Air Force Life Cycle Management Center

Integrity - Service - Excellence

A Digital Engineering Toolchain for Architecture-Centric Decision Making

Using Open Standards, Architectures, and Model Based Systems Engineering for Agile Acquisitions

23 October, 2019

Mr. Christopher Garrett
Open Architectures and Standards Technical Expert
AFLCMC/EZAC
christopher.garrett.17@us.af.mil

Mr. Matthew Cotter
Senior Multi-Disciplinary Systems Engineer
MITRE
mjcotter@mitre.org

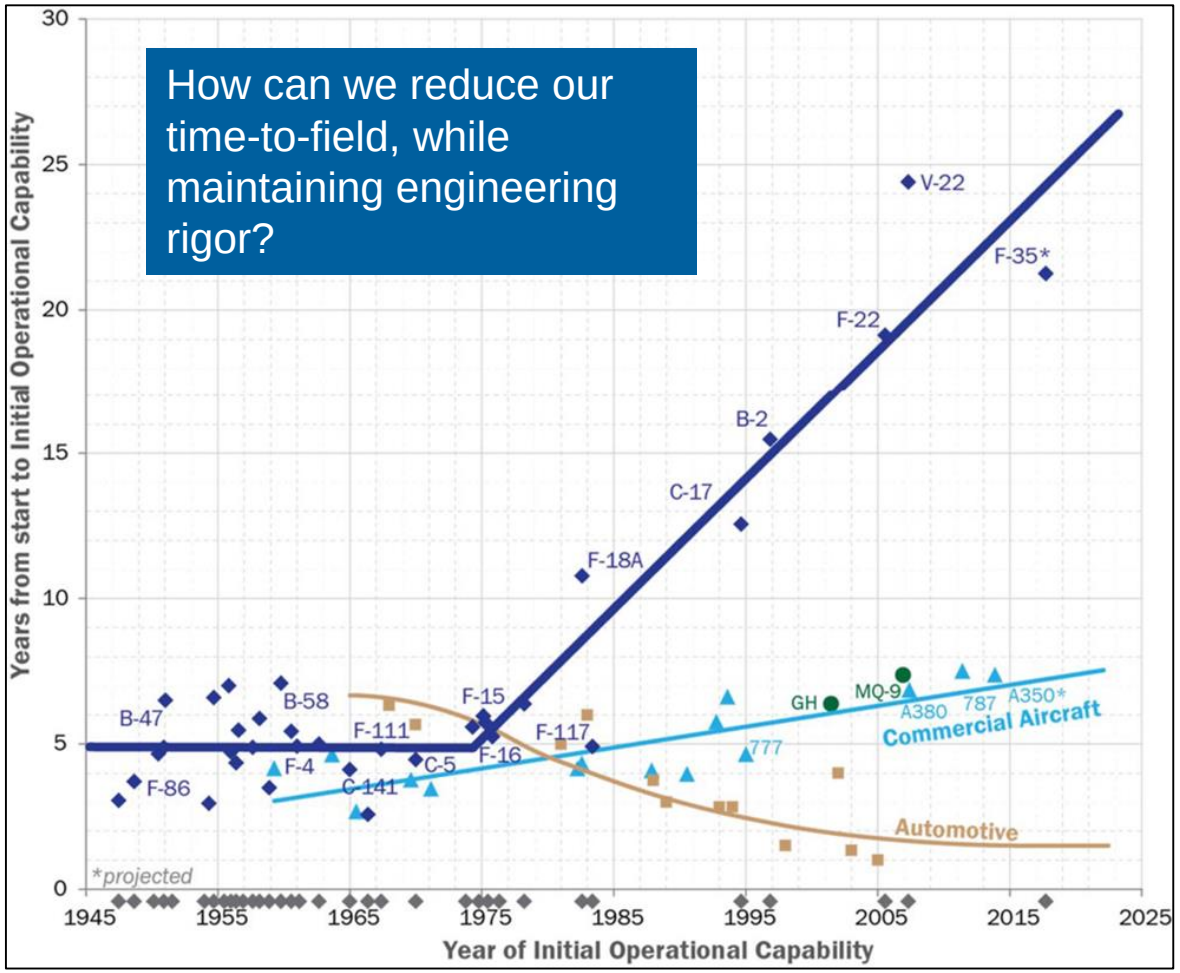
U.S. AIR FORCE

Agenda

1. **BLUF**
2. Introduction
3. Making Educated Decisions with a Digital Engineering "Toolchain"
4. Conclusions

BLUF

- "Current acquisition processes and engineering methods hinder [the ability to meet] demands of exponential technology growth, complexity, and access to information"
  - *Digital Engineering Strategy (DES), June 2018.*
- The Air Force **must** refine and develop innovative engineering methods, processes and tools to combat these challenges
- More specifically, the Air Force would greatly benefit from the ability to rapidly assess capability within the context of other engineering trades
- The following presentation outlines a repeatable engineering process, and highlights re-usable engineering tools, that can be utilized to **inform an investment decision that considers cyber-resiliency, mission effectiveness, operational robustness, and cost**



Agenda

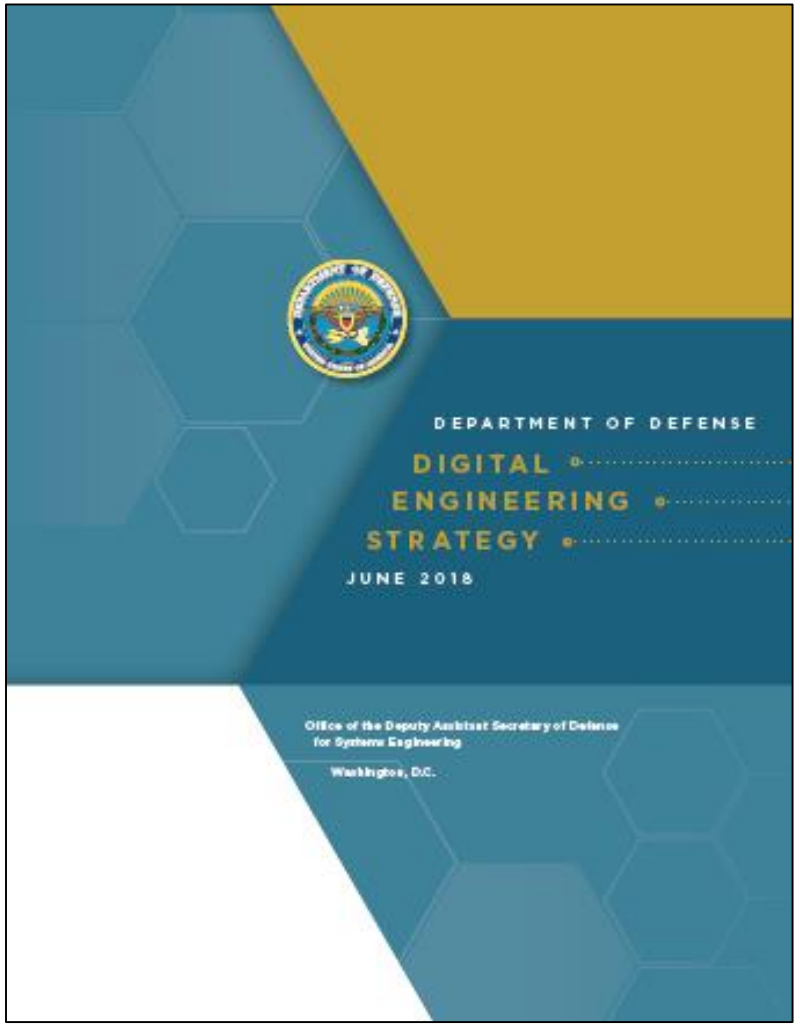
1. BLUF
2. **Introduction**
3. Making Educated Decisions with a Digital Engineering "Toolchain"
4. Conclusions

An Overview of Digital Engineering

- **Digital Engineering (DE):** "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 Strategy, June 2018*

- DE Initiative being led by the Office of the Under Secretary of Defense for Research and Engineering (USD(R&E))

