Introduction to Artificial Intelligence

Departamento de Automática

Objectives

1. Think over the meaning of intelligence
2. Understand Artificial Intelligence (AI) as a Computer Science discipline
3. Describe the historical roots of AI
4. Elemental AI terminology
5. Introduce some AI applications

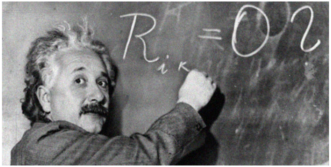
Objectives

Russell, S., Norvig, P. (1995). *Artificial Intelligence: A modern approach*. Prentice-Hall.

Table of Contents

1. Introduction
  - Intelligence
  - Artificial Intelligence
  - Approaches to Artificial Intelligence
  - Related fields
2. History
  - Timeline
  - Success milestones
3. Building Terminator
  - Introduction
  - Hardware
  - Chess
  - Speech synthesis
  - Speech recognition
  - Speech undestanding
  - Image recognition
  - Learning
  - Plan and make decisions
  - General Artificial Intelligence
4. AI applications
  - Disciplines and techniques
  - Application domains
5. AI in space: Why Mars?
  - Introduction
  - Evolution of Mars landers
  - MER: Spirit and Opportunity
  - Phoenix Mars Lander
  - MSL
  - Insight Lander
  - M2020
  - ExoMars

What is intelligence?

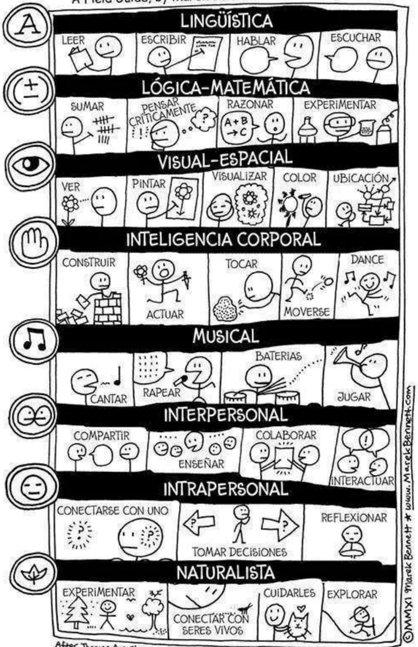


(Source)

(Source)

INTELIGENCIAS MÚLTIPLES

A Field Guide, by Marek Bennett



After Thomas Armstrong, MULTIPLE INTELLIGENCES IN THE CLASSROOM

Introduction

Intelligence (I)

Definition of intelligence

"A very general mental capability that, among other things, includes the ability to reason, pose, solve problems, think abstractly, understand complex ideas, learn quickly and learn from experience"

Gottfredson, 1997

Not only from books, limited academic ability, or make good tests

- It reflects a broader and deeper capacity

Introduction

Intelligence (II)

Alternative definition: Capacity to **learn** and **solve** problems (Websters dictionary)

- The ability to solve novel problems

Introduction

Artificial Intelligence (I)

Definition of AI

Build machines that perform tasks that were previously performed by human beings

- People process information slowly but in parallel
- Computers are incredibly fast but essentially linear
- It reflects a broader and deeper capacity
- Intelligence requires knowledge: Learning

Introduction

Artificial Intelligence (II)

Alternative definition: **Understand** and **build** intelligent entities

- Understand: Use computers to study intelligence (*Science*)
- Build: Solve real problems using knowledge and reasoning (*Engineering*)
- Intelligent entity = agent

AI deals with **algorithms** and **knowledge representation**

- AI is not restricted to any programming language

Introduction

Approaches to Artificial Intelligence (I)

Two goals: Humanity and rationality

- Human: Like human beings
- Rational: Doing the right thing
- The right thing: What is expected to maximize goal achievement, given the available information

Two dimensions: Processes (thinking) and result (acting)

Thinking humanly	**Thinking rationally**
Theories about internal activities of the brain ⇒ Neuscience	What are correct arguments? ⇒ Logics
Acting humanly	**Acting rationally**
Can machines think?	Rational agents

Introduction

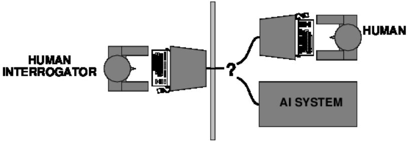
Approaches to Artificial Intelligence (II)

Thinking humanly

- Scientific theory of internal activities of the brain
- How to validate?
  - Predicting behavior of humans (**Cognitive science**)
  - Identification of neurological data (**Neuroscience**)

Acting humanly

Can machines think? Test needed: Turing test



Proposed by Alan Turing (yes, that Turing!)

