Evolving T&E to Enable DoD's Future

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September 14, 2016

DoD Tech Superiority

- **US and Allies have been able to count on a technology superiority advantage for more than 40 years**
  - Advantage built on technologies developed by and for the US military
    - Precision weapons, long-range intelligence, surveillance and reconnaissance (ISR), stealth

- **What has changed:**
  - Increasingly global access to resources, technology and talent
  - Competitors investing in capabilities directly designed to counter US technical advantage: tactics, techniques, technologies, procedures
  - Responding to such an environment requires agility and a commitment to invest to keep pace with technical opportunity
  - Drives a focus on cost and cycle time

Key Opportunities for a Third Offset Strategy

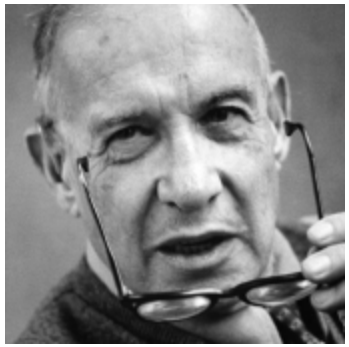
- **"First Offset Strategy" … Nuclear**
- **"Second Offset Strategy" … Stealth and Precision Strike**
- **"Third Offset Strategy"**
  - Autonomous Learning Systems
  - Human-Machine Collaborative Decision Making
  - Assisted Human Operations
  - Advanced Manned-Unmanned System Operations
  - Network-enabled, autonomous weapons hardened to operate in a future Cyber/EW Environment

Third Offset Insights

- May be as much about catch up as Technology Leadership
- Economic factors.
- Adversaries view system use constraints differently than U.S.
- UAS challenges both DoD and FAA access control.

Drucker Said…

“There is nothing so useless as doing efficiently that which should not be done at all”



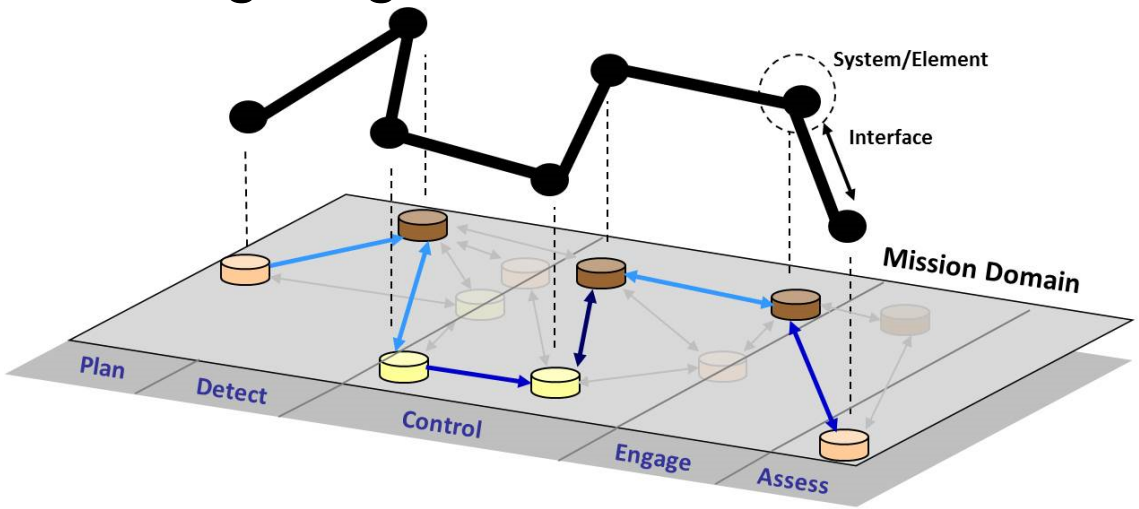
- **Mission Engineering**
- **Developmental Evaluation Framework**

“If you want something new you have to stop doing something old”

Autonomy is new…stop “T&Eing” the same old way

Mission Engineering

Mission Engineering (ME) is the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects



Engineers out the systems and activities that do not contribute to the mission

Mission Engineering

- **Engineer the requirements to ensure we are acquiring systems which will fill gaps in a mission, or multi-mission context?**
- **Test and evaluate the impact of the system(s) on mission(s) outcomes?**

