Autonomous Agents in Space Missions

Course Project

CS886 - Multi-Agent Systems for Real-World Applications

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Autonomous Agents in Space Missions

Why agents? Why autonomy?

Implementing autonomous agents is so much work – can't we just continue to do things in the same way we have done them the last 50 years?


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Need to differentiate between manned and unmanned missions.


Autonomous Agents in Space Missions

Autonomy in unmanned missions

Unmanned missions (I): Coordinating satellites in Earth orbit.

Size of the control crew (operating 24 hours/day):

- Iridium (2000): 3 persons per spacecraft
- GlobalStar (2000): 2 persons per spacecraft





Autonomous Agents in Space Missions

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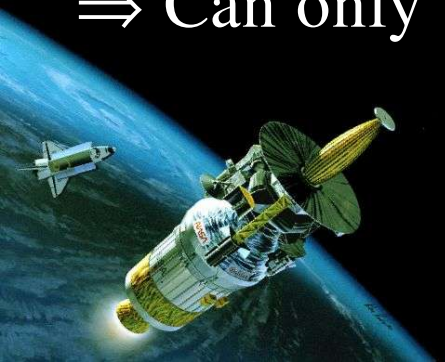
Target: 10 spacecrafts per person in 2009.

$\Rightarrow$ Can only be achieve with autonomous control agents.

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Autonomy in unmanned missions

Unmanned missions (II): Deep space missions.

- Communication latency – Earth-Mars round-trip time: 6-45 minutes; Earth-Jupiter round-trip time: 65-108 minutes.





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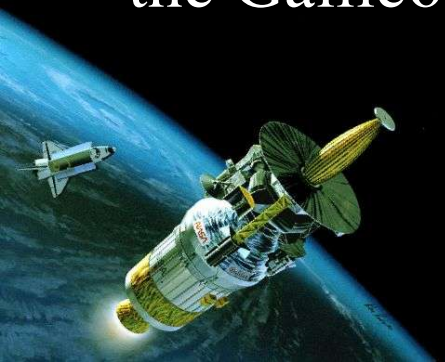
- Communication bandwidth – 128kbit/s for a Mars rover, 10bit/s for the Galileo probe (with damaged main antenna).



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Autonomy in manned missions

NASA simulation (Mars ground station) in 1998:

- 4-person crew, each crew member spent 90 minutes per day with general monitoring and maintenance.

Monitoring is *stupid* work. Should be possible to let robots do this.

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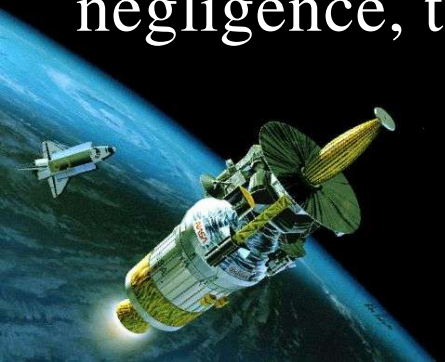
General mission safety can be increased if human actions are monitored by intelligent software agents (prevent mistakes caused by negligence, tiredness, ...).



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Why adjustable autonomy?

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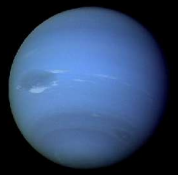
Why adjustable autonomy?

- Mission objectives can change during the mission.
- Certain experiments may need to be repeated because the desired information could not be extracted.
- It is impossible to foresee all possible events. For increased safety, the autonomous agent should ask for help in certain situations.





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Autonomous Agents in Space Missions

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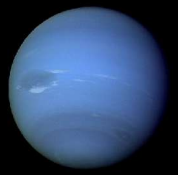
Every space mission is dangerous operation. New technology, such as autonomous control agents, increases the risk even more.

⇒ Mission managers are ***very*** reluctant...





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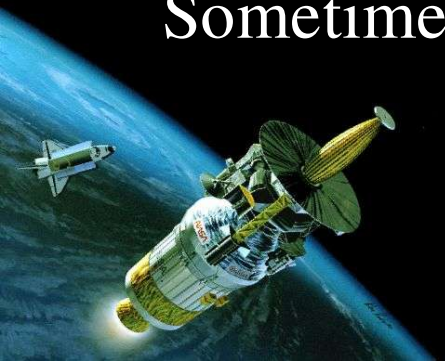
⇒ Lots of theoretical research, but very few actual implementations. Sometimes hard to tell if a proposed architecture is really good...

