

The Architecture of Engineering: Exploring Complex Engineering Projects Using the Design Structure Matrix Approach

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Scale and Scope of Engineering Projects



AvaTech Snow Profiler



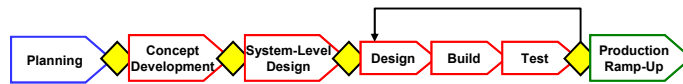
Virgin Galactic Spaceship

Three Perspectives in Planning Development of Complex Products

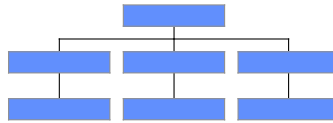
- Product/System



- Process

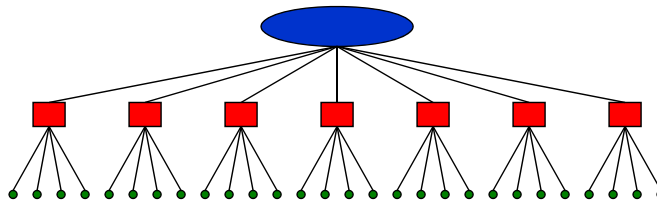


- Organization



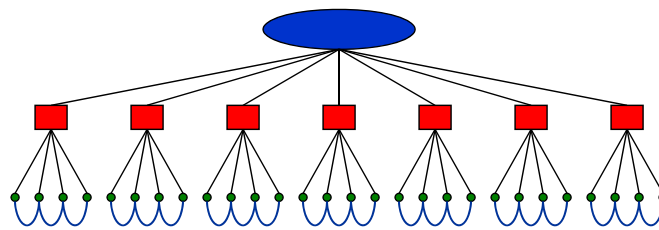
Decomposition: The Key to Managing Complexity

- Decompose a complex **product/system** into sub-systems and components
- Decompose a complex **process** into sub-processes and tasks
- Decompose a large **organization** into teams and individuals



Decompositions Exhibit Architecture

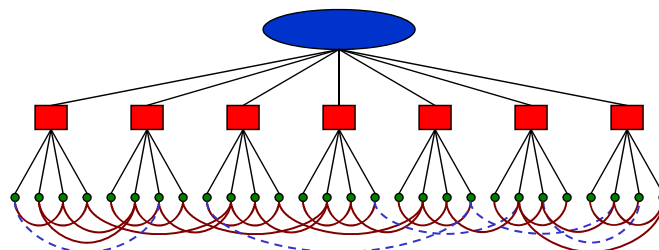
- The pattern of interactions between the decomposed elements define the architecture
 - Product/system architecture
 - Process architecture
 - Organization architecture



“simple architecture”

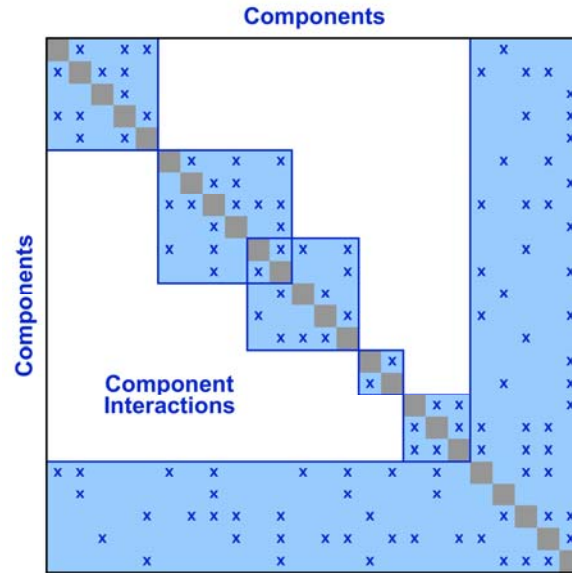
Decompositions Exhibit Architecture

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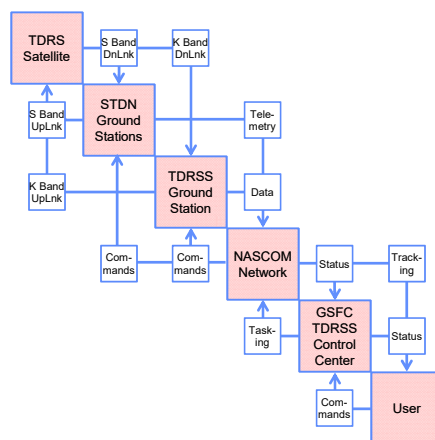


“complex architecture”

