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

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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.

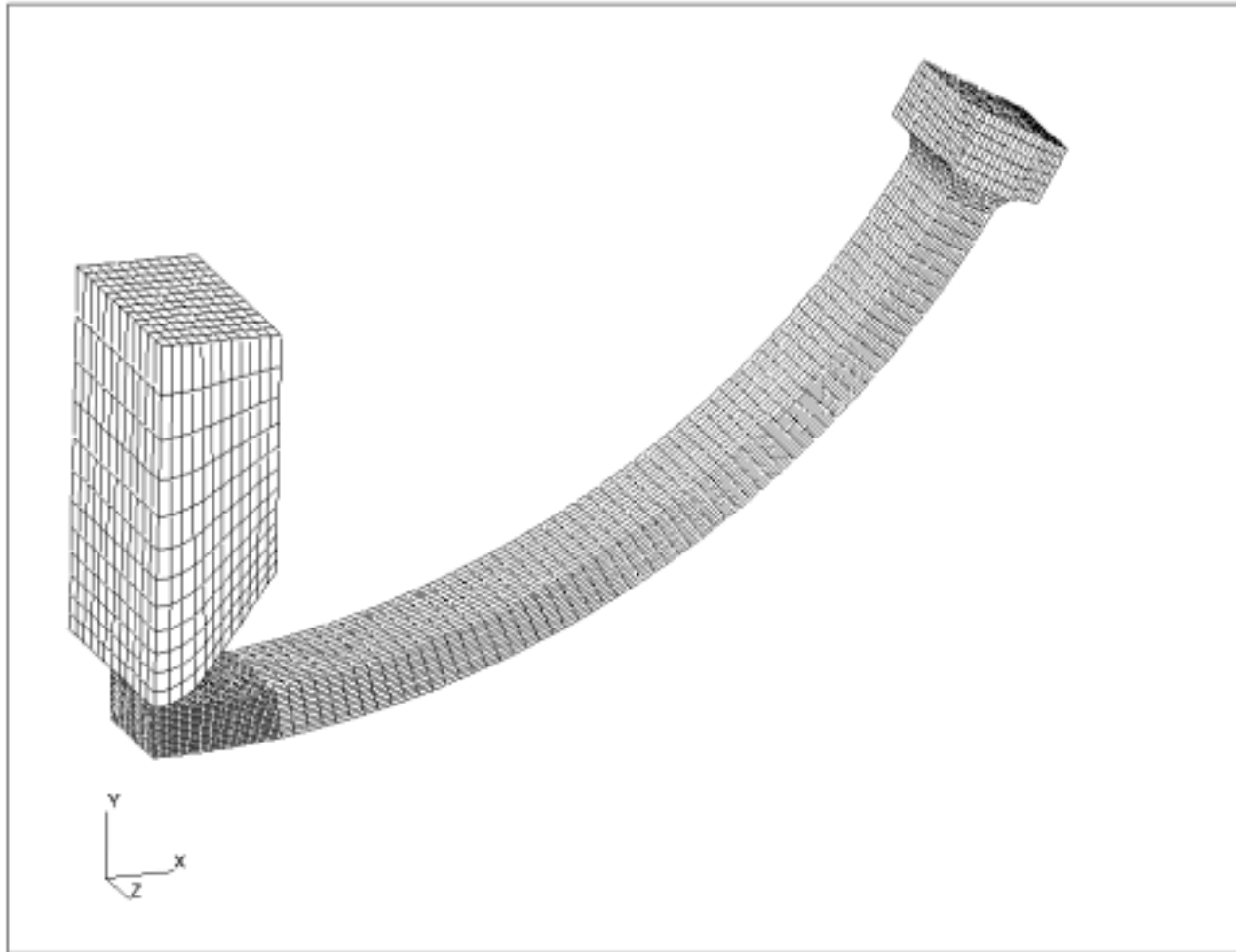
- **Goal**

- 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.

