

Modernized GPS & Digital Anti-Jam Contributions to the Range and Lethality Challenge of MDO

Future Force Capabilities Conference
Unconventional Emerging Armaments
20 Sep 2022

Justin R. Wymore Sr., BAE Systems/NSS



NOT EXPORT CONTROLLED PER ES-NSS-082622-0042

Unclassified. Distribution Unlimited

BAE SYSTEMS

Agenda

- Role of precision in achieving weapons lethality at extended range
- Role of precision geolocation for autonomous/semi-autonomous loitering munitions
- Guidance, Navigation, and Control (GNC) trade space
- Assured Position, Navigation, and Timing (APNT) Threat Model, technologies, and trade-offs
- Available APNT Hardening Solutions

Role of Precision



NOT EXPORT CONTROLLED PER ES-NSS-082622-0042

Problem to be Solved

Problem: GPS jamming and spoofing by adversaries severely impacts the precision and lethality of our weapon systems

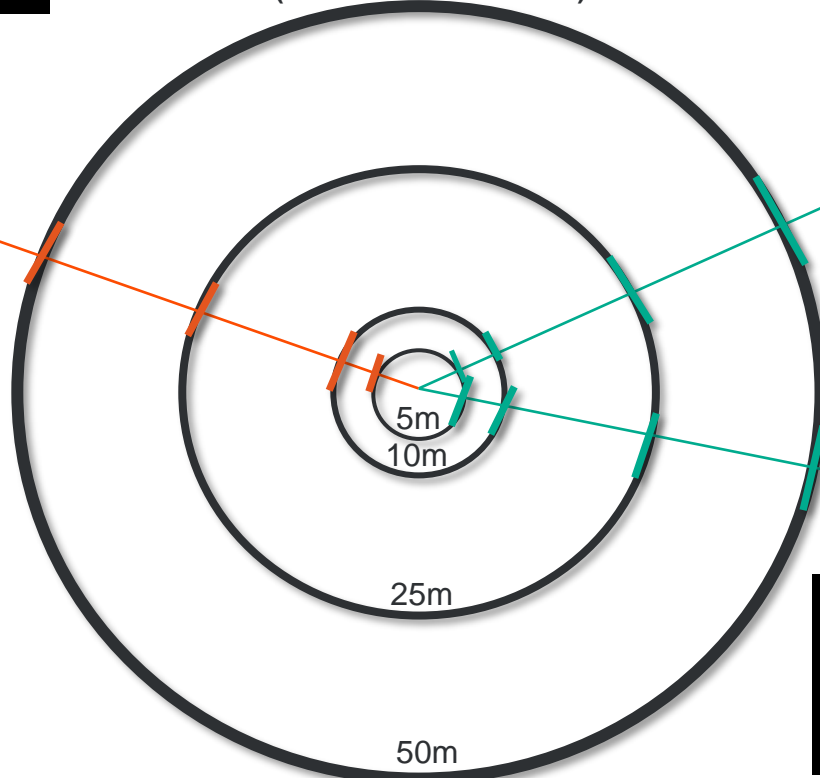
- GPS is the predominant method of attaining absolute precision guidance due to its accuracy (sub-2 meter), availability (worldwide), accessibility (unlimited number of simultaneous users), reliability, and per-user cost (free)
- Adversaries continue to evolve their threat systems against GPS
- Absolute precision is becoming even more critical in an MDO environment (Multi-Domain Operations / Maritime Distributed Operations (MDO) / Joint All-Domain Operations (JADO))
- Weapons precision is highly correlated to lethality, mission success, and reduced costs

Adversary Navigation Warfare (NAVWAR) systems threaten our ability to execute MDO/JADO

Relationship Between Precision & Lethality

CEP

(Circular Error Probable)



Frag Effects (Dispersion Factor)

CEP (m)	N hits
5	579
10	145
25	23
50	6

- These numbers represent the number of hits expected from a fragmentation warhead with 182K fragments against a single, man-sized target.
- A standard 500-pound Mk 82 bomb produces <3000 fragments.

Frag kinetic effect is not generalized here, though armor is unlikely to be stopped by a general purpose fragmentary warhead

Blast Effects (Dynamic Pressure)

CEP	Warhead
5	82
9.16	502
10	653

CEP	Warhead
18.32	4017
25	10208
50	81667

- To achieve 7psi with a 500lb-class warhead requires CEP < 9.16m.
- Doubling CEP to 18.32m, requires a warhead of 4017lbs
- 500lb warhead yields 7psi dynamic pressure at a range of 9.16m but only 0.875 psi at 18.32m