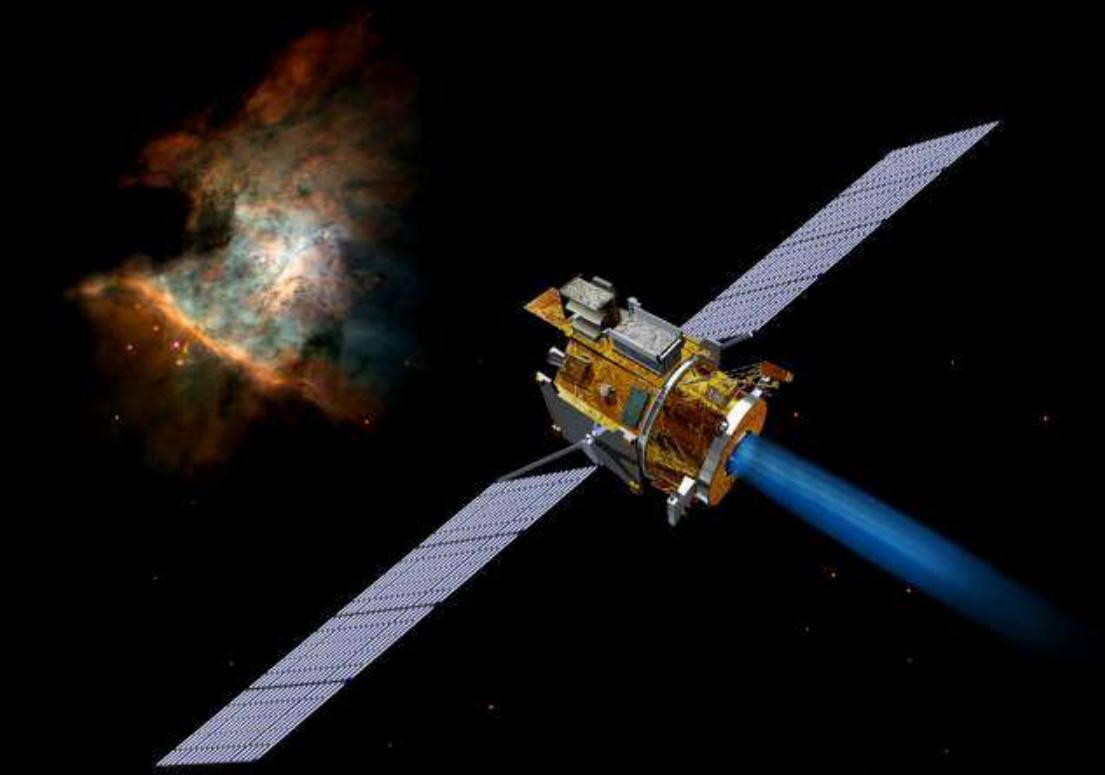







Autonomous Agents in Space Missions

Autonomous spacecraft control: Deep Space One



Launched: October 24, 1998
Retired: December 18, 2001

First part of NASA's *New Millennium Program*. Testbed for new technologies, e.g. autonomous control system.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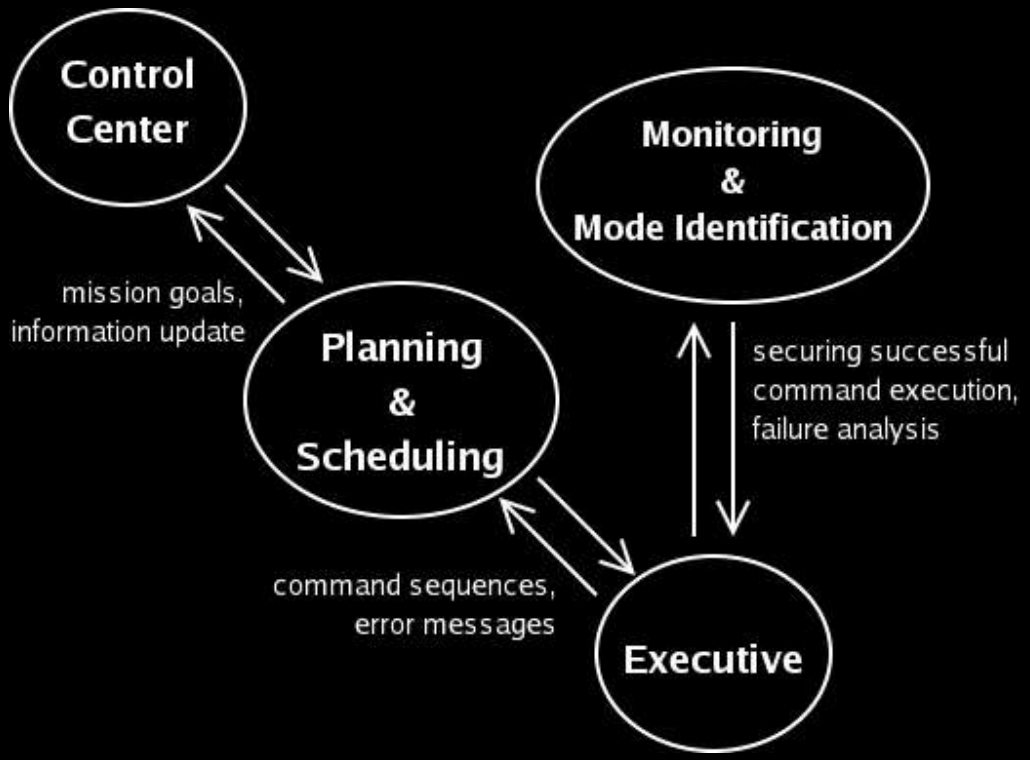

- *Mode Identification* can infer which component is defective if a command fails.
- *Executive* can refuse to execute a given command sequence.
- *Planner* can modify the set of goals, e.g. for navigation purposes.

Autonomous Agents in Space Missions

Autonomous vehicle control: Mars rover

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Autonomous vehicle control: Mars rover

Rover control so far:

- Ground control sends command sequence.
- Rover executes commands, sends “success” or “failure”.
- Ground control sends next command sequence.

Possible for Sojourner (1997, total distance: 100m) or current rover missions (up to 100m per day).

Would be good if a rover could travel several kilometers per day!





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- Rover gathers more data through its cameras and other sensors than it can send to Earth.
- Rover encounters an interesting site, sends pictures to Earth. When the data has been processed, ground control decides that the rover should conduct additional experiments. Drive back???





Autonomous Agents in Space Missions

Autonomous vehicle control: Mars rover

Solution: On-board analysis of the pictures gathered by the rover.

- Detect objects, determine feature values, classify.
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- Objects are given priorities that reflect their unusualness; pictures with high priority are sent to Earth first.
- If a highly unusual object is encountered, the rover interrupts its trip in order to conduct additional measurements on the object.
