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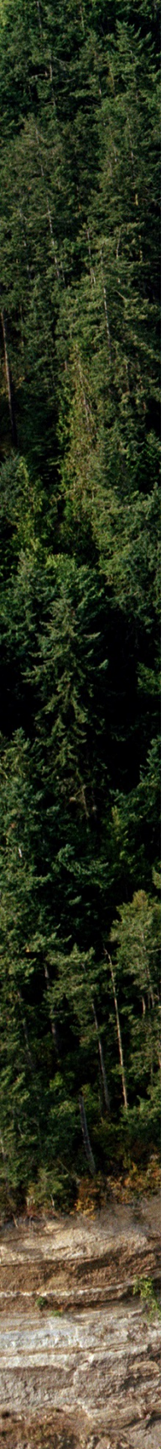
Pacific Northwest National Lab (PNNL) and Marine Autonomy

Theodore (Ted) Nowak
Data Scientist

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy



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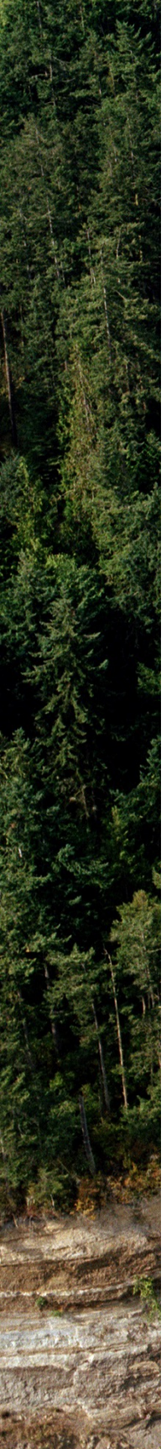
- About me
- Overview of Pacific Northwest National Lab (PNNL) and the Marine and Coastal Research Lab (MCRL) in Sequim
- Introduction to Artificial Intelligence (AI)
- Marine AI at MCRL



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Interrupt me at any time and ask me anything!

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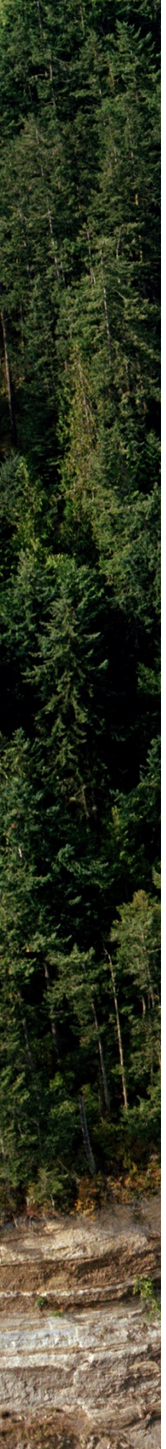
About me

- BS Electrical Engineering
- Minors in Spanish, History, Physics
- Staff Research Engineer
- MS Robotics
- Machine Learning Researcher
- Marine Robotics Researcher



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About Pacific Northwest National Lab (PNNL)

An overview of the lab and its operations

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DOE's 17 **national laboratories** tackle critical scientific challenges

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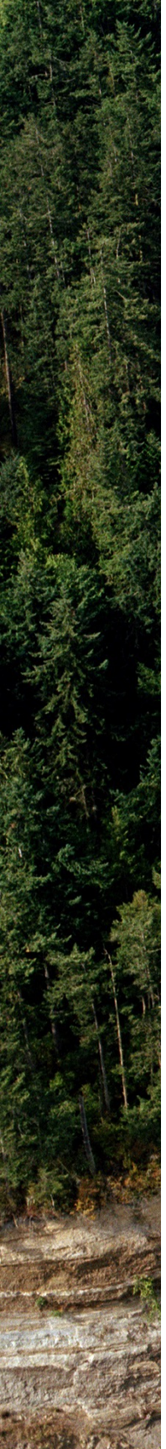
Of which **9** are operated by **Battelle Memorial Institute**



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PNNL's Mission

- Reinventing Chemical Conversions and Energy Storage Materials
- Understanding Multiscale Earth Dynamics and the Role of Coastal Systems
- Understanding, Predicting, and Controlling the Phenome
- Scalable Machine Reasoning for Scientific Discovery
- Energy Decarbonization through Grid Control and Energy Storage
- Accelerating Development and Characterization of Nuclear Material Processing

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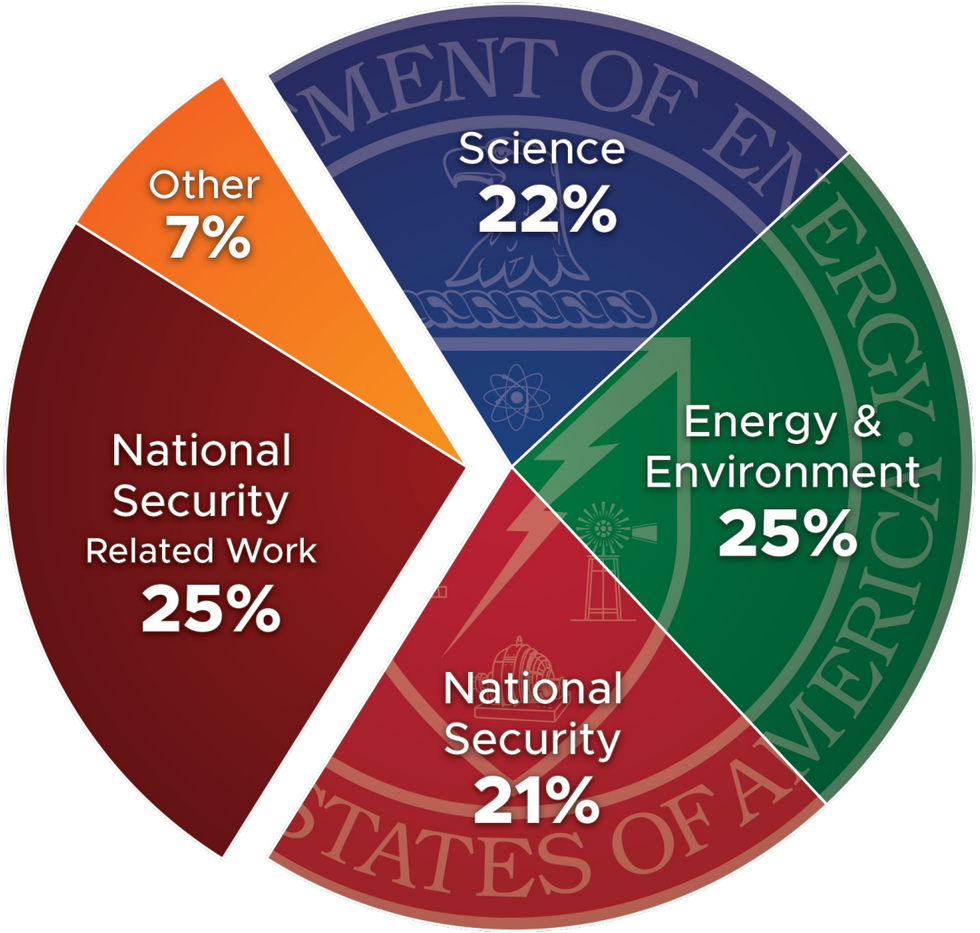
PNNL is DOE's **most diverse national laboratory**

5,300 Staff

$1.24B Spending

1,755 Peer-reviewed Publications

247 Invention Disclosures



FY 2021 Staff

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A regional, national, and international **scientific resource**

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Marine and Coastal Research Lab at PNNL Sequim

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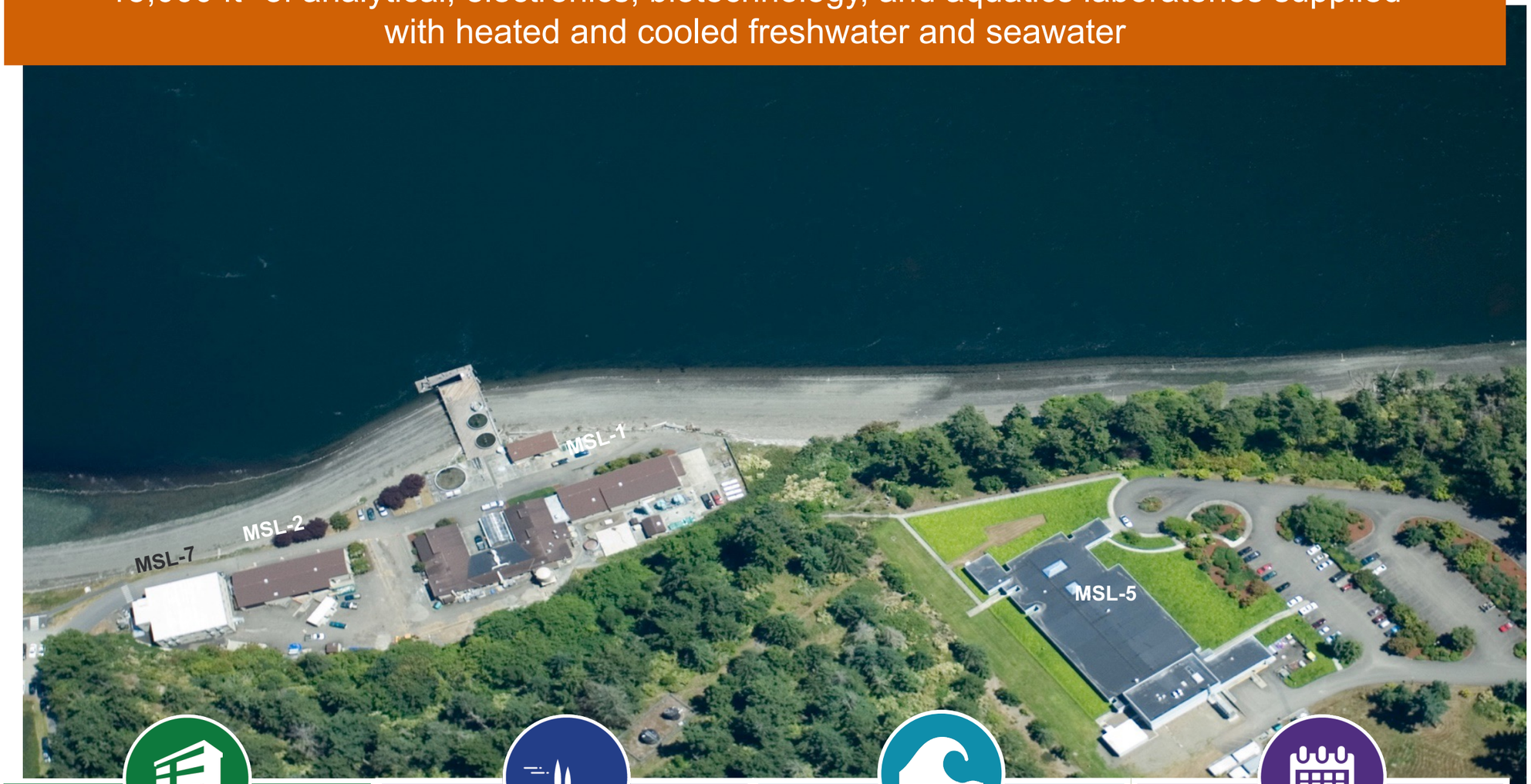
Research Campus

