CALS/EC Korea'99
Seoul, Korea
July 10-12, 1999

Georgia Institute of Technology

EC/CALS-related Projects in the Engineering Information Systems Lab

Robert E. Fulton and Russell S. Peak

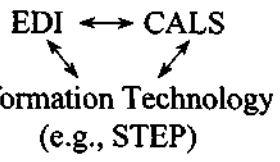
Georgia Institute of Technology
CALS Technology Center
Engineering Information Systems Lab
eislab.gatech.edu

Georgia Tech CALS Technology Center

Established 1988 by Profs. Robert E. Fulton and James I. Craig

Information Technology for Life Cycle Engineering and Business Applications

THRUSTS -
- Applied Research
- Graduate Students
- Demonstration Projects
- Education/Training
- Consulting
- Technology Transfer



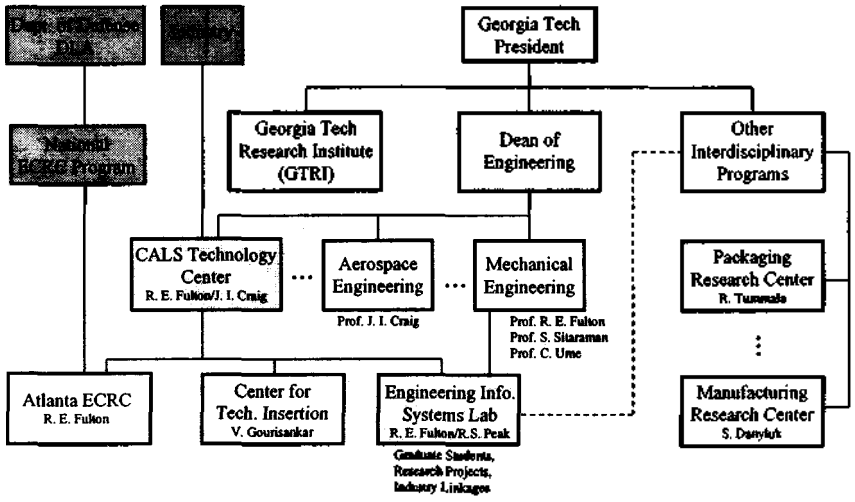
EXAMPLE SPONSORS

Digital Equipment	Motorola	Boeing
US Air Force	DARPA	SDRC
US Army AMCOM	DoD / DLA	NASA
General Motors	NCR	Bell South
Shinko Electric	Lockheed	NSF
Emory Hospital	Russell Mfg.	IBM

GIT Material Handling Research Center Consortium
GIT Manufacturing Research Center Consortium

CALS = Computer-Aided Life-cycle Support

CALS Technology Center Management Organization



CALS Technology Center Divisions

- **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

EIS Lab People

Faculty & Staff
Tal Cohen - Researcher
Robert Fulton - Director, Professor
Haruko Peak - Technical Assistant
Russell Peak - Asst. Director, Researcher
Andrew Scholand - Researcher
Adrienne Rollerson - Student Assistant
Miyako Wilson - Researcher
CALS Technology Center Staff

Visiting Researchers
Sunn-ho Kim, Myong-Ji University, Korea
Changhee Han, KAIST, Korea
Ryuichi Matsuki, Shinko Electric, Japan

Graduate Researchers
Angela Birkes
Ashok Chandrasekhar
Selcuk Cimtalay
Xiaoling He
Chien Hsiung
Donald Koo
Dennis Ma
M.C. Ramesh (Trilogy)
Andrew Scholand
Srivatsa Shamanna (ITI)
Miyako Wilson
Sai Zeng

Undergraduate Researchers
Steven Smith

EIS Lab Alumni

Engineering Information Technology
CAD/CAE/CAM, Analysis Integration

Masters
Wei Chang, General Motors
Janice Chinn, U. S. Air Force
Michael Y. Gabertan, Motorola
Neil Hall, IT Co.
Trey Jernigen, Lockheed
Miyako Wilson, Georgia Tech (3Q99)

PhD
Bipin Chadha, Lockheed
Gintas Jazbutis, SDRC - Boeing Consultant
Deeptendu Majumder, Computervision Corp
Russell Peak, Georgia Tech CALS Tech. Center
Ravi Rangan, SDRC - Boeing Consultant
Diego Tamburini - SDRC - Boeing Consultant
Ching-Yang Wang, Boeing
Pete Whelan, Sematech
Chao-pin Yeh, Motorola
Wen Zhou, Motorola

Parallel Processing

PhD
C. Chiang, University in Taiwan
Kuoning Chiang, Taiwan Super Computer Center
Dietmar Goelich, MBB/Daimlar Benz
Jason Har, Korea
Rong Fu Ou, Engineering Consulting Firm
Phillip Su, NASA Langley Super Computer Project
Sang Synn, Hyundai Heavy Industries Co. Ltd.

Example Information Modeling Research and Industry Linkages

Topic	Graduate Student	Industry Linkage
Engineering Data Modeling Methods	Gintas Jazbutis	AT&T
Database Approach for Design Changes	Tal Cohen	GM
Database Approach for Aircraft Conceptual Design	Neil Hall	Lockheed, McDonnel Douglas
Reengineering Aircraft Maintenance/Repair	Angela Birkes, Tal Cohen	WR-ALC
Laser Scanning of 3D Part Geometry	M. C. Ramesh	WR-ALC
STEP Models for Forging	M. C. Ramesh	Lockheed Martin
Prototype Multimedia Autobroker	Angela Birkes, Chien Hsiung	BellSouth, DEC, Emory Hospital
Virtual Manufacturing Assembly	Chien Hsiung	
Multimedia Database on Olympic Construction	Angela Birkes	
Parametric FEA Modeling Methodology	Wen Zhou	Motorola
Assembly of Product Data to Support Analysis	Diego Tamburini	STEP Tools Inc.
PWA Component Layout Optimization	Andrew Scholand	GT MARC
Electronic Component Design Optimization	Selcuk Cimtalay	GT MARC

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.