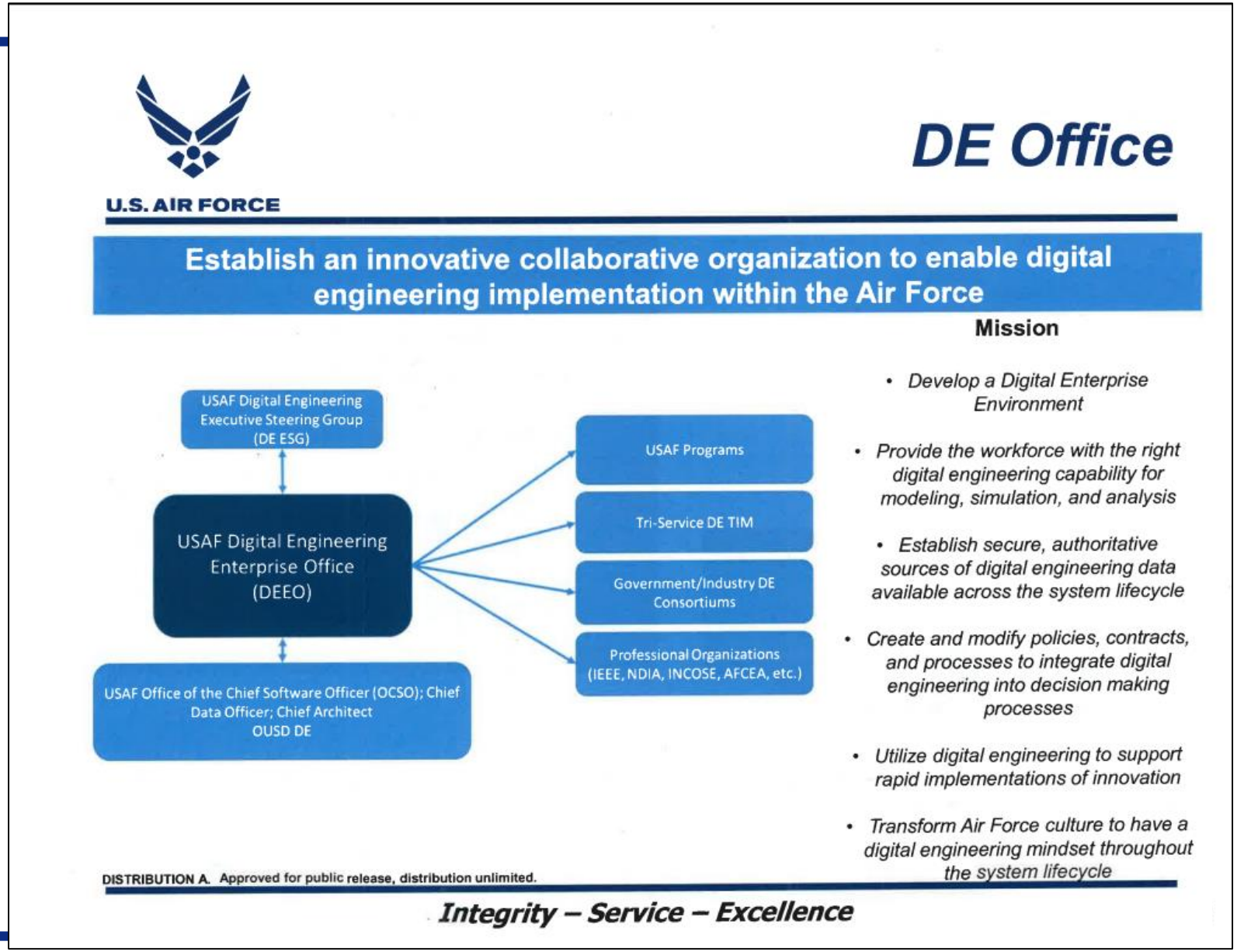
- **Digital Engineering Strategy**
  - Describes the "what" necessary to foster DE practices
  - Practitioners and Services must determine the "how"



An Overview of Digital Engineering (cont.)

- **Air Force Digital Engineering Enterprise Office (DEEO)** actively seeking to establish an innovative, collaborative organization that promotes DE
  - *"US Air Force Digital Engineering Enterprise", Mr. Jeffrey Mayer, June 2019*

- This work supports the AF Mission:
  - "Provide the workforce with the right digital engineering capability for modeling, simulation and analysis"



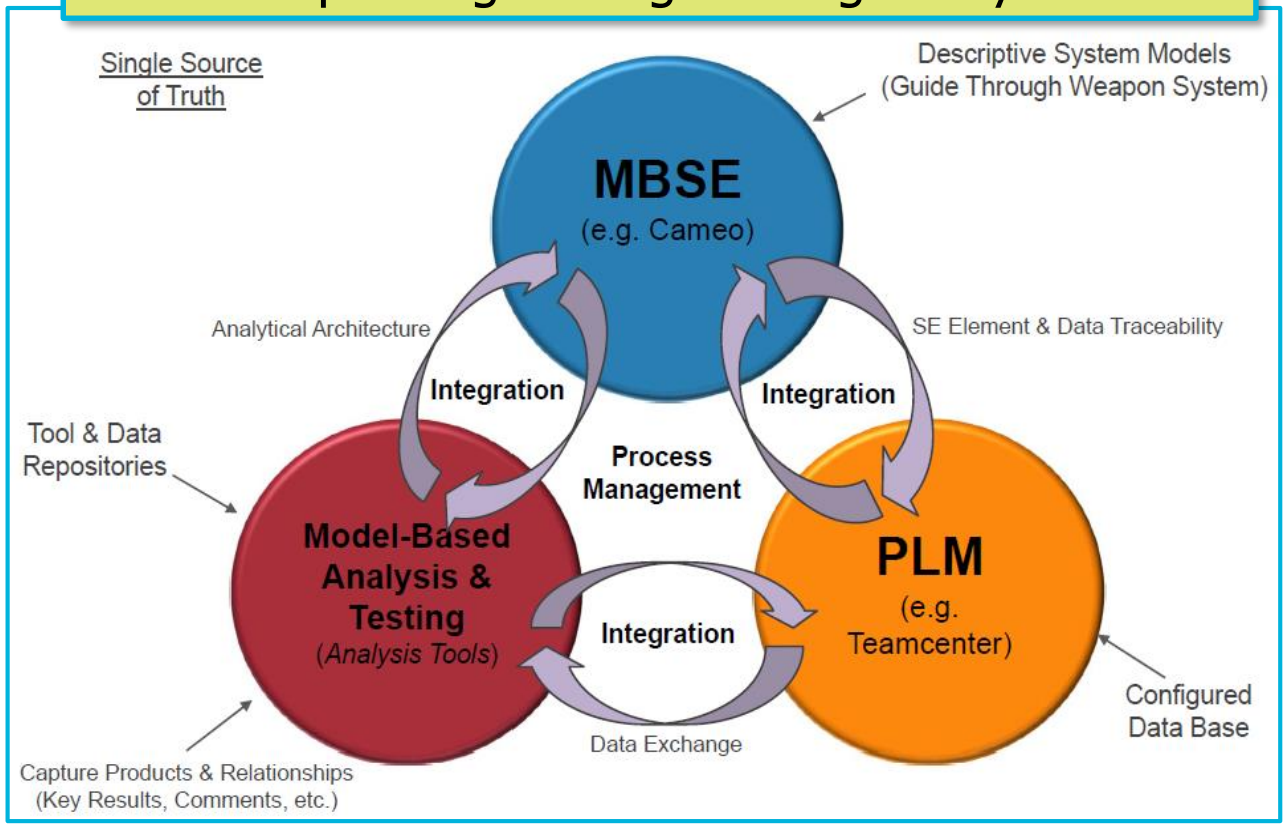
DE Confusion: Need to establish the fundamentals

- Overabundance defining the "what", but not the "how" of DE, MBE, and MBSE
- There are some fundamentals that we must do in order to go fast and maintain agile architectures
  1. Build our systems in modern architecture & design tools (e.g. Rhapsody, Cameo, Sparx)
  2. Use standards to build the reference architecture
  3. Build an ecosystem that integrates weapon system design with program office analytical functions (e.g. costs) and lifecycle management (e.g. PLM)
  4. Automate as many parts of the engineering ecosystem as possible

- **Arch Tool**
- **Standards**
- **Ref Arch**
- **Ecosystem**
- **Automation**

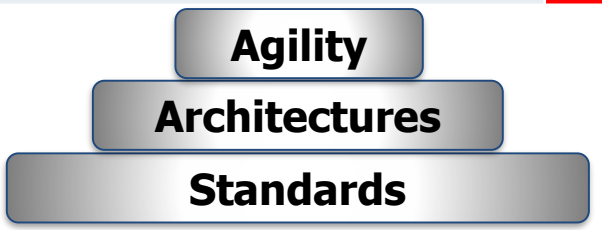
Go Fast!!!

