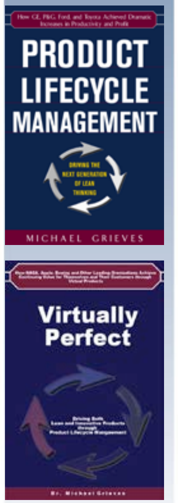
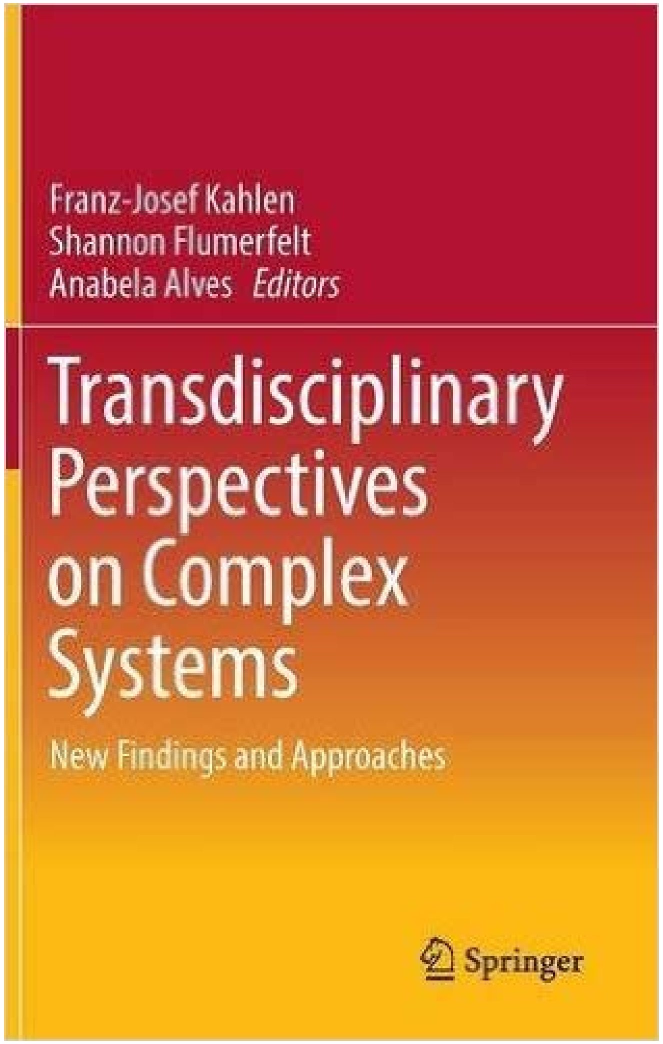
Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems

Dr. Michael Grieves
Florida Institute of Technology
Center for Advanced Manufacturing and Innovative Design (CAMID)

AIAA – CASE
Complex Aerospace Systems Exchange





Problem with Metaphors

- Glosses over substantive differences between source and target domains
- Hinders work on detail execution issues
- Leads to misleading assumptions
- Assumes that everyone has same cognitive framework

