Navy/NSF-UNOLS Scientific Committee on Oceanographic Aircraft Research (SCOAR)
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US Coast Guard UxS/UAS Update

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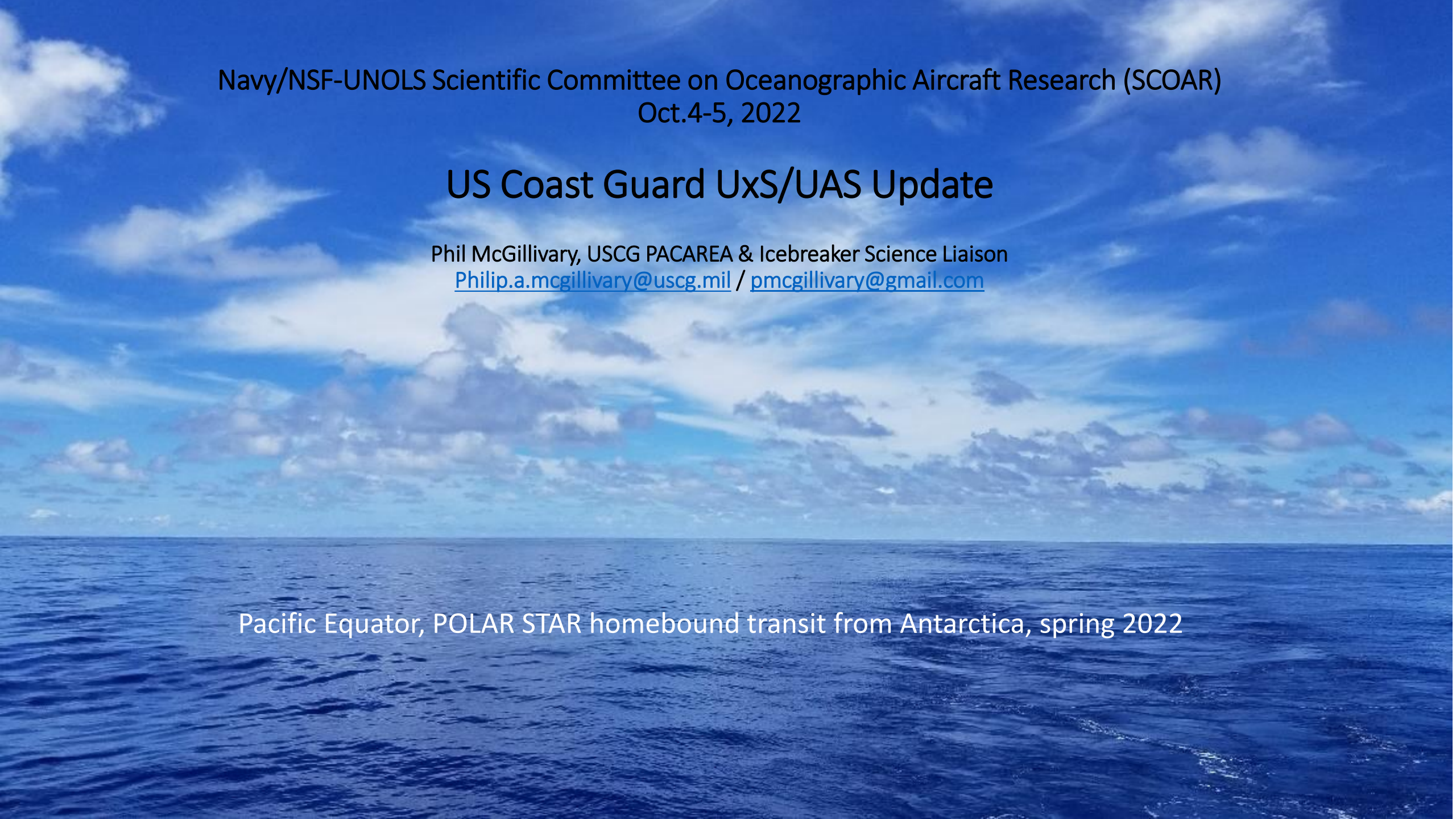


