SoSECIE Webinar

Welcome to the
2021 System of Systems Engineering Collaborators
Information Exchange (SoSECIE)

National Defense Industrial Association

We will start at 11AM Eastern Time

You can download today's presentation from the SoSECIE Website:

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NDIA System of Systems SE Committee

- **Mission**
  - To provide a forum where government, industry, and academia can share lessons learned, promote best practices, address issues, and advocate systems engineering for Systems of Systems (SoS)
  - To identify successful strategies for applying systems engineering principles to systems engineering of SoS
- **Operating Practices**
  - Face to face and virtual SoS Committee meetings are held in conjunction with NDIA SE Division meetings that occur in February, April, June, and August

NDIA SE Division SoS Committee Industry Chairs:
Mr. Rick Poel, Boeing
Ms. Jennie Horne, Raytheon
OSD Liaison:
Dr. Judith Dahmann, MITRE

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- I have muted all participant lines for this introduction and the briefing.
- If you need to contact me during the briefing, send me an e-mail at sosecie@mitre.org.
- Download the presentation so you can follow along on your own
- We will hold all questions until the end:
    - I will start with questions submitted online via the CHAT window in Teams.
    - I will then take questions via telephone; State your name, organization, and question clearly.
- If a question requires more discussion, the speaker(s) contact info is in the brief.

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2021-2022 System of Systems Engineering Collaborators Information Exchange Webinars

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February 9, 2021
Fuzzy Architecture Description for Handling Uncertainty in IoT Systems-of-Systems
Flavio Oquendo

February 23, 2021
Interface Management- the Neglected Orphan of Systems Engineering
Paul Davies

March 9, 2021
Distributed Architecture for Monitoring Urban Air Quality: A Systems Engineering Approach
Adrián Unger, Tom McDermott and Philip Dewire

April 6, 2021
Holistic architecture description for a future Global Health Assurance Systems of Systems
Adrián Unger

April 20, 2021
Leveraging Set-Based Practices to Enable Efficient Concurrency in Large Systems and Systems-of-Systems Engineering
Brian Kennedy

2021-2022 System of Systems Engineering Collaborators Information Exchange Webinars

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May 4, 2021
OUSD R&E: USD(R&E) Mission Engineering (ME) State of Practice
Elmer L. Roman

May 18, 2021
Application of Probabilistic Graph Models to Kill Chain and Multi-Domain Kill Web Analysis Problems
Jason Baker and Valerie Sitterle

June 1, 2021
Applying an MBSE Approach for Evaluating Shipyard Operations
David Jurkiewicz

June 15, 2021
Implementing a Digital Engineering Environment for Mission Engineering
Jason Anderson and Jeffrey Boulware

June 29, 2021
Digital Engineering: From Toolchain to Platform
Dr. Aleksandra Markina-Khusid

Addressing the Sustainable Development Goals with a System-of-Systems for Monitoring Arctic Coastal Regions

Evelyn Honoré-Livermore, Roger Birkeland, Cecilia Haskins

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Dr. Cecilia Haskins

Evelyn Honoré-Livermore

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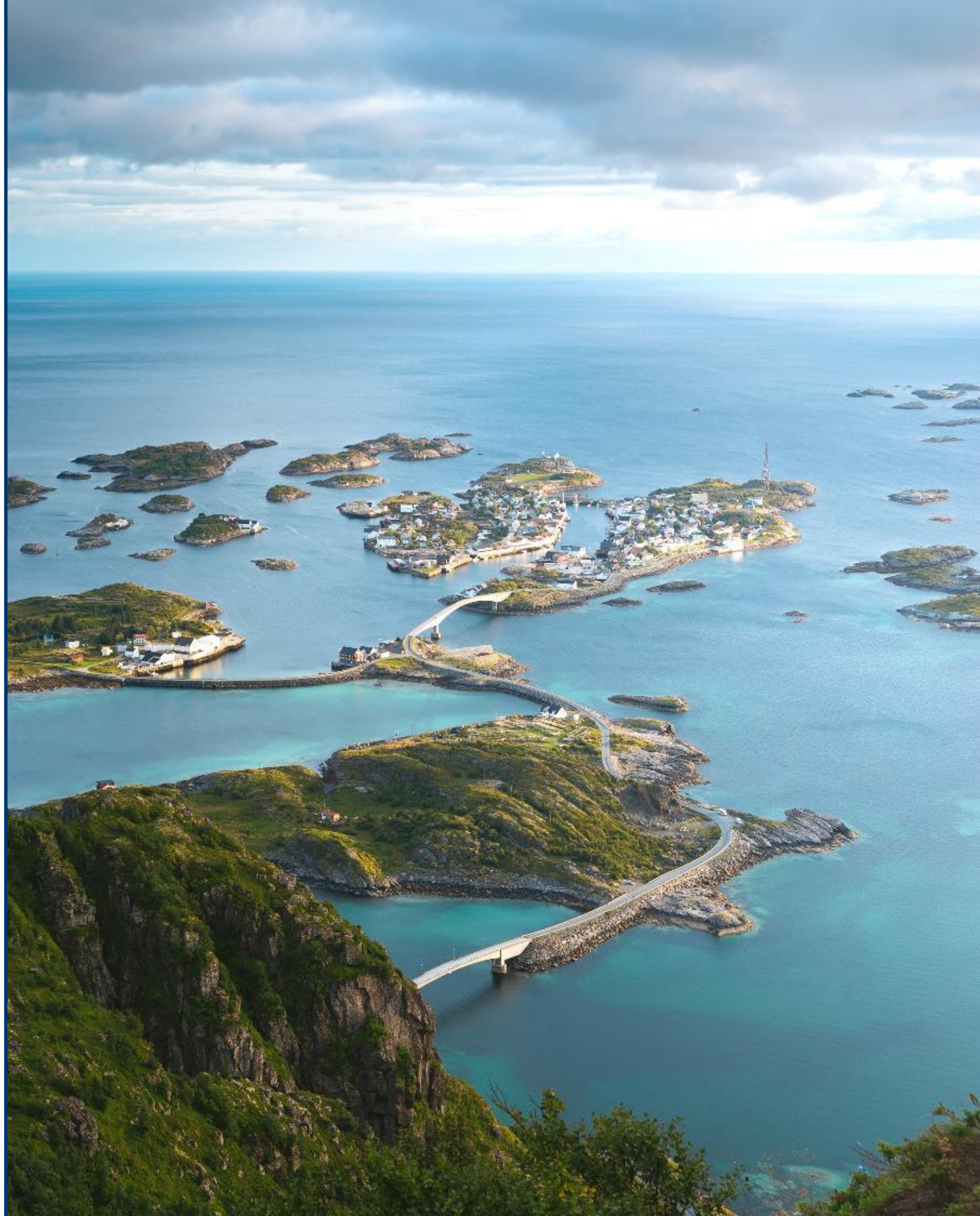


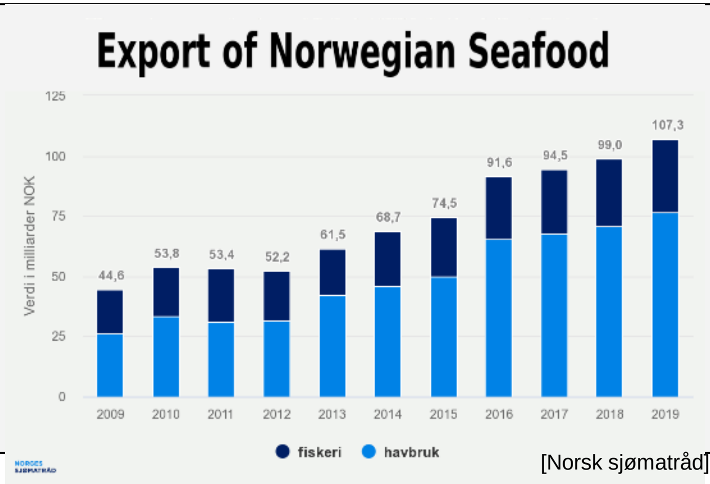
Managing coastal regions – why?

THE CONTEXT

Norway + Ocean = True

Coastal zones are rich in fish that visit the Norwegian Sea from the North Atlantic or from the Barents Sea

Norway is responsible for ⅓ of the salmon production in the world, and of all the seafood produced in Norway, 95% is exported

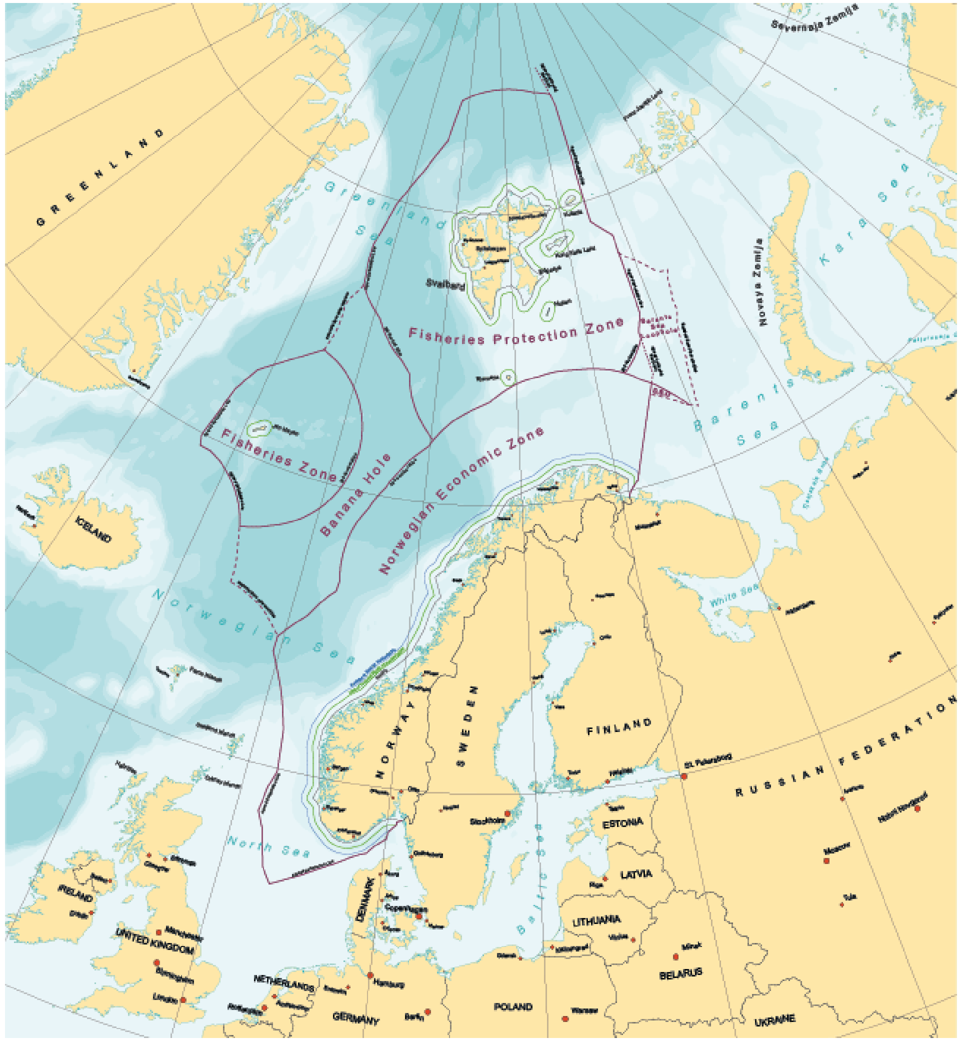


[Norsk sjømatråd]

The Norwegian continental shelf is 4 times the the Norwegian mainland, and ⅓ of the area of Europe is the Norwegian continental shelf

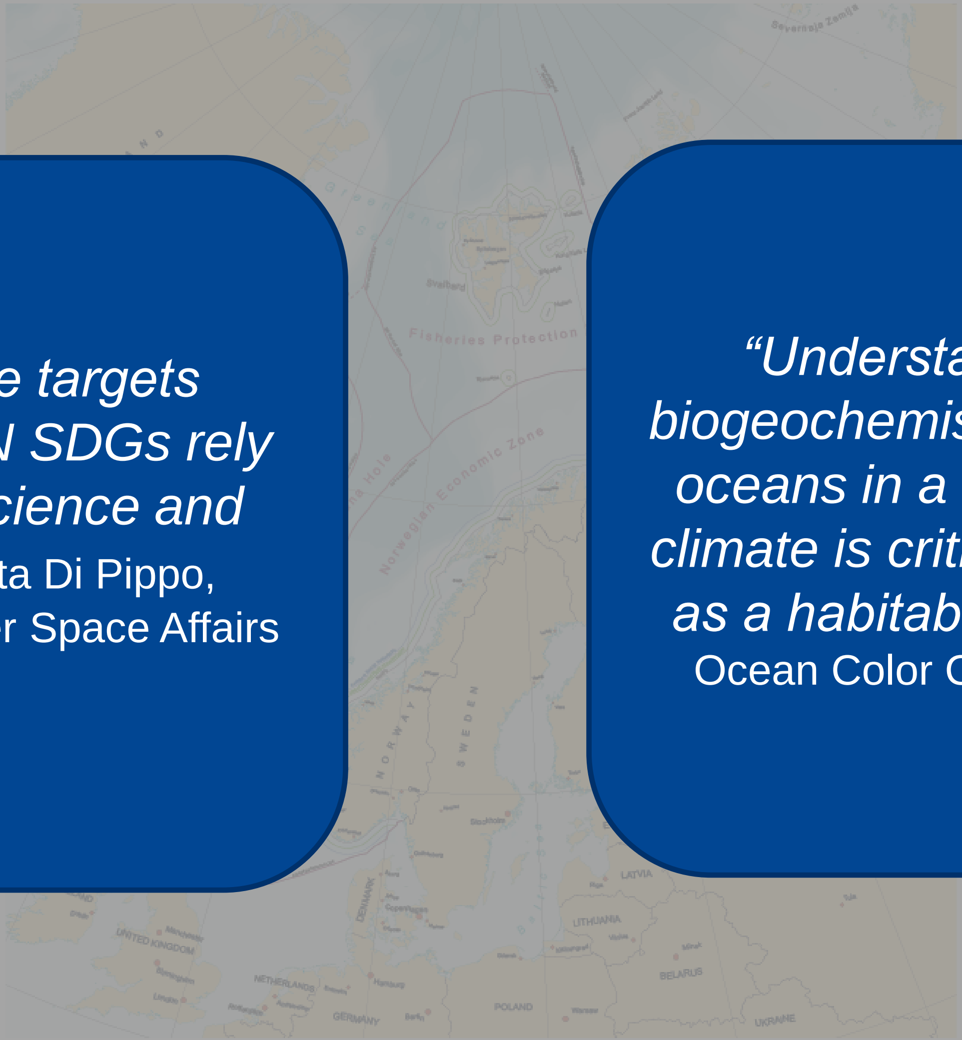
[Slide credit: Sivert Bakken, NTNU]

