learning, interpreting, and adapting to the diver's behaviour and physical state

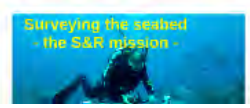
CADDY

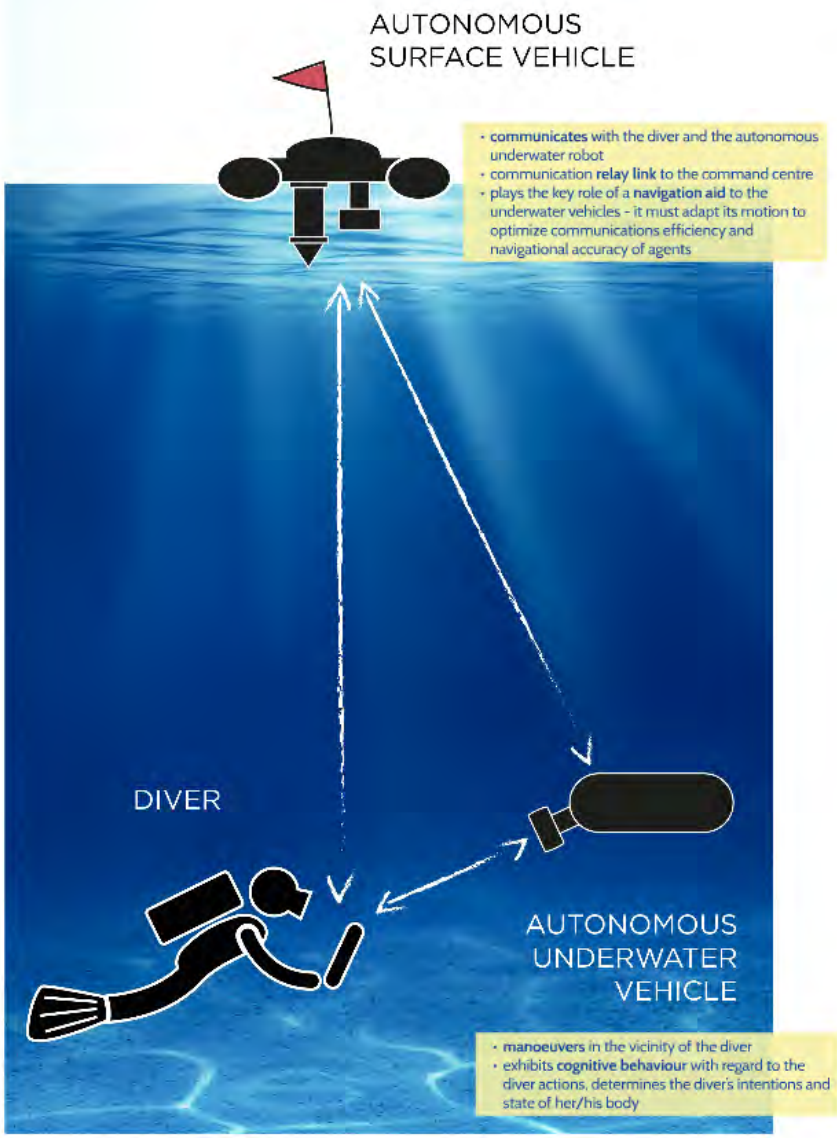
Cognitive Autonomous Diving Buddy

http://www.caddy-fp7.eu/

Key facts:
FP7-ICT Cognitive Robotics STREP with 7 partners
EU contribution: €3,7 million, (FER €709,000)
Duration: 36 months, starting 01/01/2014
Coordinator: UNIZG-FER

Consiglio Nazionale delle Ricerche
ISR LISBOA
JACOBS UNIVERSITY
universität wien
Newcastle University
DAN EUROPE





What?

Set up symbiotic links between a human diver and a set of companion autonomous robots (underwater and surface).

How?

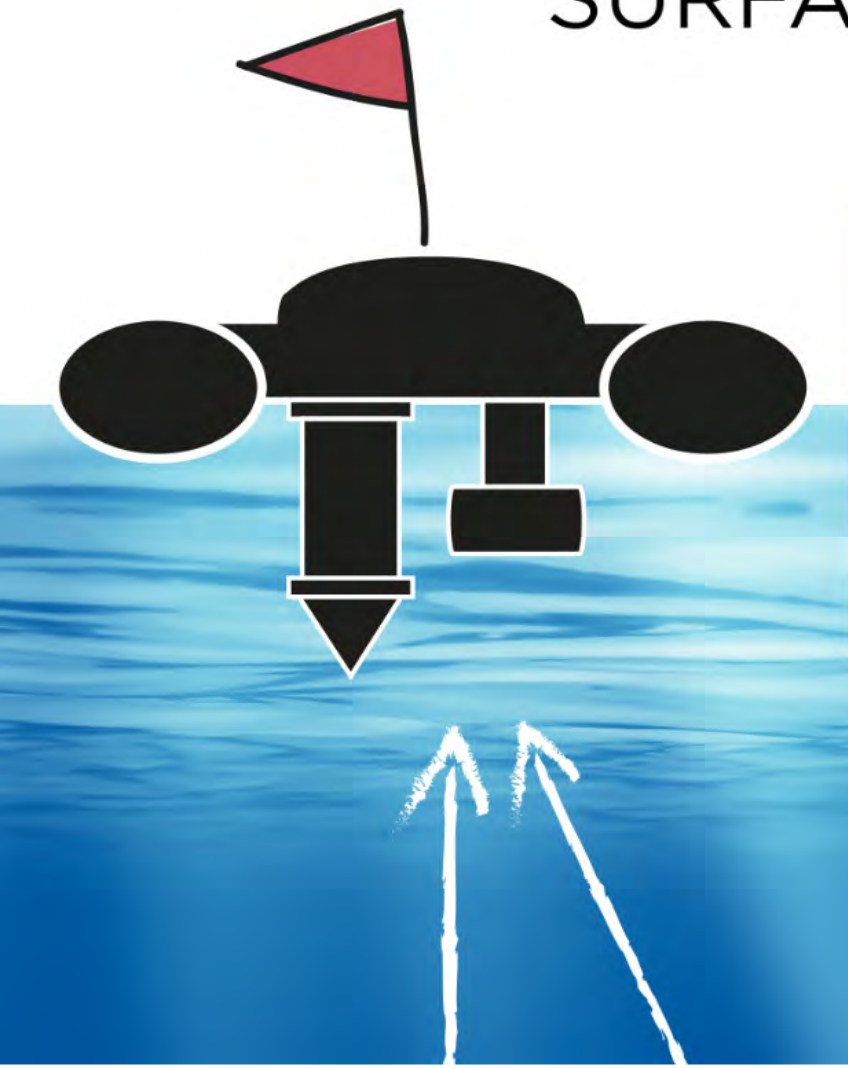
By developing a multicomponent, highly cognitive robotic system capable of learning, interpreting, and adapting to the diver's behaviour and physical state

CADDY

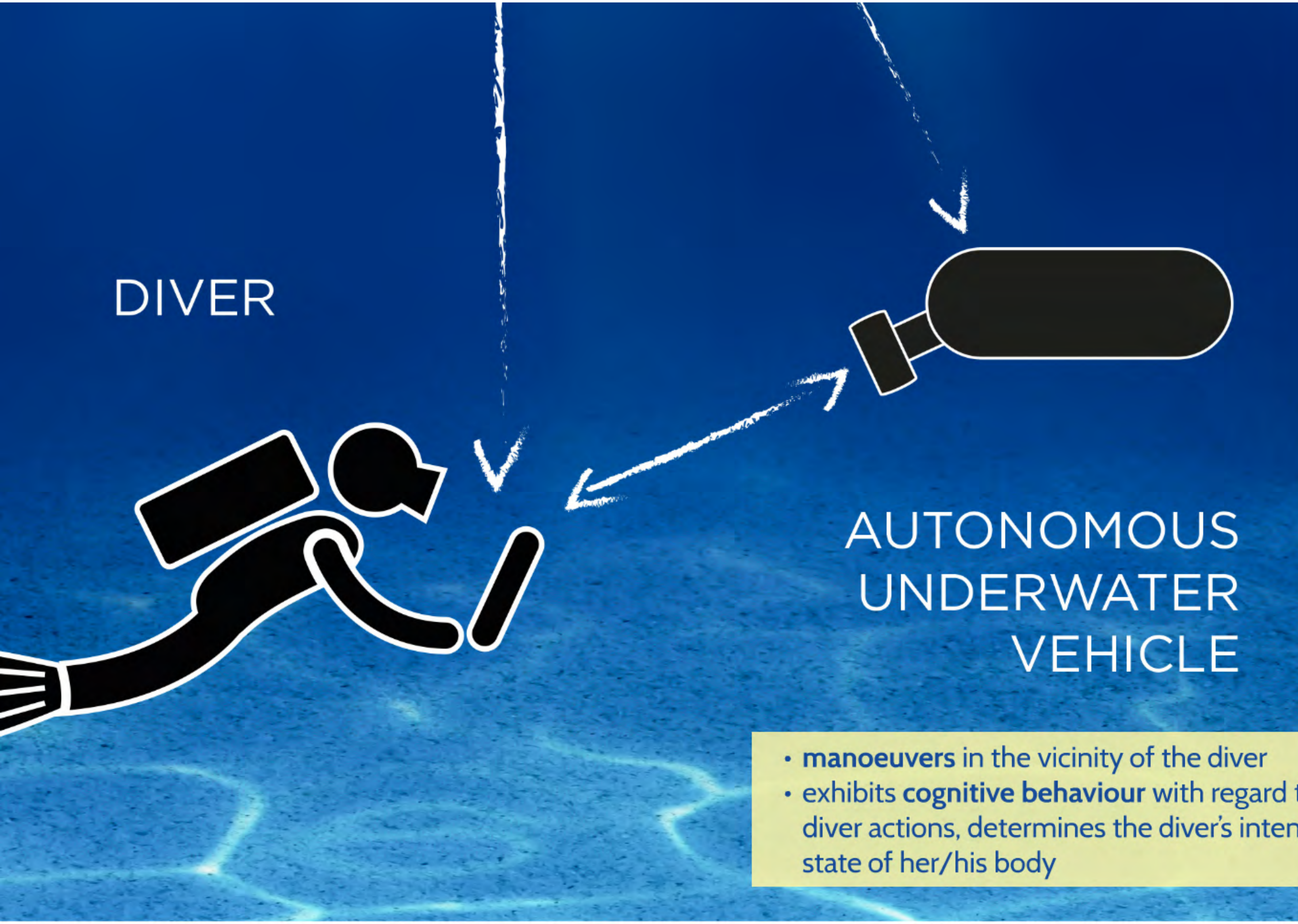
Cognitive Autonomous Diving Buddy

Key facts:
FP7-ICT Cognitive Robotics STREP with 7 partners

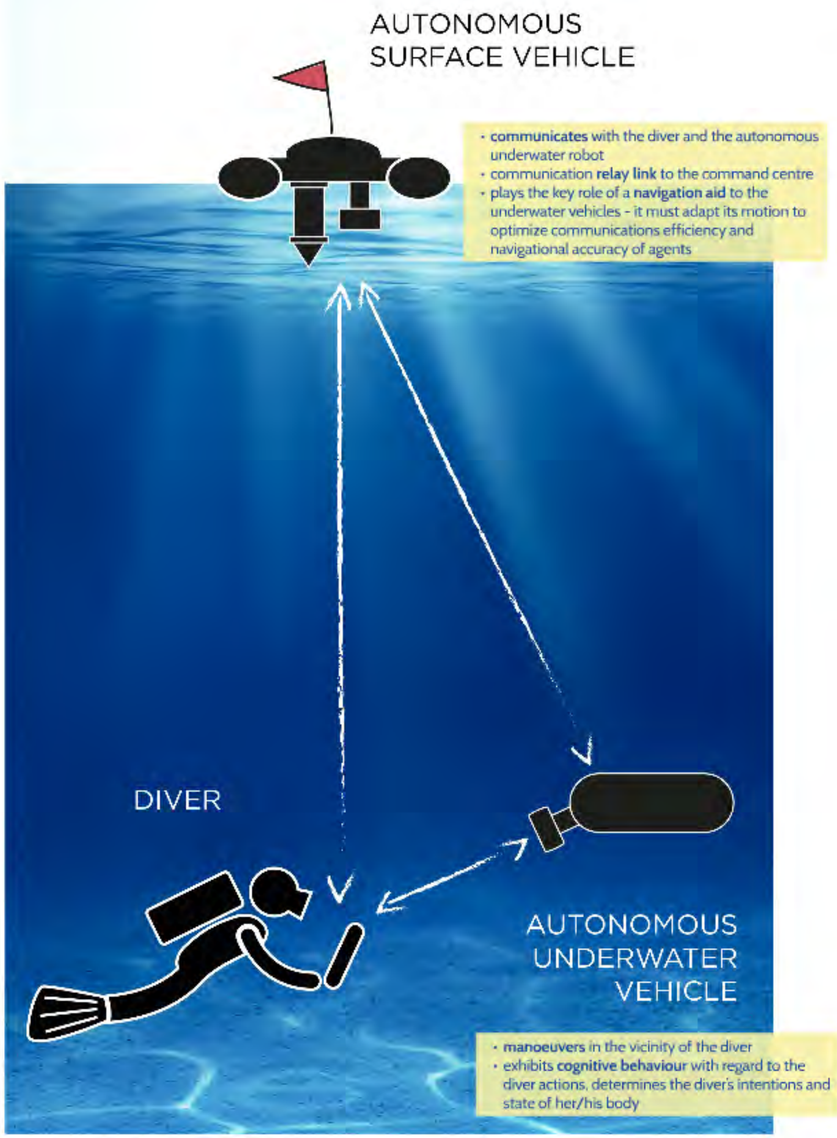
AUTONOMOUS SURFACE VEHICLE



- **communicates** with the diver and the autonomous underwater robot
- communication **relay link** to the command centre
- plays the key role of a **navigation aid** to the underwater vehicles - it must adapt its motion to optimize communications efficiency and navigational accuracy of agents



- **manoeuvers** in the vicinity of the diver
- exhibits **cognitive behaviour** with regard to the diver actions, determines the diver's intentions and state of her/his body



What?

Set up symbiotic links between a human diver and a set of companion autonomous robots (underwater and surface).

How?

By developing a multicomponent, highly cognitive robotic system capable of learning, interpreting, and adapting to the diver's behaviour and physical state

CADDY

Cognitive Autonomous Diving Buddy

Key facts:
FP7-ICT Cognitive Robotics STREP with 7 partners

Diver safety

- more than 50% of accidents happen while the divers were not accompanied.
- loss of conscience, N2 narcosis

Surveying the seabed - the S&R mission -

- Task: search a specified underwater area and recover one or more objects.
- Setting up transect rope (time-consuming, extra divers)
- diver then follows the line


Challenging UW operations
- archaeological site -
• multiple rectangular frames placed for site referencing
• measuring, sketching, taking photos
• Diver may decide to change the mission.

universitat wien

Newcastle University

- cooperates with diver
- guides the diver along predetermined transects allowing her/him to execute the most productive tasks

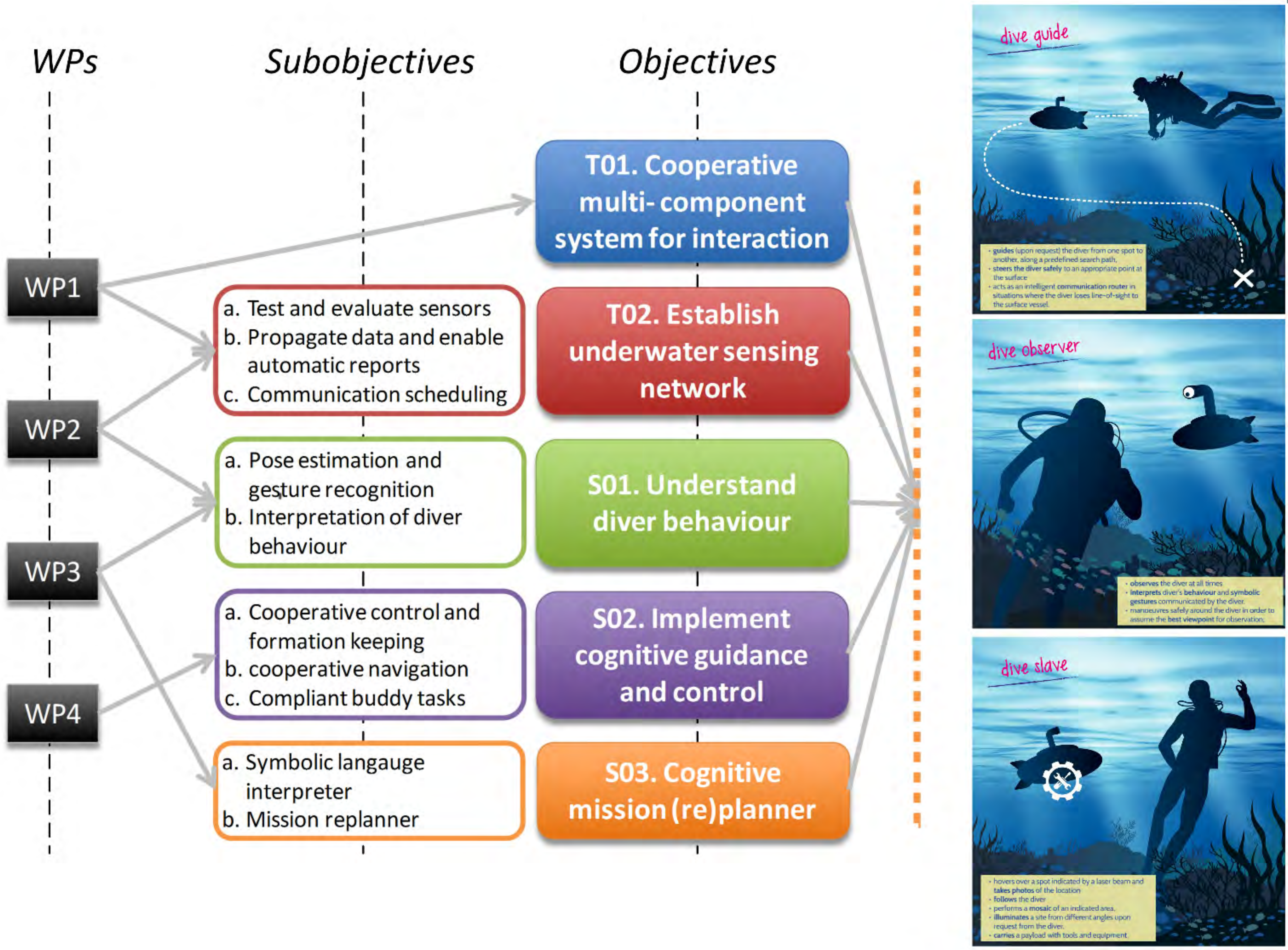
- enables precise navigation to the site via an optimal route

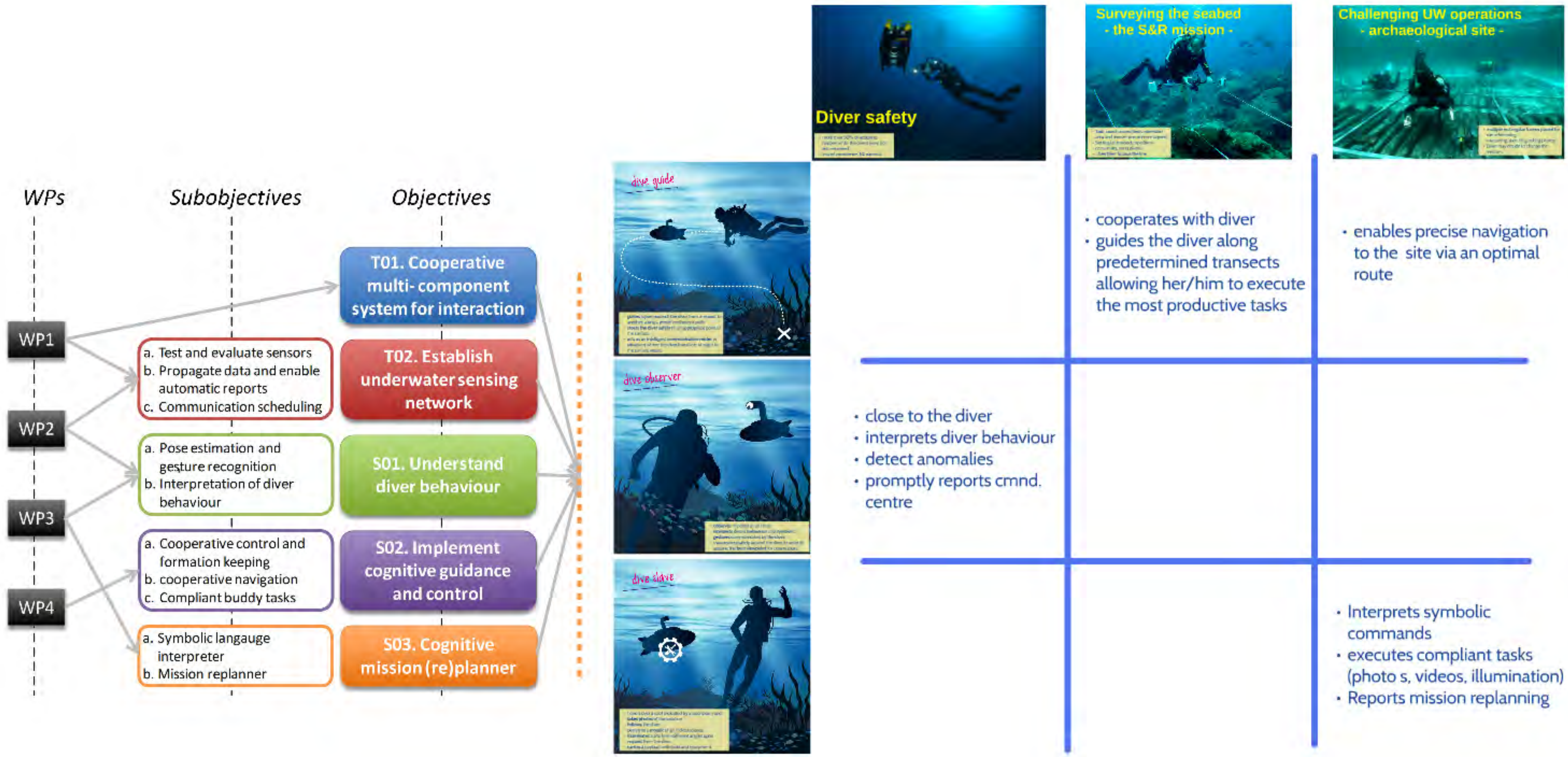

dive guide
• **guides** (upon request) the diver from one spot to another, along a predefined search path,
• **steers the diver safely** to an appropriate point at the surface
• acts as an intelligent **communication router** in situations where the diver loses line-of-sight to the surface vessel.


dive observer
• **observes** the diver at all times
• **interprets** diver's **behaviour** and **symbolic gestures** communicated by the diver.
• manoeuvres safely around the diver in order to assume the **best viewpoint** for observation;

- hovers over a spot indicated by a laser beam and **takes photos** of the location
- **follows** the diver
- performs a **mosaic** of an indicated area,
- **illuminates** a site from different angles upon request from the diver,
- **carries** a payload with tools and equipment.

	Diver safety	Surveying the seabed - the S&R mission -	Challenging UW operations - archaeological site -
dive guide		• cooperates with diver • guides the diver along predetermined transects allowing her/him to execute the most productive tasks	• enables precise navigation to the site via an optimal route
dive observer	• close to the diver • interprets diver behaviour • detect anomalies • promptly reports cmnd. centre		
dive slave			• Interprets symbolic commands • executes compliant tasks (photo s, videos, illumination) • Reports mission replanning

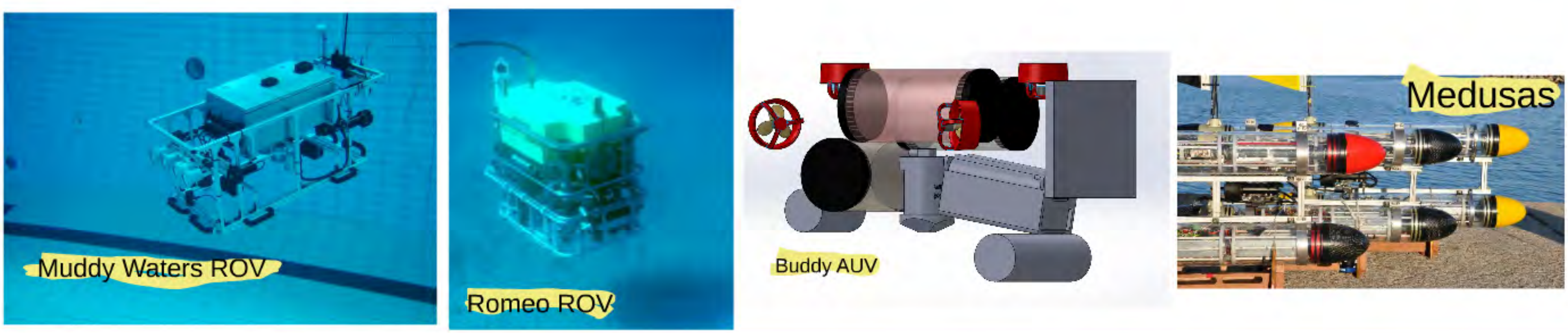

WPs
Subobjectives
Objectives
WP1
WP2
WP3
WP4
T01. Cooperative multi- component system for interaction
a. Test and evaluate sensors
b. Propagate data and enable automatic reports
c. Communication scheduling
T02. Establish underwater sensing network
a. Pose estimation and gesture recognition
b. Interpretation of diver behaviour
S01. Understand diver behaviour
a. Cooperative control and formation keeping
b. cooperative navigation
c. Compliant buddy tasks
S02. Implement cognitive guidance and control
a. Symbolic langauge interpreter
b. Mission replanner
S03. Cognitive mission (re)planner
dive guide
• guides (upon request) the diver from one spot to another, along a predefined search path,
• steers the diver safely to an appropriate point at the surface
• acts as an intelligent communication router in situations where the diver loses line-of-sight to the surface vessel.
dive observer
• observes the diver at all times
• interprets diver's behaviour and symbolic gestures communicated by the diver.
• manoeuvres safely around the diver in order to assume the best viewpoint for observation;
dive slave
• hovers over a spot indicated by a laser beam and takes photos of the location
• follows the diver
• performs a mosaic of an indicated area.
• illuminates a site from different angles upon request from the diver.
• carries a payload with tools and equipment

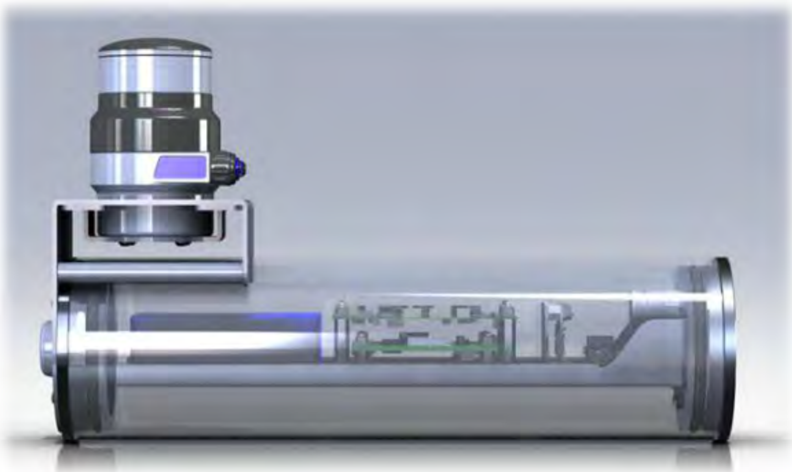

Diver safety
Surveying the seabed - the S&R mission -
Challenging UW operations - archaeological site -
WPs
Subobjectives
Objectives
WP1
WP2
WP3
WP4
a. Test and evaluate sensors
b. Propagate data and enable automatic reports
c. Communication scheduling
a. Pose estimation and gesture recognition
b. Interpretation of diver behaviour
a. Cooperative control and formation keeping
b. cooperative navigation
c. Compliant buddy tasks
a. Symbolic langauge interpreter
b. Mission replanner
T01. Cooperative multi- component system for interaction
T02. Establish underwater sensing network
S01. Understand diver behaviour
S02. Implement cognitive guidance and control
S03. Cognitive mission (re)planner
dive guide
dive observer
dive slave
• cooperates with diver
• guides the diver along predetermined transects allowing her/him to execute the most productive tasks
• enables precise navigation to the site via an optimal route
• close to the diver
• interprets diver behaviour
• detect anomalies
• promptly reports cmnd. centre
• Interprets symbolic commands
• executes compliant tasks (photo s, videos, illumination)
• Reports mission replanning

Surface segment

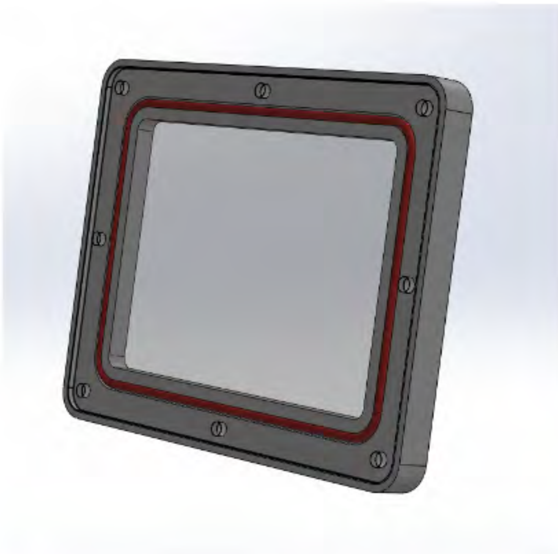
Linking the diver

Underwater segment



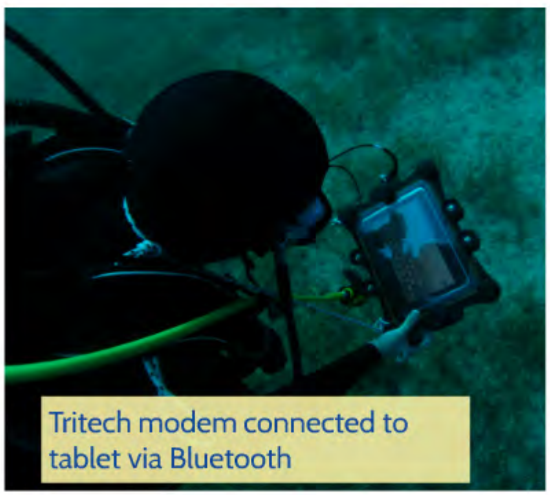



Goggles with LED array for diver guidance
Microprocessor and Attitude Unit
Acoustic modem and ranging device

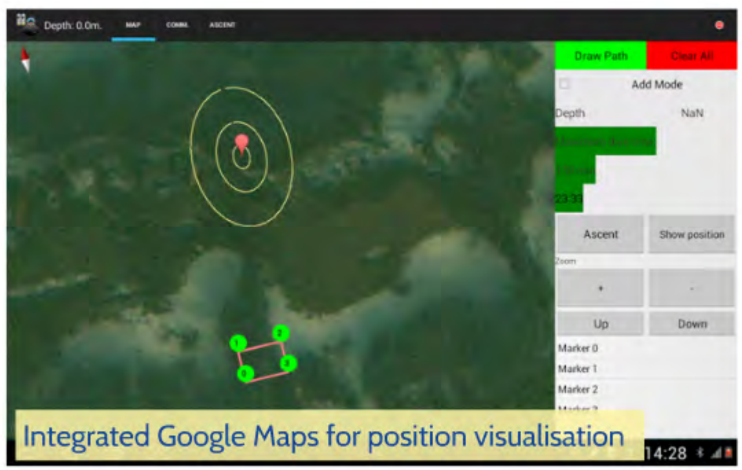


Comms interface with custom and predefined messages – only 40bit/s!!

Connected via Tritech modem with the surface platform (USBL)



Tritech modem connected to tablet via Bluetooth



Integrated Google Maps for position visualisation

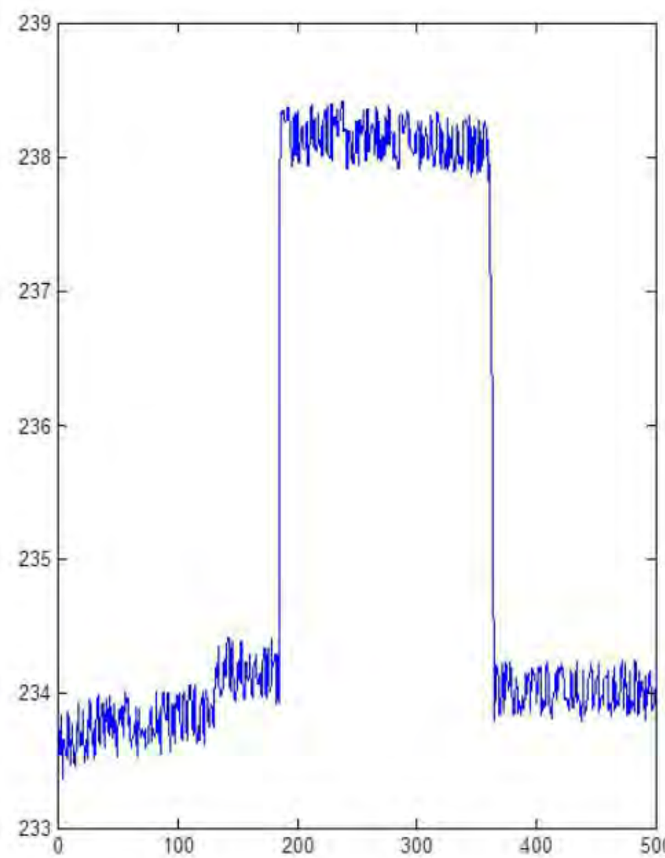
Dive computer

New miniature modem/USBL to replace Micron

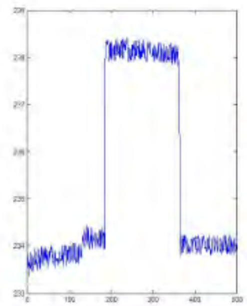
- 100bps data rate
- more efficient protocols (1-2kbps by end 2014)
- USBL positioning integrated in all units

Tank tests

- USBL fix repeatability assessed (<< 1 deg).
- Range repeatability <10cm.
- ~1 fix per second

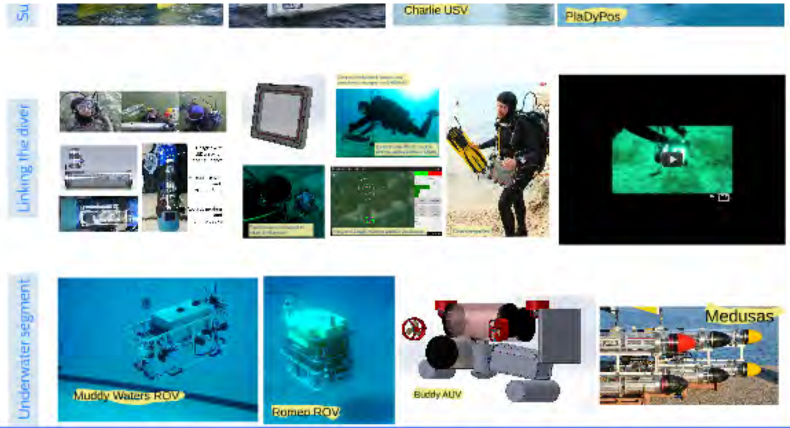


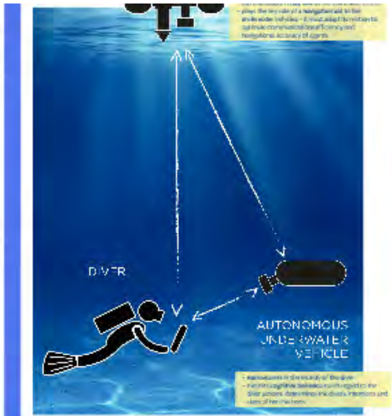
- USBL positioning integrated in all units



Tank tests

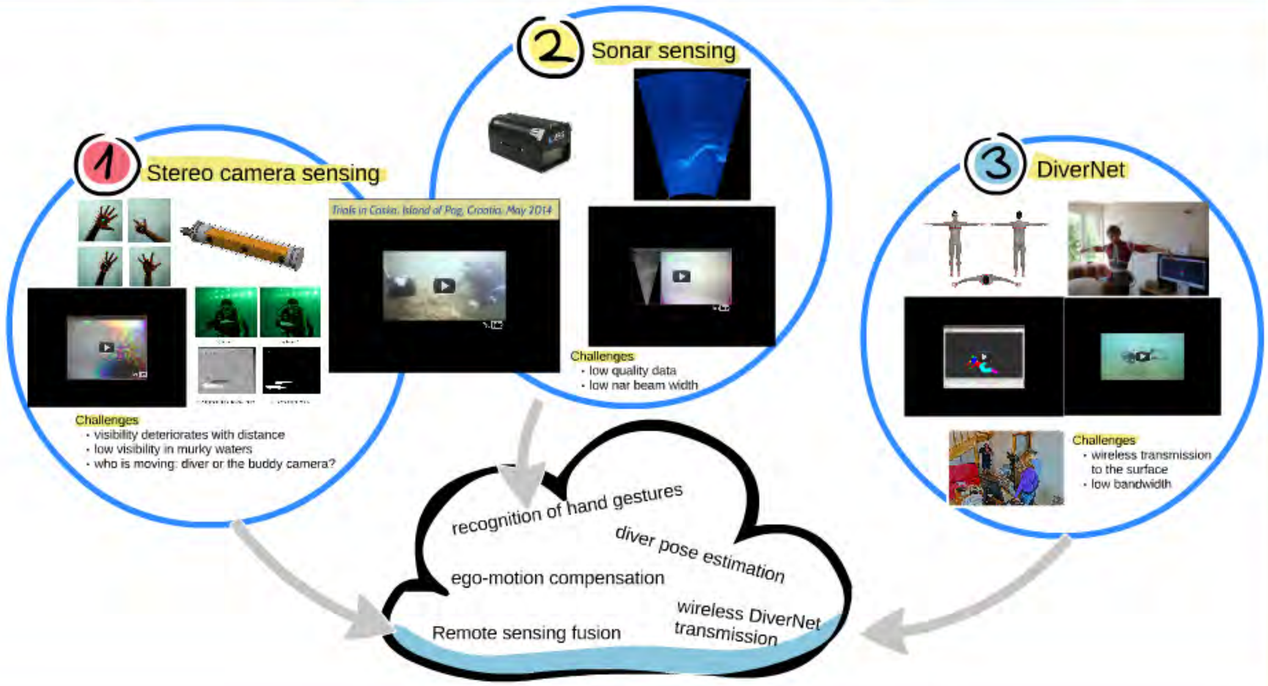
- USBL fix repeatability assessed (<< 1 deg).
- Range repeatability <10cm.
- ~1 fix per second





2

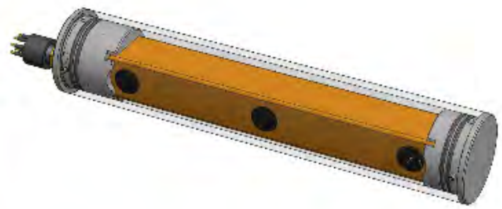
e diver

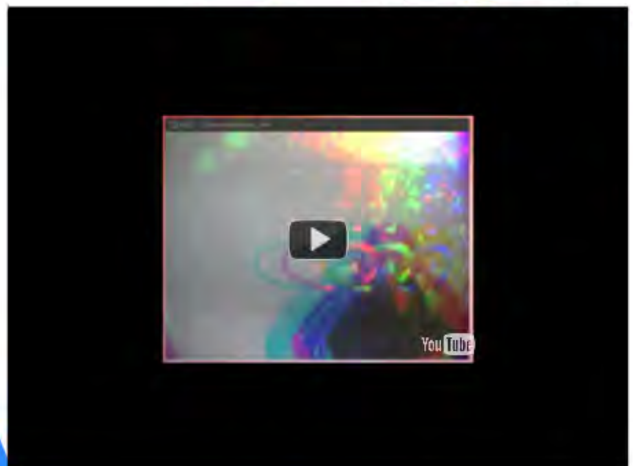


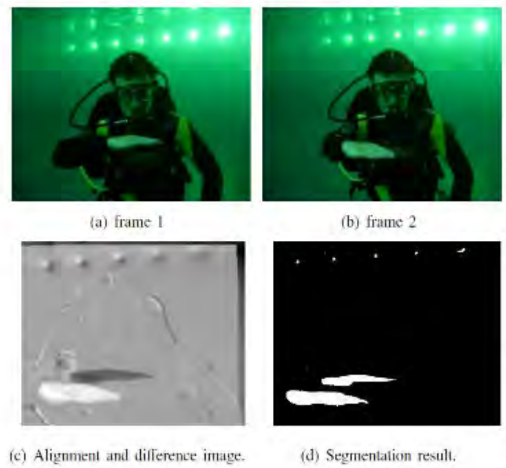
Recognition of hand gestures

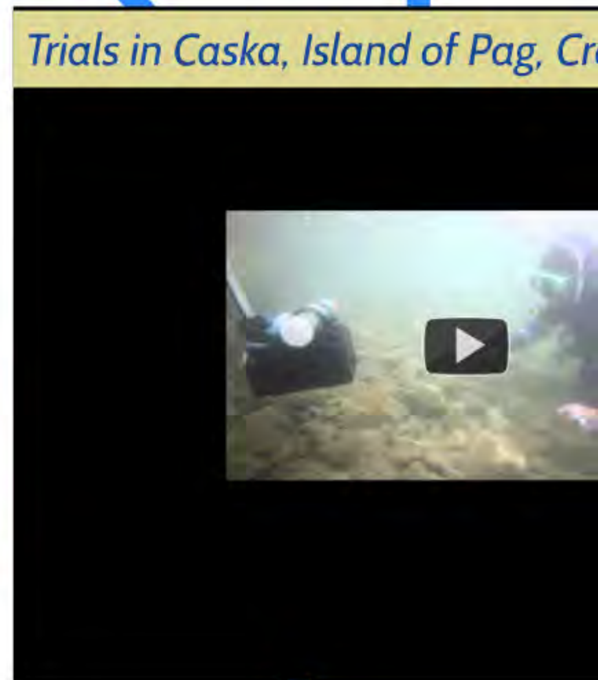
Pose int

1 Stereo camera sensing





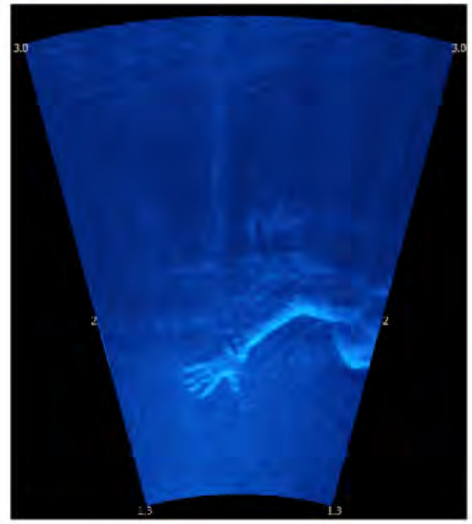




Challenges

- visibility deteriorates with distance
- low visibility in murky waters
- who is moving: diver or the buddy camera?

2 Sonar sensing



ng

in Caska, Island of Pag, Croatia, May 2014

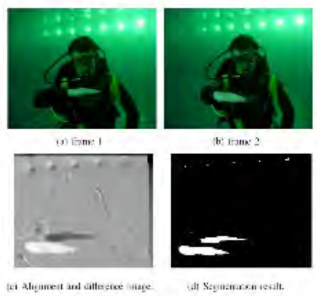
Challenges

- low quality data
- low nar beam width


2 Sonar sensing


1 Stereo camera sensing



Trials in Caska, Island of Pag, Croatia, May 2014


Challenges
- low quality data
- low nar beam width

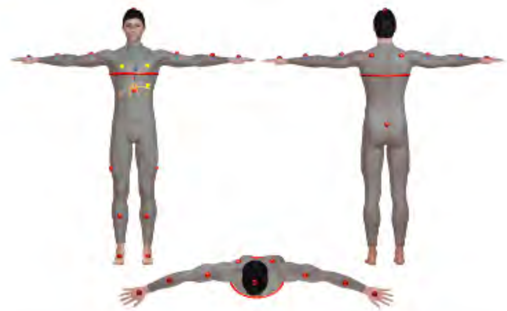
Challenges
- visibility deteriorates with distance
- low visibility in murky waters
- who is moving: diver or the buddy camera?

recognition of hand gestures

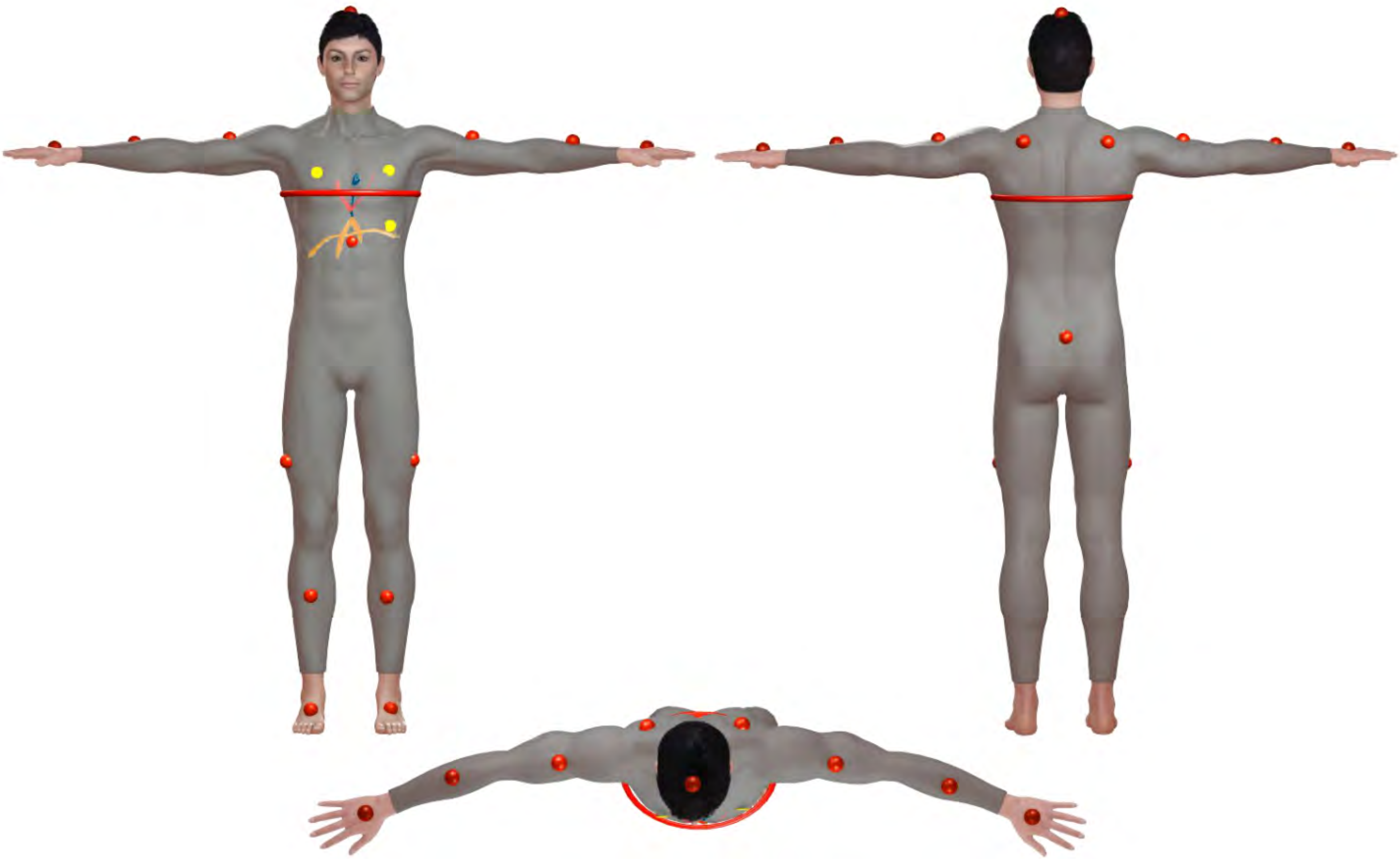
diver pose estimation

ego-motion compensation

3 DiverNet

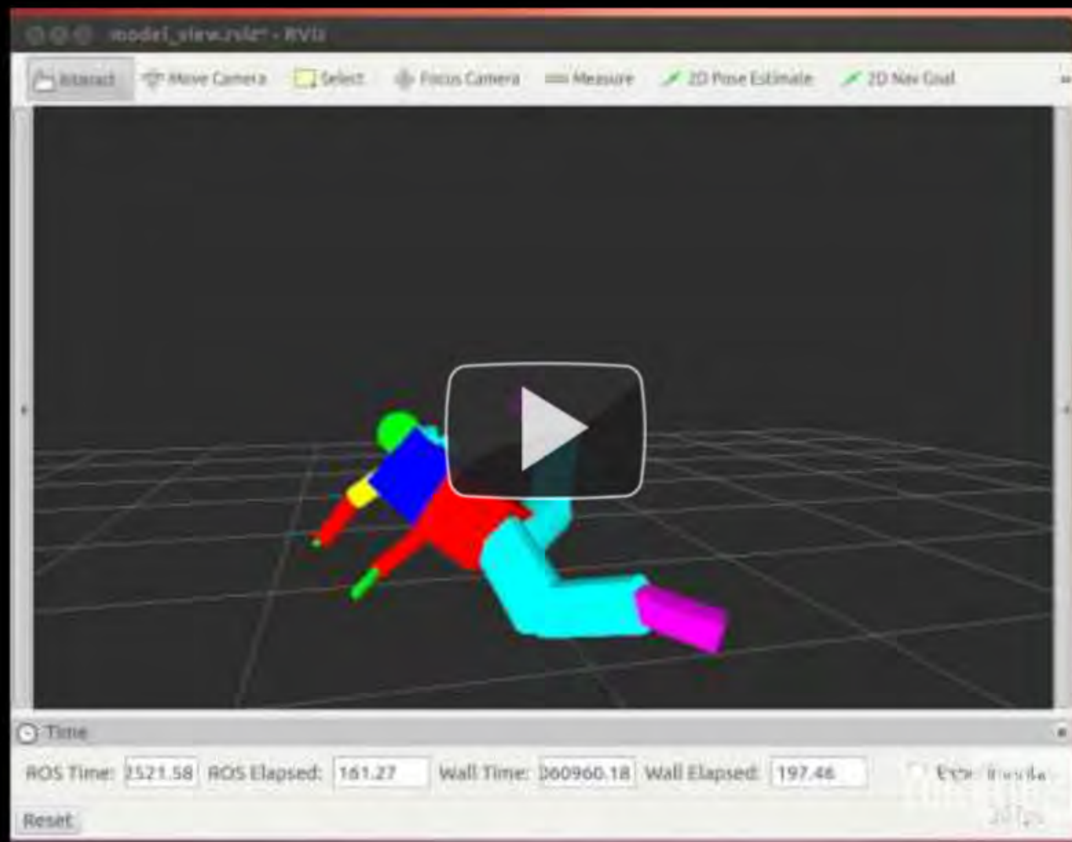


Challenges
- wireless transmission to the surface
- low bandwidth

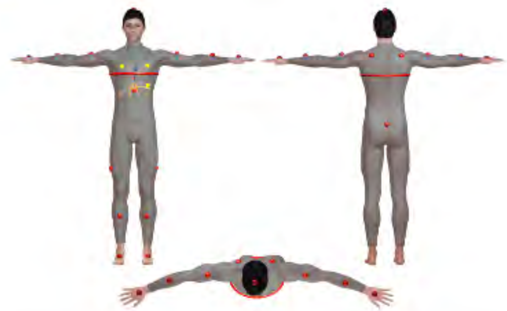



CADDY
CADDY

YouTube


Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Nav Goal
Time
ROS Time: 2521.58
ROS Elapsed: 161.27
Wall Time:
Wall Elapsed: 197.46
Reset

3 DiverNet

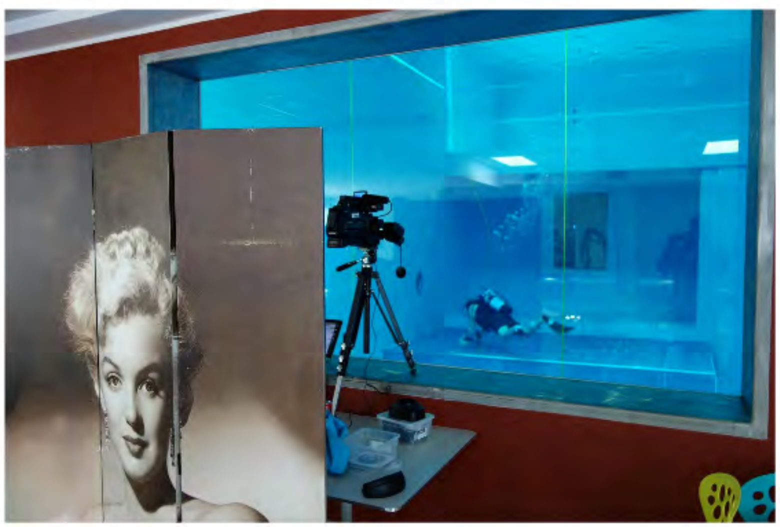


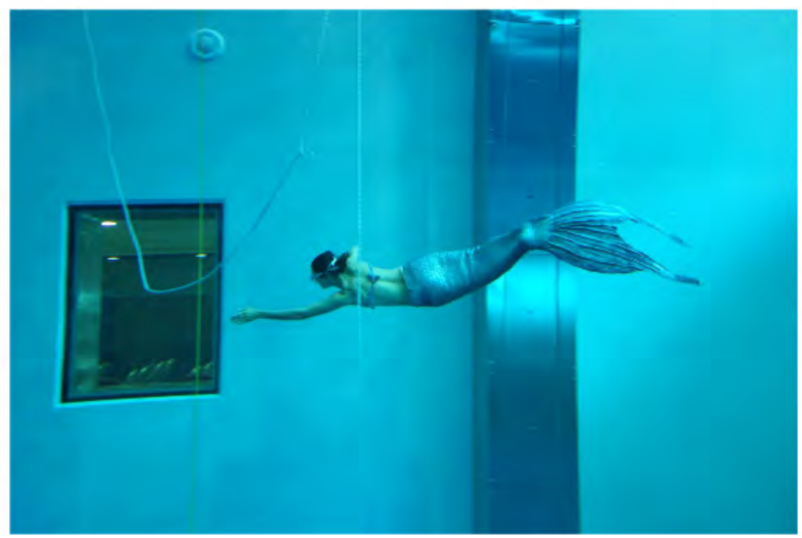
Challenges

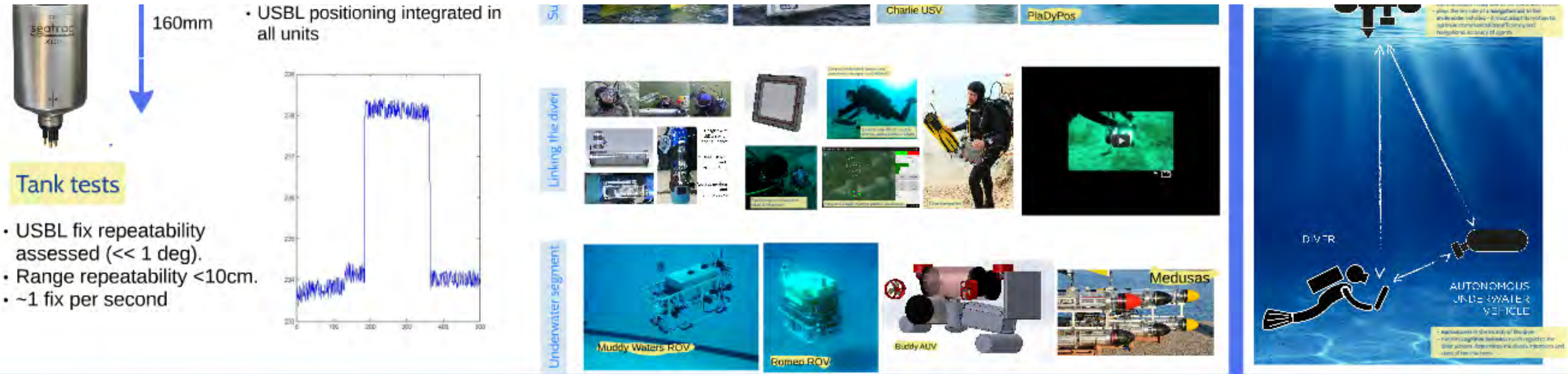
- wireless transmission to the surface
- low bandwidth

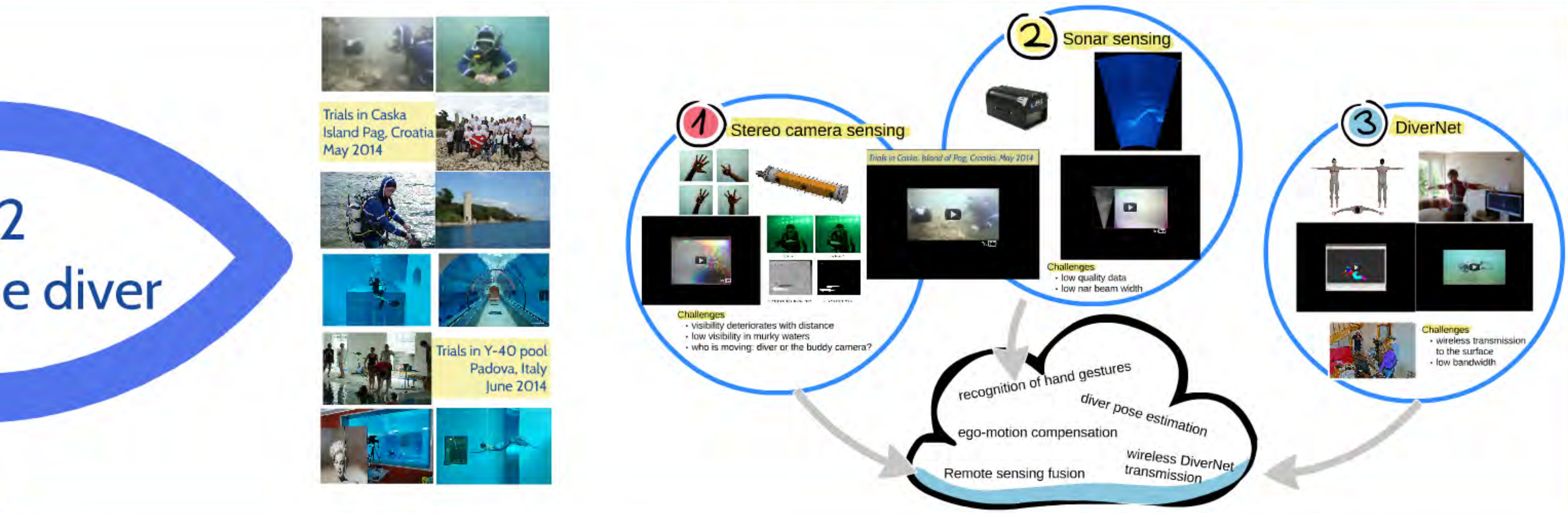
Trials in Caska Island Pag, Croatia May 2014

Trials in Y-40 pool
Padova, Italy
June 2014



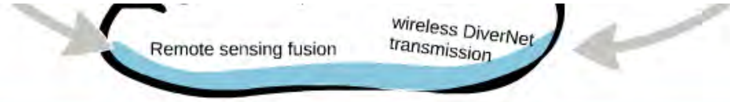


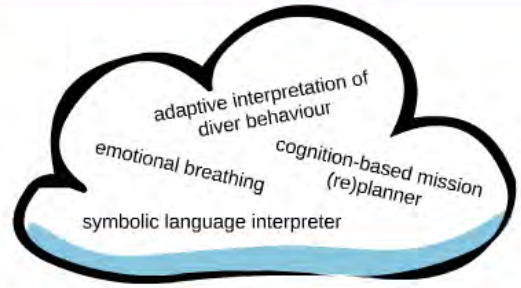




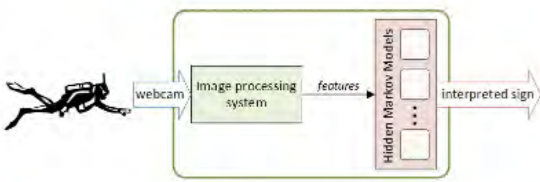
Recognition of hand gestures

Pose int





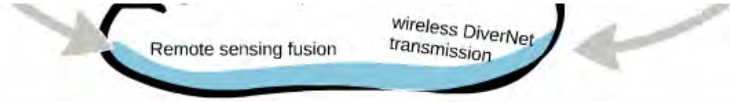
Recognition of hand gestures

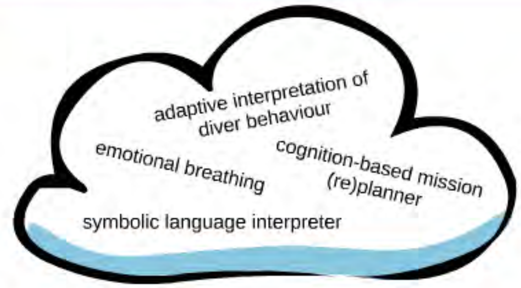


WP3 Understanding the diver

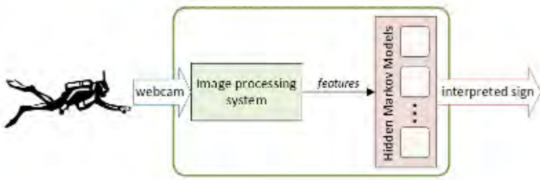
Pose interpretation

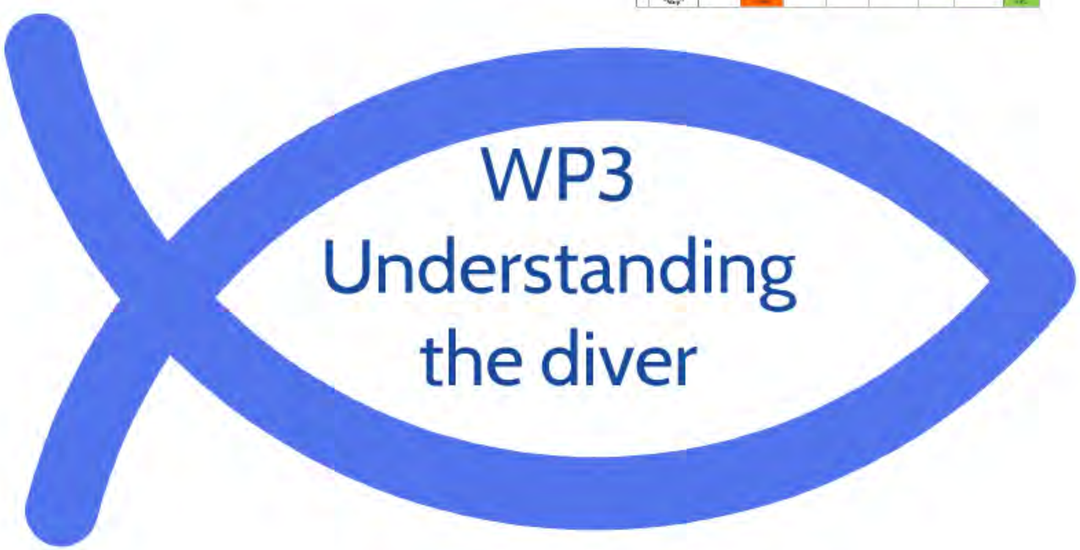
Pose interpretation



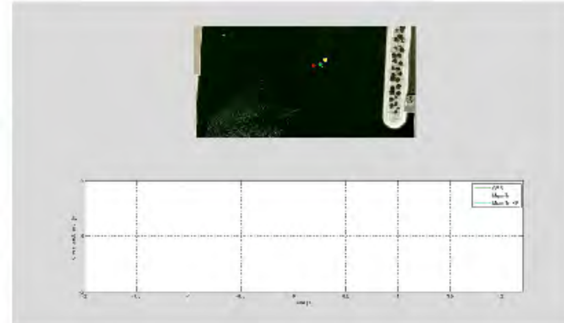


Recognition of hand gestures

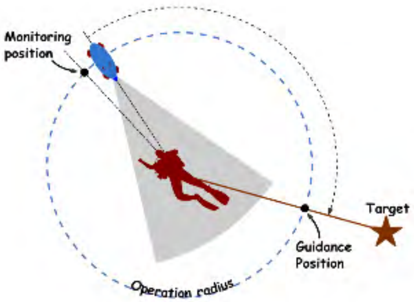




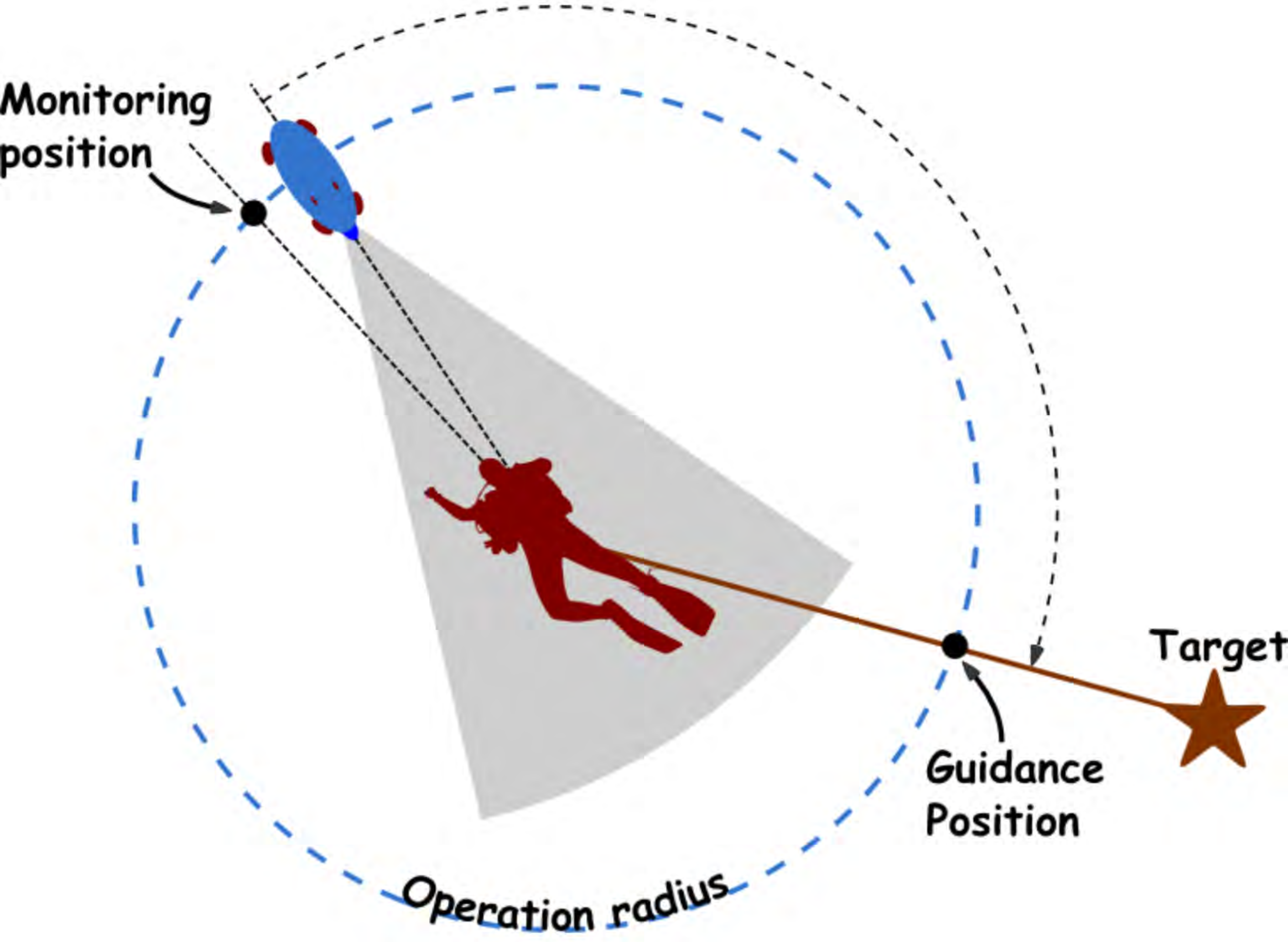
Pose interpretation

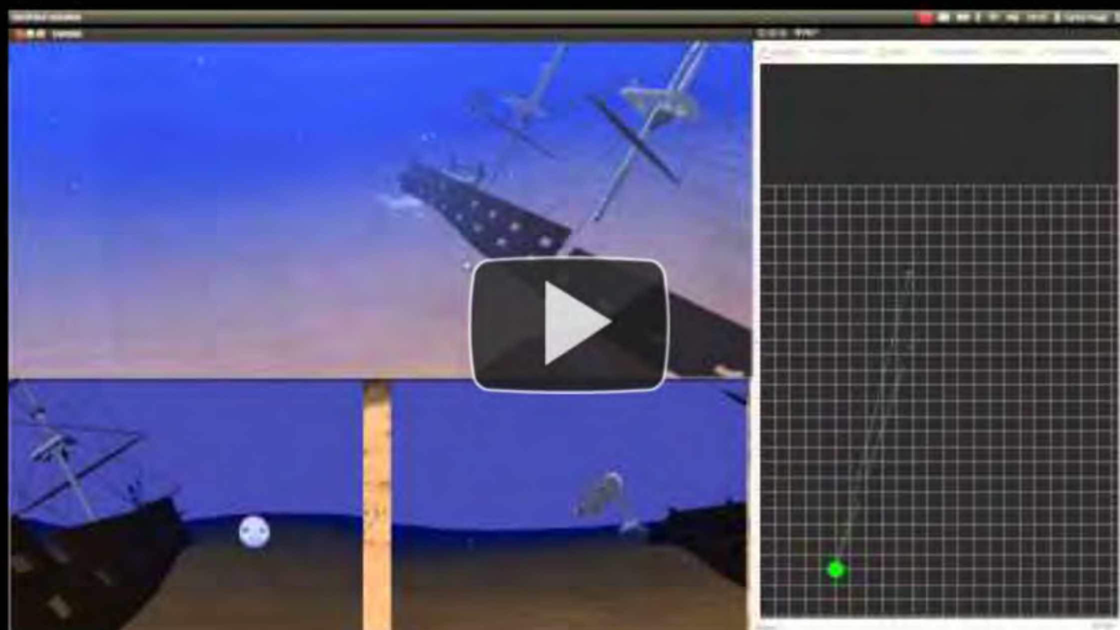


Cooperative control and optimal formation keeping

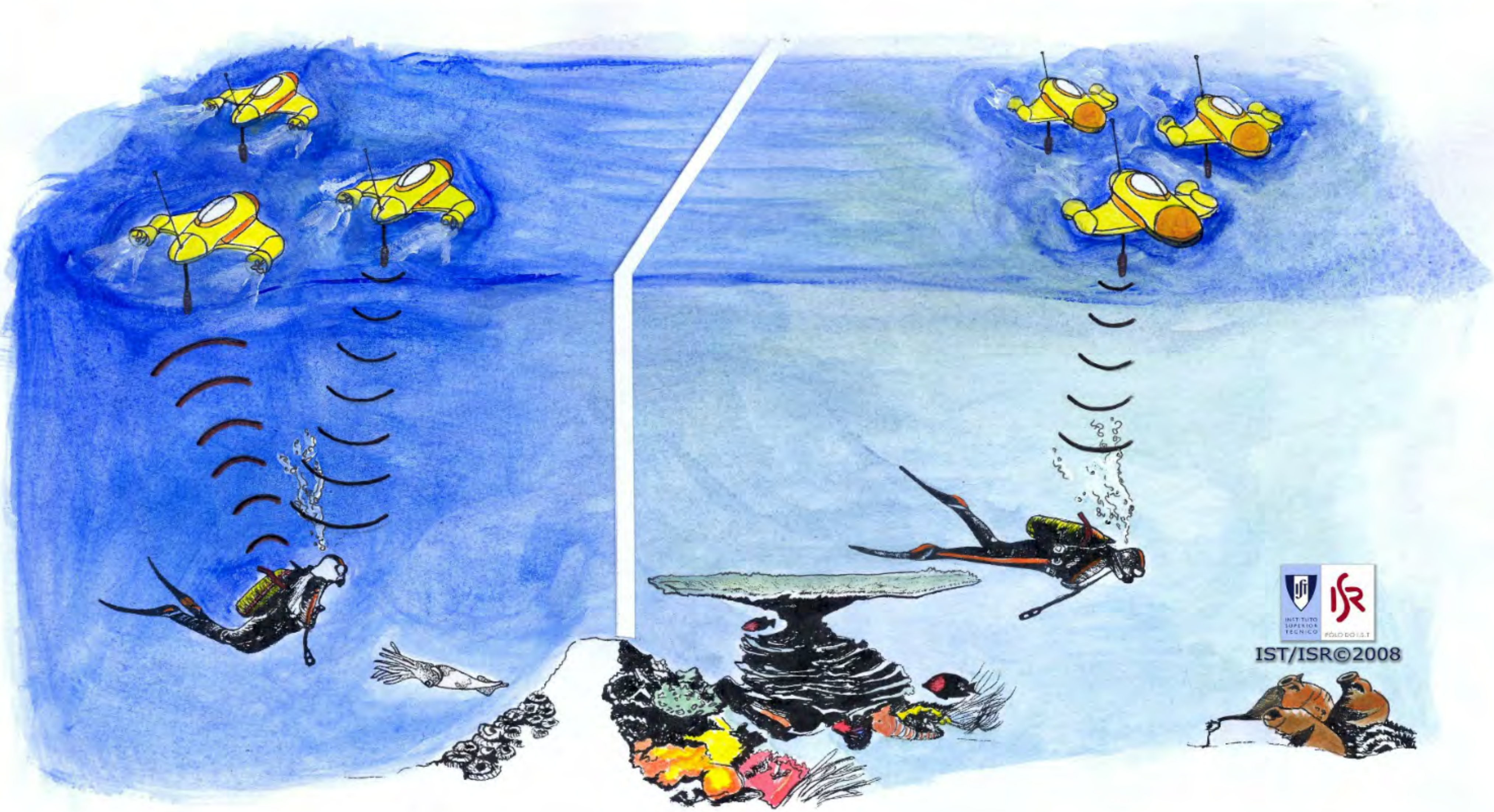


WP4
Diver-robot

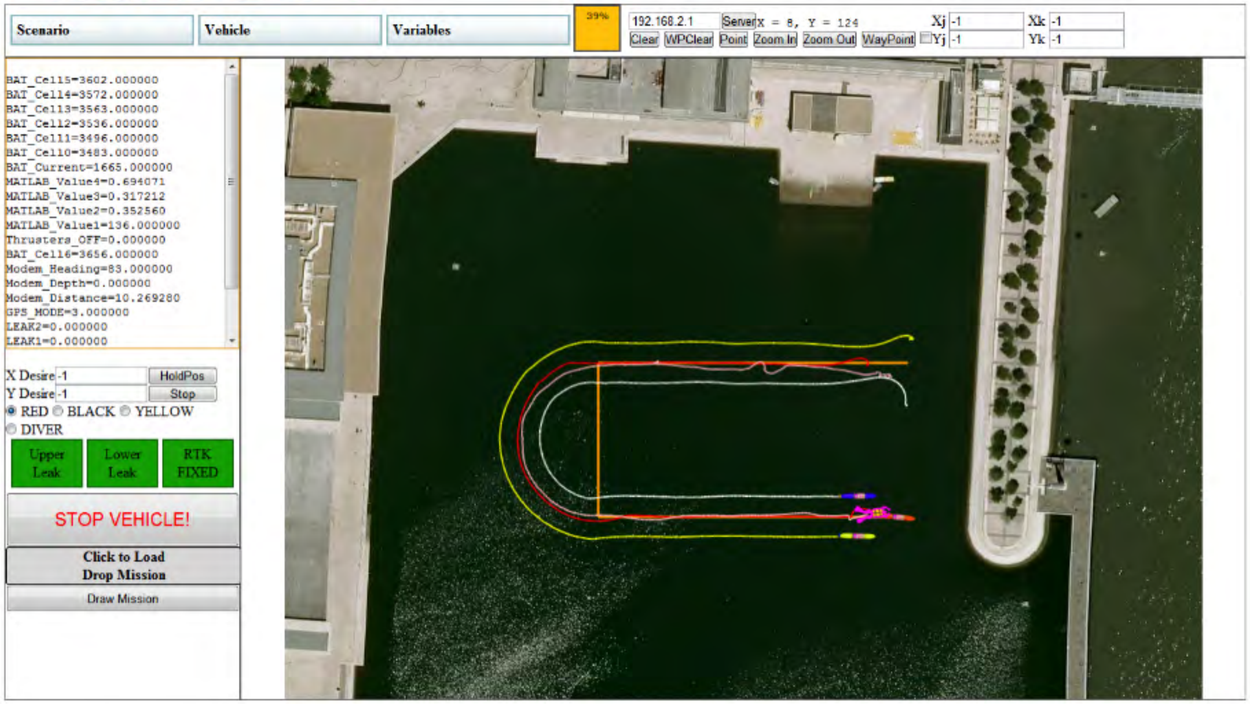

Monitoring position
Target
Guidance Position
Operation radius

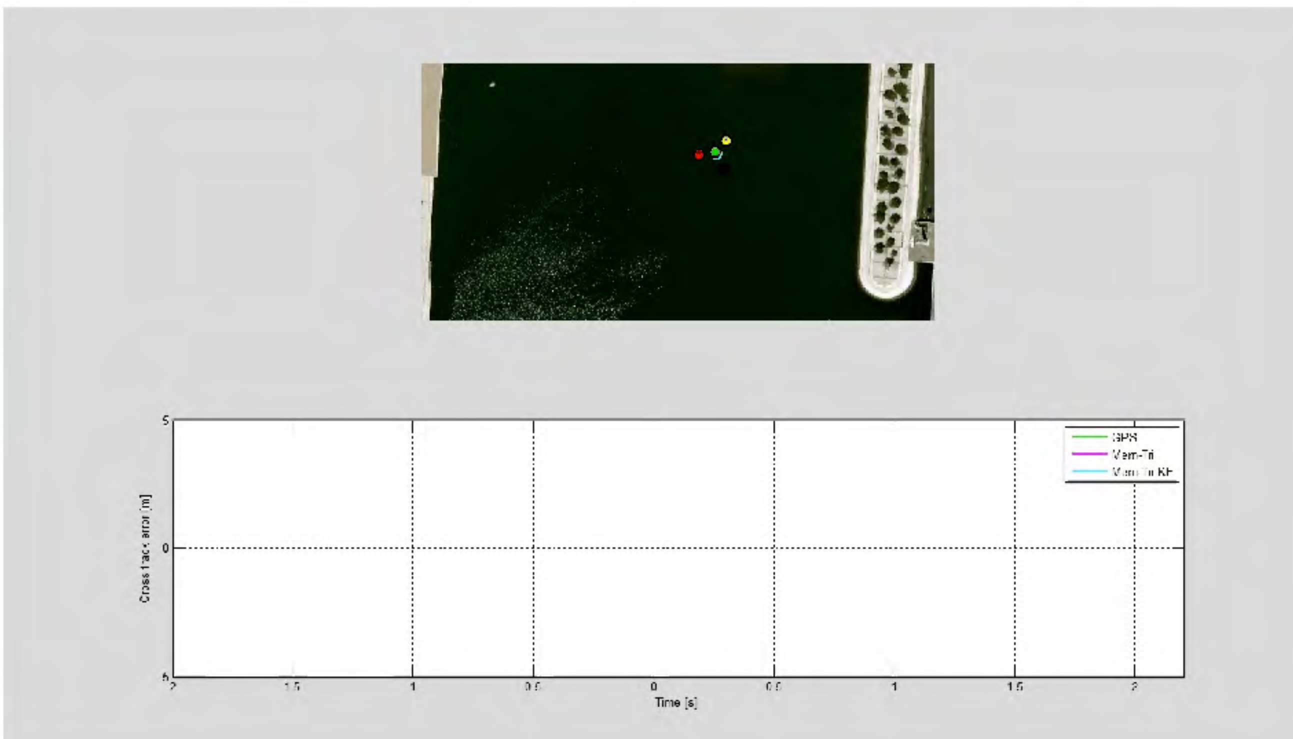


Cooperative distributed navigation and local



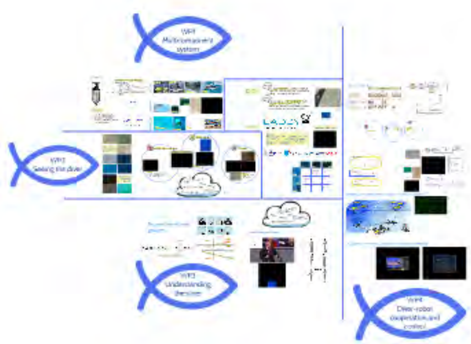
a localization





ISR©2008


WP1
Multicomponent
system
Tank tests
WP2
Seeing the diver
Stereo camera sensing
Sonar sensing
DiverNet
Remote sensing fusion
What?
Set up symbiotic links between a human diver and a set of companion autonomous robots (underwater and surface).
How?
By developing a multicomponent, highly cognitive robotic system capable of learning, interpreting, and adapting to the diver's behaviour and physical state
CADDY
Cognitive Autonomous Diving Buddy
Key facts
Duration: 36 months starting 01/01/2014
Coordinator: UNIZG-FER
Control architecture
Cooperative distributed navigation and localization
Cooperative control and optimal formation keeping
Recognition of hand gestures
Pose interpretation
symbolic language interpreter
WP3
Understanding
the diver
WP4
Diver-robot
cooperation and
control



Thank you!

breaking the surface 2014

BIOGRAD NA MORU, CROATIA 5th Oct. - 12th Oct.

http://bts.fer.hr

- 2009 - 2011: funded by EC within FP7 CURE project
- 2012 - 2014: funded by ONR Global

marine biology
+
marine archaeology
+
marine security
+
marine robotics

lectures
+
hands-on tutorials
+
demonstrations
+
company presentations

Challenges for Mediterranean biodiversity

ferdinando boero
University of Salento, CNR-ISMAR, CoNISMa

In the beginning…

- For a very long time, environmental monitoring in the seas focused on physics, chemistry and biogeochemistry

- This led to the development of powerful and reliable instruments that allow keeping physical conditions under constant control over vast surfaces, with satellites

- Below the sea surface, however, specific instruments had to be designed (e.g. gliders), and they invariably focused on physical variables

under the sea…

- Buoys, moorings, etc. allow measuring a series of variables at specific points along the depth gradient

- Oceanographic vessels and submersibles (either manned or unmanned) can measure variables and take incredibly detailed pictures of the sea bottom.

