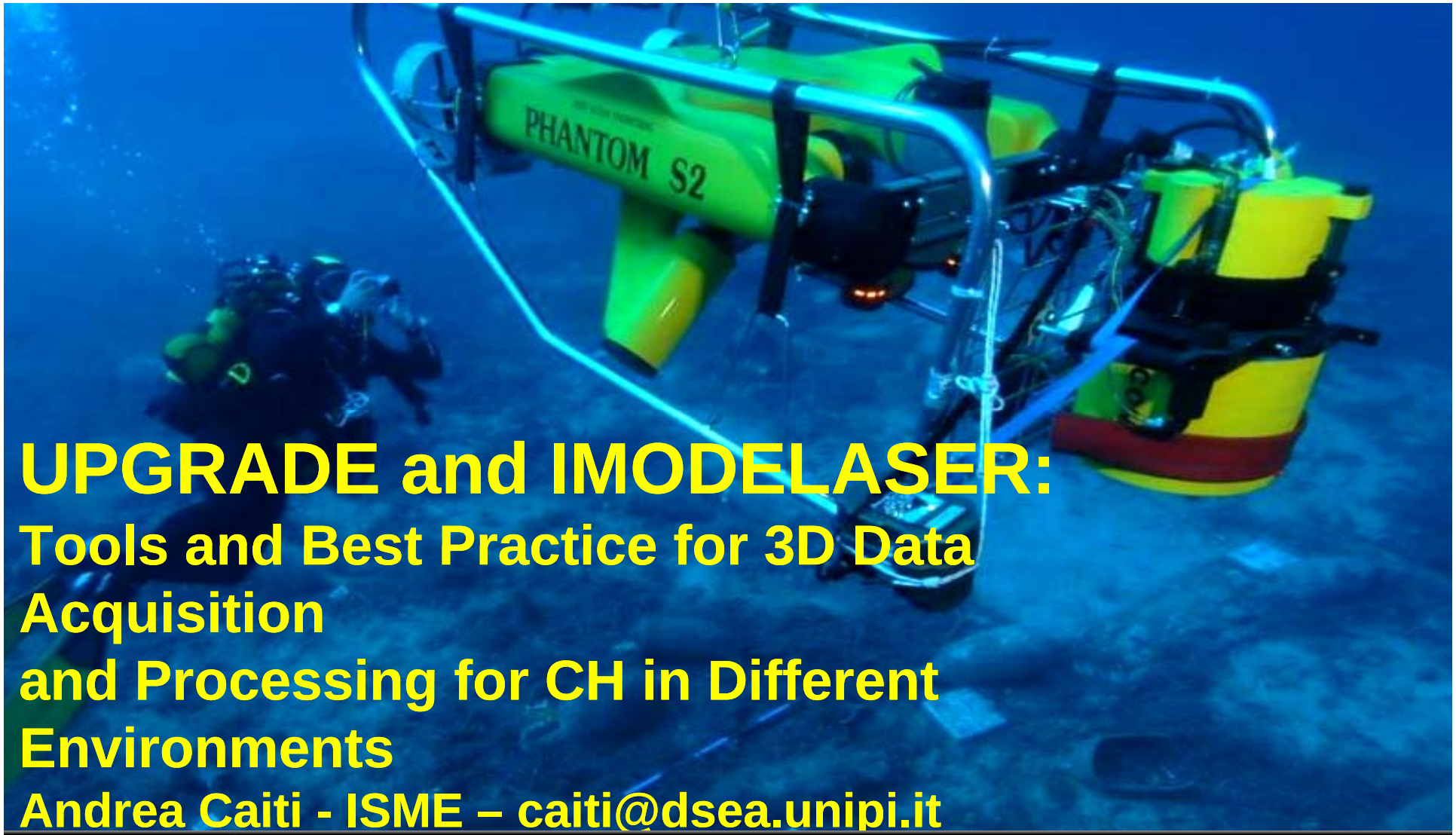



# UPGRADE and IMODELASER:

## Tools and Best Practice for 3D Data Acquisition and Processing for CH in Different Environments

Andrea Caiti - ISME – caiti@dsea.unipi.it

EPOCH

THE EUROPEAN RESEARCH NETWORK OF EXCELLENCE IN OPEN CULTURAL HERITAGE

# UPGRADE and IMODELASER

Tools and Best Practice for 3D Data Acquisition
and Processing for CH in Different Environments

Acquisition and processing of 3D data for CH documentation

3D models as a mean for visualization and presentation of artefacts, but also:
- a form of digital preservation
- a basis for archaeological and/or architectural analysis.

NEW TOols Needed: IMODELASER and UPGRADE
practices and tools for efficient data gathering and 3D documentation.

***IMODELASER:*** optimization of terrestrial image-based 3D modelling by means of integrating laser scan data with close-range photogrammetry: from data capture to outlier filtering to edge-preserving 3D models

***UPGRADE:*** towards widely automated underwater archaeological surveys: integration of optical, acoustical and navigation data

# IMODELASER

## Combining photogrammetry and terrestrial laser scanning for high quality 3D modelling

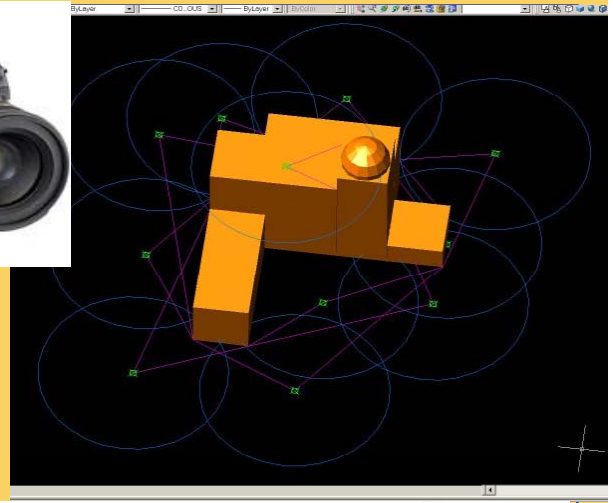
ETH Zurich - Chair of Photogrammetry & Remote Sensing
*A. Gruen, S. Sotoodeh, D. Novak, M. Sauerbier*

***Goal:***
Combine the advantages of laser scanning (high point density) and close range photogrammetry (high accuracy edge modelling) to overcome the specific weaknesses of both technologies

Case Study: ETH Sternwarte by G. Semper (Observatory), 1861 – 1864

# IMODELASER

## Field equipment

***Imaging:***

Camera

- Nikon D2XS, 12 MP, 5.5 um pixel size
- Average distance to object = 15m
- Lens focal distance = 18mm
- Expected RMSE in object space = 2.75 mm