15,000 ft^2 of analytical, electronics, biotechnology, and aquatics laboratories supplied with heated and cooled freshwater and seawater



10
Facilities and structures

117
Acres DOE-owned
(140 acres currently Battelle-owned)

5000
Acres submerged

80+
Staff and researchers

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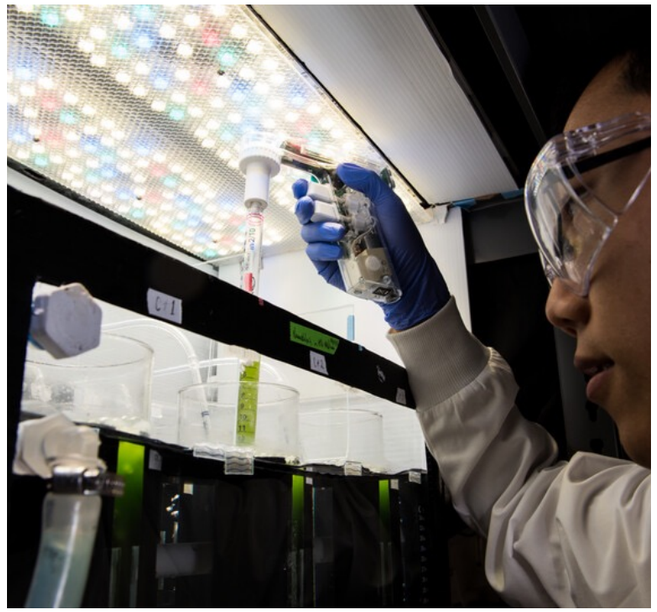
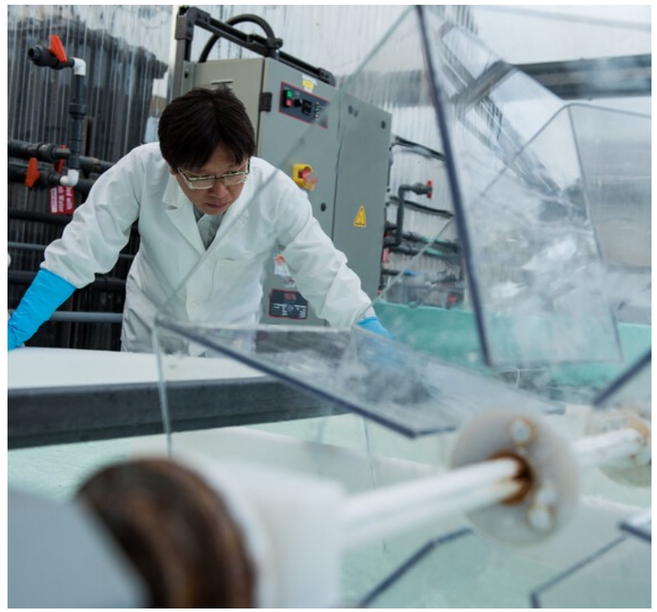
Marine and Coastal Research and Capabilities

- 70+ research scientists
- Disciplines: ecology, marine biology, oceanography, biogeochemistry, marine engineering, coastal modeling
- Research focus areas: habitat restoration, coastal and aquatic ecology, bioenergy, analysis of metals and organics, earth system models and environmental monitoring





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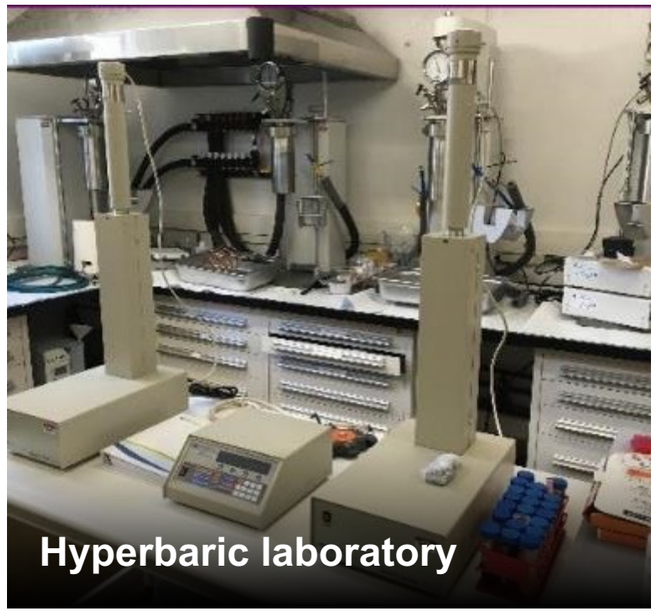
Research Facilities

- 15,000 sq. ft. of laboratories
- Seawater and freshwater labs
- BSL2 molecular microbiology and toxins labs
- Arctic research labs
- Isolation labs
- Marine mesocosm tanks


Marine mesocosm tanks


1100 L circulation tank for generating Frazil sea ice

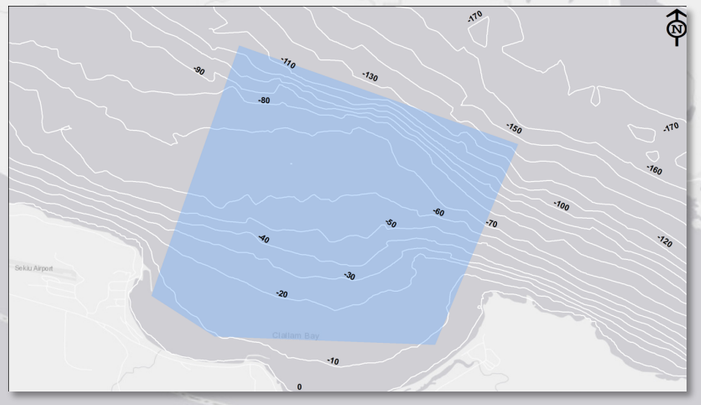

Hyperbaric laboratory


Algal culture laboratory

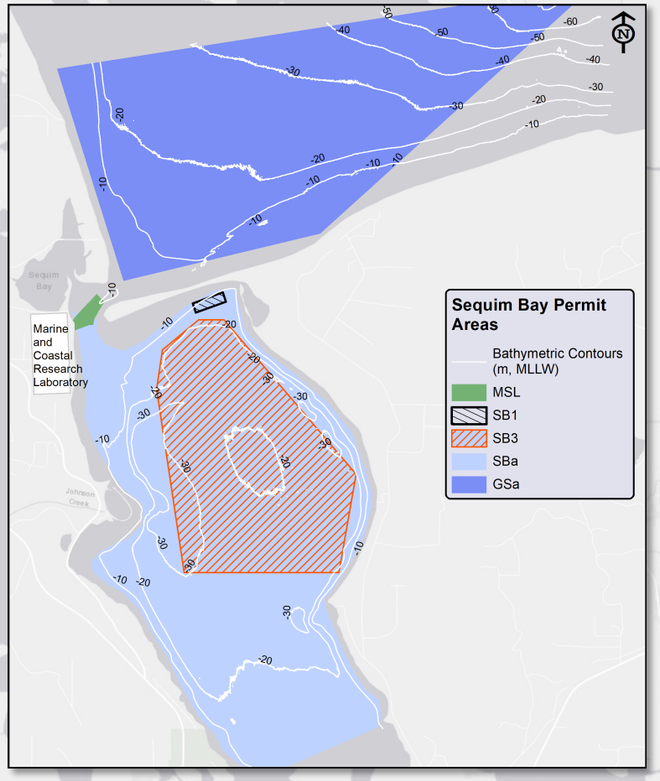
Outdoor Capabilities

- Meteorological station
- Water level recorders
- Survey levels and equipment
- Outdoor experimental tanks
- Anechoic tank
- Wet and dry lab facilities
- Ambient seawater delivery system
- Deep artesian freshwater well
- Waste water treatment system

Permits within Sequim and Clallam Bay



Clallam Bay



Sequim Bay

Research Activities	Project Areas					
	MSL	SB1	SB3	SBa	GSa	Clallam
Acoustic device operation	x	x	x	x	x	x
Autonomous underwater vehicle operations	x	x	x	x	x	x
Sea bed installations	x	x	x	none	none	x
Surface platforms and buoys	x	x	x	none	none	x
Surveys and sediment sampling	x	x	x	none	none	x
Electromagnetic field operation	x	none	none	none	none	x
Dock installations	x	none	none	none	none	none

