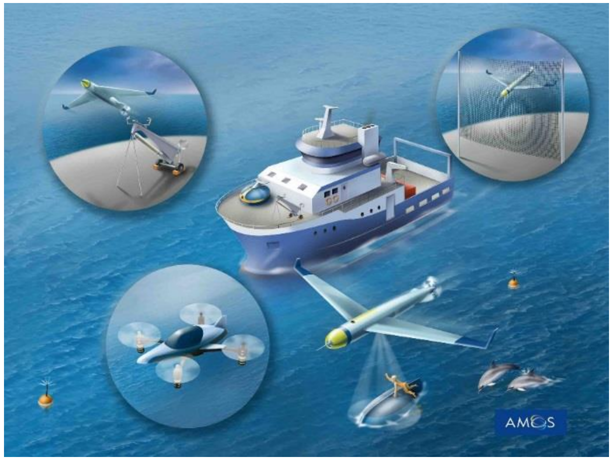
Polarconference 2016 – DTU 1-2 Nov 2016

DTU

Unnamed Surface Vessels

Unmanned Surface Vessels
- Opportunities and Technology



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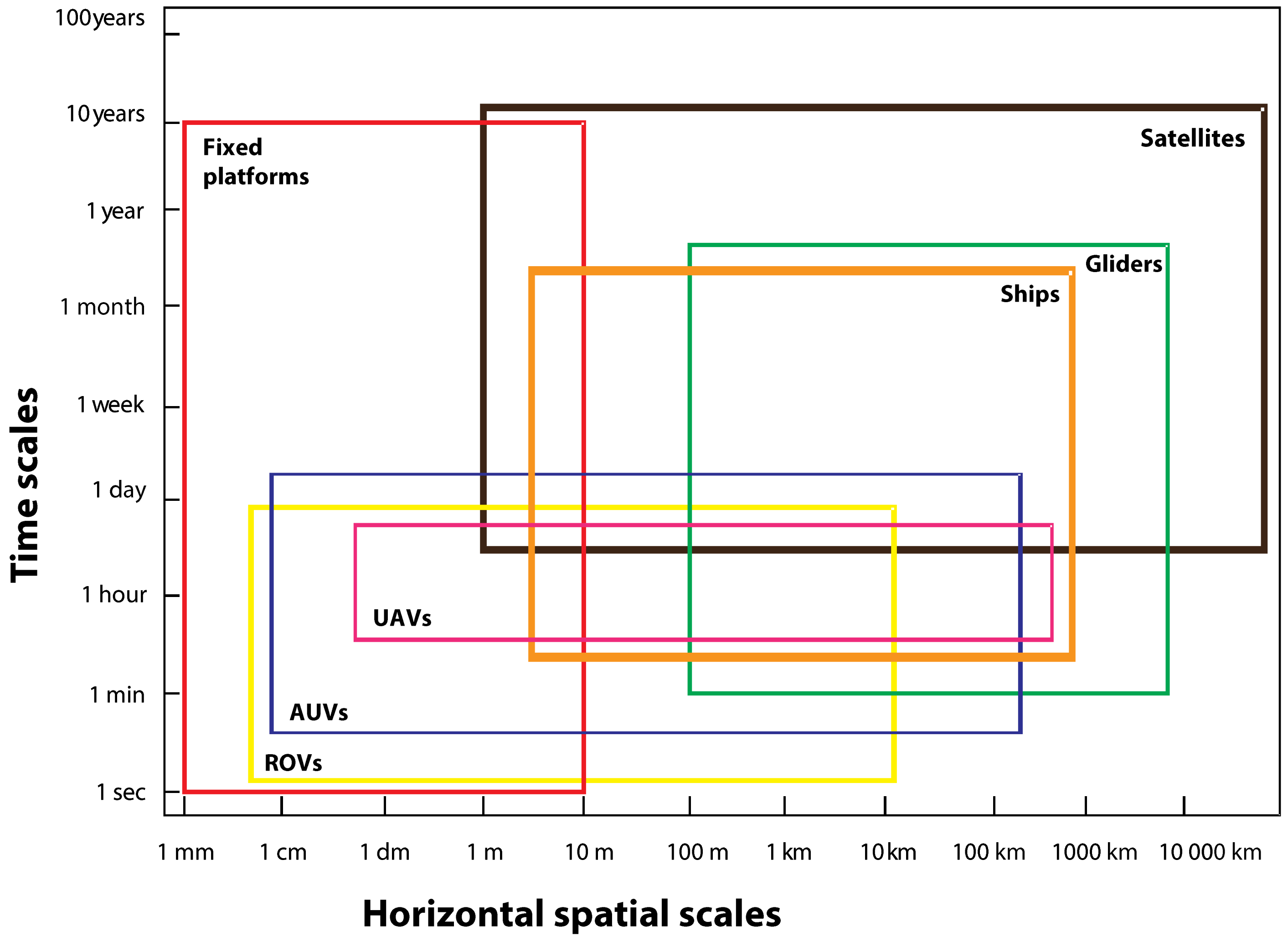
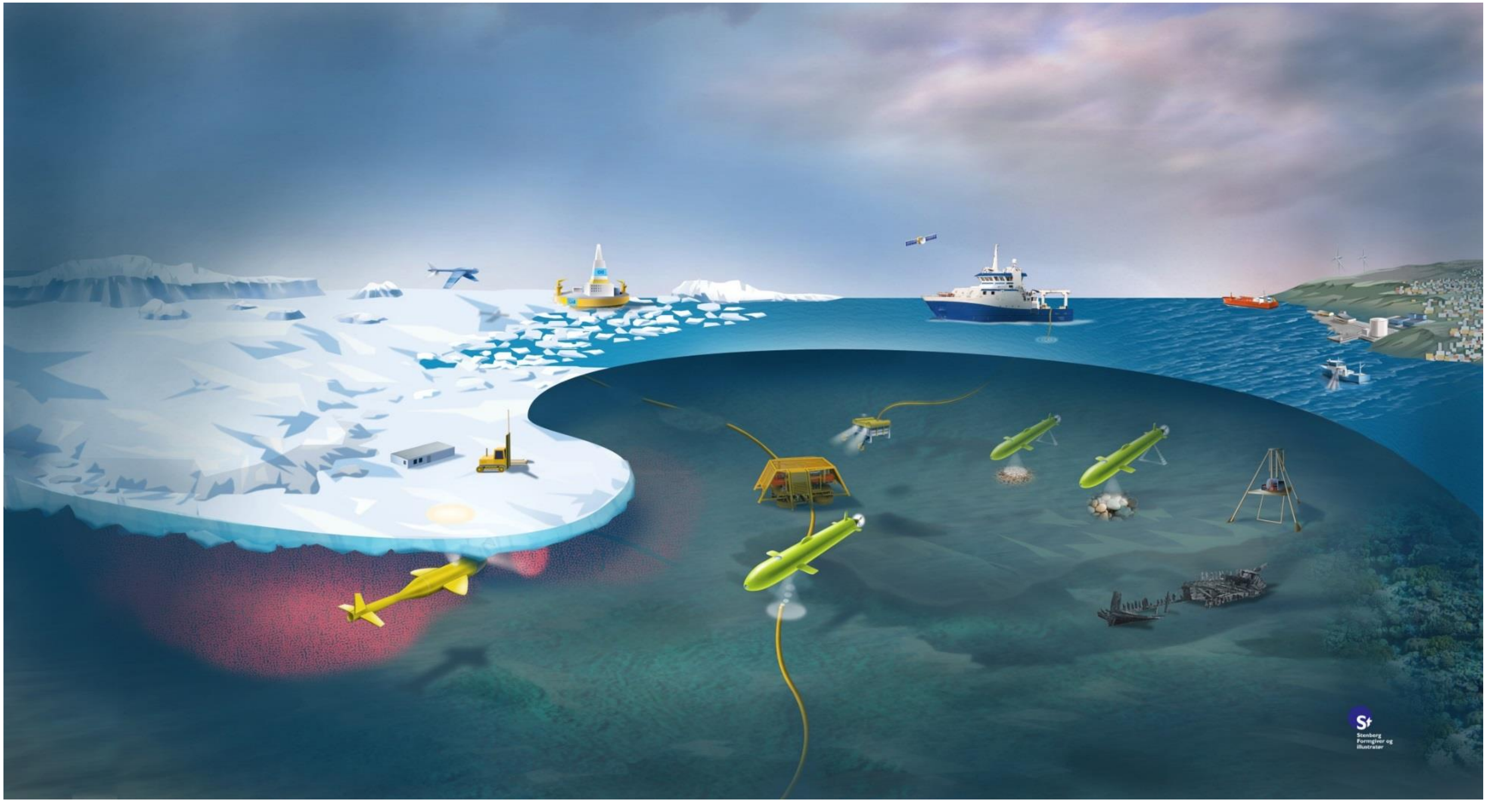
DTU Elektro
Institut for Elektroteknologi

