Rethinking the Design Process
iSIGHT Framework

Presentation to TFAWs 2001

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Product Creation:
A Brutally Multidisciplinary Challenge!

Collaboration Across Engineering Disciplines, Organizations, Product Components and Lifecycle Stages

Airframe Structure
- Aerodynamics
- Heat Transfer
- Structural Mechanics
- Structural Dynamics

Propulsion
- Engine Cycle
- Aerodynamic
- Structural Mechanics
- Combustion
- Structural Dynamics
- Weight

Mission
- Fuel Burn
- Economic Analysis
- Range
- Takeoff Gross Weight

Noise
- Airport Noise
- Cabin Noise

Electronic
- Guidance/Control
- Communications
- Electric Power Supply

Cost
- Manufacturing Cost
- Inventory/Financial Cost
- Product Lifecycle Cost

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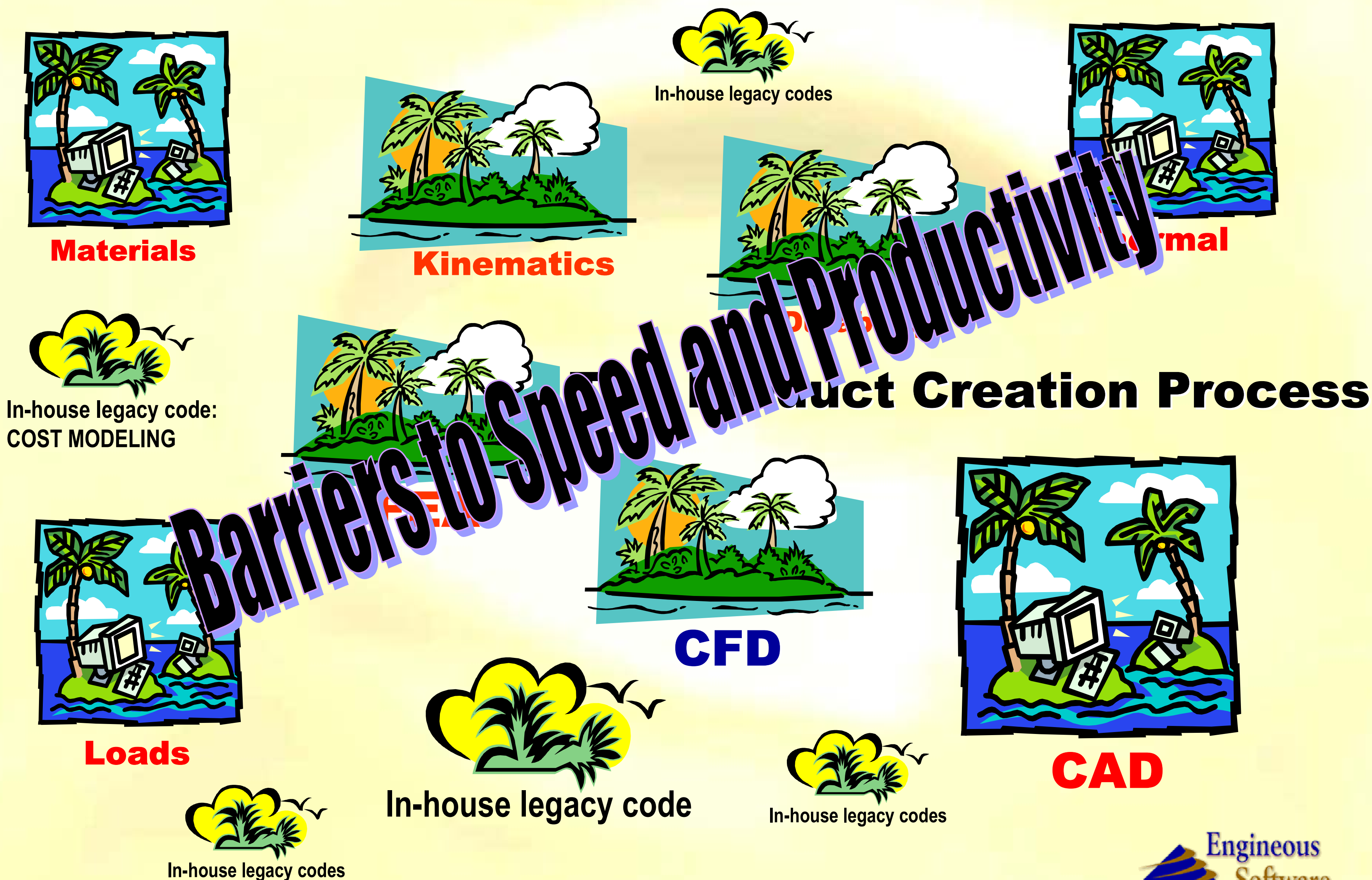
Design Data Islands



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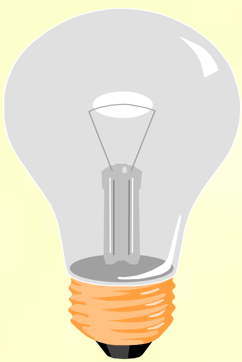
Engineous History

A catalyst for engineering innovation!



Engineous

iSIGHT

"Software Robot" at MIT Invented by Dr. Tong	Engineous at GE >10 Years - $12 Million	1996 - Engineous founded 2001 - iSIGHT 6.0 released
1st. Generation	2nd Generation	3rd Generation
1979	1983	1996

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Engineous People –Educational Snapshot

70 People Worldwide

- 61 Degreed Engineers
- 42 w/Advanced Engineering Degrees
- 10 Doctorate Level
- Industry Specific Experts- Automotive and Turbo Machinery. Substantial background at GM, GE, Cray Research, and NASA.
- Dr. Siu Tong – Founder and Chairman

  Over 20 years experience in the technology industry as a senior manager and in product research and development.

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Helping Our Customers

Engineous Deploys Resources and Technology to:

1. Help our clients integrate their diverse design tools

2. Automate their iterative design processes

3. Accelerate finding the best design solution

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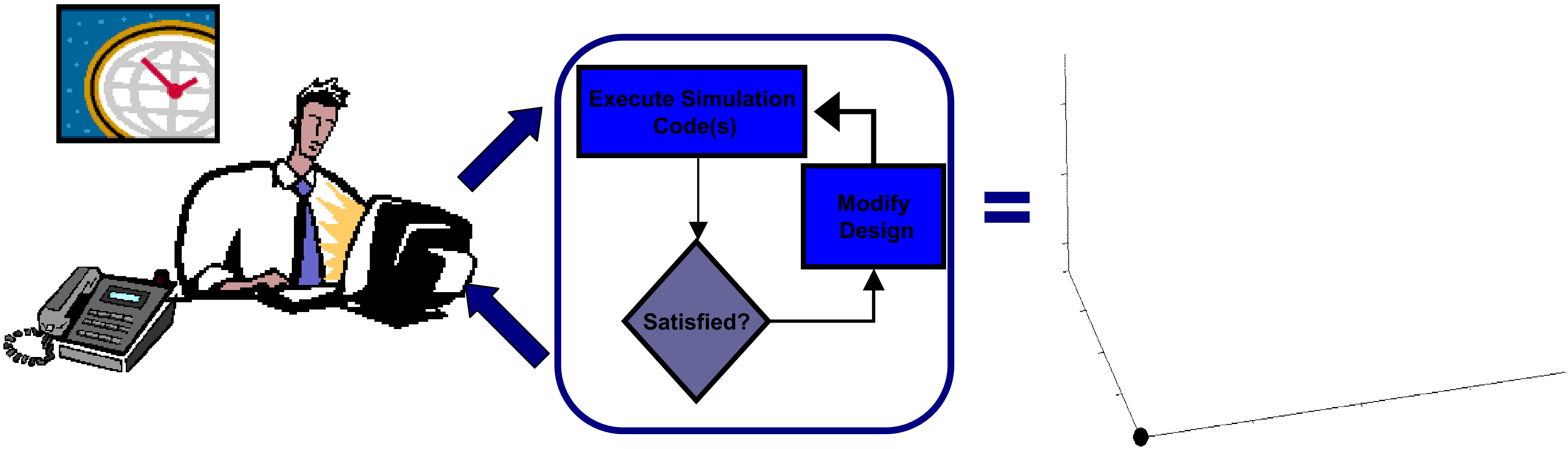
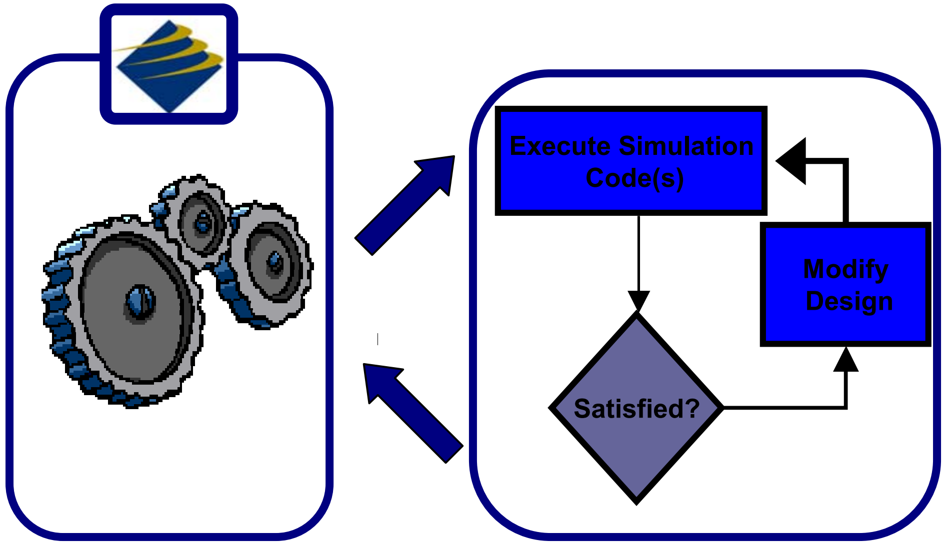
Manual Design Evaluation Process

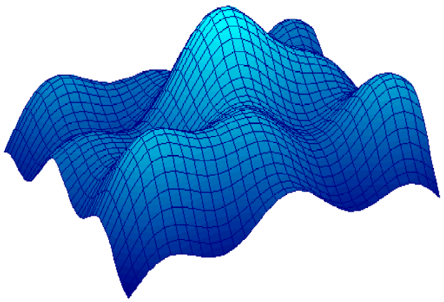


Manual Design Process
- Time consuming
- Error prone tasks
- Engineers spend more time preparing

Results
- Produces limited number of designs
- Produces questionable design quality
- Fewer design alternatives

iSIGHT Software Robot





iSIGHT - Software Robot

- Engineer defines simulation process
- Engineer defines goals and constraints
- Robot applies design intelligence
- Automates and iterates design process
- 24 hour workday

Results

- Increased evaluations
- Improved quality
- Engineers spend more time evaluating
- Multiple design alternatives
- Saves valuable engineering time
- Greater product knowledge

