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Mission Preparation and Training Equipment for the European Robotic Arm

Simulation for mission validation and operations training

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Summary

This document contains a paper presented at the 6th International Workshop on Simulation for European Space Programs (SESP 2000). SESP 2000 was held at the European Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands, from 10 to 12 October 2000. The paper addresses the Mission Preparation and Training Equipment (MPTE) for the European Robotic Arm (ERA) and focuses on the use of simulation for mission validation and operations training. An MPTE system, which was installed at ESTEC at the time of the workshop, has been demonstrated to two groups of workshop participants.

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SIMULATION FOR MISSION VALIDATION AND OPERATIONS TRAINING

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ABSTRACT

The International Space Station (ISS) will host the European Robotic Arm (ERA) which is an ESA project with Fokker Space as prime contractor. A major part of the operational ground-infrastructure of the ERA system is called the ERA Mission Preparation and Training Equipment (MPTE) designed and built by the National Aerospace Laboratory NLR of the Netherlands in close co-operation with Spacebel Trasys Association (STA) of Belgium, and Fokker Space. MPTE will be used a.o. for ERA mission preparation and operations training. One of the sub-tasks of mission preparation is mission validation. The requirements of mission validation and operations training can be met through simulation, therefore an MPTE Simulation Facility has been developed to support these two tasks.

The simulation facility combines a set of simulation and visualisation tools. The available simulators are based to a large extent on simulation models that are also used for ERA system design and verification. In addition, they communicate with actual flight-hardware and -software such as the ERA Control Computer and the IVA and EVA Man-Machine Interfaces. The simulators are connected to a visualisation tool which generates representative views of the ERA operators' working environment. This setup allows for a dual use of the simulation facility, since mission validation mainly requires the simulation system to mimic the detailed internal workings of the real system, and operations training requires the simulation system to mimic the system's usage characteristics.

1. INTRODUCTION

The International Space Station (ISS) will host a number of robotic manipulators, each with different characteristics and capabilities. One of these robots is the European Robotic Arm (ERA) which will operate on the Russian Segment (RS) of ISS. ERA is developed under the umbrella of ESA's manned-space program. The ERA project is performed in co-operation with the Russian Aviation and Space Agency Rosaviakosmos (RKA). The ERA systems are designed and built by a large number of European companies led by prime contractor Fokker Space (FS) of the Netherlands.

A major part of the operational ground-infrastructure of the ERA system is called the ERA Mission Preparation and Training Equipment (MPTE). MPTE will be used to plan, prepare, train and support ERA operations. MPTE is designed and built by the Dutch National Aerospace Laboratory (NLR) in close co-operation with Spacebel Trasys Association (STA) of Belgium, and Fokker Space.

MPTE provides a set of simulators that can be used to support the preparation of ERA missions and the training of ERA operators in executing these missions. When preparing a mission, simulation is used to validate the prepared mission with respect to the goals the mission was set out to achieve. For operations training, simulation provides the trainee with a flight-representative ERA system and working environment.

This paper focuses on the design and use of the MPTE simulators used for mission validation and operations training (section 4). But first a short description of the ERA system is given (section 2), followed by an introduction of the main MPTE functions and the role of simulation for each of these functions (section 3).

2. EUROPEAN ROBOTIC ARM

The operational ERA system is composed of the European Robotic Arm itself, together with Man-Machine Interfaces (MMI) for control of ERA from inside (IVA-MMI or IMMI) and outside (EVA-MMI or EMMI) the space station. The system will initially be used to support assembly and servicing operations on the Russian Segment of the ISS.

ERA is an 11 meter long robotic manipulator arm with 7 Degrees Of Freedom (DOF) that will operate on the outside of the space station. Its main elements are one elbow joint (1 DOF), two carbon-fibre limbs, two wrist joints (3 DOF) and two end-effectors (ERA's "hands"), configured symmetrically with respect to the elbow joint. This configuration allows

ERA to move across the station by grappling any one of a number of basepoints with either one of its two end-effectors. A limited number of basepoints will be available on the Russian Segment of ISS. Each basepoint will be able to provide ERA with power and communication lines.

During operations ERA is controlled using the IMMI and/or EMMI. The IMMI is a laptop based user interface for use inside the space station. It provides the operator with command and control capabilities, a telemetry representation, and an artificial view on ERA and its operating environment. The EMMI is a space-qualified and robust user interface for commanding ERA from outside the space station. It has less monitoring capabilities than the IMMI but similar commanding capabilities.