- Geology receives lots of attention

Progress…

- All this gave us a lot of insight about how the oceans are made and work
- but the measure of the presence and activity of life remained rather primitive (just some pigments, i.e. more chemistry than biology)
- Apparently, the expression of life was considered as a negligible detail…

The revolution

What is GES?

- **better be familiar with this concept!**

- **G**ood
- **E**nvironmental
- **S**tatus

- **And how to measure it?**

The descriptors

- **Descriptor 1**. Biodiversity is maintained
- **Descriptor 2**. Non-indigenous species do not adversely alter the ecosystem
- **Descriptor 3**. The population of commercial fish species is healthy
- **Descriptor 4**. Elements of food webs ensure long-term abundance and reproduction
- **Descriptor 5**. Eutrophication is minimised
- **Descriptor 6**. The sea floor integrity ensures functioning of the ecosystem
- **Descriptor 7**. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
- **Descriptor 8**. Concentrations of contaminants give no effects
- **Descriptor 9**. Contaminants in seafood are below safe levels
- **Descriptor 10**. Marine litter does not cause harm
- **Descriptor 11**. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

Troubles begin

- **Biodiversity is maintained**
- This is descriptor nr 1, the most important one.
- Is there a way to measure biodiversity in an automatic way, with a machine?

What the hell it is?

- biological diversity is the variety of life and its processes; and it includes the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.
- Genes, Species, Communities

How many species are there on Earth?

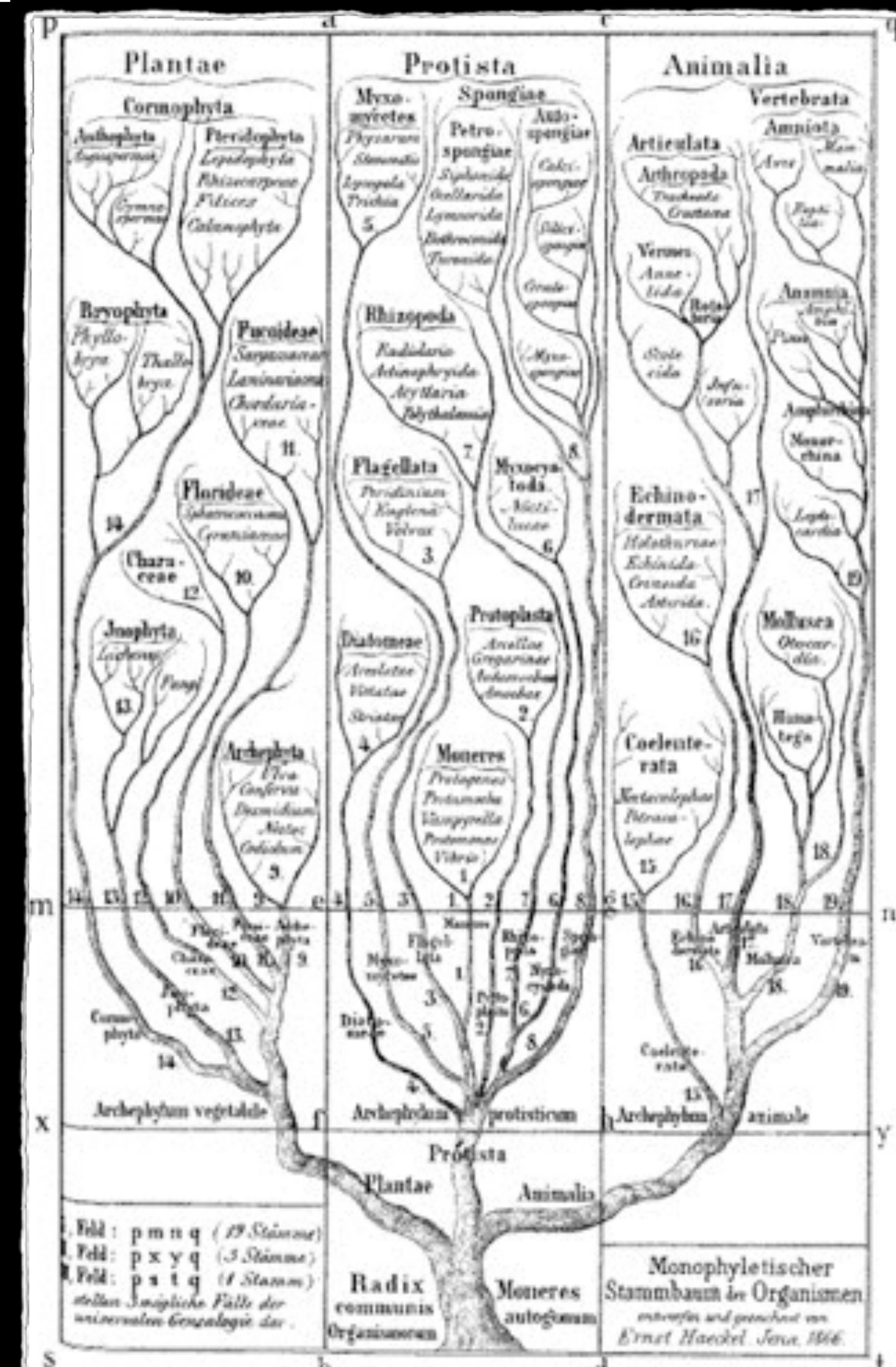
- Strange enough, we do not know

- So we should monitor the unknown

- Maybe some are more important than others….

- But how can we assess the importance of what we do not know?

- Whales and dolphins are not enough!

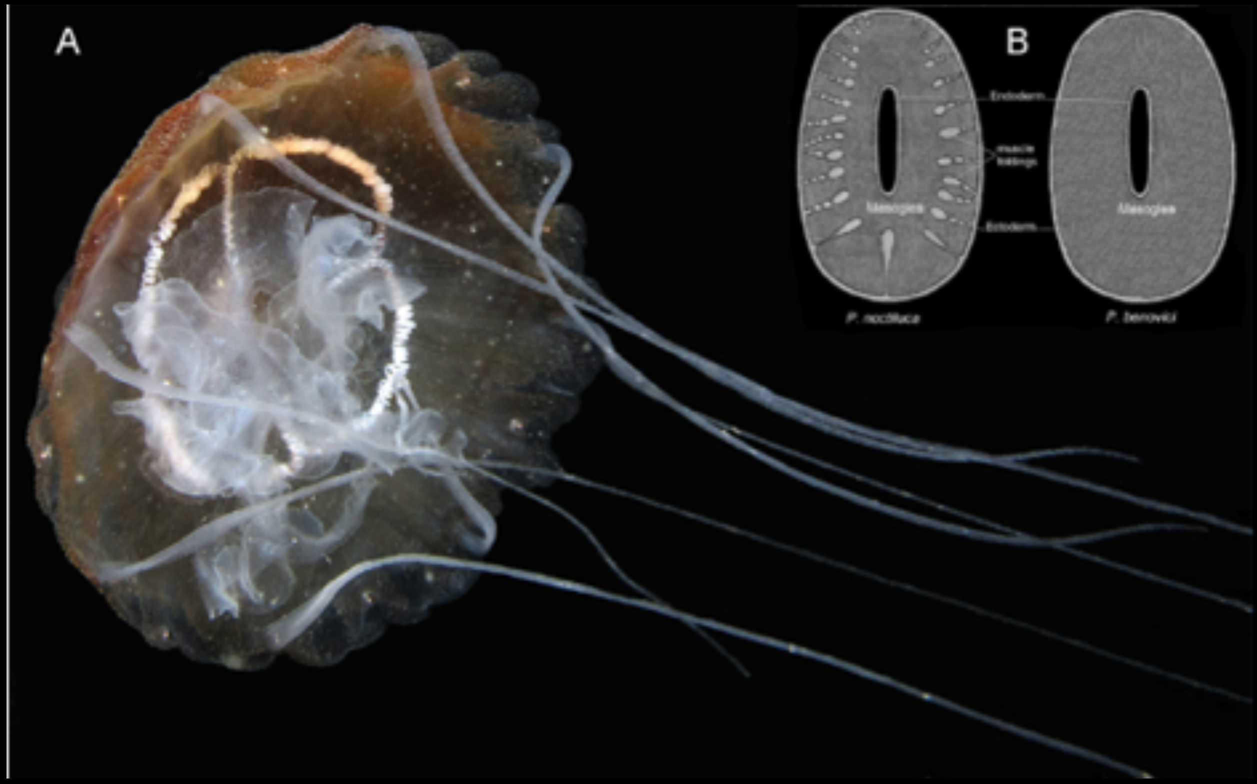


Traditional ways to measure biodiversity

- Sampling of specimens (from microbes to large vertebrates)
- analysis of specimens (both morphological and genetic)
- identification of specimens
- description of new species if the specimens are not referable to already described species
- 2 million described species
- they might be 8 millions

but this is only the beginning

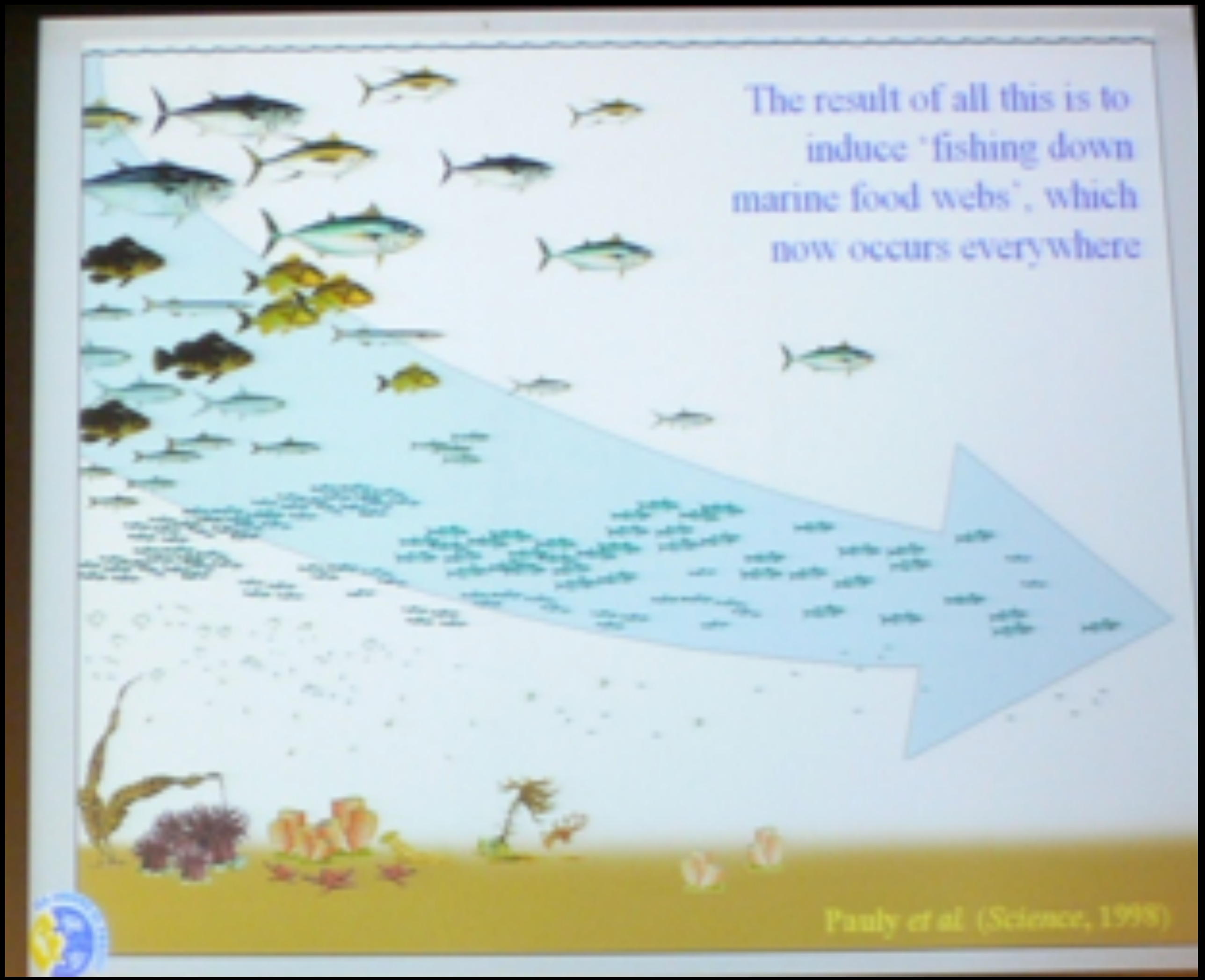
- Descriptor 2: **Non-indigenous species do not adversely alter the ecosystem**
- This is even more difficult. How to identify NIS? and how to assess if their presence is altering the ecosystem in an adverse faction?
- Is there an automated way to detect alien species?
- Is there an automated way to check the status of ecosystems in relation with the presence of NIS?



The answer is: NO!

Something feasible

- Descriptor 3: **The population of commercial fish species is healthy**
- The information comes from fisheries statistics, but we know that they are unreliable (fishermen lie).
- How to measure the health of fish populations?

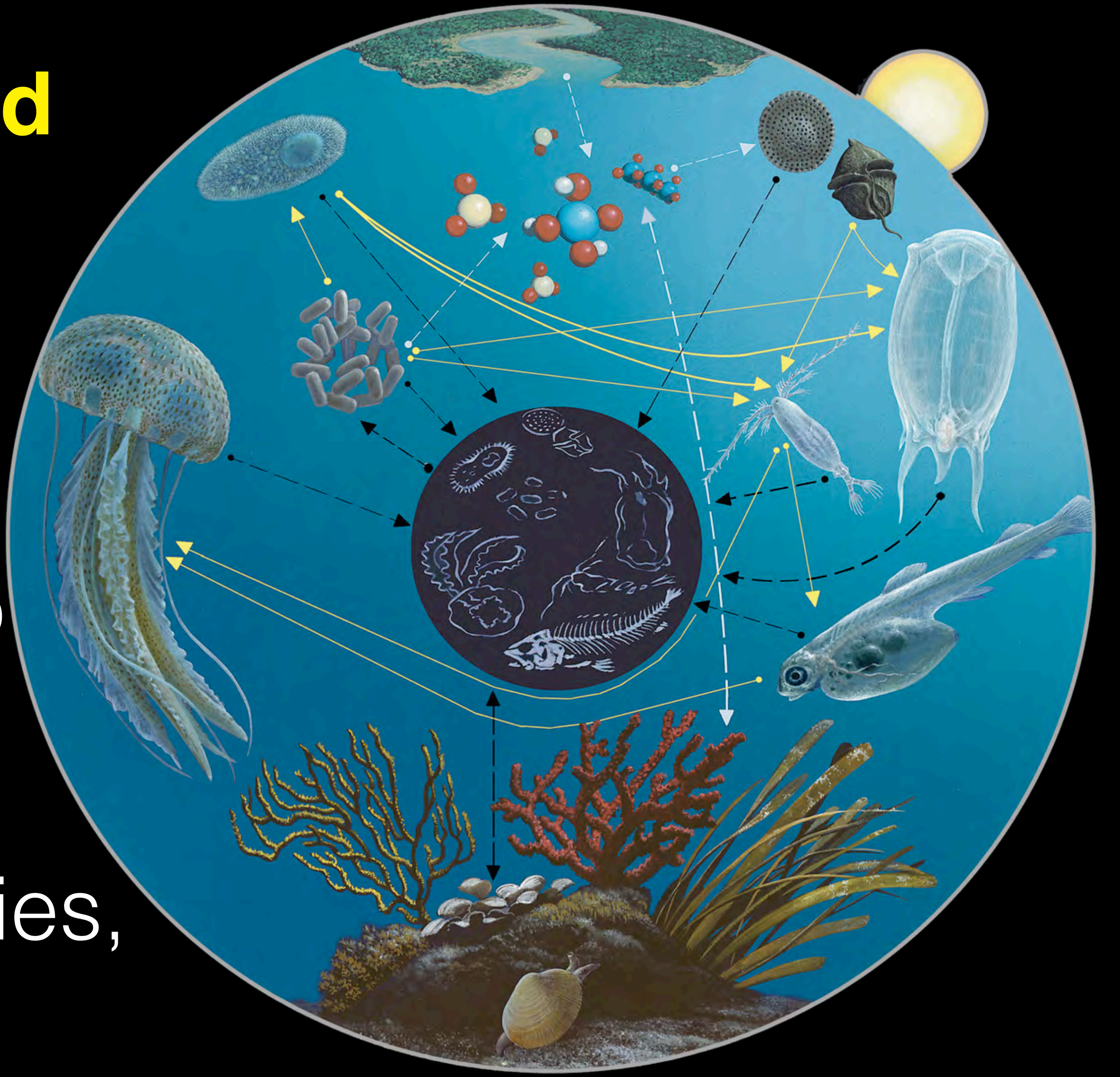


This is very difficult…

- Descriptor 4: **Elements of food webs ensure long-term abundance and reproduction**

- The elements of food webs are simply: the species, and we go back to descriptor nr 1!

- But if we do not know the species, how can we assess their abundance and reproduction?



ahhhh…. some chemistry!

- Descriptor 5: **Eutrophication is minimised**

Apparent relief: some geology!

- Descriptor 6: **The sea floor integrity ensures functioning of the ecosystem**

- But if it is easy to assess the sea floor integrity with some beautiful machine, how to assess the functioning of the ecosystem???

Apparent relief some more: physics at last!

- Descriptor 7: **Permanent alteration of hydrographical conditions does not adversely affect the ecosystem**
- Again this disturbing obsession with the ecosystem…

Back to the good old days

- Descriptor 8: **Concentrations of contaminants give no effects**
- This is beautiful and easy…. and luckily the ecosystem is not mentioned…

Monitoring fish markets

- Descriptor 9: **Contaminants in seafood are below safe levels**

Descriptor 10: **Marine litter does not cause harm**

and do not come out just with microplastics….

Dulcis in fundo

- Descriptor 11:
  Introduction of energy (including underwater noise) does not adversely affect the ecosystem

- Ecosystem again!

The philosophy behind all this

- Physics, chemistry, and geology are essential to define the status of the environment
- but they are **not sufficient**
- We focused **only** on them for a very long time
- Those days are gone
- Now we must look at the thing that makes this planet unique: **life**!

Infinite opportunities

- This revolution (i.e. realizing that life is the most important phenomenon on the planet) opens the way to unprecedented opportunities
- We must develop machines that keep biodiversity under control
- Biologists and engineers have lots of work to do and they must do it together…

F1000Research
F1000Research 2013, 2:181 Last updated: 10 SEP 2013

OBSERVATION ARTICLES

A salp bloom (Tunicata, Thaliacea) along the Apulian coast and in the Otranto Channel between March-May 2013 [v1; ref status: awaiting peer review, http://f1000r.es/1ok]

Ferdinando Boero[1,2], Genuario Belmonte[1], Roberta Bracale[1], Simonetta Fraschetti[1], Stefano Piraino[1], Serena Zampardi[1]

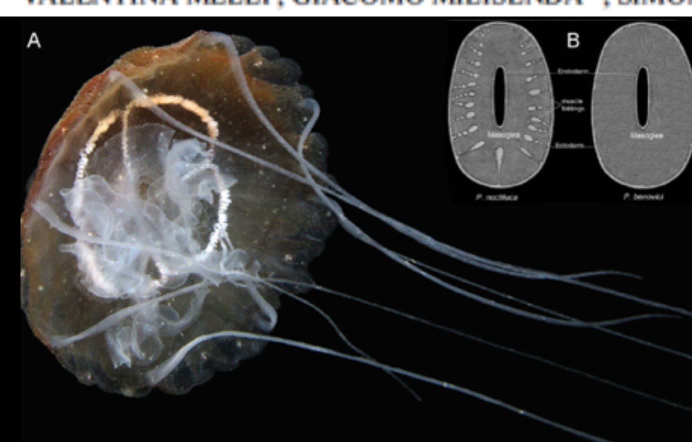
[1]Universita' del Salento, DiSTeBA, 73100 Lecce, Italy
[2]National Research Council, Institute of Marine Sciences, 16149 Genoa, Italy

Zootaxa 3794 (3): 455–468
www.mapress.com/zootaxa/
ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)
http://dx.doi.org/10.11646/zootaxa.3794.3.7
http://zoobank.org/urn:lsid:zoobank.org:pub:3DBA821B-D43C-43E3-9E5D-8060AC2150C7

Article

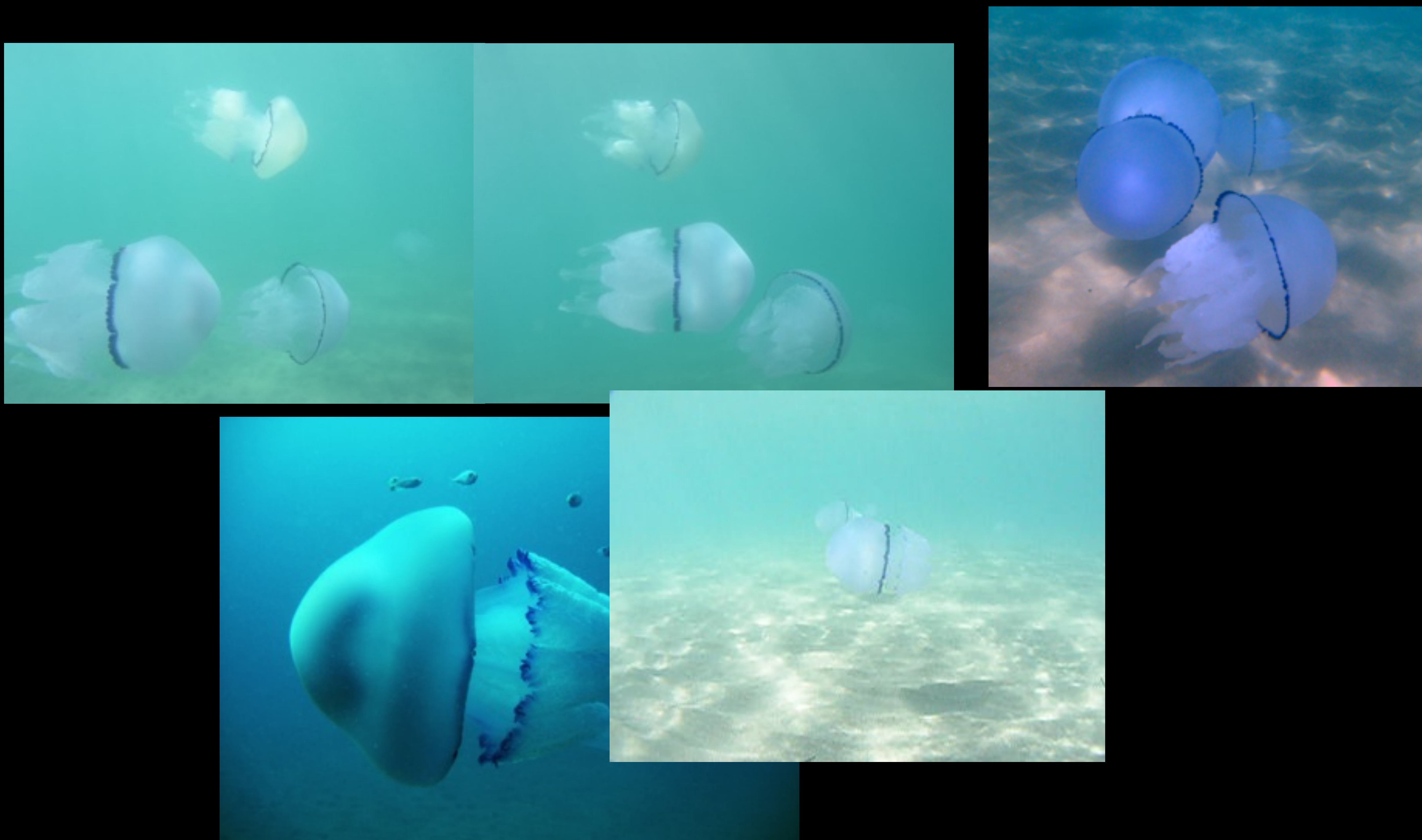
***Pelagia benovici* sp. nov. (Cnidaria, Scyphozoa): a new jellyfish in the Mediterranean Sea**

STEFANO PIRAINO[1,2,5], GIORGIO AGLIERI[1,2,5], LUIS MARTELL[1], CARLOTTA MAZZOLDI[3], VALENTINA MELLI[3], GIACOMO MILISENDA[1,2], SIMONETTA SCORRANO[1,2] & FERDINANDO BOERO[1,2,4]



These findings have hit the media in a massive way promoting a series of projects dedicated to improve our understanding of environmental issues in the marine realm

Resident bloom at Taranto



When faced with a difficult question, we often answer an easier one instead, usually without noticing the substitution.

But, this time, those who pose the question (the biologists) will notice the trick and will not accept substitutions

CURRENT TRENDS IN PROFESSIONAL DIVING EQUIPMENT: ANY ROOM FOR ROBOTICS?

EMRA '14 Workshop
CNR, Rome
June, 09th – 10th 2014

www.cns-international.com

EMRA'14

INTRODUCTION

- **Point of view: diving contractor's perspective**

INTRODUCTION

- **Point of view: diving contractor's perspective**

- **Scope of this presentation: two questions**

1) Any room for robotics in professional diving?

2) Why should robotics be interested in professional diving and vice versa?

- **Structure:**
  - Introduction to O&G Offshore Diving Market
  - Introduction to CNS International srl
  - Diving & Robotics: Current Trends
  - Diving & Robotics: Potential Developments
  - Diving & Robotics: Barriers to Entry
  - Conclusions

EMRA'14

Offshore Diving for Oil & Gas Industry

- **O&G Offshore Diving Market**
- CNS International srl
- D & R: Current Trends
- D & R: Potential Developments
- D & R: Barriers to Entry
- Conclusions

EMRA'14

Industrial Diving: Past, Present & Future

•**Beginning:** Developing Offshore Oil & Gas Industry – Exploring diving possibilities

•**O&G Offshore Diving Market**
•CNS International srl
•D & R: Current Trends
•D & R: Potential Developments
•D & R: Barriers to Entry
•Conclusions

EMRA'14

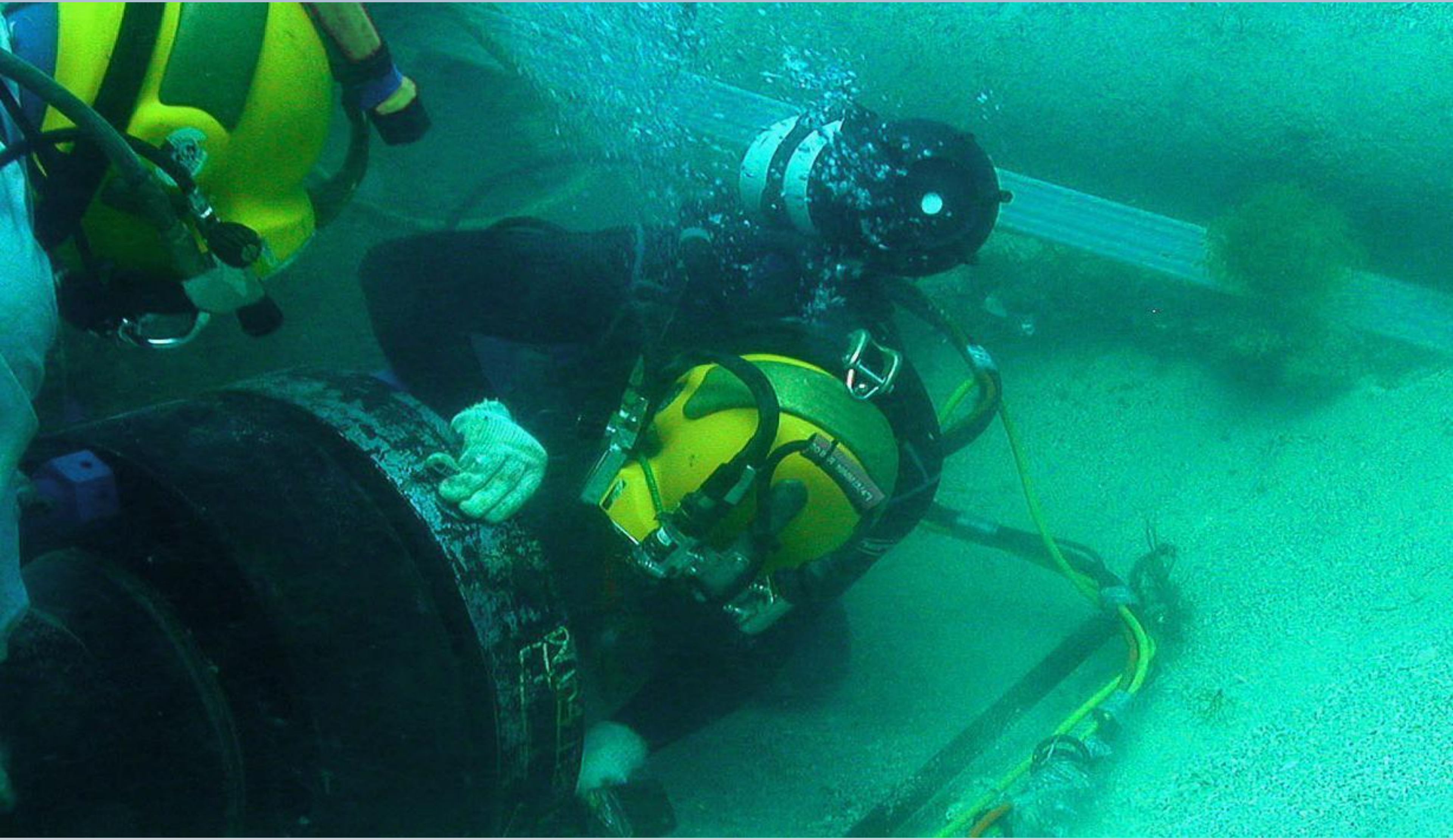
Industrial Diving: Past, Present & Future

•**Beginning:** Developing Offshore Oil & Gas Industry – Exploring diving possibilities

•**Present:** Current diving activities – Safety, Skills and Performance

- 200 HP
- Up to - 3000 / - 4000 msw
- 300 kg payload
- 1200 kgf bollard pull in each direction

Section 1 - Offshore Diving for Oil & Gas Industry



- **O&G Offshore Diving Market**
- CNS International srl
- D & R: Current Trends
- D & R: Potential Developments
- D & R: Barriers to Entry
- Conclusions

EMRA'14

Industrial Diving: Past, Present & Future

- **Beginning:** Developing Offshore Oil & Gas Industry – Exploring diving possibilities

- **Present:** Current diving activities – Safety, Skills and Performance

  - **Air Diving:** 0 - 50 msw
  - **Sat diving:** 30 – 300 msw
  - **ROV (Remotely Operated Veichle):** 0 – 6000 msw
  - **AUV (Autonomous Underwater Vehicle)**

EMRA'14

Industrial Diving: Past, Present & Future

•**Beginning:** Developing Offshore Oil & Gas Industry – Exploring diving possibilities

•**Present:** Current diving activities – Safety, Skills and Performance

•**Future:** Trends – Increase Safety & Performances rather than Water Depth

EMRA'14

CNS International srl

- **+30 years experience**
- **worldwide operations**
- **high end clients**
- **highest standards**
- **+850.000 manhours in Saturation habitat (last 10 years)**

EMRA'14

CNS International srl

- +30 years experience
- worldwide operations
- high end clients
- highest standards
- +850.000 manhours in Saturation habitat (last 10 years)

IMCA Contractor Member
International Marine Contractors Association www.imca-int.com

REPSOL
TOTAL
ExxonMobil
eni
saipem
ارامكو السعودية
Saudi Aramco

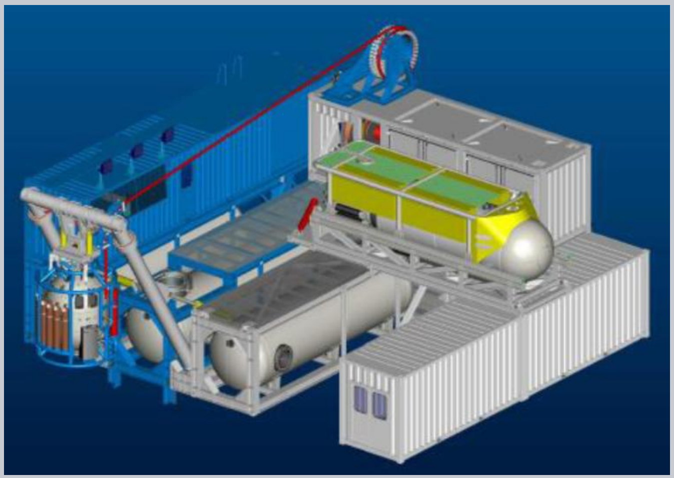
CERTIFIED QUALITY MANAGEMENT SYSTEM ISO 9001:2008
SINCERT DNV

FPAL empowered by Achilles Registered

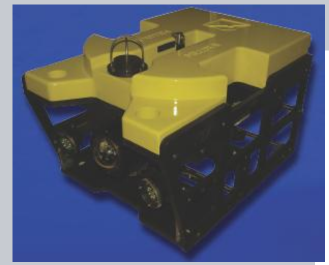
EMRA'14

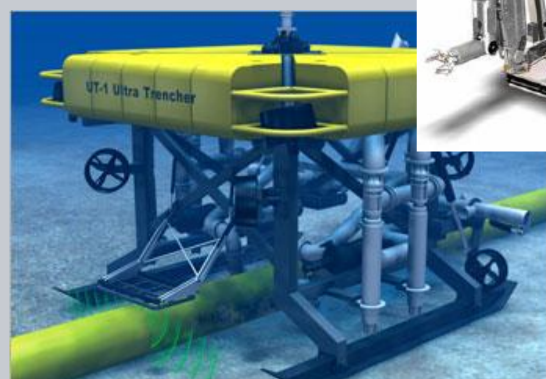
Industrial Diving and Robotics Present Scenarios

Diving System Automation



Un-Manned Operations

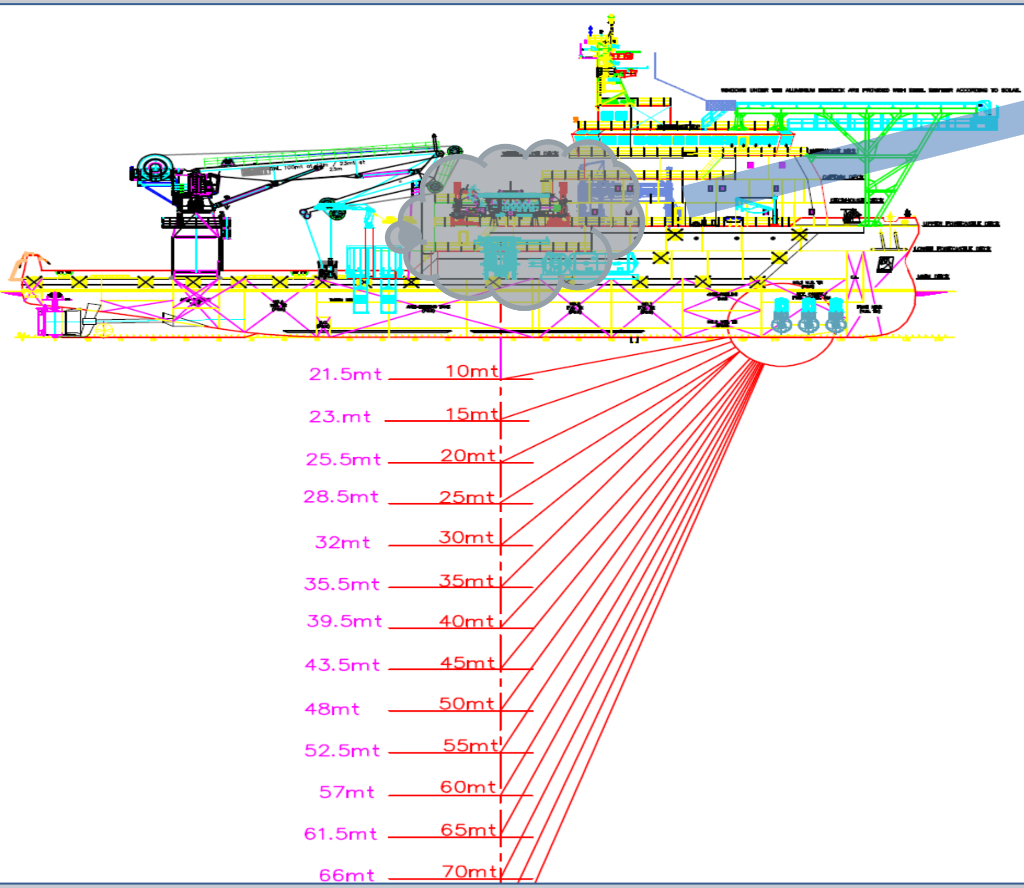




Credits to: Perry Slingsby, SMD, Modus, Kongsberg

- O&G Offshore Diving Market
- CNS International srl
- **D & R: Current Trends**
- D & R: Potential Developments
- D & R: Barriers to Entry
- Conclusions

Industrial Diving and Robotics Potential Developments

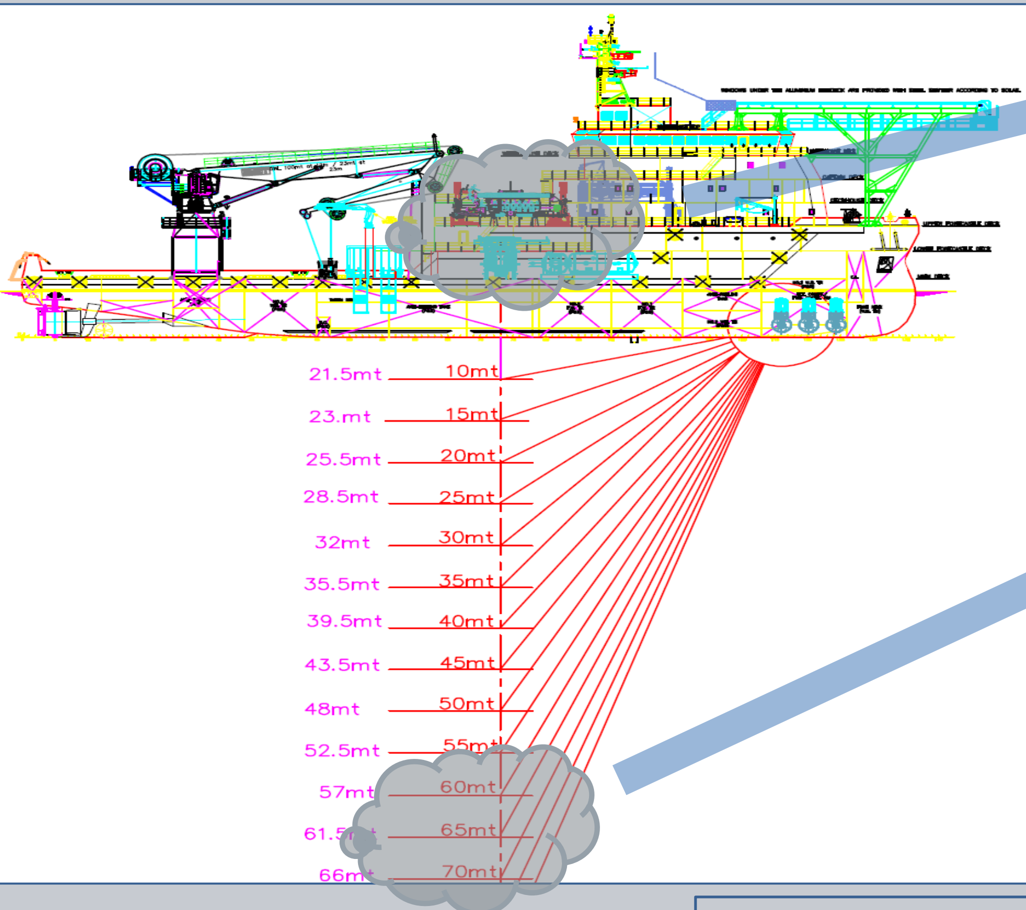


TOPSIDE

- Diving System Automation
- Life Support Automation
- Vessel Integration
- *Telemedicine*

EMRA'14

Industrial Diving and Robotics Potential Developments



TOPSIDE

- Diving System Automation
- Life Support Automation
- Vessel Integration
- *Telemedicine*

UNDERWATER

- Sheltering / emergency monitoring
- Divers monitoring in low visibility
- Independent Activities

EMRA'14

Industrial Diving and Robotics: A straight path?

HSE

CULTURE

SPECIFIC & RELIABLE

LEGISLATION & REGULATION

ENVIRONMENT

- O&G Offshore Diving Market
- CNS International srl
- D & R: Current Trends
- D & R: Potential Developments
- **D & R: Barriers to Entry**
- Conclusions

EMRA'14

Back to Questions

1) Any room for robotics in professional diving?

Topside & Underwater Diving Team Support

Underwater side activities

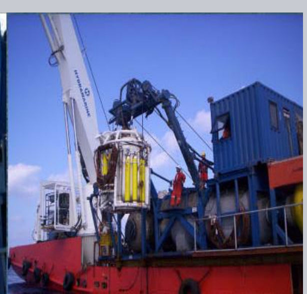
2) Why should robotics be interested in professional diving and vice versa?

Safety Impact

Unique Environment

Unexplored Market

Performance Improvement

- O&G Offshore Diving Market
- CNS International srl
- D & R: Current Trends
- D & R: Potential Developments
- D & R: Barriers to Entry
- **Conclusions**

EMRA'14

CNS INTERNATIONAL

INDUSTRIAL DIVING

YOUR DIVING PARTNER

Thank You!

Massimo Garbo
massimo.garbo@cns-international.com

www.cns-international.com

EMRA'14 workshop

June 9-10 2014, Rome, Italy

FOLAGA and UMA: two Stories from Research to Market

alessio turetta

GRAALtech

OUTLINE

- Company Introduction
- The FOLAGA story
- The UMA story
- Current Developments

OUTLINE

- Company Introduction
- The FOLAGA story
- The UMA story
- Current Developments

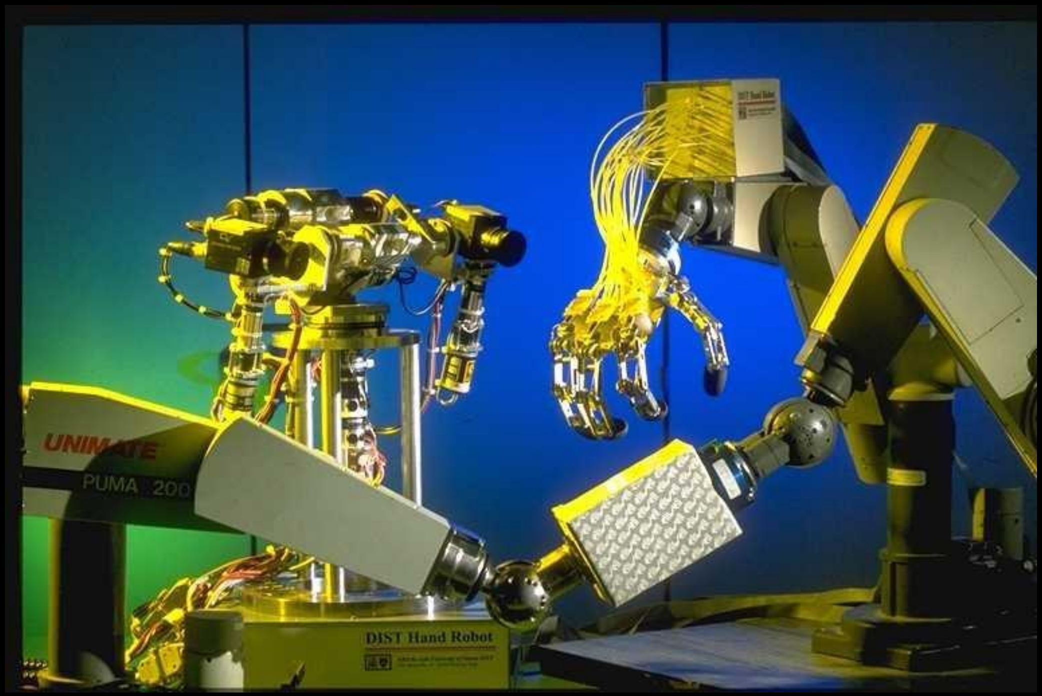
WHERE WE ARE

- Genova, Italy
  (around 500 km north from here)

THE NAME

GRAALtech

THE NAME



G.R.A.A.L. @ UNIGE
(Genoa Robotic And Automation Lab)

Prof. Pino Casalino
Director of ISME

GRAALtech

A BIT OF HISTORY…

- Established in 1998
  (as a society on campus)

A BIT OF HISTORY…

- Established in 1998
  (as a society on campus)
- Full-time operative since 2001
  (change of partnership)
- New office opened in 2007
  (around 200 squared meters)
- New hirings in the period 2011-2013
- Current headcount: 9 FTE + 4 PTE
  - 3 Ph.D engineers
  - 6 engineers
  - 2 technicians
  - 2 administrative

WHAT DO WE DO

Mission

” Create innovative mechatronic devices responding to customer demands”

Main application domain

Underwater and Marine Applications

MAIN SKILLS

- Design and development of mechatronic systems
- Robots for non standard applications (underwater, inspection, space, …)
- Custom sensors design and development
- Modeling and simulation
- Advanced control algorithms
- Real-time SW architectures
- Embedded systems (microcontrollers, DSPs, FPGAs)

LAB FACILITIES

- Mechanical workshop
- Electronic laboratory

GRAALtech

WET FACILITIES

- Mechanical workshop
- Electronic laboratory
- Pool
- Tank with sand

GRAAL tech

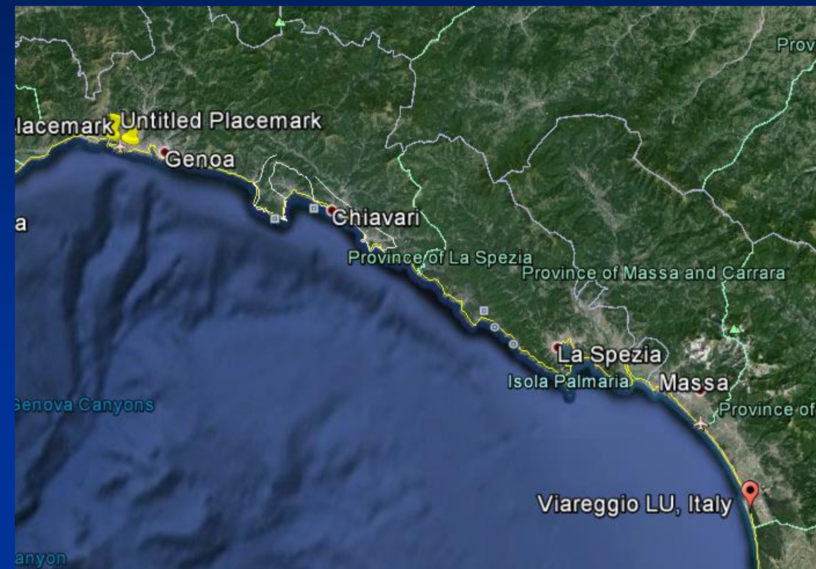
WET FACILITIES

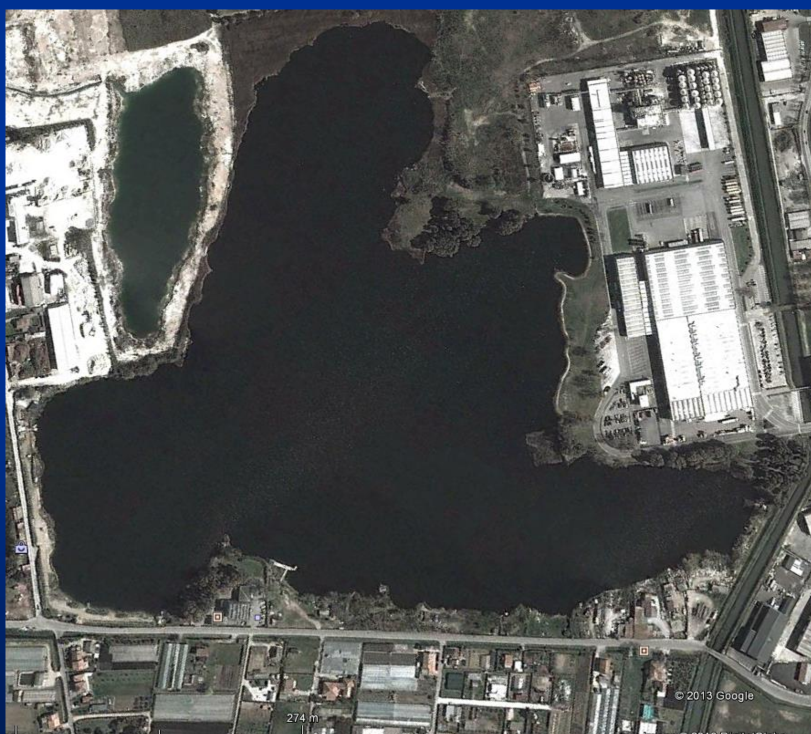
- Easy access to sea

GRAALtech

WET FACILITIES

- Easy access to sea
- Easy access to Viareggio lake
  (120 km from Genova)





GRAAL tech

MAIN CUSTOMERS

Universities and Research Institutes

- CMRE - (NATO)
- ISME – Integrated Systems for Marine Environment (Italy)
- European Joint Research Centre ISPRA (Ispra)
- CNR
- National University of Singapore (Singapore)
- Fraunhofer Institute - Bonn (Germany)
- IMEDEA (Spain)
- University of Genova
- University of Verona
- University of Calabria
- University of Palermo
- University of Pisa

MAIN CUSTOMERS

Industries

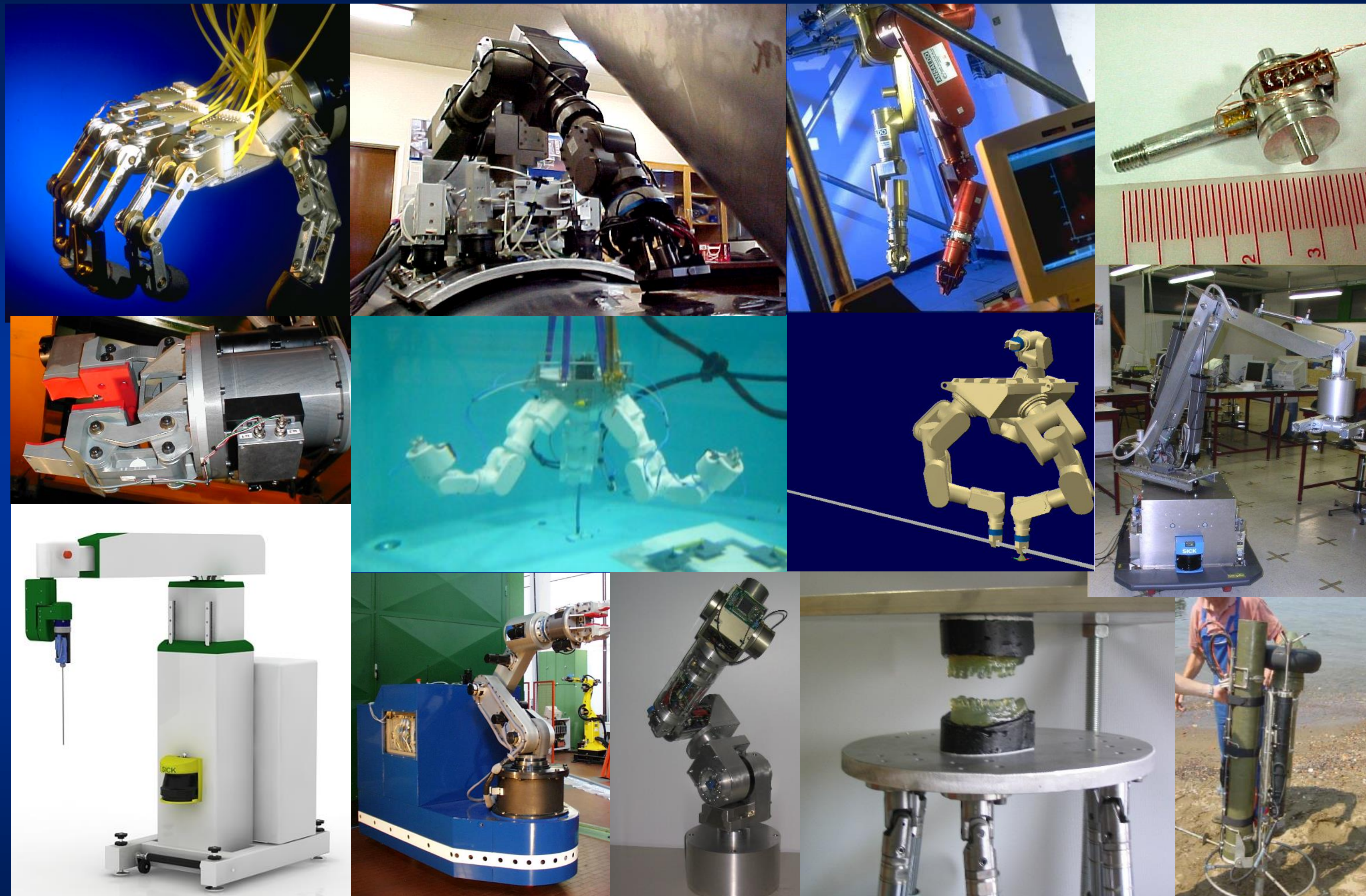
- CGG Veritas
- Harris Corporation
- Balluff GMBH
- Thales Alenia Space S.p.a.
- Selex S.I. S.p.a.
- Fantuzzi Reggiane S.p.a.
- Sofar S.p.a.
- Sirti S.p.a.
- Wind River Italia S.r.l.
- Tecnospazio S.p.a.
- Belotti Handling S.p.a.
- Osram S.p.a.
- Sciro S.p.a.

MAIN CUSTOMERS

Research Projects from Public Institutions

- EU projects
  - MEPEMS
  - HAB-BUOY
  - HISMAR
  - CO3AUVs
  - TRIDENT
  - ROBOCADEMY
- National Institutions
  - Towfish
  - SlimControl
  - Wireless Underwater Acoustic Network
  - Cormorano
  - Atlante

….OTHER PIECES OF HISTORY



GRAALtech

OUTLINE

- Company Introduction
- The FOLAGA story
- The UMA story
- Current Developments

WHAT DOES FOLAGA MEAN ?

FOLAGA is a bird …

that lives in marsh, lagoons and coastal areas. It stays on the water surface and dives at shallow depths in search of food

… but it is also an AUV

originally designed for oceanographic missions in which it had to navigate on surface and dive vertically on the point of interest for collecting measurements.

BEFORE FOLAGA (late 2002)

Dr. Alberto Alvarez, IMEDEA, NURC

«Can you Graal Tech realize a **LOW COST** profiler ?»

THE FIRST VEHICLE

2004

SUCCESSIVE DEVELOPMENTS

- Different versions realized by Graal Tech during years
  (with suggestions and technical support coming from NURC, ISME, NUS)
  - Changing the position of actuators
  - Changing the type and number of actuators
  - Changing the control electronic
  - Adding sensors
  - Adding functionalities
  - …

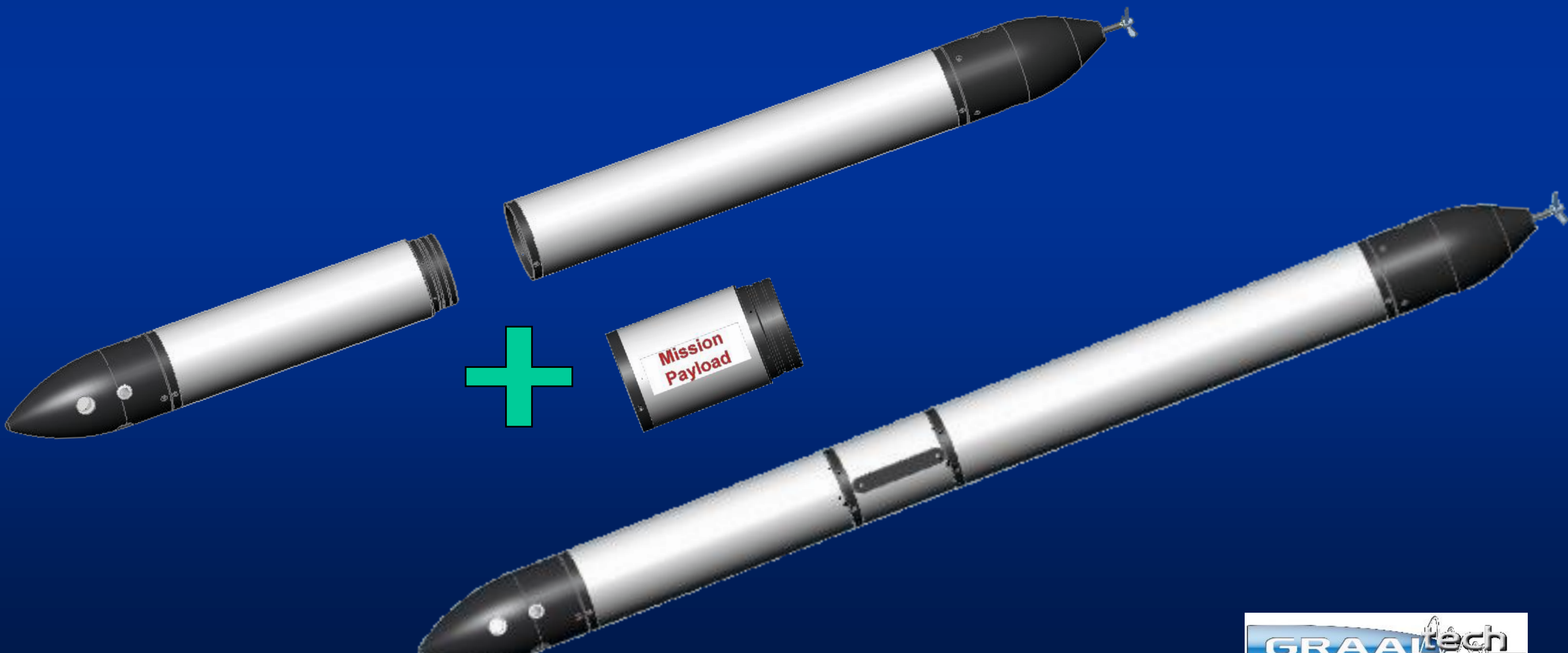
SUCCESSIVE DEVELOPMENTS

- 1st key improvement: variable buoyancy system (2006)

SUCCESSIVE DEVELOPMENTS

- 1st key improvement: variable buoyancy system (2006)

- 2nd key improvement: payload modularity (2008)



SUCCESSIVE DEVELOPMENTS

- 1st key improvement: variable buoyancy system (2006)
- 2nd key improvement: payload modularity (2008)
- Current FOLAGA generation is a unique low-cost hybrid vehicle



A Low-cost

Hybrid Vehicle

WHY LOW-COST ?

- What exactly “low” means ?
  - current price: around 40K Eur

- A low cost design…

  … maintains operational costs affordable

  … reduces impact of any losses or damages during missions

  … allows missions with a large number of deployed devices

  … enables synergic efforts from more partners

  … allows to consider every vehicle as an “expendable” device

WHY HYBRID?

"hybrid" does not always mean "strange creature"…

WHY HYBRID?

… sometimes it refers to alternative power systems…

biofuel

WHY HYBRID?

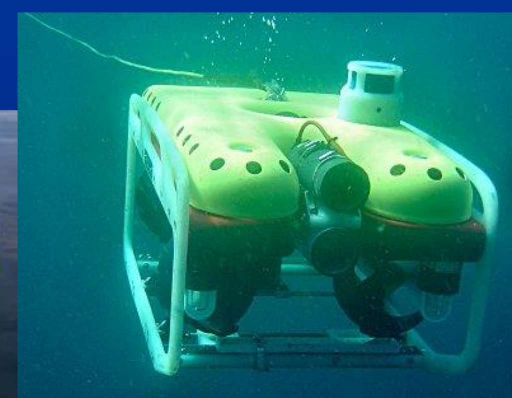
… here it refers to unusual motion capabilities …

WHY HYBRID?

