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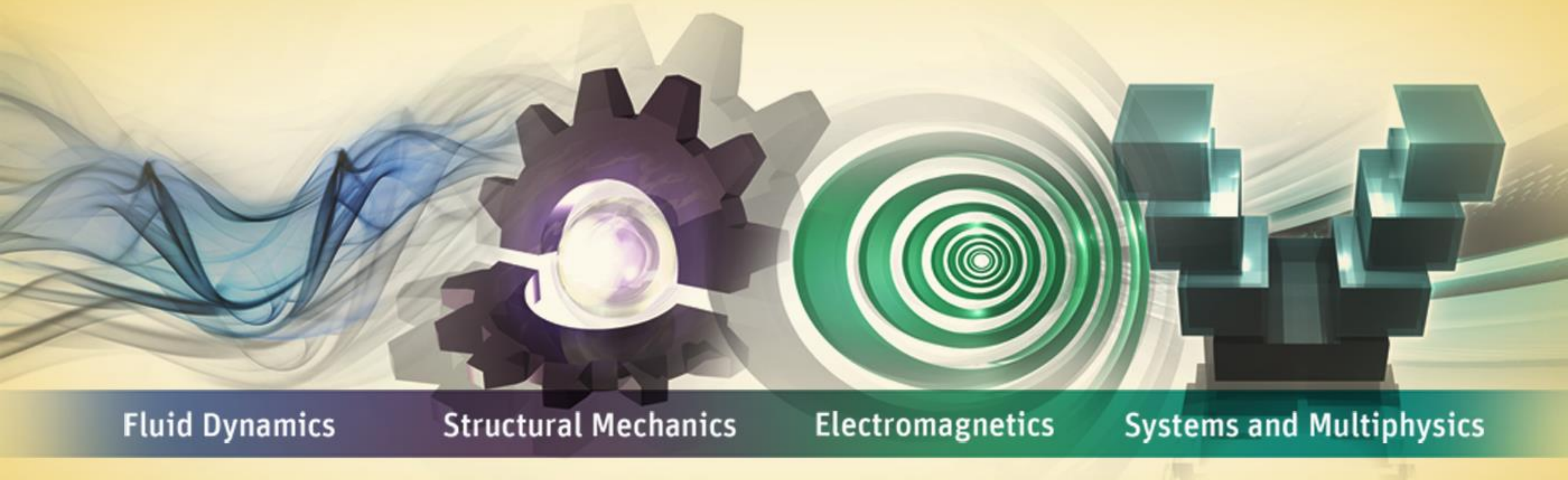
Explicit Drop Test and Submodeling with ANSYS LS-DYNA



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Contents & Abstract

A consumer electronics drop-test case study is presented to demonstrate a methodology to rapidly obtain high-accuracy results from an explicit analysis using submodeling. Global/local models of a mobile electronic device with a BGA package are prepared within the Workbench environment (for LS-DYNA export), then solved and post-processed with LS-DYNA.

Introduction

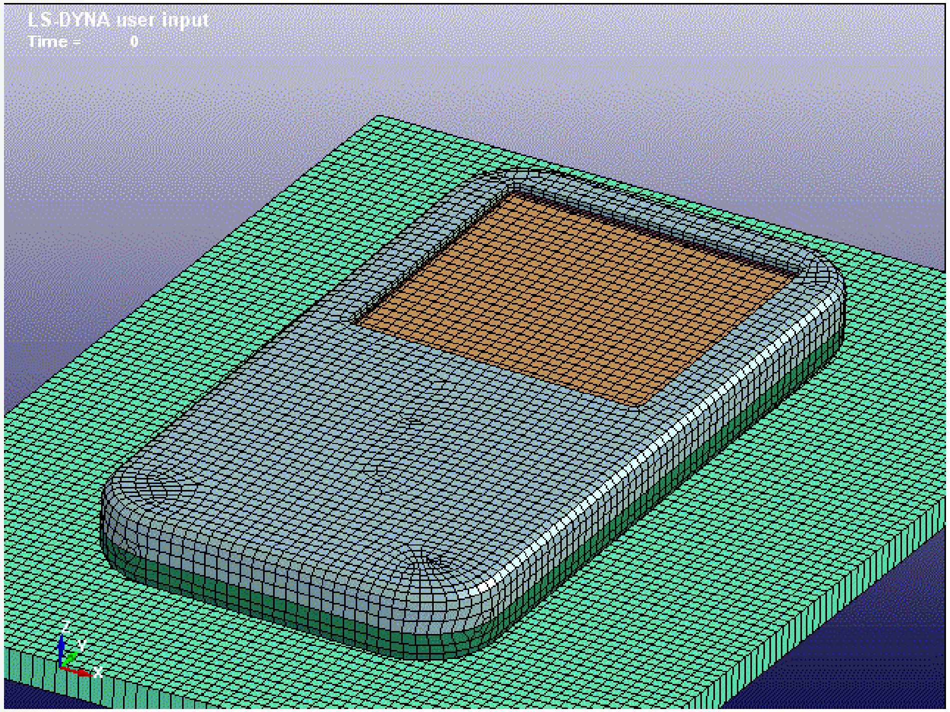
- The purpose of this presentation is to provide the audience with:
  - Basic workflow in performing an explicit analysis with ANSYS LS-DYNA for Workbench
  - Background and tips on explicit modeling features
  - Detailed information on submodeling with LS-DYNA
- Content is targeted towards engineers who are already familiar with ANSYS implicit structural analysis, and looking to implement advanced explicit structural analysis.

