Affordability Benefits of Digital Engineering

Agenda

- Hello from the OEM COG!

- Introduction to Digital Engineering
  - Terminology and Definitions

- Affordability Benefits of Digital Engineering on the T-7A RED HAWK APT Program
  - Industry Perspective from Brian Beyer

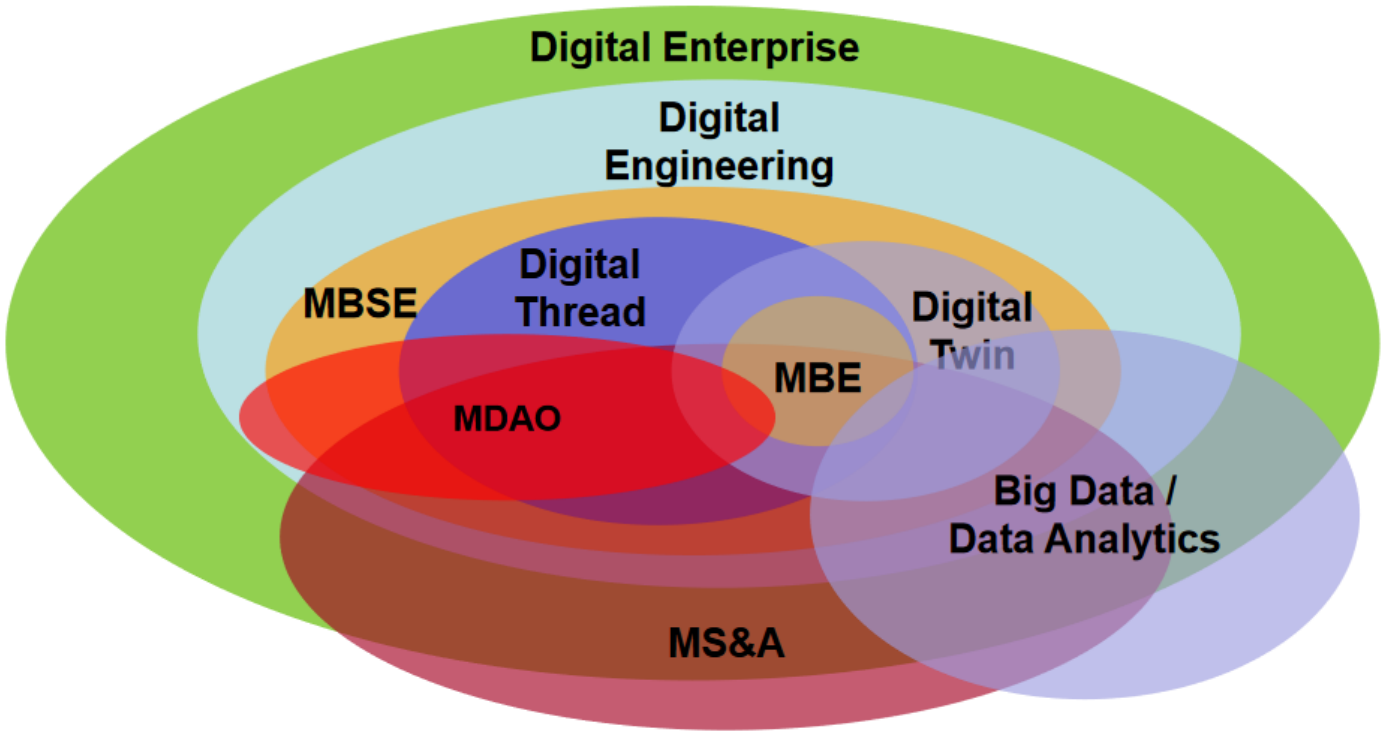
What is the ICEAA OEM COG

- **O**riginal **E**quipment **M**anufacturers' **C**ooperative **O**pportunities **G**roup
  - An industry consortium affiliated with ICEAA's cost & technical communities
  - Current participants include
    - BAE Systems, Ball Aerospace, Boeing, Huntington Ingalls Industries
    - Lockheed Martin, Northrop Grumman Corporation, Raytheon Technologies

