Malta Summer School 2018
Operational Oceanography for Blue Growth

Digital Age in Operational Oceanography

the cloud and consumer technology

Graham Worley

Bangor University
(thanks to David Mills)

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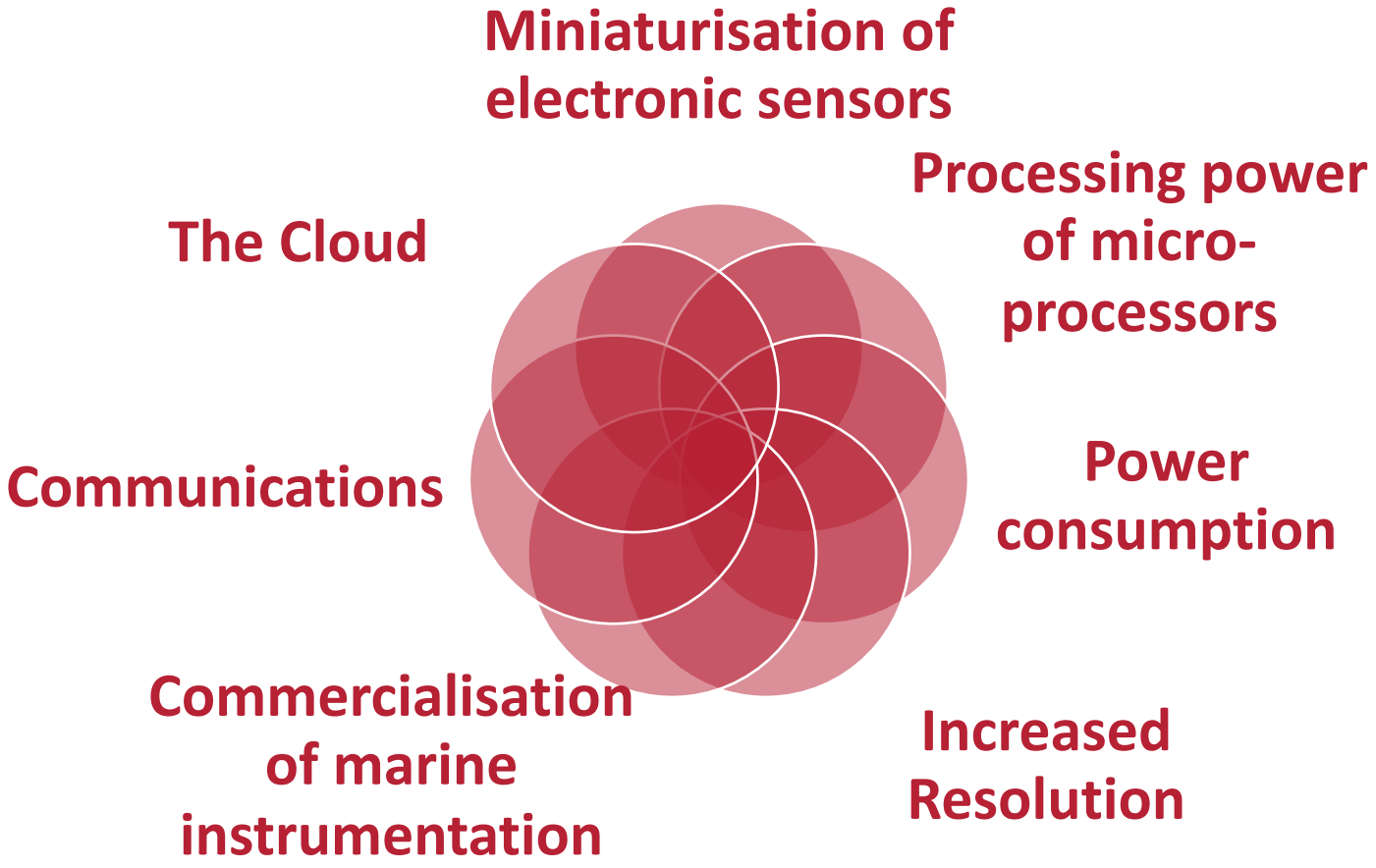
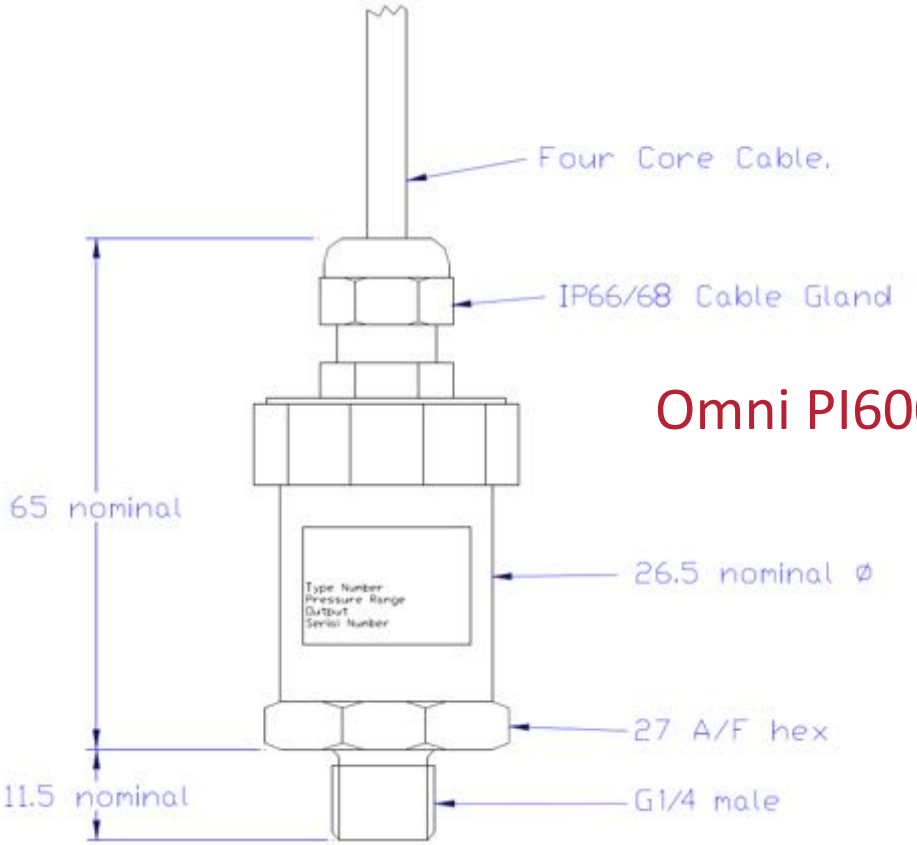
Drivers for the development of Digital Operational Oceanography

