Scientific Power Grids: An Industrial Perspective

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Outline

- **Setting**
- **Parallelism - winning battles!** Wars?
- **Application Frameworks**
- **Grid Frameworks**
- **Enabling tools**
- **Challenges**

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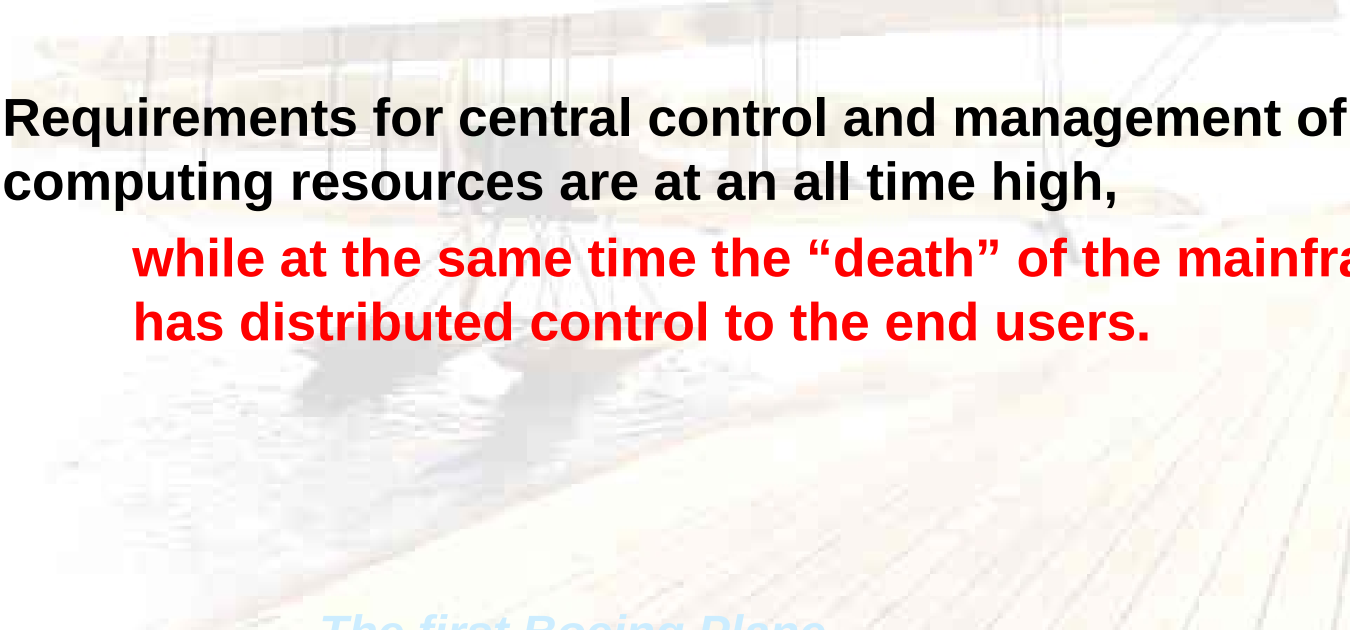
Setting

- **Highly competitive markets, drive low margins in many market sectors (certainly in aerospace)**

  this results in product/cost focus often at the expense of innovative approaches to infrastructure

- **Requirements for central control and management of computing resources are at an all time high,**

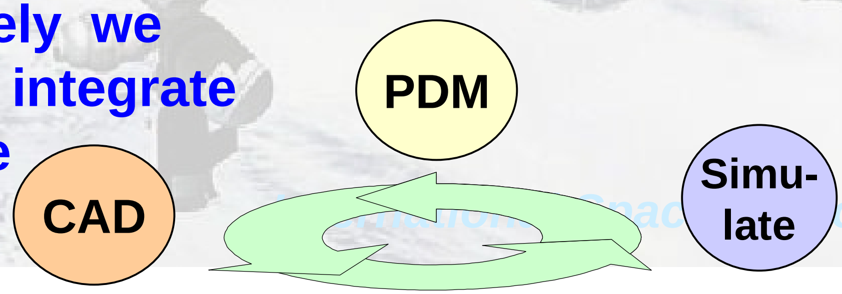
  while at the same time the "death" of the mainframe has distributed control to the end users.



The first Boeing Plane

Opportunity

- Fortune 500 companies have enterprise-wide computing challenges
  - Challenging scientific computing simulations are still required to meet future competitive product design needs
  - CAD systems must be integrated, distributed, and support haptics, VR, and AR modality
  - Business systems (people management, MRP, PDM) are approaching tens of terabytes of storage, and geographic distribution and synchronization
- Ultimately we need to integrate all three



Focus - Scientific Computing

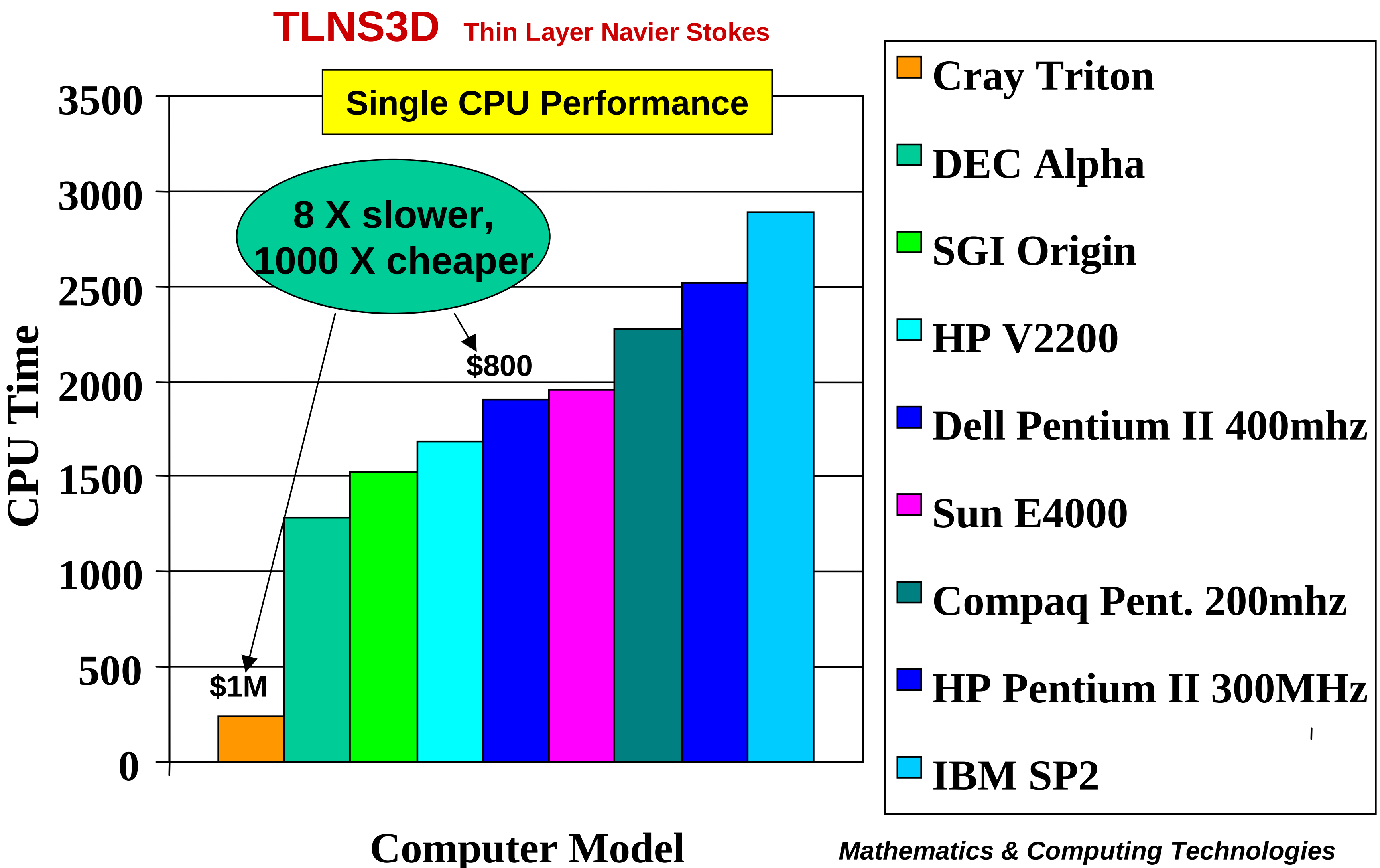
- **Today, let's focus on scientific computing**
- **Vector computing is everyone's favorite**
  - **Modest parallelism**
  - **Shared memory**
  - **Decades of supporting a cadre of Fortran production codes**
  - **Only one problem: computer companies could no longer deliver the differential power, at an affordable price and pace**
- **Parallel computing is NOW, the ONLY solution to high-end computational requirements**
- **There still is a reluctance to "jump in the water", why?**

