UNMANNED AND AUTONOMOUS SYSTEM TEST ROADMAP

Bio Background

Confidence in Unmanned & Autonomous Systems

- Thomas Tenorio is a Subject Matter Expert supporting the Roadmap effort for Unmanned and Autonomous Systems Test. He is the currently President of the INCOSE Enchantment Chapter. He has over 25 years experience in Test and Evaluation at White Sands Missile Range and the High Energy Systems Test Facility. He is currently employed by NCI as a Principal Systems Analyst supporting the Systems Engineering Directorate. Technical support areas include Unmanned and Autonomous Systems, real-time target control systems, decision architecture development, and enterprise software. His work with Department of Defense contractors also includes ICE Inc., Rhino, Northrop, ATA, Lockheed, and BDM. He has a MS in Computer Science from NMSU and a BBA in Information Technology and Accounting from ENMU.
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Caution Work In Progress

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DISCLAIMER: This presentation provides an overview of a Work In Progress initiative to create a Unmanned and Autonomous Systems Test (UAST) Roadmap. The research attempts to build on the forecasts and conclusions of the FY09 DoD Unmanned Systems Integrated Roadmap (USIR) to create an investment framework for Science & Technology investments in UAST. It is a collection of knowledge claims and findings gathered over the past year. It does not represent the official position of the Test Resource Management Center (TRMC), NCI, any other corporation, or any agency of the U.S. Government. A UAST Roadmap will only be released once it goes through a formal vetting process by TRMC that has yet to be determined.

Unmanned & Autonomous Systems Test

Science & Technology

The Autonomy Challenge

Latest Defense Science Board Study

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THE UNDER SECRETARY OF DEFENSE

3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

MAR 29 2010

ACQUISITION,
TECHNOLOGY
AND LOGISTICS

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference - Defense Science Board Task Force on the Role of Autonomy in Department of Defense (DoD) Systems

Dramatic progress in supporting technologies suggests that unprecedented, perhaps unimagined, degrees of autonomy can be introduced into current and future military systems. This could presage dramatic changes in military capability and force composition comparable to the introduction of "Net-Centricity." It is important that DoD understand and prepare to take maximum practical advantage of advances in this area. The timing is especially important as we introduce significant numbers of unmanned systems into the force and perhaps limit their capability by imposing restraints associated with manned concepts upon the capabilities of new systems.

http://www.acq.osd.mil/dsb/tors/TOR-2010-03-29-Autonomy_in_DoD_Systems.pdf

UAST Roadmap 1

A reference document for an emergent challenge

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Vision

T&E to increase confidence in the use of UAS that are effective, suitable, survivable, and safe

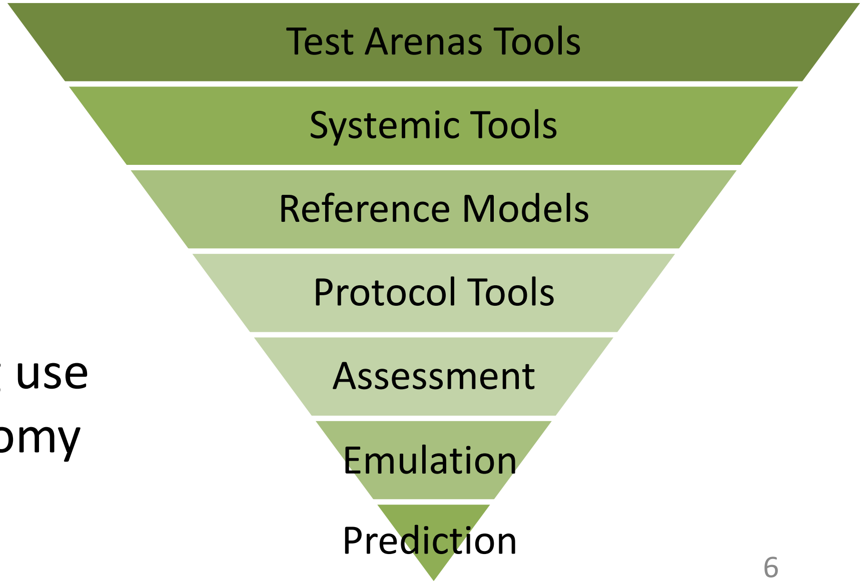
Definition

UAST RM 1 isn't:

- a comprehensive multi-year study of a slowly evolving problem
- a set of predictions based on clearly understood autonomy test methodologies

UAST RM 1 is:

- a discovery framework leveraging emerging use cases and predictions for UAS driving autonomy
- a description of key enabling technologies



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UAST Roadmap 1

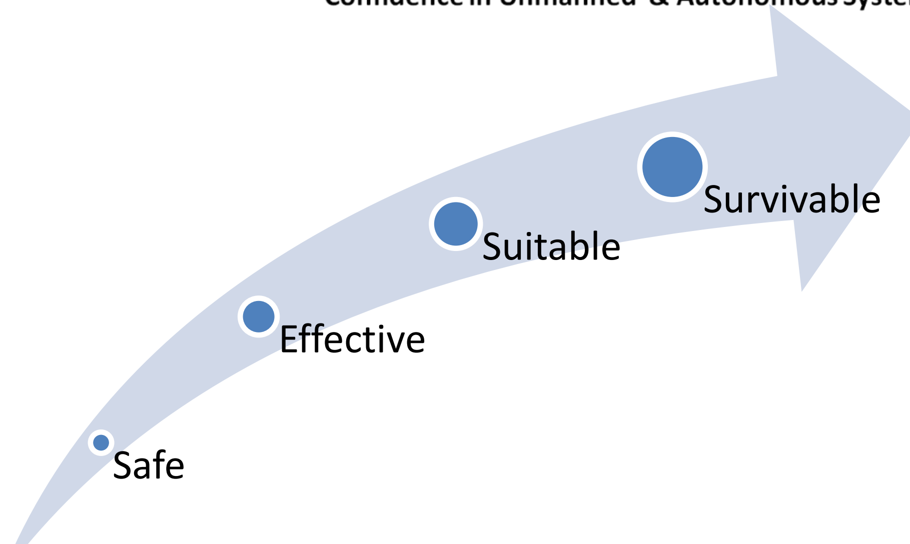
Drivers of T&E for UAS

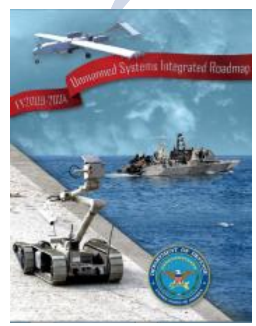
Warfighter Need

- Effectiveness of UAS in chosen mission
- Suitability of UAS for mission success
- Survivability of UAS in mission
- Safety criterion of UAS in mission

Test and Evaluation Need

- Science & Technology to support UAST technology development
- UASTs that address increasing levels of automation and appropriate levels of autonomy
- UASTs that expedite transition of UAS to Warfighter
- Agile UAST deployment





Drivers of Test & Evaluation Current FY2009 – 2034 Unmanned Systems Integrated Roadmap

Goal 5. Foster the development and practice of policies, standards, and procedures that enable safe and effective operations between manned and unmanned systems.

Goal 6. Implement standardized and protected positive control measures for unmanned systems and their associated armament.

Goal 7. Ensure test capabilities support the fielding of unmanned systems that are effective, suitable, and survivable.

UAST Roadmap 1

A challenging exercise

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The actors

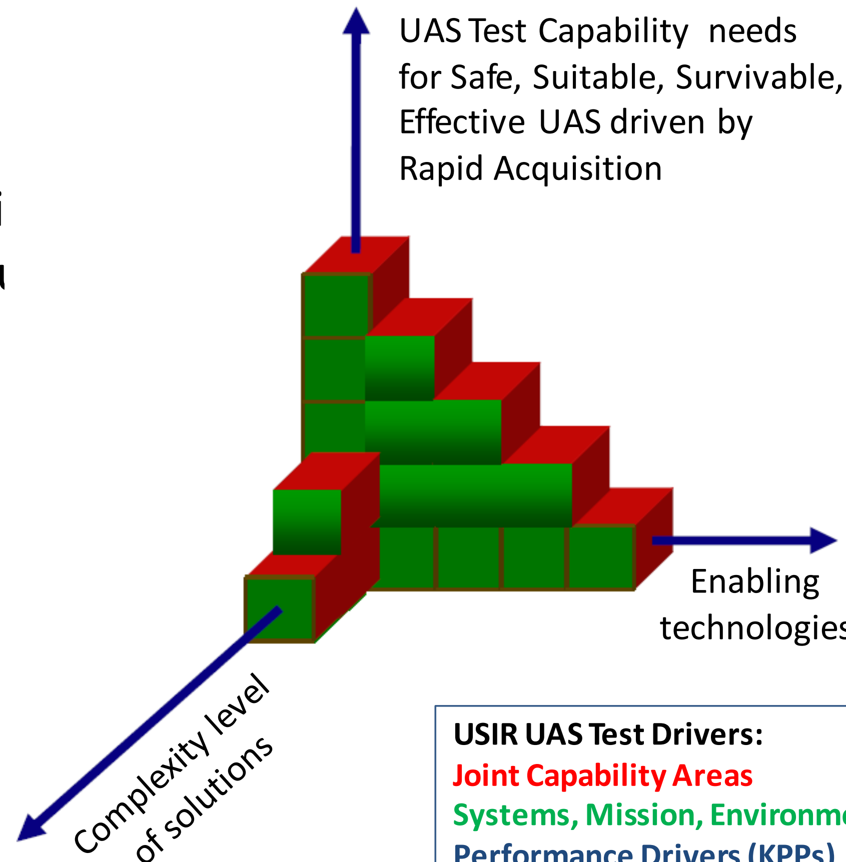
- T&E Capability Developers requiring
- risk mitigation solutions for advanced tech development
- challenged by need for safe, suitable, survi effective UAS for Warfighter thru DoD Acqu

Schedule

- From January 2010 to September 2010
- Draft presentation: April 2010

The process

- Revisit FY2009 Unmanned System Integrated Roadmap for UAS performance and technology forecasts driving autonomy and safety



USIR UAS Test Drivers:
Joint Capability Areas
Systems, Mission, Environment
Performance Drivers (KPPs)
Technology Drivers (KSAs)

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UAST Domains

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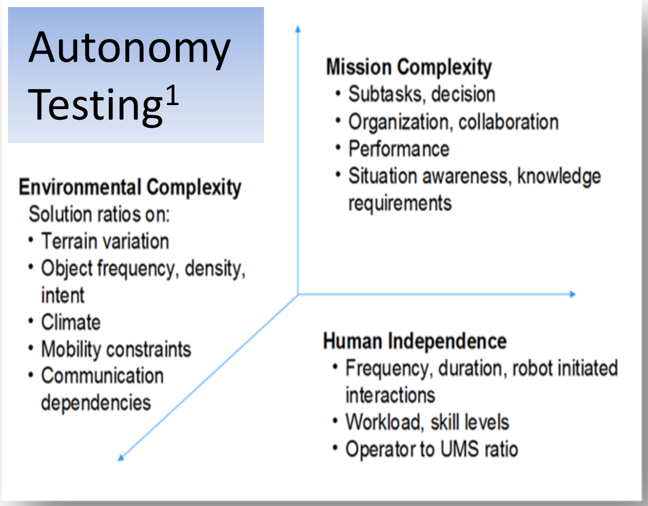
Unmanned and Autonomous Systems Test

- 5 Physical Domains: Space, Air, Ground, Maritime Surface, Maritime Underwater
- Moving beyond tele-operations to increased automation and autonomy
- From single to team to collaborative



1 http://www.isd.mel.nist.gov/projects/autonomy_levels/

Mission and Environment Test

- Mission Complexity drivers for autonomy
- Environment Complexity drivers for autonomy

Test Driven by Joint Capability Areas

- T&E will assess whether new or modified systems deliver their intended capability within the applicable functional capabilities area supporting realistic test environments, including joint mission and joint test environments, to assess an individual system's contribution to joint mission capability.[2]

2 Defense Acquisition Guidebook9.1.2. Relationship of the Joint Capabilities Integration and Development System (JCIDS) to Test and Evaluation (T&E)

Why a UAST Roadmap?

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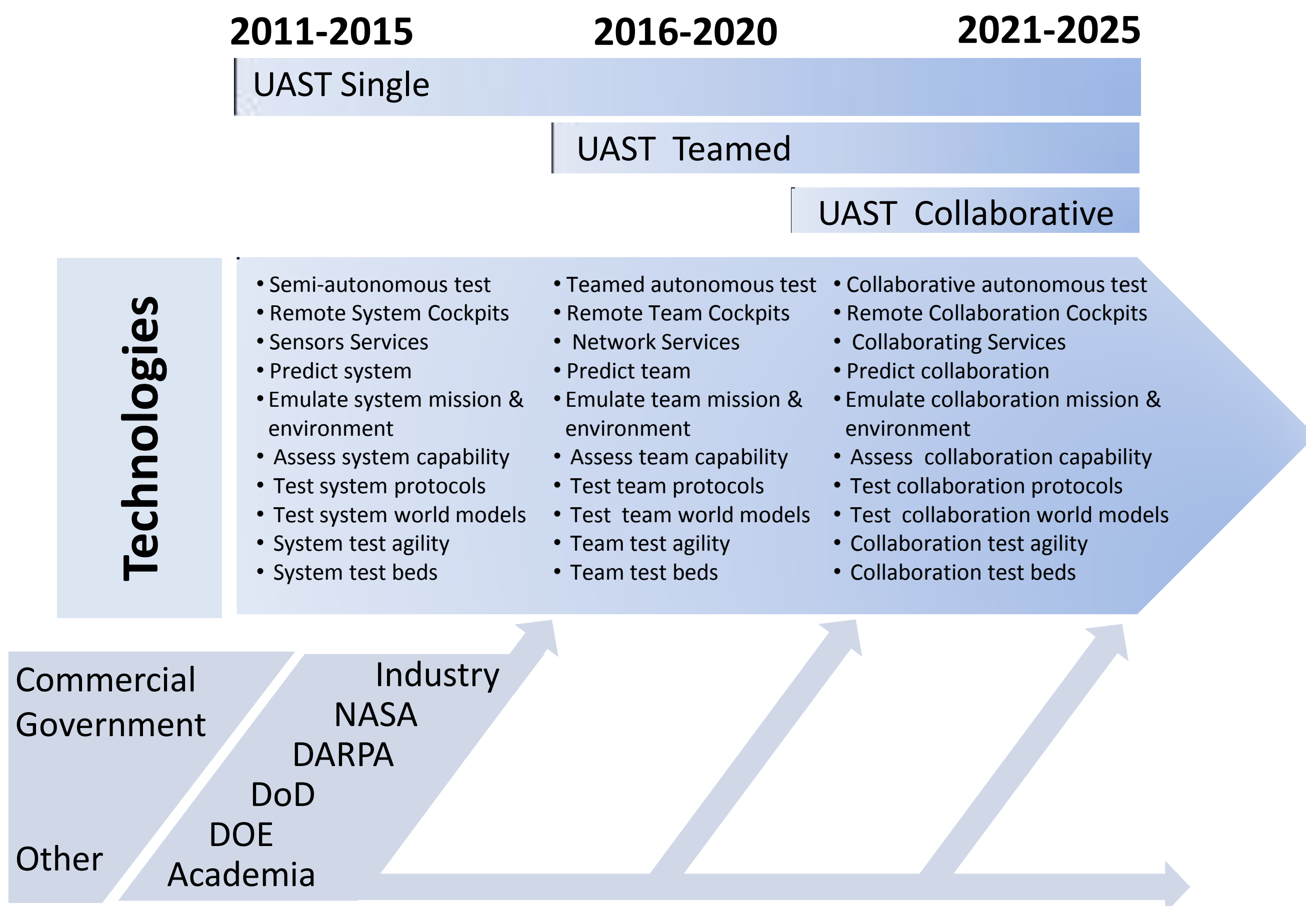
- A CONSENSUS ON UAST PROBLEM
- A CONSENSUS ON UAST FORECAST
- A CONSENSUS ON UAST INVESTMENT FRAMEWORK



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A CONSENSUS ON UAST PROBLEM

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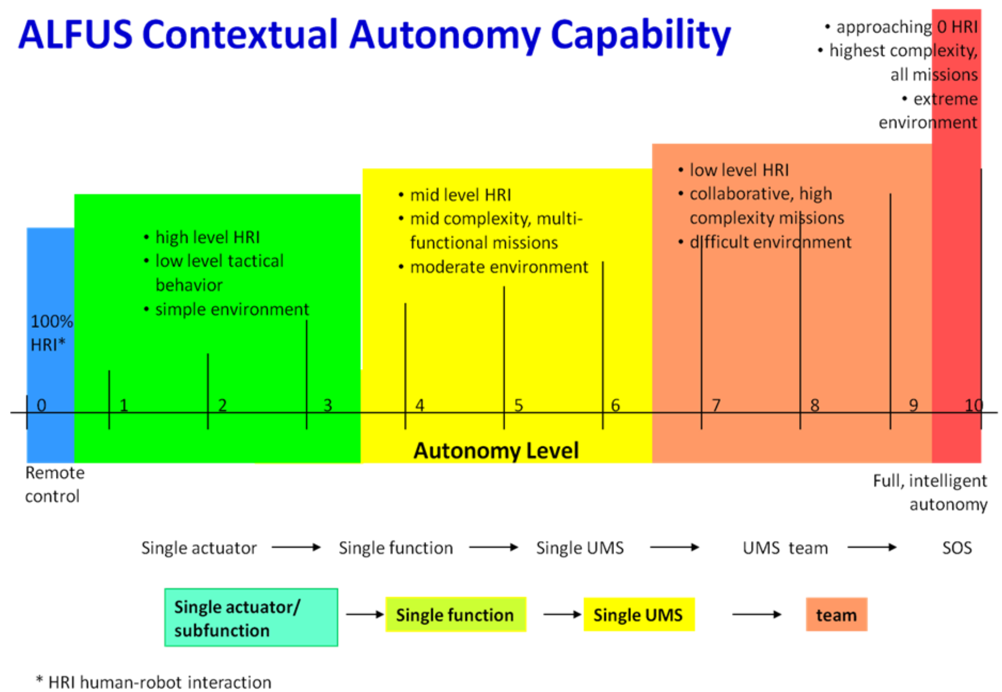
1) EXECUTIVE SUMMARY
2) The Challenge Ahead: The Testing of Autonomy
3) T&E Alignment with USIR
4) The USIR Programs of Record
5) The USIR Non-Programs of Record
6) The USIR Technology Forecasts
7) The UAST Investment Framework
8) USIR Performance Envelope & Technology Category Forecasts
9) USIR and UAST Technology Group Use Cases



Epoch I: Single System UAS Test
- Single system Semi-autonomy
- Simple Environment
- Simple Mission

Epoch II: Teamed UAS Test
- Teamed Semi-autonomy
- Moderate Environment
- Mid-complexity Mission

Epoch III: Collaborating UAS Test
- Collaborative autonomy
- Complex Environment
- Complex Mission

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CH 1 - EXECUTIVE SUMMARY

Confidence in Unmanned & Autonomous Systems

UAST Goal 1. ANSWER THE CALL: UAST for Effective, Suitable, and Survivable UAS

UAST Goal 2. Support UAST challenges of automation and autonomy, Expanding autonomous behavior

UAST Goal 3. Improve UAST for Effectiveness, leveraging of Universal Joint Task List (UJTL) & Joint Urgent Operational Need Statements (JUONS) for T&E implications

UAST Goal 4. Expedite UAST relevance for rapid pace and tempo of UAS deployment, Level of investment in UAST as risk reduction mechanism, R&D dove-tailing into UAST

UAST Goal 5. Address Interoperability challenge of increasing autonomy at all component and subsystem levels, UAST based on common interfaces

UAST Goal 6. Foster UAST for Safety, Sense and Avoid challenge, T&E role in Safety Verification and Range Safety

UAST Goal 7. Exploit Evolving UAS Standards and Architecture for Early-Onset and Model-based T&E and E-Stops for Safety and positive control assessment

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CH 2 - The Challenge Ahead: The Testing of Autonomy, the Contrast between Manned and Unmanned

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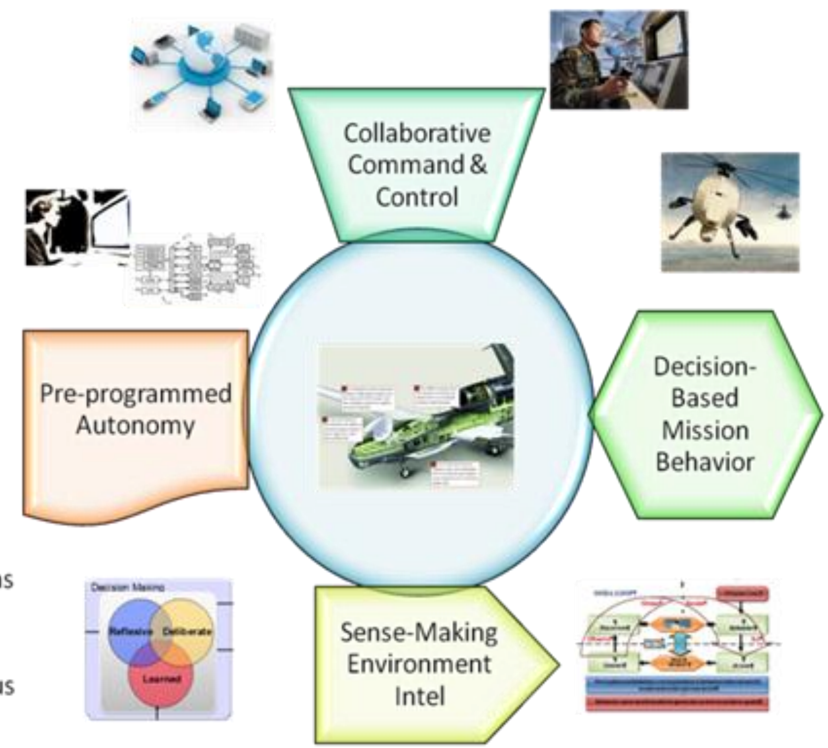
- The T&E of Manned Systems is Different from Unmanned
- Collaborative Command and Control – Remote cockpits and teaming
- Autonomy for Mission Complexity
- Autonomy for Environmental Complexity
- Human Independent Operations

Manned Systems:

- On-board Intelligence
- On-board Mission & Environment Decision Dynamics
- Onboard Assessment of Mission and Effects

Unmanned Systems:

- Shift to Off-board Operations and Programmed On-Board Behavior Creating Unprecedented Autonomous Capabilities and Effects



- Identify systemic barriers to fully realizing the potential of autonomous systems including failures of imagination and constraints of current doctrine, self-imposed handicaps imposed by applying manned concepts to new systems, lack of an informed, motivated industrial base, and DoD's current acquisition processes.[1]

1. Defense Science Board Task Force Study: 2010-03-29, "Role of Autonomy in Department of Defense (DOD) Systems"

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CH 3 - T&E Alignment with USIR Goals

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FY2010-2015 Unmanned and Autonomous Systems Test Roadmap	FY2009-2034 Unmanned System Integrated Roadmap (USIR)
Goal 1. ANSWER THE CALL: UAST for Effective, Suitable, and Survivable UAS	USIR Goal 7. Ensure test capabilities support the fielding of unmanned systems that are effective, suitable, and survivable
Goal 2. Support UAST challenges of automation and autonomy, Expanding autonomous behavior	USIR Goal 2. Support research and development activities to increase the level of automation in unmanned systems leading to appropriate levels of autonomy, as determined by the Warfighter for each specific platform
Goal 3. Improve UAST for Effectiveness, leveraging of Joint Capability Areas, Universal Joint Task List (UJTL), & Joint Urgent Operational Need Statements (JUONS) for T&E implications	USIR Goal 1. Improve the effectiveness of COCOM and partner nations through improved integration and Joint Services collaboration of unmanned systems
Goal 4. Expedite UAST relevance for rapid pace and tempo of UAS deployment, Level of investment in UAST as risk reduction mechanism, R&D dove-tailing into UAST	USIR Goal 3. Expedite the transition of unmanned systems technologies from research and development activities into the hands of the Warfighter
Goal 5. Address Interoperability challenge of increasing autonomy at all component and subsystem levels, UAST based on common interfaces	USIR Goal 4. Achieve greater interoperability among system controls, communications, data products, data links, and payloads/mission equipment packages on unmanned systems, including TPED (Tasking, Processing, Exploitation, and Dissemination)
Goal 6. Foster UAST for Safety, Sense and Avoid challenge, T&E role in Safety Verification and Range Safety	USIR Goal 5. Foster the development and practice of policies, standards, and procedures that enable safe and effective operations between manned and unmanned systems
Goal 7. Exploit Evolving UAS Standards and Architecture for Early-Onset and Model-based T&E and E-Stops for Safety and positive control assessment -- measures for unmanned systems and their associated armament. Adopt a standard unmanned systems architecture and associated standards for unmanned systems capable of weapons carriage	USIR Goal 6. Implement standardized and protected positive control for unmanned systems and their associated armament.
Goal 8. Enhance UAST to evaluate the achievement of supportability goals, the adequacy of the support package for the system, logistics supportability	USIR Goal 8. Enhance the current logistical support process for unmanned systems

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CH 3 - T&E Alignment with USIR Findings and Forecasts

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USIR FRAMEWORK	UAST LEVERAGING OF FINDINGS AND FORECAST
9 Joint Capability Areas	The JCAs driving Mission requiring UAS autonomy for 311 named systems
27 Programs of Record	Test and Evaluation for Safe, Effective, Suitable, Survivable UAS
111 Non-Programs of Record	Future Challenges for Next Generation UAS and Rapid Acquisition T&E
68 Technologies	Technology Forecasts of UAS Key System Attributes (KSAs) affecting Autonomy
29 Performance Envelopes	3 Epoch Forecasts of UAS Key Performance Parameters (KPPs) driving Autonomy
17 Technology Categories	3 Epoch Forecasts of UAS Key System Attributes (KSAs) driving Autonomy
UAST Use Cases for 3 EPOCHS	Test Scenarios of UAS across spectrum of single system, teamed, and collaborative Autonomy
S&T for T&E of UAS for 3 Epochs	S&T for UAST across spectrum of single system, teamed, and collaborative Autonomy

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CH 4 - The USIR Programs of Record (POR)

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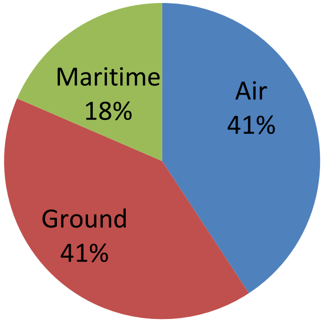
27 PORs in Epoch I Era
RTD&E window for 16



Joint Capability Areas driving Mission

1. Force Application
2. Command and Control
3. Battlespace Awareness
4. Net-Centric
5. Building Partnerships
6. Protection
7. Logistics
8. Force Support
9. Corporate Management and Support

Epoch I: Single System UAS Test (2010-2014)	Epoch II: Teamed UAS Test (2015-2019)	Epoch III: Collaborating UAS Test (2020-2025)
Single system Semi-autonomy	Teamed Semi-autonomy	Collaborative autonomy
Simple Environment	Moderate Environment	Complex Environment
Simple Mission	Mid-complexity Mission	Complex Mission

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CH 4 - The USIR Programs of Record - 11 Air Systems

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Windows of T&E Opportunity: RDT&E Epoch I (6), RDT&E Epoch II (1)*

