The Computing & Interdisciplinary Systems Office

Annual Review and Planning Meeting

October 9-10, 2002

Coupled Fluid and Structural Analysis of Pump Stages for Space Propulsion Systems

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Coupled Fluid and Structural Analysis of Pump Stages for Space Propulsion Systems

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Objective

- **Develop a coupled fluid/structure analysis tool for rocket turbopumps.**
- **Advance hardware concepts and designs.**
- **Improve safety, reliability, and cost of space transportation.**

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Background

- **High power density of rocket engine pumps requires high-fidelity definition of pump environments.**
- **Currently, pump stage interaction effects and fluid/structure interaction effects are not modeled properly during the design cycle.**
- **Cavitation is not modeled during pump design cycle.**

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Coupled Fluid/Structure Analysis with Cavitation Modeling

- Flow: HPUMP3D (3D, unsteady Navier-Stokes code)
- Structure: ANSYS
- Coupling: Unified NPSS tool

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Validation of Flow Code for Rocket Engine Pumps

- RLV pump stage
- Deep-throttle turbopump stage
- Cavitation in a cascade of pump blades

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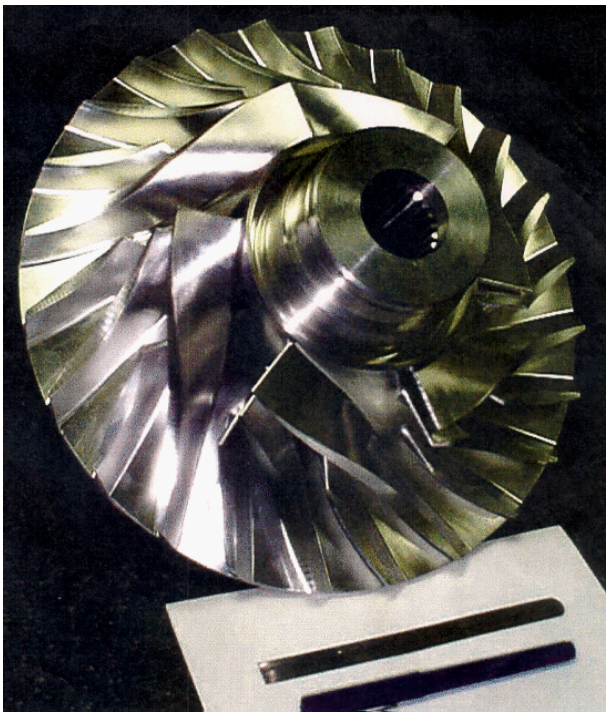
Impeller from RLV Pump Stage



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Computational Grid for Numerical Flow Analysis of RLV Pump Stage

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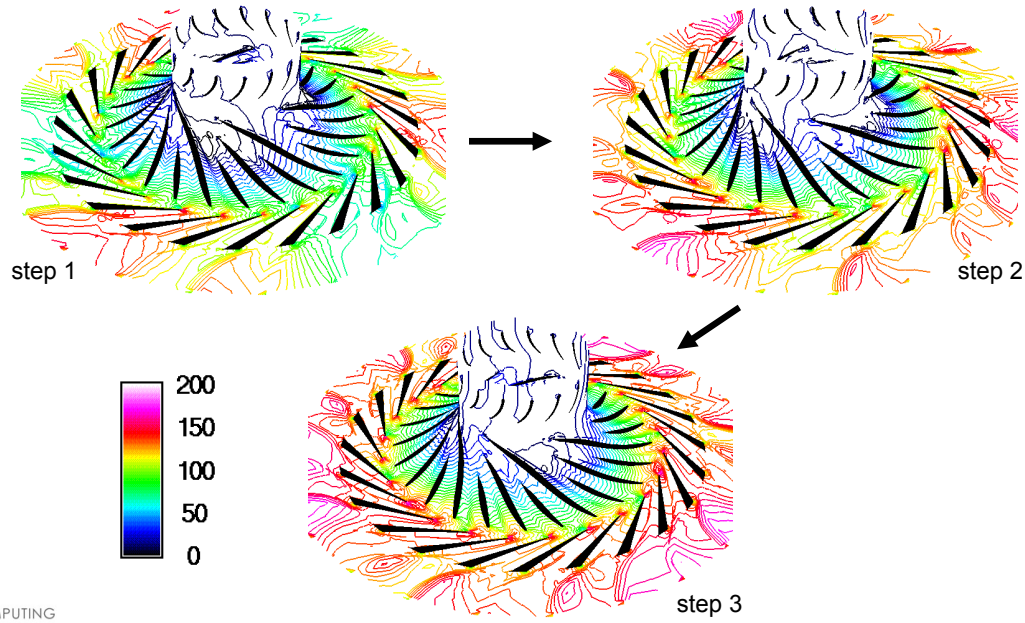
Mid-Span Pressure Contours at Three Different Time Steps (65% Mass Flow)



