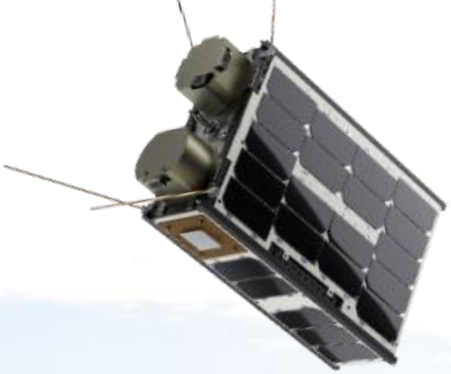
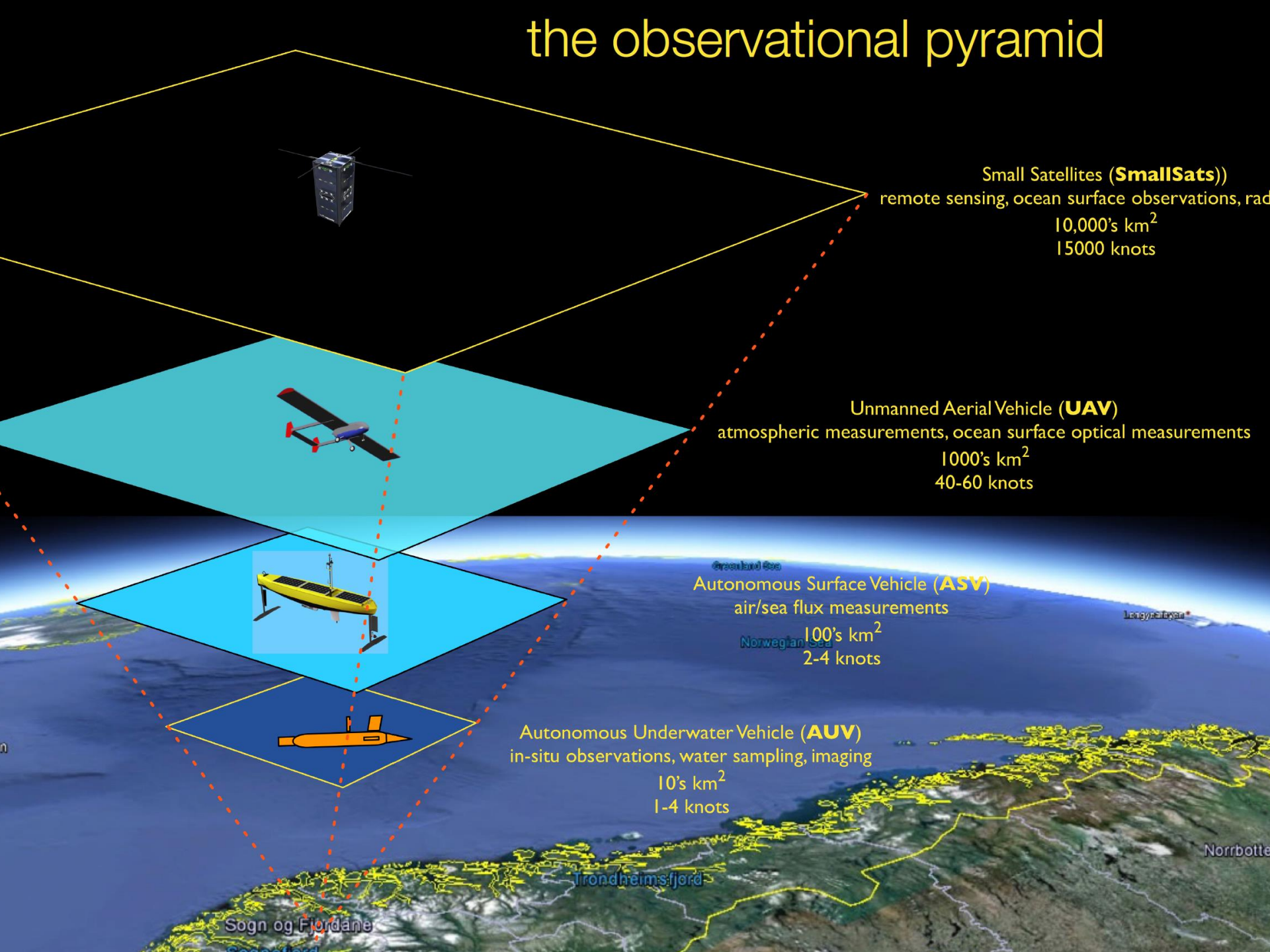
Coordinated marine and aerial vehicles with SmallSats

Professor Tor Arne Johansen
Center for Autonomous Marine Operations and Systems
Norwegian University of Science and Technology, Trondheim, Norway

