AI Planning in Context

AI Planning in the Context of Domain Modelling, Task Assignment and Execution

Overview

- Context of Practical Systems
- Context of Task Assignment & Execution
- Context of Multiple Agents
- Context of Plan Representation & Use
- Example Practical Planners
- Planning++

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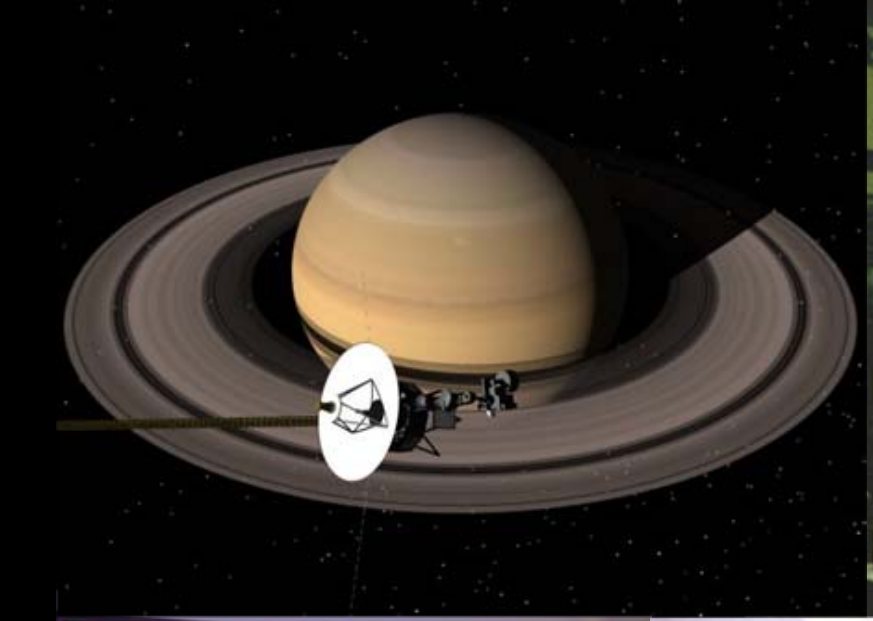












LONDON

Practical AI Planners

Planner	*Reference*	*Applications*
STRIPS	Fikes & Nilsson 1971	Mobile Robot Control, etc.
HACKER	Sussman 1973	Simple Program Generation
NOAH	Sacerdoti 1977	Mechanical Engineers Apprentice Supervision
NONLIN	Tate 1977	Electricity Turbine Overhaul, etc.
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SIPE-2	Wilkins 1988	Oil Spill Response, Military Planning, etc.
O-Plan	Currie & Tate 1991	Search and Rescue, Spacecraft Operations, etc.
SHOP/SHOP-2	Nau et al. 1999	Evacuation Planning, Forest Fires, Bridge Baron, etc.
I-X/I-Plan	Tate et al. 2000	Emergency Response, etc.

Course Reading

- **Review of AI Planners to 1990**
- Hendler, J.A., Tate, A. and Drummond, M. (1990) “AI Planning: Systems and Techniques”, AI Magazine Vol. 11, No. 2, pp.61-77, Summer 1990, AAAI Press.
- http://aaaipress.org/ojs/index.php/aimagazine/article/download/833/751

- **Knowledge-Based Planners**
- Wilkins, D. E. and desJardins, M. (2001) “A Call for Knowledge-based Planning”, AI Magazine, Vol. 22, No. 1, pp. 99-115, Spring 2001, AAAI Press.
- http://www.aaai.org/ojs/index.php/aimagazine/article/view/1547/ or http://www.ai.sri.com/pub_list/808

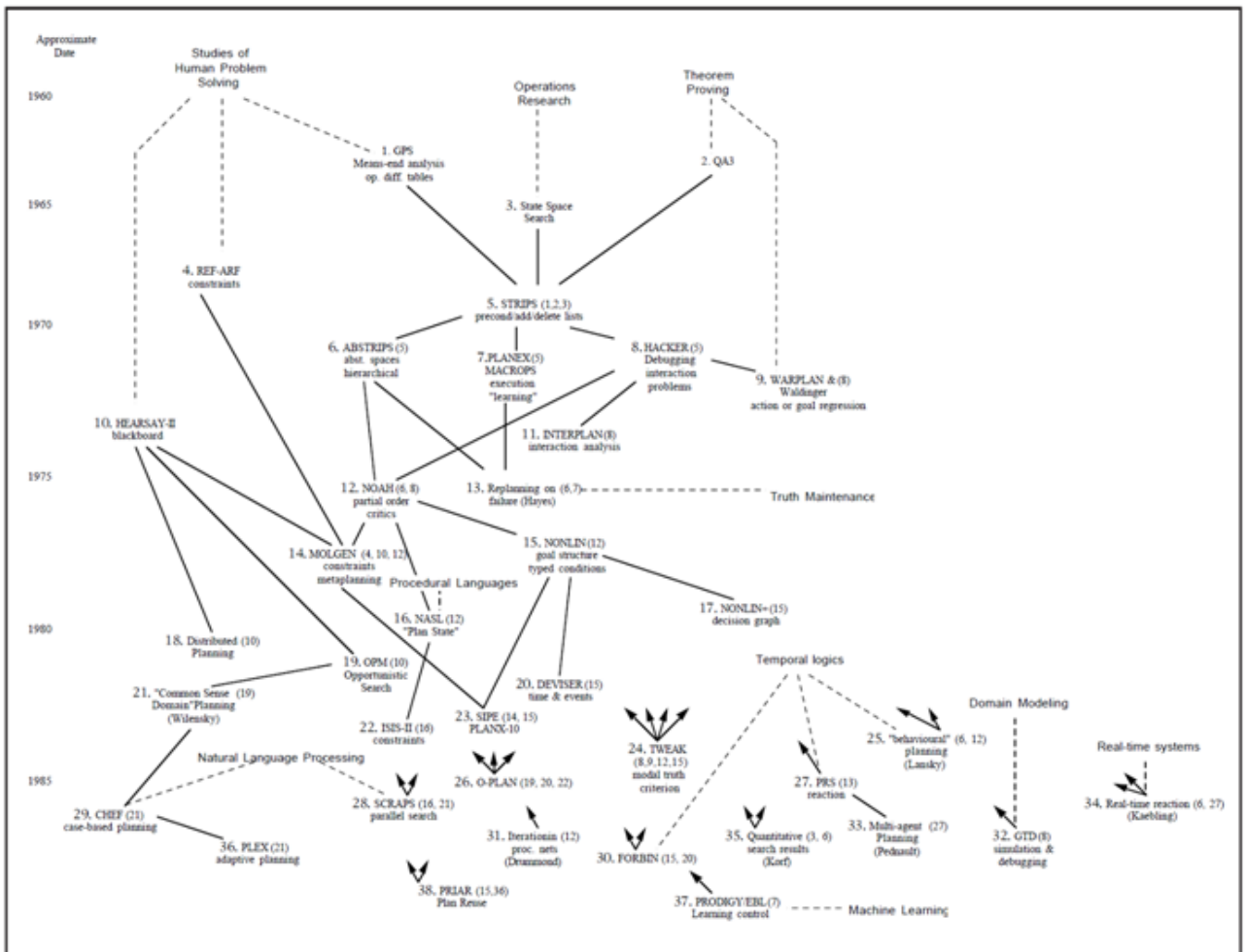
- **O-Plan Paper**
- Tate, A. and Dalton, J. (2003) “O-Plan: a Common Lisp Planning Web Service”, invited paper, in Proceedings of the International Lisp Conference 2003, October 12-25, 2003, New York, NY, USA, October 12-15, 2003. http://www.aiai.ed.ac.uk/project/ix/documents/2003/2003-luc-tate-oplan-web.pdf

