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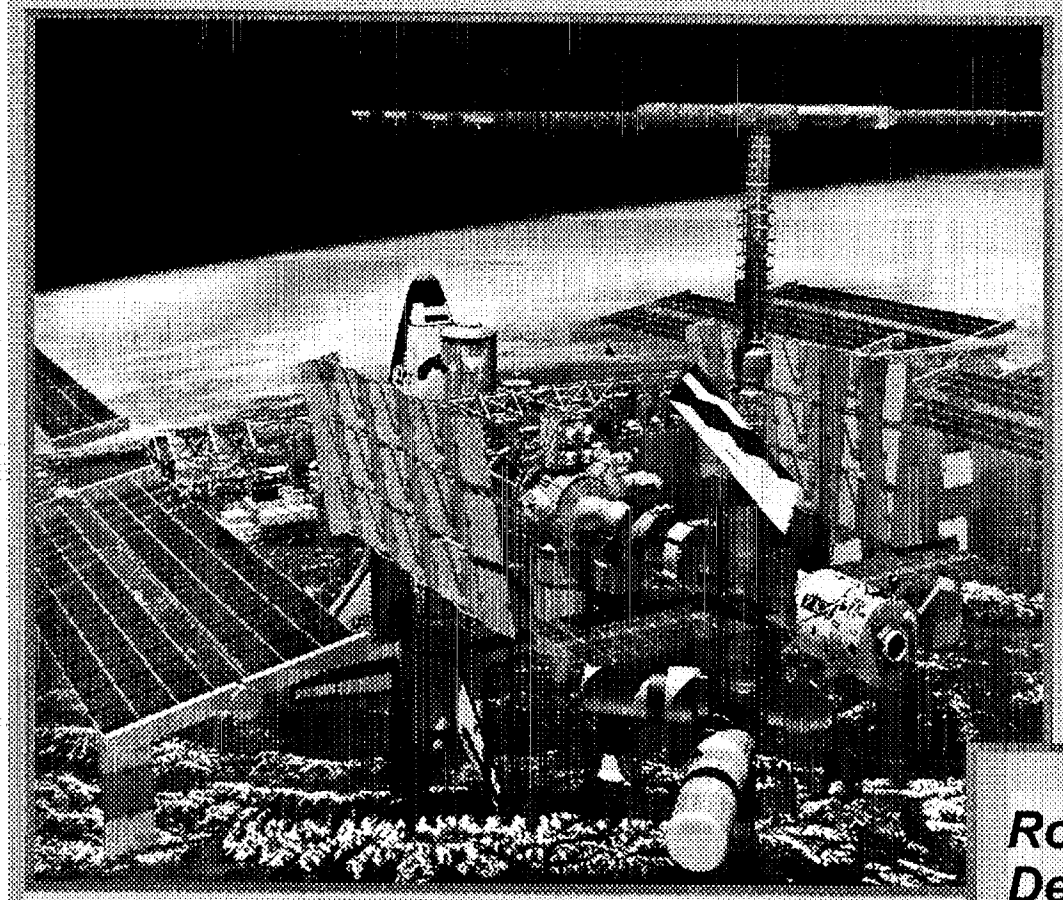
August 11, 2000
Guest Speaker

Fluid Physics Research on the International Space Station

Robert Corban
NASA Glenn Research Center

NASA/CP—2000-210470



Fluids Physics Research on the International Space Station

Robert Corban
Deputy Project Manager
Fluids & Combustion Facility
August 11, 2000

NASA/CP—2000-210470

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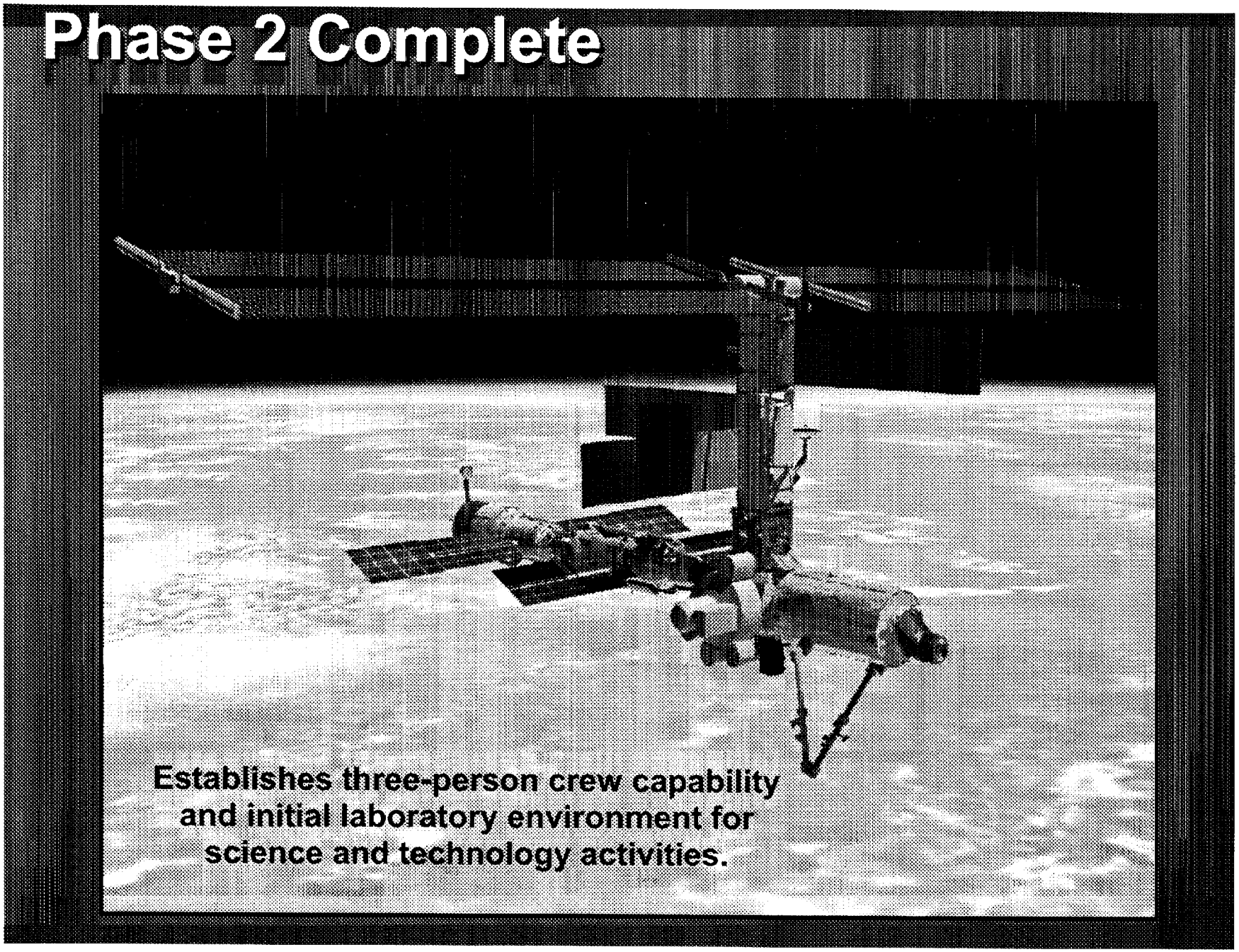
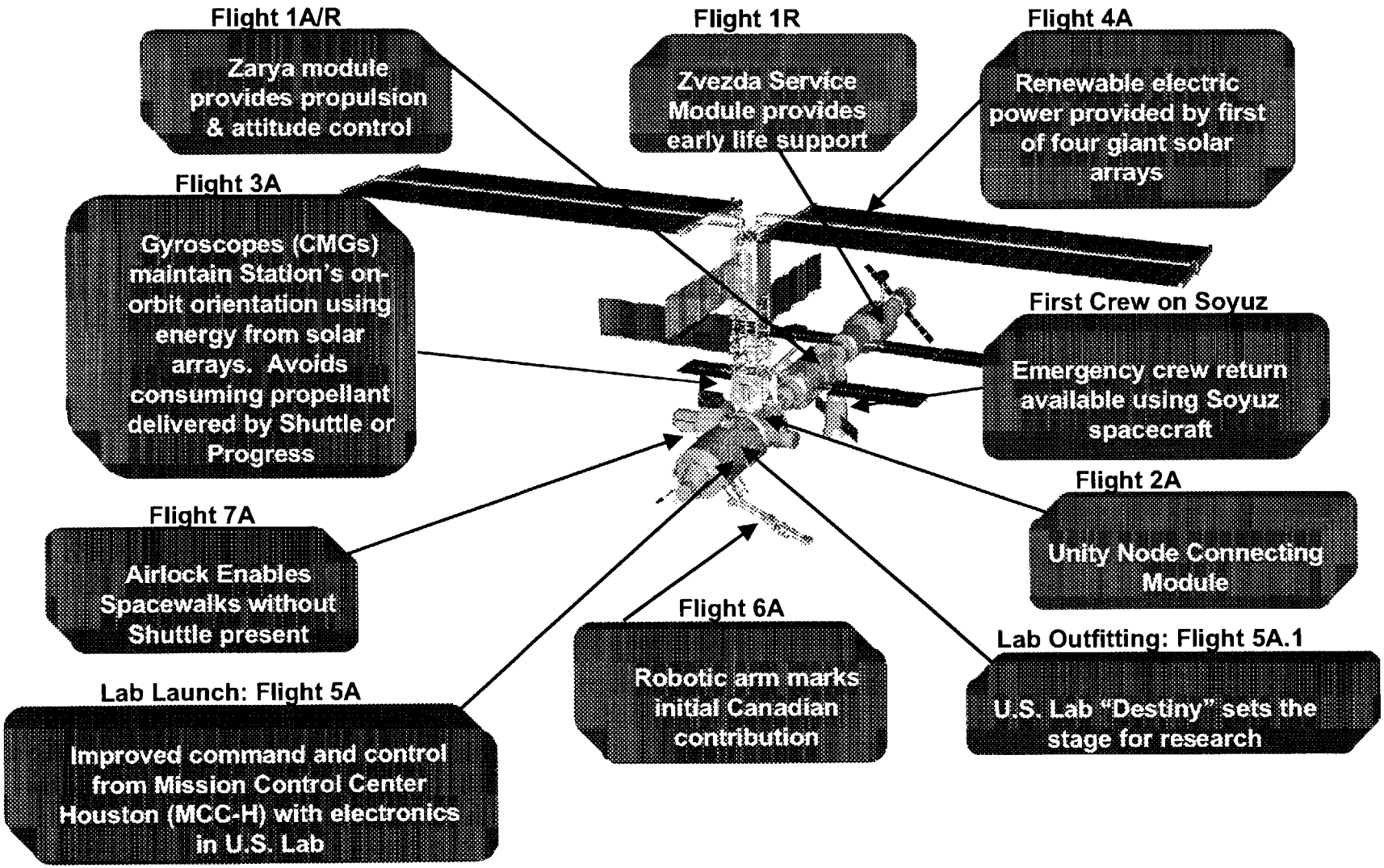
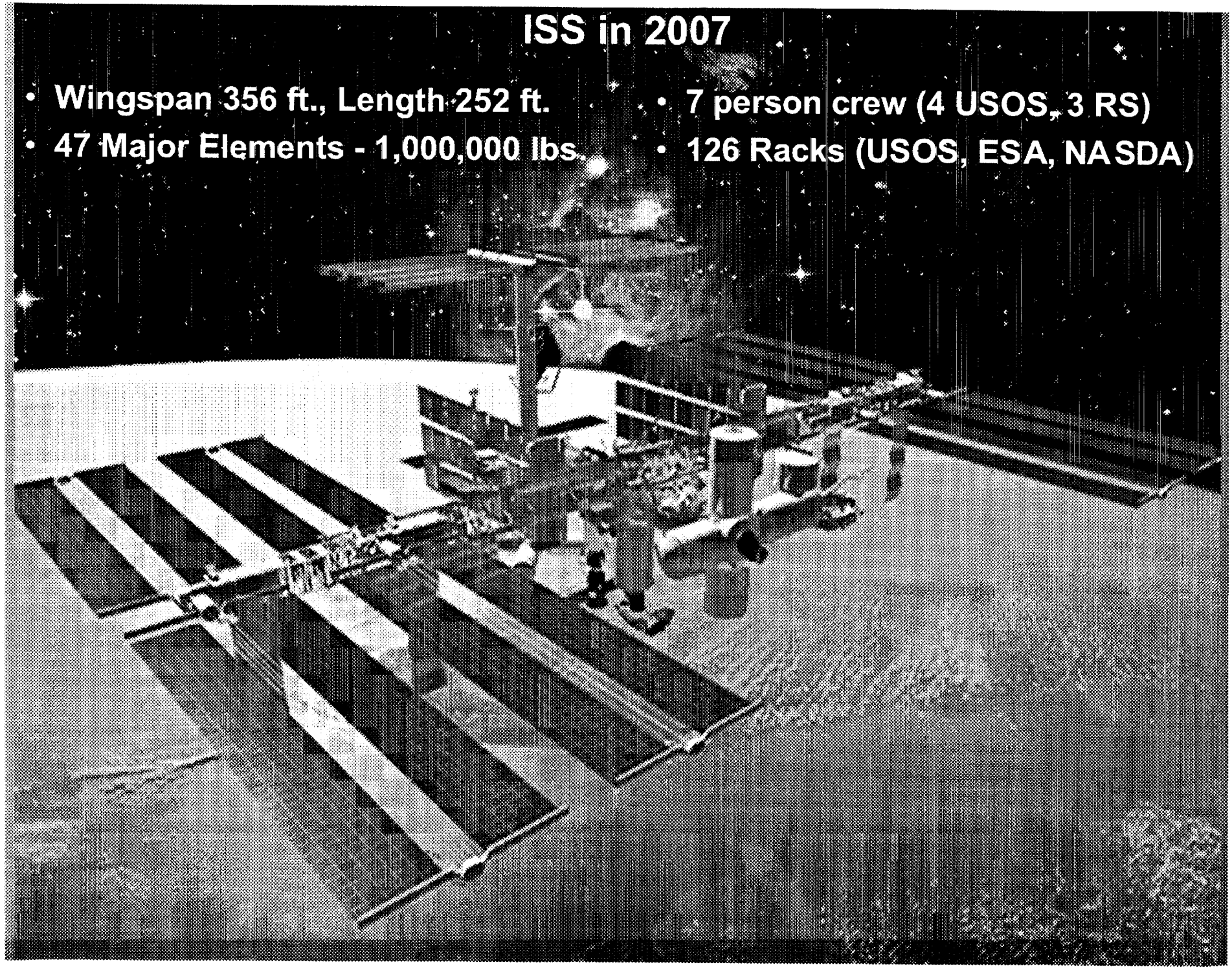

