



Securing PNT as a Critical Element to Operational Effectiveness Across the DoD

DSI'S ASSURED PNT (APNT) SUMMIT

Ms. Meggan Schoenberg, Principal Director, (INSS)
Office of the Assistant Secretary of Defense for Critical Technologies
(OASD (CT))

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@OUSDRE

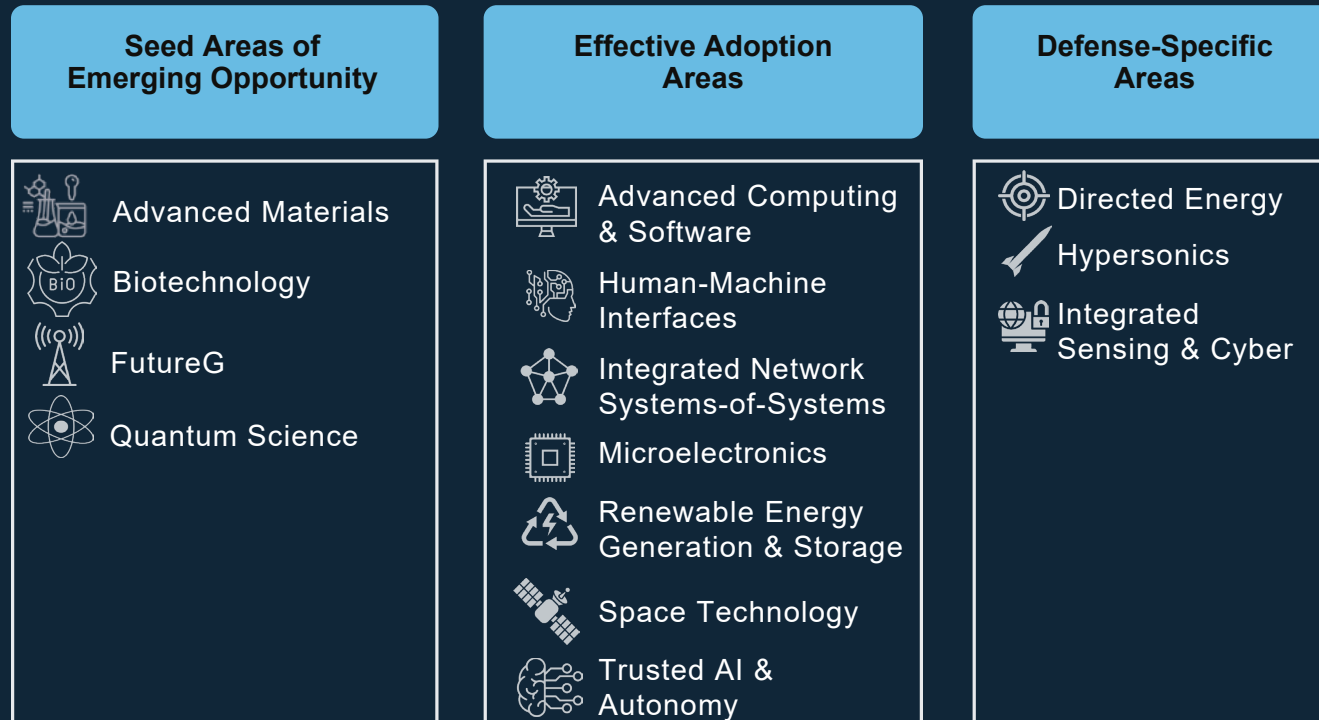


CRITICAL TECHNOLOGY AREAS



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The creation of the Office of the Assistant Secretary of Defense for Critical Technologies was informed by the 2022 and 2019 National Defense Strategies, which initially established the previous modernization priority areas. Expanding on the original priorities, there are now 14 critical technology areas that are vital to maintaining the United States' national security, grouped into three categories.





INTEGRATED NETWORK SYSTEM OF SYSTEMS



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C3

Resilient Interoperable Secure Trusted Hyper-Mobile

Automated C2 Orchestration



Challenge: Without fully connected DoD networks: impaired situational awareness, delayed response, miscommunication, compromised OPSEC, loss of C2, diminished confidence and moral, and strategic vulnerabilities will occur.