Norway + Ocean = True




www.incose.org/symp2020

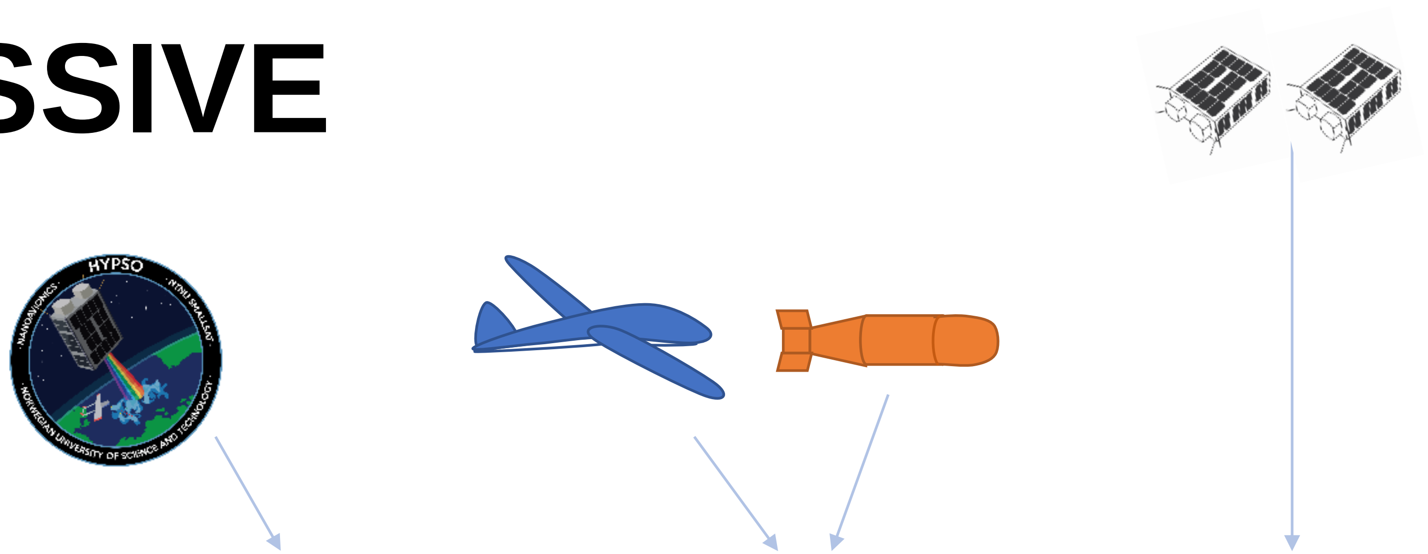
Norway + Ocean = True



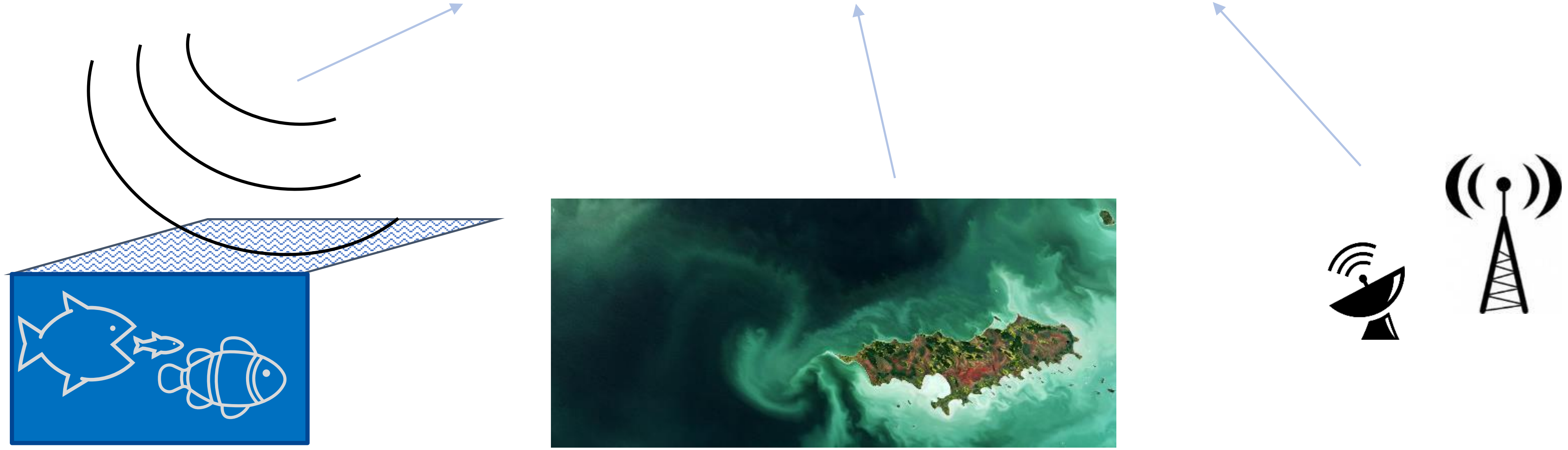
“Close to 40 % of the targets underpinning the 17 UN SDGs rely on the use of space science and technology” – Simonetta Di Pippo, Director of UN Office for Outer Space Affairs (2018)

“Understanding the ecology, biogeochemistry and hazards of our oceans in a varying and changing climate is critical to sustaining Earth as a habitable planet” – International Ocean Color Coordinating Group (2008)

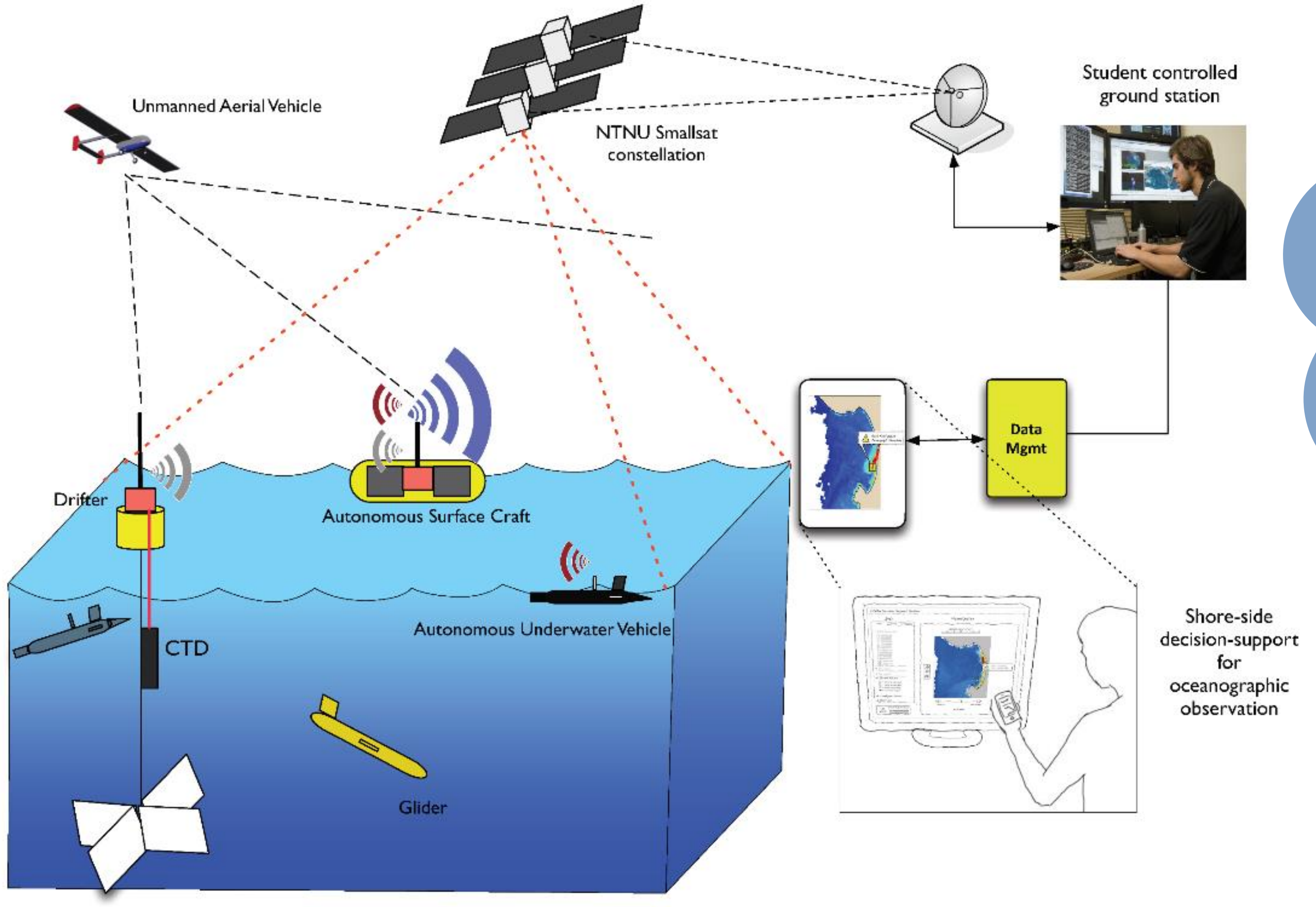
MASSIVE



Mission-oriented autonomous systems with small satellites for maritime sensing, surveillance, and communication

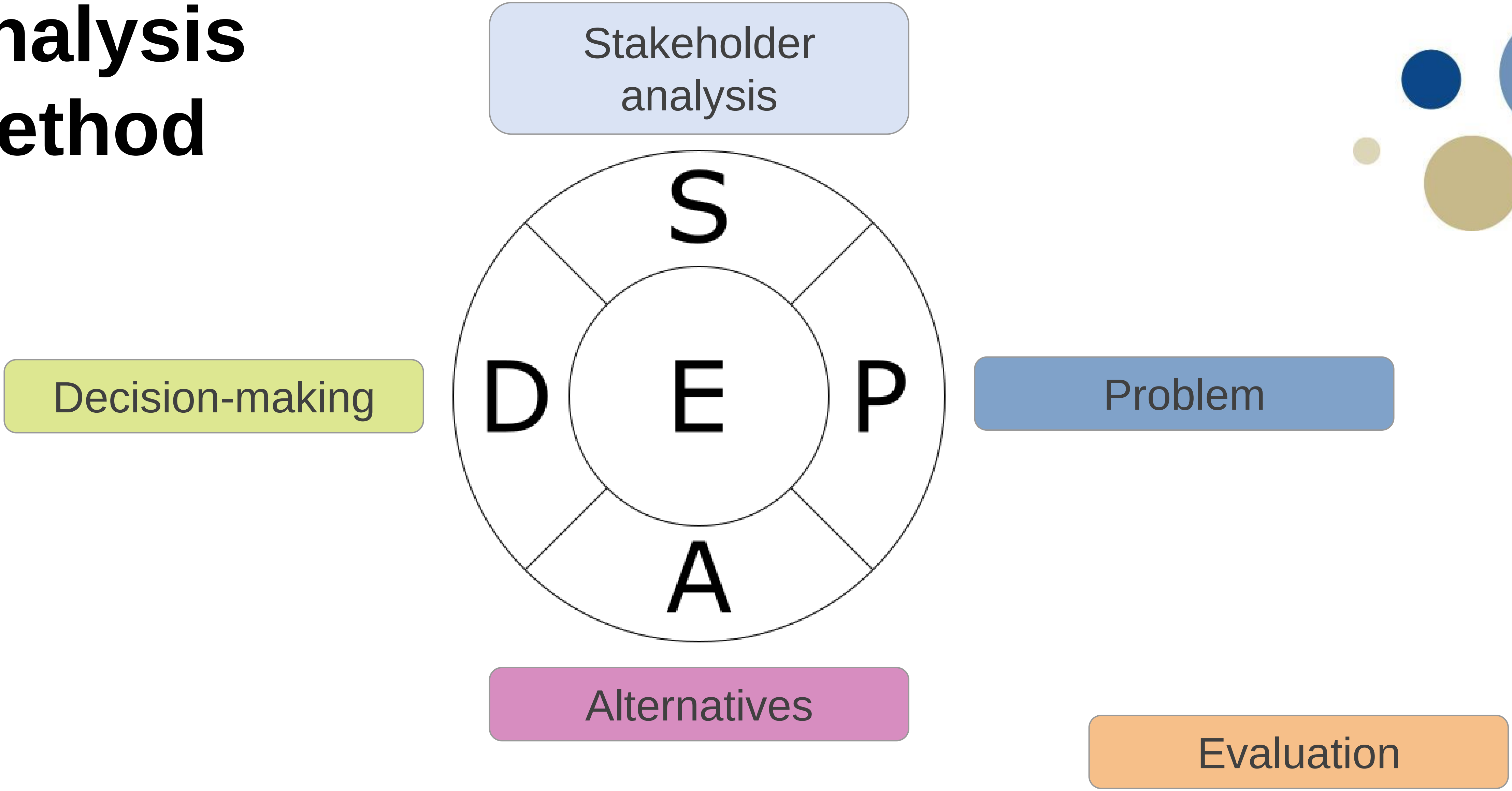


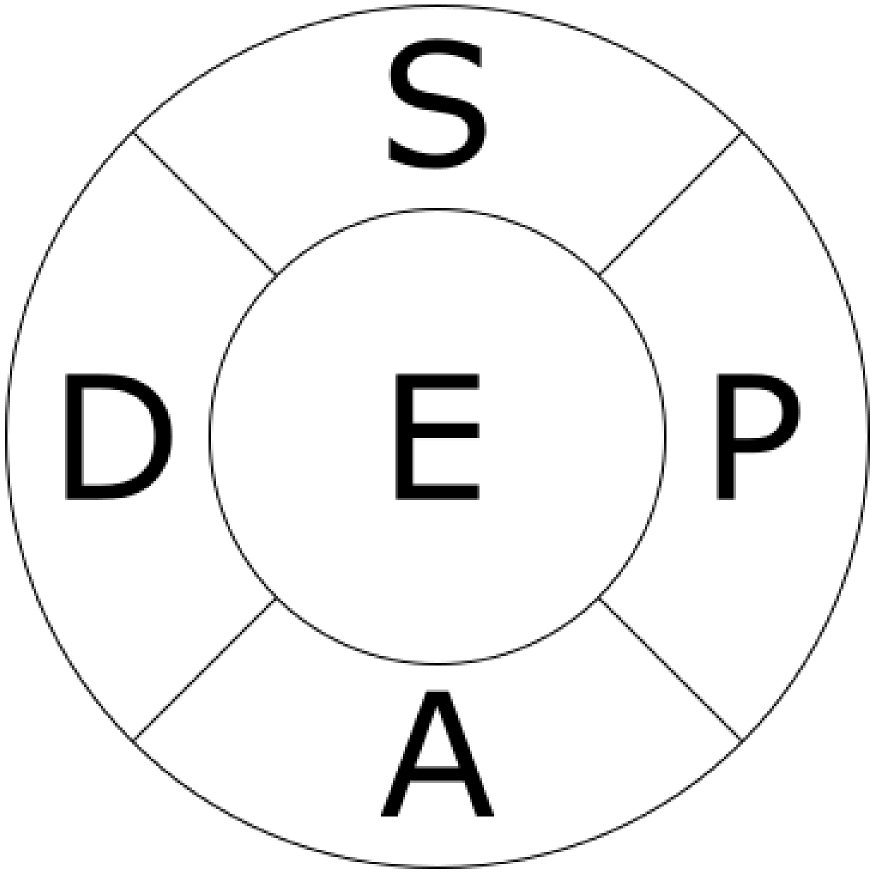
Managing coastal regions



How can viewing the MASSIVE project as an SoS produce a system that supports the scientific community and informs decision-makers?