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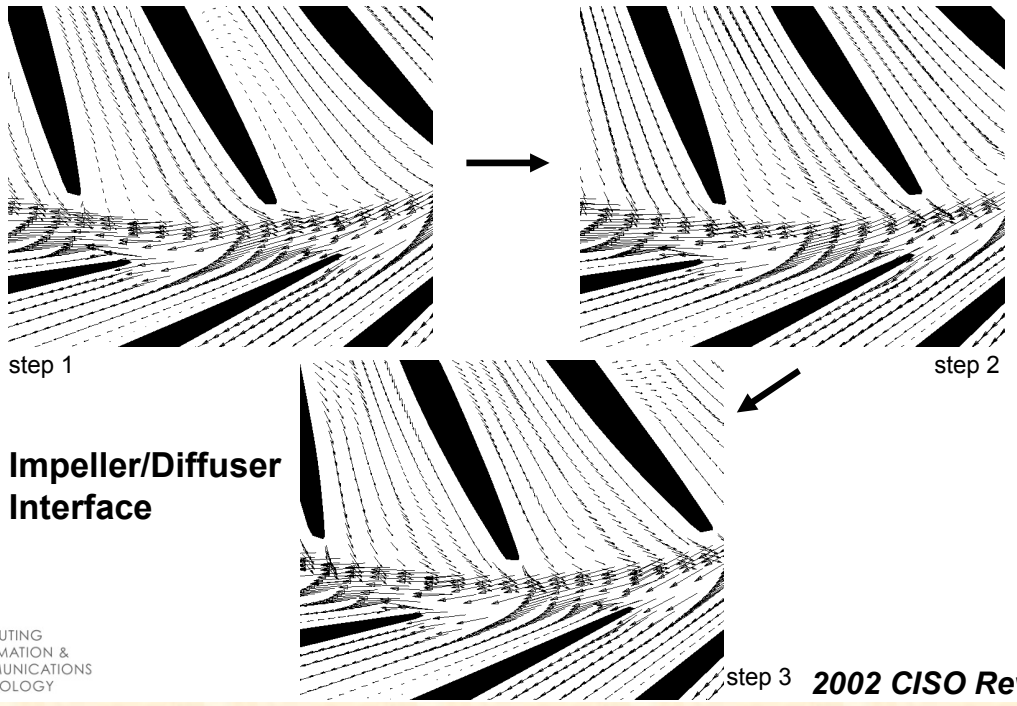
Mid-Span Velocity Vectors at Three Different Time Steps (65% Mass Flow)