ERA has three operational modes:

- Fully automatic mode; the operator uses mission specific command datasets (prepared using MPTE) built up from single commands and “Auto Sequences” (sets of closely related commands) to control ERA.
- Partially manual mode; the operator uses pre-defined, generic “Mini Auto Sequences”.
- Fully manual mode; the operator directly controls the rotations of ERA’s joints (one at a time) or a Cartesian motion parameter.

Under nominal conditions ERA is operated in fully automatic mode. A more thorough description of ERA operations can be found in [Schoonejans, 1999].

3. MISSION PREPARATION AND TRAINING EQUIPMENT

The ERA Mission Preparation and Training Equipment provides ground support functions for ERA operations before, during and after the actual execution of a mission. An ERA mission is defined as a complete end-to-end sequence of ERA operations from one period of hibernation to the next.

The following main functions of MPTE can be discerned:

- mission preparation,
- operations training,
- online mission support, and
- mission evaluation.

Mission preparation and operations training would normally be done before the execution of a mission, the online mission support tools are used during mission execution, and mission evaluation is performed after the mission has finished. These four main functions of MPTE are described in more detail in the following subsections. Since simulation is extensively used for mission preparation and operations training (sections 3.1 and 3.2 respectively) these MPTE functions are described more thoroughly. Online mission support and mission evaluation (sections 3.3 and 3.4 respectively) use simulation only indirectly. A complete description of all the MPTE functions can be found in [Pronk, 1999].

Three almost identical versions of MPTE will be installed. One at each of the following locations:

- S.P. Korolev Rocket and Space Corporation Energia and Mission Control Centre (RSC/E-MCC), Korolev, Moscow Region, Russia; to be used for support of flight operations (preparation, support and evaluation of flight missions)
- Gagarin Cosmonaut Training Centre (GCTC), Star City, Moscow Region, Russia; to be used for training of ERA operators (preparation of training missions, operator training based on flight and training missions, evaluation of trainees).
- ESTEC, Noordwijk, the Netherlands; to be used for training of Russian instructors and other MPTE operators, and for maintenance of flight and ground operational software.

3.1 Mission preparation

Under nominal circumstances, ERA will operate in fully automatic mode (when not in hibernation). Since this mode requires the use of mission specific datasets built up from single commands and Auto Sequences, these datasets must be prepared beforehand. MPTE provides the tools to do this.

An outline of a mission, which describes the tasks to be performed by ERA and includes details of the space station configuration, is input from high-level space station mission planners. This outline – the Russian Segment Mission Plan (RSMP) and some additional data – is the starting point for MPTE mission preparation. The MPTE mission preparation operator is provided with tools (including a Path Planner based on the commercial RobCAD tool) to create a detailed ERA Operations Plan (EOP) based on generic commands and command sequences, taking into account restrictions posed by the ERA system, the ISS geometry, the mission environment and the available resources. Based on this EOP, mission preparation results in a package of mission specific datasets, consisting of command lists and updates of flight-software. The command lists define in great detail every action that has to be taken by ERA. A software update could for instance contain an updated model of the space station geometry to be used for collision avoidance.

Verification and validation of these results are very important steps in the mission preparation process and thus supported by MPTE. The goal of mission verification is to make sure that a correct mission has been prepared, i.e. the system will not do anything it is not allowed to do. Mission validation must show that the prepared mission achieves the goals that were set out for this particular mission, i.e. what the system does is actually useful and matches the goals set out by the high-level space station mission planners. In case a mission has been verified and validated it can be qualified for actual use on board the ISS. After qualification such a mission can no longer be changed. However, it can be used as a starting point for a new mission.

MPTE provides a set of tools dedicated to mission verification. The correctness at bitlevel of the results of mission preparation is checked by matching these results against the ERA data and command dictionnaries. In addition, the commands related to movements of ERA are checked by the Path Planner tool with respect to the constraints of the local geometry and the ERA system. This check is based on RobCAD's collision detection capabilities.

