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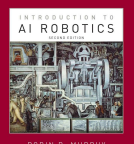
# Automation and Autonomy

**What is the difference between automation and autonomy?**

**Why does it matter that there is a difference between autonomy and automation?**

**What are the advantages of autonomy over automation? Can you tell me when to use one over the other? How much autonomy do I need?**



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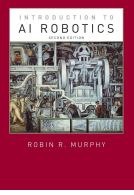
# Chapter Objectives

- Describe *automation* and *autonomy* in terms of a blending of four key aspects: generation or execution of *plans*, deterministic or non-deterministic *actions*, closed-world or open-world *models*, and signals or symbols as the core knowledge *representation*.
- Discuss the *frame problem* in terms of the *closed-world assumption* and *open-world assumption*.
- Describe *bounded rationality* and its implications for the design of intelligent robots.



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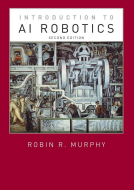
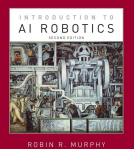
# Chapter Objectives (Cont.)

- Compare how taking an automation or autonomy approach impacts the programming style and hardware design of a robot, the functional failures, and human error.
- Define the *substitution myth* and discuss its ramifications for design.
- List the five trade spaces in human-machine systems (*fitness*, *plans*, *impact*, *perspective*, and *responsibility*), and for each trade space give an example of a potential unintended consequence when adding autonomous capabilities.



# Recap: What are Intelligent Robots?

- In AI, a robot is a **physically situated intelligent agent**
- An intelligent agent is a system that perceives its environment and takes actions which maximize its chances of success. *(Russell & Norvig 2003)*
- Typically think of an agent being able to SENSE, PLAN, ACT, LEARN
- AI traditionally divides research into seven major areas: *knowledge rep, natural language, learning, planning and problem solving, inference, search, vision*



# Autonomy Definition

- Autonomy (Merriam-Webster) is *the quality or state of being self-governing, self-directing freedom and especially moral independence*
- But in robotics "self-governing" is from the mechanical tradition of self-governing

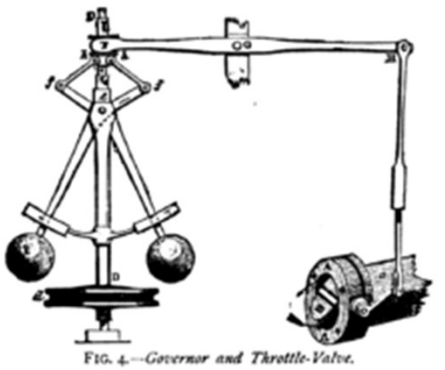
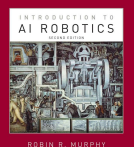


FIG. 4.—*Governor and Throttle-Valve.*

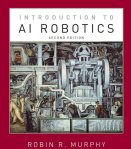
- And **bounded rationality** notes all cognitive agents have limits
  - While a robot may dynamically adapt or replan to overcome the occurrence of unmodeled events in the **open world**, it cannot go beyond what it was programmed to do.



# Autonomy Definition (Cont.)

- Remember: *Intelligent agent* is a system that perceives its environment and takes actions which maximize its chances of success
  - **Therefore an intelligent agent is self-governing and autonomous, even it is a heavily bounded agent**

- Robot autonomy is often viewed as requiring the generation and execution of actions to meet a goal or carry out a mission, where execution may be confounded by the occurrence of unmodeled events (**open world**), requiring the system to dynamically adapt or replan
  - **Note that autonomy is about the robot maximizing success for a specific goal or mission**



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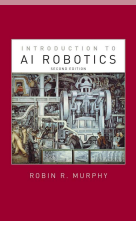
# Autonomy: Space Robots

- Designed for exploring Mars
- Operate in environments that can only be estimated
- Make decisions in real-time rather than wait for the time delay in communicating with humans on Earth
- Focus on artificial intelligence approaches rather than control theory

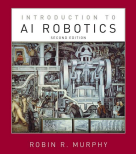
**Situated agents since they sense or reason about the world, and make decision to maximize its success**



# 3 Automation: Industrial Robots

- Designed for rapid, accurate repetitious movements
- Workspace is fixed and parts presented in the correct posture
  - Eliminating the need for external sensing
- Focus on control theory, joint movement to get fastest, repeatable trajectory
- Recently, adding sensors to reduce need for fixturing