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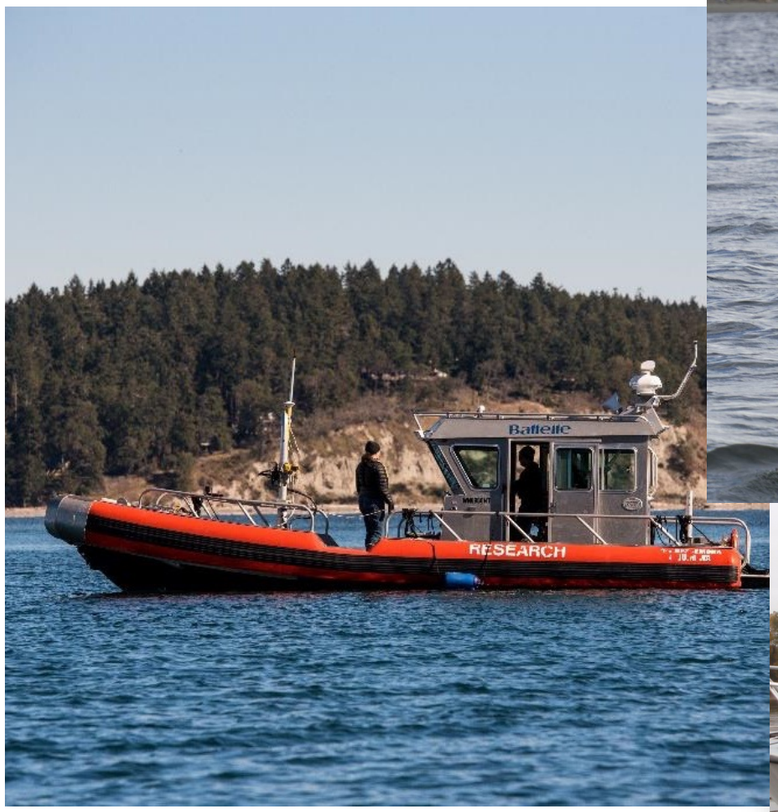
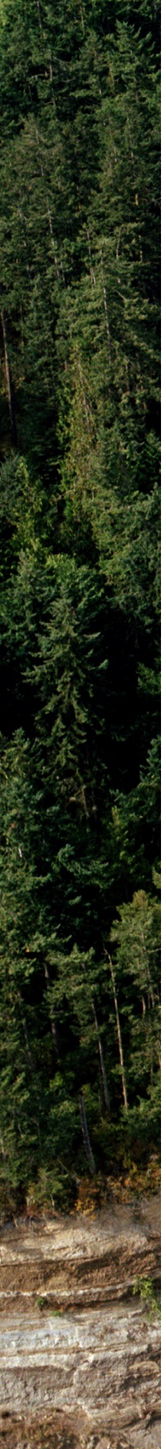
Vessels





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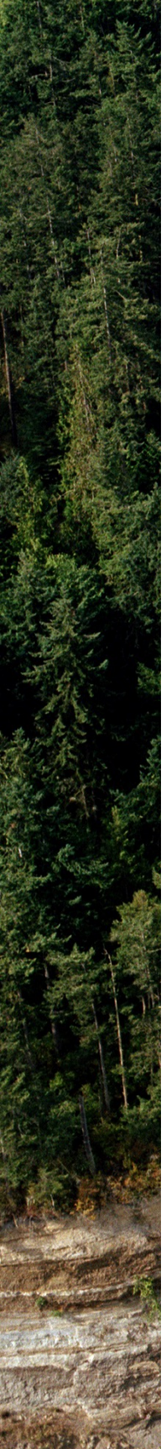
Artificial Intelligence (AI)

A history of and introduction to AI



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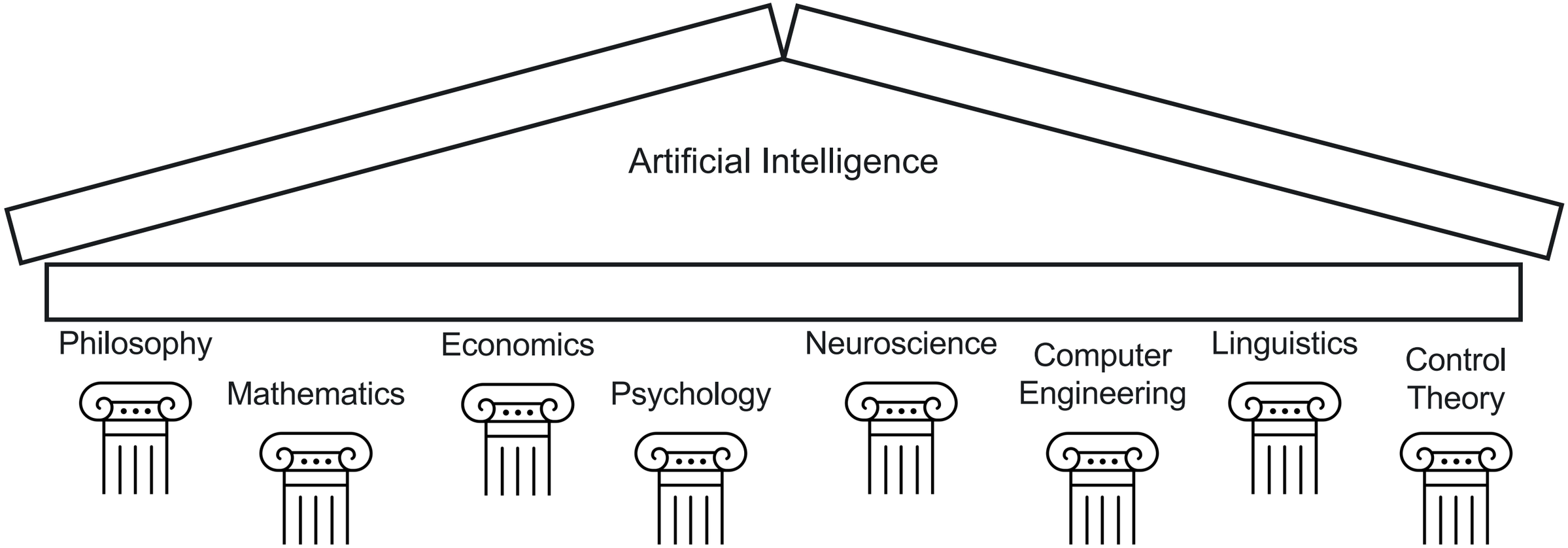
Definitions of Artificial Intelligence

Thinking Humanly	**Thinking Rationally**
"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense." (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998) "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

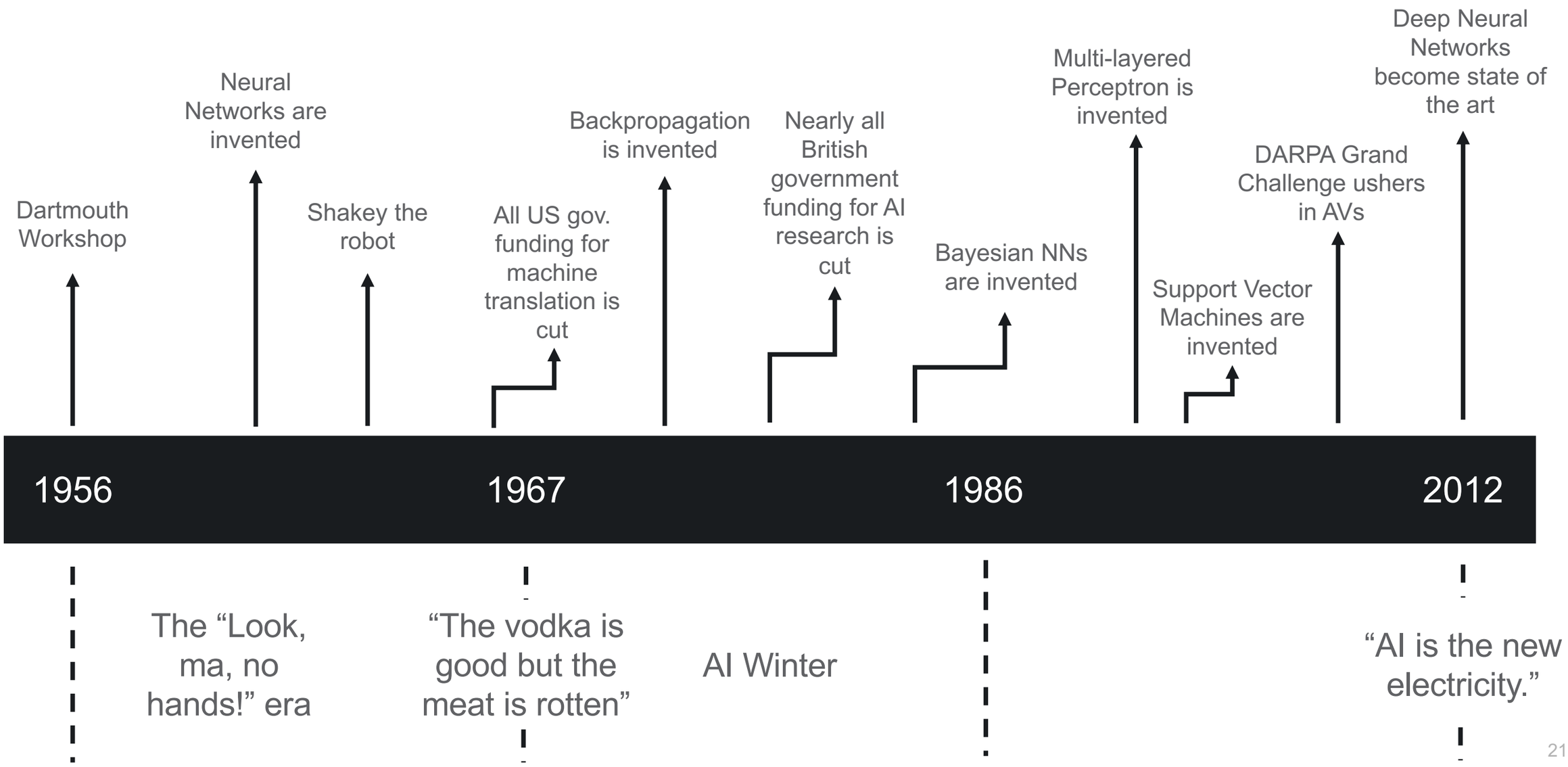
Russell and Norvig: Artificial Intelligence: A Modern Approach. 2010