We are winning Battles

- **Developing parallel codes requires investment**
- **Investment requires stability**
  - **Industry invests in software for decades, not 18 months**
  - **Computational infrastructure has been changing too rapidly**
- **Nevertheless, in recent years, many application codes have been (modestly) parallelized**

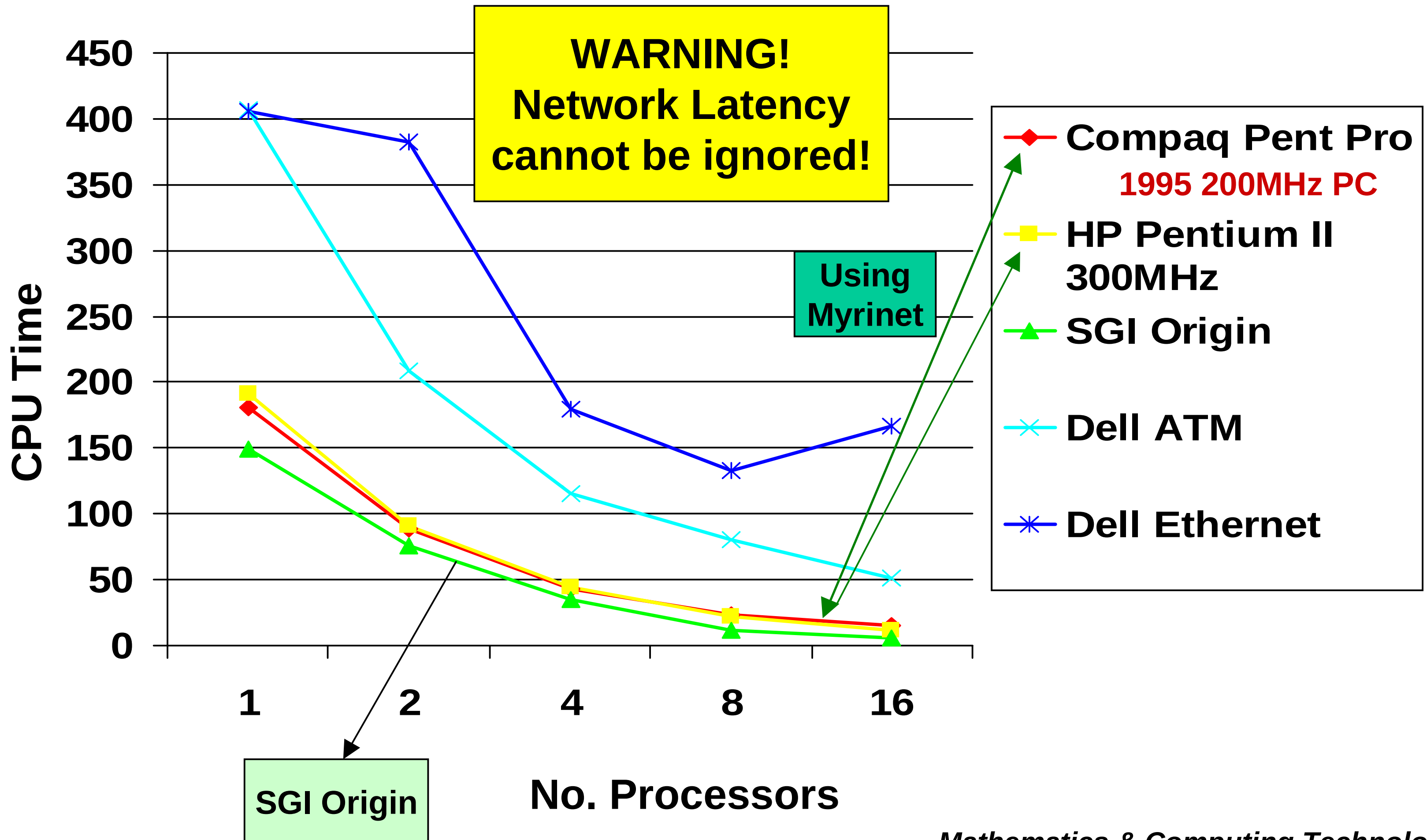
Let's look at some examples from
the Boeing High Performance Computing Benchmark Suite
a project in the High-Performance Distributed Computing program. The team members are Subhankar Banerjee, David Levine, and Joe Manke.