Phase 2 Complete
Establishes three-person crew capability
and initial laboratory environment for
science and technology activities.

GRC Microgravity Science Program

Fluids and Combustion Facility

On-Orbit Assembly Through Phase 2



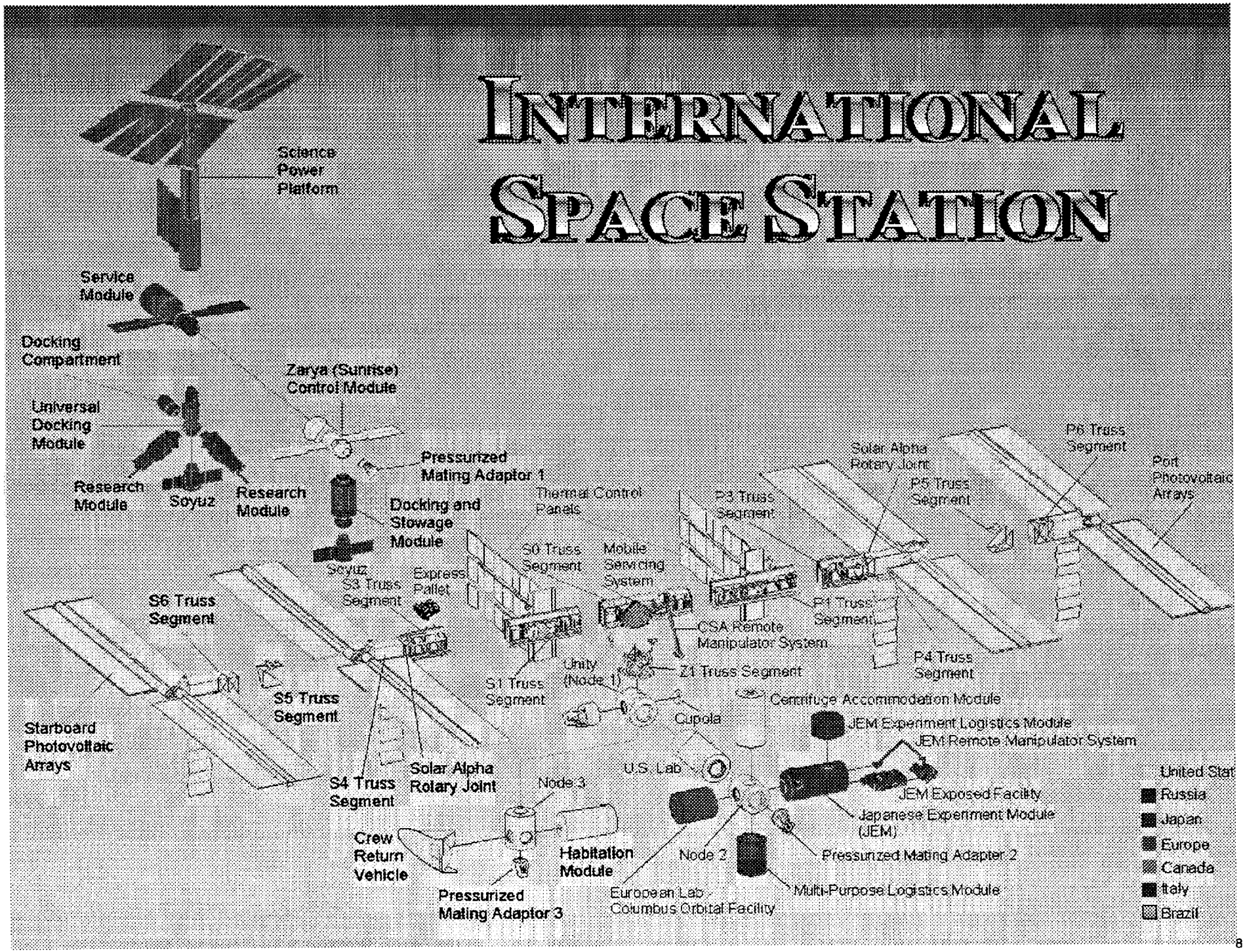

ISS in 2007
• Wingspan 356 ft., Length 252 ft.
• 47 Major Elements - 1,000,000 lbs.
• 7 person crew (4 USOS, 3 RS)
• 126 Racks (USOS, ESA, NASDA)

ISS in 2007

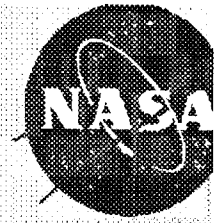
- **2M lines of flight code**
  - 4M lines of ground/test code
- **Integrated logistics program consisting of:**
  - 5 different vehicles visiting ~14 times each year
    - STS (5), Progress (5), Soyuz (2), HTV (1), ATV (1)
  - 4 launch systems in different countries
    - Shuttle, Ariane, Soyuz, HII
  - More than 40,000 items to track on orbit at any given time
  - 2 crew rescue vehicles attached to ISS
    - (CRV/Soyuz)
  - 10 - 20 EVAs per year
    - Russian, U.S.

ISS, The Overall Challenge

- Building and assembling the ISS is a major undertaking with no parallel in the history of space flight
  - Involves 16 countries, 47 major elements, and more than 100 smaller ones
  - Requires 47 space flights just to assemble (38 shuttle and 9 Russian)
  - At assembly complete, ISS will consist of 1 million pounds of hardware orbiting the earth every 90 minutes with 6 laboratories available full time to conduct research for at least 10-15 years
- More than a half million pounds of hardware has been delivered to the Space Station Processing Facility at KSC, where it is undergoing integrated testing and preparation for launch
  - Hardware for 9 of the next 10 flights is currently at KSC with more on the way
  - Testing and preparation of the hardware is complete for some elements and progressing well for the remainder
  - The hardware will be ready to meet the launch schedules for the upcoming missions


INTERNATIONAL SPACE STATION
Science Power Platform
Service Module
Docking Compartment
Zarya (Sunrise) Control Module
Universal Docking Module
Pressurized Mating Adaptor 1
Research Module
Soyuz
Research Module
Docking and Stowage Module
Soyuz
Express Pallet
S3 Truss Segment
S6 Truss Segment
S5 Truss Segment
Starboard Photovoltaic Arrays
S4 Truss Segment
Solar Alpha Rotary Joint
Crew Return Vehicle
Pressurized Mating Adaptor 3
Node 3
Habitation Module
European Lab Columbus Orbital Facility
Node 2
Multi-Purpose Logistics Module
Pressurized Mating Adaptor 2
U.S. Lab
Cupola
Japanese Experiment Module (JEM)
JEM Exposed Facility
JEM Remote Manipulator System
JEM Experiment Logistics Module
Centrifuge Accommodation Module
Z1 Truss Segment
Unity (Node 1)
S1 Truss Segment
S0 Truss Segment
Mobile Servicing System
Thermal Control Panels
P3 Truss Segment
CSA Remote Manipulator System
P1 Truss Segment
P4 Truss Segment
Solar Alpha Rotary Joint
P5 Truss Segment
P6 Truss Segment
Port Photovoltaic Arrays
United Stat
Russia
Japan
Europe
Canada
Italy
Brazil

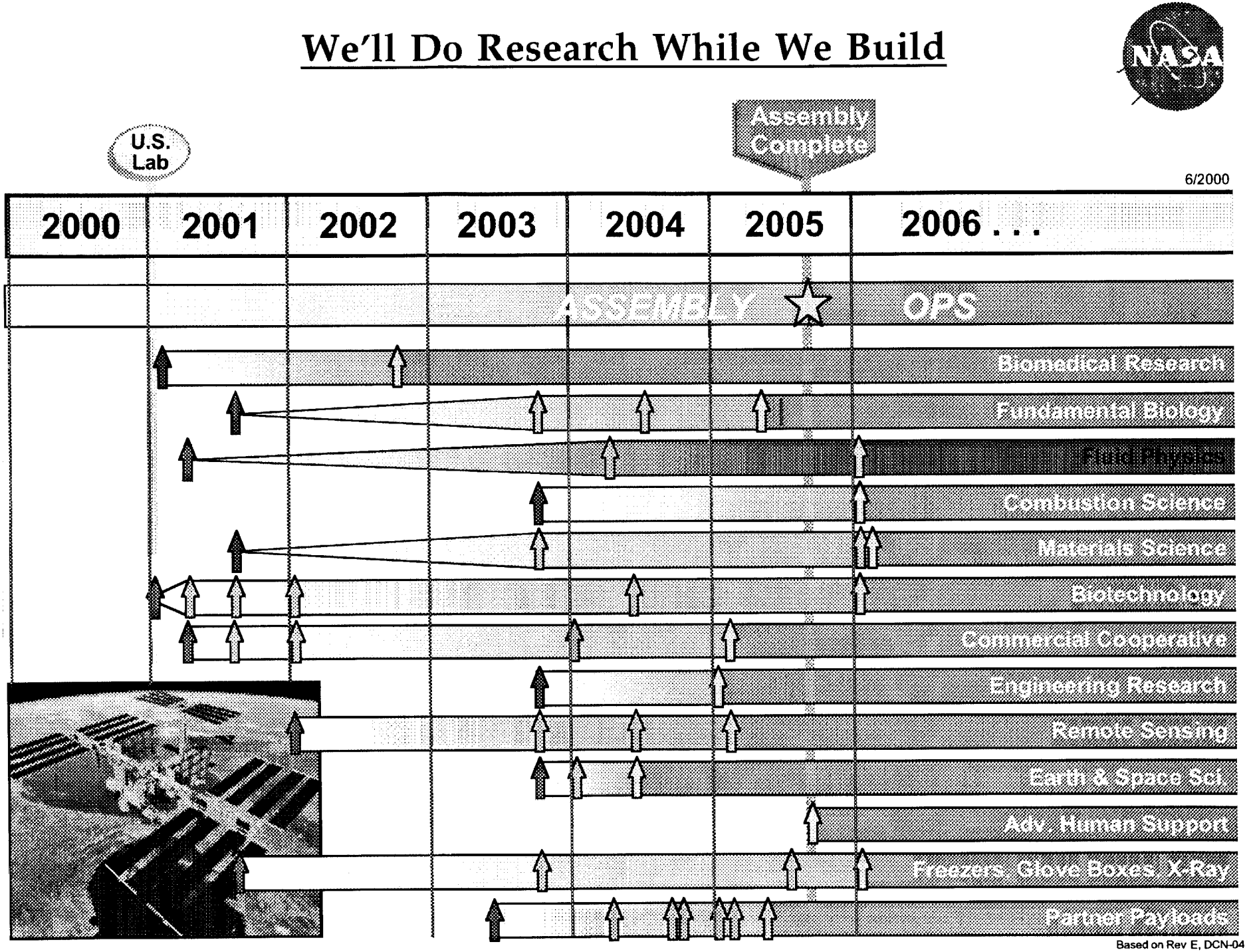
Space Station Research
An Investment in Our Future



