NA Regional Summit 2008 NAFEMS

2020 Vision of Engineering Analysis and Simulation

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Simulation Training Challenges in the 2020 Workplace

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Overview

- CAE Associates
- Changing Simulation Landscape
- Need for Simulation Training
- Student Expectations
- Management Expectations
- A Proposed Approach

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CAE Associates

- Consulting Company Focused on Engineering Simulation Since 1981
  - Consulting services for wide range of industries.
  - Regional sales, marketing, and telephone hotline support for ANSYS software.
  - FEA/CFD training and mentoring.
- Educating Engineers in Practical Use of Simulation for Over 25 Years
  - > 200 training days per year.
  - > 700 students per year.

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Changing Simulation Landscape

- Analysis Specialists → Generalists
- Simulation Requirements Much More Complex
  - Assemblies
  - Nonlinear Analysis
    - Geometric
    - Contact
    - Material
  - Multiphysics
- Simulation Software is Easier to Use
- How Must Simulation Training Adjust to Accommodate the Changing Landscape?

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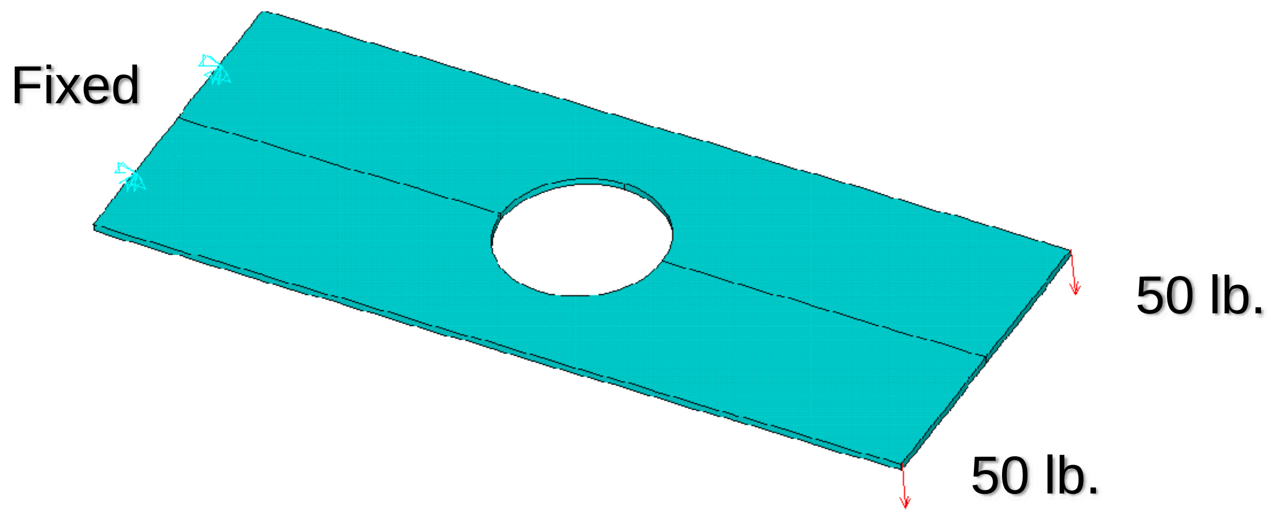
The Need For Simulation Training

- Is Training Still Necessary?
  - You bet – simulation is not robust.
    - Small error in the input, approach, or assumptions can result in a large error in the solution.
    - Still working in the “GIGO”* mode.
  - Poor simulation results are generally not conservative.
  - We are not close to pushbutton simulation without proper training.
    - Software ease of use – much easier to get the wrong answer if you don’t understand what you are doing!

