

Iceland 
Liechtenstein
Norway grants

Closing Event of the PT02 Programme

Integrated Marine and Coastal Waters Management “Achieved Outcomes”

December 6th - Lisbon

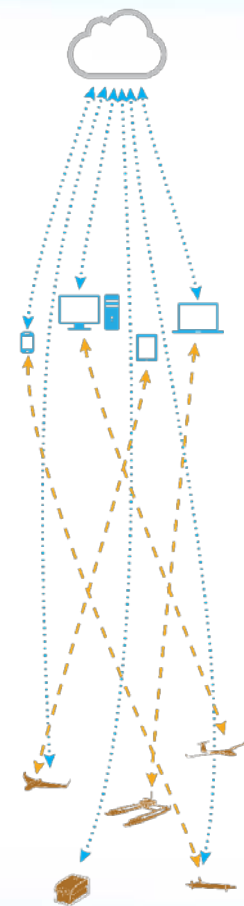
Networked Ocean

Networked ocean and air vehicles for communications and data collection in remote oceanic areas

Presenter: António Sérgio Ferreira (asbf@lsts.pt)

Outline

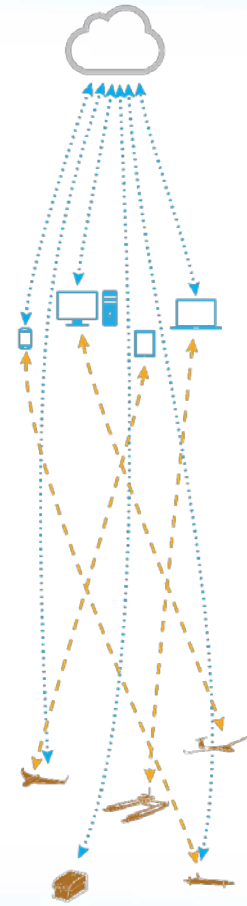
1. Project Overview
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 - b. Global Reasoning
 - c. A Particular View
 - d. Autonomous Approach
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 - b. Software Backbone
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Project Overview

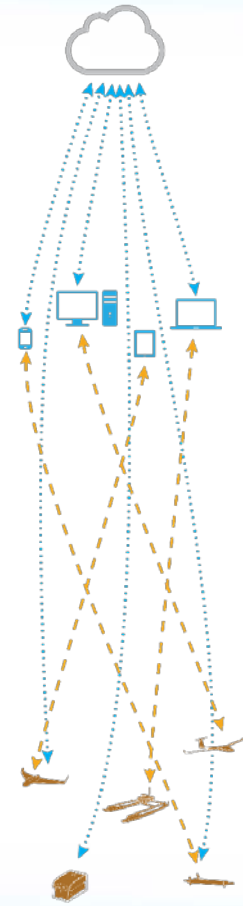
Project Overview: Overall Objectives

- Development & demonstration at sea of a networked vehicle system for persistent communications and data collection in remote oceanic areas;
- Autonomous surface vehicles with support for smart routing communication protocols, via persistent unmanned air vehicle (UAV) relays, or delayed data transfer using passing vessels as data mules;
- Unmanned vehicles with on-board deliverable planning capabilities for unattended operations in remote locations;



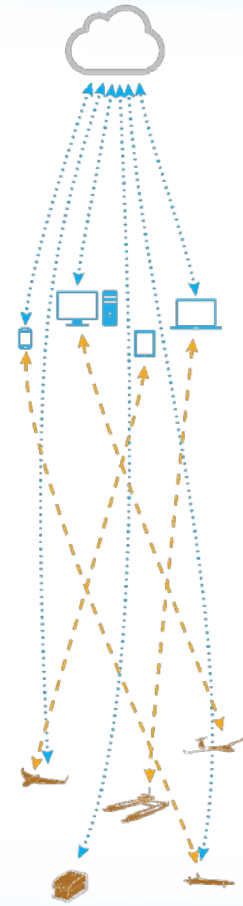
Project Overview: Overall Objectives

- UAVs with advanced radio technology for long range communications;
- Land, or ship-based, control stations providers of advanced planning and execution control capabilities, as well as dissemination of data to service providers.



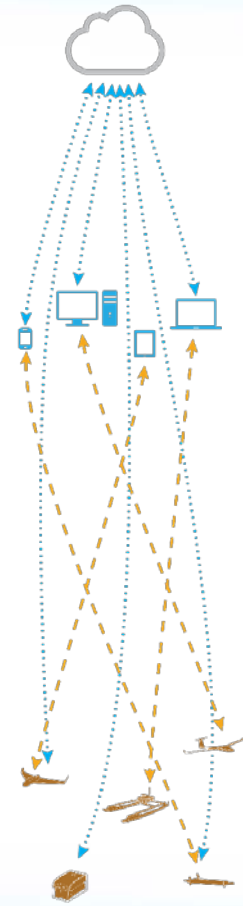
Project Overview: Global Reasoning

The oceans global "real estate" scope;



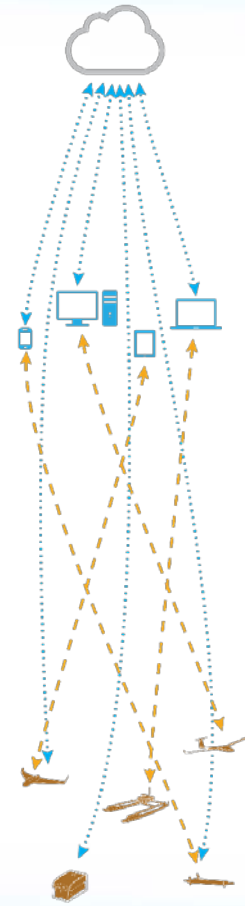
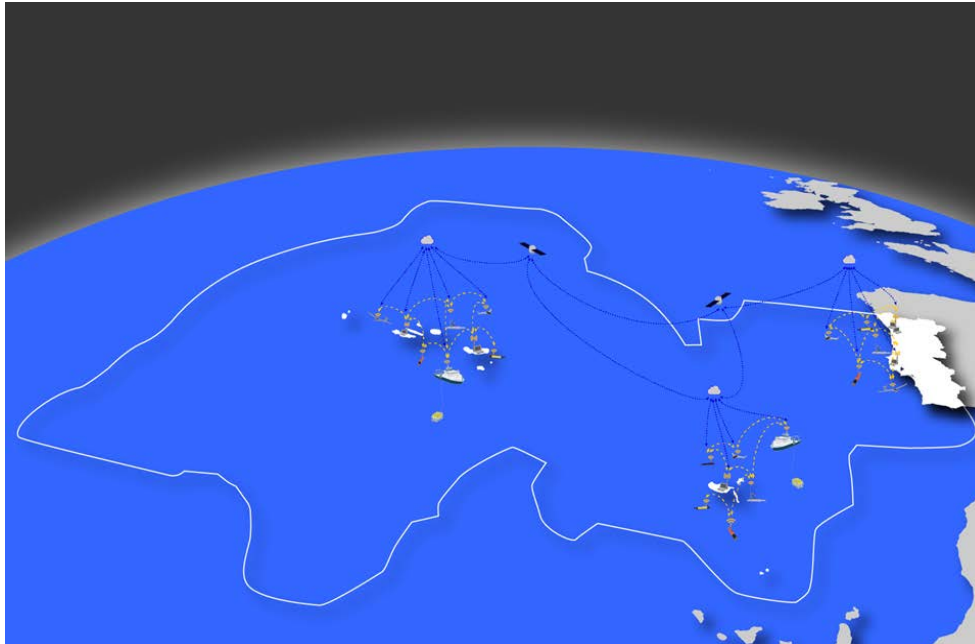
Project Overview: Global Reasoning