- **Improving Industrial Processes**
  - Combustion Science
  - Fluid Physics
  - Materials Science
- **Increasing Fundamental Knowledge**
  - Fundamental Physics
  - Fundamental Biology
  - Earth Science
  - Space Science
- **Looking After Our Health**
  - Biomedical Research
  - Crew Care and Countermeasures
  - Protein Crystal Growth Research
  - Cell and Tissue Science
  - Advanced Medical and Life Support Technologies
- **Enabling Exploration**
  - Engineering Research
  - Scientific Research
- **Researching Tomorrow's Products Today**
  - Commercial Cooperative Research
  - Testbed for New Commercial Processes, Products, and Services

NASA/CP—2000-210470

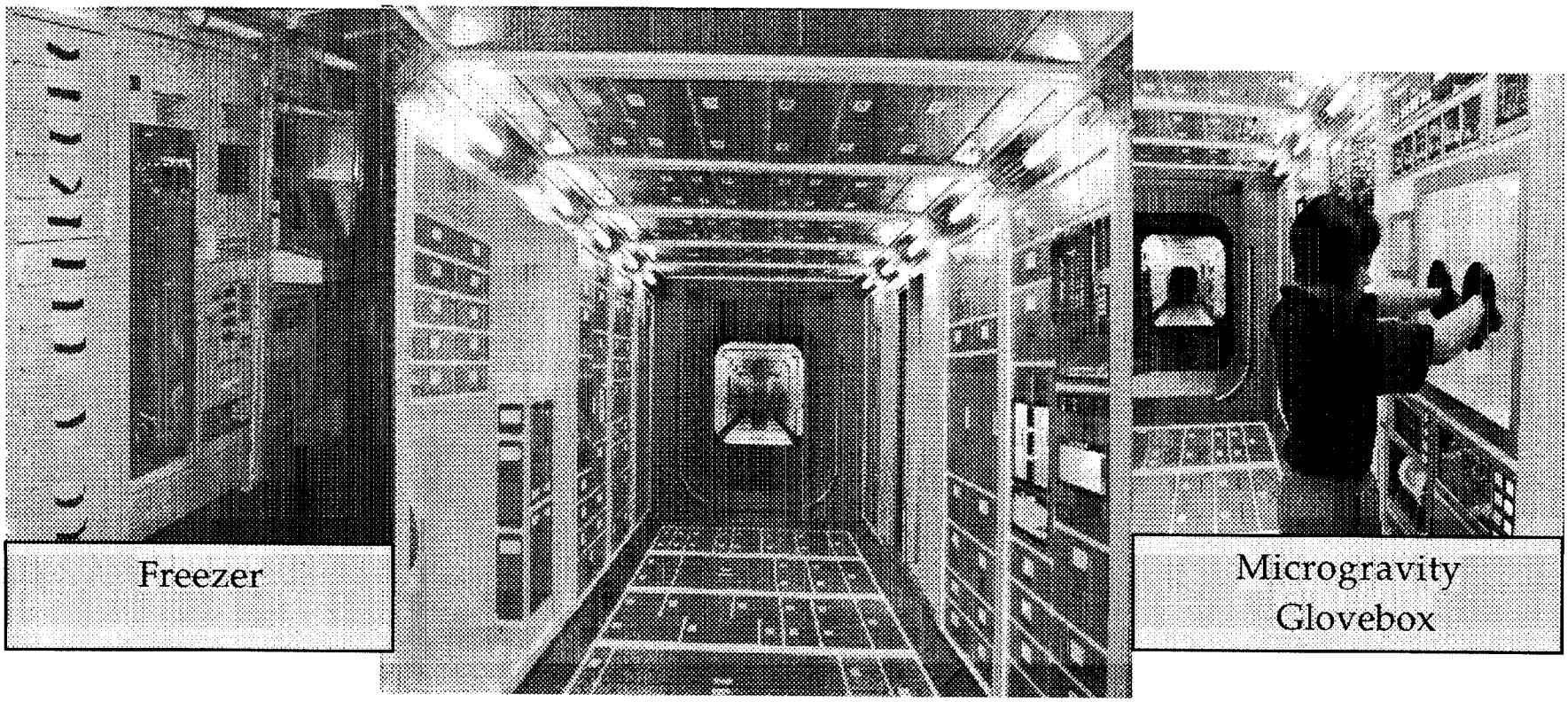
We'll Do Research While We Build



GRC Microgravity Science Program

Fluids and Combustion Facility

Facility for World-Class Research U.S. Laboratory Module Interior



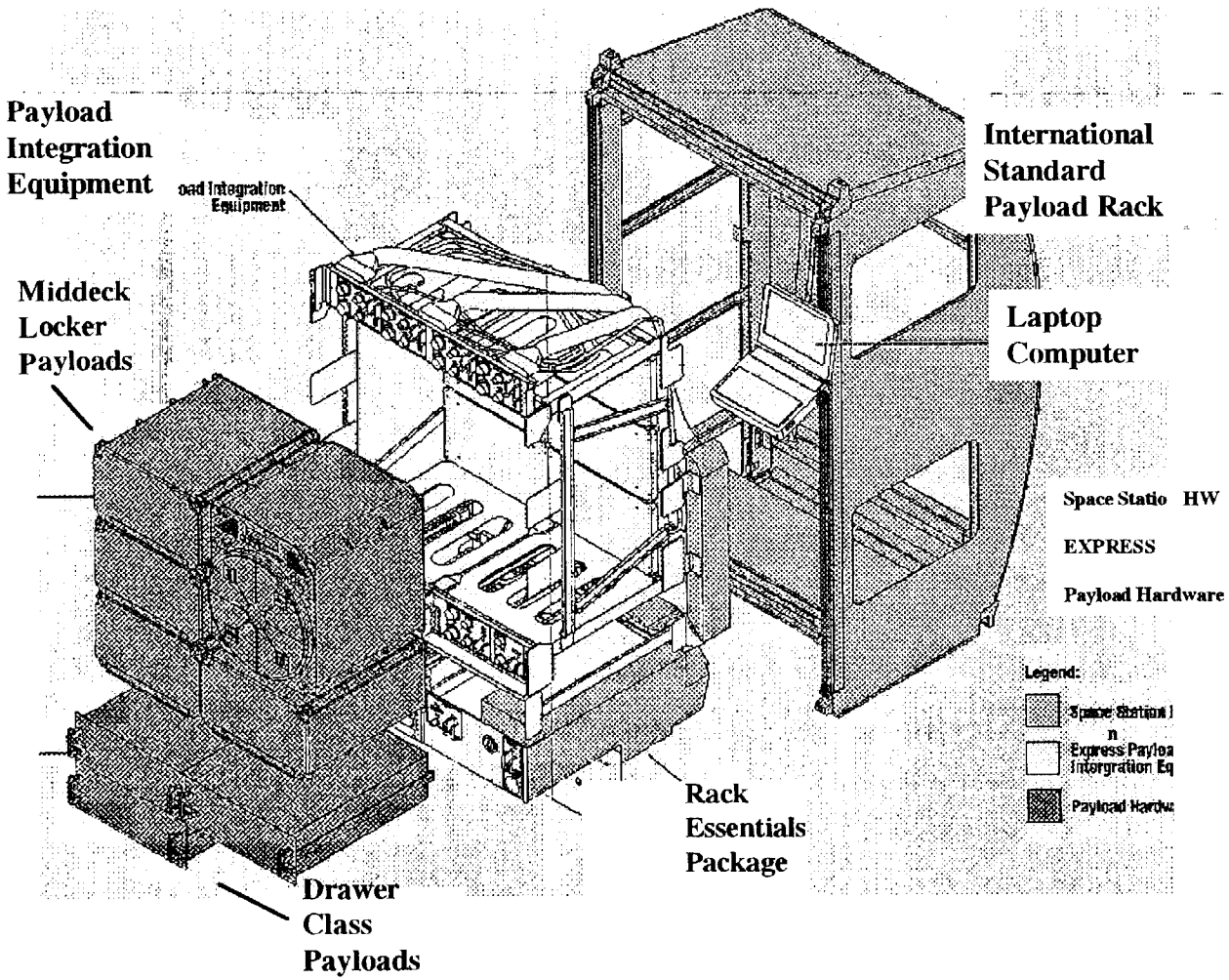
The Space Station is the largest structure ever built in Space

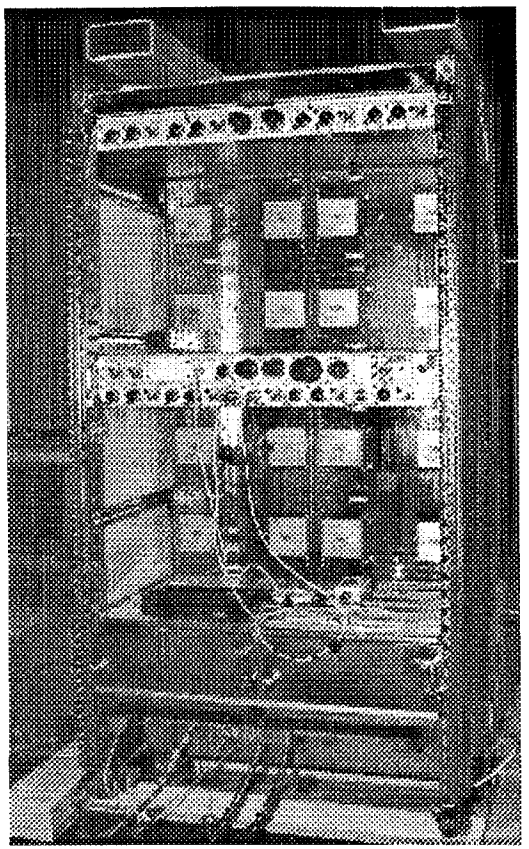
- Pressurized volume will be roughly equivalent to the interior of two 747 jets
- 6 labs with 24 experiment racks (about the size of a refrigerator) and 11 vibration isolation racks for experiments that require quiescent environment