System Acquisition

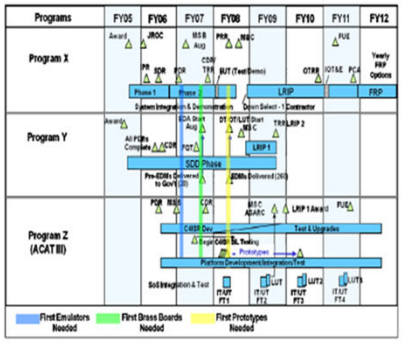


Figure 3.5-1 System-of-Systems Schedule (optional) (sample)
Note: Include an as-of date – time sensitive figure

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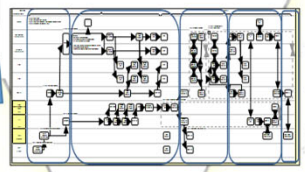
Operations

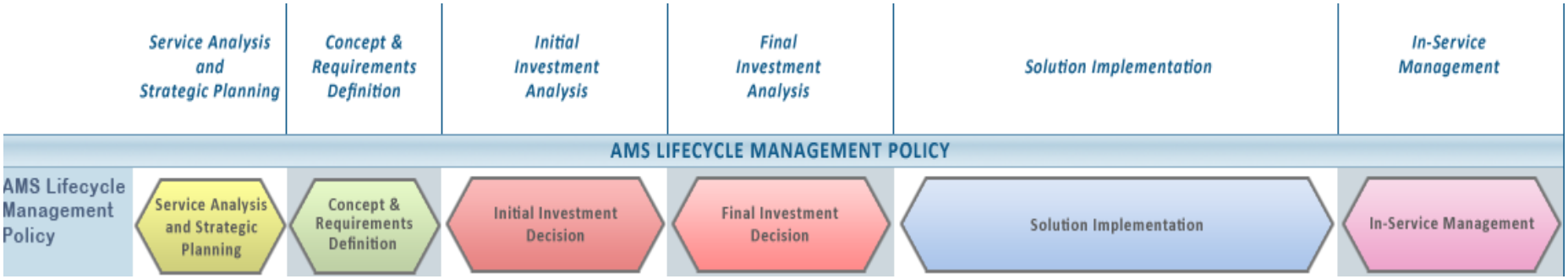


Mission/SoS Architecture/Engineering

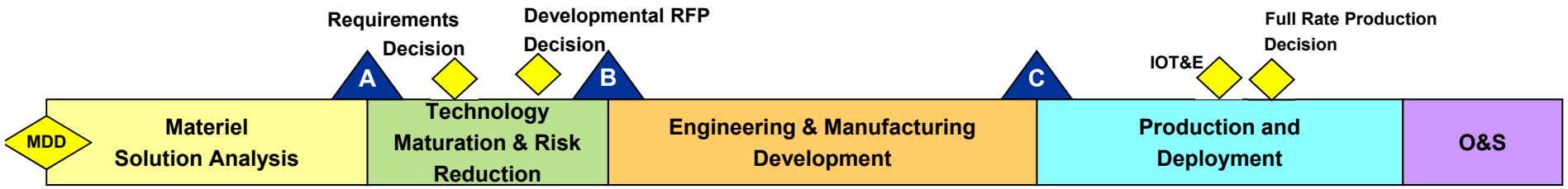
- **Engineer systems so they will work effectively in the mission(s) environments where they will operate?**

We All Have Milestones and Decisions…

FAA
Acquisition Management System



DoD 5000



Shouldn't T&E be designed to support decisions?

Developmental Evaluation Framework (DEF)

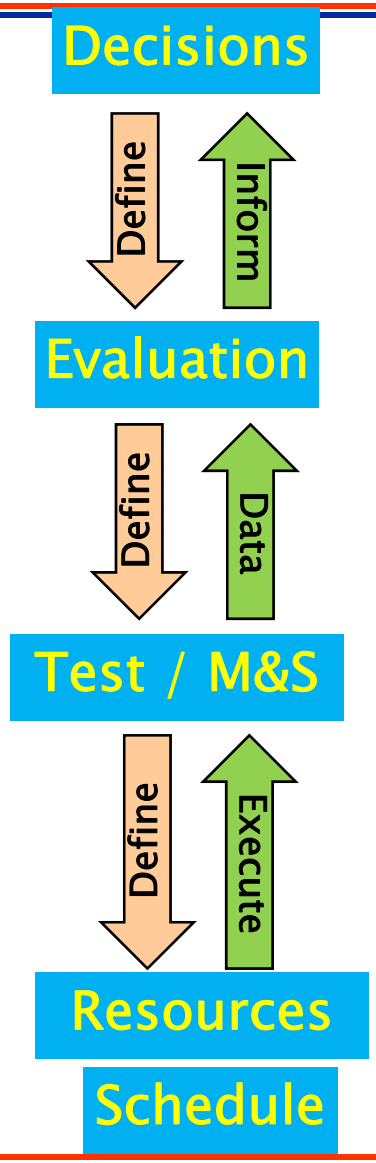
DEF is test planning so that data from tests, when executed and analyzed, will provide *needed* knowledge to decision makers.