Analysis method



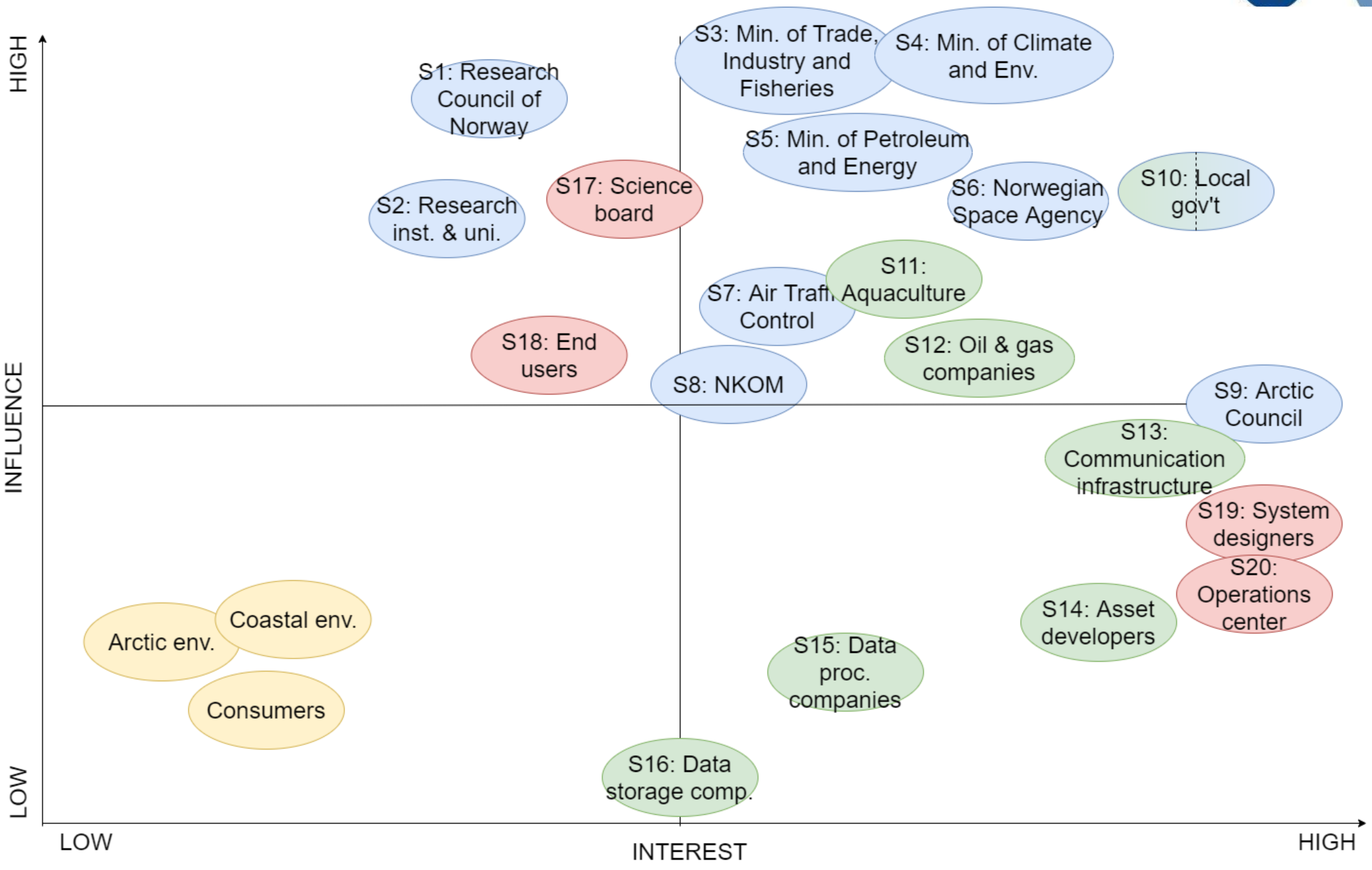


Stakeholder analysis

Who cares?

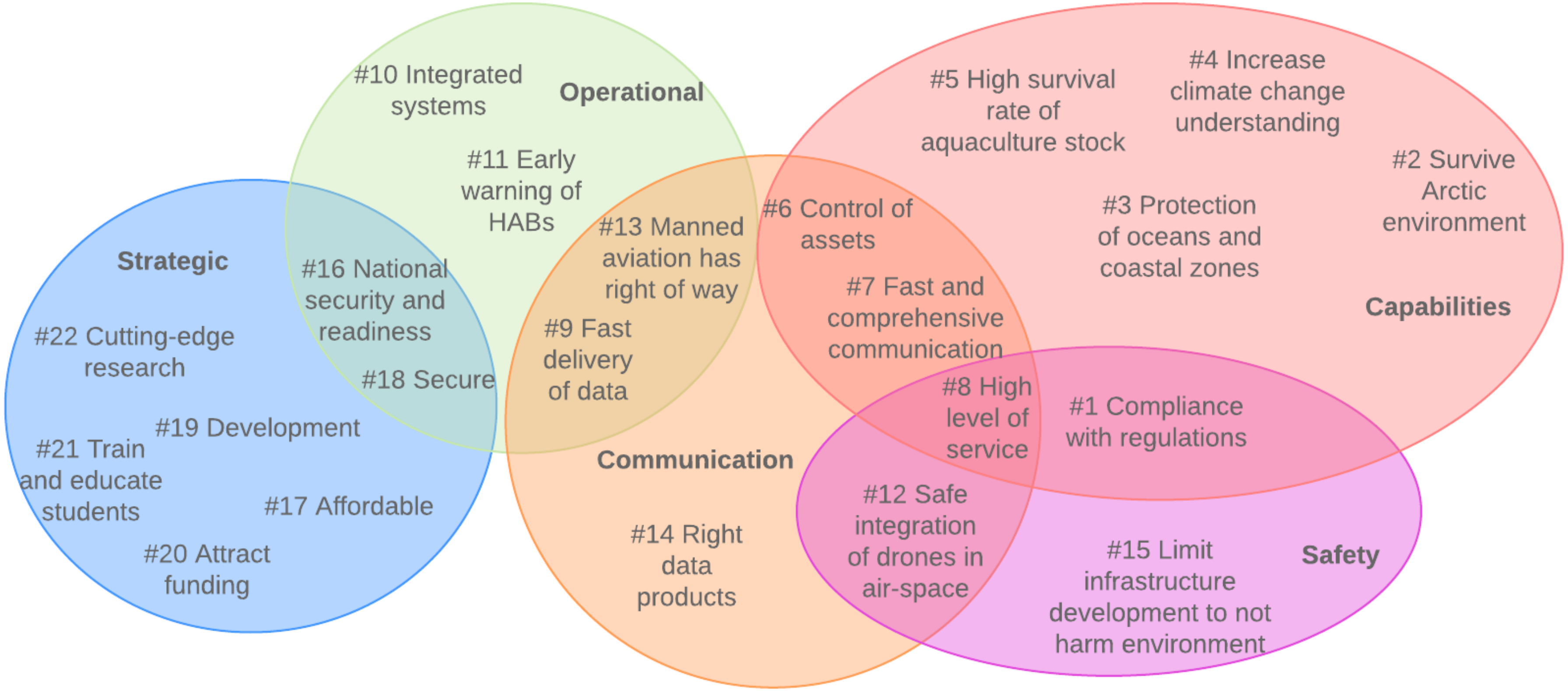
Stakeholder analysis

- "Hot topic" → High level of interest
- Expect movement as SoS matures
- Helpful to make decisions on how to manage stakeholders



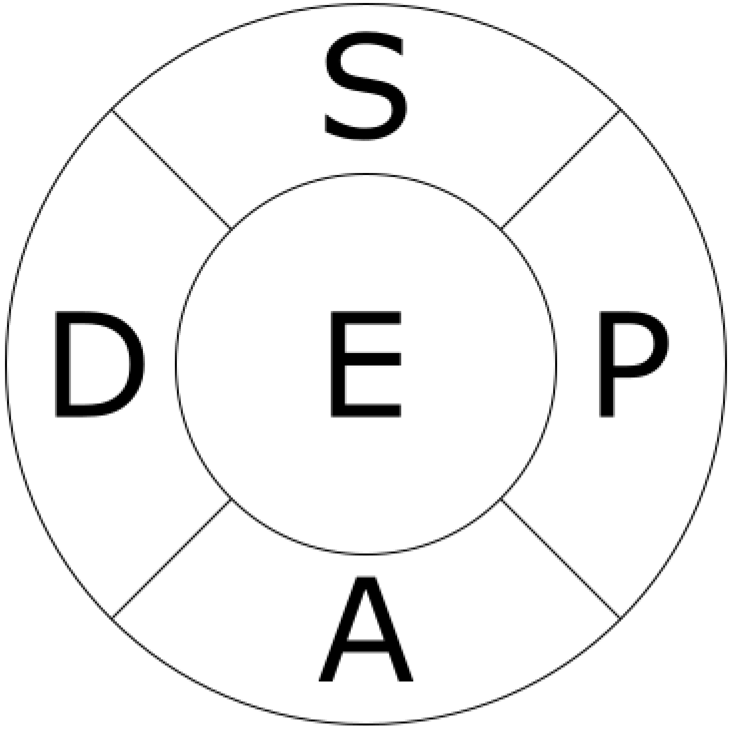
Red: MASSIVE; Blue: public; Green: enabling technology; Yellow: passive.

Stakeholder analysis



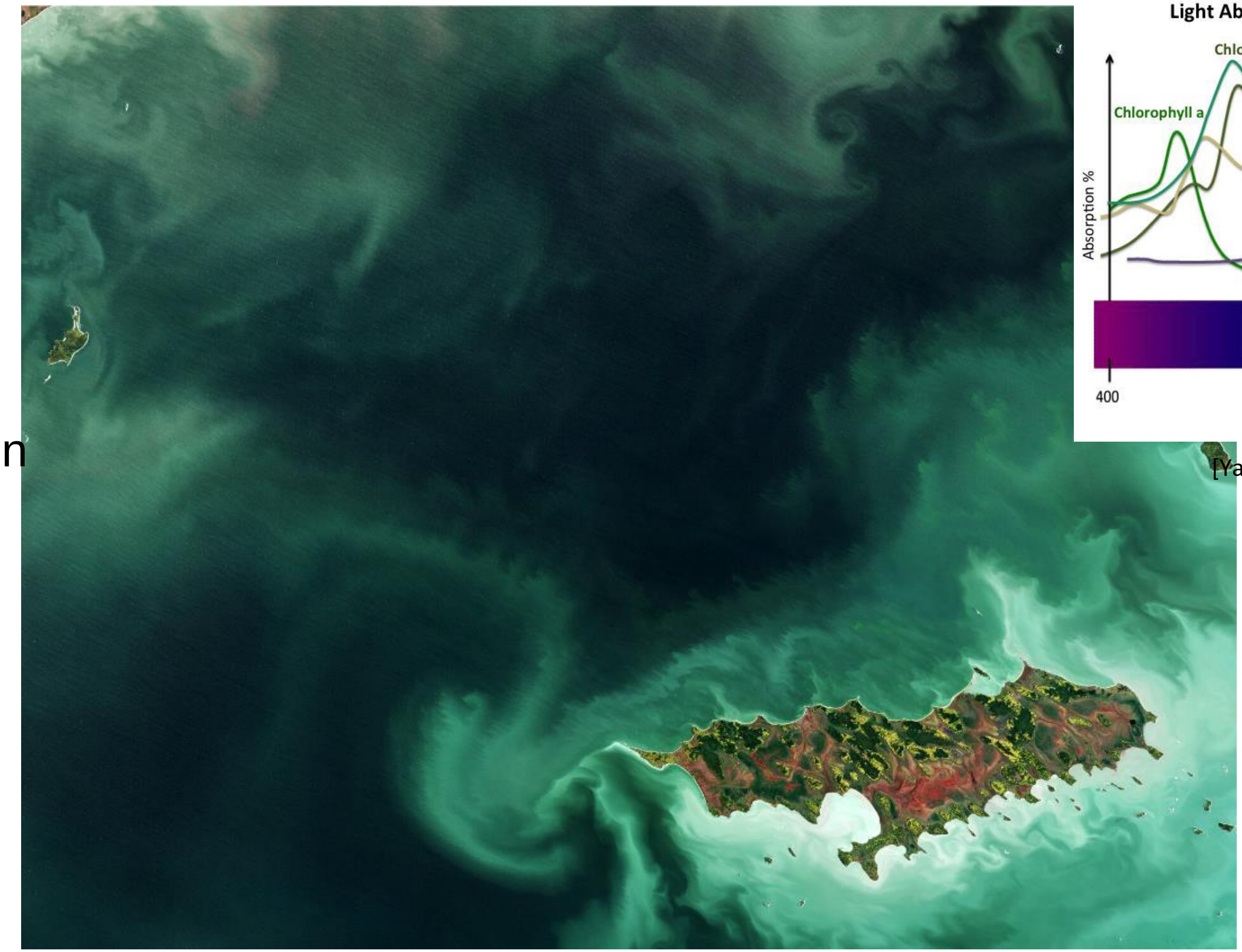
Detecting Oceanographic Phenomena

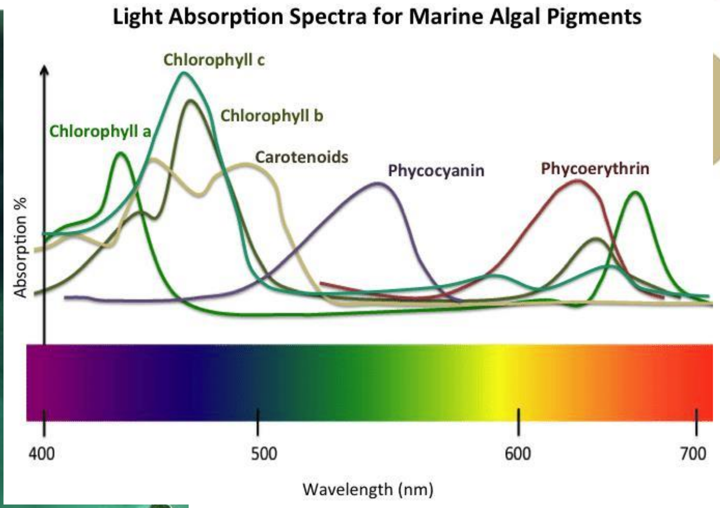
PROBLEM



Problem: Detecting Oceanographic Phenomena

Phenomena:
- Temperature
- Salinity
- Current
- Wind
- Height
- Phytoplankton





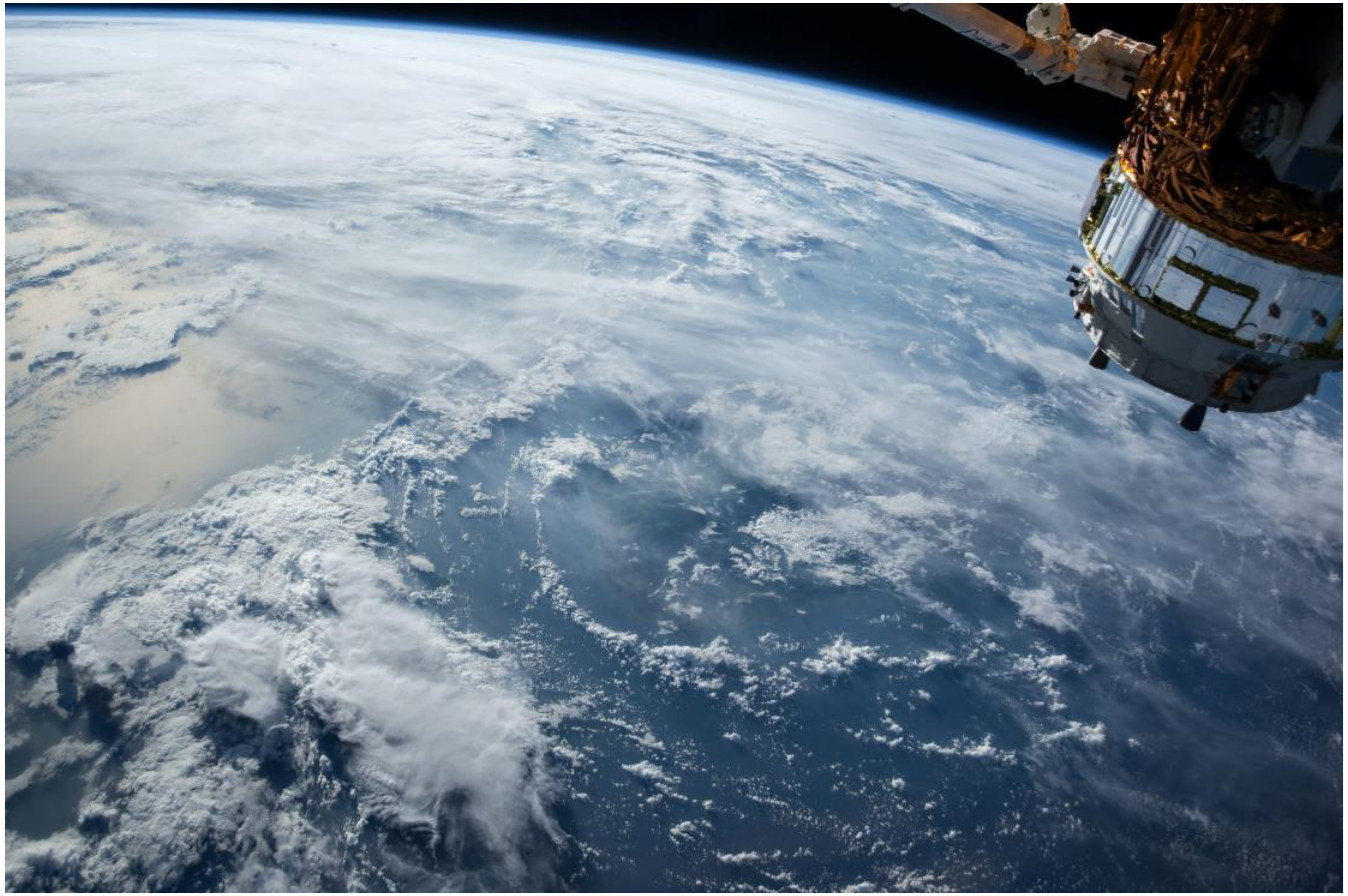
[Yarish 2012]