Foundations of AI

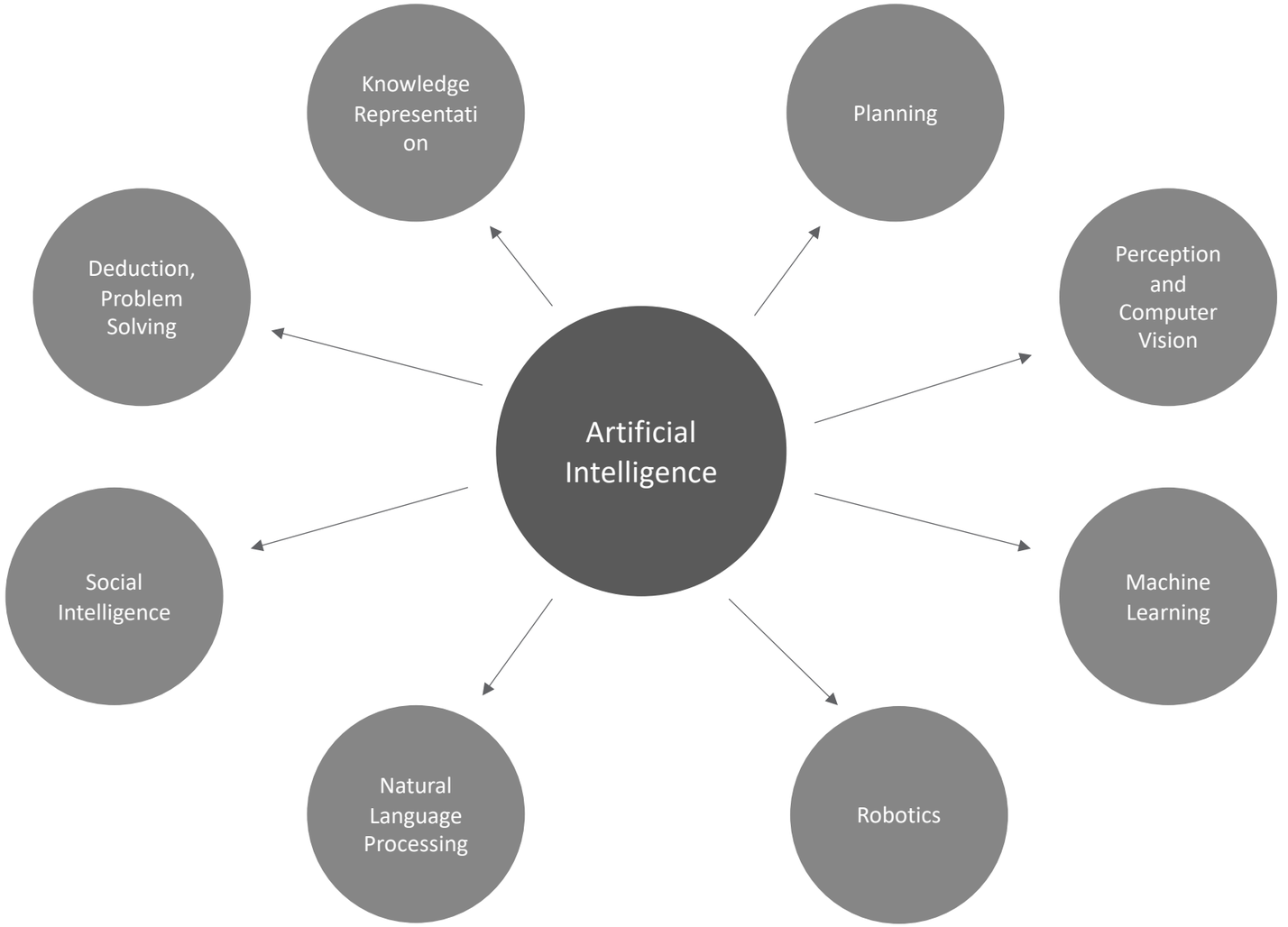
Pillars of AI:



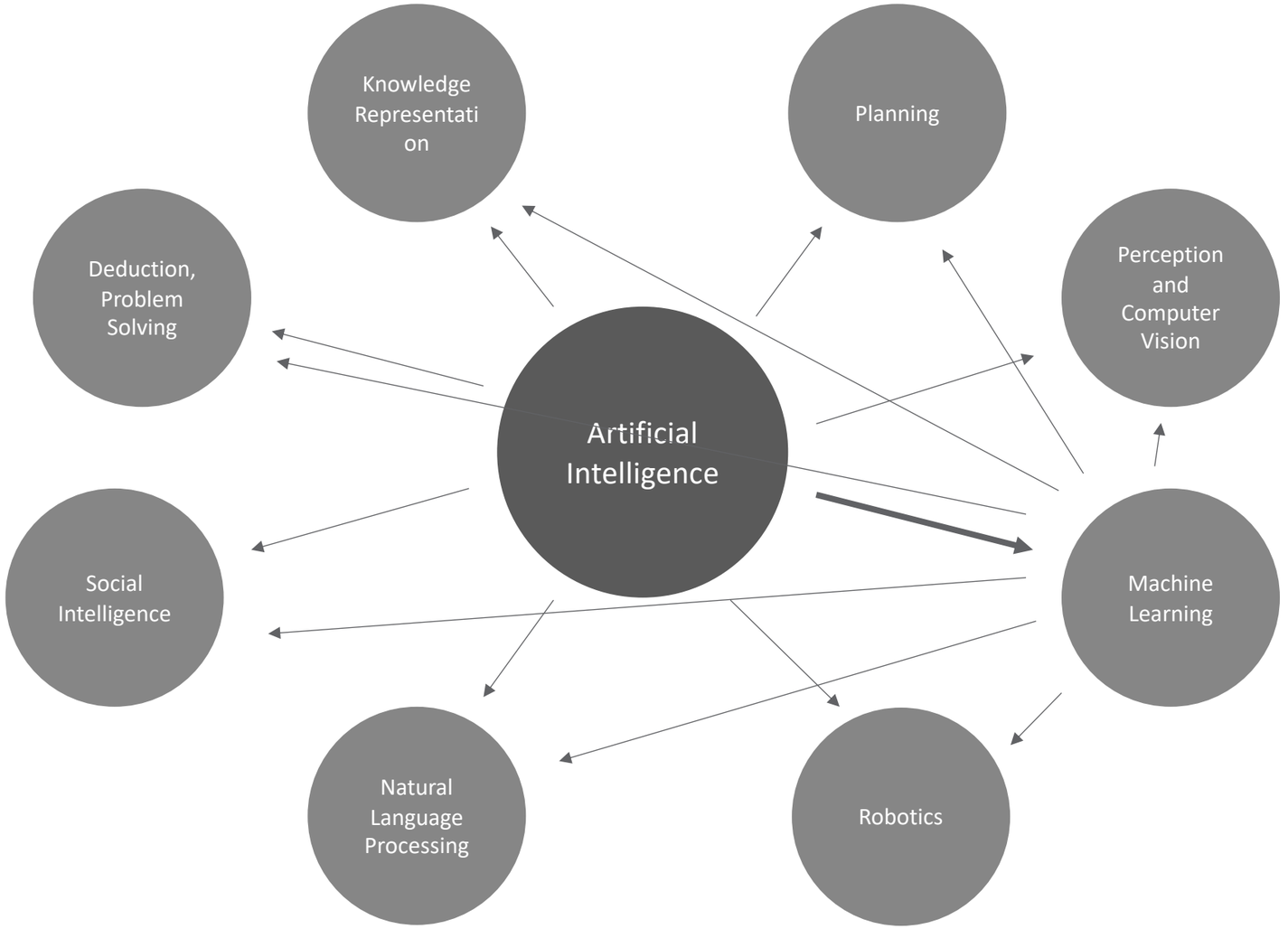
A Timeline of AI



So what is AI?


Knowledge Representation
Planning
Deduction, Problem Solving
Perception and Computer Vision
Artificial Intelligence
Social Intelligence
Machine Learning
Natural Language Processing
Robotics

So what is AI?


Knowledge Representation
Planning
Deduction, Problem Solving
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Artificial Intelligence
Social Intelligence
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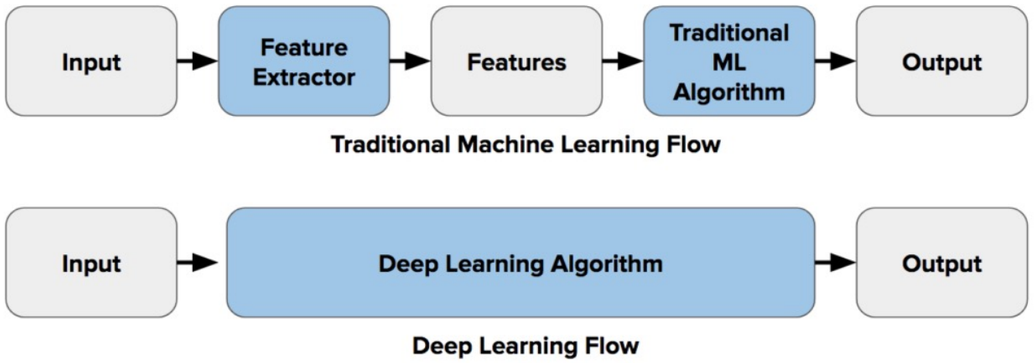
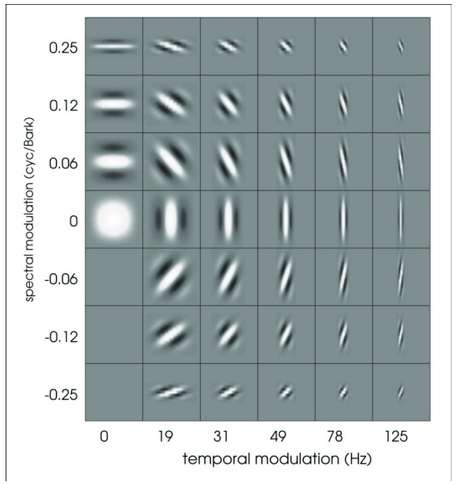
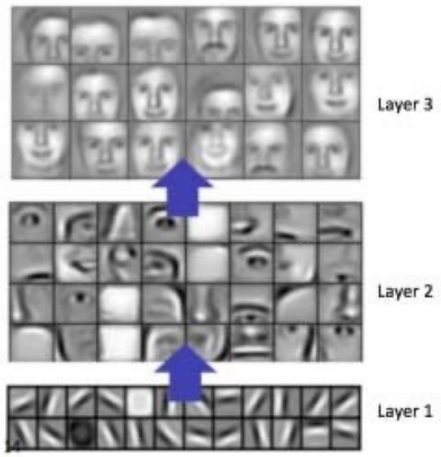
Robotics