ANSYS LS-DYNA

- Explicit Dynamics is a solution method used to simulate short-duration highly-nonlinear structural events.
  - Examples: Drop impact, metal forming, car crash, explosions
  - Features: Erosion, ALE, automatic contact, failure
- ANSYS LS-DYNA for Workbench leverages convenience and advanced capabilities of ANSYS Workbench to prepare analyses for LS-DYNA.
  - A majority of the engineering effort associated with explicit dynamics is devoted to geometry preparation and meshing.
  - Access to full range of Workbench features including DesignModeler, FE Modeler, parameterization, bi-directional CAD, coupled physics
- The LS-DYNA solver offers submodeling – a powerful and relatively new capability for the explicit solver.
  - A majority of non-engineering time with explicit dynamics is typically devoted to solution processing.
  - Submodeling compresses the processing requirements to obtain detailed results at specific locations within the assembly.

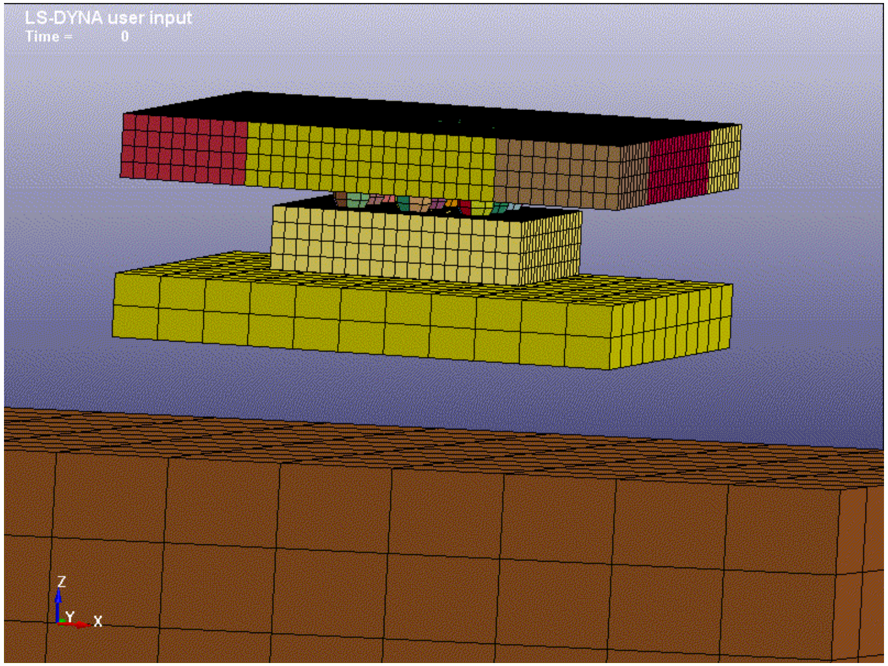
Description of Problem

- A mobile device experiences failure in electronic components caused by drop impact.
- Simulate to assess damage to solder joints in the BGA package.
  - Follow-up to evaluate design revisions
- Need accurate results quickly!
  - ANSYS LS-DYNA for Workbench with submodeling
- Submodeling technique is employed
  - First solve global model for the entire mobile device assembly
  - Second solve local model for the BGA package on PCB



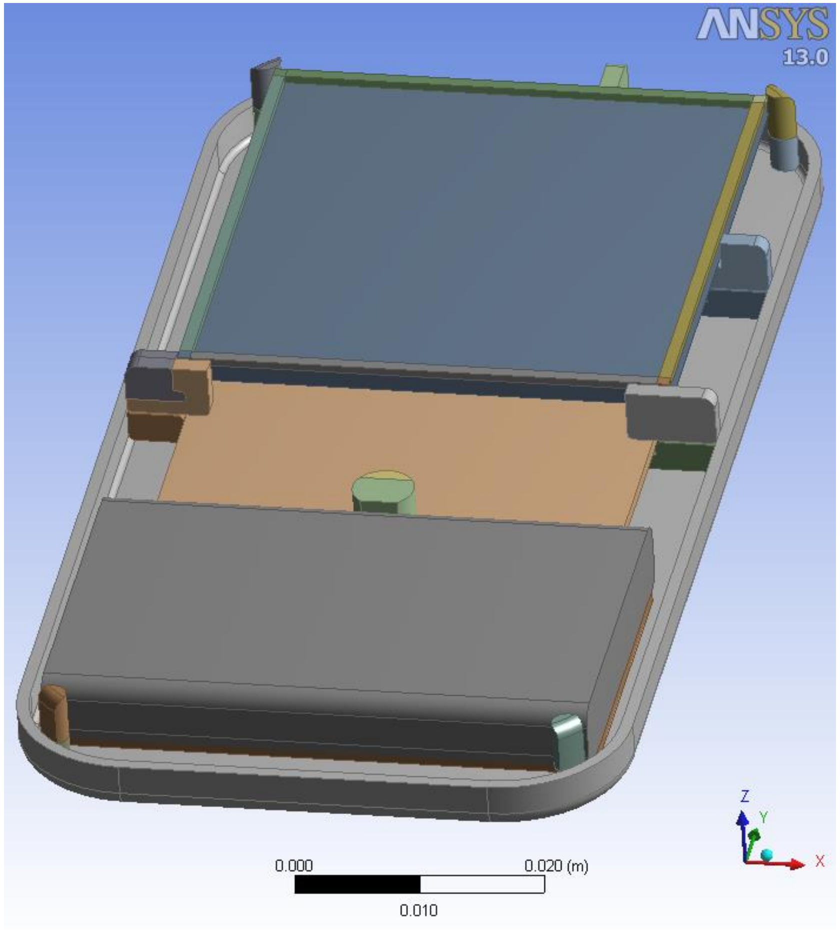
Simulation Workflow

1. **Geometry**: Import CAD and prepare for analysis using ANSYS DesignModeler.
2. **Meshing**: Discretize for explicit using ANSYS Meshing.
3. **Setup**: Prepare the analysis using ANSYS Explicit for LS-DYNA.
   - Materials
   - Contacts & Connections
   - Solution settings
   - Command Objects
4. **Solve & Results**: Obtain the solution using LS-DYNA solver and review results using LS-PrePost (or /POST1).



