DREAMS System

DISTRIBUTED ROBOT&AUTOMATION ENVIRONMENT AND MONITORING SUPERVISION UTILISATION IN EUROPA

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ABSTRACT

In order to prepare the future EUROPA robotic mission carried out by a collaboration between the Italian and the European Space Agencies, theses have selected the **DREAMS** System for the on ground robot monitoring and control stations. The target application concerns the payload manipulation and inspection using the SPIDER arm, a classical rigid robot manipulator. Particularly, the tasks foreseen are payload installation/removal, samples exchange, payload inspection, etc. The **DREAMS** System has been developed by TRASYS Space and its capabilities have been already successfully demonstrated in 2000 at ESTEC laboratories where is now operating the JERICO Evaluation Testebed.

1. INTRODUCTION

For automation and robotics missions in space ESA has chosen the following technologies:

1. Use of off-line programming as basis of the specification/validation of the robotic tasks;
2. Use of calibration to cope with positioning inaccuracies;
3. The Interactive Autonomy as operational mode of execution;
4. Remote and distributed control;
5. Integrated and user friendly programming environment,

here after briefly described.

1) Off-line programming Following this programming methodology all the positions that a robot must reach during the experiment execution are fixed and defined a priori. This methodology is often used when the environment of the robot is structured and known. Dedicated and very efficient robotics CAD tools support off-line programming.

2) Calibration technology Necessary conditions to succeed the experiments specified using off-line programming methodology are first, the availability of a robot with a very predictable Cartesian and dynamic behaviour, and second, an accurate knowledge of the working environment position. Therefore it is necessary to improve the absolute positioning accuracy of the robot with respect to its working environment, and to identify the real position of the environment with respect the robot. This can be achieved using advanced calibration techniques.

3) The **Interactive Autonomy operational mode** includes two aspects:

1. *Autonomy:* The nominal task of the robot is pre-programmed and its safe execution (e.g. against collision) is verified on ground. Once the task has been validated a robot task file is produced and up-loaded to the robot controller for later execution. The robot task file is a high level description of the activities that the robot must perform. Low level control (i.e. automatic control feedback) is considered to be provided by the robot controller.

2. *Interactivity:* In case of anomalies or divergence between the expected experiment results and the actual ones, the possibility exists for an operator or a scientist to interact with the executed process. Those interactions provide the necessary flexibility for handling anomalies. The interactions are performed at task or action level making use of pre-programmed recovery sequences. Once the anomaly is solved, the operator may resume to the nominal experiment plan.

4) Remote and distributed control The need to control from the earth a robot in the space imposes the remote control. Moreover, in order to offer the possibility to various types of users, either experimented in robotics or scientists with no knowledge in the field, to run experiments by their home bases, a distributed control will be necessary.

5) Integrated user friendly environment
Presently, all the previous items are considered in the robotics community separately. *Their integration into a coherent, user friendly environment that guides the operator from the specification of the robotics operations to their validation and execution is one of the main challenges of this project.*

The experience gained by TRASYS using off-line programming methods and tools and Interactive Autonomy operational mode in the successful ESA/NASDA joint experiments, performed in the framework of the VIABLE project, have been considered on the design and implementation of **DREAMS** System to facilitate the operation execution.

The resulting **DREAMS** technology and solution shall be re-usable for future participation in:

- Payload Tutor (PAT), an ASI proposal to NASA for internal robotics. PAT has been proposed to NASA as a mean to automate operations on NASA Express racks. PAT is expected to reduce significantly crew workload;
- European Technology Exposure Facility (EuTEF), an ESA programme. Although EuTEF is a self-contained programme, the work performed on JET could prove the validity of the **DREAMS** system for EuTEF

The document is structured as follows.

The second section provides the **DREAMS** architecture breakdown. We briefly describe the functionality of the s/s and their organisation in operational environments.