Pacific Equator, POLAR STAR homebound transit from Antarctica, spring 2022

CG Completes UxS Strategy & UxS Implementation Plans

- A Coast Guard Working Group, headed by CAPT Thomas Remmers, delivered a CG UxS Strategy document within the first 100 days in office of the new CG COMDT ADM Linda Fagan as part of her Command initiatives. She is expected to sign off on this before the middle of October.
- A CG UxS Implementation Plan, which is the next step in CG planning, has also been completed, and will begin review after the UxS Strategy document is signed off on.
- The CG UxS Strategy plan is based around the concept of UxS as part of an operational ‘ecosystem’.

CG UxS Strategy

- The CG UxS Strategy plan is based around the concept of UxS as part of an operational ‘ecosystem’ defined around the mission. CG has 11 mission areas: Port, Harbor & Coastal Security; Drug Interdiction; Aids to Navigation; Search & Rescue; Living Marine Resources (Fisheries, Endangered Species Protection); Safety of Life at Sea; Defense Readiness; Migrant Interdiction; Marine Environmental Protection (Oil Spills, Pollution); Ice Operations; and, Other Law Enforcement.
- Given a mission, UxS must first be ‘Commanded’, then sensors must be chosen and integrated into a system of manned and unmanned assets, then the Tactical Communications Network must be established. Once fielded UxS data must be stored and managed, including analysis using AI/ML, and finally that data will be used for additional Command/Control Actions/Decisions. It is worth noting here that CG AI/ML division directors were among the key subject matter experts on the core CG UxS Working Group.

CG UxS Strategy: Three Strategic Lines of Effort

- Three Strategic lines of effort:

  1 – Determine use of UxS to improve mission execution, especially for Maritime Domain Awareness

  2 – Develop & deploy Counter-UxS technologies to defend against threats & unlawful UxS use

  3 – Establish a regulatory framework for unmanned vessels as part of the Marine Transportation System

CG UxS Strategy: Five Strategic Goals

1 – Focus on capabilities of UxS/C-UxS to enhance and integrate with existing (manned) capabilities (and address capability gaps)

2 – Establish framework for UxS in the Marine Transportation System

3 – Continuously test and learn to continuously innovate with UxS

4 – Build partnerships w/ federal & other stakeholders for UxS & C-UxS

5 – Accelerate delivery of key enablers & technologies, eg AI/ML & comms & data standards for interoperability w/ federal maritime & other federal agencies

CG UxS Strategy: Current UxS Projects

- VTOL & BVLOS UAS ops
- Sensor fusion for collision avoidance
- Oil detection, including under ice
- Confined space inspections
- C-UAS capabilities & C-UxS capabilities for ports/harbors
- Enhanced comms networking, including at high latitudes
- AI/ML testing/use for data analysis/operational decision making
- Development of maritime UxS policies
- Development of a CG UxS Capabilities Office to manage CG UxS ops

CG UxS Strategy: Strategic Objectives

1 – Create a CG UxS Capabilities office to coordinate UxS ops

2 – Create a framework for UxS ops in the Marine Transportation System

3 – Continuously test to enable continuous innovation

4 – Build partnerships with other stakeholders

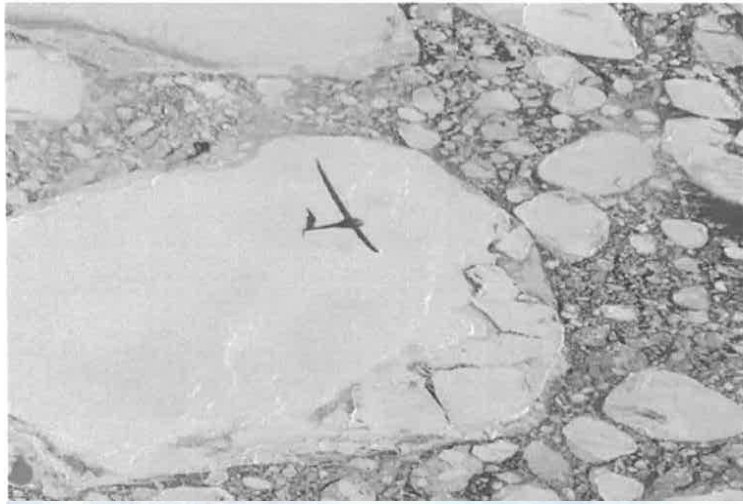
5 – Accelerate delivery of key enablers like ML/AI & Comms technologies

