Operating the European Drawer Rack on the ISS

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The Erasmus User Centre, located at ESTEC in Noordwijk, will have overall responsibility for the preparation and execution of operations for the European Drawer Rack (EDR) facility in the European Columbus laboratory on the International Space Station (ISS). Together with the national User Support and Operations Centres (USOCs) involved in the operation of experiments on the ISS, it will form the network conducting the decentralised payload operations baselined for the European elements of the ISS.

The European Drawer Rack (EDR)

Utilisation features

The European Drawer Rack, housed within the Columbus laboratory, is a multi-user facility supporting and providing services to experiments accommodated in three ISIS (International Sub-rack Interface Specification) Drawers and four ISS Lockers (Fig. 1). It is a flexible, multidisciplinary experiment carrier. The scientific and observation instrumentation is provided by the experiment developer and integrated into the Drawers and Lockers, which are provided by ESA. Several experiments can be monitored and controlled in parallel, autonomously or with ground intervention, and with or without ISS crew intervention, as required. They share the electrical power, data and video services, cooling and venting capability provided by the EDR.

An experiment in the EDR can be accommodated within a single Drawer or Locker, or may occupy a combination of both. As the individual Drawers and Lockers are exchangeable in orbit, this allows for the exchange of a complete experiment in the former case, or of only one subsystem of an experiment in the latter.

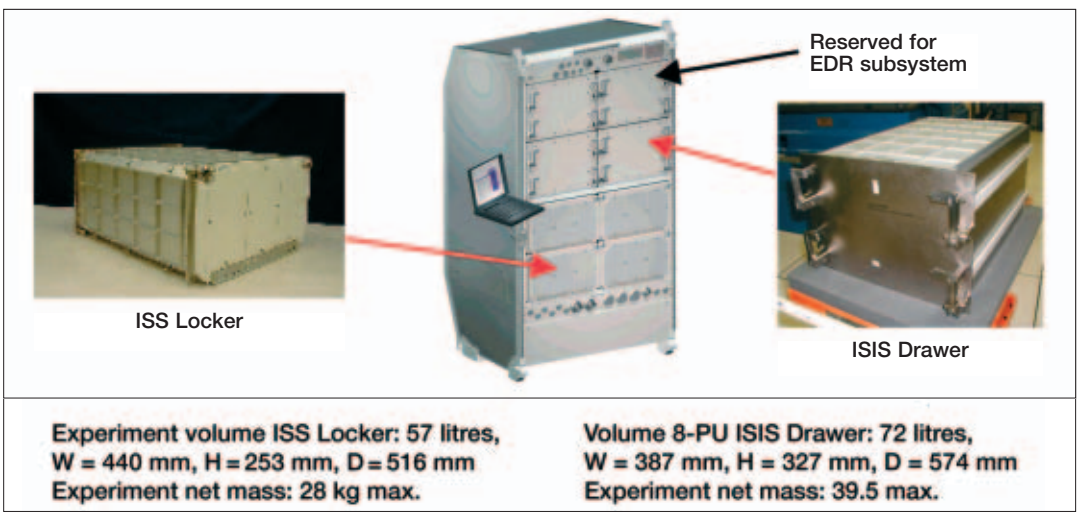

Figure 1. The European Drawer Rack (EDR) can accommodate two types of experiment containers: the ISS Locker (left) and the ISIS Drawer (right)

The ISIS Drawers and ISS Lockers provide mechanical compatibility with the NASA Express Transport Rack. The ISS Lockers are also mechanically compatible with the interfaces on the Space Shuttle's mid-deck (e.g. DC voltage supplies), where it is planned to transport Locker inserts. This facilitates flexible experiment turnaround, with exchanges of experiment samples or diagnostic instruments. The data handling is also standardised and complies with the NASA Express Rack Protocol, allowing standardised integration test procedures.

The EDR provides the Drawers or Lockers with the following Columbus system resources:
– DC power (28 and 120 V)
– data exchange (RS-422 and Ethernet)
– high-speed telemetry or digital video interfacing
– vacuum, venting and nitrogen gas supply.