Introduction

Approaches to Artificial Intelligence (III)

Real Turing test at the Royal Society (2014)

Chat 1

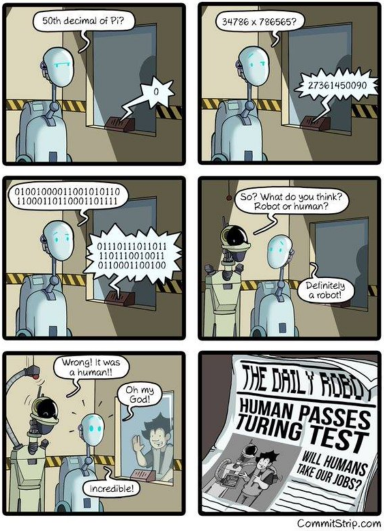
```
[16:28:55] Judge: how tall are you
[16:29:18] Entity: almost 6 feet tall
[16:29:46] Judge: how heavy are you
[16:30:12] Entity: just over ten stone
[16:30:47] Judge: what is your gender
[16:30:59] Entity: male
[16:31:45] Judge: what is your bmi
[16:31:54] Entity: i have no clue
```

Chat 2

```
[16:29:04] Judge: how tall are you
[16:29:10] Entity: My height is about 160 cm - it's 5 feet 4 inches.
[16:29:37] Judge: how heavy are you
[16:29:59] Entity: My grandfather taught me not to disclose non-solicited information about
myself. Like on the question 'Do you have watch' - never tell time, but answer 'Yes' or
'No'. I always follow his advice. And I forgot to ask you where you are from ...
[16:31:09] Judge: what is your gender
[16:31:17] Entity: I'm a young boy, if you care to know. And not very ugly, by the way!
```

Introduction

Approaches to Artificial Intelligence (IV)



Introduction

Approaches to Artificial Intelligence (IV)

Thinking rationally

- "Laws of thought"
- Aristotle: What are correct arguments? ⇒ **Logic**
- Connects Philosophy, Mathematics and AI
- Problems
  - Not all intelligent behavior is deliberative
  - What is the purpose of thinking?

Acting rationally

Agent: Entity that perceives and acts

- A robot may be seen as an phisical agent
- Amazon recommender system
- Spam filter

Computational constrains: Design the best program with available resources

Introduction

Related fields

Philosophy	Logic, methods of reasoning, mind as physical system, foundations of learning, language, rationality
Mathematics	Formal representation, proof algorithms, computation, (un)decidability, (in)tractability, probability
Probability	Modeling uncertainty, learning from data
Economics	Utility, decision theory, rational economic agents
Neuroscience	Neurons as information processing units
Psychology	How do people behave, process cognitive information, represent knowledge
Computer Engineering	Build fast computers
Control theory	Optimization
Linguistics	Knowledge representation, grammars

History

Timeline (I)

1943 Early beginnings

- McCulloch & Pitts Boolean circuit model of brain

1950 Turing

- Turing's "Computing Machinery and Intelligence"

1952 Look, Ma, no hands!

1956 Birth of AI

- Dartmouth meeting: "Artificial Intelligence" adopted

History

Timeline (II)

1950s Early AI programs

- Samuel's checkers program
- Newell & Simon's Logic Theorist

1955-65 Great enthusiasm

- Newell and Simon: GPS, general problem solver
- McCarthy: Invention of LISP

1966-73 Reality dawns

- AI discovers computational complexity
- Limitations of existing neural networks methods identified
- Neural network research almost disappears

History

Timeline (III)

1969-79 Adding domain knowledge

- Early development of knowledge-based systems

1986- Raise of Machine Learning

- Neural Networks return to popularity
- Major advances in Machine Learning and its applications

1990- Role of uncertainty

- Bayesian networks for knowledge representation

1995- AI becomes a science

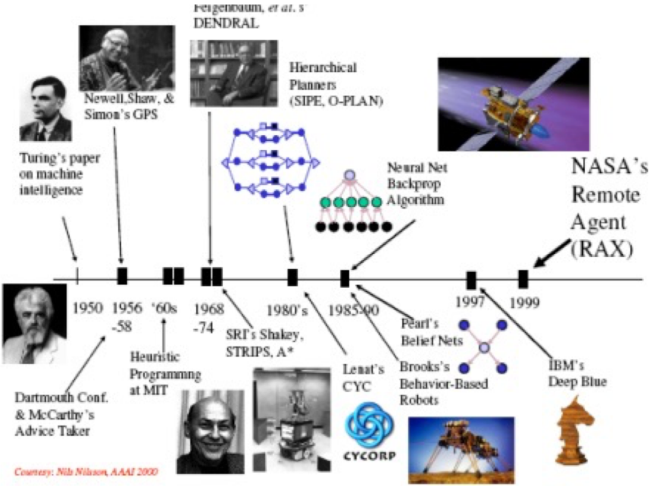
- Integration of learning, reasoning and knowledge representation
- AI used in vision, language, data mining, etc

