



ACQUISITION INNOVATION
RESEARCH CENTER



Bayesian-methods for Test & Evaluation of Learning-Based Systems

21 Sep 2022



INTRODUCING THE TEAM

*We have a **transdisciplinary team**, which is necessary to address the challenges of T&E for LBS

Purdue



Virginia Tech
National Security Institute



Jitesh Panchal >>
Professor

PhD, **Mechanical Engineering**;
Design & Manufacturing;
Computational Engineering
Human-Machine Interactions



Laura Freeman >>
Executive Director, Deputy,
National Security Institute;
PhD, **Statistics**
Test & Evaluation



Peter Beling >>
Director,
Intelligent System Lab;
PhD, Operations Research;
AI Systems Engineering
& **Cyber Resilience**



Atharva Sonanis >>
MS student
Mechanical Engineering;
AI algorithms



Paul Wach >>
PhD Candidate;
Systems Engineering;
Digital Transformation



Justin Krometis >>
PhD, **Mathematics**;
Data analytics



Tim Sherburne >>
MS, **Computer Science**;
Software engineering



PROJECT OVERVIEW

***We have all the piece (e.g., framework, systems, mission, testing, data) to address the question of data right.** To what extent do we need access to training data, algorithms, hardware, software, and to what level of detail?

Project Objectives

Value to Government:

1. Characterize assurance trade space of: (increase in) data/model rights on (decrease in) need for testing and (increase in) confidence

Research:

1. Create a T&E framework for Learning-Based Systems
2. Characterize the change in operational conditions (*ops*) and adversarial actions (*act*)
3. Characterize equation of change in *ops/act* to change in system implementation

Project Summary Status

Target scenario of unmanned aerial vehicle (UAV) object detection, classification, and trajectory mapping

Research team consists of Purdue and Virginia Tech members

Purdue:

- Focus on **UAV simulation and drone** surrogate to **solicit data** to support probabilities of object detection
- Leverage the **You Only Look Once (YOLO) agent**

Virginia Tech National Security Institute

- Using data collected from Purdue team to **construct Bayesian Network**
- Correlating data to **systems theoretic framework** that enables mathematical precision of **equivalence mapping** between context of the simulation, surrogate drone, and fielded drone
- **Operationalizing** using **digital engineering (DE)** and **model-based systems engineering (MBSE)** principals and software

Silverfish description

Prohibited Area:

- ~100 acres \approx .16 sq. miles

Obstacle Deployment:

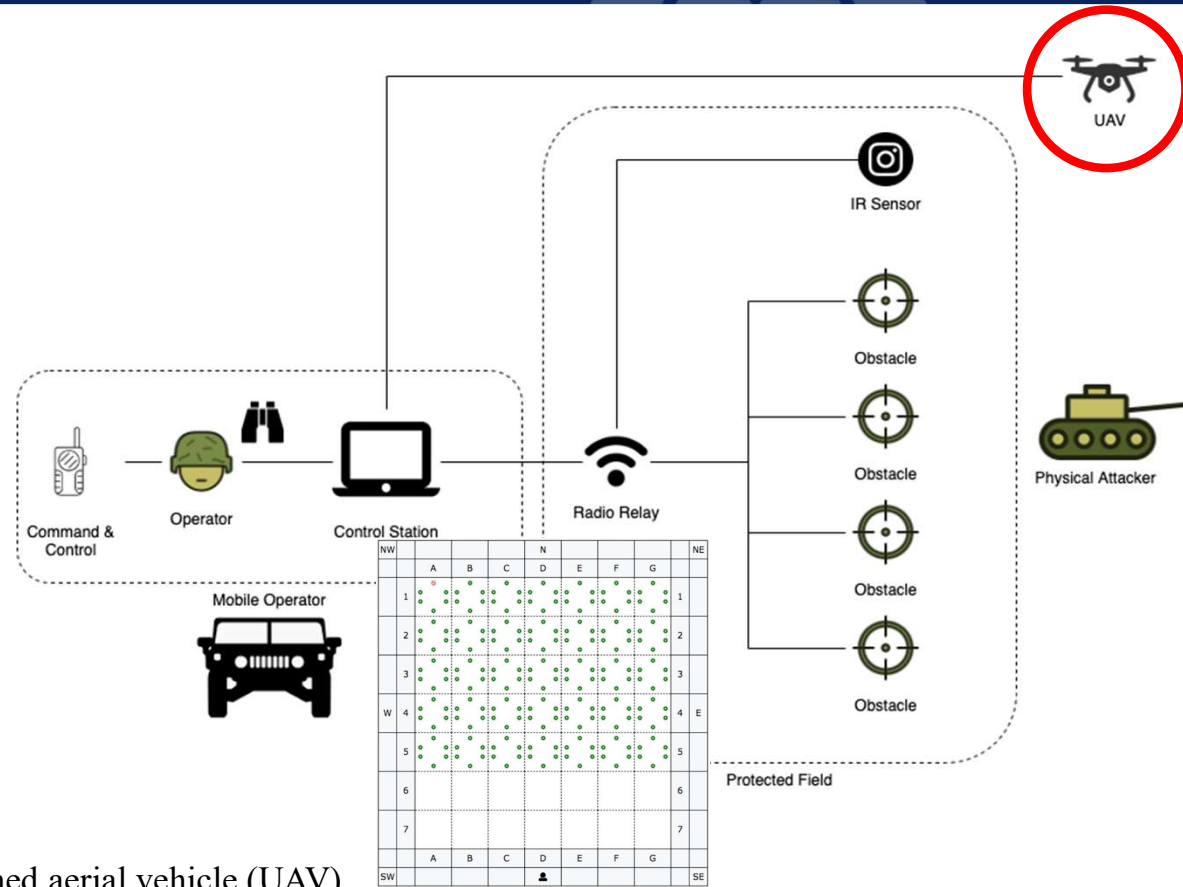
- ~50
- Aligned to Compass Coordinates (Operator Observation Point)

