# Future EM Tool Requirements for Industry-Based Hardware Designs

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**Future Directions in IC and Package Design Workshop (FDIP)**
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# Agenda

- Current Business Situation
- What are our Design Challenges?
- New Technology
- Model Formats
- User Experience
- Computing Platforms
- Tool Development Challenges
- Design Services

# Current Business Situation

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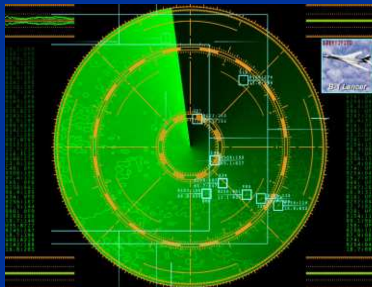
# Current Business Situation

**Continually Less People, More Complex Designs.**

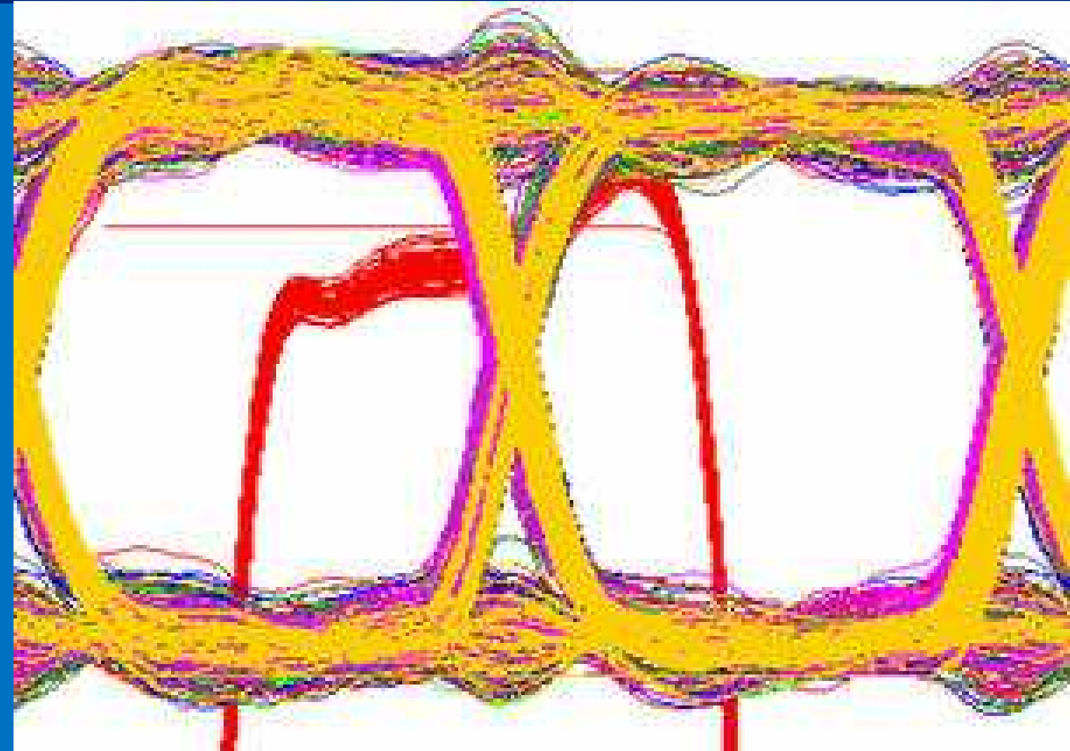
**Not as much about what we can DO**

**but what can we NOT DO !**



**5-year Radar for this talk**

# Our Design Challenges



# Our Design Challenges – Current Process

- Technology Evaluation
- Device Modeling
- Interconnect Modeling
- System-Level Modeling
- Simulation
- Measurement and Validation

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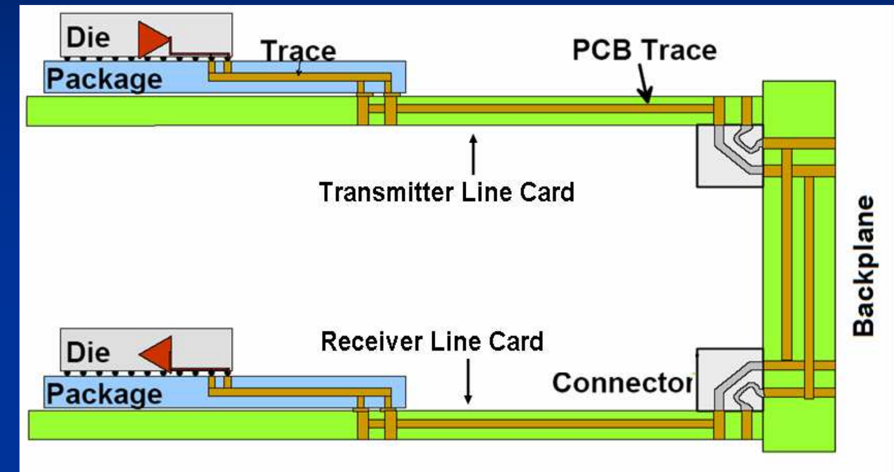
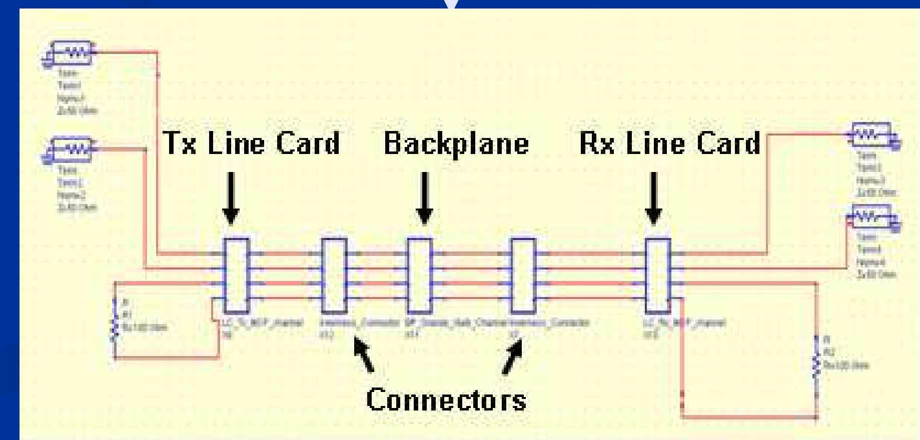
# System model / Interconnect Model

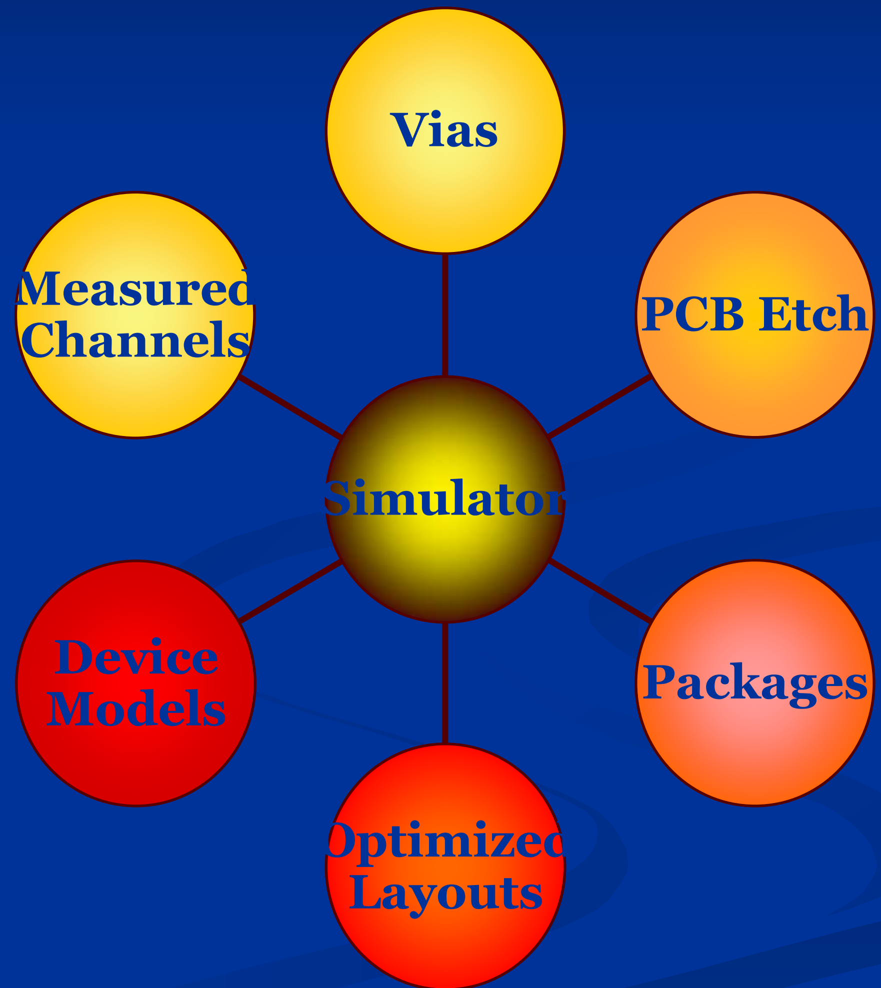
- Each component in the System is modeled separately
- Individual S-param model blocks are obtained after simulation
- These S-parameter blocks are interfaced to form the system model.



