An Architecture For Space Weather Services

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CA³ : Soft-computing and autonomous agents group @ UNINOVA, Portugal

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Space Weather Workshop

esa

UNINOVA

Instituto de Desenvolvimento de Novas Tecnologias

Agenda

- Rationale
  - *The background behind the presentation and the identified opportunities for Space Weather Services*
- An Architecture for Space Weather Services
  - *A description of the architecture and its services provided*
- Case studies
  - *Projects inside ESA that have already used the concepts shown*
- Conclusions & Future Work

Agenda

- Rationale
  - Background @ ESA
  - Issues and Opportunities in Space Weather
- An Architecture for Space Weather Services
- Case studies
- Conclusions & Future Work

Presentation of CA^3 group

- CA^3 stands for Soft-Computing and Autonomous Agents
- It is a research group integrated in Uninova
  - a non-profit University-Enterprise Research Institute
  - located in the New University of Lisbon campus

CA^3 group develops research mostly in the area of soft-computing

- Research areas
  - **Soft-Computing**
    - Fuzzy Logic
    - Decision Support Systems
    - Machine Learning
    - Data Mining
    - Optimisation Problems
    - Evolutionary Computation
  - Multi-Agent Systems (MAS)

On-going projects @ ESA

- The group is actively involved in projects for ESA (ESOC, ESTEC and ESRIN)
- In partnership with Spanish company GTD is developing R&D projects in:
  - Spacecraft Components Optimisation and Health Monitoring & Diagnostic
  - Decision Support systems for aerospace operations
- In partnership with Spanish companies Starlab and GTD:
  - Knowledge-Enabled Services for Earth Observation

Identified issues and opportunities in Space Weather

- Given our experience, this talk is clearly set on
  - **Satellite operators (in our case ESOC)**
- Creating innovative solutions for operations problems
- Has made us realize some issues and opportunities for Space Weather Services in this context

One of the best examples comes straight out of one of ESTEC's sponsored studies

Table A2.2. Assessment of current practice.

Problem	Current practice	Assessment
In-orbit anomalies resulting in phantom commands, mode switching, **corrupt memory,** parts failure.	Anomalies are recorded. Operators try to identify cause, but this is often very difficult. Any identified cause is fed back to designers to improve future design. Some warnings and nowcasts are monitored so that staff can be on alert.	In general operators do not have expertise in space physics and enough data on the plasma environment at the spacecraft at the time of anomaly to identify the cause as space weather reliably. Some operators assign cause to space weather if all other causes can be eliminated. Feedback into design is very important but takes years. Requires data on SW events to identify any SW cause of anomalies.
Reduced satellite lifetime through	Operators switch off some	

- Horne, Richard, *Space Weather Parameters Required by the Users Synthesis of User Requirements - WP1300 and WP1400*, BAS, Alcatel Study, page 34

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- **Low usage in operational contexts due to lack of technical knowledge of the subject matter of SW**
- **Atribution of anomalies to Space Weather is hard**
- **Low cycle of feedback from operations data to designer/manufacturer**

Another view on the problem from our side

- No integration of Space Weather data & info with the rest of the mission exists
- Space Weather considerations are not necessarily included in the standard processes to operate the spacecraft
- No clear, simple, reliable and easy to use Space Weather data provider exists

Agenda

- Rationale
- An Architecture for Space Weather Services
  - Services provided
  - The architectural view
  - Enabling technologies
- Case studies
- Conclusions & Future Work

Space Weather Services proposed include:

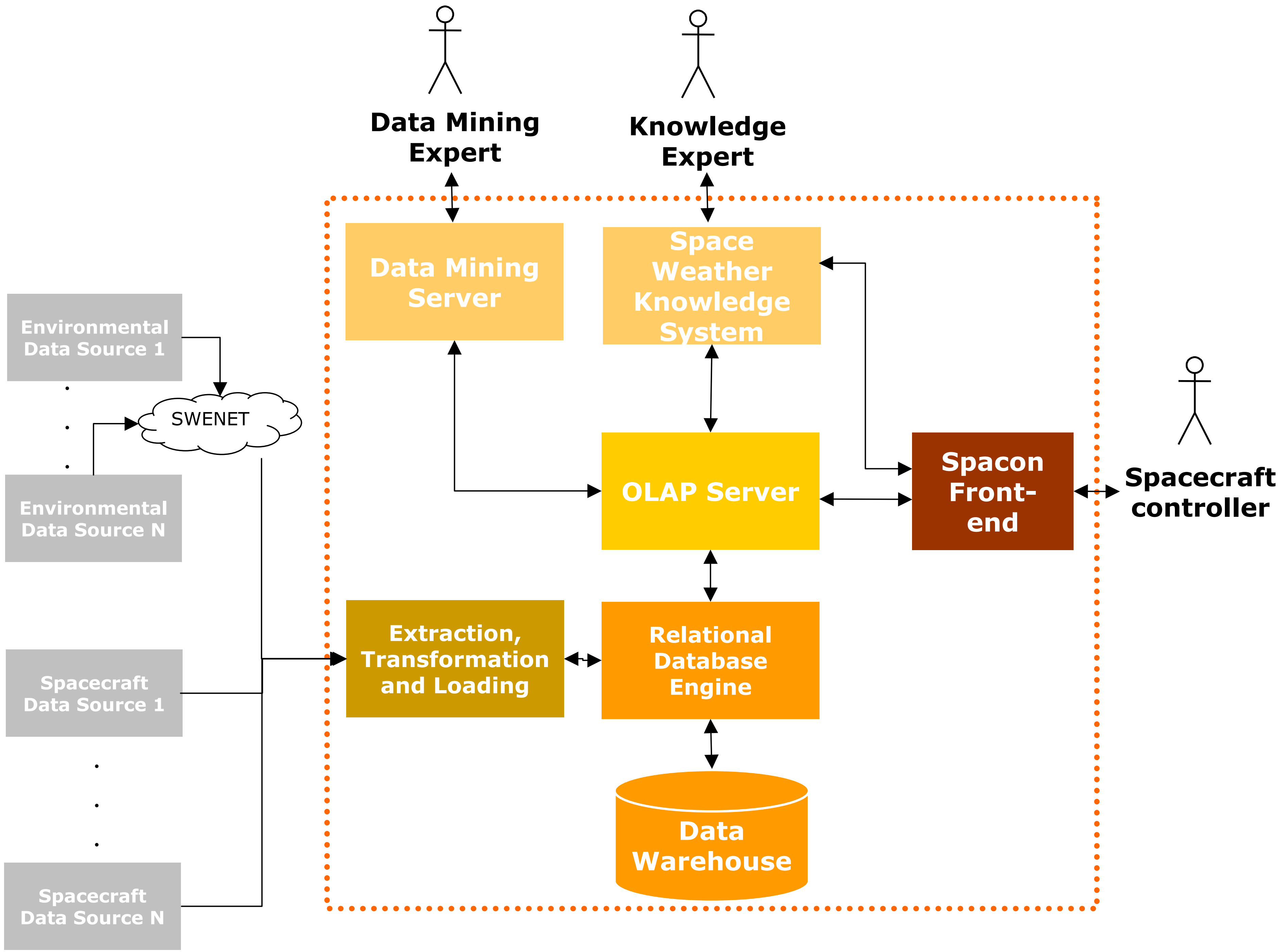
Service	*Enabling technologies*
Nowcast of relevant space weather events with explanations and direct relationship with S/C data	▪ Data warehousing ▪ On-Line Analytical Processing (OLAP) ▪ Knowledge systems ▪ Fuzzy Logic
Space Weather Data analysis and exploration by end-users	▪ Data warehousing ▪ OLAP
Short-term (hours) forecasts for Environmental events, of most relevance to operations	▪ Data Mining, KDD ▪ Data warehousing