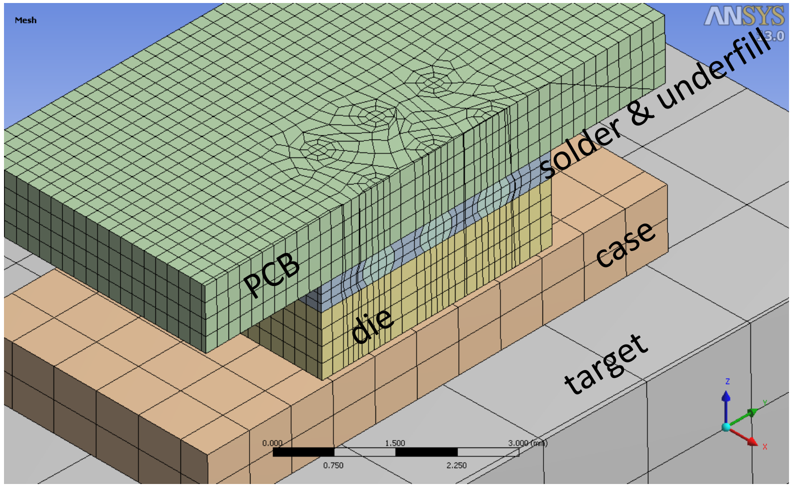
Geometry Preparation

- Geometry modifications are not required, but offer a high ROI for solution accuracy & time.
- Slice to enable sweep meshing
  - Ribs are separated from the case, and interact via contact.
- Slice to enable top-quality elements
  - Important in thin components and critical regions (silicon, foam adhesive)
- Group multi-body parts to reduce contact requirements.

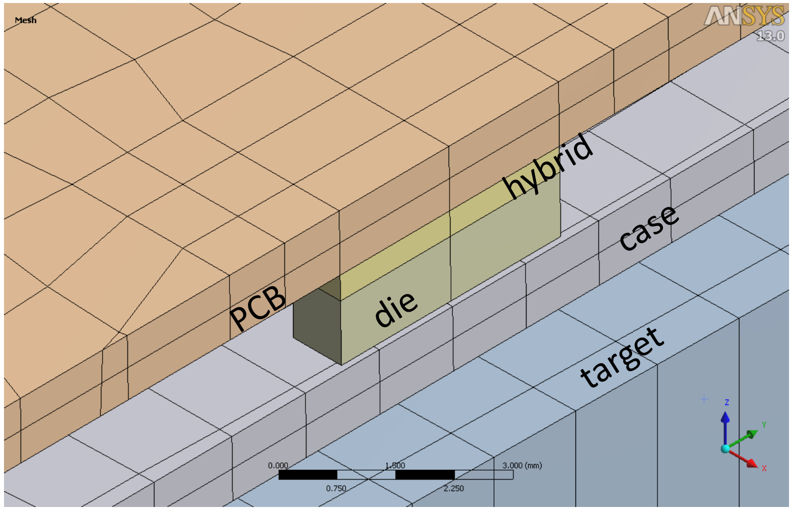


Geometry – Local vs. Global

- Local & global features are included in the geometry, and suppressed in DesignModeler as required.
- The global model substitutes a volume-averaged hybrid BGA/underfill region with equivalent properties.
- Note that the submodel includes part of the case and target because of contact interactions.



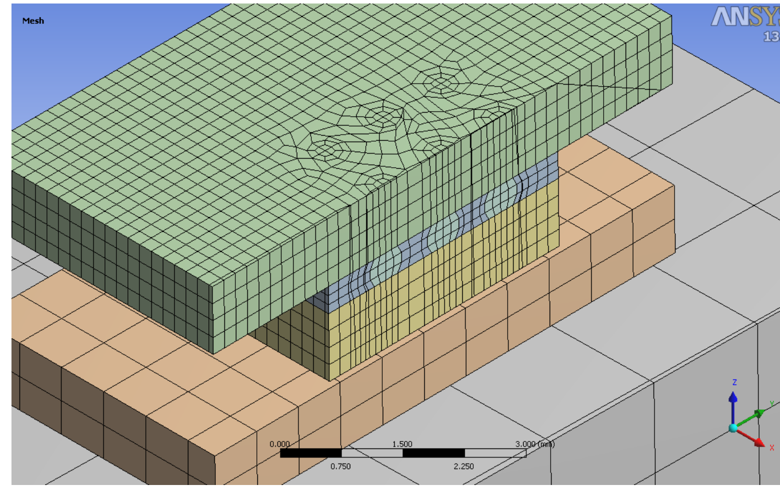
Densely meshed local model.



Coarsely meshed global model.

Meshing – General Considerations

- Smallest element typically controls the solution timestep
  - Based on time for a shockwave to cross through the element.
- Preferred meshing methods:
  - Swept hex (more efficient/accurate)
  - Patch independent low/high order tet (quick, easy, no hourglassing)
  - Multizone hex (flexibility)
  - Avoid hex-dominant (poorly shaped and pyramids)
  - Avoid patch-dependant tet (poorly shaped)