Categories of System Behavior

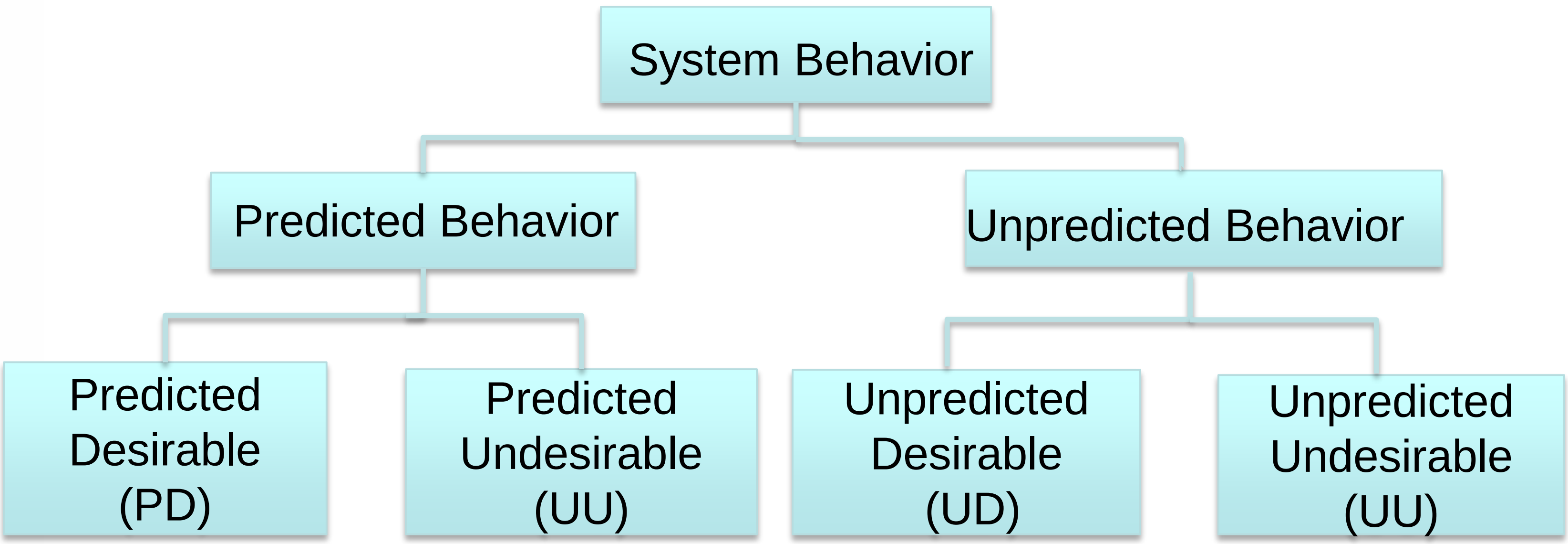
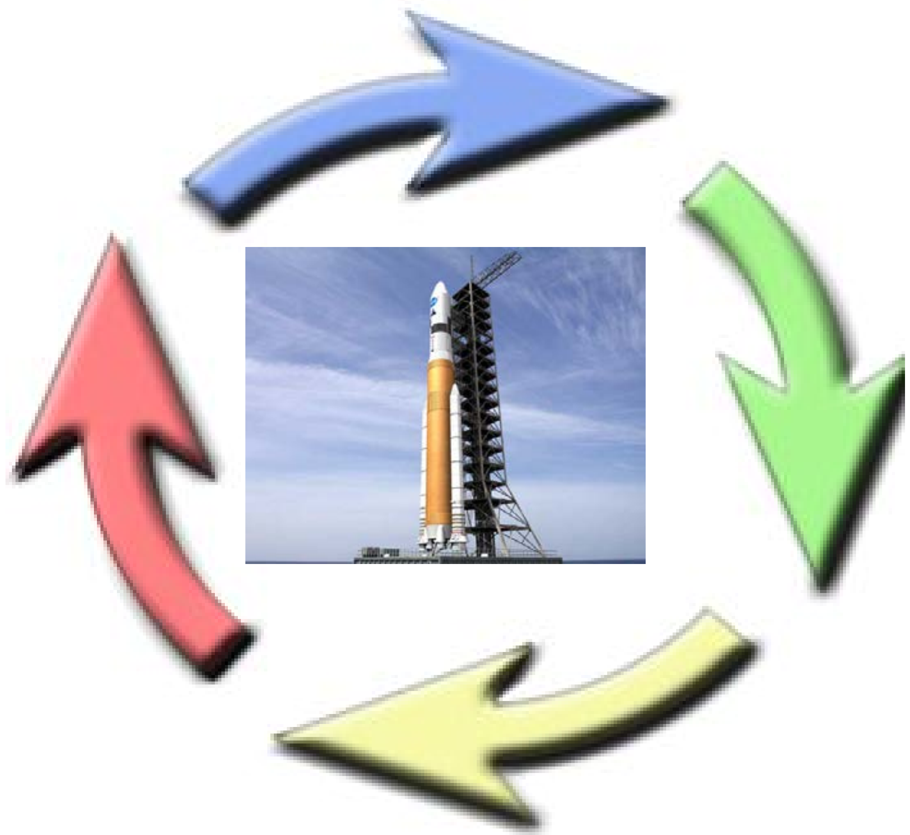


