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Air Force Research Laboratory



Modeling Fluid- Structure Interaction in ANSYS Workbench

31 August 2016

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AFRL/RQRM
Sierra Lobo, Inc.

Integrity ★ Service ★ Excellence

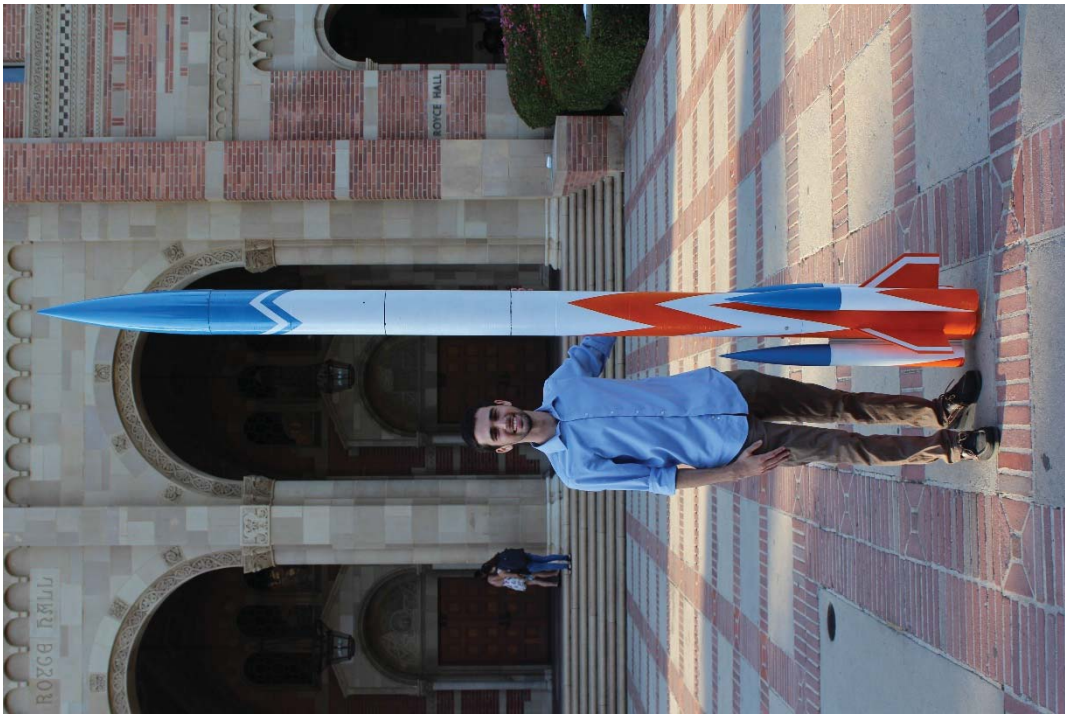




About Me



- **UCLA Aerospace Engineering '17**
 - Vishal Parikh Memorial Scholarship/AFRL Internship
- **UCLA Rocket Project**
 - Propulsion Chief Engineer '16-'17
 - Create a student-built hybrid rocket motor
- **AFRL/RQRM Aging & Surveillance (A&S) Group**





Outline



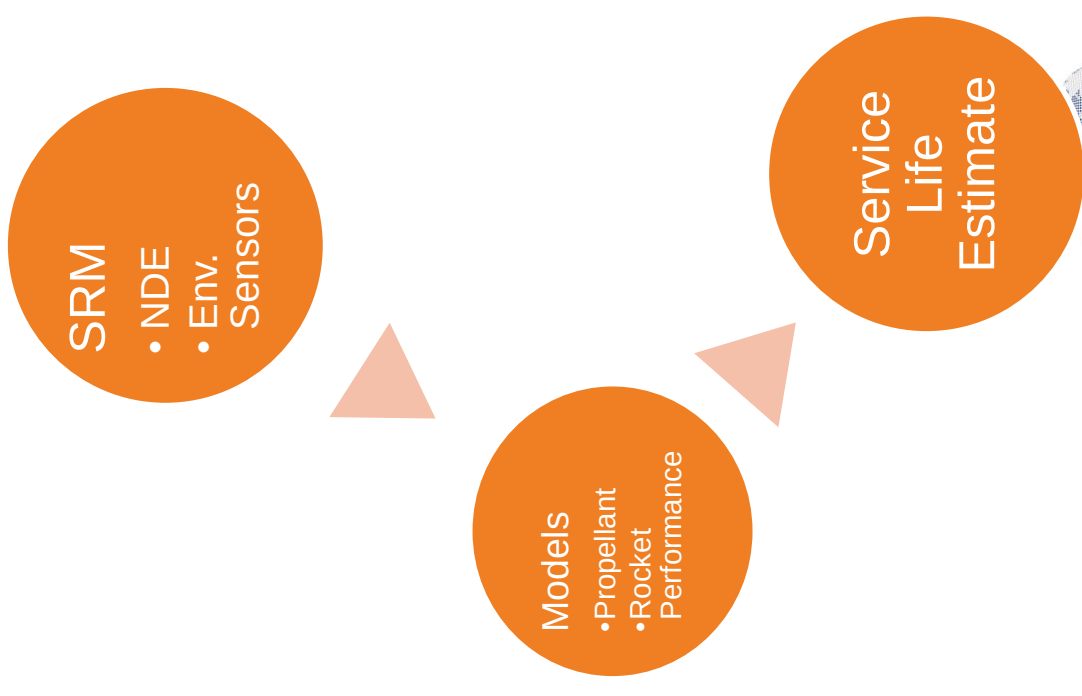
- Aging & Surveillance Overview
- Fluid-Structure Interaction (FSI)
- ANSYS Workbench Capabilities
 - Performing FSI Analysis in ANSYS Workbench
 - 1-Way FSI
 - 2-Way FSI
 - Automating FSI Analysis
- Conclusions & Future Work
- Acknowledgements