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Design Automation

iSIGHT

↓

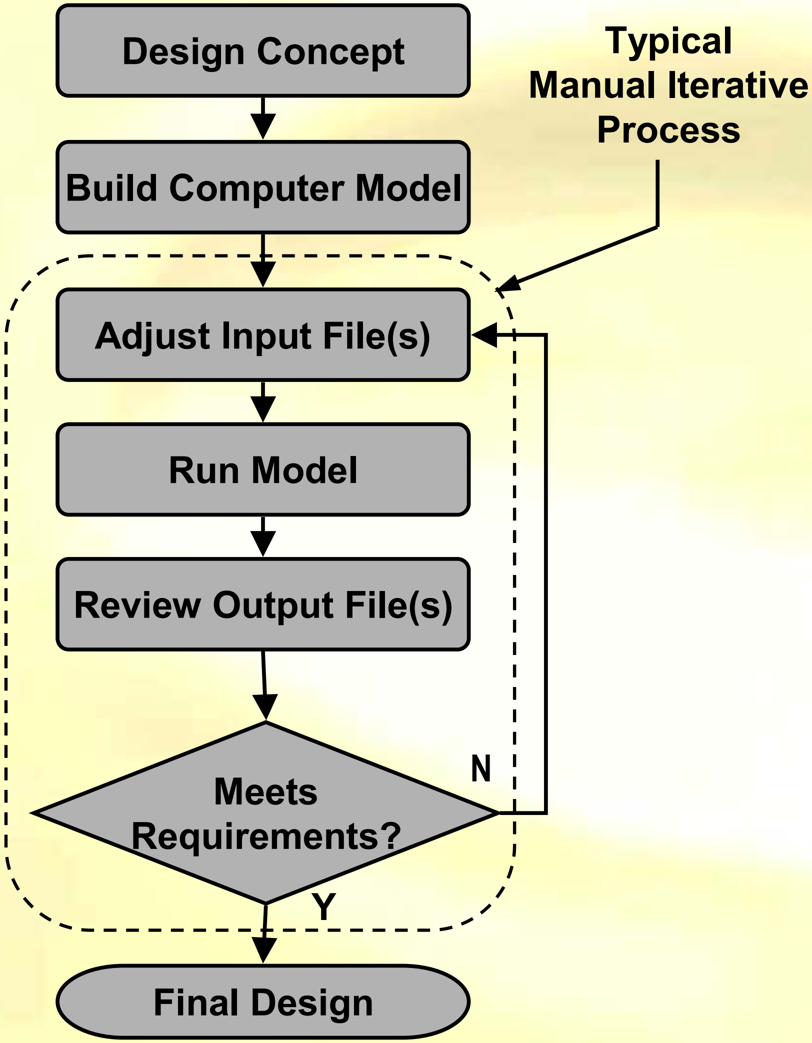
Integrates the Process

↓

Automates the Execution

↓

Evaluates the Alternatives



<u>How does iSIGHT Modify Designs?</u>

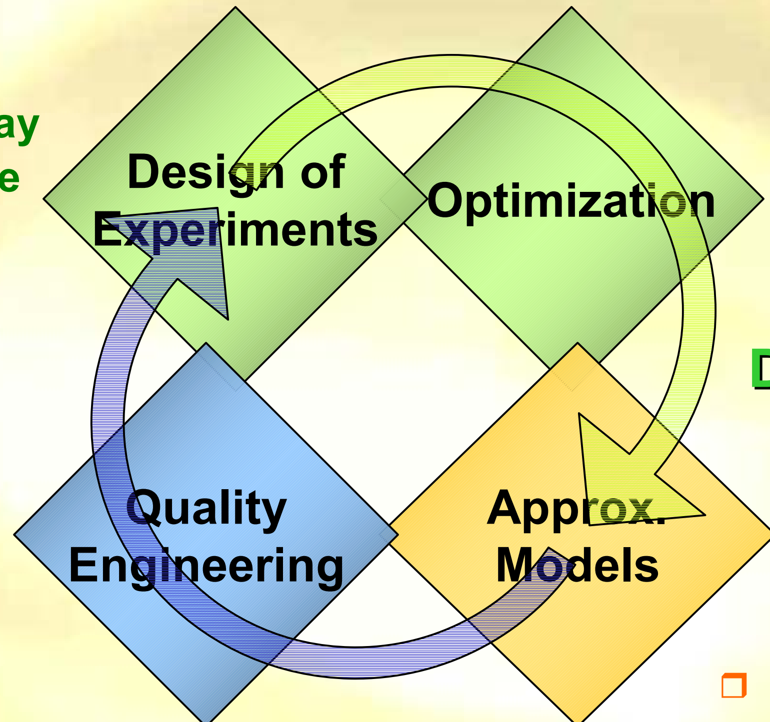
By Applying Design Intelligence to the iterative process through Design Study Tools

- ***Deterministic***
- ***Stochastic***

Complete Design Exploration Engine

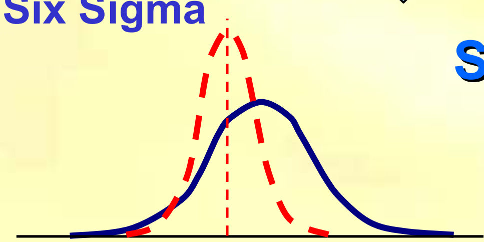
- Central Composite
- Full Factorial
- Orthogonal Array
- Latin Hypercube
- Parameter
- Database

- Rule-based
- Exploratory (GA etc)
- Gradient-based
- Mixed Variable



Deterministic Methods

- Monte Carlo
- Taguchi Robust Design
- Reliability Analysis
- Reliability-based Optimization
- Design for Six Sigma



Stochastic Methods

- Taylor Series
- Response Surface
- Variable Complexity

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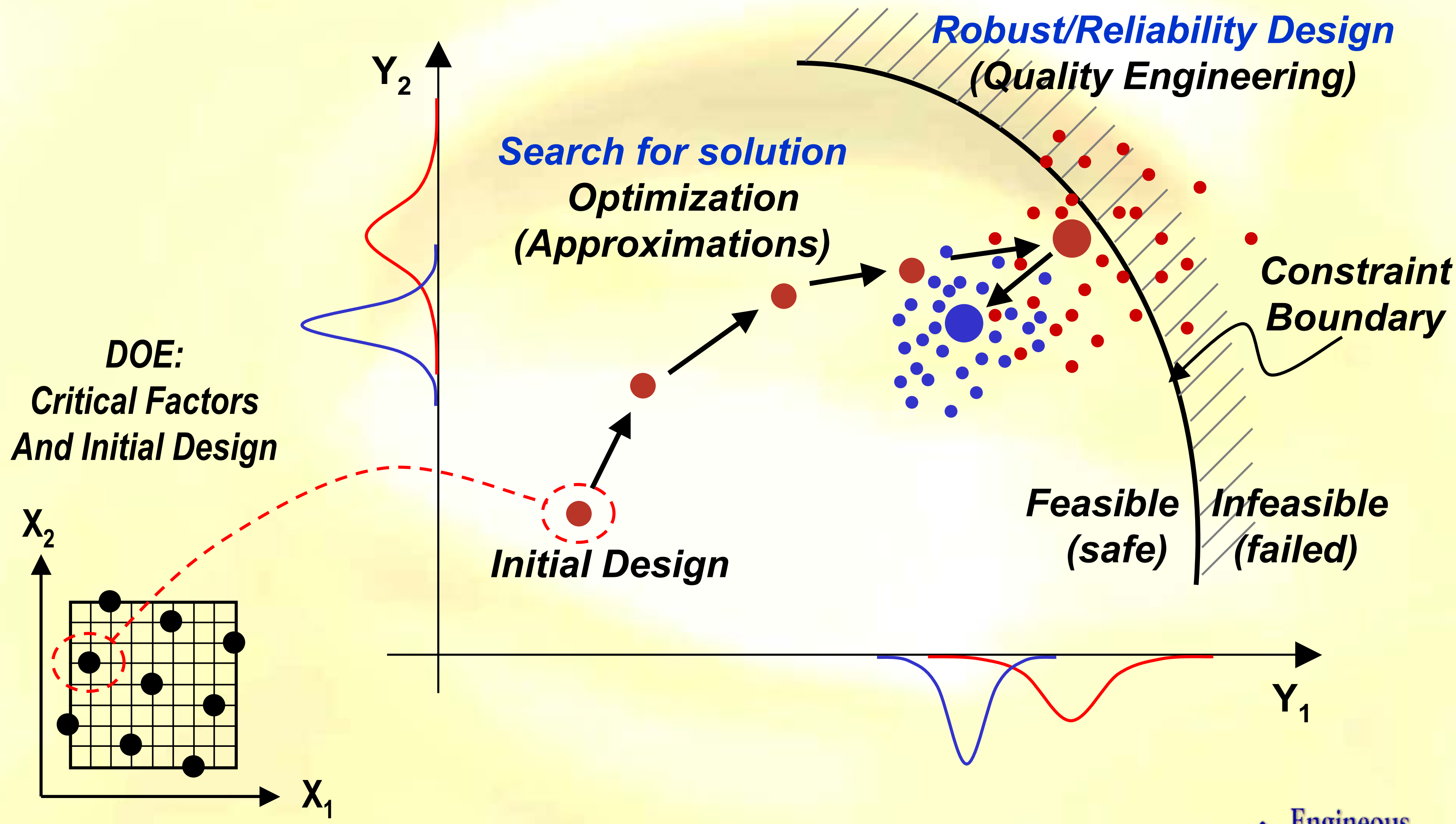
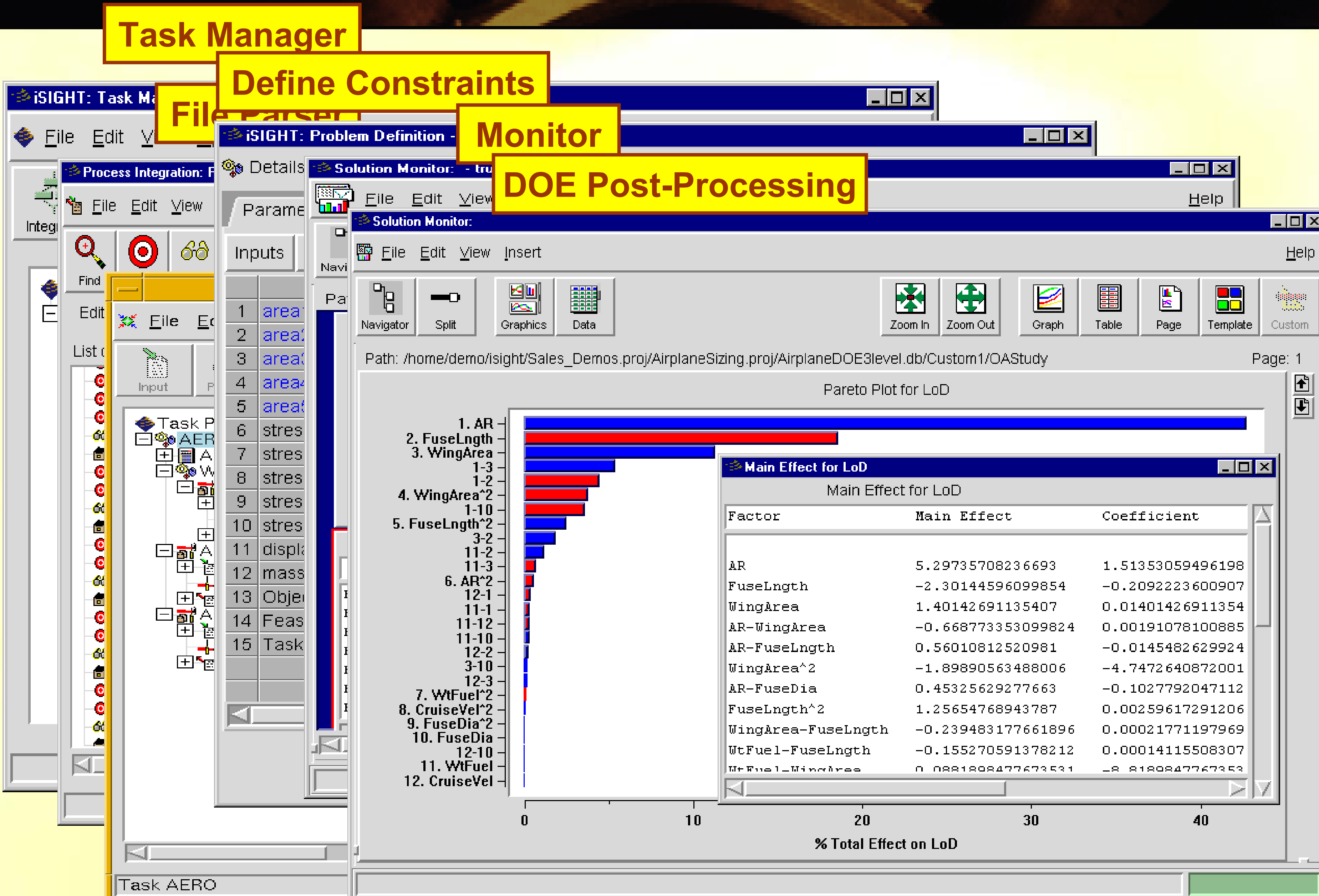
New Design Process



