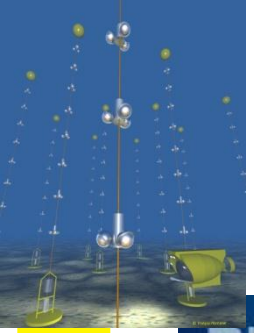
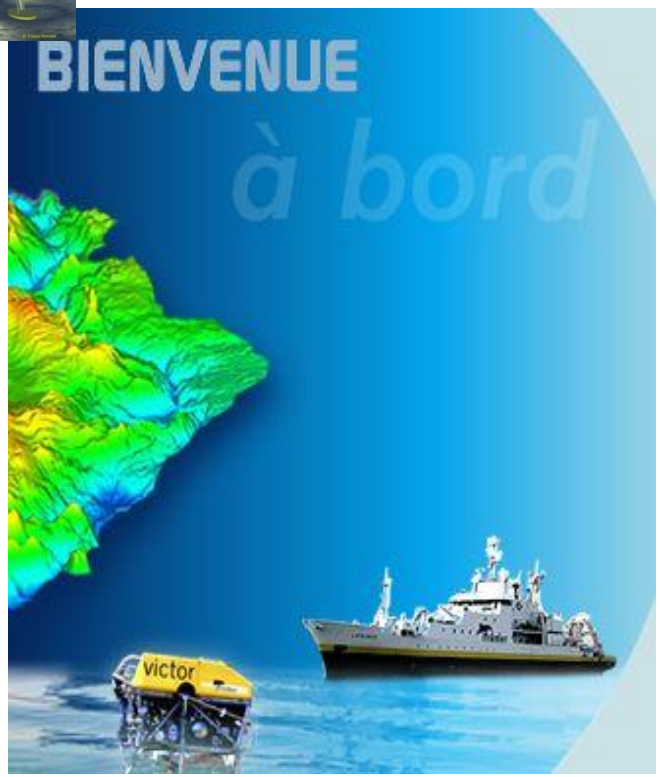


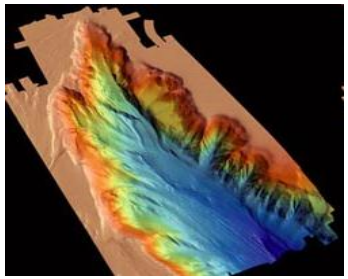
Welcome on board

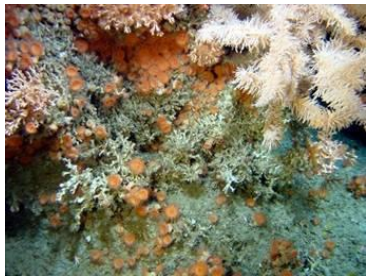
Bienvenidos a bordo

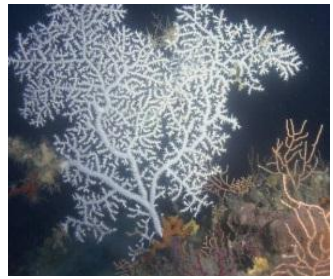
Herzlich Willkommen



L'imagerie des fonds de mer – les robots sous-marins profonds



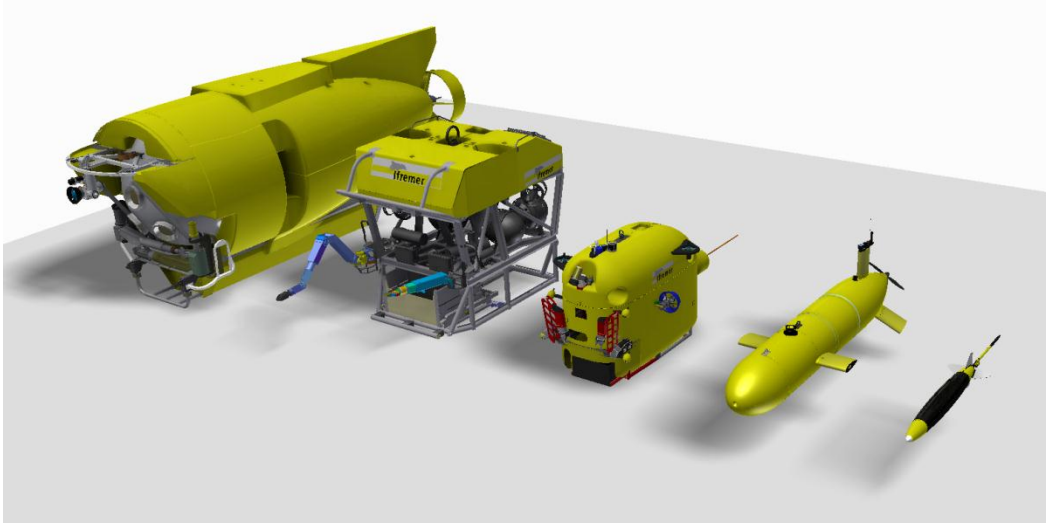




http://www.ifremer.fr/flotte/index.htm
Dr Jan Opderbecke
Dr Aurélien Arnaubec
Unit for Underwater Systems

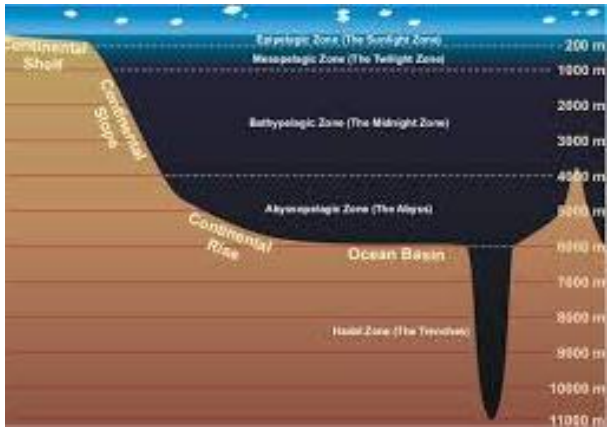
Underwater systems and sea-floor imaging

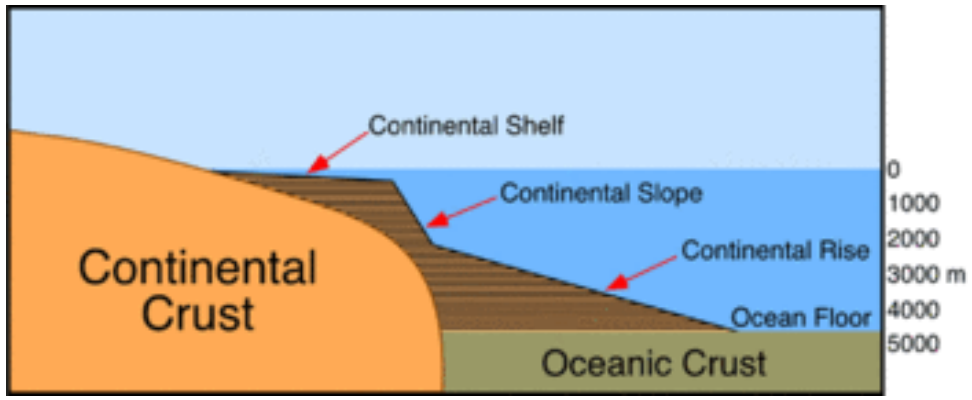
- Ifremer's fleet of underwater systems
- Seafloor perception, imaging and mapping
- Usage and processing of optical images



The deep-sea environment

- Pressure, conductivity, limited signal propagation, high viscosity
- Hostile environment for humans … and machines

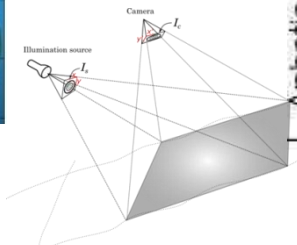


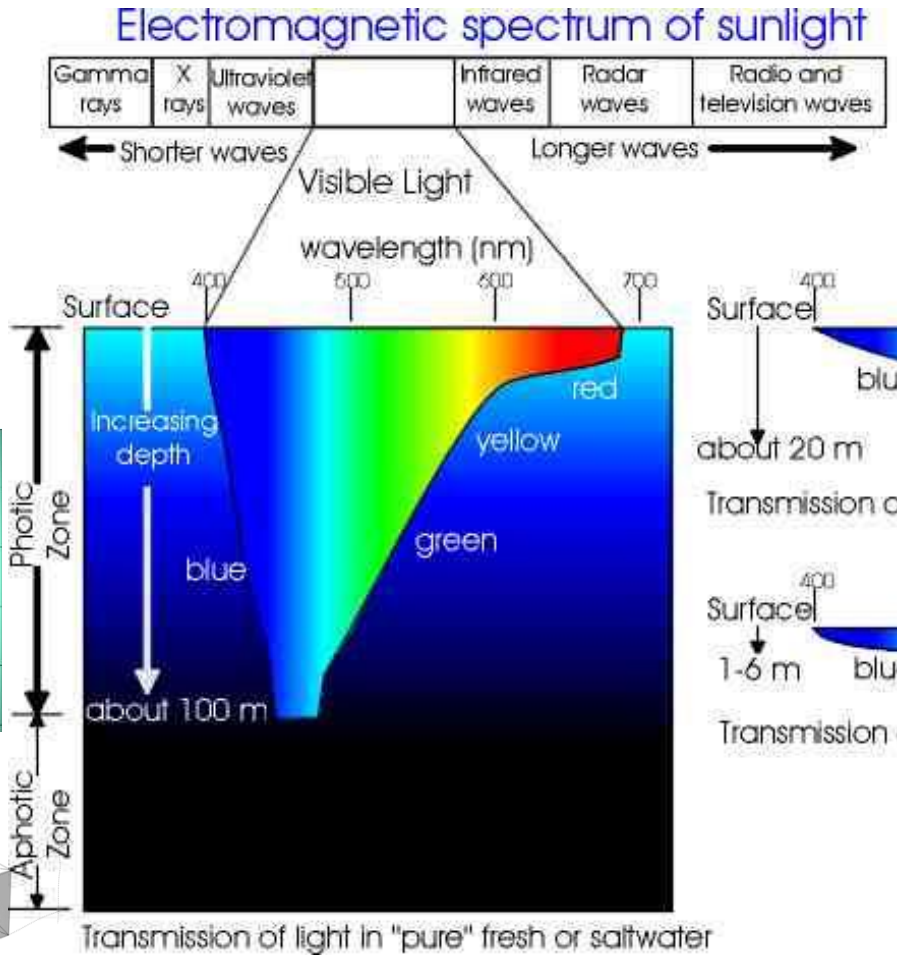


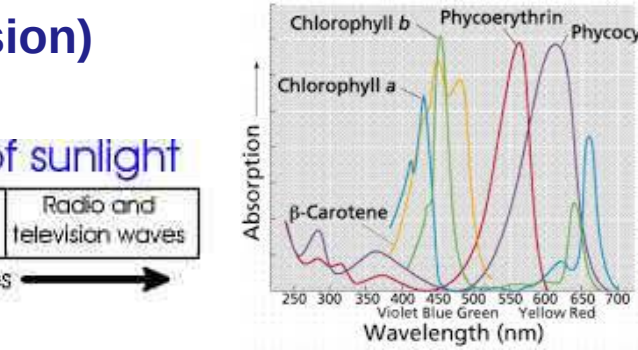
Optic waves

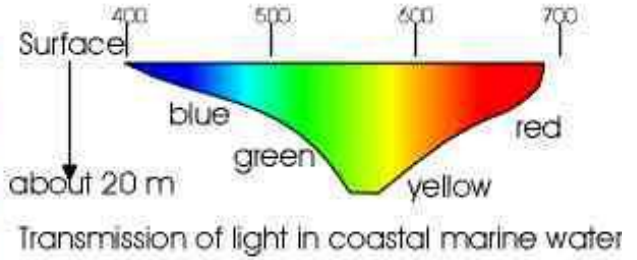
Propagation : **5m (color imaging) , 15m (monochrome imaging) ,**

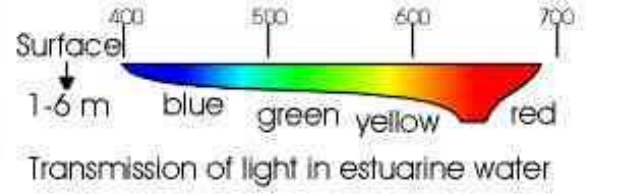
100m (directive signal transmission)





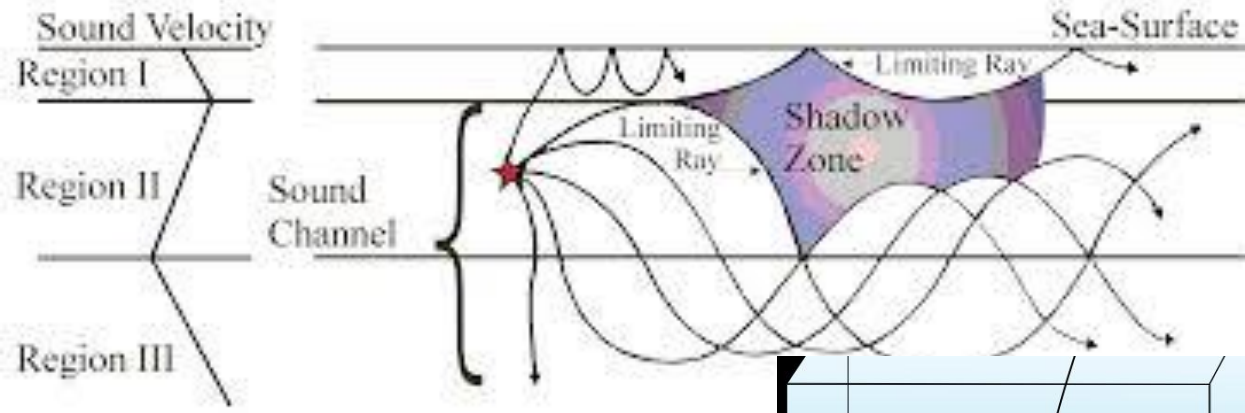


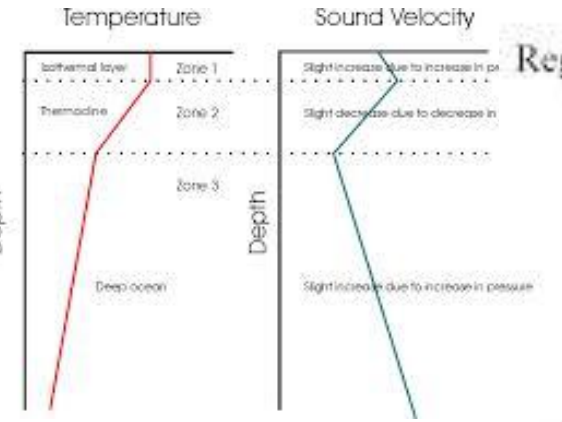


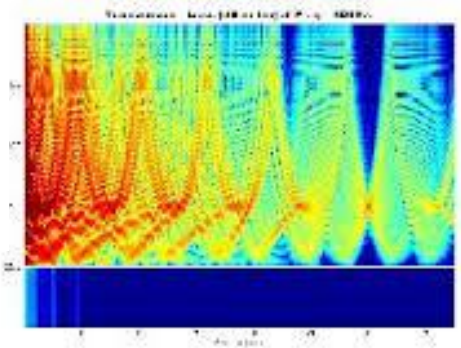


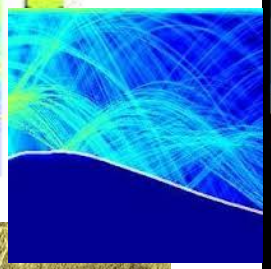
Acoustic waves

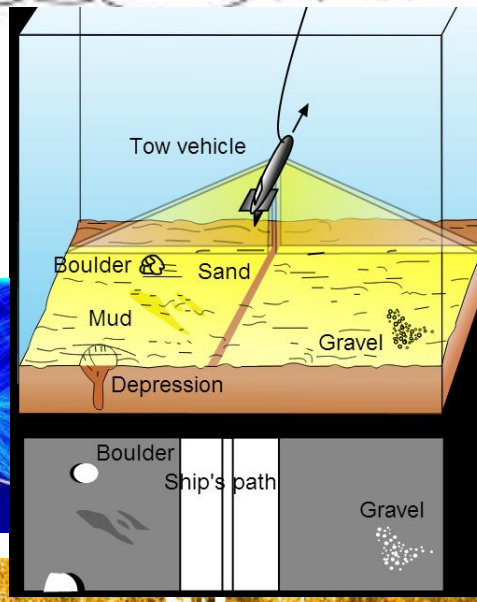
Propagation : 50m @1 MHz, 100m@100 KHz, 10km@10KHz, 100km@100Hz

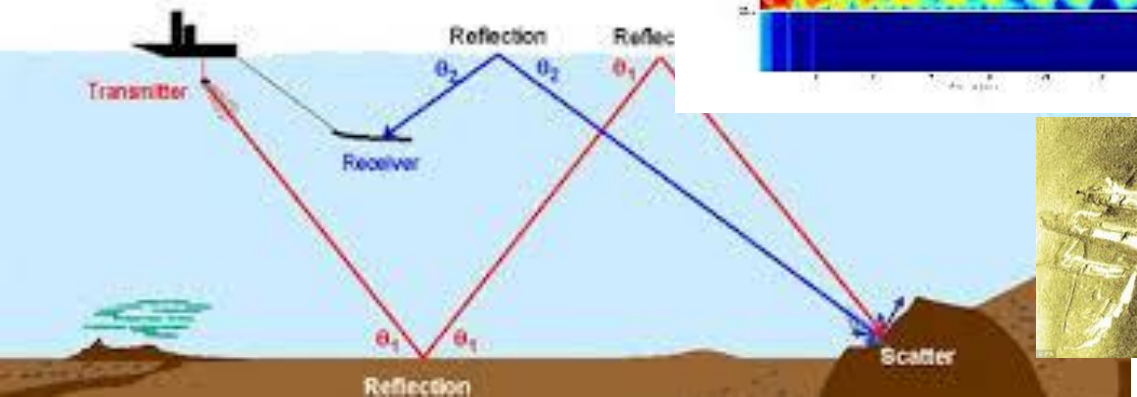


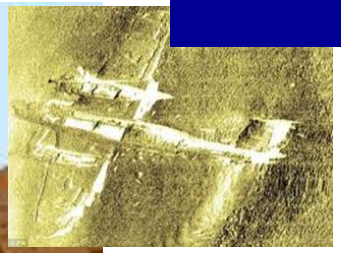


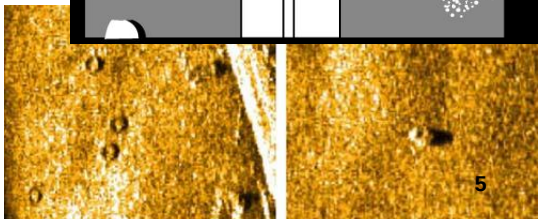








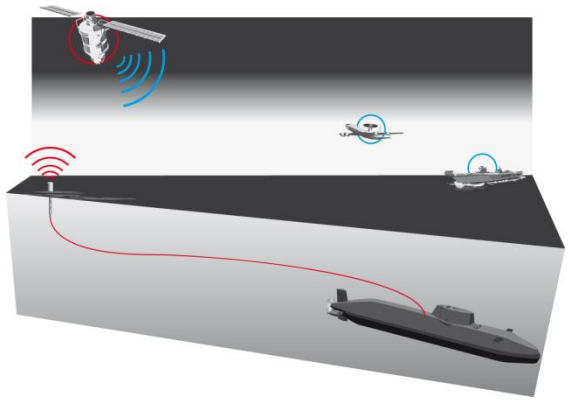




Electromagnetic waves

Propagation (comms): 1m (wifi), 10m (mw), <100m (lw)

No imaging, radar etc.