Time – space coverage of technologies



Mapping and monitoring of marine resources and environment for governance and decision making. Territory surveillance, security.



Unmanned surface vehicles USV

USVs:

- Own missions
  - Surveillence
  - Intervention
  - Rescue
- Integrated missions air
- Support for underwater
- Mission specific design: speed, range, instruments

Lower cost than manned

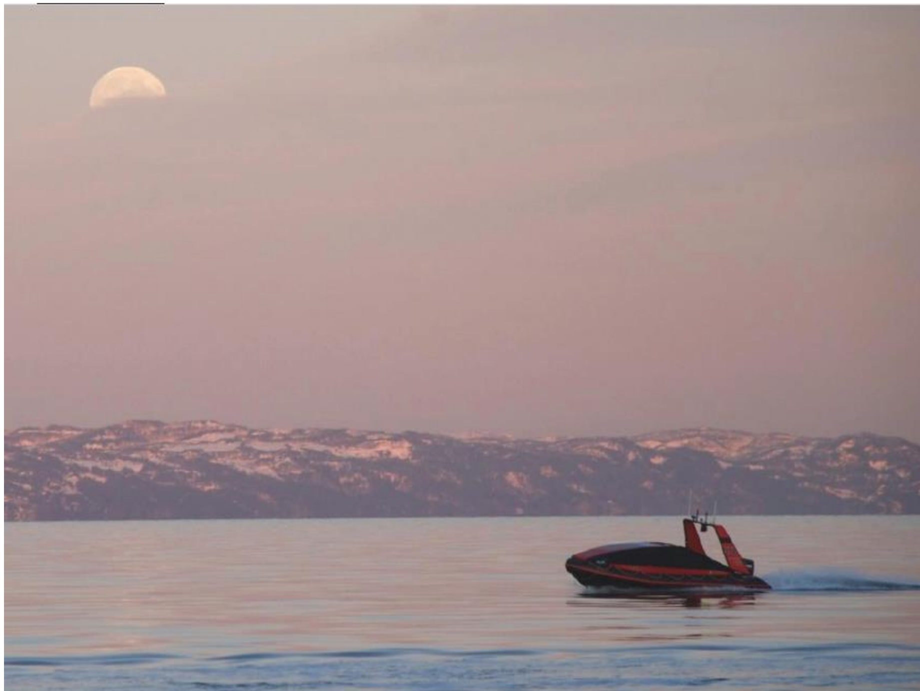
24/7 and long endurance

Multi-vehicle operation

Excelent for tedious tasks

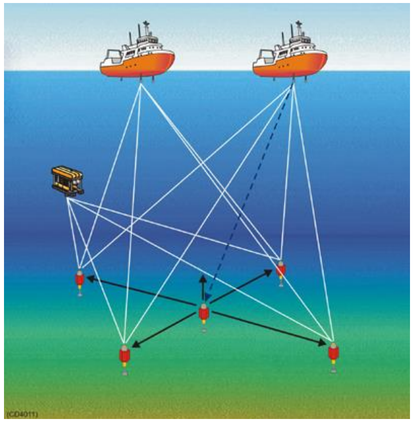
Smaller environment footprint

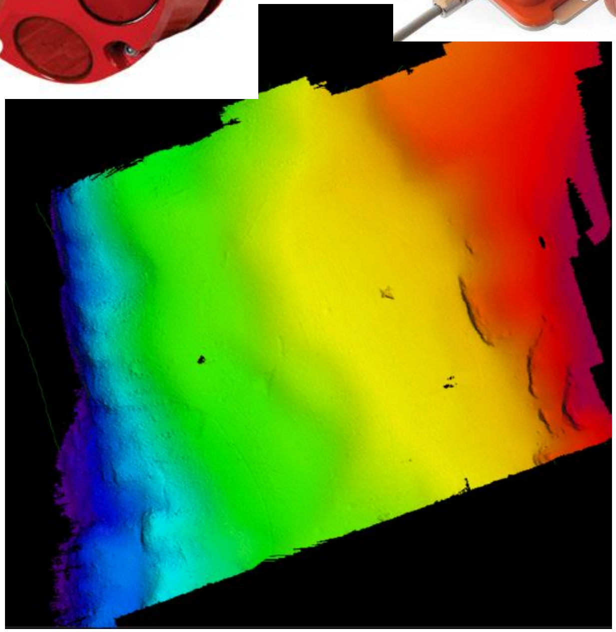
Autonomy in operation: Maritime Robotics (Trondheim)



Images used by courtsey of Maritime Robotics (patented technologies)

Navigation sensors -





- Position:
  - GPS at surface for position fix
  - Acoustics
  - Optics (images, video, laser)
- Depth (pressure)
- Altitude and relative velocity to water or seafloor (Doppler Velocity Log)
- Orientations and accelerations, (Inertial Measurement Units)
- Radar (various bands to distinguish different objects)
- Vision systems visible, infrared, multi-spectral, stereo-vision.

Increasing the Level of Autonomy

Level	Descriptor	Guidance	Navigation	Control	EEM
10	Fully autonomous	Human level decision making	Human like navigation capabilities	Same or better performance as for a piloted vehicle in the same conditions	Very High
...					
4	Real-Time Obstacle/Event Detection and Path Planning	Hazard avoidance, Real-time path planning and re-planning	Perception capabilities for obstacles, targets and environment, low fidelity situation awareness	Robust trajectory tracking capabilities	Mid-low
3	Fault/Event Adaptive USV	Low-level decisions and execution of pre-programmed tasks	Detection of hardware and software faults	Robust adaptive controller	Low
2	ESI Navigation (e.g. non-GNSS)	Waypoint guidance of pre-planned paths	Sensing and state estimation by the USV, all perception and situational awareness by the operator	Control commands are computed by the autopilot	Low
1	Automatic Control	Waypoint guidance of pre-planned paths	Sensing and state estimation by the USV, all perception and situational awareness by the operator	Control commands are computed by the autopilot	Low
0	Remote Control	Performed by external system (mainly human operator)	Sensing done on-board the vehicle, data are processed externally (human operator)	Control commands are given by a remote external system	Very Low

Kendoul, F., **Survey of Advances in Guidance, Navigation, and Control of Unmanned Rotorcraft Systems**, J. Field Robotics, 29, 2012

