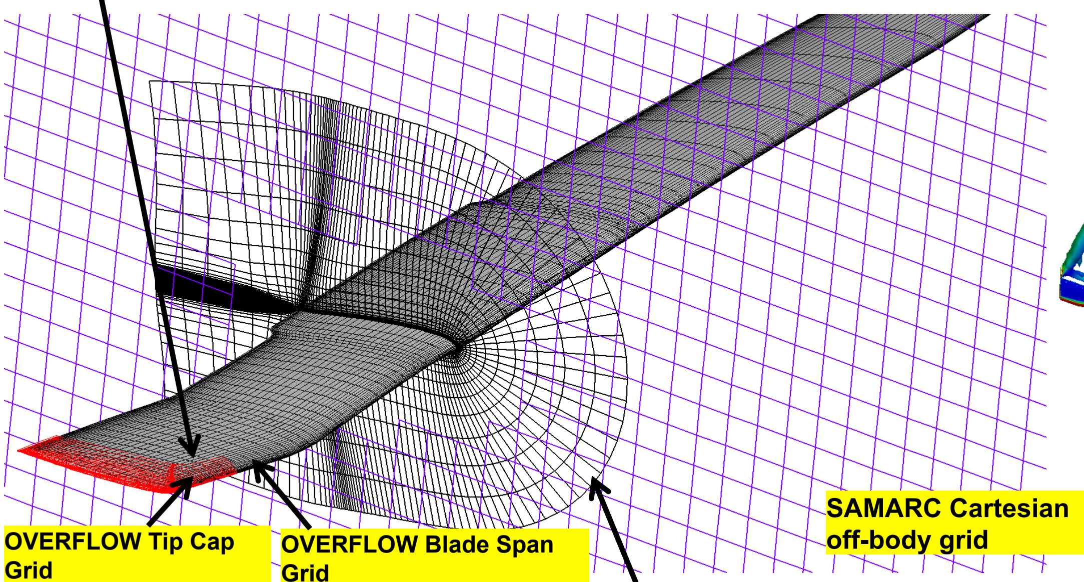
Outer boundary overset communication handled by PUNDIT

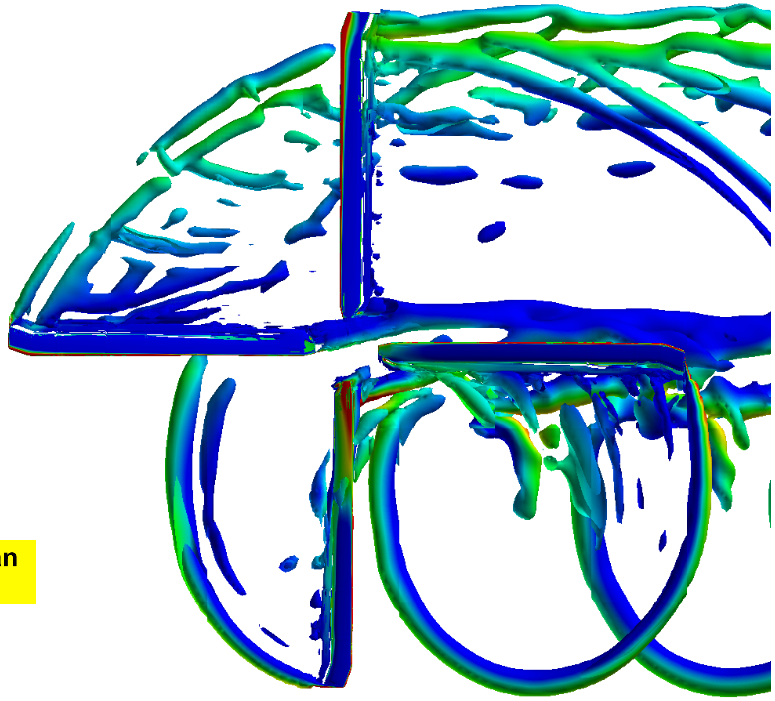
Rotor with Prescribed Blade Deformations



