Systems Engineering Analysis Cohort 24 (SEA-24)

"High Altitude ASW for the P-8A"

FPR

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Overall Brief Classification: UNCLASSIFIED

SEA-24 Cohort Members

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Surface Warfare Officer

UTAS Project Objective

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(U) Project objective is to develop a System of Systems (SoS) utilizing an expendable Unmanned Targeting Air System (UTAS) with an integrated Magnetic Anomaly Detection (MAD) system to enhance the P-8A's High Altitude ASW operations.

Two Concepts of Employment

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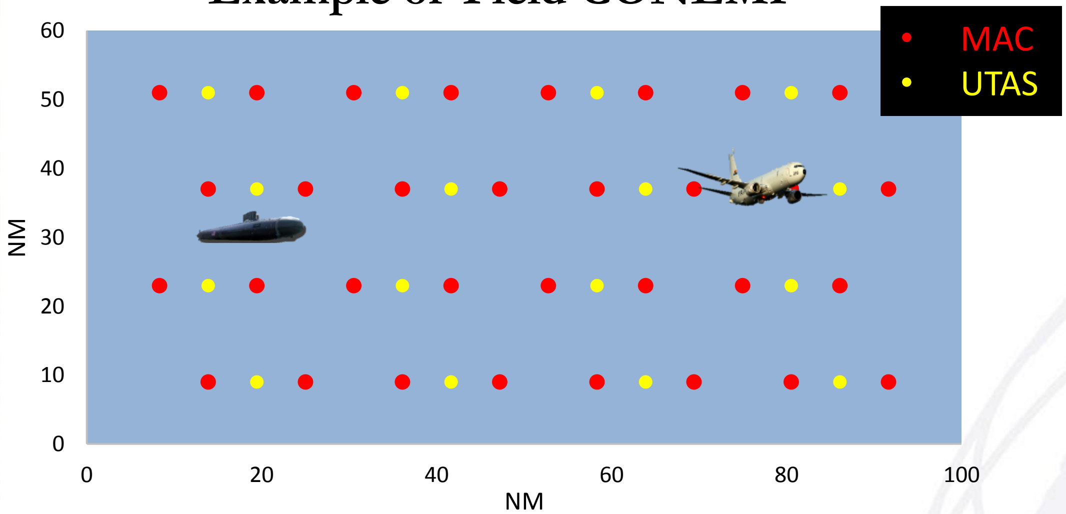
Example of Field CONEMP



(U) As part of the System of Systems development, two concept of employment to conduct effective High Altitude ASW with a P-8A and UTAS were formulated

Concept of the Employment

- **(U) Field:**
  - UTAS employed concurrently with the 32-post MAC sonobuoy field
  - UTAS loiter in an evenly distributed hexagonal pattern until MAC contact
- **(U) Swarm:**
  - P-8A transits to location of contact and employs one or multiple UTAS

BLUF

(U) The use of autonomous UTAS is a cost-effective solution to improve the High Altitude ASW capability of the P-8A

Dependent on the concept of employment and mission requirements

- **(U) Hunt & Kill ASW Mission:**
  The Field CONEMP with 16 UTAS significantly reduced time latency of a UTAS asset to the contact location
- **(U) Routine Maritime Patrol/ASW Mission:**
  The Swarm CONEMP is a lower cost alternative while still improving the P-8A ASW mission
- **(U) Most Important Future Development: Endurance**
  Improvements to UTAS endurance enables the continuous performance of Field CONEMP for duration of P-8A ASW mission

CAPSTONE Timeline

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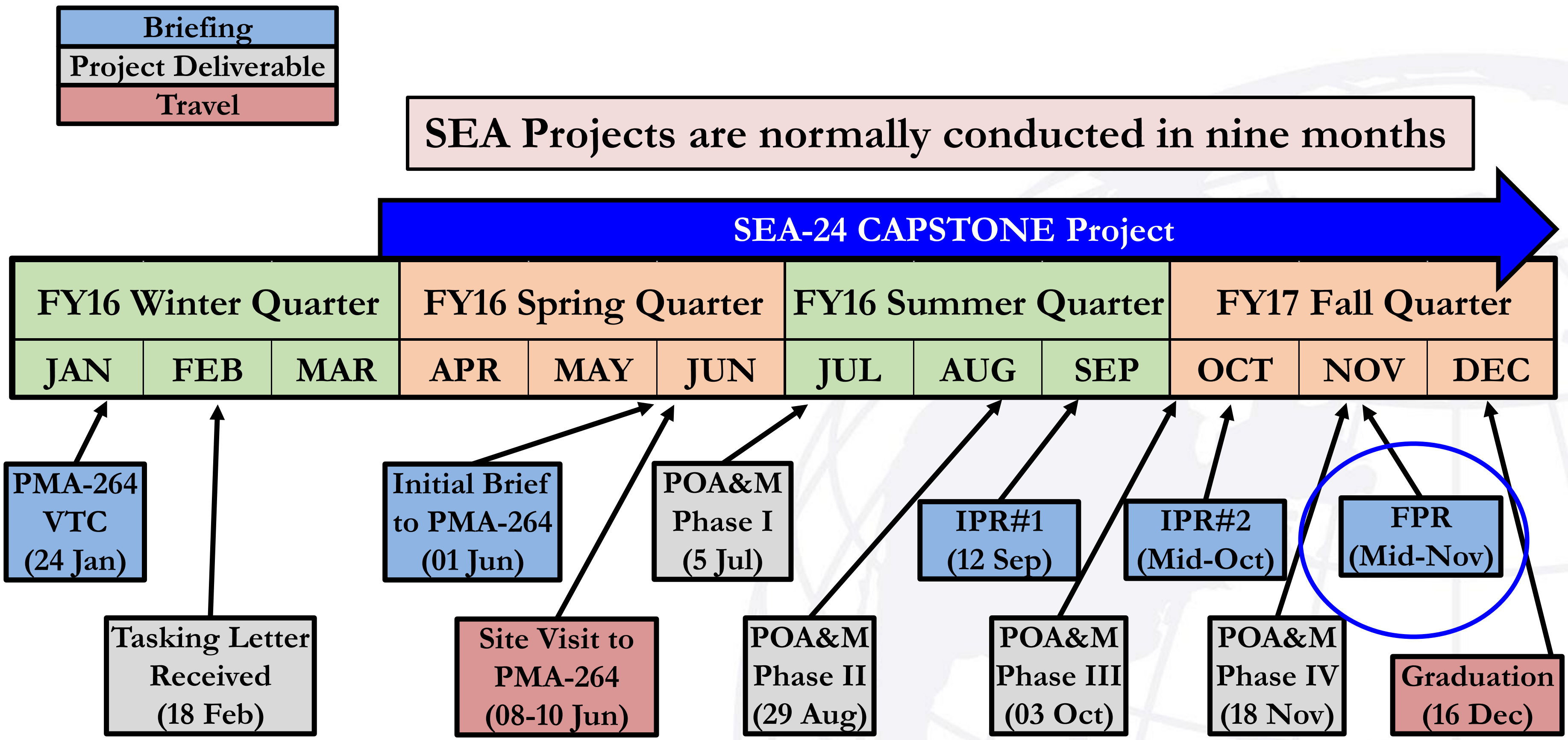

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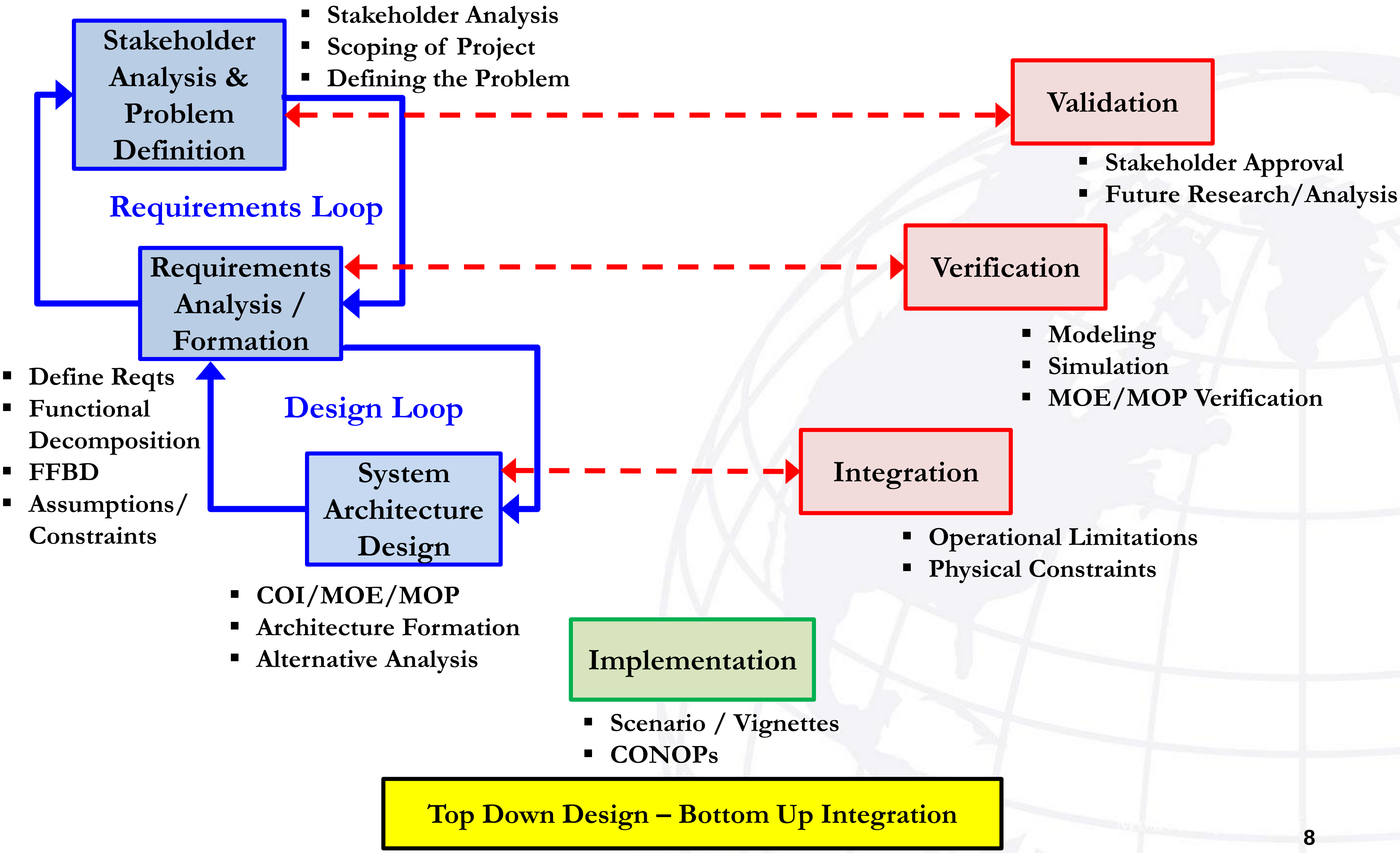
Tasking Scoped Further

(U) Scoped Tasking:

(U) SEA-24 will investigate a systems of systems (SoS) centered around the P-8A Poseidon and the Coyote® Unmanned Targeting Air System (UTAS) with MAD sensor in an attempt to reduce the time to Find, Fix, Track, Target, and Engage (F2T2E) a submarine while carefully considering cost, operator task saturation, P-8A sonobouy storage capacity, and projected technological advancements in the 2025-2030 timeframe to ensure each system architecture is a viable system in support of High Altitude ASW (HAASW) operations.

Systems Engineering “V”



Stakeholders

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NPS
Monterey, CA

COMNAVAIRFOR
Coronado, CA

OPNAV
Washington, D.C.

NAVAIR ASW
Systems PMA-264
Patuxent River, MD

Primary:
- NAVAIR ASW Systems (PMA-264)
- OPNAV Warfare Integration (N9I)

Secondary:
- OPNAV Air Warfare (N98)
- Commander, Naval Air Forces (CNAF)
- Naval Postgraduate School (NPS)

Requirements

(U) Project Tasking Requirements:

(U) The System of Systems (SoS) shall:

1. Provide extended search and detection capability for the P-8A
2. Provide sufficient information to support effective ASW operations
3. Operate in a challenging electromagnetic (EM) environment

(U) Scoped Requirements:

(U) The System of Systems (SoS) shall:

1. Employ an Unmanned Targeting Air System (UTAS) from P-8A with Magnetic Anomaly Detection (MAD) sensor
2. Minimize time required to Find, Fix, Track, Target, & Engage a submarine.

Enhanced FFBD

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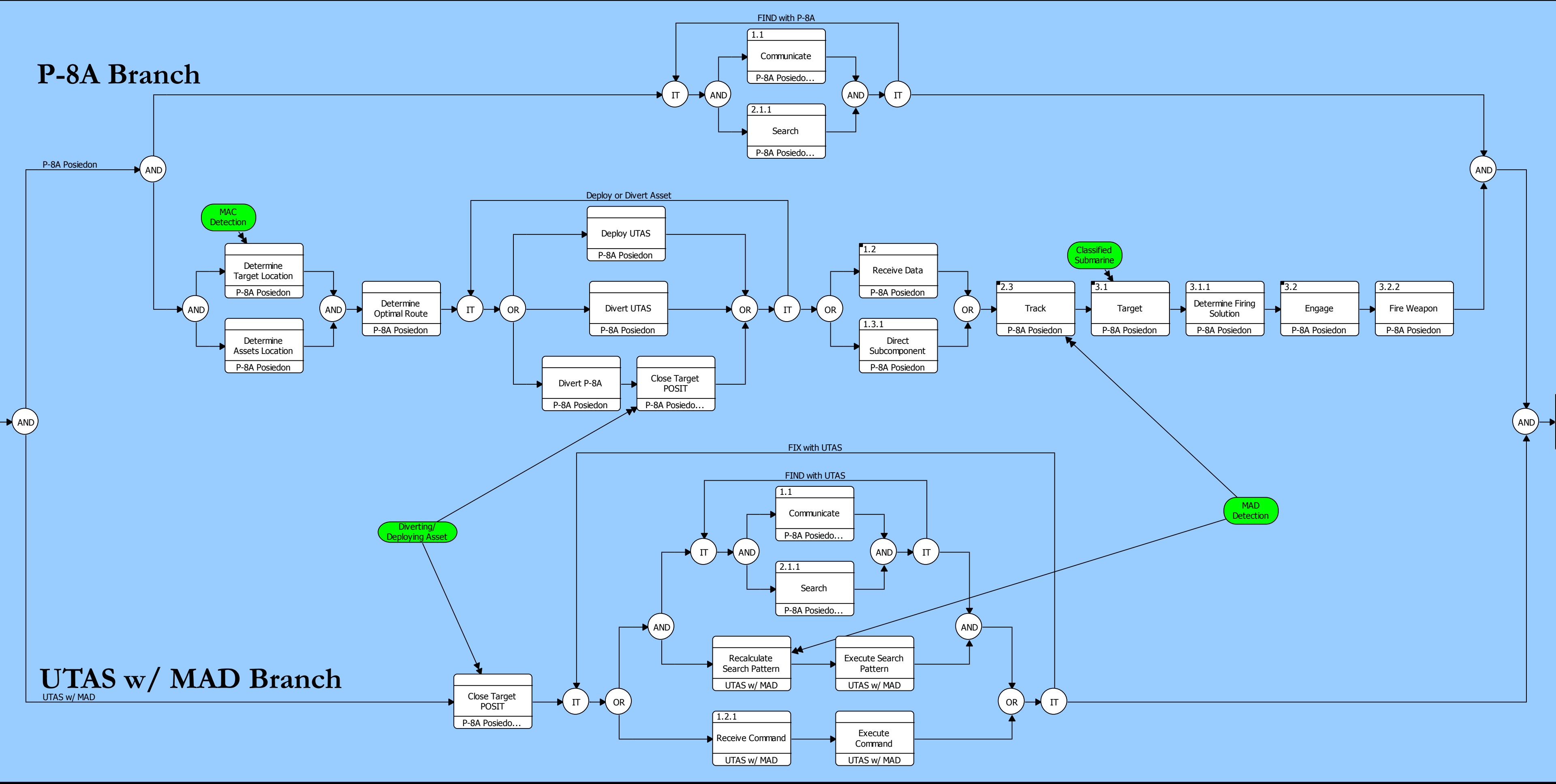
"Prosecuting a Submarine with P-8A"