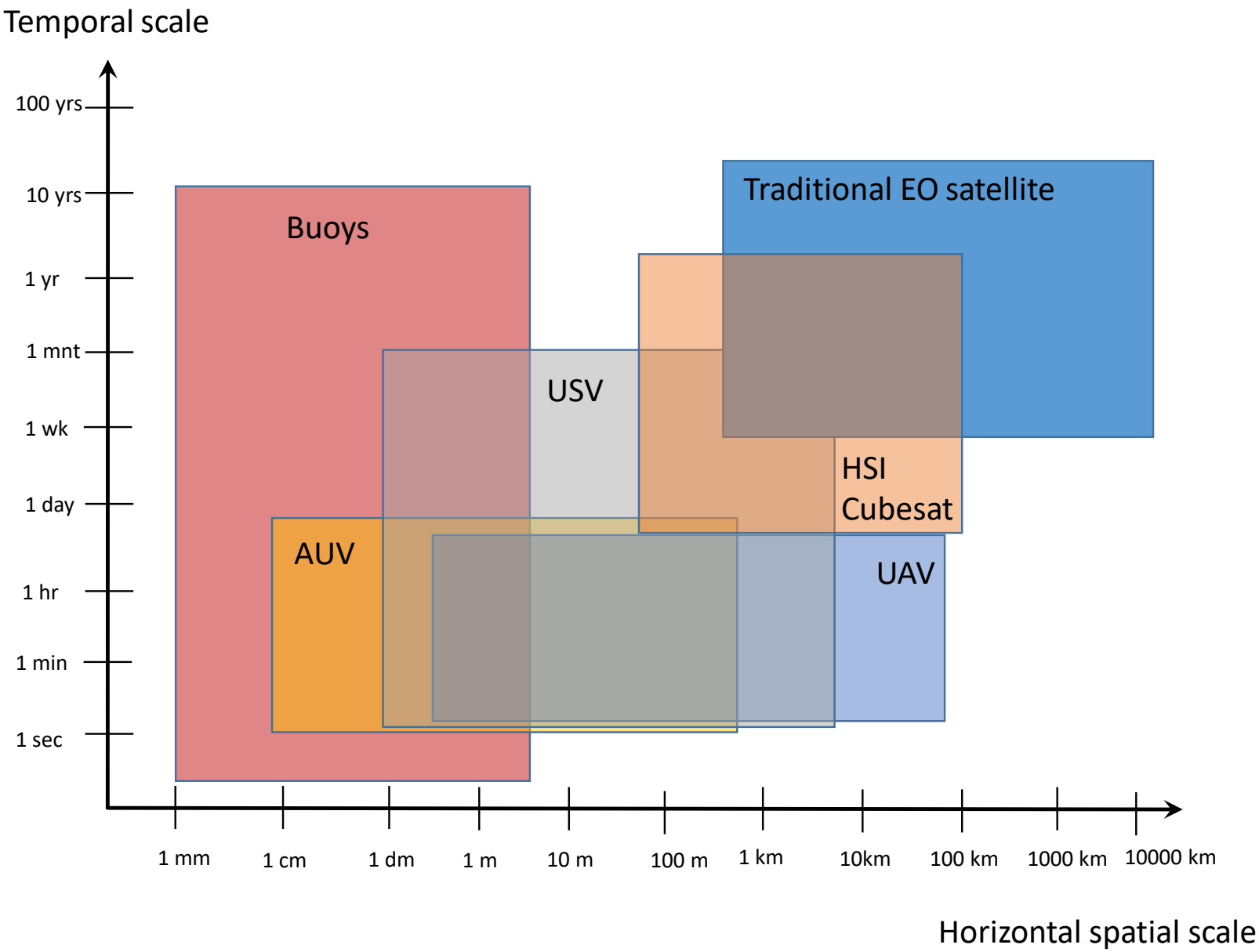
Instrument carrying robots



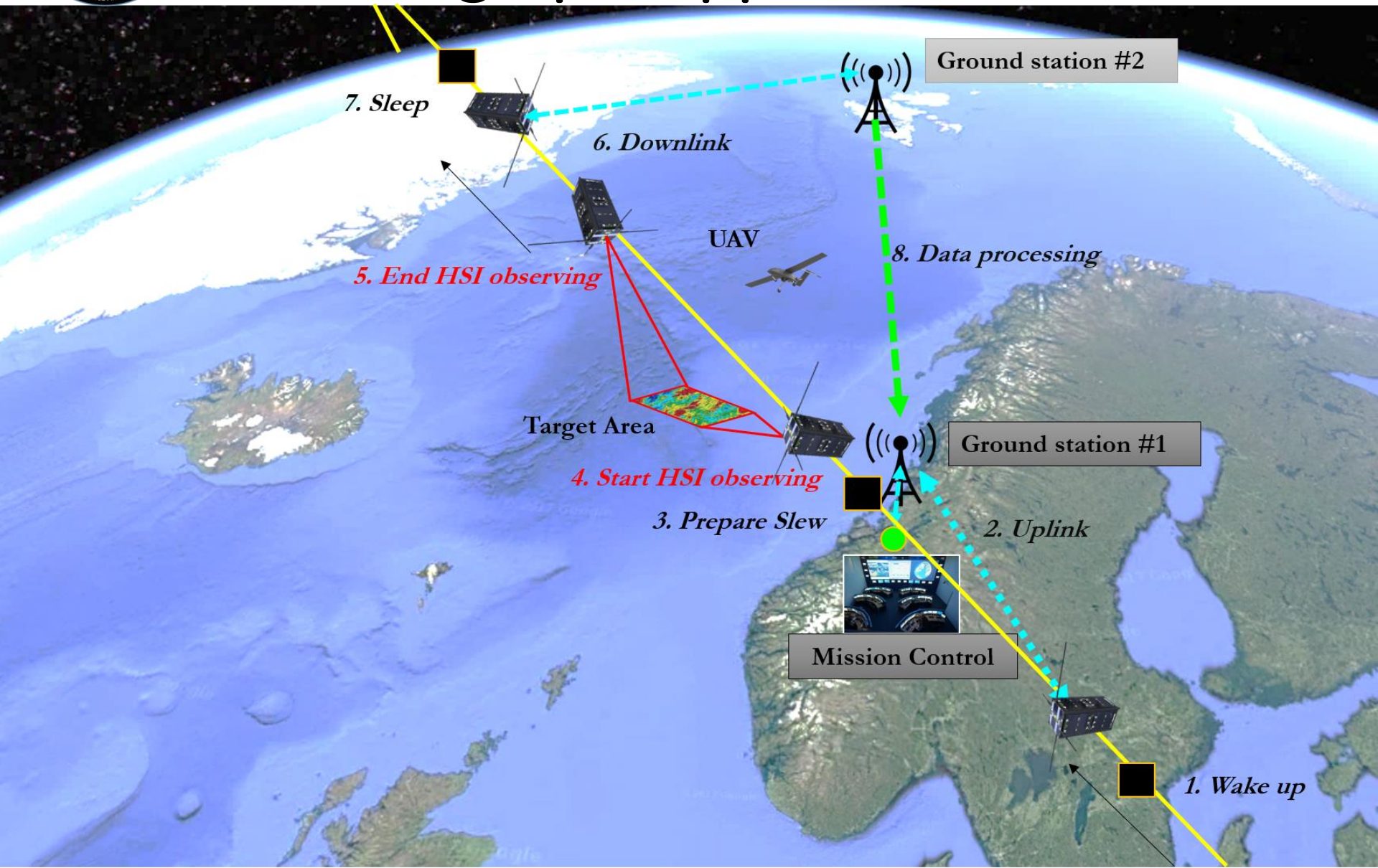
the observational pyramid



Observation platform capabilities



HYPSO: Hyper Spectral Imager for Ocenaograpic Applications



Research Article | Vol. 26, No. 5 | 5 Mar 2018 | OPTICS EXPRESS 6021

Optics EXPRESS

Do it yourself hyperspectral imager for handheld to airborne operations

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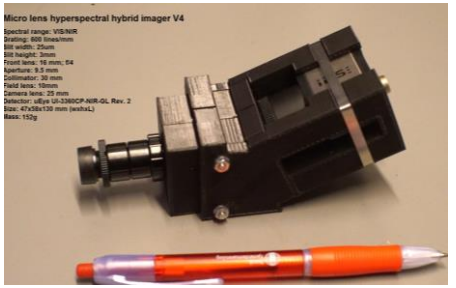
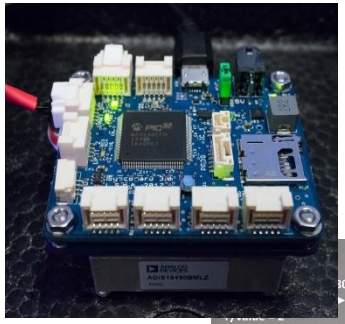
Abstract: This study describes rapid prototype construction of small and lightweight push broom Hyper Spectral Imagers (HSI). The dispersive element housings are printed by a thermoplastic 3D printer combined with S-mount optical components and commercial off-the-shelf camera heads. Four models with a mass less than 200 g are presented with a spectral range in the visible to the near-infrared part of the electromagnetic spectrum. The bandpass is in the range from 1.4 - 5 nm. Three test experiments with motorized gimbals to stabilize attitude show that the instruments are capable of push broom spectral imaging from various platforms, including airborne drone to handheld operations.

