UDT UNCREWED SYSTEMS

0900-0905 Motivation (Maguer)

0905-0910 Endurance (Gormley)

0910-0917 Autonomy & Navigation (Storkersen)

0917-0925 MUS interoperability enablers (Maguer)

0925-0932 Engineering & Security (Colby)

0932-1000 Q&A

- **NATO Strategic Context**
  - Supremacy in the maritime domain, since 1949, is one of NATO key strategic objectives.
    - **NATO ALLIANCE Maritime Strategy** developed in 2011, reinforced in 2018, relying upon maritime forces to provide a spectrum of options through deterrence and collective defense, Crisis Management, Cooperative Security and Maritime security in order to face the emerging and rapidly evolving threats in the maritime domain
  - Need for adaptation is greater than ever, considering:
    - The seriousness and complexity of maritime security challenges faced by NATO
      - Resurgence of Russia as an assertive maritime power
      - Asymmetric threats from outside Europe's border
      - Renovated strategic relevance of the North Atlantic and Artic seaways
    - And more over,
      - Rapid progress made by peers competitors in maritime warfare capabilities
      - The lack of private S&T investments for underwater applications
      - Defense budget reduction of NATO's members (replacement of like-for-like capabilities may not provide the best solution and may be unaffordable. Need for alternative solution)
  - Equally, The ALLIANCE finds itself in a new and dynamic reality, marked by growing uncertainty, risk and rapid scientific and technological challenge with the potential to disrupt the global strategic balance

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- **NATO Strategic S/T initiatives to maintain its maritime dominance**
  - **NATO S/T Strategy (2018)** to maintain NATO's scientific and technological advantage by generating, sharing and utilizing advanced scientific knowledge, technological developments and innovation to support the Alliance's core tasks
  - Be part of the current explosion in emerging technology as they offer great opportunity – and potential perils – for NATO with respect to maintaining its technological and operational advantage, and for maintaining interoperability
    - **NATO Allied Command Transformation (ACT) Emerging and Disruptive Technology (EDT) Roadmap (2018)**
    - **NATO S/T Trends 2020-2040**

    Key emerging and disruptive technologies include areas such as Data, Artificial Intelligence, Autonomy, Space, Quantum, Hypersonic and new missile technologies
  - Continue in strongly investing in Maritime Unmanned systems (MUS), Big data, AI and advances in autonomy which are opening up dramatic new solutions (CMRE worked on this since 2000)
    - Without forgetting (learning from the UAV turmoil experience) that they also bring significant challenges to be resolved.
      - The scale of change required in the maritime domain is monumental
      - And will radically affect all aspects of DOTMLPFI (Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities and Interoperability).

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- **NATO Activities on Maritime Unmanned systems (MUS)**
  - **NATO ACT POW to CMRE**
    - Improve Alliance ability to counter threats in the underwater domain, through the development and test of a network of autonomous MUS, securely communicating and persistently operating with collaborative behaviors in complex environment
  - **Maritime Unmanned Systems Initiative (MUSI)**, NATO Defence Investment (DI)
    - Multi-national cooperation framework for the introduction of MUS capabilities. 13 NATO nations in October 2018 declared their willigness and intend to:
      - Build the MUS business case
      - Ensure coherence and interoperability of MUS solutions developed among them
      - Enable innovative MUS solutions at lower risk and cost, and higher quality
  - **Science and Technology organization (STO) panels activities**
    - Situation Awareness of Swarms and Autonomous Systems, Securing unmanned and autonomous vehicles for missions assurance, Autonomy in communications-limited environment, …

Both programs are covering a wide range of MUS aspects/challenges such as:

- Endurance (how to bring UW operations from hours/days to weeks/months)
- Accurate Navigation over days/weeks/months in GNSS denied environments
- Autonomy, Big data, Artificial intelligence
- Secure C3 networks, information and mission assurance
- Human / Machine interaction
- Testing, evaluation, V&V, trust and experimental efforts (real and digital twin)
- Development of concept of operations and standards

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0932-1000 Q&A

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0905-0910 Endurance (Gormley)