GRC Microgravity Science Program

Fluids and Combustion Facility

Expedite the PRocessing of Experiments to Space Station - EXPRESS

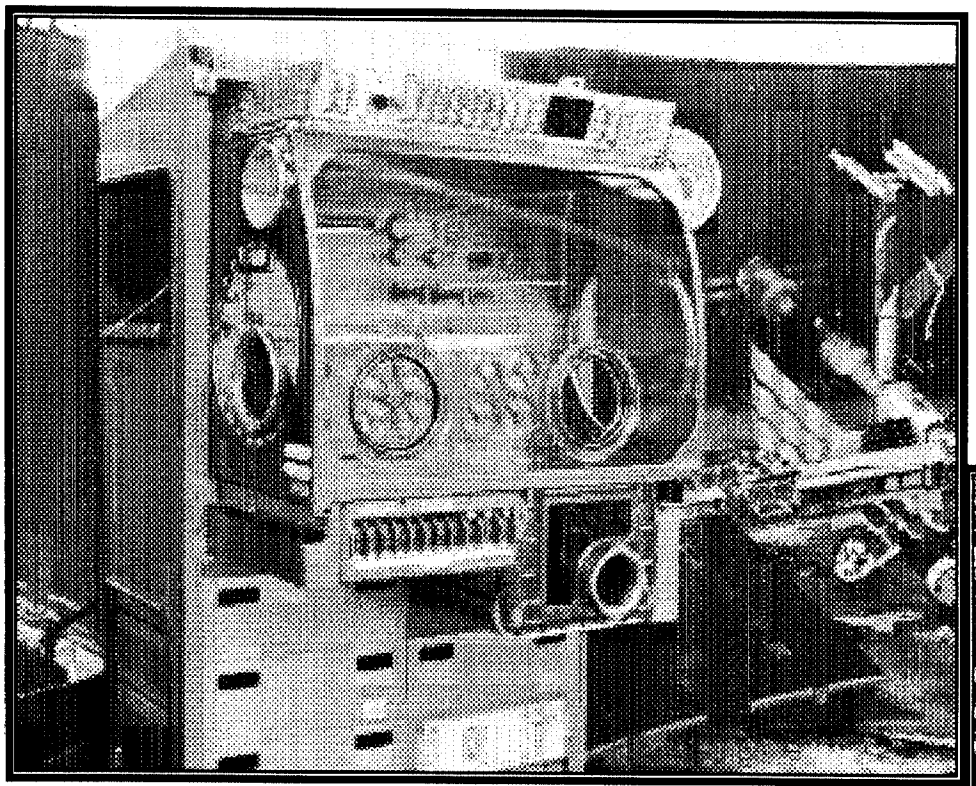




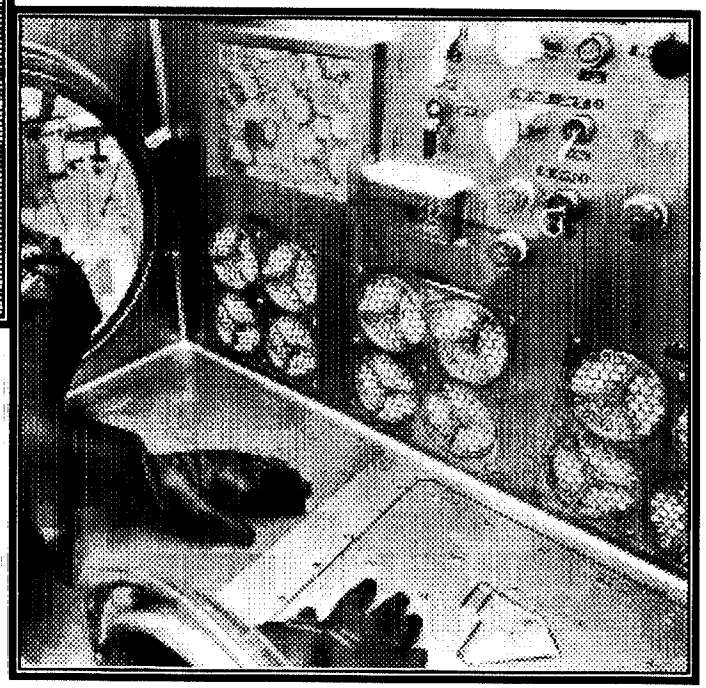
Developed by: MSFC

Launch Date: 2001

Microgravity Science Glovebox



Managed by: MSFC
Developed by: ESA
Launch Date: September 2001



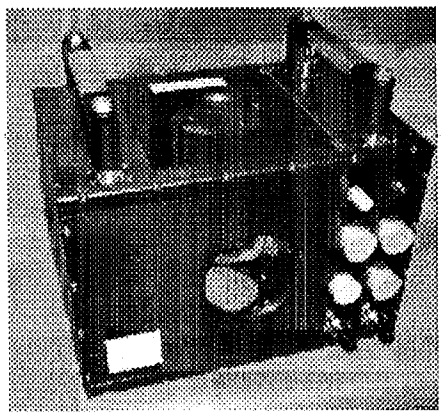
Work Volume: 255 liters
Power Available: 1 KW (for PI usage)
Containment: 2 Levels
Video: 3 Color Cameras
1 B&W Camera
4 Digital Recorders

astrium

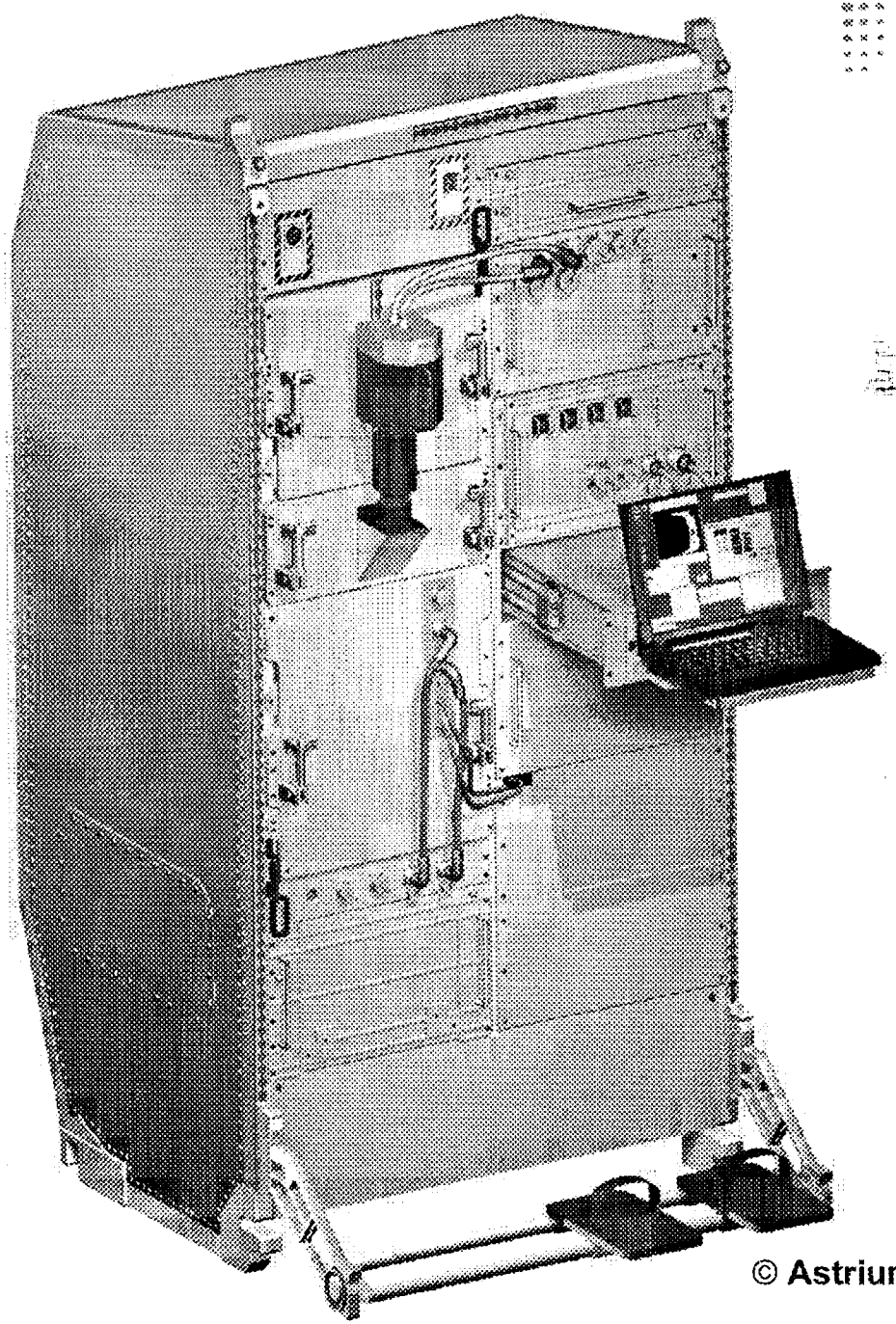
Fluid Science Lab

Developed by: ESA

Launch Date: September 2001



Exp, Container:	40 x 27 x 28 cm
Power Available:	100 -200 W (430 W Max)
Containment:	2 - 3 Levels
Mass (Typical):	20-30 kg (40 kg max)
Central FOV:	80 x 80 mm



FSL Optical Diagnostic Methods Science Lab

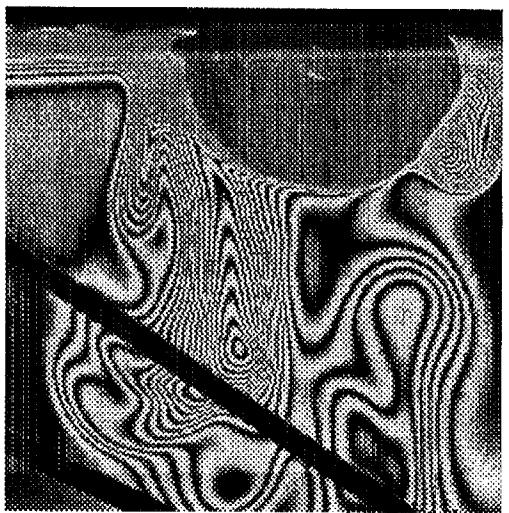
astrium

Diagnostic Elements:

- Variable Background illumination
- Variable Lightsheet (f. Velocimetrie, PIV)
- Schlieren
- Wollaston/Shearing Interferometer (var. Sensitivity)
- Electronic Speckle Pattern Interferometer (ESPI)
- Holographic Interferometer (with TPC)
- Holography
- Standard Recording with dig. CCD (1K_, 30 Hz)
- Frontmounted CCD Cameras (Highspeed, Highres., Film)
- Experimentspec. Diagnostics (Tomograph., LDA, spher. Optics, direct Laserbeam, etc.)
- digital + analog Videointerfaces at Exp. Container

Video Management Unit:

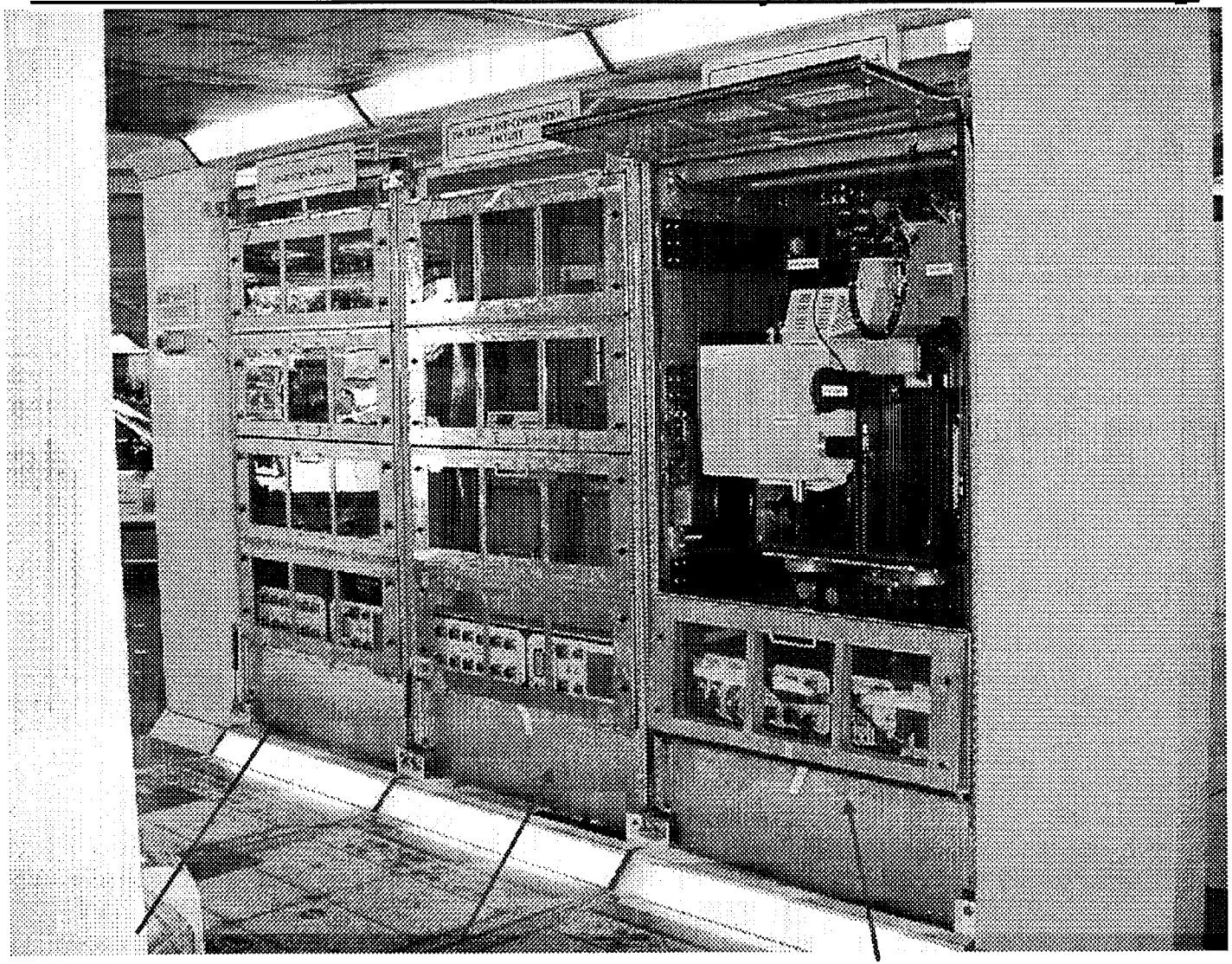
- Simultaneous Management of 3 CCD-Cameras
- Intermed. Recording of Video Data (36 GB HDD, Tape)
- Variable Videodata Compression (JPEG)



GRC Microgravity Science Program

Fluids and Combustion Facility

ISS Fluids and Combustion Facility in US Lab Mockup



Combustion Integrated Rack (CIR)

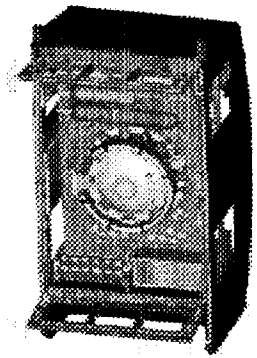
Shared Accommodations Rack (SAR)

Fluids Integrated Rack (FIR)