Figure 1

Product Lifecycle – 4 Phases

Production

Creation

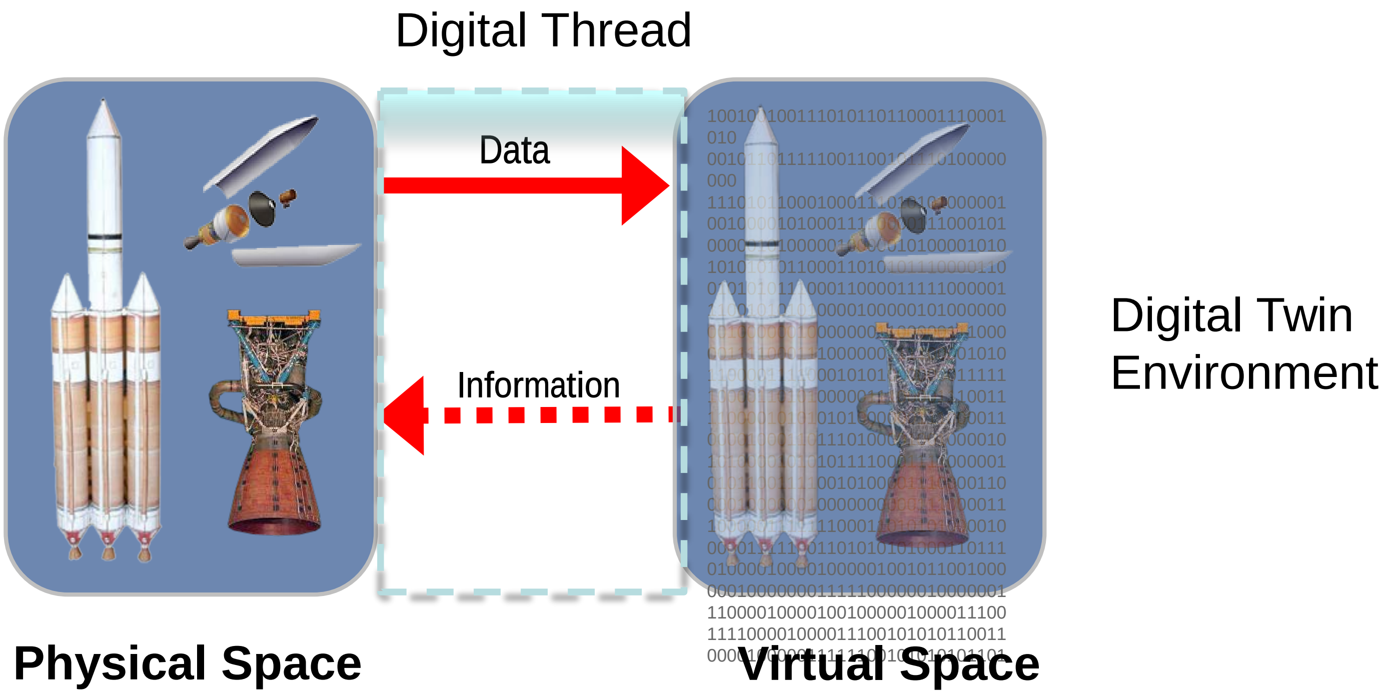


Operations

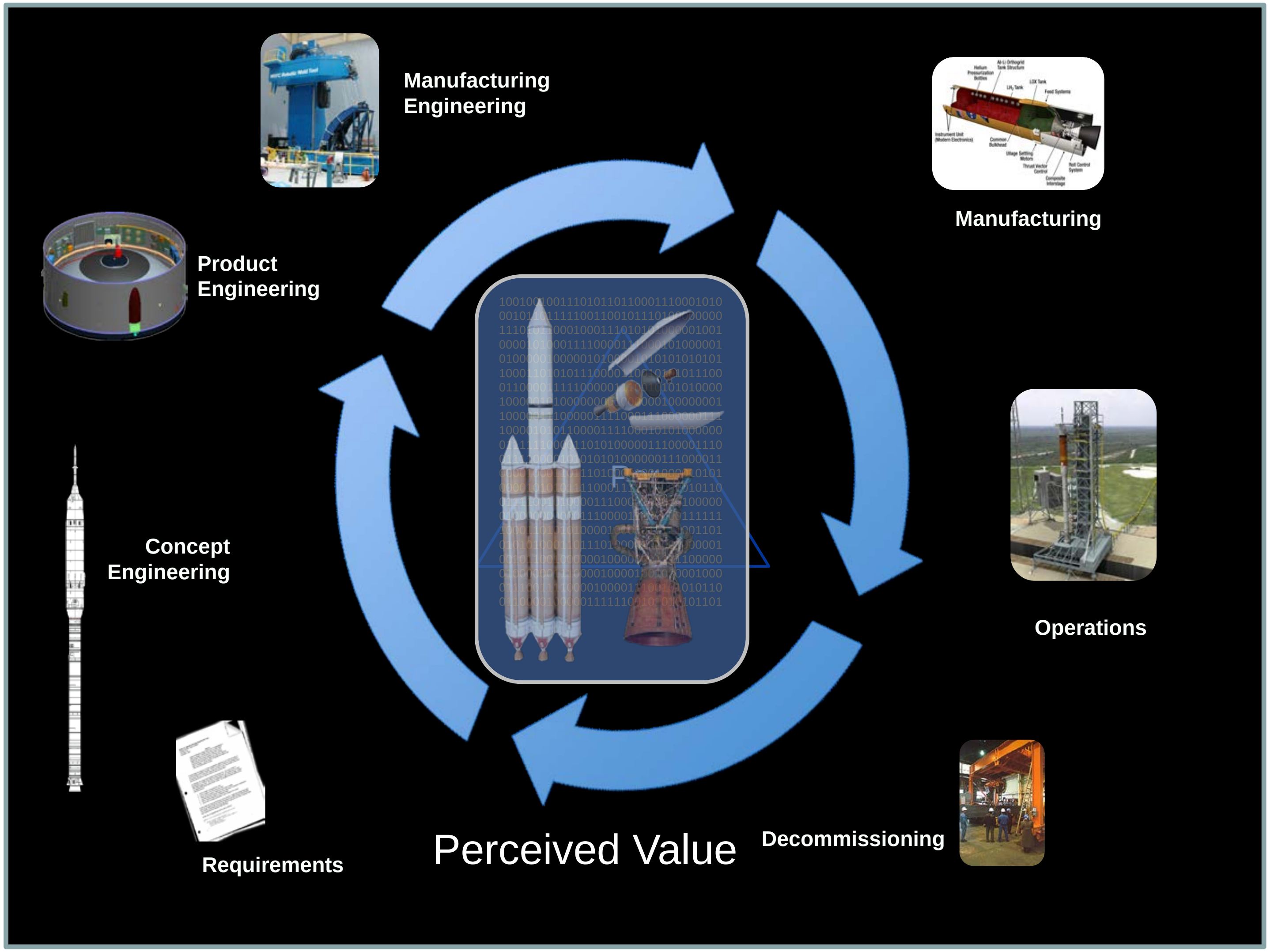
Disposal

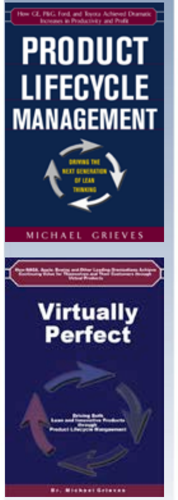