… and it means: *“**3 vehicles with just one!**”*

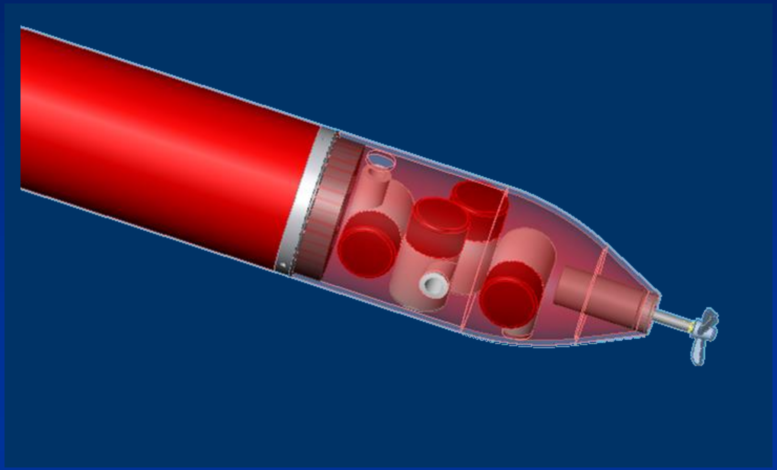
Functionalities of different classes of underwater vehicles:

- Surface and underwater navigation (AUV-like)
- Gliding capability (Glider-like)
- Vertical diving and hovering capability (ROV-like)

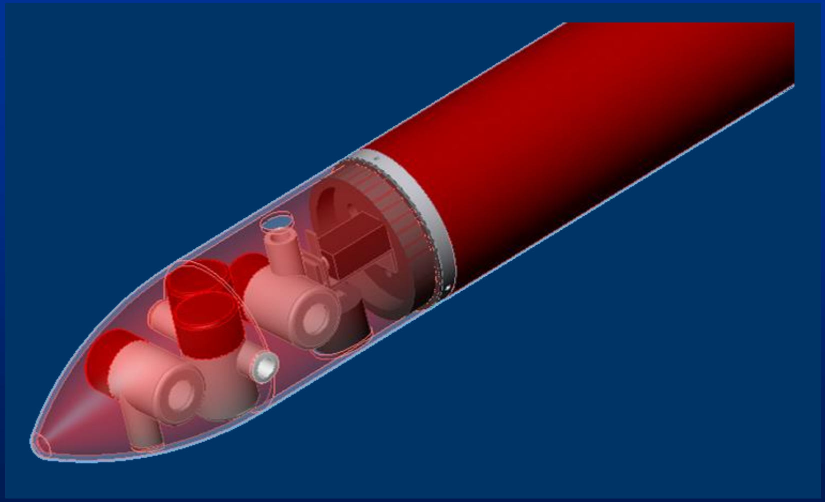


GRAALtech

FOLAGA ACTUATORS



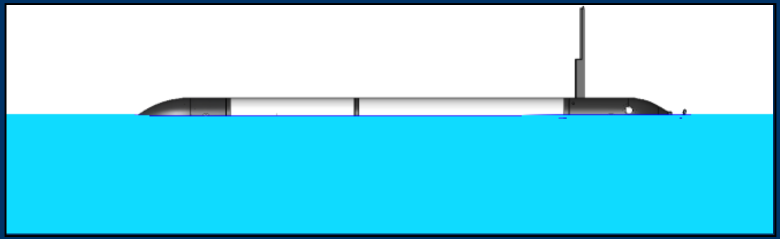
Bow cap with:
- 2 vertical (diving) pump
- 2 horizontal (steering) pumps



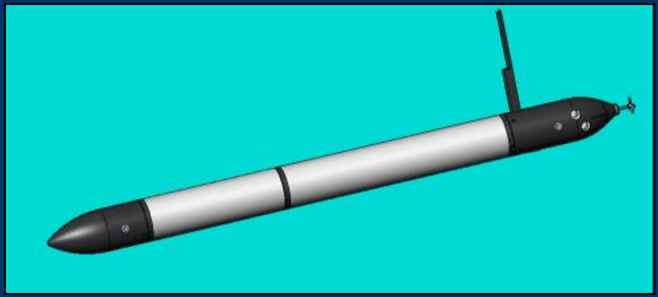
Stern cap with:
- 2 vertical (diving) pumps
- 2 horizontal (steering) pumps
- propeller

FOLAGA MANEUVRABILITY

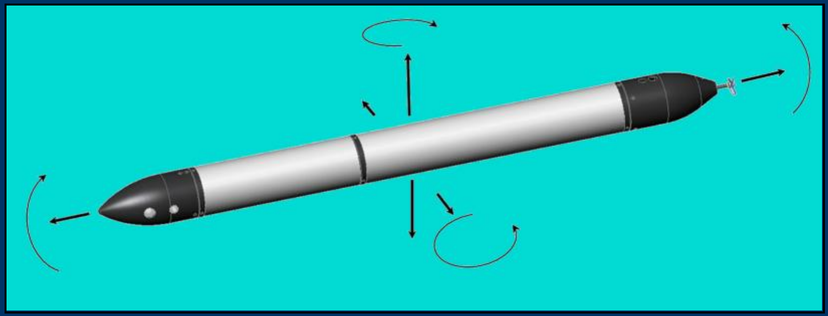
Surface navigation



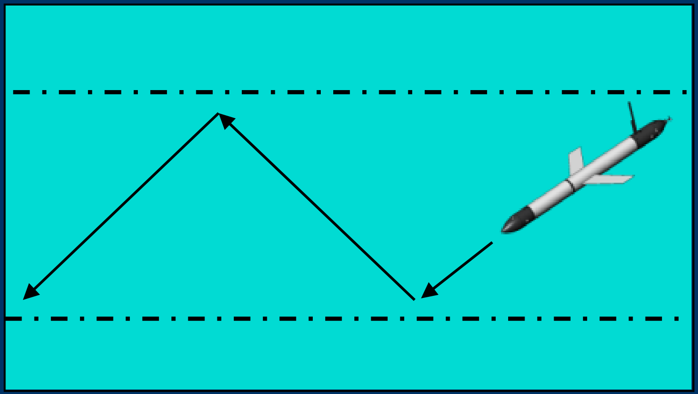
Underwater navigation



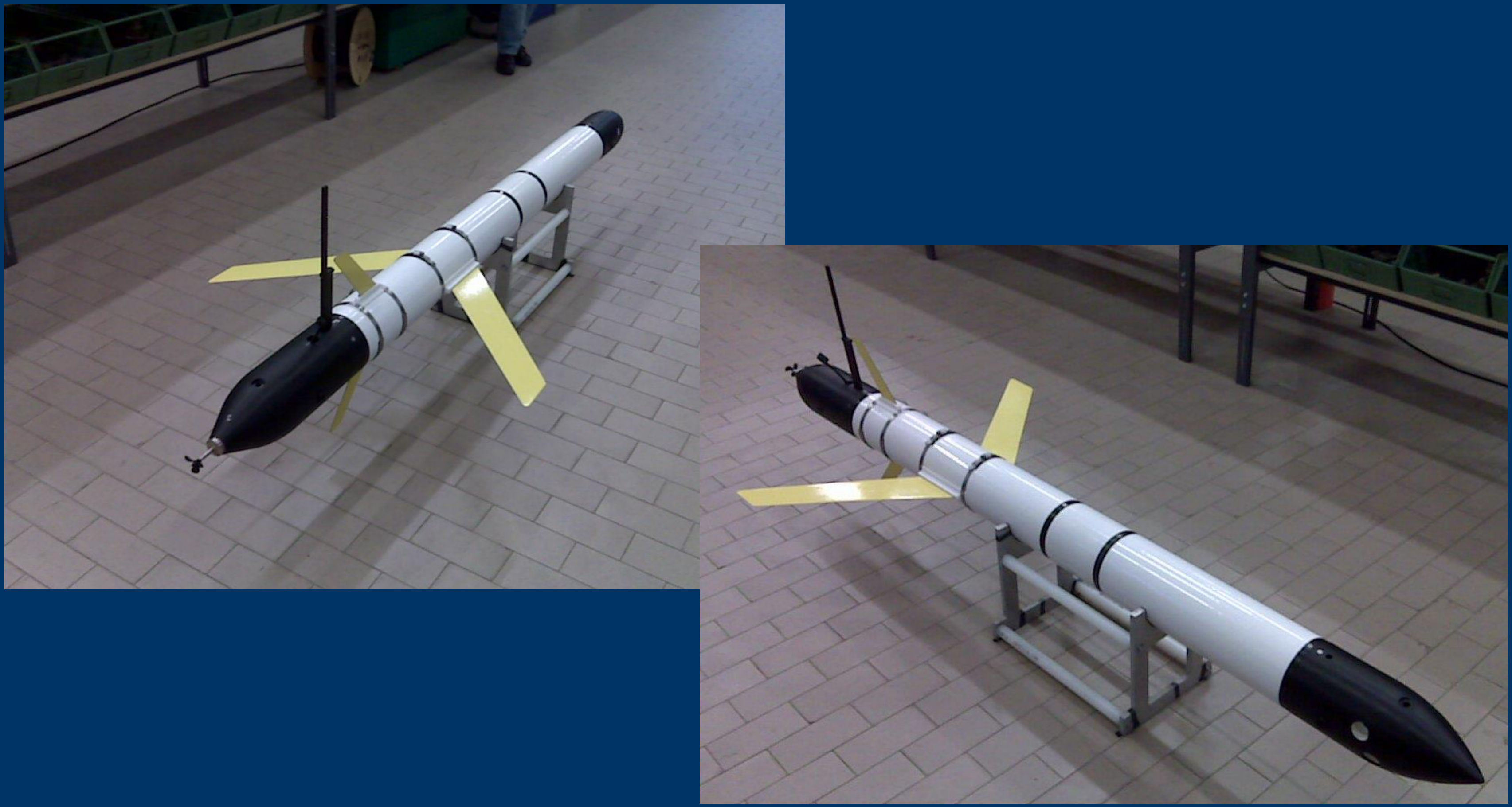
ROV capability



Glider capability

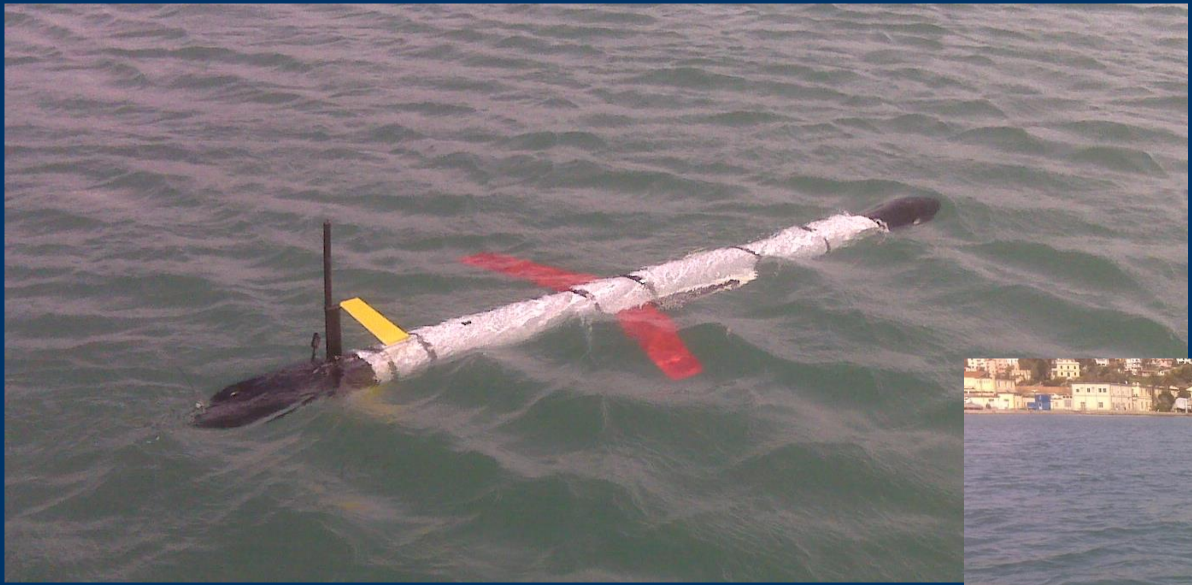


GLIDER MODE

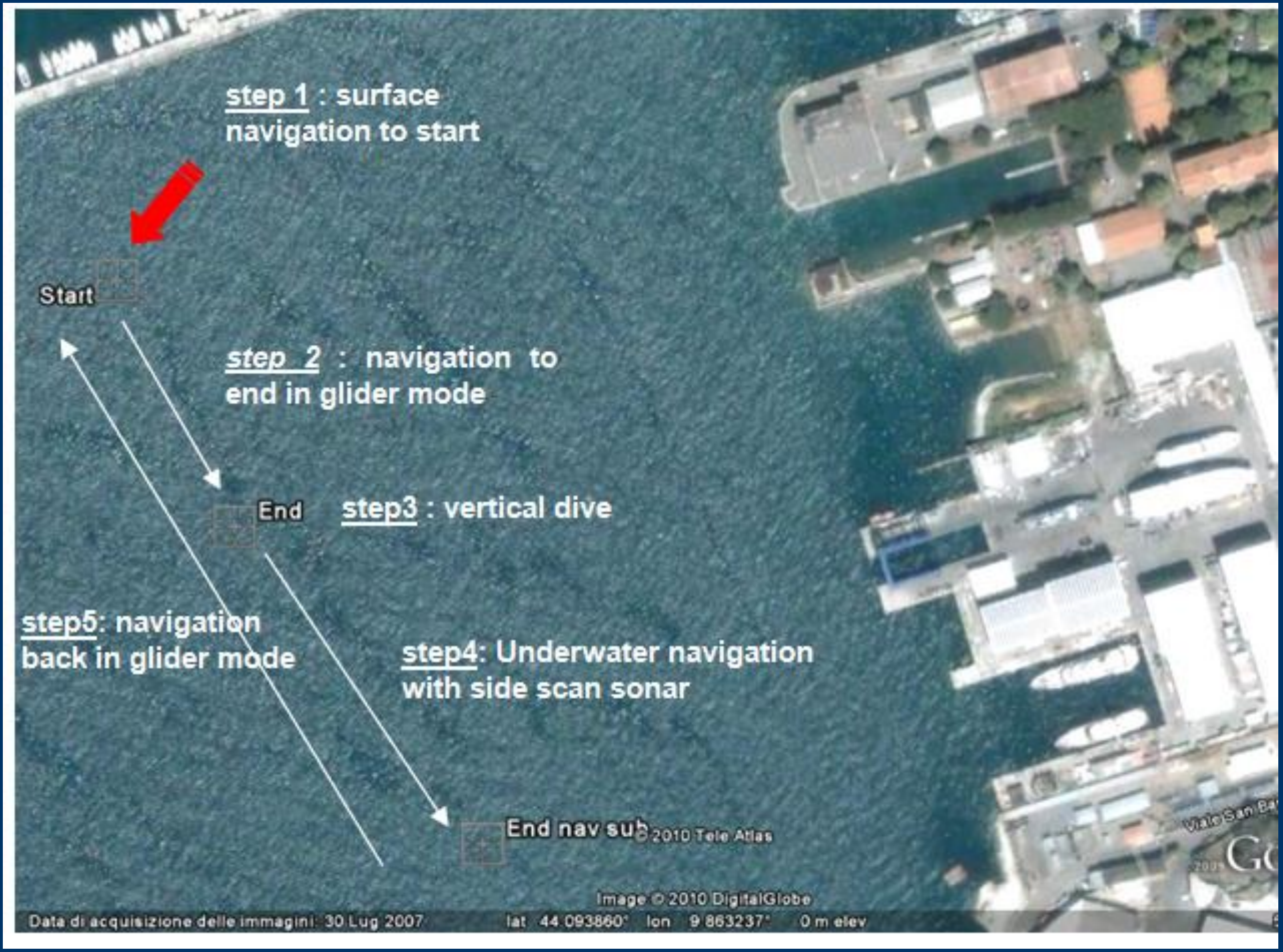


GRAAL tech

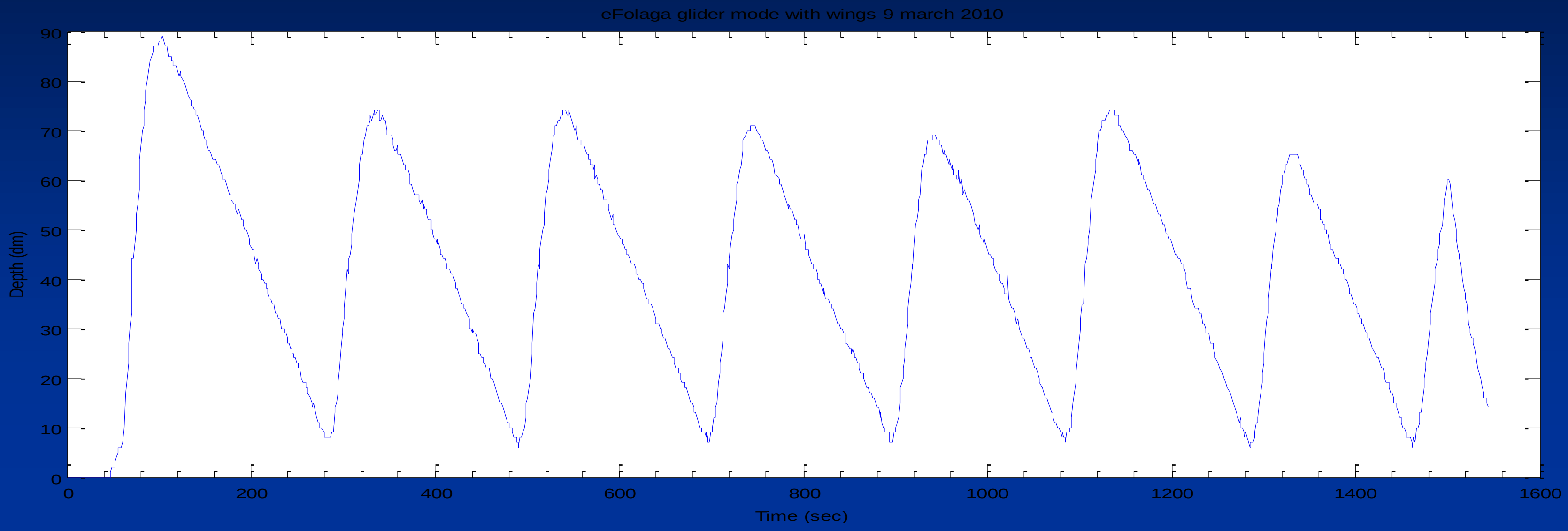
GLIDER MODE

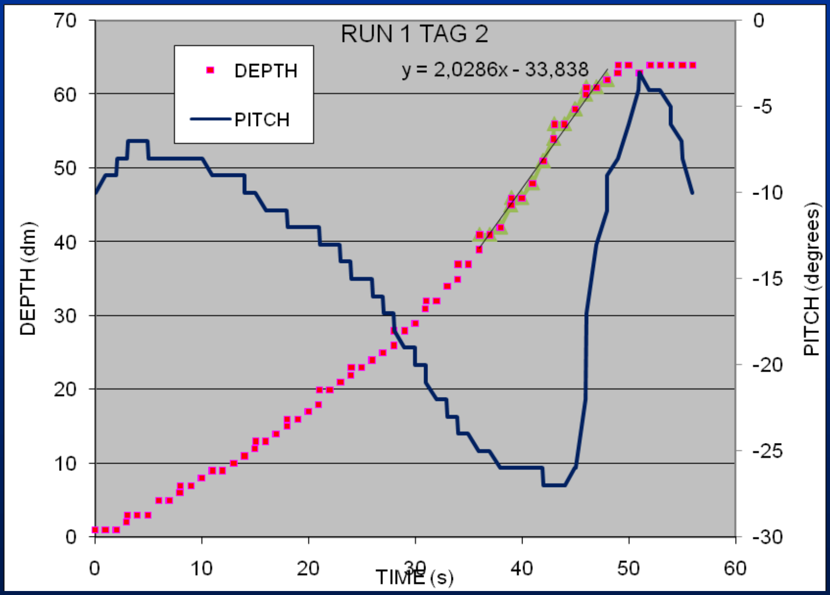


AUV/GLIDER MODE – COMBI MISSION



AUV/GLIDER MODE – COMBI MISSION





GRAALtech

MAIN FEATURES

Max length:	2222 mm
Diameter:	155 mm
Weight in air:	32 kg
Max speed:	2 knots (4 knots if required)
Max depth:	80 m (in underwater nav.)
Gliding scope:	0-50 m
Navigation sensors:	GPS (on surface), depth-meter, 3D inclinometer (yaw, pitch, roll), humidity sensor, battery charge
Communication:	multi-radio link on surface acoustic modem (optional)
Energy Storage:	NiMH Batteries 12 Volt 45 Ah
Endurance:	6 hours at max speed
Software:	Windows Graphical User Interface

FOLAGA
Payload Modules

PAYLOAD MODULARITY

SIDE SCAN SONAR MODULE

NAVIGATION MODULE

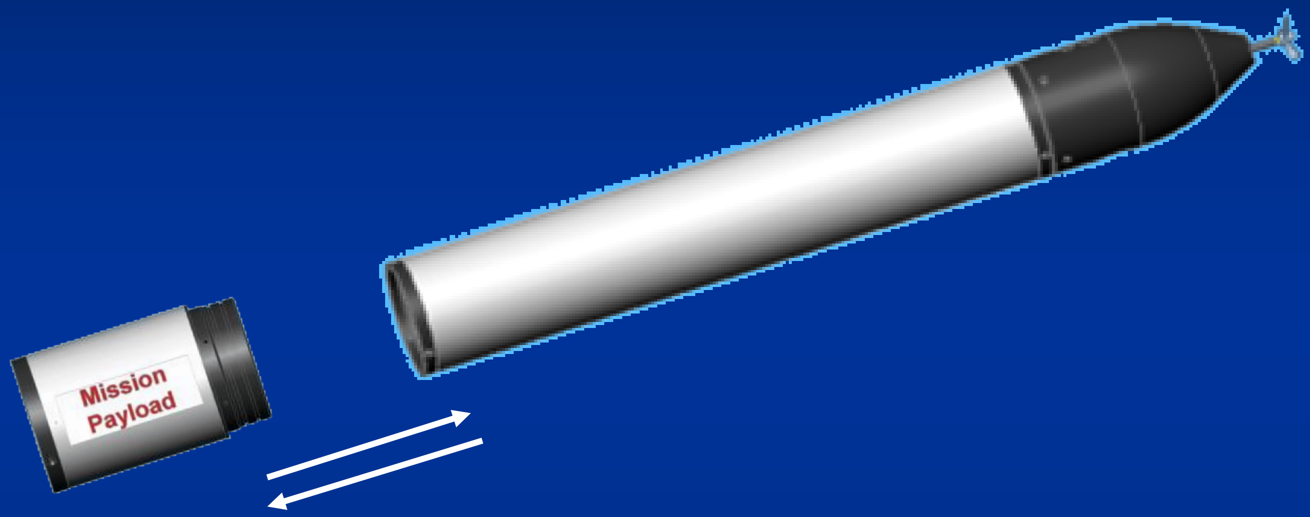
UNDERWATER COMMUNICATION MODULE

GRAAL tech

ACOUSTIC ARRAY

GRAAL tech

PAYLOAD-DRIVEN MODE



Control command / feedback through a TCP link

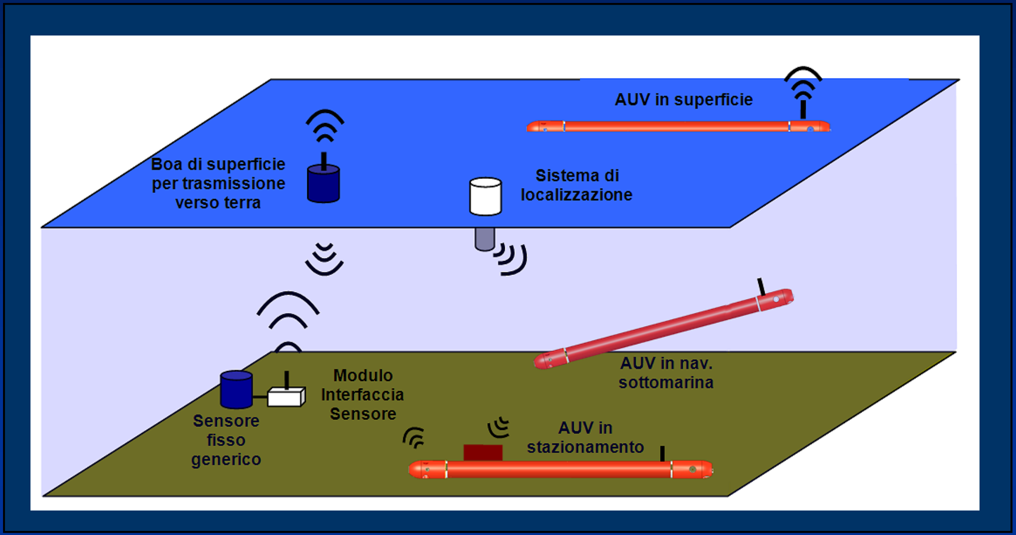
FOLAGA

Customers

DELIVERED SYSTEMS

- CMRE (Center for Maritime Research & Experimentation)
  - 5 AUV
  - Payload modules
- SIIT (Italian District on Intelligent Integrated Systems)
  - 2 AUVs
  - Payload modules
- NUS (National University of Singapore)
  - 2 AUVs
- ISME (Interuniversitary Center on Integrated Systems for Marine Env.)
  - 1 AUV @University of Salento
  - 1 AUV @University of Genova (older release)
  - 1 AUV @University of Pisa (older release)
- IMEDEA (Mediterranean Institute for Advanced Studies)
  - 1 AUV (older release)

UNDERWATER WIRELESS SENSOR NETWORK (2007-2008)



PSTL - Funded project

- Modular UWSN (Underwater Wireless Sensor Network)

Goal of the project

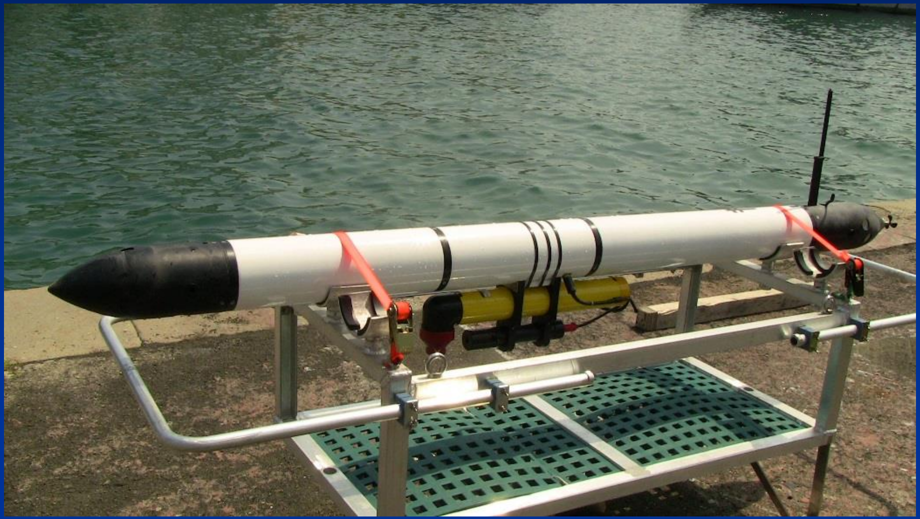
- Development of an integrated system for:
  - Acoustic Communication
  - Ground Communication
  - Underwater vehicles tracking
  - Underwater Sensors Data Acquisition

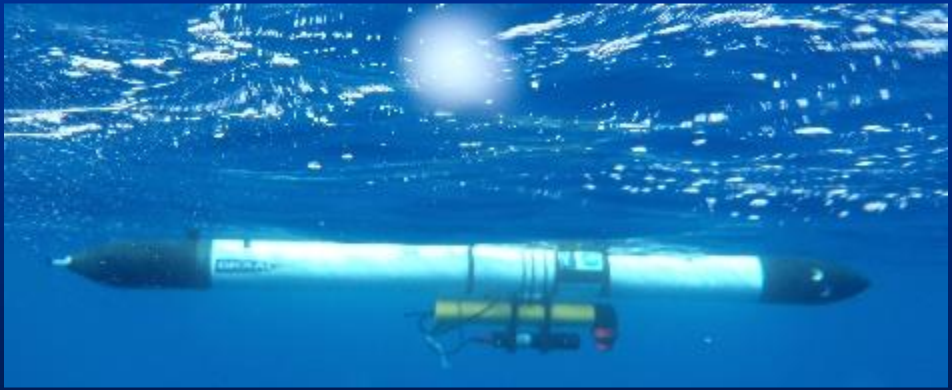
Graal Tech role

- Development of the submerged buoy for sensor acquisition and acoustic data communication
- Development of the surface acoustic-radio gateway

UNDERWATER WIRELESS SENSOR NETWORK (2007-2008)

UAN (2008-2011)





EU - STREP project

- UAN (Underwater Acoustic Network)

Goal of the project

- Development of a network of acoustically-linked heterogeneous surface and underwater devices

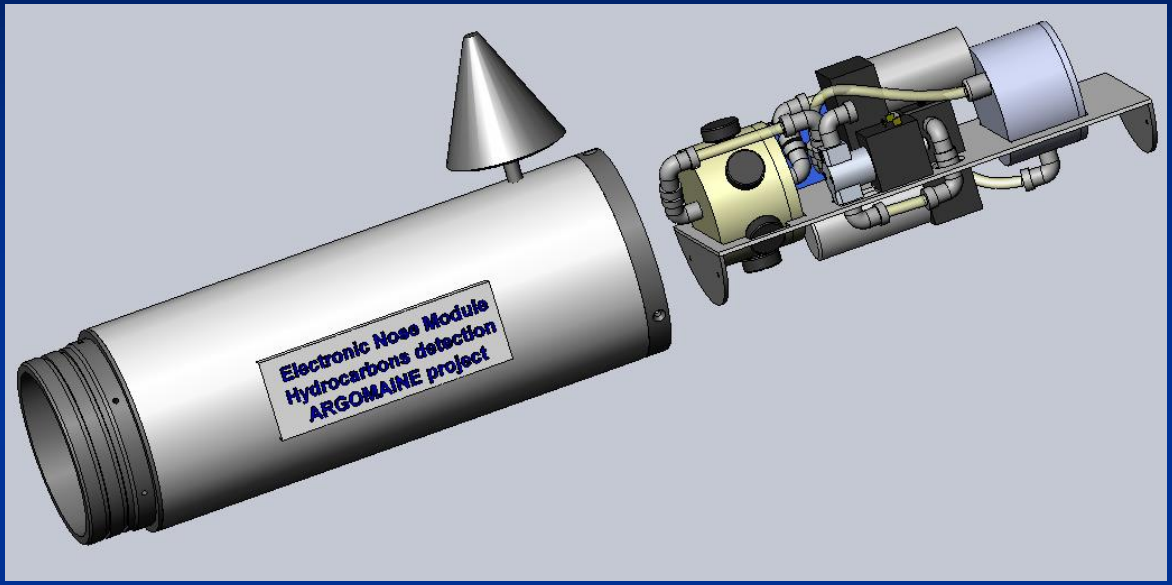
Graal Tech role

(as a subcontractor)

- Performing communication tests with a Kongsberg modem

GRAAL tech

ARGOMARINE (2009-2012)



EU - STREP project

- ARGOMARINE (Automatic oil-spill recognition and geopositioning integrated in a marine monitoring network)

Goal of the project

- Development of devices for marine environmental monitoring

Graal Tech role

(as a subcontractor)

- Development of an eFOLAGA electronic nose module for Hydrocarbons detection

ARGOMARINE (2009-2012)

SLIMCONTROL (2010-2012)

Liguria Region funded project

- Slimcontrol

Goal of the project

- Development of an integrated system for environmental and safety monitoring within the first mile of sea

Graal Tech role

- Development of a gateway buoy for controlling FOLAGA vehicles and interrogating submerged buoys

GRAAL tech

CO^{3}AUV (2009-2012)

EU - STREP project

- CO^{3}AUVs (Cooperative Cognitive Control of Autonomous Underwater Vehicles)

Goal of the project

- Development of a team of cooperating AUVs for different kinds of mission

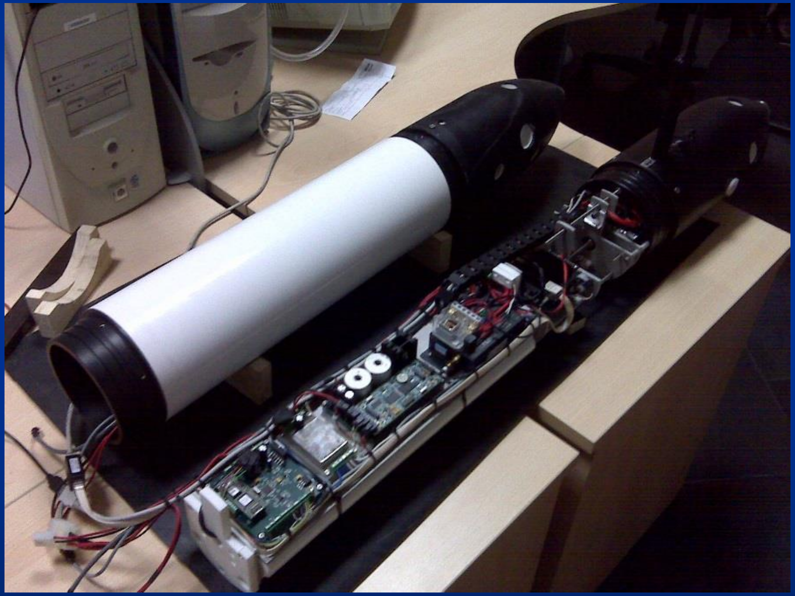
Graal Tech role

- Development of the underwater coordination infrastructure

CO^{3}AUV (2009-2012)

Graal Tech main activities

- A software framework enabling underwater communication and localization of multiple AUVs has been developed and validated



WHOI Micromodem

CO^{3}AUV (2009-2012)

Graal Tech main activities

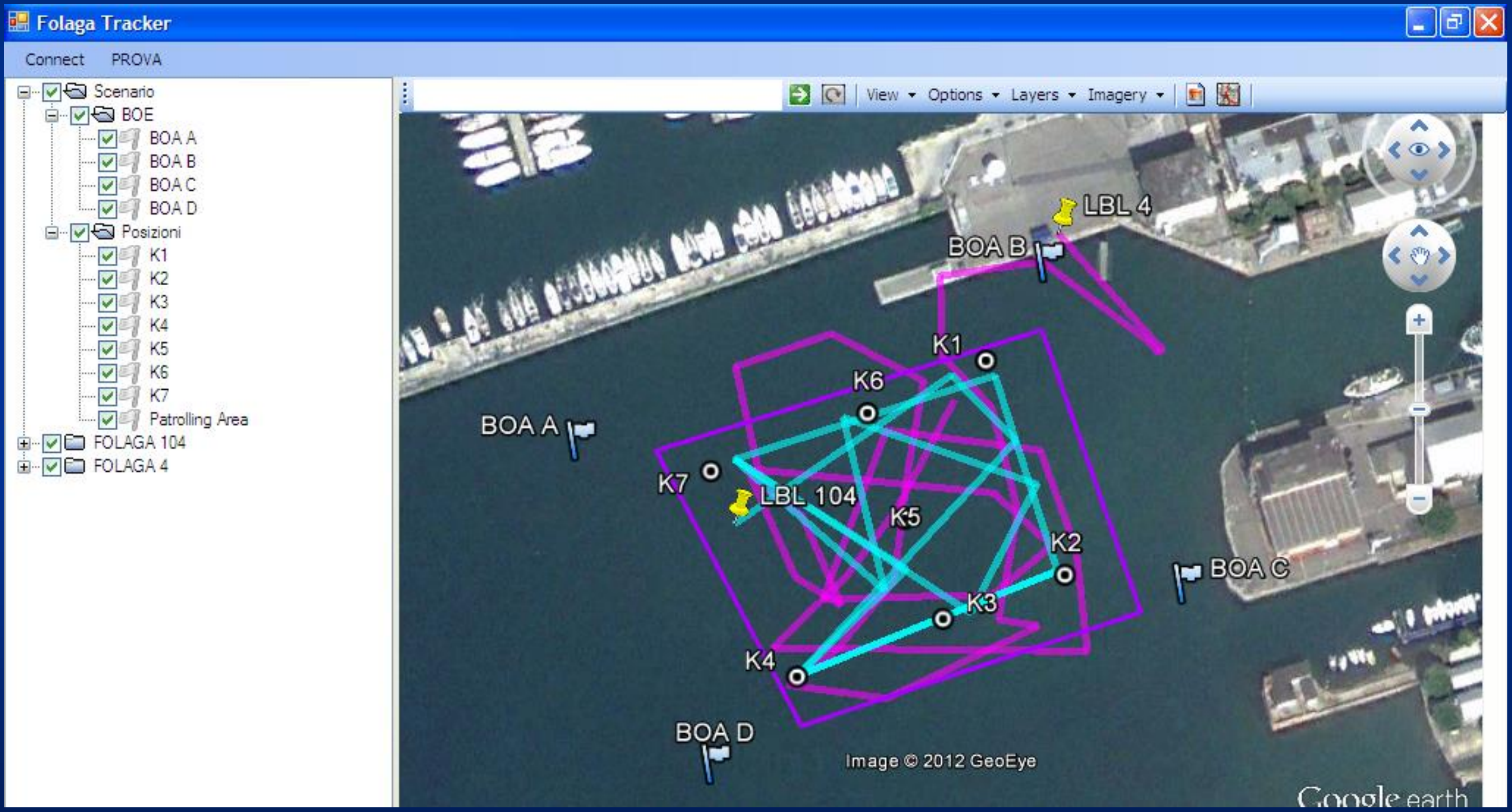
- A gateway buoy was employed for
  - Monitoring the mission execution
  - Sending commands to the team of AUVs

GRAAL tech

CO^{3}AUV (2009-2012)

Graal Tech main activities

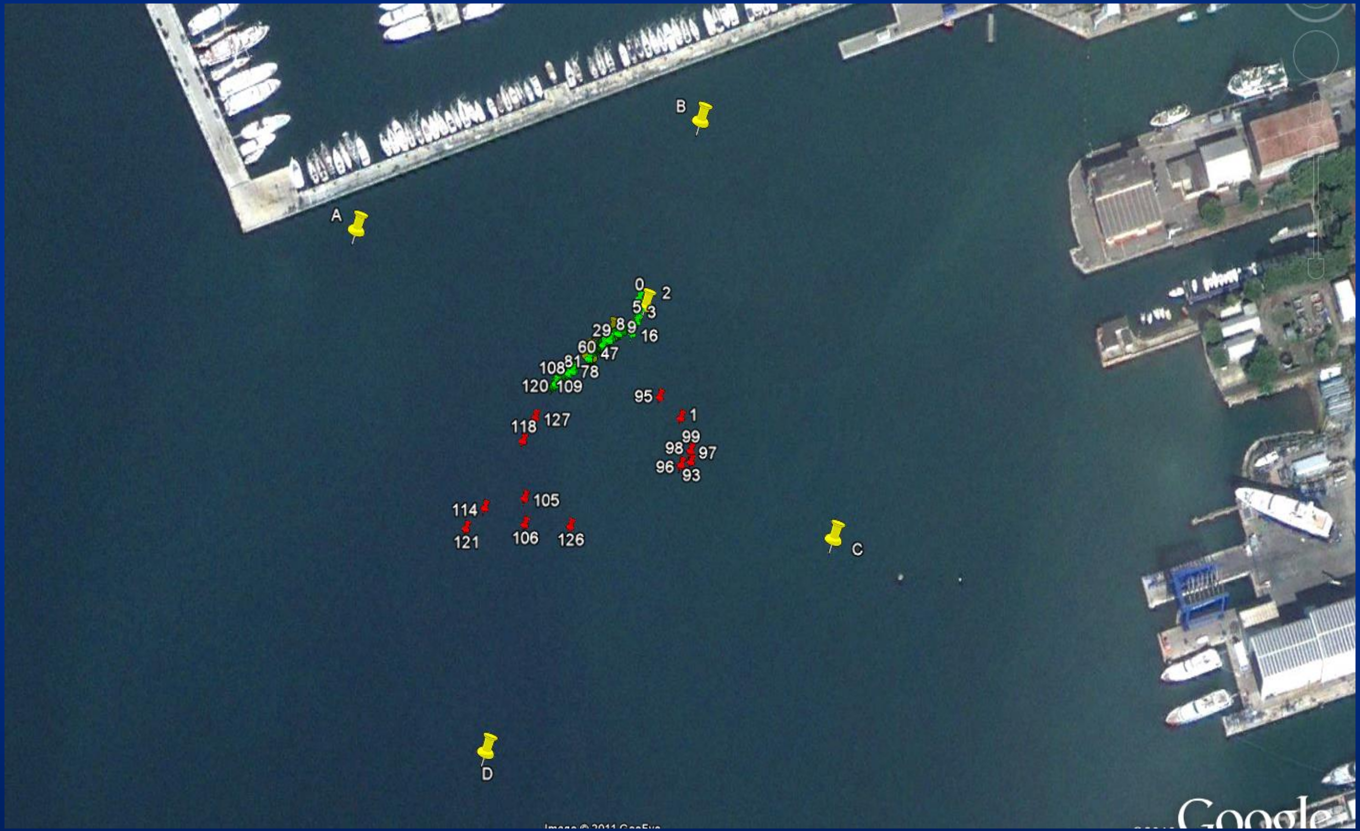
- A Multi-AUVs Software GUI has been developed



CO³AUV (2009-2012)

Graal Tech main activities

- A new LBL trilateration-based algorithm has been developed…

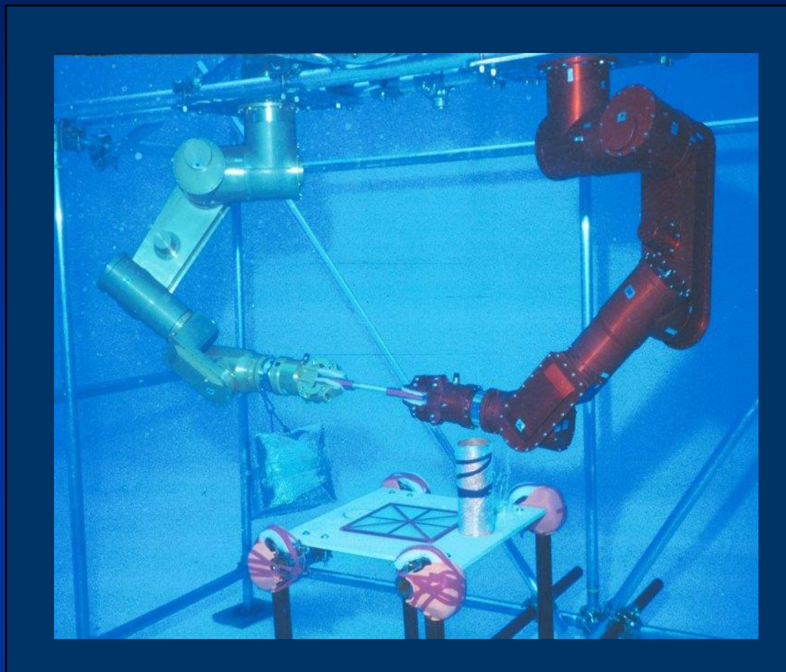


published at OCEANS 2011, Kona, Hawaii, USA, September 2011

OUTLINE

- Company Introduction
- The FOLAGA story
- The UMA story
- Current Developments

BEFORE UMA: AMADEUS@UNIGE (1997-1999)

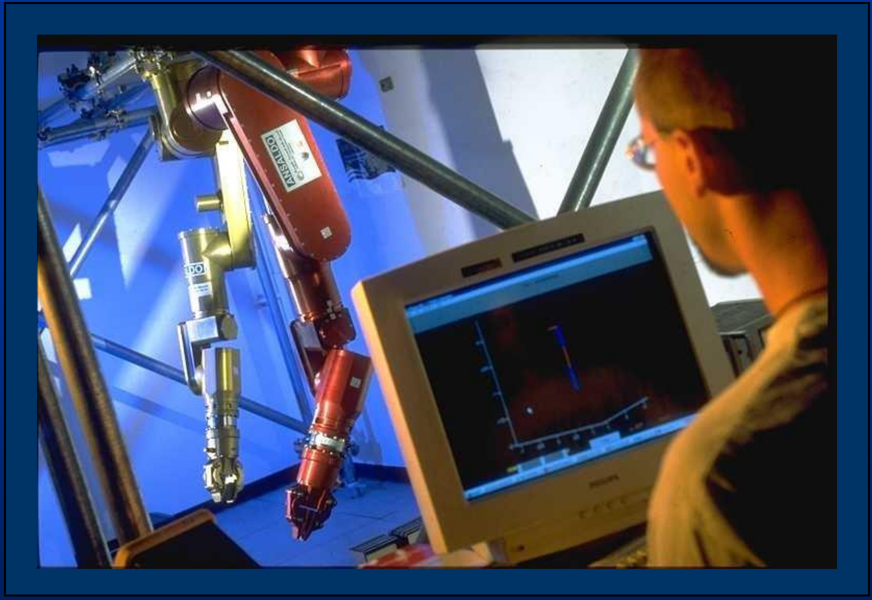


EU project

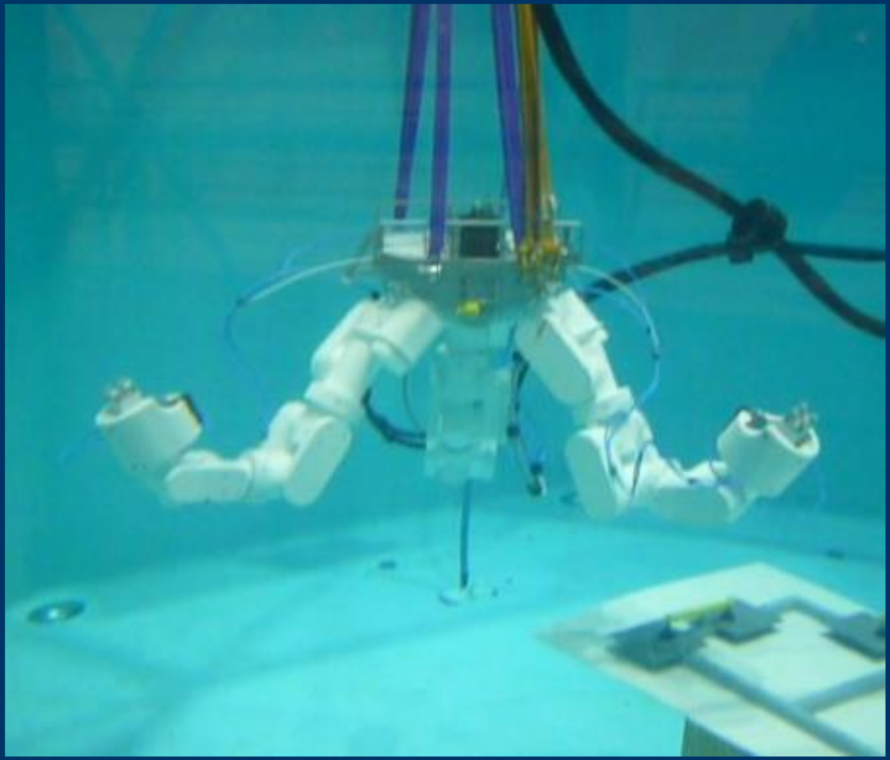
- AMADEUS (Advanced MAnipulation for DEep Underwater Sampling)

Goal of the project

- Building an underwater dual-arm cell for performing manipulation on the seabed



BEFORE UMA: EWM (Eurobot Wet Model) (2005-2006)



Customer

- Alcatel Alenia Space for ESA

Goal of the project

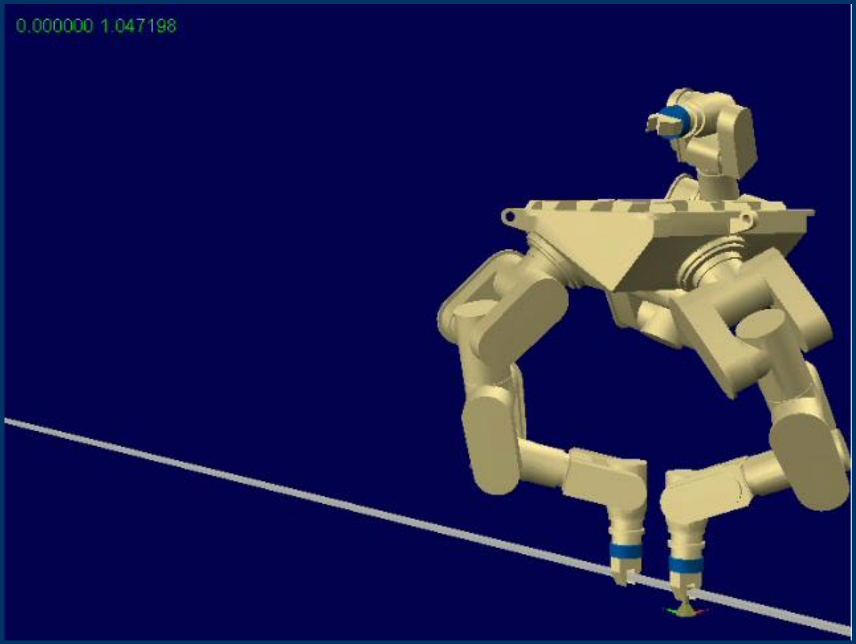
- Realization of a 3-arms robotic system for training astronauts at the Eurobot maneuvering

Graal Tech role

- Design and development of the 7 d.o.f. manipulators
- Definition of the control system algorithms and architecture

GRAAL tech

EWM (Eurobot Wet Model) (2005-2006)



THE TRIDENT PROJECT

TRIDENT (2010-2013)

EU - STREP project

- TRIDENT (Marine Robots and Dexterous Manipulation for Enabling Autonomous Underwater Multipurpose Intervention Missions)

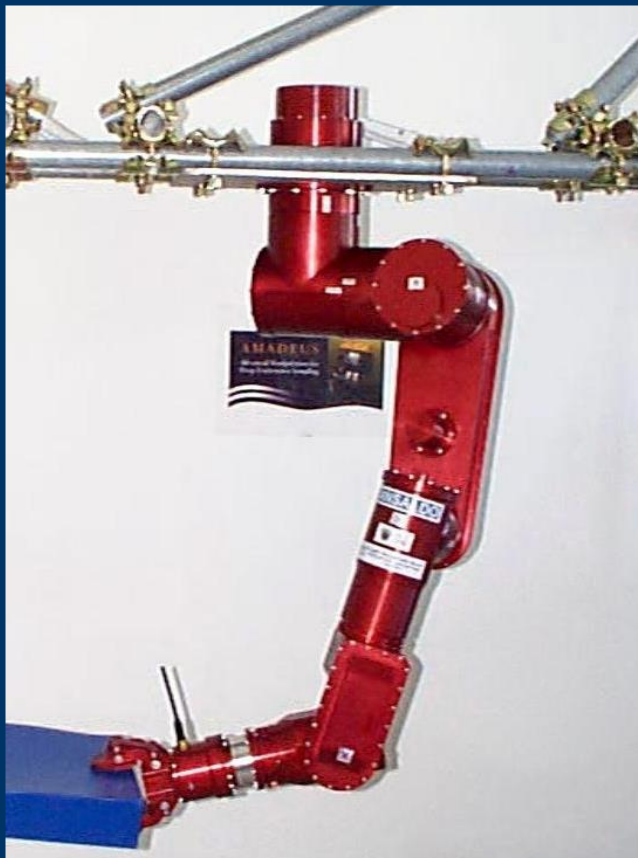
Goal of the project

- Development of a an autonomous underwater vehicle for intervention mission

Graal Tech role

- Development of a redundant underwater arm

TRIDENT (2010-2013) – Design Approach

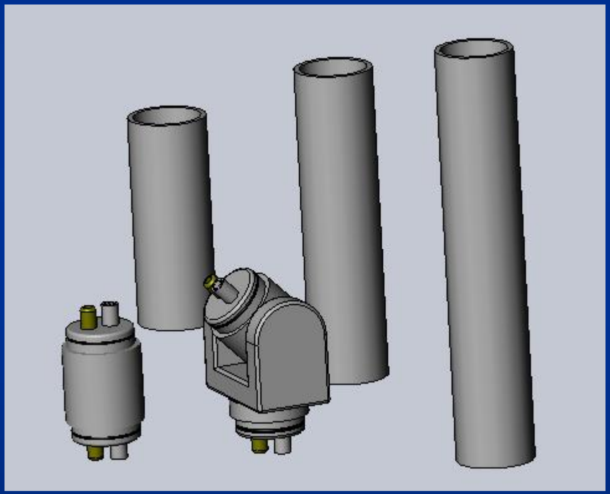


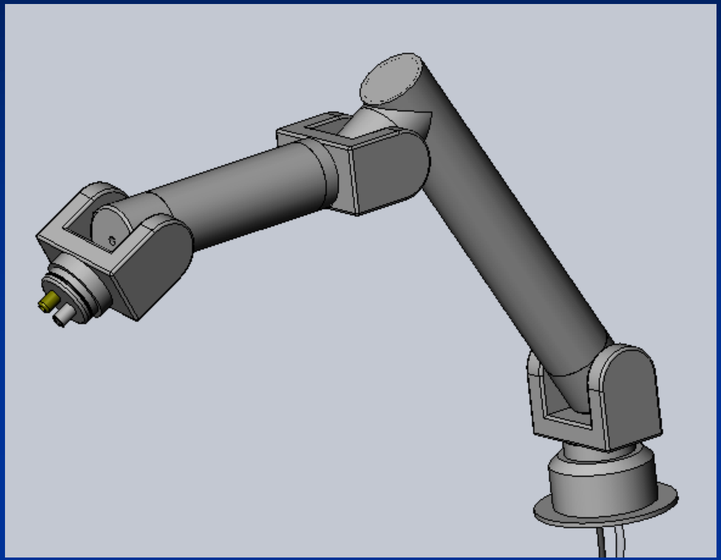
Huge number of
wires out

Conventional manipulator's design approach

- All the sensors and motors wires connected to an external control hardware

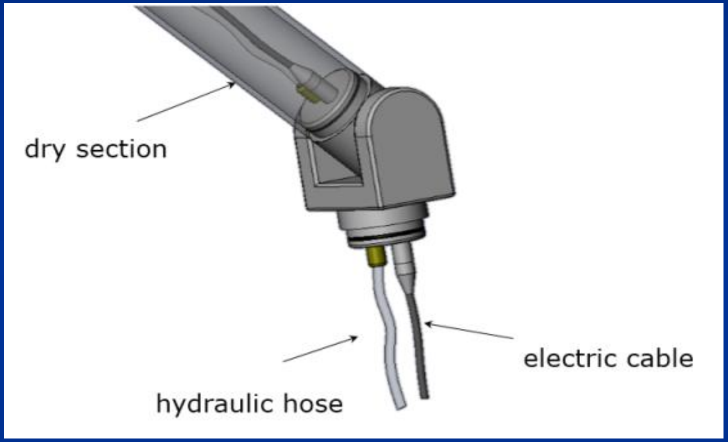
TRIDENT (2010-2013) – Design Approach





- 1st Underwater Modular Arm: UMA

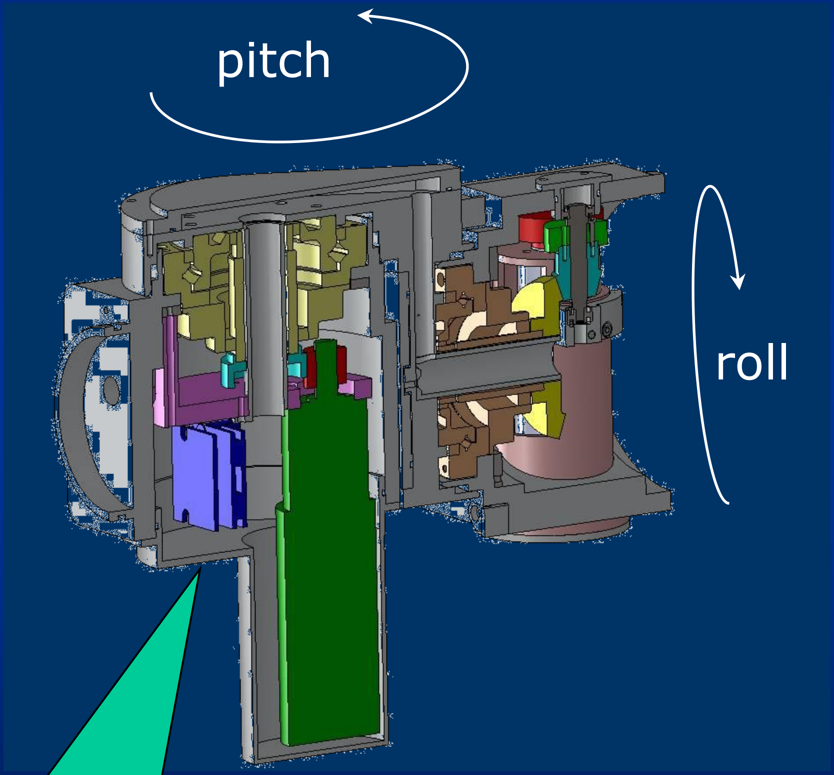
TRIDENT (2010-2013) – Design Approach



- 1st Underwater Modular Arm: UMA

UMA – Basic Joints

just 4 wires out
(2 power+2 CAN bus)



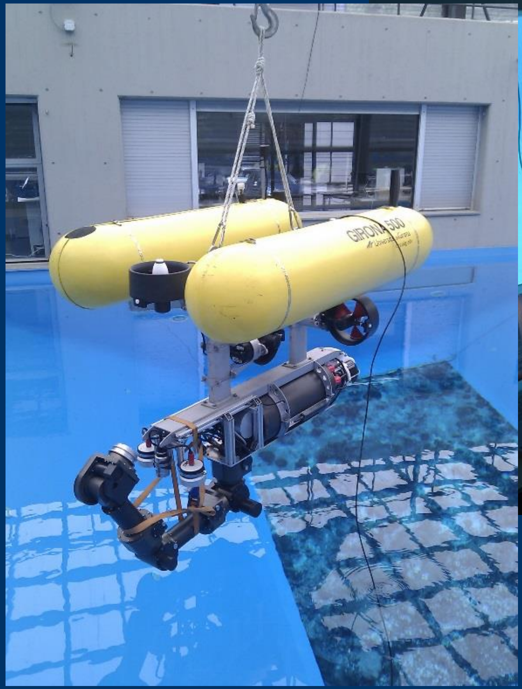
embedded
joint controller

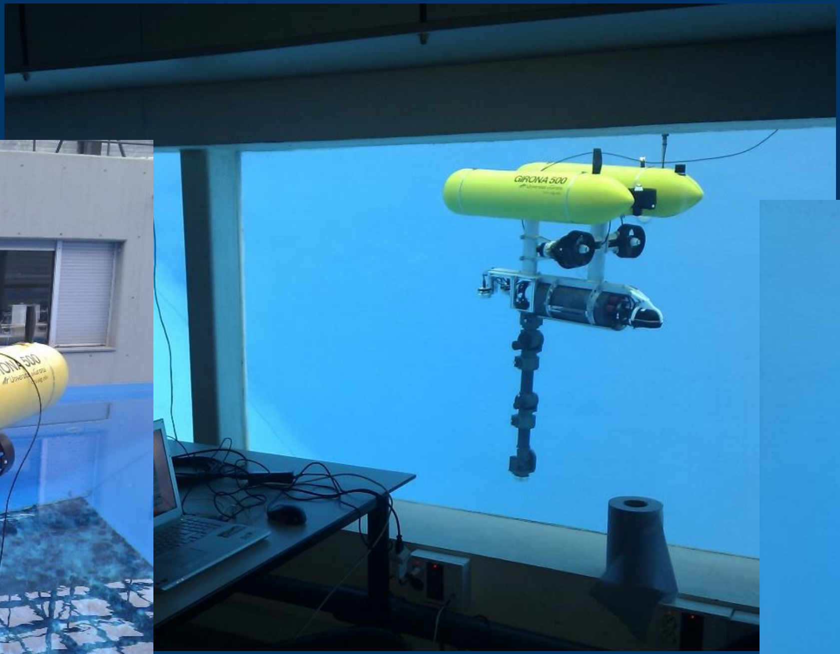
UMA – The set of components

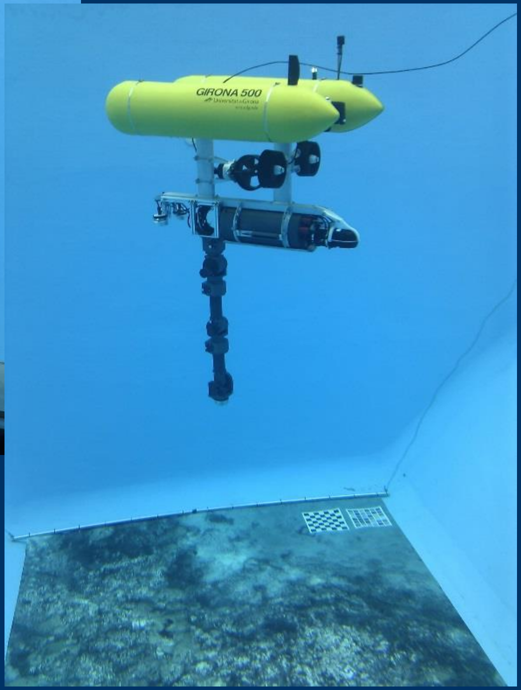
GRAALtech

UMA – Different Configurations

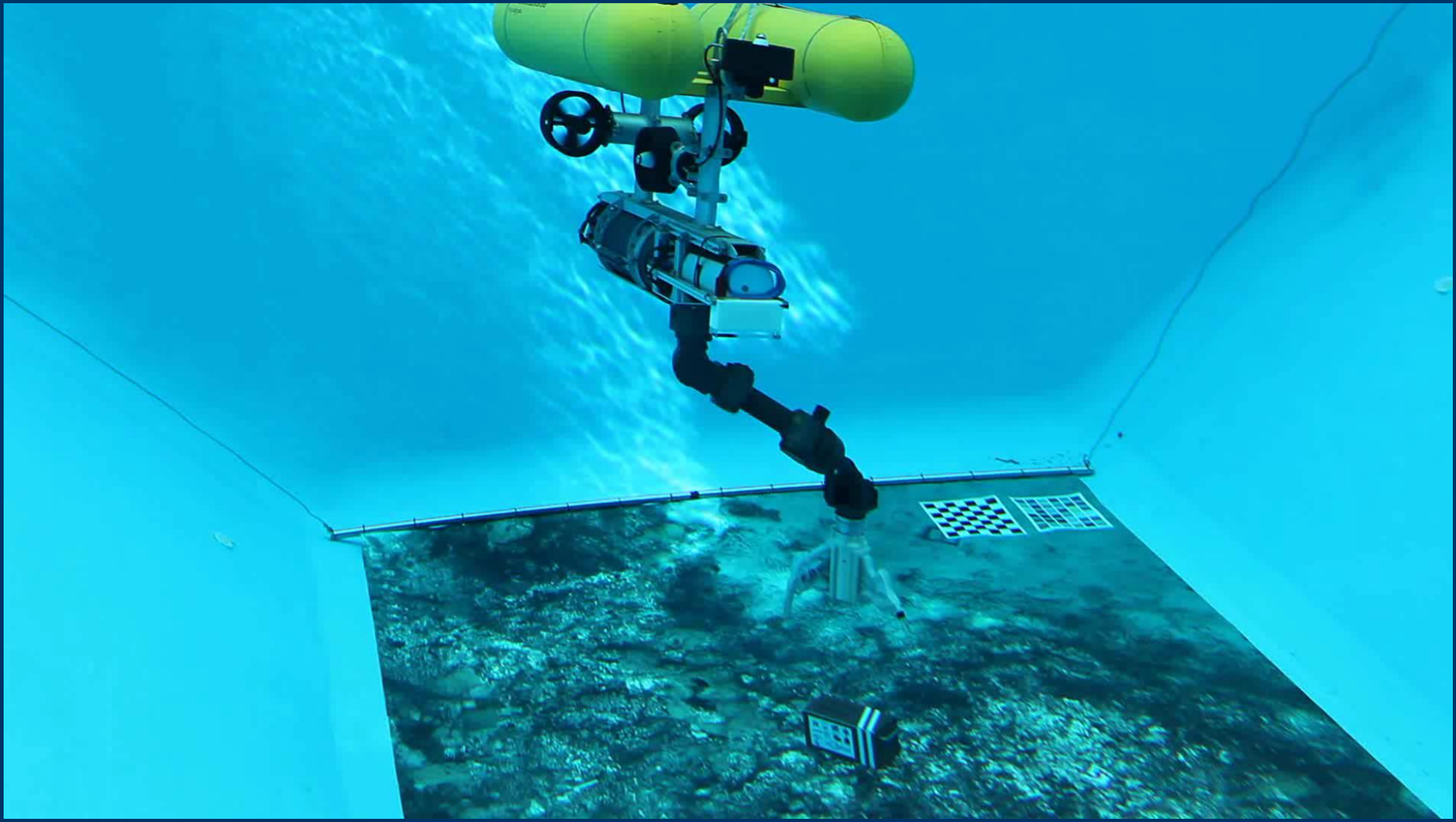
UMA – On Girona500 AUV



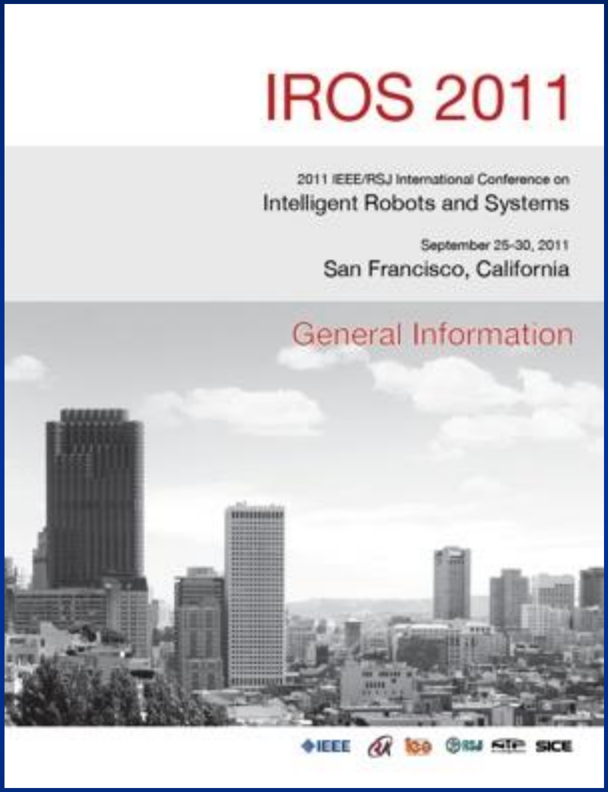




UMA – On Girona500 AUV



TRIDENT (2010-2013)



<u>Graal Tech coorganizer of:</u>

First Workshop on Autonomous Underwater Robotics for Intervention
IROS 2011, September 25-30, 2011, San Francisco, CA, USA

MAIN FEATURES

- Number of axes: user selectable
- Weight in air: configuration dependent (28 kg for the TRIDENT arm)
- Weight in water: configuration dependent (14 kg for the TRIDENT arm)
- Lenght: configuration dependent (1 m for the TRIDENT arm)
- Lifting capability: configuration dependent (10 kg for the TRIDENT arm)
- Max operative depth: 100 m
- Control system: embedded servo joint-level control at 200 Hz
- Sensors: joint position with high resolution and accuracy
- Extra data-lines available for:
  - 6 axis force/torque sensor
  - camera or other in-hand sensors

GRAALtech

UMA

Customers

DELIVERED SYSTEMS

- 6-d.o.f. @ OTO MELARA, Italy (a Finmeccanica company)

- 6 d.o.f. @ Harris Corporation, US

- 7 d.o.f. @ ISME

GRAALtech

OUTLINE

- Company Introduction
- The FOLAGA story
- The UMA story
- Current Developments

CURRENT ACTIVITIES

FOLAGA

- New modules under development for CMRE
- 1 active research project with Italian Navy
- 2 research projects with Italian Navy under discussion (confidential)
- 1 project under discussion with an Indian istitution (confidential)
- team of AUVs to be used for derisking tests with CGG (confidential)
- team of AUVs to be used within FP7 Robocademy
- 2 pending H2020 project proposals

UMA

- Development plan identified
  - Realization of a gripper
  - Improving the functionalities of the control system
  - Increasing operative depth and speed
- 3 pending H2020 project proposals
  - 1 at the second stage

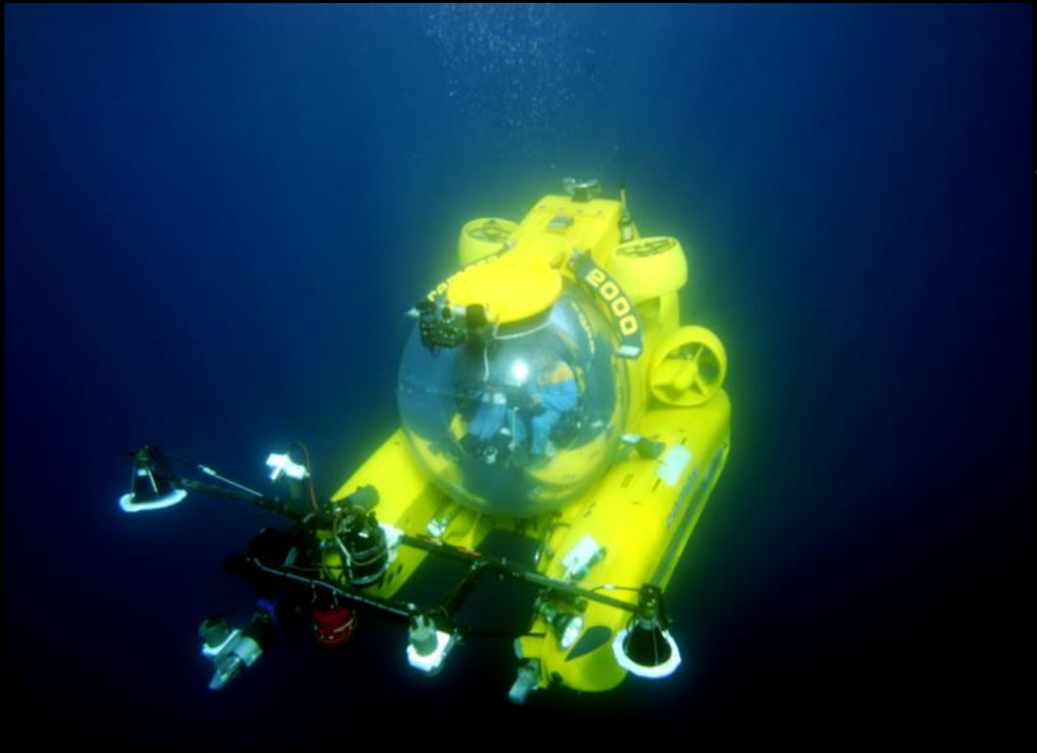
GRAALtech

NEED MORE INFO

www.graaltech.it

alessio.turetta@graaltech.it

SEE YOU NEXT YEAR IN GENOVA!



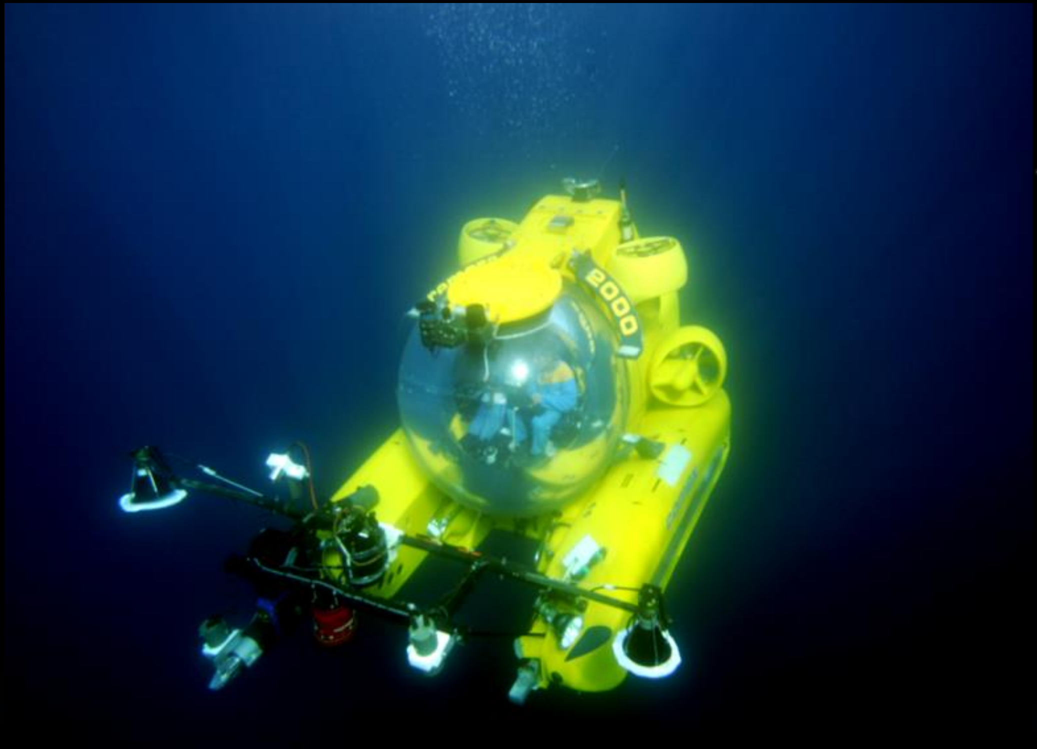
From Sea to Space

Subsea Robotics at COMEX

Dr. Peter WEISS, p.weiss@comex.fr

OVERVIEW

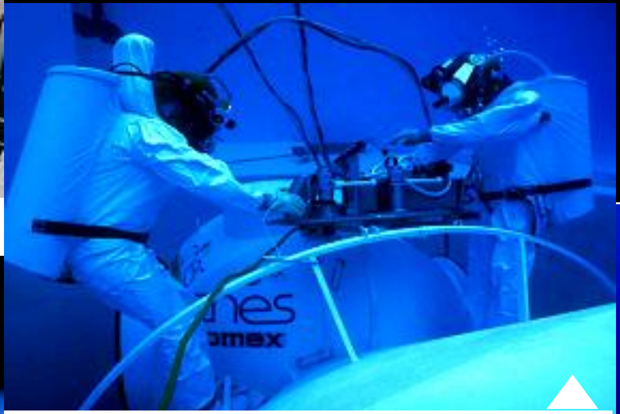
- Subsea robotics and space robotics
  common challenges and solutions
- Project MOONWALK
  human robot cooperation for planetary exploration
- Project MEUST / ANTARES
  subsea robotics for space research
- Project ROV3D
  3D photogrammetry



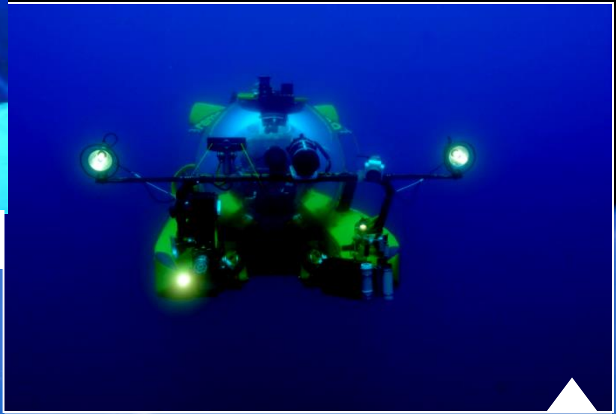
First some words about COMEX

The ***Compagnie Maritime d'Expertise*** (**COMEX**) was founded in 1961 by Henri Germain Delauze (1929-2012).
The company became a worldwide pioneer in the development of technologies for human interventions in extreme environments.

Saturation dive 180m under ice (1969)



Astronaut EVA training (1990)



The submersible REMORA 2000

Marine Operations

Oceanographic vessel « Minibex »

Oceanographic vessel « Janus »

Submarine « Rémora 2000 »

Expertise in the design, installation and maintenance of subsea equipment.
Intervention depth up to 2 500m.

Engineering

Testing services (hyper and hypobaric)

Special machine Engineering

Hyperbaric Chambers

Engineering expertise in the development of high pressure equipment.
Human intervention in extreme environments.

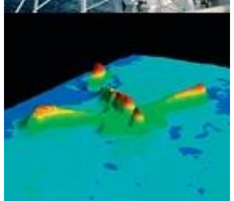
Marine Operations

From Sea to Space

Subsea Robotics at COMEX

Experienced, multi-disciplinary engineers and crews to serve throughout the entire management of operations.




Main Features:

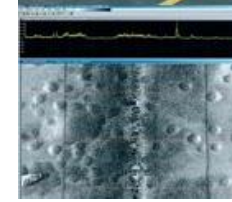
-DP Oceanographic Research vessels “JANUS” and “MINIBEX”

-Manned submersible “REMORA 2000” (-610 m)

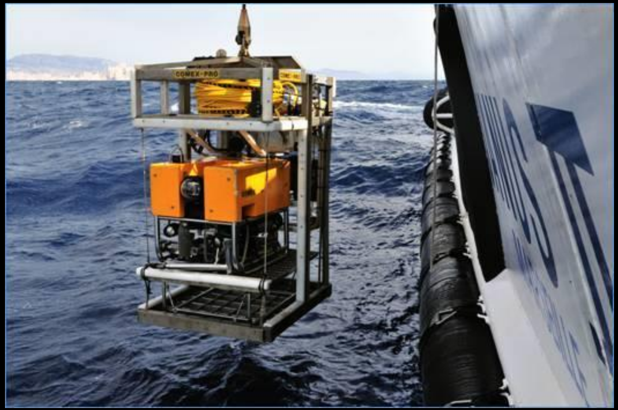
-Remote Operated Vehicles (-2 500 m)

-Our crew of experts is operating all over the globe.

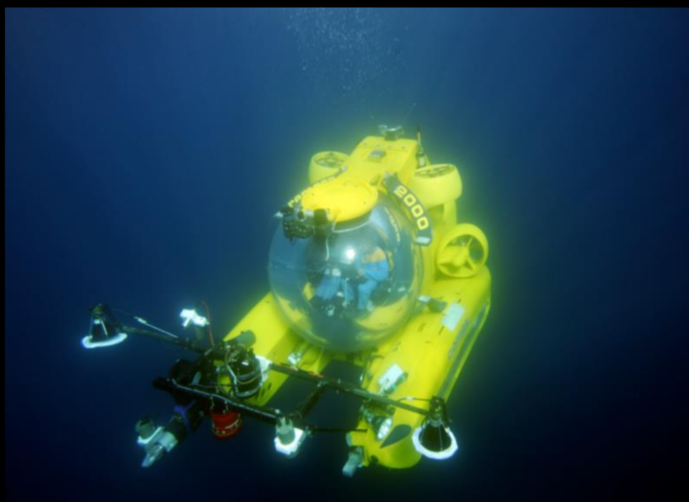
- Engineering support in various fields
(subsea mining, marine renewable energies, defense, …)

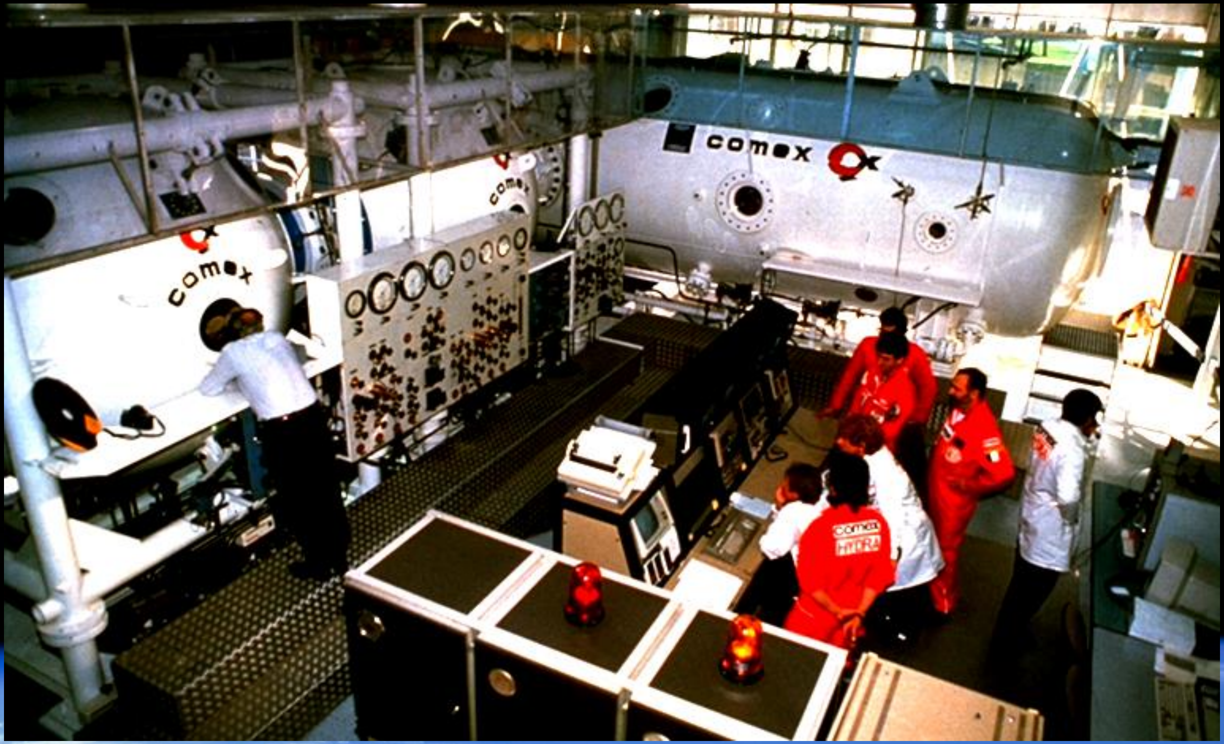
Subsea Intervention to -2500 msw



Manned submersible REMORA 2000



Engineering



Integrated solution provider for projects related to high or low pressure applications and the intervention of humans in extreme environments.

Main Features:

- Pressure testing devices ranging from vacuum to 400bar

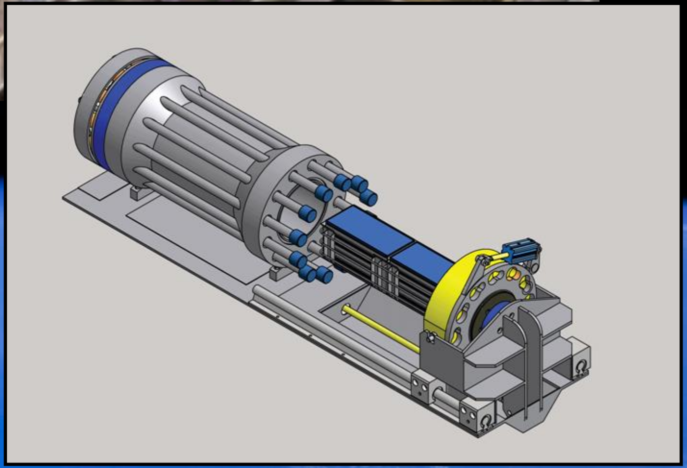
-Engineering of testing chambers (high pressure, high temperature)

-Test and design of protection garment for human intervention in extreme environments.

-Expertise and simulation (CAD, FEM).

-Maintenance of equipment around the globe.