- **Optimum-AIV Paper**
- Tate, A. (1996) “Responsive Planning and Scheduling Using AI Planning Techniques – Optimum-AIV”, in “Trends & Controversies – AI Planning Systems in the Real World”, IEEE Expert: Intelligent Systems & their Applications, Vol. 11 No. 6, pp. 4-12, December 1996.
- http://www.aiai.ed.ac.uk/project/oplan/documents/1996/96-ieee-is-trends-and-controversies-orig.pdf

- **SHOP/SHOP2 Applications Paper**
- Nau, D., Au, T-C., Ilghami, O., Kuter, U., Wu, D.,Yaman, F., Muñoz-Avila, H., and Murdock, J.W. (2005) Applications of SHOP and SHOP2, IEEE Intelligent Systems, March-April 2005, Vol. 20, No. 2, pp.34-41, Computer Society.
- http://www.cs.utexas.edu/~chiu/papers/Nau05shop2.pdf

- **Other Practical Planners**
- Ghallab, M., Nau, D. and Traverso, P. (2004) “Automated Planning – Theory and Practice”, Chapters 19, 22 and 23, Elsevier/Morgan Kaufmann.

Origins of some well known AI Planners



Hendler, Tate and Drummond,
AI Magazine, 1990

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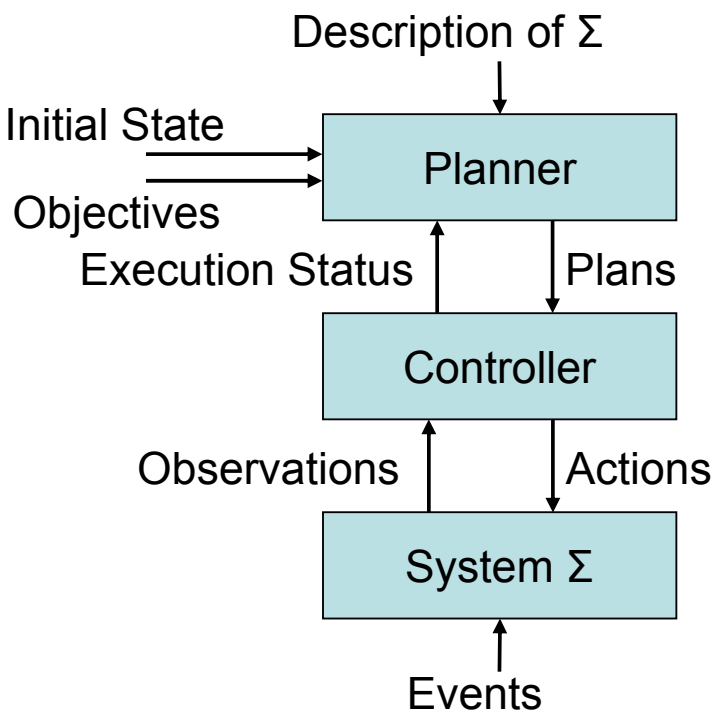
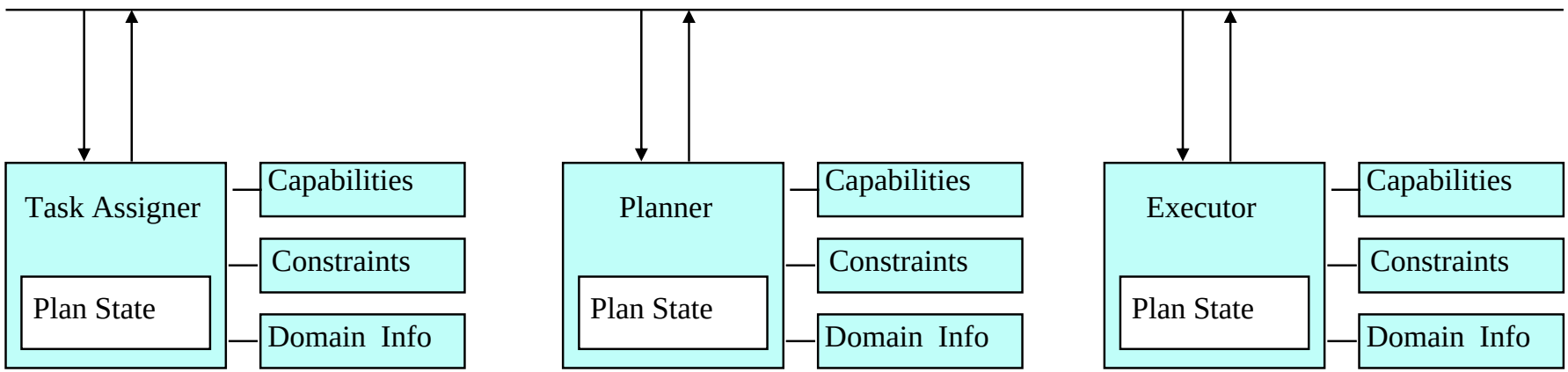
Dynamic Planning



- problem: real world differs from model described by Σ
- more realistic model: interleaved planning and execution
  - plan supervision
  - plan revision
  - re-planning
- dynamic planning: closed loop between planner and controller
  - execution status

O-Plan 3 Levels of Agents: Task Assignment, Planning & Execution



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Multiple-Agent Platforms behind some Practical AI Planners

- Multiple Planning Agents (MPA) platform is the basis for the SRI International SIPE-2 Planner

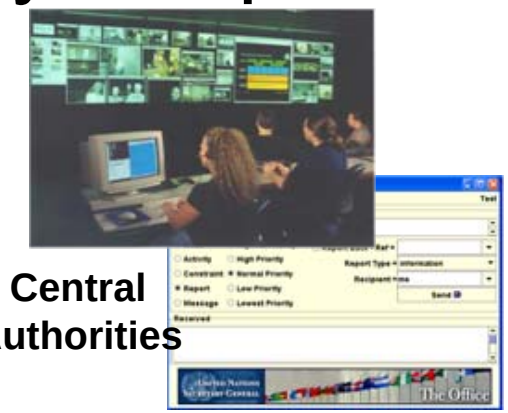
- The Open Planning Architecture is the basis for O-Plan and is designed to handle multiple planner roles and levels, such as task assigner, planner, planning specialists, plan execution

- I-X is intended to support multiple types of command, sense-making, analysis, planning (I-Plan), decision making, execution and communications agents even in mixed agent frameworks.