Cell Grid:

- \approx 300 ft. x 300 ft.
- 6 Munitions per Cell (Ready/fired state)

Vehicle Traversal:

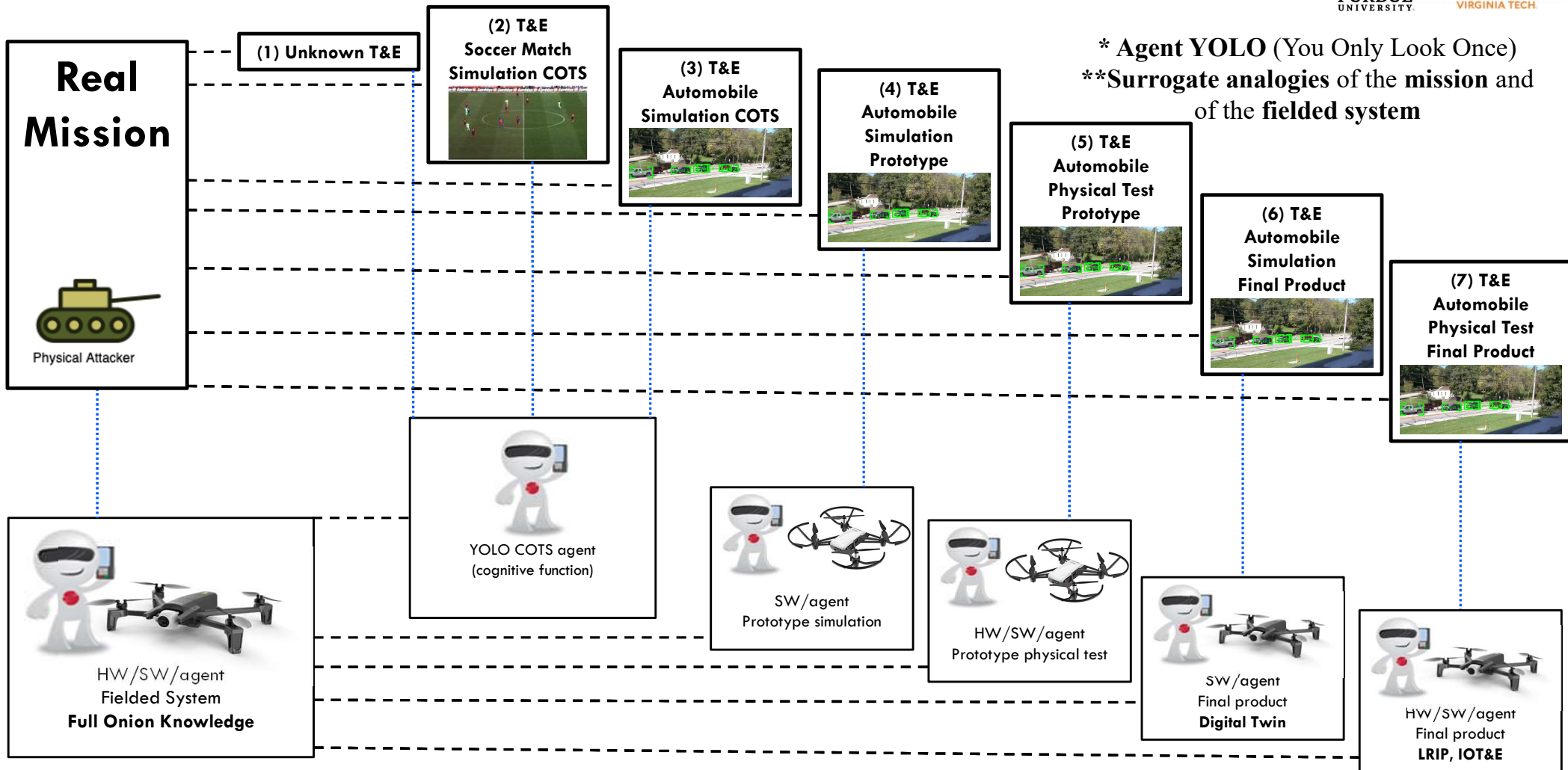
- Max Speed = 10 mph \approx 15 ft/sec
- 20 seconds/grid
- 2.3 min/protected area



