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National Aerospace Laboratory NLR

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Summary

This document contains a paper to be presented at the 7th International Workshop on Simulation for European Space Programmes (SESP 2002). SESP 2002 has been held at the European Space Research and Technology Centre (ESTEC) in Noordwijk, The Netherlands, from 12 to 14 November 2002.

The paper addresses the Mission Preparation and Training Equipment (MPTE) for the European Robotic Arm (ERA) and focuses on the simulators to be used in the operational phase of ERA onboard the Russian Segment (RS) of International Space Station (ISS).

One of the MPTE systems has already been installed at ESTEC. This facility can be used for demonstration to the Workshop participants.

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ABSTRACT

The European Robotic Arm (ERA) developed under an ESA project with Dutch Space as prime contractor, will be hosted by the Russian Segment of the International Space Station (ISS). The Mission Preparation and Training Equipment (MPTE) is a major part of the ERA operational ground infrastructure, designed and developed by the National Aerospace Laboratory NLR in the Netherlands in co-operation with the Spacebel-Trasys Association of Belgium and Dutch Space.
A major subsystem of the MPTE is the simulation and visualisation subsystem, used to support flight and ground software maintenance, mission validation, training and mission evaluation. For this purpose a number of MPTE simulators have been developed to support the ERA operational phase.

The design of MPTE simulators is based on re-use of existing software to the maximum extent, both simulation and visualisation software tools and model software. Eurosim and the Image Generation System (IGS) developed under ESA projects are used as generic simulation and visualisation software platforms. The ERA Simulation Facility (ESF) concurrently developed by Dutch Space to support ERA hardware and software development and testing is re-used as the robotics simulation model kernel. This implies the re-use of ERA hardware-in-the-loop elements: the ERA Control Computer (ECC), the EVA MMI, and the IVA MMI. In addition, the development of the simulators is based on a phased approach, leaving critical operational aspects like non-nominal situations and simulation control flexibility being part of the final development.

In 2000 the so-called pre-flight version of the MPTE was presented and demonstrated during SESP 2000. This paper will focus on the upgraded MPTE simulation and visualisation function and features. In particular, simulation session management, environment simulation control, simulation of failures and failure injection control, resulting in non-nominal situations will highlighted. Also problems in development and integration will be discussed.

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 Dutch 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 support maintenance, planning, preparation, training, on-line and off-line 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 Dutch Space.
MPTE provides a set of simulators that can be used to support the maintenance of flight and ground operational software, 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, implementation and use of the MPTE simulators used for software maintenance, mission preparation/validation, operations support and operations training (section 4). But first a short description of the ERA system is given (section 2), followed by a short 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.

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 [2].

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:

- maintenance of flight and ground operational software,
- mission preparation,
- operations training,
- online mission support, and
- mission evaluation.

Maintenance of operational software will be done on an irregular base dependent on the need for debugging and/or software upgrading.
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 off-line after the mission has finished. These five main functions of MPTE are described in more detail in the following subsections. A complete description of all the MPTE functions can be found in [1], [4].

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

- 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, 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 on the ground with the MPTE.
Based on a high-level space station mission plan, the Russian Segment Mission Plan (RSMP), a detailed ERA Operations Plan (EOP) is prepared. From this EOP, a package of mission specific datasets will be extracted, consisting of command lists and possibly updates of flight-software. This includes detailed path planning, with path verification using ROBCAD's kinematics simulation and collision detection capabilities, and command syntax and constraints verification.

Before the datasets 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). These datasets are 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, 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 (geometry data), is required.

Based on the mission’s datasets, the mission to be validated is simulated. One or more operators may act as ERA operator and use an IMMI and/or EMMI linked to the real-time simulator to control the ERA mission. 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. 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.

The mission preparation function is also used to define missions that are 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. A strict separation of the three types of missions (flight, training and verification) is therefore maintained by MPTE.

3.2 Operations Training

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 must be trained to familiarise 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.

