THE AFIT OF TODAY IS THE AIR & SPACE FORCE OF TOMORROW

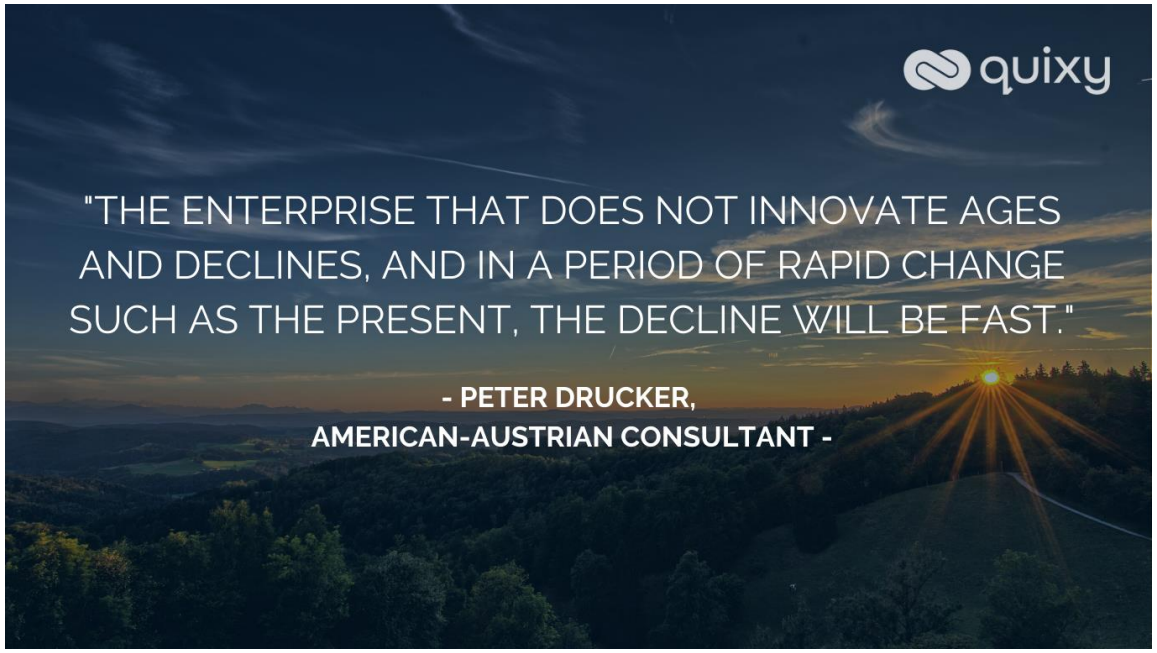
AFIT Digital Innovation & Integration Center of Excellence
DIICE – "We put the odds in your favor"

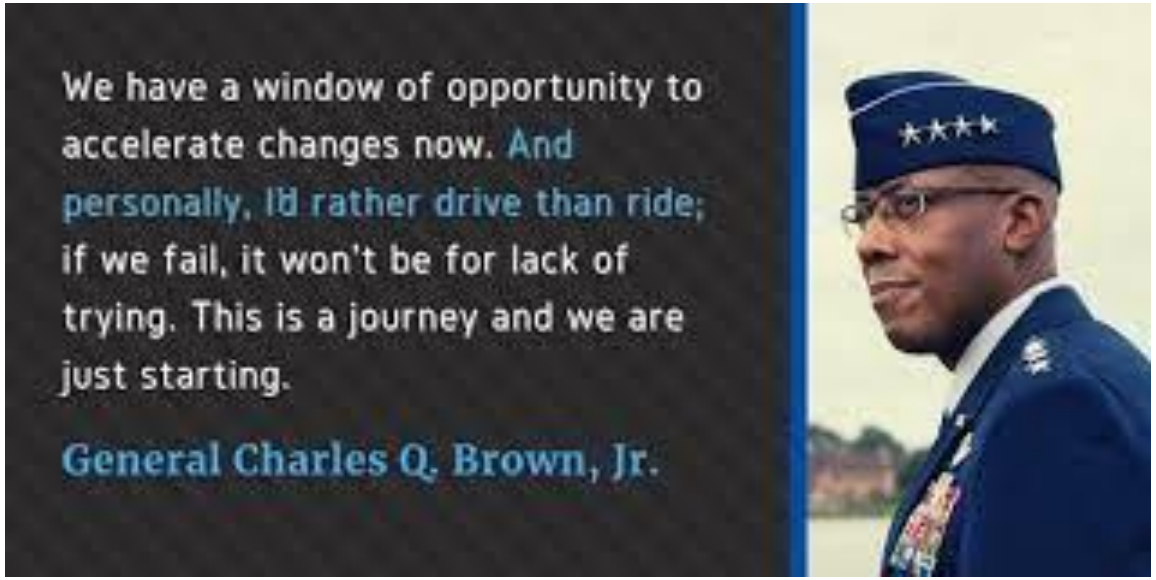
Col Jason Anderson, PhD, AFIT/EN (Director)
Mr. Rick Sugarman, AFIT/LS (LS Lead)
LtCol Amy Cox, PhD, AFIT/EN (EN Lead)
LtCol Paul Beach, PhD, AFIT/EN (Deputy)

First-Thank you

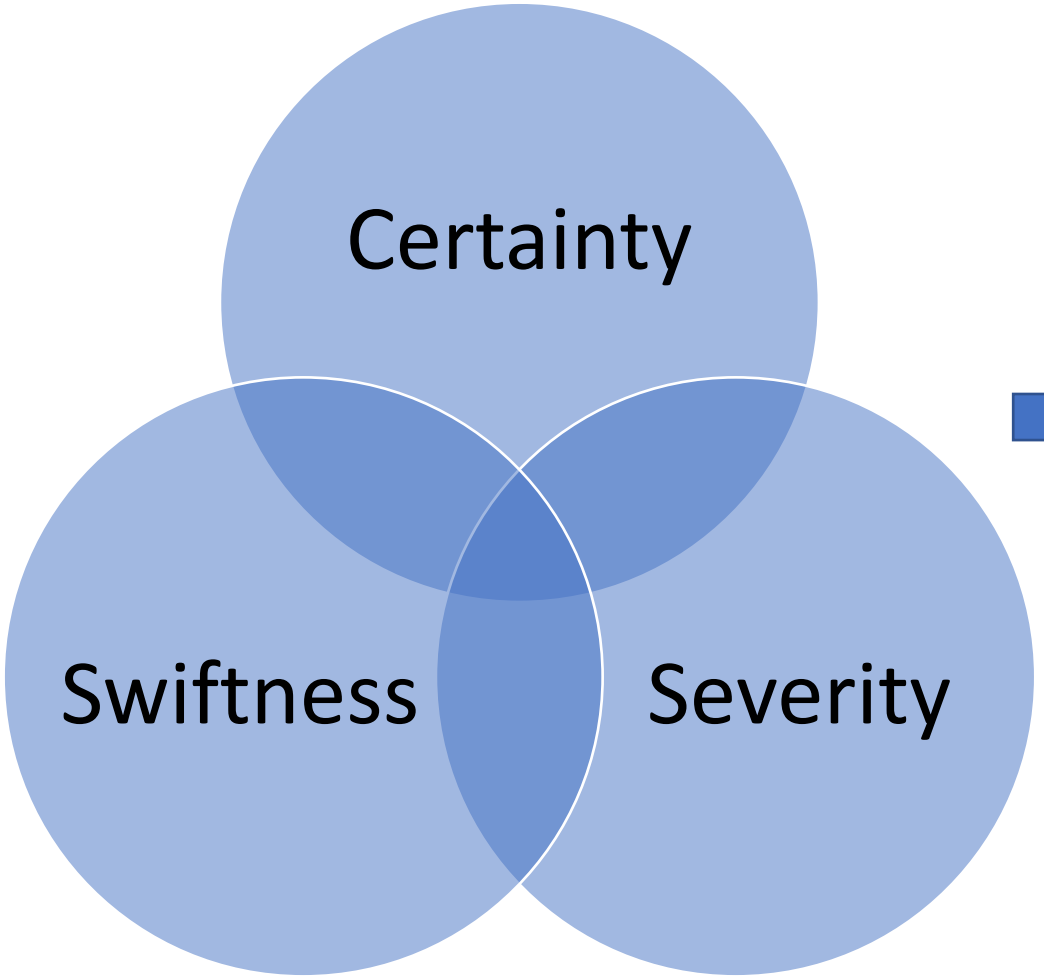
- It has been a long road, but all those previous efforts have been instrumental in standing up the Digital Innovation and Integration Center of Excellence. Thank you for all the help!
- Thank you to AFMC for providing the resources necessary for DIICE

Why Digital


quixy
"THE ENTERPRISE THAT DOES NOT INNOVATE AGES AND DECLINES, AND IN A PERIOD OF RAPID CHANGE SUCH AS THE PRESENT, THE DECLINE WILL BE FAST."
- PETER DRUCKER,
AMERICAN-AUSTRIAN CONSULTANT -


We have a window of opportunity to accelerate changes now. And personally, Id rather drive than ride; if we fail, it won't be for lack of trying. This is a journey and we are just starting.
General Charles Q. Brown, Jr.

Principles of Deterrence

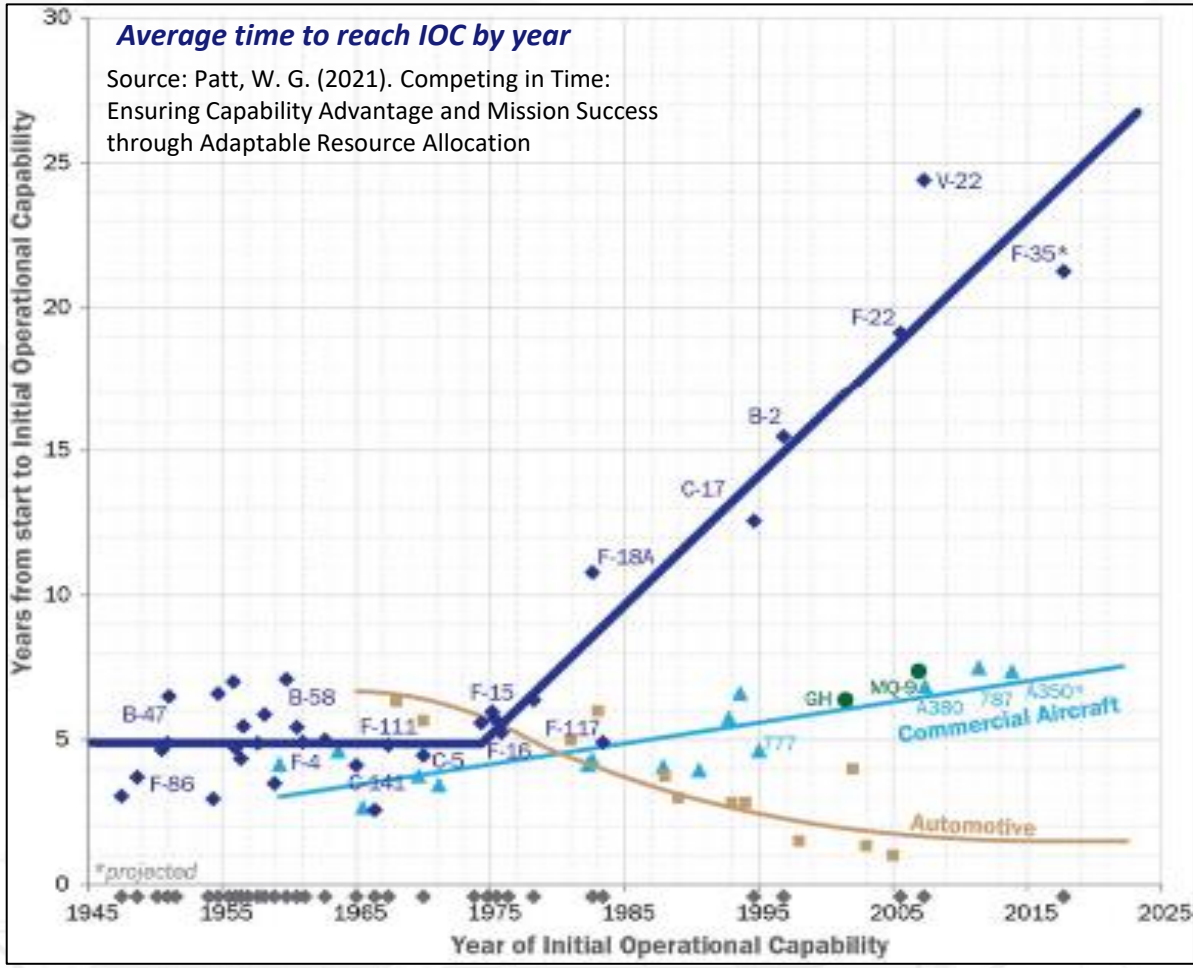


Certainty, swiftness, and severity are all predicated on your **capability** compared to your enemies

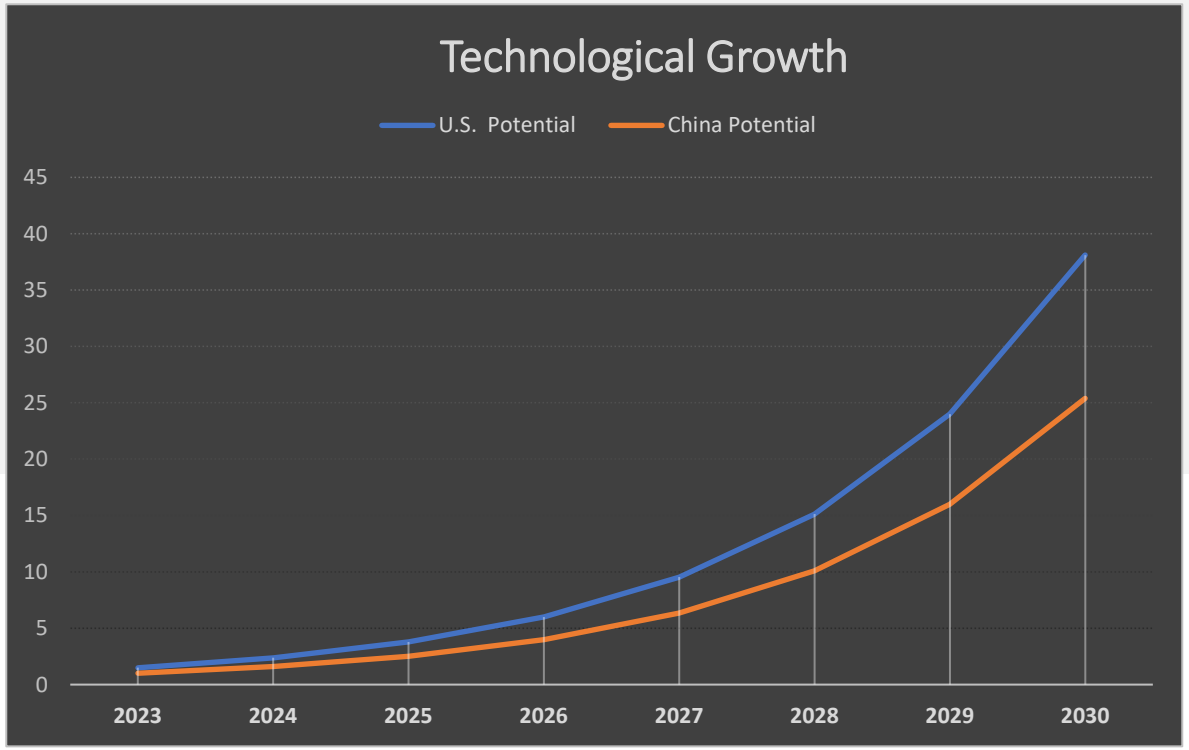
Competing in Time

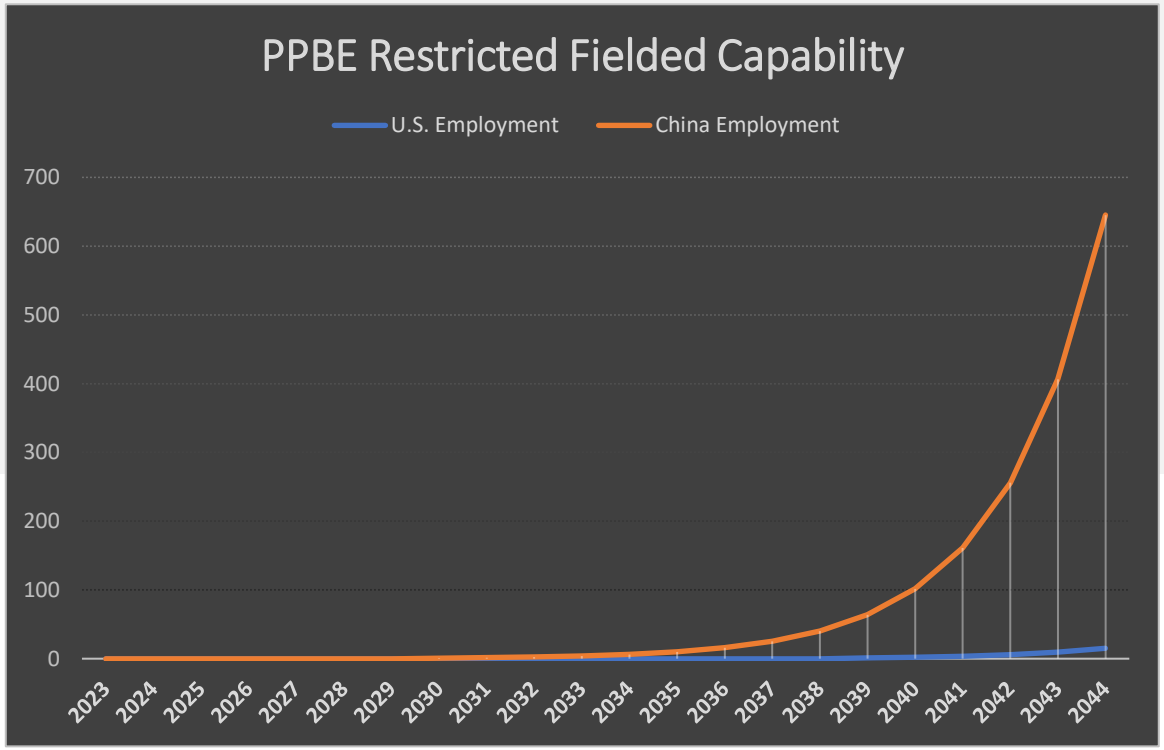
- "it takes the **US on average sixteen years** to deliver an idea to operational capability, versus **fewer than seven for China**"
- "The **PPBE's inflexibility increases the difficulty of rapidly shifting funding to emergent innovations**"
- "Defense acquisition process and legacy defense industrial base approach struggle to accommodate timely adoption of these emerging technologies"
- "**Competitive advantage** in decision-centric operations (whether budgeting or on the battlefield) **comes from the scale of available options, tempo of decision-making, and superior decision processes**"

Digital Transformation yields smarter, faster decision making; but flexible funding and agility in HOW we resource is essential



Competitive Advantage





1.5x

U.S. Technological Advantage

+

16 Year PPBE US

Or

7 Year PPBE China

=

42.6x

China Capability Advantage

Better Capability, Faster

Research | Develop | Design | Test | Supply | Sustain | Maintain | Retire

Prototype | Requirements | Analysis | DT & OT | SLEP | Modernize | DMSMS

Skyborg

- First flight in 36 mo from concept dev.
- Modularity enables >10 variations
- Digital models enables rapid design/test/validate cycles w/warfighter feedback

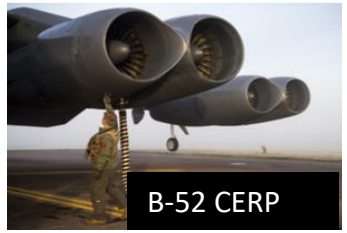
Sentinel

- >6B design variants analyzed to optimize performance
- ~6 month reduction in time to SRR
- VR based training for operators/MX

NGAD

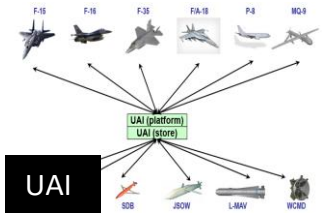
- Months → Days for software development & release
- 1000's of high fidelity design iterations
- Months → Weeks prep time for acq. reviews
- Pivot w/evolving threat

B-52 CERP



- >60 day reduction in time to PDR w/shared digital tool environment
- Months saved in virtual validation of assembly & MX
- Virtual training opportunities for crews/MX

UAI



- >2 yrs, $2M saved in ICD dev't and SIL testing for F-15/SDB II integration
- For NATO munitions: 19 & 15 months saved on wpn integration compared to 5 year nominal avg

A-10 Re-Wing

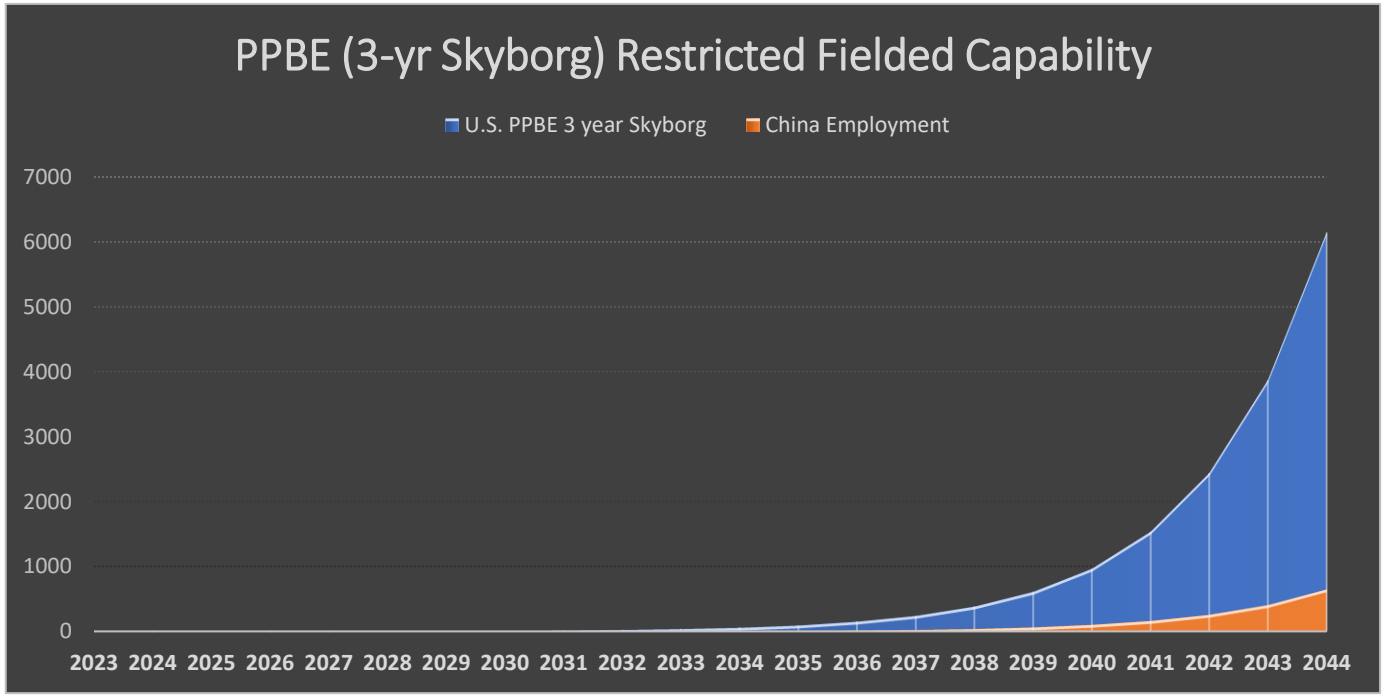
- ~1 yr saved in design qualification
- ~60% reduction in sustainment eng response time
- 2000 hrs of A/C downtime reduced to 700 hrs

Foundational Supporting Capabilities

- Model Based System Engineering (MBSE)
- Threat Informed Mission Modeling
- Acquisition Data Management
- Open Standards
- Reference Architectures
- Automated Certification Processes
- Authoritative Sources of Truth (ASoT)
- Enterprise Tools
- PLM & linkage to Log-IT
- Robust IT Infrastructure
- Workforce Training
- Enterprise Policy & Governance
- Digital Culture

Overcoming silo's and enabling enterprise scale requires enterprise investment

Technological Advantage Overlayed w/ Skyborg PPBE



9.5x

U.S. Capability Advantage

The Sensible Path

- Control that which you can control!
- - Does MBSE, DE, and Digital Integration Enable Faster Decision Making by Expediting Our Expansive Decision-Making Processes?

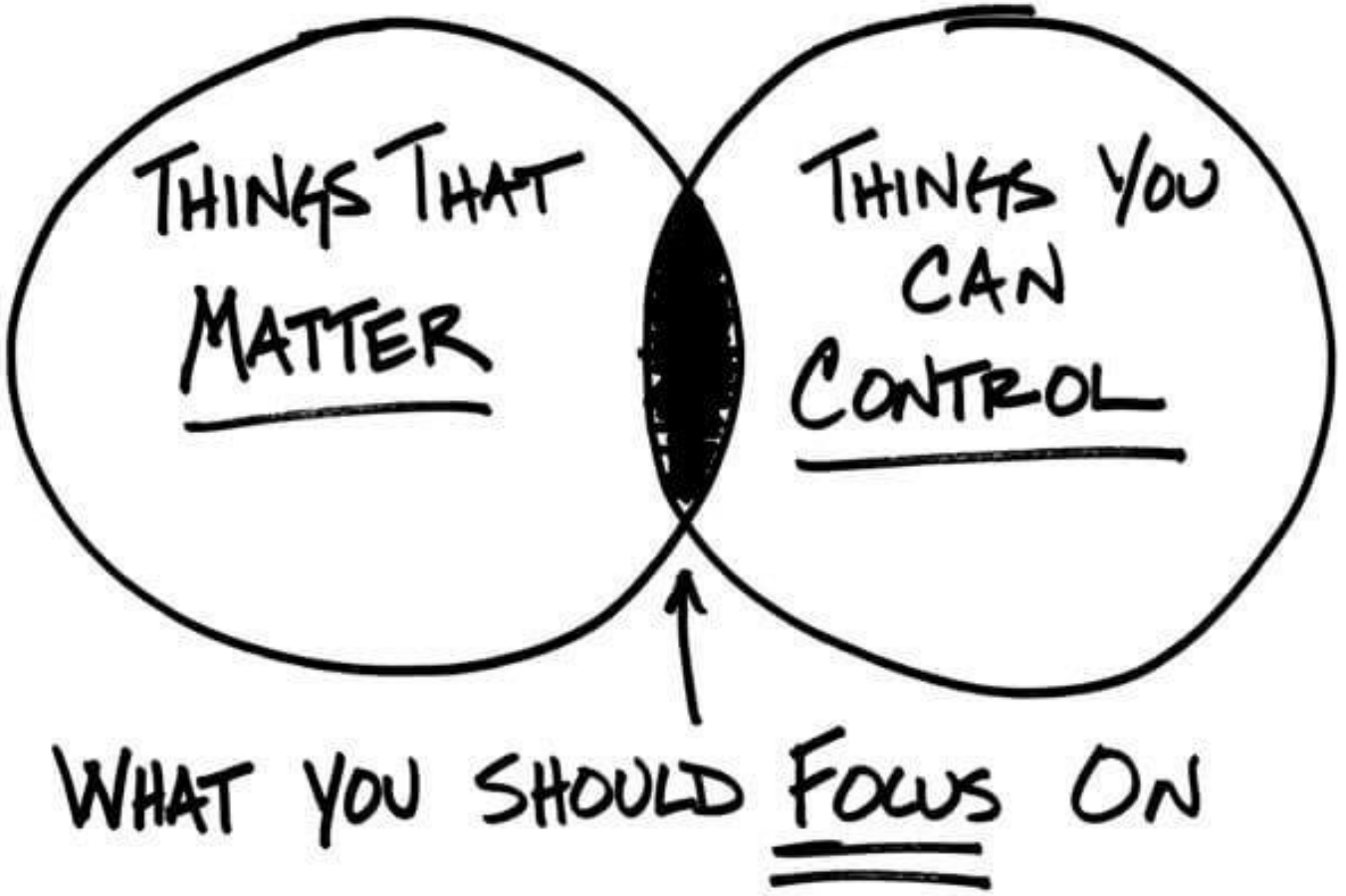


Image from https://www.lutz.us/focus-efforts-control/

AFIT Multi-disciplinary Research Centers

Digital Integration & Innovation Center of Excellence

STAT in T&E

Cyberspace Technical Center of Excellence (CyTCoE)

"We put the odds in your favor"

Center for Operational Analysis (COA)

Center for Space Research and Assurance (CSRA)

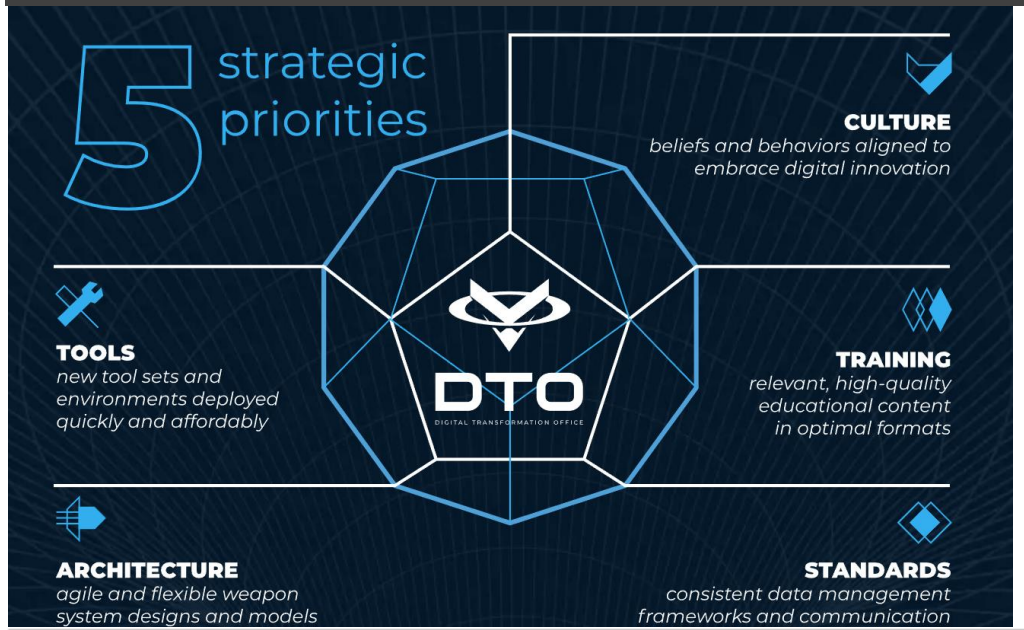
Technical Intelligence Studies and Research (CTISR)

Nuclear Expertise for Advancing Technologies (NEAT)

Vision and Characteristics

- Characteristics of DIICE
  - ***Digitally*** capable **–** deliver digital solutions
  - ***Innovative*** – future focused people that ensure the warfighters are ready
  - ***Integrative*** – people who understand the domain, so the right solutions emerge
  - ***Connective*** – collaboration occurs after connection
  - ***Enabling*** – focus on producing, and empowering our customers
- Vision Statement:
- *"Our vision for the Digital Innovation and Integration Center of Excellence is to be the premier provider of advanced digital solutions to the Air Force. We will be digitally capable, fostering a culture of innovation, and be at the forefront of digital engineering advancements that provide the Air Force with integrative solutions for a decisive advantage in the digital battlefield. We will enable our team of experts to push the boundaries of what is possible and develop solutions that drive real value for the warfighter and the nation. Our center will be a hub of connection and knowledge sharing, attracting the brightest minds and fostering partnerships with industry and academia."*

DIICE: Four Lines of Effort with DTO Alignment



- LOE 1: Education Excellence
- LOE 2: Research and Tech Transfer
- LOE 3: Consulting
- LOE 4: Best Practices

DTOs Priorities / AFITs LOEs	Culture	Tools	Architecture	Training	Standards
LOE 1: Educational Excellence	1	2	2	1	2
LOE 2: Research and Technology Transfer	2	1	1	2	2
LOE 3: Consulting	1	2	2	2	2
LOE 4: Best Practices	2	2	2	2	1