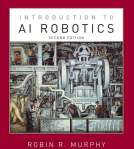
**Not situated agents since they do not sense or reason about the world, only perform pre-programmed actions.**



# So What's the Difference?

- Automation is about physically-situated tools performing highly repetitive, pre-planned actions for well-modeled tasks under the **closed world** assumption

- Autonomy is about physically-situated agents who not only perform actions but can also adapt to the **open world** where the environment and tasks are not known a priori by generating new plans, monitoring and changing plans, and learning within the constraints of their bounded rationality



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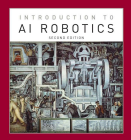
# Closed World Assumption

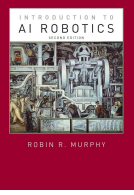
- ***Execution of precise, repetitious actions or sequence in a controlled or well-understood environment***

# Closed World Assumption

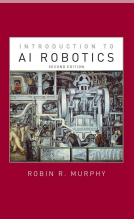
**CLOSED WORLD**

- Everything relevant is known *a priori*, that there are no surprises
- Everything relevant can be completely modeled
- If world is modeled accurately enough, **can create stable control loops to respond to all expected situations**
- If world is controlled, **can minimize or eliminate sensing**



# But What If Not Closed World?


- **Open World Assumption**
- Models may be available but are only partially (and unpredictably) correct
- Must be able to **sense relevant aspects** of the world in order to **dynamically adapt actions** (e.g., act as an agent)



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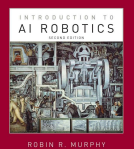
OPEN WORLD

- This is associated with being autonomous



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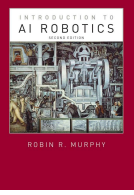
# WHY DOES IT MATTER THAT THERE IS A DIFFERENCE BETWEEN AUTONOMY AND AUTOMATION?

3 Reasons why

But not always



# 3 It Affects Programming Style

- Closed world
- Delegating for a small set of repetitious tasks

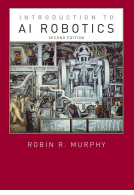
→ Focus is on formal, stable control loops

*Automation*

- Open world
- Delegating for a variety of tasks while operating in dynamic environments

→ Focus is on artificial intelligence

*Autonomy*



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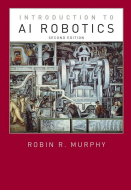
# It Affects Hardware Design

- Autonomy requires **rich sensing** in order to monitor the key elements of the dynamic world;
  - So a robot designed for automation or for teleoperation is not necessarily able to be used autonomously by just adding software.
- Intelligent robots should be viewed from an ecological design perspective:
  - What capabilities does the robot need to perform its functions in a particular environment?
- Adding new sensors to an unintelligent robot later may be impossible due to the change in size and weight of the robot, the lack of capacity on the internal electrical and power buses, or even the lack of a surface for mounting.



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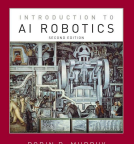
# It Affects How Systems Fail

- Two major failure mode of intelligence in robots
  - Functional failures, where the robot does what it was programmed to do but not what was intended.
  - Human errors, stemming from the **substitution myth** that a machine can perfectly replace a human for particular task

- Functional Failures
  - If the robot's expectation of the environment is incorrect in a complex world, it may get the equivalent of "tunnel vision" and miss things



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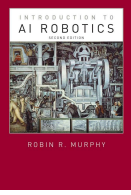
# How Systems Fail (Cont.)

- Human errors
  - While automation and autonomy are intended to eliminate or reduce human involvement, these capabilities often introduce human or operator errors because any robot is part of a larger human-machine system
- Human Out-Of-The-Loop (OOTL) control problem
  - No matter how independent of a human the robot is, if something goes wrong, a human is expected to take over for the robot or to intercede.
  - But it may not be cognitively possible for a human to react fast enough or to comprehend what the robot has been doing and what is going wrong and to determine why and then to correctly solve the problem.



