Outcome of the 7th Int. Workshop on Planning & Scheduling for Space

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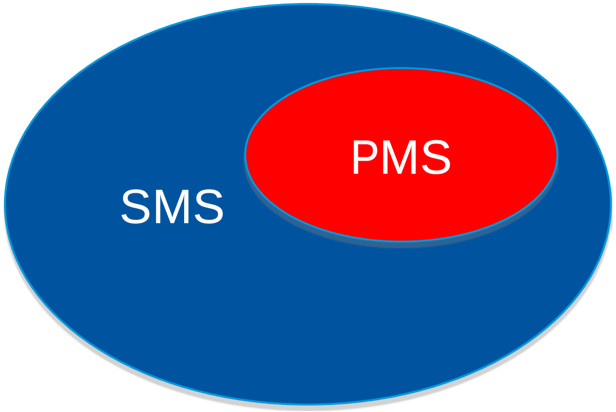
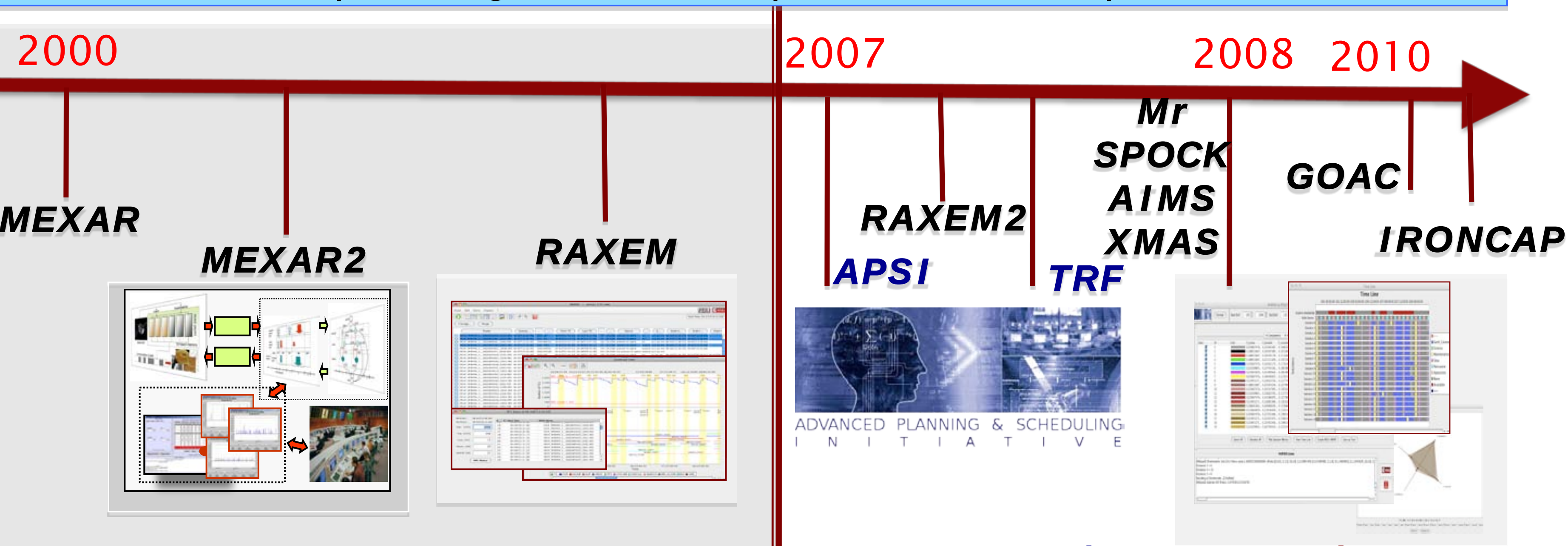


IWPSS11 Papers temporarily available at http://bit.ly/iwpss

Where do we stand in ESA with constraint satisfaction P&S applications

Timeline of planning tools development for ESA space contexts



"**Product Driven**" **Design and Development**

"**Process Driven**" **Approach to Application Design and Development**

IWPSS Topics

1. **Recent advances in planning and scheduling and plan execution**:
   - These include advances in domain representation, algorithmic methods, treatment of uncertainty, verification, and embedded architectures for planning, scheduling, and plan execution applicable to space missions, including robotic operations.