- If an extremely highly unusual object is encountered, the rover stops and waits for further commands from the control center.

Autonomous Agents in Space Missions

The Personal Satellite Assistant

From a 1998 shuttle mission report:

"One astronaut, Andy Thomas, will undertake several hundred research runs involving 26 different science projects in five disciplines. The projects are provided by 33 principal investigators [...]"

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The Personal Satellite Assistant

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The Personal Satellite Assistant

From the NASA PSA page:

"The PSA is an astronaut support device designed to move and operate independently in the microgravity environment of space-based vehicles. The PSA will assist astronauts who are living and working aboard the Space Shuttle, Space Station, and during future space exploration missions to the Moon and Mars."

Autonomous Agents in Space Missions

The Personal Satellite Assistant

Environmental Health Monitoring

PSAs are keeping track of gas levels, air pressure, temperature.

Communications

PSAs are equipped with microphones, speakers, camera, display.

Crew Worksite Support

PSAs can keep track of inventory or search for a special item that one of the astronauts needs for an experiment but cannot find.

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The Personal Satellite Assistant

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- When should an agent abandon a current task and help another agent?
- When should an agent risk running out of energy?
- When should an agent inform one of the human crew members about a discovery just made?





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Forecast: Autonomous systems will evolve, but very slowly. NASA knows this is a possibility to save hundreds of millions of dollars per mission.


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Thank you!