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- What are critical parameters in selecting an energy source?
  - Maximum required power and energy
    - Difference between power (kW, determines size of motor/engine) and energy (kWh, determines size of fuel tank/battery capacity)
    - Not just upon discharge - may be defined by recharge time
  - Maximum operating depth
    - Pressure-tolerant or 1-atm battery?
- What are significant tradeoffs made when selecting an energy source?
  - Cost
  - Lifetime/#cycles, fueling logistics
  - Performance
    - Capacity, max charge/discharge rates, thermal concerns, shape of discharge curve
  - Safety
    - Fire/explosion, esp. during charging
    - Regulatory/testing requirements, inc. operational, storage, and transport
  - Resiliency; built-in redundancy; complexity of battery management system
- R&D topics
  - SiC anodes
  - Solid-state electrolyte
  - Lithium metal anodes
  - Nickel-rich cathodes (up to 80% or more)
  - Efficient recycling

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0932-1000 Q&A

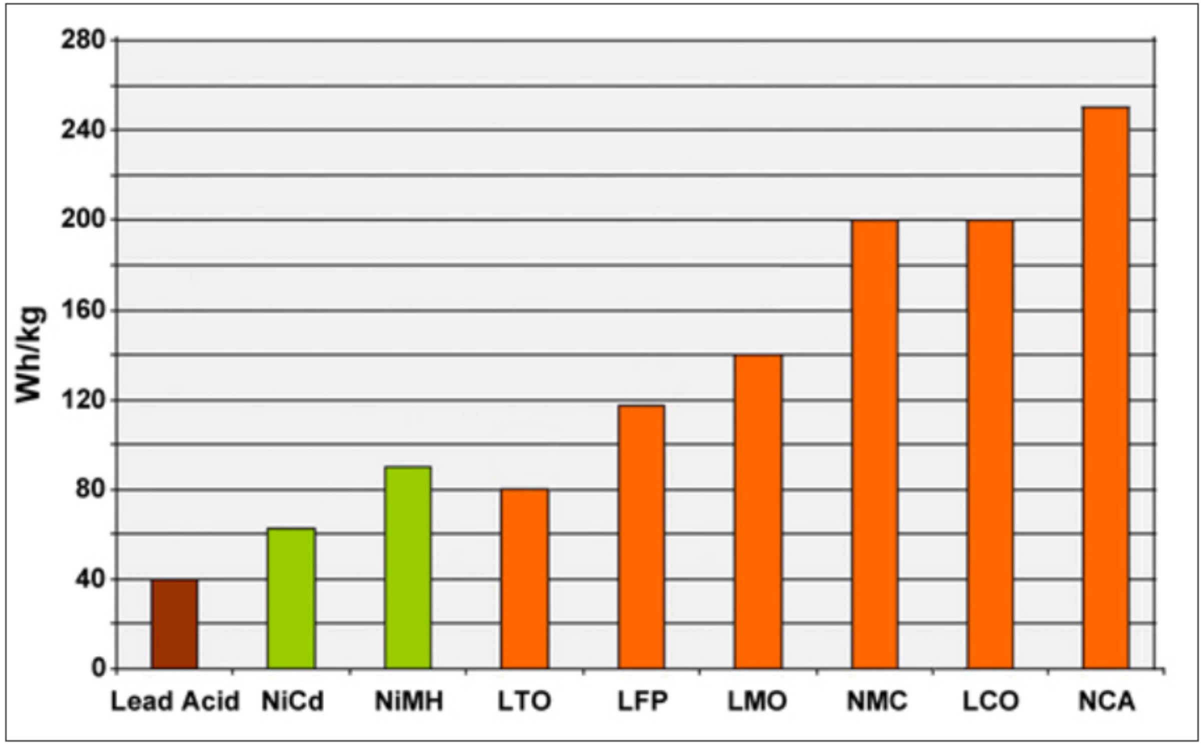

Figure 15: Typical specific energy of lead-, nickel- and lithium-based batteries.
NCA enjoys the highest specific energy; however, manganese and phosphate are superior in terms of specific power and thermal stability. Li-titanate has the best life span.
Courtesy of Cadex