- Our mission is to
  - Create a dialogue between ICEAA and our OEM members
  - Explore ways ICEAA can provide support & solutions tailored to our OEM community
  - Provide a forum where OEM members can communicate & share best practices
  - Advance the technical interests of the OEM cost analysis profession

ICEAA OEM COG

Digital Enterprise Ecosphere



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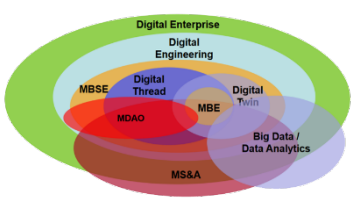
NOT TO SCALE

Source:
US Air Force Digital Enterprise Global Product Data Interoperability Summit 2018
Col Paul Harmer, PhD, Deputy Director Engineering, AFMC
Dr. Paul Hartman, Former Director, Ctr Ops Analysis, AFIT

Digital Engineering (DE)



- An integrated approach to building trusted sources of data and models that are used in a continuum across engineering disciplines. Digital Engineering is used throughout the lifecycle of a program from conception through decommissioning.

- An integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal.

- Digital Engineering aims to modernize and achieve efficiency and consistency in engineering and leverages the use of computer models and data to integrate engineering tasks across disciplines, virtually, before going to production.

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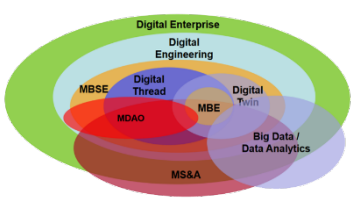
From Public Sources, Professional Organizations, DoD, Industry OEMs

Model-Based Engineering (MBE)



- Treats models as an integral part of the technical baseline (as opposed to documents). MBE is an overarching term that includes Systems Engineering-related MBSE, Business Analysis/Process-related BPM, and Knowledge Engineering-related Ontology Engineering.

- An approach to engineering using models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition lifecycle.

- Virtual representations (models) of a product that accurately reflects the geometry and behavior of the physical product they represent ... the authoritative source of the product definition for use in manufacturing and maintaining the product throughout its lifecycle.

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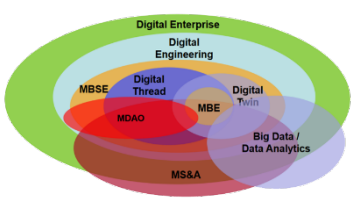
From Public Sources, Professional Organizations, DoD, Industry OEMs

Model-Based Systems Engineering (MBSE)



- The formalized application of modeling functions, requirements, interfaces, and architecture to support system engineering activities. MBSE improves knowledge capture and communication to improve SE execution.

- The formalized application of modeling to support system requirements, design, analysis, verification & validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.

- Using system models to support requirements in design, analysis, V&V in the early stages of design; aspects of MBE specifically associated with SE; includes behavioral analysis, system architecture, requirement traceability, performance analysis, simulation, test, etc.

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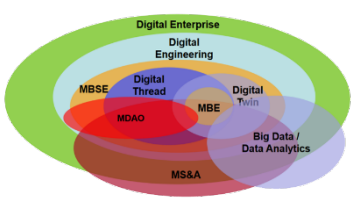
From Public Sources, Professional Organizations, DoD, Industry OEMs

Digital Thread



- A communication framework that connects traditionally siloed elements in design, manufacturing and support, and provides an integrated view of an asset throughout its lifecycle
- Digital connections among authoritative, historical, & cross-discipline technical data; ... throughout a product's life cycle.
- Complete collection of data & information that ties the virtual representation and physical object that flows through the entire production lifecycle.
- A communication & data flow framework that allows an integrated view of a product across its entire lifecycle.... an unbroken link from the original computer model to the final physical product... full traceability and connectivity from concept through design, manufacturing, and service.

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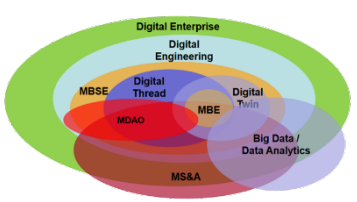
From Public Sources, Professional Organizations, DoD, Industry OEMs

Digital Twin



- A virtual representation that serves as the real-time digital counterpart of a physical object or process.
- A virtual representation of a physical object or system to enable understanding. The digital twin stores all of the knowledge about an asset, from its inception through its manufacture and service life.
- A virtual representation of a physical object or process.... [used to] test and validate products in a virtual environment before the products even exist in the real world... give engineers early warning of product failures to prevent unplanned downtime and improve product performance. ...Once it exists, can be used to troubleshoot failure conditions, assess impact of new mission environments, and evaluate product improvements.