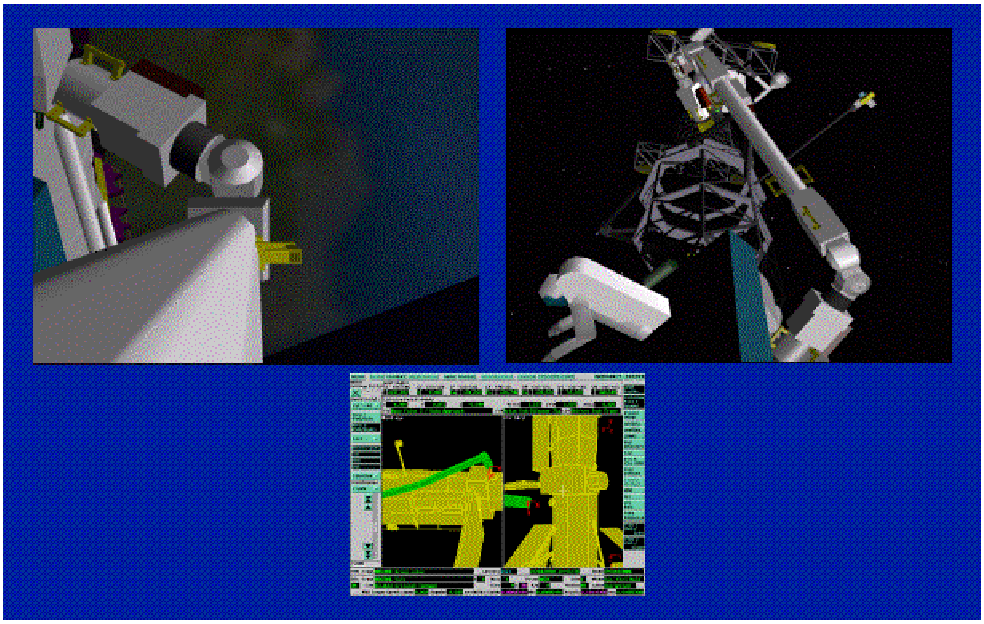

Figure 1: Simple representation of IVA station with two screens providing the trainee with Russian Segment and ERA camera views and an IMMI.

The training support facility comprises:

- ERA operator interfaces: IVA station, EVA station, 2nd EVA station
- 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 (see figure 1). In addition, it includes a laptop from which the cosmonaut can control camera views, light sources (on/off) and the ERA emergency switch (by Hard Emergency Stop, HES). 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). The actions of the trainee can be monitored using an observation camera, and keystrokes on the MMI keyboard are logged. 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, positioned on a so-called Removable Work Places (RWP) or Cosmonaut Support Tools (CST). 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 position of the simulated view. An observation camera can be used to monitor the actions of the EVA station trainee. The EMMI, the large screen, the joystick and the monitor are all directly linked to the MPTE simulator.
The second EVA station provides the environment for a second cosmonaut by a large monitor with an artificial view on ERA and its environment. In this station also a second EMMI can be installed from which the second cosmonaut may support ERA operations control.

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 GUIs 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 artificial pint of view. A copy of the IMMI screen is also available. The views, camera images and the intercom communications can be recorded with a VCR.

The MPTE training facility configuration, required for training, depends on the scope of the training, either IVA training, EVA training, or combined IVA and EVA training.

3.3 Online Mission Support and Mission Evaluation

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 among other things 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, using flight representative data.
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.

3.4 Software maintenance

The MPTE software maintenance facility, only installed at ESTEC, includes the 'kernel' ERA simulators to support in particular the flight software verification. Debugged software and/or functional upgrades of flight software will be tested using the ERA specific Simulation Facility (ESF). This facility is also used as the kernel for the MPTE simulators.