System Name	POR / NPOR	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	Corporate Management & Support	Description	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
Broad Area Maritime Surveillance Unmanned UAS (BAMS UAS)	POR	X				X	X		X		Navy variant of the Block 20 RQ-4B Global Hawk with specific capabilities developed for the persistent maritime and littoral ISR mission.	Current			
MQ-1C Extended Range/Multi-purpose (ER/MP)	POR	X	X	X							The MQ-1C ER/MP UAS will provide Division Commanders with a much improved real-time responsive capability to conduct long-dwell, wide-area reconnaissance, surveillance, target acquisition, communications relay, and attack	Current			
Micro Air Vehicle (MAV), Battlefield Air Targeting Micro Air Vehicle (BATMAV) – WASP III	POR	X	X								Provides the ground Soldier with Reconnaissance and Surveillance and Target acquisition (RSTA). Uses autonomous and manual flight to provide dedicated reconnaissance support and early warning to the platoon and company	Current			
Vertical Take-off and Landing Tactical Unmanned Air Vehicle (VTUAV MQ-8 Fire Scout)	POR	X	X	X		X	X				Used afloat and ashore by United States Navy (USN) units to provide local commanders real-time imagery and data to support Intelligence, Surveillance, and Reconnaissance (ISR) requirements.	Near			
RQ-4 Global Hawk	POR	X				X	X		X		High-altitude, long-endurance unmanned aircraft designed to provide wide area coverage of up to 40,000 nm2 per day.	Near			
MQ-1 Predator	POR	X	X	X							Provide Division Commanders with a much improved real-time responsive capability to conduct long-dwell, wide-area reconnaissance, surveillance, target acquisition, communications relay, and attack missions.	Near			
WARRIOR A/I-GNAT	POR	X	X	X							Slightly larger than the Gnat 750, has external hard points, an unencrypted air-to-air data link ability and updated avionics.	Near			
MQ-9 Reaper	POR	X	X						X		Medium- to high-altitude, long-endurance UAS. Primary mission is to act as a persistent hunter-killer for critical timesensitive targets and secondarily to act as an intelligence collection asset.	Near			
Class I UAS XM-156	POR	X					X				Provides the ground Soldier with Reconnaissance and Surveillance and Target acquisition (RSTA). Uses autonomous flight and navigation, laser designation, and operates on the FCS network.	Near			
Small Unmanned Aircraft System (SUAS) (Raven)	POR	X				X					Develop a digital data link with swappable modules to change frequencies (16 channels (L-Band)/15 channels (S-Band)) with 15 Km+ range. Provide air-to-air relay capability between SUAS with adaptive transmit power	Near			
RQ-11 Pathfinder Raven	POR										The Raven was developed in 2002 from the Flashlight SUAS and Pathfinder ACTD. In 2004, the Army introduced the RQ-11A Pathfinder Raven as an interim solution to an urgent need for unprecedented situational awareness and	Near			

Joint Capability Areas

T&E Support Windows	
T&E Technology Development Window	
T&E Support Windown Unspecified in USIR	
System in Production	

Test Window

UAST Roadmap 1

CH 4 - The USIR Programs of Record - 11
Ground Systems

Confidence in Unmanned & Autonomous Systems

System Name	POR / NPOR	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	porate Management & Support	Description	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
Windows of T&E Opportunity: RDT&E Epoch I (5)															
Small Unmanned Ground Vehicle (SUGV)	POR	X	X			X	X				Small robotic vehicle that assists the Soldier with reconnaissance while aiding the understanding and visualization of the tactical picture.	Current			
MK 3 MOD 0 RONS	POR	X		X					X		Complements/augment the EOD technician when performing reconnaissance, access, render safe, pick-up and carry away, and disposal during extremely hazardous missions involving UXOs and IEDs.	Current			
MK 1 MOD 0 Robot, EOD	POR	X	X								Complement/augment the military EOD technician performing reconnaissance, disruption, and disposal during extremely hazardous EOD missions involving UXOs and IEDs.	Current			
MK 2 MOD 0 Robot, EOD	POR	X		X							Complement/augment the military EOD technician performing reconnaissance, disruption, and disposal during extremely hazardous EOD missions involving UXOs and IEDs.	Current			
Multi-function Utility/Logistics and Equipment (MULE) ARV Assault Light (ARV-A(L))	POR	X		X	X	X	X	X			Provide unmanned reconnaissance and firepower to destroy armor targets and is equipped with a Medium Range EO/IR sensor and Aided Target recognition capability to identify targets.	Near			
Multi-function Utility/Logistics and Equipment (MULE) Countermine (MULE-C)	POR	X		X	X	X	X	X			The MULE-Countermine will move out front of the Force with the capability to detect, mark and neutralize anti-tank mines.	Near			
Multi-function Utility/Logistics and Equipment (MULE) Transport (MULE-T)	POR	X		X	X	X	X	X			Workhorse designed to carry the equipment of two squads (1900 lbs) during dismounted operations. The platform fulfills several other roles: recharge batteries used by the dismounted soldiers, communications relay and	Near			
MK 4 MOD 0 Robot, EOD	POR	X		X					X		Consists of six UGV's and two operator control stations (OCS). The UGV is teleoperated via an RF link from the OCS and is designed to deliver an explosive counter-charge or other EOD explosive tool to the target area.	Near			
Mobile Detection Assessment Response System (MDARS)	POR	X		X		X					Provides installation commanders an electro-mechanical capability to conduct semi-autonomous random patrols and surveillance activities to include barrier assessment and theft detection functions.	Near			
Anti-Personnel Mine Clearing System, Remote Control (MV-4B)	POR	X		X							Provides a standoff tele-operated AP landmine and obstacle clearing and neutralization force protection capability to support assured mobility, force protection, maneuver and maneuver enhancement objectives.	Near			
CBRN Unmanned Ground Vehicle Advanced	POR	X		X							Integration of chemical and radiological sensors onto an unmanned ground vehicle.	Near			

T&E Support Windows	
T&E Technology Development Window	
T&E Support Windown Unspecified in USIR	
System in Production	

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CH 4 - The USIR Programs of Record - 5 Maritime Systems

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System Name	POR / NPOR	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	Corporate Management & Support	Description	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
Windows of T&E Opportunity: RDT&E Epoch I (4)															
Battlespace Preparation Autonomous Undersea Vehicle (BPAUV)	POR										Allow for autonomous localization, identification and neutralization of undersea mines. The craft will be launched from a host ship, pier or small boat, transit to the minefield, conduct its pre-assigned mission, and return to the	Current			
Surface Mine Countermeasure (SMCM) Unmanned Undersea Vehicle (UUV) Increment 1	POR	X		X					X		The SMCM UUV Increment 1 is a user-operational evaluation system (UOES) employed by the Naval Oceanography Mine Warfare Center (NOMWC) UUV Platoon from MCMs and crafts of opportunity.	Near			
Surface Mine Countermeasure (SMCM) Unmanned Undersea Vehicle (UUV) Increment 2	POR	X		X					X		The SMCM UUV Increment 2 is a UOES employed by the Commander, Naval Meteorology and Oceanography (CNMOC) UUV Platoon from MCMs and crafts of opportunity.	Near			
Littoral Battlespace Sensing - AUV (LBS-AUV)	POR	X									Provide the ability to collect strategic oceanographic data that is required to characterize sound propagation conditions and performance capability of active and passive acoustic sensors and weapon systems in shallow-	Near			
Littoral Battlespace Sensing – Glider (LBS-Glider)	POR	X									The LBS-Glider will enhance the Joint Force Maritime Component Commander's (JFMCC's) awareness of the ocean environment through a wide-area, long-endurance sensing capability that replaces the need for employment of	Near			

T&E Support Windows	
T&E Technology Development Window	
T&E Support Window Unspecified in USIR	
System in Production	

Pre-test Development Opportunity

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CH 5 - The USIR non-Programs of Record (NPOR)

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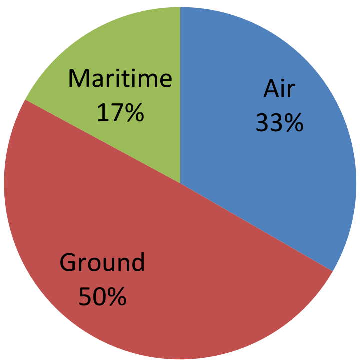
111 NPORs across 3 Epochs
82 NPORs in RTD&E



The Windows of Opportunity for UAS T&E
Air Domain: 28 T&E Windows - RDT&E Epoch I (14), RDT&E Epoch II (5), RDT&E Epoch III (9)
Ground Domain: 39 T&E Windows - RDT&E Epoch I (21), RDT&E Epoch II (10), RDT&E Epoch III (8)
Maritime Domain: 15 T&E Windows - RDT&E Epoch I (9), RDT&E Epoch II (6), RDT&E Epoch III (?)

Epoch I: Single System UAS Test (2010-2014)	Epoch II: Teamed UAS Test (2015-2019)	Epoch III: Collaborating UAS Test (2020-2025)
Single system Semi-autonomy	Teamed Semi-autonomy	Collaborative autonomy
Simple Environment	Moderate Environment	Complex Environment
Simple Mission	Mid-complexity Mission	Complex Mission

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CH 5 - The USIR NPORs - 37 Air Systems

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28 Windows of T&E Opportunity: RDT&E Epoch I (14), RDT&E Epoch II (5), RDT&E Epoch III (9)

System Name	POR / NPOR	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	porate Management & Support	Description	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
MQ-5B Hunter	NPOR	X		X							Equipped with heavy fuel engines (HFE), state of the art avionics, and the capability to carry munitions has proven to	Current			
Special Operations Forces Long Endurance Demonstration (SLED)	NPOR	X									The SLED ACTD will demonstrate military utility and affordability of the A-160 Hummingbird UAS and its ability to	Current			
A160 Hummingbird	NPOR										A160 Hummingbird is a long endurance VTOL UAS using a revolutionary Optimum Speed Rotor (OSR), low drag	Current			
Aerosonde	NPOR										Aerosonde is a long-endurance (38-hour) SUAS. Aerosonde can carry a family of compact payloads including television	Current			
Aqua/Terra Puma	NPOR										The Puma is an evolution of AeroVironment's earlier Pointer hand-launched design and comes in two variants: Aqua Puma	Current			
Buster	NPOR										BUSTER is a SUAS on contract with the Army Night Vision Laboratories, Fort Belvoir, Virginia, which is using BUSTER as	Current			
FINDER	NPOR										A Predator can carry two FINDERS simultaneously, one on each of the two outboard hard points on the Predator's wing,	Current			
Maverick	NPOR										Maverick is an unmanned version of the Robinson R22 helicopter. Frontier modified it in 1999 to serve as a testbed	Current			
Onyx Autonomously Guided Parafoil System	NPOR										Onyx is an autonomously guided parafoil system developed by the Army Natick Soldier Center. Onyx systems are air-	Current			
Combat Medic UAS for Resupply & Evacuation	NPOR	X	X	X	X			X	X		Purpose is to design, develop and demonstrate enabling technologies for delivery of medical supplies and Life Support	Near			
STUAS/Tier II	NPOR	X	X	X	X	X	X				Provide persistent Intelligence, Surveillance, and Reconnaissance (ISR) support for tactical level maneuver	Near			
Unmanned Combat Aircraft System - Demonstration (UCAS-D)	NPOR	X	X	X		X					Demonstration of critical technologies for a carrier suitable, low observable (LO) air vehicle in a relevant environment.	Near			
High Altitude Persistent/Endurance UAS	NPOR	X	X			X	X				Ability to remain on station for a period of months at a time unrefueled. This system with provide the Combatant	Near			
EOD UAS	NPOR	X	X	X							Small (potentially VTOL) UAS for EOD reconnaissance and possible comms relay for EOD UGVs.	Near			
Communications Relay UAS	NPOR	X				X	X				Provide relay for BLOS comm when satellite relay capability is either unavailable or impractical. Remain airborne and on	Near			
Floating Mine Neutralization UAS	NPOR	X	X								Allow for autonomous detection and neutralization of surface, Currentsurface, and floating sea mines. The craft	Near			
Off Board Sensing UAS	NPOR	X	X								Provide fire support for under the weather and threat standoff target positive identification (PID) to increase	Near			
Precision Acquisition and Weaponized System (PAWS)	NPOR	X	X								Provide tactical UAV with limited collateral damage weapon.	Near			
Weaponborne Bomb Damage Information UAS	NPOR	X	X								Deployed from the MOP tail-kit during weapon flight. Preprogrammed via the MOP to fly to specific coordinates	Near			

Legend
T&E Support Windows
T&E Technology Development Window
T&E Support Windown Unspecified in USIR
System in Production

UAST Roadmap 1

CH 5 - The USIR NPORs - 37 Air Systems

COGNITIVE HAZARD
UAST
Confidence in Unmanned & Autonomous Systems

28 Windows of T&E Opportunity: RDT&E Epoch I (14), RDT&E Epoch II (5), RDT&E Epoch III (9)

System Name	POR / NPOR	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	Corporate Management & Support	Description	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
WMD Aerial Collection System (WACS)	NPOR	X	X								Will investigate the integration of chemical and radiological sensors to develop a multi-sensor unmanned aerial collection	Near			
RQ-7 Shadow	NPOR	X		X							Rail-launched via catapult system. Operated via the Army's One System GCS and lands via an automated takeoff and	Near			
Class IV UAS	NPOR	X					X				Brigade level Vertical Take-off and Landing (VTOL) UAV, designed for launch and recovery from unprepared and	Near			
Global Observer	NPOR	X									Addresses the capability gaps identified above with a hydrogen powered high altitude long endurance (HALE) UAS.	Near			
Vehicle Craft Launched Unmanned Aircraft System (VCUAS)	NPOR	X									Carried in a 72" × 30" × 20" case that transforms into a pneumatic launcher, it can be launched from small vessels	Near			
Zephyr High Altitude Long Endurance (HALE) UAS	NPOR	X									A Zephyr HALE UAS with a communications relay payload, orbiting for weeks at a time at 40,000ft+ provides a comms	Near			
Small Armed UAS	NPOR		X								Small <100 lbs attack UAS with precision strike capability that can be employed at LOS/BLOS ranges. Either	Near			
Air Refueling UAS	NPOR				X				X		Tanker UAS system capable of automatically air-refueling Air Force, other Service and coalition aircraft with compatible air	Mid			
Next Generation Bomber UAS	NPOR		X								Medium to heavy attack bomber capable of penetrating heavily defended targets and deliver a broad spectrum of	Mid			
Automated Combat SAR Decoys	NPOR	X	X	X					X		The unmanned systems will be ground mobile and produce a physical and acoustic signatures similar to a human target in	Far			
Automated Combat SAR Recovery	NPOR	X	X	X					X		Employ silent drive technologies, stealthy maneuvering, and high resolution sensors for personnel detection. Carry basic	Far			
High Speed UAS	NPOR	X	X								System capable of rapid deployment at extreme Mach with trans-continental range to reach world-wide within 2-3 hours	Far			
Air-to-Air UAS	NPOR		X								UAS to conduct air-to-air combat operations. UAS can fly into areas the US does not have aerial dominance and engage in	Far			
SEAD/DEAD UAS	NPOR		X								UAS capable of recognizing enemy IADS and missle systems, locating, targeting, attacking and destroying them. Perform	Far			
Airborne Tele-surgery	NPOR							X			Provide the capability to conduct tele-surgery during airborne transport operations using rear area surgeons.	Far			
Precision Air Drop/Firefighting UAS	NPOR				X						Tactical airlift aircraft with autonomous airdrop capability that, if required, can recognize a visual target and self-	Far			
Strategic Airlift UAS	NPOR				X						Extreme heavy-lift Inter/Intra theater airlift able to land and deliver equipment to friendly forces or remove equipment	Far			
Tactical Airlift UAS	NPOR				X						Inter/Intra theater airlift able to land and deliver equipment to friendly forces or remove equipment and personnel from	Far			

Legend
T&E Support Windows
T&E Technology Development Window
T&E Support Windown Unspecified in USIR
System in Production

UAST Roadmap 1

CH 5 - The USIR NPORs – 55 Ground Systems

COGNITIVE HAZARD

UAST

Confidence in Unmanned & Autonomous Systems

39 Windows of T&E Opportunity: RDT&E Epoch I (21), RDT&E Epoch II (10), RDT&E Epoch III (8)

System Name	POR / NPOR	ttlespace Awareness	Force Application	Protection	Logistics	mmand and Control	Net-Centric	Force Support	uilding Partnerships	te Management & Support	Description	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
											an arm with a camera as the head.				
PackBot Explorer	NPOR	×		×		×	×	×	×		Configured for remote reconnaissance and detection, detection of nuclear, biological and chemical weapons	Current			
PackBot FIDO	NPOR	×		×		×	×	×	×		Robotic bomb dog, used for IED detection of vehicle and personnel borne explosives.	Current			
PackBot Scout	NPOR	×		×		×	×	×	×		Configured for remote reconnaissance and detection, detection of nuclear, biological and chemical weapons	Current			
xBot (PackBot Fastac)	NPOR	×		×		×	×	×	×		Designed to fill an operational need for a man-portable, small (less than 50 lbs.), stable reconnaissance platform	Current			
Route Runner	NPOR	×		×		×	×	×			Tele-operated control system to remotely operate a High Mobility Multipurpose Wheeled Vehicle (HMMWV or	Current			
Small Armed UGV Advanced	NPOR		×	×				×			Remote maneuverable unmanned armed vehicle operating on all-terrain, such as mud, sand, rubble-type	Current			
Talon Eng/3B	NPOR	×		×	×						Provides soldiers the ability to visually identify IED from standoff range safe enough so that the operator has a	Current			
Tunnel Reconnaissance UGV	NPOR	×									and short-range reconnaissance missions.	Current			
Assault Breacher Vehicle (ABV)	NPOR										The Marine Corps program Assault Breacher Vehicle (ABV) is a tracked, combat engineer vehicle designed to	Current			
Crusher Unmanned Ground Combat Vehicle	NPOR										The Crusher vehicle was designed and built within the DARPA Tactical Technology Office's (TTO) UPI program	Current			
Omni-Directional Inspection System (ODIS)	NPOR										The Omni-Directional Inspection System (ODIS) is a prototype under-vehicle inspection platform that weighs	Current			
Robotic Combat Casualty Extraction and Evacuation	NPOR										Prototype robotic patient extraction and evacuation system with teleoperation, semi-autonomous, and	Current			
Robo-Trencher	NPOR										The Air Force Robo-Trencher is a fielded, converted Ditch Witch 7610 trencher used by engineering	Current			
Throwbot	NPOR										Throwbot is a small, throwable robot designed for building clearing and short-range reconnaissance missions. It has	Current			
Toughbot	NPOR										Toughbot is a small, throwable robot designed for building clearing and short-range reconnaissance	Current			
Gladiator Tactical Unmanned Ground Vehicle (TUGV)	NPOR										The Marine Corps program Gladiator is an armed, armored combat robot to reduce risk and neutralize	Current			
Contaminated Remains/Casualty Evacuation & Recovery	NPOR	×	×	×	×			×	×		Design, develop and demonstrate a working prototype of a combined UGS/UAS for the recovery of incapacitated,	Near			
Battlefield Casualty ExtractionRobot (BCER)	NPOR	×		×	×	×		×			Robotic casualty extraction system that can negotiate varied terrain with infantry soldiers and ride on other	Near			
Battlefield Extraction-Assist Robot (BEAR)	NPOR	×		×	×	×		×			This highly agile and powerful mobile robot is capable of lifting and carrying a combat casualty from hazardous	Near			
Defender	NPOR	×	×	×	×				×		Augment the base defense force providing patrol, sentry, and alarm response duties as needed within the	Near			
Nuclear Forensics Next Generation UGV	NPOR	×	×	×				×	×		Purpose of this project is to seek advancements in our ability to perform rapid and safe ground sample collection	Near			
Autonomous CASEVAC & Enroute Care System (ACES)	NPOR			×	×			×	×		Robotic patient extraction evacuation and enroute care system with tele-operation, semi-autonomous, and	Near			
Advanced EOD Robot System (AEODRS)	NPOR	×		×					×		Robots in the AEODRS family will be capable of autonomous tactical behaviors that will significantly	Near			
Autonomous Expeditionary Support Platform (AESP)	NPOR		×	×	×						Hybrid diesel electric, self recovery equipped, 48" fording, 120 & 240 VAC & 0-60 VDC power generating UGV	Near			
Combat Engineering & Support Robotic System	NPOR			×	×				×		Provide the capability to conduct airfield construction and repair tasks in a combat environment while minimizing the	Near			
F6A - ANDROS	NPOR	×		×					×		Small-sized (350lbs) EOD robot capable of remotely performing reconnaissance and delivering EOD tools to	Near			
HD-1	NPOR	×		×					×		Incorporates emerging radio technology; extends stand-off range; increased handling capability and ability to	Near			

T&E Support Windows	
T&E Technology Development Window	
T&E Support Windown Unspecified in USIR	
System in Production	

UAST Roadmap 1

CH 5 - The USIR NPORs – 55 Ground Systems

COGNITIVE HAZARD

UAST

Confidence in Unmanned & Autonomous Systems

39 Windows of T&E Opportunity: RDT&E Epoch I (21), RDT&E Epoch II (10), RDT&E Epoch III (8)

System Name	POR / NPOR	espace Awareness	rce Application	Protection	Logistics	mand and Control	Net-Centric	orce Support	ding Partnerships	Management & Support	Description	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
Talon IV	NPOR	×		×	×						Provides soldiers the ability to visually identify IED from standoff range safe enough so that the operator has a	Near			
All Purpose Remote Transport System (ARTS)	NPOR			×				×			Remotely employ an array of tools and attachments to detect, assess, and render safe large IEDs and large-	Near			
Autonomous Targets	NPOR							×		×	Provide a more realistic and effective training and OT&E experience to better prepare the force and evaluate	Near			
CBRN Unmanned Ground Vehicle Advanced Concept Technology Demonstration	NPOR	×		×							Integrated Chemical and radiological sensors onto an unmanned ground vehicle.	Near			
Intelligent Mobile Mine System	NPOR	×	×								Mobile Robotic platform that will support Infantry, Armor and Engineer units with a protective mining mission	Near			
Martitime Interdiction Operations UGV	NPOR	×		×							Develop and demonstrate a marinized, small UGV to support at-sea maritime interdiction operations including	Near			
Mine Area Clearance Equipment (MACE)	NPOR			×	×						The system can clear a mine path 11.5 ft wide. The flail assembly consists of a rotating axle with 72 chains	Near			
Automated Aircraft Refueling	NPOR				×						Increase the efficiency of ground support operations through automation of Automated Aircraft Refueling the	Near			
Automated Cargo Handling/Aircraft Loading	NPOR				×						Provide the capability for automated unmanned cargo handling and aircraft loading to improve the efficiency of	Near			
Covert Tracking/Sensor Robot	NPOR	×									Small UGVs and sensors used to attach and track vehicles covertly. UGVs will be remotely driven (without	Near			
Riverine Operations UGV	NPOR	×									Develop and demonstrate a UGV capable of inspecting river bottoms for possible caches of weapons or other	Near			
SOF Beach Reconnaissance UGV	NPOR	×									Deployed by the SEAL team from underwater, traverse the surf zone to the beach, and provide an initial view of	Near			
Talon EOD	NPOR	×		×							Provides soldiers the ability to visually identify IED from standoff range safe enough so that the operator has a	Near			
Dragon Runner	NPOR										Dragon Runner is a joint development effort between the Marine Corps Warfighting Laboratory (MCWL) and	Near			
Crowd Control System (Non-lethal Gladiator Follow-on)	NPOR		×	×				×			Several uses to include combat missions involving direct fire, scouting missions, crowd control, cordon and search	Mid			
Next Advanced EOD Robot	NPOR	×		×					×		Develop and transition specific technologies to SDD for AEODRS replacement in 2023.	Mid			
Automated Aircraft Decontamination	NPOR			×	×						Provide the capability to conduct equipment and aircraft decontamination in a highly contaminated environment	Mid			
Next Generation Maritime Interdiction Operations UGV	NPOR	×		×							Next gen that will continue to develop and demonstrate a marinized, small UGV to support at-sea maritime	Mid			
Automated Aircraft Inspection	NPOR				×						Provide the capability to conduct automated aircraft inspections of both exterior and interior components.	Mid			
Automated Munitions Handling/Loading	NPOR				×						Provide the capability for automated unmanned munitions handling and aircraft loading to improve the efficiency of	Mid			
Autonomous Convoy	NPOR				×							Mid			
Next Generation Tunnel Reconnaissance UGV	NPOR	×									Next gen tunnel reconnaissance UGV to develop technologies for exploring and mapping tunnel complexes	Mid			
UAS-UGV Teaming	NPOR	×	×	×	×						Identifying and designing cross-domain teams (i.e., use of a UAS to quickly transport a UGV into hostile/difficult	Far			
Next Generation Small Armed UGV	NPOR		×	×				×			Next gen small armed UGV with remote maneuverable unmanned armed vehicle operating on all-terrain, such as	Far			
Automated Bare Base/Shelter Construction UGV	NPOR			×	×						Provide the capability for automated bare base and shelter construction to minimize the time and personnel	Far			
Automated Facilities Services	NPOR			×	×						Provide the capability to conduct routine facilities housekeeping, maintenance, and food service support	Far			
Automated Aircraft Maintenance	NPOR				×						Provide the capability to conduct automated aircraft maintenance. Capability to perform scripted routine and	Far			

T&E Support Windows	
T&E Technology Development Window	
T&E Support Windown Unspecified in USIR	
System in Production	

UAST Roadmap 1

CH 5 - The USIR NPORs – 19 Maritime Systems

Confidence in Unmanned & Autonomous Systems

15 Windows of T&E Opportunity: RDT&E Epoch I (9), RDT&E Epoch II (6), RDT&E Epoch III (?)

System Name	POR / NPOR	tlespace Awareness	Force Application	Protection	Logistics	mmand and Control	Net-Centric	Force Support	ilding Partnerships	e Management & Support	Description	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
SEAFOX USV	NPOR			X							USV designed to support remote, unmanned Intelligence, Surveillance, and Reconnaissance (ISR).	Current			
Defense Acquisition Challenge Program (DACP) – Very Shallow Water (VSW) Neutralization 1st Generation –	NPOR										This effort is intended to field unmanned systems to support the MCM mission at NSCT ONE in order to get	Current			
MK 18 MOD 1 (SWORDFISH) Search-Classify-Map (S-C-M) Unmanned Undersea Vehicle (UUV)	NPOR										This effort is intended to field unmanned systems to support the MCM mission at NSCT ONE in order to get	Current			
Reacquisition-Identification (R-I) Unmanned Undersea Vehicle (UUV)	NPOR										Potentially a variant of the MK 18 MOD 1 (SWORDFISH), the Reacquisition-Identification (R-I) UUV will be modified	Current			
Bottom UUV Localization System (BULS)	NPOR	X	X	X					X		Allow for autonomous localization, identification and neutralization of undersea mines. The craft will be	Near			
Hull UUV Localization System (HULS)	NPOR	X	X	X					X		Allow for autonomous localization, identification and neutralization of limpet mines. The craft will be launched	Near			
Mine Counter Measures USV with Unmanned Surface Influence Sweep System (USV w/US3)	NPOR	X	X	X					X		The MK 18 MOD 1 SWORDFISH is part of the "toolbox approach" to equipping Naval Special Clearance Team	Near			
Next Generation USV with Unmanned Surface Influence	NPOR	X	X	X					X		Allows for semi-autonomous magnetic and acoustic influence sweeping of mines in the shallow and deep	Near			
VSW UUV Search, Classify, Map, Identify, Neutralize (SCMI-N)	NPOR	X	X	X					X		Allow for autonomous localization, identification and neutralization of undersea mines. The craft will be	Near			
Harbor Security USV	NPOR	X	X	X							Medium sized, high speed USV (7m) with thermal/optical/CBRN (Chemical, Biological,	Near			
Next Generation Surface-launched Mine Counter-Measures Unmanned Undersea Vehicle (SMCM UUV)	NPOR	X		X					X		Allows for semi-autonomous undersea mine hunting in the shallow and deep water regime. The system will be able	Near			
Remote Minehunting System (RMS)	NPOR	X	X	X		X					Determines the presence or absence of naval mines to an acceptable level of confidence to enable ships to	Near			
Surface-launched Mine Counter-Measures Unmanned Undersea Vehicle (SMCM UUV)	NPOR	X		X					X		Allows for semi-autonomous undersea mine hunting in the shallow and deep water regime. The system will be able	Near			
Airborne Mine Neutralization System	NPOR		X	X							Ability to rapidly neutralize in-volume, close-tethered and proud bottom mines. Also, the ability for positive	Near			
Amphibious UGV/USV	NPOR	X	X								Development of an amphibious platform to enable water-borne delivery of ground systems, ground delivery of	Near			
Anti-Submarine Warfare USV	NPOR	X									Designed as an common unmmaned surface platform capable of carrying and operating different ASW	Near			
Large Displacement UUV	NPOR	X									Provide the Joint Forces Commander (JFC) with the ability to perform missions beyond the volume and	Near			
Autonomous Undersea Mine Layer	NPOR	X	X						X		Allow for autonomous deployment of undersea mines. The craft will be launched from a host ship (the Littoral	Mid			
Autonomous Undersea Mine Neutralization	NPOR	X		X					X		Allow for autonomous neutralization of undersea mines. The craft will be launched from a host ship (the Littoral	Mid			

T&E Support Windows	
T&E Technology Development Window	
T&E Support Window Unspecified in USIR	
System in Production	

UAST Roadmap 1

CH 6 - Technology Forecasts of UAS Key System Attributes (KSAs) affecting Autonomy

COGNITIVE HAZARD UAST

Confidence in Unmanned & Autonomous Systems

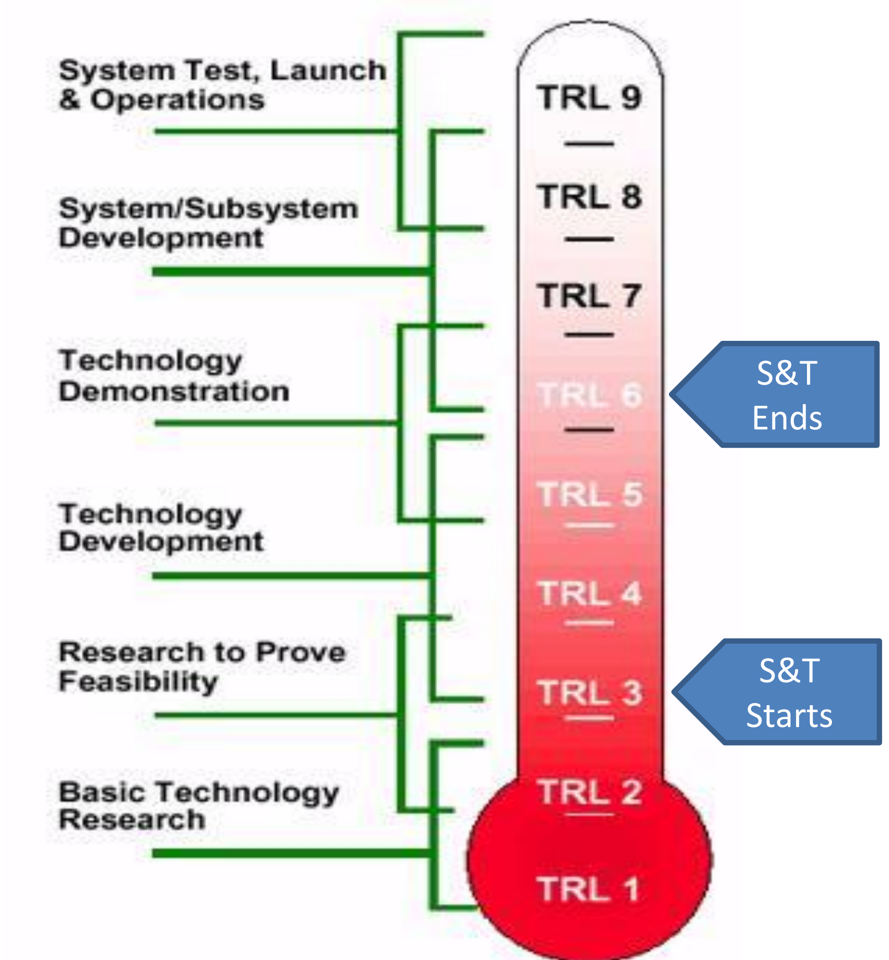
Key System Attributes (KSAs)

The Capability Development Document (CDD) provides the Key Performance Parameters and Key System Attributes that provide a focus for the T&E program.