After verification of these datasets, but before they are qualified for actual use on the ISS, they are validated with respect to the goals of the mission, using one of the MPTE simulators (see section 4). MPTE mission preparation has so far resulted in a mission specific package of datasets consisting of command lists and flight-software updates. This data is stored in MPTE's mission database. Qualified datasets can be extracted from the mission database for uplinking to the MCC and onwards to the ISS and ERA. A similar action is the first step of a simulation session: the datasets of the mission to be simulated (which have not been qualified yet), are extracted from the mission database and placed in the simulator's data-structure. The MPTE simulators use these unaltered datasets as input for a simulation run, so the simulations are based on actual flight-data. In addition to these datasets, some mission specific input regarding the configuration of ERA and especially its environment, is required. This additional data, which is mostly related to geometry and comprises for instance a geometrical model of the space station, is based on the same high-level input that was used as the starting point for mission preparation, and is prepared in parallel with the mission specific datasets.

Based on the mission's datasets and the additional data, the mission to be validated is simulated. One or more mission preparation operators act as ERA operator and use an IMMI and/or EMMI linked to the real-time simulator to control the ERA mission, just as a cosmonaut would do on board the ISS. The MPTE simulator contains a detailed model of the ERA system and re-uses the flight-software of the ERA Control Computer (ECC), IMMI and EMMI, so the behaviour of the simulated system closely matches the real system. Views of ERA and its working environment are generated by the Image Generation System, based on data provided by the MPTE simulator and the prepared geometrical models. The mission is validated when it has been executed without errors from start to finish and the mission's goals have been achieved. Discrepancies can result in an iterative process of operations plan updates and validation sessions. Finally a mission is validated and mission preparation completed.

The mission preparation function is also used to define missions that are only meant for training purposes (they may for instance contain intended faults) or for verifying new flight-software. Flight, training and verification missions all have to be validated as part of mission preparation, although the goals of validation are slightly different for the three types. Once validated, only flight missions can be qualified for flight. Training and verification missions can never be qualified for flight. A strict separation of the three types of missions (flight, training and verification) is therefore maintained by MPTE.

3.2 Operations training

Besides mission preparation, the second important task supported by MPTE is training of the cosmonauts who will operate ERA, and the ground personnel who will support these operations, such as the MPTE operators. The ERA operators, both on the ground and in space, must be trained to familiarize themselves with the ERA system and with specific missions. The MPTE provides the facility to support this kind of operator training. When using the MPTE training support facility, familiarity with the ERA system is achieved by executing training missions, for instance derived from ERA reference missions. Familiarity with a specific flight mission is achieved by executing this specific mission using the facility.

The training support facility comprises three main elements:

- an IVA station,
- an EVA station, and
- an instructor station.

The IVA station is representative of the working environment of a cosmonaut who is operating ERA from inside the ISS. It consists of a flight-representative IMMI, an intercom system and two monitors displaying simulated camera views. The intercom system is used for communicating with other trainees and the training instructors. The monitors are similar to those available to the cosmonaut onboard the space station. They can display any of the video images captured by simulated Russian Segment (RS) cameras, or the video images captured by one of the simulated ERA Camera and Lighting Units (CLU). ERA is normally not in the direct view of a cosmonaut in IVA so there is no 'window' view. The actions of the trainee are monitored using an observation camera. The IMMI and the two monitors are directly linked to the MPTE simulator. In the current installation of MPTE at ESTEC the elements of the IVA station have been placed in a mock-up of a part of the Zvezda module.

The EVA station is representative of the working environment of a cosmonaut operating ERA from the outside of the space station. It consists of a flight-representative EMMI, an intercom system, a large screen showing the cosmonaut's simulated view on ERA, the ISS, the earth, sun and moon, and a joystick that can be used to control this simulated view. An observation camera is used to monitor the actions of the EVA station trainee. In addition, a large monitor can provide a second EVA cosmonaut with an artificial view on ERA and its environment. The EMMI, the large screen, the joystick and the monitor are all directly linked to the MPTE simulator. In the current installation of MPTE at ESTEC the elements of the EVA station have been placed in a room which can be completely darkened. Both IVA and EVA station lack artificial micro-gravity.

The instructor station is the control centre of the MPTE training support facility. It is used to control the simulator which provides the trainees with the required feedback and it is used to monitor the actions of the trainees. The simulator is controlled via a set of Graphical User Interfaces (GUI). The simulator has been designed to require a minimum of instructor interactions during execution of a mission, but to allow for a maximum in flexibility. In addition to these GUI's the instructor has copies of the IVA and EVA station views and monitors showing the observation camera images. A dedicated 'instructor view' provides the instructor with the capability to look at the simulated environment from any angle. A copy of the IMMI screen is also available. The views, camera images and the intercom communications can be recorded with a VCR, although some limitations apply.