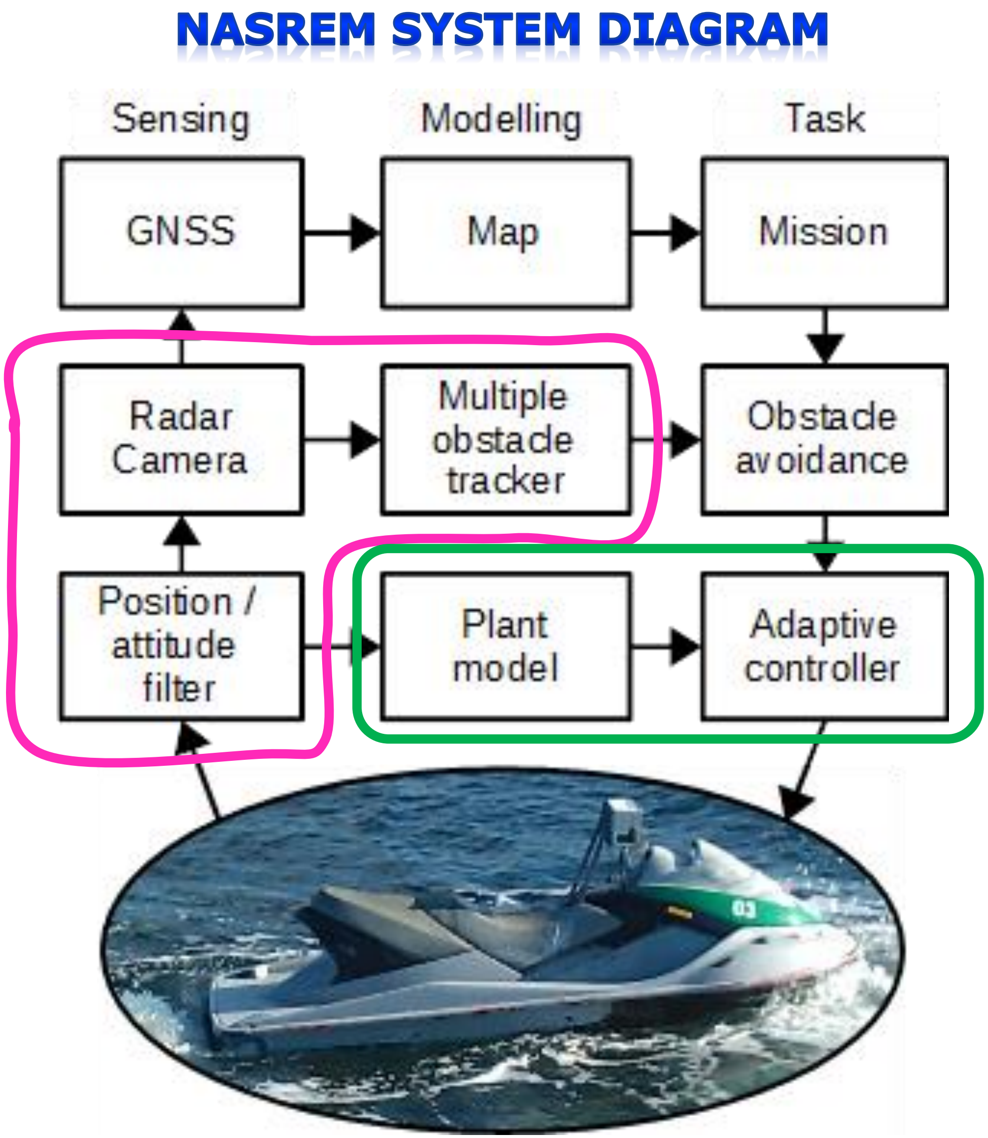
Obstacle Detection for High-Speed Unmanned Surface Vehicle

- High-speed unmanned surface vehicle
- Desired **Autonomy Level 4**
  - Robust adaptive controller ✓
  - Perception capabilities for obstacles/environment ✗
  - Hazard avoidance/path re-planning ✗

DETECTION REQUIREMENTS

- **Class of obstacles**
  - Boats, yachts, and buoys with radar reflectors
- **Range of detection (30m/s)**
  - Safety: 60m
  - Evasive: 30m

Dan Herman: Overall System Architecture

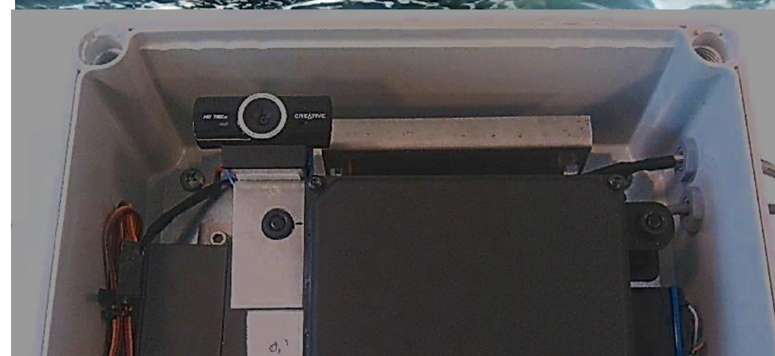


- **Previous work**
  - Plant model
  - Way-point controller
  - Station keeping controller
- **Contributions**
  - Vision assisted position and attitude filter
  - Multiple obstacle tracker

Herman, Galeazzi, Andersen and Blanke: Smart Sensor Based Obstacle Detection for High-Speed Unmanned Surface Vehicle. IFAC-Papers Online vol 48 (16), pp190-197,
DOI: 10.1016/j.ifacol.2015.10.279

Vehicle & Sensors Suite

- **Unmanned marine craft**
  - Modified for autopilot and remote control
- **Sensors for obstacle detection**
  - Automotive scanning radar
    - Mid range: 50m +/- 45º
    - Long range: 175m +/- 15º
    - Vertical FOV: 5º
    - Fs = 20Hz
  - Onboard low-cost camera
    - Resolution 640 x 480 pixels
    - FOV: 52º x 39º
    - Fs = 10 fps
- **Navigation sensors**
  - GPS (Fs = 3-4 Hz)
  - 6DOF IMU (Fs = 100Hz)
  - 3DOF Magnetometer (Fs = 100Hz)