These resources are provided by the following subsystems:
– Power Distribution Unit (PDU)
– Process Control and Command Unit (PCCU)
– Ethernet Hub for Payload LAN Connection
– Video Management Unit (VMU)
– Avionics Air Assembly (AAA) for air cooling
– Water Cooling
– Utility Distribution Panel (UDP)
– Laptop Computer.

The EDR's scientific capabilities were described in ESA Bulletin 108 (November 2001 issue).

Table 1. EDR facility resource consumption estimates used for operations reference-scenario development

Facility	Characteristic	Resources needed
PCDF	Mass	66 kg 28(L) + 38(D)
	Crew	< 2 hrs/week
	Power	< 330 W
	Data	2 Mbit/s
FAST	Mass	56 kg
	Crew	< 2 hrs/week
	Power	< 130 W
	Data	1 Mbit/s
BMTC	Mass	< 81 kg
	Crew	< 2 hrs/week
	Power	< 550 W
	Data	2 Mbit/s
MSF	Mass	< 48 kg
	Crew	< 2 hrs/week
	Power	< 700 W
	Data	0.02 Mbit/s

Payload capacity
The following experiment configuration has been used as a working reference payload complement for
performing operational analyses (see Table 1):
– PCDF: Protein Crystallisation Diagnostic Facility (accommodated in 1 Drawer and 1 Locker)
– FAST: Facility for Adsorption and Surface Tension (accommodated in 2 Lockers)
– BMTC: Biotechnology Mammalian Tissue Culture facility (accommodated in 1 Drawer and 1 Locker)
– MSF: Materials Science Facility (a hypothetical payload, assumed to be accommodated in 1 Drawer).

This payload complement would occupy all the accommodation space available in the EDR, i.e. 3 Drawers and 4 Lockers.

At the time of writing, one facility has already been officially selected and is under development, namely the PCDF, while the FAST is currently under consideration. The likely initial configuration for the EDR to be launched with the Columbus laboratory itself is shown in Figure 2.

ESA is also pursuing the selection of experiments to be uploaded and integrated into the EDR once the Columbus laboratory is in orbit. These include experiments on thermal-transport phenomena in magnetic fluids, diffusion and Soret coefficient measurements, metal foams, and space combustion research, fundamental and applied studies of emulsions, biotechnology mammalian tissue cultures and critical-point phenomena, which are the subject of Announcements of Opportunity. In addition, approximately one-third of the utilisation opportunities will be reserved for commercial applications.

Under the terms of the ISS Utilisation agreement, 8.3% of the Station's overall resources will be available to ESA and hence the European users. This extends to all types of resources, such as power, crew time, visibility periods, and data downlinking and uplinking capacity. If one assumes that the resources available to Europe are distributed evenly between the five most resource-demanding European facilities, namely the Materials Science Laboratory (MSL), the Fluid Science Laboratory (FSL), Biolab, the European Physiology Modules (EPM), and the European Drawer Rack (EDR), then the resources specifically available for the EDR will be as indicated in Table 2. This means, however, that at this stage the ISS resources required by the EDR to support and operate the payloads listed above, and have them operating in parallel,

would considerably exceed the projected utilisation share.

Ground segment

The EDR ground segment will be connected with the Erasmus User Centre in Noordwijk, designated as the Facility Responsible Centre (FRC) for the EDR, via the Interconnection Ground Subnetwork (IGS). The IGS facilitates all data exchange (science data, voice, video, telemetry/telecommand) between the Columbus Control Centre (Col-CC) and all of the User Support and Operations Centres (USOCs). The EDR ground segment will include three co-operating USOCs.

As discussed above, the Erasmus FRC will take full responsibility for the EDR as a system, but may delegate EDR experiment operations to the Belgian User Support and Operation Centre (B-USOC) and to the Dutch Utilisation Centre (DUC). The B-USOC and the DUC will assume responsibility for multi-user facilities accommodated within the EDR in one or more Drawers/Lockers, as Facility Support Centres (FSCs). The B-USOC will have permanent FSC responsibility for the Protein Crystallisation Diagnostic Facility and will focus on science mission planning and operations (Figs. 3 & 4).