GUI Interface



Connectivity
A Sampling of Applications in Use at Our Customer Sites

- ASCII-based I/O Files using iSIGHT GUI

Structures:	**NASTRAN, MARC, ABAQUS, ANSYS**
Metal Forming:	**DEFORM, Procast**
CFD:	**STAR-CD, FLUENT, CFX, TASCflow, ST[illegible]M**
Crash/Impact:	**Pam-Crash, [illegible]**
Injection Molding[illegible]	**[illegible]**
[illegible]cs	**[illegible]**
[illegible]	**ADAMS, DADS, Matlab, Matrix-X**
Engines:	**GT-Power, [illegible]**
Semiconducto[illegible]	**[illegible]**
CAD/[illegible]	**[illegible], Unigraphics, CATIA, PATRAN, Acumen, Hyper-Mesh, Gridgen, HICAD/CADAS etc.**
Turbomachinery	**Concepts NREC COMPAL, CCAD**
Thermo Cycle Analysis	**Legacy codes at GE, Toshiba, Honeywell, P&W, etc.**
General Math/Plotting:	**Mathcad, S-PLUS**
Many Internal Programs	

Virtually any Application or Simulation Code

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Platform Utilization

- Unix
  - Sun, SGI, HP, IBM, etc.
- Windows
  - NT, 2000
- Linux

- Parallel and Distributed Processing
  - Run multiple codes in parallel
  - Run parallel techniques (i.e., DOE, GA)
  - Distributed and enabled across heterogeneous network

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Application Examples

- Multi-Stage Power Generator Steam Turbine
- DARPA: Integrated Disk Design & Manufacturing
- DARPA AIM (Project for Accelerated Insertion of Materials)
- Airframe/Propulsion Optimization
- Navy Propeller Conceptual Design
- Aerospike Nozzle Design
- America's Cup Yacht Design Prada's Luna Rossa

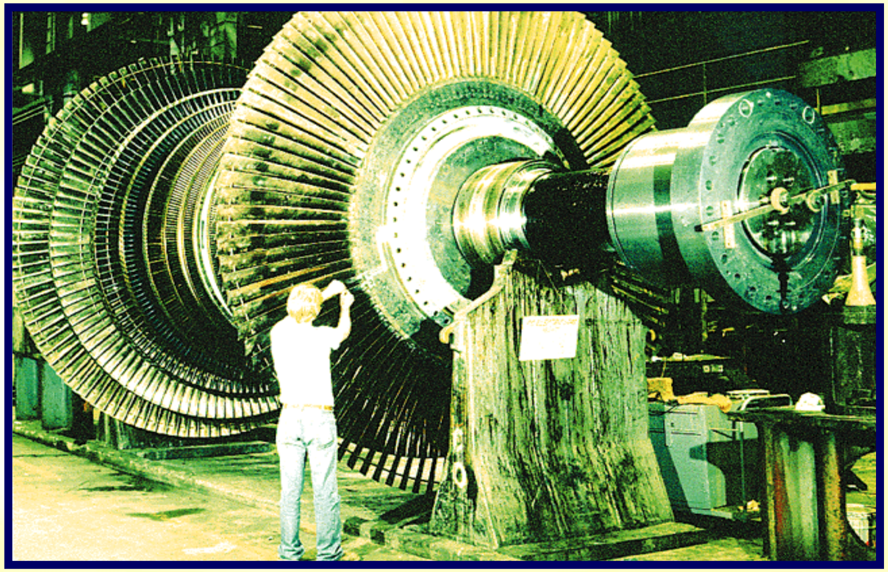
Multi-Stage Power Generator Steam Turbine

Problem: Reduce time required to design power plant turbines

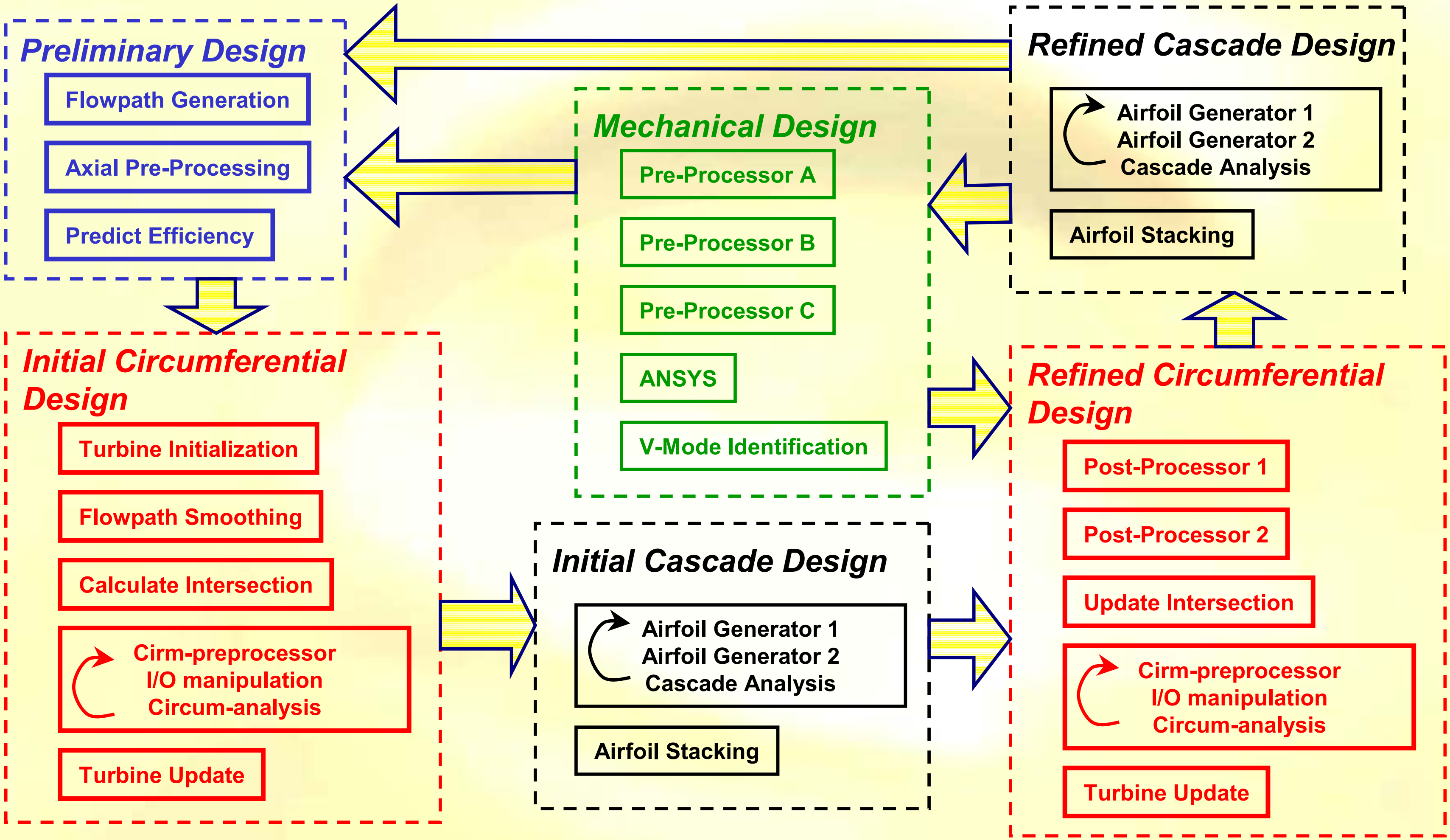
Solution: Use Engineous software to integrate 29 codes

Result:

- **Design time reduced from 1 year to hours**
- **Major competitive advantage for GE Power Systems**



Multi-Stage Power Generator Steam Turbine



DARPA Program

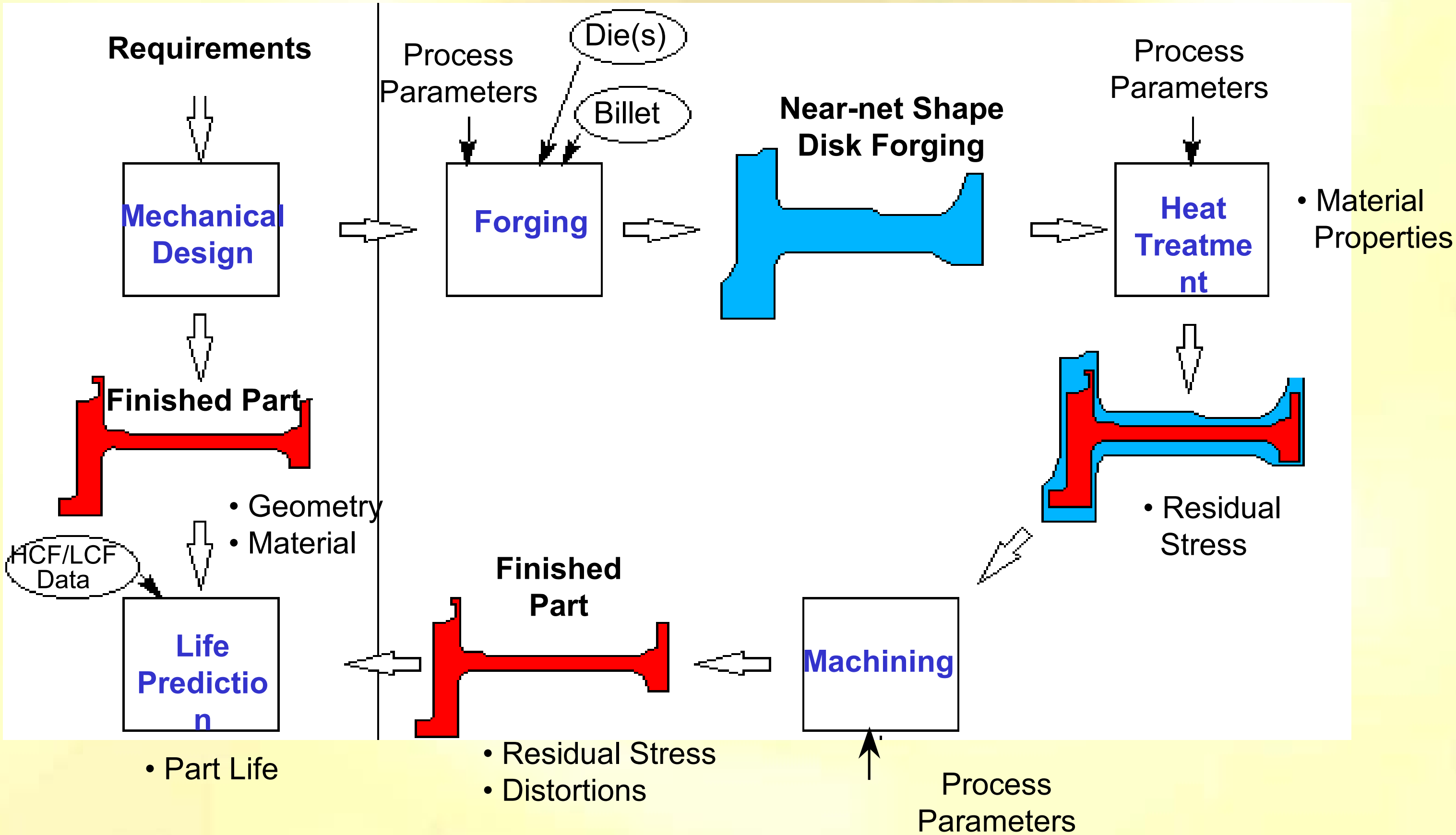
- Integrated Turbine Disk Design

- Objective:
- Demonstrate geometry and finite element based multidisciplinary optimization (MDO) for complex product and process development

DARPA: Integrated Disk Design & Manufacturing

Design

Manufacturing



DARPA: Integrated Disk Design & Manufacturing

- Mechanical Design
  - Meet Requirements
  - Minimize Weight
  - Minimize Cost
- Forging
  - Near Net Shape
  - Minimize Forging Operations
  - Formability
- Heat Treatment
  - Requisite Material Properties
  - Minimize Residual Stress
  - No Cracking
- Machining
  - Minimize Distortion
  - Minimize Number of Operations
- Life prediction
  - Required Life

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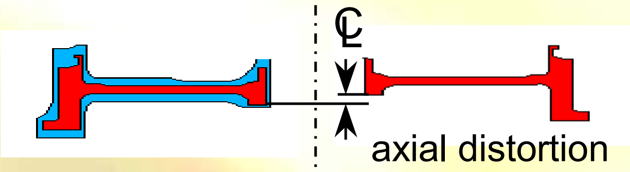
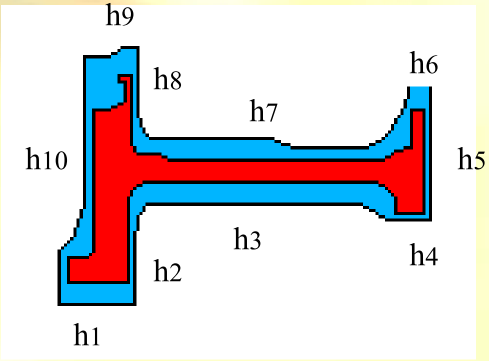
DARPA: Integrated Disk Design & Manufacturing