*GIGO – Garbage In, Garbage Out

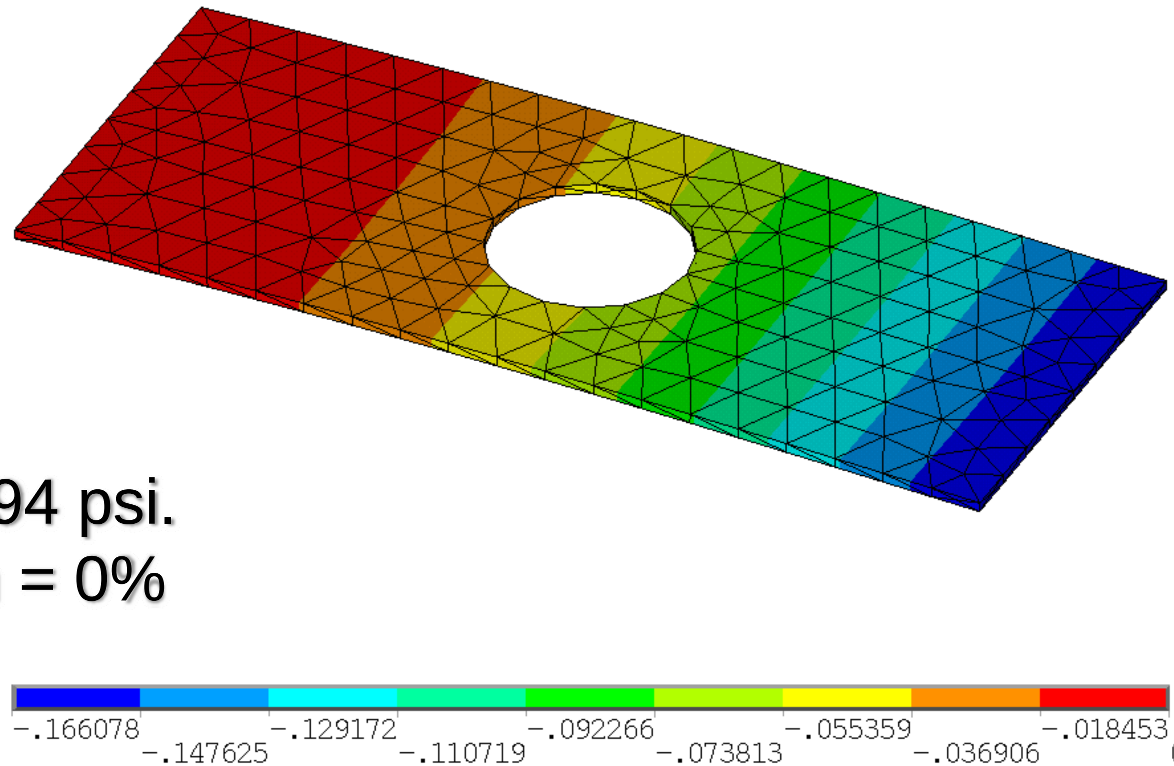
Example – Plate With a Hole

- 10”x4”x0.1” thick steel plate
- Material yield is 120 ksi.
- Fixed along one edge
- Subject to 50 lb. force at each corner
- Predict deformation, stress, plastic strain



Approach A (untrained user)