Monitoring of key issues affecting ocean sustainability and stewardship



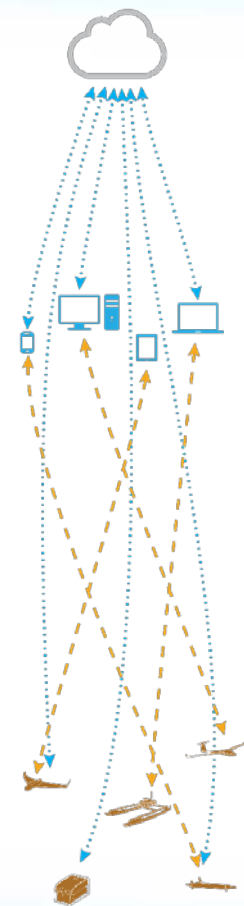
Project Overview: A Particular View

Current Portuguese initiative to extend the continental shelf



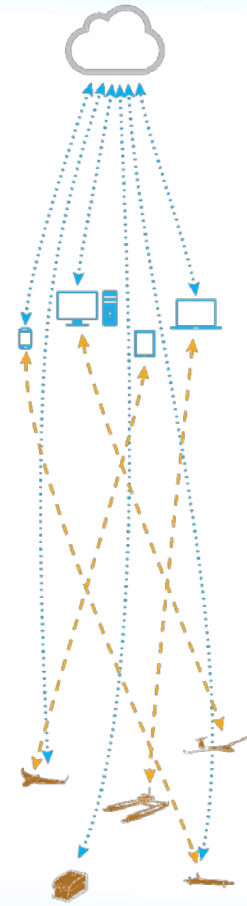
Project Overview: Autonomous Approach

Challenges of inaccessibility and expense



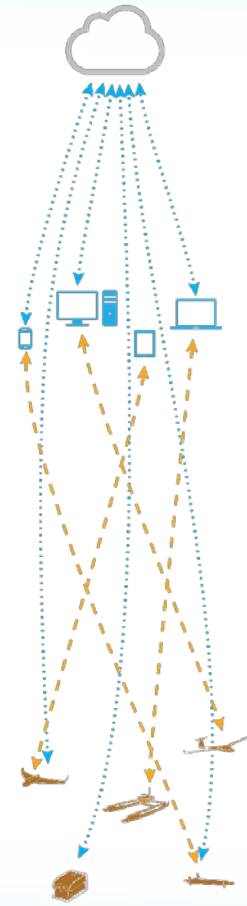
Project Overview: Autonomous Approach

A sustained, persistent and affordable presence in the ocean requires innovative approaches to systems development, operations and management.



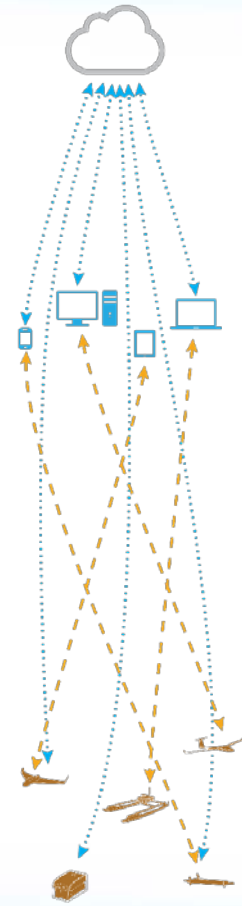
Project Overview: Autonomous Approach

1. Increase the number of systems (buoys, drifters, floats, etc.);
2. Develop and deploy new fleets of robotic vehicles;
3. **Network** existing systems and new robotic vehicle systems;
4. Command and control **networks** of manned and unmanned vessels;
5. Create an organizational framework to **manage and coordinate** the system.



Project Overview: Autonomous Approach

We take these guys...



Project Overview: Autonomous Approach

...use and empower their available assets...

ANKA

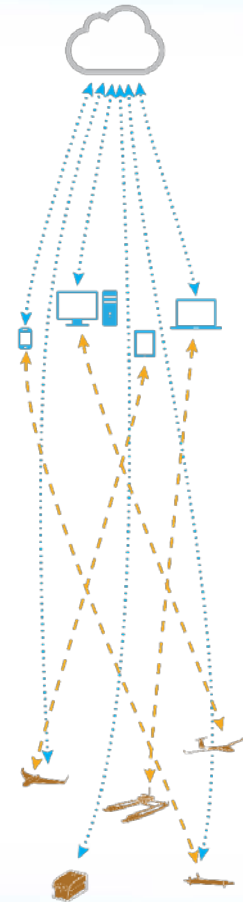


- Primarily designed for depth-sounding in shallow waters
- Manoeuvrable, rather than fast
- Instrumentation is composed of a GPS, AHRS, a single beam sounder for depth ranging and two forward looking sonars for close navigation

Telemetron



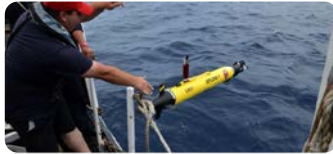
- Multi-purpose unmanned vehicle for offshore and coastal applications
- Conversion of a POLARCIRKEL manned vessels into a vehicle capable of autonomous navigation
- Integrated bathymetry system, AIS transmitter, radar and long range radio communication system



Project Overview: Autonomous Approach

...use and empower their available assets...

LAUV

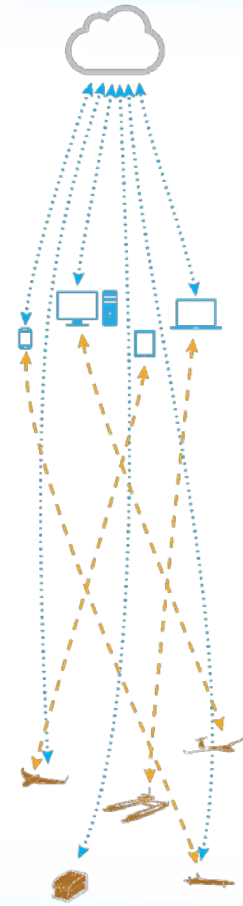


- Lightweight, modular platform capable of carrying a set of different sensors and sonars
- Targeted at cost effective oceanographic, environmental and inspection surveys in order to fulfil a wide range of scientific, civilian and military application

X8



- Easy-to-launch, quick-recovery electrical aerial system
- Designed for fast algorithm testing, terrain mapping and operational surveillance
- Configured for the communication tests with the Maritime Broadband Radios (MBR)



Project Overview: Autonomous Approach

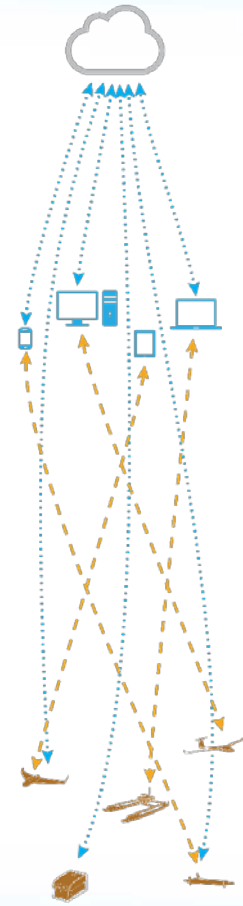
...use and empower their available assets...