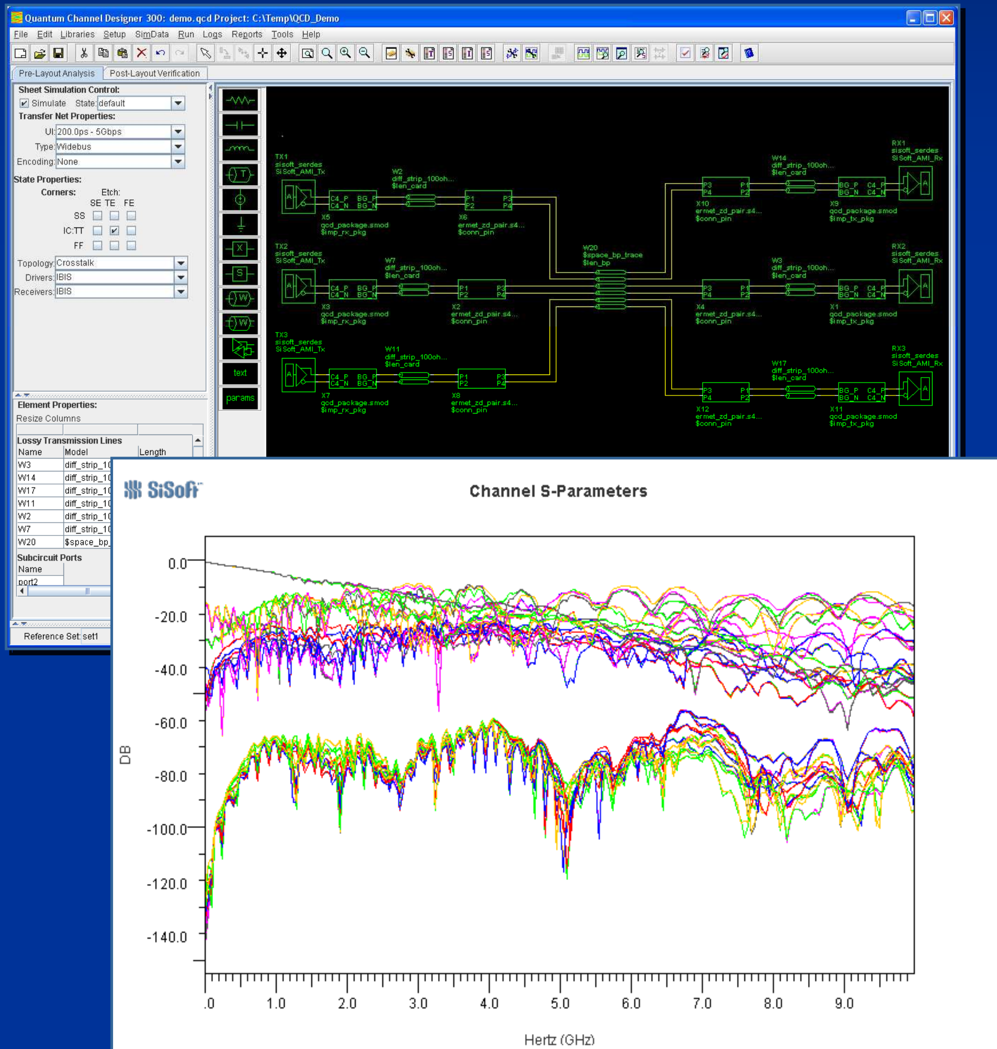



# Library of Components

- Vias
- Traces
- Optimized layouts
- Packages
- Channels, etc.
- Covers the design space of interest
- Simulator can draw from predefined libraries to do optimization

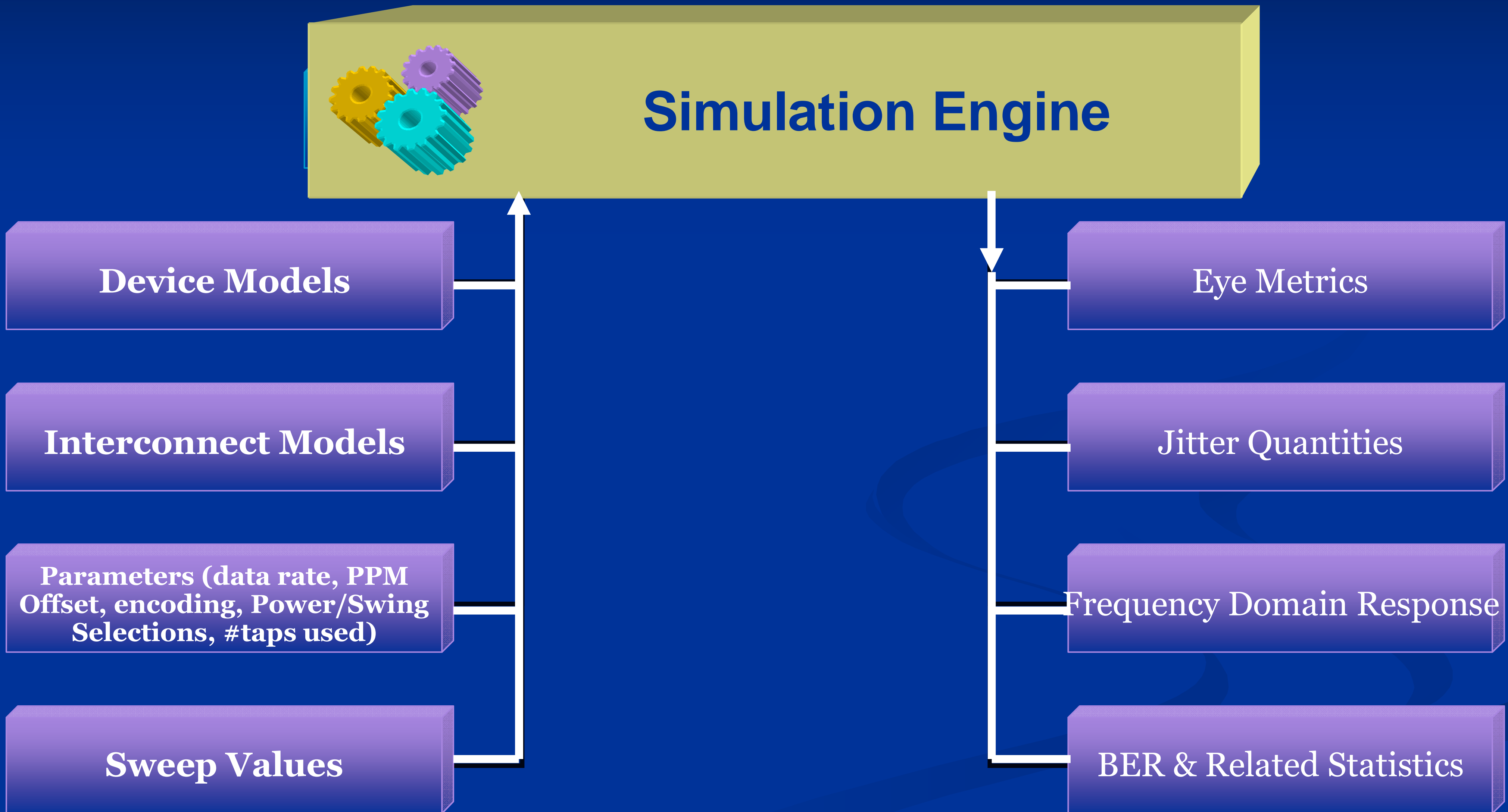


# Building a Complete Channel Model




- All of the components can be cascaded in a schematic tool, such as that available in SiSoft Quantum Channel Designer (QCD)
- A frequency sweep can be setup, and the composite channel model can be created
- QCD can perform the SerDes simulation as well