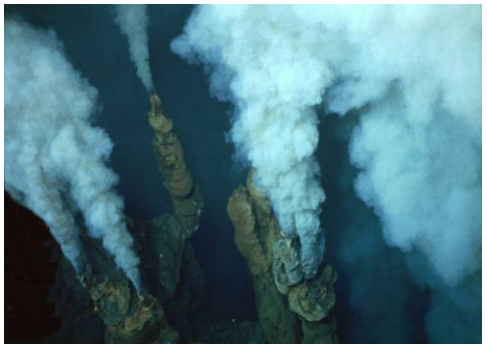


Topic I - active geological processes

- ➔ Margins / Cold seeps : geologie meets biology
- ➔ Hot seeps : hydrothermal vents…
- ➔ Slope instability : tsunami, offshore facilities
- ➔ Seismic structures : earthquake risk …

Landslide
- Turbidity current

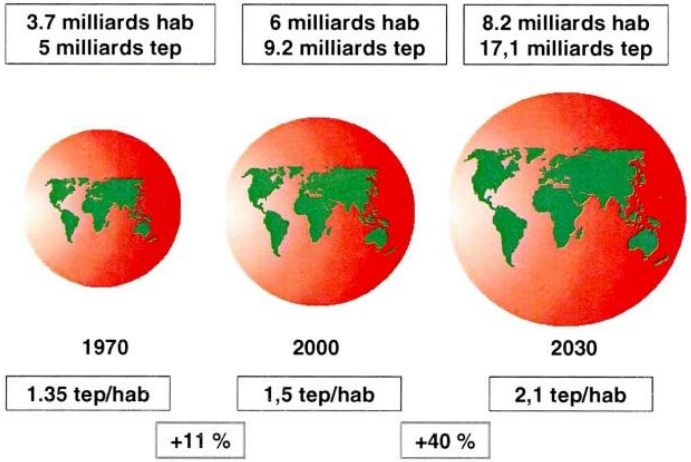
Gas hydrates

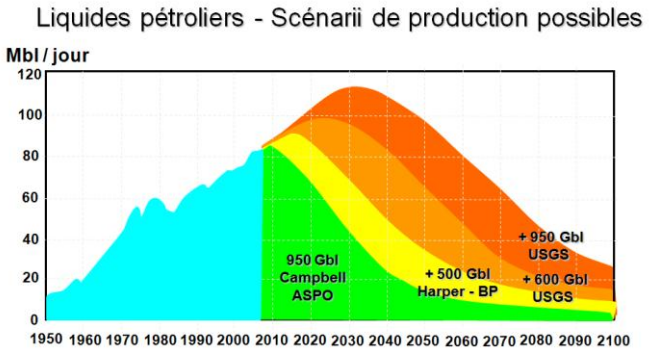


Hydrothermal vents

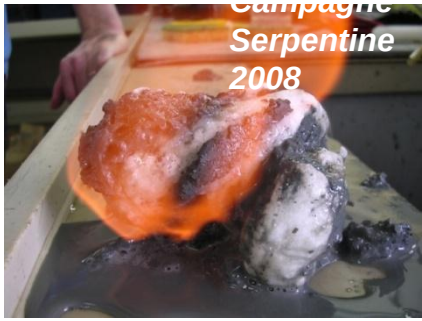
Maramara sea tectonic fault

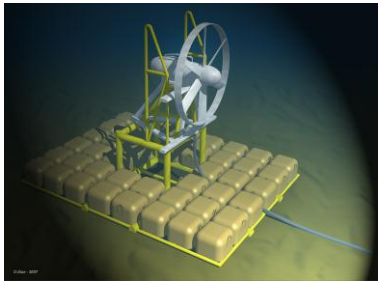
Topic II – marine energy resources





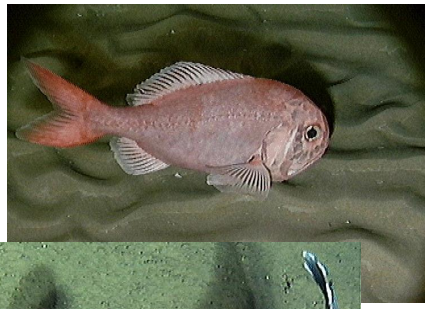
- **CO2 reduction and sequestration**
- **Oil , Gaz, Hydrates**
- **Hydrogen**
- **Biomass, algae, plankton**
- **Renewable resources**
- **Mineral ressources:**
  - Hydrothermal sulfures Cu, Zn, Pb, Co, Ag, Au
  - Polymetalic Nodules Ni, Cu, Co, Mn(Pacific)
  - Cobalt crust Ni, Cu, Co, Mn, P(Pacific)

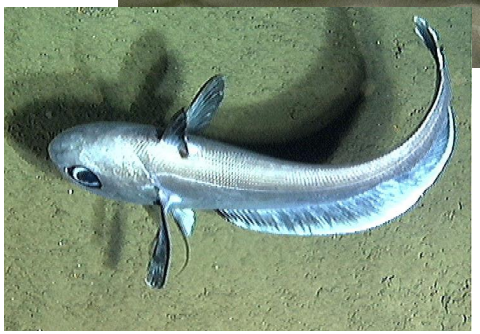


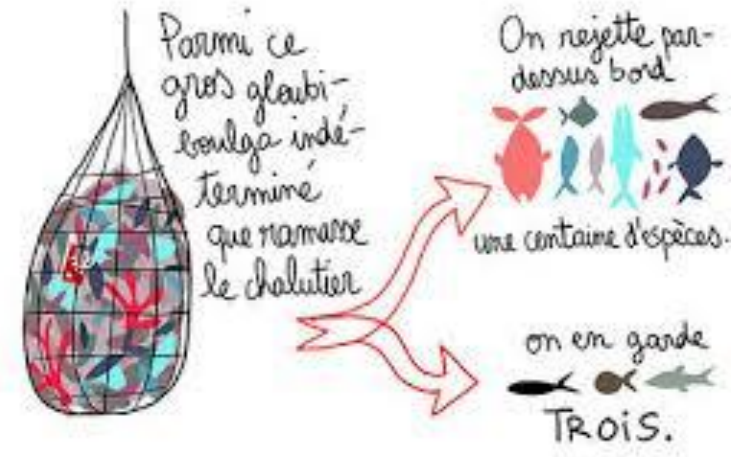


Topic III - living resources stock monitoring for sustainable exploitation

- behaviour
- densities
- habitat
- fisheries impact







Topic IV - benthic biodiversity

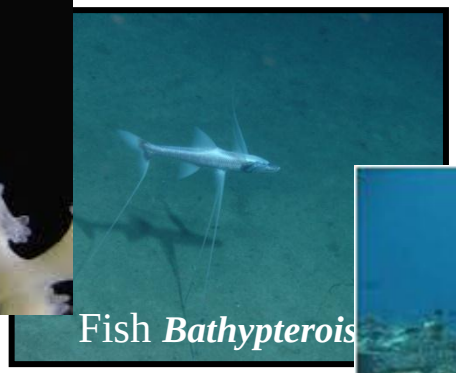

Vestimentiferan worms


Bivalves Vesicomyidae

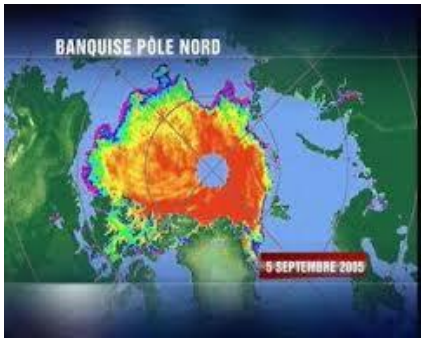

Benthodytes gigantea

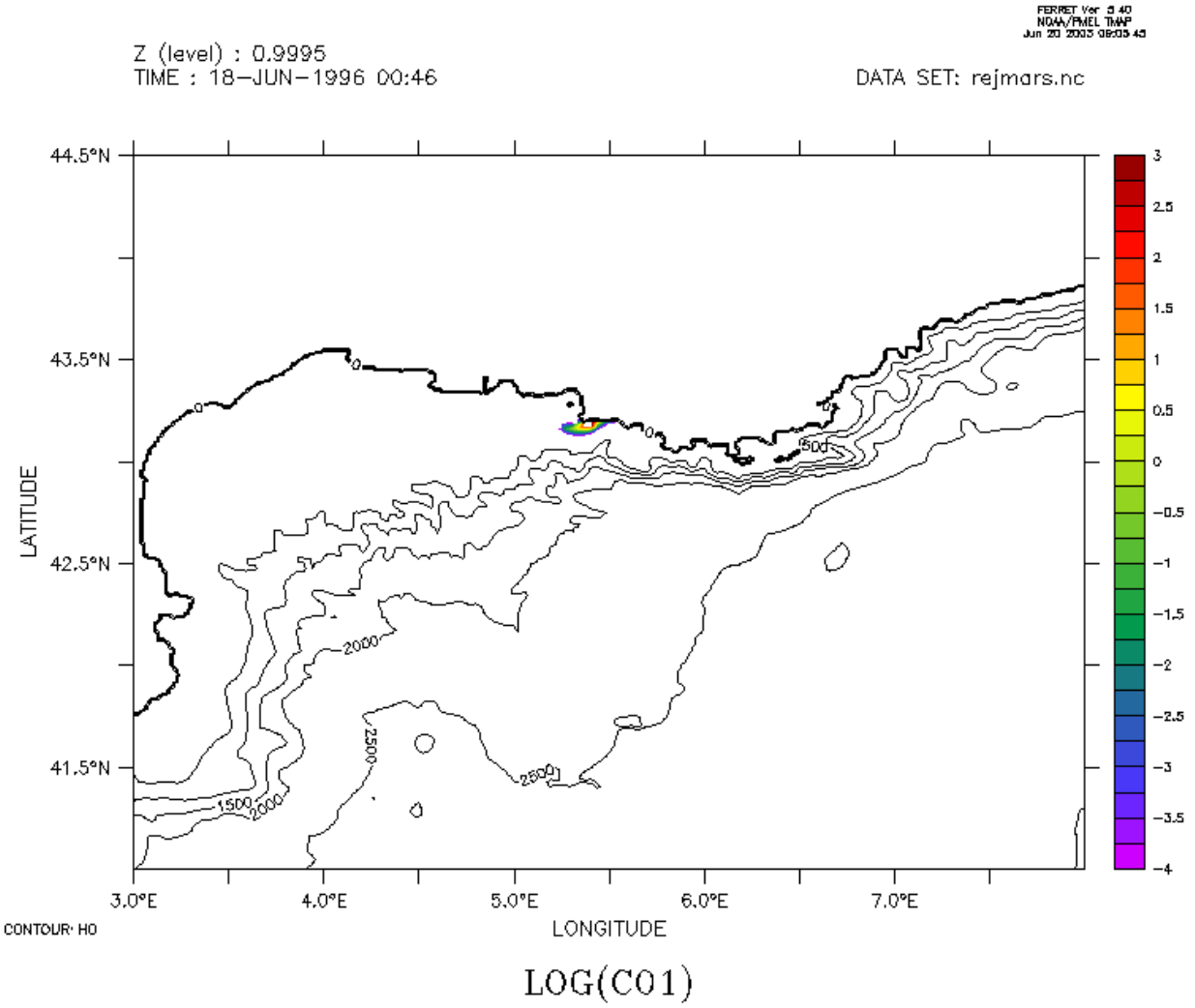

Bivalves ***Bathymodiolus***


Cold water coral

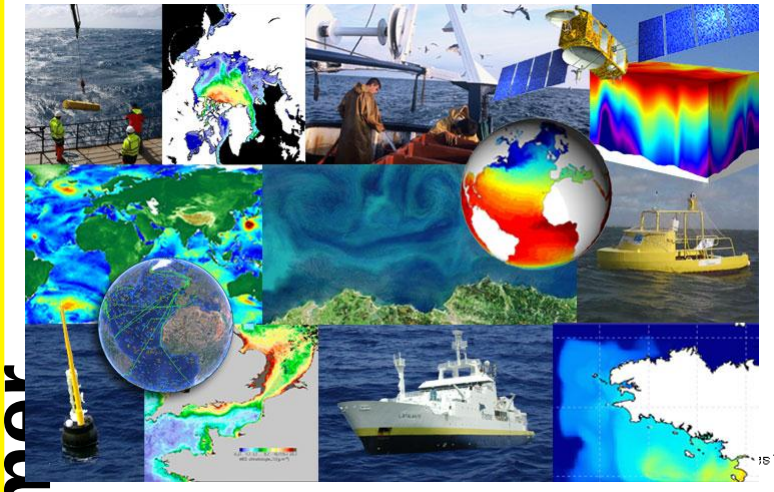

Fish ***Bathypterois***

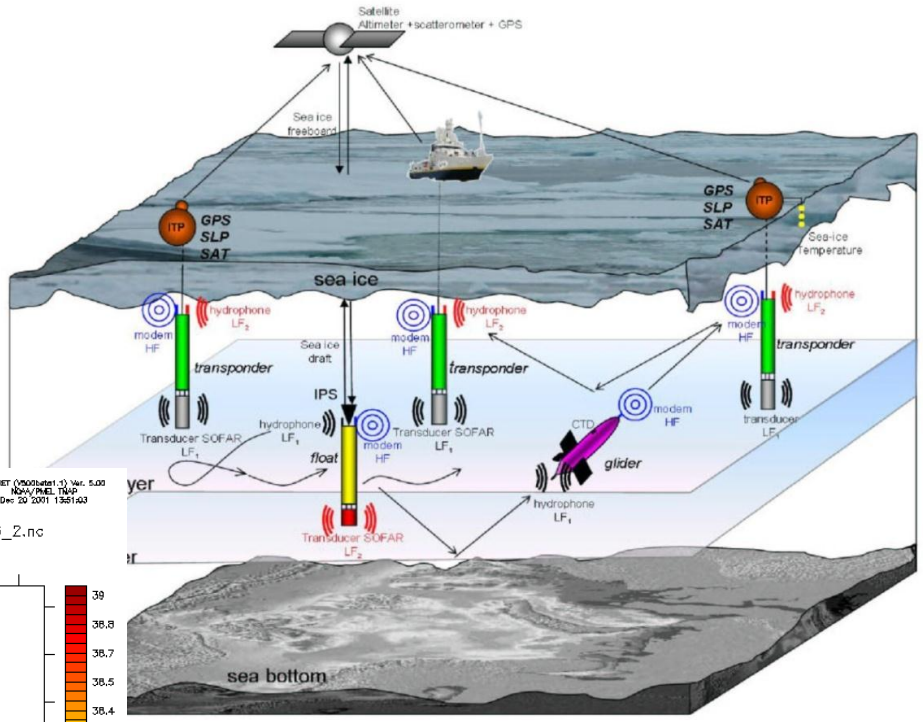
Topic V - chemical pollutant transports

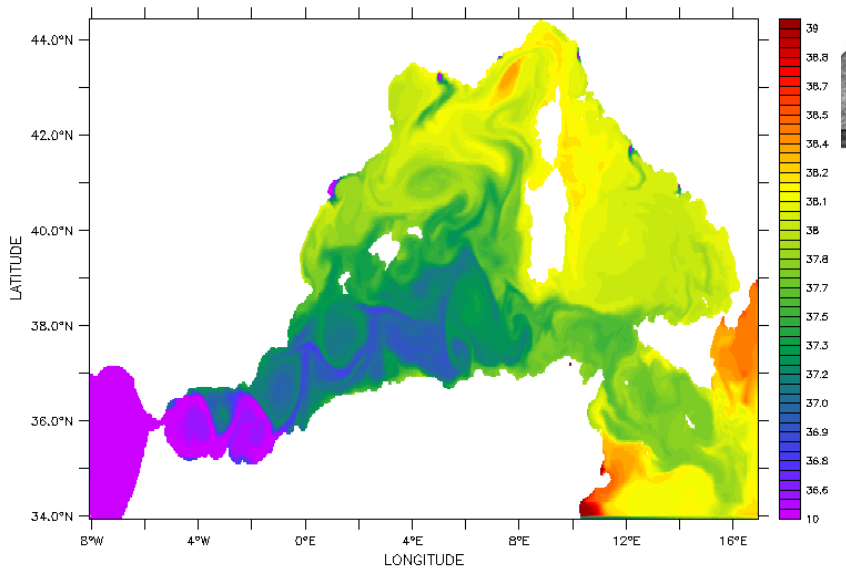


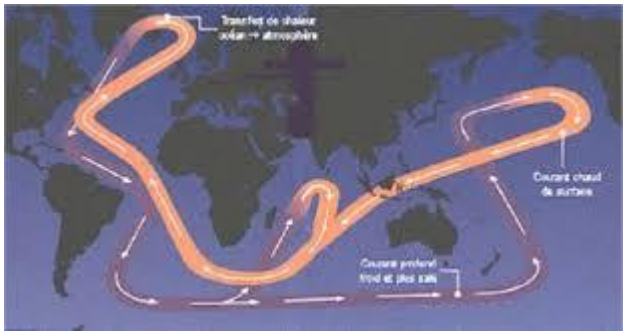


Topic VI – climate and global warming





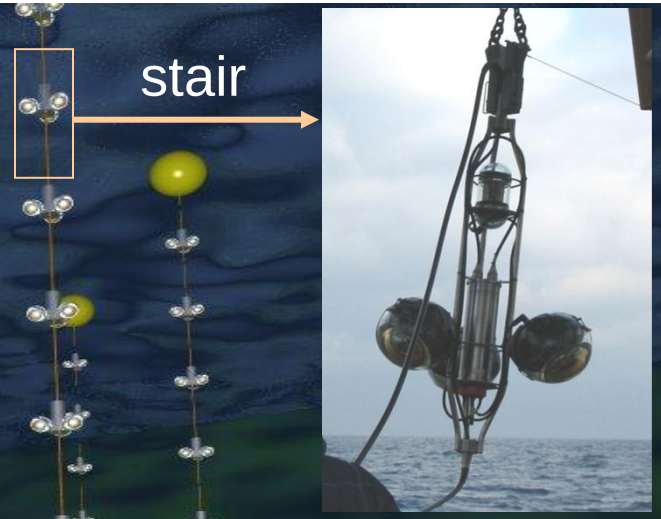




Objective VII : National deep sea intervention capability

BEA - black box search, “first aid” on Prestige wreck site
ANTARES deep sea observatory (Neutrino telescope)

- 900 PMTs
- 12 lines
- 25 stairs / line
- 3 PMTs / stair



underwater technology in ocean sciences

*from **pioneers***

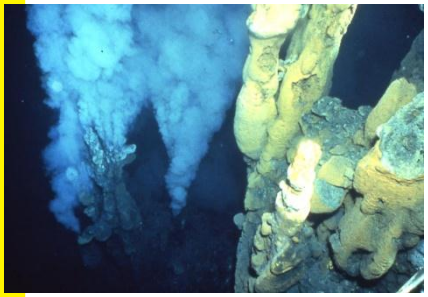
Sampling
Manipulating
Photo-Video
Measuring

DISCOVERY

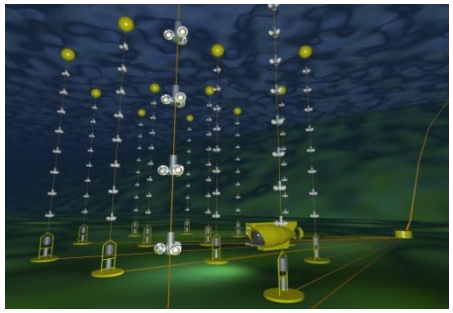
*to **specialists***

Digital photo & HD video
Multibeam seabed mapping
Sub-bottom profiling
ADCP, CTD … ocean modeling
Remote & automatic manipulating
« Almost GPS » georeferencing

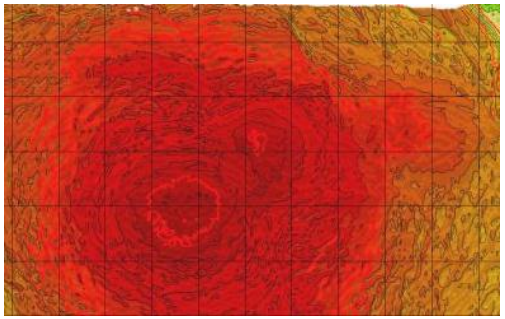
QUANTITATIVE OBSERVATION
MONITORING
UNDERSTANDING THE OCEANS
SUSTAINABLE USE OF RESOURCES



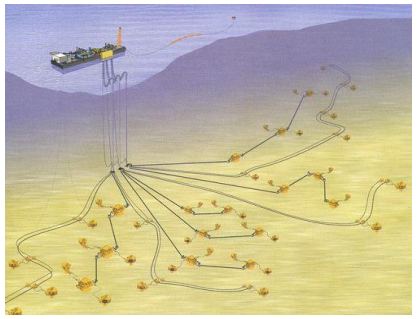
Ocean science



Infratructure project



Monitoring, surveillance



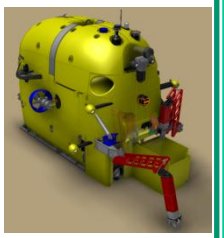
Industry

Robot systems

Human Intervention

From survey to Intervention

Hybrid



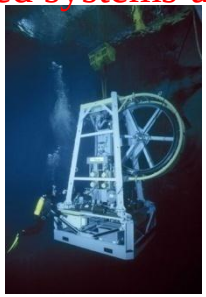
2500m, 8h

Autonomous

ASTERX
3000m,100km,24h

Cabled systems and ROV

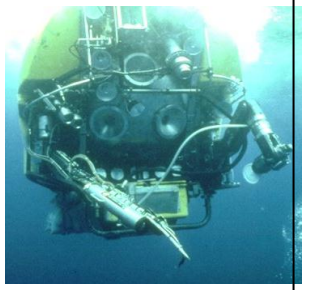
>100km
Sev Days



local,sev h

sev km, 72h

HOV: Nautile

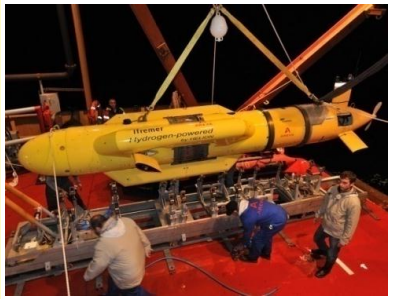


sev km, sev h

Ifremer

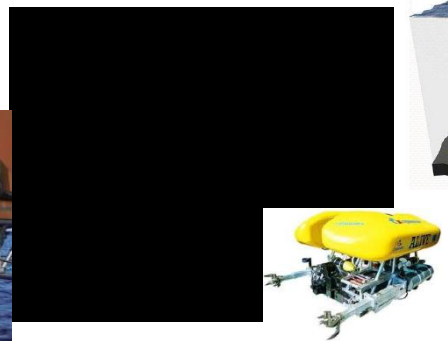
Task Complexity

Fuel Cell Autonomy

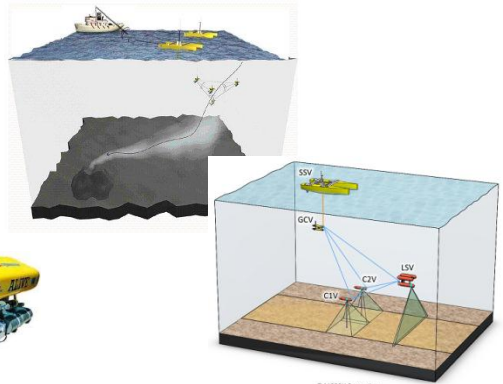


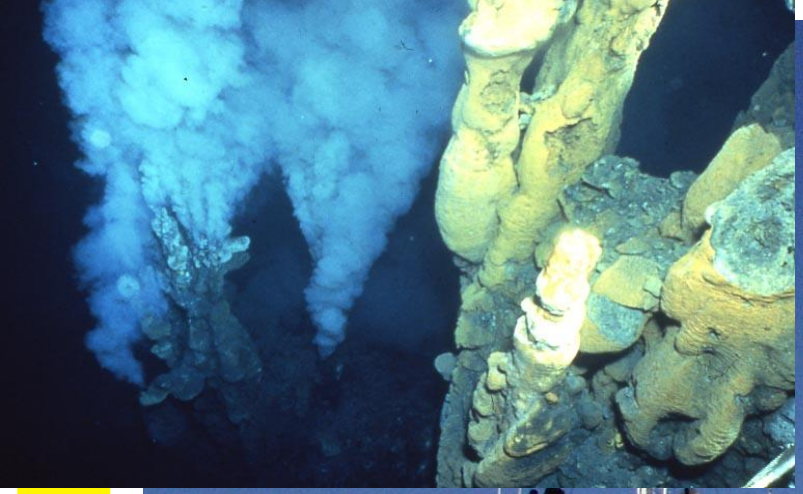
Swimmer Docking

Alive Intervention



Grex, Morph cooperating fleet





Nautile HOV

1693 dives in 20 years

A reference in ocean science, deep water operation, engineering

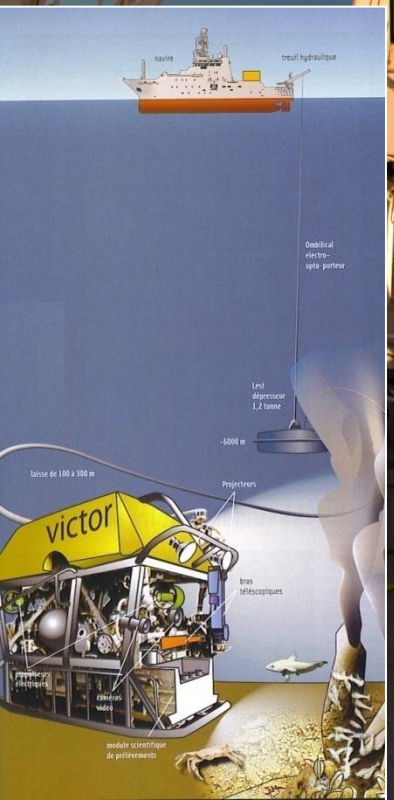
Nautile : system characteristics

- length 12m, 18t, 6000m depth rated
- 80t of equipment mobilized
- 3 people onboard - 1 scientist
- 8 crew on vessel
- 1 dive / day, 8hrs, 5hrs on bottom
- vessel 80m min
- day cost > 40k€