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From Public Sources, Professional Organizations, DoD, Industry OEMs

Affordability Benefits of Digital Engineering on the T-7A RED HAWK APT Program

Brian Beyer
Technical Fellow in Systems Engineering
The Boeing Company

T-7A Red Hawk
Advanced Pilot Training Program
Affordability Benefits of Digital Engineering

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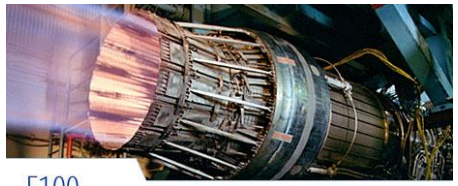
Brian is a Senior Principal Systems Engineer in BDS currently assigned to Development Excellence and BDS Bombers and Fighters SEIT team. He was most recently on the BDS PE and OpEx Team serving as a Start Right Leader to BDS Development Programs. Prior to this, Brian was on the MQ-25 program developing and implementing the program's cost to win strategy and served as the T-X Affordability Lead Engineer from concept development to proposal submittal. In past roles he has served as an affordability [and Lean + leader] for the Training Systems division of BGS, lead for Direct Attack Weapons Affordability/ Lean team, lead of the FCS MGV Affordability team, and senior engineer for F/A-18 Producibility team. Brian is a certified VSM Leader, L+DBR Consultant, and Six Sigma Black Belt. He is a metallurgical engineer from MS&T and has a MS in System Engineering. Brian is an avid cyclist, enjoys coaching FIRST Robotics, and camping with the boy scouts. He and his wife, Vanessa, have 3 children and live in St. Louis, MO.



Metallurgical Engineer with SE Masters

Six Sigma Process Excellence

FUTURE COMBAT SYSTEMS
FCS
One Team-The Army/Defense/Industry

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Agenda

- **Current State of Digital Engineering**
- **Digital Engineering at Boeing**
- **T-7A Program Overview**
- **Model Based Value/ Benefits**
  - Development
  - Production
  - Sustainment
- **Digital Engineering is a Journey**

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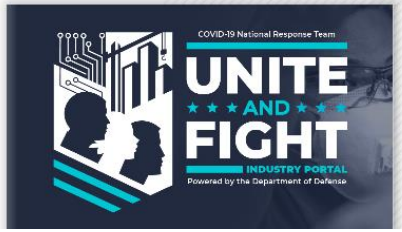
What's going on with AF Acquisition, Technology, Disruptive Agility?

- **Digital Trinity – Digital Engineering, Agile Software, and Open Architecture**
- **AFWERX: AF Ventures, SPARK Innovation, PRIME Transition**
- **Become an "Innovator in Tech": "Commercial" AF and Space Force**
- **Artuu – AI assisted Pilot (R2D2), Autonomy**
- **Kubernetes and Edge Computing, Hackathons**
- **Quantum Computing/ Effects**
- **"*eCreate before you aviate*" – F1 teams use digital twin to optimize virtually**
- **Build it "virtually, 100 times" – *e*T-7A first AF "all digital, *e-series*" program**
- **Fighter Planes are a thing of the past** *(E.Musk)*
- **Era of "volatility"… "the only sustainable advantage we have is Agility!"** *(J. Bezos)*

AFWERX
AFVENTURES
Leverages commercial innovation and investment to solve problems

AFWERX
PRIME
Identifies and primes nascent tech sectors

AFWERX
SPARK
Empowers Airmen and Space professional innovation



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T-7A Digital Engineering

- **Digital engineering is an approach that takes traditional engineering processes used to develop, fabricate, build, test and produce a system and places them in a *digital collaborative environment that leverages a single source of design data, interconnected models, analysis, and simulation***

