Underwater Vehicles

Unmanned / Autonomous

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OVERVIEW

- Acronyms
- Types of Vehicles
- Communications
- Famous UUVs
- Industry UUVs
- U.S. Navy
- Mine Countermeasures (MCM)
- China
- R&D

Acronyms

- AUV Autonomous Underwater Vehicle
- ASV Autonomous Surface Vehicle
- ROV Remotely Operated Vehicle
- UMV Unmanned Maritime Vehicle
- USV Unmanned Surface Vehicle
- UUV Unmanned Underwater Vehicle

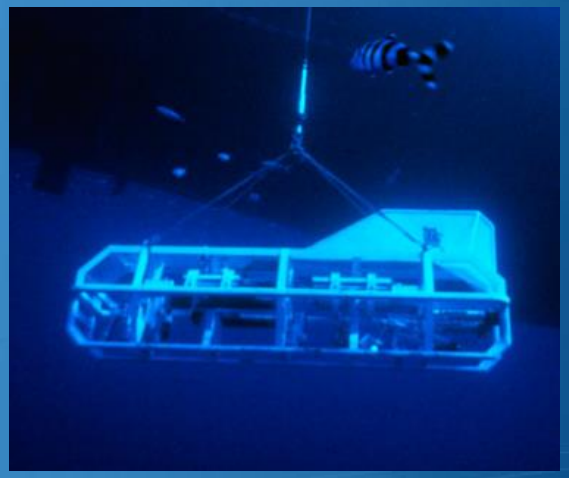
Vehicle Types

- Surface Vehicles (ASV/USV)
  - Shallow or hazardous water
  - Marine biological research
  - Search & Rescue
- Underwater Vehicles (AUV/UUV)
  - Oceanography / Deep sea research
  - Oil rigging / ship hull / pier inspection
  - Mines and unexploded ordnances (UXO)
  - Surveillance
  - Weapons of war

Communications

- At the surface
  - RF, Wi-Fi, GPS
- UUVs
  - Tether ,e.g., fiber optic
  - Acoustic modem (underwater)
    - 31.2 kbits/s over 1000 m range (shallow water)
    - 6.9 kbits/s over 8000 m range (deep water)
- Alternate solutions
  - UUV can surface and act as antenna or link to GPS
  - Prepositioned beacons / “Phone booths”