Technology Readiness Level (TRL)

Technology Readiness Level (TRL) is a measure used by some United States government agencies and many of the world's major companies (and agencies) to assess the maturity of evolving technologies (materials, components, devices, etc.) prior to incorporating that technology into a system or subsystem.

The USIR provided TRL forecasts of key UAS technologies that serve as windows into when new test and evaluation will be required .



UAST Roadmap 1

CH 6 - Technology Forecasts of UAS Key System Attributes (KSAs) affecting Autonomy

Confidence in Unmanned & Autonomous Systems

UAST Investment Areas	POR Technology Drivers
Predicting Unmanned and Autonomous System Behavior	6, 4, 45, 10, 19, 32, 15, 14, 61, 12, 25, 28, 38, 39, 43, 44, 51, 68, 41, 11,30
Emulating Mission and Environmental Complexity	42, 40, 13, 8, 55, 56, 23, 24, 20, 47. 65
Assessing UAS Effects and Capabilities	ALL
Protocols and Design	3, 16, 60, 35, 48, 5, 18, 26, 31, 34, 52, 49, 2
Test Bed and Environment	21, 58, 17, 33
Reference Data and Data Sets (Ground Truth, Decision, & Behavior)	54, 27, IA, IB
Tools and Techniques	46, 9, 29, 36, 37, 62, 63, 64, 7, 22, 53, 67, 59, 66, 50, 57

UAST Roadmap 1

CH 6 - Technology Forecasts of UAS KSAs affecting Autonomy – Assess & Predict

COGNITIVE HAZARD UAST

Confidence in Unmanned & Autonomous Systems

Technology Enablers	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	Corporate Management & Support	Description	Performance Attributes	UAST Capability Framework Area	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
D.4 Artificial Muscle Systems	x		x					x		Develop actuation technologies based conceptually on human muscle that	High actuation forces and speeds; integrated force and strain sensing;	Predict	Current			
D.6 Autonomous Robotic Capability Suite (ARCS)			x		x		x			The Autonomous Robotic Capability Suite (ARCS) program addresses a	Collaborative unmanned systems behaviors; ability to search for, detect	Predict	Current			
D.45 Navigation			x		x		x			The Autonomous Robotic Capability Suite (ARCS) program addresses a	Mission complexity; maneuverability; architecture unlimited; autonomous	Predict	Current			
D.10 Biomimetic Human Detection	x	x								Human detection based on emulation of biological sensors, including visual,	Detection of humans as well as a dog can.	Predict	Current			
D.19 Cooperative Multi-Vehicle Road Network Search	x									This system consists of multiple autonomous UAS that modify their	Teaming within Domain	Predict	Current			
D.32 Intelligent Mobile Grenade			x							The Intelligent Mobile Grenade system will be a Mobile Throwable Robotic	TBD	Predict	Current			
D.15 Collaborative Networked Autonomous Vehicles (CNAV)	x	x			x	x				The Collaborative Networked Autonomous Vehicles (CNAV) program	Mission Endurance in Weeks; Operational Control 1:# within Domain	Predict	Near			
D.14 Chemical Robots (ChemBots)	x	x	x							The Chemical Robots (ChemBots) program is developing soft, flexible,	Adaptive Tactical Behaviors, Expanded Environmental Difficulty, Mission	Predict	Near			
D.61 Sense and Avoid (S&A)	x	x	x							Developing technologies that would support the UAS ability to maintain safe	Maintain safe separation from obstacles both in flight and on the ground	Predict	Near			
D.12 Bird Dog/Warfighter's Associate	x	x								The robot will possess empathy with the human operator, and will be able to take high-level commands from the operator	Environmental awareness; Human detection and tracking	Predict	Near			
D.25 Hierarchical Collaborative Behaviors	x	x								The human commander will be able to control a group of heterogeneous robots	Autonomous mission planning; Natural language interface; Robotic empathy	Predict	Near			
D.28 Human Detection on the Move	x	x								More advanced human detection based on a number of emerging technologies,	Detection from a platform moving at application-appropriate speed.	Predict	Near			
D.38 Man-Portable ISR Robot	x		x							This project will develop enhanced UGV capabilities that specifically support persistent surveillance and reconnaissance applications. Enhancements will include, at a minimum: Power duration of up to 72	Long-range communications.; extended mission endurance; cross-country mobility	Predict	Near			
D.39 Micro Air Vehicle (MAV)	x		x							The Micro Air Vehicle (MAV) Advanced Concept Technology Demonstration	Individual system; Spectrum Constrained RF; Mission endurance in	Predict	Near			
D.43 Multi-modal Human Detection	x	x								Human detection based on the integration and fusion of a number of	Classification of human vs. other anomalies with certain detection and	Predict	Near			
D.44 Nano-Flapping Air Vehicle	x	x								The Nano-Flapping Air Vehicles program will develop flapping air vehicle	Teleoperation; Individual system; Mission endurance in hours; Obstacle	Predict	Near			
D.51 Organic Air Vehicle – II (OAV-II)	x	x								The Organic Air Vehicle – II (OAV II) program developed lift augmented	Individual system; Spectrum Constrained RF; Mission endurance in	Predict	Near			
D.68 Vulture	x				x					The goal of the Vulture program is to develop a high altitude, long endurance	Individual System; Spectrum Independent – Hopping; Mission	Predict	Near			
D.41 Multi Dimensional Mobility Robot (MDMR)	x									The Multi Dimensional Mobility Robot (MDMR) program will investigate using	Individual System; Spectrum Independent – Hopping; Mission	Predict	Near			
D.11 BioRobotics										The BioRobotics (formerly Biodynotics) program will increase the capabilities of	Performance Attributes: Individual System; Spectrum Independent –	Predict	Near			
D.30 Hybrid Bio-mechanical Systems	x	x	x	x			x	x	x	Develop technologies to support hybrid bio-mechanical actuators, manipulators,	OPSEC – Signature Low	Predict	Far			

Joint Capability Areas

S&T Major

S&T Minor

TRL < 3 (EPOCH I)			
TRL < 3 (EPOCH II)			
TRL < 3 (EPOCH III)			
TRL >= 3 (EPOCH I)			
TRL >= 3 (EPOCH II)			
TRL >= 3 (EPOCH III)			
TRL independent (EPOCH I)			
TRL independent (EPOCH II)			
TRL independent (EPOCH III)			

Changing Epochs

UAST Roadmap 1

CH 6 - Technology Forecasts of UAS KSAs affecting Autonomy – Assess & Emulate

COGNITIVE HAZARD UAST

Confidence in Unmanned & Autonomous Systems

Technology Enablers	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	Corporate Management & Support	Description	Performance Attributes	UAST Capability Framework Area	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
D.65 Tactical Amphibious Ground Support System (TAGS)	X	X	X	X						TAGS-CX was developed as a MULE surrogate robotic platform to	Applies to survivability, limited environmental difficulty, and mission	Emulate	Current			
D.42 Multi-mission Modular Unmanned Aircraft System (UAS) Chemical,	X									The Multi-mission Modular Unmanned Aircraft Systems (UAS) Payloads	C. Performance Enabled: Mission Package Product Line Independent;	Emulate	Current			
D.40 Modeling and Simulation	X	X	X	X	X	X	X	X	X	Robotics have rapidly become a disruptive technology within the United	Accurate reflection of specific system concepts and designs from the onset;	Emulate	Near			
D.13 CENTAUR Ground Mobility System	X	X	X	X		X	X			CENTAUR Ground Mobility System is a concept and technology feasibility effort	Initially teleoperation (wireless), but the object systems should be autonomous;	Emulate	Near			
D.47 Nightingale II – Integrated UAS/UGV System	X	X	X	X			X	X		The objective of this research effort is to develop and integrate the requisite	MeMedical Resupply; Casualty Extraction and short-range Evacuation;	Emulate	Near			
D.8 Battlefield Extraction – Assist Robot (BEAR)	X		X	X	X		X			A highly agile and powerful mobile robot capable of lifting and carrying an injured	Lift and carry 300 – 500 lbs.; Safely lift, carry and extract a casualty; Scale stairs	Emulate	Near			
D.55 Robotic Extraction, Evacuation and Enroute Combat Casualty Care			X	X			X	X		This program involves building a prototype robotic patient extraction and	Casualty Extraction and short-range Evacuation, Logistics/Cargo Delivery,	Emulate	Near			
D.56 Robotic Force Health Protection Payloads for Unmanned Ground	X		X				X	X		The objective is to develop modular payload units that can be easily	CBRN standoff detection; neutralization; remediation	Emulate	Near			
D.23 Front End Robotics Enabling Near-Term Demonstration (FREND)	X				X	X				The goal of the Front End Robotics Enabling Near-Term Demonstration	Teaming within domain; Mission Endurance in days; Route Planning;	Emulate	Near			
D.24 Heterogeneous Airborne Reconnaissance Team (HART)	X									The Heterogeneous Airborne Reconnaissance Team (HART)	Operational Control 1:# within Domain	Emulate	Near			
D.20 Covert & Self-concealing Behaviors	X	X	X							Develop technologies to enable robotic systems to autonomously enact covert	Autonomous Adaptive Tactical Behaviors, All-Weather Environmental	Emulate	Mid			

TRL < 3 (EPOCH I)
TRL < 3 (EPOCH II)
TRL < 3 (EPOCH III)
TRL >= 3 (EPOCH I)
TRL >= 3 (EPOCH II)
TRL >= 3 (EPOCH III)
TRL independent (EPOCH I)
TRL independent (EPOCH II)
TRL independent (EPOCH III)

UAST Roadmap 1

CH 6 - Technology Forecasts of UAS KSAs affecting Autonomy – Assess & Protocols

COGNITIVE HAZARD UAST

Confidence in Unmanned & Autonomous Systems

Technology Enablers	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	Corporate Management & Support	Description	Performance Attributes	UAST Capability Framework Area	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
D.16 Communications/Navigation Network Node (CN3)	X					X				Unmanned undersea vehicles (UUVs) can serve as critical communication and	Bandwidth; Teaming Within Domain	Protocol	Current			
D.60 Self-Forming Unmanned Aircraft System (UAS) Communications	X					X				This system consists of a system of UAS that provide the Warfighter(s) in the	Bandwidth; Teaming Within Domain	Protocol	Current			
D.17 Complex Terrain Mobility	X	X	X	X						Develop technologies that would support mobility across complex terrain.	Enhanced maneuverability; efficient voice control: RSTA & survey;	Protocol	Near			
D.35 Ku MiniTCDL for STUAS/Tier II	X	X	X	X						This effort provides additional United States Navy (USN) funds to the current	Lightweight Transceiver; directional antenna efficient in Ku Band	Protocol	Near			
D.48 Non-Radio Frequency (RF) Communications	X	X	X	X						Develop a robust wireless communication system for UGV's that	Robust performance in environments with EMI; Robust LOS and NLOS	Protocol	Near			
D.5 Automatically Deployed Communication Relays	X	X				X				RF relay "bricks" are automatically launched from a moving ground robot	Bandwidth capable of carrying two real-time video channels.	Protocol	Near			
D.18 Constrained Radio Frequency (RF)		X		X					X	For UGVs, develop robust RF system that is resistant to EMI and provide very	Robust performance in environments with EMI. Robust Line of Sight (LOS)	Protocol	Near			
D.26 High Speed Intelligent Networked Communications	X	X				X				Unmanned systems will be networked using the Global Information Grid (GIG).	Flexible frequency hopping; Energy aware/efficient routing	Protocol	Near			
D.31 Intelligent Frequency Selecting Radio Frequency (RF)	X		X					X		Develop and field frequency agile radio systems for UGVs that utilize next	Robust performance in environments with EMI; robust LOS and Non Line of	Protocol	Near			
D.34 Joint Tactical Radio System (JTRS) Networked Communications	X	X				X				Communication networks will be based on the Joint Tactical Radio System	Secure communications.	Protocol	Near			
D.52 Passive Signature Management	X	X	X							Develop technologies that would support a passive RF signature	Ingress and egress undetected or if detected have a very low probability of	Protocol	Near			
D.49 Opportunistic Communications	X	X	X			X				Develop technologies to support unmanned systems communications	Natural Language Understanding; Multi-Frequency Communications;	Protocol	Far			
D.2 Active Signature Management	X	X	X							Develop technologies that would support actively managing RF signature	Ingress and egress undetected from low, medium, and high-threat	Protocol	Far			
D.3 Architecture Proprietary	X	X	X	X	X	X	X	X	X	Continue to develop and refine interface architectures and standards defining the	As a message standard, JAUS does not have a measurable performance.	Protocol	Current			

TRL < 3 (EPOCH I)			
TRL < 3 (EPOCH II)			
TRL < 3 (EPOCH III)			
TRL >= 3 (EPOCH I)			
TRL >= 3 (EPOCH II)			
TRL >= 3 (EPOCH III)			
TRL independent (EPOCH I)			
TRL independent (EPOCH II)			
TRL independent (EPOCH III)			

UAST Roadmap 1

CH 6 - Technology Forecasts of UAS KSAs affecting Autonomy – Assess, Test Beds, & Reference Data

COGNITIVE HAZARD
UAST
Confidence in Unmanned & Autonomous Systems

Technology Enablers	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	Corporate Management & Support	Description	Performance Attributes	UAST Capability Framework Area	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
D.21 Electromechanical / Hydraulic	X	X	X	X	X	X	X	X	X	Develop technologies that would provide ground robotic vehicles with an	Increased lift weight; safe operation of heavy doors at side and front slopes.	Test Bed	Current			
D.58 Safety Response	X	X	X	X	X	X	X	X	X	In March 2006, the Defense Safety Oversight Council Acquisition and	Weaponization safety; software safety; power system safety	Test Bed	Near			
D.33 Joint Convoy Active Safety System (JCASS)			X							The Joint Convoy Active Safety System (JCASS) plans to leverage current S&T	Operator interventions (day & night) 1 per 100 hours; System Operations	Test Bed	Near			
D.54 Real-time High Fidelity World Modeling	X	X								3D world modeling for navigation/mission planning or	Real-time modeling; 1 cm resolution; Accurate color representation	Reference Data	Current			
D.1 3D World Modeling - UAS	X	X								3D world modeling for either navigation/mission planning or	Enough resolution and accuracy to enable autonomous robot navigation or	Reference Data	Near			
D.1 3D World Modeling - UGV	X	X								3D world modeling for either navigation/mission planning or	Enough resolution and accuracy to enable autonomous robot navigation or	Reference Data	Near			
D.27 Highly Representative World Model	X	X	X	X		X	X	X	X	Develop technologies to enable robotic systems to perceive, store, and	Natural Language Understanding; Autonomous Adaptive Tactical	Reference Data	Far			

TRL < 3 (EPOCH I)	
TRL < 3 (EPOCH II)	
TRL < 3 (EPOCH III)	
TRL >= 3 (EPOCH I)	
TRL >= 3 (EPOCH II)	
TRL >= 3 (EPOCH III)	
TRL independent (EPOCH I)	
TRL independent (EPOCH II)	
TRL independent (EPOCH III)	

UAST Roadmap 1

CH 6 - Technology Forecasts of UAS KSAs affecting Autonomy – Assess & Systemic Tools

COGNITIVE HAZARD UAST

Confidence in Unmanned & Autonomous Systems

Technology Enablers	Battlespace Awareness	Force Application	Protection	Logistics	Command and Control	Net-Centric	Force Support	Building Partnerships	Corporate Management & Support	Description	Performance Attributes	UAST Capability Framework Area	Opportunity	Epoch I 2009-2017	Epoch II 2018-2025	Epoch III 2026-2034
D.46 Next Generation Power Resources	x	x	x	x	x	x	x	x	x	Develop technologies that would provide unmanned with the enhanced,	Environmental Difficulty, OPSEC Signature, Mission Endurance,	Systemic Tools	Near			
D.9 Bio-mass Reactor Power	x	x	x				x	x		Develop technologies to support bio-mass reactors to provide electrical	Mission endurance in months	Systemic Tools	Near			
D.29 Human-Like Dexterity	x		x					x		Current EOD UGVs have demonstrated their usefulness in providing remote	Manipulator/end effector dexterity and tactility equal to or greater than that of a	Systemic Tools	Near			
D.36 Local Visualization	x		x					x		Performed as part of JGRE Tactical Behaviors effort, Local Visualization is a	Increased overall situational awareness and visualization capabilities of one or	Systemic Tools	Near			
D.37 Manipulator Dexterity	x		x					x		Development of a manipulator and end effectors that are modular in nature and	Commonality across a family of manipulators; modularity within each	Systemic Tools	Near			
D.62 Sensors to Enable Robust Harsh-Weather Operations	x	x			x					Develop technologies that enable unmanned systems to operate in all	The ability to see and sense in all weather conditions without limiting or	Systemic Tools	Near			
D.63 Stealthy, Persistent, Perch and Stare (SP2S)	x	x			x					DARPA's Stealthy, Persistent, Perch and Stare (SP2S) program is	Teaming within Domain; RF-based; Mission endurance: hours to days ;	Systemic Tools	Near			
D.64 Super Dexterity	x		x					x		Manipulator and end effectors based on polymer muscle technology.	Manipulator/end effector dexterity and tactility much greater than that of a	Systemic Tools	Near			
D.7 Battery Powered - Long Endurance Power Source for Small UGVs		x							x	Develop technologies to advance power and energy densities and integrate	The Performance attributes include limited, expanded, and all weather	Systemic Tools	Near			
D.22 Extreme Weather Capable (Sensors, Electro-mechanical)	x	x								UUV and USV systems must be able to adapt to foul weather, under tropical or	Sensor accuracy, mechanical quieting (minimal acoustic signature), advanced	Systemic Tools	Near			
D.53 Rapid Eye	x							x		The goal of the Rapid Eye program is to develop a high altitude, long endurance	Individual System; Spectrum Constrained RF; Mission Endurance in	Systemic Tools	Near			
D.67 Voice Control	x	x								Voice control teleoperation of a mobile robot, supplementing traditional control	Speech recognition in noisy or windy environments; teleoperation	Systemic Tools	Near			
D.57 Safety Response (Anti-tampering)			x							Develop technologies that would provide scaleable anti-tampering	Man Dependent Situational Awareness, Military Asset Protection and Robotic	Systemic Tools	Near			
D.59 Safety Response (CBRN)			x							Develop technologies that would enable unmanned systems to conduct survey	Characterization of atmospheres; collection of samples; provide sensor	Systemic Tools	Near			
D.66 Vision of the Trauma Pod							x			The vision of the Trauma Pod program is to develop a rapidly deployable	Autonomous mobility; mission endurance in hours; expanded	Systemic Tools	Near			
D.50 Opportunistic Power Grazing	x	x	x	x			x	x		Develop technologies to enable robotic systems to autonomously find and	Autonomous Adaptive Tactical Behaviors; All-Weather Environmental	Systemic Tools	Far			

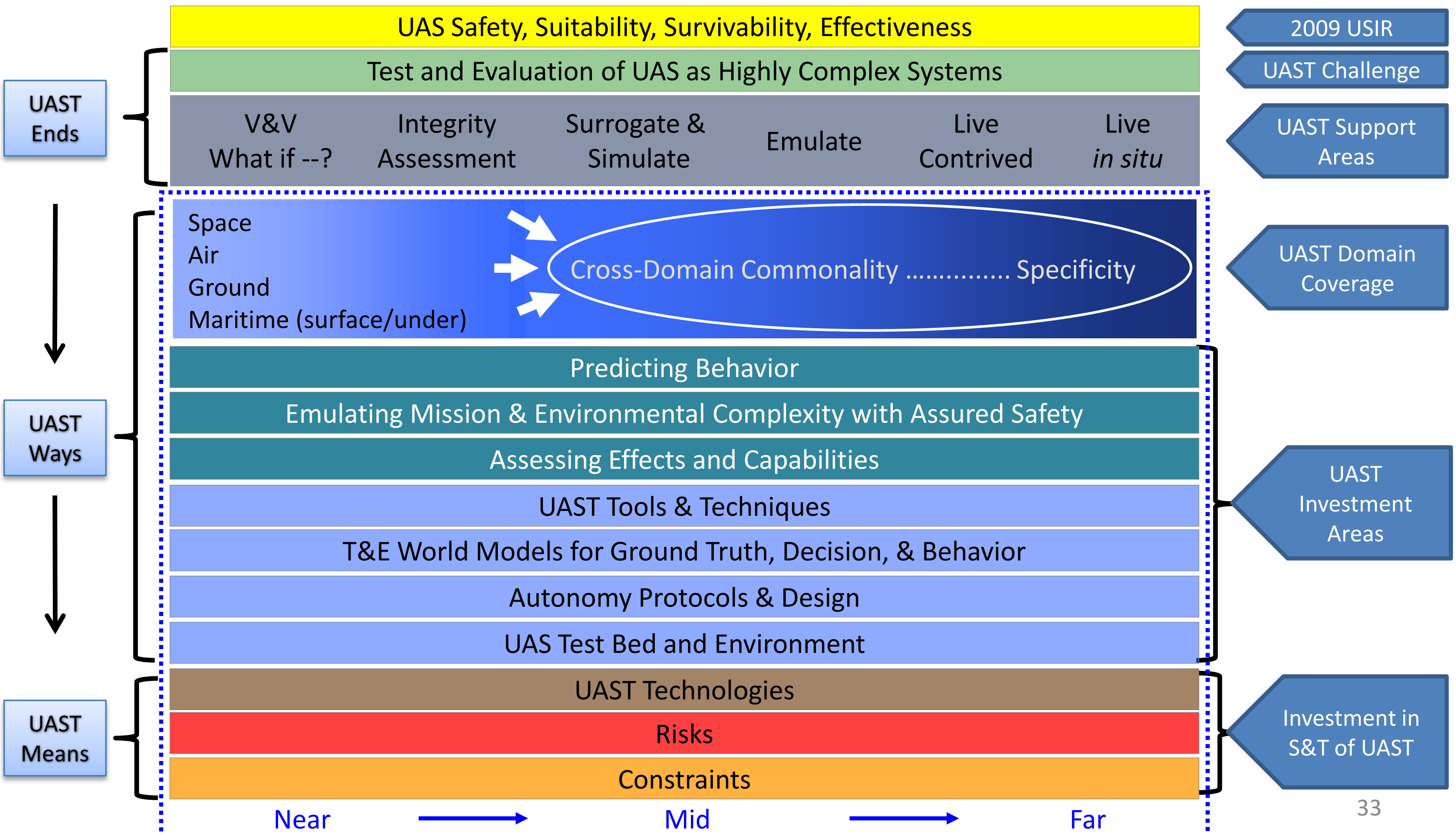
TRL < 3 (EPOCH I)			
TRL < 3 (EPOCH II)			
TRL < 3 (EPOCH III)			
TRL >= 3 (EPOCH I)			
TRL >= 3 (EPOCH II)			
TRL >= 3 (EPOCH III)			
TRL independent (EPOCH I)			
TRL independent (EPOCH II)			
TRL independent (EPOCH III)			

UAST Roadmap 1

CH 7 - The UAST Investment Framework

COGNITIVE HAZARD UAST

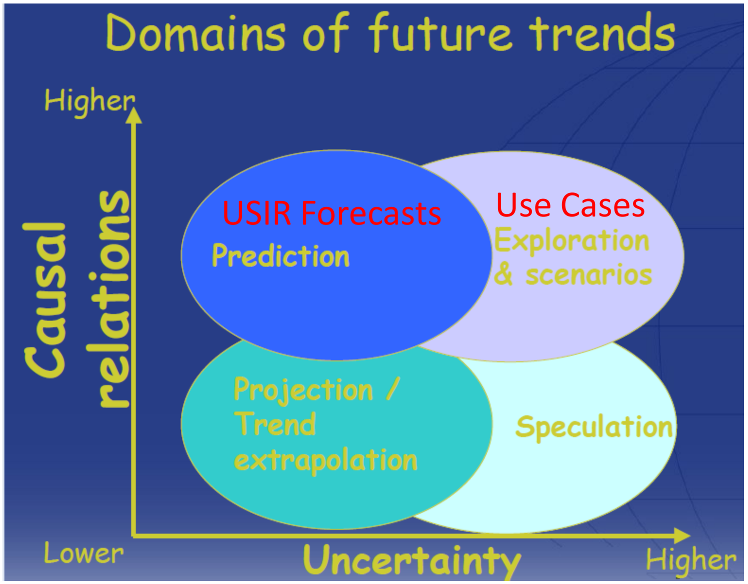
Confidence in Unmanned & Autonomous Systems



UAST Roadmap 1

CH 8 - USIR Performance Envelope & Technology Category Forecasts

Confidence in Unmanned & Autonomous Systems



Defense Science Board Task Force 2010-03-29	[Role of Autonomy in Department of Defense (DOD) Systems]

You are requested to form a Task Force that will inform the Department's plans in this area; specifically, the Task Force should:

- Review relevant technologies and ongoing research and development (R&D) of autonomous systems to evaluate the readiness of autonomous systems, or autonomy improvements, for introduction into DoD.
- Identify and review current plans of the Military Departments for the integration of autonomy in current or near-term systems and employment of next-generation autonomous systems and analyze missed opportunities.
- Assess the personnel training and force structure impacts of various improvements to autonomy, including opportunities, to reduce weapon system and associated personal forward footprint.
- Identify new opportunities for more aggressive application of autonomy to U.S. military materiel and the benefits this might provide to our military posture and the accomplishment of military missions.
- Comment upon the potential value of autonomy to both symmetric and asymmetric adversaries and, where possible, review available intelligence, and provide the basis for net assessment.