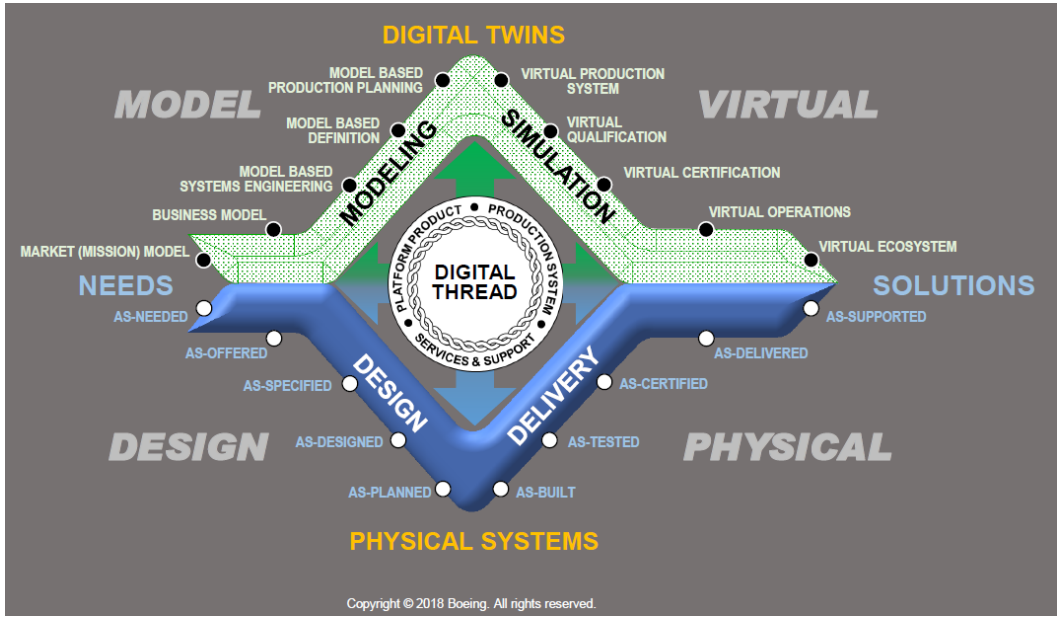
- **The use of digital engineering on T-7 has reduced the time and cost to develop, fabricate, build, test and produce the APT system**

  - Increasing collaboration among the many different stakeholders involved

  - Integrated Models make it easier to share and re-use design and analysis data

  - Allows the team to build and test the system virtually prior to fabrication and assembly

  - Reduce/eliminate errors by having one common source of truth (design data)



https://gpdisonline.com/wp-content/uploads/2018/09/Boeing-DanielSeal-The_System_-Engineering_V_Is_It_Still_Relevant_In_the_Digital_Age-MBSE-Open.pdf?pdf=Boeing-DanielSeal-The_System_-Engineering_V_Is_It_Still_Relevant_In_the_Digital_Age-MBSE-Open
Source: Dan Seal (Boeing MBE transformation)

Boeing T-7A Advanced Pilot Training

Play Video #1
Hi AoA, MBE

Purpose Built – Aircraft

- Designed for AETC
- Advanced cockpit
- Stadium seating
- Fighter-like performance
- Safe, stable, fly-by-wire controls

Purpose Built – Ground Based Training

- Highly immersive training
- Offload skill development
- Complete advanced training solution
- Embedded training

Purpose Built – Support

- Designed for the maintainer
- High wings
- Easy reach access panels
- Fewer / common fasteners
- Modular seat maintenance
- Easy seat changes
- Quick engine changes