However some assumptions must be pointed out to understand the rationale of this solution

- This is a proposal for an infrastructural IT solution assuming that:
- SW data is available in (near) real-time
  - Some NOAA provider or equivalent must exist
- Scientific knowledge can be obtained from external sources/other partners and used in the implementation as an input

With the previous in mind a interesting opportunity also comes up

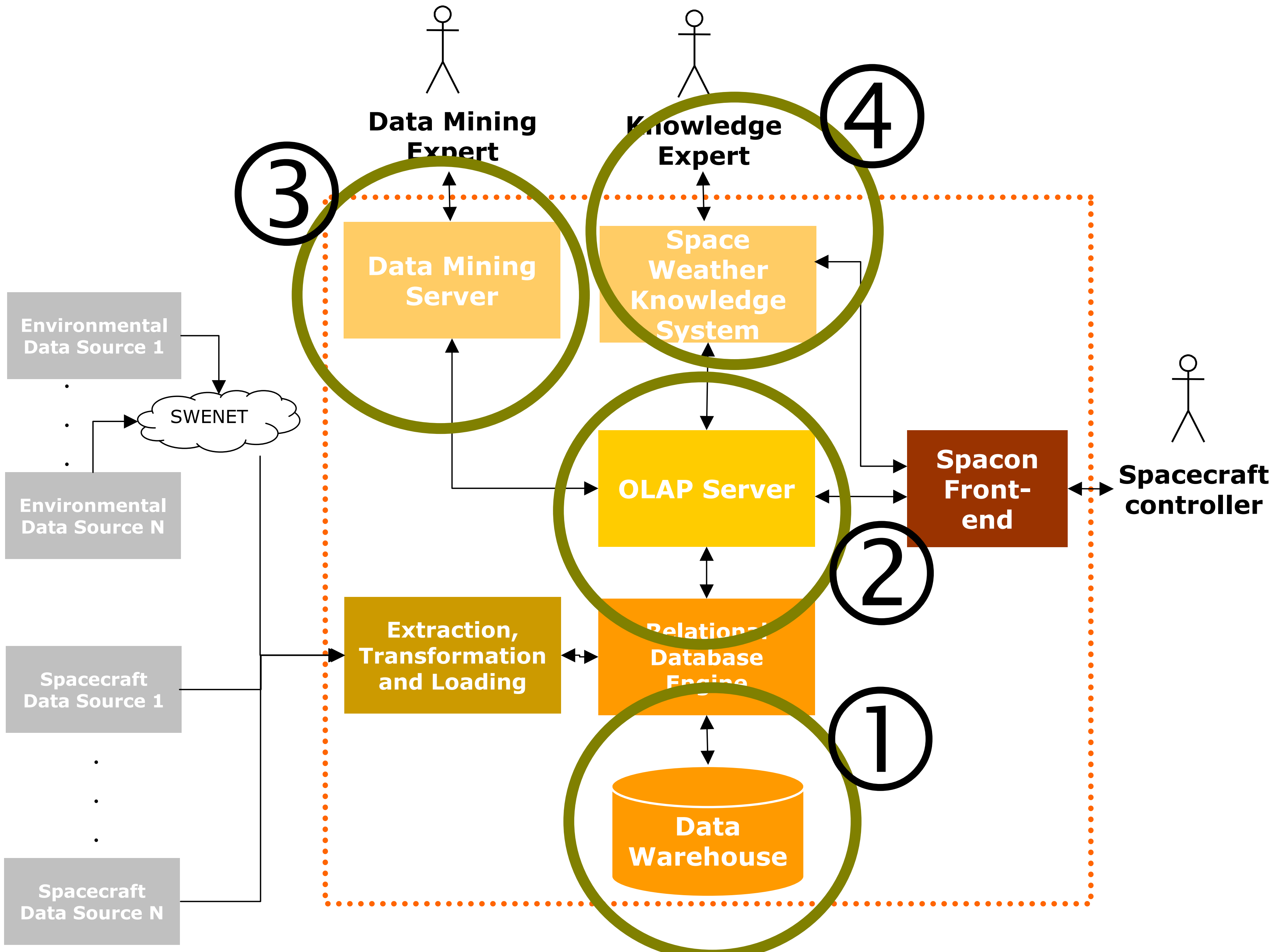
- An infrastructural generic approach, IT-oriented, makes possible the
- Opportunistic usage of available data at a given moment for a specific task
  - Usage of data without guarantees of coverage/availability
  - Usage of heterogeneous data sources simultaneously
  - Usage of results from the several Institutions and Research Centres in the Space Weather services when possible/valid