Cost, Always Good Incentive

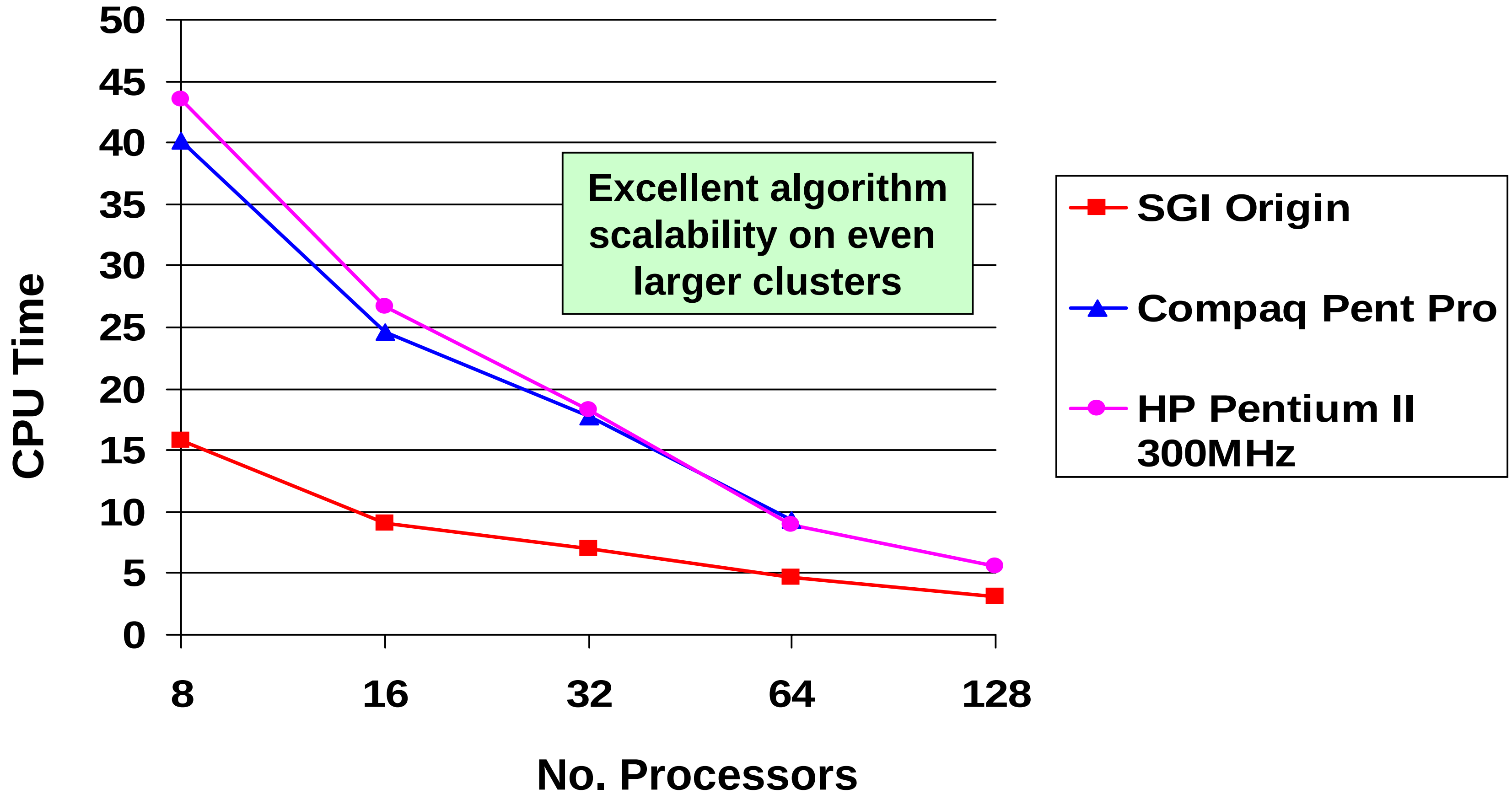


Fast Multipole Method

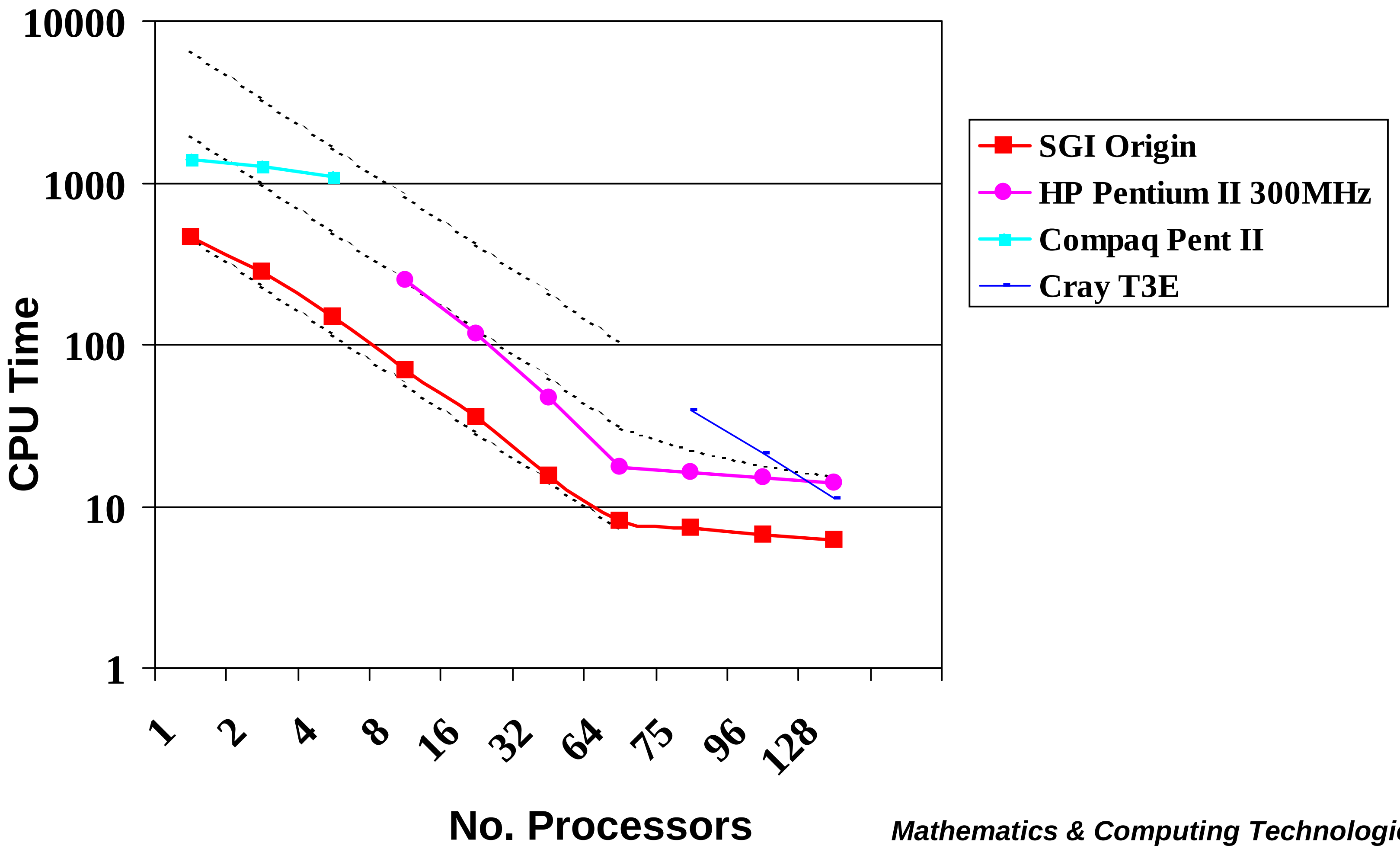
PARADYM (radar cross section)



OVERFLOW Wing Body (3.5M pts, 6 zones)
(Overflow HSCT CFD)



Multiple CPU Comparison
(OVERFLOW HSCT CFD)



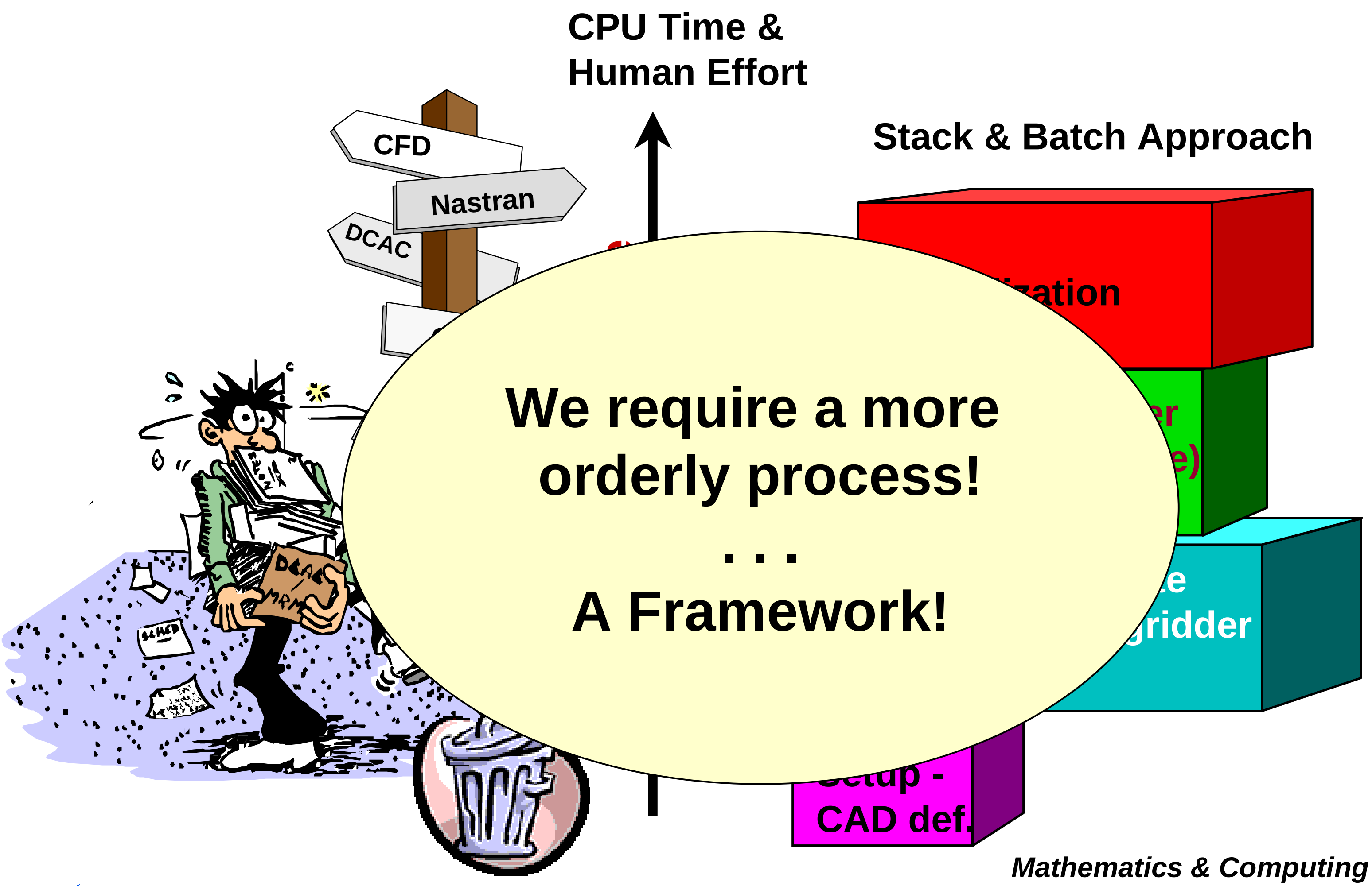
High Speed Connectivity Key

- **High speed networks enable "payoffs from" cluster computing, but private protocol networks add cost**
- **Web usage and media content are driving the need for network bandwidth up, and as a result driving costs down**
- **Consequently, clustering of resources promises to be common and cheap:**
  - **NGI, Internet II will exceed today's Myrinet-type speeds even over long distances**
  - **Access to data (science, weather, CAD, etc.) will be fast and cheap, even if quite remote**