CG UxS Strategy: Comments…

- Setting up the CG UxS Capabilities Office is key; an ancillary component of this is developing CG UxS personnel training and personnel capabilities for UxS operation and data analysis/operationalization. The option of how and when to contract for UxS systems operation is still under discussion.
- Setting up the Data Management/Analysis structure is also key.
- Obviously, improving comms capabilities/bandwidth is key to at-sea UxS use for command/control, data transmission, and networking UxS with each other, not just as standalone UxS systems and with integration into manned systems as well.
- Another key Strategic Objective for the CG is analysis of the cost/benefit of UxS: how much will it cost to use UxS, and what cost and operational benefits will that have. This is not as straightforward as one might think, so how to do this is still a critical issue.
- Finally, the forthcoming Strategic Implementation Plan lays out details on mission-specific CG use of UxS.

Upcoming UxS Use by CG

- CG D17 (Alaska) has purchased a number of s-UAS and trained locals in Alaska to use them to monitor the effects of permafrost melt on destabilization of fuel oil tanks. Previously the CG has been spending @$3M/yr for inspectors to travel to examine the 300+ tanks, a process time-consuming & expensive.
- CG continues using ScanEagle UAS; CG also looking toward VTOL UAS for the future as possible. CG also wishes to improve S-UAS capabilities in the Arctic by making use of i-SAR systems to see through fog/clouds as soon as feasible.
- CG R&D Center conducted UAS trials in the Arctic jointly with Canada for identification and classification of oil spills in ice-infested waters.
- CG is increasing use of the MQ-4C Predator HALE UAS, based on successful use previous year; additional platform time requested from DHS. One goal will be to integrate Predator data with ship and ship-based s-UAS use, and use HALE UAS for data communications and data analysis.
- CG is also interested in joint testing of the VANILLA M-UAS with other federal agencies for maritime ops (eg Navy). NASA just tested VANILLA for ice surveillance off the North Slope, shown upper right, see: https://vanillaunmanned.com/news/vanilla-uas-arctic-operations
- CG recently received 6 Ocean Aero Triton ASVs (w/ retractable sails & diving capabilities, shown lower right). Integrating these w/ HALE UAS & S-UAS systems as part of a network is a testing goal for 2023; NOAA has offered to partner with CG on this.



Upcoming UxS Use by CG

- CG White Hulls are currently using Navy RORO C-UAS systems; as these are becoming more “necessary” given W.Pac. & Arctic deployments, CG is considering purchasing some of these rather than continuing to borrow them from the Navy.
- CG plans to pursue testing of a smaller, portable air search radar system in the future to enable use on all vessels (see example pictured at right).
- All 3 new CG Polar Security Vessels will have Air Radar, so will be UAS capable
- Both HEALY & POLAR STAR are planned to have STARLINK Mobile comms antennas in 2023 to facilitate use of UxS data transmissions/analysis.
- HEALY, which does not have an Air Search Radar, is pursuing opportunities to test tethered UAS.
- CG will also be testing UAS ML/AI software for target recognition
- HEALY is pursuing opportunities to test data and command/control exchanges with UAS deployed from other vessels using the protocol outlined in Baghdady et al., 2020 for direct communication between US and Allied partner vessels and their UxS.
- Reference: Enabling Interoperability among Disparate Unmanned Vehicles via Coordinated Command, Control, and Communication Strategies. J. Baghdady, et al., 2020. Oceans 2020, Oct. 5-14, Singapore, see: https://ieeexplore.ieee.org/abstract/document/9389223