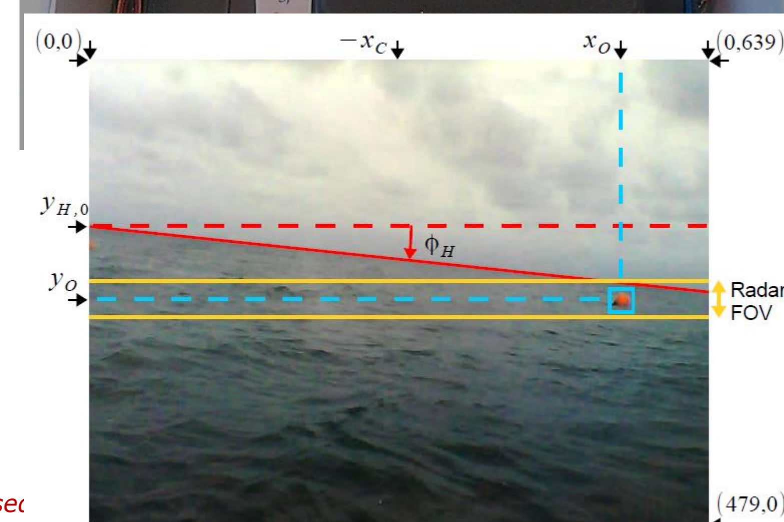
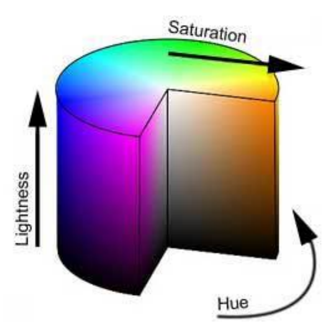
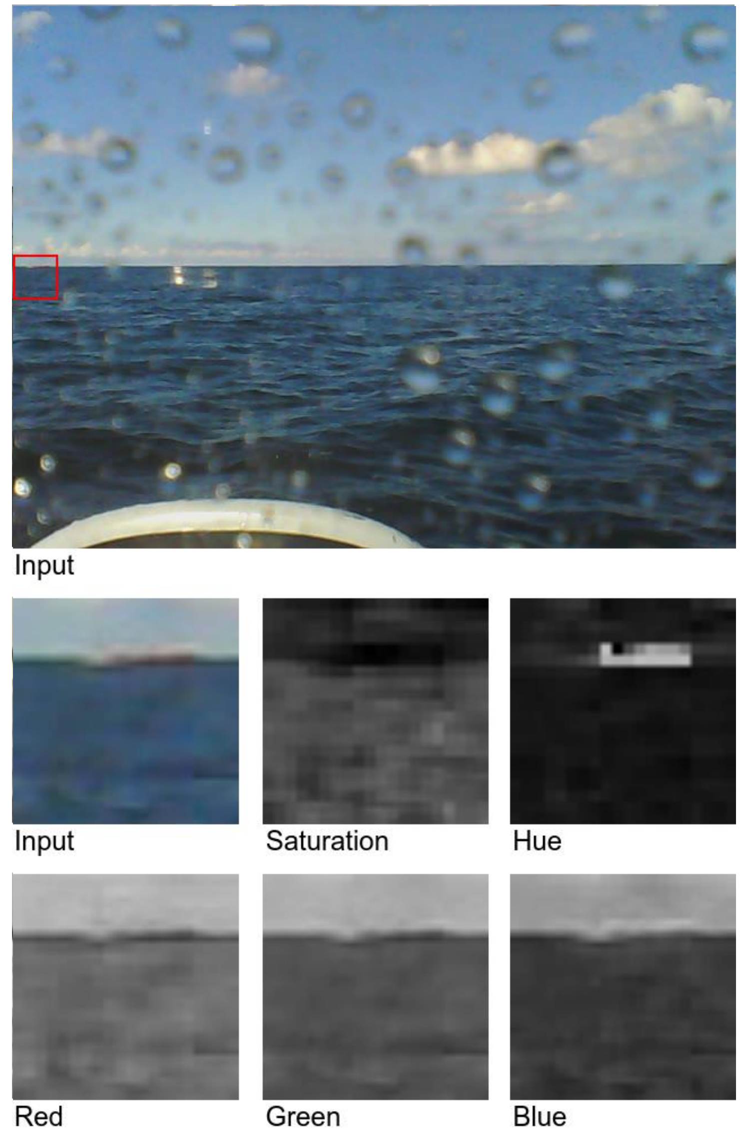


Image Object Detection: Challenges

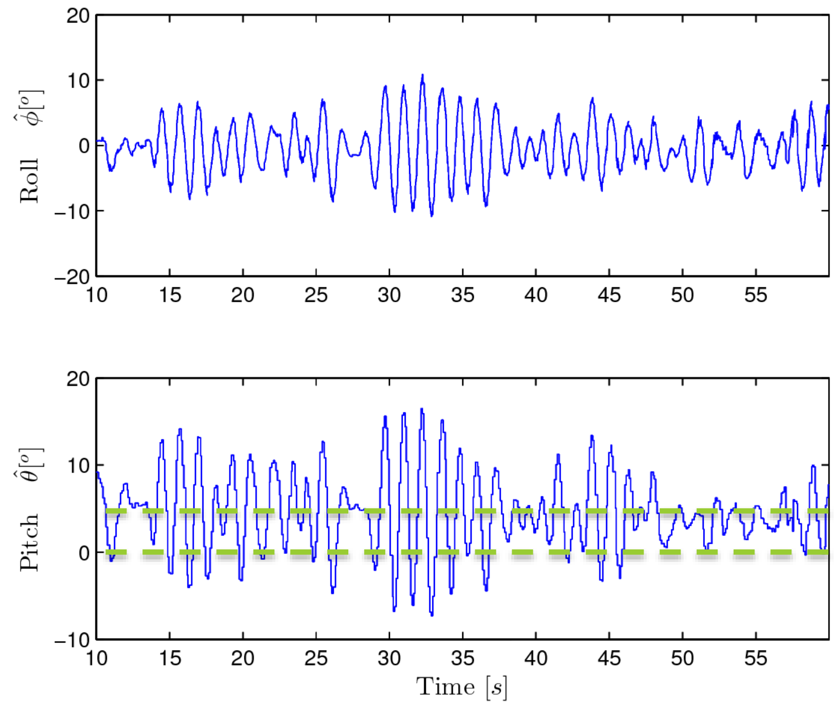
- **Illumination**
  - Overcast
    - Constant illumination
    - Detectable: RGB and saturation
  - Sun reflections
    - Numerous false detections
    - Detectable: RGB
  - Good illumination
    - Detectable: Saturation and hue
- **Post-processing detection**
  - Adaptive threshold