Application Challenges

- **Many industrial applications are one or two decades old -- why?**
  - **They are continually enhanced and validated by testing and use**
  - **New codes are not trusted (nor should they be)**
  - **What pays the bills is the process being supported, not the application's isolated results**
  - **More resolution, higher model fidelity, while important, don't necessarily improve the process results**
- **Rather than refine the analysis, we desire to optimize against often conflicting constraints, and multiple goals**
- **Complexity is enormous, tradeoffs are not understood**
- ***We use mathematical optimization, but seek "improvement" in objectives, not absolute min or max.***

Current Industrial Approach to MDO



Application Framework

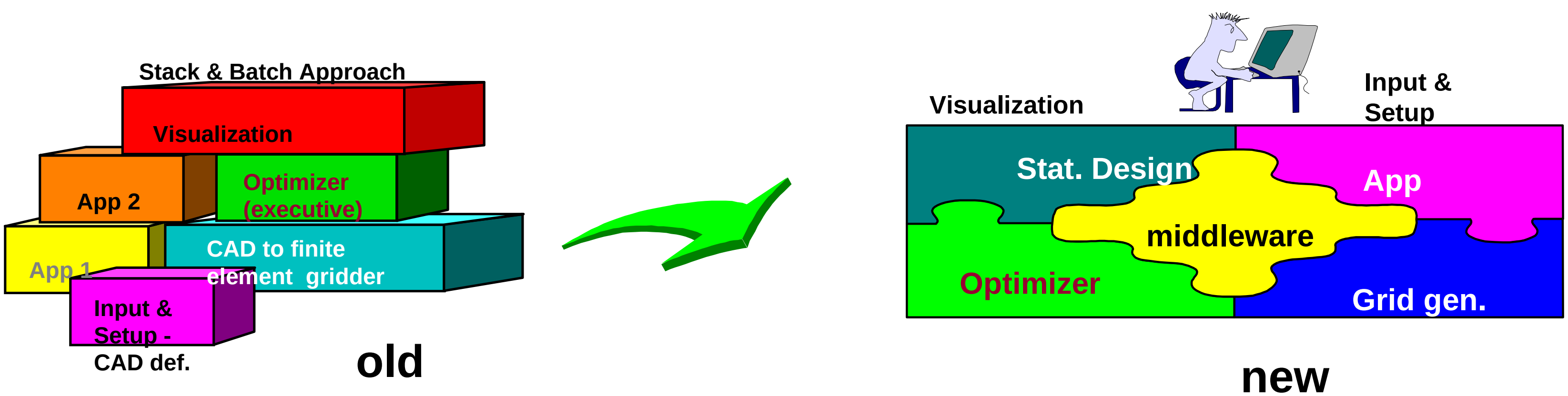
- **Systematic use of tried and true analysis codes**
- **Support multiple objectives and constraints**
- **Support design trade studies**
- **Goals**
  - **improvement in the design, manufacturability and/or maintenance**
  - **easy collaboration among disciplines**
  - **gain insight**
  - **human in the loop, when required**
  - **lower cost and shorten process cycle time**
  - **take advantage of distributed hardware, data, and expertise**

DESIGN EXPLORER (DE)

AN EXAMPLE OF AN APPLICATION FRAMEWORK

Design Explorer is the focus of a multi-year collaboration between researchers at Boeing and Rice University on the topic of optimization of approximate models.

Ref.: Andrew Booker, Paul Frank, John Dennis, Doug Moore, and David Serafini, "Managing Surrogate Objectives to Optimize a Helicopter Rotor Design" , AAIA MDO 98-4717



Mathematics & Computing Technologies
Phantom Works

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DE’s Framework Features

- **Can be configured to the problem type**
- **Exploits decision tools**
  - **Statistical design techniques**
  - **Global domain behavior**
  - **Parameter sensitivity analysis**
- **Decouples the actual application from the executive process**
  - **can “wrap” the function evaluation into the system**
  - **can couple multiple applications**
  - **can provide insight**
- **Utilizes new approaches to optimization**
  - **Surrogate model (to save computational overhead and gain insight)**
  - **Meta-algorithm optimization (to achieve accurate “true” solution)**

DE’s Framework Features

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  - Global o
  - Paramet
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  - can “wra
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  - Surrogate model
  - **Meta-algorithm optimization**

Optimization Techniques

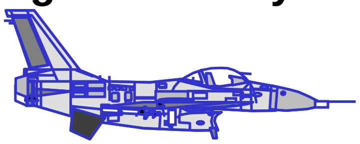
Small-scale, calculus-based, local opt:
- **NPSOL** - SQP Method
- **HDNLPR** - SQP Method

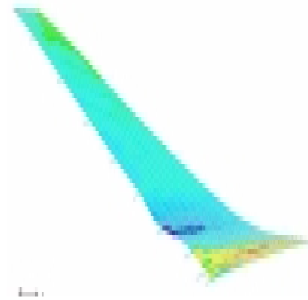
Large-scale, calculus-based, local opt:
- **HDSNLP** - Schur-complement method
- **Interior Point Method** - prototype code

Small-scale, bounds constrained, global opt:
- **Globopt** - Stochastic, multi-start local opt
- **Direct** - Subdivision method

Widely Dispersed Applications--but One Framework

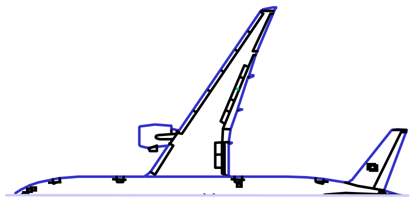
3-D Fighter Aerodynamics



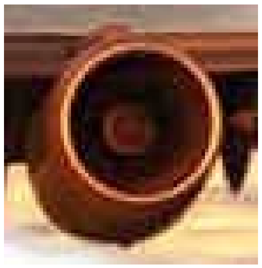


Shot peen forming of wing skins

Rotor Design

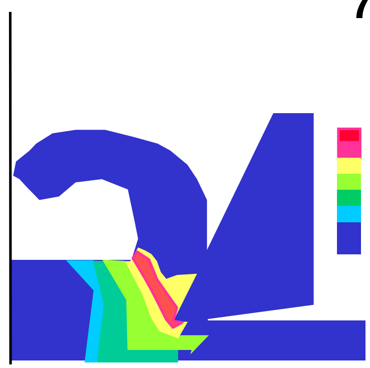


Engine Nozzle Performance

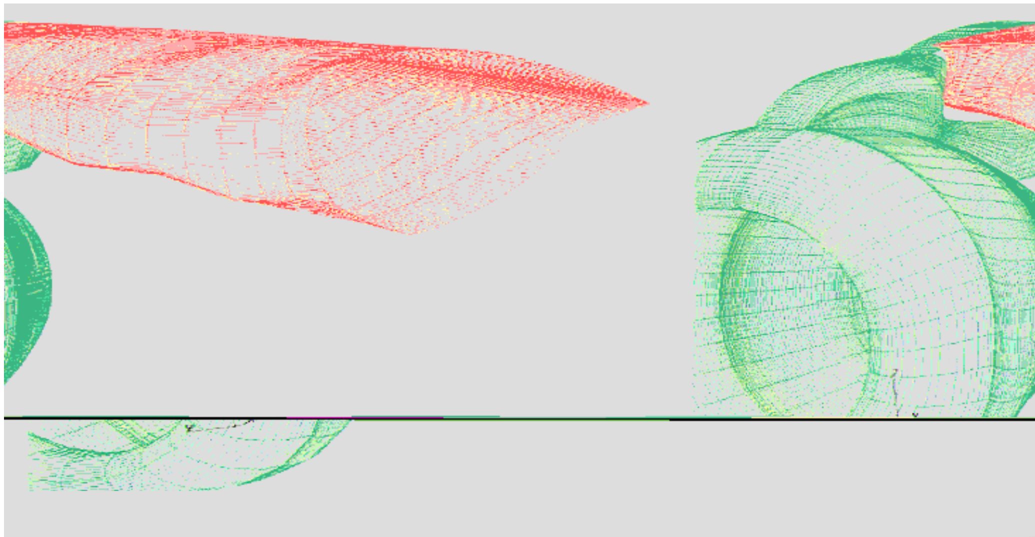


Multidisciplinary wing planform design & 777 Engine Duct Seals

Machining, riveting, and drilling (simulation)