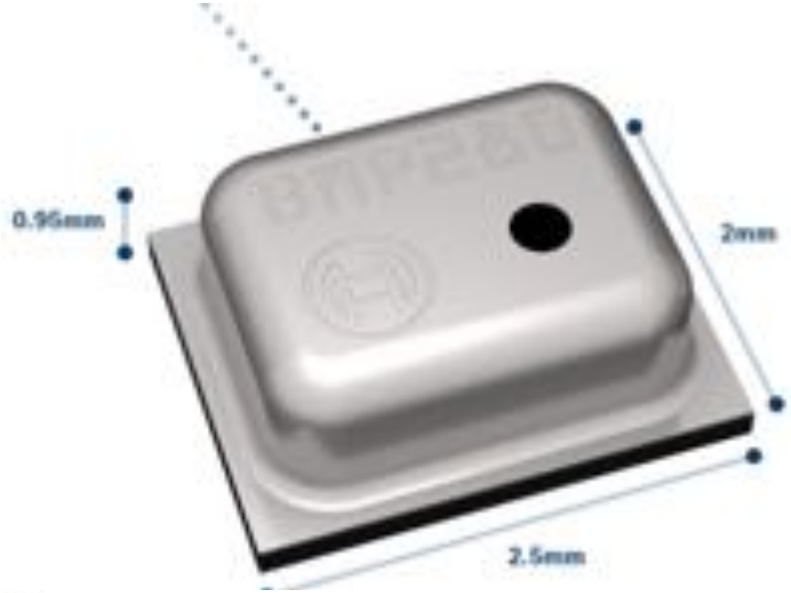


Miniaturisation of sensors



Omni PI600 4-20mAmp Sensor

Bosch BMP280



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JERICO next

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Processing power of micro-processors

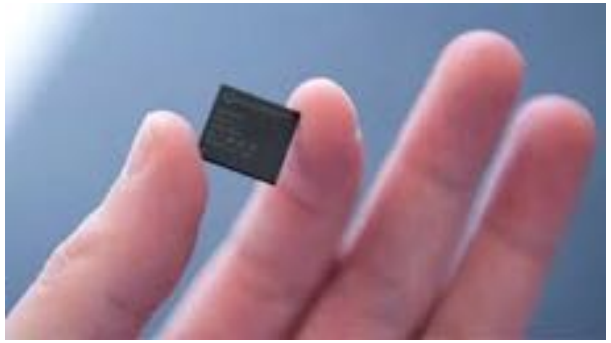
MOS 6502 1980s

0.430 MIPS at 1.000 MHz

Qualcomm Snapdragon 800 2010s

(based on ARM Cortex A57)

~14,000DMIPS at 2.8GHz



Power consumption of micro-processors

Intel Pentium Pro 1990s

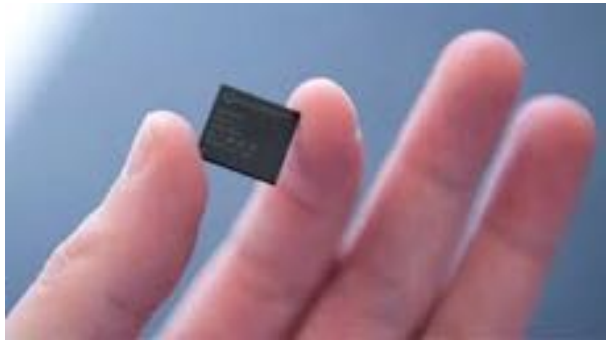
541MIPS 50 Watts

Qualcomm Snapdragon 800 2010s

(based on ARM Cortex A57)

3-4 Watts

SOC



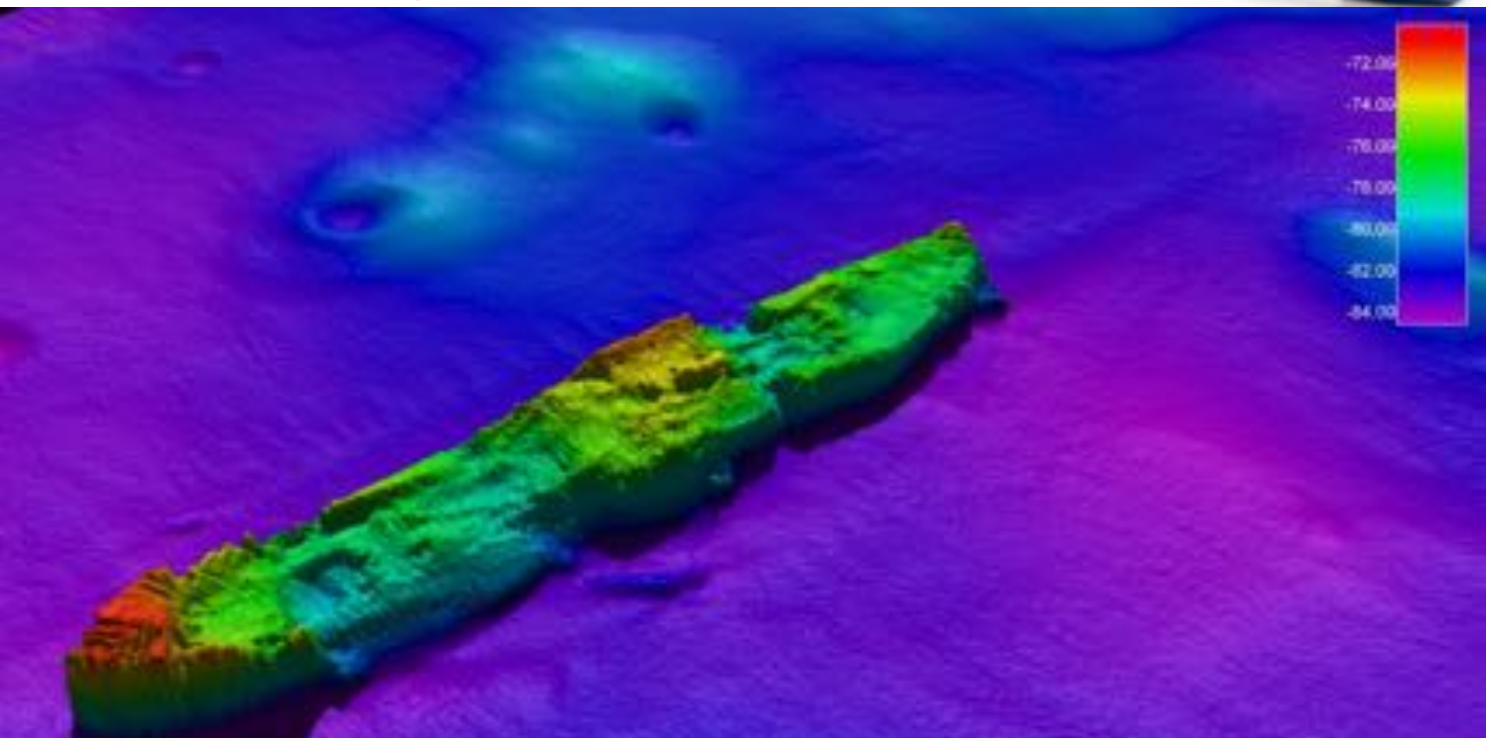
Resolution

SeaBat T50-P / 7125

512beams 0.5x1 degree

300Gbytes of data a day

<0.5m grid



Communications

1990s Telephone Modem 9600 bits/s

X25 Leased Line 2400 – 2048k bit/s

2010s

5-12Mbits/s

2400bits/s

100Mbit/s to 10Gbit/s

400kbit/s

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Cloud Computing

Azure

Software As A Service (SAaS)