The role and responsibilities of the Erasmus User Centre

The Erasmus User Centre will be responsible for EDR operation during both the mission-preparation and mission-execution phases, covering a variety of tasks:

– strategic and tactical planning
– payload integration
– payload operations preparation

Figure 2. The probable configuration of the European Drawer Rack (EDR) to be launched with the Columbus laboratory

Table 2. EDR resource allocations as a function of total ESA resources on the ISS

Type of constraint		EDR resource budget estimate	Estimate ESA resources on ISS	Unit
Mass	Envelope	500 (launch) < 650 (in orbit)		kg
	Upload, pressurised	200.0	1000.0	kg/year
	Download, pressurised	156.00	780.00	kg/year
	Upload, unpressurised	60.00	300.00	kg/year
	Download, unpressurised	60.00	300.00	kg/year
Crew		0.5 (empty) to 2 (full)	1.4-2.6 (initial) to 12.5 (steady phase)	hours/week
Power	Average	0.5 (< 3kW)	2.49 (30 kW for ISS)	kW
Data	Average data rate	< 0.71	3.57 (43 Mbps ISS)	Mbps
	Maximum low and medium rate	1.5	1.5	Mbps
	Maximum high rate	30	30	Mbps

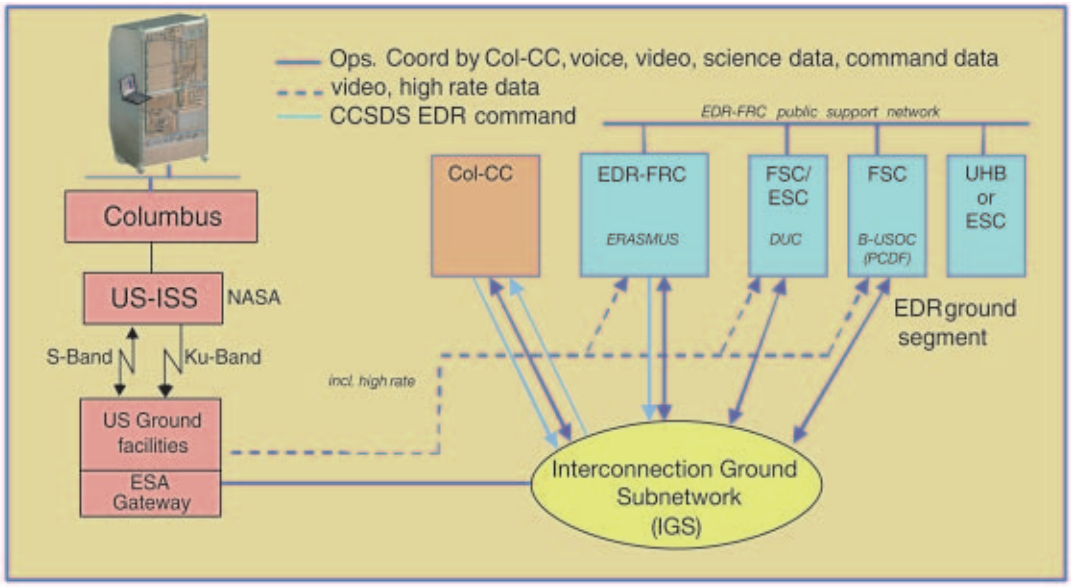

Figure 3. Connection of the EDR experimenter teams to the Erasmus User Centre

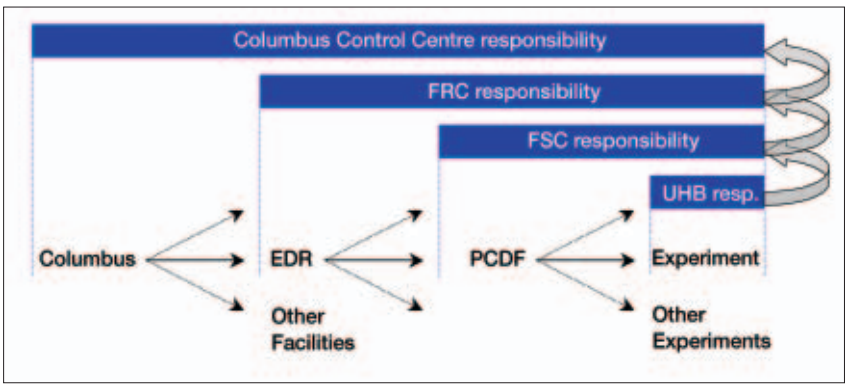

Figure 4. Division of responsibilities between the various EDR-involved centres

- operations support training
- payload execution-level planning
- payload operations execution
- facility health and status monitoring
- post-mission evaluation and post-mission-Increment operations
- reports and configuration management
- experiment preparation and promotion
- logistic support for experiment up- and down-loading.

Operational products will be an output from these tasks to the Columbus Control Centre prior to each new mission Increment.

Predefined resource envelopes will be allocated as part of the scheduling of experiments. Depending on the specific resource demands of the various experiments, several may be operated in parallel, or operations may be reduced during certain phases to a subset of the Drawers/Lockers. There may be up to four mission Increments (uploads) each year.

The EDR industrial developer will perform the initial payload integration for the Columbus launch, with the participation of the Erasmus FRC. For all subsequent Drawers and Lockers prepared during the in-orbit lifetime of the EDR, responsibility for flight acceptance will lie with the Erasmus FRC. The latter will also support the scientific investigators and payload providers during the development of their payloads, including provision of technical support for interface specification, operation concept definition and test verification.