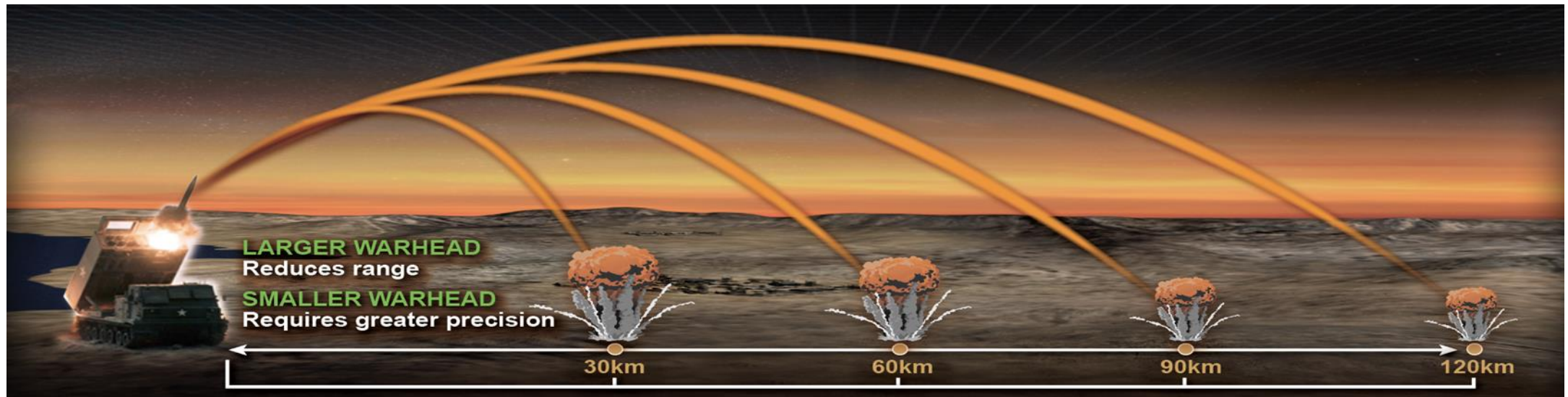
5 psi will kill troops in the open, while 7 psi will kill a light armored vehicle

CEP	PSI
5	43.04022
9.16	7
10	5.380027
18.32	0.875
25	0.344322
50	0.04304

Precision is the primary influence on lethality of weapons at range

Role of Precision in Weapons Effects (Range)

Precision v. Lethality: Function of the mass & volume required by the warhead's damage mechanism and the mass and volume required by the guidance set

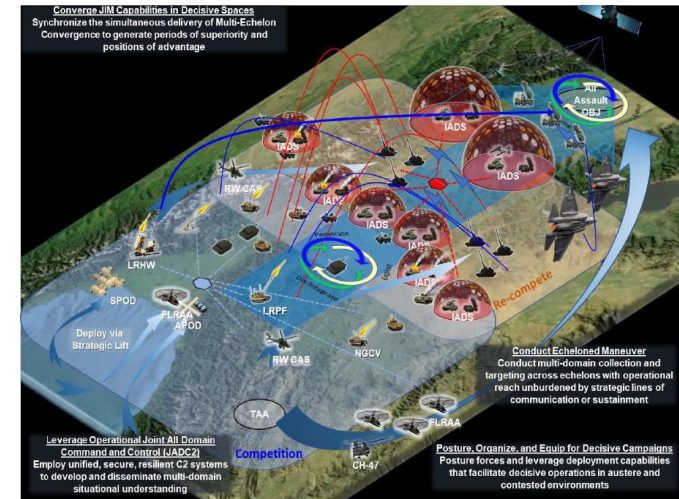


Precision v. Range : Adds the complication of the mass required for the additional propellant