Legend: 1=Directly creating and shaping outcomes, 2=Influencing outcomes

DIICE SWOT Analysis

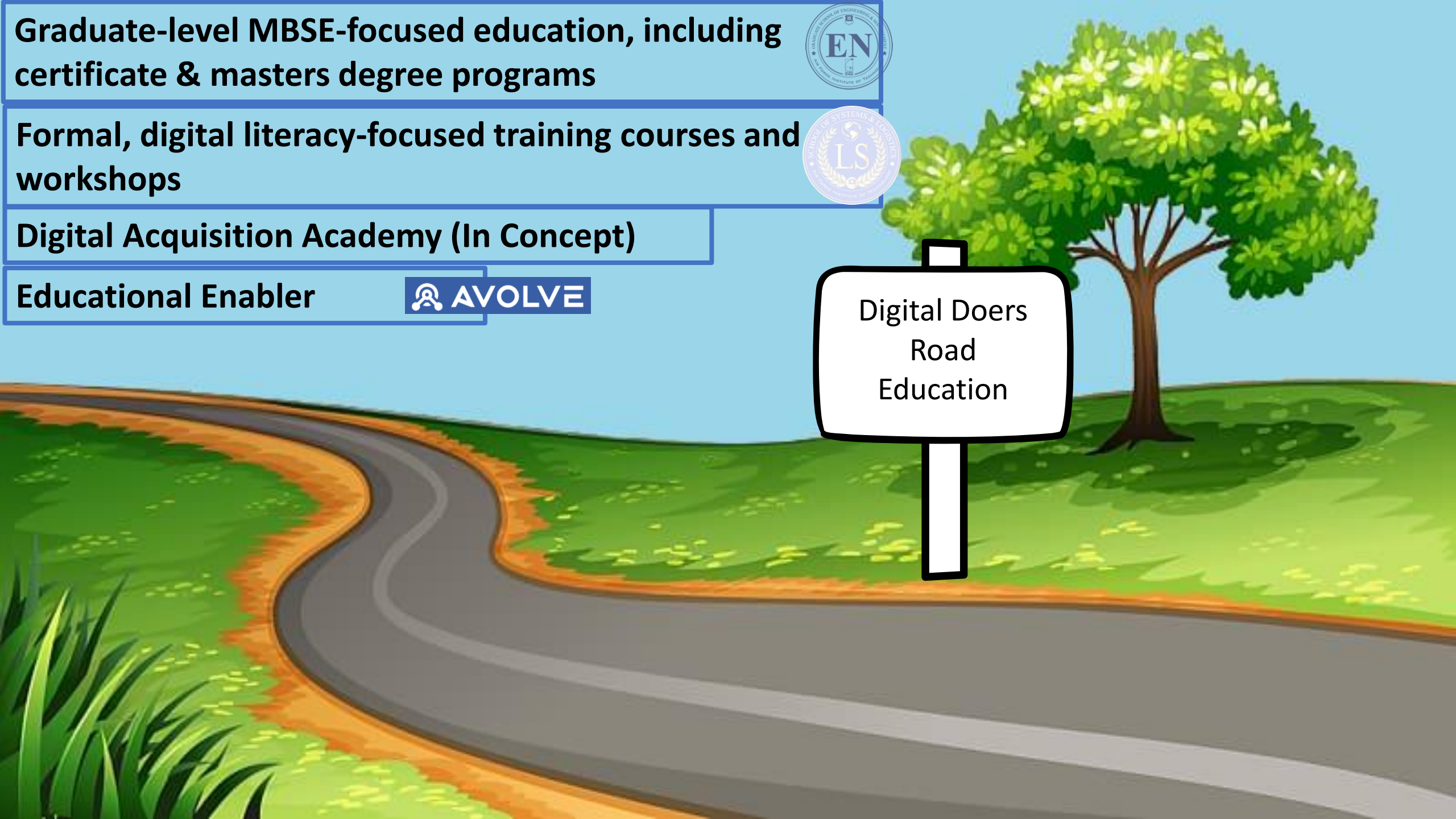
Strengths • MBSE capabilities from EN/LS (Mature and growing) • DTO/AFMC proximity • Dayton Digital Collaboration (Govt, Industry, Academic)	**Weakness** • Availability of MBSE SMEs • Digital Approach is in its infancy, potential for high impact
Opportunities • Bring together AFITs multifunctional centers/schools for synergistic impact (research, education, consulting, best practices) • Leverage DAF student research	**Threats** • Size of digital scope across acquisition lifecycle • Leadership turnover • Cultural challenges • Availability of tools and architecture • Policy maturity

Graduate-level MBSE-focused education, including certificate & masters degree programs

Formal, digital literacy-focused training courses and workshops

Digital Acquisition Academy (In Concept)

Educational Enabler AVOLVE



Digital Literacy – Continuing Education with AFIT/LS

Digital Acquisition & Materiel Management continuing education provided by the School of Systems & Logistics (AFIT/LS)

- Primarily funded by SAF/AQH (DAWDA)
- "Digital" context in many existing courses and workshops

<u>Highlighted education</u>:

- WKSP 0732*: Current Topics in Digital Acquisition & Digital Materiel Management
- WKSP 0696*: Applied MBSE Using SysML
- SYS 282: Mgmt of the Systems Engineering Process
- Avolve Learning Paths*

* - Free to eligible defense industry contractors

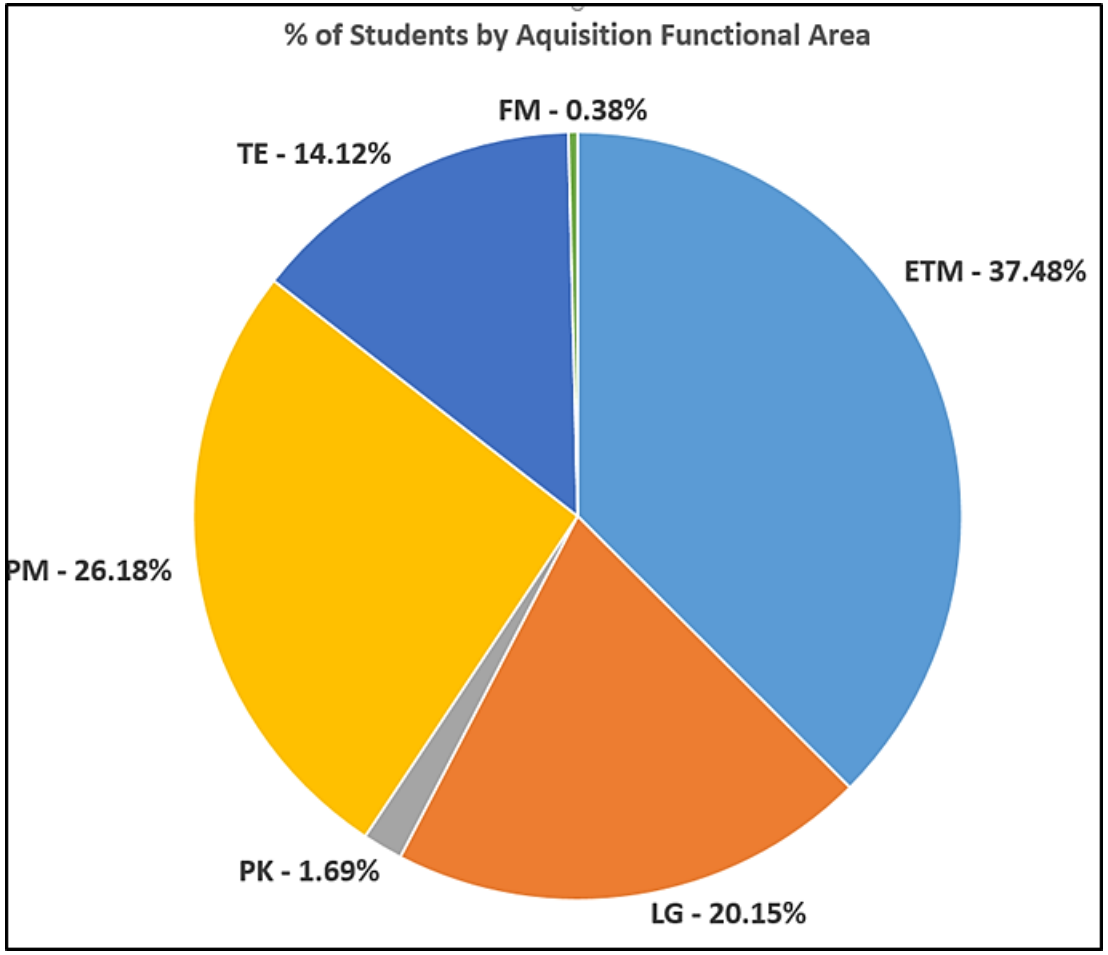
- **Formal Courses & Workshops**
- **Educational Resources**
- **Research & Consulting**

https://www.afit.edu/ls

Digital literacy at AFIT
https://www.afit.edu/DIGLIT/

WKSP 0732: Current Topics in Digital Acquisition and Digital Materiel Management

- Multiple offering, various topics
- Over 700 students taught in one year since March 2022
- Multifunctional student attendance (see pie chart)
- Subject matter expert presenters



TE – Test and Evaluation
FM – Financial Management
ETM – Engineering and Technical Management
LG – Logistics
PK – Contracting
PM – Program Management

WKSP 0732: Current Topics in Digital Acquisition and Digital Materiel Management

2022 Topics

- Digital Acquisition Overview Awareness
- Test and Evaluation within the Digital Transformation
- Introduction to User Experience (UX) Design
- Digital Acquisition and Risk Management
- Modeling and Analyzing System Requirements
- Unified Architecture Framework (UAF) Versus the Department of Defense Architecture Framework (DoDAF)
- A Short Introduction to the Unified Architecture Framework (UAF)
- Using the Systems Modeling Language (SysML) within the Unified Architecture Framework (UAF)
- Updates on Digital Engineering and Test & Evaluation from the DE T&E Summit
- Parallel Modeling Networked Cooperative Autonomous Munitions
- Model-Based Request for Information Strategies
- Using Avolve for Digital Transformation Education
- Development of a Model-Based Framework on User Toolkits
- A Systems Thinkers Look at the Digital Transformation
- Model-Based Monte Carlo Simulations

2023 Topics (Currently scheduled thru May)

- An Agile Mindset and Manifesto
- Acquisition / Engineering Transformation & Modernization
- Risk & Requirements Collaboration in Digital Materiel Management
- A Short Introduction to the Unified Architecture Framework (UAF) v1.2
- Using SysML for Requirements Management
- A Systems Thinkers Look at the Digital Transformation
- DAF Digital Guide Website Review
- Design Trade Studies Using SysML
- Agile Model-Based Systems Engineering
- Using Avolve for Digital Transformation Education

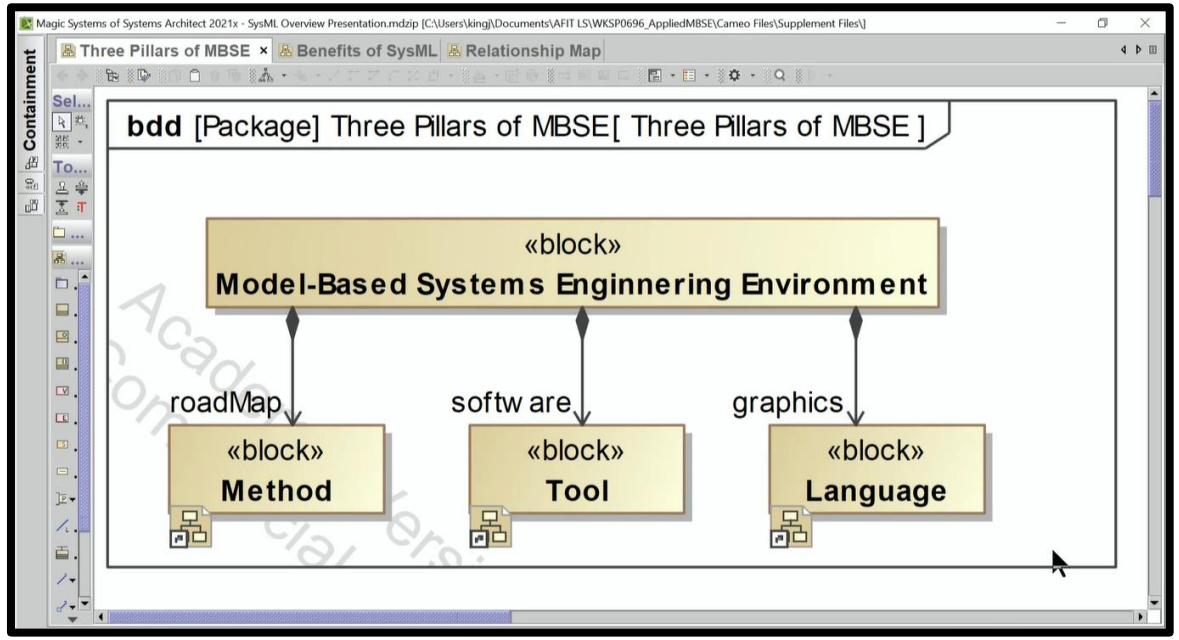
To sign up for an offering(s), go to https://forms.osi.apps.mil/r/UXuQfpZM64. This sign-up form is accessible via DAF365/AFNET.

Recordings of some previous offerings are found on the Avolve website at https://avolve.apps.dso.mil. Type in the topic name in the search bar.

WKSP 0696: Applied MBSE Using SysML

- Hands-on intro for all functional career fields
- Teaches foundations of how to create and use a system model using the SysML language and the CATIA Magic Systems of Systems Architect (formerly Cameo Systems Modeler) tool
- https://www.afit.edu/LS/course.cfm?c=353

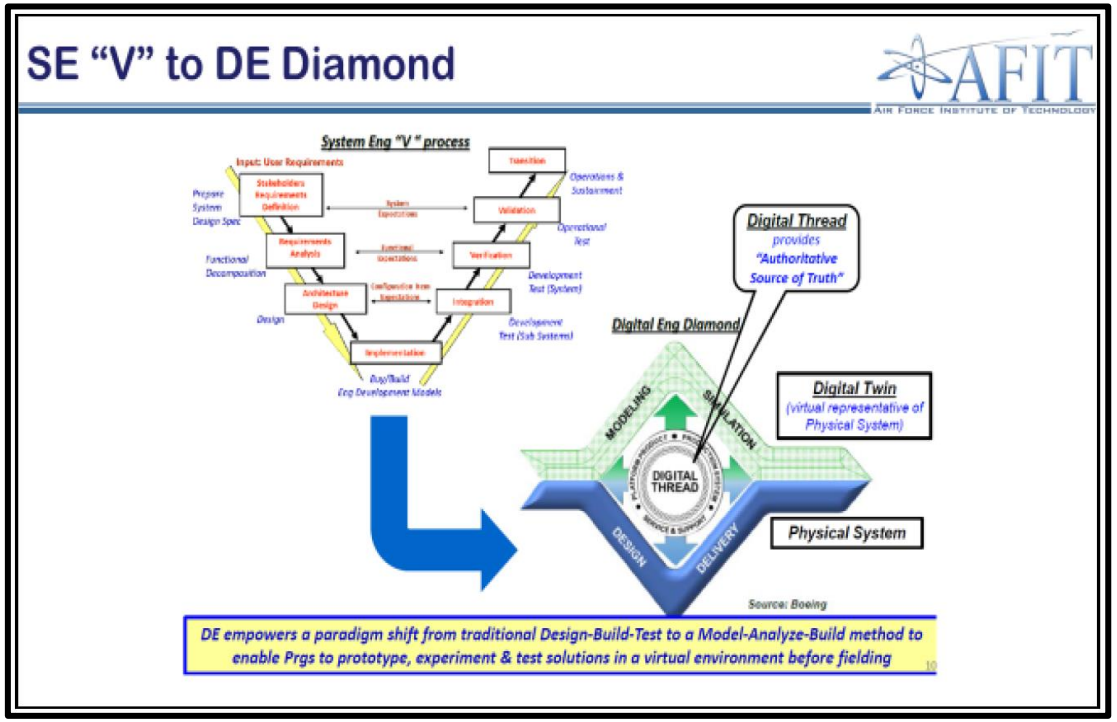
Location	Offering #	Start Date	End Date
WPAFB, OH	23I	14 Mar 2023	15 Mar 2023
Live Internet	23J	04 Apr 2023	07 Apr 2023
Live Internet	23K	02 May 2023	05 May 2023
WPAFB, OH	23L	31 May 2023	01 Jun 2023
Edwards AFB, CA	23M-O	21 Jun 2023	22 Jun 2023
Live Internet	23N	25 Jul 2023	28 Jul 2023
WPAFB, OH	23O	29 Aug 2023	30 Aug 2023
Live Internet	23P	19 Sep 2023	22 Sep 2023



SYS 282: Management of the Systems Engineering Process

- Presents activities and tools for implementing and managing the SE process during various phases of the system life cycle, and the interactions between SE and all disciplines/functions
- https://www.afit.edu/LS/course.cfm?c=85

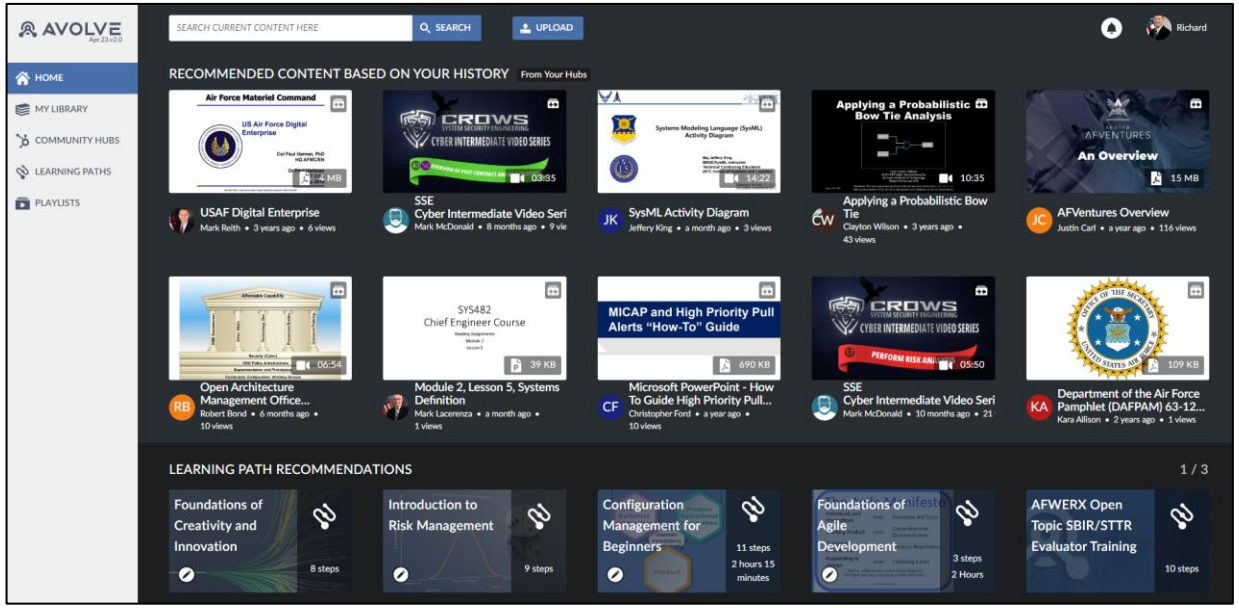
Location	Offering #	Start Date	End Date
Kirtland AFB, NM	23G-O	21 Mar 2023	23 Mar 2023
WPAFB, OH	23H	11 Apr 2023	13 Apr 2023
Tinker AFB, OK	23I-O	18 Apr 2023	20 Apr 2023
Live Internet	23J	01 May 2023	19 May 2023
Lackland AFB TX	23K-O	06 Jun 2023	08 Jun 2023
Edwards AFB, CA	23L-O	27 Jun 2023	29 Jun 2023
Robins AFB, GA	23M-O	11 Jul 2023	13 Jul 2023
Offutt AFB, NE	23N-O	08 Aug 2023	10 Aug 2023
Peterson SFB, CO	23O-O	22 Aug 2023	24 Aug 2023
Live Internet	23P	11 Sep 2023	29 Sep 2023



AVOLVE

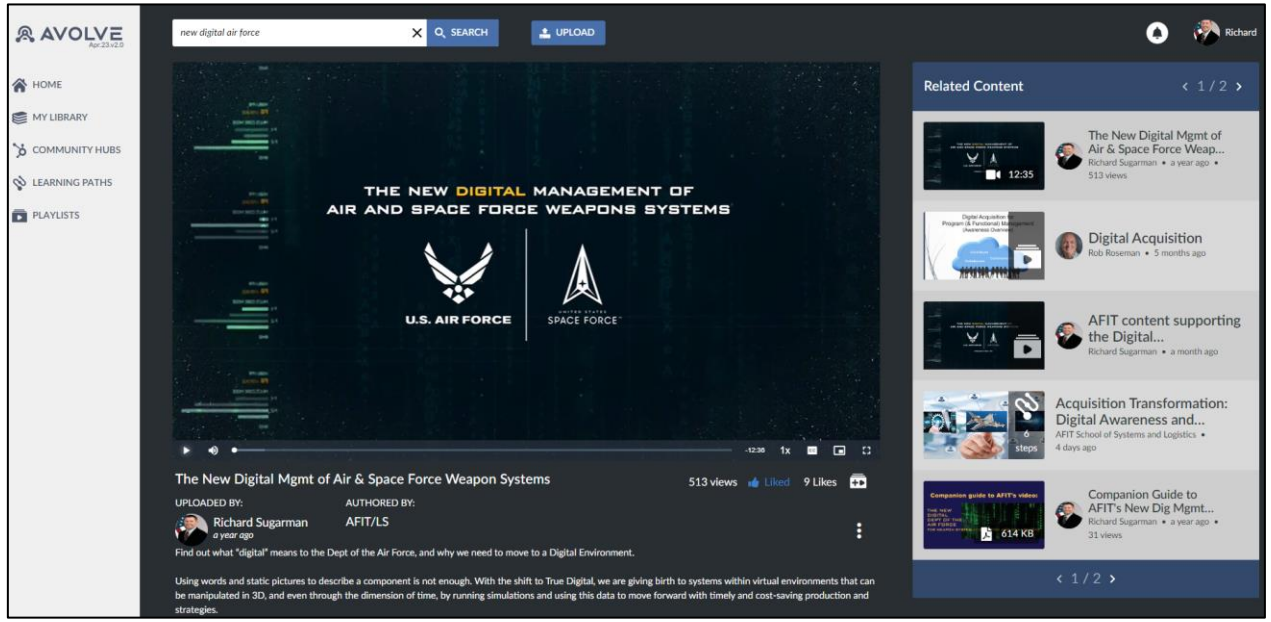
https://avolve.apps.dso.mil

(Note: 1st login requires setting up a Platform One & Avolve account)



- Content sharing application with Netflix/YouTube-type of look & feel
- Crowd-sourcing of content, increased accessibility to DoD-focused content

- Content organized into domain “hubs” & “tag” searchable
- Knowledge-centric vs. Organization-centric
- CAC authenticated – IL-4 certified

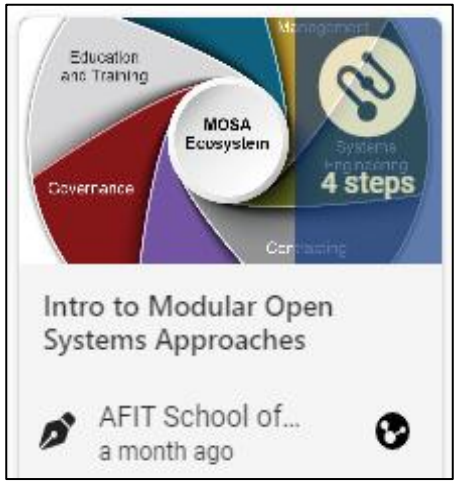


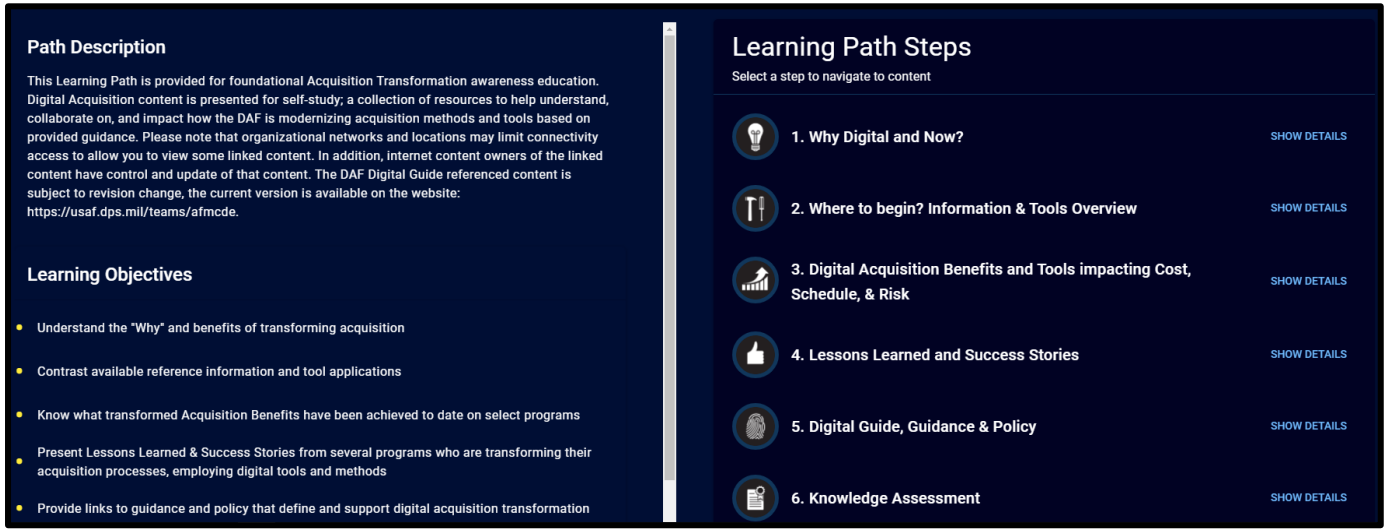
Learning Paths

Guided Educational Resources

- Curated paths of content designed to support Agile Airman concepts
  - Learner-centric
  - Competency-based
  - Accessible anywhere/anytime

- Three Digital-related Learning Paths available now:
  - Acquisition Transformation: Digital Awareness and Overview
  - Intro to Modular Open Systems Approaches
  - Foundations of Agile and DevOps

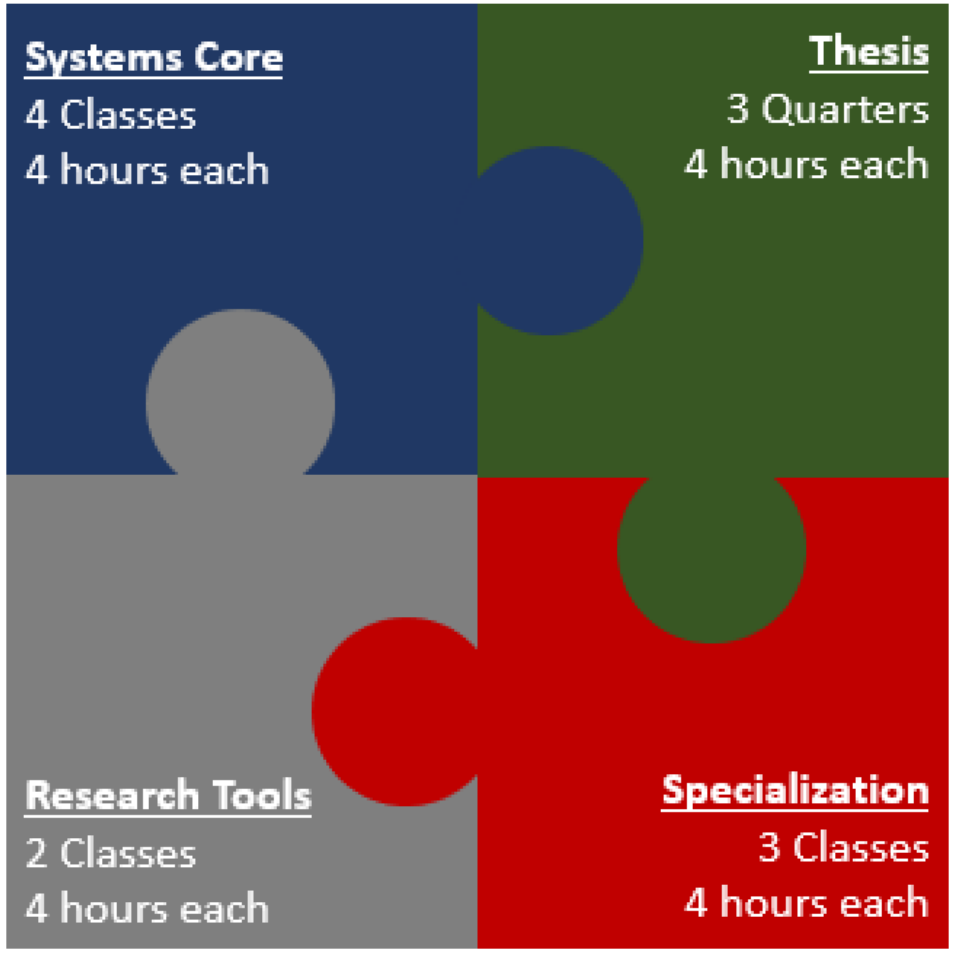




Log into Avolve at https://avolve.apps.dso.mil
Click on Learning Paths on left-hand menu

If you do not have CAC-access, can still learn more about Avolve at: https://www.afit.edu/CYBER/page.cfm?page=1849

LOE 1.2: Graduate Education - Systems Engineering



Modular Master's Degree

- Fully online/residence
- Digital/modeling core
- 7 domain specializations
- Thesis/Capstone options
- Defense focused
- Certificate option

By the Numbers:

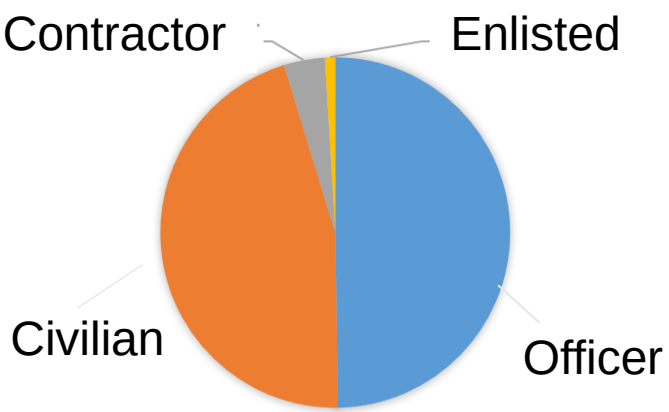
2003 to 2022: 1009 grads

AY 2002: 1 grad

AY 2022: 108 grads

- 3 PhDs (1 res, 2 part-time)
- 27 MS Thesis (19 res, 8 part-time)
- 27 ME Capstone (20 res, 7 part-time)
- 51 Graduate Certificates (SAF/AQ Sponsored)

Global Reach to Total Force:

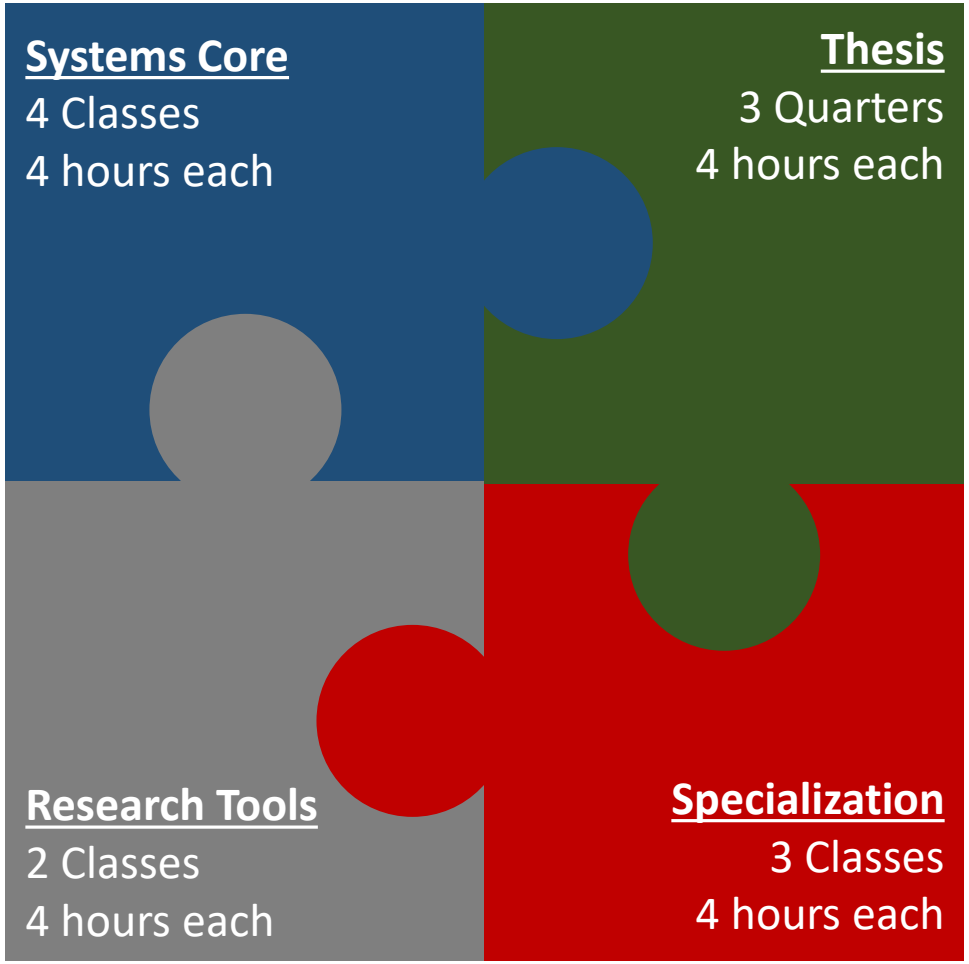


Model-Based SE Foundation with Defense Specializations and Research

Systems Engineering (GSE)
Independent Research Focus (Thesis)

SE Foundations
(SENG 520)
Agile Software
(SENG 593)
Architecture
(SENG 640)
Select One:
Advanced Topics
(SENG 670)
Project Management
(SENG 610)

Statistics
MATH or STAT at 500 or higher
Research Methods
(RSCH 630)



Thesis
Intensive independent research effort leveraging toolsets gained through coursework.