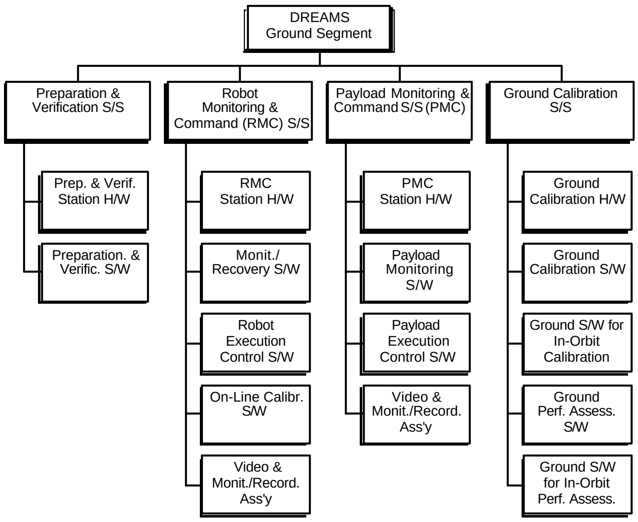
In the third section we present the instantiation of **DREAMS** for EUROPA ground segment. The installation/development of the supporting S/W, the activity analysis programming and the MMIs design done in **DREAMS** have already been presented at ASTRA 2000 Conference. Here we discuss only the new developments in the framework of the EUROPA ground segment.

Conclusions and remarks will be given in the last Section.

2. DREAMS ARCHITECTURE

The **DREAMS** System consists of the H/W and S/W necessary:

1. To provide the users of the ground segment with an *integrated robot programming environment* that supports the preparation and the execution of experiments in a methodical, reliable and user friendly way. The passage from the conception of the experiments to their execution will follow four phases: the pre-preparation phase, the



preparation and validation phase, the utilisation phase and the contingency phase which are explained later on;

DREAMS Architecture Breakdown

2. To enable different types of users to *remotely control* the robot facility. Users with sufficient robotics knowledge, using remote robot monitoring and command environments will be able to prepare, validate and run new or predefined experiments. Scientists, not expert in robotics, from their home base, will be able to submit for execution predefined scientific experiments.

To fulfil the objectives the **DREAMS** ground segment consists of four s/s.

The **Preparation and Verification S/S** will provide the necessary H/W and S/W environment to prepare and verify all activities of the robot facility. A ground operator will be able to develop new activities or to instantiated predefined ones (e.g. move payload from nest x to nest y, etc) and to verify them by simulation with respect to pre-defined criteria (e.g. collisions, timing constraints, resource availability, etc).

The **Robot Monitoring and Command S/S** will provide the necessary H/W and S/W environment to execute and monitor a complete activity plan. From the control point of view this s/s will support the start, the pause, the stop and the resume of activities. On the other side, for the monitoring purposes, the status of the activities execution will be provided as well as a predefined subset of the available telemetry (e.g. joint values, force/torque forces, …) necessary to conduct experiments. Camera snapshots or live video will be displayed to enhance user's perception of the robotic cell during operations.

The **Payload Monitoring and Command S/S** will provide the necessary H/W and S/W environment for a scientist, in a user home base, to request for execution and to monitor pre-defined activities on the allowed payload. The command request (start-pause-stop-resume) is submitted to the Robot Monitoring and Command s/s for validation and execution. The monitoring will be done both using high level graphic simulation based on the telemetry data and possibly image(s) of the video down link.

The **Ground Calibration S/S** will provide the entire infrastructure to measure, calibrate and verify the performances of the manipulation s/s and the payloads s/s.

3. DREAMS INSTANTIATION FOR EUROPA

The EUROPA Ground Control Station consists on the h/w and s/w necessary:

1. To provide the EUROPA operators with an *integrated facility monitoring & command and robot monitoring & program environment* that supports the preparation and the execution of EUROPA experiments in a methodical, reliable and user friendly way. The passage from the conception of the experiments to their execution and post-processing follows six phases: the pre-preparation phase, the preparation and validation phase, the training phase, the utilisation phase, the contingency phase and the post-operations phase which are explained later in this section. The DREAMS system is the core of the Ground Control Station.
2. To enable different types of users to *remotely control* the EUROPA facility in a secured way. Users with sufficient robotics knowledge, using remote robot monitoring and command environments will be able to prepare, validate and run new or predefined experiments. Scientists, not expert in robotics, from their home-base, will be able to submit for execution predefined scientific experiments.