Contrast with testing that is performed "because we always do it this way" which results in piles of data that one can only *hope*, when analyzed, will provide knowledge to the decision makers.

Note: Decision makers are at all levels from design engineers, system engineers to senior executives to the President.

Eliminate that which should not be done at all…

Developmental Evaluation Framework



Developmental Evaluation Objectives	System Requirements and T&E Measures		Decisions Supported							
			Decision #1		Decision #2			Decision #3	Decision #4	
			DSQ #1	DSQ #2	DSQ #3	DSQ #4	DSQ #5	DSQ #6	DSQ #7	DSQ #8
Functional evaluation areas System capability categories	Technical Reqmts Document Reference	Description	Identify major decision points for which testing and evaluation phases, activity and events will provide decision supporting information. Cells contain description of data source to be used for evaluation information, for example: 1) Test event or phase (e.g. CDT1....) 2) M&S event or scenario 3) Description of data needed to support decision 4) Other logical data source description							
Performance										
Performance Capability #1	3.x.x.5	Technical Measure #1	DT#1		M&S#2				DT#4	M&S#2
	3.x.x.6	Technical Measure #2	M&S#1		DT#3				DT#4	M&S#2
Performance Capability #2	3.x.x.7	Technical Measure #3				DT#3			IT#1	
	3.x.x.8	Technical Measure #4				M&S#4			IT#1	
Interoperability										
Interoperability Capability #3	3.x.x.1	Technical Measure #1				DT#3		DT#4		
	3.x.x.2	Technical Measure #2		IT#2		M&S#4		DT#4		
Interoperability Capability #4	3.x.x.3	Technical Measure #3		IT#2				IT#1		M&S#2
	3.x.x.4	Technical Measure #4						IT#1		DT#3
Cybersecurity										
SW/System Assurance	PPP 3.x.x	SW Assurance Measure #1			SW Dev Assess		SW Dev Asses	SW Dev Assess		
RMF		RMF Contol Measure #1	Cont Assess		Cont Assess	Cont Assess	Cont Assess			
Vulnerability Assess		Vul Assess Measure #1				Blue Team			Blue Team	
Interop/Exploitable Vuln.		Vul Assess Measure #2				Red Team			Red Team	
Reliability										
Reliability Cap #1	4.x.x.1	Technical Measure #11		M-demo#1						IT#5
	4.x.x.2	Technical Measure #12		M-demo#1				IT#2		IT#5
	4.x.x.3	Technical Measure #13				M-demo#2		IT#2		
Reliability Cap #2	4.x.x.4	Technical Measure #14				M-demo#2		IT#2		

Drucker Also Said…

"If you want something new you have to stop doing something old"

Autonomy is new and challenging…

stop "T&Eing" the same old way

Autonomous Systems Eras and Testing Challenges

Automated Era…

- Preprogrammed commands with explicit tasks
- Deterministic behavior
- Dependence on reliable communications

Testers need to…

- **Verify action**
- Measure physical properties such as position, path, speed, separation distance, completion of event

Autonomous Era…

- Explicit tasks
- Simple decisions made based on environment
- Behaviors are preprogrammed
- Structured independence, locally aware

Testers need to…

- **Verify reasoning process**, not just action
- Verify that SUT perceived situation correctly and meant to act the way it did

Intelligent Era…

- Independent reasoning
- Experience driven
- Adaptive
- High decision complexity
- UAS-to-UAS cooperation
- Adversary interaction
- Unstructured independence
- Distributed understanding