Design Structure Matrix (DSM): Product/System Architecture

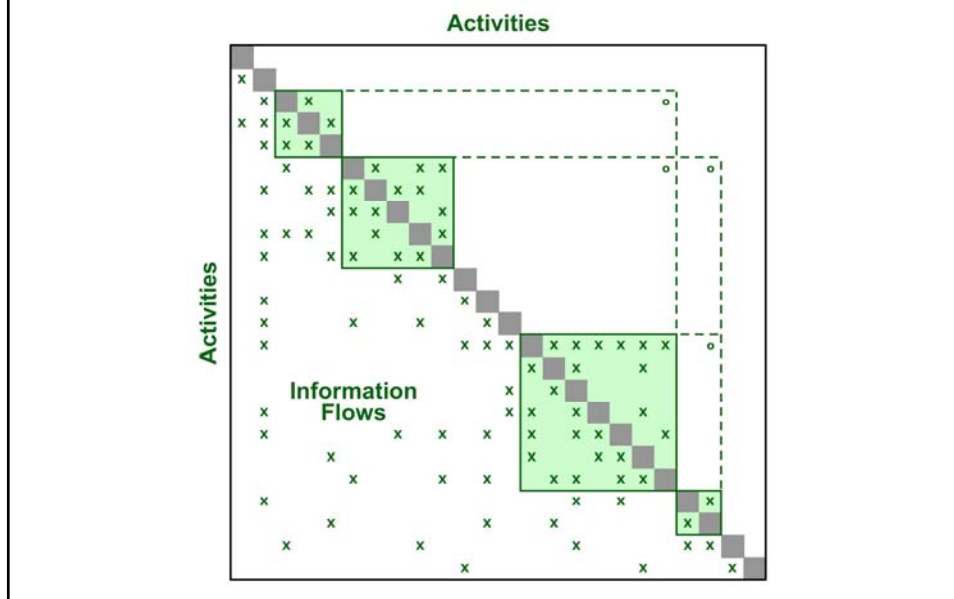


Systems Engineering N² Chart

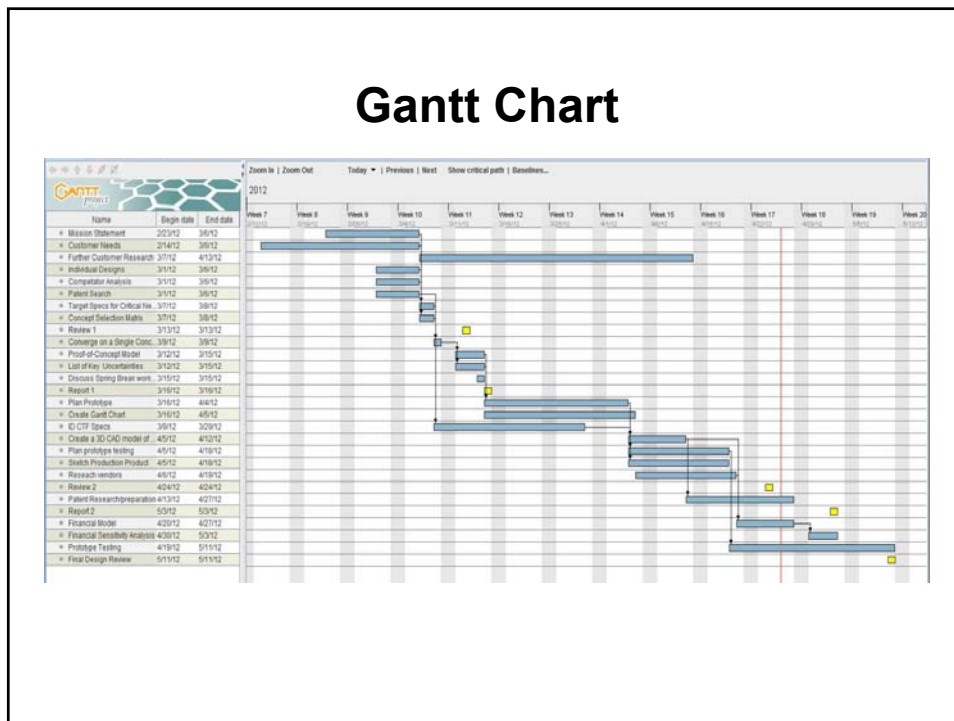


Ref: R.J. Lano, *A Technique for Software and Systems Design*, 1979

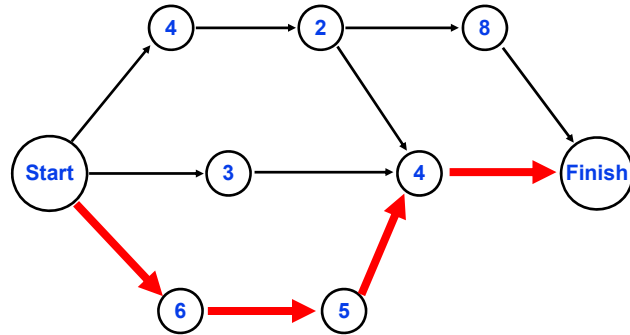
Design Structure Matrix (DSM): Process Architecture



