Drop and Impact of Mobile Telephone

Jason Mareno
Sr. Applications Engineer
Mallett Technology, Inc.
Research Triangle Park, NC

Analysis Goals

- Survive everyday drops
  - Routine drops from 0.5 to 1.7 meters
  - Various Impact orientations
- Design Cycle – Time is Critical!
  - Typical product life cycle of only 12 months
  - Each week late corresponds to enormous loss
  - Balance risk and reward
- *Develop a technique that can provide accurate predictive data in a timeframe consistent with the needs of the rapid development cycle.*

Analytical Challenges

- Complex assembly of many components
  - Component interaction: rigid links, constraints, contact, etc...
  - Small, intricate, and delicate components; accurate yet efficient mesh is required
  - Large deflections and many contact interfaces; nonlinearities abound

- *Develop a technique that can provide accurate predictive data in a timeframe consistent with the needs of the development cycle.*

Failure Modes

- Majority of failures occur when one component moves/deforms further than anticipated and unexpectedly collides into another component
  - Exterior housing deflects so far that it crushes a delicate antenna contact
  - Protective frame around LCD transmits significant forces to glass display
  - Circuit board deflects so far that solder joints are cracked
- *Highly accurate stress calculations not required; only an accurate representation of deformed shape versus time*

Analytical Goal

- Quickly and accurately predict component interaction and deflection.

- Global model must quickly predict "what will hit what" and "how far things will bend"

- If needed, use submodels to calculate stresses as necessary.

- *The mesh must represent stiffness accurately, and stresses approximately.*

Time Integration Scheme

- Explicit integration is required for impact – the "knee jerk" response

- Explicit method:
  - High-quality, structured mesh
  - Critical timestep dependent upon element size
  - Tiny features and complex geometry drive both modeling and solution time
    - Tetrahedrons decrease timestep by ~3.8X
    - Widespread mass scaling not valid option

- Successful, but takes too long (modeling time)

Time Integration Scheme

- Implicit method:
  - Tetrahedrons and small elements do not affect timestep size
  - High order elements
  - Longer solution, but less modeling (~3 weeks)
 - Increased debug time

Typical, contemporary mobile phone

Event Characterization

- Contemporary phones typically maintain contact with the floor for two to three milliseconds and resonate with significant amplitude for up to three milliseconds during rebound. *Total event duration is estimated at six milliseconds.*

- For component-level tests, industry-standard shocks are half-sine, up to 2900 multiples of gravity (G), and as short as 0.3 milliseconds in duration.

- Shock waves on the order of 1.7kHz (0.6 msec period) can be anticipated in the circuit board during an assembly-level drop test.
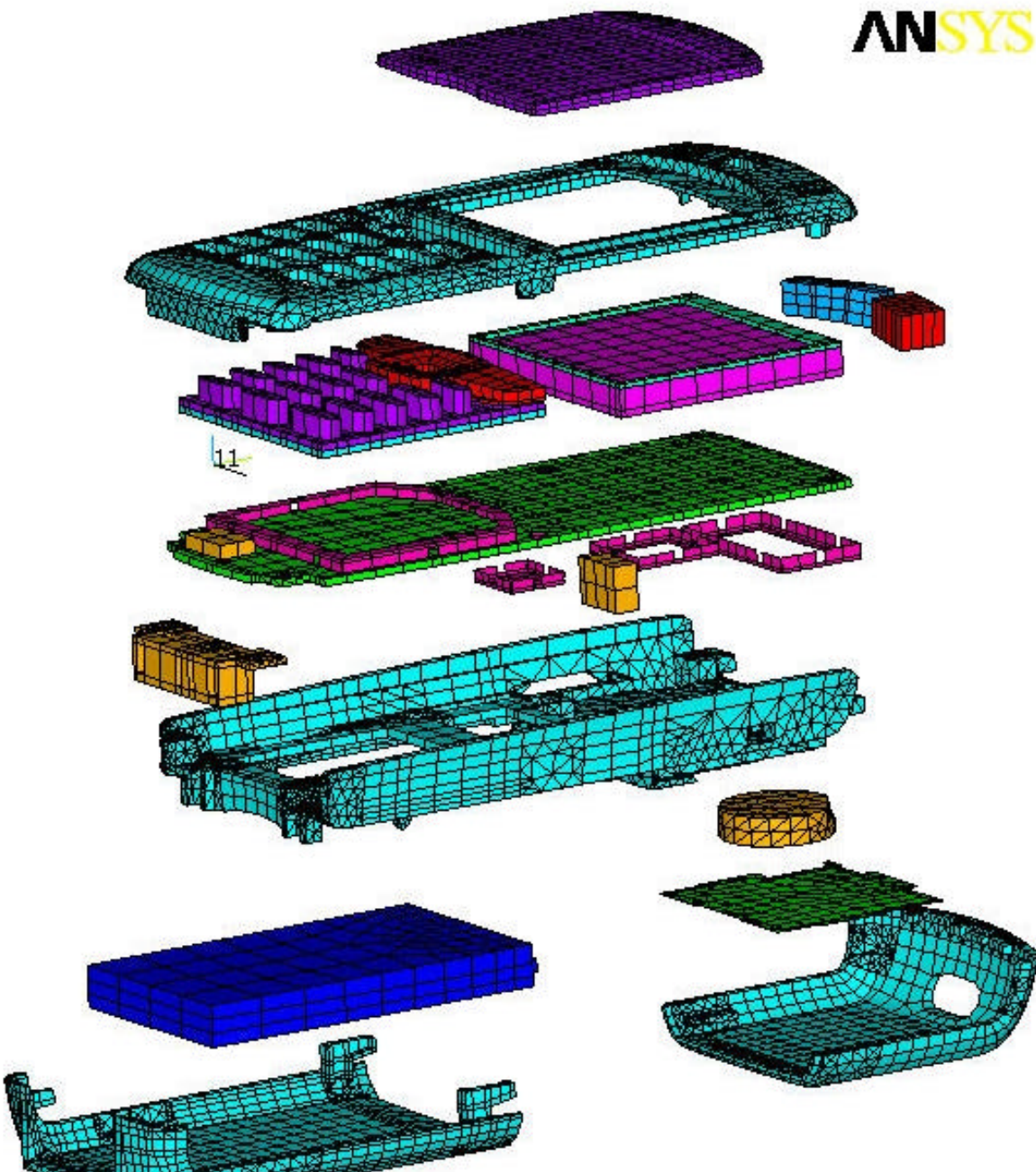
- 19 solid bodies

