Forsvarets forskningsinstitutt

A2: Future Technologies and Requirements

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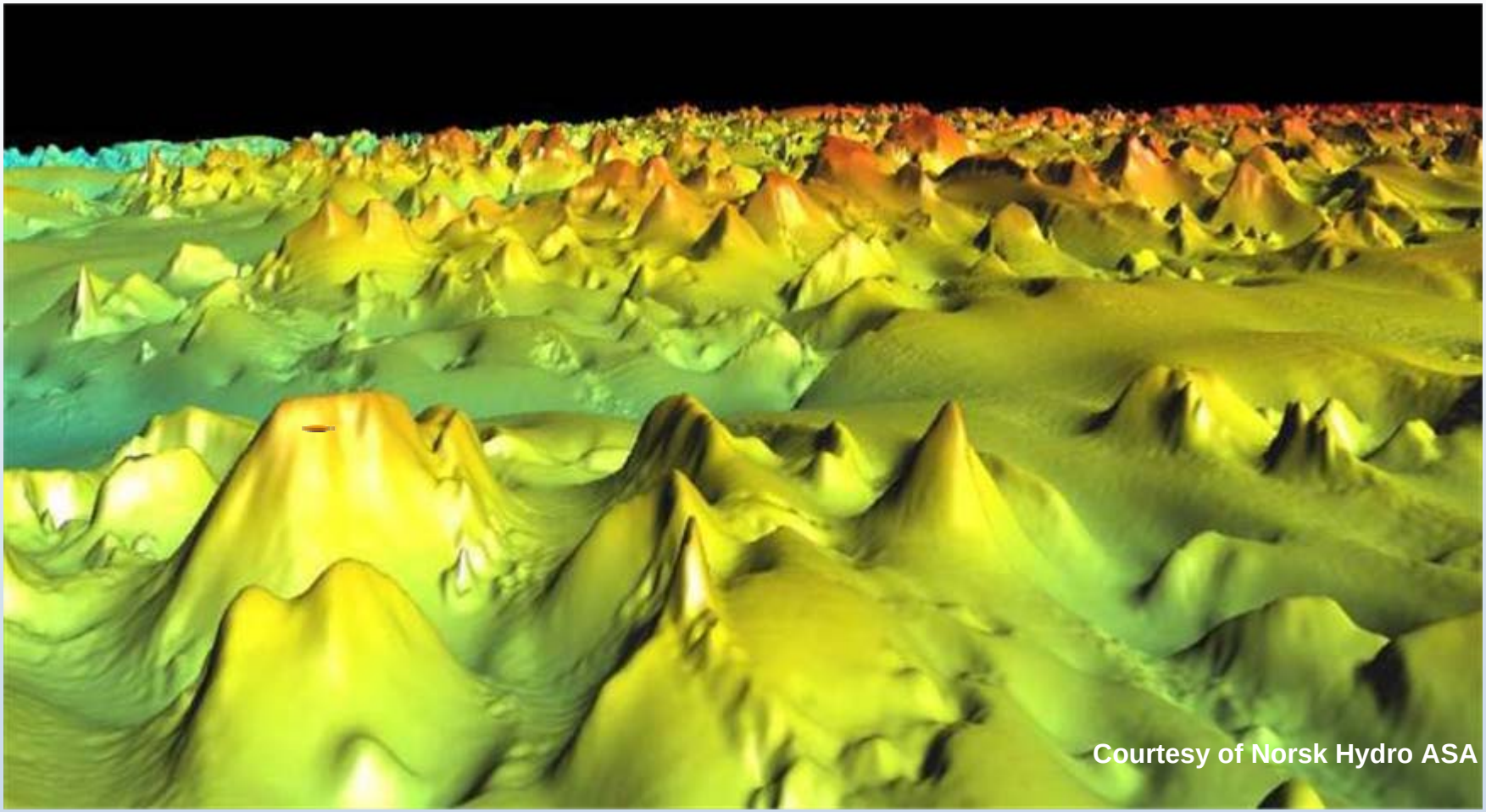
The HUGIN family