2000- Popularity of Soft Computing / Bioinspired algorithms

2010- Machine Learning meets large databases: Big Data

History

Timeline (IV)



History

Success milestones

- Deep Blue defeated Garry Kasparov in 1997
- Proved the Robbins conjecture, unsolved for decades
- No hands across America
- During the 1991 Gulf War, US forces deployed an AI logistics planning and scheduling program that involved up to 50,000 vehicles, cargo, and people
- NASA's on-board autonomous planning program controlled the scheduling of operations for a spacecraft
- Proverb solves crossword puzzles better than most humans
- Robot driving: DARPA grand challenge 2003-2007
- 2006: Face recognition software available in consumer cameras
- 2011: IBM Watson defeats human players in Jeopardy!
- 2016: First AI to defeat a Go human champion

Building Terminator (I)

Terminator

- Come on, do you really do not know what Terminator is?
- Classical action movie filmed in 1984
- Relates a robot from 2029 chasing Sarah Connor
- ... and self-aware AI named Skynet that leads the raise of the machines

(Video trailer)

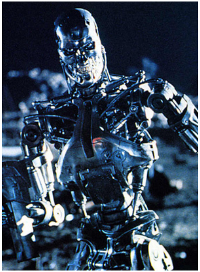
Building Terminator (II)

The main character is a T-800 robot, terminator

- T-800 is a robot model designed to exterminate humans

T-800 displays very advanced features

- Plan how to exterminate Sarah Connor
- Speak easily with humans
- Recognize human faces
- Navigate vehicles
- Diagnose on-board problems
- Make life-and-death decisions
- Understand human emotions



Terminator was sci-fi in 1984 ... Is it still sci-fi?

Building Terminator (III)

Imagine we want to build T-800 ... What would we need?

- Fast hardware?
- Chess-playing at grandmaster level?
- Speech interaction?
- Learning?
- Image recognition and understanding?
- Planning and decision-making?

Let’s analyze them

AI applications

Building Terminator (IV)

Human skill	AI field
Motion control	Robotics
Image reconition	Computer vision
Speech understanding	Natural Language Processing
Reasoning	Automatic reasoning
Plan	Planning & Scheduling
Learn	Machine Learning
Drive vehicles	Control
Play chess	Search

And, of course, we need some hardware

Building Terminator

Hardware (I)

How complicated is our brain?

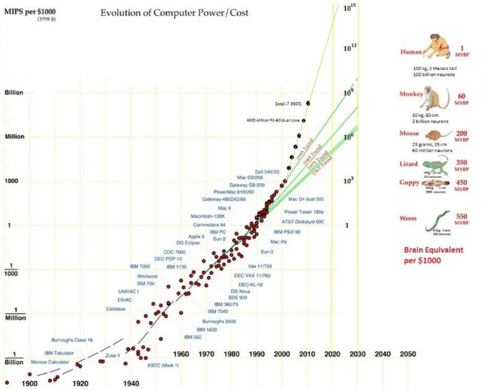
- A neuron is the basic information processing unit
- Arround 10^{12} neurons in a human brain with (10^{14}) synapses
- Processing time: $1ms$

How complex can we make computers?

- 10^{8} or more transistors per CPU
- Supercomputers with thousands of CPUs
- Processing time: 10^{-9}s

Building Terminator

Hardware (II)



(Source)

Conclusion

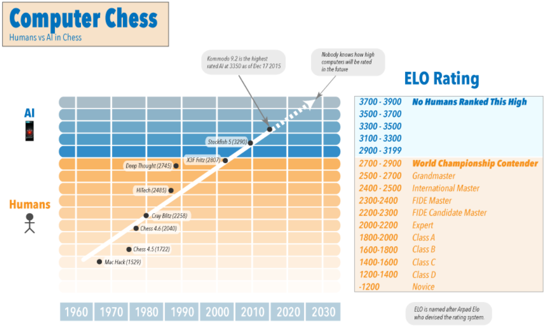
- YES, in a future we will have computers with as many processing units than human brains
  - But, with fewer interconnections, and much faster
- Processing power does not make behave like a brain

Building Terminator

Chess (I)

Chess is a classic benchmark in AI

- AI techniques: Classic search



(Source)