Impeller/Diffuser Interface

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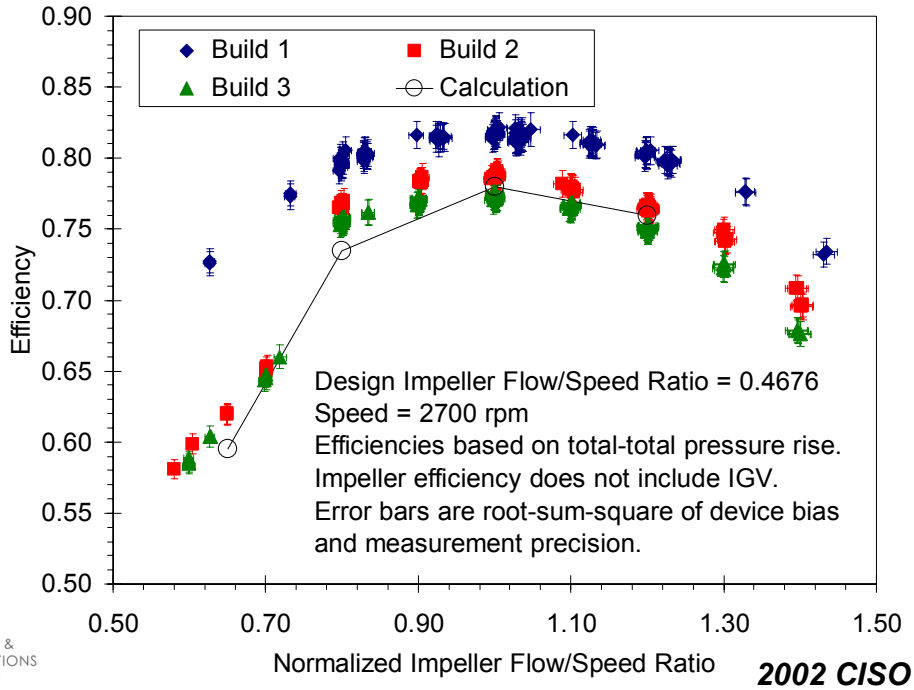
Comparison of Measured and Calculated Stage Hydraulic Efficiency



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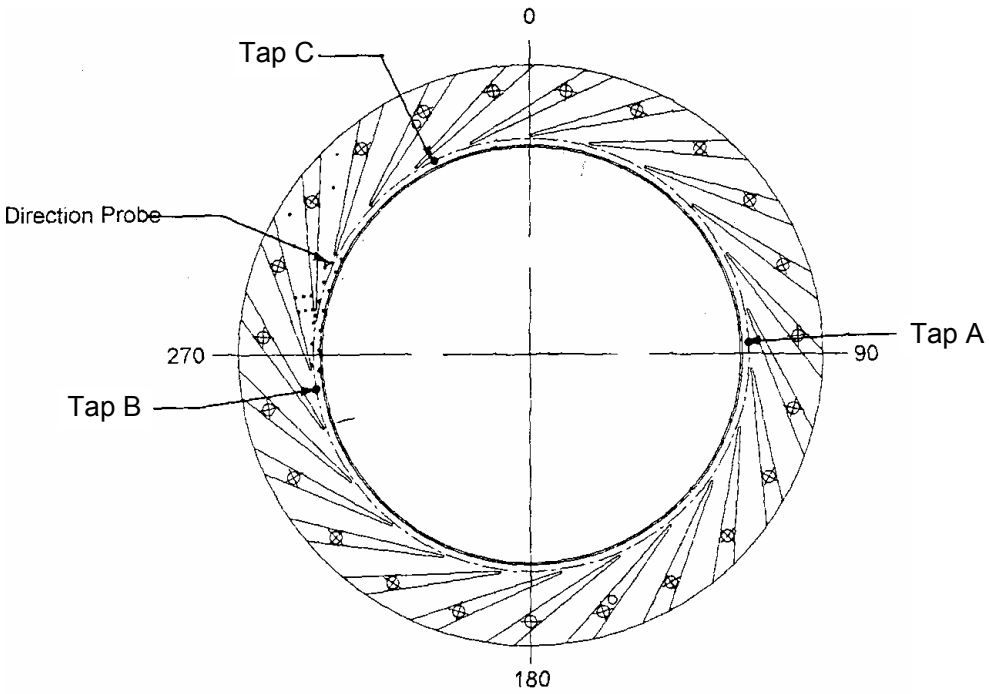
Unsteady Pressure Instrumentation