Pre-installed ready-to-use software:

- Microsoft Office 365
- Adobe Creative Cloud

Combines storage, computing and software as one service

Infrastructure As A Service (IAaS)

Public cloud: On-demand Pay as You Go

Storage – massively scalable

Compute – 1 to thousands of cores

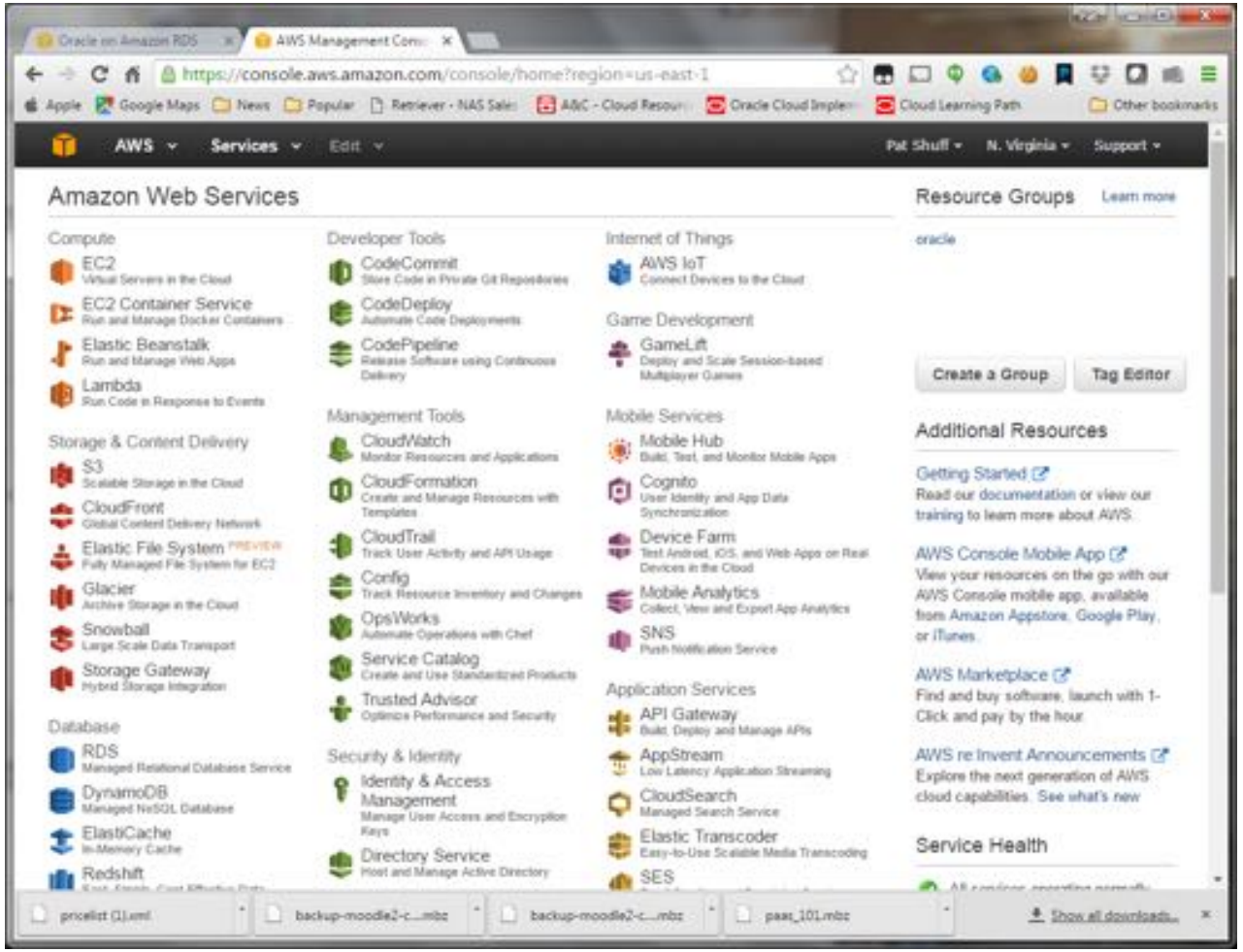
Automation

Scalability

Orchestration

Cloud Computing – Lightweight scalability

No more heavy machines….point and click deployment…



Cloud Computing – Storage

Scale – 1byte to infinity

Cost – 360 USD per Tbyte per annum

Accessibility

Security / Encryption

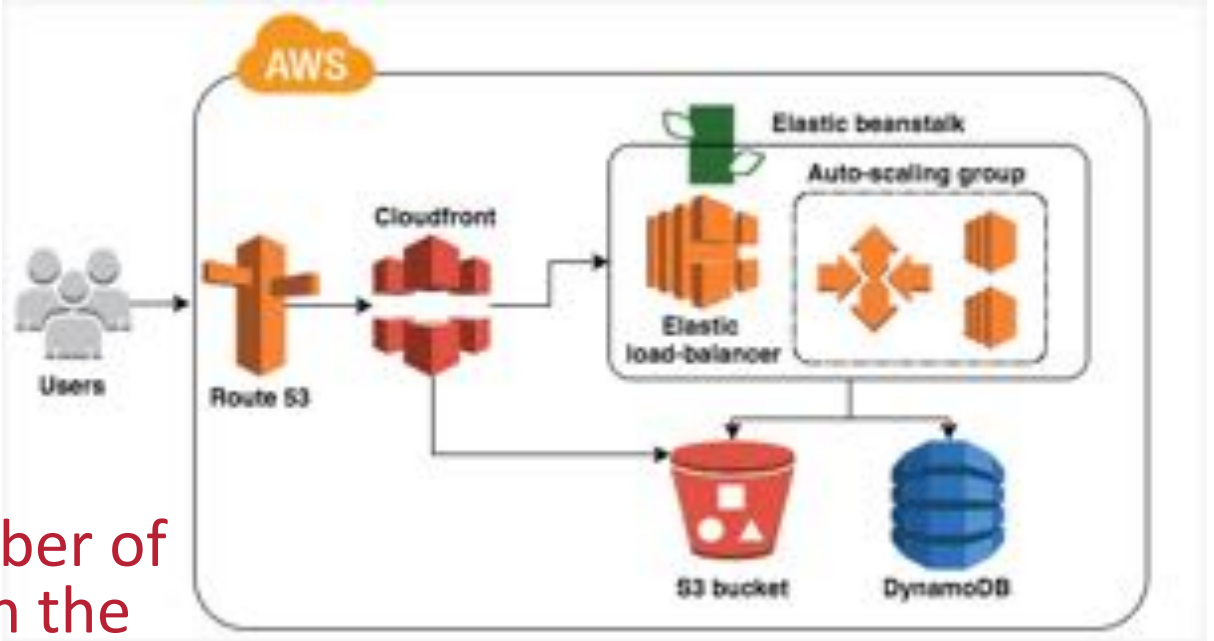
Programmability - S3 Application Programming Interface

Amazon S3

Cloud Computing – Data Delivery

AWS Elastic beanstalk

- Orchestration
- Auto-scaling
- Fault-tolerant
- Geo-localised



- Can serve any number of people anywhere in the world.
- No longer constrained by power of one or two servers in the laboratory.