Conclusion: YES

Building Terminator

Chess (II)

AlphaGo

In 2015, an AI beats the best human Go player

- Historic mildstone

Go is much harder from AI perspective

- Huge branching factor
- Fuzzy heuristics

AI techniques

- Monte-Carlo Search Trees
- Deep neural networks

Next challenge: StarCraft II

Building Terminator

Speech synthesis

Three different problems to make computers talk

- (Speech synthesis), speech recognition and speech understanding

Speech synthesis: Generate sound from text

- Translate text to phonemas: “fictitious” ⇒ fik-tish-es
- Generate sound from phonema: ”tish”⇒ Sound

Difficulties

- This approach makes sounds unnatural
- Sounds are not indepentent (almost solved)
- Show emotions, emphasis, semantic-aware pronuntiation

Conclusion

- YES for words
- NO for complete sentences

Building Terminator

Speech recognition

Speech recognition: Map sounds into a list of words

- Classic (and difficult) problem in AI
- Techniques: Neural networks, Hidden-Markov Chains, Deep Learning, ...

Recognizing single words from a small vocabulary

- Numbers, city numbers, names, ...
- Highly successfull solutions (99 % accuracy)

Recognizing normal speech is much more difficult

- Large vocabularies
- Continous sound (detect word boundaries)
- Humans use context to recognize speech
- Background noise, accents, other speakers, ...
- Modern systems with 60 %-70 % accuracy

Conclusion: YES for restricted problems, NO for normal speech

AI applications

Building Terminator: Speech understanding

Speech understanding: What is the meaning of the speech?

- Another classic (and difficult) problem in AI
- Same than text mining
- Techniques: Knowledge representation, ontologies, ML, NLP

Very hard problem

- Natural language is ambigous ⇒ Different interpretations
- Meaning depends on the context

Example: “Time flies like an arrow”

- What does it mean?

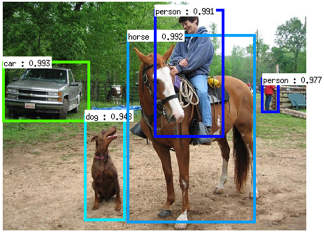
Normal speech is too hard ⇒ Formal representation of knowledge

- Semantic Web, ontologies, deep neural networks (recently), etc

Conclusion: NO

Building Terminator

Image recognition



(Source)

Several tasks:

- Segmentation, object recognition, (image synthesis), etc

Technology

- Deep neural networks

Conclusion: NO for general recognition, YES for restricted domains

Building Terminator

Learning (I)

Consider a selft-driving car, we could ...

- ... program a huge number of rules
- ... or we could drive and let the computer learn

(Source)

Machine Learning

- Allows computers to do things without explicit programming
- Many techniques: Neural networks, decision trees, bayesian networks, ...
- Huge number of applications
- Hot topic nowdays (and job opportunities!)

Building Terminator

Learning (II)

Another discipline: Expert systems

- It maintains a knowledge base, facts base and interence engine
- Expert systems can learn

Other approaches: Case Based Reasoning, Reinforcement Learning, probabilistic learning, Deep Learning, ...

- (Video)

Conclusion: YES

Building Terminator

Plan and make decisions

Intelligence involves solving problems, making decisions and plans

- Plan: Sequence of actions to achieve a goal
- Techniques: Search

Example: You want to plan a trip to Caribe

- Decide on dates, flights, airport transport, hotel, fit timetables, ...

It is a hard problem

- World is not predecible (flights can be delayed)
- Huge number of details, common sense constrains decisions

Life-and-death decisions: (Video)
Conclusion: NO for real-world planning, YES for restricted domains

Building Terminator

Artificial General Intelligence

State-of-the art AI is competitive in very restricted domains

- How AI generalizes to broad domains?
- Artificial General Intelligence
- State-of-the-art uses Deep Reinforment Learning (neural networks)

General AI is a controversial field

- Eventually, we could develop an *intelligence explosion* ...
- ... and a *superintelligence* ...
- ... or even a *strong* AI

AI applications

Disciplines and techniques

AI disciplines techniques

Disciplines

- Automatic reasoning
- Planning
- Agents
- Expert systems
- Computer vision
- Evolutionary Computation
- Natural Language Processing
- Machine Learning
- Knowledge representation
- ...

Techniques

- Neural networks
- Search algorithms
- Genetic Algorithms
- Case Based Reasoning
- Logic
- Fuzzy logic
- Web mining
- Ontologies
- ...