- technical & operational safety constraints
- external safety commission
- 2000 dives in 27 years

deep manned submersibles

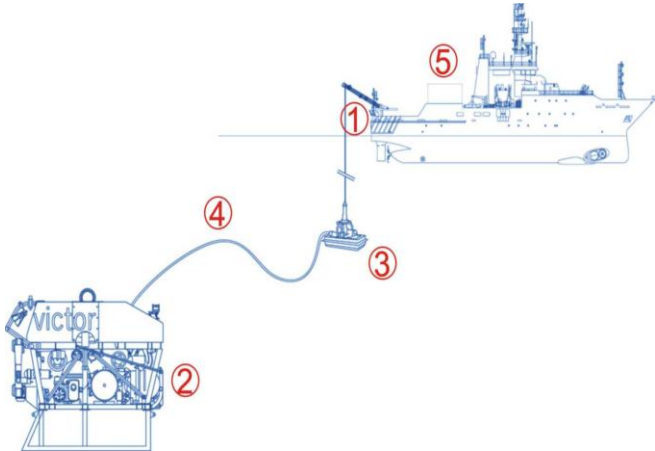
Name	Year of launch	Operator	Max Depth
CYANA-Stopped	1970	IFREMER/FRANCE	3000m
ALVIN	1964	WHOI/USA	4500m
NAUTILE	1985	IFREMER/FRANCE	6000m
SEACLIFF-Stopped	1986	USNAVY/USA	6000m
MIR(1 and 2)	1987	Institue of Oceanology/RUSSIE	6000m
SHINKAI 6500	1989	JAMSTEC	6500m
Jiaolong	2010	China SOA	7000m



Victor 6000 Ifremer

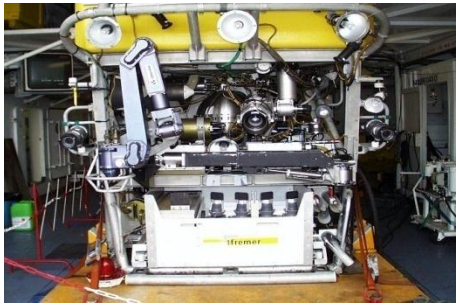
Victor 6000 : system characteristics

- 4t ROV, 2 manipulators, 6 x video
- 9 operators for 24/24 operation
- max dive duration > 100h
- data production : 1.5TB/Day
- vessel 80m min
- 20 ft shelter with 4 work places (2 scientists)
- 8000m cable, power 2000V, 5 OF
- 6 KW lighting



Victor 6000, module I : measuring and sampling

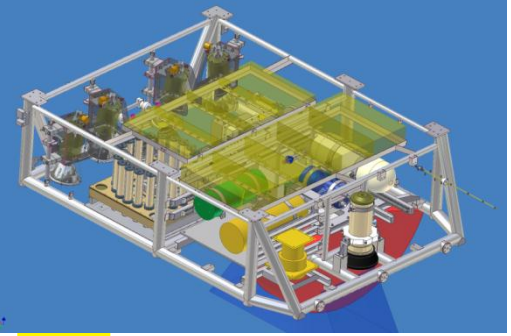
Victor with sampling tool sled



In situ chemical analysis

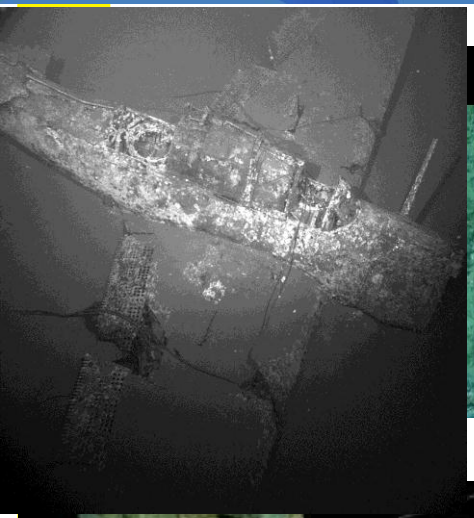
sediment coring

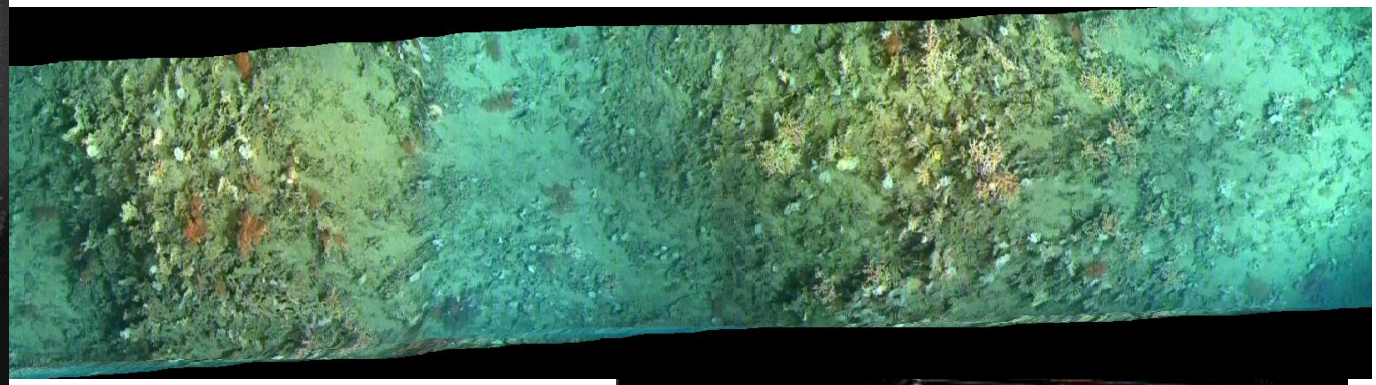
Sediment coring, water sampling, fauna sampling, chemical sensors, etc.

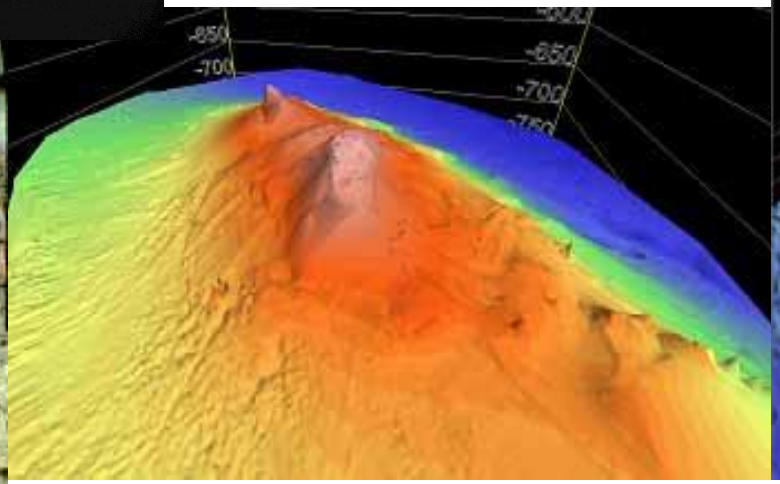


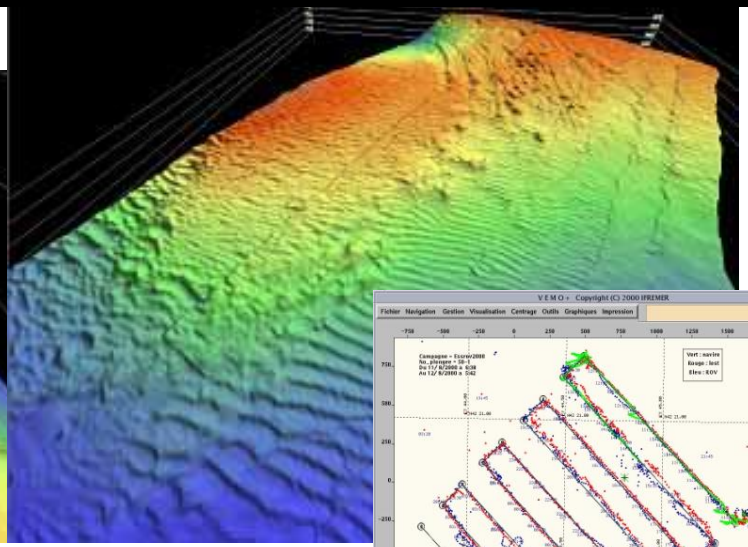
Victor 6000, module II : Mapping and imaging

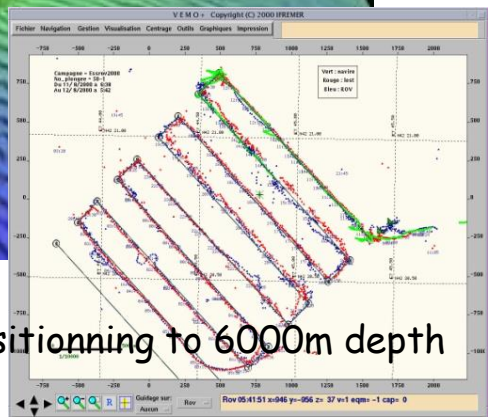
MBES, subbottom profiling, high dynamics still camera, HD vertical video and real time mosaicking, etc.



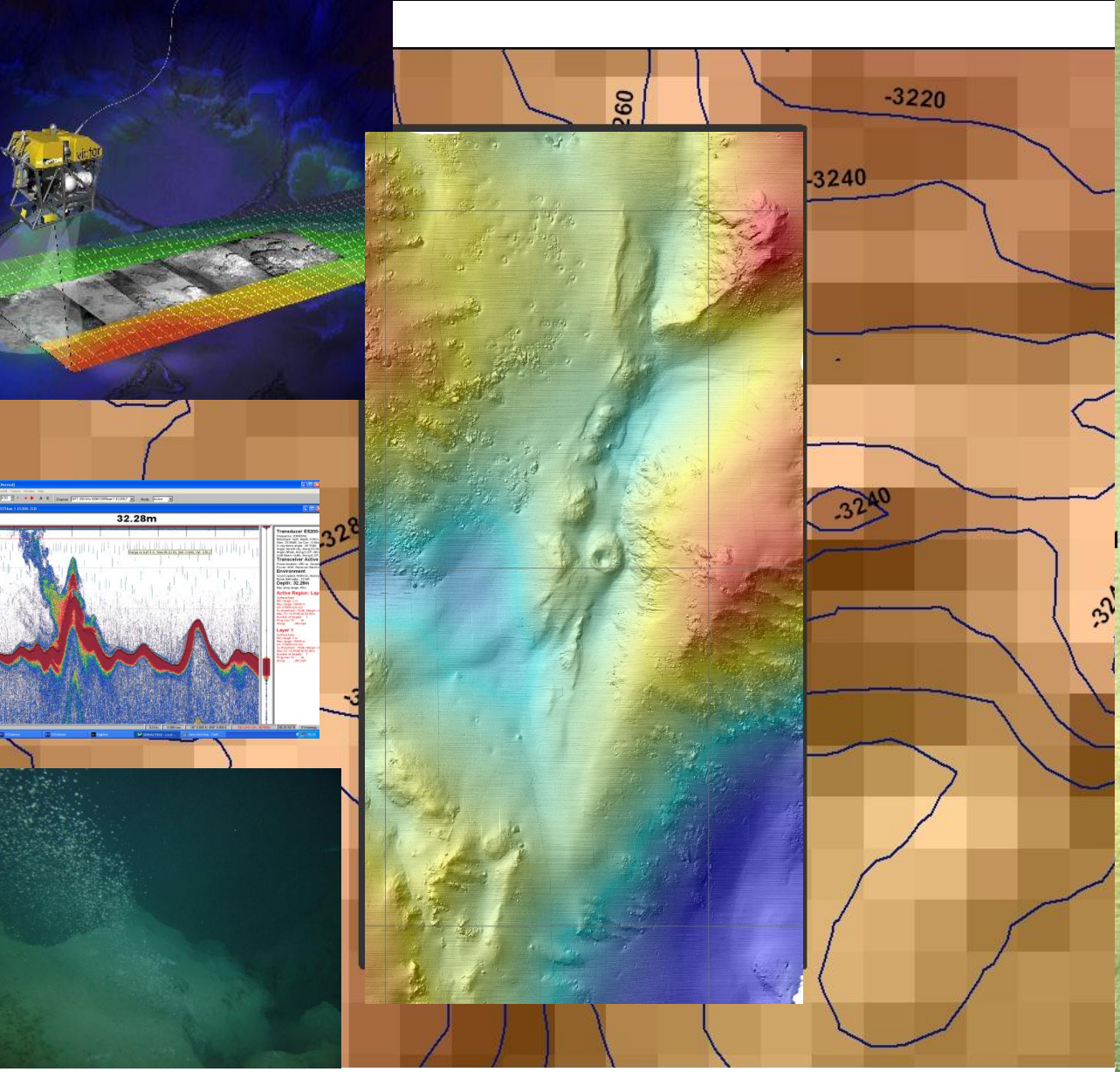


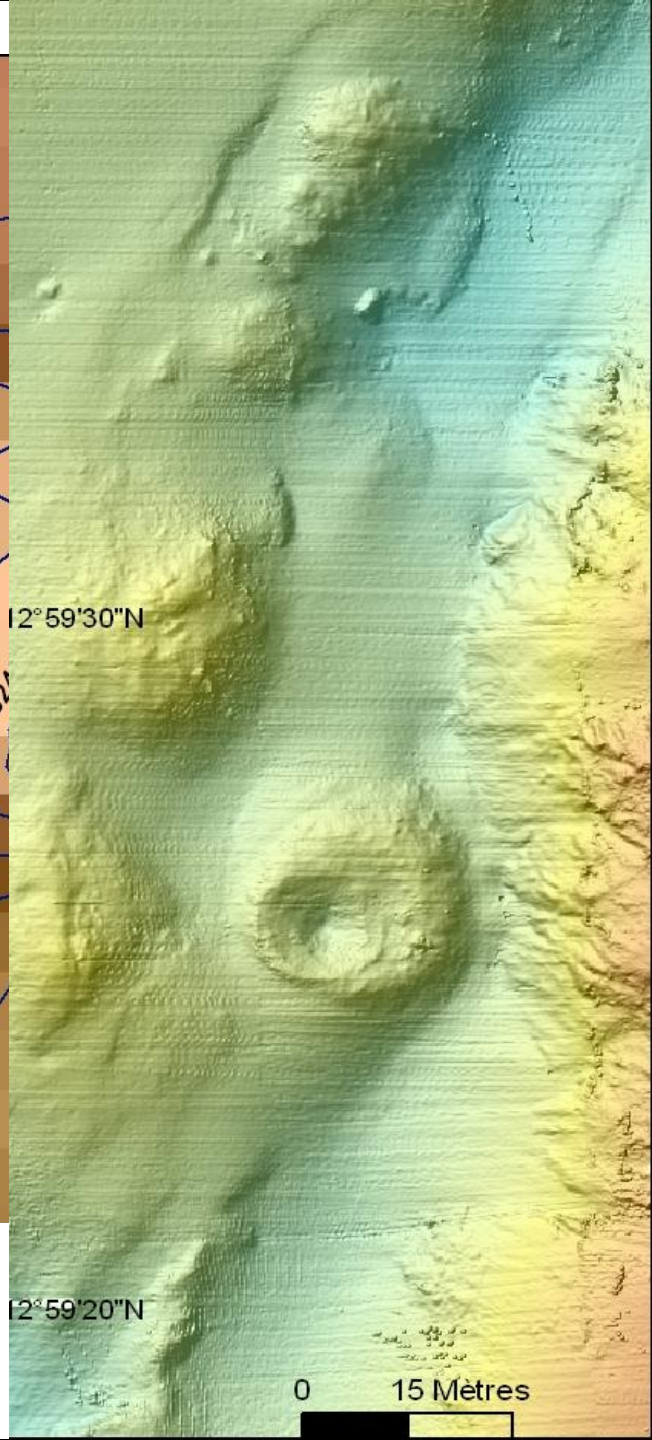




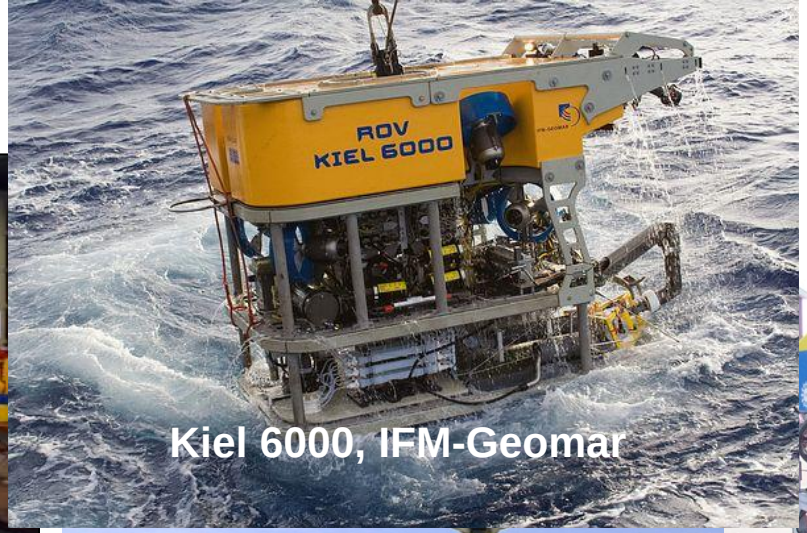


Positionning to 6000m depth





high Resolution multi beam mapping -
H2 natural seeps (deepest active site in Atlantic)
Serpentine cruise with Victor/MMR



Kiel 6000, IFM-Geomar

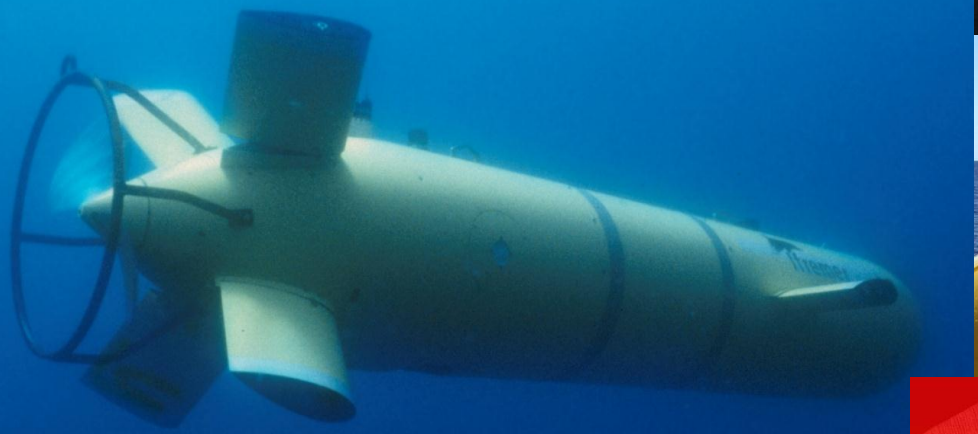

JASON- WHOI

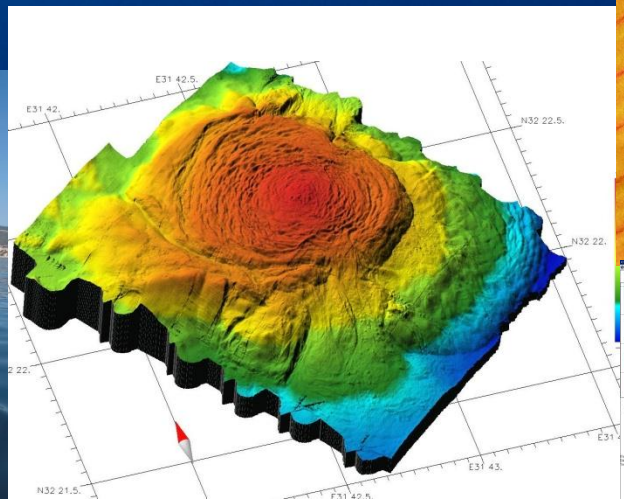
Quest- Marum

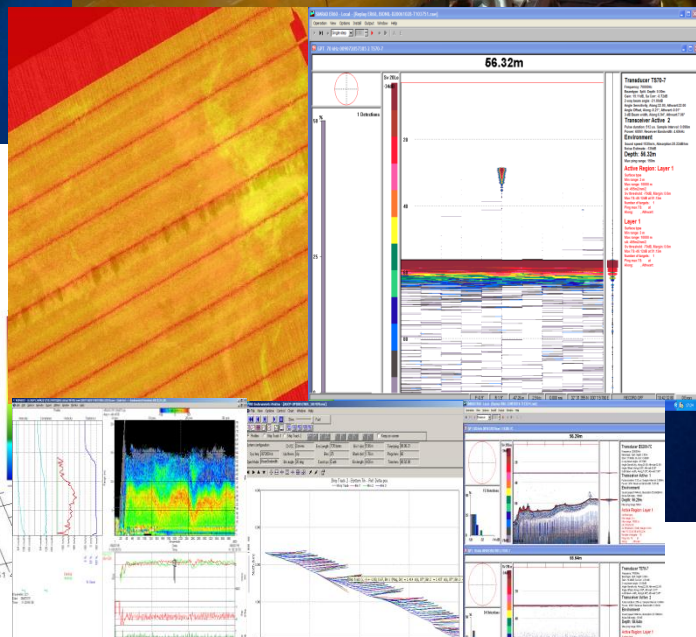

Tiburon MBARI

Ifremer

A milestone :
survey AUVs for ocean science



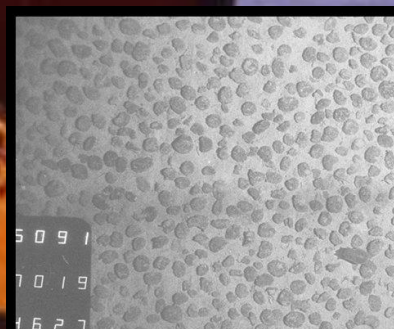




The First deep sea scientific AUV : *Epaulard 1980*

Depth rating 6000m, 3tons, payload 20kg, endurance 6hours
Automaton, with Guide rope altitude servoing

Supervised by acoustic
And positioned by acoustic SBL



IFREMER AUV Fleet

AsterX

IdefX

aster^{X} & *idef*^{X} AUVs

800kg

200kg (pl)