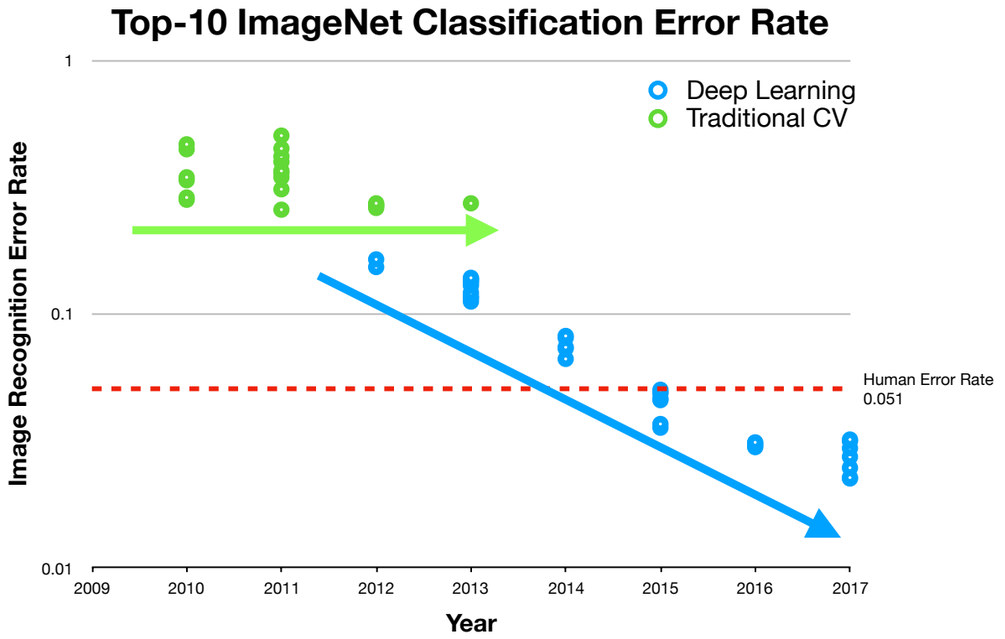
Why AI is Hot

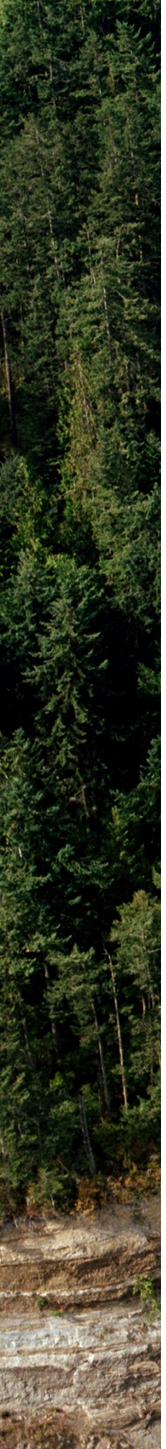
- Something called Deep Learning has broken prior barriers in AI











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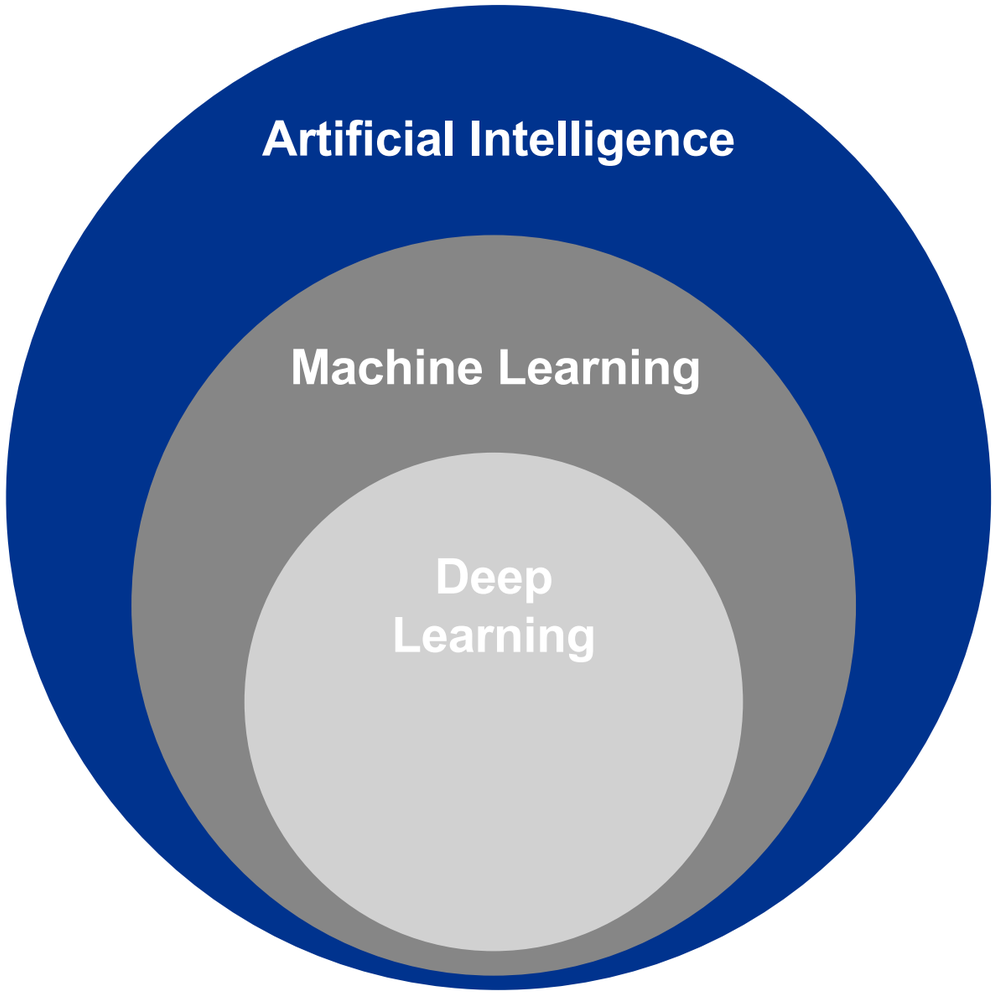
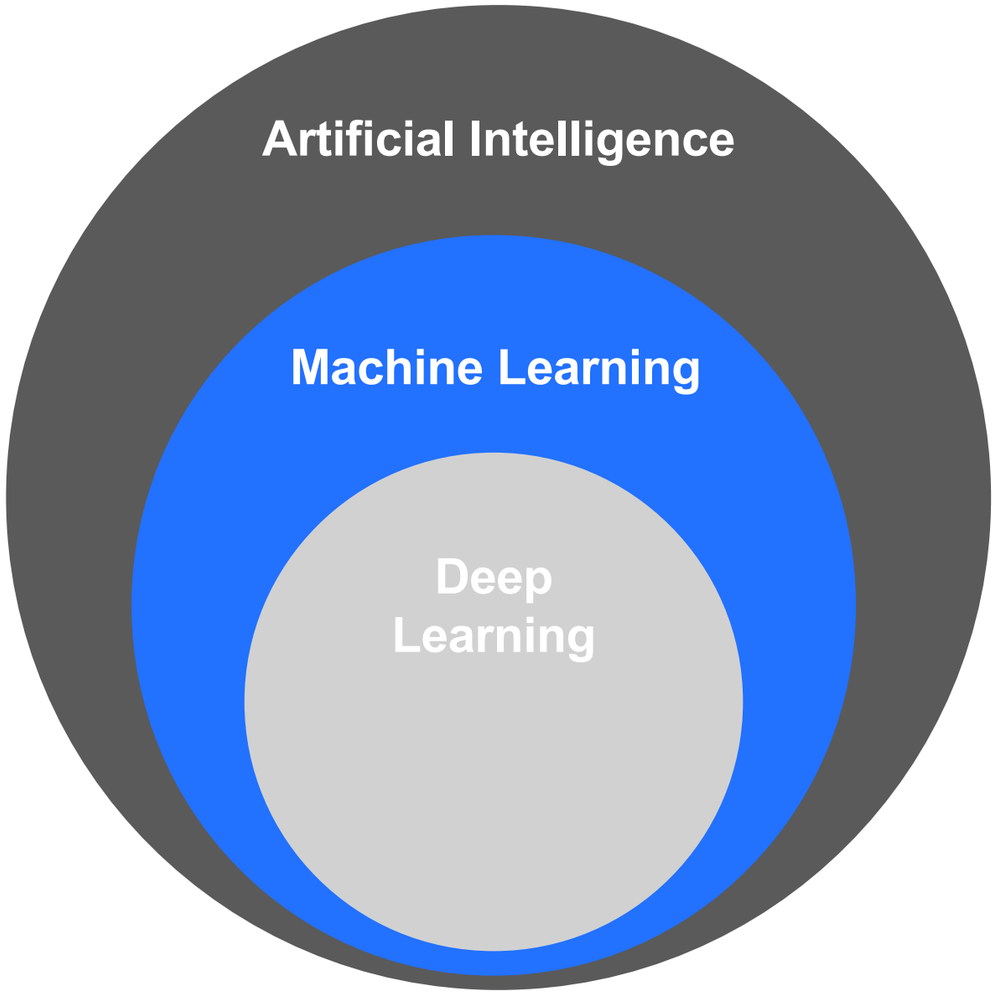
Artificial Intelligence