Problem: Detecting Oceanographic Phenomena - example

Harmful Algal Blooms

[Slide credit: Sivert Bakken, NTNU]

Problem: Detecting Oceanographic Phenomena



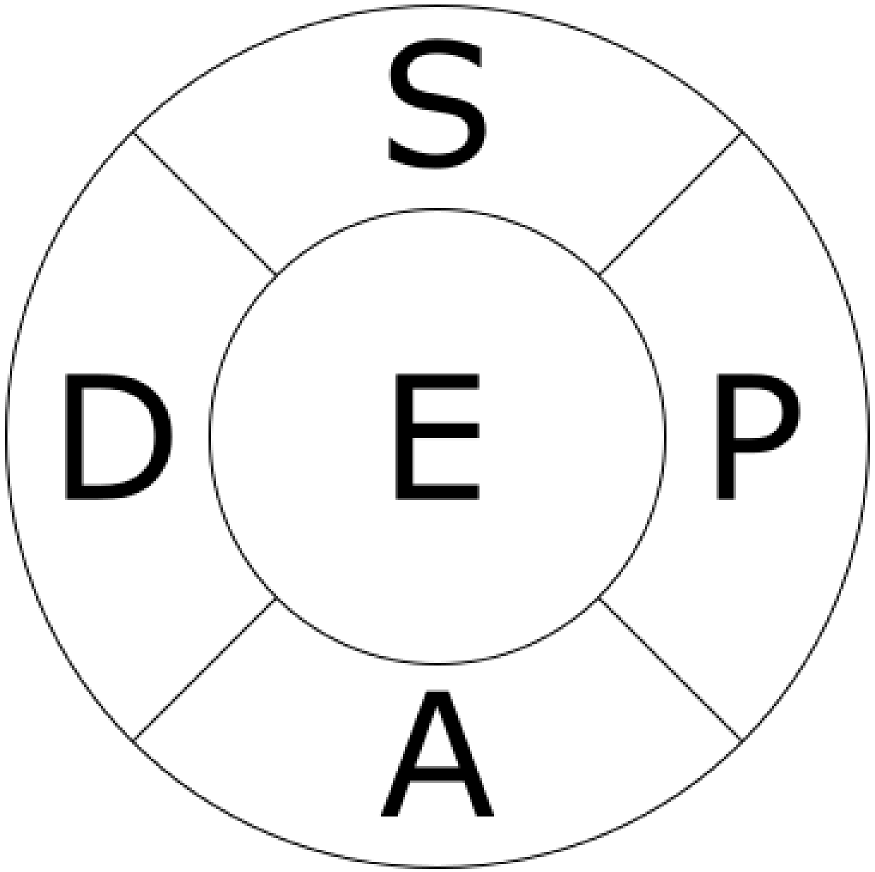
Use-cases

- **UC-1: Nominal (low resolution) monitoring of the coast (large coverage area).** Requirements: multispectral imaging; medium-scale distributed SST, SSH, salinity, ocean current, and sediment data; edge computing capabilities and low data rate (LDR) OR high data rate (HDR) and ground system computing.

- **UC-2: On-demand high resolution monitoring of HABs (medium coverage area).** Requirements: hyperspectral imaging with high temporal and spatial resolution, plus UC-1.

- **UC-3: Aquaculture monitoring (small coverage area).** Requirements: high frequency oceanographic phenomena monitoring; multispectral imaging; off-board HDR.

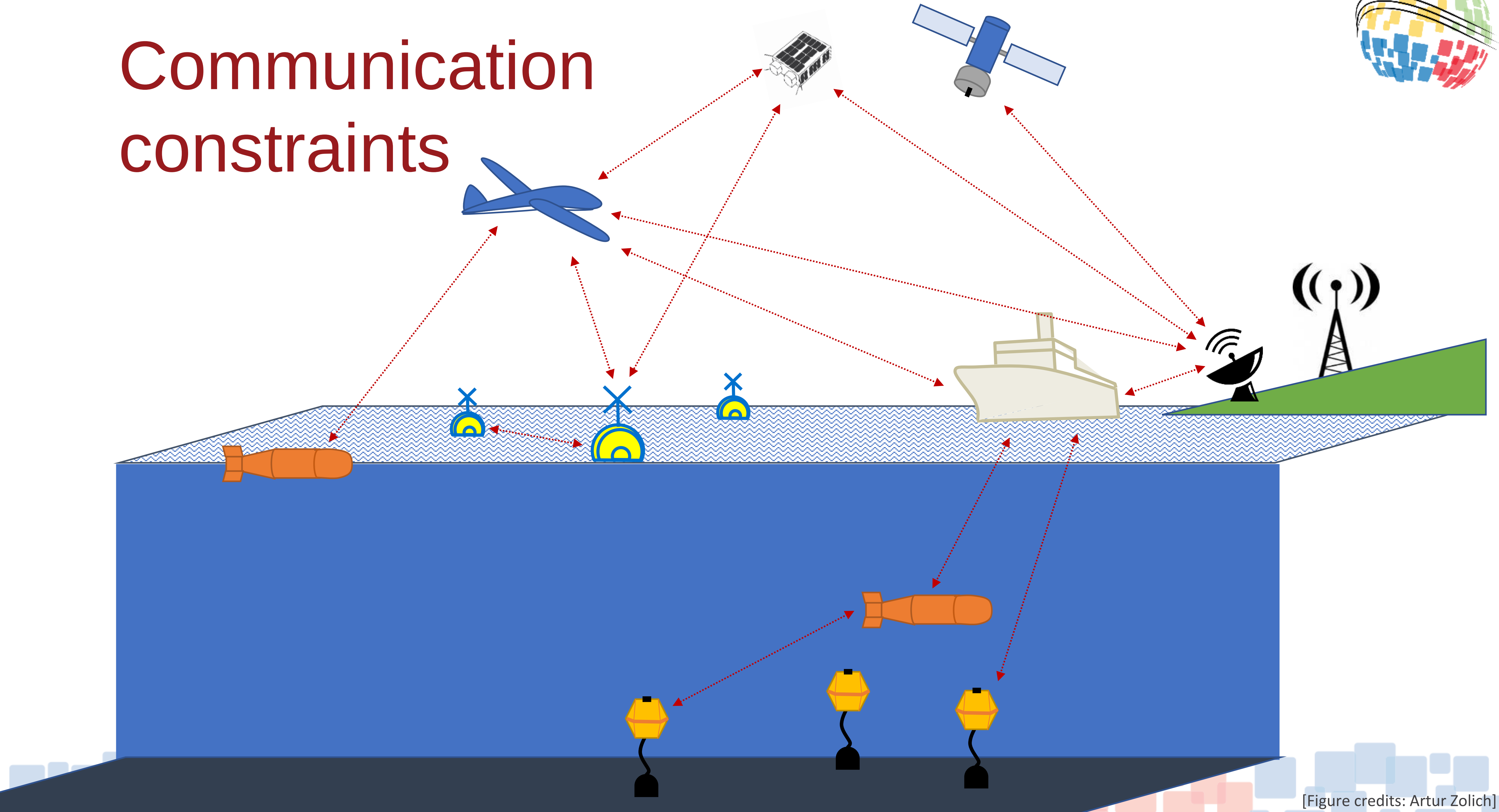
- **UC-4: High-resolution monitoring of the coast (various coverage area).** Requirements: high frequency oceanographic phenomena monitoring; hyperspectral imaging with high temporal and spatial resolution. LDR or HDR is dependent on edge computing capabilities.



Problem

Constraint: Communication gaps

Communication constraints



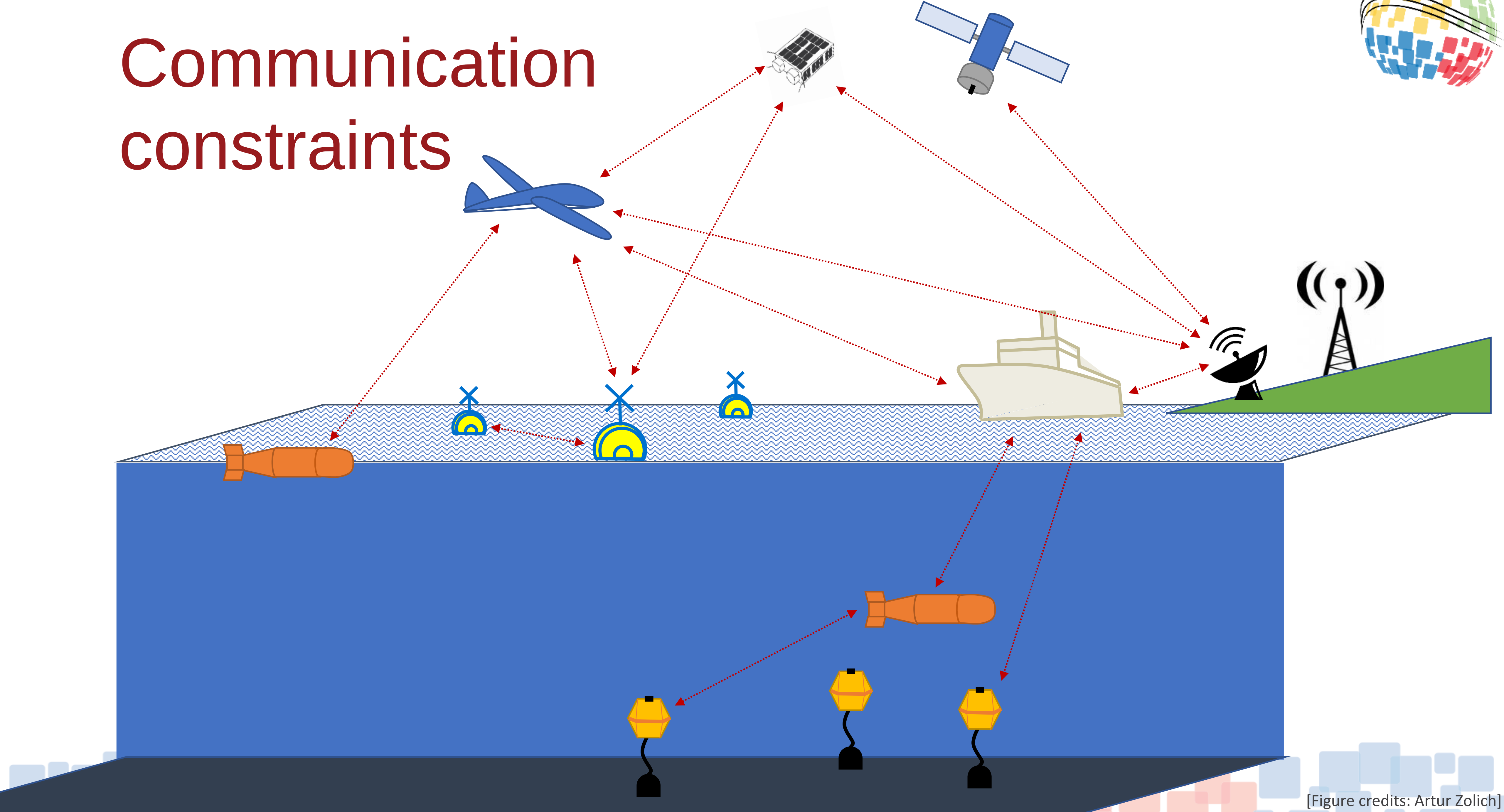
[Figure credits: Artur Zolich]

Communication gaps

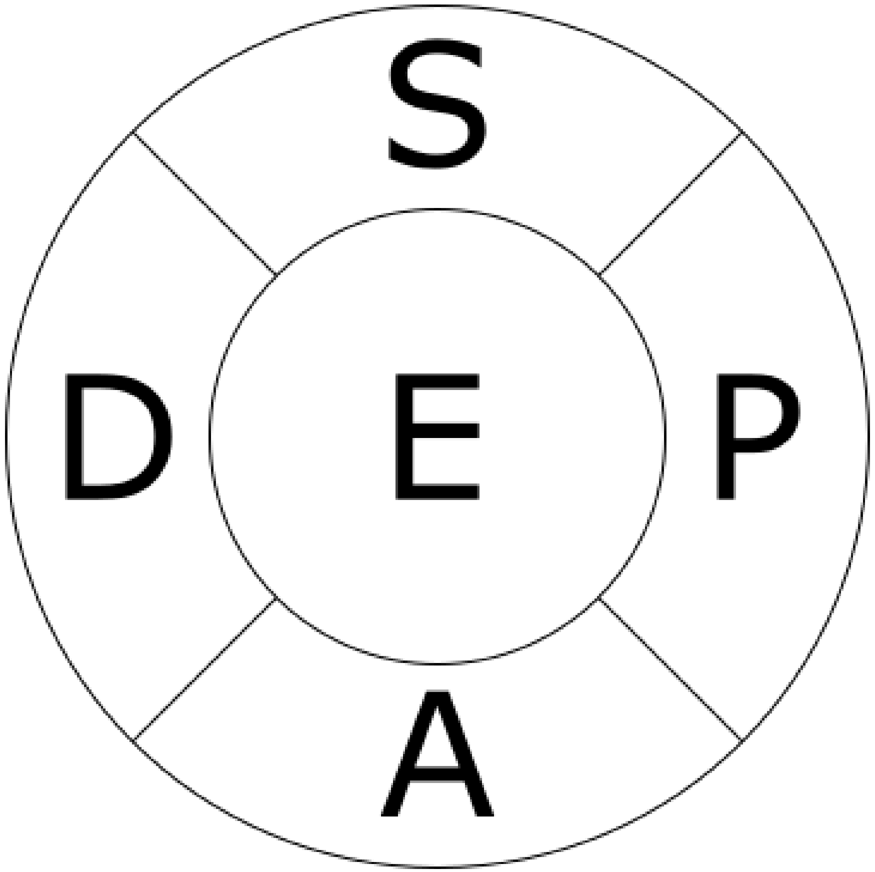
Geostationary satellites have poor coverage in areas north of 75°