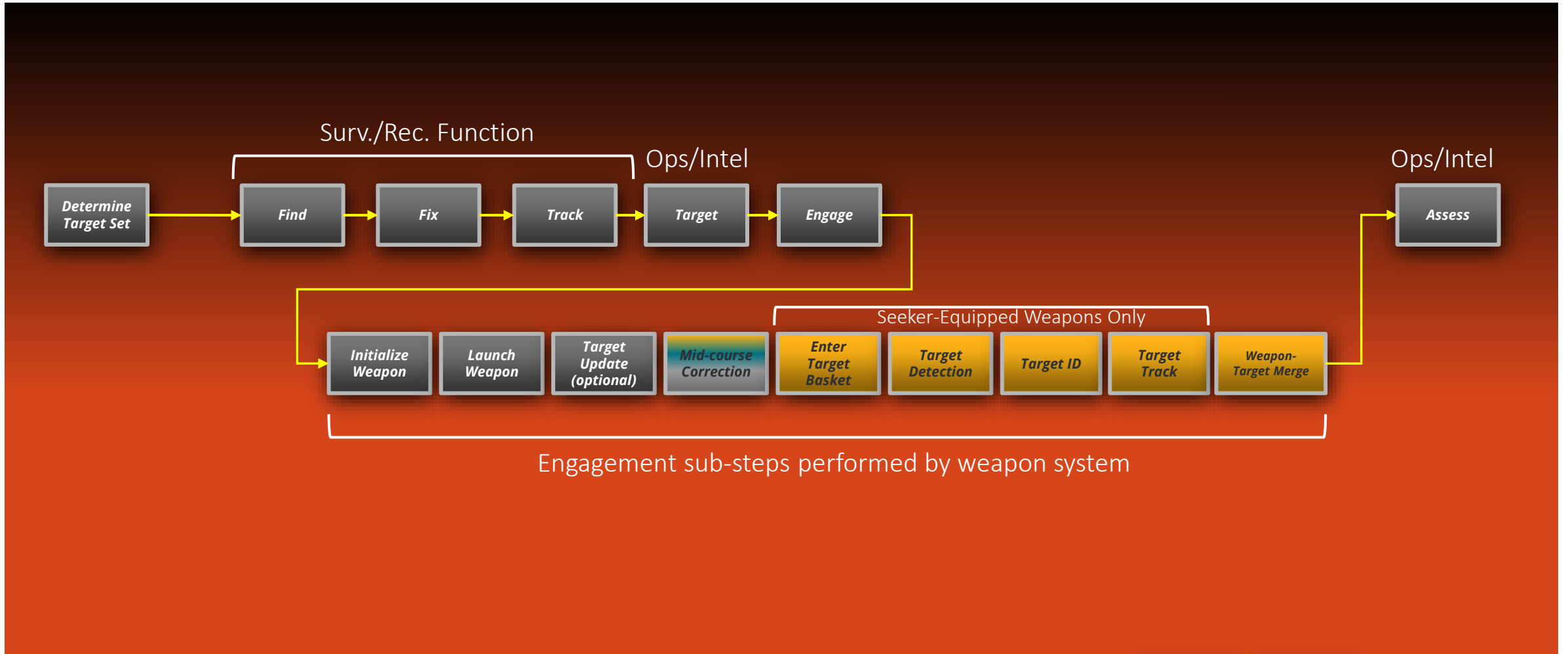
Role of Precision in MDO

- Multi-Domain Operations changes current “fire-enabled maneuver” concept to “maneuver-enabled fires” - disaggregated and dispersed forces able to mass forces or effects while remaining mobile
- Precision and the associated shot-doctrine significantly impacts logistics and battlefield mobility
- Without precision munitions, each weapon has a larger CEP and correspondingly lower P_k , which:
- Requires more shots per target to achieve $P_k > 1$
- Requires additional time to prosecute each target
- Increases vulnerability to counter-battery fire
- Limits the lethality of an individual fires platform
- Increases the requirement for battlefield replenishment



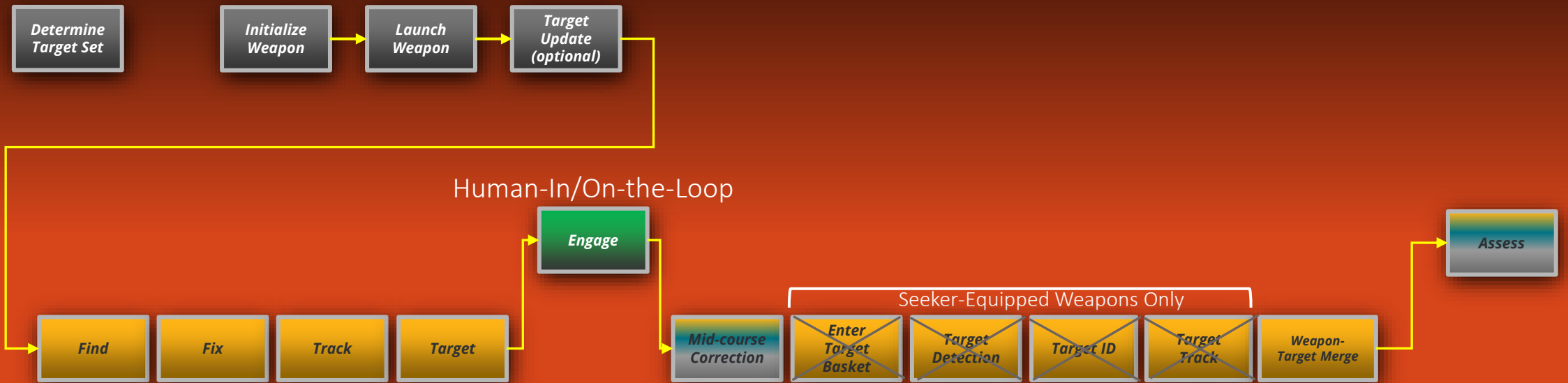
MDO requires precision to achieve required maneuver-enabled fires

Traditional Kill Chain



NOT EXPORT CONTROLLED PER ES-NSS-082622-0042

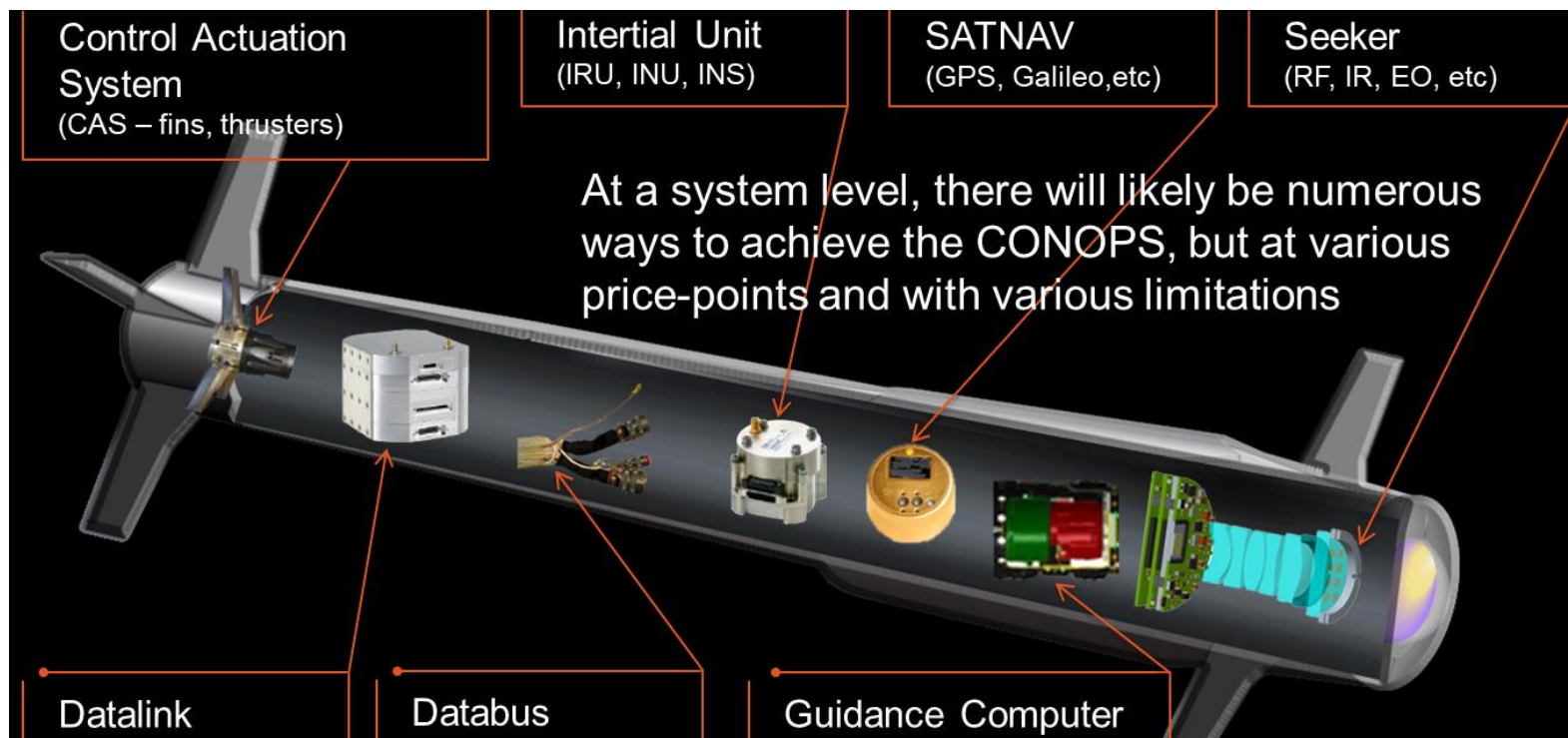
Autonomous/Semi-Autonomous Loitering Munitions Kill Chain