The *Pre-preparation phase* of the EUROPA Ground Control Station covers the overall work station layout definition for the EUROPA specific activities, activities library definition and the EUROPA workcell model generation. The *Preparation and Validation phase* consists in specifying and validating robotic activities by simulation and/or using the GRM. The *Training phase* consists in training different operator(s) class to operate on the EUROPA facility. During *the Utilisation phase* the robotic activities are downloaded in the robot controller, and then, launched and supervised. In case of *Contingency* recovery procedures could be prepared, validated and finally activated to handle the situation. The *Post-operations phase* consists in analysing the telemetry data using the ground segment and checking that the actual system performances comply with the nominal ones.

The considered sub-systems are regrouped in three categories of control stations in order to propose to users with different background the adequate environment to prepare and to execute calibration, robotic and scientific activities in-site or remotely.

The **central Robot Monitoring & Command** Station provides the Preparation & Verifications s/s, the O/G Data Handling s/s, the Facility Monitoring & Command s/s, the Robot Monitoring & Command s/s and the Calibration and Performance Assessment s/s.

Its main characteristic is that it is the only control station that has direct access to the flight segment and the on-board controller. Its operator is the only responsible to handle contingency situations. The central RMC is unique, it is situated in the Facility Control Centre and its operator is a robotics and operations expert.

The **remote Robot Monitoring & Command** Station, as the central RMC Station, provides the Calibration and the Performance Assessment s/s, the Preparation & Verifications s/s and the Robot Monitoring & Command s/s. But, during operations it does not directly address the on-board controller, using for that functionality of the central RMC Station. The remote RMC operator is a robotics expert located at his home base.

The **Payload Monitoring & Command** Stations provide the Payload Monitoring & Command s/s. During operations they address the on-board controller through the central RMC Station. The PMC Stations operators are scientists located at their home bases and controlling experiments of scientific interest.

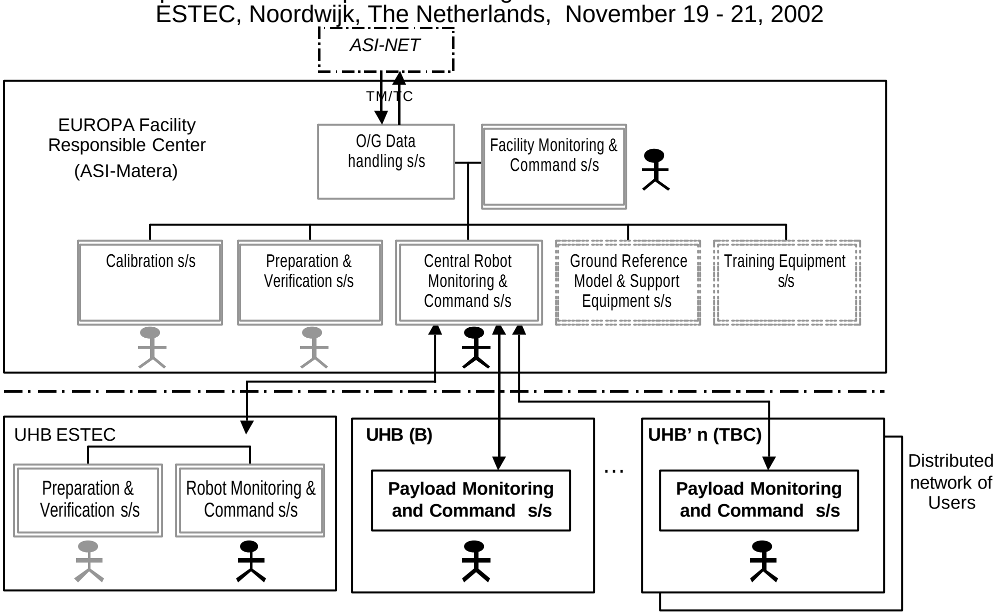
One major development is the installation and configuration of **SCOS 2000** tool, developed by ESA, in the Central Monitoring and Command Station. **SCOS 2000** is a configurable and open MCS application framework to be used to implement Facility Monitoring and Control TM/TC related functionality. It provides a library of components and mechanisms for handling objects within a spacecraft control and checkout system. Its functionality can be extended to cover other type of mission needs as the EUROPA one. It supports CCSDS TM/TC packet standards, and the ESA Packet Utilisation Standard. In particular the latter enables high level interaction between on-board applications and the control application on ground. This will allow the possible extension of **DREAMS** system to other robotics mission like ERA operations, telemanipulation and teleoperation applications, ….