***Laser scanning***

Scanner

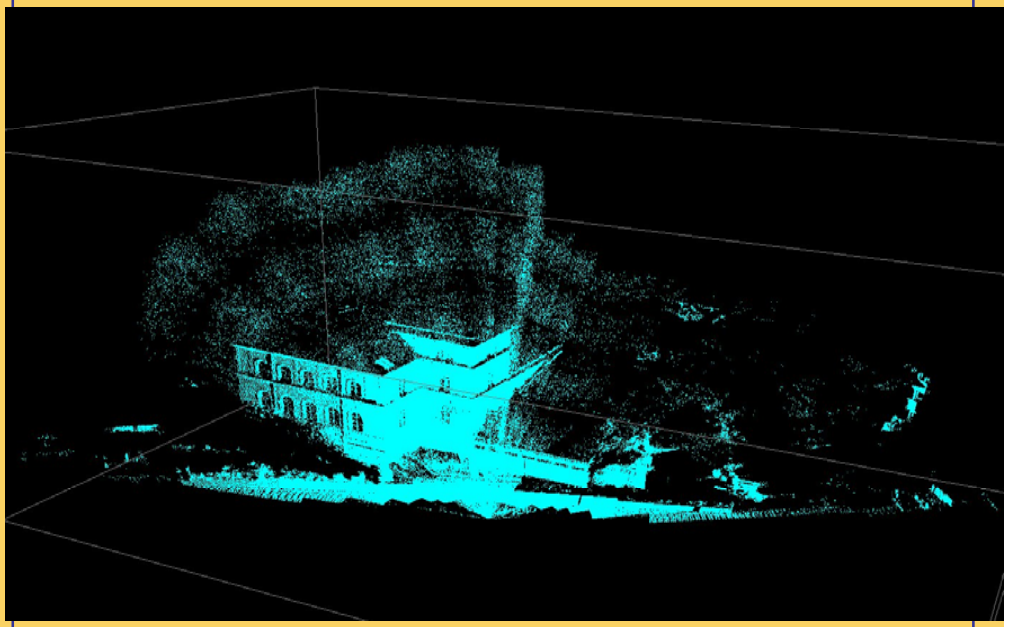
- Faro, Laser Scanner LS
- Distance: 70m
- Linearity Error: 3 mm at 10 m
- Vertical Field of View: 320°
- Horizontal Field of View: 360°
- 10 scanning positions, Point space in object space = 3 mm

# IMODELASER

## HOD (Hierarchical Outlier Detection)

Clusters a point cloud and detects outlier clusters using proximity graphs (EMST, Gabriel Graph) in two phases:

- the first phase copes with large scale outliers
- the second phase tackles small scale outliers
- the final result is the cleaned point cloud out of outliers, also clustered
- Inputs: 3D point clouds (XYZ)
- Output: Clustered/cleaned point cloud



# IMODELASER

## HOD (Hierarchical Outlier Detection)


Original point cloud

Clean point cloud

Clean point cloud

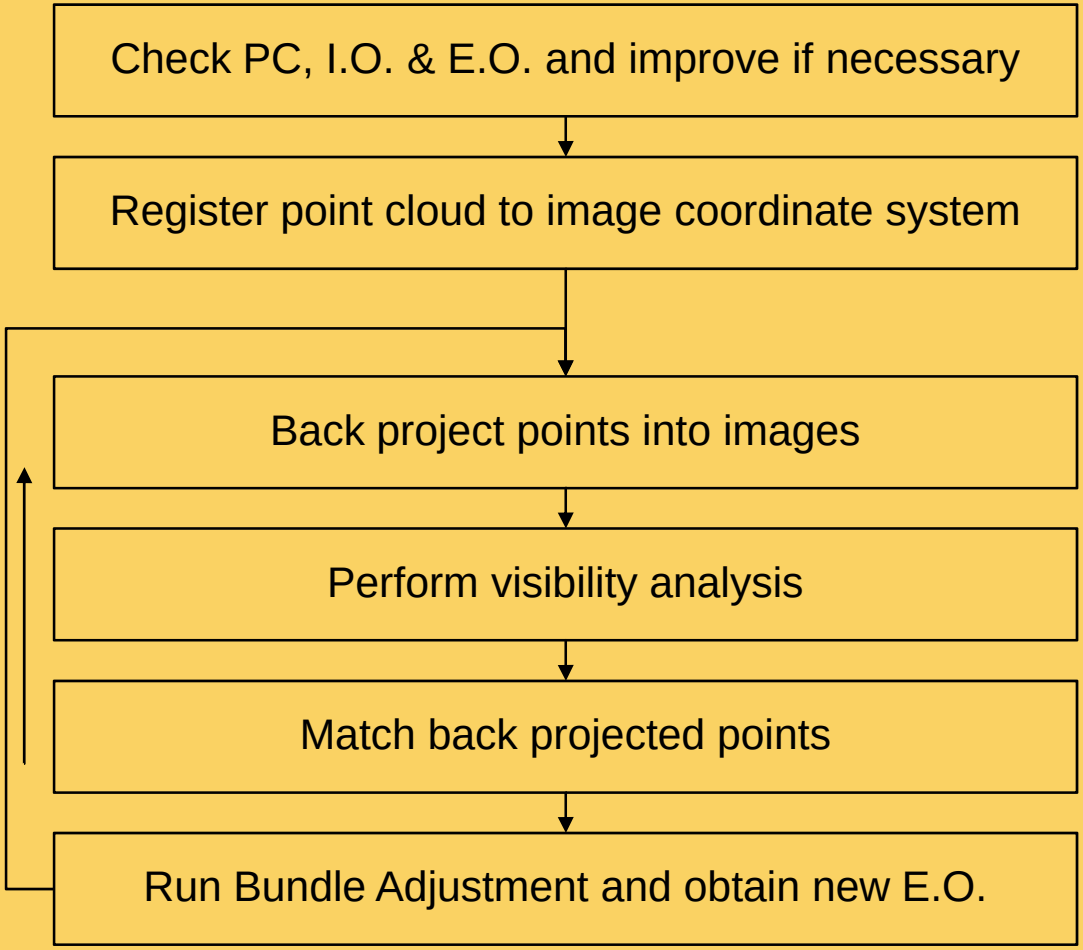
# IMODELASER

## Orientation of images with respect to a point cloud system

Precisely oriented images allow for special processing of point clouds:

- Edge constraint triangulation
- Blunder detection and removal
- Precise parameters for texture mapping

This leads to an overall improved representation of the 3D model.
An iterative, semi-automatic work flow is suggested.