Multiple Agents in the Context of Communications for Emergency Response

Command and Control

Collaboration and Communication

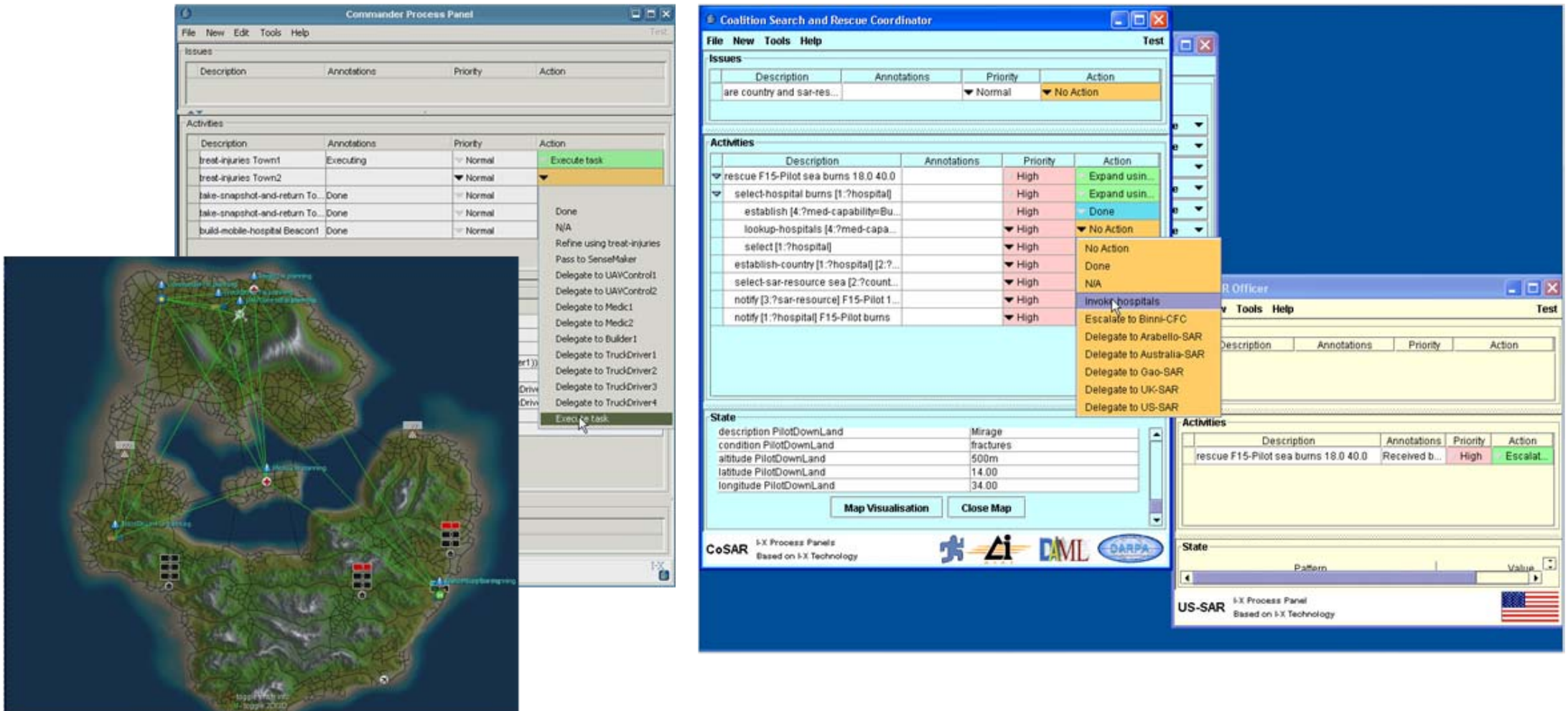


Central Authorities

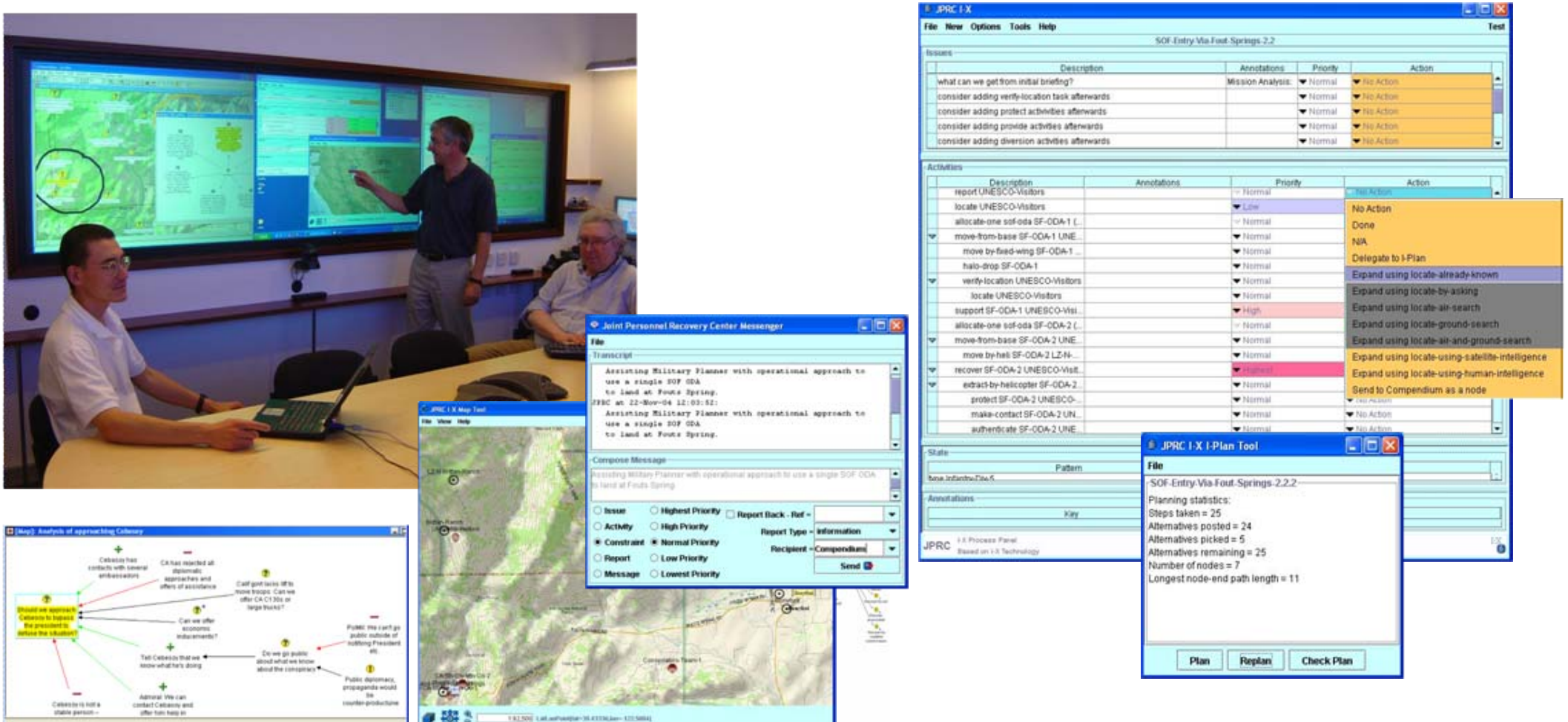
Emergency Responders

Isolated Personnel

Example I-X Multiagent Applications



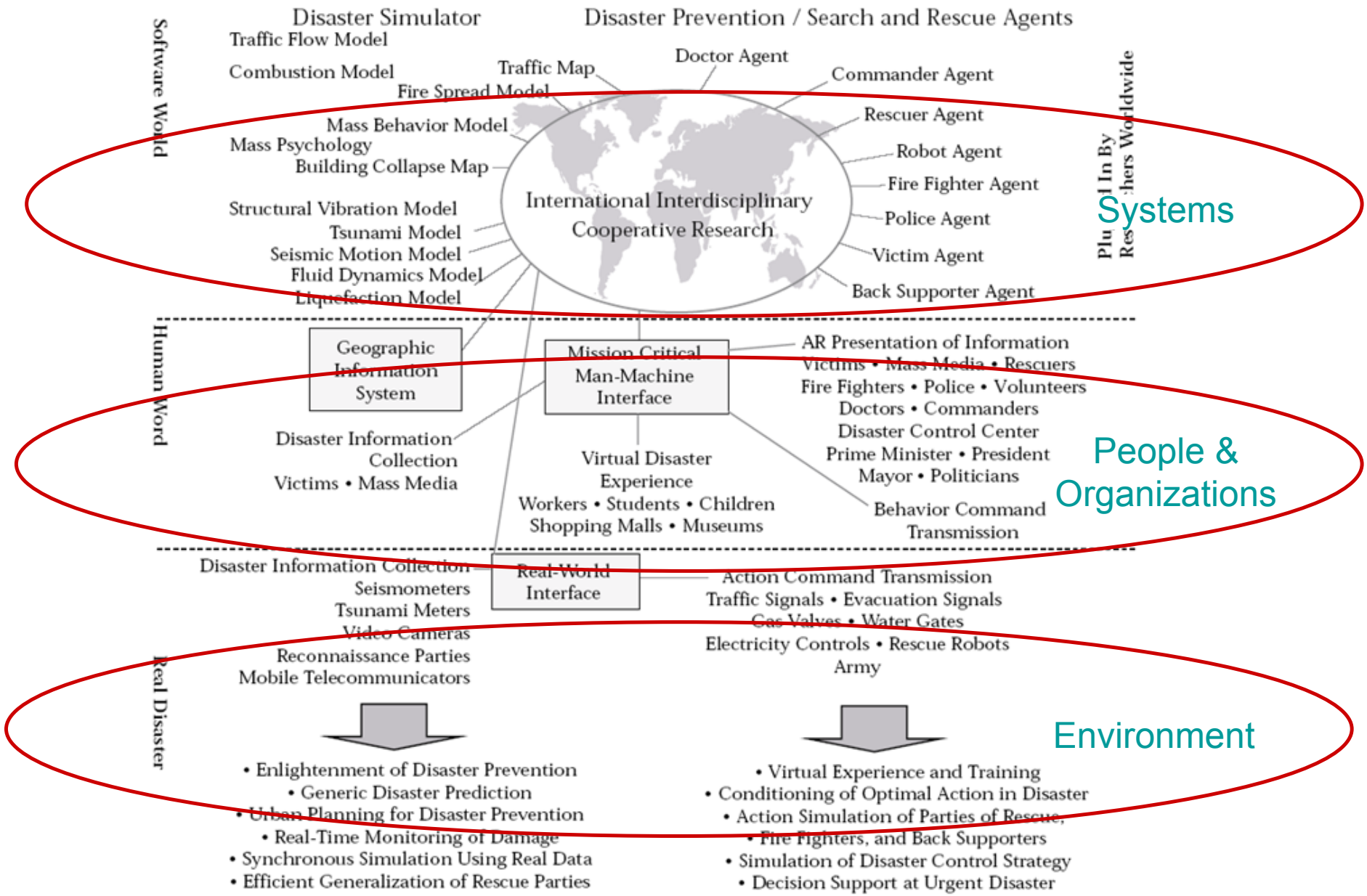
Example I-X Multiagent Applications



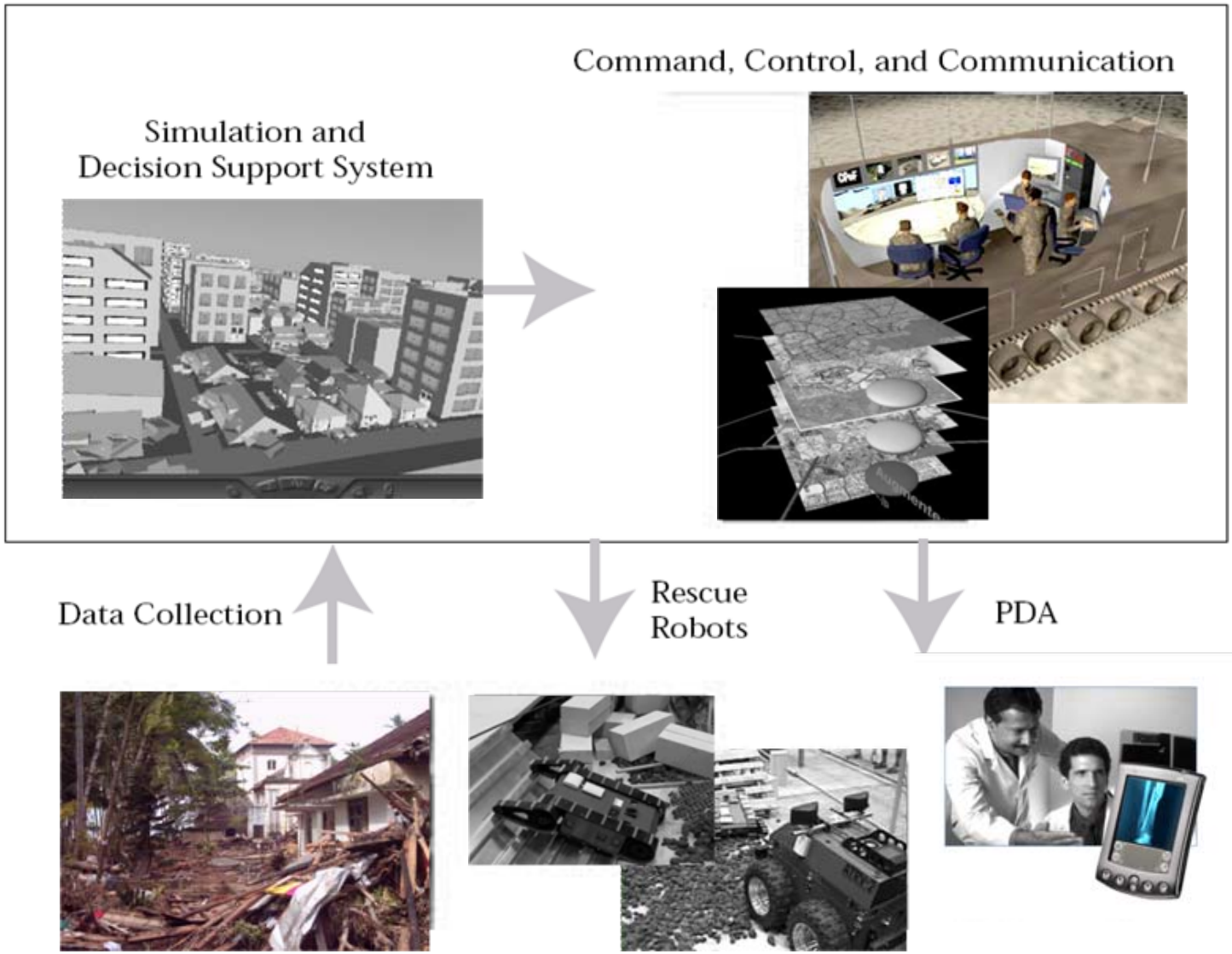