The Erasmus FRC is responsible for analytical integration of each new Drawer payload, to ensure that the specifications and design will enable safe and correct interfacing with the EDR. The final step in the acceptance process is the physical integration of the Drawer/Locker instrument into the EDR engineering model located at the FRC. Once this final step has been completed and all associated tests passed successfully, the Drawer/Locker will be loaded into the relevant space-transportation vehicle that will bring it to the ISS. For Drawers, this is the MPLM which is launched in the Space Shuttle's cargo bay, whereas Lockers are launched in the Shuttle's mid-deck.

Workload

Utilisation bounded by 75% of EDR payload capacity during steady-state operation has been used to dimension the EDR support services. This is deemed to be a reasonable envelope based on the current EDR resource constraints and the assumption that continuous and simultaneous use of all Drawers will not be feasible:

- Most of the proposed experiment facilities for the EDR comprise more than one ISIS Drawer/ISS Locker, and typically use two. With seven slots for Drawers/Lockers, the number of teams that can operate in parallel will be three on average, and be limited to four.
- The number of Drawer/Locker exchanges is limited by the up- and down-load constraints

and limited crew availability for installation. With 200 kg of up-load capacity and 156 kg of down-load capacity available per year, this limits the annual exchange capacity to a maximum of three ISIS Drawers or four to five ISS Lockers.
– Crew time is an additional parameter that limits the number of exchanges that are feasible per year.
– The peak power and the communication bandwidth available are limited and have to be shared between the Drawers and Lockers being hosted.

A reasonable workload for the EDR ground-segment team has been estimated to consist of:
– The monitoring of two double Drawer/Locker and one single Drawer/Locker payload.
– The preparation of one Drawer exchange per mission Increment.
– The acceptance of one novel payload upload per year.

This overall workload will be shared between the Erasmus FRC and the B-USOC and DUC Facility Support Centres.

Special facilities

To support the development, qualification and in-orbit maintenance of EDR and its payloads, the Erasmus FRC will make use of the Payload Integration and Operation Reference Facility (PIORF). The PIORF is a representation of the end-to-end data-management system as seen by EDR and its payloads. It incorporates the EDR Electrical Engineering Model and provides a simulation of the Columbus data transmission protocols and support services. The Electrical Ground Support Equipment used during the development of EDR and of its payloads is used to operate them. Using the PIORF, it will be possible to validate changes to operations procedures, software updates or new payload experiments prior to deployment in the EDR flight segment.