# IMODELASER

## Work flow

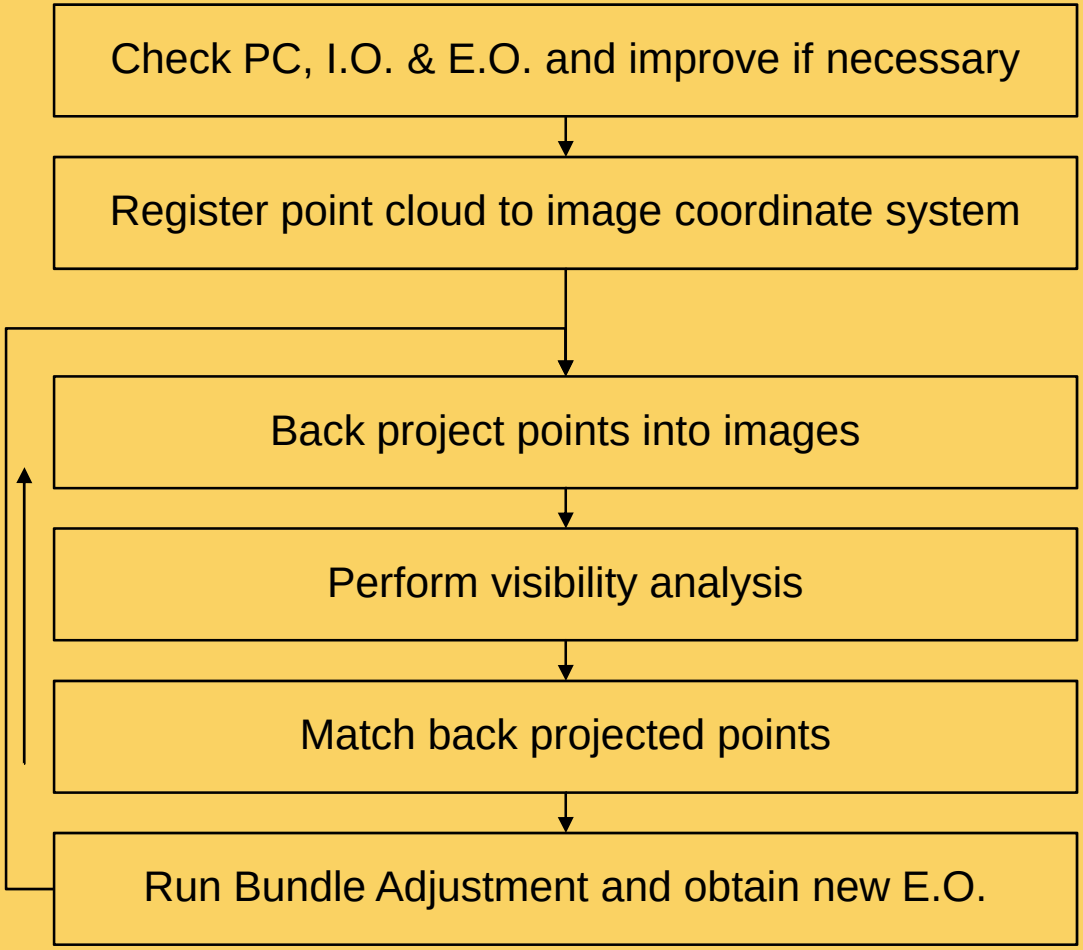
***Back projection***
Projection of 3D points back into the images

***Visibility analysis***
Removal of occluded points to decrease mismatch, computation

***Matching***
Match homologous, back projected points in images

***Bundle adjustment***
To acquire refined orientation parameters

***Iterate until satisfactory***



# IMODELASER

## Results – Visibility Analysis and Matching

# IMODELASER

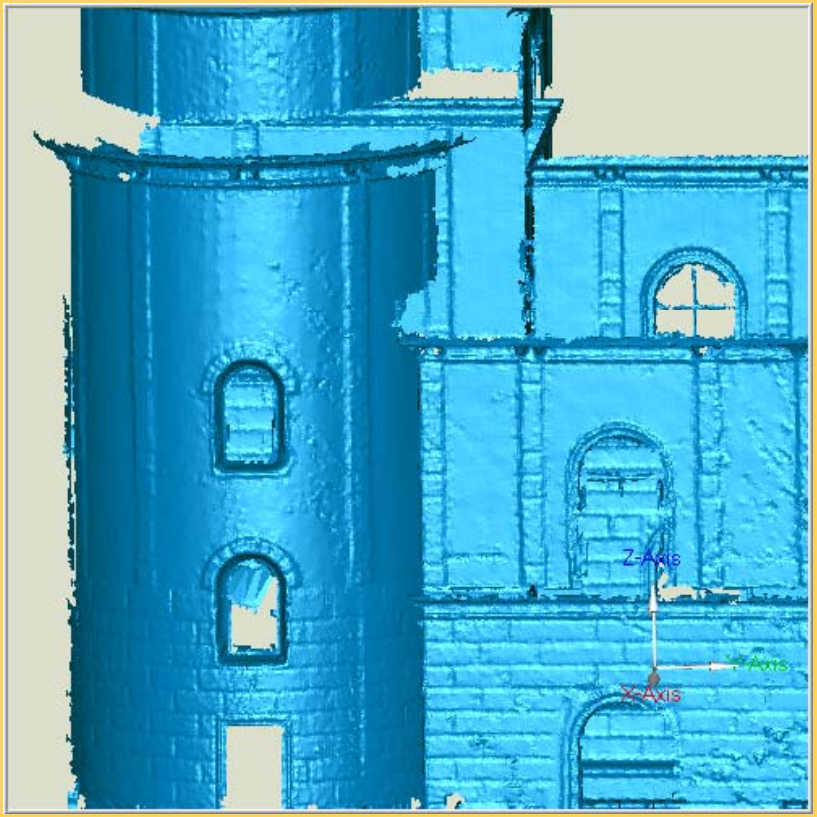
## Results – Bundle adjustments

# IMODELASER

## 3D Surface Reconstruction tool

***Constructs a 3D surface out of a point cloud***

- Using proximity graphs (EMST, Gabriel Graph, KNN)
- 3D Delaunay triangulation followed by sculpturing
- Inputs: 3D point clouds (XYZ)
- Output: surface triangles in OFF format