Design of hyperbaric equipment



Test pools

Hyperbaric and Hypobaric testing

Hyperbaric and Hypobaric testing

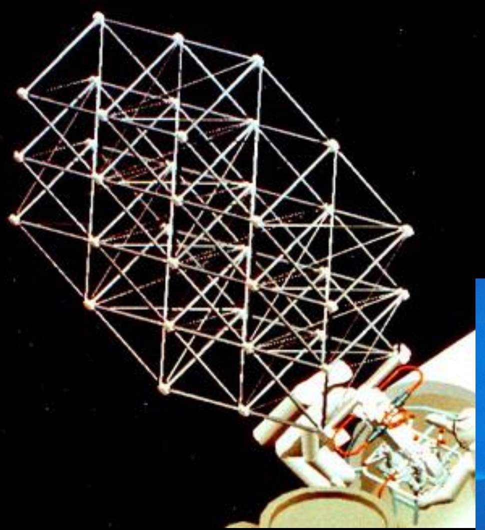
40 000 m

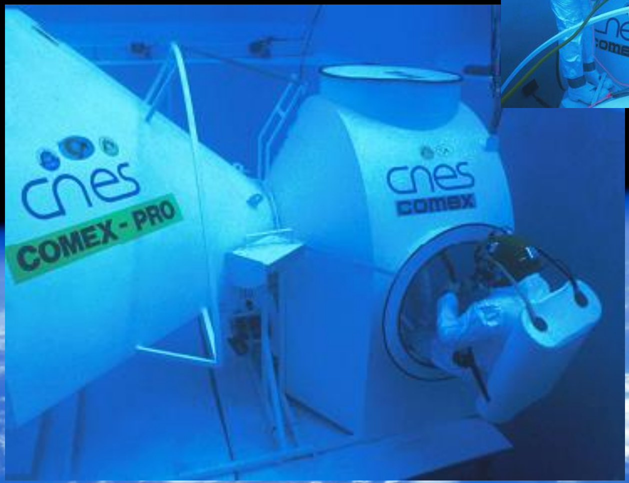
0

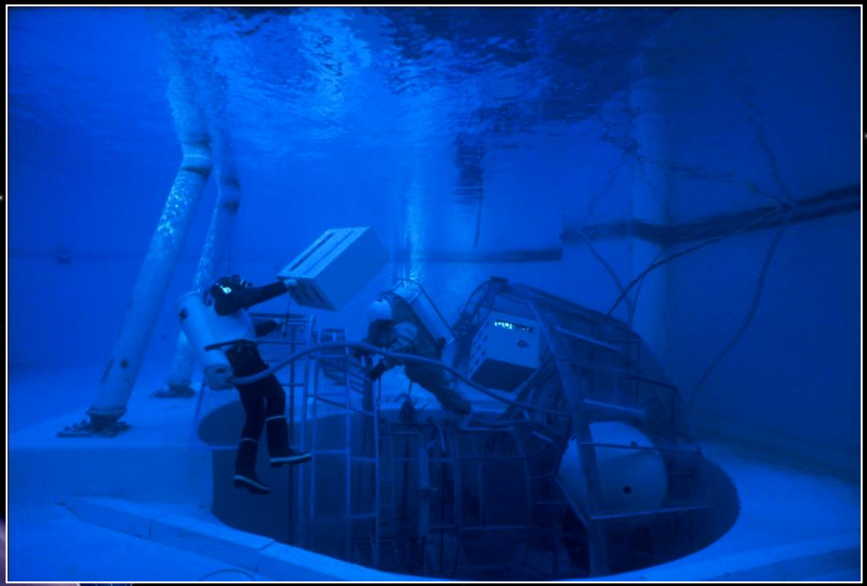
4000 MSW

CHAMBERS	VOLUME	Size : diameter = Ø, Length = l, Height = h		FLUIDE UNDER PRESSURE	PRESSURE	
		Internal	Access or door		Hypobaric (Bar)	Hyperbaric (Bar)
CAISSON B	7,6 m^3	Ø = 1,8 m l = 2 m	Ø = 0,6 m	Air	0.015	10
C 2500	30 m^3	Ø = 2,45 m l = 7,5 m	Ø = 0,6 m	Air, N_2, He...	0.015	20
C 2400	35 m^3	Ø = 2,3 m l = 9 m	Ø = 0,7 m	Air, N_2, H_2, Water...	0.015	60
CE 1000	1,7 m^3	Ø = 1 m l = 2,2 m	Ø = 1 m	Water	0.010	70
EMS 800	21 m^3	Ø = 2,4 m	Ø = 0,73 m	Air, N_2, H_2, He...	0.015	80
C 1200	4 m^3	Ø = 1,5 m h = 2,2 m	Ø = 0,6 m	Air, N_2, H_2, He...	0.010	120
HTP 140	22,4 dm^3	Ø = 0,25 m h = 0,46 m	Ø = 0,25 m	Air, N_2, H_2, He...	0.010	140
HTP 200	5 dm^3	Ø = 0,15 m h = 0,3 m	Ø = 0,15 m	Air, N_2, H_2, He...	0.010	200
CE 2000	216 dm^3	Ø = 0,20 m l = 6,9 m	Ø = 0,2 m	Water	0.010	200
HTP XF	47 dm^3	Ø = 0,28 m h = 0,75 m	Ø = 0,25 m	Air, N_2, H_2, He...	0.010	200
CE 2500	160 dm^3	Ø = 0,68 m h = 0,52 m	Ø = 0,68 m	Water	0.010	250
CE 4000	8 m^3	Ø = 2,5 m	Ø = 2,5 m	Water	0.010	400

Neutral Buoyancy Simulations and Training







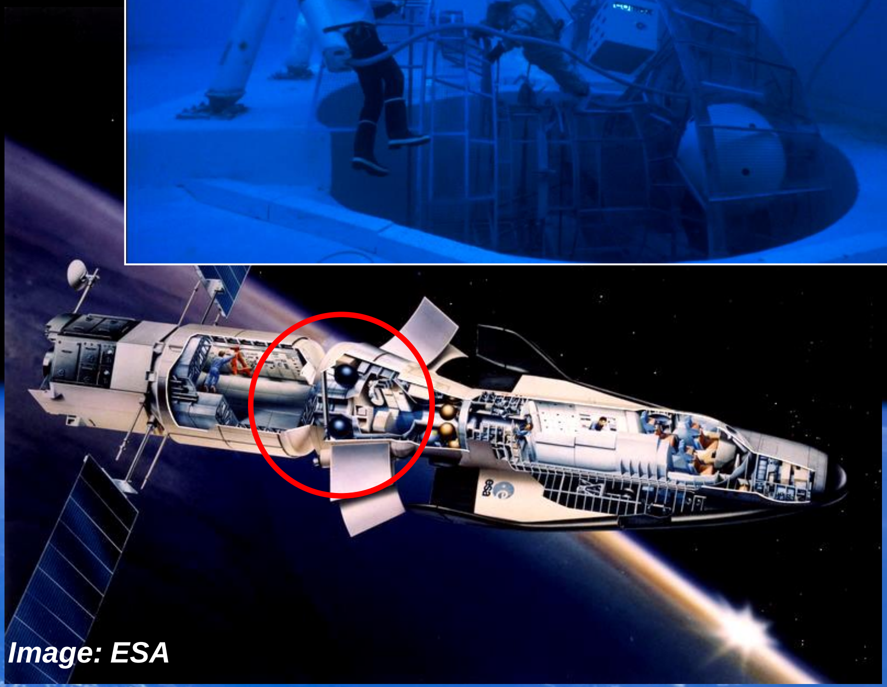


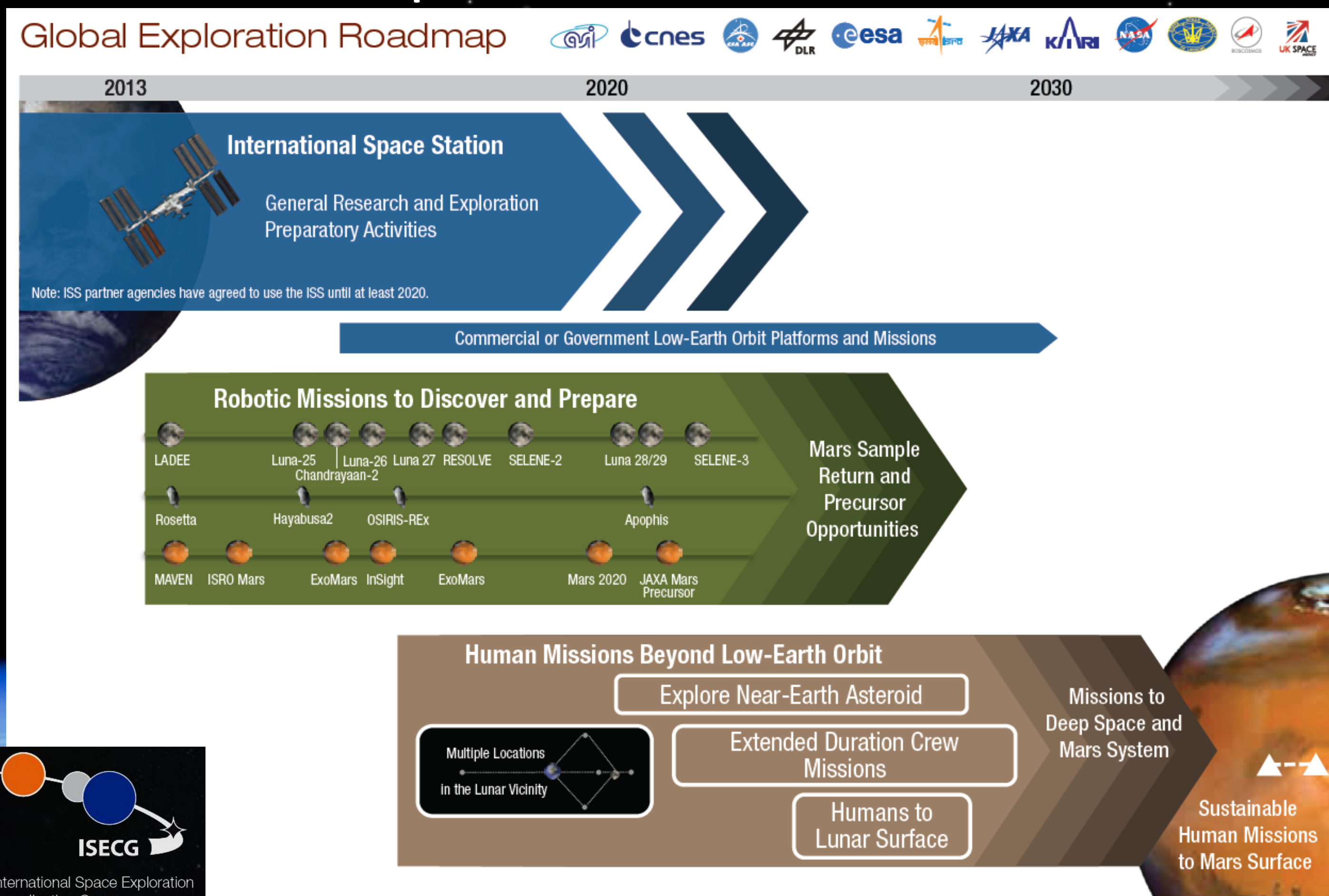
Image: ESA

Subsea robotics and space robotics
Common challenges and solutions

Common challenges in space and subsea robotics

The next "Giant Leap"

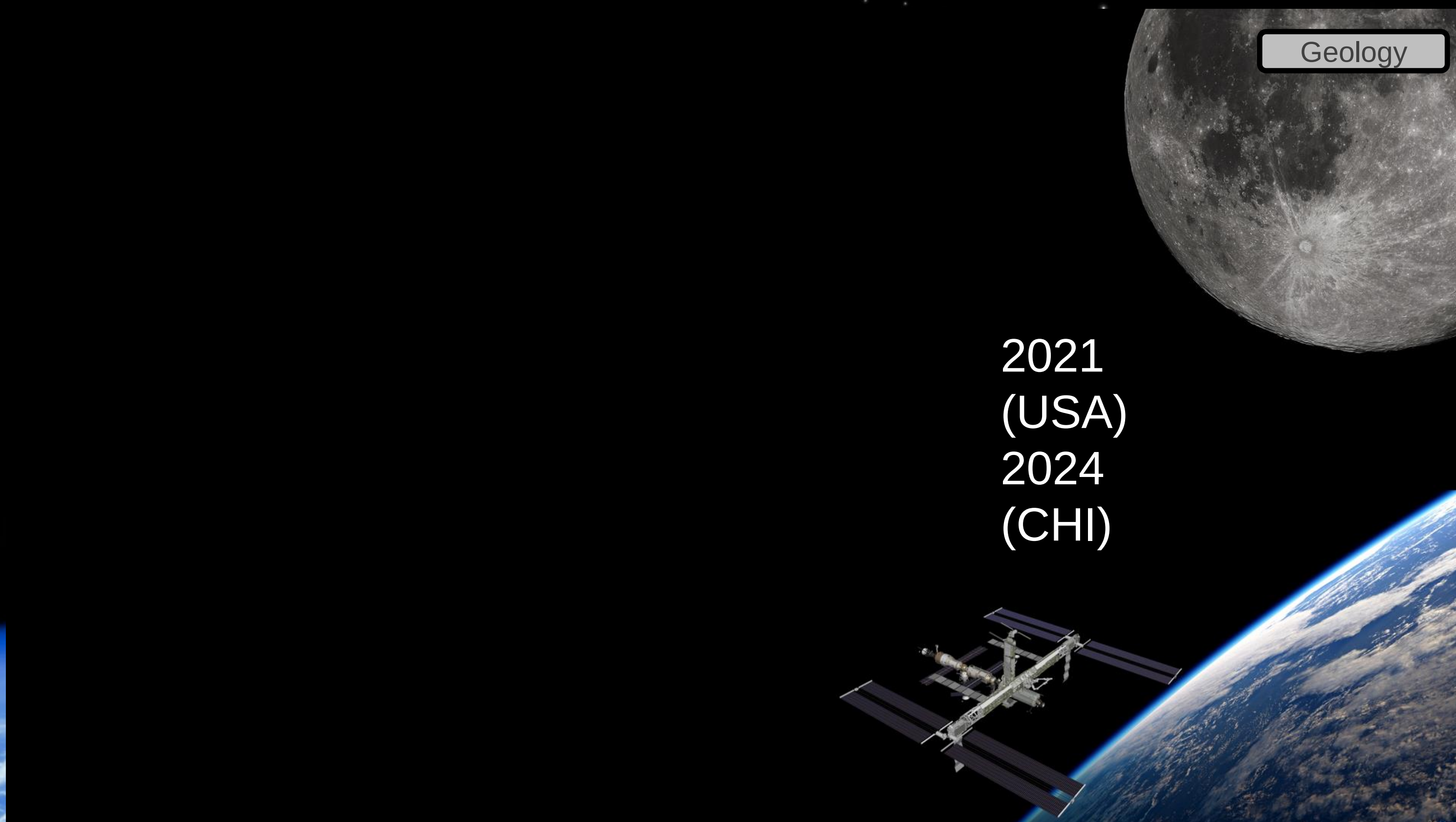
Common challenges in space and subsea robotics



ISECG
International Space Exploration Coordination Group

Common challenges in space and subsea robotics

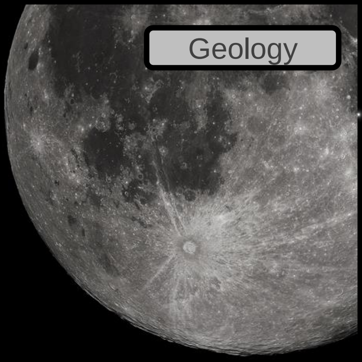
Common challenges in space and subsea robotics

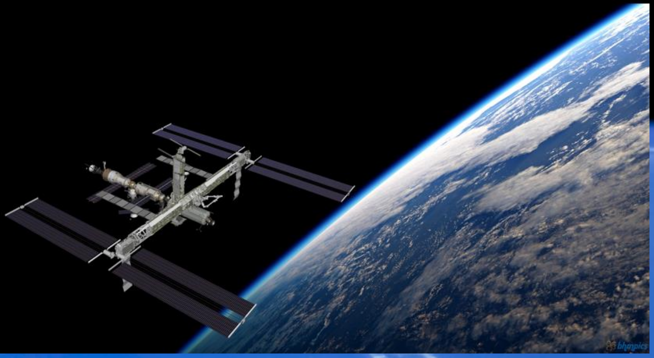


Common challenges in space and subsea robotics

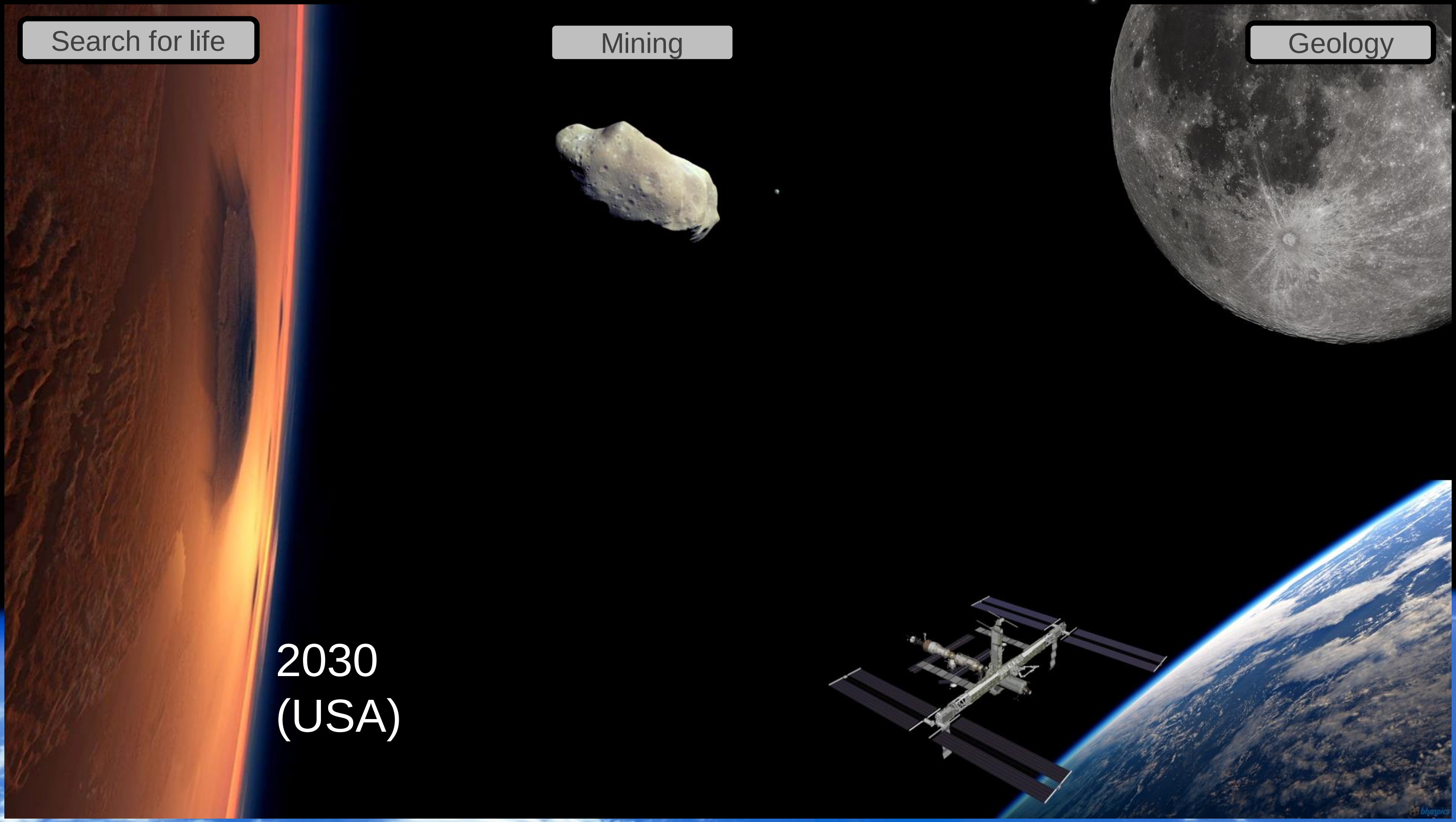
Mining

2025 (USA)

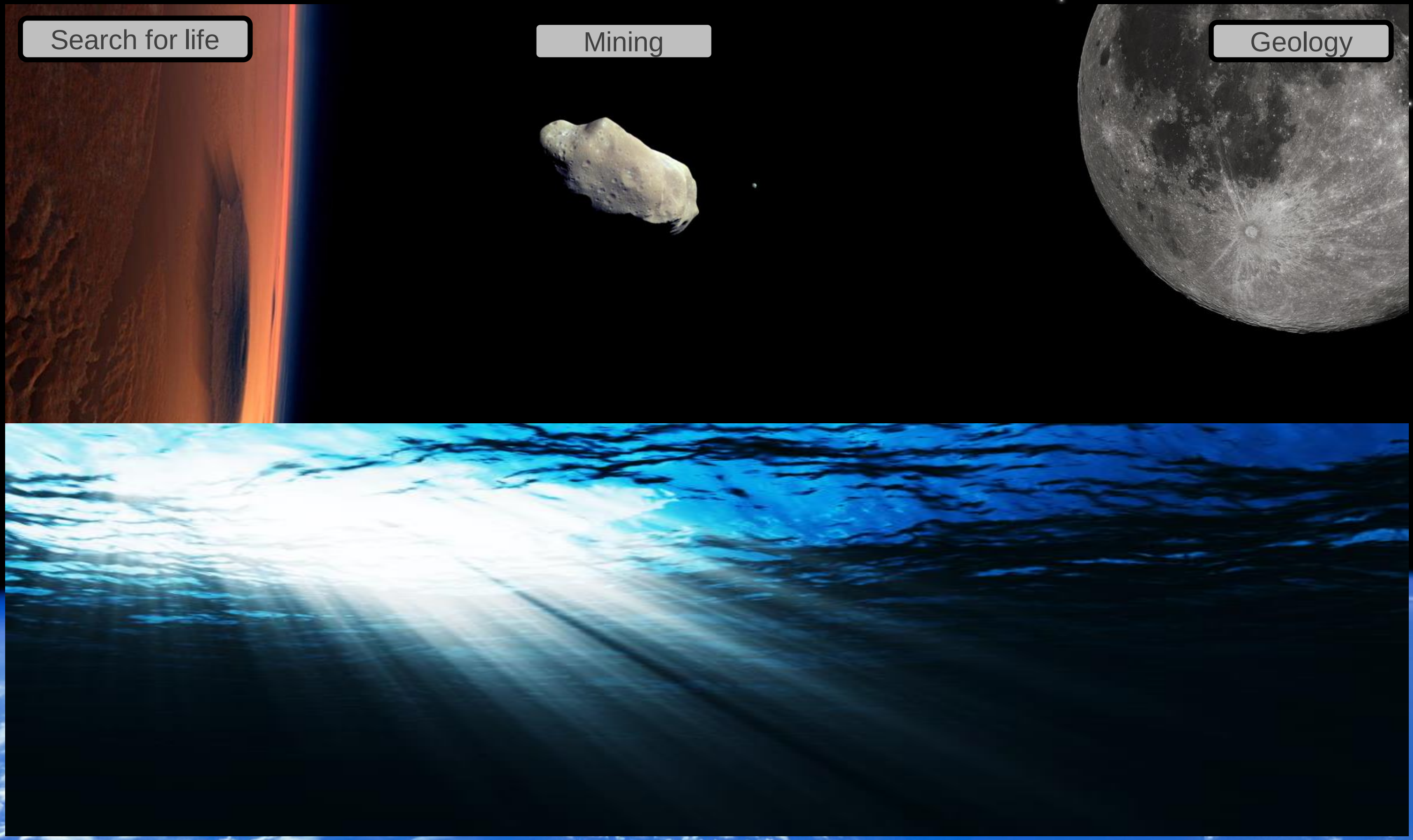




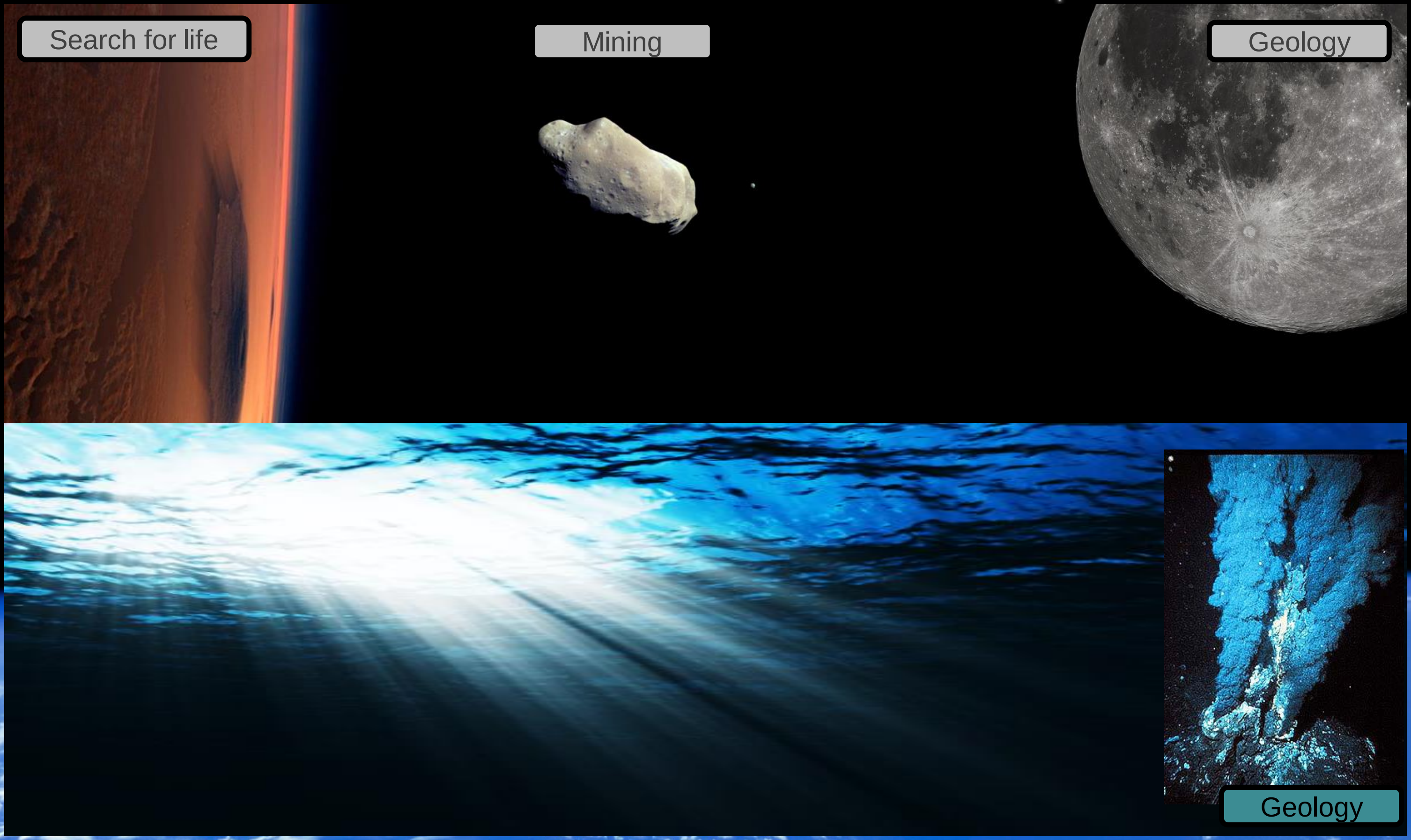
Common challenges in space and subsea robotics



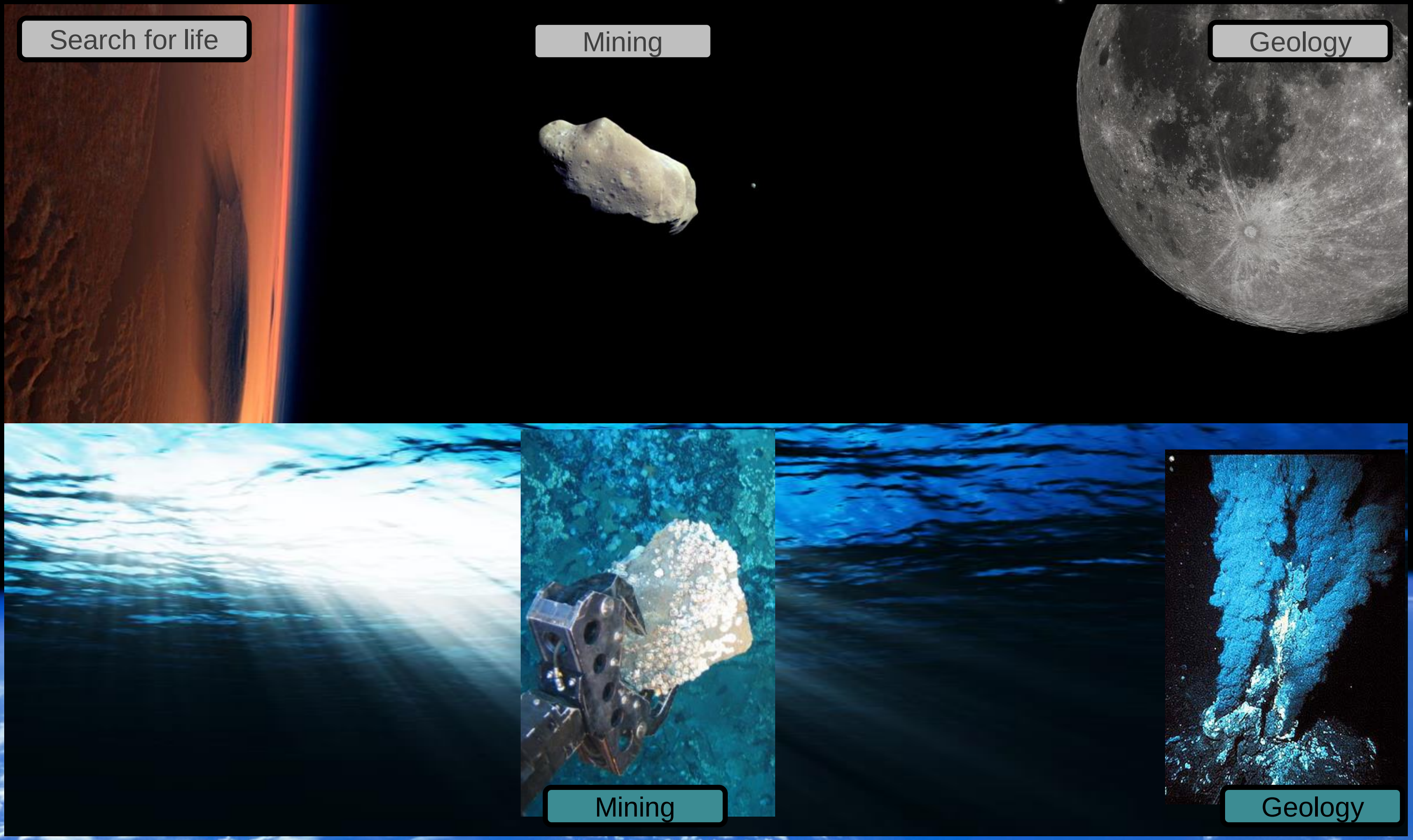
Common challenges in space and subsea robotics



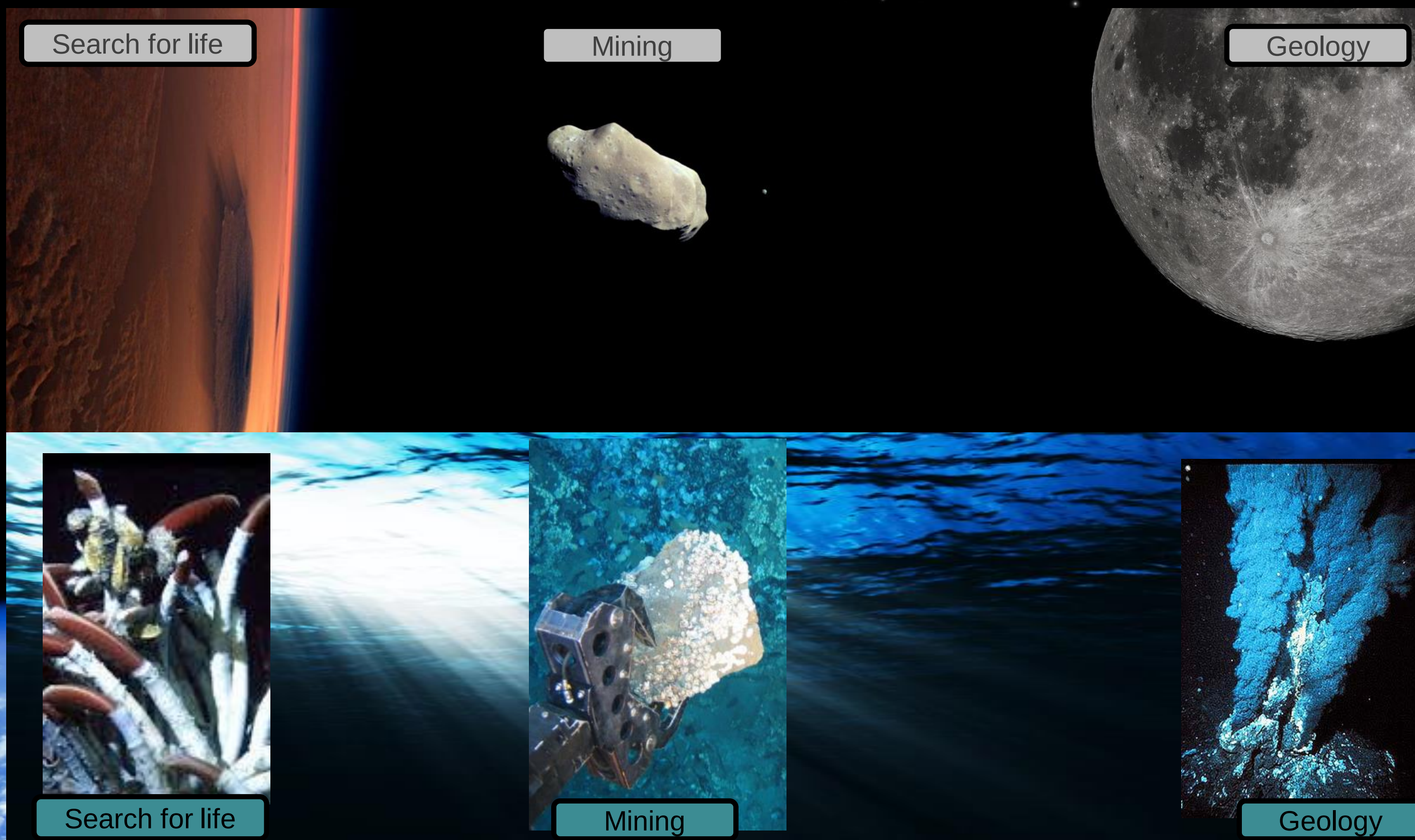
Common challenges in space and subsea robotics



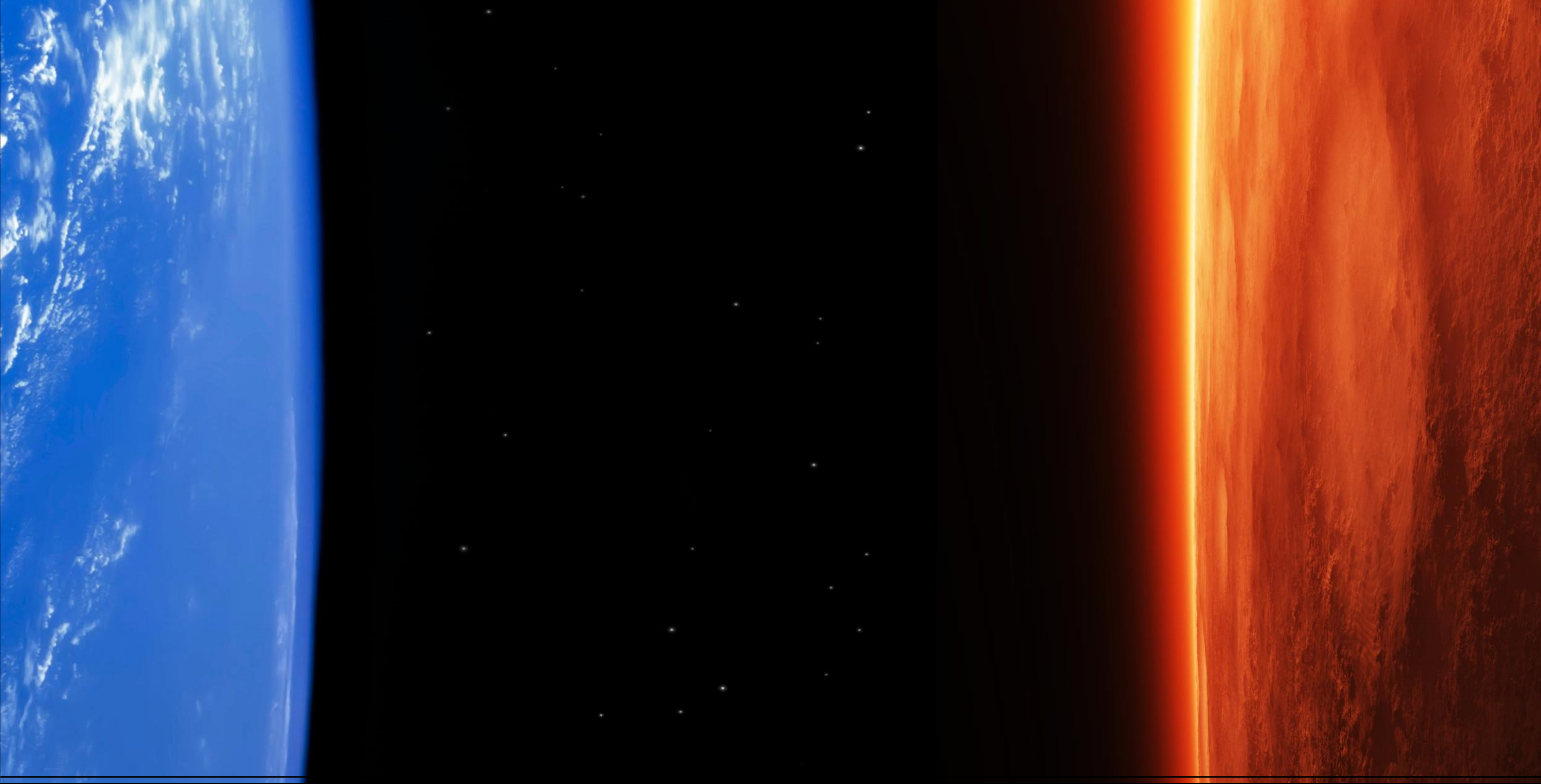
Common challenges in space and subsea robotics



Common challenges in space and subsea robotics



Common solutions in space and subsea robotics



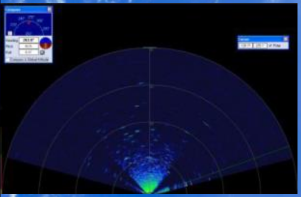
Photos: Ifremer, NASA, JPL, FASTER project, MORPH project, TR Launay

Common solutions in space and subsea robotics

Communication
(delay, bandwidth)

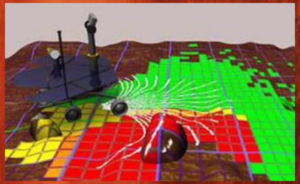
Photos: Ifremer, NASA, JPL, FASTER project, MORPH project, TR Launay

Common solutions in space and subsea robotics



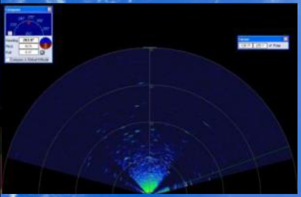
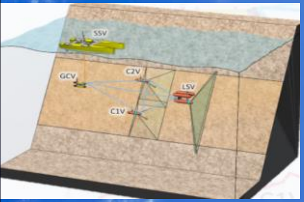
Communication (delay, bandwidth)

Autonomous navigation, positioning, mapping



Photos: Ifremer, NASA, JPL, FASTER project, MORPH project, TR Launay

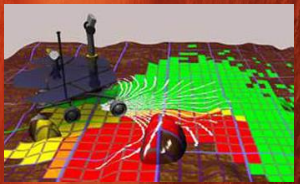
Common solutions in space and subsea robotics

Communication (delay, bandwidth)

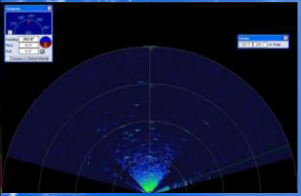
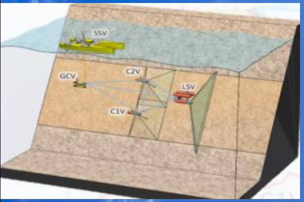
Autonomous navigation, positioning, mapping

Robot Cooperation


Photos: Ifremer, NASA, JPL, FASTER project, MORPH project, TR Launay

Common solutions in space and subsea robotics

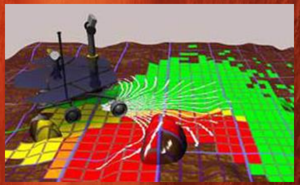




Communication
(delay, bandwidth)

Autonomous navigation,
positioning, mapping

Robot Cooperation

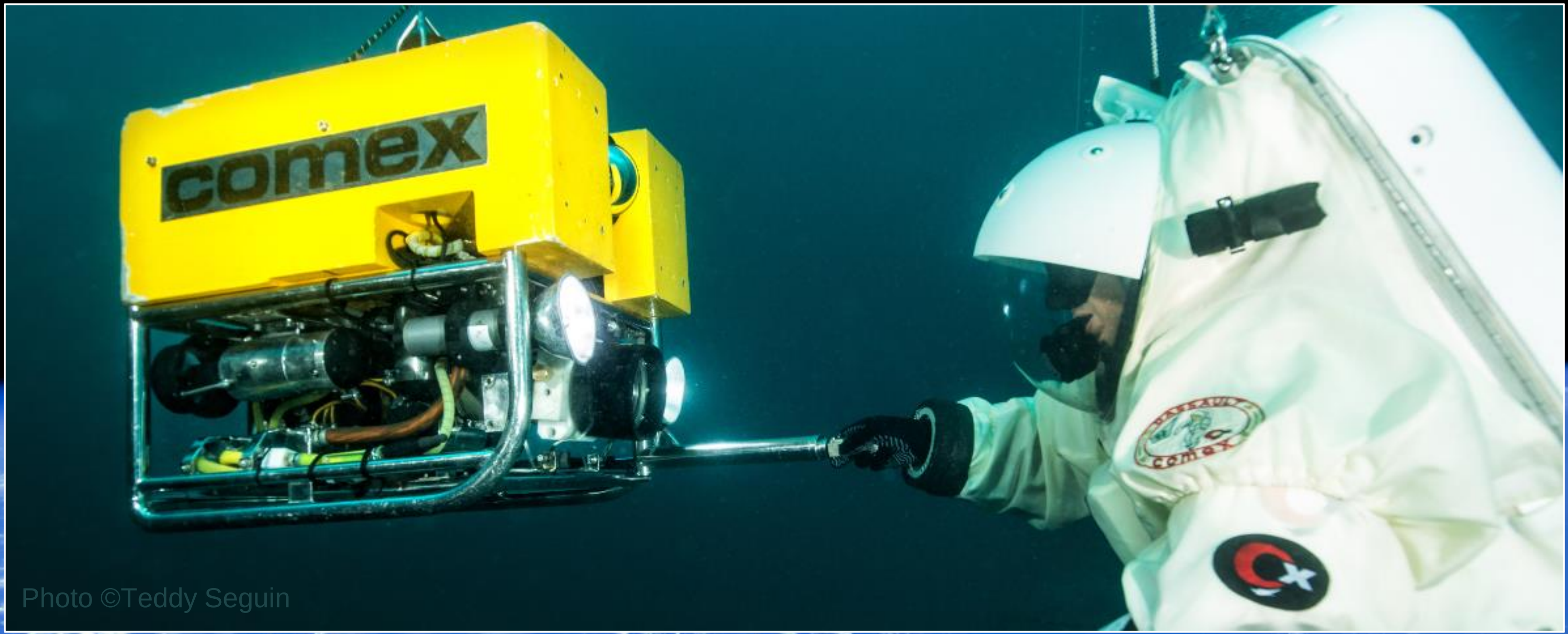
Robotic Sampling
(Handling, analysis)

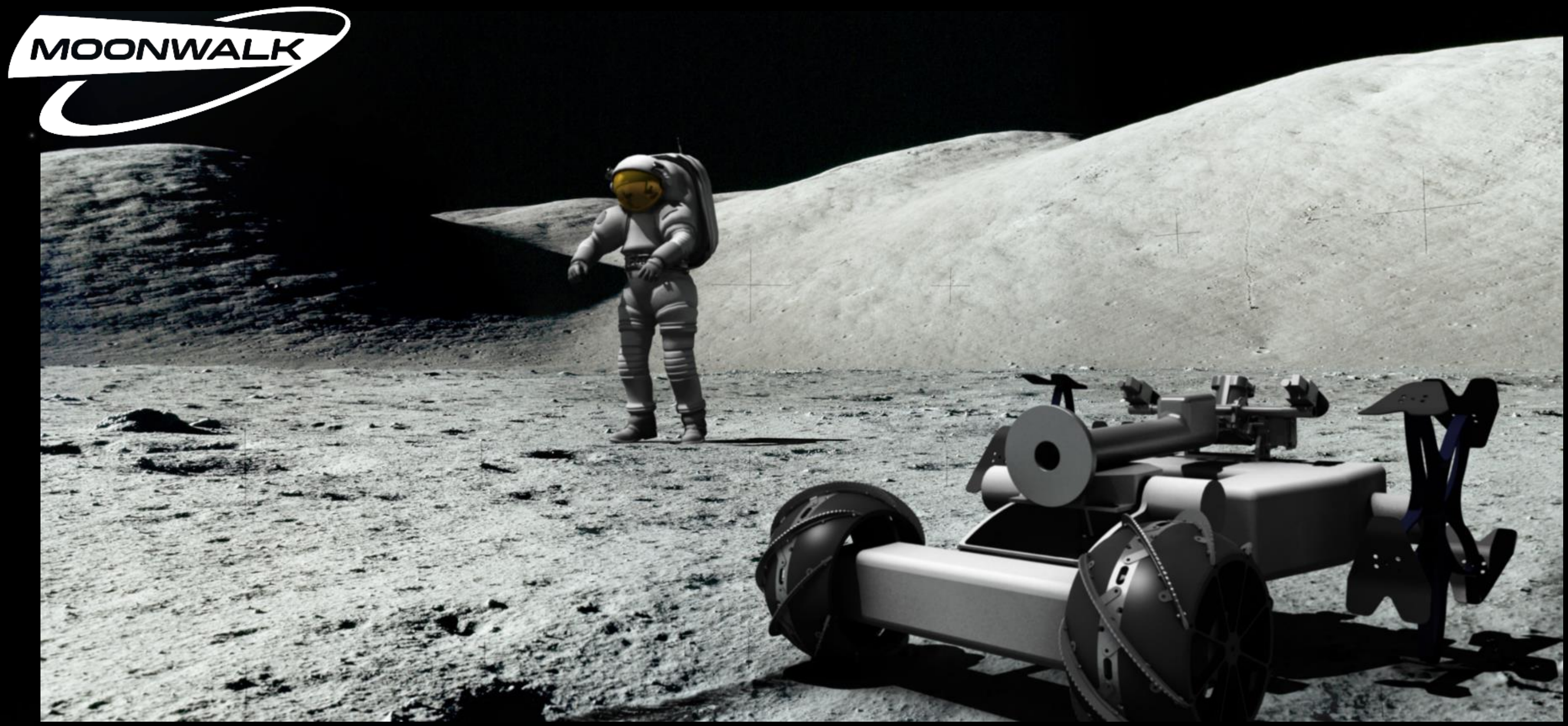



Photos: Ifremer, NASA, JPL, FASTER project, MORPH project, TR Launay

The message I want to transmit is that developments in robotics for submarine applications and space applications can profit from each other.

The H2020 framework offers great possibilities to build up synergies between sectors (BLUE GROWTH / SPACE)



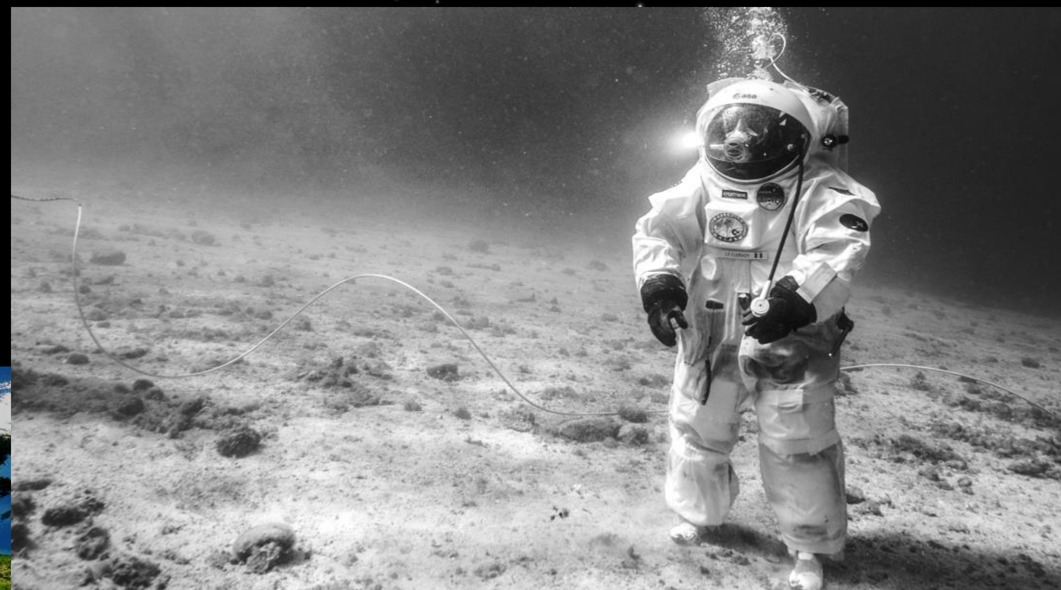


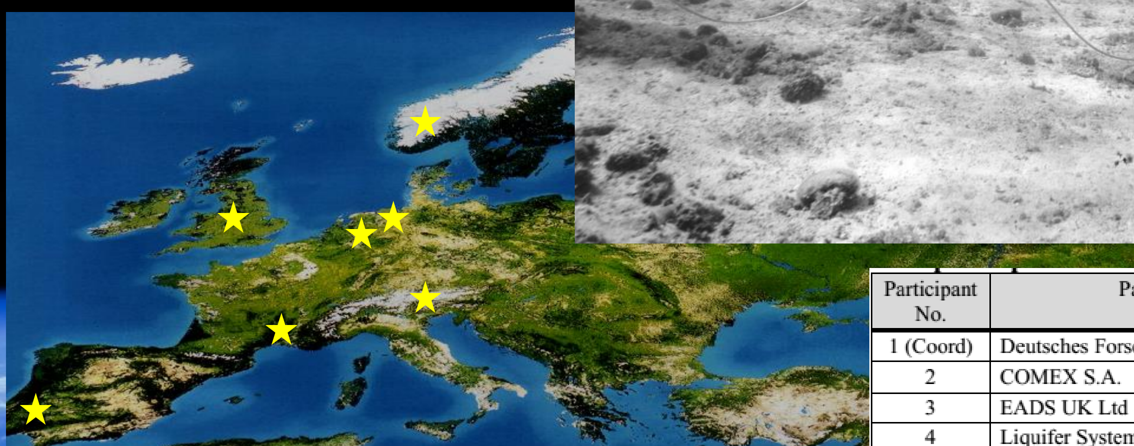
From sea to space

Project MOONWALK

(European Commission – FP7)

The Objective of MOONWALK is to develop an European Infrastructure for human and robotic mission simulations





Participant No.	Participant Organization Name	Participant Short Name	Country
1 (Coord)	Deutsches Forschungszentrum für Künstliche Intelligenz	DFKI	Germany
2	COMEX S.A.	COMEX	France
3	EADS UK Ltd	EADS	United Kingdom
4	Liquifer Systems Group GmbH	LSG	Austria
5	Space Applications Services N.V./S.A.	SPACE	Belgium
6	NTNU Centre for Interdisciplinary Research in Space	NTNU	Norway
7	Instituto Nacional de Técnica Aeroespacial	INTA	Spain

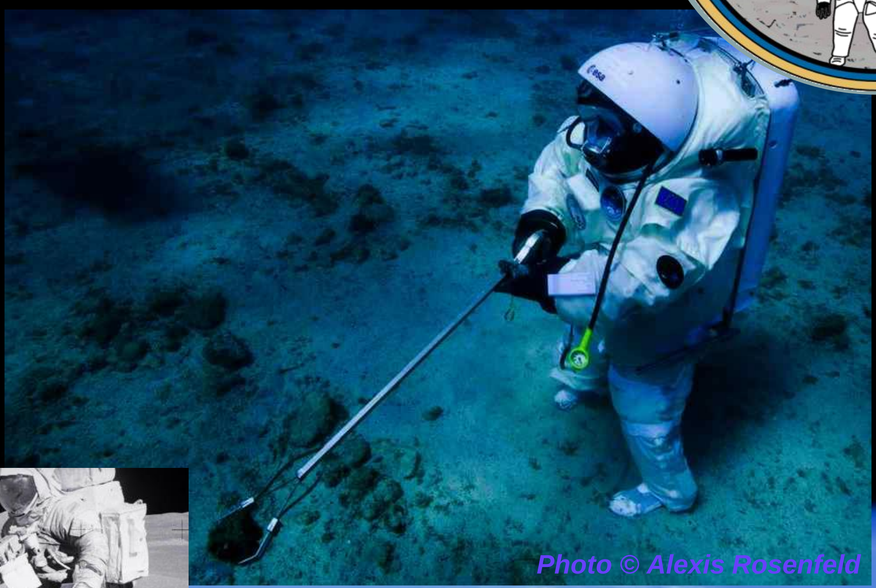
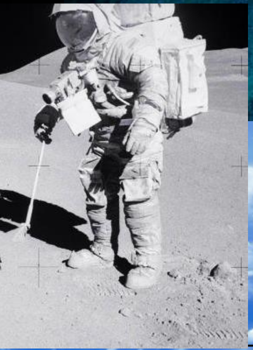


Photo © Alexis Rosenfeld


Photo © Alexis Rosenfeld



Objectives:

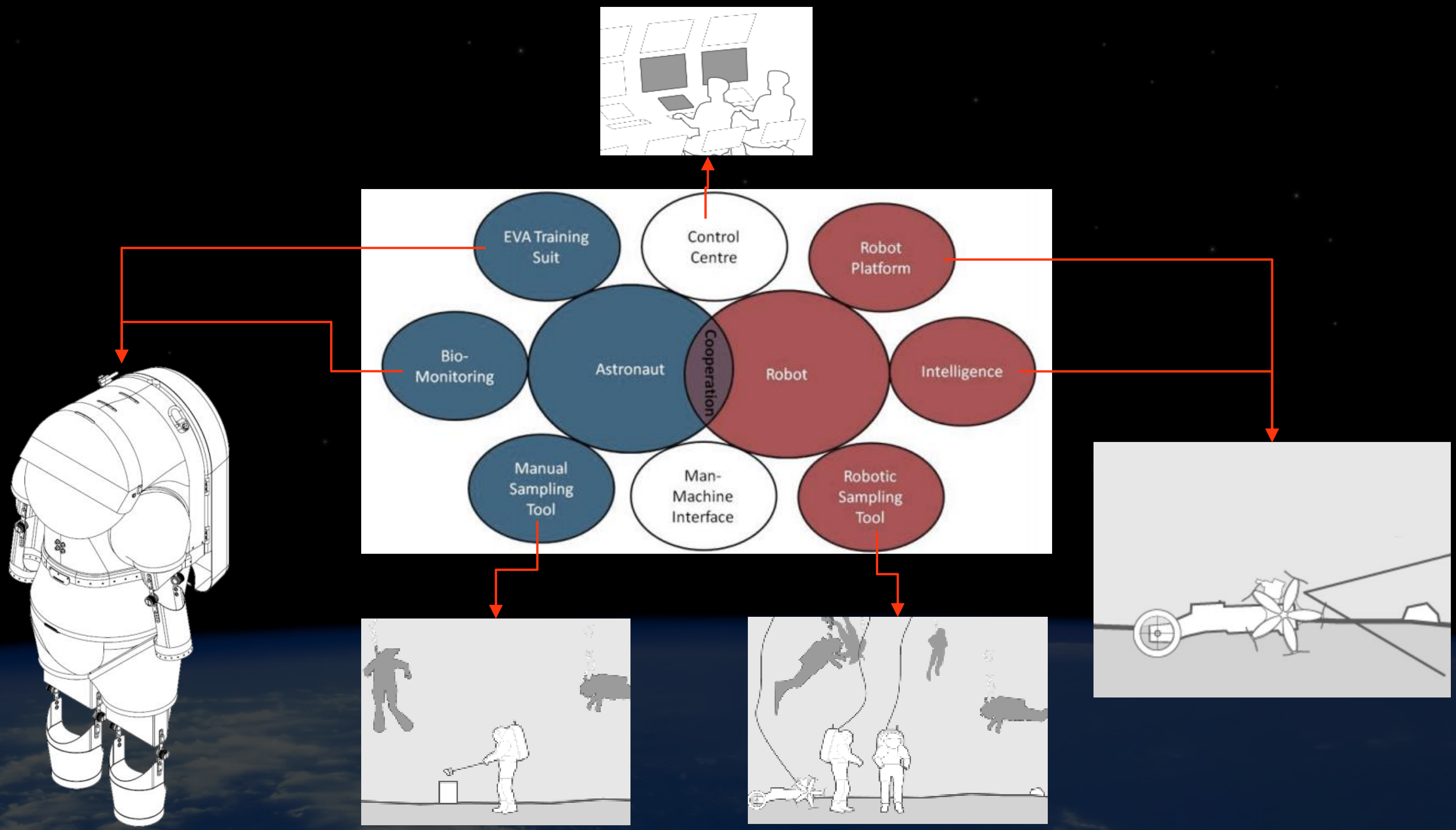
A. *Simulation of human-robot and human-human cooperation in extreme environments with a Control Centre in the loop.*

B. *Developing the infrastructure in Europe to perform lunar and martian surface mission simulations (robotic platforms, training suits)*

C. *Develop procedures and tools for sampling activities during surface EVA*

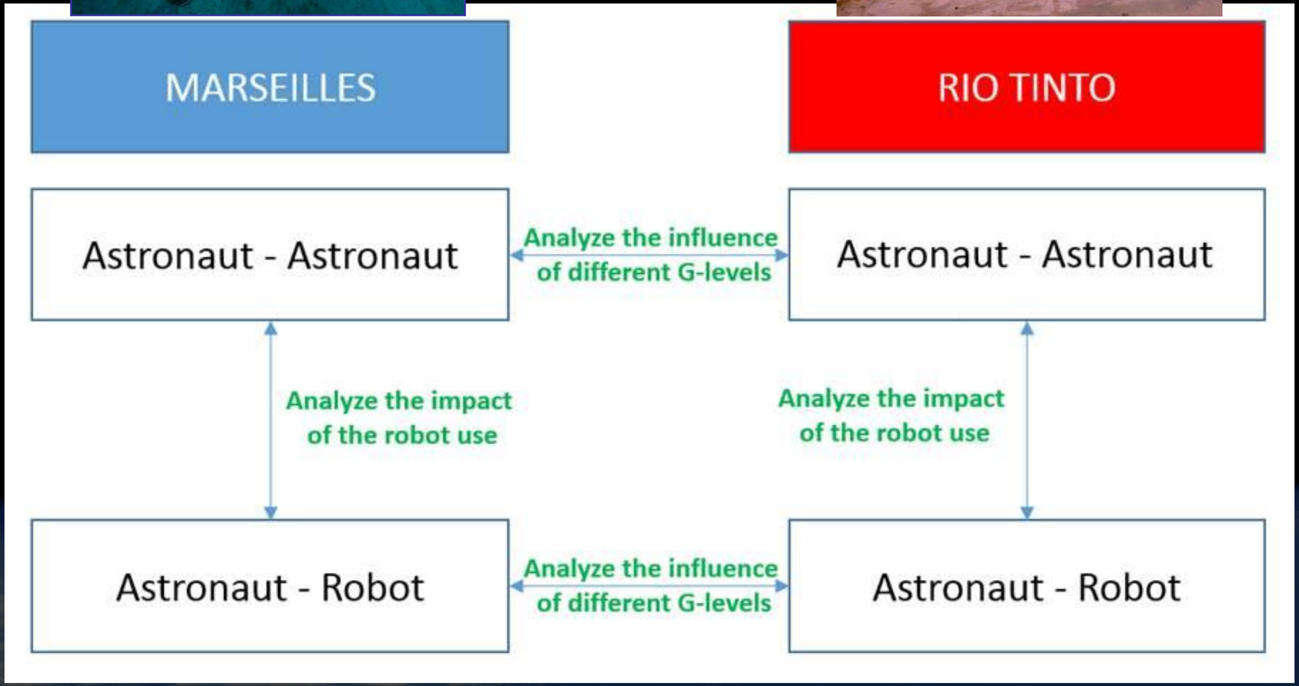
Dr. Peter WEISS, p.weiss@comex.fr

The outcome in terms of infrastructure for future simulations



Dr. Peter WEISS, p.weiss@comex.fr

Simulation scenarios and analysis



Dr. Peter WEISS, p.weiss@comex.fr

Some of the outcome will be…

- interaction between the "astronaut" (= some kind of diver) and the robot
- gesture control of the robot
- biomonitoring of the astronaut
- communication with the control center with a large delay

Photo © Alexis Rosenfeld

Dr. Peter WEISS, p.weiss@comex.fr

From sea to space

Project MEUST

(European Union)

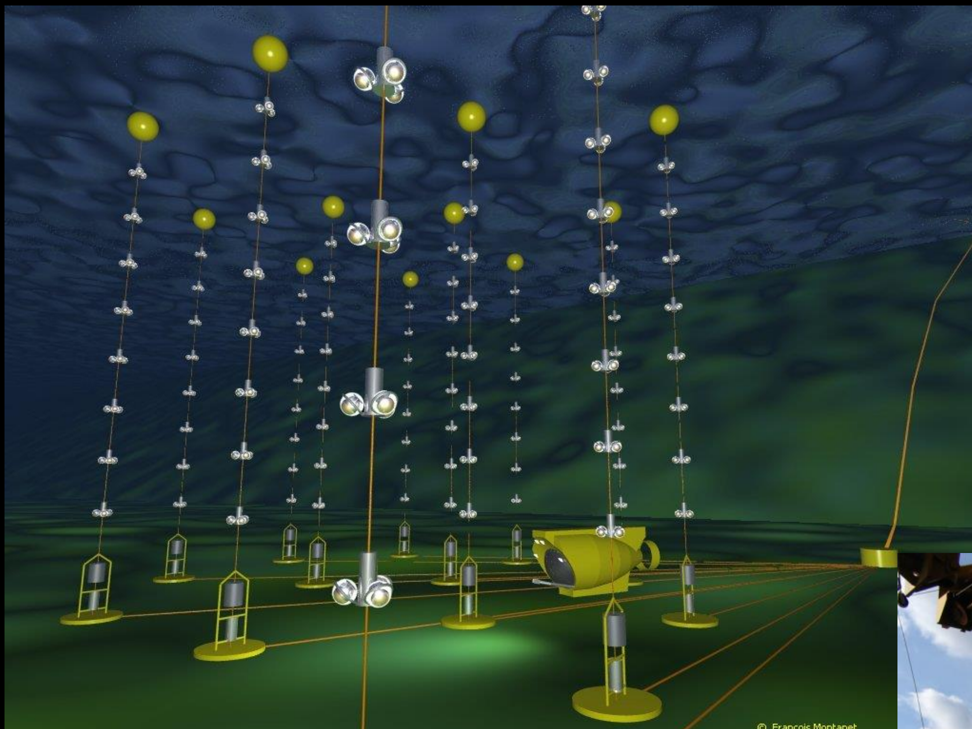


Image: François Montanet

The objective of MEUST is the extension of the ANTARES towards KM3NeT, a future European deep-sea research infrastructure and neutrino telescope

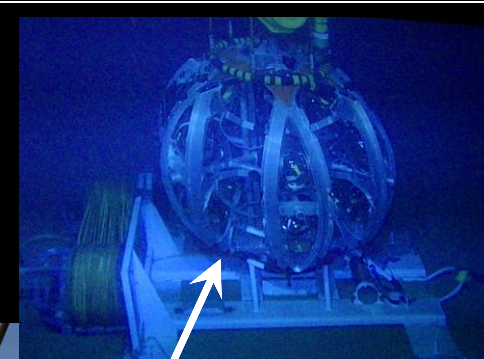
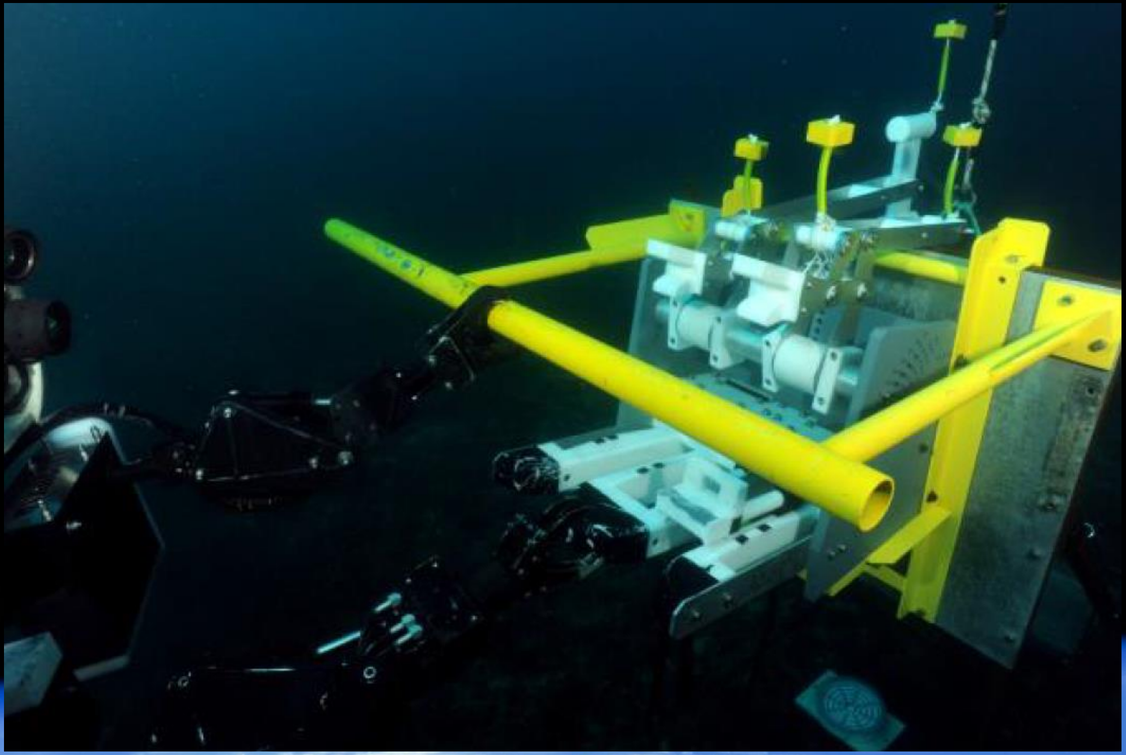
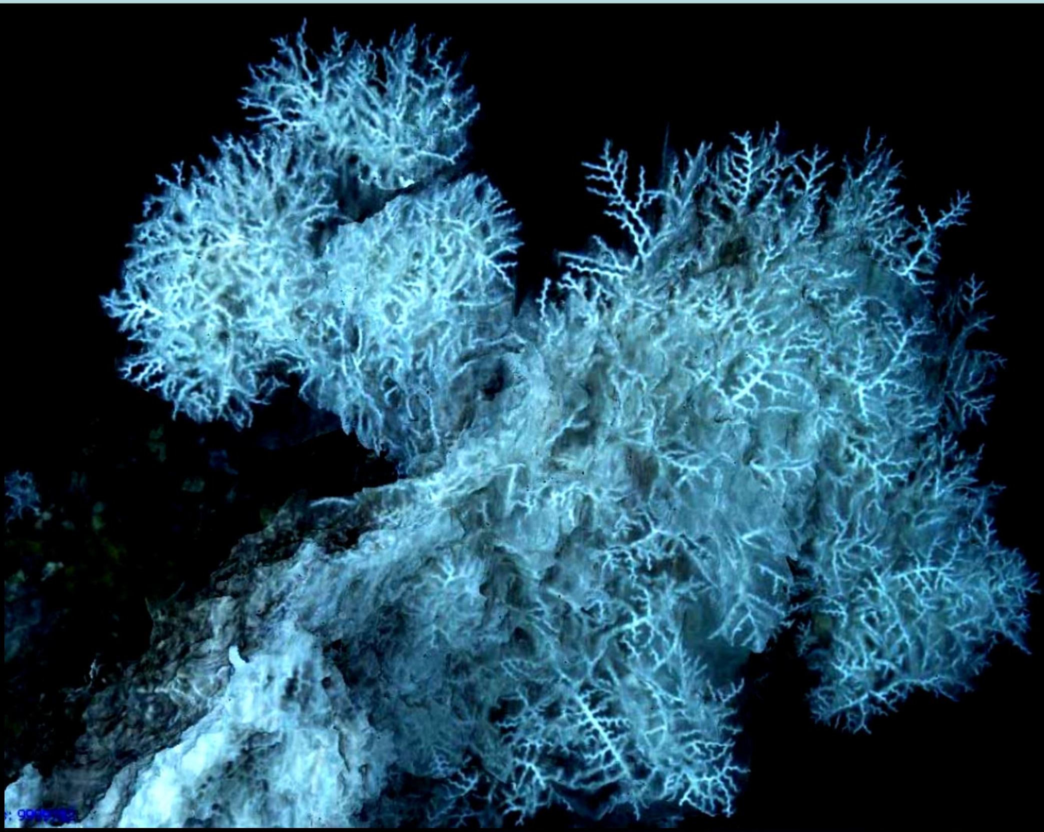


Photo: CEA Irfu

Teleoperation (wet-mate connectors) by using a "light" ROV (not WorkClass)





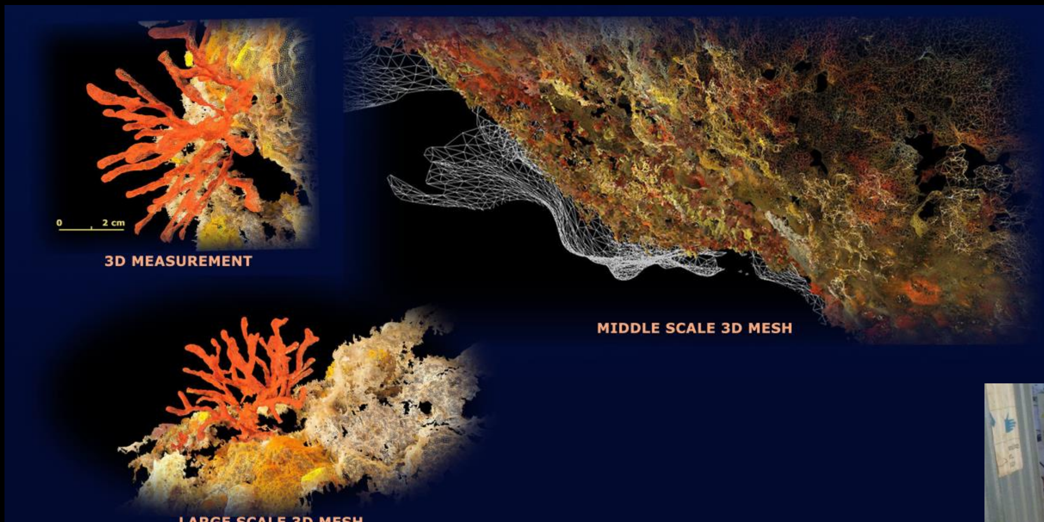
From sea to space

Project ROV3D

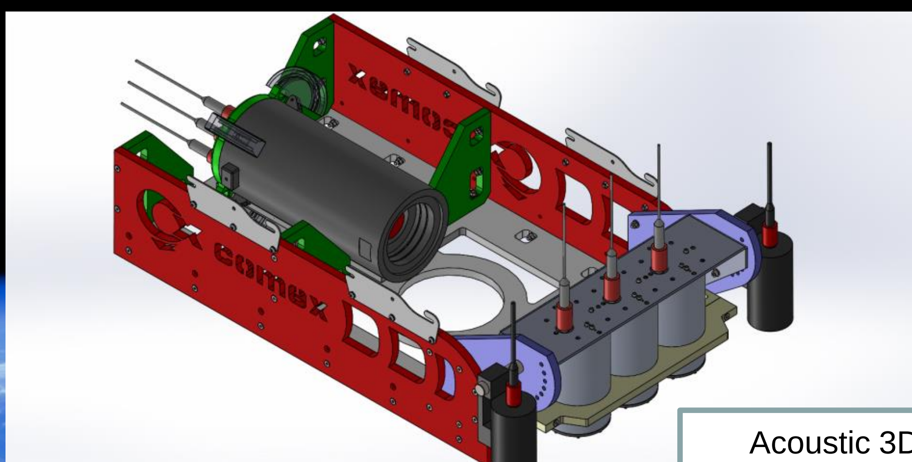
(FUI: OSEO/BPI + Conseil Regional + MPM + FEDER/EU)

From Sea to Space

Subsea Robotics at COMEX



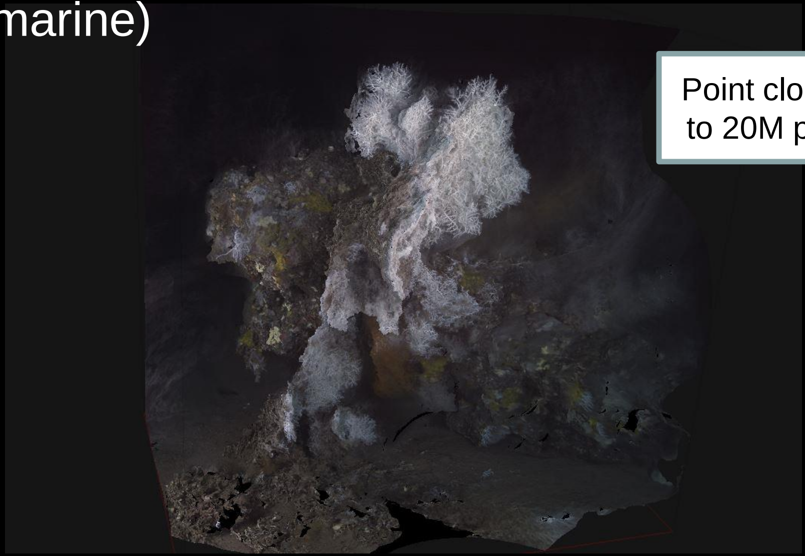
The objective of ROV3D is to develop and validate a 3D photogrammetry system using two series of optical and acoustic sensors.