Figure 2

Digital Twin Model

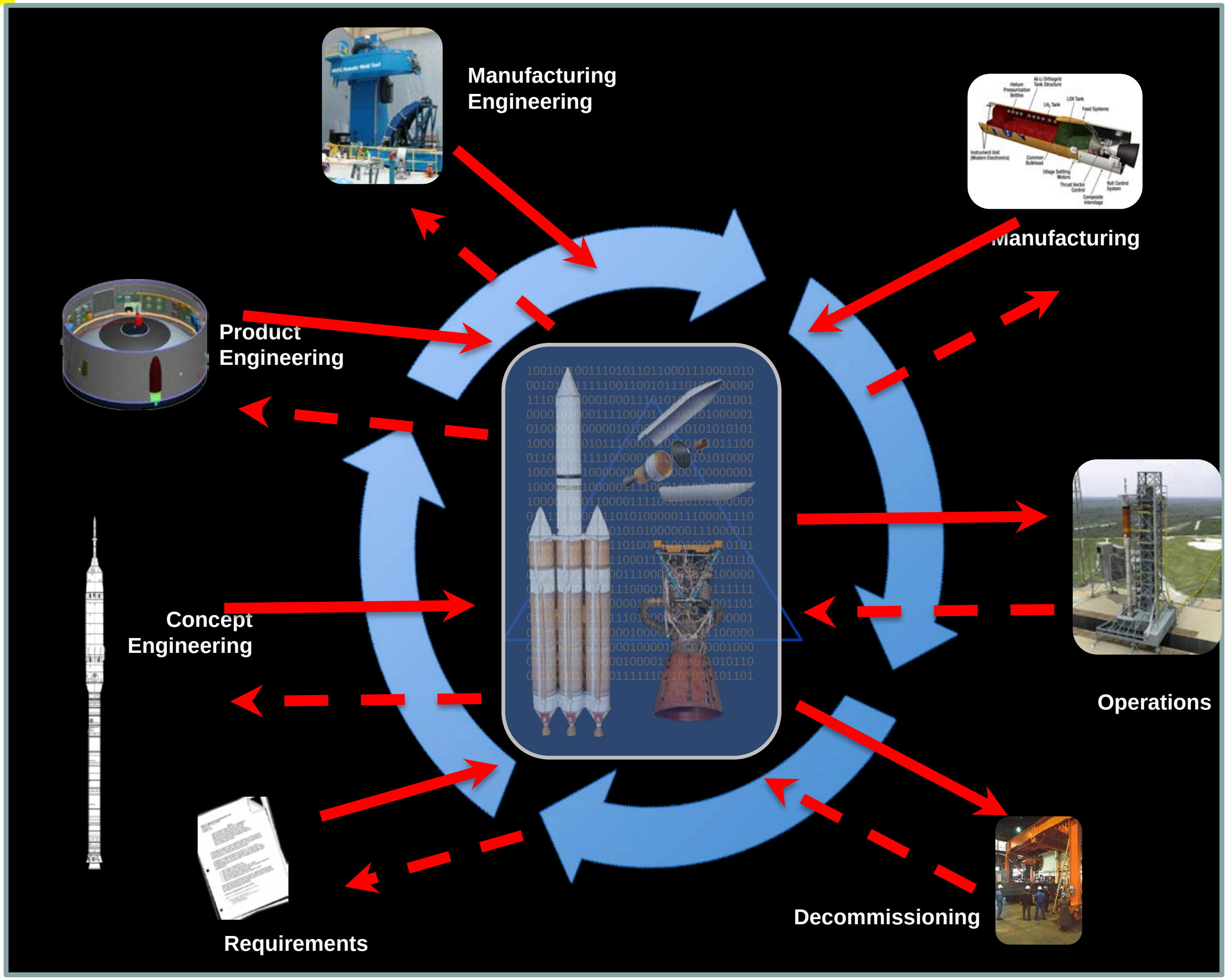


Digital Twin Through the Lifecycle





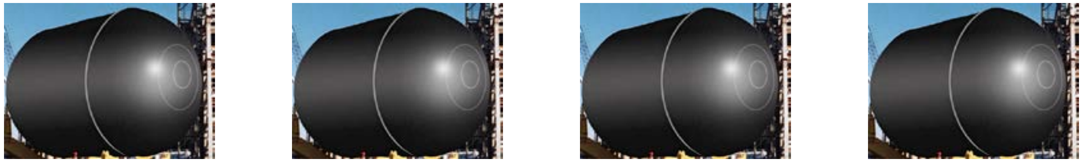
Digital Twin Through the Lifecycle