AI applications

Application domains (I)

Genetic Algorithms

- Optimization of production chains
- Optimization of airline planes and crews
- Antenna design

Expert Systems

- Decision making in financial markets
- Fraud detection
- Medical diagnosis systems

Neural networks

- Face recognition
- Robot control
- OCR

AI applications

Application domains (II)

- Handwriting recognition (reading service postcodes USA)
- Search engines on the Web and Semantic Web
- Bio(logical) computing
- Anti-spam email
- Proof of theorems automatically
    - Using new methods of inference to prove new theorems

Why Mars?

Introduction (I)

Mars is a lot like Earth

- About 1/2 size than Earth
- Martian day slightly under 25 hours
- Avg. temp -63º (-140ºC to 20ºC)

Distant past

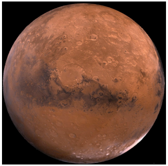
- Evidence of oceans and warm temperatures
- It may have harbored life

Present

- Frozen water and a thin atmosphere of carbon dioxide remain
- It is possible that it harbors life today
- Earth is sending many robotic spacecraft to investigate

Future

- Mars has all of the materials needed to support human civilization
- Several nations interested in sending humans to Mars in the future

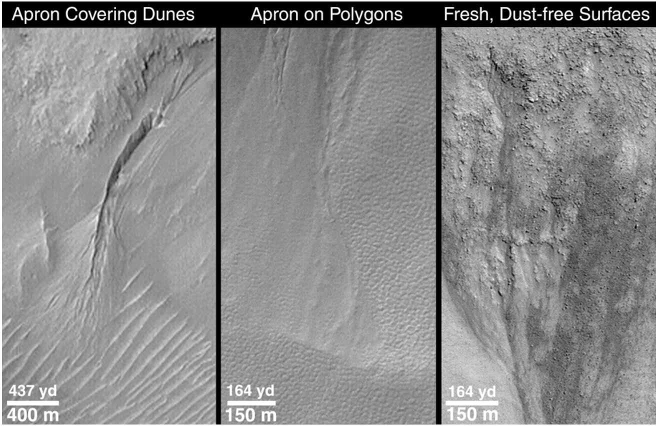


(Source)

Why Mars?

Introduction (II)

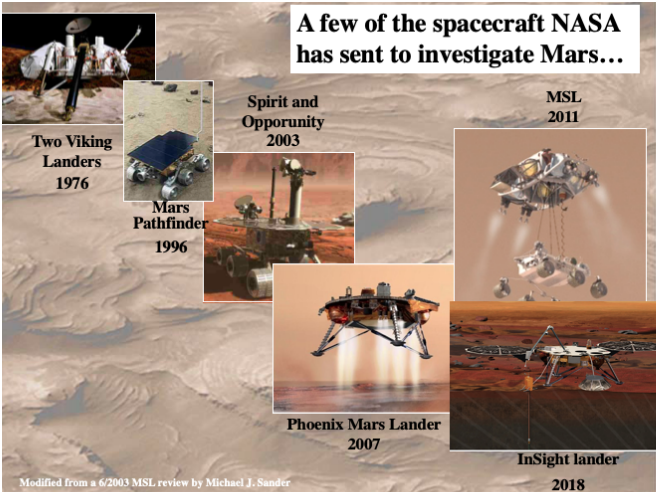
Strong evidence of recent water activity



(Source)

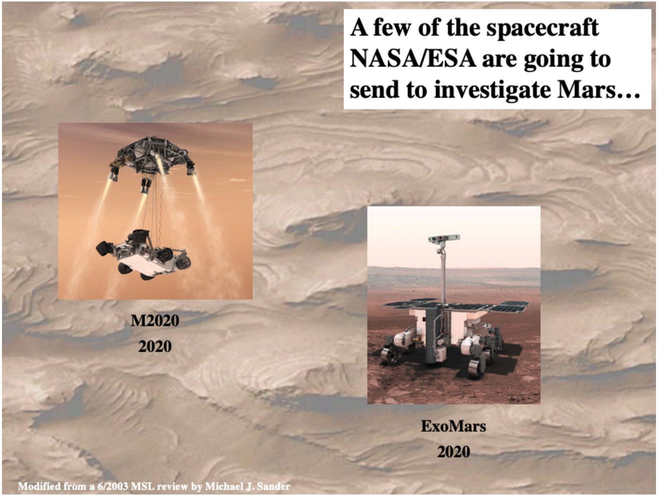
Why Mars?