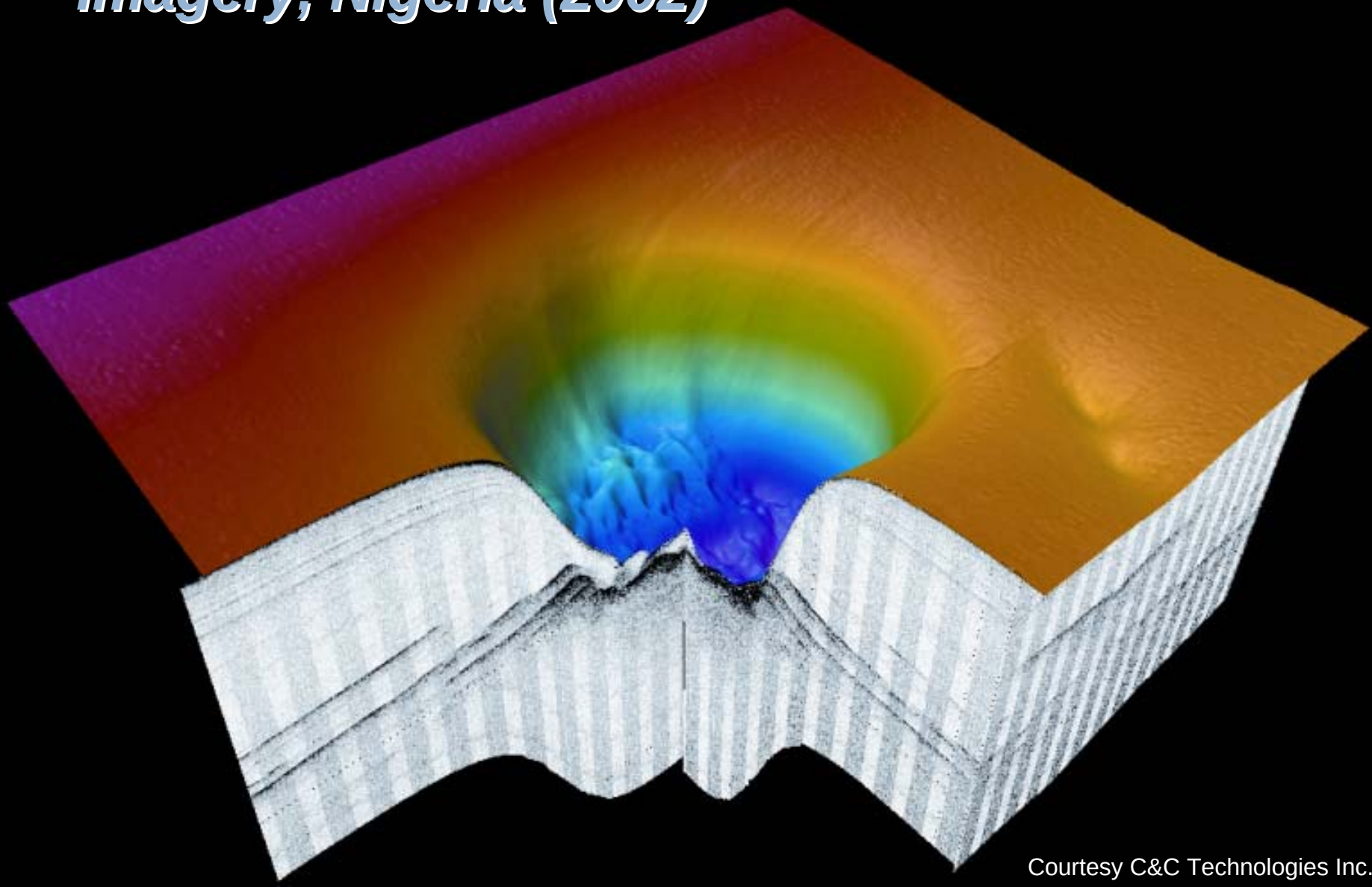
- Developed by FFI in collaboration with Kongsberg Maritime
- HUGIN AUVs are operated commercially by offshore survey companies
  - C&C Technologies Inc, USA (HUGIN 3000 (2) and HUGIN 4500)
  - Fugro NV, The Netherlands (HUGIN 3000)
  - Geoconsult AS, Norway (HUGIN 3000)
- Commercial HUGIN operations since 1997
  - More than 80,000 line km billed
  - 10000 operational hours accumulated
  - From the Barents Sea to Brazil and Austraila.
- Royal Norwegian Navy (HUGIN 1000)
  - Military operations since 2001
  - In NATO exercises since 2003
  - In standing NATO force in 2004

HUGIN from the Ormen Lange field, The North Sea



Ca. 2x2 km; the peaks are 30-50 m high

Swath Bathymetry and Sub-Bottom Imagery, Nigeria (2002)



Courtesy C&C Technologies Inc.

What are the main benefits with AUVs?

- Search and survey operations. ”Going to the end of the world”
  - AUVs are optimized for survey, ROVs for intervention
- Go where you want to go
  - Close to the bottom
  - Pre-programmed mission pattern
  - Follow features of interest
  - Under the ice
- Co-localized multi-sensor information
- Cost-effective use of ships and resources
  - Large area coverage rate from AUVs
  - Research vessel operation independently from AUV
  - Multi vehicle operation
- Added benefit from better data quality and option for adaptive behavior

Technology drivers in future ocean science missions

- Going longer
- Going deeper
- Going under ice
- Going on its own
- Covering more ground
- Adapting to environment
- Adapting to sensor information
- Need for more detailed information
- More precise geo-referencing of data
- More sensors onboard at the same time
- Interacting with other autonomous systems
- Reporting back to base and re-tasking mission
- Making it back ”home” safe, even in bad weather

Mapping of requirements vs technologies

Mission requirements	Consequence for technology
Going longer	Batteries and fuel cells
Going deeper	Structural issues/ Batteries/ Navigation
Going under ice	Control/ Sustainability/ Navigation
Going on its own	Control/ Sustainability/ Adaptivity/ Communication
Covering more ground	Batteries/ Sensor performance
Adapting to environment	Control/ Adaptivity/ Sensors
Adapting to sensor info	Control/ Adaptivity/ Sensors
More detailed information	Sensors/ Navigation
Geo-referencing of data	Navigation
More sensors onboard	Sensors and sensor fusion
Interacting with other AUVs	Control/ Communication/ adaptivity
Reporting back to base	Communication
Making it back ”home”	Sustainability/ Launch&Recovery