Autonomy requires precision geolocation, or it's just "remote control"

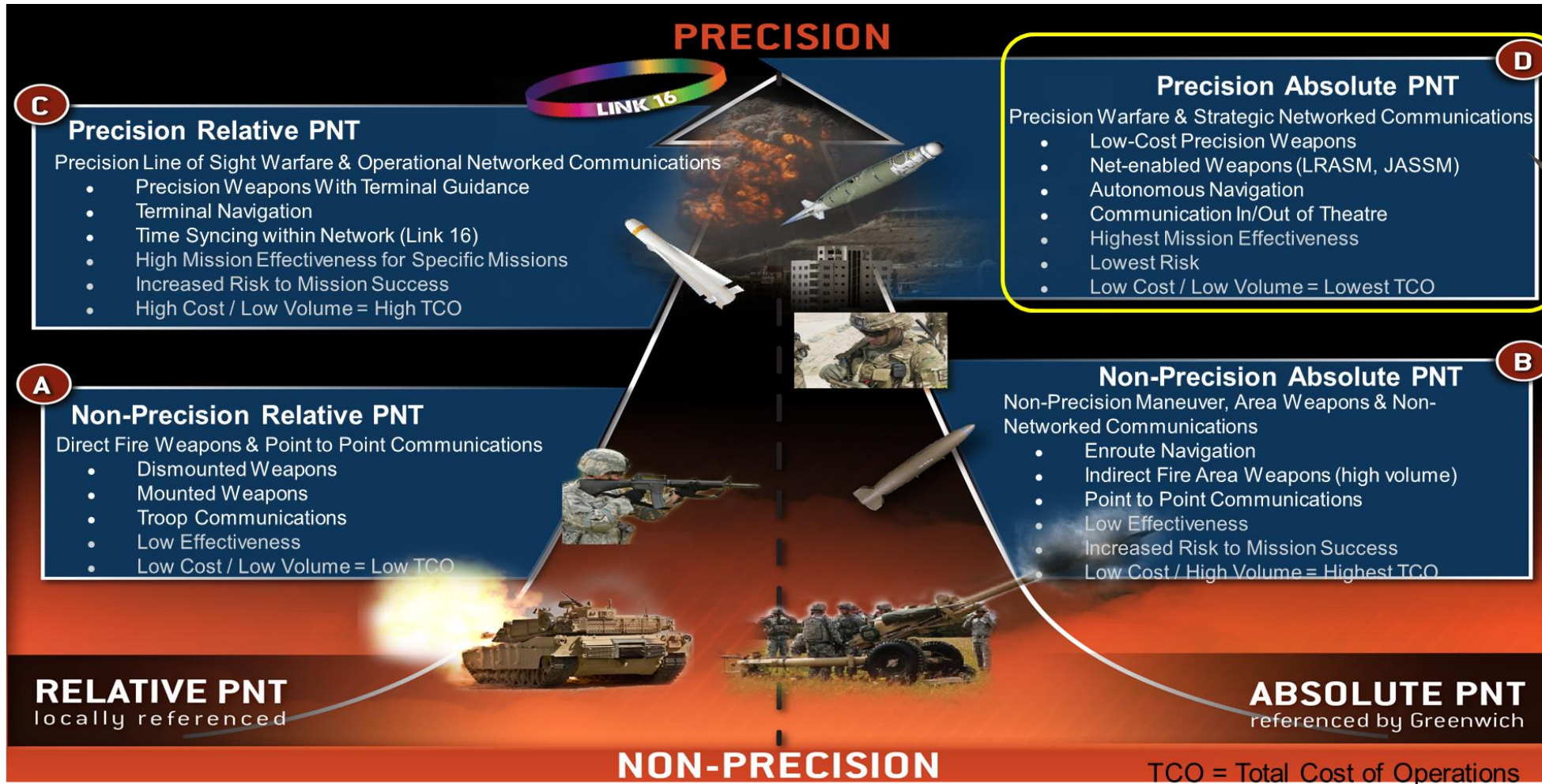
NOT EXPORT CONTROLLED PER ES-NSS-082622-0042