(U) Functional sequencing assists with computer-based model creation

Scenario Description (SIPR)

Critical Assumptions

- (U) Initial MAC Area of Uncertainty (AOU) (XX NM radius)
- (U) P-8A operational speed and mission time (350 kts / 5 hrs)
- (U) P-8A probability of localization using legacy sonobuoys (0.70)
- (U) TACSIT (Air/Surface/Water Space)
- (U) Phase of Hostilities / Weapons Release
- (U) MAD detection equates to localization (UTAS maneuvering)
- (U) Environmental variations ignored
  - Wind Speed, Sound Propagation, XBT Conditions
- (U) 32-36 UTAS allocated for total P-8A mission
  - Based upon XXX total SLC storage capacity

Red text indicates classified information

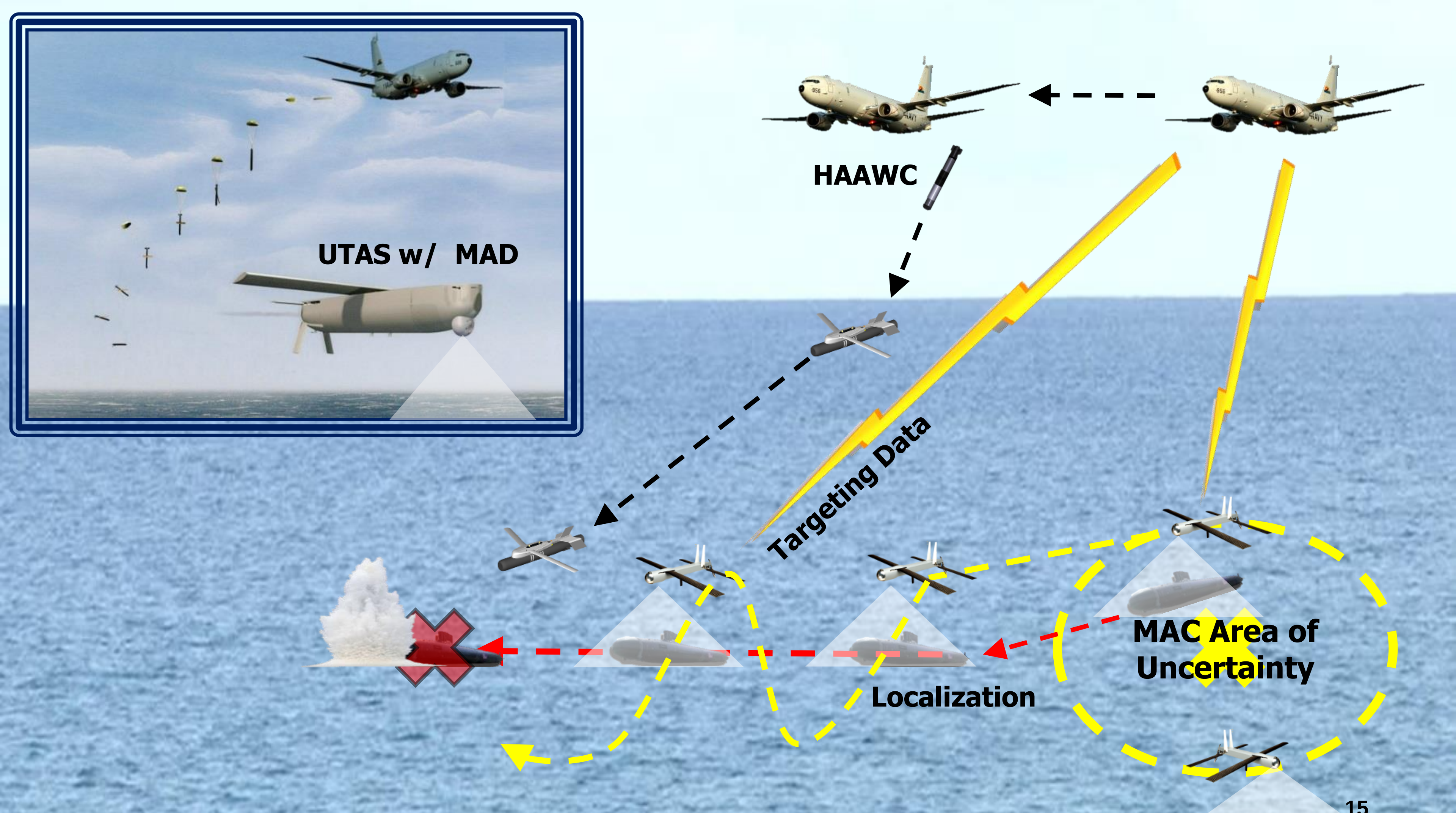
Initial Operational Concept

(U) "The Magnetic Anomaly Detection (MAD) for Unmanned Targeting Air System (UTAS) project will develop and deliver a remotely piloted small or midsize UTAS capable of being launched from the P-8A. UTAS will have a digital magnetometer sensitive enough to detect a threat submarine at a specified slant range." – PMA-264

Initial CONOPs (SIPR)

Operational Concept

High Altitude ASW w/ P-8A



KPP MOE/MOP

(U) Key Performance Parameters mapped to applicable MOE/MOP will be focus point of modeling/simulation and follow-on analysis

(U) Primary KPP: Time to Complete F2T2E

- MOE – Effectiveness of system at ASW operations given varying architectures
  - MOP – Mean time to complete F2T2E

(U) Secondary KPP: Probability of Detection

- MOE – Effectiveness of system at ASW operations given varying architectures
  - MOP – Total probability of detection given architecture
  - MOP – Mean time to lay MAC field

(U) Tertiary KPP: Endurance

- MOE – UTAS operational endurance
  - MOP – Probability of detection given UTAS endurance

(U) CAIV: Cost as an Independent Variable

Design Variables

(U) In order to flex the performance of the system, several design variables were varied for sensitivity analysis

(U) Design Variables

- **UTAS speed:**
  70, 85, 100, 110 (knots)
- **Sub speed:**
  3, 6.5, 10 (knots)
- **Number of MAC contacts:**
  6 "worst case" contacts
- **Field CONEMP:**
  8, 12, 16 (Number of UTAS)
- **Swarm CONEMP:**
  1, 2, 3, 4 (Number of UTAS)

(U) Design Constants

- **Op Area dimensions**
  100 NM x 60 NM
- **MAD sweep width**
  1 NM
- **P-8A on-station time**
  5 hour mission
- **P-8A speed**
  350 kts
- **P-8A sonobuoy storage**
  XXX SLC capacity

Model Construction

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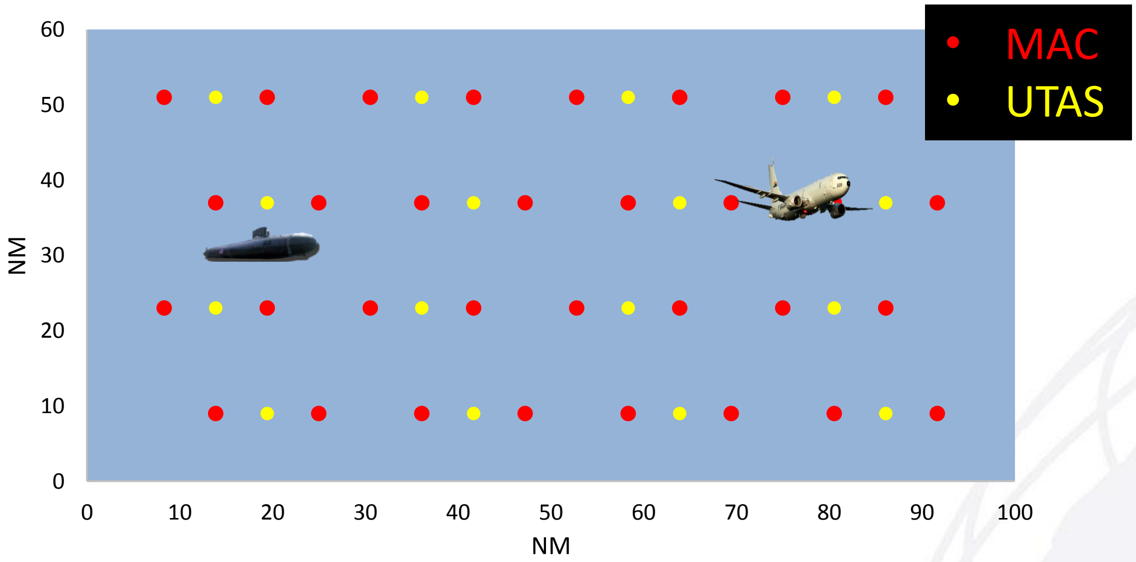

(U) Key Inputs

- UTAS speed
- P-8A speed
- Sub speed
- MAD sweep width
- MAC hit location/time
- # of MAC hits

- (U) Computer-based Monte Carlo simulation using Distribution Processing
- (U) Time-based model analyzing fly-to times to place a UTAS on station at a MAC contact location
- (U) MAC contact populated at a random time and random location
- (U) P-8A will deploy UTAS concurrently with MAC for Field CONEMP
- (U) Tracking the location of the P-8A is crucial for Swarm CONEMP

Field has Shortest Time Latency

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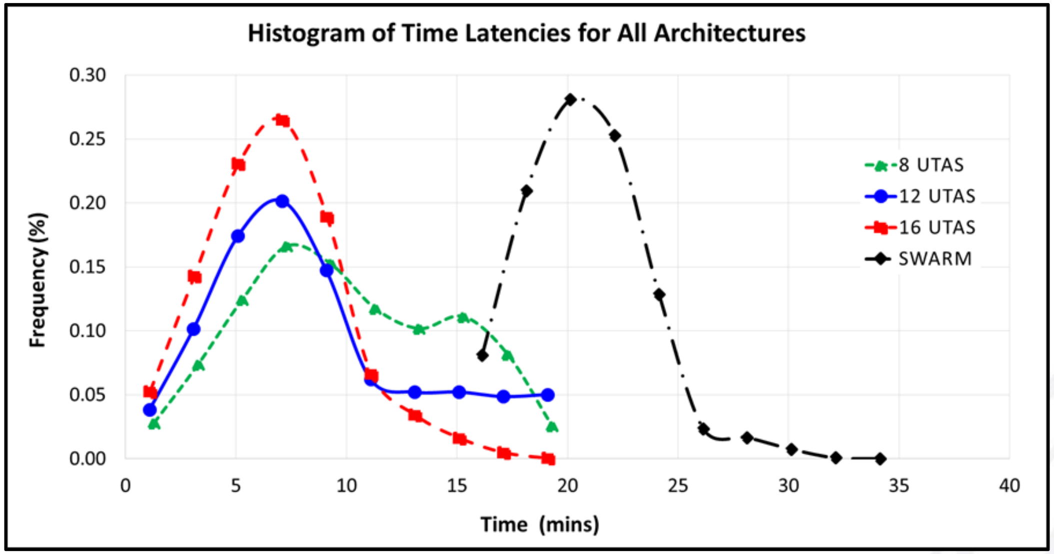
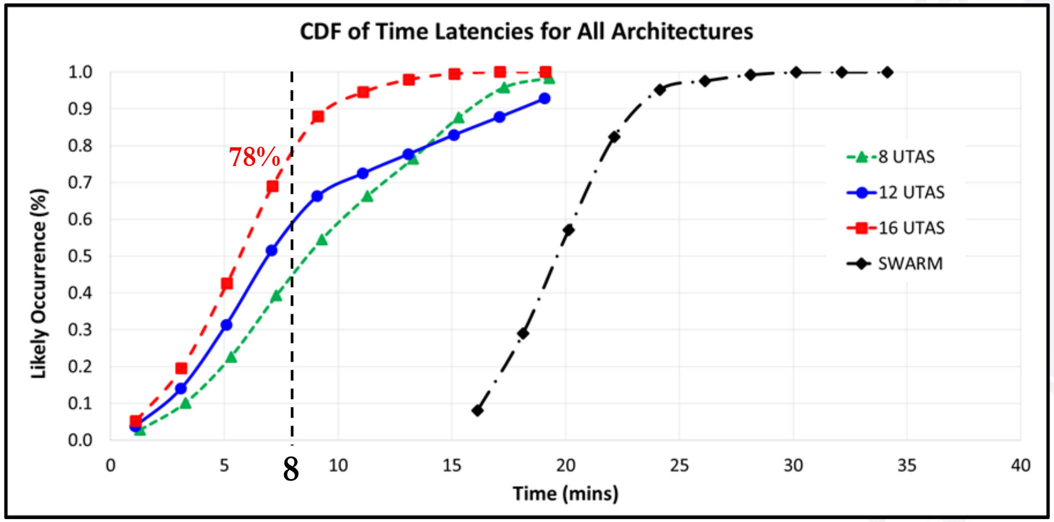




70-knot UTAS speed

(U) P-8A Fly-To Time

- Mean: 20.7 mins
- 90% CI: 16.6 - 25.1 mins

(U) 16U Field Fly-To Time

- Mean: 6.8 mins
- 90% CI: 2.1 - 12.3 mins

Field CONEMP achieves shorter time latency to contact location than P-8A

- 8 mins time latency achieves 0.7 probability of localization 14 mins after MAC contact
- Likelihood to achieve 8 mins:
  - 16U: 78% likely
  - P-8: 0% likely

Flaming Datum Search

(U) Origin:

- The Flaming Datum problem is one of relocating an enemy target that is fleeing after momentarily revealing its position (i.e. submarine engagement)
- Time-varying area resulting from latency of ASW asset on-station time

(U) Challenge:

- How can we get an ASW asset to the MAC datum as quickly as possible?

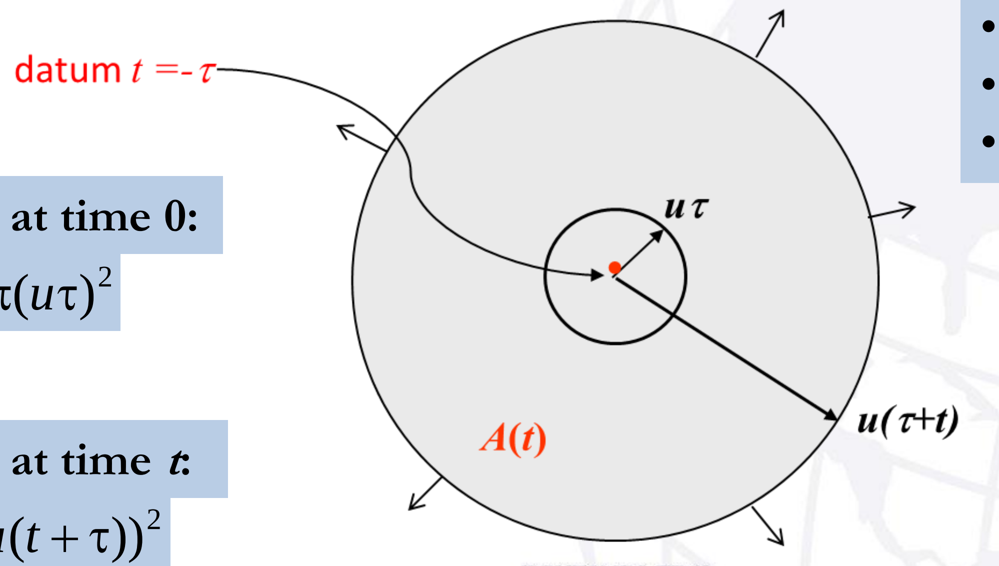
- Target evasion speed, u
- Search speed, v
- Time late, τ

Search area at time 0:

$$A(0) = \pi(u\tau)^2$$

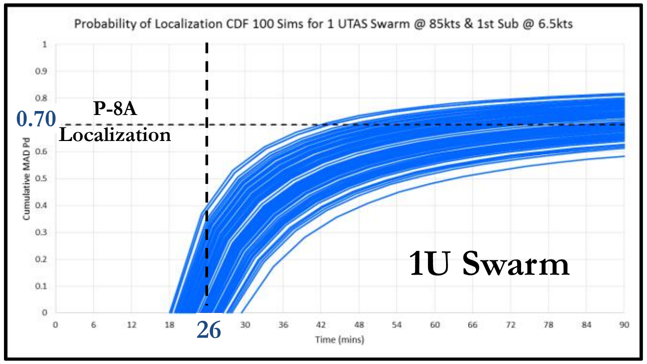
Search area at time t:

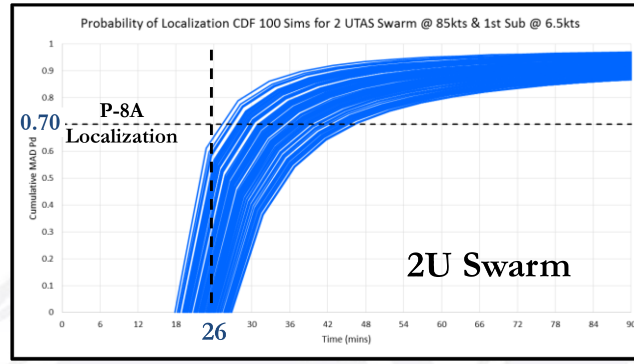
$$A(t) = \pi(u(t+\tau))^2$$



CONEMP Comparison

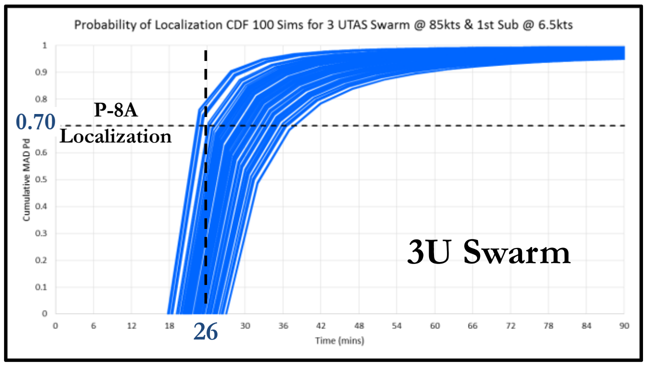
UTAS: 85kts / Sub: 6.5kts

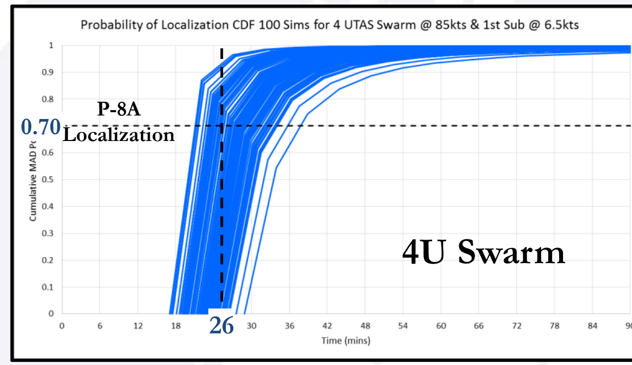




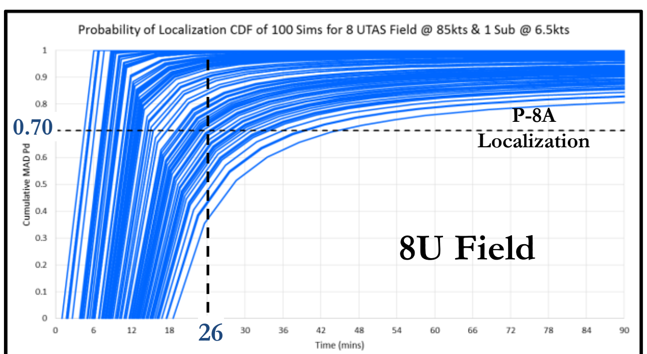
(U) SWARM:

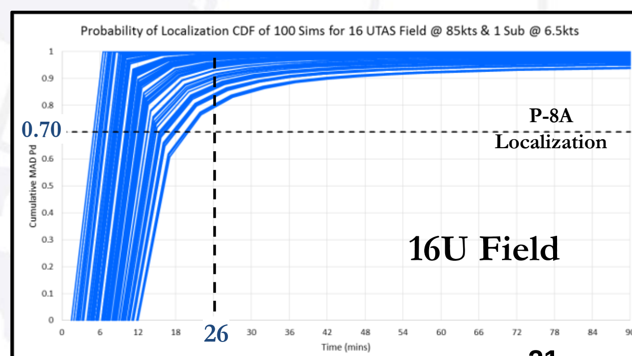
- Less variance in the Swarm latency due to consistent delivery times from P-8A
- 15 mins of "Prep Time" accounts for shift in time latency to right





(U) FIELD:
16U has more consistent "fly-to" times due to wider UTAS distribution





Field has Superior Cumulative P_D

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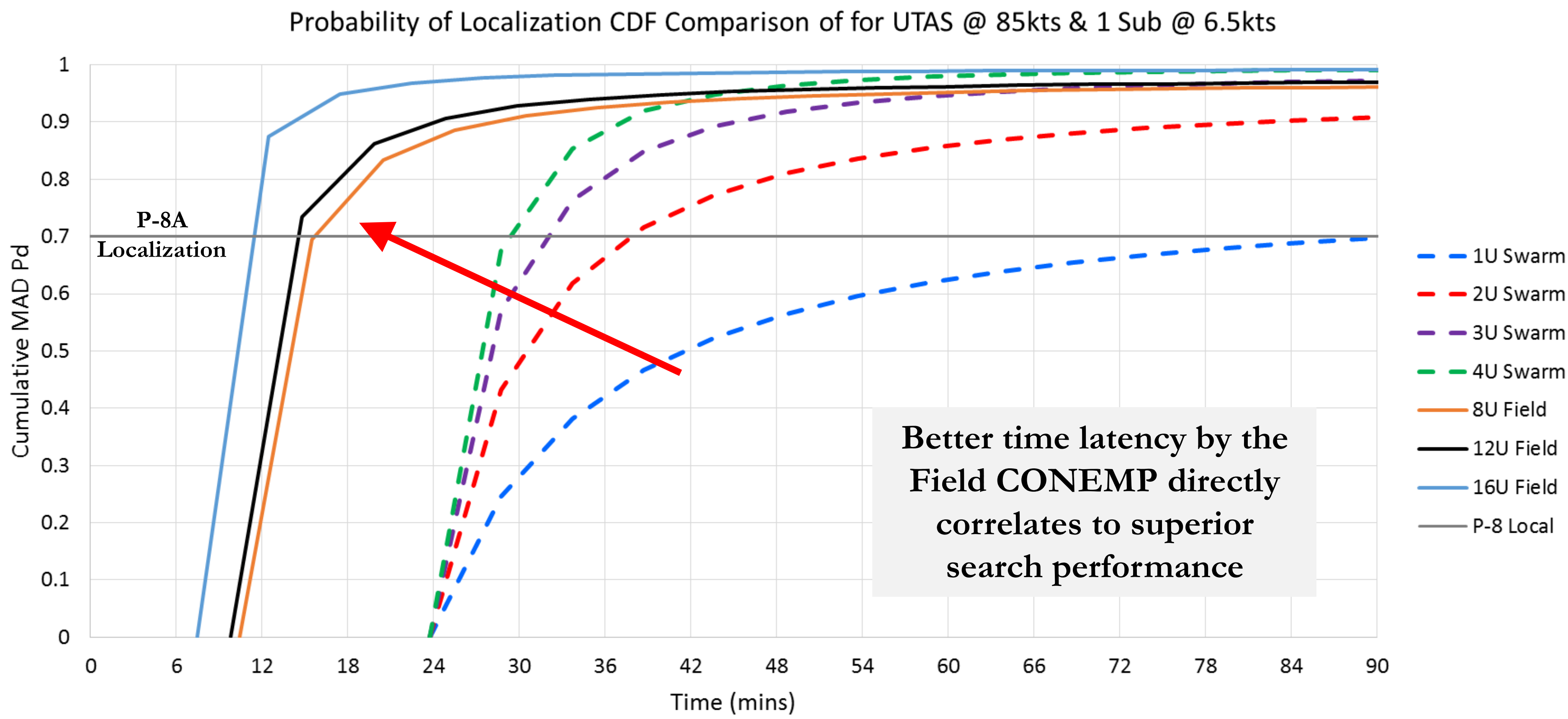

Best/Worst:

- 16U Field variant achieves 0.7 probability of localization at MAC hit +9 mins
- 1U Swarm variant unable to achieve 0.7 probability of localization within MAC hit +90 mins

UTAS: 85 kts / Sub: 6.5 kts

Field Best for Multiple Contacts

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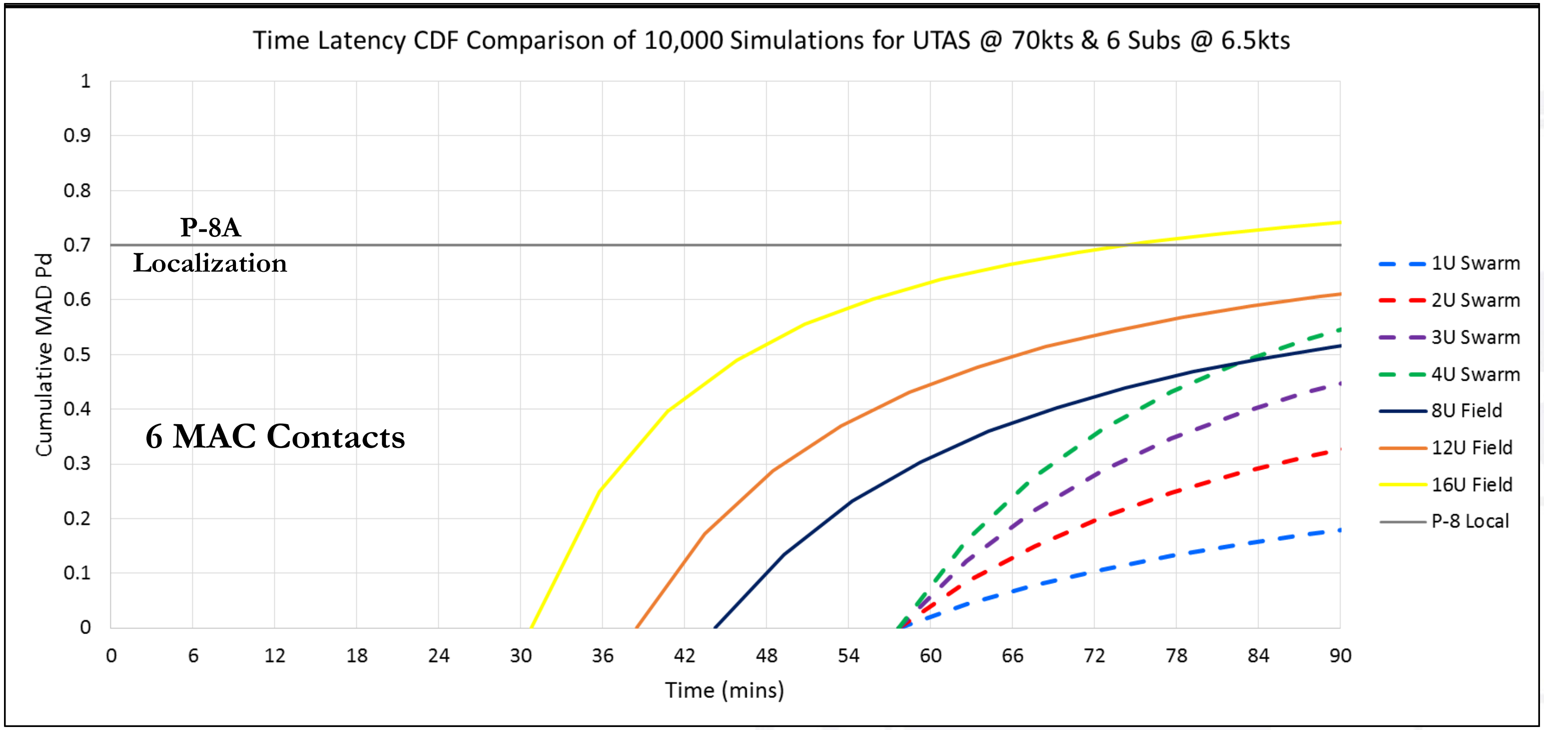

- (U) Field CONEMP:
    - 16U outperforms all other CONEMP variations as multiple contacts populate
    - Overall, Field CONEMP has a lower time latency and higher probability of localization than the Swarm CONEMP
- (U) At 6 MAC contacts, only 1U unable to achieves baseline probability in 90 mins

UTAS: 70 kts / Sub: 6.5 kts

Saturated Worst Case

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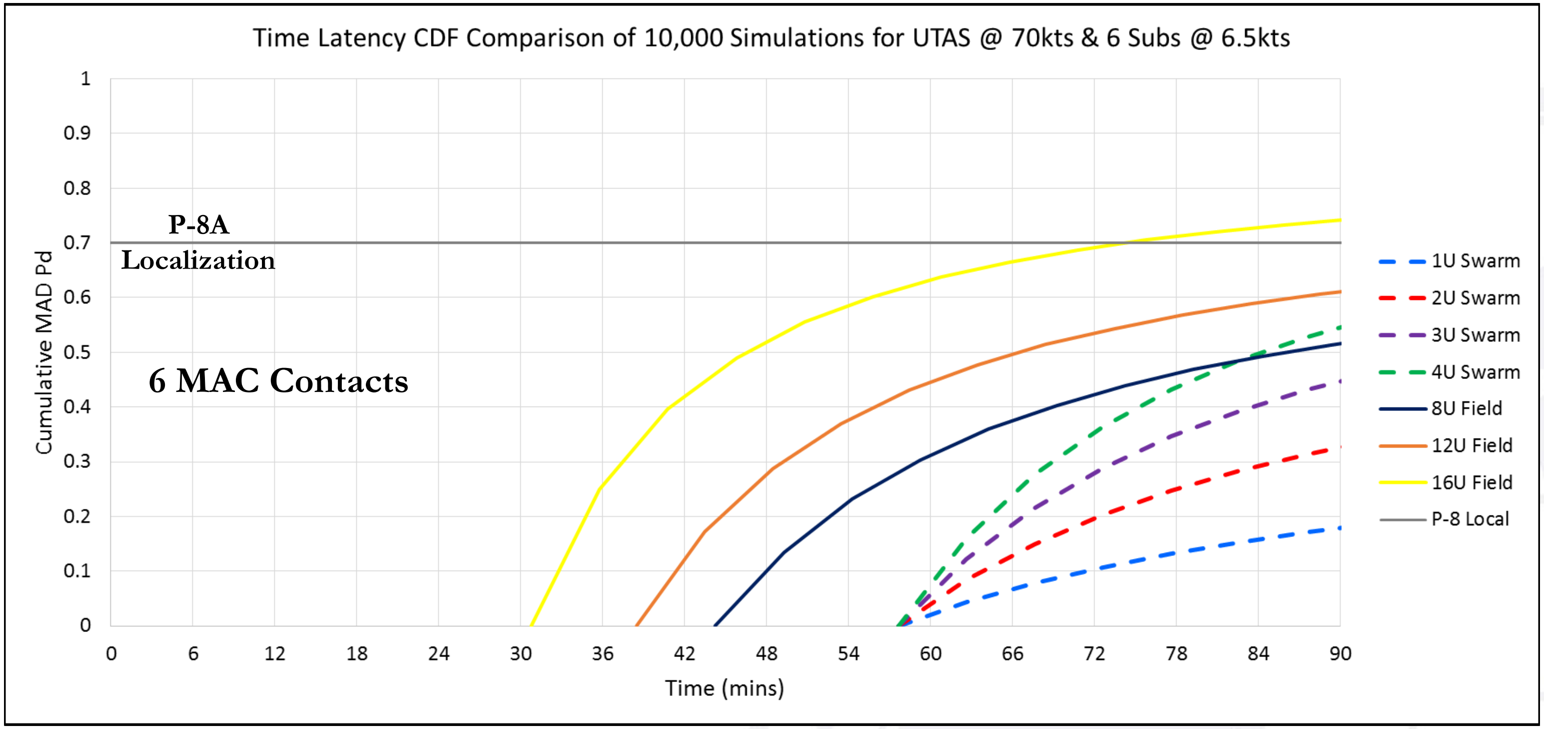