Evolution of Mars landers (I)



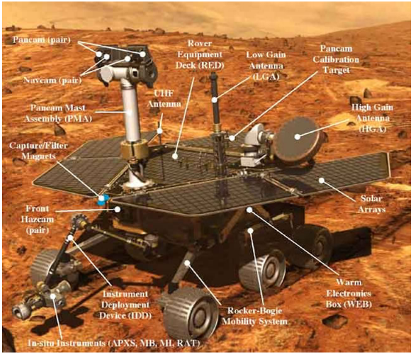
Why Mars?

Evolution of Mars landers (II)



Main missions to Mars

Spirit and Opportunity (I)



Launch:

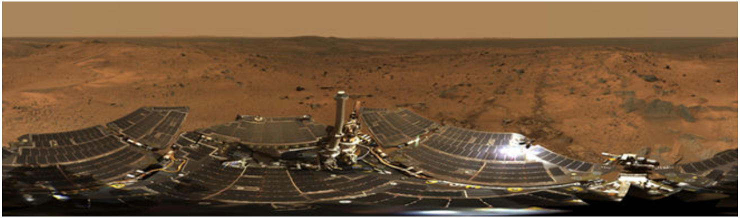
- Jun 10, 2003 (Spirit)
- July 7, 2003 (Opportunity)

Landed:

- Jan 4, 2004 (Spirit RIP - March 22, 2010)
- Jan 25, 2004 (Opportunity)

Main missions to Mars

Spirit and Opportunity (II)

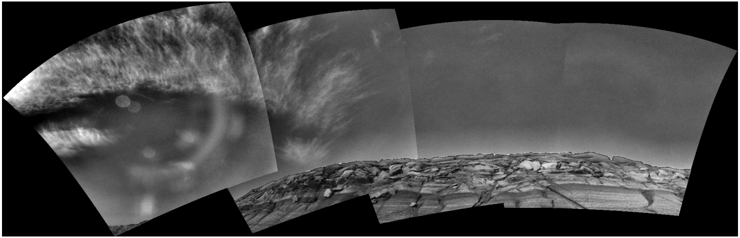


- Some Mars rocks contain minerals that only form in water
- Some sediment layers were formed in standing water
- Mars was covered with standing water in the past
- Mars used to be much warmer and wetter

Main missions to Mars

Spirit and Opportunity (III)

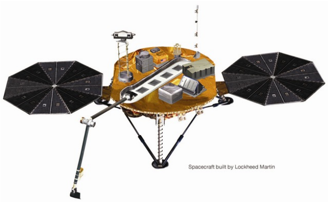
Clouds of water vapor on Mars



(Video Sunset) (Video MER by Steve Squyres)

Main missions to Mars

Phoenix Mars Lander (I)



Features

- Launch: August 27, 2007
- Landed: May 25, 2008
- Operated until November 2008

Goals

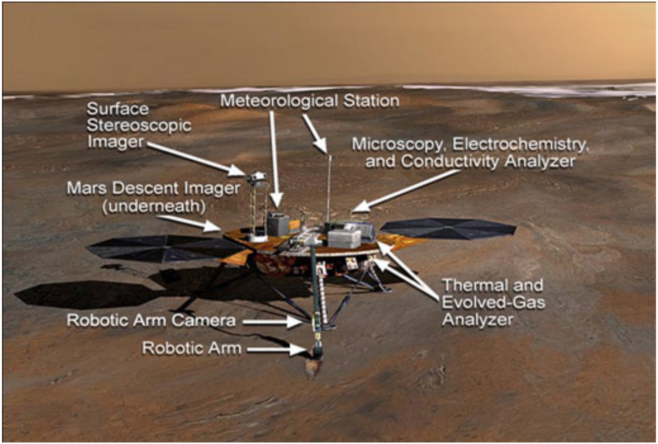
- Study the history of water in the Martian artic
- Search for evidence of a habitable zone and assess biological potential

How?

- Land in the Martian Arctic
- Dig through regolith to water ice
- Analyze ice samples in on-board

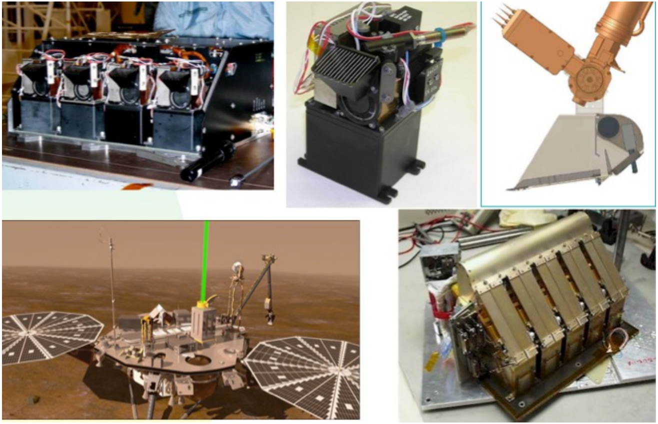
Main missions to Mars

Phoenix Mars Lander (II)