# IMODELASER

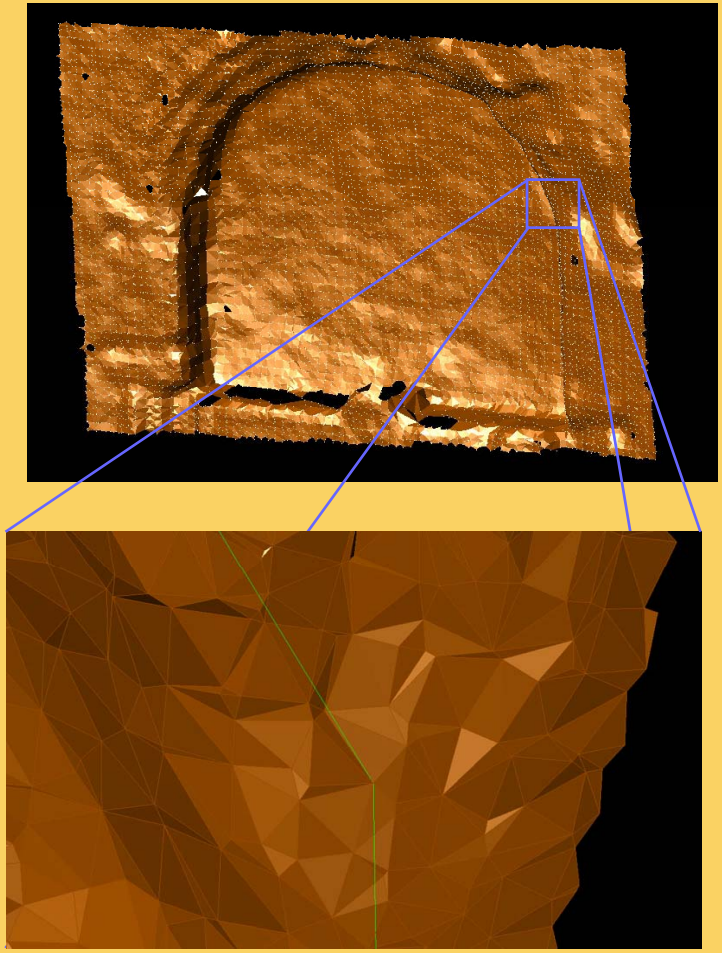
## 3D Edge-Constrained Surface Reconstruction tool

***Constructs a 3D surface out of a point cloud and includes edge information***

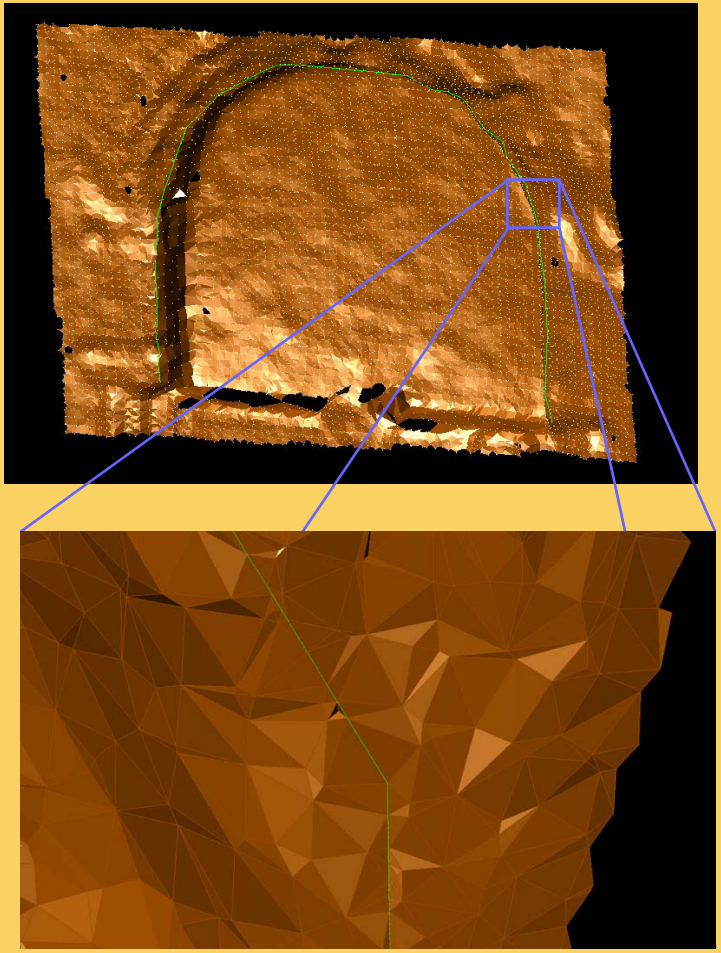
- Using proximity graphs (EMST, Gabriel Graph, KNN) while respecting the defined 3D edges
- 3D edge-constrained Delaunay triangulation followed by constrained sculpturing
- Inputs: 3D point clouds (XYZ) + 3D edge file (OFF format)
- Output: surface triangles in OFF format

# IMODELASER

## Influence of edge constraints in the surface reconstruction



Before using the edge constraint
(the edges is just overlaid)



After using the edge constraint

**Green line** is an edge constraint

# IMODELASER

## Availability and contacts

***Services:***

- "How-To" instructions for data acquisition, required data formats and introduction into the methodology in our labs.
- Processing of data by our staff and partly by clients (e.g. point measurements, image orientation) or by clients themselves.

***Series of Tools*** (surface reconstruction, hole filling) which run under Linux, available as Open Source; Point Measurement has to be performed using external software (e.g. Photomodeler (commercial) or others (OS))

***Data Formats:***

*Import*: Point Clouds (XYZ, OFF), others possible after conversion
*Export*: VRML, COLLADA

***Contact:*** *Martin Sauerbier*, Institute of Geodesy and Photogrammetry
Wolfgang-Pauli-Strasse 15 CH-8093 Zurich
martin.sauerbier@geod.baug.ethz.ch

# UPGRADE

## Equipments and data management tools for underwater archaeology

Underwater PhotoGRammetry and Archaeological Data Enhancement - UPGRADE

## Partnership

Ciencia Viva, PORTUGAL
CNRS - UMR 694 - MAP GAMSAU, Ecole d'Architecture de Marseille, FRANCE
DRASSM – Département des Recherches Archéologiques Subaquatiques et Sous-Marines, FRANCE
IST - Instituto Superior Técnico, PORTUGAL
ISME - Interuniversity Ctr. Integrated Systems for the Marine Environment, ITALY
SIMVIS - University of Hull – Simulation and Visualization Research Group, Hull, UK
UIBK - Institute of Geodesy, University of Innsbruck, Innsbruck, AUSTRIA

# UPGRADE

## Objectives

Development of a software suite, together with a set of best practice recommendations, for the *integration and fusion of acoustical, optical and platform navigation data* in the exploration and mapping of underwater archaeological sites.

Automatization of the data fusion  process

Construction of integrated, geo-referenced, large-to-medium 3-D scale maps of underwater archaeological areas from optical and acoustic data.

***Bring the data collection process in the underwater field closer to the standards already reached by land archaeology***

# UPGRADE

## Specific items

- accurate navigation of underwater platforms with affordable sensors;
- underwater images automated photogrammetry with environmental disturbances;
- estimation of camera parameters and adaptation of standard calibration software to the underwater case;
- integration of Digital Terrain Models (DTM) at different resolution scale with 3-D information from photogrammetric data;
- compatibility of DTM+photogrammetry with archaeologically oriented metadata;
- compatibility of DTM+photogrammetry with 3-D Virtual/Augmented reality systems, with particular attention to requirements in the education and learning sector and to standards supported or indicated within EPOCH.