- Fill solid with tetrahedra (linear)
- Apply bc’s
- Solve



Max. Disp = .166”
Max Stress= 24,294 psi.
Max Plastic Strain = 0%

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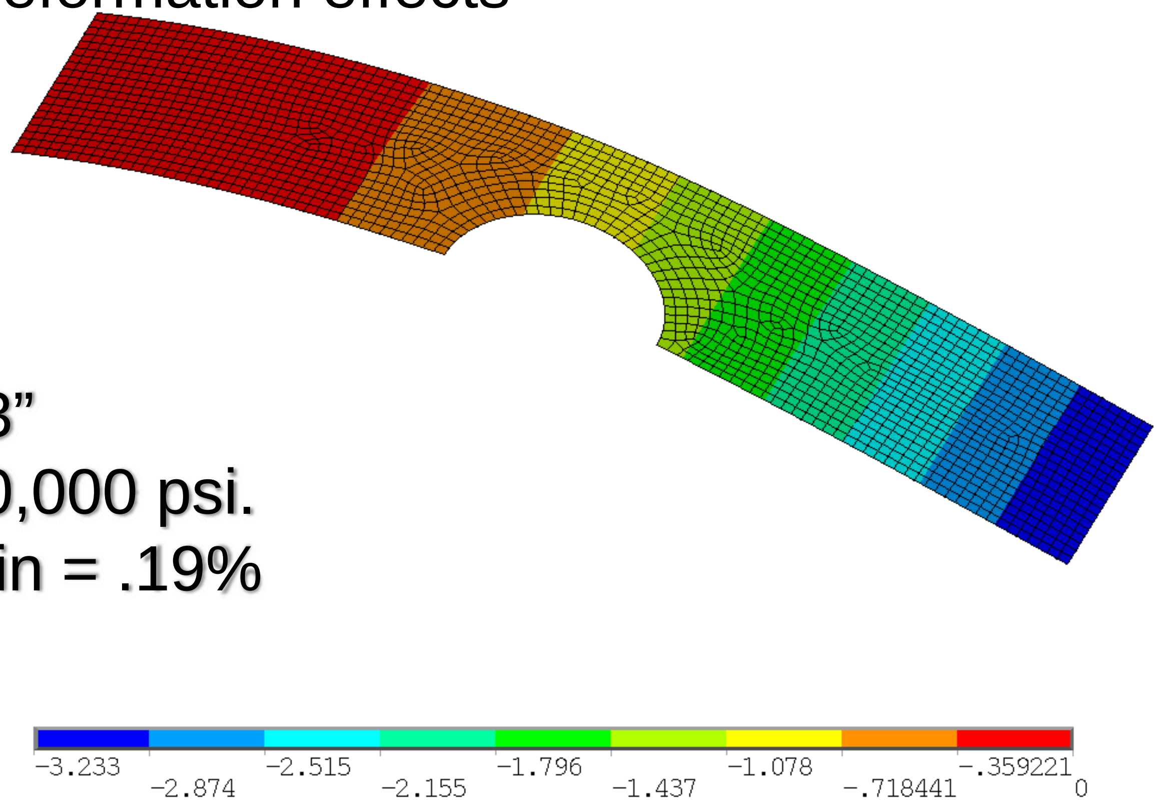
Approach B (trained user)

- Use shell elements
- Take advantage of symmetry
- Include large deformation effects
- Apply bc's
- Solve



Max. Disp = 3.23”
Max Stress= 120,000 psi.
Max Plastic Strain = .19%

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Student Differences

Traditional Student

- "Analysis Specialist"
  - Simulation is main focus.
  - Performs detailed computations on a daily basis.
  - Versed in engineering and simulation theory.
- Looking for the simulation training to allow analysis of anything that crosses their path.

Today's Student

- "Generalist"
  - Design/Project engineer - simulation only a small part of responsibilities.
  - Often not familiar with details of engineering or simulation theory.
- Looking for the simulation training to help them develop better products.

Student Training Expectations

Traditional Expectations

- Refresh underlying theory.
- Basic understanding of how the software works "under the hood".
- Learn how to use the software.
- Establish baseline from which to springboard to solution of complex industry problems.

Today's Expectations

- Learn how to use the software.
- Step-by-step guided workshops.
- Click-by-click template for how to solve their particular, complex, industry-specific problem(s).

Student Training Expectations

- Primary Differences
  - From the student perspective, theory now takes a back seat.
    - Underlying engineering theory not considered a prerequisite – relying on the simulation code for this.
    - Little interest in the “guts” behind the numerical solution.
    - Focus is on practical solution of complex problems.
  - Student expectation is to jump to the top of the learning curve for their specific application as opposed to getting a leg up.

“I am not interested in the theory, just tell me which menus to pick on to get to the answer!”

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Today's Management Expectations from Simulation Training

- Thorough understanding of simulation theory and limitations.
- Ability to validate and have confidence in the solution.
- Alignment with corporate "standard analysis process".
- Ability to think through a new problem and extend training material to future applications.
- Ability to immediately apply training to solving real, complex company problems.