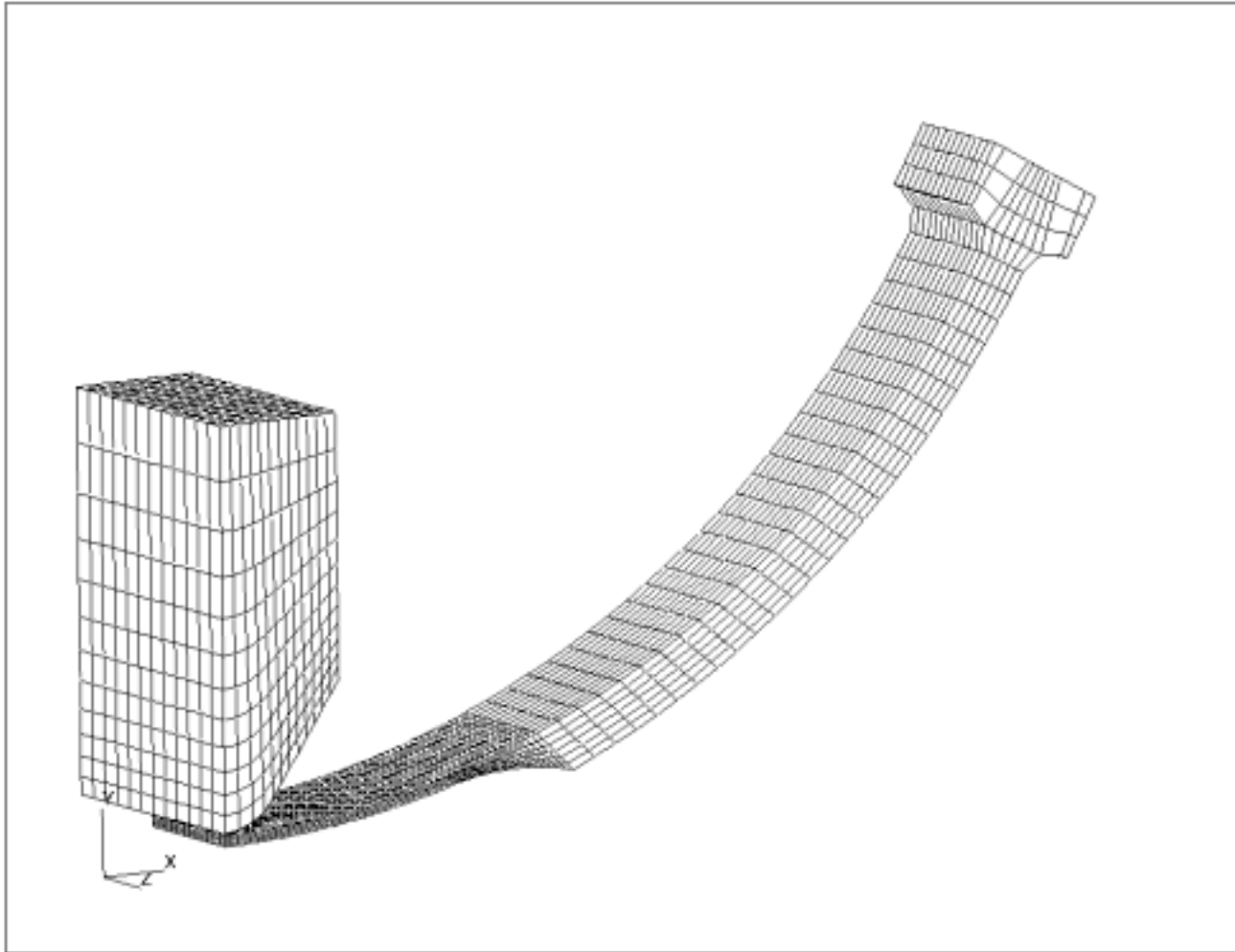
Geometry and The Model (1)



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.

