Product Data-Driven Analysis in a Missile Supply Chain

http://eislab.gatech.edu/projects/proam/

ProAM

Project Demonstration

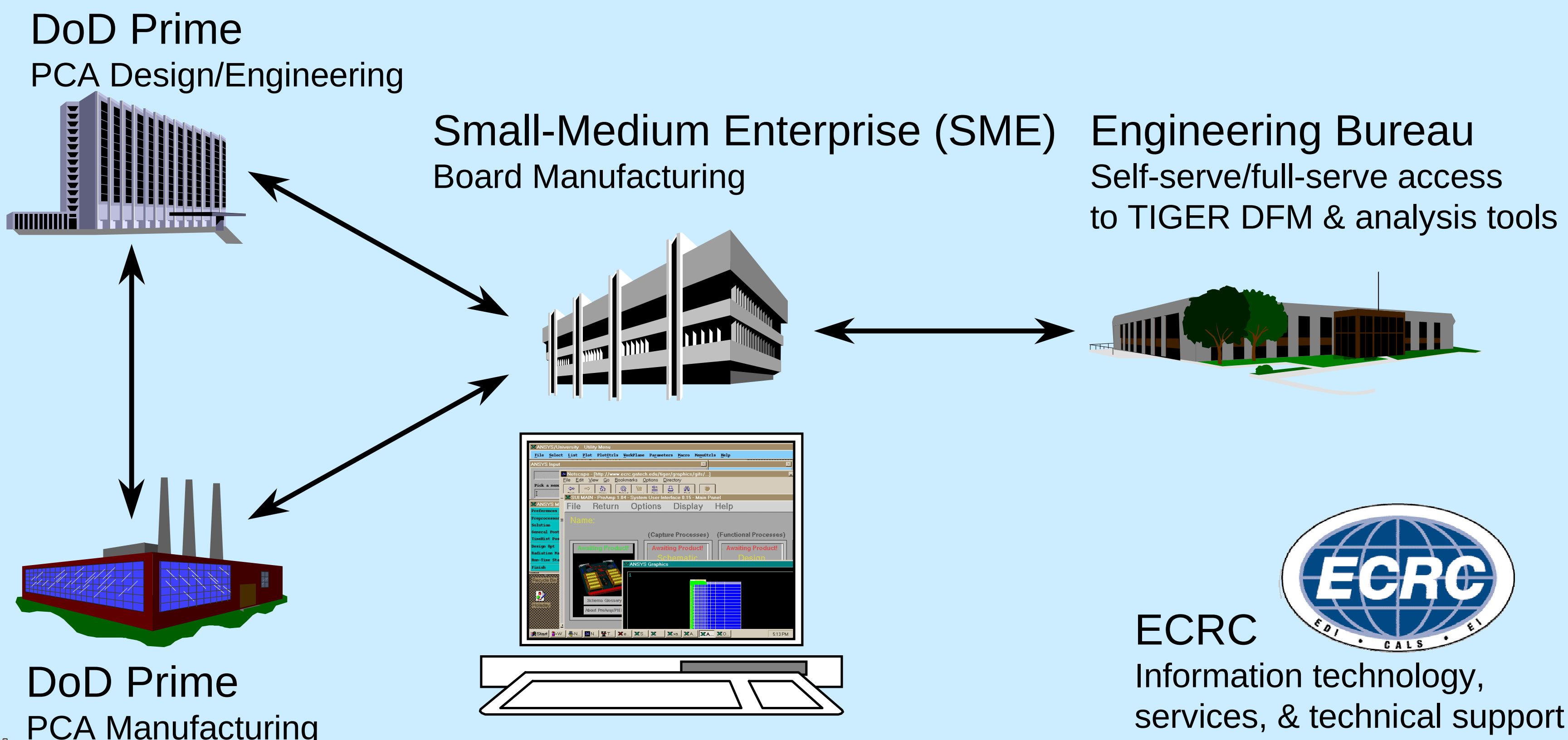
June 17-18, 1999
Manufacturing Research Center
Georgia Tech
Atlanta

Handout 1a

First Generation (2/97): TIGER Tools & Techniques

BAA 95-23

Advanced engineering collaboration among DoD Primes & SMEs, using standards-based tools (TDI/EDI & STEP), facilitated by ECRC technology & services

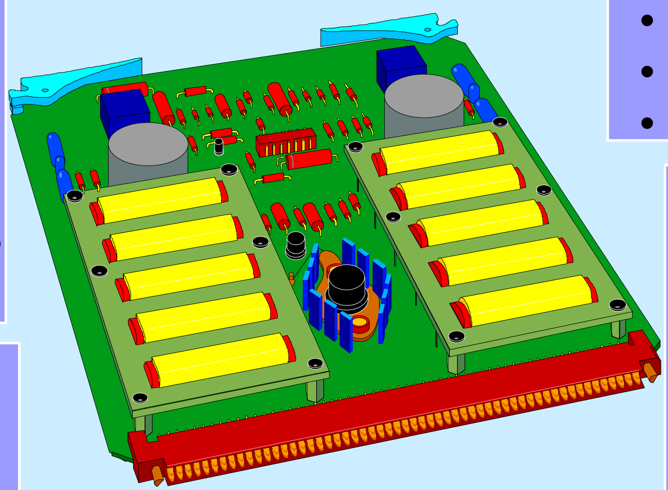


STEP AP 210
PWA/B Design Information

Product Structure/ Connectivity
- Functional
- Packaged

Part
- Functionality
- Termination
- Shape 2D, 3D
- Single Level Decomposition
- Material Product
- Characteristics

Physical
- Component Placement
- Bare Board Geometry
- Layout items
- Layers non-planar, conductive & non-conductive
- Material product



Configuration Mgmt
- Identification
- Authority
- Effectivity
- Control
- Requirement Traceability
- Analytical Model
- Document References

Geometry
- Geometrically Bounded 2-D Shape
- Wireframe with Topology
- Advanced BREP Solids
- Constructive Solid Geometry

Requirements
- Design
- Allocation
- Constraints
- Interface

Technology
- Fabrication Design Rules
- Product Design Rules

ProAM Project Highlights

Title: Product Data-Driven Analysis in a Missile Supply Chain (ProAM)

Sponsor: National ECRC Program

From DoD DLA/DISA Joint Electronic Commerce Program Office (JECPO), via subcontract under Concurrent Technologies Corp. (CTC)

Technical Team: AMCOM - Stakeholder, Atlanta ECRC/Georgia Tech (lead)

SMEs: Circuit Express (Tempe), S3 (Huntsville)

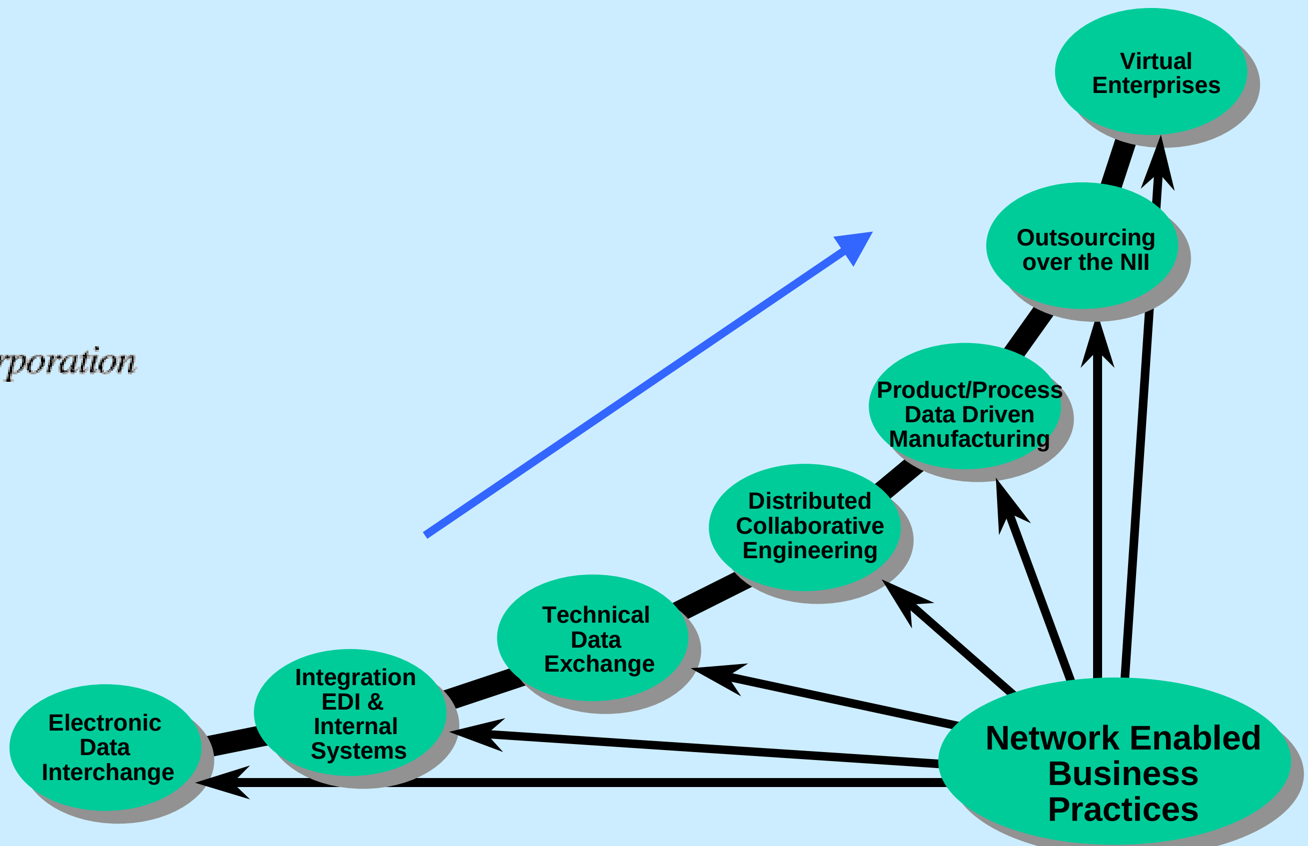
Duration: 8/97-6/99

Focus:
- X-Analysis Integration (XAI) techniques
- Engineering Service Bureau (ESB) paradigm
- Electronics domain (PWA/Bs) - STEP AP210, etc.

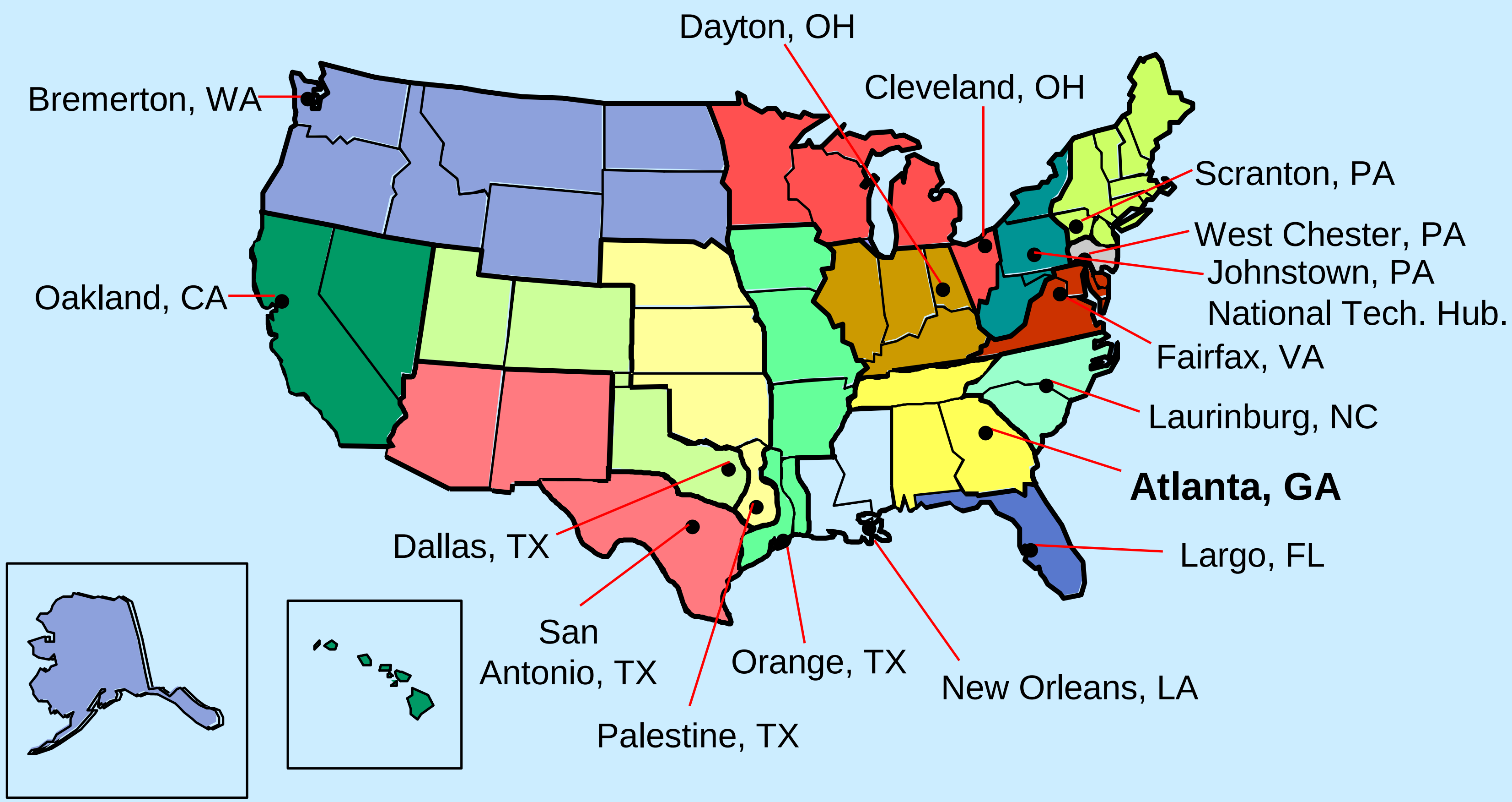
Extensions:
- Transform demo ESB into SME commercial pilot
- Release next-generation XAI toolkit

