Using Explicit FE Analysis for Structural Analysis of Impact : From Simple Calibrations to Very Complicated Models

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Return to Agenda

OUTLINE

- FAA Debris Mitigation Phase 1 Project (1998)
- After-Project Activity
- Real-world Application Examples
- Further Goal and Plans

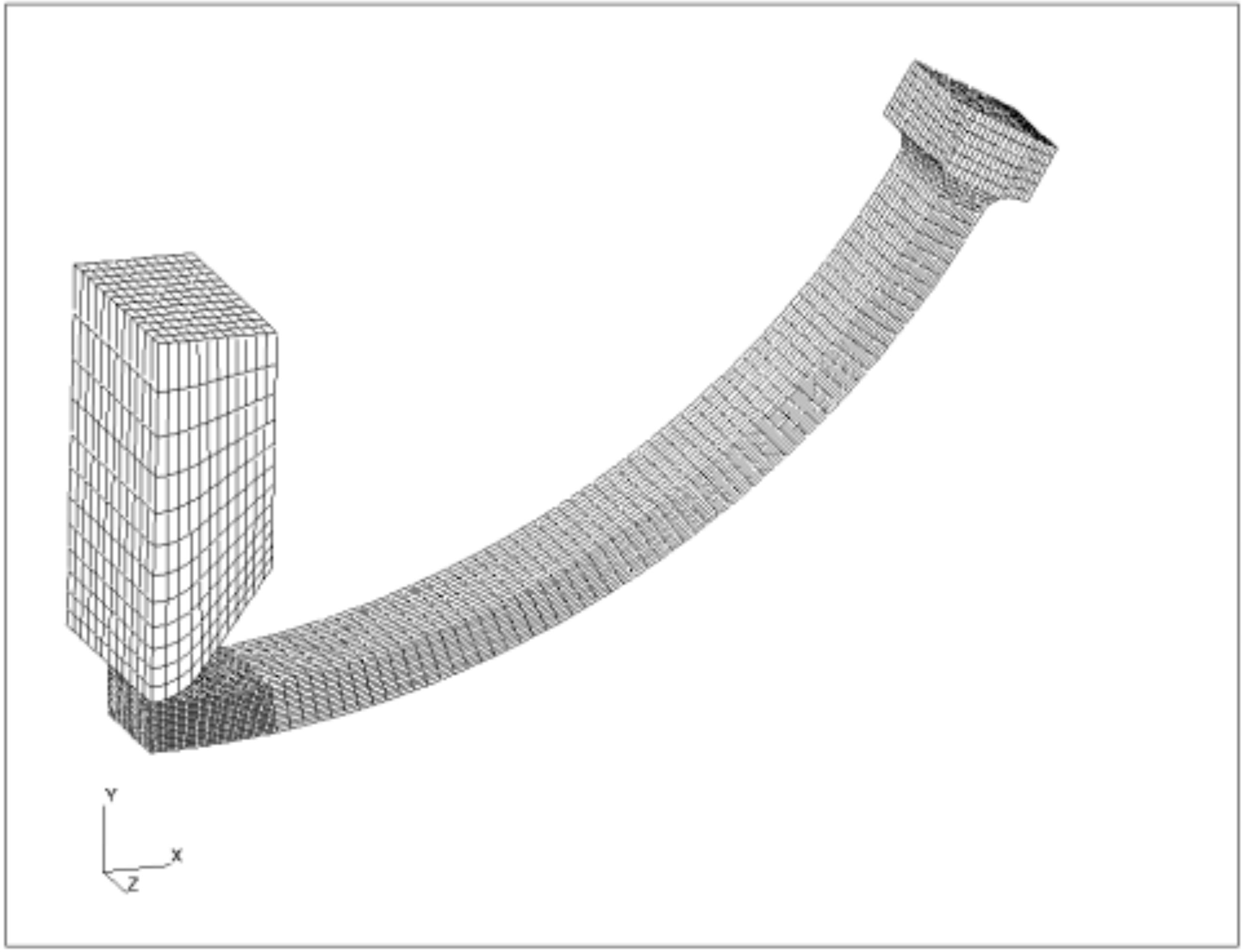
FAA Debris Mitigation Phase 1 Project (1998)