Aging & Surveillance Problem



- A&S attempts to figure out how an individual motor will behave after being stored for a period of time.
- Develop ways to gather data on individual motors.
- Model curing and aging of propellant, liner, and case, which all have changing mechanical properties.
- Model firing of motor to determine final behavior.
 - Goal was to use ANSYS Workbench to analyze fluid-structure interaction.
- Give a service life estimate for each individual motor, instead of a fleet wide SLE.

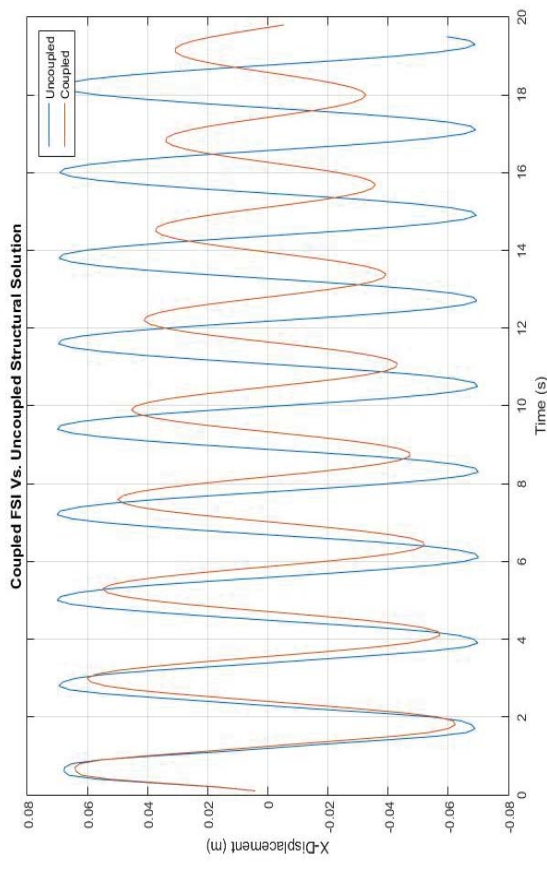
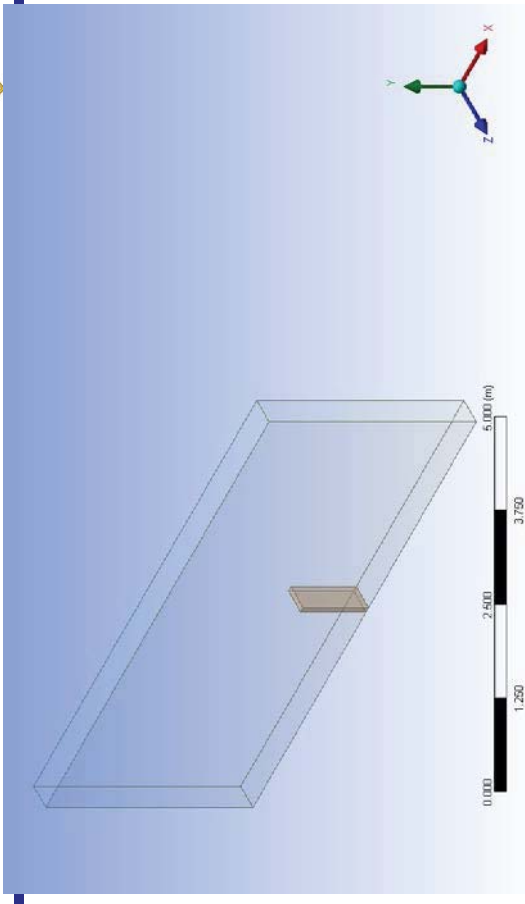




Fluid-Structure Interaction



- Fluid exerts loads on a solid structure, which then deforms.
 - Deformed solid changes the fluid flow characteristics.
- Situation can be modeled with various degrees of coupling between CFD and structural solvers.
 - CFD → Structural
 - CFD ↔ Structural
- In an A&S scenario, FSI is between combustion gas and remaining solid propellant.
 - Nonlinear viscoelasticity of materials makes simulation even more difficult.