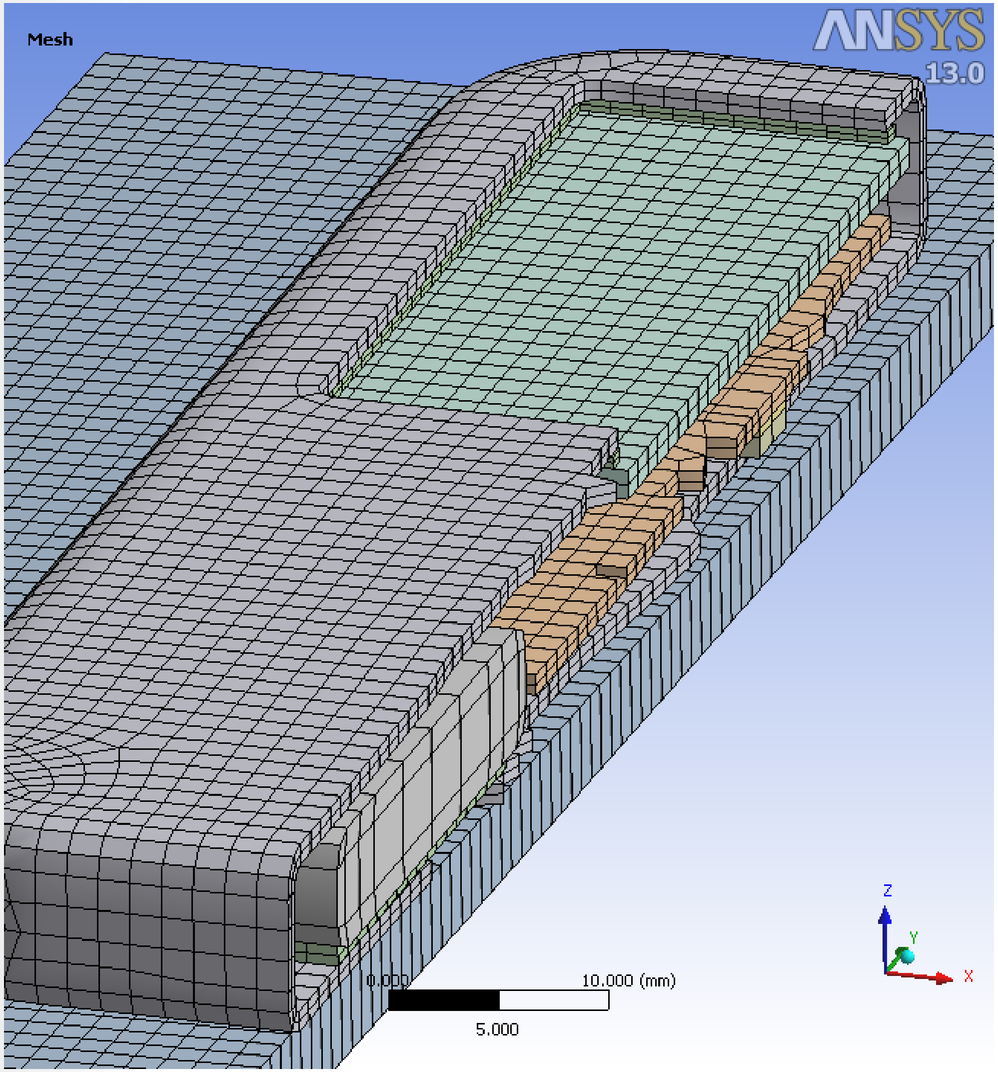


$$\Delta t \le \frac{l}{c} = \frac{l}{\sqrt{E/\rho}}$$

Where:
l is element characteristic dimension
c is the material speed of sound
E is Young's Modulus
ρ is the material density

Meshing

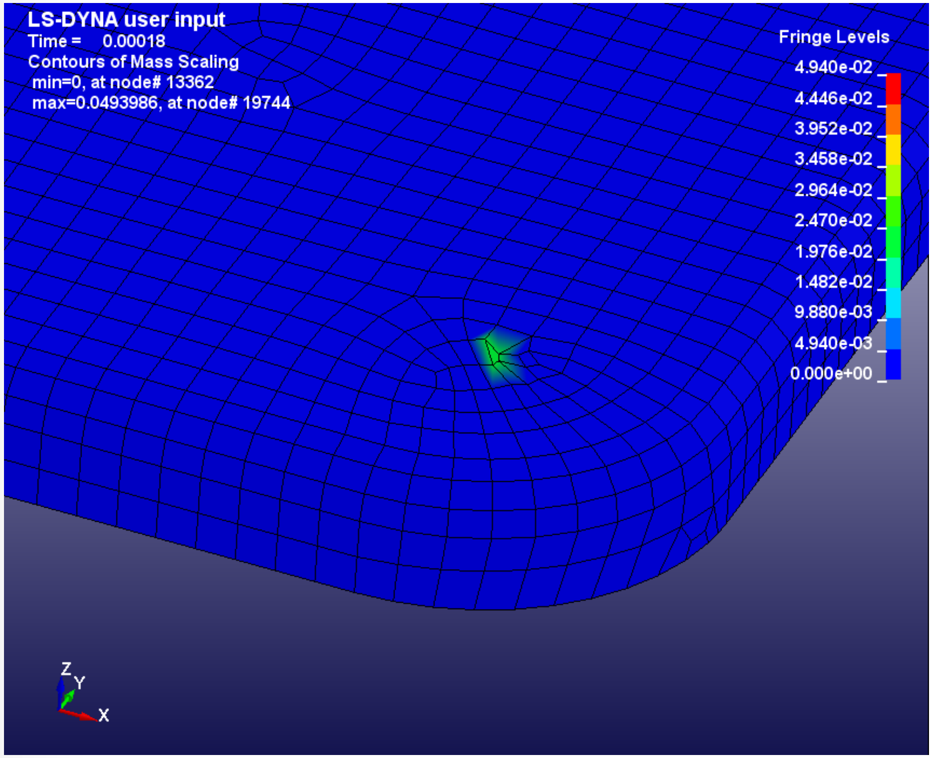
- Uniform mesh sizing is desirable in regions of interest
  - Enlarged mesh size in non-critical parts (battery).
- Swept hex mesh on thin parts (case): Method -> Sweep -> Automatic Thin -> All Quad -> # Divisions
- “All Quad” setting enables fully-integrated hex formulation (in case of hourglassing). No prisms.
- Mass Scaling should be considered during the meshing/solution process.
  - Identify mesh features that can be improved to reduce mass scaling effects.