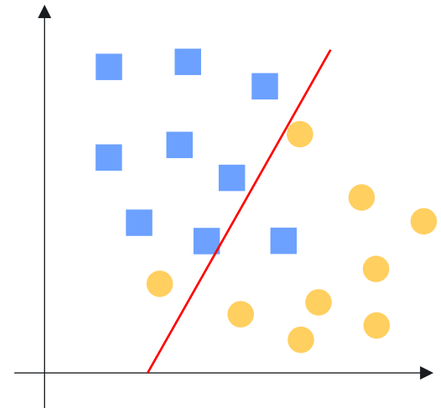


Machine Learning

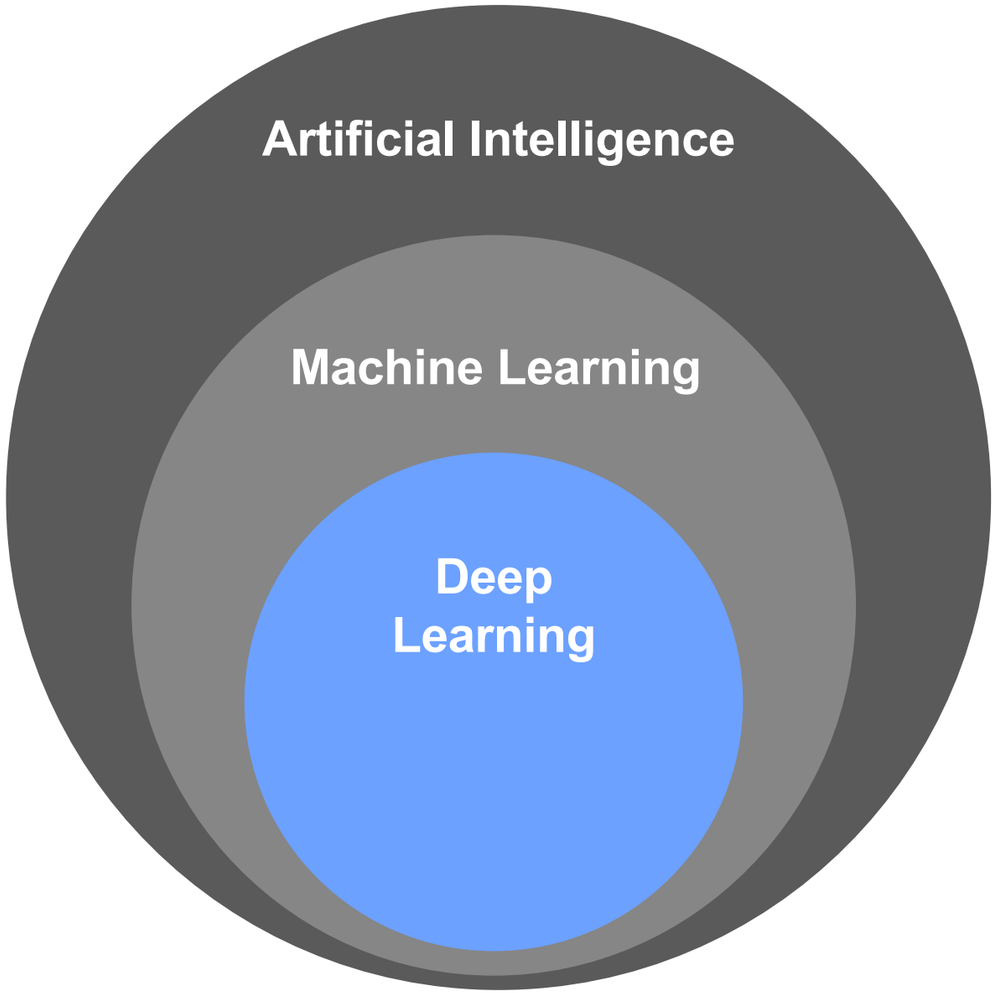


"[ML uses] algorithms and statistical models to analyze and draw inferences from patterns in data"

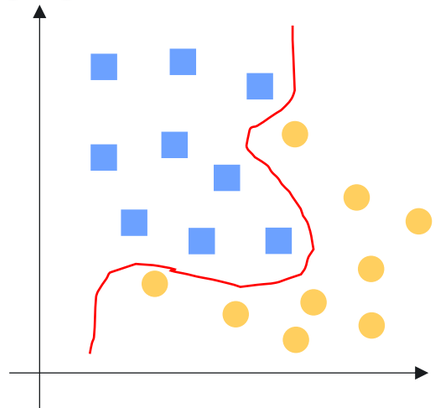
- (some) **Popular Methods**
  - Linear-Logistic Regression
  - Random Forests
  - Support Vector Machines
  - Bayesian Models

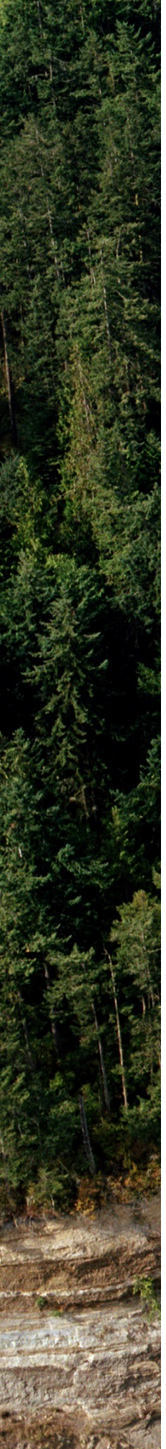


Deep Learning



- Subset of ML which extend previous *neural network* approaches, made applicable with the increase in available compute
- Neural networks are made up of successive *layers*
- “Deep” as in more layers





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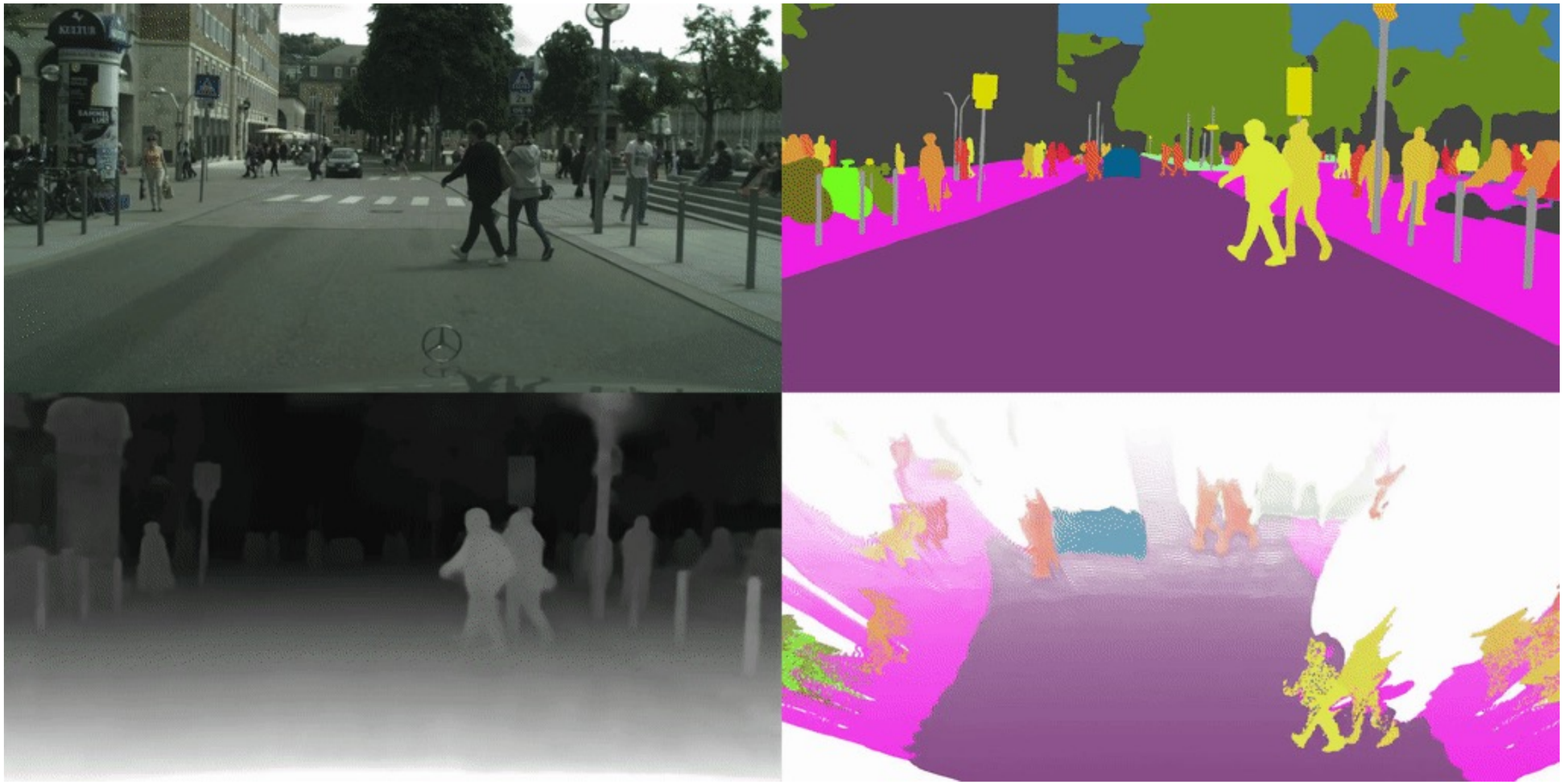
An Example – Semantic Segmentation



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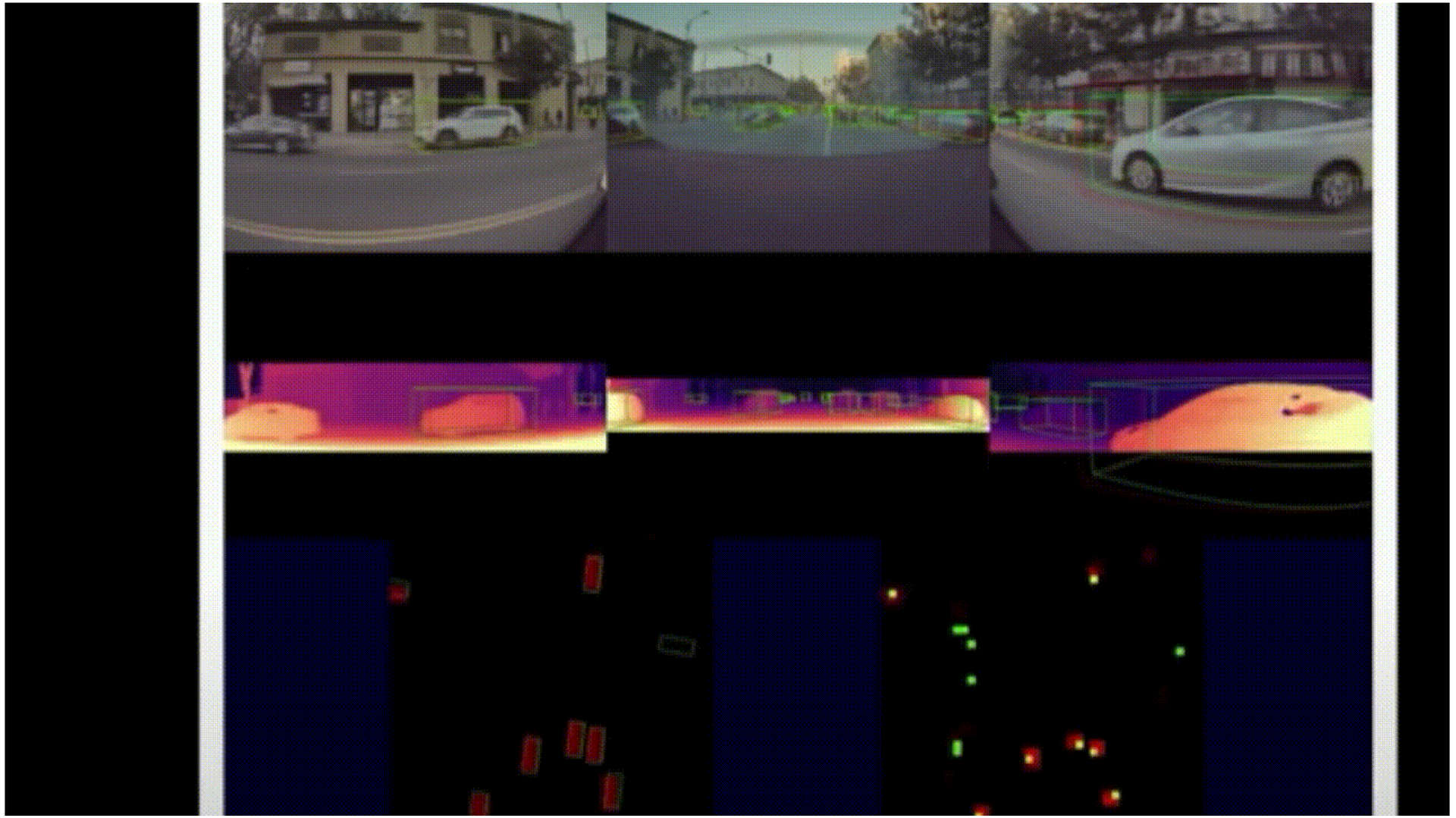
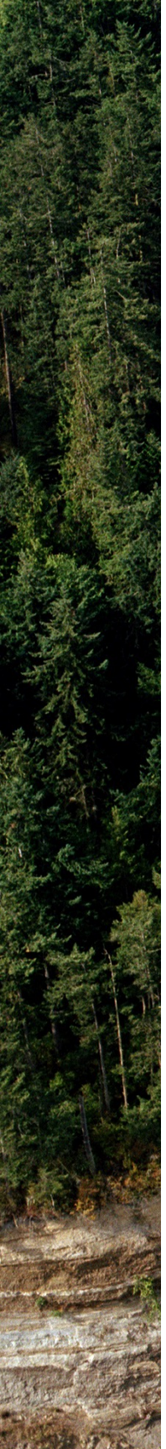
An Example – Autonomous Driving