Digital Twin Types

- Digital Twin Prototype (DTP)

- Digital Twin Instance (DTI)



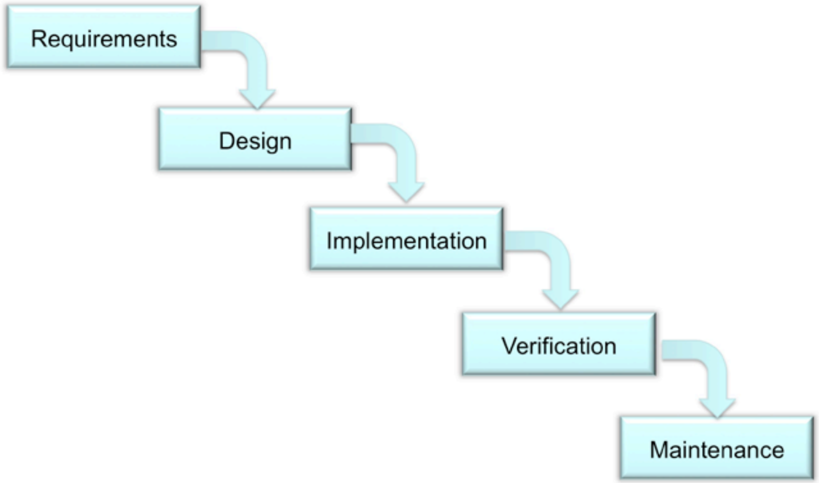
Interrogative

- Digital Twin Aggregate (DTA)