2. **Operational challenges of space applications:**
   - These are challenging problems currently solved by humans, which typically involve optimizing science returns in the face of mission cost and resource limitations, responding to unanticipated events, and operating in a partially understood environment.

IWPSS Topics

3. Issues in deployment:

- Gaining mission acceptance of a planning and scheduling technology involves balancing the promise of a new technology with the need for safety, reliability, and usability. This includes the representation's understandability, controllability of the underlying algorithms, interfaces to other tools, as well as the user interface.

4. Past and current deployments:

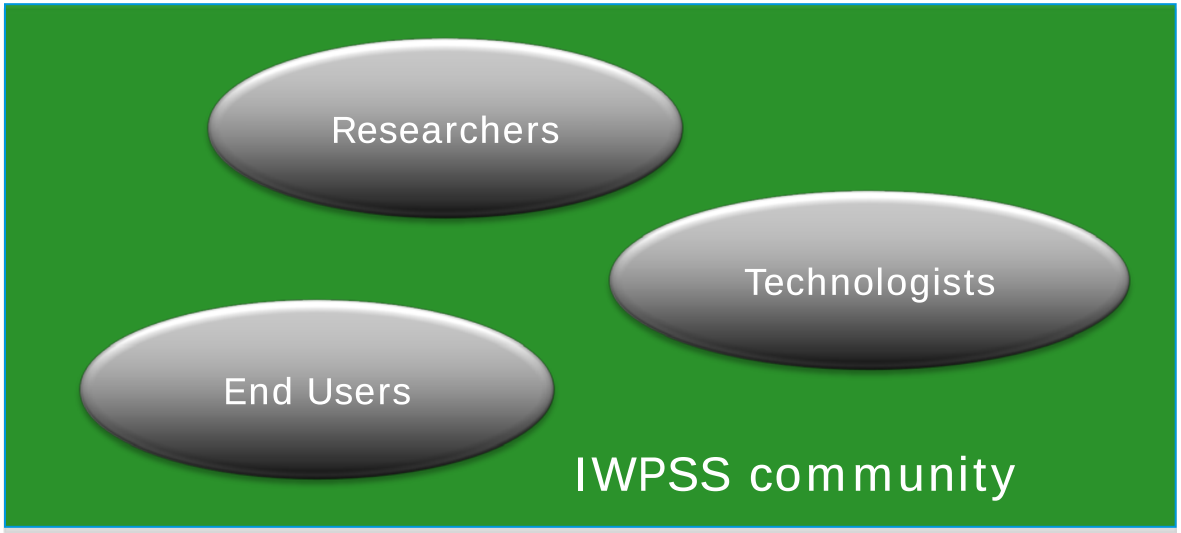
- There have been a number of past infusions of planning and scheduling technologies into missions, and each resulted in lessons learned when overcoming deployment obstacles as well as system use during the mission.

IWPSS Objectives

1. The aim of this workshop is to **discuss** the topics and other related issues in the context of space missions and applications :

    a. **deployed applications** of planning and scheduling technology
    b. **requirements** for planning and scheduling in future missions
    c. **Innovative** planning and scheduling **technology**:
        - planning and scheduling with time constraints;
        - planning and scheduling with uncertainty and resources;
        - mixed-initiative problem solving;
        - robustness and fault tolerant schedules;
        - robust optimization;
        - task execution.

