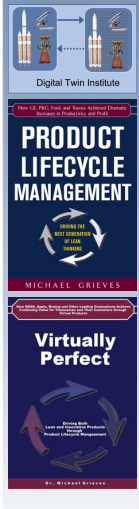
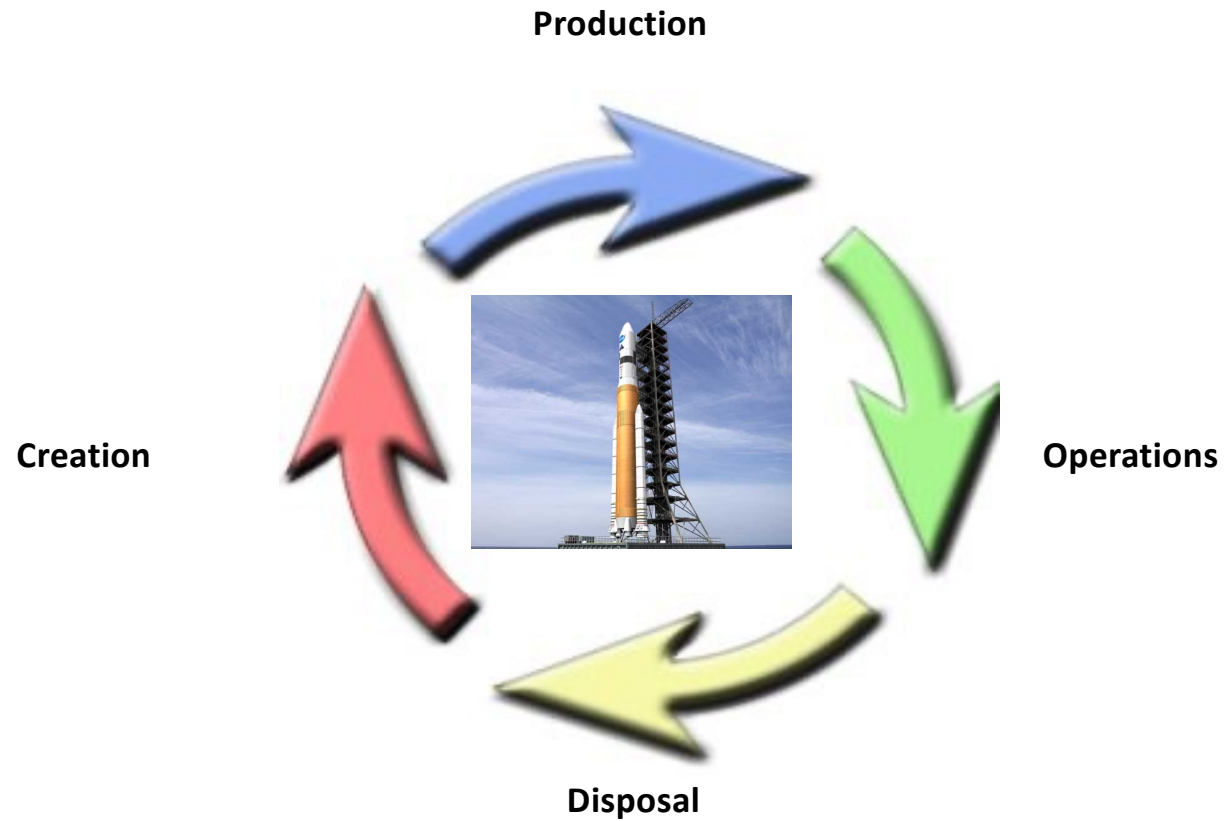


# Digital Twin's, Models, And Systems Engineering: Integrating 21<sup>st</sup> Century Product Development Concepts

Dr. Michael Grieves  
Chief Scientist / Exec Director  
Digital Twin Institute  
October 4, 2023