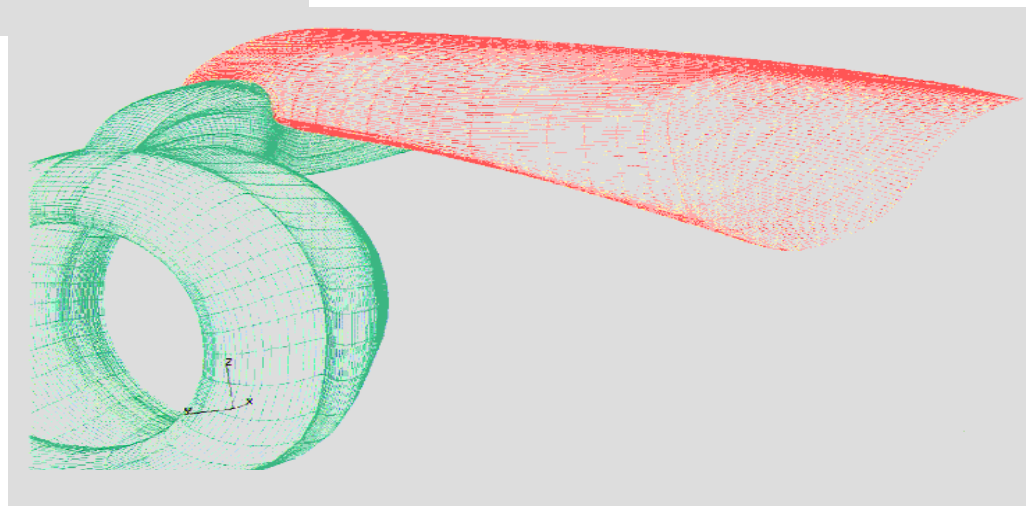


Constrained Optimization - Pays Off!



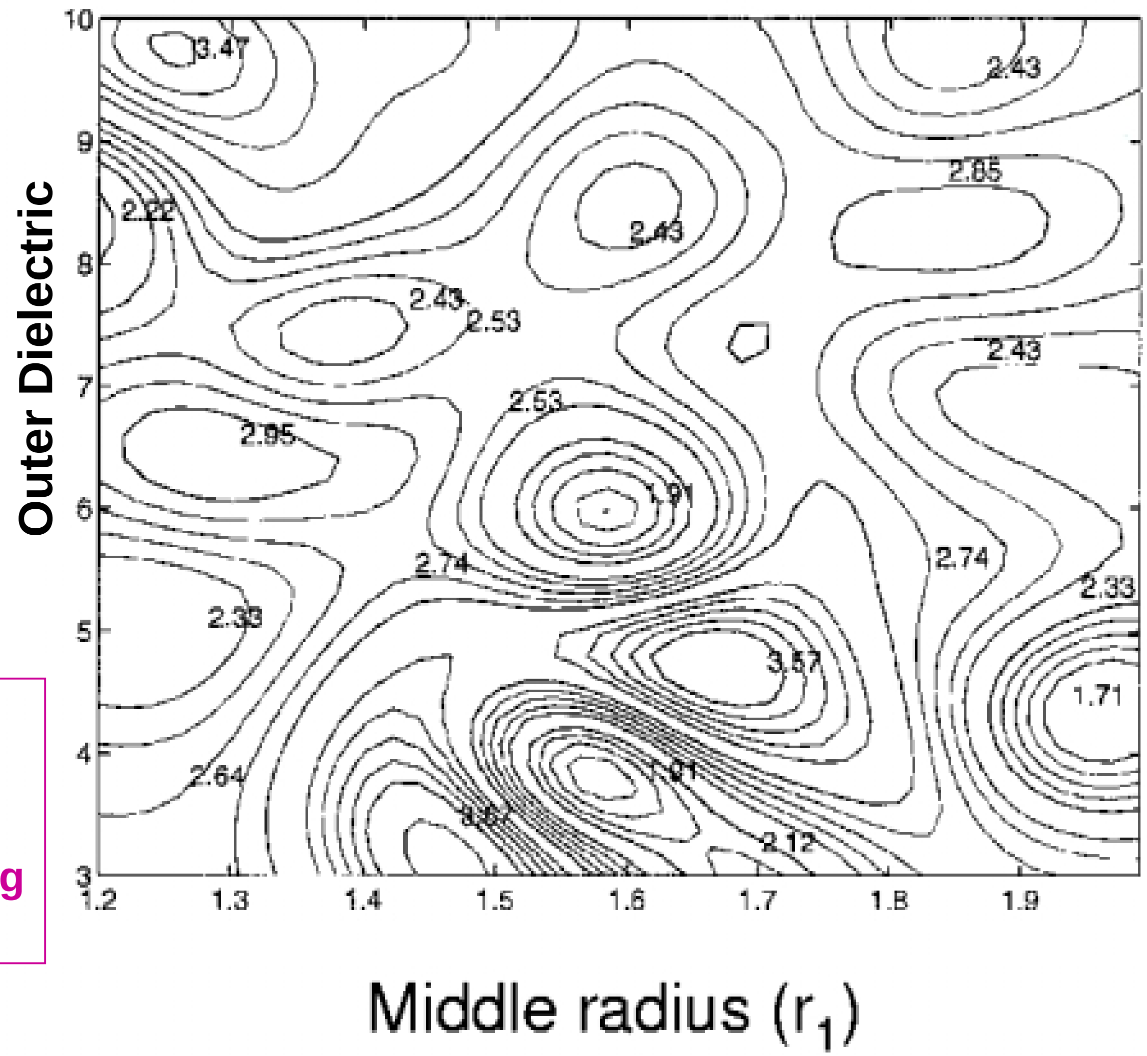
Significant improvement in cruise performance, not manufacturable

Just a tad less performance, but manufacturable



“Industrial” Surfaces

- Expensive to evaluate
- Many variables
- Sensitivity to parameters unknown
- One function evaluation is a supercomputing problem



Multiple Objectives
- find absolute max
- minimize the max
- tradeoffs among competing objectives

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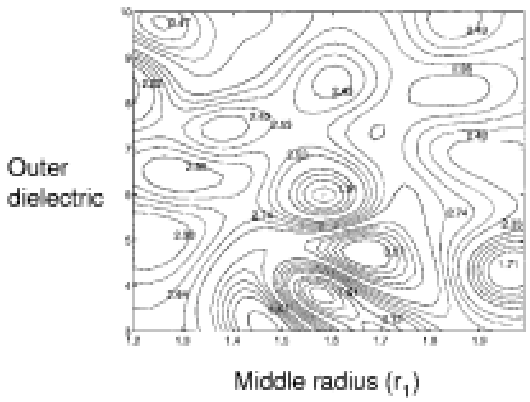
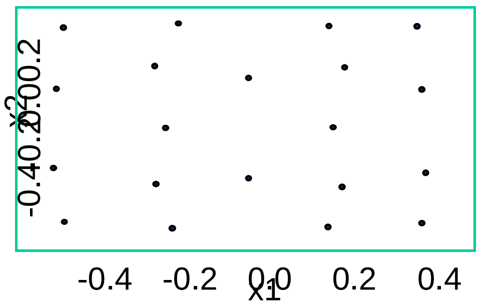
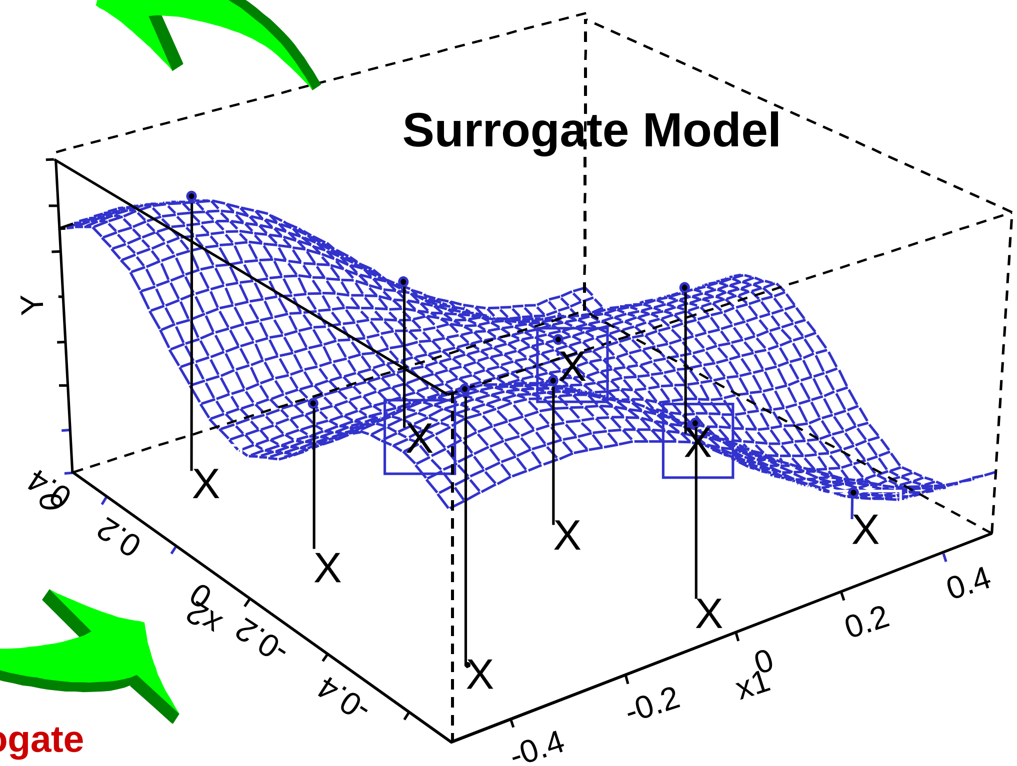
Step 1 - Build/Maintain Surrogate Model



Statistical analysis of global modeling evaluation pts.