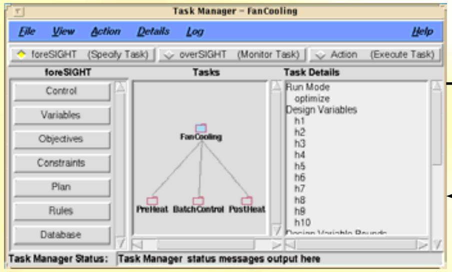
The Problem: Residual Stresses Introduced during Heat Treatment lead to distortions of the Finished Part

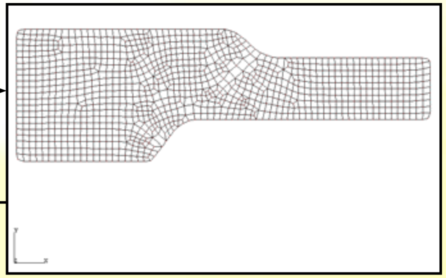


Minimize Non-uniform Cooling for Reduced Residual Stresses
Cooling Rate Constraints for Creep Performance
Surface Heat Transfer Coefficients h_i



The Tools: **iSIGHT** **Finite Element Analysis (DEFORM)**

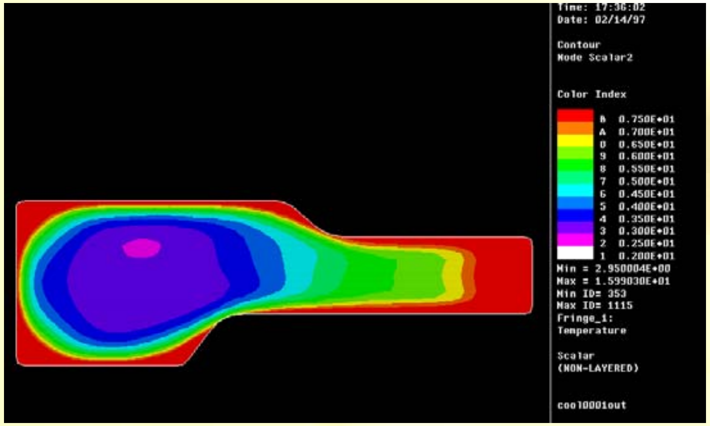




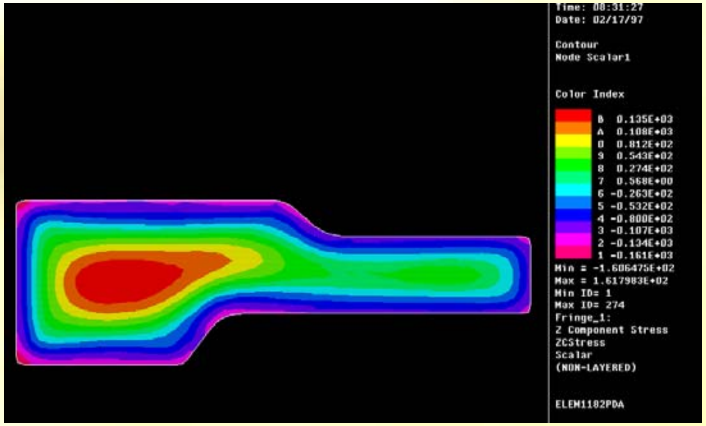
Cooling Rate Optimization

DARPA: Integrated Disk Design & Manufacturing

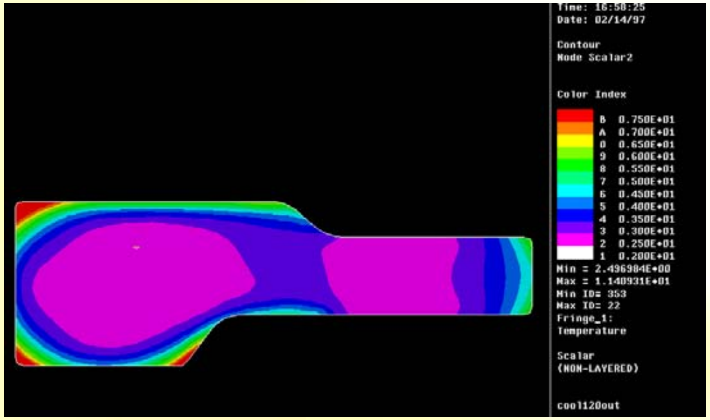
Initial Cooling Rates



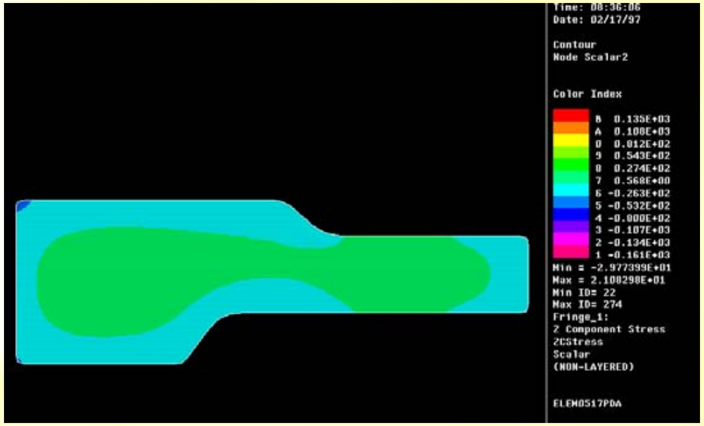
Initial Hoop Stress Distribution



Final Cooling Rates



Final Hoop Stress Distribution



- Cooling Rate Distribution more Uniform
- Cooling Rate Target Met

Maximum Stresses Reduced by about 80 %

Cooling Rate and Stress Results

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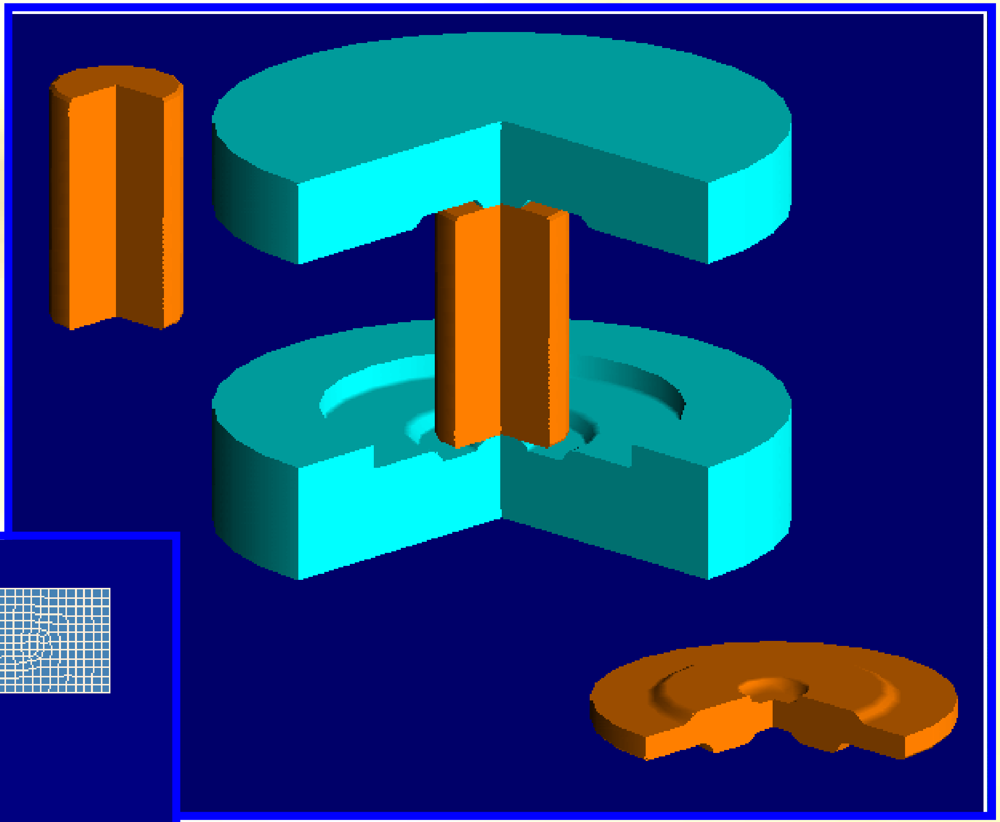
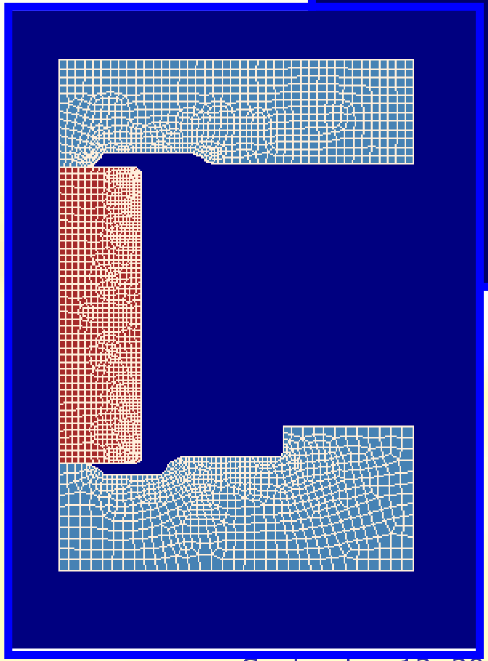
DARPA: Integrated Disk Design & Manufacturing

Forging Die Speed Optimization

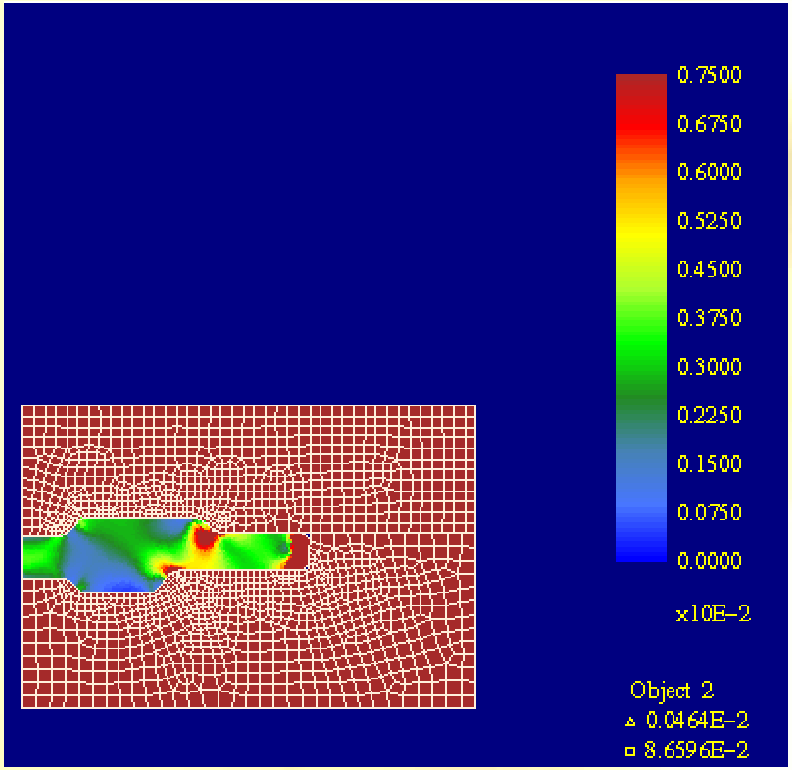
Objective:

To forge the billet into a high pressure turbine disk such that the maximum strain rate in the deformable work piece never exceeds 0.008 s^{-1} during forging.