X-Analysis Integration (XAI/DAI) Research

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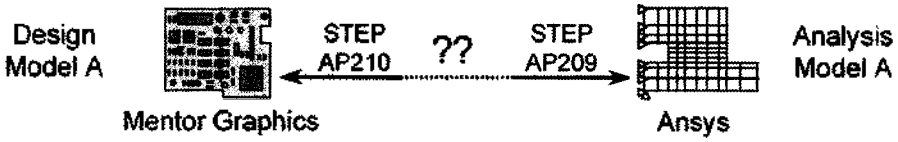
Design-Analysis Integration

- **Goal:**
  Improve the product development process by integrating design and analysis models
- **Challenges:**
  - Heterogeneous Transformations
  - Diversity: Disciplines, Fidelity, Design Tools, Analysis Tools
- **One Solution:**
  The Multi-Representation Architecture (MRA)
- **Initial Focus:**
  Automation of routine analysis

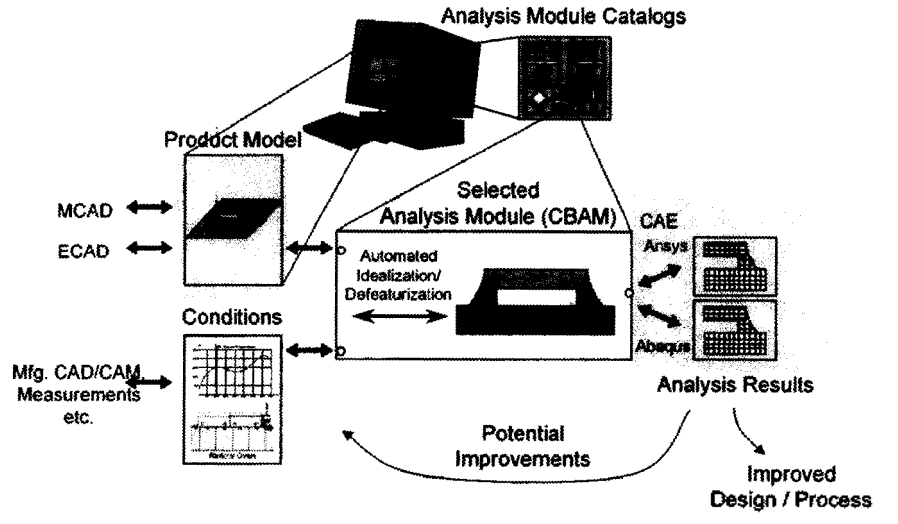
Analysis Integration Challenges: Heterogeneous Transformations

- Homogeneous Transformation

- Heterogeneous Transformation



Analysis Integration Thrust

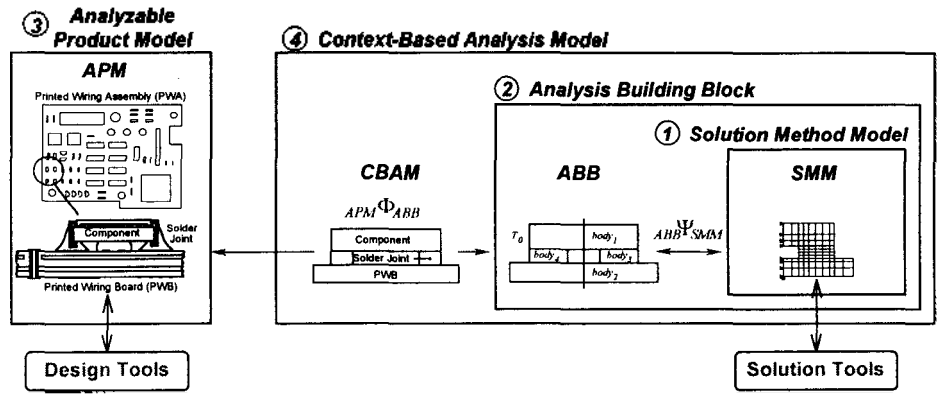


Components of EIS Lab Analysis Integration Technique

- Conceptual architecture: MRA
- Methodology
- General purpose MRA toolkit: *XaiTools*
  - Toolkit architecture
  - Users guide
  - Tutorials (work-in-process)
- Product/company-specific applications
  - PWA/Bs (ProAM)
  - Aerospace structural analysis (Boeing PSI)
  - Chip packaging/mounting (Shinko)

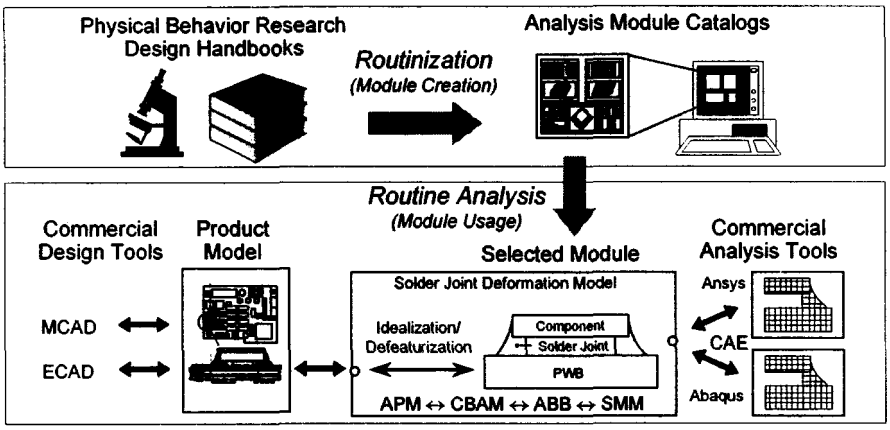
See http://eislab.gatech.edu/ for references

Multi-Representation Architecture (MRA) for Design-Analysis Integration



- Composed of four representations (information models)
- Provides flexible, modular mapping between design & analysis models
- Creates automated, product-specific analysis modules (CBAMs)
- Represents design-analysis associativity explicitly

Design-Analysis Integration Methodology



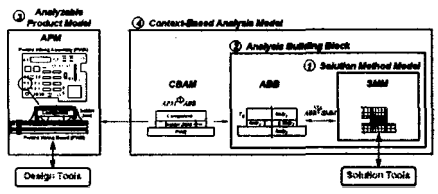
- Provides technique to bridge CAD-CAE gap
- Uses AI & info. technology: objects, constraints, STEP