ANSYS Workbench



- **Multiphysics application containing multiple solvers.**

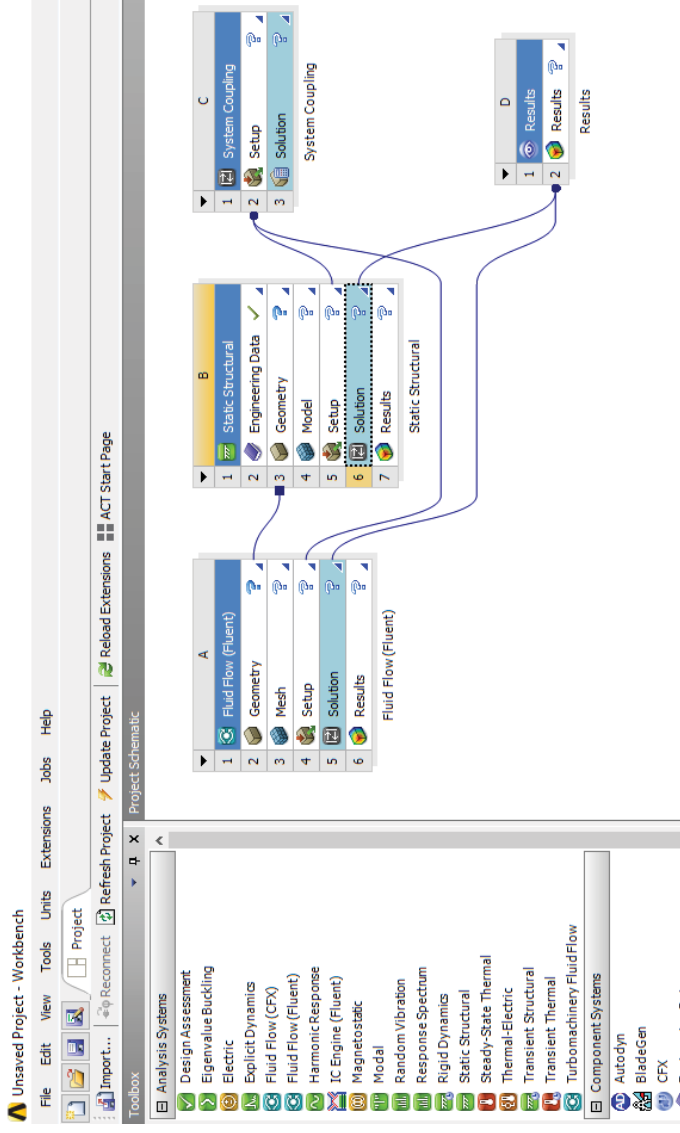
- Fluid, Structural, Dynamics, Thermal, Electromagnetic

- **Steady state and transient simulations are possible.**

- **For FSI:**

- CFD Solver: Fluent
 - Structural Solver: ANSYS Mechanical

- **Important limitation is that data transfers are only supported for 3D simulations.**

