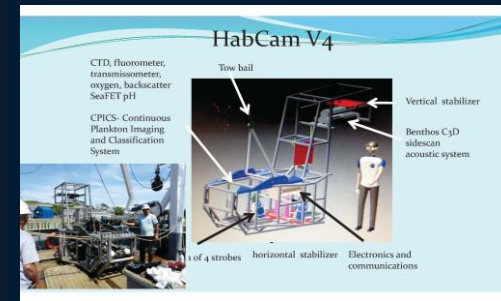# Emerging Technologies

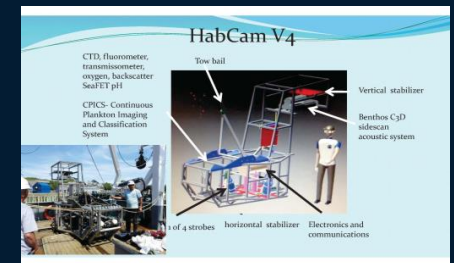The purpose of our report is to highlight some emerging technologies that are:

- proven in research laboratories,
- are commercially available,
- do not require significant additional development costs, and
- are relevant to NOAA's mission related to marine ecosystems.

This is not "blue sky", as the implementation time frame is from the present to 5 years out.

Emerging Technologies

These technologies have potential advantages to NOAA for providing more coverage in time and space with less human intervention, thus making more efficient use of large infrastructure assets including ships and moorings, and offering the potential for long-term cost savings.

HabCam V4

CTD, fluorometer, transmissometer, oxygen, backscatter, SeaFET pH

Tow bail

CPICS- Continuous Plankton Imaging and Classification System

Vertical stabilizer

Benthos C3D sidescan acoustic system

1 of 4 strobes   horizontal stabilizer   Electronics and communications

Emerging Technologies

NOAA personnel are currently involved in the development, testing and evaluation of some of these systems. Thus appropriate expertise resides within the agency to help broaden their use within NOAA.
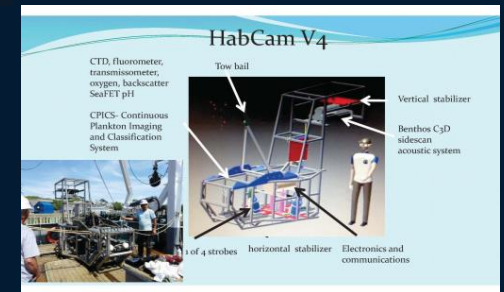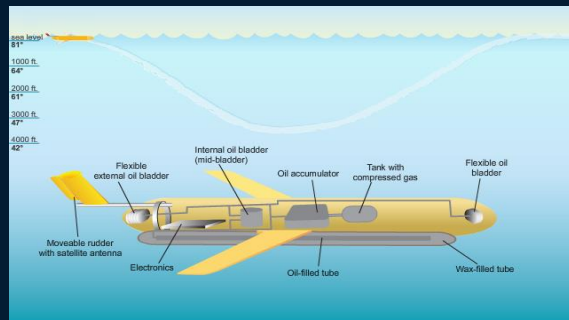
'OMICS

The most promising area of 'omics for NOAA is likely genomics, because the technology has advanced to the point that genomic techniques can be used to scan the marine environment for species and habitat conditions in ways that dovetail with a set of NOAA's core missions.

'OMICS

Environmental DNA (eDNA) identifies the presence or absence of any particular organism.

Applications include:
- monitor for conservation and management of fish, coral and others organisms;
- increase temporal coverage of target species and ecosystems;
- assess sea food safety; and
- examine human-ecosystem interactions.

'OMICS

Simple 'omics sensors can be deployed on moorings, gliders, floats and other sensing systems.

NOAA is developing the capacity to utilize the multiple applications of 'omics relative to its multiple missions.
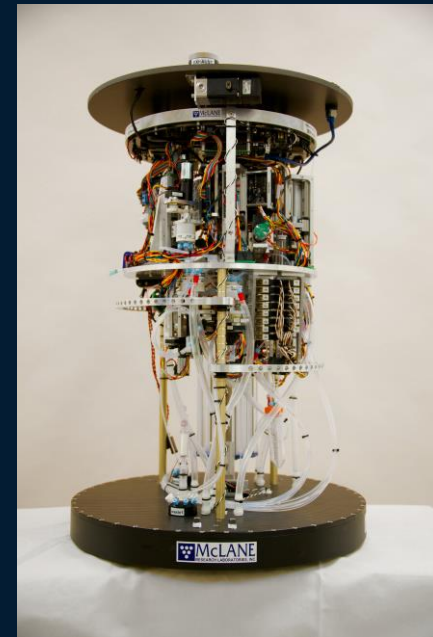
Environmental Sample Processor (ESP) – an autonomous and moorable 'omics sensor (not an example of a simple sensor!)

Unmanned Underwater Vehicles (UUVs)

Robotic vehicles, autonomy and artificial intelligence in the form of driverless cars and trucks promises to revolutionize the U.S. and global transportation industry. Similar changes are occurring in the way we sample and study the ocean in the form of gliders, various motorized (propelled) and sailed surface and underwater vehicles, and ship-launched drones.

