



Fluids and Combustion Facility—Fluids Integrated Rack

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FLUIDS AND COMBUSTION FACILITY - FLUIDS INTEGRATED RACK

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Abstract

The Fluids Integrated Rack (FIR) is a modular, multi-user facility to accommodate a wide variety of microgravity fluid physics science experiments on-board the US Laboratory Module of the International Space Station (ISS). The FIR is one of three racks comprising the Fluids and Combustion Facility (FCF). The FCF is being designed to increase the amount and quality of scientific data and decrease the development cost of an individual experiment relative to the era of Space Shuttle experiments. The unique, long-term, microgravity environment and long operational times on the ISS will offer experimenters the opportunity to modify experiment parameters based on their findings similar to what can be accomplished in ground laboratories. The FIR concept has evolved over time to provide a flexible, "optics bench" approach to meet the wide variety of anticipated research needs. The FIR's system architecture presented is designed to meet the needs of the fluid physics community while operating within the constraints of the available ISS resources.

Introduction

The Fluids and Combustion Facility (FCF) will consist of two major research facilities, fluid physics and combustion physics, sharing three International Standard Payload Racks (ISPRs). The ISPRs comprising the FCF have been designated the Combustion Integrated Rack (CIR) (reference 1), the Fluids Integrated Rack (FIR) and the Shared Accommodations Rack (SAR) (Figure 1). Paramount to the FCFs flexible design is the ability for the FIR and CIR to function independently as single "integrated" racks allowing for early science research opportunities (accommodating ISS launch manifests) and maximizing early on-orbit opportunities when ISS resources may not support two/three rack operations.

The CIR is the first of the three FCF ISPRs to operate on ISS, currently manifested to be launched aboard Utilization Flight #3 (9/2001). The FIR is next scheduled to fly less than a year later on Utilization Flight #5 (6/2002) and will join the CIR in single "integrated" rack operations. The SAR will follow more than two years after the CIR launch (UF 7) and will provide the CIR and FIR enhanced avionics and experiment support equipment required to meet the full set of facility science requirements.

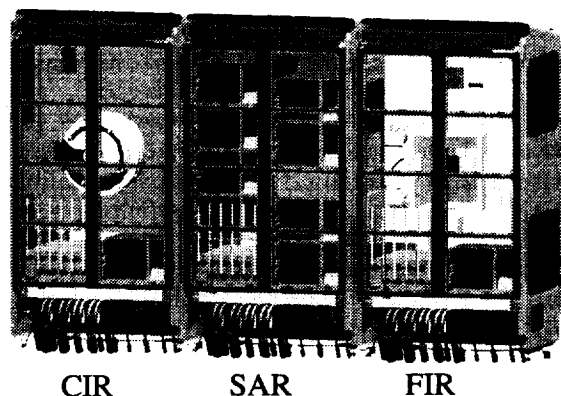


Figure 1 - Fluids and Combustion Facility

The FCF shall be designed to operationally support a minimum of 100 Principle Investigator (PI) experiments over a ten-year period after the assembly of the International Space Station and FCF is complete. To sustain this average of 10 PIs per year, the FCF will be designed to keep PI hardware development costs in the range of \$2M per PI experiment. Also, the upmass (mass that is launched to ISS) per PI will need to be less than 75 kg. This is significantly less than past experiments developed for use in prior pressurized science carriers such as Spacelab and Spacehab. FCF developers are challenged to meet these requirements for an effective research facility for the fluids and combustion communities.

Mission: Fluid Physics Research

Sustained, systematic fluid physics research in a microgravity environment provided by the ISS is the principle mission of the FIR. Fluid physicists can use the unique long-term microgravity environment of ISS to isolate and control gravity-related phenomena, and to investigate phenomena and processes that are normally masked by gravity effects and thus are difficult to study on Earth. The FIR can be utilized to better understand the physical principles governing fluids, including how fluids flow under the influence of energy, such as heat or a magnetic field; how particles and gas bubbles suspended in a fluid interact with and change the properties of the fluid; how fluids interact with solid boundaries; and how fluids change phase, either from fluid to solid or from one fluid phase to another.

The universal nature of fluid phenomena makes their study fundamental to science and engineering. Fluids microgravity experiments can provide a unique insight into the behavior of multi-phase flows, boiling, condensation, colloid physics, and surface tension controlled flows. These insights are vital to understanding, controlling, and improving many processes, such as:

- improving materials processing,
- understanding of how pollutants are transported and dispersed in air and water,
- improve the stability and performance of power-generating stations,
- prediction of near and long term weather patterns,
- fluid flow in the human body and other living systems.