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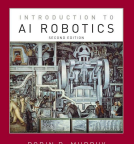
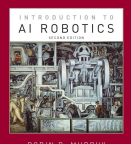
# So It Does Make A Difference

- Plans
- Actions
- Models
- Knowledge Representation

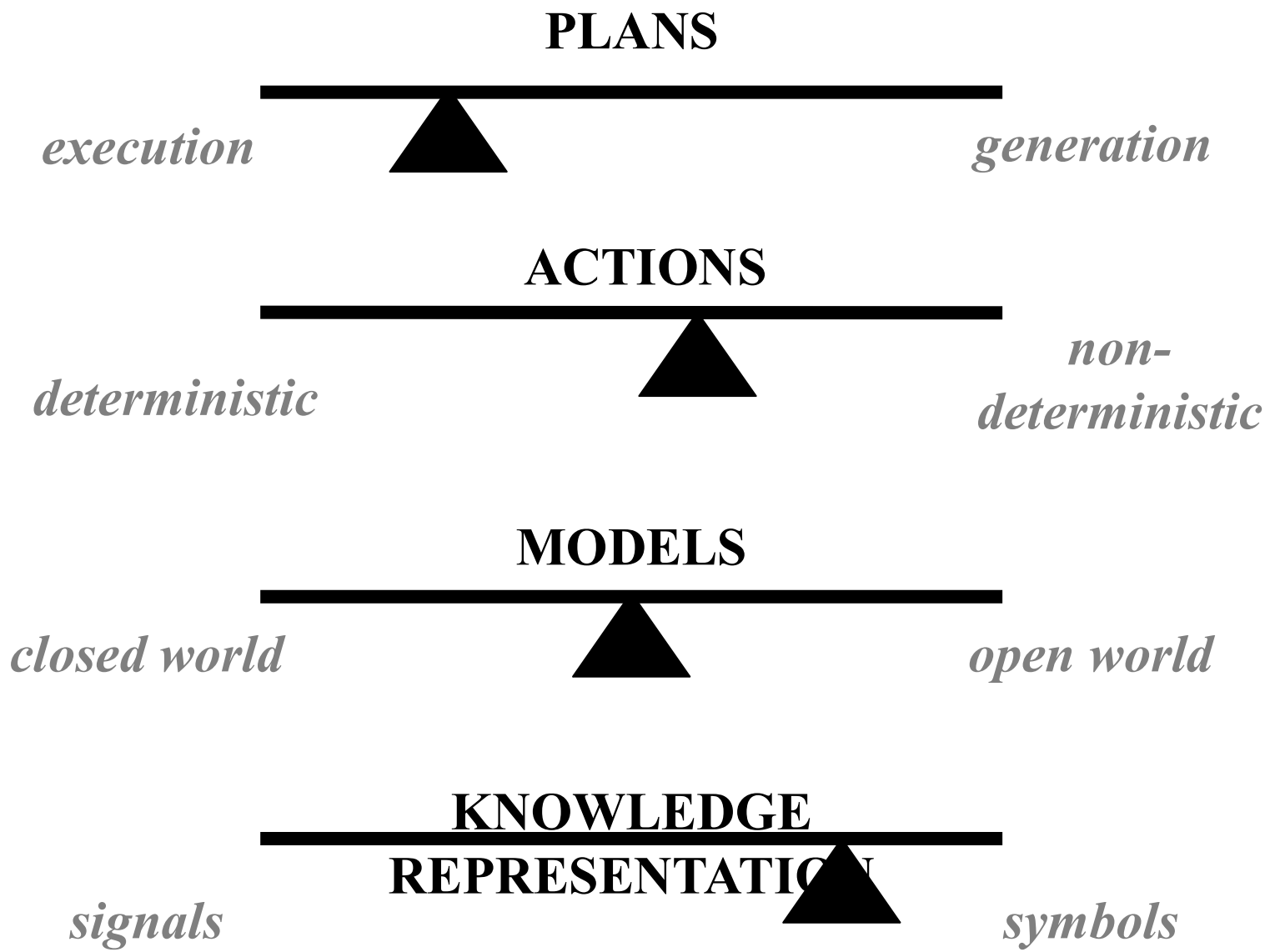


# 3 Can You Solve a Problem With Automation or Autonomy?

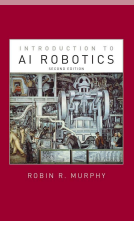
| | Automation | Autonomy |
|---|---|---|
| **Plans** | • Execution: perhaps plan once, then repeat that plan forever | • Generate: constantly generating new plans |
| **Actions** | • Deterministic: can model the system deterministically | • Non-deterministic: system is too complex to model deterministically |
| **Models** | • Closed world: the model contains everything | • Open world: models will only be partial |
| **Repre-sentation** | • Signals: control or decision-making is at the signal level | • Symbols: control or decision-making is with symbols or labels |