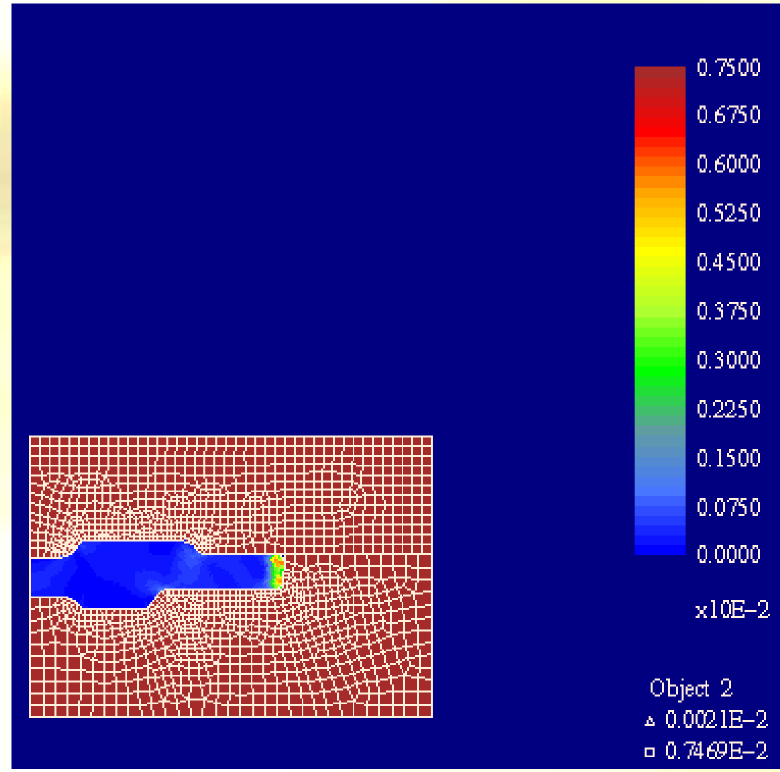




DARPA: Integrated Disk Design & Manufacturing



Conventional Approach Results



Optimized Approach Results

Forging Die Speed Optimization:
Equivalent Strain Rate Contours

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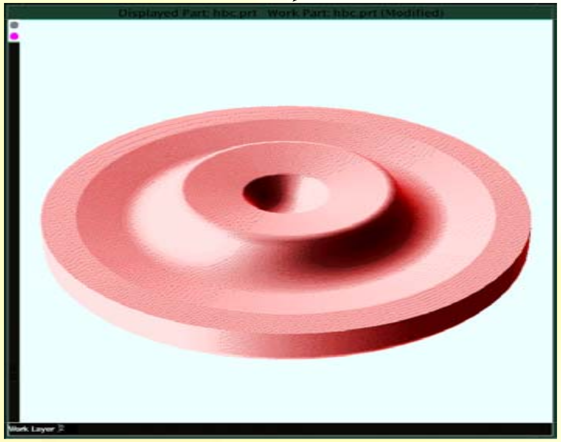
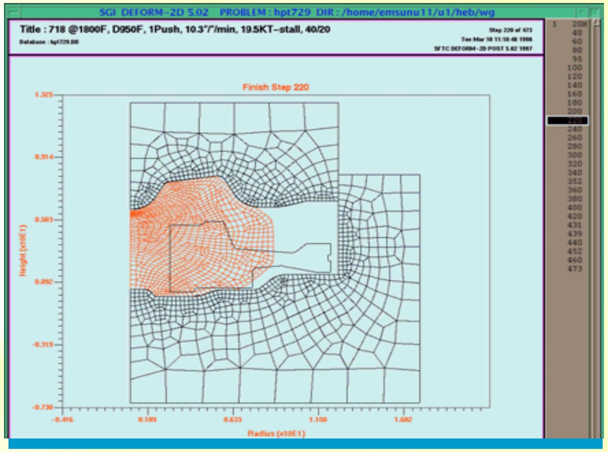
DARPA: Integrated Disk Design & Manufacturing

iSIGHT

Unigraphics



DEFORM



Forging Die Shape Optimization

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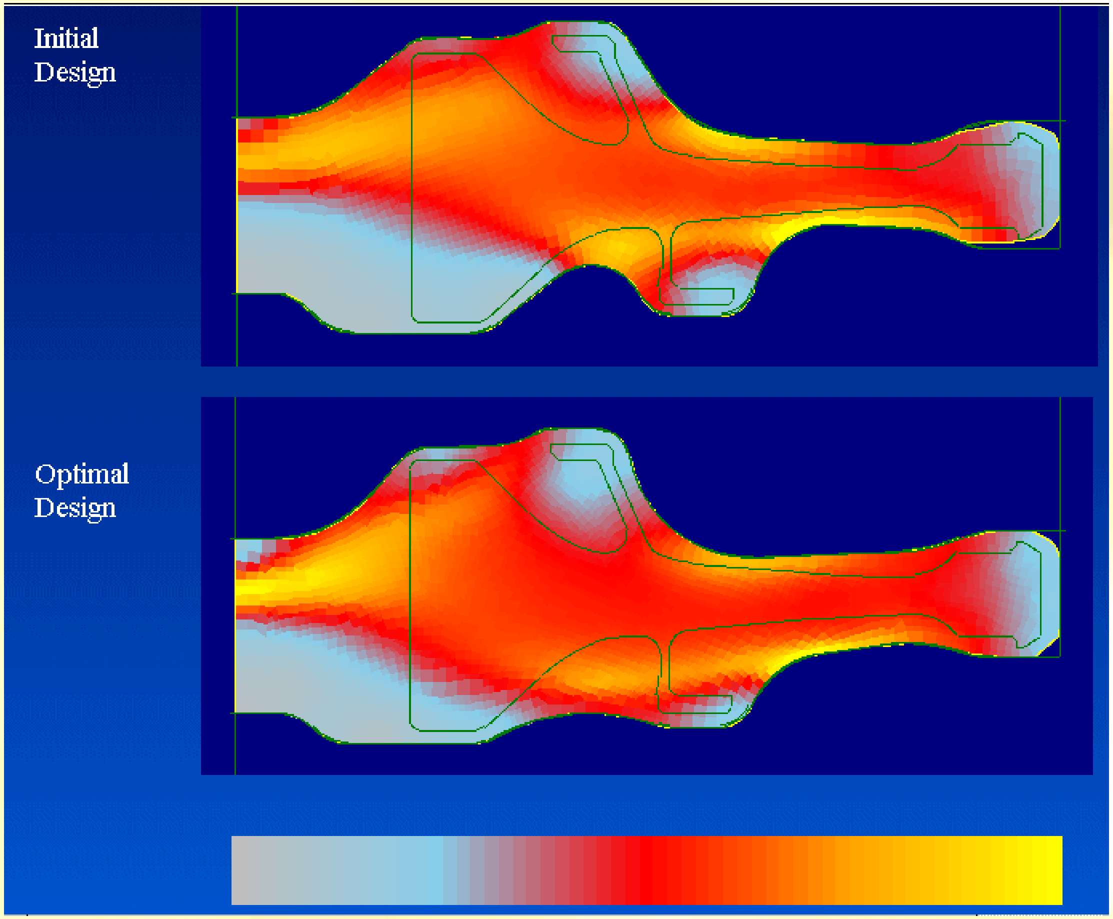
DARPA: Integrated Disk Design & Manufacturing



The strain distributions of the initial and optimal designs. The low strain region is reduced in the optimal design. All data is normalized.

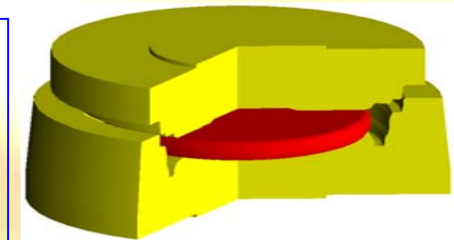
Forging Die Shape Optimization:

Normalized Strain Distributions

DARPA: Integrated Disk Design & Manufacturing

High Pressure Turbine Disk

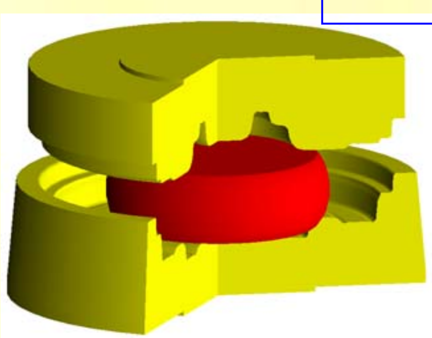
Stage 9 Compressor Disk

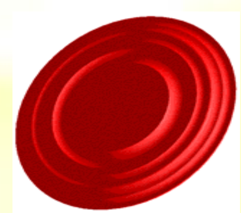


Summary:

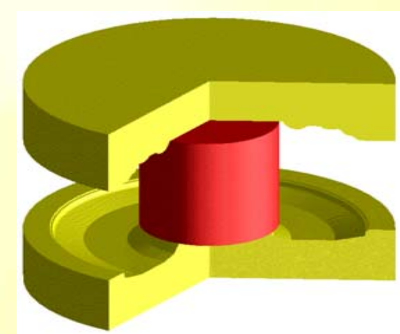
- **Forging Optimization System Has Been Applied to Several Disks**
- **Demonstrated Weight Reductions of 11% (average) Over Manually Optimized Designs**
- **Transition of Software to Forging Vendors In-Progress**

Stage 1 Fan Disk





Forward Seal



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September 12, 2001

DARPA AIM (Project for Accelerated Insertion of Materials)

- **Goal:**

  Develop a rotor component design system - called "aimSIGHT" - that allows material forming process parameters to be tuned automatically to achieve desired material properties and component performance, thereby dramatically reducing the time needed to develop new materials

  Account for real world uncertainties in manufacturing process, material properties, tolerances, material behavior predictions, etc.

- **Team Members:**

  Pratt & Whitney (Lead)
  Scientific Forming Technologies Corp.
  Ladish Co.
  Engineous Software Inc.
  Brown University
  Carnegie-Mellon University
  University of Connecticut
  Drexel University
  Lehigh University
  University of Michigan
  Michigan Technological University
  MIT
  Northwestern University
  West Virginia University

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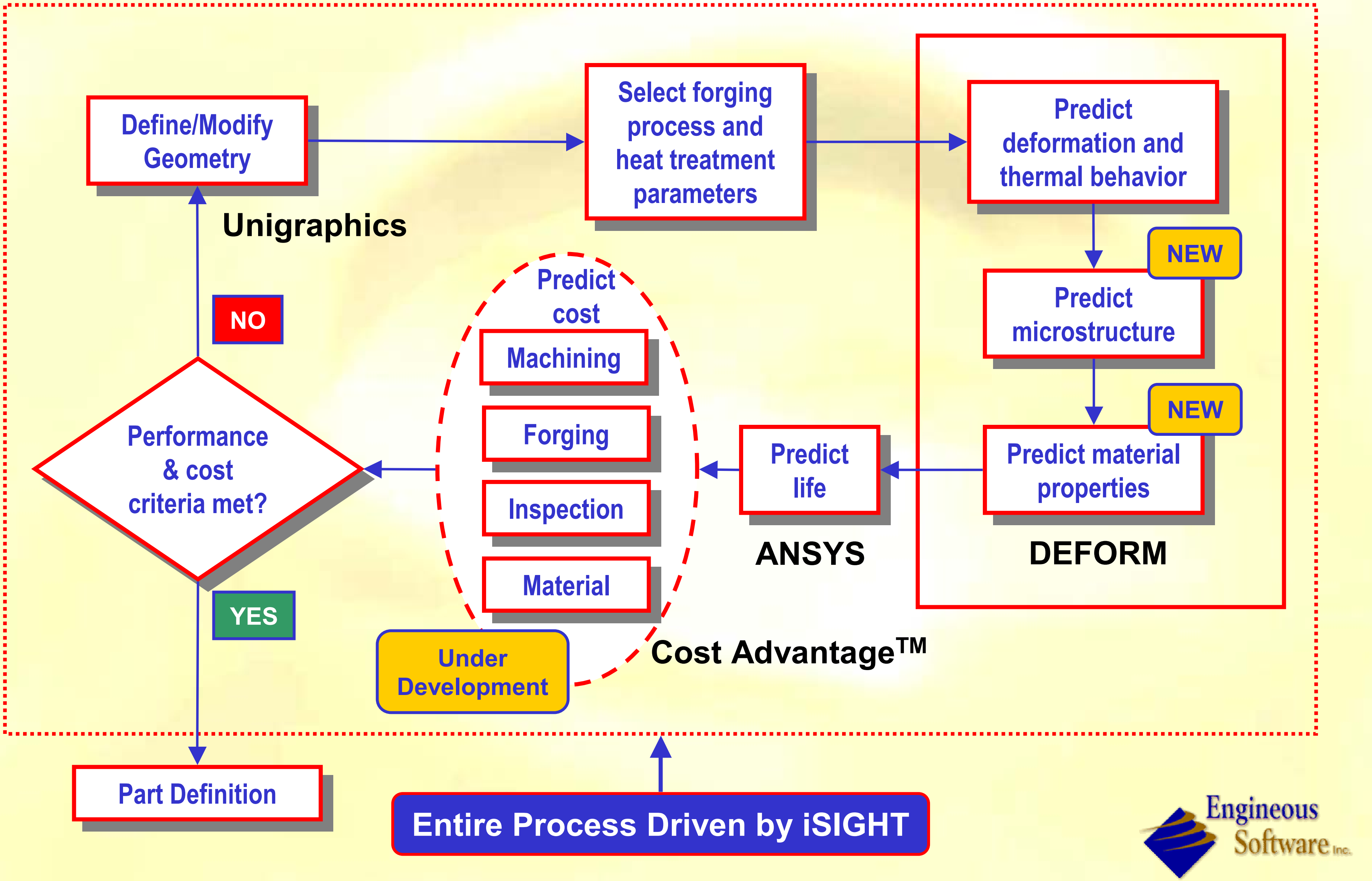
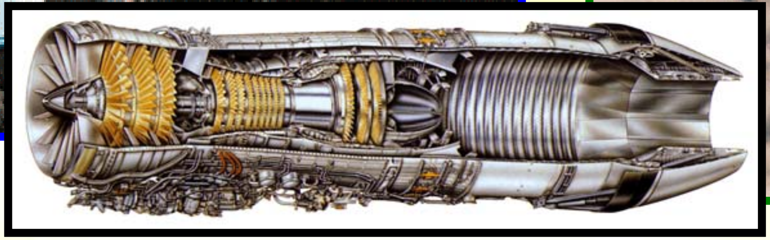
"aimSIGHT" Design System