Traditional Approach

Traditional Training Approach

- Analyst
- Simulation Theory Training
  - FEA
  - CFD
- Introductory Software Training
- Advanced Software Training
  - Dynamics
  - Heat Transfer
  - Nonlinearities
  - Electromagnetics
- Practice, Practice, Practice

Goal

Traditional Approach

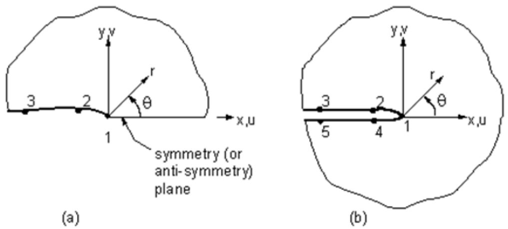
Lecture & Scripted Sample Input Files

Numerical Methods

CAE ASSOCIATES

- Special commands exist to calculate the stress intensity factors at each location along a crack front.
  - In ANSYS, the KCALC command (Main Menu> General Postproc> Nodal Calcs> Stress Int Factr) calculates the mixed-mode stress intensity factors K_I, K_{II}, and K_{III}.
  - This command is limited to linear elastic problems with a homogeneous, isotropic material near the crack region.

Figure 12.6 Typical Path Definitions



(a) a half-crack model and (b) a full-crack model

Sample Input

A sample input listing for a submodeling analysis is shown below:

```
!  Start with coarse model analysis:
/FILNAME,coarse          ! Jobname = coarse
/PREP7                   ! Enter PREP7
...
...                      ! General coarse model
...
FINISH

/SOLU                    ! Enter SOLUTION
ANTYPE,...               ! Analysis type and analysis options
...
D,...                    ! Loads and load step options
DSYMM,...
ACEL,...
...
SAVE                     ! Coarse model database file coarse.db
SOLVE                    ! Coarse model solution
                         ! Results are on coarse.rst (or rmg, etc.)
FINISH

!  Create submodel:
/CLEAR                   ! Clear the database (or exit ANSYS and re-enter)
/FILNAME,submod          ! New jobname = submod
/PREP7                   ! Re-enter PREP7
...
...                      ! Generate submodel
...

!  Perform cut boundary interpolation:
NSEL,...                 ! Select nodes on cut boundaries
NWRITE                   ! Write those nodes to submod.node
ALLSEL                   ! Restore full sets of all entities
NWRITE,temps,node        ! Write all nodes to temps.node (for
                         !   temperature interpolation)
SAVE                     ! Submodel database file submod.db
FINISH

RESUME,coarse,db         ! Resume coarse model database (coarse.db)
/POST1                   ! Enter POST1
FILE,coarse,rst          ! Point to coarse model results file
SET,...                  ! Read in desired results data
CBDOF                    ! Reads cut boundary nodes from submod.node and
                         !   writes D commands to submod.cbdo
BFINT,temps,node         ! Reads all submodel nodes from temps.node and
                         !   writes BF commands to submod.bfin
FINISH                   ! End of interpolation

RESUME                   ! Resume submodel database (submod.db)
/SOLU                    ! Enter SOLUTION
ANTYPE,...               ! Analysis type and options

/INPUT,submod,cbdo       ! Cut boundary DOF specifications
/INPUT,submod,bfin       ! Interpolated temperature specifications
DSYMM,...                ! Other loads and load step options
ACEL,...
...
SOLVE                    ! Submodel solution
FINISH

/POST1                   ! Enter POST1
...
...                      ! Verify submodel results
...
FINISH
```

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What Should We Do Today?