- **Worst Case Comparison:**
  - Field CONEMP: Contacts occur in close proximity
  - Swarm CONEMP: Contacts populates while P-8A is laying MAC buoy field
- 16U Field outperforms all other CONEMP variations due to better time latency
- After 6 MAC contacts, only 16U achieves baseline probability within 90 mins

UTAS: 70 kts / Sub: 6.5 kts

Speed & Endurance Sensitivity

(U) UTAS Characteristic Analysis:

- (U) Speed:
  - Swarm CONEMP:
    - Minimal increase in probability of localization because delivery times remain unchanged with P-8A
  - Field CONEMP:
    - Large improvement because delivery times are dependent on the UTAS transit from loiter location
- (U) Endurance:
  - Field CONEMP:
    - Heavily dependent on an increase in battery life to support continuous performance of CONEMP
    - Improving UTAS endurance will impact mission cost and P-8A storage constraints

Impact of Increasing Swarm Speed

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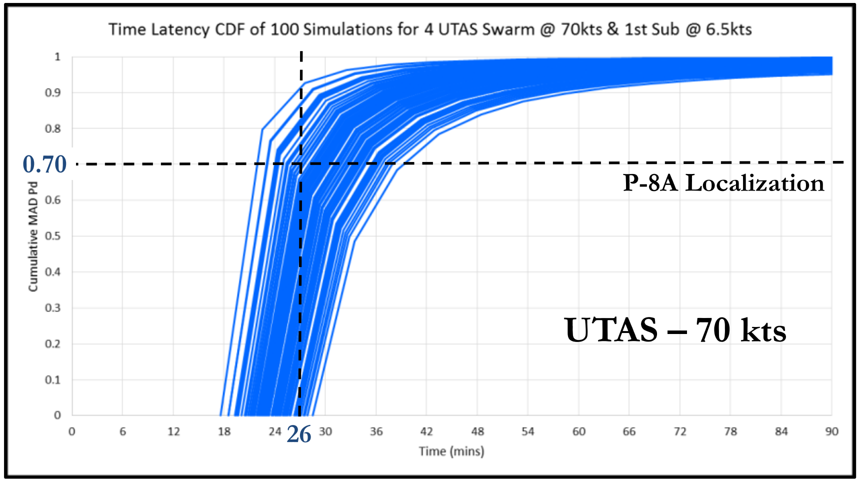
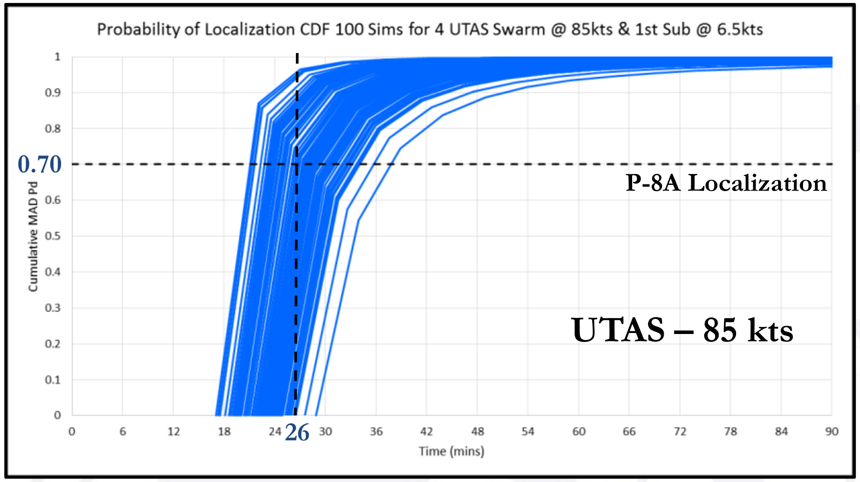
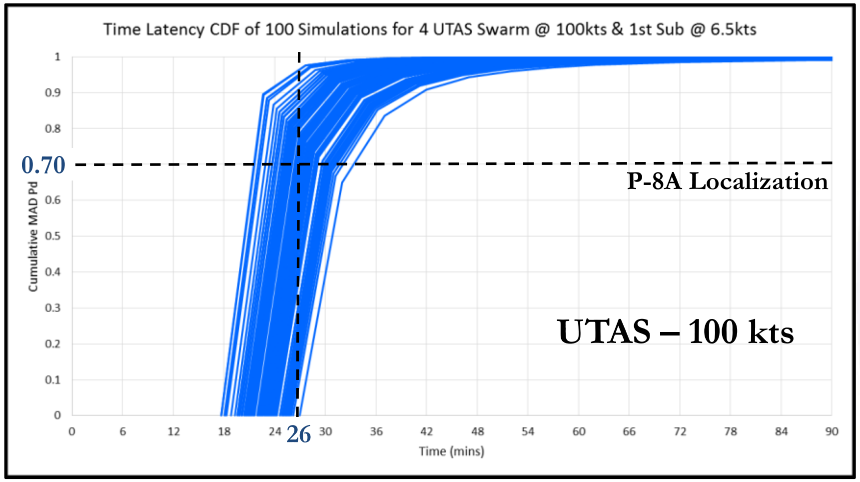
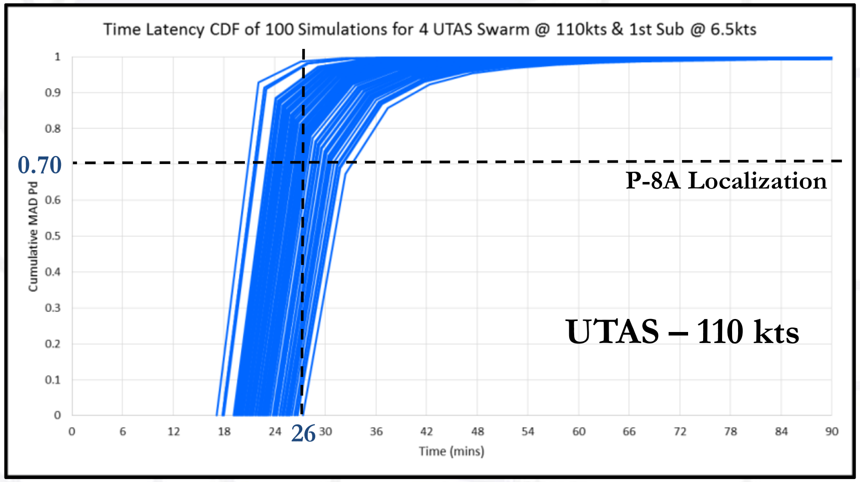




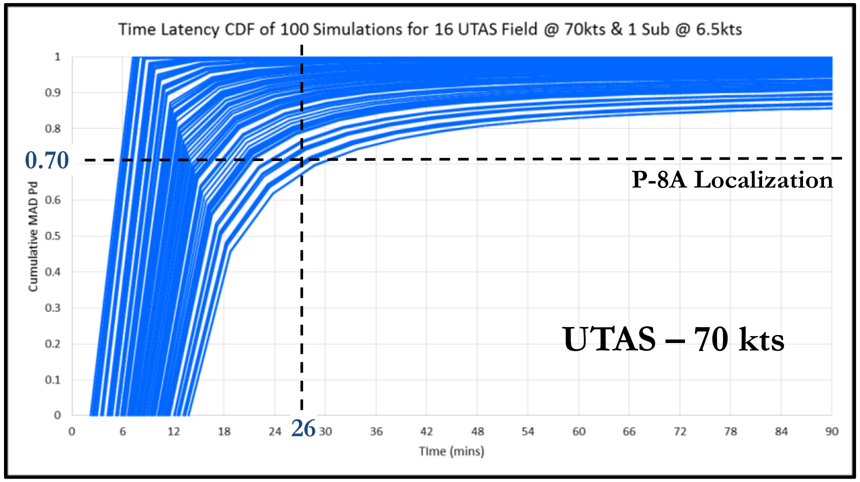
(U) As UTAS speed is increased, "fly-to" times for the P-8A remain unchanged and only a small improvement in Probability of Detection is achieved

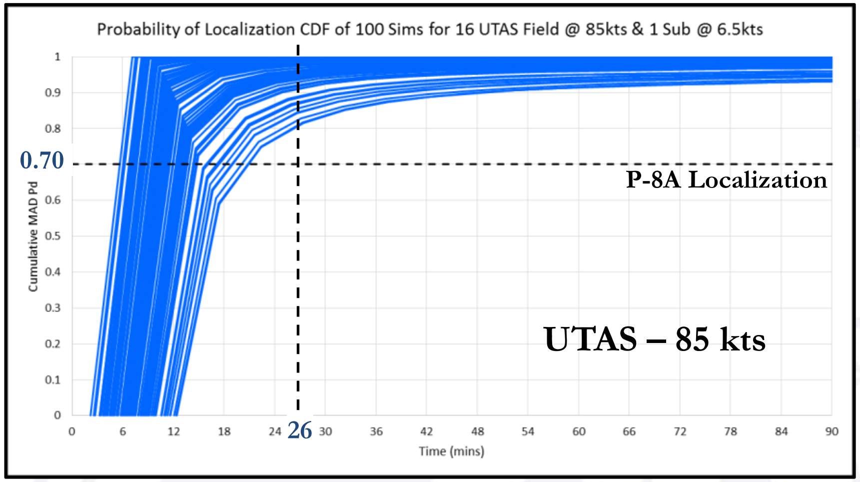




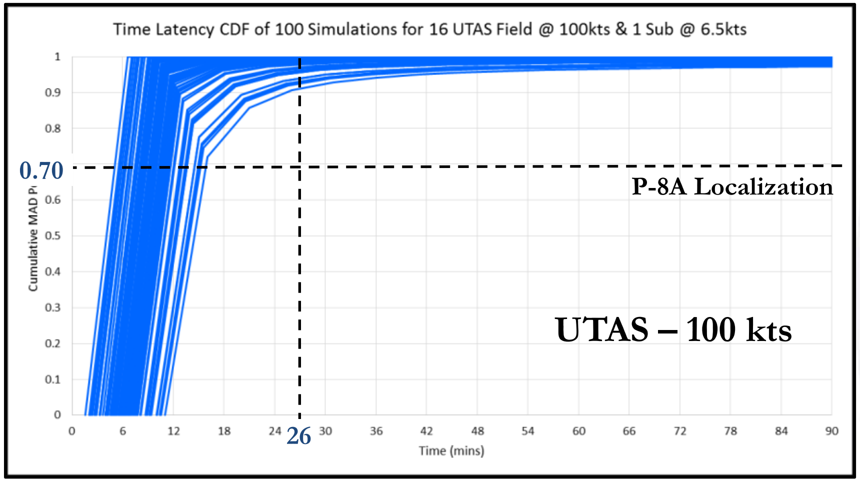
4 UTAS Swarm & 1 Sub @ 6.5kts

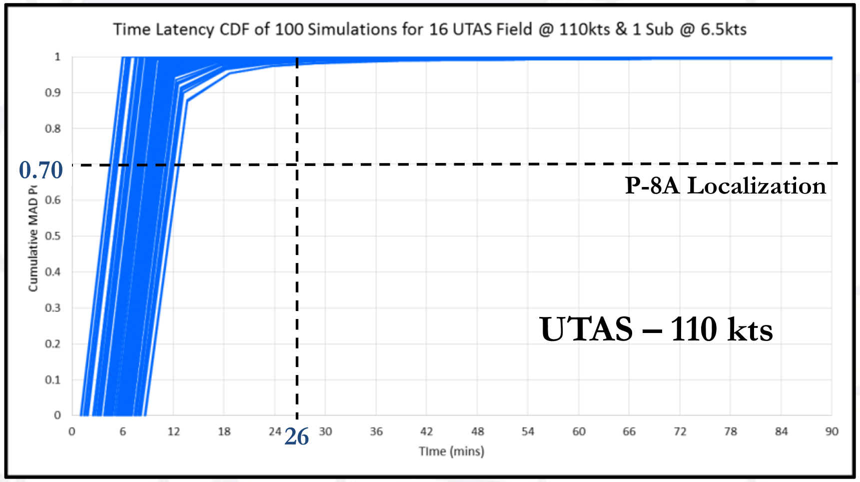
Impact of Increasing Field Speed





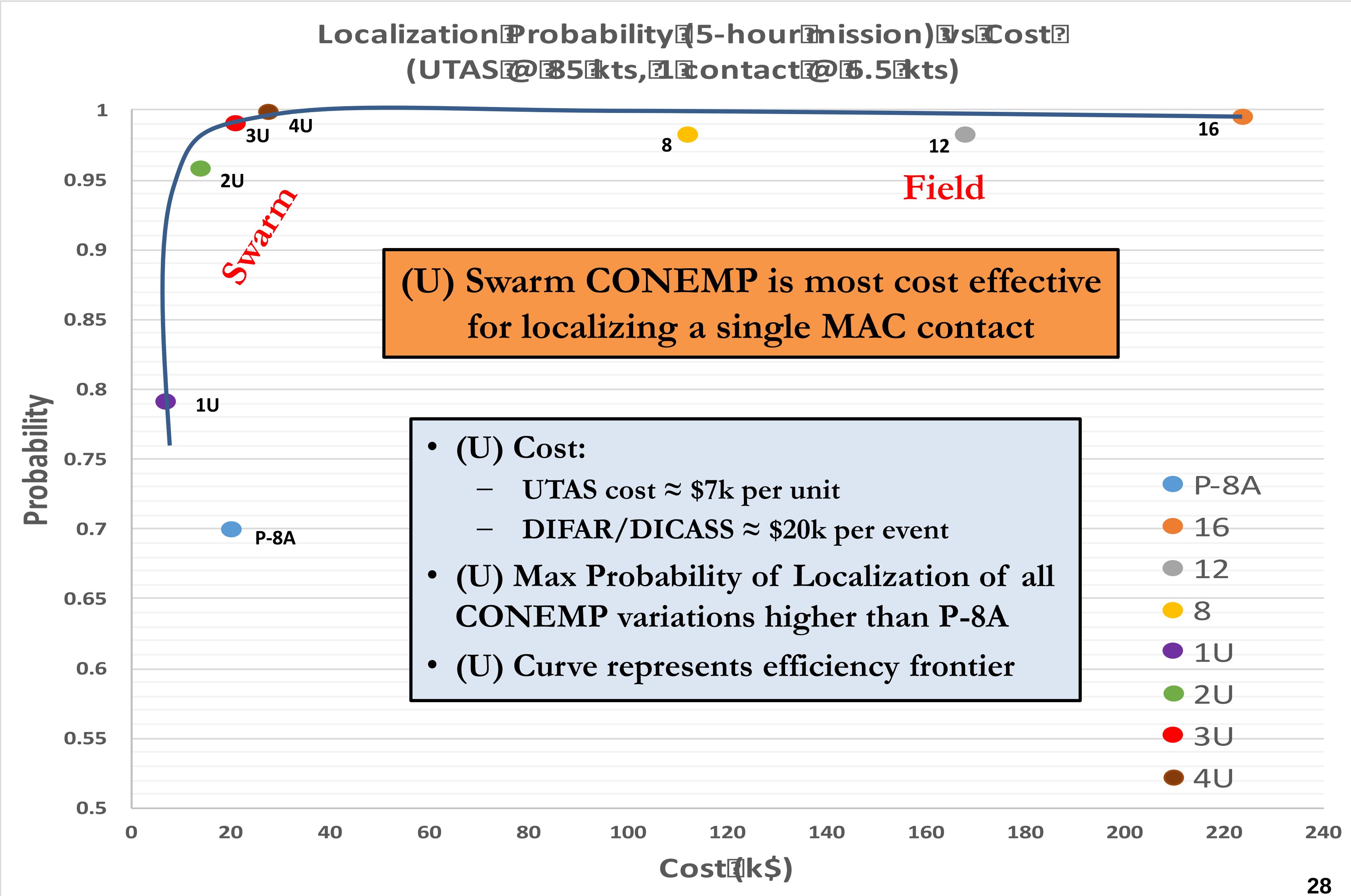
(U) As UTAS speed is increased and "fly-to" times are decreased, less variance in time latency results in significant improvement in Probability of Detection