Example I-X Multiagent Applications

You can view video demonstrations of a couple of sample applications of I-X in the context of multiagent systems

- CoSAR-TS: Coalition Search & Rescue Task Support
- I-Globe: Planning and Execution in a Dynamic multiagent environment



Adapted from H. Kitano and S. Tadokoro, RoboCup Rescue A Grand Challenge for Multiagent and Intelligent Systems, AI Magazine, Spring, 2001. (aaai.org)



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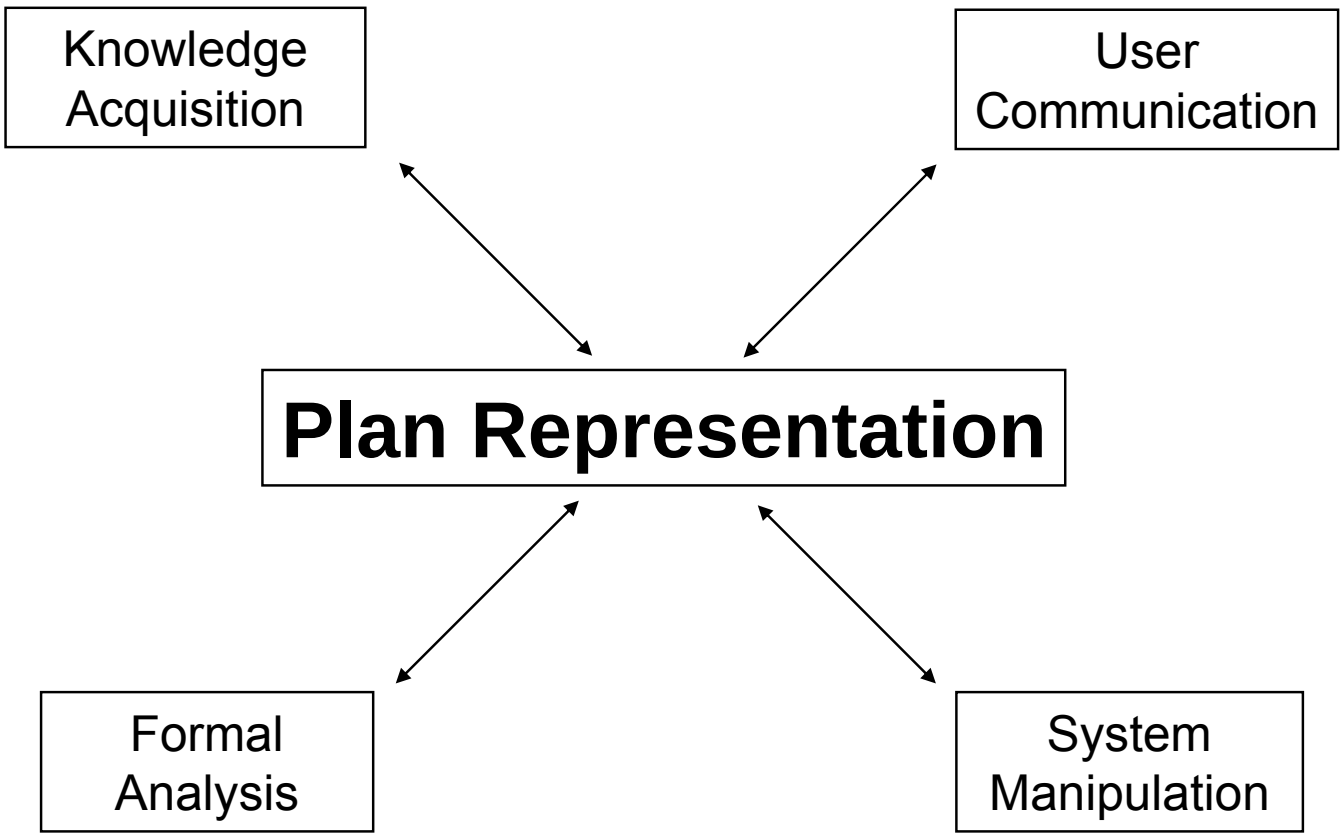
Plan Representation & Use

- Plan representation itself an important area.
- Plans are used in many areas beyond activity planning … such as situation understanding and summarisation, natural language interpretation and generation, etc.
- Plans provide an ontological and formal representation core for a wide range of practical applications and uses.