Enabling technologies for AUVs

- Control technology
  - Integrity, sustainability
  - Adaptive behavior
  - Post-mission automated analysis
  - Coordinated multi-system operations
- Precise autonomous navigation
  - Aided inertial navigation tool box
  - Positioning of data (geo-referencing)
- Advanced power sources
  - Batteries
  - Fuel cells
  - Closed cycle engines

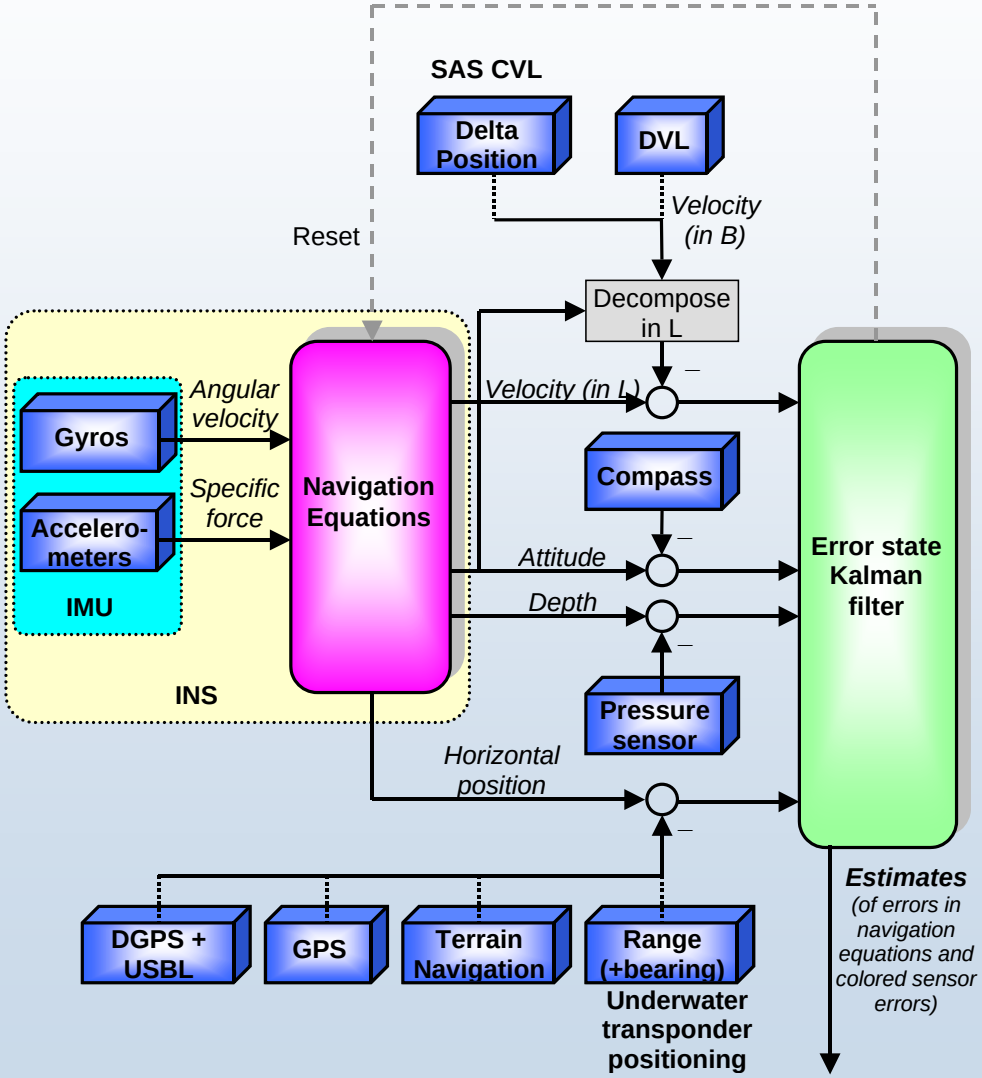
Enabling technologies for AUVs…

- Communication (Acoustic, radio, satellite)
  - Robust, long range and high data rate acoustic communication
  - Over-the-horizon communication
  - High bandwidth mid-range RF communication

- Sensor technologies
  - Traditional sensors like CTD, SSS, MBE, SBP, FES, LOPC, ..
  - Synthetic Aperture Sonar (SAS)
  - Laser imaging systems
  - Others for specific scientific purposes

- Networking of systems (Systems-of-systems)
  - Multiple AUVs, individual or coordinated operations
  - AUVs interacting with subsea monitoring networks

Integrated Inertial Navigation System



Features:

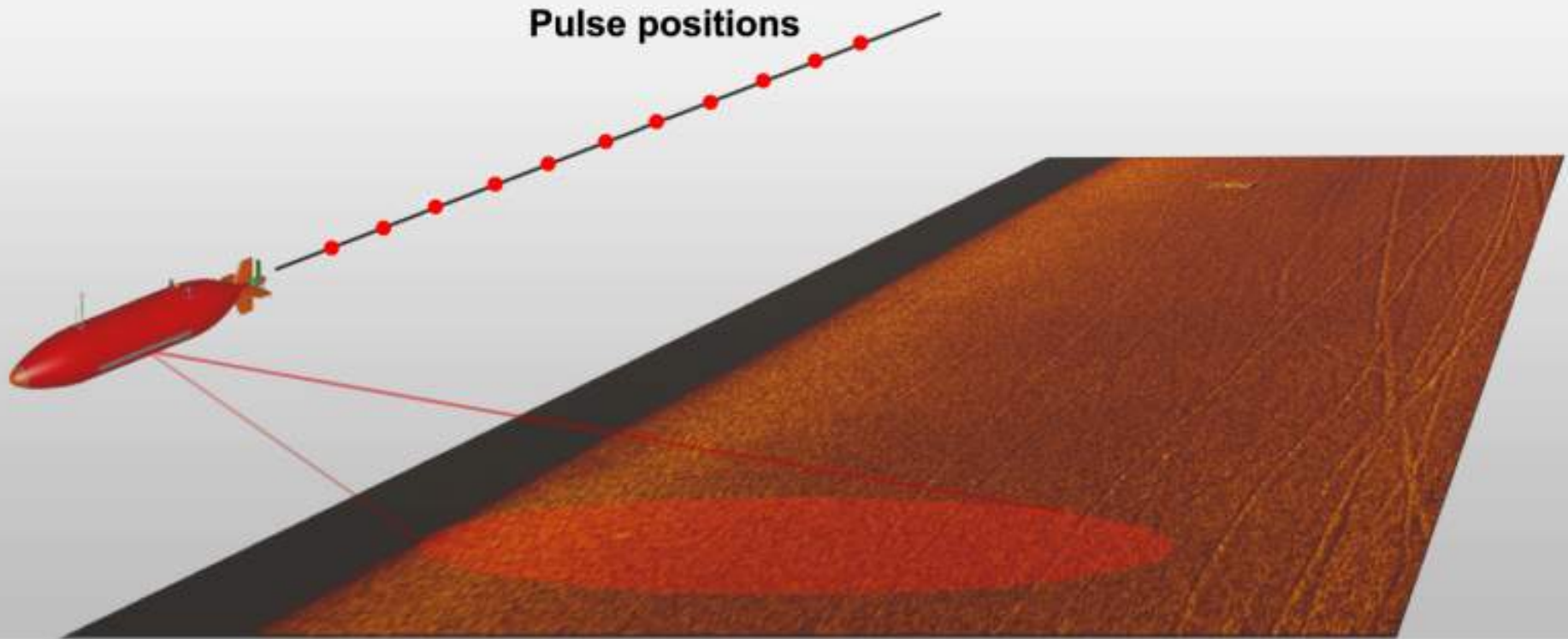
1. A core velocity aided INS that handles submerged navigation without position updates for long periods of time.
2. A toolbox of navigation techniques to serve a wide range of applications:
   - DGPS-USBL
   - GPS
   - Terrain navigation
   - UTP
   - SAS velocity aiding
   - NavLab post-processing