The EDR FRC also plans to have at its disposal a number of items of transportable Experiment Ground Support Equipment (ExGSE) able to stimulate the power, cooling, and command and data interfaces of an experiment under development. These ExGSEs will be used to test and verify – without the need for access to the EDR flight or engineering models – that an experiment, once accommodated in the EDR, will work correctly and also respect the applicable interface and operational specifications and constraints. It is the intention that the ExGSEs will also be used to develop and test ground and on-board software.

An EDR and PCDF Virtual Model and Software Simulator will provide a flexible tool for the preparation and validation of EDR operational plans and experiment procedures and for the training of ground operators. As a secondary objective, it will help in the presentation and demonstration of the EDR's capabilities to potential users.

An EDR Multimedia Web Server will provide user-friendly access to:
– all the technical documentation required by the experiment developers

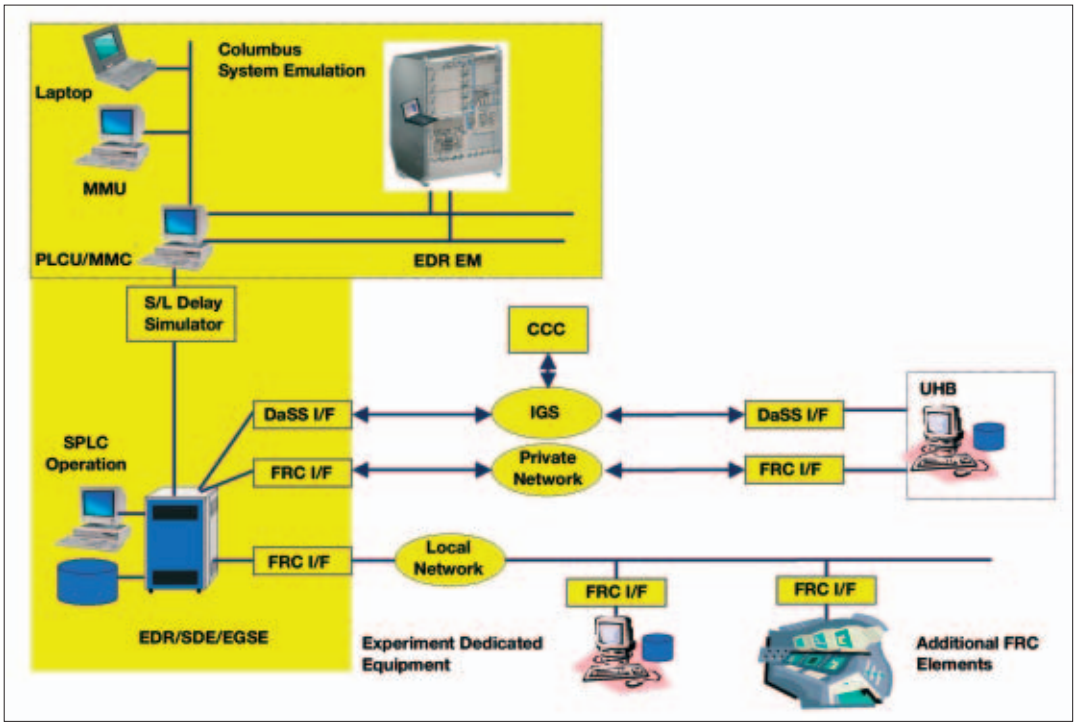

Figure 5. Ground Payload Integration and Operation Reference Facility (PIORF) to support the development and qualification of new EDR payloads

– the records of EDR flight events and of its in-orbit performance
– experiment data and video buffers and replays
– the knowledge acquired during the integration of EDR Drawers or Lockers
– EDR utilisation planning
– user training materials and plans
– an archive of valuable products and data.

The Server will also give access to multimedia products, such as 3-D animations, simulation videoclips, and 3-D images.

The above facilities will be developed under ESA's technical management by Belgian and Dutch industry.

Operating concept
The following functions will be executed by the EDR Facility Responsible Centre within the Erasmus User Centre at ESTEC:
– control over access to the ground and on-board services and resources
– monitoring of experiment resource consumption
– formatting and transmission of experiment commands, and generation and transmission of facility commands
– reception, archiving, display and distribution of housekeeping and science data
– generation, validation and uploading of experiment operation procedures and schedules
– integration and distribution of planning information.