4 MPTE SIMULATION AND VISUALISATION FACILITY

As identified before, all MPTE dynamic simulators are based on the real-time ERA Simulation Facility (ESF) kernel, as used for flight software verification. The simulation requirements of mission validation and operations training are met by the MPTE Simulation (and Visualisation) Facility, thereby combining different (sub-)functions in one facility (see figure 2). 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. The kinematics simulator used in path planning is not part of this MPTE Simulation Facility.

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).

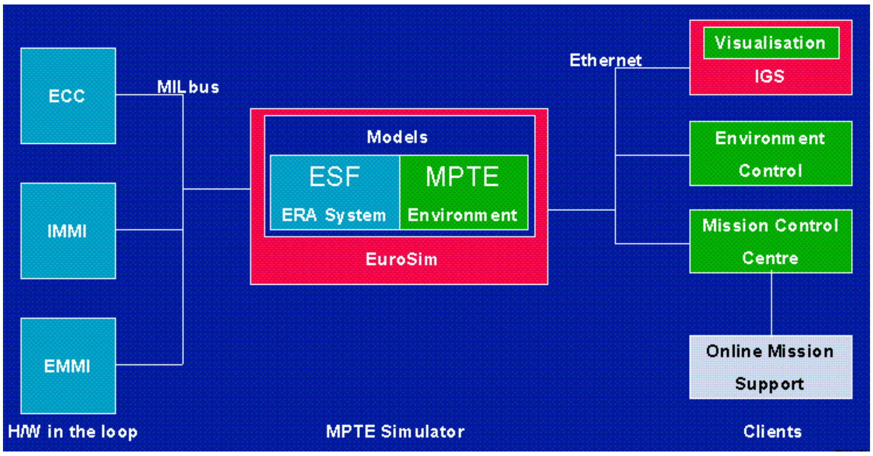

Figure 2: Schematic overview of the MPTE Simulation Facility.

For both mission validation and operations training, simulation is a powerful and obviously useful technique. 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. 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 [3].

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.

To support the process of preparation of simulator configurations and data for mission simulation, an MPTE specific shell has been developed to support the MPTE operator. This simulation session manager will be described in section 4.3.

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 <u>mission manipulation</u> (pause, rewind, forward and restart a mission) (see section 4.4 and 4.5).

The MPTE specific models comprise 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 the ESF has been developed on various objectives, different configurations were developed. In general two configurations are relevant for the MPTE, the so-called ESF-HIL and ESF-SIL configurations. The ESF-HIL configuration connects the EuroSim based simulator through a MIL1553 bus interface to a Hardware-in-the-Loop (HIL) ERA Control Computer (ECC) breadboard running flight-software. ESF-SIL connects through a simulated MIL1553 bus interface to a emulated 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 [3].
These two ESF configurations are the basis of the two main MPTE Simulator configurations: MPTE-HIL and MPTE-SIL. 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. However, mission manipulation and fault injection can only be used with the SIL version of the simulators.

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 emulated 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 Simulator Session Manager

The Simulation Session Manager (SSM) guides the user through the steps of creating a simulation session, starting up a simulation session, to store simulation results and to view and analyse simulation results. With the SSM the user is able to create a simulation session. The following parameters can be set:

- Mission ID;
- Simulator (HIL/SIL);
- Visualisation (IVA, EVA or IVA/EVA).

(Figure 3 gives an example of one of the subwindows of the SSM for selection of the simulator configuration.)

After defining a session, the SSM retrieves datasets and additional simulation data from the ERA Mission Database, and stores this data in a simulation session directory. Simulation initial conditions file template and MDL-file template are stored as well in the simulation data directory. The mission visualisation tool is used to retrieve the geometrical models and additional visualisation data for the current mission from the visualisation database and stored in the simulation data directories for use with the Image Generation System.

