Economics of Digital Twins in Aerospace and Defense

SYSTEMS PLANNING & ANALYSIS

ICEAA International Cost Estimating & Analysis Association

ICEAA Southern California Chapter

SoCal Chapter In-Person Workshop

Wednesday, October 16 | 9:00am-5:00pm (pacific)

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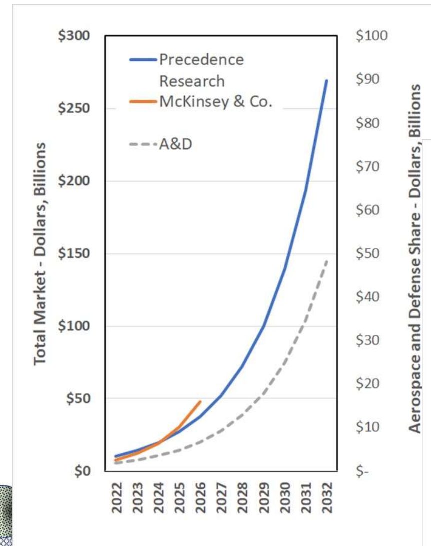
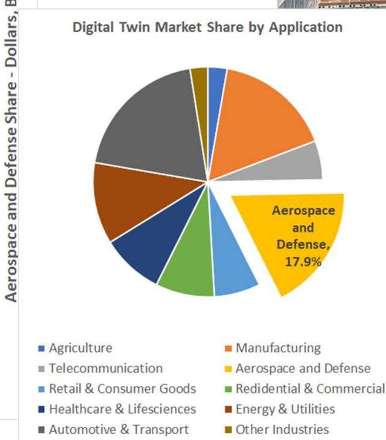
16 October 2024

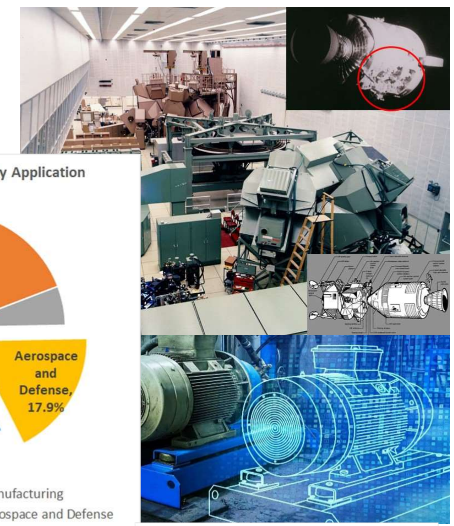
Originally presented at the ICEAA Professional Development & Training Workshop 14 – 16 May 2024, Minneapolis, MN

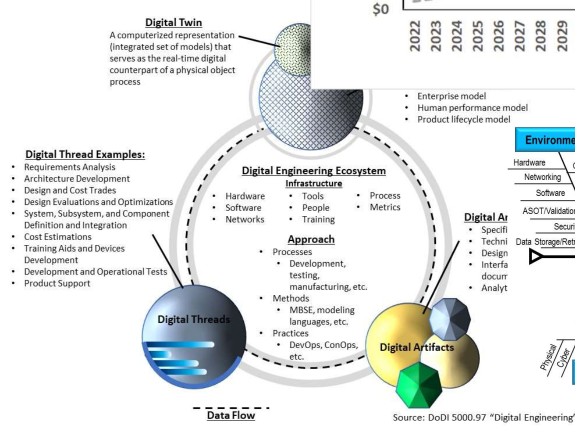
Agenda

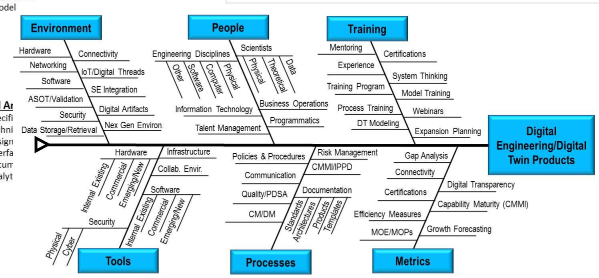
- Introduction
- Digital Engineering
- Digital Twin Investment
- Digital Twins in Aerospace and Defense
- Benefits and ROI
- Summary
- Future Work