Not all elements of the MPTE training facility are required for every training. Three types of training are discerned:

- IVA training: one cosmonaut in IVA operates ERA; the EVA station is not used;
- EVA training: one cosmonaut in EVA operates ERA; the IVA station is not used; a second EVA cosmonaut can use the EVA station large monitor;
- combined IVA and EVA training: one cosmonaut in IVA and one in EVA operate ERA; all stations are used.

The system is limited to providing three distinct views on the simulated environment, so in case of combined IVA and EVA training, the instructor view is no longer available.

Operations training with MPTE is based on flight-representative data resulting from mission preparation, and on flight-representative user-interfaces. It is also based on a real-time simulator which uses the same high-fidelity models of the ERA system and its environment that are used for mission validation. Therefore the trainees should be able to obtain valuable experience in operating the ERA system and executing specific missions. This way

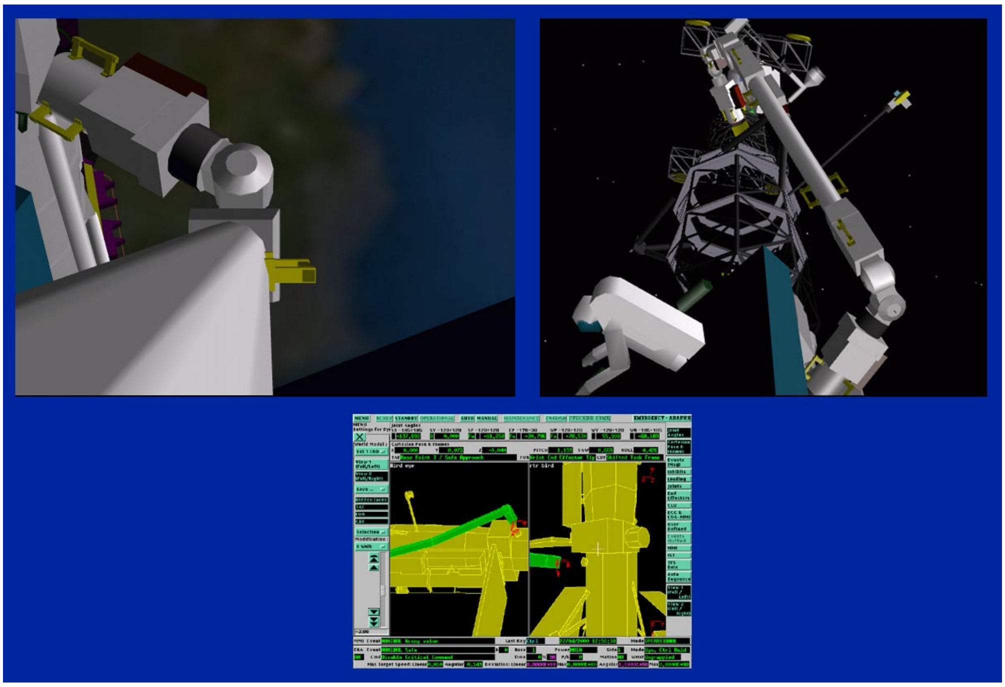

Figure 1: Simple representation of IVA station with two screens providing the trainee with Russian Segment and ERA camera views, and an IMMI.

simulation aids in assuring that not only a mission has been prepared correctly, but the people that will execute this mission have been sufficiently prepared as well.

In addition to using the MPTE training facility to master working with the ERA system, ERA operators will for instance be trained with a mock-up of ERA in a neutral buoyancy tank, with a laptop-based Refresher Trainer for onboard training, and with other dedicated training facilities such as Mission Control Centre simulators. An overall training plan is still under development.

3.3 Online mission support

Online Mission Support (OMS) is used during the actual execution of an ERA mission to monitor and store the telemetry that is sent in real-time by the ERA system to the Mission Control Centre (MCC) on the ground. The OMS stores the telemetry data it receives in a database based on the Columbus Ground System (CGS). It also presents the OMS operator with a large number of user-selectable synoptic displays, showing the incoming data in real-time. These data comprise a.o. calibrated engineering values, command verification data and memory-dumps, and is used for instance to ‘copy’ the IMMI screen as seen by the cosmonaut. The real telemetry received by OMS can be replaced by flight-representative telemetry that is generated by the MPTE simulators which are used for mission validation and operations training. So OMS can play a role in mission validation and operations training, and the OMS operator can be trained as well.