- **Background**
  - Joint effort of Honeywell (AlliedSignal) ,Boeing, Pratt & Whitney and Lawrence Livermore National Laboratory (LLNL) in 1998.
  - Honeywell was under the subcontract to LLNL.
- **Goal**
  - Accurate prediction of the effect of uncontained engine debris on aircraft structures.
  - Calibrate LL-DYNA3D to match simple specimen test result.
  - Understand different material models in LL-DYNA.
  - Explore and understand the characteristic of LL-DYNA3D.

Tasks

- **Lab Experiment**
  - Simple drop test on specimens.
  - Two specimen geometry, 2 materials (Al 2024 & Ti 6-4), various drop height
- **Numerical Experiment (LL-DYNA3D)**
  - Modeled to simulate the test conditions and geometry
  - Use different material models for the same test
- **Post-test activities**
  - Head-to-head comparison between test results and LL-DYNA3D
  - Observations, conclusions and recommendations.

Geometry and The Model (1)



Geometry 1 : Thick 120 Degree Arc Specimen; Symmetric Model

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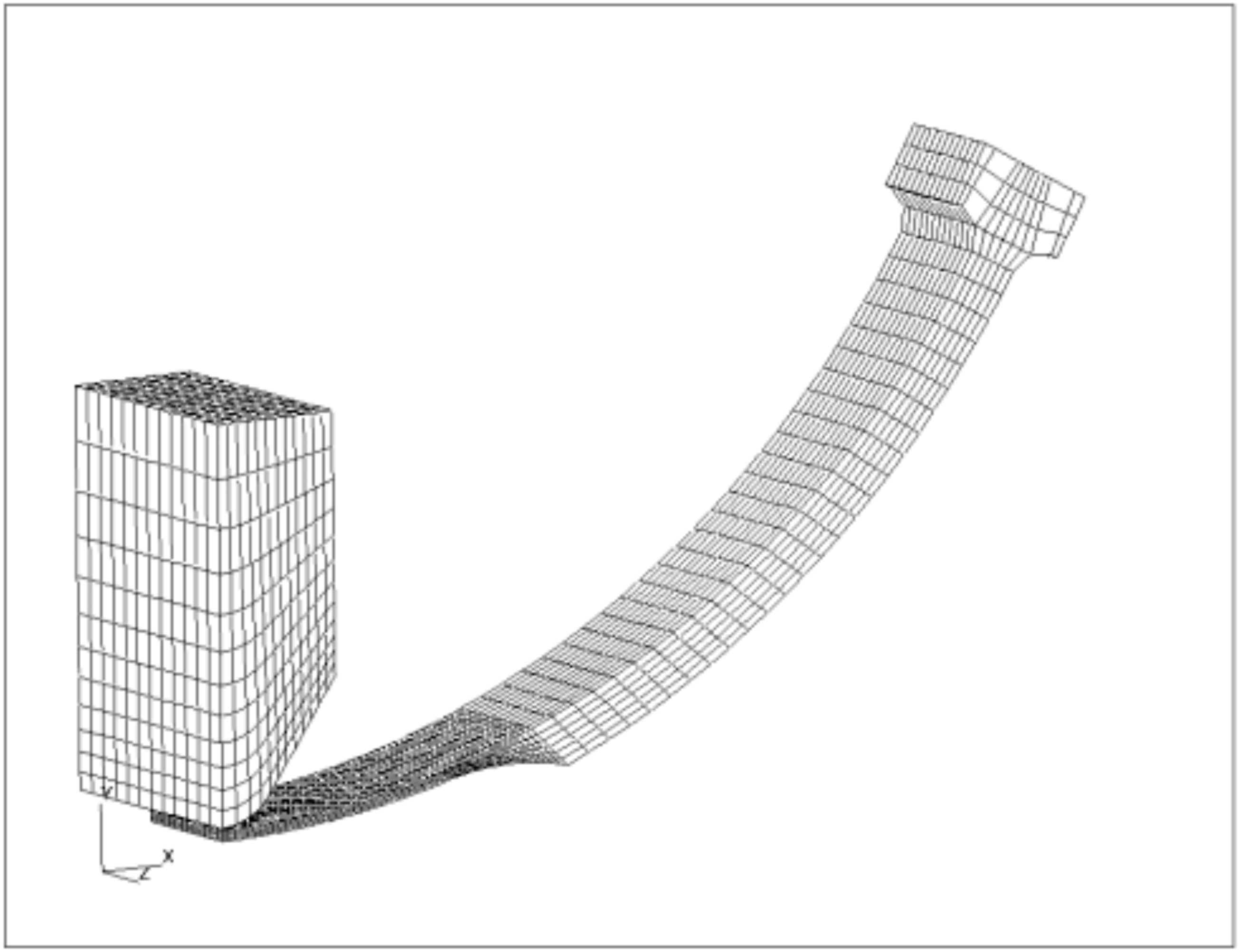
Geometry and The Model (2)