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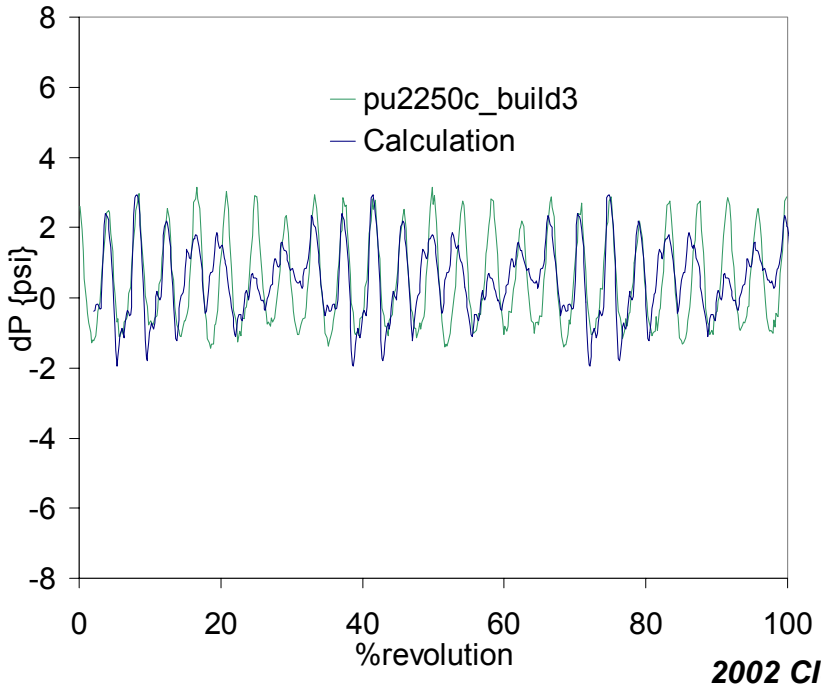
Comparison of Measured and Calculated Unsteady Pressure from Tap C



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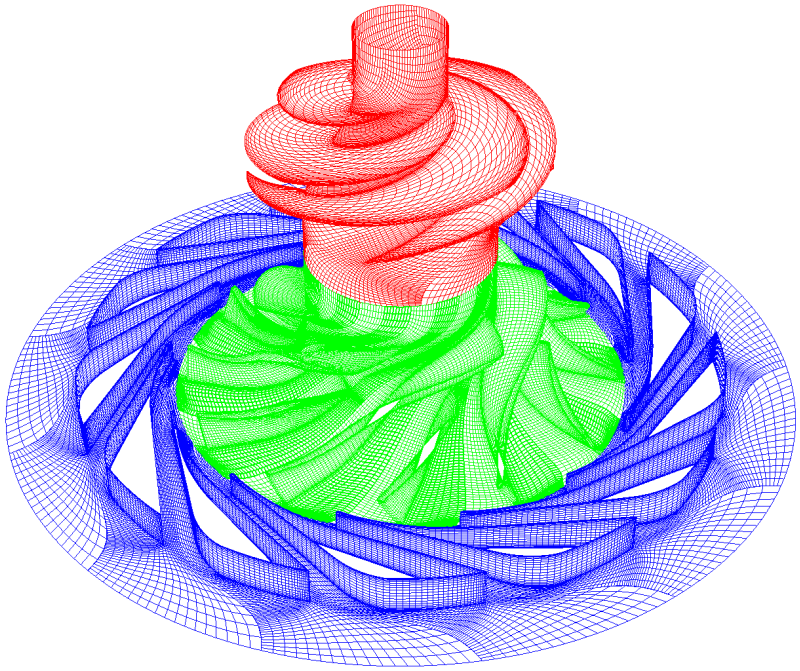
Deep-Throttle Stage Grids (inducer + impeller + diffuser)