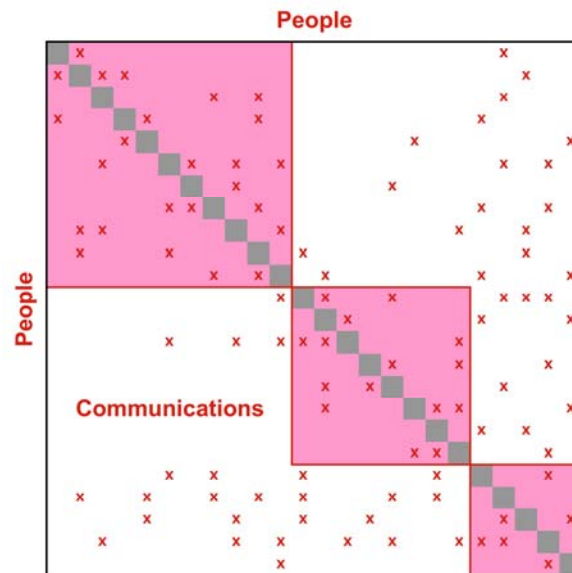
Gantt Chart



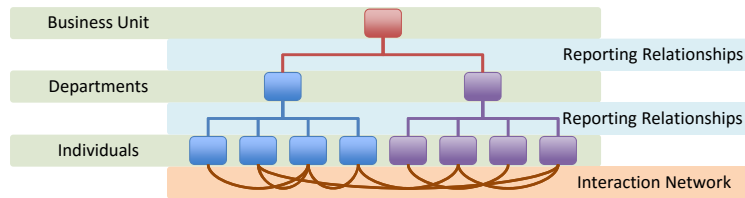
PERT and CPM Charts



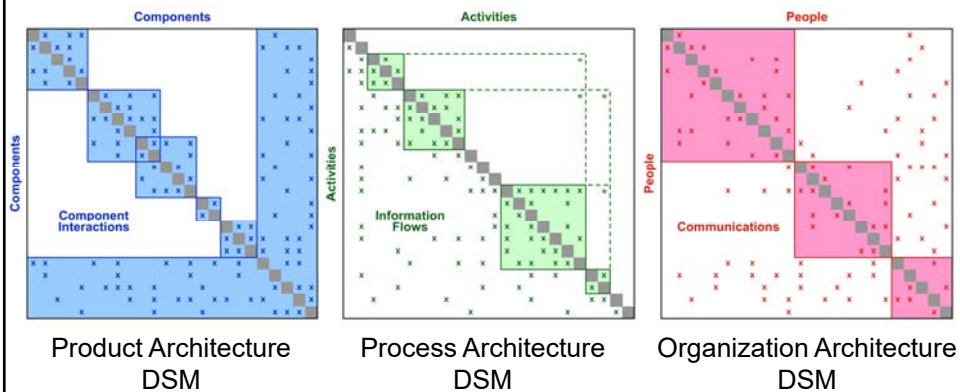
Design Structure Matrix (DSM): Organization Architecture