XaiTools

Prototype X-Analysis Integration Toolkit

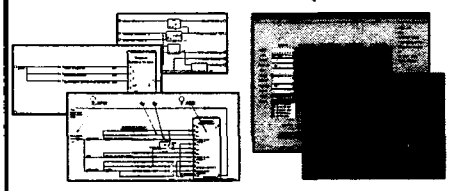
Second Generation - Java-based

Multi-Representation Architecture (MRA)

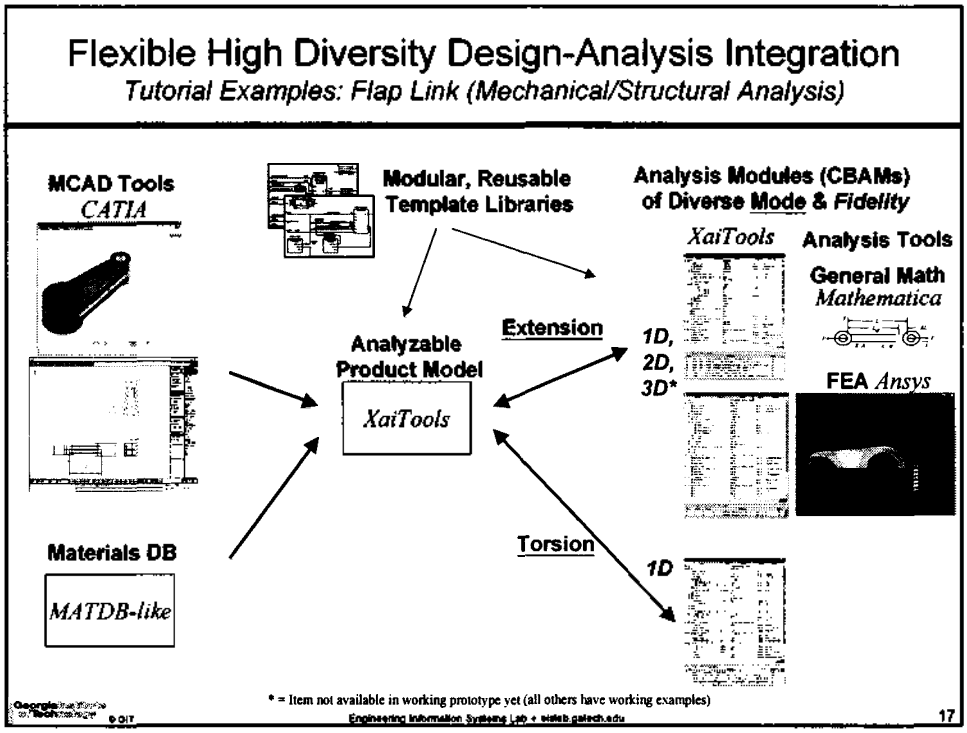


Analysis Modules & Building Blocks

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.