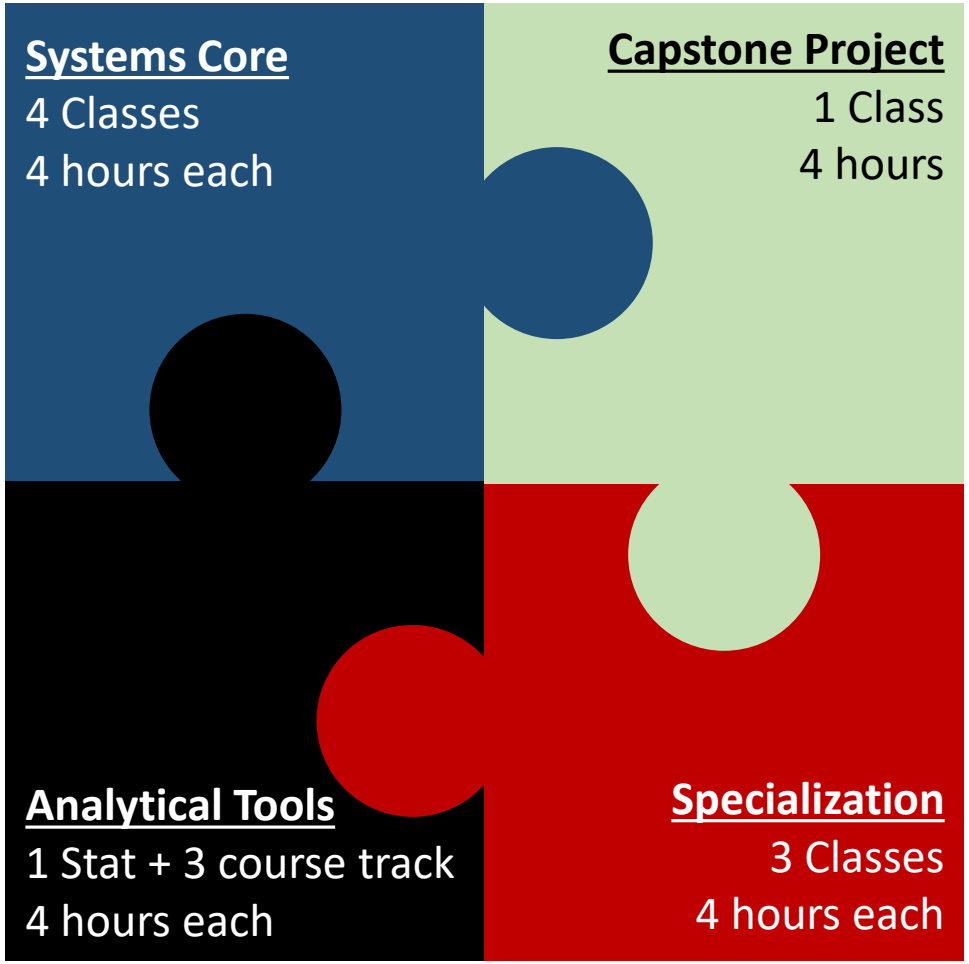
Specialization
Human Systems
Space Systems
Cyber Systems
Advanced Systems Analysis
Small Unmanned Aerial Systems*
Navigation
Test and Evaluation**

* In-residence only
** Separate selection process

Applied Systems Engineering
Tools Focus (Capstone)

SE Foundations
(SENG 520)
Agile Software
(SENG 593)
Architecture
(SENG 640)
Select One:
Project Management
(SENG 610)
Advanced Topics
(SENG 670)

Statistics
MATH or STAT at 500 or higher
Analysis Track (pick one)
Advanced System Analysis
Test and Evaluation**



Capstone
Independent research project leveraging toolsets gained through coursework.

Specialization
Human Systems
Space Systems
Cyber Systems
Advanced Systems Analysis
Small Unmanned Aerial Systems*
Navigation
Test and Evaluation**
Nuclear***

* In-residence only
** Separate Competitive Process
*** ASE program only

How long does it take? How many students?

	FA23	WI24	SP24	SU24	FA24	WI25	SP25	SU25	FA25	WI26	SP26	SU26
40 RS	SE Core/Certificate				STAT	Domain Track			Analysis Track			Capstone
40 DL	SE Core/Certificate				STAT	Specialization			Methods	Thesis		
20 DL		SE Core/Certificate				Degree Follow-on to meet student's needs						
	20 DL		SE Core/Certificate				Degree Follow-on to meet student's needs					
		20 DL		SE Core/Certificate				Degree Follow-on to meet student's needs				

- AFIT resources (RS): We have 40 resident (RS) openings each fall. Priority to military assignment system.
- AFIT resources (DL): We have 20 distance learning (DL) openings each fall. Priority to any sponsored students.
- AFMC/ENS (DL): 20 openings each fall and spring (40 total). Priority to AFMC sponsored personnel.
- Digital Center (DL): We have 20 DL openings each Winter and Summer (40 total). Priority to AFMC.

- Total annual starts: 140
- Year round quarterly starts for online, fall starts for in residence

Who can legally be an AFIT student

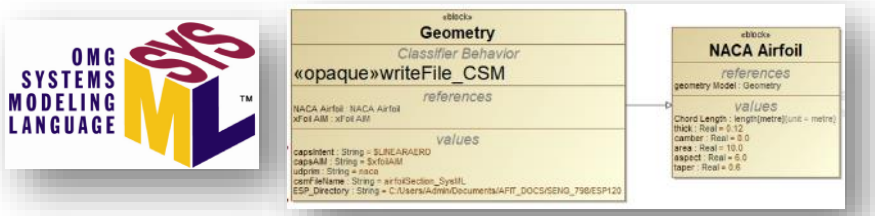
- Air Force and Space Force Personnel (all civilian and military)
- All federal government (ex. NASA, DOE, DHS)
- Any DoD CAC holders (ex. Air Force contractors)
- Critical infrastructure (ex. ODOT)

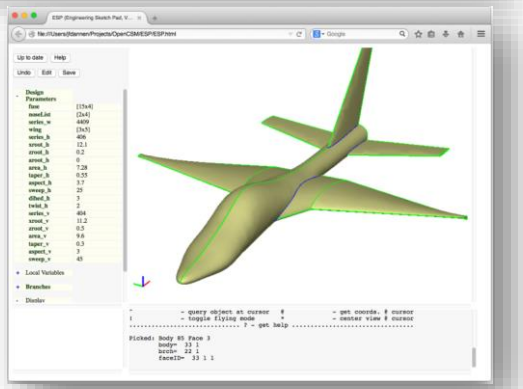
Would you like to know more?

- (937) 255-3636 ext:4626
- https://www.afit.edu/ENV/

LOE 2: Applied Research

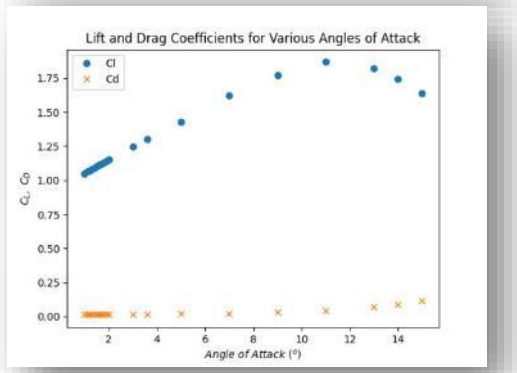
- Model Integration
  - Python
  - AFSIM
  - MATLAB
  - Engineering Sketch Pad
- Reference Architectures
  - Human Systems
  - Weapons, UAS, CubeSat
  - Automated Processes
  - Digital Twins
- Transition: Legacy to Digital
  - Air Worthiness and Test
  - Requirements and Acquisition
  - Model Validation
- Mission
  - Mission engineering
  - Wargaming
  - Reverse engineering



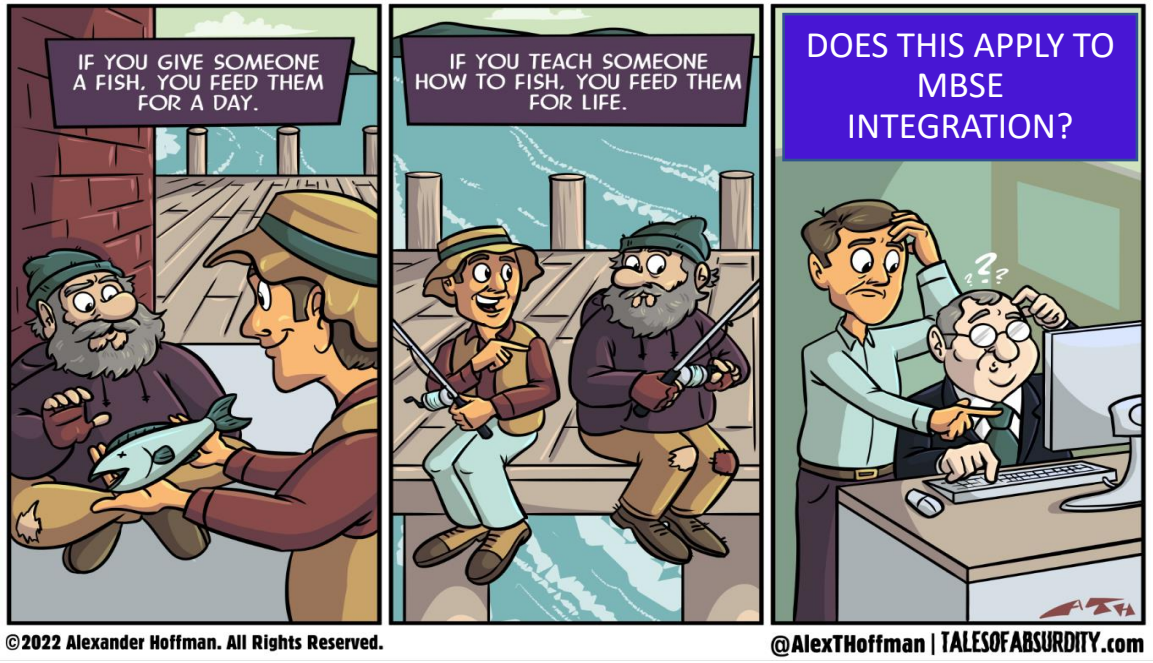


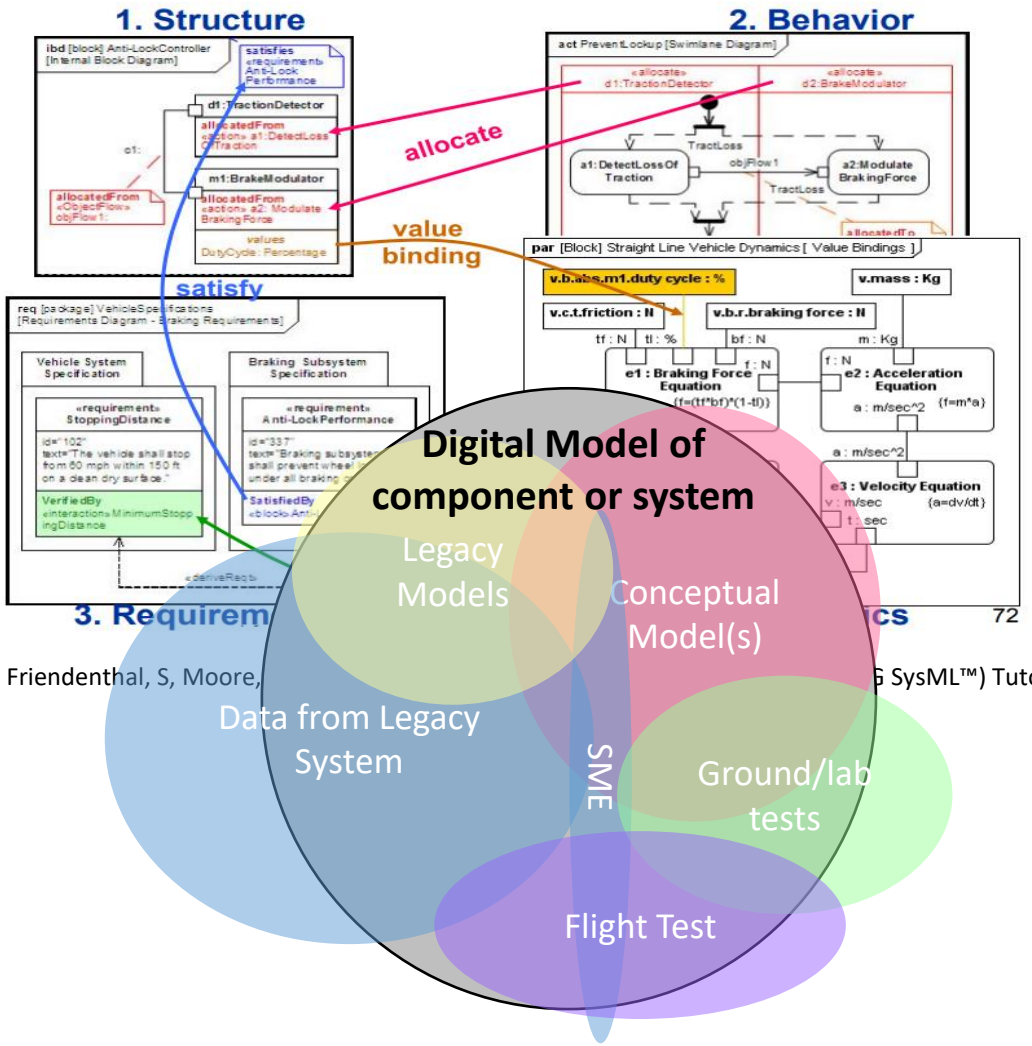
esp

XFOIL
Subsonic Airfoil Development System



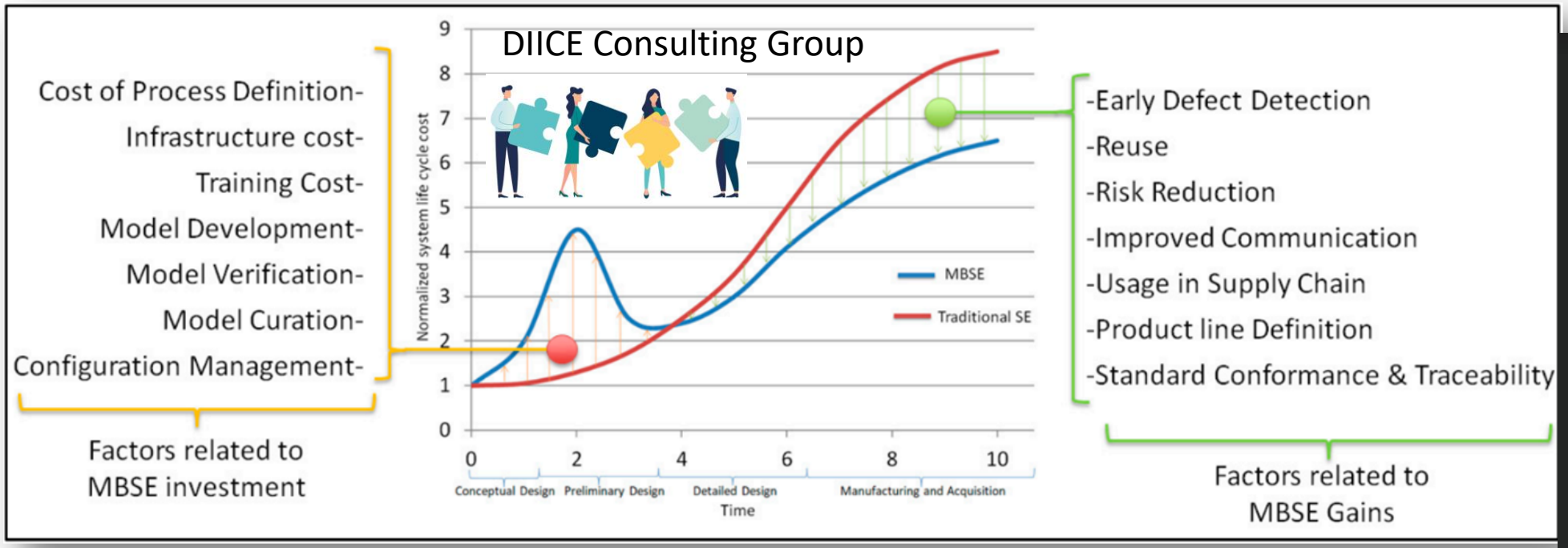
LOE 3: Consulting Development Art of the Feasible

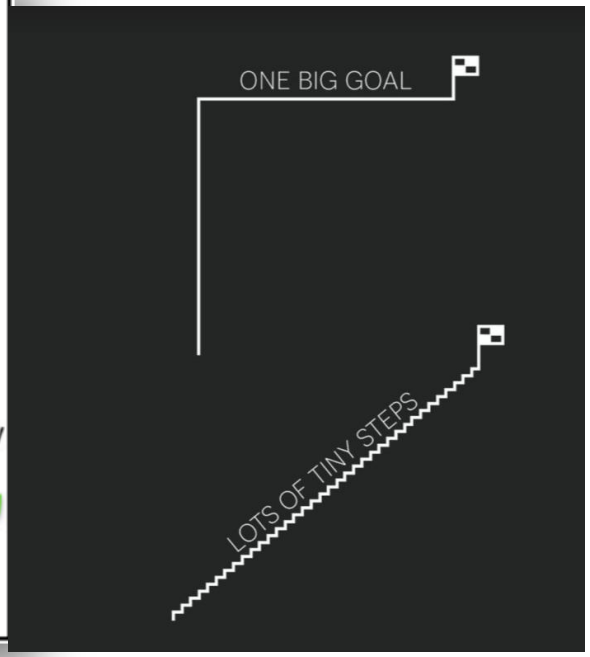




Friendenthal, S, Moore, [illegible] SysML™) Tutorial, 2009

LOE 3: Consulting





Ref: Madni, A. Purohit, Shatad (2019) Economic Analysis of Model-Based Systems Engineering. *Systems*, 7(12), 1-18

Goal – Provide AFMC Programs the means to get over the digital hump by delivering models, education, and strategies to the level they can sustain.

LOE 4: Best Practices

- LOEs 1-3 culminate into Best Practices from DIICE and integrate them with others into the Digital Guide
- Useful Artifacts
  - **Best Practices** are created through **Research Efforts**, **Use Cases**, **Education**, and synergized **Collaboration** with **Industry**, **Government**, and **Academia** that inform future efforts, policy, standards, education, and research.
  - Annual Publications and Repository of **Accessible MBSE Research** (Typology, with Artifacts)

https://blog.contendersolutions.com/5-it-management-best-practices-for-success-2021

Last thoughts

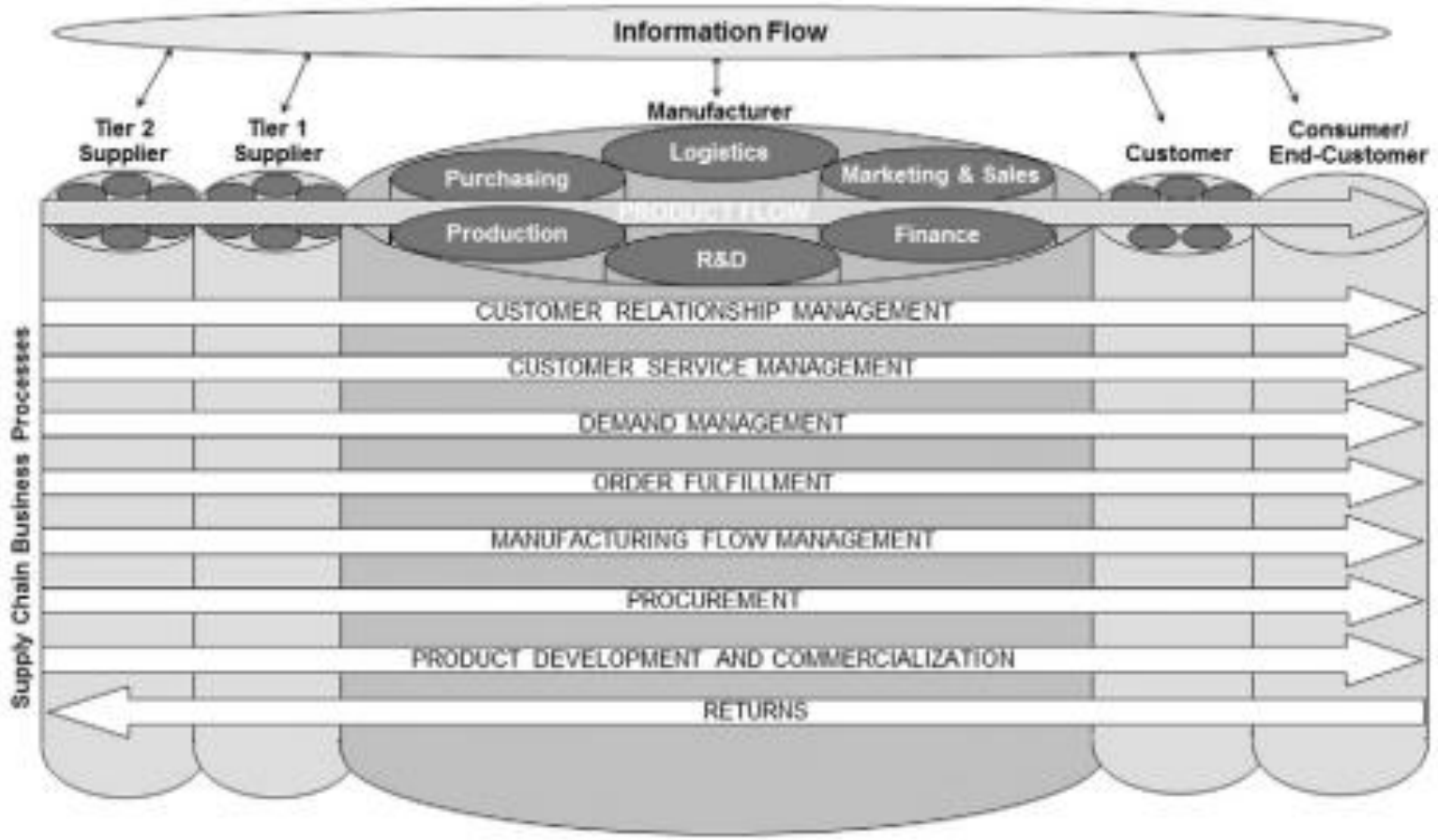


Fig. 1. The supply chain management framework in 2000 (Source: Lambert & Cooper, 2000).

DALL-E Art

Model Based

SYSTEMS ENGINEERING

Use of MBSE and a Reference Architecture in a Rapid Prototyping Environment

John Colombi, Ph.D., john.colombi@us.af.mil
David Jacques, Ph.D., David.jacques@us.af.mil
Professors of Systems Engineering
Department of Systems Engineering and Management

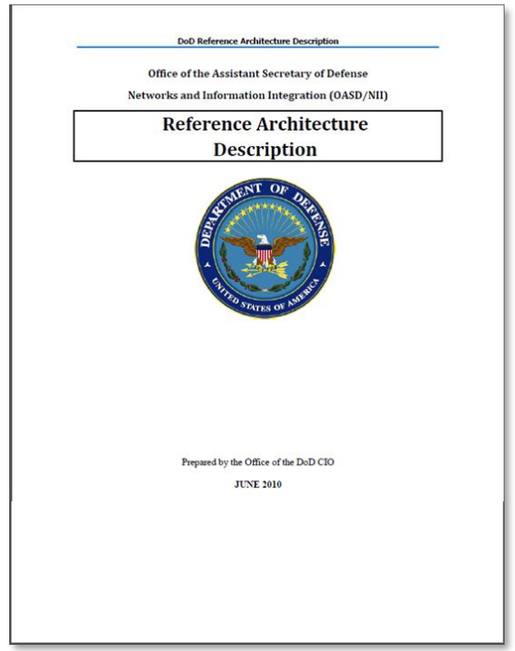
The views expressed are those of the authors and do not reflect the official policy or position of the United States Air Force, United States Space Force, the Department of Defense, or the United States Government.

Acknowledgement to our many students

Reference Architectures

- **Definition:** “An authoritative source of information about a specific subject area that guides and constrains the instantiations of multiple solution architectures”.*
  - An RA is typically company/consortium or domain focused, captures a shared understanding across multiple products, and are based on concepts proven in practice

- **Roles:****
  - Provide a common language across stakeholder
  - Provide consistency of implementation
  - Supporting the validation of solutions against proven RA
  - Encourage adherence to standards, specifications, and patterns


DoD Reference Architecture Description

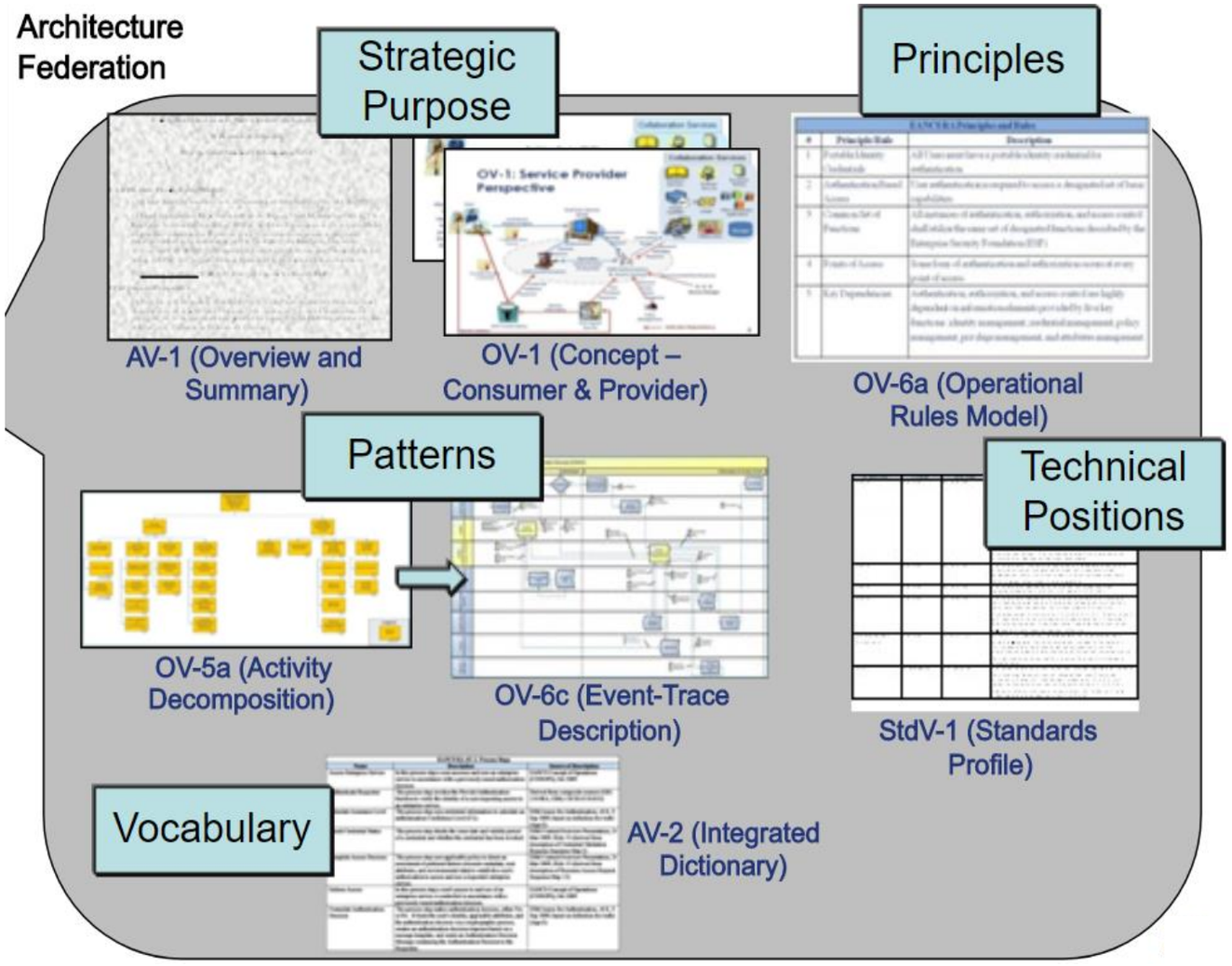
Office of the Assistant Secretary of Defense
Networks and Information Integration (OASD/NII)

Reference Architecture Description

Prepared by the Office of the DoD CIO
JUNE 2010

*Office of the Assistant Sec. of Defense, 2010, **Cloutier, et.al., *Systems Engineering,* 2010

Contents



Historic

Generally

- Purpose, Logical Structure
- Interconnection and Interface Patterns
- Standards
- Glossary

Modern

Historic +

Distributed for DE Tool use

Style Guide, Report Generation

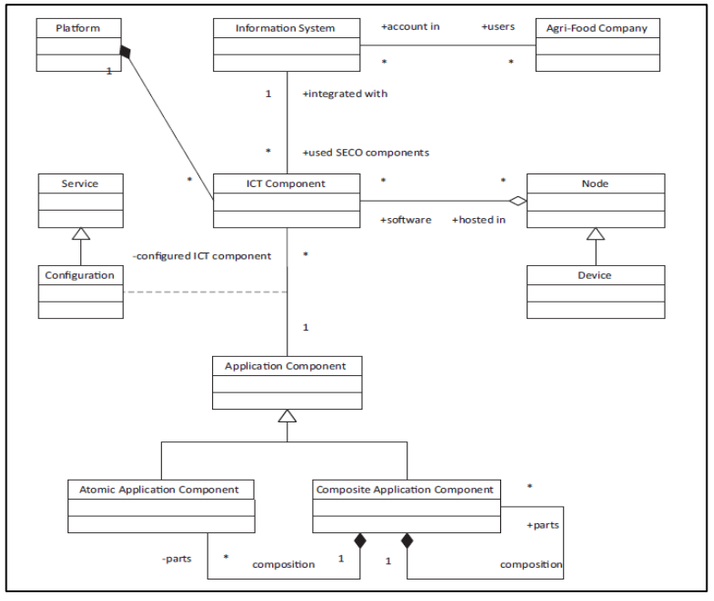
Component Library, Requirements

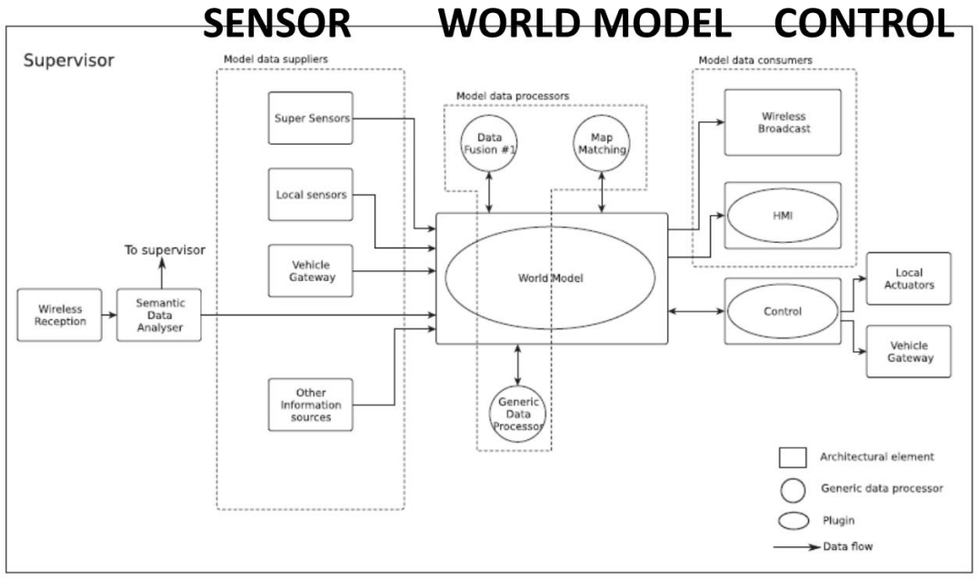
Design Method/Activities

Validation Suites/Rules

Lots of Reference Architectures (RA)

- Meisson and Volsard - RA for Early Warning for disaster management
- Kruize, Wolfert et.al. - RA for development of Farm Software Ecosystems
- Branscomb, Paredis et.al. - RA for Vehicle Architecture Modeling Framework
- Behere, Torngren et.al. - RA for cooperative driving
  - Guidelines for cooperative adaptive cruise control system for commercial trucks



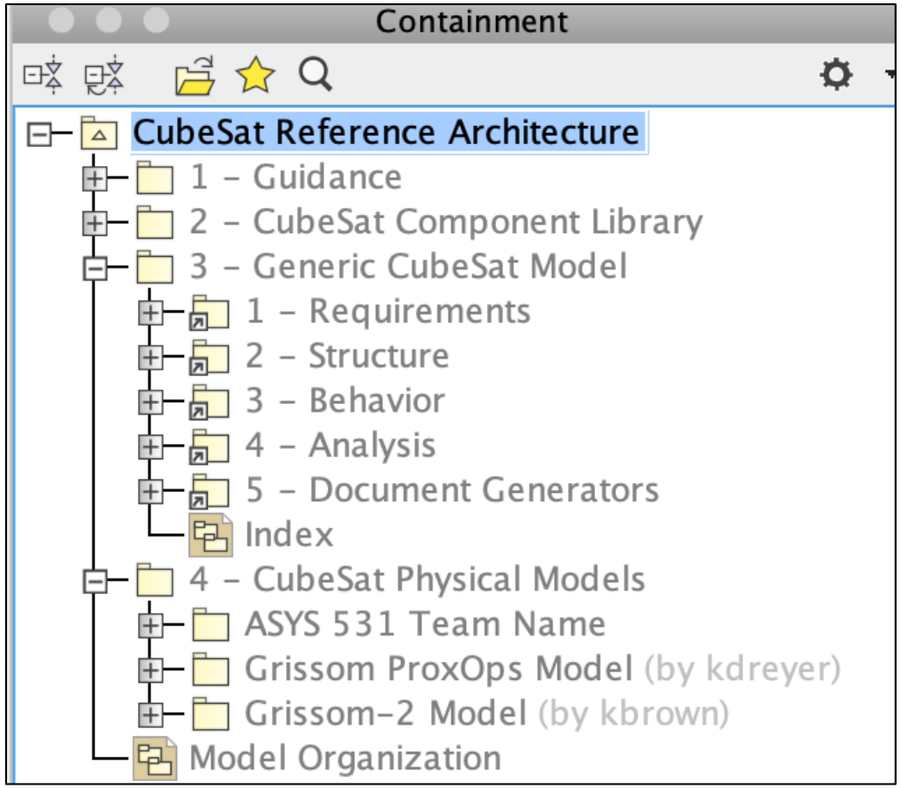


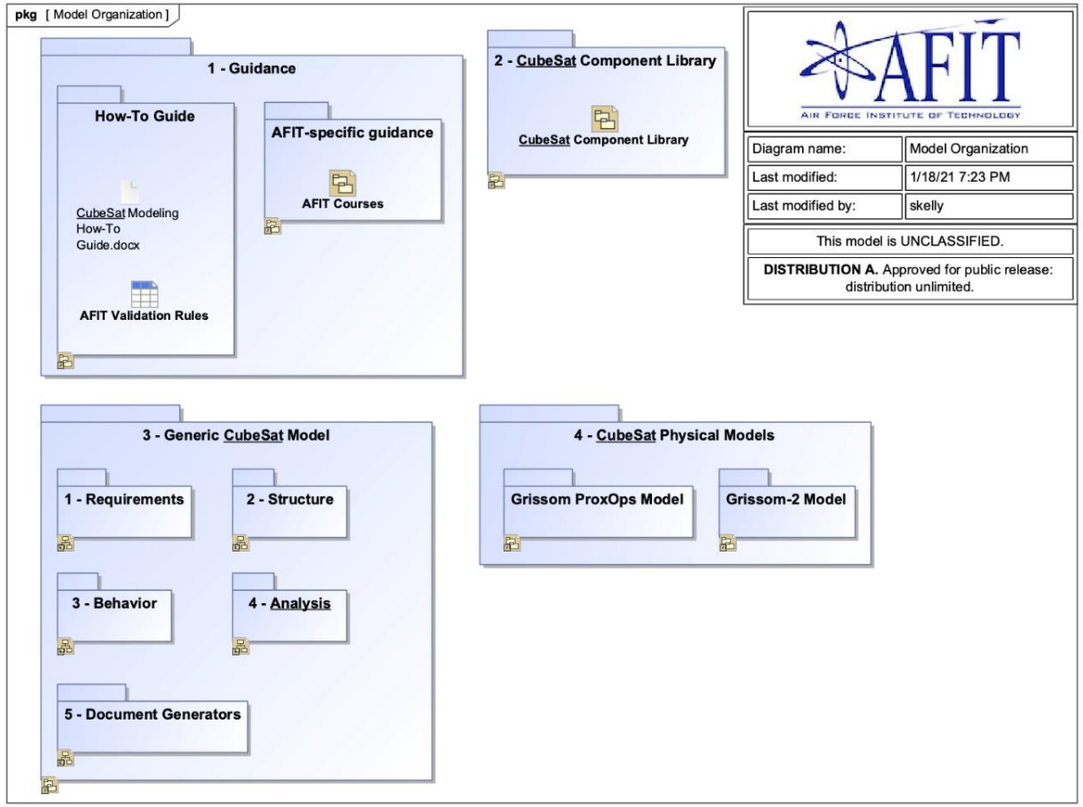
AFIT use of Reference Architectures

- **Autonomous System Reference Architecture (ASRA)**
  - Models and simulation developed, implemented and tested in conjunction with AFIT Autonomy and Navigation Technology (ANT) Center
  - Distributed, collaborative heterogeneous multi-vehicle missions
- **Reference Architecture for CubeSat Development**
  - Models that serve as basis for design, analysis, V&V of future missions launched by AFIT Center for Space Research and Assurance (CSRA)
- **Small UAV Reference Architecture**
  - Models for use in UAS design sequence (design-build-test)
  - Typical use cases, functions, logical and physical architectures (multi-rotor, fixed wing and hybrid), COTS component library + Extensions