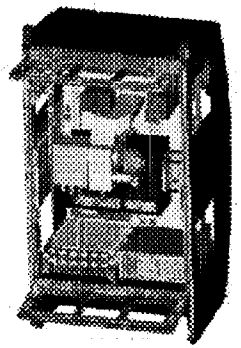
GRC Microgravity Science Program

Fluids and Combustion Facility

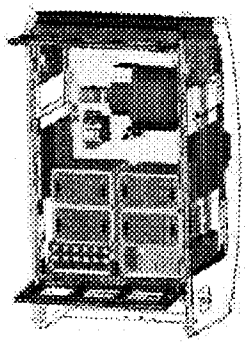
FCF Flight Segment



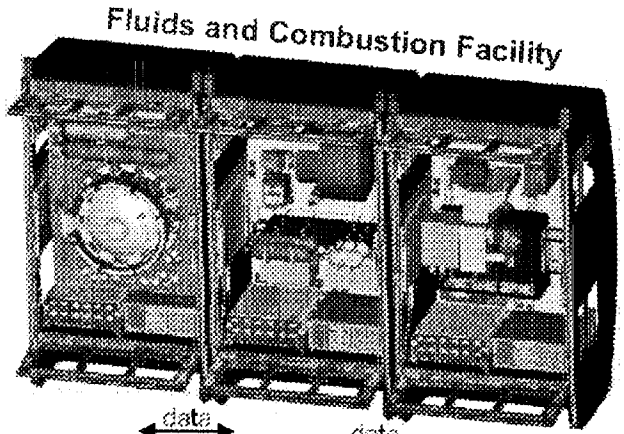
Combustion Integrated Rack (CIR) UF-3



Fluids Integrated Rack (FIR) UF-5



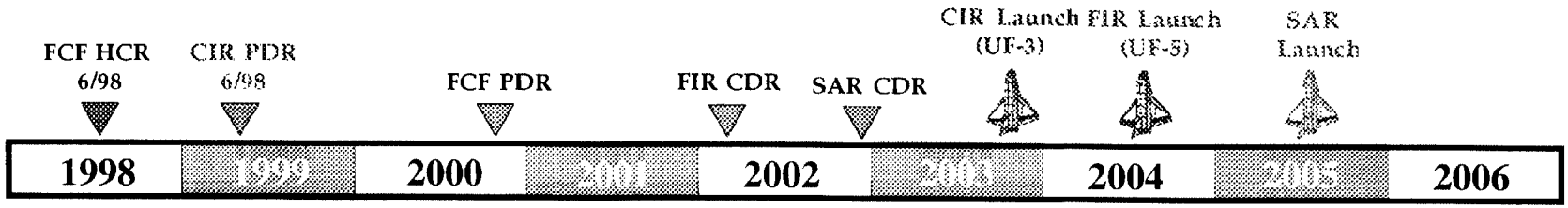
Shared Accommodations Rack (SAR) 2006



CIR and FIR operate independently until SAR is deployed to ISS.

Assembly of FCF is completed by the addition of the SAR. Fluid Physics and Combustion Science disciplines then share racks and mutually necessary hardware/software.

FCF will accommodate all envisioned experiments at the rate of 10 or more per year for the lifetime of the Space Station.

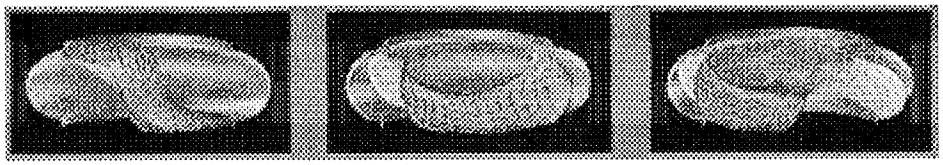


GRC Microgravity Science Program

Fluids and Combustion Facility

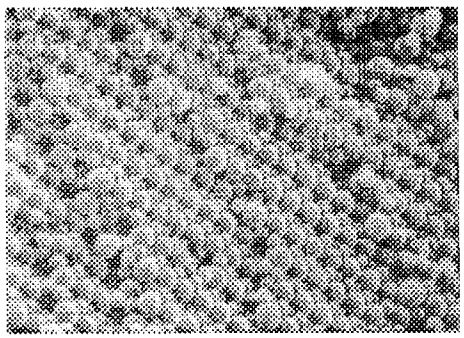
Mission: Fluid Physics Research

Interfacial Phenomena



Interfacial configuration experiment (ICE)