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
Analyzable
Product Model
XaiTools
Extension
1D,
2D,
3D*
FEA Ansys
Materials DB
MATDB-like
Torsion
1D
* = Item not available in working prototype yet (all others have working examples)
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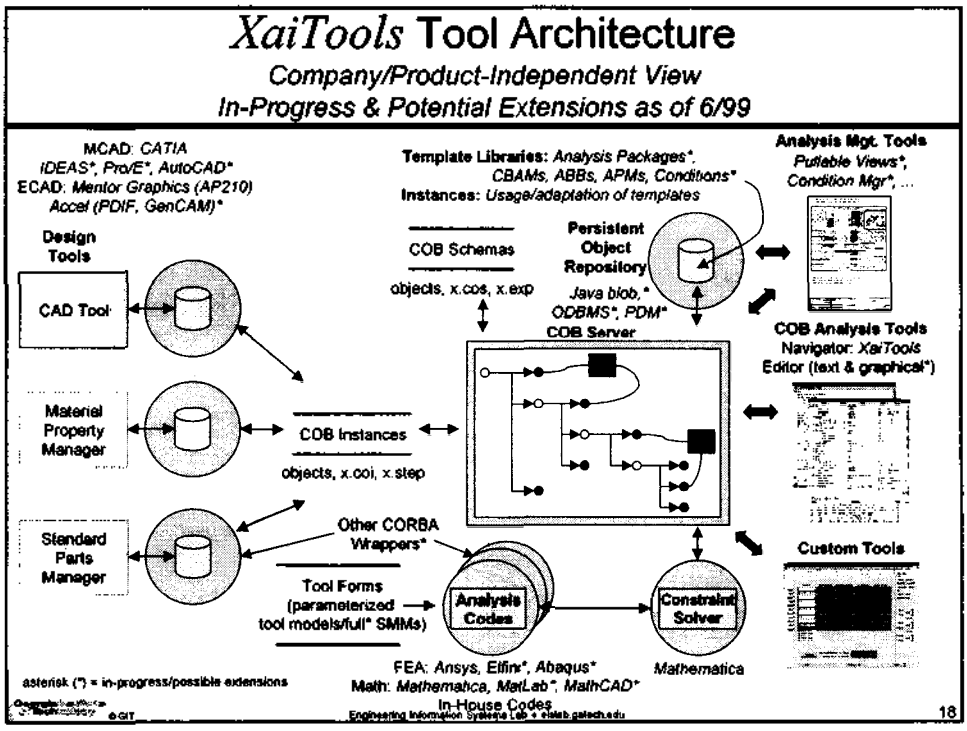
XaiTools Tool Architecture
Company/Product-Independent View
In-Progress & Potential Extensions as of 6/99
MCAD: CATIA
IDEAS*, Pro/E*, AutoCAD*
ECAD: Mentor Graphics (AP210)
Accel (PDIF, GenCAM)*
Design
Tools
CAD Tool
Material
Property
Manager
Standard
Parts
Manager
Template Libraries: Analysis Packages*,
CBAMs, ABBs, APMs, Conditions*
Instances: Usage/adaptation of templates
COB Schemas
objects, x.cos, x.exp
Persistent
Object
Repository
Java blob,*
ODBMS*, PDM*
COB Server
COB Instances
objects, x.coi, x.step
Other CORBA
Wrappers*
Tool Forms
(parameterized
tool models/full* SMMs)
Analysis
Codes
Constraint
Solver
Mathematica
FEA: Ansys, Elfini*, Abaqus*
Math: Mathematica, MatLab*, MathCAD*
In-House Codes
asterisk (*) = in-progress/possible extensions
Analysis Mgt. Tools
Putable Views*,
Condition Mgr*, ...
COB Analysis Tools
Navigator: XaiTools
Editor (text & graphical*)
Custom Tools
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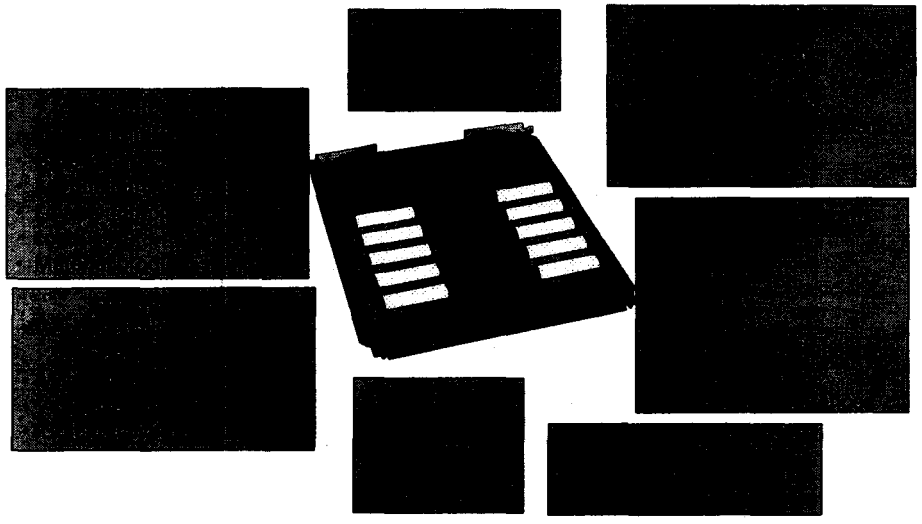
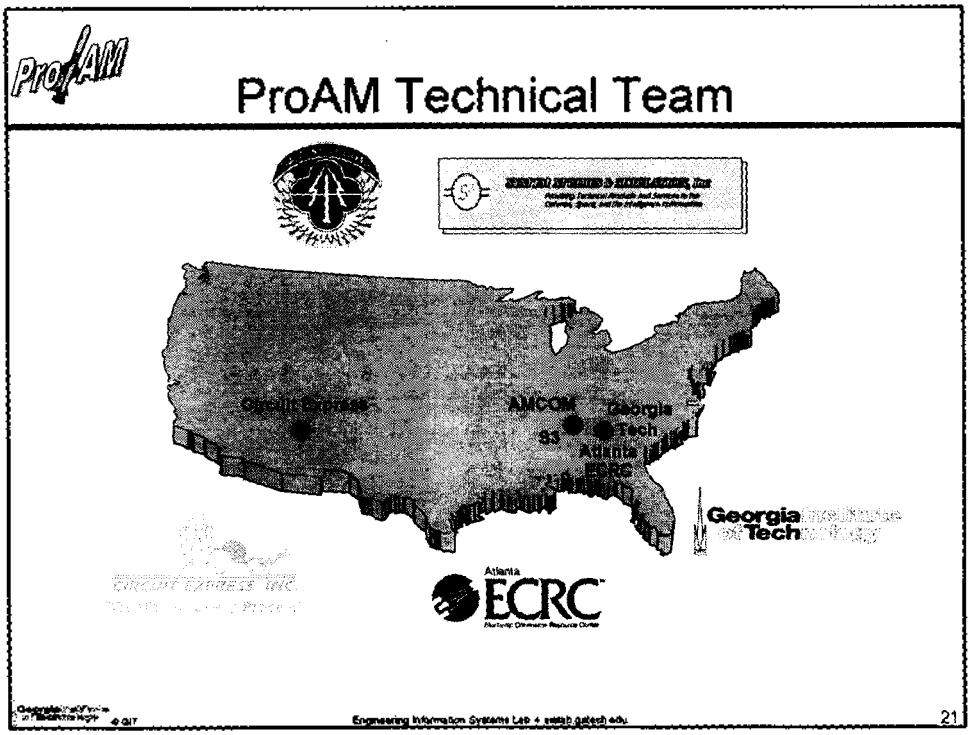
Example Projects

- 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)

STEP AP 210 PWA/B Design Information




ProAM
ProAM Technical Team
AMCOM
S3
Georgia Tech
Atlanta
ECRC
Georgia Tech
Atlanta
ECRC
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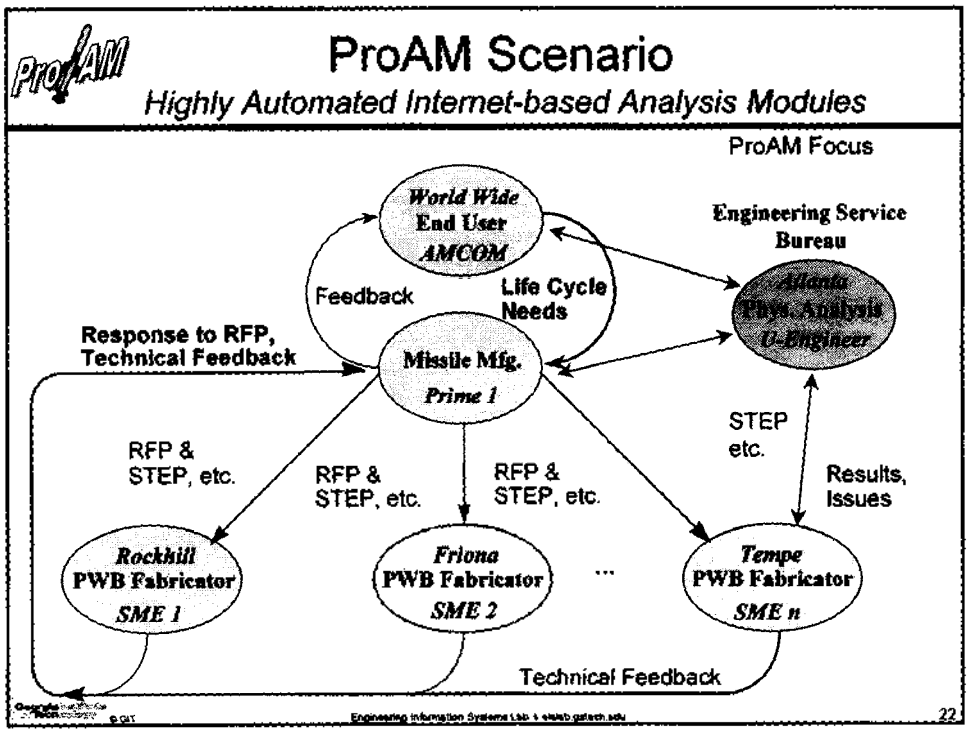