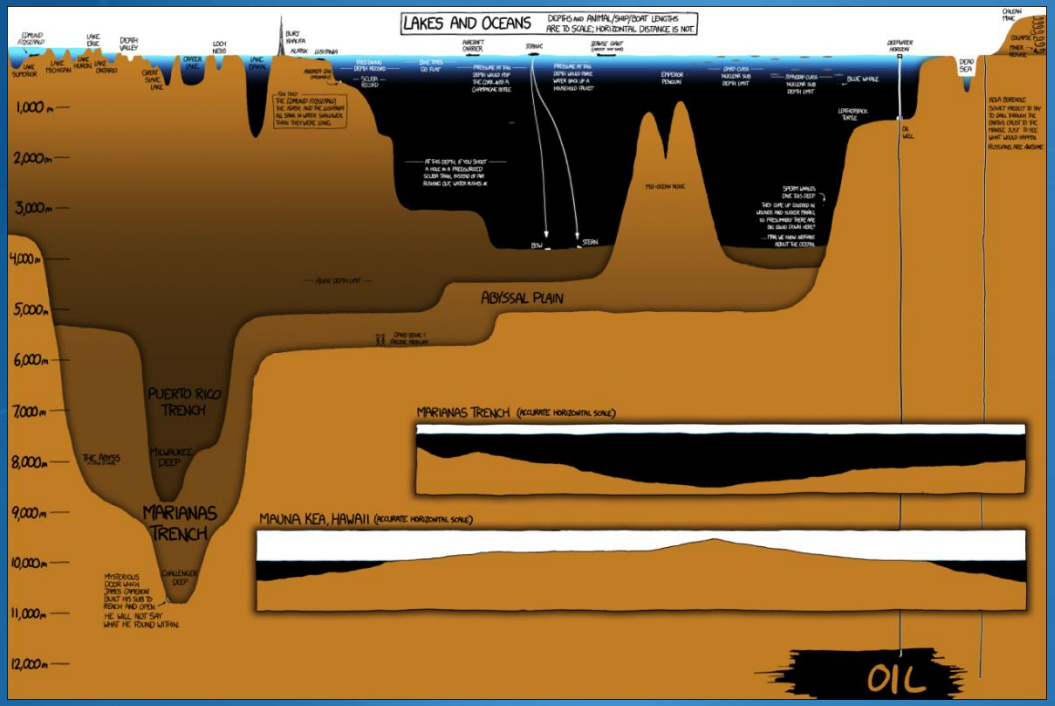
Titanic



- Sank in 1912
  - Depth: (12,500 ft, ≈ 2.37 miles)
- Discovered in 1985 by ROV Argo
  - Towed from surface by ship
  - Acoustically Navigated Geological Underwater Survey (ANGUS) – a towed imaging system w/ 35mm camera
- Alvin (1986) – manned sub
  - ROV Jason Jr.
    - First fiber-optically cabled deep sea robot
    - Used to film dangerous wreckage

Challenger Deep

- The deepest known location in the ocean, at the bottom of the Marianas Trench (35,797 ft, or ≈6.78 miles)



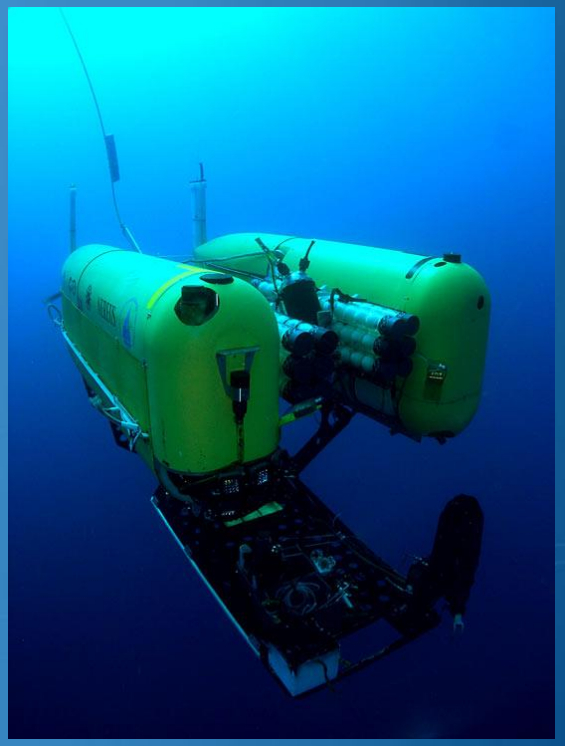
- Two unmanned descents

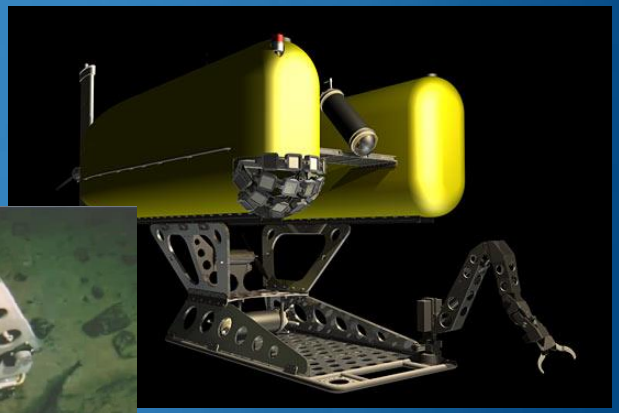
Challenger Deep

- Kaikō (1995)
  - 10 ton vehicle and launcher system
    - Connected via 250 m long tether
    - Launcher helped sink ROV
  - Equipment: altimeter, sonar, GPS, compass
  - Two manipulator arms for collecting samples
  - Tethered to ship via 12,000 m long 4.5cm dia. optical and copper conductors.