Data Mining Expert
Knowledge Expert
Data Mining Server
Space Weather Knowledge System
Environmental Data Source 1
SWENET
Environmental Data Source N
OLAP Server
Spacon Front-end
Spacecraft controller
Extraction, Transformation and Loading
Relational Database Engine
Spacecraft Data Source 1
Spacecraft Data Source N
Data Warehouse

Enabling Technologies

1. Data Warehousing
2. Multi-dimensional functionalities: OLAP
3. Data Mining & Knowledge Discovery in Databases
4. Knowledge Systems



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3
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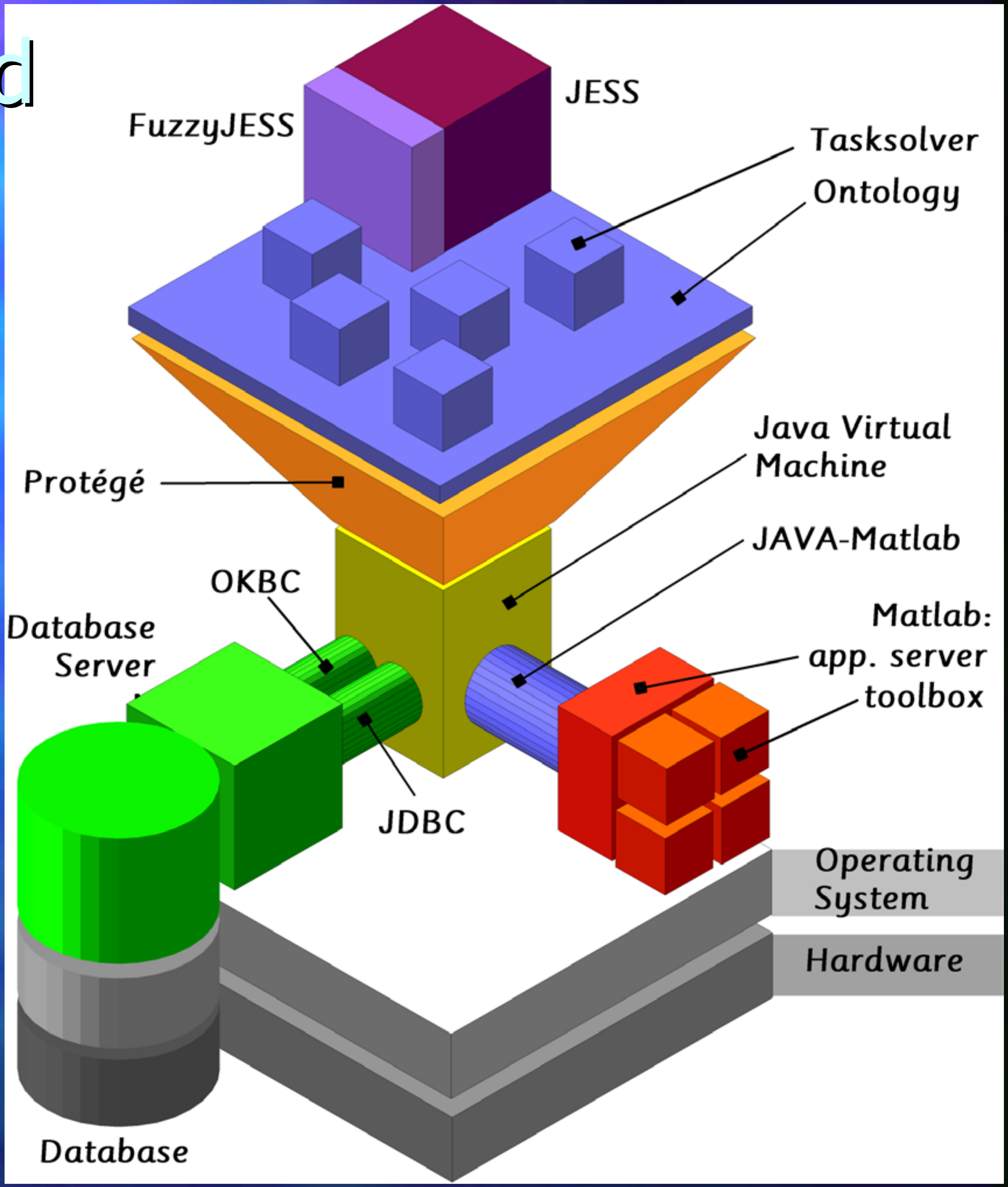
Knowledge Enabled Services

