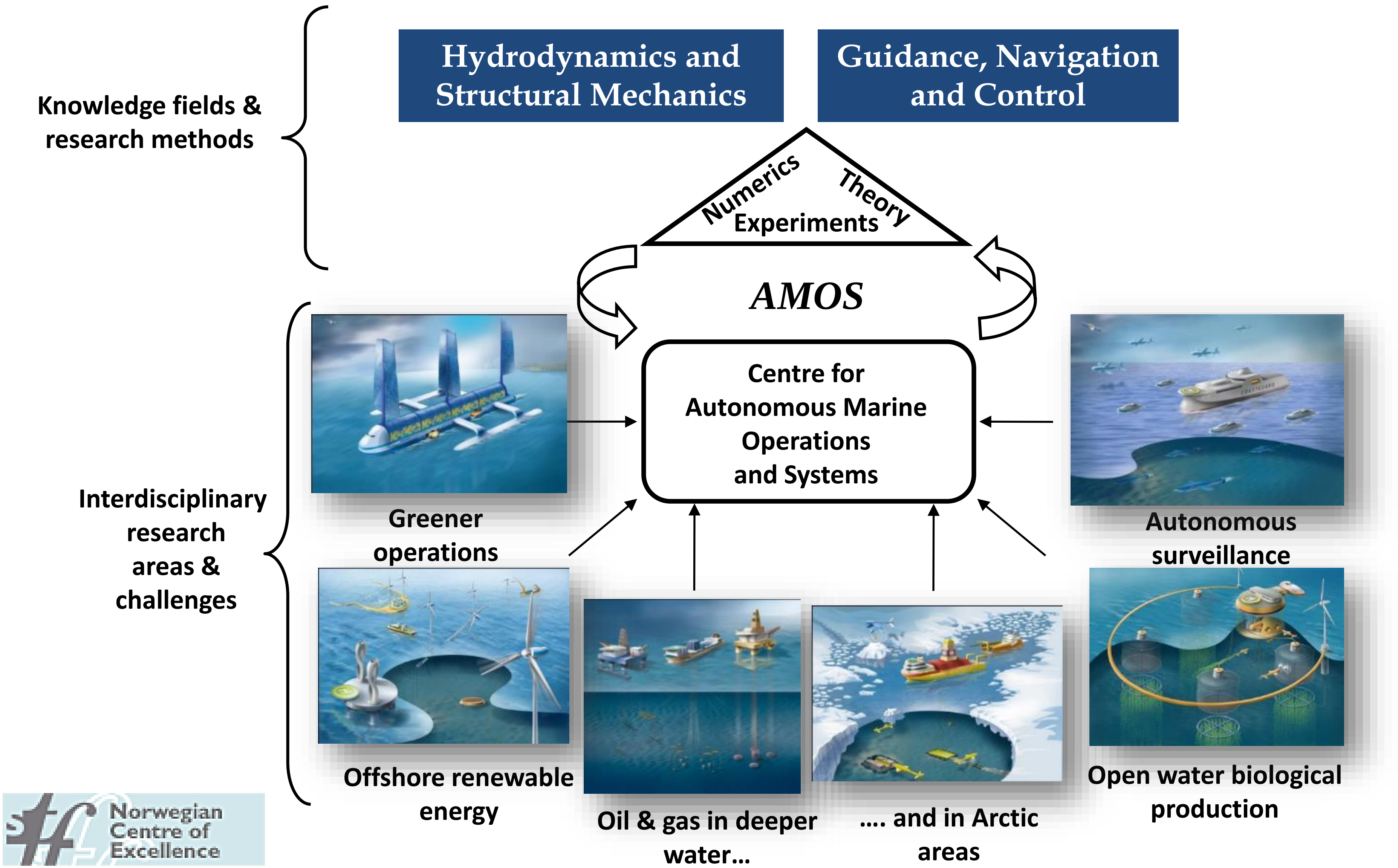
Small Satellites for Oceanography

Coordinated maritime observations and surveillance from autonomous aerial, surface and underwater robots and small satellites

Professor Tor Arne Johansen, NTNU-AMOS

NTNU AMOS Center for Autonomous Marine Operations and Systems



NTNU AMOS partners

The Research Council of Norway

Statoil

DNV·GL

NTNU

SINTEF

Faculty of Engineering (IV)
- Department of Marine Technology

Faculty for Information Technology and Electrical Engineering (IE)
- Department of Engineering Cybernetics

Faculty of Natural Science (NV))
- Department of Biology

SINTEF Ocean

SINTEF Digital

NTNU AMOS Facts and Figures (Phase 1: 2013-2017)

Personnel by October 2016:

6 Key scientists/professors
2 Scientific advisors/professors
10 Adjunct professors
13 Affiliated professors
9 Post Docs/researchers
5 visiting profs./researchers
87 PhD candidates
2 administrative staff
2 + lab engineers
3 Spin off companies

Partners:

The Research Council of Norway, NTNU, Statoil, DNV·GL, MARINTEK SINTEF, SINTEF

International collaborators from: Denmark, Sweden, Portugal, Italy, Croatia, the Netherlands, Estonia, Check Republic, USA, Australia, Brazil, Ukraine, UK

National collaborators: University of Tromsø, UNIS, UNIK, Kongsberg Maritime, Rolls-Royce Marine, FMC, Ecotone, Maritime Robotics, FFI, NGU, Ulstein Group, Eelume, NORUT, Marine Technologies, Akvaplan Niva, …

Norwegian Centre of Excellence

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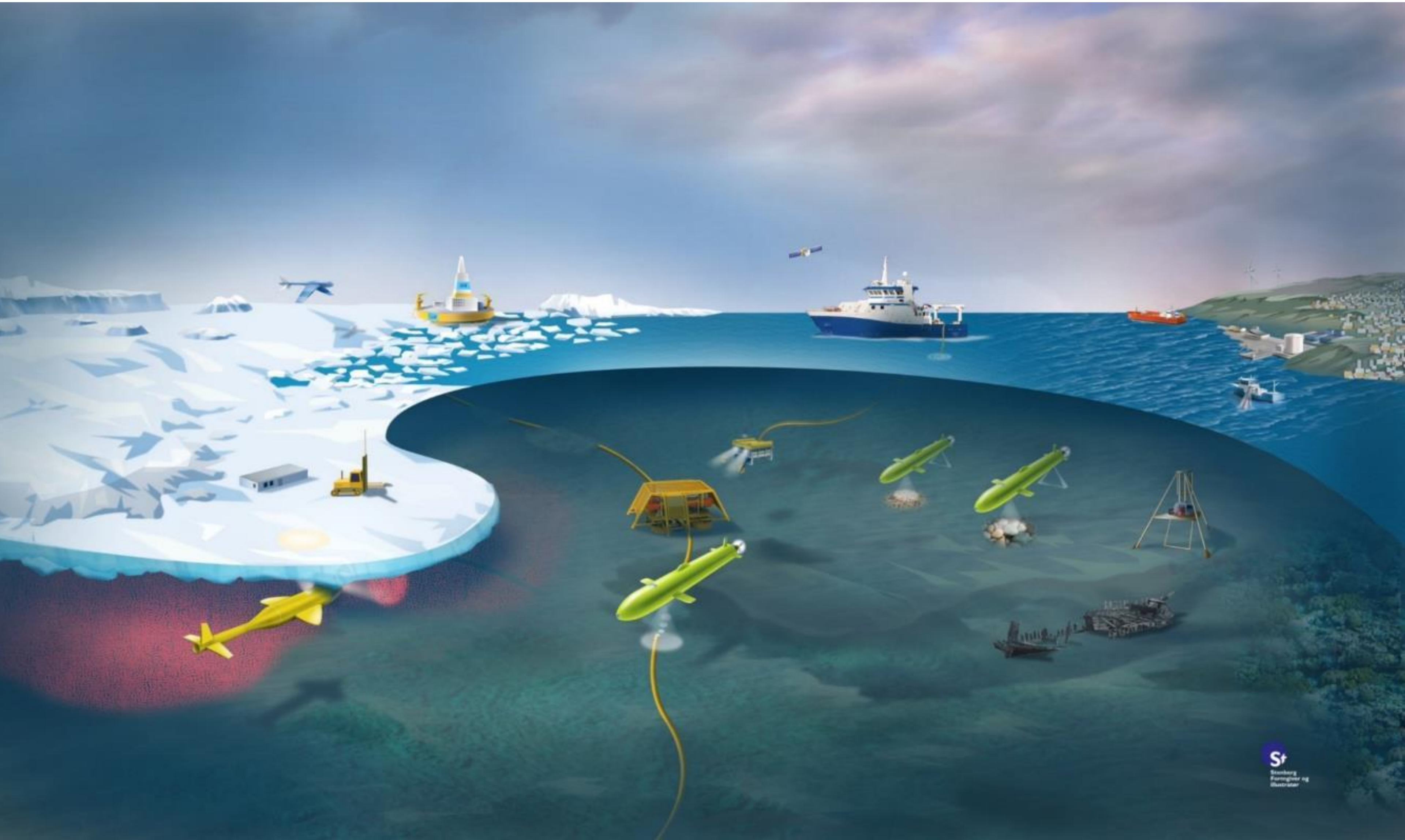
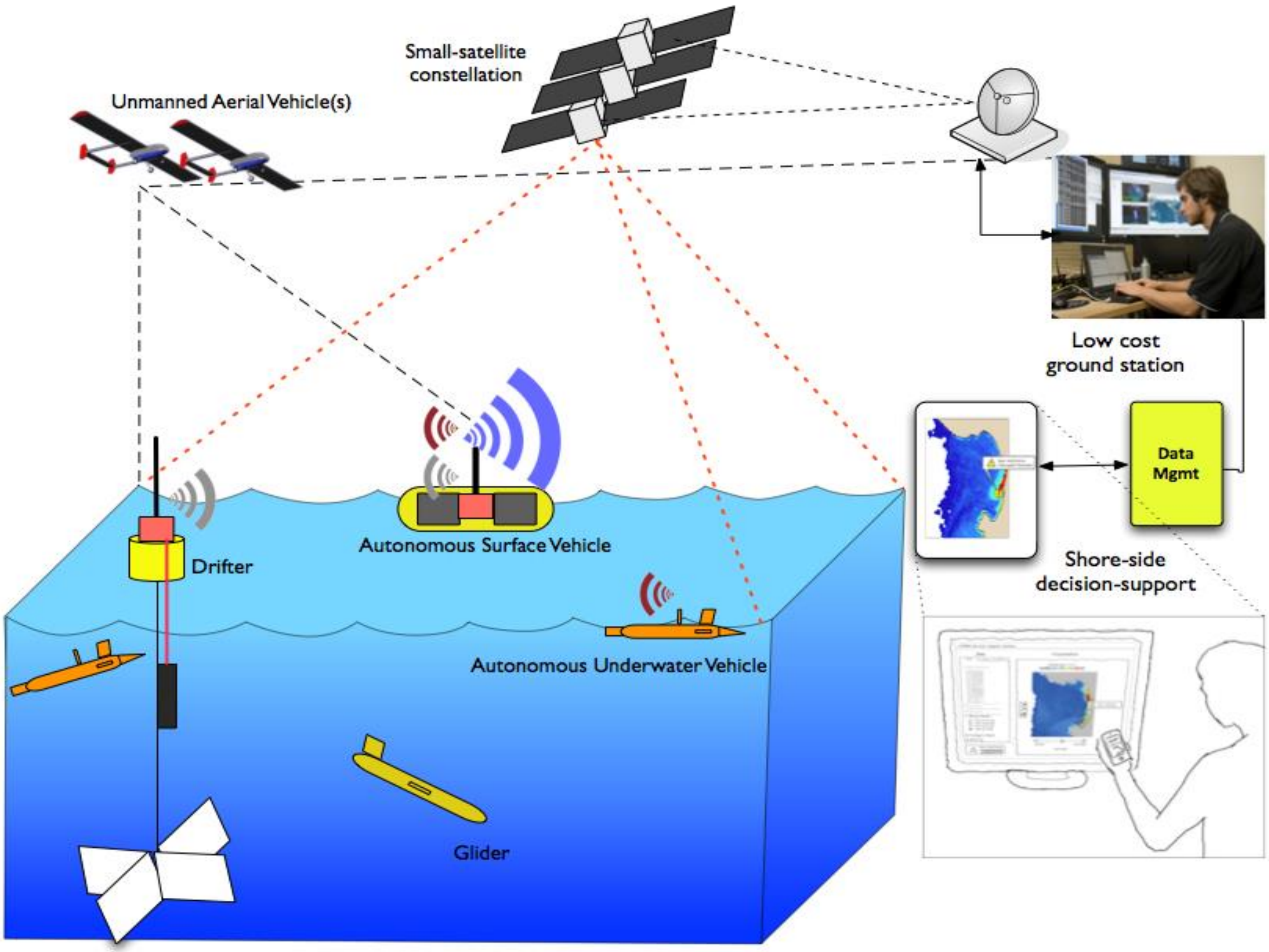
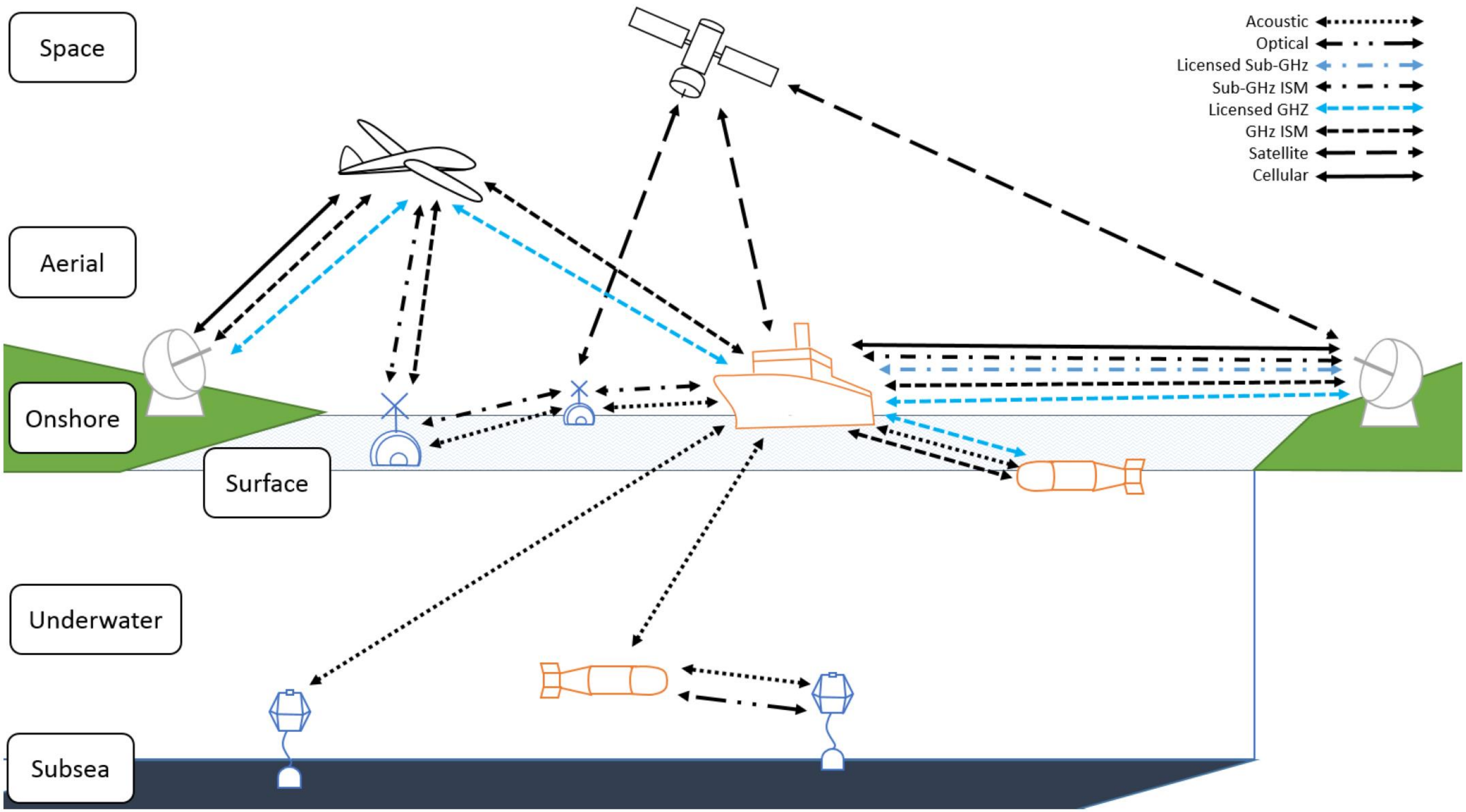