QUANTUM SCIENCE, TECHNOLOGY, AND ENGINEERING



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Quantum Science Knowledge-driven

Processes, Controls & Materials

Harnessing Entanglement
(e.g. quantum networking)

Quantum Computer Science

**Three kinds of
research &
development
To answer
What, How &
Why**

**Success needs
them all plus a
workforce
(the Who)**

Quantum Technology Applications-driven

Navigation and Timing

Spectrum, Imaging, & Detection
(e.g. electromagnetic sensors)

Computing

Specialized Components

Quantum Engineering Process-driven

Integration and Architectures



QUANTUM TECHNOLOGY IN NAVIGATION



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THE THREATS TO RADIOFREQUENCY (RF) ARE MATURE, BUT WE DO NOT HAVE TO LOOK FAR FOR OPTIONS TO AVOID THESE THREATS.



Bathymetry Navigation:

matches depth soundings with seafloor maps



Image-aided Navigation:

matches electro-optical images with overhead imagery



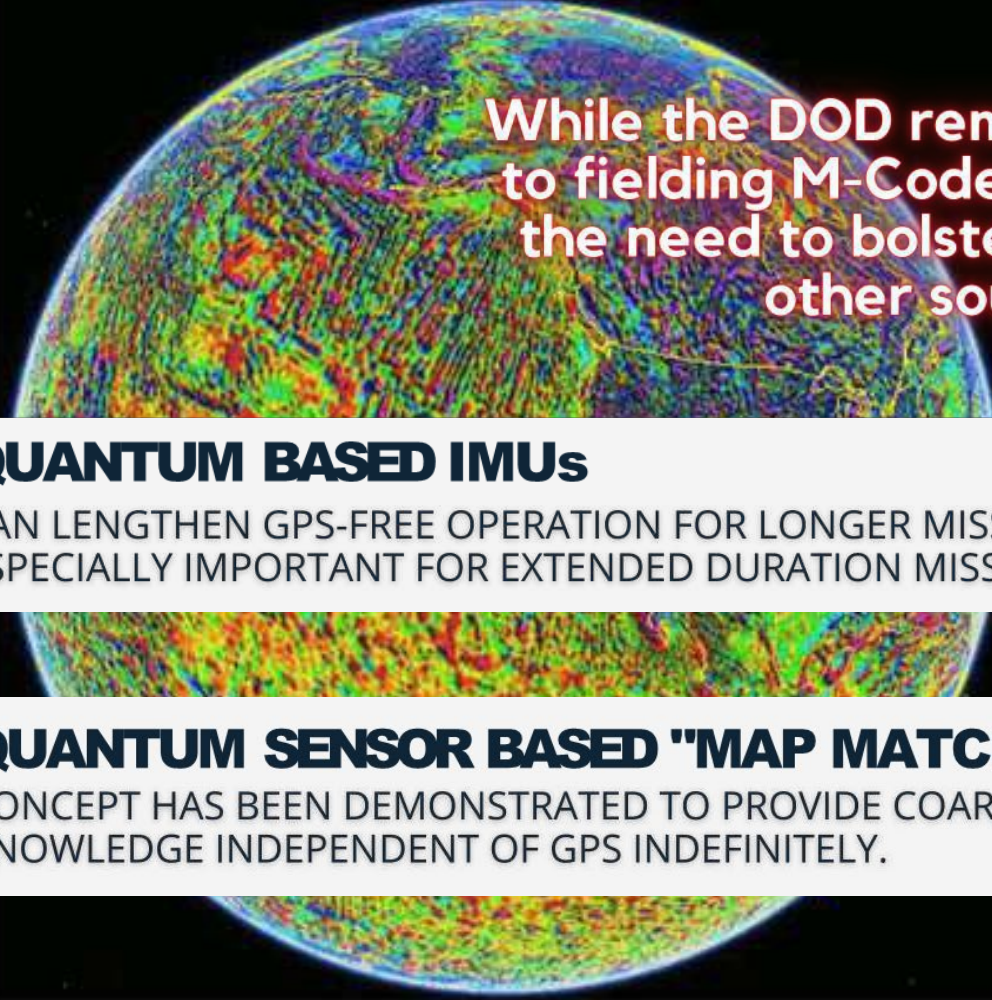
Magnetic Anomaly Navigation:

matches magnetometer data with maps of the magnetic variations in the Earth's crust



Gravimetry Navigation:

can do the same for the variations in Earth's gravitational field



While the DOD remains committed to fielding M-Code, we recognize the need to bolster PNT through other sources.