3.4 Mission evaluation

For evaluation of a completed mission the telemetry data stored by OMS is used. Detailed analysis of relevant parameters can be performed using built-in evaluation functions of CGS or by using a set of external applications. The telemetry data can also be used to recreate the same kind of high quality views as are generated by the MPTE visualisation tools for mission preparation and operations training. This allows for a visual recreation of the executed mission. In addition the stored TM data can be translated into an initial condition for the MPTE simulators. This means it is possible to repeat parts of an already executed mission on the ground for evaluation or perhaps instructional purposes.

4. MPTE SIMULATION FACILITY

The simulation requirements of mission validation and operations training are met by the MPTE Simulation Facility, thereby combining different (sub-)functions in one facility. The MPTE simulation facility consists of two main elements: the MPTE simulators and the visualisation tools. These two elements are described in the following subsections, but in the first subsection some of the objectives which were taken into account for the design of the MPTE Simulation Facility are described.

4.1 Design objectives

The design of the MPTE is based to the maximum extent on the use of existing (commercial) tools and facilities. Such tools are the real-time simulation facility EuroSim, including the Image Generation System (IGS), the Columbus Ground System (CGS), ESA’s Position and Environment Model (PEM), MultiGen and RobCAD. Also, developments from other ERA projects are re-used, such as elegant breadboard versions of ERA flight-hardware running flight-software, and development support models from the ERA Simulation Facility (ESF). This approach has also been applied to the design of the MPTE simulation tools.

For both mission validation and operations training, simulation is a powerful and obviously useful technique. It allows for a detailed analysis of the correctness of a prepared mission before the mission is actually executed. It also allows for the operator to get experienced in handling the system, without any risks to both the real system and its environment (including the operator). However, each of these two tasks has its own specific objectives, since mission validation is aimed at the correct functioning of the system, and mission training is aimed at the correct functioning of the operator(s). This may lead to the conclusion to develop different simulators for each of these tasks. But if one simulator is to be used for both tasks, this simulator has to meet the sum of the requirements as set by each task.

Mission validation mainly requires the simulation system to mimic the detailed internal workings of the real system in its operational environment. Ideally the datasets prepared for a specific mission are validated using an exact copy (both hard- and software) of the real system. Operations training on the other hand requires the simulation system to mimic the external characteristics (the “look and feel”) of the real system in great detail. The operator should experience as little difference as possible between operating the simulated and the real system. By basing the MPTE Simulation Facility on the tools that were used for ERA system verification – which include flight-representative user interfaces and which run actual flight-software – the main requirements of mission validation and operations training are both met.

4.2 MPTE simulators

The MPTE simulators are implemented on the commercial EuroSim platform. EuroSim is a complete real-time simulation environment with hardware-in-the-loop capabilities. It supports all phases of the simulation life-cycle (simulator development and simulation preparation, execution and analysis) through Graphical User Interfaces. EuroSim has a client/server architecture, with the server running the real-time simulation models and the clients being either EuroSim tools or applications created by the user. EuroSim is described in more detail in [Schulten, 2000].

The MPTE Simulators are built from models re-used from the ERA Simulation Facility (ESF) and a number of MPTE specific models. The ESF models basically represent the ERA system itself, whereas the MPTE models mainly define the system's environment and provide training support functions.

In the early stages of the design of MPTE it was decided that ESF, which was at that time already under development by Fokker Space as a design and verification simulator for the ERA system, would be the basis for the MPTE simulators that were to be used for mission validation and operations training. ESF, in its different incarnations, is thus used for design simulations, for verification of the ERA system, for mission preparation and for operations training. The main components of ESF are ERA subsystem models such as a manipulator dynamics model, an actuator model, sensor models, a joint control model and communication models, and models of ERA's external interfaces such as the ISS Russian Segment Central Post Computer (CPC) and Mass Memory Unit (MMU). Some additions to ESF functionality have been made for MPTE, especially with respect to the injection of simulated faults and to mission browsing (pause, rewind, forward and restart a mission).