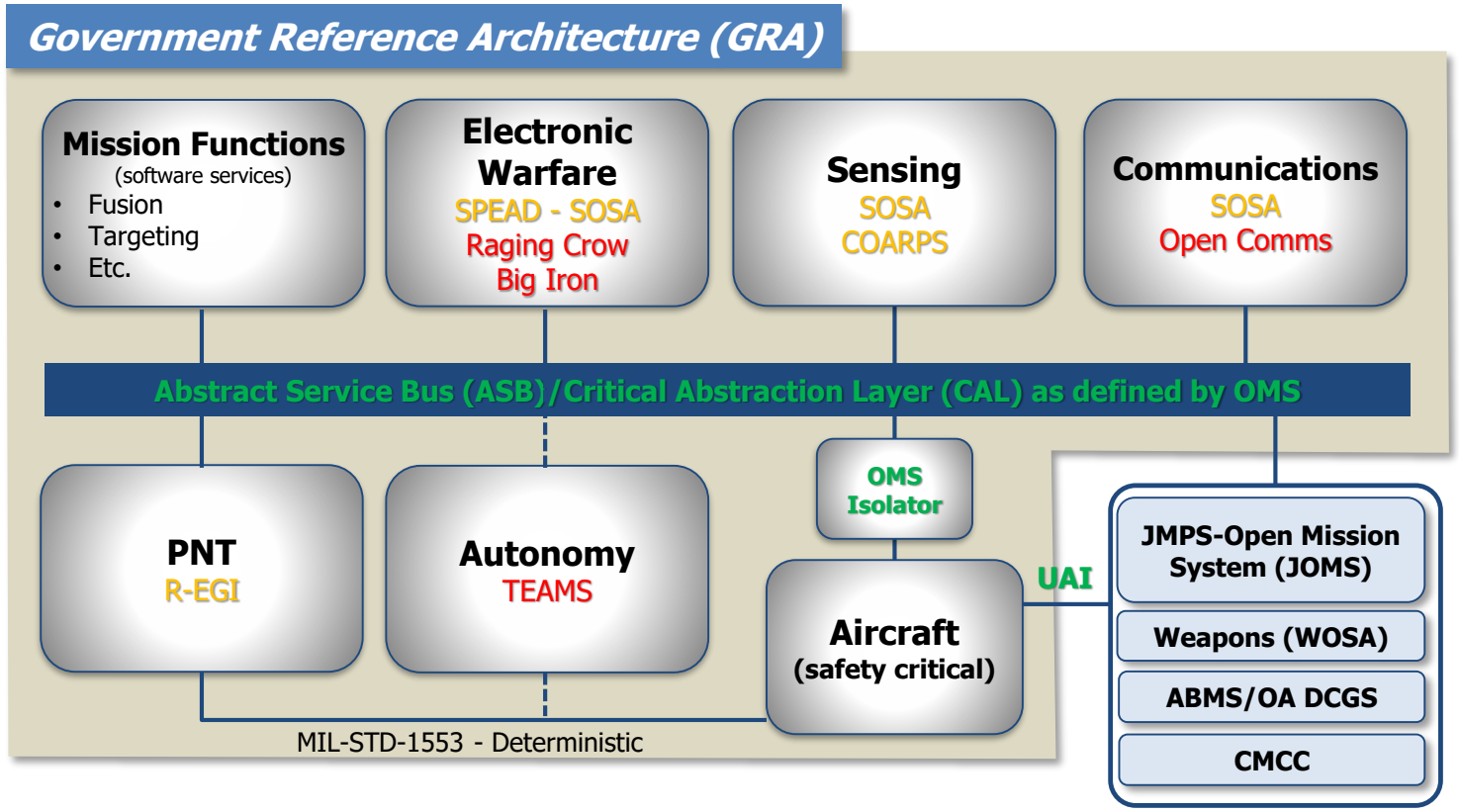
Example: Digital Engineering Ecosystem



Introduction: Government Reference Architecture for Avionics

Standard	TRL
OMS/UCI	9
Universal Armament Interface (UAI)	9
Future Airborne Capability Environment (FACE)	8
Sensor Open Systems Architecture (SOSA)	6
Scalable Payload for EA Development (SPEAD)	6
Common Open Architecture Radar Program Specification (COARPS)	5
Resilient – Embedded GPS/INS (R-EGI)	4
Open Comms	3
Teaming-Enabled Arch for Manned-Unmanned Systems (TEAMS)	2
Simulator Common Arch Requirements & Standards (SCARS)	2
Big Iron	1
Raging Crow (unfunded)	1





- Tie to AF & DoD enterprise architecture
- Focus toward program offices, programs of record
- Enable early Verification & Validation of requirements
- Manage open standards and architectures with OAMO
- ***GO FAST!***

Introduction: Reference Architecture Benefits

- Provides starting point for acquisition programs
- Guides and constrains the development of more detailed architectures
- Serves as a requirements specification for derived architectures
- Enables maximum opportunities for commonality and interoperability across a capability area
- Provides technical insight and ownership of AF programs
- Aids testing through incremental improvement
- Fundamental to acquisition Agility
- Improves technology transfer significantly
- Promotes competition
- Enhances innovation

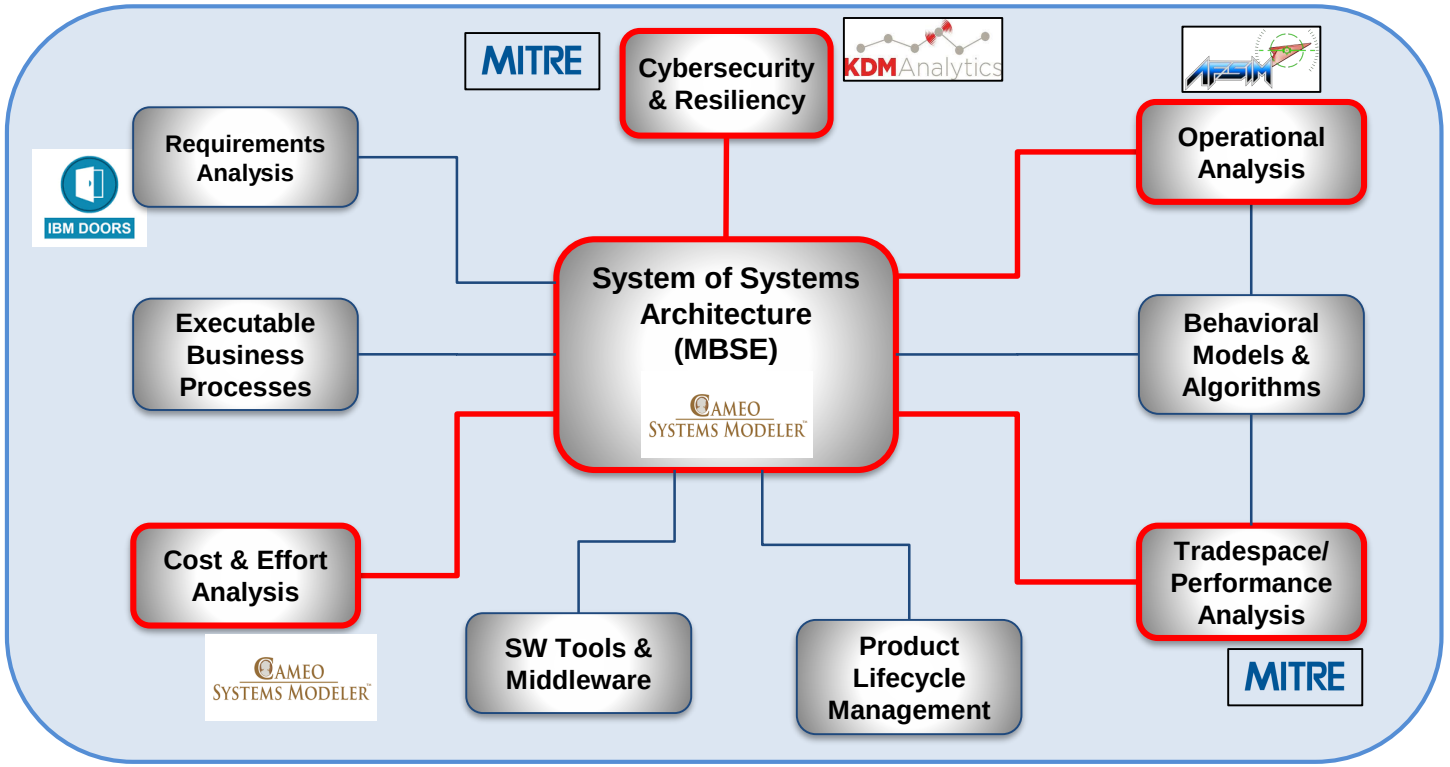
Agenda

1. BLUF
2. Introduction
3. **Making Educated Decisions with a Digital Engineering "Toolchain"**
4. Conclusions

Digital Engineering Toolchain

- Leverage GRA & System Architecture for Architecture centric analysis
  - Entities
  - Attributes
  - Relationships
- Connect analytical tools via **Application Programming Interfaces (API's)**
  - API = a re-usable set of functions / subroutines used for software development
- Avionics (bottom-up) approach
- Tie Solution Architecture to DoD Enterprise Architecture
- Enable Multi-Domain Analysis
- Automate the Process
- Link Architecture to tools for **early, dynamic, & continual analysis** of requirements
- Maintain authoritative source of truth