ProAM
ProAM Scenario
Highly Automated Internet-based Analysis Modules
ProAM Focus
World Wide End User AMCOM
Engineering Service Bureau
Atlanta Phys. Analysis O-Engineer
Feedback
Life Cycle Needs
Response to RFP, Technical Feedback
Missile Mfg. Prime 1
STEP etc.
RFP & STEP, etc.
RFP & STEP, etc.
RFP & STEP, etc.
Results, Issues
Rockhill PWB Fabricator SME 1
Friona PWB Fabricator SME 2
...
Tempe PWB Fabricator SME n
Technical Feedback
22

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

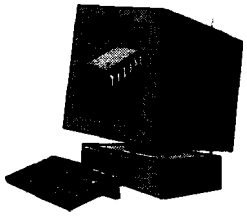
- More accurate data → Better analysis
- Bottom line drivers:

Higher Yields, Lower Cost,
Better Quality, Fewer Delays

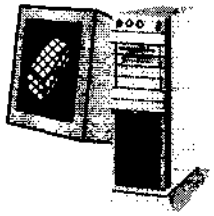
Barriers to SME Analysis

- 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

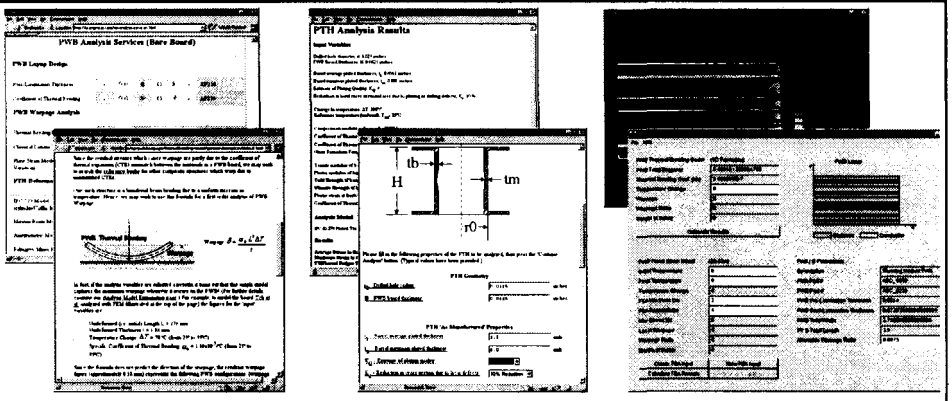


Analysis Model



Skilled Personnel

Internet-based Engineering Service Bureau (ESB) Tools

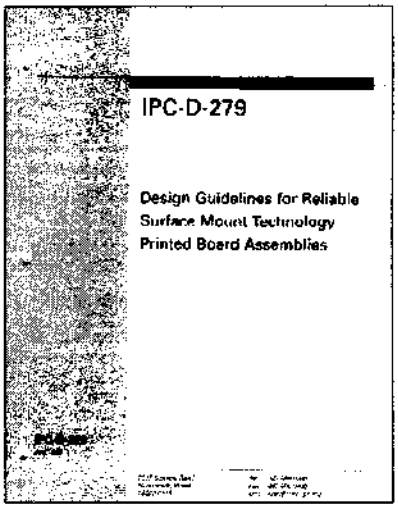


Analysis Documentation Ready-to-Use Analysis Modules

Lower cost, better quality, fewer delays in supply chain

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

Tedious to Use



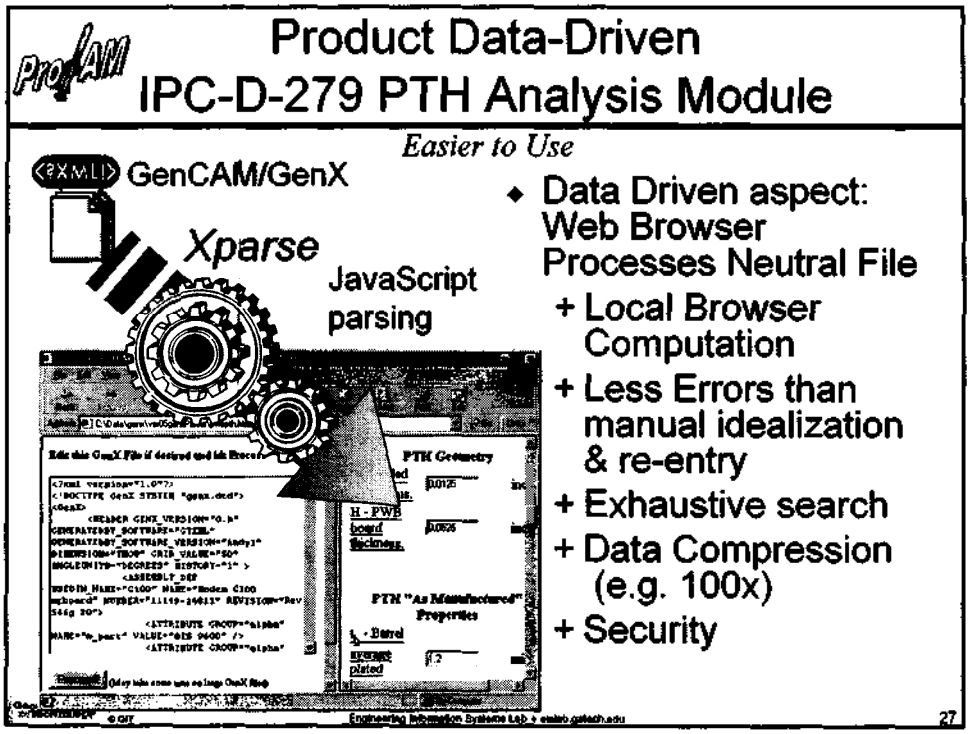
PTH/PTV Fatigue Life Estimation

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

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

$$N_f^{-0.6} D_f^{0.75} + 0.9 \frac{S_u}{E} \left[\frac{e^{D_f}}{0.36}\right]^{.01785 \log \frac{10^3}{N_f}} - \Delta\varepsilon = 0$$

