Hidden Impacts of Producibility on System Affordability and Design-Manufacturing Interdependence

NDIA Systems Engineering Conference
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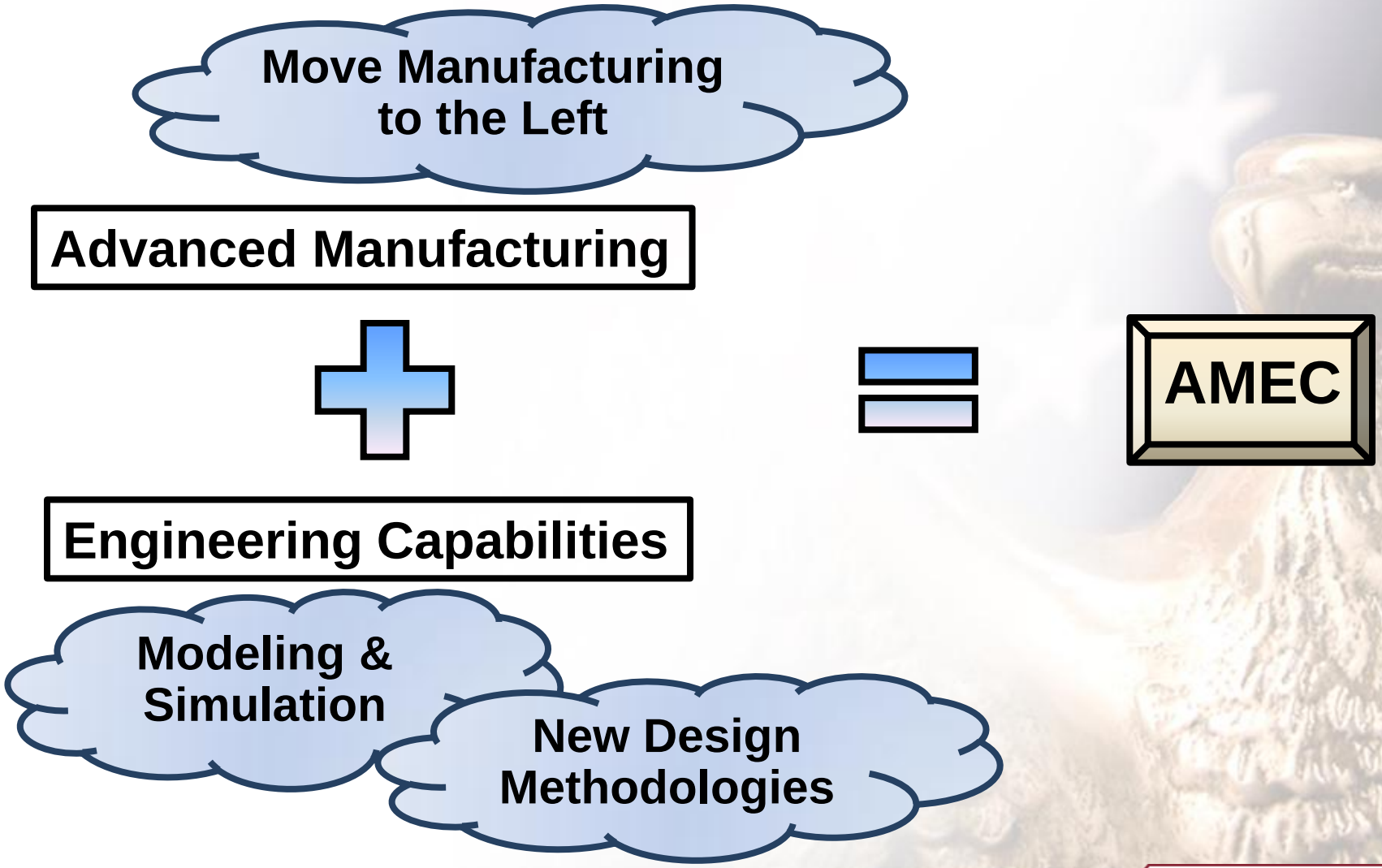
Chairman NDIA AMEC Committee

AMEC Charter & Mission



AMEC M&S White Paper

- **Based on 18 month study on current DFM practices***
  - **Analytical producibility analysis tools lacking**
  - **Many producibility issues inadvertently designed-in**
  - **Current commercial DFM analysis tools inadequate**
  - **Manufacturing M&S a critical missing research area**

- **Roadmap development underway for key focus areas**
  - **Systems engineering trade study and design methodologies**
  - **System integration, assembly, and test modeling**
  - **Enterprise level supply chain design and analysis methods**
  - **Electrical, mechanical, and assembly yield modeling**
  - **Quantitative DFX analyses including complexity characterization**
  - **Life cycle cost modeling including uncertainty and risk impact**

*NDIA Manufacturing Division White Paper, "21st Century Manufacturing Modeling & Simulation Research and Investment Needs," Released May 2011.