Now that all the simulation data is prepared, the simulation environment will be checked and (when necessary)

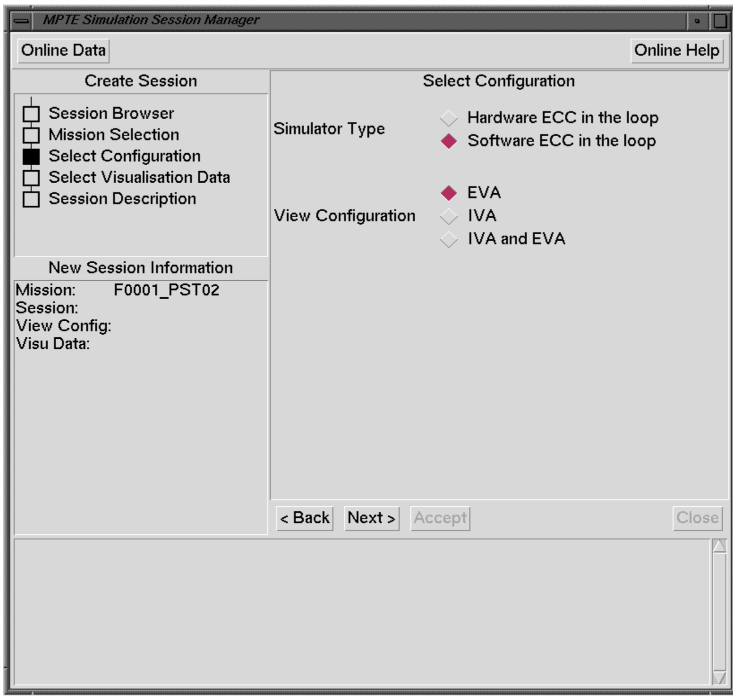

Figure 3: One of the SSM User interfaces to support selection of the simulator configuration.

will be fixed. When the environment is suitable for running a simulator, the selected session will be activated. The (emulated) ECC to be used is started now. The EuroSim Test Controller can be started and can be used to start the simulator. The EuroSim Mission Tool, which can be started up via the Test Controller, is used to load the EuroSim script file prepared for this mission. With the use of the Control of Simulated Environment GUI the simulation operator is able to set the simulated environment to a suitable state for this mission. For instance the payloads that are relevant for this mission are positioned, the simulated cosmonauts are positioned, and the types of view (views as seen by the simulated ERA camera´s, Russian Segment camera´s or the cosmonauts) that the Image Generation System should generate are selected. All other clients and GUI's can now be started up (Mission Control Centre GUI, Control of Simulated Failures GUI, Mission Manipulation GUI).

After the mission has been executed to completion, the simulator and its clients can be stopped. During the simulation session a lot of data has been recorded and stored. This data is now used to either validate the mission or to evaluate the training results. All simulation results can be shown via the SSM.

4.4 Mission Manipulation

The Mission Manipulation function provides the facilities that allow an MPTE user to:

- interrupt an ongoing simulation session and save the current simulation state,
- restore a saved simulation state and resume the session from that moment onward,
- browse a mission plan and select any discrete moment from which to start a simulation session,
- browse an interrupted mission or restored mission, that was saved earlier, and select any discrete moment in that mission from which to restart a simulation session,
- browse an ERA move in "Fast Forward" mode,
- edit ERA's pose at a selected point,
- select one of three ERA simulator configurations, each with a different combination of hardware and software components.

4.5 Fault Injection

The Control of Simulated Failures GUI (FIC) will be used to inject simulated failures in the simulation models, IGS, IMMI and FI-EMMI. During simulation, this GUI can be started via a button on the SSM. A failure can be injected in the following sub-systems:

– CLU (see figure 4)
– Wrist
– End Effector
– Joints
– AOCS
– IMMI
– FI-EMMI.