CubeSat Reference Model

- Kaslow, Ayres, et.al.* - MBSE Reference Model for development of Cubesats
  - Partnering with the Object Management Group (OMG) and the International Council on Systems Engineering (INCOSE)
  - Help Cubesat developers proceed from conceptual need to on-orbit operations





Support Student Workflow

Index of most important efforts (and diagrams)

Requirements
Requirements Organization

Source Documentation:
- Source Documentation Table

Required Capabilities and Design Constraints:
- Required Capabilities Table
- Design Constraints Table
- Required Capabilities and Design Constraints Traceability Matrix
- Mission Need Statement
- Operational Context
- Goals and Objectives Table

Stakeholder Analysis:
- Stakeholders and Their Concerns
- List of Stakeholder Needs
- Stakeholder Needs to Concerns Matrix
- Stakeholder Needs to MCD Matrix

Mission Requirements:
- Mission Requirements Table
- Mission Requirements Traceability Matrix
- Mission Requirements Derivation Matrix

Key Performance Parameters:
- Key Performance Parameters Table
- Key Performance Parameters Traceability Matrix

System Requirements:
- System Requirements Table
- SR to MR Traceability Matrix

Subsystem Requirements:
- Subsystem Requirements Table
- Subsystem Requirements Derivation Matrix

Structure
Mission Context bdd

Mission Context:
- Mission Context
- Simplified Mission Context

Operational Domain:
- Operational Domain bdd

Environment:
- CubeSat Environment bdd

CubeSat:
- CubeSat bdd (additional layers linked within)
- CubeSat State Machine

Launch Vehicle:
- Launch Vehicle bdd

Ground Segment:
- MC3 Remote Ground Terminal bdd

Orbit:
- Mission Parameters bdd

Behavior
Behavior Organization

OV-1:
- OV1 - High Level Operational Concept

Mission Phases:
- Mission Phases
- Mission Phases

Use Cases:
- Operational Use Cases
- Operational Use Case Descriptions

Fault Management:
- Fault Management
- Fault Management

CubeSat Activities:
- CubeSat Mission Activity Decomposition

Analysis
Analysis Organization

Trade Studies:
- Trade Studies

Verification Analysis (parametric diagrams):
- Thermal Analysis Model
- Power Analysis
- Image Quality Analysis
- Orbit Analysis
- LMMT Integration
- Uplink Analysis

Hardware Tests:
- Hardware Tests
- Subsystem Requirements Verification Table

Document Generators
Document Generators Organization

Mission Capabilities Document (MCD):
- Mission Capabilities Document

Stakeholder Analysis Report (SAR):
- Stakeholder Analysis Report

CONOPS:
- CONOPS

Mission Requirements Document:
- Mission Requirements Document

Operational Requirements Document:
- Operational Requirements Document

Space Vehicle Requirements Document:
- Space Vehicle Requirements Document

Test Plan & Report:
- Test Plan & Report Elements

Generic Model Template:
- Generic Model Document

System Modeling Guidance

- 1 – Guidance
  - AFIT-specific guidance
  - How-To Guide
    - Process
    - Rules
      - Validation Profile
      - Rules
      - Behavior Diagrams
        - Activity Diagrams
        - Use Case Diagrams
      - General Rules
        - Diagrams
        - Distribution
        - Element Colors
        - Glossary
        - ID Naming
        - Language and Method
        - Naming
        - Packages
        - Units
      - Requirement Diagrams and Tables
        - Requirement Diagram/Table General Rules
      - Structure Diagrams
        - Block Definition Diagrams
        - Internal Block Diagrams
    - SysML Diagram Types
    - How-To Guide Navigation
    - CubeSat Modeling How-To Guide.docx

Validation Profile

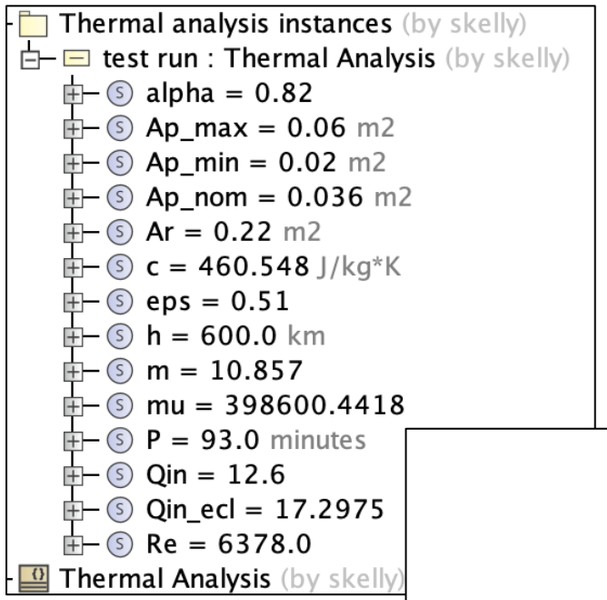
			Activity	NotEquals1	error	Activities must be named.
			Actor	Not1	error	All Actors must have names.
BLOCKNAME	BLOCKNAME	Completeness	Block [Class]	NotEquals1	error	Blocks must be named.
CONSTRAINTTYPE	CONSTRAINTTYPE	Completeness	ConstraintProperty [Property]	Not1	error	Constraint properties must be typed by constraint blocks.
DIAGRAMNAME	DIAGRAMNAME	Completeness	Diagram	NotEquals1	error	Diagram names may not be blank.
ENTRYEXITNAME	ENTRYEXITNAME	Completeness	Pseudostate	Or1	error	Entry and exit points for state machines must be named.
OPERATIONNAME	OPERATIONNAME	Completeness	Operation	NotEquals1	error	Operations must be named.
PACKAGENAME	PACKAGENAME	Completeness	Package	NotEquals1	error	Packages must be named.
PARATYPE	PARATYPE	Completeness	Parameter	IfThenElse1	error	All parameters owned by operations must be typed.
SIGNALNAME	SIGNALNAME	Completeness	Signal	NotEquals1	error	All signals must be named.
STATENAME	STATENAME	Completeness	State	Or2	error	States must be named.
STMACHINENAME	STMACHINENAME	Completeness	StateMachine	NotEquals1	error	State machine names may not be blank.
USECASENAME	USECASENAME	Completeness	UseCase	NotEquals1	error	Use Cases must be named.
VALUENAME	VALUENAME	Completeness	ValueProperty [Property]	NotEquals1	error	Value properties must be named.
VALUETYPE	VALUETYPE	Completeness	ValueProperty [Property]	Not1	error	Value properties must be typed by value types.

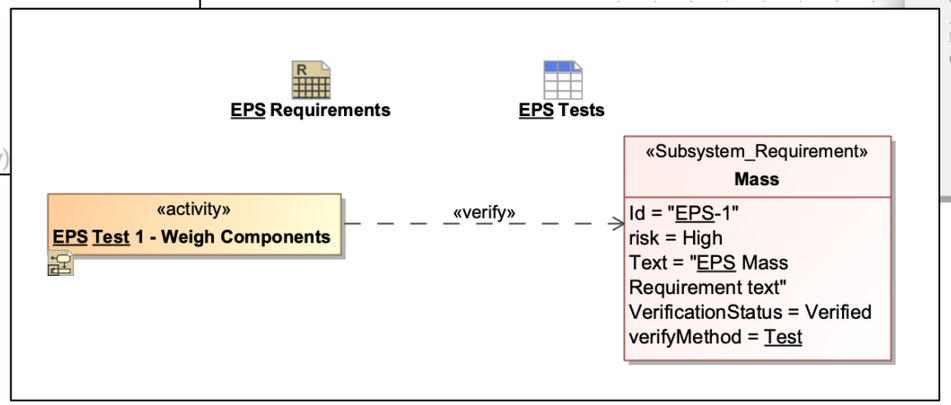
General modeling conventions and style rules

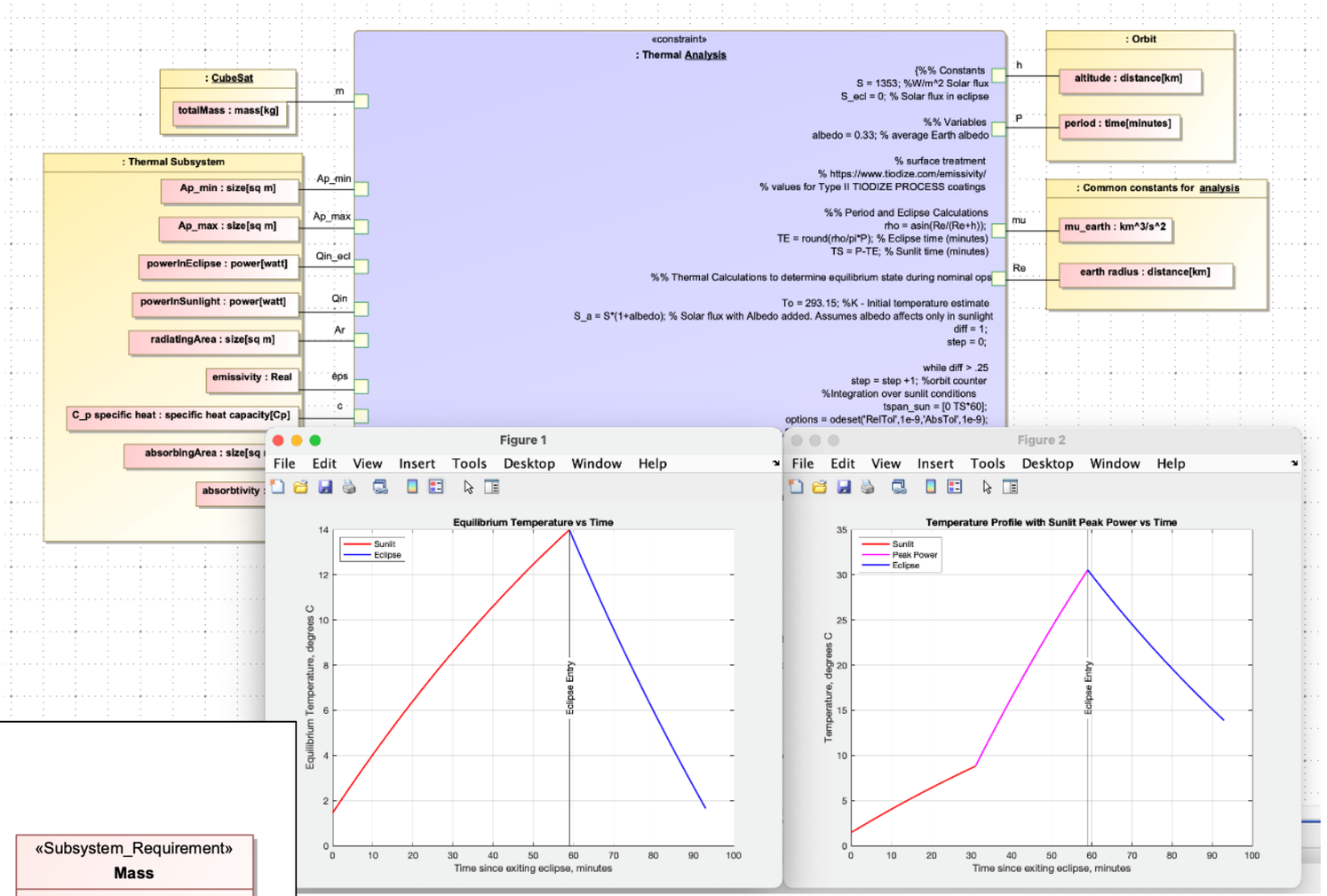
How-to guide provided

Analysis and Reusable Patterns

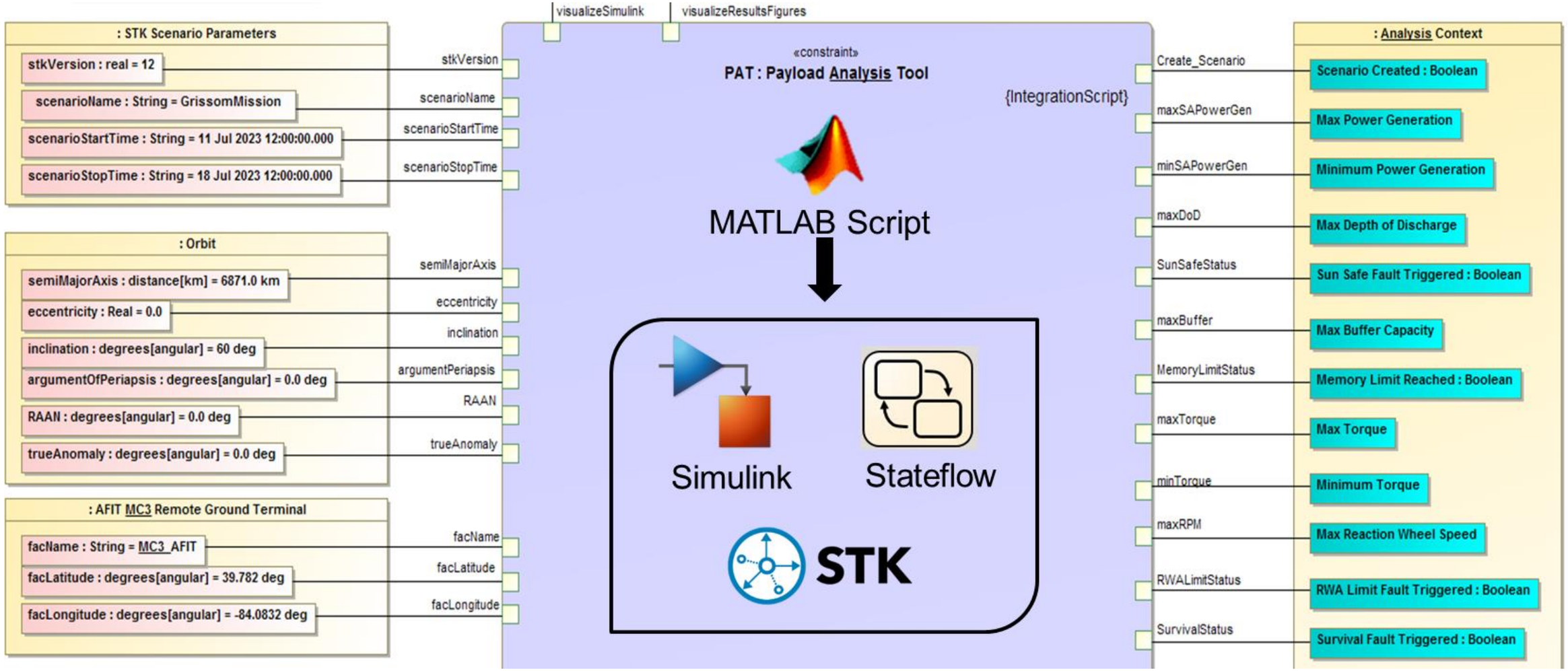
- Trade studies
- Analysis patterns for MATLAB/ STK integration
- Hardware testing workspace





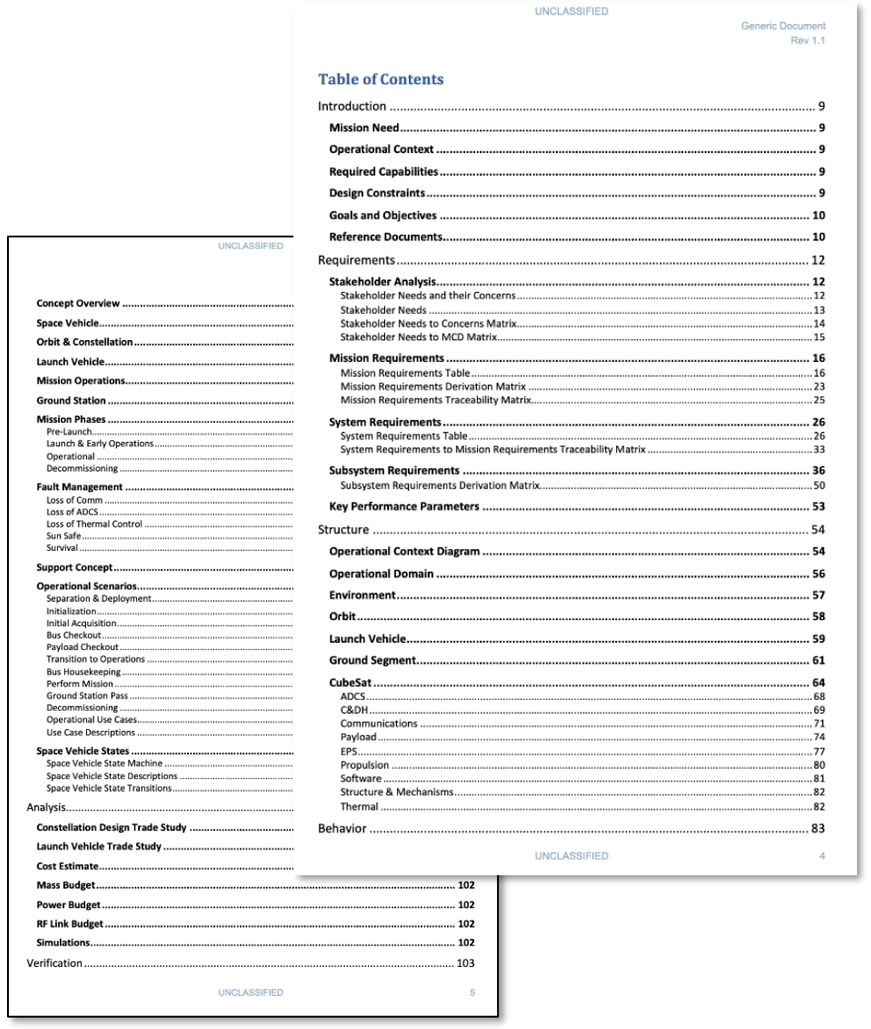


Payload Analysis Tool



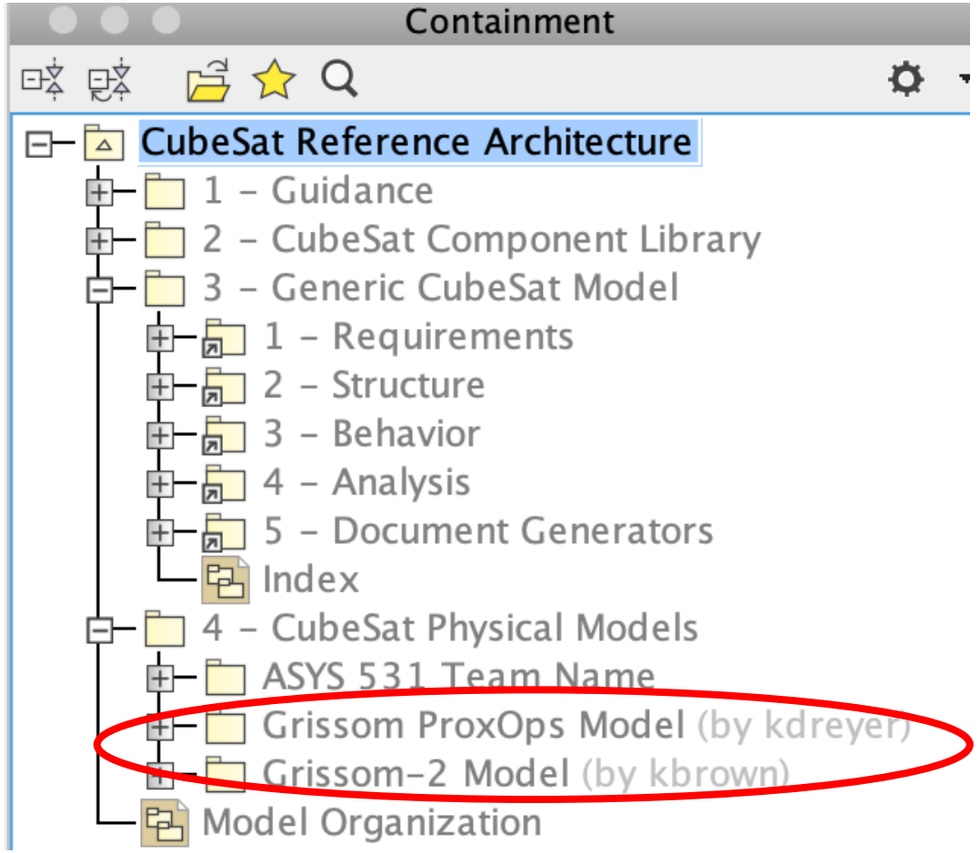
- Currently verifies compatibility and constraints associated with multiple payload, power and data storage/comm
- Research adding support for propulsion

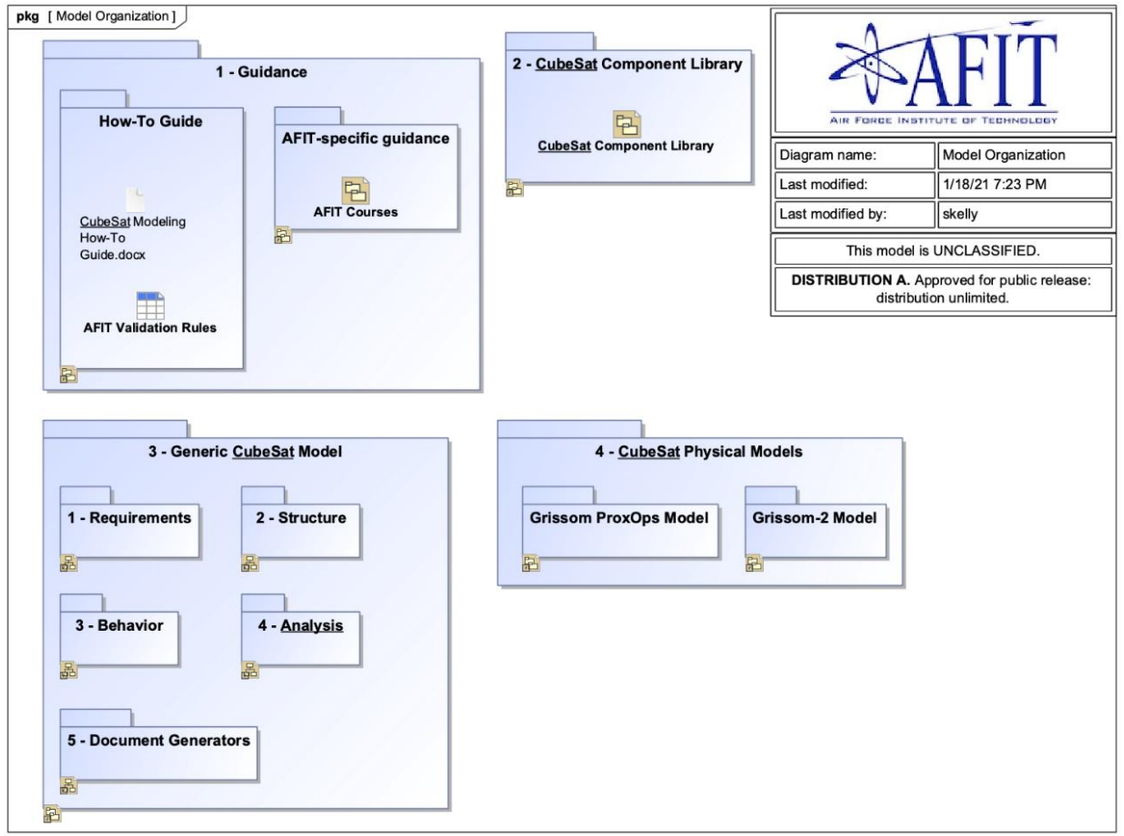
Document Generators



Automatically generate stakeholder documentation from the model using Apache's Velocity Templating Language

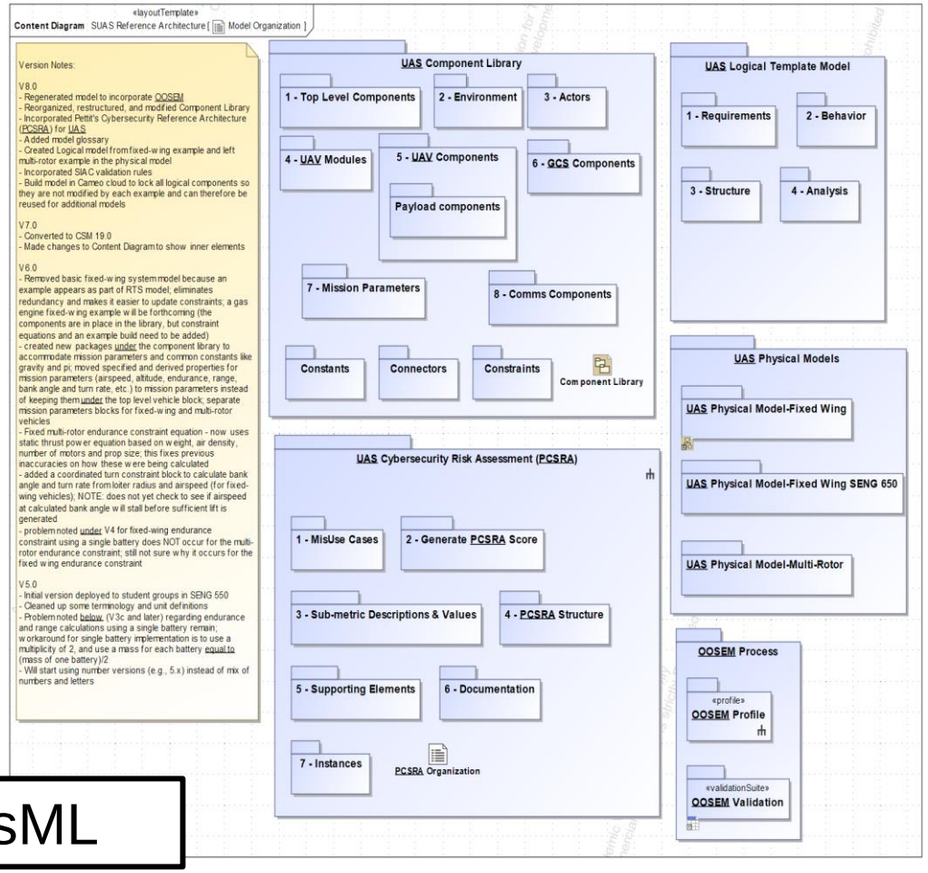
Instances/ Applications of CubeSat RA





Small UAV Reference Arch

- **“Practice what we preach”**
  - Start class with Reference Architecture
  - Iterate/ update model over 3 courses track (Design, Build, Test)
  - Learn Agile/ Rapid prototyping
  - Use model to:
    - analyze requirements,
    - perform sizing analysis (weight, battery, sensor/payload, etc),
    - document PDR (functional),
    - conduct CDR (function, physical, I/F),
    - trace test planning
    - Update Tech Perf Metrics/ Risk
    - Support TRB/SRB,
    - System Verification Review (SVR)
    - Research in DE/MBSE



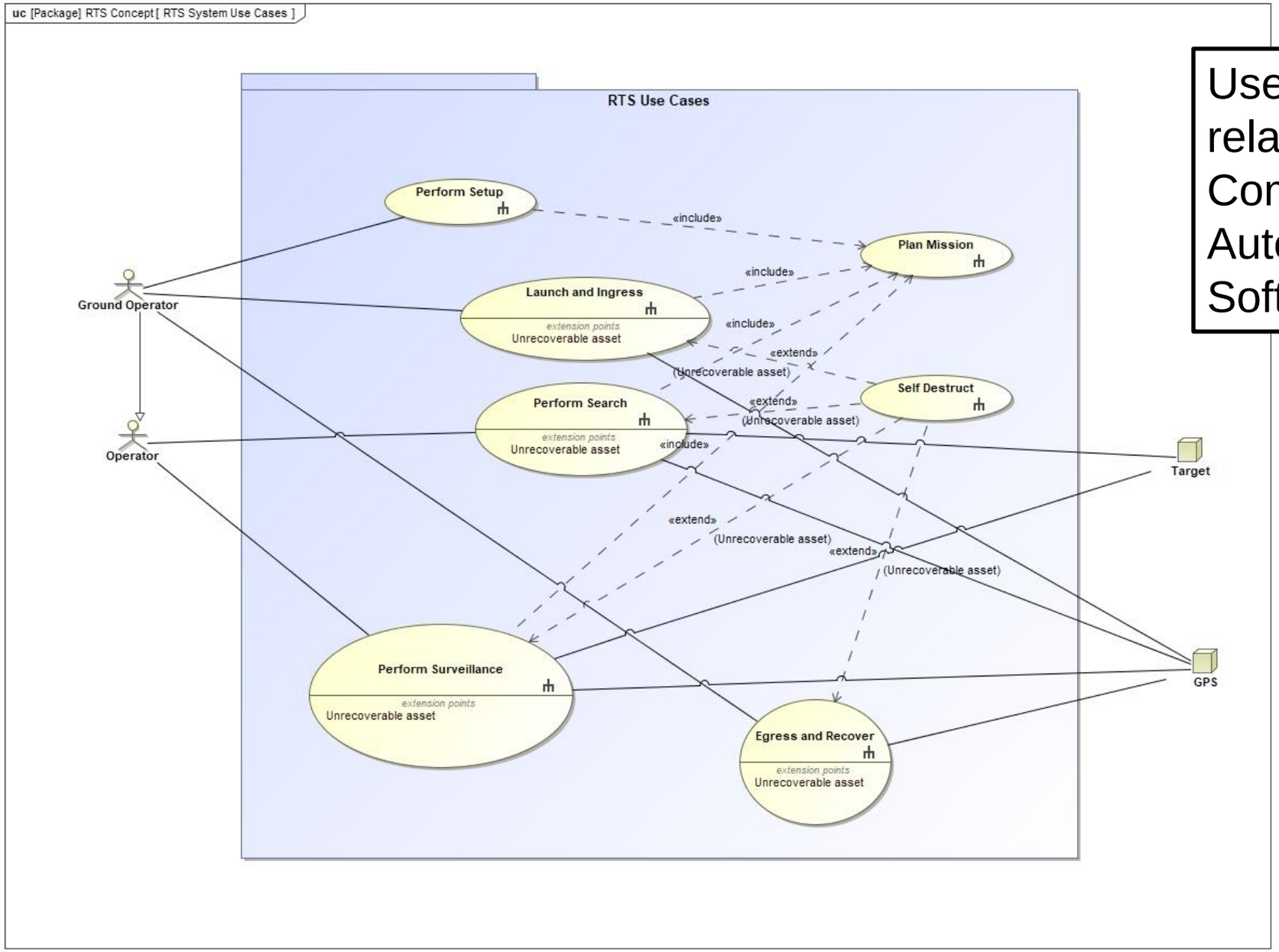
Built in SysML

Using the SUAS Reference Architecture

- Students typically follow an Object Oriented SE Methodology
  - Given draft CONOPS and draft stakeholder requirements
  - CONOPS scenarios are refined with Use Cases; systems requirements defined
  - Use Cases support functional decomposition, with traceability to requirements
  - Functional allocation used to define a physical architecture (to include external systems and operators)
  - Test cases established for verification and validation