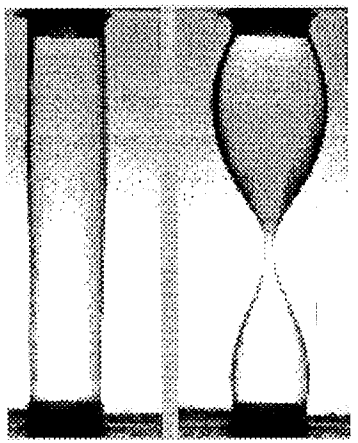
Complex Fluids



colloidal crystals

16 Basis Experiments

Dynamics & Stability



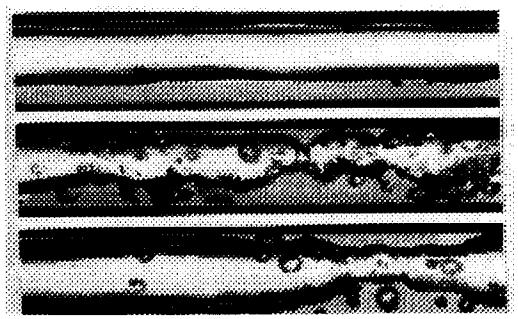
Electrohydrodynamics

Multiphase Flow and Heat Transfer

Normal Gravity

Lunar gravity

Microgravity



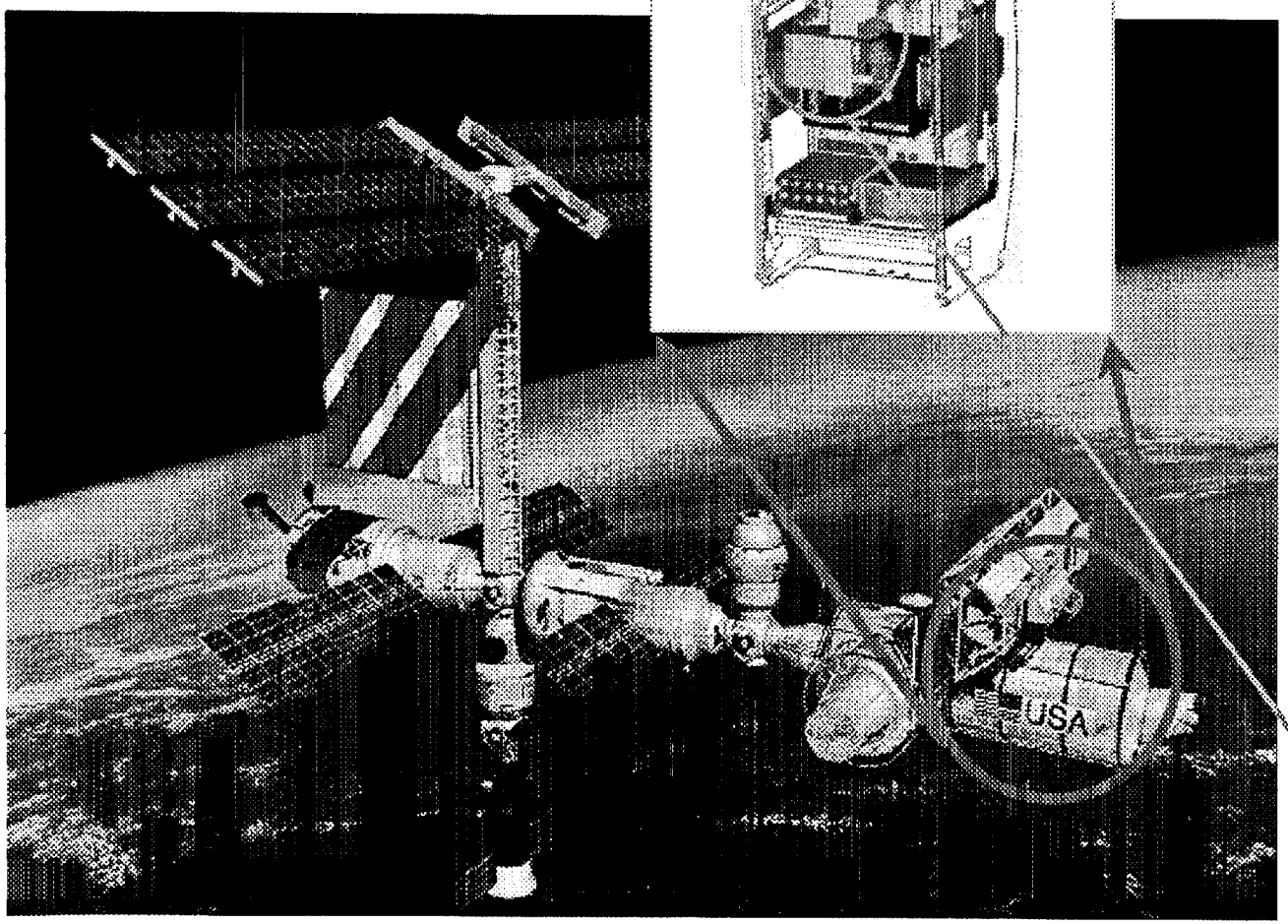
Gas

Liquid

GRC Microgravity Science Program

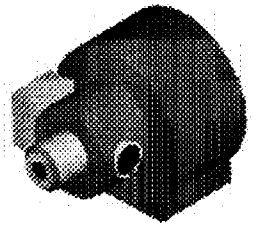
Fluids and Combustion Facility

Typical ISS Increment - Diverse Fluids Science Complement

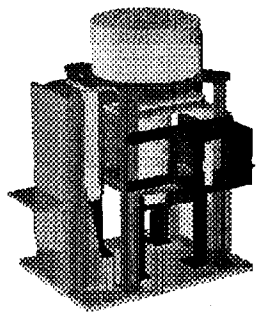


Fluids Integrated Rack with LMM

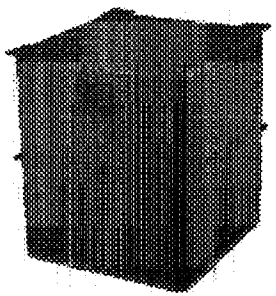
Example Experiment Packages



Pool Boiling



Microscale Hydrodynamics

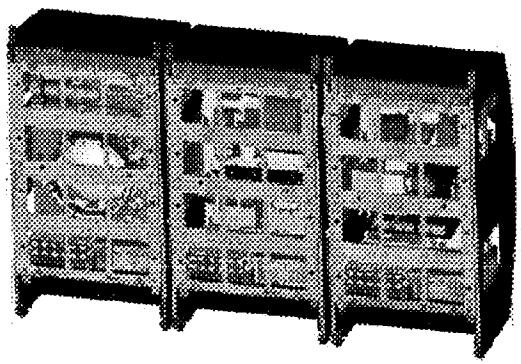


Physics of Colloid In Space

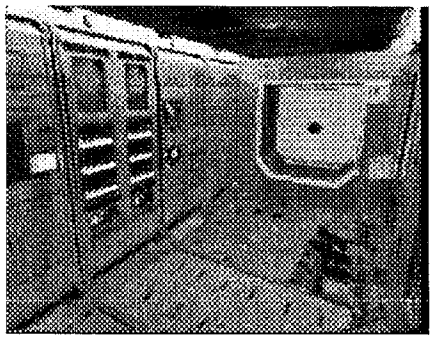
GRC Microgravity Science Program

Fluids and Combustion Facility

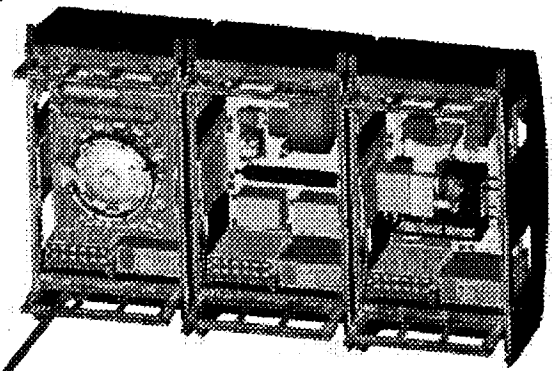
FCF Hardware Development Plan



Protoflight Unit

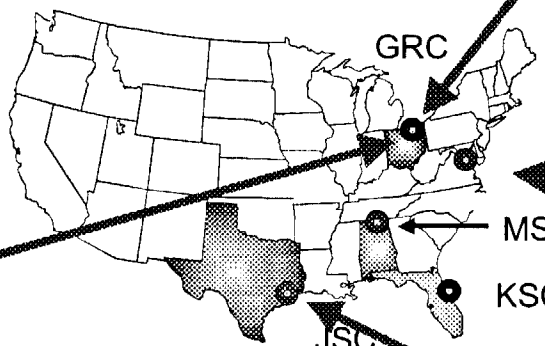


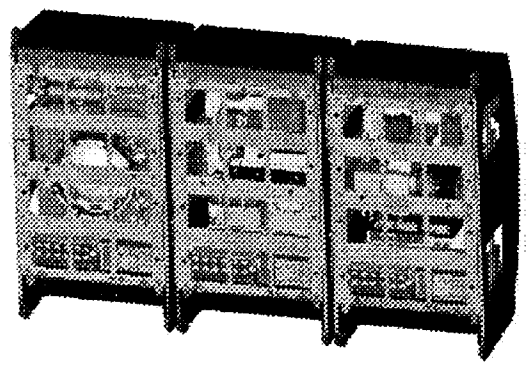
ISS US Laboratory



Engineering Development Unit

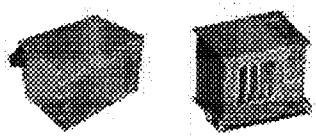
Remodeled Engineering Unit



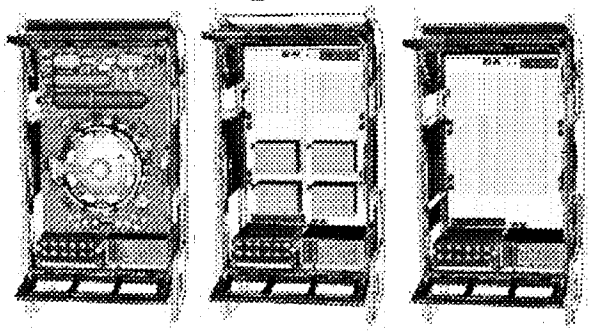


Ground Integration Unit

Identical to Protoflight Unit



Diagnostic Simulators



Payload Training Center

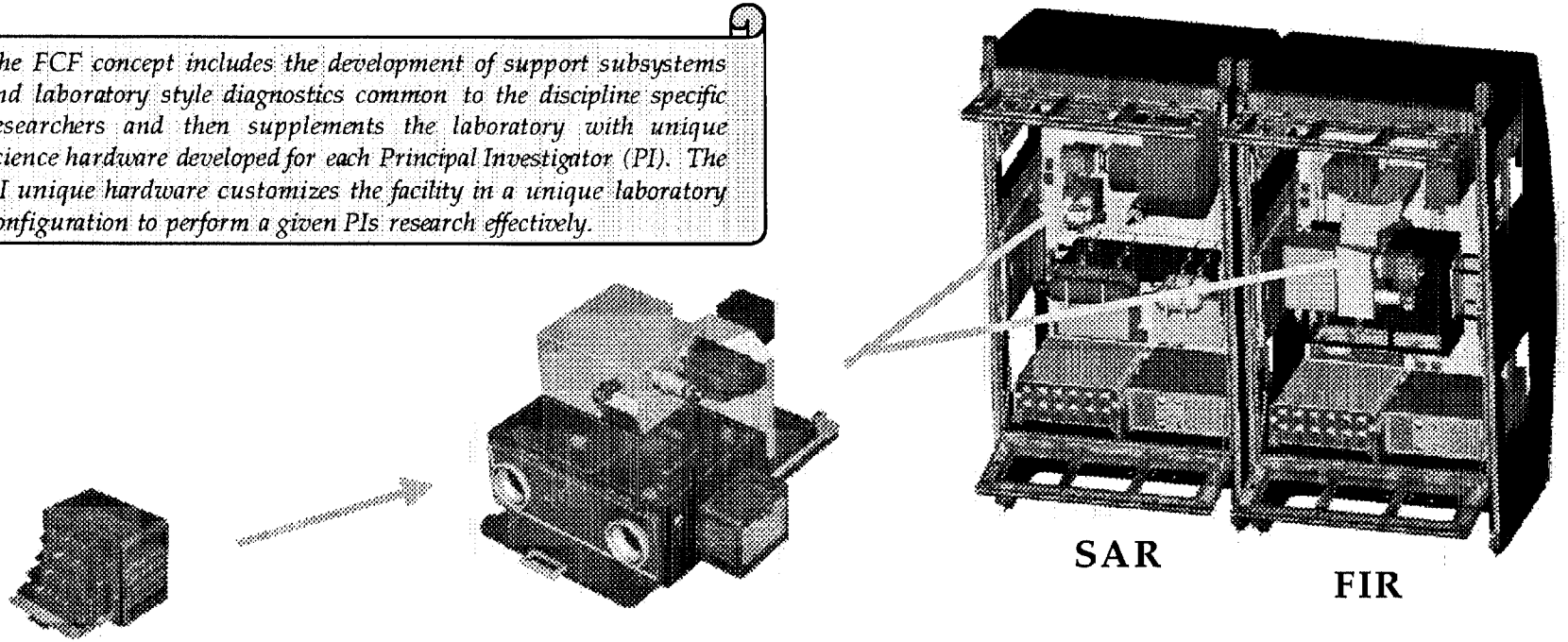
(PTC) Trainers

GRC Microgravity Science Program

Fluids and Combustion Facility

Integrated FIR/SAR System

The FCF concept includes the development of support subsystems and laboratory style diagnostics common to the discipline specific researchers and then supplements the laboratory with unique science hardware developed for each Principal Investigator (PI). The PI unique hardware customizes the facility in a unique laboratory configuration to perform a given PIs research effectively.



PI Specific Samples

- Samples with supporting hardware
- Specific Conditioning
- Specific Diagnostic

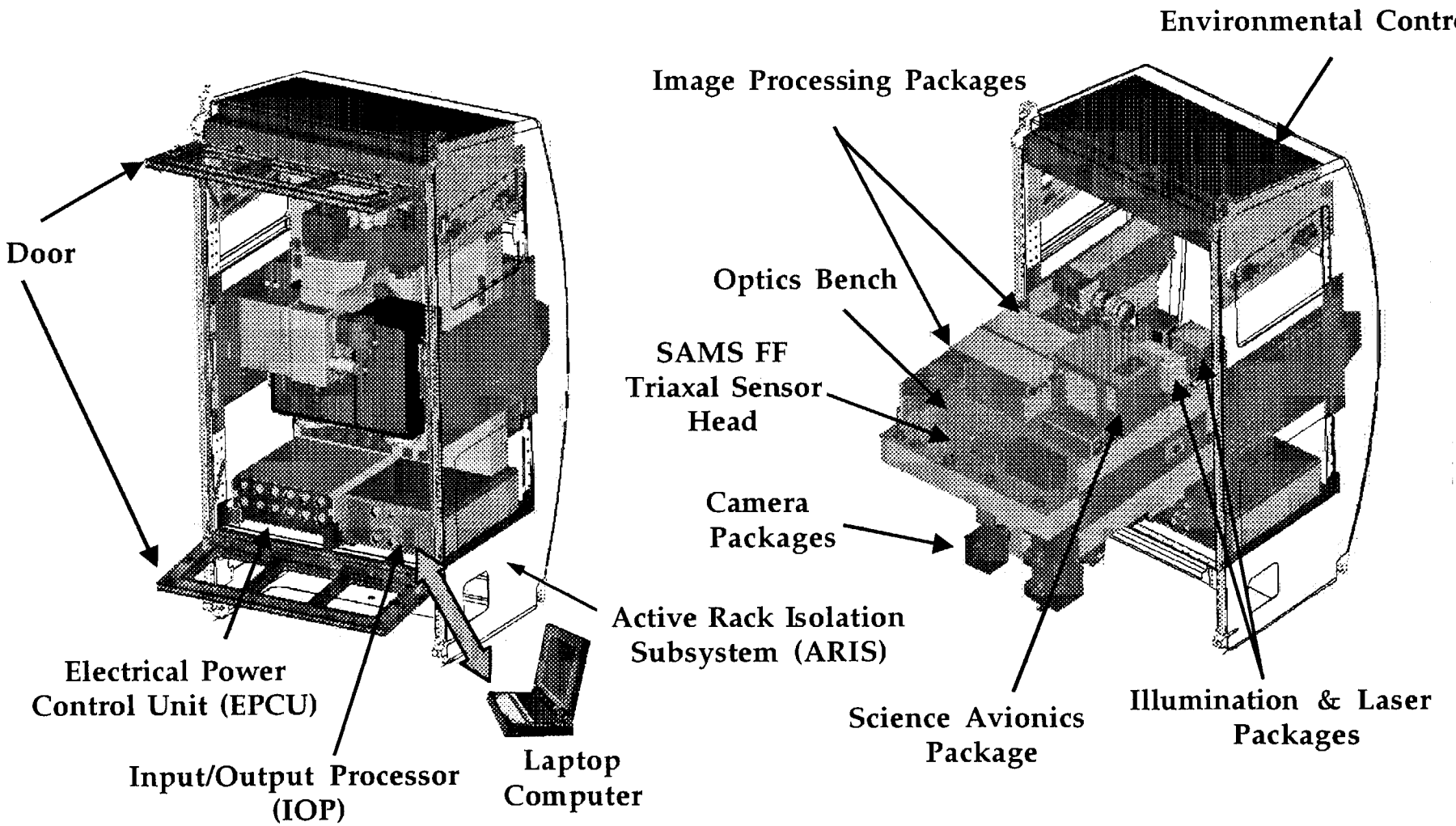
Multi-User Apparatus

- Science Infrastructure (hardware/software) items that uniquely meet the needs of the PIs
- Unique Diagnostics
- Specialized Imaging
- Fluid Containment

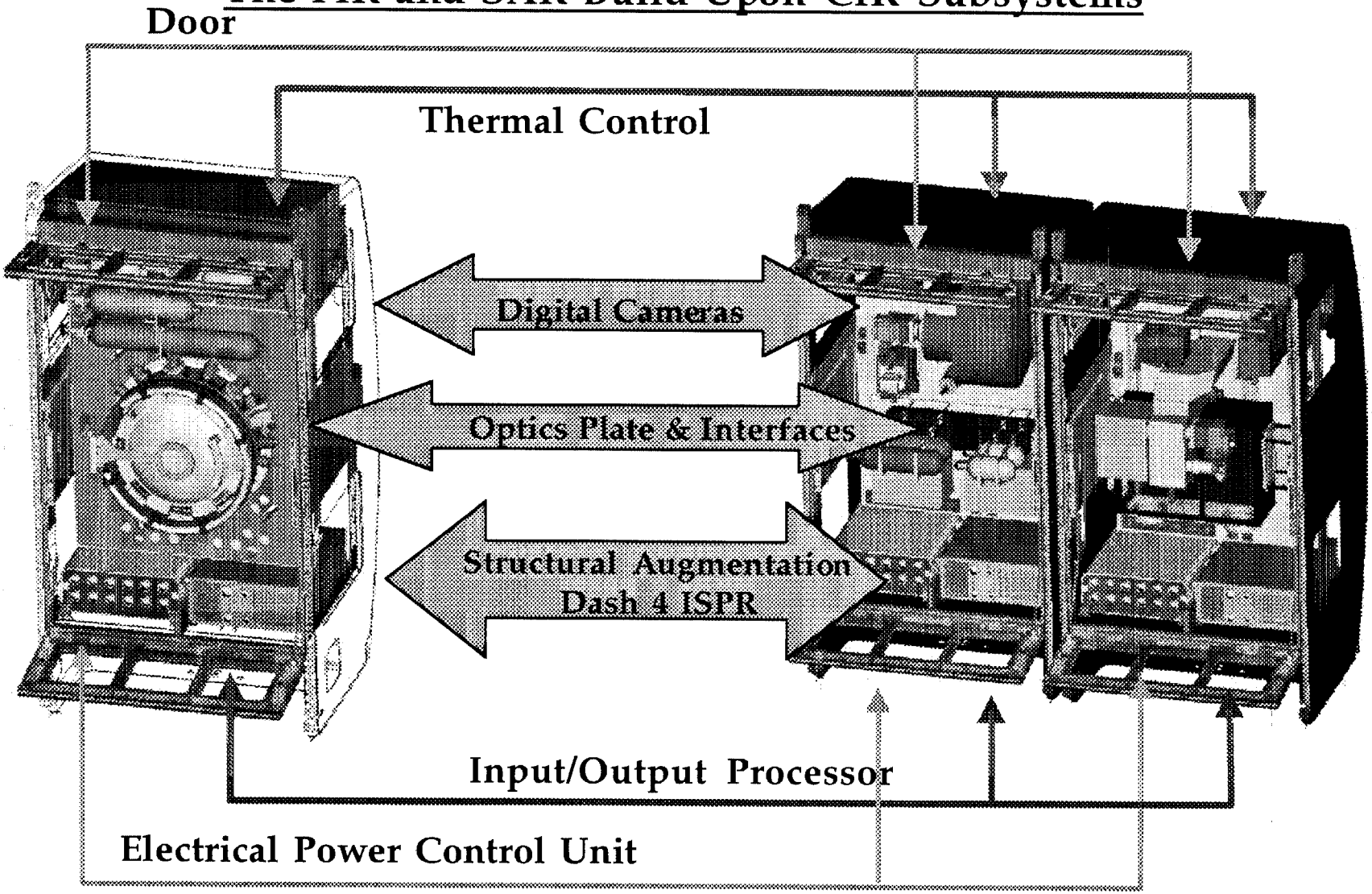
Fluids Integrated Rack/ Shared Accommodations Rack

