The European Drawer Rack for the ISS and its Scientific Capabilities

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The European Drawer Rack (EDR) provides accommodation for small and modular experiments, as well as distributing Columbus laboratory services to the EDR payloads. One of its fundamental goals is to support the development of smaller sub-rack payloads through the provision of accommodation and flight opportunities for quick-turnaround missions. The EDR's design is oriented towards user-friendliness and flexibility of experiment accommodation and operation. This article describes its accommodation in the Columbus laboratory, the services that it offers to its payloads, as well as briefly addressing EDR operations and some of the logistical aspects of payload integration and exchange.

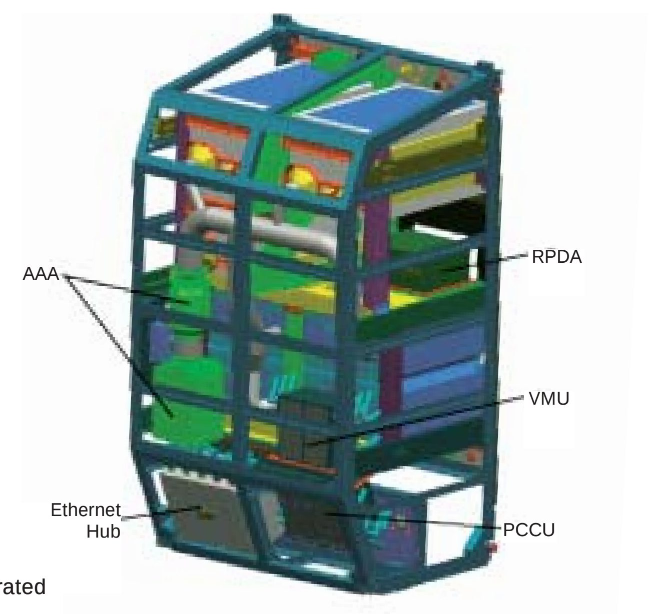
Figure 1a. Artist's impression of the EDR with two payloads (PCDF and FAST) integrated

The design concept

The European Drawer Rack (EDR) is part of the initial Columbus laboratory launch configuration. It incorporates International Sub-rack Interface Specification (ISIS) Drawers and ISS Lockers to allow the easy accommodation of small- to medium-size type payloads (so-called 'Class-II' payloads). This use of standard drawers and lockers will provide a rapid-turnaround capability and hence a greater number of flight opportunities for the user community. The EDR will include a first set of drawers and lockers equipped with experiments selected through European and international Announcements of Opportunity.

The EDR is a multi-user facility (Fig.1) that provides the infrastructure for accommodating and servicing Class-II payloads in an International Standard Payload Rack (ISPR). Modularity and standardisation have been major design drivers for the EDR, both to

Figure 1b. Rear of the EDR with major subsystems



provide a maximum of flexibility and interchangeability for the payloads, and to make optimum use of standardised technology development for the Space Station. At present the Rack can accommodate up to three ISIS drawers and up to four ISS lockers in parallel. In order to service a large number of small, quick-turnaround payloads, its design is optimised for the parallel accommodation of three to four payloads, i.e. each requiring an average of two drawers and/or lockers. A larger number of small payloads can always be accommodated, albeit with the possibility of resource distribution and utilisation restrictions. The resource management at EDR level includes the monitoring/supervision of resources to individual payloads, but not process control for individual experiments, which are in general expected to provide their own intelligence and processing capabilities.

Accommodation in Columbus

EDR will be accommodated in an International Standard Payload Rack (ISPR), manufactured by Ishikawajima-Harima Heavy Industries (IHI) of Japan, which is the current rack standard for European payloads on Columbus. The ISPR will be modified to allow locker accommodation and achieve compatibility with the ISIS standard.

The EDR will be launched with Columbus, with an initial payload complement integrated into the rack, to respect the 500 kg EDR launch-mass allocation. Once in orbit, the overall EDR mass will be limited by the mass-carrying capability of the ISIS drawers and ISS lockers to approximately 650 kg.

Resources provided by Columbus to the EDR include: main and auxiliary power, data uplinking and downlinking, thermal control, and gas and vacuum supplies and venting.

Major development challenges

During the EDR design phase, considerable effort has been made to maximise the number of standard containers (lockers and drawers) available to payloads. Simple payload exchange also requires that payloads be installed and removed by front access to the rack. This necessitated the accommodation of EDR carrier subsystems in the back of the rack, which in turn led to very crowded arrangements with serious difficulties in servicing and repair. Some design constraints and access requirements of standard equipment to be used by EDR turned out to be incompatible with the access constraints imposed by a tilted rack, so that finally one payload drawer ‘slot’ on the front of the rack had to be allocated to EDR subsystems.