Uses of a Plan Representation



Plan Representation & Use

- AI planning work has influenced standards related to process and plan representations used by many industries and fields. E.g.,

- MIT Process Handbook Process Interchange Format (PIF)
- NIST Process Specification Language (PSL)
- DARPA Shared Planning & Activity Representation (SPAR)
- ISO 18629 Industrial Automation Systems and Integration - Process Specification Language

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Nonlin (1974-1977)

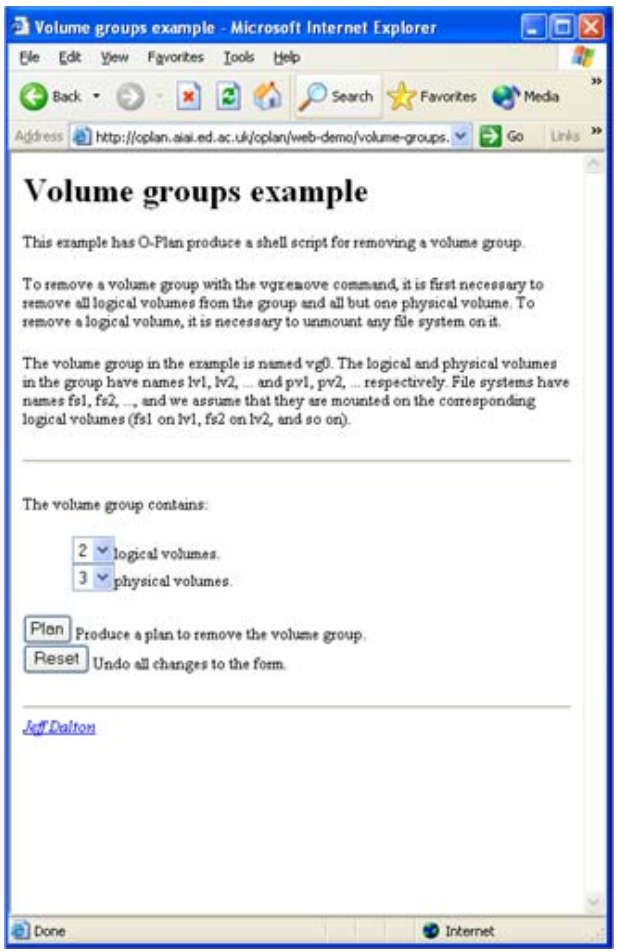
- Hierarchical Task Network Planning
- Partial Order Planner
- Plan Space Planner
- Goal structure-based plan development – only considers alternative “approaches” based on plan rationale
- QA/“Modal Truth Criterion” condition achievement
- Condition “types” to limit search
- Allows for multiple “contributors” to achieve facts for plan robustness
- “Compute Conditions” for links to external data bases and systems (attached procedures)
- Operations Research algorithms for time and resource constraints

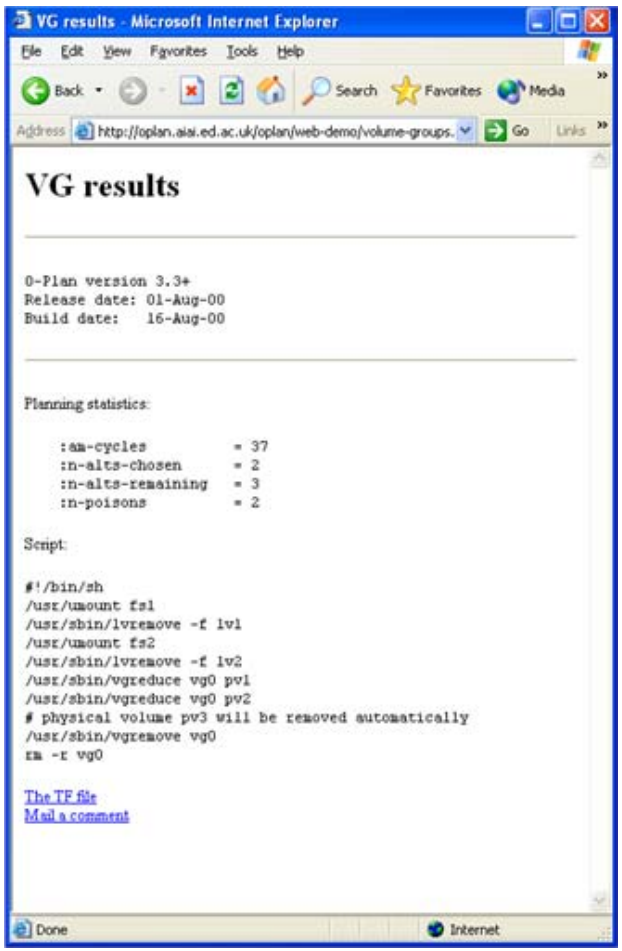
- Nonlin core is a basis for text book descriptions of HTN Planning

O-Plan (1983-1999) Features

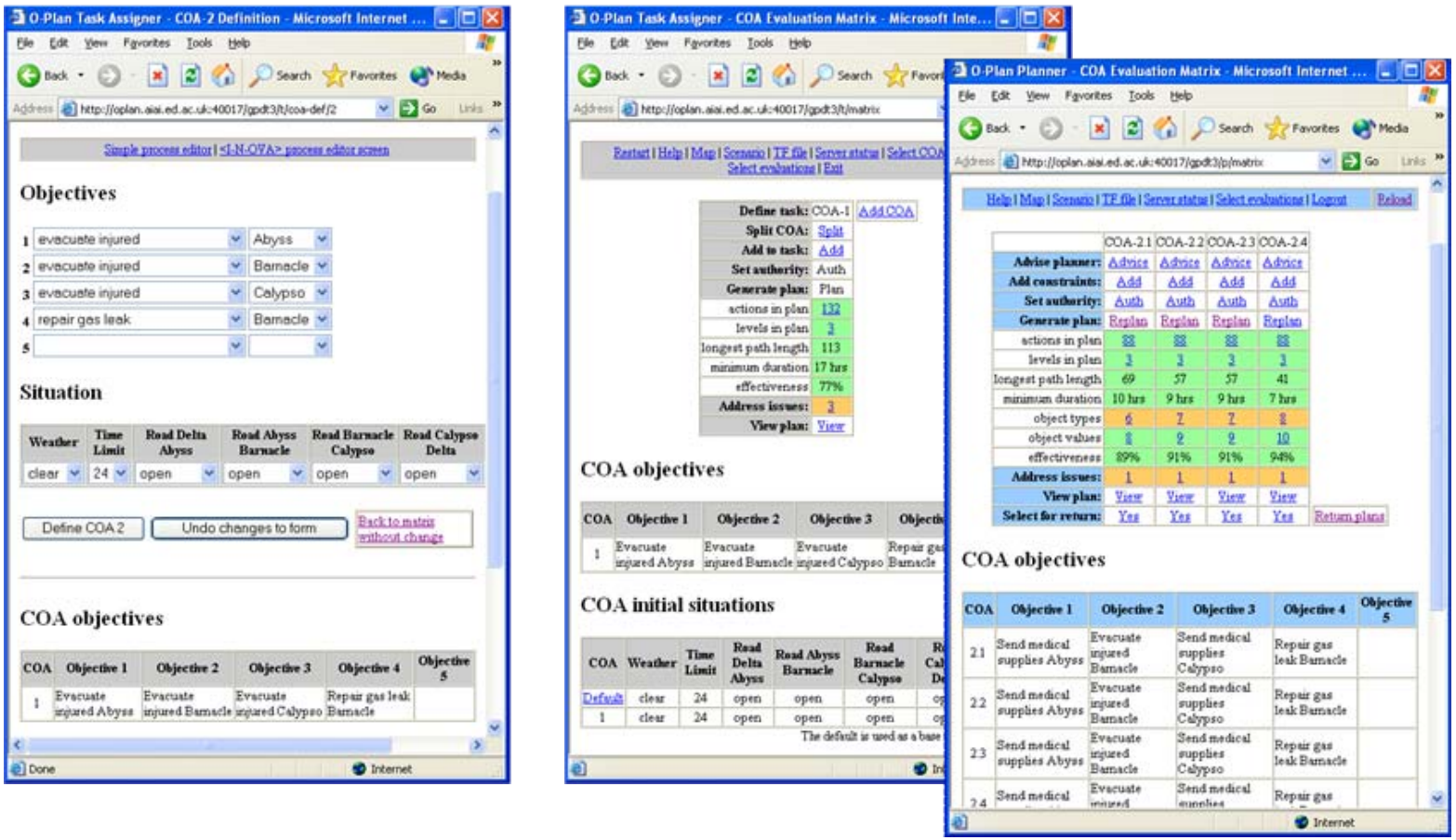
- Domain knowledge elicitation and modelling tools
- Rich plan representation and use
- Hierarchical Task Network Planning
- Detailed constraint management
- Goal structure-based plan monitoring
- Dynamic issue handling
- Plan repair in low and high tempo situations
- Interfaces for users with different roles
- Management of planning and execution workflow