QUANTUM BASED IMUs

CAN LENGTHEN GPS-FREE OPERATION FOR LONGER MISSION TIMES, ESPECIALLY IMPORTANT FOR EXTENDED DURATION MISSIONS.



QUANTUM SENSOR BASED "MAP MATCHING"

CONCEPT HAS BEEN DEMONSTRATED TO PROVIDE COARSE POSITION KNOWLEDGE INDEPENDENT OF GPS INDEFINITELY.



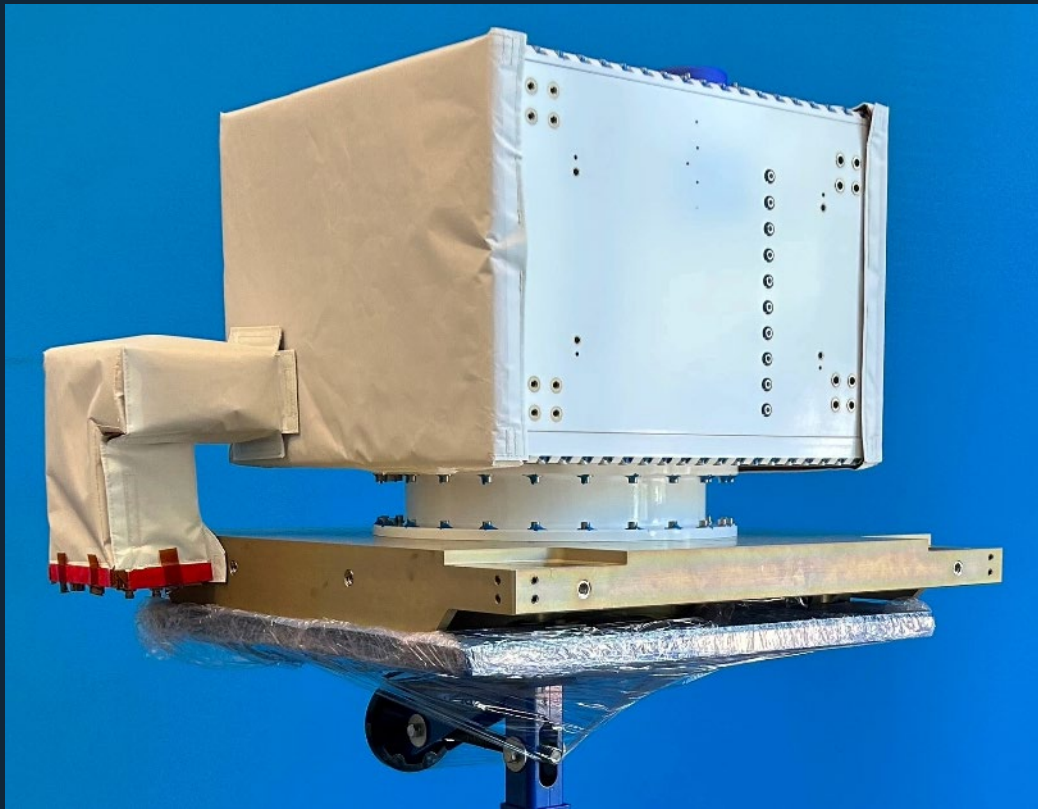
ATOMIC GYROSCOPE SPACE DEMO TRANSITION EXAMPLE FROM OUSD R&E



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POTENTIAL TO GREATLY REDUCE THE RELIANCE ON GPS FOR NAVIGATION AND TIMING, EVEN REMOVING THE NEED FOR GPS IN SOME SCENARIOS.