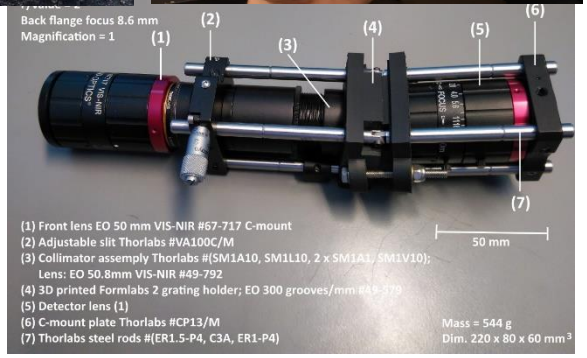
OCIS codes: (120.4570) Optical design of instruments; (300.6550) Spectroscopy, visible.

References and links

1. G. Vane, *Imaging Spectroscopy II* (SPIE, 1987).
2. W. L. Wolfe, *Introduction to Imaging Spectrometers* (SPIE, 1997).
3. E. Herrala and J. Okkonen, "Imaging spectrograph and camera solutions for industrial applications," Int. J. Pattern Recognit. Artif. Intell. **10**(01), 43–54 (1996).
4. T. S. Hyvarinen, E. Herrala, and A. Dall'Ava, "Direct sight imaging spectrograph: a unique add-in component brings spectral imaging to industrial applications," Proc. SPIE **3302**, 165–175 (1998).
5. F. Sigernes, K. Heia, H. Nilsen, and T. Svenøe, "Imaging spectroscopy applied in the fish industry?" Norw. Soc. Image Process. Pattern Recogn. **2**, 16–24 (1998).
6. F. Sigernes, D. A. Lorentzen, K. Heia, and T. Svenøe, "Multipurpose spectral imager," Appl. Opt. **39**(18), 3143–3153 (2000).
7. J. Hosen, H. H. Helgesen, L. Fusini, T. A. Johansen, and T. I. Fossen, "A Vision-aided Nonlinear Observer for Fixed-wing Unmanned Aerial Vehicle Navigation," J. Guid. Control Dyn. **39**(8), 1777–1789 (2016).
8. P. J. Miller, "Use of tunable liquid crystal filters to link radiometric and photometric standards," Metrologia **28**(3), 145–149 (1991).
9. F. Sigernes, Y. Ivanov, S. Chernouss, T. Trondsen, A. Roldugin, Y. Fedorenko, B. Kozelov, A. Kirillov, I. Kornilov, V. Safargaleev, S. Holmen, M. Dyrland, D. Lorentzen, and L. Baddeley, "Hyperspectral all-sky