O-Plan Unix Sys Admin Aid





O-Plan MOUT Task Description, Planning and Workflow Aids



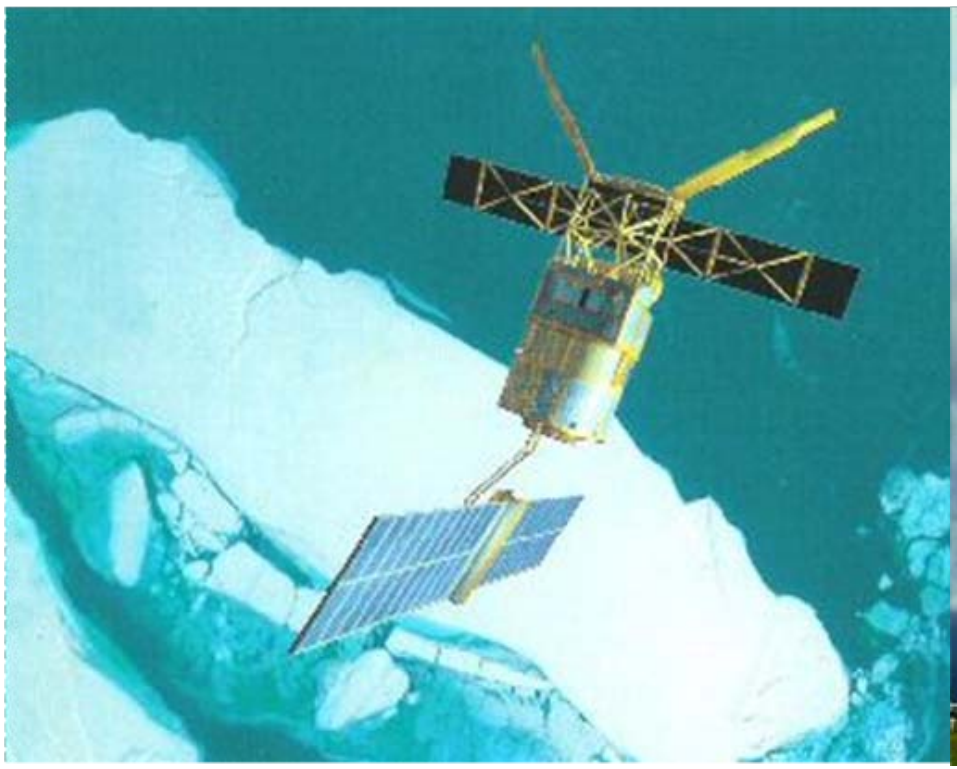
Try out O-Plan as an Example Planner

- Web accessible HTN AI Planner: See http://www.aiai.ed.ac.uk/project/oplan/web-demo/

- Try the Unix Systems administration script generator. Consider other applications for which this generation technique may be suitable.
- Try a few block stacking examples, and ponder why the “Sussman Anomaly” task was not able to be solved by early AI planners.
- Try the “three pigs” resource constrained house building examples. Look at the domain and task description file. Can you explain why some tasks need little or no search and others more? Why does one task have no solution in the given domain?

- :am-cycles = Agenda management cycles (problem solving cycles)
- :n-alts-chosen = Number of alternatives chosen. 0 means the planner had no search at all
- :n-alts-remaining = Number of alternatives remaining. Indicating choices possible.
- :n-poisons = Number of dead ends reached (diagnostic - should be same as :n-alts-chosen)

Optimum-AIV



Optimum-AIV (1992-4) Features

- Based on O-Plan design
- Rich plan representation and use
- Hierarchical Task Network (HTN) Planning
- Detailed constraint management
- Plan and User rationale recorded
- Dynamic issue handling
- Plan repair using test failure recovery plans
- Integration with ESA’s Artemis Project Management System

Typical Features of Practical AI Planners

- Hierarchical Task Network (HTN) Planning
- Partial Order Planning (POP)
- Rich domain model
- Detailed constraint management, simulations and analyses
- Integration with other systems (user interfaces, databases, spreadsheets, project management systems, etc).