Defense Innovation Unit (DIU) Project Spotlight | 27 September 2023



- *Quantum Sensing* is the most mature and promising for use in military technologies reliant on accurate PNT
- DIU in collaboration with OUSD R&E kicked-off a quantum sensing initiative in late 2020 focused on moving atomic sensors out of the lab to the real world
- Vector Atomic (California start-up) in partnership with Honeywell Aerospace delivered a fully integrated, high-performance atomic gyroscope
- First atomic gyroscope to undergo space qualification and is expected to be the first atomic inertial sensor to operate in space



ATOMIC GYROSCOPE SPACE DEMO TRANSITION EXAMPLE FROM OUSD R&E



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Physics package for atomic gyroscope. Courtesy of Vector Atomic

“This project represents decades of investment by the DoD, particularly DARPA, into quantum based inertial sensors. It is so exciting to see the capabilities come to fruition, thanks to this development push from DIU and funding support from OUSD R&E amongst many other agencies,” said Dr. John Burke (PD of Quantum Science at OUSD R&E)



QUANTUM TECHNOLOGY IN TIMING



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ATOMIC CLOCKS *CRITICAL HEARTBEAT OF GPS*

OU SD (R&E) IS ACTIVELY DEVELOPING A NEW GENERATION OF ATOMIC CLOCKS FOR SEVERAL TYPES OF MISSIONS THAT MAY ELIMINATE THE NEED FOR GPS TO PROVIDE ACCURATE TIME OVER THE DURATION OF A MISSION.

Currently the Space Force has 37 PNT on-orbit assets primarily as GPS (II/III) systems.

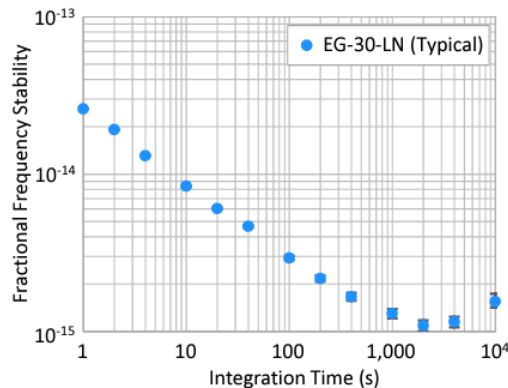


TIMING IS EVERYTHING

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POTENTIAL TO GREATLY REDUCE THE RELIANCE ON GPS FOR NAVIGATION AND TIMING, EVEN REMOVING THE NEED FOR GPS IN SOME SCENARIOS.

Evergreen-30 (EG-30) : Rackmount Optical Clock



Features

- Instability 2.5×10^{-14} at 1 s; 5×10^{-15} at 1 d
- Ultralow phase noise
- 100 MHz, 10 MHz, and 1 PPS outputs
- 1064 nm CW and 1560 nm comb output
- Low environmental sensitivity
- 3U 19-inch rackmount package
- Vacuum- and cavity free-design

- Vector Atomic is a 5-year-old California start-up focused on fielding and commercializing atomic instruments
- Atomic instruments e.g. atomic clocks measure time using the resonant frequencies of atoms, which act as the beats, or ticks, of the clock
- Conventional atomic clocks are based on clusters of cesium atoms that emit light with high frequency oscillations when illuminated by a laser source
- Optical clocks based on different elements (e.g. the EG-30 device shown to the left is an iodine optical clock) can emit light at even higher frequency oscillations, therefore providing ticks more precisely than conventional atomic clocks



QUANTUM TECHNOLOGY READINESS LEVELS: A CHALLENGE FOR INDUSTRY

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Readiness Level	Technology	Manufacturing	Integration	System
9	System proven through successful operations	Full Rate Production	Operational System	Operational system
8	System proven through test and demonstration	Low Rate Initial Production	Actual system demonstration	Actual system demonstration
7	System prototype demonstration in an operational environment	Pilot Line Capability	Validated integration of technologies	System prototype demonstration in an operational environment
6	System prototype demonstration in a relevant environment	Prototype system or subsystems in the production environment	Complete information exchange for the application	System prototype demonstration in a relevant environment
5	Breadboard validation in a relevant environment	Prototype components in a production environment	Sufficient control to manage integration	System component validation
4	Breadboard validation in laboratory environment	Technology produced in a laboratory environment	Sufficient detail in Q&A of the integration	System component verification
3	Experimental validation	Manufacturing proof of concept identified	Technologies shown to be compatible	System proof of concept
2	Analytic studies & simulation	Manufacturing concepts identified	Ability to characterize interface	System technologies
1	Basic principles observed / reported	Manufacturing implications identified	Interface between technologies identified	System concept