RV Gunnerus

NTNU AMOS
Centre for Autonomous Marine
Operations and Systems

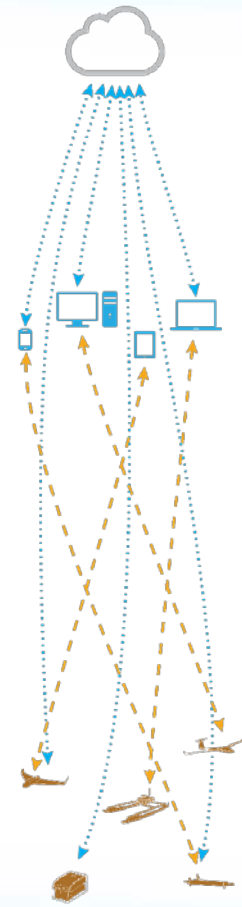
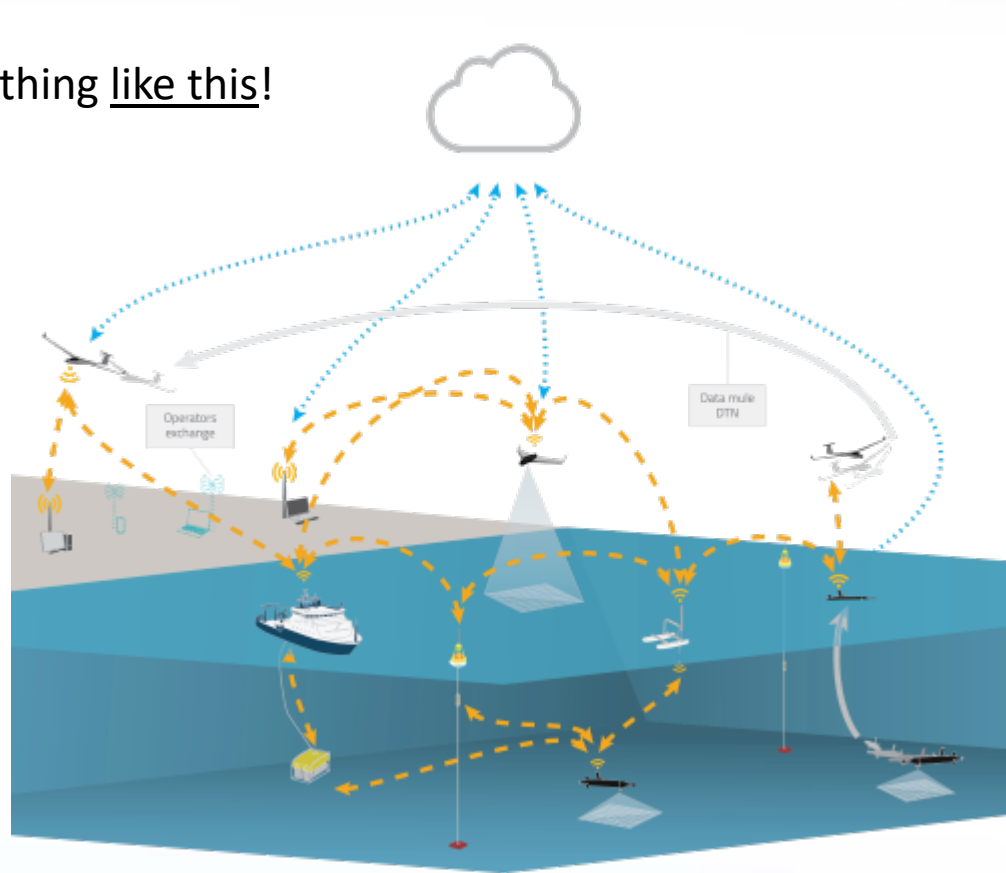


- Fitted with the latest technology for a variety of research activities within biology, technology, geology, archeology, oceanography and fisheries research
- Dynamic positioning system and a HiPap 500 unit
- Installed with MBR communication system to work as node



Project Overview: Autonomous Approach

...to achieve something like this!

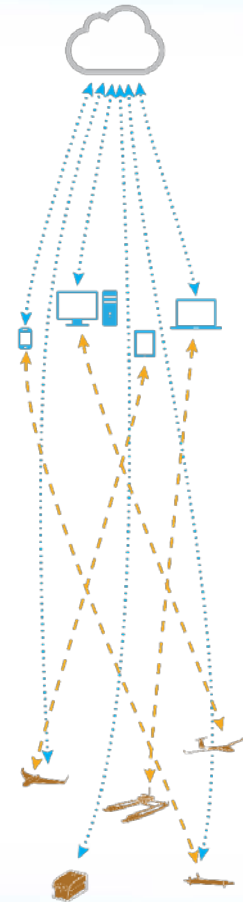


Working Background

Working Background: Small Backstory

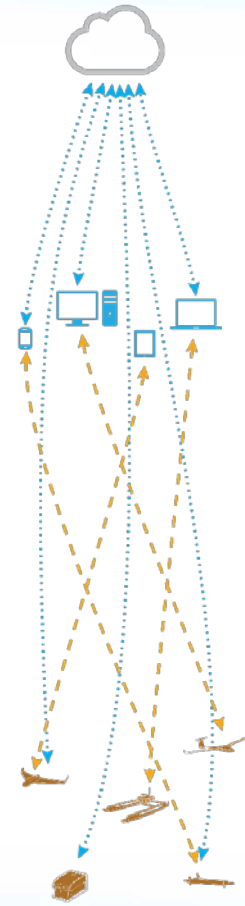
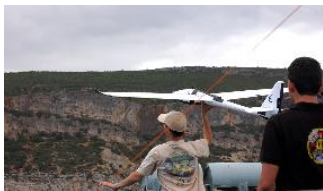
The LSTS team...

- **Created:** 1997
- **Composed by:** students, researchers and professors from Electronic, Software and Mechanical Engineering and Computer Science
- **Funding:** FCT, FP7, NATO, Gulbenkian, Ministry of Defence



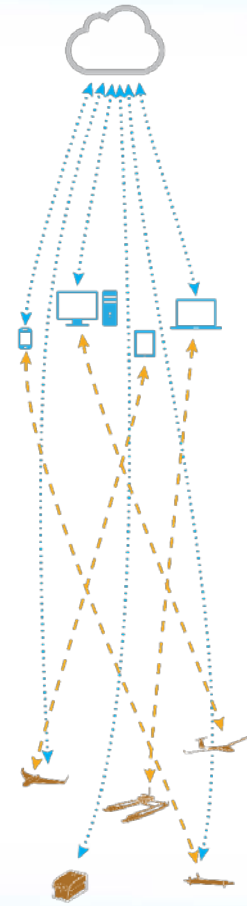
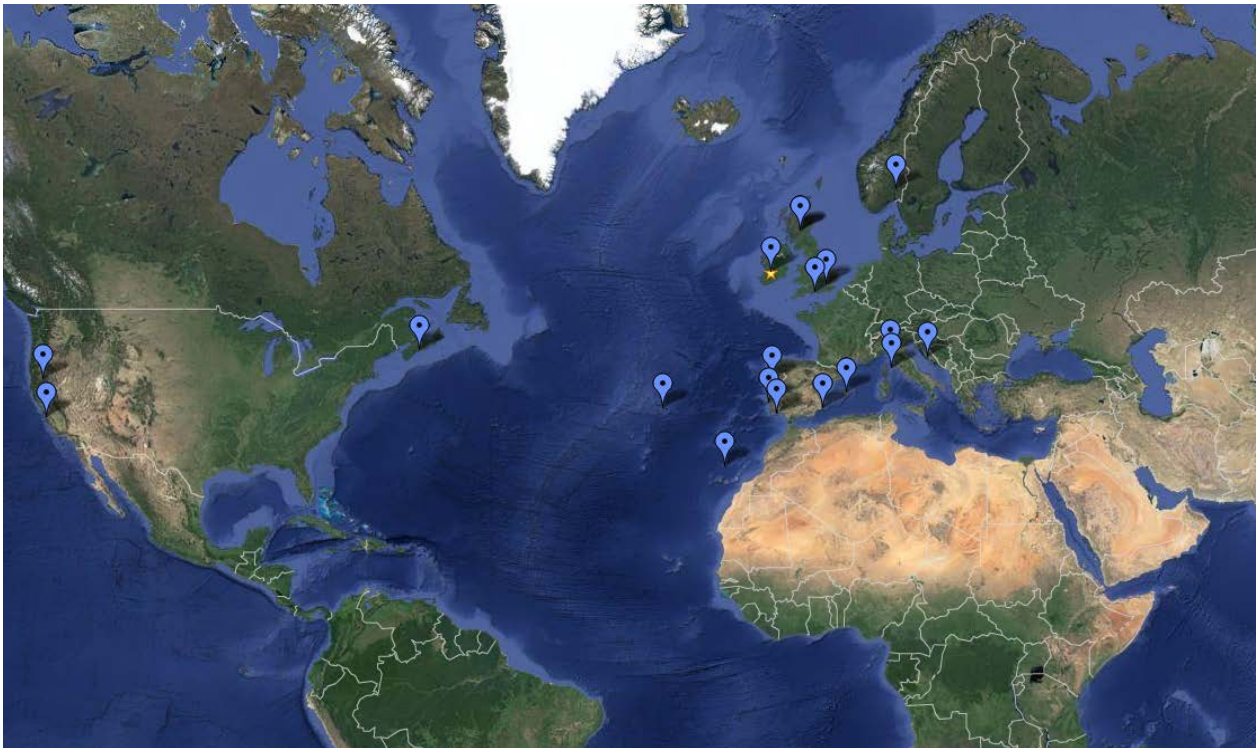
Working Background: Small Backstory