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


Product Data-Driven
IPC-D-279 PTH Analysis Module
Easier to Use
GenCAM/GenX
Xparse
JavaScript
parsing
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
PTH Geometry
PTH "As Manufactured"
Properties
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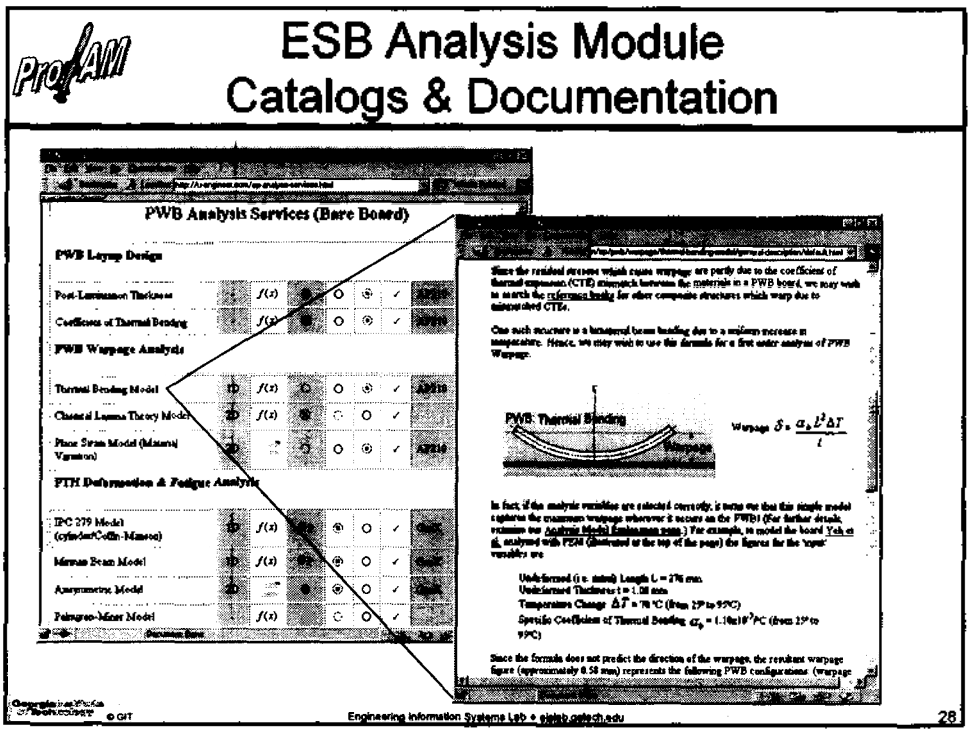
ESB Analysis Module
Catalogs & Documentation
PWB Analysis Services (Bare Board)
PWB Layup Design
PWB Warpage Analysis
PTH Deformation & Fatigue Analysis
PWB: Thermal Bending
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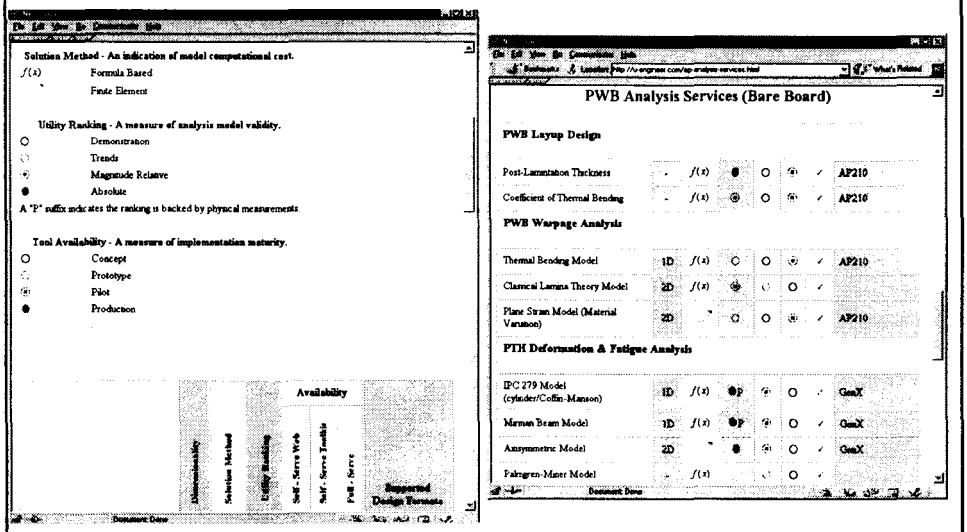
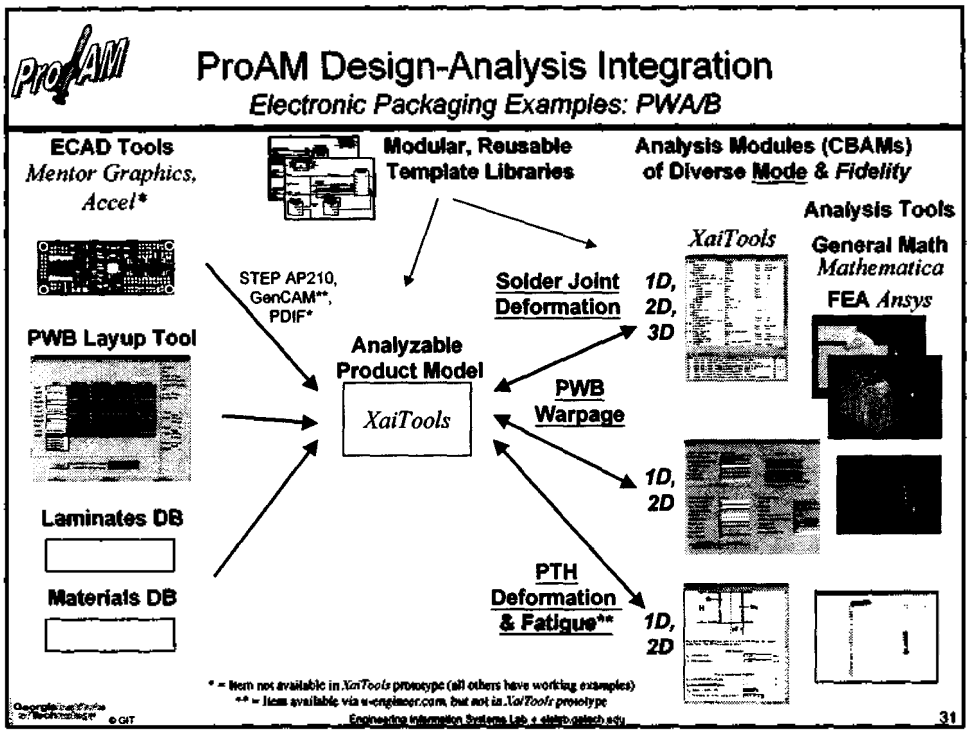
Analysis Modules Attributes