INTEROPERABILITY OF QUANTUM WITH OTHER PNT TECHNOLOGIES

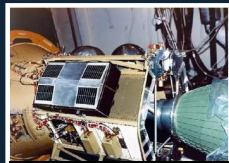
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Milestones of GPS provide an example of how PNT technology can evolve



1960: ARPA launched Transit, the first satellite in what would become the world's first GPS



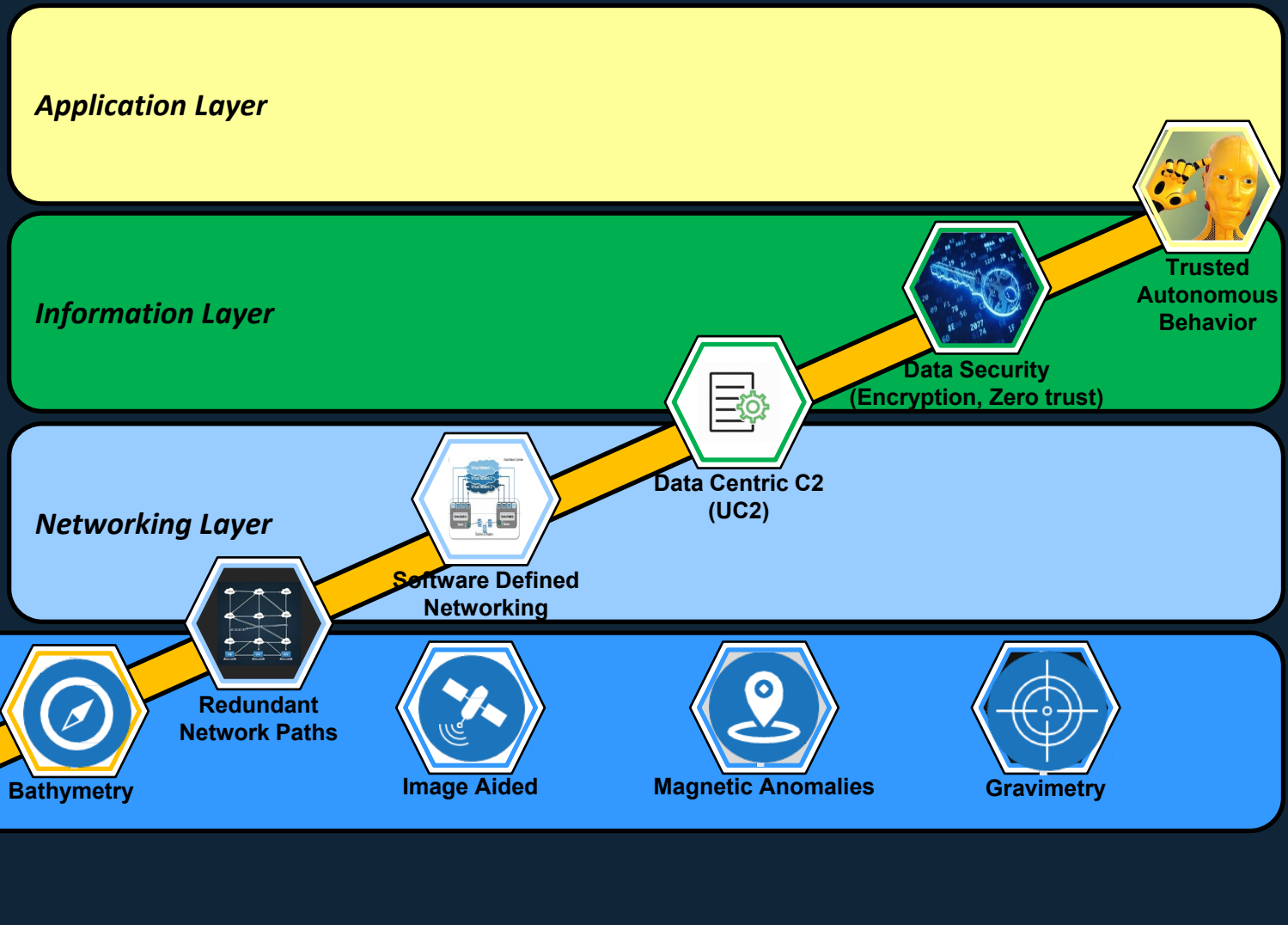
1967 & 1969: 2 Timing satellites improved location accuracy