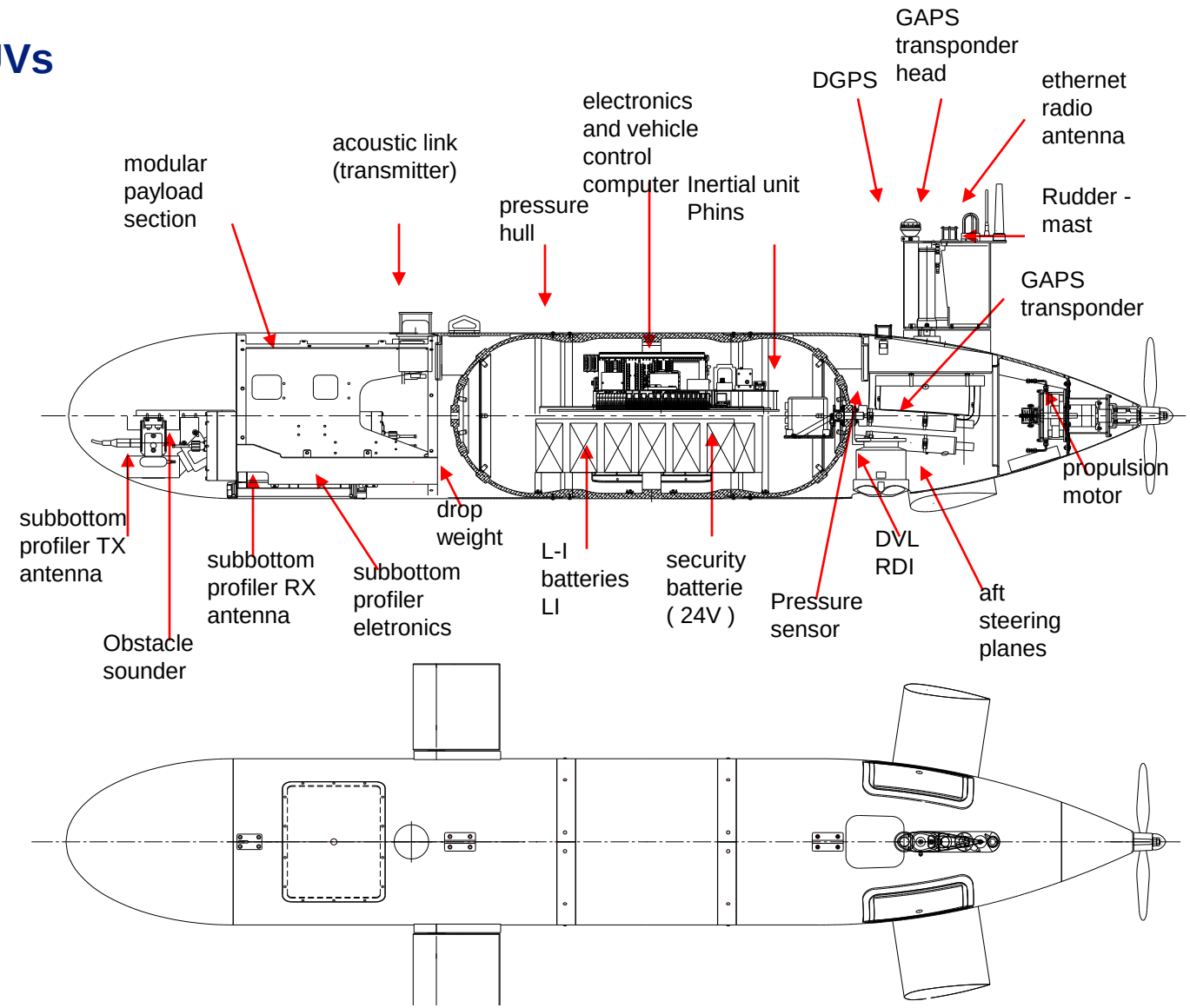
4,5 m

14 kWh

80km (3nds)

1 – 5 knts

3 operators

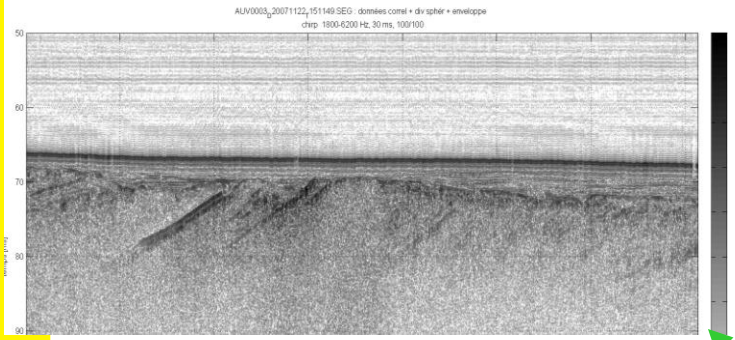


Requirement : a cost-efficient & versatile system :

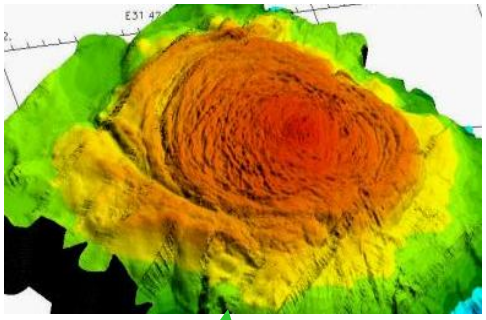
routine operation, small vessel depl., fast mobilization, reduced team, multiple payloads

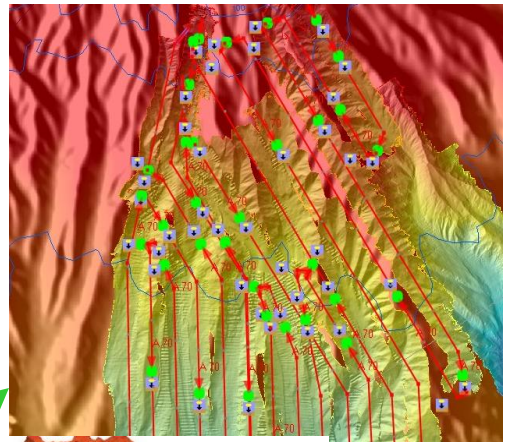
Geophysics payload

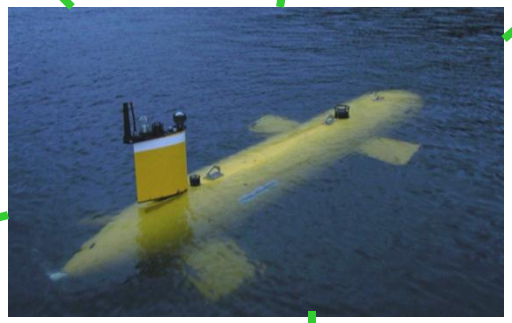
multibeam – subbottom profiler – gas detection - magnetometer



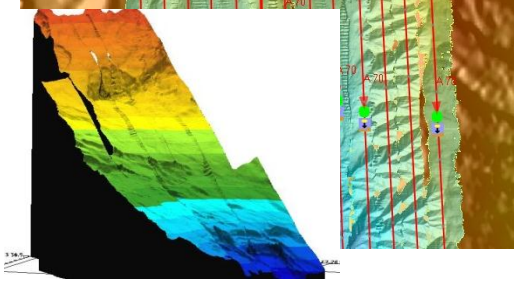
iXSEA *echoes 10000*



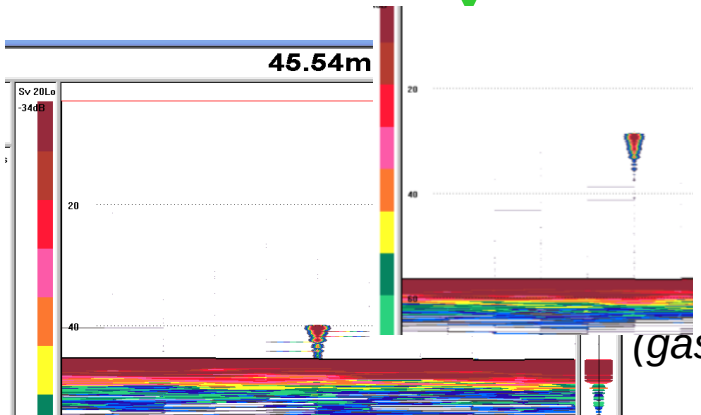




EM2000 (imagery)



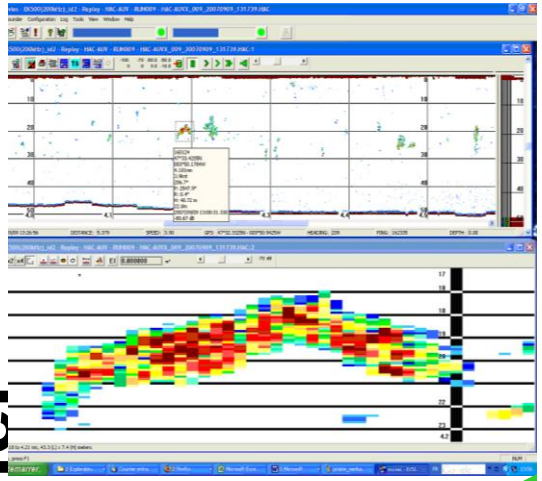
Kongsberg *EM2000*



Kongsberg *EK60 (gas plume)*

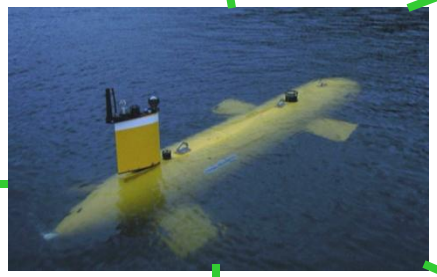
Environment and fisheries payload

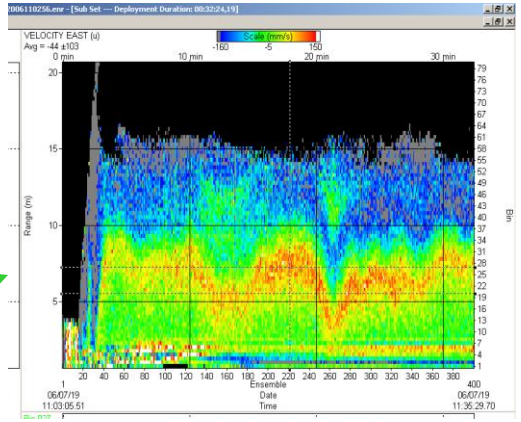
Acoustic Doppler current profiling – fisheries monobeam sonar



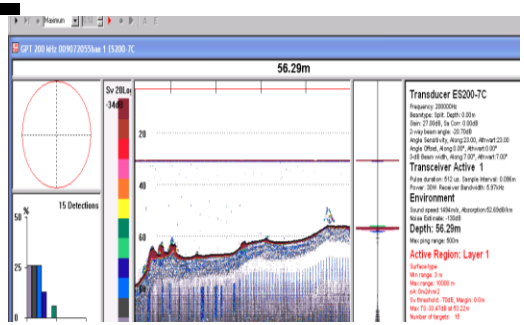
SIMRAD *EK60 70 KHz*
downwards orientation

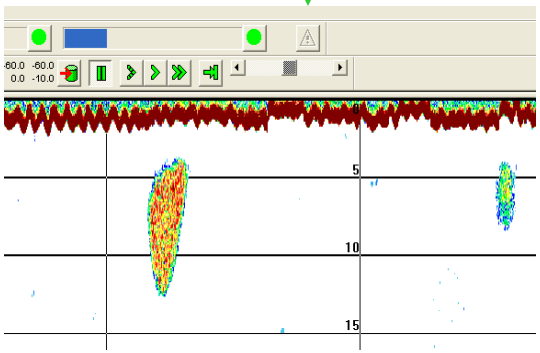
Satlantic *ISUS*
nitrate sensor
(Septembre ’08)



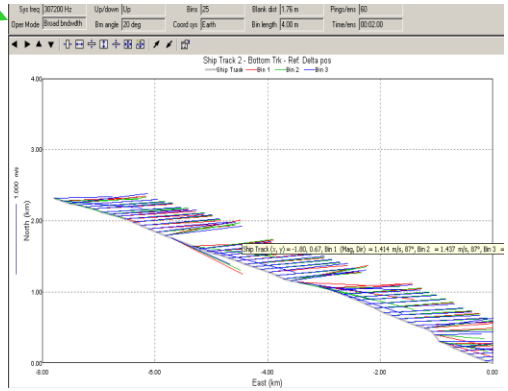


RDI ADCP *1200 KHz*
upwards orientation
(monitoring of fine layers)





SIMRAD *EK60 200 KHz*
upwards orientation



RDI ADCP *300 KHz*
(current modelling)

AUV seabed mapping

multibeam – subbottom profiler – gas detection - magnetometer

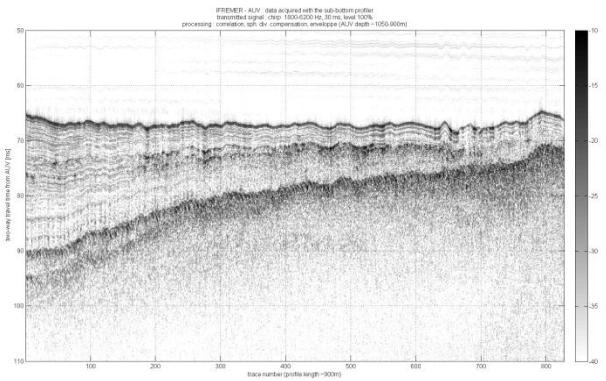
AUV Subbottom profiler Echos 5000

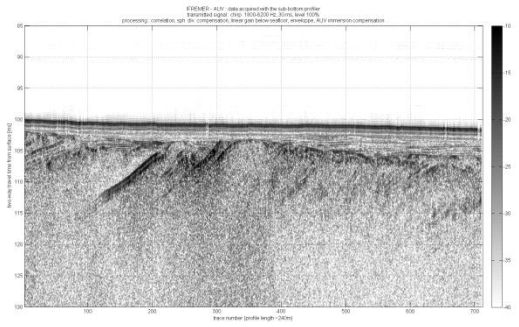
Collaboration : IXSEA/IFREMER

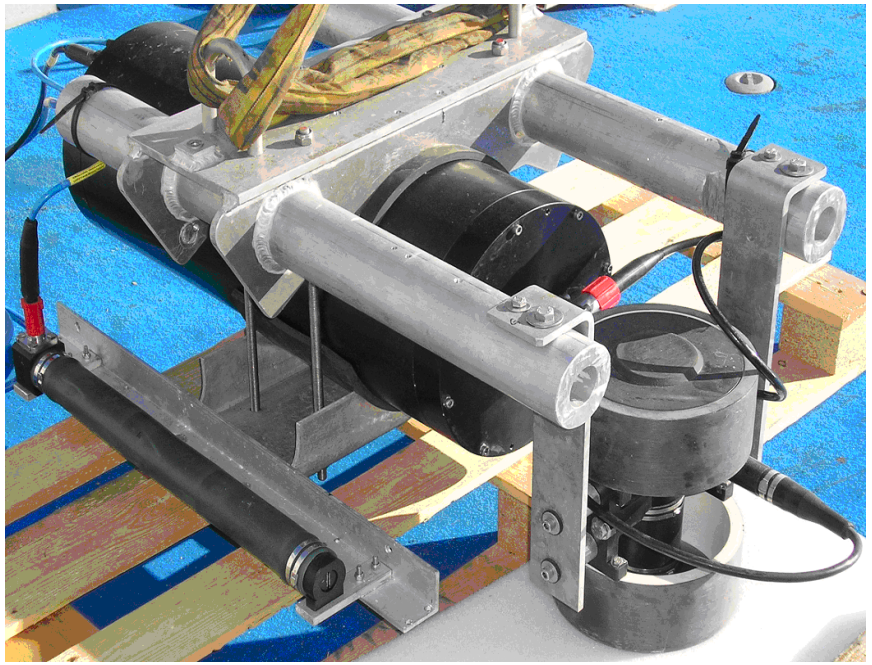
Tx Janus-Helmholtz (1800-6200 Hz)

Vertical resolution : ~ 25 cm /

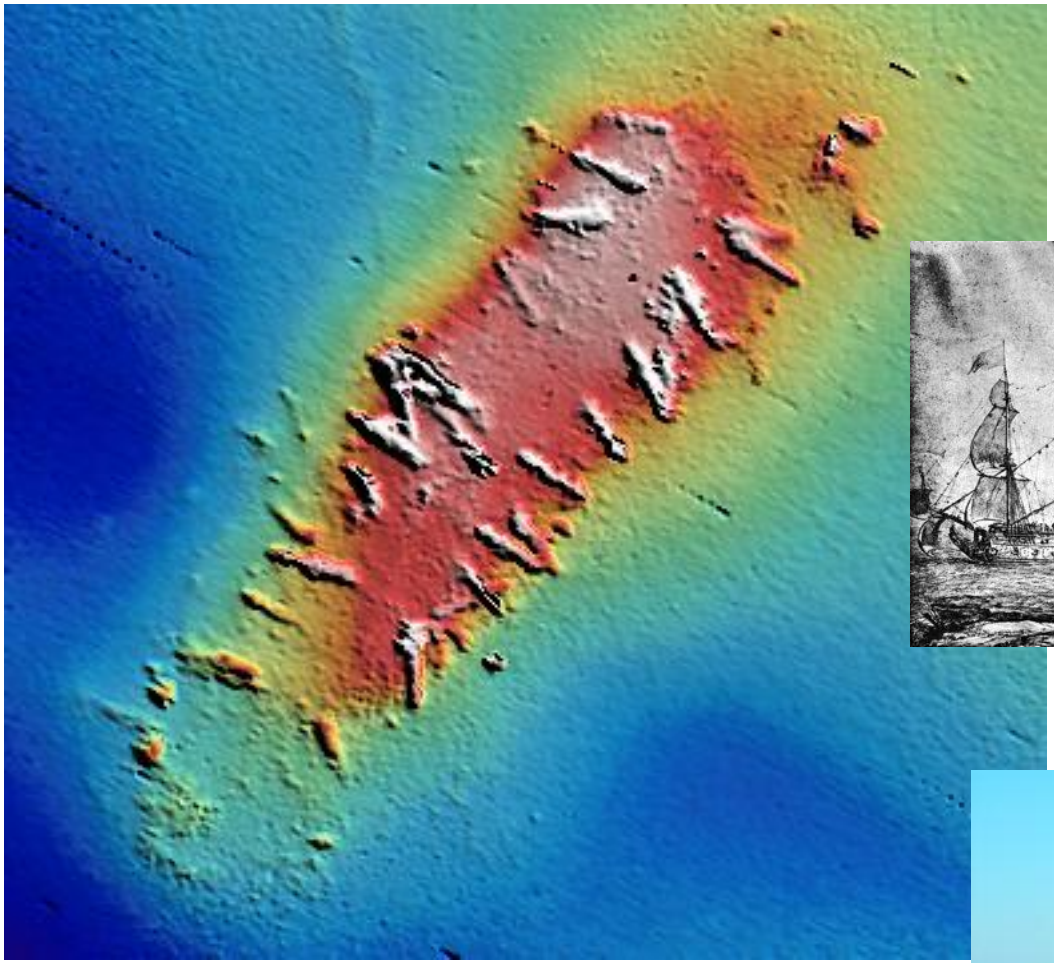
max penetration: ~ 50 m



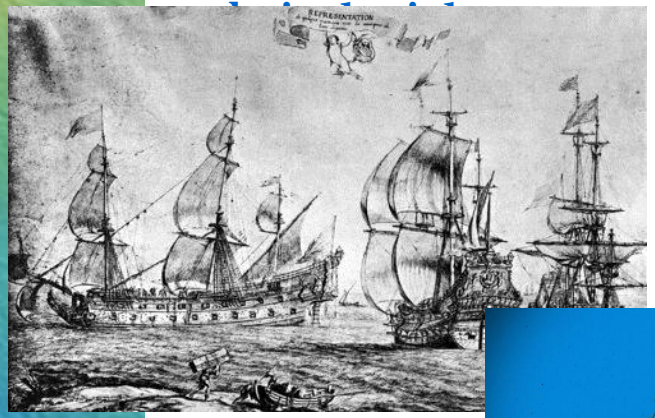




High resolution bathymetry - EM2040 on AUV
for French Government Submarine Archeologic Department

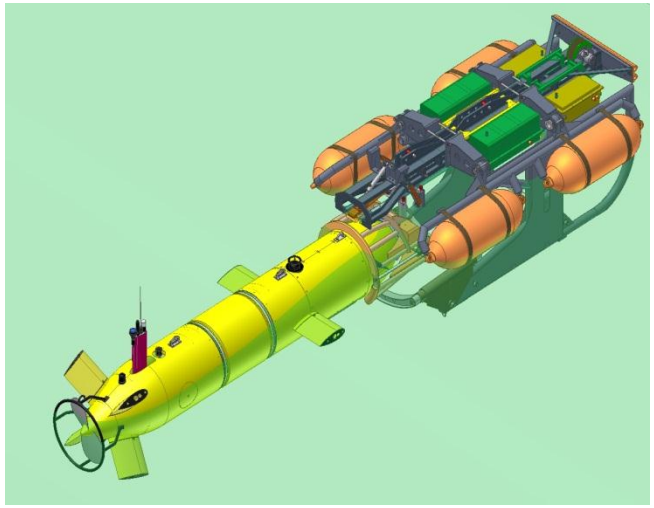


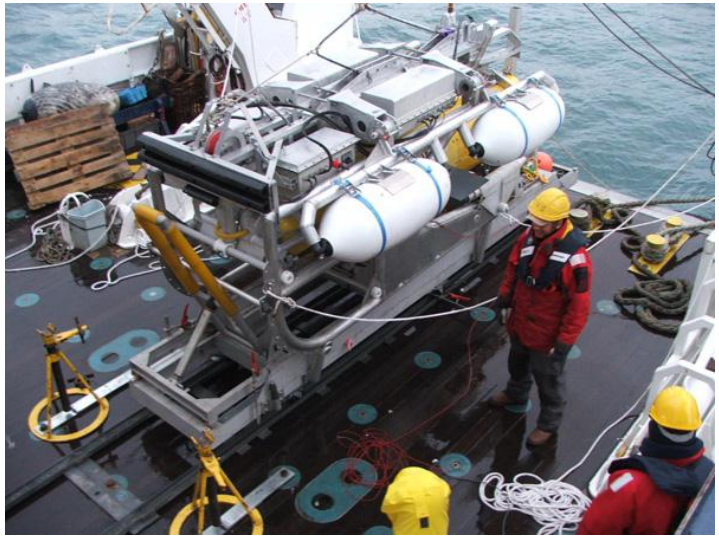
The vessel *La Lune* sank in 1664, the wreckage was discovered off Toulon at 90m depth by Nautile in 1993 on a