Validate



Build surrogate multidimensional model

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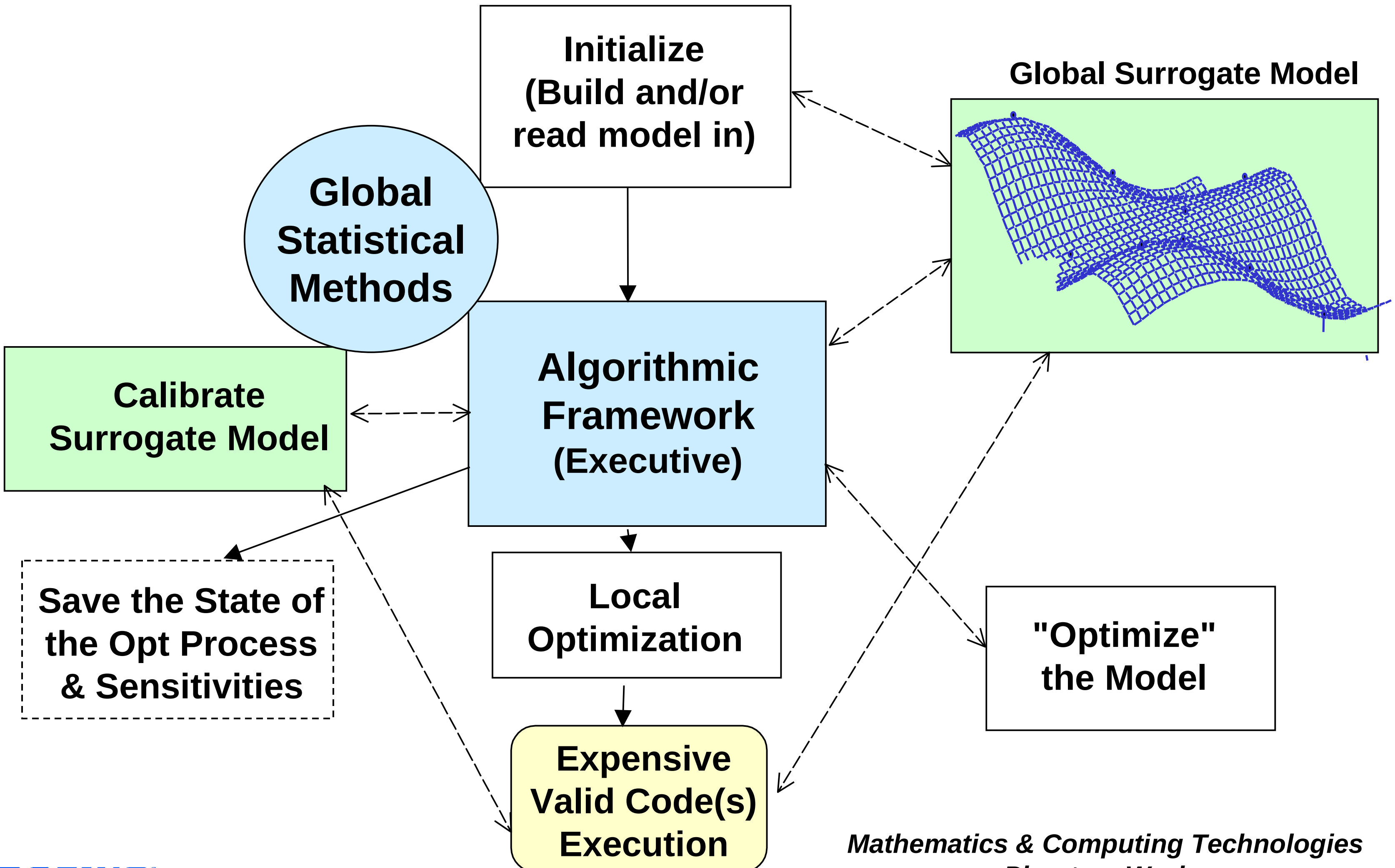
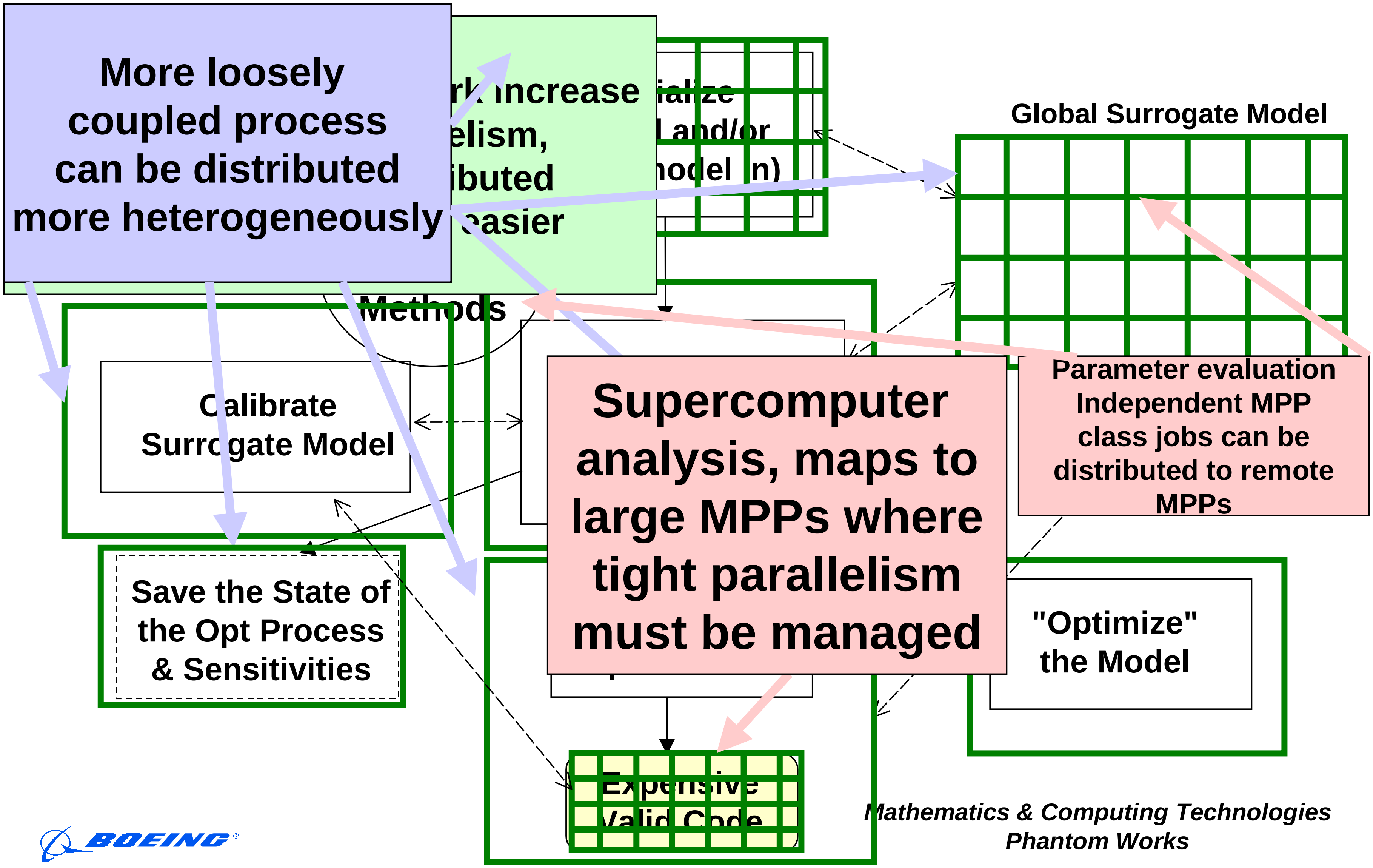
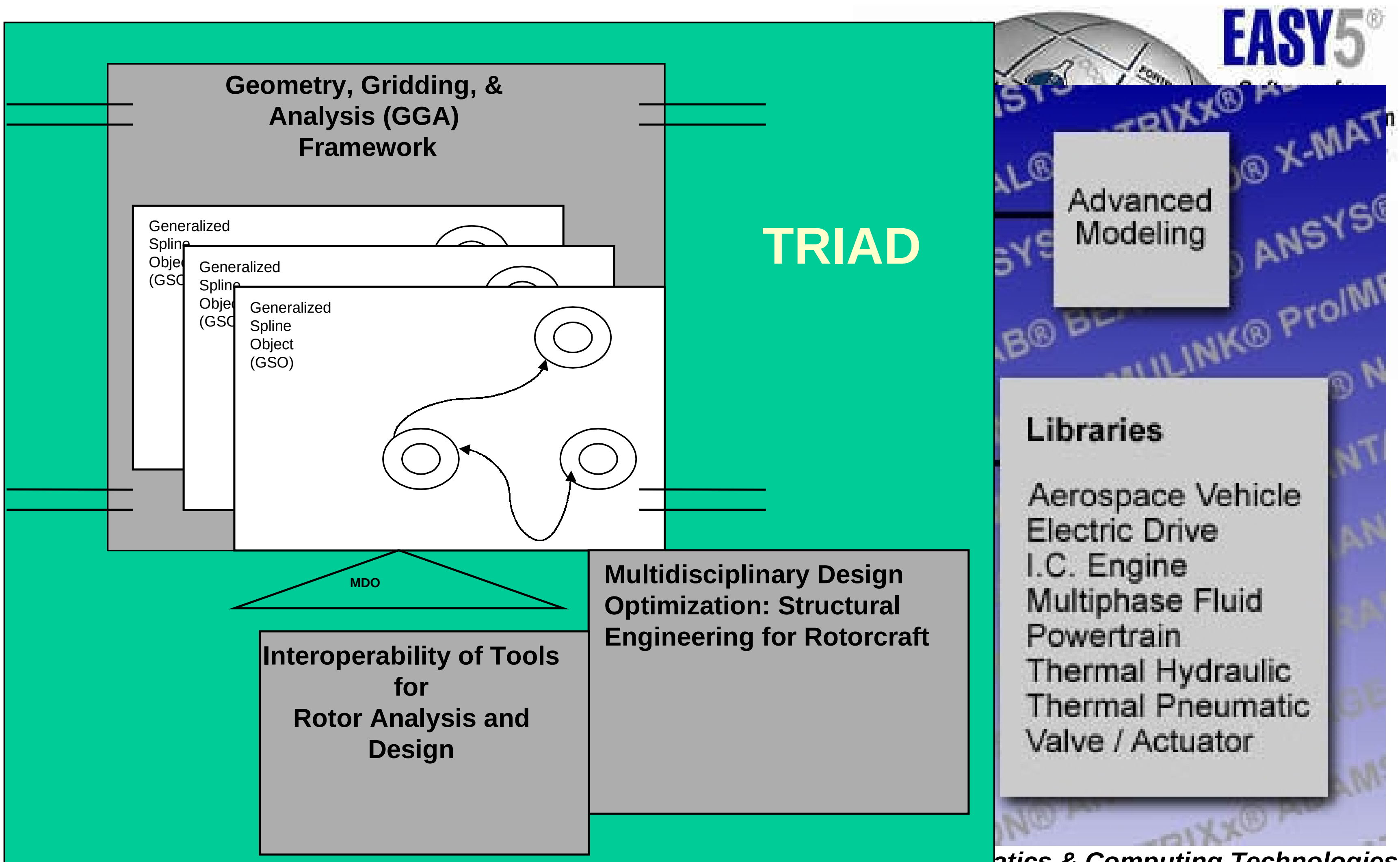
The Framework