Rotor with Prescribed Blade Deformations

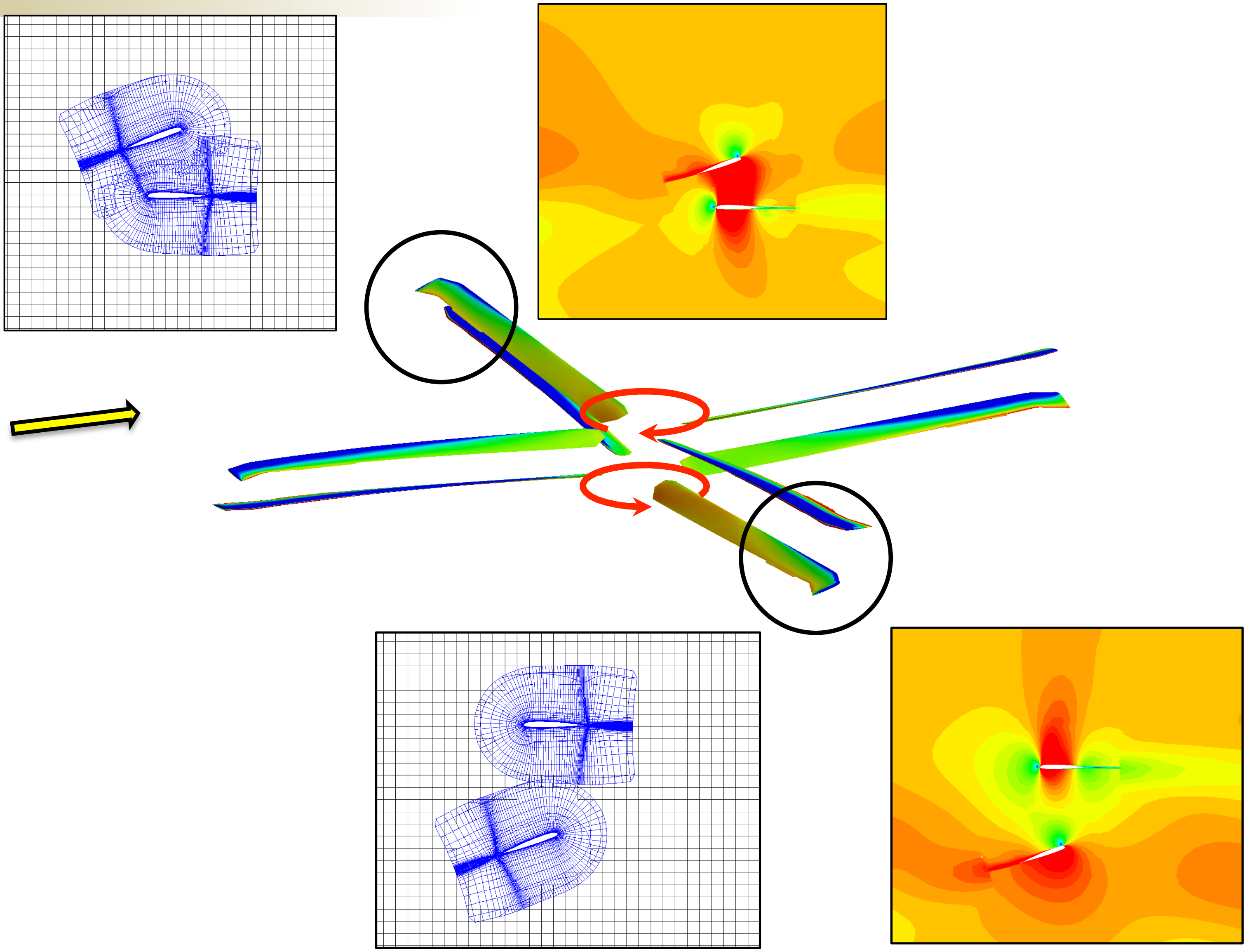
Wall-wall overlap region overset communication b/w tip cap and blade grid handled by OVERFLOW





Outer boundary overset communication b/w near-body OVERFLOW grid and off-body SAMARC grid handled by PUNDIT

