Reducing Design Rework using Set-based Design in a Model Centric Environment

Sponsor: OUSD(R&E) | CCDC

By
Mr. Shawn Dullen
7th Annual SERC Doctoral Students Forum
November 18, 2019
FHI 360 CONFERENCE CENTER
1825 Connecticut Avenue NW, 8th Floor
Washington, DC 20009

www.sercuarc.org
Problem

- Engineering design issues are a major concern for the DOD and most Industries
- Engineering design issues lead to reworking the design
- Rework can take up a significant amount of total design time
- The severity depends on where it is found during the product development life-cycle

(Adopted from Defense Systems Management College, 1993)

(Adopted from Orator, 2004)
What is the Nature of Design Rework?

Figure 1: Information flow diagram and DSM (adopted from Cho and Eppinger, 2001)

Figure 2: System Dynamics Model (adopted from Taylor and Ford, 2006)

Figure 3: Network Model (adopted from Braha and Bar-Yam, 2007)

Figure 4: Arena Model (adopted from Yang et al., 2014)

Figure 5: GERT (adopted from Nelson et al., 2016)
Information Exchange

Rework caused by information uncertainty/ambiguity
Complexity

(adopted from Jepperson, 2013)

Rework caused by misalignment of activities and organizational structure
• Susceptible to the same causes of rework as sequential and concurrent design

• Converging too early to a point design

• Overly constraining the design

Rework occurs because decisions are made with uncertain information
Propose reducing Rework using Set-Based Design

- System and subsystem solutions are defined as sets
- Subsystems are explored in parallel to systems solutions
- Sets are narrowed while improving the level of abstraction and analysis
- Imposes minimal constraints
- Decisions are delayed until adequate information is available

<table>
<thead>
<tr>
<th>System</th>
<th>Map Design Space</th>
<th>Integrate by Intersection</th>
<th>Establish feasibility before commitment</th>
<th>Design Convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsystem A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsystem B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsystem C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subsystem D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Level of Abstraction

- 1st principle models
- Dynamic Multi-physics models
- Fully Detailed 3D CAD models
- Final Point Design

Dynamic Multi-physics models
What is the current state of SBD Procedural Models?

• What are the strengths and limitations to these approaches and models?

• How is knowledge developed, captured, and reused to cause convergence of sets

• What Digital Engineering (DE) tools were recommended/used to enable SBD?

Figure 1: Partial Rolls-Royce Lean Product Development Model (modified from Al-Ashaab et al., 2013)
Future Work

• Opportunity to solidify guidance on how to implement SBD
  — How to narrow sets while improving level of abstraction and level of analysis
  — How to define and reason about sets
  — How to capture and reuse knowledge
  — Illustrated industrial application

• Opportunity to improve the connection of SBD to SE technical processes

• Opportunity to implement SBD in a DE Environment
  — What tools are best suited for knowledge development, capturing and reuse
  — How can model centric engineering and rapid-prototyping be utilized to accelerate learning
  — Application of integrated multi-fidelity models to include multi-physics models


GAO. (2014a). Canceled DOD programs: DOD needs to better use available guidance and manage reusable assets.

GAO. (2014b). Where should reform aim next.
References


Gumina, J. M. (2019). A SET-BASED APPROACH TO SYSTEMS DESIGN


References