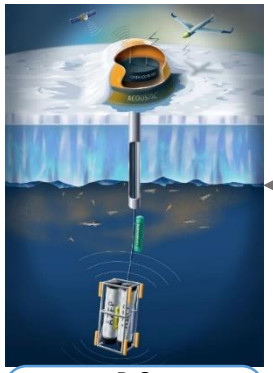


The ArcticABCD project: Autonomous drifting buoys in the Arctic

All data
Housekeeping data
Sensor data

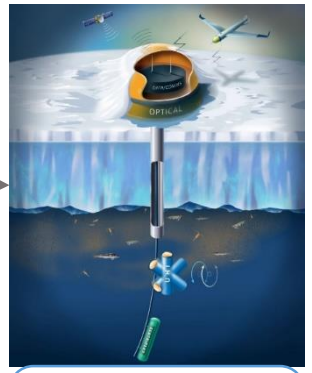
P-1
Ice parameters monitor

P-2
Underwater light measuring node



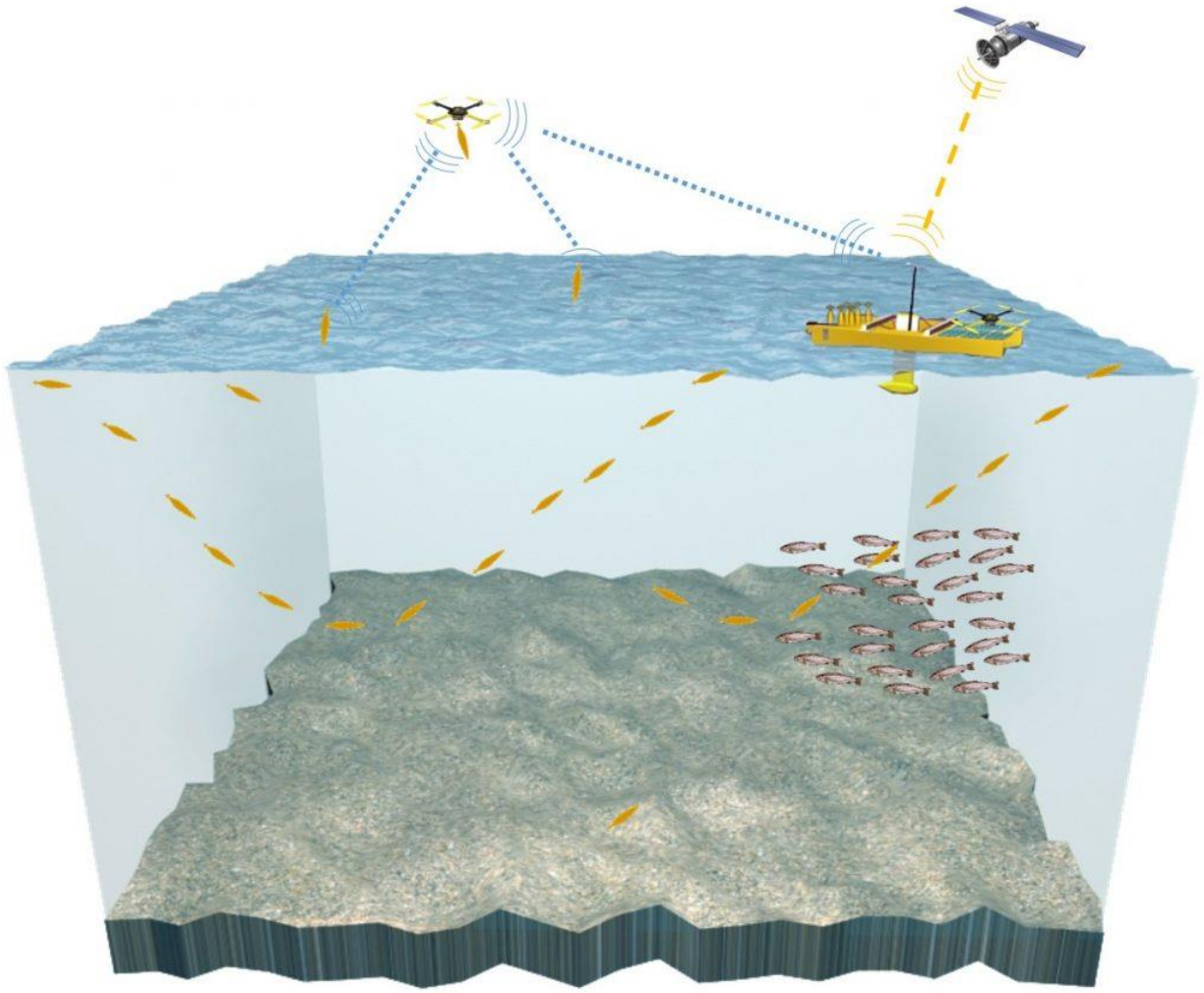
P-3
Acoustic Zooplankton Fish Profiler node

P-6
Archival unit



P-4
Underwater Hyperspectral Imager node

OASYS – Ocean-Air synoptic operations using coordinated autonomous robotic SYStems and micro underwater gliders