Power sources for generic deep water AUVs

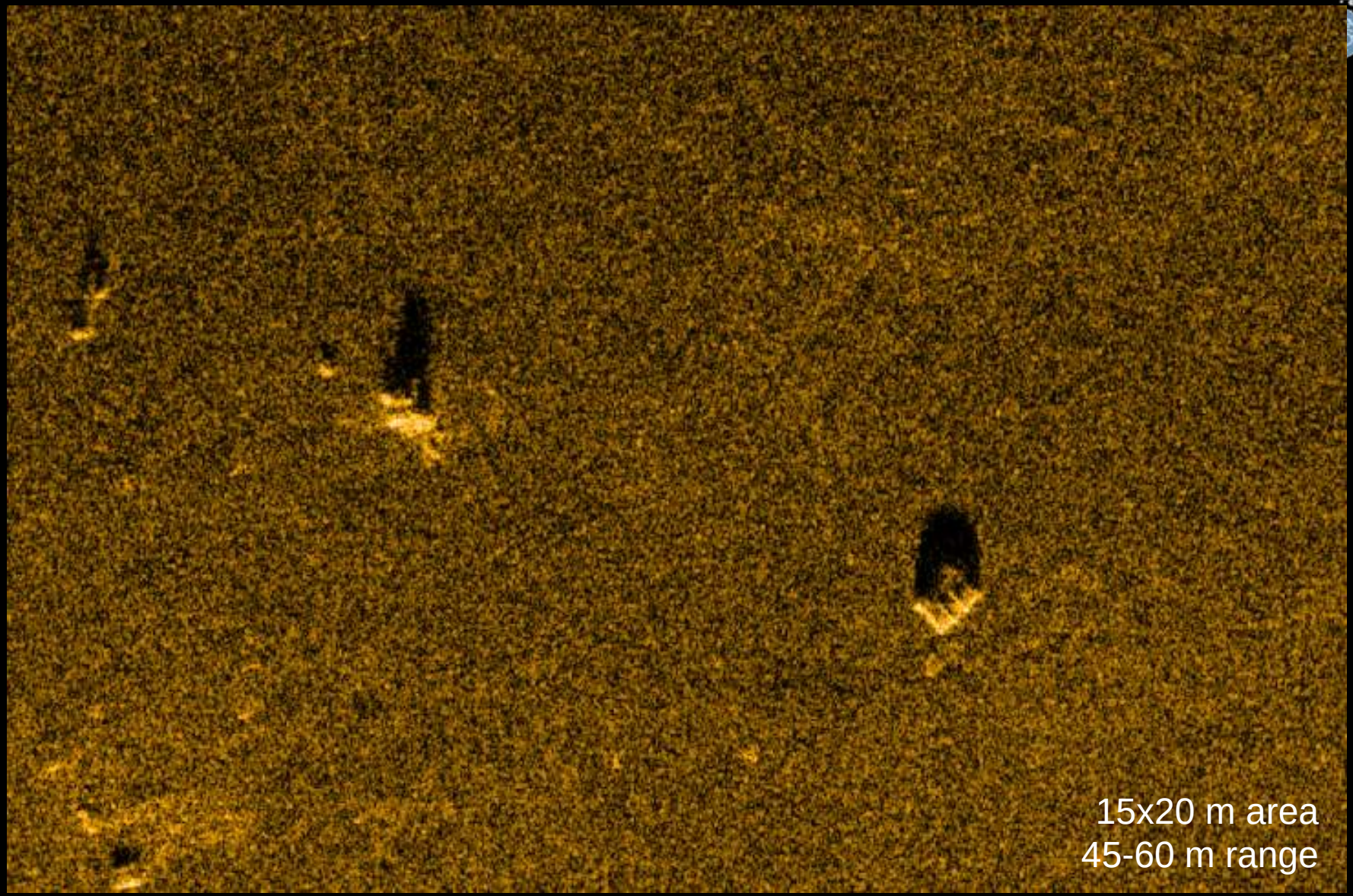
Technology	Type	Energy density (Wh/dm^3)	Endu-rance (hours)	Safety	Cost	Logistics/ Mainte-nance
Lead acid	Recharge able	10-20	4-8	High	Low	Low
NiCd/NiMH	Recharge able	10-30	4-12	High	Low	Low
Alkaline batteries (heated to +45C)	Primary	10-30	4-12	High	Low/ high	Low
Silver-Zinc	Recharge able	30-50	12-20	Med	High	Med
Lithium ion (D cells)	Recharge able	40-70	16-28	Med	Med	Low
Lithium polymer (poach)	Recharge able	50-75	23-30	Med	Med	Low
Aluminium-Oxygen	Semi-fuel cell	80-90	32-36	Med	Med	High
Hydrogen-Oxygen	Fuel cell	100+	40+	Low	Med	High
Lithium batteries	Primary	100-150	40-60	Low	High	Low

Synthetic Aperture Sonar

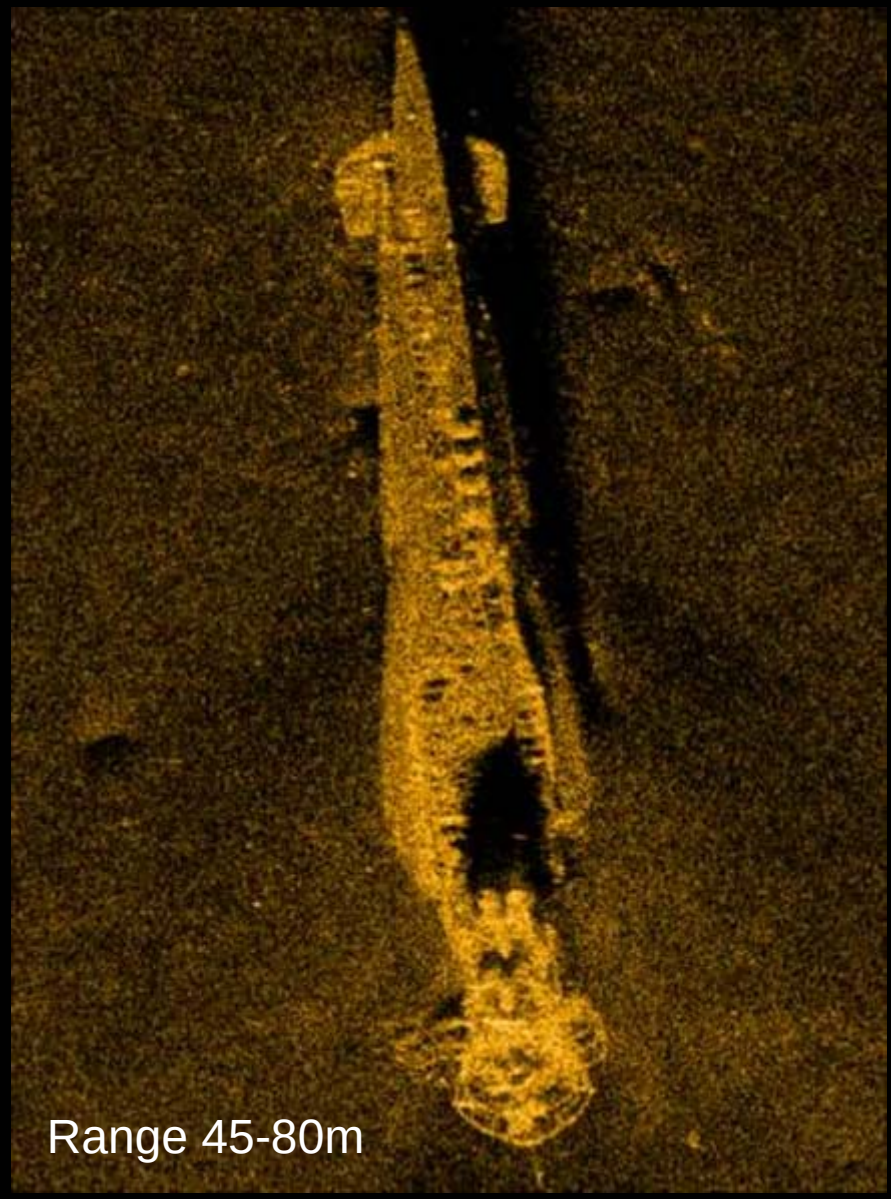
- Coherent combination of pings to increase along-track resolution
- Two vertically separated receive arrays give bathymetric mapping capability (interferometry)