An Example Digital Engineering Toolchain



Items highlighted in **RED** are the focus of this demonstration

Case Study: Joint Close Air Support (JCAS)

- **Objective:** Employ Digital Engineering methods to conduct trade studies in an agile, rapid manner with authoritative, dynamic sources of data
  - Pivot from **document-based** acquisition to **model based** acquisition
- **Input:** Joint Staff J6 Joint Mission Thread for Digitally Aided Close Air Support*
- **Problem Statement**: Within a ***Joint Close Air Support (JCAS) mission***, how can the insertion of new capability impact:
  1. Cyber Resiliency
  2. Mission Effectiveness (Probability of Kill)
  3. Operational Robustness
  4. Cost (Developmental, Operational)

Scenarios Of Interest:

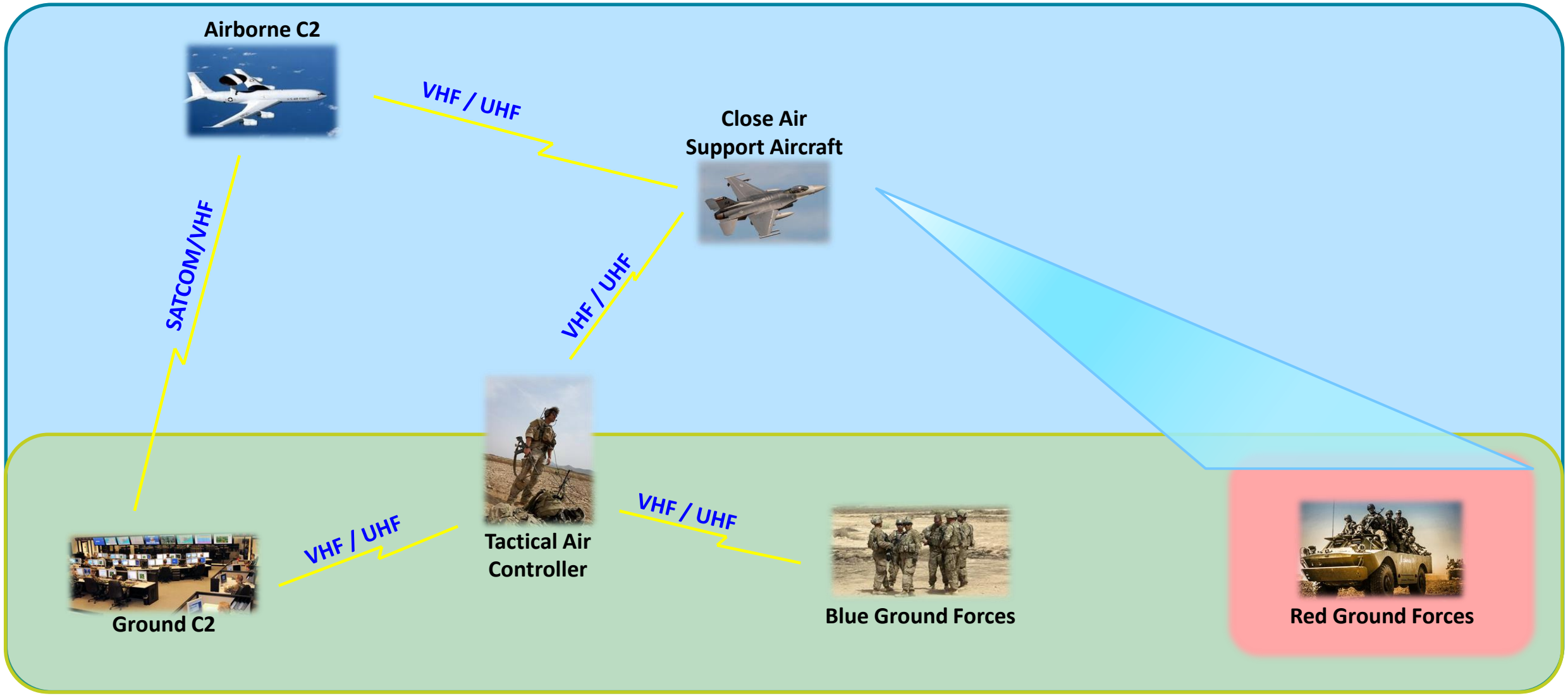
Scenario #1: Traditional CAS

Scenario #2: Digitally Aided CAS
Scenario #1
+ UAV
+ ROVER III Technology

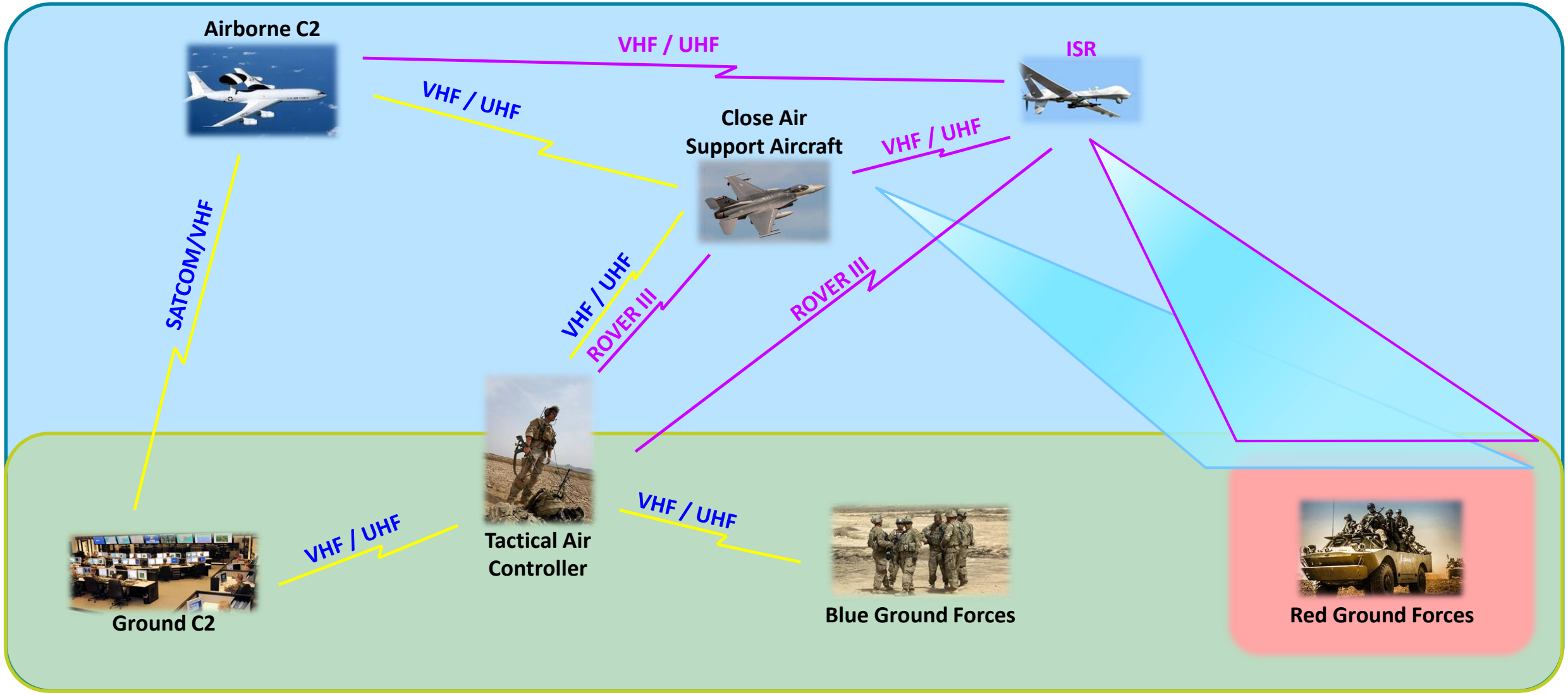
Scenario #3: Digitally Aided CAS+
Scenario #2
+ Handheld Link 16 Technology