# Product Lifecycle – 4 Phases



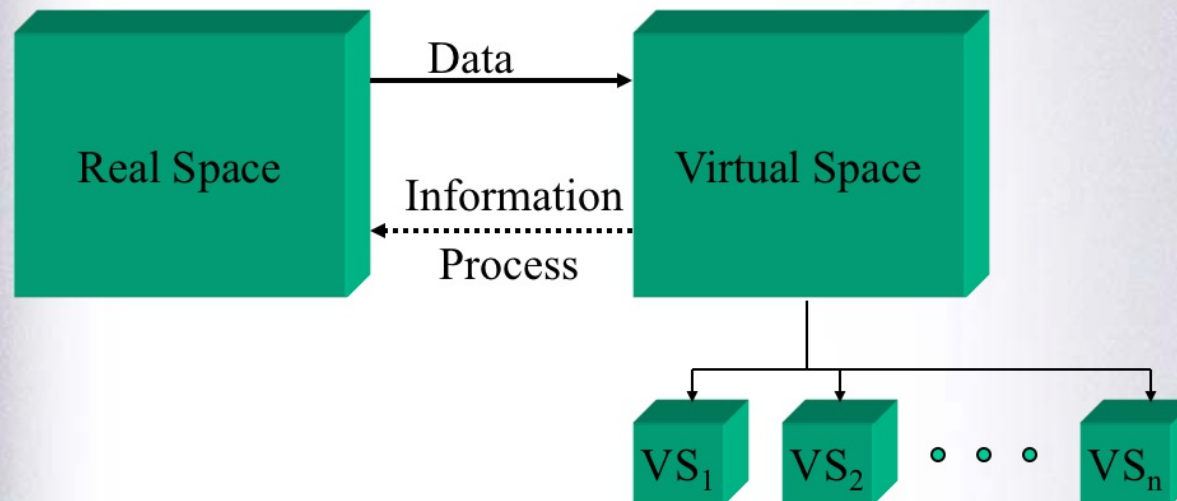
PRODUCT  
LIFECYCLE  
MANAGEMENT

MICHAEL GRIEVES

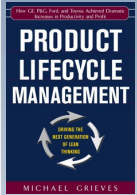
Virtually  
Perfect



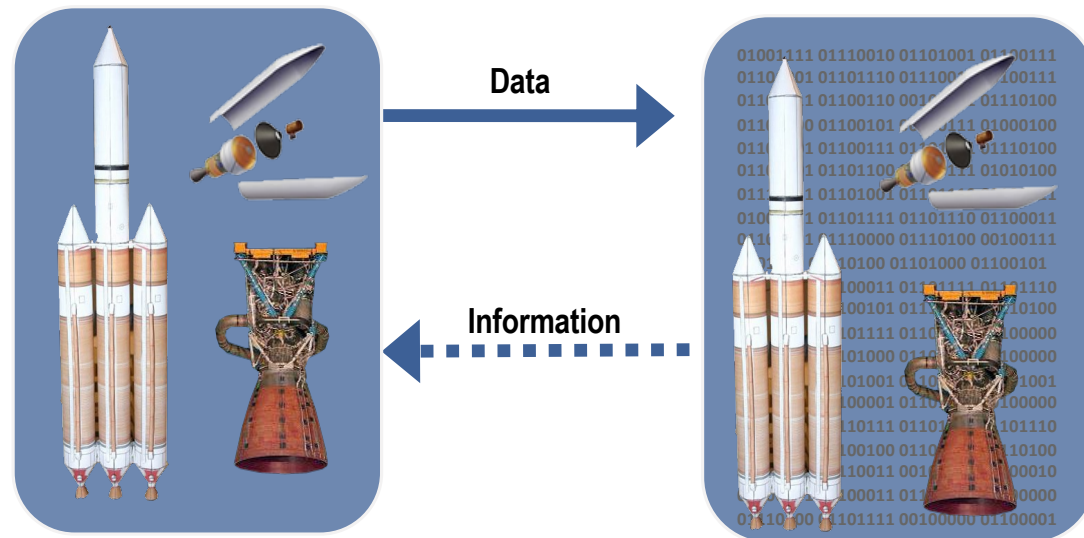
# Conceptual Ideal for PLM



SME MANAGEMENT FORUM  
OCTOBER 31, 2002 • TROY, MI



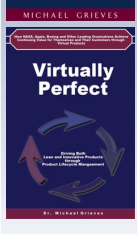
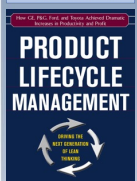
# Digital Twin Model