# UPGRADE

## Data format and data flow

Definition of EXIF and XML formats to describe navigation data and camera parameters

Software tools and a specific protocol to associate (in EXIF/XML format) navigation data to images taken by digital cameras or videocameras mounted on underwater vehicles

Automatic data conversion from EXIF/XML to XML, and/or X3D, employing the software Arpenteur, a photogrammetric model and a Photomodeler project

Software tools to generate automatically a 3D VRML script to show the camera position and the projection of photographs onto an approximated model of the seabed

Techniques for constructing realistic immersive visualizations of underwater sites, using state-of-the-art computer graphics facilities, have been investigated, starting from the analysis of available material (pictures, videos)

# UPGRADE

## ROV-generated integrated data

Video Stream

Optical Image (JPEG)

Telemetry DATA (EXIF area)

Seabed image

| | | |
|---|---|---|
| x | = | 5 |
| y | = | 4 |
| dist | = | 3 |
| z | = | 3 |
| yaw, pitch, roll | | |
| RPM | = | 0 |
| sonar ping | = | |
| z scout = | | 2 |
| scout data | = | |

x = UTM32 east coordinate (meter) of ROV position
y = UTM32 north coordinate (meter) of ROV position
dist = seabed distance (meter) from ROV position
z = depth (meter) of ROV
yaw, pitch, roll = yaw, pitch and roll angle (degree) of ROV
RPS = thrusters RPS related to the ROV
sonar ping = sonar data
z scout = depth (meter) computed by the usbl related to ROV position
scout data = full data scout related to ROV position

# UPGRADE

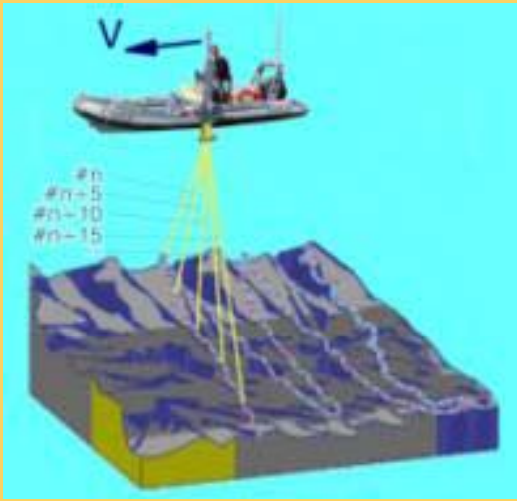
## Acoustic-based underwater map construction

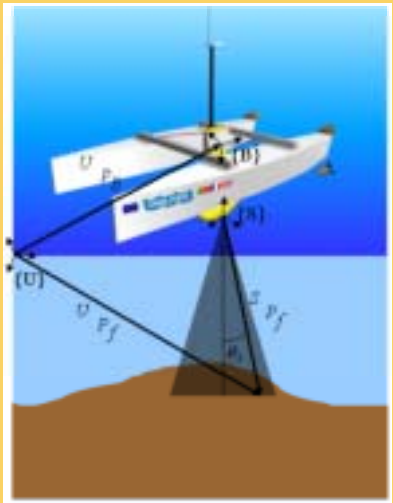
A set of terrain map generation tools for archaeological surveys

Hardware: test of mechanically scanned pencil beam sonar (shallow water) and single beam echosounders, to be installed on autonomous vehicles or on manned surface vehicles

Acoustic data integrated with navigation: GPS with RTK, attitude reference unit

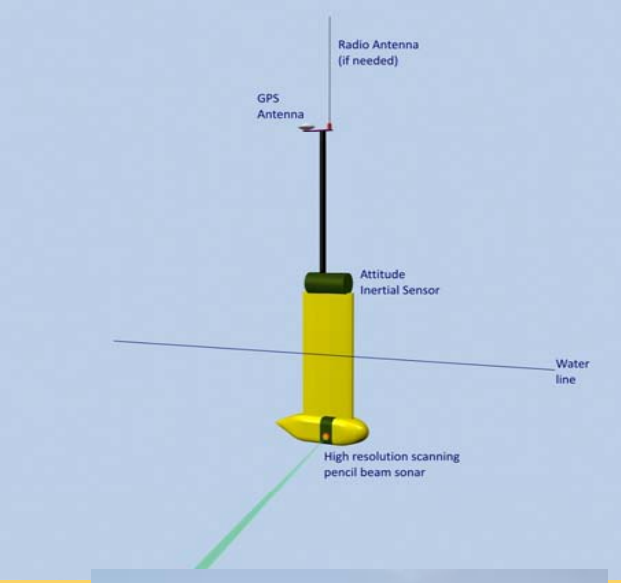
Software for data acquisition and processing (including outlier detection and geo-referencing) and map construction.