*J6 Digitally Aided Close Air Support (DACAS) Tier II Joint Mission Thread documentation; https://wmaafip.csd.disa.mil/Project/DetailsLandingPage?aId=26&prjId=45&prjVId=U45&secVId=U0

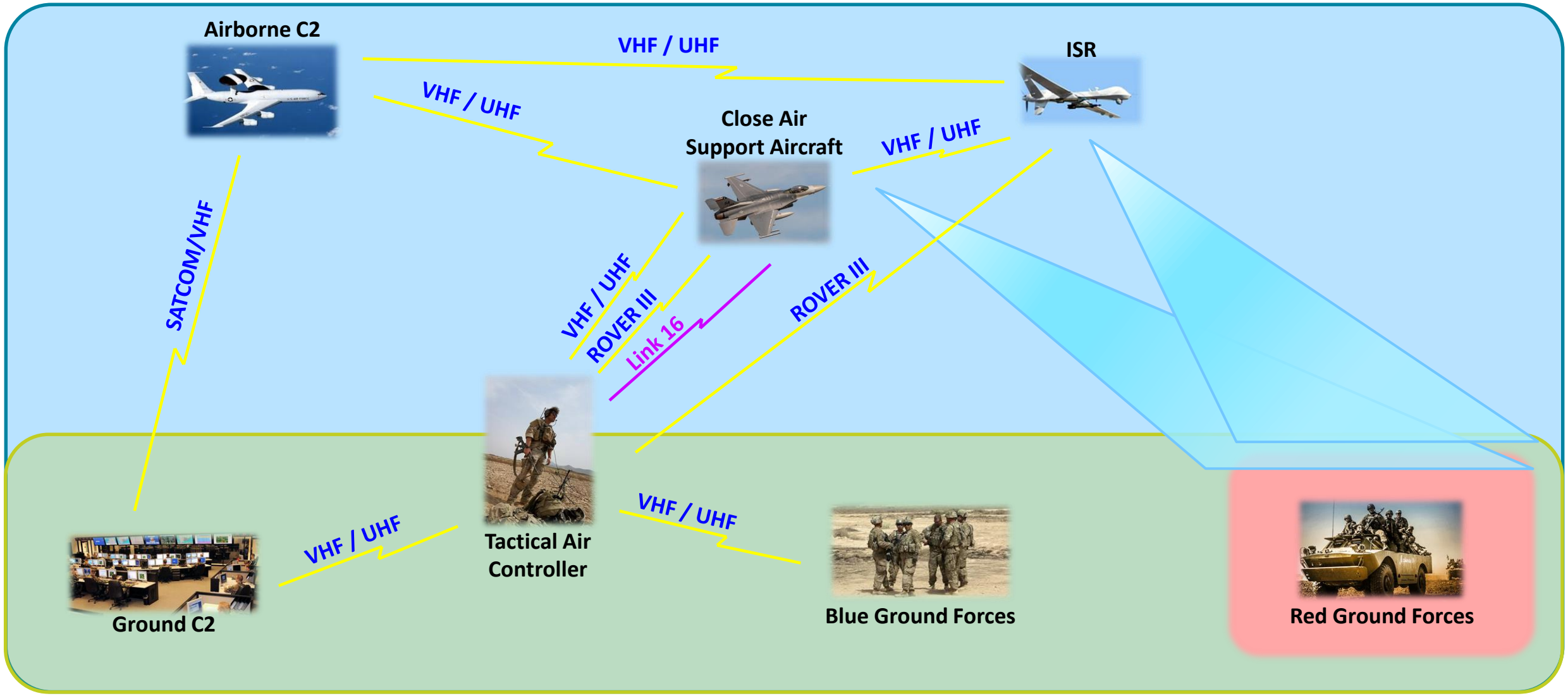
OV-1 Diagram: Scenario #1 – Traditional Close Air Support (CAS)



OV-1 Diagram: Scenario #2 - Digitally Aided CAS



OV-1 Diagram: Scenario #3 - Digitally Aided CAS+



DE Toolchain: MBSE Architecture

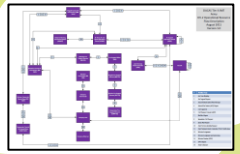
- Translating an architecture to a single, systems model allows for re-use of GRA information and standards, and enables agile architecture analysis

CAMEO SYSTEMS MODELER™

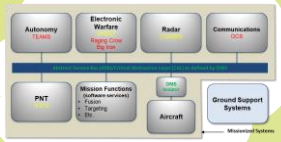
Static Joint Mission Thread (JMT) DoDAF Views & GRA

OV-1

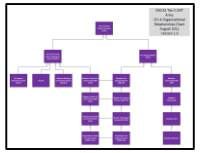
OV-2



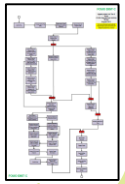
GRA (tbd)



OV-4



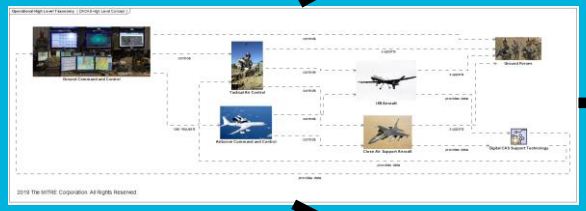
OV-5b



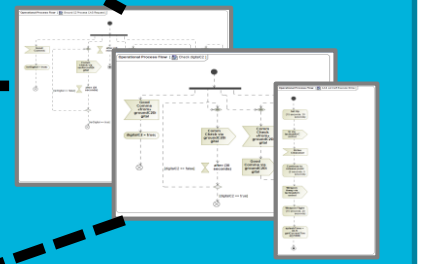
Cohesive, Traceable System Model

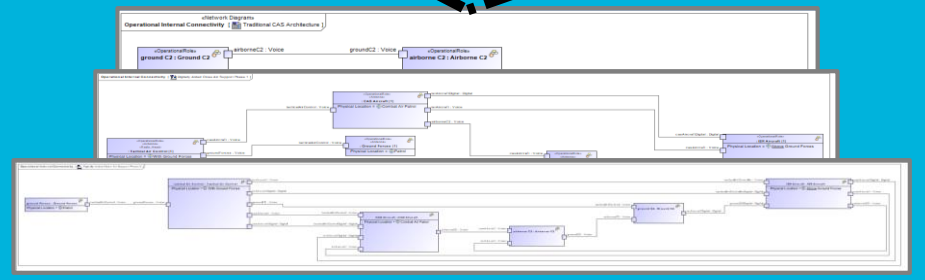
Mission Decomposition

System Decomposition



System Behaviors





System Interface Specifications

DE Toolchain: Cyber Resiliency/Risk

- **Overview:** Calculate, analyze and report on metrics for the likelihood, and consequence, of information availability, data corruption, and more based on the information exchanges, interfaces, and activities defined within your system model
  - **Tool:** Blade RiskManager (KDM Analytics)
- **Value Added:** Cost & time savings by having automated analysis and report generation be tightly integrated from an authoritative technical baseline

The Process

1. Blade RiskManager Pulls Architecture data from Cameo

2. Engineer Adds / Modifies / Analyzes the system's Risk Profile; Changes are kept in sync with Cameo Model

3. Engineer generates and delivers auto-generated risk report from Blade RiskManager

Cameo Model

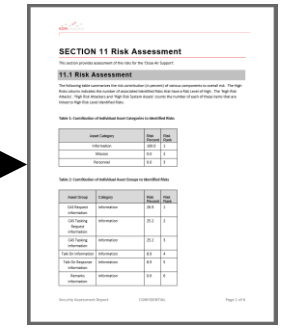
Risks to Test Mitigation

LI / IMPACT	I1 - Negligible	I2 - Minor	I3 - Moderate	I4 - Major	I5 - Catastrophic
L5 - Near Certainty	R1 - 0	R2 - 0	R3 - 0	R4 - 0	R5 - 0
L4 - Probable	R1 - 1	R2 - 2	R3 - 13	R4 - 11	**R5 - 11**
L3 - Occasional	R1 - 0	R2 - 0	R3 - 11	R3 - 1	R4 - 0
L2 - Remote	R1 - 0	R2 - 0	R2 - 0	R2 - 0	R3 - 0
L1 - Improbable	R1 - 0	R1 - 0	R1 - 0	R2 - 1	R2 - 0