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- Other options
  - AgZn – expensive, newer Li ion batteries outperform it, other difficulties
  - ‘Seawater’ battery – needs KOH, low power
  - Semi-cells – electrolyte+oxidizer
  - Fuel cells
    - Gas, liquid, or solid fuels (buoyancy change)
    - Complex balance-of-plant
    - Dynamic response

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- First European MCM capability based on truly unmanned systems will be operational before the end of this decade (2030)
  - Flexible, modular and scalable capabilities that may be operated from vessels of opportunity, allowing for effectiveness and potential cost reductions
  - Toolbox of multi role AUVs and USVs with a high degree of individual autonomy and navigation performance and operating in a coordinated system-of-systems.
  - Manned ship tens of nautical miles away
  - Reliable communication is not available
- Must be capable of performing all phases of a MCM operation without intervention from human beings
  - The toolbox must do REA, seabed mapping, seabed characterization, mine detection, classification, identification, localization and neutralization
  - And mine sweeping
- Techniques to support autonomy (AUVs)
  - SAS processing, mapping and high resolution acoustic imagery, automated target recognition, automated target classification, adaptive mission planning, change detection and real time mission performance assessment.
- Techniques to support GPS independent navigation
  - DVL aided INS and SAS micronavigation
  - Terrain navigation, Feature based navigation, SLAM
- Other applications: ASW, surveillance, ISR, submarine ops.

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- **NATO Multi-domain MUS Command, Control C2 Architecture (STANAG 4817)**
  - To be developed from STANAG 4586 on UAV C2 (using UCS model) with the following objectives:
    - Define a common architectural framework for a MDCS
    - Identify key functional sub systems needed for an MDCS to interact with operators, legacy and future MUS, and external systems
    - Provide explicit support for increasing levels of autonomy
  - Define Common Autonomy Architectures, Data Models, and Message Sets for **Vehicle to Vehicle interoperability and distributed architectures**
- **Information assurance for MUS system of system**
  - Provide Information (and Mission) Assurance in the autonomy-driven maritime battlespace (surface, underwater, and potentially air)
    - Confidentiality, Integrity, Availability (Authentication, Non-Repudiation)
    - Secure positioning/localization/synchronization
    - Cross-domain / Cross-platform security
    - Cyber physical system (data-centric) resilience and security (e.g. unattended crypto)

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- **Secure communication interoperability**
  - Support the development of standardized communication solutions for the underwater domain including:
    - Acoustics/optics (e.g. JANUS STANAG)
    - Cognitive Software defined modem for interoperability and adaptation to complex environment
    - Physical layer security adapting to channel characteristics
    - Cross-layer (network, transport and data-link) synchronization
    - Coordination with international efforts (IETF) to standardize Delay/Disruption Tolerant (DTN) protocols

- **MUS Validation & Verification**
  - Testing autonomous systems is still an unsolved key area . V&V much more complex for unmanned than for manned systems, as dealing with non-deterministic cases that autonomy will generate in response to complex environments
  - Many of the necessary processes, systems, test infrastructure, and other capabilities simply do not exist
  - Measures must be developed to address state space adequacy, trust, and human-machine interaction.
  - No clear definition of mission, safety and security requirements
  - Models and live virtual constructive (LVC) (DIGITAL TWIN) test beds are needed to support robust testing while minimizing risk and cost.

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0932-1000 Q&A

Engineering Technology in to Capability

- Engineering a solution that works in operational conditions
  - Launch and recovery, storage, maintenance, warship constraints
- Dealing with 'off nominal' conditions
  - Degraded capability, failures, difficult environmental conditions
- Integrating with the user and system enterprise
  - Becoming part of the broader C4I system and military enterprise
- Safety and security
  - Vulnerability - can it be safe if isn't secure?
- Trust and Adoption
  - Users must build trust in the system to be confident in using it
- Where is the tipping point?
  - When do unmanned systems become sufficiently capable that it is worth disrupting current capability delivery mechanisms?

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LIVE Q&A

PLEASE SUBMIT YOUR QUESTIONS

VIA THE CHAT BOX