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Why Focus on Producibility?

- **Production cost components**
  - **Direct material and labor costs**
  - **Factory overhead/burden costs**
- **Producer vs. user LCC drivers**
  - **Low yield & process inefficiencies**
  - **Manufacturing process complexity**
  - **Excessive quality specs/controls**
- **Product cost reduction strategies**
  - **Post-NPI value engineering**
  - **Lean out existing processes**
  - **New material/process technologies**

Inadvertently Designed-In Producibility Issues Drive Significant "Hidden" Costs

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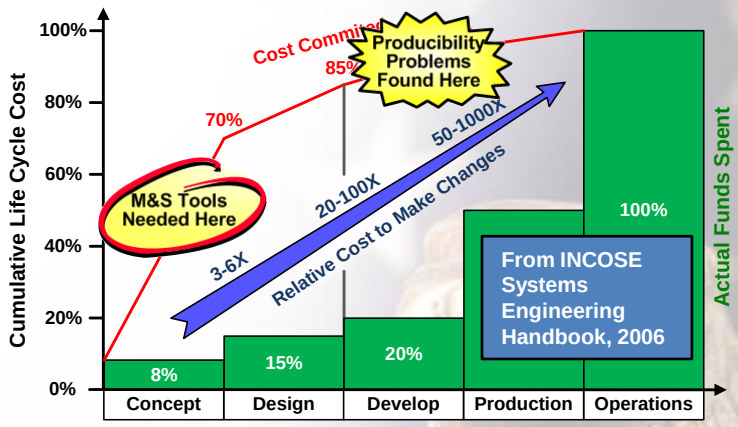
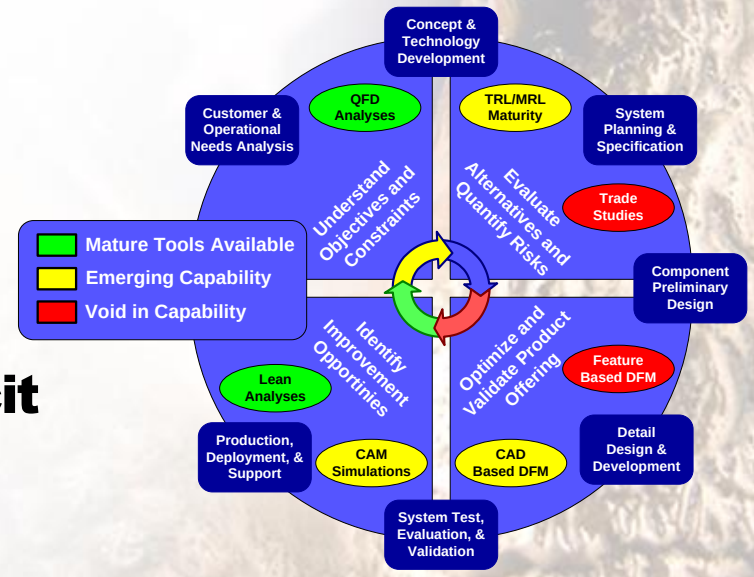
Design-Manuf Interdependence

- **Early design decisions lock-in cost**
  - Trade studies focus on performance
  - Exotic materials used to save weight
  - Design thrown across the "globe"