Airframe/Propulsion Optimization



The Problem:

Determine the optimal cycle and minimum engine size to match a given engine to an airframe for optimal aircraft performance.

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Integrated Airframe/Propulsion Optimization

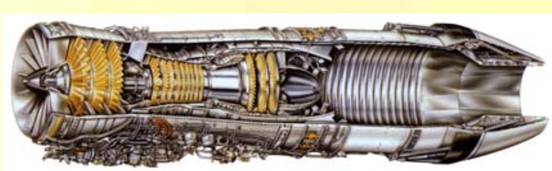
Objective: Determine the optimal cycle and minimum engine size to match a given engine to an airframe for optimal aircraft performance.

Mission
- Maneuvers
- Cruise
- TO/LD

Engines
- F404
- F110
- F120

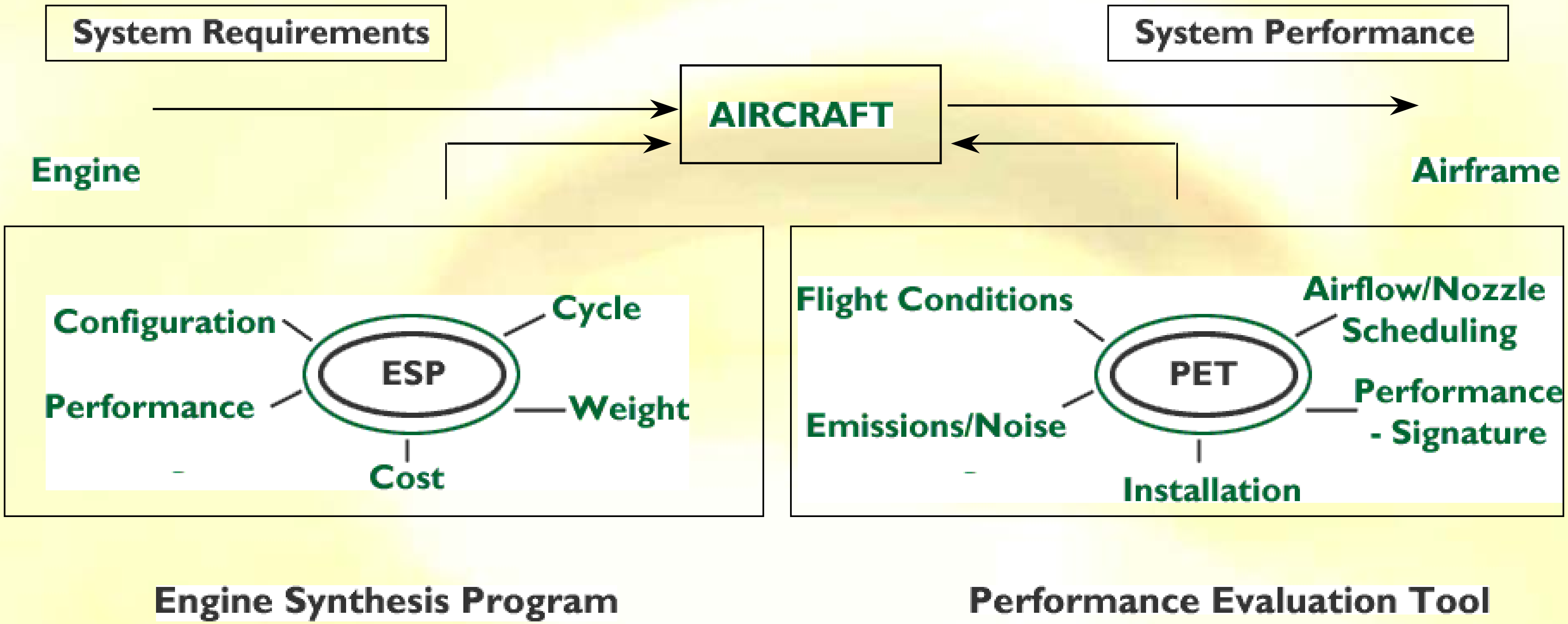
Airframes
- Commercial
- Fighter
- Bomber

Propulsion Installation → **Engine Sizing** ← **Inlet & Nozzle Selection**



Optimum Aircraft Performance

Integrated Airframe/Propulsion Optimization



<u>Conclusion</u>: Design optimization using preliminary design tools allows efficient evaluation of complex engineering systems & scenarios that can improve designs to achieve enhanced performance and reduce cycle times at lower cost

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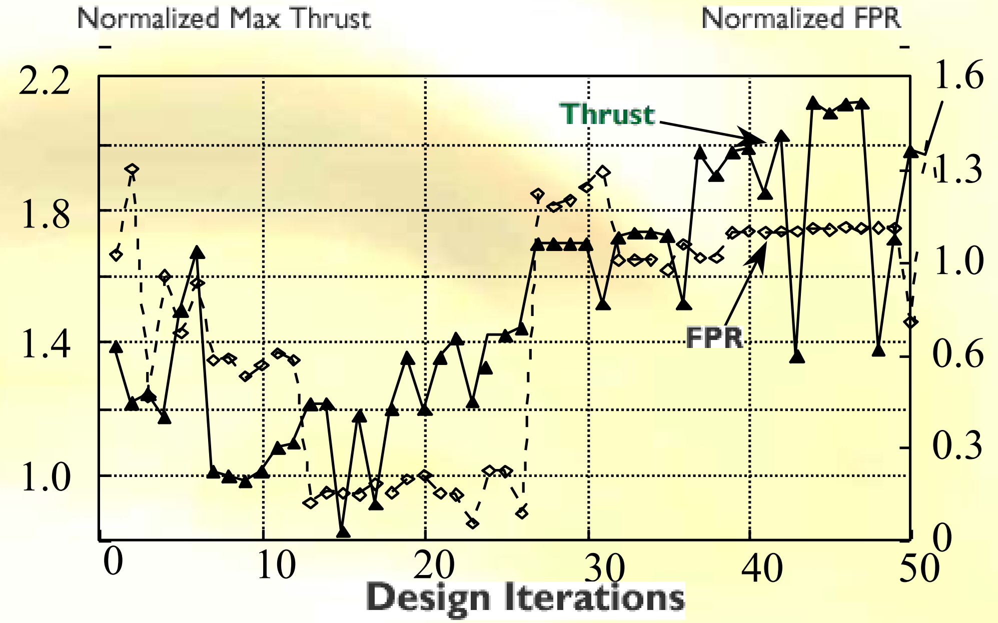
Integrated Airframe/Propulsion Optimization

Performance Optimization

Maximum Thrust

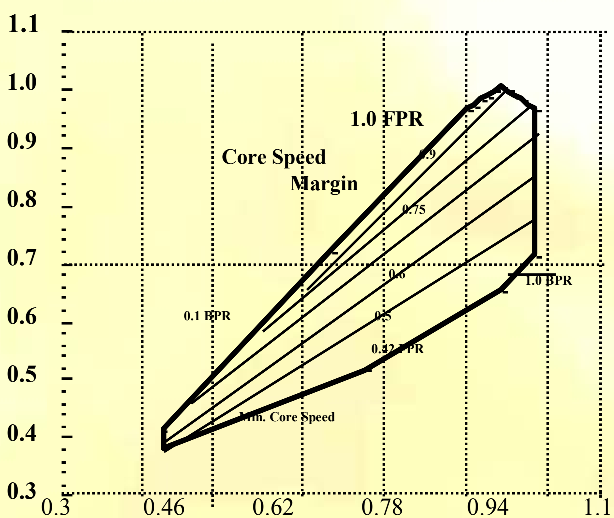
Subject to Constraints

0.0	<	ByPass Ratio	< 1.0
0.4	<	Fan Pressure Ratio	< 1.0
0.4	<	Overall Pressure Ratio	< 1.0
0.2	<	Inlet Airflow	< 1.0
0.8	<	Throttle Ratio	< 1.0