Electronic Commerce Resource Centers (ECRCs)

Provide assistance to government organizations and small to-medium-sized enterprises (SMEs) by introducing electronic commerce into their business practices

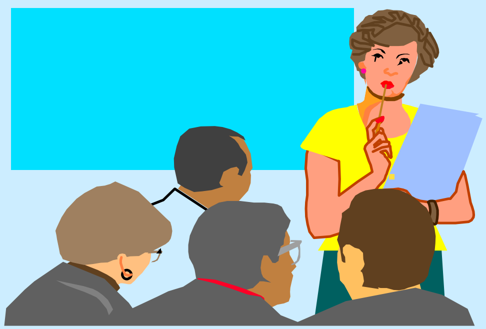


Regional ECRCs



ECRC Core Functions

Outreach



Education & Training

Consultation & Technical Support

Technology Development

ECRC Course Curriculum

- Getting Started with Electronic Commerce
- Business Opportunities With the DoD Through EDI
- Electronic Funds Transfer
- Internet Basics for Small & Medium-sized Companies

- Technical Data Exchange
- Legacy Data Management
- STEP and Product Data Modeling

Contacts for ECRC Services &Course Schedules:
Atlanta ECRC: www.ecrc.gatech.edu, ecrcinfo@ecrc.gatech.edu, 800-894-8042
National ECRC: www.ecrc.ctc.com

Outline

Welcome & Background

Project Overview

- Team
- Motivation & Objectives
- Tasks
- Deliverable Highlights

Break

SME ProAM Experiences

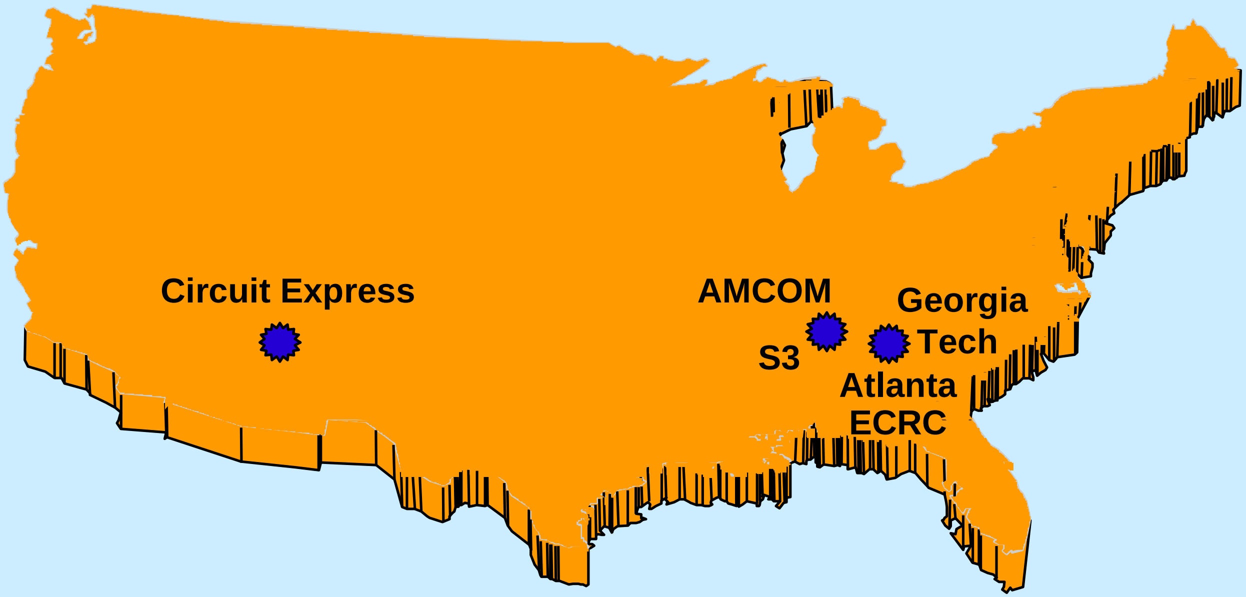
- PWA/B Designer & Fabricator Perspective - Phillip Spann (S3)
- PWB Fabricator Perspective - Jake Roberts (Circuit Express)

Wrap-Up

Discussion - All

Overview of Afternoon Sessions

ProAM Technical Team



AMCOM Mfg. Science & Technology
Group Mission & Objective
http://www.redstone.army.mil/mrdec/mst/

MISSION - Advance the state-of-the-art in manufacturing technologies required for production of Army missile and air vehicle systems

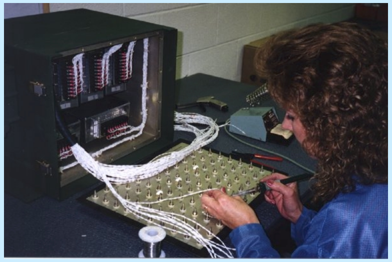
OBJECTIVE - Development and implementation of advanced manufacturing technologies required to assure both the availability and affordability of defense materiel through:

- **Early identification of new technology insertions into existing / future systems**
- **Identification of manufacturing risks / unknowns associated with new technology applications**
- **Investments in research, development, and implementation of advanced manufacturing capabilities**

Other MS&T Activities

- Electronics Fabrication and Analysis Lab to support AMCOM Research and Development
  - PWB Design, Fabrication, Assembly & Test
  - Cable and Wire Harness Fabrication, Assembly & Test
  - PSPICE Circuit Analysis





AMCOM MS&T Role in ProAM

Army Aviation & Missile Command (AMCOM) Manufacturing Science & Technology group helped provide Customer Interface:

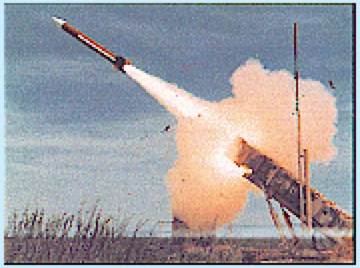
- PWB SME's
- Rapid Prototyping Shops

As Stakeholder, MS&T group provided Technical Oversight for DLA and CTC:

- Performance and Schedule

AMCOM MS&T
ProAM Team Members

• Daron Holderfield	Technical Oversight
• Jeff Carr	Requirements Planning
• Jim Bradt	Requirements Planning



Georgia Tech
CALS Technology Center

- **Engineering Information Systems (EIS) Lab**
  - Applied Research ↔ Industry Projects
  - Graduate Students, University Courses
- **Atlanta Electronic Commerce Resource Center (ECRC)**
  - Helping DoD Vendors Move Up the Electronic Commerce Continuum
  - Training, Outreach, Technical Support & Services
- **Center for Information Technology Insertion (CITI)**
  - Industrial-Strength Information Technology Solutions

Engineering Information Technology
Research, Education, & Insertion

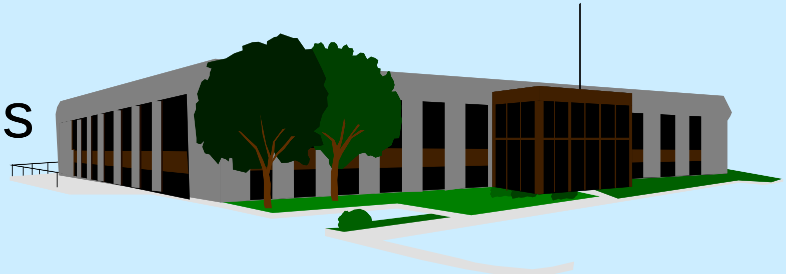
Electronic Commerce Resource Centers (ECRCs)

National Program

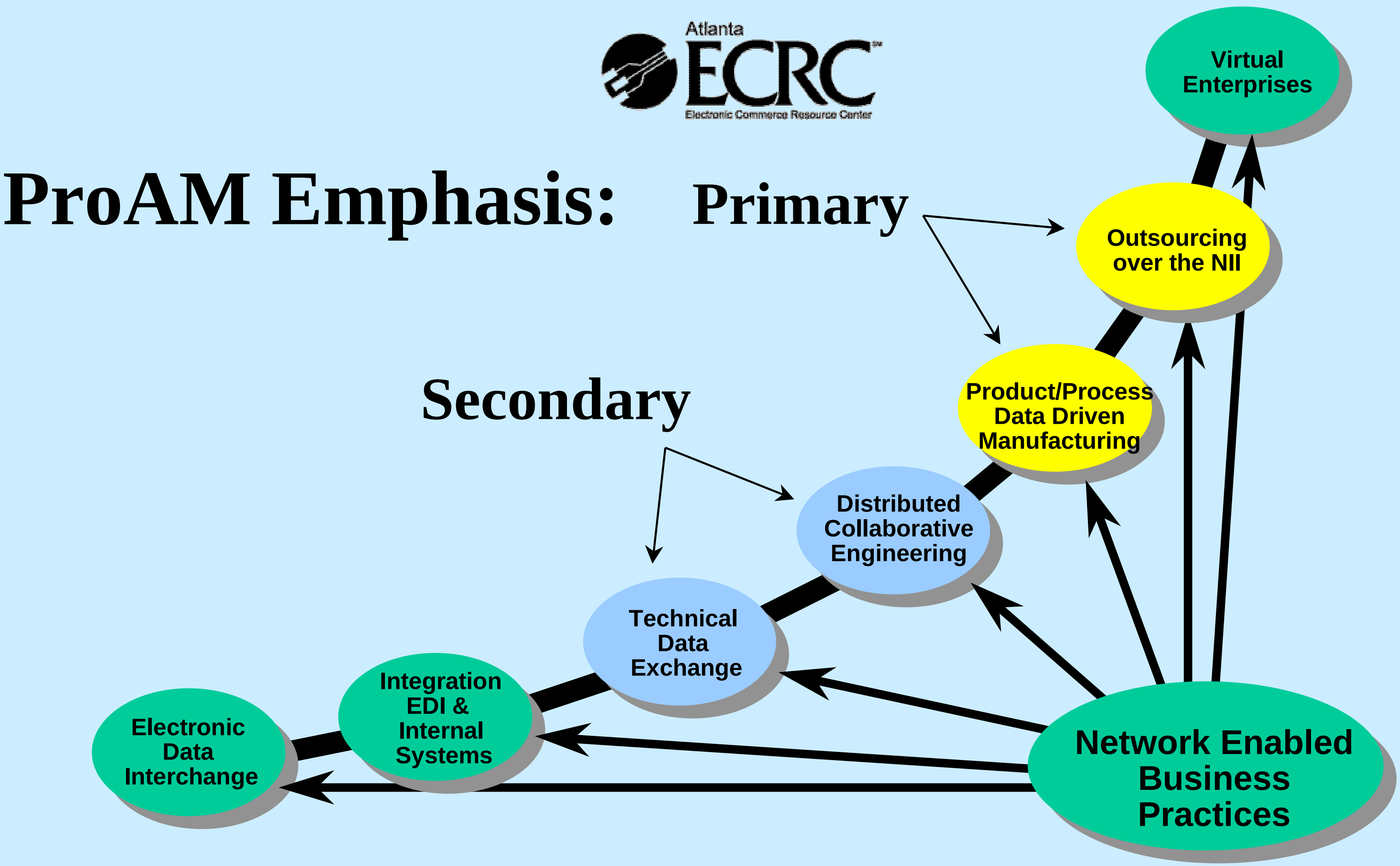
Provide assistance to government organizations and small-to-medium-sized enterprises (SMEs) by introducing electronic commerce into their business practices

Atlanta ECRC Role in ProAM

- Program management & National ECRC interface
- Engineering service bureau infrastructure
- Information technology support for SMEs (Small-Medium Enterprises)
- Technology transfer to SMEs



Helping Organizations Move Up the Electronic Commerce Continuum



Georgia Tech EIS Lab Research Thrusts

- Analysis Integration
  - Design-Analysis Integration (DAI)
  - X-Analysis Integration (XAI)
  - Modular parametric finite element modeling
  - Optimization
- Engineering Information Technology
  - Internet-based engineering service bureaus (ESBs)
  - Engineering change management
  - Product modeling
  - Engineering information standards (e.g., STEP)
- Parallel Processing

Applications

Aerospace, Automotive, Electronic Packaging, etc.

Example EIS Lab Projects

- Team Integrated Electronic Response (TIGER)
  - Sponsor: Defense Advanced Research Prog. Admin. (DARPA) *(SCRA subcontract)*
  - Period: 9/95-3/97
- Subsystem Interface Integration (SII)
  - Sponsor: NASA *(Lockheed Martin subcontract)*
  - Period: 12/97-5/98
- Product Data-Driven Analysis in the Life Cycle Support Process
  - Sponsor: Wright Patterson Air Force Base (WPAFB)
  - Period: 12/97-6/98
- Product Data-Driven Analysis in a Missile Supply Chain (ProAM)
  - Sponsor: Defense Logistics Agency National ECRC Program
  - Stakeholder: U. S. Army Missile Command (AMCOM)
  - Period: 8/97-6/99
- Design Analysis Associativity Technology for PSI (PSI-DANTE)
  - Sponsor: Boeing
  - Period: 9/97-12/98 (Phase 1)
- Design Analysis Integration Research for Electronic Packaging
  - Sponsor: Shinko Electric
  - Period: 1/99-12/99 (Phase 1)

CALS Technology Center
Primary ProAM Technical Team

- *Bob Fulton* - Atlanta ECRC program mgt.
- *Donald Koo* - Warpage tool and FEA R&D
- *Russell Peak* - Program mgt., overall R&D
- *Andy Scholand* - ESB, CORBA, GenCAM/GenX, and electronic packaging R&D; SME interface
- *Diego Tamburini* - Product Model and STEP R&D
- *Sai Zeng* - Layup tool and STEP R&D
- *Miyako Wilson* - XAI toolkit and STEP R&D

AMCOM Supply Chain SME: Systems Studies & Simulation, Inc. (S3)

SYSTEM STUDIES & SIMULATION, Inc

Providing Technical Products and Services to the Defense, Space, and the Intelligence communities

- Small Business (75+ Employees)
- Minority And Woman-Owned
- Alabama Corp. Established In 1993
- Provides Technical & Program Mgt. Services: DoD, NASA, U.S. Army, Intelligence Community, ...