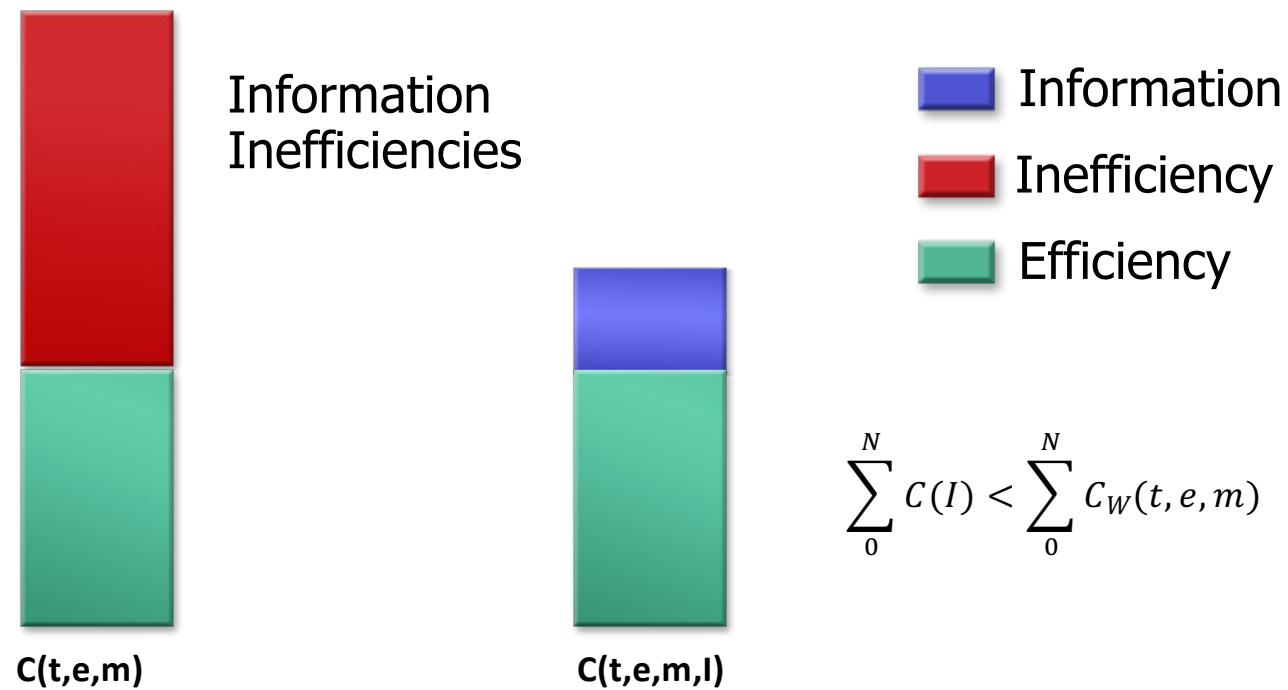
Physical Space

Virtual Space

20<sup>th</sup> Century      **Work Activity**      21<sup>st</sup> Century  
Substituting information for wasted physical resources



# Information as Task Wasted Time, Energy, Material Substitute

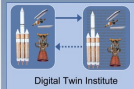
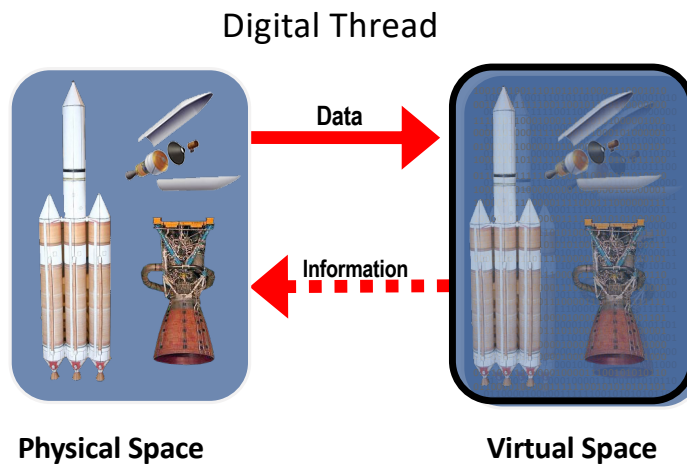
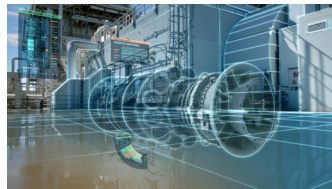
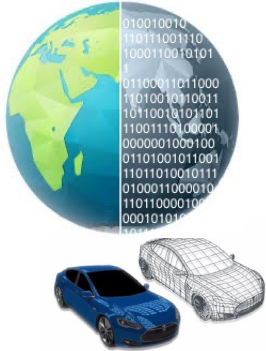


$$\sum_0^N C(I) < \sum_0^N C_W(t, e, m)$$

**Task: Goal Seeking Activity with  
Minimum Physical Resources**



# Digital Twin Model Scope & Scale - Tangible



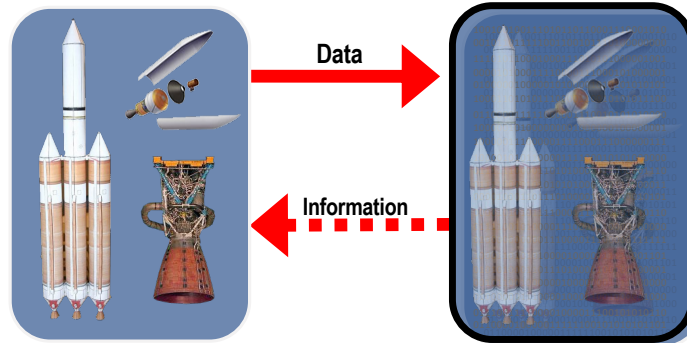
# Digital Twin Model Scope & Scale - Intangible