The MPTE specific models provide the functions that are required for mission validation and operations training which lack in the ESF models. They comprise for instance models to keep track of mission time, to define the orbital environment (attitude of sun, moon, earth and stars with respect to the space station), to define and control the ISS environment (which contains payloads, cosmonauts, lights, camera's), to represent Mission Control Centre (MCC) functions, to detect collisions, and to introduce simulated faults. Many of these models interface with the MPTE visualisation tools. Some of the models have been implemented as external clients to the simulator, particularly the MCC model and the user interfaces which control many aspects of the simulated environment and fault injection. The orbital environment model is based on ESA's Position and Environment Model (PEM). All models have been designed with maximum flexibility in mind. For instance the values of all model parameters can easily be changed by the user and most manual control actions can be made automatic through the use of EuroSim Mission Definition Language (MDL) scripts.

Since ESF has many purposes, a number of different configurations exists. The two configurations most relevant to the MPTE simulators are the so-called ESF-HILT and ESF-SILT configurations, which are very similar. The ESF-HILT configuration connects the EuroSim based simulator through a MIL1553 bus interface to a Hardware-in-the-Loop-Test (HILT) ERA Control Computer (ECC) breadboard running flight-software. ESF-SILT connects through a simulated MIL1553 bus interface to a simulated ECC and thus does not require a hardware ECC. Both configurations use a MIL1553 bus interface to connect to a flight-representative IMMI and/or EMMI. More details of ESF can be found in [Schulten, 2000].

These two ESF configurations are the basis of the

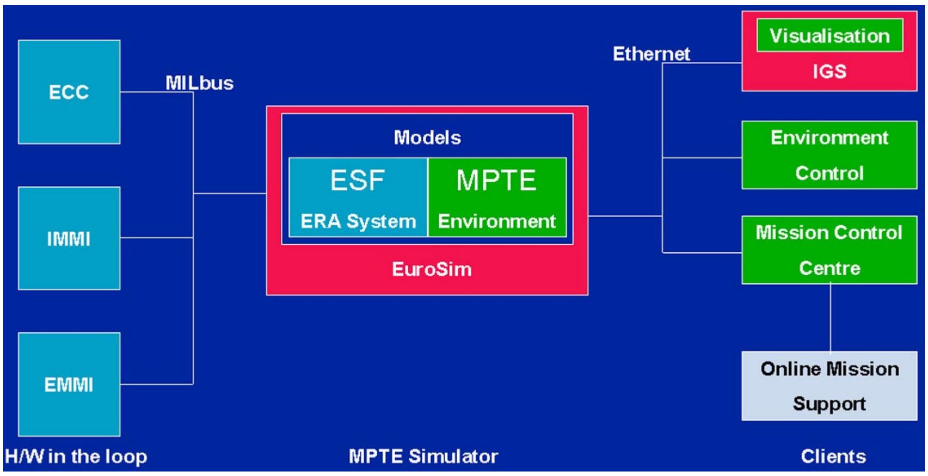

Figure 2: Schematic overview of the MPTE Simulation Facility.

two main MPTE Simulator configurations: MPTE-HILT and MPTE-SILT. They combine the MPTE specific models with the models of the ESF-HILT and ESF-SILT configuration respectively. The only real difference between these MPTE simulators is the use of the HILT or SILT ECC. Although MPTE-HILT is primarily meant for mission validation and MPTE-SILT for operations training, they can both be used for either of these two MPTE simulation functions. There is hardly any difference in operational use and capabilities. Since the MPTE simulators also use a MIL1553 bus interface to connect to the IMMI and/or EMMI, they combine hardware-in-the-loop and man-in-the-loop simulations.

A multi-processor Silicon Graphics Onyx2 InfiniteReality2 and single-processor Silicon Graphics O2 are used to run the MPTE simulators. During a simulation run the Onyx2 does most of the processing. It runs the MPTE simulator (3 CPU's), the visualisation tools (2 CPU's) and if applicable the SILT ECC(1 CPU). The ECC (if applicable), IMMI and EMMI are connected to the Onyx2 via a flight-representative MIL1553 bus. The O2 is used to display the simulation operator's user interfaces and run some of the MPTE simulator's external clients.

4.3 Visualisation tools

In real life the ERA operators base their actions to a large extent on visual cues. The EVA operator, looking over the EMMI, has a direct view of ERA and its working environment. The IVA operator uses the ISS Russian Segment video camera's and ERA's Camera and Lighting Units (CLU) in addition to the IMMI"s synoptic displays, to monitor the mission's progress.