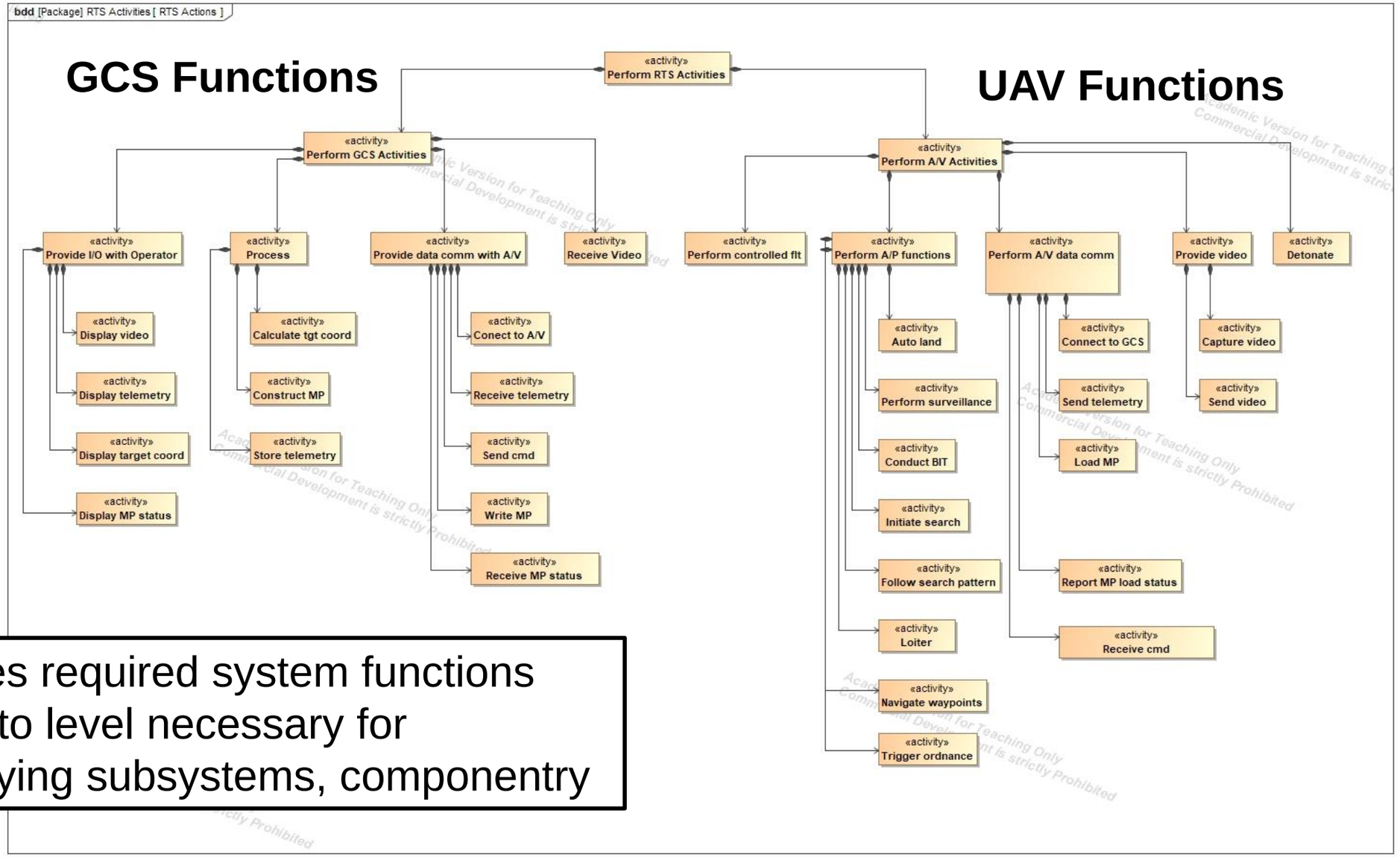
- Architecture models are “deliverables” at PDR, CDR and SVR (post flight)

Remote Targeting System (RTS)



Use Cases can be directly related to Objectives or Composite Behaviors for Autonomous Systems Software Agents

RTS: Activities



Defines required system functions down to level necessary for specifying subsystems, componentry

RTS: Logical Vehicle Design

bdd [Block] Air Vehicle [Air Vehicle]

«block»
Air Vehicle
values
cost : Real{redefines cost}
totalCost : Real{redefines totalCost}
mass : mass[kilogram]{redefines mass,unit}
totalMass : mass[kilogram]{redefines totalMass,unit}

airframe {subsets subCost, subsets subMass} — 1

«block»
Airframe
values
Wingspan : mm : length[millimetre]{unit}
Length : mm : length[millimetre]{unit}
Ailerons present : Boolean = false
Flaps present : Boolean = false
Elevator present : Boolean = false
Rudder present : Boolean = false
Gas engine present : Boolean = false
Servos per elevator : Integer = 1
Number of motors : Real = 1.0
Retracts present : Boolean = false
Number of retract servos : Integer = 0
Make and model : String
cost : Real{redefines cost}
totalCost : Real{redefines totalCost}
L/D : Real = 9.0
Elevons present : Boolean = true
mass : mass[kilogram] = 3.41{redefines mass,unit}
totalMass : mass[kilogram]{redefines totalMass,unit}

propeller {subsets subCost, subsets subMass} — 1

«block»
Propeller
values
Blade count : Integer
Diameter : m : length[metre] = 0.5{unit}
Pitch : length[millimetre]{unit}
Make and model : String
cost : Real = 10.0{redefines cost}
totalCost : Real{redefines totalCost}
Effciency : Real = 0.8
mass : mass[gram]{redefines mass,unit}
totalMass : mass[gram]{redefines totalMass,unit}

motor {subsets subCost, subsets subMass} — 1

«block»
Motor
values
kV rating : Integer = 340
Min cell count : Integer = 6
Max cell count : Integer = 8
Max current : A : electric current[ampere] = 50.0{unit}
Max power : W : electric power[watt]{unit}
Make and model : String
cost : Real = 200.0{redefines cost}
totalCost : Real{redefines totalCost}
Thrust at mid throttle : grams : mass[kilogram] = 1.5{unit}
Current at mid throttle : A : electric current[ampere] = 10.0{unit}
Efficiency : Real = 0.85
mass : mass[kilogram] = 0.083{redefines mass,unit}
totalMass : mass[kilogram]{redefines totalMass,unit}

ESC {subsets subCost, subsets subMass} — 1

«block»
ESC
values
Min cell count : Integer = 2
Max cell count : Integer = 12
BEC included : Boolean
Max BEC current : A : electric current[ampere] = 0.0{unit}
Max current : A : electric current[ampere] = 90.0{unit}
Make and model : String
cost : Real = 100.0{redefines cost}
totalCost : Real{redefines totalCost}
mass : mass[gram]{redefines mass,unit}
totalMass : mass[gram]{redefines totalMass,unit}

servo {subsets subCost, subsets subMass} — 2

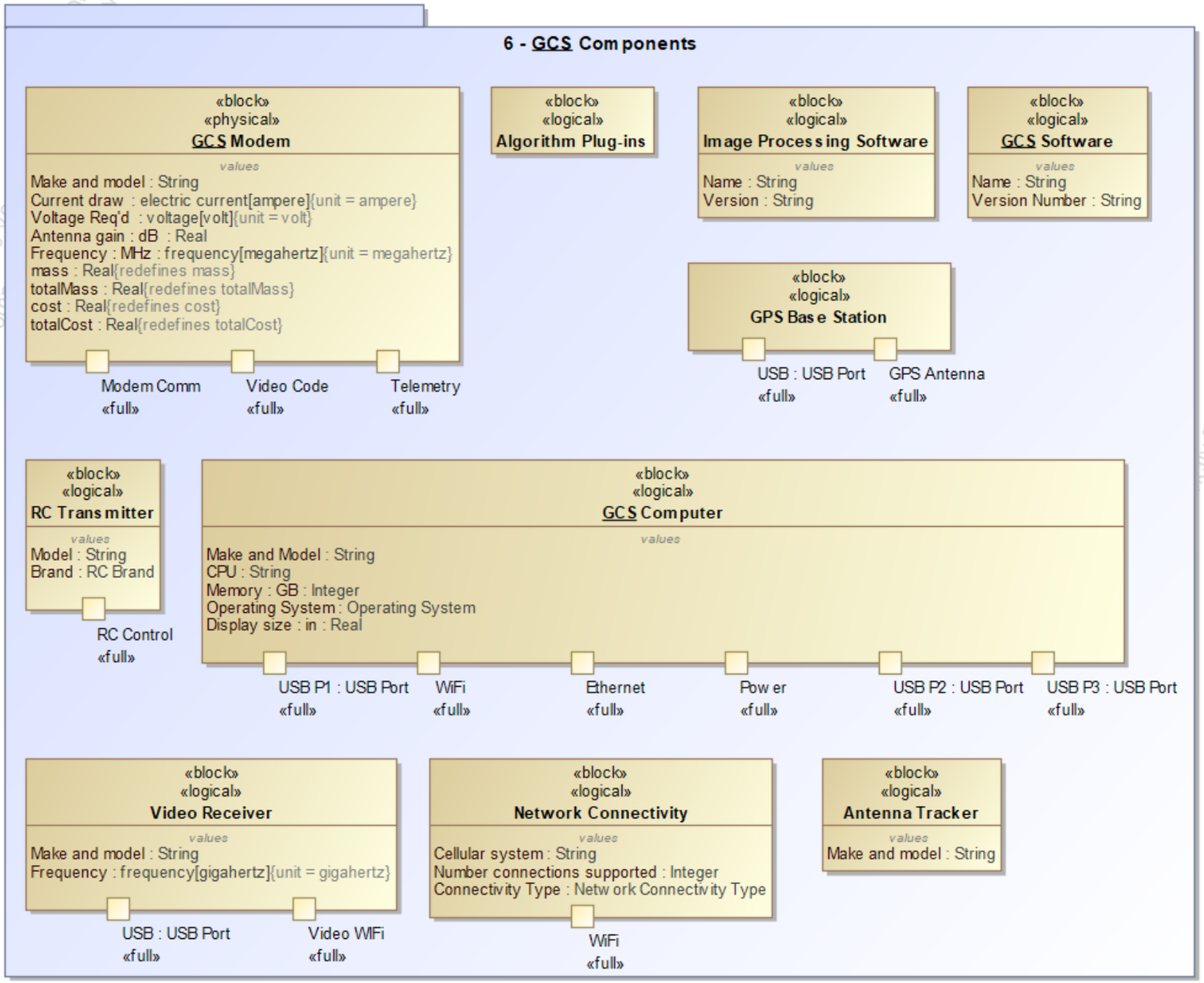
«block»
Servo
values
Max current : A : electric current[ampere]{unit}
Torque : kg-cm : Real
Speed : s : time[second]{unit}
Make and model : String
Digital : Boolean = false
Voltage Req'd : V : voltage[volt]{unit}
cost : Real{redefines cost}
totalCost : Real{redefines totalCost}
mass : mass[gram]{redefines mass,unit}
totalMass : mass[gram]{redefines totalMass,unit}

Academic Version for Teaching Only
Commercial Development is strictly Prohibited

bdd reflects design choices to combine with stock airframe (not including autopilot, comm, and payload, which are defined in parallel branches

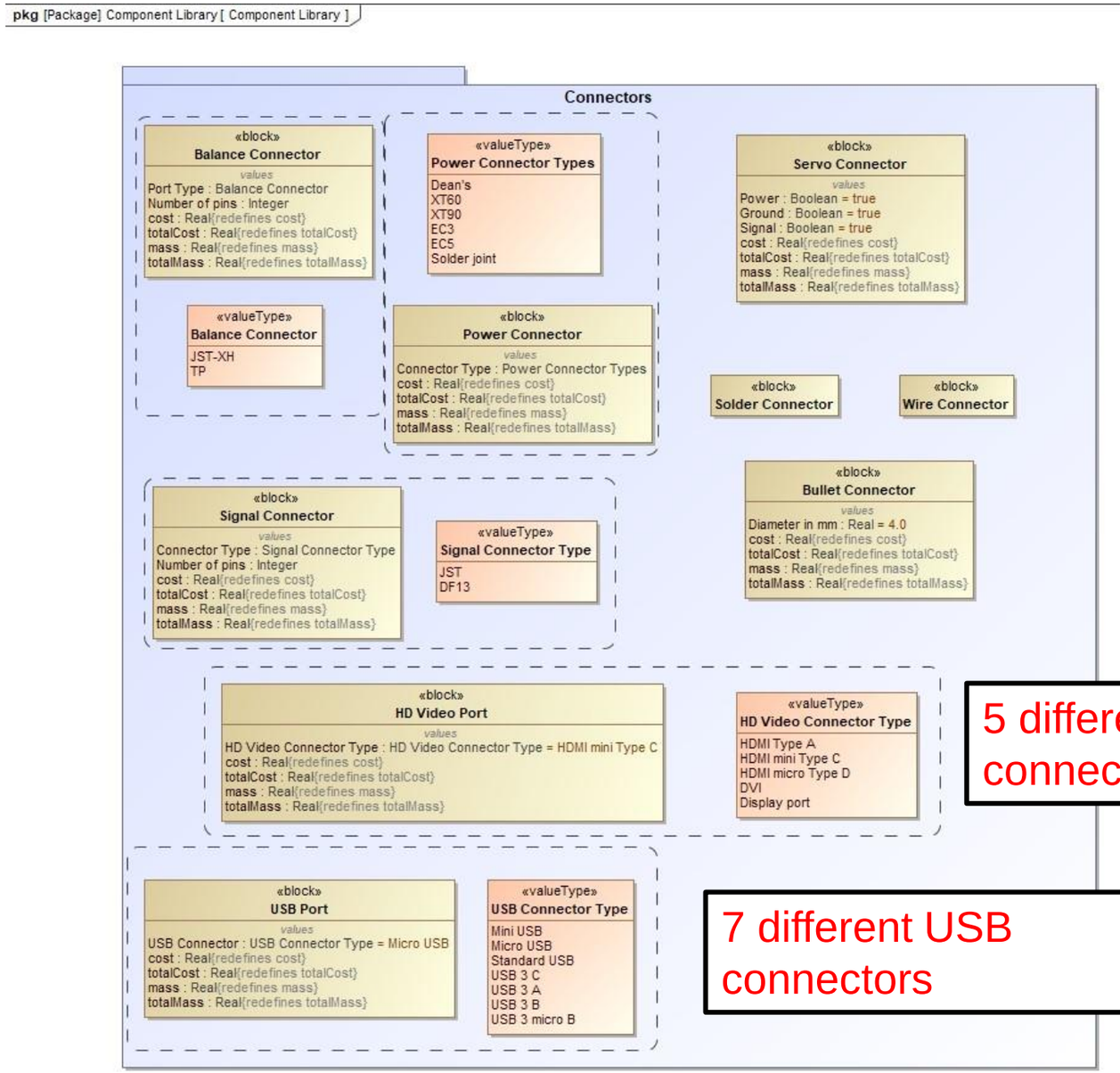
Common Components

Pre-built component blocks with standard interfaces facilitate rapid design through re-use

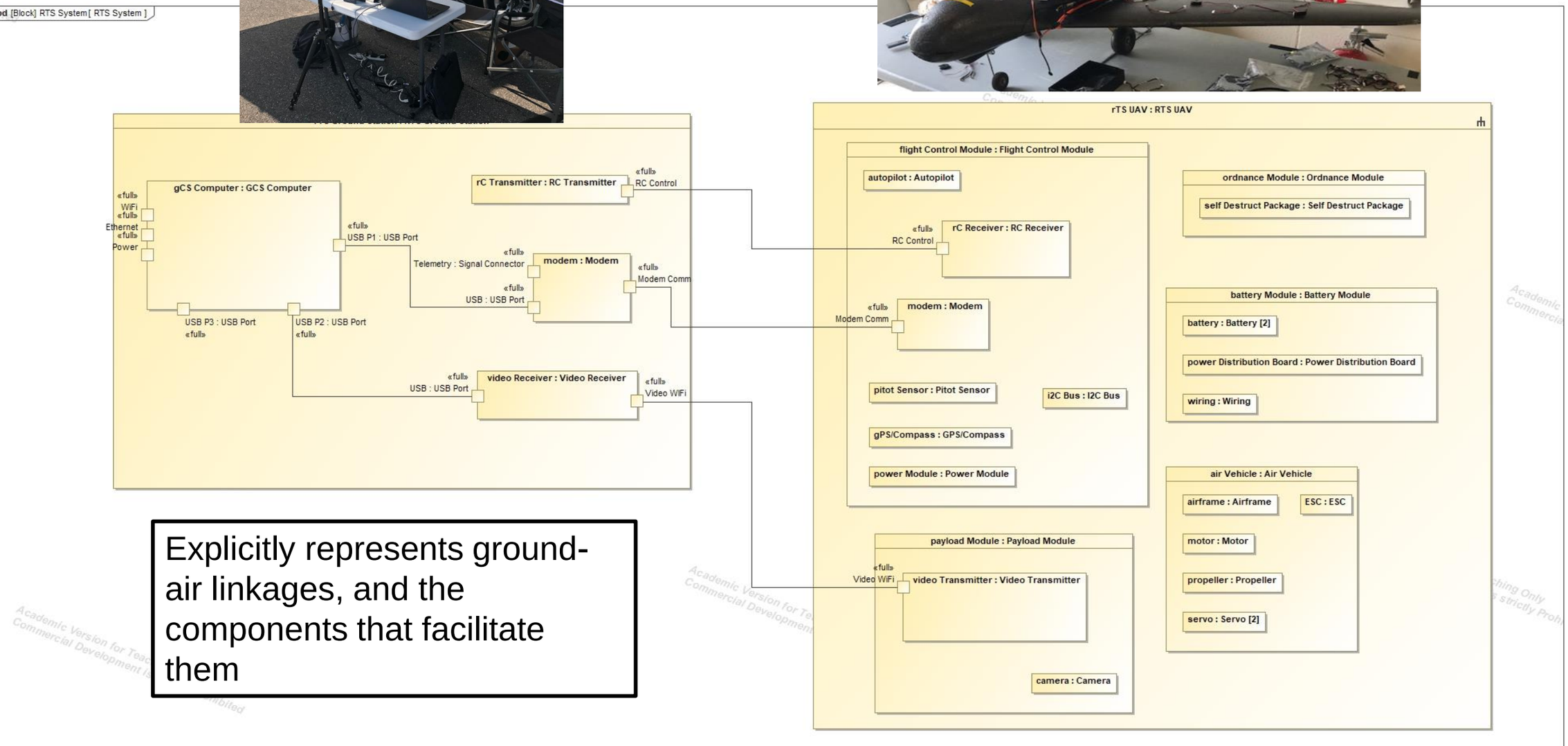


Common Connectors

Pre-typed ports and connectors facilitate integration of COTS components

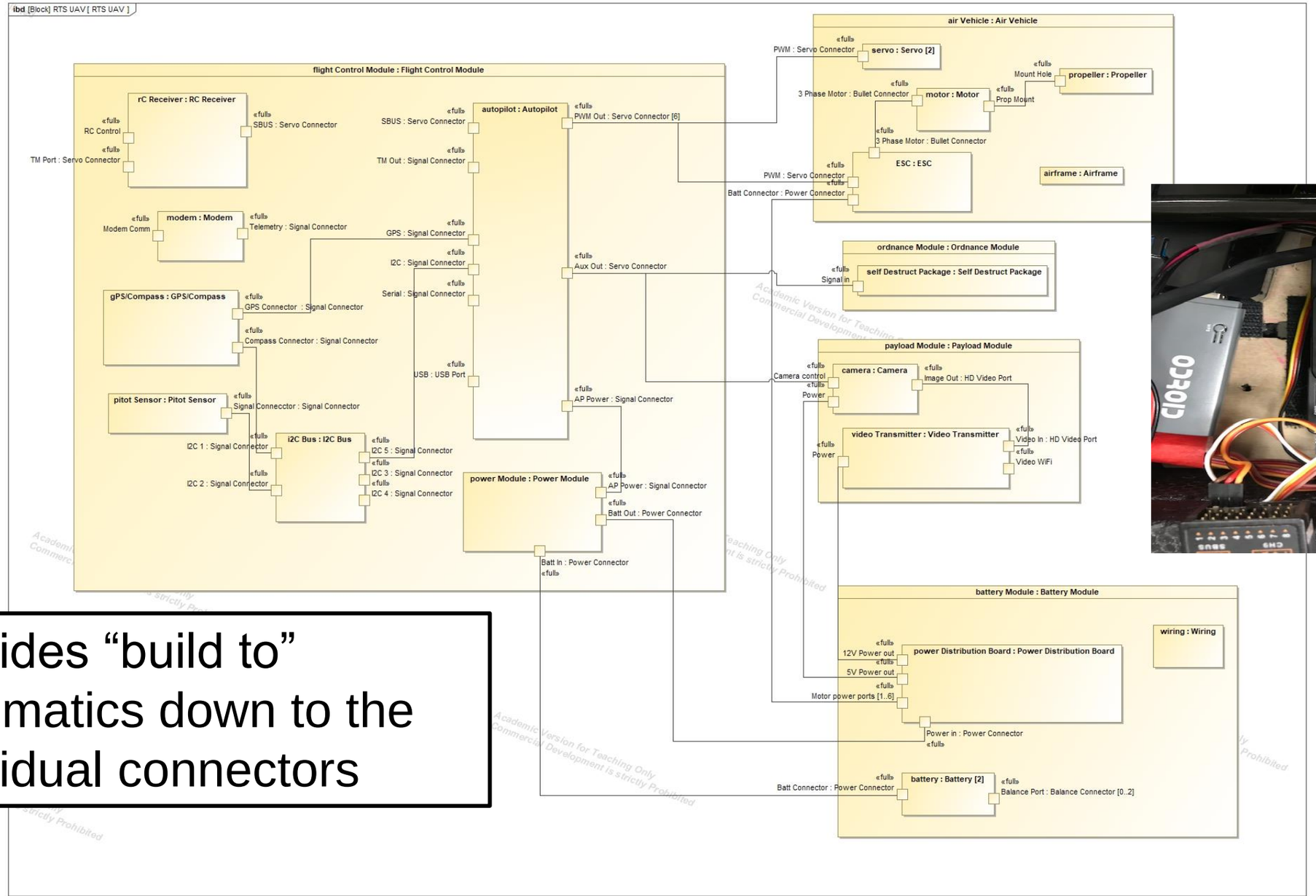


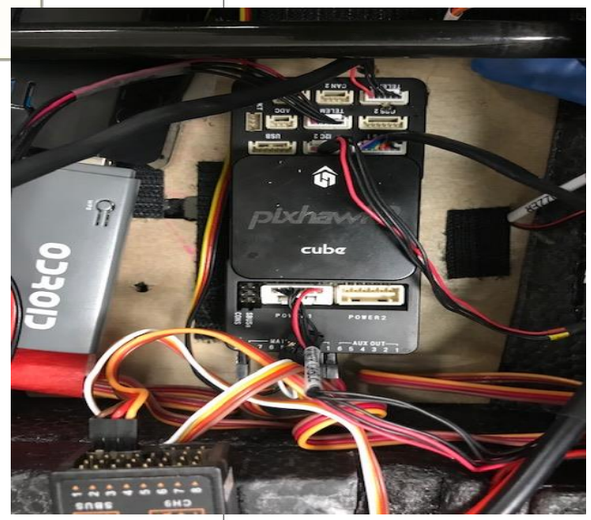
System Level connections (ibd)



Explicitly represents ground-air linkages, and the components that facilitate them

Vehicle schematics (ibd)



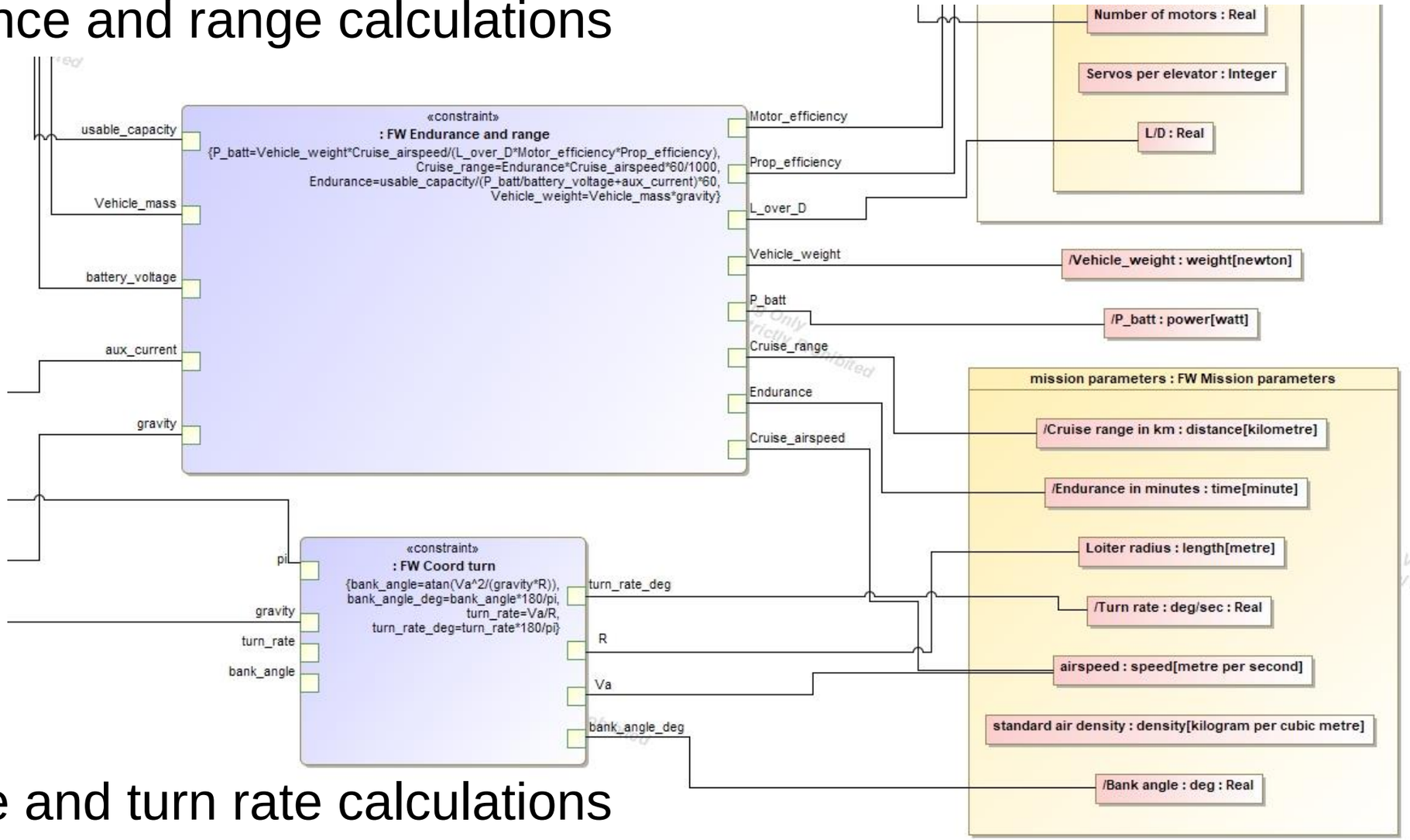


Provides “build to” schematics down to the individual connectors

Parametric analysis & constraints

Component property values

Endurance and range calculations

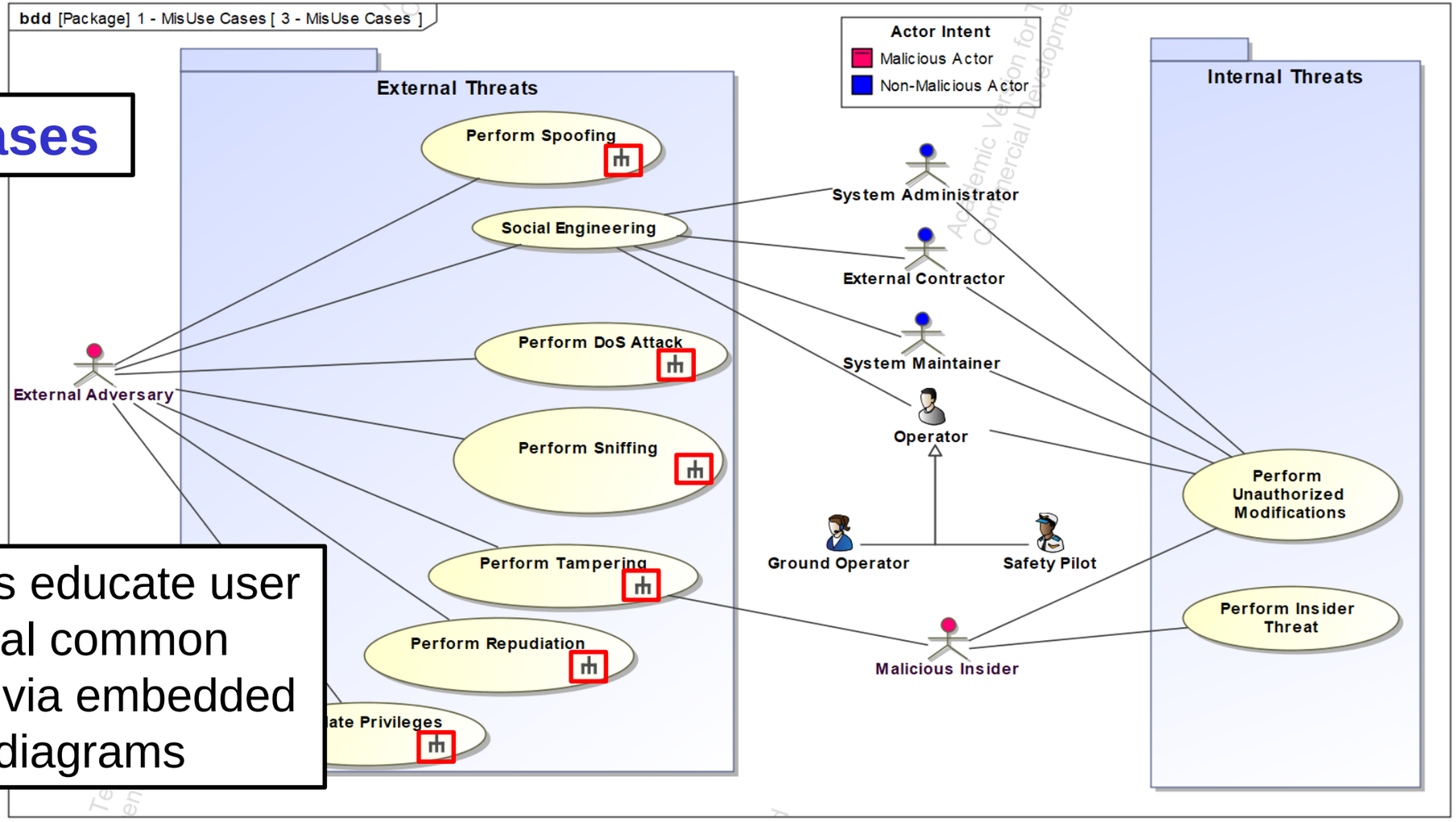


Roll angle and turn rate calculations

Extending the Reference Architecture

- **Research efforts in Digital Engineering**

MisUse Cases

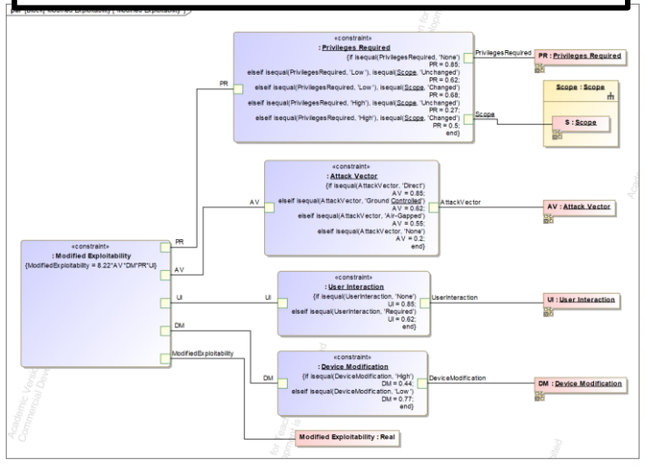


Misuse Cases educate user on potential common cyberattacks via embedded activity diagrams

Cybersecurity Risk Assessment

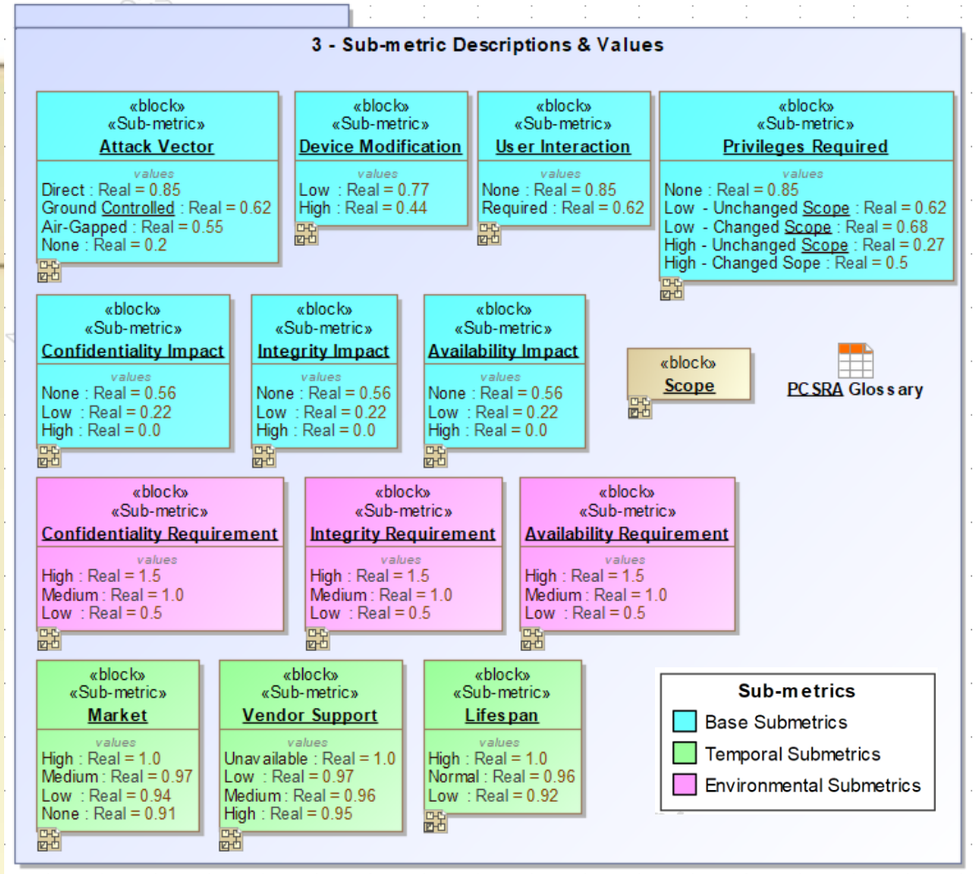
Designed based on the Common Vulnerability Scoring System (CVSS)