Geometry 2 : Thin 120 Degree Arc Specimen; Symmetric Model

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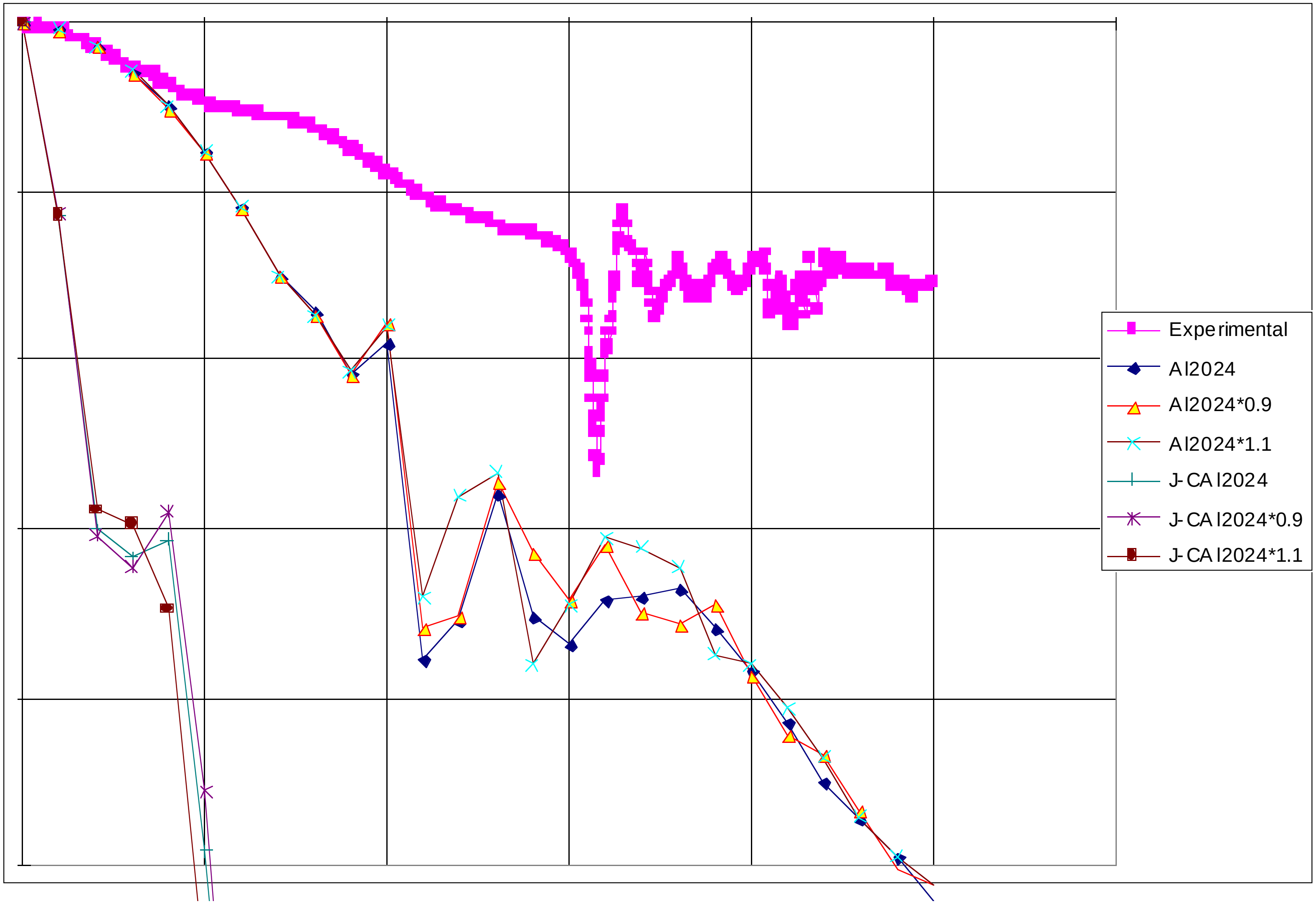
Numerical Experiment