The very limited space available for EDR subsystems and the constraints imposed by the standardised support equipment made it necessary to optimise the allocation of resources to payloads. It turned out to be impossible to route all available resources to all payload slots in parallel. Safety constraints also had to be respected. The actual routing of cabling and piping to payloads itself turned out to be a major design constraint. While ISIS drawers allow most electrical connections to be routed through self-mating connectors at the back of the drawer, the operating concept for ISS lockers necessitates that all resources except air cooling be connected to the front of the locker. This leads to a very large number of connectors – electrical, water, gas and vacuum – being on the front of the rack. Consequently, the assessment of resource distribution to EDR payloads is still on-going.

EDR services and resources

The distribution of centralised resources is mainly realised using five EDR subsystems:

- Power Distribution Unit (PDU)
- Process Control and Command Unit (PCCU)
- Ethernet Hub
- Video Management Unit (VMU)
- Avionics Air Assembly (AAA).

Water, nitrogen and vacuum resources are simply routed to so-called ‘Utility Distribution Panels’ (UDPs) at the front of the rack, but there are no active control elements in the EDR carrier for these resources, other than a manual shut-off valve for the nitrogen line. The payloads will have to provide the necessary connectors, jumper cables and piping to access the resources at these interface locations, as well as all payload-internal connections between drawers and/or lockers via the front of the rack. A laptop computer, which will not be physically integrated into the EDR rack, provides the main interface for the crew to monitor, control and command the EDR system.

Physical accommodation

EDR payloads are to be accommodated in combinations of standardised 8-Panel Unit ISIS drawers and/or ISS lockers, the main mechanical characteristics of which are given in Table 1. The exact combination of drawers and lockers depends on the EDR payload complement and has to be agreed with the EDR payload integrator. A first set of drawers and lockers will be procured as part of the EDR development effort and may be made available to users; subsequently, payload developers will be expected to procure their own drawers and/or lockers.

Power distribution
The EDR PDU receives Columbus main power at 120 V DC, converts it partially into 28 V DC and distributes both voltages to the EDR subsystems and drawer/locker interfaces. The PDU is based on the Remote Power Distribution Assembly (RPDA), which is an ESA standardised and configurable system. Each ISIS drawer will have a 120 V DC power connection to the PDU. At least one drawer supply will be rated for 10 A. The 120 V DC connectors to the drawers are self-mating at the back of the drawer.

There will be four 28 V DC/10 A outlets at the front of the rack, which are primarily intended to supply the ISS lockers. Three of these outlets are branched in parallel to self-mating connectors at the back of the ISIS drawers. However, for each outlet only one branch of the 28 V DC supply may be used at any time. The 28 V power supply thus becomes a time-lined resource.