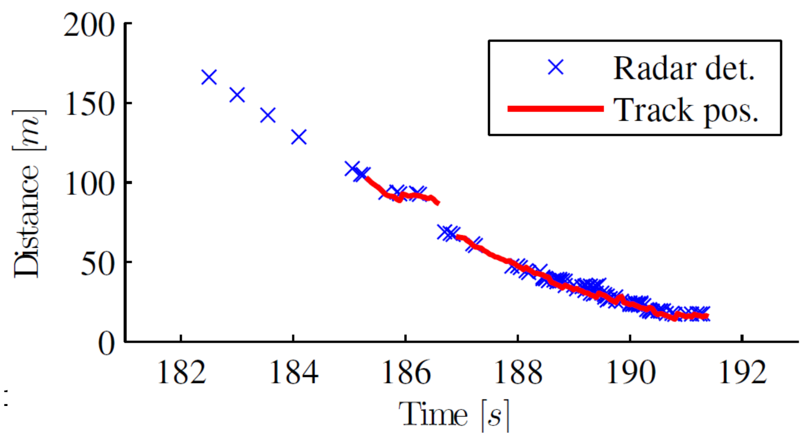


Sea Trial – Track Persistence Assessment

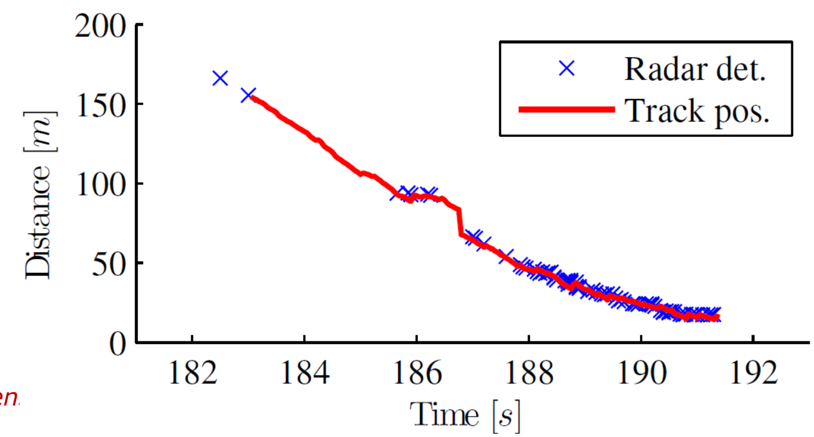
- **Pitch and roll motion**
  - Exceed radar vertical FOV
- **Radar maintained**
- **Radar assisted by vision**
  - Range of detection increased (doubled)
  - Increased track persistence