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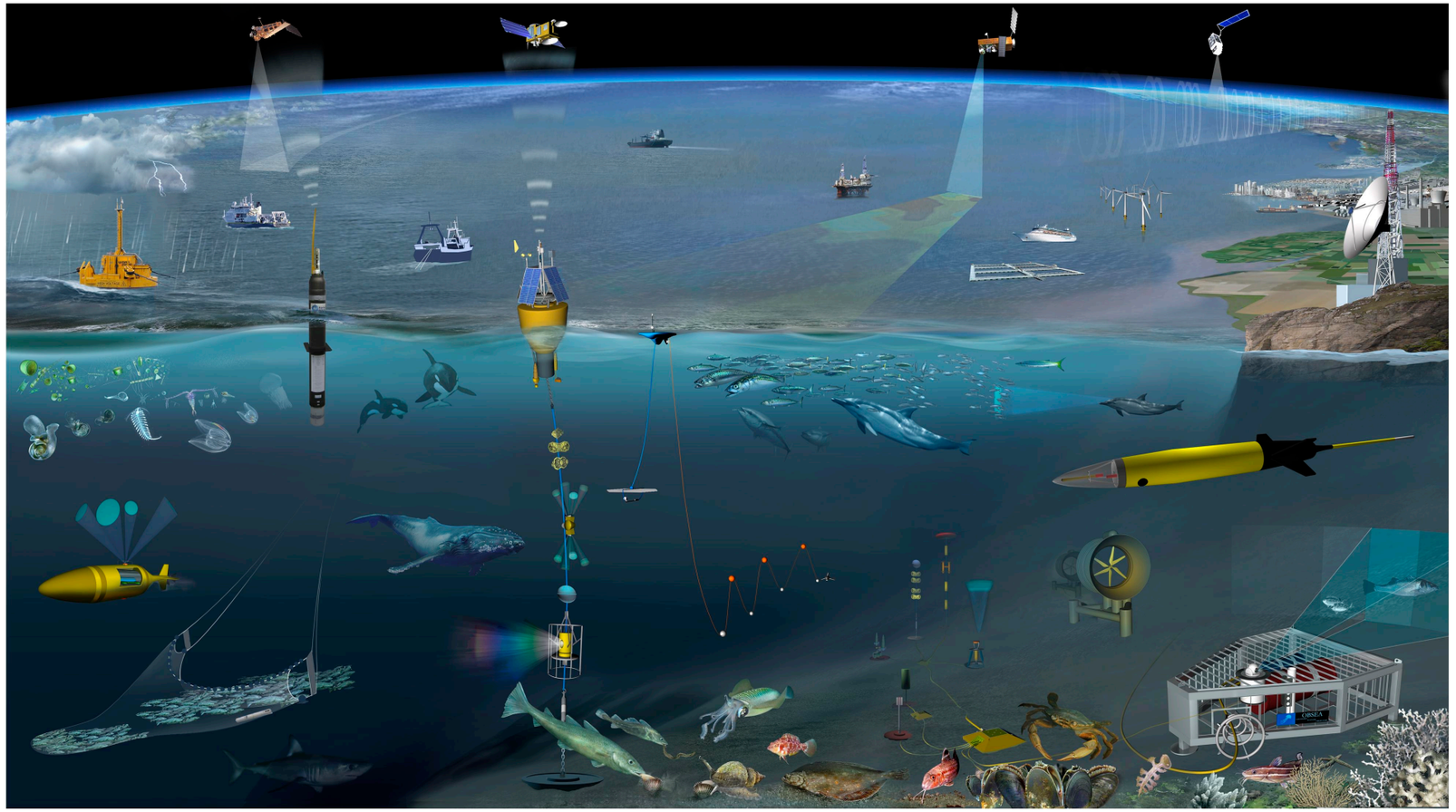
Maritime Artificial Intelligence (AI)

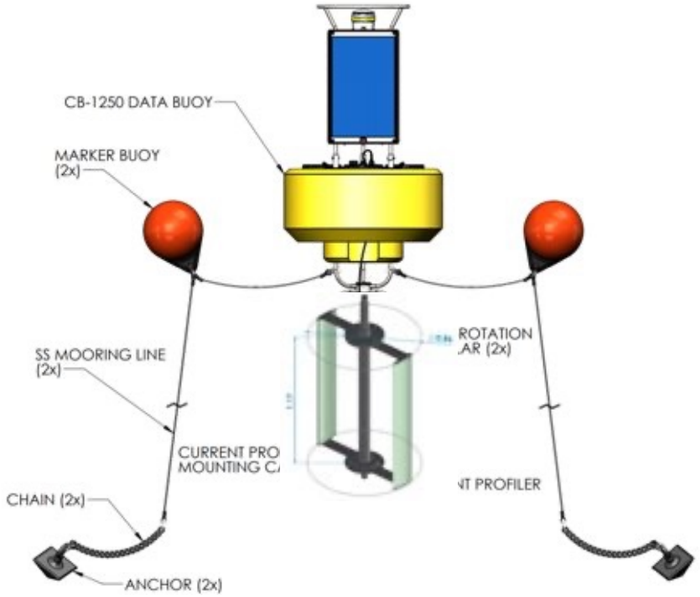
Maritime AI at PNNL's MCRL

Overview of Maritime AI

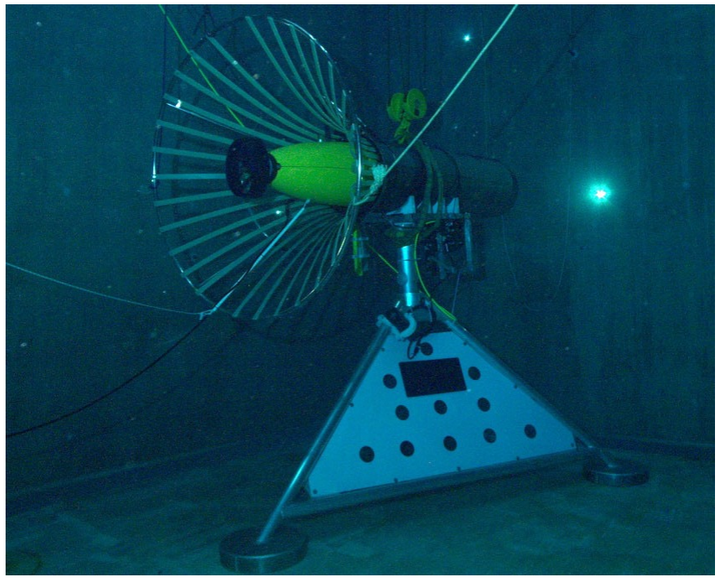
- Underwater mapping
- Object Detection
- Object Tracking
- Multiple Sensor Aggregation
- Autonomous navigation, motion, and planning
- Autonomous and persistent exploration
- Etc.



Autonomous Energy Harvesting



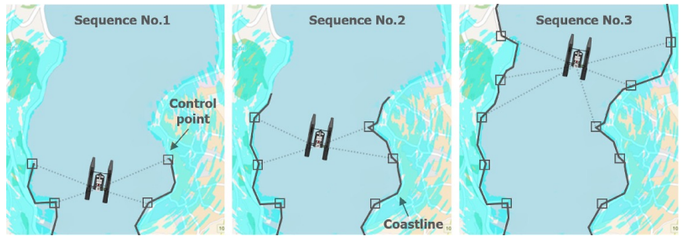
Renewable Energy Buoy



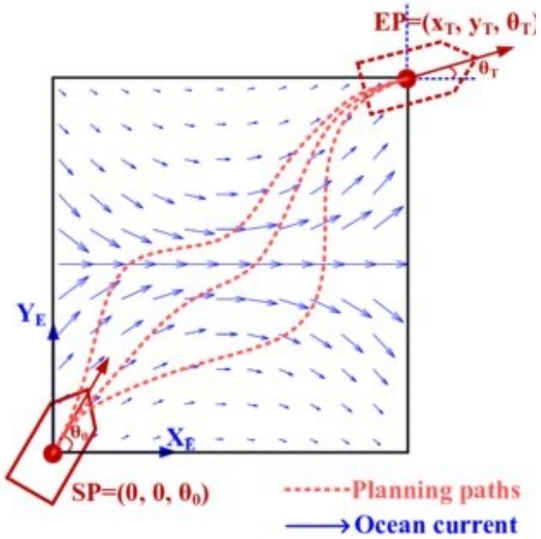
Autonomous Underwater Vehicle (AUV) docked

Autonomous Surface Vessel (ASV)