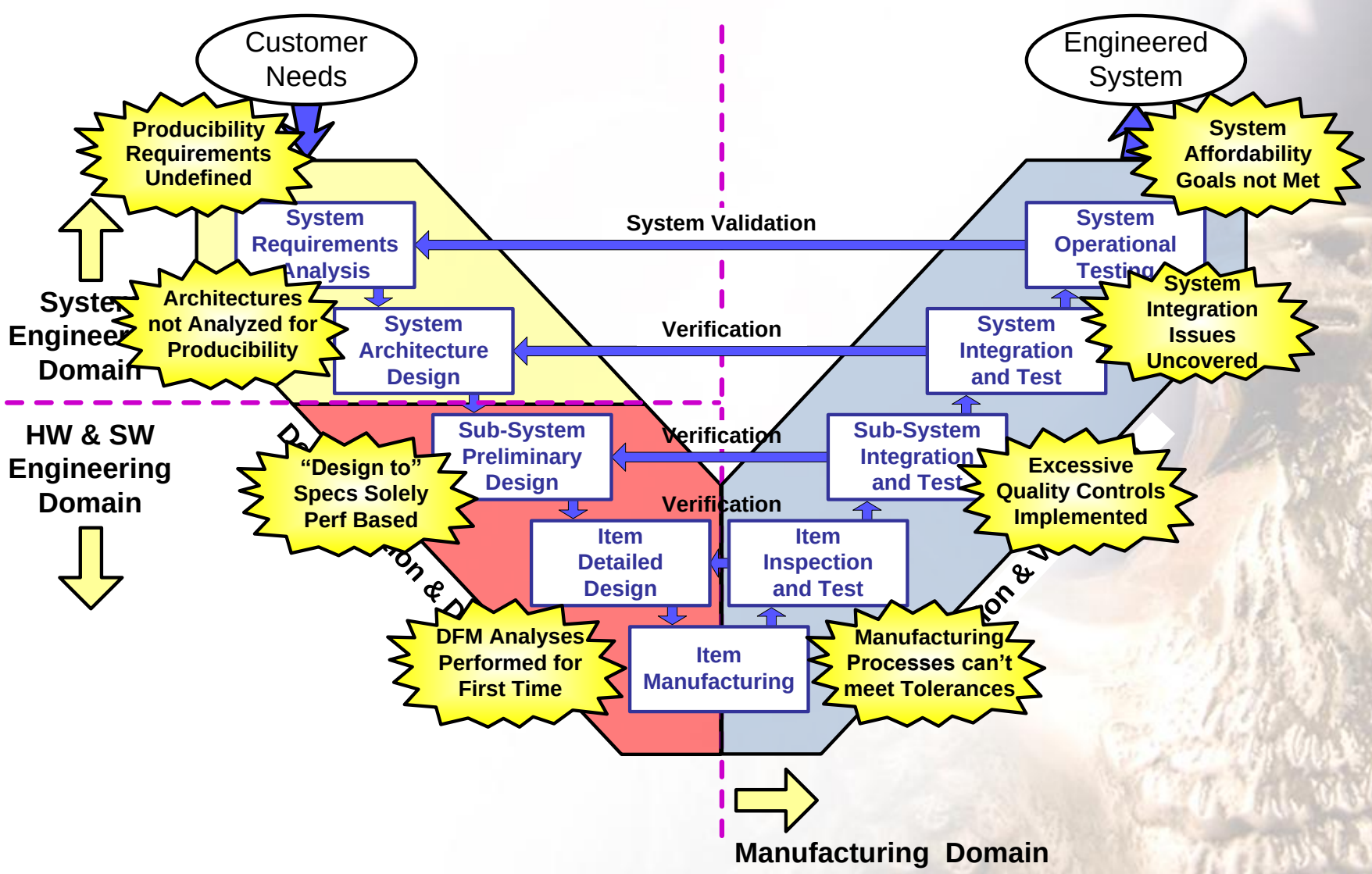
- **Moving manufacturing to the "left"**
  - Concurrent engineering teams
  - Early supplier involvement
  - Design for manufacturing (DFM)



- **Quantitative DFM tools lacking**
  - Manufacturing knowledge mostly tacit
  - High level DFM guidelines/checklists
  - Rule-based CAD/CAM occurs too late

M&S Enabler to Move Manufacturing Left

Role of Systems Engineering



It All Starts with Requirements....