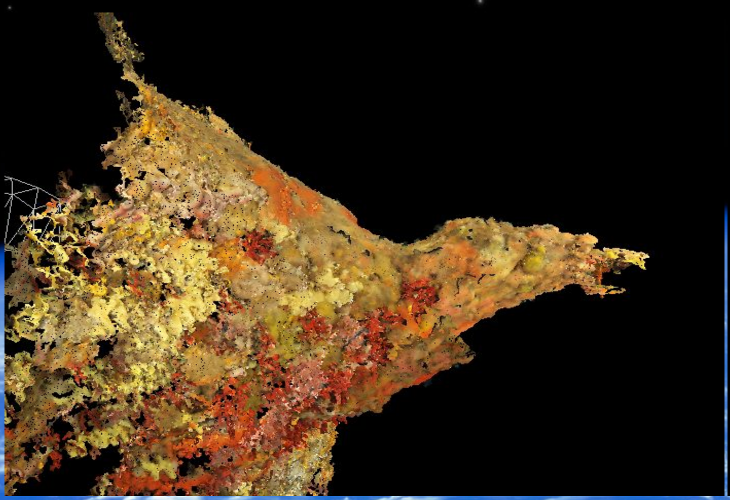
Acoustic 3D scanner
HR model by optic sensors

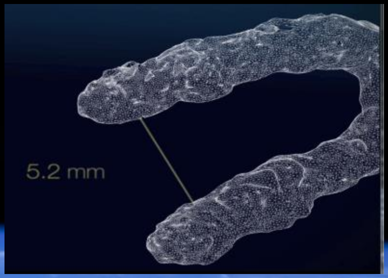
Submarine or
ROV deployment

Natural structure – Coral 220m depth (submarine)



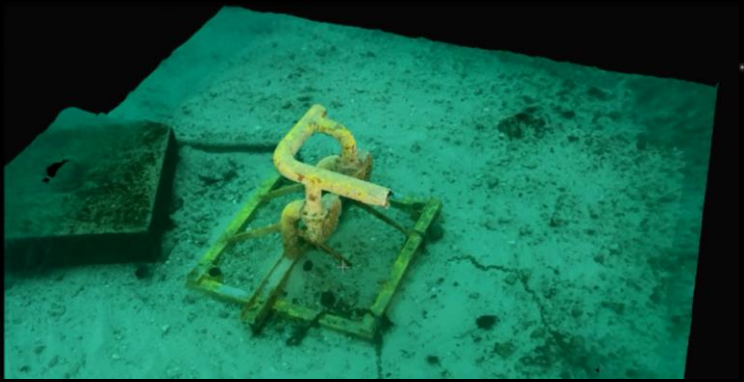
Point cloud up to 20M points

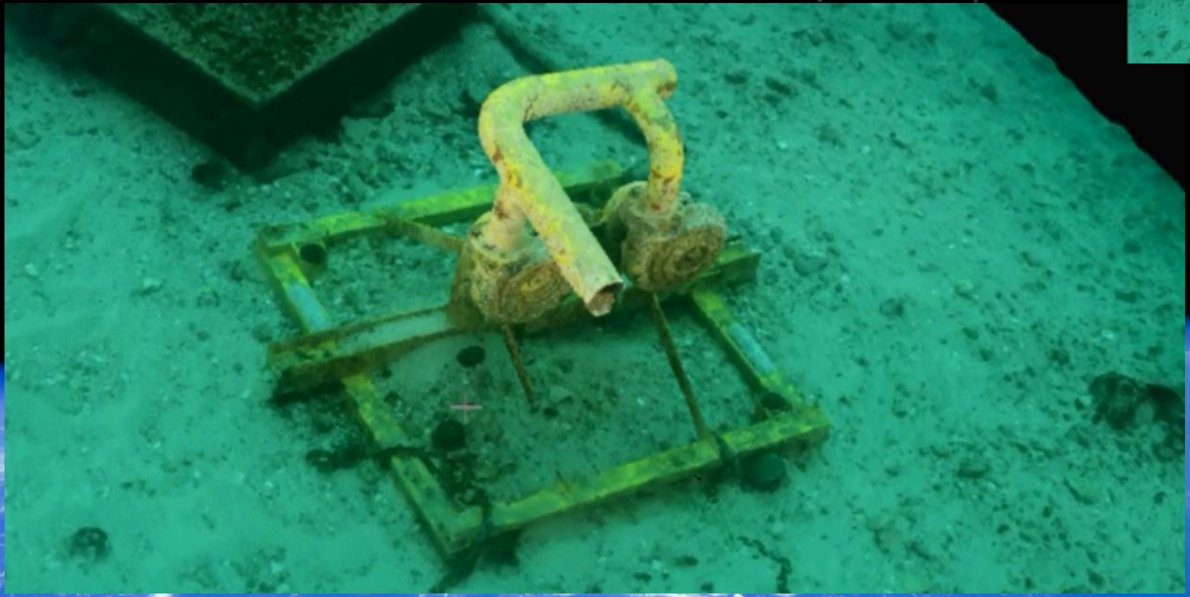




Resolution in the order of mm
(can be 1/10mm)

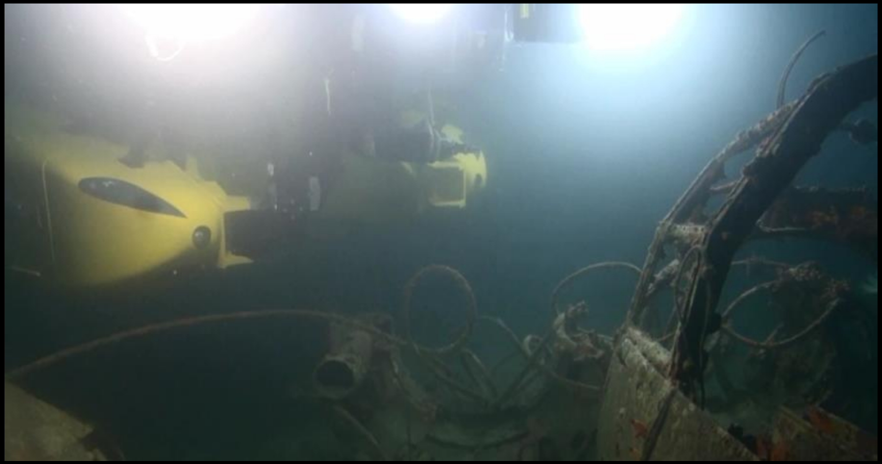
Industrial structure – INPP training structure 30m depth (diver)

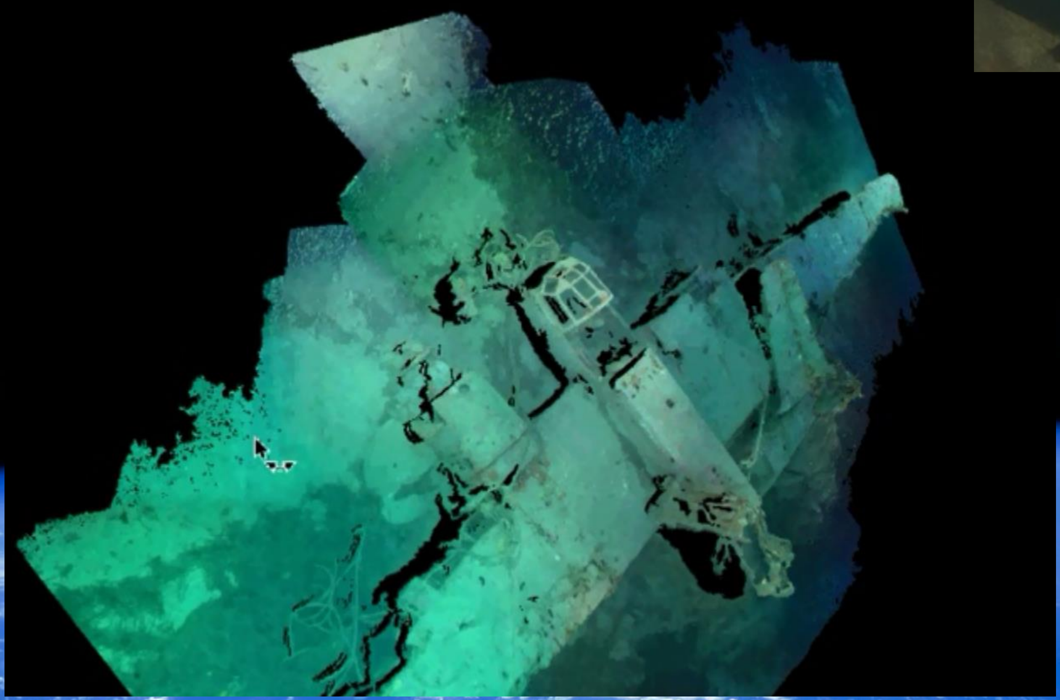




Real time processing software to assist navigation

Wreck – Airplane 55m depth (submarine)





Film ROV3D

Conclusions

- There are many common challenges in space and subsea robotics. Cooperation might lead to novel solutions in both fields.
- Horizon2020 offers the frame to built up synergies between the space and subsea robotics community

Conclusions

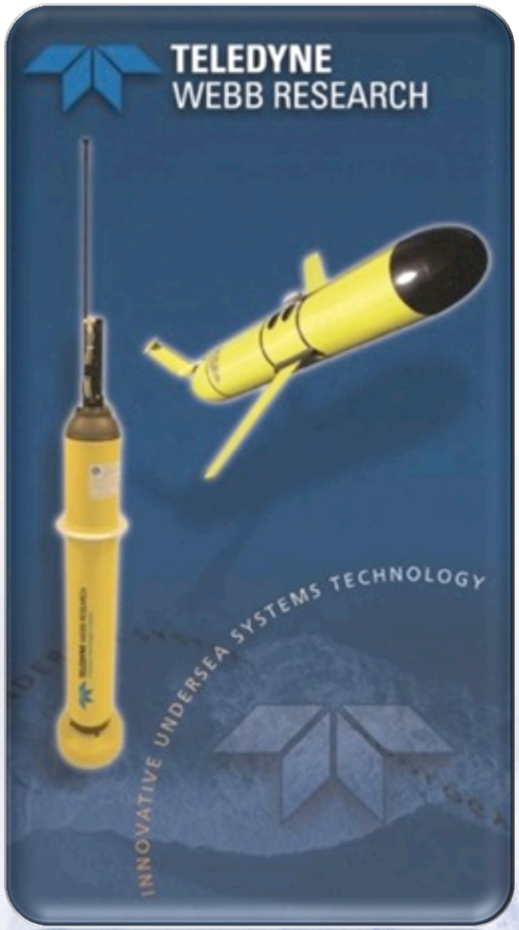
Advancing Unmanned Maritime Vehicle Capabilities through Networking and Modularity

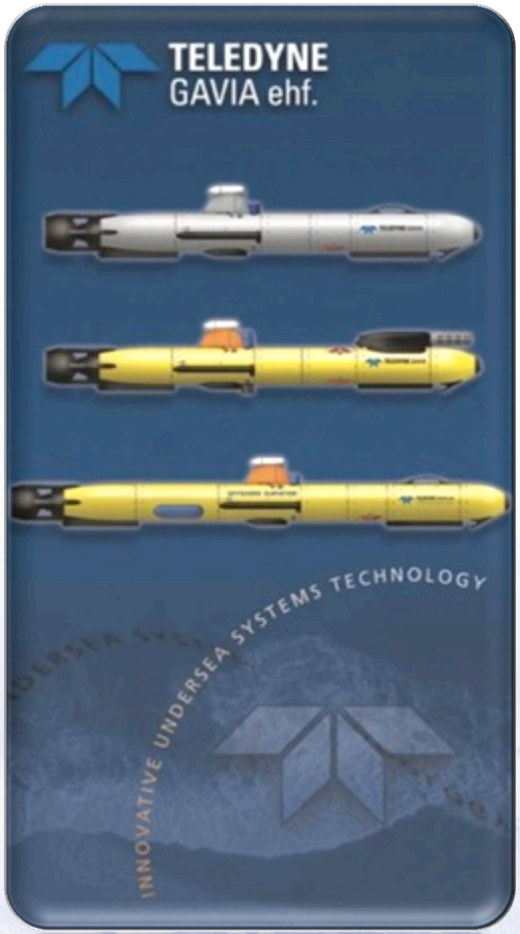
Justin Manley, Teledyne Marine Systems

BENTHOS • GAVIA • WEBB RESEARCH

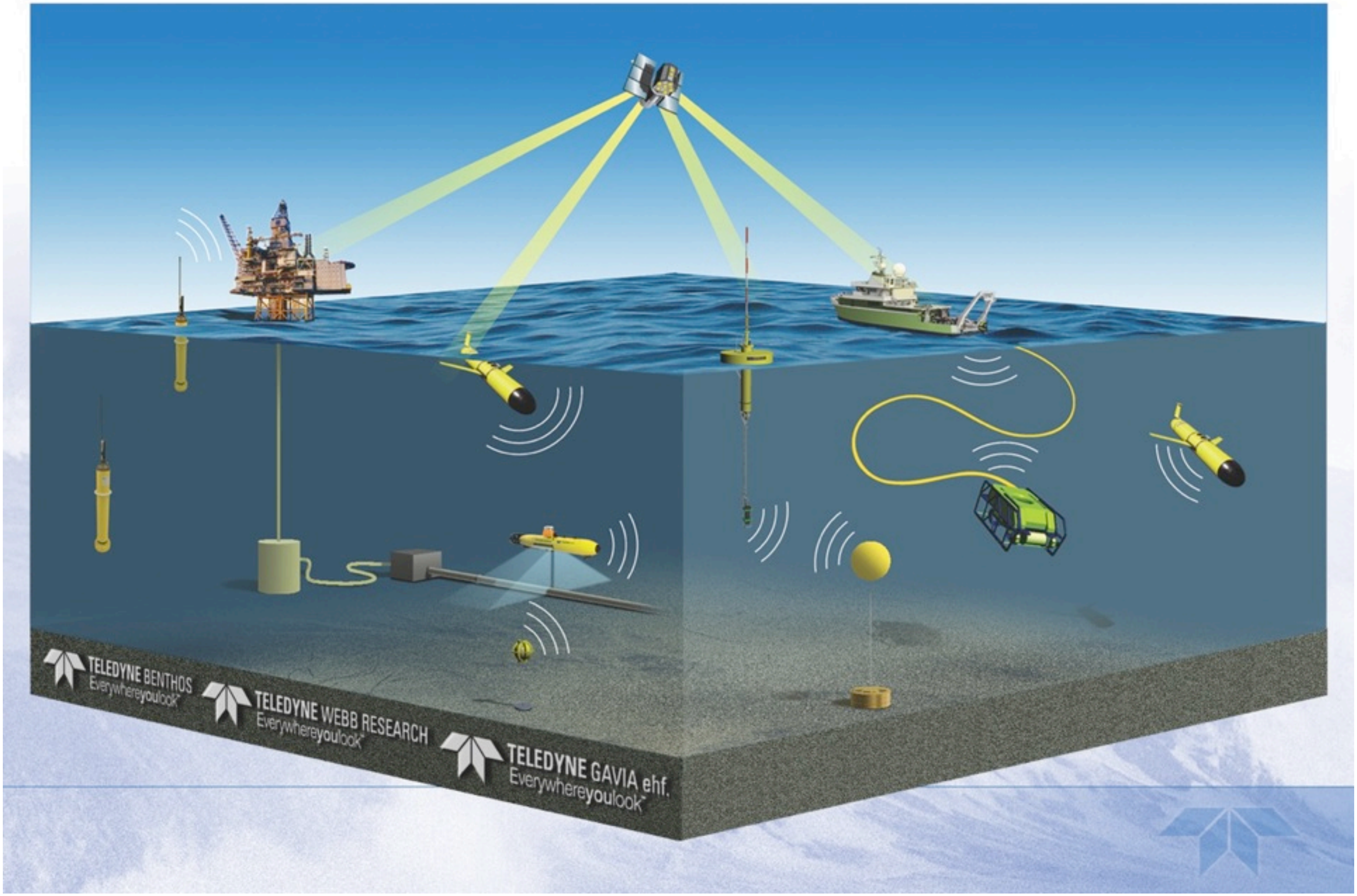
TELEDYNE MARINE SYSTEMS
Everywhereyoulook™

Teledyne Marine Systems
Three portfolios coming together

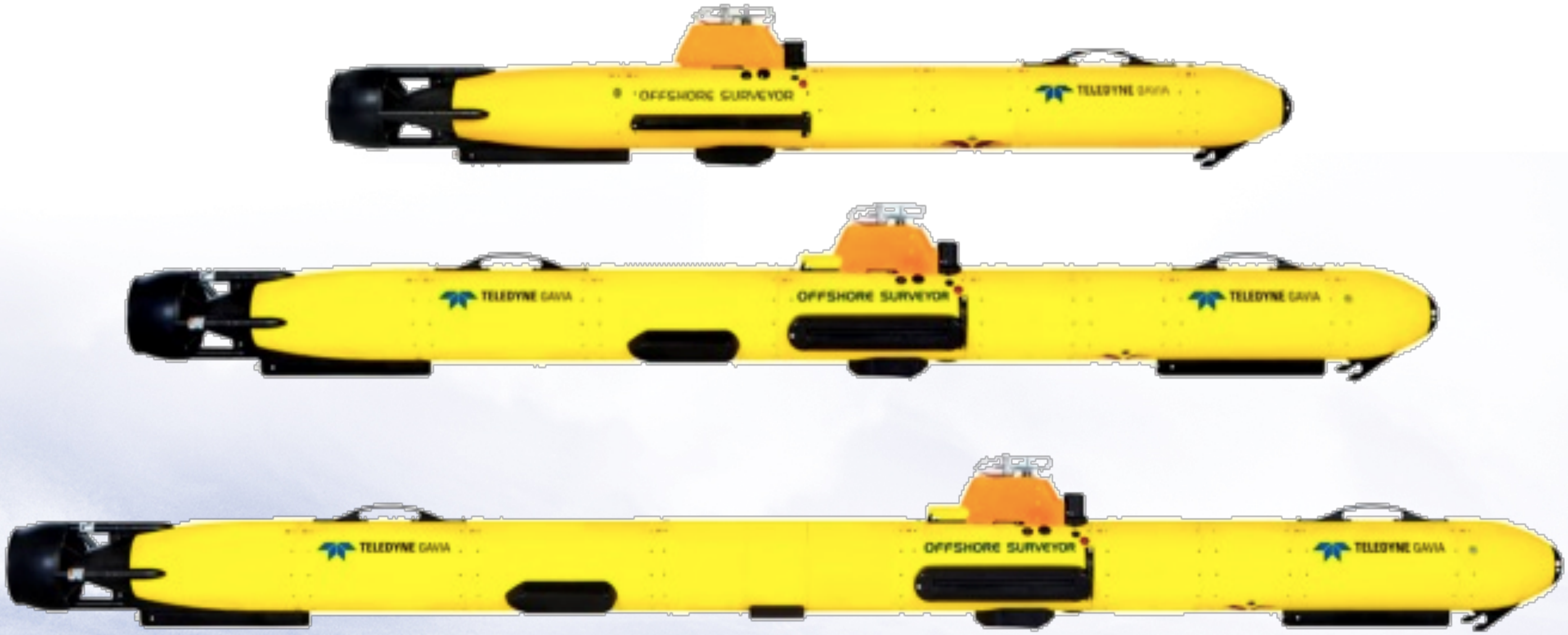




The Networked Future



Gavia AUV: System Configurations



Same Gavia AUV (200mm diameter), three different missions:

Top; Configured for INS-navigated side-scan debris-clearance survey (single battery, 5 hour endurance).
This is 1.8m long and weighs less than 50kg

Middle; Hydrographic mapping configuration: dual batteries, side scan and GeoSwath swath bathymetry.

Bottom; Geophysical survey configuration: as middle, plus sub-bottom profiler.
Over 3m long, and weighs more than 100kg in air (8-10 hours with two batteries)

Low Logistics: Shipping the AUV

- Rotomold Cases
- Dangerous goods shipping drum for batteries

Worldwide commercial use: Gavia AUV

Pipeline Inspection, Pre-route Survey, Platform, Seabed, Site, Debris & Scour Survey

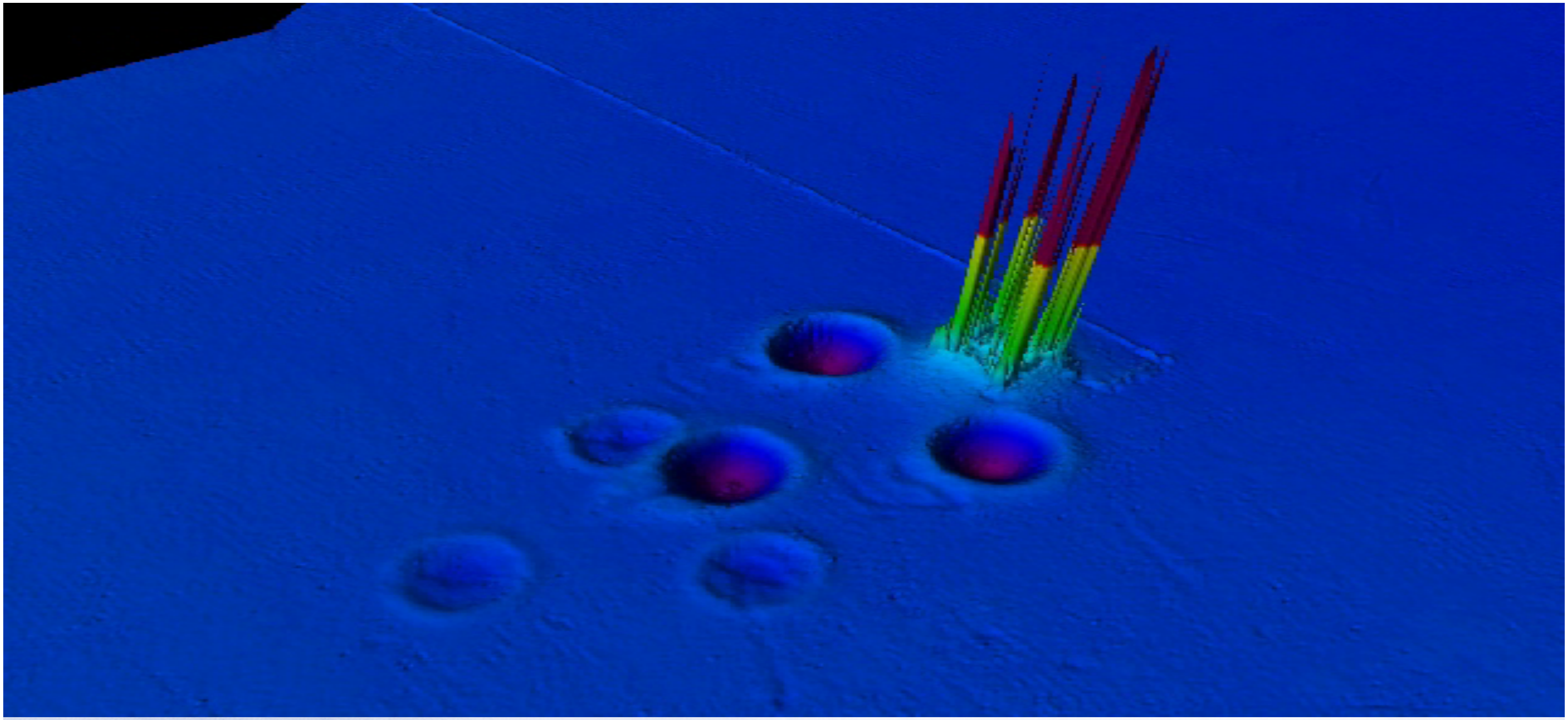
Benefits of Low Logistics CONOPS

Operations in the Caspian Sea

Image: NCS Survey and BP Azerbaijani Subsea Performance Unit

Gavia AUV returning from a platform in the Adriatic Sea.

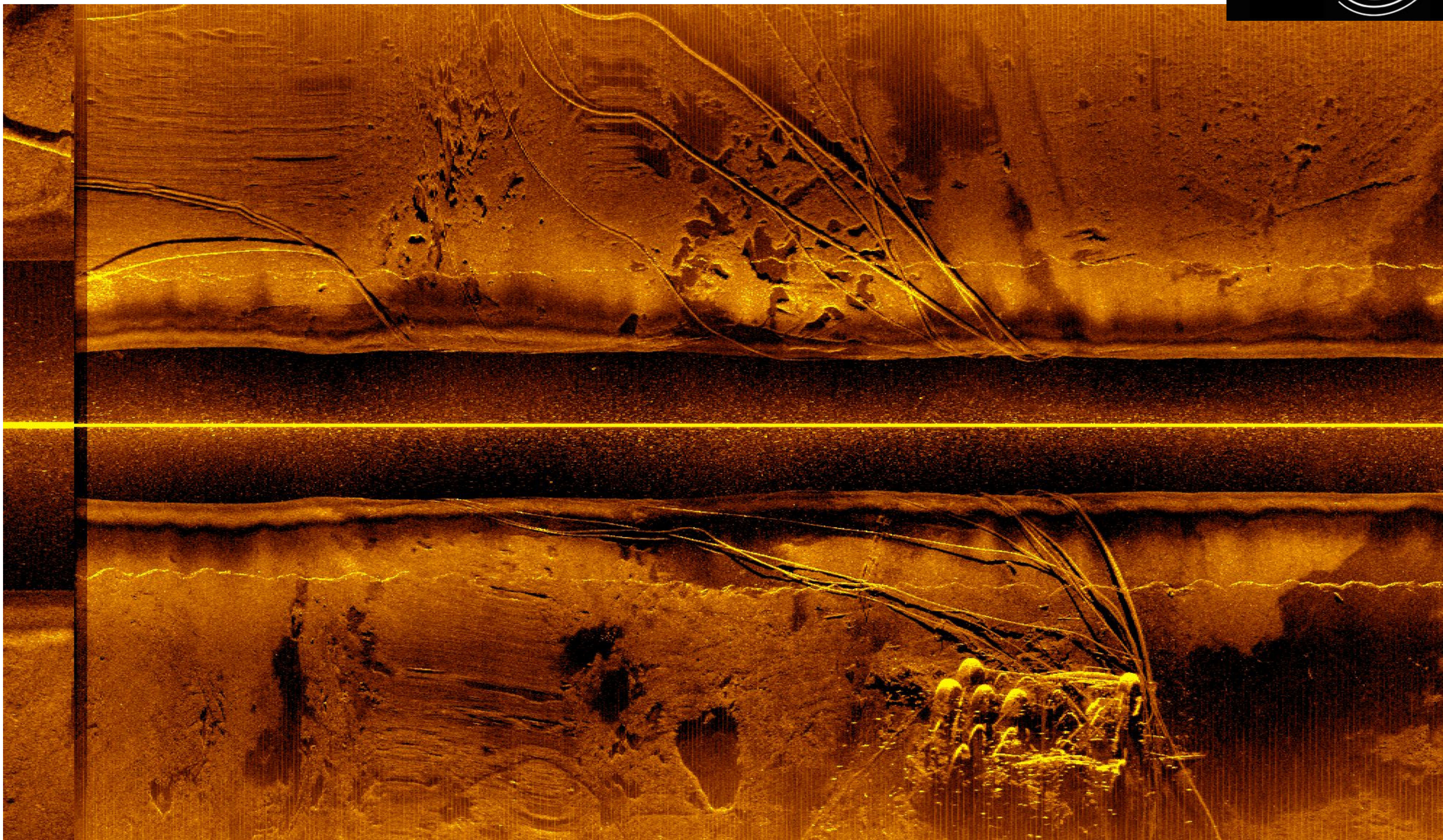
Image: GAS Survey srl, Bologna, Italy.



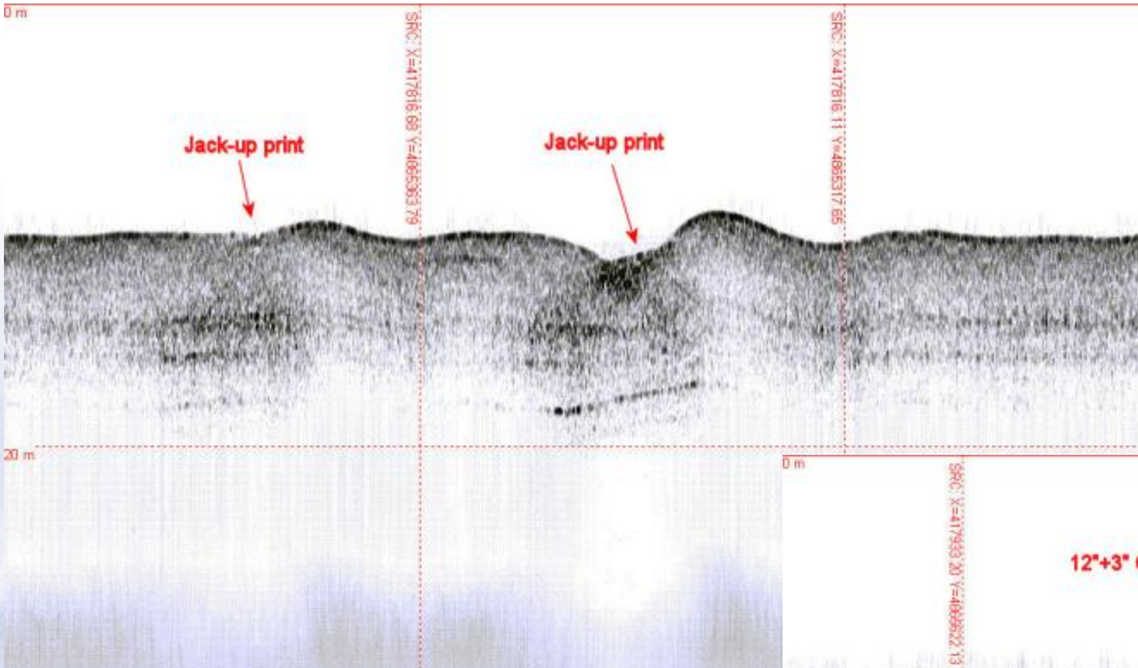
Gavia AUV gathered 500kHz GeoSwath data around an oil rig in the Adriatic showing ocean floor features from previous jack up rig placement and legs of current rig extending from the ocean floor. Data courtesy of GAS Srl.

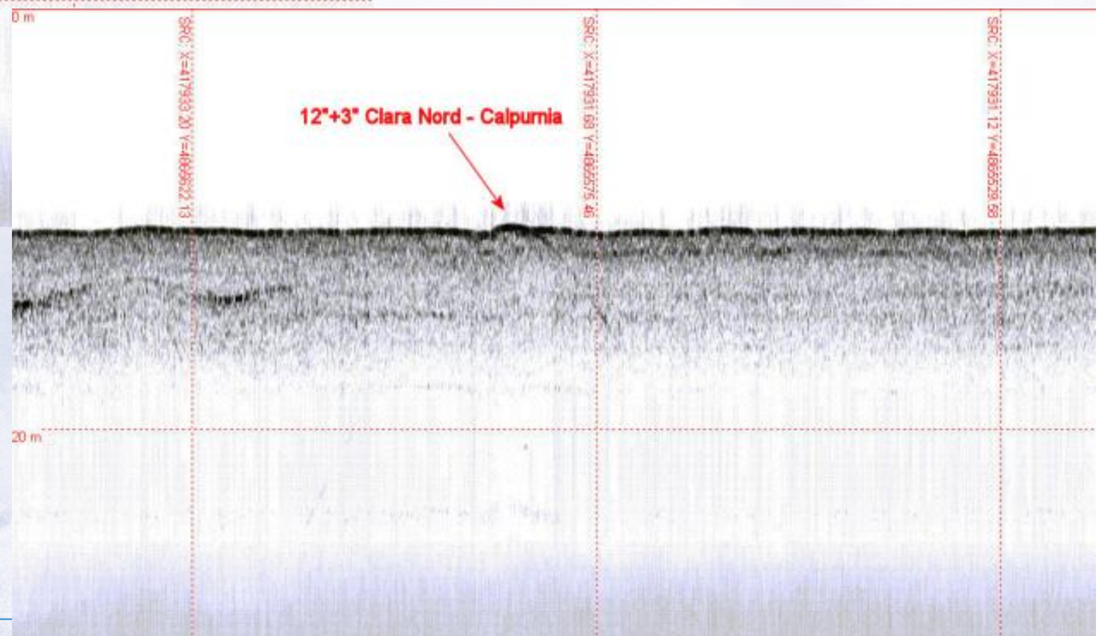
Pipeline Inspection in US GoM

NCS survey



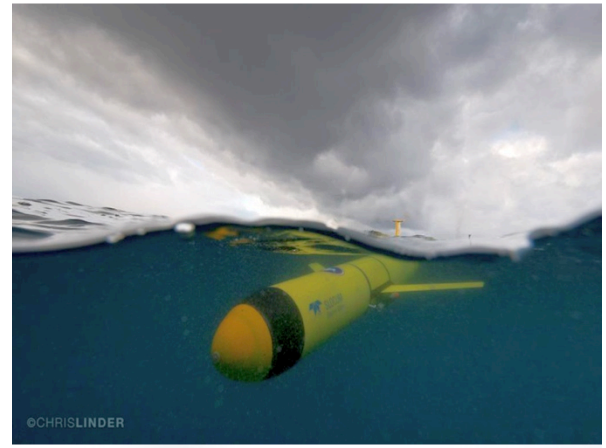
Initial survey operations of Teledyne Benthos Gavia SBP with GAS SRL, Italy



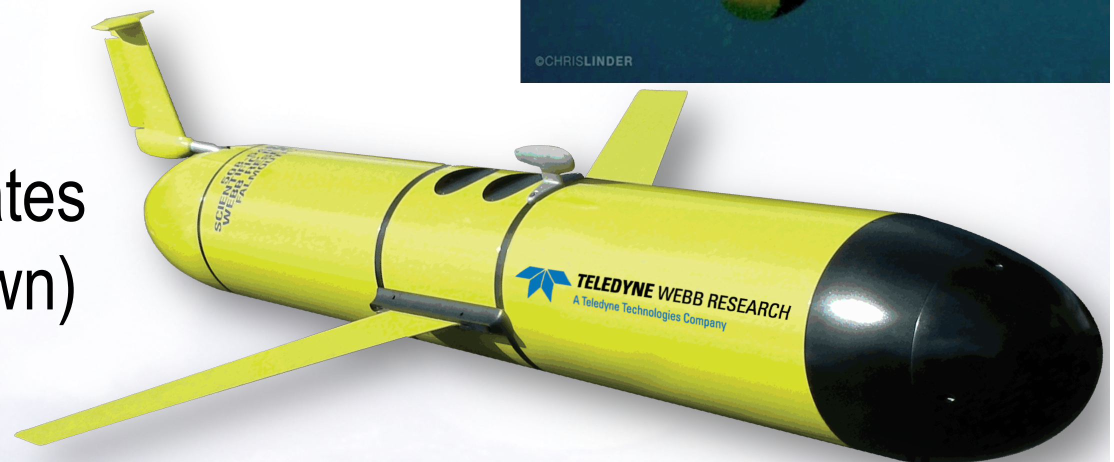


Data courtesy of GAS SRL, Italy

The Slocum Glider



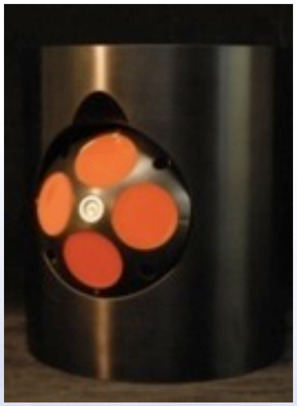
- Mass is constant
- Variable buoyancy creates vertical force (up or down)
- Wings convert vertical force to horizontal motion
- Hybrid capability
- Long endurance



Modular Payloads

Current ROV Family

Teledyne Marine Hardware Ecosystem



DVLs, Imaging Sonar & SBP underway

Motion sensors & USBL available

ROV Payload Concept: Modularity

The Gavia AUV uses a modular architecture that is market proven and already supports:

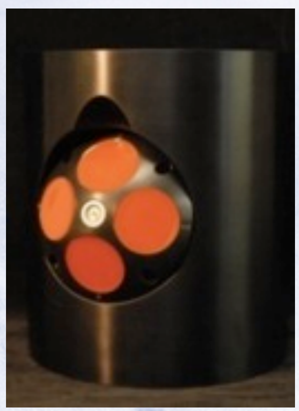
-DVL w/full INS

-Sub-bottom profiler

-Geoswath bathymetry

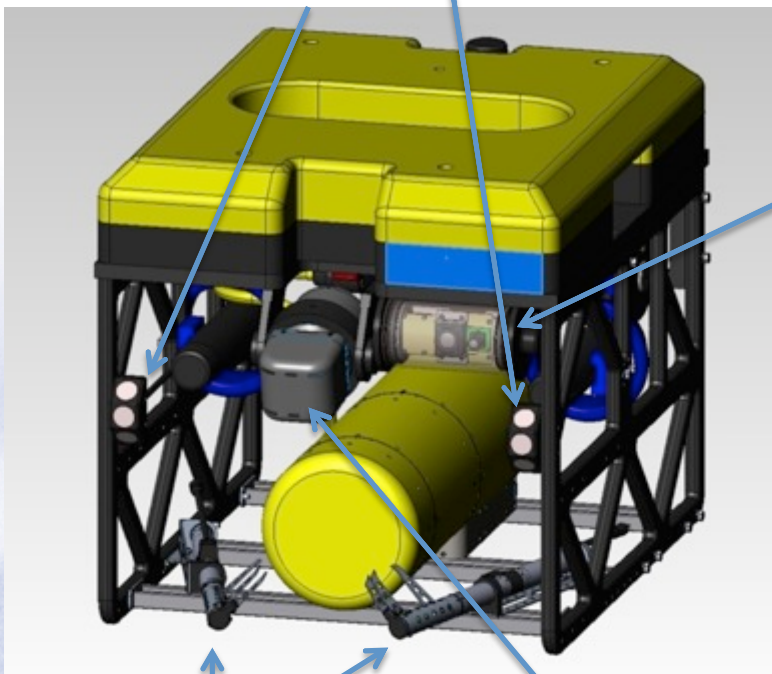
- MB1 module . . .
- RESON module . . .

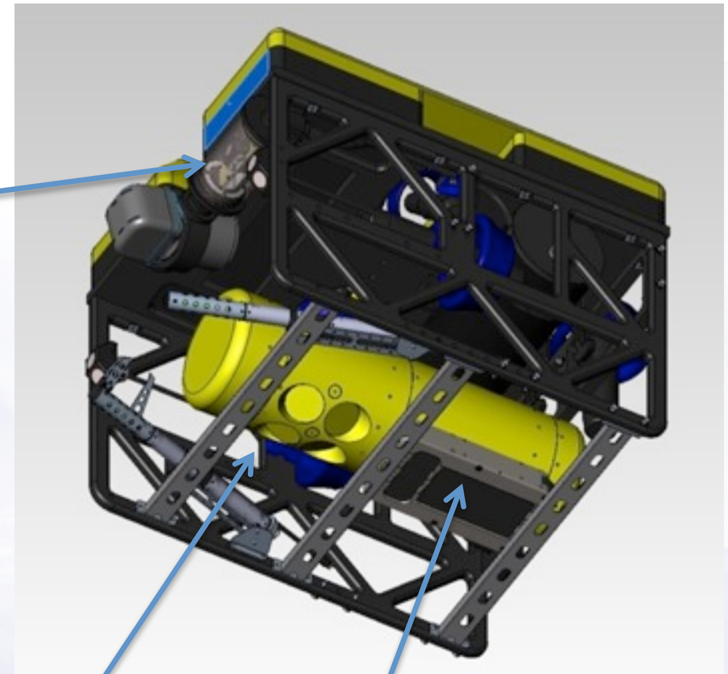
DVL



MB1

Teledyne Marine Systems
Modular Payload Concept: Sample Integration





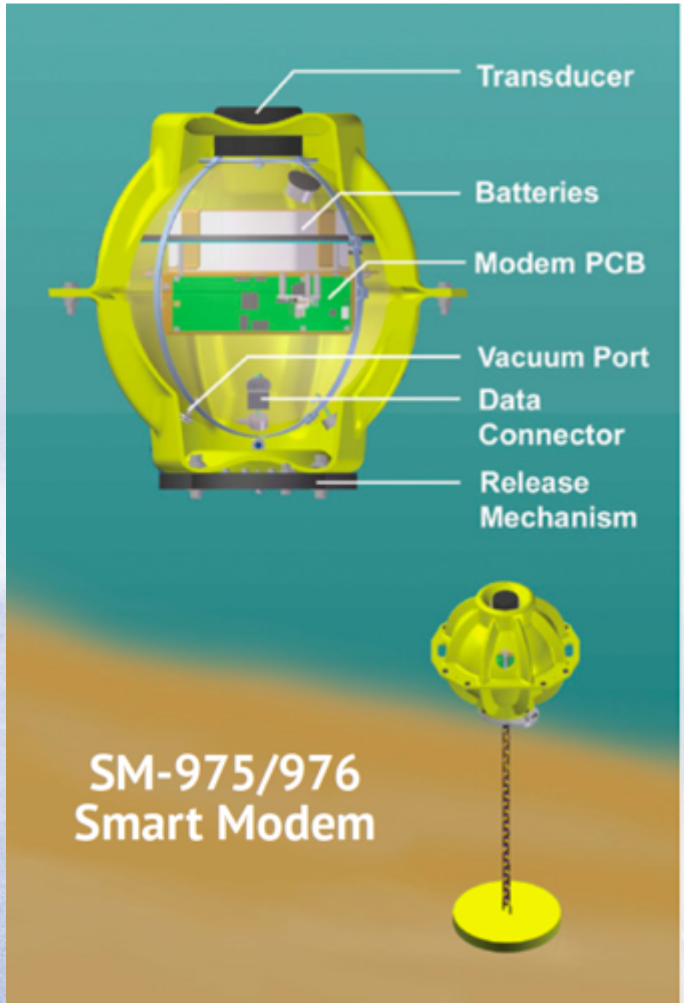
Subsea acoustic communications

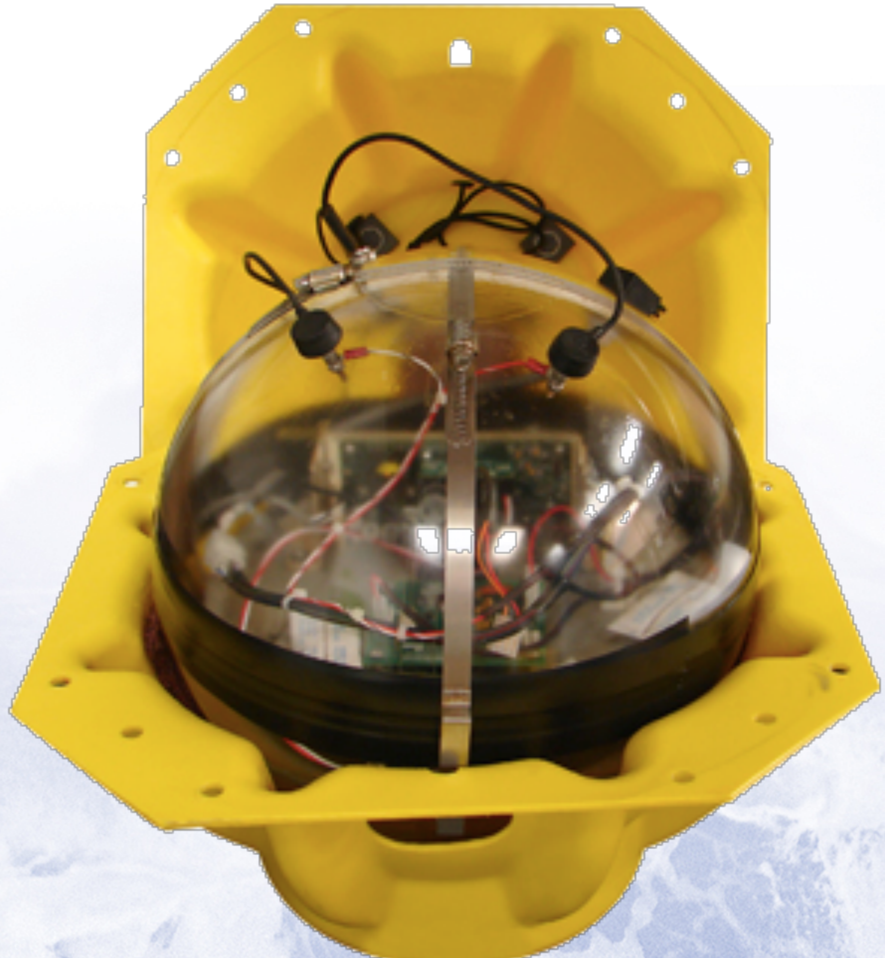
- <u>Present Capabilities </u>(5 kHz band, 11.5, 18, 25 kHz center frequencies)
  – Multi-channel, MFSK: 140, 300, 600, 800, 1200 bps
  – MPSK: 2560, 5120, 10K bps
  – Differential OFDM (binary, quadrature) : 950, 1850, 3700 bps
  – Range, frequency and condition dependent ~1000m to beyond 6000m
  – Range measurement (0.5 m resolution) with every transmission

Streaming videos under sea, not so much, moving 144 character messages, definitely

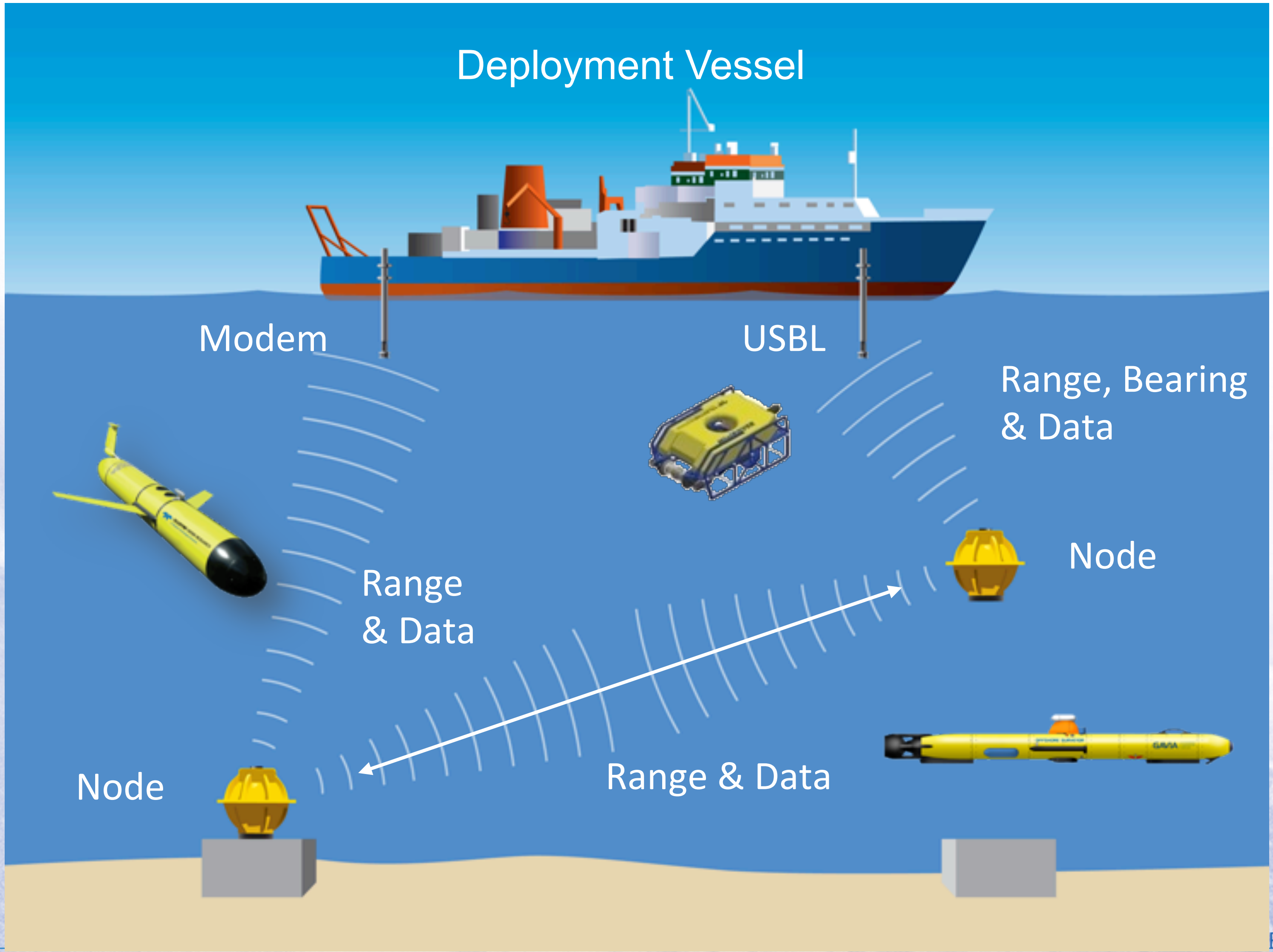
Thanks to Netflix and Twitter for their innovative services and their logos used here

Subsea Nodes: Science, Seismic, Telemetry and Positioning



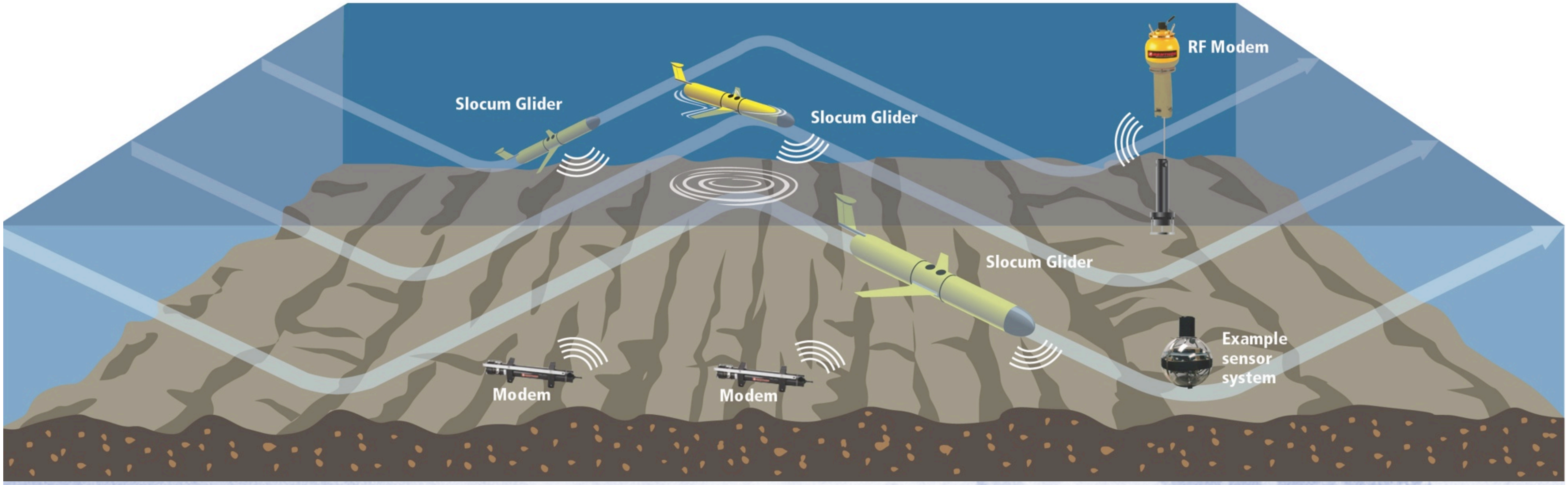


Telemetry and Positioning, Multipurpose

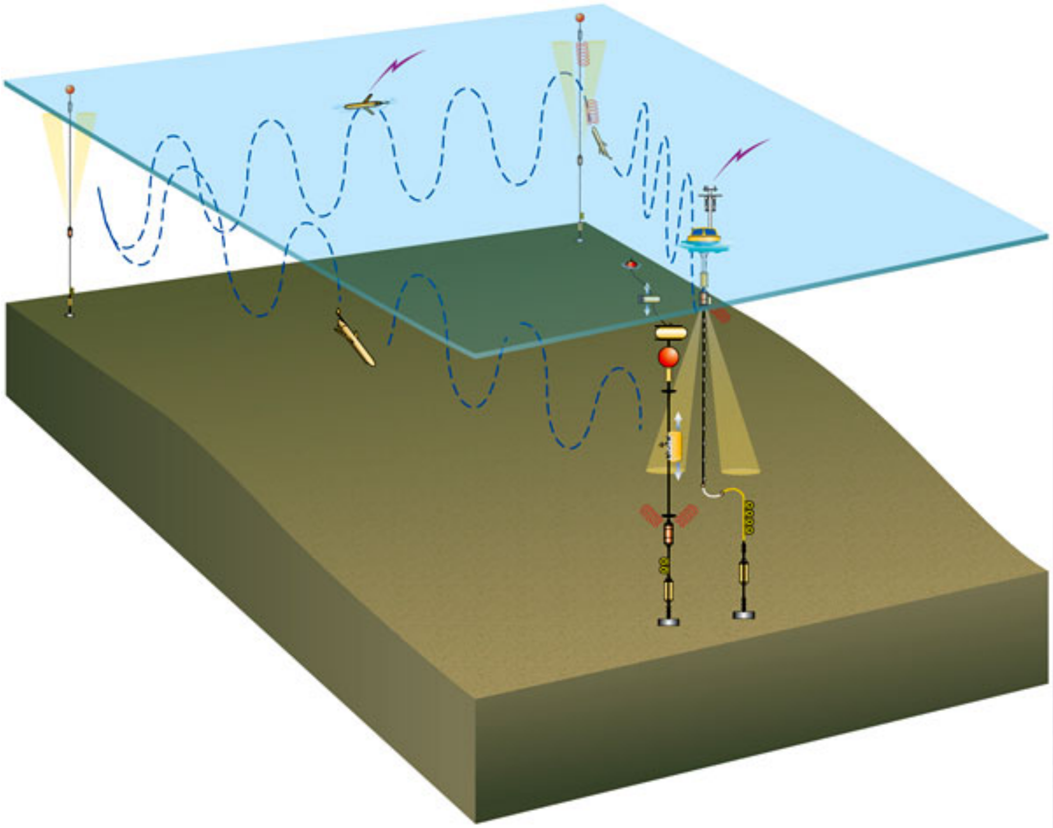


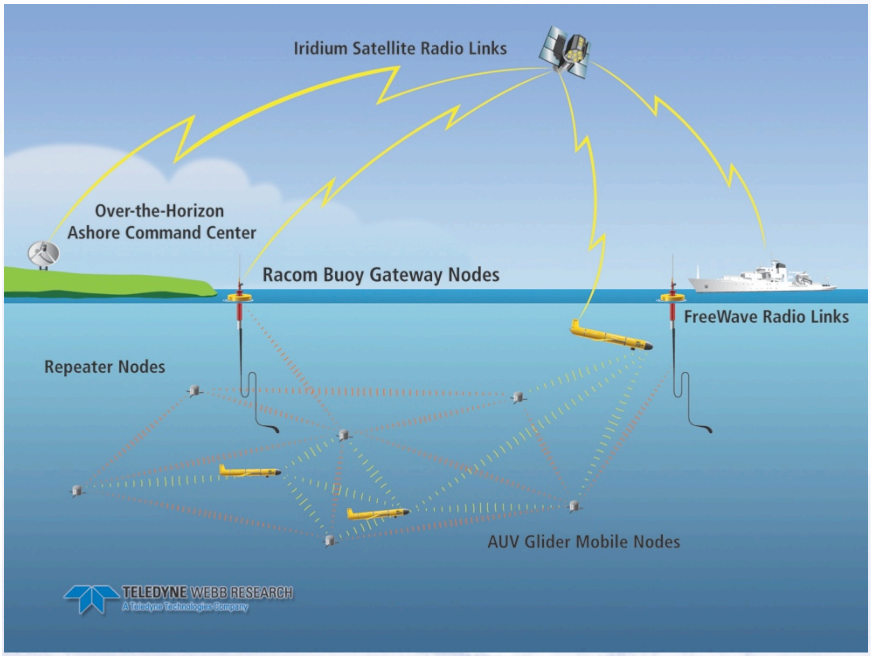
Cutting the Cord, Simple Networked Operations

- Full water column data collection and exfiltration (wireless from seafloor to shore)



Gateway Gliders

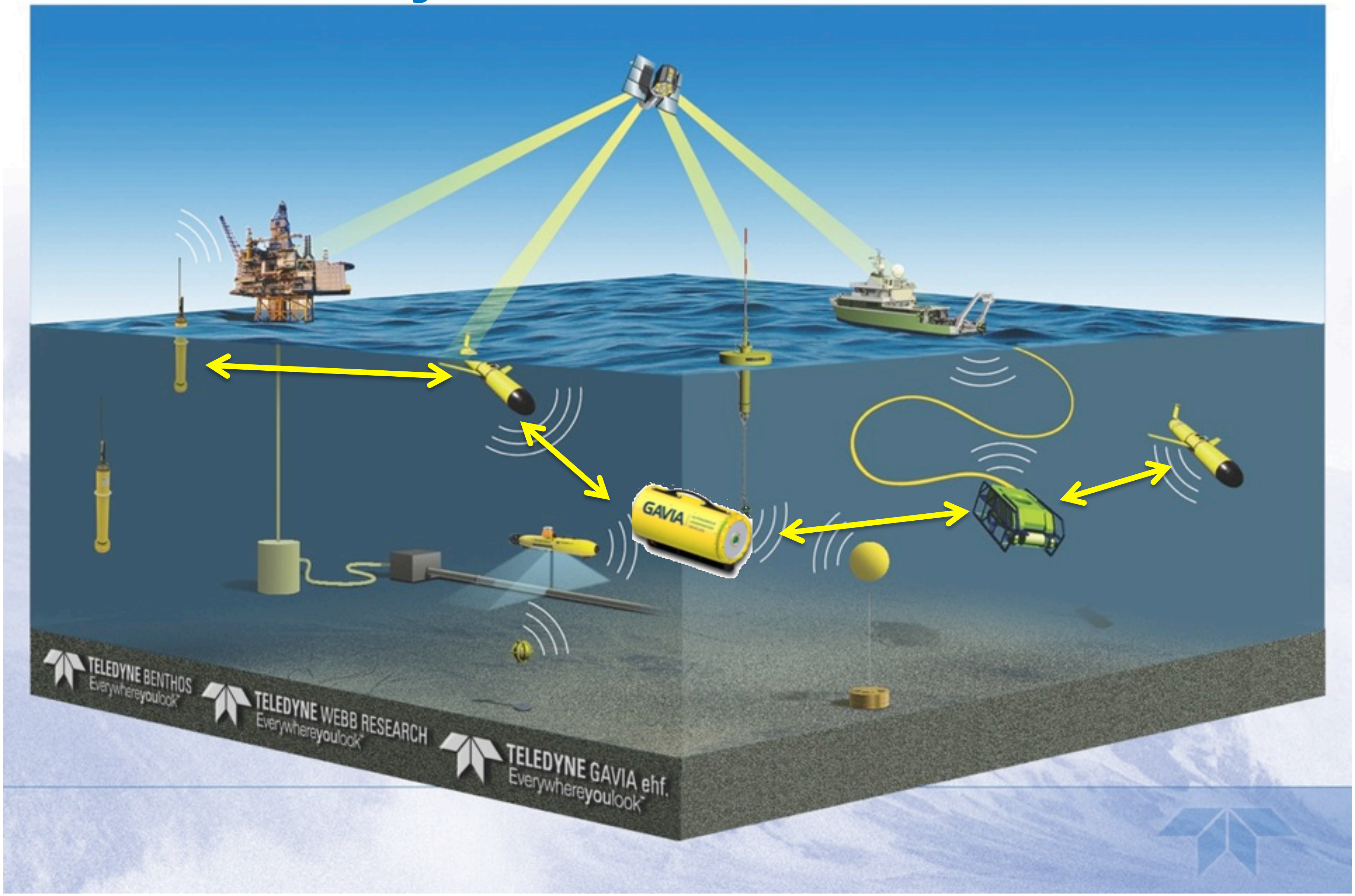




Integrated Modem for C2 and Data Transfer

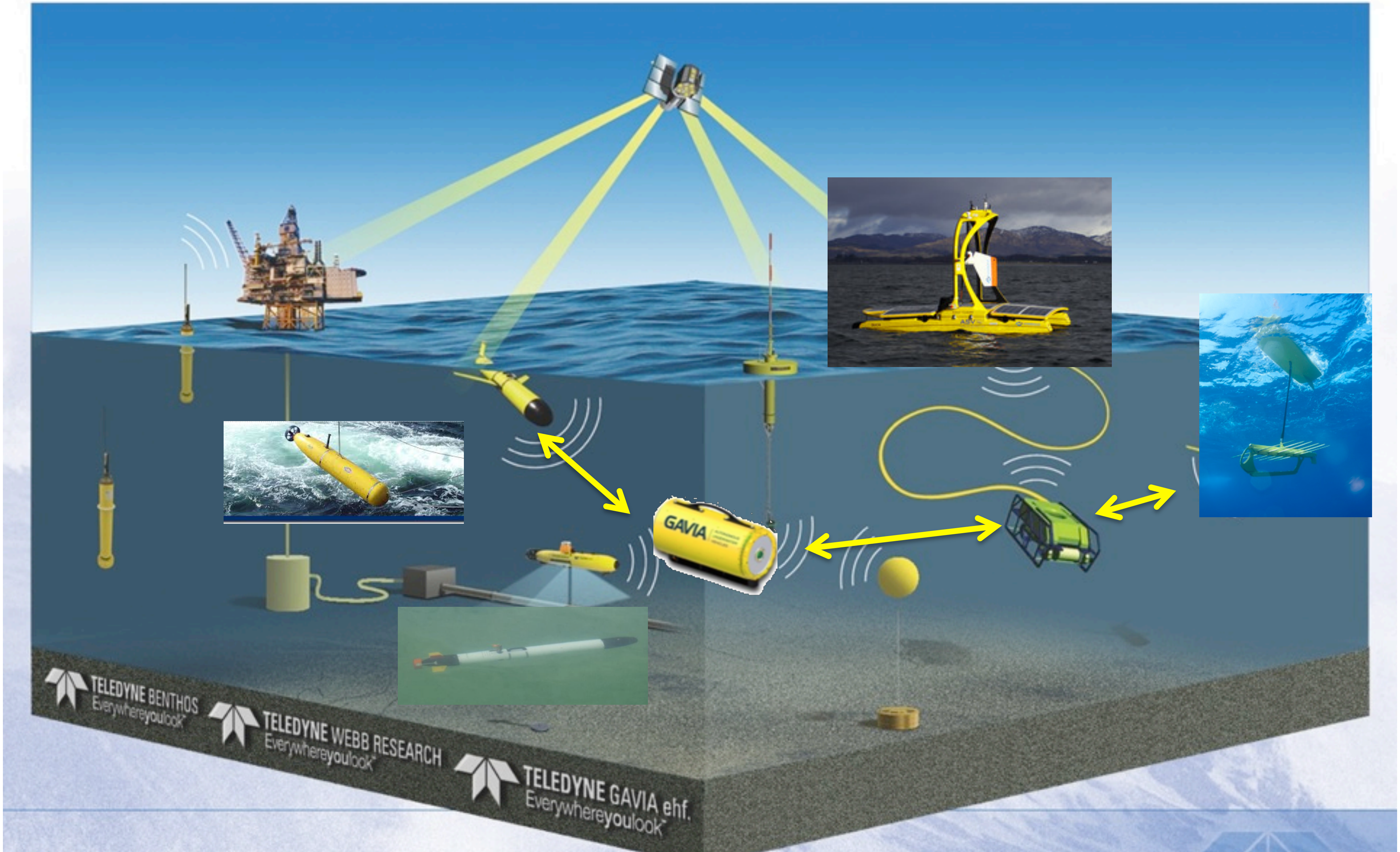
The Networked & Modular Future

How many combinations will add value?



The Networked & Modular Future

Will it cross manufacturers?



Images courtesy OceanServer Technologies, Bluefin Robotics, Liquid Robotics, and ASV Ltd.

Questions

Justin E. Manley,
Senior Director, Business Development

Justin.manley@teledyne.com

+1 508-564-2960

The Oil & Gas Industry Requirements for Marine Robots of the 21st century

Laura Gallimberti

www.eninorge.no

Outline

- Introduction: fast technology growth
- Overview underwater vehicles development
  - Subsea Yesterday : ROV
  - Subsea Today : AUV
  - Subsea Tomorrow: Hybrid ROV/AUV or I-AUV
- Main Requirements for subsea unmanned vehicles development
- Oil & Gas industry need of advanced underwater vehicles

Technology development

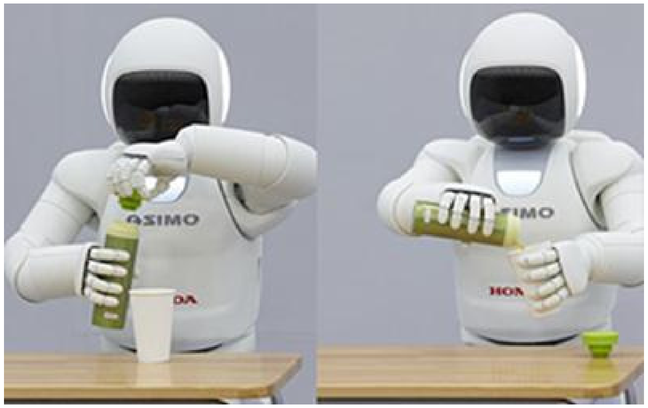
YESTERDAY

TODAY

- Autonomous navigation system
- Self-charging to the docking station
- Intelligent combination of real-time sensory feedback
- High performance lithium-ion battery

Today extreme technology advancement

- Advanced Intelligence capabilities
- Advanced Physical Capabilities
- Improved Task Performing capabilities :
  - tactile sensor
  - force sensor
  - object recognition technology based on visual and tactile senses



Oil and Gas Industry Goal

SUBSEA ASIMO ?

- What does it means:
  - Able to move where and when it's required
  - Able to recognize objects and manipulate them
  - Reliability
  - Robustness
  - Advanced sensors
  - Enough stamina to finish the job

Subsea yesterday :Remotely operated vehicle ROV

- ROV is a mature technology able to remotely execute unmanned underwater operations ranging as
  - simple observation
  - data collection
  - transmission of information
  - Manipulator and tooling operations
- but it is still moving towards new developments
  - all electric ROV, TMS and more advanced sensors
  - Increase efficiency (30% and more), smaller and lighter units, with higher power
  - better reliability (less parts), smaller umbilicals, more sophisticated tooling
  - advancement in launch and recovery systems.

Subsea Today: AUV

- Autonomous underwater vehicles (AUVs) are used:
  - in subsea survey
  - as a tool for inspection tasks
- AUV requires no cables
- It can be configured with different sensors
- AUV can:
  - Follow pre-programmed missions,
  - Transmit small amounts of data
  - Obstacle avoidance systems
  - Run several hours before the battery needs recharging
  - Active control
  - Consider safety, energy use, and time to reach the destination

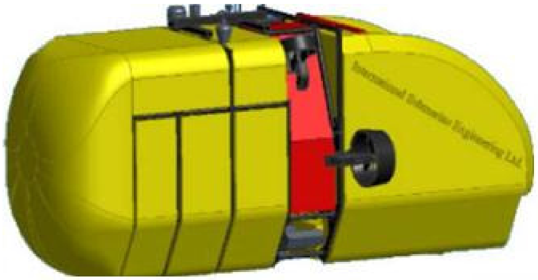
eni norge

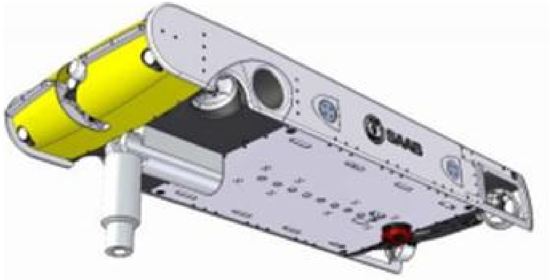
Source Images published by : Lockheed Martin, Bluefin Robotics, Kongsberg

Subsea Tomorrow: Hybrid ROV/AUV or I-AUV

A subsea ASIMO will require:

- Advance Intelligence capabilities
- Advance Physical Capabilities
- Improve Task Performing capabilities :
  - Intervention Capacity
  - Electric manipulators
  - Automated component change (remove human error)
  - 3D monitoring systems (bad visibility navigation)
  - Wireless communication
  - Advanced Sensors Technology
  - Power autonomy





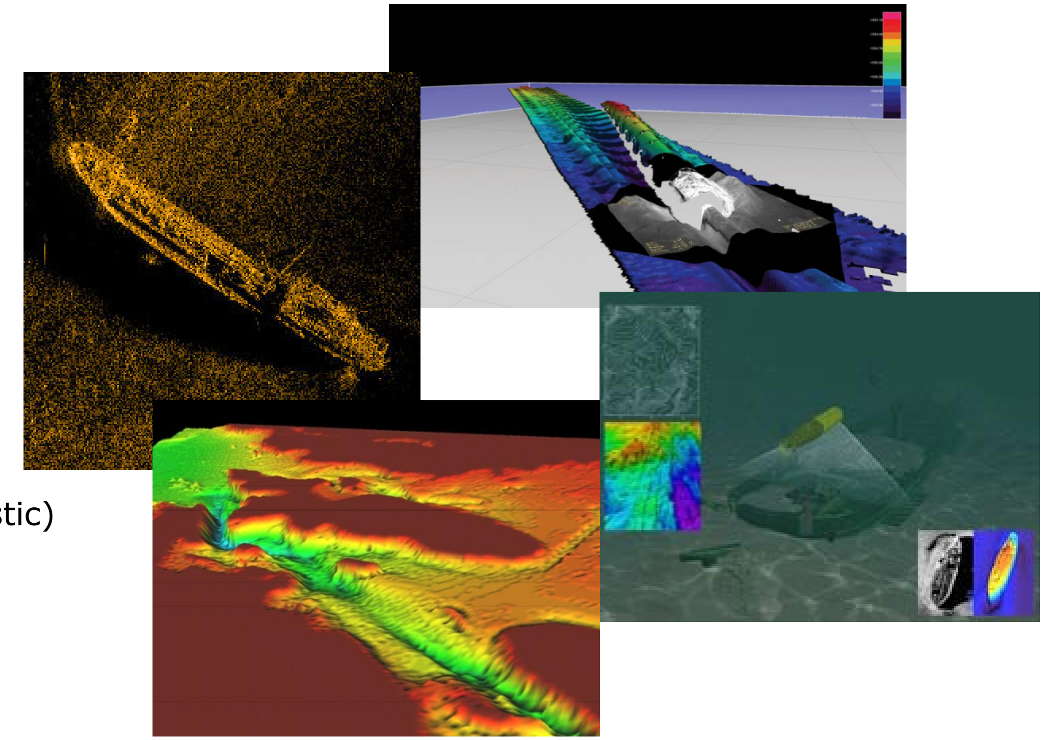
Source Images published by : Swimmer Cibernetix; Seaeye Sabertooth AUV, Subsea7 AIV

Intervention Capacity

- Challenges while working with manipulators under water
  - Motion of operating vessel
  - Motion of the ROV/AUV (currents, swell and pulling forces)
  - Human error
- Development of force-feedback manipulator to protect sensitive equipment on the seabed
- Development of electric manipulator to reduce power consumption
- Development of locking system solution to lock the AUV to the structure, and do automated manipulator and tooling tasks

Advanced Sensor Technology

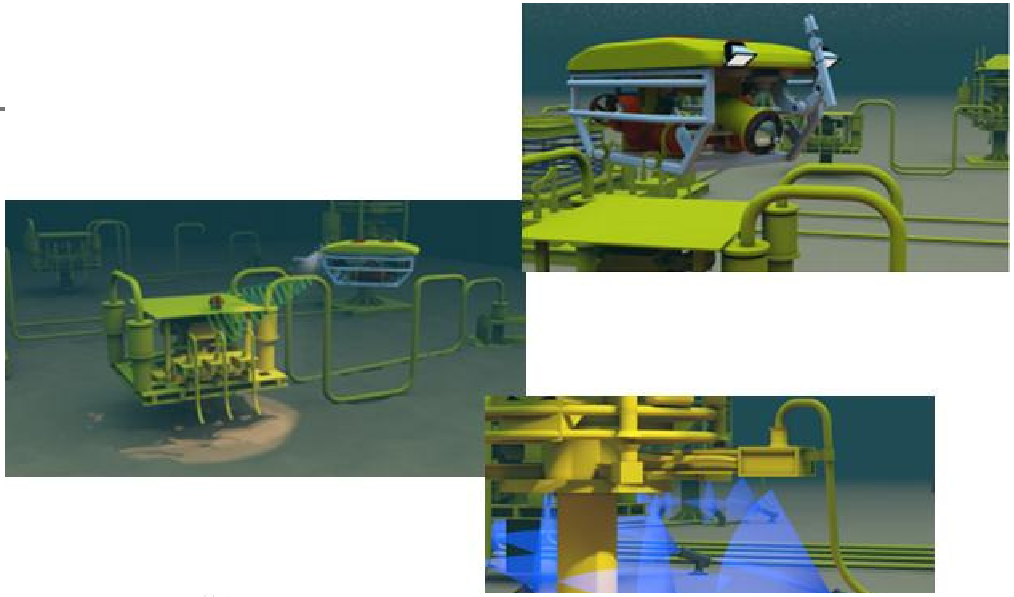
- All subsea operations are based on feedback from sensors on the vehicle
- Imagery Digital Video -HD Digital Video -4K
- New Survey and Inspection Sensors
  - Laser Profilers
  - Synthetic Aperture Sonars
  - MBE Water Column Logging
  - Optical Sensors

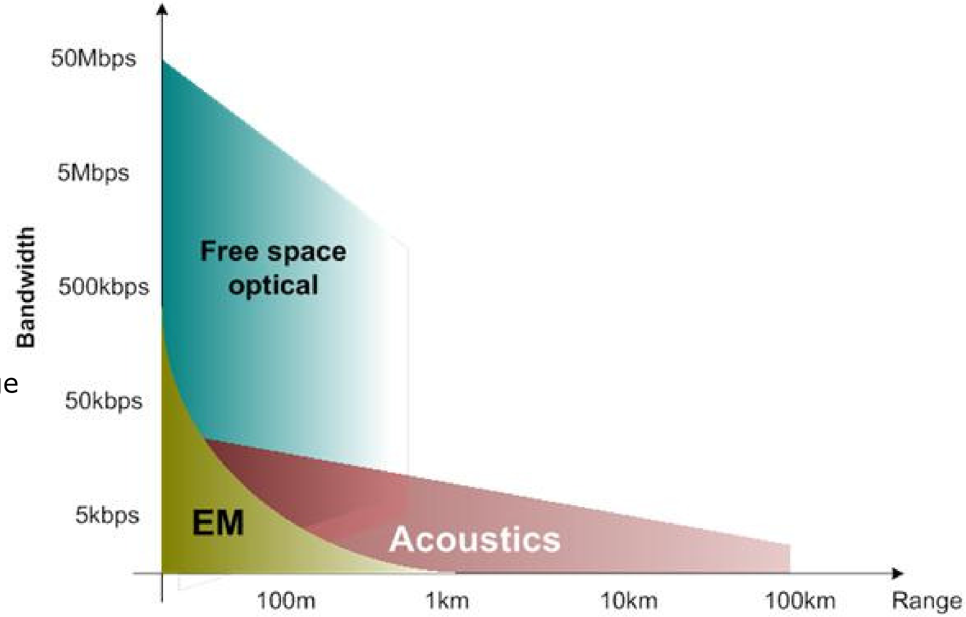


- Peripheral Sensors
  - Positioning (DVL, INS, gyros, sonars, acoustic)
  - Hydrocarbon Sniffers
  - Magnetometers
  - Forward Looking sonars
  - SVP/ CTD
- The challenge is to implement new sensors and real time-processing to enable subsea vehicles into performing new tasks, like detection of chemicals, acoustic patterns (leaks, propeller noise, position, 3D..)