# Simulator Flow



# Our Design Challenges

## Link Speeds

- Serial
  - 10 Gbs links? 20 Gbs? 25 Gbs?
  - Serdes designs currently aiming for 14 Gbs
  - Silicon vendors now working on 20 Gbs
  - 20 Gbs will be Standard in 5 years

# Our Design Challenges

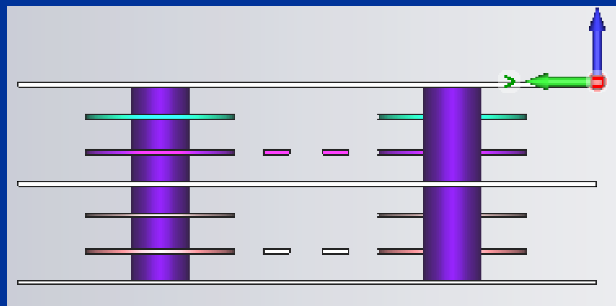
## Link Speeds

- Widebus
  - Switching speed is approaching Serdes speeds.
  - Already designing 1666MT/s DDR3.
  - 2 Gbs Advanced Memory Links soon to emerge?
  - Require 3D tools for analysis
  - Sensitive to stub lengths, layer selection, etc.

# Our Design Challenges

## Serial Channels – Physical Demands

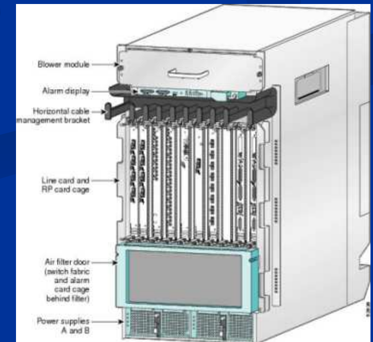
- 25 inch links now standard @ 7Gbs
- 20-slot chassis, 40 inch links coming soon?
- More than 2 connectors in the link?
- Division of the link? Repeaters?
- Routing Layer Control



# Our Design Challenges

## Serial Channels – Simulation Challenges

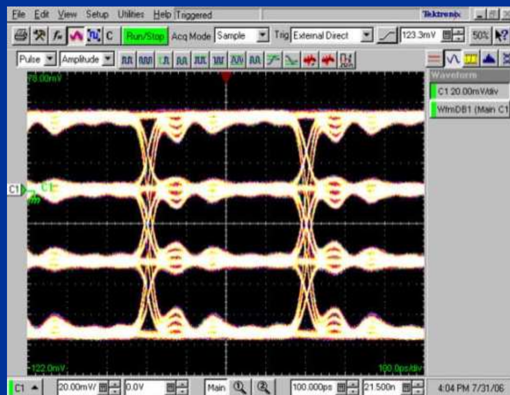
- Large systems, many slots, many types of cards.
- Impossible to simulate ALL possible link configuration combinations for a system design. Would take 3-5 years!
- Need methods, decision criteria, for reducing the data set to be analyzed.
- Simulate a subset of link parameters representative of the entire set.

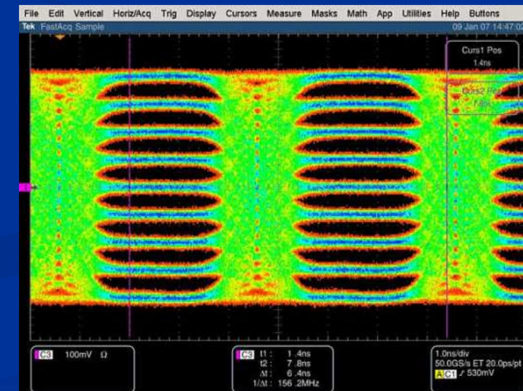


# Our Design Challenges

## Multi-level Signaling

- At what speed does this become necessary?
- Some think 20Gbs is end of binary signaling
- How do we implement it?
- QAM protocol? 4-bits, 6 levels?
- More bits per symbol, higher Gbs w/ lower symbol rate





Photos: Tektronix

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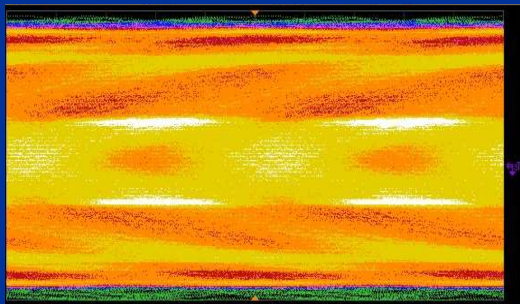
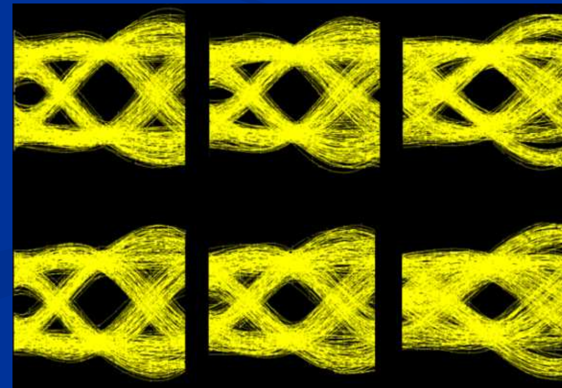
# Our Design Challenges

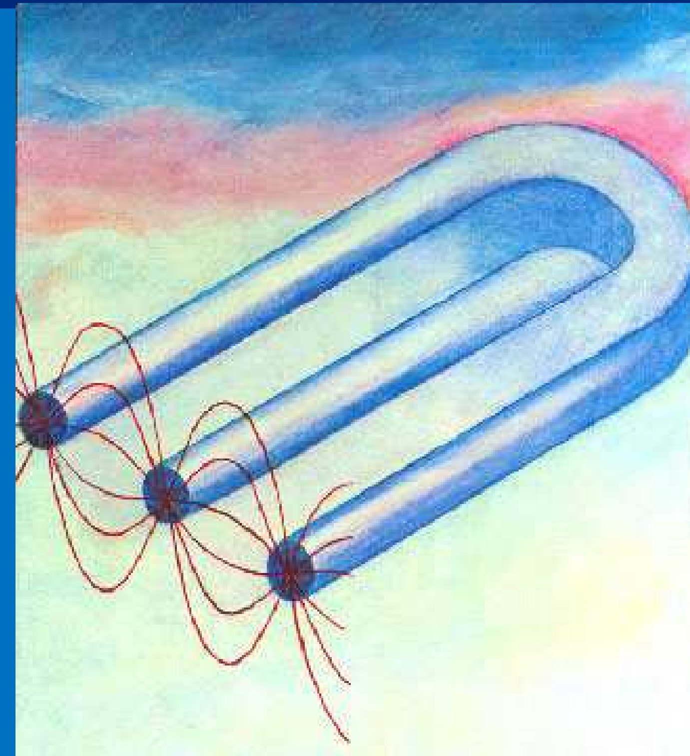
## Link Loss Limitations

- Is there a “Magic Number” for Link Loss?
- Where insertion loss overwhelms the ability to recover the signal?
- Independent of Serdes I/Os used ?
- For current designs, any channel losing more than 20dB cannot recover the signal.