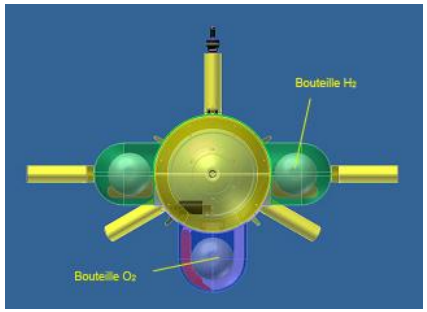
Wreckage mapped by AUV aster[X]
From 10m height, grid 10cm, canons ~0.5m

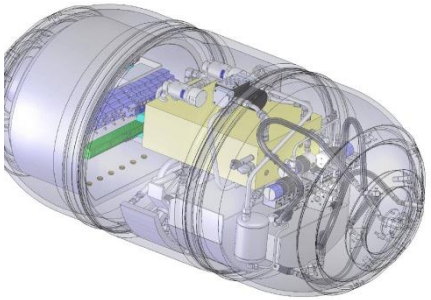
launch and recovery cage CALYSTE

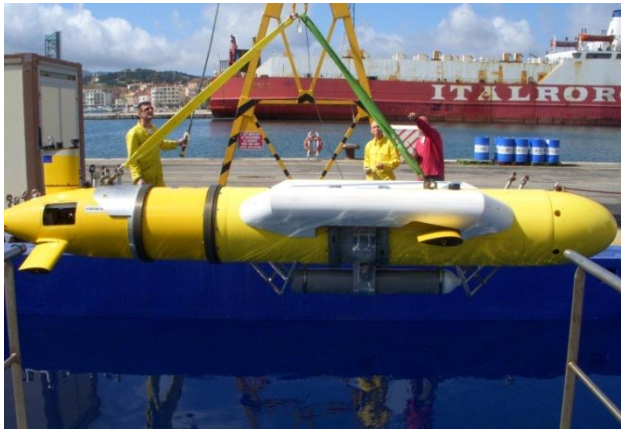




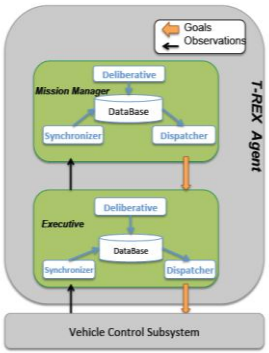
Fuel Cell: H2/02 experiment
Objective 300kms endurance
36kWh, Vehicle Weight +800kgs Length + 1m



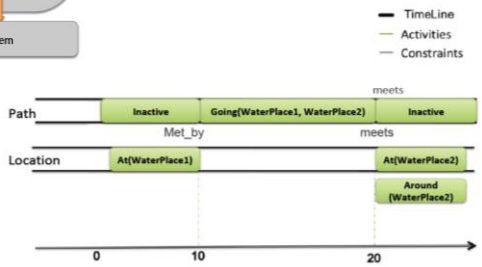




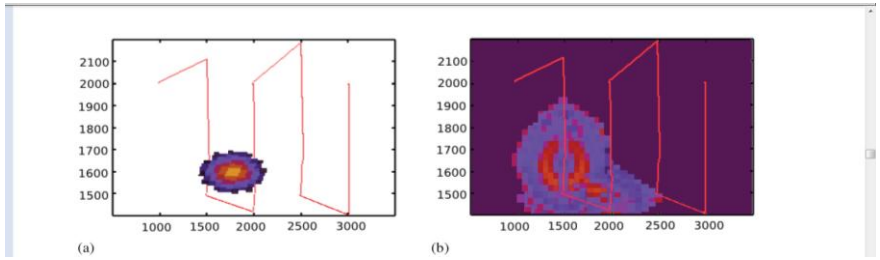
Adaptive sampling – dynamic behaviour on AUV

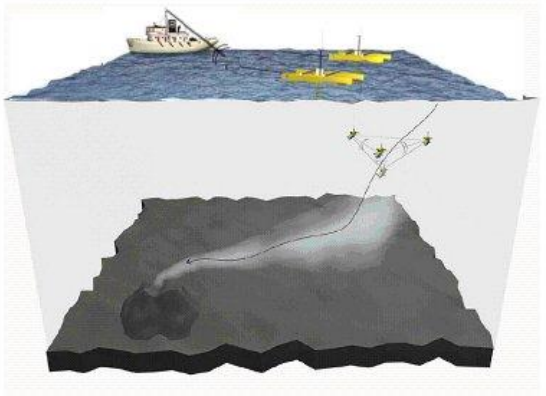


- LAAS-CNRS & MBARI
- T-REX planner - scheduler
- N vehicle low bandwidth comm



- FP7 - Morph
- 3 level task architecture
- Simple architeture





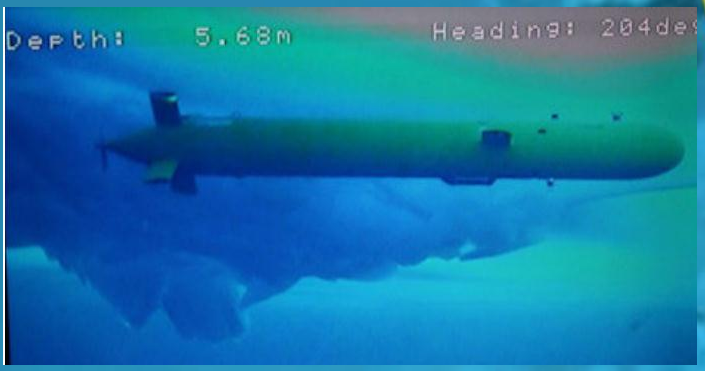
Operational AUVs at Ifremer – feedback and perspectives

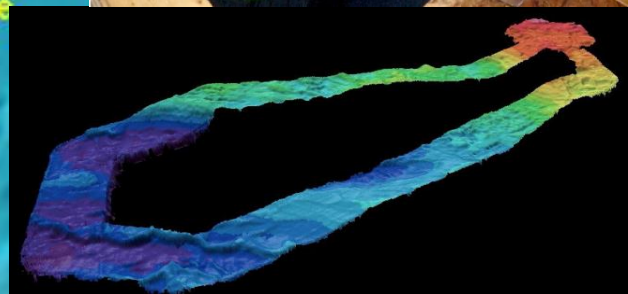
3000m AUV investment [K€]	
engineering	300
pressure hull	100
main mech. Structure	50
buoyancy	80
batteries	150
uw connectors & cables	100
nav instruments	200
comm devices	100
electric system & controller	100
actuators	80
surface system	50
acoustic positionning	200
payload	200
spares (70% of HW)	720
total investment	**2 130**

amortization [€]	
deployments per year	60
mobilisations per year	5
mobilized days /year	85
number of years	10
total deployments	600
amortization p. depl.	3.6
investmt per deploymt	**3.6**

running cost [k€]	
maintenance per year	51
maintenance per depl.	0.9
obsolescence per year	72
obsolescence per depl.	1.2
maintenance pers. per yr	25
opertion per. per yr	128
personnel per depl.	2.5
running cost per deploymt	**4.6**

AUV only : 800km dive under the ice
The Canadian DRDC cornerstone project

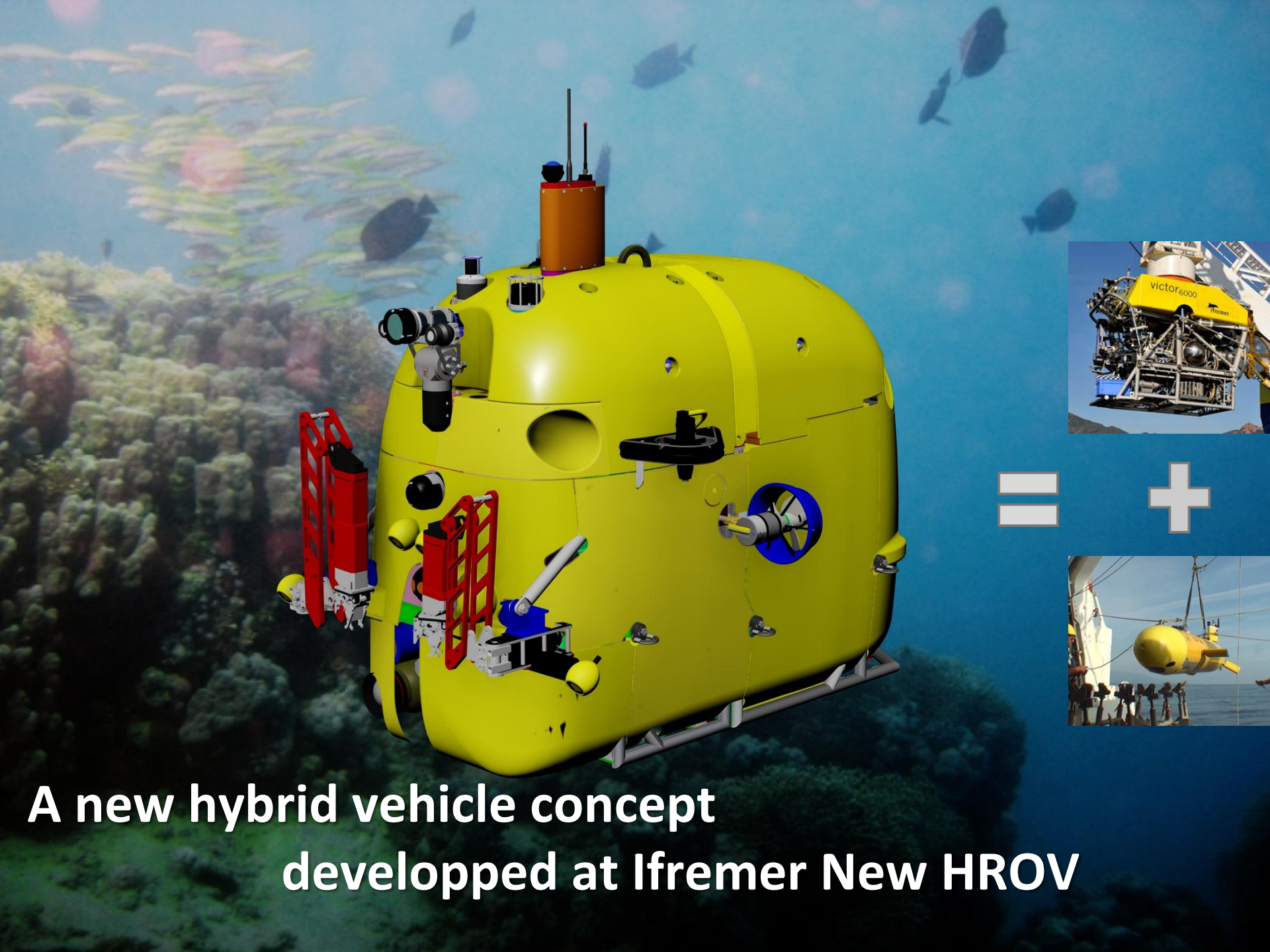




Mission 2:
Survey at Remote
Ice Camp (280 km)

Mission 1:
Survey en-route to
Remote Ice Camp
(320 km)

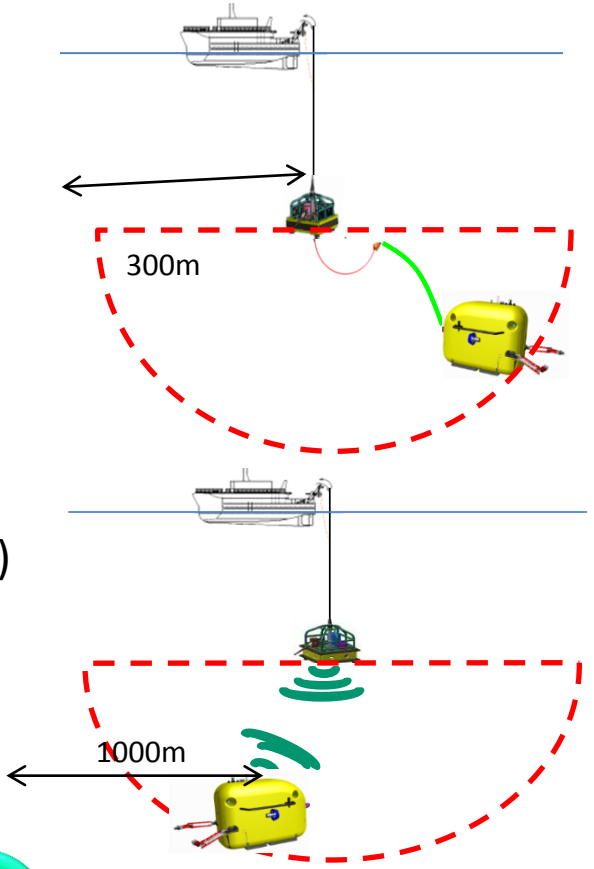
Mission 3:
Survey en-route to
back to Main Ice
Camp (320 km)



A new hybrid vehicle concept developped at Ifremer New HROV

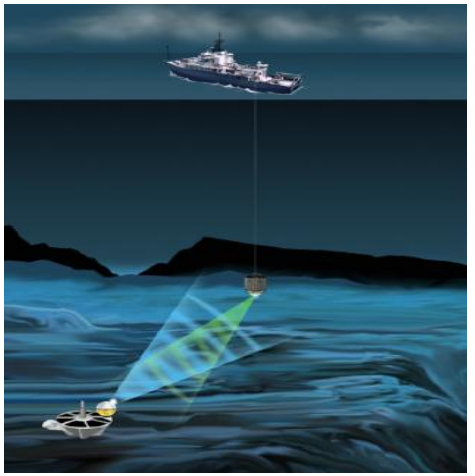
H-ROV?

- **Deployement:**
  - **(ROV) mode**
    - Communication : managed optical fiber
    - Deployement with depressor weight or cage(0-2500m)
    - Direct OF deployement in shallow water (0-200m)
  - **(AUV) mode**
    - Acoustic and optical links
    - Modem(s) on intermediate Dead weight



Deployement from an non specialised ship with no DP

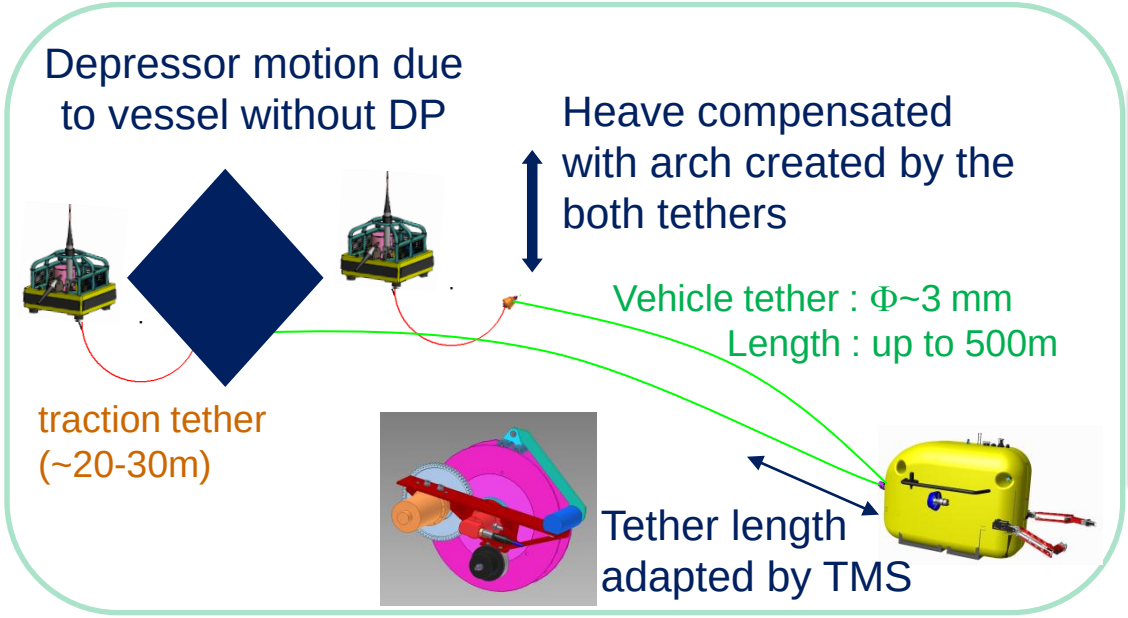
➔ OPEX and accessibility optimised



HROV Innovative deployment*

(ROV mode)

- **Deployment with a dead weight or directly from the vessel (low depth)**
- **Specific tether management system on vehicle**
- **“Double tether system” allowing vehicle towing on short traction tether**



Advantage :
Reversible system : same tether for all dives (reduction of operating cost)
Drawback :
HROV and vessel motions are limited by the length of the tether

HROV objectives

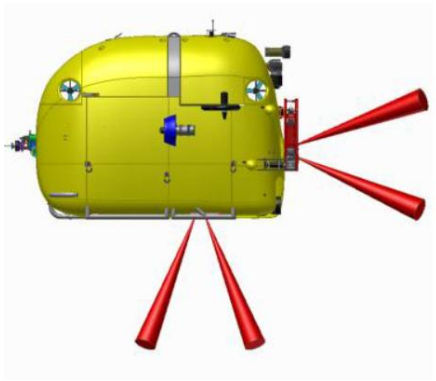
<u>Coastal applications</u> up to 2500m (Mediterranean Sea): It is to say From Non DP small Coastal Ship

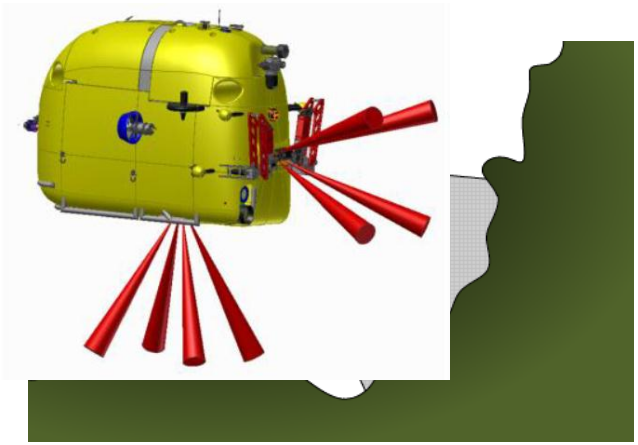
<u>Missions :</u>

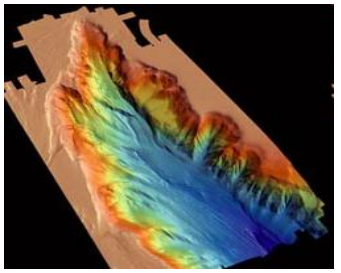
- Close-up inspection
- Sampling and light tools manipulating
- High resolution & geo-referenced optical imaging
- Acoustic mapping

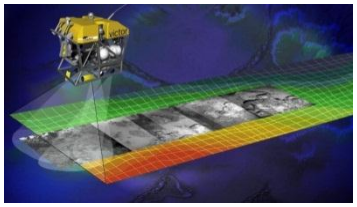
Ability to work on <u>steep slopes</u>

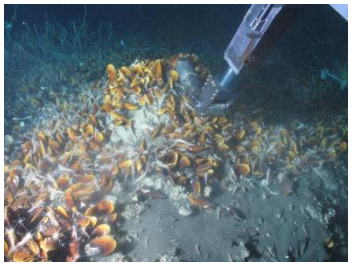
- Mediterranean canyon for example
- 2 DVL used for geo-referenced navigation