- Bond via shared nodes wherever possible, e.g. screw joints

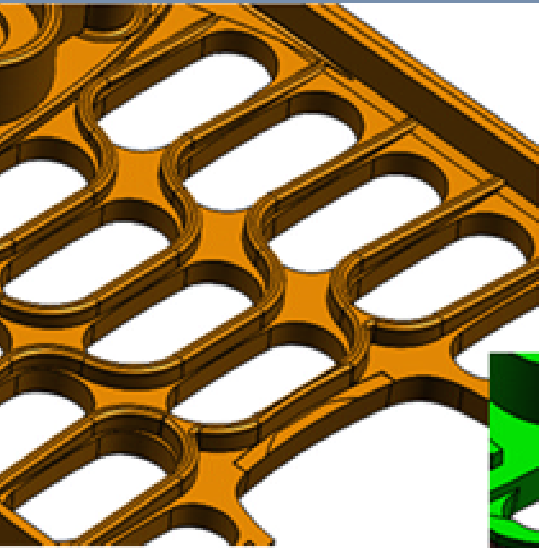- Quasi-rigid links (beams where needed

- 55 contact interfaces
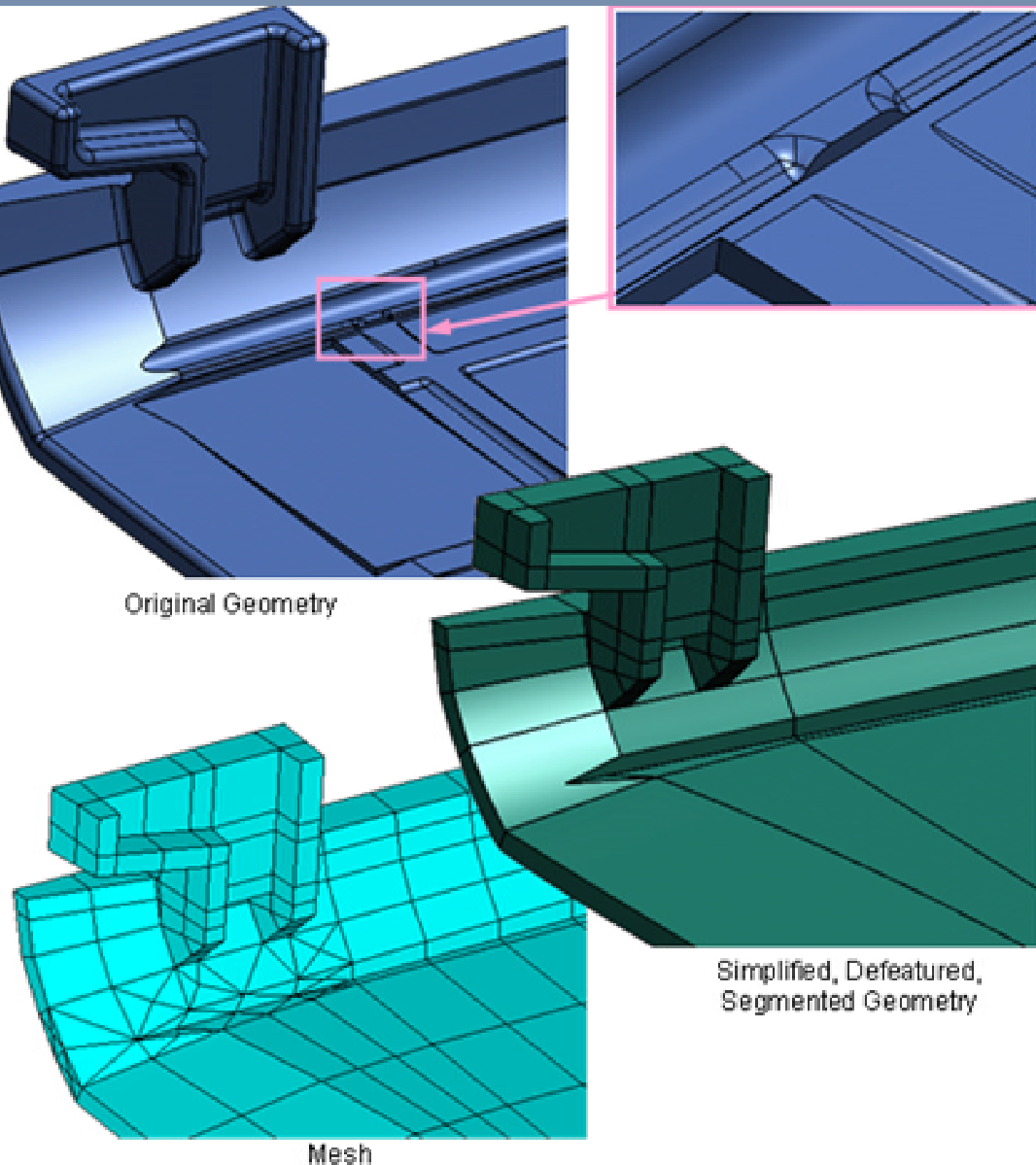
Original Geometry