# New Technology



# New Technology

## Manufacturing Tolerances

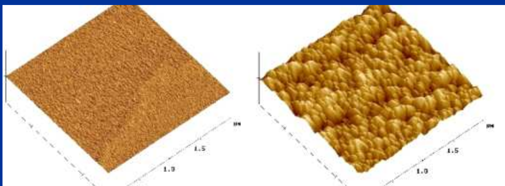
- Inclusion of Manufacturing Tolerances into modeling and simulation.
- Manufacturing tolerances become MUCH MORE significant as link speeds increase.
- Tools need to account for these tolerances in their modeling and solutions.
- Multiple variables: Dk, Df, trace geometries, dielectric and copper properties, etc. need to be accounted for.

| LYR | Cust Range | Cust Tar | Material | Est Thk | Dk 10 G |
|---|---|---|---|---|---|
| | | | SM | | |
| 1 | | | .5 oz + plating | 2.20 | |
| | | 3.65 | 2113 | 3.90 | 3.5 |
| 2 | | | .5 oz | 0.60 | |
| | | 4.00 | 2113 | 4.00 | 3.5 |
| 3 | | | .5 oz | 0.60 | |
| | | 4.25 | 2116 | 4.50 | 3.7 |
| 4 | | | .5 oz | 0.60 | |
| | | 4.00 | 2113 | 4.00 | 3.5 |
| 5 | | | .5 oz | 0.60 | |
| | | 4.25 | 2116 | 4.50 | 3.7 |
| 6 | | | .5 oz | 0.60 | |
| | | 4.00 | 2113 | 4.00 | 3.5 |
| 7 | | | .5 oz | 0.60 | |
| | | 4.25 | 2116 | 4.50 | 3.7 |
| 8 | | | .5 oz | 0.60 | |
| | | 4.00 | 2113 | 4.00 | 3.5 |
| 9 | | | .5 oz | 0.60 | |
| | | 4.25 | 2116 | 4.30 | 3.7 |
| 10 | | | 1 oz | 1.20 | |
| | | 2.00 | ZBC-2000 | 2.00 | 3.2 |
| 11 | | | 1 oz | 1.20 | |

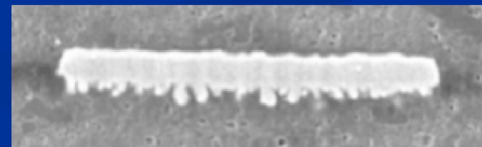
# New Technology

## Surface Roughness

- How do we model it accurately?
- Current tools have approximations, not very good ones, many “work-arounds”.
- How big of a factor is the roughness in our sims?
- How does it affect our Line Loss??
- Need flexibility/methods to easily design-in the surface roughness parameters.
- Difficult to separate the Dk/Df material values from copper roughness, as they affect each other. A dielectric will show different Dk/Df depending upon the roughness of the copper.
- Need libraries for surface roughness factors vs. materials, processes.



Tampere University of Technology / Centre for electron Microscopy, Finland (TUT/CEM)

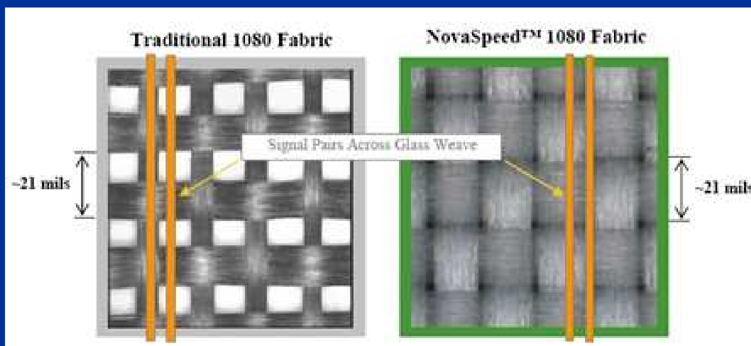


Edwards, Terry. Foundations for Microstrip Circuit Design. John Wiley and Sons, 1992.

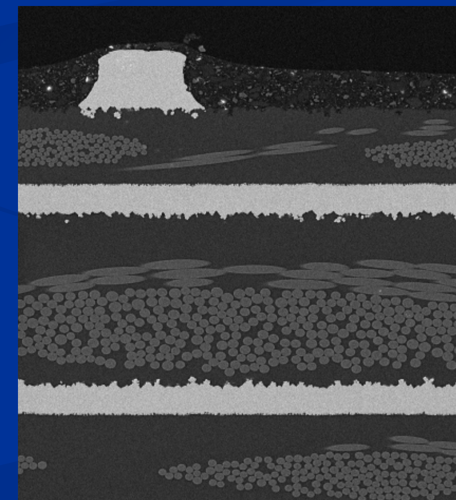
# New Technology

## Glass Weave

- Glass Weave pattern under the traces affects the signal propagation.
- We need a way to use the glass weave pattern and properties in our models and sims.




http://www.bethesignal.net/blog/BlogImages/2009-04_novaSpeed.jpg, Bogatin Enterprises LLC

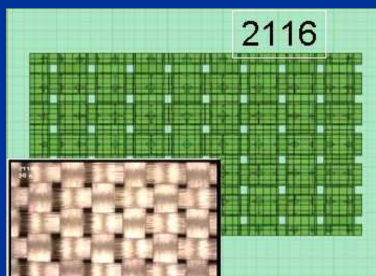


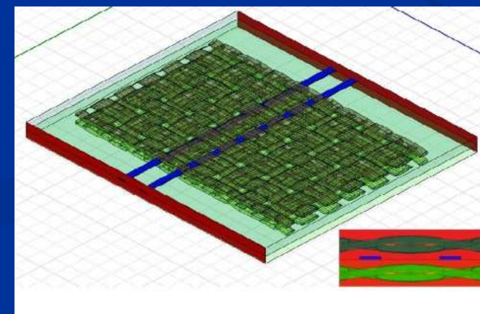
ORNL SEM
Electromagnetic Field Dynamics inside Small Conducting Spheres, Paul G. Huray, et al, 10/07

# New Technology

## Glass Weave

- Extraction and knowledge of how the fiber weave is located in the board vs. the traces.
- Dk, Df, fiber vs resin, orthogonal routing.
- Model the modal wave effects on differential pair phase tolerances (Intel work).
- Modeling, simulations, with the use of solid material w/ no fiber, like Teflon.



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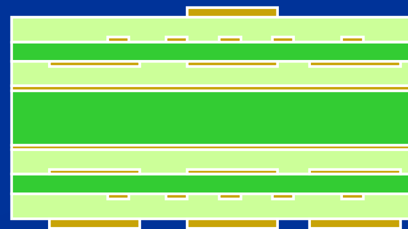
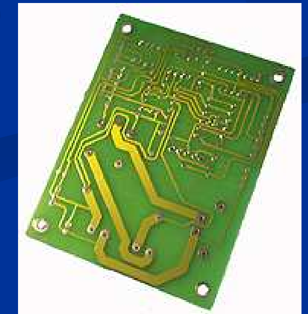
# New Technology

## Inhomogeneous materials

- How do we handle inhomogeneous materials in the models and simulations?
- What kind of models do we use?
- How get enter the homogeneity factors into the tool? Parameters? Measurements?
- How do we predict the level of dielectric homogeneity?
- The copper squeezing out resin during lamination, viscosity effects, Impedance effects?

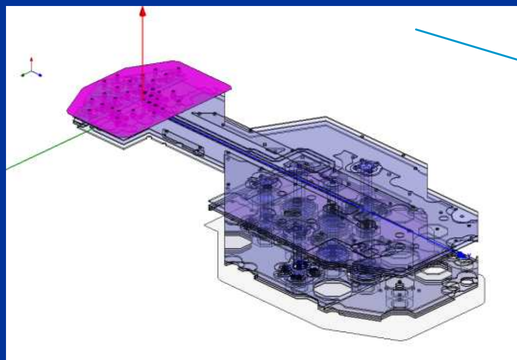


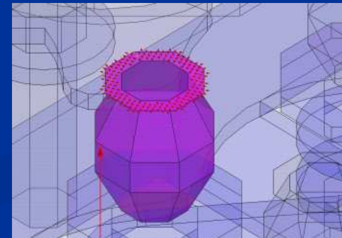


# New Technology

## Port Assignments

- Port Assignments continue to be a challenge
- Need more intelligence in the port selection! Both in the Tools and Users!
  - i.e. Poorly-placed ports too close to sections of non-linear geometry produce inaccurate results.

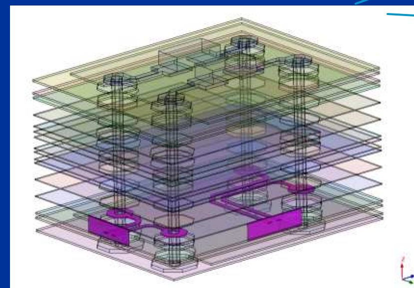


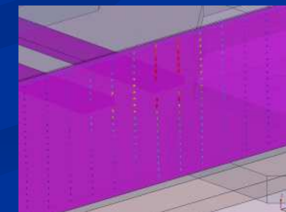


# New Technology

## Port Assignments

- Vendors supplying models need to better define where the ports are.
- Tools should check port assignments before/during solving, issue warnings if too close to sections of non-linear geometry.
- Tools should give feedback on quality of port assignments.