Computational Opportunities in Frameworks



Other Boeing Frameworks



Outline

- ✓ Situation - Opportunity
- ✓ Parallelism - winning battles! Wars?
- ✓ Application Frameworks

Next let's look at the infrastructure

- **Grid Frameworks**
- **Enabling tools**
- **Challenges**

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Grid Frameworks

- **Grid frameworks vary in tools, philosophy, & adaptability**
  - **Application specific tools (e.g. SCIRun)**
  - **Object component based (e.g. Legion)**
  - **Custom use of commodities (ORBs, Jini, Java, ActiveX . . .)**
  - **"Bag of Services", (e.g., Globus Toolkit)**
- **Impact on application designers/users**
  - **Design and execution**
  - **Transition to grid paradigm is a key issue**
  - **User responsibilities vary:** Do very little just supply the function box? And/or provide schedule? And/or develop framework? And/or schedule assets and download executables? . . .
- ***A Grid Infrastructure may be useless, unless users provide application frameworks! Applications will never have grand impact without grid infrastructures!***

Grid Frameworks

Application Specific

Provides a specific set of tools such as numerical libraries, specific operations that distribute over grids or clusters, using specific tools (e.g. MPI)

Object Models

Flexibility and extensibility of component object based systems. Applications can be wrapped, even parallel jobs can be wrapped, but the parallel implementation must be carried out by other means.

Custom Use of Commodities

Use the ubiquitous languages and techniques available because of the Web and/or widespread tools (Java, ActiveX). Exploit VM and the fact that most clients and servers will have common interpreters, languages and communication abilities.

Grid Frameworks

Bag of Services

Appealing approach to those who cannot jump in all at once. Use the layers of tools in a gradual manner or grouped to achieve desired needs. (Walk, skip, run)

Resource management	**GRAM**
Communication	**Nexus**
Information	**MDS (structure and state info)**
Security	**GSI**
Health and status	**HBM**
Remote data access	**GASS**
Executable management	**GEM (construction, caching & location)**

Common Grid Concerns

- Executive control
  - Throughput (of the job stream) vs. performance (of the individual application)

    NEW ISSUE - Framework throughput
  - Schedule and synchronization model
  - Control given by the application and user schedule or by system agents and reactive resource allocation agents

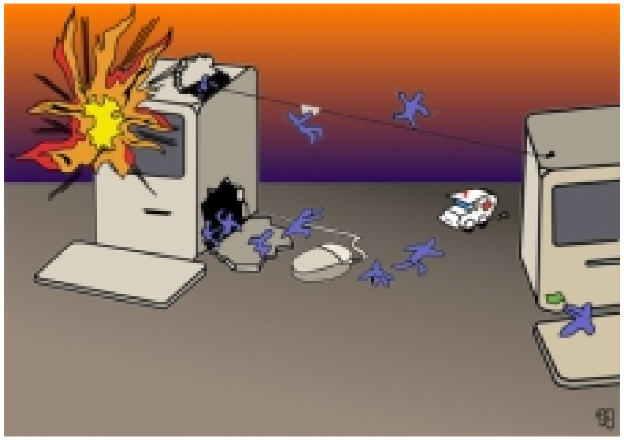
    Deterministic/repeatable VS serendipitous/variable
- Management of "executables" and data
  - Application control vs. middleware control
  - Persistence or not
- Resource management and asset control (including accounting)
- Information (data) access and data synchronization (integrity)
- Network and platform QoS
  - Security (without fire walls)
  - System health, status, and recovery

Some Related Boeing Activities

- KAoS Agents Architecture
  - Structured frame work, extensible
  - Standard discourse
  - Example: NOMAD (next slide)
- Intrusion Detection and Health Maintenance
- Global-mobile (active and hybrid) network
- Services tools
  - Example: SWAN Heralds (next slide)
- Component based systems (tools for builders)
- Parallel computing and performance/scalability modeling
- Data modeling and warehouse architecture
- CAD independent visualization, display, immersion, & simulation of product data
- Collaboration tools
- Pervasive computing

Example: NOMAD

- **Collaboration between Boeing and Univ. of W. Florida** (Suri, Bradsahw, Breedy,Ditzel, Hill, Pouliot, and Smith. Darpa Supported).
- **Agent based infrastructure**
  - **Persistent with "strong" mobility**
  - **Context mobility (captures state independent of machine)**
  - **Supports security AND policy**
    - **Capacity permissions**
    - **Agent initiated check pointing to other VMs for reliability**
  - **Moves philosophically from "orchestrated control" to "serendipitous control"**
  - **For example, consider a NOMAD based approach to resource scheduling**