Reach into system model elements using Parametric Constraints



«block»
«logical»
UAS Enterprise

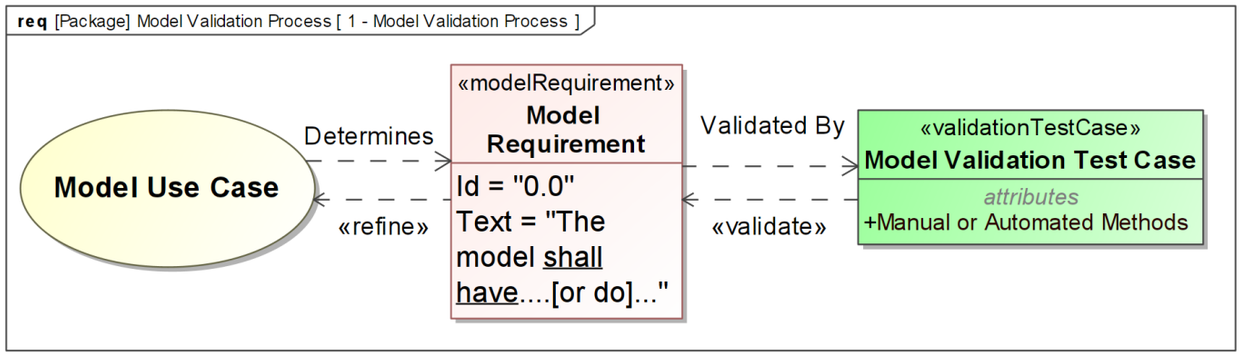
values
AV : Attack Vector = None
DM : Device Modification = Low
PR : Privileges Required = High
S : Scope = Unchanged
UI : User Interaction = Required
CI : Confidentiality Impact = High
II : Integrity Impact = Low
AI : Availability Impact = Low
M : Market = Medium
VS : Vendor Support = High
L : Lifespan = Low
CR : Confidentiality Requirement = Low
IR : Integrity Requirement = Low
AR : Availability Requirement = Low
PCSRA Score

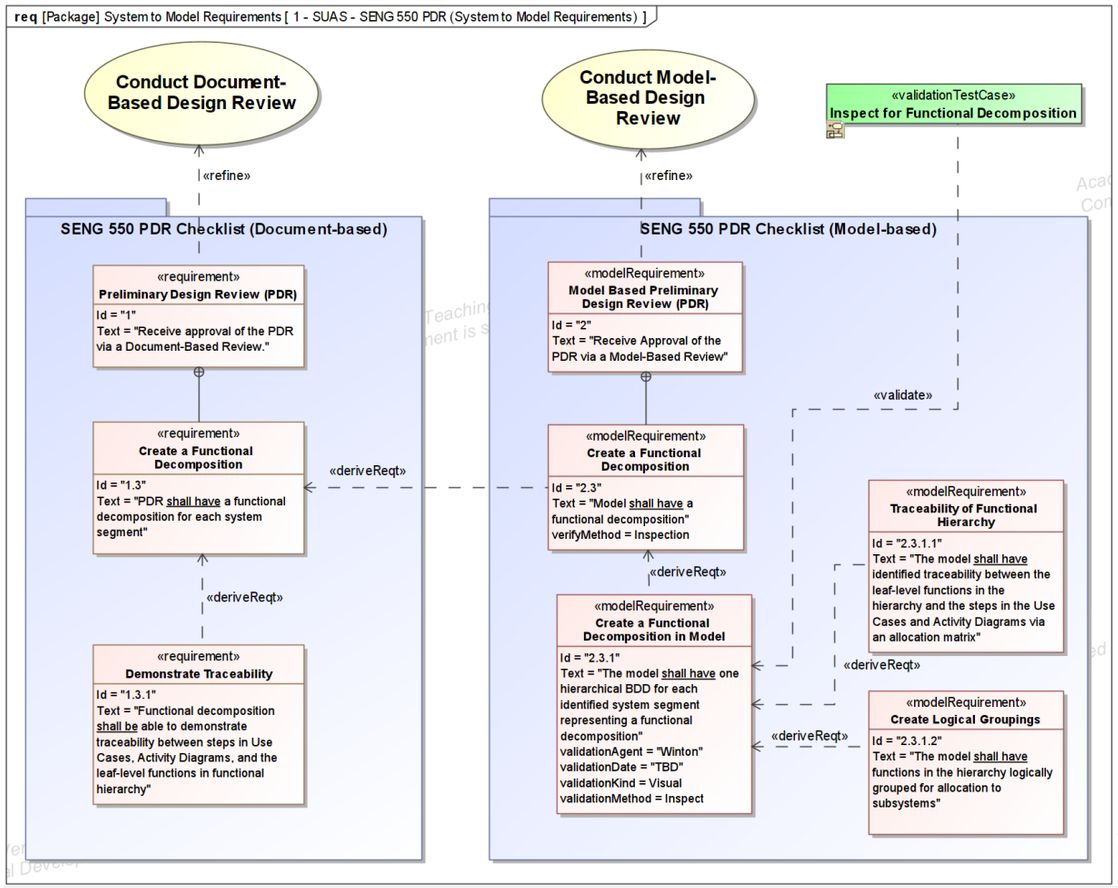


Designer can manually change these values based on their specific UAS

Extending the Reference Architecture

- **Research efforts in Digital Engineering**
- ***Validation of Digital System Models, March 2023***
  Capt James Winton. Research sponsored by: F-16, AFLCMC/WAM





Tuition Free Policy

Air Force Graduate School of Engineering & Management

- https://www.afit.edu/EN/
- Free to Air Force military and civilians. Open to defense contractors

Opportunities for Certificate or Masters programs

- **Systems Engineering Certificate (4 courses)**
- **Master of Science in Systems Engineering**
  Thesis. available entirely via Online, 9 courses + thesis
- **Master of Engineering in Applied SE**
  Non-thesis. available entirely via Online, 11 courses + capstone

Where (to apply): https://www.afit.edu/Admissions/
What (you need): BS (Engineering, STEM), GPA(≥ 3.0), ~~GRE (V ≥ 153, Q ≥ 148)~~
… Apply regardless of your academics.
When (to apply): Anytime. Eligibility good for 3 years. Apply now (why not?!)

Questions?

Air Force Institute of Technology

Adoption of Model-Based Systems Engineering in Traditional DoD Systems

Capt Patrick Assef, AFNWC/NXEE
Lt Col Jeremy Geiger, AFIT/ENV

12 May 2023

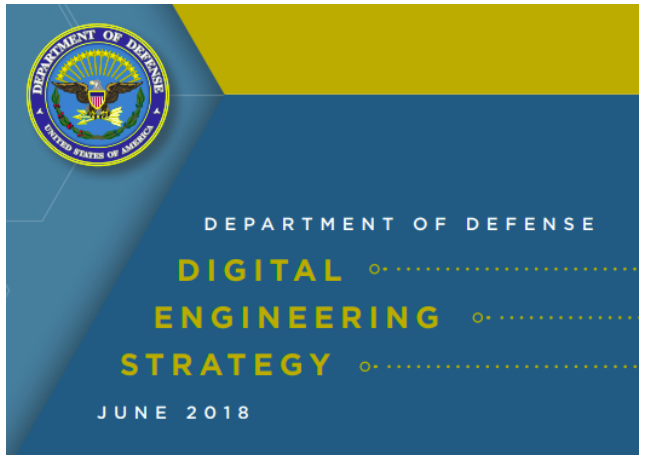
Overview

- Background & Research Questions
- Research Methods
- Results & Conclusions
- Ongoing Efforts

Background

"…the next big paradigm shift for military tech dominance. Rather than just building better systems, it builds systems better…"

-Dr. William Roper, *There is No Spoon*



USAF announces launch of new Digital Transformation Office

10 Jun 2021 (Last Updated June 10th, 2021 17:06)

The new DTO office will support collaboration and sharing of best practices and lessons learned.

DAYTON BUSINESS JOURNAL

New Air Force center to support military's digital transformation, aided by Dayton companies

Need for Digital Transformation

Initial Guidance failed to provide:

- Time/Cost/Schedule expectations
- Single, Department-wide software tool
- Licenses
- Training
- Templates
- Classification guidelines

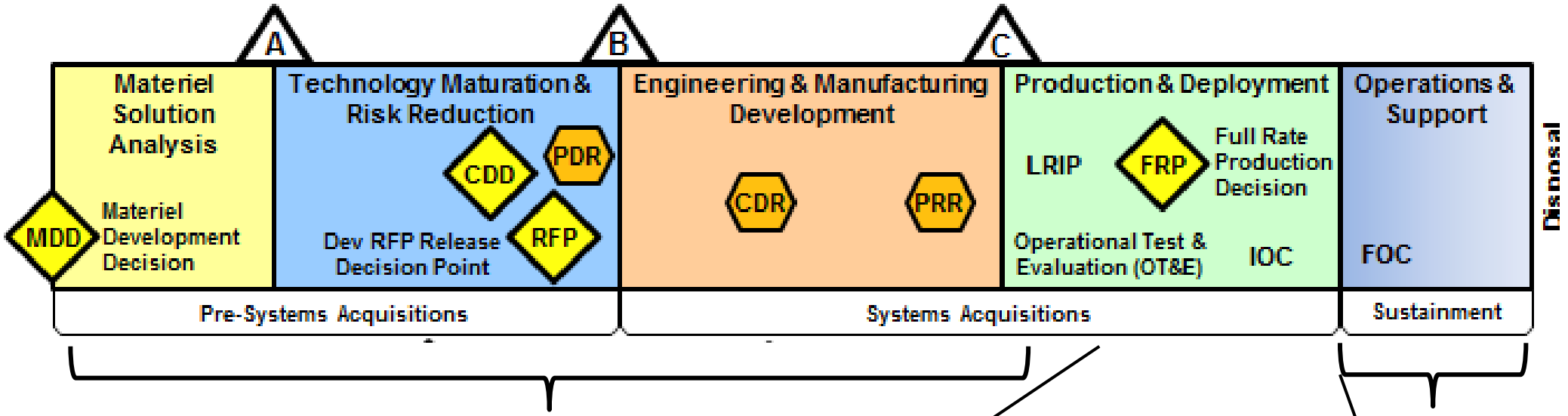
Program Office's Need to determine:

- State of current systems engineering tools (i.e. document based)
- Desired end state (i.e. Model Based Systems Engineering)
- What Software is Needed (licenses, cost, AFNet approval, long-term support)
- Staff (user) training requirements
- Cost & Schedule impacts
- Unique program gains/pitfalls





How are Programs Effected?



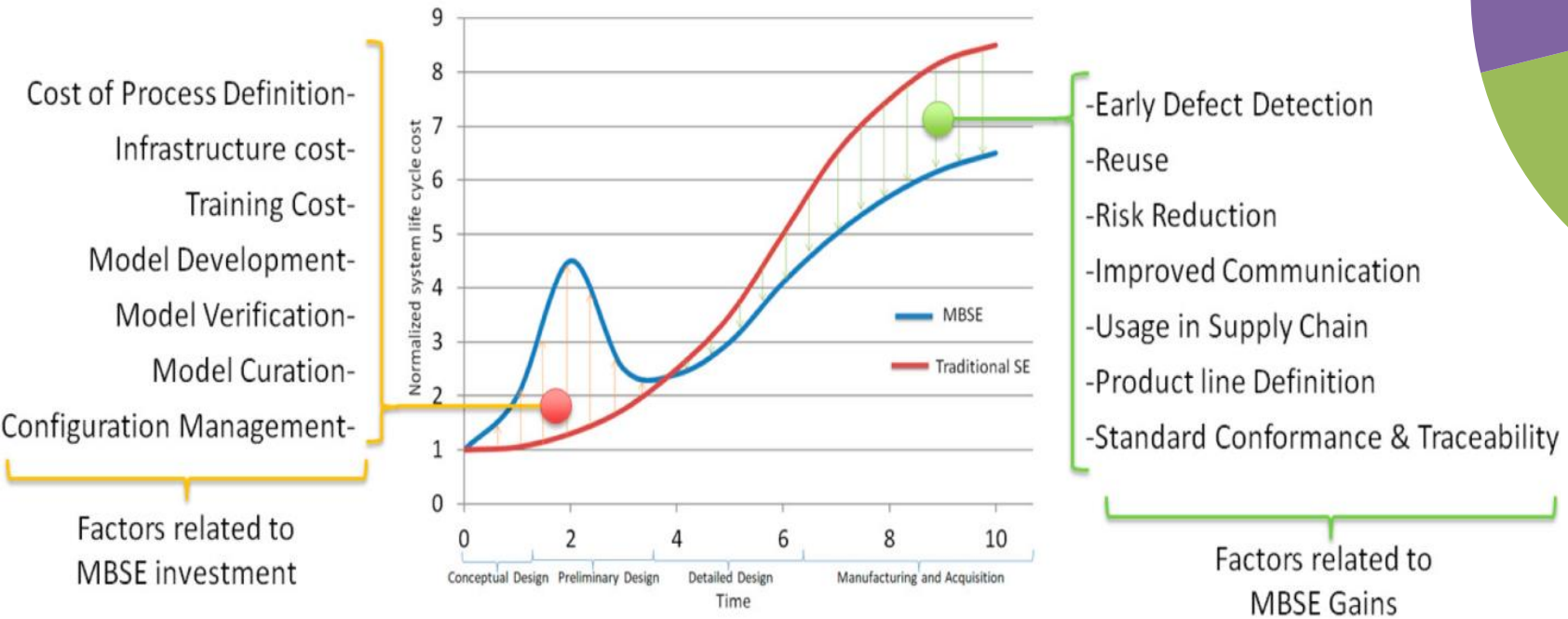
Program Start:
"Ground-up"

Program Closure:
Not worthwhile

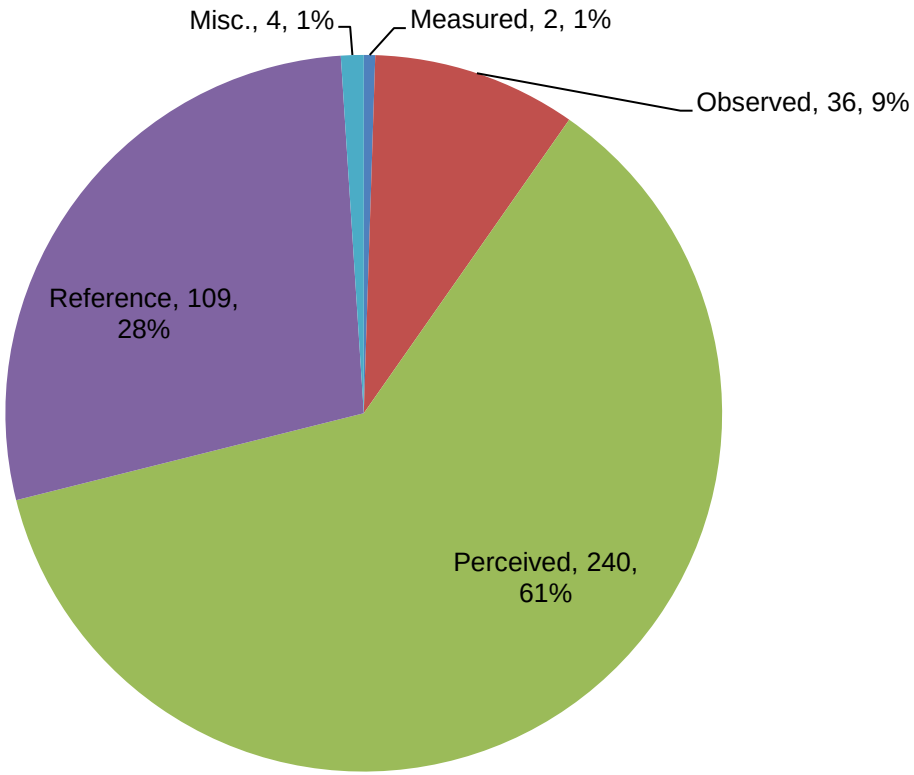
~80% of DoD programs are firmly in Operations & Sustainment phase

What Does Everyone Else Think?

- **Literature gaps:**
  - Capturing MBSE efforts/benefits
  - Transitioning existing systems to MBSE



(Madni & Purohit, 2019:13)



(Henderson & Salado, 2020:59)

Research Questions

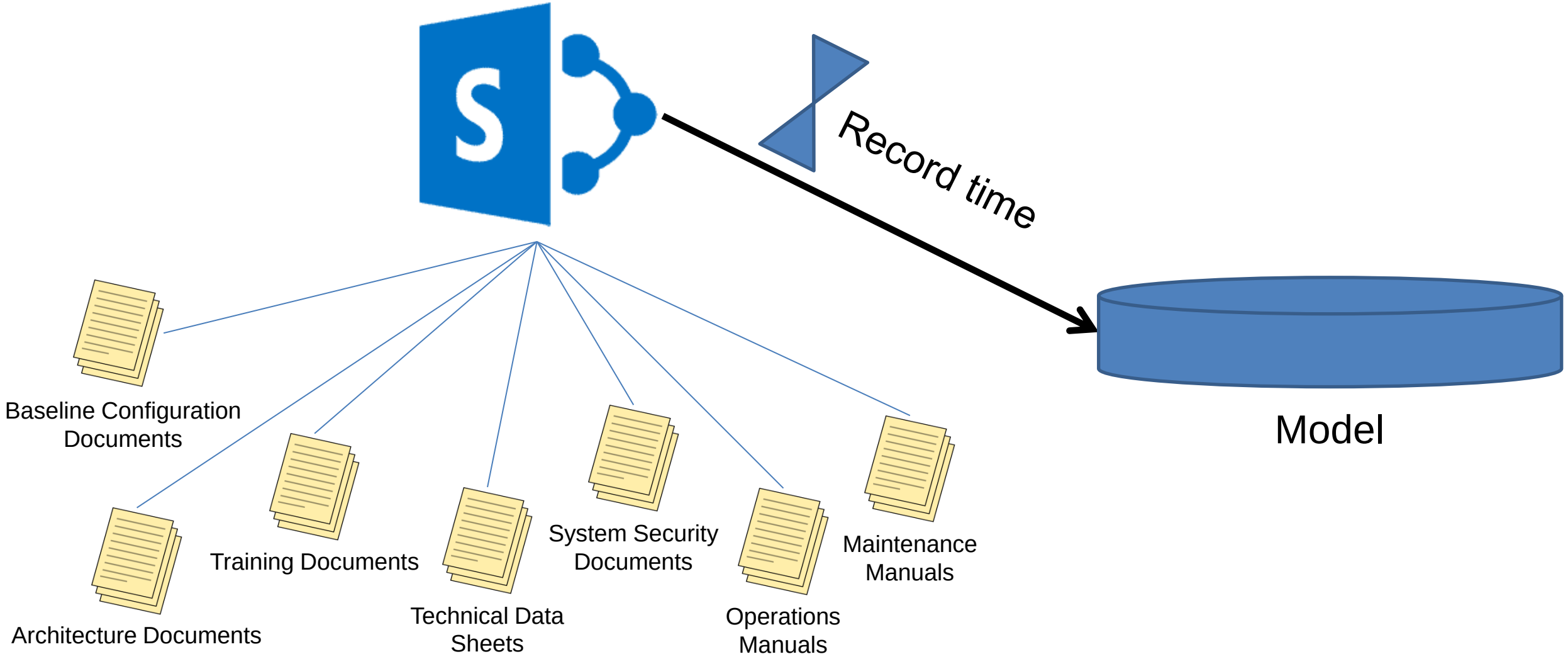
1. **What effort is required to transition an existing SoS to MBSE?**
2. **How can the effort be measured?**
3. What types of costs are associated with MBSE adoption?
4. What resources are available for program offices wishing to transition to MBSE?

Overall Methodology

- **Document-based system or System of Systems (SoS)**
- **Repository of available SE documents**
- **Record time to transition documents to model**
- **MBSE costs (Madni & Purohit, 2019:13)**
  - Process definition
  - Infrastructure
  - Training
  - Model-related
- **Gather MBSE resource information**
  - INCOSE, Object Management Group, DTO

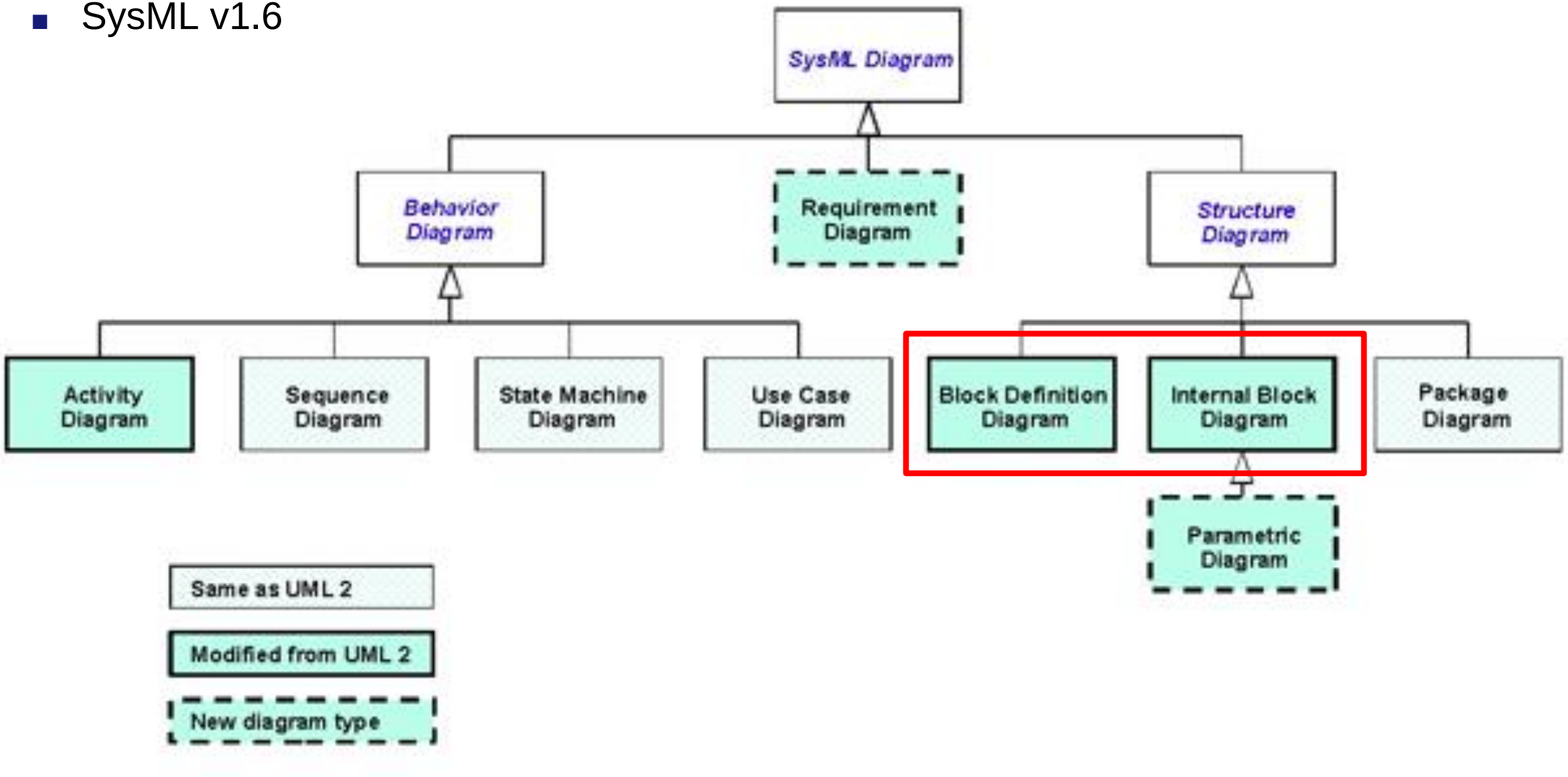
Methodology – Data Collection

- **System of Interest: ACAT III (<$200M RDT&E and <$920 Procurement)**

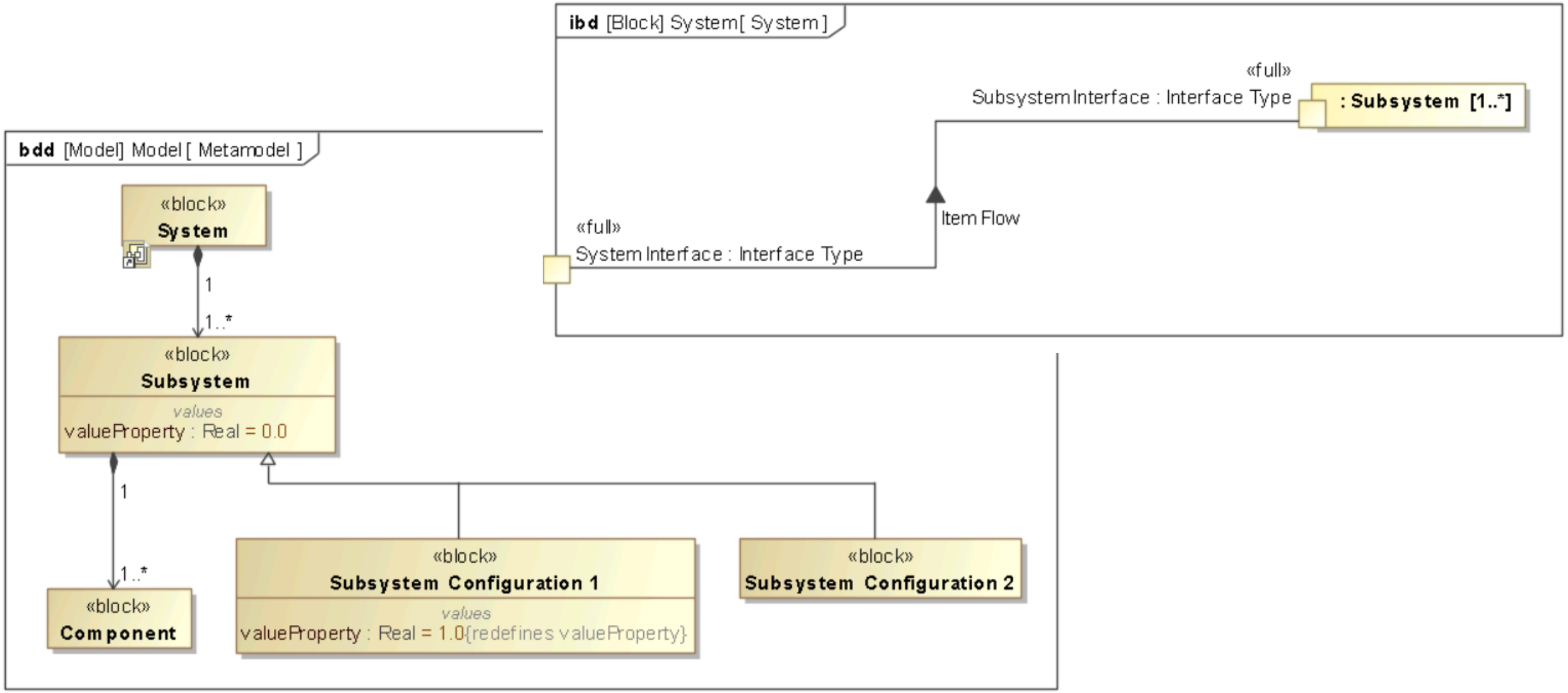


Methodology – Cameo Systems Modeler

- **Cameo Systems Model V19.0 SP4**
  - SysML v1.6



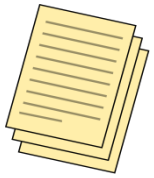
Methodology – Cameo Systems Modeler



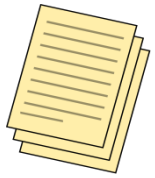
Results – Effort

Category 1

Maintenance Manual



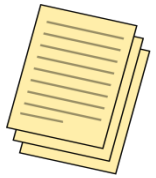
Operations Manual



Technical Data Sheet

ICD

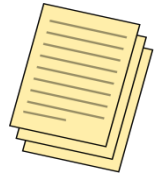
Category 2



Operations Manual

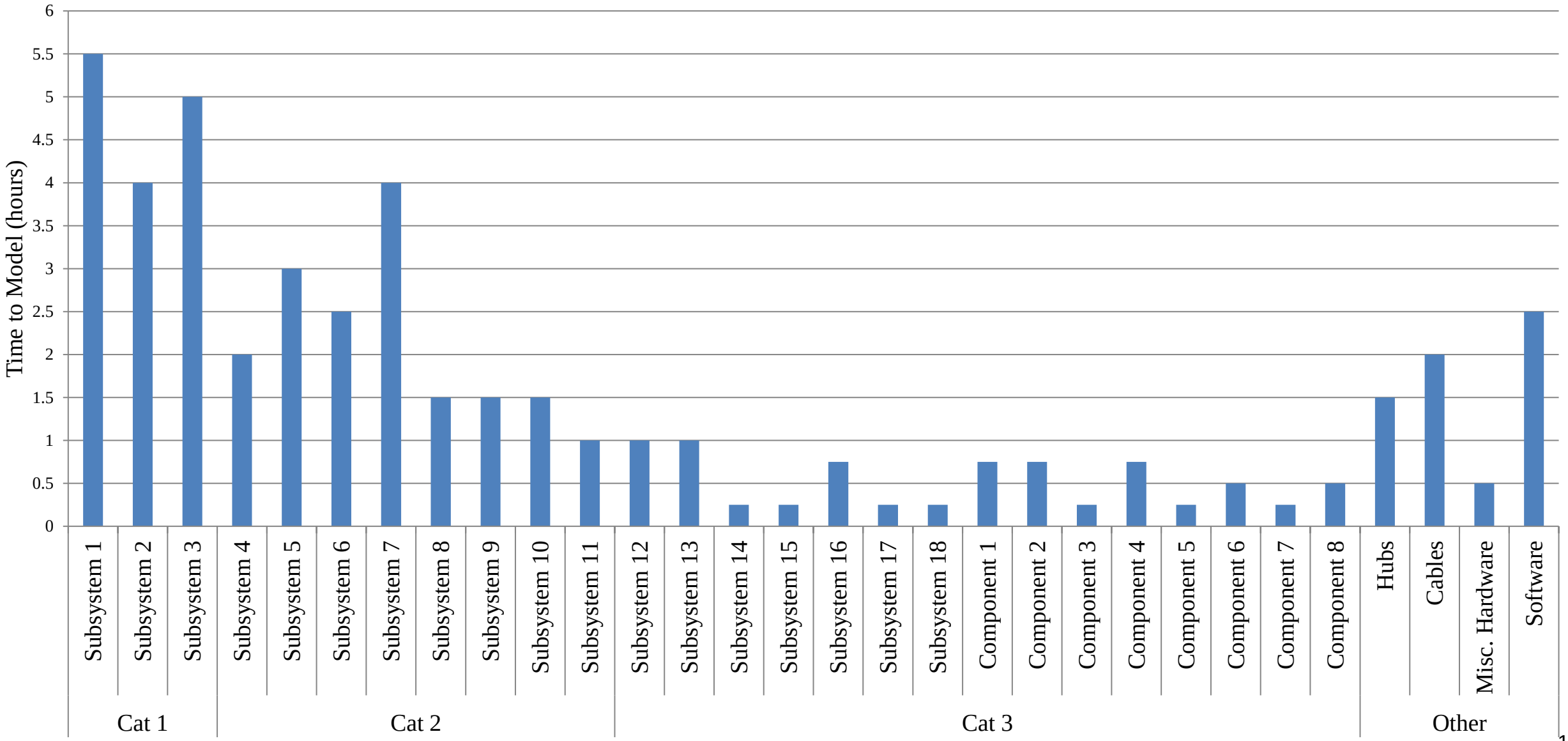
Technical Data Sheet

Category 3



Technical Data Sheet

Results – Effort



Results – Effort

Portion	Time Spent Transitioning to MBSE (hrs)	Time Spent Transitioning to MBSE (%)
Subsystems/ Components	45.75	49.6
SoS Structure	38.5	41.7
Model	8	8.7
Total	92.25	100

Results – Effort

Model Portion	Average Time to Model (hours)
Category 1 Subsystem/Component	4.833
Category 2 Subsystem/Component	2.125
Category 3 Subsystem/Component	0.5167
Cabling	0.069/cable
Power/Data Hubs	0.375/hub
Software	0.05/piece of software
Miscellaneous Hardware	0.125/component
SoS	1.283 per subsystem or component
General Modeling	0.267 per subsystem or component

Research Questions

1. What effort is required to transition an existing SoS to MBSE?
2. How can the effort be measured?
3. **What types of costs are associated with MBSE adoption?**
4. **What resources are available for program offices wishing to transition to MBSE?**

Methodology – Resources

Software	Name of the software.
Company	Company which develops the software.
Country of Origin	Country where the company is located.
Number of Users	Numbers of users of the software.
Version	Different versions of the software available, ordered from least amount of features to most.
Price	Price of the software, rated on a scale of $ (low) to $$$ (high).
Purchase Options	Perpetual, rental, and/or subscription.
License Type(s)	Standard, floating, or both.
Modeling/Simulation	Modeling and/or simulation.
Cloud Service	Does the software offer a cloud service for model storage and collaborative work?