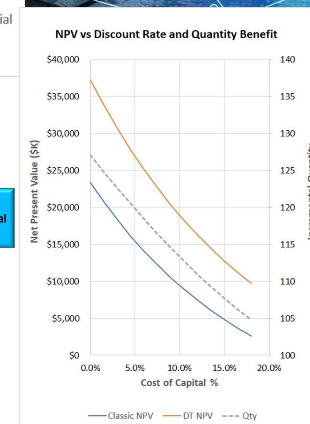






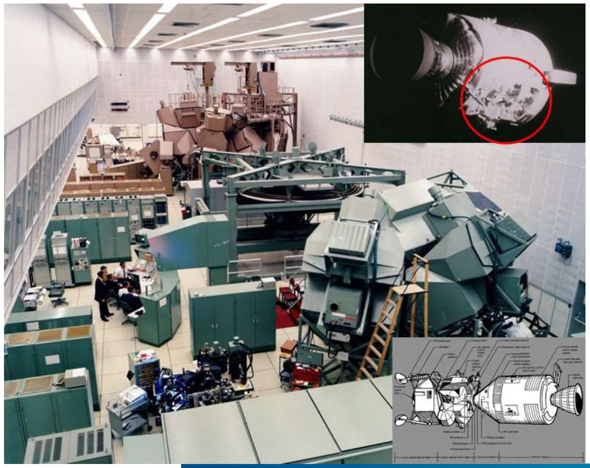




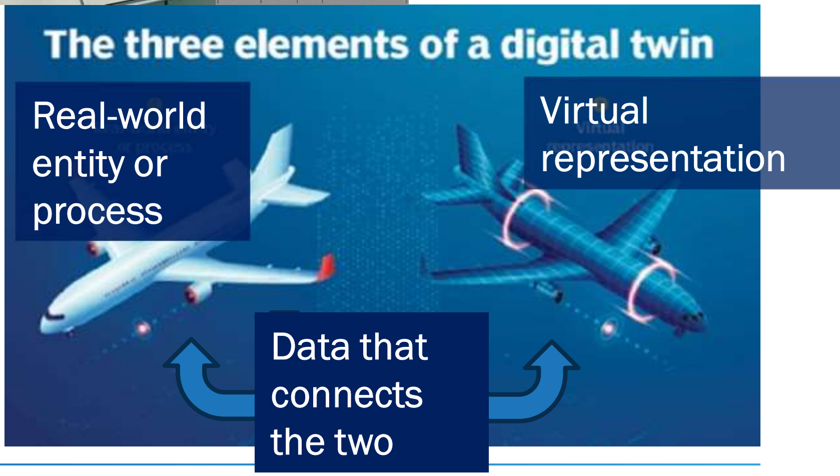


Introduction

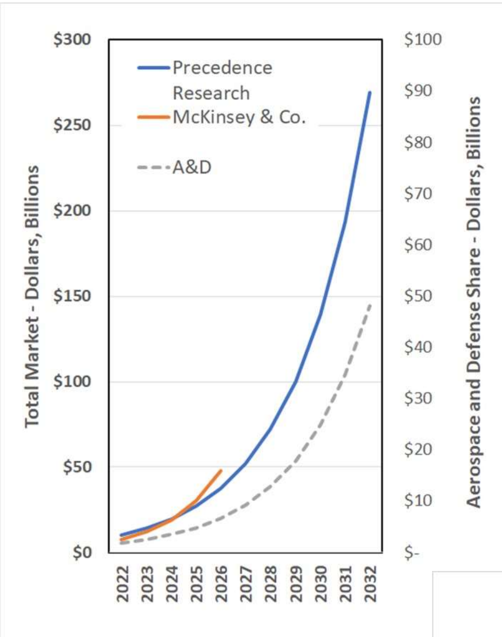
- Aerospace and Defense is in a digital transformation
- From Document to Model Based methodologies
- Use of Model Based System Engineering (MBSE)
  - Has significantly grown
  - Is cost efficient
  - Reduces development time to market
- Digital Twins are a Key element of MBSE
  - Bridge the gap between model and physical or process
  - Allow for what-if's with minimal cost and impacts
  - Can reduce total cost of ownership

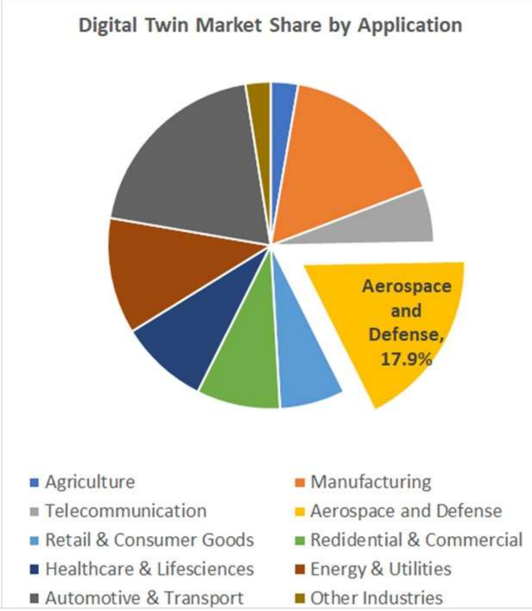


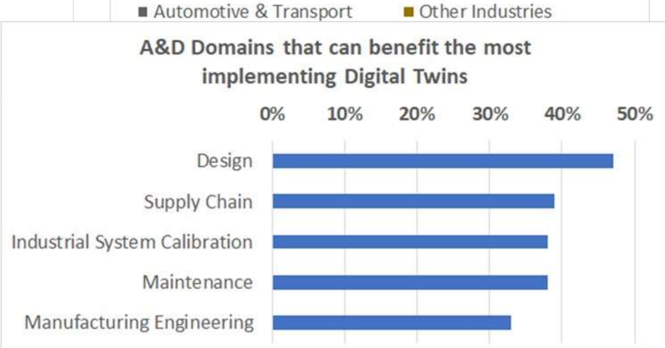
Apollo Simulators at Mission Control in Houston. The Lunar Module Simulator is in the foreground, the Command Module Simulator is at the rear. Image credit: NASA



Introduction (cont.)