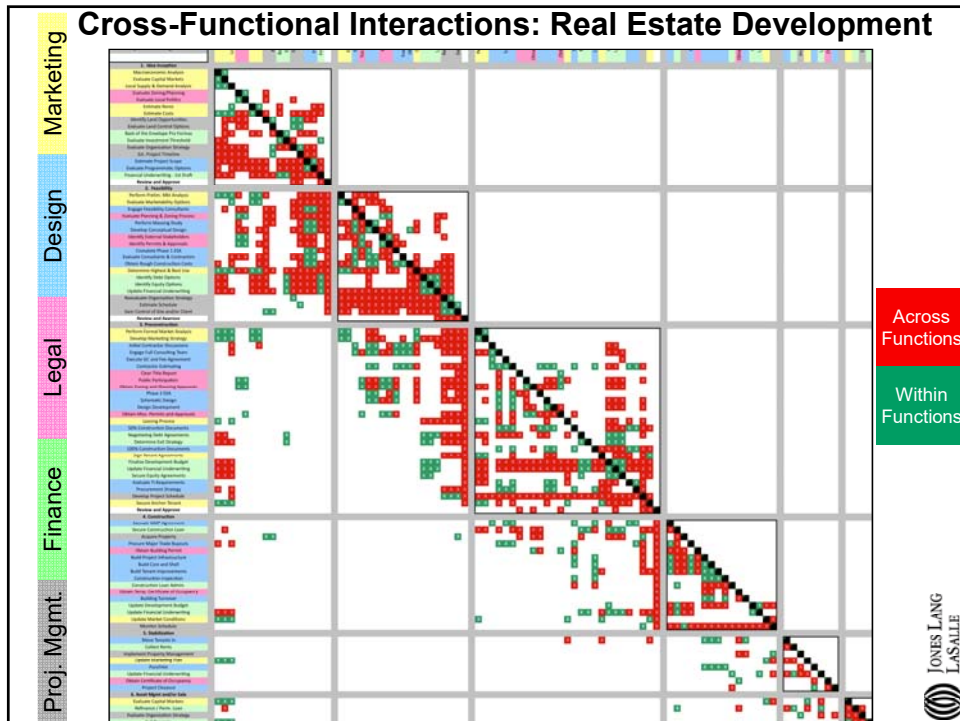
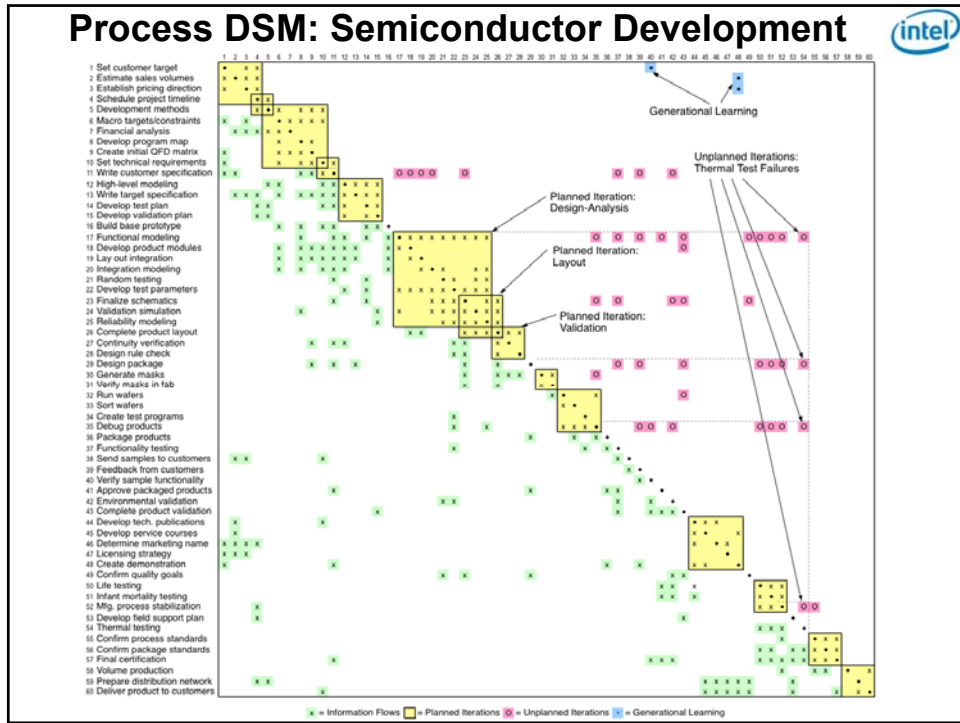