Flexible for Future Growth

T-7A Aircraft Features & Affordability Benefits

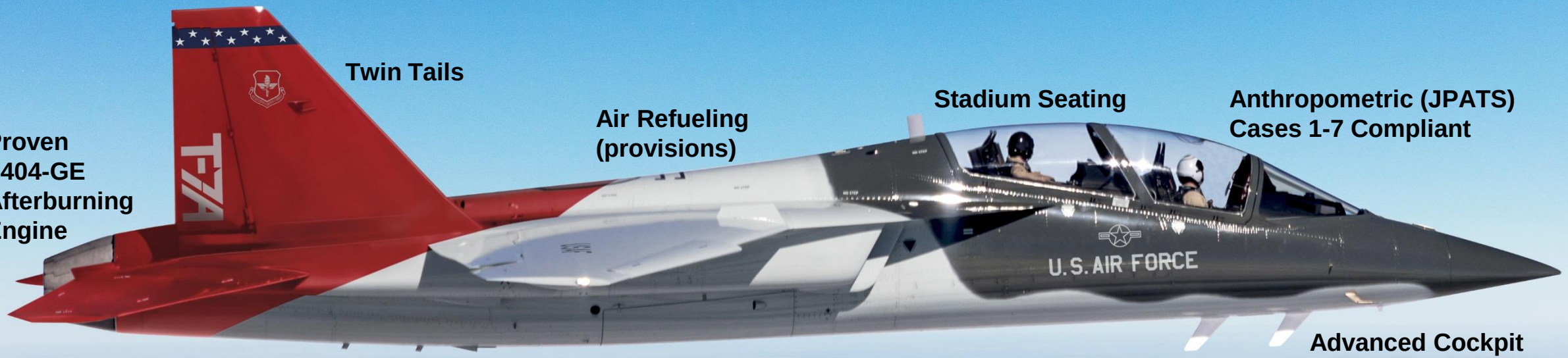
Twin Tails

Proven F404-GE Afterburning Engine

Air Refueling (provisions)

Stadium Seating

Anthropometric (JPATS) Cases 1-7 Compliant



Digital Fly-by-Wire Flight Controls

Maintenance-friendly design

Trailing Edge Flaperons

Cambered Wing

Leading Edge Slats

Leading Edge Extension (LEX)

Advanced Cockpit

Digital Glass Cockpit
Reconfigurable Large Area Display
Open Systems Architecture

Next Generation Affordable Training

Design – Build Integration

- **T-7A was designed with all of the engineering functions engaged, but also manufacturing operations, test, and support and sustainment folks.**

https://www.defensedaily.com/digital-engineering-leads-fast-joining-t-7a-forward-aft-fuselage-boeing-says/air-force/
https://aviationweek.com/awin/program/400850#

75% improvement in first-time engineering quality, 50% reduction in software development time and 80% reduction in assembly time