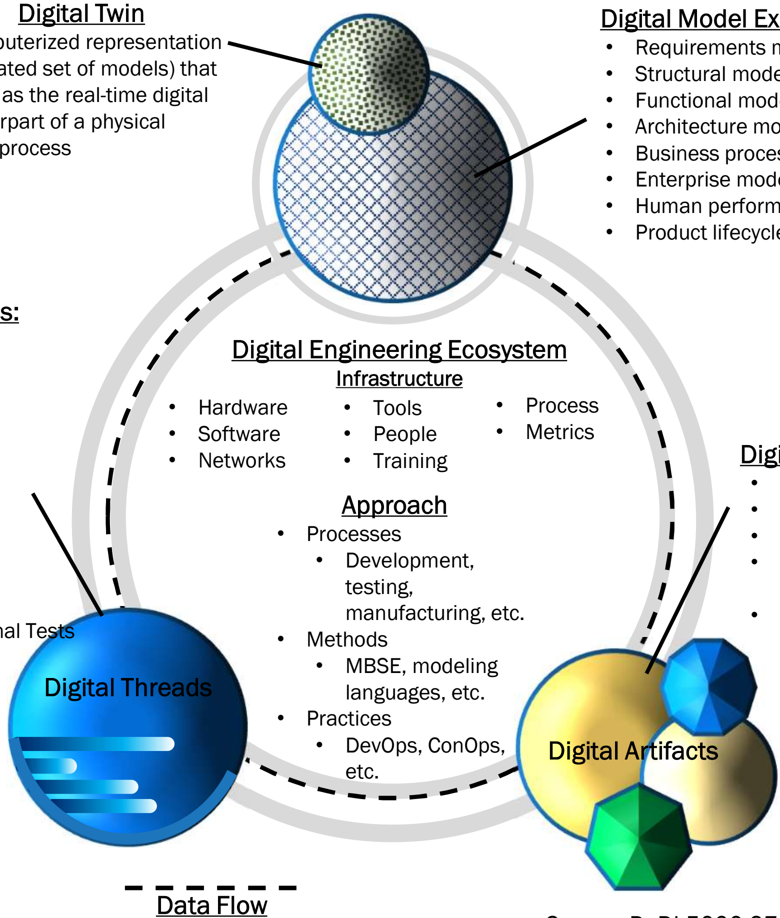
- Global Market Trends
  - In 2022 estimated to be $10.5B
  - By 2032 expected to be $269.1B
  - Market expected to grow 38.7% CAGR 2022 – 32
  - Aerospace and Defense 18% of market share
  - Largest market is in Asia Pacific Region
  - Fastest growing is North America
- Aerospace and Defense Anticipated Benefits in
  - Improved Design and Development
  - Improved Supply Chain and Logistics
  - Improved Calibration
  - Improved Maintenance
  - Improved Manufacturing

Digital Engineering

Digital Twin
A computerized representation (integrated set of models) that serves as the real-time digital counterpart of a physical object process

Digital Model Examples:
- Requirements model
- Structural model
- Functional model
- Architecture model
- Business process model
- Enterprise model
- Human performance model
- Product lifecycle model

Digital Thread Examples:
- Requirements Analysis
- Architecture Development
- Design and Cost Trades
- Design Evaluations and Optimizations
- System, Subsystem, and Component Definition and Integration
- Cost Estimations
- Training Aids and Devices Development
- Development and Operational Tests
- Product Support