Coax Rotor



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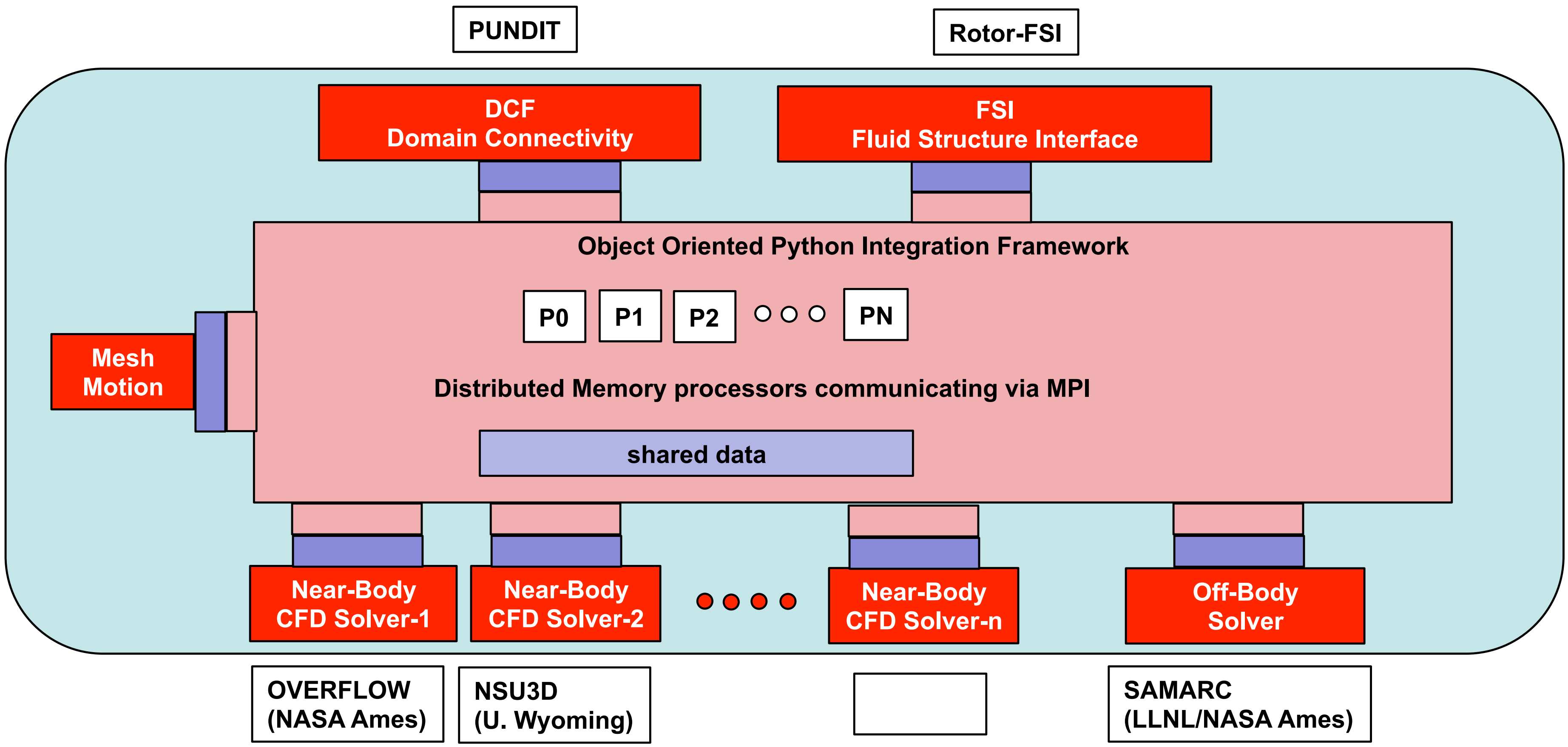