Other CG UxS Updates

- CG Sector San Diego is the designated CG UxS testbed
- CG Blue Technologies Center of Excellence at Scripps continues to work on UxS tech. POCs are: Dr. Peter Vandeventer (peter.e.vandeventer@uscg.mil) and Jennifer Ibaven (Jennifer.m.Ibaven@uscg.mil).
- LCDR Matt Hardgrove recently arrived as CG PACAREA UxS POC

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- Navy has already set up a UxS Central database/ops shop; NOAA is working on setting theirs up, and CG will be setting theirs up in the coming year to work with both NAVY and NOAA UxS ops centers.

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Other CG UxS Updates

- CG HQ has issued new guidelines for S-UAS use by CG units that are much less restrictive on use; the principal requirement is that systems be from the ‘approved’ “Blue List” that meets national cybersecurity requirements.
- Blue List UAS currently include no VTOL UAS (other than quadcopters), but the list is constantly expanding, so this may change
- Current Blue List UAS v.2.0 are listed at: https://www.diu.mil/latest/blue-uas-2-0-cleared-list-access-to-broader-variety-of-capable-unmanned

Blue List 2.0 UAS (Alphabetically)

Ascent Aerosystems Spirit (twin rotor vertical helo)

Blue Halo Intense Eye V2 (quadcopter)

FLIR ION M440 (quadcopter)

Freefly Systems AltaX (quadcopter)

Inspired Flight IF750 & IF1200 (quad & hexacopter)

Parrot Anafi USA GOV and USA MIL (quadcopters)

SenseFly eBee Tac (fixed wing pusher prop)

Skydio X2D (quadcopter)

Teal Golden Eagle (quadcopter)

Vantage Robotics Vesper (quadcopter)

Wingtra WingtraOne (fixed wing twin prop)

…the problem: none have very long ‘legs’….need to get something like Latitude Engineering/L3Harris FVR-90 VTOL UAS (https://www.l3harris.com/all-capabilities/fvr-90-airframe) (upper pix) or the somewhat similar Fixar VTOL UAS (https://fixar.pro) (lower pix) on the Blue List if possible for ship/icebreaker use…

Speaking of the need for VTOL UAS for ships, etc.: DARPA RFP

- On Sept. 20, 2022 DARPA had a “proposer’s day” for their new ANCILLARY RFP for “AdvaNced aircraft Infrastructure-less Launch and RecoverY” program
- Basically this is for ships and elsewhere lacking infrastructure where VTOL UAS are desired for low weight, high payload, long endurance UAS that can operate in adverse weather, and are ideally 3D printed
- So far they seem to be leaning toward tail-sitters, but are still making determinations…
- The only problem: any DARPA solution will be several years off…

Arctic Council upcoming May 2023 UAS Workshop

- In May 2023 Norway takes over as Chair of the Arctic Council (from Russia, which has been on hold since the invasion of Ukraine).
- Rune Storvold, Arctic Council UAS SME has proposed convening an Arctic UAS Workshop in conjunction with the start of Norway's Chairmanship. The Workshop would be a follow-up to the previous 2008, 2011 and 2014 workshops which resulted in four publications on UAS use in the Arctic (Recommendations for Safe and Expeditious use of Unmanned Aircraft to Take Critical Environmental Measurements in the Arctic: Results of the Arctic Monitoring and Assessment Program Workshop of Scientists and Aviation Authorities from the Arctic Countries, Oslo, 2008; Enabling Science use of Unmanned Aircraft Systems for Arctic Environmental Monitoring, 2012; Arctic Scientist Remotely Piloted Aircraft Systems Operator's Handbook, 2015; and, Implementing Scientific Data Collection across the Arctic Oceanic Region Utilizing Unmanned Aircraft Systems (UAS), 2015).
- The goal of the proposed workshop is: 1) to incorporate UAS into the Arctic Council's SAON – Sustained Arctic Observing Network; 2) to get Arctic Council countries to commit to sustained routine UAS transects of the Arctic & move away from solely expeditionary UAS use; and, 3) to develop sensor standards and inter-calibration exercises, which could even be useful for Russia in future.
- McGillivary has been asked to assist in organizing the Workshop.