Challenger Deep

- Nereus (2009)
  - Hybrid ROV (HROV)
    - Tethered (micro-thin fiber optic)
    - Autonomous
  - Speed: 3kt
  - Power: Rechargeable lithium ion battery packs
  - 2 fore & aft thrusters
  - Manipulator arm, controlled by a “master”
  - Rock sampling/drilling

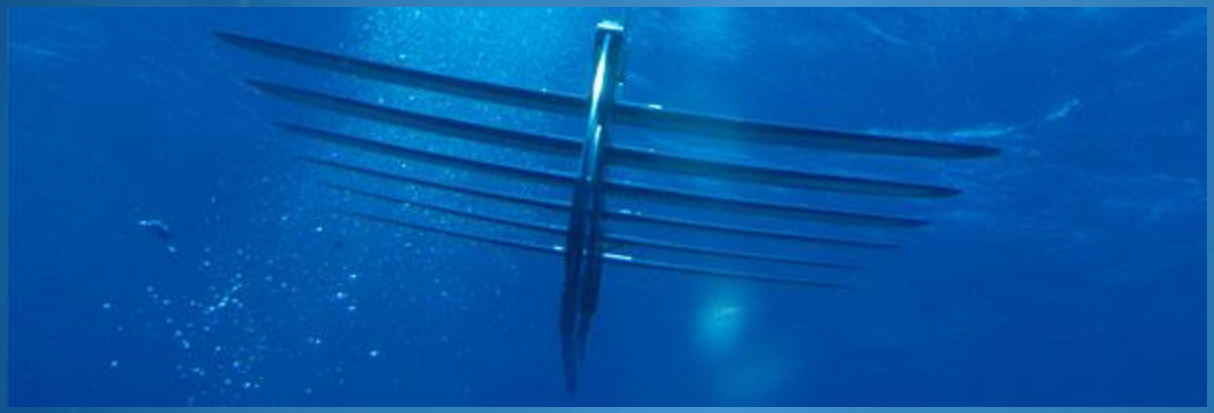




ASVs

- Wave Glider SV Series (Liquid Robotics)
  - Autonomous
  - Gather weather data
  - First vehicles to cross the Pacific Ocean
    - Duration: indefinite (300,000 nautical miles)
    - Power: ocean wave energy for propulsion

ASVs



- Sensor Hosting Autonomous Remote Craft (SHARC) (Liquid Robotics)
  - Acoustically silent
  - Propulsion energy mechanically harvested from ocean waves
  - User-integrated sensor / comm. payloads
  - GPS / satellite comm.
  - Solar powered

USVs

- Catamaran 4.0 (Sea Robotics, Inc.)
  - United States Geological Survey (USGS)
  - Surveys oyster beds
  - Sonar
  - GPS
  - RF comm. system
  - Echo sounder
  - Heave sensing system

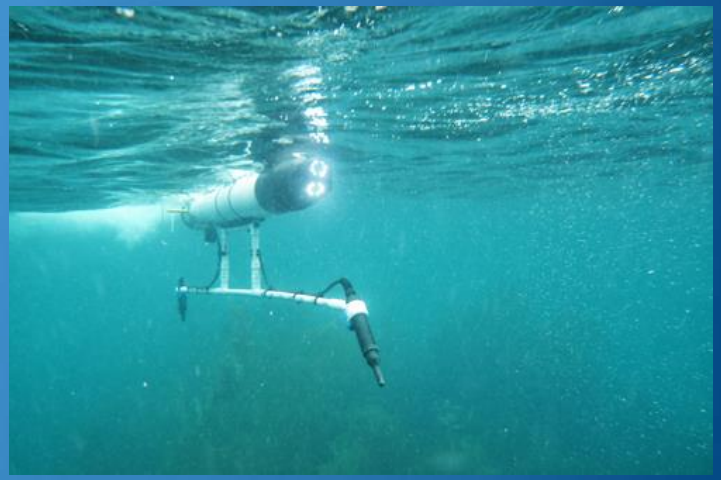
USVs

- Blackfish (QuinetiQ)
  - Diver/swimmer and harbor threat response
  - Water based security
  - Electronics are modular
  - Speed: < 45 kts (≈52mph)
  - Comm: High speed command & control data radio
    - Full motion video, Wi-Fi
  - Time: 1 Hour
  - Power: battery