*Focus of current study is on the unmanned aerial vehicle (UAV)

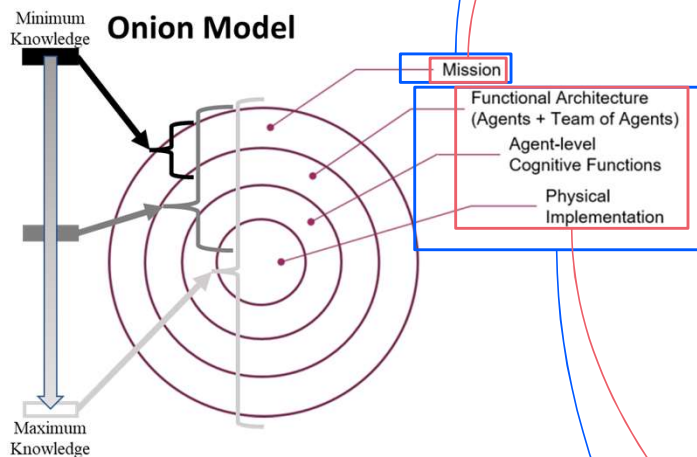
**Mission of UAV is to detect attacker

Understanding the Complexity Through Analogies



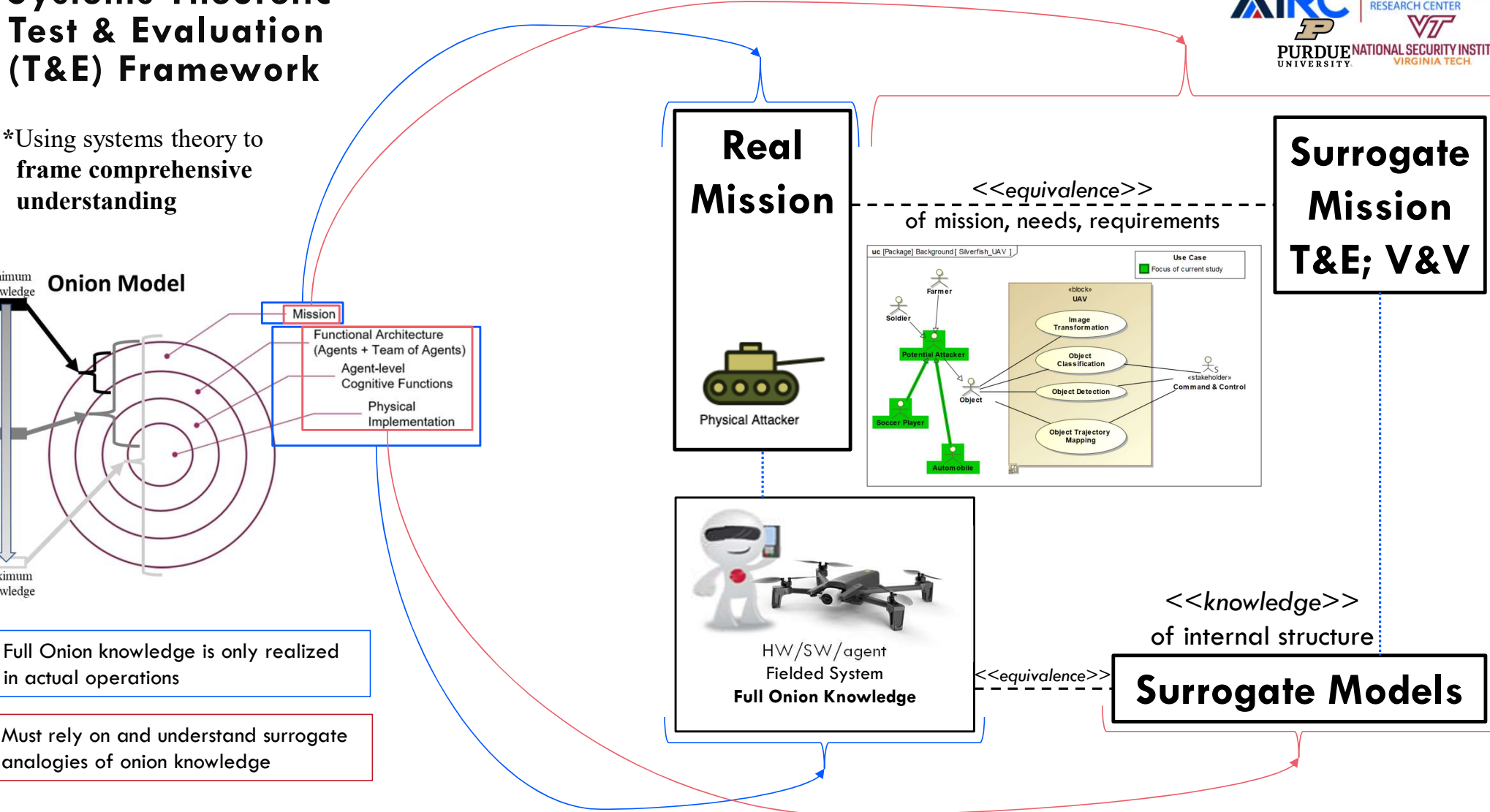
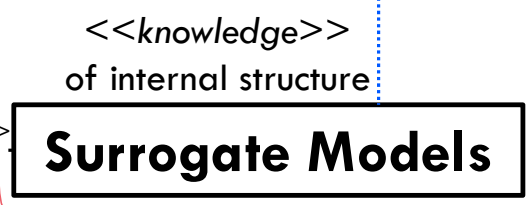
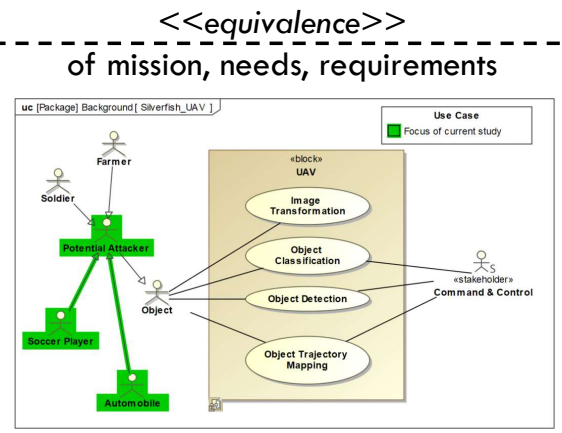
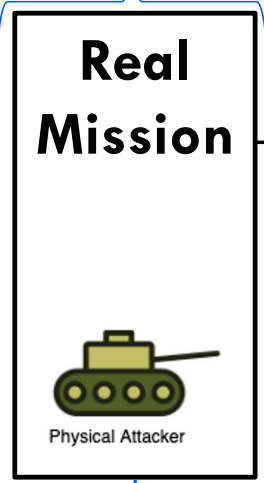
Systems Theoretic Test & Evaluation (T&E) Framework

