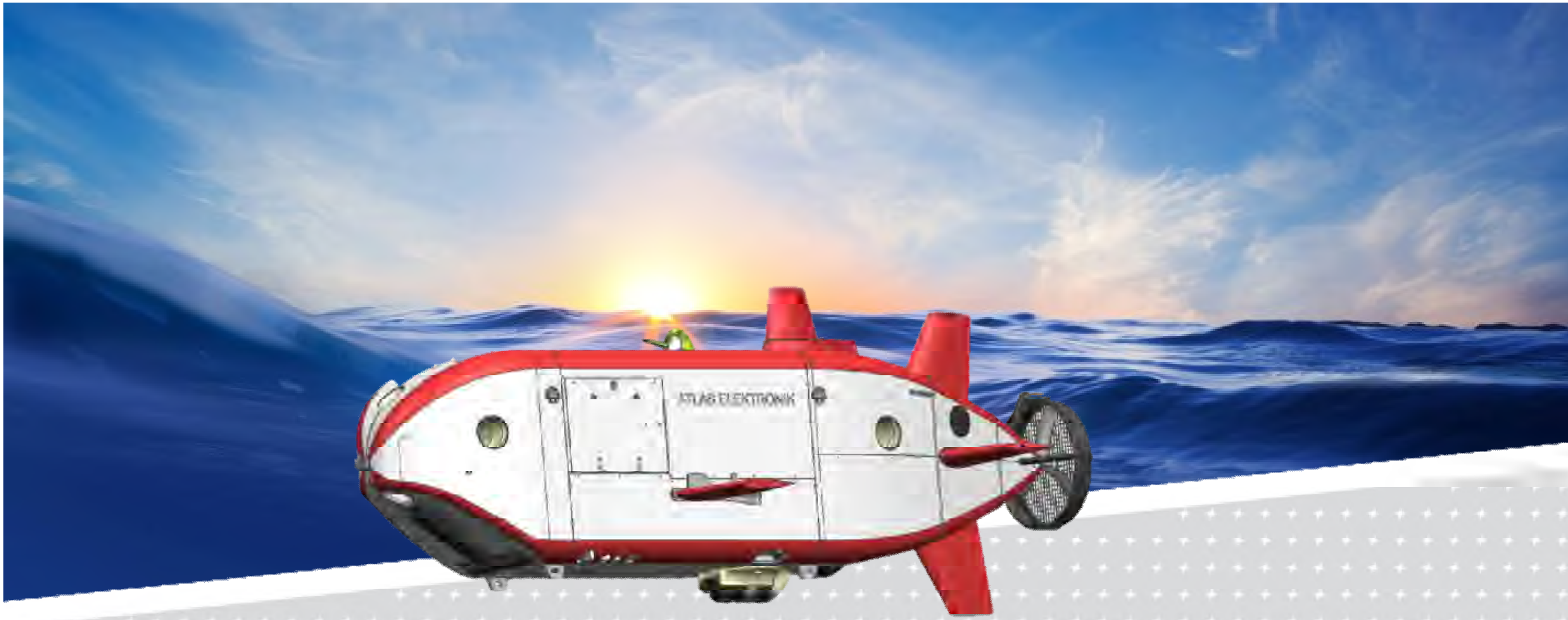

Simulation based design & development of autonomous underwater vehicle IMGAM

Dr. –Ing. Max Abildgaard

… a sound decision

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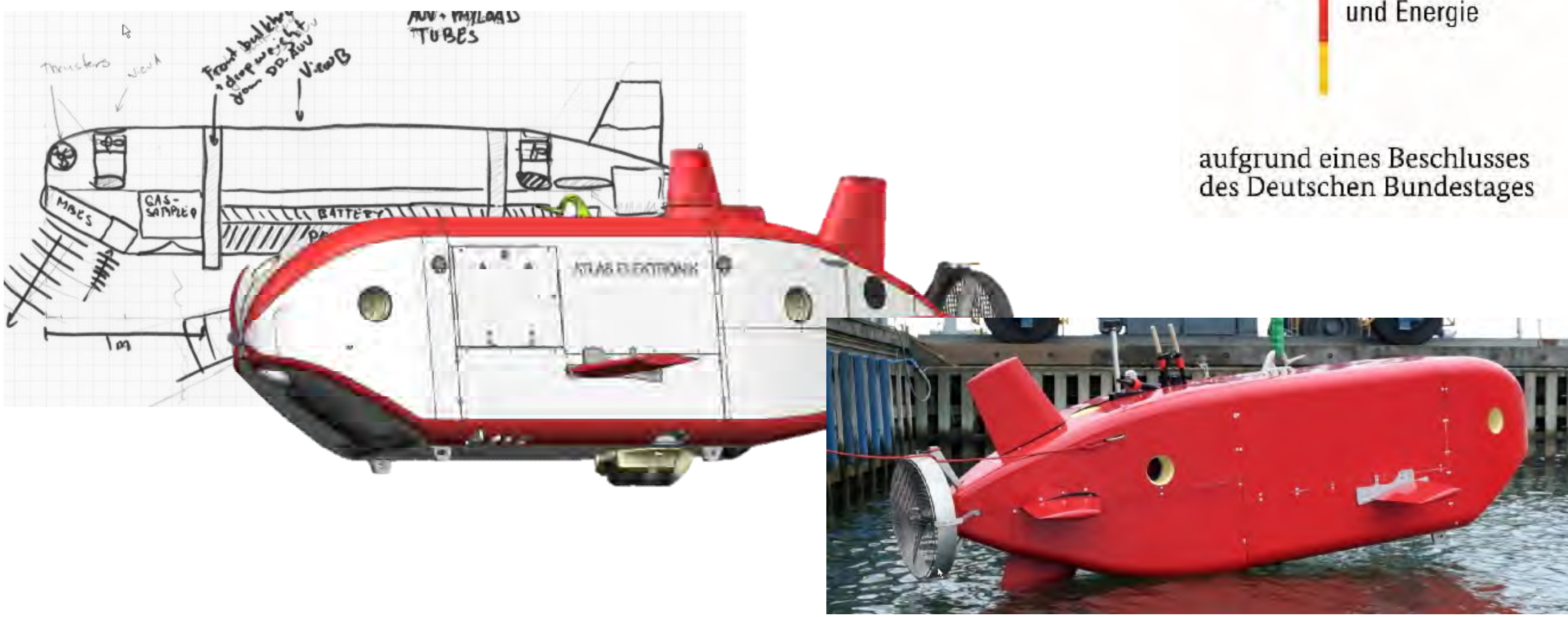
A joint company of ThyssenKrupp and Airbus DS