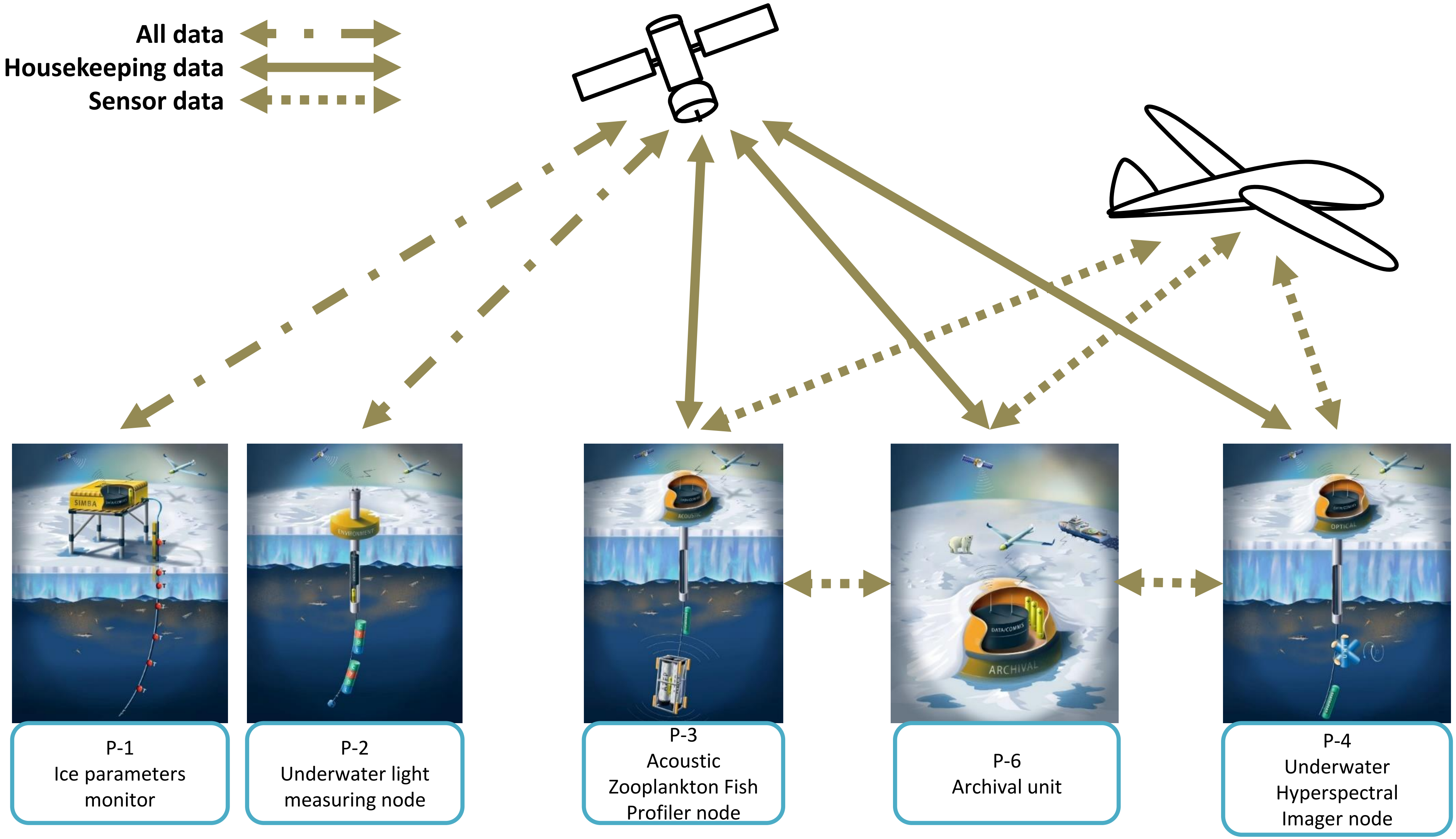
Coordinated observations



First step: Communication Network



The ArcticABC project:
Autonomous drifting buoys in the Arctic



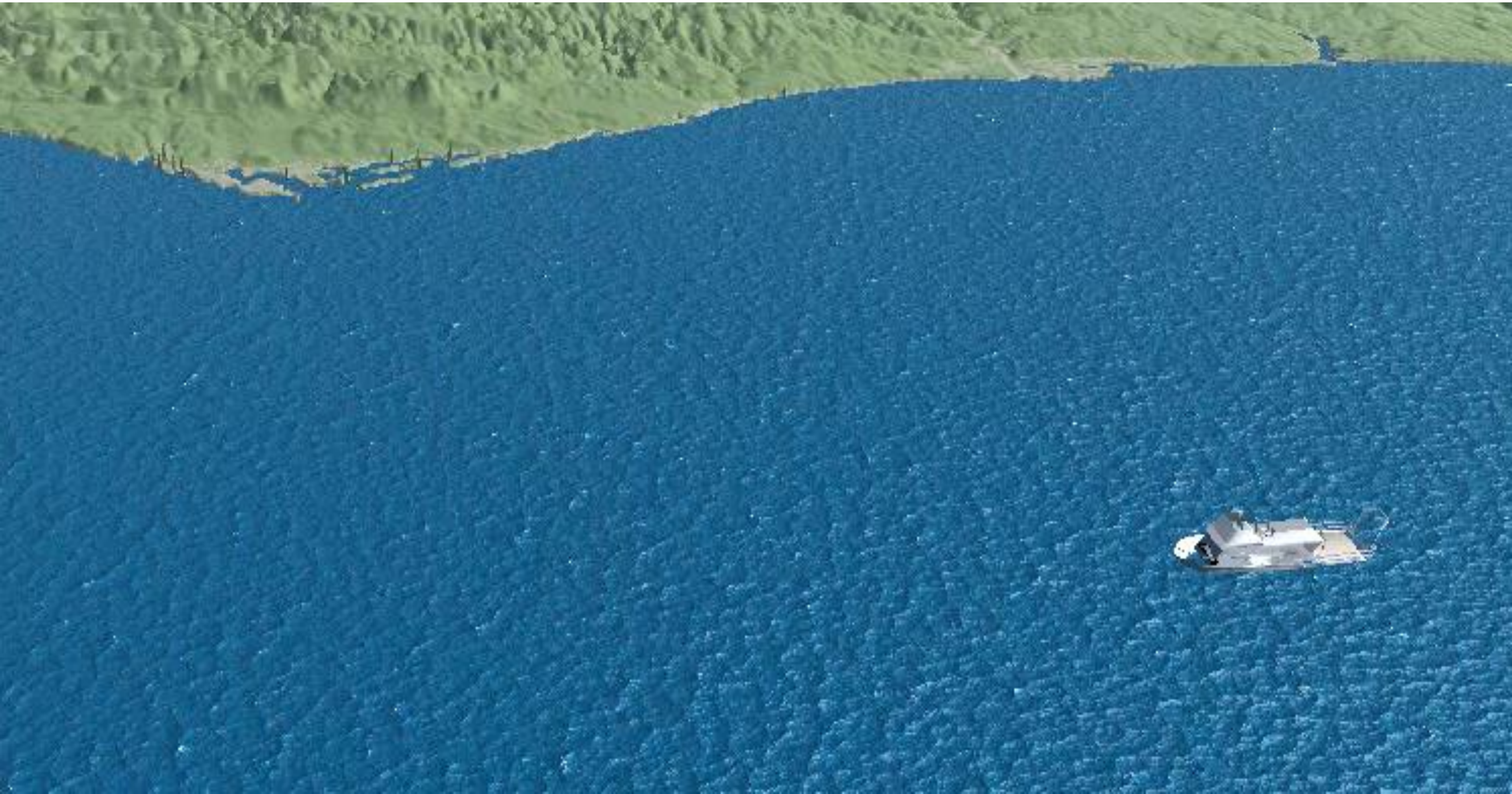
Sunfish tracking

M. Faria, J. Pinto F. Py, J. Fortuna, H. Dias, R. Martins, F. Leira, T. A. Johansen, J. Sousa, K. Rajan, Coordinating UAVs and AUVs for Oceanographic Field Experiments: Challenges and Lessons Learned Experiments in UAV and AUV control for Coastal Oceanography, IEEE Int. Conf. Robotics and Automation, Hong Kong, 2014