GNC Trade Space



NOT EXPORT CONTROLLED PER ES-NSS-082622-0042

Precision v. Non-Precision / Absolute v. Relative Reference Frame



Quadrant D, precision absolute PNT, is what enabled the RMF and will likewise enable MDO/JADO

Guidance, Navigation, and Control Trade Space

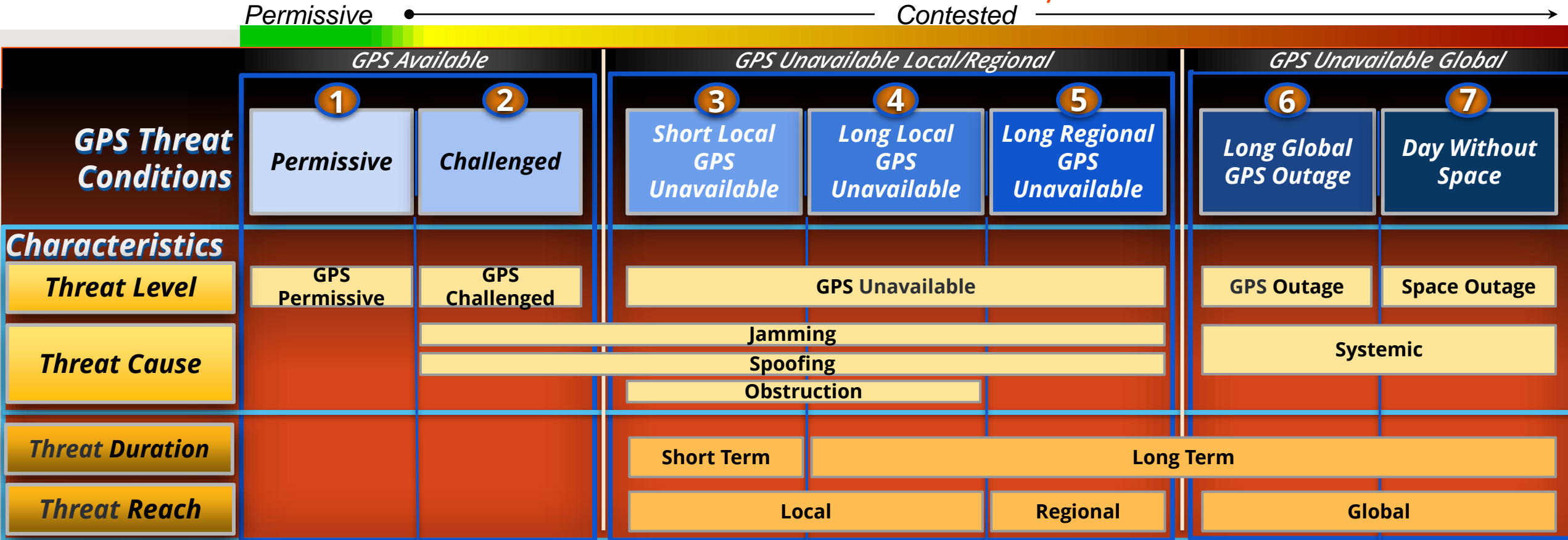
- There are two general approaches to precision guidance: Guide-onto-Target (GoT) (“Quadrant C”) and Guide-onto-Location-in-Space (GoLiS) a.k.a. Coordinate-Seeking Weapon (CSW) (“Quadrant D”)
- There are up to seven key elements of a modern GNC system that make a “smart” weapon smart - control actuation system (CAS), inertial unit, guidance computer, seeker, databus, SATNAV, and datalink
- The interplay between the various elements constitutes the trade space in achieving the target discrimination, desired CEP, and resultant P_k
- At extended ranges, achieving affordable precision is dependent on a SATNAV capability
- SATNAV remains the least expensive and most effective PNT source at the user-equipment level to get the weapon to the target or close enough for affordable terminal seekers to resolve the target and complete the engagement

SATNAV is necessary to achieve affordable precision in support of MDO / JADO

Assured PNT Threat Model, Technologies, and Trade-Offs

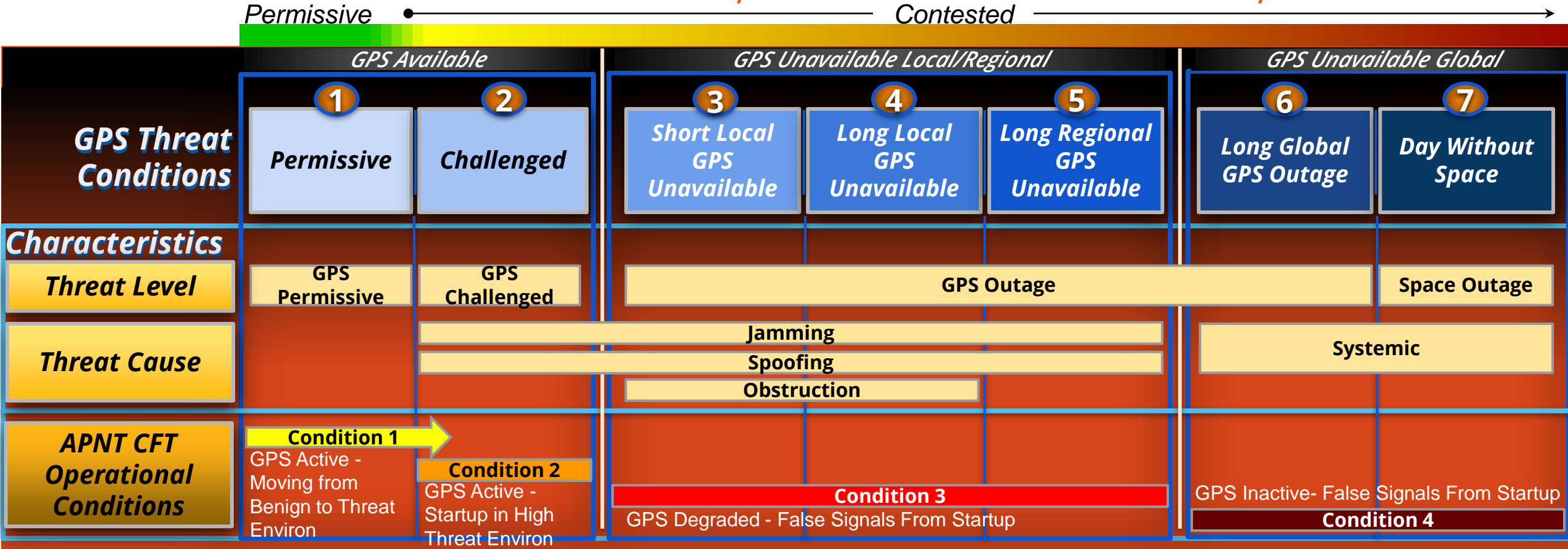
NOT EXPORT CONTROLLED PER ES-NSS-082622-0042