AUTOMATION




AUTONOMY



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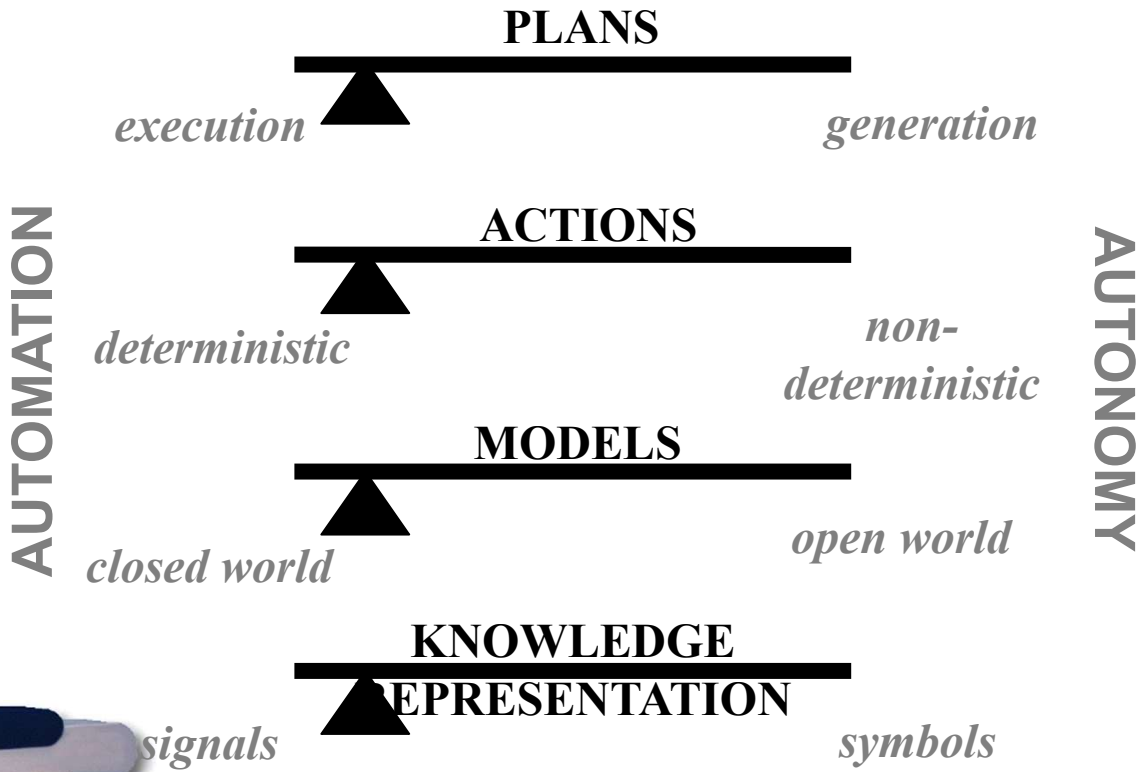