The EDR experiments themselves will be designed to operate autonomously under the control of the experiment computer or EDR computer, which provide the means for experimenter intervention by telecommand (e.g. start/stop/suspend/resume experiment procedure, switch power supply on/off, switch cooling system on/off, upload files, etc.).

The principal elements involved (Fig. 6) are:

– the EDR PCCU based on the ESA Standard Payload Computer (SPLC) with its interface to EDR subsystems and Drawers/Lockers

– the EDR crew laptop computer

– the Electrical Ground Support Equipment (EGSE) of the SPLC providing the basic software environment for medium-rate telemetry and commanding via the ground-to-space link

– the Erasmus FRC server

– one or more clients at remote user locations, linked via the EDR FRC public support network or the IGS.

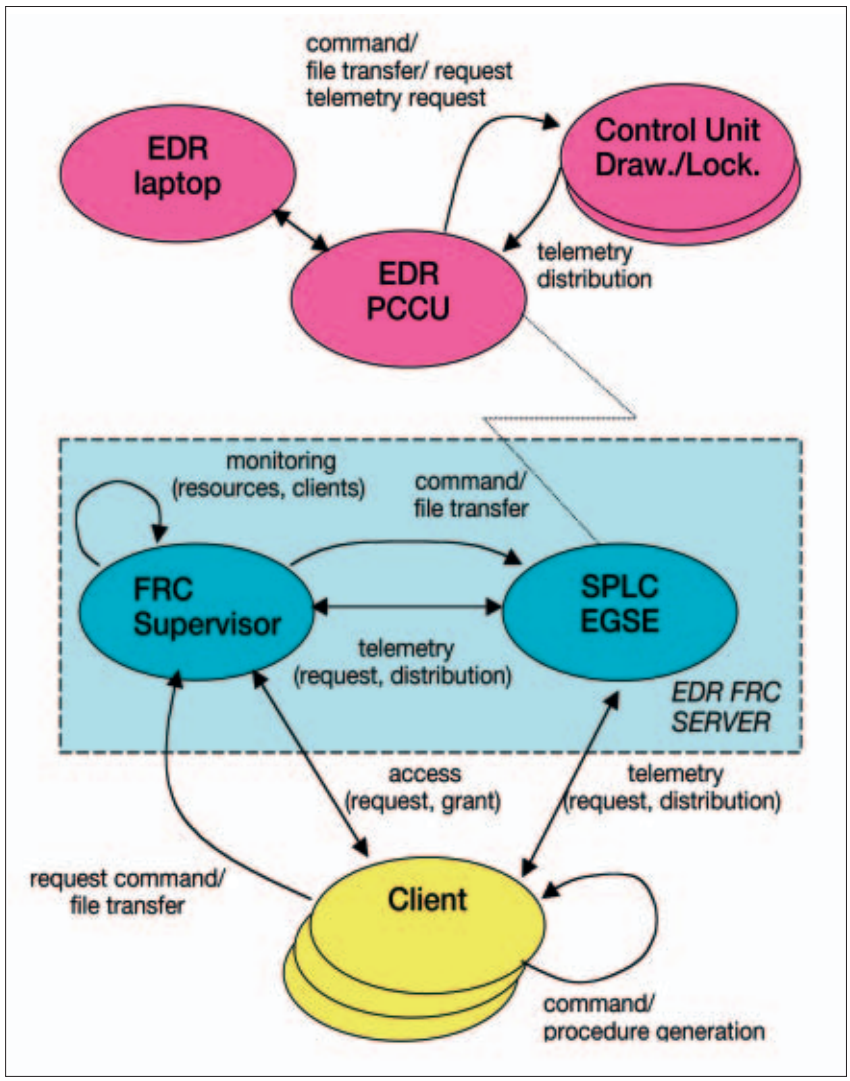

Figure 6. The concept of distributed EDR experiment operations using the client-server paradigm

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