Integrated Product Design Simulation

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DOME (distributed object-based modeling environment)

Publications: http://cadlab.mit.edu
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<tr>
<th>Report Date</th>
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**Title and Subtitle**
Integrated Product Design Simulation

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**Supplementary Notes**

**Abstract**

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**Classification of this page**
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**Limitation of Abstract**
UU

**Number of Pages**
31
Integrated Product Design Simulation

Outline

Design context
Need
Concept
Scenario
Barriers addressed
Applications
Product Design

Modeling context

Planning  Concept design  Detail design  Testing  Ramp up
Design Modeling
Techniques

- Sketch models and mockups
- Integrated physical models
- Domain models and simulations
- Integrated product design simulation

*From: Ulrich and Eppinger, Product design and development, 2000*
Need

Integrated system modeling and simulation

Mathematically predict and analyze the integrated behavior of products throughout the pre-prototype design cycle
Benefits

Simulation-based integrated system analysis

Polaroid LCD projector

**Seamless mathematical integration:**
- geometry, engineering,
- life-cycle analysis,
- customer and
- intent-to-purchase simulations

**Result:**
- integrated trade-off cycle time reduced from 3 months to 15 seconds

“not generally feasible”
Hypothesis

Limitation is simulation synthesis, not analysis

Mathematical system modeling techniques do not match design synthesis needs
Mismatch

Traditional model integration methods

Explicit, fixed scope, command and control

Implicit, emergent

Existing methods do not accommodate flexible model growth, change, emergence, or rapid transitions between synthesis and analysis
Synthesis Mismatch

Consequences

Infeasible because of design ...

- complexity, scale, rate of change
- heterogeneity
- proprietary knowledge

Cutkosky, 1996
DOME

Research goal

A new infrastructure for building the integrated simulations needed in design analysis

Fundamentally resolve traditional integration barriers
Future Design

Engineering emergent systems

product
infrastructure
urban environment
society
sustainability
DOME Inspiration

Hypertext (WWW)

Revolution in infrastructure for building information networks—breaking control barriers

Any individual can add content

Any individual can access remote material and create local links to relevant materials

Result: an emergent network of information services
DOME Concept
World-wide Simulation Web

Any individual can make interfaces to focused simulations operable over the Internet

Any individual can access remote interfaces and create local mathematical links or bridge models between simulation elements

Result: an emergent network of parametrically coordinated simulations
DOME Application
Proof of concept field study

21 external simulations
3000 parameters

- OEM
  - engineering
    - sheet metal integration
    - performance specifications
  - purchasing
    - cost targets
door cost
  - commodity strategy
certification supplier selection

proxy

Seal supplier 1
- design costing analysis

Seal supplier 2
- design costing analysis
Integrated Simulation Synthesis

Participants build models using tools appropriate for their discipline
Integrated Simulation Synthesis
Participants define parametric interfaces to their focused simulations
Integrated Simulation Synthesis
Participants deploy interfaces on Internet-accessible DOME servers
**Integrated Simulation Synthesis**

Participants create DOME bridge models between interface elements

**System integrator**

**Engineer**

**CAD designer**
New Integration Infrastructure
World-wide Simulation Web

Any individual can make interfaces to focused simulations operable over the Internet

Any individual can access remote interfaces and create local mathematical links or bridge models between simulation elements

A domain independent simulation infrastructure
**Integrated System Analysis**

Participants apply tools to elucidate tradeoffs, optimize designs, and understand system interactions

**Examples:**
- Decision theory (Kim and Wallace, 1999)
- Genetic optimization (Gruininger, Senin and Wallace, 1996)
- System structure analysis (Abrahamson and Wallace, 1999)
- Model customization (Ferara and Wallace, in progress)
Ford Application

Results

Rapid system model development and evolution

(Integration process was 12 person days)

Interoperability of services between heterogeneous applications without sharing proprietary data models

Design tradeoff speed

(Ford engineer to supplier analyst: 10s vs. ~2 weeks)

Rapid design comparison of local design and supplier changes with global tradeoff viewpoint
New Integration Infrastructure
Fundamentally resolve traditional integration barriers

Complexity, scale, rate of change

Emergent vs. explicit system definition
New Integration Infrastructure
Localized definition of interfaces and relationships

$Z = f(X, Y)$

$Q = f(X, Y, P)$

$R = f(Z, Q)$

DOME Plugin

interface definition

external program
New Integration Infrastructure
Fundamentally resolve traditional integration barriers

Heterogeneity, proprietary information

Parametric consistency vs. data model sharing
New Integration Infrastructure
Local solvers share causal mapping for externally accessible interface parameters

Serrano and Gossard
Kim and Wallace
Ueberle
## Industry Pilot Applications

### Recently completed or ongoing

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<td>Door glass system</td>
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<td>Integrated simulation across the design/supply chain</td>
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<tr>
<td><strong>Ford</strong></td>
<td>Fuel economy</td>
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<td><strong>Ford</strong></td>
<td>Vehicle platform design</td>
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<td>Parametric assemblies with multiple CAD systems</td>
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<td><strong>LG Electronics</strong></td>
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<td><strong>Boeing</strong></td>
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<td><strong>US Navy</strong></td>
<td>Aircraft carrier ordinance delivery</td>
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<td>Life-cycle cost reduction</td>
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Vehicle Platform Application

Geometric assemblies

Traditional integration approach:
Each company has an official CAD system
All suppliers must use the official CAD system
Suppliers must provide native part geometry to automotive company
Vehicle Platform Application

Parametrically editable assemblies
Vehicle Platform Application
Parametrically editable assemblies
Vehicle Platform Application
Parametrically editable assemblies
Application

Manufacturing object module: MOM

DOME world

LABVIEW plugin

Computer with I/O card

Programmable logic controller

Machine tool world