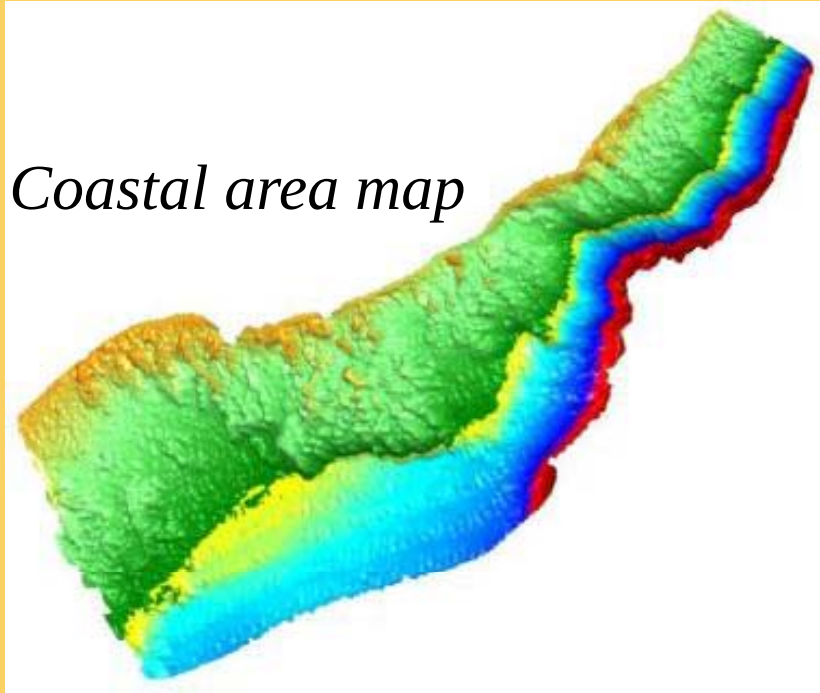



# UPGRADE

## Terrain-map generation: a case study



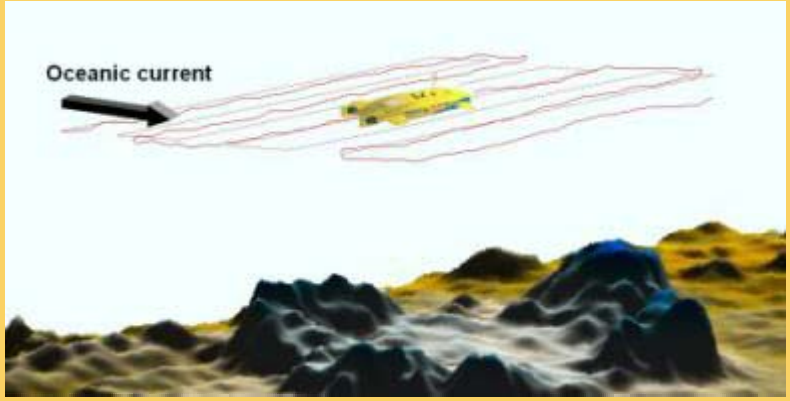

From tools to Terrain Map



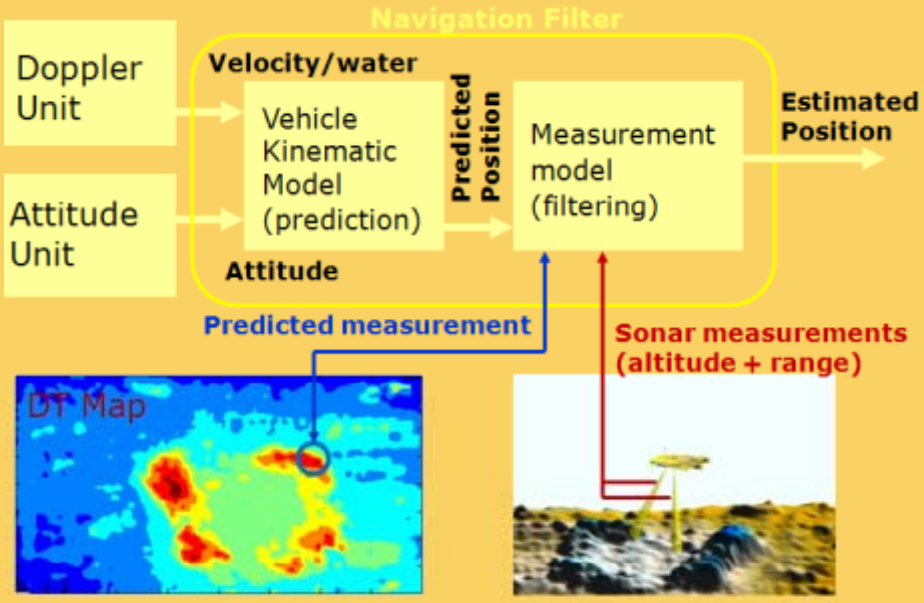
# UPGRADE

## Terrain-based navigation

Development of algorithms and software for terrain-based navigation systems that can exploit the availability of existing digital terrain maps to accurately position a platform underwater. Algorithms were assessed in simulation.



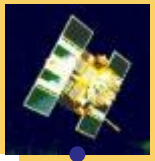

***Using terrain information as a Navigation Aid***

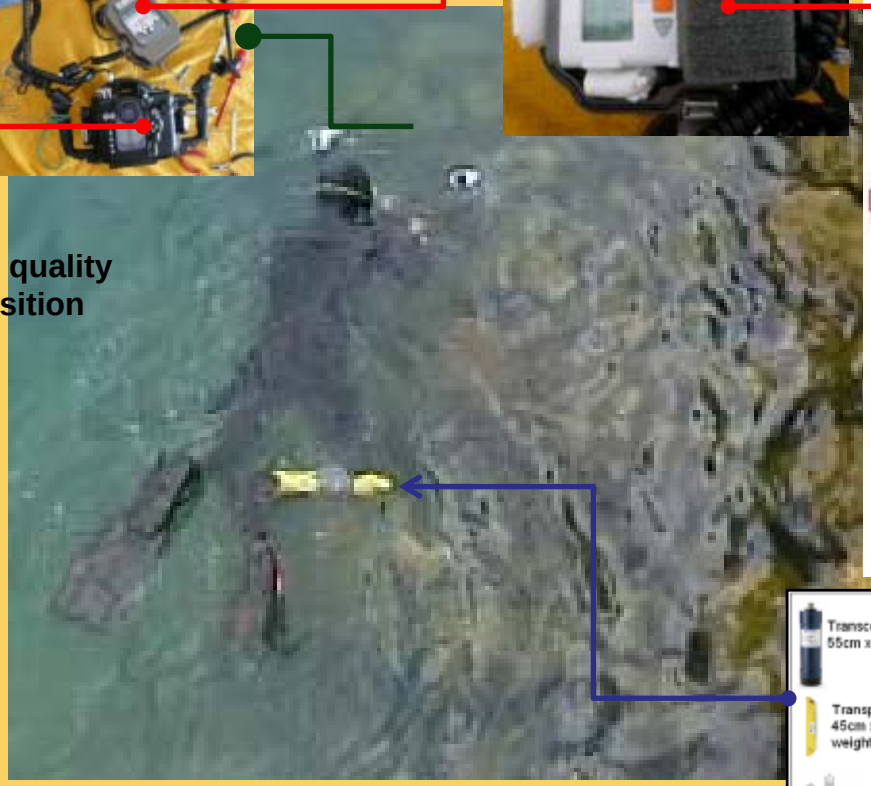


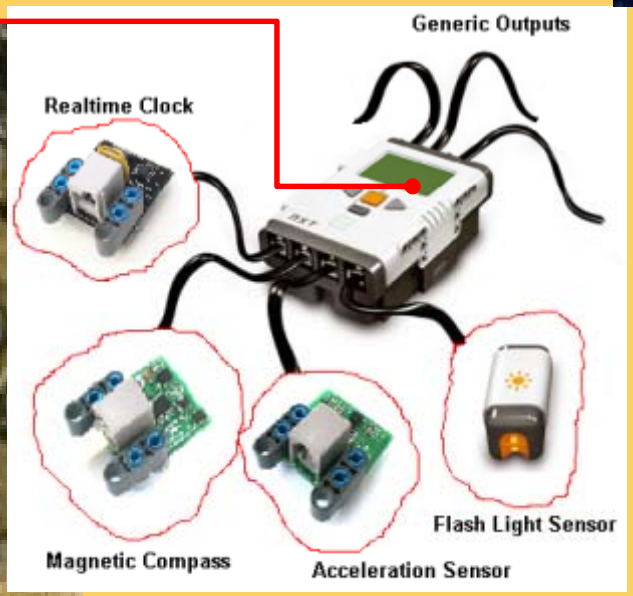
# UPGRADE

## PUT: a portable underwater tracker

**Data acquisition, processing and archiving**

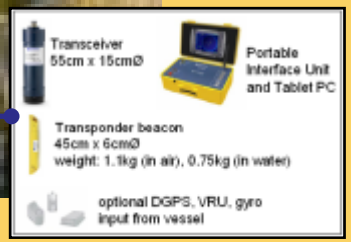







Nikon D200

**Optical high quality image acquisition**




Sonardyne USBL

**DIVER position measurement**

# UPGRADE

## Snake Mosaicking using SIFT

Development of “quick-and-dirty”, almost real-time, photomosaicking software tool from camera and video survey in the field. It relies on the EXIF data format previously defined

# UPGRADE

Experiments have been carried on in the framework of 4 missions:

Pointe de la Voile, Marseille (France): preliminary study.