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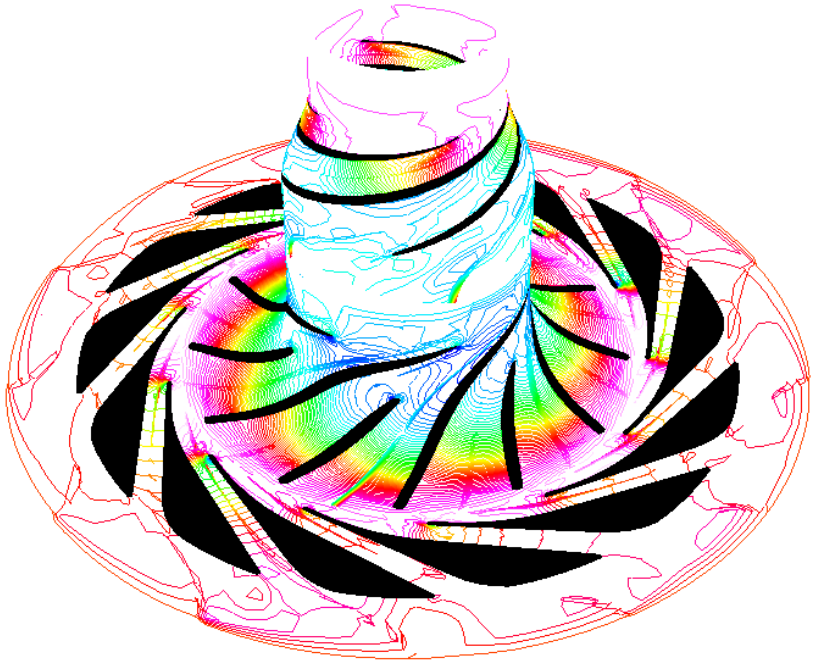
3D Steady Combined Pressure Field at Midspan



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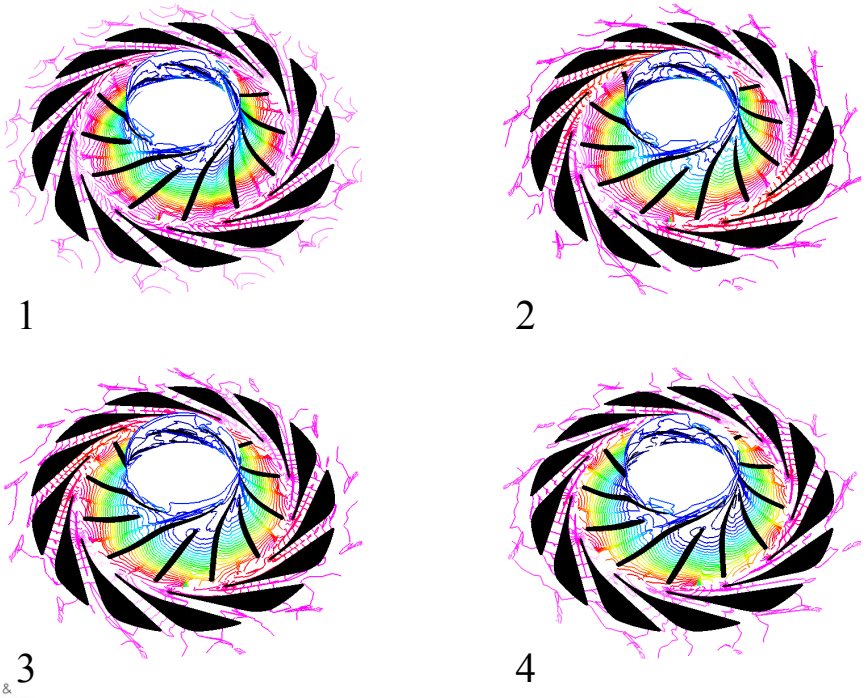
Midspan Static Pressure Distribution