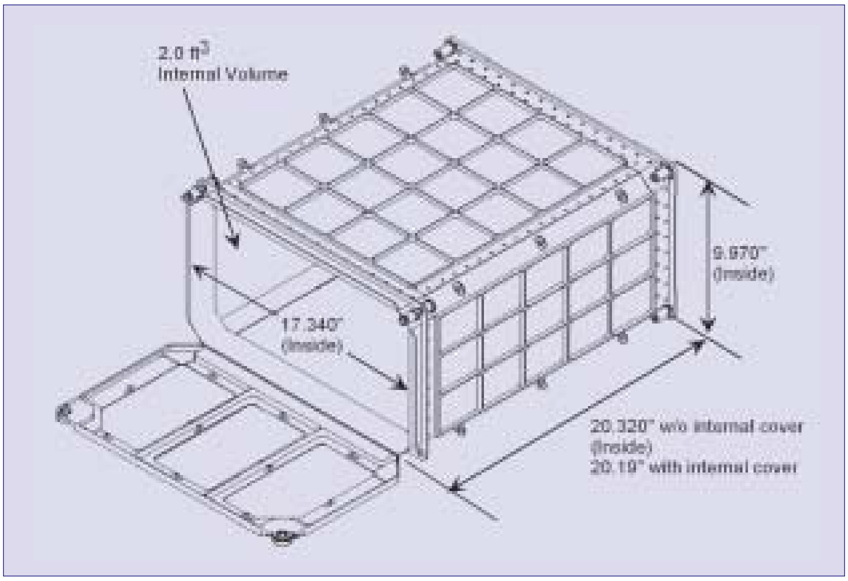


Figure 2a. ISS locker

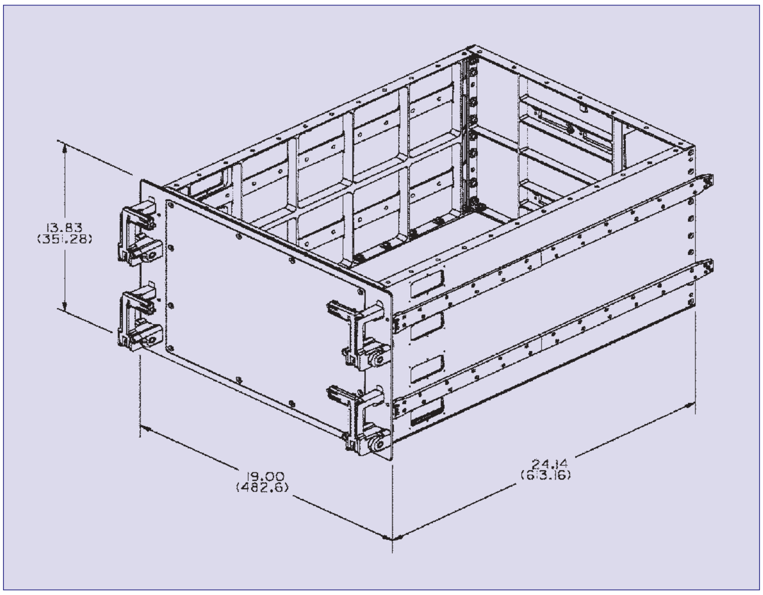


Figure 2b. 8-Panel Unit ISIS drawer

Table 1. Mechanical characteristics of ISIS drawers and ISS lockers

ISIS Drawer Characteristics	
Number of ISIS drawers in EDR	3 (8-PU size)
Volume per drawer available to users (L x W x H)	72 litres 574 x 387x 327 mm^3
Nett mass available to users	39.5 kg
ISS Locker Characteristics	
Number of ISS lockers in EDR	4
Volume per locker available to users (L x W x H)	57 litres 516 x 440 x 253 mm^3
Nett mass available to users	27 kg

The 28 V DC power supply is limited to 280 W per outlet. In principle, it will be possible to route more than one outlet to any given locker or drawer, but payloads wishing to use this feature would have to observe very stringent grounding requirements to avoid ground loops and cross-talk between power supplies. Similar considerations hold for the possible combination of 120 and 28 V DC supplies in any given ISS drawer. The overall power consumption of the EDR payload complement will be limited to 2200 W. Constraints imposed by the EDR thermal-control system may, however, limit the usable power to lower values under certain circumstances. In case of main power loss, approximately 600 W of auxiliary power can be made available to EDR payloads via a manual switch-over. Use of auxiliary power will usually be limited to thermally controlled storage, and must not be proposed for safety-critical operations.

Data handling and commanding
The central data processing system of the EDR, the PCCU, is a standardised system based on the Standard Payload Computer (SPLC). The PCCU software allows reconfiguration in orbit for each new payload increment by uplinking the necessary changes to the system and payload application software.

The main functions of the PCCU include:
- management of the communication interface with Columbus
- management of the laptop interface
- management of the communication interface with EDR payloads
- EDR monitoring and control at system level

- monitoring and control of EDR payload resources
- EDR subsystem management and control
- downlinking of EDR payload data (except high-data-rate connection, which uses the VMU described below)
- distribution of external commands (ground and/or crew) to payloads
- distribution of Columbus time and ancillary data to payloads.

The communication protocol to be used in between the EDR PCCU and the EDR payloads will be the NASA Express Rack protocol. The payload side of this interface has been developed as part of the SPLC industrial contract, and the relevant software will be available directly from the SPLC developer.

The sampling rate of the PCCU for payload housekeeping and scientific data is selectable up to 1 Hz. As EDR will in general accommodate autonomously operating payloads, only very limited processing capabilities will be provided for simple payloads that do not possess any dedicated intelligence. On the EDR Utility Distribution Panel there are connectors for the direct acquisition of four temperatures (thermistor voltages) and four discrete status signals. The EDR will also be able to send up to four discrete commands to such payloads.