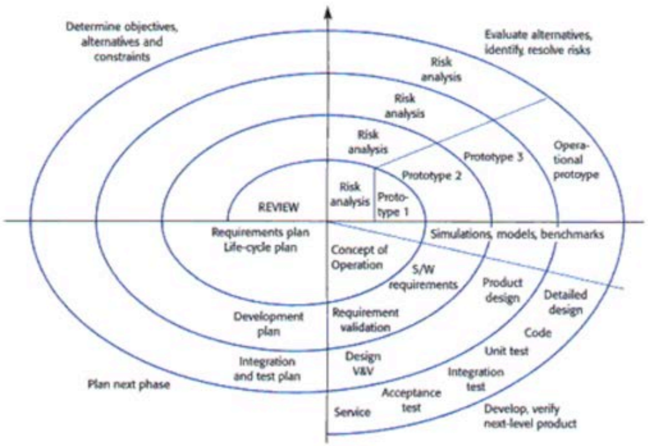
Prognostics

System Engineering Models

Waterfall Model



Spiral Model



VEE Model

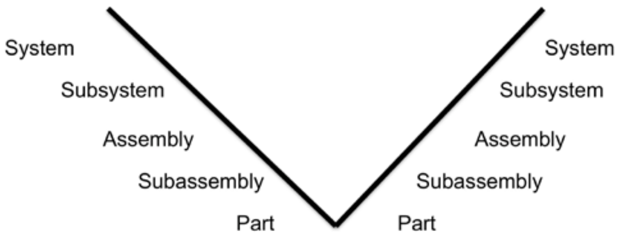


Figure 4

Digital Twin Implementation Model