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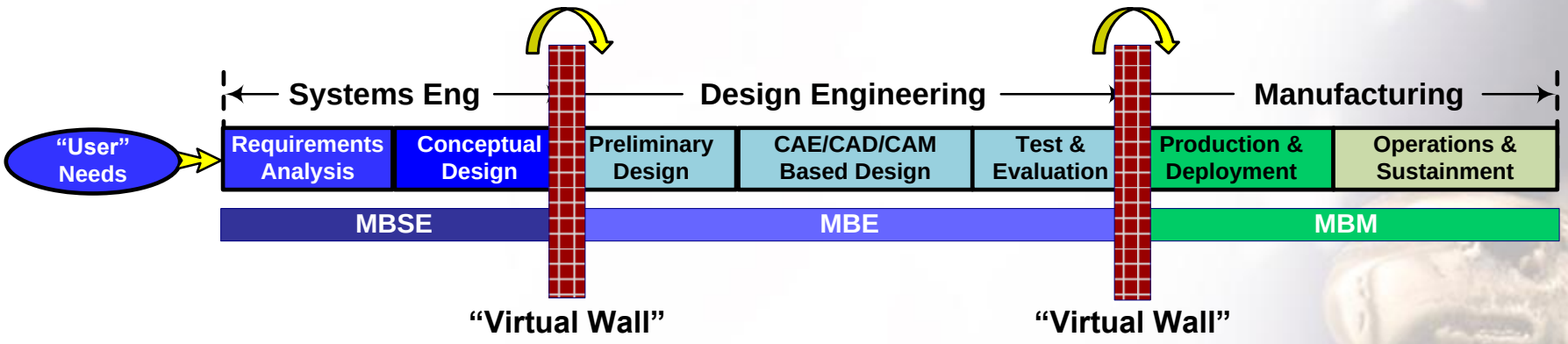
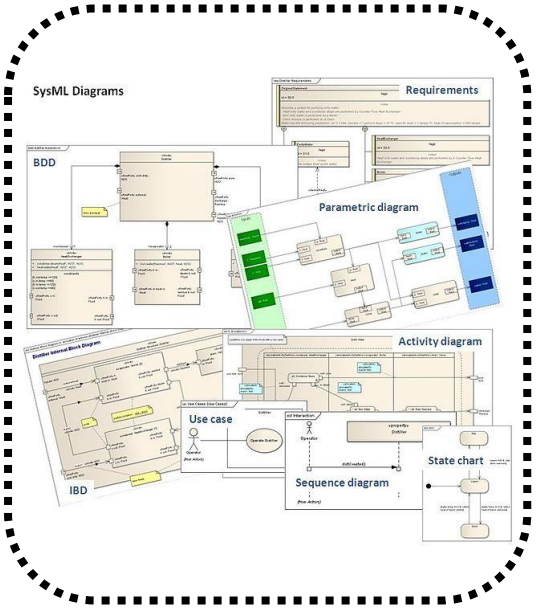
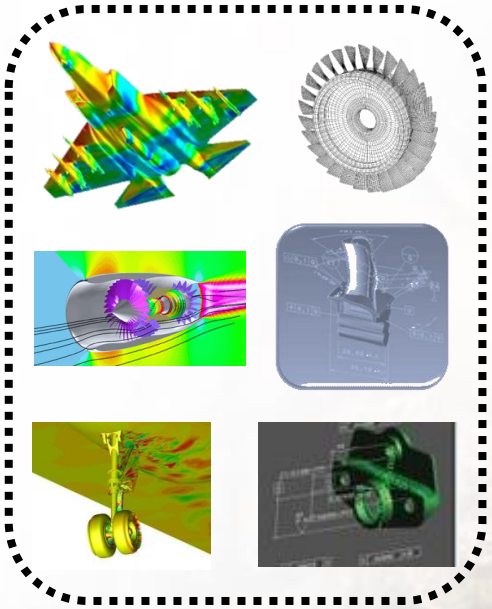
Current Model-Based Approaches



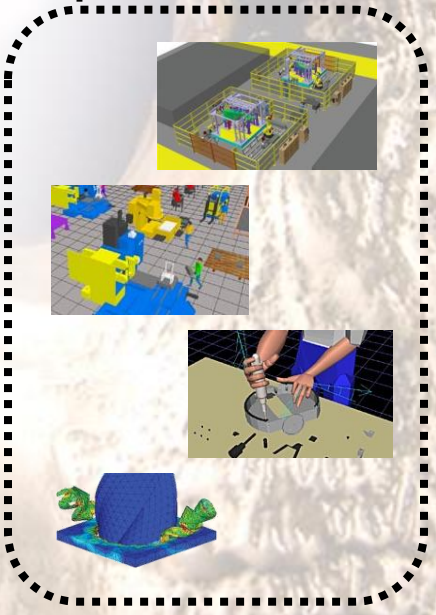
"Function Centric"



"Geometry Centric"



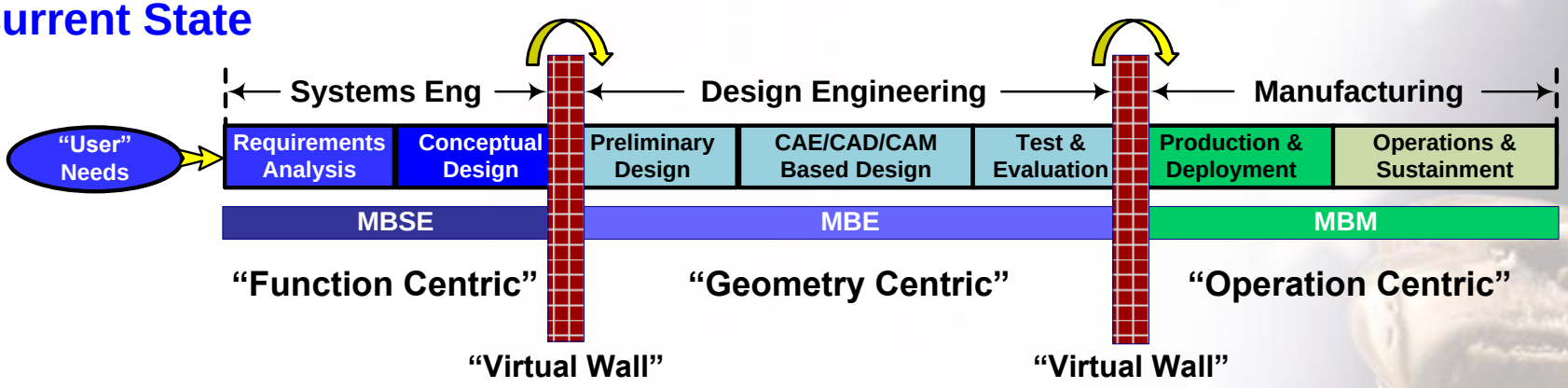
"Operation Centric"