[Ahlenius 2016]

Communication constraints



[Figure credits: Artur Zolich]



Alternatives

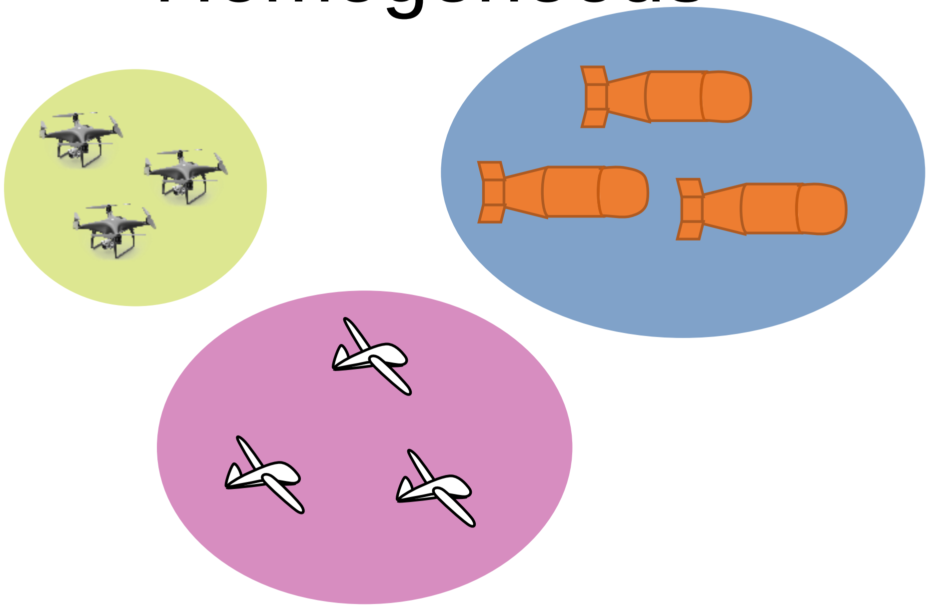
Multi-robot, space-based, and ground-based systems

Multi-robot systems

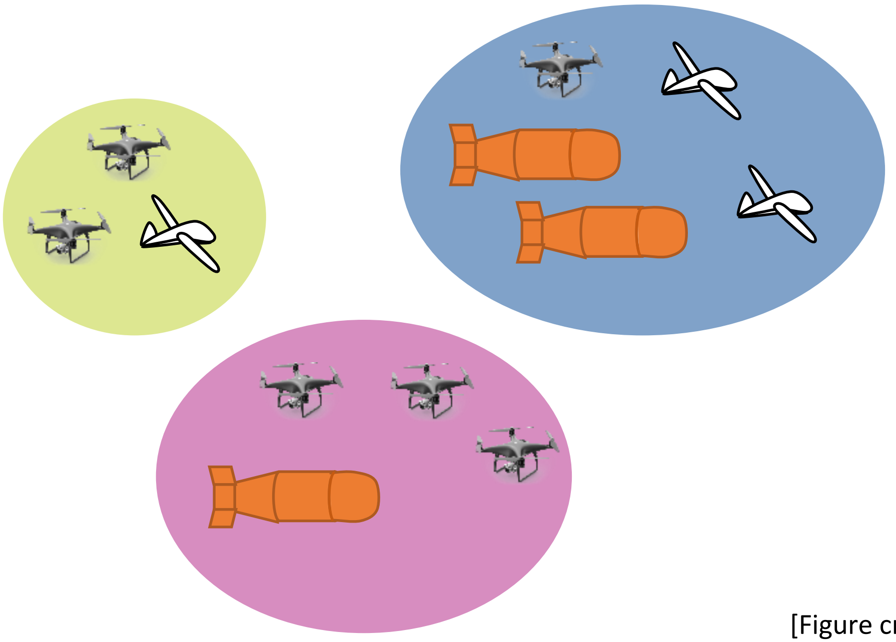
- Different autonomous vehicles have different capabilities
- Looking at how they can fulfill the various use-cases
- Cost and interoperability

"a system composed of multiple assets where each asset has an individual and a collective task and must have knowledge about the other assets and their movements and performance to achieve the collective mission"

Homogeneous



Heterogeneous



[Figure credits: Artur Zolich]

Multi-robot systems

- Different autonomous vehicles have different capabilities
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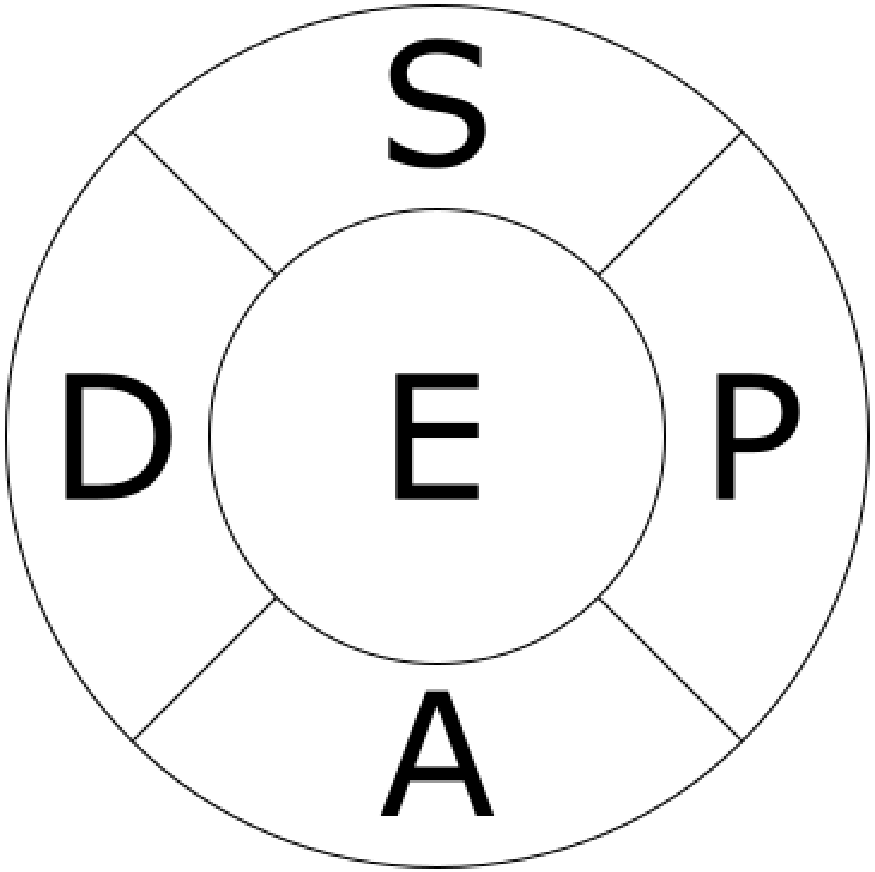
- Cost and interoperability

"a system composed of multiple assets where each asset has an individual and a collective task and must have knowledge about the other assets and their movements and performance to achieve the collective mission"

	UAV			AUV			ASV		
Type **Range**	<25 kg	>25 kg	Fixed wings	Light AUV	AUV	Gliders	Renew. energy	Boats	Vessels
0-10 km	X		X	X	X			X	
10-100 km		X	X		X	X	X	X	
>100 km		X	X			X	X		X
Property									
Arctic env.	-	-	+	+	+	+	-	-	-
Precise obs.	++[a]	+	-		+	-	+	-	-
Communication	-	+	+	-	-	-	+	++	++

Space segment alternatives

	Monolithic satellites			Small satellites			Stratospheric UAVs		
Type Range	C2	Payload datalink	EO	C2	Payload datalink	EO	C2	Payload datalink	EO
Maturity	+++	+++	+++	++	-	-	---	---	---
Cost	---	---	---	++	++	++	--	--	--
Field-of-view	++	++	++	+	+	+	+	+	+
Payload size > 10 kg	N/A[a])	+++	+++	N/A	-	-	N/A	-	--
Temporal res.	-	-	-	++	++	++	+	+	+
Payload spatial res.	N/A[a])	N/A	++	N/A	N/A	+	N/A	N/A	-
Payload spectral res.	N/A[a])	N/A	+++	N/A	N/A	+	N/A	N/A	+
Spectral avail.	+++	+++	N/A[b])	+	-	N/A	+	-	N/A



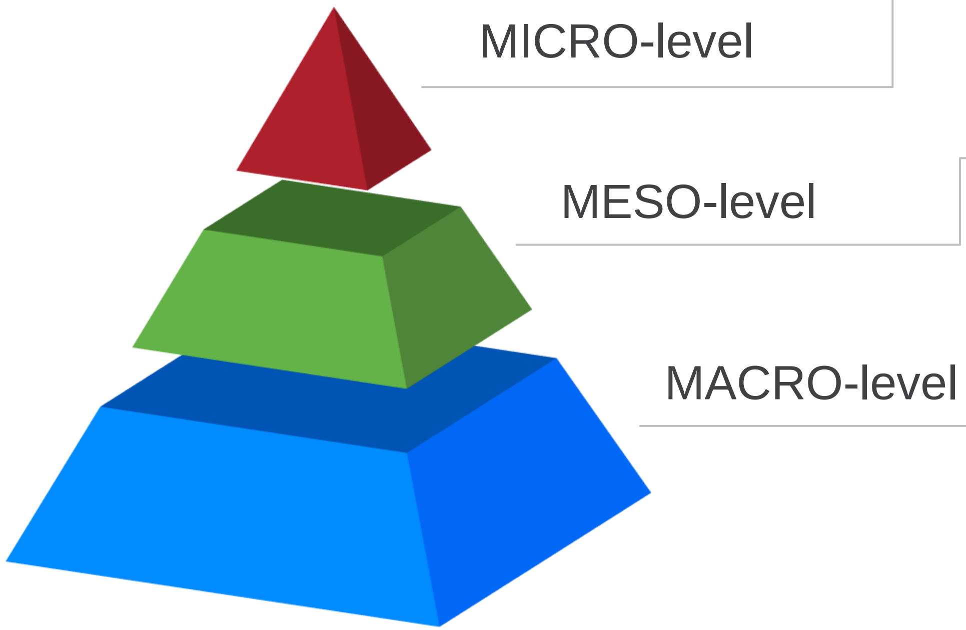
Decision-making

Why SoS? Decision-making for managing coastal regions

MASSIVE as an SoS

Operational independence	• Each system is developed to operate independently • Can reach decisions independently
Managerial independence	• Systems are developed in different phases by different projects
Evolutionary development	• The systems can be upgraded and updated after deployment
Emergent behavior	• No single system can monitor the coast without cooperation
Geographical distribution	• Developing organizations not co-located • No physical interactions between systems

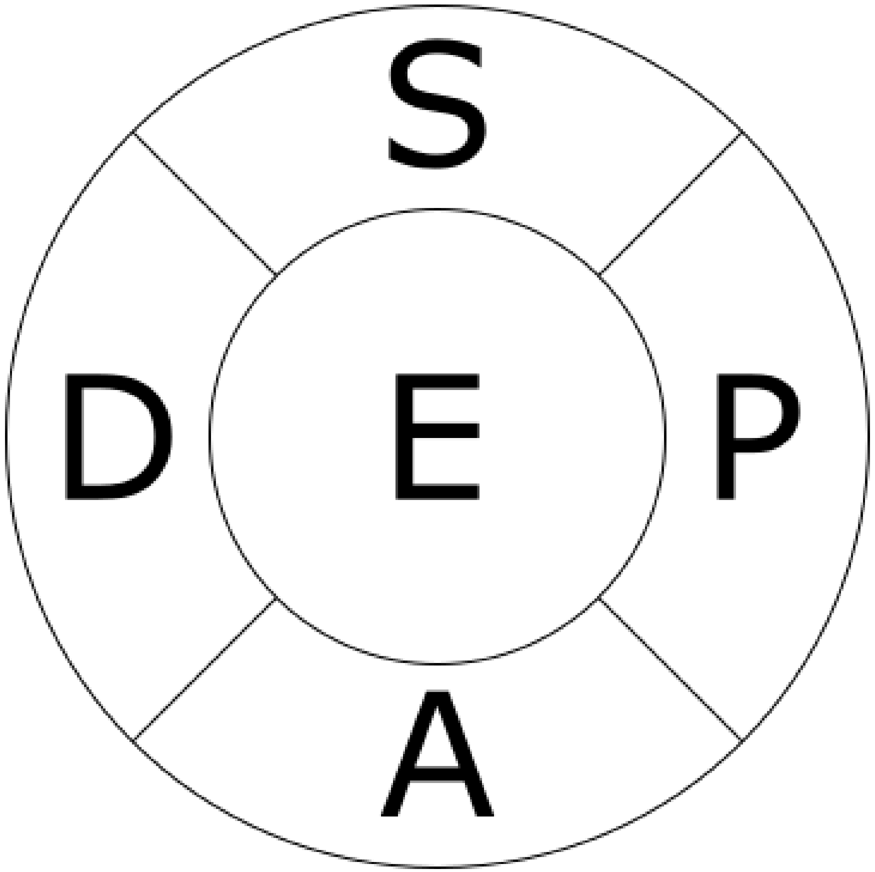
Decision-making for Arctic coastal region



Local governments
Access rights

National and local governments
System and activities

Multinational scale
Political decisions

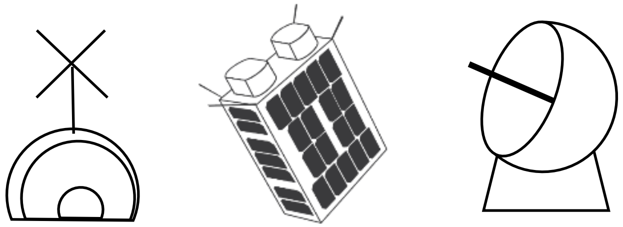


Evaluation

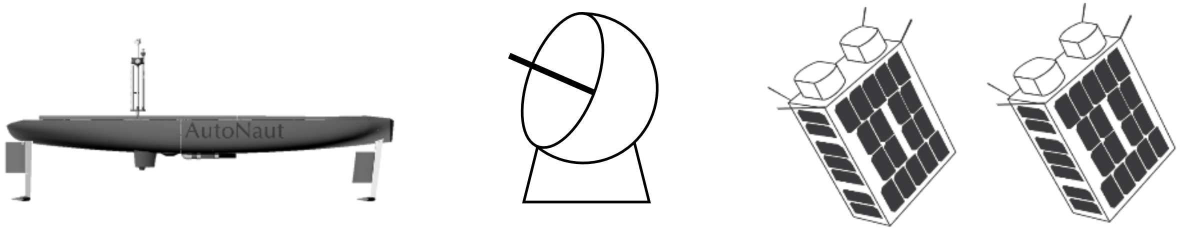
How can viewing the MASSIVE project as an SoS produce a system that supports the scientific community and informs decision-makers?