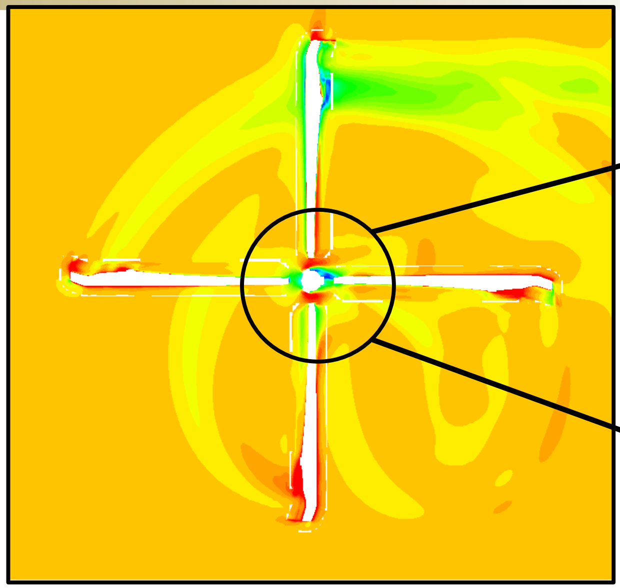
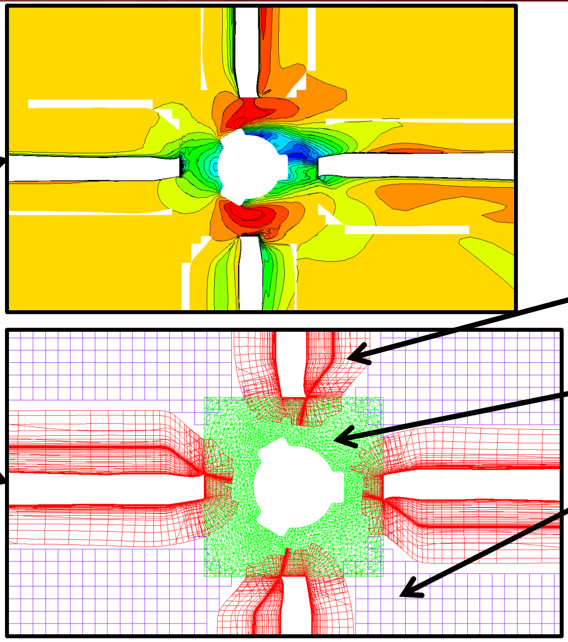
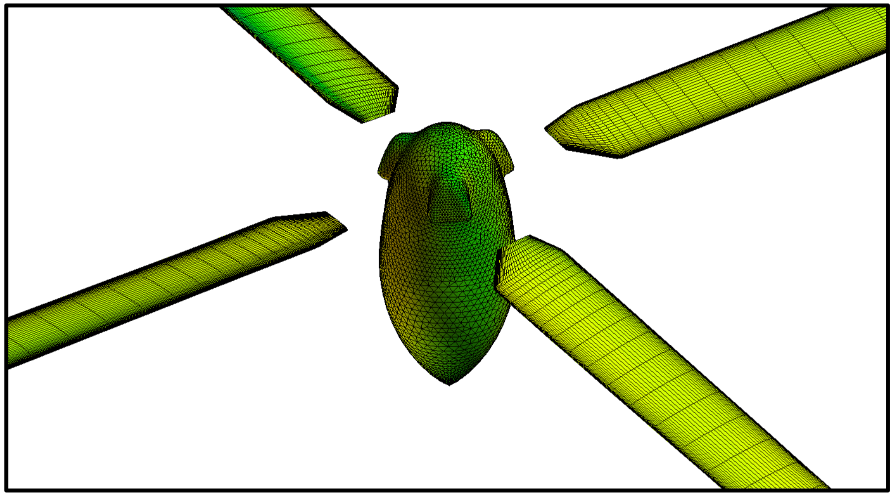
Two Near-body Solvers