T&E for Future Autonomy KPPs

Over time a set of metric classes will be developed that (a) contain the key performance parameters (KPPs) of a UAS, (b) identify the limits of the UAS in the team, and (c) have predictive power.

UAST Roadmap 1

CH 8 - USIR Performance Envelope & Technology Category Forecasts – Prediction Needs

COGNITIVE HAZARD
UAST
Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	S&T Technology Areas (Epoch I) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch II) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch III) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Collaboration	p	1. All	Predicting Unmanned and Autonomous System Behaviors	Single-agent collaboration/cooperation strategies	Teaming w/in Domain, Collaboration Across Domains Multi-agent collaboration/cooperation strategies	Teamed Collaboration
Awareness	p	1. All		Sensor Data. Perception Loops. UAS has to coordinate sensing and motion under the constraints imposed by the task. To	Situational Awareness. multi-agent collaboration/cooperation strategies	Actionable Information
Dependency	p	2. Air		Man Dependent Sense and Avoid / Off Board SA	Sense and Avoid	Fully Autonomous / On Board SA
Maneuverability	p	3. Ground		Simplest Task / Man Dependent SA / Off Board SA	Limited adaptation, Real-time, and Planning Sense and Avoid	Fully Real-Time Planning, Team of Teams Collaboration, Fully Auto / On Board SA
Environment	p	3. Ground		Basic Tasks / Teleoperated. Human in the loop acts as complete supervisor	Human Approves Decisions. UAS can perform some task independent of the human	Fully Autonomous, Approaching Zero Human Interaction
Obstacle Avoidance	p	4. Maritime		Fixed Obstacle Avoidance	Dynamic Obstacle / Threat Avoidance	Target Motion Analysis (TMA) Adaptive Re-planning
Recognition	p	4. Maritime		Object Recognition. High-level object modeling, detection, and recognition, in improved scene understanding, and in	Target Classification	Intelligent Identification
Human Detection	t	1. All		Multi-Modal. multi-modal sensory information (e.g., proprioceptive, tactile, vision); structured spatio-temporal	On The Move	Biomimetic

UAST Roadmap 1

CH 8 - USIR Performance Envelope & Technology Category Forecasts – Emulation Needs

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	S&T Technology Areas (Epoch I) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch II) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch III) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Mission Complexity	p	1. All	Emulating Mission and Environmental Complexity with Assured Safety	Operator Controlled		Autonomous Adaptive Tactical Behaviors
Environmental Capability	p	1. All		Limited Environmental Difficulty	Expanded Environmental Difficulty	All-Weather Environmental Difficulty
Sensor Ranges	p	2. Air		Current. Dynamic range limits on sensor range in perception loops and data fusion	25% Extended	50% Extended
Icing	p	2. Air		Visual Meteorological Conditions - Light, Environmental representation of icing conditions	Moderate	Severe
Turbulence	p	2. Air		Light	Moderate	Severe
Precipitation	p	2. Air		Light	Moderate	Severe
Speed	p	3. Ground		20 mph. UGV will be able to travel up to 20 mph and expected to traverse all types of roads and mild terrain. The	UGV will be able to travel up to 45 mph and expected to traverse all types of roads and moderatly complex terrain.	90 mph
Environmental Capability	t	1. All			Sensors to Enable Robust Weather Flexibility	Extreme Weather Capable
Navigation	t	2. Air		Waypoint Navigation - GPS / INS Dependent	Waypoint Navigation - GPS Independent	Intelligent, Adaptive Navigation - GPS Independent
Obstacle Avoidance	t	2. Air		Sense and Avoid	Dynamic	

UAST Roadmap 1

CH 8 - USIR Performance Envelope & Technology Category Forecasts – Assessment Needs

COGNITIVE HAZARD
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Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	S&T Technology Areas (Epoch I) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch II) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch III) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Mission Endurance	p	1. All	Assessing UAS Effects and Capabilities	Hours	Days Months	Years
Speed	p	2. Air		Subsonic	Transonic	Super / Hypersonic
Stealth	p	2. Air		Signature High		Signature Low
Maneuverability	p	2. Air		1 “G”	9 “G”	40 “G”
Self Protection	p	2. Air		Threat Detection	Threat Jamming and Expendables	
Survivability	p	3. Ground		Basic Teleoperations		Fully Auto w Real Time, Urban Combat, On-Off Road Operations,
Human Robot Interaction	t	1. All		Voice Control	Bird Dog/Warfighter’s Associate	Hierarchical Collaborative Behaviors
Obstacle Avoidance	t	1. All		Sense and Avoid	Dynamic Obstacle Avoidance	
Navigation	t	3. Ground		Tele-Op and Limited Waypoint	Waypoint w/ Obstacle Detection, Limited Visual Odometry	Intelligent Visual Navigation

UAST Roadmap 1

CH 8 - USIR Performance Envelope & Technology Category Forecasts – Protocol and Test Bed Needs

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	S&T Technology Areas (Epoch I) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch II) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch III) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Commands	p	1. All	Autonomous Test Protocols and Design	Physical Human Machine Interfaces	Scripted Voice Command / Hand Signals	Natural Language Understanding
Product Line	p	1. All		Mission Package Product Line Dependent		Product Line Independent Dependent
OPSEC	p	1. All		Signature High		Signature Low
OPSEC	p	4. Maritime		Minimize Detectability (Acoustic / Electromagnetic / Radar / IR)		Stealth Technology
Navigation	p	4. Maritime		GPS / Inertial Navigation		Independent Navigation
Frequency	t	3. Ground		Constrained RF	Frequency Hopping Non-RF Comms	Opportunistic Comms
Frequency	p	1. All	Test Bed and Environments for UAST	Constrained RF	Frequency Hopping	Multi-Frequency Communications
Power	t	1. All		Battery Powered	Next Gen Power Resource	Bio Mass Reactor Powered/ Opportunistic Power Grazing
Signature Management	t	1. All		Passive	Active	Covert and Self Concealing Behaviors

UAST Roadmap 1

CH 8 - USIR Performance Envelope & Technology Category Forecasts – Reference Data and Tool Needs

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	S&T Technology Areas (Epoch I) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch II) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch III) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Operational Control	p	1. All	UAST Reference Data Sets (Ground Truth, Decision, & Behavior)	1 Operator / Platform	1 Operator / Domain	1 Operator / Team
Architecture	t	1. All		Proprietary	Standard	Standard Unlimited
World Model	t	1. All		Simple. Current UAS's can navigate safely and robustly in unstructured 2D environments and perform simple pick	Artificial	High representative
Visualization	t	3. Ground		Local		
Mobility	t	3. Ground		Complex Terrain		
Bandwidth	p	1. All	UAST Tools and Techniques	Limited	Advanced Bandwidth Management	Autonomous Bandwidth
Maintenance	p	1. All		Operator		Automated
Communication	t	1. All		Relays Automatically Deployed. Increased mobility and improved perception, intelligence, and	Seamless cooperation interfaces using gesture, voice, and communication-through-the-task.	High Speed Intelligent Network Comms
Mechanical Systems	t	3. Ground		Electro-Mechanical / Hydraulic Systems	Artificial Muscle Systems	Hybrid Bio-Mechanical Systems
Dexterity	t	3. Ground		Manipulator	Human-Like. biological analogs (e.g., human muscles) are far superior to engineered systems in terms of	Super

UAST Roadmap 1

USIR and UAST Technology Group Use Cases

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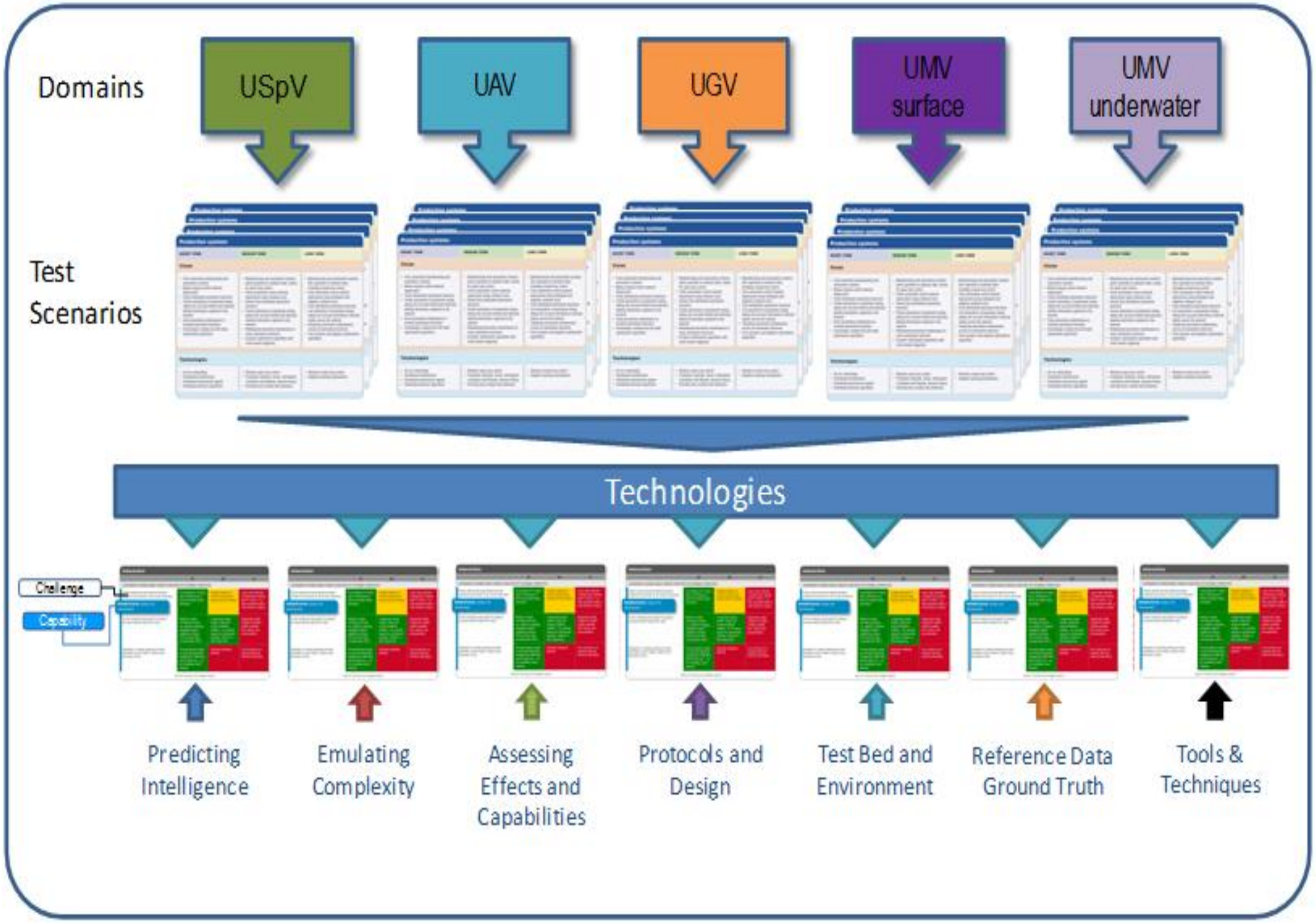
Confidence in Unmanned & Autonomous Systems

Mapping T&E technologies to test scenarios

The fielding of 138 systems identified in the USIR has resulted in a growing pool of test scenarios critical to the fielding of any system. The goal of the UAST technology group is to capture and consolidate test cases into a set of cases that facilitates high value investment for increased confidence in UAS use.



UAST Roadmap 1

USIR and UAST Technology Group Use Cases – Leveraging USIR findings

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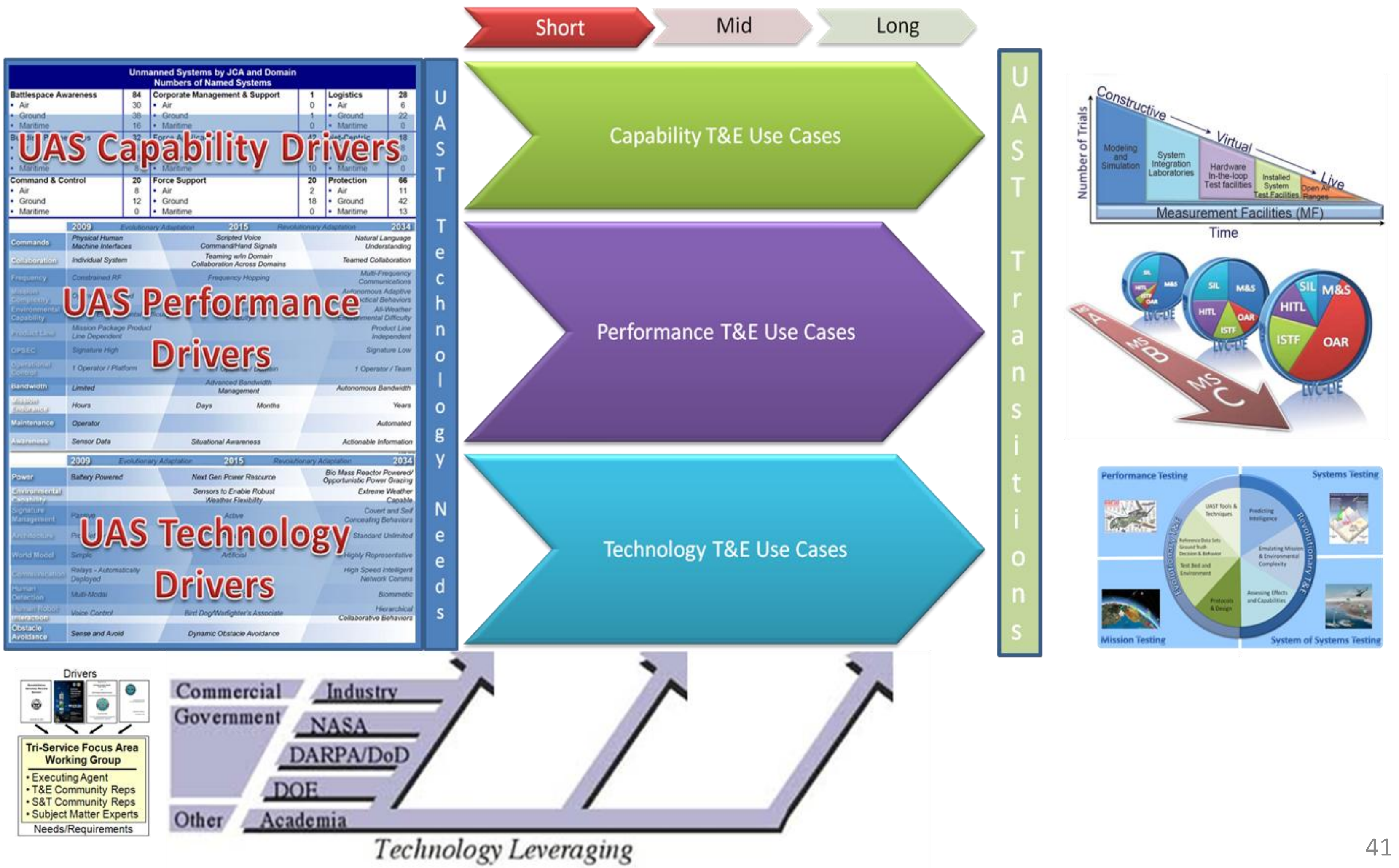

UAST Roadmap 1

USIR and UAST Technology Group Use Cases – Use Cases from T&E Practitioners

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Use Case ID	Type	Domain	UAST Capability Framework	Use Case Label	USIR Performance Technology Driver	Performance / Technology
1	POR	ALL		Monitor Autonomous Processing States	Top Level Use Case	N/A
1		All	Systemic Tools	Self test acuity	Maintenance	Performance
1		Ground	Reference Data	Perception assessment reference data sets	Visualization	Technology
2		ALL		Real time monitoring of the SUT	Top Level Use Case	N/A
2		Air	Predict	Sensory and Communications Resourcing and Management Schema	Dependency	Performance
2		Air	Assess	Maneuver Behavior Context	Maneuverability	Performance
2		Ground	Emulate	Real-time monitoring	Speed	Performance
3		ALL		UAS Collaboraion Evaluation	Top Level Use Case	N/A
3		All	Systemic Tools	Cooperative communication clusters in ad-hoc networks for better connectivity power utilization etc. Integration o	Communication	Technology
4	NPOR	UUV		Underwater communications systems to verify Autonomus status	Top Level Use Case	N/A
5	POR	UGV		Mission Means Framework	Top Level Use Case	N/A
5		All	Emulate	Mission based design of experiments for test development	Mission Complexity	Performance
5		Ground	Assess	Mission means framework and mission based T&E	Survivability	Performance
6	BOTH	ALL		Real time verification of autonomous status/behavior	Top Level Use Case	N/A
6		All	Predict	Autonomous status behavior sensors	Awareness	Performance
7	POR	UUV		Assesment of UAS behavior given the environment and external stimuli	Top Level Use Case	N/A
8		UUS/USV		Autonomous behavior assesment of a UUV inavigation, collaboration and sensing required in order to complete the mission.	Top Level Use Case	N/A
8		All	Protocols	Verification of maritime navigation techniques of controller system interaction	Navigation	Performance
8		Air	Emulate	High Order Data Representation	Icing	Performance
8		Air	Emulate	High Order Data Representation	Turbulence	Performance
8		Air	Emulate	High Order Data Representation	Precipitation	Performance
8		Maritime	Predict	Assessment of UUS / USV	Obstacle Avoidance	Performance
8		Maritime	Predict	High Order Data Representation	Recognition	Performance
8		All	Predict	High Order Data Representation	Human Detection	Technology
9		ALL		Data monitored from the UAS computation status to determine the behavior states of the system.	Top Level Use Case	N/A
9		All	Systemic Tools	Communications would more effectively monitor UAS performance.	Communication	Technology
10	POR	UUV		Lack of data transmission capability in the received data	Top Level Use Case	N/A
10		All	Systemic Tools	Test applications benefit from advances in sensor networks perception software and communications networks.	Communication	Technology
10		All	Systemic Tools	Protocols for sparse highly volatile multi-hop ad-hoc networks with high bandwidth and low latency.	Communication	Technology
11	POR	UAV		Real-time monitoring of the UAS status in a minimally invasive fashion	Top Level Use Case	N/A
11		Air	Assess	Real-time Monitoring of Status	Stealth	Performance
11		Air	Assess	TSPI for sense and avoid compututation	Maneuverability	Performance
11		Ground	Predict	Environmental Models	Environment	Performance
11		Ground	Predict	Target Representation	Environment	Performance
11		Ground	Predict	Monitoring in Environment	Environment	Performance
11		Ground	Predict	Stimulus	Environment	Performance
12	BOTH	ALL		Monitoring the systems behavior under a variety of stimuli including known targets that mimic the given threat.	Top Level Use Case	N/A
12		All	Emulate	Destructable targets	Environmental Capability	Performance
12		Air	Assess	Sensing and signature measurements	Stealth	Performance
12		All	Test Bed	Signature limit testing	Signature Management	Technology
12		Maritime	Protocols	OPSEC signature vulnerability maritime	OPSEC	Performance
12		Air	Assess	UAS countermeasures	Self Protection	Performance
13		ALL		Targets and stimuli in some cases the test environment itself used to drive specific behavrioal outcomes	Top Level Use Case	N/A
13		All	Emulate	Simulated targets	Environmental Capability	Performance
14	POR	UUV		Evaluation of the UAS behavior	Top Level Use Case	N/A
15		ALL		Determination of whether UAS was successful in completing its mission given known (and unknown) stimuli such as the targets presented to the area	Top Level Use Case	N/A
15		All	Protocols	TSPI for human controlled maritime single and multi-system UAS	Navigation	Performance
15		All	Assess	Dynamic limit assessment of Sense and Avoidance	Obstacle Avoidance	Technology
15		Maritime	Predict	Static obstacle sensing	Obstacle Avoidance	Performance
15		Maritime	Predict	World model representation of static objects	Obstacle Avoidance	Performance
15		Maritime	Predict	Ground truth representation comparison assessment	Obstacle Avoidance	Performance
15		Maritime	Predict	Internalized world model	Obstacle Avoidance	Performance
16		ALL		Auto Traffic Deconfliction (Auto collision Avoidance Algorithm)	Top Level Use Case	N/A
16		Air	Predict	Auto traffic deconfliction	Dependency	Performance
16		Ground	Predict	Multi-level Maps and Modeling	Maneuverability	Performance
16		All	Assess	Auto traffic deconfliction	Obstacle Avoidance	Technology
16		Maritime	Predict	Sensor/Sensor processing capabilities such as:TSPI Kinematic Optical Imagery etc. Multi-level Maps and Modeling	Obstacle Avoidance	Performance
16		All	Assess	FAA certification	Obstacle Avoidance	Technology
16		Air	Emulate	Air space deconfliction	Navigation	Technology
17	POR	UAV		Certification of UASs for FAA Certification standards	Top Level Use Case	N/A
18		ALL		Monitior UAS cognitive status	Top Level Use Case	N/A
19		ALL		Communication Link(s) Certification	Top Level Use Case	N/A
19		All	Assess	Long term communication and sensor systems test capability	Mission Endurance	Performance
19		All	Test Bed	Effective spectrum use and allocation ground	Frequency	Performance
19		All	Systemic Tools	Bandwidth measurement and allocation certification	Bandwidth	Performance
19		All	Protocols	Effective spectrum use and allocation ground	Frequency	Technology
20	POR	UAV		Small Lightweight TSPI unit with transmit capability	Top Level Use Case	N/A
21		ALL		Certification of UASs for FAA Certification	Top Level Use Case	N/A
22		ALL		Monitor and test a team of UAS conducting the mission in a difficult littoral environment.	Top Level Use Case	N/A
23	BOTH	ALL		Integrating Cognition and Autonomy Effects	Top Level Use Case	N/A
24	POR	UAV		Autonomous and sometimes being externally controlled handoff testing	Top Level Use Case	N/A
24		All	Predict	Small lightweight TSPI	Awareness	Performance
24		Air	Assess	Tracking technologies	Stealth	Performance
24		Ground	Emulate	Ground based TSPI Small lightweight TSPI	Speed	Performance
25	BOTH	ALL		Kinematic data acquisition system for two- or three-dimensional motion analysis	Top Level Use Case	N/A
25		Air	Assess	Kinematics	Maneuverability	Performance
25		Ground	Systemic Tools	Kinematics data for actuator motion	Mechanical Systems	Technology
25		Ground	Systemic Tools	Kinematics data for actuator motion	Dexterity	Technology
26	POR	UAV		Resource aware systems (sensors and communications	Top Level Use Case	N/A
26		All	Assess	Data mining and management of long duration tests	Mission Endurance	Performance
26		All	Predict	Communications Standards	Collaboration	Performance
26		Air	Assess	Resource Awareness	Speed	Performance
26		All	Systemic Tools	Improvements in localization in UWB networks and better spectrum utilization.	Communication	Technology
26		Ground	Assess	TSPI for human controlled ground single and multi-system UAS	Navigation	Technology
27	POR	UUV		Modeling & Simulation of Cognizant UAV Systems	Top Level Use Case	N/A
27		All	Reference Data	Model representation of cognitive agents	World Model	Technology
28	POR	UAV		RCC 319 Compliant Encoded FTS System	Top Level Use Case	N/A
28		All	Test Bed	Effective spectrum use and allocation ground	Frequency	Performance
28		All	Protocols	Effective spectrum use and allocation ground	Frequency	Technology
29	POR	UAV		A High Altitude Long Endurance (HALE) ISR UAVV downloads gathered sector data to GIG-enabled server as part of its daily operations.	Top Level Use Case	N/A
30	POR	UAV/USV		A Maritime Reconnaissance and Patrol Aircraft captures additional information for part of the HALE sector and uploads to GIG-enabled server.	Top Level Use Case	N/A
31	POR	UAV/USV		Common Ground Station (CGS) operators task a Navy UUV team to monitor a suspicious cargo ship identified by correlating GIG-enabled server data.	Top Level Use Case	N/A
31		All	Protocols	Common ground station for JAUS SAE-AS/4 unmanned manned systems compliance	Commands	Performance
31		All	Reference Data	Common ground station tester robotics and targets	Operational Control	Performance
31		All	Protocols	Common ground station for JAUS SAE-AS/4 unmanned manned systems compliance	Product Line	Performance
31		All	Systemic Tools	Integration of wide-area local-area and personal-area networks for more seamless local-to global coverage heterog	Communication	Technology
32	POR	UAV/USV		The UUV team executes its mission without communication and re-establishes communications with the CGS upon completion.	Top Level Use Case	N/A
33	POR	UAV/USV		A Small Tactical UAS (STUAS) is launched from a Navy surface vessel to monitor the suspicious cargo ship form the air. The STUAS periodically uploads its data to the GIG.	Top Level Use Case	N/A
34	POR	UAV/USV		A command activity is alerted to the presence of an identified vessel of a rogue nation about to delivered illegal cargo into the port of another nation.	Top Level Use Case	N/A
35	POR	UAV/USV		A US navy surface vessel attempts to stop and search the rogue vessel, but is fired upon.	Top Level Use Case	N/A
36	POR	UAV/USV		A Navy strike aircraft is commanded to engage and destroy the target. The strike asset receives supporting data from the GIG.	Top Level Use Case	N/A
37	POR	UAV/USV		UAV autonomous onboard collision avoidance capability	Top Level Use Case	N/A
38	BOTH	ALL		Ground truth assessment compared to UAS world model	Top Level Use Case	N/A
38		All	Predict	Ability to collect/compare situational awareness to ground truth	Collaboration	Performance
38		All	Emulate	Mapping localization and navigation systems rely on two-dimensional representations.	Environmental Capability	Performance
38		All	Predict	Ability to collect/compare situational awareness to ground truth	Awareness	Performance
38		Air	Predict	Ability to collect/compare situational awareness to ground truth	Dependency	Performance
38		Air	Assess	Ability to collect/compare situational awareness to ground truth	Maneuverability	Performance
38		Ground	Reference Data	Representation of ground truth for elementary behavior and decision assessment on ground mobility	Mobility	Technology
38		Ground	Predict	Ability to collect/compare situational awareness to ground truth	Environment	Performance
38		Air	Emulate	Truth data to verify dynamic limits of navigation	Navigation	Technology
38		Maritime	Predict	Ability to collect/compare situational awareness to ground truth	Recognition	Performance
38		Air	Emulate	Dynamic limits of obstacle avoidance for the whole system involving manned and unmanned vehicles	Obstacle Avoidance	Technology
38		All	Predict	Ability to collect/compare situational awareness to ground truth	Human Detection	Technology