PNT Threat Environment - Common Model for Analysis



This is the basic threat model that we use for our PNT threat analysis. . .

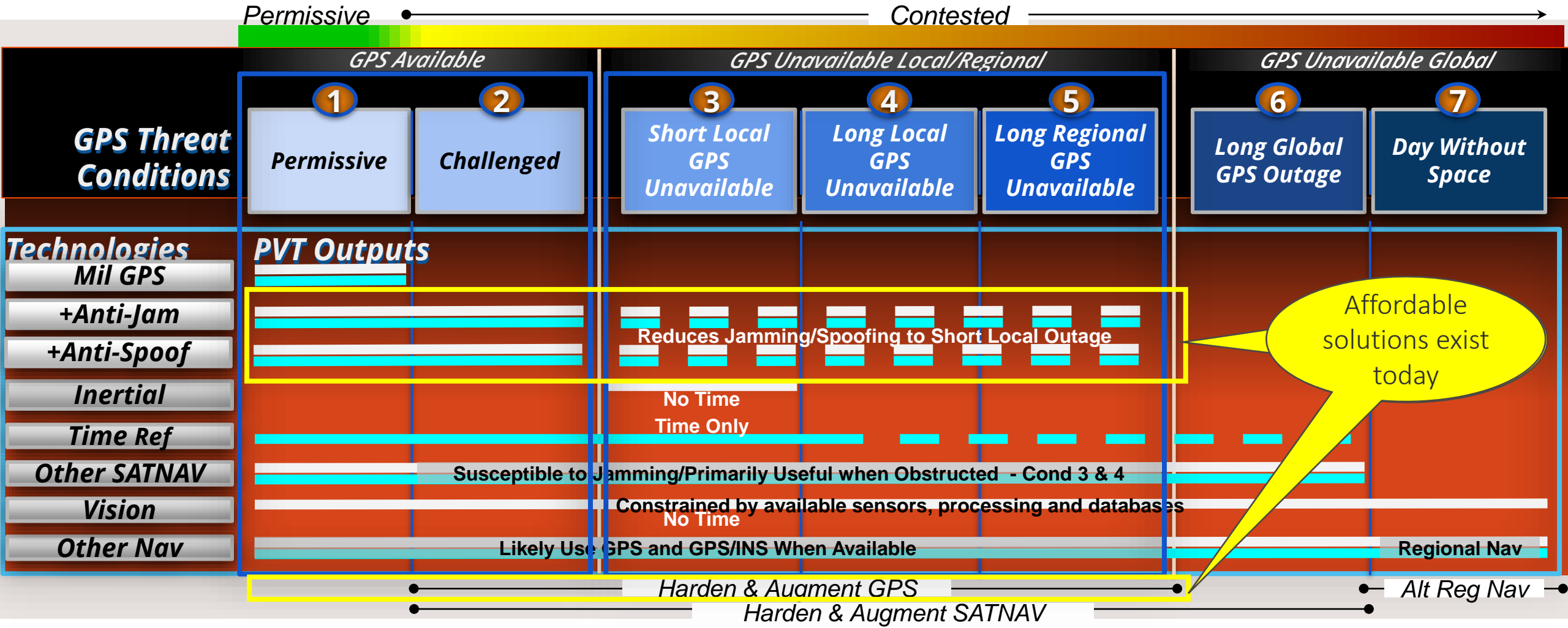
PNT Threat Environment – US Army PNT CFT Conditions Overlay



...with PNT CFT Threat Conditions overlaid: Column 3 thru 5 threats and 6/7 are combined in the Army model