http://www.youtube.com/watch?v=rdvdomFYT7M

AUVs

- IVER-2 Series (Ocean Server)
  - Multi-AUV Shark Tracking
    (Lab for Autonomous and Intelligent Robotics (LAIR), Harvey Mudd College)
  - 2+ AUVs “swarmed”
  - Particle filter determines sharks’ position, velocity, and orientation
  - Stereo hydrophone system detects tagged shark via acoustic communication
    - Formation control
    - Shark state estimation



U.S. Navy

- The Navy Unmanned Undersea Vehicle (UUV) Master Plan (2004)

  http://www.navy.mil/navydata/technology/uuvmp.pdf

  (Approved for Public Release)

- Develop 4 UUV classes:
  - Man Portable (<100 lbs)
  - Light Weight (~500 lbs)
  - Heavy Weight (~3000 lbs)
  - Large (~20,000 lbs)

Mine Countermeasures

- UUVs can be used to hunt and neutralize mines.
  - Detect (D)
  - Classify (C)
  - Identify (I)
  - Neutralize (N)

Mine Countermeasures

- Neutralizers:
  - Autonomous neutralizer (small anti-mine torpedo)
  - Stationary bomblet to be placed and detonated remotely.
    - Cost-effective

"USV delivery is attractive because, for example, four 30-knot USV's carrying 135 autonomous neutralizers each, could deliver their entire payload in four hours"

Mine Countermeasures

- Remote Environmental Monitoring Unit System (REMUS) (U.S.)
  - Shallow water mine detection
  - Hydrographic reconnaissance

- Espadon (“Swordfish”)
  - Towed sonar
  - Autonomous mine-hunting AUVs.

Mine Countermeasures

- Workhorse USV (Sea Robotics, Inc.)
  - North Atlantic Treaty Organization (NATO)
  - For the Center for Marine Research and Experimentation (CMRE)
  - To “improve payload capacity and efficiency of the … mine neutralization system”
  - 350 kg payload
  - All electric or electric/diesel hybrid
  - 5m/s

Mine Countermeasures

- Seafox (Atlas Elektronik /Ultra Electronics)
  - Royal Navy, UK
  - Guided via fiber optic cables
  - Highly maneuverable
  - Used in Iraq & Libya
  - Expendable

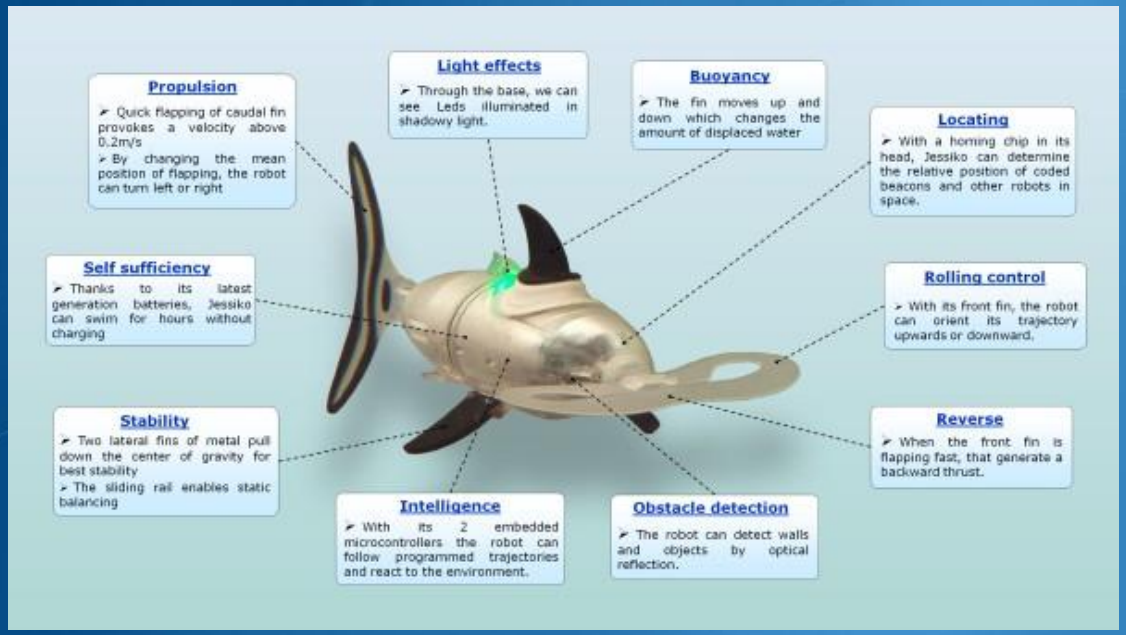
1. Seafox identifies target
2. Places a shaped charge
3. Mine detonation