16 UTAS Field & 1 Sub @ 6.5kts

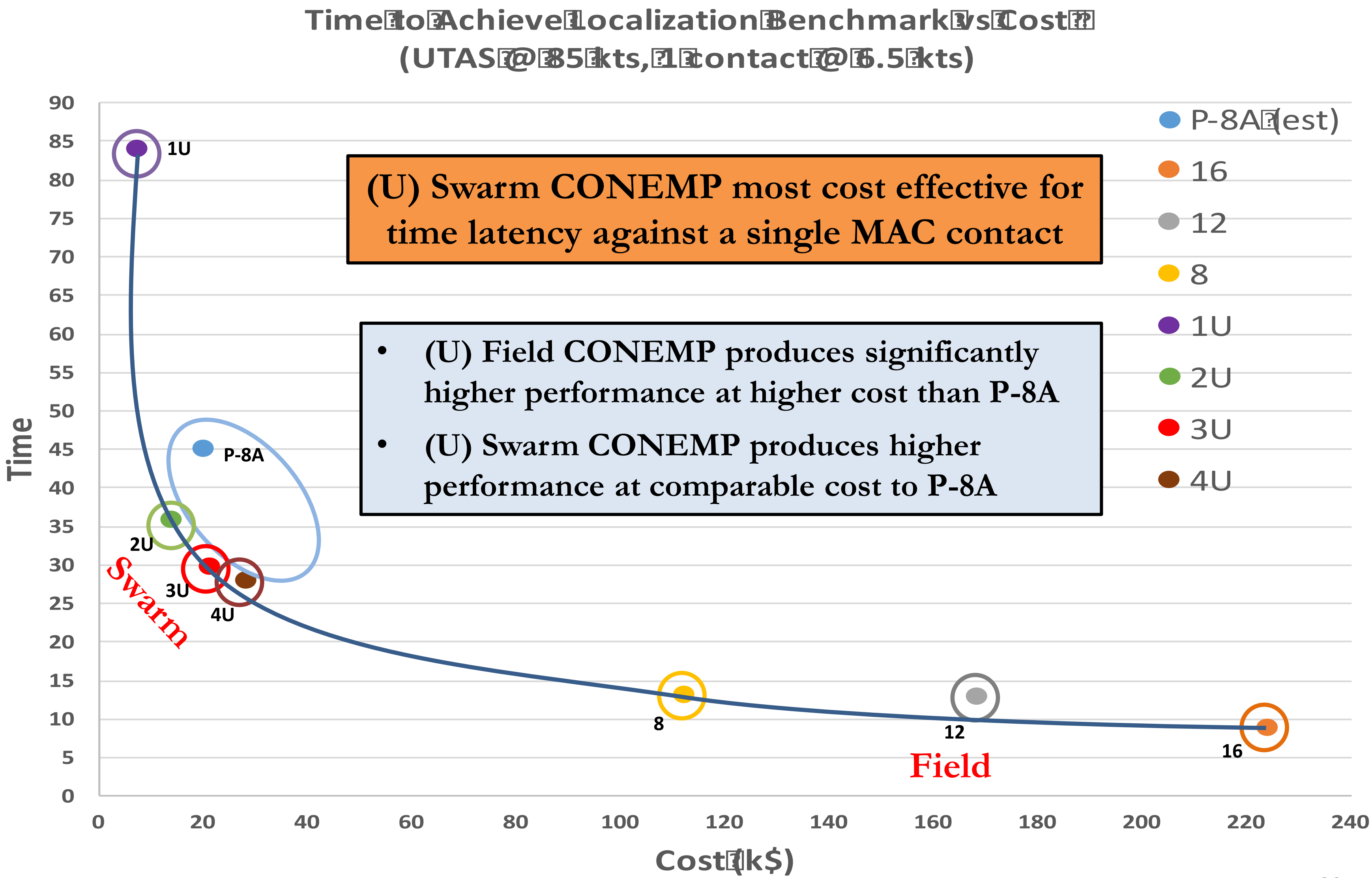
Localization Event Cost vs. P_D



(U) Swarm CONEMP is most cost effective for localizing a single MAC contact

- (U) Cost:
  - UTAS cost ≈ $7k per unit
  - DIFAR/DICASS ≈ $20k per event
- (U) Max Probability of Localization of all CONEMP variations higher than P-8A
- (U) Curve represents efficiency frontier

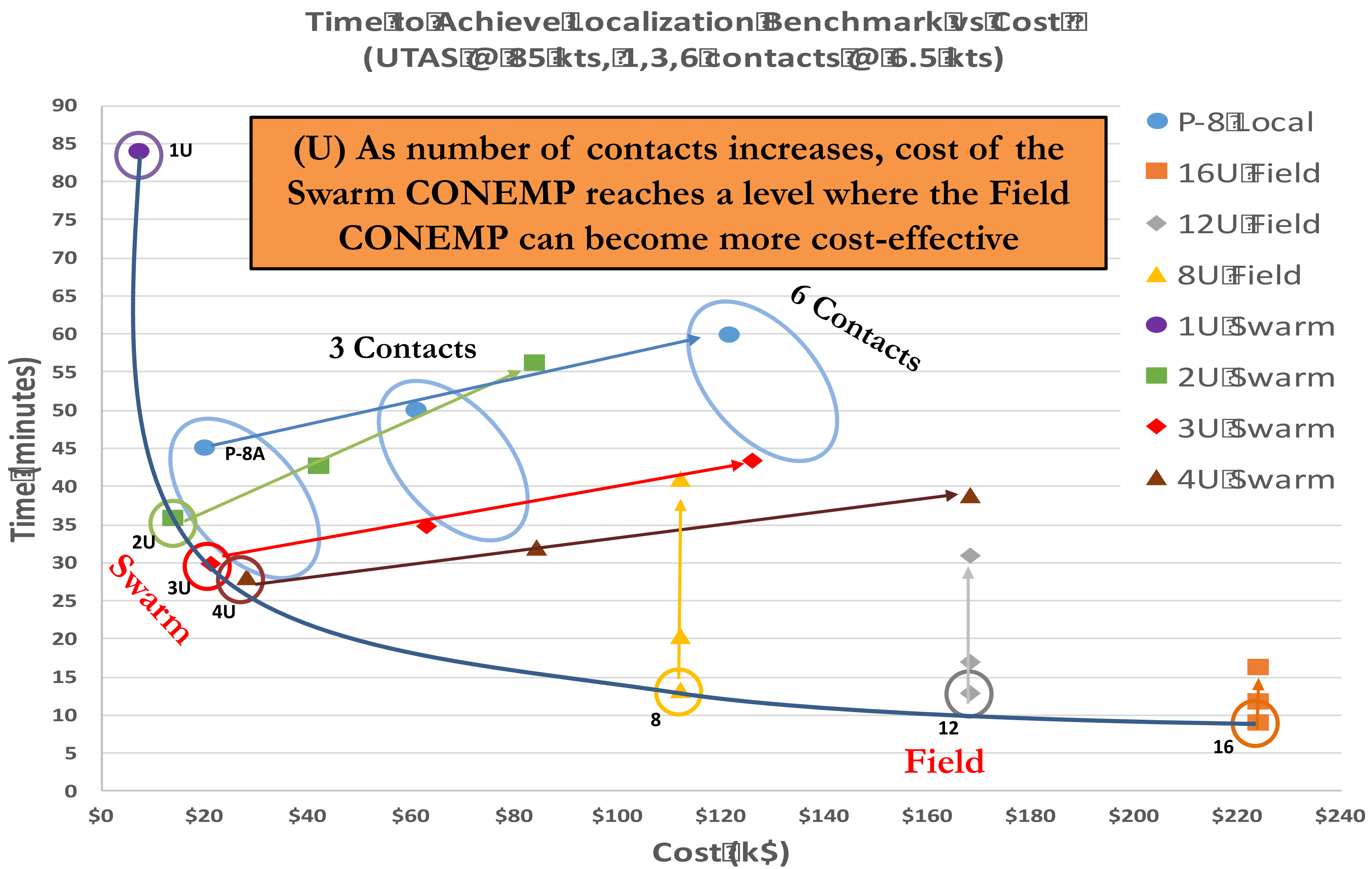
Localization Event Cost vs. Latency



(U) Swarm CONEMP most cost effective for time latency against a single MAC contact

- (U) Field CONEMP produces significantly higher performance at higher cost than P-8A
- (U) Swarm CONEMP produces higher performance at comparable cost to P-8A

Benefit is # of Contacts Dependent



Recommendation

(U) Recommend continued development of autonomous UTAS as a cost-effective solution to improve the HAASW capability of the P-8A

Dependent on the concept of employment and mission requirements

- **(U) Hunt & Kill ASW Mission:**
  - The Field CONEMP with 16 UTAS is recommended because it significantly reduces time latency of a UTAS to the contact location
- **(U) Routine Maritime Patrol/ASW Mission:**
  - The Swarm CONEMP is recommended as a lower cost alternative while still improving the P-8A ASW mission
- **(U) Most Important Future Development: Endurance**
  - Recommend improving UTAS endurance to enable continuous performance of Field CONEMP for duration of P-8A ASW mission

Questions?

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Back-up Slides

Project Tasking

(U) Tasking:

(U) Design a fleet system of systems and concept of operations for employment of a **cost effective and resilient unmanned and manned system capable of providing extended sensor search and detection capability for the P-8A** in the 2025-2030 timeframe. Consider manned and unmanned systems to provide sufficient information **to support effective antisubmarine and anti-surface operations to Find, Fix, Track, Target and Engage sequence**. With each alternative, develop a concept of operations, while considering employment requirements, operating areas, bandwidth and connectivity, interoperability, sensor data processing, transfer and accessibility and logistics. Generate system requirements for platforms, sensors, and communications in a challenging EM environment. Develop alternative architectures for platforms, sensors, manning, command and control, intelligence collection/dissemination and consumption, communication and network connectivity, and operational procedures. Address the costs and effectiveness of your alternatives in an area anti-submarine and anti-surface mission areas.

Problem Statement

(U) Problem Statement:

(U) SEA-24 will investigate cost-effective and resilient systems of systems (SoS) to extend sensor search and detection capability for the P-8A in the 2025-2030 timeframe using manned and unmanned systems to provide sufficient information supporting effective high altitude antisubmarine warfare (HAASW) operations in the find, fix, track, target, and engage (F2T2E) sequence.

SEA-24 Project Concept

(U) SEA-24 must develop a System of Systems design where system architecture becomes the focus of the analysis.

- (U) How can we employ a UTAS with MAD sensor to sufficiently support the P-8A during High Altitude ASW (HAASW) operations?
- (U) How can we reduce the time required to Find, Fix, Track, Target, and Engage a submarine with a P-8A?
- (U) What becomes the more important UTAS performance trait for each SoS architecture design?
  - UTAS speed vs. UTAS endurance

(U) Is a SoS employing UTAS with MAD better than the current doctrine of using DIFAR/DICASS sonobuoys in the Find, Fix, Track, Target, and Engage sequence in terms of time, mission cost, and added functionality to the P-8A ASW mission?

Functional Decomposition

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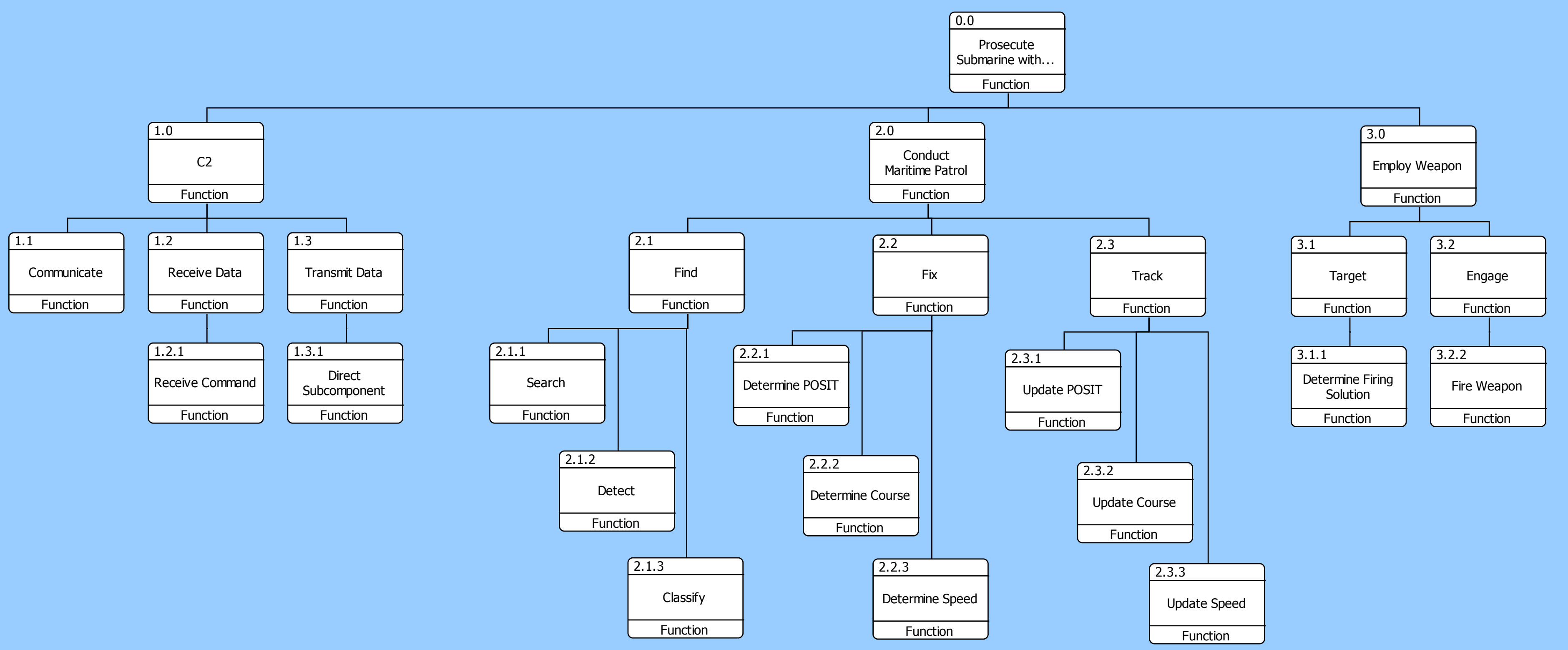
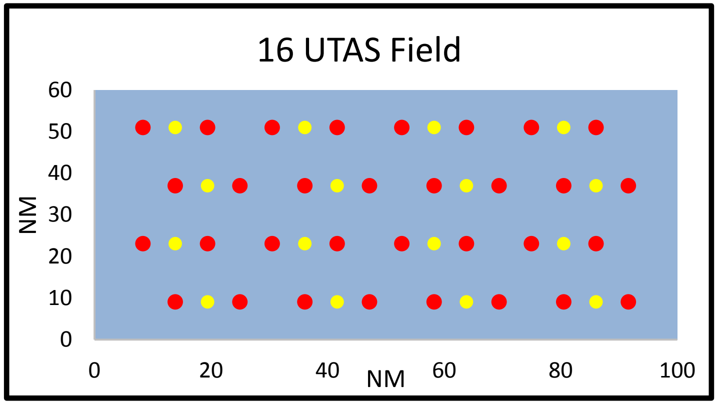
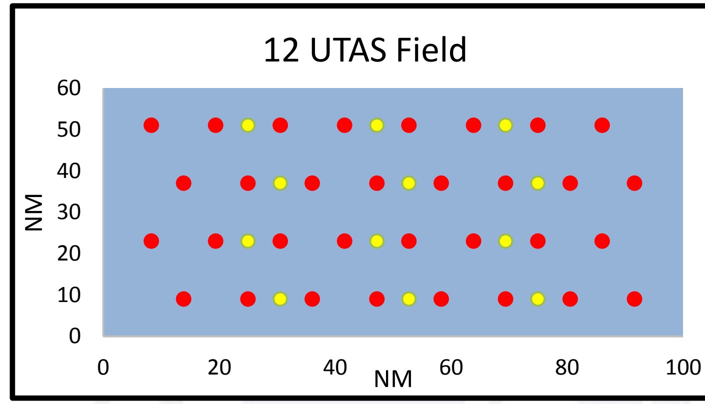


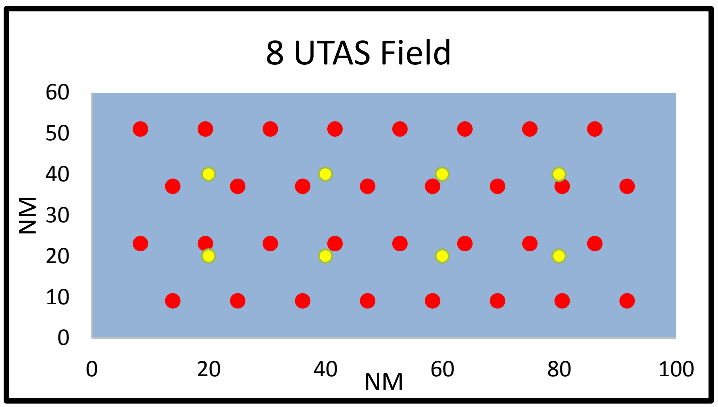
Critical Operational Issues

COI	Issue	Question
1	Endurance	Are the achievable SWaP endurance rates of a UTAS platform sufficient to support effective P-8A ASW operations?
2	Transportability	Can the UTAS platform be stored and launched from a P-8A platform to support effective ASW operations?
3	Compatibility	Is the UTAS platform compatible with P-8A ASW mission and communication systems?
4	Command and Control (C2)	Can UTAS provide sufficient information to support effective P-8A ASW operations?
5	Speed	Can the UTAS platform operate at sufficient speeds to support effective P-8A ASW operations?
6	Automation	Can the UTAS platform operate autonomously in support of effective P-8A ASW operations?
7	Employment	Can the UTAS platform be readily employed from the P-8A platform to support effective ASW operations?
8	Survivability	Can the UTAS platform survive a challenging electromagnetic (EM) and physical environment?
9	Reliability	Does UTAS platform reliablity align with the required reliability for P-8A ASW operations?
10	Availability	Does UTAS platform availability align with the required availability for P-8A ASW operations?