Selecting suitable working positions for the EVA operator and the right camera's for the IVA operator is also part of mission preparation and thus mission validation. Since these visual cues play such a vital role during ERA operations, they have to be available during operations training as well. Therefore an important part of the MPTE Simulation Facility is dedicated to visualisation, as can also be deduced from the descriptions of the EVA and IVA stations in section 3.2.

The visualisation tools used to generate the required views are based on the Image Generation System (IGS). IGS is a companion tool to EuroSim, based on the VEGA and Performer 3D graphics libraries. It links objects in the simulation model to geometrical objects in a virtual world and renders views of this virtual world.

In parallel to preparation of a mission, an updated geometrical model of the operational environment for this specific mission is developed, comprising such elements as the ISS, ERA, payloads, cosmonauts and the earth. This geometrical model is input for IGS and linked to the MPTE simulator when this particular mission is executed, either for mission validation or operations training. IGS renders a maximum of three views on the virtual world defined by the updated geometrical models. What is rendered on these views is completely controlled by the simulation operator. Graphical User Interfaces allow the operator to select many types of images (Russian Segment camera views, ERA CLU views, cosmonaut views, instructor views) to be displayed on either one of the three views. Camera effects such as noise, eclipse and glare can also be applied.

Hardware limitations (the Onyx2 has one graphics pipeline) and the requirements with respect to resolution and refresh-rate of the views available for operations training, dictate that only three distinct views can be rendered simultaneously. The Onyx2 multi-channel capabilities and some video distribution hardware are used to display the right view on the right screen, depending on the applicable visualisation configuration. The visualisation configurations match the three training configurations mentioned in section 3.2. These configurations are used for both mission validation and operations training.

5. CURRENT STATUS AND FUTURE DEVELOPMENTS

At the moment of writing, system testing of the first version of the MPTE system has been completed. The hard- and software of the first of three systems has been installed at ESTEC. The second and third MPTE systems destined respectively for RSC-E/MCC and GCTC in Moscow are still to be delivered. Training of a first group of MPTE users from ESA and Russia will take place in the near future at ESTEC.

A second version of MPTE is already under development. This version will provide some additional functionality, comprise an update to the latest versions of ERA flight-standards and -software, and accommodate some of the comments and requests resulting from the first users' experiences. Delivery of this second version is foreseen for late 2001.

Some of the important additional functionality for the MPTE Simulation Facility that will be available in the second version of MPTE is:

- mission manipulation; this allows to rewind, pause or fast-forward a simulated mission and start or continue the mission from selected points.

- fault injection; a set of simulated faults can be selectively switched on or off for training purposes.
- creation of initial conditions from telemetry; to start a simulated mission based on recorded telemetry from real missions for evaluation or training purposes.

Furthermore, attention will be paid to the integration of the MPTE Simulation Facility with (existing) Russian Segment simulation facilities, and to the programmatic interfaces with the Russian Segment operations and training plans.

6. REFERENCES

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7. ACRONYMS AND ABBREVIATIONS

CGS	Columbus Ground System
CLU	Camera and Lighting Unit
CPC	Central Post Computer
DOF	Degree Of Freedom
ECC	ERA Control Computer
EMMI	EVA-MMI
EOP	ERA Operations Plan
ERA	European Robotic Arm
ESA	European Space Agency
ESF	ERA Simulation Facility
ESTEC	European Space Technology Centre
EVA	Extra-Vehicular Activity
FS	Fokker Space
GUI	Graphical User Interface
GCTC	Gagarin Cosmonaut Training Centre
HILT	Hardware-In-the-Loop-Test
IGS	Image Generation System
IMMI	IVA-MMI
ISS	International Space Station
IVA	Intra-Vehicular Activity
MCC	Mission Control Centre
MDL	Mission Definition Language
MMI	Man-Machine Interface
MMU	Mass Memory Unit
MPTE	Mission Preparation and Training Equipment
NLR	Dutch National Aerospace Laboratory
OMS	Online Mission Support
PEM	Position and Environment Model
RKA	Russian Aviation and Space Agency
RS	Russian Segment
RSC/E	Rocket and Space Corporation Energia
RSMP	Russian Segment Mission Plan
RTR	Refresher Trainer
SILT	Software-In-the-Loop-Test
STA	Spacebel Trasys Association
TM	Telemetry