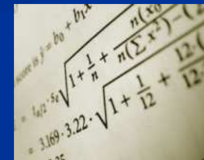


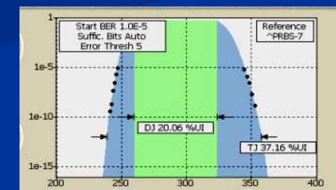


# New Technology

## Statistical Analyses

- Dependent Variable Sensitivity Analysis
- Sensitivity analysis can indentify highest return on analysis efforts. Maybe we don’t have to analyze them all?
- Reduce churn, reduce the number of variables in solutions.
- Statistical distributions of manufacturing and materials variances
  - statistical-based sweeps of parameters
- Input data set probabilistic selection.





# New Technology

## Model, Simulation, Accumulation of Tolerances

- Tools should report accuracy, tolerances, with models, simulation, results.
- Need to report an overall estimate of accuracy of the total solution!
- What is the model accuracy ±% ?
- What are the Serdes I/Os modeling accuracies?
- How do the tolerances accumulate across the many models and simulations?
- Reports of Eye Opening sizes, ± 5mV? ±50mV? 100mV? 5ps? 50ps?

# New Technology

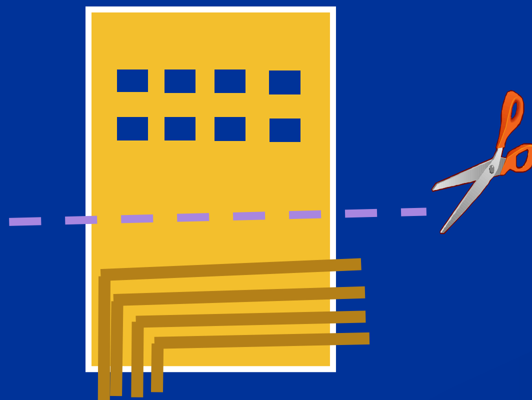
## Model, Simulation, Accumulation of Tolerances

- Are we looking for solutions below the "noise level" of our modeling and simulations?
- Don't give us 20 digits if not significant!
- I see many people arguing over 2 ps in a 2 ns budget!
- Comparison to measuring land, the survey is very accurate (inches), and reported. Why not same for our modeling and simulations?
- As customers we should hold the tool creator responsible for this.

# New Technology

## Model Order Reduction Techniques

- Many research reports on this area – simplifying the models.
- Reductions of matrices orders, etc.
- How can we “cut” the models to simplify the models? Representing only the part of the structure which interacts w/ the primary model, like the bottom ½, ¼, etc.
- Partial field-penetration models?



$$A = \begin{matrix} - \\ \uparrow \\ ml \\ \downarrow \\ - \end{matrix} \overset{\left| \leftarrow mu \rightarrow \right|}{\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdot & \cdot & a_{1p} & 0 & \cdot & \cdot & 0 \\ a_{21} & a_{22} & a_{23} & & & & \cdot & 0 & & \cdot \\ a_{31} & a_{32} & a_{33} & & & & & \cdot & 0 & \cdot \\ \cdot & & & \cdot & & & & & \cdot & 0 \\ \cdot & & & & \cdot & & & & & \cdot \\ a_{q1} & & & & & \cdot & & & & \cdot \\ 0 & \cdot & & & & & \cdot & & & \cdot \\ \cdot & 0 & \cdot & & & & & \cdot & & \cdot \\ \cdot & & 0 & \cdot & & & & & \cdot & \\ 0 & \cdot & \cdot & 0 & \cdot & \cdot & \cdot & & & a_{nn} \end{bmatrix}}$$

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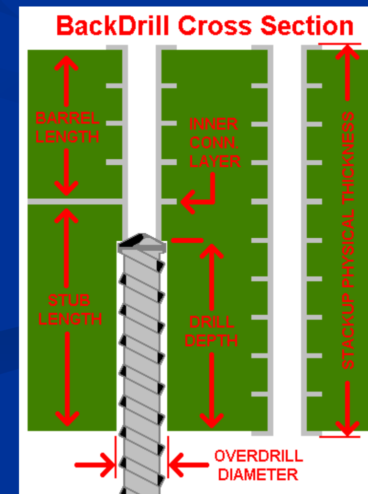
# New Technology

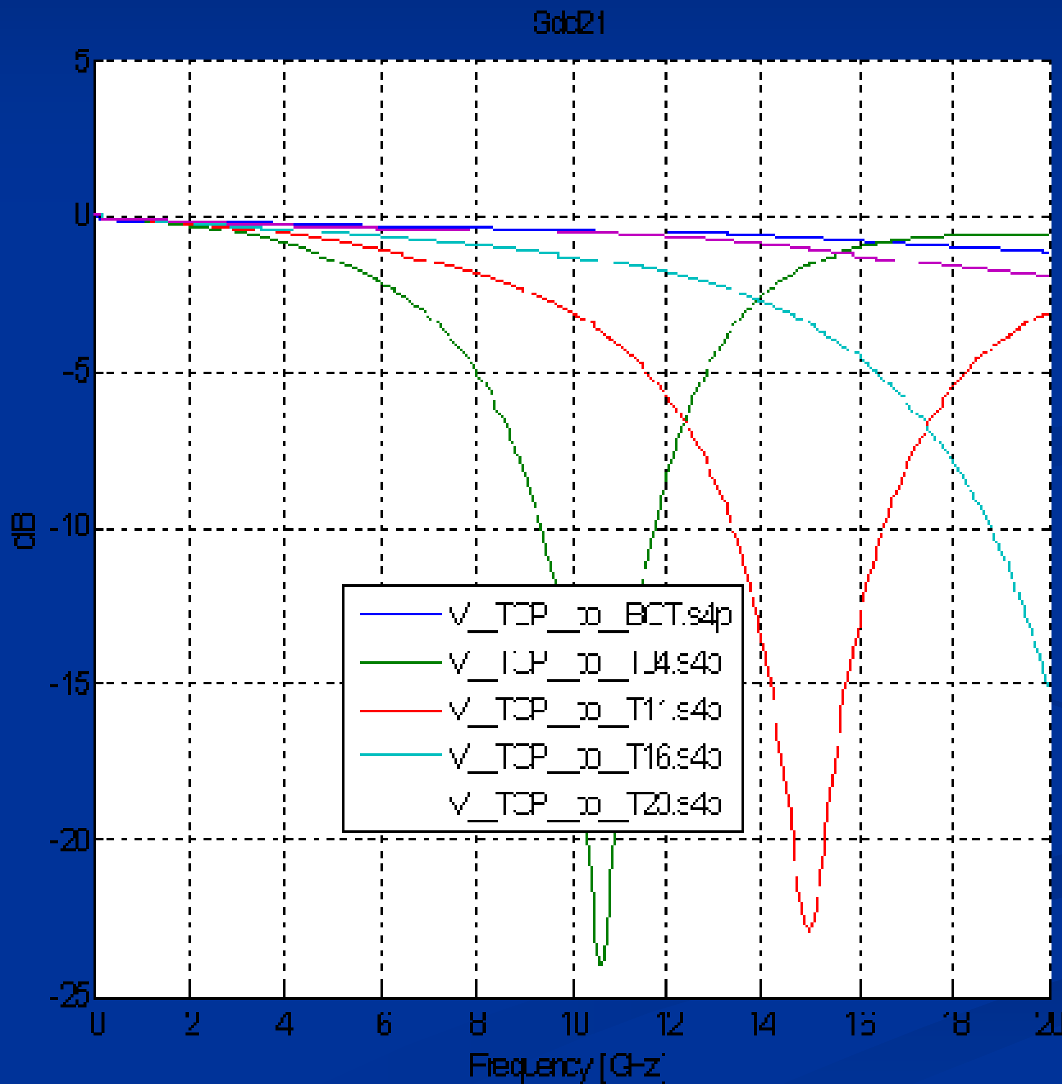
## Backdrill Modeling

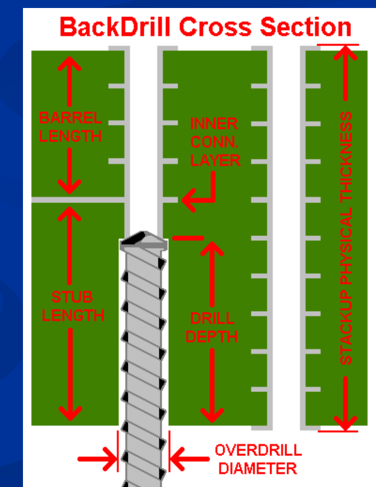
- Incorporation of backdrill parameters into the model solutions.
- Perform Before/After analyses, show the differences on plots, solutions.
- Tools can intelligently suggest layers for drill depths, grouping layers, etc.
- Tools should use “intelligent” via chopping, so we don’t have to redraw via.
- Knowledge of the Cut / Do Not Cut Layers, variance between them.