Advanced Pilot Training System – Ground Based Training

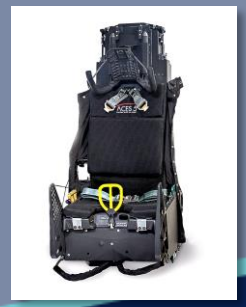
Common Software Environment

Ground Egress Trainer

Operational Flight Trainer

Weapon System Trainer

Part Task Trainer



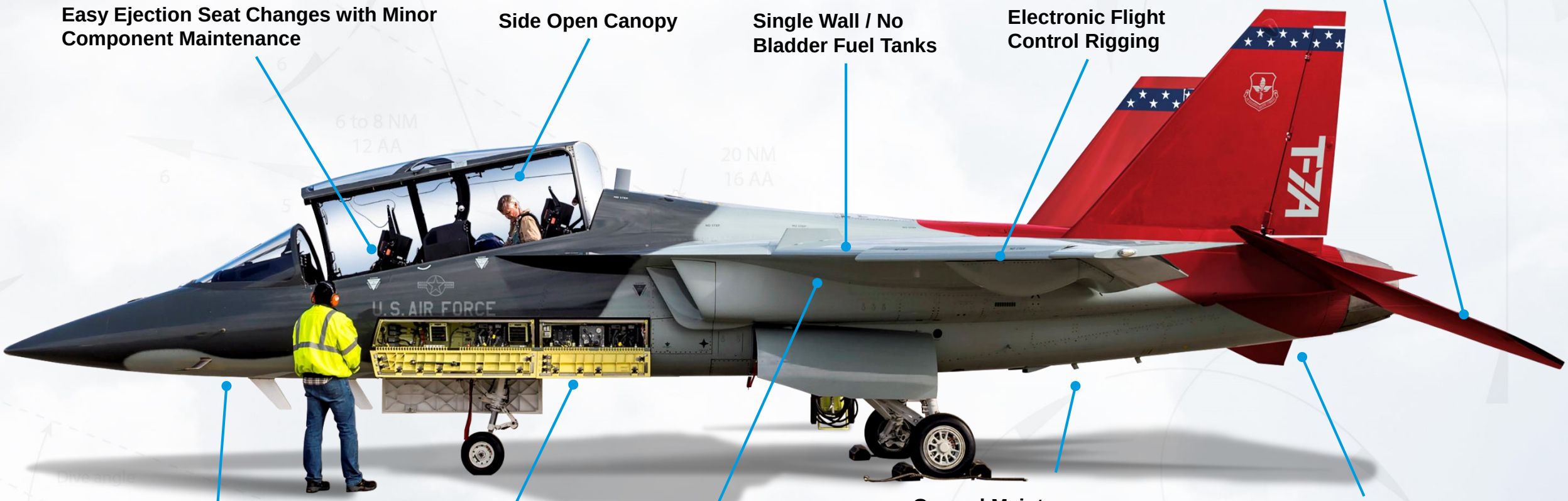
Ejection Seat Trainer

Unit Training Device

Mission Debrief Station

Play Video #2
Engine Shut-off

Purpose Built With Maintainers in Mind



Accessibility + Maintainability + Availability = Pilot Throughput

https://www.aflcmc.af.mil/News/Article-Display/Article/2787616/virtual-reality-brings-t-7a-tasks-to-life/

Q & A

Digital Engineering

Questions and Discussion

Back-up Info

- **Reference information (from public webpages)**

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Digital Planes (Digitally Engineered program)

- Boeing's Red Hawk trainer jet is the first plane to earn an "e" designation, as the eT-7A
- "The service acquisition executive will determine whether an acquisition program meets the digital acquisition threshold," Air Force spokeswoman Ann Stefanek said. If a system qualifies for the 'e' in development, it will drop the designation when it begins production.
- Digital Engineering involves creating a nearly perfect virtual model and environment to learn and experiment so that the physical system is fully integrated and tested before it is producted. Digital Engineering is more that just using computers – it involves creating a digital thread connecting the digital twin models to make authoritative virtualization and reality.
- Digital Engineering provides us the ability to create, modify, test, assemble, and experiment in the virtual world before ever bending metal in a physical world.
- The Digital Trinity of the air force includes Digital Engineering, Agile Software, and open architectures.

https://www.airforcemag.com/air-force-introduces-e-planes-for-the-digital-era/
https://www.af.mil/Portals/1/documents/2021SAF/04_Apr/FY19_FY20_Dept_of_the_Air_Force_Acquisition_Biennial_Report_final.pdf

Background info on e-Series designation (no longer in vogue)

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Understanding Acquisition Trends

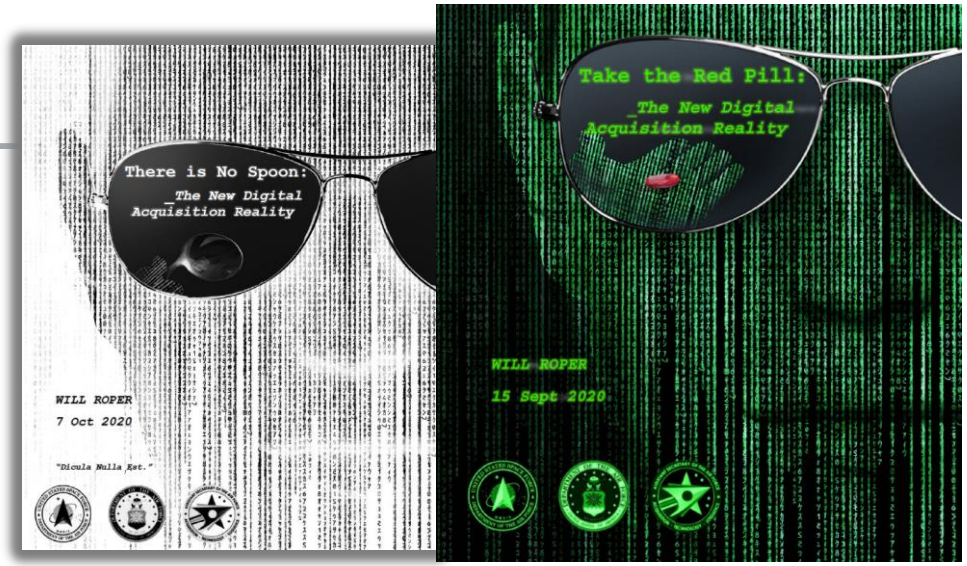
Dr. Will Roper – Asst Sec. of Air Force Acquisition (2020)