Simplified, Defeatured,
Segmented Geometry

Mesh

Battery Cover

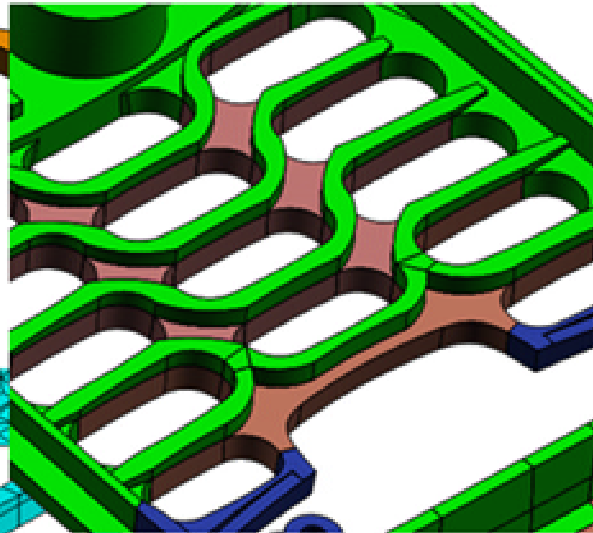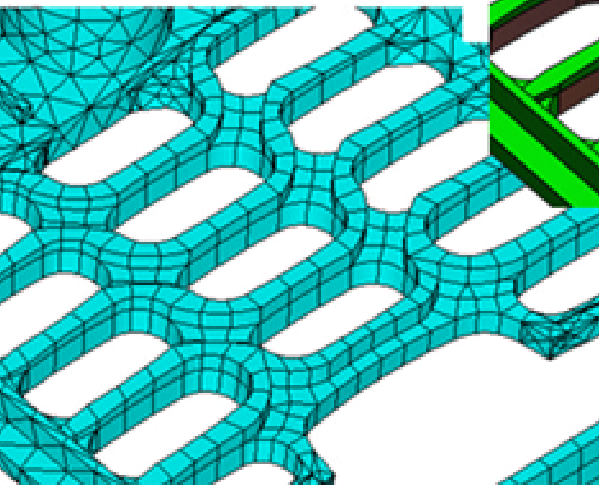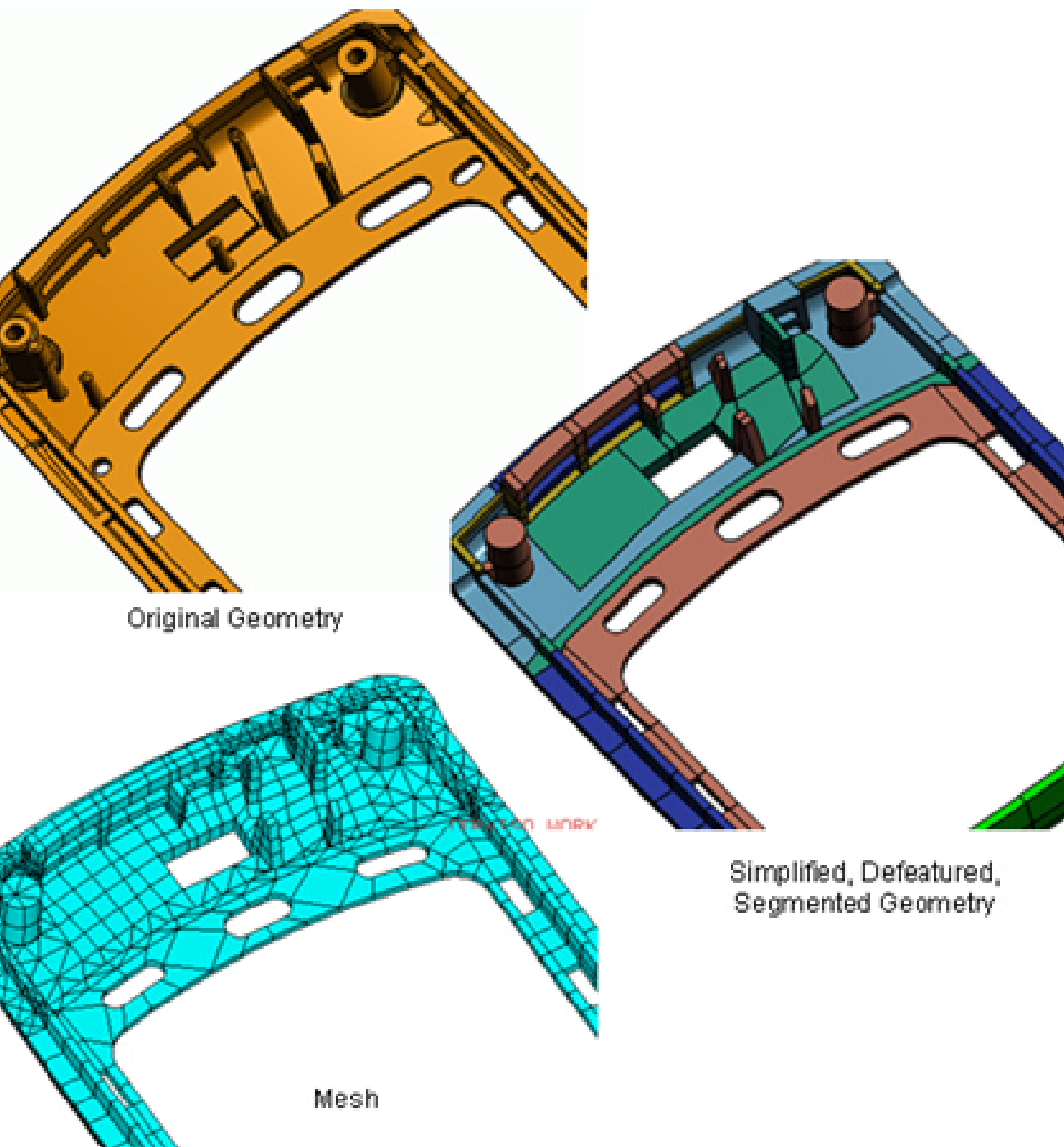Original Geometry