Results – Resources

Software	Developer	Country of Origin	No. of Users	Variation	Price (USD)	License Type	Purchase Options	Modeling/ Simulation ?	Cloud Service?
Astah	Change Vision, Inc.	Japan	640,000	astah SysML	$	Both	Perpetual or subscription	Modeling	N
				astah System Safety	$	Both		Modeling	Y
Cameo Systems Modeler	Dassault Systemes (aquired from	France		Architect Edition	$$-$$$	Both	Perpetual or subscription	Modeling	Y
				Enterprise Edition	$$$	Both		Both	Y
Capella	Multiple	France	50+ organizational users	N/A	Free	N/A	N/A	Modeling	?
Engineering Systems Design Rhapsody	IBM	USA		Architect for Systems Engineers	?	Both	Perpetual or subscription	Modeling	Y
				Designer for Systems Engineers	?	Both		Both	Y
Enterprise Architect	Sparx Systems	Australia	850,000+ licenses sold	Professional	$	Both	Perpetual or subscription	Modeling	Y
				Corporate	$	Both		Modeling	Y
				Unified	$	Both		Both	Y
				Ultimate	$$	Both		Both	Y
GENESYS	Vitech	USA		N/A	$$$	Both	Perp. or sub.	Both	Y
Innoslate MBSE	SPEC Innovations	USA	2000+ companies	N/A	?	Both	?	Both	Y
Modelio	Modeliosoft	France		N/A	Free	N/A	N/A	Modeling	N
Papyrus	CEA LIST, Eclipse Foundation	France		N/A	Free	N/A	N/A	Both	N
SCADE Architect	Ansys	USA		N/A	?	?	?	?	?
Software Ideas Modeler	Software Ideas	Slovakia		Premium	$	Both	Perpetual or subscription	Modeling	Y
				Professional	$	Both		Modeling	Y
				Ultimate	$	Both		Modeling	Y
Visual Paradigm	Visual Paradigm	Hong Kong	320,000+ people	Modeler	$	Both	Perpetual, subscription, or rental	Modeling	Y
				Standard	$	Both		Modeling	Y
				Professional	$	Both		Modeling	Y
				Enterprise	$$-$$$	Both		Modeling	Y
Windchill Modeler	PTC	USA		N/A	?	?	?	?	?

Methodology – Resources

Organization	Organization which offers the course.
Course	Title of the course.
Price	Price of the course, if there is one.
Language/Tool	What MBSE language(s) and tool(s) the course uses.
Level	The MBSE skill level of the course: beginner, intermediate, or advanced.
Length	Length of the course.
Course Delivery	How to course is taken: in-person, synchronous remote, or asynchronous remote.

Results – Resources

Organization	Course	Price	Language/Tool	Level	Length	Delivery
AFIT	SENG 520 Foundations of Systems Engineering	?	SysML/Cameo	Beginner	10 weeks	In-person or Virtual
	SENG 660 Advanced Principles of Engineering Design	?	SysML/Cameo	Advanced	10 weeks	In-person or Virtual
	Tailored Program Specific Modeling and Cameo Course	?	SysML/Cameo	Varies	1-4 weeks	In-person or Virtual
Cal Tech	Model-Based Systems Engineering (MBSE) Certificate Program	$2,850	SysML	Beginner	5 days	Virtual - Sync
Dassault Systemes	SysML Intensive with MBSE Using Cameo Systems Modeler	Paid	SysML/Cameo	Beginner	5 days	In-person or Virtual
	Teamwork Cloud Project Strategies and Best Practices	Paid	SysML/Cameo	Intermediate	2 days	In-person or Virtual
	Simulation Toolkit with Cameo Systems Modeler	Paid	SysML/Cameo	Advanced	5 days	In-person or Virtual
DAU	CENG 001 Coursera-MBSE (Model-Based Systems Engineering)	Free		Intermediate	11 hours	Virtual - Async
IBM	IBM Engineering Systems Design Rhapsody plus SysML for MBSE	Paid	SysML/Rhapsody	Intermediate	24 hours	In-person or Virtual
	Quick Starts: IBM Engineering Systems Design Rhapsody for MBSE	Free	Rhapsody	Beginner	2 Hours	Virtual - Async
	Accelerated IBM Engineering Systems Design Rhapsody for Existing UML/SysML Users	Paid	UML or SysML/Rhapsody	Advanced	24 hours	In-person or Virtual
MIT xPro	Architecture and Systems Engineering: Models and Methods to Manage Complex Systems	$3,249	SysML	Beginner	17 weeks	Virtual - Sync
NASA	Foundations of MBSE (APPEL-vMBSE1)	Free	General MBSE	Beginner	1 day	Virtual - Sync
	Applied MBSE (APPEL-vMBSE2)	Free	General MBSE	Intermediate	2 days	Virtual - Sync
	Model Based Systems Engineering Design and Analysis (APPEL-vMBSE3)	Free	General MBSE	Advanced	3 days	Virtual - Sync
NAVAIRU	CORE-410-102 Basic SysML (101/201)	Paid	SysML	Beginner		
	CORE-410-103 Intro to SysML	Free	SysML	Beginner	4 hours	Virtual - Async
	CORE-411-115 SE Bootcamp	Free	General MBSE	Beginner	5 days	In-person
	CORE-411-116 SET for PMs and IPTLS	Free	General MBSE	Beginner	3 hours	Virtual - Async
	CORE-41B-2001 A Look Ahead at SysML v2 by Sanford Friedenthal	?	SysML	Intermediate		
	CORE-41B-200121 Language, Profile, & Framework	?	SysML	Intermediate		
	CORE-41B-200211 Cameo Collaborator-Tutorial	?	SysML/Cameo	Intermediate		
	CORE-44W-190314	?	SysML	Intermediate		
	CORE-450-195 Applying Open Architecture Through MBSE for Applications at NAVAIR	?	UML & SysML	Intermediate		
	CORE-4KB-181219 Application of MBSE in the Development of UPneXt	?	General MBSE	Beginner		
	CORE-4M2-107 SysML Intensive with MBSE using CSM	?	SysML/Cameo	Intermediate	5 days	
Naval Postgraduate School	SE4930 Model-Based Engineering Course	$2,500		Intermediate	10 weeks	Virtual - Sync
	MBSE Certificate Program	$10,000		Intermediate	1 year	Virtual - Sync
PivotPoint Technology	Essential MBSE + SysML Applied	Paid	SysML/Various	Beginner	3-5 days	In-person or Virtual
	Intermediate MBSE + SysML Applied	Paid	SysML/Various	Intermediate	4-5 days	In-person or Virtual
	Advanced MBSE + SysML Applied	Paid	SysML/Various	Advanced	3-5 days	In-person or Virtual
Sparx Services	MBSE using Sparx EA	Paid	SysML/Enterprise Architect	Intermediate	5 days	In-person or Virtual
SPEC Innovations	IST 101 Introduction to Innoslate	Paid	LML/Innoslate	Beginner		In-person or Virtual
	IST 201 Innoslate for MBSE	Paid	LML/Innoslate	Beginner	2 days	In-person or Virtual
	IST 501 Intermediate Innoslate Application	Paid	LML/Innoslate	Intermediate	3 days	In-person or Virtual
	IST 705 Advanced Innoslate Workshop	Paid	LML/Innoslate	Advanced		In-person or Virtual
Teaching Science and Technology, Inc.	MBSE Course with Workshop	$980	General MBSE/Innoslate	Beginner	4-5 days	In-person or Virtual
Thales	Arcadia & Capella MBSE training	Paid	Capella	Beginner	3 days	
Visual Paradigm	Visual Paradigm Essential	Free	Visual Paradigm	Beginner	5+ hours	Virtual - Async
Vitech	MBSE Tutorial	Paid	General MBSE	Beginner	2 hours-2 days	
	Introduction to MBSE with GENESYS	$1,995	GENESYS	Intermediate	5 days	Virtual - Sync

Conclusion

1. **What effort is required to transition an existing SoS to MBSE?**
   - 92.25 hours: 45.75 on subsystems/components, 38.5 on structure, 8 on general modeling
2. **How can the effort be measured?**
   - Subsystem/component categories, time to model
3. **What types of costs are associated with MBSE adoption?**
   - Process definition, model-related, infrastructure, training
4. **What resources are available for program offices wishing to transition to MBSE?**
   - 5 processes, 13 software tools, 41 training resources

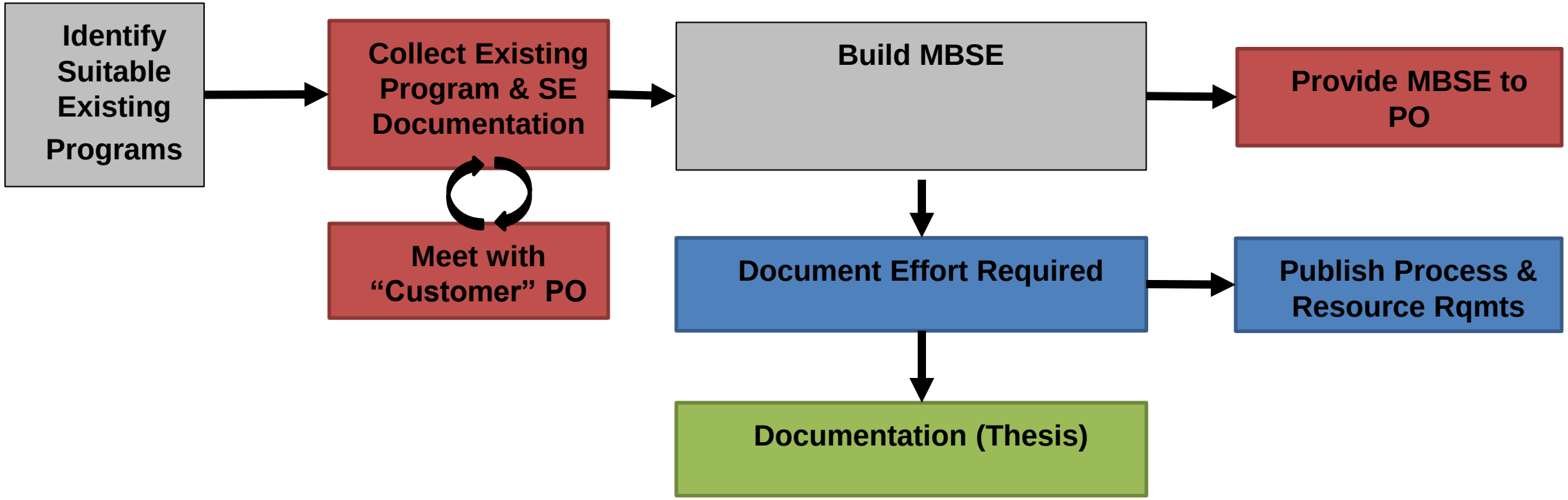
Validating Results with Continued Research

- **Significant Interest in this Effort**
- **Need to Expand single data point**
  - Resources, Time, Program Size, Program Lifecycle Phase, Classification,

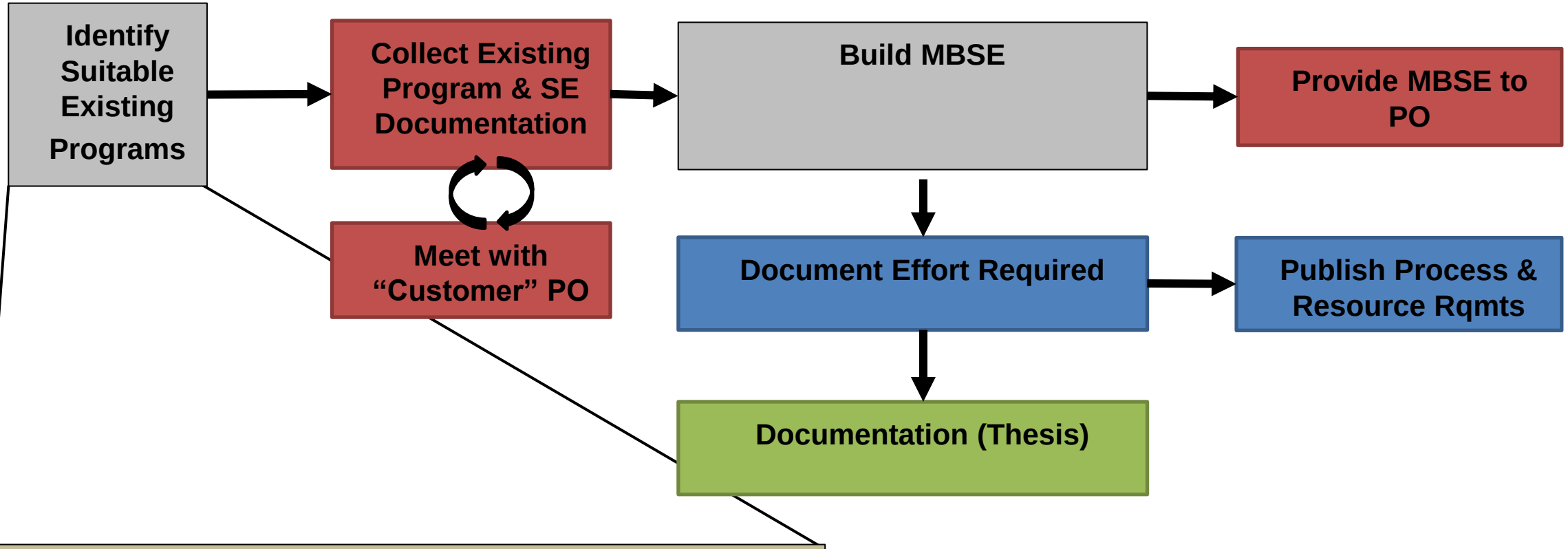
Research Team Objectives:

- Identify “best” software tools
- Identify training requirements
- Identify resources (time / cost / effort) required to transition
- Disseminate research findings to community in timely manner

And the Process Continues…



And the Process Continues…

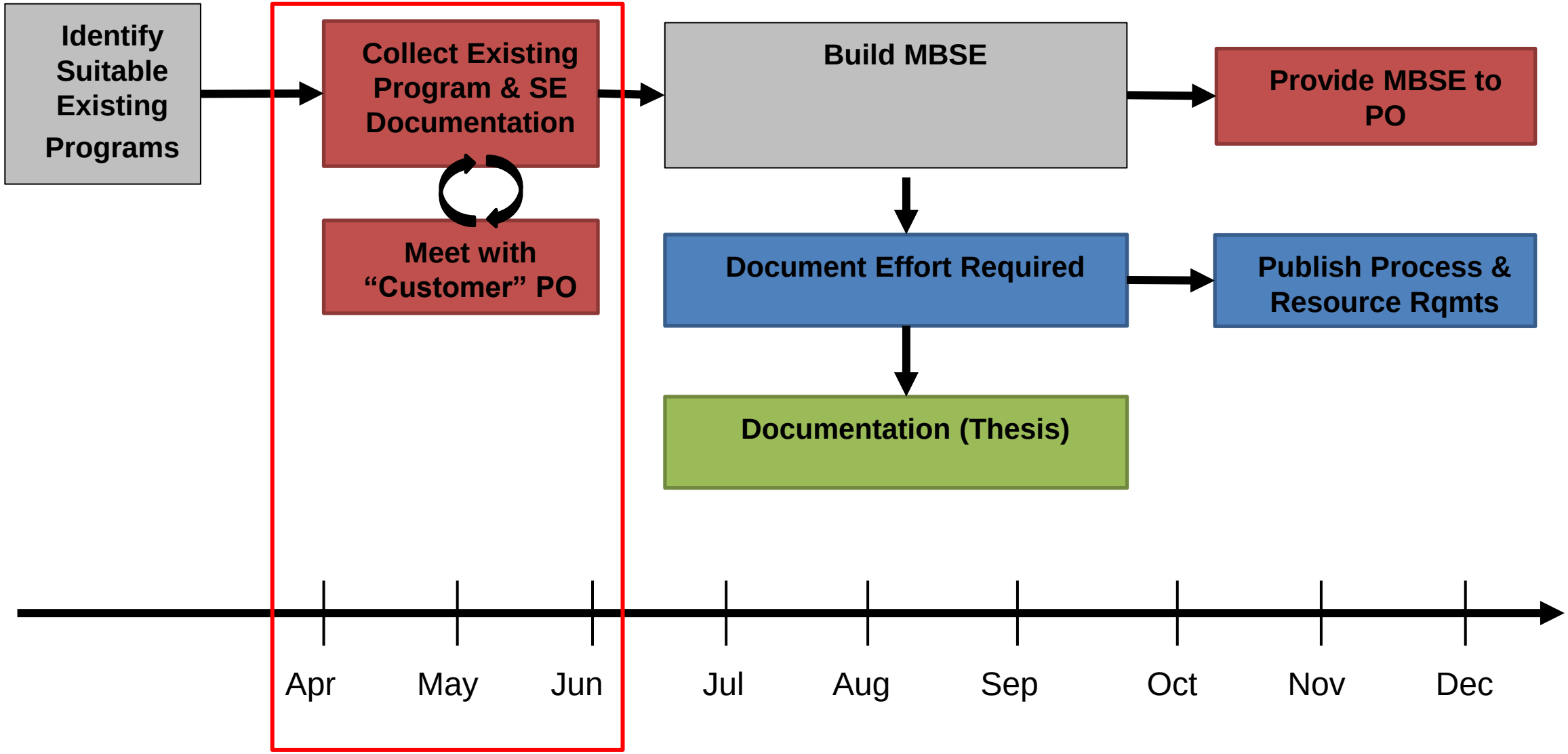


- Briefed Potential Program Partners
- Identified Program Needs
- Estimated Effort Required
- Ranked Effort Viability
- Matched Student Researcher with Programs

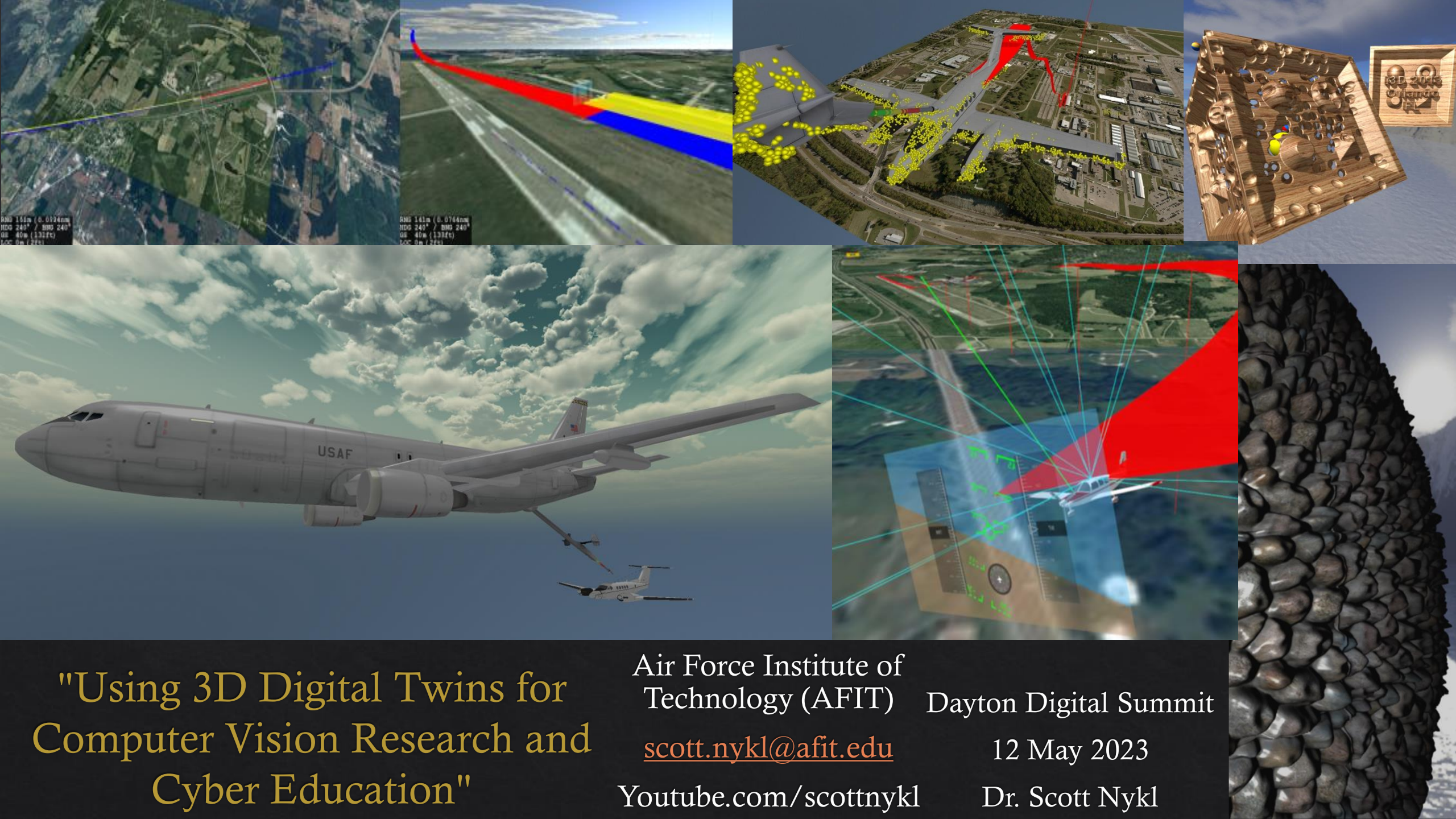
Current Research Team Membership

- **Faculty**
  - Lt Col Jeremy Geiger
  - Lt Col Kip Johnson
  - Lt Col Amy Cox
  - Dr. John Colombi
- **Students**
  - Lt Jacob Thomas
  - Capt Cole Piper
  - Capt Emily Tritschler
  - Capt Elizabeth Pennington
  - Lt Anthony Condurso
  - Capt Justin Moore
- **Engineers**
  - Mr. Christian Varadi
  - Mr. Mark Reunsch

And the Process Continues…



Questions



"Using 3D Digital Twins for Computer Vision Research and Cyber Education"

Air Force Institute of Technology (AFIT)

scott.nykl@afit.edu

Youtube.com/scottnykl

Dayton Digital Summit

12 May 2023

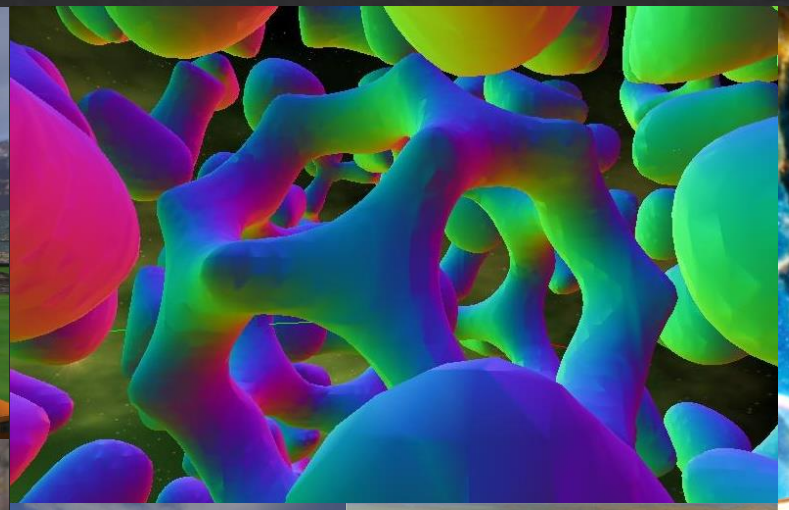
Dr. Scott Nykl

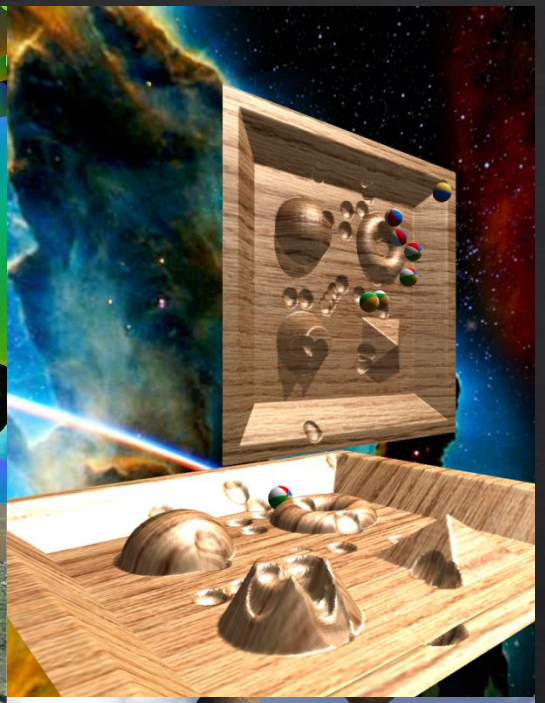

RANGE ROVER
OHIO
OPEN GL

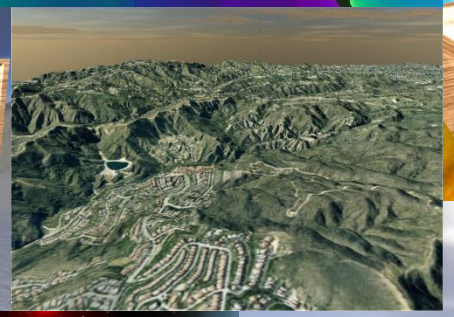

NEXT WEEK
Duke Burger


QUAKE

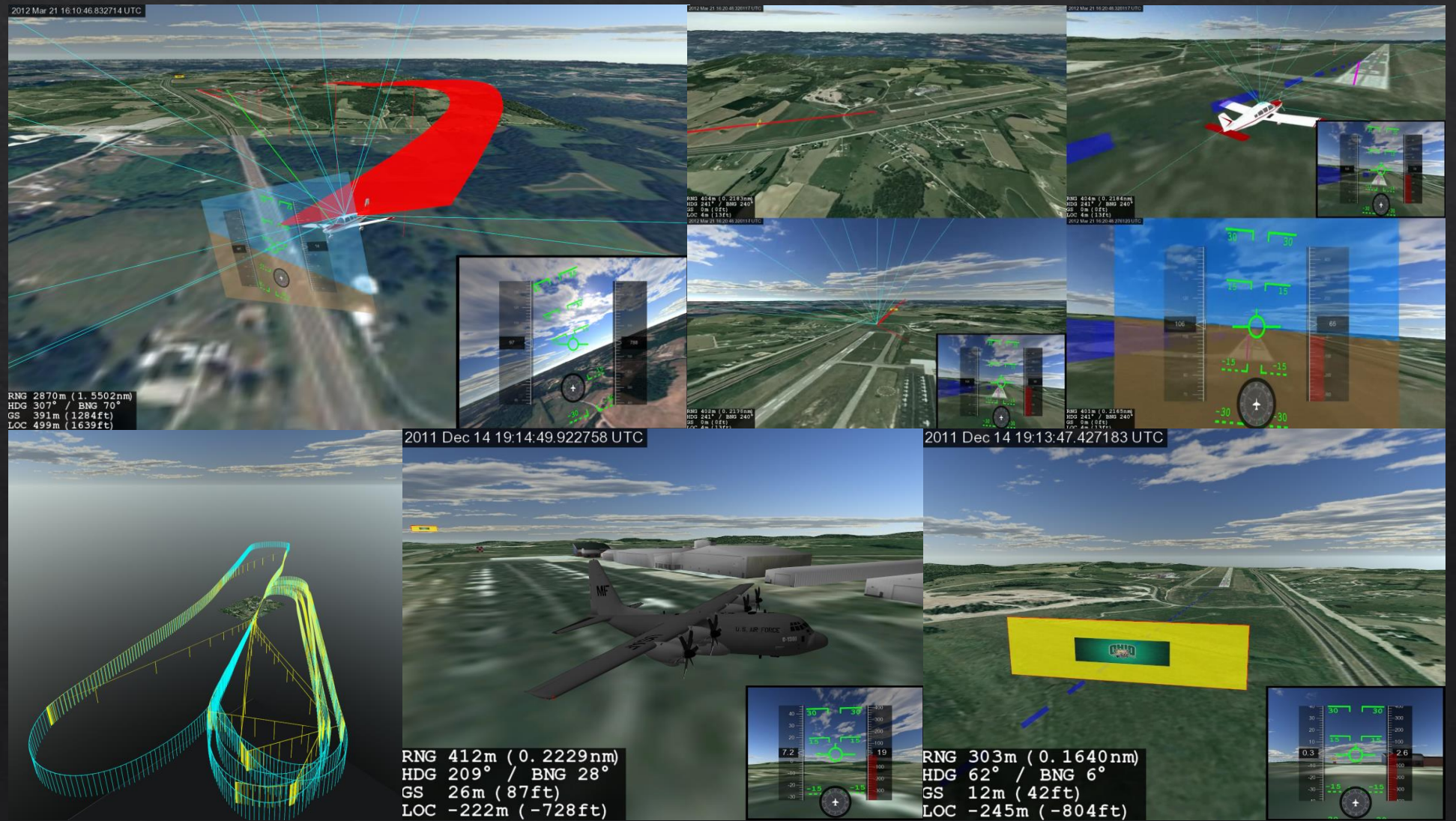
Visualization digests complexity, lets one absorb knowledge







Virtual Worlds naturally map to 3D geospatial information.



Humans Perceive Data Visually

```
26811  39.2112007141113 -82.2249069213867 178.958694458008 0.555690646171157 -0.822189390659332 0.12333932518959 0.829523444175720 0.558241546154022 -0.0160381775349379
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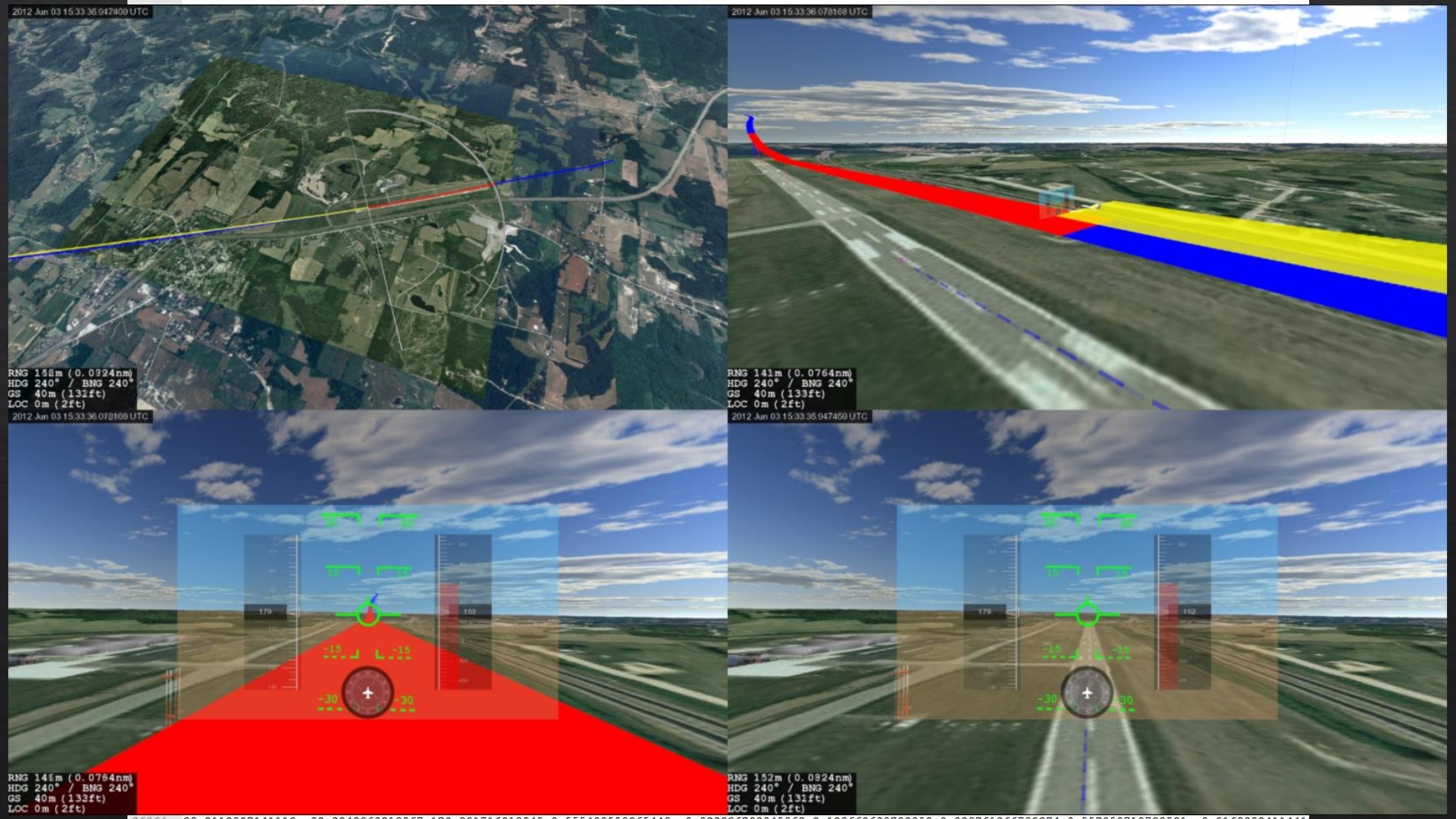


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26865  39.2112045288086 -82.2249069213867 178.922271728516 0.555425763130188 -0.822346270084381 0.123486235737801 0.82974249124527 0.5578922622935638 -0.01684147492051
```
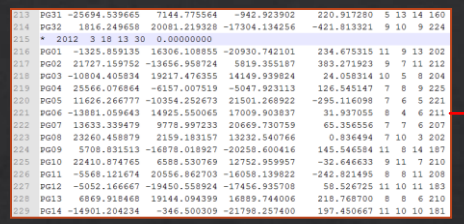
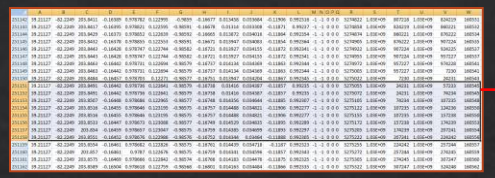
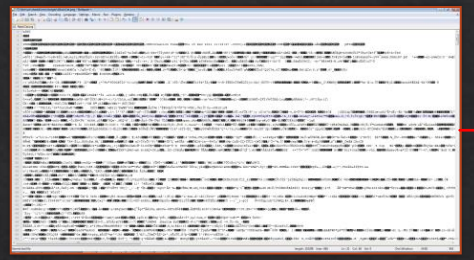
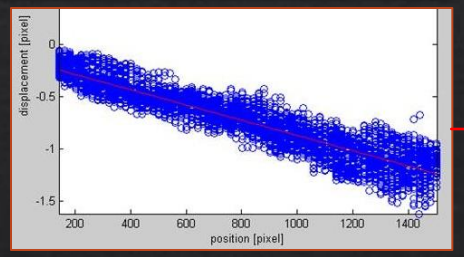

Unification of Sensor Fusion

Disparate, non-uniform inputs → Coherent, naturally understandable virtual world, real-time updates









3D World

Video – Virt World mirror Real World, in Real Time

- Affine RT Link.mp4
- Reduce Bandwidth
- Leverage a-priori information
- New abilities possible w/ common frame & viz (sat LOS intuition)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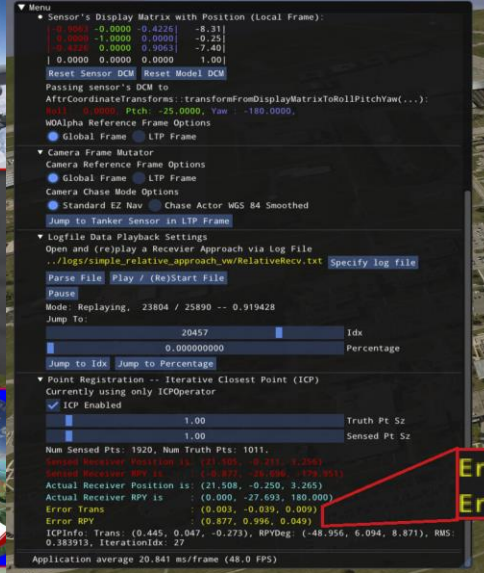
Automated Aerial Refueling

- Relative Positioning using Stereo Vision
- GPS-Denied Environments

- Automated Aerial Refueling
- Stereo Vision for Relative Navigation
- Real Time 3D Virtual Worlds
- Modeling & Simulation
- Synthetic Sensor Generation & Real Time Analysis

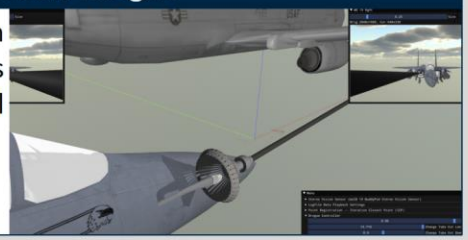
- Dr. Scott Nykl
- Build: 642 Room: 203 x4395



Towards Autonomous Aerial Refueling

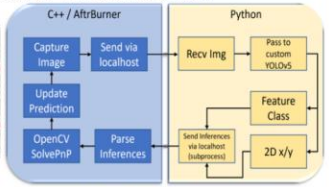
AFIT's DoD Leading Research into Autonomous Refueling for USAF Boom and Probe-N-Drogue

AFIT is developing stereo and monocular visual relative navigation algorithms for pose estimation. These algorithms enable Autonomous Aerial Refueling systems to safely approach, connect, and transfer fuel between a tanker and receiver.