1978 - 1993: NavStar-Global Positioning System



2023: Lockheed Martin completes delivery of 10th GPS 3 satellite





THE MISSING LAYERS OF ORCHESTRATION WITH POSITIONING AND TIMING

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LAYER 8	Orchestration	Blue Force network awareness, use, and mission-outcomes optimized over space-time; Red Force behavior modeling	wQoE
Layer 7	Applications, Autonomy, Machine Learning and MEC	Data access (HTTP, HTML, CoT), usage (AFTADS, JSON) storage (DTN), sharing (MFA), OODA-Loops, cyber (PCAP ML, XDS), app config updates; network slicing at the autonomy layer	Cyber Contested PK
Layers 4-6	Transport, Session, Presentation (Crypto, DTN)	Data that mediates exchanges: JTIDS modes, DNS, SIP, BGP, relay; Type -1, -2, and Coalition Crypto; SSL, Snow, TRANSSEC	
Layer 3	Network – Data that Enables Assured Delivery	RF Nets: SINCGARS setup, SRW, WNW, MANET, 2G, 5G, PTW Cable Nets: TCP/IP connections, UDP/IP connectionless, MPLS	CEMA Contested QoS
Layer 2	Link – The Sequence of PHY Layer Signals Used to Connect Nodes	RF Link - Channel Symbols, FH, DSSS, Framing, Sync, FEC, ARQ, Admission Control, Sleep Modes, Black-side Routing Cable Link – PoP, Cable Cross-Connect, Framing, Sync	DECM Contested
Layer 1	PHY – The Physical Mechanism Used to Connect the Nodes	RF PHY - Frequency, Bandwidth, Pt, FH, Beams, G/T, Diversity Cable PHY - Endpoints, Transit, Data Rate, BER	RF Contested TLE
LAYER 0	Space x Time – The Geospatial Layer Over Time	Where are the nodes in Space-Time-Movement over Space X Time changes FNC3 contact envelopes (Availability, SNR, BER, Rb)	[Entity, Position, Time] [Altitude, Velocity]

Thank You to Dr. Joe Mitola for this Figure!