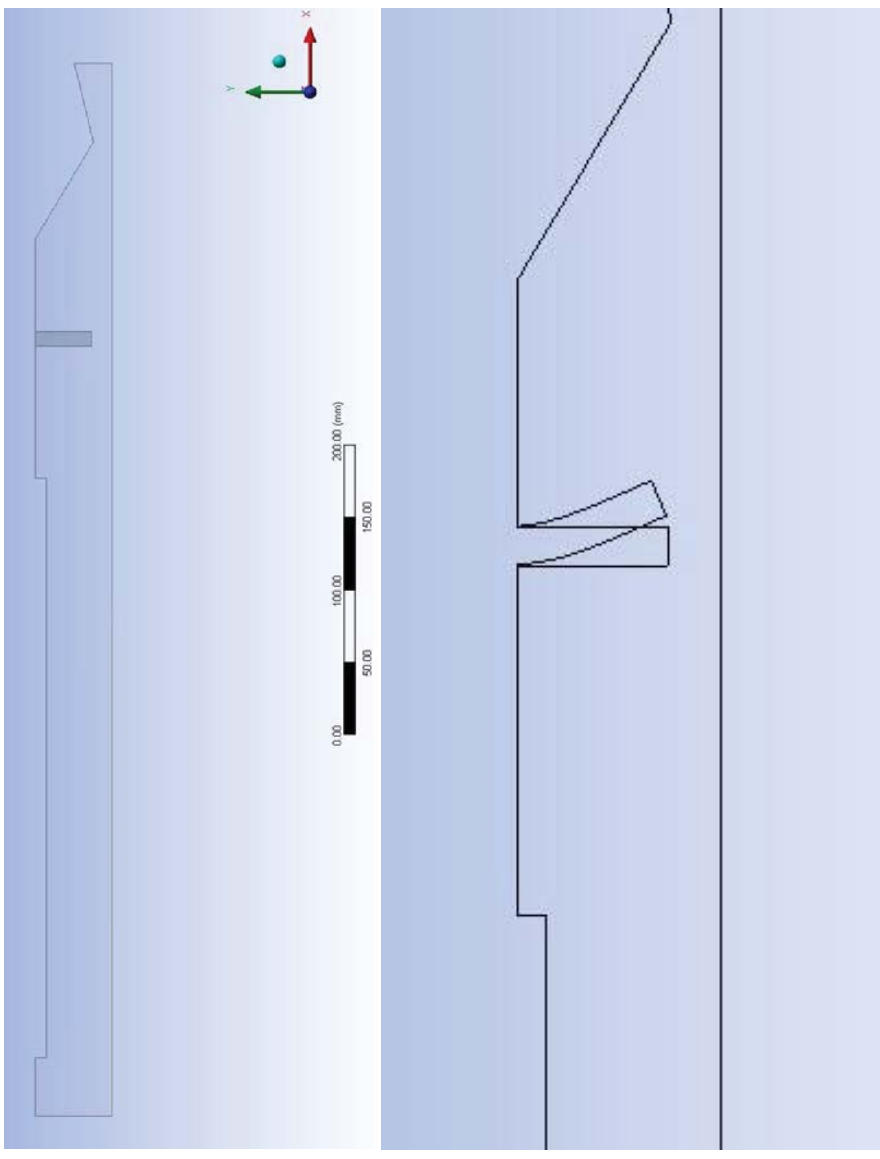




1-Way Steady State FSI



- 2D axisymmetric geometry.
- Fluent adjusts the inlet mass flux using a user defined function (UDF).
 - $\dot{m}/A = \rho \times \dot{r} = \rho \times aP^n$
- Exporting and reimporting data allows workaround for 3D limitation.
- Solution is not coupled fully, lacks accuracy in situations with large deformations.
- 1-way data transfer does not support transient simulation.

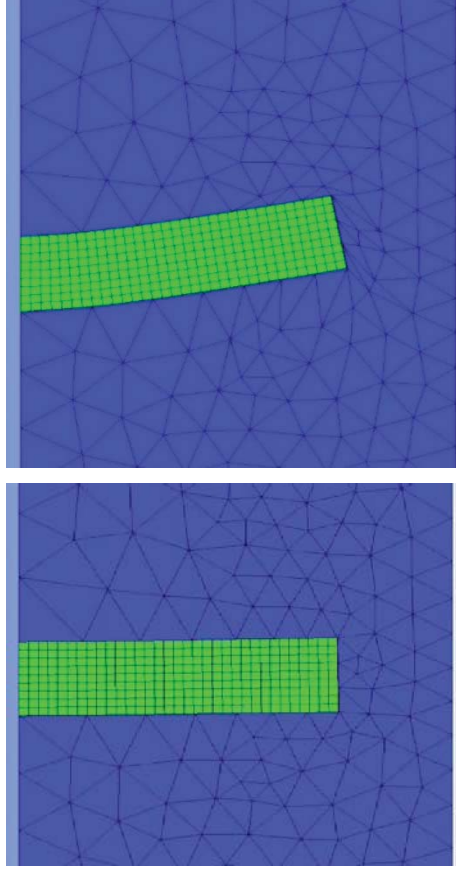
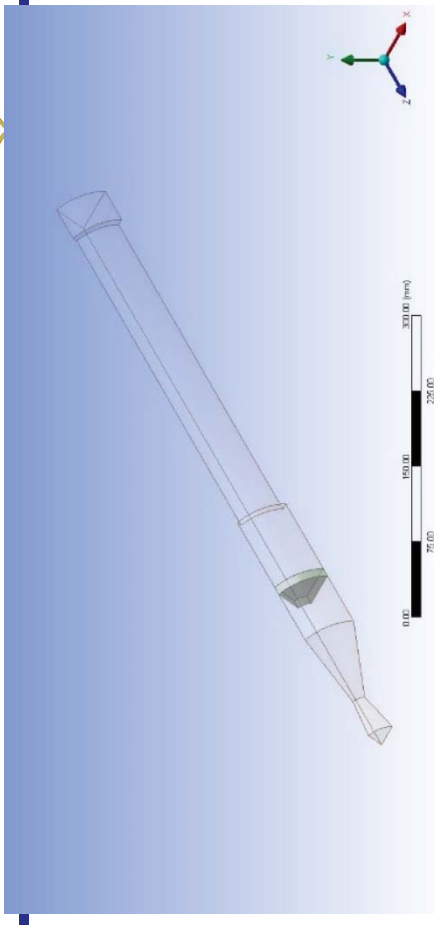