UAST Roadmap 1

USIR and UAST Technology Group Use Cases – Use Cases from T&E Practitioners

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Use Case ID	Type	Domain	UAST Capability Framework	Use Case Label	USIR Performance Technology Driver	Performance / Technology
39	NPOR	UGV		Mobile robot navigation internal and external assesment. Common components path planning and obstacle avoidance (may) play a key role.	Top Level Use Case	N/A
39		Ground	Predict	Mobile Robotic Navigation	Maneuverability	Performance
40	BOTH	ALL		Human system interaction and detection of modalities	Top Level Use Case	N/A
40		All	Assess	Human system assessment HRI will only be accepted if they are responsive to the user on a time-scale the user fin	Human Robot Interaction	Performance
41	POR	UAV/USV		The interaction of the ground or surface-based human operators with mission planning systems and GIG component must be tested within the context of Concepts of Operation (CONOPS) development for a particular unmanned	Top Level Use Case	N/A
41		All	Predict	Remote control deconfliction	Collaboration	Performance
41		All	Predict	Human-machine Interaction	Collaboration	Performance
41		All	Assess	Human system assessment HRI will only be accepted if they are responsive to the user on a time-scale the user fin	Human Robot Interaction	Technology
42	BOTH	UGV		Control and Management of Autonomous Mobile Sensors	Top Level Use Case	N/A
42		All	Reference Data	Command and Control of UAS - single team collaborating	Operational Control	Performance
42		All	Test Bed	Control and management of autonomous comms in test environment	Signature Management	Technology
42		Ground	Reference Data	Command and Control of UAS - single team collaborating	Mobility	Technology
42		Maritime	Predict	Human system interaction and detection	Human Detection	Technology
43	BOTH	ALL		Towards a Taxonomy of Performance Metrics, Bounds and Tests for Tracking and SLAM Algorithms	Top Level Use Case	N/A
43		All	Reference Data	JAUS compliance	Architecture	Technology
43		All	Reference Data	STANAG compliance	Architecture	Technology
43		All	Reference Data	Emergent standards compliance	Architecture	Technology
43		All	Reference Data	Taxonomy of Performance Metrics	Architecture	Technology
43		All	Reference Data	Representation of ground truth for elementary behavior and decision assessment	World Model	Technology
43		All	Reference Data	Higher Order Data Representations	World Model	Technology
44	POR	UGV		Modelling Team Coordination in Multi-agent Planning	Top Level Use Case	N/A
44		Air	Emulate	Path planning and obstacle avoidance	Obstacle Avoidance	Technology
45	POR	UAV		The Challenges of Commanding and Controlling Systems Consisting of Autonomous Entities	Top Level Use Case	N/A
46	BOTH	ALL		Human Interaction with Increasingly Autonomous Systems	Top Level Use Case	N/A
46		All	Assess	Human Models for Increasing Autonomous Effects	Human Robot Interaction	Technology
46		All	Assess	Human Models for Increasing Autonomous Effects	Obstacle Avoidance	Technology
47	POR	UGV		Uncertain Terrain Geometry Estimates	Top Level Use Case	N/A
47		All	Assess	Uncertain terrain assessment	Obstacle Avoidance	Technology
48	BOTH	ALL		Higher Order Data Representation	Top Level Use Case	N/A
48		All	Reference Data	Reactive ground truth representation	Operational Control	Performance
48		All	Protocols	High order data representation	Navigation	Performance
48		Ground	Reference Data	Reactive ground truth representation	Mobility	Technology
48		All	Assess	High order data representation	Obstacle Avoidance	Technology
49	BOTH	ALL		Reactive Data Gathering	Top Level Use Case	N/A
49		Air	Predict	Reactive Data Gathering	Dependency	Performance
49		Ground	Predict	Reactive Data Gathering	Maneuverability	Performance
49		All	Predict	Reactive Data Gathering	Human Detection	Technology
50	BOTH	ALL		Measuring Emergence in Cooperative Autonomy	Top Level Use Case	N/A
51	BOTH	ALL		Decision Maker Evaluation Framework	Top Level Use Case	N/A
51		All	Systemic Tools	Impacts of communication on decision making and behavior.	Communication	Technology
52	BOTH	ALL		Modular Assessment Framework for Autonomous Systems	Top Level Use Case	N/A
52		All	Protocols	Test frameworks for componentized testing of autonomous functions	Product Line	Performance
52		All	Assess	ALFUS, NASA, FLOOT Assessment Frameworks	Human Robot Interaction	Technology
53	BOTH	ALL		Deriving Safety Requirements for Autonomous Systems	Top Level Use Case	N/A
53		All	Test Bed	System safety interupts in physical ground environments	Frequency	Performance
53		All	Predict	Model based analysis for planning and safety assessment	Awareness	Performance
53		Air	Predict	Fail-safes	Dependency	Performance
53		All	Protocols	System safety interupts in physical ground environments	Frequency	Technology
54		Air	Emulate	Integrated Sensor Support Teams	Sensor Ranges	Performance
54		Air	Emulate	High Altitude UAVs	Icing	Performance

Use Case ID	Type	Domain	UAST Capability Framework	Use Case Label	USIR Performance Technology Driver	Performance / Technology
57	BOTH	ALL		Mission Based Test and Evaluation of UAS	Top Level Use Case	N/A
57		All	Emulate	Mission Based T&E Multi-level Maps and Modeling	Mission Complexity	Performance
57		All	Emulate	Multi-level Maps and Modeling	Environmental Capability	Performance
57		All	Protocols	Multi-level Maps and Modeling	Navigation	Performance
57		All	Emulate	Multi-level Maps and Modeling	Environmental Capability	Technology
57		Air	Emulate	Multi-level Maps and Modeling	Navigation	Technology
57		Ground	Assess	Multi-level Maps and Modeling	Navigation	Technology
57		Ground	Assess	Spatio-Temporally consistent Scene Classification in Urban Environments	Navigation	Technology
58	BOTH	ALL		Human Sensor Integration - Cognitive Overload	Top Level Use Case	N/A
58		Air	Emulate	Human Sensor Integration	Sensor Ranges	Performance
59	BOTH	ALL		Environmental Effects Addressable by Unmanned Autonomous Systems	Top Level Use Case	N/A
59		Air	Emulate	Environment Effects of Icing at High Altitudes	Icing	Performance
59		Air	Emulate	Severe Environment Flight	Icing	Performance
59		Air	Emulate	Severe Environment Flight	Turbulence	Performance
59		Air	Emulate	Severe Environment Flight	Precipitation	Performance
59		All	Emulate	Environmental Effects	Environmental Capability	Technology
61	BOTH	ALL		Safety in the Battlespace for Unmanned Autonomous Systems	Top Level Use Case	N/A
61		Air	Emulate	Flight Dynamics Effects and Characterization	Turbulence	Performance
61		Air	Emulate	Flight Dynamics Effects and Characterization	Precipitation	Performance
61		Ground	Emulate	Flight Dynamics Effects and Characterization	Speed	Performance
61		Ground	Emulate	Ground Safety and Fail Safes	Speed	Performance
62	BOTH	ALL		Unmanned Autonomous Navigation	Top Level Use Case	N/A
62		Air	Emulate	Truth data for navigational accuracy in geospatial environments	Navigation	Technology
62		Ground	Assess	Verification of navigation techniques of controller system interaction	Navigation	Technology
63	BOTH	ALL		Unmanned Autonomous Tracking of High-Velocity Systems	Top Level Use Case	N/A
63		Air	Assess	High velocity TSPI	Speed	Performance
64	BOTH	ALL		Unmanned Autonomous System E-stops	Top Level Use Case	N/A
64		Air	Assess	Autonomous E-stops	Speed	Performance
65	BOTH	ALL		Unmanned Autonomous System Stealth Testing	Top Level Use Case	N/A
65		Air	Assess	Stealth Effects	Stealth	Performance
66	BOTH	ALL		Unmanned Autonomous System Stealth Testing	Top Level Use Case	N/A
66		Ground	Assess	Measurement analysis and prediction of behavior for survivability	Survivability	Performance
68	BOTH	ALL		Unmanned Autonomous System Stealth Testing	Top Level Use Case	N/A
68		All	Protocols	Testing of unmanned with manned systems for NATO STANAG 4586 compliance	Commands	Performance
69	BOTH	ALL		Autonomous Payload Sensors - Independent Navigation	Top Level Use Case	N/A
69		All	Protocols	Autonomous payload control	Product Line	Performance
70	BOTH	ALL		OPSEC Testing Unmanned and Autonomous Systems	Top Level Use Case	N/A
70		All	Protocols	OPSEC signature network effects	OPSEC	Performance
71	BOTH	ALL		Beyond RF communications for Unmanned and Autonomous Systems	Top Level Use Case	N/A
71		All	Protocols	Non-RF comms	Frequency	Technology
72	BOTH	ALL		Automated and Autonomous Testing for Comm Disrupts	Top Level Use Case	N/A
72		All	Test Bed	Assessment of autonomy limits and responses due to disruptive communications	Frequency	Performance
72		All	Protocols	Assessment of autonomy limits and responses due to disruptive communications	Frequency	Technology
73	BOTH	ALL		Alternative Energy for Test Technologies on Unmanned and Autonomous Systems	Top Level Use Case	N/A
73		All	Test Bed	Alternative power sources	Power	Technology
75	BOTH	ALL		Representation of Knowledge for Unmanned and Autonomous Systems	Top Level Use Case	N/A
75		Maritime	Predict	Effective representation of multiview data	Recognition	Performance
76	BOTH	ALL		Resilient Behavior of Supervised Autonomy for Unmanned and Autonomous Systems	Top Level Use Case	N/A
76		All	Protocols	Resilient networks	Frequency	Technology
77	BOTH	ALL		Autonomous Collaboration Test and Evaluation for Unmanned and Autonomous Systems	Top Level Use Case	N/A
77		All	Reference Data	Collaborative mission planning for hand-off operations and relay support	Operational Control	Performance
77		Ground	Reference Data	Collaborative mission planning for hand-off operations and relay support	Mobility	Technology

UAST Roadmap 1

USIR and UAST Technology Group Use Cases – Mapping Test Scenarios to USIR Forecasts

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USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	T&E Use Cases
Collaboration	p	1. All	Predicting Unmanned and Autonomous System Behaviors	Remote control deconfliction (41) Ability to collect/compare situational awareness to ground truth (38) Human-machine Interaction (41) Communications Standards (26)
Awareness	p	1. All		Small lightweight TSPI (24) Autonomous status behavior sensors (6) Ability to collect/compare situational awareness to ground truth (38) Model based analysis for planning and safety assesment (53)
Dependency	p	2. Air		Auto traffic deconfliction (16) Ability to collect/compare situational awareness to ground truth (38) Sensory and Communications Resourcing and Management Schema (2) Fail-safes (53) Reactive Data Gathering (49)
Maneuverability	p	3. Ground		Multi-level Maps and Modeling (16) Reactive Data Gathering (49) Mobile Robotic Navigation (39)
Environment	p	3. Ground		Environmental Models (11) Target Representation (11) Monitoring in Environment (11) Stimulus (11) Ability to collect/compare situational awareness to ground truth (38)
Obstacle Avoidance	p	4. Maritime		Static obstacle sensing (15) World model representation of static objects (15) Ground truth representation, comparison, assessment (15) Internalized world model (15) Sensor/Sensor processing capabilities such as:TSPI, Kinematic, Optical Imagery etc. Multi-level Maps and Modeling (16) Assessment of UUS / USV (8)
Recognition	p	4. Maritime		Ability to collect/compare situational awareness to ground truth (38) High Order Data Representation (8) Effective representation of multiview data (75)
Human Detection	t	1. All		Human system interaction and detection (42) Ability to collect/compare situational awareness to ground truth (38) High Order Data Representation (8) Reactive Data Gathering (49)

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USIR and UAST Technology Group Use Cases – Mapping Test Scenarios to USIR Forecasts

COGNITIVE HAZARD UAST

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	T&E Use Cases
Mission Complexity	p	1. All	Emulating Mission and Environmental Complexity with Assured Safety	Mission based design of experiments for test development (5) Mission Based T&E Multi-level Maps and Modeling (57)
Environmental Capability	p	1. All		Destructable targets (12) Simulated targets (13) Mapping, localization, and navigation systems rely on two-dimensional representations. (38) Multi-level Maps and Modeling (57)
Sensor Ranges	p	2. Air		Human Sensor Integration (58) Integrated Sensor Support Teams (54)
Icing	p	2. Air		Environment Effects of Icing at High Altitudes (59) High Altitude UAVs (54) Severe Environment Flight (59) High Order Data Representation (8)
Turbulence	p	2. Air		Severe Environment Flight (59) High Order Data Representation (8) Flight Dynamics Effects and Characterization (61)
Precipitation	p	2. Air		Severe Environment Flight (59) High Order Data Representation (8) Flight Dynamics Effects and Characterization (61)
Speed	p	3. Ground		Ground based TSPI Small lightweight TSPI (24) Real-time monitoring (2) Flight Dynamics Effects and Characterization (61) Ground Safety and Fail Safes (61)
Environmental Capability	t	1. All		Multi-level Maps and Modeling (57) Environmental Effects (59)
Navigation	t	2. Air		Truth data to verify dynamic limits of navigation (38) Multi-level Maps and Modeling (57) Air space deconfliction (16) Truth data for navigational accuracy in geospatial environments (62)
Obstacle Avoidance	t	2. Air		Dynamic limits of obstacle avoidance for the whole system involving manned and unmanned vehicles (38) Path planning and obstacle avoidance (44)

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USIR and UAST Technology Group Use Cases – Mapping Test Scenarios to USIR Forecasts

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USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	T&E Use Cases
Mission Endurance	p	1. All	Assessing UAS Effects and Capabilities	Long term communication and sensor systems test capability (19) Data mining and management of long duration tests (26)
Speed	p	2. Air		High velocity TSPI (63) Autonomous E-stops (64) Resource Awareness (26)
Stealth	p	2. Air		Sensing and signature measurements(12) Tracking technologies (24) Stealth Effects (65) Real-time Monitoring of Status (11)
Maneuverability	p	2. Air		Kinematics (25) TSPI for sense and avoid compututation (11) Maneuver Behavior Context (2) Ability to collect/compare situational awareness to ground truth (38)
Self Protection	p	2. Air		UAS countermeasures (12)
Survivability	p	3. Ground		Measurement, analysis and prediction of behavior for survivability (66) Mission means framework and mission based T&E (5)
Human Robot Interaction	t	1. All		Human system assessment HRI will only be accepted if they are responsive to the user on a time-scale the user finds reasonable (i.e., the system cannot take too long to respond nor can it respond incorrectly too often) (40, 41) ALFUS, NASA, FLOOT … Assessment Frameworks (52) Human Models for Increasing Autonomous Effects (46)
Obstacle Avoidance	t	1. All		Dynamic limit assessment of Sense and Avoidance (15) Human Models for Increasing Autonomous Effects (46) High order data representation (48) Uncertain terrain assessment (47) Auto traffic deconfliction (16) FAA certification (16)
Navigation	t	3. Ground		TSPI for human controlled ground single and multi-system UAS (26) Verification of navigation techniques of controller system interaction (62) Multi-level Maps and Modeling (57) Spatio-Temporally consistent Scene Classification in Urban Environments (57)

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USIR and UAST Technology Group Use Cases – Mapping Test Scenarios to USIR Forecasts

COGNITIVE HAZARD UAST

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	T&E Use Cases
Commands	p	1. All	Autonomous Test Protocols and Design	Testing of unmanned with manned systems for NATO STANAG 4586 compliance (68) Common ground station for JAUS (SAE-AS/4) unmanned manned systems compliance (31)
Product Line	p	1. All		Test frameworks for componentized testing of autonomous functions (52) Common ground station for JAUS (SAE-AS/4) unmanned manned systems compliance (31) Autonomous payload control (69)
OPSEC	p	1. All		OPSEC signature network effects (70)
OPSEC	p	4. Maritime		OPSEC signature vulnerability maritime (12)
Navigation	p	4. Maritime		TSPI for human controlled maritime single and multi-system UAS (15) Verification of maritime navigation techniques of controller system interaction (8) Multi-level Maps and Modeling (57) High order data representation (48)
Frequency	t	3. Ground		Effective spectrum use and allocation ground (19, 28) System safety interupts in physical ground environments (53) Non-RF comms (71) Assessment of autonomy limits and responses due to disruptive communications (72) Resilient networks (76)
Frequency	p	1. All	Test Bed and Environments for UAST	Effective spectrum use and allocation ground (19, 28) System safety interupts in physical ground environments (53) Assessment of autonomy limits and responses due to disruptive communications (72)
Power	t	1. All		Alternative power sources (73)
Signature Management	t	1. All		Signature limit testing (12) Control and management of autonomous comms in test environment (42)

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USIR and UAST Technology Group Use Cases – Mapping Test Scenarios to USIR Forecasts

COGNITIVE HAZARD UAST

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	T&E Use Cases
Operational Control	p	1. All	UAST Reference Data Sets (Ground Truth, Decision, & Behavior)	Reactive ground truth representation (48) Command and Control of UAS - single, team, collaborating (42) Common ground station tester robotics and targets (31) Collaborative mission planning for hand-off operations and relay support (77)
Architecture	t	1. All		JAUS compliance (43) STANAG compliance (43) Emergent standards compliance (43) Taxonomy of Performance Metrics (43)
World Model	t	1. All		Representation of ground truth for elementary behavior and decision assessment (43) Model representation of cognitive agents (27) Higher Order Data Representations (43)
Visualization	t	3. Ground		Perception assessment reference data sets (1)
Mobility	t	3. Ground		Representation of ground truth for elementary behavior and decision assessment on ground mobility (38) Reactive ground truth representation (48) Command and Control of UAS - single, team, collaborating (42) Collaborative mission planning for hand-off operations and relay support (77)
Bandwidth	p	1. All	UAST Tools and Techniques	Bandwidth measurement and allocation certification (19)
Maintenance	p	1. All		Self test acuity (1)
Communication	t	1. All		Impacts of communication on decision making and behavior. (51) Communications would more effectively monitor UAS performance. (9) Test applications benefit from advances in sensor networks, perception software, and communications networks. (10) Protocols for sparse, highly volatile multi-hop, ad-hoc networks with high bandwidth and low latency. (10) Improvements in localization in UWB networks and better spectrum utilization. (26) Integration of wide-area, local-area, and personal-area networks for more seamless local-to global coverage(heterogeneity). (31) Cooperative communication clusters in ad-hoc networks for better connectivity, power utilization, etc. Integration of the cellular and satellite phone networks to augment other networks. (3)
Mechanical Systems	t	3. Ground		Kinematics data for actuator motion (25)
Dexterity	t	3. Ground		Kinematics data for actuator motion (25)

UAST Roadmap 1

A CONSENSUS ON UAST FORECAST
A UAST S&T investment framework for unfolding UAS

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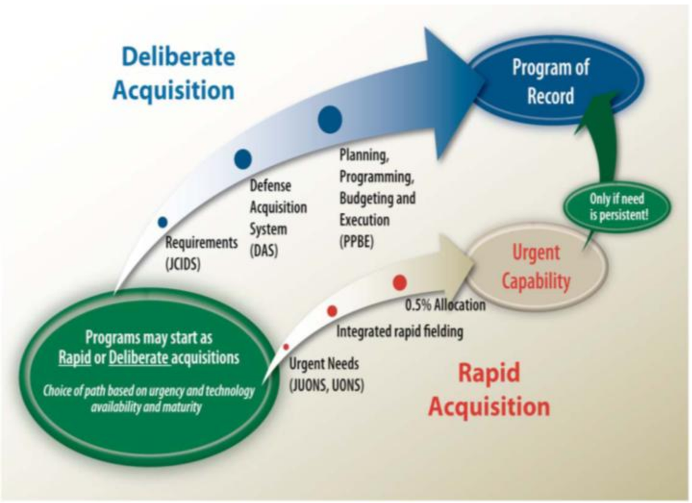

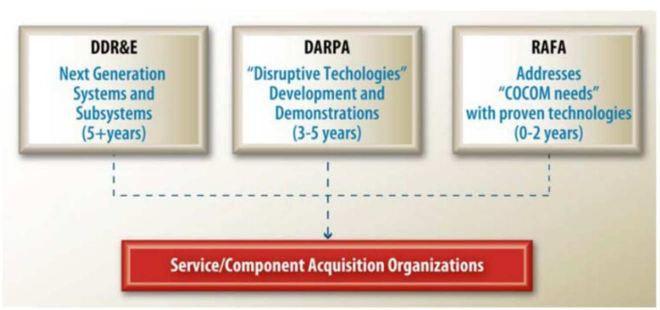

10) The UAST Exemplars of Future UAS
11) The UAST Capabilities Reference Framework
12) The Usage Case: Predicting Unmanned and Autonomous System Behavior
13) The Usage Case: Emulating Mission and Environmental Complexity
14) The Usage Case: Assessing UAS Effects and Capabilities
15) The Usage Case: Protocols and Design
16) The Usage Case: UAS Test Bed and Environment
17) The Usage Case: Reference Data Sets (Ground Truth, Decision & Behavior)
18) The Usage Case: Tools and Techniques
19) S&T Implications: Predicting Unmanned and Autonomous System Intelligence
20) S&T Implications: Emulating Mission and Environmental Complexity
21) S&T Implications: Assessing UAS Effects and Capabilities
22) S&T Implications: Protocols and Design
23) S&T Implications: UAS Test Bed and Environment
24) S&T Implications: Reference Data Sets (Ground Truth, Decision & Behavior)
25) S&T Implications: Tools and Techniques

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CH 10 The UAST Exemplars of Future UAS

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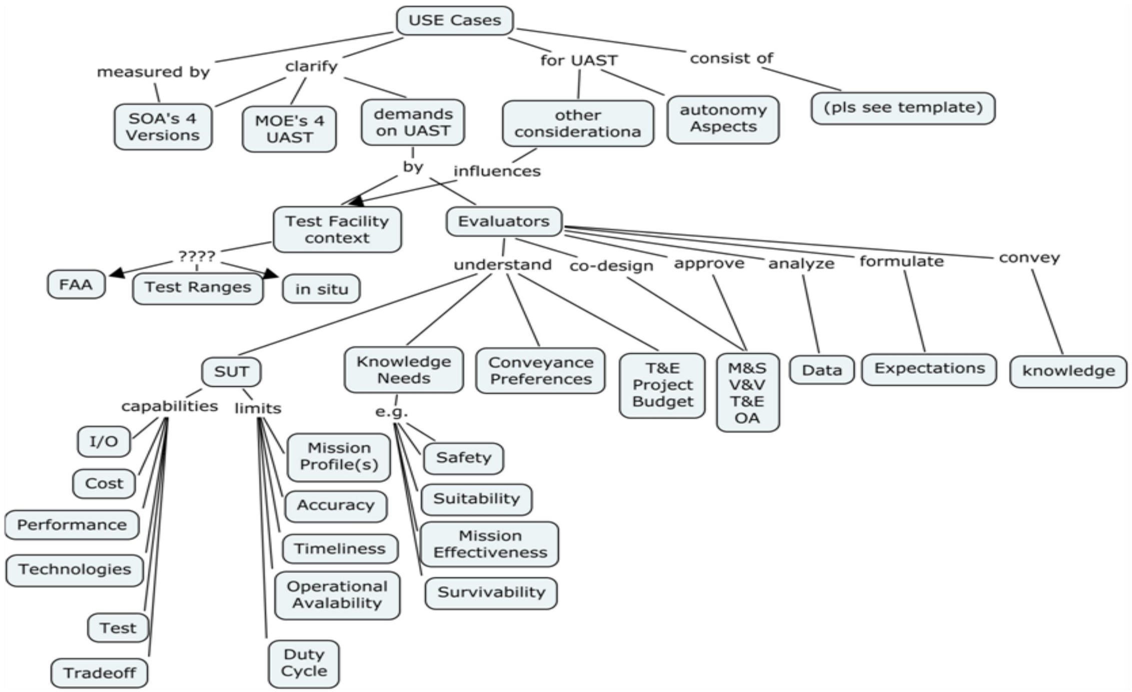
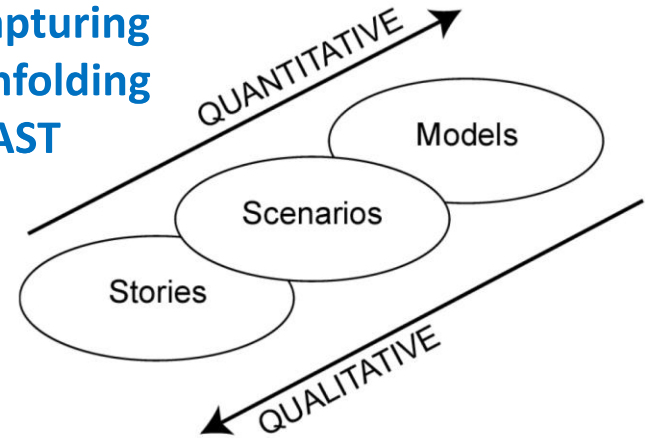


Capturing Unfolding UAST



"Exemplar (n.) A model, original, or pattern, to be copied or imitated; a specimen; sometimes; an ideal model or type, as that which an artist conceives. "

Normal and Rapid Fielding

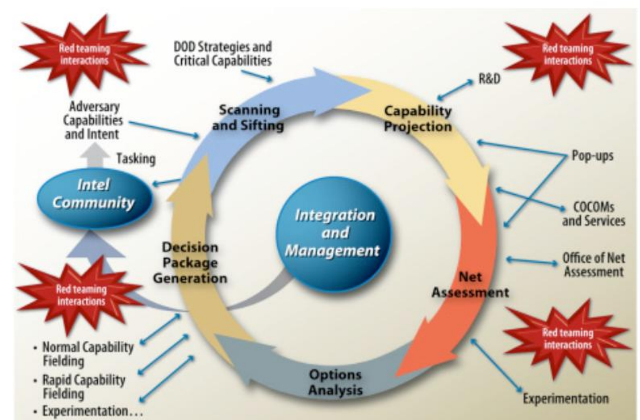


Figure 2-10. Surprise Management Cycle

http://www.acq.osd.mil/dsb/reports/ADA513074.pdf

UAST Roadmap 1

CH 11 The UAST Capabilities Reference Framework

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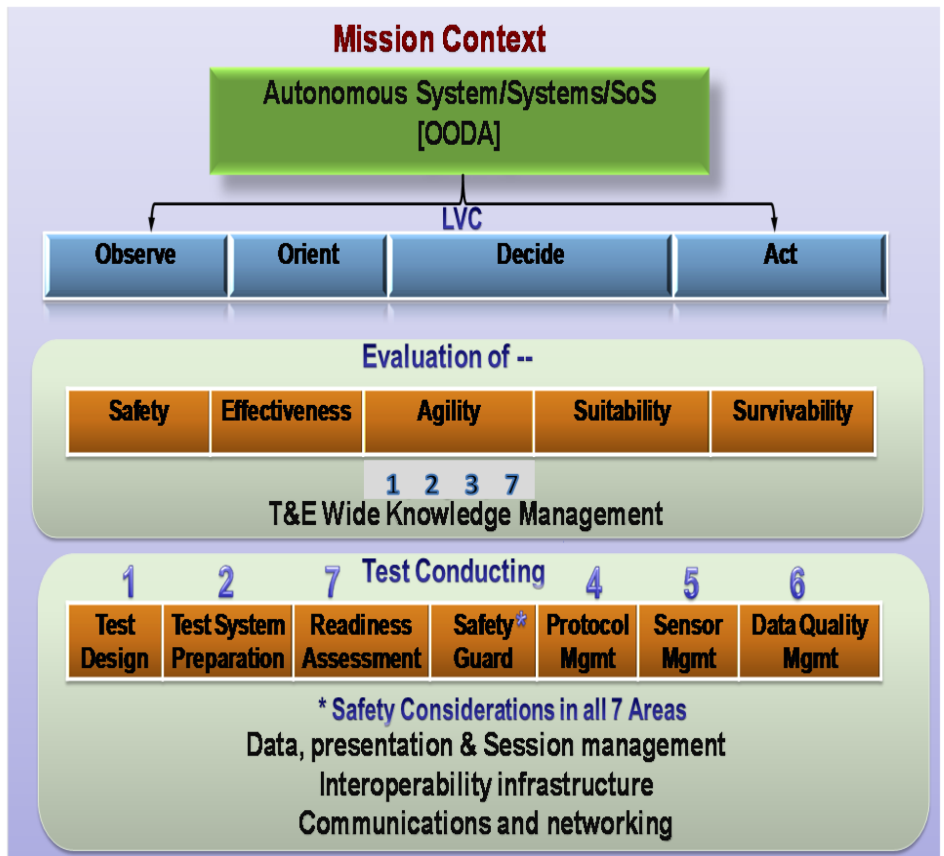
UAST Categories applied to UAST Systems Engineering Capabilities Reference Framework