IWPSS Community & Format



1. To encourage **interaction** among the groups of the **IWPSS community**,
2. Make use of the **commentary format**
   a. Paper presentation
   b. Commentary presentation
   c. Discussion
3. Make use of **panel session** with dynamic interaction with audience

IWPSS Statistics

- 60 participants from Europe, United States, China

- Representations from
  - Academia
  - Industry
  - Agencies (NASA, ESA, DLR, CNES, ASI)

- Content
  - 2 **keynote presentations**
  - 13 Papers with **commentary**
  - 8 Papers
  - 5 Posters
  - Panel session on **"Prospects for a Standard Timeline Representation and API for Space Mission Operations"**

Hot Topics from Presentations

1. **Recent advances in planning and scheduling and plan execution**:
    - Schedulling Results from the THEMIS Observation Schedilung Tool (to assist Mars Odyssey instrument onboard acquisition of both target and general acquisitions with multiple algorithms)
    - A Status Report on the Development of the JWST Long Range Planning System
      (Use of multi-objectives algorithms and representation of the Pareto surface
    - Innovative Rover Operations Concepts – Autonomous Planning (definition of concepts, interactions and algorithms for planning and controlling the activities of an interplanetary rover with high degree of autonomy)
    - Scheduling Onboard Processing for the Proposed HyspIRI Mission (X-Band direct broadcasting, automated product generation selection with onboard data preprocessing to detect events)

2. Operational challenges of space applications:

- On-board decision making on data downloads
  (science data volume generation uncertain)
- Automated Scheduling for TerraSAR-X/TanDEM-X
  (merged missions with inter-satellite constraints)
- Automated Scheduling for NASA's Deep Space Network
  DSN Scheduling Engine
  (use of systematic search and repair based algorithms, used for different phases and purposes)

3. Issues in deployment:

- Herschel Mission Planning Software
  (Inspector and mid/longterm Scheduler (HILTS) and the short-term scientific Mission Planning system (SMSP)
- The Challenge of Configuring Model-Based Space Mission Plannners
  (constraints correctly represented in the planners' model – updating issue)

4. Past and current deployments:

- Evaluation of the Mars Express Planning & Scheduling Approach over the Lifetime of the Mission (reimplementation of existing tool’s functionality into “corporate” Mission Planning System for future reuse; automation of planning sub-tasks with overall supervisory and go-nogo role of human in the loop)
- Massaging the Plan with the Language for Mission Planning (Using the Language for Mission Planning (MLP) for supporting VEX mission planning)

Panel Discussion

Prospects for a Standard Timeline Representation and API for Space Mission Operations

1. Common Timeline Functions
   a. Representation
   b. Constraints
   c. Dependencies
   d. Conflict detection
   e. Activity placing (incl. Conflict resolution)
   f. What-if analysis
   g. Visualization

Panel Discussion

What can we standardize ?

1. Core functionality is there, acrosss organizations
2. Timeline representation & reasoning :
   unified functionality is difficult and limiting
3. Standard can over-constrain further technology evolution
4. Standard for Planning services definition OK (see CCSDS)
5. Start making use of (common) APIs
6. It is an engineering problem, not a research problem
7. Space mission operations is more scheduling than planning
8. Semantic and ontology for timeline is feasible

Panel Discussion

What is boiling in the pot ?

1. Increased focus on onboard implementations
2. Knowledge engineering
3. integration between P&S and V&V
4. Combining the very different modelling frameworks of P&S and combinatorial optimization
5. Multi-objective optimization and Pareto surface representation

Panel Discussion

What is requested ?

1. More investment in timeline representation
   (if one day we want to introduce a standard)
2. More investment on verification and validation of AI algorithms
3. Operator interaction is very important (standard references and guidelines at operator level) being the driver for the kind of service to be provided
4. More integration between science and platform P&S
5. Common representation and APIs for interfaces with human and with onboard autonomous system (rover, satellite)
6. Increase level of awareness and sharing between agencies on the AI P&S experiences and issues
7. Start working on inter-agency "joint" projects

Summary

1. The IWPSS community is vibrant and expanding
   a. New interest of China and non aerospace companies and institutions
2. Trend to focus on on-board implementation, after on-ground operational validation and exploitation
3. AI P&S is key enabler for on-board autonomy
   a. Re-scheduling for opportunistic science
   b. Re-sceduling due to anomalies or contingencies
   c. Increased level of quality science return
4. Standardization is still premature, however standards P&S services definitions, semantics and ontologies is viable now

Researchers

Technologists

End Users