Organization Chart



Three Primary DSM Types



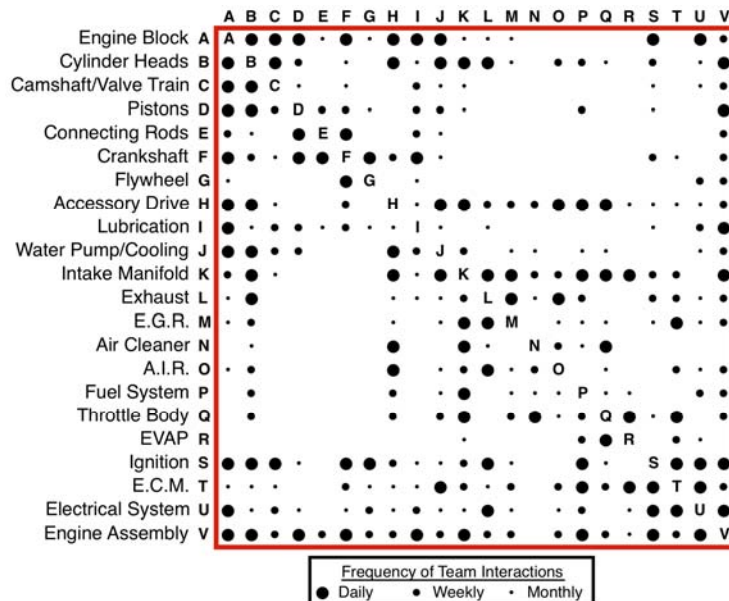


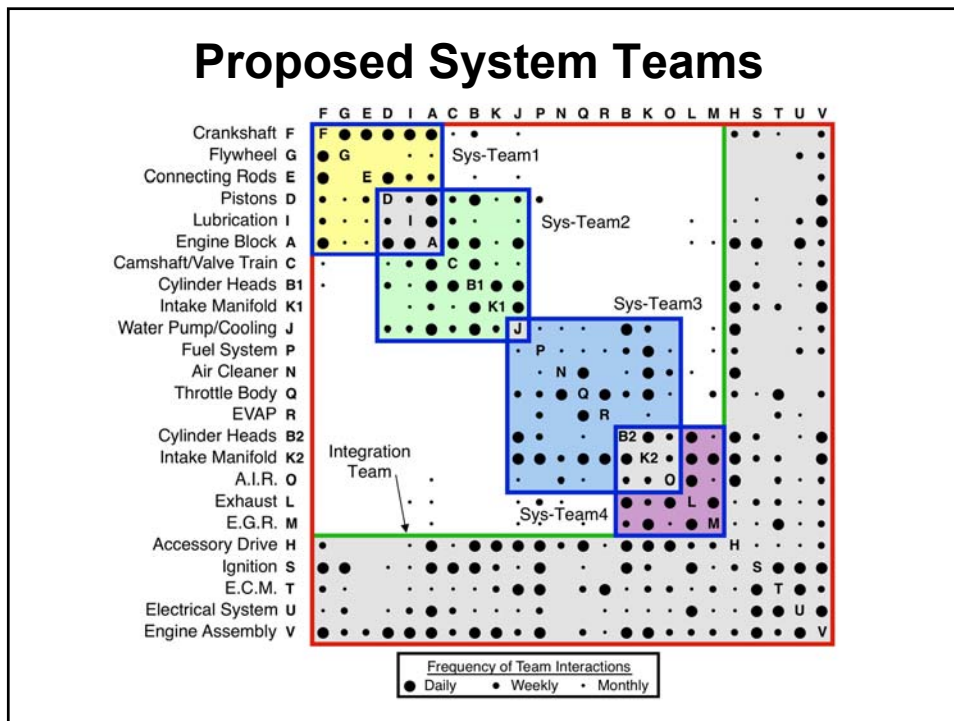
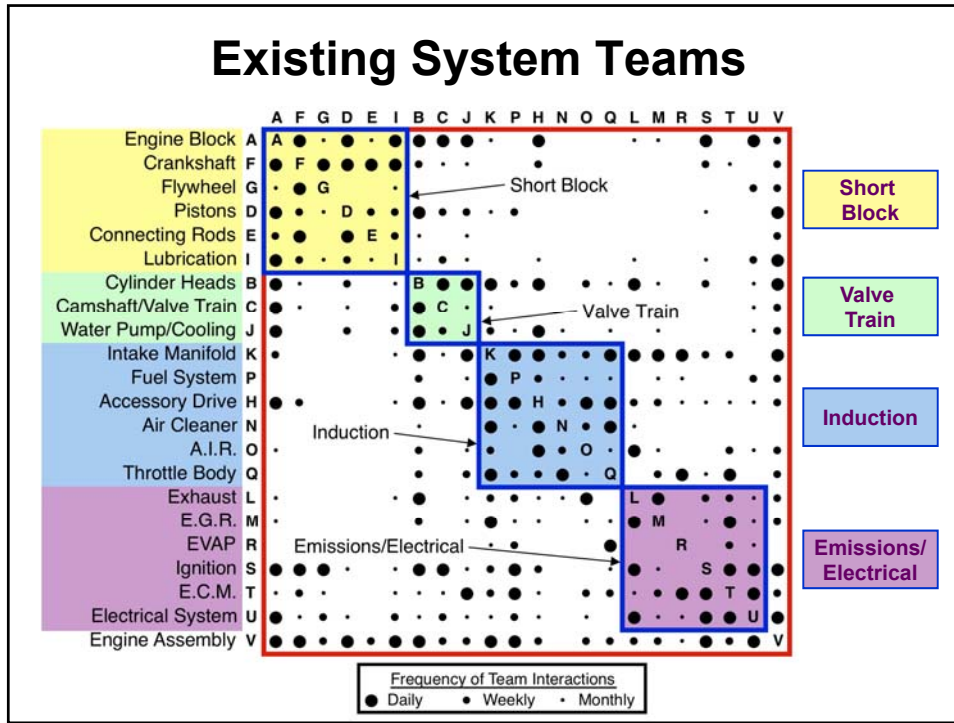
Organization DSM Example: Engine Development

- Site: General Motors Powertrain Division
- Product: “new-generation” engine
- Structure: 22 PDTs involved simultaneously