L. L. Sousa, F. López-Castejón, J. Gilabert, P. Relvas, A. Couto, N. Queiroz, R. Caldas, P. Sousa Dias, H. Dias, M. Faria, F. Ferreira, A. S. Ferreira, J. Fortuna, R. J. Gomes, B. Loureiro, R. Martins, L. Madureira, J. Neiva, M. Oliveira, J. Pereira, J. Pinto, F. Py, H. Queirós, D. Silva, P. B. Sujit, A. Zolich, T. A. Johansen, J. Borges de Sousa, K. Rajan, Integrated monitoring of Mola mola behaviour in space and time, PLOS One, 2016;

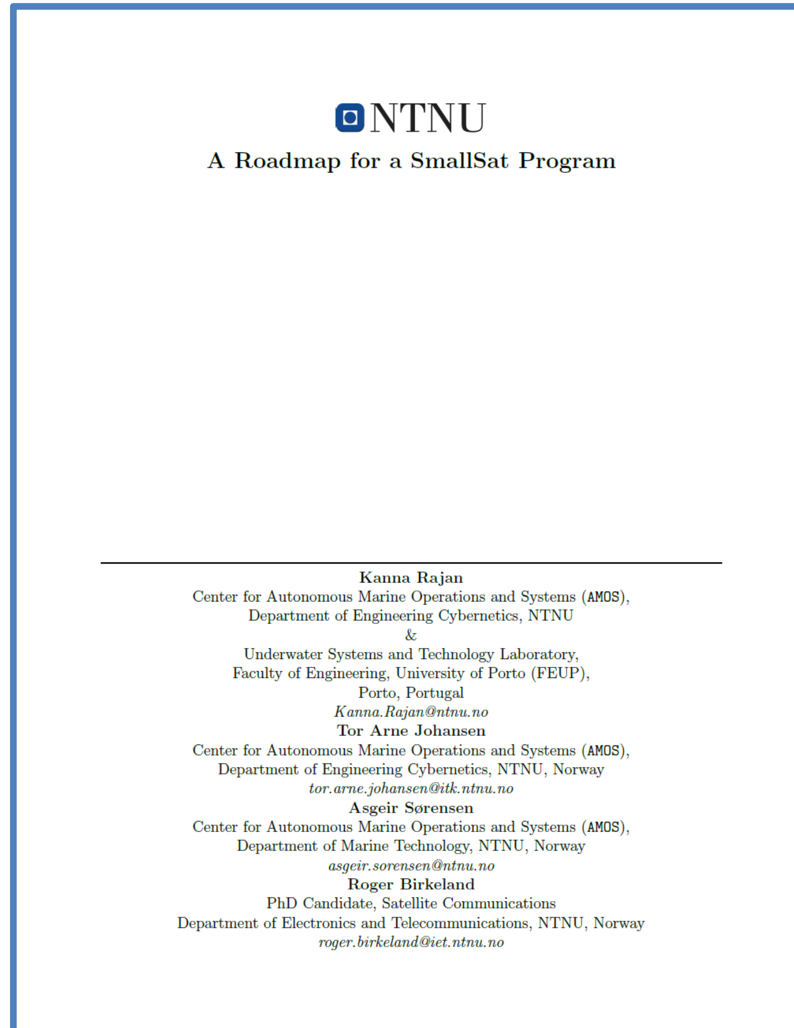
Coordinate Sensing and Control with UAV, AUV, ASV and satellites

Example: Sunfish Tracking with Univ. Porto, Azores, Madeira. REP-13, REP-14, REP-15, ...



Next step for AMOS: Small satellites

- Driven by **game-changing concepts, technology platforms and launch services** that is about to become widely available and affordable
- Unique robotic perspective: Our own satellites are part of a coordinated and controlled robotic network of **autonomous robotic systems for ocean observation, communication and surveillance**.
- **Single-purpose small satellites for remote sensing and communication**. Under our control they can serve targeted coordinated observation missions for spatial, temporal and spectral properties, beyond the capabilities of today's commercial satellite services.