Same Problems now Happen Virtually...

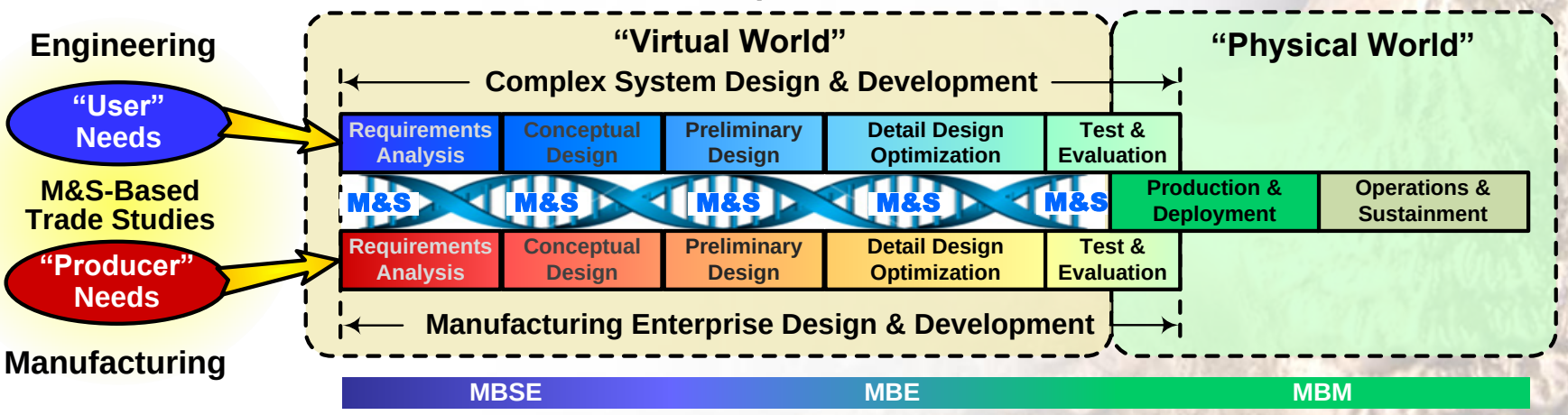
M&S-Enabled Concurrent Eng

Current State



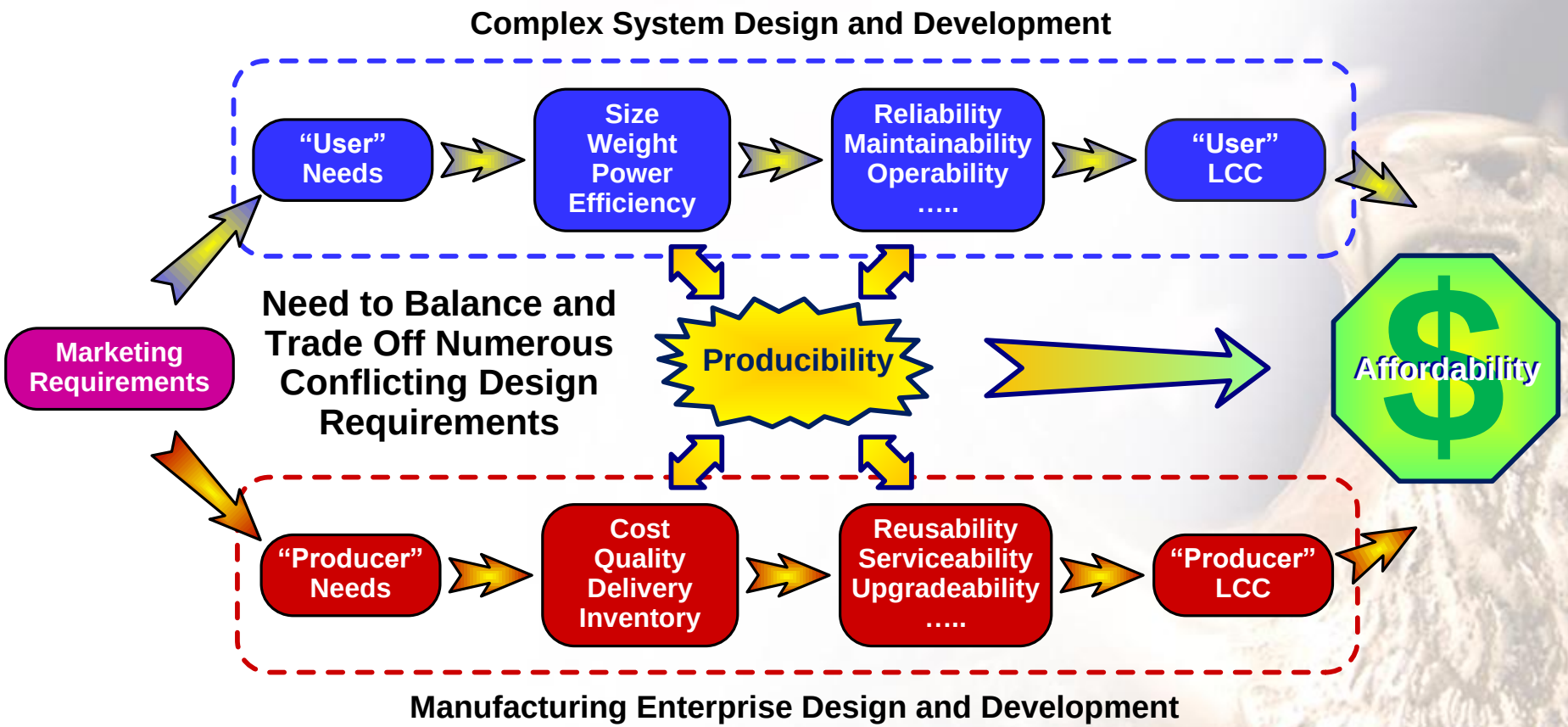
Transforming the Design Space

Future State



"Re-Engineering" Design & Manufacturing

Role of Producibility in Trade Space



Producibility a Critical "x"
Driving the Big "Y" of Affordability

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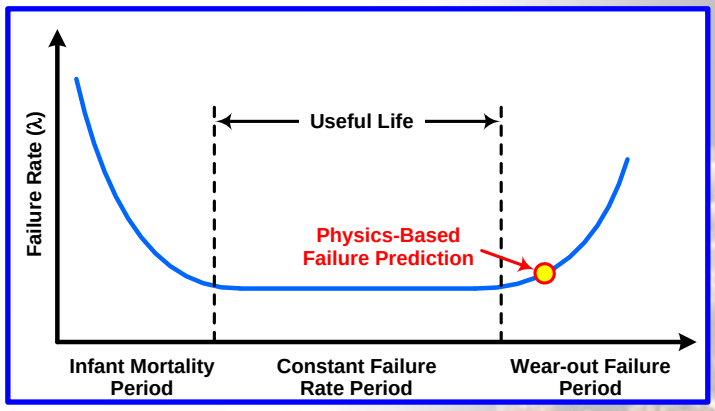
Reliability Engineering Discipline

Reliability Theory

Reliability: Probability that a device will perform its intended function during a specified period of time under stated conditions.

Physics of Failure Analysis



Analytical Basis

$$MTBF = \frac{1}{\lambda} = \frac{total\ operating\ hours}{number\ of\ failures}$$

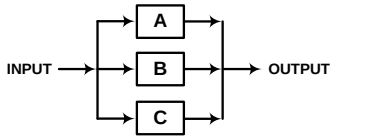
$$R(t) = \int_t^{\infty} f(t)dt = e^{-\lambda t}$$