SENSOTEK SAS: Small objects

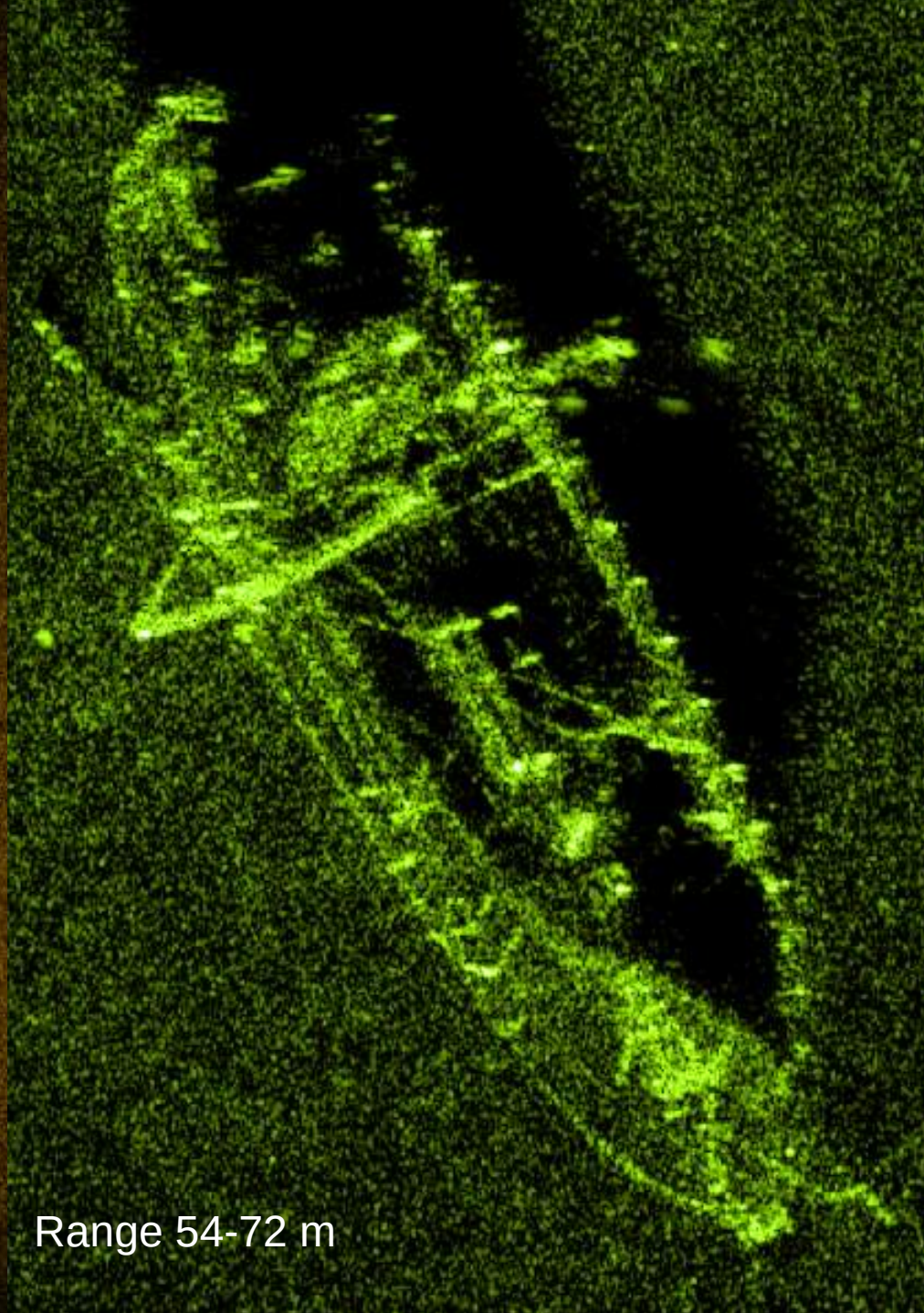


SENSOTEK SAS: WW2 U-boat wreck



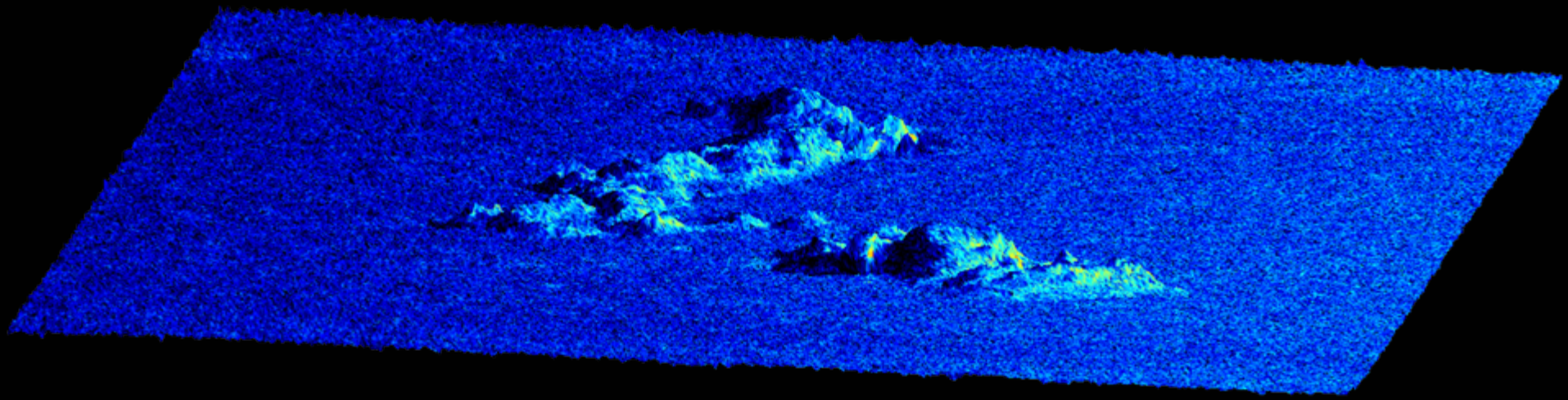
SENSOTEK SAS: Fishing boat

Range 40-120 m

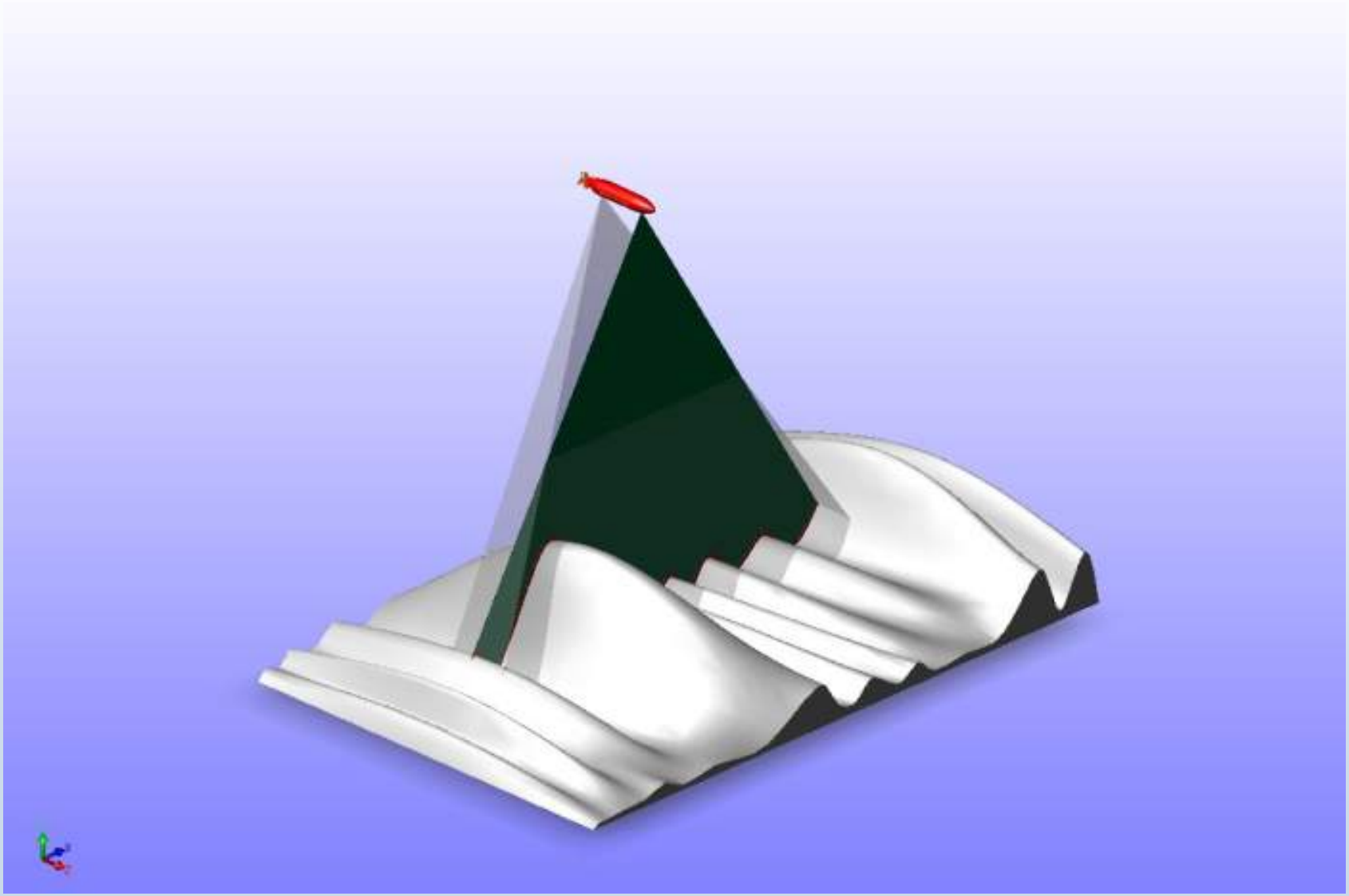


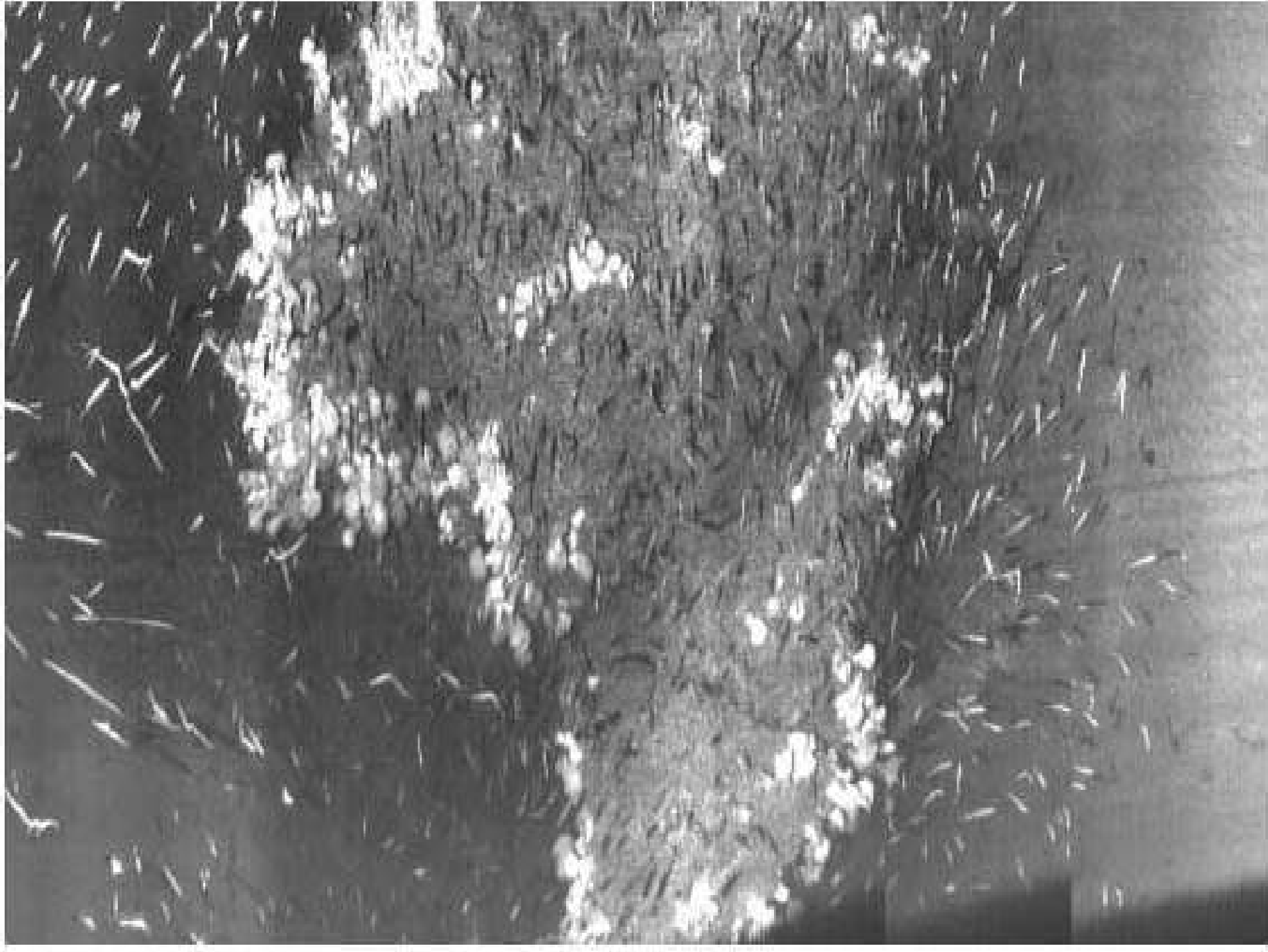
Range 54-72 m

SENSOTEK Interferometric SAS



Laser based optical imagery





Lessons learned

- ”There is no way around actually doing it”
- ”Test early, test often – at sea. Use the sea as our laboratory”
- ”Do everything in parallel. Have the capability grow”
- ”AUVs is all about doing the right compromises. It’s about balance and beauty”
- ”It is not the high-tech that kills you - it’s the low-tech”
- ”The ”high-tech” is mostly overestimated in terms of value and underestimated in terms of development cost and time. Focus on the stuff that really makes a difference”

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