Introduction

Gefördert durch:

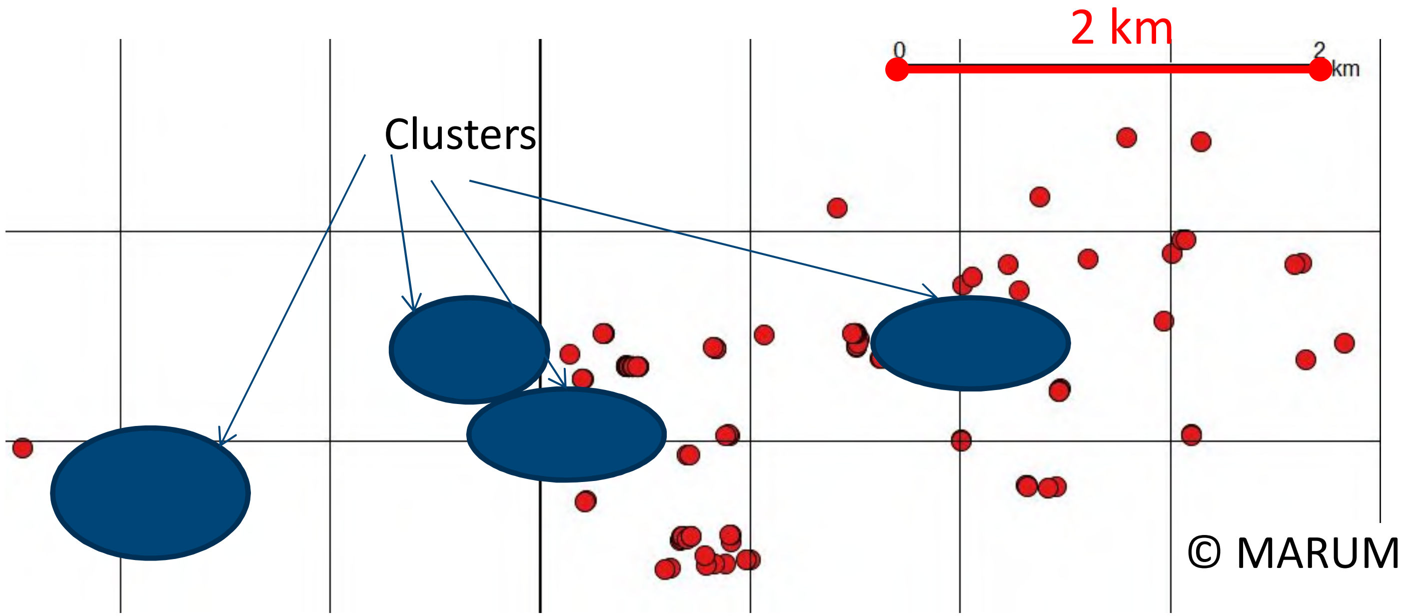
Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages



- IMGAM (*Intelligentes Monitoring von Gasaustritten im Meer*, Engl.: *Intelligent monitoring of gas emanations in the ocean*)
- Goal: Develop a system with the capability to autonomously locate gas flares and perform sampling of these and bring these samples back to ship for further analysis
- Close cooperation with MARUM, who delivers gas sampling hardware, flare detection software and, ultimately, is the user of the system

On the topic of gas flares…..



- Methane gas can be found exiting the sea floor and rising through the water column.
- In deeper waters, the methane is found in the form of methane-hydrate-ice. These sites are interesting in terms of possible future mining – but since the methane hydrate dissolves when the temperature rises, they are also a concern in terms of global warming
- Flare sites are often found as clusters within relatively confined areas
- The vehicle shall enable scientists to obtain individual, geo-referenced samples from multiple positions inside flare clusters

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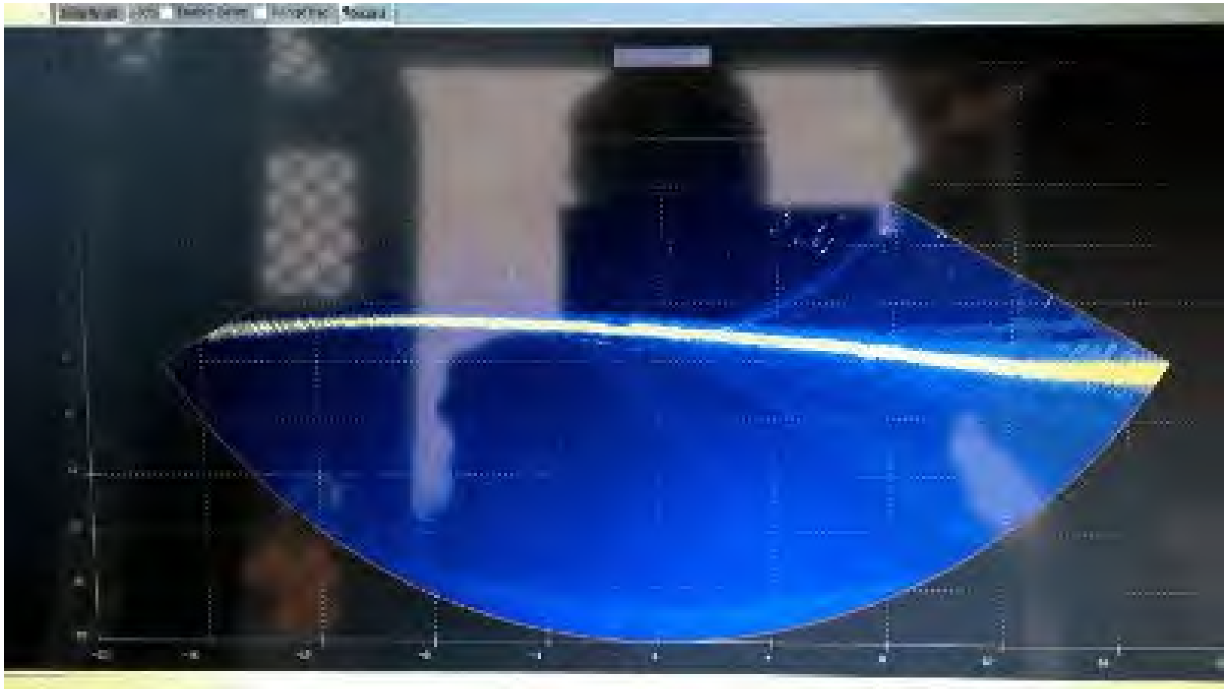
Detecting gas flares