PDT Interactions

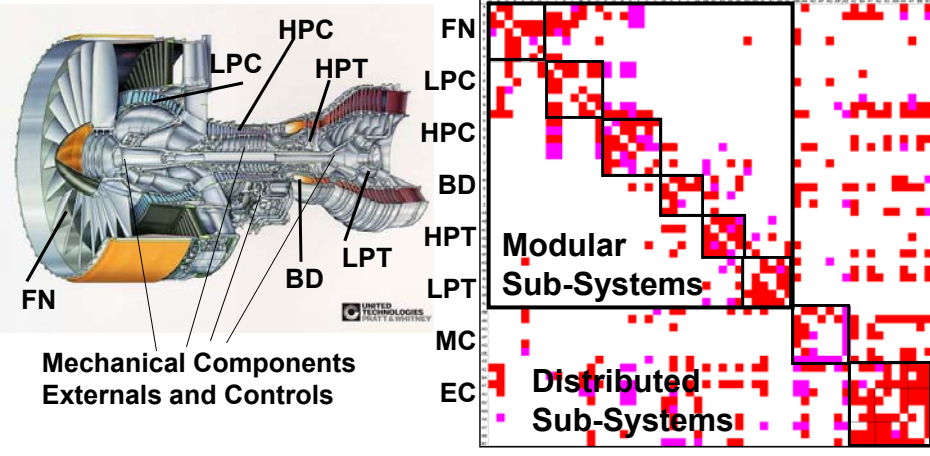




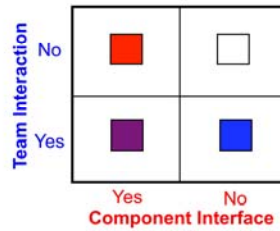
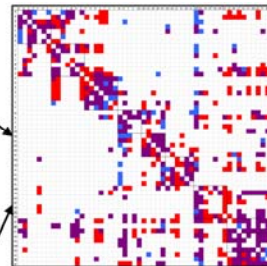
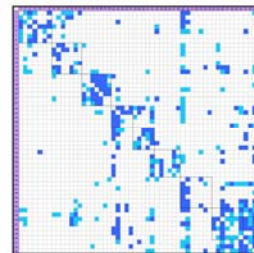
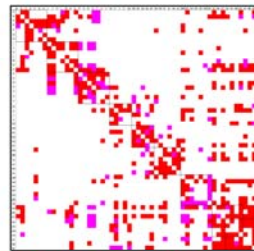
System Architecture DSM Example: Pratt & Whitney 4098 Jet Engine

- 8 Sub-Systems
- 54 Components
- 569 Interfaces

- Design Interfaces:
- Spatial • Structural
 - Energy • Materials
 - Data/Controls



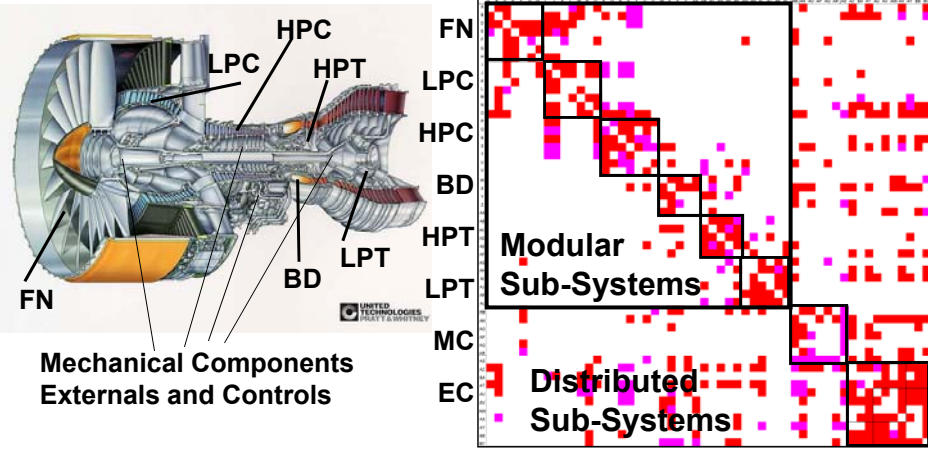
Comparing System Architecture to Organization Structure: Mapping Component Interfaces to Team Interactions



Component Interfaces: P&W 4098 Jet Engine

- 8 Sub-Systems
- 54 Components
- 569 Interfaces

- Design Interfaces:
- Spatial • Structural
 - Energy • Materials
 - Data/Controls

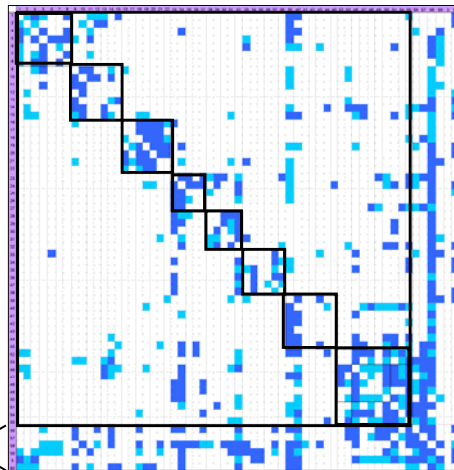


Team Interactions: P&W 4098 Jet Engine

- 60 design teams:**
- 54 component teams
(grouped into 8 module teams)
 - 6 system integration teams

- Low intensity interaction
- High intensity interaction

System integration teams



Most Team Interactions Match Component Interfaces

Team Interactions	No (2453)	■ 228 (8%)	□ 2225 (78%)
	Yes (409)	■ 341 (12%)	■ 68 (2%)
		Yes (569)	No (2293)
		Component Interfaces	

- Sosa, Eppinger, and Rowles, "Identifying Modular and Integrative Systems and Their Impact on Design Team Interactions", *Journal of Mechanical Design*, June 2003.
- Sosa, Eppinger, and Rowles, "The Misalignment of Product Architecture and Organizational Structure in Complex Product Development", *Management Science*, Dec. 2004.