1. Predicting Unmanned and Autonomous System Behaviors (T&E/Assessment)
2. Emulating Mission and Environmental Complexity with Assured Safety (T&E/Assessment)
3. Assessing UAS Effects and Capabilities (Evaluation and Assessment)
4. Autonomous Test Protocols and Design (T&E)
5. Test Bed and Environments for UAST (T&E)
6. UAST World Models (Ground Truth, Decision, & Behavior) (T&E)
7. Tools and Techniques for Systemic UAST (T&E/Assessment)



UAST Roadmap 1

CH 12 The Usage Case: Predicting Unmanned and Autonomous System Behavior

COGNITIVE HAZARD

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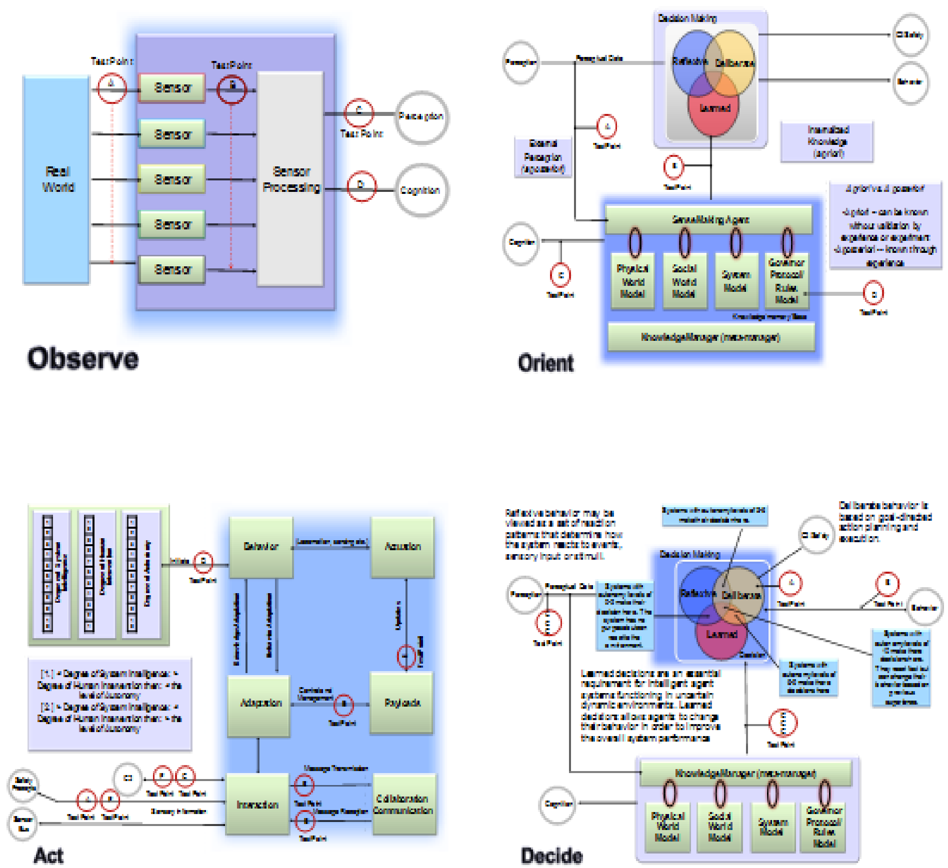
S&T to perform calculations which predict performance of UAS and test/validate these predictions

- standards and guidelines for transfer of knowledge regarding system under test
- predict behavior using appropriate visualization/computational techniques
- distinguish critical aspects/variables of problem from noncritical aspects/variables
- identify when a model or calculation returns valid or invalid results by:
- comparing results to known concepts, facts, data
- validating the model
- performing sensitivity analysis
- performing dimensional analysis



UAST Roadmap 1

CH 13 The Usage Case: Emulating Mission and Environmental Complexity

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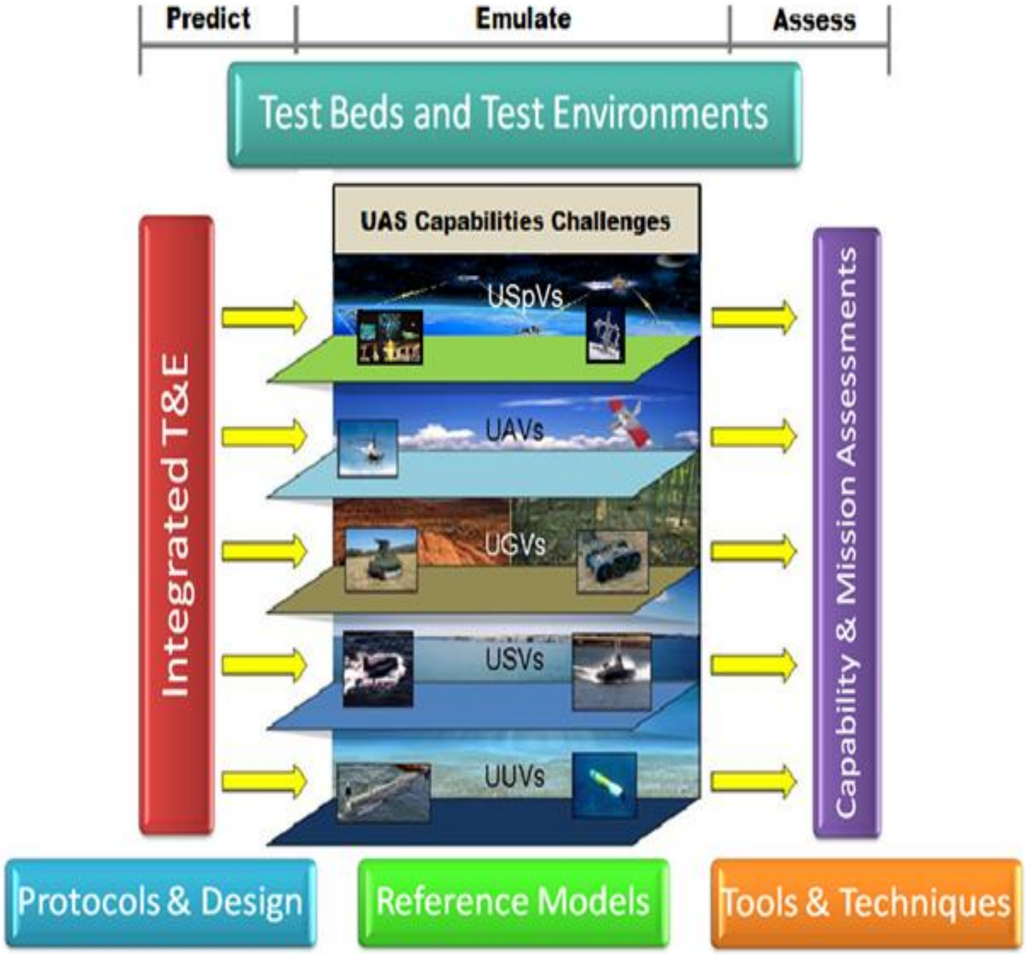
Emulating Mission and Environmental Complexity: S&T to support the physical T&E of UAS in complex mission and environmental scenarios

- unpredictable behavior handling
- sense-and-avoid
- emergent phenomena
- reliable fail-safes
- test frameworks/test harnesses
- terrain and ground truth representation
- behavior stimulation



UAST Roadmap 1

CH 14 The Usage Case: Assessing UAS Effects and Capabilities

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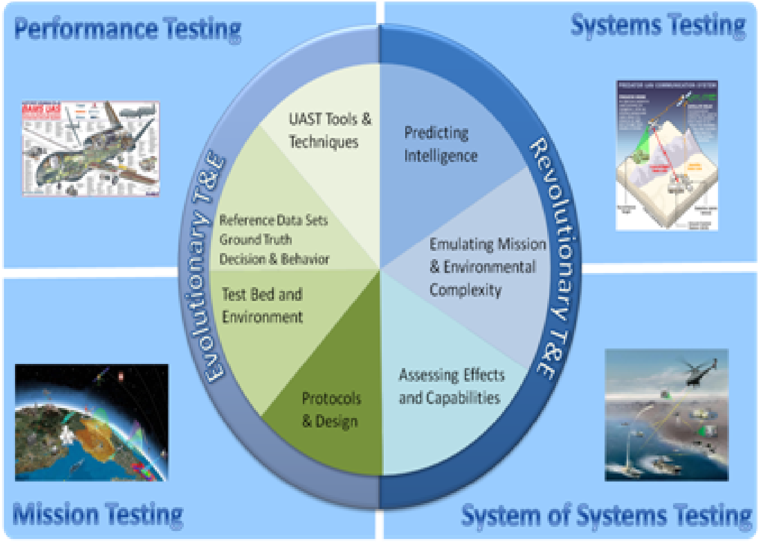
S&T to support the analysis of UAS to support the fielding of unmanned systems that are effective, suitable, and survivable

- Autonomy metrics
- Measures of Performance
- Measures of Effectiveness
- -ilities: adaptability, flexibility, interoperability
- Collaborative control
- Knowledge and decision-making from data to information to valued information and the right time
- UAS self monitoring and reporting built into vehicles complementing external monitoring and reporting capabilities of test infrastructure



Prioritized capability needs of the warfighter that include:

Reconnaissance and Surveillance
Target Identification and Designation
Counter-Mine and Explosive Ordnance Disposal
Chemical, Biological, Radiological, Nuclear, Explosive (CBRNE) Reconnaissance

UAST Roadmap 1

CH 15 The Usage Case: Protocols and Design

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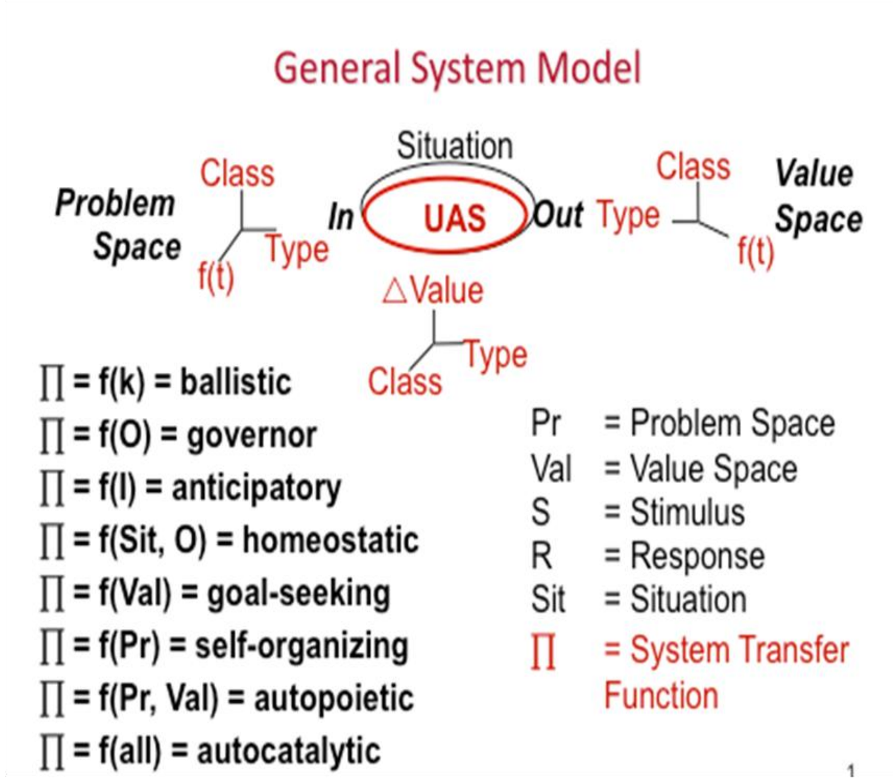
S&T for conceiving, planning and confirming testing capability
- Ontology of UAST
  - Classes of UAS
  - Autonomy of UAS
  - Types of Testing (individual to swarms)
- Methodology of UAST
  - Stimulus and Measures
  - UAS limits
  - Analysis of Alternatives
- Test Scenario synthesis
  - System to Capability Testing
  - UAST interfaces to Test Construct
- Test analysis, interpretation, knowledge claims, and reporting
- UAST(I) configuration Model Generation
- Cross-UAS Usage Case Repository



UAST Roadmap 1

CH 16 The Usage Case: UAS Test Bed and Environment

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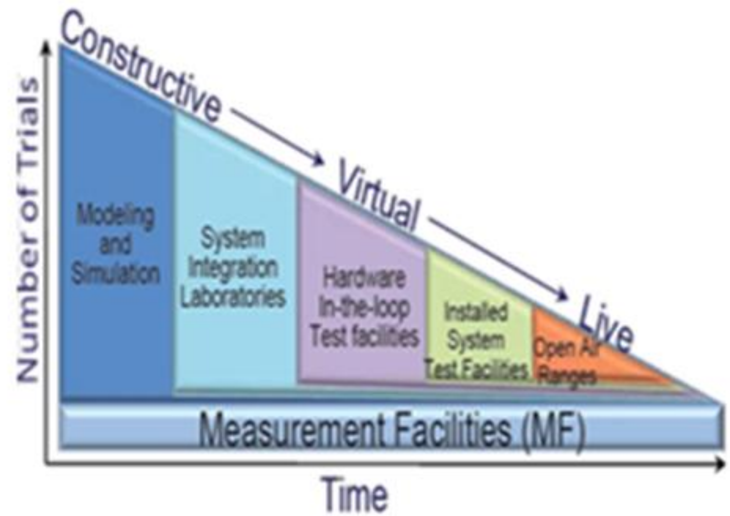
S&T for physical test capabilities associated with Test Bed and Environment

- Stimulus selection or generation
- Sensors
- Data Acquisition and Management
- Data compression and characterization (signatures)
- Data reduction/analysis/interpretation
- Power Technologies: providing increased mission time and capability without increasing the logistics footprint.
- Test conducting including situation awareness
- Test operations safety



UAST Roadmap 1

CH 17 The Usage Case: Reference Data Sets (Ground Truth, Decision & Behavior)

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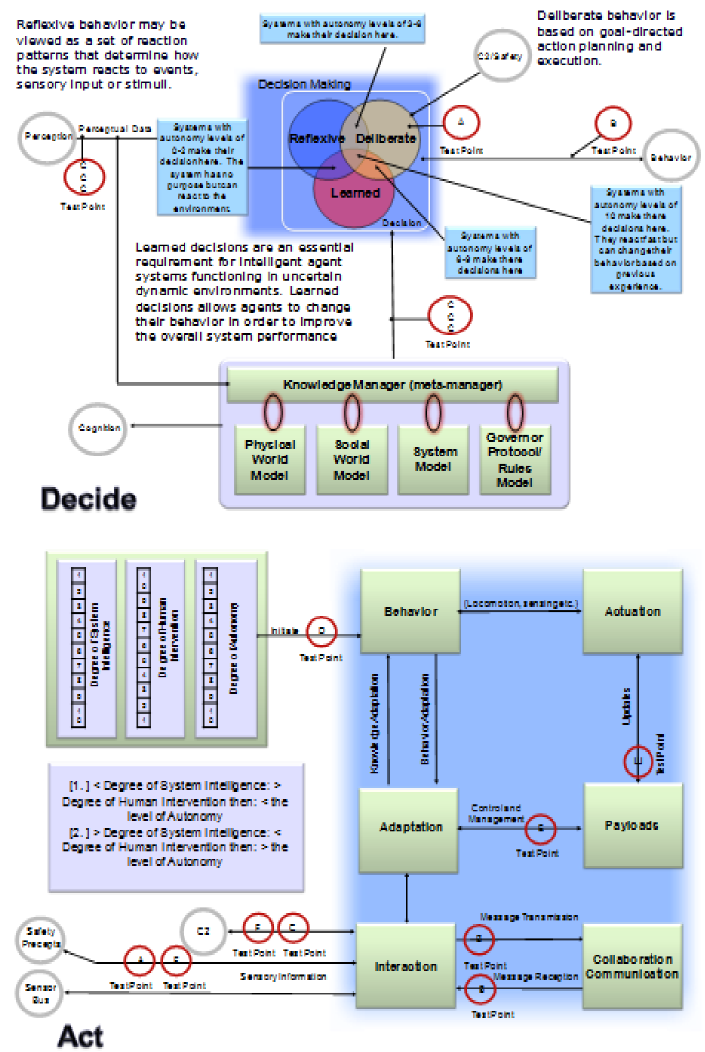
S&T for testing Decision & Behavior as it relates to Ground Truth Data and Referenced Data Sets

- Repository of Geo, Environmental, Modeling &Simulation results, etc.
- Acquisition/Generation
  - Contrived Data Sets
  - Surveyed/measured data sets
- Surveying/measuring situations contemporaneous with test operations (over-the-shoulder verification of what the UAS experienced)
- Tools, metrics and algorithms for assessing mismatches between robot understanding of an environment or situation and provided ground truth



UAST Roadmap 1

CH 18 The Usage Case: Tools and Techniques

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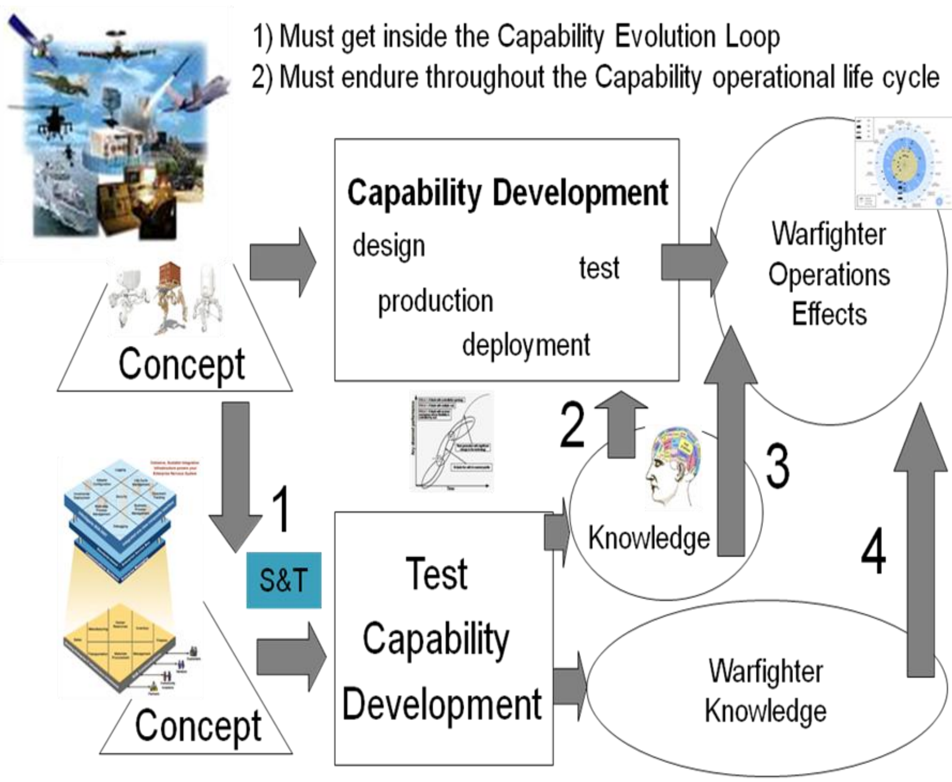
S&T for UAST responsiveness, productivity and innovation

- Analysis of Test Requirements
- Architecture/Design of test episodes
- Test Planning/Timeline
- Evaluating UAS Effectiveness
- Discovering UAS capability limits
- Evaluating likelihood of fratricide.
- Evaluating likelihood of cyber security intrusion.
- Assessing the risk of errors and omissions in test findings and conclusions
- Quantifying the cost-effectiveness of the UAST configuration and operation used in the test episode.
- Systematizing UAST(s). UAST as a composable infrastructure that supports test-specific, plug-in modules.

The Tester Evolution Loop



UAST Roadmap 1

CH 19 S&T Implications: Predicting Unmanned and Autonomous System Intelligence

COGNITIVE HAZARD UAST

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USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	**S&T Technology Areas (Epoch I)** Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	**S&T Technology Areas (Epoch II)** Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	**S&T Technology Areas (Epoch III)** Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Collaboration	p	1. All	naviors	Predicting Collaboration ALFUS 1-3 Realistic modeling of collaboration for mission planners - Single-agent collaboration/cooperation strategies Decision analysis tool for collaboration for hardware in the loop test facilities - Single-agent collaboration/cooperation strategies	Predicting Collaboration ALFUS 4-6 Realistic modeling of teamed collaboration for mission planners - Teaming w/in Domain, Collaboration Across Domains Multi-agent collaboration/cooperation strategies Decision analysis tool for teamed collaboration for hardware in the loop test facilities - Teaming w/in Domain, Collaboration Across Domains Multi-agent collaboration/cooperation strategies	Predicting Collaboration ALFUS 7-10 Realistic modeling of collaboration for mission planners - Teamed Collaboration Decision analysis tool for collaboration for hardware in the loop test facilities - Teamed Collaboration
Awareness	p	1. All		Predicting perception limits based on single-agent collaboration - sensor data Predicting behavior based on UAS awareness for mission planners - sensor data Predicting situational awareness and comprehension for mission planners - sensor data	Predicting perception limits based on single-agent collaboration - Situational Awareness. Predicting behavior based on UAS awareness for mission planners - Situational Awareness. Predicting situational awareness and comprehension for mission planners - Situational Awareness.	Predicting perception limits based on single-agent collaboration - Actionable Information Predicting behavior based on sensor inputs for mission planners- Actionable Information Predicting situational awareness and comprehension for mission planners - Actionable Information
Dependency	p	2. Air		Prediction sense and avoid for design	Prediction sense and avoid for design	Prediction sense and avoid for design

UAST Roadmap 1

CH 20 S&T Implications: Emulating Mission and Environmental Complexity

UAST COGNITIVE HAZARD

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	S&T Technology Areas (Epoch I) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch II) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch III) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Mission Complexity	p	1. All	ty with Assured Safety	Emulating system behavior in a mission complexity framework for complete life cycle - operator controlled engagement of mission complexity epoch I Measuring system behavior with a variety of simulity in context of mission means framework - operator controlled engagement of mission complexity epoch I	Emulating system behavior in a mission complexity framework for complete life cycle - operator controlled engagement of mission complexity epoch II Measuring system behavior with a variety of simulity in context of mission means framework - operator controlled engagement of mission complexity epoch II	Emulating system behavior in a mission complexity framework for complete life cycle - Autonomous Adaptive Tactical Behaviors engagement of mission complexity epoch III Measuring system behavior with a variety of simulity in context of mission means framework - Autonomous Adaptive Tactical Behaviors engagement of mission complexity epoch III
Environmental Capability	p	1. All		Development of technologies for behavior representation in advanced geospatial environments - Limited Environmental Difficulty Emulating environmental features for behavior assessment - Limited Environmental Difficulty Emulating environmental features that involve surrogate agents for behavior assessment - Limited Environmental Difficulty	Development of technologies for behavior representation in advanced geospatial environments - Expanded Environmental Difficulty Emulating environmental features for behavior assessment - Expanded Environmental Difficulty Emulating environmental features that involve surrogate agents for behavior assessment - Expanded Environmental Difficulty	Development of technologies for behavior representation in advanced geospatial environments - All-Weather Environmental Difficulty Emulating environmental features for behavior assessment - All-Weather Environmental Difficulty Emulating environmental features that involve surrogate agents for behavior assessment - All-Weather Environmental Difficulty

UAST Roadmap 1

CH 21 S&T Implications: Assessing UAS Effects and Capabilities

COGNITIVE HAZARD UAST
Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	S&T Technology Areas (Epoch I) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch II) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch III) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Mission Endurance	p	1. All		Assessing UAS effects and capabilities with increasing mission endurance - hours Frameworks for persistent information requiring new approaches for knowledge aggregation - hours Power technologies scalable to expanding mission endurance - hours	Assessing UAS effects and capabilities with increasing mission endurance - day and months Frameworks for persistent information requiring new approaches for knowledge aggregation - day and months Power technologies scalable to expanding mission endurance - day and months	Assessing UAS effects and capabilities with increasing mission endurance - years Frameworks for persistent information requiring new approaches for knowledge aggregation - years Power technologies scalable to expanding mission endurance - years
Speed	p	2. Air		Reliable non-intrisive fail-safe mechanisms to ensure safety for Subsonic uas	Reliable non-intrisive fail-safe mechanisms to ensure safety for Transonic uas	Reliable non-intrisive fail-safe mechanisms to ensure safety for Super / Hypersonic uas
Stealth	p	2. Air		Assessing unmanned aerial systems signature and counter-measures and capabilities with Epoch I stealth Address automated signature reduction associated with stealth and develop assessment of Epoch I unmanned aerial systems Technologies for signature testing based on passive UAS signature	Assessing unmanned aerial systems signature and counter-measures and capabilities with Epoch II stealth Address automated signature reduction associated with stealth and develop assessment of Epoch II unmanned aerial systems Technologies for signature testing based on active UAS signature	Assessing unmanned aerial systems signature and counter-measures and capabilities with Epoch III stealth Address automated signature reduction associated with stealth and develop assessment of Epoch III unmanned aerial systems Technologies for signature testing based on integrated UAS signature

UAST Roadmap 1

CH 22 S&T Implications: Protocols and Design

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	**S&T Technology Areas (Epoch I)** Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	**S&T Technology Areas (Epoch II)** Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	**S&T Technology Areas (Epoch III)** Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Commands	p	1. All	Design	Sequencing of test for human machine interface Test specified by advancing standards in autonomous behavior Ground station for JAUS compliance testing	Sequencing of test for human machine interface - Scripted Voice Command / Hand Signals Test specified by advancing standards in autonomous behavior - Scripted Voice Command / Hand Signals Ground station for JAUS compliance testing - Scripted Voice Command / Hand Signals	Sequencing of test for human machine interface - Natural Language Understanding Test specified by advancing standards in autonomous behavior - Natural Language Understanding Ground station for JAUS compliance testing - Natural Language Understanding
Product Line	p	1. All		Testing technologies for black box testing of proprietary systems Inter-domain challenges of UAS built for specific missions Sequence testing of navigation control from autonomous payload Interface management for mission dependent product lines Test message and hand shake definition technologies	Testing technologies for grey box testing of standards based systems Inter-domain challenges of UAS built for multiple missions Sequence testing of navigation control from autonomous payload based on standards Interface management for mission dependent product lines based on open standards Test message and hand shake definition technologies based on open standards	Testing technologies for white box testing of standards based systems Inter-domain challenges of collaborative UAS built for multiple missions Sequence testing of navigation control from autonomous payload based on open standards Collaborative interface management for mission dependent product lines based on open standards Test message and hand shake

UAST Roadmap 1

CH 23 S&T Implications: UAS Test Bed and Environment

Confidence in Unmanned & Autonomous Systems

USIR Performance Technology Drivers	Performance (p) Technology (t)	Domain	UAST Capabilities Reference Framework (T&E Capabilities)	S&T Technology Areas (Epoch I) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch II) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges	S&T Technology Areas (Epoch III) Modeling and Simulation Centers System Integration Labs Hardware in-the-loop Test Facilities Installed System Test Facilities Open Air Ranges
Frequency	p	1. All	nd Environments for UAST	Technologies for dynamic spectrum band allocation - Constrained RF Assessment of behavior relative to spectrum operations - Constrained RF Test operations gaurantee e-stop frequency allocation - Constrained RF Command and control frequency data capture - Constrained RF	Technologies for dynamic spectrum band allocation - Frequency Hopping Assessment of behavior relative to spectrum operations - Frequency Hopping Test operations gaurantee e-stop frequency allocation - Frequency Hopping Command and control frequency data capture - Frequency Hopping	Technologies for dynamic spectrum band allocation - Multi-Frequency Communications Assessment of behavior relative to spectrum operations - Multi-Frequency Communications Test operations gaurantee e-stop frequency allocation - Multi-Frequency Communications Command and control frequency data capture - Multi-Frequency Communications
Power	t	1. All		Alternative power for onboard test technologies across multiple domains - Battery Powered Long duration power technologies - Battery Powered Maritime environment power technologies - Battery Powered Extreme environment power technologies - Battery Powered	Alternative power for onboard test technologies across multiple domains - Next Gen Power Resource Long duration power technologies - Next Gen Power Resource Maritime environment power technologies - Next Gen Power Resource Extreme environment power technologies - Next Gen Power	Alternative power for onboard test technologies across multiple domains - Bio Mass Reactor Powered/ Opportunistic Power Grazing Long duration power technologies - Bio Mass Reactor Powered/ Opportunistic Power Grazing Maritime environment power technologies - Bio Mass Reactor Powered/ Opportunistic Power