Communication

- Subsea communication is divided in
  - Cabled (FO with High bandwidth)
  - Wireless (limited due to water properties)
- Autonomous systems are dependent on a combination of the following technologies:
  - Acoustics
    - Proven Tech
    - Relatively high / flat bandwidth
    - Noise / channel dependent
  - EM / Radio
    - High bandwidth at short range, low bandwidth long range
    - Subject to interference from nearby sources of EMI (Electromagnetic Interference)
    - Large antenna & lots of power required for long range
  - Optical
    - Ultra high bandwidth at short range
    - Turbidity / water clarity dependent

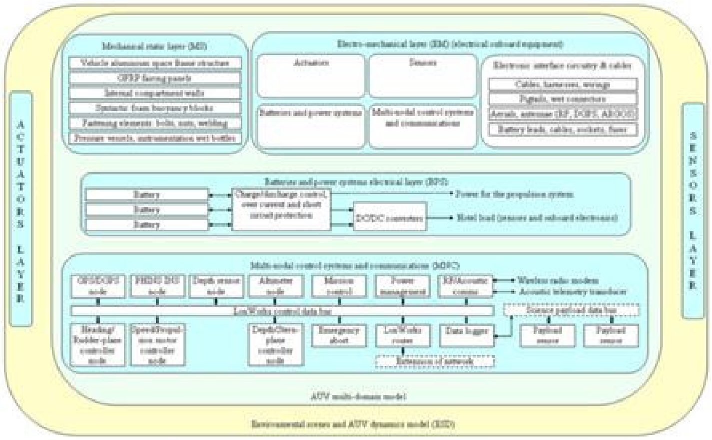


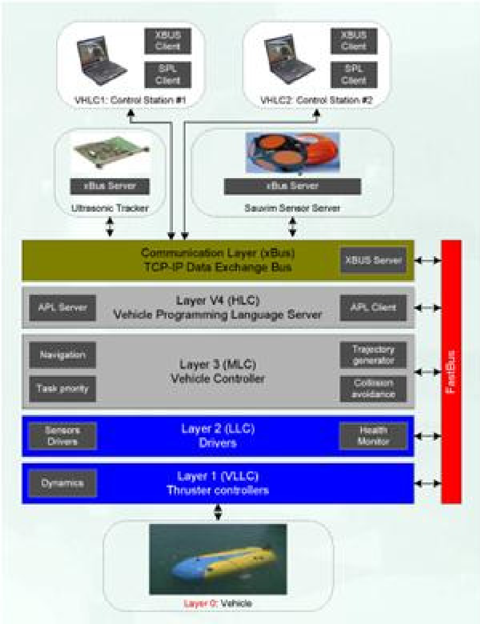


Source published by : WFS Technologies, Sonardyne

Artificial Intelligence (AI)

- Today operations of UV are dependent of human control, and programming.
- Ideally, AUVs should be able to perform complex, long-duration missions without the need for human intervention
- By implementing smart architectural structure, the vehicle may make its own decision.
  - Automatic navigation systems with ability to change trajectory based on mission goals
  - Manipulator control, automated intervention, based on 3D models, also based on live data processing.
  - Automated valve operations
  - Emergency detection and actions
  - Onboard adaptive control software system that integrates automated planning and probabilistic feature detection within a hybrid executive

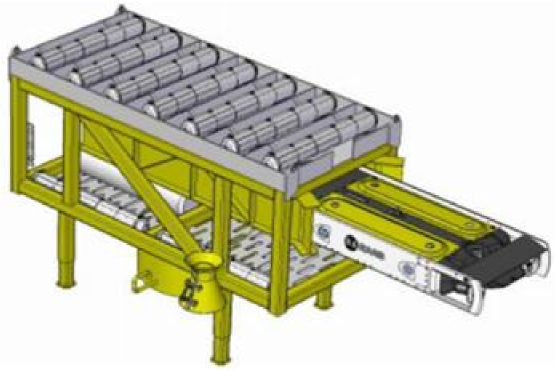


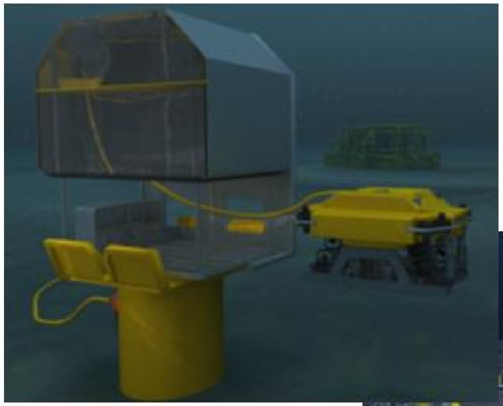


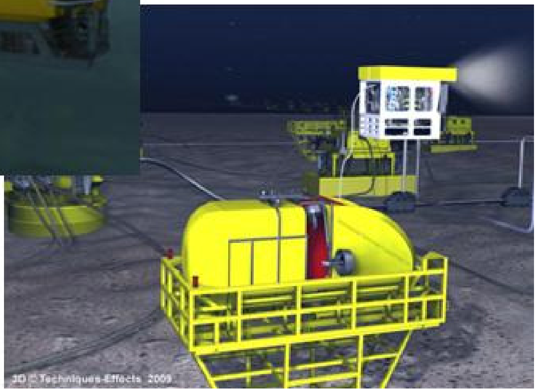
Source Images published by : Autosub AUV, Sauvim

Resident systems

- Due to the subsea processing capabilities, a demand for a resident ROV/AUV/AIV system for
  - emergency preparedness,
  - identification of problems,
  - intervention on components
  - manual override of processes
  - 24/7 availability, with onshore operators
- Docking station main requirement:
  - Smart design to guarantee an easy park of the vehicle inside the garage
  - Fast and reliable power charging system
  - Modular system equipped with different tools
  - Communication system to exchange data with surface





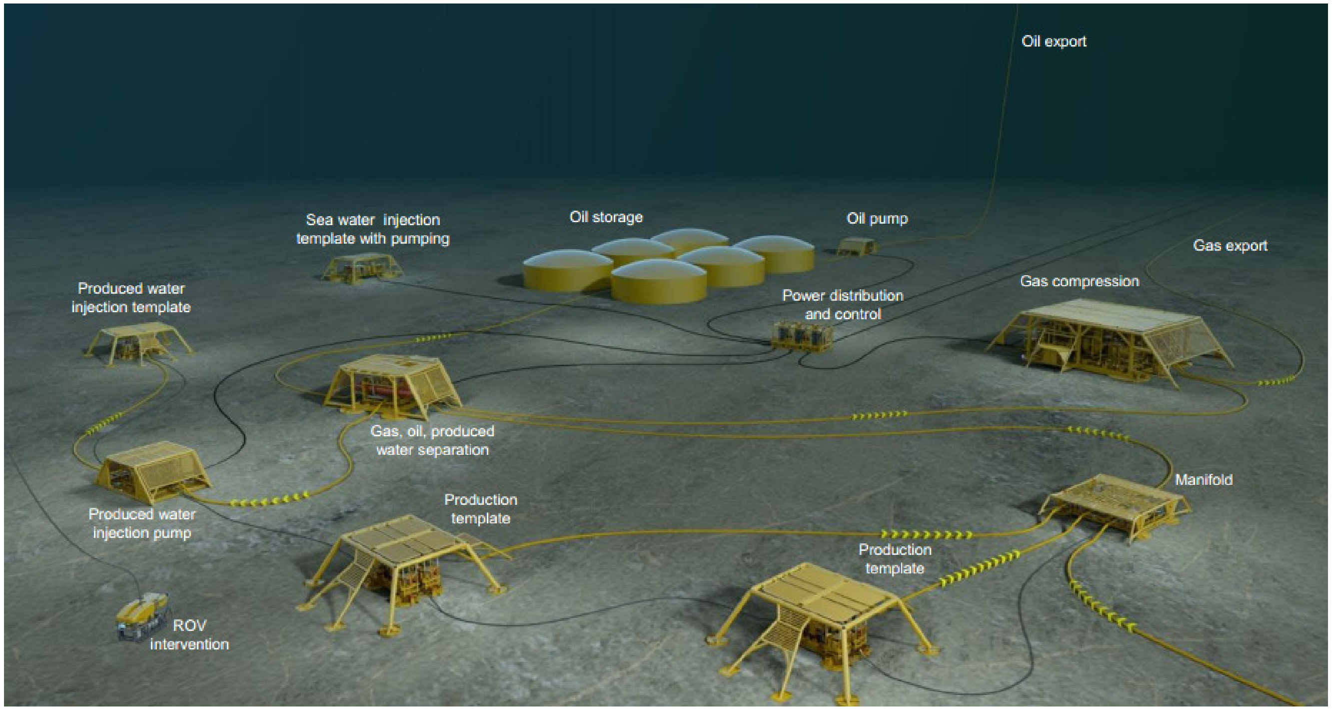


Source images published by :Swimmer Cibernetix; Seaeye Sabertooth AUV, Subsea7 AIV, Oceaneering

Why subsea ASIMO? Concept of Subsea Factory

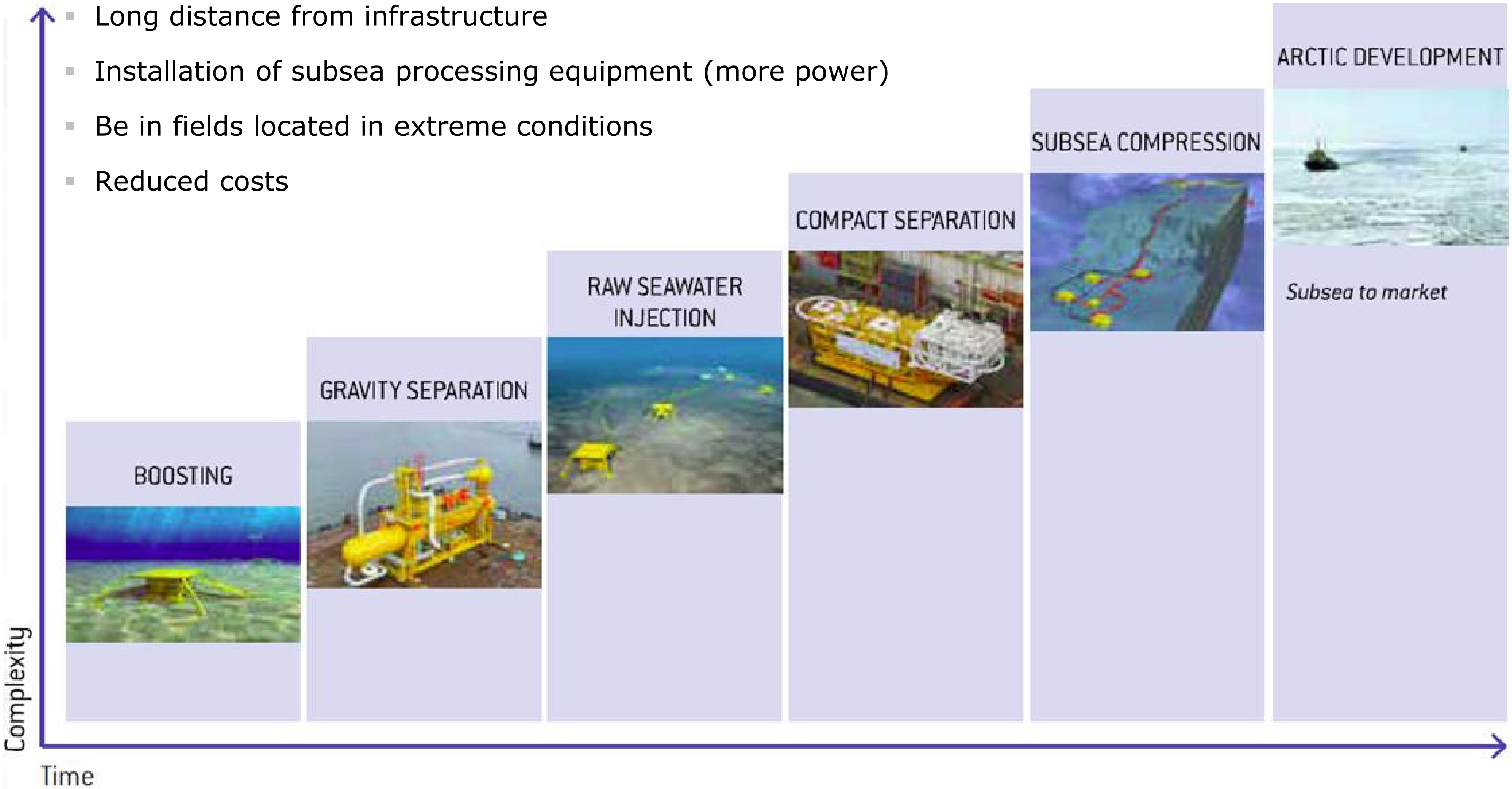
- The offshore industry is moving functionality from the platform to the bottom of the sea to achieve even greater levels of productivity on smaller and less accessible oil and gas fields.

- Motivation for subsea processing :
  - increasing the oil recovery
  - reduced cost
  - reducing topside weight
  - no weather dependency
  - optimized production
  - reduced HSE risks



Roadmap for Subsea

- Installation of SPS tends to:
  - Go deeper
  - Long distance from infrastructure
  - Installation of subsea processing equipment (more power)
  - Be in fields located in extreme conditions
  - Reduced costs



The future: combination of technologies

- What will be possible in the future with new technology:
    1. A permanent underwater vehicle able to navigate and connect to a point without piloting
    2. Vehicle able to do automated intervention tasks by itself
    3. Operations are controlled from shore based on generic commands, and vehicle sends feedback trough the production systems power and communication lines.
    4. Subsea infrastructure need to be installed with power and communication nodes for subsea vehicles.

THANK YOU VERY MUCH

eni norge

CALZONI

Research Activities in Maritime Robotics for Mobility and Manipulation: Industrial and Academic Perspectives

Raffaele Grandi, PhD
Research Engineer @ Calzoni
raffaele.grandi@l-3com.com

EMRA'14

Workshop on EU funded Marine Robotics and Applications
9-10 June 2014 - CNR, ROME Italy

Outline

- Company presentation
  - Operational headquarters
  - Product lines overview
  - Unmanned Surface Applications
- Projects Involvement
  - **European Defence Agency (EDA)**
    - Harbor Protection Systems (**HaPS**) [2010-2013]
    - Network Enabled Cooperation System of Autonomous Vehicles (**NECSAVE**) [2013-2016]
    - Modular Lightweight Minesweeping (**MLM**) [2012-2014]
  - **Seventh Framework Programme for Research (FP7)**
    - **ICARUS** Unmanned Search and Rescue [2013-2016]

Company Presentation – #1/3

Milan

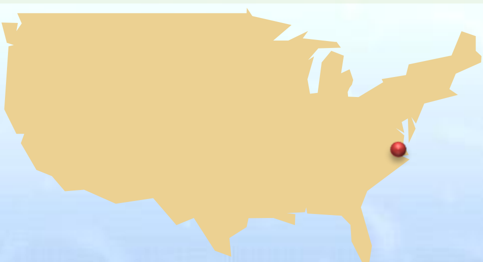
Via Rimini, 22
20142 Milano
– Italy
Tel: +39 02 581881
Fax: +39 02 58188250

Bologna

Via A. De Gasperi, 7
40012 Calderara di Reno (BO)
– Italy
Tel: +39 051 41377
Fax: +39 051 4137555

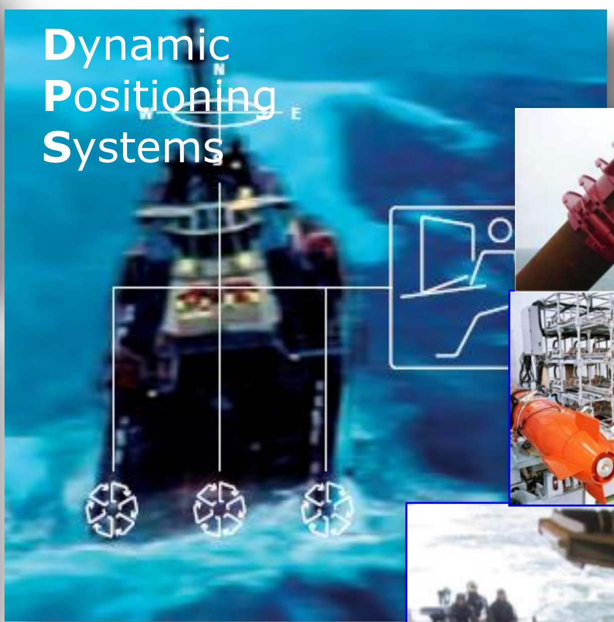
Toms River, NJ

16 Madison Avenue
Building 2 Suite 2B
Toms River NJ 08753 USA
Tel: +1 (732) 244-2799



Calzoni is part of L-3 Communications Corporation since 2012

Company Presentation – #2/3



Naval
Handling
Systems

Company Presentation – #3/3

- Special Naval Applications
- Department focused on Unmanned Surface Vehicles (USVs)

U-Ranger is mainly devoted to Maritime Security

MiniRanger -MineSweeping

USV Handling System

Remote MWS

Delivered to Italian Navy

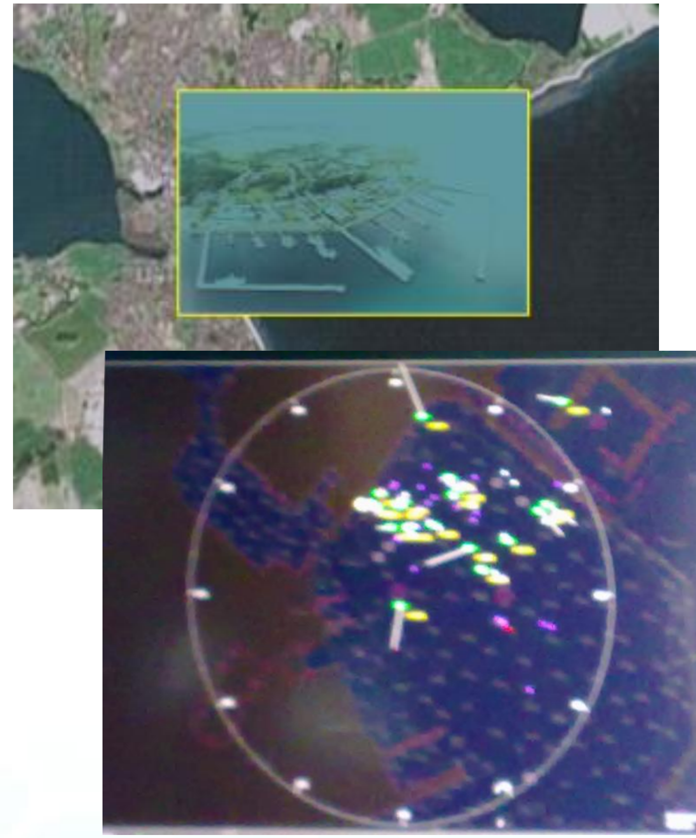
EDA – HaPS – [2010-2013]

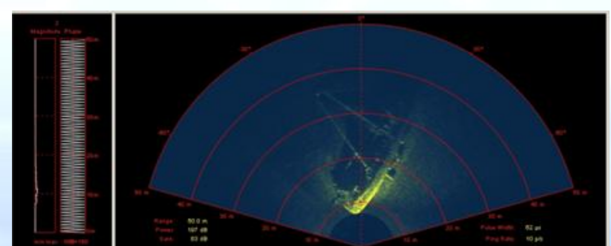
EUROPEAN DEFENCE AGENCY

HaPS

Harbor Protection Systems

EDA – HaPS – Harbor Protection Systems – #1/3





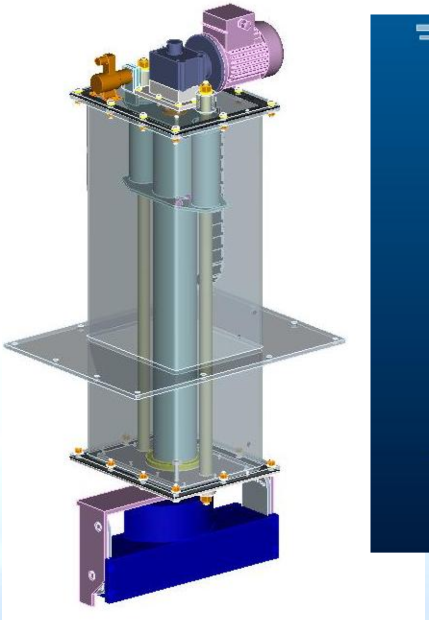
- <u>Background</u>
  - Naval forces need more secure bases when participating in international operations
  - They have to bring suitable security systems
  - Available systems have limited detection ranges of small targets
  - Lethal countermeasures might be restricted by local authorities
- <u>Objectives</u>
  - Studying and evaluating protection technologies for forces which are call into foreign harbors or naval bases
  - Improving reaction time and minimize required manning
  - Focus attention on small underwater threats

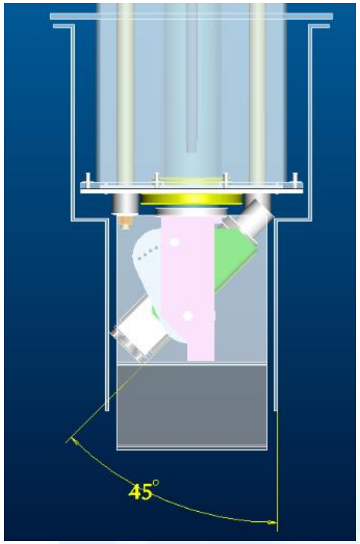
EDA – HaPS – Harbor Protection Systems – #2/3

- Research topics and activities
  - Focus on sensor technologies, sensor fusion and non-lethal countermeasures
  - Measure performance of available sensors, and compare with models
  - Developing fusion algorithms for detection, classification and tracking
  - Developing concepts for non-lethal countermeasures
  - Evaluating the available components in two sea trials
- Partners
  - Atlas Elektronik - Germany
  - Wehrtechnische Dienststelle für Schiffe und Marinewaffen, Maritime Technologie und Forschung – Germany
  - **Calzoni - Italy**
  - Centro di Supporto e Sperimentazione Navale (CSSN) - Italy
  - Comando Forze CMM (COMFORDRAG) - Italy
  - Whitehead Alenia Sistemi Subacquei (WASS) – Italy
  - Forsvarets Forskningsintitutt (FFI) – Norway
  - Kongsberg Defence and Aerospace (KDA) – Norway
  - Saab Underwater Systems – Norway
  - Totalförsvarets forskningsinstitut (FOI) - Norway

EDA – HaPS – Harbor Protection Systems – #3/3

- **Calzoni U-Ranger used as "moving arm" of the system with NLW**
  - Integration of the releasing system for bubbles generation capsules (WASS)
  - Integration of the underwater airgun (KDA)
  - Hostile Forces (underwater) Interception





EDA – NECSAVE – [2013 - 2016]

EUROPEAN DEFENCE AGENCY

NECSAVE

Network Enabled Cooperation System of Autonomous Vehicles

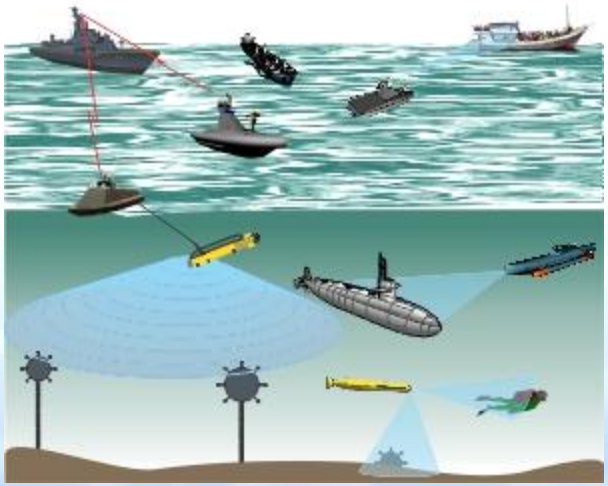
EDA – NECSAVE – Network Enabled Cooperation System of Autonomous Vehicles – #1/3

- Background
  - Few legal frameworks to encompass the operation of UxVs.
  - Lack of standards for inter-operability and communications
  - Commercial vehicles have not been developed as open systems
  - State of the art coordination and control algorithms for heterogeneous vehicles lack testing and evaluation with real vehicle systems, lacking the capability to design and deploy networked vehicle systems in a systematic manner and within an appropriate scientific framework

- Objectives
  - The objective of NECSAVE is to develop, test and evaluate tools and methodologies for the Network Enabled Capability (NEC) swarms of heterogeneous ocean and air going unmanned vehicles for operations in challenging environments.

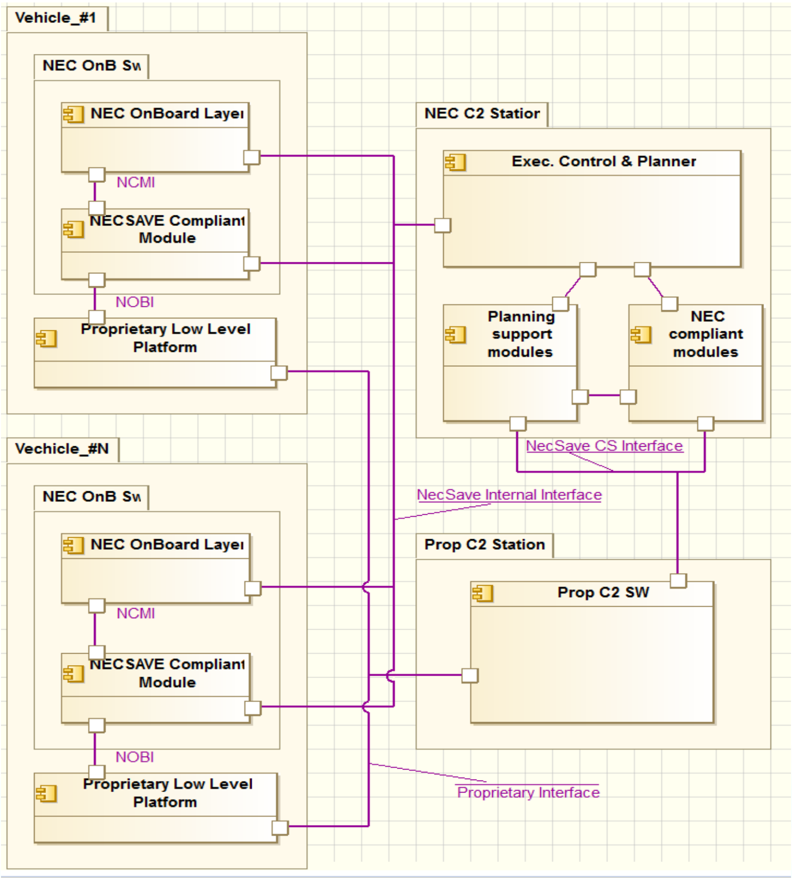
EDA – NECSAVE – Network Enabled Cooperation System of Autonomous Vehicles – #2/3

- Research topics and activities
  - To develop a dynamic networks of computational components
  - To design architecture for automated or semi-automated, distributed teams of agents
  - To incorporate human intervention in mission planning and execution;
  - To develop a fault-tolerant design and disruptive tolerant networks
  - To evaluate the available components in three sea trials
- Partners
  - University of Porto – Portugal
  - Port of Leixoes (APDL) – Portugal
  - OceanScan – Portugal
  - **Calzoni – Italy**
  - UCM – Spain
  - TNO – The Netherlands
  - Royal Military Accademy - Belgium



EDA – NECSAVE – Network Enabled Cooperation System of Autonomous Vehicles – #3/3

- <u>Company Involvement</u>
  - Designing of the global NECSAVE architecture
  - Implementation and integration of part of the NECSAVE layer onboard U-Ranger
  - Testing the integrations in the project sea trials



- Original note from official documentation
  - NECSAVE results will be tested in the UMS-project "Modular Lightweight Minesweeping MLM" which will attempt to emulate the signature of a ship by using signature generators carried by USVs in formation.

EDA – MLM – [2012 – 2014]

EUROPEAN DEFENCE AGENCY

Modular Lightweight Minesweeping

European Defence Agency

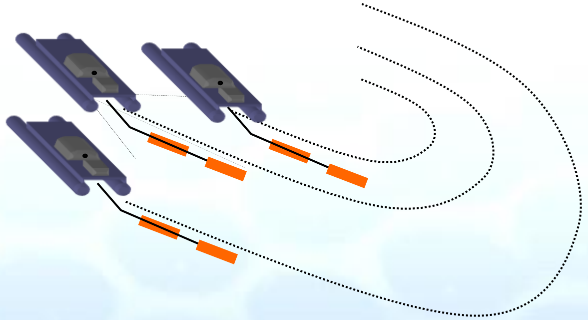
MLM

Modular
Lightweight
Minesweeping

EDA – MLM – Modular Lightweight Minesweeping – #1/3

- Background
  - Today the minesweeping is mainly done by using long and heavy towed buoys that generate the pressure and electro-magnetic signatures of vessels
  - Minesweeping is viable only by using strong and power boats (mine hunters) or by using helicopters towing effectors

- Objectives
  - The key idea is to build a minesweeping system combining several effectors, on board or towed by a coordinated team of USV

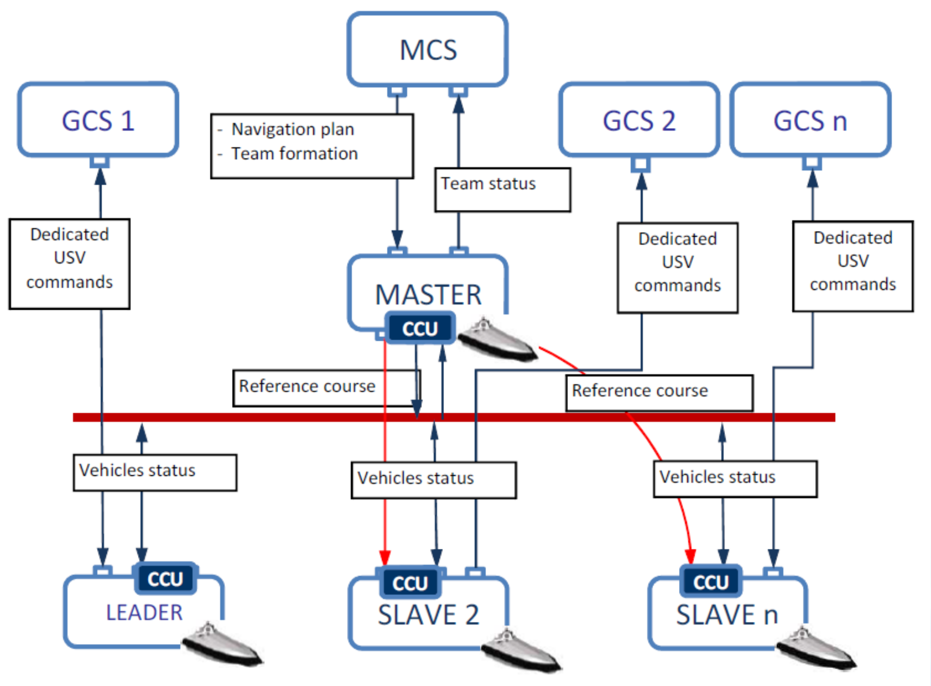


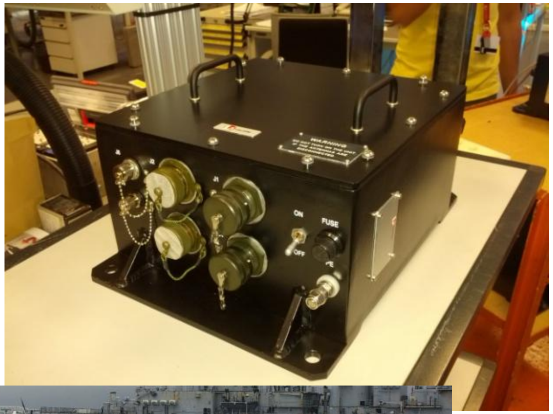
EDA – MLM – Modular Lightweight Minesweeping – #2/3

- Research topics and activities
  - Integration of different effectors
  - Studing coordination algorithm from a theoretical point of view creating numerical models
  - Creating and integrating hardware and software resources on the available vessels
  - Testing results in appropriate sea trials
- Partners
  - Forsvarets forskningsInstitutt (FII), Norway
  - Thales Underwater Systems SAS, France
  - DCNS S.A., France
  - SIEL s.r.l., Italy
  - **Calzoni s.r.l., Italy**
  - CTM – R&D Marine Technology Centre S.A., Poland

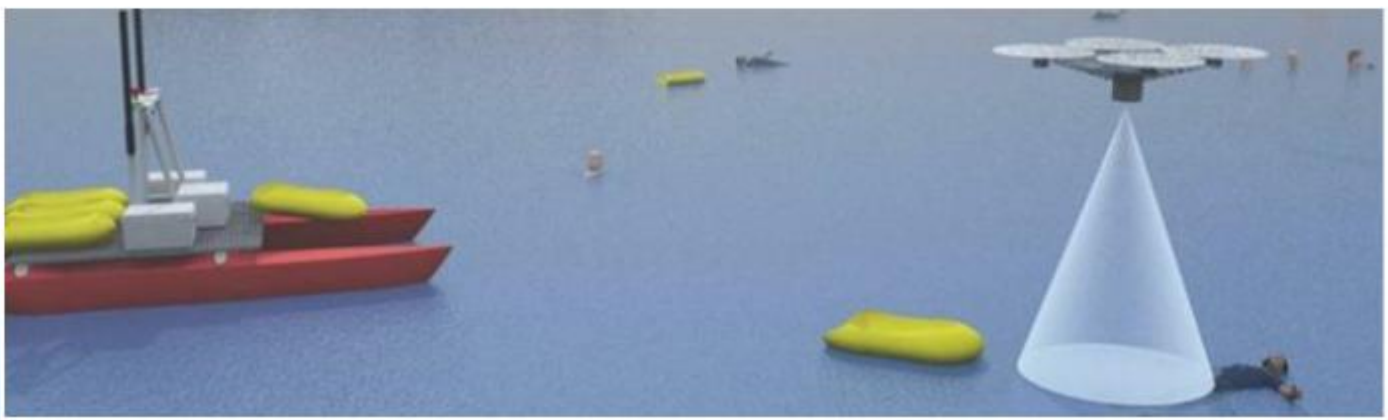
EDA – MLM – Modular Lightweight Minesweeping – #3/3

- <u>Company Involvement</u>
  - Development of the Coordination and Control Units (CCUs)
  - Development of the Coordination and Control Algorithm
  - Integration of CCUs with the available boats (also U-Ranger)





FP7 – ICARUS – [2013 – 2016]



FP7 – ICARUS Unmanned Search and Rescue #1/4

- Background
  - The interoperability and the equipments for SAR operations of first responders in disasters are judged not suitable for a quick action
  - European Commission confirmed that there exists a large discrepancy between the (robotic) technology developed in laboratory and the use of such technology on the terrain for Search and Rescue (SAR) operations and crisis management


2012 Costa Concordia Disaster


2011 Tōhoku Earthquake and Tsunami

FP7 – ICARUS Unmanned Search and Rescue #2/4

- Objectives
  - To develop innovation for improving the management of a crisis
  - To reduce the risk and impact of the crisis on citizens
  - To use unmanned search and rescue devices embedded in an appropriate information architecture in order to inform crisis personnel about real danger present on the ground

- Research topics and activities
  - To develop Intelligent Self-Organizing and Cognitive Network
  - To develop Robotics Interconnection Architecture with UxVs
  - To develop Humans Detection System in Marine Environment
  - To study and develop Advanced Obstacle Avoidance and Advanced SAR Techniques
  - To evaluate the developed system in appropriate sea-trials

FP7 – ICARUS Unmanned Search and Rescue #3/4

- Partners
  - ECOLE ROYALE MILITAIRE - KONINKLIJKE MILITAIRE SCHOOL (Belgium)
  - SPACE APPLICATIONS SERVICES NV (Belgium)
  - ESTUDIOS GIS S.L. (Spain)
  - Aerospace Technology Centre (ASCAMM Foundation) (Spain)
  - The Fraunhofer Institute for Reliability and Microintegration IZM (Germany)
  - INSTYTUT MASZYN MATEMATYCZNYCH (Poland)
  - JMDTHEQUE SARL (France)
  - TECHNISCHE UNIVERSITAET WIEN (Austria)
  - INTEGRASYS, S.A. (Spain)
  - Skybotix AG (Switzerland)
  - QUOBIS NETWORKS SL (Spain)
  - INESC PORTO - INSTITUTO DE ENGENHARIA DE SISTEMAS E COMPUTADORES DO PORTO (Portugal)
  - UNIVERSITE DE NEUCHATEL (Switzerland)
  - Eidgenössische Technische Hochschule Zürich (Switzerland)
  - ATOS SPAIN SA (Spain)
  - TECHNISCHE UNIVERSITAET KAISERSLAUTERN (Germany)
  - NATO Undersea Research Centre (Italy)
  - **CALZONI SRL (Italy)**
  - METALLIANCE SA (France)
  - ESRI PORTUGAL - SISTEMAS E INFORMACAO GEOGRAFICA SA (Portugal)
  - SPACETEC PARTNERS SPRL (Belgium)
  - ESCOLA NAVAL (Portugal)
  - BELGIAN FIRST AID AND SUPPORT TEAM (Belgium)
  - ECOLE POLITECHNIQUE FEDERALE DE LAUSANNE (Switzerland)

FP7 – ICARUS Unmanned Search and Rescue #4/4

- Company Involvement
  - Integration of the U-Ranger USV in a SAR system
  - Integration of U-Ranger and Obstacle Avoidance and Control Station (developed by NURC)
  - Development of handling systems onboard the USV

Video from original ICARUS project presentation

Conclusions and future work

- **Conclusions**
  - Strong effort in the development of Maritime Robotics Applications
  - Calzoni R&D Department focused on Unmanned Surface Vehicle Application in a stand alone way or integrated with **the other domains (aerial & underwater)**
- **Future work**
  - Improving the **autonomous capability** of our vehicles in term of **intelligence**, **collaboration** and **coordination**
  - Developing general & special purpose USVs
  - Participating to minewarfare USV operations (i.e. MLM2)
  - High Interest in other EDA, FP7, H2020,… projects
  - High interest in creating **collaborations** with Universities and Industrial partners

Thank you for your attention

raffaele.grandi@l-3com.com

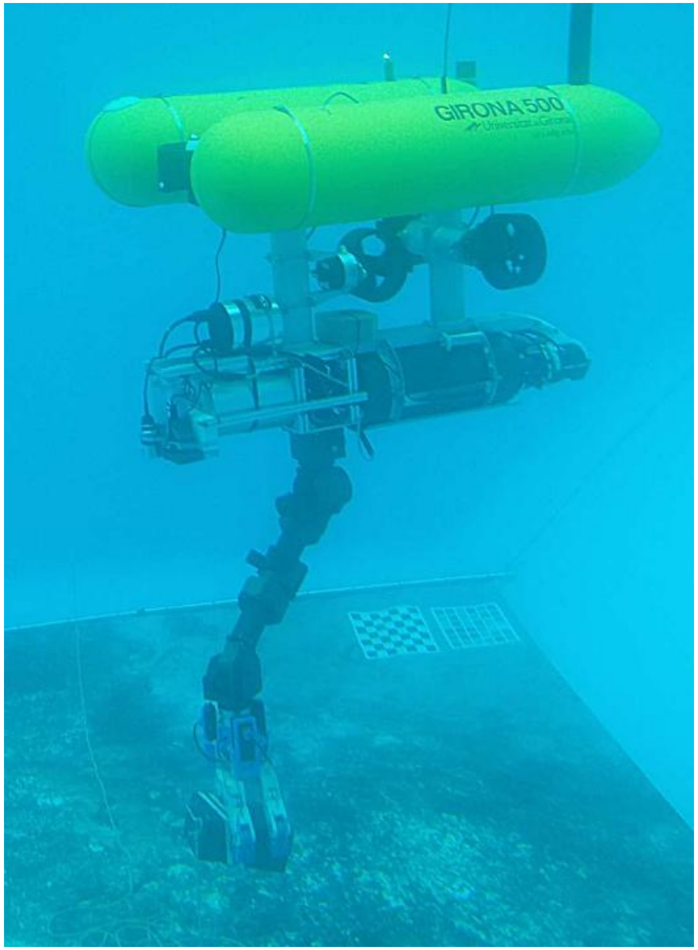
A Three-Fingered Cable-Driven Gripper for Underwater Applications

Jeferson Bemfica, Claudio Melchiorri, Lorenzo Moriello,
Gianluca Palli, Umberto Scarcia
DEI - Università di Bologna, Italy

- **TRIDENT - FP7 project**
  - **Objective**: developing an autonomous system composed by
    - Surface Vehicle (called *Support Vehicle*)
    - Underwater vehicle equipped with a 7 DOF robotic arm and a **gripper**
  - **Tasks**:
    - Creating a map of a seabed region
    - Recognize a specific target (an orange box in the trials)
    - Reach and recover the target using the gripper
- Involvment of the **DEI-UniBO Robotics Group** in the designing and realization of the gripper

Specifications (TRIDENT)

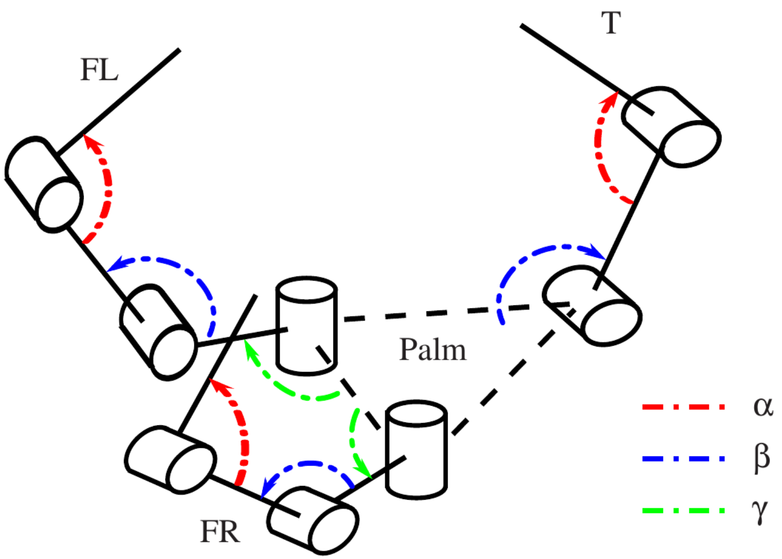
- Maximum **depth 100 m** (10 bar)
- Maximum **object dimensions**: a sphere with diameter **up to 200 mm**
- Objects of **variable size and shape** performing static grasps
- **Both force- and form- closures** grasps with irreversible constraints are considered
- Precision and parallel grasps are desirable
- **Local compliance on finger surfaces** and/or actuation compliance is desirable for system safety issues
- The sensory equipment of the gripper should consider **force/torque (or tactile) sensors**
- **Low encumbrance** of the arm/gripper system during navigation is required

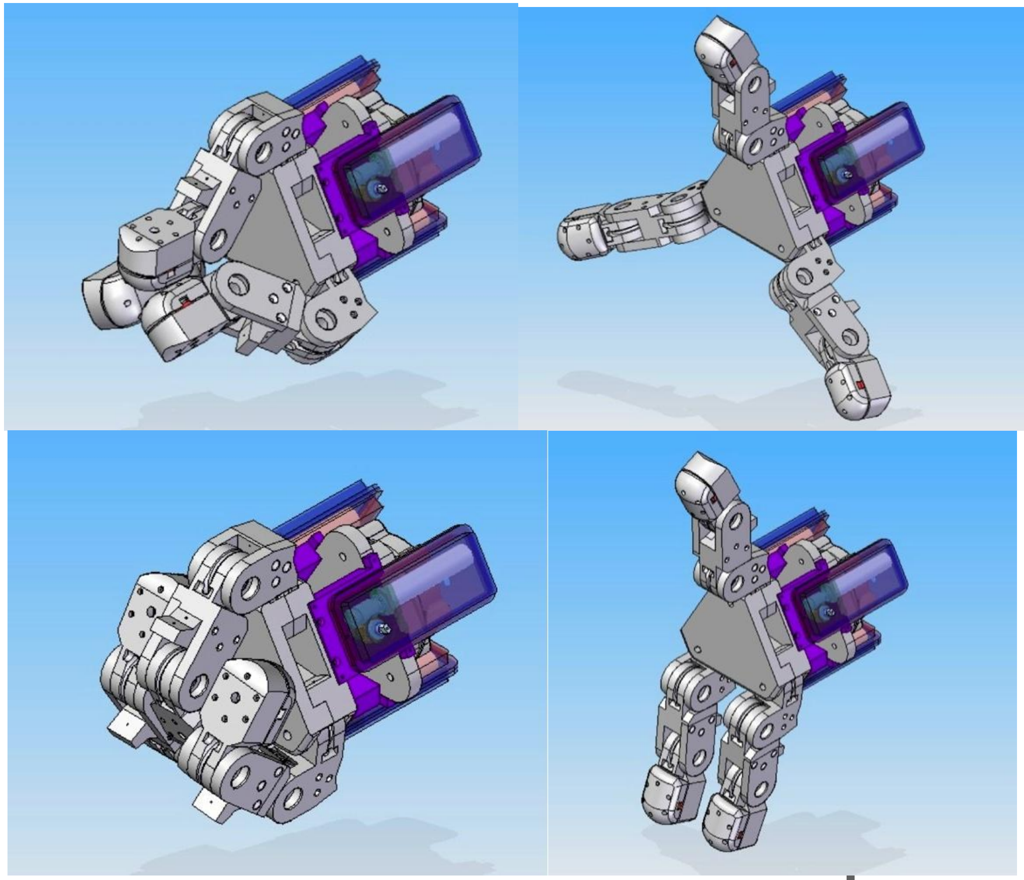


Gripper Version 2.0

3 DoF Gripper

- 3 Modular Fingers
- 8 Joints
- 3 Motors (3 DoF)
- Coupled Joints: 2-3-3

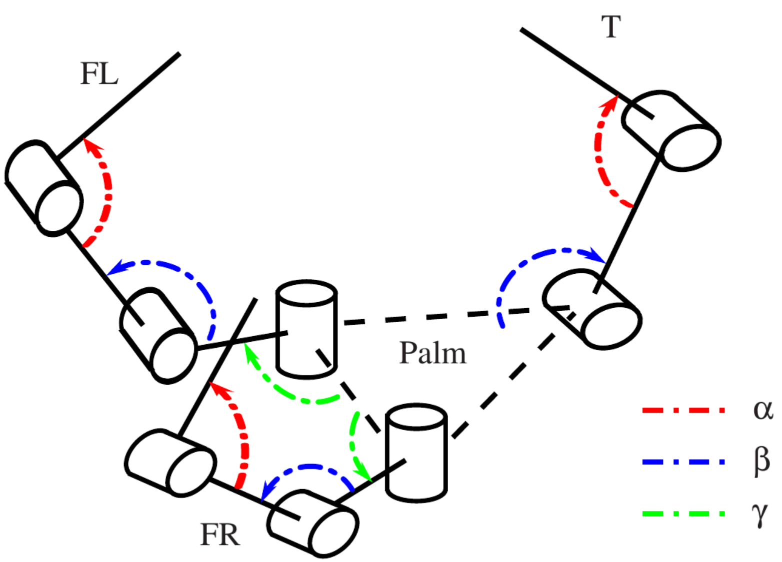


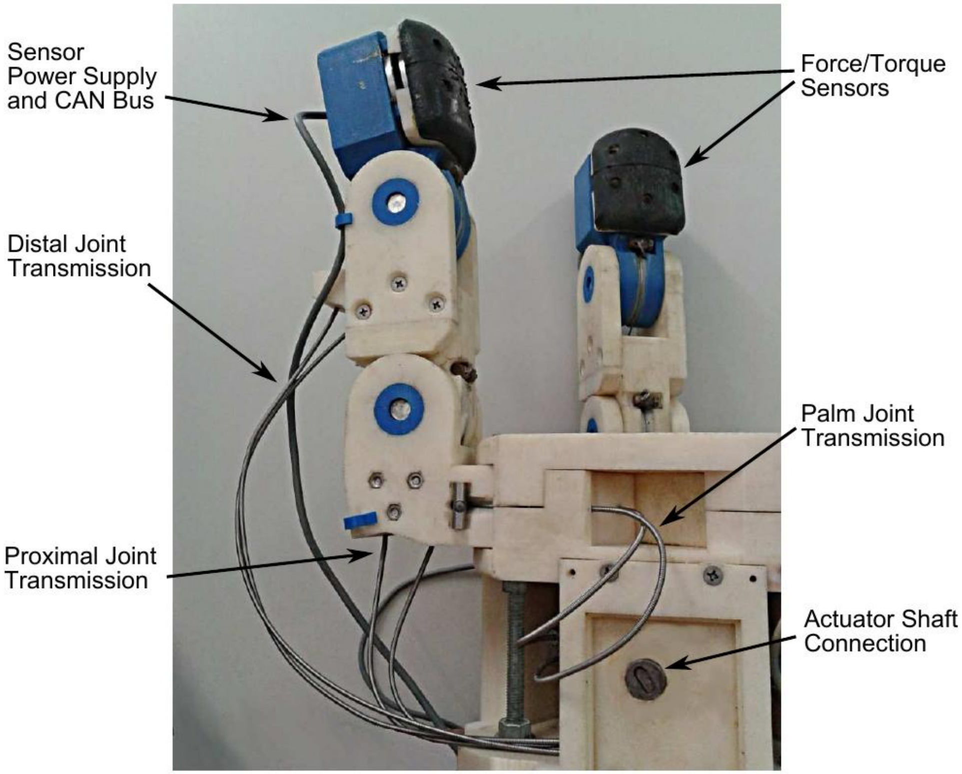


Gripper Version 2.0

Main Characteristics

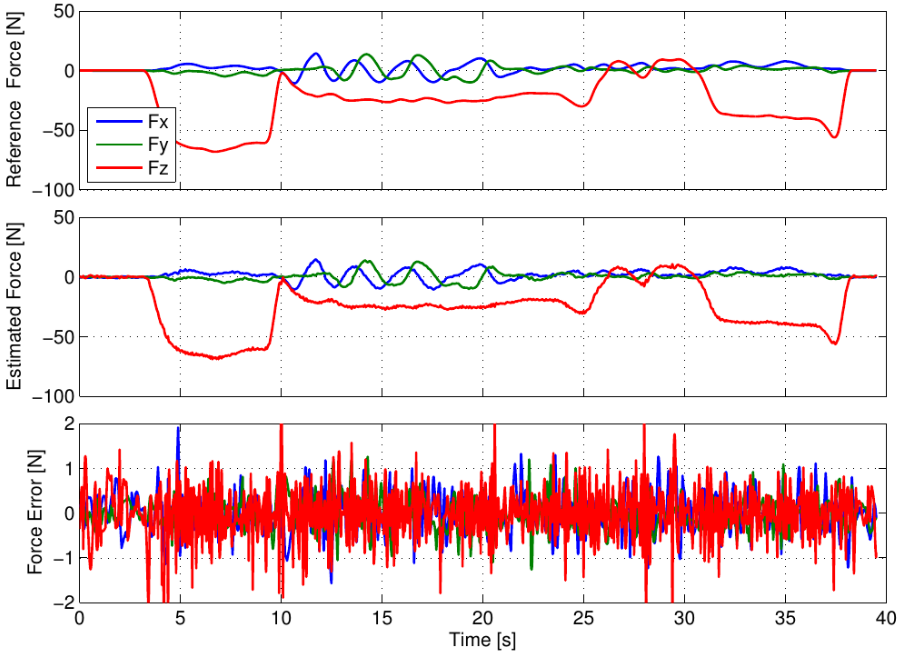
- Cable-based Transmission
- Modular Actuation
- Fingertip Force/Torque Sensors
- Manufactured in ABS Plastic and Al
- CAN Bus for Actuators and Sensors
- Maximum Fingertip Force: Up to 150 N

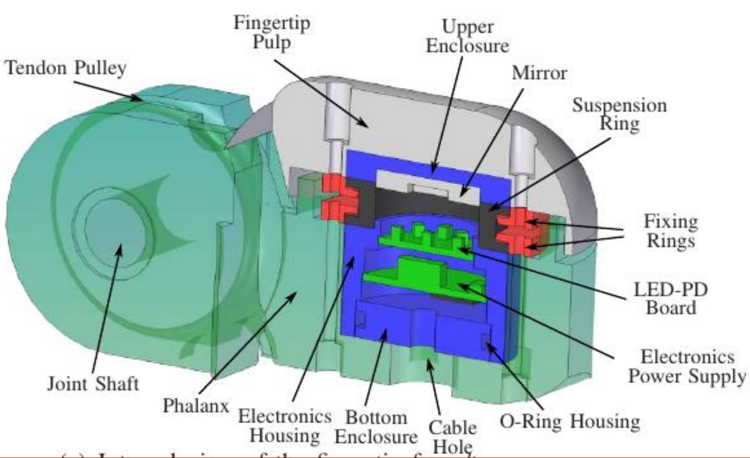


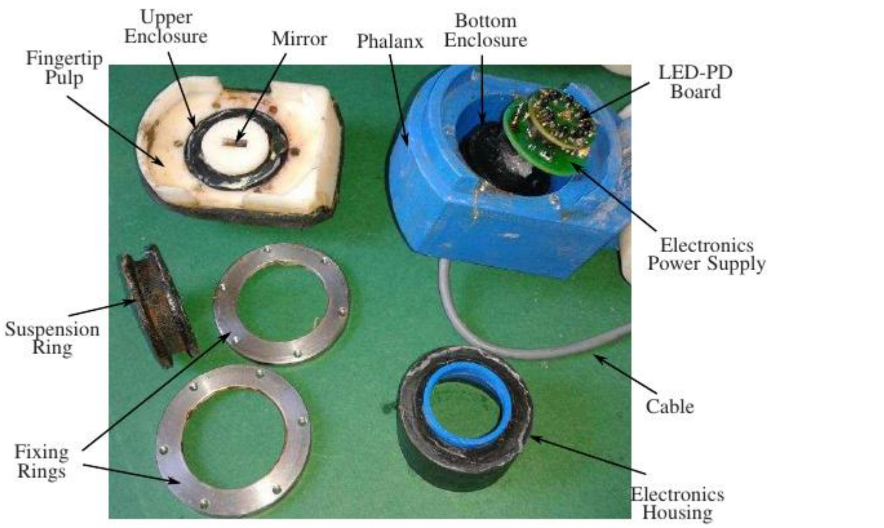


Gripper Force/Torque Sensors

- Multi-axes Force/Torque Sensors
- Based on Optoelectronic Components
- Installed in the Fingertips (and Wrist)
- Integrated Acquisition and Communication via CAN Bus

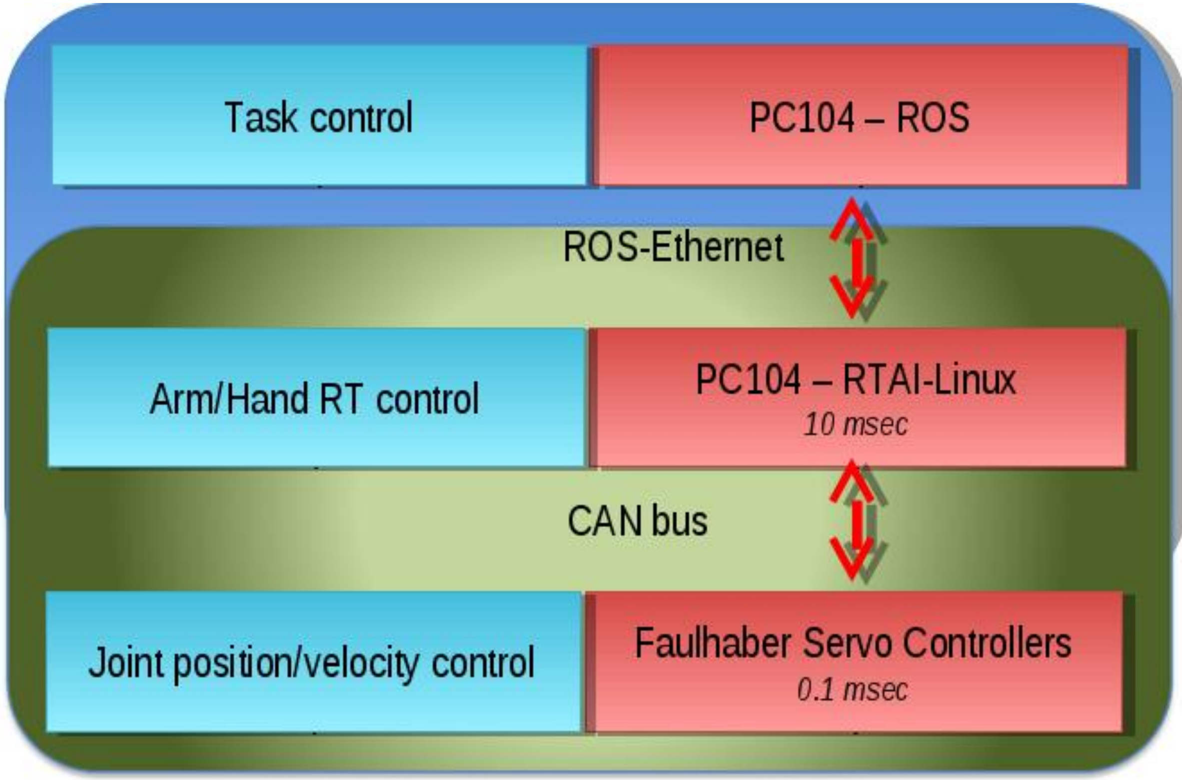






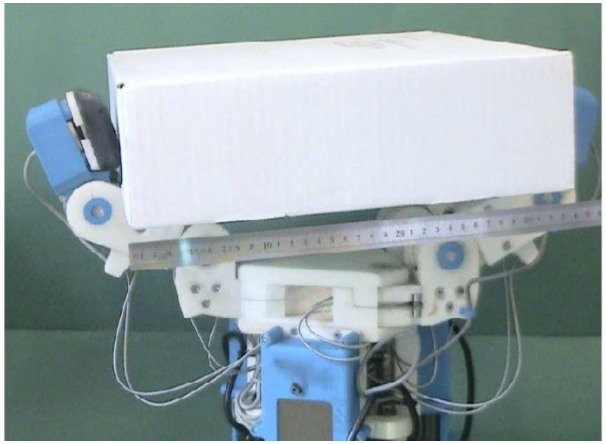
Software Control Architecture

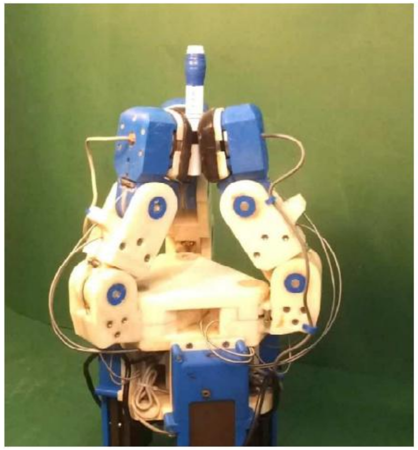
- HW platform: PC104 running the control of both the arm and the gripper
- CAN-Bus at 1Mbit/s for communication with the 7+3 motors (arm/gripper) and 3 sensors (4 included the wrist)
- Control system developed in RTAI-Linux/C++
- Sampling time: 10 ms
- Hierarchical structure
- Interfaced with ROS



Grasp Evaluation

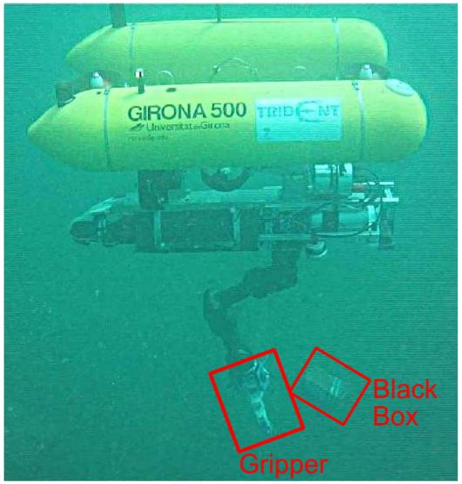
- Power grasps involving the palm
- Parallel grasps on very thin objects
- Tripod grasps on cilindrical objects with radius less than 10 mm
- Maximum Grasping Width: 340 mm

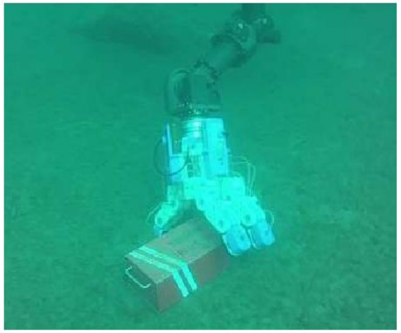




Sea trials

- Final test performed in Port de Soller, Maiorca
- Autonomous operations of the overall system have been successfully executed
- The seafloor mosaic is generated on the survey phase
- The AUV performed autonomous detection of the dummy black box to be recovered
- The black box recovery stage was autonomously initiated by the system
- A robust vision system has been implemented on the AUV by using both a 2D camera and a 3D vision system
- The black box has been autonomously grasped and brought to the surface by the AUV



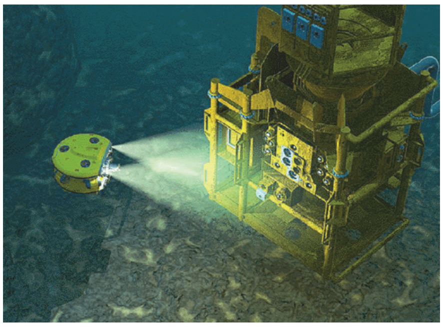


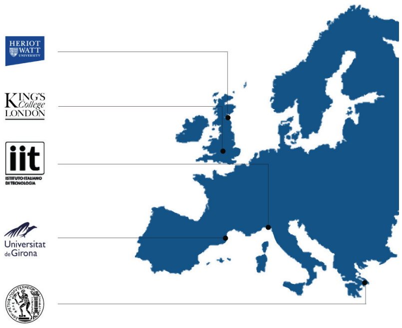
Conclusions and future work

- University of Bologna is working on the **development of robots** mainly designed for **complex tasks in underwater environment**
- Developing of **complex grasp and manipulation abilities**
- Developing of **complex tasks execution and managing**
- **Collaboration** activities and **know-how** transfer with **Calzoni**
- Collaboration for H2020 project participation

Thanks for the attention

Pandora
Persistently Autonomous Robots

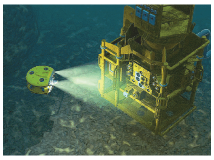


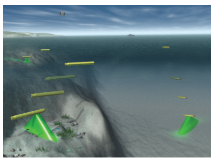


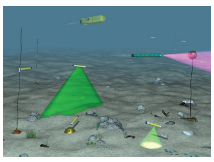
PANDORA - Persistent Autonomy through Learning, Adaptation, Observation and Replanning

Pandora
Persistently Autonomous Robots

Vision: Persistent Autonomy

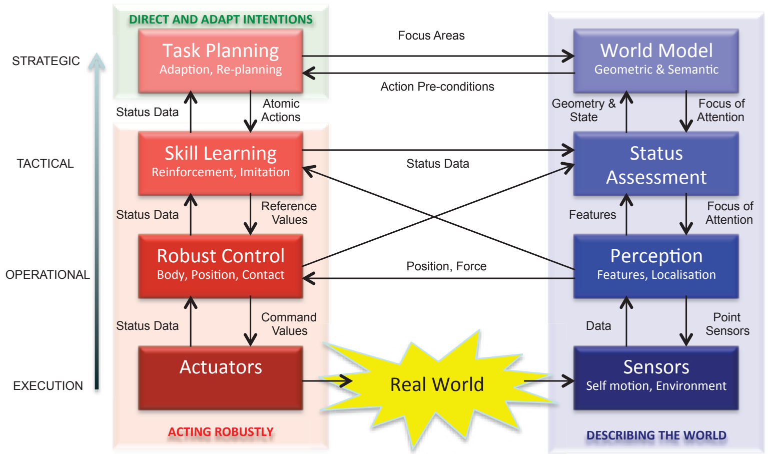




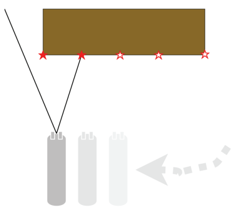
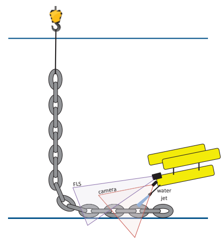
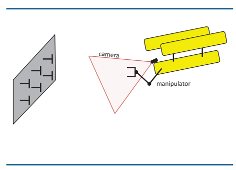
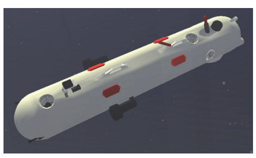
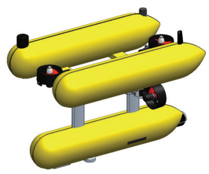
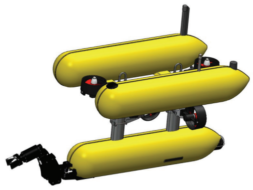


- operate successfully while unsupervised and without recourse to a human operator
- for extended lengths of time
- in environments that are not completely known
- adapting purpose in response to unexpected events and disturbances
- on different scales in space and time
- whilst interacting with the environment
- and recovering from errors in task execution.

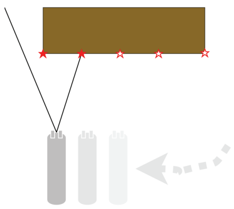
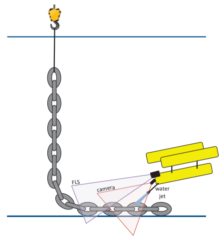
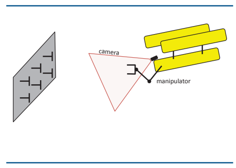
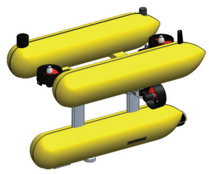
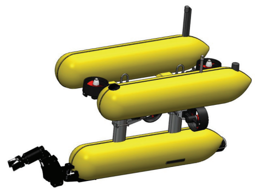
System Architecture



Pandora scenarios

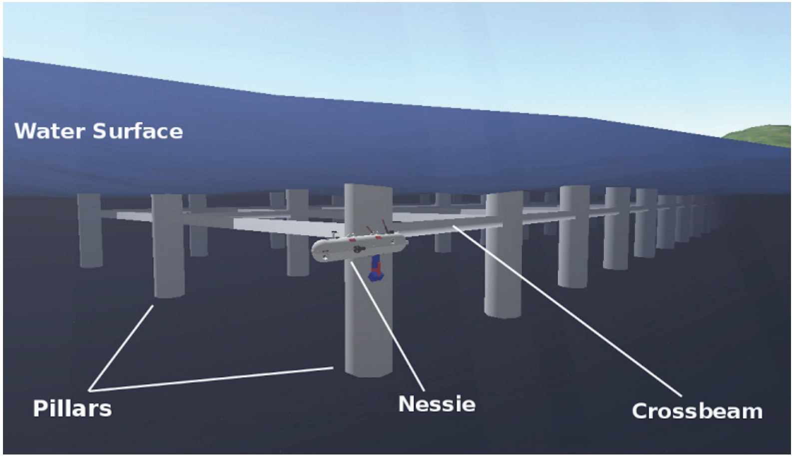
A. STRUCTURE INSPECTION	B. CHAIN CLEANING AND INSPECTION	C. VALVE TURNING
		
HWU, Fort William	UdG, CIRS water tank	UdG, CIRS water tank
		
Nessie VI AUV	Girona 500 AUV	Girona 500 AUV

Pandora scenarios

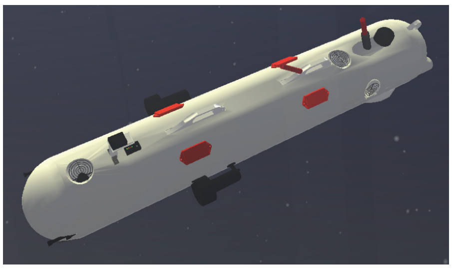
A. STRUCTURE INSPECTION	B. CHAIN CLEANING AND INSPECTION	C. VALVE TURNING
		
HWU, Fort William	UdG, CIRS water tank	UdG, CIRS water tank
		
Nessie VI AUV	Girona 500 AUV	Girona 500 AUV

Structure inspection scenario

Simulated FW TUC pier

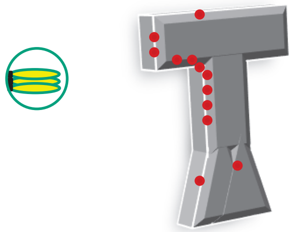


Nessie VI AUV

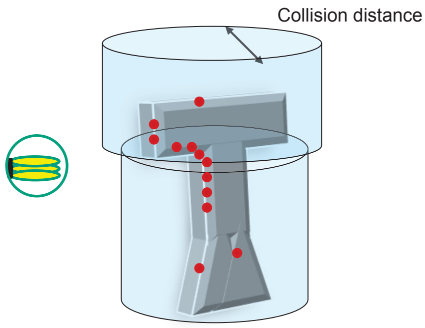


- AUV for designed surveys and inspection
- Hover & pitch control
- Used in OSL for 3 years
- Imaging and profiling FLS:
    - Blueview P900-2250 Dual Frequency
    - Blueview MB2250 micro-bathymetry + P&T

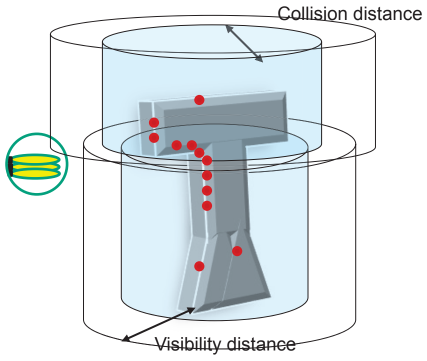
Structure inspection scenario



Structure inspection scenario

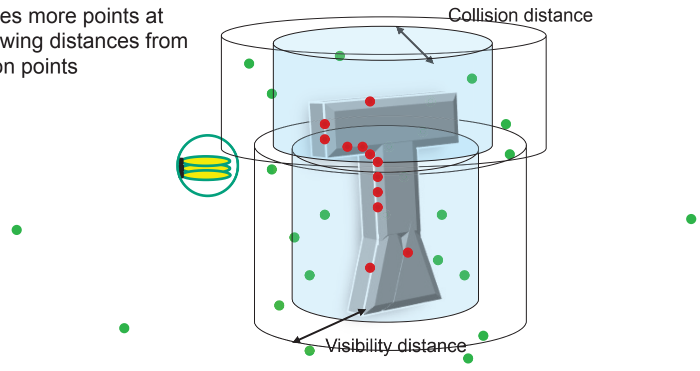


Structure inspection scenario



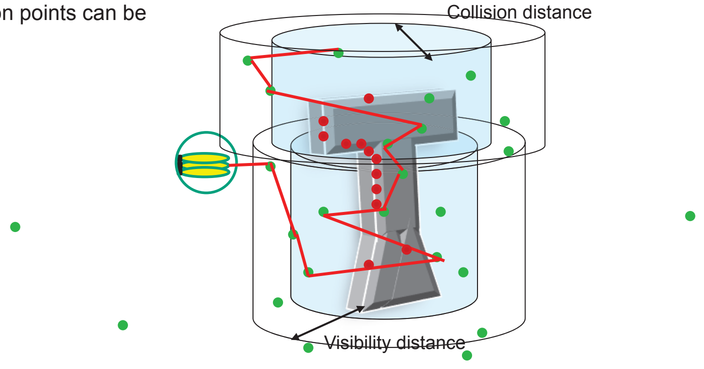
Structure inspection scenario

The PRM selects waypoints from a biased distribution that places more points at good viewing distances from inspection points



Structure inspection scenario

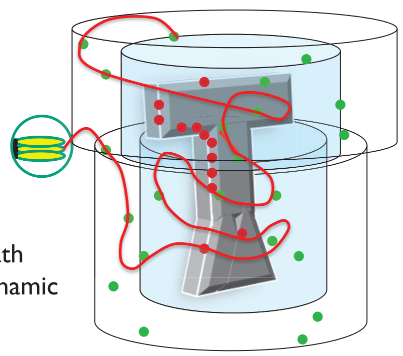
A path is planned between waypoints from which the inspection points can be seen



Structure inspection scenario

Planning for limited time and energy budget.