SWAN Heralds

- **Goal:** **provi**
  scalable syn
- **Approach**
  - **Automa**
  - **Minimal**
  - **Maintair**
- **Advantage**
  - **Scales t**
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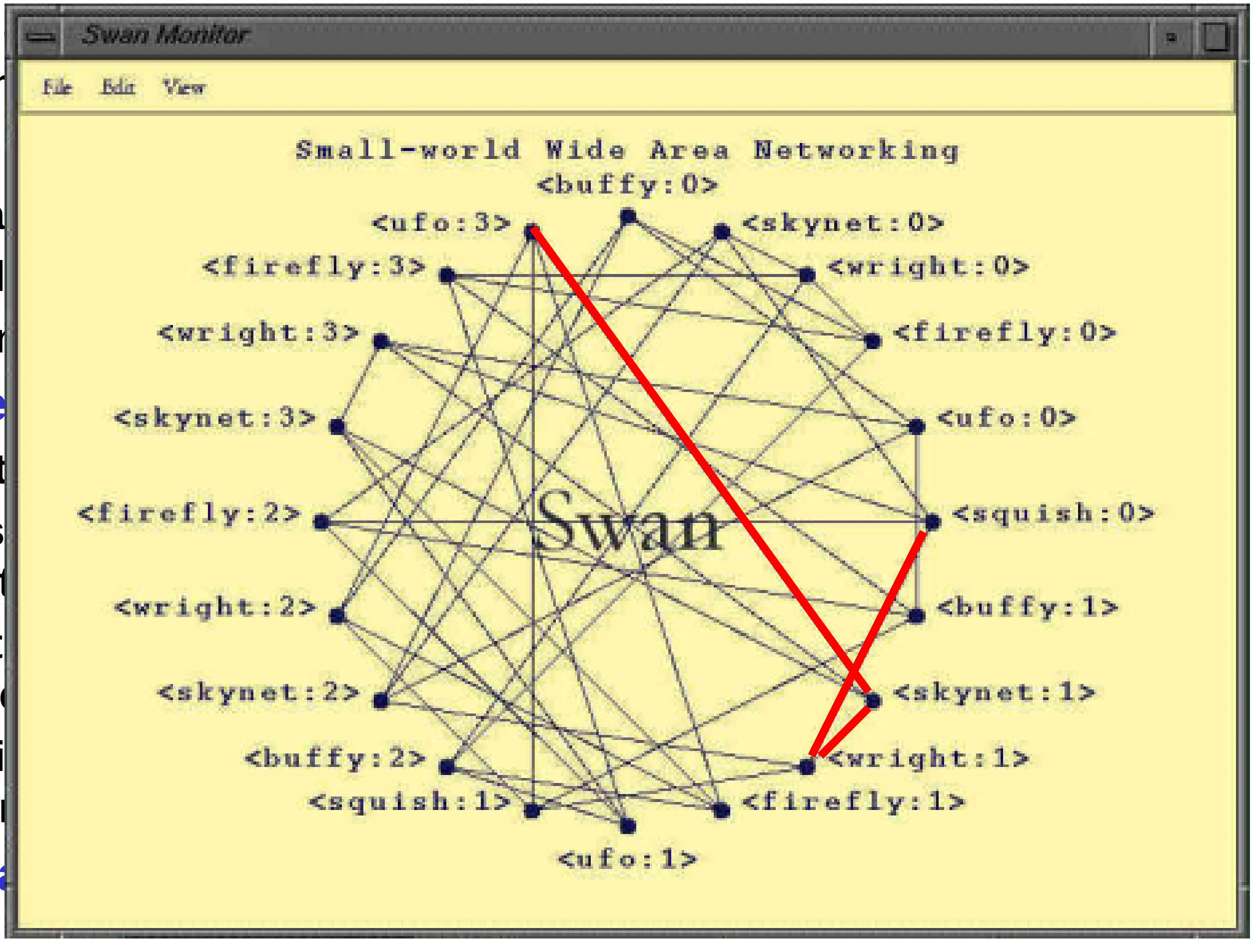
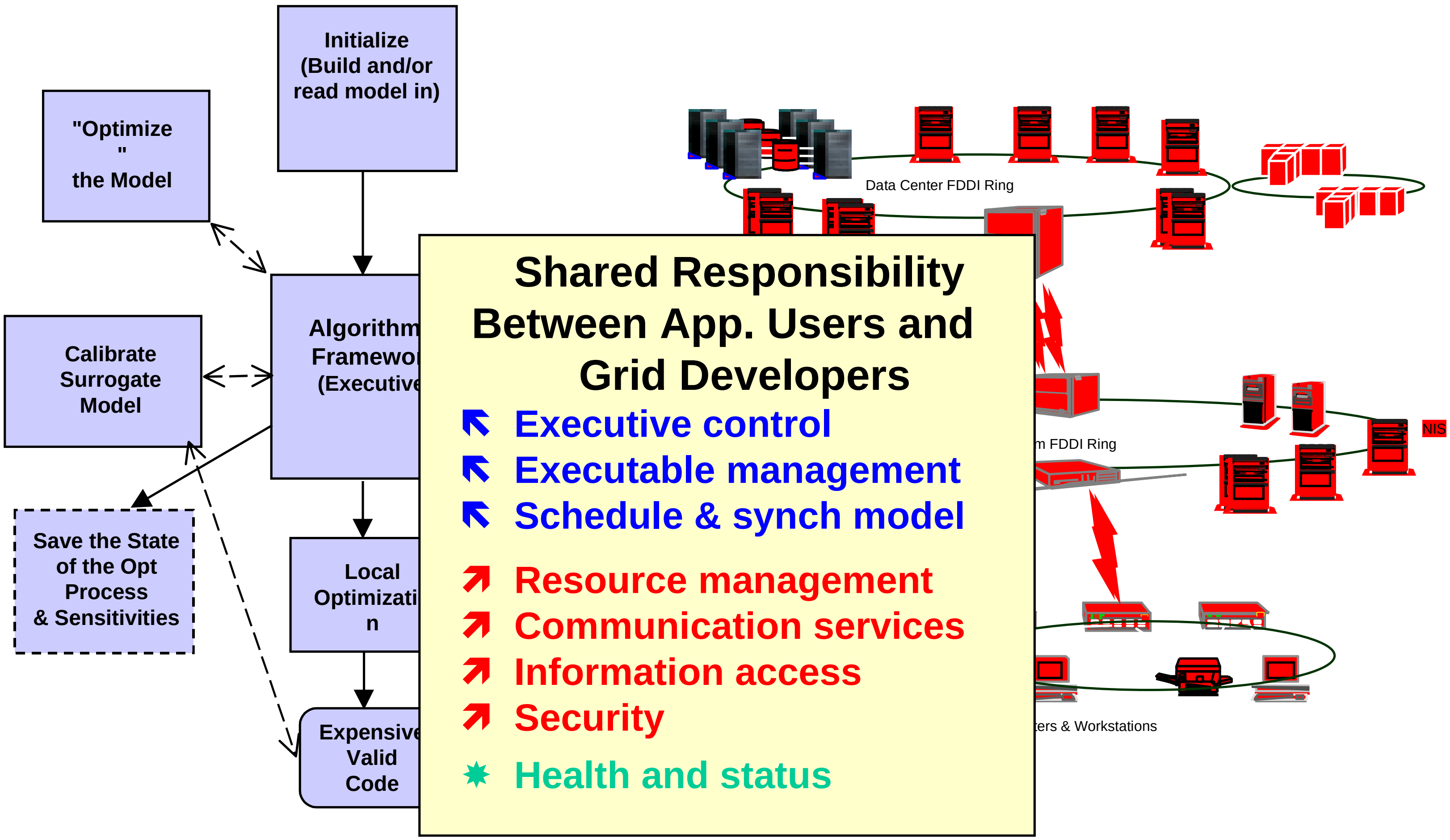
- **Commercia**



Mapping App Frameworks to Grid Frameworks



Shared Responsibility Between App. Users and Grid Developers

- Executive control
- Executable management
- Schedule & synch model
- Resource management
- Communication services
- Information access
- Security
- Health and status

Summary and Recommendations

- **Application frameworks are necessary for industrial use of grid frameworks**
- **Grid frameworks must provide stable models of computation, synchronization, with ease use**
- **TRANSITION to grid computing by industry requires an enduring model for grid frameworks. THIS IS A RESEARCH FRONTIER**
- **Industry must take more central control of computing assets and provide strong strategic planning for (often reluctant) user communities**
- **Infrastructure technologies must be supported and mature: security, intelligent agents, QoS, active networks, mobile networks, visualization and media, distributed data access and update**


Thank you
Q & A
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