Fourteen experiments were selected to represent the vast fluid physics experiment possibilities from the current microgravity science ground and flight experiment program. These experiments provide an "envelope" of types of measurement techniques currently envisioned by the scientists. These fourteen experiments cover four major areas in fluid physics research:

- Complex Fluids (colloids, gels, foams, magneto-rheological fluids, and granular systems)
- Multiphase Flow and Heat Transfer
- Interfacial Phenomena
- Dynamics and Stability (drop dynamics, capillarity, & magneto/electrohydrodynamics)

A significant effort in gaining a clear definition and understanding of these science experiments and associated requirements has been extremely important to develop the overall FIR system architecture and associated services.

Carrier: International Space Station

The International Space Station (ISS) differs from the Space Shuttle science platform used in the past in that ISS provides a long-duration laboratory that will provide unprecedented opportunities for science, technology, and commercial investigations in a microgravity environment. The FCF will be located in the United States Laboratory (US Lab) module of the ISS. The US Lab will provide a pressurized, controlled environment with resource provisions (communications, power, cooling, etc.) routed to each system and payload location (Figure 2).

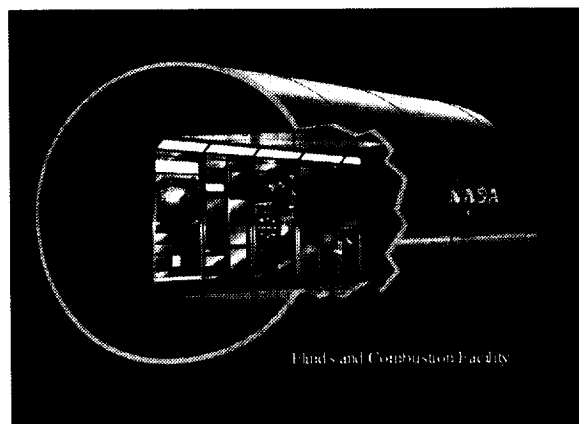


Figure 2 - FCF in ISS US Laboratory

The FCF depends on the ISS to provide the essential resources to perform scientific investigations. Typical ISS resources used to design the FIR are shown in Table 1. Current ISS resource estimates to FIR are due to the fact that ISS is also being developed in parallel. It is conceivable that the ISS resources available to support FIR may exceed the maximum limits identified during the operational life of the facility. Every effort has been made to assure that the utilization of additional resources is not precluded by the FCF design.

Typical FIR Resources Provided by ISS

Rack Volume	ISPR (~ 1.6 m ³)
Rack Upmass	700 Kg/rack
Resupply Upmass	300 Kg/yr
Resupply Flights	2 - 4 Year
Power (typical)	1.5 KW @ 120 Vdc
Power (peak)	3 KW
Energy	~5000 KW-hr/yr
On-Orbit Stowage	~ 0.5 ISPR
Thermal Cooling	1.5 KW
Crew Time	50 -100 hrs/yr
Downlink (avg)	3 Mbits/sec
Microgravity	10 ⁻⁴ g's (w/o ARIS)
ISS Services	Vacuum
	Overboard Vent
	GN ₂ Supply

Table 1 - ISS Resources

Fluids Integrated Rack

The system architecture for a space station facility to perform fluid physics experiments has gone through various iterations to achieve the science needs and evolving space station vehicle accommodations.^{2,3} Direct interaction with fluid physics scientists, selection of an initial set of Principle Investigators, maturity of the ISS, and commonality with the CIR architecture has led to the current FIR concept.

The FIR concept (Figure 3) is based on a "carrier" approach that provides common services needed by nearly all fluids physics researchers to minimize the hardware required to be developed and launched for each experiment. Since a majority of hardware is reused, the FIR concept saves both development costs and total upmass required to perform the experiments.