*Using systems theory to frame comprehensive understanding



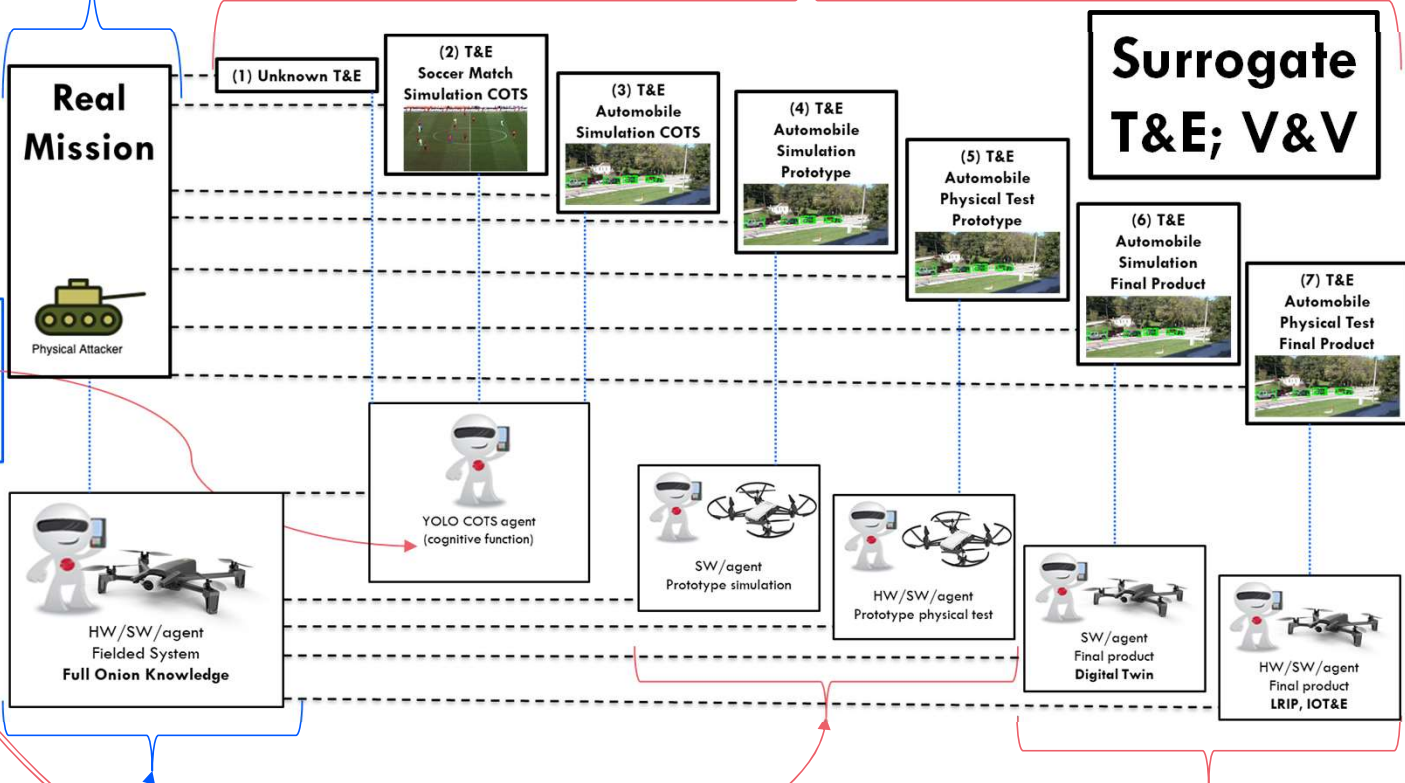
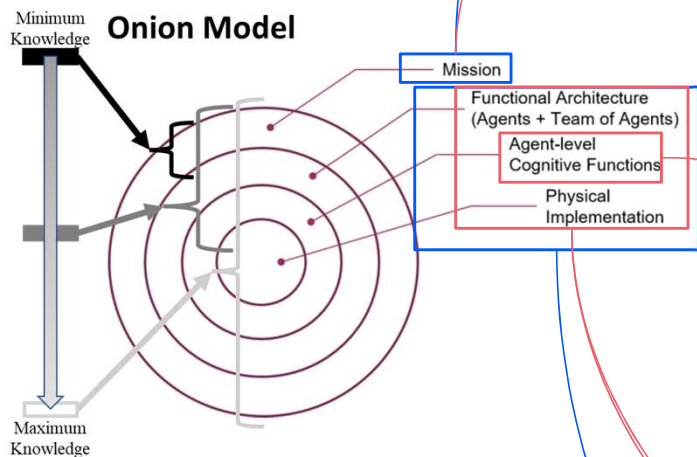
Full Onion knowledge is only realized in actual operations