The LSTS active fleet...



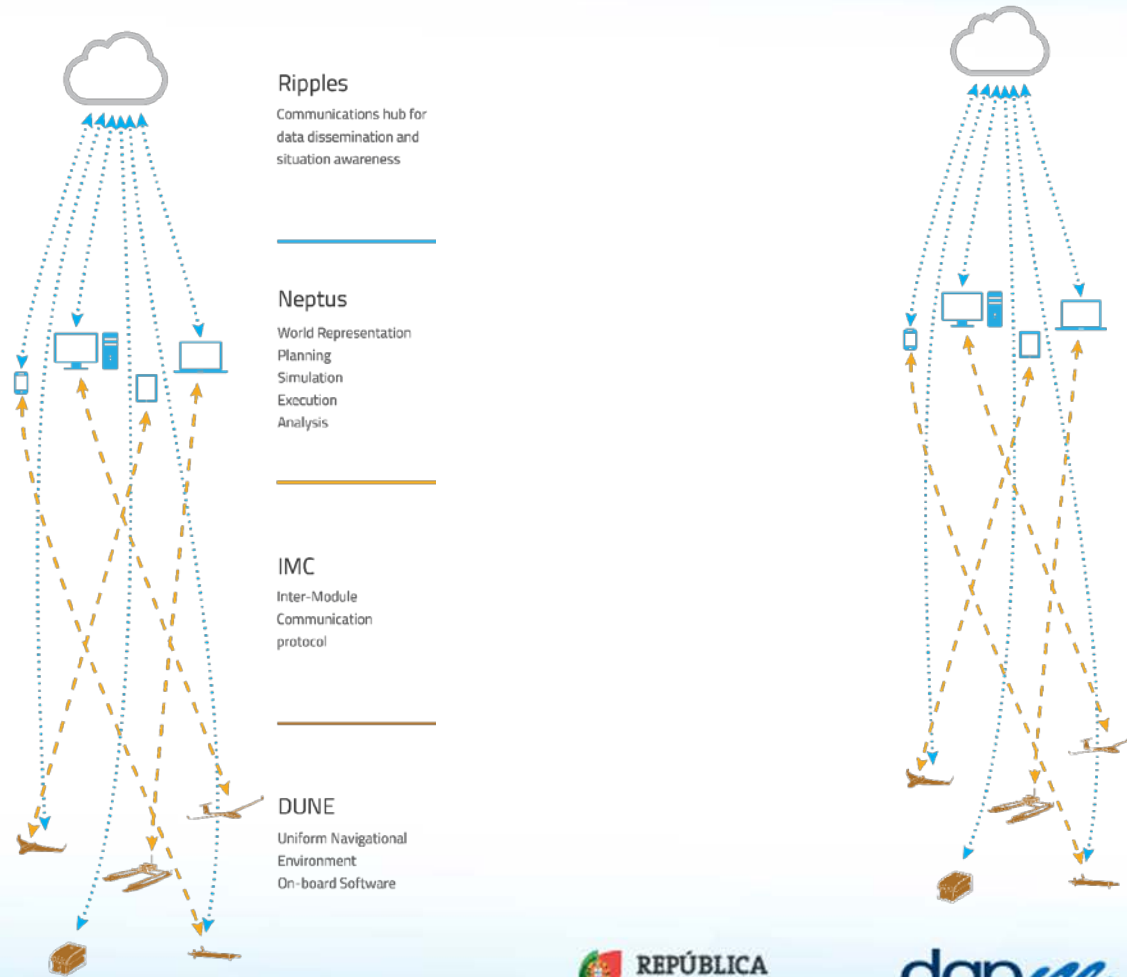
Working Background: Small Backstory

Where we've been...



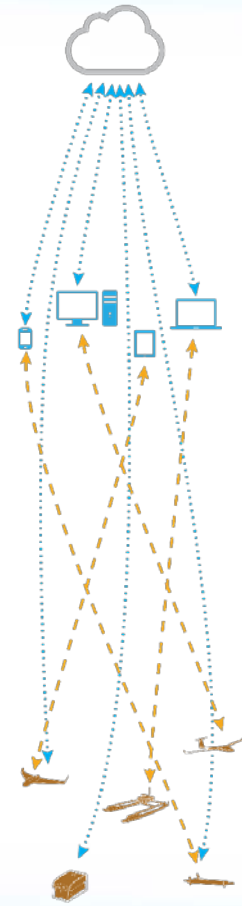
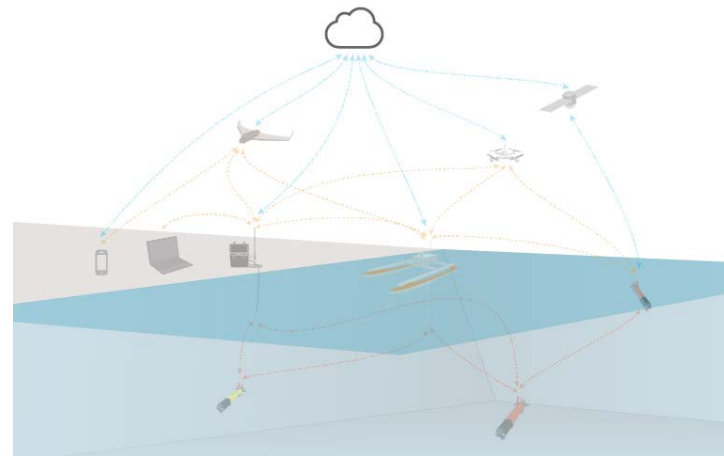
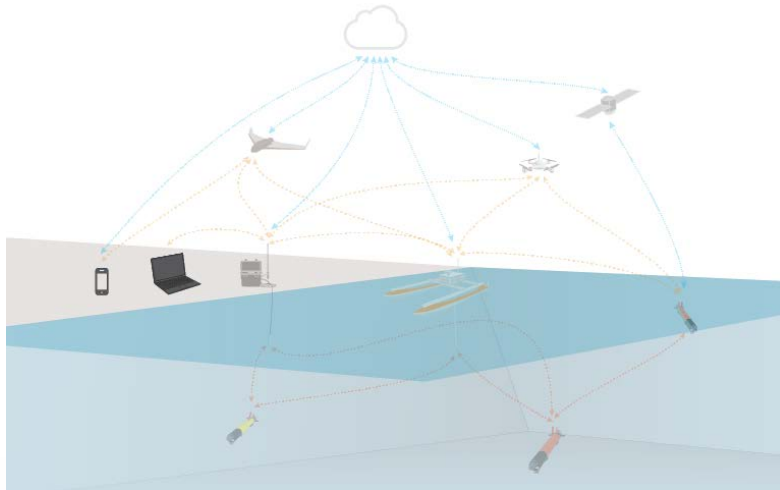
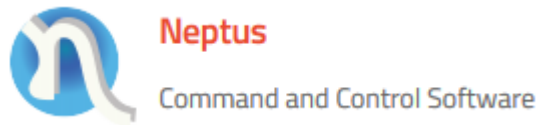
Working Background: Software Backbone

How have we been doing it?