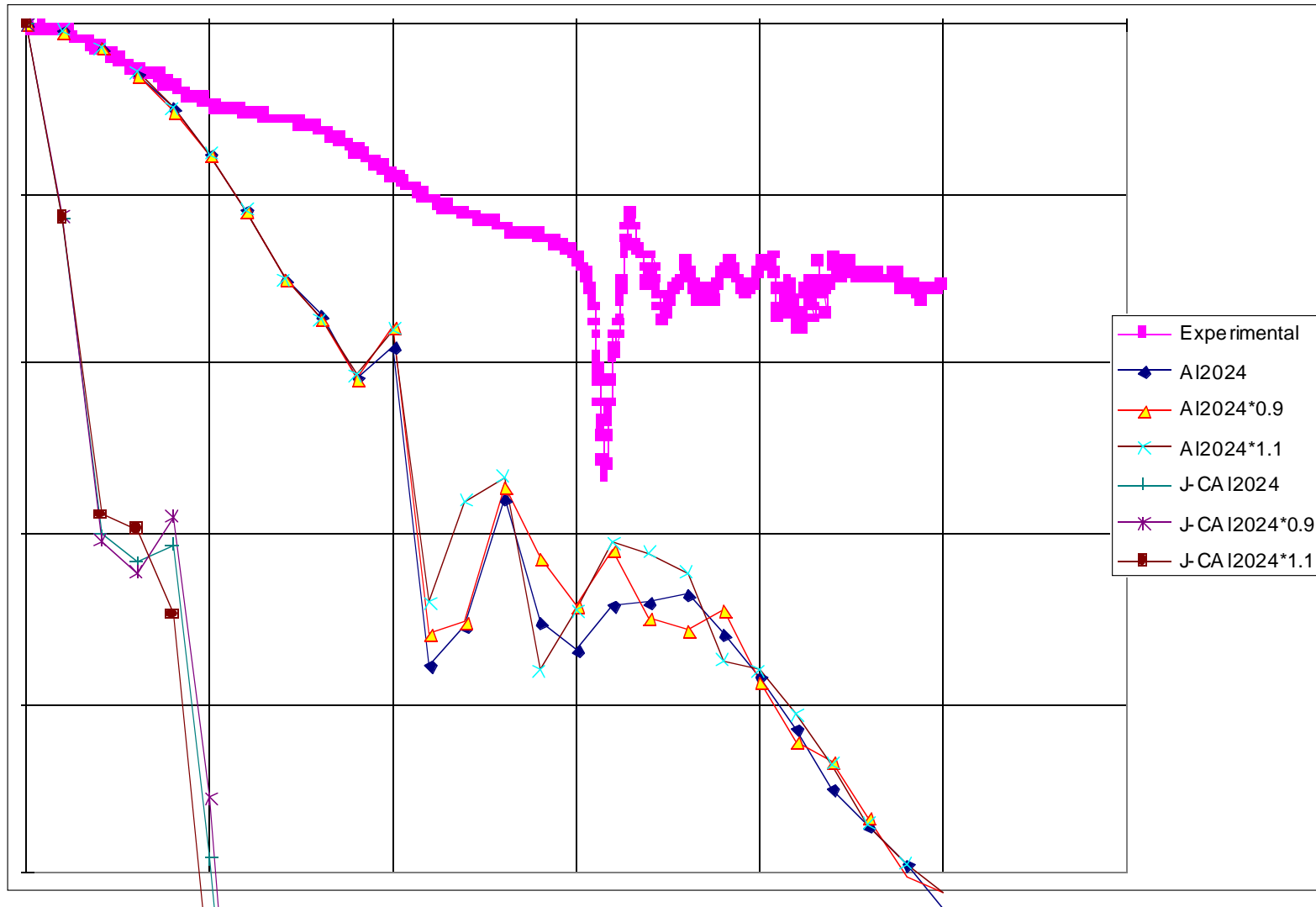
- **Correlation Between Test and Numerical Simulation**

- 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.