The FIR system derived from the science requirements and the ISS requirements has the following subsystems determined to be essential to perform the microgravity fluid physics experiments:

- ISPR/Structural Subsystem
- Active Rack Isolation System (ARIS)
- Optics Bench
- Diagnostics
- Electrical Power Subsystem
- Environmental Control Subsystem
- Command and Data Management Subsystem
- Experiment Specific Hardware

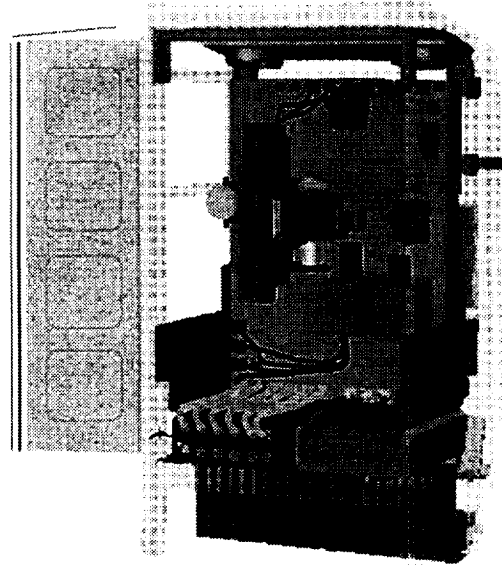


Figure 3 - Fluids Integrated Rack

ISPR/Structural Subsystem

The ISPR/Structural Subsystem performs load transmission, mechanical vibration attenuation, acoustic emissions attenuation, physical containment, and physical access functions associated with the transport and operation of the facility. The FIR Rack utilizes the NASA International Space Station Rack (ISPR) as the basic structure for payload equipment to provide an enclosed volume of approximately 1.6 m³ and supporting 700 Kg of mass (Figure 4). The ISPR has a bowed back to provide maximum volume if properly utilized and mounts directly into the ISS US Lab (Figure 5). The ISPR is designated a "Dash 4" rack since it does not utilize two drawer support posts in the centerline of the rack. This allows for a more open rack and thus, has only four support posts. Each post of the NASA ISPR includes provisions for structural mounting of payload equipment.

The lower portion of the ISPR provides a utility pass-through area for routing utility lines between the payload rack and the US Lab utility interface panel and between adjacent racks (Figure 5). The ISPR accommodates inter-rack connectivity such that utility lines may be routed through the pass-through area to the cutout located at either of the lower rack sides. The FIR will utilize this cutout to interface key data and communication lines with the SAR.

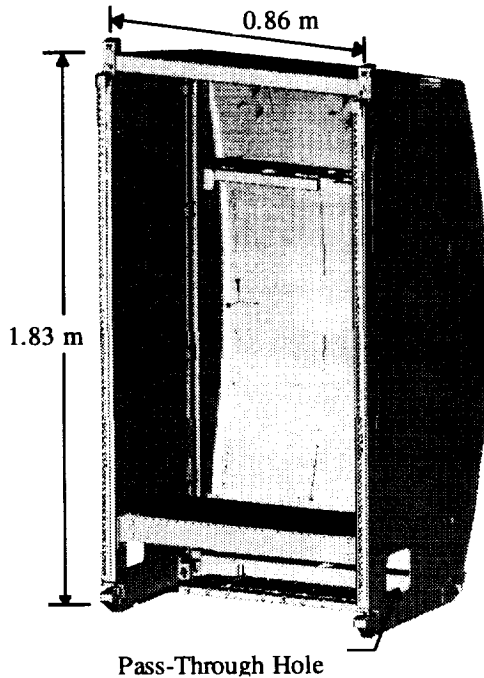


Figure 4 - Four Post ISPR

The front of the ISPR will be sealable via a door to prevent exchange of dust, particulates, and other materials with the US Lab cabin, provide containment of the air for thermal control and fire suppression, and also to minimize acoustic and thermal impacts to other US Lab users. The door is composed of segmented panels mounted in a bi-fold hinged frame that also provides rack structural stiffening and load distribution during transport to/from orbit. The segmented panels will allow for physical mounting of status panels and provisions for attachment of other monitoring devices, such as an operational video monitor.

In addition to the rack closure door, additional structural components are required to stiffen and strengthen the rack to accommodate 700 Kg of payload mass and meet the minimum natural frequency requirement of 25 Hz. These stiffening components are being evaluated as integral parts of other subsystems, such as the thermal control unit to minimize mass and package interferences.