  April 21, 2021

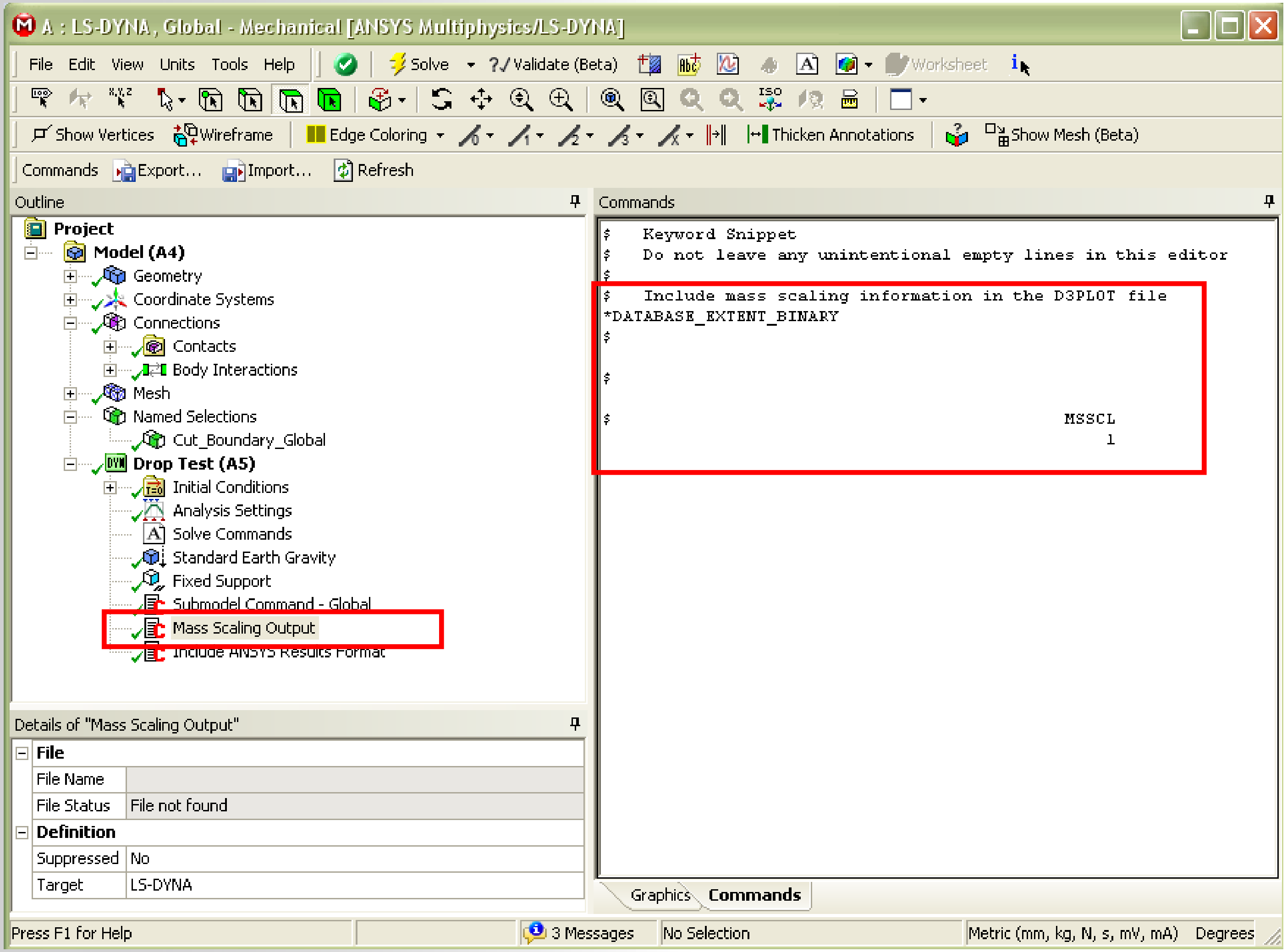
Mass Scaling

- Mass Scaling is a powerful tool to speed-up solutions
  - Increase minimum time step by artificially increasing density
  - Applicable to poorly shaped elements
  - Users discretion in evaluating validity
- Extend the D3PLOT database to include Mass Scaling & Timestep informaiton
  - Insert an LS-DYNA Command Object
  - Review graphically in LS-PrePost
- Alternate - Review MATSUM and GLSTAT text output files