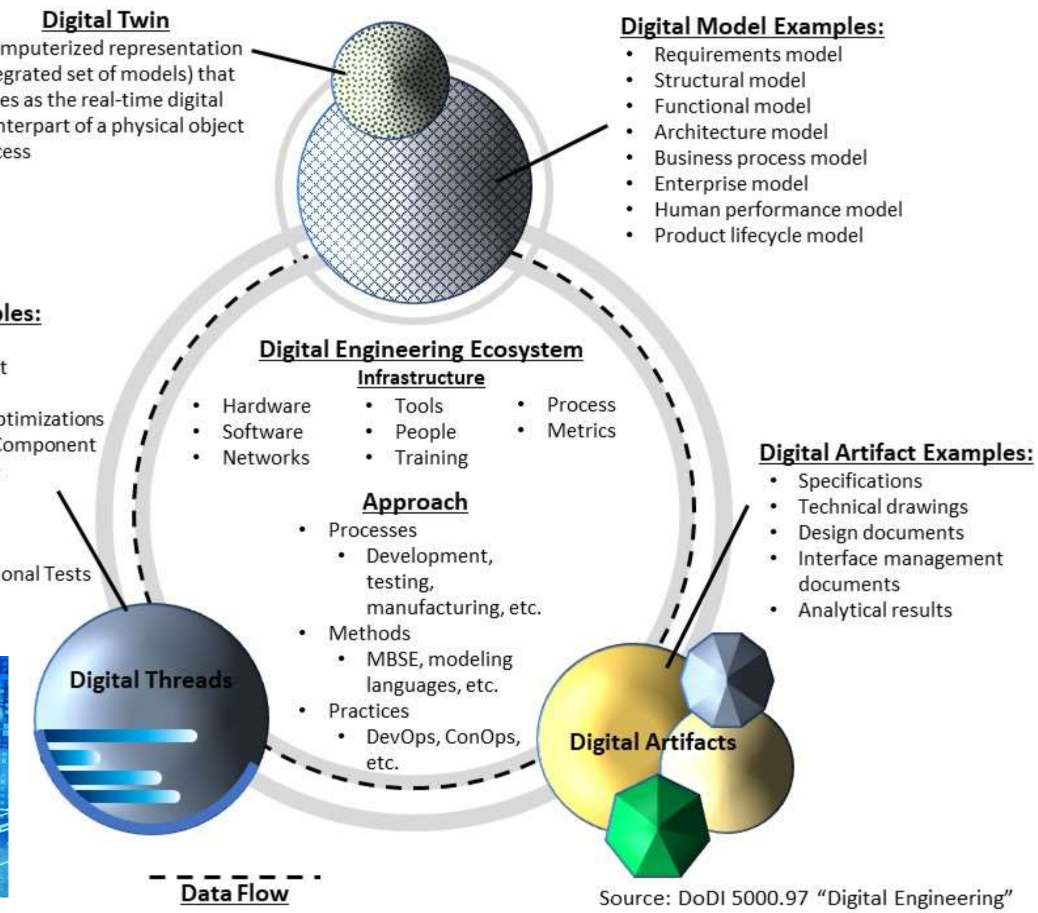
Digital Artifact Examples:
- Specifications
- Technical drawings
- Design documents
- Interface management documents
- Analytical results

Source: DoDI 5000.97 "Digital Engineering"

- DAU Definition
  - An integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal
  - MBSE and Digital Twins Support lifecycle analysis
- System Level Thinking
  - Foundational to MBSE and DTs
  - Is a holistic approach to analysis
  - Systematic framework for consistency and repeatability
- Digital Engineering Components
  - Infrastructure
  - Process, methods and practices

Digital Engineering (cont.)

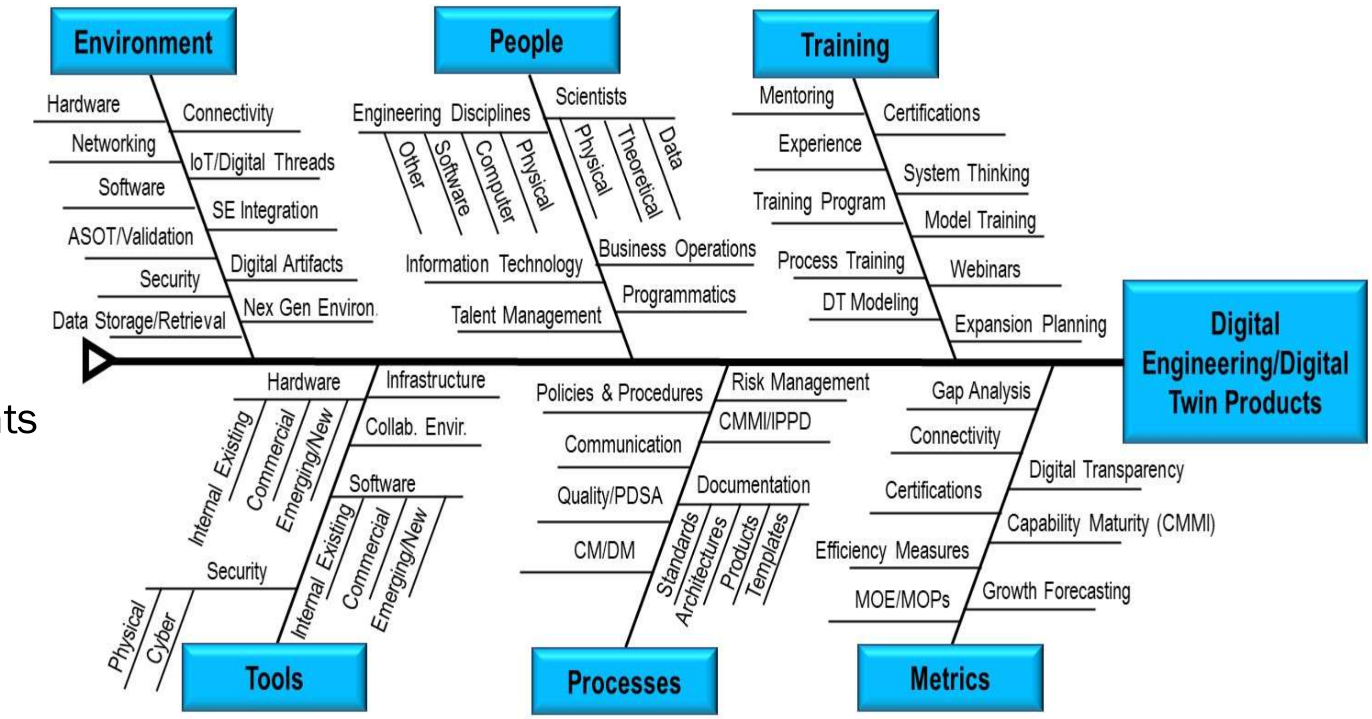
- Modeling, Analysis & Simulation (MA&S)
  - Modeling – Conception, Creation & Refinement of Models
  - Analysis – Process of systematic and reproducible examination to gain insight
  - Simulation – process of using models to predict and study behavior or performance of a SOI
- Digital Engineering Enablers
  - Digital Models
    - Purpose driven modeling
    - Digital Twins (Enabler)
  - Digital Artifacts
    - Supports traceability
    - Reproducible
  - Digital Threads
    - Bridges data using eco system
    - Contains lifecycle elements