Active Rack Isolation System

FIR experiments will be sensitive to motion and vibration induced by other ISS systems, users, the crew and associated ISS activities, such as docking, EVA, thruster firings, etc. In order not to disturb these experiments, ISS designers have

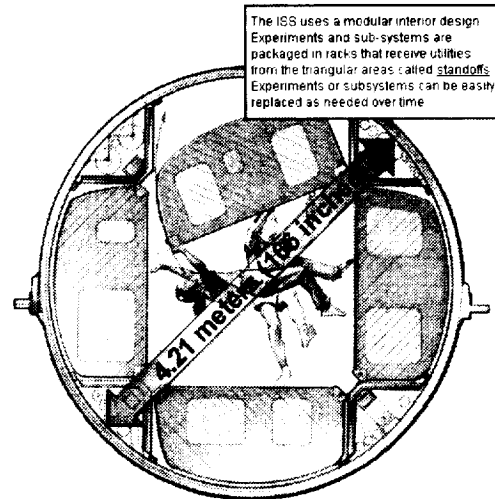


Figure 5 - ISPR Mounting in the US Lab

developed the Active Rack Isolation System (ARIS) to isolate the ISPR from major mechanical disturbances that might occur on the ISS, essentially acting as a shock absorber. ARIS provides the unique ability to 'float' an entire ISPR and isolate it from external vibration sources with minimal encroachment on internal rack volume through an electronic sensing and control of eight electro-mechanical rack isolation actuators. ARIS provides rack level attenuation of on-orbit low frequency/low-amplitude mechanical vibrations transmitted from the US Lab to the FIR rack when science operations are conducted.

Optics Bench

The FIR provides the Principle Investigator (PI) with a Laboratory style "Optics Bench" on which an experiment will be configured. The optics bench features the capability to remove and replace different PI specific experiment packages. The optics bench approach is a common feature between the CIR and FIR designs. This unique design offers the advantage of utilizing the surface area on both sides of the bench and the entire ISPR volume. The optics bench folds down to allow access to science support packages located on the back side (Figure 6).

The optics bench spans two thirds of the ISPR (Figure 3). The optics bench provides nearly one square meter of surface area on the front for which experiment hardware may be configured. The plate on the front will provide an optical precision alignment surface and a stable thermal environment. This front optics plate serves as the

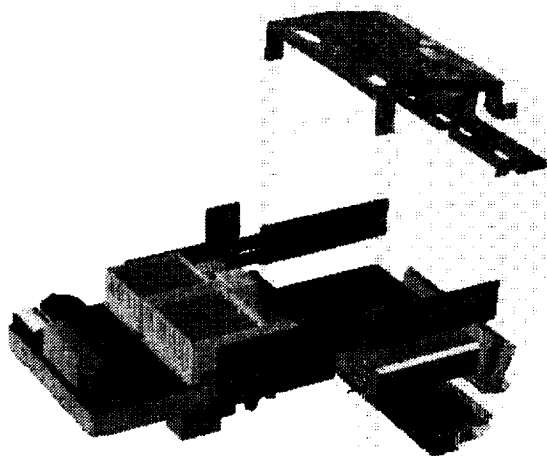


Figure 6 - Access to Optics Bench Back

mounting platform for the optics, samples, and experiment-specific packages.

Standardized interfaces will be utilized to permit flexibility in equipment placement and replacement/upgrades, including standardized mounting and electrical connections. The standard interfaces will provide electrical power, video and digital data acquisition, and control. Electrical harnessing and tubing will be inside the plate (similar to walls in a building) to provide maximum volume for the experiment and simplify crew interfaces. Feedthrough hole locations are provided on the optics bench as a means to route unique cables and laser fiber cables to the science hardware.

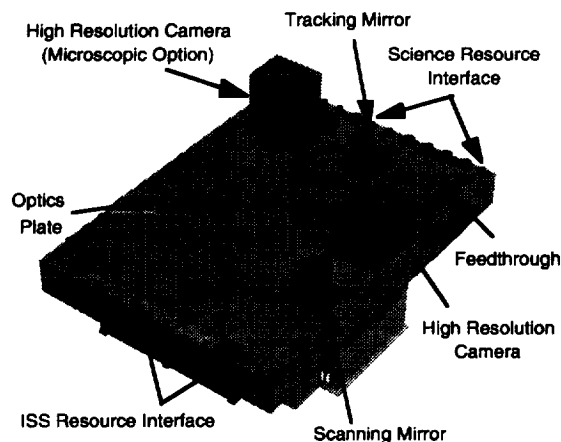


Figure 7 - Front Side of FIR Optics Bench

The back of the optics bench is dedicated to mounting several multi-function, non-intrusive optical diagnostics packages, and science avionics support packages to be described below. The diagnostic and avionics packages mounted on the back generate the most heat and are thus isolated to provide a better temperature-controlled environment for the science investigations (Figure 8).