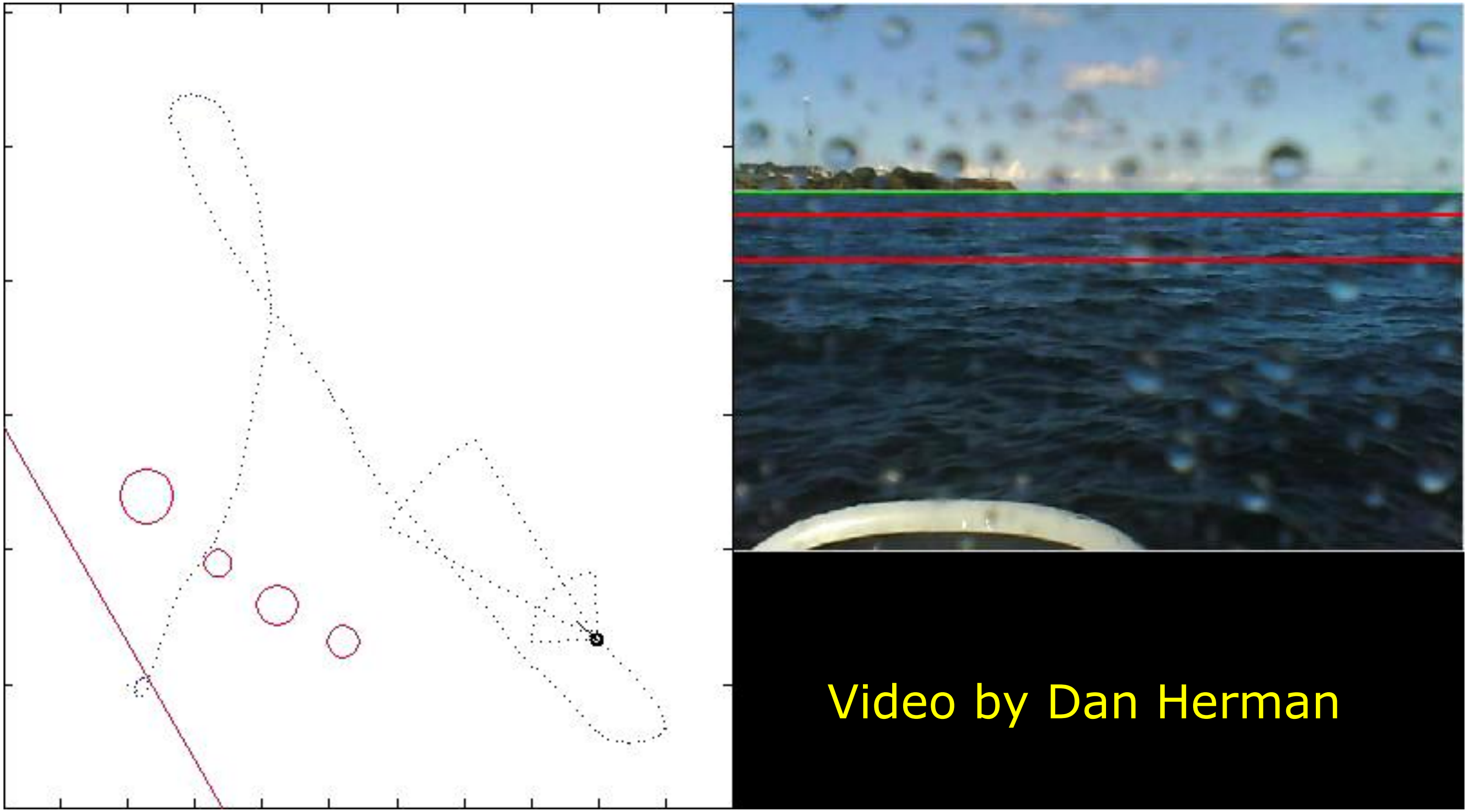
RADAR



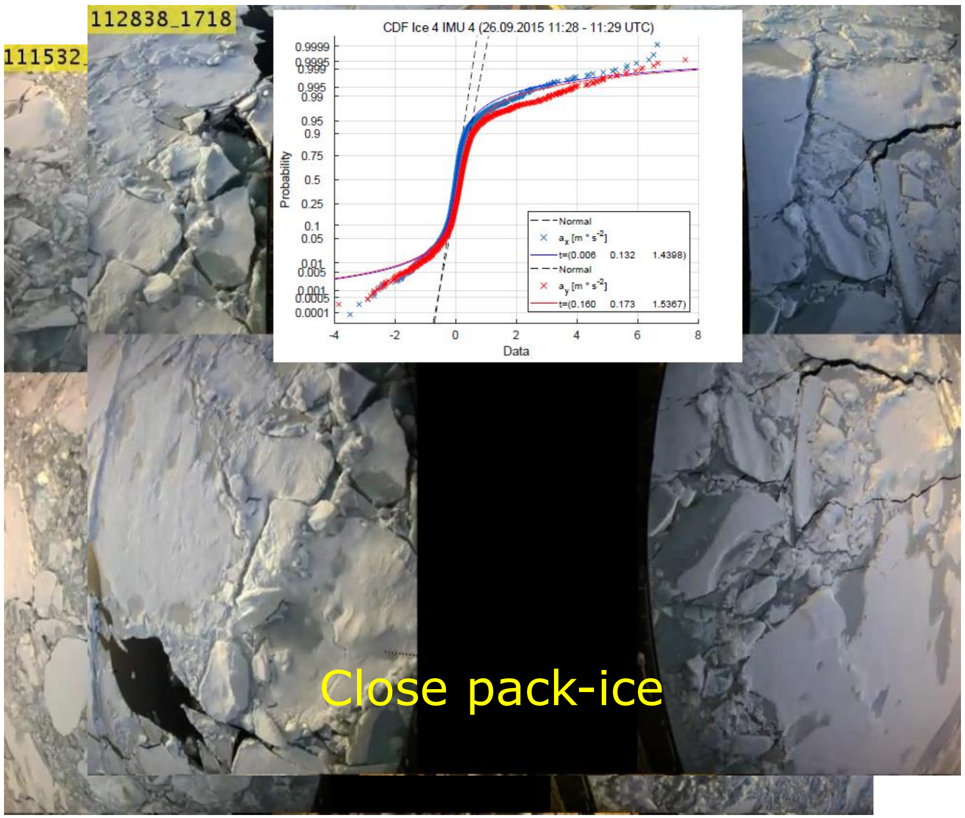
RADAR + VISION



Results: Obstacle detection for safe navigation



Vehicles in ice ??