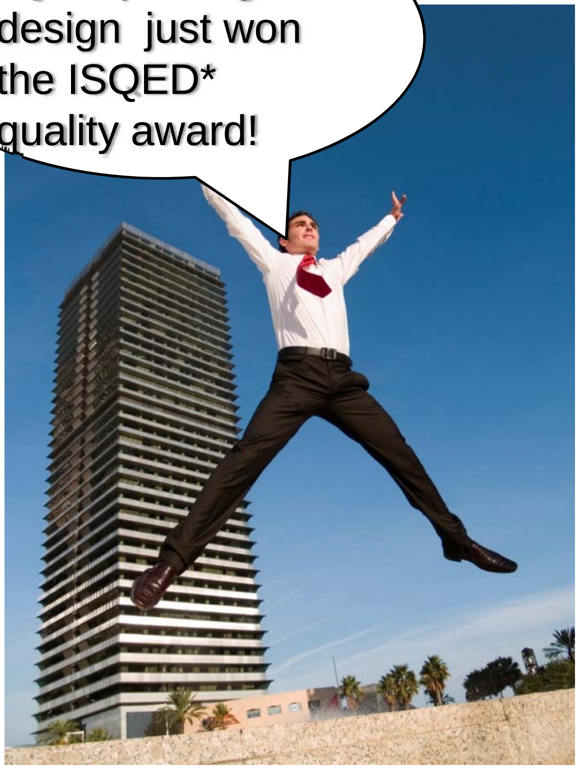
Today's Training Approach

- Designer/Project Engineer

??

Goal

My IC package design just won the ISQED* quality award!



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*ISQED -International Society for Quality Electronic Design

How to Make Everybody Happy?

- Secret to happiness is: Low(er) Expectations.
- Not practical for management to think that every designer can also be an expert analyst.
  - Background and desire are usually not there.
  - Time to get the proper experience is not there.
- Not practical for students to completely ignore the theory and numerical analysis procedures.
  - Required in order to make proper modeling decisions.
  - Understanding is required to assess complexity of analysis, verify accuracy, remedy non-convergence, etc.
- Compromise is the key.

One Solution – Customized Training and Mentoring

- Focus on student and management main objective:

Solve Real, Complex Company Problems

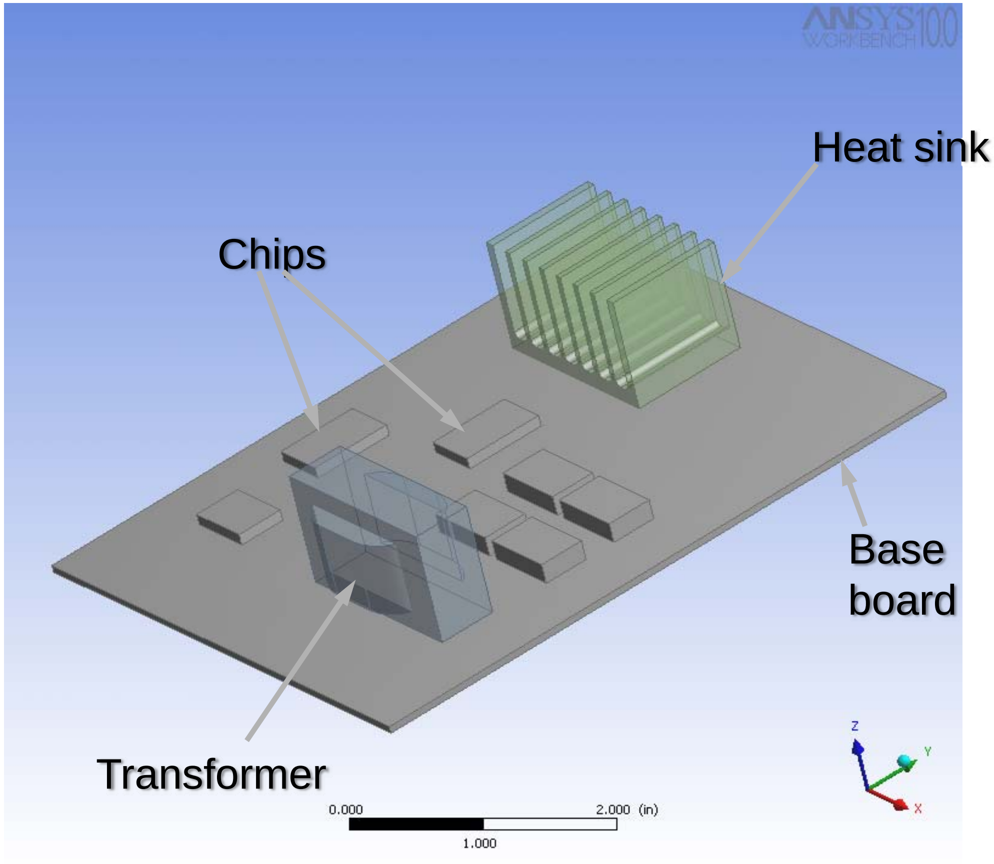
- Tailor training to solve a particular problem or class of problems.
- Temper management expectations by adding "*as related to application X*" to each one.
- Limit theory to that specific to the application and analysis type(s).
- By narrowing the approach to solve the problem at hand, we have a workable approach from both perspectives.