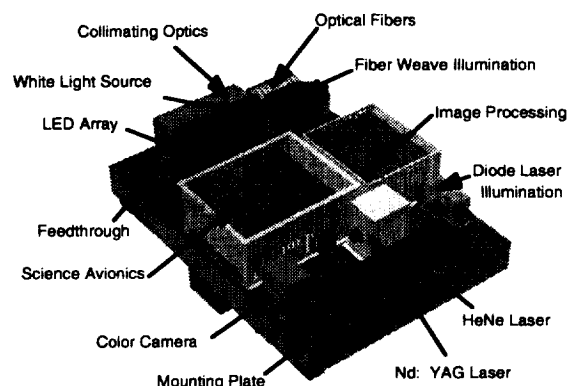


Figure 8 - Back Side of FIR Optics Bench

Command and Data Management Subsystem

The FCF FIR Command and Data Management Subsystem (CDMS) includes all hardware and software to provide command, control, health and status monitoring, data acquisition, data processing, data management, timing and crew interface functions for the FIR (Figure 9). The FIR CDMS consists of three major packages: the Input/Output Processor (IOP), the Fluids Science Avionics Package (FSAP), and the Image Processing Package (IPP). The IOP is located in a drawer below the optics bench. The other two packages (IPP, FSAP) are located on the back of the optics bench. All of the packages are air cooled by the Environmental Control Subsystem. The overall approach to the CDMS development is to utilize commercial off-the-shelf computer cards and associated support electronics to the extent practical.

The FIR's master control is provided by the Input/Output Processor (IOP) which provides command processing, control, resource allocation, data processing, caution and warning, software and data table upload and timing functions. The IOP will perform data acquisition of system, environmental and ancillary sensor data to provide rack health and status information. In addition, the

IOP will process and transmit data in support of the fluids science

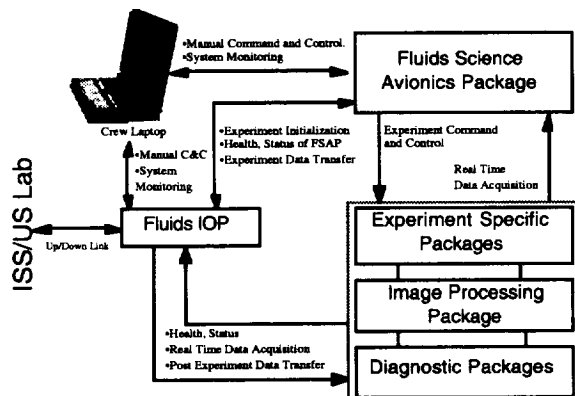


Figure 9 - CDMS Architecture

including experiment sequencing, and control of predetermined functions. The IOP will function as the rack interface to the ISS by supporting the High Rate Data Link (HRDL), Ethernet, and MIL-STD-1553 interfaces.

The Fluids Science Avionics Package (FSAP) is a data acquisition and control package that will provide an enhanced set of science I/O, controllers, and signal conditioning capable of supporting a wide array of fluid science categories. The FSAP will provide closed loop control of the science experiment packages that include controllers for motion and temperature, support of motorized positioners and Thermo Electric Coolers (TEC), and interfaces for specialized devices such as Photomultiplier Tubes and Avalanche Photodiodes. Signal Conditioning will also be provided to support measurement devices such as thermocouples and transducers to measure pressure, strain, force, and flow rates. Additionally, the FSAP provides storage of the acquired data and is capable of transferring the data to the IOP for subsequent downlink.

The FIR will support the capability of providing extensive image acquisition, processing and management, as is typically required for fluids physics experiments. There will be one Image Processing Package (IPP) housing two Image Processing and Storage Units (IPSU) to provide this capability. The IPP provides the image capture and processing for two high-resolution digital cameras. Each camera interface consists of a PowerPC based single board computer, a MIL-STD-1553B communications interface, an Ethernet communications interface, image collection,

processing, and memory cards, and a removable 9 GB hard drive of which 7 GB will be available for image storage. The IPSU will be capable of collecting data at 40 Mbytes / second nominally. Data can be passed from IPSU memory (256 MB) to a more permanent storage area or directly to the IOP for downlink. The IPSU will store video data in a digital format. The data acquired will be compressed (if required) to reduce memory and transfer bandwidth and processed to support closed loop control scenarios such as focus, zoom, and particle auto-track capability.