Working Background: Software Backbone

Mapping it to our initial system vision...



Working Background: Software Backbone

Mapping it to our initial system vision...



Neptus

Command and Control Software

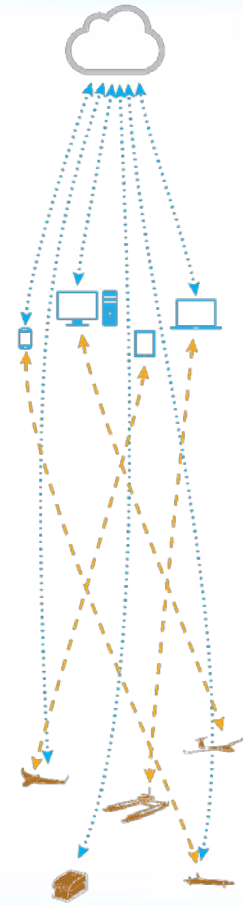
- Distributed command and control infrastructure
- Written in Java and currently runs in Linux and Microsoft Windows
- Supports the full mission life cycle: planning, simulation, execution and post-mission analysis
- Plans can be simulated and validated before execution



Ripples

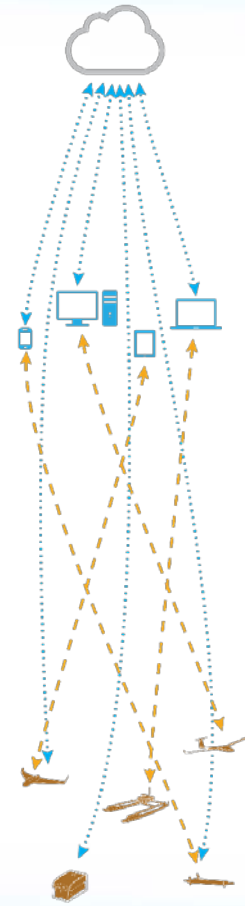
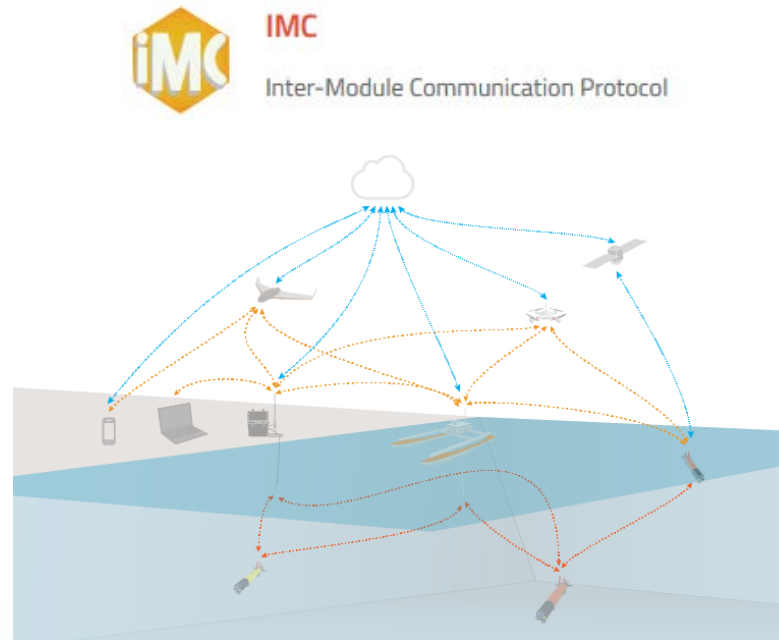
Data Centralization

- Communications hub for data dissemination and situation awareness
- Assets are updated in real-time on browsers
- Different map sources can be used
- Maps can also be augmented with extra layers
- All data being sent and received from remote devices is stored in Ripples



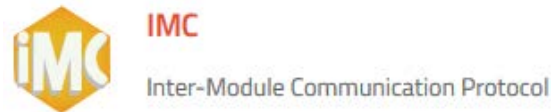
Working Background: Software Backbone

Mapping it to our initial system vision...

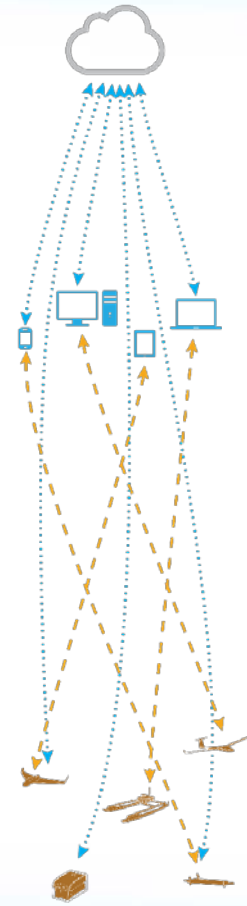


Working Background: Software Backbone

Mapping it to our initial system vision...

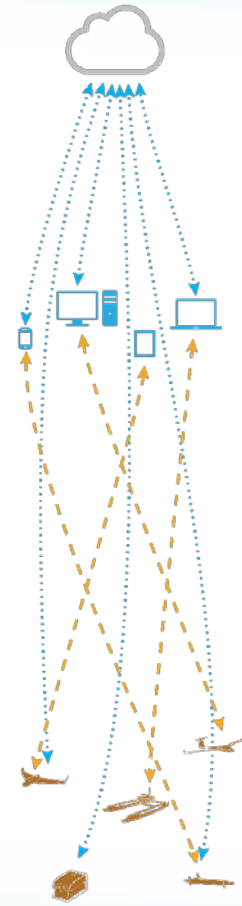


- Message-oriented protocol for networked vehicles systems
- Abstracts hardware and communication heterogeneity by providing a shared set of messages that can be serialized
- Does not impose or assume a specific software architecture for client applications



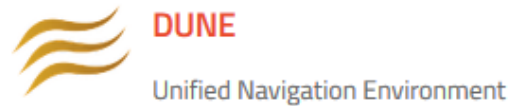
Working Background: Software Backbone

Mapping it to our initial system vision...

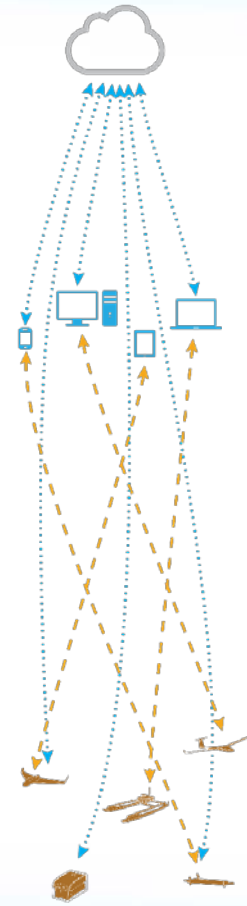


Working Background: Software Backbone

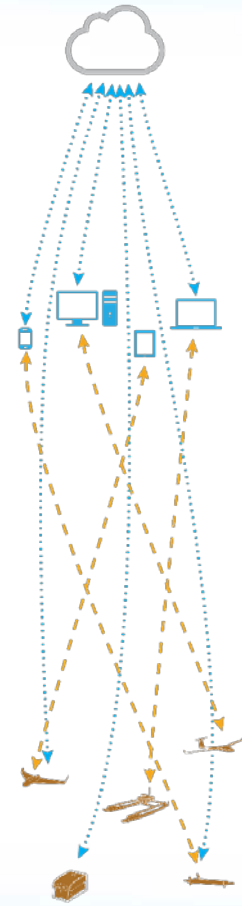
Mapping it to our initial system vision...