Customized Training and Mentoring

- Fastest way to ramp from no or little simulation expertise to solving real, complex, practical problems.
- Focus is problem-specific.
  - Starts off with an actual problem or component.
  - Step-by-step analysis procedure is mapped out:
    - Goals
    - Assumptions, Modeling Techniques
    - Physics (Structural, Thermal, Electrical, Magnetic, Fluid, etc.)
    - Boundary Conditions and Loads
    - Incorporate Company’s “Standard Process”
    - Results Evaluation and Verification

Example

- Design of a Printed Circuit Board - Challenging
  - Conjugate thermal-fluid analysis to predict temperature distribution.
  - Nonlinear static structural analysis to predict life due to thermal cycling.
  - Response spectrum analysis to assure drop test survival.



Example - Traditional Approach

- Required Analyses and Training Classes
  - CFD (4 days)
  - Thermal (3 days)
  - Static Structural (5 days)
  - Nonlinear Structural (3 days)
  - Dynamic Structural (3 days)
- Training Uses Generic Examples and Workshops

Example - Traditional Approach

- At the end of 18 days of training, engineer will have been exposed to a variety of different types of analysis.
  - Much more than needed for this project.
  - Likely to forget most of it.
  - Will have a big headache.
- Will have zero practical insight into how to go about modeling the PC board.
  - This process will be learned mostly through trial and error and will take a long time.
  - During this time, engineer will face constant harassment about why the project is delayed.

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Example - Traditional Approach

- When results are finally achieved, chances are:
  - They are incorrect due to improper assumptions or boundary conditions for this type of problem.
  - They take too long to re-produce due to poor modeling judgments.
    - Renders optimization studies useless.
- Final outcome
  - Product late to market and not optimized.
  - Engineer is frustrated.
  - Management thinks simulation is a waste of time.

Example - Customized Training

- Model of representative PC Board is used as the example problem for all training.
- All training workshops tailored to this application.
- Only relevant portions of each training class are covered.
  - Training time drops from 18 to about 6 days.
  - Modeling techniques appropriate to this particular configuration are emphasized.
  - Assumptions particular to this type of analysis are outlined.

