Universidad de Alcalá

Space missions based on AC

ISG
Intelligent Systems Group

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- **Real domains in P&S**
- Real domains in Intelligent Execution
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- Conclusions

Real domains: P&S

- Legacy planners:
  - NONLIN+ (Tate y Whiter, 1984): general planning architecture, precursor of current planners
  - SIPE (Wilkins 1988): independent domain planner and 1st in managing consumable and producible resources and managing conflicts. Used in air and military campaigns
  - DEVISER (Vere 1983): based on NONLIN, was used in Voyager to photograph Jupiter, Saturn and its satellites in 1979, 1980 and 1981

Real domains: P&S

- New approaches:
  - HSTS (Muscettola 1994): integrates P & S, applied to the problem of planning observations in the Hubble Space Telescope
  - O-PLAN2 (Tate et al., 1994): based on NONLIN and Blackboard techniques. Applications: rescue coordination, military operations, space missions
  - NMRA (Muscettola and Smith, 1997): New Millennium Remote Agent was the first time that an AI agent controls a spacecraft for 6 days: the Deep Space One (DS-1)

Real domains: P&S

- New approaches:
  - ASPEN (Rabideau *et al.* 1999): JPL-NASA P&S system
    - Earth Orbiting (EO-1): controllable by a small group
    - Citizen Explorer: small mission with teaching purposes
    - Antarctic Mapping Missions: Mars-01 Marie Curie rover
  - EUROPA (Frank, Jónsson and Morris 2000): MSL or Phoenix

Real domains: P&S

System	Mission	Year	Used	Techniques
DEVISER	Voyager	1977	On-ground	POP
PLANIT-II	Galileo Mars Pathfinder Spitzer Space Telescope	1995 1997 2003	On-ground On-ground On-ground	Used by AI experts who provide specific Scheduling algorithms
HSTS	DS-1	1998	On-board	HTN & SAT & Refinement CS
ASPEN	AMM-2	2000	On-ground	Repair CS
PROBA	Proba	2001	On-board	OR
ASPEN & CASPER	EO-1	2003	On-board	Repair CS
MPS	Smart-1	2003	On-ground	OR
EUROPA/ MAPGEN	MER	2003	On-ground	HSTS descendent
MEXAR-2	Mars Express	2005	On-ground	Refinement CS
EUROPA2/ ENSEMBLE	Phoenix MSL	2007 2009	On-ground On-ground	HSTS descendent

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Intelligent Execution

System	Mission	Year	Technology
SCL	Clementine FUSE EO-1	1994 1999 2001	Time and event-based commanding Rule-based firing of procedures Integrated with on-board science planning
MPF/MER/MSL Family	Mars Pathfinder Lander Mars Exploration Rovers Mars Science Lab Rover	1996 2003 2009	Similar to 3T architectures
Remote Agent Exec	DS-1	1998	Integrated with HSTS & Livingstone
VML	Mars Odyssey Spitzer Space Telescope Phoenix Mars Lander otros	2001 2003 2007	Sequencing procedural language Has flown on numerous NASA spacecraft

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Fault Protection

System	Mission	Year	Technology
Livingstone/ Livingstone2	DS-1 EO-1 X-34 vehicule X-37 vehicule	1998 2001 2002 2002	Uses a model to find the most likely combination of failures that predicts: - Observed value of the sensors - Simulation of electronics - Simulation of the propulsion system
Spacecraft Command Language	Clementine	1994	Rule Based Fault protection and recovery system in operations
Cassini AACS	Cassini	1996	Rule Based Fault protection and recovery system in operations
FDIR system	MER	2003	It incorporates at subsystem level fault protection in subsystem behaviors (i.e. arm) and a set of system-level fault responses for when disabling a behavior for a particular subsystem is not sufficient (i.e. battery)

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Conclusions

- Brief overview of techniques applied to Autonomy for space
- Among the techniques: AI Planning and Scheduling, Intelligent Execution and Fault Protection

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