San Nicola Island, Tremiti Archipelago (Italy): test of calibration procedure, software testing and data gathering.

Barco da Telha, Sesimbra (Portugal) (UPGRADE partially supported): photomosaicing with divers and testing of tracking tools and procedure.

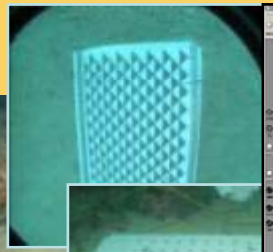
Elba Island, Tuscany Archipelago (Italy) (UPGRADE partially supported): test of photomosaicing with divers and testing of tracking tools and procedure.

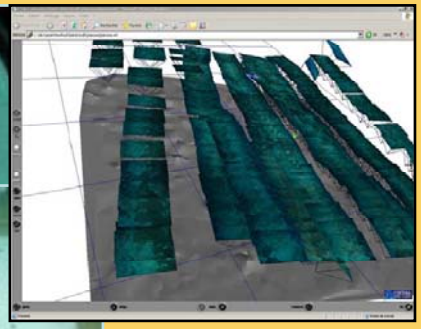
# UPGRADE

Pointe de la Voile, Marseille (France)
Year 2006 (-100m)

San Nicola Island
Tremiti Archipelago (Italy)
May 2007 (-60m)

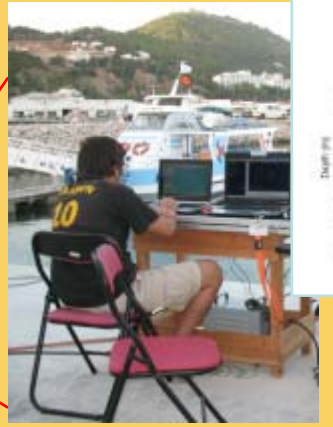
http://www.marlintremiti.it/labsub.html

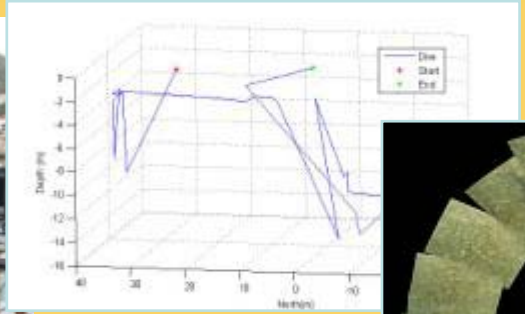


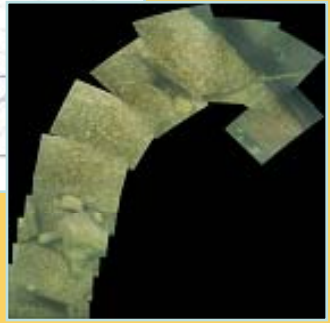


# UPGRADE

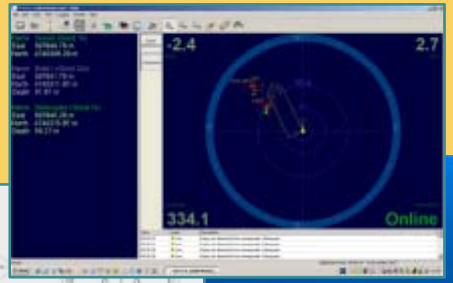
Barco da Telha
Sesimbra (Portugal)
October 2007 (-58m)

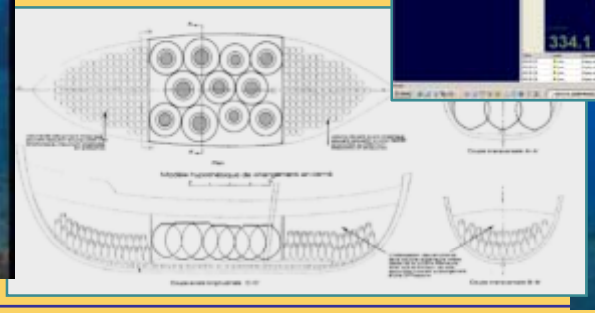


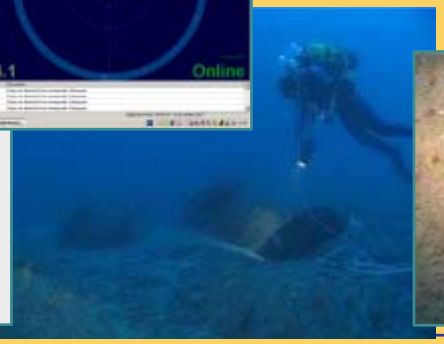




Elba Island
Tuscany Archipelago (Italy)
November 2007 (-63m)