Logistics

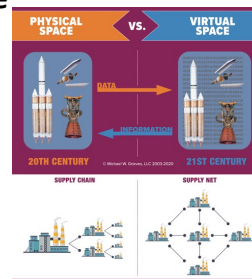


Process Industry



Physical Space

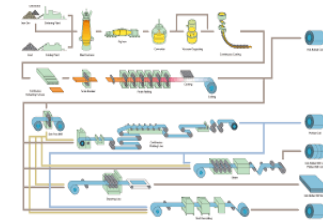
Virtual Space



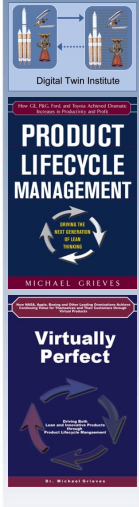
Supply Chain



Economic Systems



Manufacturing Process





# Digital Twin Types (DT)

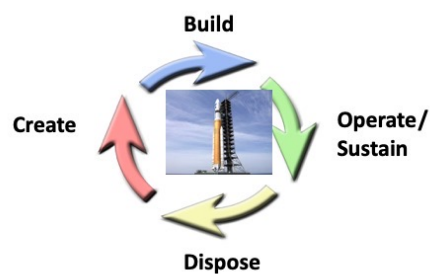
## Digital Twin Prototype (DTP)

All Products that CAN BE made



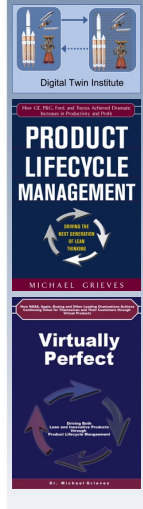
## Digital Twin Aggregate (DTA)