2-Way Steady State FSI

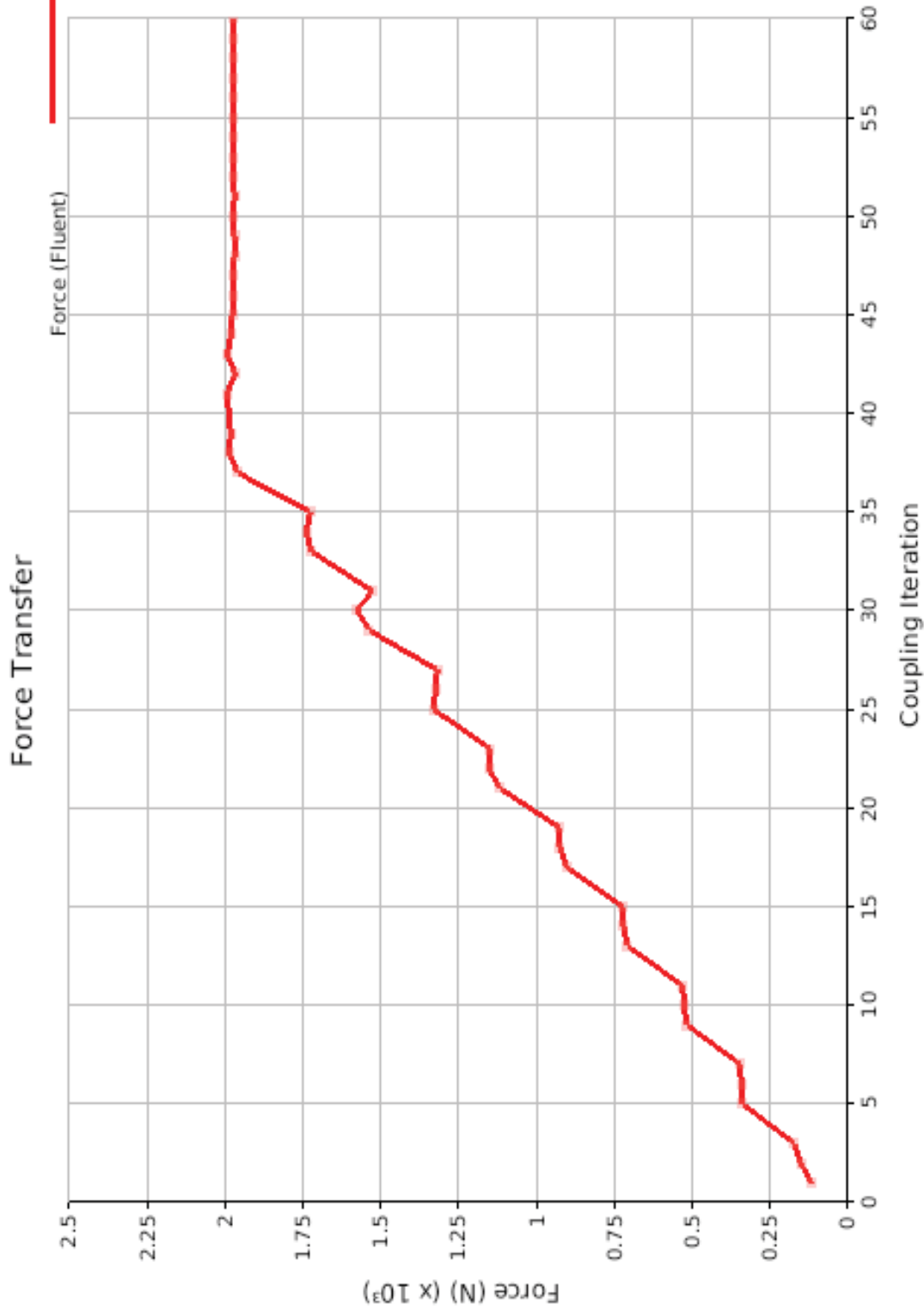


- The fluid mesh is deformed along with the structure.
- Revolved version of 2D geometry.
- Force ramping was used to prevent excessive overshoot in solid.
 - Not valid for transient simulations.
- Max deformation was about 66% of a 1-way solution on the same geometry.
 - 9.3 mm vs 5.9 mm