- A Multibeam sonar, mounted with a viewing angle 30° forward of vertical is used.
- Flares are seen very clearly as “blobs”, moving upward as vehicle moves forward
- The detection algorithm clusters “blobs” together into chimney-like structures, which are geo-referenced and passed on to the vehicle’s control system

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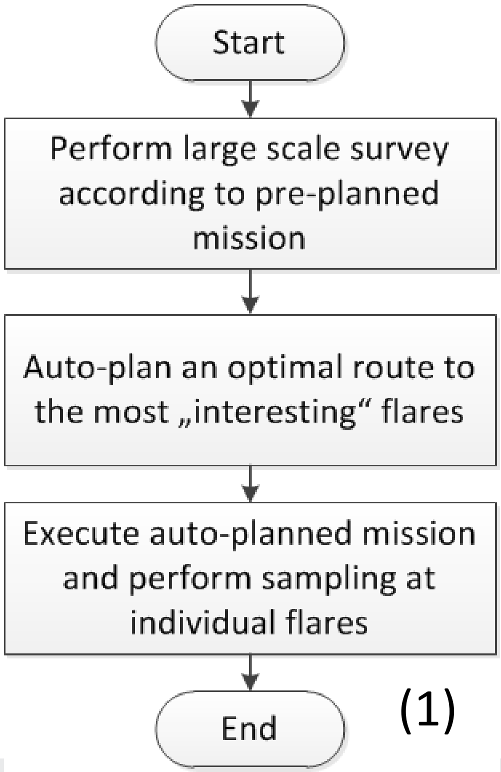
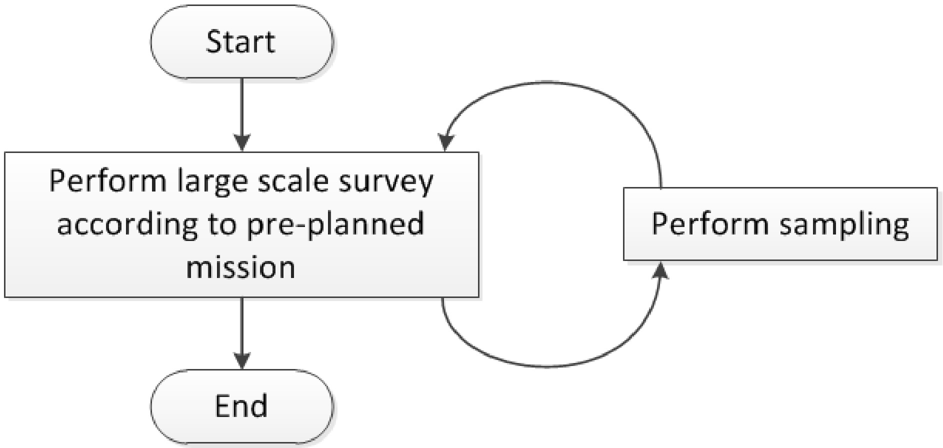
Concept development (1/2)

- **First**: Brainstorm, visualize, model, understand how a standard mission should be structured. 2 concepts were formulated:
  1. Large scale initial survey first, then decide on best targets, then go to each flare individually and sample these
  2. Large scale survey with interrupts whenever an „interesting“ target is seen



(1)



(2)

Concept development (2/2)

- **Secondly**: Evaluate concepts:
    1. Allows (ideally) that only the „best, most „interesting“ flares are sampled. But has drawback that time passes between initial survey and sampling → navigation drift → flares will not be at position where last seen. Furthermore: Vehicle will cover the area twice.
    2. Drawback: Surveys end when gas sampling capacity is full. Not possible to perform top-down “quality based” selection/ranking among detected flares. Advantages: Less artificial intelligence required, simplicity, total area coverage.

- **Furthermore:** Simulation showed high robustness of concept (2) against variations in currents (direction and magnitude).

- **Third:** Decision on concept 2. Then define a step-wise breakdown of sampling sequence. Then define requirements with regards to vehicle capabilities