Must rely on and understand surrogate analogies of onion knowledge



Systems Theoretic Test & Evaluation (T&E) Framework

*Using systems theory to frame comprehensive understanding



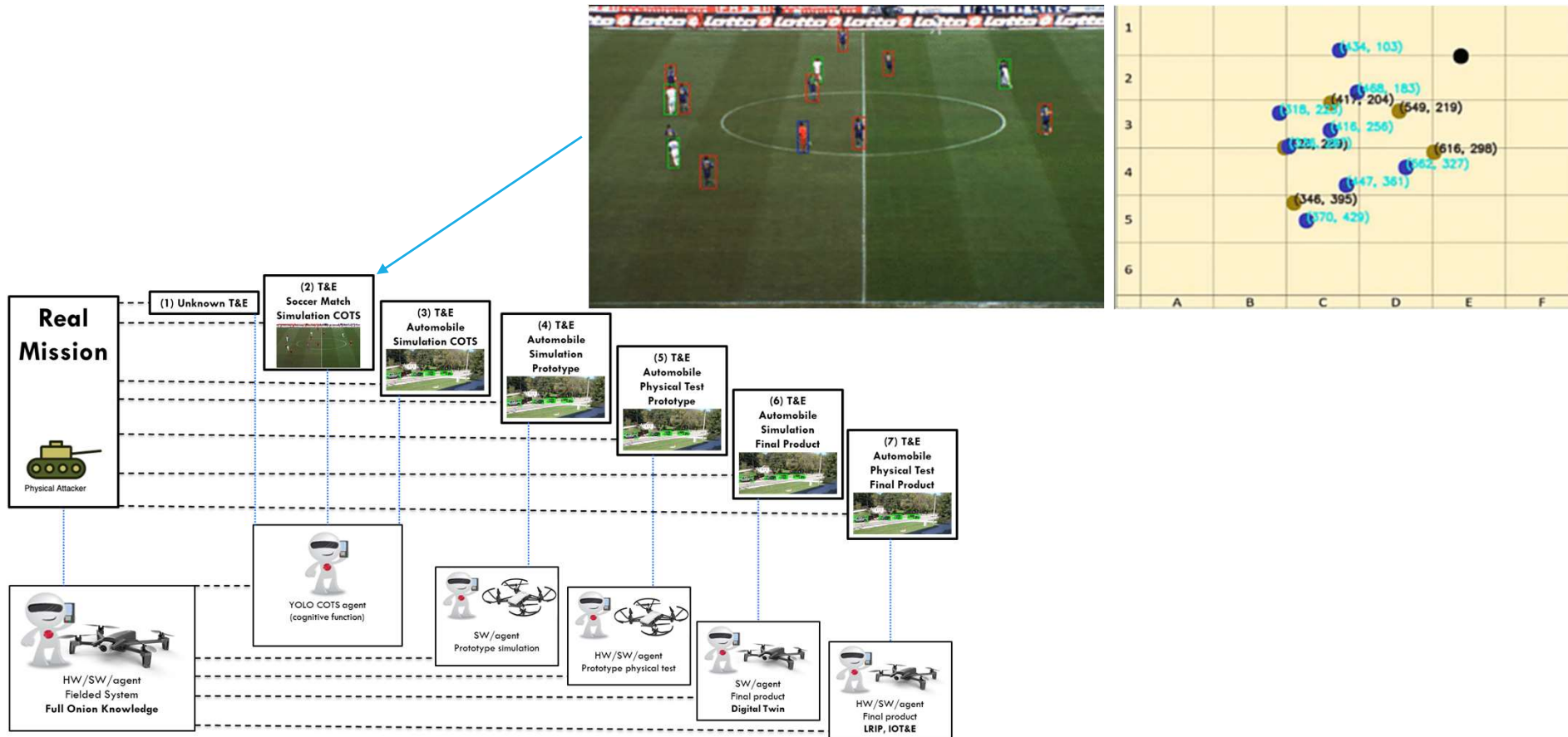
Surrogate T&E; V&V