Evaluation of MASSIVE

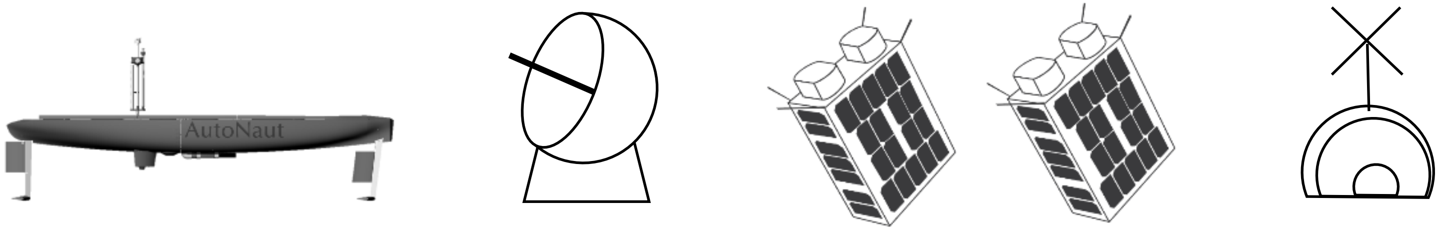
UC-1: Nominal monitoring of the coast



UC-2: On-demand high resolution monitoring for HAB



UC-3,4: Aquaculture monitoring, high resolution monitoring



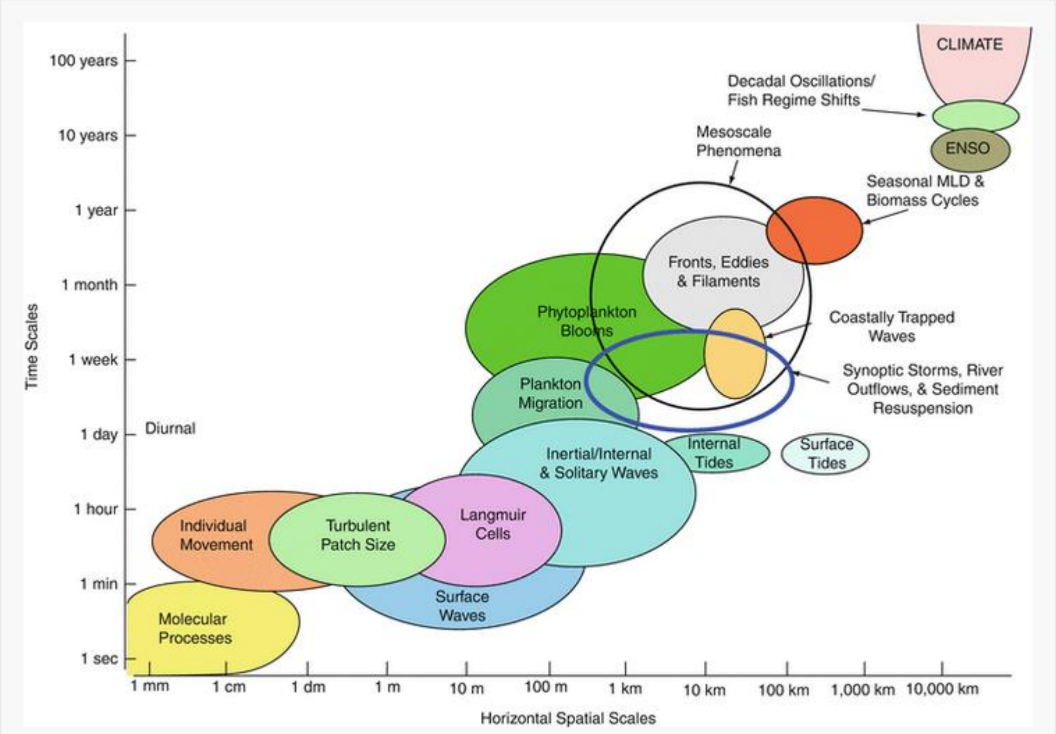
[Figure credits: Artur Zolich]

The AutoSat

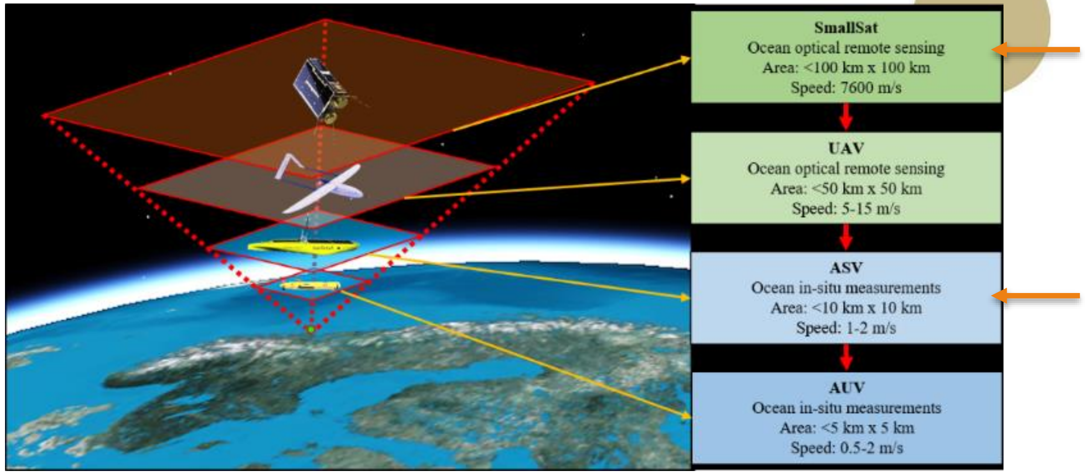
UC-2 ELABORATION

On-demand high resolution monitoring for HAB

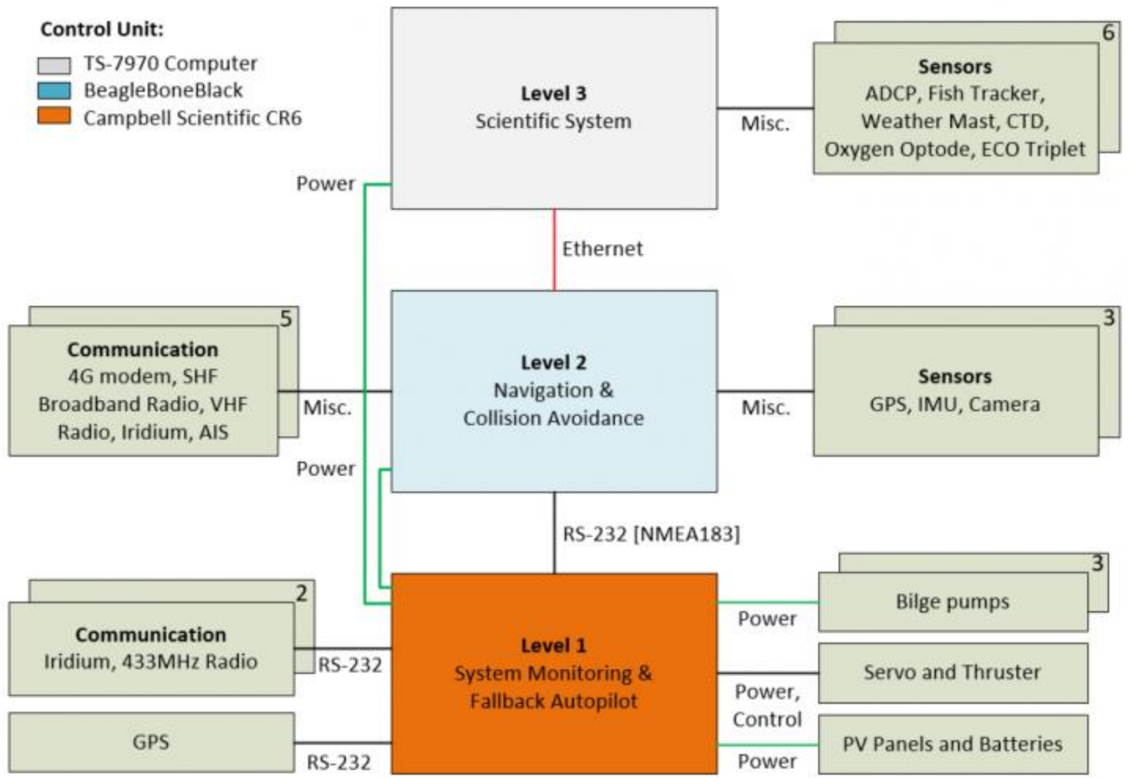
- Integration of existing assets
- Each asset works fine alone



Ocean Observatories and Information: Building a Global Ocean Observing Network. Figure 1
A stommel diagram showing the range of spatial and temporal scales over which ocean processes operate. The figure was constructed by Tommy Dickey and is published with his permission



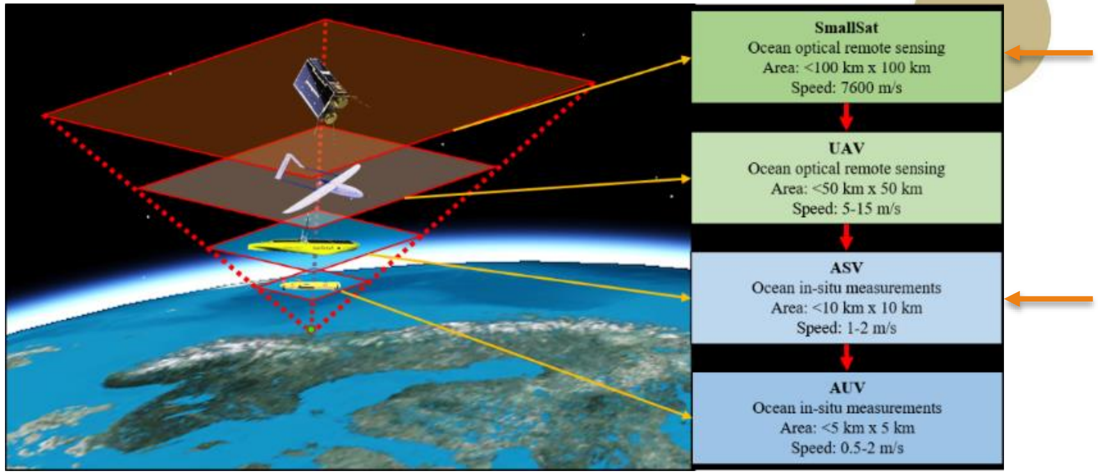
[Schofield et al. 2012]



Photos: Jahn Ivar Kjølseth

On-demand high resolution monitoring for HAB

- Integration of existing assets
- Each asset works fine alone
- Missing interface definition
  - Information sharing
  - Physical communication layer
- Need for a Mission Coordinated Control Center



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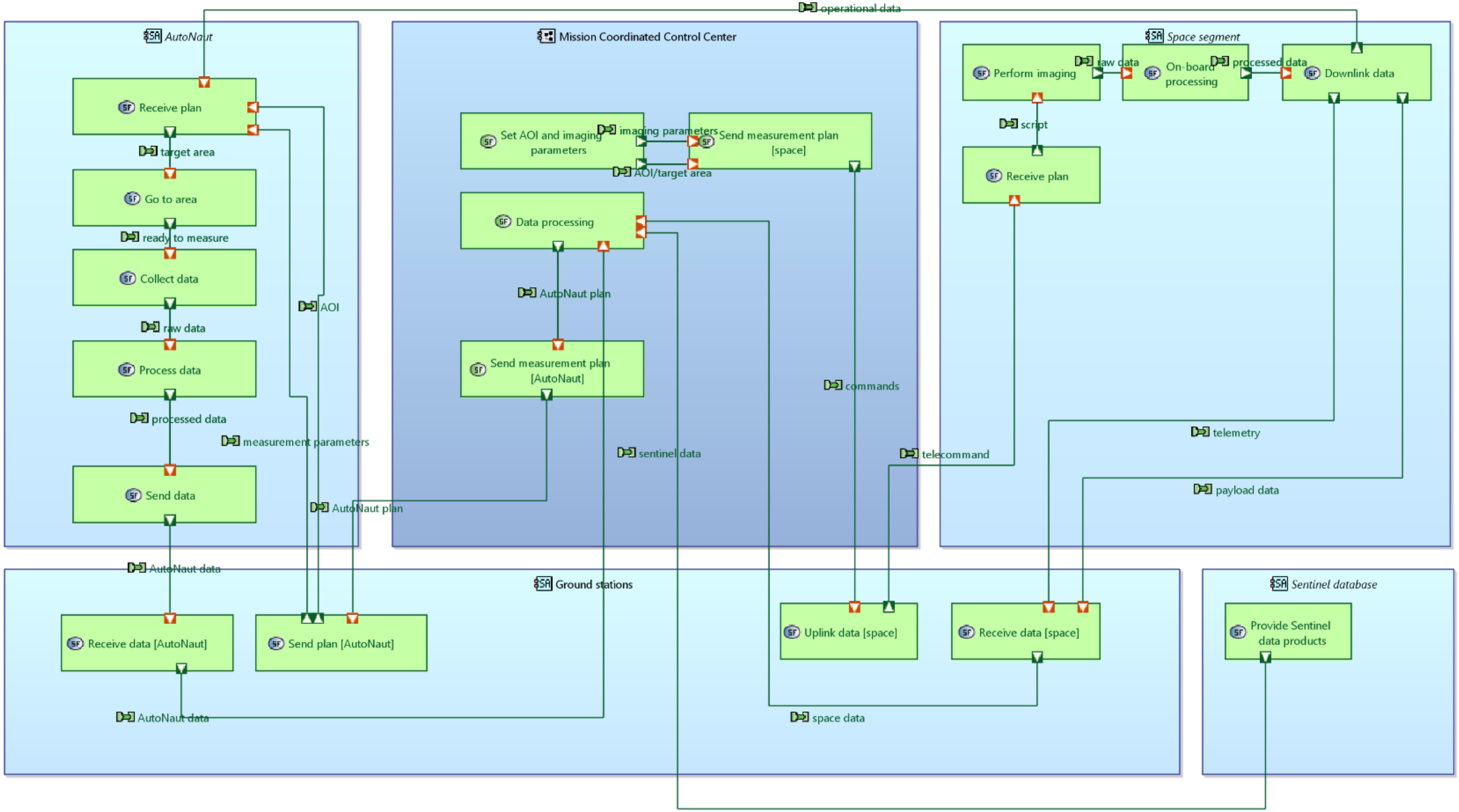
Operational Analysis