NHABON Sept. 21, 2022 Teleconference on “Remote Sensing, Observing and Forecast Using Drones, Hyperspectral Sensors and Satellites”

- HABs have been detected off the west coast and now Alaska for the past several years
- While satellites can map the extent of such HABs, in situ sampling is necessary to determine both species present and the toxicity of the HAB blooms
- A program is being set up in Alaska to monitor HABs but sampling oceanic blooms 20-40 miles from shore is planned on being conducted with helicopters for at least the near future
- Developing long-range UAS with sea surface sampling capabilities for HAB monitoring would be a much preferable alternative moving forward

New UAS technical capabilities: Comms

- Iridium Certus now has available 3 antennas for UxS and a satellite modem; all are 22/88 kbps uplink/downlink
- Iridium Certus Stub antenna, 1.02 ounces, 0.73”x1.76”
- Iridium Certus Patch antenna, 5 ounces, 3.5” diameter
- Iridium Certus Mast-mount antenna, 3.53 ounces, 4.92”x1.77”
- And there is also an Iridium Satellite Modem for UAS, the DLS-100 which is 10-32C DC in, <1.75A @12V input; 26.2 ounces, 1.5”x8.7”x2.7” for BVLOS command/control & data comms.

New UAS technical capabilities: Comms

- Lockheed will launch 3 small satellites in 2023 as a test of JADO (Joint All Domain Ops). They will be optically linked surveillance satellites intended as a demo of resilient surveillance and communications capability in case larger satellites are damaged.
- The three satellites are also a demo of using RF comms for swarm positioning.
- Two of the satellites are Pony Express 2 satellites (see: https://www.nanosats.eu/sat/pony-express-2) which are Cubesats, and the other is a similar Tactical Intelligence, Surveillance and Reconnaissance (ISR) comms sat. They are scheduled for Dec. 31, 2022 launch.
- Their first intended use is during the US-only joint DoD/CG Northern Edge exercise conducted in odd years, to be undertaken @May 2023. CG D17 and MIFCPAC will work with Navy to evaluate how these satellites could be used for directing ship-based UAS and/or processing their data in near-real time.

New UAS technical capabilities: High Altitude Pseudo-Satellite Comms

- HAPS comms activities are still ongoing…
- An industry HAPS Alliance was formed in Feb. 2020, including Alphabet, Aerovironment, Softbank, AT&T, T-Mobile, Airbus, Nokia Facebook and others.
- The goal is to provide backup comms for satellites for when rain or atmospheric turbulence may compromise optical sat comms, and to provide lower latency comms than via satellites
- Platforms are expected to fly at @20km, having a 70-80km footprint (versus 350-1100km for Starlink Space-X satellites)
- Data rates of 40Gb/sec have been demonstrated already and may be improved upon
- DoD is funding SCOS, the Strategic C4ISR to Operationalize the Stratosphere project for testing high altitude balloons and solar HALE UAS for the same issues that the HAPS Alliance is working on this.

New UAS technical capabilities: UAS, HAPS and Satellite Optical Comms

Some advances in both free space optical & quantum comms with UAS have been demonstrated:

See: Turbulence-resilient pilot-assisted self-coherent free-space optical communications using automatic optoelectronic mixing of many modes. R. Zhang et al., Oct. 2021, Nature Photonics. https://doi.org/10-1038/s41566-021-0087-w .

This paper demonstrated a mechanism of self-correction of optical comms using two beam transmission of a data beam and a ‘tone’ beam, and when the pair are mixed turbulence can be compensated for with data rates up to 12Gb/sec.