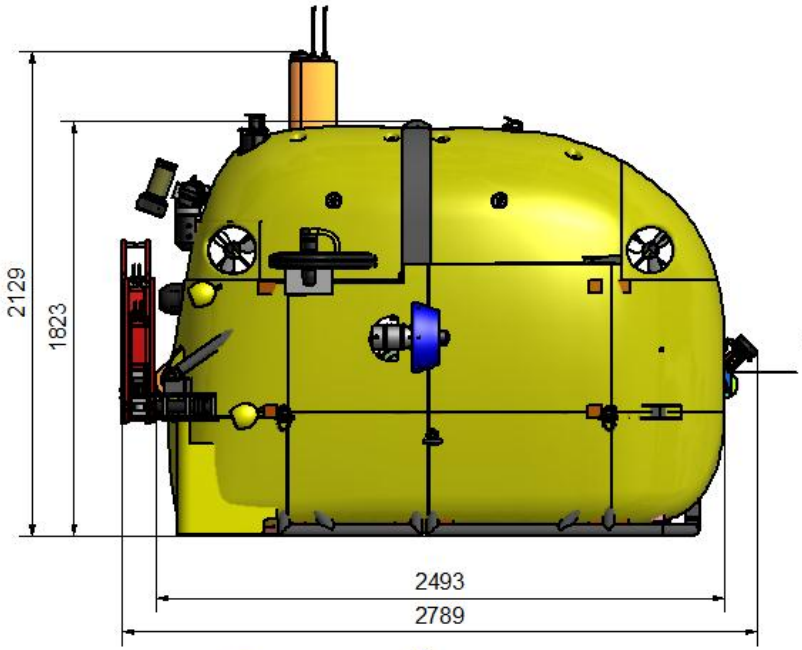


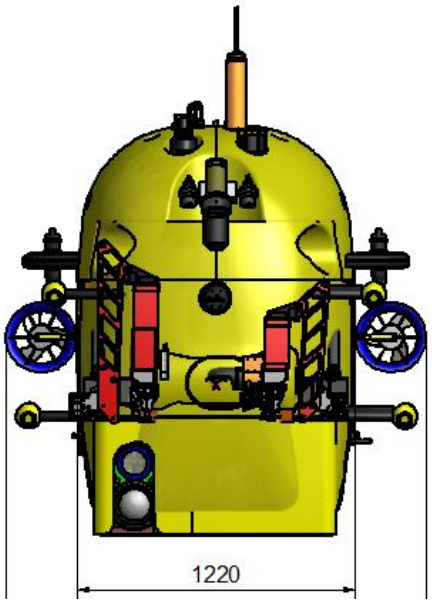


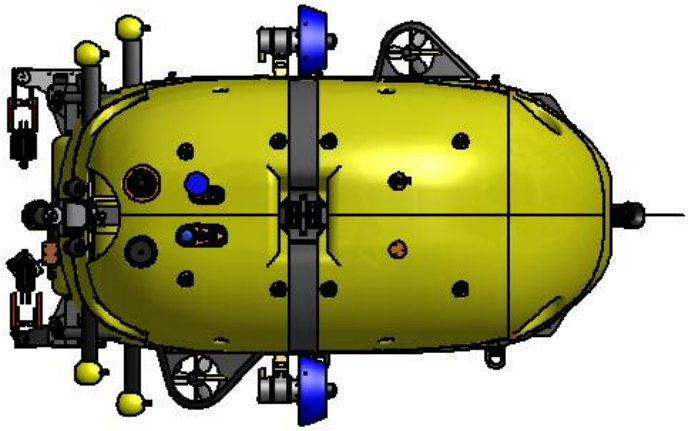


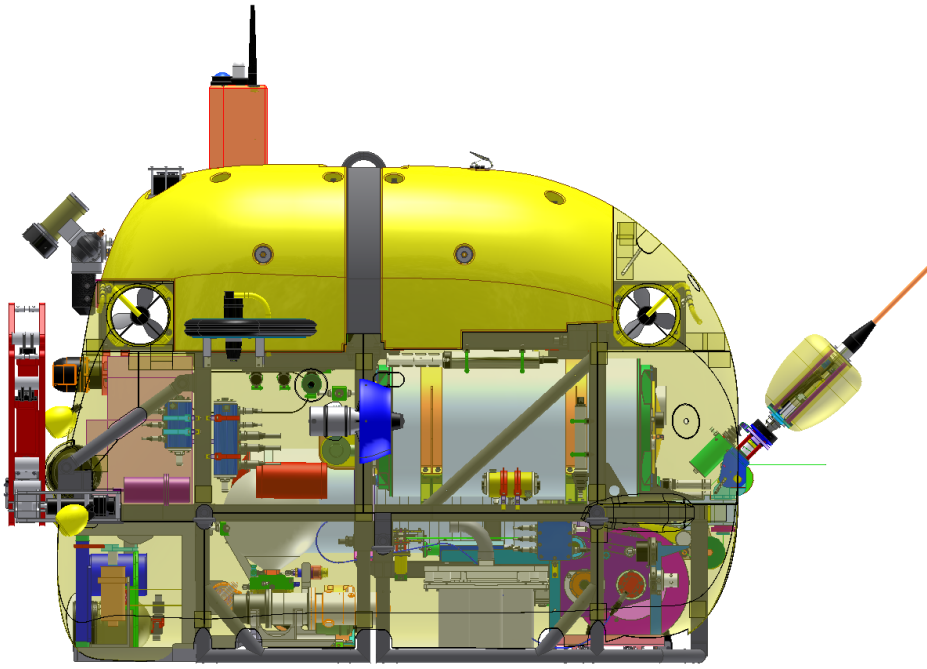


Le véhicule HROV

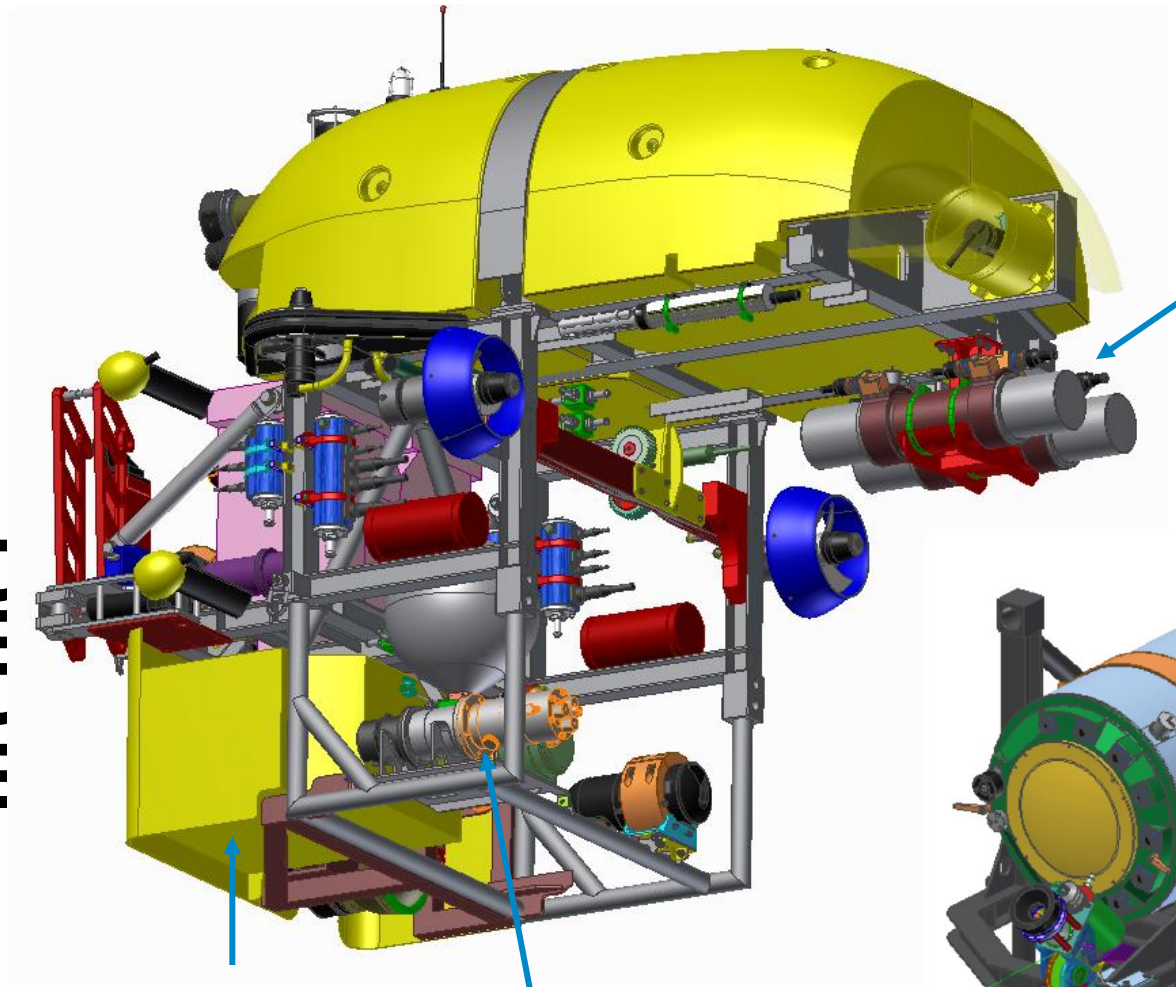


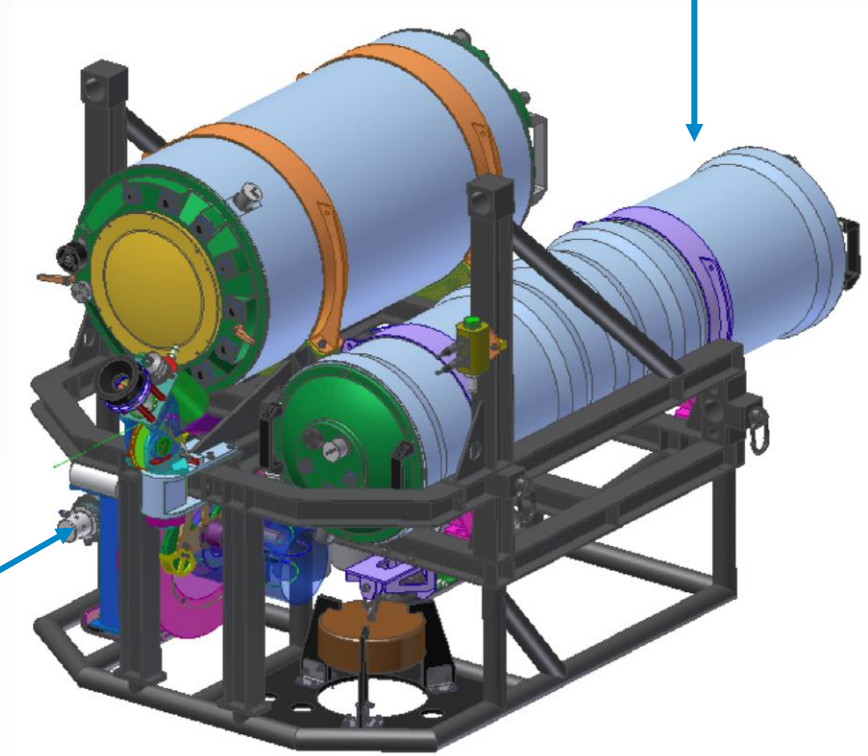




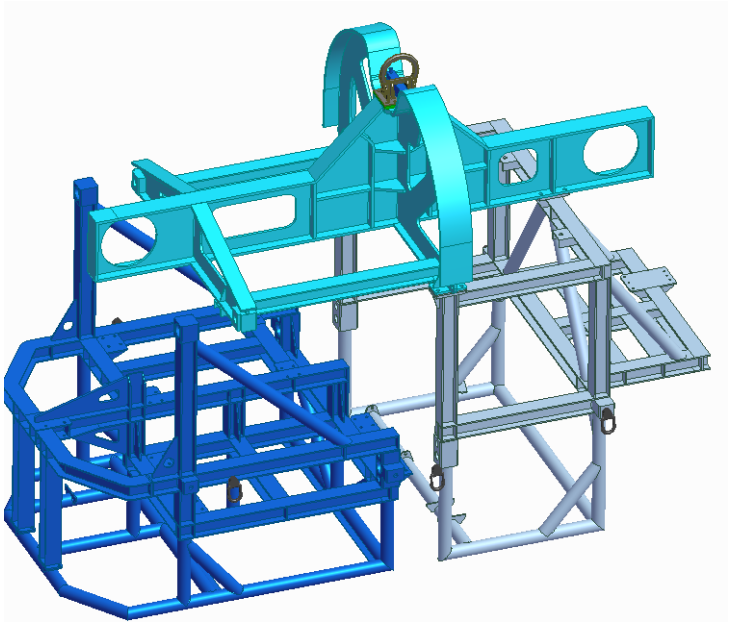


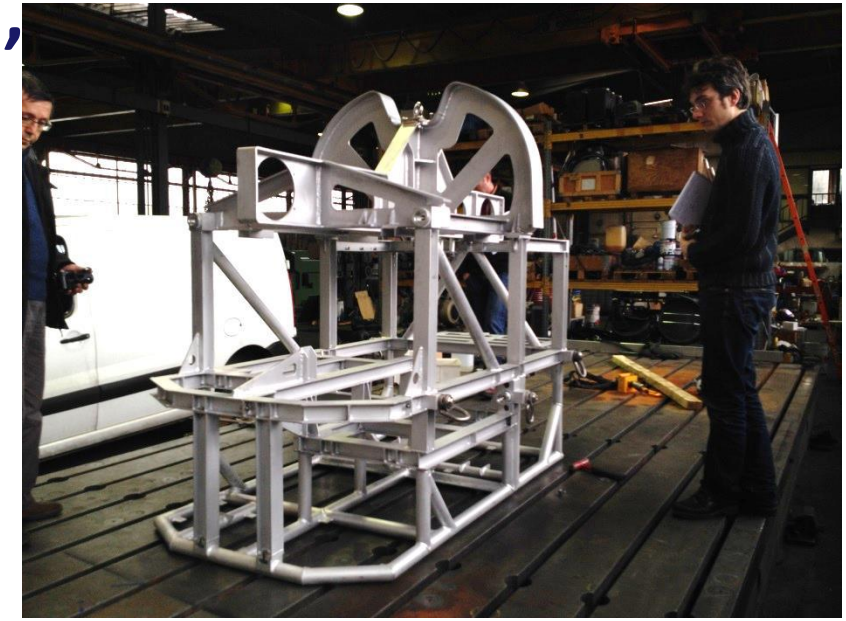
Aménagement : modularité et maintenabilité

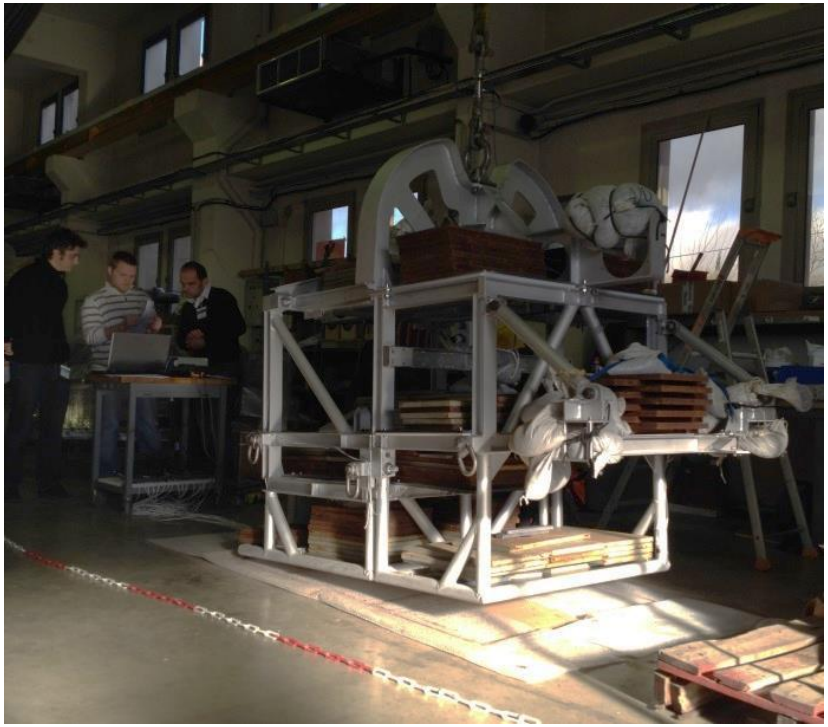




Réalisation de l’

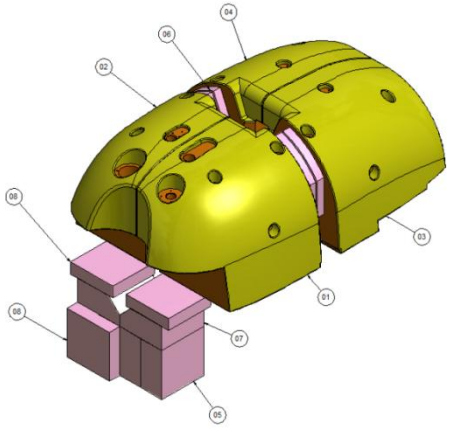


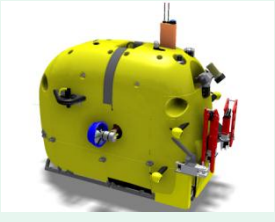




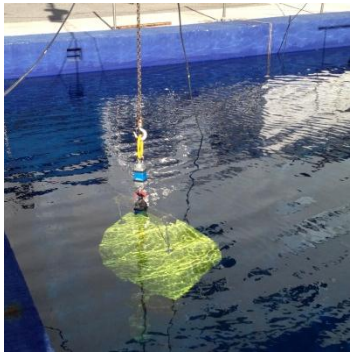
Pesée/flottabilité : 2 configurations possible

- Adaptation de la flottabilité en fonction de la charge utile à embarquer
- Changement de configuration : ajout/suppression de flotteurs additionnels (rose)



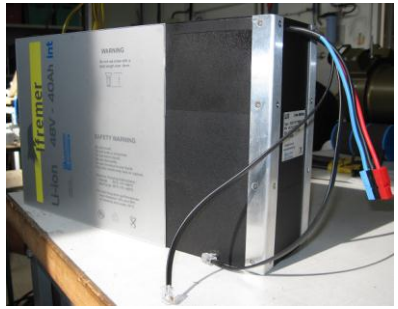
	Configuration légère (sans flotteur additionnel)		Configuration lourde (avec flotteur additionnel)	
	masse dans l'air	Poids dans l'eau	Poids dans l'air	Poids dans l'eau
Véhicule complet	**1,6 tonne**	- 5 daN	**1,8 tonne**	- 5 daN
Charge utile	80 kg	50 daN	220 kg	120 daN
Exemple	Configuration cartographie 		Configuration prélèvement 	

- Réalisation des flotteurs : mousse syntactique et peau polyuréthane



Energie / autonomi

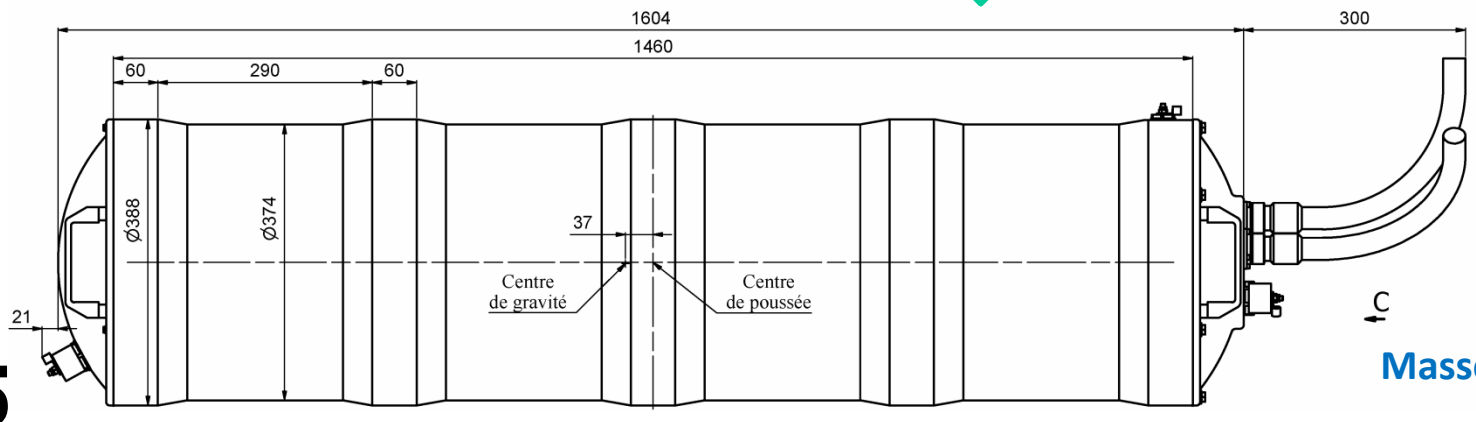
- Energie : 20kWh de batteries Li-ion
- 13kWh en 150V pour propulsion et l'éclairage
  - ✓ Une batterie Saft intégrée dans l'enceinte batterie
  - ✓ Masse batterie ~ 135kg
  - ✓ Longueur ~ 1,3m / diamètre ~ 310mm
- 6kWh en 48V pour l'électronique
  - ✓ 3 modules 2kWh AUV intégrés dans l'enceinte électronique



Type de mission	Estimation autonomie utile au fond (descente/remontée déduite)
Inspection locale - 0,5nd	7h à 12h
Travail au point fixe	8h à 12h
Survey à 1 nœud	5h à 10h
Survey à 1,5 nœud	3h à 4h
Survey à 2 nœuds	1h30 à 2h

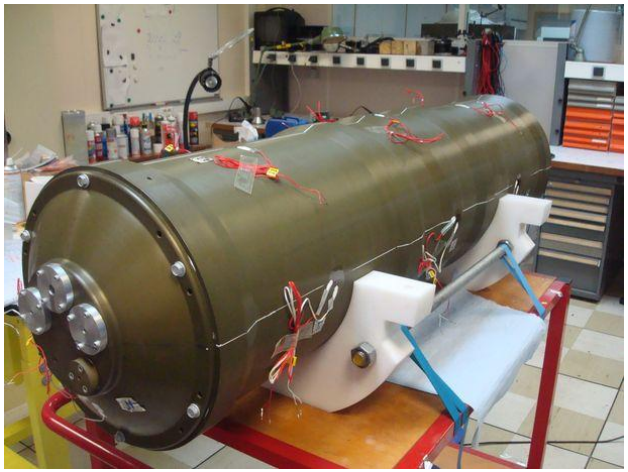
Enceinte batterie

- Intégration de la batterie 150V

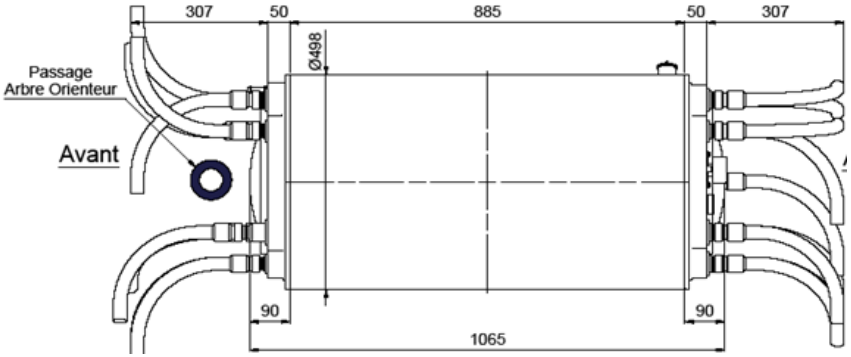


Masse ~ 250kg

- Aléa technique : non-tenue de l'enceinte batterie à la qualification en caisson

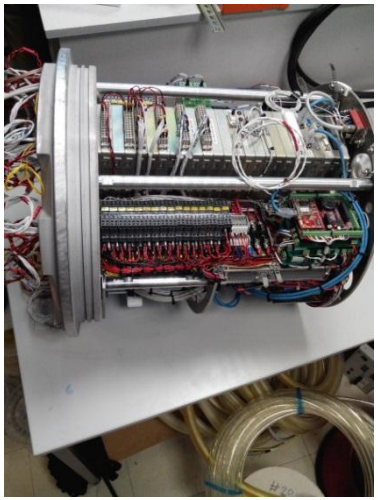


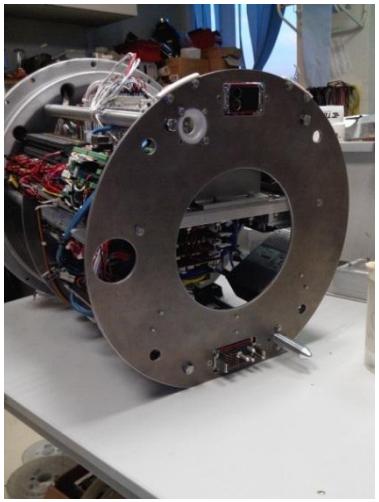
Enceinte électronique

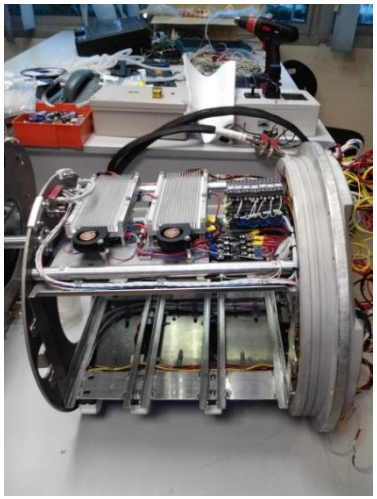


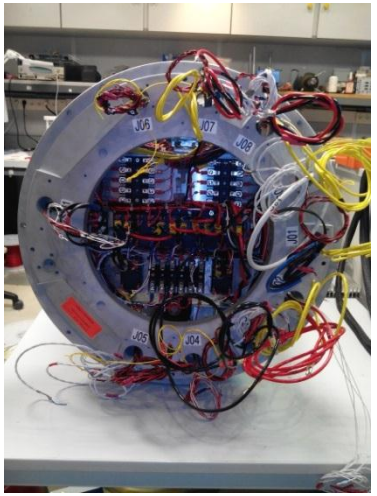
Masse ~ 160kg

- Intégration enceinte en 2 châssis pour faciliter les maintenances à bord :
  - ✓ Châssis puissance : Batteries 48V, relayage 150V pour actionneurs, génération alimentation pour éclairage, mesure TMS et régleur.
  - ✓ Châssis C/C : Calculateur, génération BT, relayage équipements, capteurs, hubs, télétransmission, gestion sécurité.