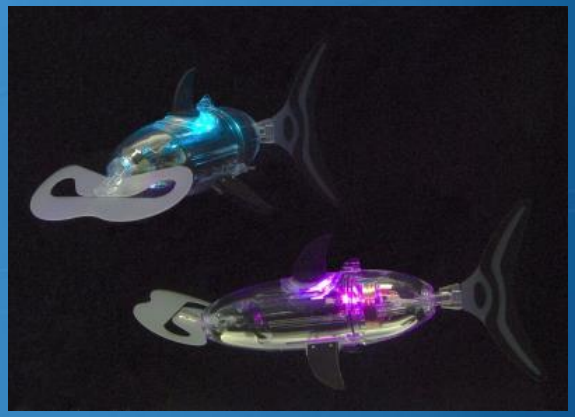
China

- CR-01 (Explorer)
  - First long-range AUV in China
  - Zhishui 3 UUV
- SPC-3 UUV robofish
  - Duration: 6.25 h
  - Speed: 1.03 m/s
  - Flapping foil propulsion

In Development

- Jessiko V4 (RobotSwim)
  - 20 cm length
  - Autonomous or swarm





http://www.youtube.com/watch?v=n4TstTDa78w

In Development

- Soft Robot-Stingray
  (Mechatronics Research Laboratory, Massachusetts Institute of Technology)
  - Rubber polymer
  - Servo actuators move in front, creating a waveform to mimic natural movements

http://www.youtube.com/watch?v=YeCGa8z7QGw

In Development

- AquaJelly (Festo)
  - Emulates swarming behavior

    http://www.youtube.com/watch?v=mKMN-dz8n3k&list=WL4F5FCF293F3ADC4A

- RoboJelly (Virginia Tech)
  - Client: Office of Naval Research
  - Intended for surveillance

    http://www.youtube.com/watch?v=b0qf1sl2aBA&list=WL4F5FCF293F3ADC4A

In Development

- Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV)
  - DARPA, Built by SAIC
  - Unmanned vessel to “robustly track quiet diesel electric submarines”
  - 3 goals:
    1. Develop a platform with the intention that “a human is never intended to step aboard at any point”
    2. Ability to enable independent systems for a variety of missions, over thousands of miles and for long durations.
    3. Use unique characteristics of the system for nonconventional sensor technologies.