Steady-State FSI Force Ramping

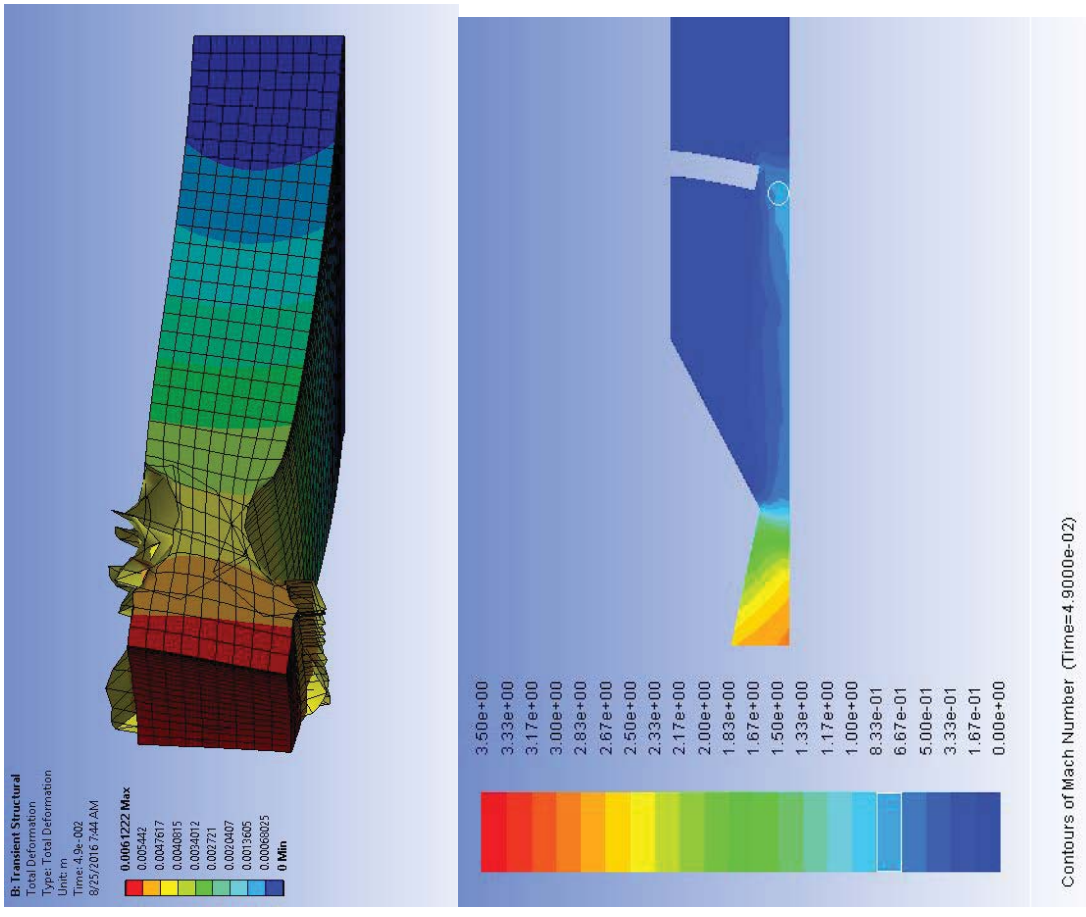




2-Way Transient FSI

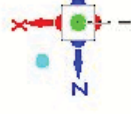
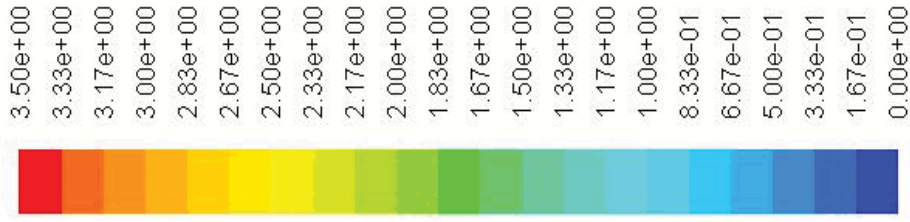


- Overshoot issues were solved by making the time step very small (0.001 seconds).
 - Once transients die down the time step can be increased.
- Becomes useful when UDF's simulating actual motor behavior are integrated into fluid solution.
 - Transient ignition, nozzle erosion, and more.
- The propellant flap initially chokes the flow, then the flow becomes subsonic.
 - Important to avoid bore choking when designing actual motors.
- Results approach the steady state solution before breaking down from excessive deformation.