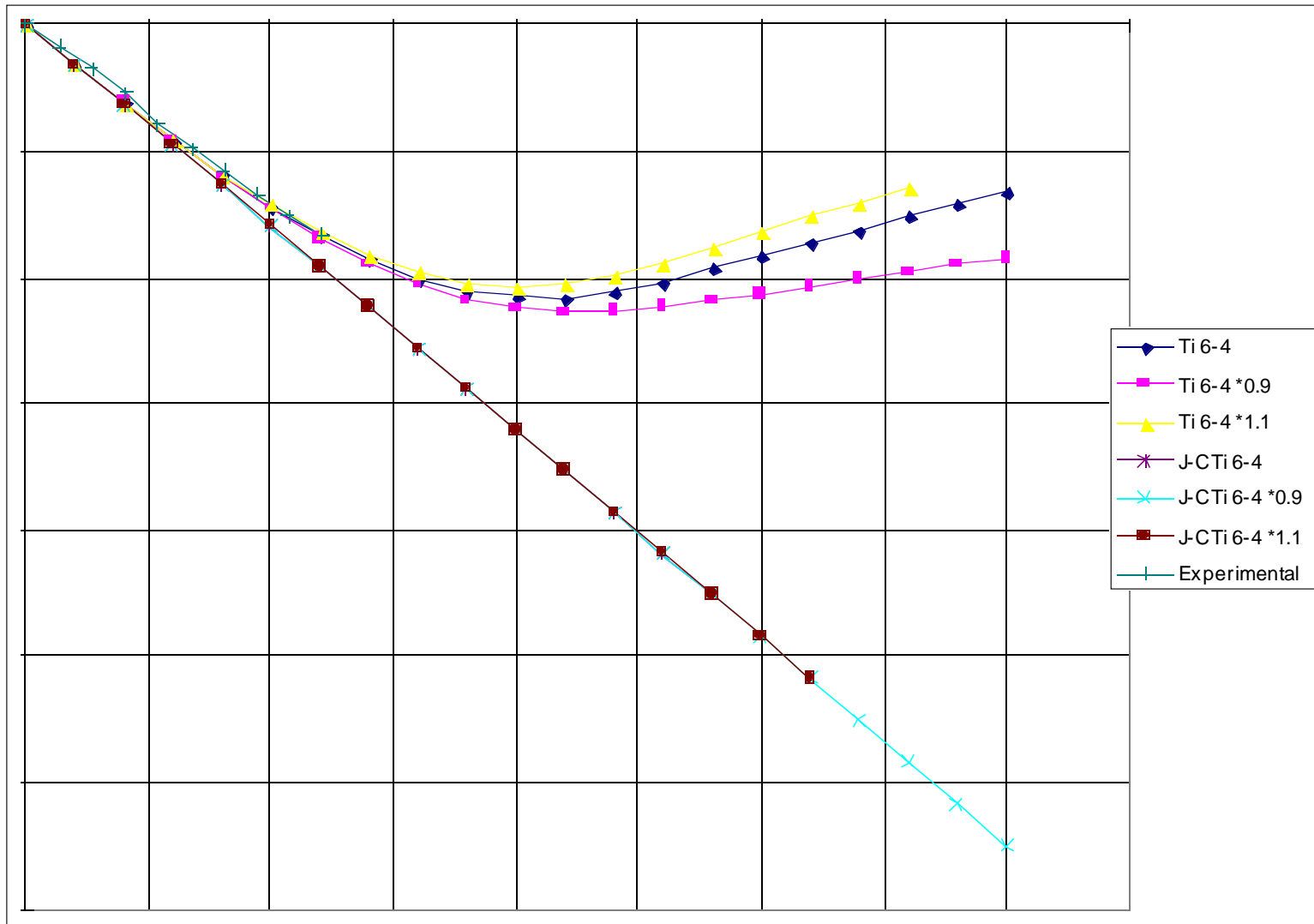
Example Data from the Test (1)



Thick Al Specimen. Strain VS Time

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Example Data from the Test (2)



Thick Ti Specimen. Displacement VS Time (Bounced Back)

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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.