Simplified, Defeatured,
Segmented Geometry

Mesh

Front Housing

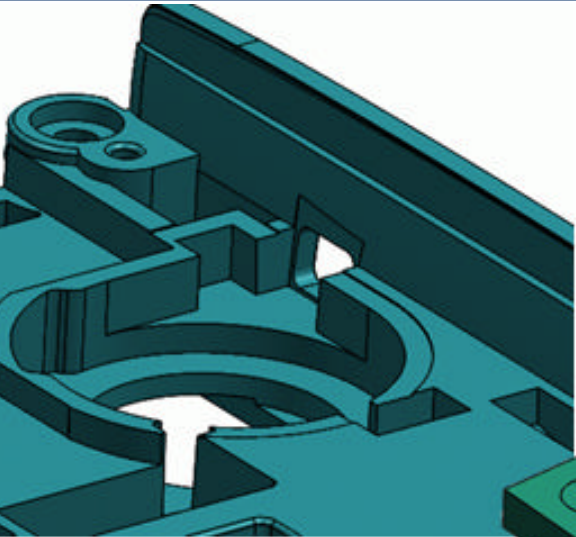Original Geometry

Simplified, Defeatured,
Segmented Geometry

Mesh

Front Housing

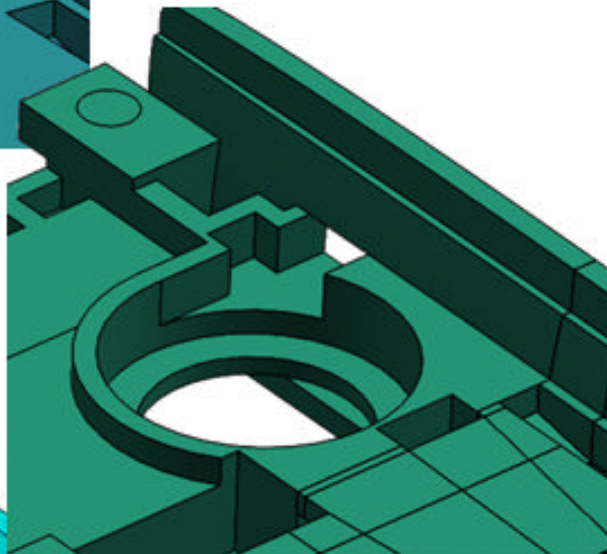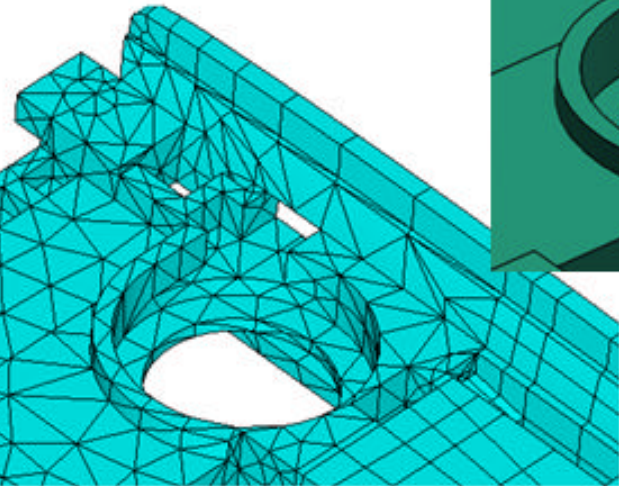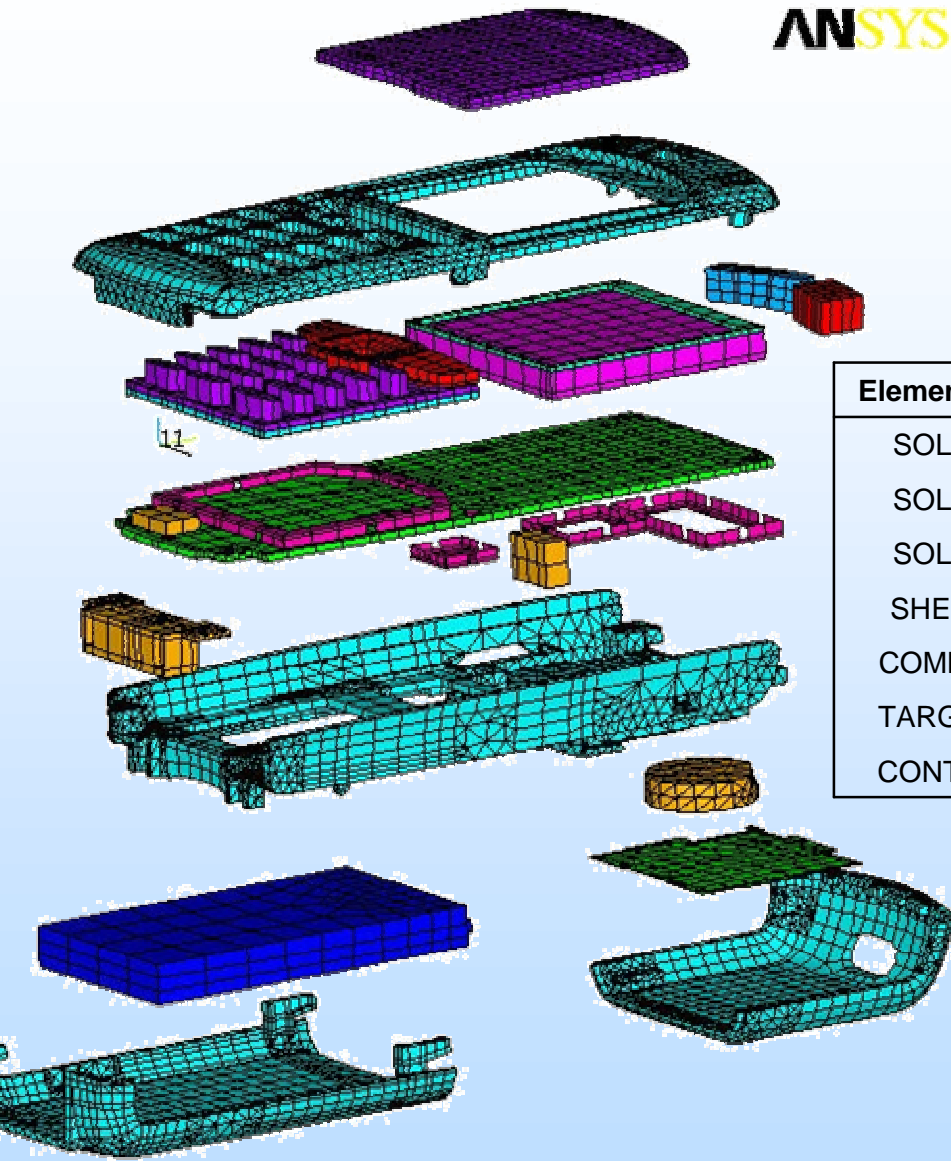Original Geometry