Effect of Organization/System Boundaries

Data set: 569 component interfaces

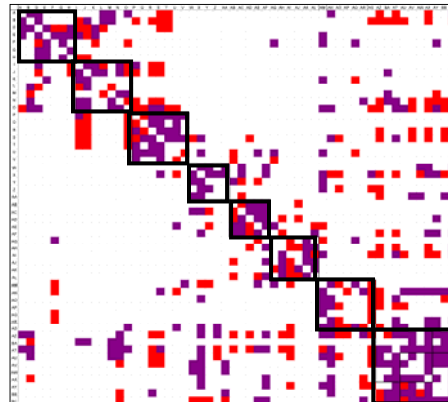
Team Interactions	No	■	□
	Yes	■	■
		Yes	No
		Design Interfaces	

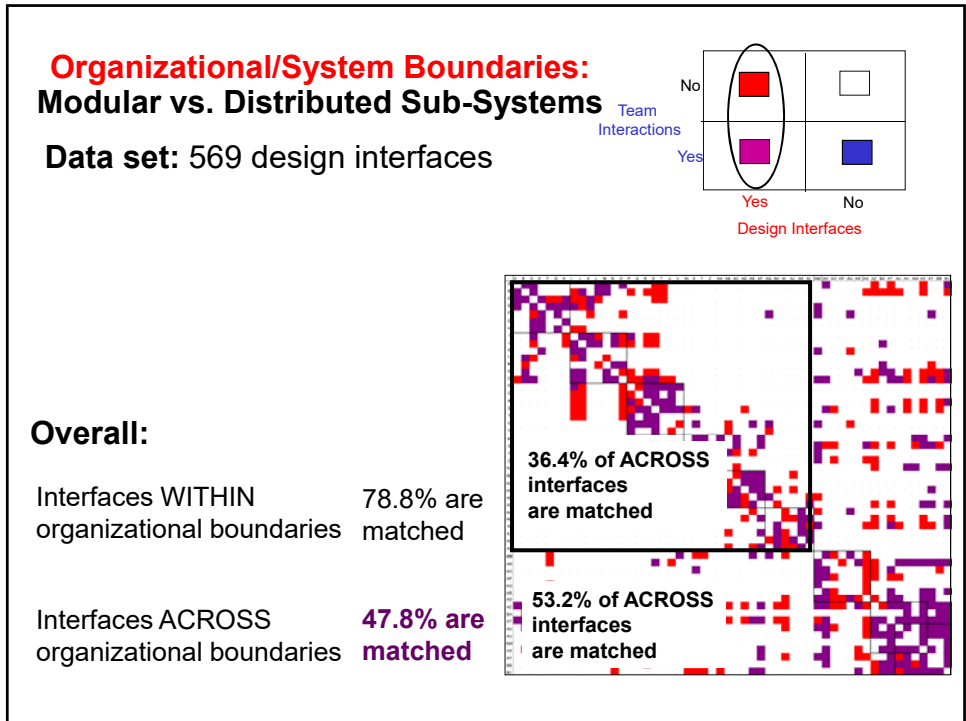
First criterion:

- Interfaces matched by team interactions ■ **59.9%**
- Interfaces NOT matched by team interactions ■ **40.1%**

Second criterion:

- Interfaces WITHIN organizational boundaries 78.8% are matched
- Interfaces ACROSS organizational boundaries 47.8% are matched