Cloud Computing – Compute Resource

Supercomputing - HPC in the cloud for modelling

1 to many traditional virtual machines

Custom machine images (AMIs)

CfnCluster – AWS CloudFormation Cluster

NETFLIX

15 billion forecast per day via AWS

The Weather Company
An IBM Business

AWS EC2 Powers NETFLIX

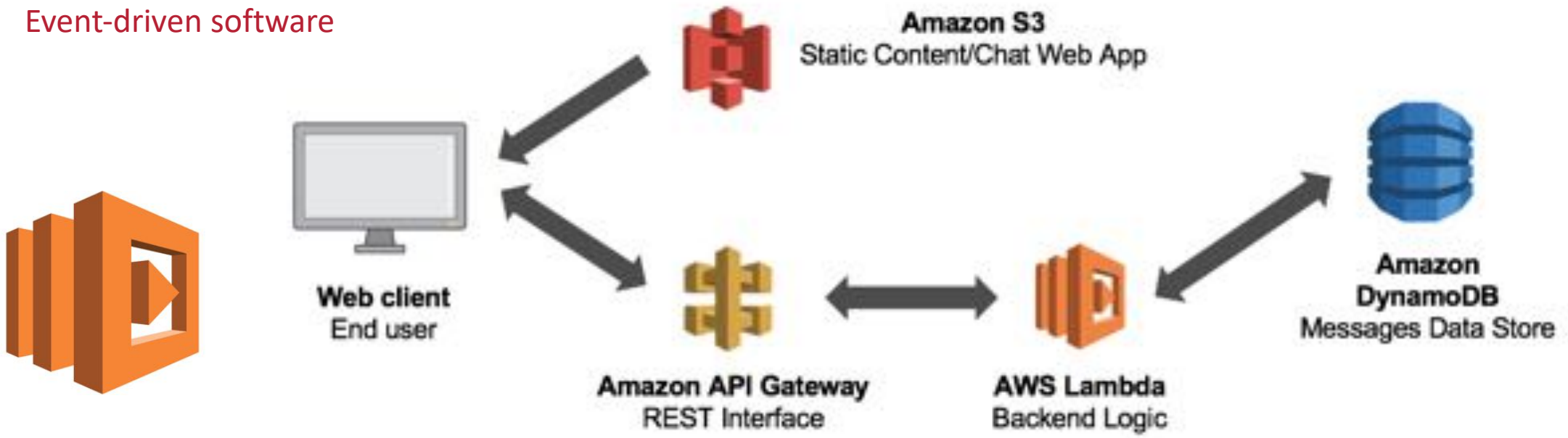
Cloud Computing – Compute Resource

Functional Computing - Lambda Functions

Virtual Machines – High idle-time

Lambda functions – No idle-time charging

Event-driven software



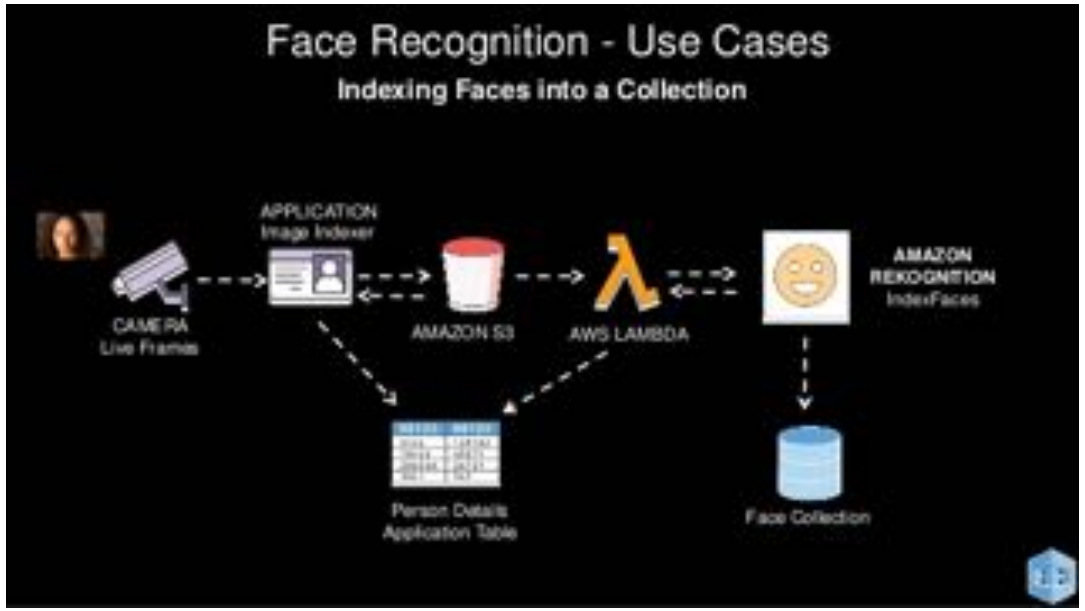
Cloud Computing – Compute Resource

Analytical Computing

Tailored software services powered by virtual machines and lambda functions

Machine Learning – On-demand regression analysis on a massive scale

Amazon Machine Learning



Re-purpose face recognition services for feature detection?

- **Detection of fronts**
- **Wave / Surface current analysis**
- **Beach morphology**