All Products that HAVE BEEN made



## Digital Twin Instance (DTI)

Individual Products that ARE made



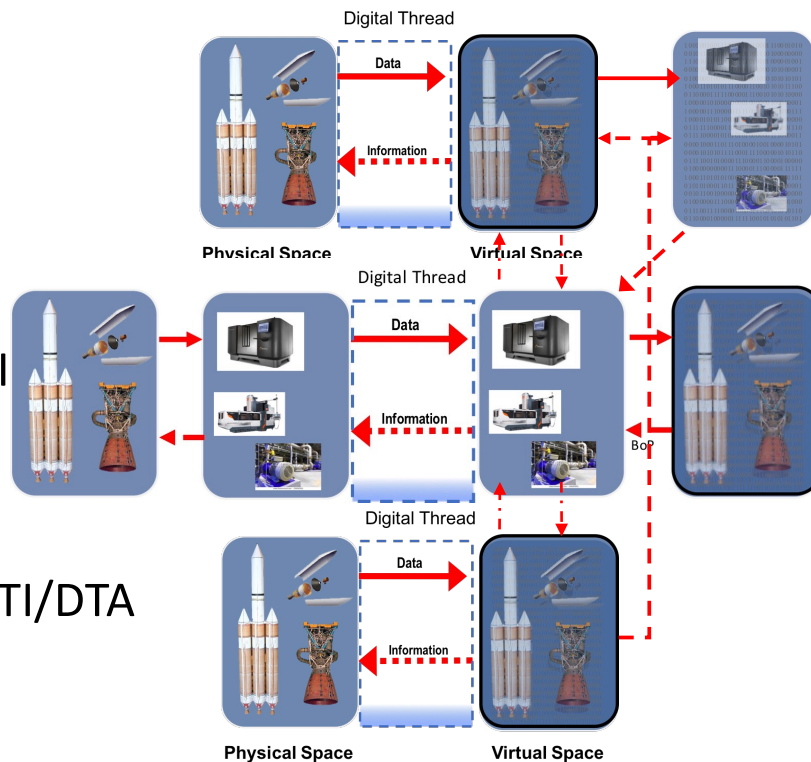


# Digital Twin Model through the Lifecycle

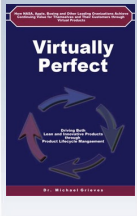
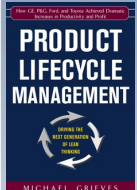
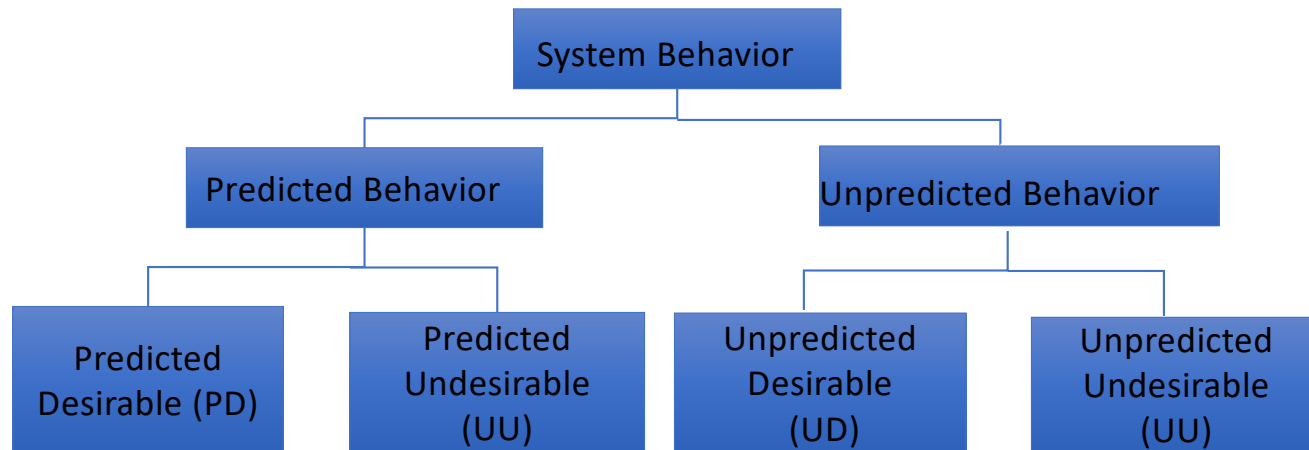
Create DTP

Build DTP/DTI

Sustain DTP/DTI/DTA

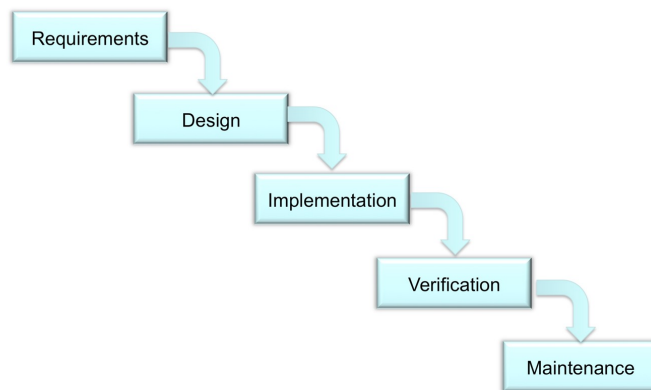


# Categories of System Behavior

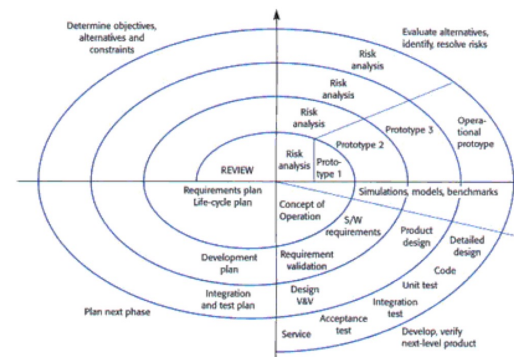


# System Engineering Models

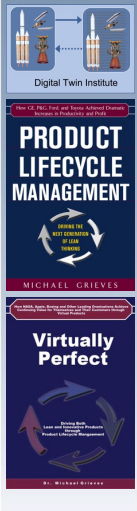
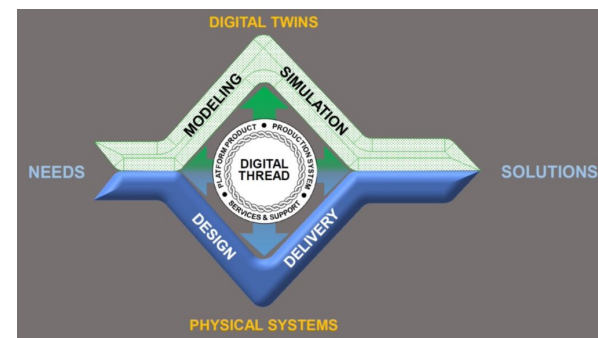
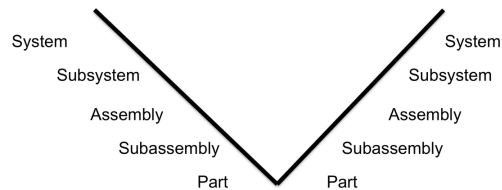
## Waterfall Model