4. CONCLUSIONS

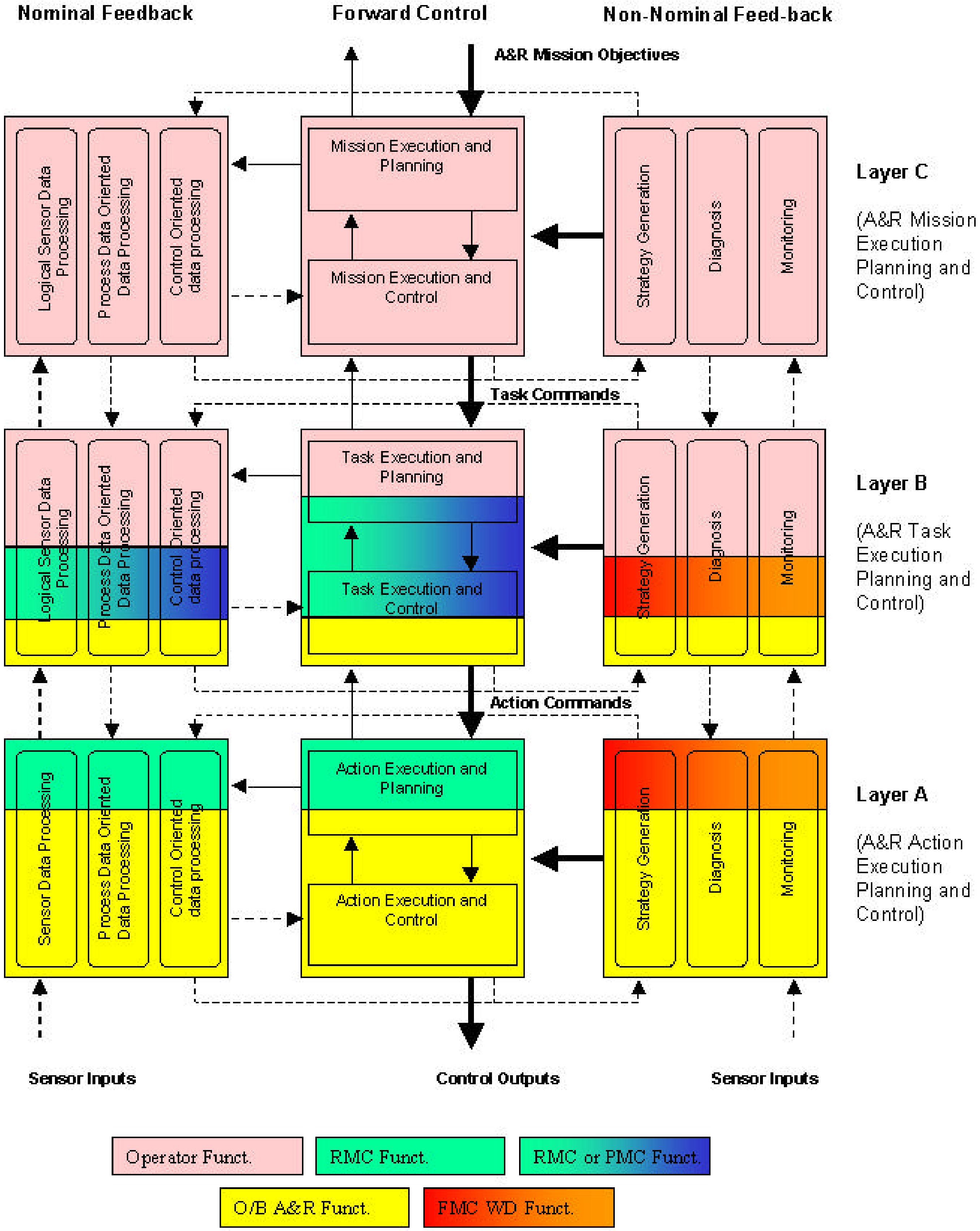
The proposed **DREAMS** system provides the possibility to prepare EUROPA automated robotic mission in space with confidence in the selected technology and development approach. The **DREAMS** system gives the possibility to enhance the following technologies:

- Use of off-line programming as basis of specification/validation of the robotic task;
- Use of calibration to cope with positioning/mechanical inaccuracies in an integrated environment;
- Use of Interactive Autonomy as operational mode of execution;
- Use of remote and distributed control stations;
- Use of an integrated and user friendly programming environment for robotic experiements.