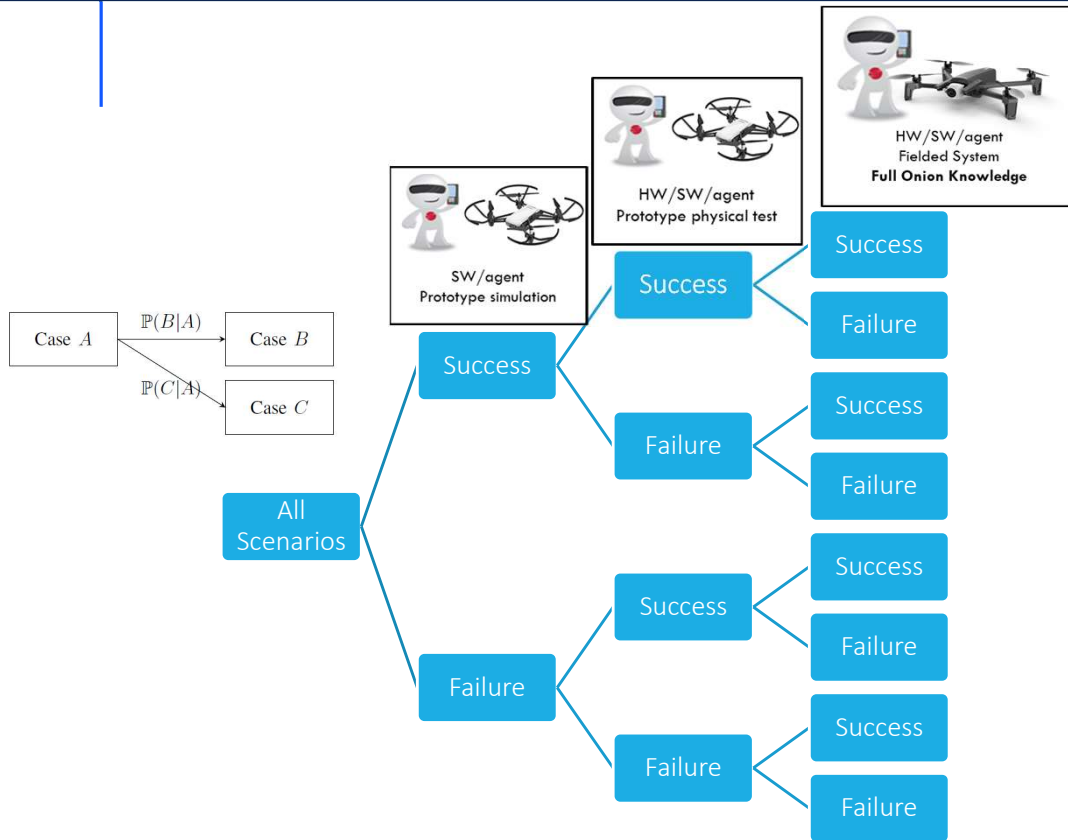
Surrogate Models

** Agent YOLO (You Only Look Once)
 *** Surrogate analogies of the mission and of the fielded system

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Role of T&E: Characterize "cost"