# New Technology

## Backdrill Modeling

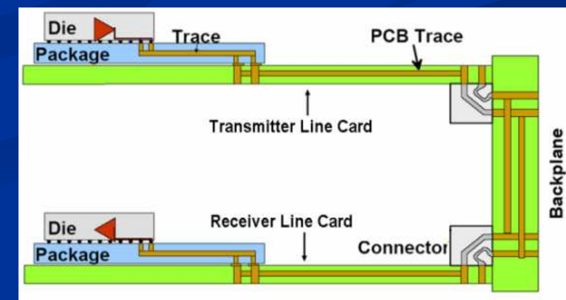


# New Technology

## Other Ideas

- How do we to handle multi-moded sections?
  - Now we avoid them, but we can't as speeds go up.
- Full EM Post-Route.
  - "Holy Grail" of EM tools
  - Tools would "do it all"
  - Extract from CAD database,
  - Use an intelligent solver
  - Pull together all parts
  - Decide which models needed
  - Simulate to get results



# Model Formats

$$
\begin{aligned}
c_{11} &= a_{11}b_{11} + a_{12}b_{21} + \ldots + a_{1m}b_{m1} \\
c_{12} &= a_{11}b_{12} + a_{12}b_{22} + \ldots + a_{1m}b_{m2} \\
c_{1p} &= a_{11}b_{1p} + a_{12}b_{2p} + \ldots + a_{1m}b_{mp} \\
c_{21} &= a_{21}b_{11} + a_{22}b_{21} + \ldots + a_{2m}b_{m1} \\
c_{22} &= a_{21}b_{12} + a_{22}b_{22} + \ldots + a_{2m}b_{m2} \\
c_{2p} &= a_{21}b_{1p} + a_{22}b_{2p} + \ldots + a_{2m}b_{mp} \\
c_{n1} &= a_{n1}b_{11} + a_{n2}b_{21} + \ldots + a_{nm}b_{m1} \\
c_{n2} &= a_{n1}b_{12} + a_{n2}b_{22} + \ldots + a_{nm}b_{m2} \\
c_{np} &= a_{n1}b_{1p} + a_{n2}b_{2p} + \ldots + a_{nm}b_{mp}
\end{aligned}
$$

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# Model Formats

## Cross-compatibility

- Models usable across multiple vendor tools, for analysis, CAD design, Mechanical design, etc.
- Models should contain enough information, but not be un-necessarily big.
- Tools should have "hooks" to allow for our customization for our specific process.  Use an AMI for access to features.

# Model Formats

## Cross-compatibility

- Tools should have the ability to write out data in different configurations
  - i.e.  we have a 16 port extraction, but some tool like StatEye will only take *.s4p files.
  - Currently, we write a utility that can post-process the 16 port with a user-defined format.
- Conversions should be included in the tool.
- NO post-processing!

# Model Formats

## Model Quality

- S- parameter models "still" have problems w/ passivity and causality!
- Tools should check passivity and causality before outputting model, and inform the user of the model quality.
- NO post-processing!
- Low-frequency issues in models – non-causal, incorrect DC solution.

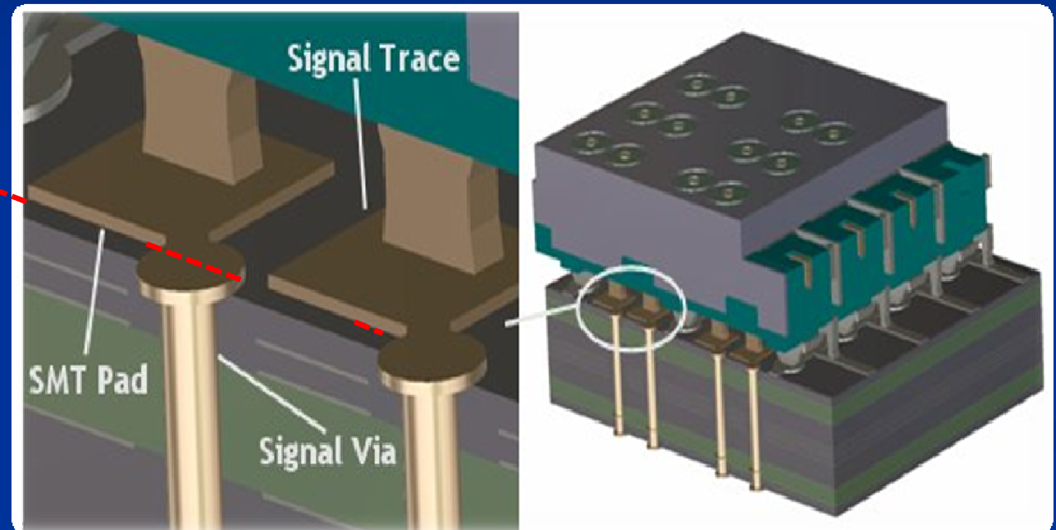
# Model Formats

## Other Model Issues

- Consistency of model boundaries and port selection
  - Where are the boundaries defined? Board level?
    - i.e. Include board in connector models?
    - What happens w/ fields at boundaries?
    - what if stackups are different?
    - Also an issue in package to board boundaries/junctions
- Use of the connector mechanical CAD models to incorporate into the board models
  - Solve the entire structure on the board.

# Connector Model Reference Plane

- Must communicate with connector vendors to understand how model was created
- The endpoints of the model provided are important
- Try to model the connecting pieces accordingly




*Computer Simulation Technology '08*

***Reference plane for 3D model highlighted above in red***

# Model Formats

## New Model Formats

- Use Touchstone 2 format as a standard. Tools should be required to support this.
- Touchstone-1 files have some limitations
  - Single port reference (usually 50 ohms) for all ports.
  - Proposals for new format to allow different port references.
  - Allows inclusion if power/ground with signal nets.
  - i.e. signals reference 50 ohms, power/ground reference 1 ohm.
- IBIS – AMI and Connector Modeling (ICN) support.

# Model Formats

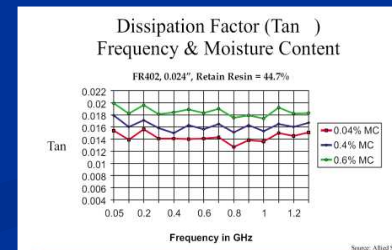
## Material Performance Parameters & Libraries

- Standard industry-wide materials databases.
  - Copper foils and roughness
  - Dielectric materials
  - F ( material, vendor, process, etc.)
- Standard materials measurement techniques. Dk/Df, etc.
  - Maybe more than one standard. Stripline, cavity resonance types.

Rohm & Haas

| Material | Composition | Dielectric Constant ( r) | Tan |
|---|---|---|---|
| Microwave Laminates | | (10 GHz) | (10 GHz) |
| Rogers RO3003 | PTFE/Ceramic | 3.00 | 0.0013 |
| Rogers RO3006 | PTFE/Ceramic | 6.15 | 0.0025 |
| Rogers RO3010 | PTFE/Ceramic | 10.2 | 00035 |
| Rogers RT/duroid 5870 | PTFE/Glass Microfiber | 2.33 | 0.0012 |
| Rogers RT/duroid 5880 | PTFE/Glass Microfiber | 2.20 | 0.0009 |
| Rogers TMM 3 | Hydrocarbon/Ceramic | 3.27 | 0.0020 |
| Rogers TMM 4 | Hydrocarbon/Ceramic | 4.50 | 0.0020 |
| Rogers TMM 6 | Hydrocarbon/Ceramic | 6.00 | 0.0023 |
| Rogers TMM 10 | Hydrocarbon/Ceramic | 9.2 | 0.0023 |
| Rogers 3001 (Bonding Film) | Thermoplastic | 2.28 | 0.003 |

DDI



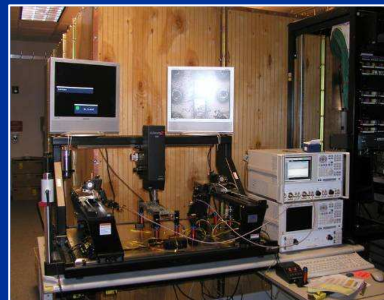

Allied Signal

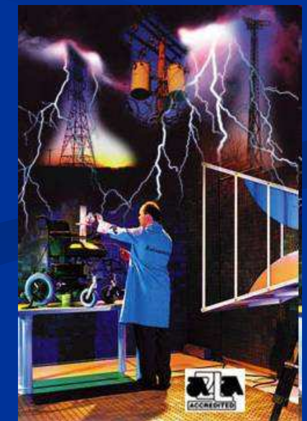
Seashore Fiberglass, Inc.