Hans-Martin Heyn (AMOS) at the North Pole

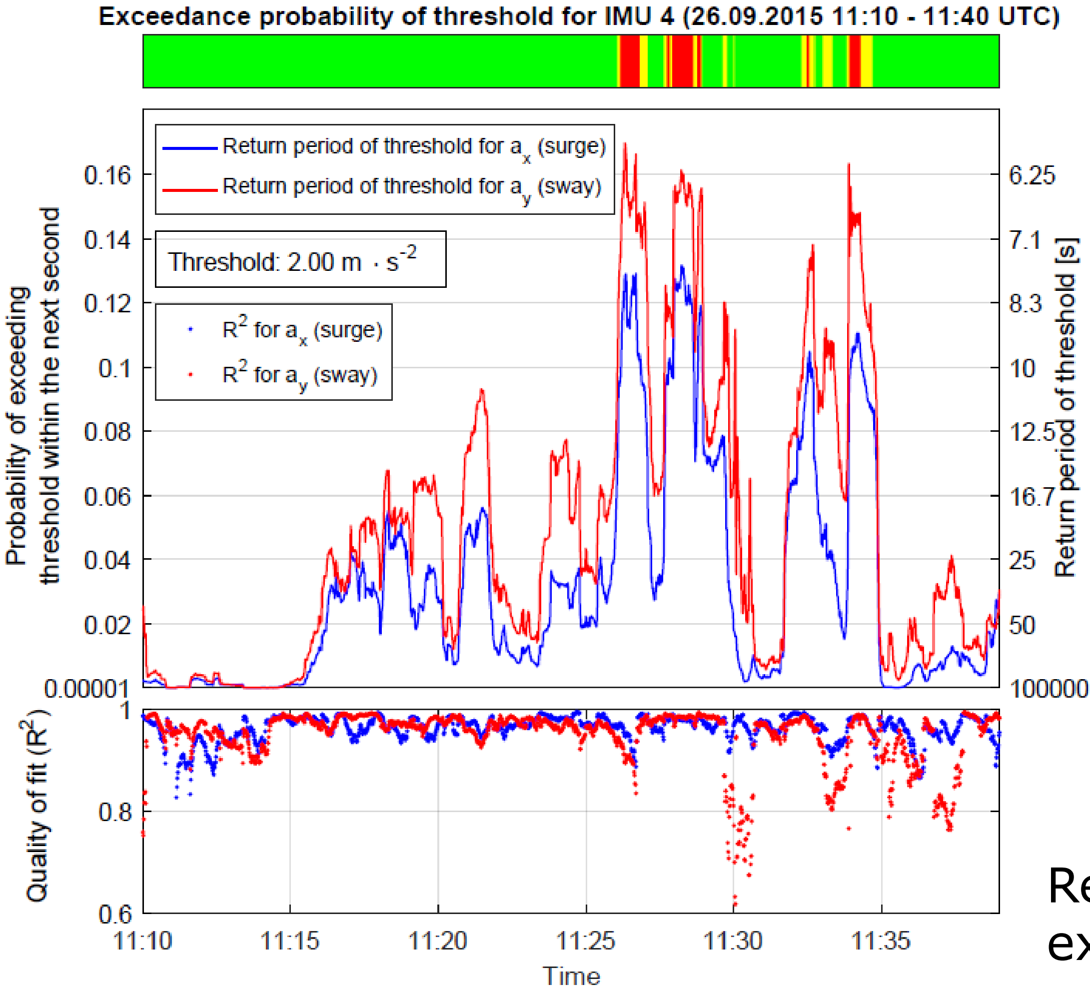
Trapped in ice for one week (dailycaller.com)

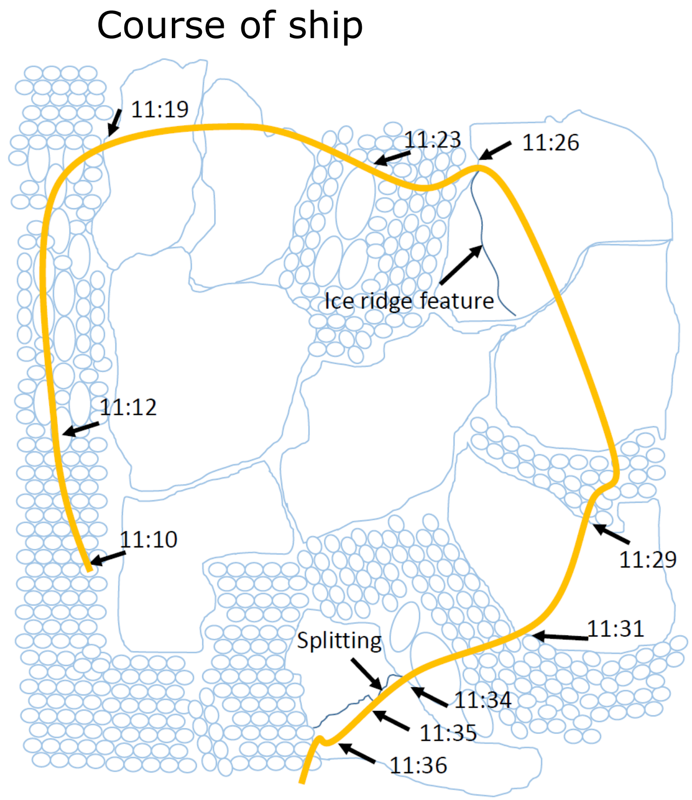
Accelerometers measure ship accelerations.
4 cameras monitor ice

Distribution of accelerations disclose type/severity of ice load.
Cameras are used for validation

Short term Ice-load prediction

**Heyn, Blanke, Skjetne: Estimation of extreme ice accelerations based on signal detection.
(NTNU – AMOS results)**





Return period is time interval expected for exceeding a certain ice load (in popular terms).

Unmanned and Autonomous Vessels: Could improve safety

“I was navigating by sight because I knew the depths well and I had done this maneuvre three or four times” . Captain Schettino Master, Costa Concordia. Source: BBC.com

How Can Autonomy Enhance Safety

Simplify information

Perception -> warn if danger

Suggest solutions

Make autopilot ”intelligent” – aware of context

Intervene in critical situations

Navigate autonomously

Supervise remotely

Øystein Engelhardsen: Autonomy at Sea. Plenary at IFAC MCMC’2015 Conference at DTU.

Development and research in the comercial area

Technology is available in the very near future.

How do we wish to take advantage of its benefits in the arctic areas