Transient FSI Results



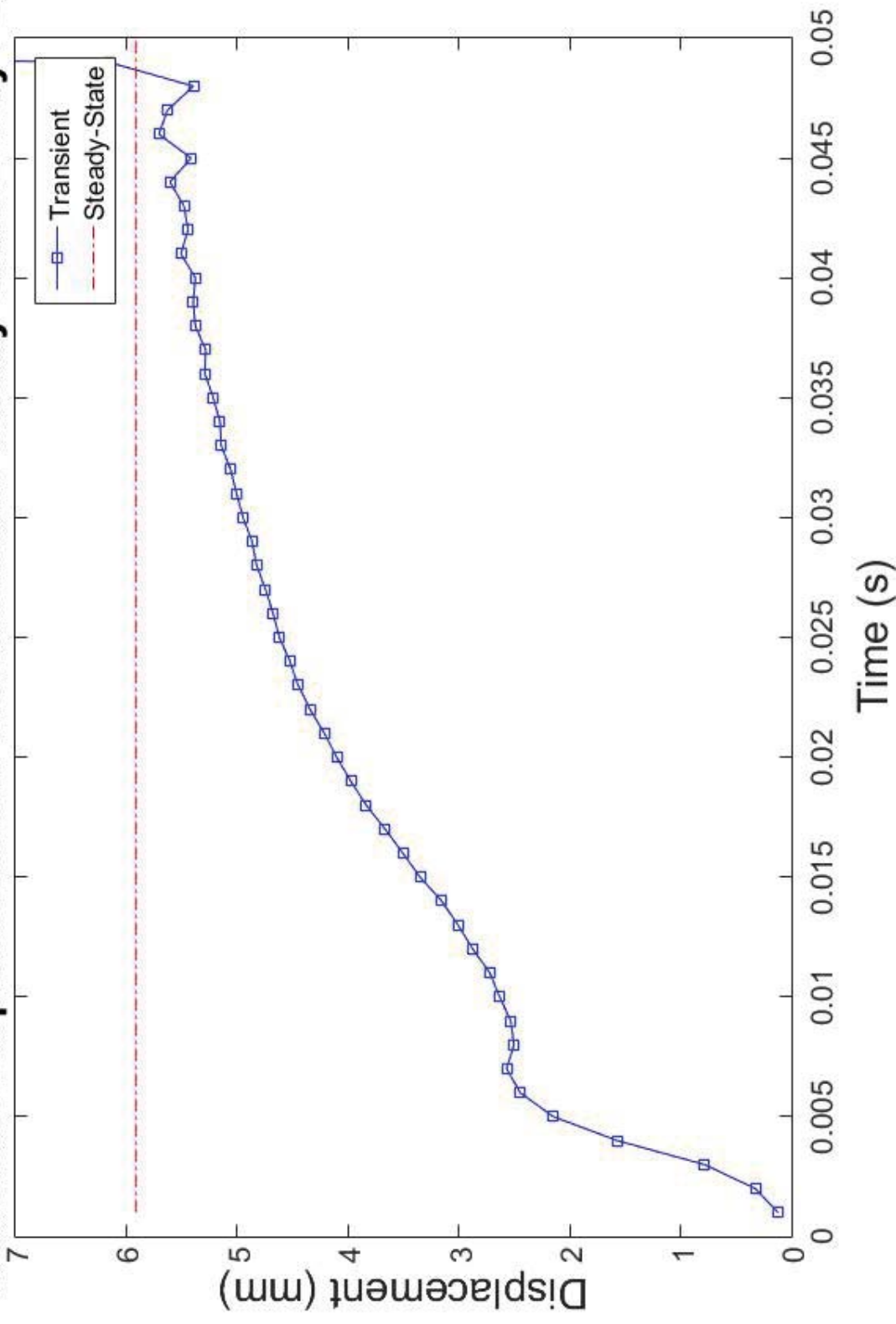
Contours of Mach Number (Time=0.00000e+00) Aug 25, 2016
ANSYS Fluent Release 17.0 (3d, dp, pbns, dynamesh, sskw, transient)