# Model Formats

## Material Performance Parameters & Libraries

- Independent verification of materials properties.
  - Some universities (MST) are currently providing this service.
- Parameters are already in proper tool formats, saves entry time/errors.
  - Tool vendors can port this data into their own pre-formatted libraries for the users.
- Updated monthly as part of maintenance plans.





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# User Experience

# User Experience

## Tools need to have more WIZARDS !!!

- For efficient entry of design parameters, models, materials. Design templates. Macros.
- Can easily and quickly generate most "commonly" used building blocks as well as effects.
- Via models of different configuration
  - PTH, PTH-with back drill, differentiall, blind-buried, etc.,
  - Amphenol has a spreadsheet in which we enter via dimensions, and it generates the HFSS model to be solved.
  - Ansoft is also offering a new via wizard.

# User Experience

## Tools need to have more **WIZARDS !!!**

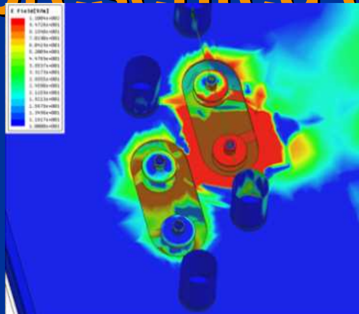
- DC blocking caps
- Models to incorporate glass weave effects of dielectrics.
- Improved Copper roughness modeling.
- Using wizards minimizes the tedious design entry times! Less time now available w/ less people.
- Sweep Wizards – variation of design parameters with minimal user interaction.
- Wizards can draw on information already available in libraries.

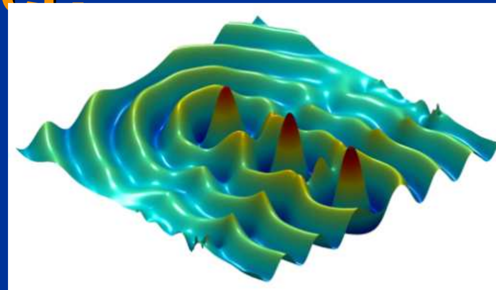
# User Experience

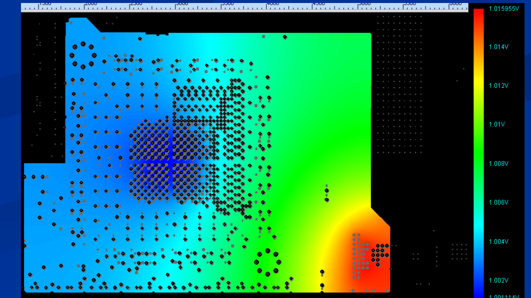
## Results Visualization Tools

- 3D, 4D, Full rotational, etc. (Gaming Controls?)
- Animation
- For 3D or 4D also provide easy way to cross-section into slices.
- Intuitive color coding.
- MatLab compatibility for post-processing.

- GUI Improvements – human factors design.
- Improved Automated Port Selection – as presented earlier.





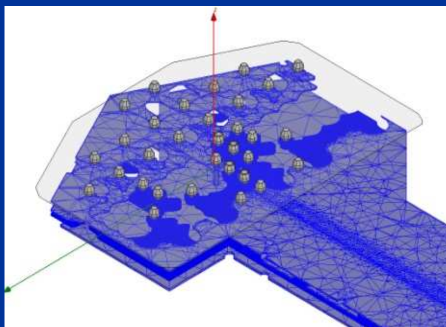


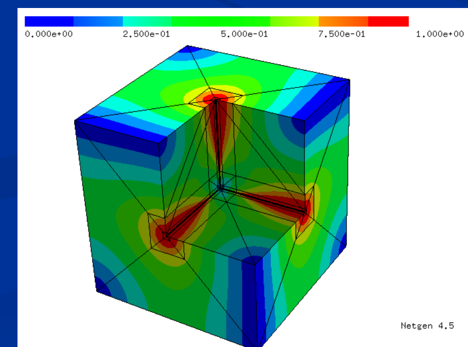
# Computing Platforms

# Computing Platforms

## Project Size

- Always want more nodes, more ports, more tetrahedrons, finer mesh.
- Need novel solutions to make large numbers of meshes solvable.
  - Use of pre-solvers. Lump tetra together where can.
  - Solve one section, pass on the fields from one to the next.
  - Re-grid, adaptable meshing

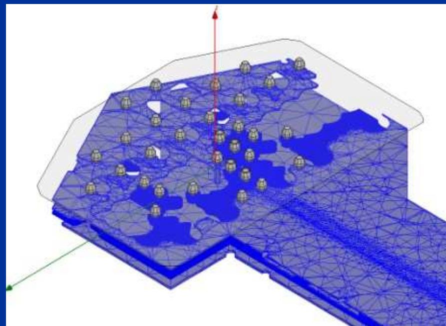


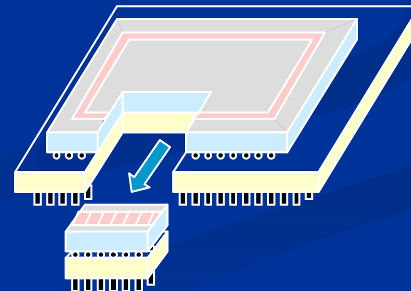


# Computing Platforms

## Project Size

- Users want to do a full package 3D wave model solution, not have to cut a slice of the package.
- Time domain solvers – experiences have shown that they do not have a good adaptive mesh, takes forever.





# Computing Platforms

## Computing Efficiency

- Run faster!  More efficient algorithms!
- Simplification of models, model-order reduction, sensitivity analysis, etc. to simplify and reduce the size of the memory requirements.  Also speeds up the solving.
- Problem doing die-to-die sims, using package, vias, traces, etc. models.

# Computing Platforms

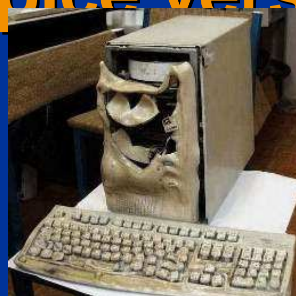
## Computing Efficiency

  - Tools can barely do one pair over the entire path
  - Need to do real-world sims w/ effects of adjacent features, vias, traces, etc.
- Support of large computational machine farms.
  - high $$
  - shared resources amongst groups.
- Dynamically adjust ram usage (not holding all memory resources)

# Computing Platforms

## Tool Robustness

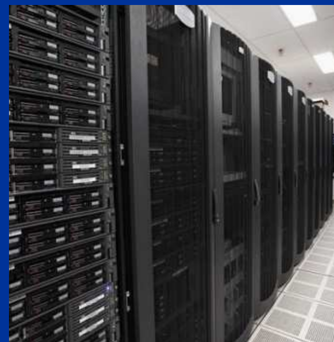
- No Crashes!
- Out of Memory – Graceful Recoveries!  Page out, notify user, etc.
- Intelligent Error Messages and Debug Assistance.
- Convergence Errors – a thing of the past!
- Automatic parameter adjustments, reporting the effects, inaccuracies, etc. of the adjustments/
- Good backwards compatibility, version control, etc. (H-Spice version issues!)



# Computing Platforms

## Multi-platform support

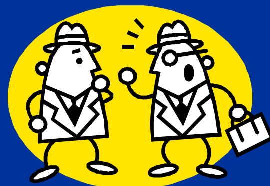
- Windows-64-bit, 32-bit, Windows-7?
- Multi-threaded – multiple processors, multiple cores
- Linux – LSF Farms
- Unix
- Cross-compatible releases.
  - Set up runs on Win32, run transparently on Linux LSF



# Computing Platforms

## Licensing

- Global Floating Licensing at a minimum.
- No up-charge for multi-core use on the same box.
- Unlimited licenses! Pay as we go!
  - Peak Demand licensing, billing by license usage, CPU time, etc.
  - Prevents users who hoard licenses in shared system (180 spice licenses for 3 days!).
  - Never run out of licenses, never waste idle licenses.