Source: DoDI 5000.97 "Digital Engineering"

Digital Twin Investment

- Elements for developing a Minimum Viable Product (MVP)
  - Environment
  - Tools
  - People
  - Processes
  - Training
  - Metrics
- Includes Physical and virtual elements
  - Data and information
  - Validated source of truth
  - Data integrates easily with multiple models/tools
  - Supports single and multiple models (portfolio)



Digital Twin Investment (cont.)

Common Digital Model Types	
1	Requirements models
2	Structural models
3	Functional models
4	Business process models
5	Architecture models
6	Enterprise models
7	Physics-based models
8	Human performance models
9	Threat models
10	Product life cycle models

Common Digital Artifacts	
1	Design specifications
2	Technical drawings
3	Design documents
4	Interface management documents
5	Analytical results
6	Bills of material
7	Reliability/Availabiltiy forecasts
8	Software source code
9	Work breakdown structure
10	Production/machining instructions
11	Test planning and cases
12	Schedules
13	Budgeting
14	Product support strategy
15	Data flow diagrams

Common Digital Threads	
1	Requirements Analysis
2	Architecture Development
3	Design and Cost Trades
4	Design Evaluations and Optimizations
5	System, Subsystem, and Component Definition and Integration
6	Cost Estimations
7	Training Aids and Device Development
8	Development and Operational Tests
9	Product Support

- Environment
  - – Digital Models
    - Used to develop the framework
    - Understand system interdependencies
    - Provide data flow to communicate information
  - – Digital Threads
    - Used to bridge internal and external environments
    - Connect and coordinate models across the life cycle
    - Contains feedback loop, increase data flow relevance
  - – Digital Artifacts
    - Used to create and communicate work products
    - Implemented using standards, rules and infrastructure
    - Enables an executable programmatic structure
- Other Enablers
  - – Common and Specialty Tools, simulators & connectivity
  - – Processes and behavioral models (CMMI, IPPD)
  - – People, Training and Metrics and Reuse

Digital Twins in Aerospace and Defense

Source: https://3d-ace.com

Product

Process

Uncover Your Plant's True Capacity

Create, maintain and drive value out of online process model-based applications. Try out scenarios in a virtual environment before implementing the improvement using Honeywell's secure virtual sandbox – so you can experiment, compare and plan. Honeywell Process Digital Twin also provides a consistent and up-to-date view of plant capabilities across all functions and skill levels. Use it as a standalone solution or as a key enabler for plant wide optimization.

Source: https://www.honeywellforge.ai/

Network

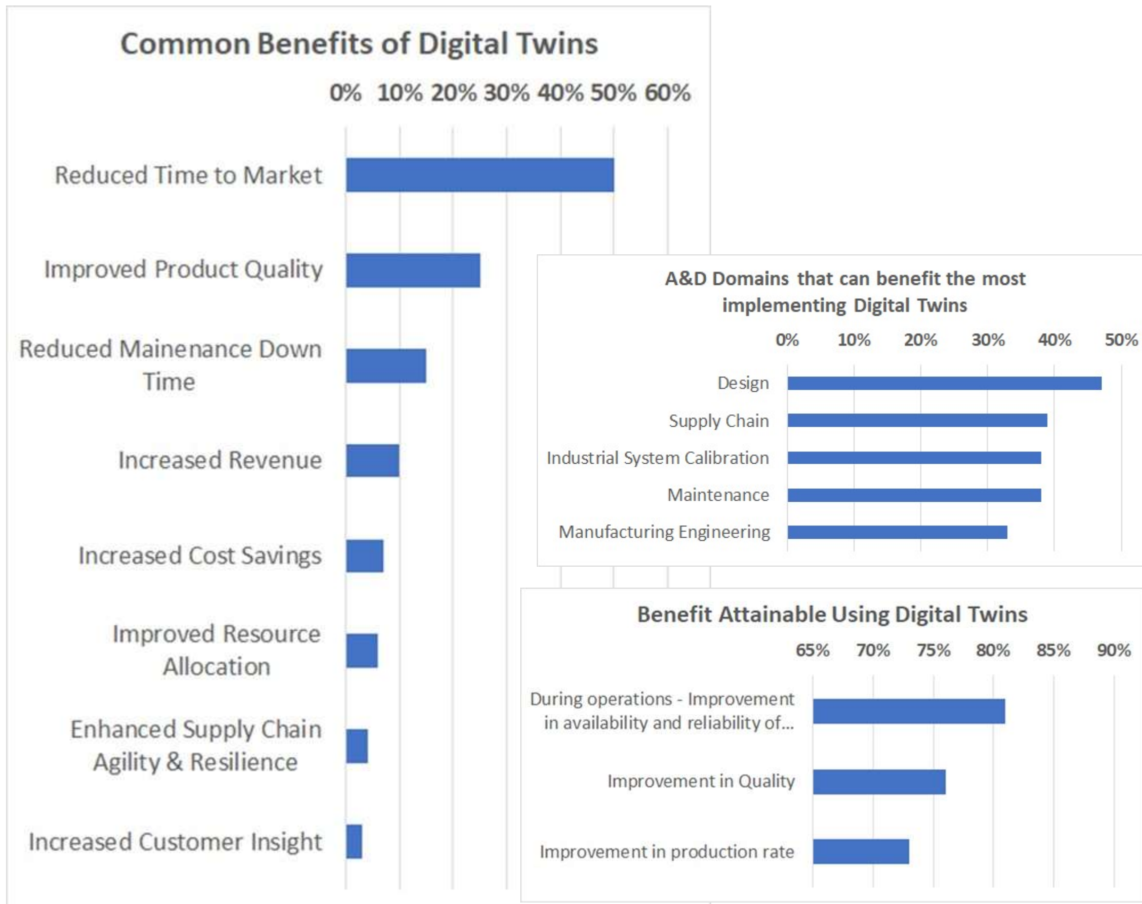
Seeing Double: How Digital Twins Are Being Used to Improve Network Design