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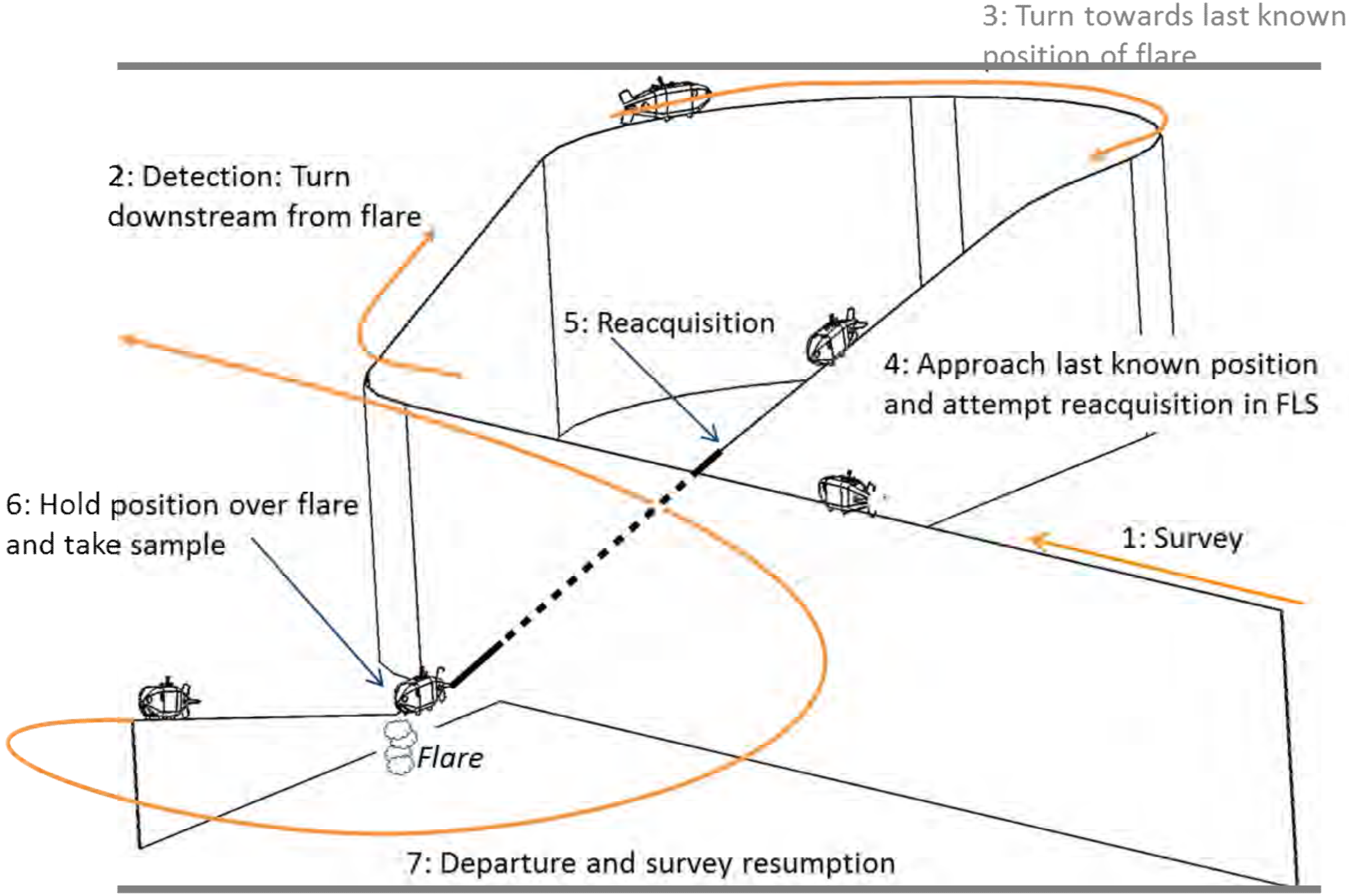
Step-wise breakdown of sampling sequence



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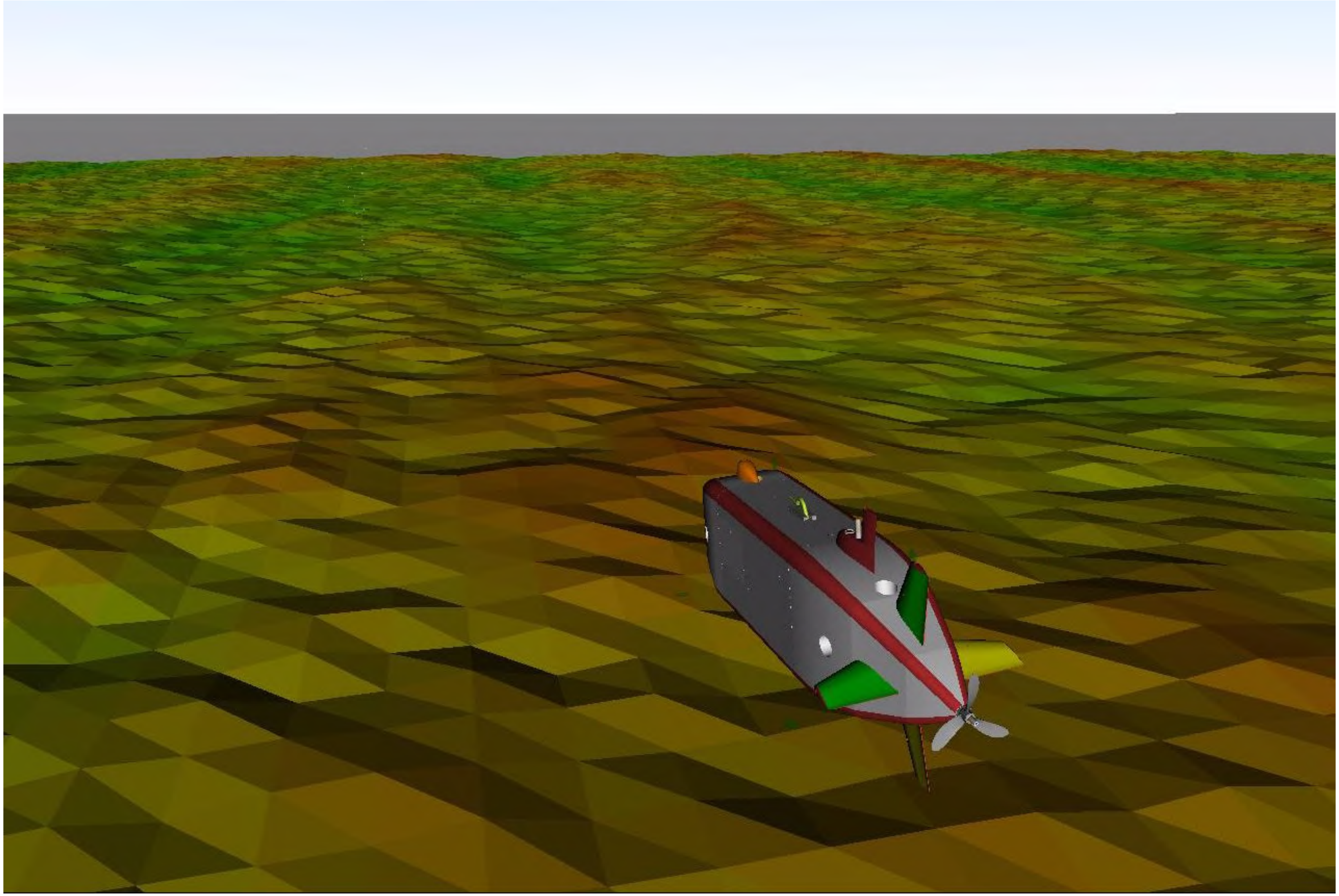
Simulation of sampling sequence