Every failure has a check-button next to the description of the failure. By activating the failure,

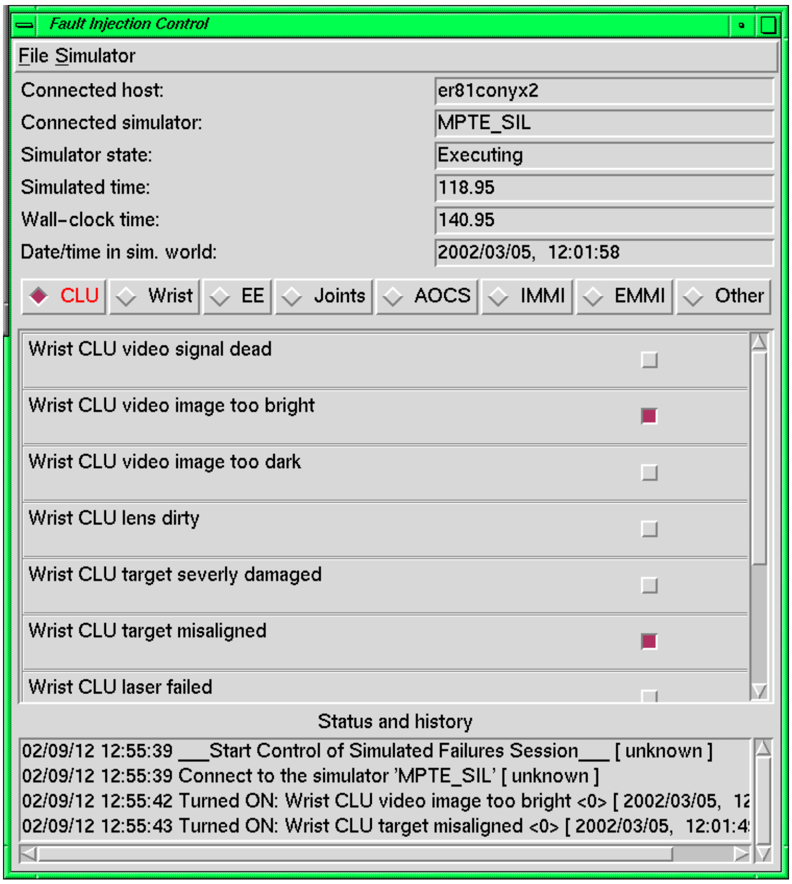

Figure 4: User interface to support injection of CLU failures.

the failure will be activated in the simulator or on the IMMI or FI-EMMI. Clicking the check-button again turns off the failure.

4.6 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 cameras 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 cameras for the IVA operator is also part of mission preparation. 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, glare and black & white 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.

On request IGS stores the data it receives from the simulator in a recorder file. IGS can reproduce from the recorder file the same views as happened during the simulation. The only exception is the instructor view: this viewpoint is always freely controllable by the simulation operator.

The MPTE visualisation tools are also capable of visualising stored telemetry for mission evaluation. The applicable telemetry data (e.g. ERA joint angles) are first converted to a recorder file and subsequently replayed in a visualisation configuration with three screens.

5 CURRENT STATUS AND FUTURE DEVELOPMENTS

At this moment the MPTE pre-flight version has been tested and accepted. The hardware and software of this first configuration 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 has been performed.
The final version of the MPTE is already implemented and integrated on subsystem level.

6 REFERENCES

[1] Pronk, Z. et al. (TBS); 1999; Mission Preparation and Training Facility for the European Robotic Arm (ERA); NLR-TP-99248, paper presented on the i-SAIRAS 1999 conference.
[2] Schoonejans, Ph. et al. (TBS); 1999; ERA, the Flexible Robot Arm; paper presented on the i-SAIRAS 1999 conference.
[3] Schulten, D.J. et al. (TBS); 2000; EuroSim and its Applications in the European Robotic Arm Programme; paper presented on the DASIA 2000 conference.
[4] Wokke, F.J.P. et.al. (TBS); 2000; Mission Preparation and Training Equipment for the European Robotic Arm, Simulation for Mission Validation and Operations Training, Paper presented on SESP 2000; ESA WPP180 page 21-26, NLR-TP-2001-048.