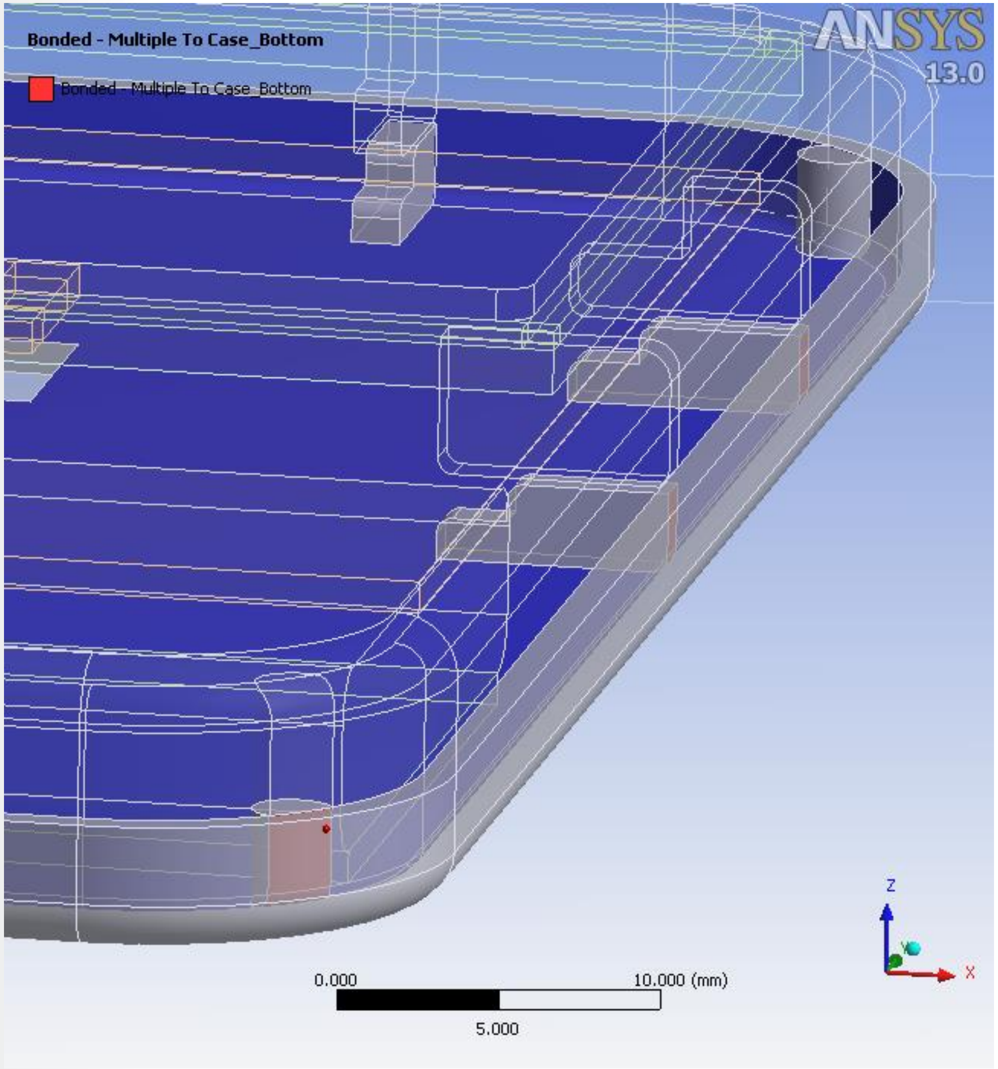

```
$   Include mass scaling information in the D3PLOT file
*DATABASE_EXTENT_BINARY
$

$

$                                                   MSSCL
                                                        1
```

Command Objects



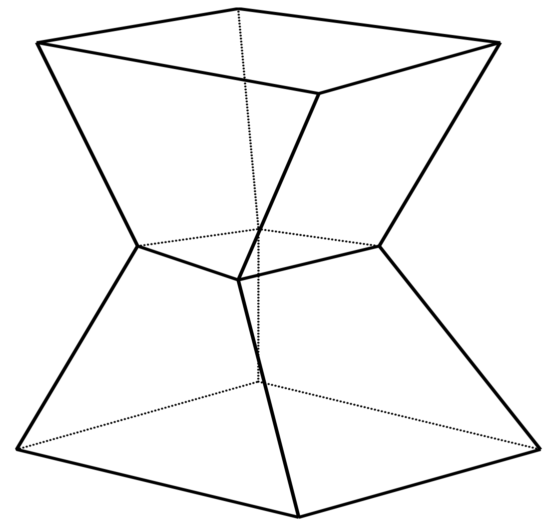
Connections

- Bonded "Contacts" account for uniform parts that were split during geometry operations to facilitate meshing.
- "Body Interactions" include automatic generalized contact
  - Also self contact
- Separate body interaction objects can be scoped to components that will contact.
  - Improve efficiency for large assemblies.
  - Example: Chip will never contact the target platform.



Element Formulation

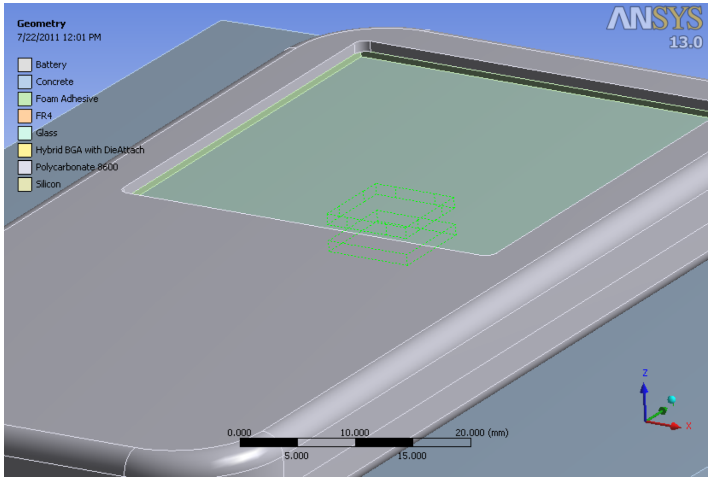
- Preliminary results show significant error associated with hourglass energy.
  - Hourglass modes are non-physical, zero-energy oscillations. Result from point loading.
  - Problematic for default hex elements.
  - Review MATSUM & GLSTAT files to verify that hourglass energy is small relative to internal energy
- Default methods to control hourglassing include: viscous and stiffness damping controls
  - mesh refinement, non-point loading
- Convert hex element type
  - Type 1 (default single-point integration hex element) → Type 2 (fully-integrated hex element)
  - Not susceptible to hourglassing
  - Increased solution time, increased accuracy
  - Apply selectively
- Modify the LS-DYNA keyword (.K) file for each applicable hex element type.