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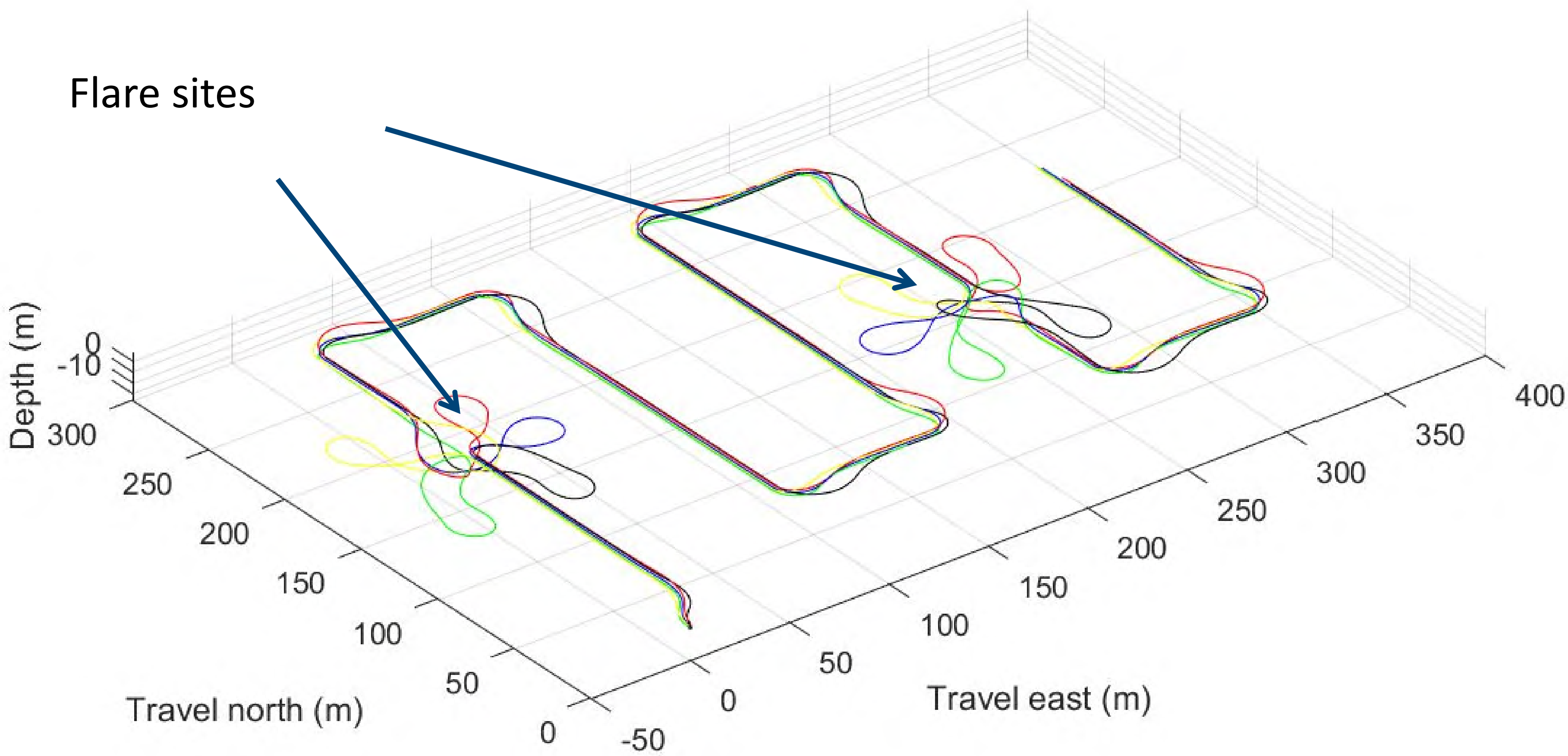
Simulation based validation of algorithm robustness despite current direction



- Figures show a standard mission with 2 flare sites. The variously colored traces show vehicle trajectory as result of 0.3 m/s current from 4 different directions

Derived requirements

Large scale survey part:

- Clean, low drag design → endurance
- High area coverage rate:
  - High-range MBES and DVL
- Proven and reliable vehicle guidance, navigation and control
- Deep sea → High grade INS, DVL, USBL
- Power buffered safety systems: Dropweight, IRIDIUM modem, acoustic beacon

Gas sampling part:

- Real time detection and classification of gas flares based on water column data
- Incorporation of a gas sampler for collection of 15 individual samples
- Gas sampling in both automated (standard sampling sequence) mode and in manual remote control mode → Fiber optic link
- Full controllability in low speed and hover and in transition from/to survey speed
- Forward, slightly downward looking sonar for position keeping during sampling
- Lights, cameras and real time display of sonar data for real time feedback to pilot
- Possibility to change, adapt, and modify sampling algorithms in short iteration cycles