- 2 Material Models
  - Material 24 (Piecewise-linear-plasticity)
  - John-Cook Model
- 3 Scale Factors for Stress-Strain Curve of Each Model
  - 0.9, 1.0, 1.1
- Totally 6 Numerical Simulation on Each Geometry / Material type.

Observation, Comparison and Conclusion

- **Material Model**
  - Johnson-Cook model was not better than the static piecewise linear plasticity model.
  - Scale factors had very little effect.
- **Correlation Between Test and Numerical Simulation**
  - Penetration properties : matched well
  - Final deformed shape : matched well
  - Displacement VS time : matched well.
  - Velocity VS time : matched OK
  - Strain VS time : too much noise. Difficult to compare.
- **Others**
  - DYNA seemed to be always on the conservative side.

Example Data from the Test (1)



Thick Al Specimen. Strain VS Time

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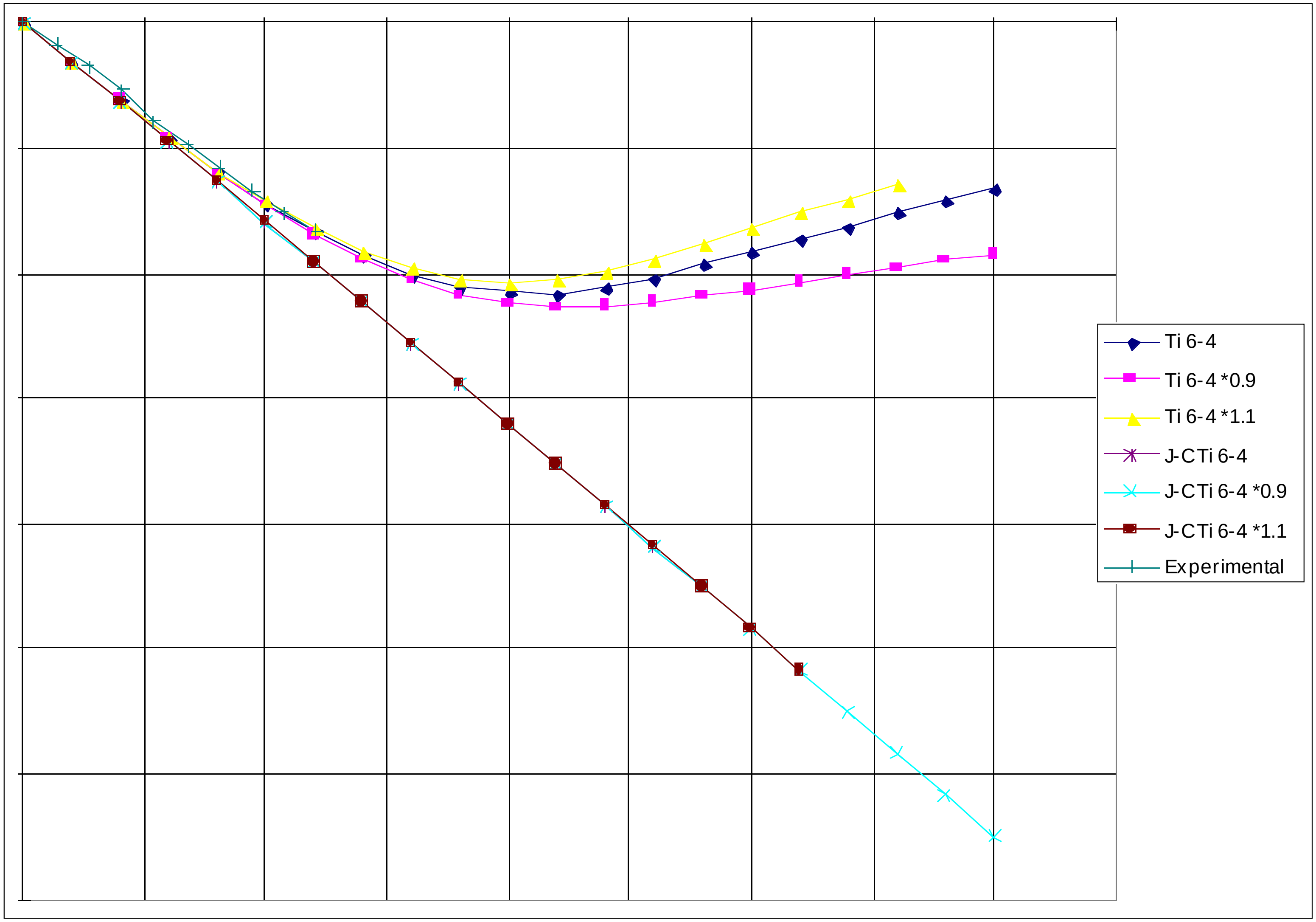
Example Data from the Test (2)