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


ProAM
ProAM Design-Analysis Integration
Electronic Packaging Examples: PWA/B
ECAD Tools
Mentor Graphics, Accel*
Modular, Reusable Template Libraries
Analysis Modules (CBAMs) of Diverse Mode & Fidelity
Analysis Tools
General Math Mathematica
FEA Ansys
XaiTools
STEP AP210, GenCAM**, PDIF*
PWB Layup Tool
Analyzable Product Model
XaiTools
Solder Joint Deformation
1D, 2D, 3D
PWB Warpage
1D, 2D
Laminates DB
Materials DB
PTH Deformation & Fatigue**
1D, 2D
* = Item not available in XaiTools prototype (all others have working examples)
** = Item available via e-engineer.com, but not in XaiTools prototype
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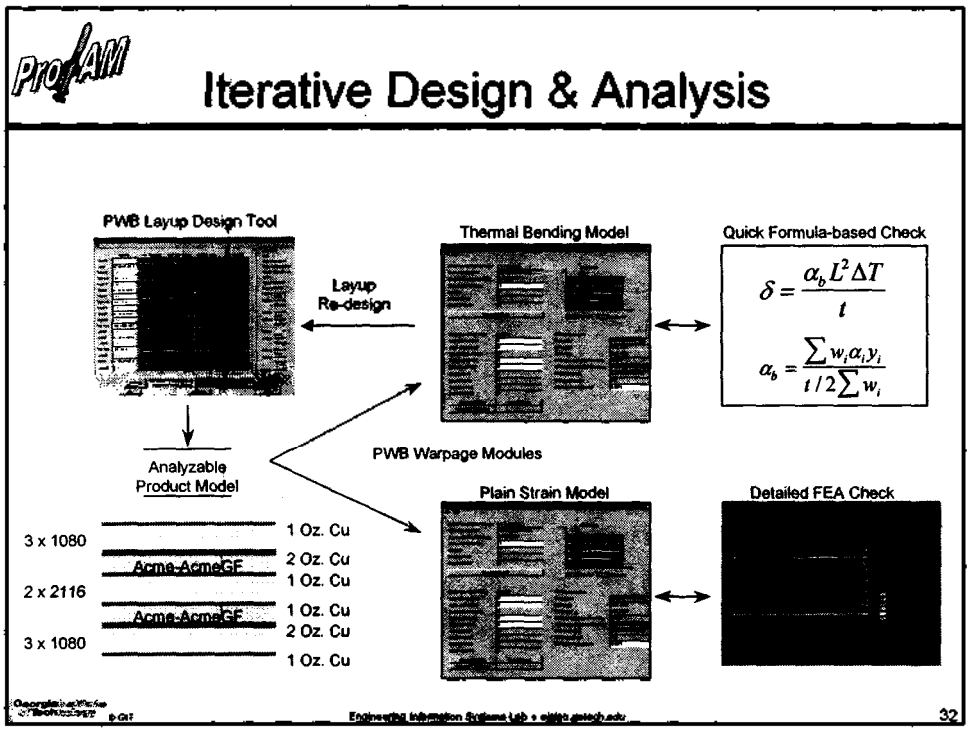
ProAM
Iterative Design & Analysis
PWB Layup Design Tool
Layup Re-design
Thermal Bending Model
Quick Formula-based Check
$\delta = \frac{\alpha_b L^2 \Delta T}{t}$
$\alpha_b = \frac{\sum w_i \alpha_i y_i}{t/2 \sum w_i}$
Analyzable Product Model
PWB Warpage Modules
Plain Strain Model
Detailed FEA Check
3 x 1080
1 Oz. Cu
2 Oz. Cu
Acme-AcmeGF
1 Oz. Cu
2 x 2116
1 Oz. Cu
Acme-AcmeGF
2 Oz. Cu
3 x 1080
1 Oz. Cu
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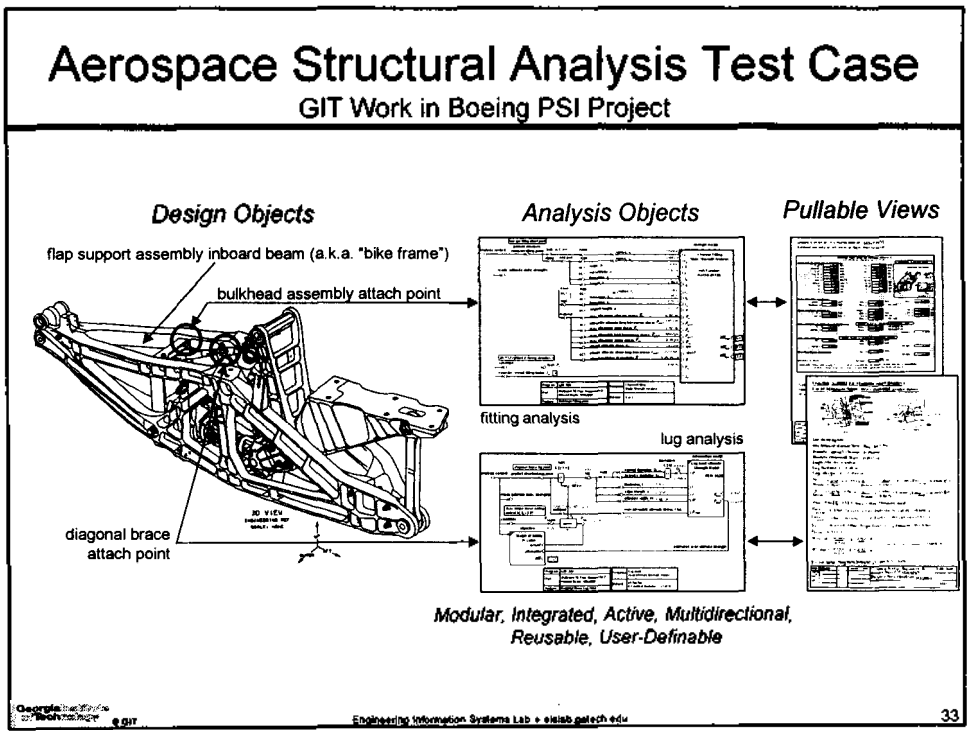
Aerospace Structural Analysis Test Case
GIT Work in Boeing PSI Project
Design Objects
Analysis Objects
Pullable Views
flap support assembly inboard beam (a.k.a. "bike frame")
bulkhead assembly attach point
fitting analysis
lug analysis
diagonal brace attach point
Modular, Integrated, Active, Multidirectional, Reusable, User-Definable
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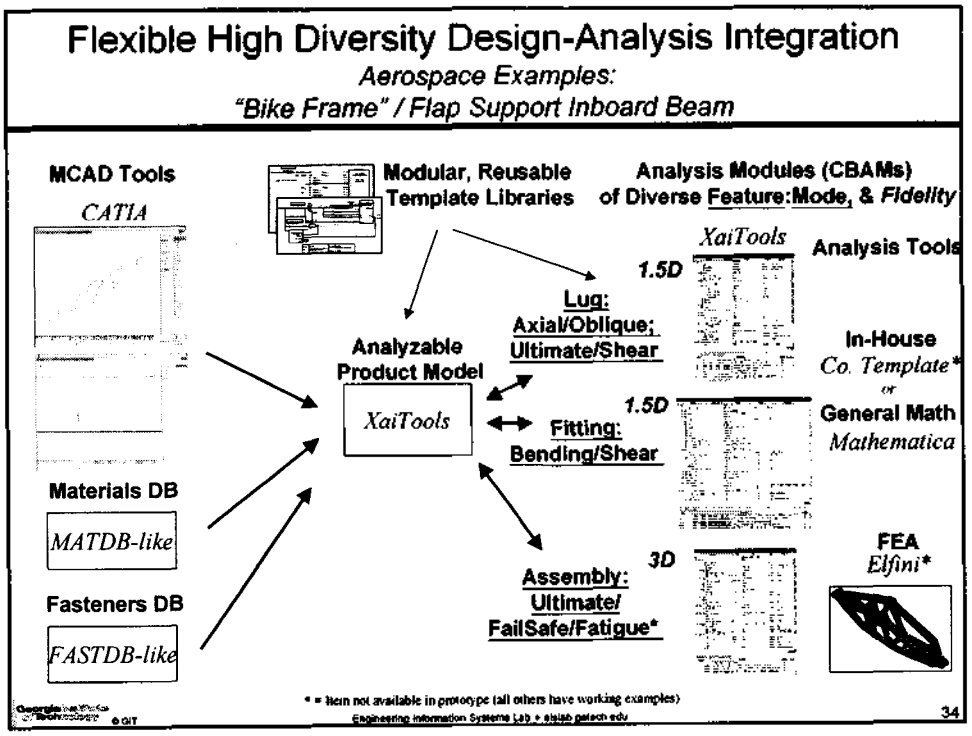