Identified Risks: (11)

Rank	Name	Category	Impact Level	Likelihood Level	Risk Level	Risk Percent
1	Corruption of CAS Check In information	Risks to information	I5 - Catastrophic	L4 - Probable	R5 - Very High	12.6
2	Corruption of CAS Approval information	Risks to information	I5 - Catastrophic	L4 - Probable	R5 - Very High	12.6
3	Corruption of AO Update information	Risks to information	I5 - Catastrophic	L4 - Probable	R5 - Very High	12.6
4	Loss of CAS Tasking information	Risks to information	I5 - Catastrophic	L4 - Probable	R5 - Very High	6.6
5	Loss of CAS Approval information	Risks to information	I5 - Catastrophic			
6	Loss of AO Update information	Risks to information	I5 - Catastrophic			
7	Loss of CAS Check In information	Risks to information	I5 - Catastrophic			
12	Denial of Ground Command and Control capability	Risks to capability	I5 - Catastrophic			
13	Denial of Airborne Command and Control capability	Risks to capability	I5 - Catastrophic			
14	Denial of Weapon Employment capability	Risks to capability	I5 - Catastrophic			
15	Denial of Weapon Guidance capability	Risks to capability	I5 - Catastrophic	L4 - Probable	R5 - Very High	2.7

Blade RiskManger User Interface



Architecture-Specific Risk Analysis Report

DE Toolchain: Mission Effectiveness

- **Overview:** Analyze the mission-level performance of your system(s) within the context of one or more mission scenarios using a stochastic simulation. Portions of the simulation can automatically be generated using your system model
  - **Tool:** AFSIM & Cameo Integration (AFRL/MITRE)
- Value Added: Cost & time savings by having partial AFSIM code be directly generated from an authoritative technical baseline

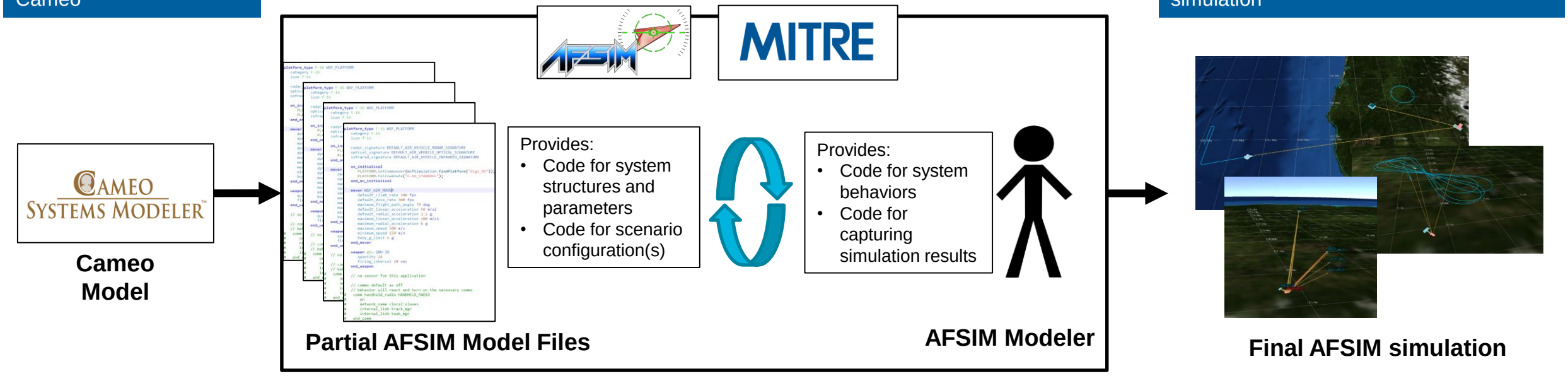
The Process

1. AFSIM / Cameo Integration Package Pulls Architecture data from Cameo

2. AFSIM / Cameo Integration generates partial AFSIM Model Files

3. AFSIM Modeler tailors partial AFSIM Model Files to complete the simulation

4. AFSIM Modeler (and stakeholders) analyze the mission effectiveness of the system by executing the complete AFSIM simulation



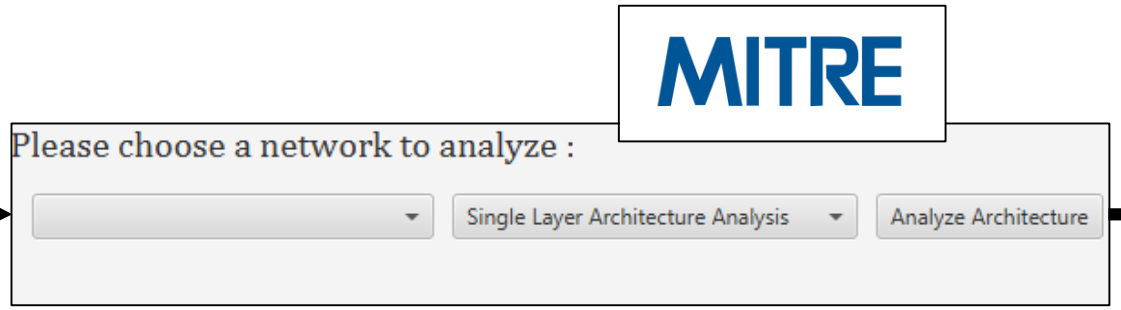
DE Toolchain: Operational Robustness

- **Overview:** Quantify how well the system can operate if communication nodes are removed from a given mission configuration, based on how your mission configuration is defined in the systems model
  - **Tool:** Operational Robustness Analysis (MITRE)
- **Value Added:** Cost & time savings by having streamlined, technical architecture analysis tightly integrated with an authoritative technical baseline

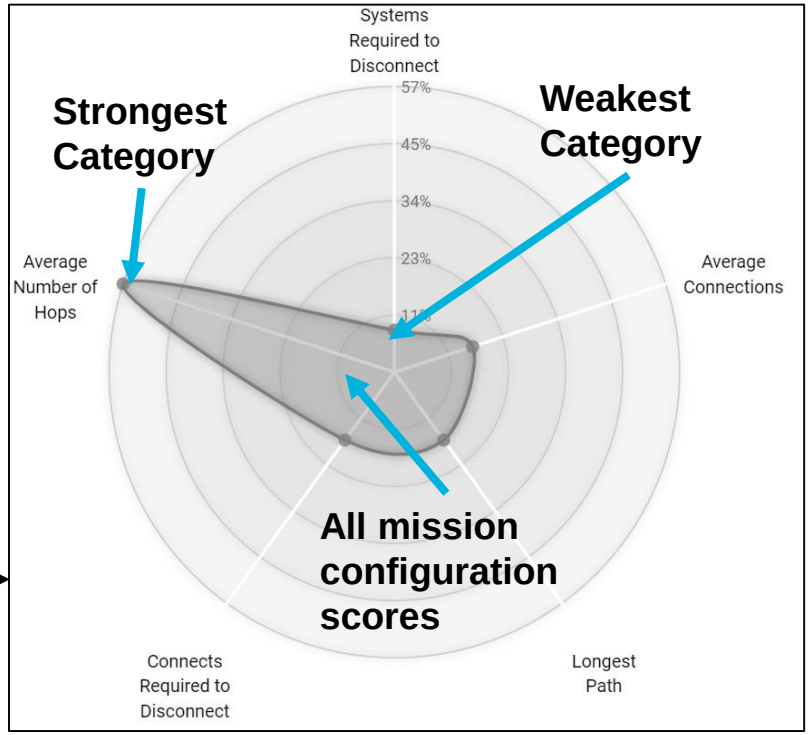
The Process

1. Operational Robustness package pulls Architecture data from Cameo
2. Engineer selects the mission scenario configuration they want to analyze
3. Operational Robustness Package calculates and generates a report corresponding to the system's operational robustness