NTNU

A Roadmap for a SmallSat Program

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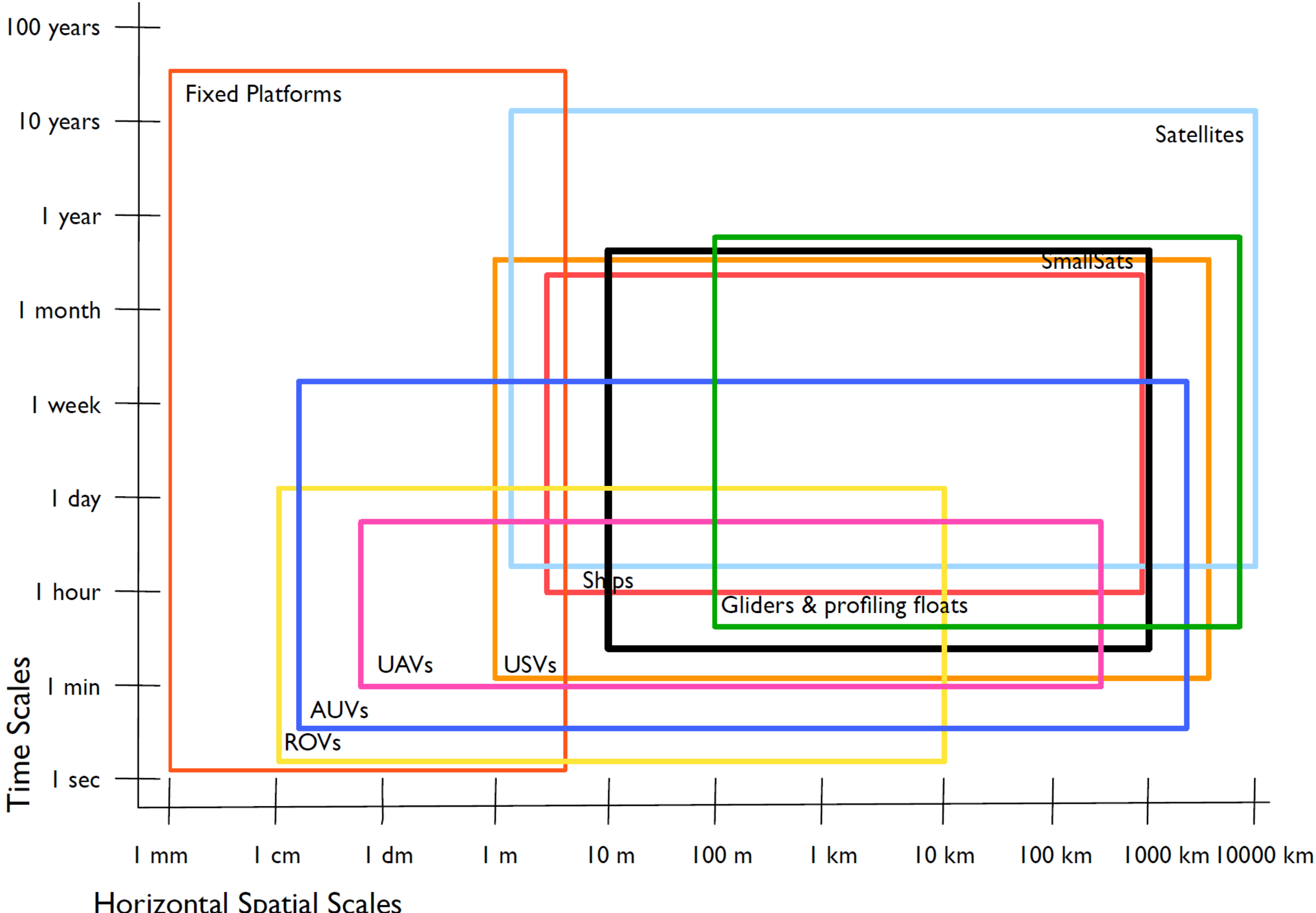
Why are SmallSats Important to Norway?