Caveat: while using 200 conditions of turbulence, the experiments were so far only done in the lab…

New UAS technical capabilities: UAS SatComms & Optical/Quantum Comms

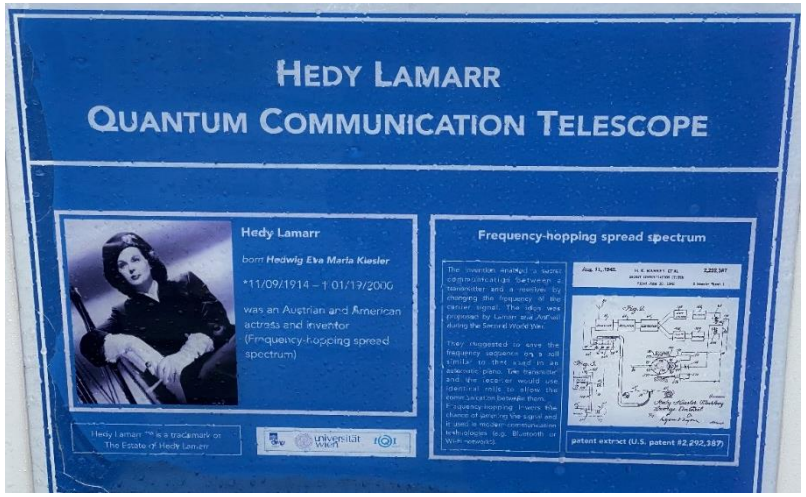
- Both Honeywell and Velaris are making s-UAS sat comms systems for streaming video and BVLOS ops.

  Velaris, @3lbs: https://www.inmarsat.com/en/solutions-services/aviation/services/velaris.html

  Honeywell, 2.2lbs: https://aerospace.honeywell.com/us/en/pages/sff-uav-satcom

New UAS technical capabilities:
UAS Optical/Quantum Comms

- Re: in Jan. 2021 China demonstrated quantum comms between two drones over a distance of 1km, and since increased that, and believe they can go up to 300km. See: Hua-Ying et al., 2021, Optical-Relayed Entanglement Distribution Using Drones as Mobile Nodes. DOI: 10.1103/PhysRevLett.126.020503. Image below left.
- AFRL project with L3Harris & FAU to develop networked UAS with quantum comms for secure/resilient ops, see:
- [What could be the key to an 'unhackable' network of drones? (govtech.com)]
- Re: US-UK-Australia-Canada QEYSSAT quantum comms satellite ready for launch fall 2023 as testbed.
- McGillivary visited world quantum comms guru Anton Zelinger at U. Vienna in June 2022; he is coordinating EU quantum comms satellite. See: https://en.wikipedia.org/wiki/Anton_Zeilinger



New UAS technical capabilities: eLORAN PNT test funded for summer 2023

- The Air Force has funded Hellen Systems for a demonstration of four (overlapping range) eLORAN systems in summer of 2023 at Lake Pend Oreille Navy base and also Mountain Home Air Force Base, both in Idaho.
- There will be opportunities for international (military) participation as well as US civilian scientist participation
- The proposal is to use AUVs to test depth penetration of the “GPS”/PNT signal from the eLORAN, expected to penetrate @100+’
- A proposal for using an ASV and UAS and the new 10MB/sec Hydromea optical modem has been put forward to the Air Force for approval
- A subsequent test has been proposed for Svalbard in winter to test in ocean and under-ice eLORAN ‘GPS/PNT’ penetration.

New UAS technical capabilities: s-UAS bioluminescence sensor

RADM Tom Donaldson has conducted field experiments with new very sensitive bioluminescence sensors for ASW (as well as whale detection)

These can be used on s-UAS as small as ScanEagles or as large as Poseidons

See: SIPR INTELDOCs under Carter.L.Johnson/biolum/summary/VTS_01_1

(1024 MB, ie@30min download including a video with sound)

Could be tested in the Arctic from ship-deployed sUAS for either ASW or whale detection