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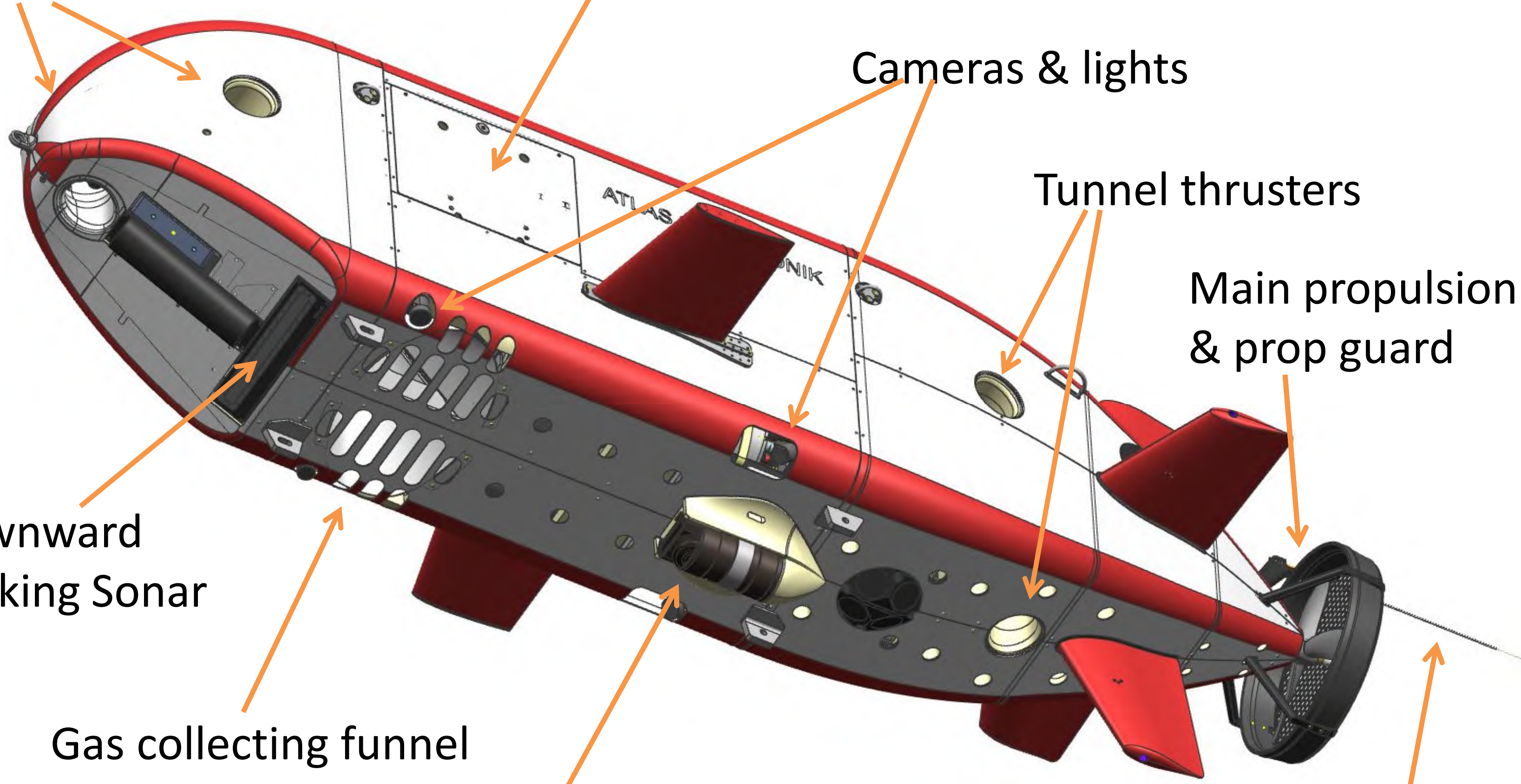
Vehicle hardware concept (1/3)



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Vehicle hardware concept (2/3)

Key specifications

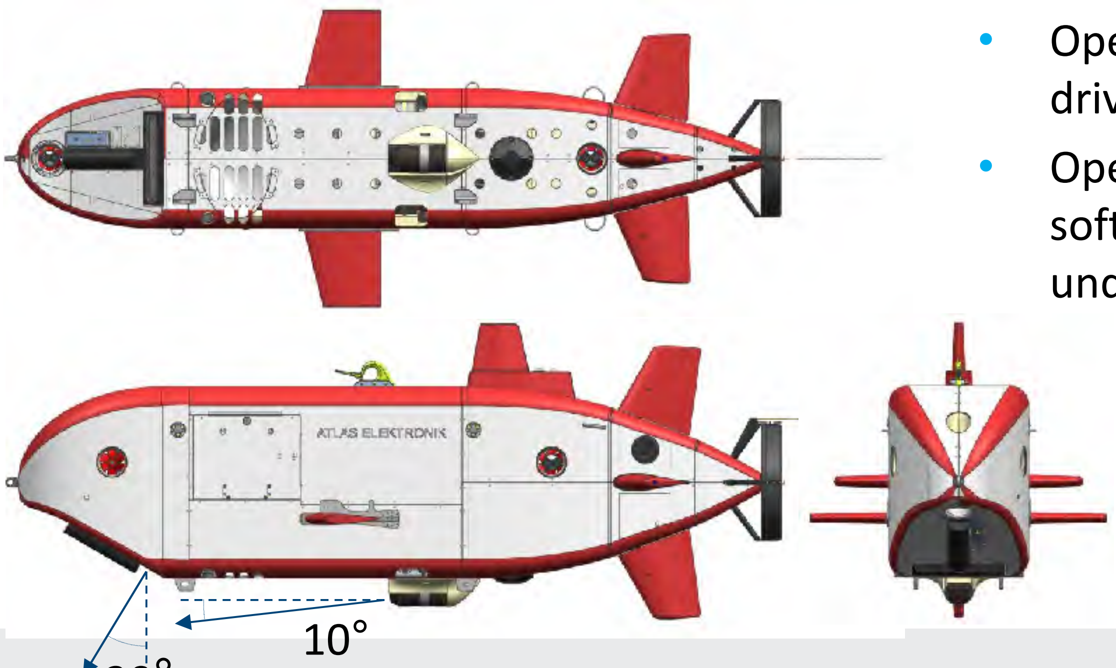
- 2000 m diving depth
- Normal surveying mode and Low-speed/hover-mode
- Fiber optic link human-in-the-loop remote control
- Generous endurance / range
- Modular construction