$$f(t) = \frac{1}{\theta} e^{-t/\theta} \qquad \lambda = \frac{1}{\theta}$$

RAMS

Reliability
Availability
Maintainability
Safety

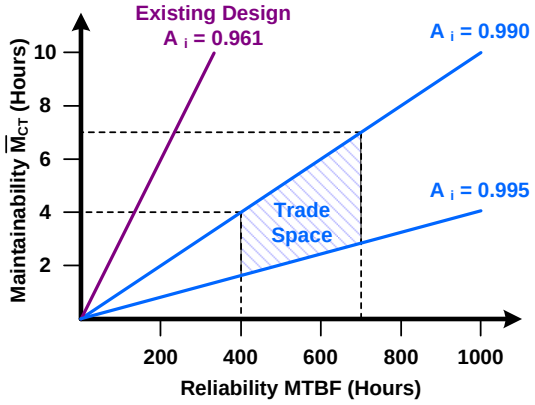
Modeling Relationships



$$R = 1 - (1 - R_A)(1 - R_B)(1 - R_C)$$

$$R = (R_A)(R_B)(R_C)$$

Trade Off Evaluations



Configuration	A_i	MTBF	$\bar{M}_{CT}$
Existing Design	0.961	125	5.0
Alternative 1	0.991	450	4.0
Alternative 2	0.990	375	3.5
Alternative 3	0.991	320	2.8

Focus is Early Detection of Failure Modes

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What About Producibility?

Merriam-Webster.com

pro·duc·ibil·i·ty *noun* \prə,d(y)üsə'bilətē\

Definition of PRODUCIBILITY

: the character, state, or fact of being producible

'pro·duce *verb*

Definition of PRODUCE

5 **a** : to cause to have existence or to happen : BRING ABOUT

b : to give being, form, or shape to : MAKE; *especially* : MANUFACTURE

'man·u·fac·ture \,man-yə-'fak-chər, ,n

Definition of MANUFACTURE

3 : the act or process of producing something

Air Force Research Lab

Producibility: A design characteristic which allows economical fabrication, assembly, inspection, and testing of an item using available manufacturing techniques. The relative ease of manufacture of an item or system.

BusinessDictionary.com

Producibility: Ease of manufacturing an item (or a group of items) in large enough quantities. It depends on the characteristics and design features of the item that enable its economical fabrication, assembly, and inspection or testing by using existing or available technology.

Defense Acquisition University

Producibility: The measure of relative ease of manufacturing a product. The product should be easily and economically fabricated, assembled, inspected, and tested with high quality on the first attempt that meets performance thresholds.

Analytical Basis needed for Producibility

AFEI nTsa PSA WID

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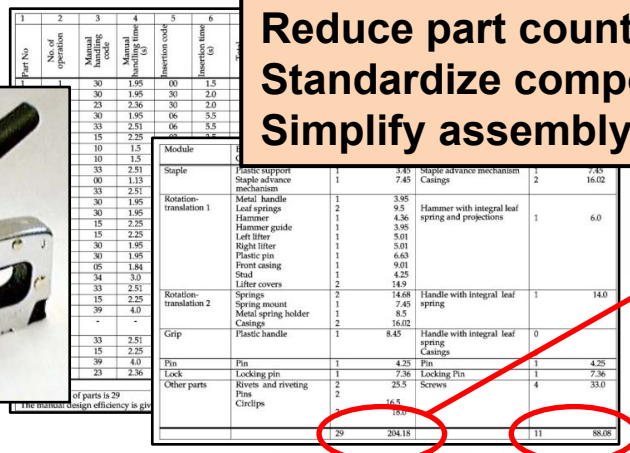
State-of-the-Art DFMA Analysis