Path cost is determined not only by length, but by momentum at start and end and kinematics



Execution of planned path under kinematic and dynamic constraints

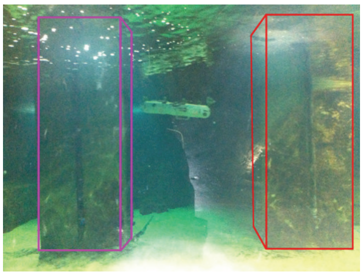
Structure inspection scenario

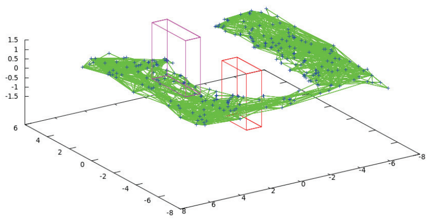
NATIONAL TECHNICAL UNIVERSITY OF ATHENS

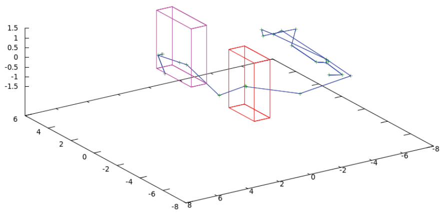
CSL

CONTROL SYSTEMS LAB

Structure inspection scenario

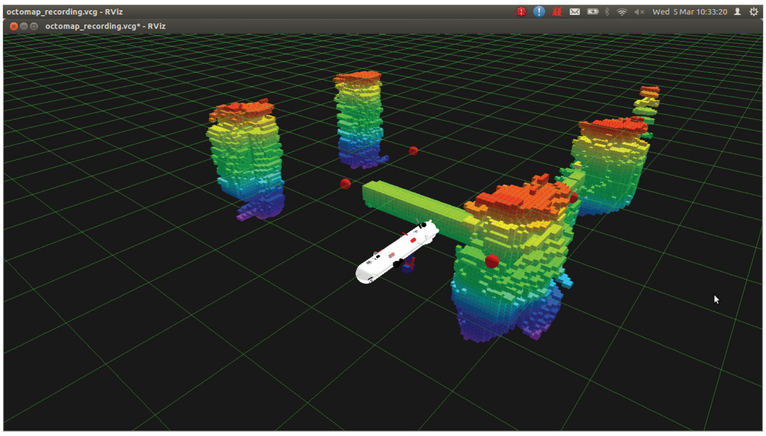






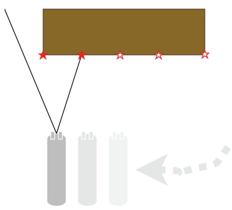
Structure inspection scenario

3D probabilistic occupancy grid
Used for Geometric Anomaly Detection

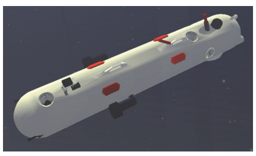


Pandora scenarios

A. STRUCTURE INSPECTION

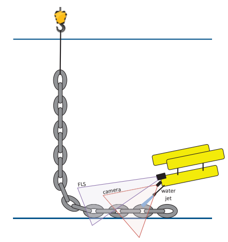


HWU, Fort William

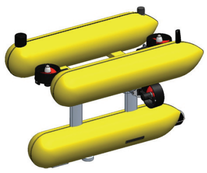


Nessie VI AUV

B. CHAIN CLEANING AND INSPECTION

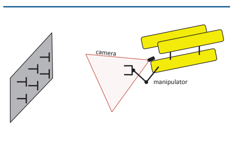


UdG, CIRS water tank

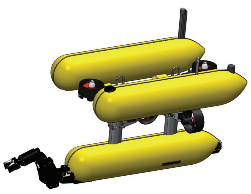


Girona 500 AUV

C. VALVE TURNING



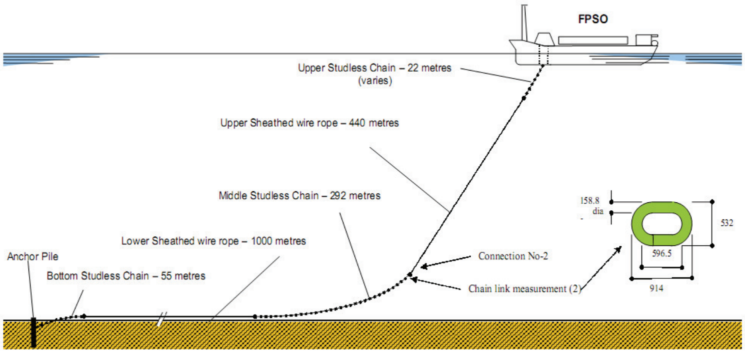
UdG, CIRS water tank



Girona 500 AUV

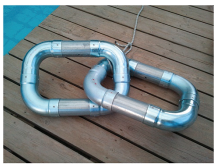
Chain inspection scenario

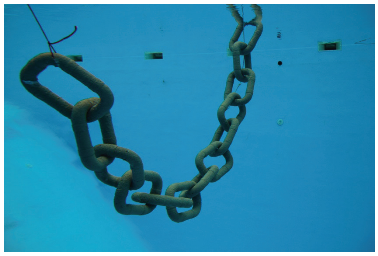
Typical FPSO mooring (Floating production storage and offloading)

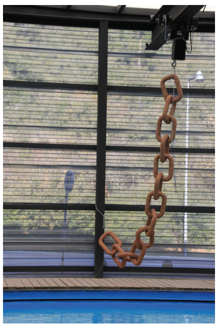


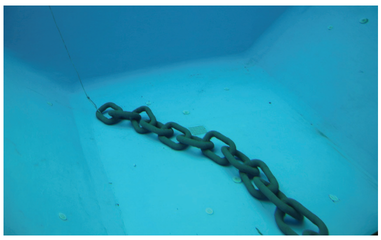
Chain mock-up

- Metal pipes
- Plastic paint simulating marine growth texture
- 580mm x 410mm link
- 13 links, 6 meters chain

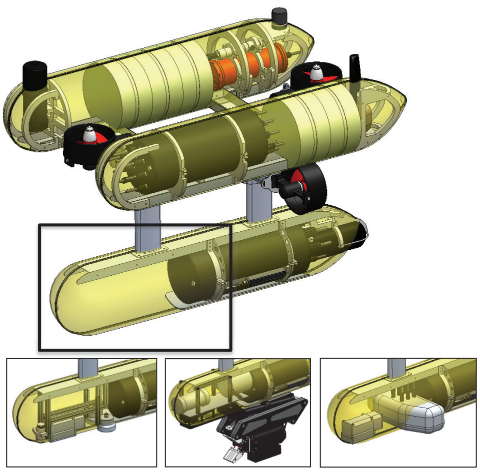


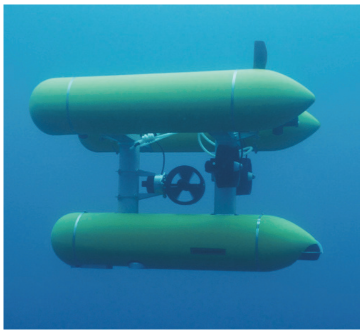






Girona 500 AUV

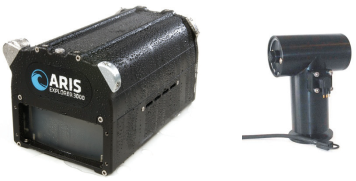


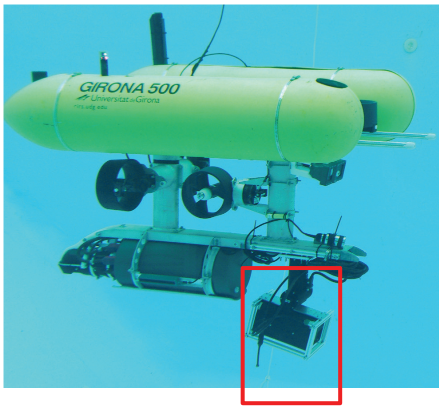


- Very Stable AUV, for data acquisition and intervention tasks
- Hovering capability
- Payload area

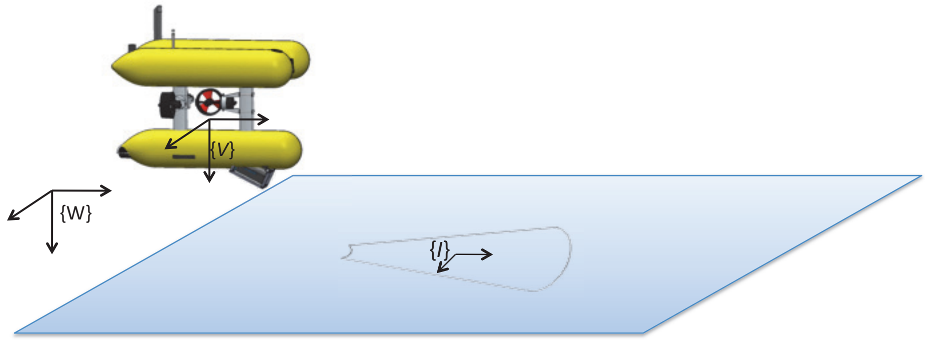
Chain inspection with FLS

- **2D Forward-looking sonar**
  - Soundmetrics ARIS Explorer 3000
  - 3MHz, 28.8° bearing x 12° elevation
  - Range: 0.7-20m; Resolution: 3mm to 10cm

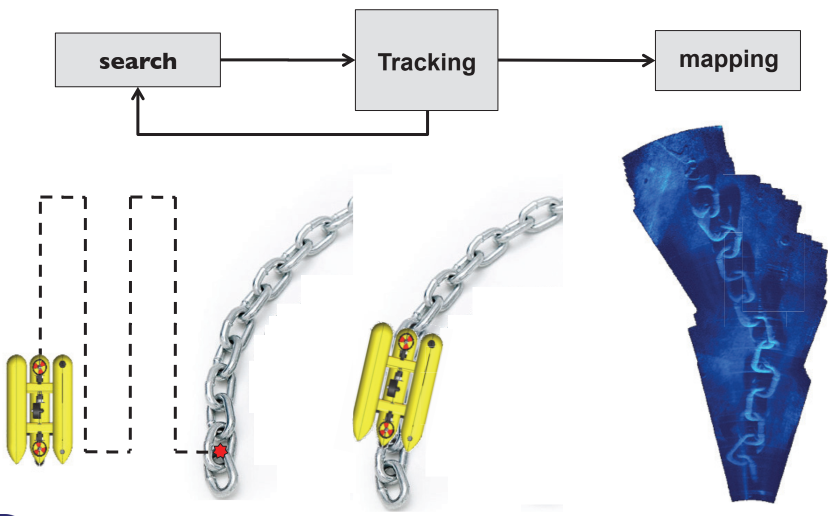


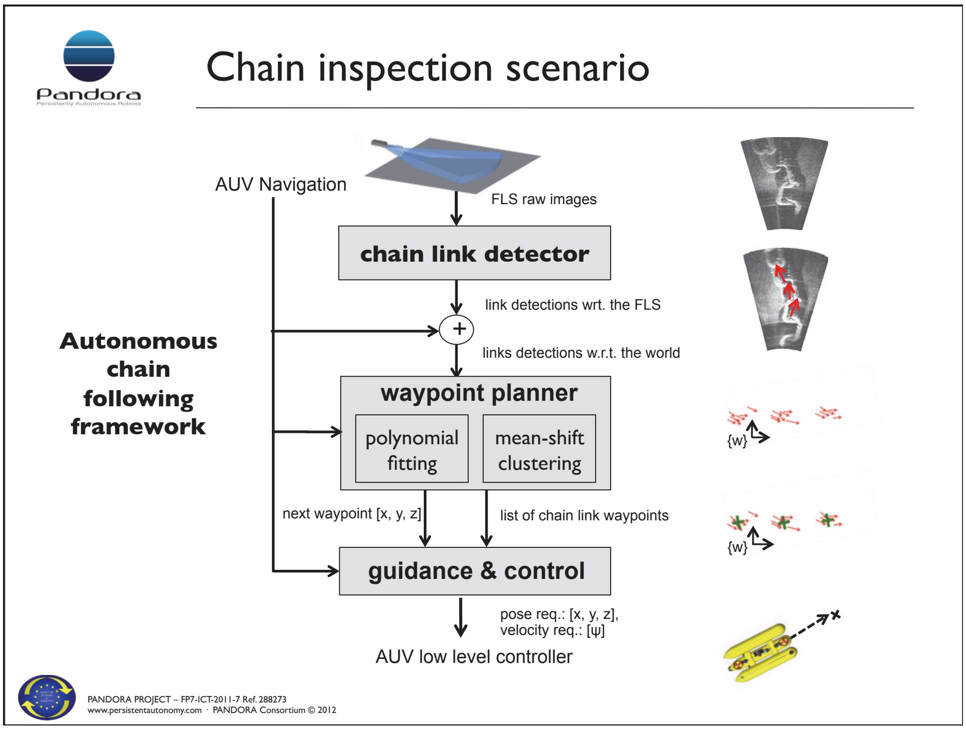


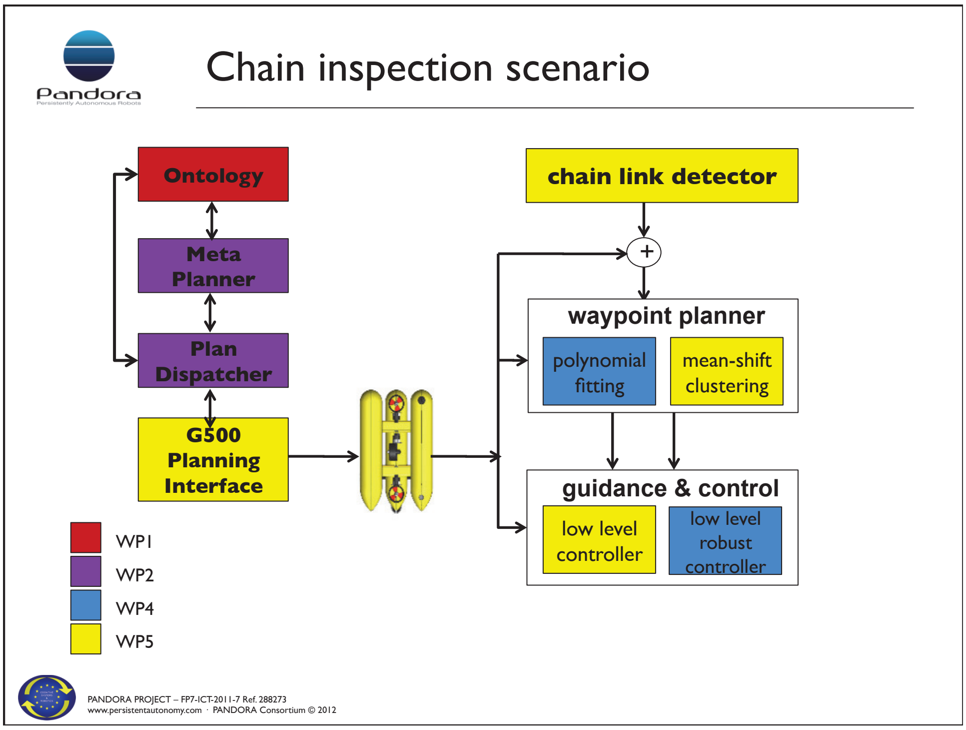
Chain inspection with FLS



Chain inspection scenario

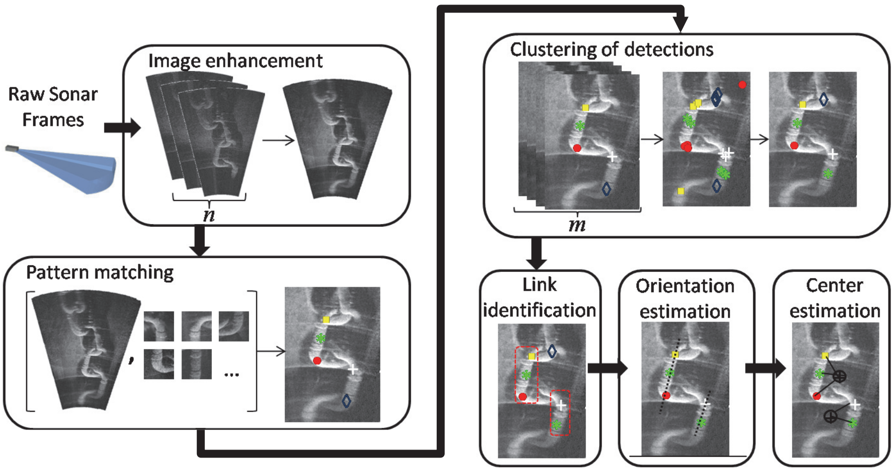



Pandora
Chain inspection scenario
AUV Navigation
FLS raw images
chain link detector
link detections wrt. the FLS
+
links detections w.r.t. the world
Autonomous chain following framework
waypoint planner
polynomial fitting
mean-shift clustering
{w}
{w}
next waypoint [x, y, z]
list of chain link waypoints
guidance & control
pose req.: [x, y, z],
velocity req.: [ψ]
AUV low level controller
PANDORA PROJECT – FP7-ICT-2011-7 Ref. 288273
www.persistentautonomy.com · PANDORA Consortium © 2012


Pandora
Chain inspection scenario
Ontology
Meta Planner
Plan Dispatcher
G500 Planning Interface
chain link detector
+
waypoint planner
polynomial fitting
mean-shift clustering
guidance & control
low level controller
low level robust controller
WP1
WP2
WP4
WP5
PANDORA PROJECT – FP7-ICT-2011-7 Ref. 288273
www.persistentautonomy.com · PANDORA Consortium © 2012

Chain inspection scenario

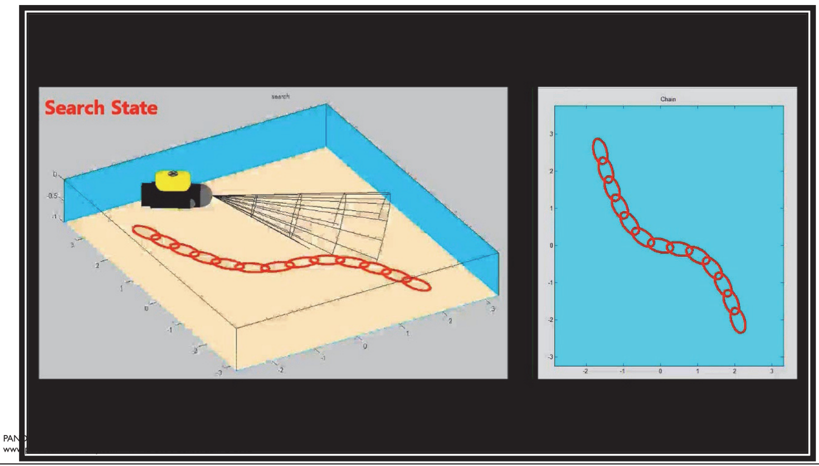
- **New Capability: Chain Link Detector**



Chain inspection scenario

- **New Capability: Link WayPoint Planner** (NTUA, UdG)

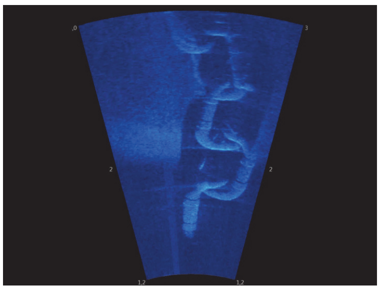
- Groups different estimations into waypoints belonging to the same link.
- Sorts the waypoints and provides the vehicle the next waypoint to follow.



Pandora
Persistently Autonomous Robots

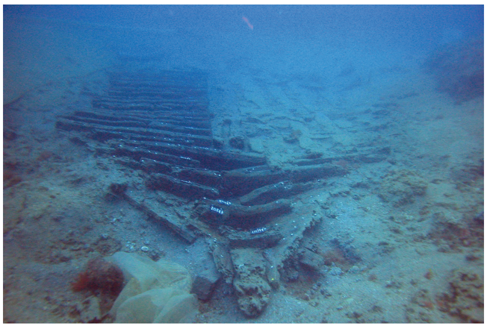
Chain mapping with FLS

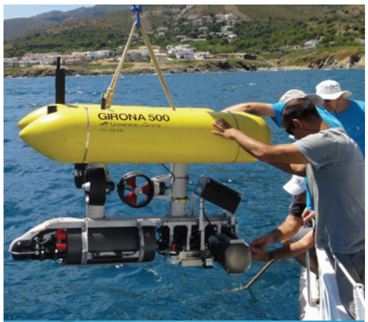
- Acoustic mosaicing for chain inspection.
- Image registration based on Fourier transform
- Pose-based graph for performing the global alignment and building a 2D mosaic.

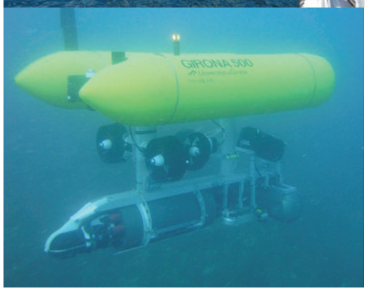


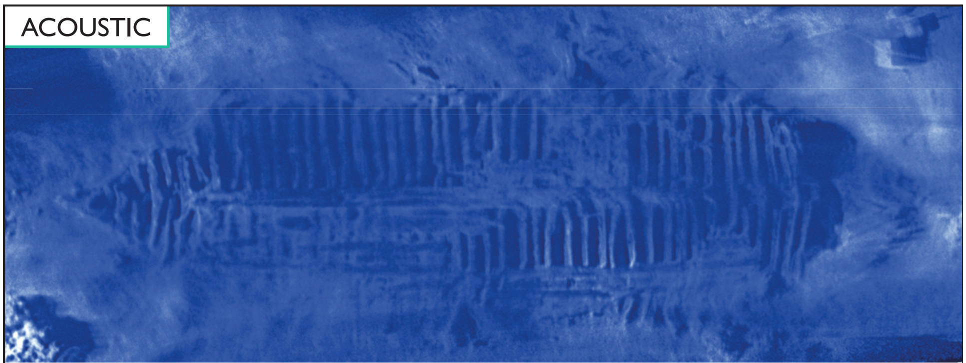
Mapping with FLS

- Cap de Vol shipwreck (Spain)
- In collab. with CASC, Dr. Gustau Vivar.
- Iberian/Roman ship
- Year: 10 B.C.
- Area: 10x4m of wooden structure
- Depth: 20m



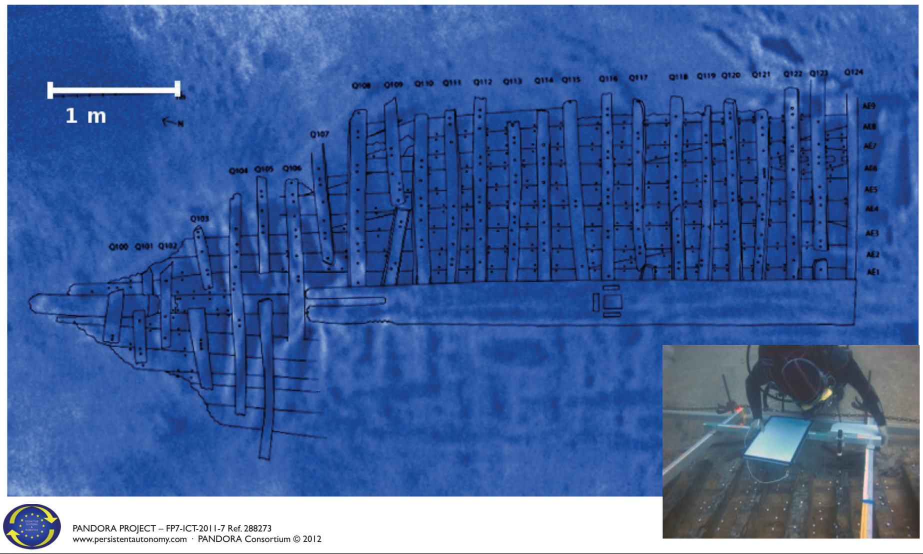






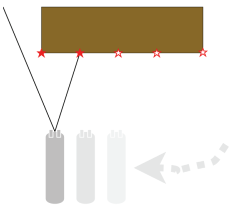
Mapping with FLS

Hand-drawn planimetric map

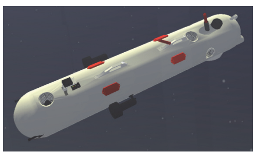


Pandora scenarios

A. STRUCTURE INSPECTION

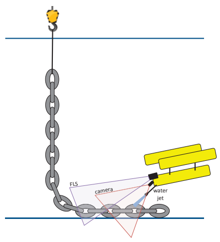


HWU, Fort William

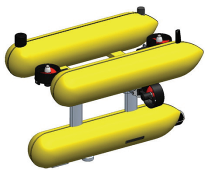


Nessie VI AUV

B. CHAIN CLEANING AND INSPECTION

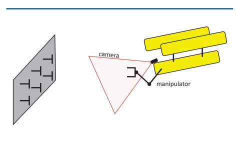


UdG, CIRS water tank

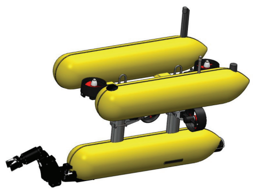


Girona 500 AUV

C. VALVE TURNING



UdG, CIRS water tank

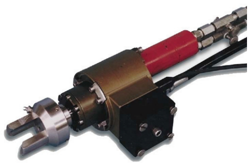


Girona 500 AUV

Valve turning scenario

Problem description:

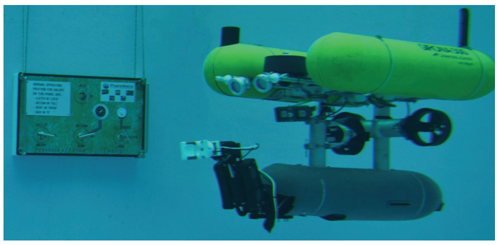
- Valve state detection (open, close, intermediate) in a ROV panel by means of a video camera
- Valve operation with a manipulator or torque tool
- Difficulty in controlling the vehicle and manipulator when approaching to the valve (free floating manipulation)
- Water current perturbations



subsea 7

Valve turning scenario

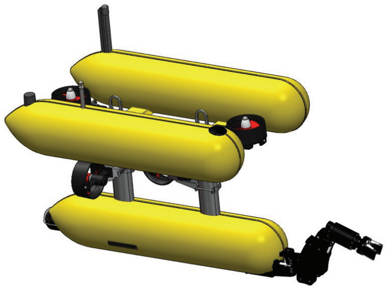
- 80cm x 60cm panel.
- 4 T-bar valve handles.
- 2 lateral panel handles.
- 90 degree free turning.

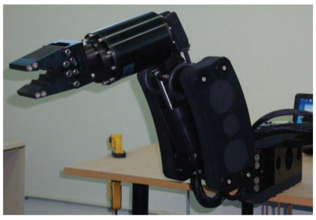


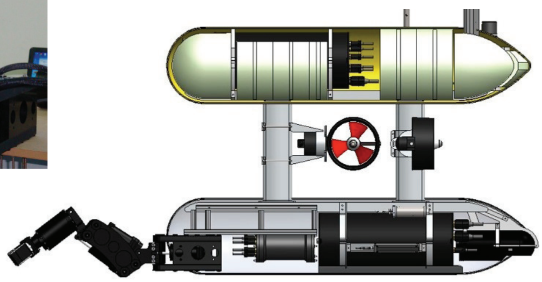
Pandora
Persistently Autonomous Robots

Valve turning scenario

- **4 DOF Electrical Manipulator**
    - ECA Robotics – ARM 5E Micro Manipulator (300 m)
    - 4 electrical DOF + gripper
    - Incremental encoder
    - Velocity and voltage control of each DOF





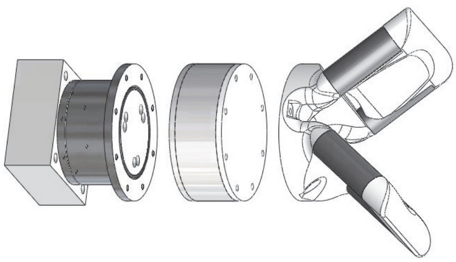


Pandora
Persistently Autonomous Robots

Valve turning scenario

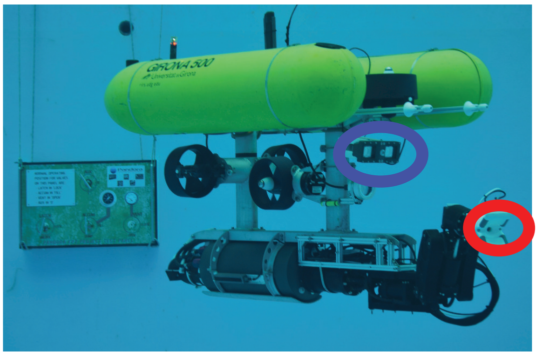
End-Effector:

- Passive gripper.
- Camera in hand.
- Force/torque sensor.



Valve turning scenario

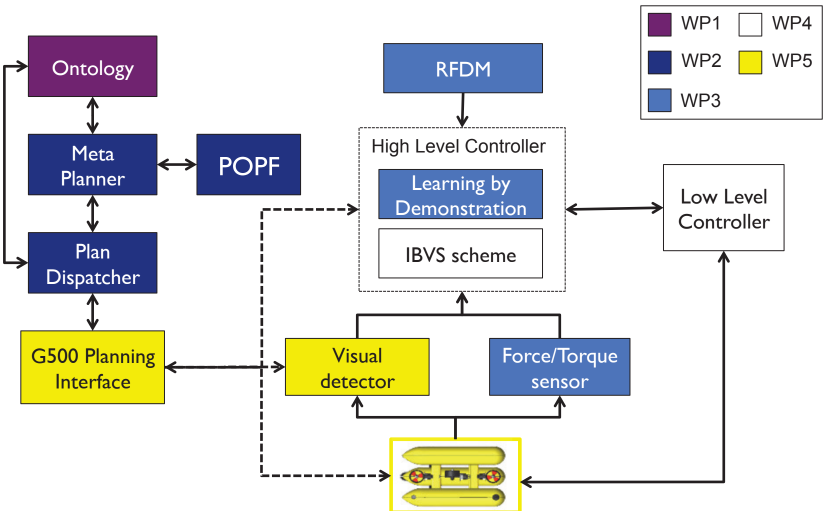
2 cameras for positioning:



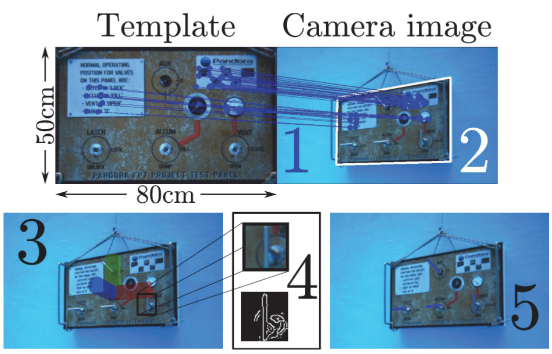
Vehicle's main camera

Camera in hand

Valve turning scenario diagram



Visual detector

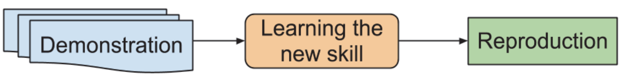


Perception module

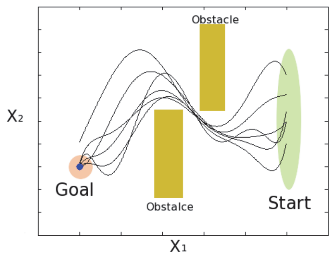
- **1, 2.** Feature extraction from a template are compared with the features of the camera.
- **3, 4, 5.** Extract region of interest around the valve and find the main line with Hough transform.

Learning by Demonstration

Learning by Demonstration

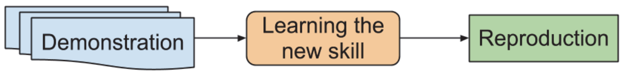


Dynamic Movement primitives

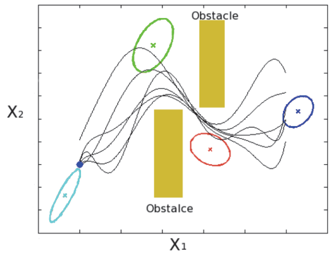


Learning by Demonstration

Learning by Demonstration

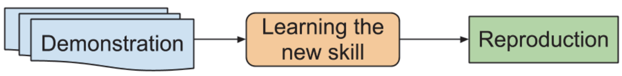


Dynamic Movement primitives

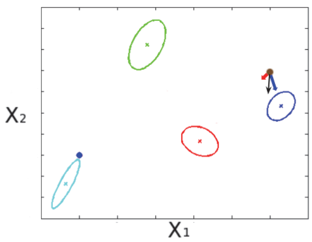


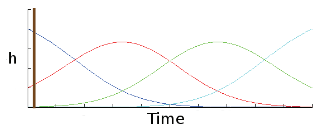
Learning by Demonstration

Learning by Demonstration



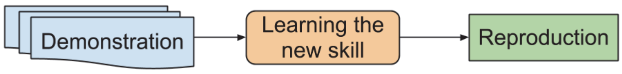
Dynamic Movement primitives



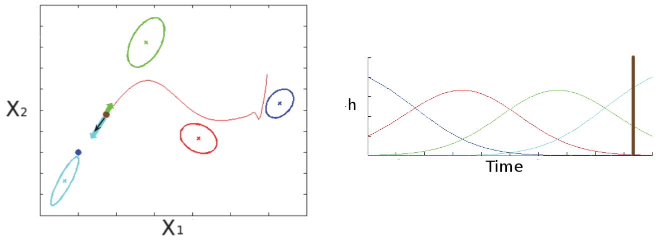


Learning by Demonstration

Learning by Demonstration

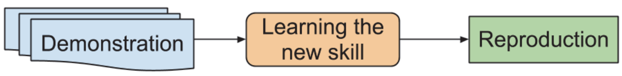


Dynamic Movement primitives

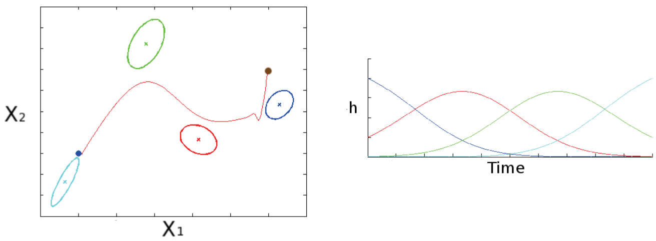


Learning by Demonstration

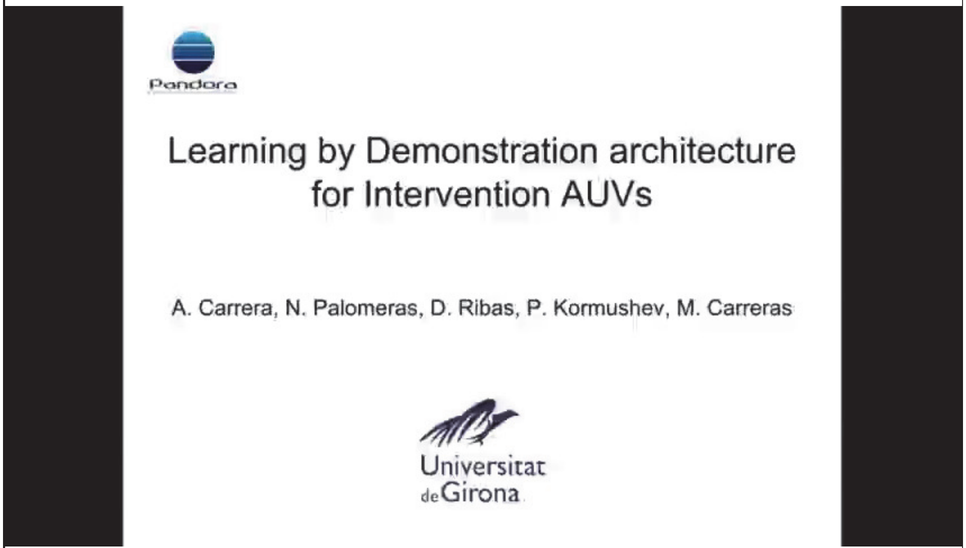
Learning by Demonstration



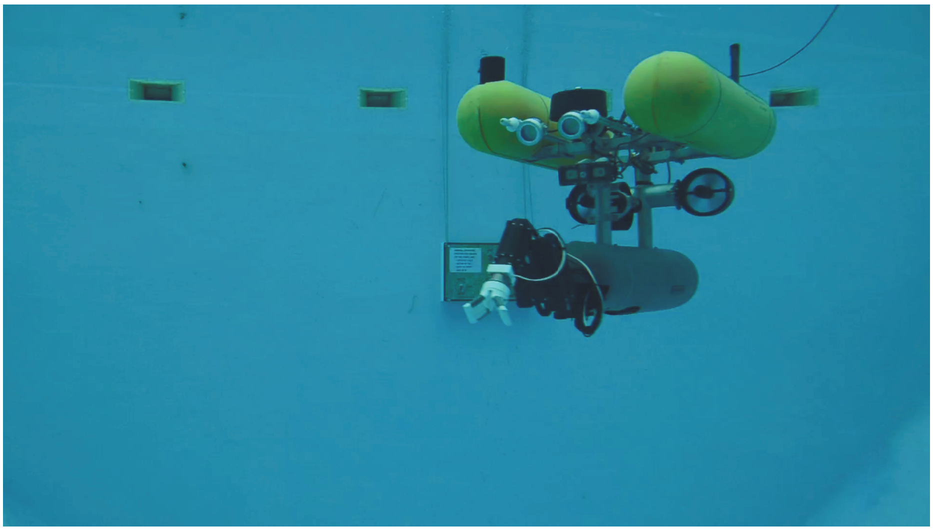
Dynamic Movement primitives



Valve turning scenario



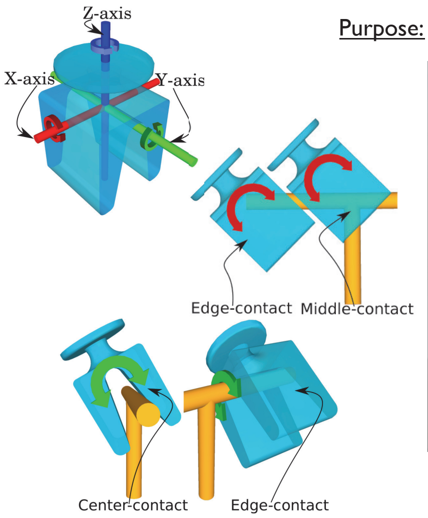
Valve turning scenario

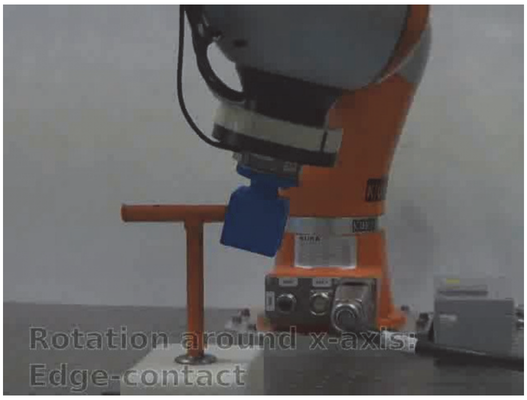


PANDORA PROJECT – FP7-ICT-2011-7 Ref. 288273
www.persistentautonomy.com · PANDORA Consortium © 2012

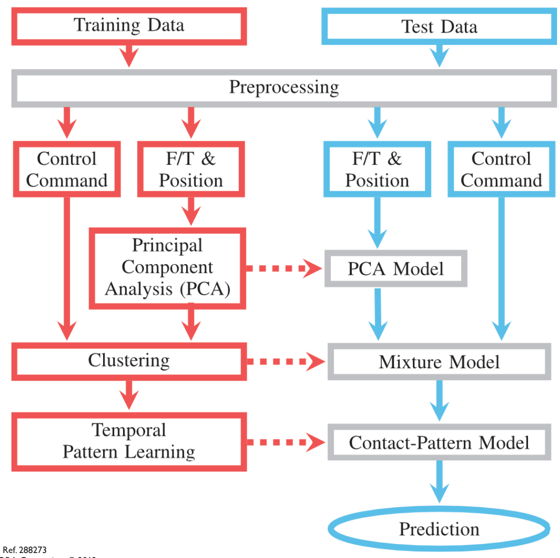
Contact State Estimation for Valve turning

Purpose: to excite the F/T sensor and collect time-series data

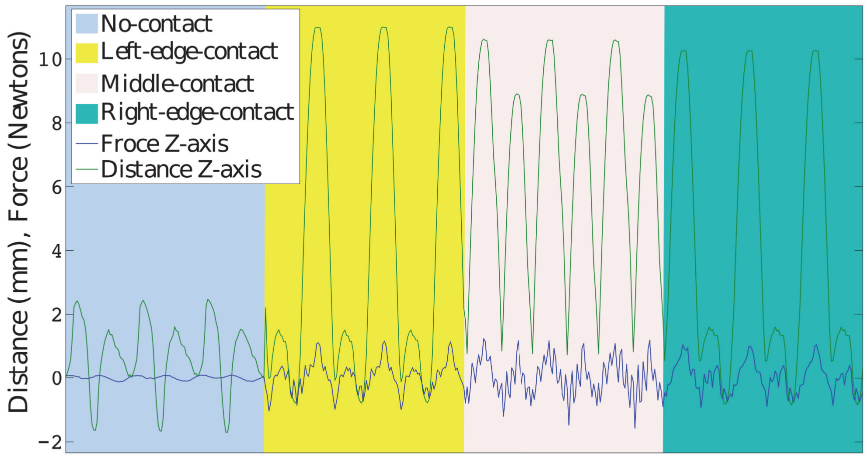




Contact State Estimation for Valve turning



Contact State Estimation for Valve turning



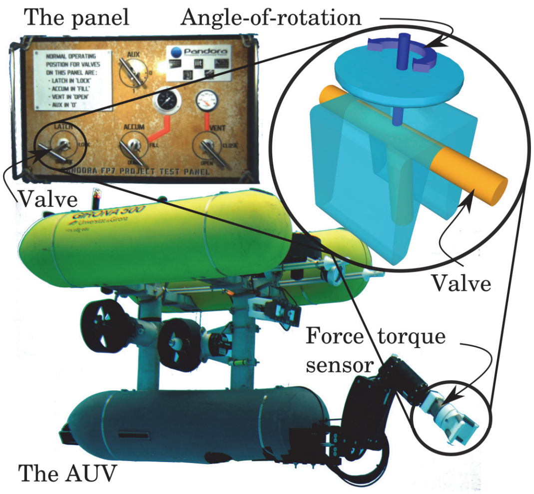
Contact State Estimation for Valve turning

Confusion matrix for the rotation around x-axis behavior, accuracy 88% ± 5%

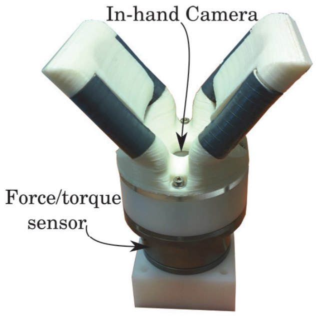
$\mathcal{N}$	$\mathcal{E_L}$	$\mathcal{M}$	$\mathcal{E_R}$	Class
36	0	0	0	No-Contact=$\mathcal{N}$
0	31	13	2	Left-Edge-Contact=$\mathcal{E_L}$
0	4	23	3	Middle-Contact=$\mathcal{M}$
0	1	0	31	Right-Edge-Contact=$\mathcal{E_R}$
100 %	86 %	64 %	86 %	Accuracy

PANDORA PROJECT – FP7-ICT-2011-7 Ref. 288273
www.persistentautonomy.com · PANDORA Consortium © 2012

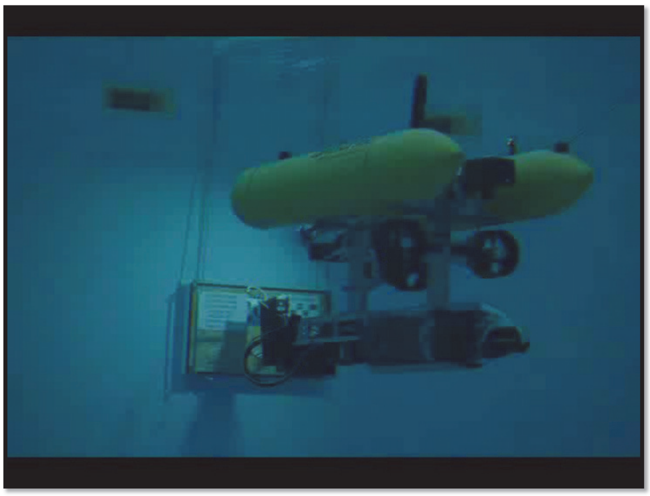
Contact State Estimation for Valve turning



- Waterproof gripper



Contact State Estimation for Valve turning



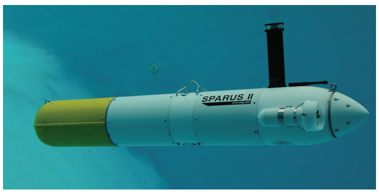
Reactive high-level layer for Valve turning

Towards Autonomous Robotic
Valve Turning

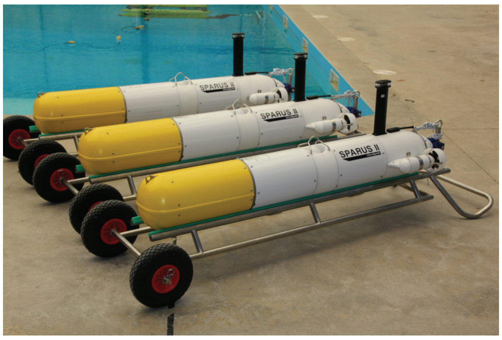
A. Carrera
S.R. Ahmadzadeh
A. Ajoudani
P. Kormushev
M.Carreras
D.G. Caldwell

euRathlon

The European Robotics Athlon:
Marine Robotics approach, La Spezia (Italy)
September 29th – October 3rd, 2014
www.eurathlon.eu



cirs.udg.edu/sparus

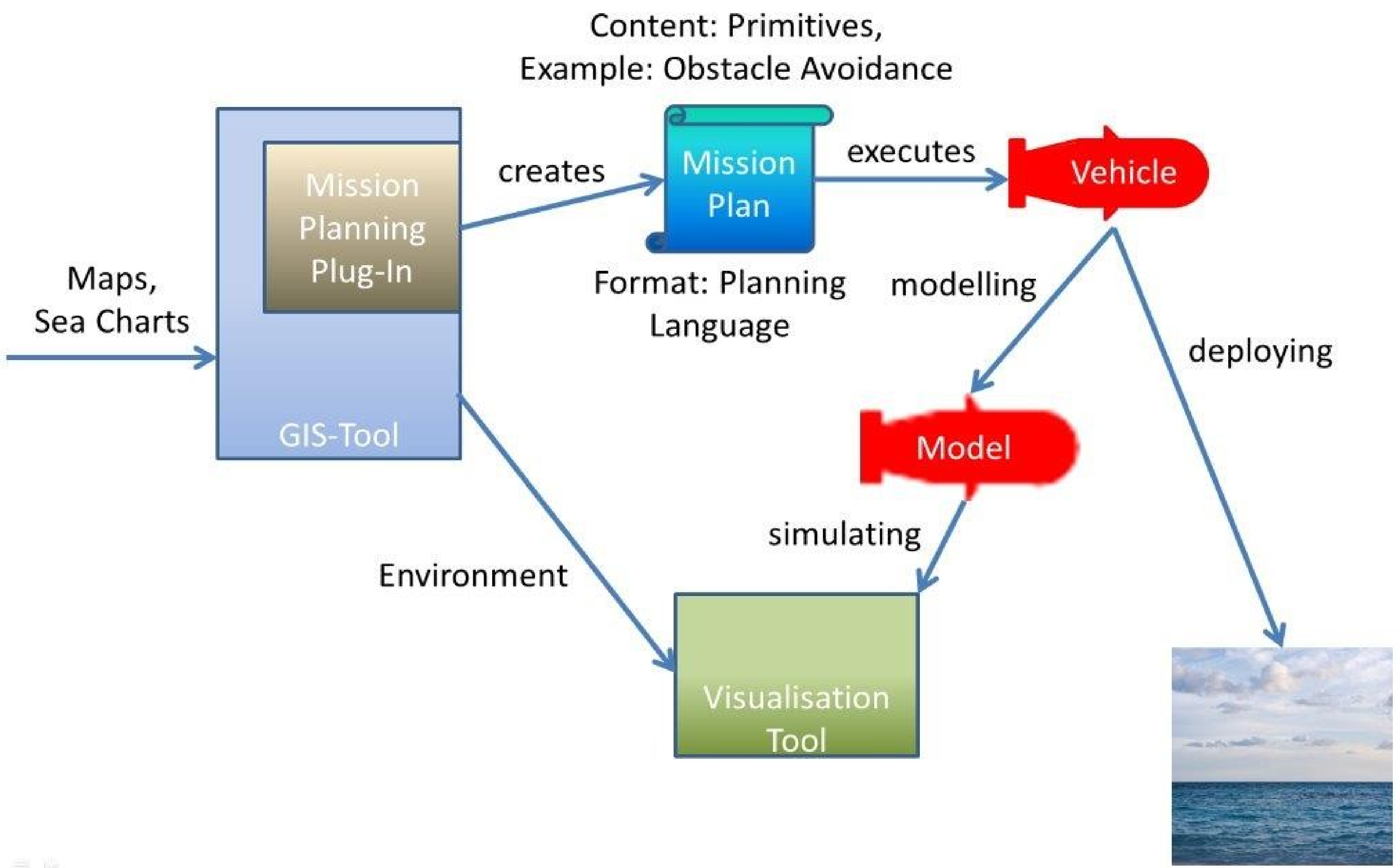


MORPH

mission planning and mission supervision

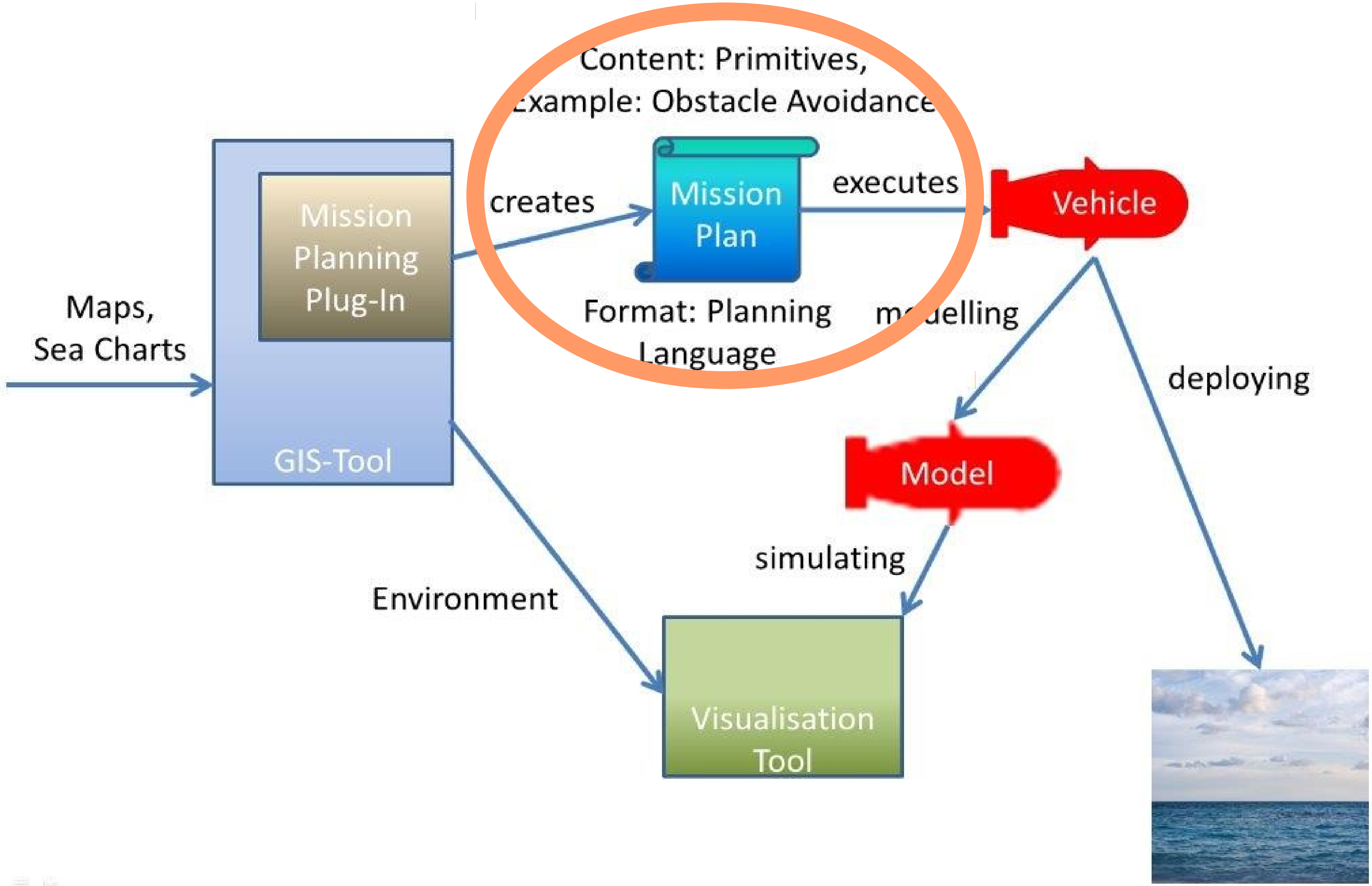
Sebastian Eckstein
TU Ilmenau

Overview


Content: Primitives,
Example: Obstacle Avoidance
Maps,
Sea Charts
Mission
Planning
Plug-In
GIS-Tool
creates
Mission
Plan
executes
Vehicle
Format: Planning
Language
modelling
deploying
Model
simulating
Environment
Visualisation
Tool

MORPH

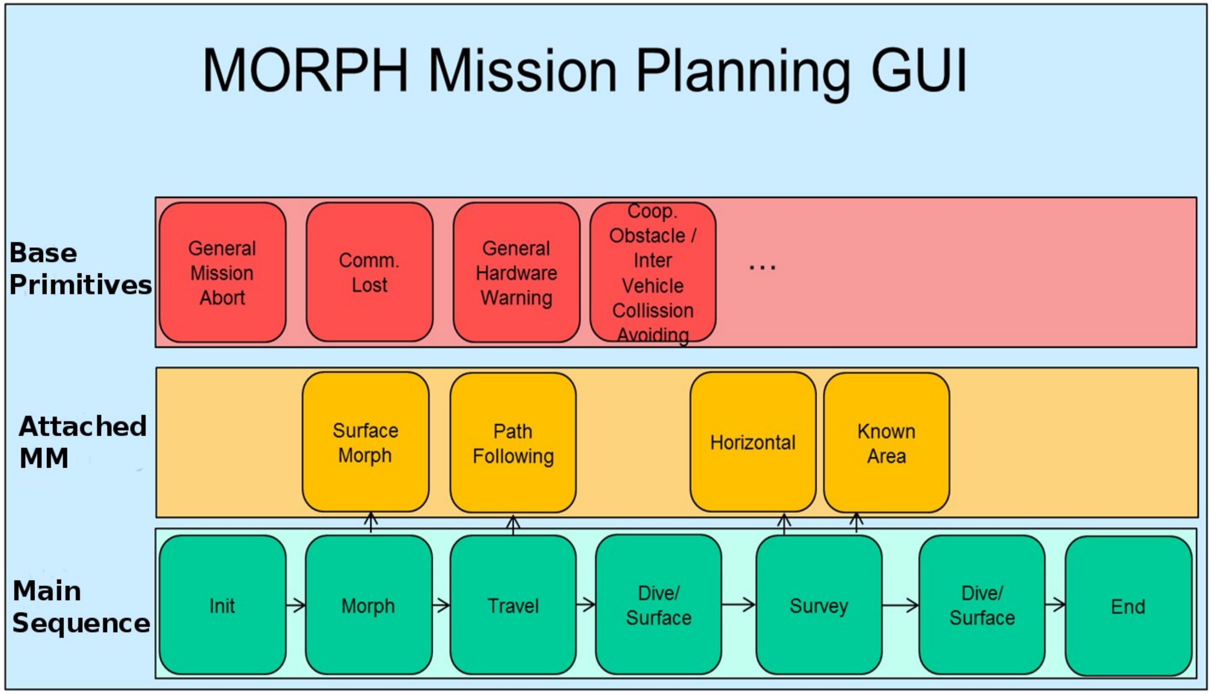
Overview



Planning paradigm

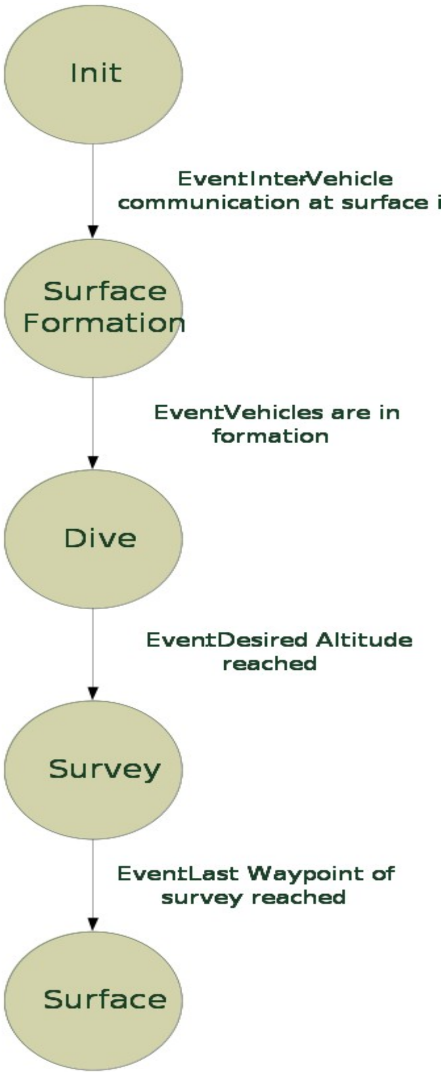
Problem: Planning of missions for teams of heterogeneous marine vehicles in event-driven scenarios

Solution: three-layered planning device with ‚Main Sequence‘ for MORPH Primitives (MPs), select MM according to MP and a third layer for Base Primitives (BP)



mission planning

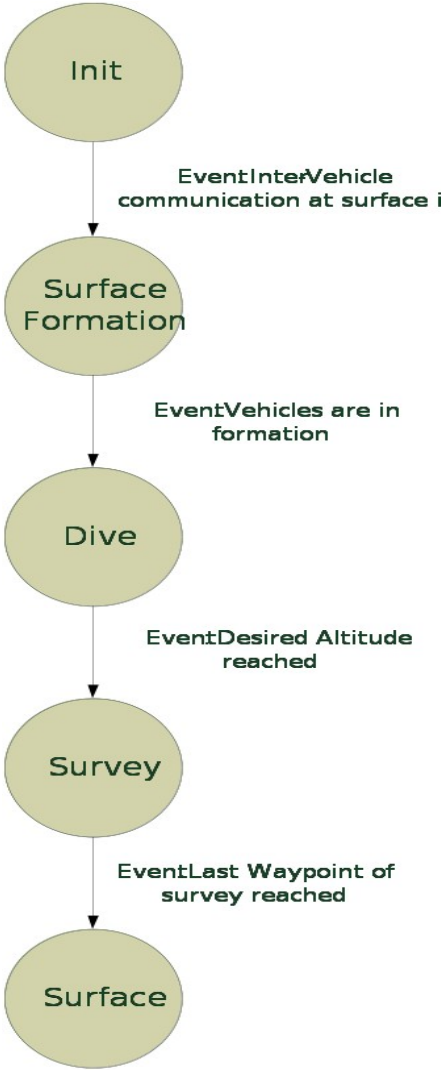
- **Morph missions**
  - Define morph missions
  - Identify simplifications
  - Event driven
  - Derive primitives



mission planning

- **Morph missions**
  - Define morph missions
  - Identify simplifications
  - Event driven
  - Derive primitives

- **List of MORPH Primitives (MP)**
  - Init, Morph, Travel, Survey, Dive, End
  - Outline plan for user



MORPH methods

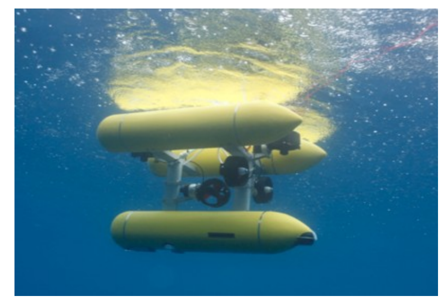
- Basic team related autonomous behaviour
- each MM will require a specific software algorithm to be developed and implemented

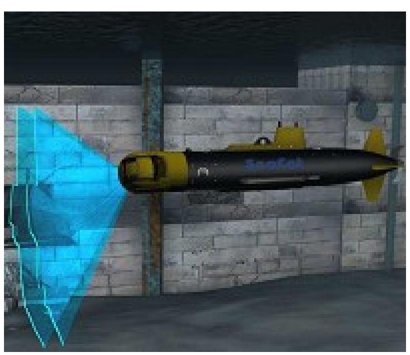
#	Name of MM	Description
1	Role Assignment	Before Deployment, load mission plans and create team
5	Surface Formation Build	2D Formation building at surface
6	General Formation Change	3D Formation building underater
7	Cooperative Path Following	Vehicles follow individual paths, velocity is adapted to preserve formation
9	Cooperative Approaching	like MM7, with amendment to detect an object

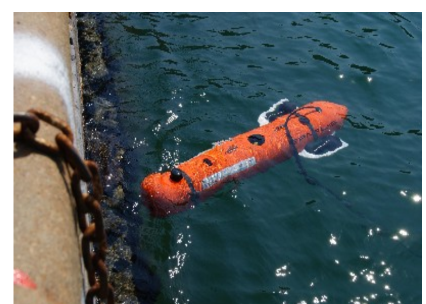
Table selected MM

missions planning

- **Vehicle level**

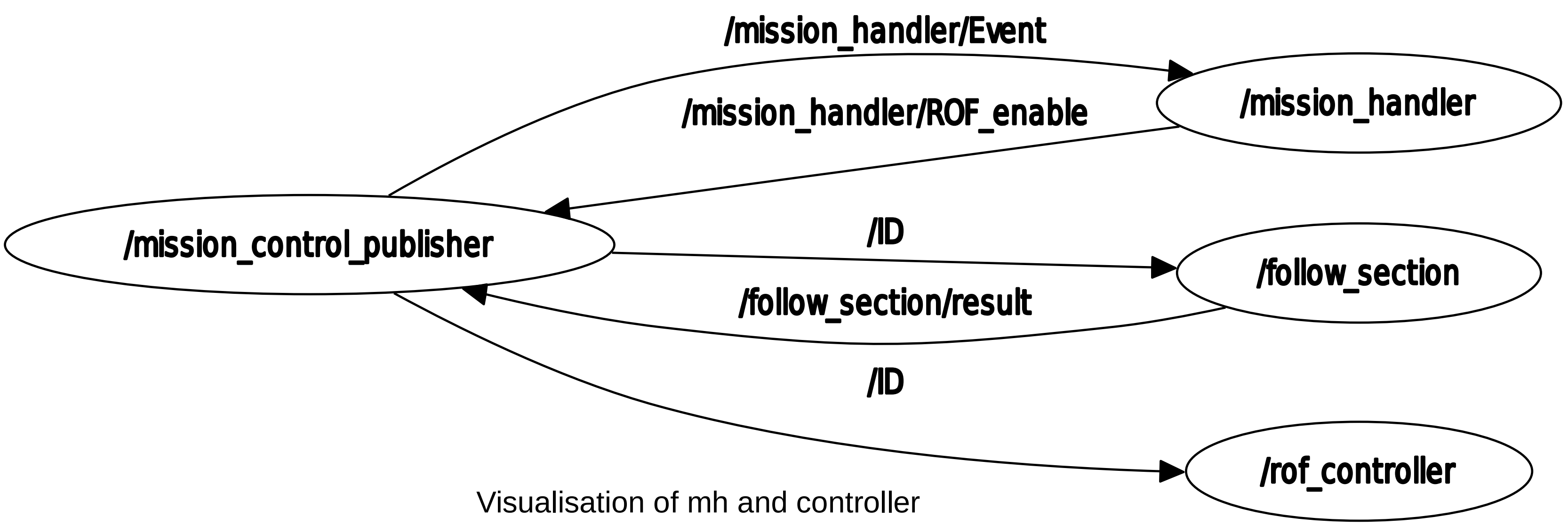






ROS

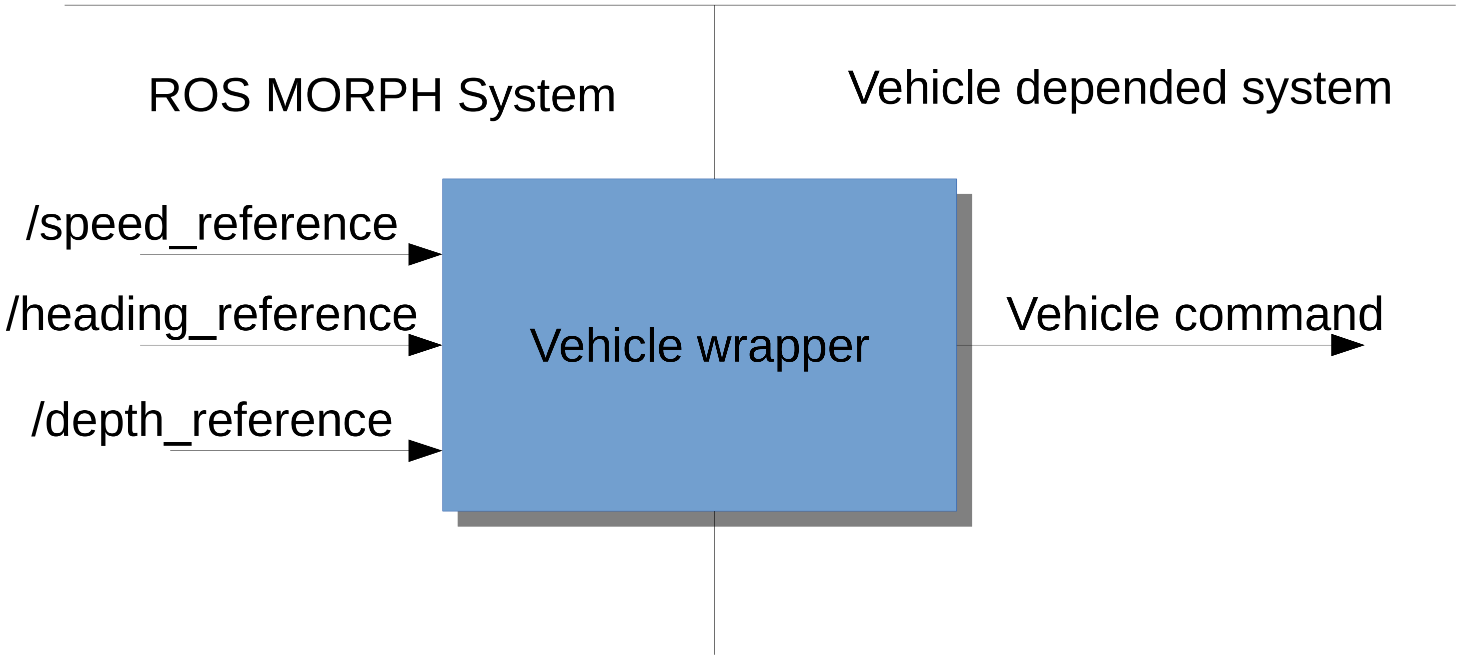
- **Using ROS**
  - middelware
  - provide communication
  - abstract vehicle abilities
  - seperate controllers
  - all partner can provide nodes



Visualisation of mh and controller

Single vehicle Primitives

- List of SVP defined
  - Example: set velocity, heading, altitude or depth
- All vehicle providers need to implement
- Translate to ROS



Base Primitives

- Security mechanisms
- Event driven
- Take over command in emergency situations
- Prioritisation needed

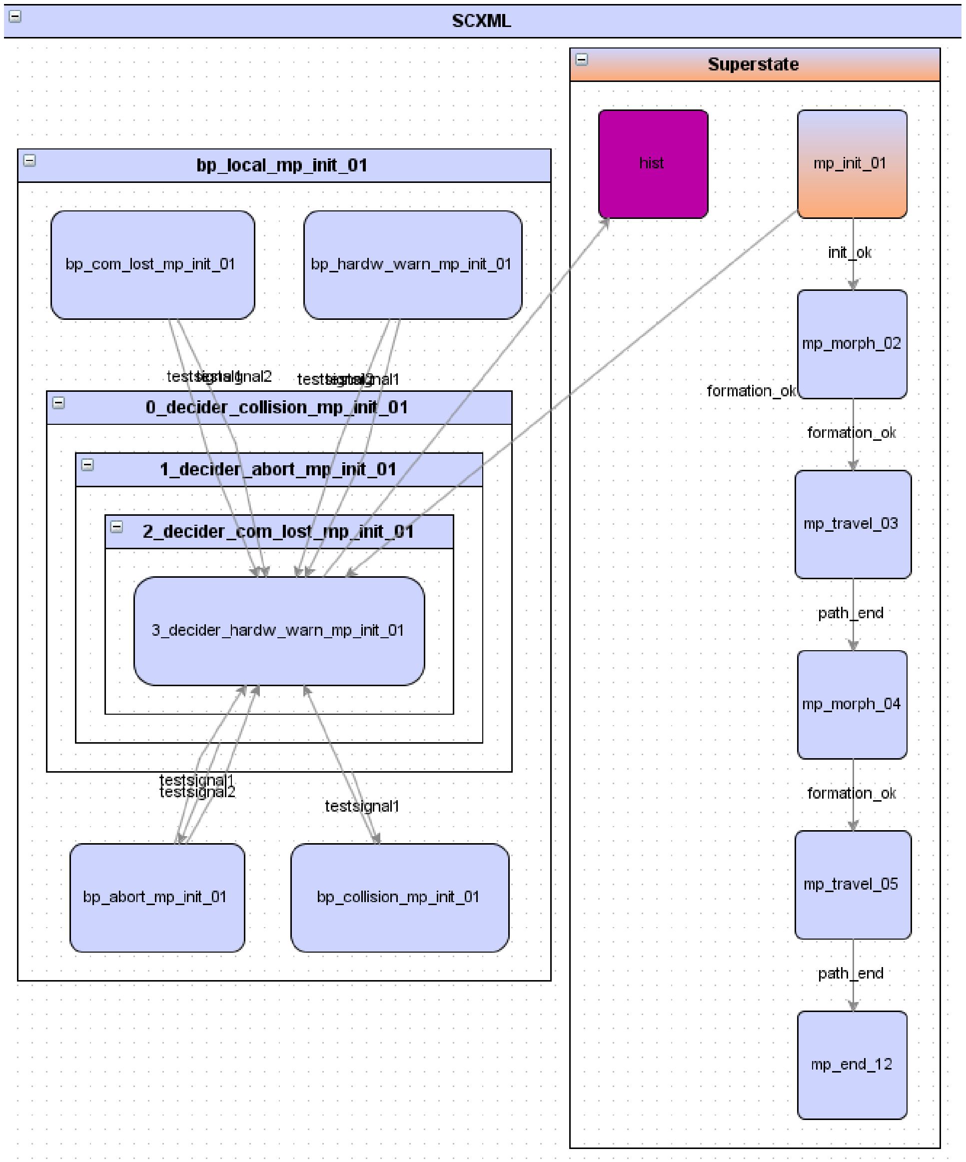
#	Name	What to do
7	General Mission Abort (GMA)	Bring vehicles to a safe surface position; follow a proceeding that was parameterized by user offline. Structure: MP Dive/Surface + SP Enhanced, MP End
8	Communication lost (to one/some or all vehicles)	Run MM Reestablish Communication (continue the current action, try to get in contact again, see below). After defined time, got to BP GMA (see above)
9	General Hardware Warning (e.g. Battery low, sensor failure)	Run MM General Hardware Warning (see below): Report to leader, in critical case activate BP GMA
10	Cooperative Obstacle / Inter Vehicle Collision avoidance	Activate MM of same name (see below)

Table Base Primitives

Planning Language

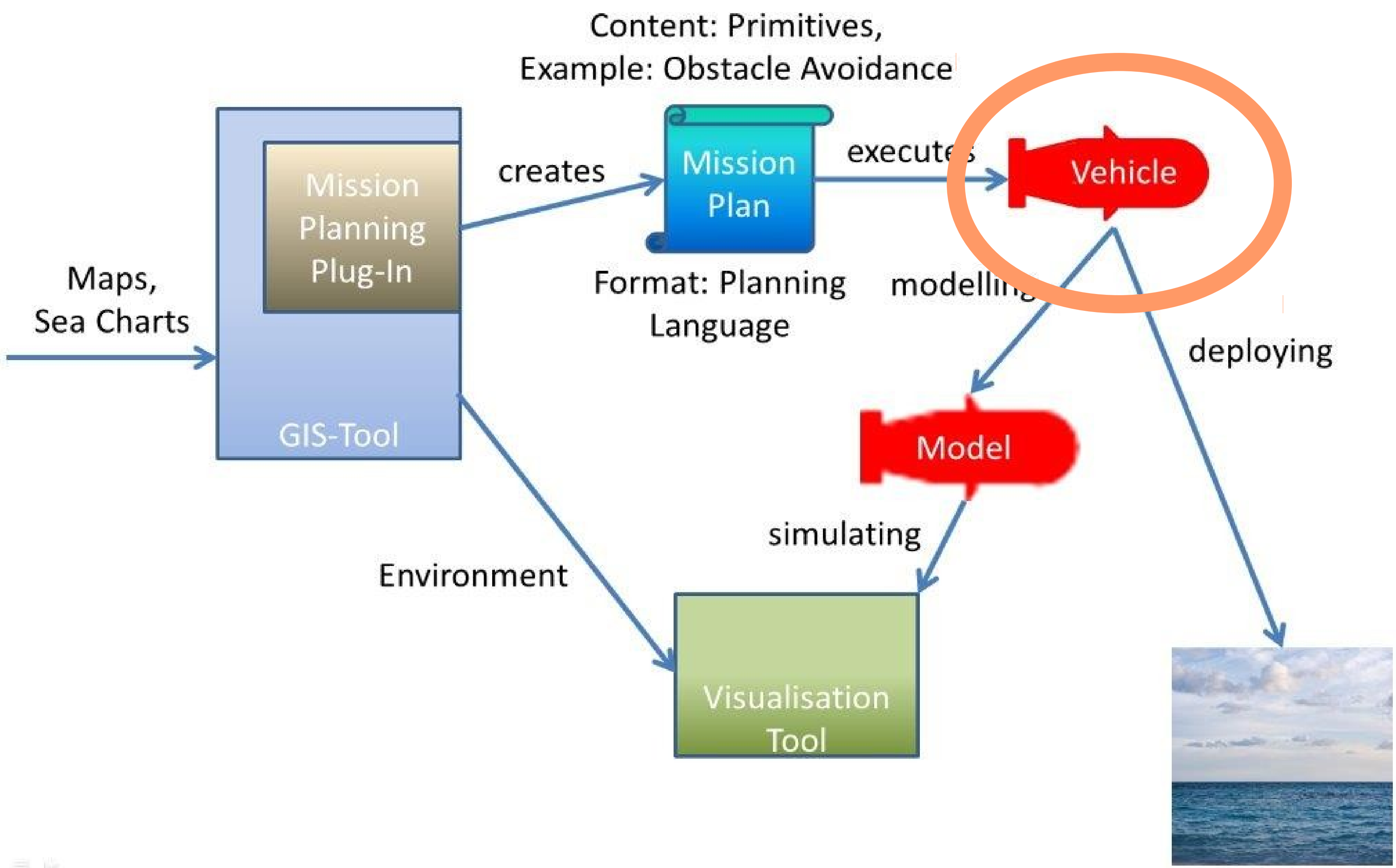
Mission Plans are stored in SCXML (Start Chart Extensible Markup Language)

- Human readable/writeable
- Parsers tested for a long time in many applications
- Event driven state change
- Prioritisation possible



MORPH

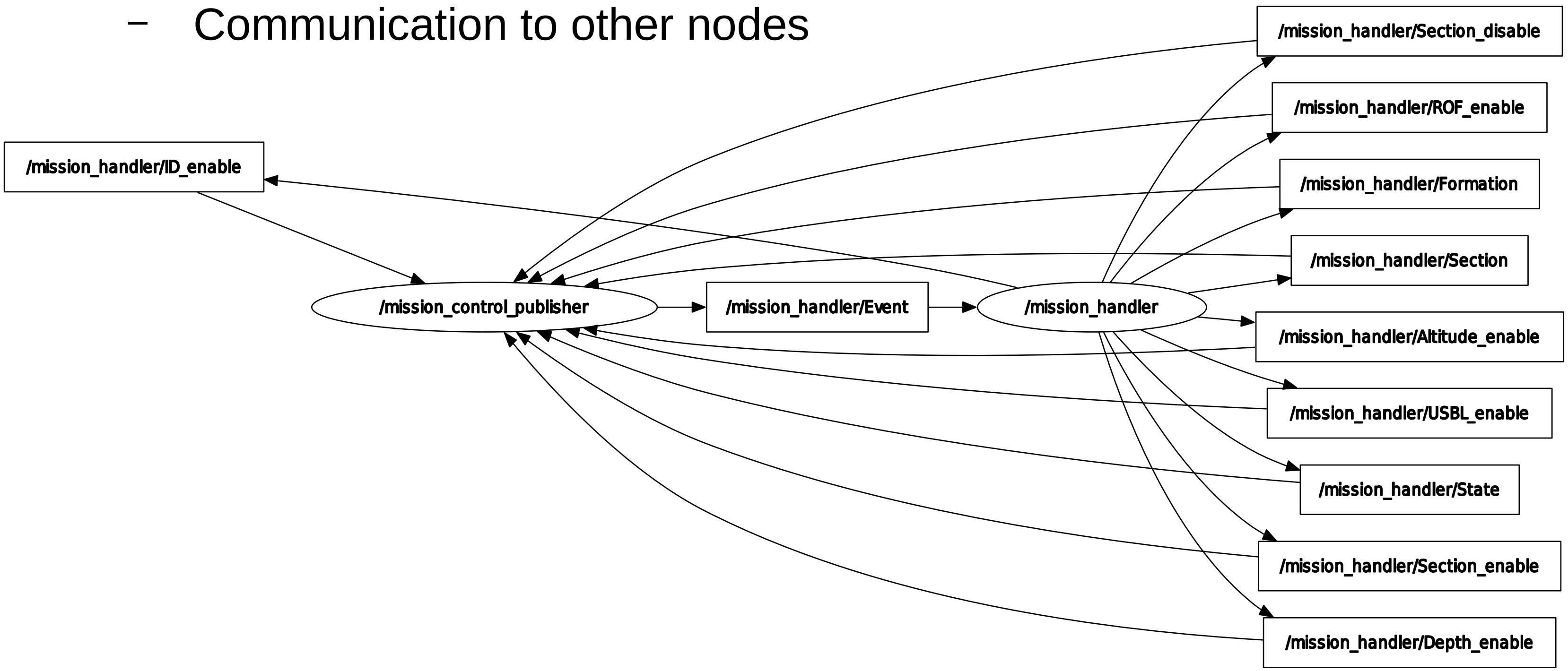
Overview



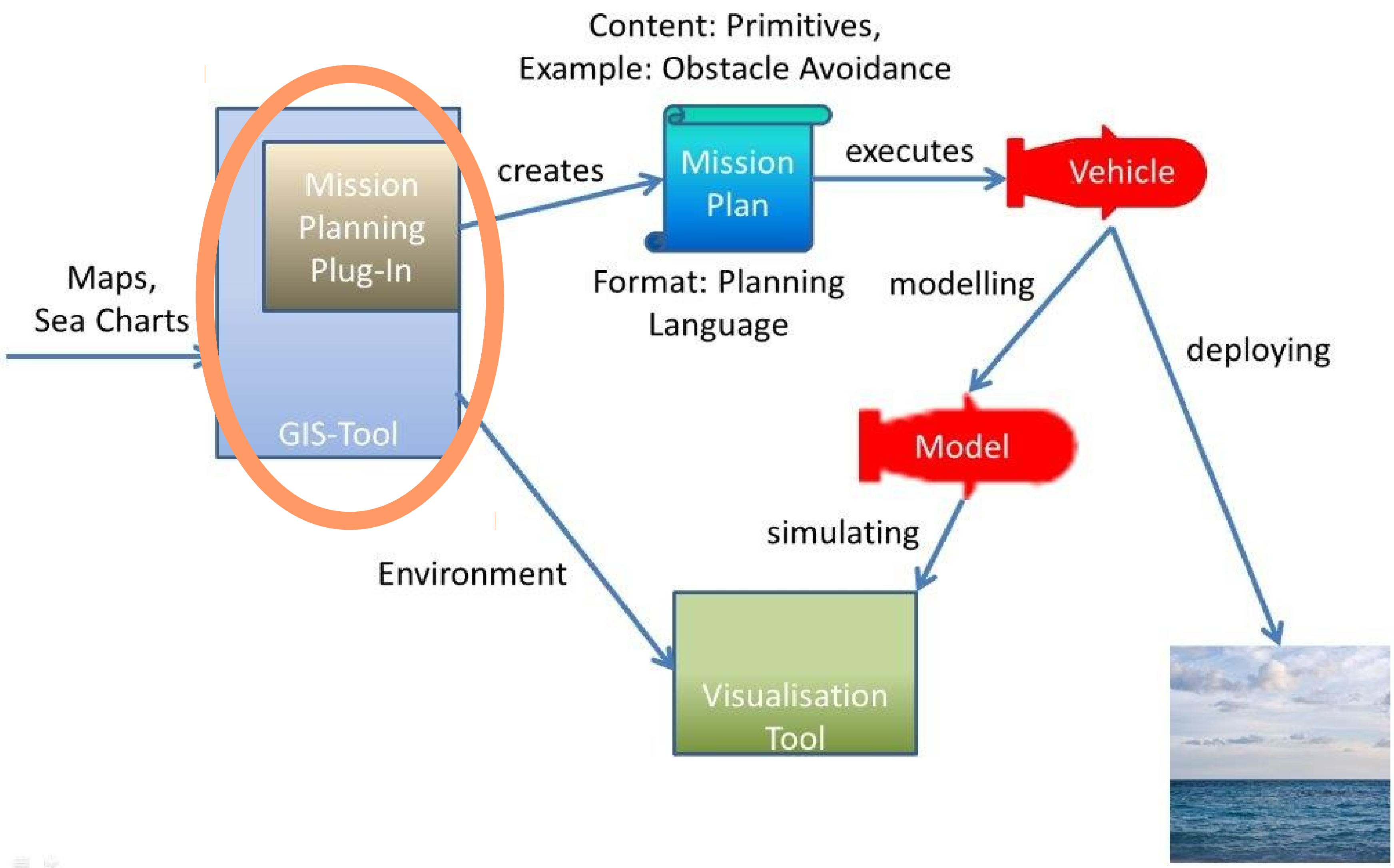
Mission handler

Mission Plans executes mission on vehicle

- Runs on every vehicle
- Send state / Synchronize vehicles
- Two parts
  - Statemachine
  - Communication to other nodes