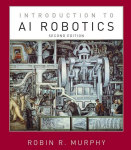

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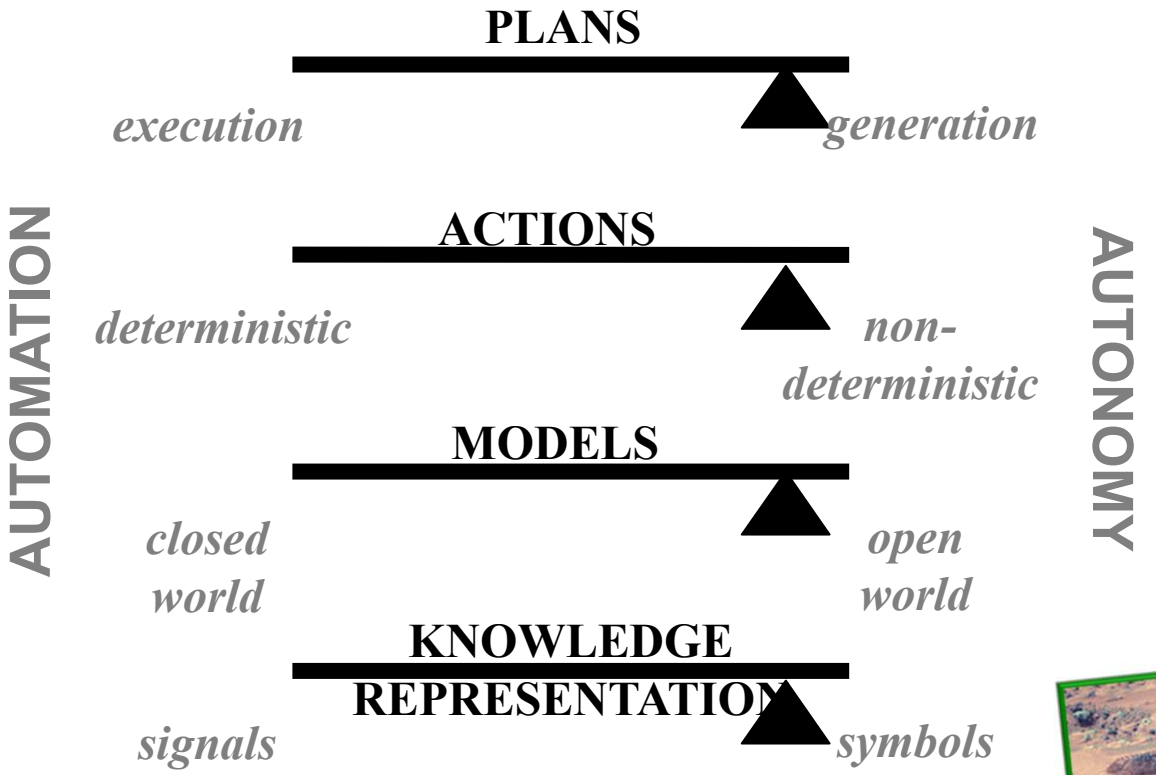
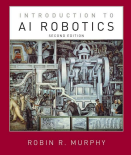
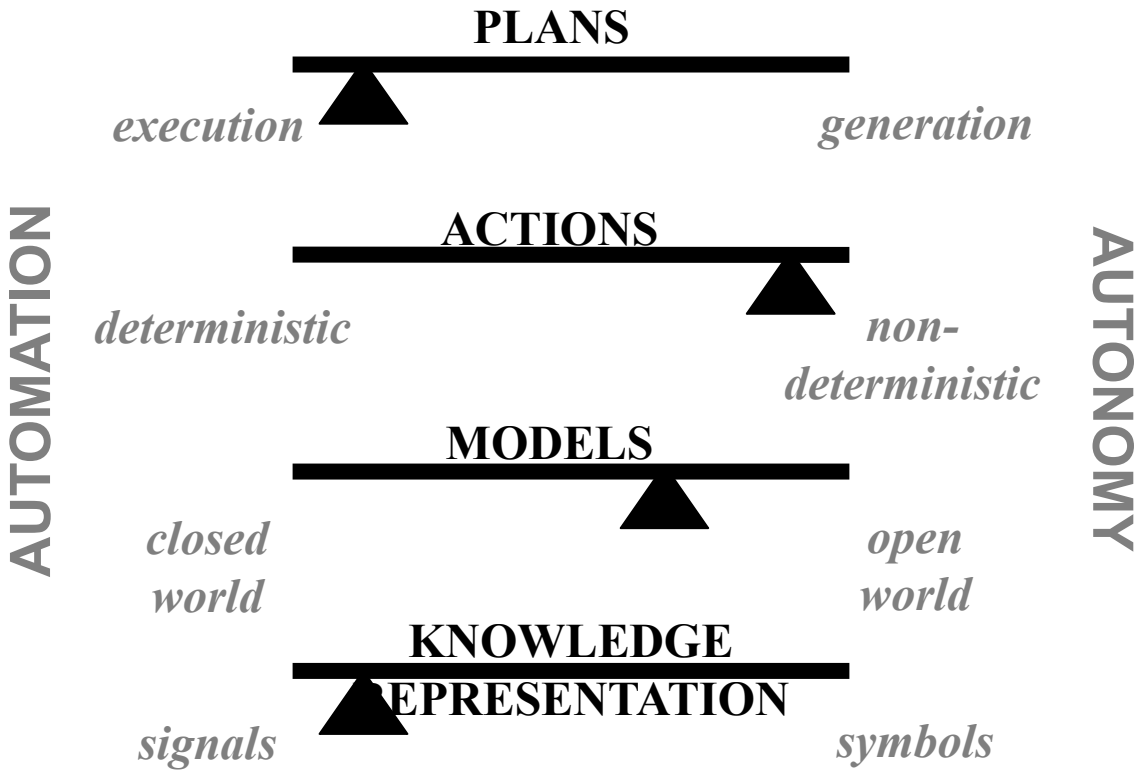
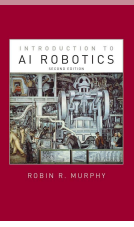