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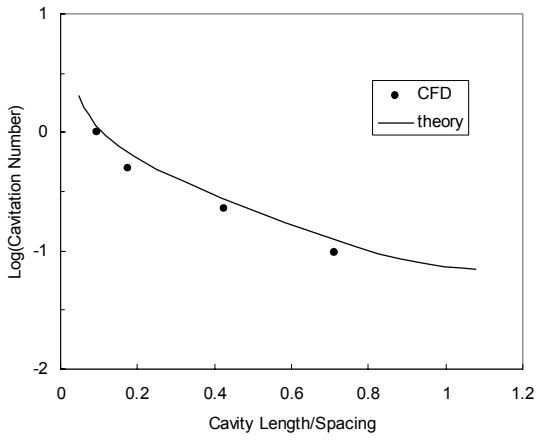
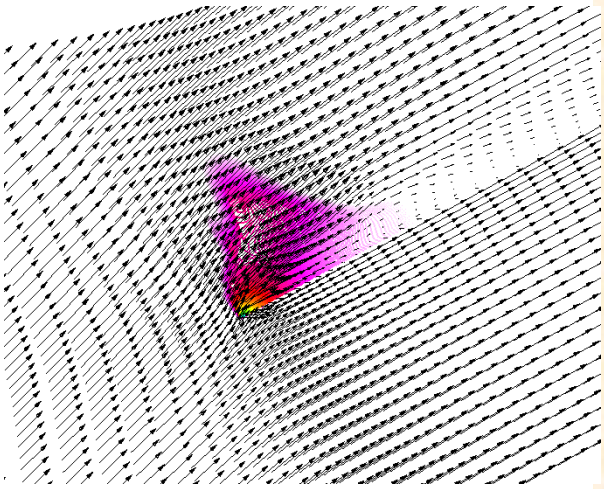
Validation of Cavitation Modeling





Comparison of cavitation length.

CFD simulation of cavitation in a cascade of flat plates.

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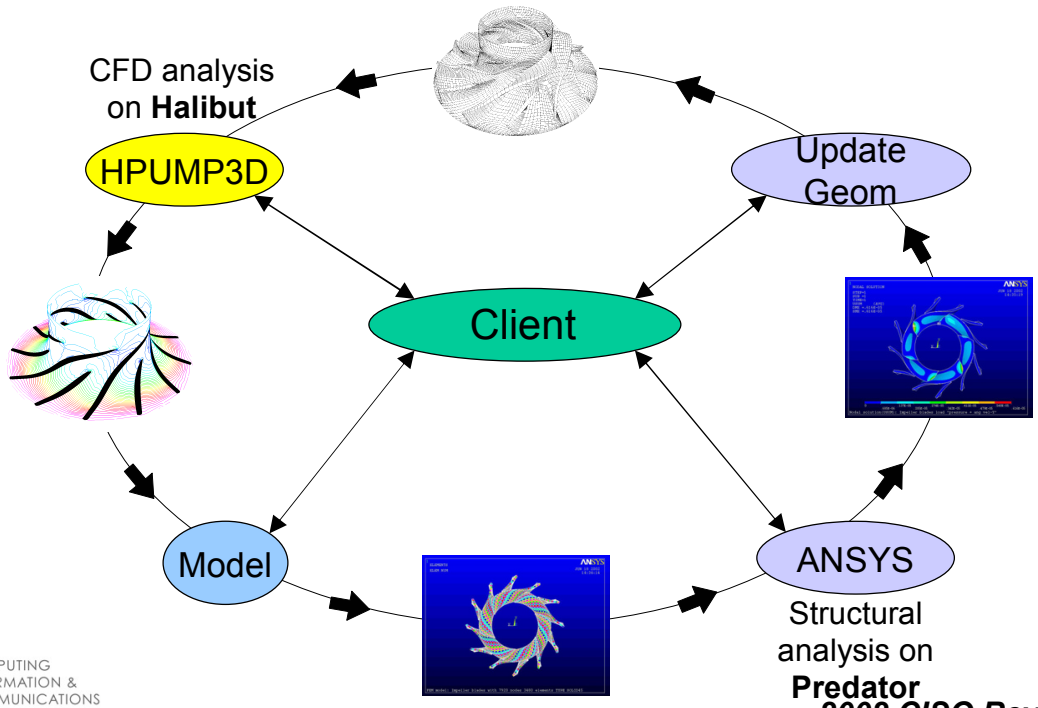
HPUMP3D ⟷ ANSYS



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Coupling of HPUMP3D and ANSYS

- **HPUMP3D - cfd code**
- **ANSYS - structure code**

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Executing Codes Using CCDK

- **Corba Component Development Kit using indirect wrapper approach.**
- **Using IOR's as location identifiers.**
- **Allows bi-directional exchange of data files.**

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Demo - program in unix script (bourne shell)

- start all remote servers.
- run 'program Client'.
- kill all servers.