The EDR PCCU receives Columbus ancillary data (e.g. loss-of-signal, GPS, microgravity values) and provides these data to EDR payloads as required. It also provides at least 50 Mbytes of memory for temporary storage of EDR housekeeping and payload scientific data, mainly intended for bridging communication outages.

Video Management Unit (VMU)

The EDR VMU is intended to handle a wide range of high-data-rate information from the EDR payloads, be it analogue video, digital video or any other high-rate digital data stream. To support this, it provides NTSC interfaces and IEEE 1355 high-speed serial lines. To limit the volume of downlinked data, the VMU allows one to select a reduced field of view (for digital images) and to perform data compression (both digital and digitised analogue images) using the JPEG standard. The VMU can also support uncompressed data transmission and video storage using any format, including 12- and 16-bit pixel depths. S-video compatible inputs may be displayed on the laptop computer connected to the EDR.

The VMU provides a mass storage capability of 72 Gbytes, the main application of which is expected to be the on-line storage of high-speed or high-resolution video, which cannot be transmitted directly to ground due to downlink limitations. After an experiment run, the user can identify particular frames, sequences, etc. for offline downlinking.

Thermal control

The EDR provides both air cooling and water cooling to payloads. The air-cooling concept is based on the AAA heat exchanger interacting with the Columbus primary water loop, while for the water cooling the primary water loop is directly routed to payloads. The overall thermal load to be dissipated from the EDR payload complement is limited to 2200 W.

The preliminary concept for EDR air cooling foresees that cold air exiting from the AAA heat exchanger will be blown into the back part of the EDR rack and will be routed to ISIS drawers through the gap between the drawers and the ISPR side walls. Each drawer requiring air will have air inlet grids on its side walls near the front of the drawer. For lockers, the air inlet will be at the back of the locker (‘rear breather’ concept). An air outlet at the back of each drawer/locker will be connected by tubing to the AAA fan, which will suck the exhaust air from each air-cooled box.

The amount of air cooling made available to EDR payloads will depend on the sharing with water cooling for each payload configuration. However, the maximum amount of air cooling that can be made available to the EDR payload complement is presently limited to 700 W. The maximum cooling-air flow rate available to a single EDR drawer/locker is 1500 litres/min.

There are two sets of water connections (two inlets and two outlets) at the Utility Distribution Panel on the front of the rack. The water from the Columbus ISPR interface will be routed directly to these interfaces. Payloads utilising water cooling will have to regulate their throughput to a 0.4 bar pressure difference between inlet and outlet for the maximum water flow rate anticipated. Payloads requiring dynamic flow control of cooling water will have to provide this capability internally. The maximum cumulative heat load that may be dissipated on both sets of water interfaces is 2000 W.

EDR control via the laptop

The EDR laptop will serve as the primary interface between the flight crew and the EDR with its integrated payloads. The laptop supports all functions necessary to monitor and control the EDR, its operation and its resource-usage envelopes, including the ability to control and command experiments. Although under nominal conditions the EDR should not require crew support, the laptop provides a standardised 'look-and-feel' Human Computer Interface (HCI) for facility control as commonly defined for the Space Station.

Fire detection and warning
The EDR will incorporate a smoke-detector assembly, which will serve as the primary fire-detection tool for the EDR system and all air-cooled payloads within it. In addition, the EDR payloads are advised to include parameter monitoring to give advance warning of a potential fire condition.

EDR payloads that do not make use of air cooling and do not provide adequate air exchange with the AAA will have to base their own fire detection exclusively on parameter monitoring. The payload providers will be responsible for verifying the adequacy of such parameter monitoring via their own safety-review process.

EDR fire suppression will be accomplished through the interface for the Portable Fire Extinguisher on the Fire Detection and Suppression Panel installed on the front of the EDR.

EDR operations
The key to efficient payload operations onboard the ISS will be optimum use of available resources, including power, cooling, telemetry, commanding, crew support, etc. all of which must be shared. As indicated in Figure 3, resources will be allocated hierarchically, starting at the overall ISS level, then to each partner's module, and finally to individual payload facilities. As one of the main drivers for EDR is to allow concurrent experiment operation, resources must be further shared among individual instruments resident in the EDR drawers and lockers. While at the ISS level resources will be relatively firm, a certain flexibility may be expected in the allocation available to a particular facility at any given time.

The EDR utilisation scenario relies on close co-operation between the supporting ground facilities. These include the Facility Responsible Centre (FRC), which is in charge of the overall EDR, and the User Home Bases (UHBs), which are dedicated to the support of individual payloads or experiments. These centres will together be responsible for preparing the EDR operations plan, and controlling and processing housekeeping and science return data.