CONEMP Alternatives





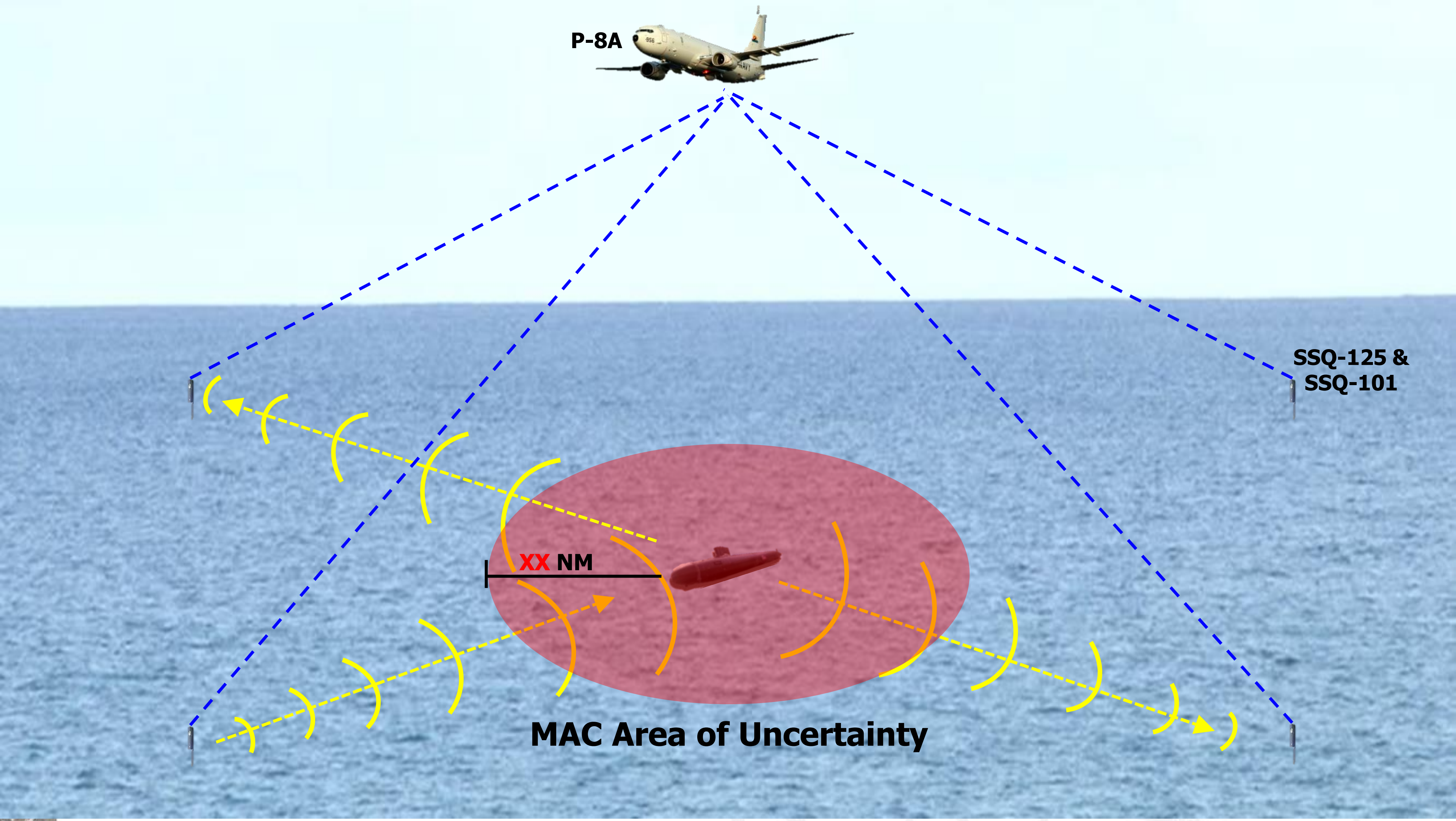


1. Laying 16 UTAS with MAC
2. Laying 12 UTAS with MAC
3. Laying 8 UTAS with MAC
4. P-8A fly to and Deploy 1
5. P-8A fly to and Deploy 2
6. P-8A fly to and Deploy 3
7. P-8A fly to and Deploy 4
8. P-8A fly to and localize with DIFAR/DICASS

- MAC
- UTAS

(U) Time-based model analyzing F2T2E sequence across multiple CONEMP using a Design of Experiments of critical input factors

MAC Area of Uncertainty



MAC & SSQ-101 Overview (SIPR)

MAD Sweep Width/Depth (SIPR)

Flaming Datum Search

$$F_T(t) = 1 - \exp\left(-\frac{wv}{\pi u^2}\left(\frac{1}{\tau} - \frac{1}{\tau + t}\right)\right)$$

- Target evasion speed, u
- Search speed, v
- Time late, τ
- Sweep width, w

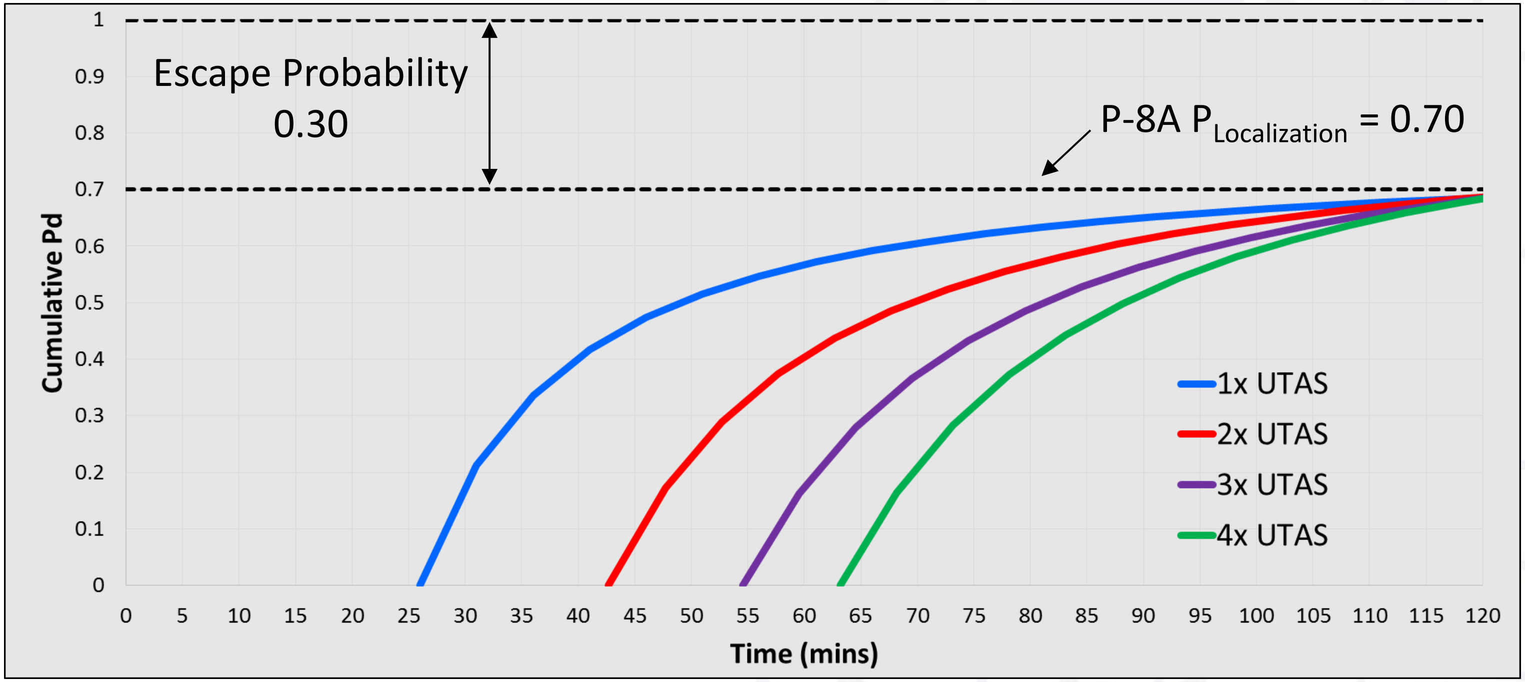
Min Time Latency Required to Meet P-8A Localization Benchmark (0.70):

1 UTAS Search: 26 mins

2 UTAS Search: 43 mins

3 UTAS Search: 54 mins

4 UTAS Search: 63 mins



How Long to Search?

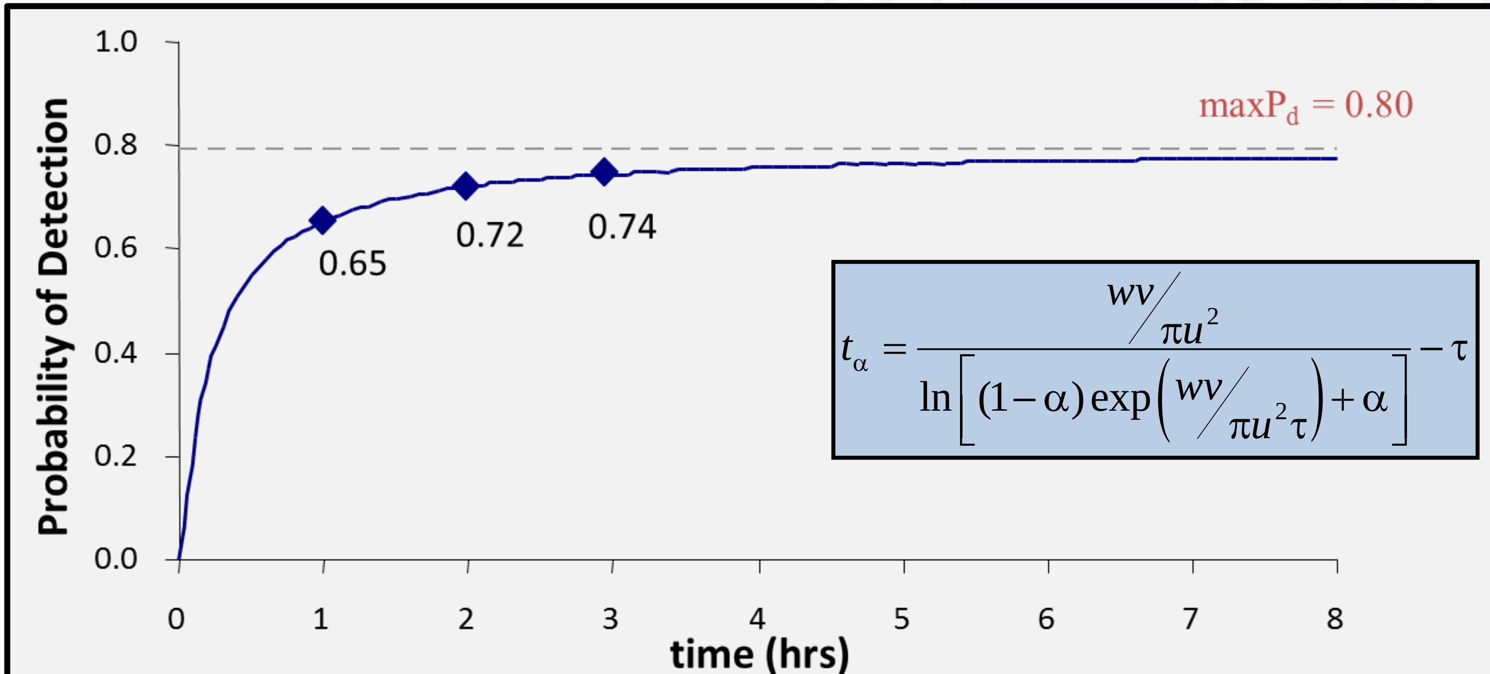
(U) "Knee of the curve" or "diminishing returns"?