Thick Ti Specimen. Displacement VS Time (Bounced Back)

Activity After the FAA Project

- **Strategy**
  - Calibrate analysis tools with existing result.
  - Predicting test using analysis tools.
  - Familiar with the analysis tool by understanding the hard science behind the algorithms and the theory.
  - Building up knowledge-based database and standard process flow.
- **Goal - Toward Complicated Modeling Techniques**
  - Build in-house pre-processor : integrate with the existing package.
  - Model all necessary parts, and capture interaction between them.
  - Overcome the numerical instability issue.

General Experience on the Explicit FEA

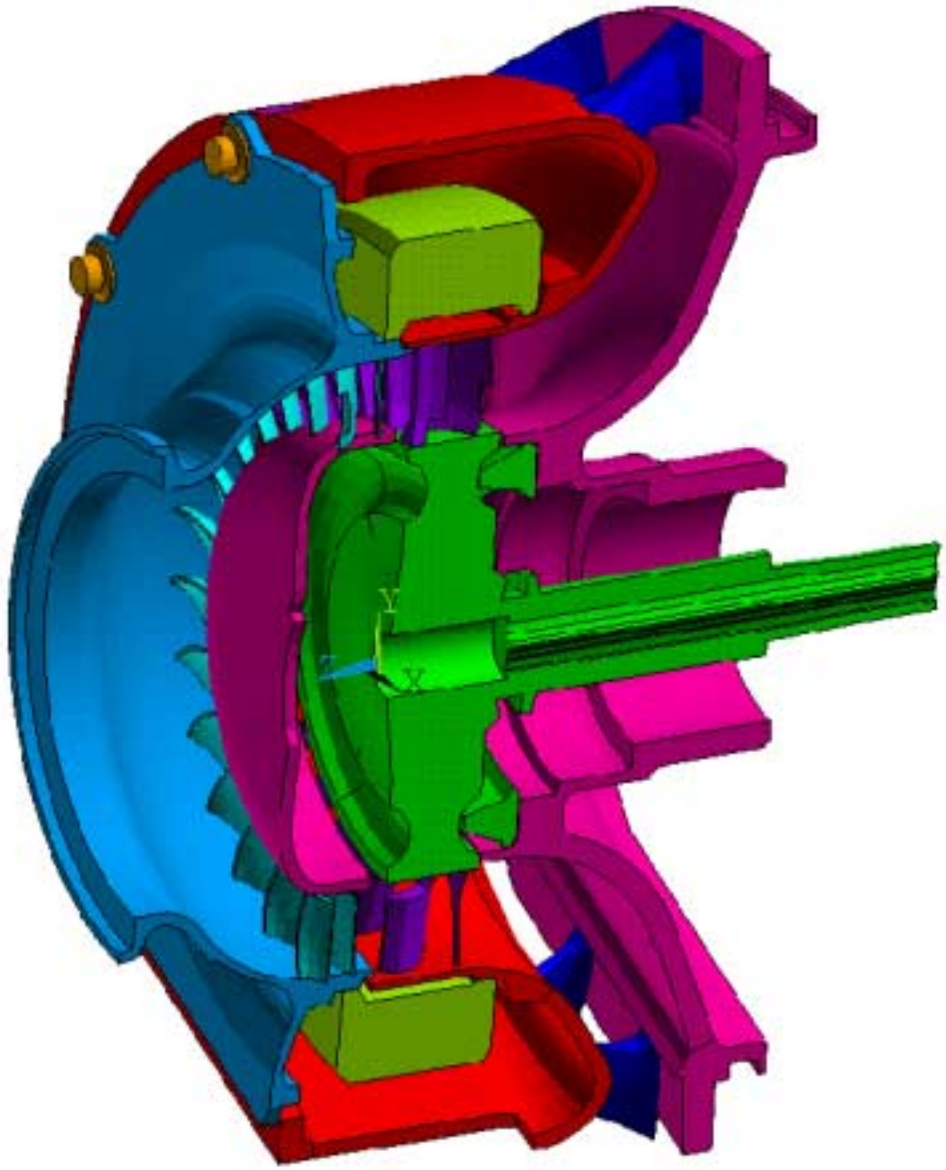
- Too many options under each item, but none of them general enough.
- Not Well-Documented.
- Limited Existing Experience.
- Numerical Instability for Complicated Models.

Experience - Fan Blade-Out

- **Parts Modeled**
  - Containment
  - Case
  - Front Frame
  - Bearing
  - Dummy inertia and mass
- **Purpose**
  - Provide guide line for design of containment.
  - To test the modeling capability.
  - To test how much the program can handle
  - To test how much detail is necessary
- **Simulation Result (see the animation).**

Experience - Tri-Hub Burst Containment

- **Parts Modeled**
  - **All major parts**
- **Purpose**
  - **Understand the possible failure mode of tri-hub burst, and prevent it.**
  - **Understand the reason of failure.**
  - **Optimize the containment system.**
- **Simulation Result (see the animation).**



Experience - Tri-Hub Burst Containment