S3 ProAM Context

- Supports AMCOM MS&T electronics lab
  - Analyze Requirements
  - Validate designs via breadboard
  - Design concepts & author specs
  - Generate mechanical designs
  - Develop electrical schematics
  - **Design PWB/As & electronic assy's**
  - Develop & conduct acceptance tests
- ProAM Team & Roles
  - *Phillip Spann* - Test case data & background, ProAM tool usage, Feedback on PWA/B designer needs
  - *Tim Thorton* - Contracting/Mgt. Point of Contact

AMCOM Supply Chain SME: Circuit Express, Inc.

CIRCUIT EXPRESS, INC.

"Quality in Every Process"

- Small business (35 employees)
- Established in 1987
- Arizona corporation
- Printed circuit board fabricator
  - Military and commercial
- Quick-turn manufacturer (same day +)

Circuit Express ProAM Context

- Supplies PWBs to AMCOM & Missile Primes
  - “Representative” high-tech SME fabricator
  - Frequent need for tools: layup design & evaluation
- ProAM Team & Roles
  - *Jake Roberts* - Test case data & background, ProAM tool usage, Feedback on fabricator needs
  - *Terry Bice* - Same

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SME ProAM Experiences

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Wrap-Up
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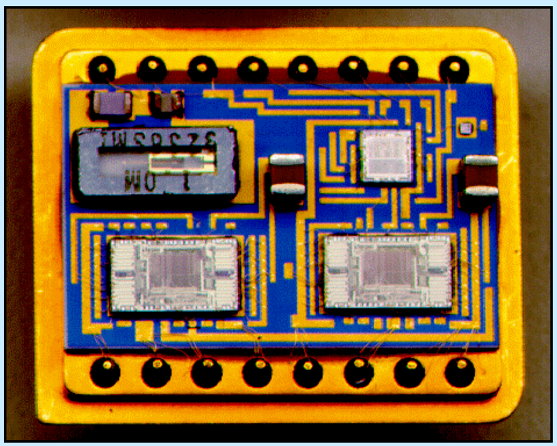
Why Electronics?
Why Analysis of Physical Behavior?

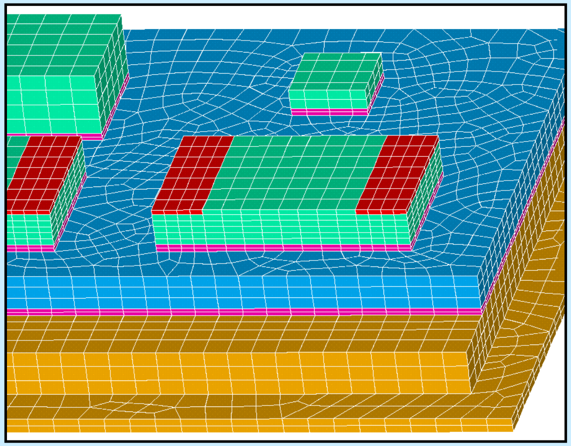
Electronics

- $300B+ industry; Critical technology

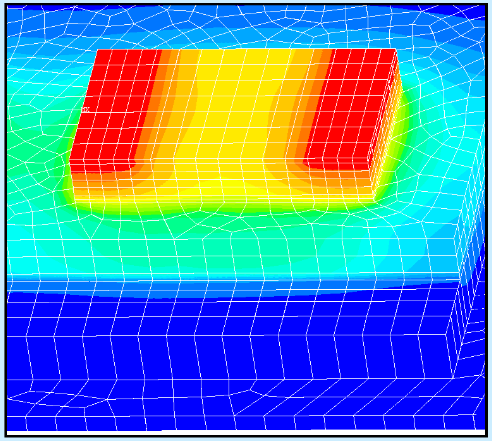
Need for Predictive Analysis

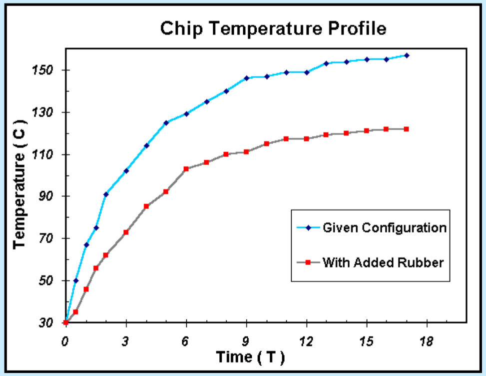


Missile MCM
with Overheating Problems



Finite Element Analysis



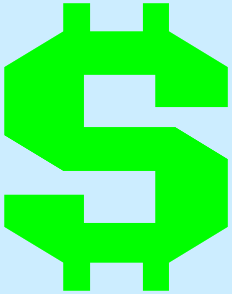


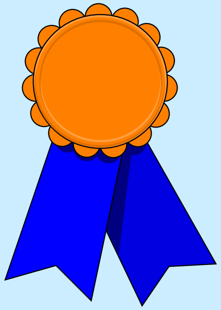
- Costly delays
- Serious consequences
- High improvement potential

Improved vs.
Existing Design

Why Do SME Manufacturers Need Analysis?

- Typically niche-experts
  - Precise mfg. process knowledge
  - Specialized product design knowledge (ex. PWB laminates)
- SME analysis needs
  - Product improvements (DFM)
  - Mfg. process troubleshooting
  - Mfg. process optimization





- More accurate data $\rightarrow$ Better analysis
- Bottom line drivers:

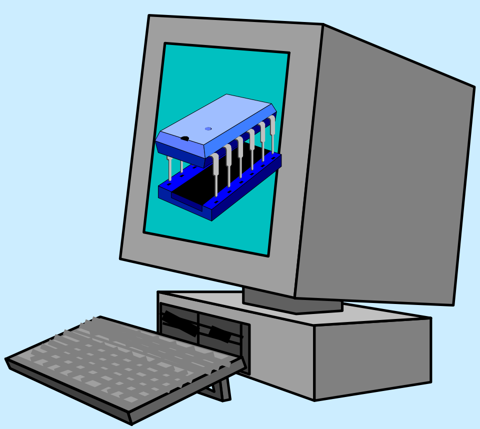
Higher Yields, Lower Cost,

Better Quality, Fewer Delays

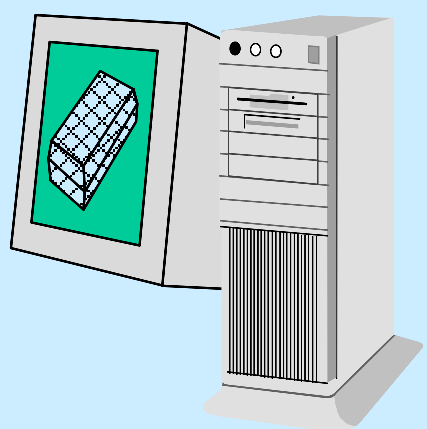
Barriers to SME Analysis

- Lack of awareness
- High costs of traditional analysis capability
  - Secondary: Specialized Software, Training, Hardware
  - Primary: Model Access/Development, Validation, Usage
- Lack of domain-specific integrated tools

Product Model



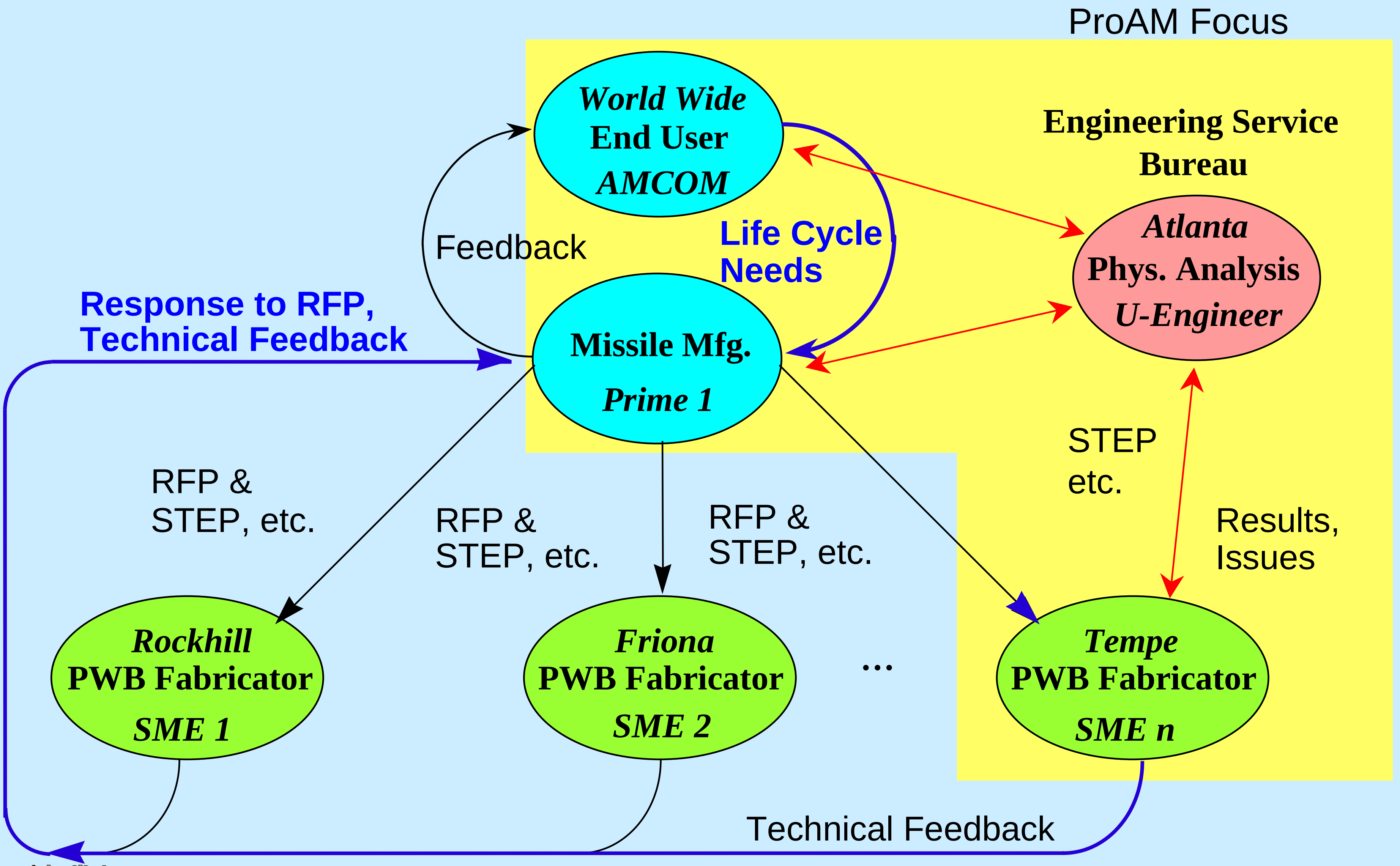
Analysis Model



Skilled Personnel

ProAM Focus

Highly Automated Internet-based Analysis Modules



ProAM Objectives

- **Extend general techniques:**
  - Internet-based engineering service bureau (ESB)
  - X-analysis integration (XAI)
    - Product data-driven plug-and-play analysis modules
    - General purpose XAI toolkit
- **Apply in specific AMCOM context:**
  - U-Engineer.com pilot commercial ESB with Internet-based PWA/B analysis tools
  - Testing by SMEs in AMCOM supply chain

Project Tasks - Overall

	9/97	10/97	11/97	12/97	1/98	2/98	3/98	4/98	5/98	6/98	7/98	8/98	9/98	10/98	11/98	12/98	1/99	2/99	3/99	4/99	5/99	6/99
Phase 0							♦				♦											
Phase 1							♦					♦		♦			♦				♦	
Phase 2												♦									♦	
Phase 3																						♦

♦ Primary Meeting / Milestone

Phase 0

1. Identify SMEs and Primes for pilot in coordination with AMCOM
2. Hold Status Review & Planning Meeting with AMCOM ♦ (3/98)
3. Baseline engineering service bureau (ESB) capabilities
4. Get selected SMEs under contract ♦ (7/98)

Phase 1

1 Hold SME Involvement Kick-Off Meeting ♦ (8/98)

2 Assess SME needs (including on-site visit) ♦ (3/98, 10/98, 5/99)

3 Setup selected SMEs with access to ESB

4 Hold WIP Demonstration ♦ (2/99)

Phase 2

1. Identify new/extended analysis needs
2. Develop and implement new analysis capabilities
3. Extend ESB capabilities
4. Release initial extensions to SMEs for testing ♦ (8/98)
5. Release primary extensions to SMEs for testing ♦ (5/99)