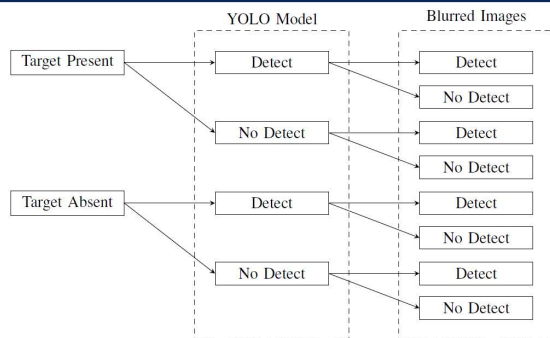
$$\begin{aligned}
 E(C) &= C_S P(S) + C_F P(F) \\
 &= \int C_S P(S|x) + C_F P(F|x) \\
 &= \int C_S P(S_{hi} | S_{lo}, S_{sim}, x) + \dots
 \end{aligned}$$

Case	Target Present?	Target Detected?	Impact of Failure	Chance of Failure	T&E Priority
True Positive	Yes	Yes	High	Low	Low (Validation)
False Negative	Yes	No	High	High	High
False Positive	No	Yes	Low	High	Medium
True Negative	No	No	Low	Low	Low

*Results from the simulation and physical test of surrogates used to inform probabilities in the Bayesian Network

**Bayesian Network provides mechanism to assess value of data rights to the Government

***T&E framework, as a whole, enables assessment of risk to mission success

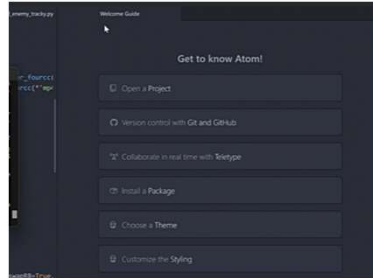


Scenario	Target	Detected	Count	Probability
True Positive	Present	Present	65	0.783
False Negative	Present	Absent	18	0.217
False Positive	Absent	Present	0	0.000
True Negative	Absent	Absent	17	1.000



Target	Detected (Clear)	Detected (Blur)	Count	Cond. Prob.
Present	Present	Present	42	0.646
Present	Present	Misdetect	1	0.015
Present	Present	Absent	22	0.338
Present	Absent	Absent	18	1.000
Absent	Absent	Absent	17	1.000

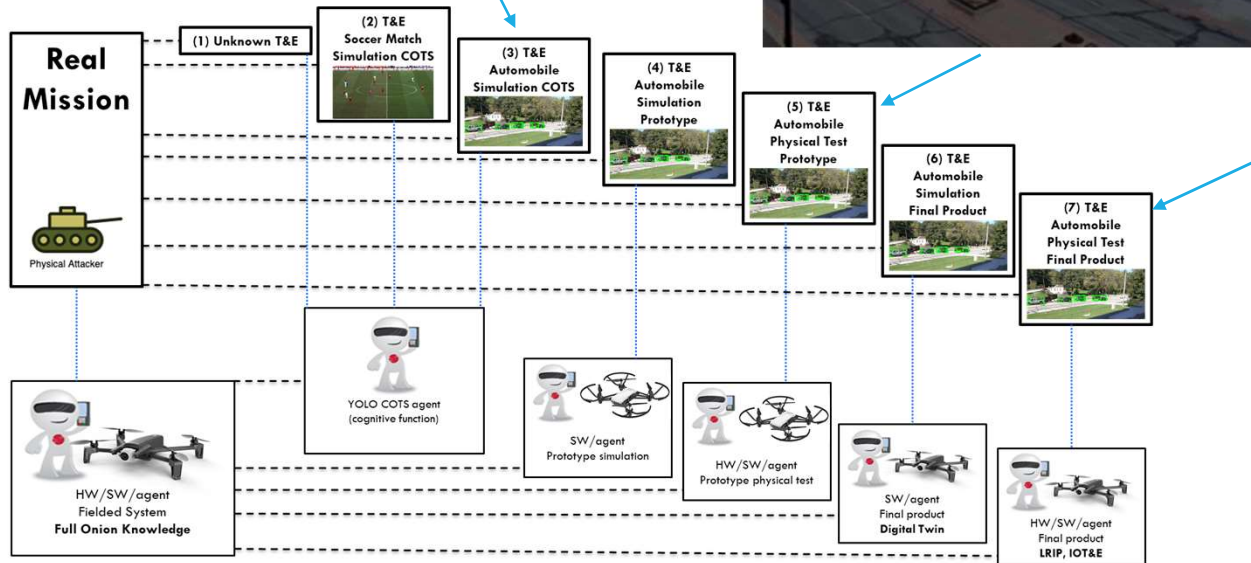
Target	Detected (Clear)	Detected (Blur)	Count	Cond. Prob.
Present	Present	Present	65	1.000
Present	Absent	Misdetect	1	0.056
Present	Absent	Absent	17	0.944
Absent	Absent	Present	1	0.059
Absent	Absent	Absent	16	0.941