Cloud Computing – In summary

Great for prototyping and production workloads
Delete when done

SEACAMS Relocatable Observatory

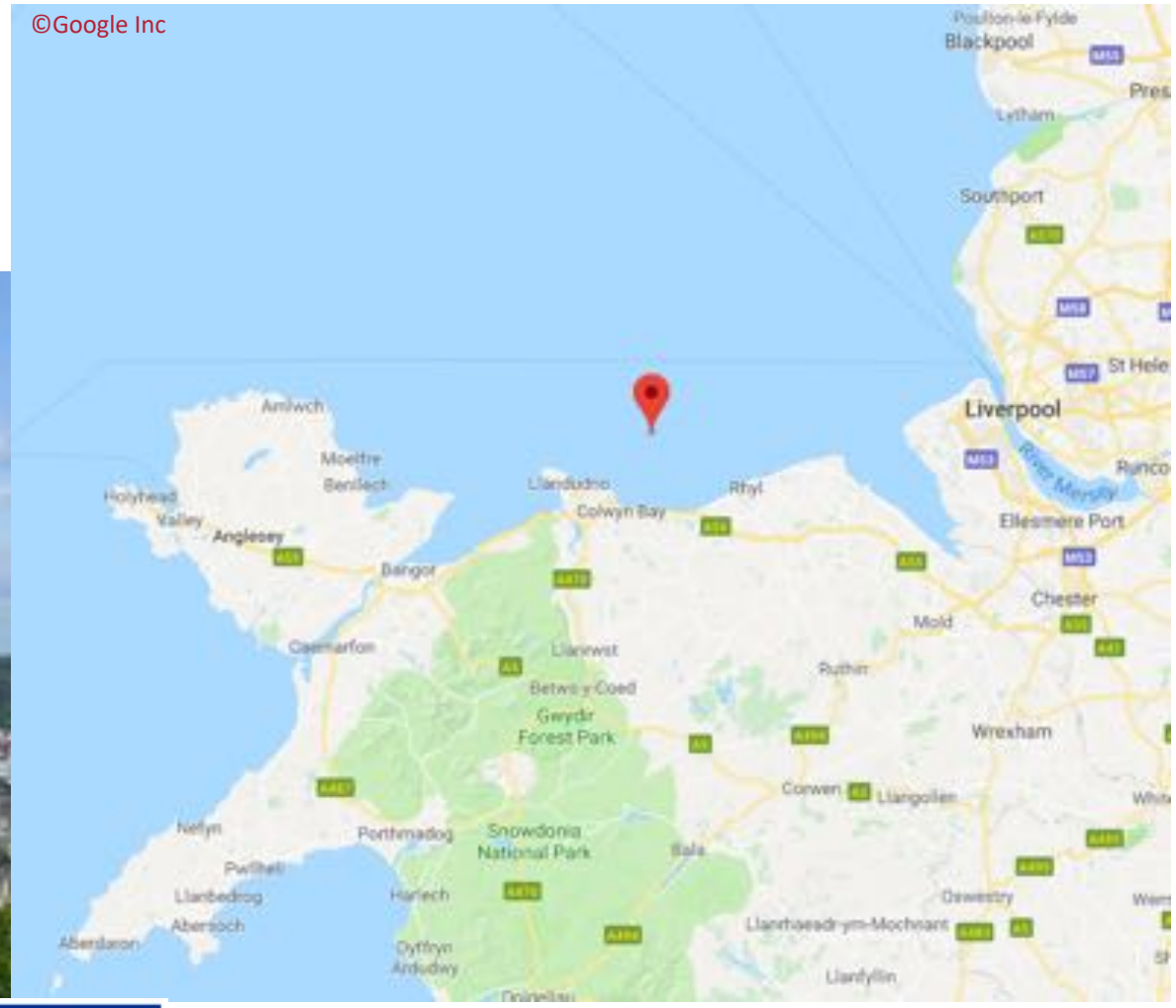
Relocatable OSIL Fulmar Buoy

4G and Iridium Coms

Multi-parameter

SEACAMS Relocatable Observatory

- 6km North-east of Llandudno



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SEACAMS Relocatable Observatory

Sub-Surface Instrumentation

- Nortek AWAC
- Campbell Scientific Turbidity Sensor
- Teledyne Acoustic Modem

Surface Instrumentation

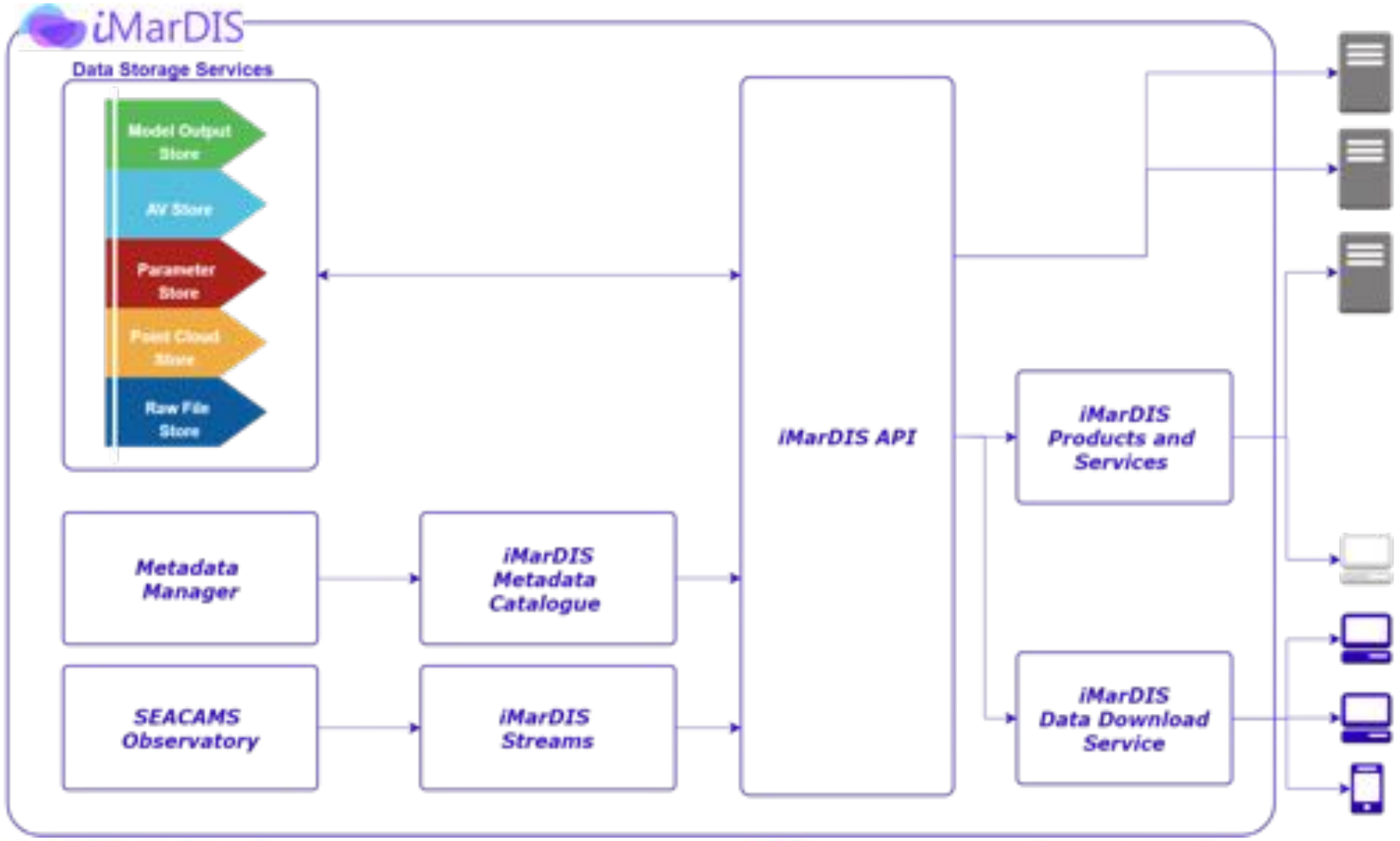
- RBR Maestro CTD (conductivity, temperature, depth, chlorophyll,
- Teledyne Acoustic Modem
- 3G Modem
- Rockblock Iridium Modem
- AirMar Wind Vane

SEACAMS Relocatable Observatory

Campbell CR6 Logger

- Assembles data frames
- Delivers to Amazon Web Services via 3G / Iridium
- IoT Internet of Things?