Hardware

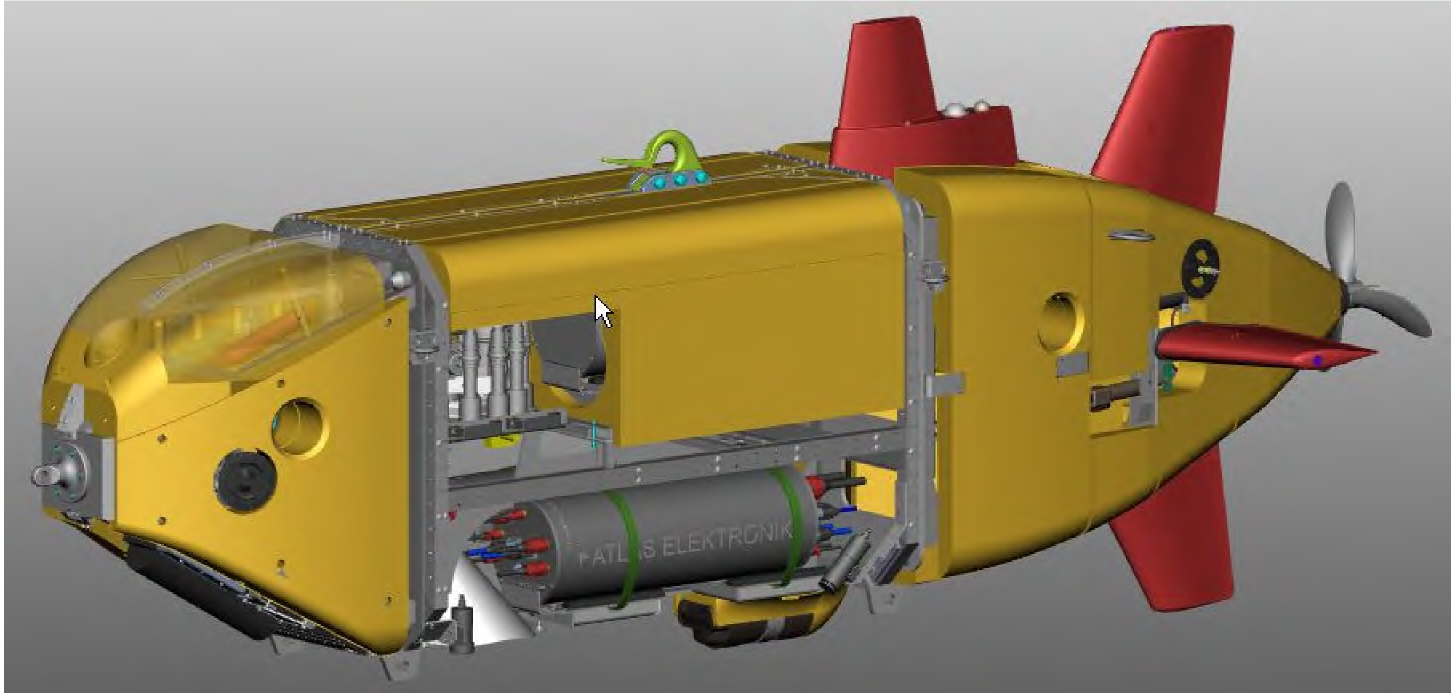
- R2Sonic 2016 MBES + Tritech Gemini 720id MBES
- Extensive hardware suite: Underwater modem, GAPS transponder, IRIDIUM
- Gas sampler for collection/storage of 15 samples

Software

- Open payload concept with “backseat-driver” functionality
- Open source Mission planning & control software “Neptus” with GIS engine underneath



Vehicle hardware concept (3/3)



- Divided into 3 sections: Payload sensors (front), batteries and housekeeping systems (middle), and propulsion and navigation (rear)
- Individual sections are welded sea-water aluminum constructions and easily modified and re-manufactured to accommodate changes to payload, range, depth, etc..

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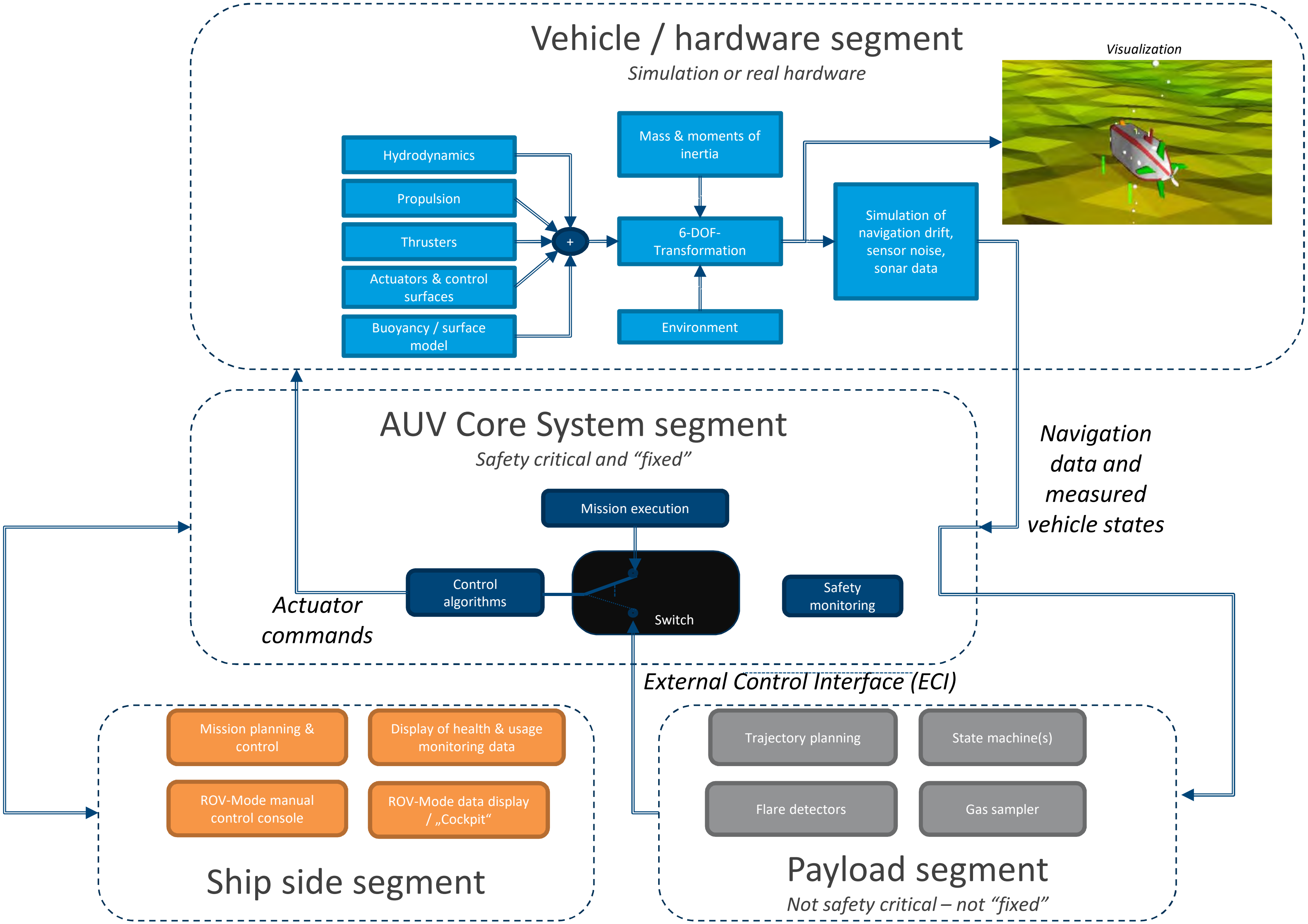
Vehicle system concept