Reduce part counts…
Standardize components…
Simplify assembly operations…

Stapler

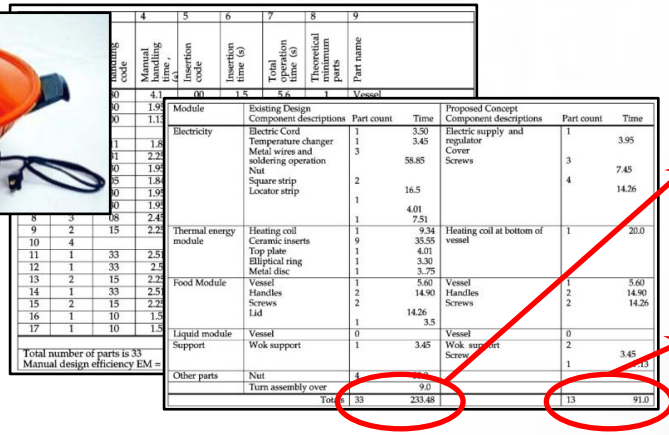


Module	Existing Design Component descriptions	Part count	Time	Proposed Concept Component descriptions	Part count	Time
Staple	Plastic support	1	3.45	Staple advance mechanism	1	7.45
	Staple advance mechanism	1	7.45	Casings	2	16.02
Rotation-translation 1	Metal handle	1	3.95			
	Leaf springs	2	9.5	Hammer with integral leaf spring and projections	1	6.0
	Hammer	1	4.36			
	Hammer guide	1	3.95			
	Left lifter	1	5.01			
	Right lifter	1	5.01			
	Plastic pin	1	6.63			
	Front casing	1	9.01			
	Stud	1	4.25			
	Lifter covers	2	14.9			
Rotation-translation 2	Springs	2	14.68	Handle with integral leaf spring	1	14.0
	Spring mount	1	7.45			
	Metal spring holder	1	8.5			
	Castings	2	16.02			
Grip	Plastic handle	1	8.45	Handle with integral leaf spring Casings	0	
Pin	Pin	1	4.25	Pin	1	4.25
Lock	Locking pin	1	7.36	Locking Pin	1	7.36
Other parts	Rivets and riveting	2	25.5	Screws	4	33.0
	Pins	2				
	Circlips	2	16.5			
			18.0			
		29	204.18		11	88.08

“As Is” Design
- 29 Total Parts
- Assy Time 204 sec

“To Be” Design
- 11 Total Parts
- Assy Time 88 sec

Electric Wok



Module	Existing Design Component descriptions	Part count	Time	Proposed Concept Component descriptions	Part count	Time
Electricity	Electric Cord	1	3.50	Electric supply and regulator	1	3.95
	Temperature changer	1	3.45	Cover		
	Metal wires and soldering operation	3	58.85	Screws	3	7.45
	Nut				4	14.26
	Square strip	2				
	Locator strip	1	16.5			
		1	4.01			
		1	7.51			
Thermal energy module	Heating coil	1	9.34	Heating coil at bottom of vessel	1	20.0
	Ceramic inserts	9	35.55			
	Top plate	1	4.01			
	Elliptical ring	1	3.30			
	Metal disc	1	3.75			
Food Module	Vessel	1	5.60	Vessel	1	5.60
	Handles	2	14.90	Handles	2	14.90
	Screws	2		Screws	2	14.26
	Lid	1	14.26			
		1	3.5			
Liquid module	Vessel	0		Vessel	0	
Support	Wok support	1	3.45	Wok support	2	3.45
				Screw	1	0.13
Other parts	Nut	4	3.60			
	Turn assembly over		9.0			
	Total	33	233.48		13	91.0

“As Is” Design
- 33 Total Parts
- Assy Time 233 sec

“To Be” Design
- 13 Total Parts
- Assy Time 91 sec

Source: R.B. Stone et. al, “A Product Architecture-Based Conceptual DFA Technique,” Design Studies, Vol. 25, No. 3, pp. 301-325, May 2004.

Simple DFMA Approaches Work for Simple Products

A&D Producibility Analysis Needs

- **Aerospace producibility challenges**
  - Maximum functionality in smallest package
  - Highly 3-D shapes with intricate features
  - Exotic hard to machine/fabricate materials
  - Tightly controlled dimensions & tolerances

- **Producibility is a "design characteristic"**
  - Ease and economy of making item(s) at rate
  - Drives manufacturing inefficiencies and risk
  - F(fit, form, function, complexity, capability,..)

- **Need quantitative analytical design tools**
  - Make "hidden factory" costs & risks visible
  - Shape design vs. verify rule adherence

M&S Enabler for Producibility Prediction

Manufacturing Paradigm Shifts

- **Manufacturing is more than a constraint on design**
  - Need to define, allocate, and flow down producibility rqmts
  - Conflicting "user" vs. "producer" needs require trade-offs
  - Producibility the "kingpin" of system affordability and cost

- **Design for manufacturing needs to become a science**
  - Analytical basis needed for producibility similar to reliability
  - Design attributes drive manufacturing complexity & yield fallout
  - Methods needed to balance assembly vs. part complexity

- **System integration and test are now part of manufacturing**
  - Encompasses mechanical, electrical, and software disciplines
  - Extensive testing currently used to detect and contain defects
  - Bulk of component producibility problems discovered here….

Scope of Manufacturing has Changed

Summary and Conclusion

- **Producibility issues drive significant "hidden factory" costs**
  - **Neglected "ility" due to lack of analytical predictive tools**
  - **M&S capabilities needed to move manufacturing to the left**
  - **Primary lever to attack affordability during early design**

- **Advanced manufacturing M&S a critical research area**
  - **Quantitative product-centric analyses to guide design decisions**
  - **Supply chain analysis tools to predict industrial base behavior**
  - **Design methods that integrate manufacturing into trade space**

- **Vision is to create a "virtual manufacturing" environment**
  - **Fusion of marketing, engineering, & manufacturing disciplines**
  - **Manufacturing enterprise designed in parallel to the product**
  - **Producibility predicted, optimized, and traded as design evolves**

Thank You
Questions?

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