- On-board software running on all LSTS network nodes;
- Is CPU architecture independent (Intel x86 or compatible, Sun SPARC, ARM, PowerPC and MIPS);
- Can be summarized as a collection of tasks, hierarchically structured, where related logical operations are isolated from each other



Working Background: Past Ventures



- FEUP
 - Vehicles
 - Tags
 - Command/Control
 - Comms
- UPCT
 - Educational Outreach
 - Modeling & Data Analysis
- NTNU
 - UAV field experience
 - Thermal imagery use
- IPMA / PO Navy
 - Ship Operations
- CIBIO
 - Tagging
 - Biology
- MBARI
 - Ecological Analysis
 - Deliberative Control
 - Operational concepts
- Liquid Robotics
 - Inter-disciplinary experience
 - Large scale field experimentation
 - Wave Glider

Working Background: Past Ventures

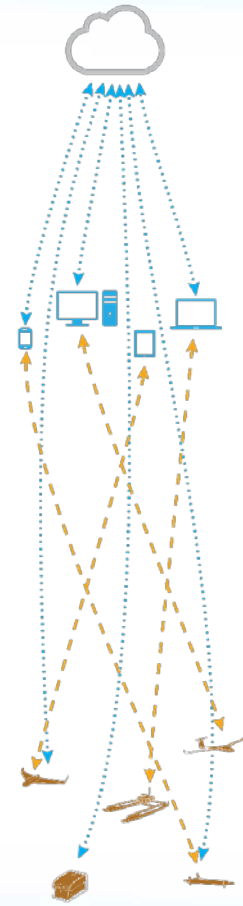
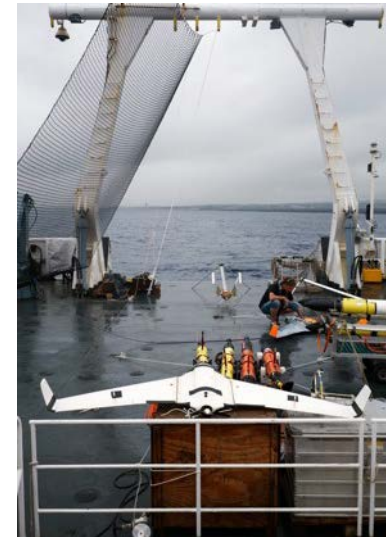


Organized by

- PO Navy
- Porto University
- Centre for Maritime Research and Experimentation
- University of Açores

Participants

- Naval Undersea Warfare Center
- Norwegian University of Science and Technology / AMOS
- Royal Institute of Technology
- NASA Ames
- OceanScan
- University of Plymouth

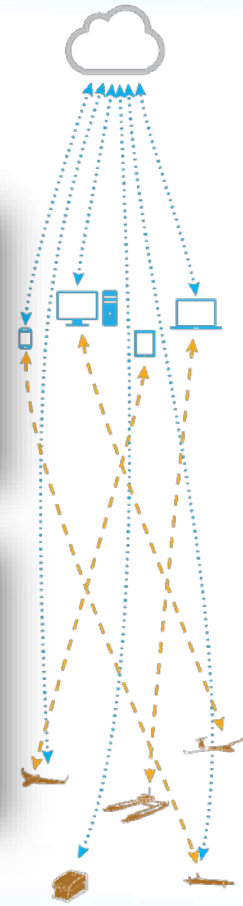


Deployments & Results

Deployments & Results

Gunnerus Exercise

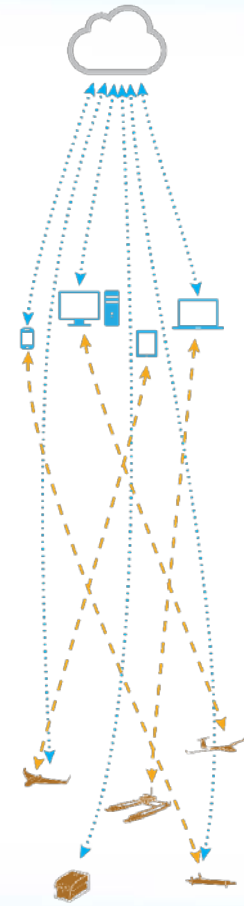
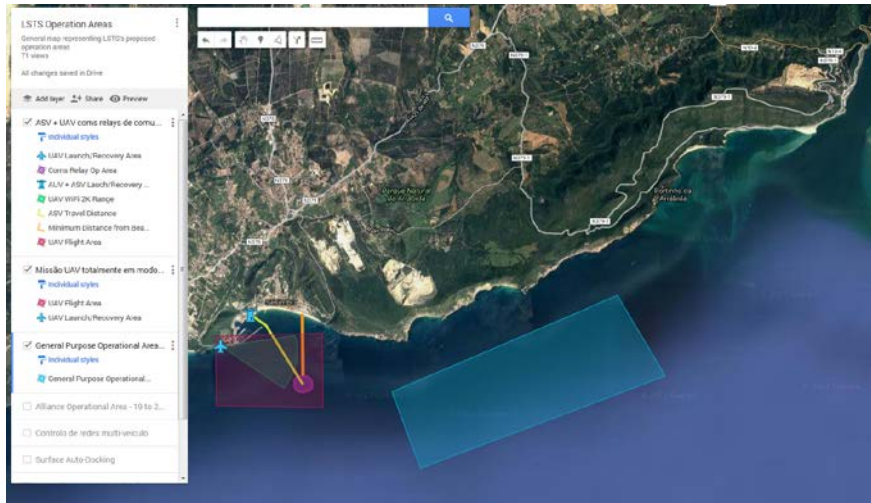
- Flights with MBR;
- Ripples integration in operational scenario;
- Initial contact with MBR setup;