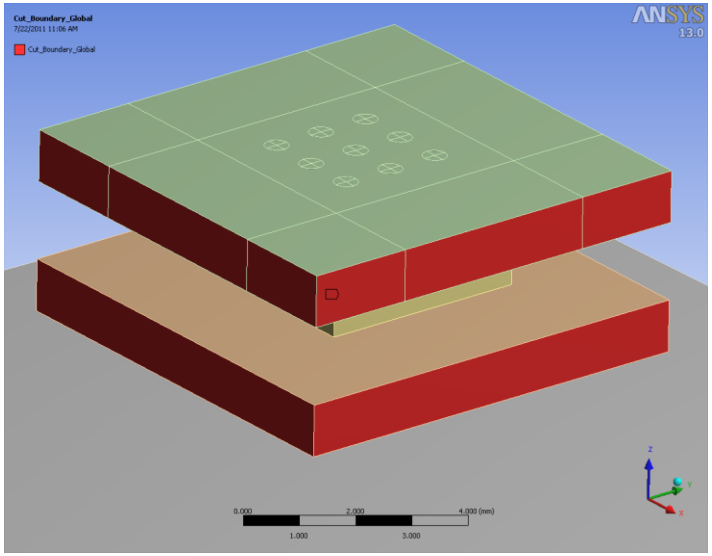


```
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$                    SECTION DEFINITIONS             $
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
*SECTION_SOLID
$  1SECID  2ELFORM    3AET
     1      13     → OK, tet elements
*SECTION_SOLID
$  1SECID  2ELFORM    3AET
     2      1      → 2
```


Submodeling in LS-DYNA

- ‘Component Analysis’ in LS-DYNA is analogous to ‘submodeling’ in ANSYS
- Efficient method for simulating detailed response of a local section within a larger structure.
- The global model is discretized to capture sufficiently accurate displacements at the cut boundary.
- The local model is discretized to sufficiently resolve results of interest.
- User can apply multiple local models
  - Multiple levels of “sub-submodel”
  - Multiple detailed component locations within a global model

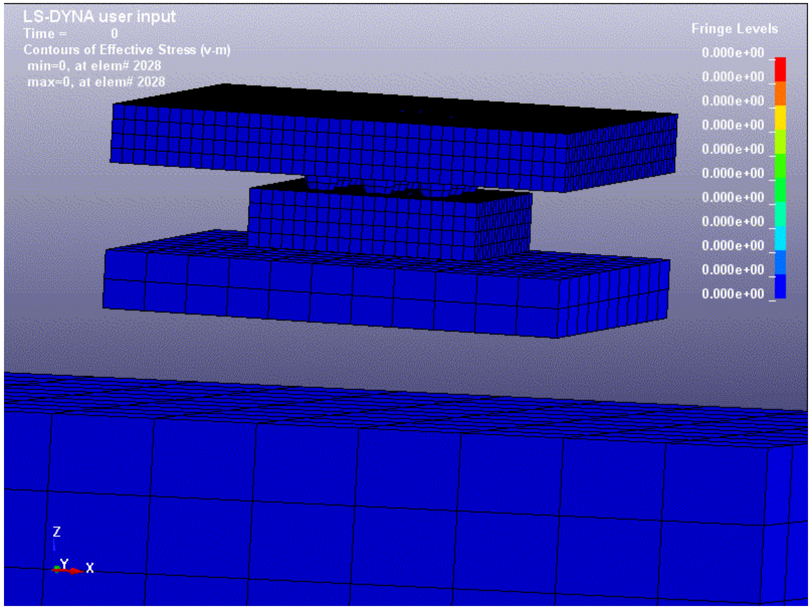




Reference “Introduction to LS-DYNA: Component Analysis”

Submodeling Boundary Conditions

- Motion from the global model drives the local model.
  - Additional loads must be specified if they are not transmitted through the cut boundary interfaces – e.g. gravity.
- Recommended to output cut-boundary data at each timestep.
- Exercise engineering judgement to ensure that changes between local/global models do not affect motion at interfaces.
  - Hybrid material → Solder Balls + Underfill
  - Include contacting components



Submodeling Steps & Commands

- Global model
  - Named Selection at “cut boundary”
  - *INTERFACE_COMPONENT command object
  - Execute solution with z=DataFilename

```
$   Define GLOBAL cut boundary condition
*INTERFACE_COMPONENT_SEGMENT
$#    ssid
         2
$
$ SSID identifies segment in .K file corresponding to
$     the cut boundary named selection.
```

```
Solve global, Identify database to write (z=):

cd C:\Work\ProjectName_files\dp0\SYS-1\MECH
ls971.exe pr=DYNA i=LSDYNAexport.k z=Global_Cut_Results
```