## Spiral Model



## VEE Model



# Digital Twin Implementation Model

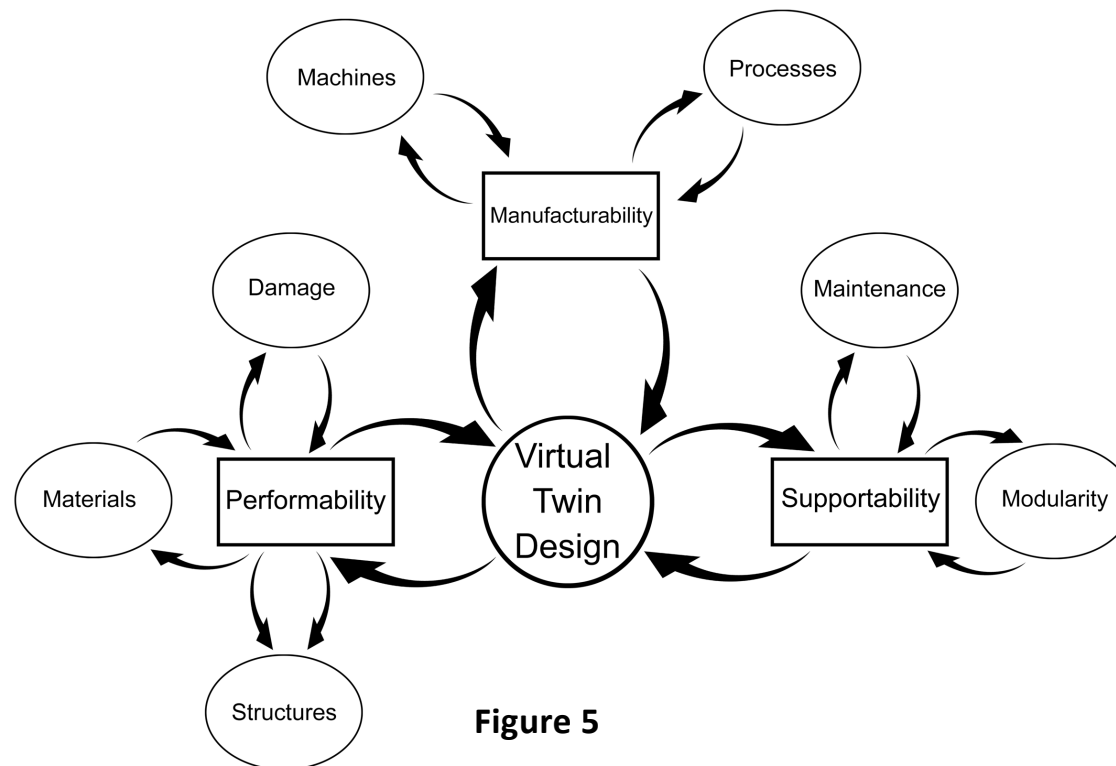
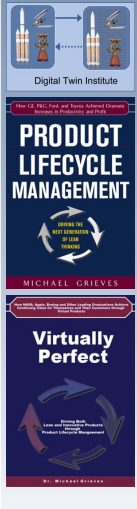