Testers need to…

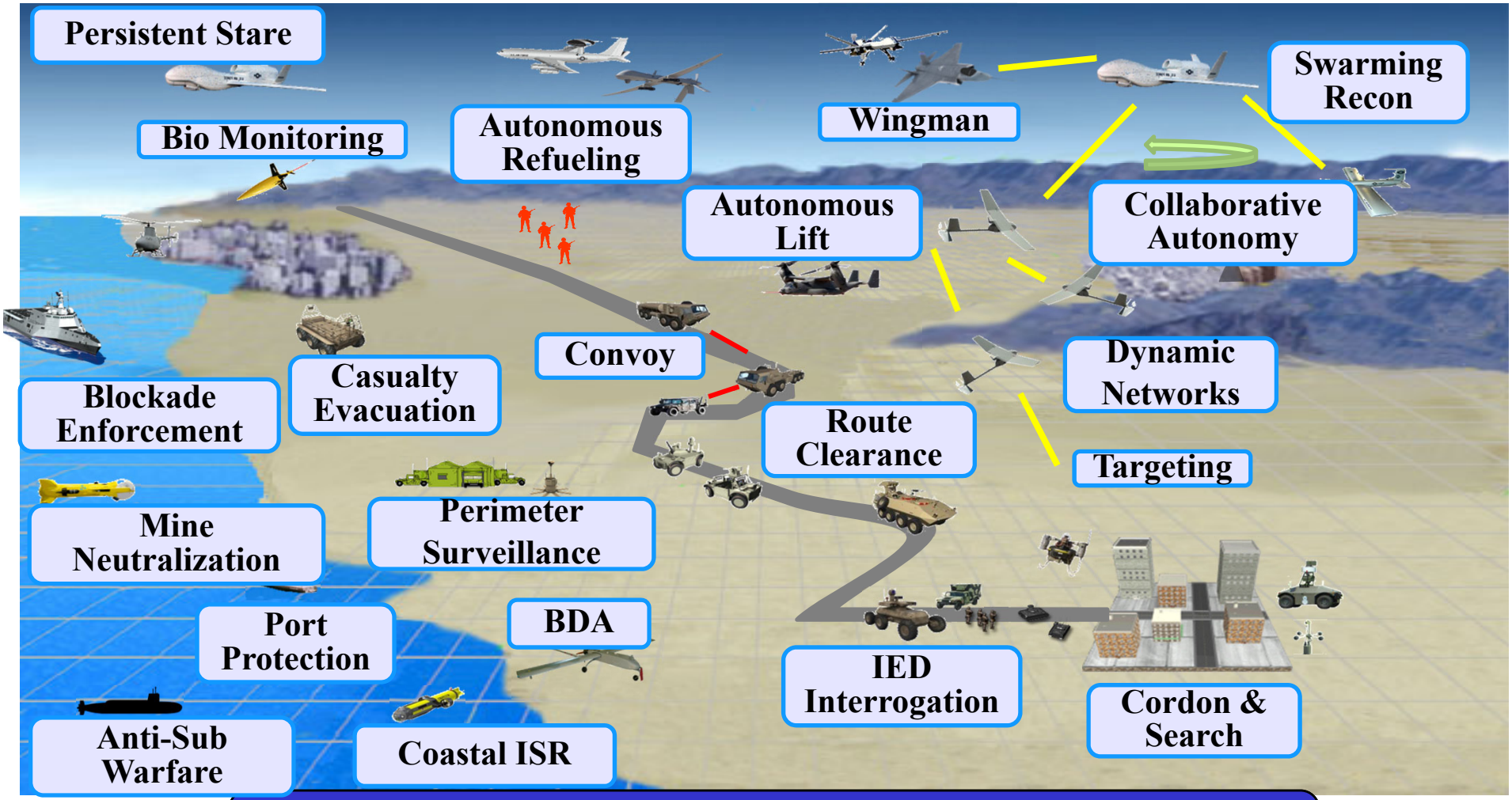
- **Verify cognition**
- Recognize that knowledge and decision ability are a function of time and experience
- Need to verify SUT had sufficient knowledge of a situation to form correct intent
- Need to verify combination of multiple mission goals

Near → Mid → Far

Time

Our Focus is on Testing *Autonomy*

Developing Missions of Autonomous Systems



Warfighters and the Public must trust the system…

Trust is built through T&E

EXHAUSTIVE TESTING IS NOT JUST COSTLY, IT'S IMPOSSIBLE

Therefore…

Stop Using Same Old Approach…

Autonomy is *Disruptive* to Traditional T&E

- **Defined System Under Test**
- **Repeatability**
- **Test Completeness**
- **Safety**

Autonomous Aerial Refueling

Autonomous Cargo Transport

Autonomous Aerial Transport

Autonomous Troop Transport

Autonomous Port Protection

Autonomous Undersea Survey

Common Autonomy Testing Questions

- How do I measure human-machine interaction effectiveness?
- How do I design tests for manned-unmanned team coordination?
- How do I develop tests for evoking emergent behavior?

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- How do I assess the decision process and cognition, especially with a learning system?
- How do I design tests for distributed teams and swarms interaction?
- How do I develop tests that fully exercise rule coverage?

- How do I create sufficiently smart actors for an immersive environment?
- How do I identify the most salient tests based on SUT parameters and mission?
- How do I measure adaptivity and emergence?