Assured PNT - Applicable Technologies

Position/Velocity █
Time █

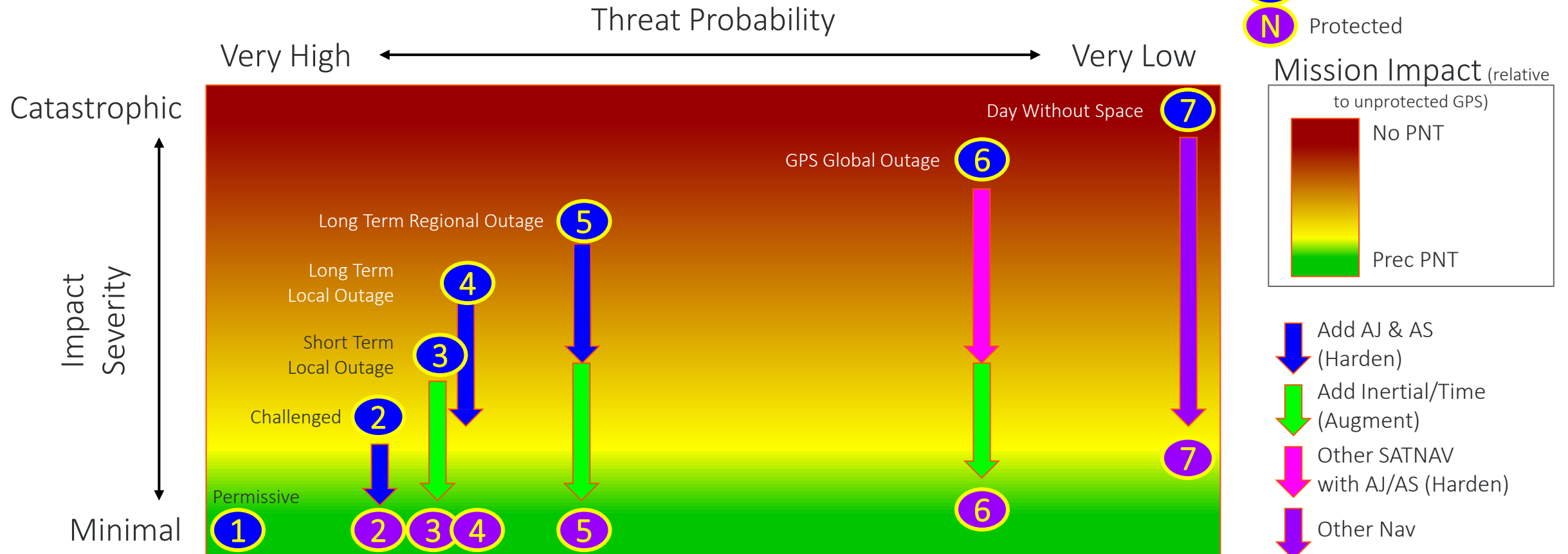


NOT EXPORT CONTROLLED PER ES-NSS-082622-0042

Non-Proprietary

BAE SYSTEMS

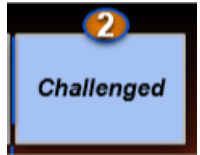
Probability v. Severity of Threats to PNT



Adversaries are working to increase probability – APNT solutions have been developed to reduce impact

Available APNT Hardening Solutions

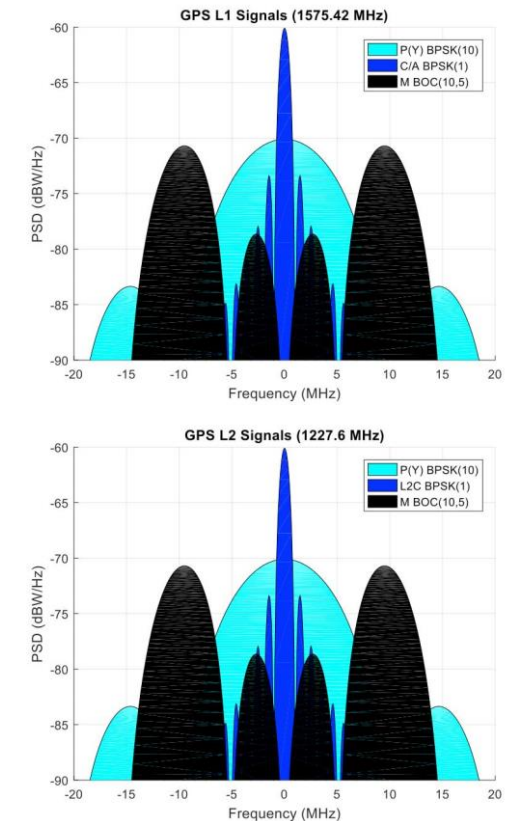
NOT EXPORT CONTROLLED PER ES-NSS-082622-0042



1. Modernized GPS with Military Code (“Toughen”)

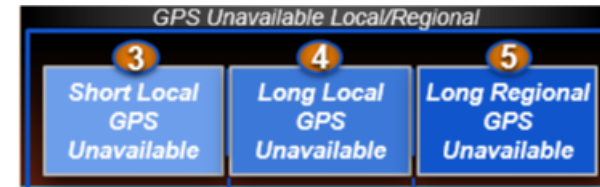
- Significantly enhanced crypto key handling
- Improved anti-spoofing (AS) over Selective Availability/Anti-Spoofing Module (SAASM) with Resilient Software Assurance Modification (RSAM)
- Improved cybersecurity
- Compatibility with Blue Force Electronic Attack (BFEA)
- System-level improvement in anti-jamming