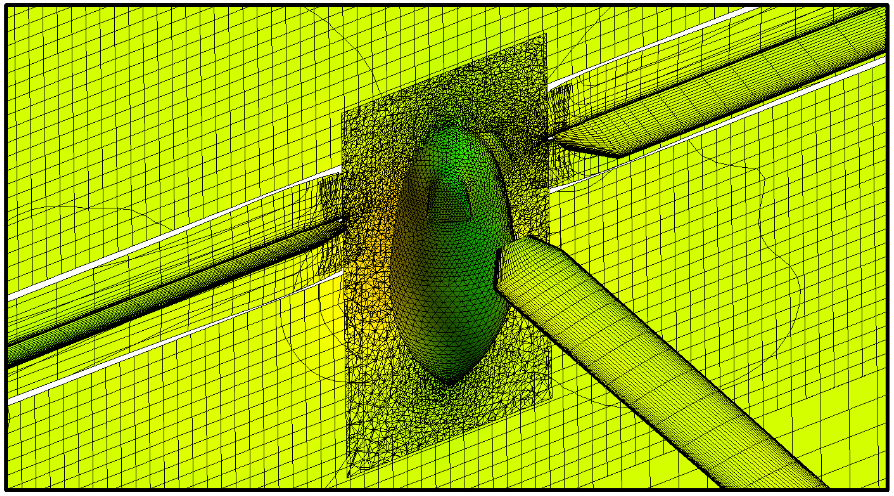


Hub + Rotor




OVERFLOW: Hexahedrals
NSU3D: Tetrahedrals
SAMARC: Cartesian





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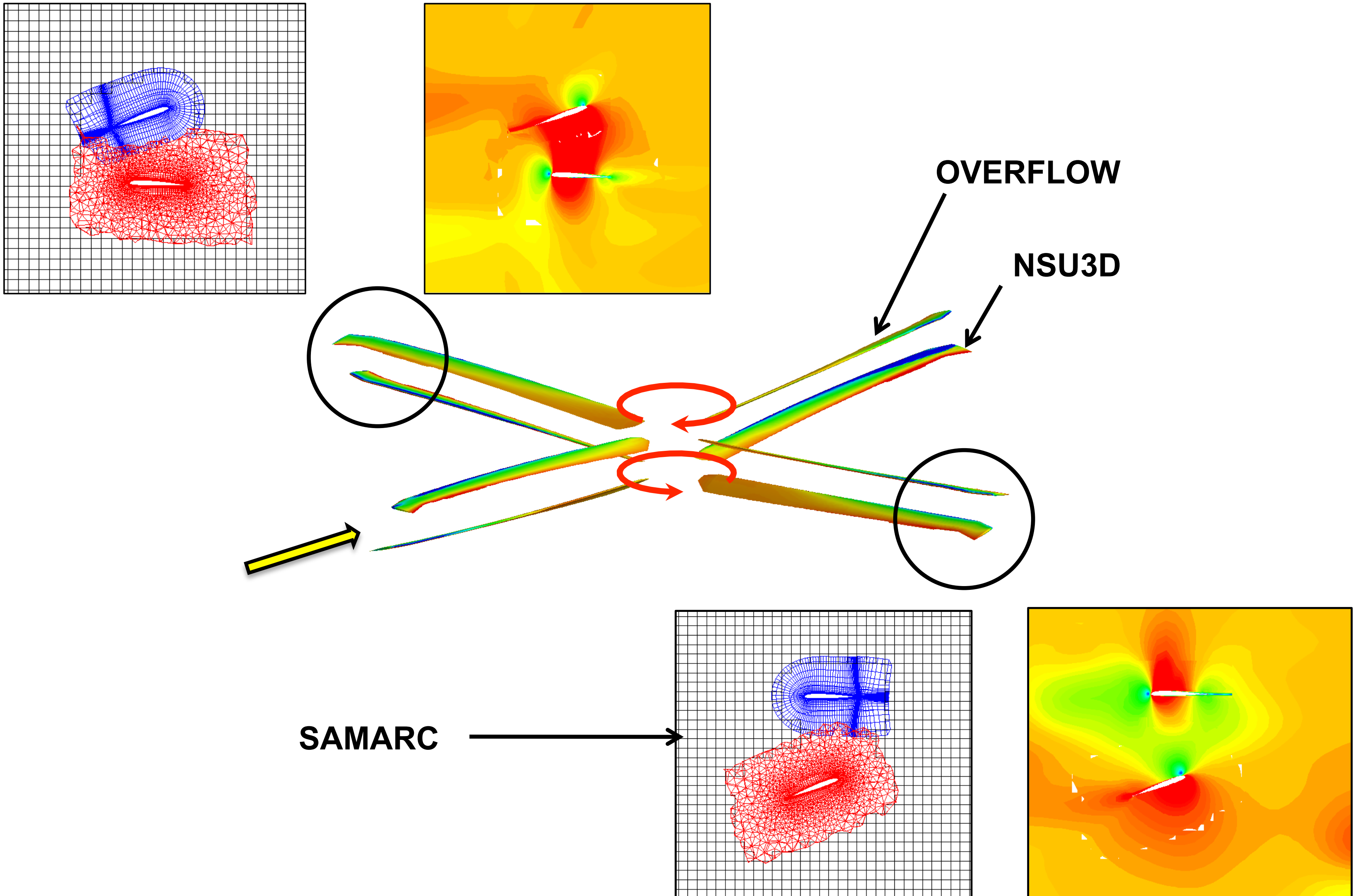
Coax Rotor, Mixed Grids

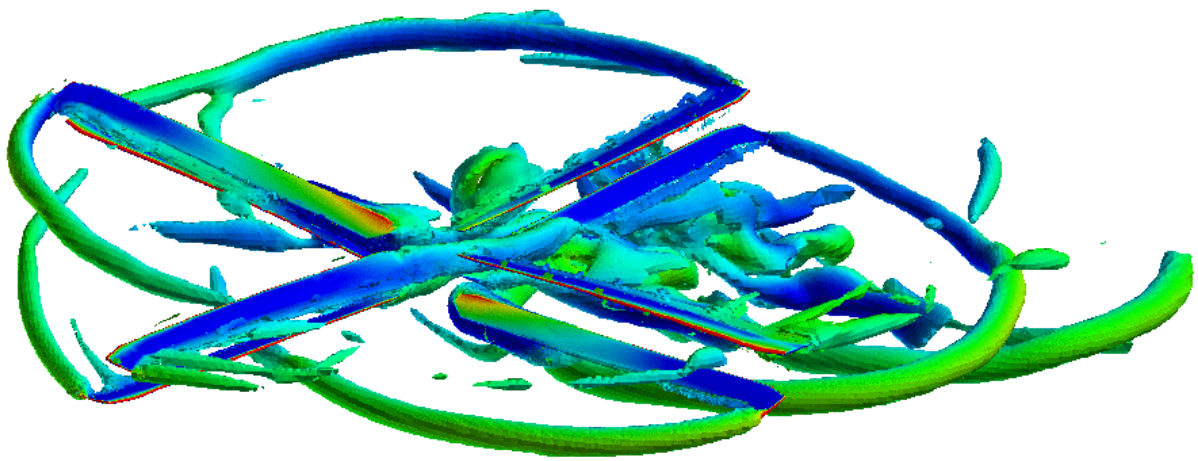


Co-Visualization

Upper rotor: OVERFLOW (structured)