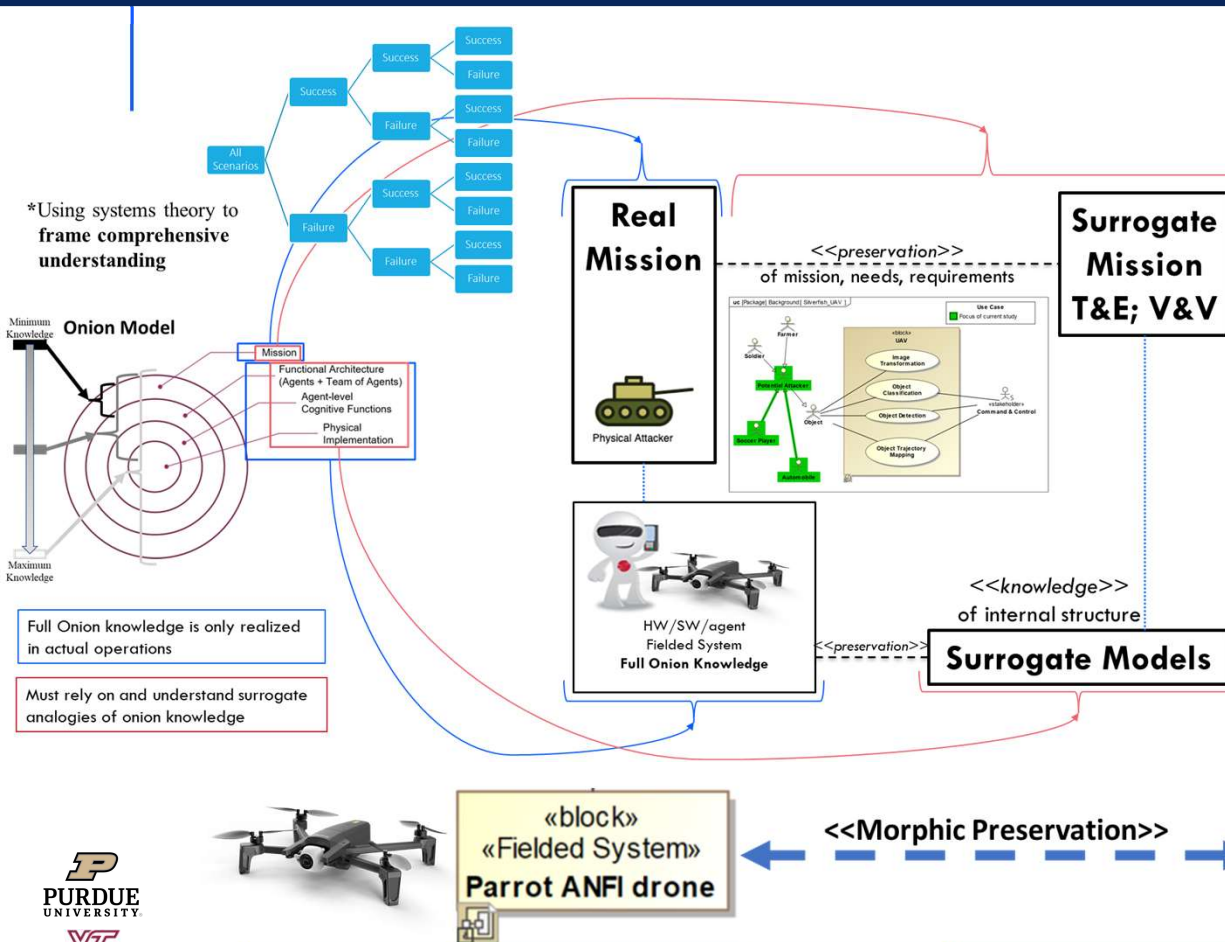


Ryze Tello Drone
5 MP Camera
720 HD Resolution



Parrot ANAFI Drone
21 MP Camera
4K HD Resolution





1. Link to LBS Lifecycle

- LBS lifecycle change a increased rate compared to traditional systems

2. Digital Twin

- Envisioning future application
- Advance the digital engineering (DE) and model-based systems engineering (MBSE) mechanisms

3. Value to the Government

- Tradespace of acquiring knowledge relative to the onion layers