Transient FSI Results



Maximum Displacement in Transient and Steady-State 2-Way FSI

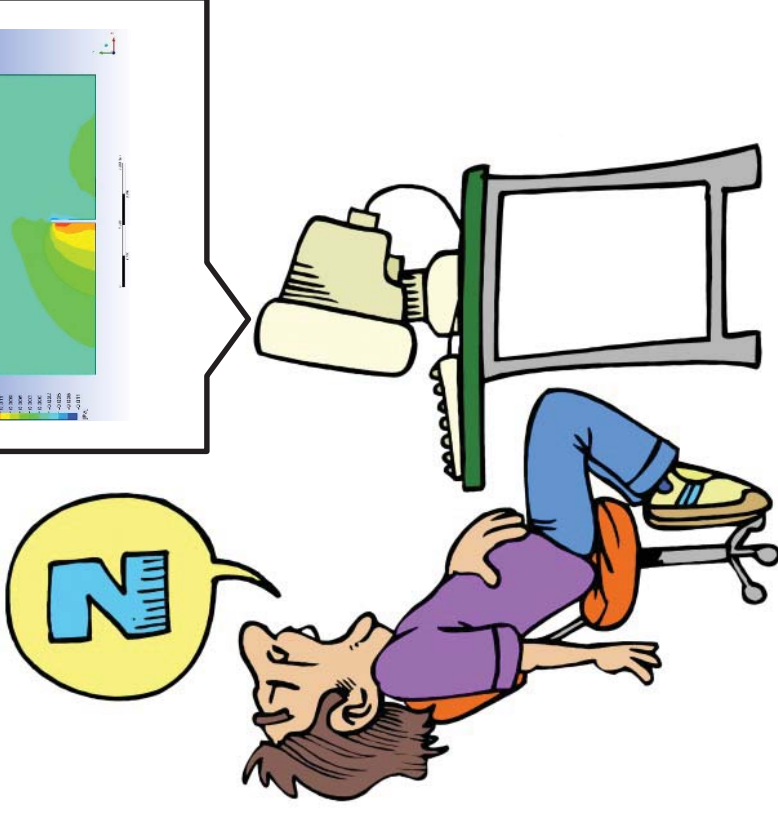




Automating ANSYS



- ANSYS can read Python scripts with instructions on how to perform an analysis.
- Fluent & Mechanical are “Data-Integrated” applications.
 - “Native” apps like System Coupling allow for direct scripting.
 - Data-integrated apps must be sent commands in their respective scripting languages.
- Most important feature (available in both Workbench and Fluent) is ability to record journals/scripts.
 - An analyst can perform the analysis once by hand, and ANSYS will create a Python file that will replicate those actions.

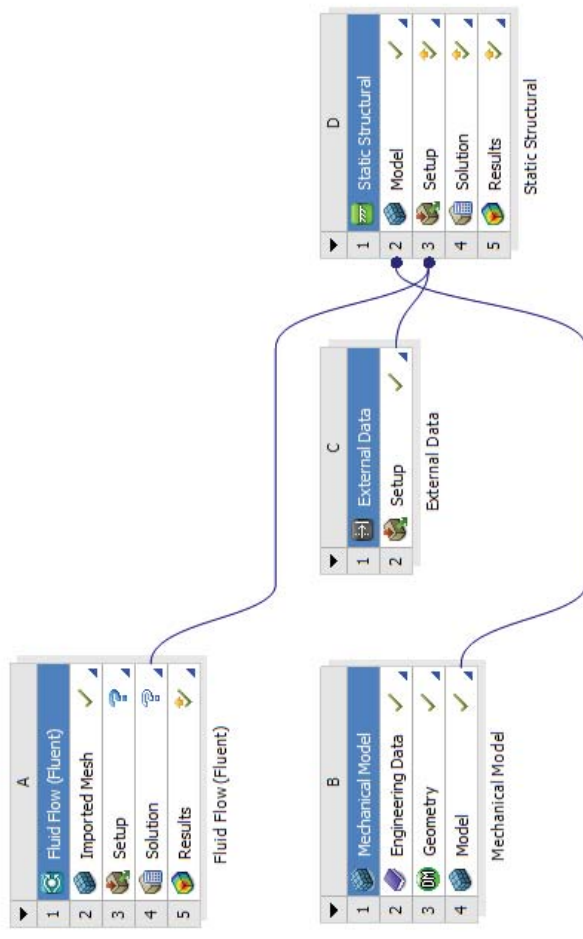




Automated 1-Way FSI



- First attempt at automated analysis.
- Automatic Integrated New Technology Enabling Rapid Numerical Solutions (AutoINTERNs)
- Reads fluid and solid geometries, sets up and solves fluid problem, exports pressure to ANSYS Mechanical, and sets up structural analysis.
- Does not give a lot of flexibility in an analysis.





Automated 2-Way FSI



- **ANSYS Guided Process**
 - XML file combined with Python script.
 - HTML and images can also be added.
- **Creates a step by step process that a user can follow.**
 - Tasks like component/data linkage creation can still be automated.
 - Others like geometry creation/import can be left to the user.
- **Once coded, files are “compiled” into a single extension file that can be loaded on any ANSYS installation.**

Transient FSI Wizard

Geometry

FLUENT Meshing

FLUENT Journal File

Use Custom Journal?

FLUENT Setup

Set up FLUENT according to the instructions of a journal file. Opting not to use one will open FLUENT and allow you to set options manually.

Mechanical Model Setup

System Coupling Setup

Help

No wizard help is available



Conclusions & Future Work



Conclusions

- ANSYS Workbench provides an intuitive framework for coupled analysis.
 - Many steps can be automated, which simplifies complicated or repeated analyses.
 - 1-way coupling is generally not adequate for SRM simulation.
- ANSYS is exportable technology, which facilitates collaboration with foreign countries.
- Existing UDFs already work with Fluent, and need no modification.
- The requirement for 3D geometry increases computational load.

Future Work

- Improve long term stability of transient simulation.
- Integrate UDF's that better model transient motor behavior.
- Validate ANSYS Workbench solutions with test data.
- Add functionality to FSI Guided Process, such as images and help files.



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