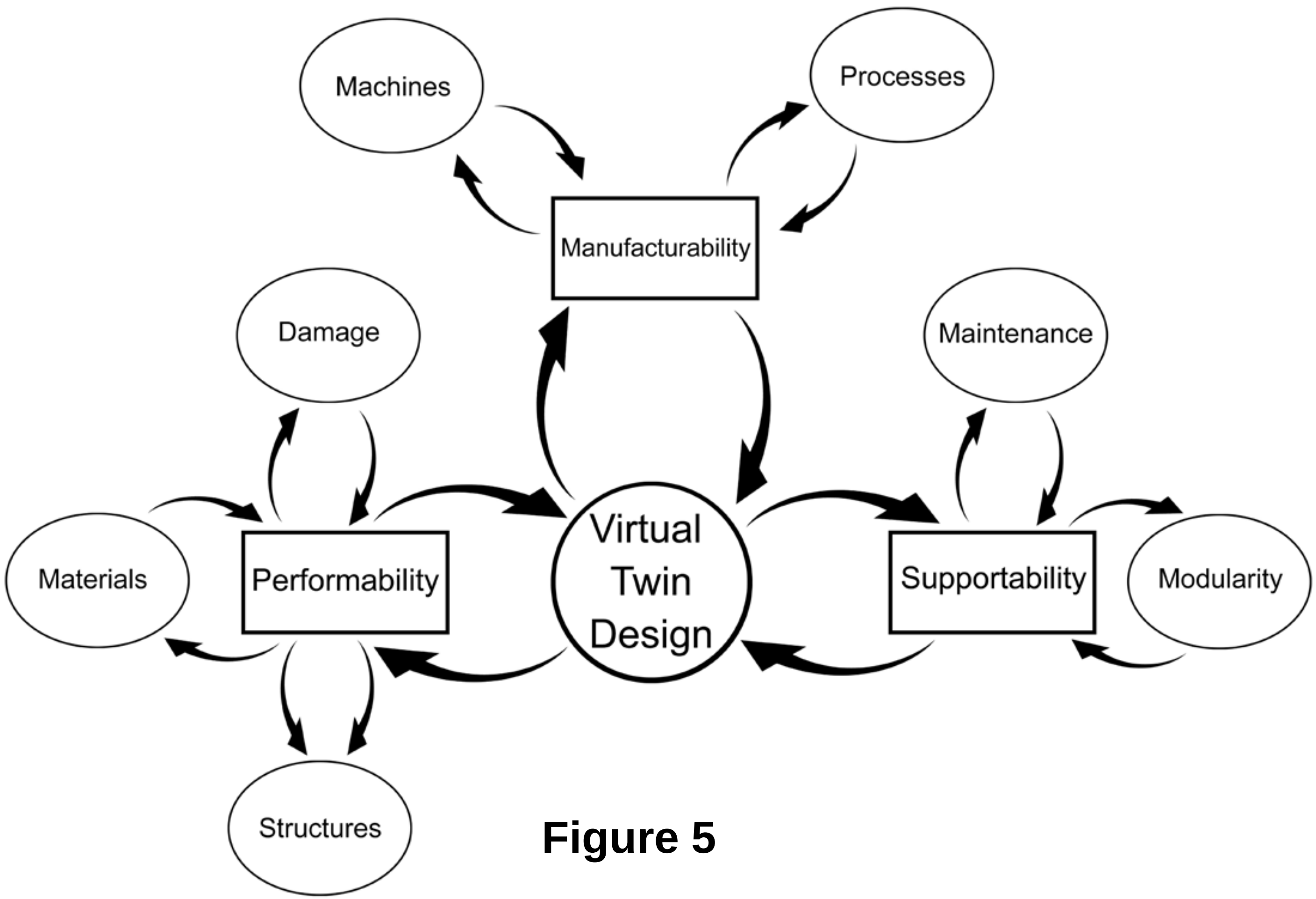


Figure 5

Real vs. Virtual Costs

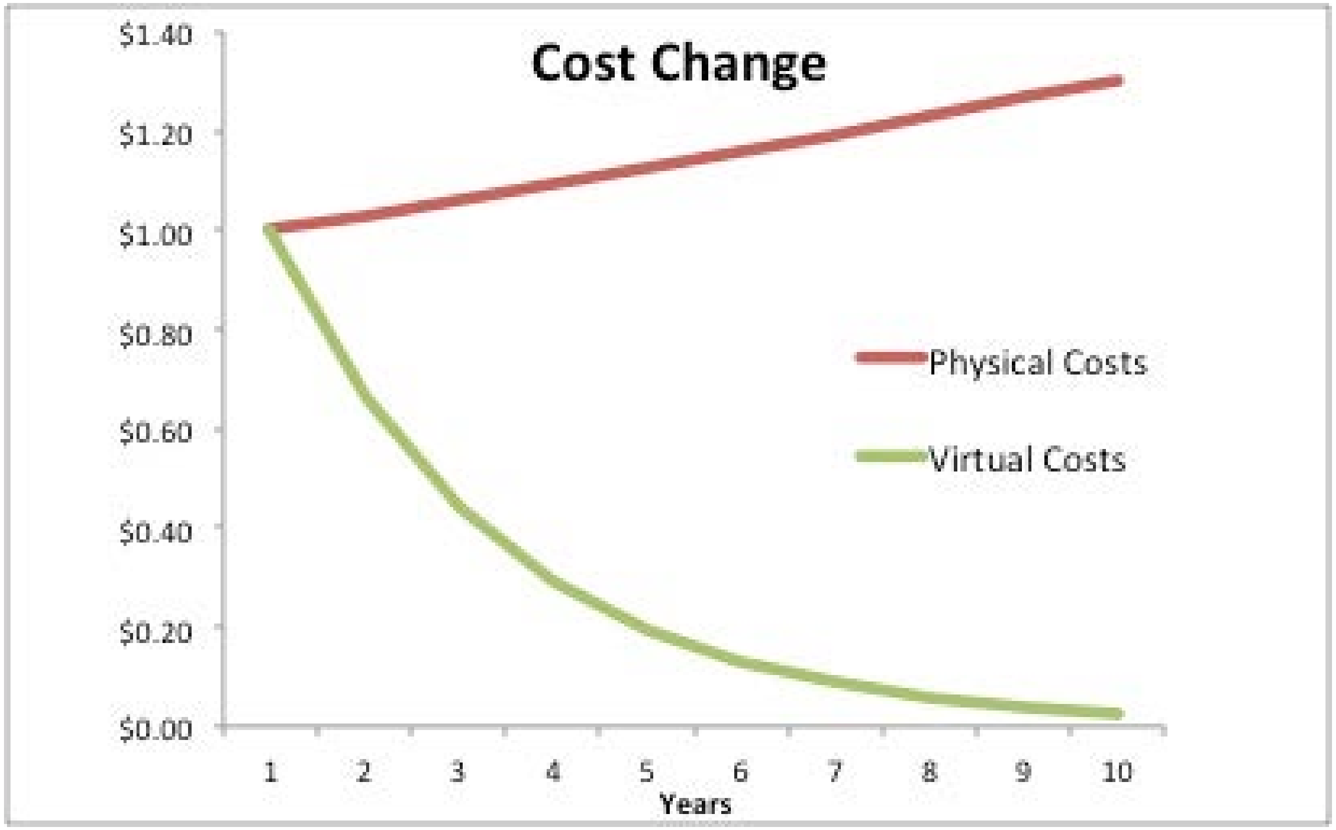


Figure 6

Obstacles

- Organizational siloing / culture
- Physical world knowledge
- Magnitude of possible system states