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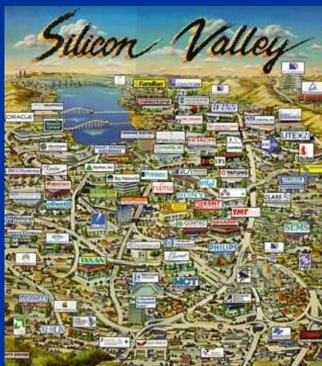
# Tool Development Challenges

# Tool Development Issues

## Commercial Vendors vs. University vs. In-House and Support

- Commercial tool vendors have resources for robust product development, long-term support.
  - For-profit corporations. Costs can be high.
- In-house tool development provides for fast turn-around, specialized features, lower-cost (?) tool sets.



# Tool Development Issues

  - With the power of MatLab, we can build in-house tools at a fraction of the cost of commercial tools.
  - Can be a long-term support problem, as employees transfer jobs, lose jobs, etc.
- University tool development – access to the latest theories, bleeding-edge technologies.
  - Same issues with long-term support. Students graduate – eventually!

# Tool Development Issues

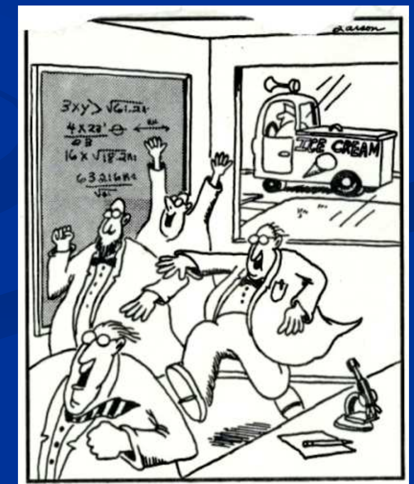
## Multi-vendor Solutions

- What happens when our process incorporates tools from multiple vendors?
- Allows the choice of the best tools, not locked into one company's offerings
- No two companies have identical needs, no "one-size-fits-all" for tools.
- Can have tool integration issues, compatibility between tool data formats.
- Can have support issues. Requires precise problem isolation and verification for each tool.

# Tool Development Issues

## Customer Technical Education

- No $$ for employees to attend conferences, technical seminars!
- Tool vendors need to offer training, education seminars at customer locations.
- Training needs to be high-level technical presentations, not just sales pitches.
- Frequent webinars on technical issues, tool usage, solving real-life problems.

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# Tool Development Issues

## Commercial Vendors and University Relationships

- We see that the new breakthroughs in theories, innovations, methods, algorithms, etc. are coming from universities.
- We expect the vendors to keep up with this university work and implement the latest.
- The commercial tool world MUST support the University world!

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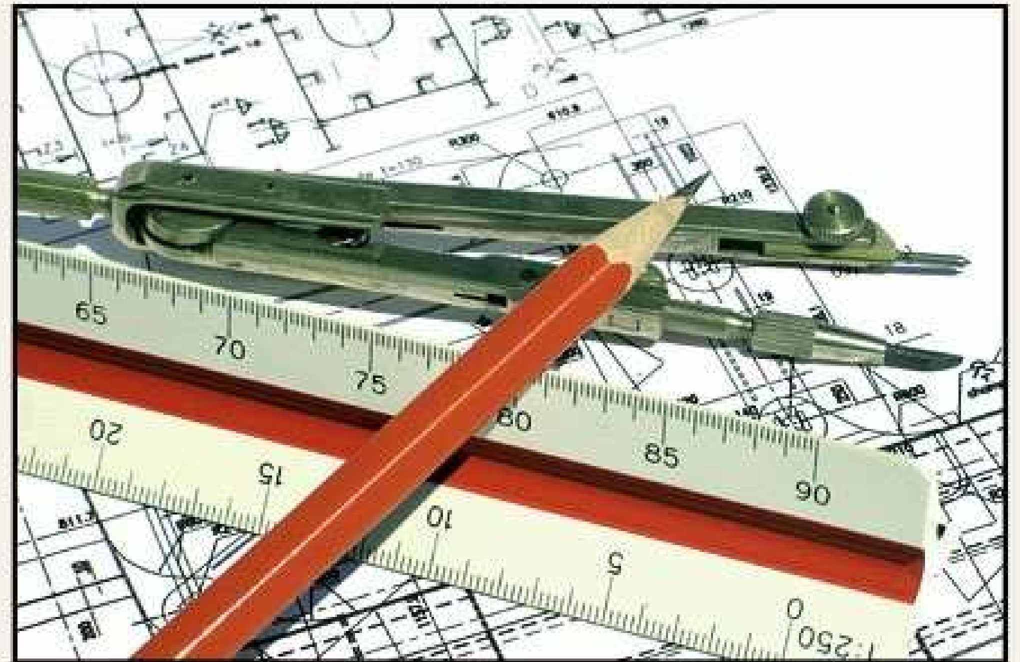
# Tool Development Issues

## Commercial Vendors and University Relationships

- Commercial companies get to pick the educated students, with their new ideas and skills, from the universities.
- Companies get a huge $$$ benefit when they hire the grads who put these new ideas into their tools.
- The commercial companies should help fund their education and development at the schools.

# Design Services



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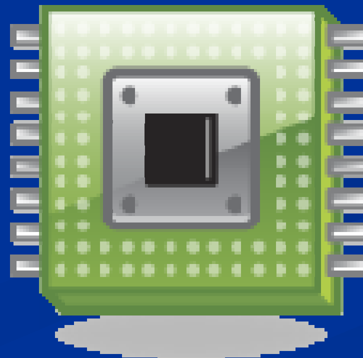
# Design Services

- As headcount shrinks, the workload is only getting worse!
- Companies need more design help from vendors.
- Vendors verify our designs around their components
  - Free service – part of sales / qualification efforts. Amortize the costs across the piece price.
  - We are currently doing this w/ connector, CPU, Serdes vendors.

Molex



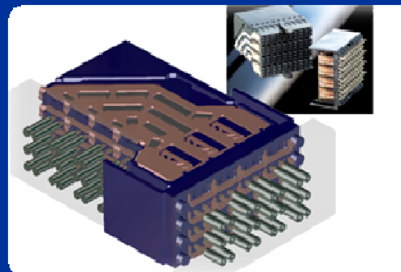
Amphenol-TCS

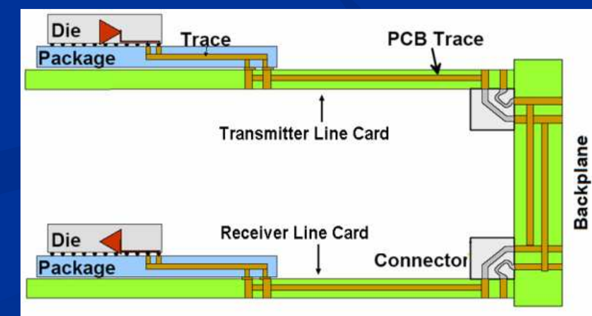
# Design Services

- We provide our channel model, they model and simulate w/ their parts, review results w/ our design team.

- Consulting services
  - Qualified in Tool Use
  - Tools vendors and/or individual consultants can provide serial channel modeling, simulation/verification services as a consulting business model.

Molex





# Summary

# Summary

- Current Business Situation
- What are our Design Challenges?
- New Technology
- Model Formats
- User Experience
- Computing Platforms
- Tool Development Challenges
- Design Services

# Summary

**Continually Less People, More Complex Designs.**

**Not as much about what we can <u>DO</u>**

**but what can we <u>NOT DO</u> !**

# Contributors

- Stephen Scearce
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- All from Cisco Systems

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- CST Computer Simulation Technology, Bad Nauheimer Str. 19, D-64289 Darmstadt, Germany, http://www.cst.com/
- Matlab, The MathWorks, Inc., 3 Apple Hill Drive, Natick, MA 01760-2098, http://www.mathworks.com/
- Agilent Technologies, Inc., 5301 Stevens Creek Blvd, Santa Clara CA 95051., http://www.agilent.com.
- Amphenol-TCS, Nashua, NH., http://www.amphenol-tcs.com
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# Thank You !!