UAST Roadmap 1

A CONSENSUS ON UAST INVESTMENT FRAMEWORK

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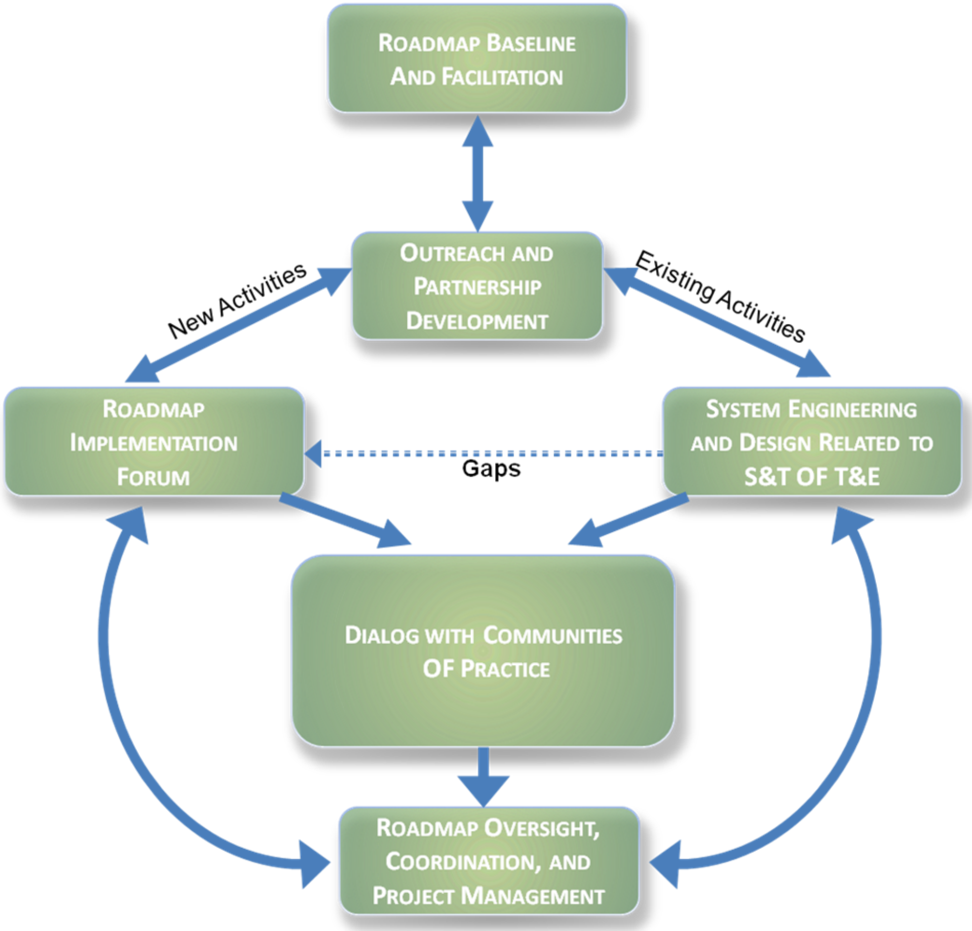
26) Path Forward: The Larger Picture
27) Path Forward: UAST Construction Approach
28) S&T Implications: Notional Budget
29) Path Forward: Usage Case Driven Investment
30) Path Forward: The Larger Picture
31) Path Forward: The Need for an Agile Roadmap Process
32) Summary Recommendation



UAST Roadmap 1

CH 26 Path Forward: The Larger Picture

COGNITIVE HAZARD **UAST**

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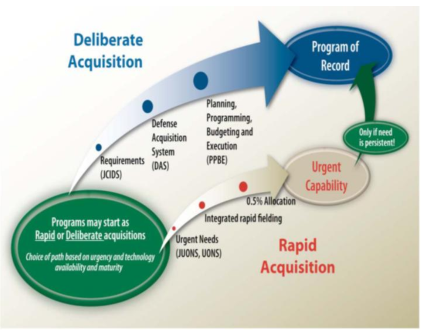
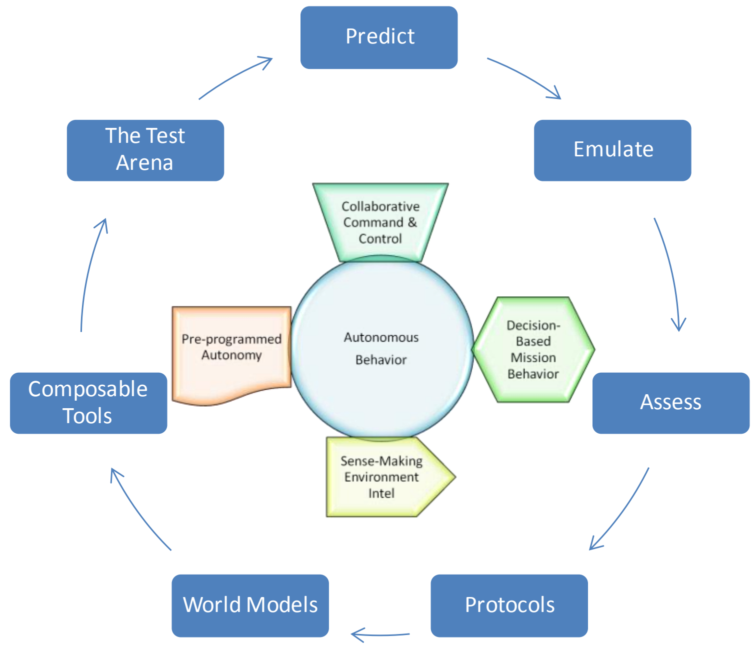


Standard System T&E

1. System Level T&E
2. Mission & Environment T&E
3. Joint Capability Areas T&E



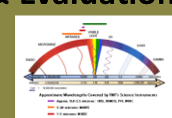
Autonomous System T&E

1. Predicting Autonomous Behavior
2. Emulating Mission and Environmental Complexity with Assured Safety
3. Assessing UAS Effects and Capabilities

Unmanned & Autonomous Systems Test

Establishing an investment process for the S&T of UAST that is sensitive to both deliberate and rapid acquisition

UAS Test & Evaluation Complementary Focus Areas



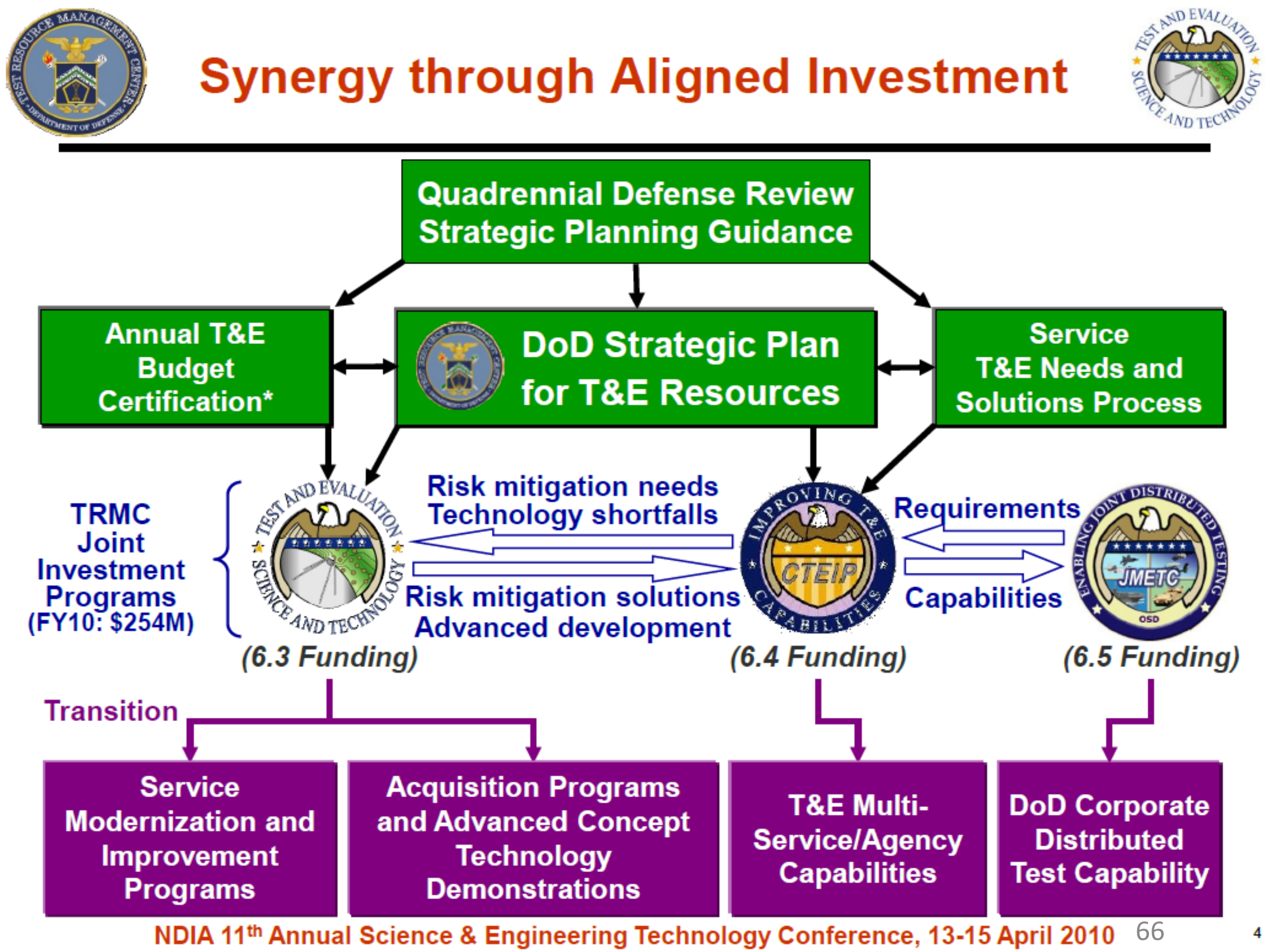
Advanced Instrumentation	**Spectrum Efficiencies**	**Multi-Spectral Sensors**	**Netcentric Systems**

UAST Roadmap 1

CH 27 Path Forward: UAST Construction Approach

S&T provides risk mitigation solutions critical for the development of T&E capabilities for UAS

Challenge:
T&E Capabilities are available in time to provide useful insight to decision-makers and warfighters



UAST Roadmap 1

CH 28 S&T Implications: Notional Budget

UAST
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Should we use USIR Budget?

The T&E budget is forecast at 15% of the average of the overall RDT&E budget. Based on this value a 3% budget for S&T of T&E has been established. The MILCON investment is based on matching the current investment rate of $5m a year based on a need for new infrastructure to address emerging test challenges in test facilities as agile test capabilities are established.

PORs FY09PB ($M)	Funding Source	FY09	FY10	FY11	FY12	FY13	TOTAL
UGV	RDT&E*	$1291.2	$747.5	$136.2	$108.7	$68.9	$2,353
	PROC*	$33.4	$42.3	$53.5	$59.5	$21.1	$210
	O&M*	$2.9	$3.9	$3.0	$12.8	$10.1	$33
UAS	RDT&E	$1347.0	$1305.1	$1076.4	$894.0	$719.5	$5,342
	PROC	$1875.5	$2006.1	$1704.7	$1734.3	$1576.2	$8,897
	O&M	$154.3	$251.7	$249.0	$274.9	$320.2	$1,250
UMS	RDT&E	$57.3	$73.8	$63.2	$70.1	$76.9	$341
	PROC	$56.7	$78.4	$95.9	$91.6	$103.7	$426
	O&M	$5.0	$4.5	$11.3	$13.5	$13.9	$48
TOTAL		$4,823	$4,513	$3,393	$3,260	$2,911	$18,900

* RDT&E = Research, Development, Test, and Evaluation; PROC = Procurement; O&M = Operations and Maintenance

Table 1. FY2009–13 President's Budget for Unmanned Systems

MILCON	$ 5	$ 5	$ 5	$ 5	$ 5
S&T for T&E	$ 7	$ 7	$ 7	$ 7	$ 7
T&E	$ 241	$ 241	$ 241	$ 241	$ 241
RDT&E	$1,607	$1,607	$1,607	$1,607	$1,607
TOTAL	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860

UAST Roadmap 1

CH 28 S&T Implications: Notional Budget

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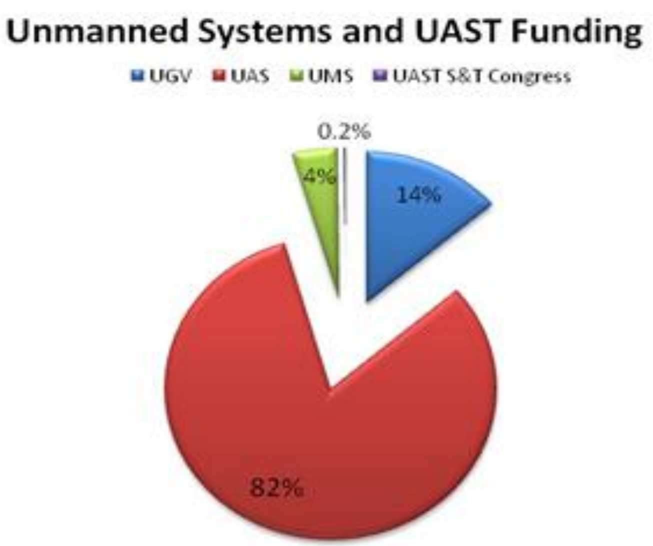
How much detail is needed?

This table maps a notional budget across all seven investment areas for an overall notional budget.

The graph shows current UAS budget by platform with sliver of investment for UAST S&T/T&E.



Unmanned and Autonomous Systems Testing (UAST)
Funding Roadmap Capabilities

Required Funding ($M)

	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	TOTAL
UAST Predicting Unmanned and Autonomous System Intelligence																		
MILCON	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 17
S&T for T&E	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 16
T&E	$ 58	$ 46	$ 27	$ 23	$ 19	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 528
RDT&E	$ 385	$ 304	$ 182	$ 153	$ 124	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 3,518
TOTAL	$ 446	$ 352	$ 2	$ 2	$ 144	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 4,078
UAST Emulating Mission and Environmental Complexity																		
MILCON	$ 9	$ 9	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 33
S&T for T&E	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 16
T&E	$ 58	$ 46	$ 27	$ 23	$ 19	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 528
RDT&E	$ 385	$ 304	$ 182	$ 153	$ 124	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 3,518
TOTAL	$ 454	$ 360	$ 2	$ 2	$ 144	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 4,094
UAST Assessing Effects and Capabilities																		
MILCON	$ 2	$ 2	$ 1	$ 1	$ 1	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 20
S&T for T&E	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 16
T&E	$ 58	$ 46	$ 27	$ 23	$ 19	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 528
RDT&E	$ 385	$ 304	$ 182	$ 153	$ 124	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 3,518
TOTAL	$ 447	$ 353	$ 2	$ 2	$ 144	$ 267	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 4,081
UAST Protocols and Designs																		
MILCON	$ 4	$ 4	$ 1	$ 1	$ 1	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 24
S&T for T&E	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 16
T&E	$ 58	$ 46	$ 27	$ 23	$ 19	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 528
RDT&E	$ 385	$ 304	$ 182	$ 153	$ 124	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 3,518
TOTAL	$ 449	$ 355	$ 2	$ 2	$ 144	$ 267	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 266	$ 4,085
UAST Test Bed and Environment																		
MILCON	$ -	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 80
S&T for T&E	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 16
T&E	$ 58	$ 46	$ 27	$ 23	$ 19	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 528
RDT&E	$ 385	$ 304	$ 182	$ 153	$ 124	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 3,518
TOTAL	$ 445	$ 356	$ 2	$ 2	$ 148	$ 270	$ 270	$ 270	$ 270	$ 270	$ 270	$ 270	$ 270	$ 270	$ 270	$ 270	$ 270	$ 4,141
UAST Reference Data and Data Sets (Ground Truth, Decision, & Behavior)																		
MILCON	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
S&T for T&E	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 16
T&E	$ 58	$ 46	$ 27	$ 23	$ 19	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 528
RDT&E	$ 385	$ 304	$ 182	$ 153	$ 124	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 3,518
TOTAL	$ 445	$ 351	$ 2	$ 2	$ 143	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 4,061
UAST Tools and Techniques																		
MILCON	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
S&T for T&E	$ 2	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 1	$ 16
T&E	$ 58	$ 46	$ 27	$ 23	$ 19	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 34	$ 528
RDT&E	$ 385	$ 304	$ 182	$ 153	$ 124	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 230	$ 3,518
TOTAL	$ 445	$ 351	$ 2	$ 2	$ 143	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 265	$ 4,061
UAST Totals																		
MILCON	$ -	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 5	$ 80
S&T for T&E	$ 12	$ 10	$ 6	$ 5	$ 4	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 7	$ 111
T&E	$ 404	$ 319	$ 191	$ 161	$ 130	$ 241	$ 241	$ 241	$ 241	$ 241	$ 241	$ 241	$ 241	$ 241	$ 241	$ 241	$ 241	$ 3,694
RDT&E	$2,696	$2,126	$1,276	$1,073	$865	$1,607	$1,607	$1,607	$1,607	$1,607	$1,607	$1,607	$1,607	$1,607	$1,607	$1,607	$1,607	$ 27,320
TOTAL	$ 3,112	$ 2,460	$ 1,478	$ 1,244	$ 1,004	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 1,860	$ 31,204

UAST Roadmap 1

CH 28 S&T Implications: Notional Budget

COGNITIVE HAZARD

UAST

Confidence in Unmanned & Autonomous Systems

Do budgets need to be significantly adjusted for each Epoch?

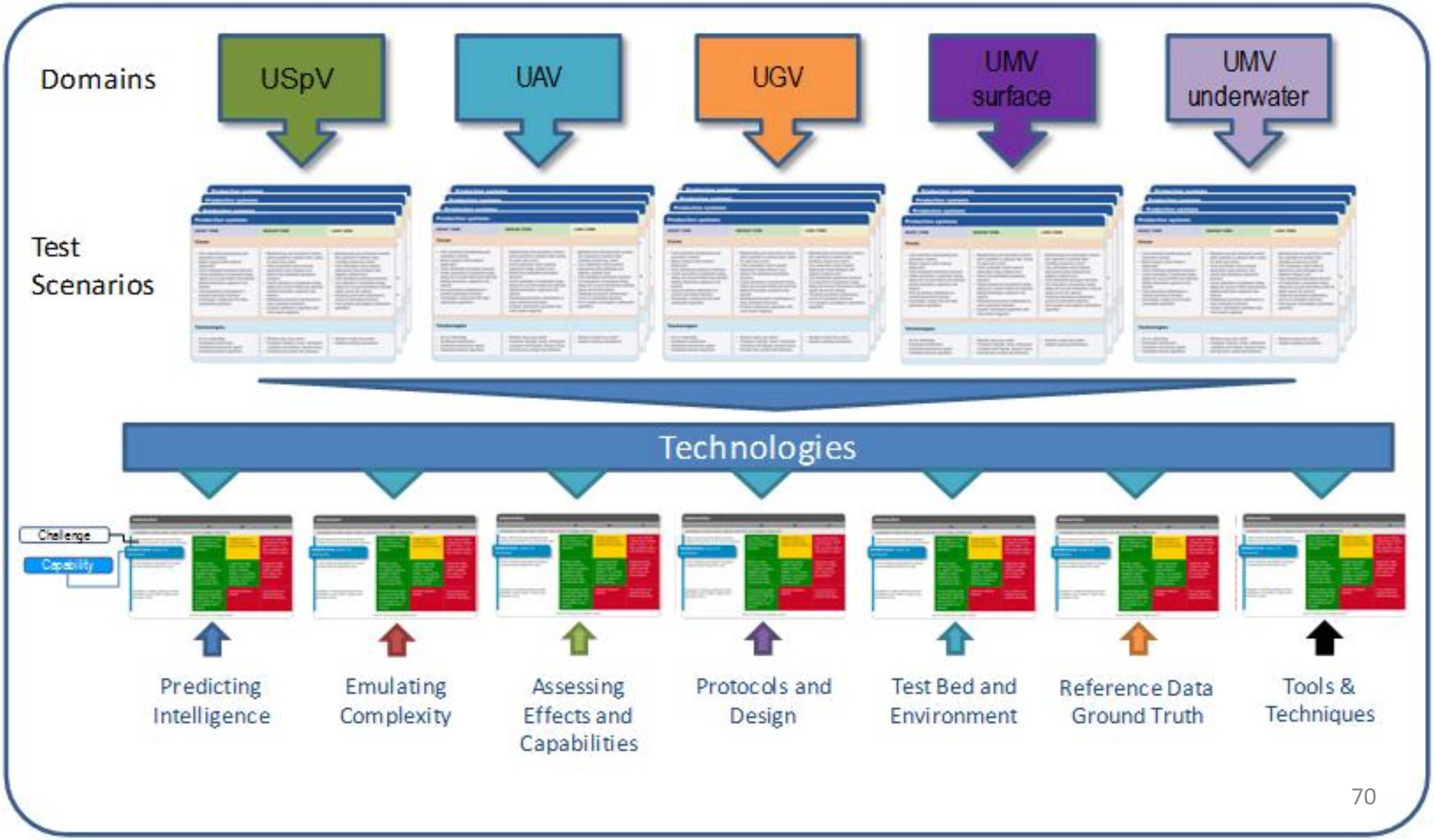
Do we need stair-step investment model as problem complexity increase?

Unmanned and Autonomous Systems Test (UAST)																	
UAST Predicting Unmanned and Autonomous System Intelligence																	
Tele-operated Systems						Multi-system Autonomy						Collaborative Autonomy					
FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY25	>FY25
UAST Predicting Unmanned and Autonomous System Intelligence																	
TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8
UAST Emulating Mission and Environmental Complexity																	
TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8
UAST Assessing Effects and Capabilities																	
TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8
UAST Protocols and Designs																	
TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8
UAST Test Bed and Environment																	
TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8
UAST Reference Data and Data Sets (Ground Truth, Decision, & Behavior)																	
TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8
UAST Tools and Techniques																	
TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8

UAST Roadmap 1

CH 29 Path Forward: Usage Case Driven Investment

COGNITIVE HAZARD UAST
Confidence in Unmanned & Autonomous Systems



UAST Roadmap 1

CH 29 Path Forward: Usage Case Driven Investment - Template

COGNITIVE HAZARD

UAST

Confidence in Unmanned & Autonomous Systems

Emphasis on Programs of Record and Operational Necessity

There are 138 systems in the USIR that are critical to understanding emergent autonomy and safety challenges. Gathering the tens of test use cases associated with each system will allow workgroup to identify patterns and then consolidate into high-value test cases that can drive UAST S&T.

UAST Case Number X: Top Level Use Case (a) – THE BASIC TEMPLATE

Use Case ID	Type	Domain	Tester	Evaluator	UAST Capability Framework	Use Case Label	USIR Performance Technology Driver	Performance / Technology
1	POR	ALL	x			Top Level Use Case (a)		
1		All			UAST Inv Area x	Top Level Use Case (a) – subcase (x)	Key Performance Parameter Forecast (i)	Performance
1		Ground			UAST Inv Area y	Top Level Use Case (b) – subcase (y)	Key Performance Parameter Forecast (j)	Technology

The USIR Forecasts of KPPs and KSAs (USIR Predictions)

KPP/KSA	p/t	Domain	UAST Framework Category	Epoch I	Epoch II	Epoch III
Key Performance Parameter Forecast (i)	p	Domain (all, air, ground, maritime)	UAST Investment Area x	Epoch I forecast for KPP forecast (i)	EPOCH II forecast for KPP forecast (i)	EPOCH III forecast for KPP forecast (i)
Key System Aspect Forecast (j)	t	Domain (all, air, ground, maritime)	UAST Investment Area y	Epoch I forecast for KPP forecast (j)	EPOCH II forecast for KPP forecast (j)	EPOCH III forecast for KPP forecast (j)

The T&E of Autonomous Behavior Needed to Meet Epoch Challenges (S&T of UAST)

KPP/KSA	p/t	Domain	UAST F. C.	UAST Use Case	Epoch I – S&T	Epoch II – S&T	Epoch III – S&T
Key Performance Parameter Forecast (i)	p	Domain (all, air, ground, maritime)	UAST Investment Area x	Top Level Use Case (a) – subcase (x)	S&T investment for epoch I	S&T investment for epoch II	S&T investment for epoch III
Key System Attributes Forecast (j)	t	Domain (all, air, ground, maritime)	UAST Investment Area y	Top Level Use Case (b) – subcase (y)	S&T investment for epoch I	S&T investment for epoch II	S&T investment for epoch III

- **Name:** Top Level Use Case (a) – the T&E challenge
- **Actors:** Stakeholder (Test Range Authority, Test Conductor, Evaluator, Test Engineer, UAST Capability Developer, UAS Test PM, UAS PEO, Warfighter)
- **Systems:** UAS(i), any system target for future testing [PORs: xxxx, yyyy, zzzz]
- **Use Case Level:** UCRL 2. Practitioner First Draft Reviewed by EA and SMEs
- **Description (subclass use cases by mission, domain, and USIR epoch):**
- Develop UAST(i), technologies for autonomy and safety testing
- USIR Subclass 1) KPP and domain – S&T investment
- USIR Subclass 2) KSA and domain – S&T investment