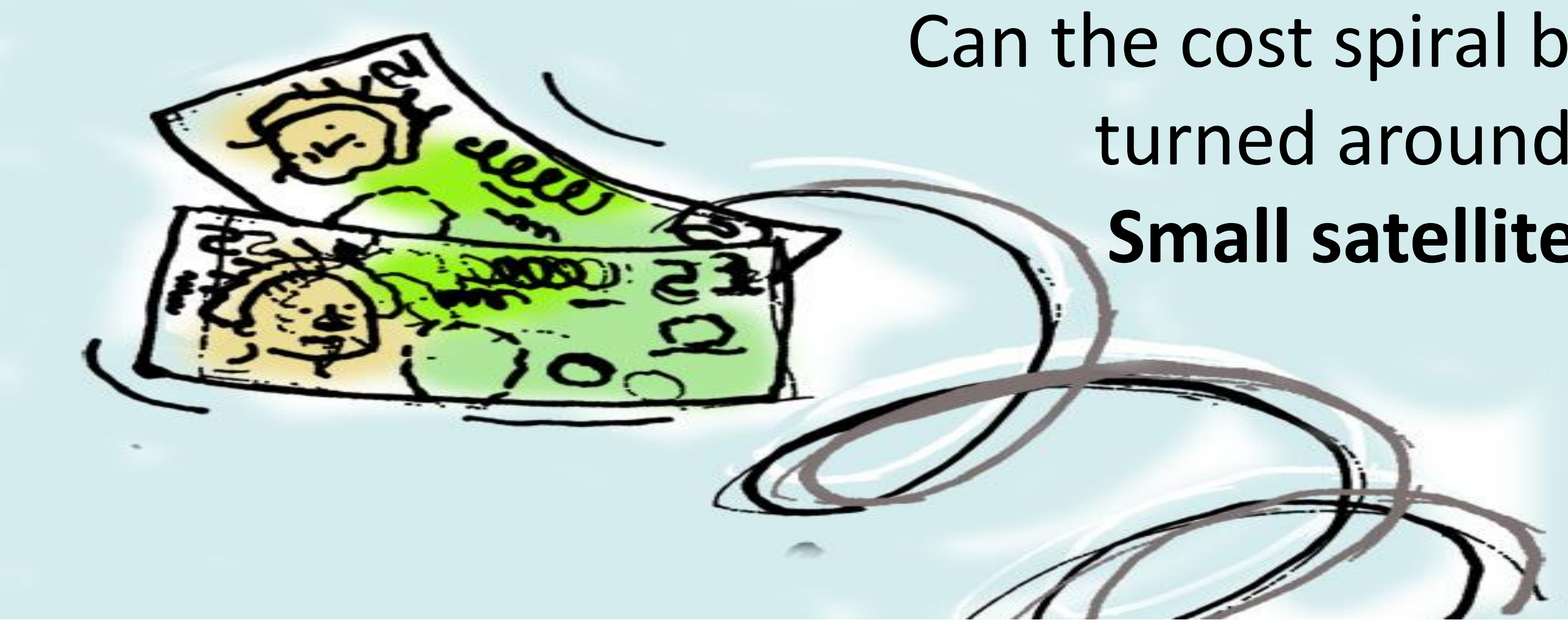
- Norway is ocean-facing
- At the bleeding-edge of observing climate change
- Harsh open water conditions
- Authority and independence for security for the homeland

How can small satellites compete with the larger conventional satellites?

Observation platforms



Sentinel 3A



Can the cost spiral be turned around?
Small satellites

- Single purpose, decidate, just what needed, nothing more
- Low energy consumption; high power capacity
- COTS components with the latest miniatyrized technology
- Software-centered, re-programable and re-configurable on the fly (Rapid systems engineering)
- Use relatively inexpensive and proven satellite kits
- Accurate pointing / attitude control
- Open system architecture; standardization
- Accept risk
- Increased numbers will reduce launch costs (eventually)

Case study: Ocean Colour

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OLCI Instrument Payload

The SENTINEL-3 Ocean and Land Colour Instrument (OLCI
ENVISAT's MERIS instrument. The main characteristics of th

- swath width: 1 270 km
- push-broom imaging spectrometer with five cameras, m in westerly direction
- spatial sampling: 300 m @ SSP
- spectrum: 21 bands [0.4-1.02] µm
- radiometric accuracy: 2% abs, 0.1% rel
- launch mass: 153 kg
- size: 1.3 m^3
- design lifetime: 7.5 years.

Figure 1: SENTINEL-3 OLCI Instrument (Credit: ESA)

The smallsat alternative:

- Swath width: 50 km
- Hyperspectral push broom with single camera
- Spatial resolution: 100 m
- Spectrum 0.4-0.9 µm ~100 bands
- Radiometric accuracy <10%
- Adaptive calibration by UAV, USV, AUV data
- Launch mass: 250 g
- Size: < 0.001 m3
- Design lifetime >2 years
- Sleep and harvest energy most of the time
- Faster revisit time (hours, not days)
- Onboard image analysis; dedicated purpose, signatures of known features
- Collaborative mission with UAV, USV, AUV
- No need to communicate raw or compressed images
- Accurate attitude control/pointing

A national competence center on small satellite systems for ocean/maritime applications

Building competence and capacity is timely and stategically important for Norway: Synergies, independence and industrial opportunities.

NTNU-AMOS wants to develop a 8-10-year program to build competence and **demonstrate the potential** through **a series of 10-20 own small satellites that are designed and operated within networks of autonomous vehicles**:

- NTNU has recently allocated 8 PhD scholarships and funding for two own 3U satellites in order to initiate this smallsat program.
- Collaborates with Norwegian Space Center on NORSAT microsatellite payloads.
- Broad and effective collaboration with the other stakeholders in academia, industry and end users is essential.