- Local model
  - Named Selection at “cut boundary”
  - *INTERFACE_LINKING command object
  - Execute solution with l=DataFilename

```
$   Define LOCAL cut boundary condition
*INTERFACE_LINKING_SEGMENT
$#    ssid      ifid
         2         1
$
$ SSID identifies segment in .K file corresponding to
$     the cut boundary named selection.
$ IFID identifies the appropriate section of cut
$     boundary data to use (in case multiple cut
$     boundaries are written to the output file).
```

```
Solve global, Identify database to read (l=):

cd C:\Work\ProjectName_files\dp0\SYS-2\MECH
ls971.exe pr=DYNA i=LSDYNAexport.k l=Global_Cut_Results
```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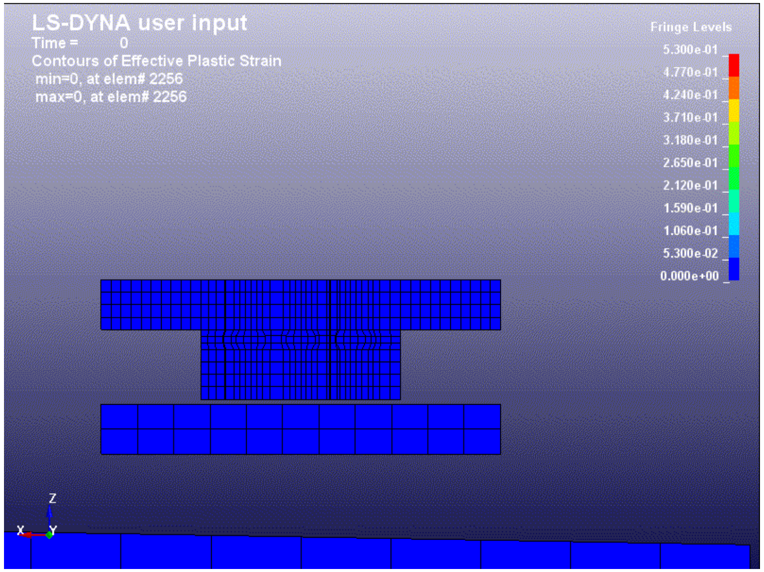
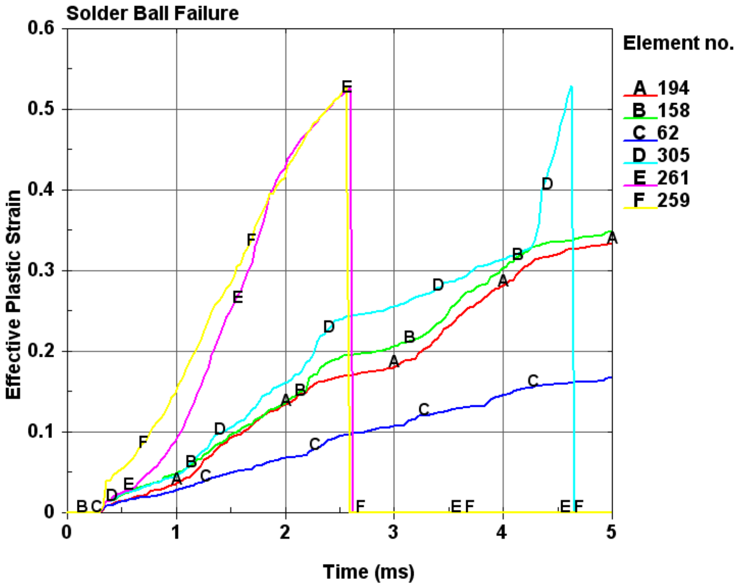
Results

- Solve times:
  - Parallel on 7 CPUs @3GHz
  - Global = 15 minutes
  - Local = 200 minutes

- Solder balls are predicted to fail for this drop condition.
  - Criteria: maximum plastic strain
  - Solder material erosion is visible in the cut-view animation.





  April 21, 2021

Summary

- This presentation has demonstrated how ANSYS products & technology can be used to characterize drop test performance of a mobile electronic device.
- These results show that ANSYS LS-DYNA submodeling techniques can be employed to rapidly and accurately obtain structural solutions for detailed components within complicated assemblies that experience short-duration, highly-nonlinear loading.

Notes

- Special thanks to Stefano Mazzalai for providing technical expertise in implementing submodeling with LS-DYNA.

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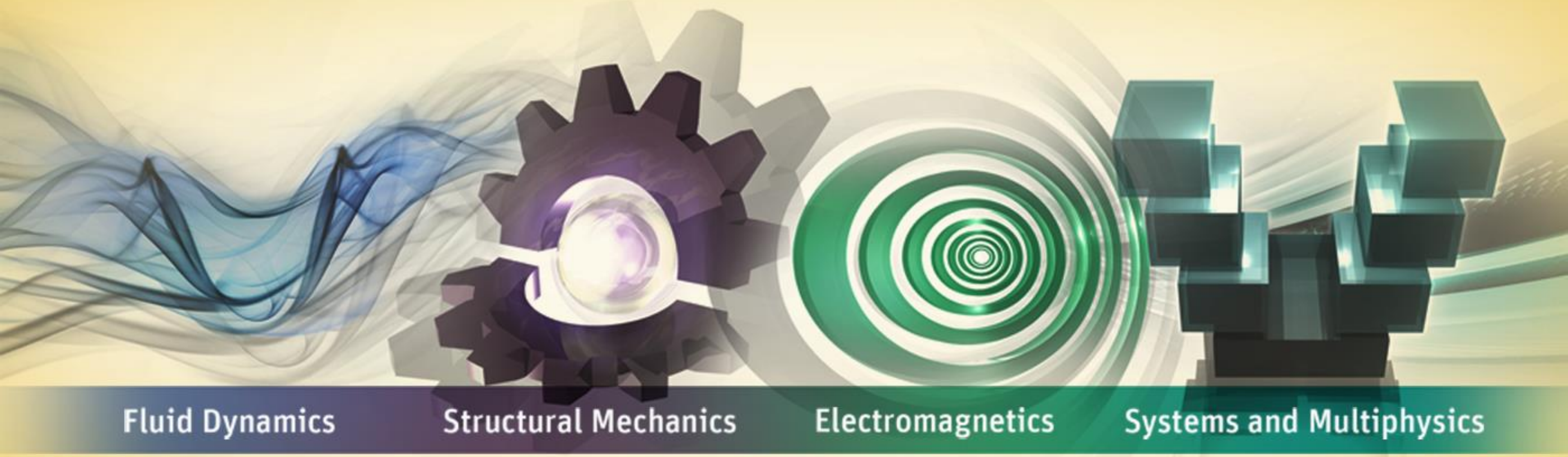
QUESTIONS ?

Thank you for your attention



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