Client - written in C++.

- creates a new copy of all remote servers.
- executes all programs in sequence as defined.
- each server is connected to an executable program.
- controls execution loop, allows exchange of data.
- catches exceptions (unix signal 1 2 3 15) and stops.

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cfd - executes cfd code - HPUMP3D

- creates output files (for grid and solution)

Model - executes a program model.f

- reads grid and solution files (from cfd code).
- creates data files for nodes, elements and pressure to be read by ANSYS. Only blade geometry data are used.

ANSYS impeller

- creates finite element model (FEM) by reading node and element data for impeller blades.
- find solution for load " pressure + angular vel".
- writes the new blade coordinates after solution.

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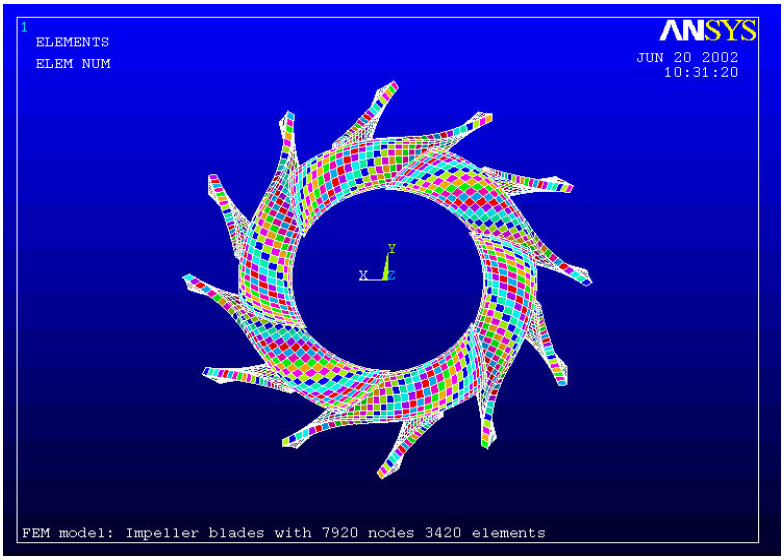
Impeller Blades: FEM Model



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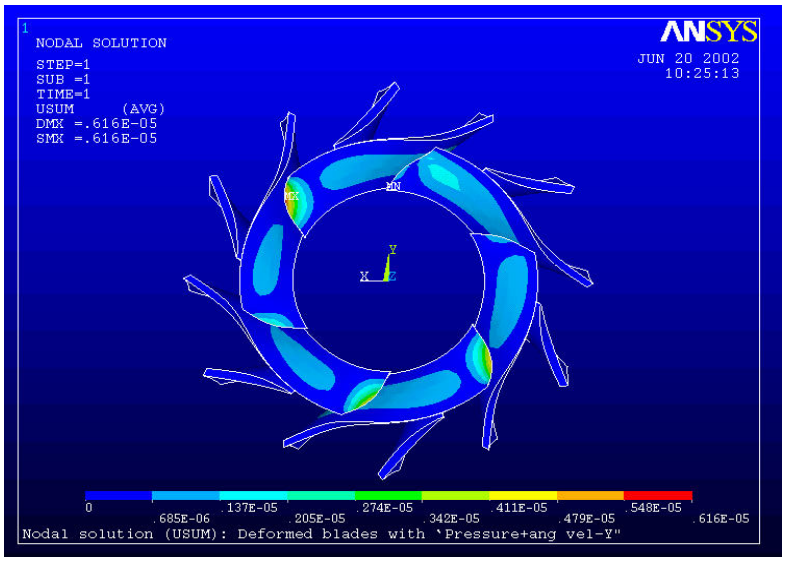
Impeller Blades: Deformed Shape



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Update geom - program in Fortran (updgrid.f)

- creates new geometry data by replacing updated blade geometry (from ANSYS) in the original cfd grid data.

- generates a new grid for cfd calculations.

Current and Future Developments

- Complete transient coupled analysis of impeller.
- Full pump stage coupled analysis (IGV + impeller + diffuser).
- Implementation and validation of cavitation capability.