Source: https://www.teoco.com

- Three Main types of Digital Twins suited to A&D
  - Product/Asset twins
    - Used for design and development
    - Enhances products features and capability
    - Reduces time to market
  - Process twins
    - Manufacturing related process, workflows
    - Optimization of resources to increase output
  - Network twins
    - Increases performance resiliency through simulations
    - Enhances supply and logistics chains
- Works well in Industry 4.0
  - High connectivity and smart sensors
  - Utilizes the "Internet of Things"

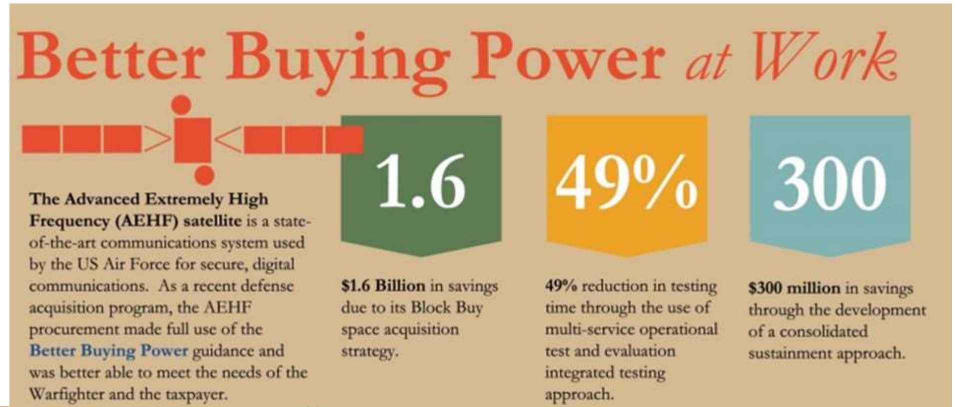
Benefits and ROI

- Recent research
  - Numerous organizations have stated benefits
    - Precedence Research
    - McKinsey & Company
    - Deloitte
  - Reduced time to market
  - Increased quality and reliability
  - Lower operating costs
- Other Benefits (soft benefits)
  - Design reuse and efficiency
  - Non-attributable simulations
  - Enhanced What-if cases
    - Testing
    - Environmental
    - Failure Mode Effects
  - Streamlined supply and logistics



Benefits and ROI (cont.)

- DT Benefit demonstrated
- How to quantify and qualify
  - Traditional Financial analysis ROI
    - Works for Industry and commercial organizations
    - Uses Net Present Value (NPV), IRR and Profitability Index (PI)
  - DoD and Government ROI
    - Harder to quantify due to multiple factors
    - A better approach is Better Buying Power
- Better Buying Power
  - Improve productivity
  - Value-Added activity
  - More capability (quantity of products)