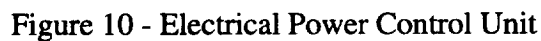
Electrical Power Subsystem

The FIR Electrical Power Subsystem (EPS) consists of an Electrical Power Control Unit (EPCU), cables from ISS to the EPCU, harnesses from the EPCU to user/facility loads, and associated interface connectors. Electrical power from the ISS is controlled and distributed throughout the FIR by the EPCU Package. The EPCU performs electrical power conditioning, optimized distribution, switching, and fault protection for the FIR.

The water-cooled EPCU is located next to the IOP and is also in a drawer. The EPCU is controlled and monitored by the IOP through a MIL-STD-1553B redundant interface.

The EPCU is an integrated power system building block (Figure 10). Two ISS 120 VDC power buses come into the FIR from ISS and are routed directly to the EPCU. The EPCU is capable of regulating the voltage to 28 VDC at an efficiency of 92%. The EPCU contains 3 kW of 120 VDC to 28 VDC converter capability in three 1 kW blocks. Any combination of two or three converters can be operated to proportionally load share power. All three converter outputs combine their power onto a common 28 VDC power bus. If an ISS bus failure, or some other failure occurs, the EPCU will shed only the required load necessary to remain below assigned bus power allocations. Load sharing between the two ISS power buses offer greater power management and scheduling flexibility. Based on science mission objectives, priorities can be assigned to each load connected to the EPCU.

The EPCU switches 48 different channels and current limits each channel to 4 amps. For crew safety, all twelve EPCU front panel output connectors are 28 VDC. Except for length, all 28 VDC four circuit cables are interchangeable and connect to the EPCU front panel connectors which are identical for reconfiguration flexibility. If necessary, limited 120 VDC from the EPCU rear



The cameras will accommodate various fixed focus and motorized zoom lenses that can be



The purpose of providing illumination sources in the FIR is to enable the cameras to obtain meaningful images of scientific phenomena, and to enable the execution of specific diagnostic techniques, such as light scattering. The illumination sources will consist of white light, laser light, and collimated laser beams. The illumination sources provided will be at a light intensity level at the test cell compatible with the

sensitivities of the selected cameras required by science. The light from each source will be transmitted to the experiment through an optical fiber; each fiber will have an industry standard optical fiber interface which is accessible from the front of the Fluids rack. The use of fiber optics also helps isolate the test cell from the heat that the light source generates. The exceptions to this are PI-provided diode lasers, which may be integrated with the experiment but will be powered by the facility-provided diode drivers

The facility will provide white light sources (gas-filled or halogen bulbs) in order to meet the requirement for acquiring color images as well as the requirement for preventing "ringing" in the image caused by light that is highly coherent. The facility will provide a range of light intensities, between 0.01 mW/cm² and 0.3 mW/cm², at a 10 cm by 10 cm area test cell. The white light sources will be delivered via an optical fiber to a woven fiber backlight which will provide uniform lighting while requiring only minimal volume (Figure 12). In addition, an LED array will be provided for short exposure times or high-frame rate imaging, as well as continuous backlighting. The LED array will illuminate the test cell directly by being positioned on the optics plate.

In addition to the white light sources, the facility will provide six lasers. The FIR provided lasers consist of a Nd:YAG, HeNe, and two pairs of laser diodes with associated driver modules. The Nd:YAG is a high quality, diode-pumped, solid state laser whose wavelength is 532 nm with a laser power of at least 60 mW from the optical fiber. The Nd:YAG beam will provide a laser suitable for critical applications, as well as sufficient power to illuminate relatively large test cell areas. A 1.0 mW single mode HeNe laser (633 nm is linearly polarized with a polarization ratio of greater than 500:1) will provide low-power laser light suitable for critical applications such as interferometry. The HeNe's laser output beam power is fixed, requiring the user to optically attenuate the beam at the output

Two pairs of laser diodes are available for illuminating large test cell areas when the beam structure is not critical. These laser pairs have a wavelength of 680 nm and 770 nm with a linewidth of less than 0.15 nm. The power delivered by each of these lasers is at least 10 mW at the test cell. The diode lasers output intensities can be attenuated by lowering their drive currents to accommodate a wide range of needs. Four well-conditioned power supply modules (diode drivers) will be provided in order to support the FIR laser

diodes and PI-provided diode lasers. This allows the FIR to accommodate some PI-specific requirements which are not met by the facility-provided lasers.