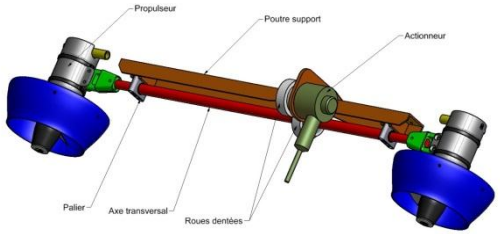


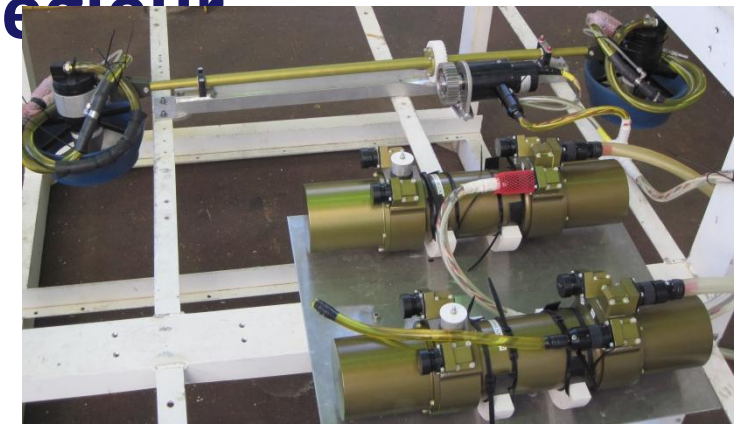




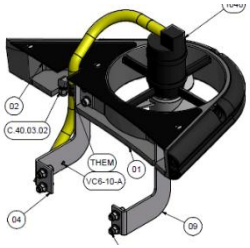
Propulsion & régleur

- La propulsion principale

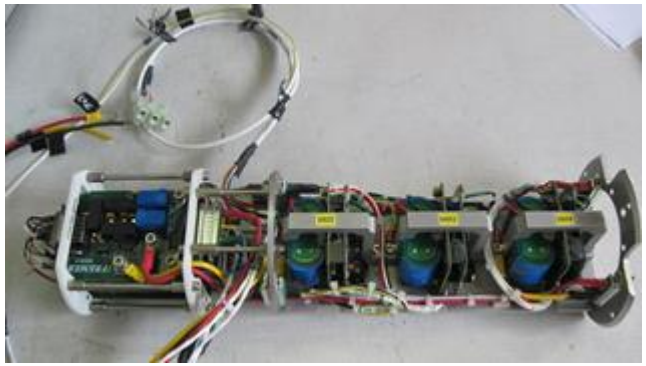




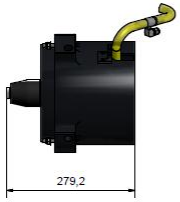
- Propulsion verticale

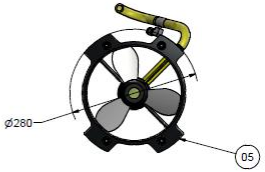


- Enceintes variateurs



- Propulsion transversale

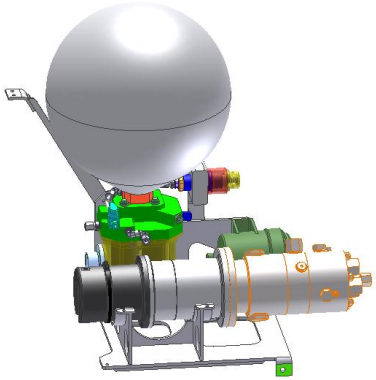




PROPULSEUR ARRIERE

- Régleur

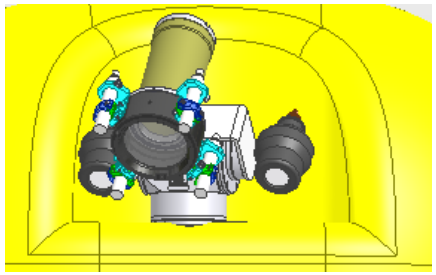
→ encore en cours d'étude



Caméra principale & éclairage

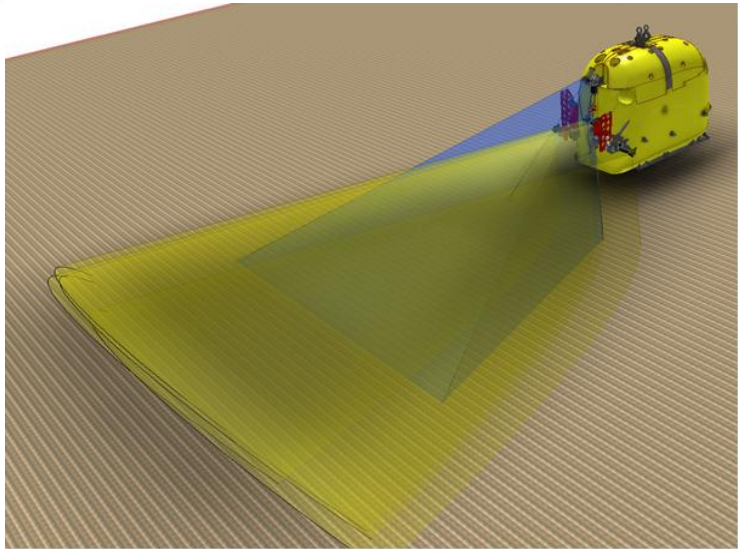
❖ Caméra principale sur Pan and tilt en partie haute du véhicule

- ✓ Choix d'une caméra HD haute sensibilité
- ✓ Intégration camera HD : Ifremer
- ✓ Intégration sur Pan&tilt Kongsberg



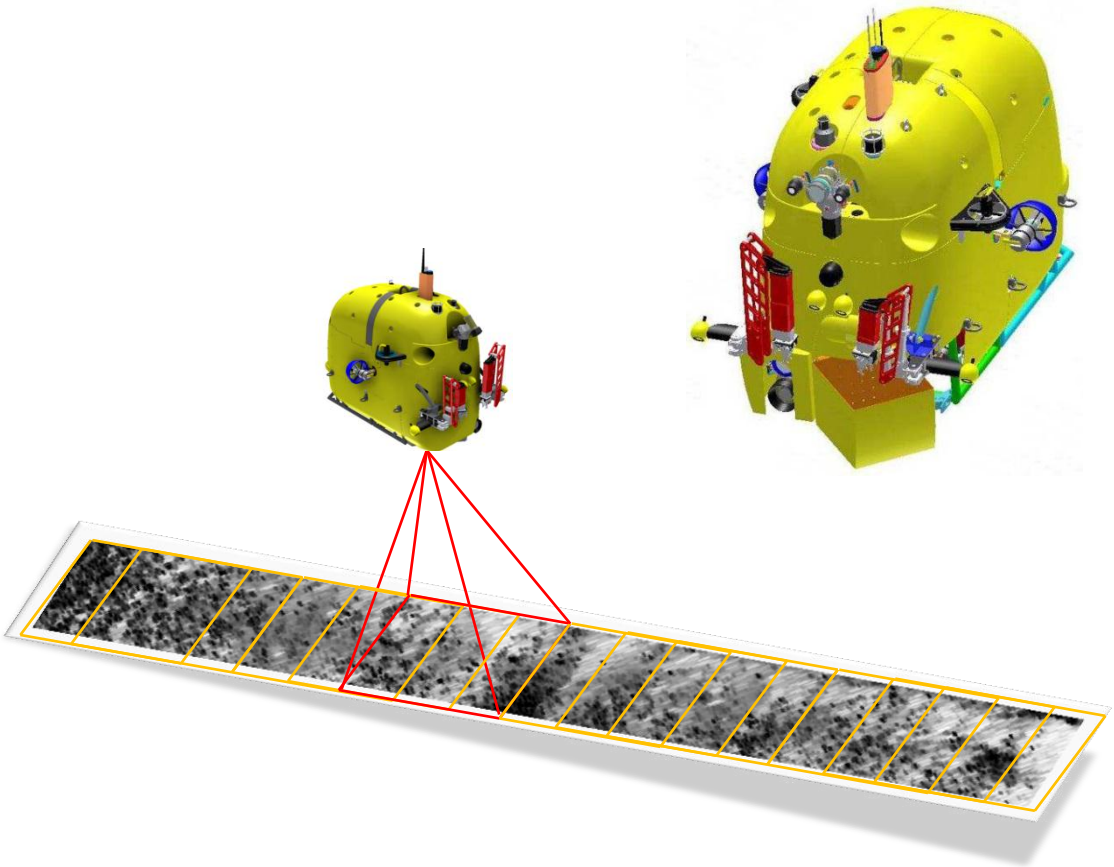
❖ Eclairage : 6 spots LED 150W

- ✓ 2 sur le pan&tilt
- ✓ 2 Au centre de la face avant
- ✓ 2 en partie basse
- ✓ Position réglable avant plongée



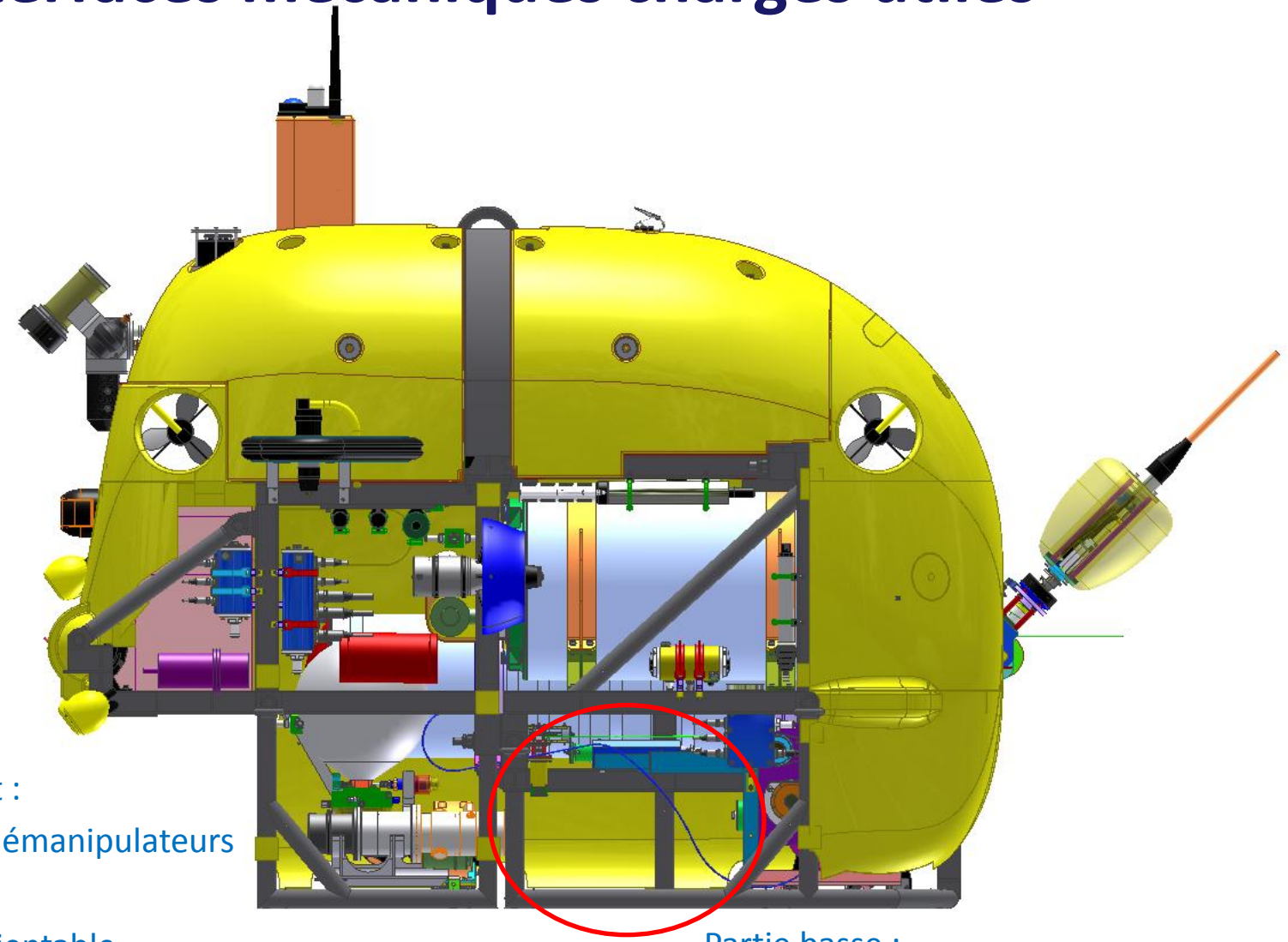
Ifremer

Ifremer



Les charges utiles

Interfaces mécaniques charges utiles



Zone avant :

- Bras télémanipulateurs
- Panier
- APN orientable
- SMF
- …

Partie basse :

- ADCP
- Aspirateur à faune
- …

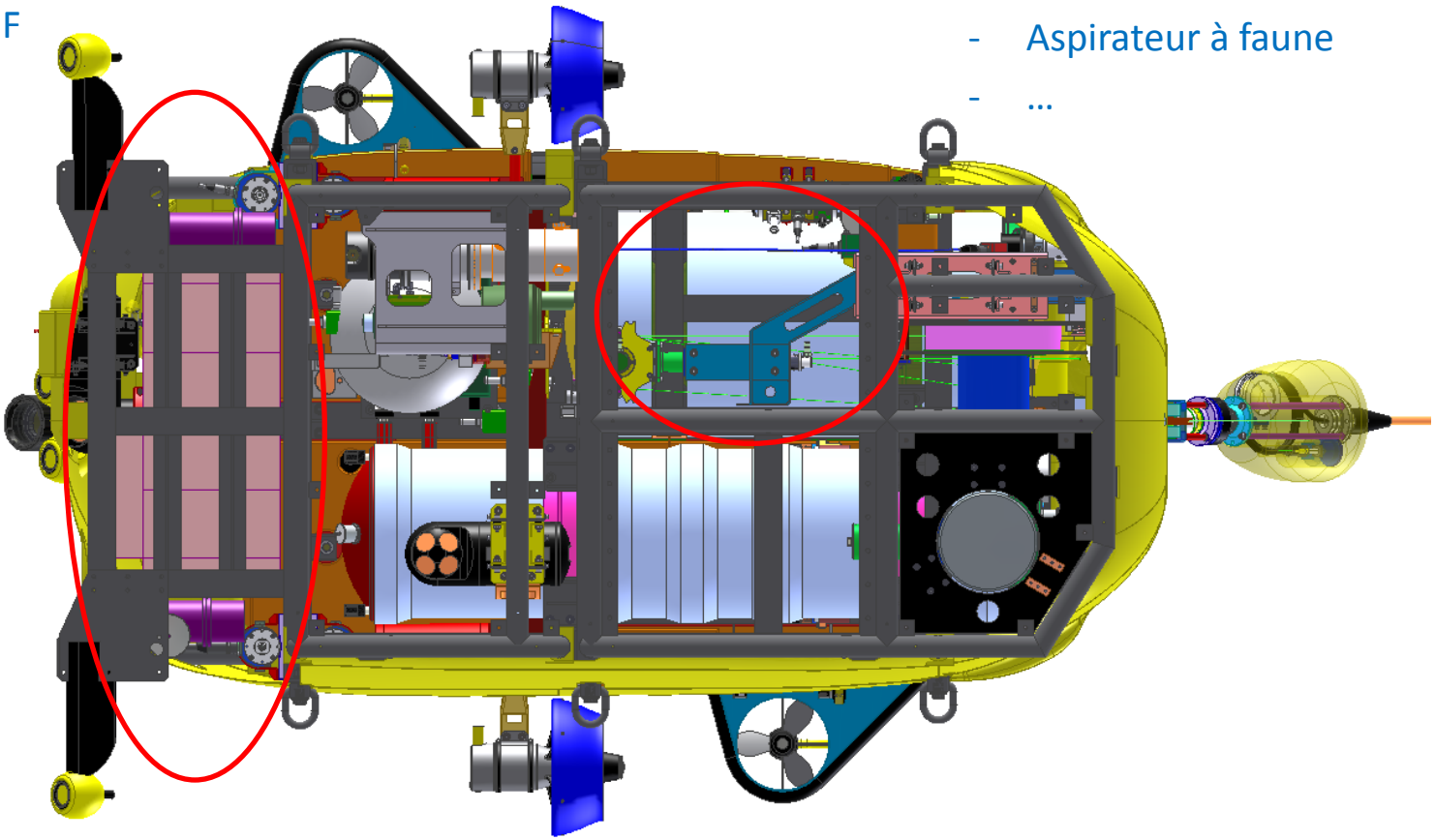
Interfaces mécaniques charges utiles

Zone avant :

- Bras télémanipulateurs
- Panier
- APN orientable
- SMF
- …

Partie basse :

- ADCP
- Aspirateur à faune
- …



Ifremer

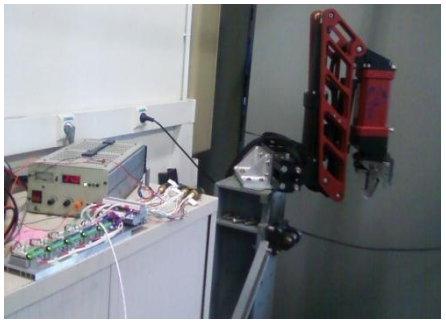
Interfaces électrique charges utiles

Interfaces disponibles	Charges utiles prévues	Inspection & Prélèvemt (bio)	Inspection & Prélèvemt (eau)	Intervention	Inspection	Cartographie optique	Cartographie acoustique
	MODE :	ROV	ROV	ROV	ROV	ROV AUV	ROV AUV
Alim 24Vdc+liaison CAN2	Télémanipulateurs	X	X	X			
Alim 24Vdc-70W & RS232 sur VCC	Panier	X	(X)	X			
	Autre équipement (ADCP, fluorimètre…)					(X)	(X)
Alim 24Vdc-70W & RS232 sur télétrans [1]	Autre équipement (ADCP, fluorimètre…)	(X)	(X)	(X)	(X)		
Alim 48V-300W + Ethernet + RS232 (calculateur) + RS232 (lien avec PHINS)	Aspirateur à faune	X					
	Préleveur d'eau		X				
	SMF						X
Alim 24Vdc-70W & RS232 sur VCC	Orienteur de charge utile (APN, camera)	X	X		X	X	(X)
Alim 12V + HD-SDI+RS232 sur télétrans [1]	Video HD (verticale)	X	X	X	X		
24V + Ethernet	APN sur orienteur	X	X		X	X	(X)

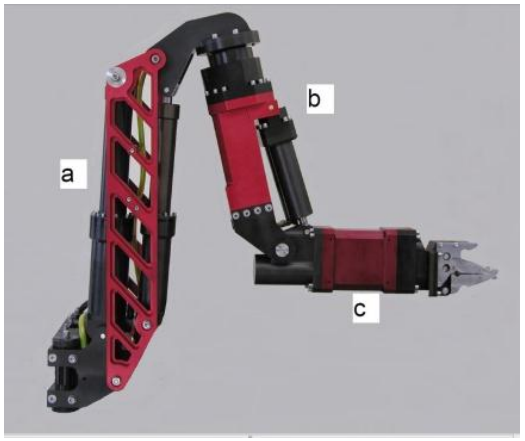
[1] Utilisable uniquement en mode ROV

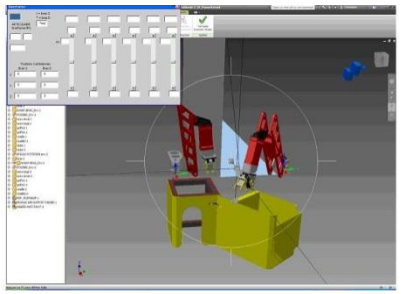
La télémanipulation

- Innovation : utilisation de bras électriques
  - ☺ Faible consommation
  - ☹ Capacité plus faible (par rapport aux bras VICTOR6000) mais cohérente avec les besoins HROV

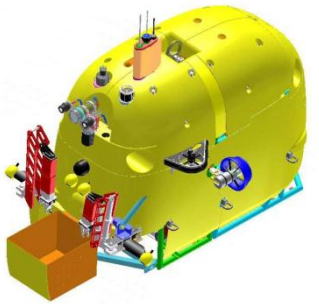


- Architecture de télémanipulation :
  - ✓ <u>Bras annexe 5 degrés de liberté</u> :
    - Saisie d'objet, clampage, reprise d'outils, …
    - Produit sur étagère
    - Pilotage articulaire ou pseudo-cartésien
  - ✓ <u>Bras dextre 7 degrés de liberté</u> :
    - Manipulation dextre
    - En cours de développement
    - Pilotage articulaire ou cartésien
  - ✓ Validation des positions et des cinématiques par simulation

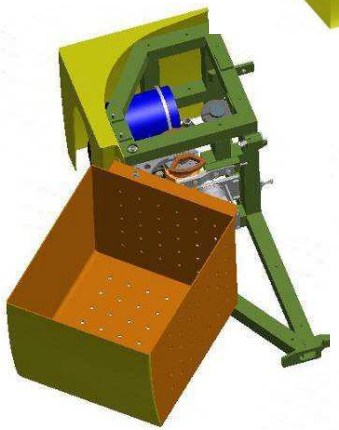


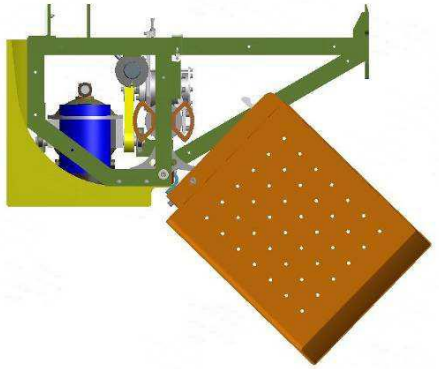


Le prélèvemer

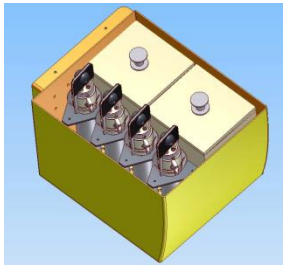


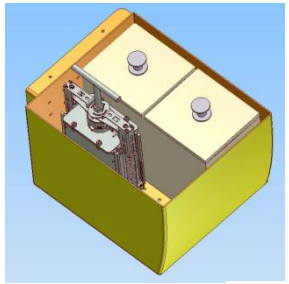
- Skid de prélèvement :
  - ✓ Panier rotatif
  - ✓ Charge utile optique (APN orientable)