OSLOMET

NTNU

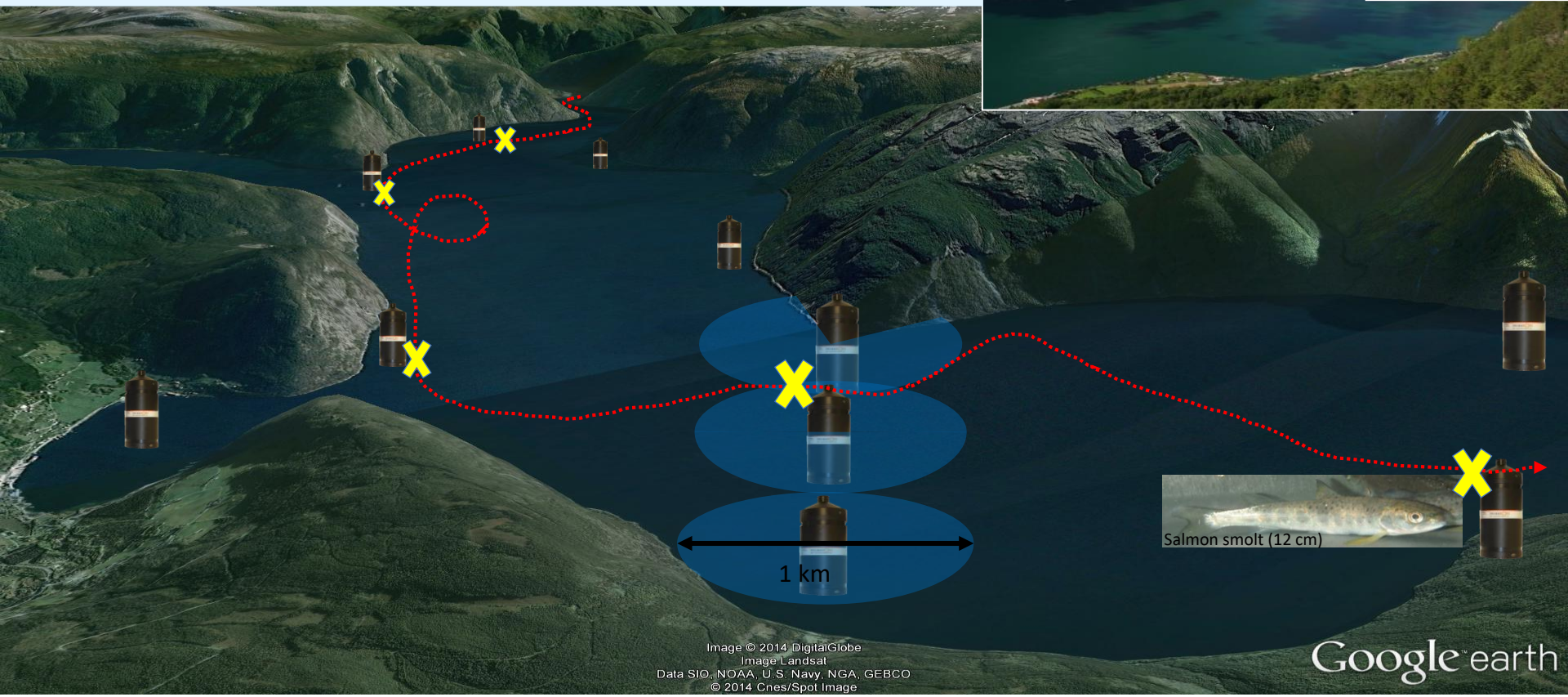
NORSK·POLARINSTITUTT

TriOS Optical Sensors

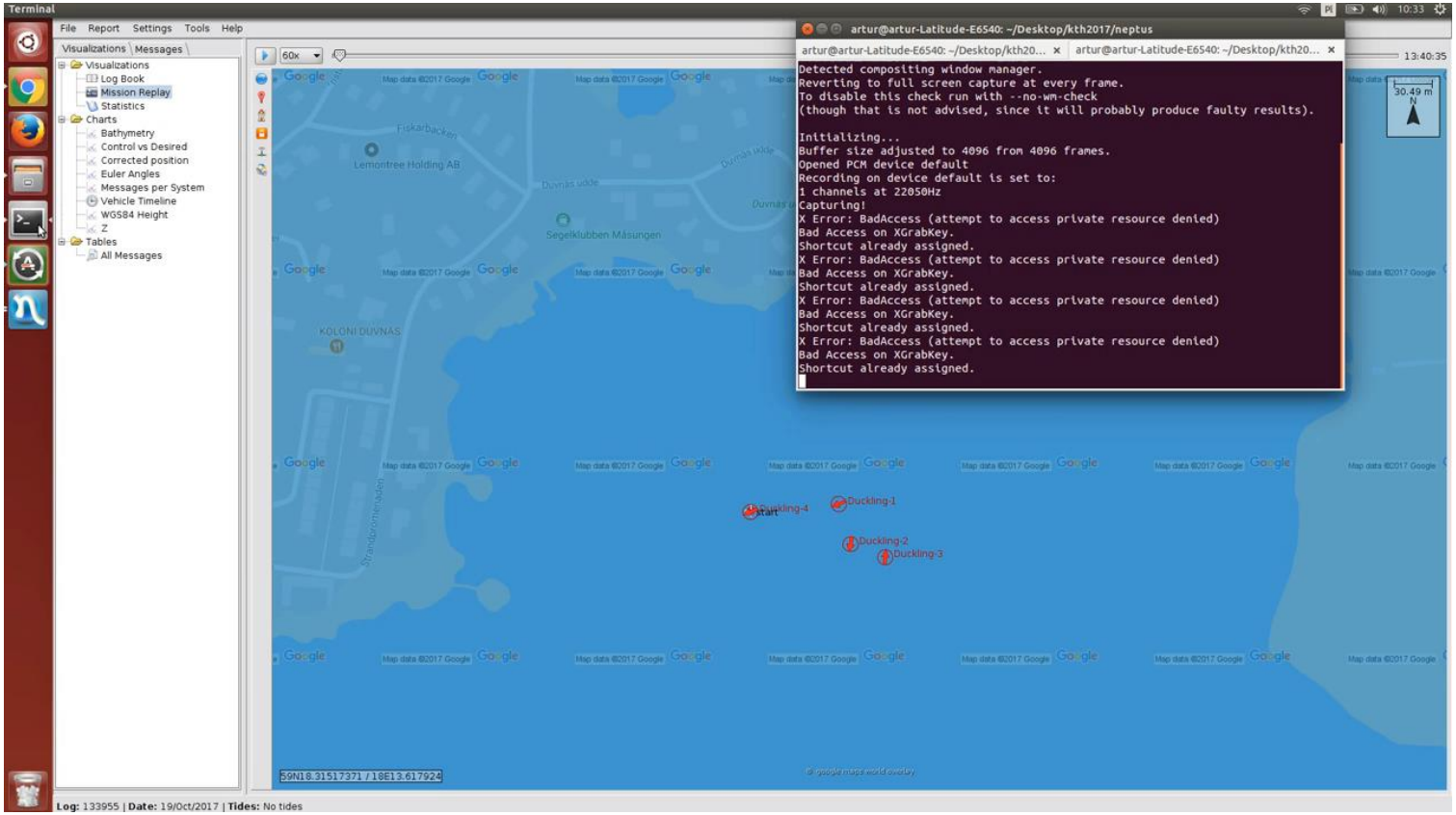
O. M. Brokstad, R. Klæboe, E. Sollesnes, B. Vågen, A. Carella, A. Alcocer, T. A. Johansen, A. P. Zolich, Towards the development of Miniature Underwater Gliders with UAV deployment/recovery capabilities, IEEE OES Autonomous Underwater Vehicle Symposium, Porto, 2018