System Analysis

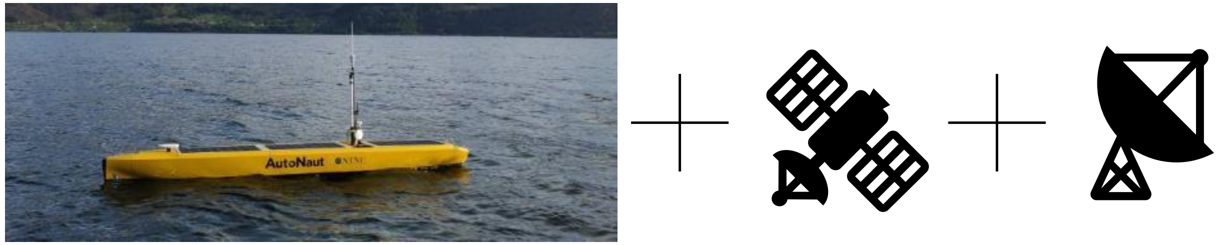
Logical Architecture

Physical Architecture

EPBS



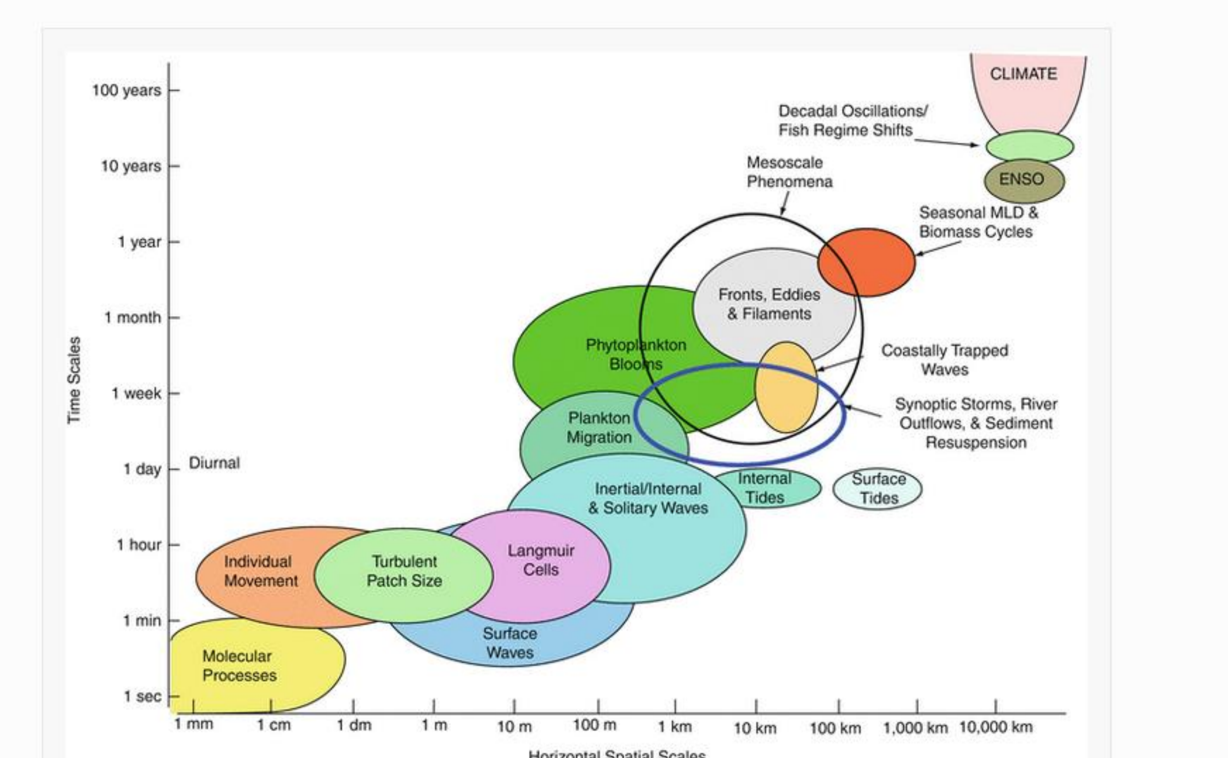
AutoSat

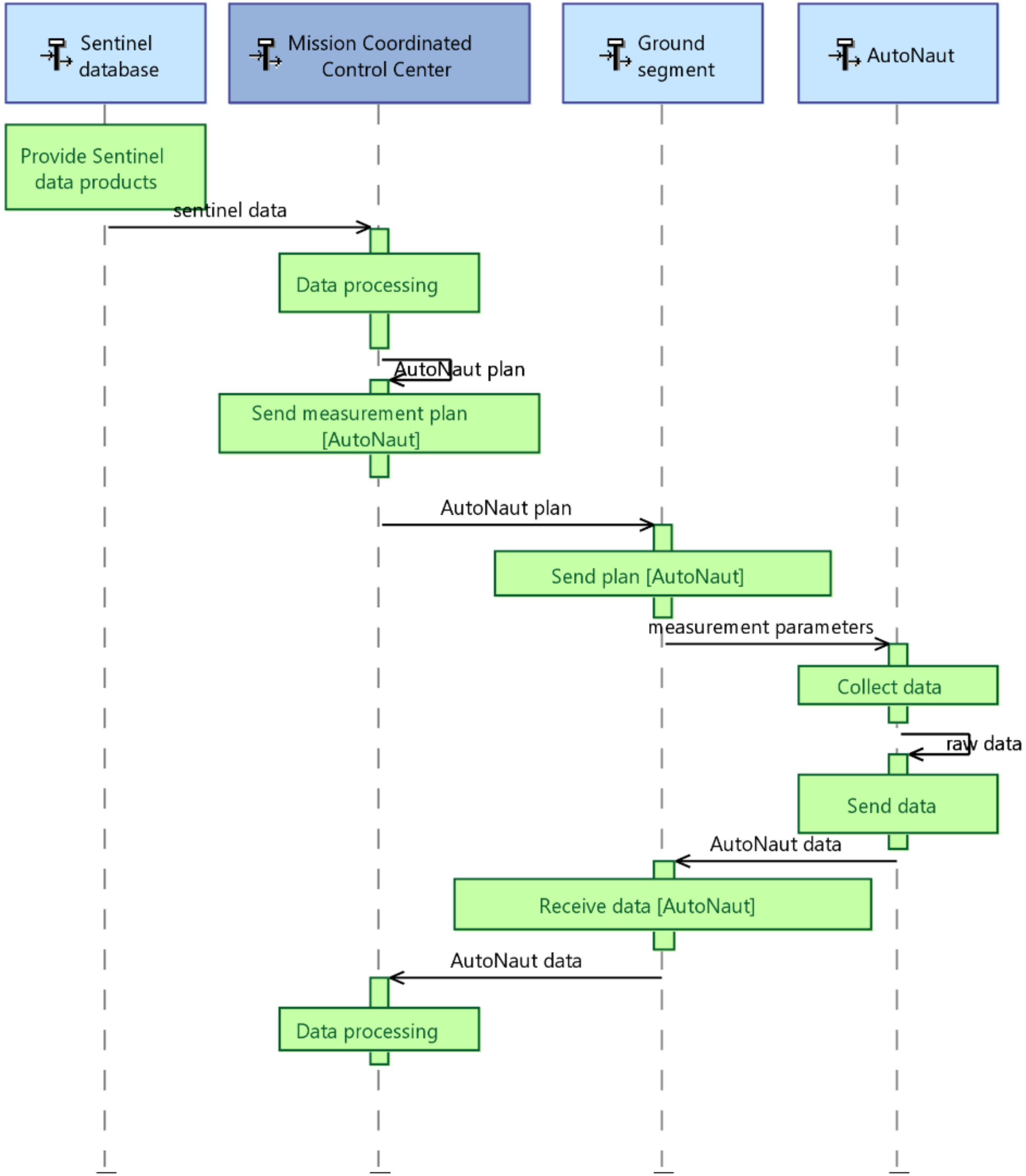


- Developed 3 scenarios
    1. Scenario 1:
        - Using existing satellite data from database
        - Command AutoNaut to take samples
    2. Scenario 2:
        - Using small satellite to gather measurements
        - Process measurements
        - Downlink measurements to ground
        - Command AutoNaut to take samples
    3. Scenario 3:
        - Using small satellite to gather measurements
        - Process measurements and create operational data product
        - Command AutoNaut to take samples

AutoSat: Scenario 1

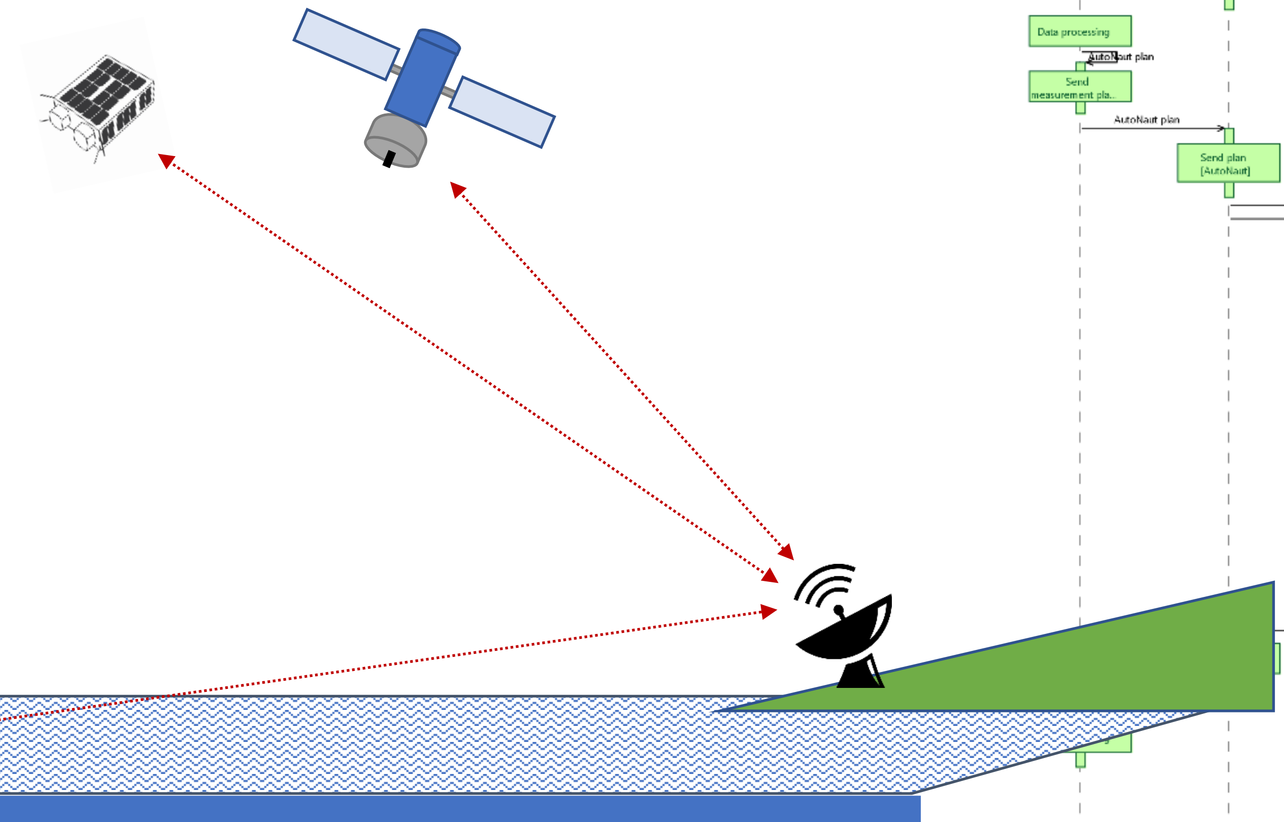
- There might be latency in data products from Sentinel
- Does not require any new capabilities

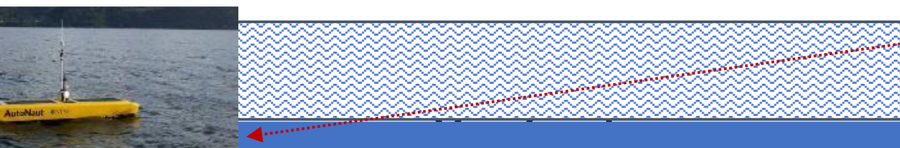


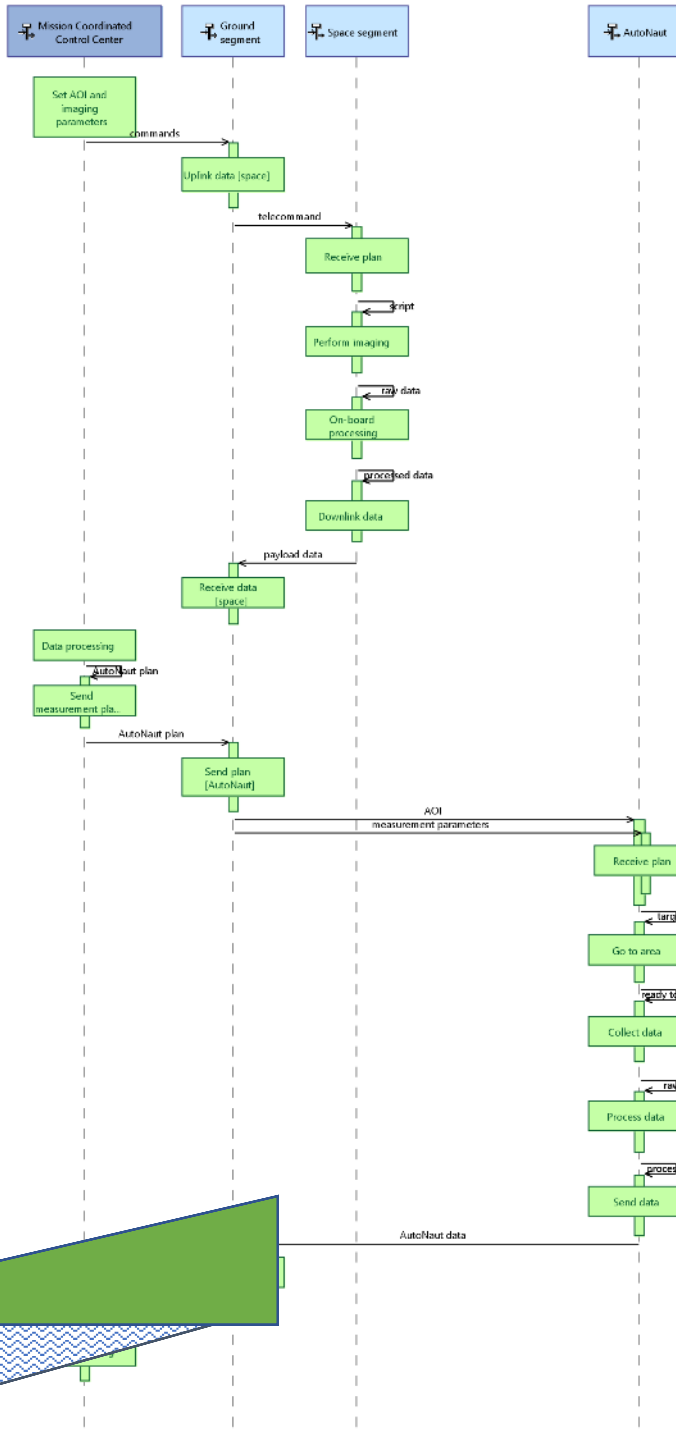


AutoSat: Scenario 2

- Using the ground segment as in-between because there isn’t direct communication between space segment and AutoNaut
    - Communication latency?
    - AutoNaut response time?
    - Limits for response range?