Automated C2 Orchestration



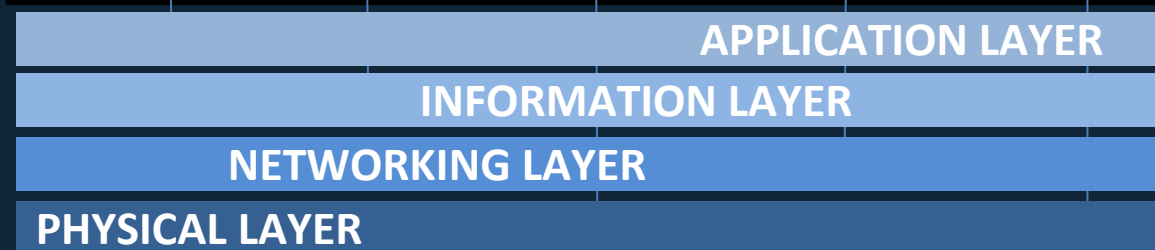
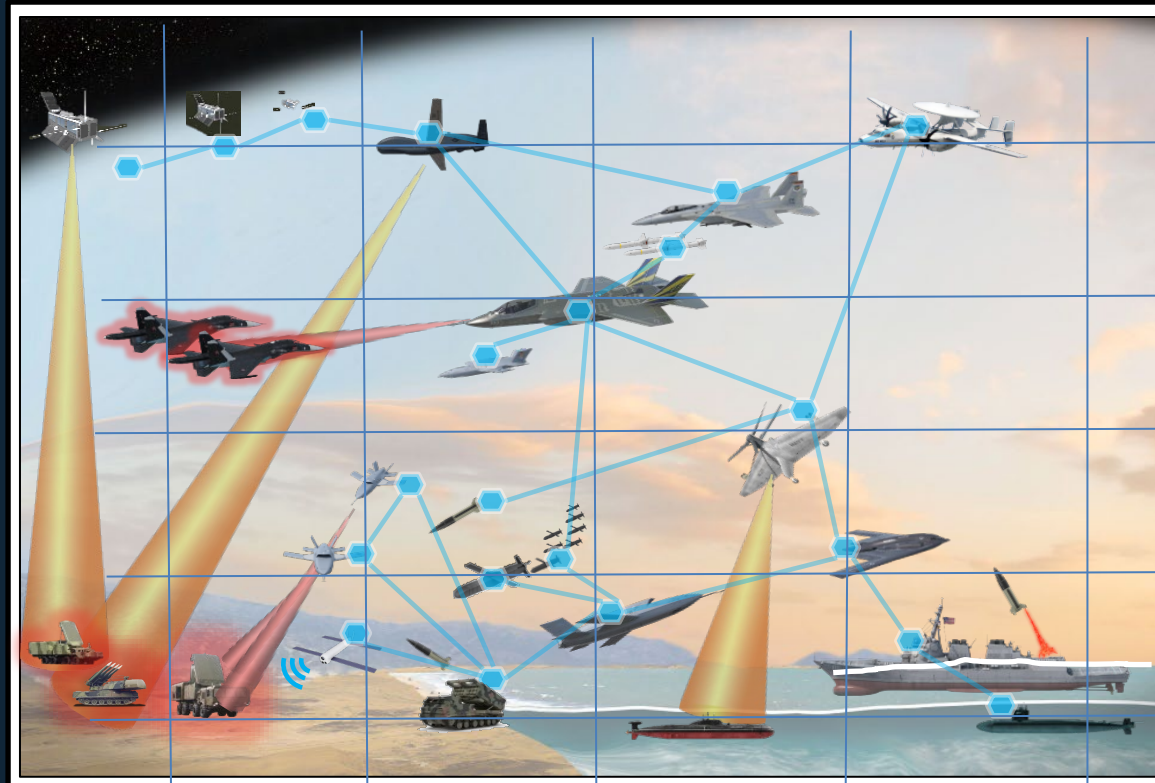


INSS CRITICALITY, CHALLENGES AND ATTRIBUTES



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Interoperability Grid of Critical Technologies with Quantum Technology



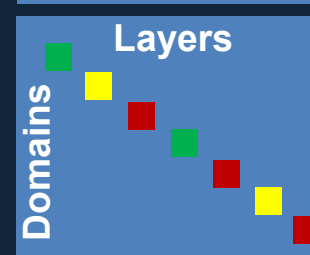
SPACE

AIR

LAND

SEA

CYBER



- Developing an architecture that allows tech insertion while maintaining interoperability
- Defining standards needed for quantum technology integration
- Measuring the lack of interoperability with metrics
 - Tracking readiness levels beyond just technology
- Defining the required Quality of Service metrics for Quantum Technology
 - Data rate, latency, jitter, packet loss, ...

Technologies at Varying Readiness Levels



THANK YOU FOR YOUR TIME!

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**Principal Director of Integrated Network
System of Systems (INSS) at OUSD R&E**

Ms. Meggan Schoenberg
meggan.m.schoenberg.civ@mail.mil

**Principal Director of Quantum Science
at OUSD R&E**

Dr. John Burke
john.h.burke51.civ@mail.mil

PNT SME at OUSD R&E/INSS

Dr. Wil Myrick
wilbur.l.myrick.ctr@mail.mil