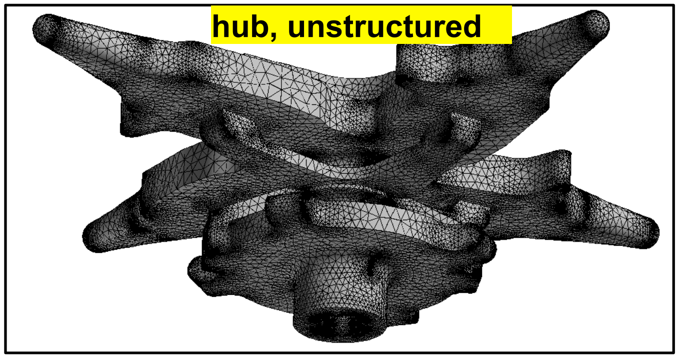
Lower rotor: NSU3D (unstructured)

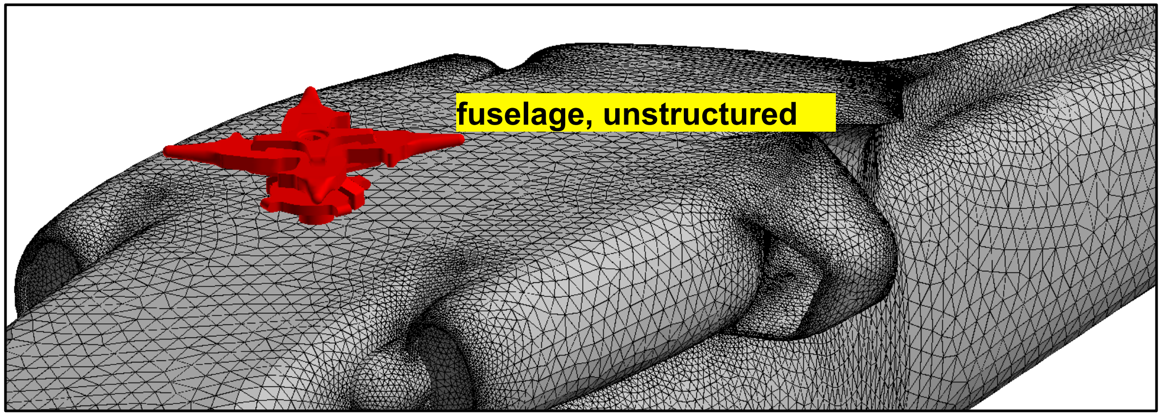
Off-body: SAMARC (Cartesian)