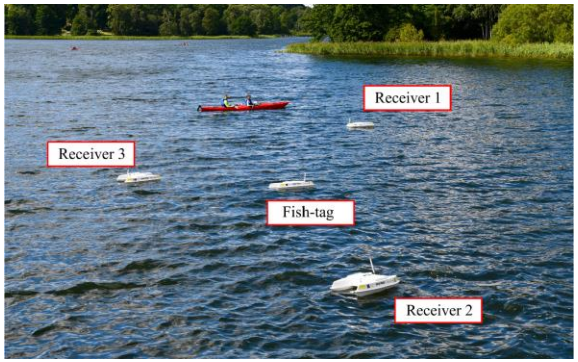
Static Receiver Arrays - "connecting the dots"

Ex.: seaward migration of salmon smolts in Inner Sognefjord, Norway



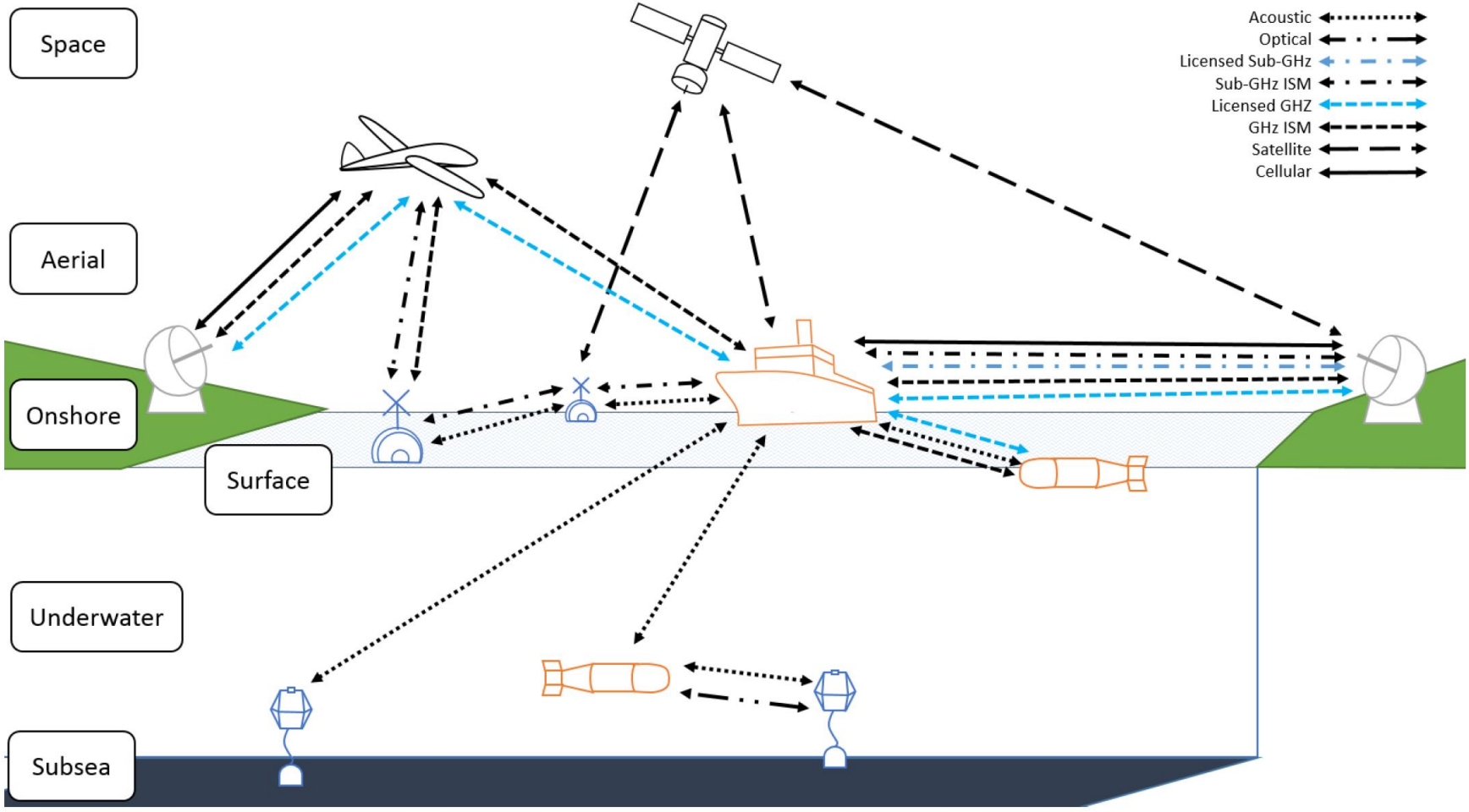
«Fish» tracking experiment with KTH in 2017