Phase 3

1. Support pilot commercial usage by SMEs
2. Hold Final Demonstration ♦ (6/99)
3. Write reports & package deliverables

Project Tasks - SMEs

Phase 1

2.1 Setup additional capabilities required to access the ProAM ESB (if any)
2.2 Attend SME participation kick-off and training meeting
2.3 Utilize ESB: current capabilities
2.4 Complete needs assessment survey
2.5 Identify potential test case
2.6 Provide test case data
2.7 Participate in Work in Progress (WIP) Meeting and Demonstration

Phase 2

2.8 Utilize ESB: extensions under development

Phase 3

2.9 Utilize ESB: completed extensions
2.10 Summarize feedback on ESB usage and project accomplishments (initial version)
2.11 Participate in Final Demo
2.12 Summarize feedback on ESB usage and project accomplishments (final version)

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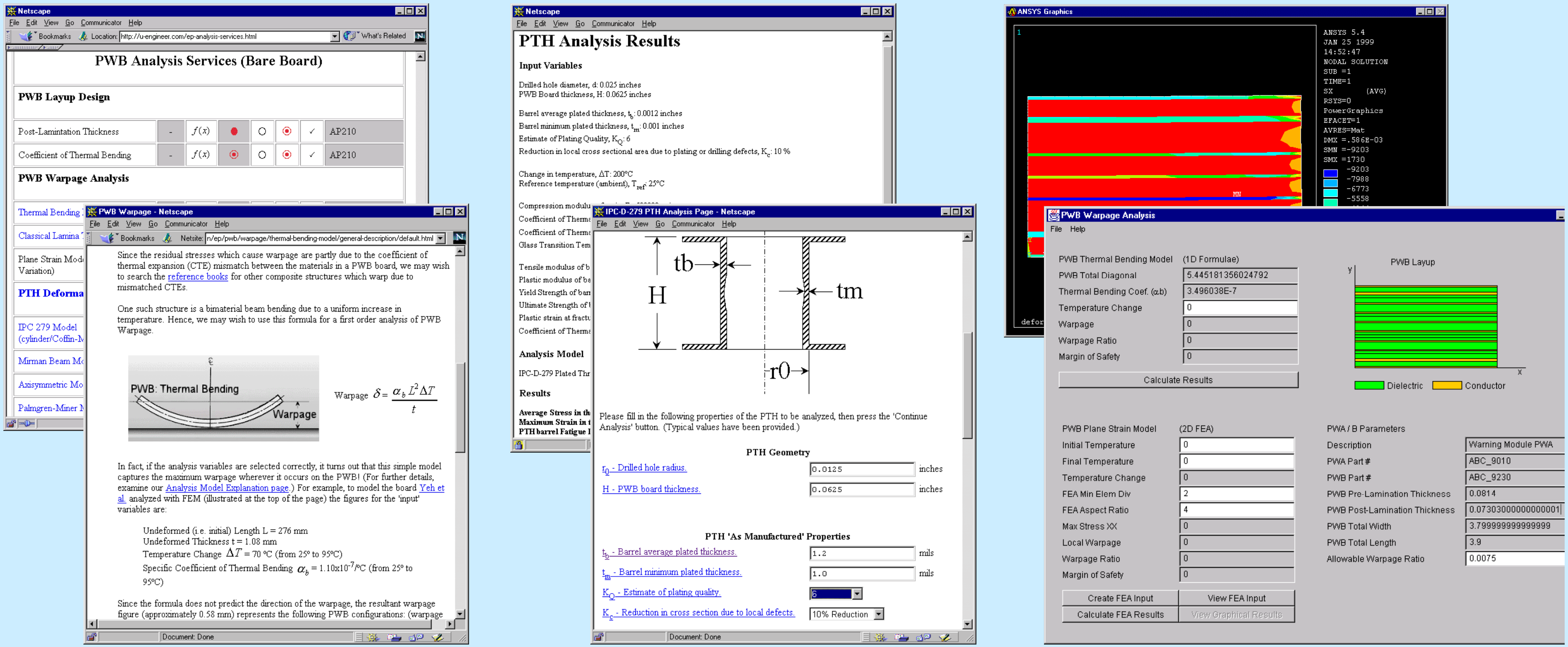
ProAM Deliverable Highlights

- **General techniques:**
  - Internet-based engineering service bureau (ESB)
  - X-analysis integration (XAI)
    - Product data-driven plug-and-play analysis modules
    - General purpose XAI toolkit
- **Applications in specific AMCOM context:**
  - U-Engineer.com pilot commercial ESB with Internet-based PWA/B-specific analysis modules & toolkit
  - Usage by SMEs in AMCOM supply chain

ESB-based Tools



Analysis Documentation

Ready-to-Use Analysis Modules

Lower cost, better quality, fewer delays in supply chain

ESB Analysis Module
Catalogs & Documentation

Netscape — Location: http://u-engineer.com/ep-analysis-services.html

PWB Analysis Services (Bare Board)

PWB Layup Design							
Post-Lamintation Thickness	-	$f(x)$	●	○	◉	✓	AP210
Coefficient of Thermal Bending	-	$f(x)$	◉	○	◉	✓	AP210
PWB Warpage Analysis							
Thermal Bending Model	1D	$f(x)$	○	○	◉	✓	AP210
Classical Lamina Theory Model	2D	$f(x)$	◉	○	○	✓	
Plane Strain Model (Material Variation)	2D		○	○	◉	✓	AP210
PTH Deformation & Fatigue Analysis							
IPC 279 Model (cylinder/Coffin-Manson)	1D	$f(x)$	●P	◉	○	✓	GenX
Mirman Beam Model	1D	$f(x)$	●P	◉	○	✓	GenX
Axisymmetric Model	2D		●	◉	○	✓	GenX
Palmgren-Miner Model	-	$f(x)$		○	○	✓	

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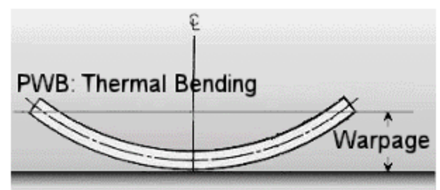
PWB Warpage - Netscape — Netsite: n/ep/pwb/warpage/thermal-bending-model/general-description/default.html

Since the residual stresses which cause warpage are partly due to the coefficient of thermal expansion (CTE) mismatch between the materials in a PWB board, we may wish to search the reference books for other composite structures which warp due to mismatched CTEs.

One such structure is a bimaterial beam bending due to a uniform increase in temperature. Hence, we may wish to use this formula for a first order analysis of PWB Warpage.



Warpage $\delta = \dfrac{\alpha_b L^2 \Delta T}{t}$

In fact, if the analysis variables are selected correctly, it turns out that this simple model captures the maximum warpage wherever it occurs on the PWB! (For further details, examine our Analysis Model Explanation page.) For example, to model the board Yeh et al. analyzed with FEM (illustrated at the top of the page) the figures for the 'input' variables are:

Undeformed (i.e. initial) Length L = 276 mm
Undeformed Thickness t = 1.08 mm
Temperature Change ΔT = 70 °C (from 25° to 95°C)
Specific Coefficient of Thermal Bending α_b = 1.10x10^{-7}/°C (from 25° to 95°C)

Since the formula does not predict the direction of the warpage, the resultant warpage figure (approximately 0.58 mm) represents the following PWB configurations: (warpage

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ESB Characteristics

- **Self-serve analysis**
  - Pre-developed analysis modules presented in product & process contexts
  - Available via the Internet
  - Optionally standards-driven (STEP, GenCAM ...):
    - » Reduce manual data transformation & re-entry
    - » Highly automated plug-and-play usage
  - Enabled by X-analysis integration technology
- **Full-serve analysis as needed**
- **Possible business models:** (beyond ProAM scope)
  - Pay-per-use and/or Pay-per-period
  - Costs averaged across customer base

Internet-based ESB Techniques

- Analysis module template & methodology
- Range of access methods:
  - Remote Tools
    - Login to remote workstation; X-Windows display
  - Thick Clients
    - Locally installed w/ Internet/LAN-based solvers via CORBA
  - Thin Clients
    - Web-based forms & solvers all located at ESB
- General web techniques
- General EC: electronic payment, etc.
  (not in ProAM scope)

ProAM Deliverable Highlights

- **General techniques:**
  - Internet-based engineering service bureau (ESB)
  - X-analysis integration (XAI)
    - Product data-driven plug-and-play analysis modules
    - General purpose XAI toolkit
- **Applications in specific AMCOM context:**
  - U-Engineer.com pilot commercial ESB with Internet-based PWA/B-specific analysis modules & toolkit
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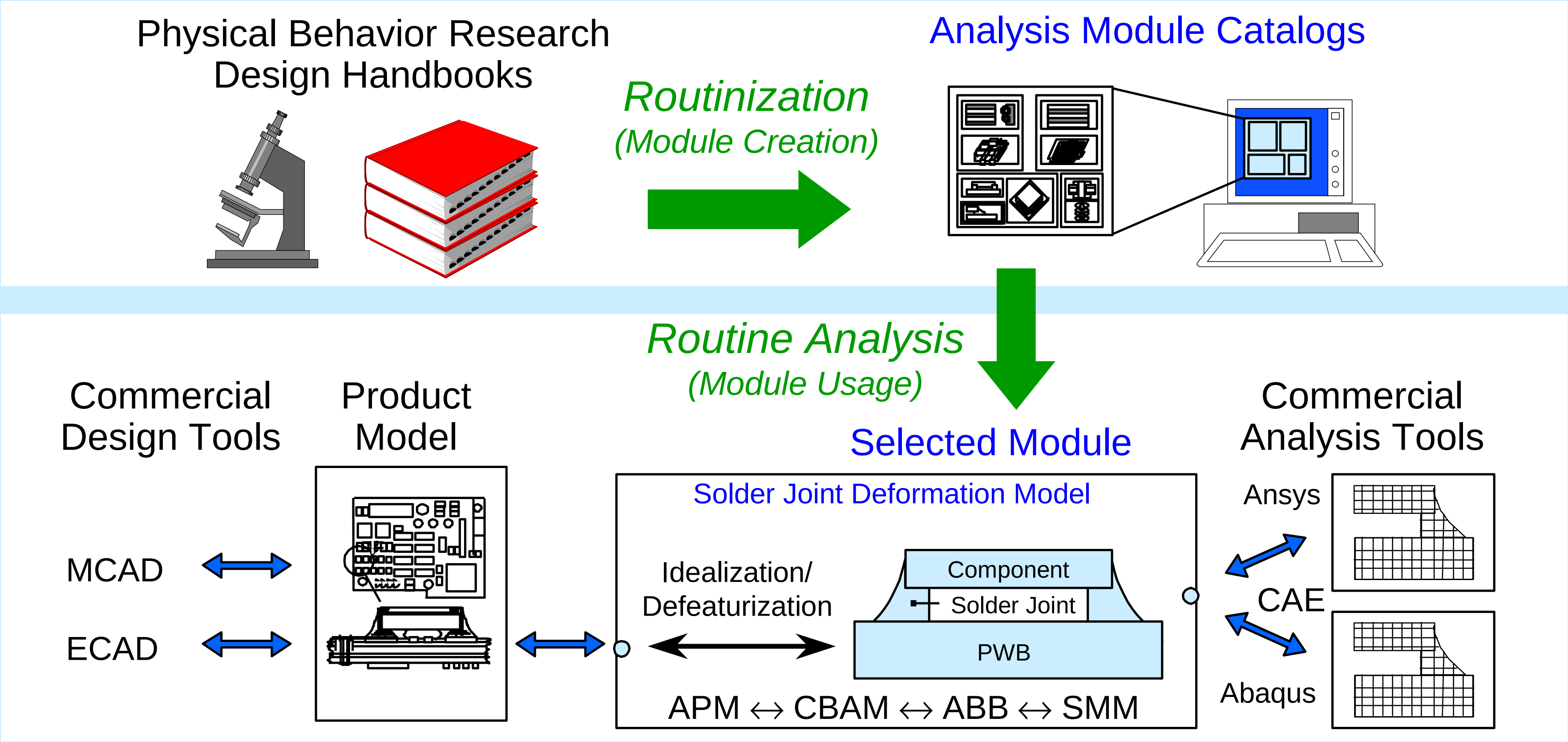
Plug-and-Play Analysis Module Creation Methodology



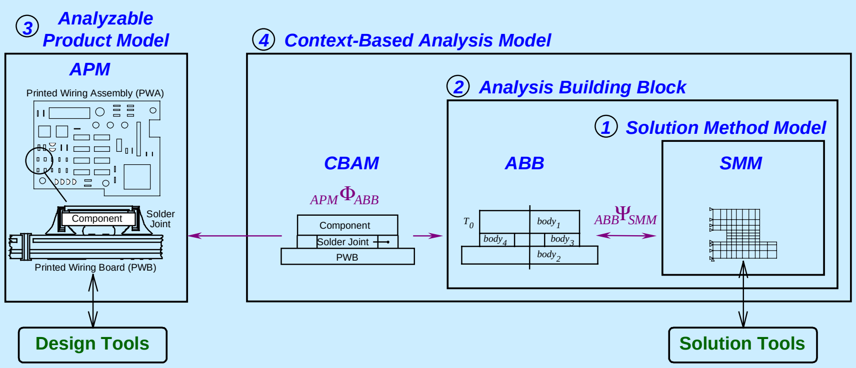
- Provides technique to bridge CAD-CAE gap
- Uses AI & info. technology: objects, constraints, STEP

XaiTools

Prototype X-Analysis Integration Toolkit

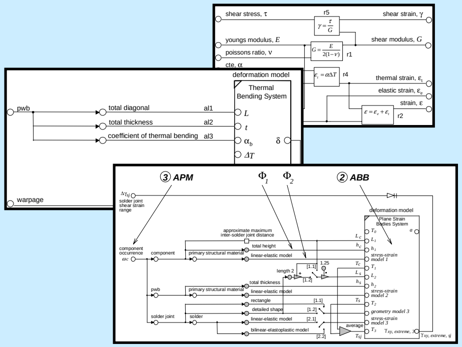
Second Generation - Java-based

Multi-Representation Architecture (MRA)

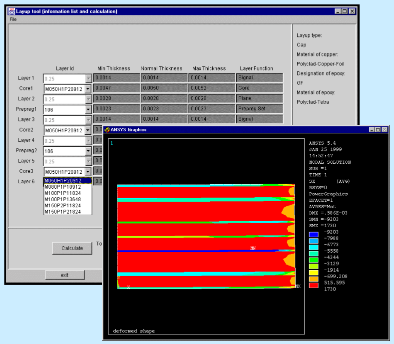


Analysis Modules & Building Blocks

Constraint Schematics



Implementations



- Product-independent MRA toolkit
- Lexical constrained objects (COBs)
  - Data-driven creation
  - User-adaptable
- Mathematica constraint solver
  - More capabilities
- SMM-type wrappings:
  - FEA tools: Ansys, Abaqus*
  - Symbolic Eqn. Solver: Mathematica
- Extended APM technique for design links:
  - CATIA MCAD modeler
- Updates/Extensions in progress*:
  - PWB/A: GenCAM; STEP AP210-based APM link w/ Mentor Graphics BoardStation
  - Generalized MCAD modeler links
  - Advanced parametric FEA transformation
  - Object-Oriented Optimization
  - CORBA-based tool interchanges
  - XML views of analysis results etc.