Simplified, Defeatured,
Segmented Geometry

Mesh

Frame

Original Geometry

Simplified, Defeatured,
Segmented Geometry

Mesh

Keypad
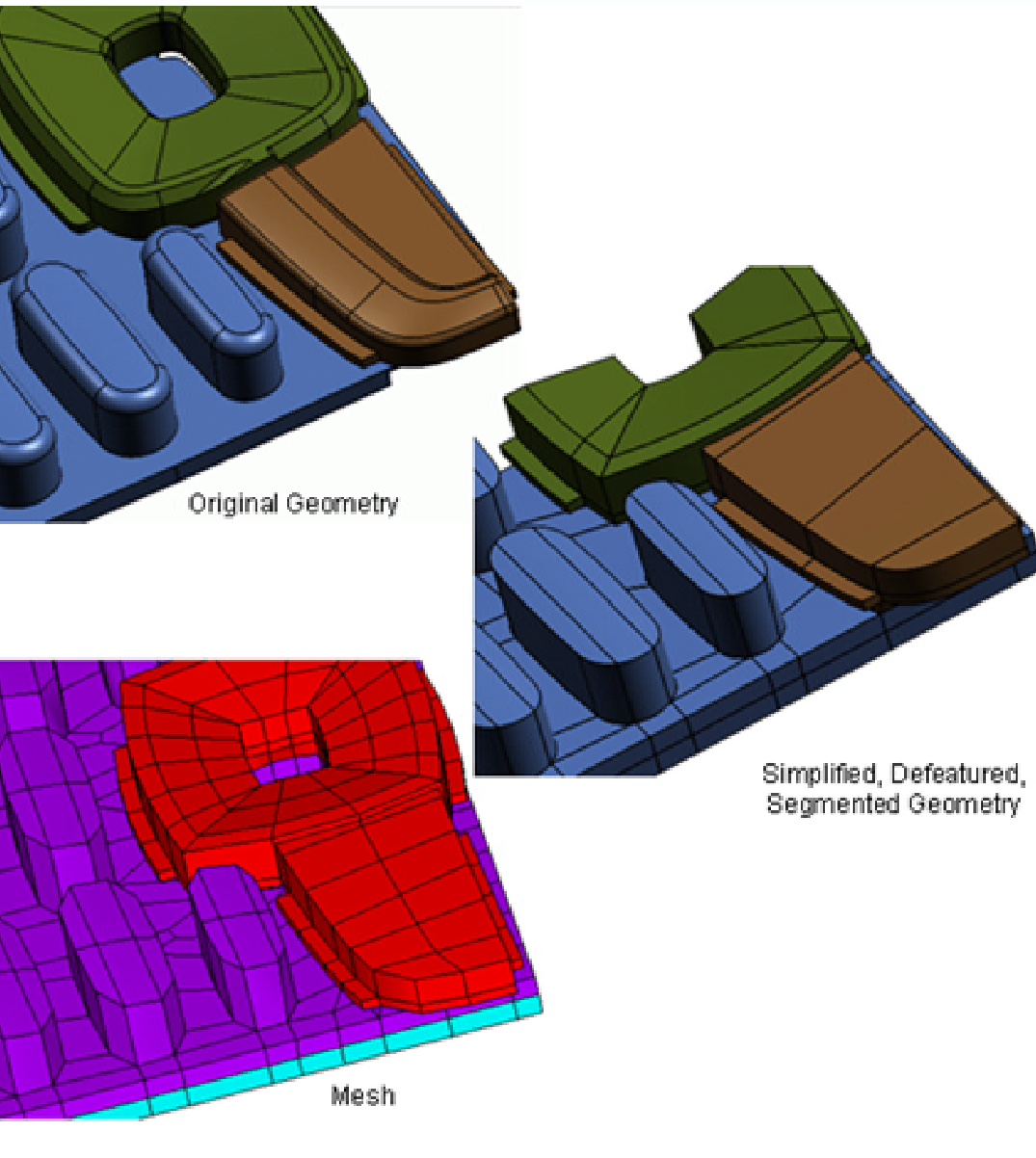
Mesh Specifics

ANSYS

Element Type	Description	Quantity
SOLID95	20-node hexahedron	5365
SOLID95	13-node pyramid	901
SOLID92	10-node tetrahedron	14,557
SHELL93	8-node shell	505
COMBIN14	2-node spring-damper link	64
TARGE170	3D surface target	1535
CONTA174	3D surface contact	2252

Total Elements:	25,179
Total Nodes:	70,270
Total DOF:	210,810

MALLETT

CREATING VALUE

Material Properties

- All materials modeled as linear elastic
    - Deflection is the primary quantity of interest
    - No 'plastic hinges' expected
    - Gross deflections not seriously affected by this assumption
- Rate dependency for thermoplastic resins roughly accounted for
- Stiffness-proportional damping
    - Material-dependent
- *(Proprietary)*

Solution Steps

- Quasi-static Initialization
  - Grommet compression, etc.
  - Contact initiation
  - Equilibrium at rest
- Initial Conditions
- Impact Event
  - Critical portion of solution
- Rebound
  - Some resonation
  - Little damage

Convergence Criteria

- Quasi-static steps controlled by the traditional L2 force residual

- Deflection is the stated goal; impact and rebound steps controlled by L2 displacement norm only

$$\sqrt{\left(209{,}900\cdot 0^2\right)+\left(100\cdot 0.0025^2\right)} \le 0.025$$

- Fidelity of contact forces/stresses not required
  - Maximum of 0.03mm contact penetration deemed acceptable
  - If highly accurate stress calculations were required, the convergence criteria would need to be reevaluated. For the stated goal of this analysis, the chosen convergence criteria more than suffice.

Time Step

- Newmark integration scheme with ?=0.5050 and ß=0.2525 (very nearly equal to the trapezoidal integration rule, or *average acceleration* scheme)

- Automatic timestepping with a maximum timestep of ?t<0.05 milliseconds (corresponds to 20pts/cycle at 1kHz)

- Period error calculated to be less than 1% at 1kHz; amplitude error is identically zero for the average acceleration scheme.

$$Period\ Error = w\,\Delta t \left[\tan^{-1} \frac{4w\,\Delta t}{4 - w^2\,\Delta t^2} \right]$$

- Rayleigh quotient was monitored. Observed minimum of 40 points per response cycle.