- Multi-agent system design
- Inference Engine: JESS & FuzzyJESS
- Knowledge Acquisition + Domain Ontologies: Protégé, CommonKADS
- Other engines: MatLab, etc



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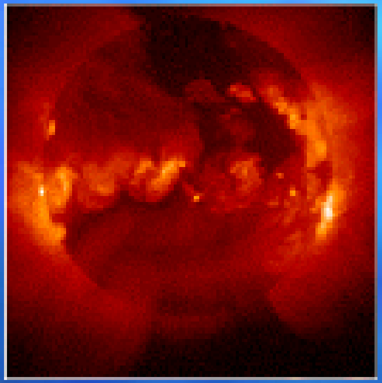
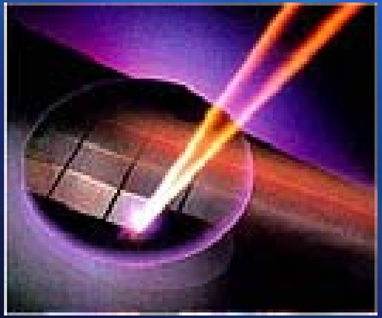
- Rationale
- An Architecture for Space Weather Services
- Case studies
  - Solar Array Monitor
  - Radiation Monitor
- Conclusions & Future Work

In the context of the "Fuzzy Logic for Mission Control Processes" project @ ESOC

- Two problems that needed Space Weather services

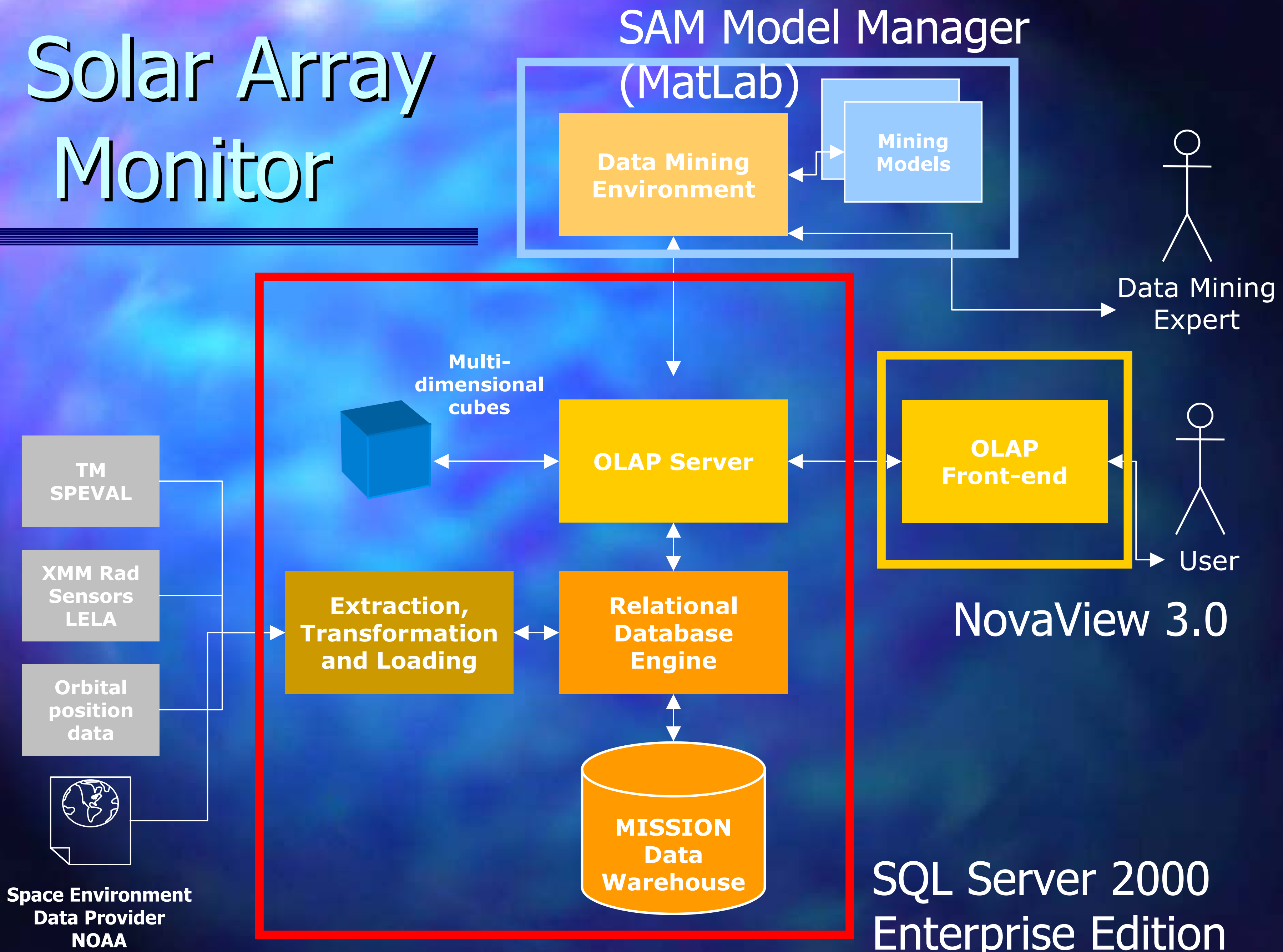


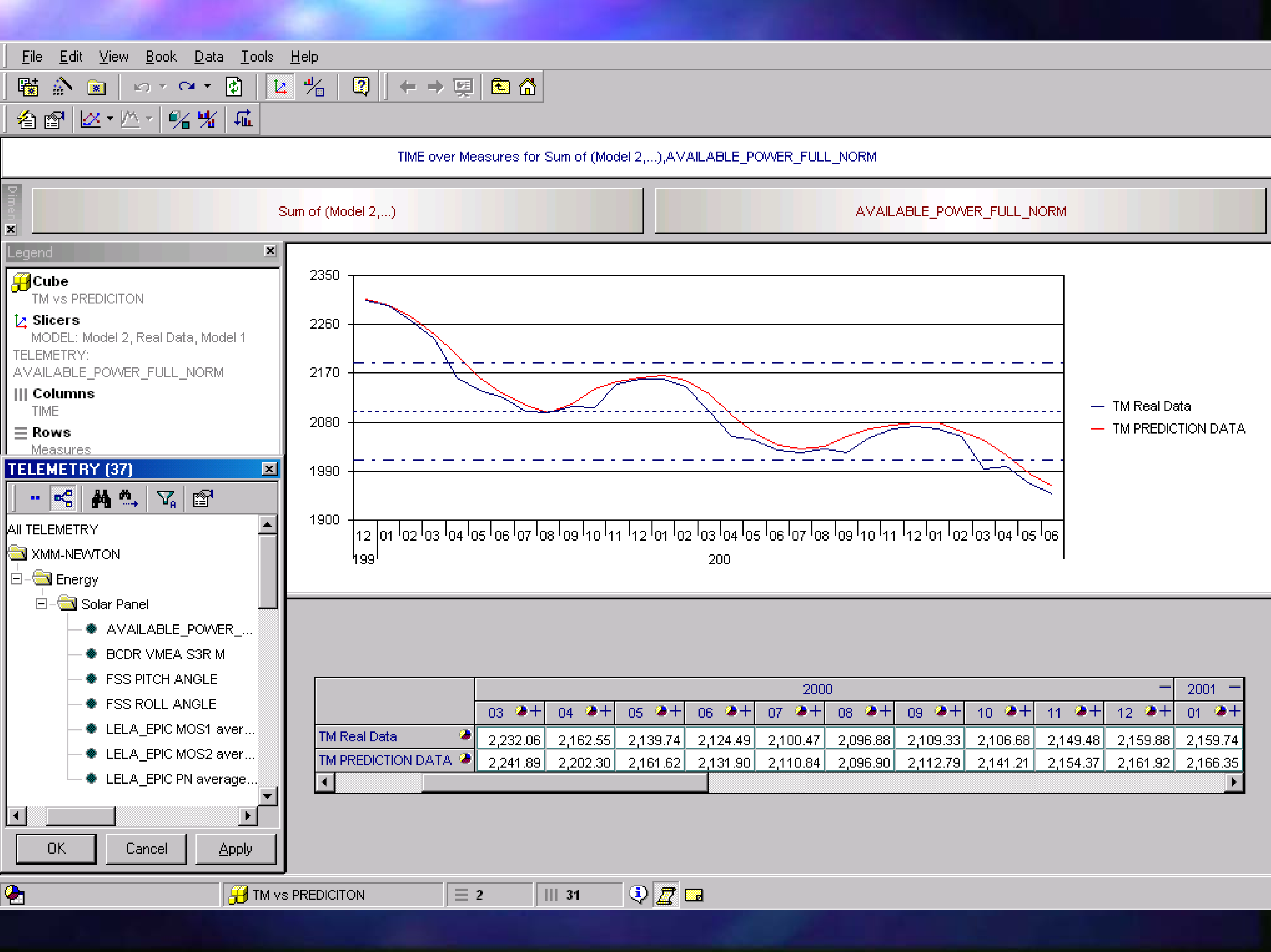
Monitor and predict radiation perturbations caused by solar flares, Van Halen Belts, radiation spike hazards – in general -, … in order to on-line decide survive strategies for the instruments, ranging from protective covers deployment, instrument shut-down and even orbit change recommendations.



Monitor and predict the accurate degradation of the solar panels on board spacecrafts.

Solar Array Monitor

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To conclude, time requirements and constraints can summarize all user requirements for this Space Weather Services architecture

- The envisioned architecture could be an infrastructure for all of these scenarios
- Quite distinct profiles can be accommodated
  - Operator
  - Space Weather Scientist
  - Spacecraft manufacturer
  - End-user of another domain

Other possibilities

- Requirements for end-user front-end application are simple to satisfy (e.g. www access to services)
- Real-time services are also feasible, depending on investments in hardware and software

Future work

- This proposal has not been selected for a full proposal by ESTEC, in the SW Pilot Project
- The ESA-Portugal Task Force has accepted to fund this project (pending on final negotiations)
- A prototype of the full architecture can be developed in 2003, the client will be ESOC at least

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