82% of maxP_d is attained after 1 hour of search

90% of maxP_d after 2 hours

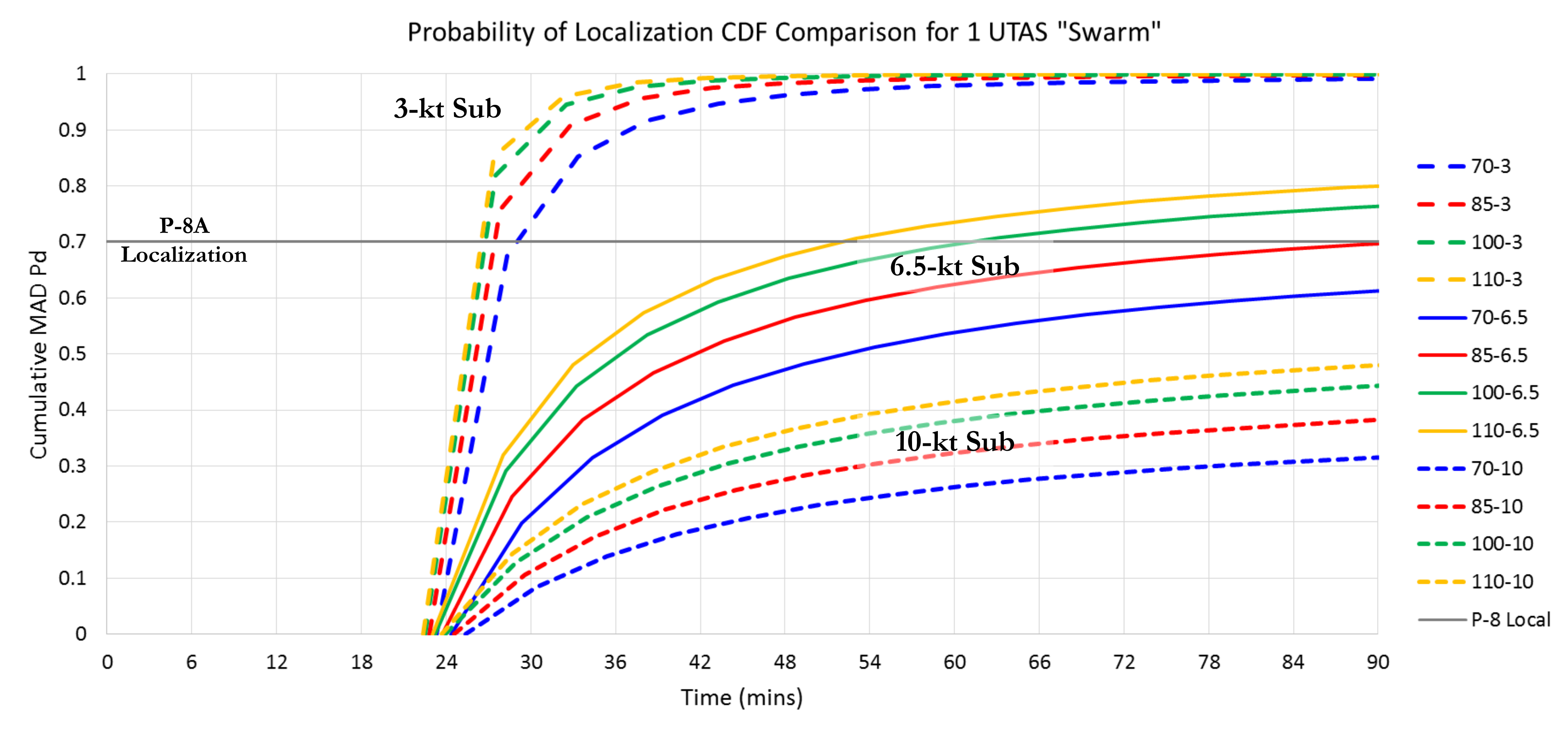
93% of maxP_d after 3 hours

- An infinite amount of time is needed to get the remaining %



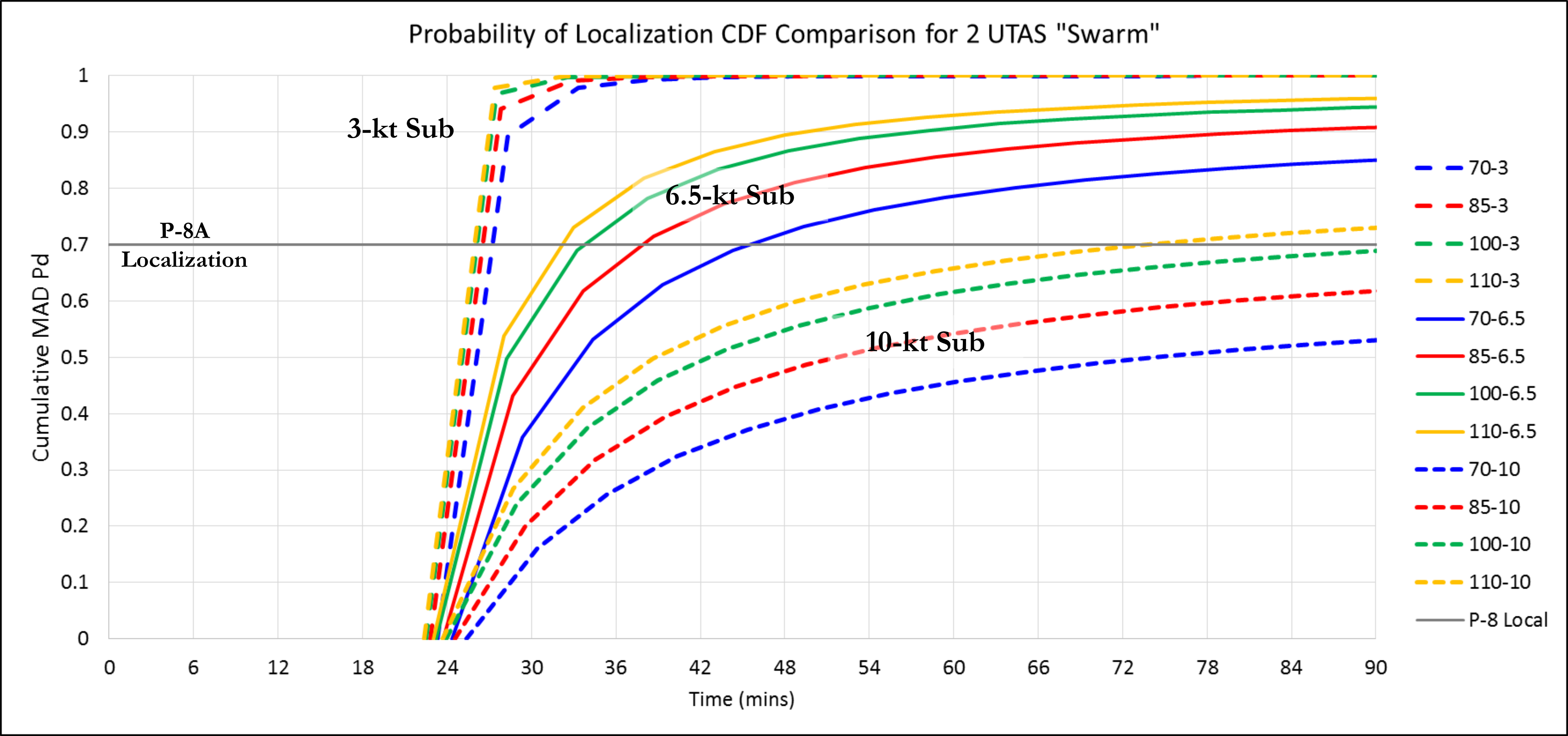
$$t_\alpha = \frac{wv/\pi u^2}{\ln\left[(1-\alpha)\exp\left(wv/\pi u^2 \tau\right)+\alpha\right]} - \tau$$