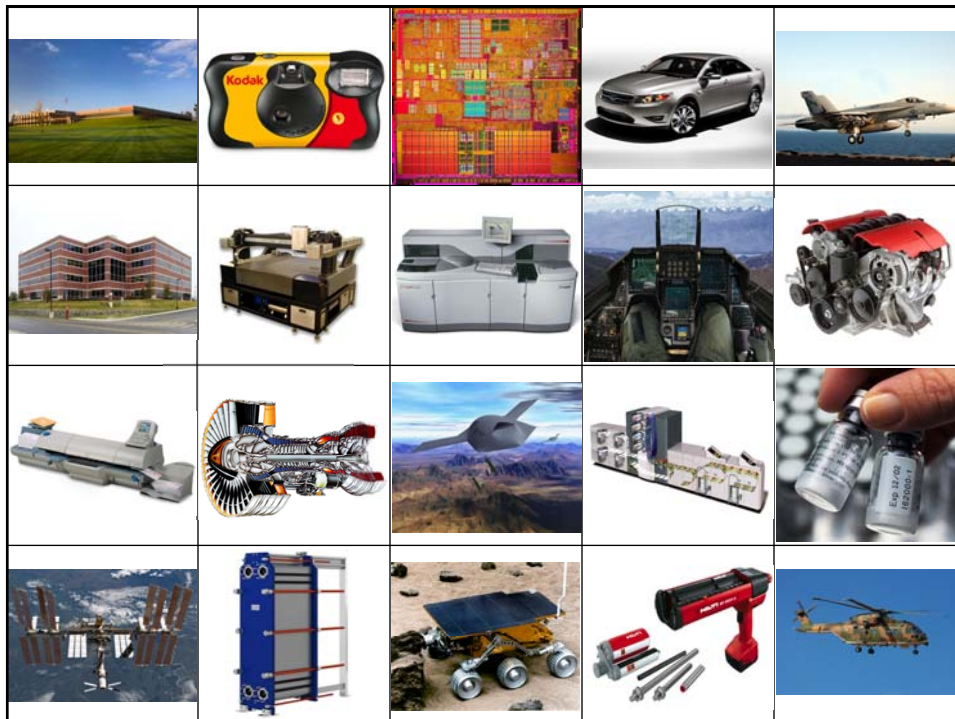
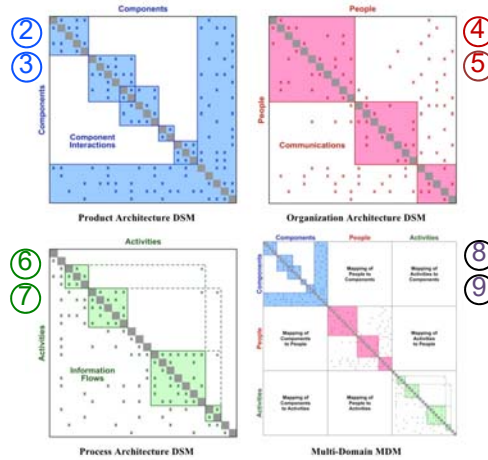
Design Structure Matrix Methods and Applications

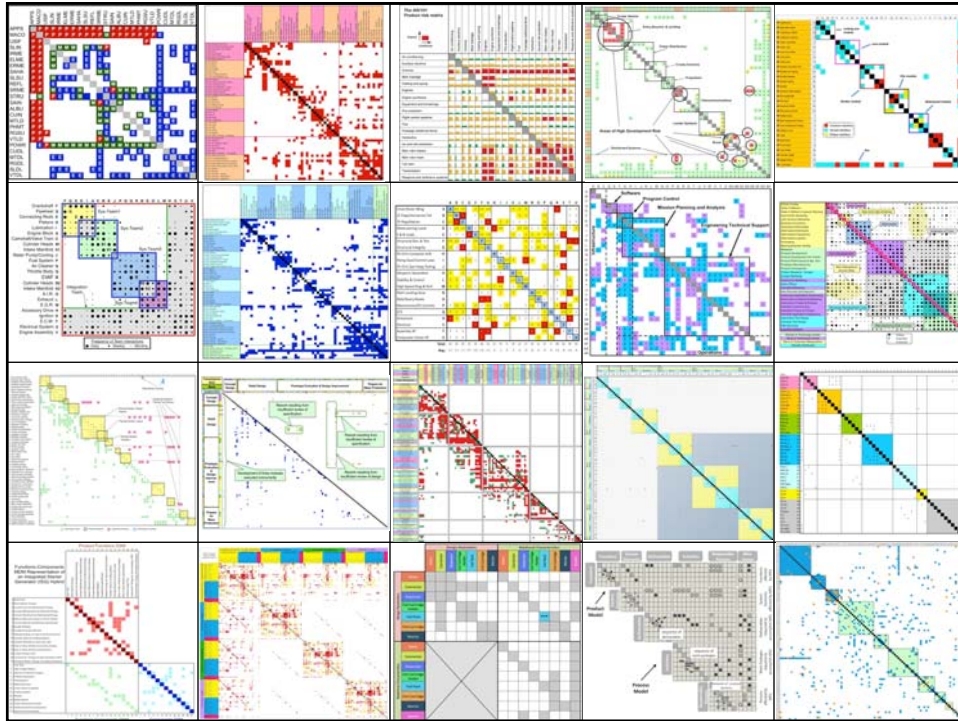
- 330 pages
- 200 color illustrations
- 44 DSM examples
- 80 contributors
- 12 reviewers

Steven D. Eppinger and Tyson R. Browning
Design Structure Matrix Methods and Applications
MIT Press, Cambridge, 2012.

Design Structure Matrix Methods and Applications

- ① Introduction to DSM Methods
- ② Product Architecture DSM Models
- ③ Product Architecture DSM Examples
- ④ Organization Architecture DSM Models
- ⑤ Organization Architecture DSM Examples
- ⑥ Process Architecture DSM Models
- ⑦ Process Architecture DSM Examples
- ⑧ Multi-Domain Architecture MDM Models
- ⑨ Multi-Domain Architecture MDM Examples
- ⑩ The Future of DSM





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