XaiTools Tool Architecture

Company/Product-Independent View

In-Progress & Potential Extensions as of 6/99

MCAD: *CATIA*
IDEAS, Pro/E*, AutoCAD**
ECAD: *Mentor Graphics (AP210)*
*Accel (PDIF, GenCAM)**

Design Tools

CAD Tool

Material Property Manager

Standard Parts Manager

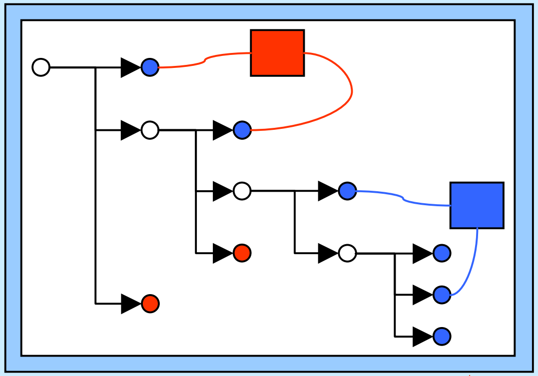
Template Libraries: *Analysis Packages*, CBAMs, ABBs, APMs, Conditions**
Instances: *Usage/adaptation of templates*

COB Schemas
objects, x.cos, x.exp

Persistent Object Repository
Java blob, ODBMS*, PDM**

COB Instances
objects, x.coi, x.step

COB Server



Other CORBA Wrappers*

Tool Forms
(parameterized tool models/full* SMMs)

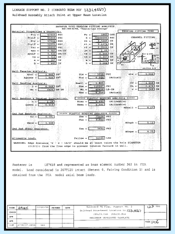
Analysis Codes

Constraint Solver

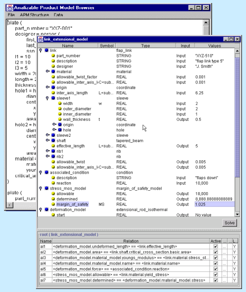
FEA: *Ansys, Elfini*, Abaqus**
Math: *Mathematica, MatLab*, MathCAD**

Mathematica

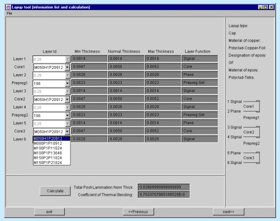
Analysis Mgt. Tools
Pullable Views, Condition Mgr*, ...*



COB Analysis Tools
Navigator: *XaiTools*
Editor (text & graphical*)



Custom Tools



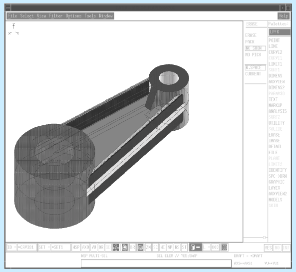
asterisk (*) = in-progress/possible extensions

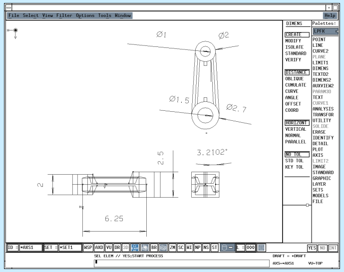
Flexible High Diversity Design-Analysis Integration

Tutorial Examples: Flap Link (Mechanical/Structural Analysis)

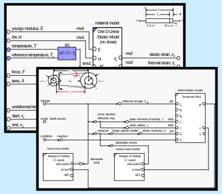
MCAD Tools

CATIA



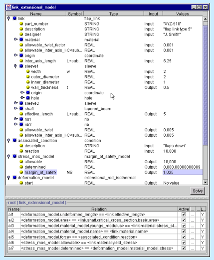


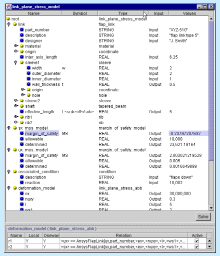
Modular, Reusable Template Libraries



Analysis Modules (CBAMs) of Diverse Mode & *Fidelity*

XaiTools

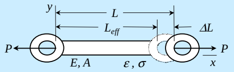




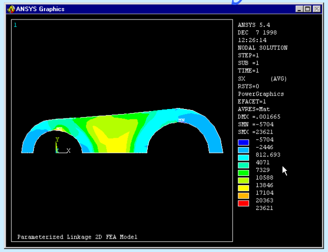
Analysis Tools

General Math

Mathematica



FEA *Ansys*



Analyzable Product Model

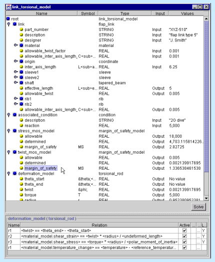
XaiTools

Extension

1D, 2D, 3D*

Torsion

1D



Materials DB

MATDB-like

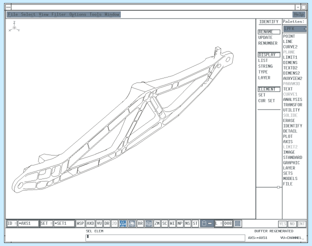
* = Item not available in working prototype yet (all others have working examples)

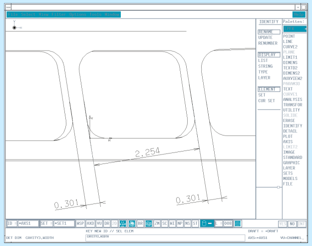
Flexible High Diversity Design-Analysis Integration

Aerospace Examples: Flap Support Inboard Beam

MCAD Tools

CATIA



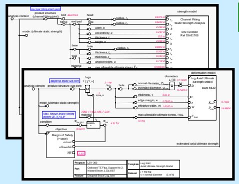


Materials DB

MATDB-like

Fasteners DB

FASTDB-like



Modular, Reusable Template Libraries

Analyzable Product Model

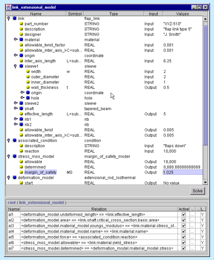
XaiTools

Analysis Modules (CBAMs) of Diverse Feature:Mode, & Fidelity

XaiTools

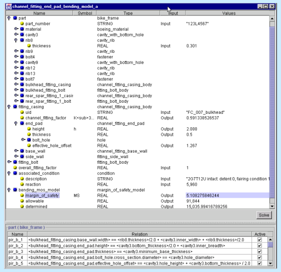
1.5D

Lug: Axial/Oblique; Ultimate/Shear



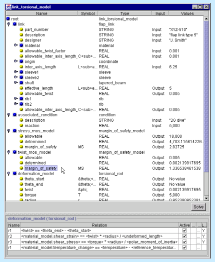
1.5D

Fitting: Bending/Shear



3D

Assembly: Ultimate/ FailSafe/Fatigue*



Analysis Tools

In-House

*IAS Template**

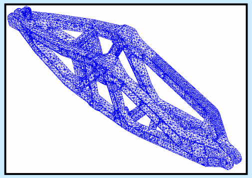
or

General Math

Mathematica

FEA

*Elfini**



* = Item not available in working prototype yet (all others have working examples)

ProAM Deliverable Highlights

- **General techniques:**
  - Internet-based engineering service bureau (ESB)
  - X-analysis integration (XAI)
    - Product data-driven plug-and-play analysis modules
    - General purpose XAI toolkit
- **Applications in specific AMCOM context:**
  - U-Engineer.com pilot commercial ESB with Internet-based PWA/B-specific analysis modules & toolkit
  - Usage by SMEs in AMCOM supply chain

U-Engineer Analysis Module Catalog with Attributes

Netscape — File Edit View Go Communicator Help

Solution Method - An indication of model computational cost.

- $f(x)$ — Formula Based
- [FE icon] — Finite Element

Utility Ranking - A measure of analysis model validity.

- ○ Demonstration
- ○ (red) Trends
- ◉ Magnitude Relative
- ● Absolute

A "P" suffix indicates the ranking is backed by physical measurements.

Tool Availability - A measure of implementation maturity.

- ○ Concept
- ○ (red) Prototype
- ◉ Pilot
- ● Production

Document: Done

Netscape — File Edit View Go Communicator Help — Bookmarks — Location: http://u-engineer.com/ep-analysis-services.html — What's Related

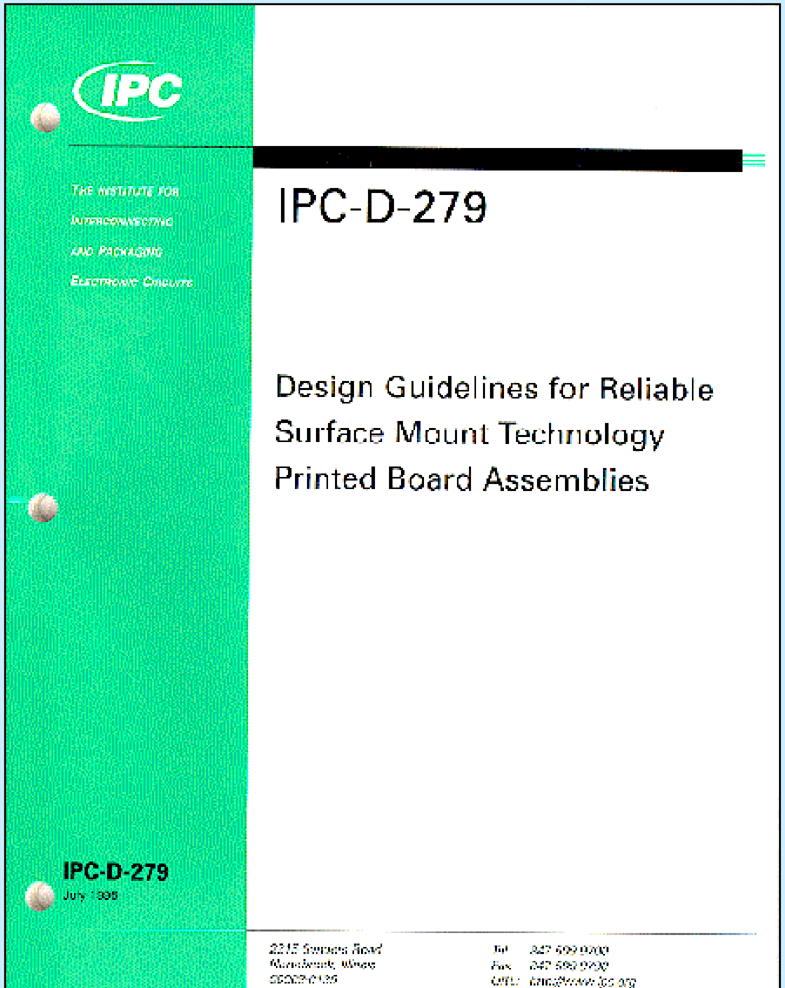
PWB Analysis Services (Bare Board)

	Dimensionality	Solution Method	Utility Ranking	Availability: Self - Serve Web	Availability: Self - Serve Toolkit	Availability: Full - Serve	Supported Design Formats
PWB Layup Design							
Post-Lamintation Thickness	-	$f(x)$	●	○	◉	✓	AP210
Coefficient of Thermal Bending	-	$f(x)$	◉	○	◉	✓	AP210
PWB Warpage Analysis							
Thermal Bending Model	1D	$f(x)$	○ (red)	○	◉	✓	AP210
Classical Lamina Theory Model	2D	$f(x)$	◉	○ (red)	○	✓	
Plane Strain Model (Material Variation)	2D	[FE icon]	○ (red)	○	◉	✓	AP210
PTH Deformation & Fatigue Analysis							
IPC 279 Model (cylinder/Coffin-Manson)	1D	$f(x)$	●P	◉	○	✓	GenX
Mirman Beam Model	1D	$f(x)$	●P	◉	○	✓	GenX
Axisymmetric Model	2D	[FE icon]	●	◉	○	✓	GenX
Palmgren-Miner Model	-	$f(x)$		○ (red)	○	✓	