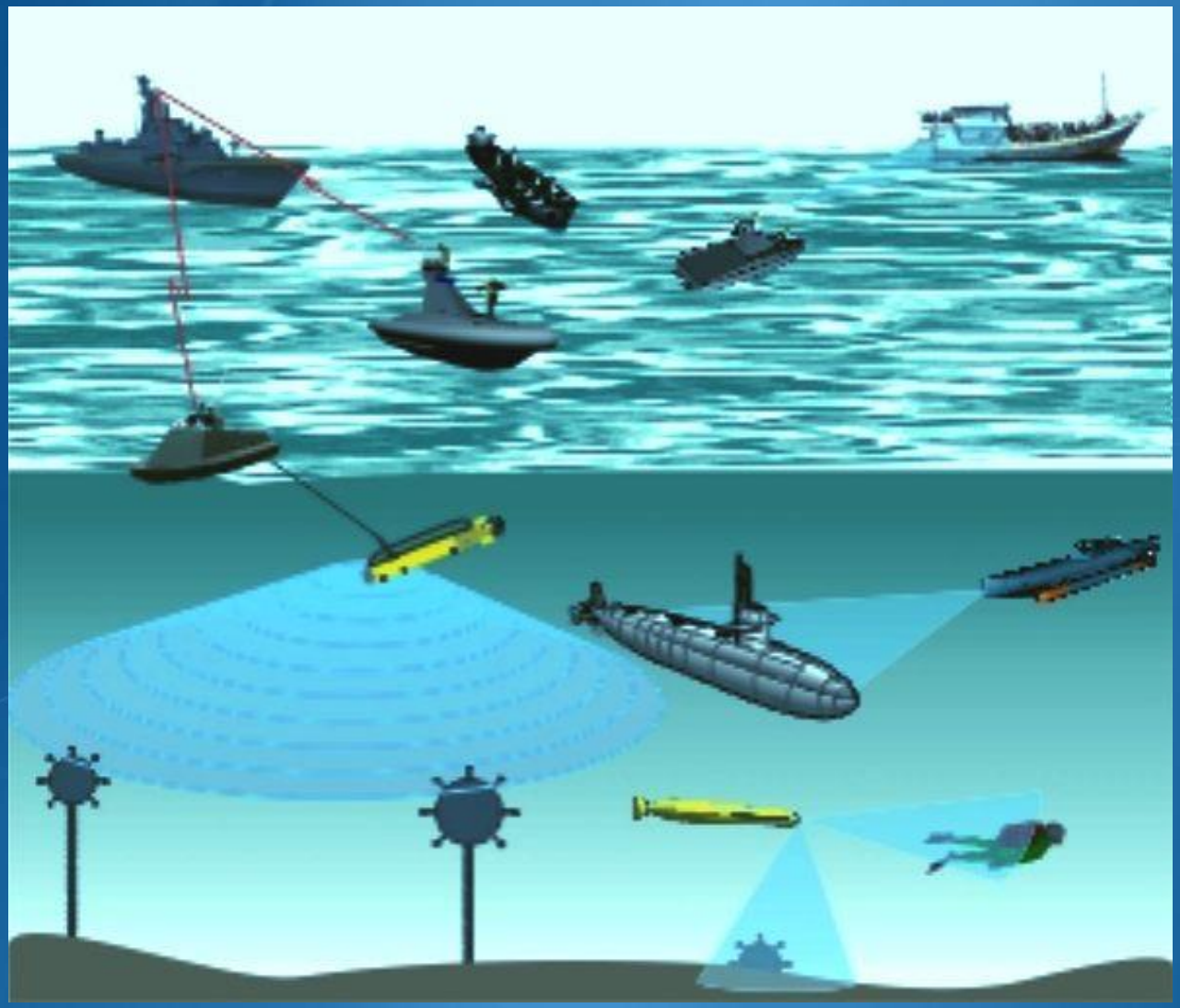
AUV/UUV Limitations

- Power
  - More difficult to propel through water than air
- Communication
  - "It's literally easier to communicate with the Mars rover than it is to communicate with a UUV at 100 nautical miles under water."
- Unlikely to replace submarines (yet)
  - Not fast enough to chase
  - Not aggressive enough for combat

Legal Issues

- Lack of legislation governing USVs in deep water
- International Regulations for Preventing Collisions at Sea (COLREGS).
  Examples:
  - System of flags and lights for communication
  - Head-on and crossing situations
  - Distress signals
- No system to define, verify, and certify seaworthiness

Questions?



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