SEACAMS Relocatable Observatory



iMarDIS
Integrated Marine Data and Information System

Cloud-based infrastructure to handle and share marine data

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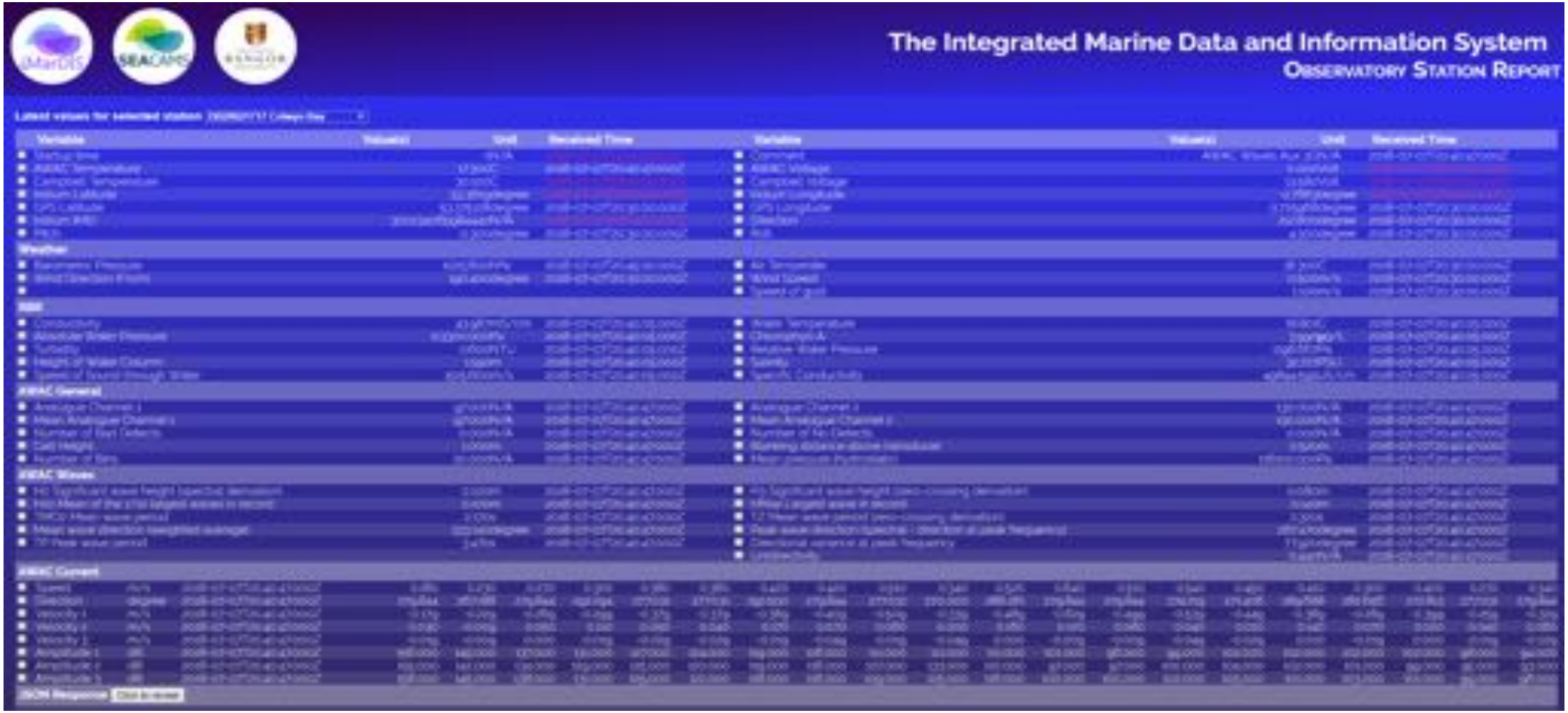
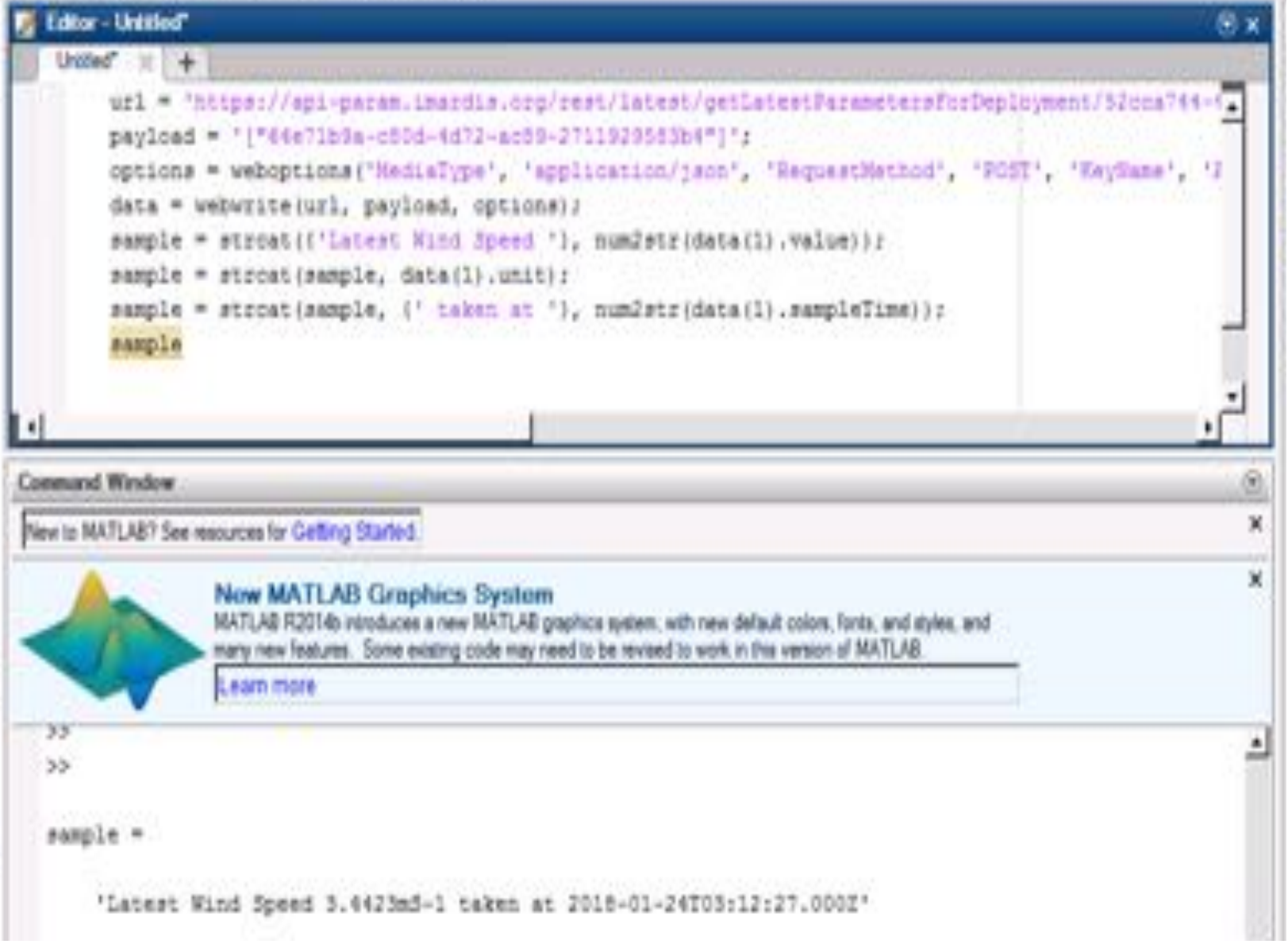
SEACAMS Relocatable Observatory