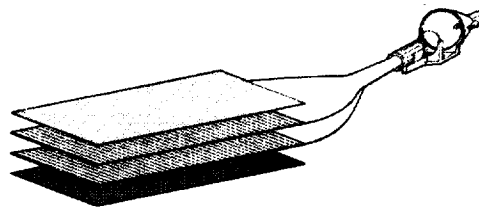


Figure 12 - Woven Fiber Backlight

Environmental Control Subsystem

The Environmental Control Subsystem (ECS) performs thermal control, fire detection, fire suppression, and gas distribution functions associated with the operation of the FIR. The FIR's thermal energy is removed directly through thermal transfer to water or indirectly through a forced convection air system. The thermal loads are rejected to the Space Station Internal Thermal Control System (ITCS) using the Space Station Moderate Temperature Loop (MTL). The thermal subsystem will be designed to remove up to 3.0 kW of waste thermal energy from the Fluids Integrated Rack.

The thermal control subsystem consists of a distributed network of plumbing to carry supply and return water flow to and from the FIR hardware, including the air-to-water heat exchanger at the top of the ISPR (Figure 13). The heat exchanger removes waste thermal energy (nominally 1500 Watts) using the ISPR internal atmosphere as the medium for thermal energy transfer. This is the main vehicle for removing bulk heat from the FIR. Air-cooled packages will be supplied with cooling air ranging from 30° C (86° F) to 43° C (110° F). The heat exchanger package consists of a set of impeller fans driving hot air over the air/water heat exchanger which includes air filtration (~300 micron) to remove the bulk of particulates that infiltrate into the airstream. The fans provide generic air flow down the front of the optic bench, though the IOP and under the plate and up the back, thus cooling the packages in the air stream. For components requiring a precise control of temperature, thermoelectric coolers, localized fans and or heat sinks will be used. The optics bench has two cold plates integrated into the optics plate to provide PI cooling, if required.

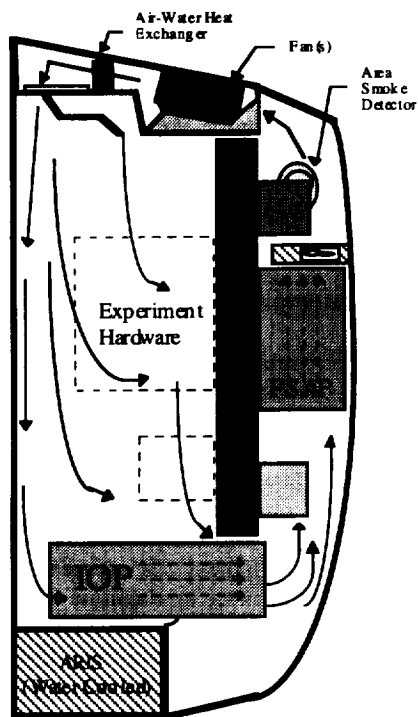


Figure 13 - Air Thermal Control

Current baseline nominal heat removal rates are as follows.

Air Cooled	1364 Watts
Cold Plates	200 Watts (PI hardware)
EPCU	105 Watts (water cooled)
ARIS	26 Watts (water cooled)
Total	1755 Watts

The fire detection package senses the presence of particulate products of combustion in the ISPR internal atmosphere and provides a fire event signal directly to the ISS Caution and Warning (C&W) System. Smoke detection is performed in the heat exchanger package by placing the sensor in the return air stream. Fire suppression is supplied by crew operated ISS Portable Fire Extinguisher (PFE) consisting of CO₂ canisters. Inlet ports on the front/top of the FIR allow crew members to connect the CO₂ canisters to the rack to reduce the oxygen concentration in the free volume of the FIR in which a fire event has occurred.

The gas distribution package provides access to ISS gaseous nitrogen, vacuum exhaust, and vacuum resource services through an interface panel. A convenient location for the FIR interface panel is currently being evaluated. The panel will provide one quick disconnect for each resource.

Flexible umbilicals will be used to interface with experiment specific hardware.

Experiment Specific Hardware

The FIR features the capability to remove and replace different PI specific experiment packages. The PI experiment specific package(s) may consist of a single self-contained unit and/or several separate components. The PI hardware will typically be a unique design, but may re-use hardware and designs from previous experiments. A set of similar experiments investigating common phenomena and/or using similar diagnostics may permit the development of a "mini-facility" that can accommodate multiple PIs to significantly lower overall PI development costs. The experiment package will typically consist of the fluids test cell(s), precision optical diagnostic instrumentation (shearing interferometry, schlieren, surface profilometry, etc.) that interface with FIR services previously discussed, and any support equipment such as injection & mixing devices, motors, critical temperature hardware, magnetic field generation, etc (Figure 14).