Flexible High Diversity Design-Analysis Integration
Aerospace Examples:
"Bike Frame" / Flap Support Inboard Beam
MCAD Tools
CATIA
Modular, Reusable Template Libraries
Analysis Modules (CBAMs) of Diverse Feature:Mode, & Fidelity
XaiTools
Analysis Tools
1.5D
Lug: Axial/Oblique; Ultimate/Shear
Analyzable Product Model
XaiTools
In-House
Co. Template*
or
General Math
Mathematica
1.5D
Fitting: Bending/Shear
Materials DB
MATDB-like
Fasteners DB
FASTDB-like
3D
Assembly: Ultimate/ FailSafe/Fatigue*
FEA
Elfini*
* = Item not available in prototype (all others have working examples)
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Analysis Integration Summary

- Strong emphasis on X-analysis integration (XAI/DAI)
- Multi-Representation Architecture (MRA)
  - Addressing fundamental XAI/DAI issues
  - General methodology --> Flexibility & broad application
- Relevant project experience and research advances
  - Product data-driven analysis (STEP AP210, GenCAM, etc.)
  - Engineering service bureau (ESB) techniques
  - Object techniques for next generation aerospace analysis systems
- Research, applications, and technology transfer
  - Analysis integration toolkit: *XaiTools*
  - Pilot commercial ESB: u-engineer.com
  - Company-tailored engineering information systems solutions
- Industry & government collaboration

For Further Information ...

- EIS Lab web site: *http://eislab.gatech.edu/*
  - Publications, project overviews, tools, etc.
  - See Publications, DAI/XAI, Suggested Starting Points
- Pilot commercial ESB: *http://u-engineer.com/*
  - Internet-based self-serve analysis
  - Analysis module catalog for electronic packaging
  - Highly automated front-ends to general FEA & math tools