Document: Done

Paper-based IPC-D-279 Plated Through Hole Fatigue Analysis

Tedious to Use


IPC

THE INSTITUTE FOR INTERCONNECTING AND PACKAGING ELECTRONIC CIRCUITS

IPC-D-279

Design Guidelines for Reliable Surface Mount Technology Printed Board Assemblies

IPC-D-279

July 1996

PTH/PTV Fatigue Life Estimation

$$\sigma_{avg} = \frac{\left[(\alpha_E - \alpha_{Cu})\Delta T + S_y \cdot \frac{E_{Cu} - E_{Cu}'}{E_{Cu} \cdot E_{Cu}'}\right] A_E \cdot E_E \cdot E_{Cu}'}{A_E \cdot E_E + A_{Cu} \cdot E_{Cu}'}$$

$$\Delta\varepsilon_{avg} = \frac{(\alpha_E - \alpha_{Cu})\Delta T \cdot A_E \cdot E_E - S_y \cdot A_{Cu} \cdot \frac{E_{Cu} - E_{Cu}'}{E_{Cu}}}{A_E \cdot E_E + A_{Cu} \cdot E_{Cu}'}$$

$$N_f^{-0.6} D_f^{0.75} + 0.9 \frac{S_u}{E}\left[\frac{e^{D_f}}{0.36}\right]^{0.1785\log\frac{10^5}{N_f}} - \Delta\varepsilon = 0$$

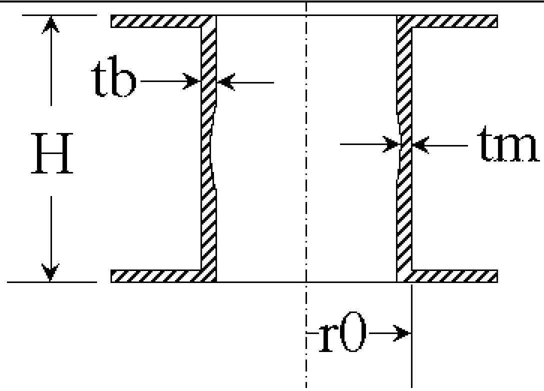
$$N_f(x\%) = N_f(50\%)\left[\frac{\ln(1-0.01x)}{\ln(0.5)}\right]^{\frac{1}{\beta}}$$

Web-based IPC-D-279 PTH Analysis Module

Easy to Use

IPC-D-279 PTH Analysis Page - Netscape

File Edit View Go Communicator Help



Please fill in the following properties of the PTH to be analyzed, then press the 'Continue Analysis' button. (Typical values have been provided.)

PTH Geometry

r_0 - Drilled hole radius.	0.0125	inches
H - PWB board thickness.	0.0625	inches

PTH 'As Manufactured' Properties

t_b - Barrel average plated thickness.	1.2	mils
t_m - Barrel minimum plated thickness.	1.0	mils
K_Q - Estimate of plating quality.	6	
K_c - Reduction in cross section due to local defects.	10% Reduction	

Document: Done

Netscape

File Edit View Go Communicator Help

PTH Analysis Results

Input Variables

Drilled hole diameter, d: 0.025 inches
PWB Board thickness, H: 0.0625 inches

Barrel average plated thickness, t_b: 0.0012 inches
Barrel minimum plated thickness, t_m: 0.001 inches
Estimate of Plating Quality, K_Q: 6
Reduction in local cross sectional area due to plating or drilling defects, K_c: 10 %

Change in temperature, ΔT: 200°C
Reference temperature (ambient), T_{ref}: 25°C

Compression modulus of resin, E_f: 500000 psi
Coefficient of Thermal Expansion of resin, α_f below T_g: 0.000067 /°C
Coefficient of Thermal Expansion of resin, α_f above T_g: 0.000315 /°C
Glass Transition Temperature, T_g: 137 °C

Tensile modulus of barrel material, E_b: 3000000 psi
Plastic modulus of barrel material, E_b': 100000 psi
Yield Strength of barrel material, S_y: 25000 psi
Ultimate Strength of barrel material, S_u: 41000 psi
Plastic strain at fracture of barrel material, D_f: 0.203
Coefficient of Thermal Expansion of barrel material, α_b: 0.000017 /°C

Analysis Model

IPC-D-279 Plated Through Hole Model

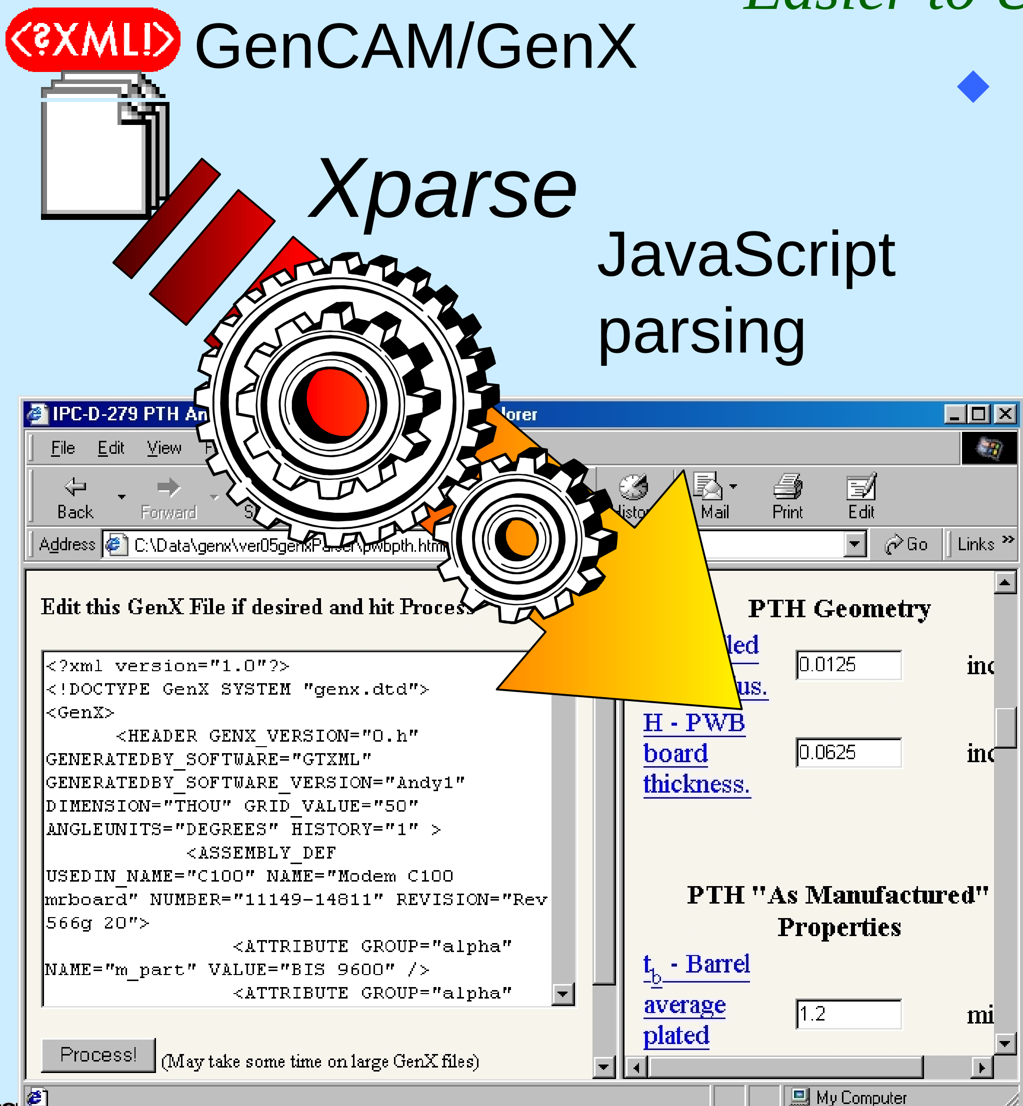
Results

Average Stress in the PTH barrel: 30.0317e3 psi
Maximum Strain in the PTH barrel: 0.121682
PTH barrel Fatigue Life: 10.61e3 cycles to 50% failure probability.

Document: Done

Product Data-Driven IPC-D-279 PTH Analysis Module

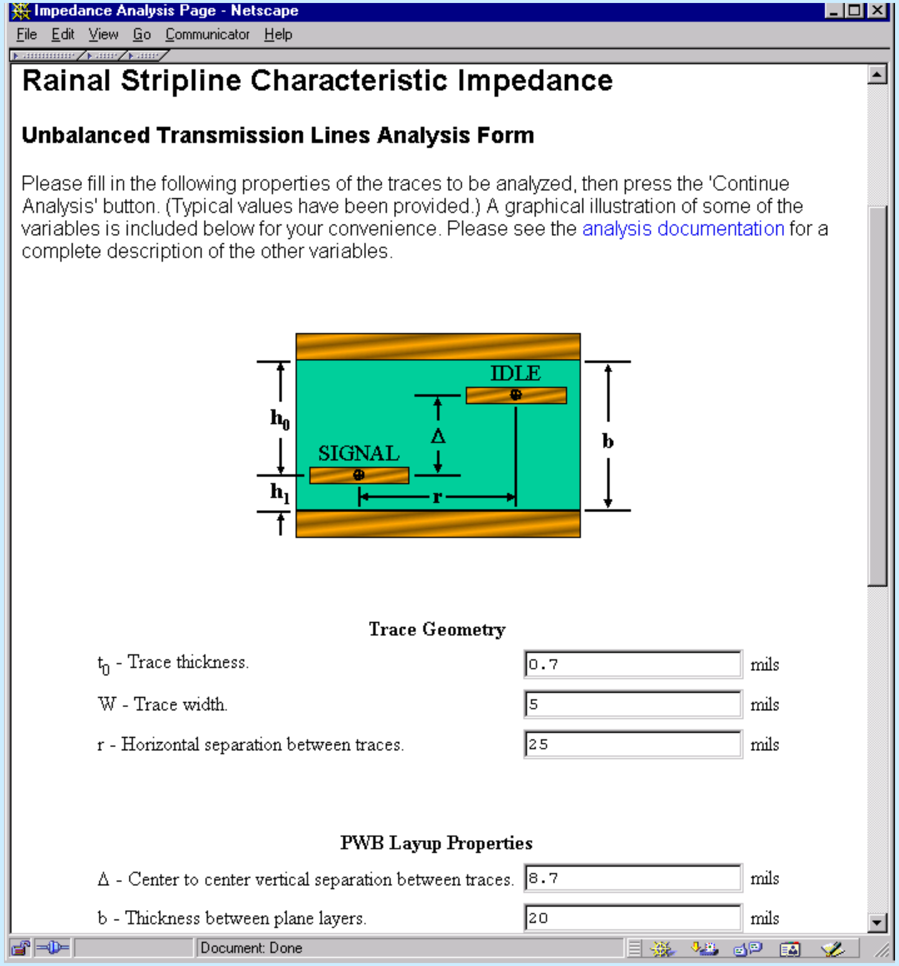
Easier to Use



- Data Driven aspect: Web Browser Processes Neutral File
  - \+ Local Browser Computation
  - \+ Less Errors than manual idealization & re-entry
  - \+ Exhaustive search
  - \+ Data Compression (e.g. 100x)
  - \+ Security

Other U-Engineer Modules

- PTH finite element analysis (FEA) module
- Impedance modules


Impedance Analysis Page - Netscape

File Edit View Go Communicator Help

Rainal Stripline Characteristic Impedance

Unbalanced Transmission Lines Analysis Form

Please fill in the following properties of the traces to be analyzed, then press the 'Continue Analysis' button. (Typical values have been provided.) A graphical illustration of some of the variables is included below for your convenience. Please see the analysis documentation for a complete description of the other variables.

Trace Geometry

t_0 - Trace thickness.	0.7	mils
W - Trace width.	5	mils
r - Horizontal separation between traces.	25	mils

PWB Layup Properties

Δ - Center to center vertical separation between traces.	8.7	mils
b - Thickness between plane layers.	20	mils