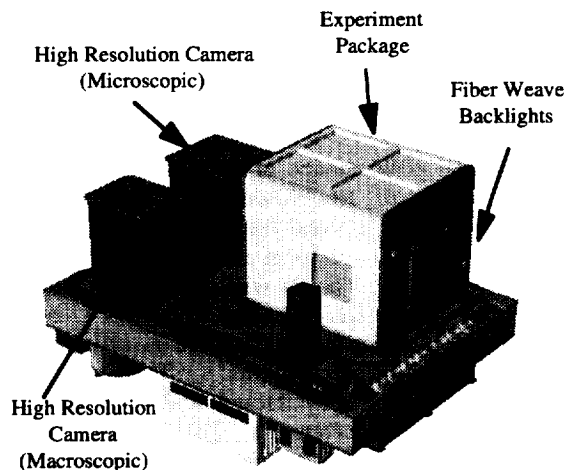


Figure 14 - Experiment Setup Example

Operations

Operations involve the logistics of transporting the FIR and experiment-specific hardware to ISS, set-up and check-out of the hardware, performance of the science mission, maintenance, and return of the hardware from orbit. All of these elements will directly affect the level of FIR utilization, its design, and ultimate appeal to the science community.

The FIR will be transported to the ISS in the Mini-Pressurized Logistics Module (MPLM). The MPLM provides provisions to mount sixteen ISPRs, not powered, in a pressurized environment. The FIR will be removed from the MPLM by the crew and carefully "floated" down to its location in the US Lab for installation. The cameras, lenses, mirrors, optics, and sensitive illumination sources will be loaded into ISS transportation drawers for initial launch via the MPLM to minimize mass. The PI experiment-specific hardware will also be transported in drawers, middeck lockers, or special transportation containers within an ISPR in the MPLM. The hardware will also be returned using the same transportation method. It is anticipated that the MPLM will be transported four times per year by the Space Shuttle to the ISS.

The FIR is being designed to minimize the crew time involved in reconfiguring diagnostics and setting up the specific experiments. Scheduled maintenance will be required of the ISS crew to recalibrate or replace sensors, replace or clean filters, and replace end-of useful-life components. It is not anticipated that on-orbit repairs will be performed, instead Orbital Replacement Units (ORU) will be transported to ISS or taken from on-orbit stowage. Stowage will be provided for science research on the ISS in passive rack locations for ORUs, science hardware, tools, etc.

During the performance of the PIs experiment the FCF will need to provide near-real-time data down-link and near-real-time command up-link to permit the PI to perform remote interaction with the experiment. The PI will need to be provided with adequate and timely data to react to unexpected scientific phenomena in order to alter the experiment procedures. The telescience operations will be conducted and supported from Lewis Research Center's Telescience Support Center (TSC) to provide this commanding capability. The ISS crew will not be the primary

FCF operators since they will have very limited time to dedicate to a specific facility due to their overall work load in day-to-day operations of the ISS. Instead, the ground team at the TSC and the PI at the remote site will monitor the health and status of FCF and the experiment and control facility functions. The PI will be provided with the necessary equipment to command sequences from the PI home site.

Summary

The FIR's system architecture presented provides the basis for which experiments just now being conceived can easily take advantage of the ISS environment at a much lower cost. The International Space Station will provide researchers an exciting opportunity to perform long-term investigations into the fundamentals of science. The FIR development is currently manufacturing a detailed mockup to examine the interfaces, human factors, packaging, and overall performance of the optics bench approach. The FIR may change from what is currently conceived since redesign is a natural part of the design process, but the fundamental capabilities presented will be maintained.

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13. ABSTRACT (Maximum 200 words) The Fluids Integrated Rack (FIR) is a modular, multi-user facility to accommodate a wide variety of microgravity fluid physics science experiments on-board the US Laboratory Module of the International Space Station (ISS). The FIR is one of three racks comprising the Fluids and Combustion Facility (FCF). The FCF is being designed to increase the amount and quality of scientific data and decrease the development cost of an individual experiment relative to the era of Space Shuttle experiments. The unique, long-term, microgravity environment and long operational times on the ISS will offer experimenters the opportunity to modify experiment parameters based on their findings similar to what can be accomplished in ground laboratories. The FIR concept has evolved over time to provide a flexible, "optics bench" approach to meet the wide variety of anticipated research needs. The FIR's system architecture presented is designed to meet the needs of the fluid physics community while operating within the constraints of the available ISS resources.				
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