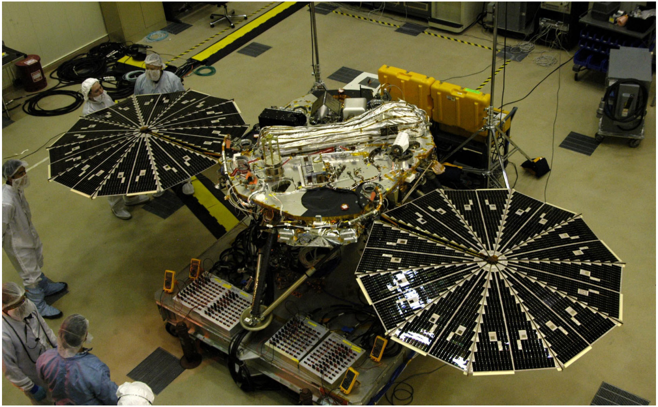
Main missions to Mars

Phoenix Mars Lander (III)

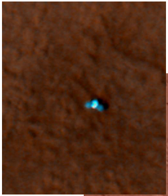


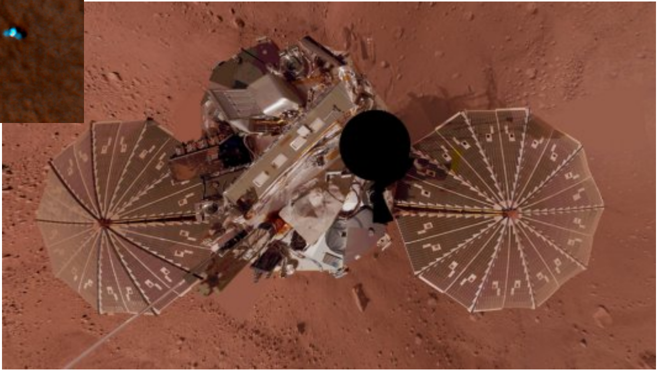
Main missions to Mars

Phoenix Mars Lander (IV)



Phoenix Mars Lander (V)

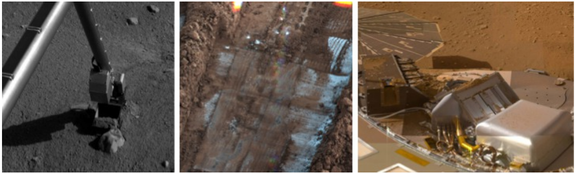




Main missions to Mars

Phoenix Mars Lander (VI)

Phoenix achievements



- Observed and sampled water ice in the Martian arctic
- Studied the water cycle
  - Sublimation of ice, precipitation of ice crystals (snow)
  - Evidence that a liquid water film can form in the soil
- Studied chemical makeup of the soil
  - Salts that typically form in presence of liquid water
  - Perchlorates that could be an energy source for life

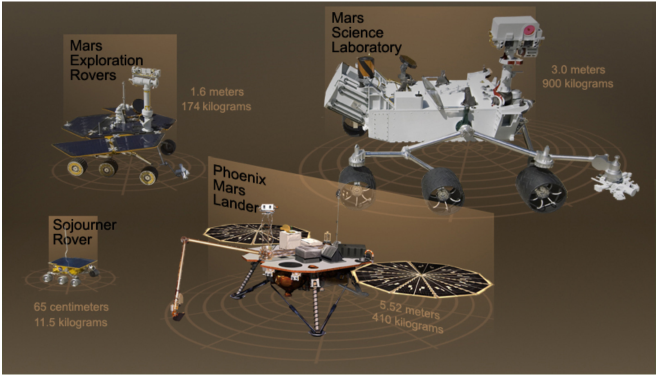
Main missions to Mars

Phoenix Mars Lander (VII)

(Video)

Main missions to Mars

MSL (I)



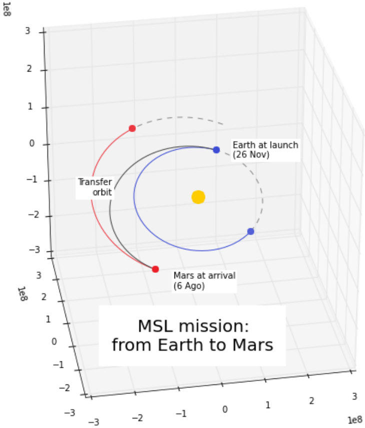
Main missions to Mars

MSL (II)