Source: https://defenseinnovationmarketplace.dtic.mil/

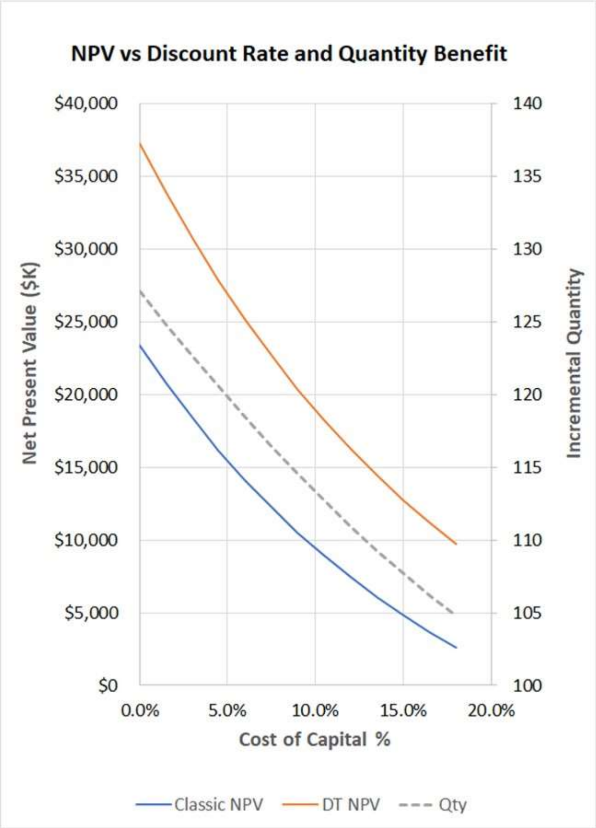
Benefits and ROI (cont.)

Investment Model

WBS	Segment	Values Classic ($K)	Digital ($K)
0	**Classic Vs Digital Twins**	**$47,650**	**$28,050**
1	*Investment Elements*	*($7,100)*	*($15,550)*
1.1	Environment	($3,500)	($5,200)
1.2	Tools	($3,600)	($7,200)
1.3	Process Development	$0	($2,050)
1.4	Training	$0	($1,100)
2	*Product Development*	*$54,750*	*$43,600*
2.1	Design	$2,800	$6,900
2.2	Development	$9,950	$8,050
2.3	Production	$15,000	$11,650
2.4	Operations/Sustainment	$27,000	$17,000

Analysis and Results

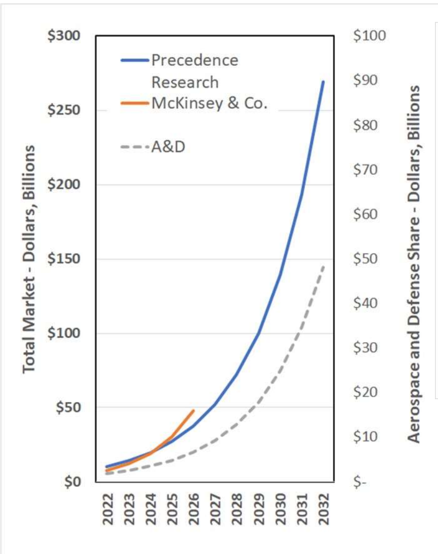
Discount Rate	Classic NPV	DT NPV	Qty	NPV Match	Benefit
0.0%	$23,400	$37,250	127	$37,250	1.32
1.5%	$20,785	$33,867	125	$33,867	1.31
3.0%	$18,379	$30,741	123	$30,741	1.31
4.5%	$16,165	$27,850	121	$27,850	1.30
6.0%	$14,126	$25,175	118	$25,175	1.30
7.5%	$12,247	$22,698	116	$22,698	1.29
9.0%	$10,515	$20,402	115	$20,402	1.29
10.5%	$8,917	$18,273	113	$18,273	1.28
12.0%	$7,443	$16,298	111	$16,298	1.28
13.5%	$6,082	$14,465	109	$14,465	1.27
15.0%	$4,825	$12,761	108	$12,761	1.27
16.5%	$3,664	$11,178	106	$11,178	1.27
18.0%	$2,591	$9,706	105	$9,706	1.26

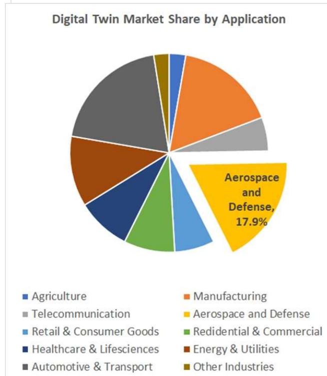


- Example Compare and Contrast
  - Government acquisition for improved Drone
  - Planned budget $50 – 80M
  - Minimum of 400 Units
- Compare Classic and Digital Development
  - Investment needed
  - Modeling and Simulation
  - Product Development
  - Production Costs
- Approach using Industry NPV
  - Model as if commercial
  - Compare NPV
  - Match Classic to Digital
  - Assess Better Buying Power Output (>25%)