Battery Cover
Disengagement
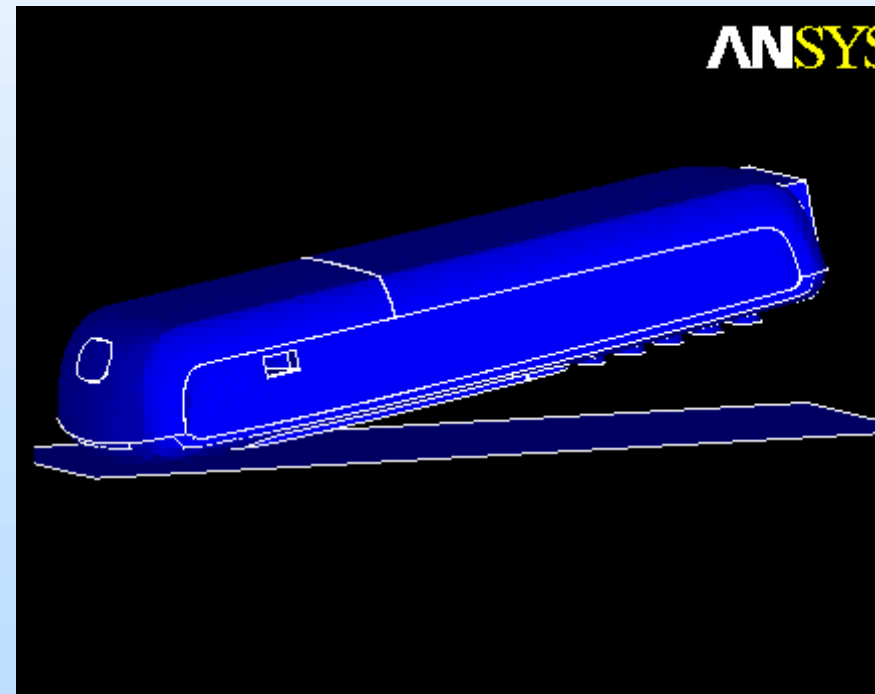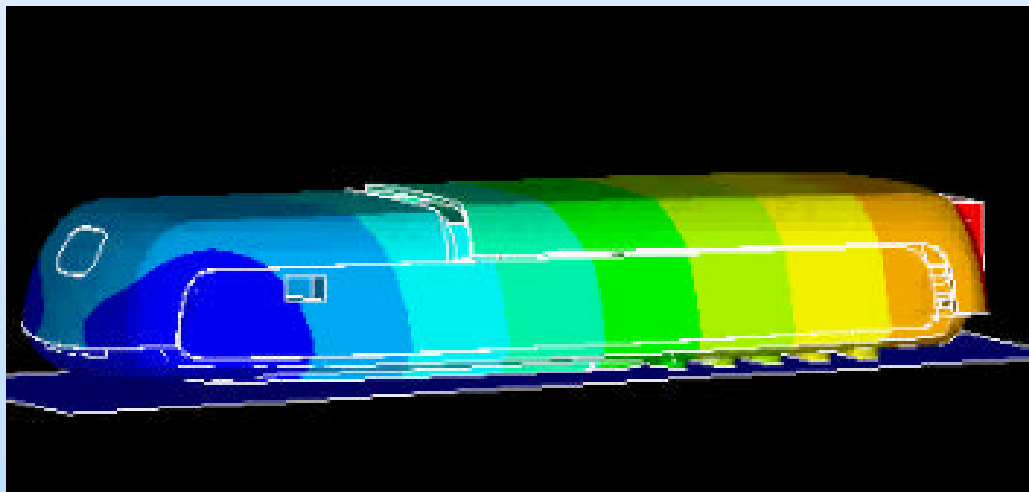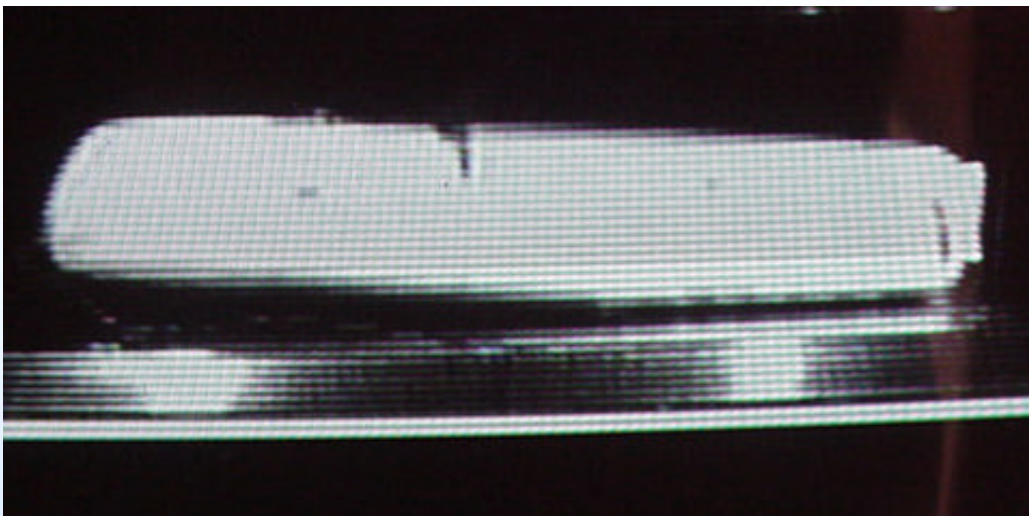
Results
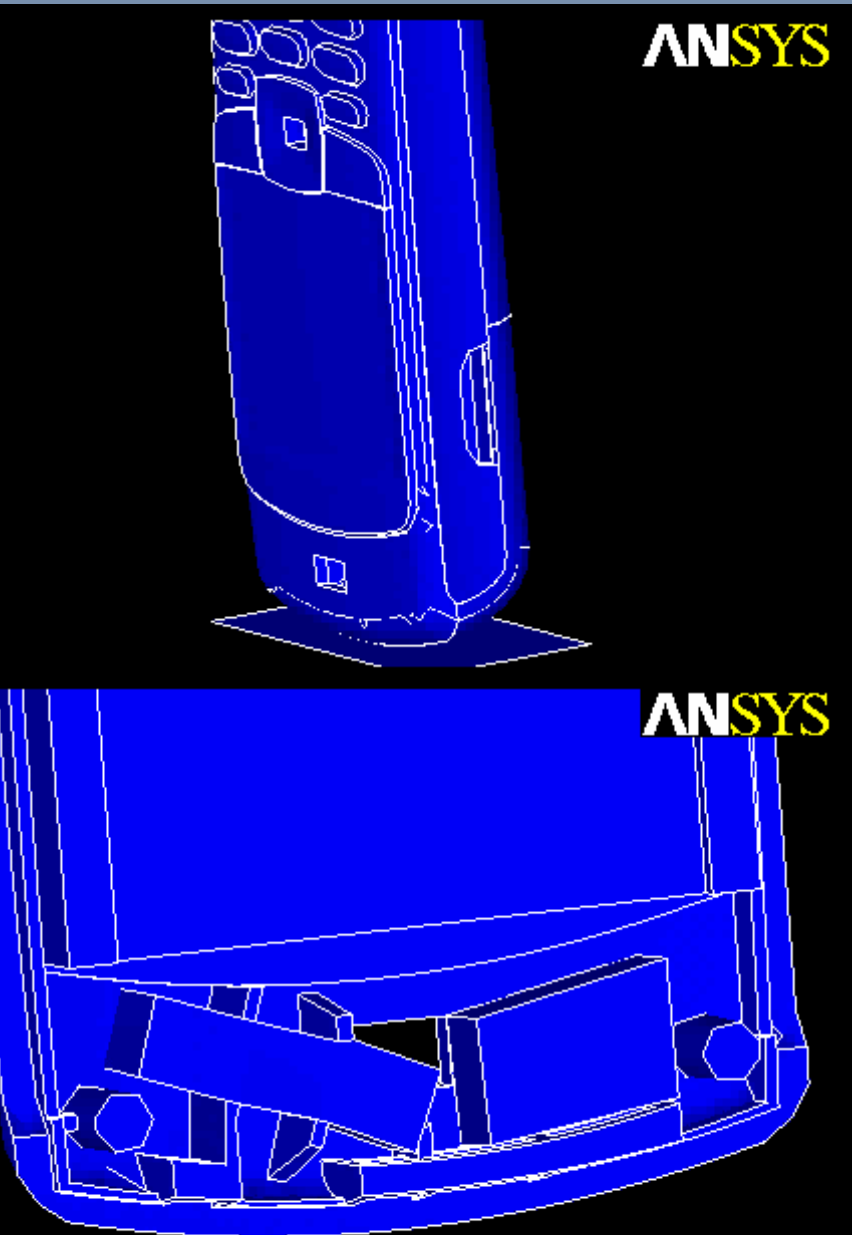
Physical test showed damage to vibrator contacts situated just inside the top housing of the phone.

The damage was well predicted by the simulations.

Simulations showed that the housing would impact and deform the circuit board in the region of the vib connector.

Prediction of these types of interactions are enough to allow designers to relocate or better support delicate components, such as connectors, that would otherwise risk being hit by other components.

Notes

- Total rebound height was also compared to tests. Depends a great deal on orientation. Data showed scatter, but in general agreement within 10-15% was achieved.

- Total turn-around time ~6 weeks
  - 3 weeks mesh generation
  - 3 weeks model debug, tweak, and solve
  - Explicit typically takes 8 weeks due to additional modeling time

- HP J6700 dual 750MHz PA-RISC processors with 2GB RAM completed in 36 hours

Conclusions

- ✓ Develop a technique that can provide accurate predictive data in a timeframe consistent with the needs of the rapid development cycle

- ✓ Highly accurate stress calculations not required; only an accurate representation of deformed shape versus time

- ✓ Implicit method is a valid option