R. P. Jain, A. P. Zolich, E. S. Erstorp, T. A. Johansen, J. A. Alfredsen, A. P. Aguiar, J. Kuttenkeuler, J. Sousa, Localization of an Acoustic Fish-Tag using the Time-of-Arrival Measurements: Preliminary results using eXogenous Kalman Filter, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Madrid, 2018

Delay- and disruption-tolerant networking



D. Palma, A. Zolich, Y. Jiang, T. A. Johansen, Unmanned Aerial Vehicles as Data Mules: An Experimental Assessment, *IEEE Access*, Vol. 5, pp. 24716 – 24726, 2017


Beyond line of sight
operations & autonomy
LCUAB
Harbak
Stokksund
Årnes
Mausund
Svellingen
Sistranda
Hammarvika
Knarrlaget
Fillan
Hitra
Sandstad
Råkvåg
Uthaug
Opphaug
Brekstad
Hasselvika
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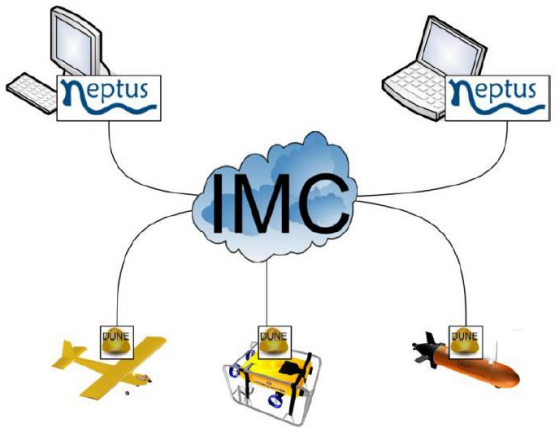
Trondheim
Sluppen
Krokstadøra
Kyrksæterøra
Aure
Vinjeøra

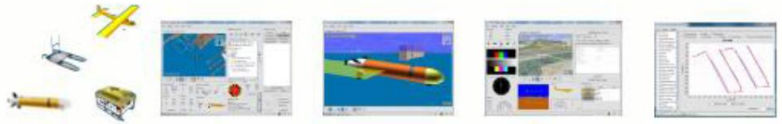
U.PORTO

Software tool chain



C4I – Command and Control Framework

Neptus



http://whale.fe.up.pt

Inter Module Communications

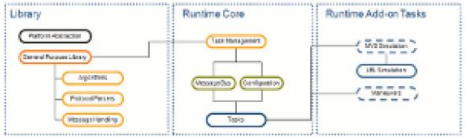
IMC

Message Protocol

http://whale.fe.up.pt

DUNE: Uniform Navigational Environment On-board software

DUNE



http://whale.fe.up.pt

Field proven: thousands of operations with air and ocean vehicles

Summary:

New robotic concepts are enabled by miniaturization of technology, lower cost, digitalization, autonomy, onboard processing, and ocean models