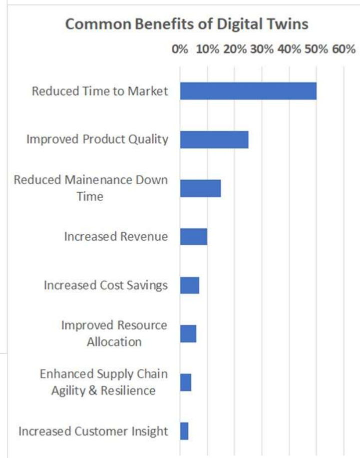
Summary

Market Growth

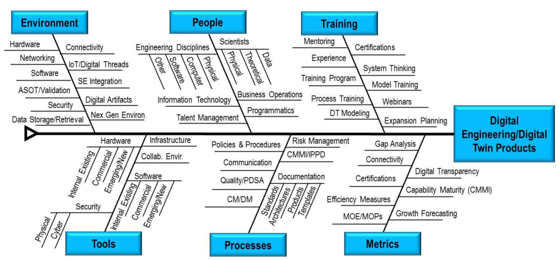




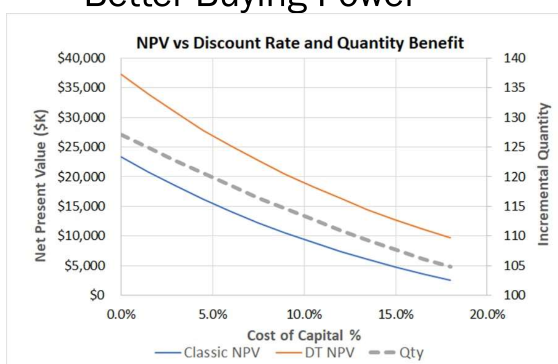
Benefits



Robust Infrastructure



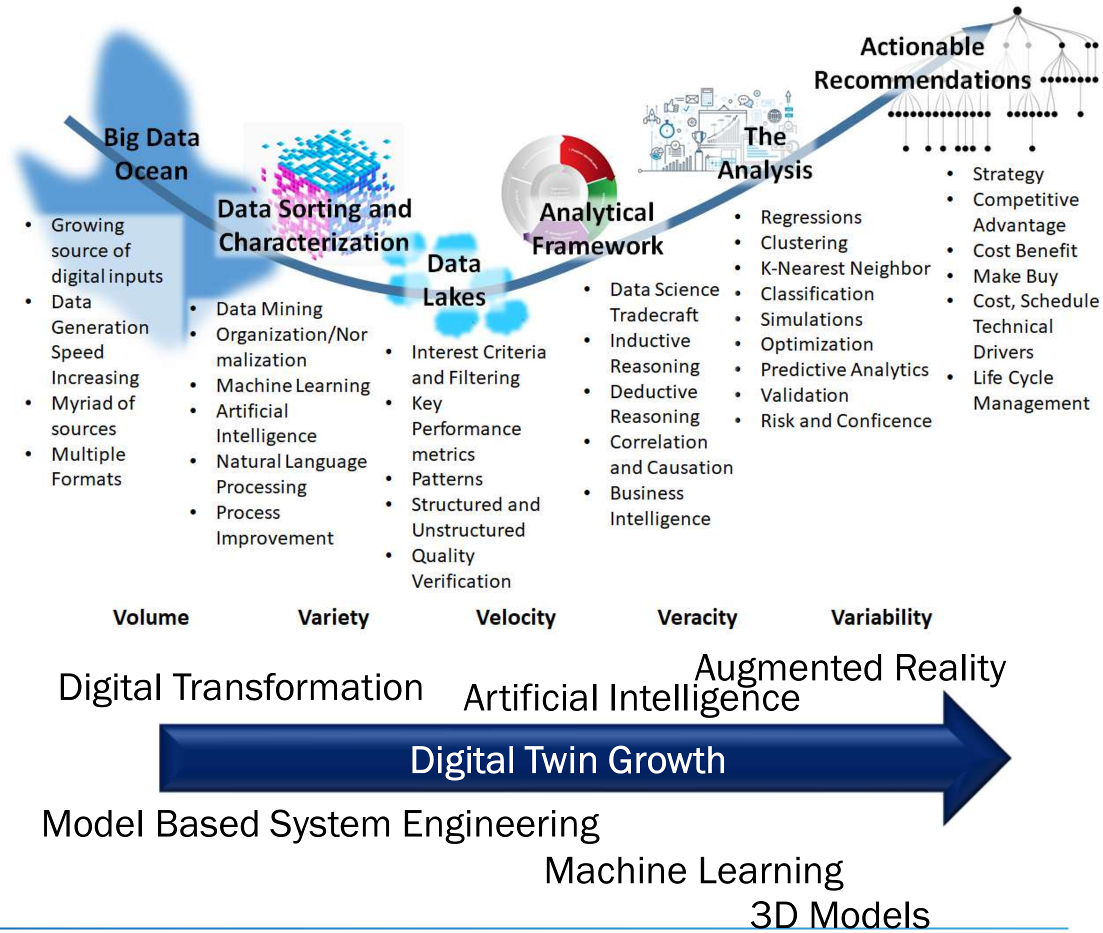
Better Buying Power



- Transitioning to a Digital Engineering
  - Requires a robust digital infrastructure
  - Explosive market for Digital Twin Development
  - Enables efficient use and reuse of MBSE and DT methods
- Implementing Digital Twins supports
  - Reduced time to market
  - Improved quality
  - Lower costs
  - Lower cost testing and evaluation
- Measuring Digital Twin benefits
  - Quantifying ROI in DoD is difficult
  - Using Better Buying Power helps solve this
    - More capability for the same budget
    - What-if Space enlarged to develop higher effectiveness

Future Work

- Digital Twin environment continues to expand
  - As more organizations see benefits
  - As more applications are available
  - Within Industry 4.0 and IoT
- Additional case studies to
  - Add fidelity to investigate wider range of modeling
  - Use Artificial Intelligence to support predictions
  - Apply machine and deep learning to expand trade space
  - Support 3D models and augmented reality



Questions

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Systems Planning and Analysis