Deployments & Results

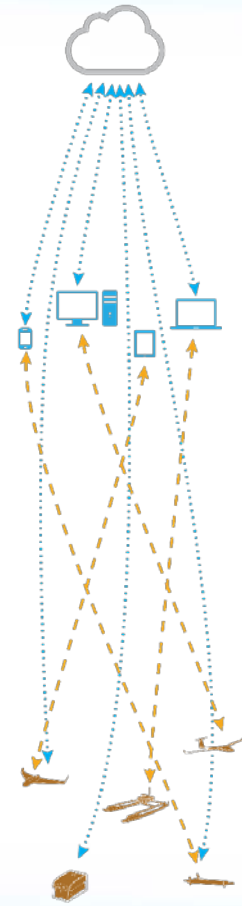
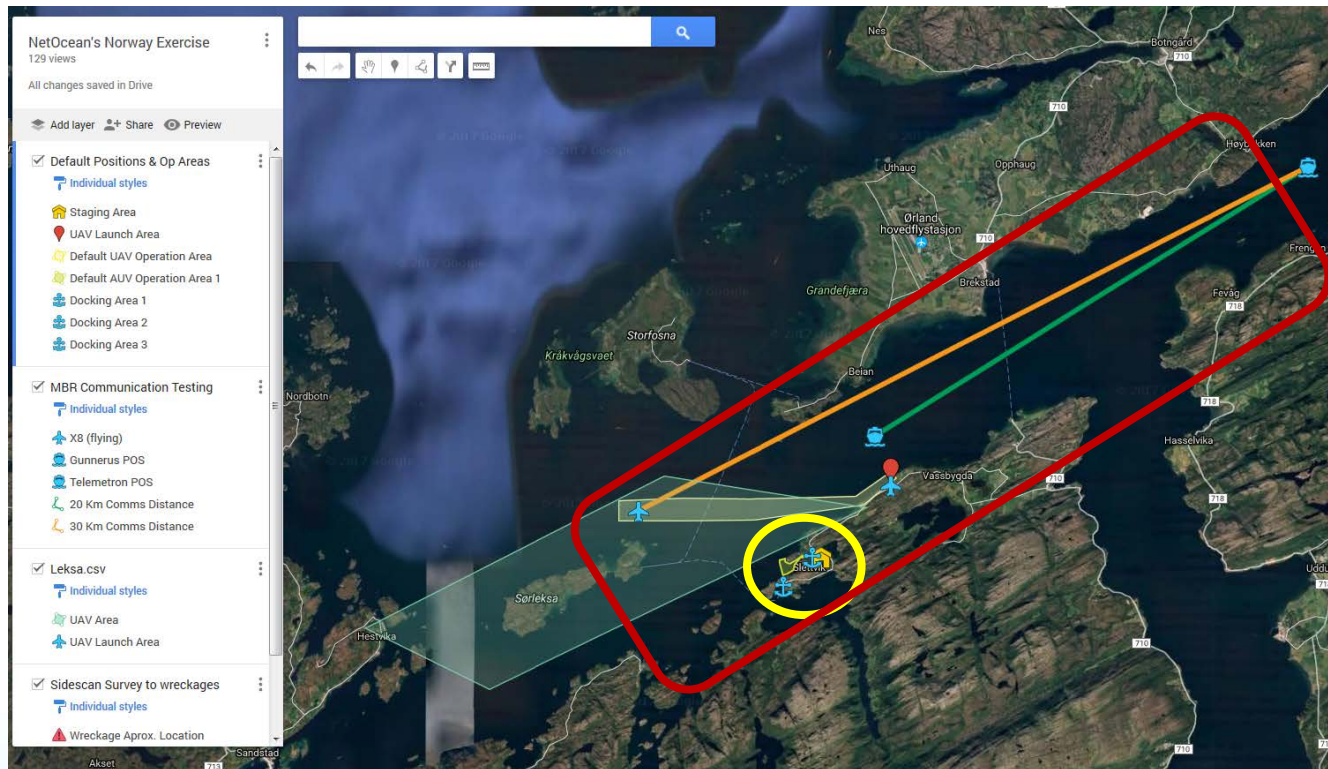
REP 16

- UAV data mule testing;
- Historical data algorithm testing;
- Web-link and Multi-hop tasks testing



Deployments & Results

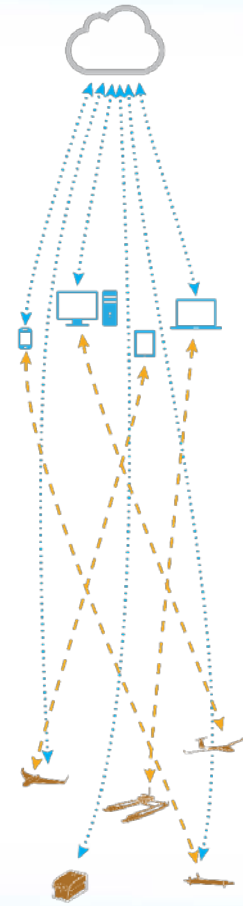
Slettvik Exercise



Deployments & Results

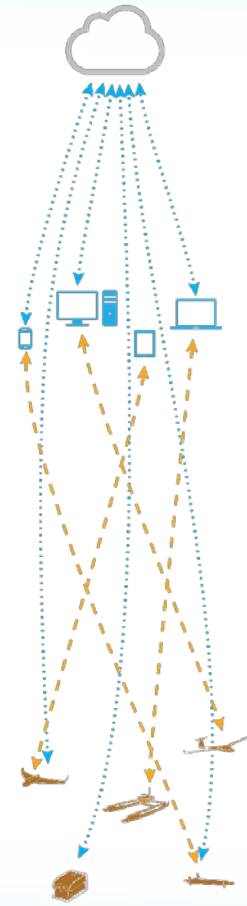
Slettvik Exercise

- MBR communication system range and routing tests;
- AUV monitoring, planning and data collection over 3G/4G;
- Multivehicle network control;
- Multiple ASV fish tracking.
- Interoperability scenarios;
- Scaling up the tool-chain;



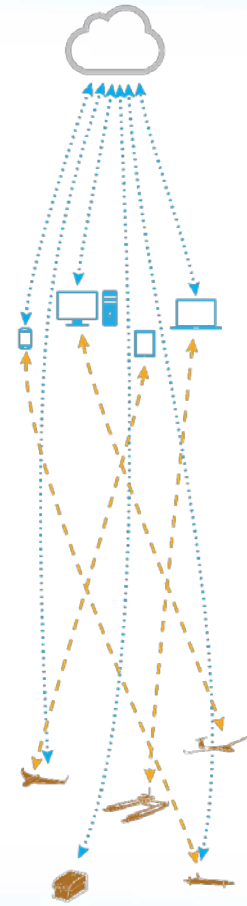
Deployments & Results

- Even with small-sized systems multivehicle deployments can be made comfortably up to the 1,5km mark with simple omnidirectional antenna setups;
- If the transmitter antenna type is changed to sectoral these limits increase up to the 5km mark;
- This allowed for the creation of medium sized communication hubs which can be entered or left by autonomous systems in a plug-and-play fashion;
- However, when distance between vehicles increased, multi-GHz ISM technologies hit a limit compensated by cellular/satcom networks



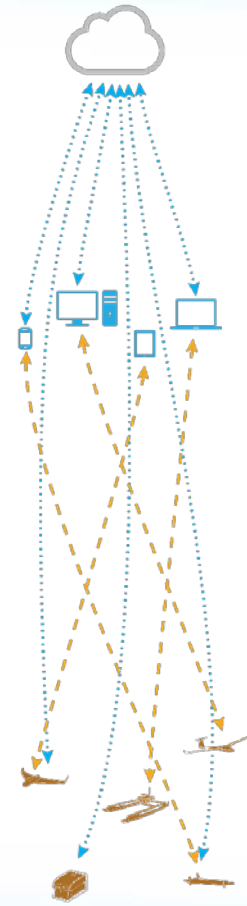
Deployments & Results

- To reduce satcom costs one method is to have only some systems with satcoms capabilities, serving as gateways for the rest of the team;
- Nevertheless, the team must be in range of the gateway vehicle and in this regard the MBR presents itself as a powerful asset by attenuating this communication need;
- MBR provided a layer of communication which allowed the operation teams to surpass Wi-Fi coverage while retaining bandwidth;
- Nevertheless, the use of these networks is not as ad-hoc and simple as the Wi-Fi solution



Deployments & Results

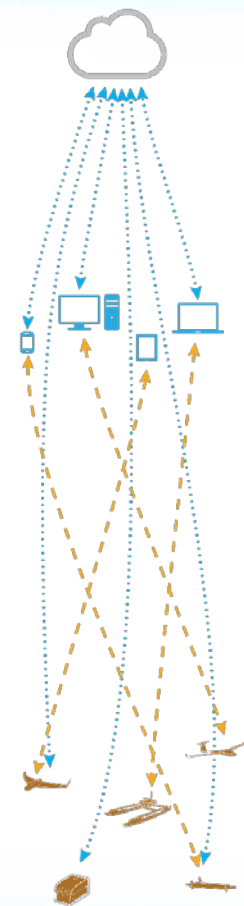
- To take advantage of the MBR all radio-nodes require common static network configuration, which included MAC and IP addresses of all devices allowed to communicate over backbone network;
- Configuration can be changed at any time, but changes should be applied to every node separately.
- Each MBR system present in the exercise had a custom, dedicated antennae array suitable for its requirements
- This proves problematic for very dynamic team configurations;
- A multi layered approach (WI-FI on all nodes and MBR on specific "stationary" elements) could prove very interesting;