Comparison for 1U Swarm



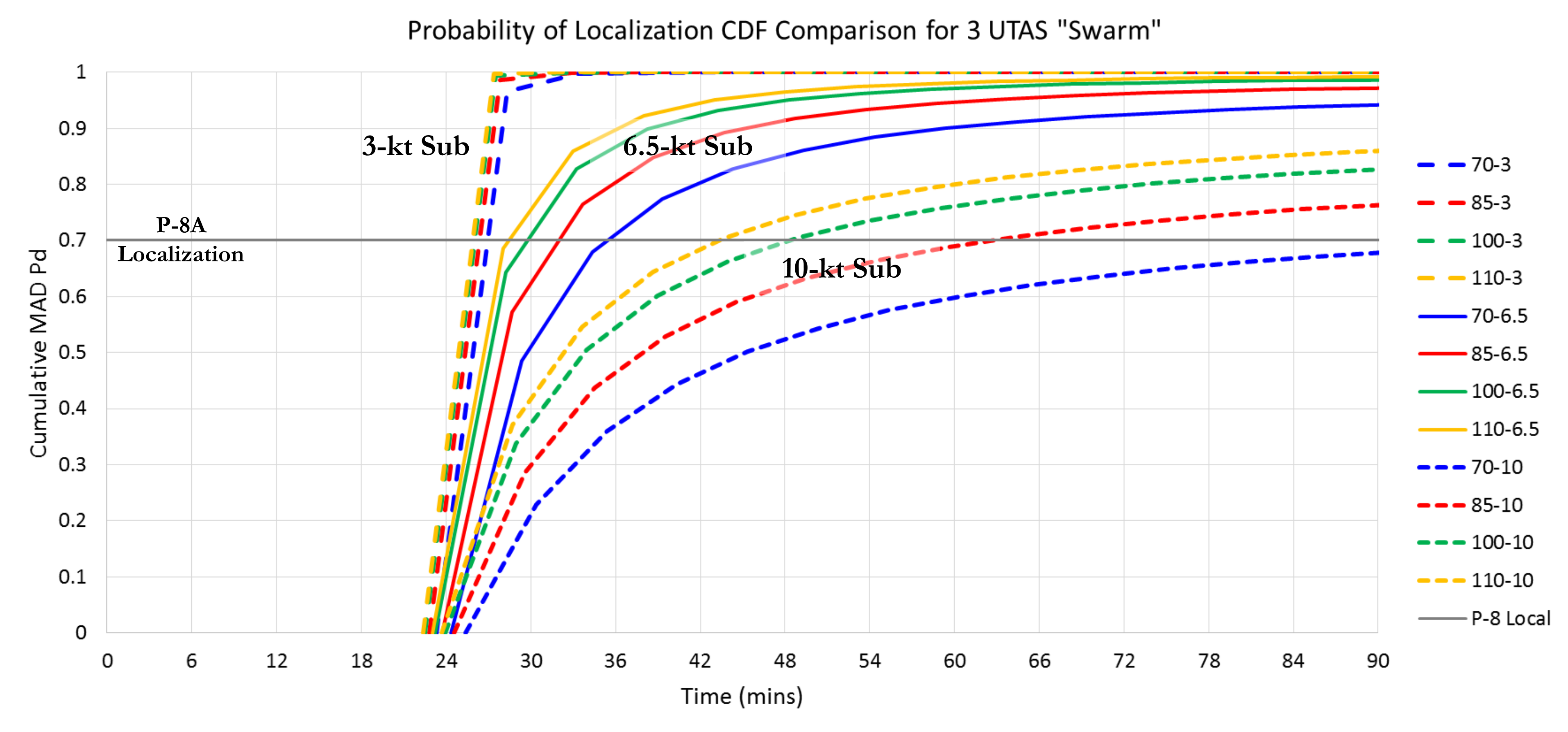
Comparison for 2U Swarm

UNCLASSIFIED



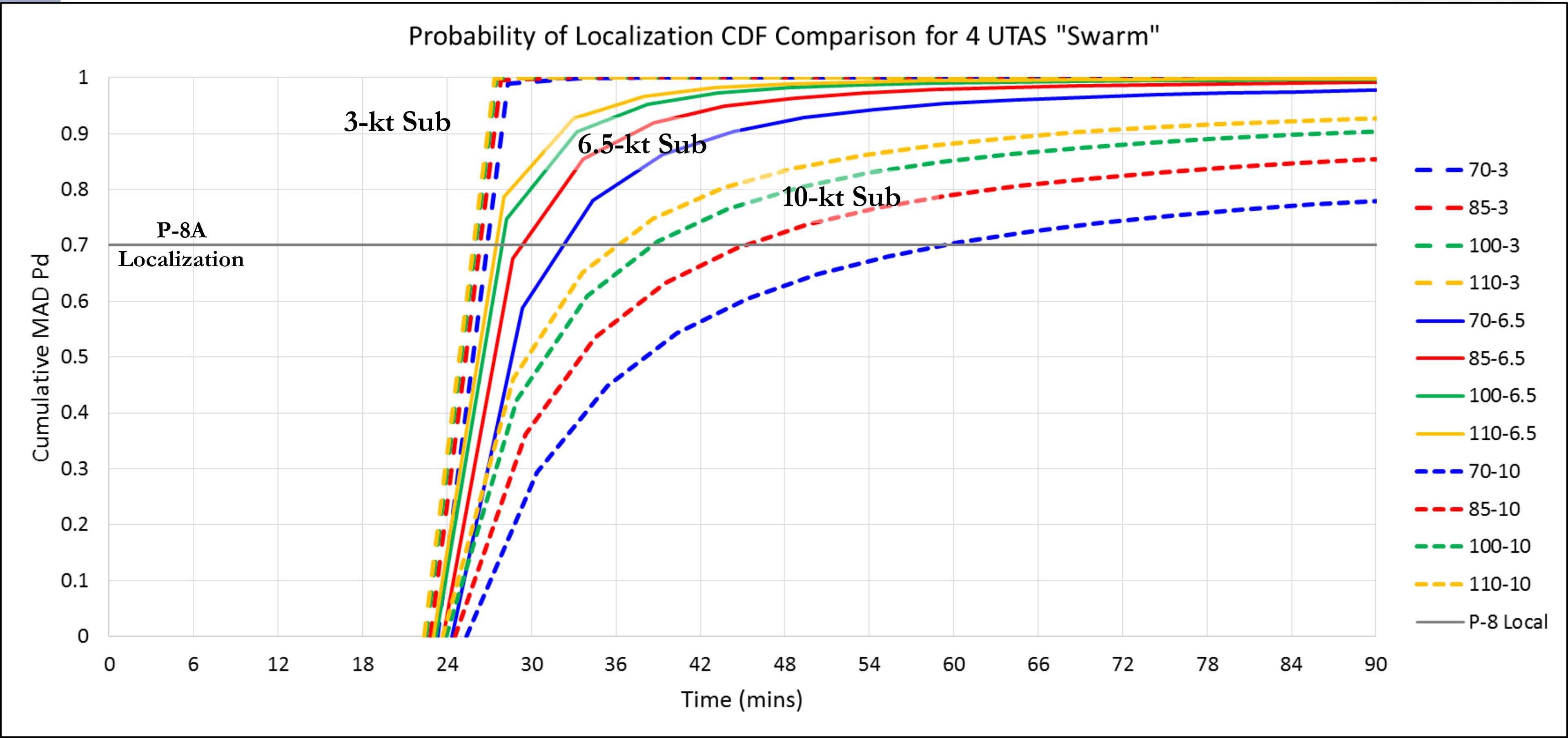
Comparison for 3U Swarm

UNCLASSIFIED

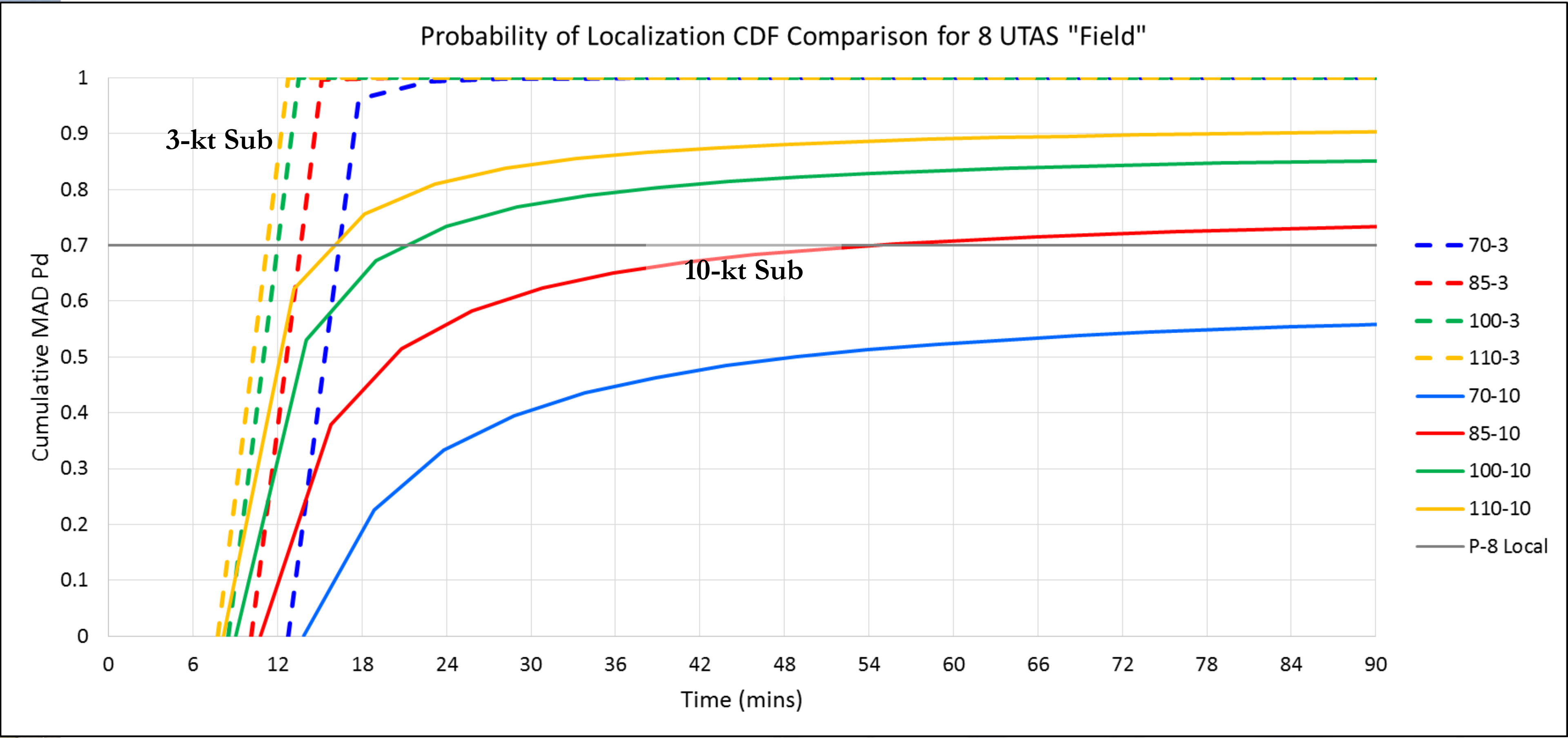


Comparison for 4U Swarm

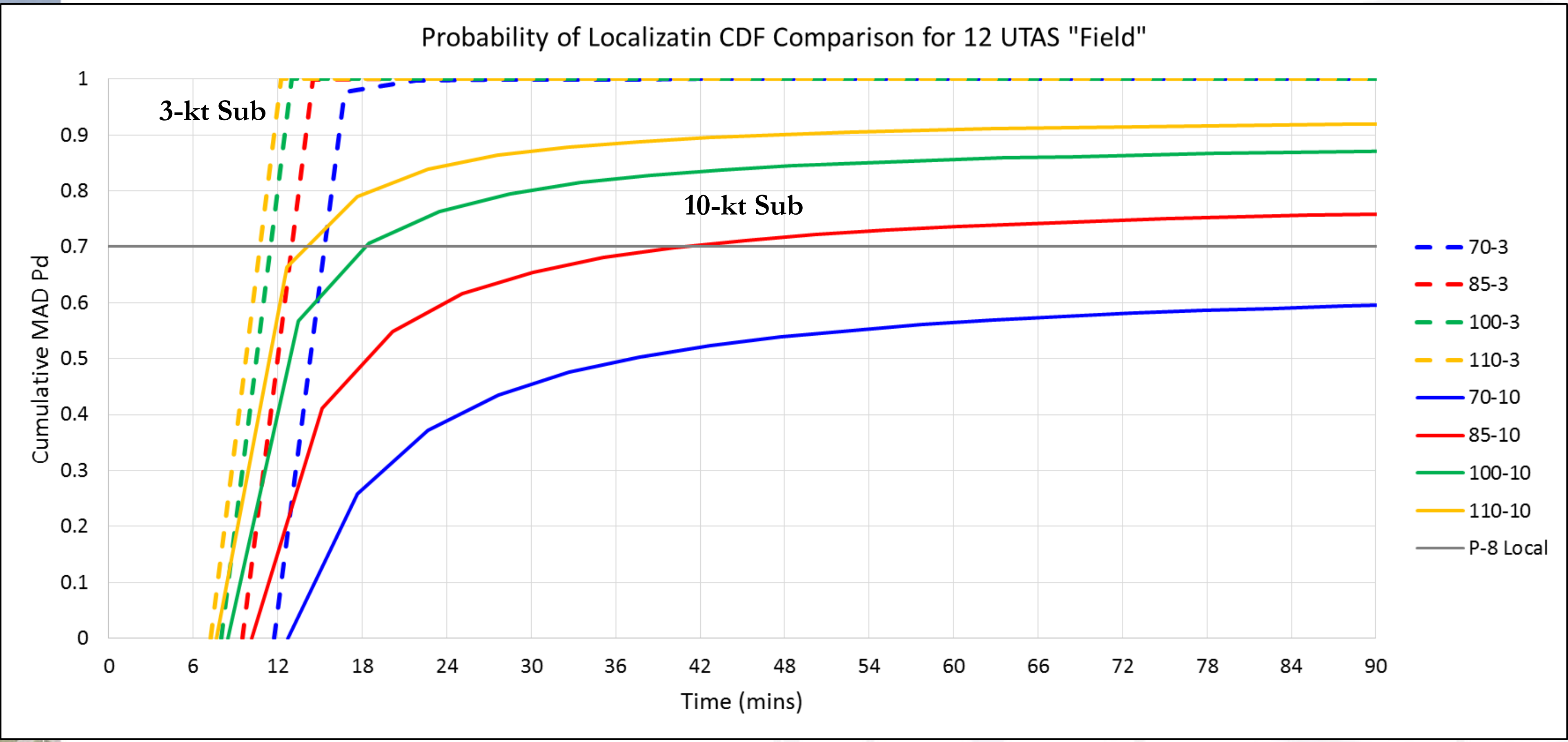
UNCLASSIFIED



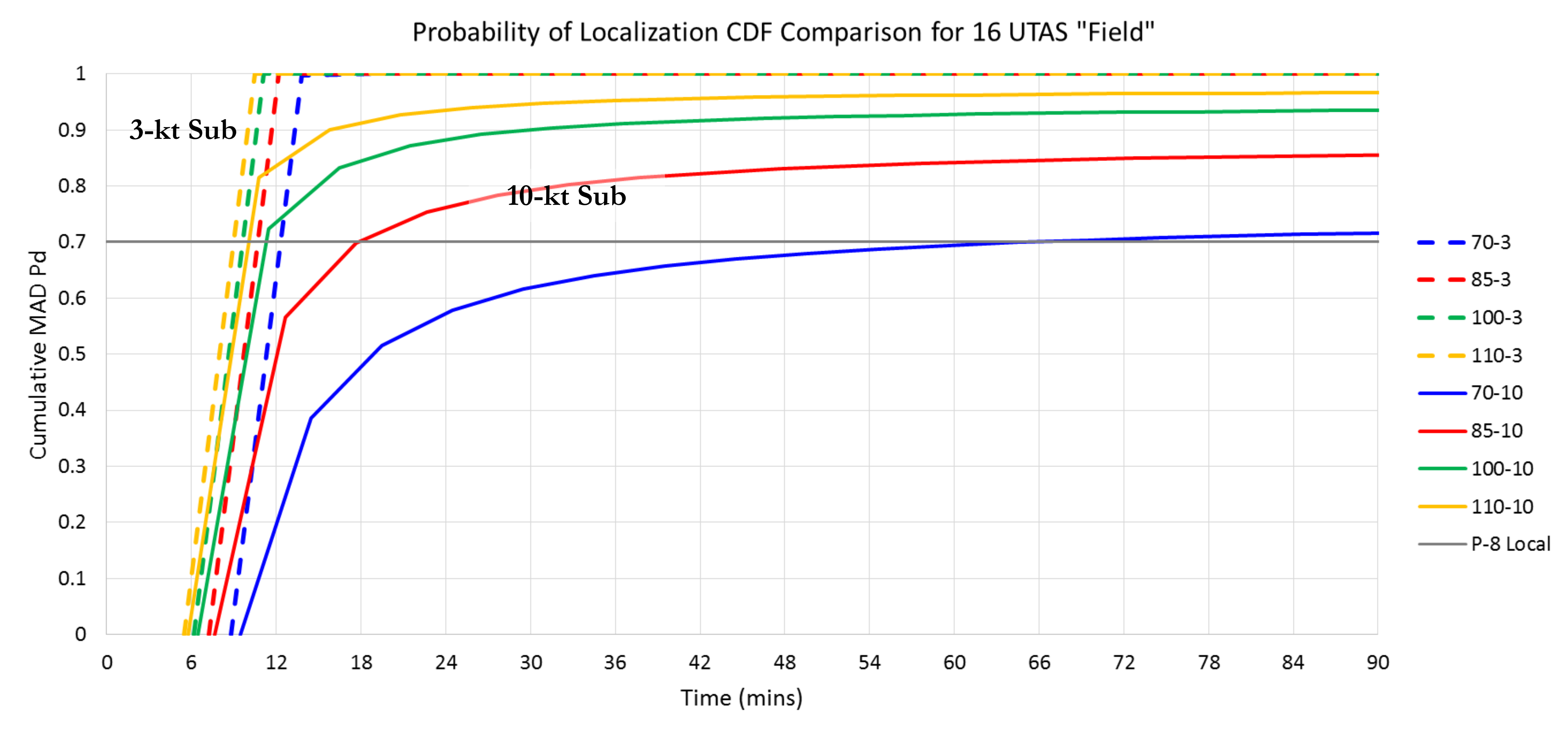
Comparison for 8U Field



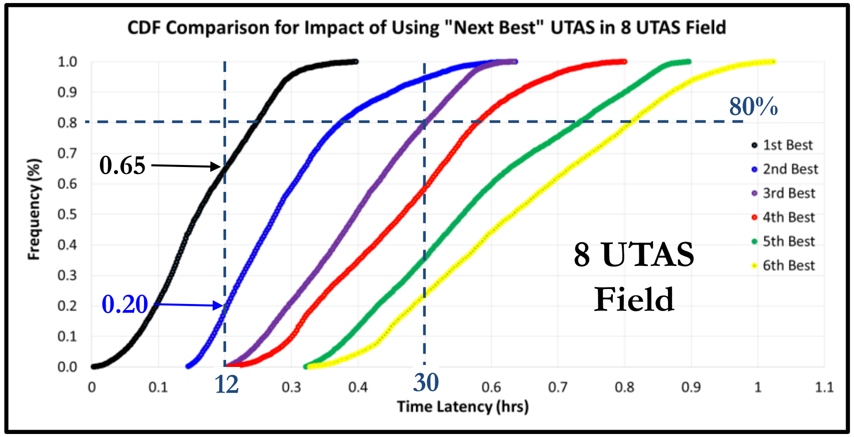
Comparison for 12U Field

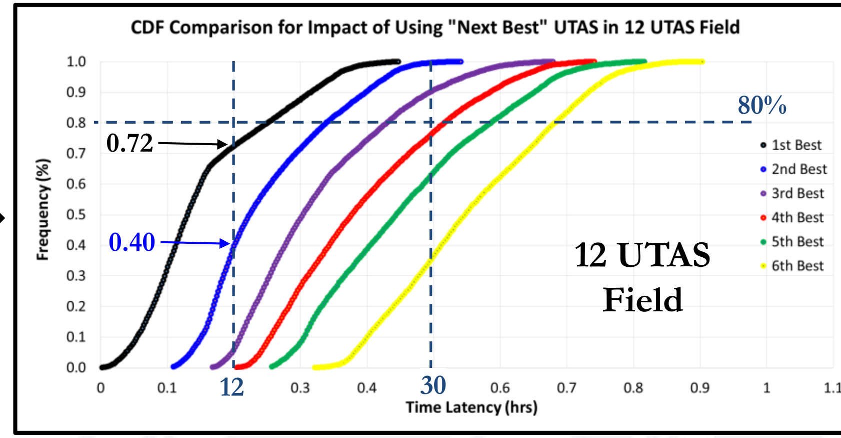


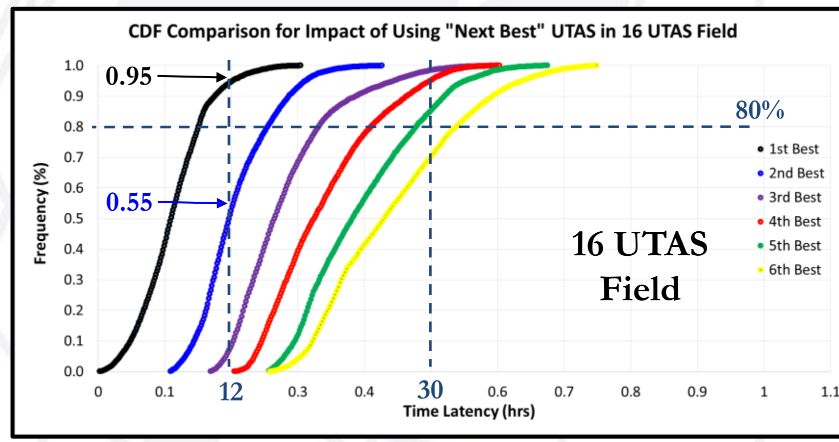
Comparison for 16U Field



"Next Best" Impact for Field





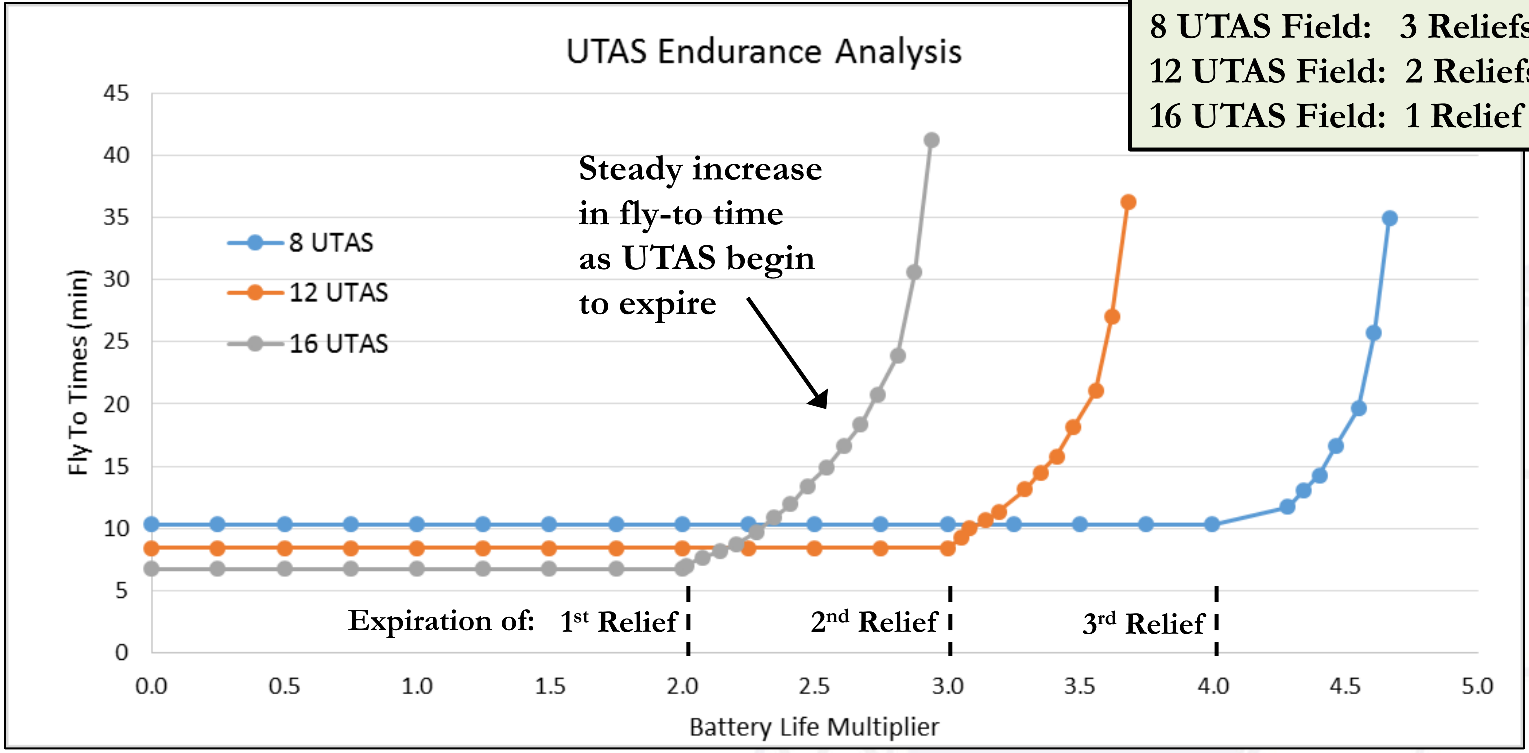


- Plots depict a cumulative distribution of the time latency frequency rates for the "next best" UTAS of a MAC hit occurring within close proximity to a previous hit
- Demonstrates a worst-case scenario for each UTAS field
- Time latency of 12 mins yields the threshold Pd value of 0.7 at MAC hit +20 mins
- Time latency of 26 mins is latest to achieve the threshold Pd value of 0.7 for sub @ 6.5 kts
  - 8x Field: 3rd, 4th, 5th, and 6th best fail
  - 12x Field: 4th 5th and 6th best fail
  - 16x Field: 5th and 6th best fail

Impact of Increasing Endurance

Assuming 32-36 UTAS loadout:

8 UTAS Field: 3 Reliefs
12 UTAS Field: 2 Reliefs
16 UTAS Field: 1 Relief



- (U) 16U Field superior performance is lost after only 1st Relief; making an improvement in battery life essential for sustainability
- (U) An increase in UTAS endurance will also improve mission cost as it will require less UTAS per mission
- (U) The projected goal for the 2025-2030 timeframe would be a 2.5 hr battery life