- "Digital engineering is a harbinger of a new type of acquisition that can save the DoD. Build fast, cheaper, and with less risk. *T-7 hit quality curve on first unit that normally would take 100 units – allows to get way down learning curve without the same cumulative quantities.*

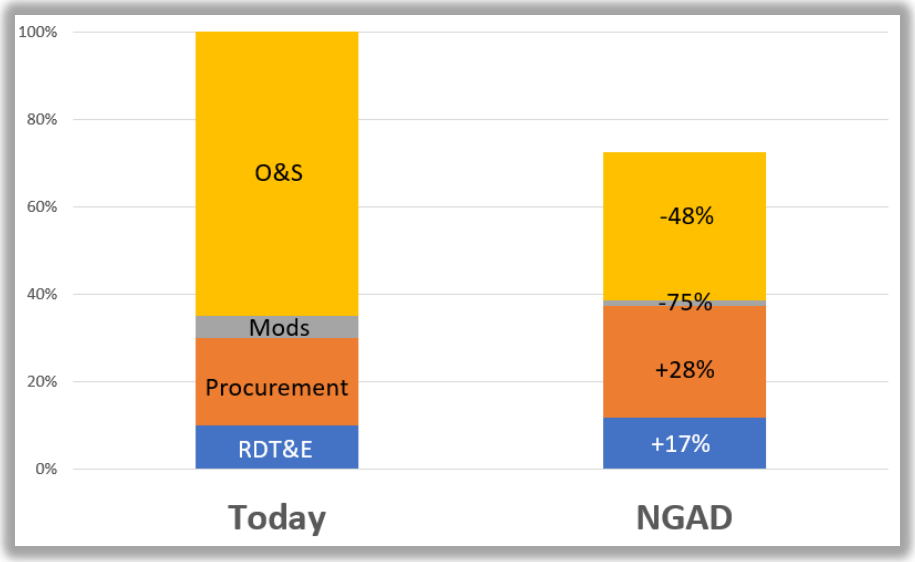
- If build faster and more iteratively, don't need mass production. Opens door to shift more cash flow into design, rather than O&S. This is at core of how US will compete against China.

- Digital engineering - first thing Roper's seen that shifts profit and cash flow opportunities back into design, rather than having that in *production and O&S*. "**DoD is like a hospital with a very small pediatric wing, and very large geriatric wing**."

Bending the Spoon: Digital Engineering Guidebook



Oct 7th revision "There is No Spoon"
Will Roper's Paper akin to "The Matrix"



Desired Paradigm Shift for NGAD

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Definitions

Model-Based Enterprise

AN ORGANIZATION that applies modeling & simulation technologies to integrate and manage its technical and business processes (NIST)

TRANSFORM BOEING to a Model-Based Enterprise (industry 4.0)

DIGITAL Boeing Business Capabilities

Model-Based Engineering

AN APPROACH to product development, manufacturing, and lifecycle support that uses a digital model and simulation to drive first time quality and reliability (NIST)

CONNECT VALUE-STREAMS for digital lifecycle data-flow (digital thread)

ARCHITECTED digital work/ info-flow

Model-Based Systems Engineering

EXECUTION OF DISCIPLINE (Systems-Engineering) using digital model principles for system-level modeling & simulation of physical and operational behavior throughout the system lifecycle (INCOSE)

EMPLOY System-level modeling & simulation (digital twin)

SIMULATED digital work/ info-flow

Model-Based Definition

A PART'S DEFINITION using a 3D model. May define feature and part characteristics within the 3D model. Industry format standard: ASME Y14.41. Boeing format: BDS-600

DEFINE product using 3D model standards

FULLY DIMENSIONED definition

Model-Based Instructions

GRAPHICAL DISPLAY of information necessary for build/assembly, including MBD engineering intent (process specs, geometric dimensions & tolerances, etc.) (NIST)

BUILD product using 3D model standards

FULLY DIMENSIONED product

NDIA National Defense Industrial Association

INCOSE International Symposium

NIST National Institute of Standards and Technology U.S. Department of Commerce

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