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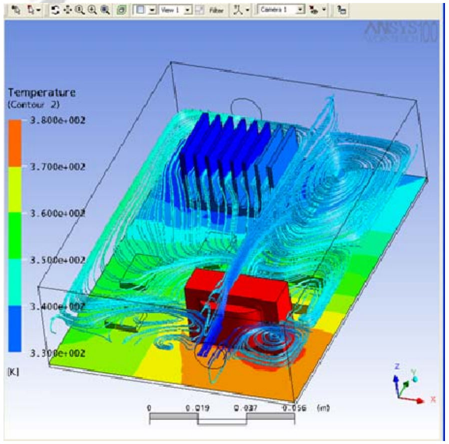
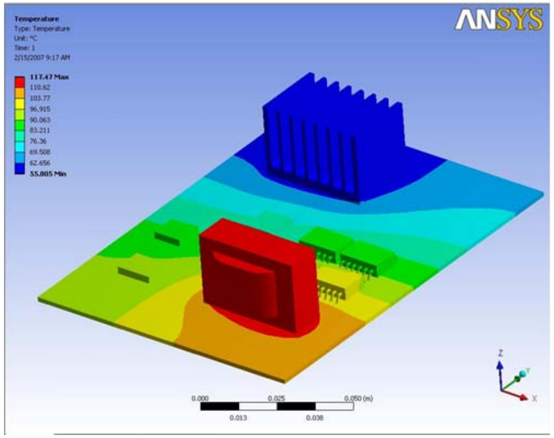
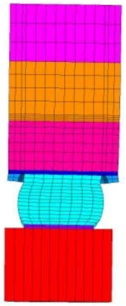
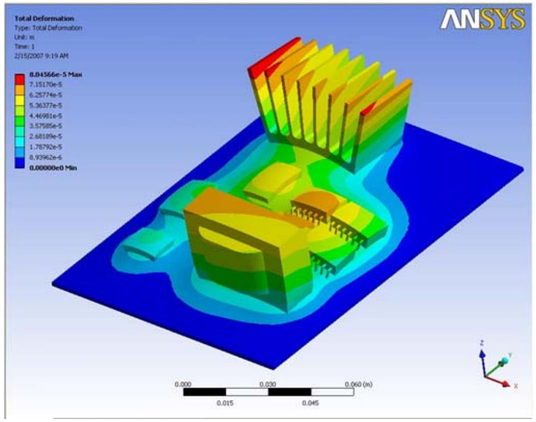
Example - Customized Training







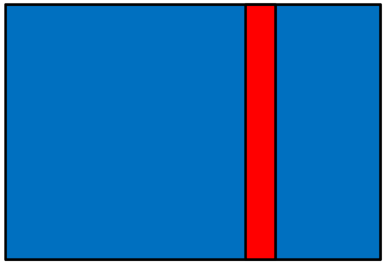


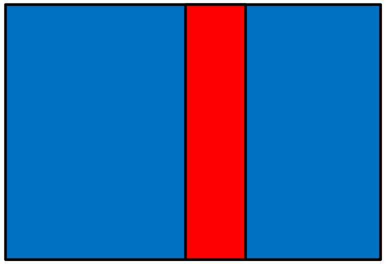
CFD

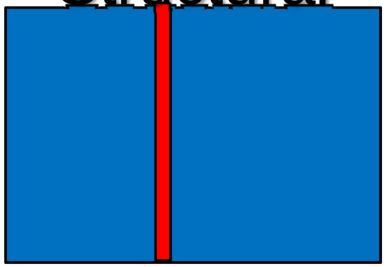
Thermal

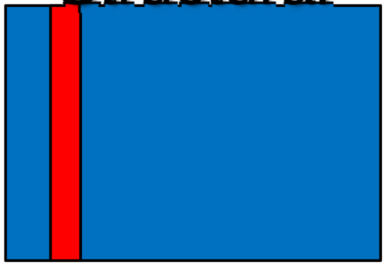
Static Structural

Dynamic Structural









Steady State
Incompressible
Single-Phase

Steady State
Conduction
Convection

Small Deformation
Plasticity

Modal
Response Spectrum

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Example - Customized Training

- Engineer is well equipped to efficiently and accurately analyze a PC board.
- Knows what to look for in the solution and how to check results.
- Can apply this knowledge immediately to subsequent designs.
- Has time to optimize the design.
- Final outcome:
  - Product optimized and first to market.
  - Management kicking itself for not implementing simulation a long time ago.

Customized Training and Mentoring

- Timeframe can vary, depending on complexity of problem and level of experience.
- In the long run, this is much more cost effective than:
  - Taking a few general training classes which cover the different analysis types and/or physics to be modeled.
  - Trying to distill the information to only what is necessary for a particular project (and forgetting the rest!).
  - Working up from generic example problems to the true problem at hand.
  - Struggling with appropriate assumptions to make.
  - Trial-and-error modeling and loading approach.
  - Uncertainty as to the validity of the results.