- Launch: Nov. 26, 2011
- Landed: August 5, 2012

Main missions to Mars

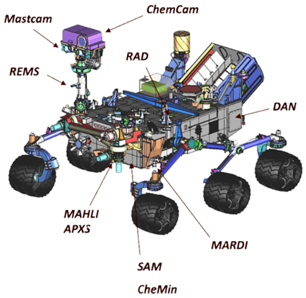
MSL (III)



(Source)

Main missions to Mars

MSL (IV)



(Source)

- Mast Camera (Mastcam)
- Chemistry & Camera (ChemCam)
- Alpha Particle X-ray Spectrometer (APXS)
- Mars Hand Lens Imager (MAHLI)
- Chemistry & Mineralogy (CheMin)
- Sample Analysis at Mars (SAM)
- Radiation Assessment Detector (RAD)
- Rover Environmental Monitoring Station (REMS)
- Dynamic Albedo of Neutrons (DAN)
- Mars Descent Imager (MARDI5)

Main missions to Mars

MSL (V)

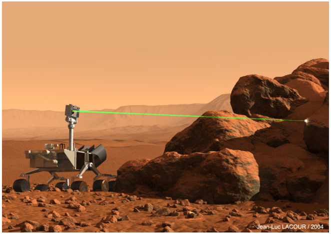
MSL goals (Primary mission 687 days)

- Assess potential habitat for life, past or present
- Assess biological potential...
- Characterize the geology of the landing region ...
- Investigate processes relevant to past habitability...
- Characterize surface radiation...

Instruments include

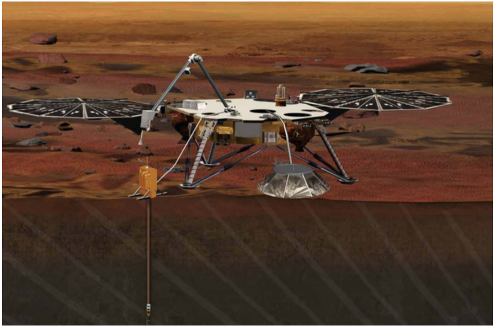
- Chemcam
- Variety of spectrometers
- Subsurface water detection

(Landing Process MSL video)



Main missions to Mars

Insight Lander (I)



- Launch: 5 May 2018
- Landing: 26 Nov. 2018

Main missions to Mars

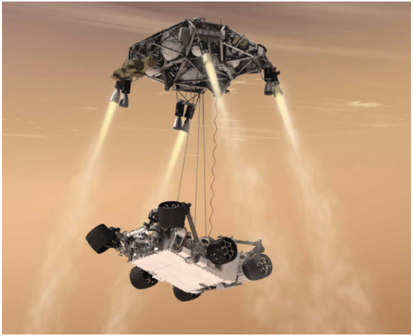
Insight Lander (II)

- Same concepts as Phoenix lander mission
- Different instruments to study the Martian interior
- The Instrument Deployment Arm & Camera will deploy 2 instruments:
  - Seismic Experiment for Interior Structure (French space agency): a seismographic instrument used to study the Martian interior and seismic activity
  - Heat Flow and Physical Properties Probe (German space agency): a self-burrowing mole that penetrates up to 5 m to measure heat escaping from interior

(Insight video)

Main missions to Mars

M2020 (I)



- Launch: Summer 2020
- Landing: February 2021

Main missions to Mars

M2020 (II)

- Shares heritage with the MSL rover with entirely new instruments
  - Use the Skycrane deployment method: rocket- powered hovering carrier to lower the rover to the surface of Mars with a tether
  - Delivery method is enhanced with Terrain Relative Navigation to enable the system to avoid hazardous terrain in selecting a location to lower the rover.
  - A drill capable of coring and caching samples for potential future retrieval to return to Earth
- More autonomous
  - An onboard scheduler to better use available time, energy, and data volume
  - Ability to autonomously target instruments based on scientist-provided criteria (SUPERCAM)

(Building M2020 video)

Main missions to Mars

ExoMars (I)

- Launch: 2020
- Landing: 2021

Main missions to Mars

ExoMars (II)

- First European funded mission: autonomous rover, automated exobiology laboratory & robotic drilling system
- Complement the ExoMars Phase 1 launched in March 2016 (Video)
- Instruments for:
  - Accurate visual and spectral characterization of the surface for molecular identification of organic compounds
  - Electromagnetic and neutron subsurface investigations to understand depositional environment (e.g. sedimentary, volcanic, and Aeolian)
- Unique contribution on exobiology to search past/present traces of life

(ExoMars Rover video)

Collorary

AI addresses the automatic problems resolution