Engine Performance Map

Normalized Thrust



Initial Design

Thrust: 1.56, Weight: 1.08

Length: 1.25, Inlet Diameter: 1.2

Inlet Airflow: 1.5, FPR: 2.4

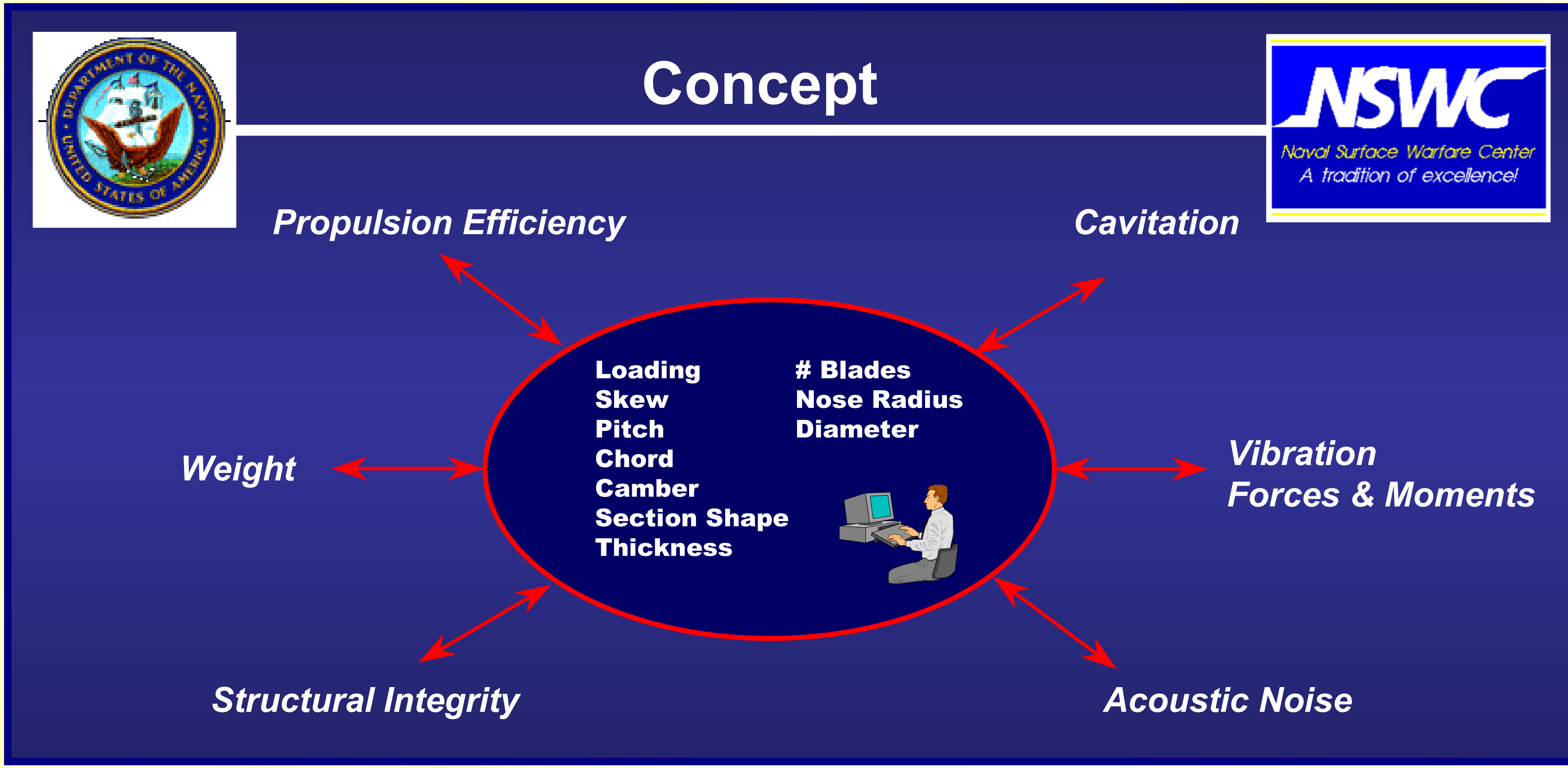
Final Design

Thrust: 2.0, Weight: 1.43

Length: 1.38, Inlet Diameter: 1.4

Inlet Airflow: 1.47, FPR: 1.7

Navy Propeller Conceptual Design



The Problem:

Balancing the <u>competing</u> design requirements and constraints of 6 engineering groups to create the best overall propeller

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Navy Propeller Conceptual Design

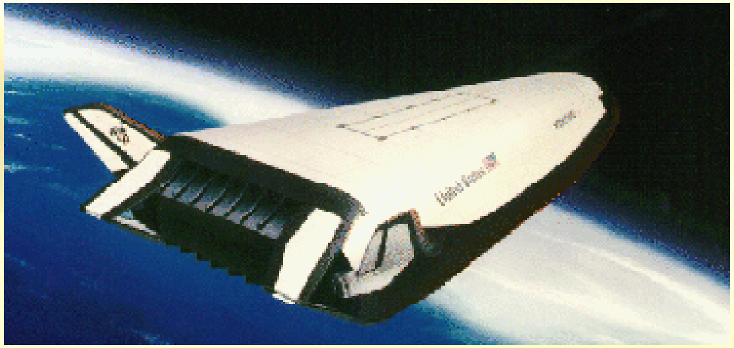
Benefits

- **Better Design in Reduced Time**
  - **Typical Single-Screw Propeller Design**

Manual	*Engineous*
70% of Time Spent Preparing Design Alternatives *30% of Time Spent Evaluating and Engineering Design Alternatives*	*5% of Time Spent Preparing Design Alternatives* *95% of Time Spent Evaluating and Engineering Design Alternatives*
Average Preliminary Design Time: 2 Months	*Average Preliminary Design Time: 3 Weeks*
Limited Number of Design Alternatives Evaluated	*10-100 Times More Design Alternatives Evaluated*

Aerospike Nozzle Design

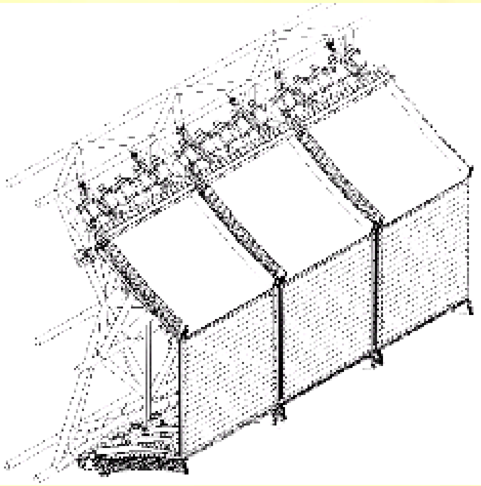
NASA Langley



- **Problem:** Minimize the Gross Lift-off Weight. Requires modeling effects of 4 domains, namely structures, CFD, baseflow, and performance domains

  18 design variables, 564 constraints

- **Solution:** Coupled iSIGHT with multiple codes and implemented multidisciplinary feasible (MDF) strategy



- **Results:**

  "iSIGHT reduces code and file management for the user"

  "iSIGHT reduces time required to explore variety of optimization schemes and design parameters"

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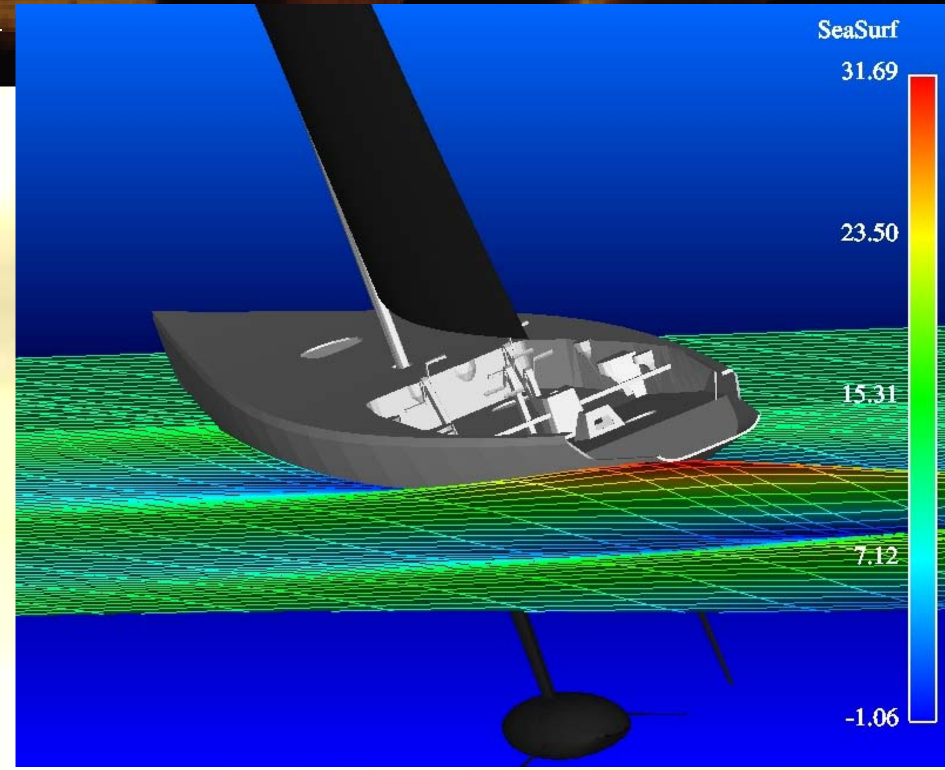
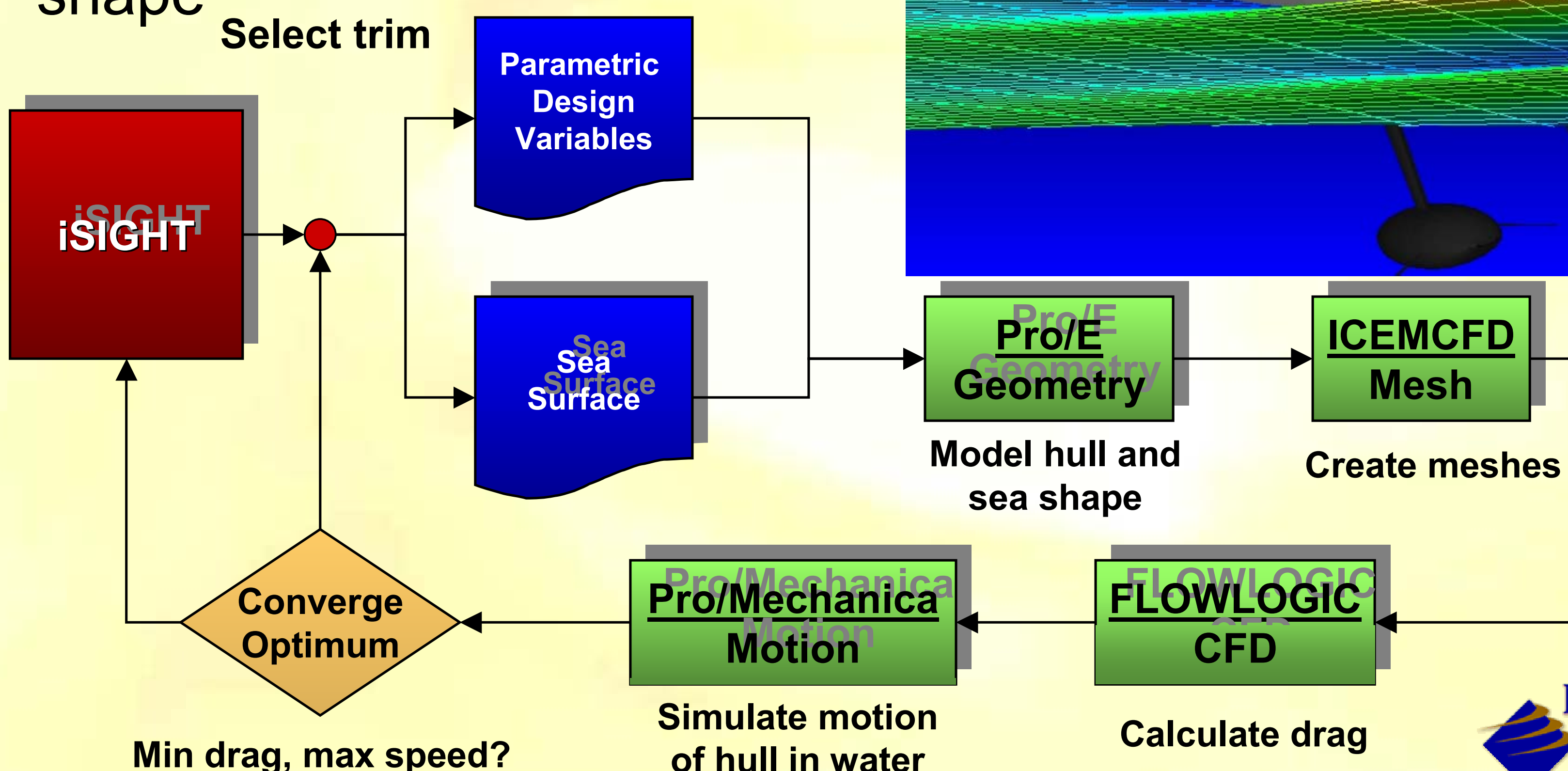
Trim Optimization

- Optimize yacht position (trim) to minimize drag and maximize speed for given sea surface shape

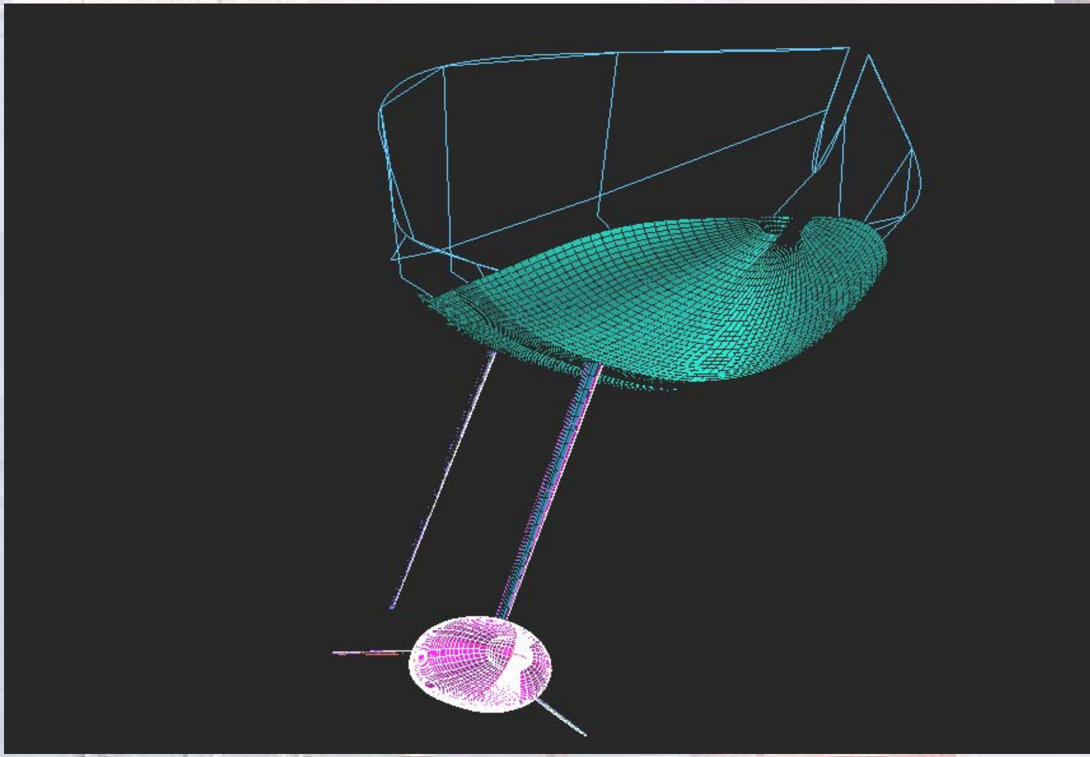




Automating Hull Design

- 1000's of configurations analyzed in CFD
- *20-50* per day
- iSIGHT-based design system directly optimizes Pro/ENGINEER model
- Final result:

  Correct new 3-D Pro/E geometry for manufacturing, no prototyping!