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Filling the Gaps - Formative Training

- Simulation training becomes much easier if students already have a good feel for numerical analysis and how the software generally works.
  - Will better understand its advantages and limitations.
  - Will better be able to judge whether a simulation will be easy or difficult.
  - Will better understand what makes results accurate and what are inherent limitations to accuracy.
  - Will not be “driving” blind.

Filling the Gaps - Formative Training

- Engineering schools are best suited to fill this void.
  - Captive audience.
  - Simulation is as essential in the engineering curriculum today as laboratory work was in the past.
  - Numerical analysis and simulation are ubiquitous in industry - should form part of core requirements in all engineering programs.
    - Virtual “labs” to augment physical labs.

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Filling the Gaps - Supplementary Training

- Software providers can help with industry-specific tutorials.
- NAFEMS training materials:
  - “How to Do Seismic Analysis With Finite Elements”
  - “How to Undertake Contact and Friction Analysis”
- Training which focuses on practical guidelines for use of simulation:
  - Classes which teach “Tips and Tricks”, the “Art” of Efficient Modeling, Solution Validation, etc.
  - Examples:
    - “Practical Stress Analysis & Finite Element Methods” – NAFEMS
    - “FEA Best Practices” – CAE Associates

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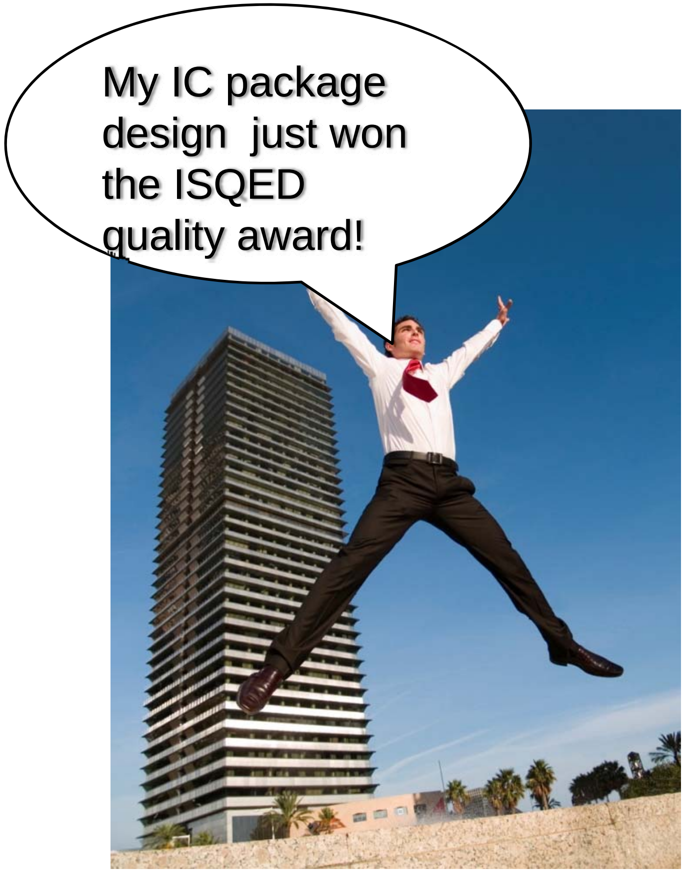
Summary of Proposed Training Solution

Today's Training Approach

- Designer/Project Engineer
- Formative Numerical Analysis Training.
- Customized, Application Specific Training and Mentoring.
- Supplementary Training.
- Practice.

Goal



Future of Simulation Training

- Will simulation training still be necessary in 2020?
  - You bet – simulation software is improving its robustness, but the complexity of problems that engineers are trying to solve is outpacing this effort.
  - Requirement that engineers have a fundamental understanding of the tools that they use and rely on for their conclusions should never disappear!

Thank You For Your Time!

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