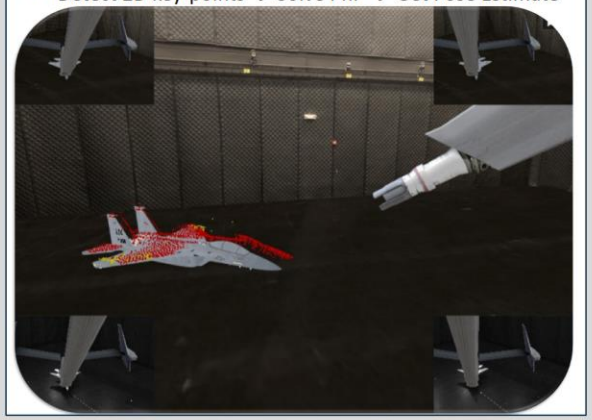


Background

- With more RPAs in the Air Force, automatic refueling would improve mission capabilities
- Object detection using Convolutional Neural Networks (CNNs) have improved significantly in previous years, enabling their usage in 6DoF Pose estimation.

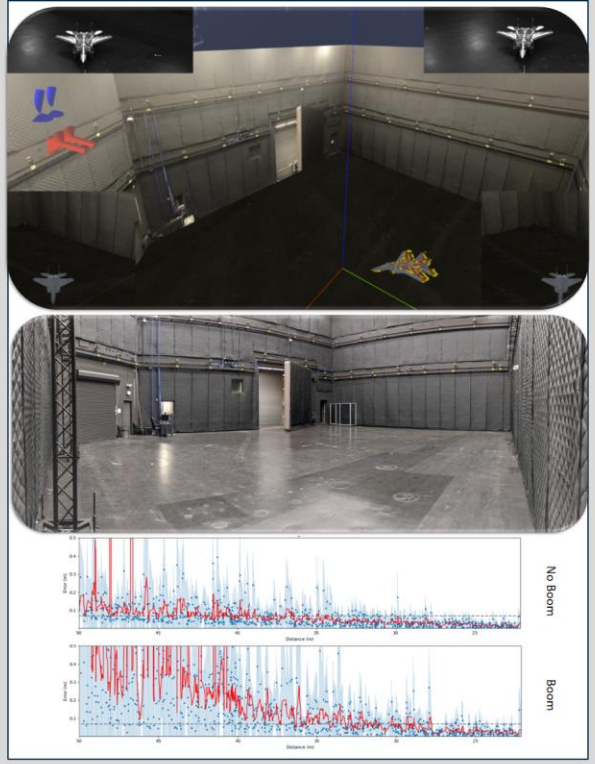


- Detect 2D key-points → Solve PnP → Get Pose Estimate



Digital Twin & 3D Augmented Reality

Results: >7cm position error @ 15m



CONTACT
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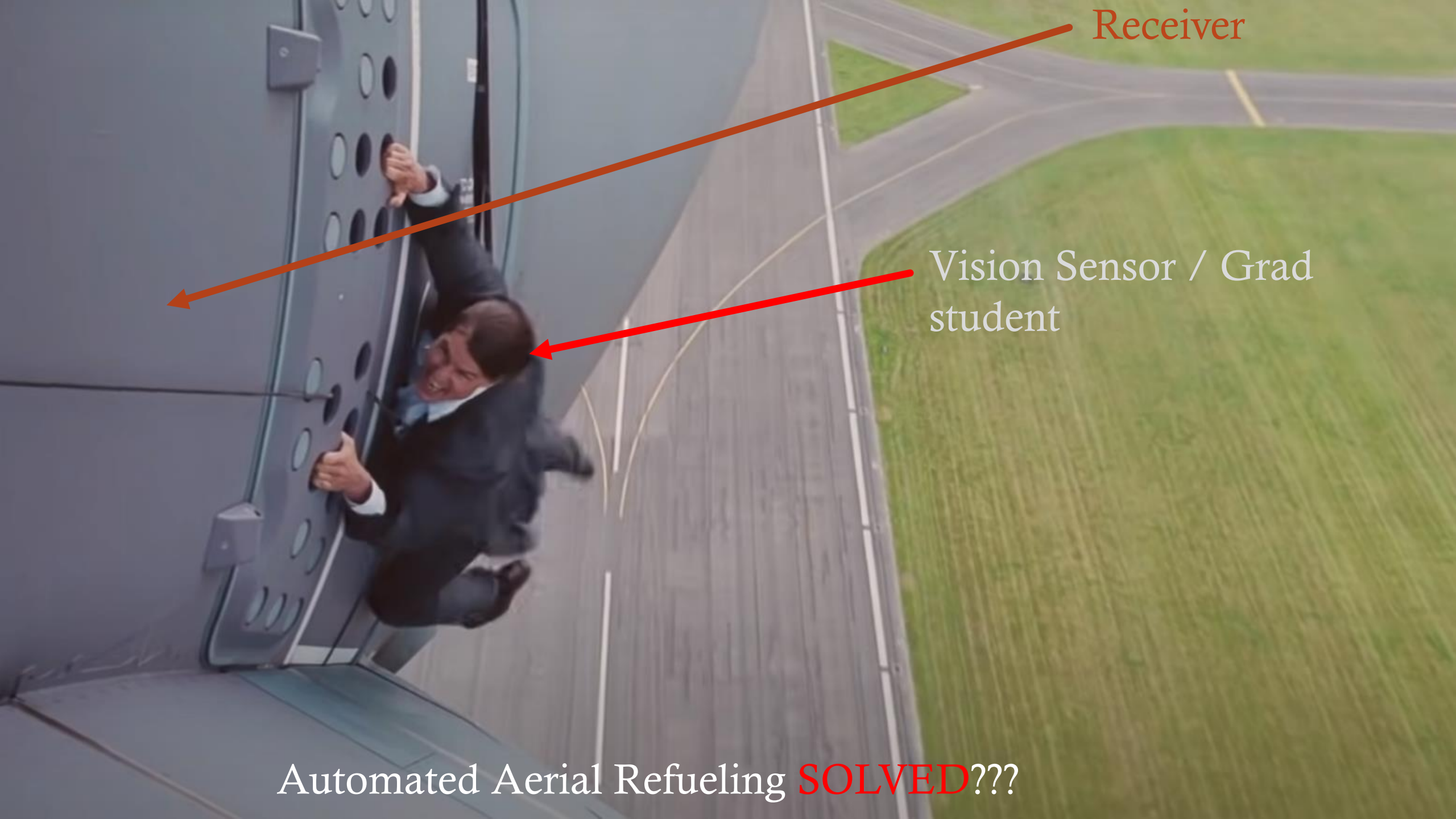
scott.nykl@afit.edu

ANT CENTER
AUTONOMY & NAVIGATION TECHNOLOGY

AFIT
AIR FORCE INSTITUTE OF TECHNOLOGY

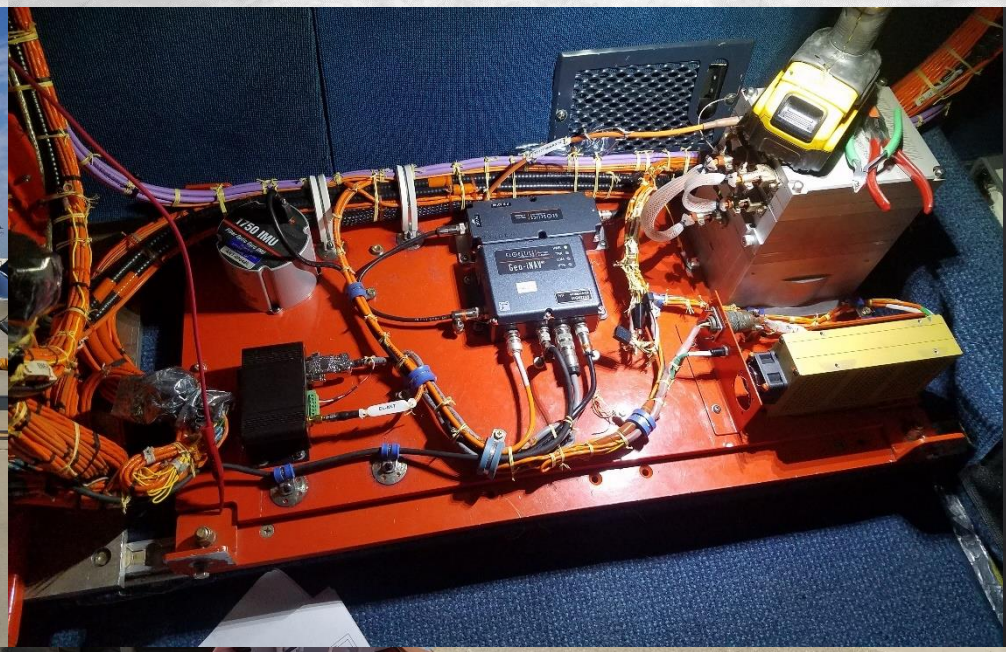
How does one automate Aerial Refueling?



Automated Aerial Refueling SOLVED???

Edwards AFB

2016, 2019



EO & LWIR

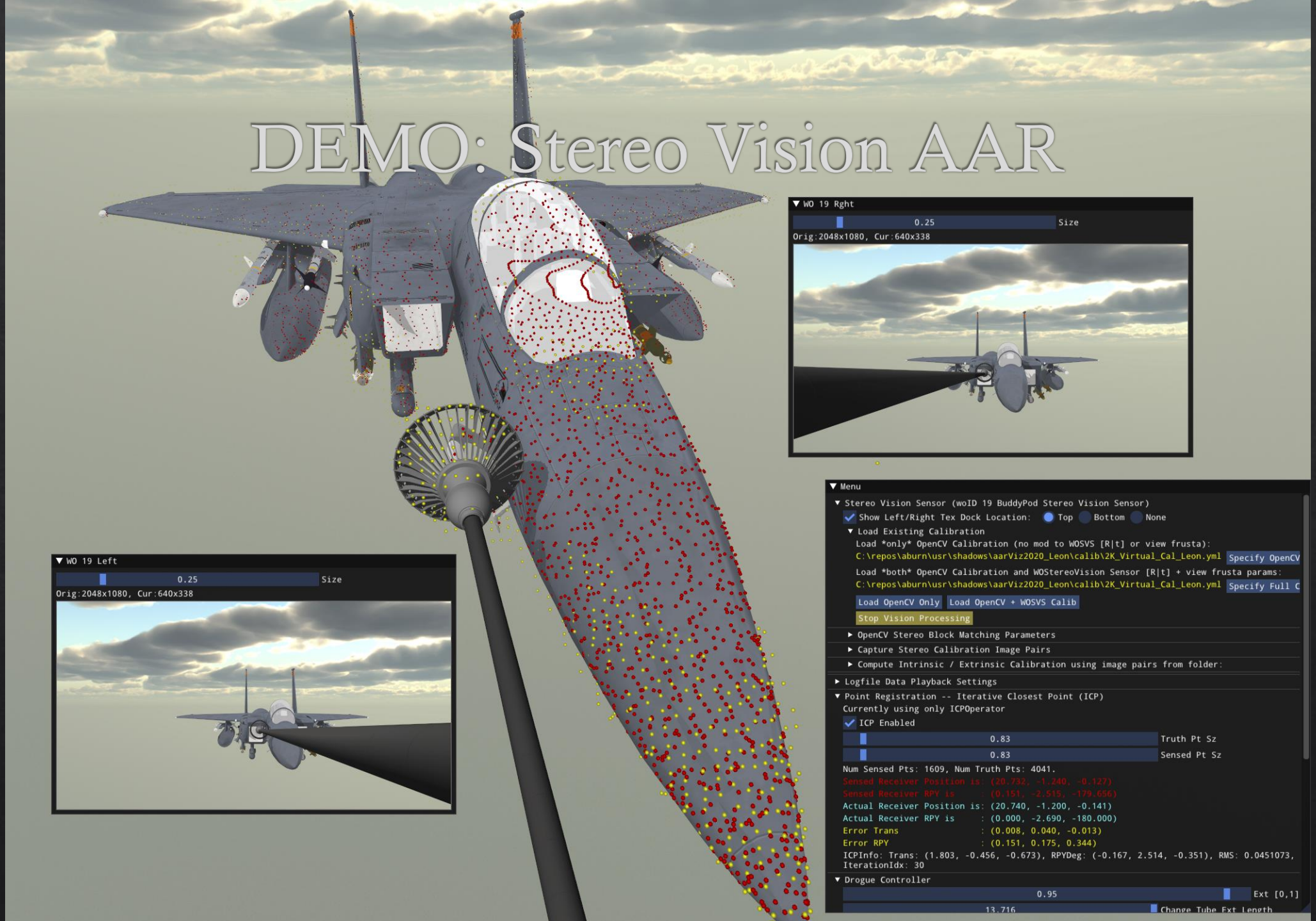
Flight Tests

$$$

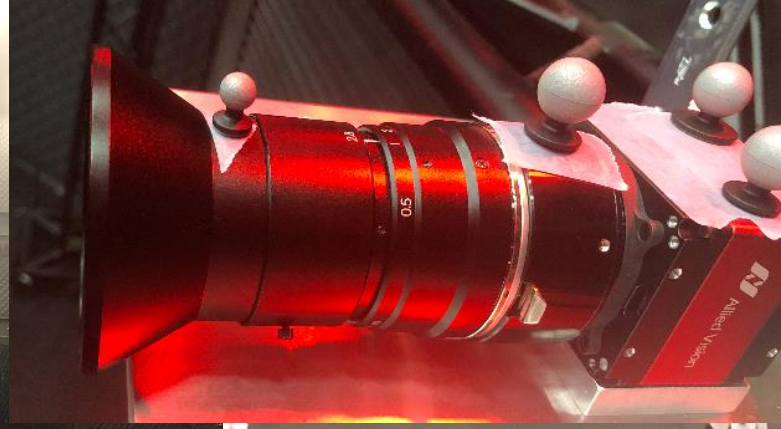
Hard

Approximate

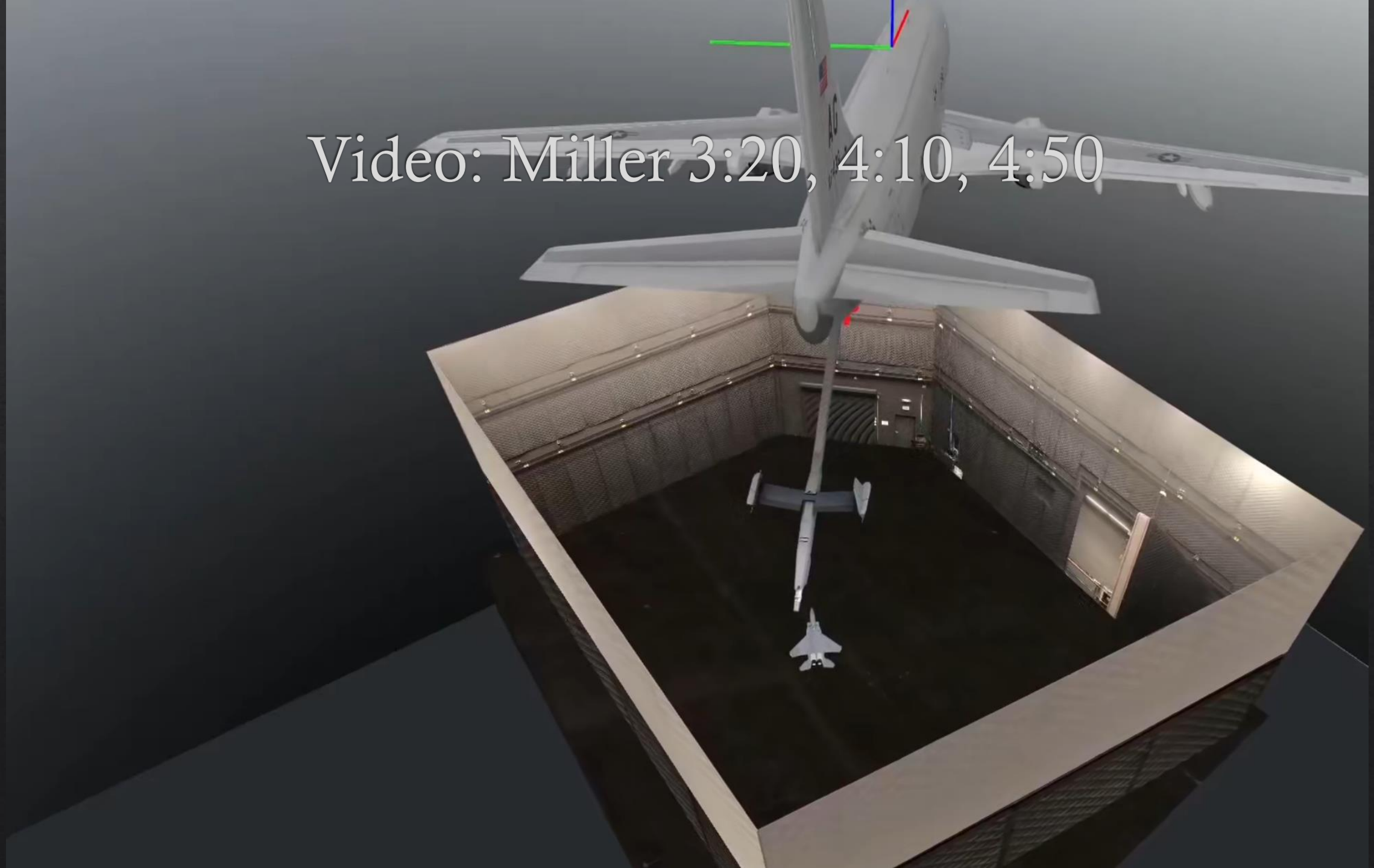
DEMO: Stereo Vision AAR




Video: ISVC 0:18, 2:50


Allied Vision


JASDF
50th
ANNIVERSARY

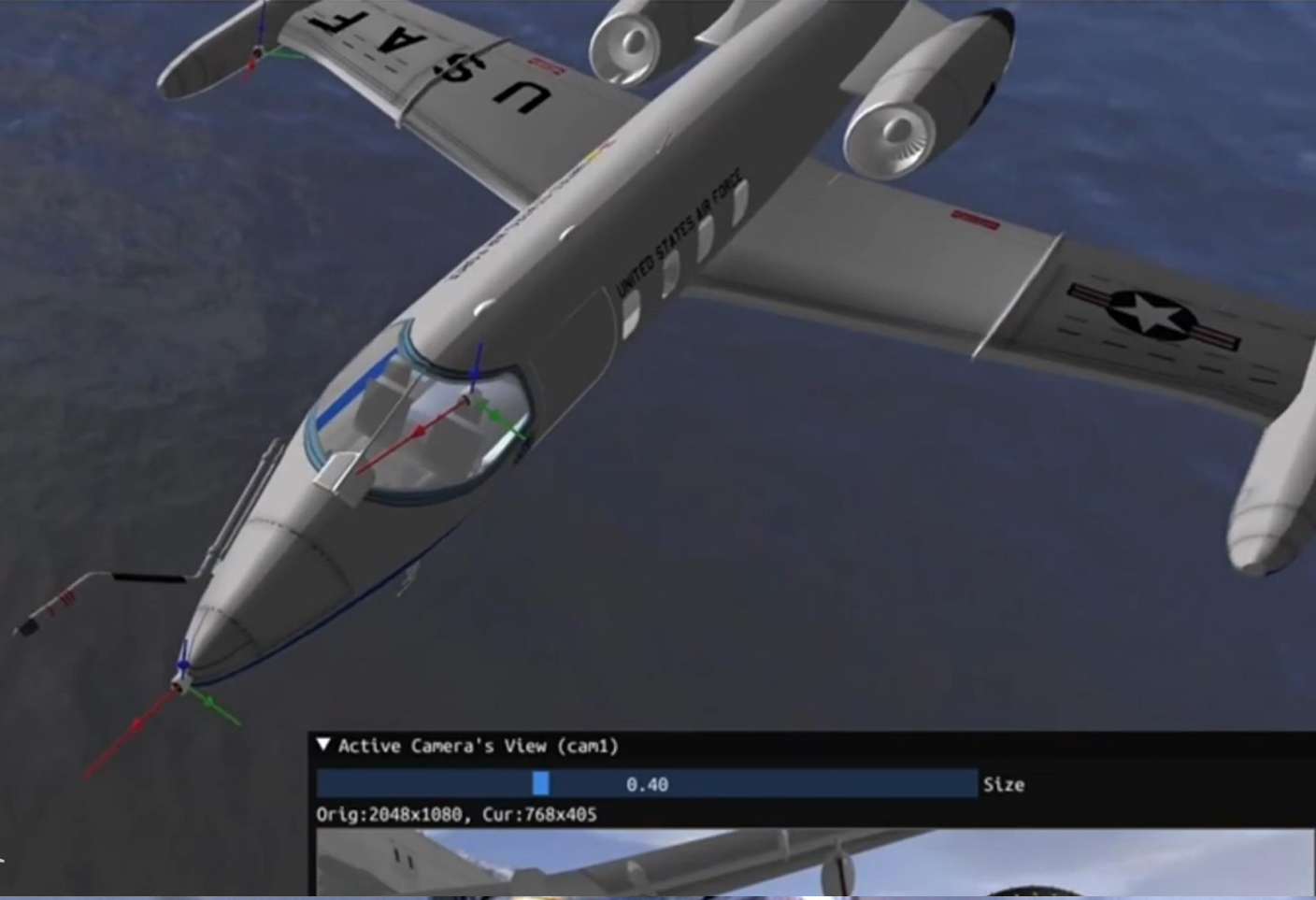

Video: Miller 3:20, 4:10, 4:50

Video: Vicon Approach

Extrinsic Calibrations?
Bumped Cameras?
Occlusions?
Can we overcome these?

Monocular-based Visual RelNav Approach

- Convolutional Neural Networks (CNN)



Air Force Materiel Command

Digital Materiel Management Keynote

Robert B. Fookes, SES
AFMC/EN
12 May 2023

AFMC Strategy Map

MISSION

Powering the world's greatest Air Force…

We develop, deliver, support, and sustain war-winning capabilities.

VISION

One AFMC--integrated, collaborative, innovative, trusted, and empowered…

Indispensable to our Nation, disruptive to our adversaries.

Our Cross-Cutting Attributes

Speed • Strength • Endurance • Balance • Flexibility • Coordination

Our Commitments

Enable DAF Priorities • Support the Warfighter & Respect the Taxpayer • Focus on Enterprise Solutions & Digital Materiel Management • Provide All Airmen the Opportunity to Reach Full Potential • Embrace Innovation

Our Lines of Effort

LOE 1 *What*: Deliver Integrated Capabilities

Integrate research, development, test, sustainment, support, and infrastructure to maximize readiness and lethality for each capability and across all capabilities.

Objectives

- **Sustain the Legacy Force:** Integrate all efforts within and across our centers by working together as One Team to ensure the current force structure is ready anytime and anywhere against any adversary.
- **Deliver the Future Force:** Create future threat-informed capabilities that deter and disrupt our adversaries using integrated intra- and inter-center One Team approaches.
- **Seek DAF Enterprise Solutions:** Through intra- and inter-center integration and coordination, deploy DAF enterprise solutions to the max extent and defer to unique solutions only when necessary.
- **Provide Responsive Support:** Deliver AFMC materiel capability and combat support when needed for warfighting and humanitarian surge requirements

LOE 2 *Who*: Strengthen Our Team

Advance the professional and personal development, retention, resilience, and innovation of our workforce so every AFMC Airman and Guardian can achieve their full potential.

Objectives

- **Develop Leaders:** Develop leaders able to create an environment where team members can professionally and personally thrive.
- **Entrust Decisions to Lower Levels:** Push responsibilities and decision-making to trained-and-ready lower levels within the command chain and empower our people regardless of rank or grade.
- **Build Full Potential Teammates:** Provide intentional opportunities for uniformed and civilian team members to achieve their professional and personal goals, removing barriers concerning diversity, equity, inclusion, and accessibility.
- **Bolster Accessions and Retention:** Embed our cross-cutting attributes into our accessions and retention processes for world-class, end-to-end personnel management.

LOE 3 *How*: Revolutionize Our Processes

Implement Enterprise Solutions, Digital Materiel Management, and other methods to revolutionize critical processes in support of mission execution and the warfighter.

Objectives

- **Build One AFMC Business Enterprise:** Inculcate internal processes that activate innovation, speed, strength, endurance, balance, flexibility, and coordination in AFMC's ability to deliver capabilities on relevant timelines in spite of fluid threat environments.
- **Employ Digital Materiel Management:** Ensure critical processes employ digital methods across the entire lifecycle--from invention to retirement--for both warfighting capabilities as well as installation and mission support capabilities.

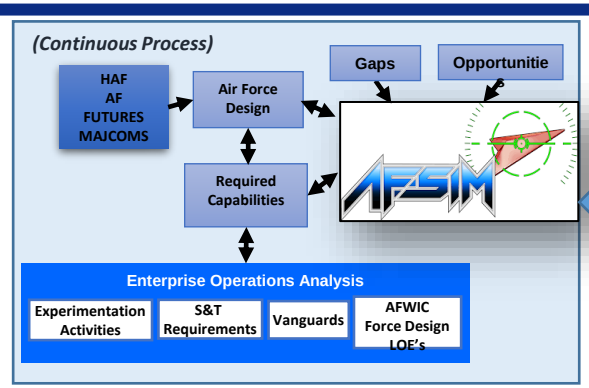
LOE 4 *Why*: Amplify Warfighting Culture

Connect every AFMC Airman and Guardian to the mission and focus the materiel enterprise on delivering capabilities and services in support of operational execution and deterrence.

Objectives

- **Connect to the Mission:** Ensure every team member and unit understands their role, value, and connection in materiel capability delivery to the operational units we support.
- **Be the Trusted Partner:** Drive toward the speed of trust with one another, the warfighter, industry, and our mission partners.

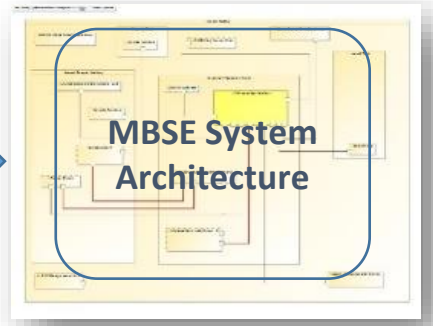
Digital Lifecycle



S&T, Prototyping, Mission Modeling

Tradespace & Operations Analysis

AF and SF Futures
MajorCommands
FieldCommands
Air Force Research Lab



Open Standards, Data, Government Reference Architecture

Requirements & System Specifications

RFP
SOW/PWS
CDRLS/DIDs
SRD/TRD

System design model, integrated design environment

System Development

Technical Reviews
Agile Development
Finance, Risk, & Log Mgt
Test & Certs

Product Lifecycle Management model supporting O&S

System Lifecycle

Supply
Maintenance
Product Support
Operations
Modifications

Standards | Reference Architecture Models | Training | Tools | Data Architecture

Digital Ecosystem Enabled By

PLM / FENCES / CloudONE / PlatformONE

DMM Initiatives

- ***Access to tools:*** **Expand cloud hosted tool environment**
  - Partnered w/AFLCMC/HN to scale Enterprise Solution tool offering to programs
- ***Training:*** **AFIT Digital Innovation and Integration Center of Excellence**
  - Partnered w/AFIT to scale training & education offerings; program execution support
- ***Culture:*** **Continued analysis and intentional design**
  - Leadership focused Digital Masterclass; continue outreach/culture design work
- ***Strategies:*** **Facilitated program workshop and support**
  - Partnering w/*Digital Enterprise Launch Team for Acquisition* (DELTA) to facilitate program strategy sessions
- ***Structure and Secure our Data:*** **Standard data formats, structures, modeling styles**
- ***Modernize IT Infrastructure:*** **Improved Authority to Operate (ATO), Evaluated Product List (EPL) processes**

Gov't/Industry Interactions

	FY21	FY22	FY23	FY24	FY25	FY26
Infrastructure						
Model Environment		Implement generic governance policies		Appropriately controlled access; Defined governance partially applied across enterprise		
		Define inter-database/tool associations	Data independent from tools; Limited item associations managed		Data portability & all data/item traceablility	
Collaboration Space		IDE/MilHub IOC	IDE FOC - partial enterprise usage	Most IPTs integrated into IDE/MilHub	IPTs interacting across enterprise via IDE/MilHub	
		Define permission roles in enterprise	Enforce permissions across enterprise	Apply applicable IP policies	Secure, monitor & control models & data across enterprise	
Process/Policy						
Model Management		Develop digital management strategy		Inconsistent support from DE tools	Infrequent support from DE tools	Mature IDE/consistent spt from DE tools
		Develop full system models across the lifecycle			Consistent institutional approach to integrated system model	
		Define & implement configuration management processes in MilHub		Apply config mgmt in MilHub to some models/data	Apply config mgmt in MilHub to all models/data in enterprise	
		Map & identify standard V&V procedures and programs for limited models & data			Partially implement V&V procedures for identified models & data	
Data Management		Continually update processes to rely on data from ASOT		Update processes via digital thread -- employ limited twins	Decision making using thread/twins	
		Ingest enterprise data into MilHub	Conform data to common architecture -- plan automation techniques		Implement automation & data reuse	
		Employ some visualization tools	Consistently deploy UI & visualization tools that contribute to some enterprise decision making			UI able to interrogate ASOT
Workforce/Culture						
Workforce Capability		Identify organizational training needs -- identify & promote courses		Develop strategic training plan; hire experts to review modeling methods/data mgmt; plan robust training		
		Identify, use, and promote common lexicons/sources across enterprise		Consistently use common lexicons/sources for lifecycle	Identify, use, and promote authoritative lexicons/sources	
Adoption		Isolated processes across enterprise use digital artifacts and data			Majority of enterprise processes & DM use dig artifacts/data	
		Utilize default architectures and begin customization for enterprise use		Define reference architectures -- plan/identify validation methods		
		Implement limited organizational coordination of digital artifact use as deliverables; Use models to record acceptance of items through model content/data review in modeling environment				
Modeling/Analysis						
Model & Data Quality		Plan/develop ASOT (MilHub)	Implement ASOT	Plan digital thread & limited twins to contribute to ASOT		
		Identify tools that assess model quality; map & define metrics for V&V of models		Implement and monitor metrics		
		Identify standard V&V procedures and programs that require V&V		Establish model dev't processes; select programs for V&V		Partially implement V&V

Legend
Level 0 Level 1 Level 2 Level 3 Level 4

One AFMC...Powering the World's Greatest Air Force


AIR FORCE MATERIEL COMMAND