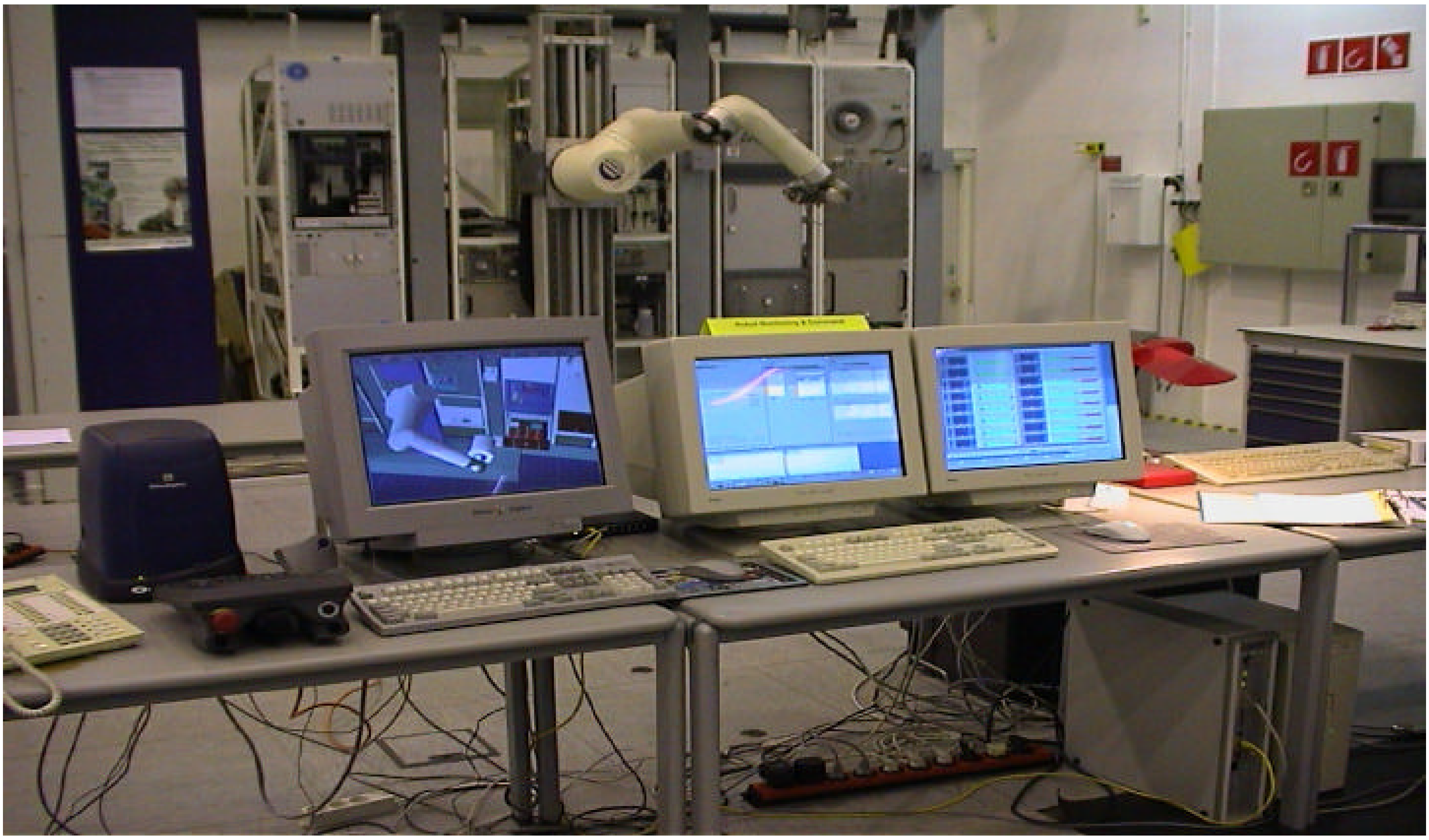
Portability, easy configurability, integration of **SCOS 2000** features will offer to **DREAMS** system the possibility to large re-use in the future robotics space missions.



EUROPA/DREAMS Control Stations



Functional Reference Model structure and DREAMS function allocation in EUROPA



The DREAMS system operational at ESTEC laboratories