The Future is now!

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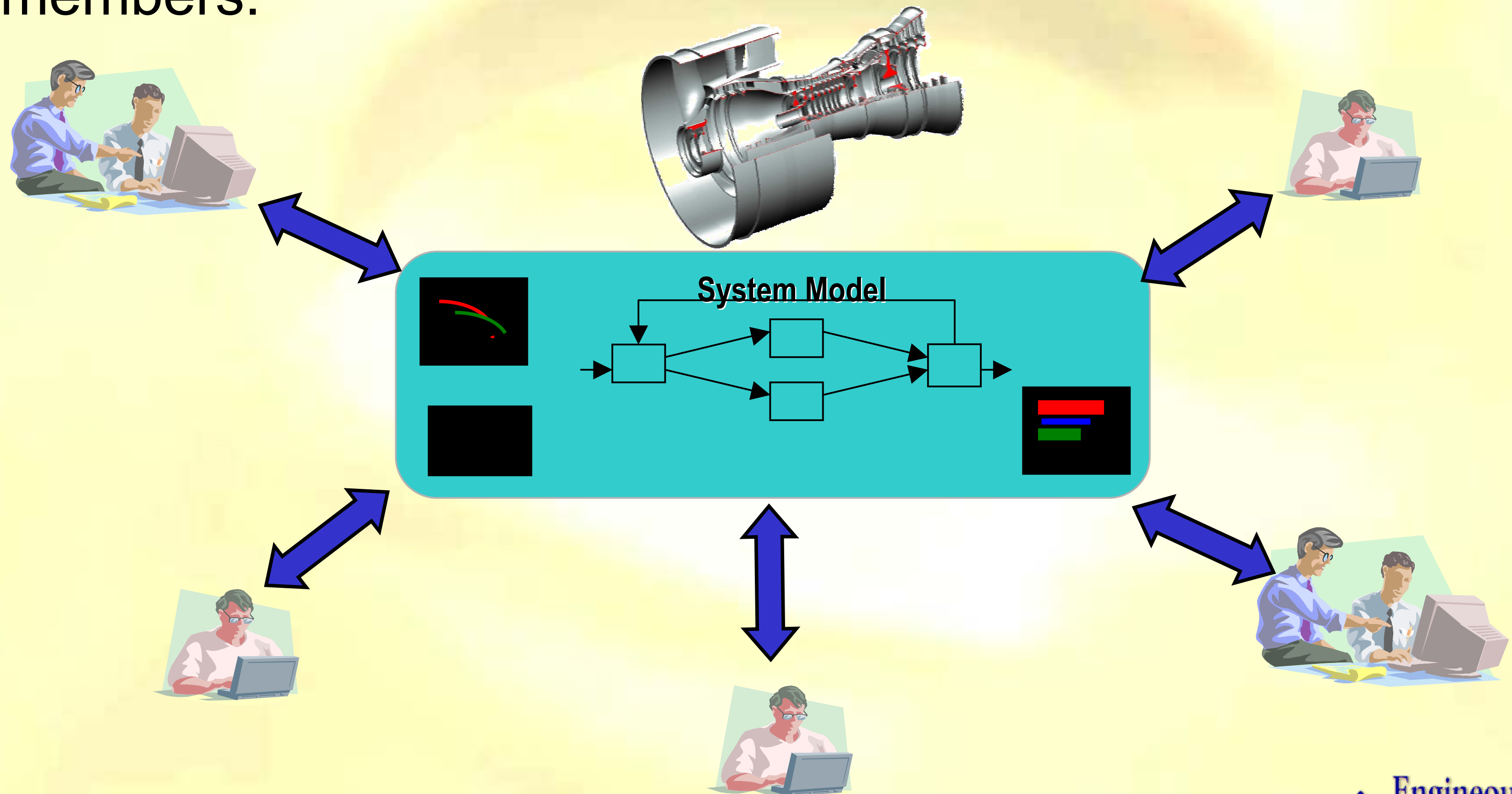
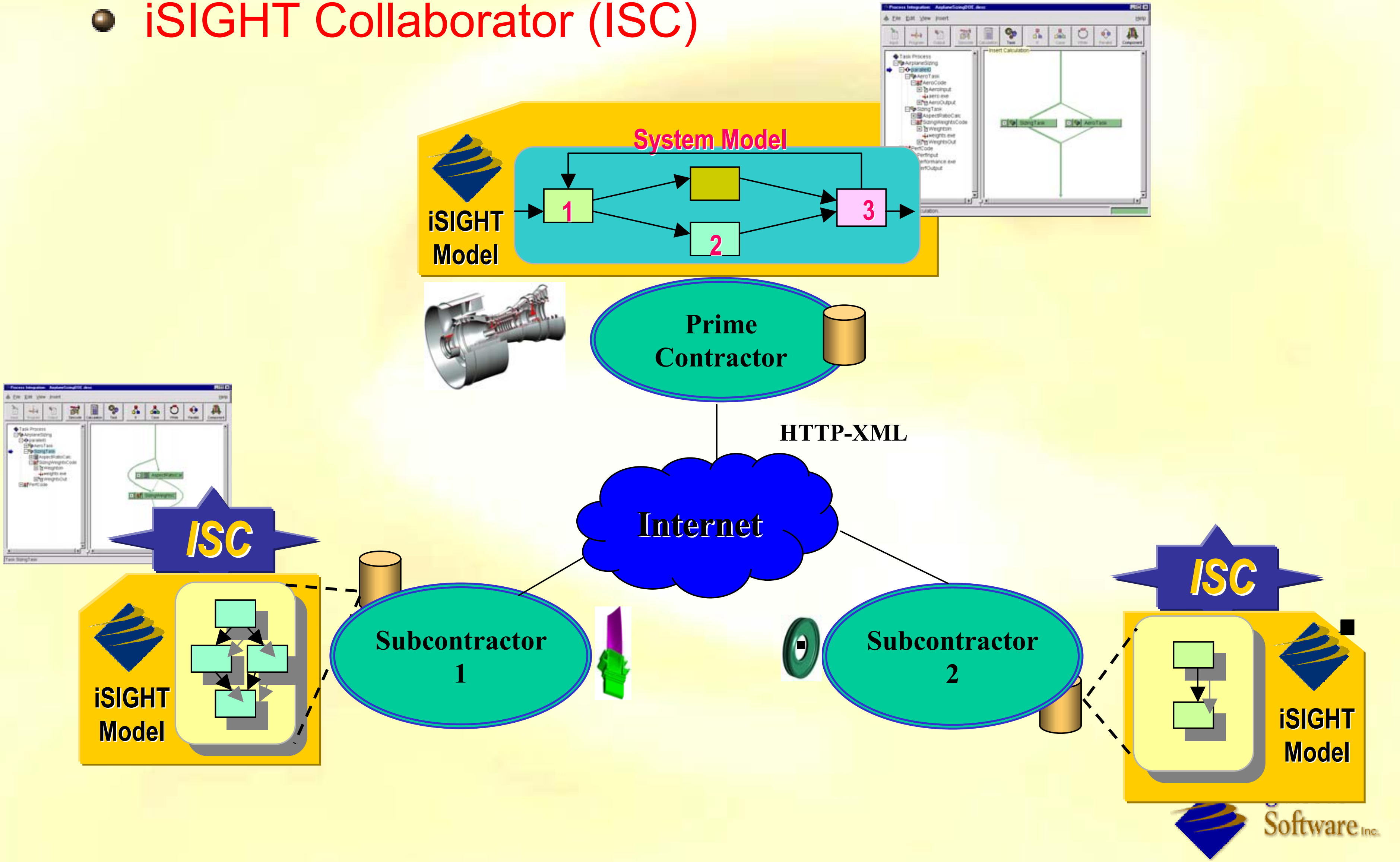
Engineering “Collaboration” through Shared Models

People interactively work with the same model, sharing control and seeing the execution results of other team members.



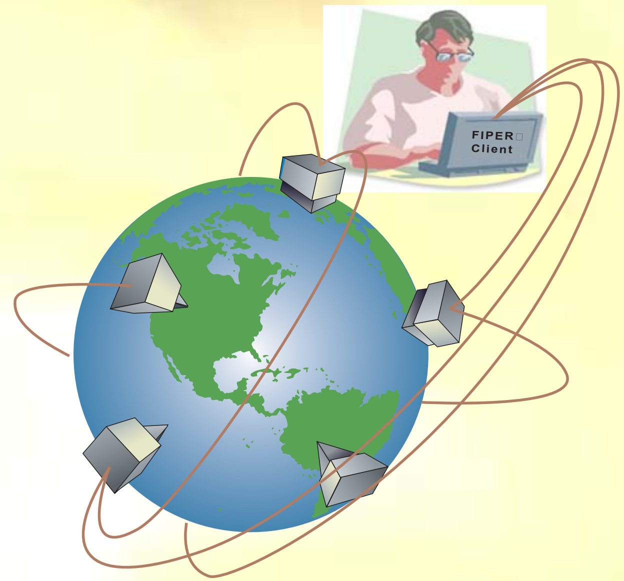
iSIGHT Collaboration

- iSIGHT Collaborator (ISC)



Next Step

- Develop a "Federated Intelligent Product EnviRonment" (FIPER) that allows companies to globally —
  - Collaborate with dispersed design teams and business partners
  - Establish standard language protocol for all design tools, legacy data and systems
  - Access best-of-breed design and analysis tools
  - Automate non-creative tasks in the design process



What is FIPER

- A NIST sponsored and funded ($21.5M) project to develop:
- An internet-based distributed framework
  - Supports collaboration among geographically distributed engineering and business partners.
- A service-oriented product development environment
  - Provides an open flexible design environment which allows universal availability and incorporation of existing data, tools/methods and processes as services.
  - Provides a common way to model your analysis and design process in conjunction with your product data.

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FIPER Consortium

FIPER

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Summary

iSIGHT provides a framework which:

- Enables data exchange between applications in similar or diverse disciplines.
- Automates the iterative nature of the design process
- Applicable in all stages of the design process.
- Allows for automation and design exploration on the component, subsystem, and/or system level
- Allows users to quickly couple and drive their design and analysis tools of choice, use “best in class” for each discipline
- Provides a set of tools to explore design alternatives and improvements

Conclusions

Utilization of the iSIGHT Framework throughout the design process (especially at the early conceptual design stage) has dramatic effects on:

- Lowering Costs
- Improving Safety and Reliability
- Reducing Design Cycle Time
- Improving Quality
- Improving Manufacturability

SLI (2nd gen) goals:

- *Reduce cost of launch to low earth orbit to $1,000 per pound of payload*
- *Improve safety of loss of crew to 1 in 10,000 flights*

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