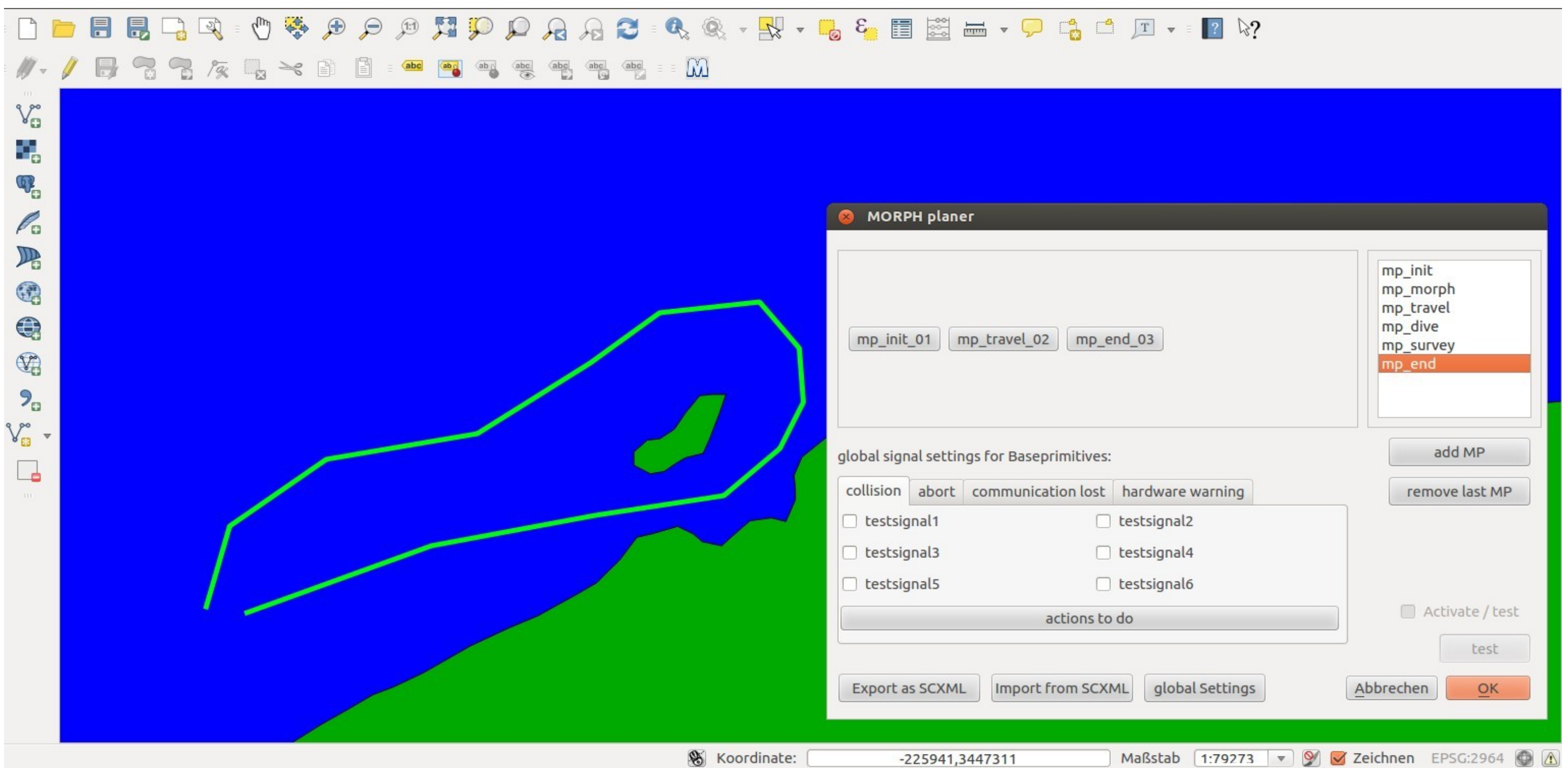


Planning GUI



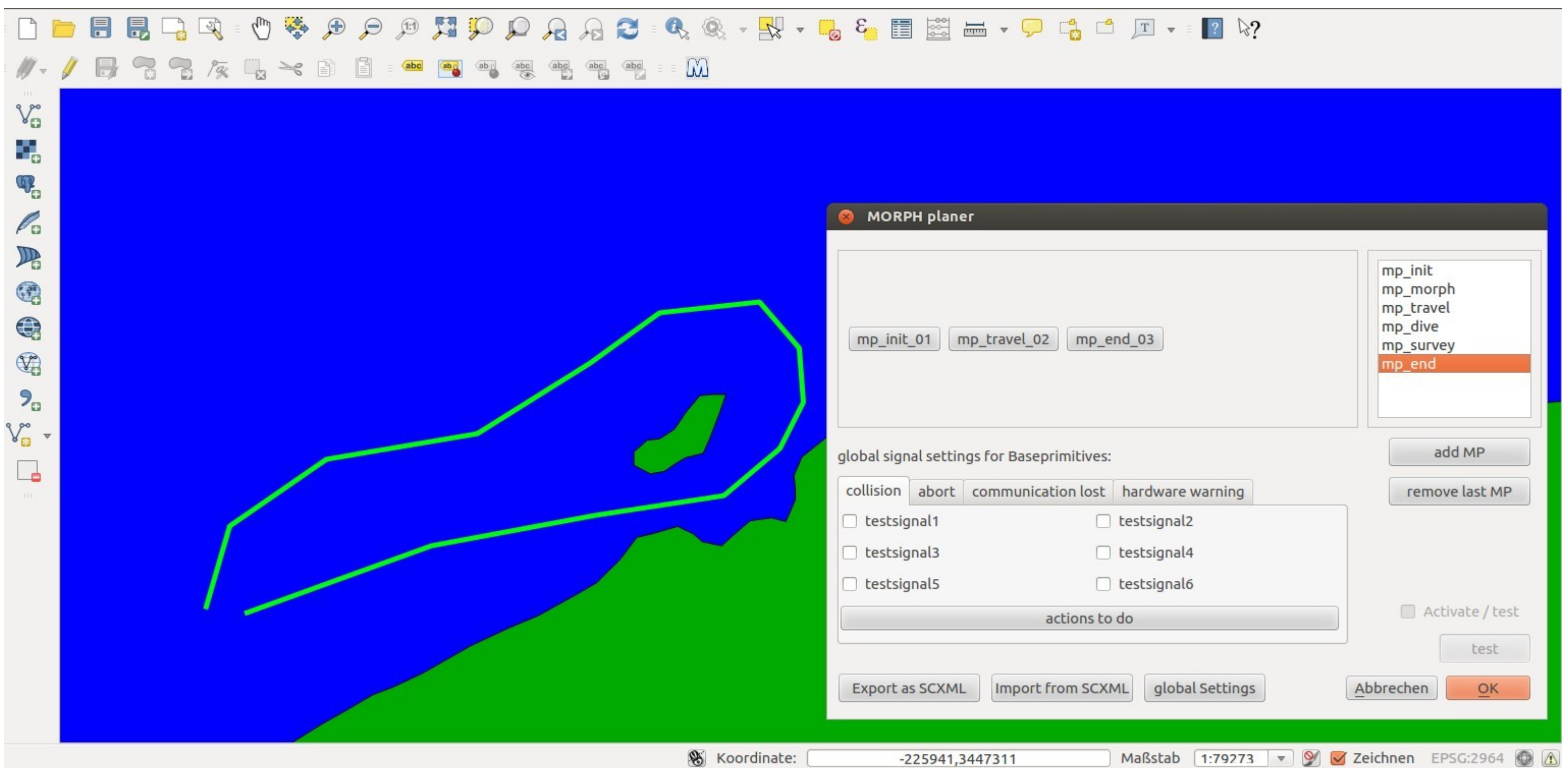
GUI

- **QGIS**
  - Support a wide range of spacial data
  - Modern qt framework
  - Nice plugin system



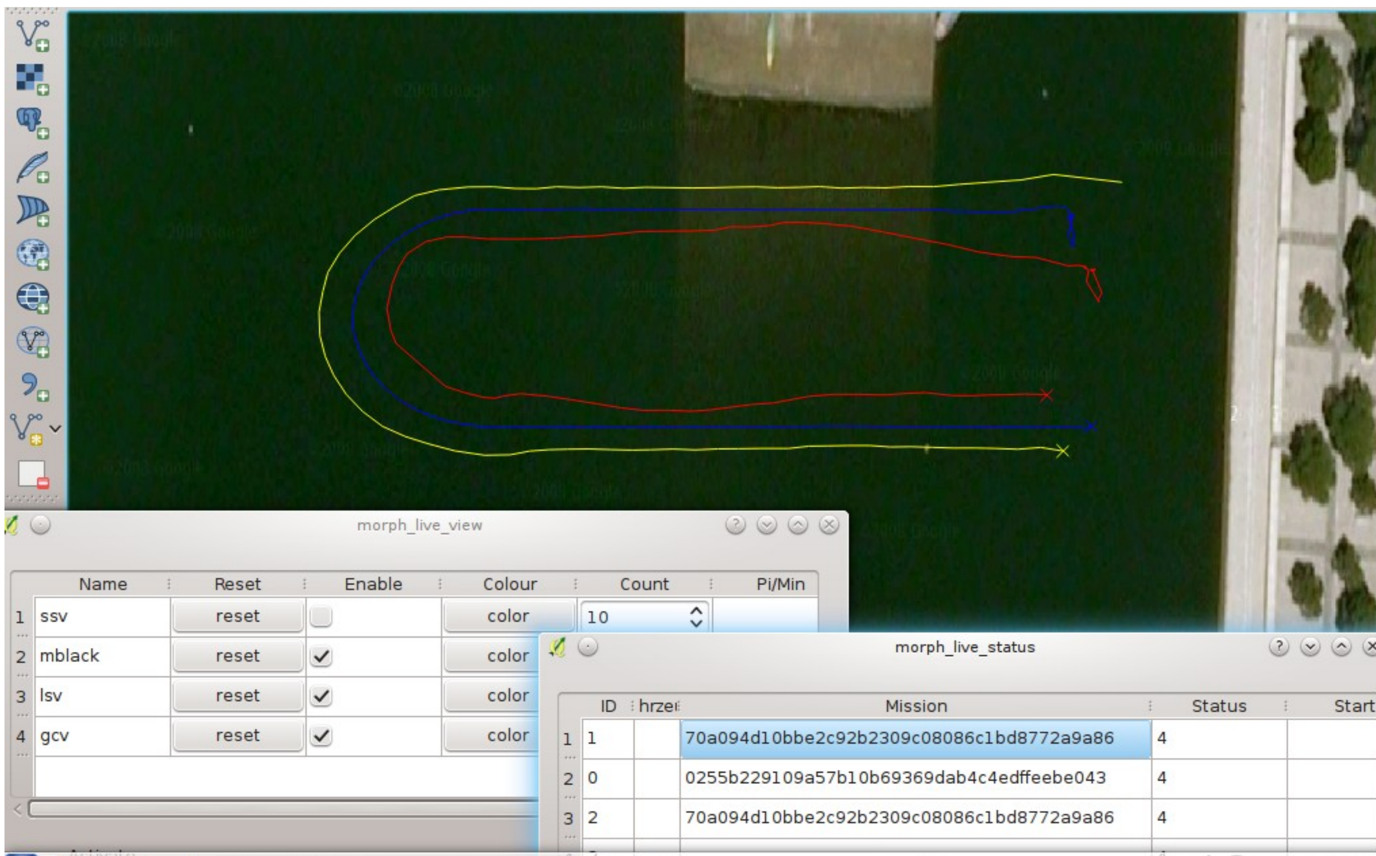
GUI

- **Planning**
  - Select MP
  - Parametrize MP
  - Import/Export Plan
  - Draw paths
  - Connect Events and BP
  - Connect Events and MP



GUI

- **Mission supervision**
  - Display vehicle position
  - Display vehicle state
  - Start/Abort missions



Thank you for your attention!

Innovations for Maritime Security

Dr.-Ing. Jeronimo Dzaack

... a sound decision

ATLAS ELEKTRONIK
A joint company of ThyssenKrupp and Airbus DS

ATLAS ELEKTRONIK
... a sound decision

Submarines

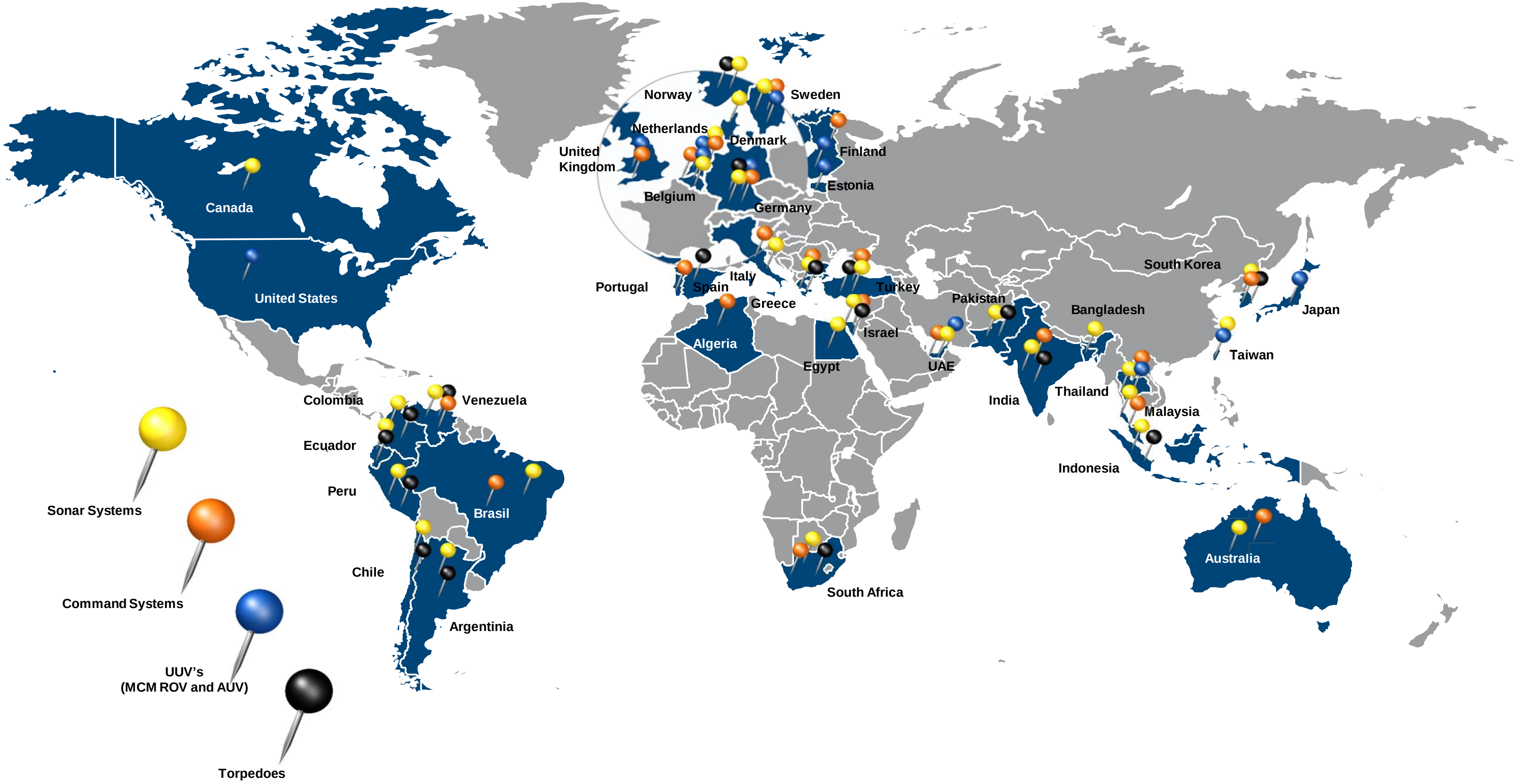
Surface Vessels

Maritime Security

Torpedos

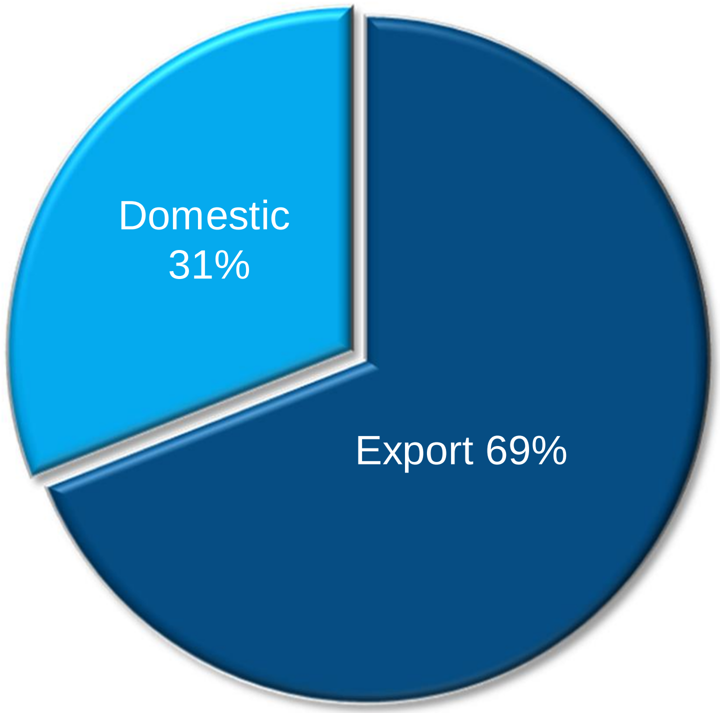
Unmanned Vehicles

A world-wide Customer Base



Turnover and Employees (ATLAS group)

Sales of the Company: 440 Mio. €



1970 employees worldwide

approx. 1300 in Bremen (approx. 1600 in Germany)

Graduate Engineers	49%
Commercial	16%
Skilled Workers	12%
Technicians	23%

Locations in Germany

Hagenuk Marinekommunikation
A company of the ATLAS ELEKTRONIK Group

Flintbek

ATLAS ELEKTRONIK
A joint company of ThyssenKrupp and EADS

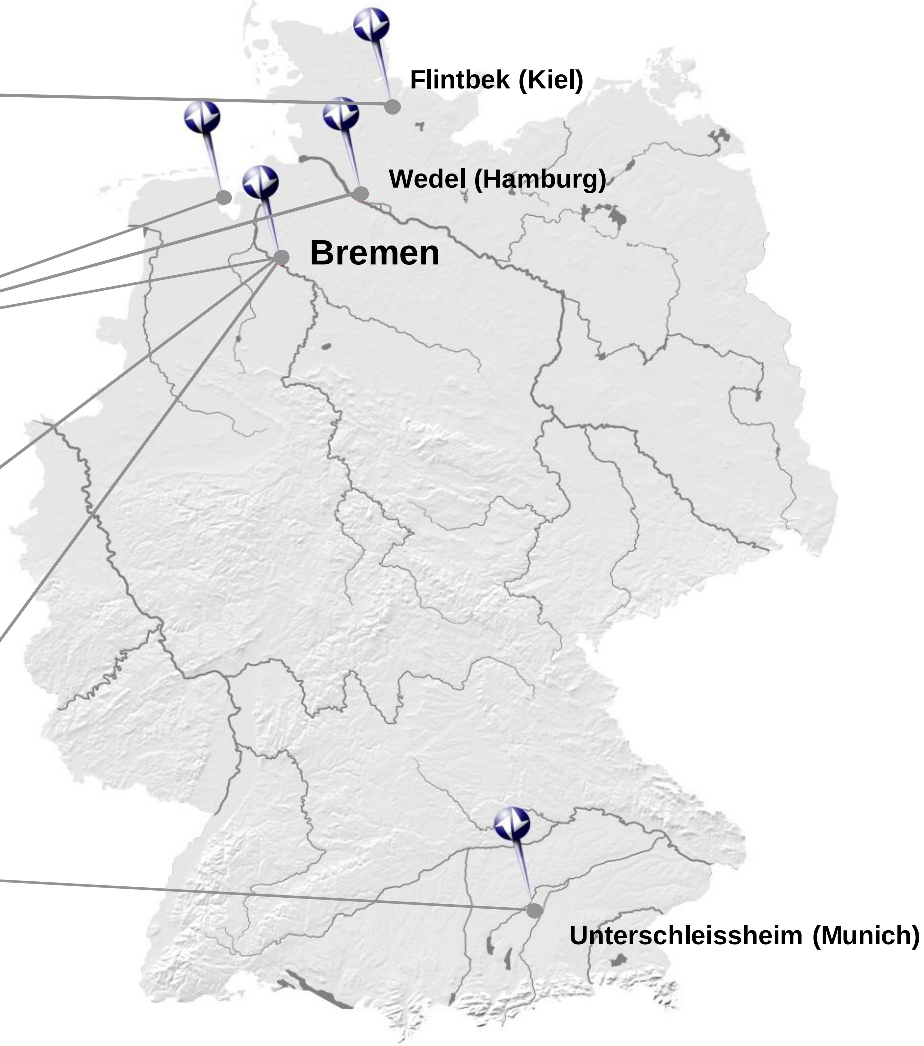
Bremen (Headquarter), Wedel, Wilhelmshaven

ATLAS HYDROGRAPHIC
A company of the ATLAS ELEKTRONIK Group

Bremen

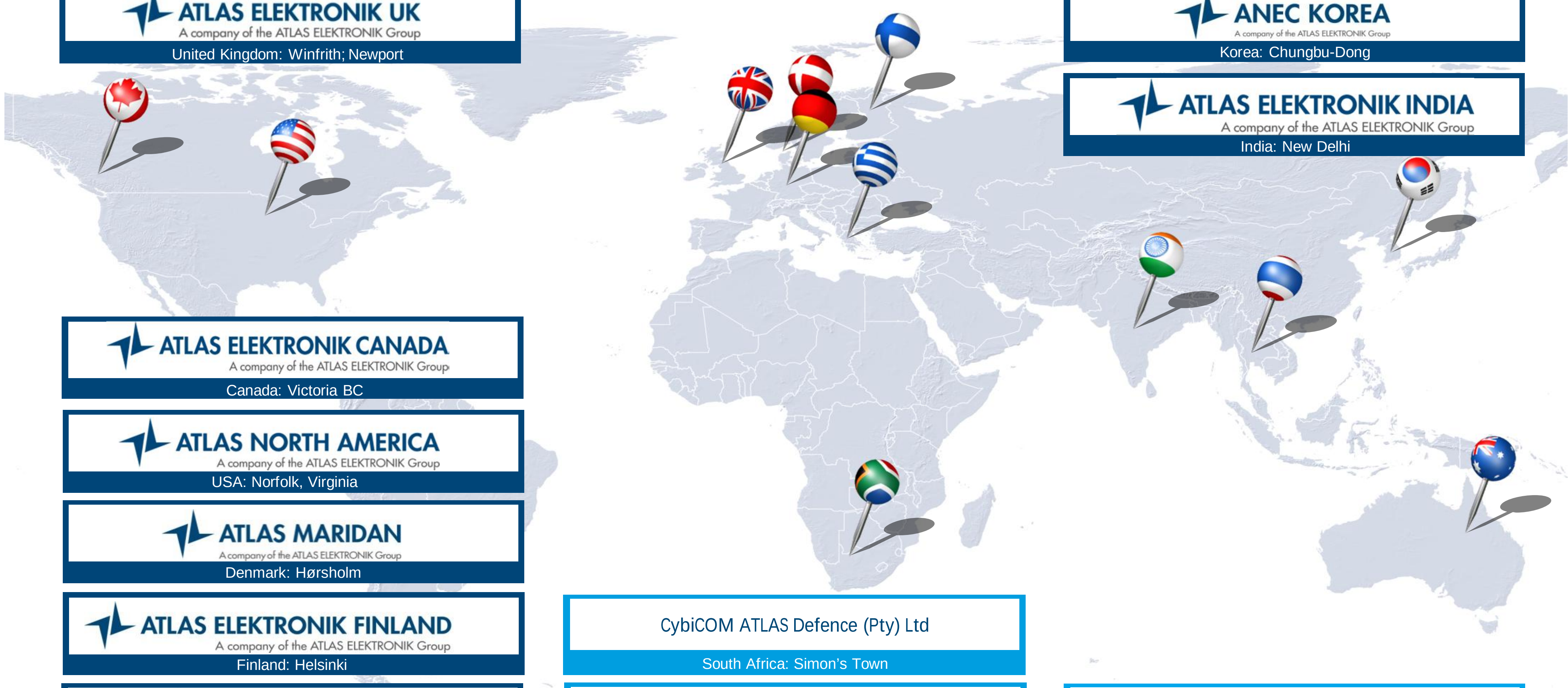
SIGNALIS
A CASSIDIAN and ATLAS ELEKTRONIK company

Bremen; Unterschleissheim



Subsidiary | Holding

Locations world-wide



ATLAS ELEKTRONIK UK
A company of the ATLAS ELEKTRONIK Group
United Kingdom: Winfrith; Newport

ATLAS ELEKTRONIK CANADA
A company of the ATLAS ELEKTRONIK Group
Canada: Victoria BC

ATLAS NORTH AMERICA
A company of the ATLAS ELEKTRONIK Group
USA: Norfolk, Virginia

ATLAS MARIDAN
A company of the ATLAS ELEKTRONIK Group
Denmark: Hørsholm

ATLAS ELEKTRONIK FINLAND
A company of the ATLAS ELEKTRONIK Group
Finland: Helsinki

SONARTECH ATLAS
A company of the ATLAS ELEKTRONIK Group
Australia: Macquarie Park

ANEC KOREA
A company of the ATLAS ELEKTRONIK Group
Korea: Chungbu-Dong

ATLAS ELEKTRONIK INDIA
A company of the ATLAS ELEKTRONIK Group
India: New Delhi

CybiCOM ATLAS Defence (Pty) Ltd
South Africa: Simon's Town

ATLAS Naval Support Centre Ltd
Thailand: Bangkok

Advanced Lithium Systems Europe
Defence Applications S.A.
Greece: Athen

Subsidiary

Holding

Agenda

Innovation

Definition, Assumptions, Scenarios, R&D

Maritime Security

Key Interests, Challenges

Innovations at ATLAS Elektronik

Diver Detection, AUVs, User Interfaces

Conclusion

Future Scenario

Innovation
„to renew or change“

Integration of new ideas into
products, services and processes.

Penetration of markets.

Change of society and business areas.

Why innovations at ATLAS Elektronik?

(Schumpeter, 1936)

Innovation

Why Innovation? Assumptions

Data

- More complex data structures
- More automation aids
- More monitoring tasks

Operator

- Mixed groups
- Smaller number of crew members
- Less constant training

Competitors / Market

- Provide new concepts

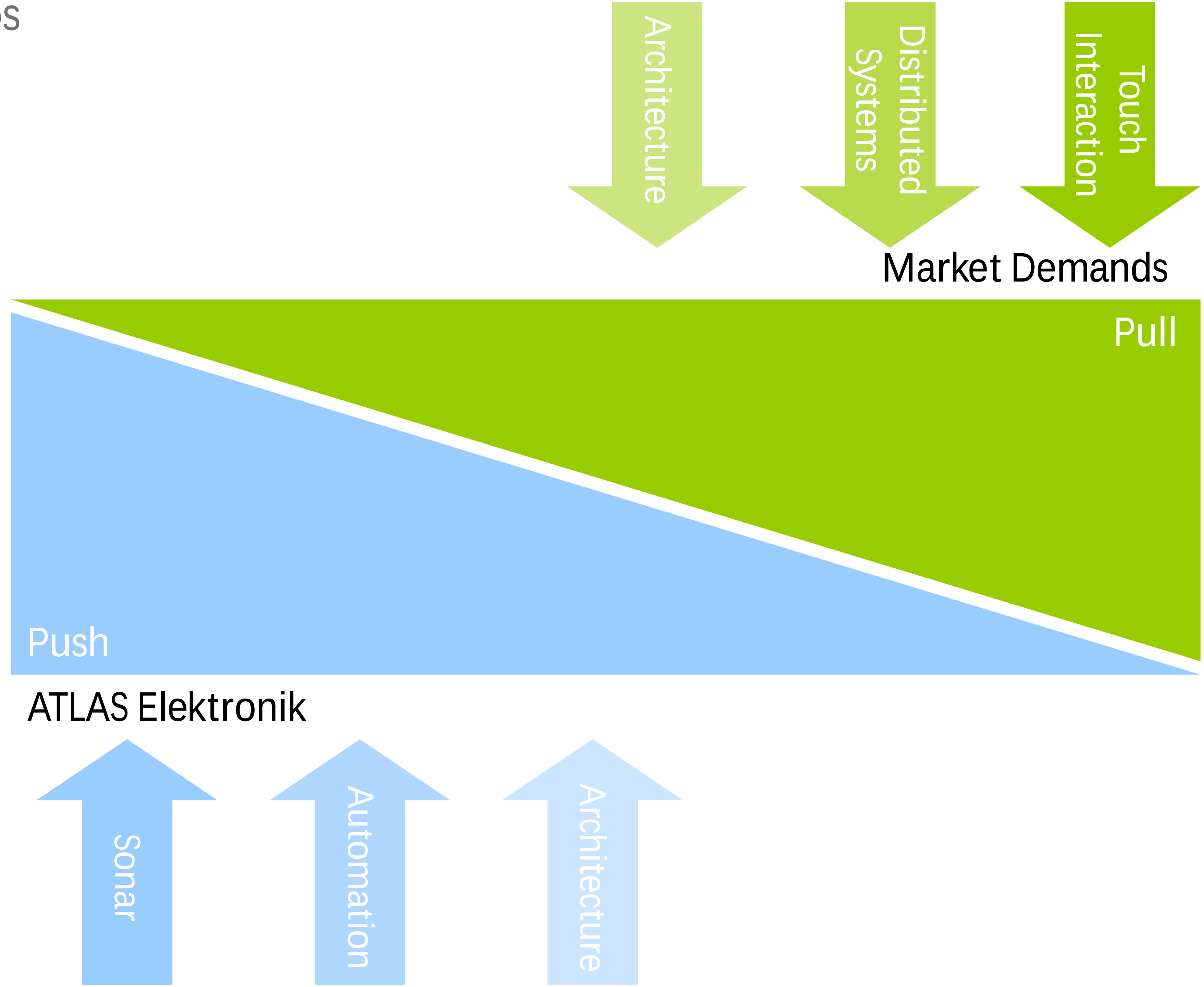
Innovation

→ Allow handling of huge and complex data

→ Support future organizational and task needs

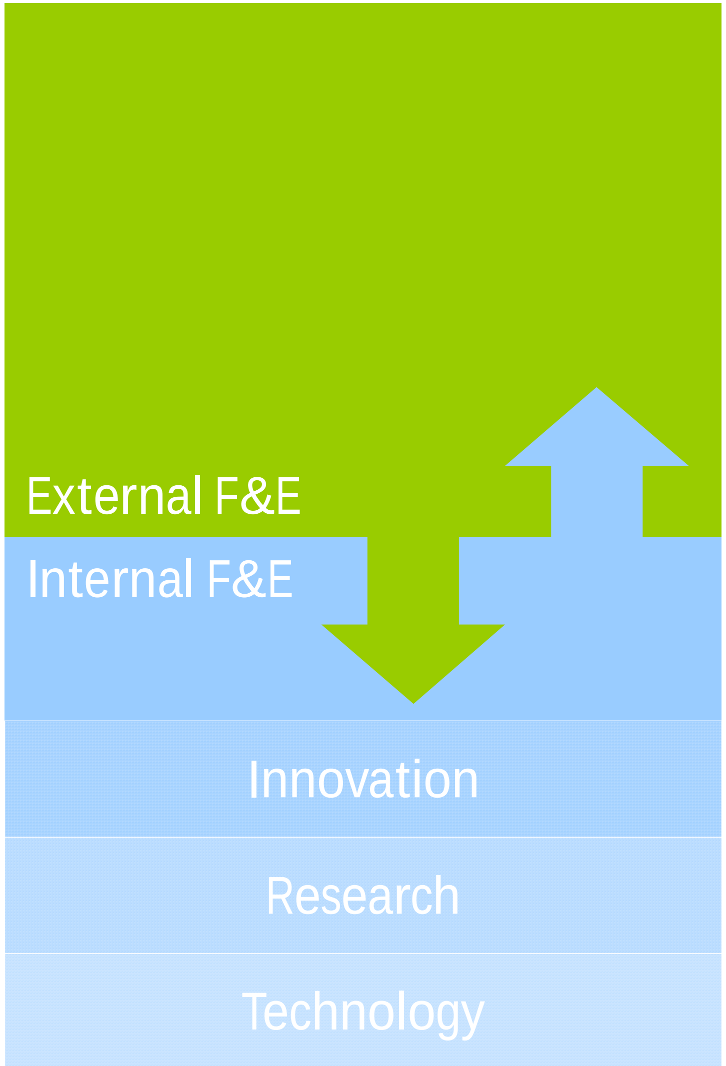
→ Be on the edge of future technologies

Innovation
Scenarios



Innovation

Research and Development at ATLAS Elektronik



PhD Theses
Master Theses
Bachelor Theses

EU Projects
National Projects

Demonstrations
Experimental Systems
Prototypes

Fraunhofer

Deutsches Forschungszentrum für Künstliche Intelligenz GmbH

EADS

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

National and International Universities

Industrialization (TRL 7-9)

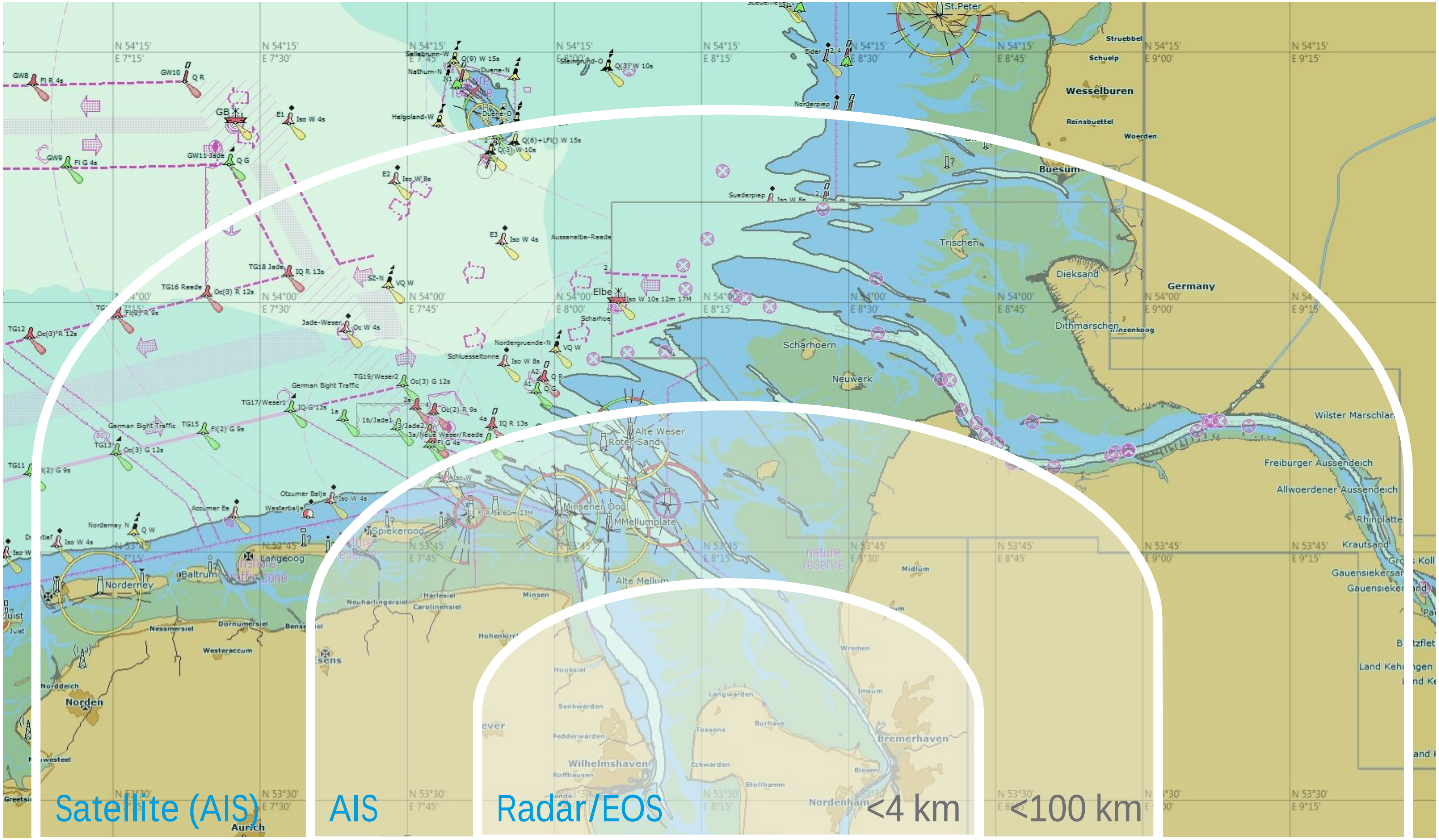
Maritime Security
Key Interests

- Protection of critical maritime infrastructure such as ports and terminals, off-shore installations and underwater pipelines and cables
- Control of maritime areas to prevent illegal activities (e.g. piracy, pollution)
- Protection of the global supply chain, the freedom of navigation and the safety and security of seafarers and passengers
- Prevention of illegal, unregulated and unreported fishing

(EU, 2014)

Maritime Security

Challenges: Protection of Maritime Infrastructures, Coastal Areas and Open Sea



Maritime Security
Innovative Technologies

Unmanned Vehicles

Diver Detection Sonar

Long Range Acoustic System

ATLAS Data Link System

User Interfaces

Cerberus – Diver Detection Sonar
Surveillance of nearby Areas

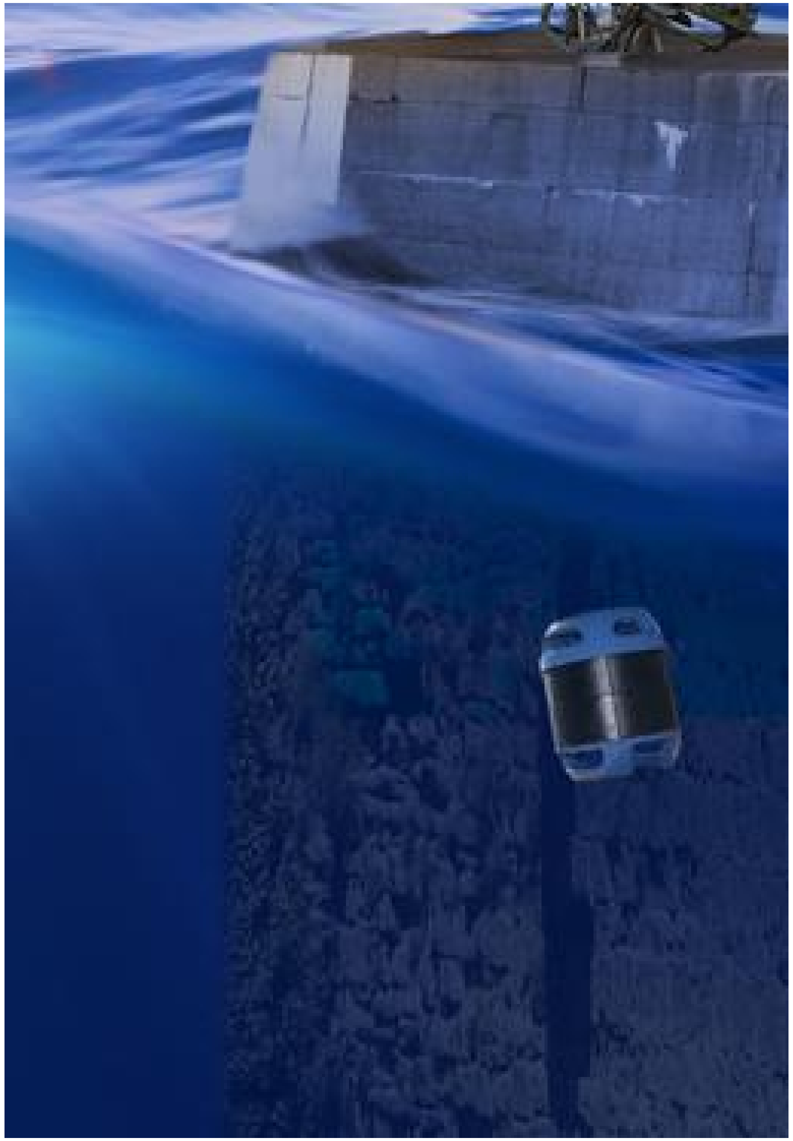
Detection and tracking of

- „Open Circuit“-Diver: 900 m / 850 m

- „Closed Circuit“-Diver: 750 m / 675 m

- Swimmer: 600 m

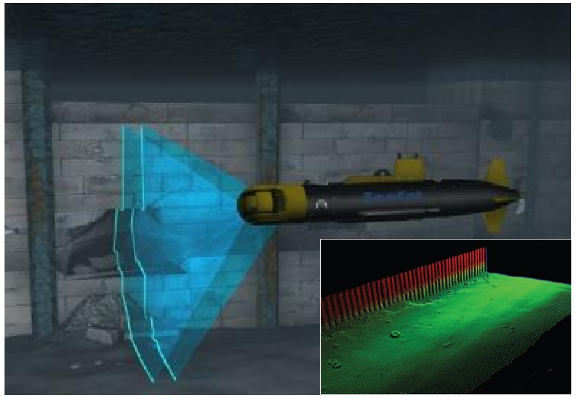
- Swimmer Delivery Vehicle: 900 m / 850 m

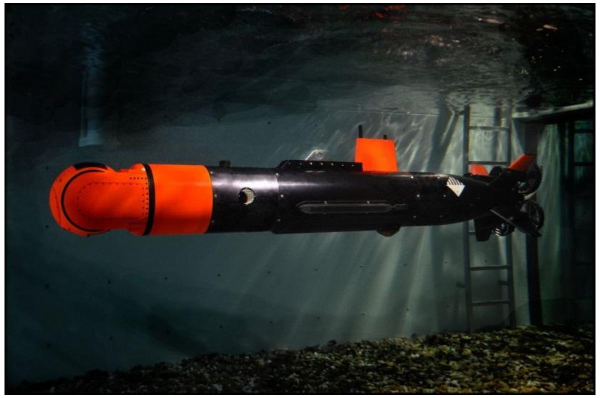


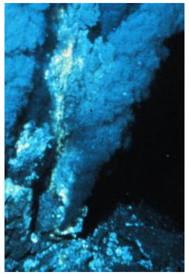
AUV / ROV

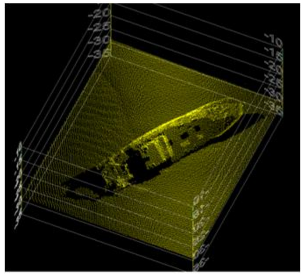
Autonomous Unmanned Vehicles

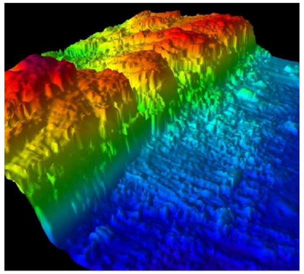
Remotely Operated Vehicles









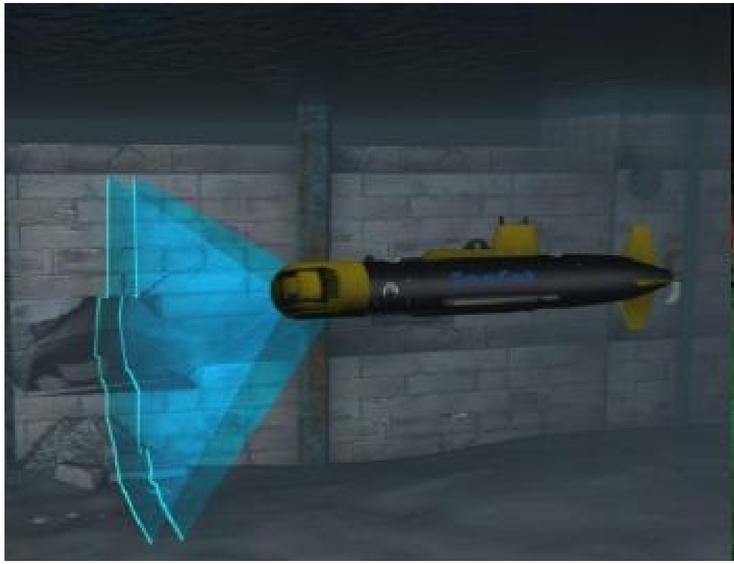
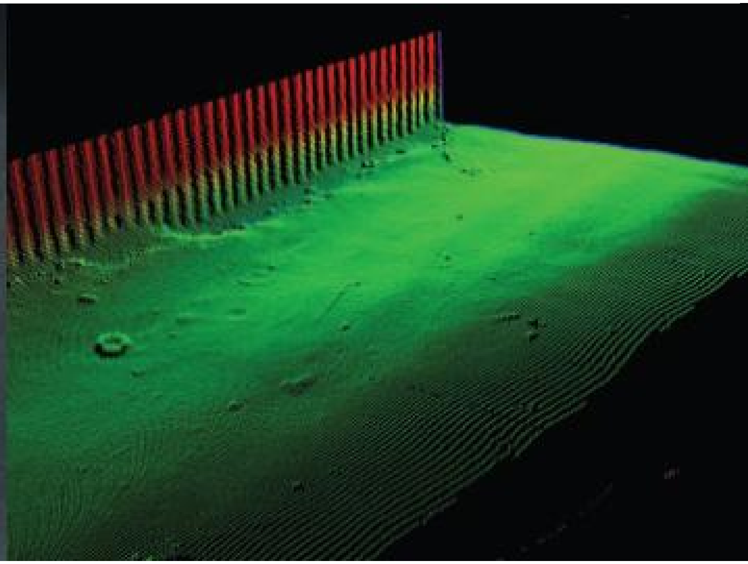
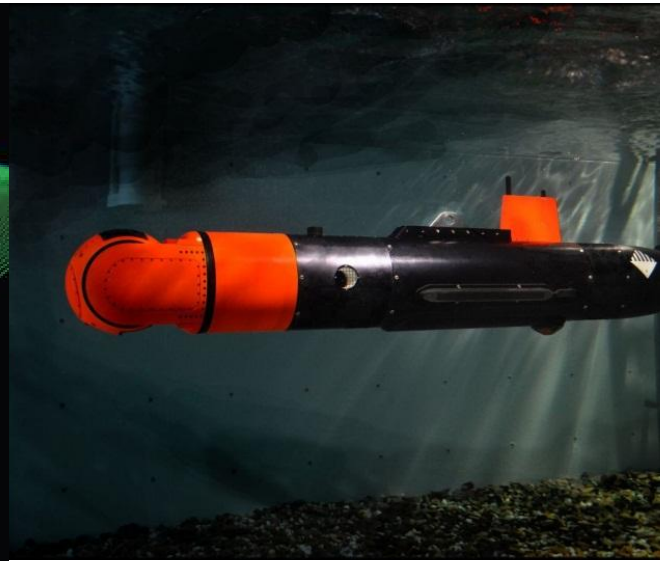


AUVs
Applications for Maritime Security I

MORPH
KAPITAS

Inspection of ground structures (e.g. harbor walls, riffs, pipelines)

Mission Goal
- Locate target area
- Provide detailed information
- Give results back during mission
- Generate underwater awareness

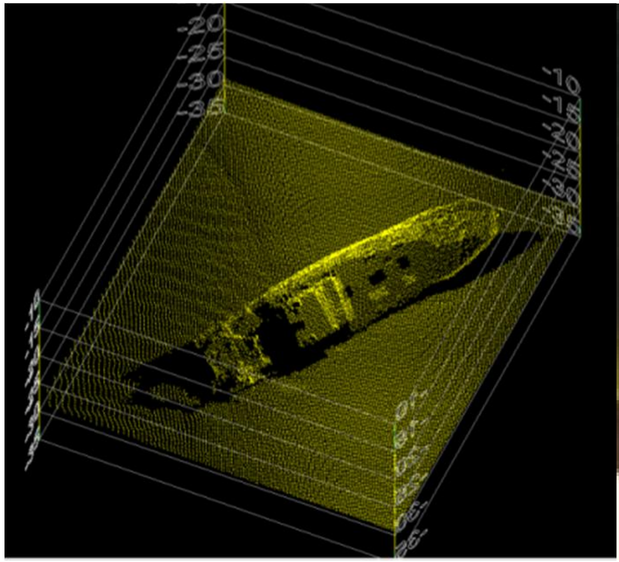




AUVs
Applications for Maritime Security II

Search and Rescue, Inspection & Identification

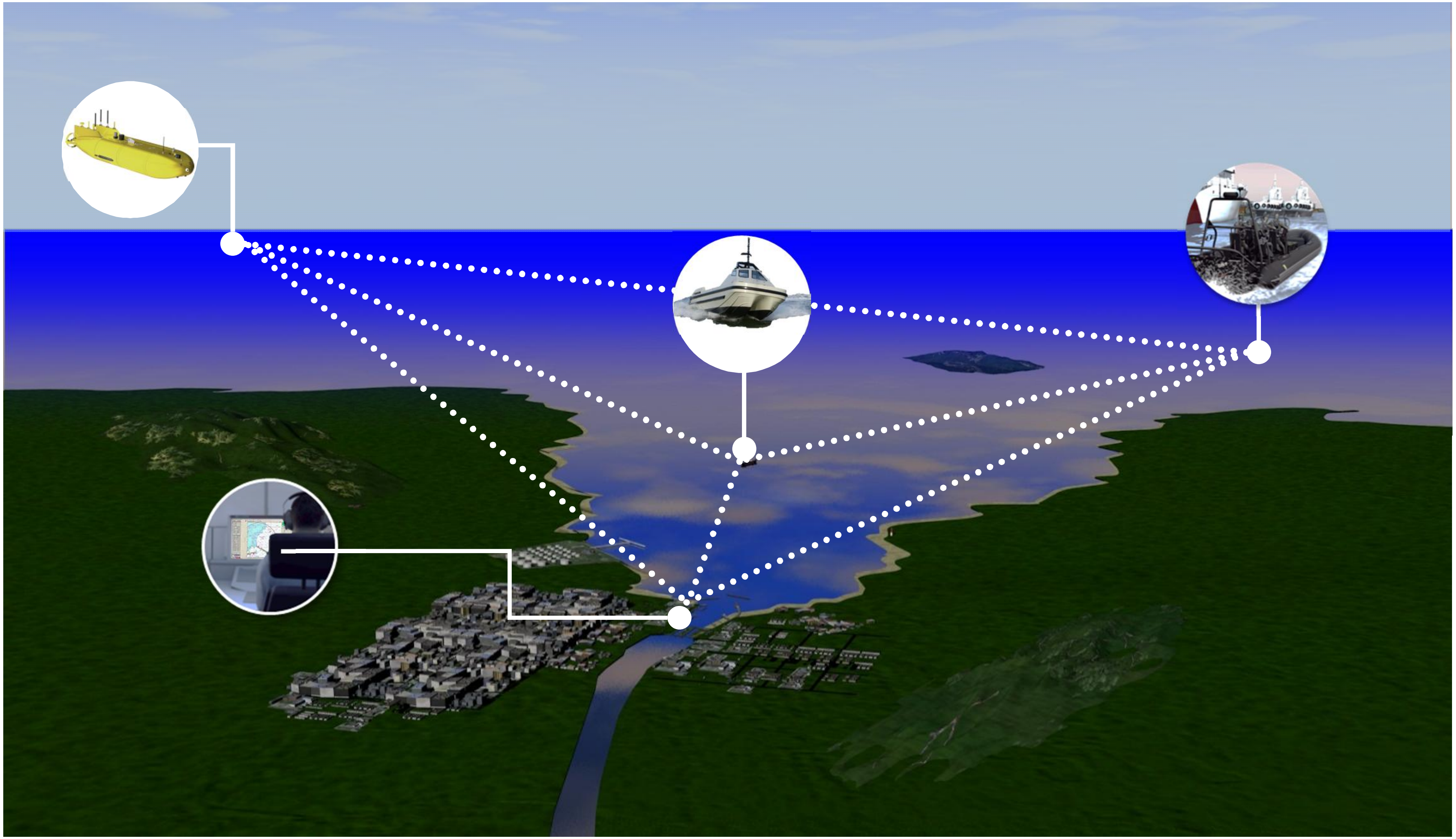
Mission Goal

- Search for targets in inspection area
- Provide detailed information
- Detect and classify targets
- Give results back during mission

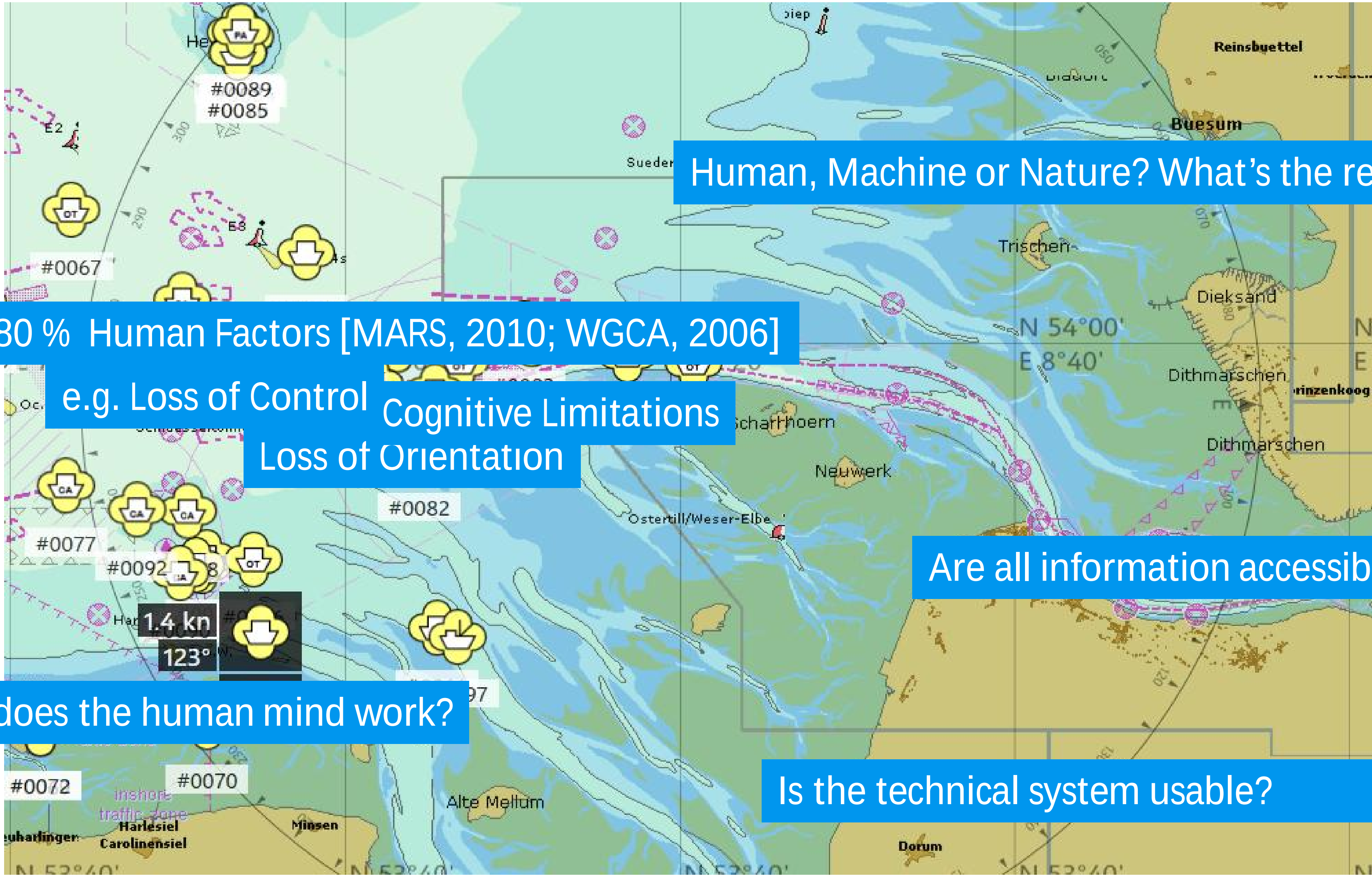


Communication and Data Exchange

Shared Operative Information and Pictures



User Interfaces



Human, Machine or Nature? What's the reason?

50 – 80 % Human Factors [MARS, 2010; WGCA, 2006]

e.g. Loss of Control

Cognitive Limitations

Loss of Orientation

Are all information accessible?

How does the human mind work?

Is the technical system usable?

User Interfaces

Control Room - Concept Study

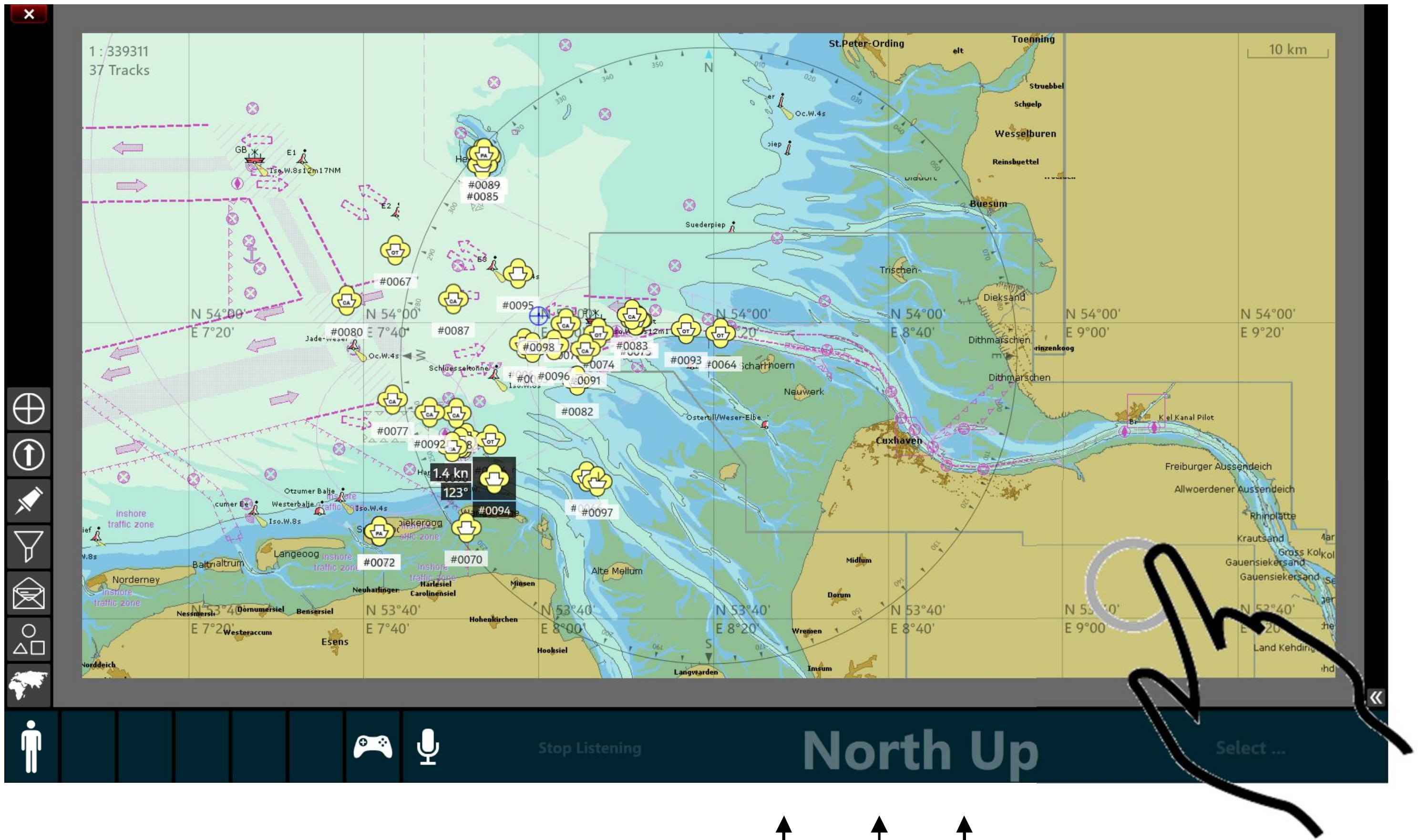
User Interfaces

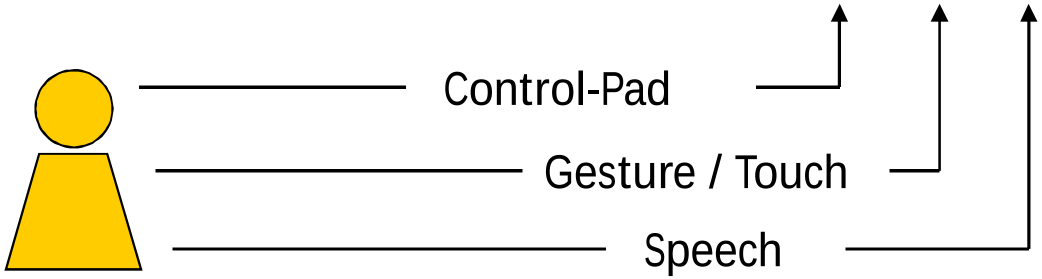
Multimodal Interaction I

Zoom in / out
Left / right
Up / down

or

Select A1176
Select + Pointing





User Interfaces

Cognitive Systems

EMSec
ECHTZEITDIENSTE FÜR DIE MARITIME SICHERHEIT security

Real-Time Services for Maritime Security

- Cognitive user interfaces
- Surface und subsurface view
- Data fusion
  - Sonar
  - Satellite
  - Radar
  - Environment
    (e.g. timetables, weather)

→ Customized services for
  - → Distributed systems
  - → Several users

AIRBUS DEFENCE & SPACE · ATLAS ELEKTRONIK A joint company of ThyssenKrupp and Airbus DS · Technisches Hilfswerk · Universität Rostock Traditio et Innovatio · DLR Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft · VDI · Bundesministerium für Bildung und Forschung

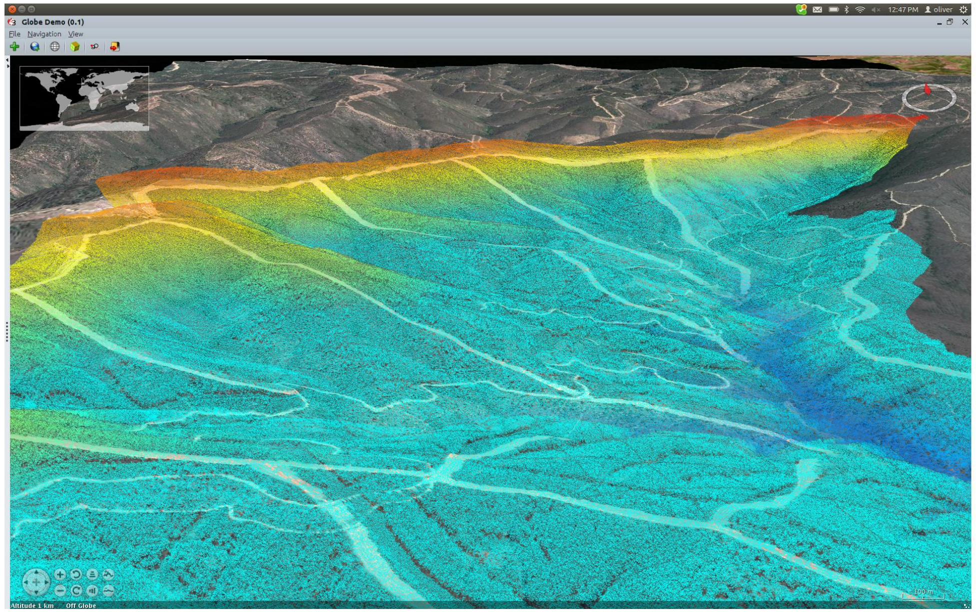
User Interfaces

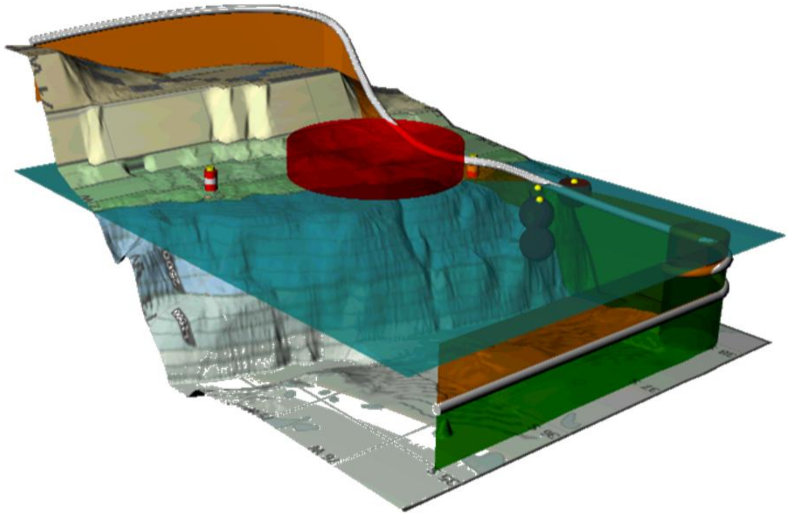
3D Charts

- Easy correlation with real views
- Change of viewing angels

→ situational awareness
→ assessment of tactical situations
→ General and detailed view

- Integration of subsurface views into the 3D view
- Integration of video data into the 3D view
- Visualization of additional data and information (e.g. sonar data, satellite images)

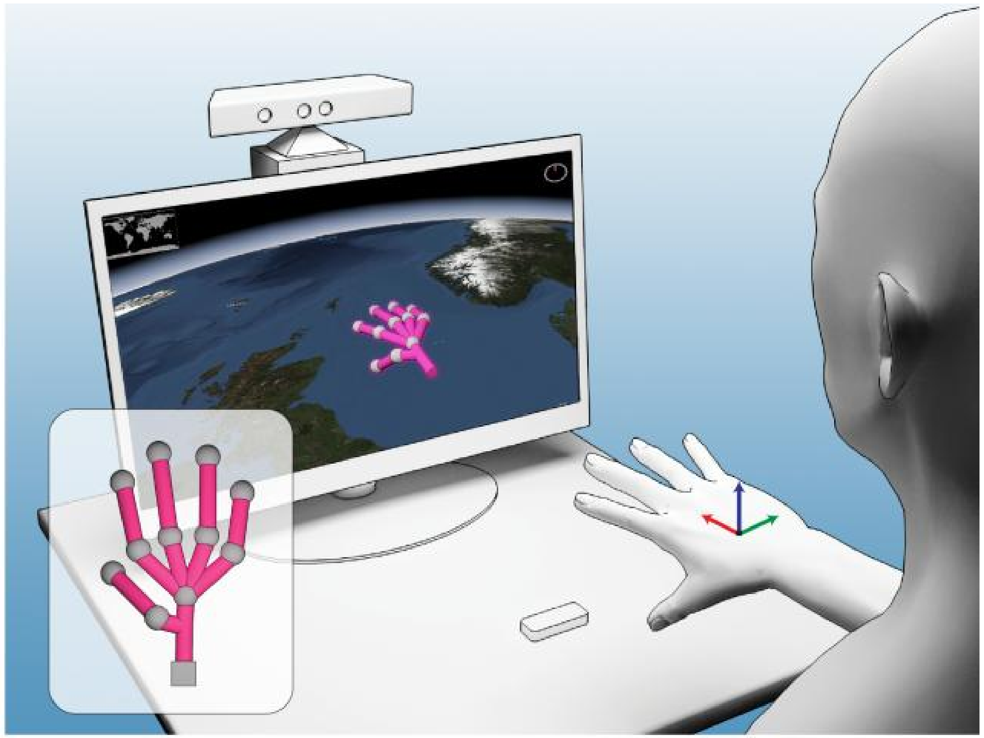


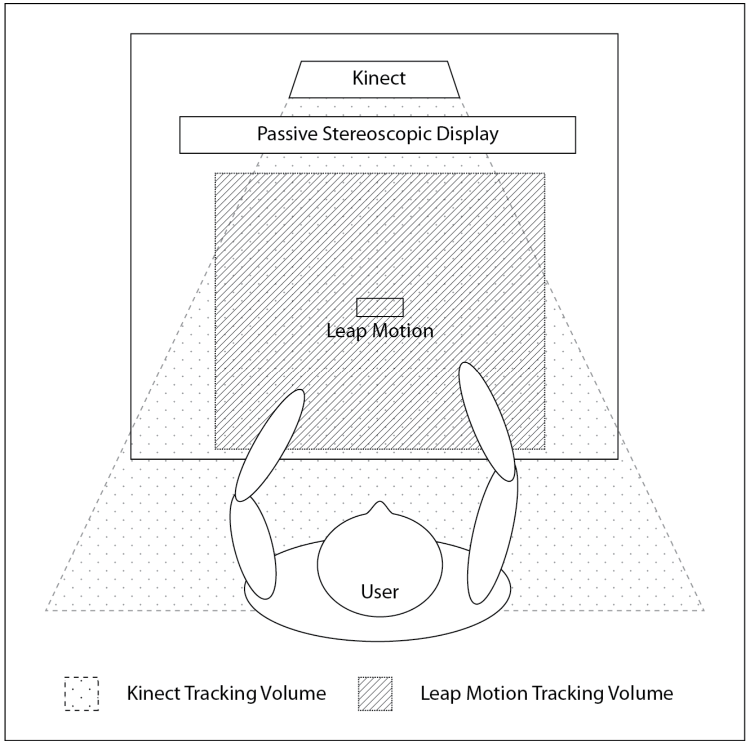


User Interfaces

Stereoscopic Displays and Interaction in 3D Spaces

- Development of an interaction model for 3D interaction spaces
- Application
  - Analysis of offshore data
  - Planning of AUV missions
  - Selection of points of interest



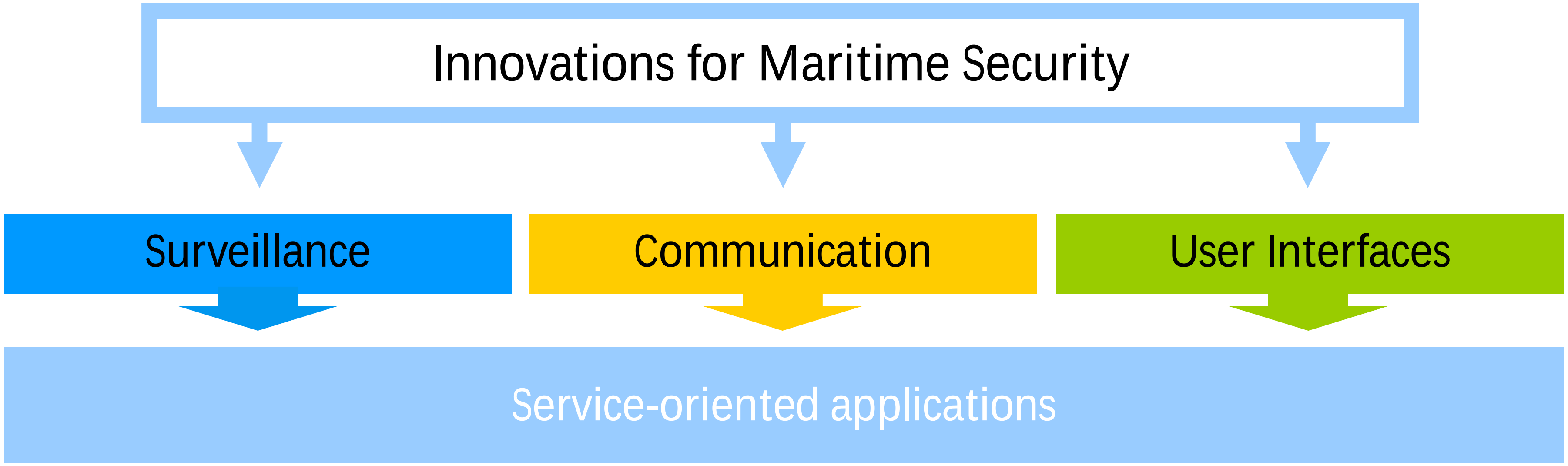


Innovations for Maritime Security

Trends we see…

- Integrated Services
- Containerized Solutions
- Task Automation
- Maritime Robotics
- Context-based Systems
- Sensor Networks
- Modular and generic Architecture

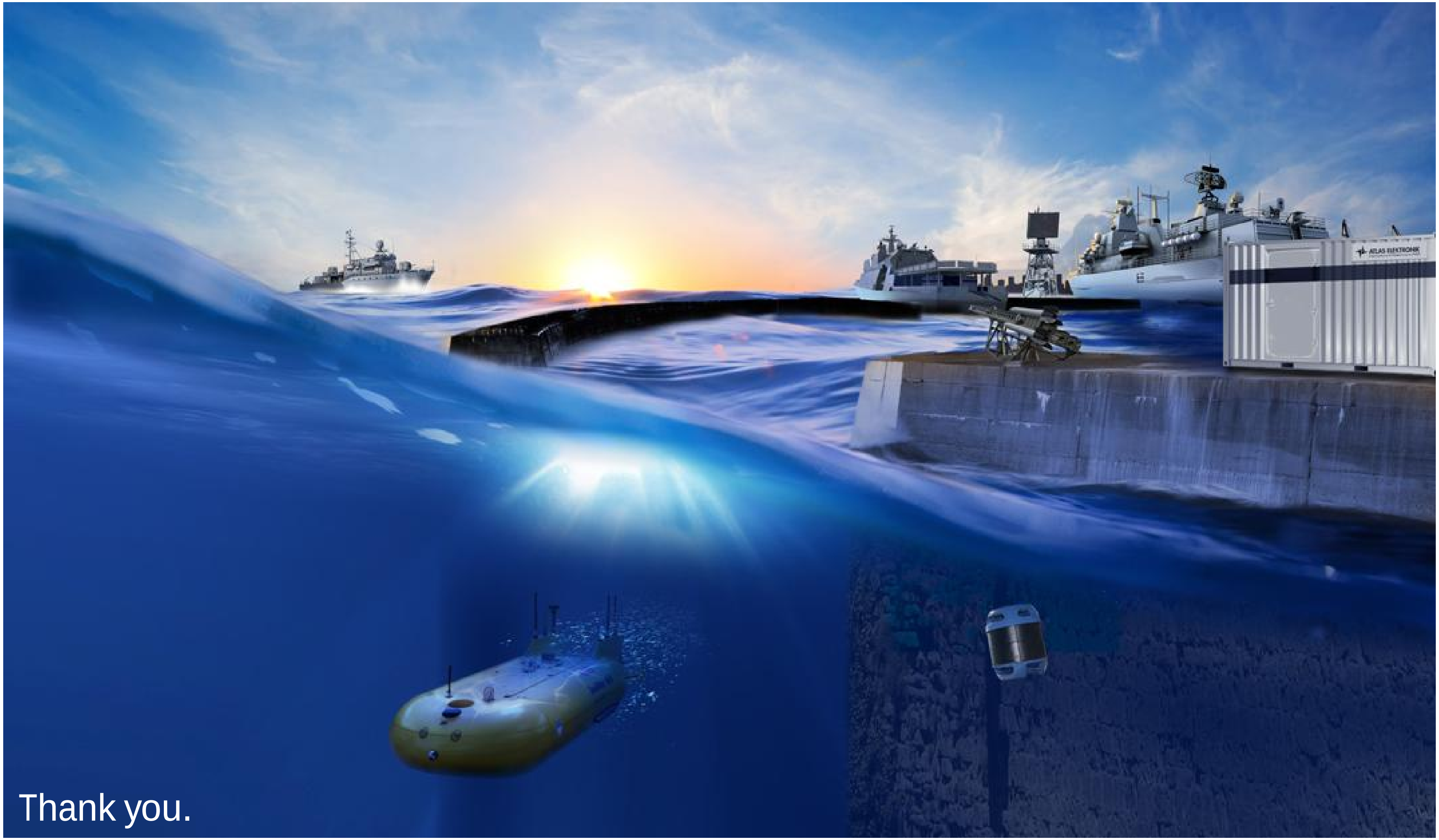
Conclusion



Integrated Human-Centered Systems
Maritime Situational Awareness
Shared Knowledge and Shared Operational Pictures

Safe Maritime Areas

Conclusion
Future Scenario



Contact

ATLAS ELEKTRONIK GmbH
Sebaldsbruecker Heerstrasse 235
28309 Bremen | Germany
Phone: +49 421 457-02
Telefax: +49 421 457-3699

www.atlas-elektronik.com

ATLAS ELEKTRONIK
A joint company of ThyssenKrupp and Airbus DS