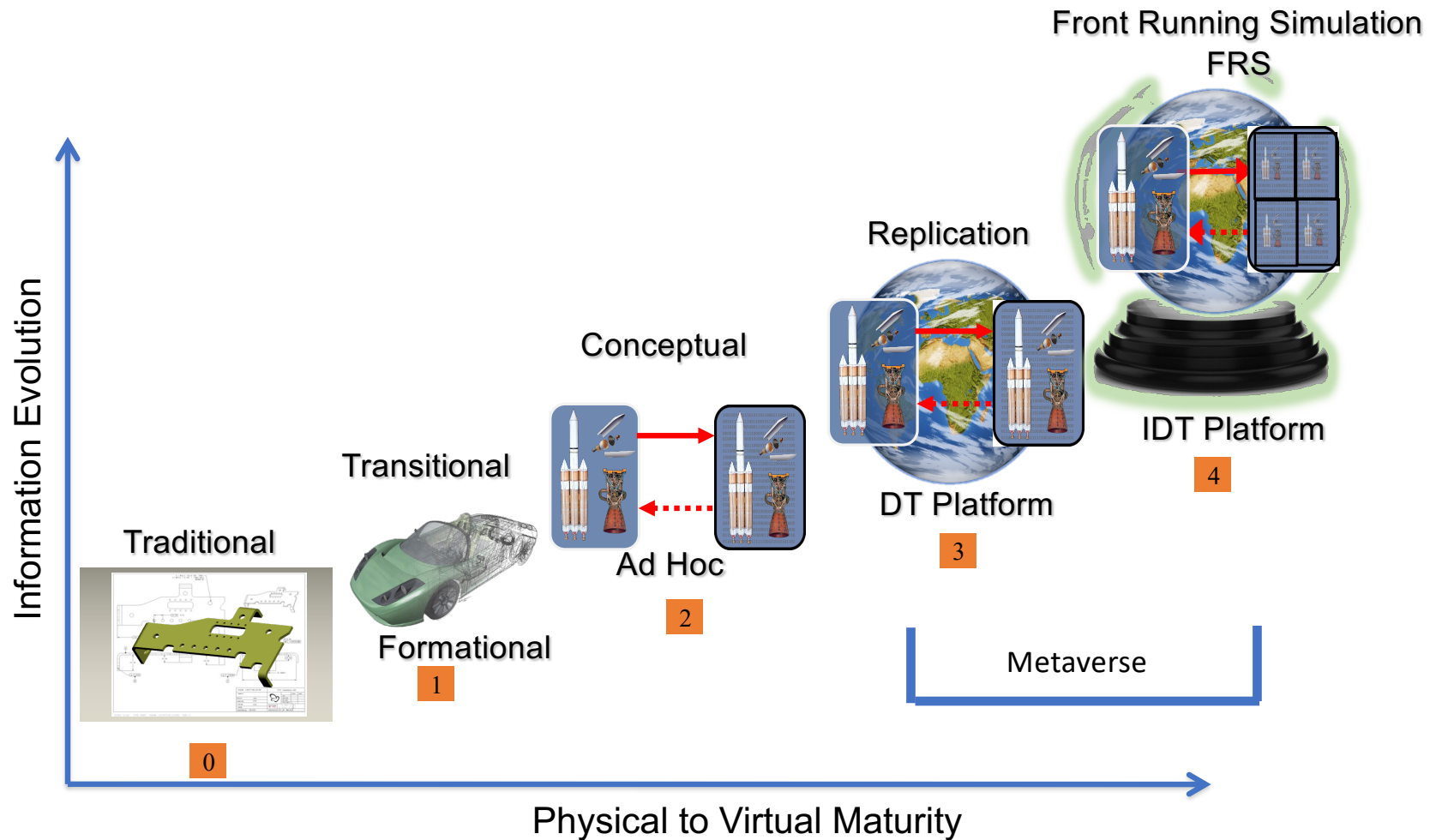
Figure 5

# Systems Engineering vs. PLM/DT

- Systems Engineering is product realization focused while PLM is product lifecycle focused;
- Systems Engineering is functionally based versus Product Lifecycle Management which is lifecycle based;
- Systems Engineering concerns itself primarily with physical products where PLM concern itself with both physical and virtual products;
- Systems Engineering is document based, while PLM is digital based;
- Systems Engineering is a much deeper discipline versus PLM, which is much broader.
- Systems Engineering degenerates into system accounting