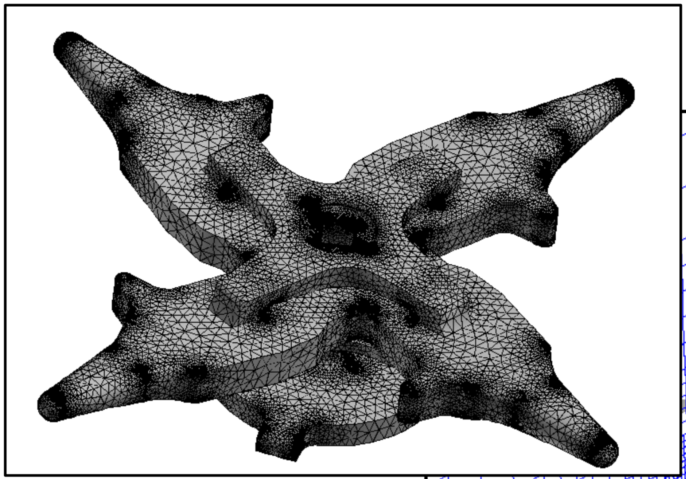


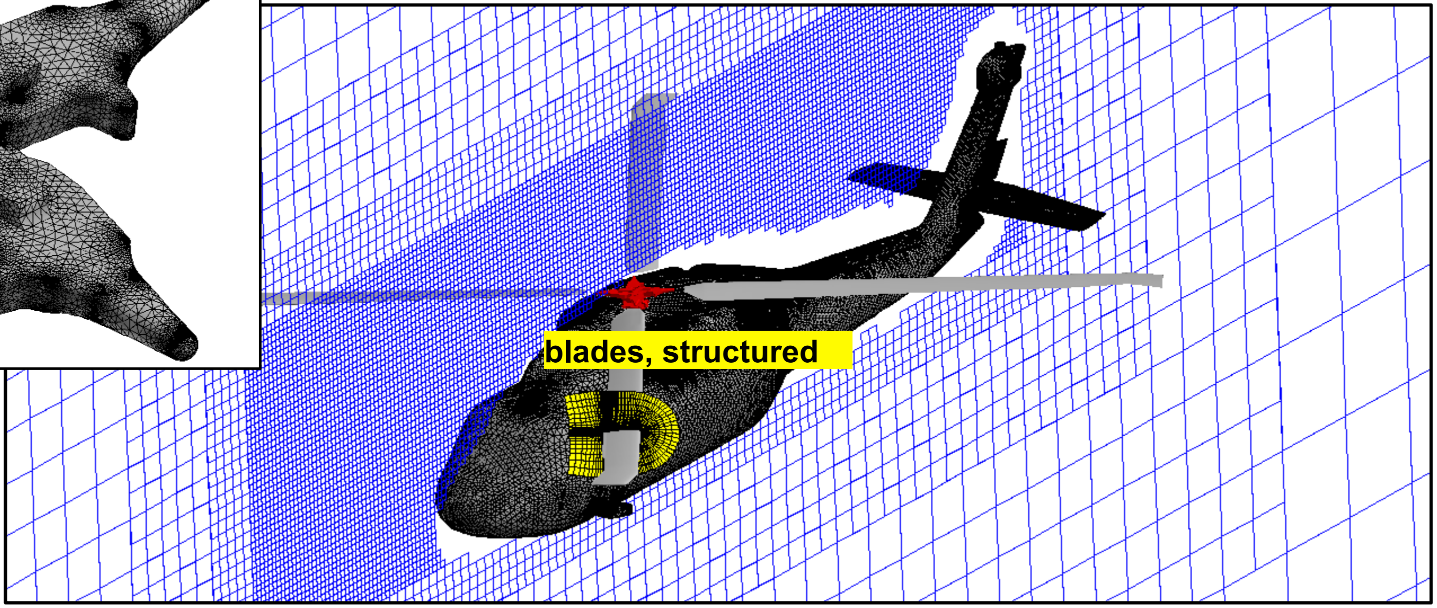
Iso-surfaces of Q criterion computed on-the-fly using the ParaView plug-in