- How do I assess maturity of learning systems?
- Can I test it safely?
- Can I test it in budget / on time?

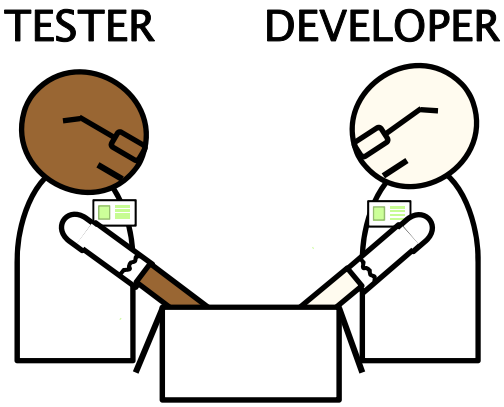
Overarching Strategy

- **Change methodologies**
  - Based on studying autonomy testing complexities
- **Invest in new test capability and improvements**
  - T&E/S&T Program
  - Central Test & Evaluation Investment Program (CTEIP)
- **Enhance the Autonomy Test Workforce**

Autonomy Test Methodology

Testers must be part of the Development Team

Testers must be involved in "white box" testing to get the confidence needed for autonomous system employment

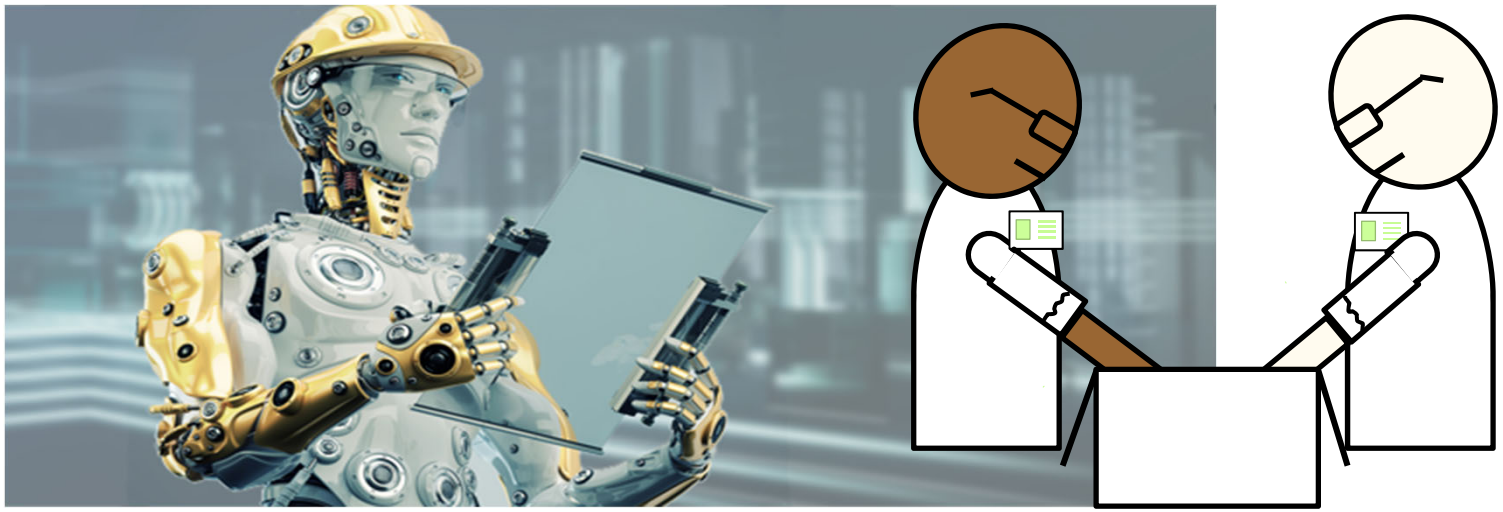


- **Trusting autonomy means trusting sensors, software, and actuators**
- **With only sensor and software output**
  - Only the end response can be adjudicated
  - Requires significantly more testing to achieve **trust** in a system
- **With insight of sensor and actuator performance and hooks into software processing**
  - **Trust** of the system comes more quickly and more affordably.

An old, but seldom used idea that now *must* be implemented…

Autonomy Test Methodology

Robots must be part of the Test Team



Automated robustness testing uses AI to cut through the endless numbers of potential tests, and **prioritizes tests that are most likely to find bugs.**

One of the new ways to T&E…

Using new T&E approaches…

AUTONOMY TESTING IS POSSIBLE

Innovate the Product…Innovate the Testing… Improve the Process…Improve the Product