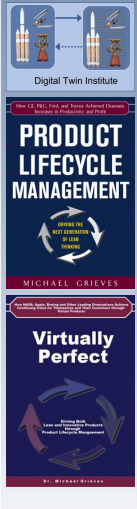


# Digital Twin Evolution



# Digital Twin Metaverse

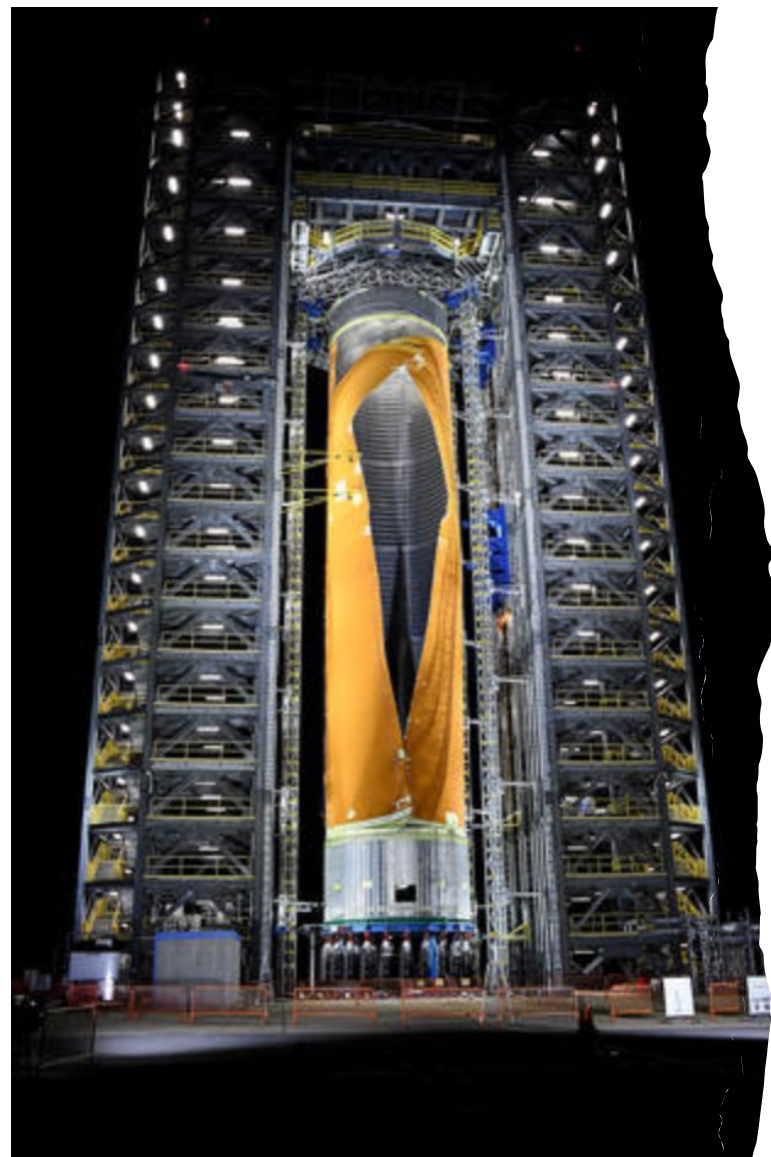
- There are multiple DT metaverses
- The DT metaverse supports both replication and prediction
- All laws of the physical universe are implemented and enforced in simulations for all inanimate objects
- DT interoperability is a requirement if multiple DTs.
- It is multiple participant immersive as avatars
- Meta capabilities are allowed for human participants as avatars
- Time can be synchronous or asynchronous with physical time depending on use case and DT type
- Cybersecurity is an embedded



Digital Twins, Simulation, and the Metaverse:

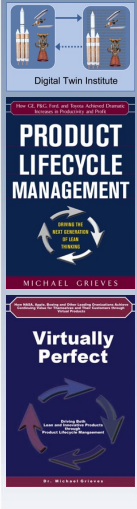
Driving Physical World Efficiency and Effectiveness through Virtual Worlds Simulation, Springer, Forthcoming

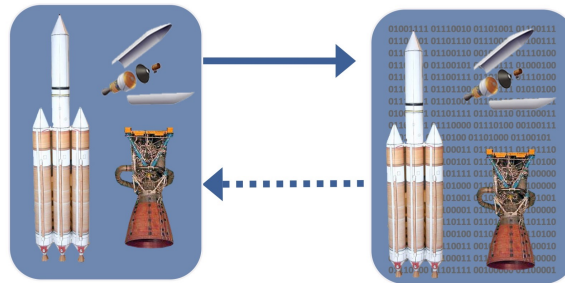




# Selected Publications

- Grieves, M., Product Lifecycle Management: Driving the Next Generation of Lean Thinking. 2006, New York: McGraw-Hill.
- Grieves, M., Virtually Perfect: Driving Innovative and Lean Products through Product Lifecycle Management. 2011, Cocoa Beach, FL: Space Coast Press.
- Grieves, M. Digital Twin: Manufacturing Excellence through Virtual Factory Replication (White Paper). 2014
- Grieves, M. and J. Vickers, Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems, in Trans-Disciplinary Perspectives on System Complexity, F.-J. Kahlen, S. Flumerfelt, and A. Alves, Editors. 2017, Springer: Switzerland. p. 85-114.
- Grieves, M., Virtually Intelligent Product Systems: Digital and Physical Twins, in Complex Systems Engineering: Theory and Practice, S. Flumerfelt, et al., Editors. 2019, American Institute of Aeronautics and Astronautics
- Grieves, M., Intelligent digital twins and the development and management of complex systems. Digital Twin, 2022, 2(8)
- <https://youtube.com/@digitaltwinDrGrieves>





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[Michael.Grieves@ucf.edu](mailto:Michael.Grieves@ucf.edu)



Digital Twin Institute

PRODUCT  
LIFECYCLE  
MANAGEMENT



MICHAEL GRIEVES

Virtually  
Perfect

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