http://www.marcianamarina.toscana.it/italiano/STAMPA/Comunicato_Nasuto_07.html

# ROV and Sensory Apparatus

PXI - FPGA

**Navigation,**
**Instruments management,**
**Data acquisition, processing and archiving**

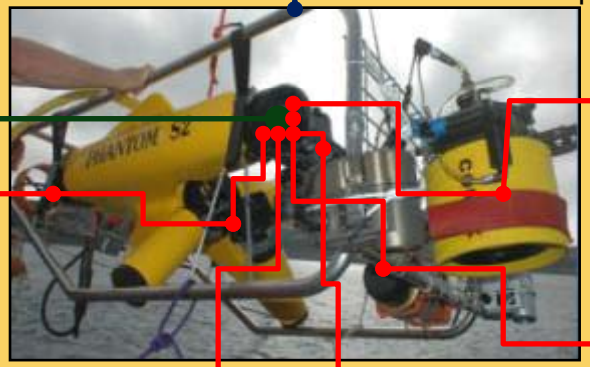

Sonardyne USBL

**ROV position measurement**

**Communication and Power Supply**

Umbilical cable

Phantom S2
Deep Ocean Engineering



68K/ColdFire
RISC MicroController

**Low Layer systems synchronization,**
**Data fusion**

4 Thrusters

**2 Horizontal act**
**2 Vertrans act**

Nikon D200

**Optical high quality image acquisition**

Kongsberg Sonar

**Bathymetric data acquisition**

Compass, IMU, depth

**Navigation data acquisition**

Sony HDR_HC7E

**Optical high quality video image acquisition**

# ROV and Sensory Apparatus

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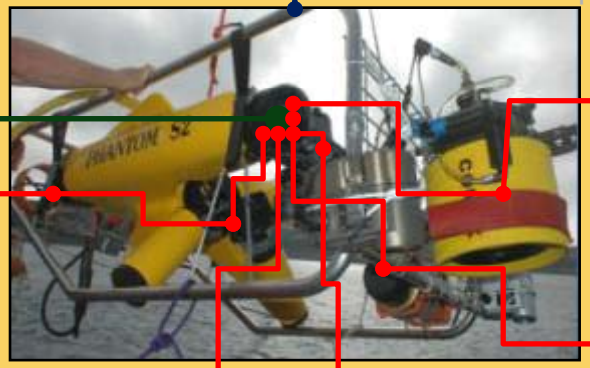

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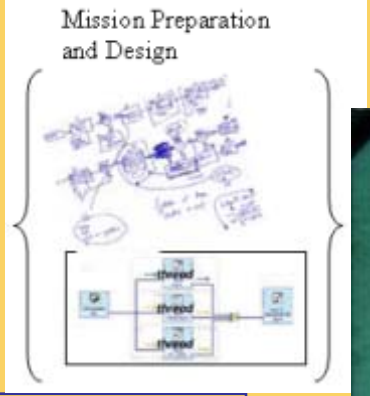
**Navigation data acquisition**

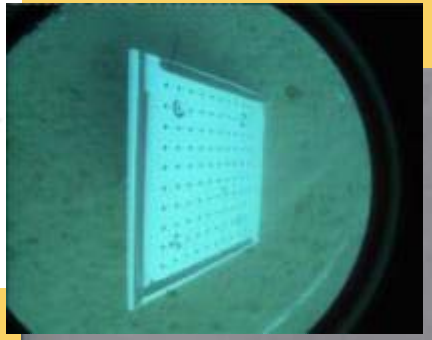
Sony HDR_HC7E

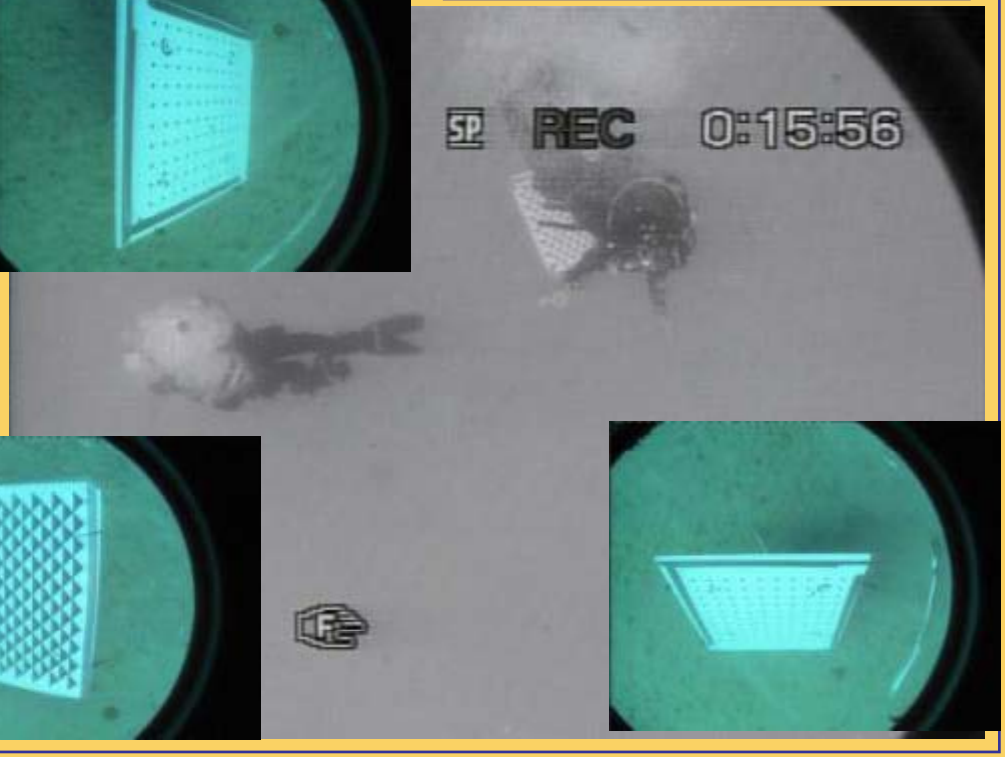
**Optical high quality video image acquisition**

# Mission Preparation and Design

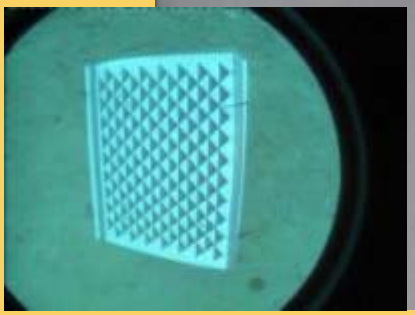




Video and photo camera calibration

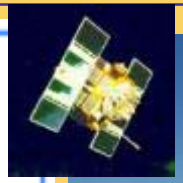


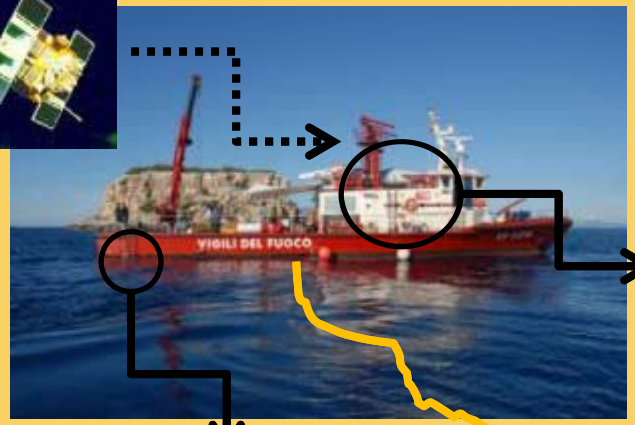



NCG parameters setting



# Georeferenced data acquisition




Umbilical cable

Acoustic links

# UPGRADE

## Availability and contacts

***Software tools:***
open source from the sites of the different partners, linked from EPOCH web site

***Hardware Tools:***
drawings of tools available from the sites of the different partners, linked from EPOCH web site, for non commercial use

***UPGRADE coordinator:***
*Antonio Pascoal*,
Institute for Systems and Robotics, Instituto Superiore Tecnico, Lisbon, Portugal,
antonio@isr.ist.utl.pt