- Parts Modeled
  - All major parts
- Purpose
  - Predict/match the test result.
  - Provide design guide line for the containment system.
- Simulation Result (see the animation).

Experience - Crashworthiness Optimization

- Challenges
  - An almost whole new research area - just began active recently.
  - Instability of the explicit FEA tool is difficult to handle.
  - Intensive computational time.
- Achievement
  - Successfully apply numerical optimization techniques to some problems.
  - Sizing optimization provide 20% to 30% weight reduction against the imperial formula.
  - Matched well with the test.

Current Capability

- High Confidence on Most of the Containment System Hub-Burst/Fan Blade-out Event.
- High Confidence on Capturing Complicated Interactions Between Parts (Usually Considered Very Difficult).
- Experience on Reverse Engineering for Existing Events (Usually Considered Very Difficult).
- Able to Model Some Details (Usually Considered Very Difficult).
- Able to Debug Numerical Instability (Usually Considered Difficult).
- Robust Internal Standard Process and Growing In-house Program Libraries.

Further Plans and Goals

- More Types of Material Failure Modeling (Ex., Brittle, Composite…)
- Extend to More Disciplines and Physical Phenomena.
- Post-Impact Simulation.
- Shaping Optimization.
- Hardware/Material Defects.
- Reverse Engineering.
- Better Interface (Pre- and Post-Processing).

- Looking for More Application and in More Fields.

Further Contact Information

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Return to Agenda