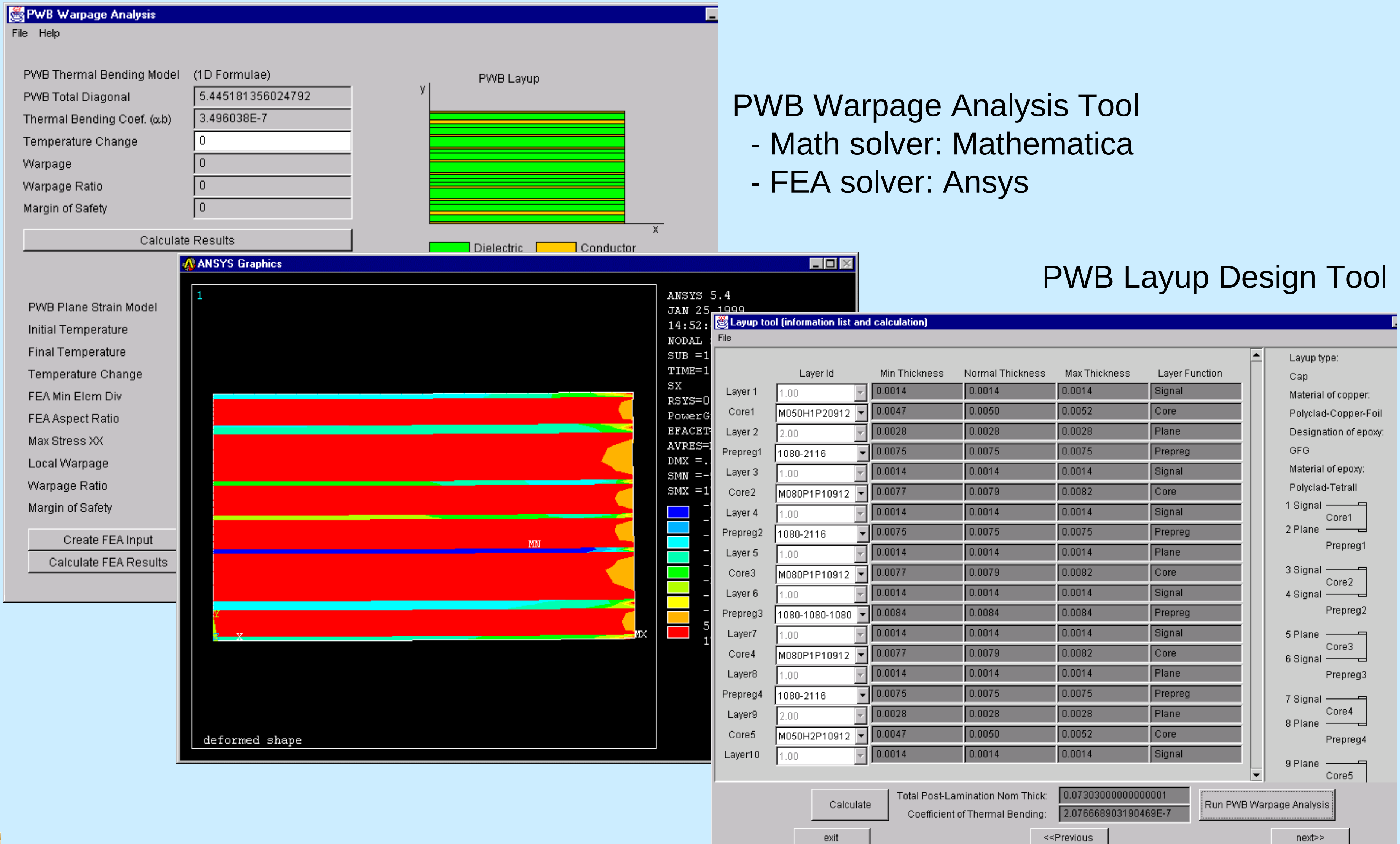
Document: Done

XaiTools PWA-B

Thick Client: Locally installed; Internet ESB/LAN-based Solvers

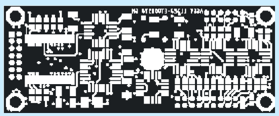
PWB Warpage Analysis Tool
- Math solver: Mathematica
- FEA solver: Ansys

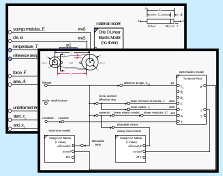
PWB Layup Design Tool



ProAM X-Analysis Integration
XaiTools PWA-B

ECAD Tools
*Mentor Graphics, Accel**



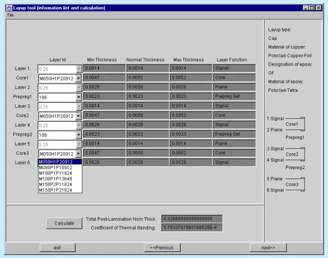


Modular, Reusable Template Libraries

Analysis Modules (CBAMs) of Diverse Mode & *Fidelity*

STEP AP210,
GenCAM**,
PDIF*

PWB Layup Tool



Analyzable Product Model

XaiTools

Laminates DB

Materials DB

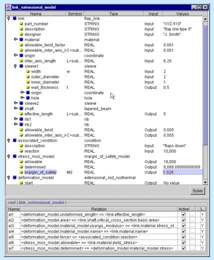
Solder Joint Deformation — *1D, 2D, 3D*

PWB Warpage — *1D, 2D*

PTH Deformation & Fatigue** — *1D, 2D*

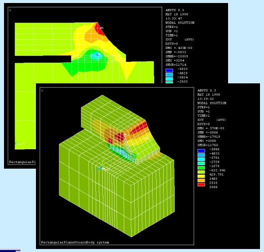
Analysis Tools

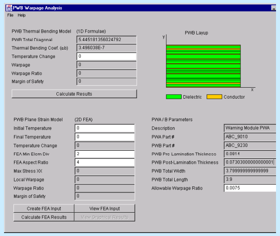
XaiTools

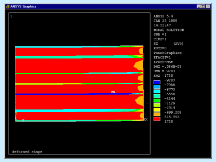


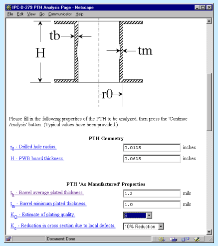
General Math *Mathematica*

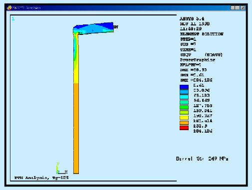
FEA *Ansys*











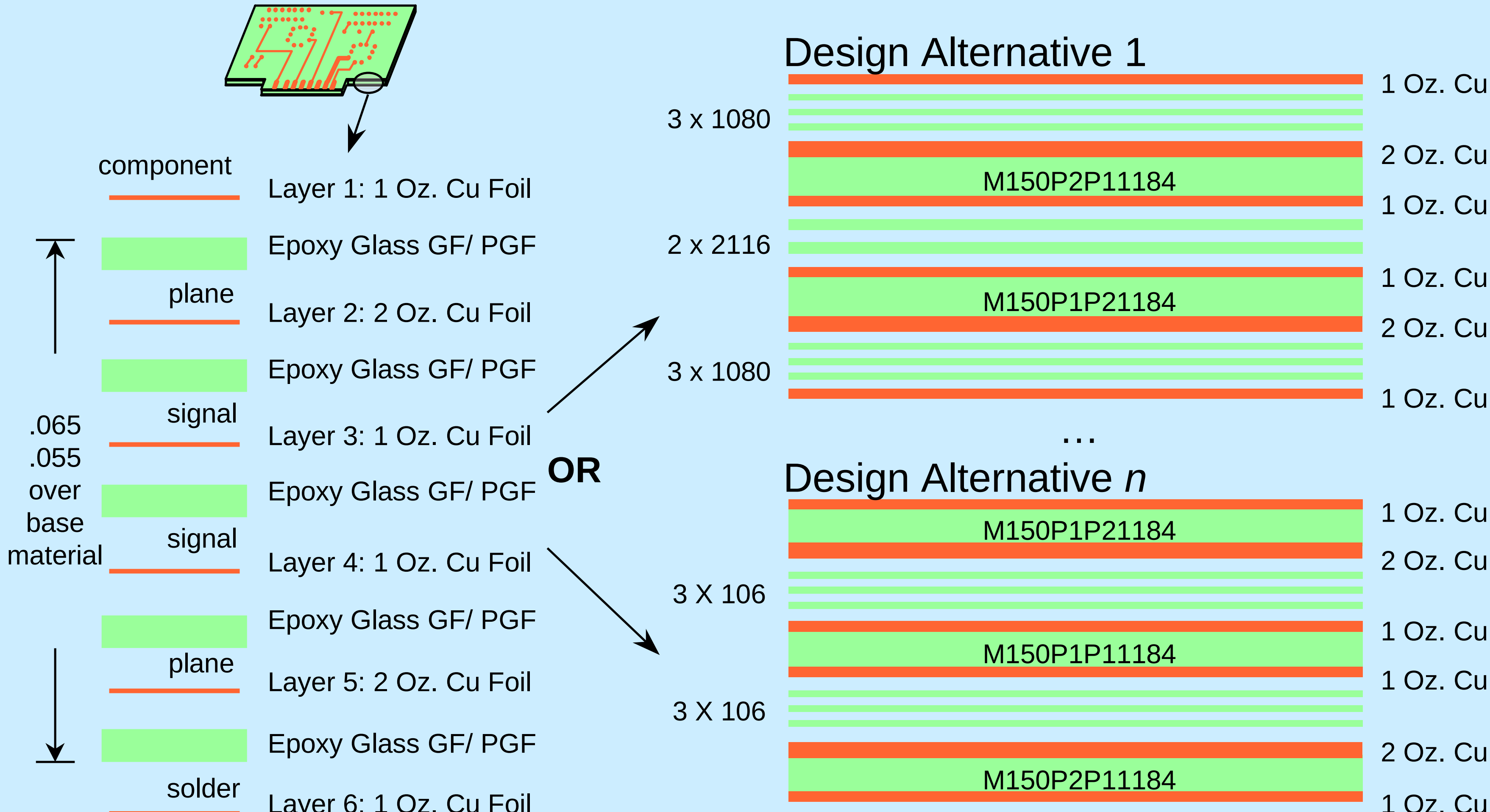
* = Item not yet available in *XaiTools* prototype (all others have working examples)

** = Item available via U-Engineer.com, but not yet in *XaiTools* prototype

Overview of PWB Layup Design

SME fabrication engineer <u>designs</u> PWB stackup details

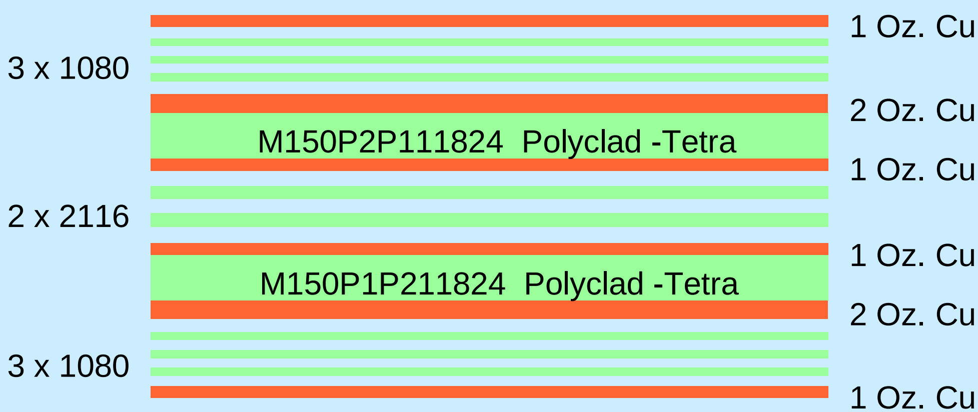
Customer Input Specs | **Fabricator Layup Design**



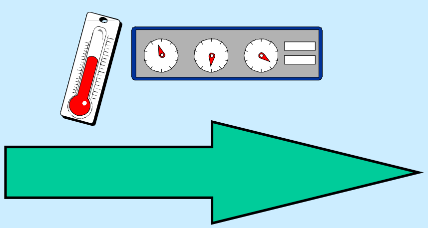
Characteristics of SME Layup Design

- ✓ Layup details impact PWB behavior:
  warpage, PTH reliability, crosstalk (impedance), etc.
- ✓ SME needs tools to evaluate alternatives
- ✓ Precise material and manufacturing process expertise of SME fabrication engineers enables more accurate analysis

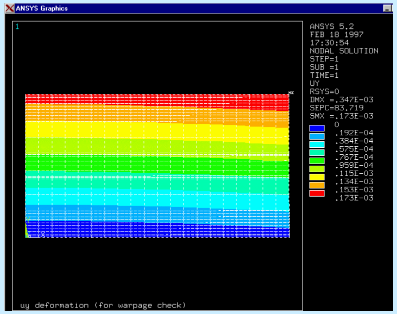
Detailed Material Characterization



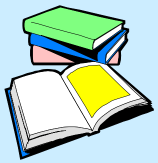
Manufacturing Conditions



Accurate Analysis Results



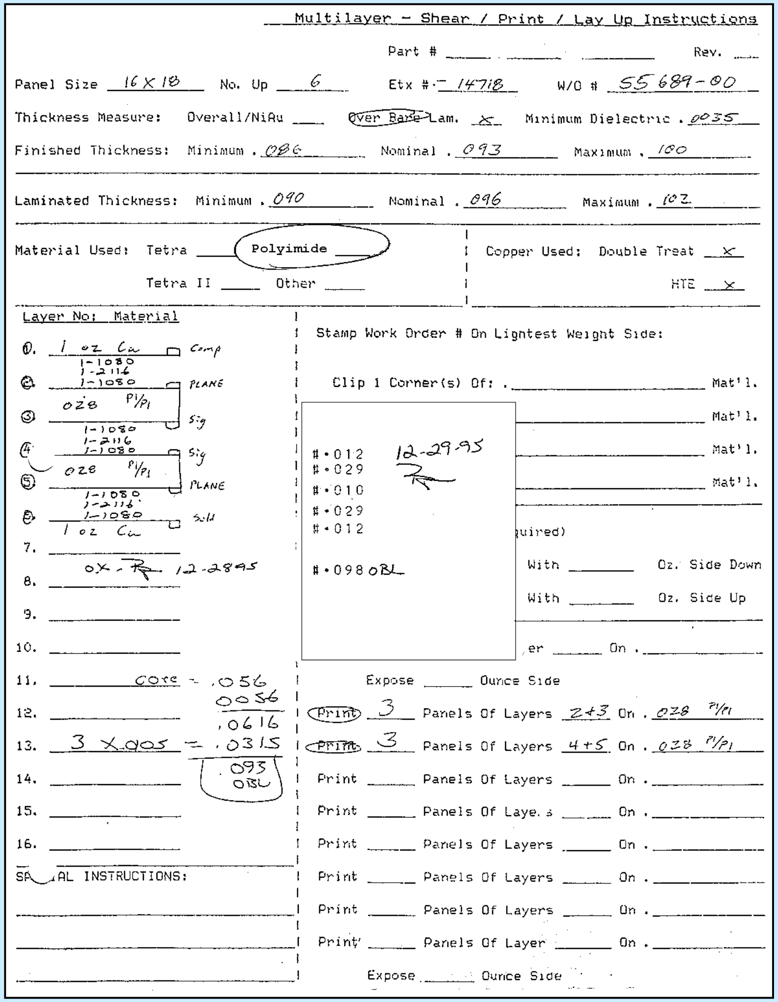
which can be compared to Prime's Specs



Post-Lamination Thickness Calculation

Typical Manual Worksheet

(as much as 1 hour engr. time)



Multilayer – Shear / Print / Lay Up Instructions

Part # ____ Rev. ____

Panel Size 16 X 18 No. Up 6 Etx # 14718 W/O # 55689-00

Thickness Measure: Overall/NiAu ____ Over Base Lam. X Minimum Dielectric .0035

Finished Thickness: Minimum .086 Nominal .093 Maximum .100

Laminated Thickness: Minimum .090 Nominal .096 Maximum .102

Material Used: Tetra ____ Polyimide ____ Tetra II ____ Other ____

Copper Used: Double Treat X HTE X

Layer No: Material

Stamp Work Order # On Lightest Weight Side:

Clip 1 Corner(s) Of: ____ Mat'l.