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General Experience on the Explicit FEA

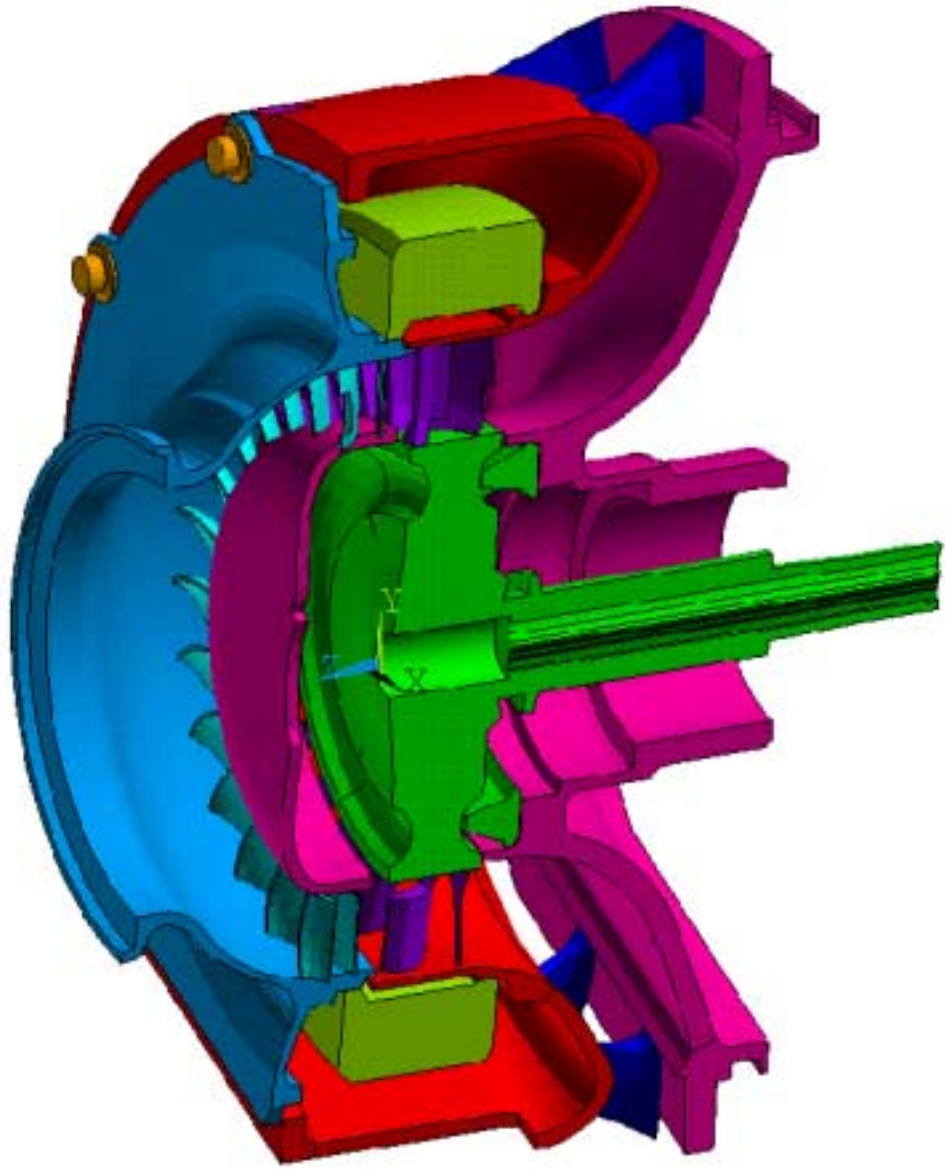
- **Too many options under each item, but none of them general enough.**
- **Not Well-Documented.**
- **Limited Existing Experience.**
- **Numerical Instability for Complicated Models.**

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.**

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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).**
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- **Looking for More Application and in More Fields.**

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