→ M-Code Mandate

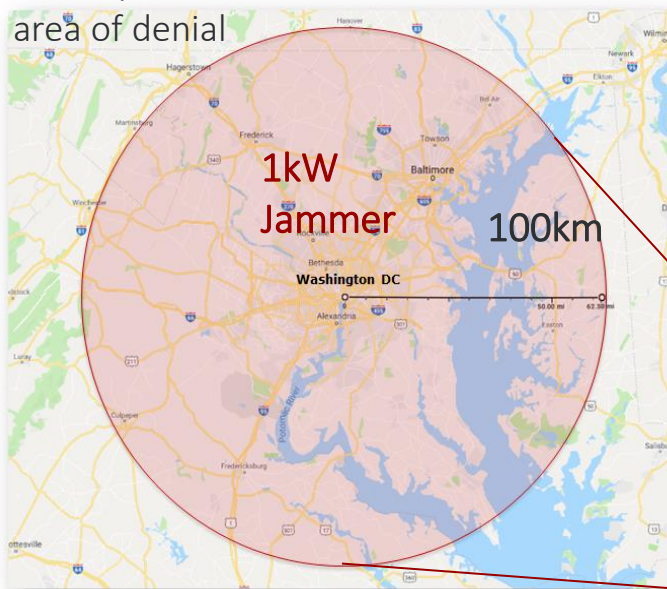


Modernized hardware with Military Code (M-Code) provides several improvements at the system level

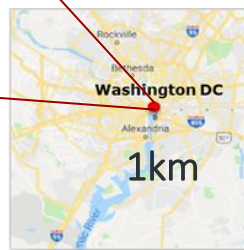
2. Digital Spatial Anti-Jamming Hardening ("Toughen")



Military GPS
area of denial



> +50dB J/S Improvement over M-Code alone



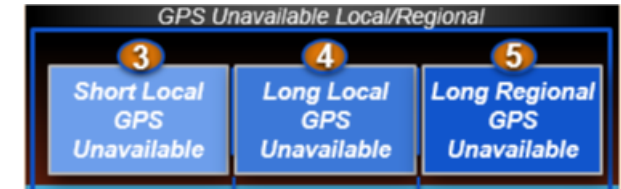
Maps are at same scale

99% Reduction in
Jammer Range



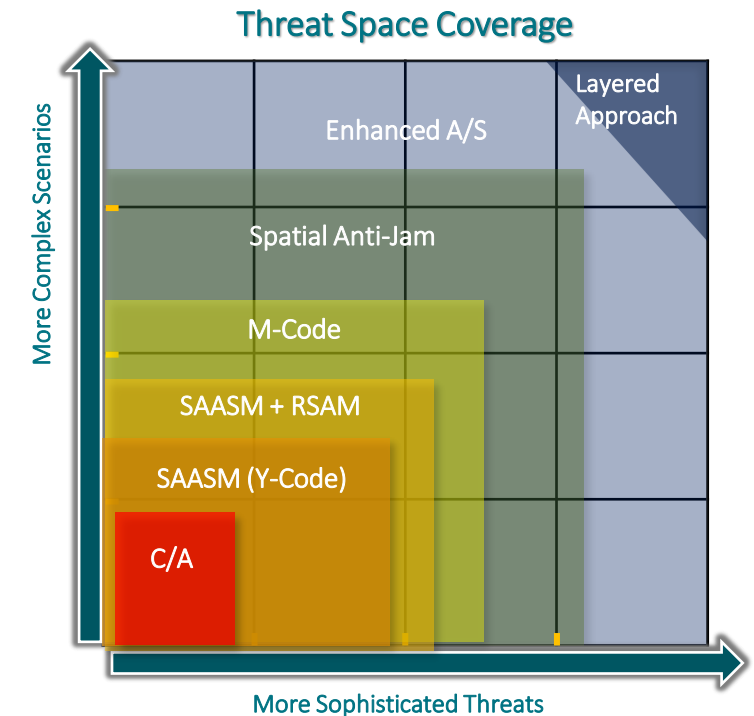
Anti-Jam electronics greatly reduce the effective area of GPS jamming

3. PNT Integrity (Anti-Spoofing) Technologies (“Toughen”)

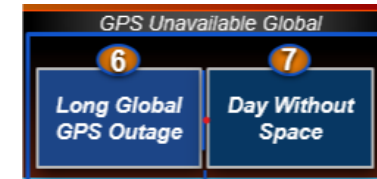


Enhanced anti-spoofing technologies – beyond those inherent in the M-Code signal – when layered on top of M-Code and digital anti-jamming technologies offers the most robust GNSS solution available

- BAE has anti-spoofing technologies beyond those created for RSAM and the Modernized GPS User Equipment (MGUE) Program of Record
- The specifics of these technologies quickly become classified and will not be further discussed here
- However, be aware that they are available, are being implemented, and have been validated by government testing



A layered approach – M-Code, digital anti-jamming & enhanced anti-spoofing provides highest level of integrity



4. “Augment”

- Add inertial and/or high-stability clock (depending on application) to dead-reckon through local GPS outages
- Add other SATNAV sources to GPS receivers (e.g. Galileo, QZSS, AltNav etc.) as hedge against GPS system-level outage (see MGUE Increment 2 requirement)
- Add non-SATNAV augmentation (e.g. vision, celestial, parabolic, datalink navigation) as hedge against “Day Without Space” (DWoS)

Summary



- Precision weapons are critical achieving the range and lethality required for mission success in the MDO/JADO battlespace
- PNT is essential to affordable precision weapons
- Solutions are available to maintain NAVWAR overmatch by toughening and augmenting GPS
- Contact Information
 - BAE Systems Weapons PNT Customer Requirements Manager – Justin Wymore
 - Justin.wymore@baesystems.com, (319) 317-5617



“Toughened”, and in some cases, “Augmented” GPS is a critical to successful implementation of MDO / JADO

Modernized GPS & Digital Anti-Jam Contributions to the Range and Lethality Challenge of MDO

Future Force Capabilities Conference
Unconventional Emerging Armaments
20 Sep 2022

Justin R. Wymore Sr., BAE Systems/NSS



NOT EXPORT CONTROLLED PER ES-NSS-082622-0042

Unclassified. Distribution Unlimited

BAE SYSTEMS