Cameo Model



Operational Robustness User Interface



Summary of Robustness Scores

DE Toolchain: Cost Analysis

- **Overview:** Integrate and synchronize cost data associated with portions of the system specification with the system model for analysis throughout engineering process
  - **Tool:** MagicDraw (Cameo) provided capability (NoMagic)
- **Value Added:** Cost & time savings by having system financial information integrated as part of the authoritative baseline

The Process

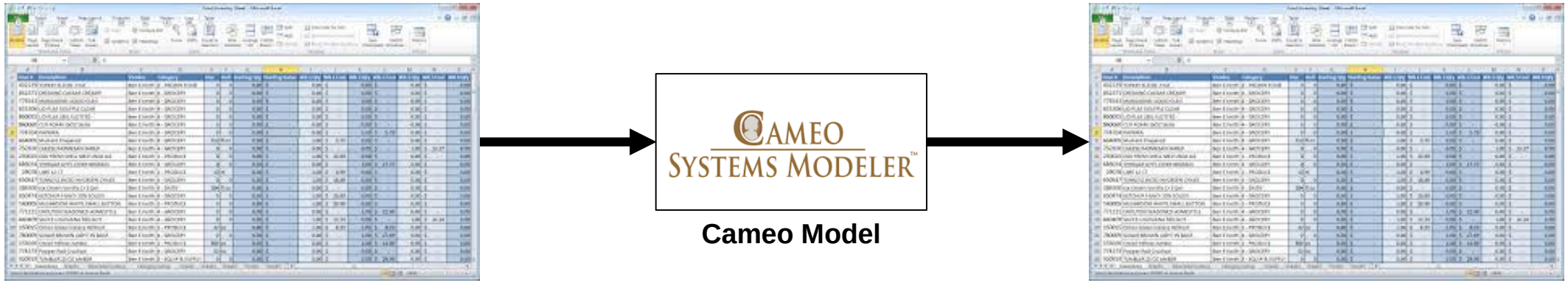
1. Cost Analysts and Engineers establish cost information in Excel-based format that fits their project needs

2a. Cameo Pulls Information from one or more Excel spreadsheets, storing the data as part of the system model

2b. The spreadsheet is *synchronized* with the system model; any changes in Excel will be displayed in Cameo

3. Engineers can update cost information from within the system model

4. Engineers can Push cost information to an updated Excel spreadsheet at any time.



Excel Spreadsheet(s)

Cameo Model

Updated Excel Spreadsheet(s)

DE Toolchain: Tradespace Analysis

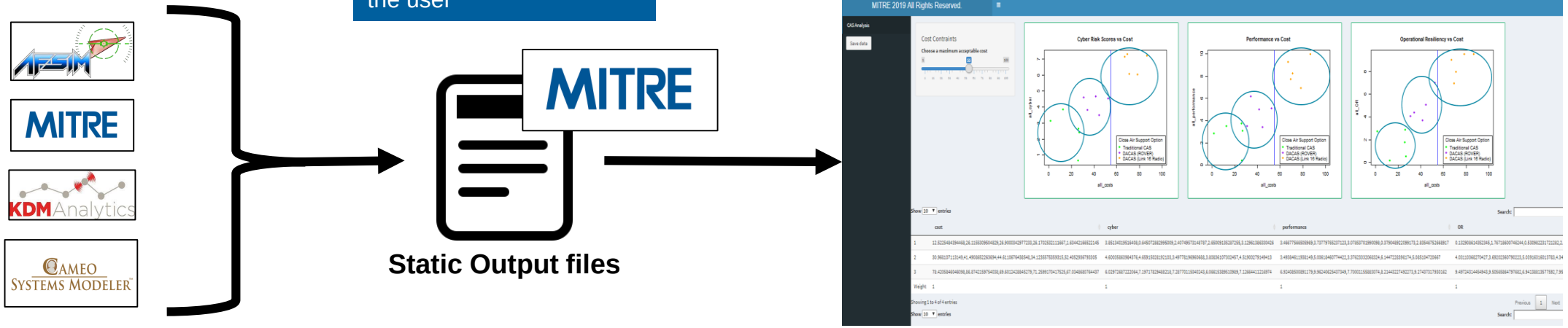
- **Overview:** Aggregate data from external analyses, that all use the same systems model, to intuitively see the optimal solution across dimensions using pareto analysis and multi-attribute utility theory (MAUT)
- **Value Added:** Presents multi-domain technical data on a single screen, allowing decision-makers to better understand the relationships between trade-offs for their systems model

The Process

1. Analysis output(s) and engineering data are collected in a series of static files

2. Tradespace Analysis Package pulls data from the series of static files; displays combined data to the user

3. The Tradespace Analysis user is able to examine, analyze, and understand trade-offs associated with their system in order to make an informed investment decision.



Previously discusses DE Tools

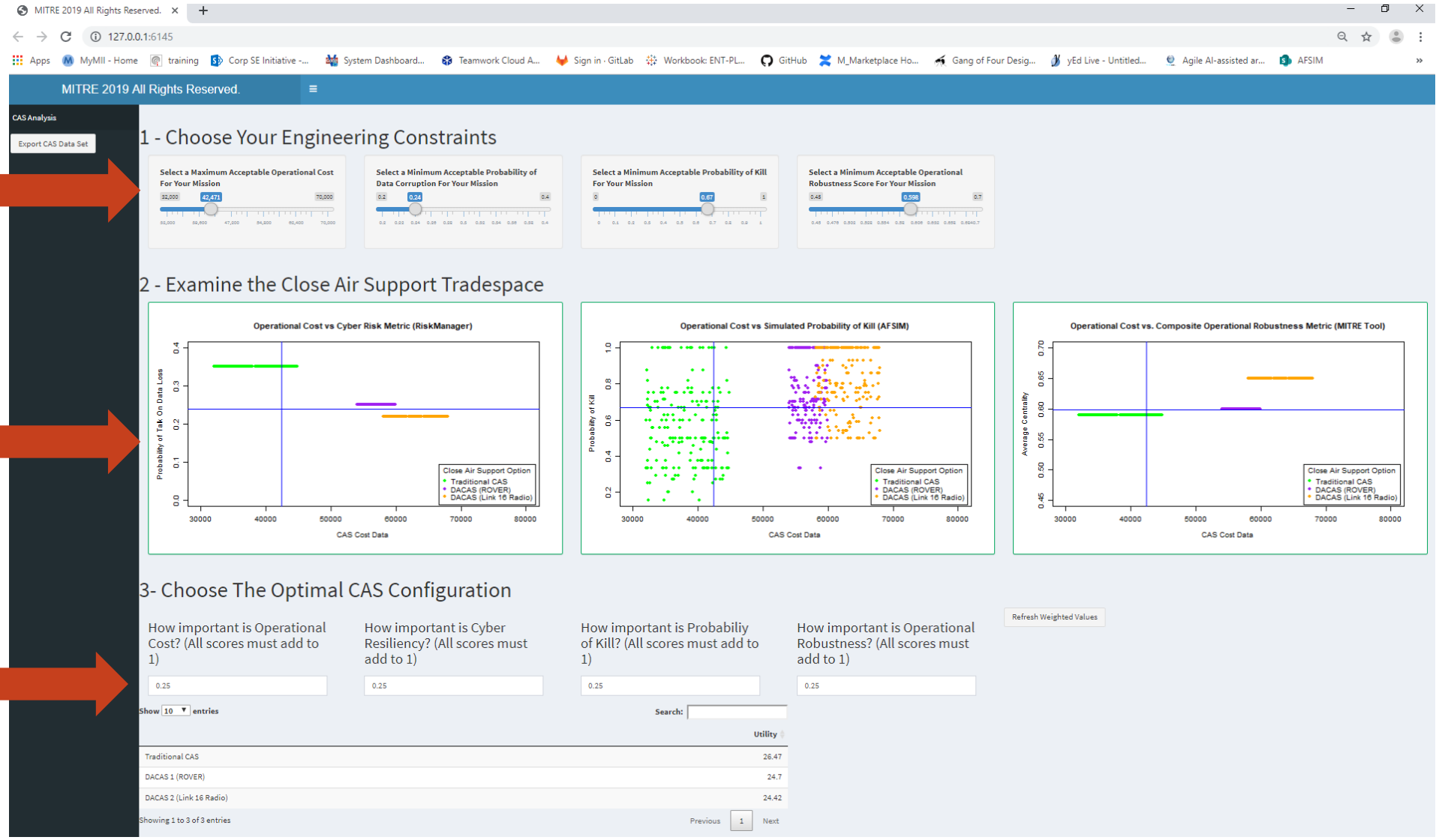
Tradespace Analysis User Interface

DE Toolchain: Tradespace Analysis Walkthrough(1)