http://www.imardis.org/observatory-live



SEACAMS Relocatable Observatory



Similar Deployment – CEFAS SmartBuoy

SmartBuoy – Near surface instruments

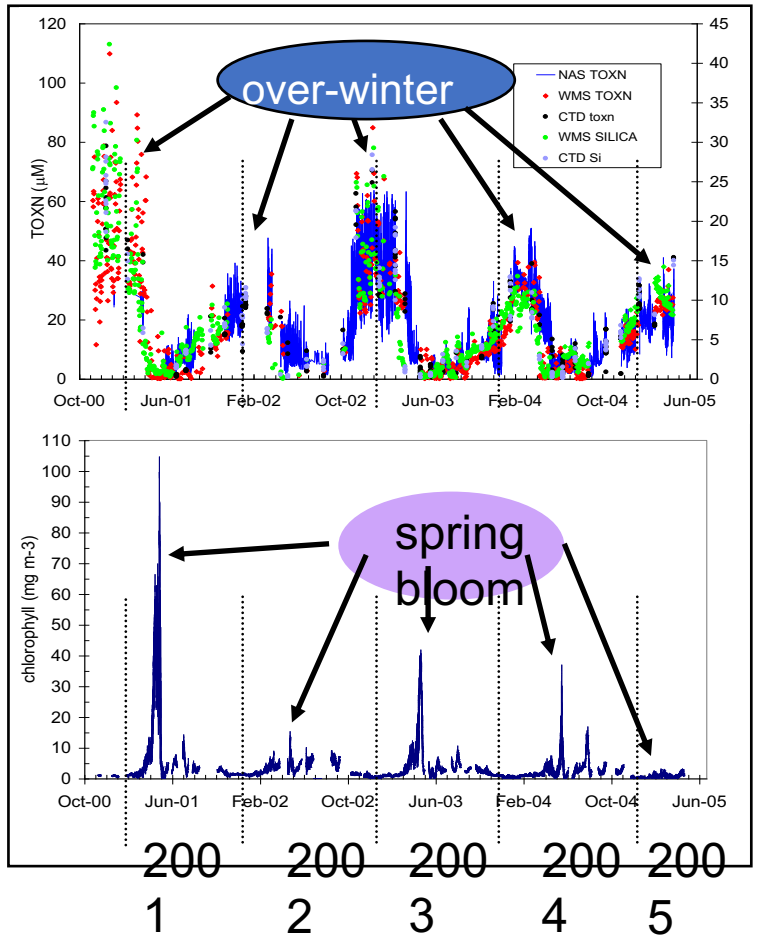
In situ nitrate analyser

Water sampler

Multichannel logger - CTD, OBS, O2

Flurometers

c Applied Oceanography - Mills

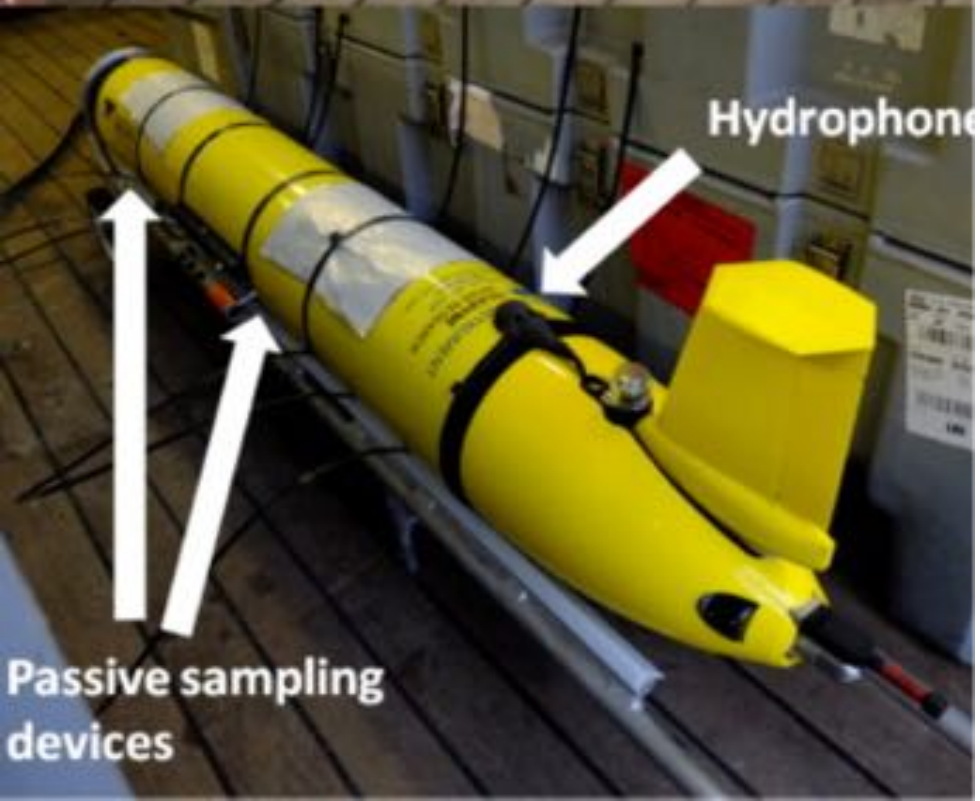


Intelligent Sensors

- Sensors with micro processors
- Internet of Things
- File their own data – Sensor Web Enablement
  SensorML describes the sensor and the data enables IoT data deposit

- Many standards – JSON over REST will eventually dominate

Autonomous Vehicles – Surface / Sub-Surface



Advantages

- Operate in adverse conditions
- High spatial and temporal resolution
- Cost efficiency (?)