The EDR is intended to support a relatively quick turnaround for 'small' payloads. It will be possible to exchange complete drawers or lockers (while EDR is powered down) without requiring modification to existing payloads or to the core facility. Such flexibility requires an implementation approach whereby the majority of the intelligence for payload operation is delegated to the individual payloads, with the EDR dedicated to resource allocation and initiation and monitoring of experiment execution.

The software and communications architecture allows in-orbit uploading and reconfiguration of both the EDR and experiment-container software. The main element of the carrier software is the EDR timeline, responsible for the overall scheduling of experiment- and EDR-related software sequences dedicated to the control of individual subsystems and experiments.

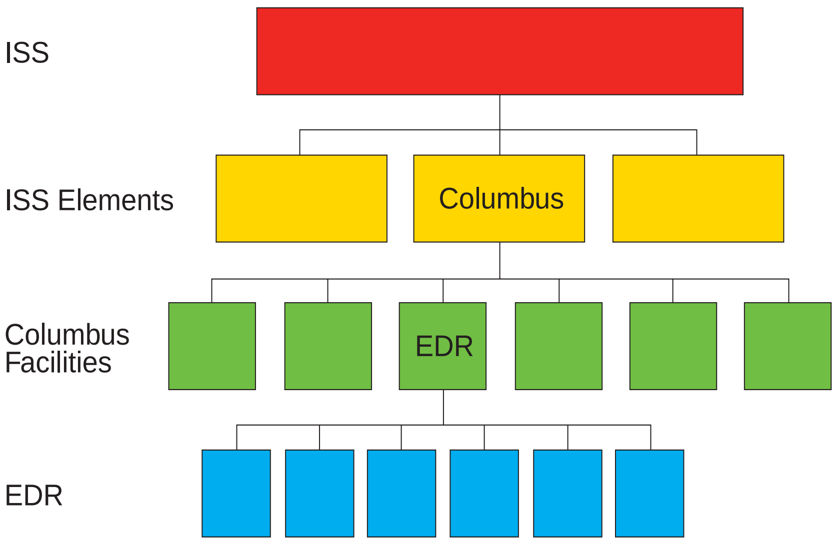


Figure 3. Space Station resource distribution

The master timeline element will be established according to a given EDR operations plan. The latter, which will be verified on the ground, will provide the best match between available EDR resources and those required for experiment execution, the goal being to maximise the number of experiments in concurrent operation.

A key EDR feature will be the ability to control experiments from the ground, allowing any combination of automatic and interactive (telescience) modes of execution.

EDR logistics
The EDR and its initial payload will be integrated into the Columbus laboratory as part of the initial payload complement, termed the 'EDR 1st Mission'. In parallel with this first mission, the preparation and ground testing of new payloads/experiments will result in new

drawers and lockers to be transported to orbit. Transportation of ISIS drawers will nominally be in a NASA Express Transport Rack (ETR) in the Multi-Purpose Logistics Module (MPLM). For the ISS lockers, the nominal means of transport will be the MPLM for unpowered lockers and the Space Shuttle mid-deck for those requiring power during transport.

Drawers and lockers will be exchanged in orbit and payloads/experiments will be processed as part of so-called 'EDR Follow-on Flights'. This implies an on-board configuration evolution, and maintenance of the subsystems and components. A payload utilisation plan will define and schedule the uploading/down-loading of EDR payloads and reconfiguration activities.

EDR payloads will be tested on the ground at various sites at drawer/locker level, using dedicated support equipment to emulate the EDR interfaces. Payload developers will therefore have to deliver ground models of their payloads to the Facility Responsible Centre (FRC), to remain in the EDR ground model for future reference testing as long as the related flight model is in orbit.

Outlook for the EDR

At the time of writing, the EDR Preliminary Design Review (PDR) is being prepared. The EDR flight unit is expected to be delivered for initial payload integration in early 2003.

The EDR's flexible design will allow shorter mission-preparation times than the 'classical' multi-user facilities and provide quick return and delivery of mission products. The payload testing and integration process is expected to be both fast and easy, and payload processing onboard of the Columbus laboratory should make optimum use of the resources allocated to the scientific users. The payloads themselves are being designed for fast and frequent turnaround, moderate use of resources, and flexibility of operation in order to fully exploit the EDR principles of payload exchange and parallel operation of small- and medium-sized payloads.

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