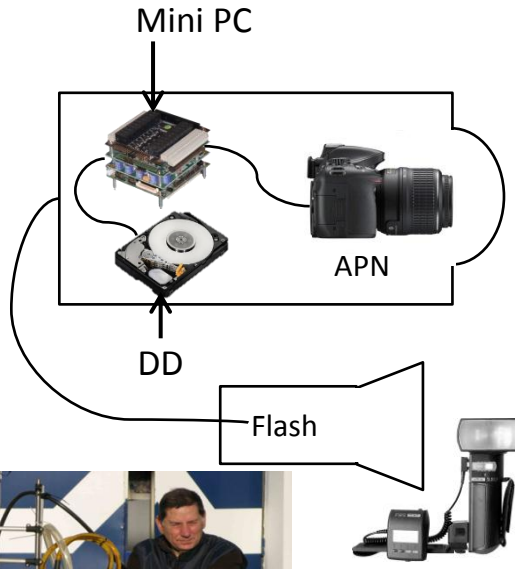
- Le panier :
  - ✓ Hauteur : 42.0 cm
  - ✓ Longueur : 53.5 cm
  - ✓ Largeur : 47.2 cm
  - ✓ Volume : 105 litres
  - ✓ Capacité d'emport : 25kg dans l'air / 12kg dans l'eau
  - ✓ Capacité de prise d'échantillon : ~ 10 kg dans l'eau (régleur : 20 litre)



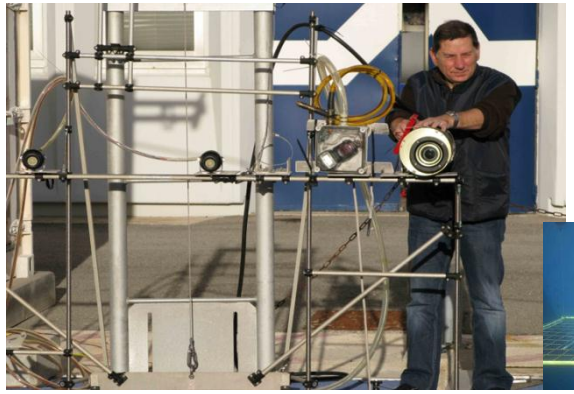


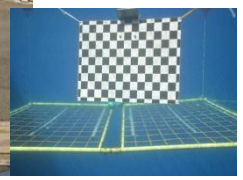
- Les outillages de prélèvement
  - ✓ Carottiers tube
  - ✓ Boites de prélèvement
  - ✓ Carottier lame
  - ✓ Aspirateur à faune (objectif) :
    - ✓ 6 bols (H=210mm max; Di=112mmm)
    - ✓ Motorisation électrique avec variation du débit d'aspiration
    - ✓ Diamètre d'aspiration = 50-54 mm

Charge utile optique : APN

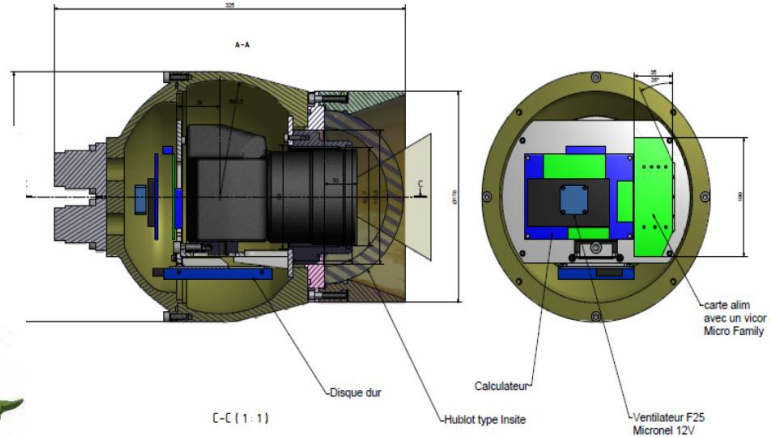


- **Matériels retenus**
  - ✓ APN : Nikon D5100
  - ✓ Calculateur embarqué pour le pilotage et la communication
  - ✓ Disque dur interne
  - ✓ Correcteur
  - ✓ Flash synchronisé : Flash Metz 200 Joules

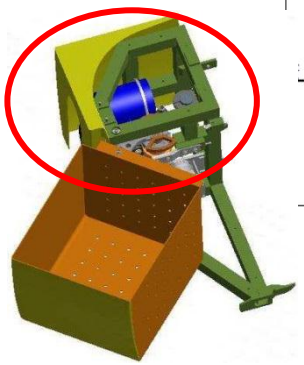




- **Intégration de l'APN**
  - ✓ Hublot plan ou sphérique ?
    essai en bassin → hublot sphérique retenu
  - ✓ Intégration dans une sphère
    Optimisation du volume et de la masse
    Forte modularité des éléments



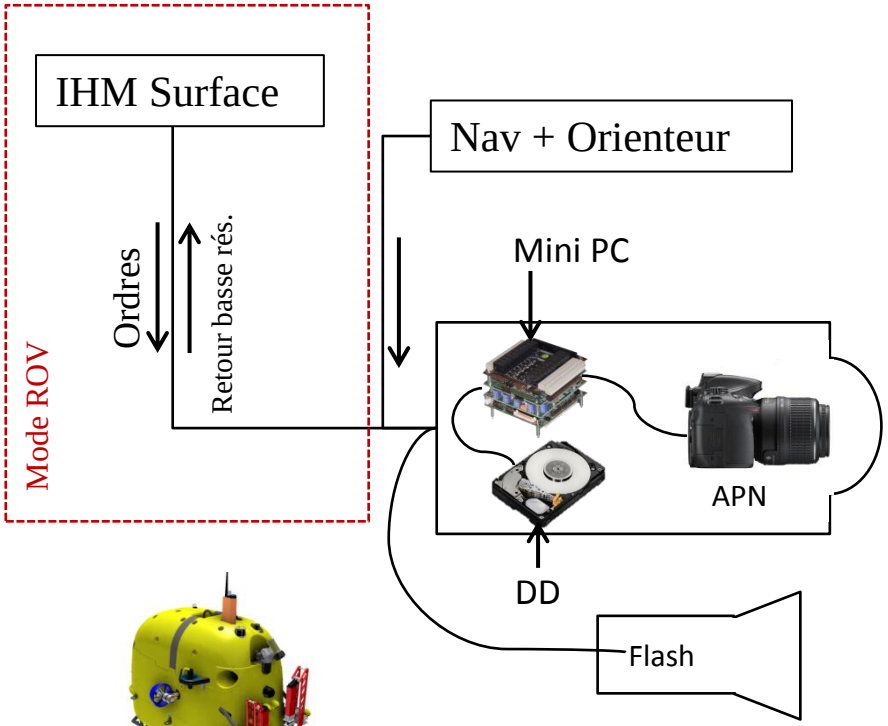
- **Intégration sur véhicule**
  - ✓ intégré au skid de prélèvement
  - ✓ APN orientable vertical/frontal

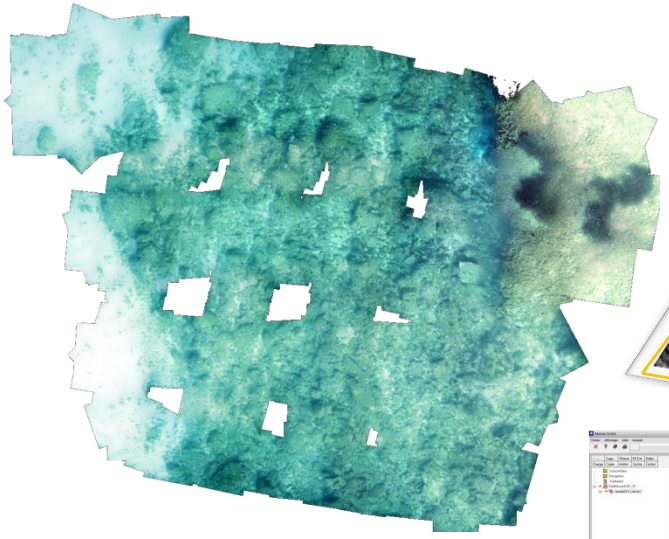


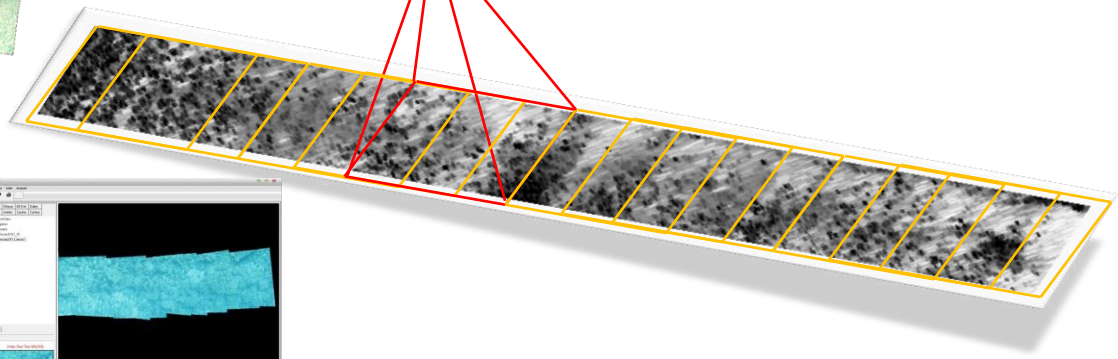
→ Permet d'orienter l'APN par rapport au fond (ortho-photo)

Charge utile optique : fonctionnalités de l'APN

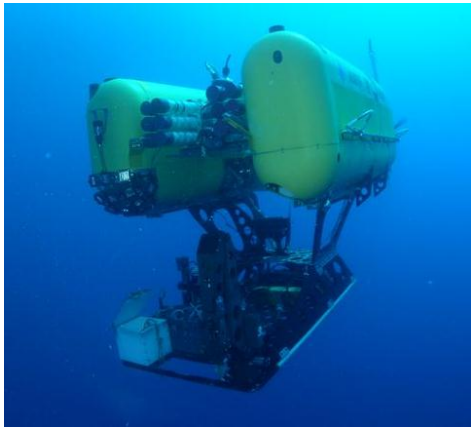
- **Mode ROV**
  - ✓ IHM de contrôle en surface
  - ✓ Photos disponibles en surface
  - ✓ Retour vidéo
- **Mode AUV**
  - ✓ Enregistrement au fond
  - ✓ Gestion autonome
- **Mosaïque 2D**







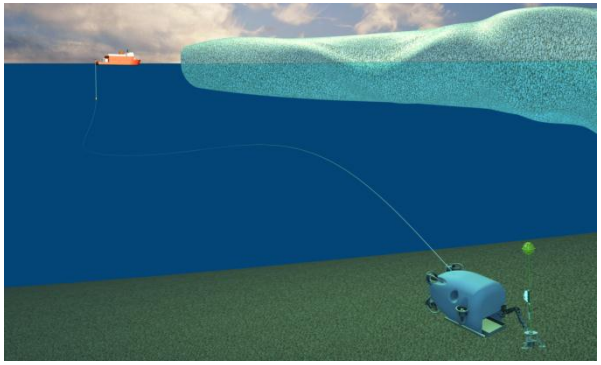
The HROV, an innovation of Ifremer ?

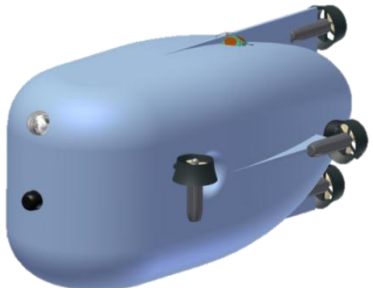


NEREUS (WHOI)

built : 2009

11000m depth rating - dive to bottom in Marianna Trench





NEREID-UI (WHOI)

In development

Objective : 20km under the ice (horizontal)

HROV (MARUM)

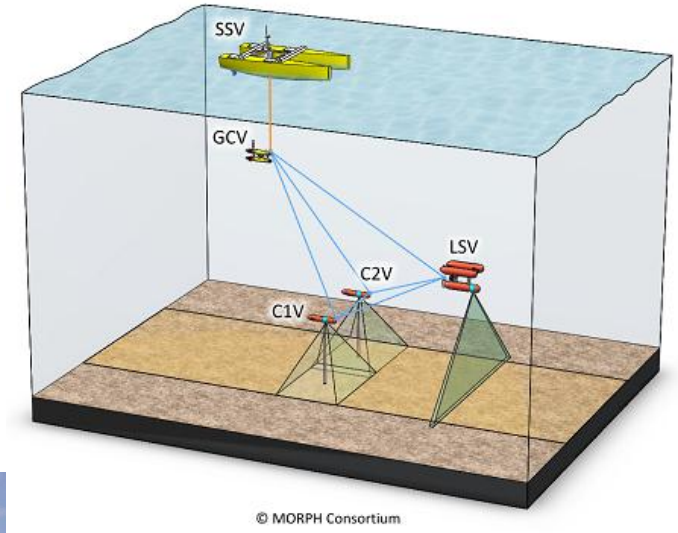
In development

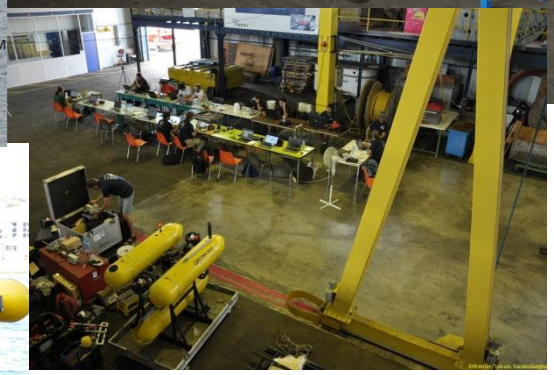
Objective : intervention – sampling under the ice

➔The HROV concept is initiated in the oceanographic community

Ifremer

Robotics sciences : the Morph project



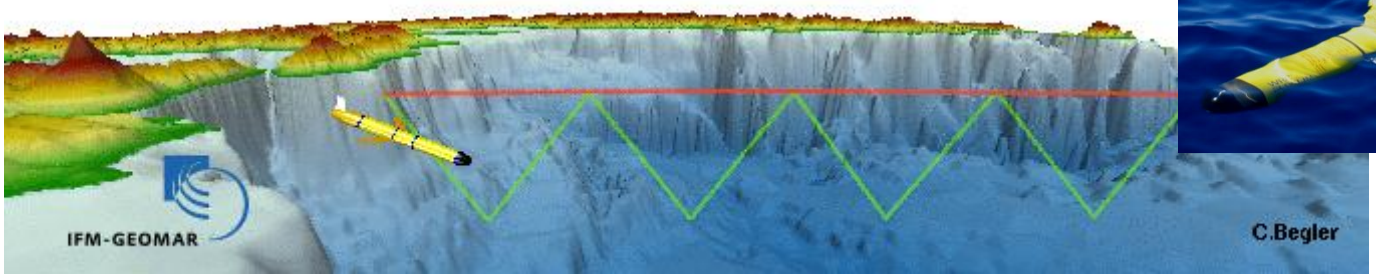


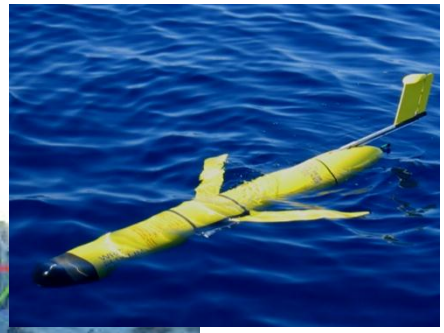
Present groundstation for a single glider

Data Center
(Coriolis, GTS, …)

Operational model
(MERCATOR, MFS, …)

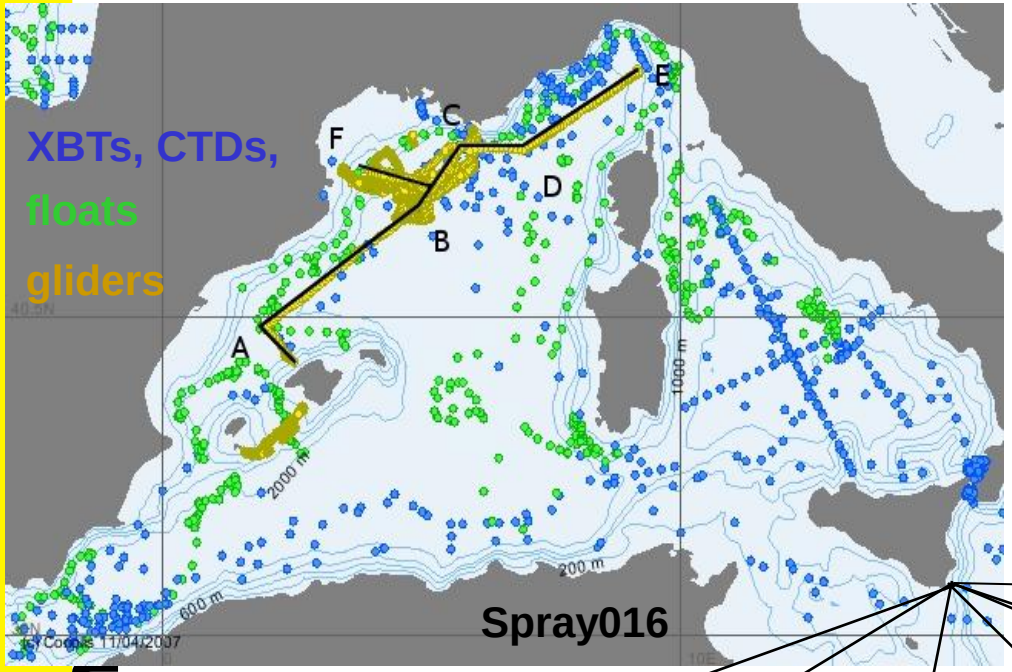
Groundstation (dockserver, Kermit, mail, …)





- Steering : partially automated (equivalent to what the WRC dockserver is doing)+alarms
- Ploting NRT data : completely automated but fixed format for plots
- Forecasting of the trajectories : completely automated with the daily updated waypoint
- Saving to Coriolis DC : automated

North Western Mediterranean Sea Observatiory in winter-spring 2007

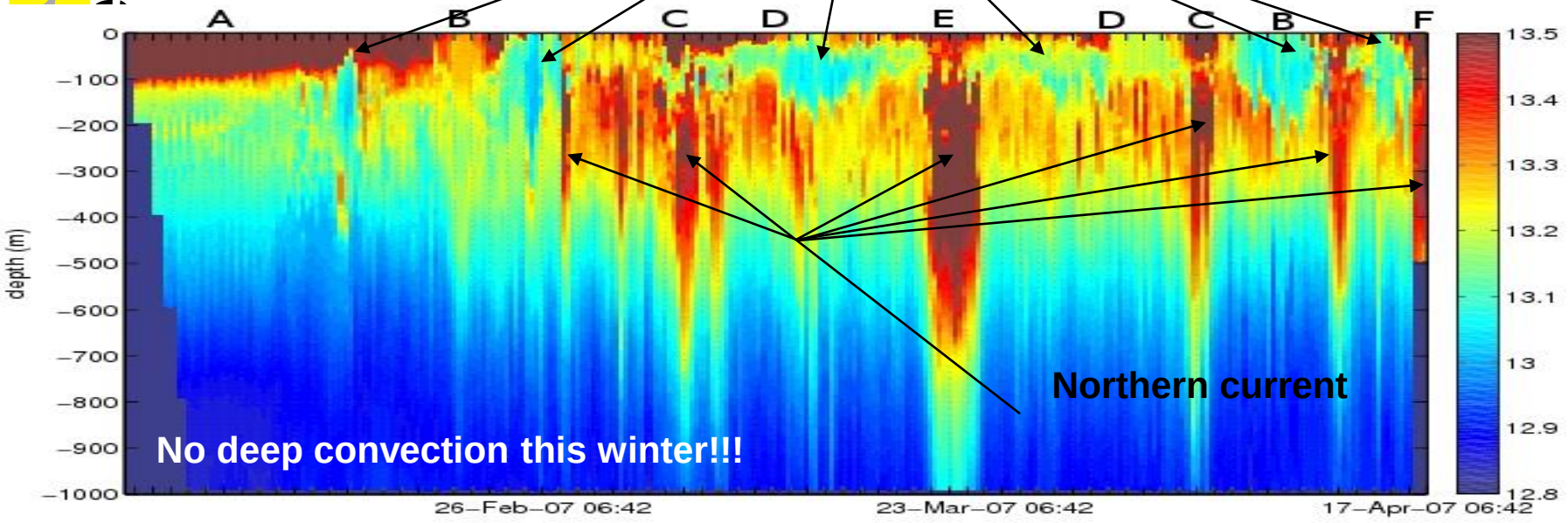


7 gliders
6 gliders simultaneously
From December 2006 to June 2007

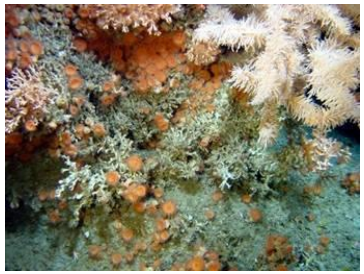
~3200 profiles
(200m and 1000m depth)

Large, meso, and small scale processes

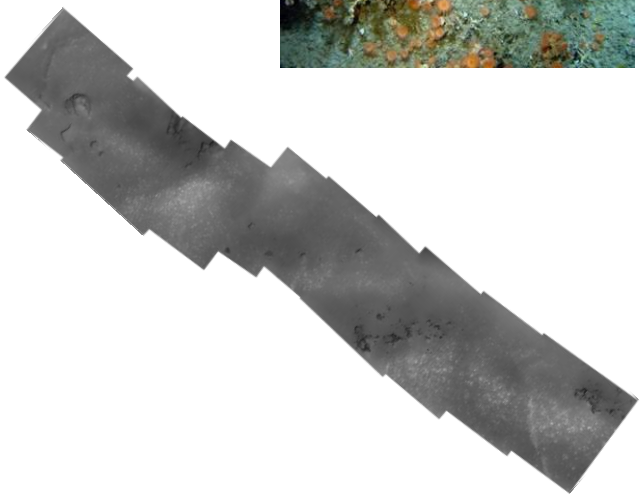
Winter mixing, subduction



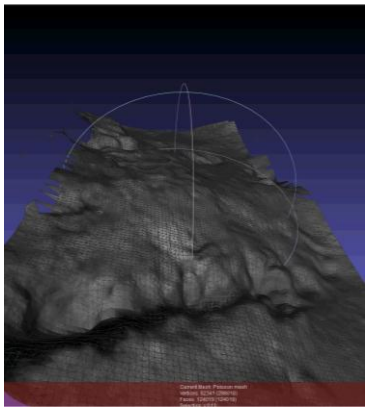
Underwater optical image processing



Goals



- High quality geo-referenced images
- Quantitative image interpretation
- Metric information from images
- Optical mapping (2D)
- Object reconstruction / optical mapping (3D)
- Automated feature detection / machine learning



Ifremer