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Planning Research Areas & Techniques

– Domain Modelling	HTN, SIPE-2
– Domain Description	PDDL, NIST PSL
– Domain Analysis	TIMS
– Search Methods	Heuristics, A*
– Graph Planning Algtms	GraphPlan
– Partial-Order Planning	Nonlin, UCPOP
– Hierarchical Planning	NOAH, Nonlin, O-Plan
– Refinement Planning	Kambhampati
– Opportunistic Search	OPM
– Constraint Satisfaction	CSP, OR, TMMS
– Optimisation Method	NN, GA, Ant Colony Opt
– Issue/Flaw Handling	O-Plan
– Plan Analysis	NOAH, Critics
– Plan Simulation	QinetiQ
– Plan Qualitative Modelling	Excalibur
– Plan Repair	O-Plan
– Re-planning	O-Plan
– Plan Monitoring	O-Plan, IPEM
– Plan Generalisation	Macrops, EBL
– Case-Based Planning	CHEF, PRODIGY
– Plan Learning	SOAR, PRODIGY
– User Interfaces	SIPE-2, O-Plan
– Plan Advice	SRI/Myers
– Mixed-Initiative Plans	TRIPS/TRAINS
– Planning Web Services	O-Plan, SHOP2
– Plan Sharing & Comms	I-X, <I-N-C-A>
– NL Generation	…
– Dialogue Management	…

Deals with whole life cycle of plans

Planning Research Areas & Techniques

- Domain Modelling — HTN, SIPE-2
- Domain Description — PDDL, NIST PSL
- Domain Analysis — TIMS

- Search Methods — Heuristics, A*
- Graph Planning Algtms — GraphPlan
- Partial-Order Planning — Nonlin, UCPOP
- Hierarchical Planning — NOAH, Nonlin, O-Plan
- Refinement Planning — Kambhampati
- Opportunistic Search — OPM
- Constraint Satisfaction — CSP, OR, Tabu
- Optimisation Method — NN, GA, Ant Colony Opt
- Issue/Flaw Handling — O-Plan

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- Planning Web Services — O-Plan, SHOP2

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- NL Generation — …
- Dialogue Management — …

Deals with whole life cycle of plans

Problem is to make sense of all these techniques

A More Collaborative Planning Framework

- Human relatable and presentable objectives, issues, sense-making, advice, multiple options, argumentation, discussions and outline plans for higher levels
- Detailed planners, search engines, constraint solvers, analyzers and simulators act in this framework in an understandable way to provide feasibility checks, detailed constraints and guidance
- Sharing of processes and information about process products between humans and systems
- Current status, context and environment sensitivity
- Links between informal/unstructured planning, more structured planning and methods for optimisation

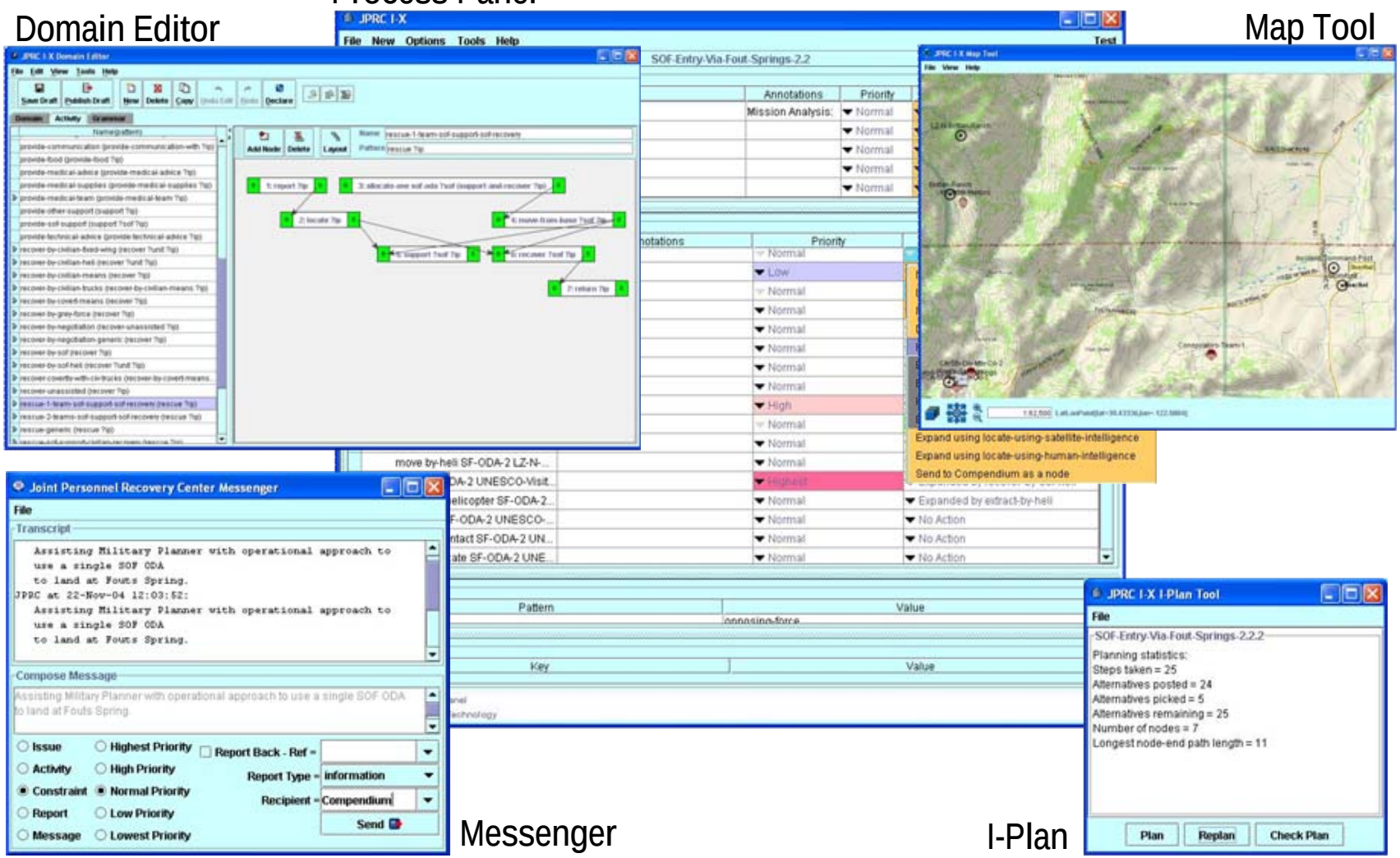
I-X/I-Plan (2000-)

- Shared, intelligible, easily communicated and extendible conceptual model for objectives, processes, standard operating procedures and plans:
  - I Issues
  - N Nodes/Activities
  - C Constraints
  - A Annotations
- Communication of dynamic status and presence for agents, and their collaborative processes and process products
- Context sensitive presentation of options for action
- Intelligent activity planning, execution, monitoring, re-planning and plan repair via I-Plan and I-P^2 (I-X Process Panels)

I-X aim is a Planning, Workflow and Task Messaging “Catch All”

- Can take ANY requirement to:
  - Handle an issue
  - Perform an activity
  - Respect a constraint
  - Note an annotation
- Deals with these via:
  - Manual activity
  - Internal capabilities
  - External capabilities
  - Reroute or delegate to other panels or agents
  - Plan and execute a composite of these capabilities (I-Plan)
- Receives reports and interprets them to:
  - Understand current status of issues, activities and constraints
  - Understand current world state, especially status of process products
  - Help user control the situation
- Copes with partial knowledge of processes and organisations

I-X for Emergency Response



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