#1: Constrain the problem by selecting desired “threshold” values across trades

#2: Examine how each alternative scenario aligns with your constraints

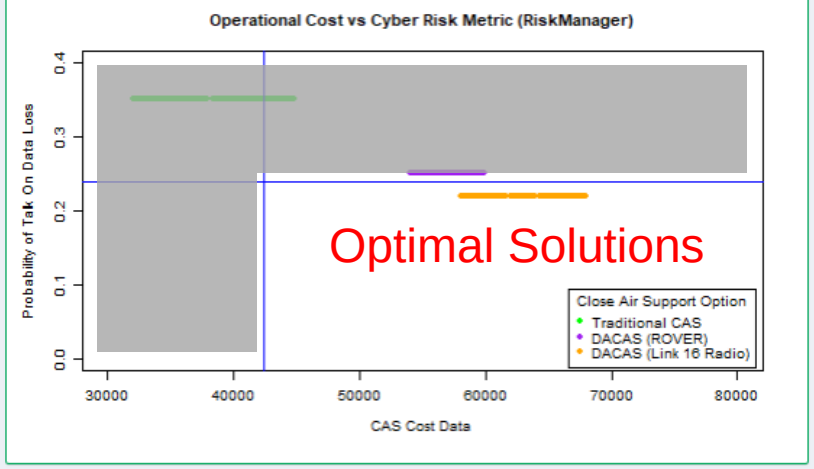
#3: Choose a solution by toggling trade “weights” that align with your program’s priorities



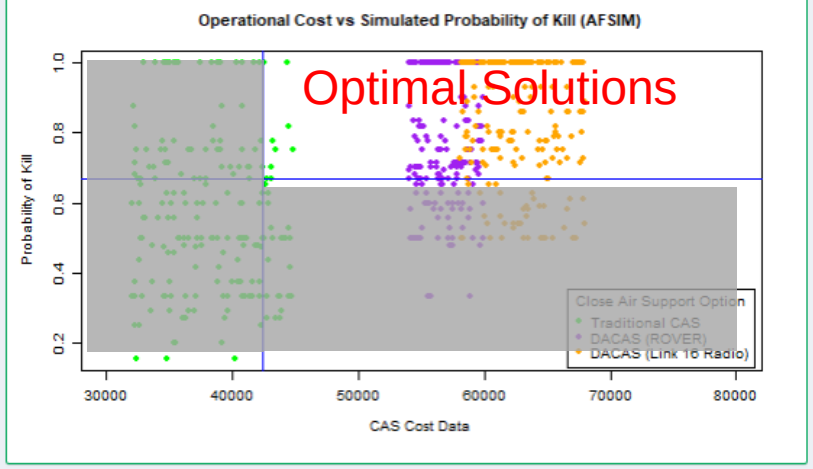
DE Toolchain: Tradespace Analysis Walkthrough(2)

- Three "dimensions" of the trade space, each receiving data from a different engineering tool
- Three scenarios to choose from, color coded.
- Can begin to determine the optimal solution based on program (or mission) specific requirements

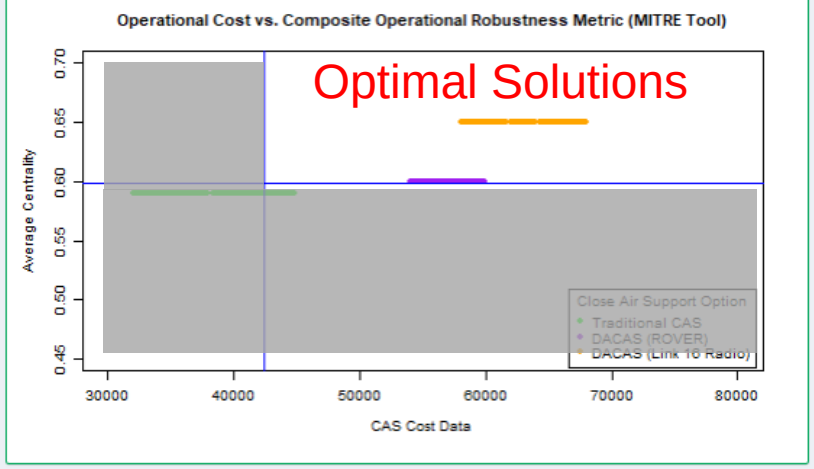
Minimize Cyber Risk, Minimize Cost



Maximize Performance, Minimize Cost



Maximize Robustness, Minimize Cost



DE Toolchain: Case Study Results

- Question: What scenario optimal balance across cyber resiliency, mission effectiveness, operational robustness, and cost?

- Answer:
  - Choose Traditional CAS if one of the following are true:
    - Minimizing cost is the most important trade to the program
    - All trades are considered equal
  - Choose DACAS #2 if one of the following is true
    - Maximizing performance is the most important trade to the program
    - Minimizing cyber risk is the most important trade to the program
  - Never choose DACAS #1. The other two scenarios are "dominant" across most trades

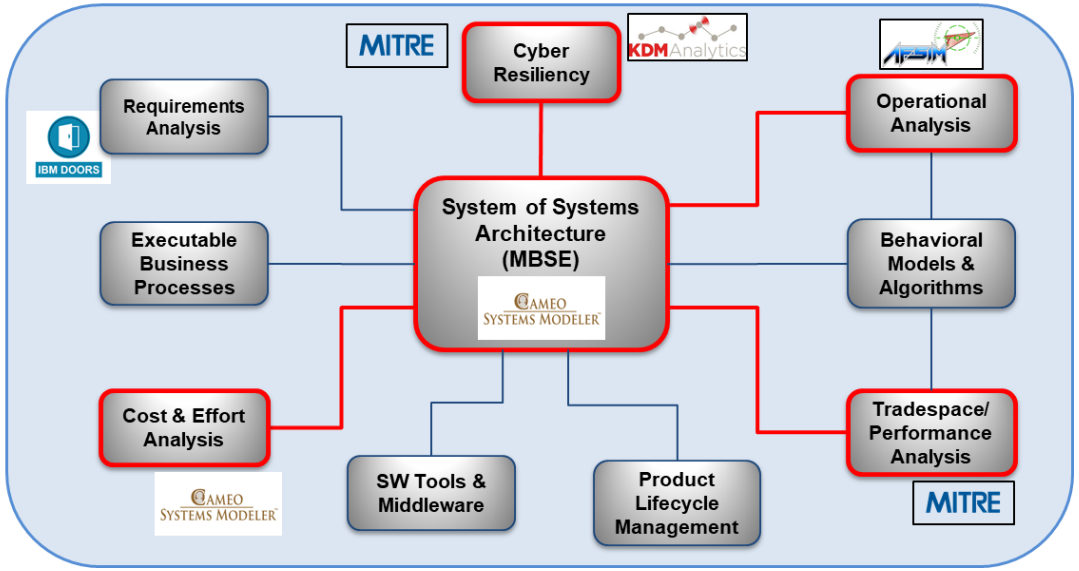
Agenda

1. BLUF
2. Introduction
3. Making Educated Decisions with a Digital Engineering "Toolchain"
4. **Conclusions**

Summary

- USAF will not GO FAST without understanding the fundamentals of MBSE/DE and how we interact with our contractors to rapidly build systems (e.g. data)
- Some imperatives are:
  1. Begin by building systems in modern architectural tools
  2. Use standards to build reference architectures across weapon systems
  3. Build an ecosystem that integrates weapon system design with program office analytical functions (e.g. costs) and lifecycle management (e.g. PLM)
  4. Automate as many parts of the ecosystem as possible

An Example Digital Engineering Toolchain



Next Steps and Recommendations

- Continue work with Open Architecture Management Office to mature Standards, Architectures, and Agile Processes
- Collaborate with AFWIC to develop Joint Mission Threads (J6)
- Engage Test Community
- Mature Digital Engineering Toolchain with authoritative data, target program of record as a pathfinder
- Design and Develop additional Analytical interfaces: PLM, Software Tools, Business Processes, Behavioral Algorithms
- Compile Documentation
- Develop Governance Processes, People, Partnerships, and Infrastructure
- Present at NDIA Systems and Mission Engineering Conference, 21-24 Oct

Questions?