Hub + Rotor + Fuselage



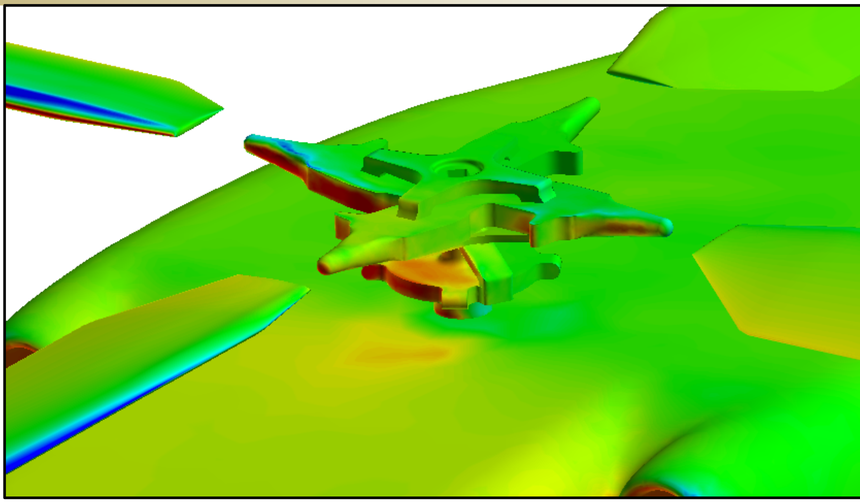


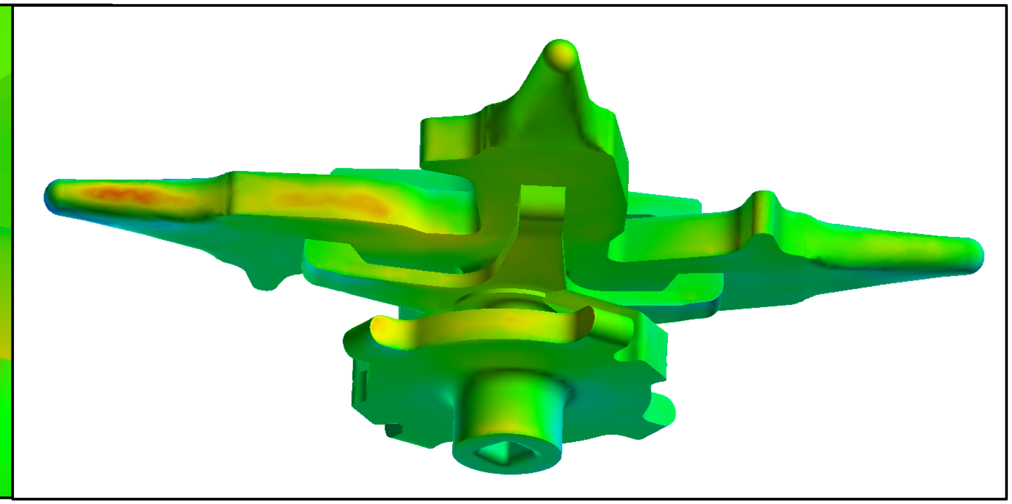


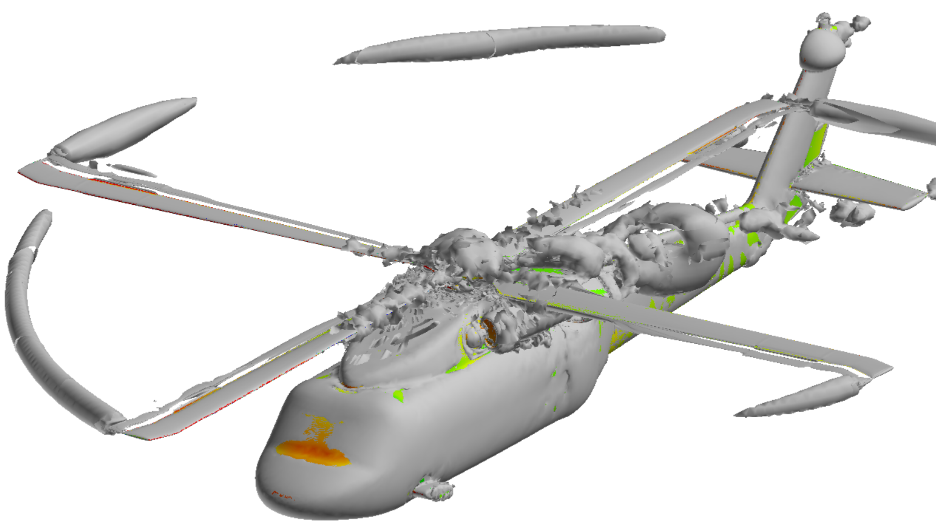


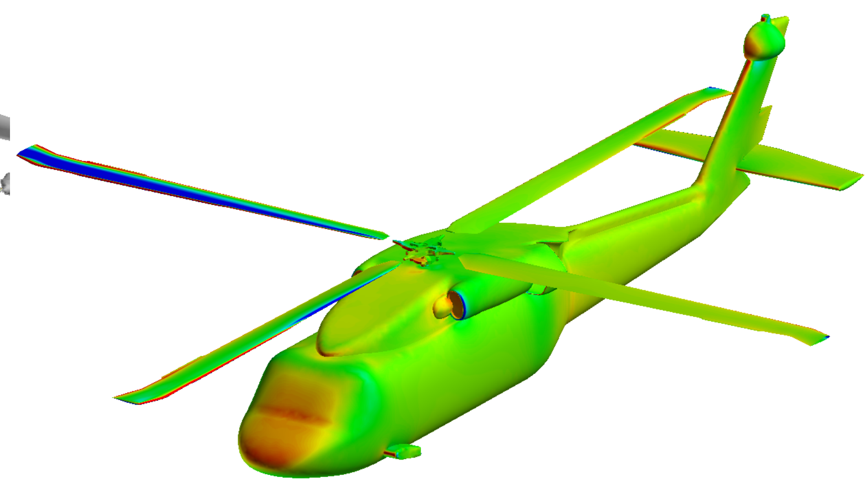
Notional hub geometry courtesy of Sikorsky
Fuselage grid courtesy of NASA Langley

Hub + Rotor + Fuselage









Notional hub geometry courtesy of Sikorsky
Fuselage geometry courtesy of NASA Langley

Summary & Ongoing Work

- HELIOS's modular, python-based framework is flexible and extensible for incorporating new modules
- The OVERFLOW code has been modularized into a HELIOS component as a near-body solver
- HELIOS framework supports multi-solver capability (NSU3D, OVERFLOW, SAMARC)
- Lends great flexibility to users

HELIOS	**OVERFLOW**
Fluid-structure Interface	High-order near-body
Co-visualization	Structured near-body
Unstructured near-body	Near-body AMR
Implicit hole cutting	Turbulence and Transition Modeling
Off-body Adaptive Mesh Refinement (AMR)	Efficiency
Modular – future add ons	Future add ons
GUI	

- Ongoing work – Alpha testing, benchmarking, and validation

End