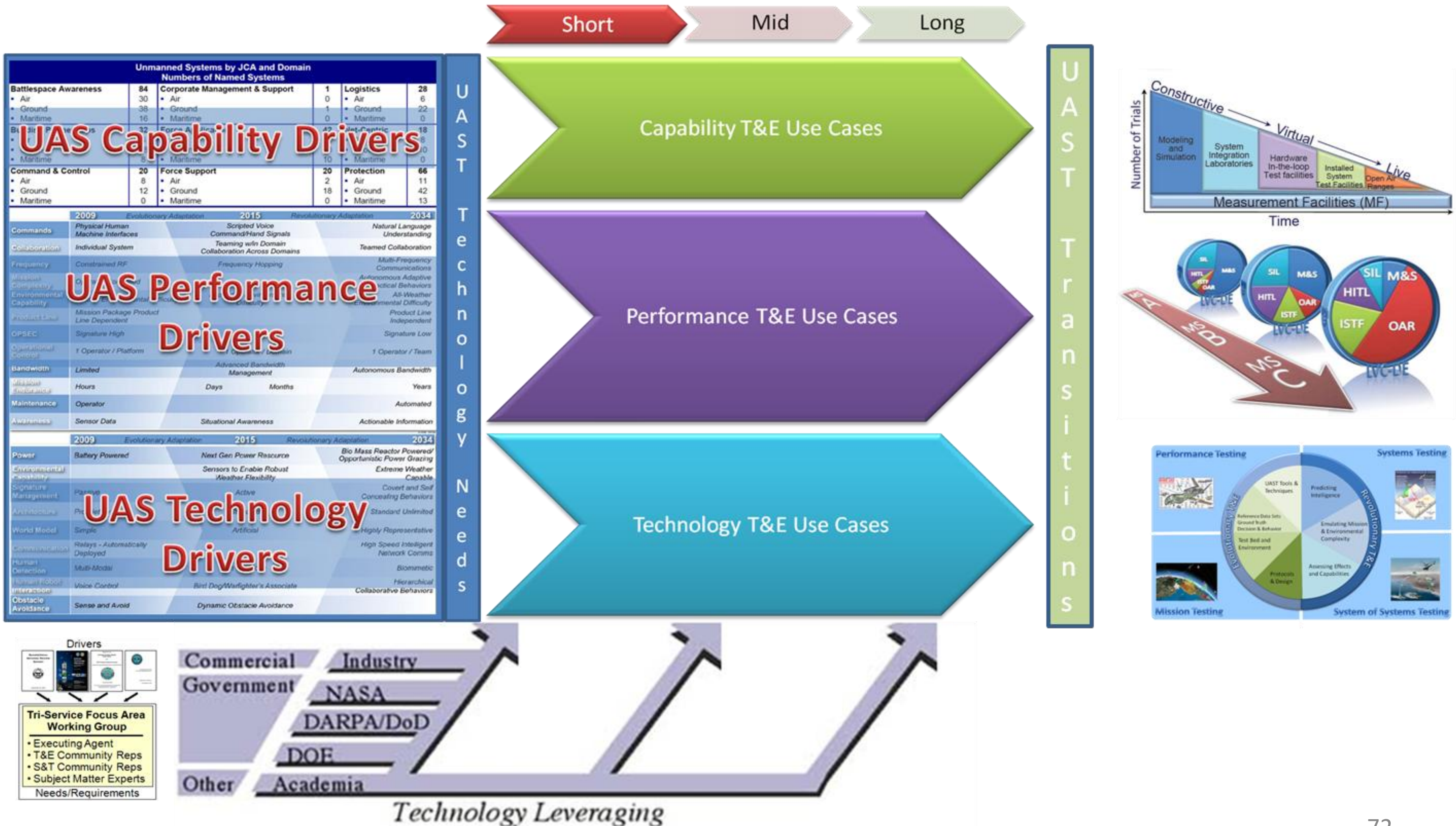
UAST Roadmap 1

CH 30 Path Forward: The Larger Picture

COGNITIVE HAZARD

UAST

Confidence in Unmanned & Autonomous Systems



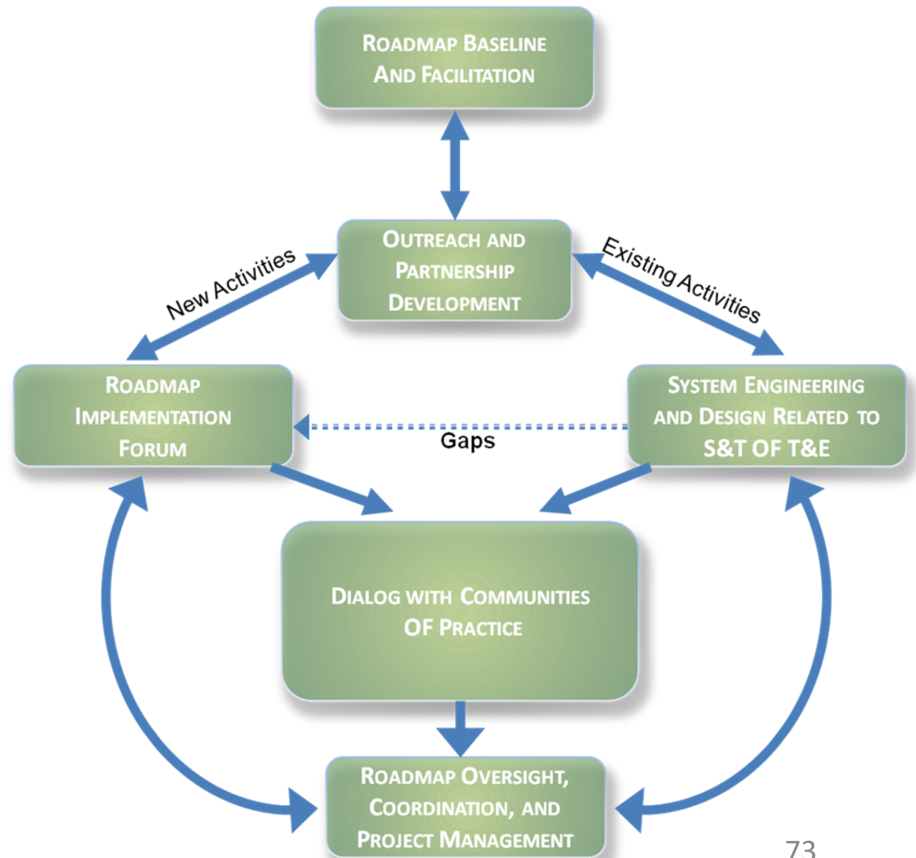
UAST Roadmap 1

CH 31 Path Forward: The Need for an Agile Roadmap Process

COGNITIVE HAZARD
UAST
Confidence in Unmanned & Autonomous Systems

Is the Pace and Tempo of T&E capability development sufficient for rapid acquisition and exponential technology associated with UAS?

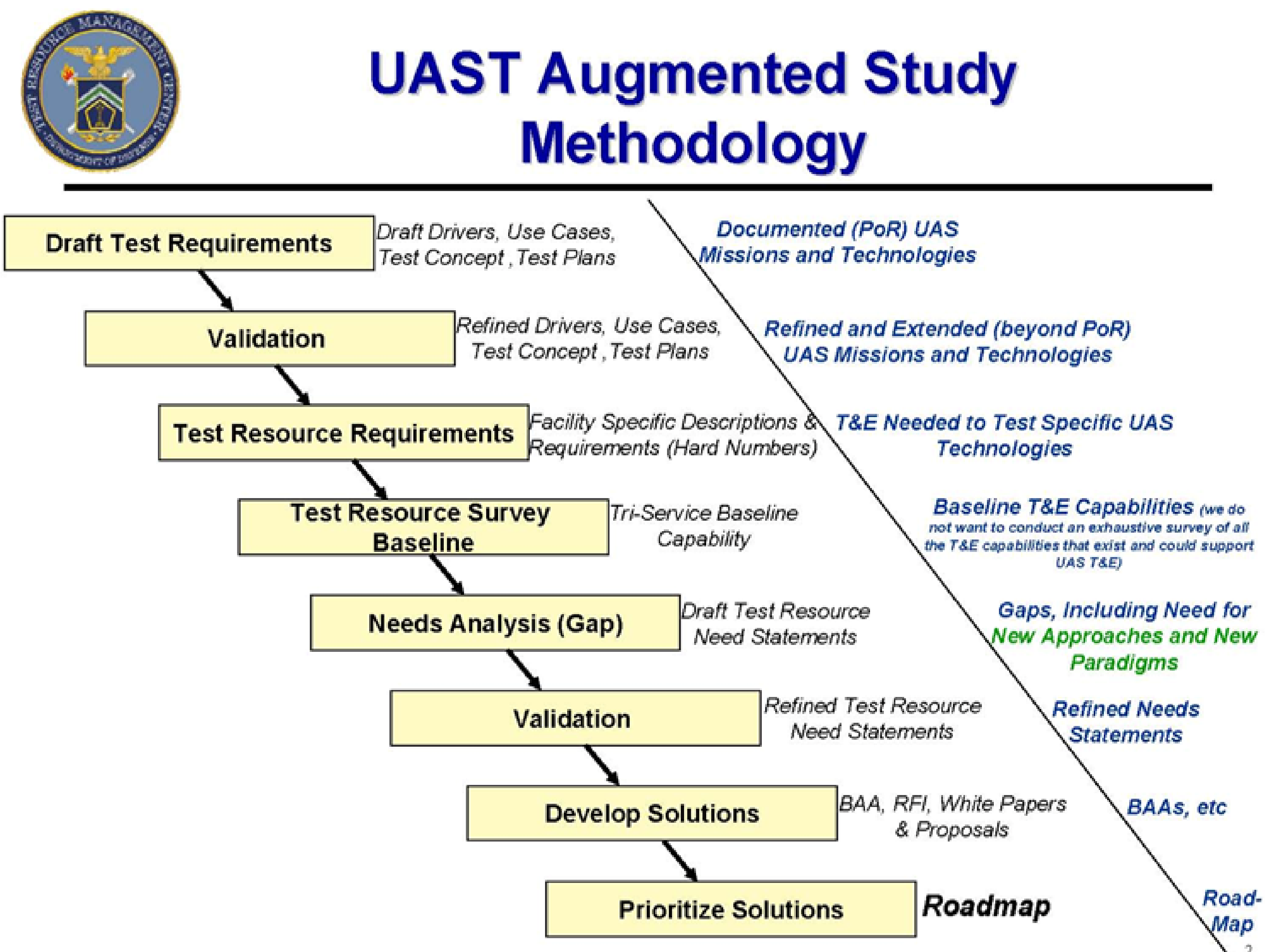
The intent of this Roadmap is to introduce concepts that will facilitate the test and evaluation of unmanned and autonomous systems.. The performance and technical challenges for test are extensive. T&E Capabilities typically take 7 years to develop. There is a nurturing of the technology in an S&T program for 3 years followed by 4 years of development in a CTEIP programs. CTEIP programs typically provide the drivers for S&T. Key drivers from CTIEP programs include Program of Record drill downs that are based on the acquisition documents driving both Test and Evaluation. Typically a Program of Record has a T&E strategy, a CONOPS, an ICD, a CDD, and finally a TEMP that must all be explored for specific requirements critical to the T&E of any System Under Test.



UAST Roadmap 1

CH 31 Path Forward: The Need for an Agile Roadmap Process

COGNITIVE HAZARD
UAST
Confidence in Unmanned & Autonomous Systems



- PORs currently have limited drivers for UAST driven by autonomy
- USIR introduced concept that NPORs are critical for understanding future need
- T&E for autonomy can be forecast based on performancee and technology forecasts that will only be possible due to increased automation and autonomy
- The need for autonomy test continues to be articulated

UAST Roadmap 1

CH 32 Summary Recommendation

COGNITIVE HAZARD

UAST

Confidence in Unmanned & Autonomous Systems

The realization of the technology targets will require continued investment in the UAST technology group for usage case development and criteria consolidation. The promise of UAS can be realized through next generation UAST developments necessitating the need for:

1. Field Office focused on the S&T for T&E of Autonomy with Assured Safety
   a. to facilitate development joint actions with two or more transition partners
   b. to engage up to five test centers to demonstrate the return on S&T investments
   c. to lead development of usage cases for clarifying and justifying TRL advancements needed for selected T&E demonstrations
   d. to oversee authorized S&T developments and identify other relevant technology advancements
   e. to oversee integration of S&T developments for autonomy with assured safety into new UAST capabilities
   f. to oversee the integration of these S&T results with S&T results by other technology groups such as net-centric, cognitive, etc.
   g. to monitor and assess UAS testing sessions to assess the value of the S&T advancements
   h. to initialize a portal for "T&E of autonomy with assured safety”
   i. to foster new relevant education through DAU
2. Resources for authoring usage cases in response to the Roadmap: includes quarterly face to face working sessions at various test centers for cross review and consolidation as well as budget justification. Also includes review and assessment of on-going S&T projects.
3. Resources for evolving the Autonomy with Assured Safety T&E capability at the pace of UAS evolutionary acquisition and Test Range evolution: includes technology development planning and budgeting session to be conducted at a level of 2 days per month with 15 people from test centers engaging in the S&T roadmap; plus technical support and session facilitation.
4. Resources for hosting collaboration with autonomy experts at NASA, DoE, FAA, and Academia in quarterly sessions.

Predicting Unmanned and Autonomous System Behaviors

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Epoch I	Epoch II	Epoch III

T&E/S&T Investments

Epoch I	Epoch II	Epoch III
Perception limit tool - single-agent collaboration	Perception limit tool - multi-agent collaboration	Perception limit tool - collaborative teaming
Automated performance predictor - Tele-operated	Automated performance predictor - Semi-autonomous	Automated performance predictor - Autonomous
Cognitive Model Human Machine Independence - Multi-Modal	Cognitive Model Human Machine Independence - On the Move	Cognitive Model Human Machine Independence - Biomemetic
Autonomy Level Metering - Tele-operated	Autonomy Level Metering - Semi-autonomous	Autonomy Level Metering - Autonomous
Test Model Correlation Tools – Tele-operated	Test Model Correlation Tools - Semi-autonomous	Test Model Correlation Tools - Autonomous
Sense and Avoid - Simplest Task / Man Dependent SA / Off Board SA	Sense and Avoid - Limited adaptation, Real-time, Planning SA	Sense and Avoid - Fully Real-Time Planning, Team of Teams Collaboration, Fully Auto / On Board SA
Safety Precepts for Distinguishing Criticality – Tele-operated	Safety Precepts for Distinguishing Criticality - Semi-autonomous	Safety Precepts for Distinguishing Criticality - Autonomous

Challenges

Epoch I	Epoch II	Epoch III
Remote Control Visualization & Computation	Teamed Autonomy Visualization & Computation	Collaborating Autonomy Visualization & Computation
ALFUS Level 1-4 Prediction	ALFUS Level 4-6 Prediction	ALFUS Level 6-10 Prediction
Remote Control Sense and Avoid	Teamed Autonomy Sense and Avoid	Collaborating Autonomy Sense and Avoid

T&E Capability

Predicting Unmanned and Autonomous System Behaviors

Emulating Mission and Environmental Complexity with Assured Safety

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Epoch I					Epoch II					Epoch III				

T&E/S&T Investments

SCUUL – Synthetic Collective Underwater Unmanned Laboratory

Epoch I

- Test Frameworks & Harnesses – tele-operated
- Behavior Stimulation
- Terrain and Ground Truth
- Framework Emergent Phenomena - static
- Fail Safes – single platform
- Mechanisms for Sense and Avoid - single
- Mitigation Tools Unpredictable Behavior - single

SCUUL

Epoch II

- Test Frameworks & Test Harnesses - Semi-autonomous
- Behavior Stimulation
- Terrain and Ground Truth
- Framework Emergent Phenomena - dynamic
- Fail Safes – teamed platforms
- Mechanisms for Sense and Avoid - teamed
- Mitigation Tools Unpredictable Behavior- teamed

Epoch III

- Test Frameworks & Test Harnesses
- Behavior Stimulation
- Terrain and Ground Truth
- Framework Emergent Phenomena – natural and collaborative
- Fail Safes – collaborating platforms
- Mechanisms for Sense and Avoid -collaborative
- Mitigation Tools Unpredictable Behavior - - teamed

Challenges

Epoch I

- Unmanned Autonomy in Mission Complexity
- Unmanned Autonomy in Environmental Complexity
- Safety of Remote Control

Epoch II

- Teamed Autonomy in Mission Complexity
- Teamed Autonomy in Environmental Complexity
- Safety of Teaming

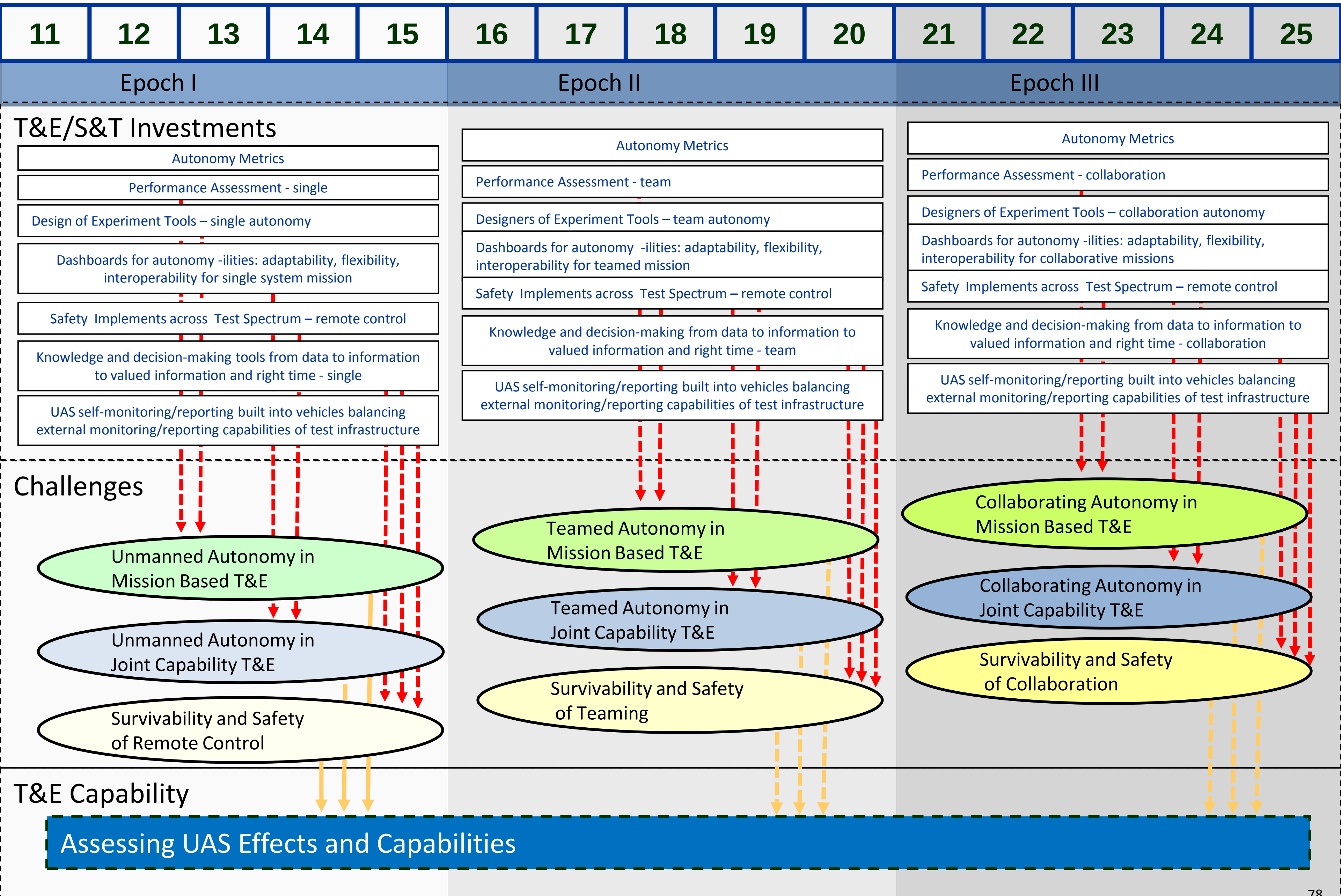
Epoch III

- Collaborating Autonomy in Mission Complexity
- Collaborating Autonomy in Environmental Complexity
- Safety of Collaboration

T&E Capability

Emulating Mission and Environmental Complexity with Assured Safety

Assessing UAS Effects and Capabilities



Autonomous Test Protocols and Design

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Epoch I					Epoch II					Epoch III				

T&E/S&T Investments

Epoch I

Ontology of UAS:
- Types of Testing (individual to swarms)
- Autonomy of UAS
- Classes of UAS

Methodology of UAST:
- Analysis of Alternatives
- Stimulus and Measures
- UAS Dynamic, Integrity and Safety Limits

Test Scenario synthesis:
- System to Capability Testing
- UAS interfaces to Test Construct

Test analysis, interpretation, knowledge claims, and reporting

UAST (I) configuration Model Generation

Cross-UAS Usage Case Repository

Epoch II

Ontology of UAS:
- Types of Testing (individual to swarms)
- Autonomy of UAS
- Classes of UAS

Methodology of UAST:
- Analysis of Alternatives
- Stimulus and Measures
- UAS Dynamic, Integrity and Safety Limits

Test Scenario synthesis:
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- UAS interfaces to Test Construct

Test analysis, interpretation, knowledge claims, and reporting

UAST (I) configuration Model Generation

Cross-UAS Usage Case Repository

Epoch III

Ontology of UAS:
- Types of Testing (individual to swarms)
- Autonomy of UAS
- Classes of UAS

Methodology of UAST:
- Analysis of Alternatives
- Stimulus and Measures
- UAS Dynamic, Integrity and Safety Limits

Test Scenario synthesis:
- System to Capability Testing
- UAS interfaces to Test Construct

Test analysis, interpretation, knowledge claims, and reporting

UAST (I) configuration Model Generation

Cross-UAS Usage Case Repository

Challenges

Epoch I
- Unmanned Autonomy Protocols
- Unmanned Autonomy Cyber Threats
- Design of Experiments Remote Control

Epoch II
- Teamed Autonomy Protocols
- Teamed Autonomy in Environmental Complexity
- Design of Experiments Teaming

Epoch III
- Collaborating Autonomy Protocols
- Collaborating Autonomy in Environmental Complexity
- Design of Experiments Collaboration

T&E Capability

Autonomous Test Protocols and Design

Test Bed and Environments for UAST

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Epoch I					Epoch II					Epoch III				

T&E/S&T Investments

Epoch I
- Stimulus selection or generation
- Sensors
- Data Acquisition and Management
- Data Compression and Characterization (signatures)
- Data reduction/analysis/interpretation
- Power Technologies: Providing increased mission time and capability without increasing the logistics footprint
- Test conducting including situation awareness
- Test operation Safety
- FAA and other Civil Coordination
- C4ISR Interoperability

Epoch II
- Stimulus selection or generation
- Sensors
- Data Acquisition and Management
- Data Compression and Characterization (signatures)
- Data reduction/analysis/interpretation
- Power Technologies: Providing increased mission time and capability without increasing the logistics footprint
- Test conducting including situation awareness
- Test operation Safety
- FAA and other Civil Coordination
- C4ISR Interoperability

Epoch III
- Stimulus selection or generation
- Sensors
- Data Acquisition and Management
- Data Compression and Characterization (signatures)
- Data reduction/analysis/interpretation
- Power Technologies: Providing increased mission time and capability without increasing the logistics footprint
- Test conducting including situation awareness
- Test operation Safety
- FAA and other Civil Coordination
- C4ISR Interoperability

Challenges

Epoch I
- Unmanned Autonomy System Evaluation
- Unmanned Autonomy in Test Management
- Range Safety of Remote Control

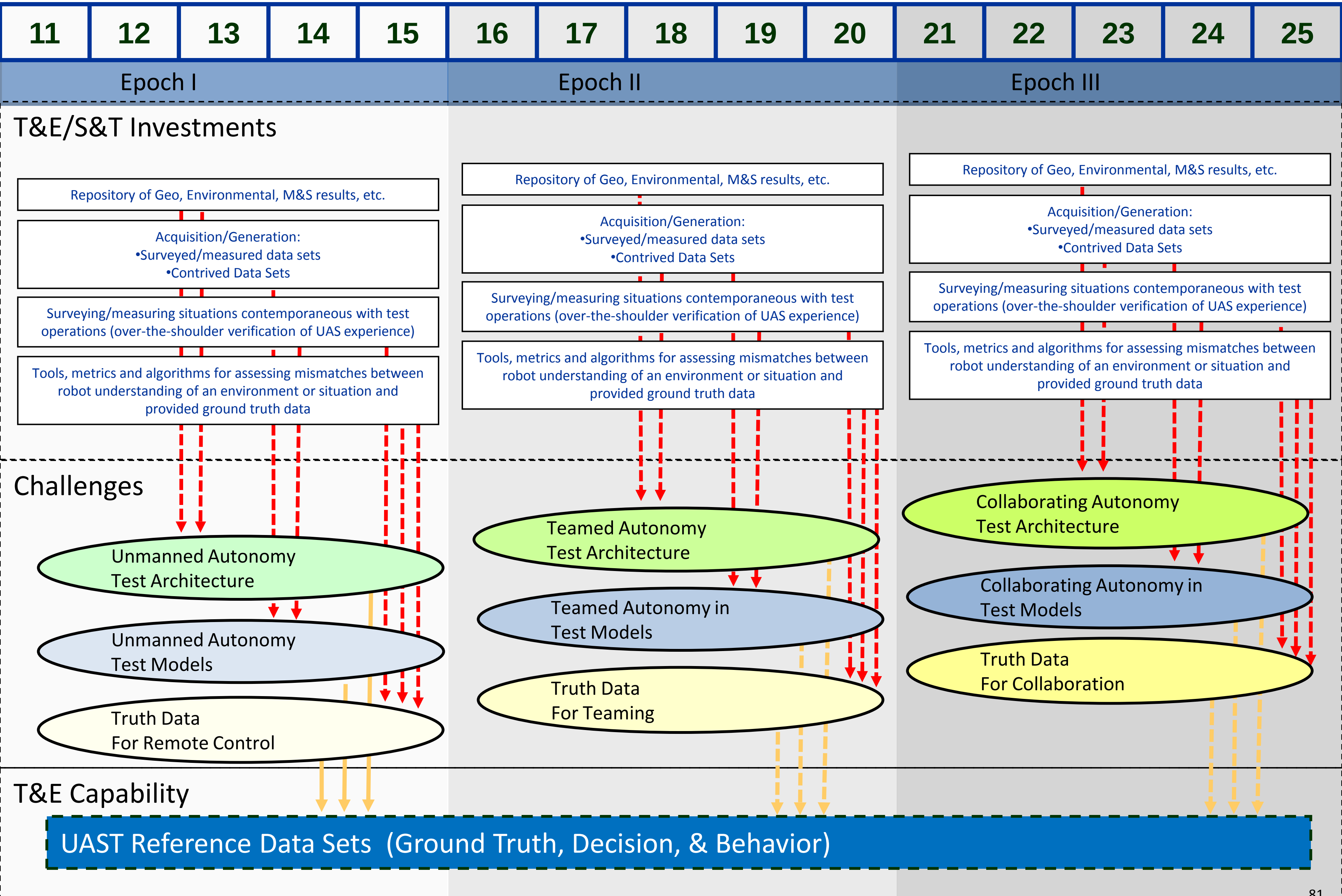
Epoch II
- Teamed Autonomy in System Evaluation
- Teamed Autonomy in Test Management
- Range Safety of Teaming

Epoch III
- Collaborating Autonomy in System Evaluation
- Collaborating Autonomy in Test Management
- Range Safety of Collaboration

T&E Capability

Test Bed and Environments for UAST

UAST Reference Data Sets
(Ground Truth, Decision, & Behavior)



Tools and Techniques for Systemic UAST

11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Epoch I					Epoch II					Epoch III				

T&E/S&T Investments

Epoch I

- Analysis of Test Requirements
- Architecture/Design of Test episodes
- Test Planning/Timeline
- Evaluating UAS Effectiveness
- Discovering UAS capability limits
- Evaluating likelihood of fratricide
- Evaluating likelihood of cyber security intrusion
- Assessing the risk of errors and omissions in test findings
- Quantifying cost-effectiveness of UAST configuration used
- Systemizing UAST(s) as a composable infrastructure that supports test-specific, plug-in modules

Epoch II

- Analysis of Test Requirements
- Architecture/Design of Test episodes
- Test Planning/Timeline
- Evaluating UAS Effectiveness
- Discovering UAS capability limits
- Evaluating likelihood of fratricide
- Evaluating likelihood of cyber security intrusion
- Assessing the risk of errors and omissions in test findings
- Quantifying cost-effectiveness of UAST configuration used
- Systemizing UAST(s) as a composable infrastructure that supports test-specific, plug-in modules

Epoch III

- Analysis of Test Requirements
- Architecture/Design of Test episodes
- Test Planning/Timeline
- Evaluating UAS Effectiveness
- Discovering UAS capability limits
- Evaluating likelihood of fratricide
- Evaluating likelihood of cyber security intrusion
- Assessing the risk of errors and omissions in test findings
- Quantifying cost-effectiveness of UAST configuration used
- Systemizing UAST(s) as a composable infrastructure that supports test-specific, plug-in modules

Challenges

Epoch I

- Unmanned Autonomy False Positives/Negatives
- Unmanned Autonomy Dynamic & Functional Limits
- Unmanned Autonomy Enterprise Tools

Epoch II

- Teamed Autonomy i False Positives/Negatives
- Teamed Autonomy Dynamic & Functional Limits
- Teamed Autonomy Enterprise Tools

Epoch III

- Collaborating Autonomy False Positives/Negatives
- Collaborating Autonomy Dynamic & Functional Limits
- Collaborating Autonomy Enterprise Tools

T&E Capability

Tools and Techniques for Systemic UAST