#.012 #.029 #.010 #.029 #.012 12-29-95

#.098 OBL

Expose ____ Ounce Side

Print 3 Panels Of Layers 2+3 On .028 P/P1

Print 3 Panels Of Layers 4+5 On .028 P/P1

Print ____ Panels Of Layers ____ On ____

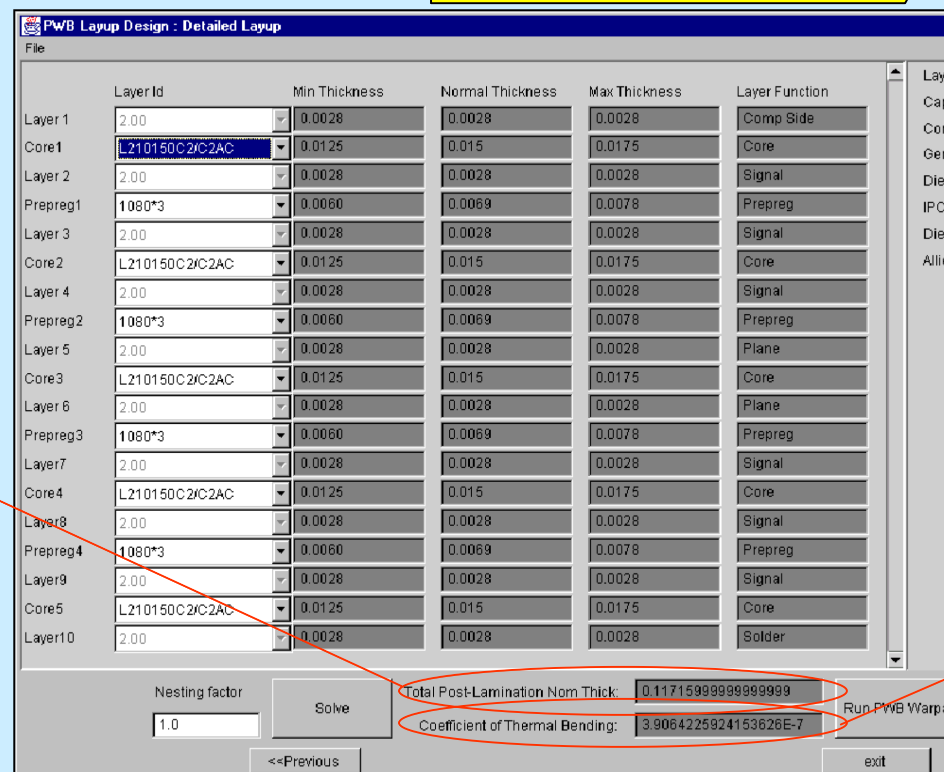
SPECIAL INSTRUCTIONS:

Tool-Aided Design

$$post\_lamination\_thickness = \sum_{1}^{n} nested\_thickess_i$$

$$nested\_thickness_{prepreg\_set} = \sum_{1}^{p} k_n t_{sf\,i} - resin\_to\_fill$$

$$\alpha_B = C_1 \frac{\sum_{1}^{n} t_i \alpha_i y_i}{(t^2/2)} + C_2 \frac{\sum_{1}^{n} |t_i \alpha_i y_i|}{(t^2/2)} + C_3$$



PWB Layup Design : Detailed Layup

	Layer Id	Min Thickness	Normal Thickness	Max Thickness	Layer Function
Layer 1	2.00	0.0028	0.0028	0.0028	Comp Side
Core1	L210150C2/C2AC	0.0125	0.015	0.0175	Core
Layer 2	2.00	0.0028	0.0028	0.0028	Signal
Prepreg1	1080*3	0.0060	0.0069	0.0078	Prepreg
Layer 3	2.00	0.0028	0.0028	0.0028	Signal
Core2	L210150C2/C2AC	0.0125	0.015	0.0175	Core
Layer 4	2.00	0.0028	0.0028	0.0028	Signal
Prepreg2	1080*3	0.0060	0.0069	0.0078	Prepreg
Layer 5	2.00	0.0028	0.0028	0.0028	Plane
Core3	L210150C2/C2AC	0.0125	0.015	0.0175	Core
Layer 6	2.00	0.0028	0.0028	0.0028	Plane
Prepreg3	1080*3	0.0060	0.0069	0.0078	Prepreg
Layer7	2.00	0.0028	0.0028	0.0028	Signal
Core4	L210150C2/C2AC	0.0125	0.015	0.0175	Core
Layer8	2.00	0.0028	0.0028	0.0028	Signal
Prepreg4	1080*3	0.0060	0.0069	0.0078	Prepreg
Layer9	2.00	0.0028	0.0028	0.0028	Signal
Core5	L210150C2/C2AC	0.0125	0.015	0.0175	Core
Layer10	2.00	0.0028	0.0028	0.0028	Solder

Nesting factor: 1.0 · Solve

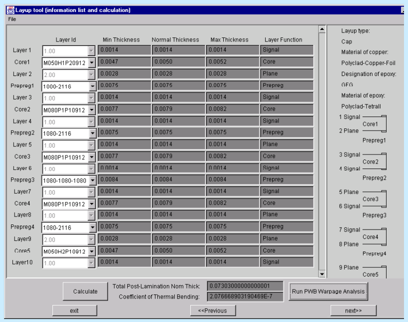
Total Post-Lamination Nom Thick: 0.11715999999999999

Coefficient of Thermal Bending: 3.9064225924153626E-7

<<Previous · Run PWB Warpag · exit

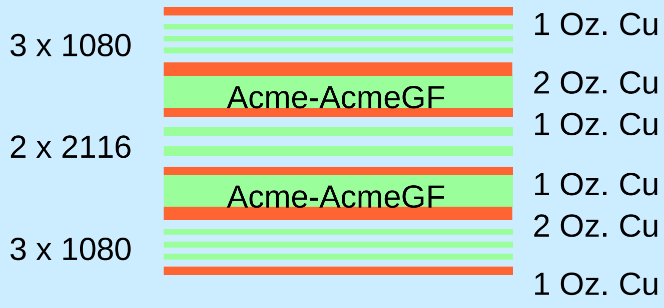
Iterative Design & Analysis

PWB Layup Design Tool



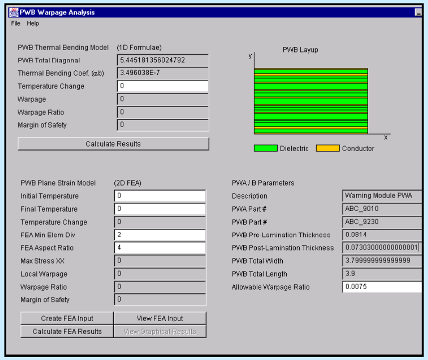
Layup Re-design

Analyzable Product Model



PWB Warpage Modules

Thermal Bending Model

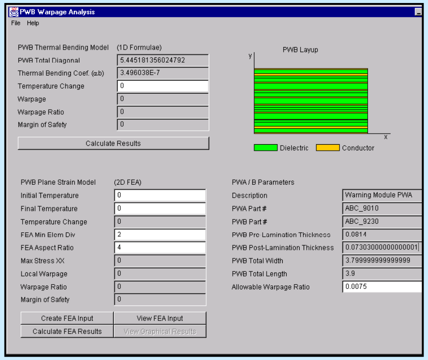


Quick Formula-based Check

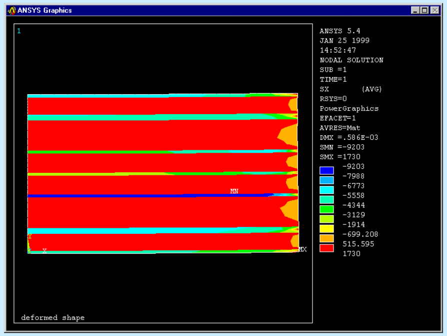
$$\delta = \frac{\alpha_b L^2 \Delta T}{t}$$

$$\alpha_b = \frac{\sum w_i \alpha_i y_i}{t/2 \sum w_i}$$

Plain Strain Model



Detailed FEA Check

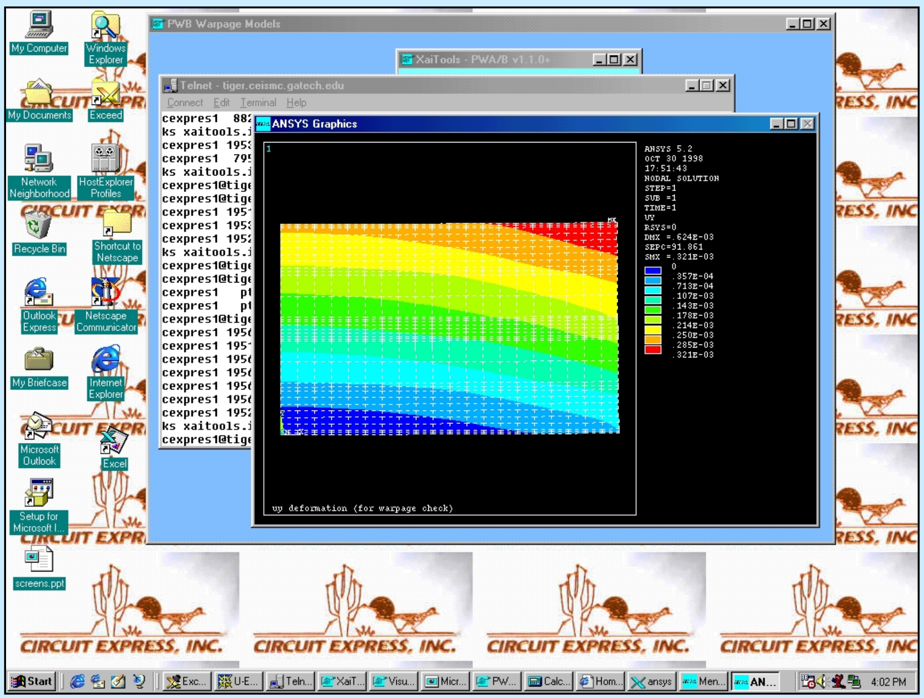


ProAM Deliverable Highlights

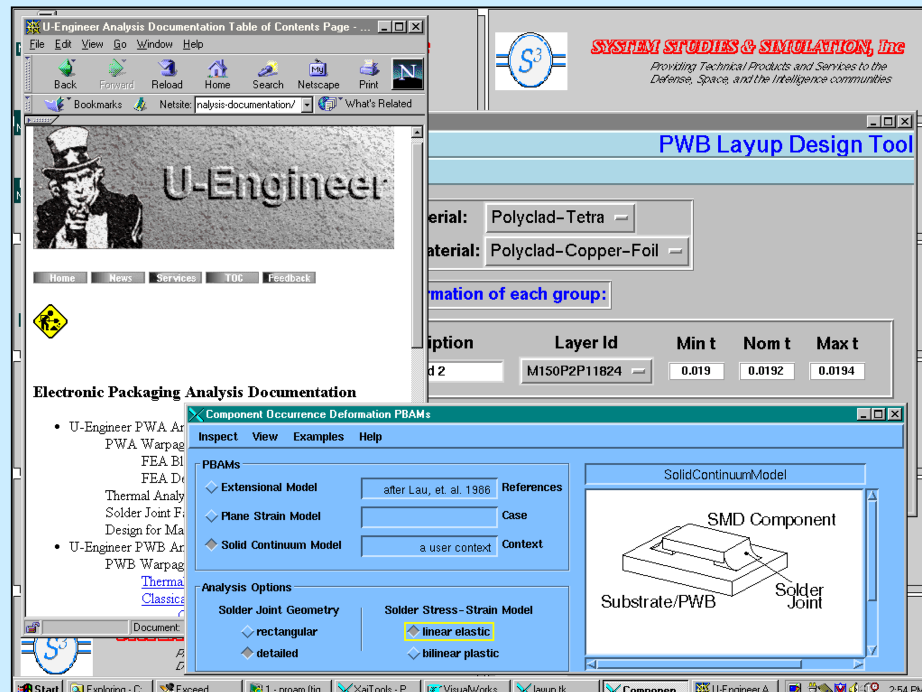
- **General techniques:**
  - Internet-based engineering service bureau (ESB)
  - X-analysis integration (XAI)
    - Product data-driven plug-and-play analysis modules
    - General purpose XAI toolkit
- **Applications in specific AMCOM context:**
  - U-Engineer.com pilot commercial ESB with Internet-based PWA/B-specific analysis modules & toolkit
  - Usage by SMEs in AMCOM supply chain

SME Pilot Usage of ProAM Tools

Circuit Express, Tempe AZ



S3, Huntsville AL



Outline

Welcome & Background

Project Overview

- Team
- Motivation & Objectives
- Tasks
- Deliverable Highlights

Break

SME ProAM Experiences

- PWA/B Designer & Fabricator Perspective - Phillip Spann (S3)
- PWB Fabricator Perspective - Jake Roberts (Circuit Express)

Wrap-Up
Discussion - All
Overview of Afternoon Sessions