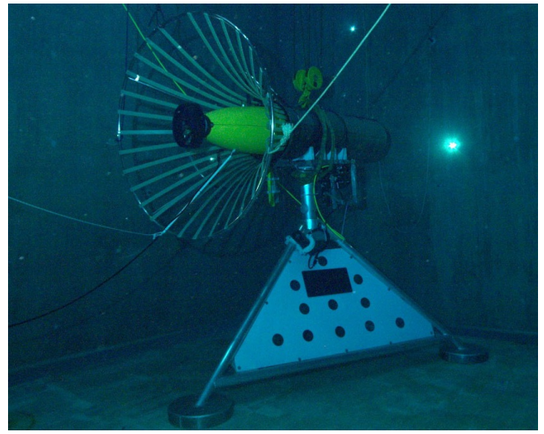
Autonomous Energy Harvesting



Simultaneous Localization and Mapping (SLAM)

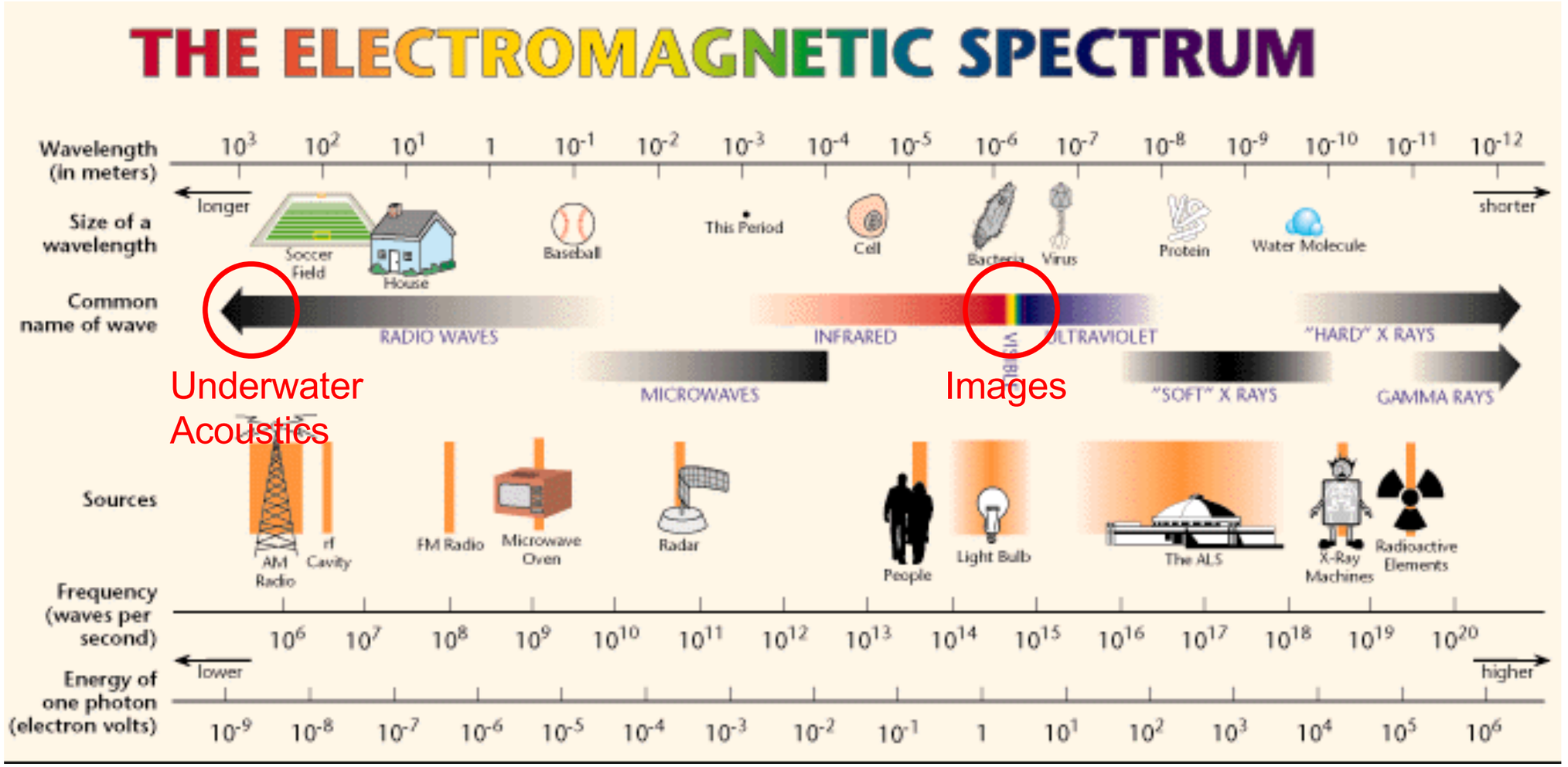


Motion Planning and Control



Docking

Eel Grass Detection, Mapping, and Monitoring



Eel Grass Detection, Mapping, and Monitoring

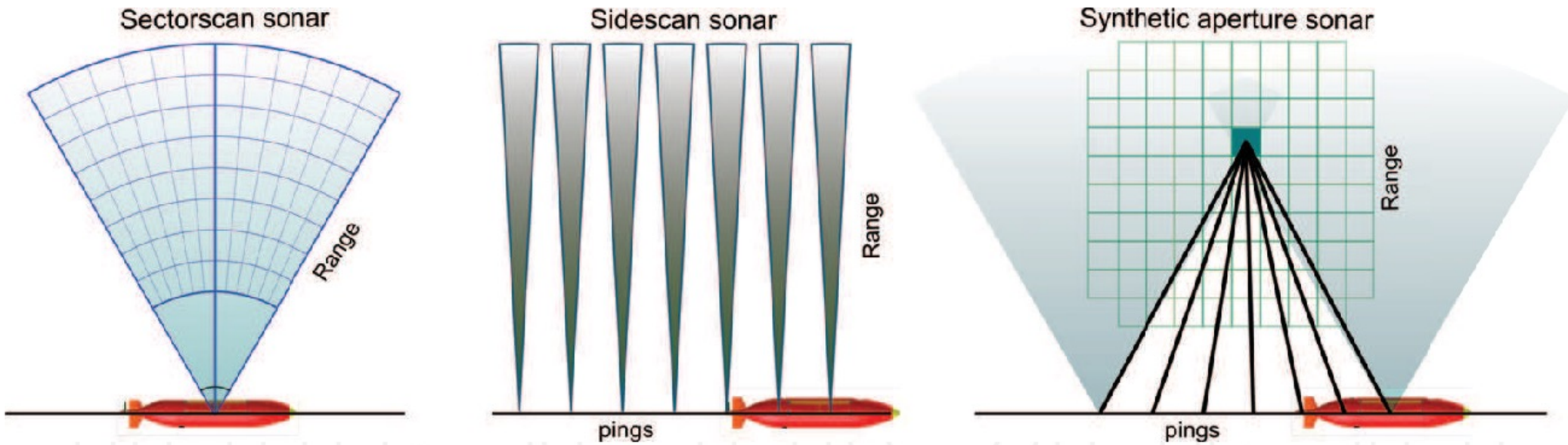
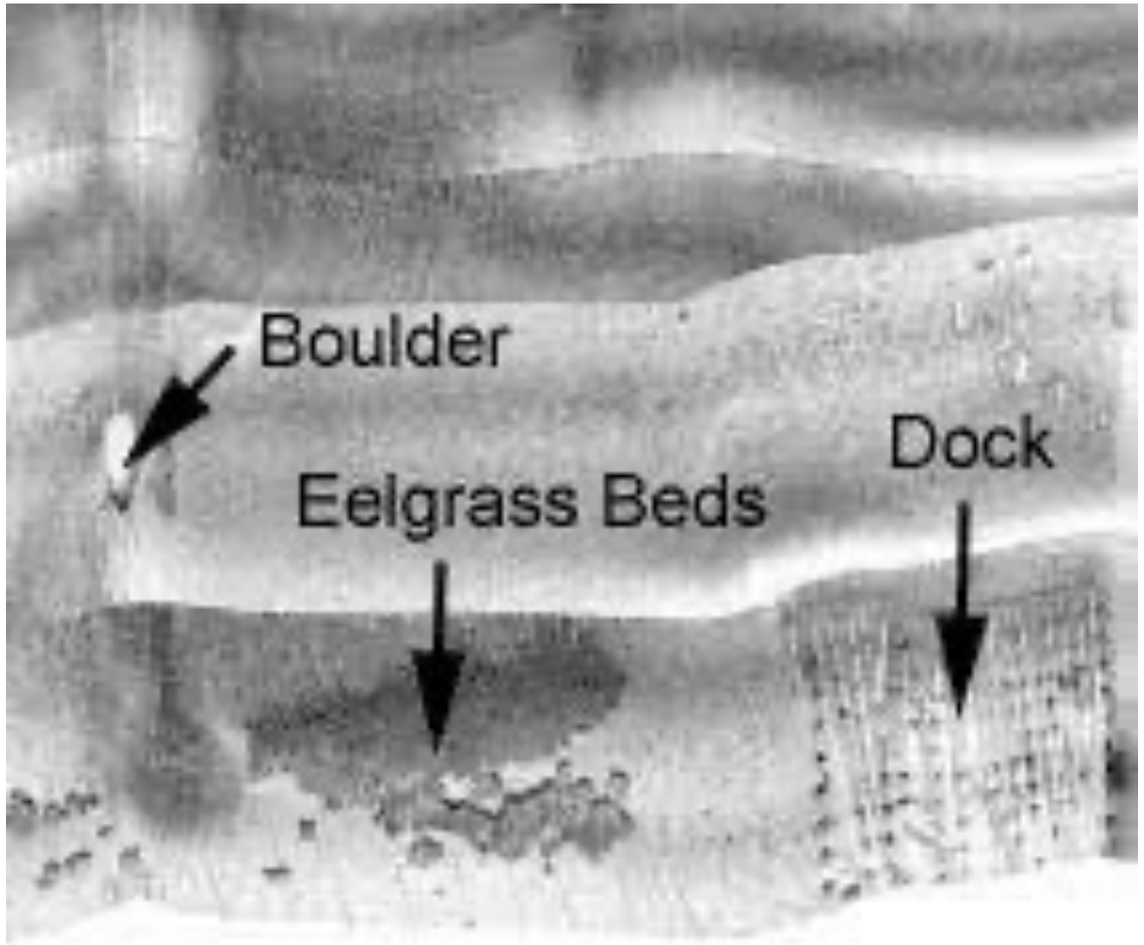


Fig. 6. Phased array imaging concepts for sonar.

Eel Grass Detection, Mapping, and Monitoring

Synthetic Aperture Sonar Data of Skagerrak Munitions Dump Site

Eel Grass Detection, Mapping, and Monitoring



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Ask me anything!

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