Outreach & Dissemination

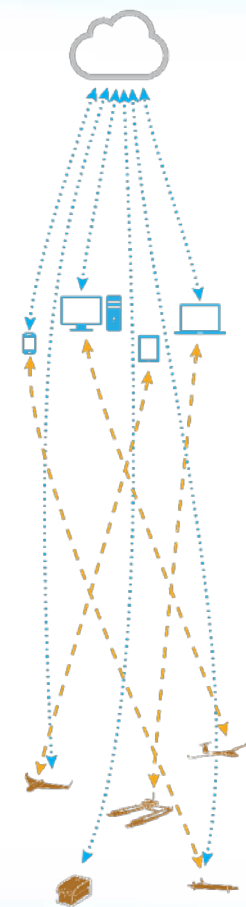
Outreach & Dissemination

- Publication "**Rapid Environmental Picture Atlantic exercise 2016:Field Report**" - Oceans MTS/IEEE 2017, Aberdeen;
- Publication "**Managing communication challenges in vehicle networks for remote maritime operations**" - Oceans MTS/IEEE 2017, Aberdeen;
- Publication "**A Formation of Unmanned Vehicles for Tracking of an Acoustic Fish-Tag**" - Oceans MTS/IEEE 2017, Aberdeen;
- Publication "**Coordinated maritime missions of unmanned vehicles - network architecture and performance analysis**" - IEEE International Conference on Communications 2017, Paris;
- Research presentation at AUV 2016 - Autonomous Underwater Vehicles 2016, Tokyo;



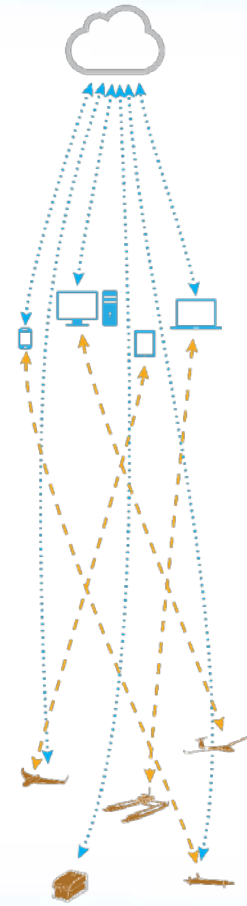
Outreach & Dissemination

- Publishing in "*Jornal da Economia do Mar*" regarding both REP16-Atlantic experiments in July and Trondheim and Slettvika September experiments
- Interview by local Trondheim media sources, at Maritime Robotics AS headquarters, regarding Trondheim and Slettvika September experiments, Trondheim;
- Interview to technical journal, hosted by NTNU-AMOS, regarding Trondheim and Slettvika September experiments, Trondheim;
- Research presentation at OCEANS 2016 MTS/IEEE Monterey, Monterey;
- Lecturing of seminar entitled Ocean observation with networked vehicle systems, Lisbon;



Outreach & Dissemination

- Workshop on the use of drones for smarter and more efficient fisheries and marine resource management, Amsterdam;
- Business2Sea, Porto;
- Publication "**Network of heterogeneous autonomous vehicles for marine research and management**" - Oceans MTS/IEEE 2016, Monterey;
- Oceanology International 2016, London;
- Oceans Business Week, Lisbon;
- Participation in the first phase of operation GUNNERUS in partnership with NTNU with the objective of integrating Neptus C4I software, Trondheim;



Ongoing & Future Endeavors

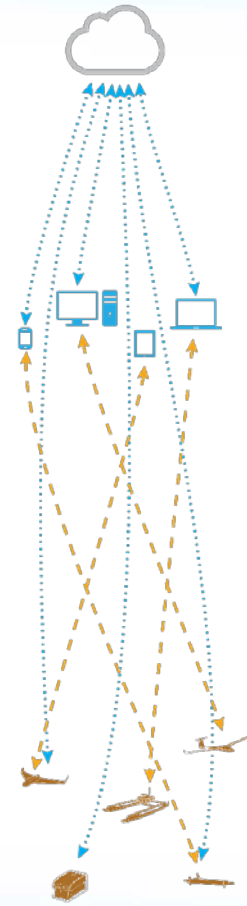
Ongoing & Future Endeavors

Approved

- Integrating and opening research infrastructures of European interest) (*INFRAIA-02-2017*) – **EUMarineRobots**
 - NTNU - Norwegian University of Science and Technology

For Submission

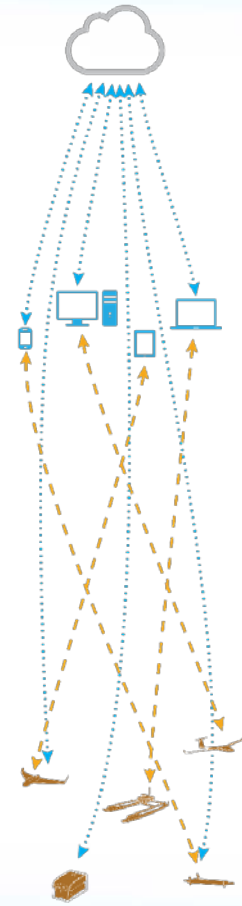
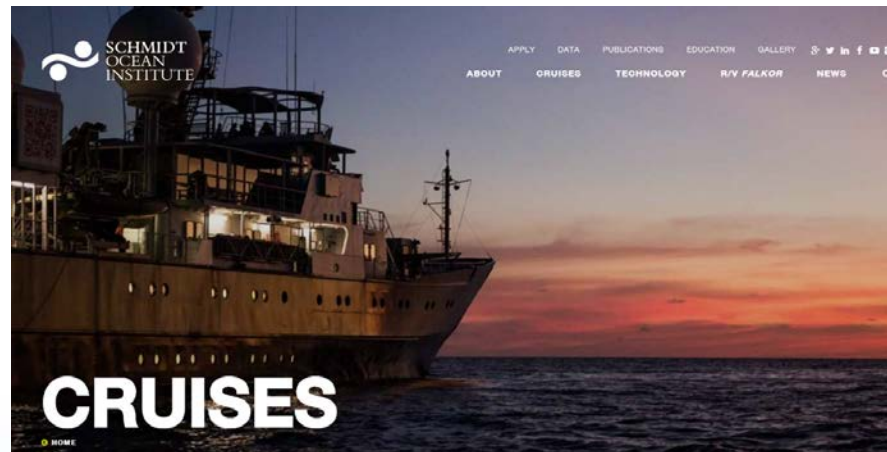
- Towards a Baltic and North Sea research and innovation programme (*BG-01-2018*)
 - NORUT - Norut Northern Research Institute
 - NTNU - Norwegian University of Science and Technology
 - Meteorologisk Institutt
 - Maritime Robotics



Ongoing & Future Endeavors

NetOS: A Shipboard Ocean Space Center for Networked Multi-Vehicle Ocean Science

NetOS is an international and multidisciplinary team, from nine institutions, that will demonstrate a novel approach to science and exploration of the changing ocean using persistent networked autonomous vehicles. In collaboration with the Schmidt Ocean Institute, NetOS will conduct synoptic studies of the Ensenada Front off the coast of California.



CONTACTS

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Thank you for your time.