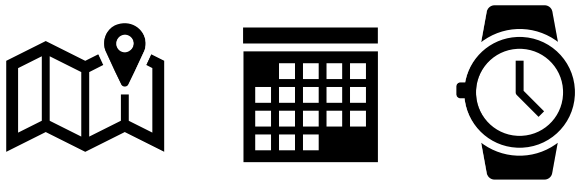




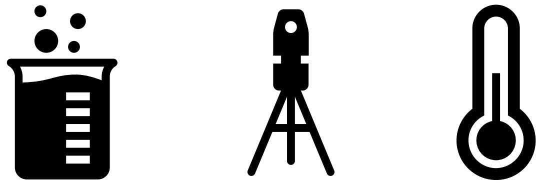


AutoSat: Scenario 3

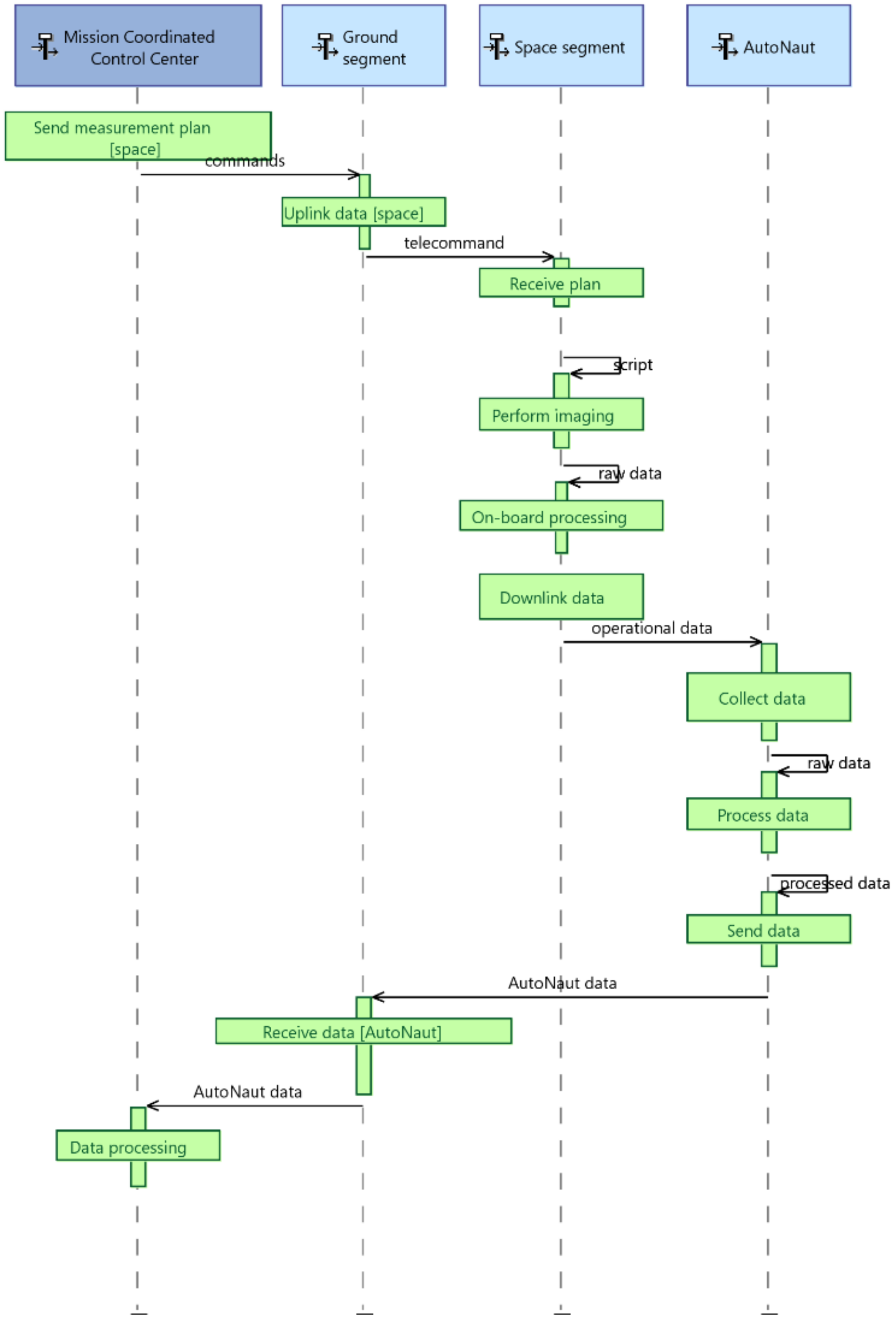
- Direct communication between satellite and AutoNaut
- Information to be shared:



Area-of-interest and time



Which measurements



AutoSat: Scenario 3

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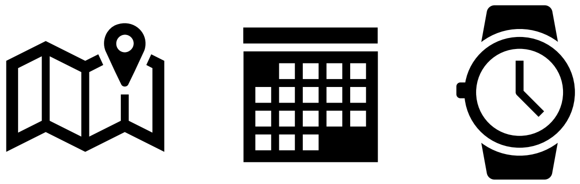
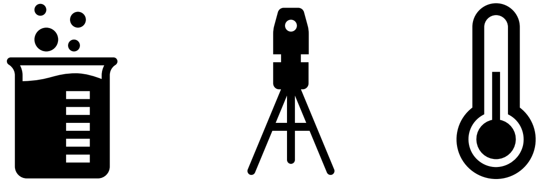
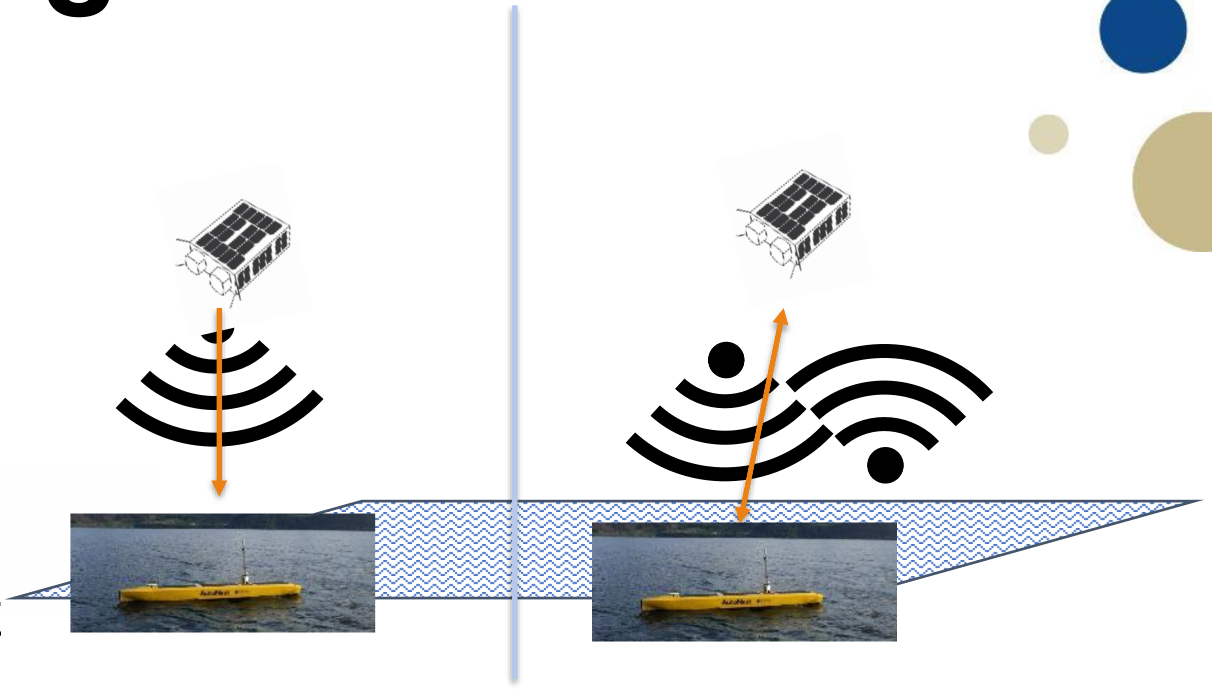


Area-of-interest and time



Which measurements



Open questions:

- Which communication system to use?
- Broadcast messages (one-way) or exchange information (two-way)?

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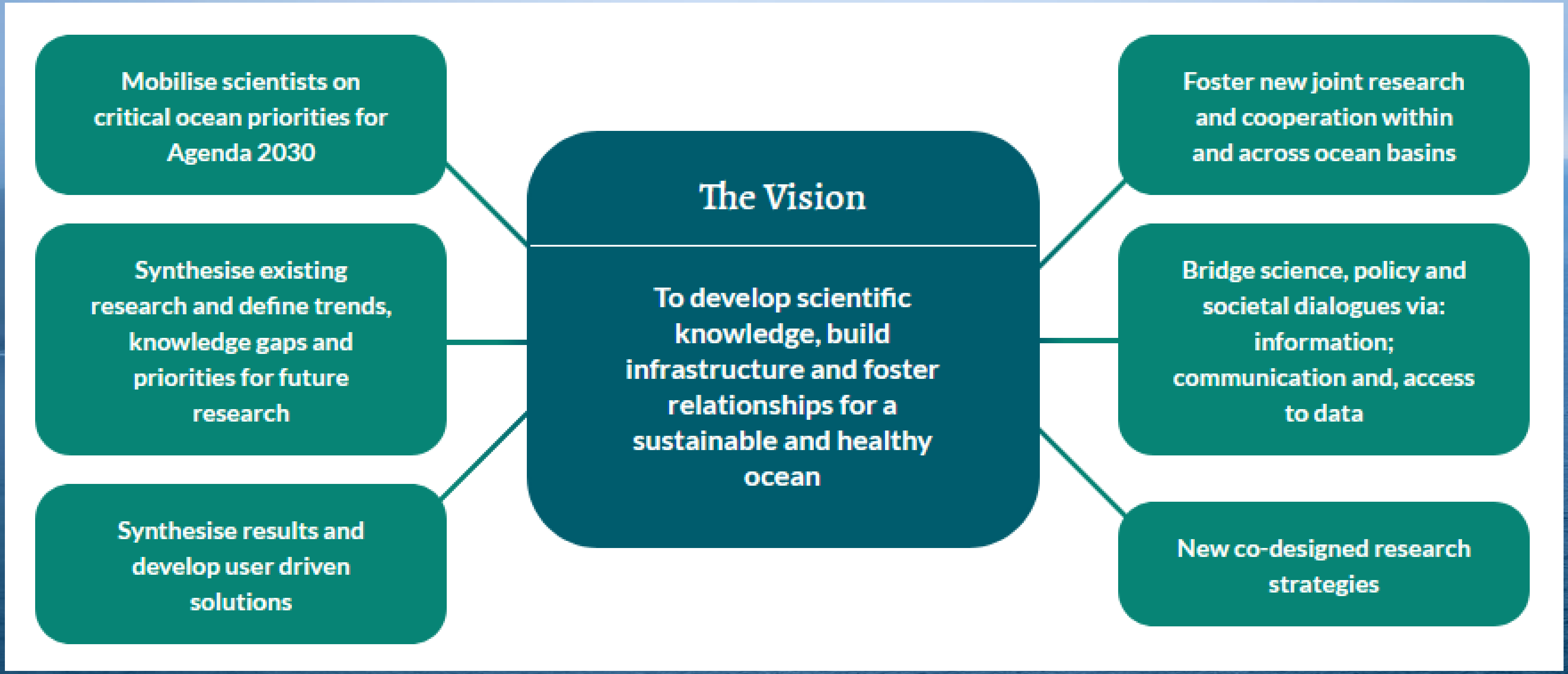
CONCLUSION AND FUTURE WORK

2021 2030 United Nations Decade of Ocean Science for Sustainable Development



Future work

Evaluate sociotechnical aspects

- Increasing infrastructure development in coastal areas
- How humans interact with the systems

Operational deployment and management

- Interoperability
- Interface management
- Allocation of functions

Thank you for listening

References

[Yarish 2012]	Yarish, Charles; Redmond, Sarah; and Kim, Jang K., "Gracilaria Culture Handbook for New England" (2012).Wrack Lines <https://opencommons.uconn.edu/wracklines/72>
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Illustrations

[Content page]	Photo by Valdemaras D. on Unsplash
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[Reindeer island]	Copernicus Sentinel data (2017), processed by ESA, CC BY-SA 3.0 IGO
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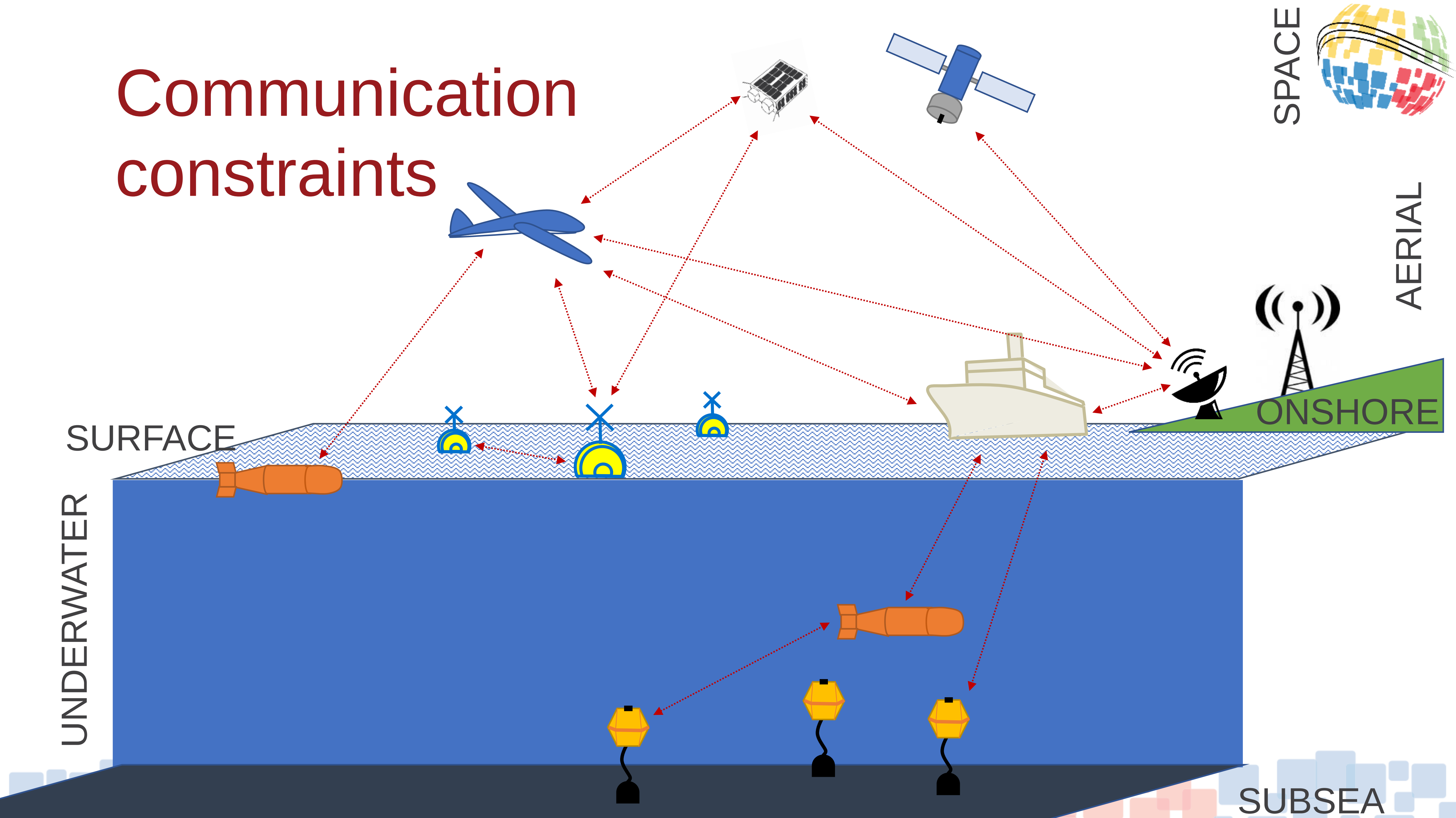
Backup slides

Communication constraints



Stakeholder analysis

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
#1			X	X	X		X	X		X	X	X	X		X	X				
#2									X		X	X		X			X	X	X	
#3	X	X	X	X	X	X			X	X	X	X		X			X		X	
#4	X	X	X	X	X	(X)			X	X	X	X					X		X	
#5			X								X									X
#6							X	X			(X)		X	X					X	X
#7							X	X		X	X	X	X						X	X
#8	X		(X)	(X)	(X)		X	X		X	X	X	X		X	X				X
#9							X	X			X	X	X		X	X				X
#10		X											X	X	X				X	X
#11			X	X	X				X	X	X				X		X	X	X	X
#12	X						X	X		X				X					X	X
#13							X	X					X						X	X
#14			X	X	X						X	X								
#15									X	X			X					X		
#16	X		X	X	X	X	X	X	X	X	X	X	X		X	X			X	X
#17	X									X	X	X		X	X	X		X		
#18	X		X	X	X		X	X	X	X	X	X	X	X	X	X				X
#19	X	X								X				X	X	X			X	X
#20		X	X	X	X									X	X	X			X	X
#21	X	X																	X	X
#22	X	X									X	X		X	X	X			X	X

Mapping between stakeholders and needs

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