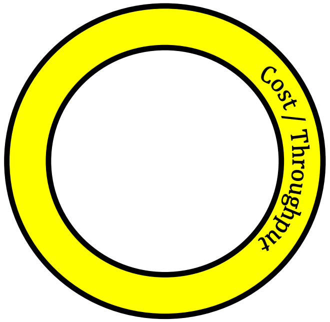
Possibilities

- Usage feedback to design
- System front-running

Additive Manufacturing

2 questions…

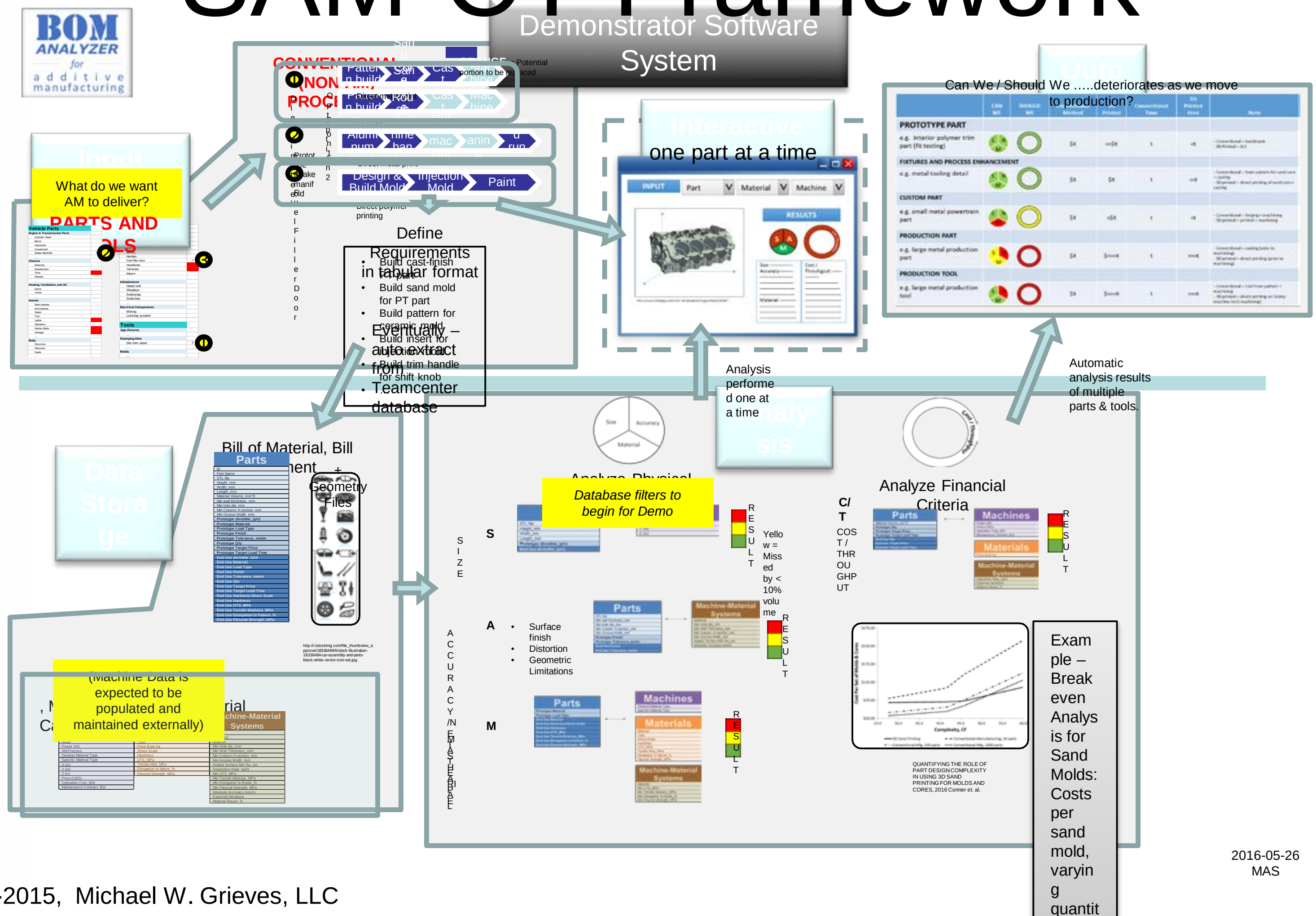
<u>Can</u> we make it?



<u>Should</u> we make it?

“The ultimate vision for the digital twin is to create, test and build our equipment in a virtual environment. Only when we get it to where it performs to our requirements do we physically manufacture it. – John Vickers, NASA Principal Technologist, The Economist

Additive Manufacturing SAM-CT Framework



2016-05-26
MAS

AM DB Architecture

Machines
ID
Manufacturer
Model
Mode
Power (W)
AM Process
General Material Type
Specific Material Type
X (in)
Y (in)
Z (in)
Price (USD)
Operation Cost $/hr
Maintenance Contract $/yr

Machine-Material Systems
ID
Machine1
Material
Min Hole dia_mm
Min Wall Thickness_mm
Min Column X-section_mm
Min Groove Width_mm
Angled Surface Min Ra_um
Deposition Rate_kg/hr
Min UTS_MPa
Min Tensile Modulus_MPa
Min Elongation to Break_%
Min Flexural Strength_MPa
Absolute Accuracy mm/m
Expected Iterations
Material Reuse_%

Materials
ID
company
Material
Type
Price $ per kg
Shore Scale
Hardness
UTS_MPa
Tensile Mod_MPa
Elongation to failure_%
Flexural Strength_MPa

Add ons:
Images
For fee add ons:
Brochures
Referrals
Demonstration videos
Training videos

Questions/Comments
mgrieves@fit.edu