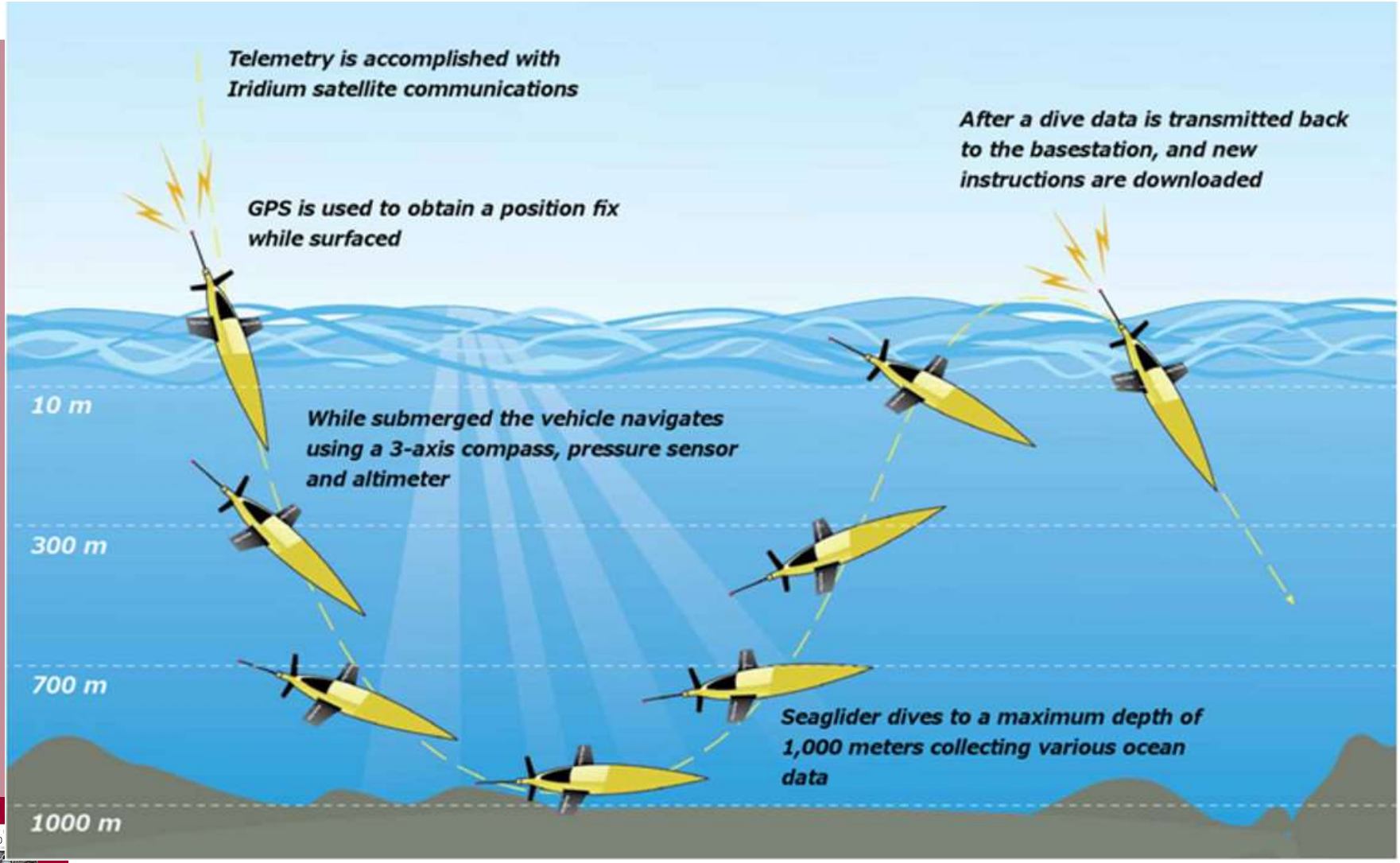



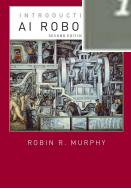


# 3 Seaglider: Long Endurance, Buoyancy-Drive Autonomous Underwater Vehicles (AUVs)

https://www.hydroid.com/seaglider



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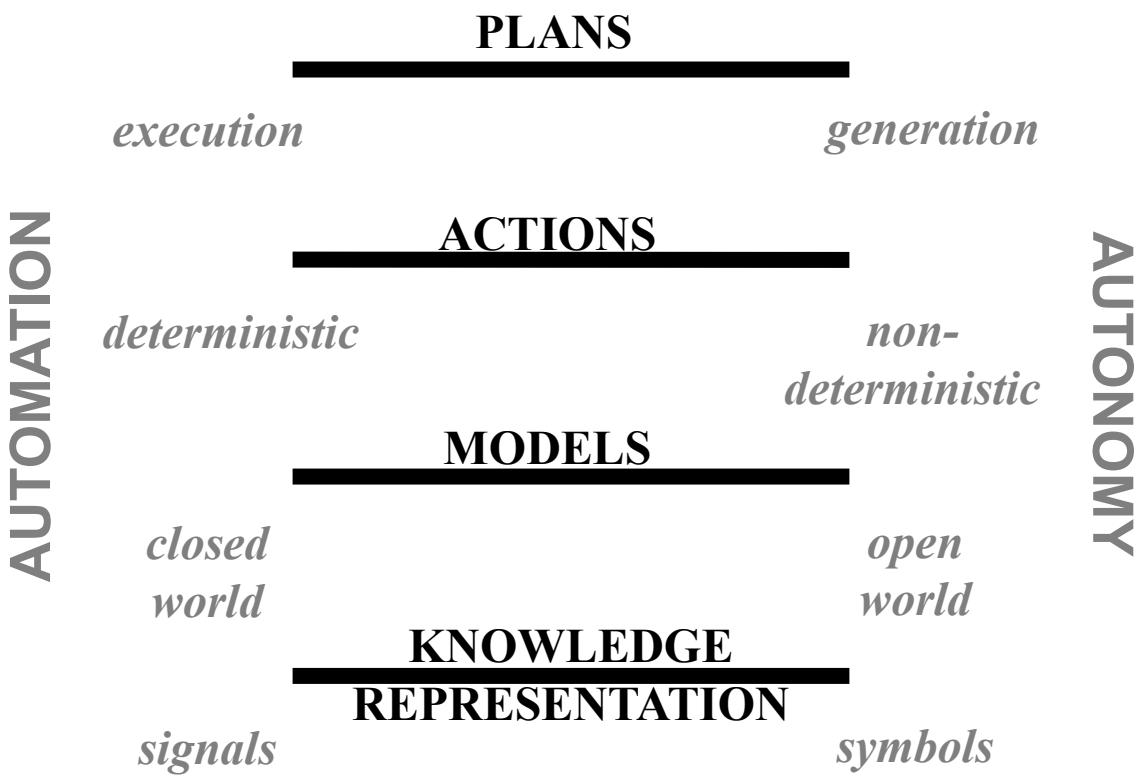
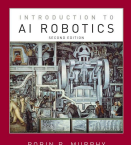
CLASS DISCUSSION



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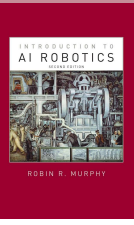
# Trade-Spaces in Adding Autonomous Capabilities

Five trade spaces in human-machine systems

- Fitness, which represents the tradeoff between optimality and resilience.
- Plans, which represents the tradeoff between efficiency and thoroughness
- Impact, which represents the tradeoff between centralized and distributed perspectives
- Perspectives, which represent the tradeoff between local and global views
- Responsibility, which represents the tradeoff between short-term and long-term goals and the decision about which agent is ultimately responsible for reaching those goals



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# To Conclude

- Intelligent robot is a physically situated *intelligent agent; it* is a system that perceives its environment and takes actions which maximize its chances of success.
- An intelligent robot is also called autonomous, where autonomous means autonomous capability, not political autonomy or that the robot can do the entire job
- If you design a robot application, you will probably use a bit of ideas from automation and autonomy but you will need to consider whether planning is involved, what kinds of actions, what type of model of the world, and knowledge representation