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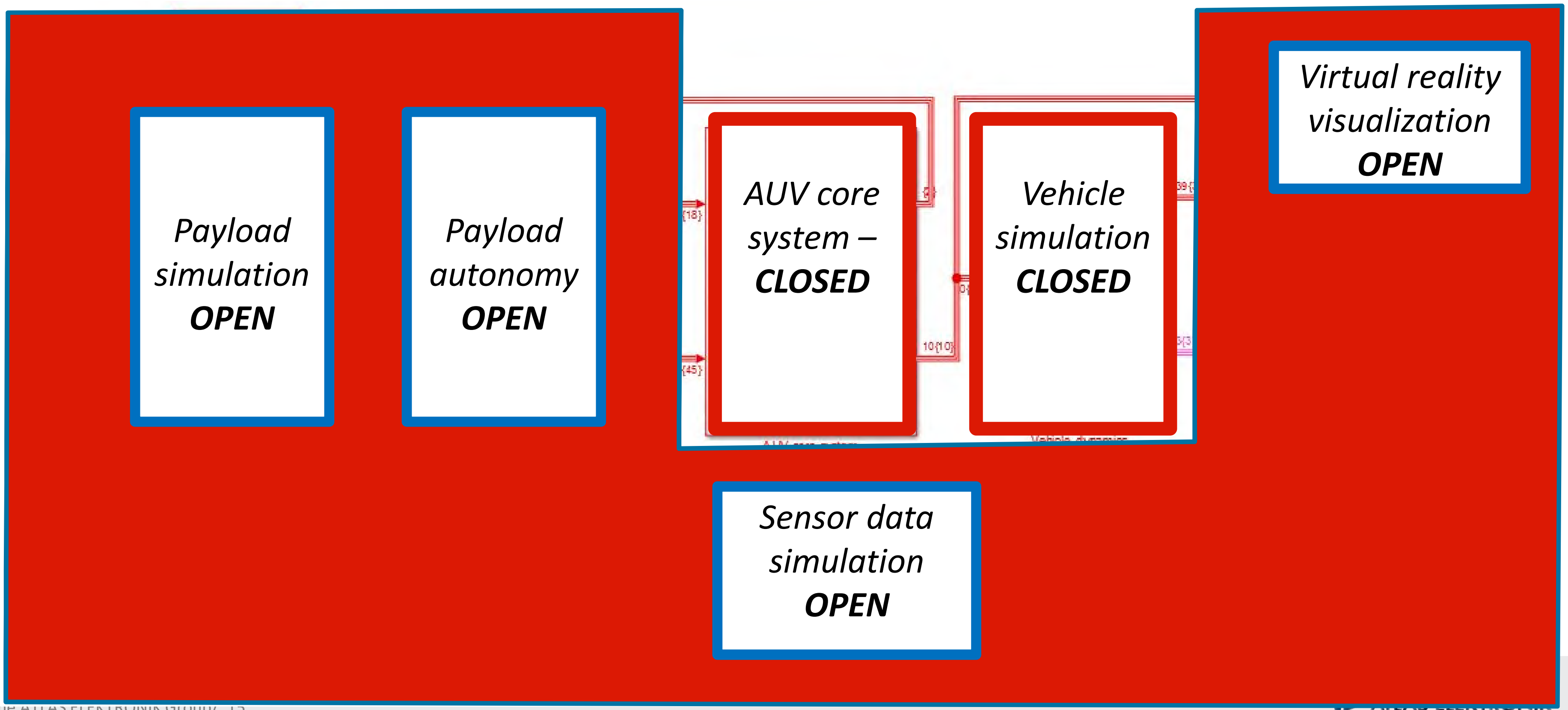
Software development concept

- A complete simulation environment with sub-models of all relevant vehicle sub systems has been realized in Matlab-Simulink.
- This environment can be put in the hands of users, who want to develop their own algorithms – but who do not want to spend their time on basic AUV systems
- Pre-compiled executables can be supplied to potential users for validation and testing purposes.



Current status

ROV-Mode tests

Deployment in North Sea, October 2016

IMGAM is still an ongoing project:

- Successful termination of 1st phase has focused on shakedown and validation of vehicle controllers in both ROV-mode (low speed and hover) and “normal” waypoint mode.
- 2nd test phase will take place in November in Øresund at Maridan‘s facility in Rungsted. This phase focuses on validation of the *standard sampling sequence*
- 3rd phase: Use phase.

Conclusion

- Concept and implementation work in IMGAM has been based around a vehicle simulation model
- This has helped to structure individual mission phases and to specify requirements for maneuverability, sensors, and payload
- The physical vehicle concept is an low-cost open-frame design, enabling easy access to systems and easy adaptation to new payloads and subsystems
- Software development takes place in a simulation environment, which can be opened to users, thereby easing the process of developing new routines and maneuver types.
- A safe system encapsulates the user developed functions and guards the vehicle against hazards.
- The system is currently in final phases of validation, set to finalize within the next few months.
- Thank you for your attention!

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