Issues

- Sensor calibration and validation
- Requires additional data/information from other sources (ships, moorings)
- Qualitative vs quantitative observations

Assessing the potential of autonomous submarine gliders for ecosystem monitoring across multiple trophic levels (plankton to cetaceans) and pollutants in shallow shelf seas. Suberg et al., 2014. https://doi.org/10.1016/j.mio.2014.06.002

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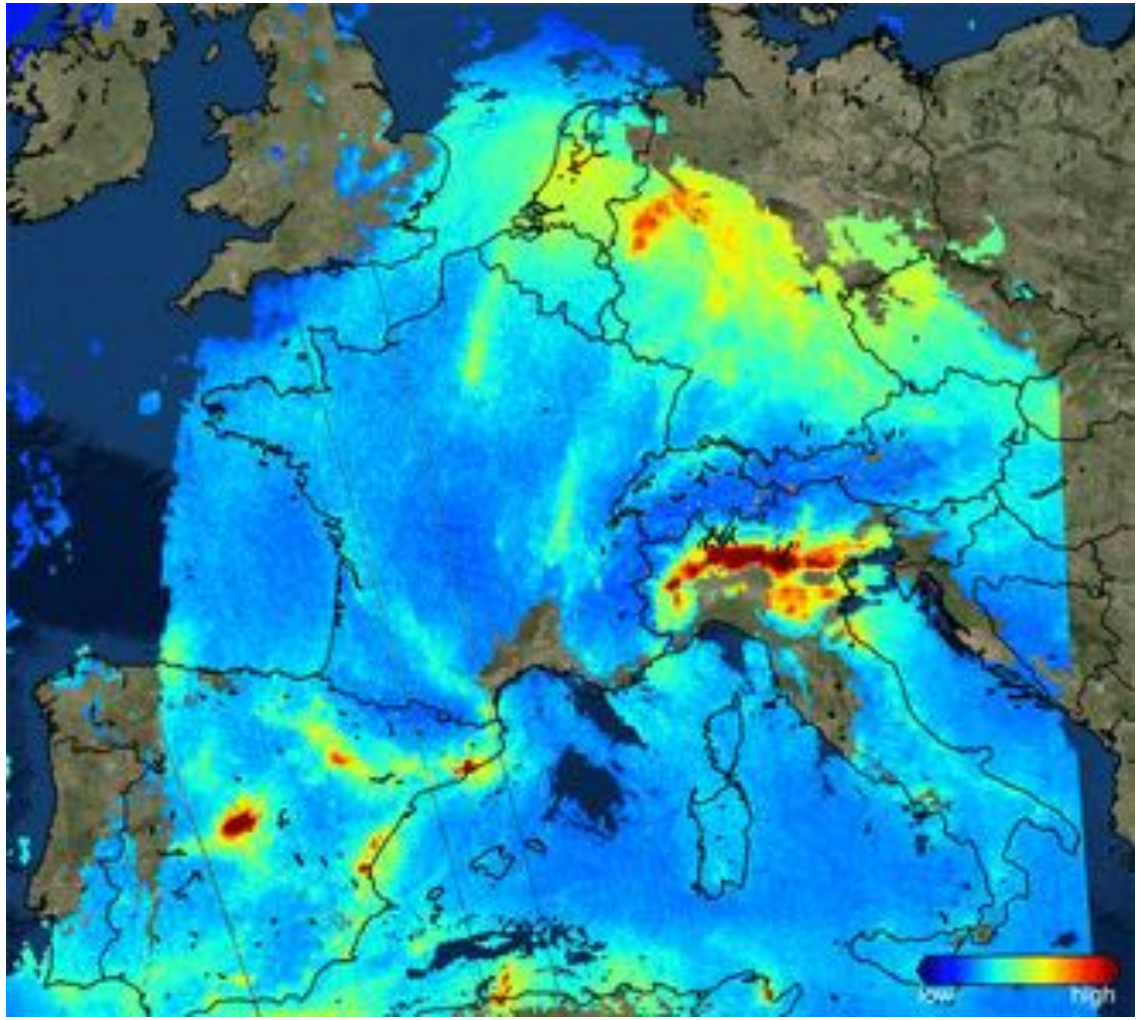
Semi-Autonomous Vehicles - Airborne

Instrumented drones - LIDAR

Remote Sensing

continual evolution

Copernicus Sentinel Data 2017 NO2



The Future

Ships are expensive

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UK-IMON International Workshop on New Monitoring Technologies:

Themes

- Autonomous systems
- Conventional systems
- Sensors
- Other data acquisition systems

VoOp

www.uk-imon/info

How can we reduce the cost of making observations ?

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UK-IMON -Autonomous platforms ranking

Platform name	Score	TRL
AUV Class #1 (small / coastal / shore based)	15	5
AUV Class #2 (medium / shelf)	15.5	5
AUV / Hybrid / longrange	14.5	2/3
AUV Class #3 (large / deep)	13.5	5
Bio-mimetic fish		1
Crawlers / rovers / benthic	13.5	3
Buoyancy Gliders deep	18.5	5
Buoyancy Gliders shallow	18.5	5
RPAs / UAVs / UAS	17	5
Mammals (OR IN OTHERS ?)	17	5
USV #1 (Short duration)	16	4/5
USV #2 (long endurance)	19.5	4/5
Buoyancy floats	20	5
Surface Drifters	19	5

Research

Operational

Key

TRL Technology Readiness Level
AUV Autonmous Underwater Vehicle
RPV Remotely Piloted Vehicle
UAV Unmanned Ariel Vehicle
UAS Unmanned Ariel Systems
USV Unmanned Surface Vehicle

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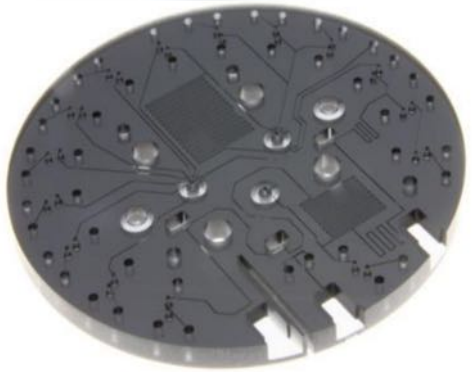
Sensor/Platform	TRL
Lab on chip	
nitrate	3
phosphate	3
silicate	3
ammonium	2
iron/manganese	2
conductivity, temperature, oxygen	3-4
nucleic acid sensor	1-2
synthetic immuno sensor - proteins, small organics, small molecules	1
cytometry	1-2
pH	3
Total Alkalinity / DIC	2
Optode CO2	3
mass spectrometry	4
"Sniffer" methan, PAH/hydrocarbon, carbon dioxide	5
RAMAN	2
ESP/nucleic acid and protein sensor	4-5
Biotaguard (mussel valve opening and sponge)	4-5
acoustic recorders (hydrophone, passive, wide range)	5
automated flow cytometry (full size, in-line, data automation, different types)	5

Sensors



Lab on a chip

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Data Sharing

- Open Data != Free Data
- Discovering data – Metadata

- Beyond metadata – NoSQL Databases

amazon DynamoDB

CouchDB relax · Redis · Neo4j the graph database · Cassandra · mongoDB · membase · riak

- More to a dataset that a title, date and creator
- Beyond OGC – JSON JavaScript Object Notation, RESTful web services

The Future

- Higher Resolutions
- Multi-parameter sensors (on a chip)
- Yet Faster Data
- Machine Learning – Targeted sampling
- Citizen Science – (e.g. beach morphology)
- Automated Model Optimisation / Validation

The Future

- Armchair Oceanography?????