Saildrone

Ship-launched drone

Riptide micro UUV

Glider

Woods Hole Oceanographic INSTITUTION
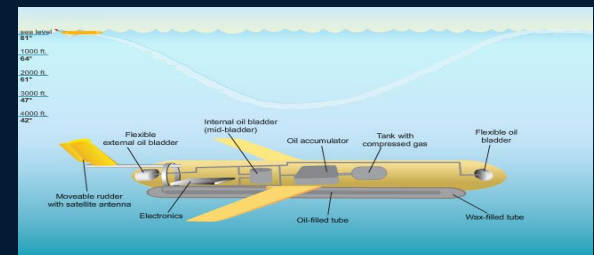
Advanced Sensors for UUVs

Saildrone

Riptide micro UUV

Increasingly sophisticated sensors to study marine ecosystems are being integrated on UUVs and autonomous surface vehicles.

Sensors are available to measure:
- phytoplankton concentration;
- phytoplankton, zooplankton and fish abundance and diversity using simple "omics" , imagery, photography and acoustic backscatter;
- primary production from the kinetics of fluorescence, photoacoustics, and stimulated oxygen kinetics; and
- passive acoustics to track tagged animals or listen for their sounds to determine presence.

Integrating Vehicles: UK's Largest Marine Robot Mission is Underway Off NW Scotland (from *Teledyne* website)

"An ambitious two-week mission involving ten marine robots has commenced off northwest Scotland. The mission comprises seven submarine gliders and three surface Wave Gliders that are working together in fleets to collect a range of environmental data."
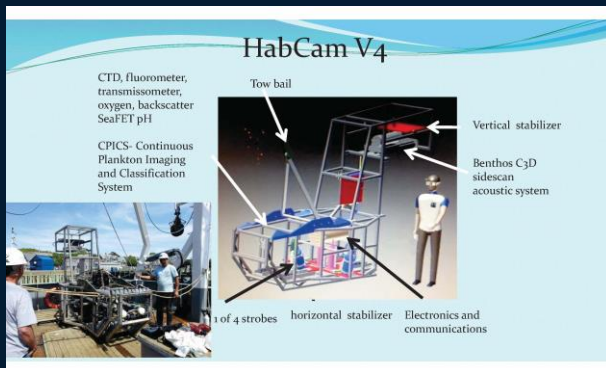

As well as collecting basic information on ocean temperature, salinity, oxygen, turbidity, and near-surface weather conditions, the gliders will also be measuring ocean currents, water depth, and the abundance of plankton in hotspots such as water mass boundaries (fronts) into waters up to a mile deep.

Digital Imaging
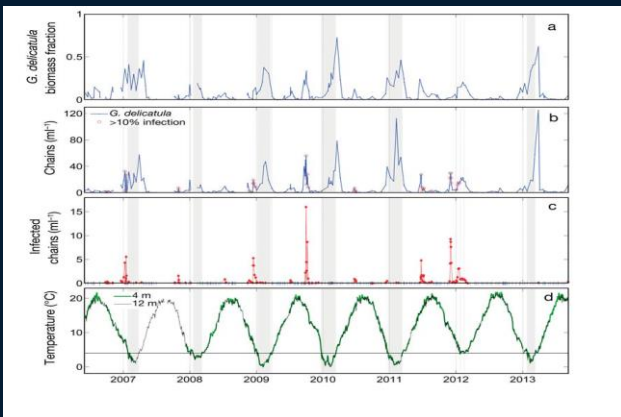
Multi-year time series from the *FlowCytobot*

- *In situ* digital imaging of marine organisms covers a wide range of spatial and temporal scales and from microbes to benthic macrofauna.
- Modern systems can rapidly record the contents of very large volumes of water.
- Owing to high data volume, analyses from the field of Informatics are required to efficiently and effectively archive and analyze the imagery.
- Software is now available that can identify some phytoplankton, zooplankton and benthic organisms to genus and provide highly accurate and precise counts within the taxa.
- Systems currently in use are towed, moored or used in shipboard laboratories.

Other Emerging Technologies

ESA's Sentinel-2/Sentinel-3 missions provide higher spatial and spectral resolution than SeaWiFS, MODIS and VIIRS improving imaging of coastal waters.

Space-borne lidars can potentially resolve vertical particle structure. Satellite lidars Have also been used to estimate phytoplankton abundance at high latitudes during low/no sunlight seasons.

CubeSats offer the potential for comparatively inexpensive space platforms. An ocean color radiometer (*Hawkeye*) for a CubeSat (*Seahawk*) is under development.

Cameras on small, ship-launched drones are a new way to observe many large marine organisms, including those that live on sea ice.

Passive Acoustic Recorders/Monitors on moorings or UUVs can monitor the environment for marine mammal and other sounds, or track tagged animals.

Recommendations

NOAA is developing the capacity to utilize the multiple applications of 'omics relative to its multiple missions. NOAA should continue to invest in these technologies and their applications. ADOPT NOW.

Many believe the future of ocean measurements will rely heavily on robotic vehicles and new sensor technologies, including measurements related to living marine resources. ADOPT NOW.

Sophisticated data analysis techniques and personnel trained to use them are required to effectively utilize the high data volume of new sensing systems ADOPT NOW.

Recommendations, cont.

Sophisticated imaging systems for shipboard laboratories, moorings, UUVs, or towed behind oceanographic ships offer the potential to fill time and space measurement gaps of important species. IMPORTANT, WATCH FOR FUTURE APPLICATIONS.

Passive acoustic sensors on moorings and mobile platforms, as well as new sensors for new orbital and suborbital platforms including ship-launched drones, aircraft and satellites are coming on line and are adding to our ocean observing capabilities. IMPORTANT, WATCH FOR FUTURE APPLICATIONS.