- Power Supply
- Avionics/Control
- Common Illumination/Lasers
- Optics Bench
- Imaging Capture
- Environmental Control
- Command and Data Handling
- Active Rack Isolation

FCF Fluids Integrated Rack Overview



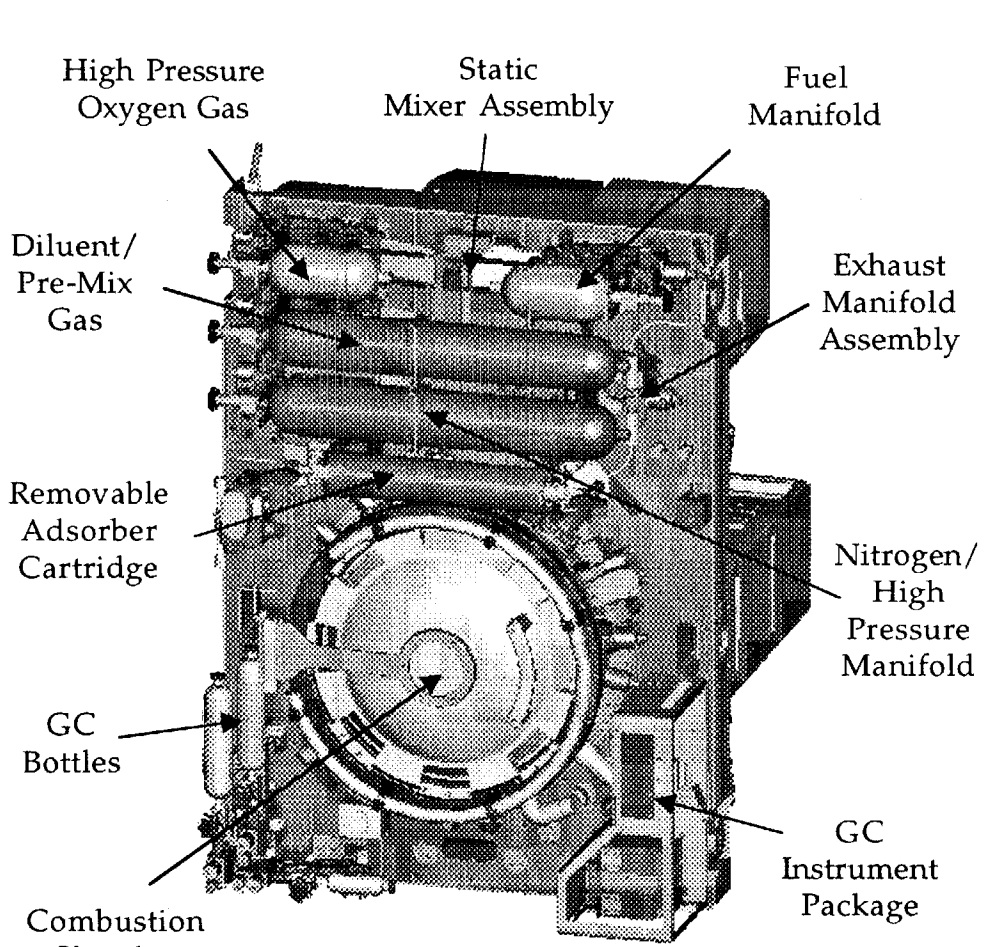
The FIR and SAR Build Upon CIR Subsystems



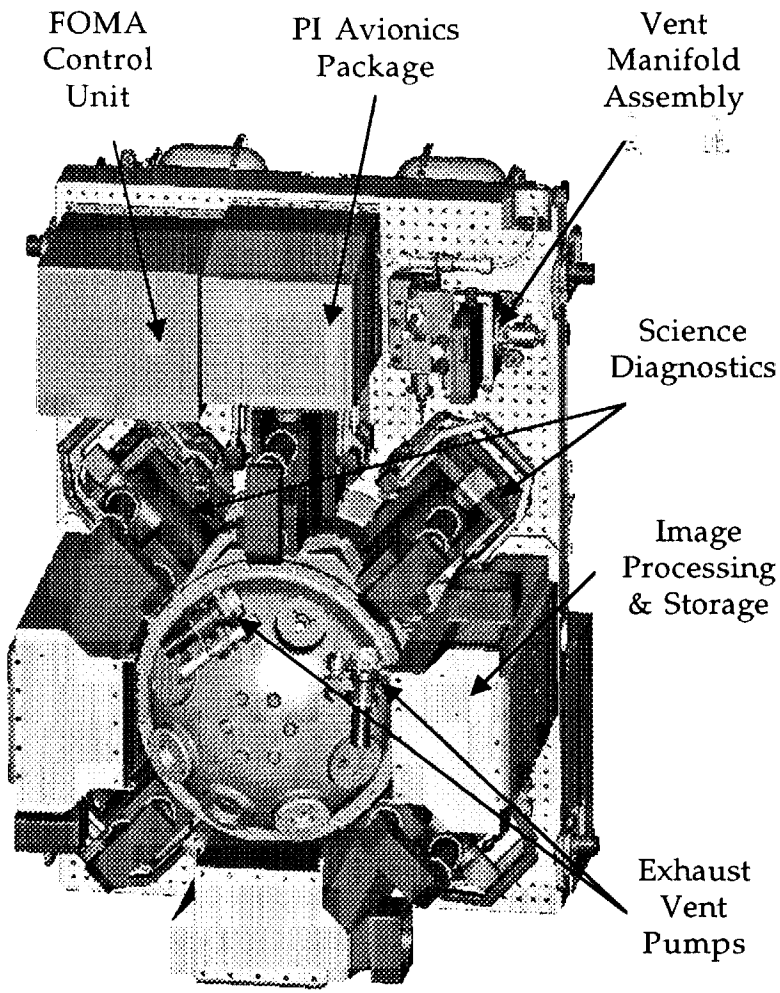
GRC Microgravity Science Program

Fluids and Combustion Facility

Combustion Integrated Rack Overview



(Front View)

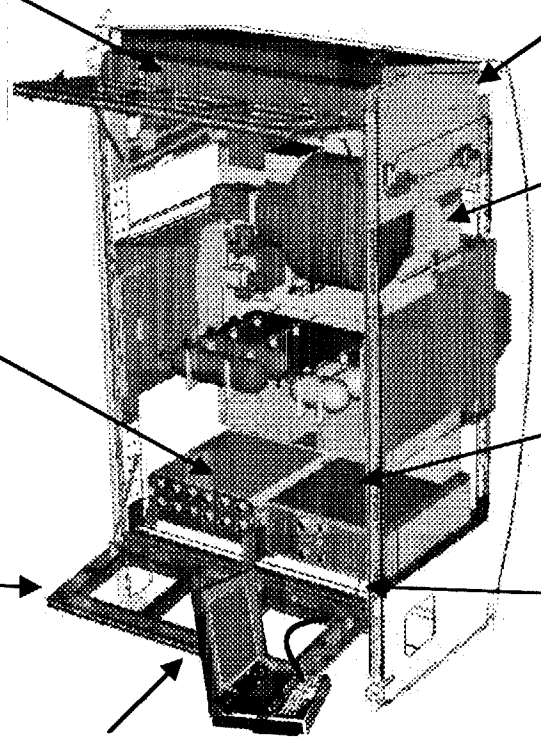


(Rear View)

GRC Microgravity Science Program

Fluids and Combustion Facility

FCF Shared Accommodations Rack Overview



Environmental Control Subsystems
- Water Thermal Control
- Air Thermal Control (Fan/Hx)
- Fire Detection and Suppression
- Gas Interfaces

Power Controller
- Electrical Power Control Unit
- 120 VDC to 28 VDC Conversion
- Configurable by User Loads

Rack Door
- Provides Thermal Containment
- Provides for Fire Detection
- Acoustic Noise Containment

Facility Laptop Computer
- Station PCS Compatible

Rack
- ARIS
- 4 Post ISPR Configuration

Utility Plate
- Translates, Folds Out for Access
- Flexible Mounting Configuration
- 16 PU Plate

Input/Output Processor
- 4 PU IOP

Rack-to-Rack Umbilicals
- Fiber
- Configurable From Front of Rack

Power, Data, Environmental Control and Structural Subsystems in SAR Patterned After Those in FCF Combustion Rack and FCF Fluids Rack.

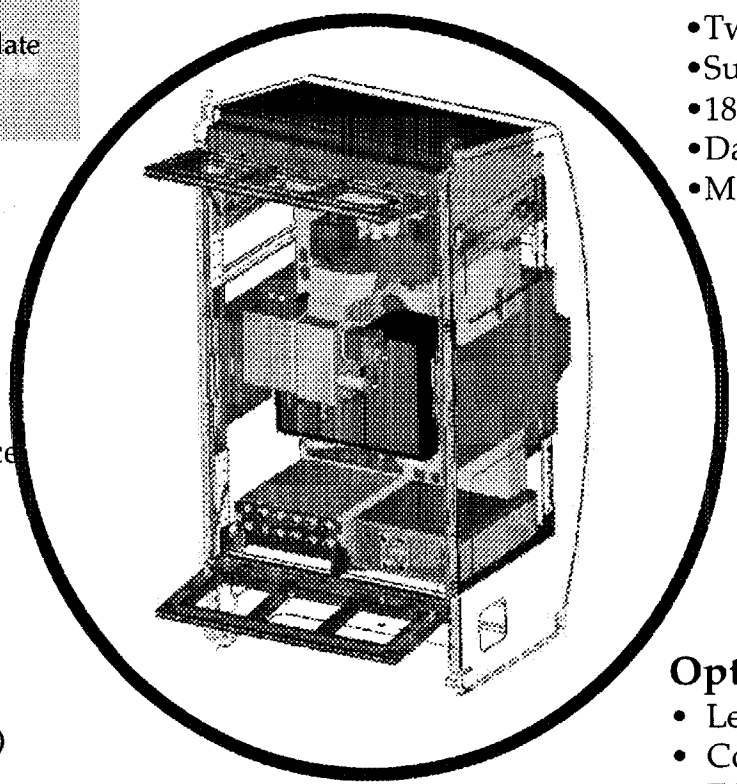
GRC Microgravity Science Program

Fluids and Combustion Facility

FIR Accommodations

FIR Features:

- Easy access via fold down bench
- Diagnostics easily reconfigured, replaced/interchanged on optics plate
- Accommodates many experiment configurations and disciplines

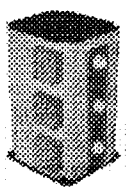


Basic Services

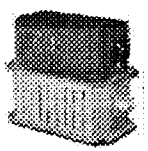
- PI Volume: 460 liters
- Rotating Optics Bench
- Electrical Power
- Remote Operation Capability
- Environmental Control
- ISS Command and Data Interface
- Control/Timing

Illumination & Laser Packages:

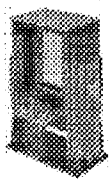
- White Light via fiber Weave
- LED Array
- Laser Diodes (680 and 780 mm)
- Nd: YAG



Laser Diodes



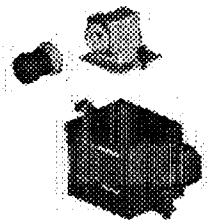
Nd:YAG



LED Array

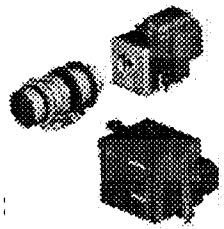
Image Processing & Storage Units

- Two Independent Image Processors
- Support for High Resolution Digital Camer
- 18.2 GB Hard Drives
- Data Compression
- Motion Control for A



Cameras:

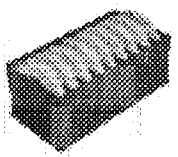
- Color Camera
- Hi Resolution
- Ultra High Speed



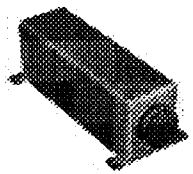
Optical Components:

- Lenses
- Collimators
- Fiber optic cables

Lenses



Optical Fibers

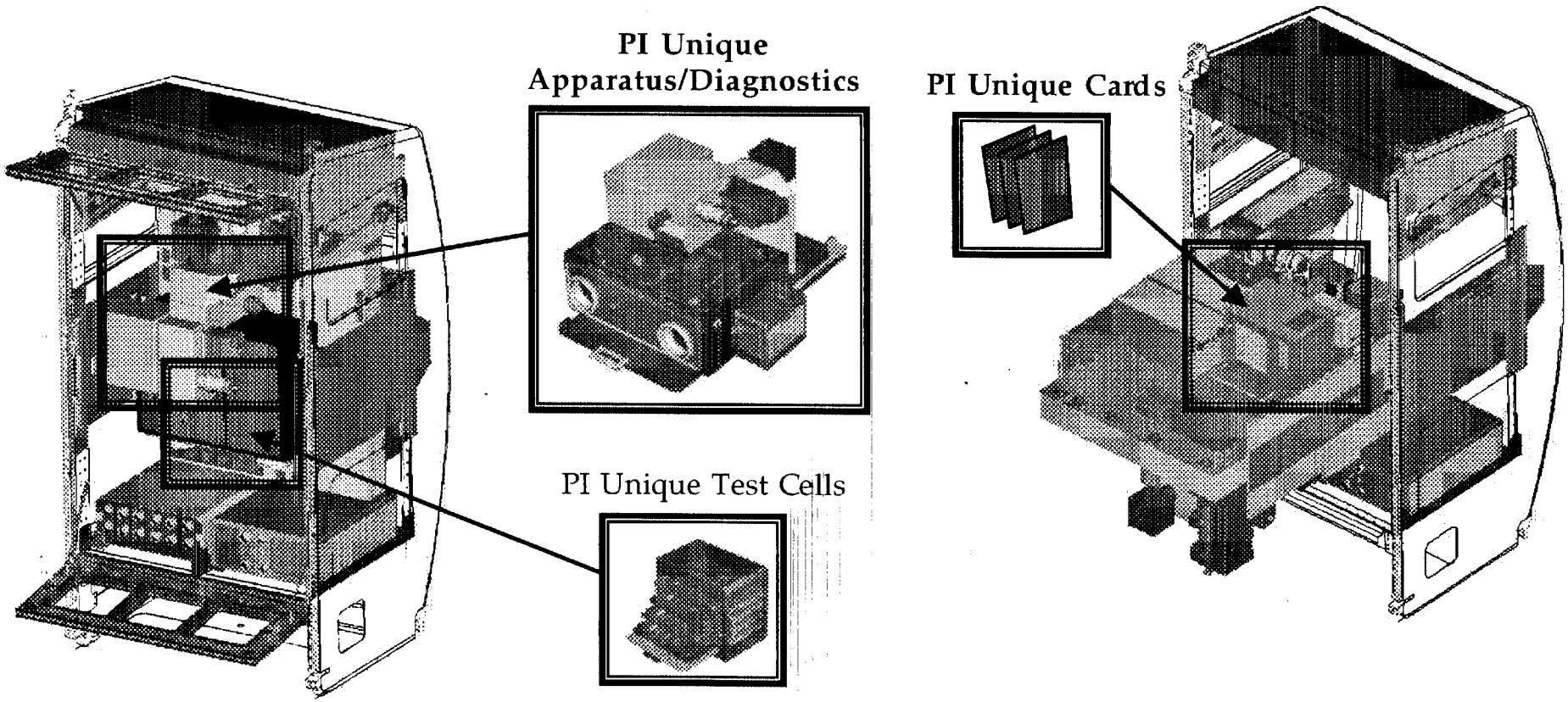


Collimating Optics

GRC Microgravity Science Program

Fluids and Combustion Facility

FCF/FIR Customized for Each New Fluid Physics Experiment



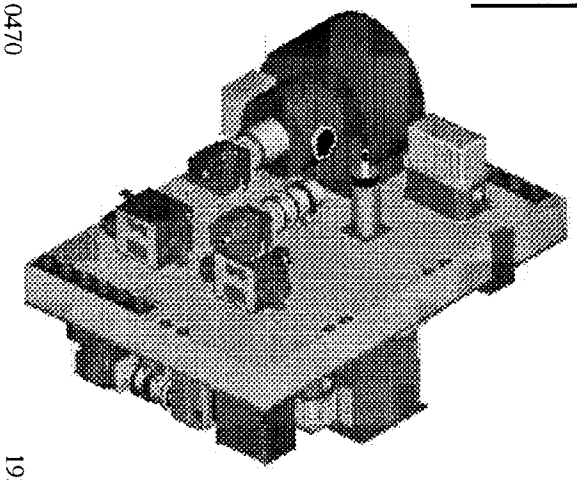
Commonly needed equipment, optimized for fluid physics experimentation, remains on-orbit and reconfigured

PI unique equipment customizes the FIR to do the required science

GRC Microgravity Science Program

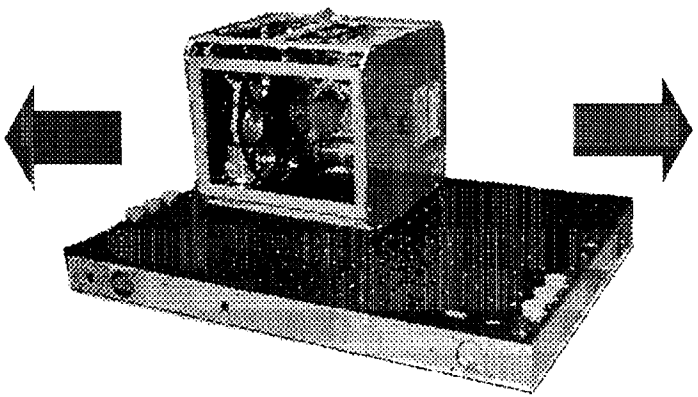
Fluids and Combustion Facility

Fluids Rotating Bench Package Overview



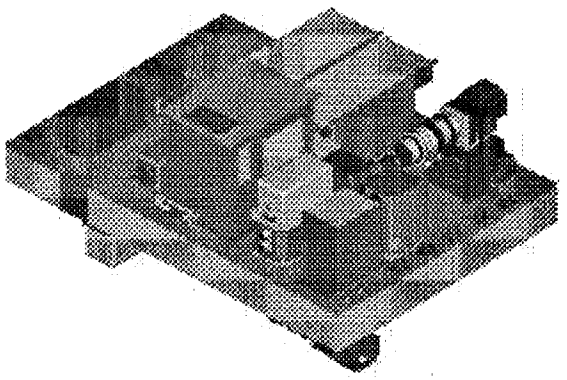
Optics Bench Front

Science



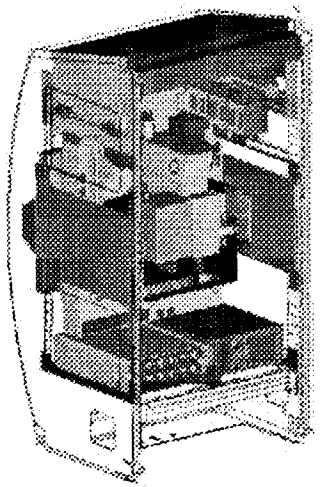
Optics Bench Concept

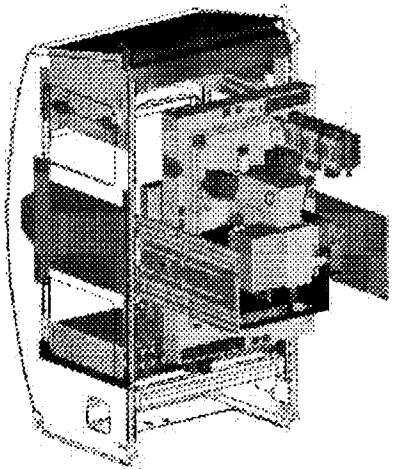
Fluids Integrated Rack

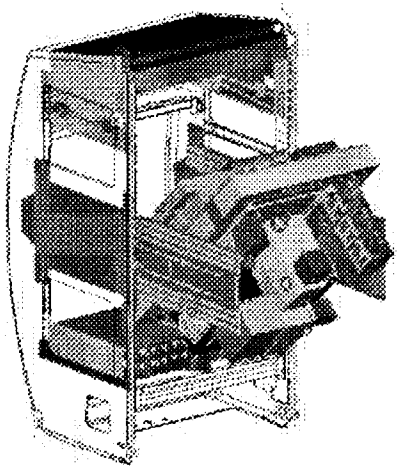


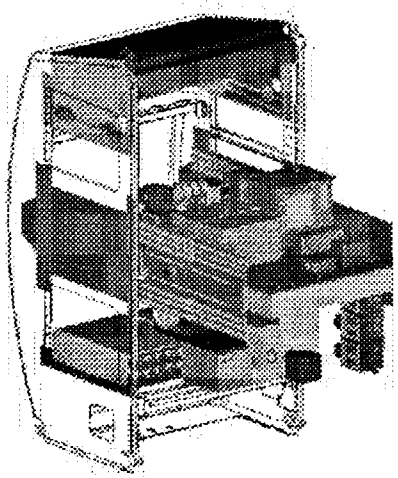
Optics Bench Rear

Science Support



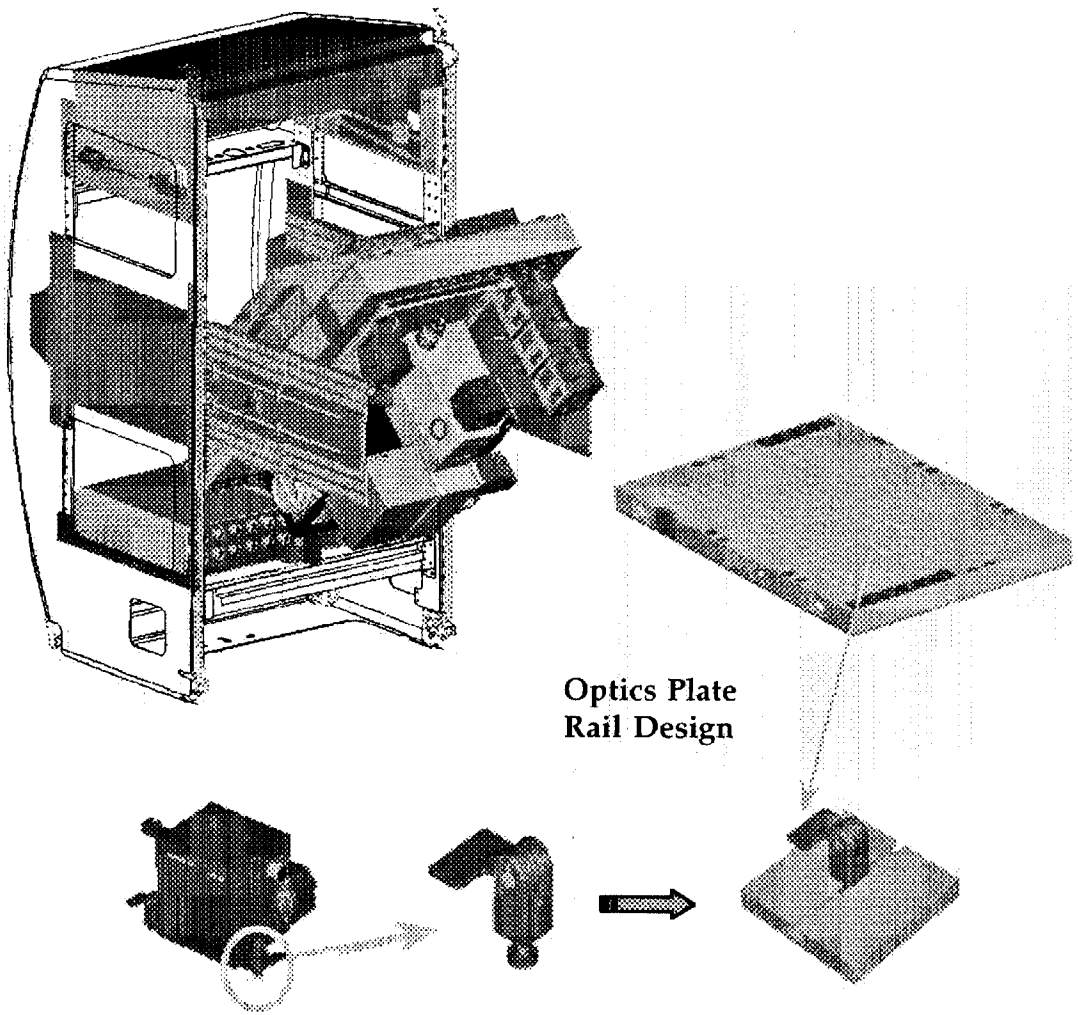






FIR Rotating Bench: Operational to Diagnostic Reconfiguration Orientations

Fluids Rotating Optics Bench Package:



Quick connect assembly attached to baseplate of package

Quick connect assembly mounted in optics plate rails

Platform for PI hardware
- 737mm x 1016mm front bench dimensions
- 460 liters available volume for PI hardware
- Allows for infinite reconfigurability for PI hardware custom set-up

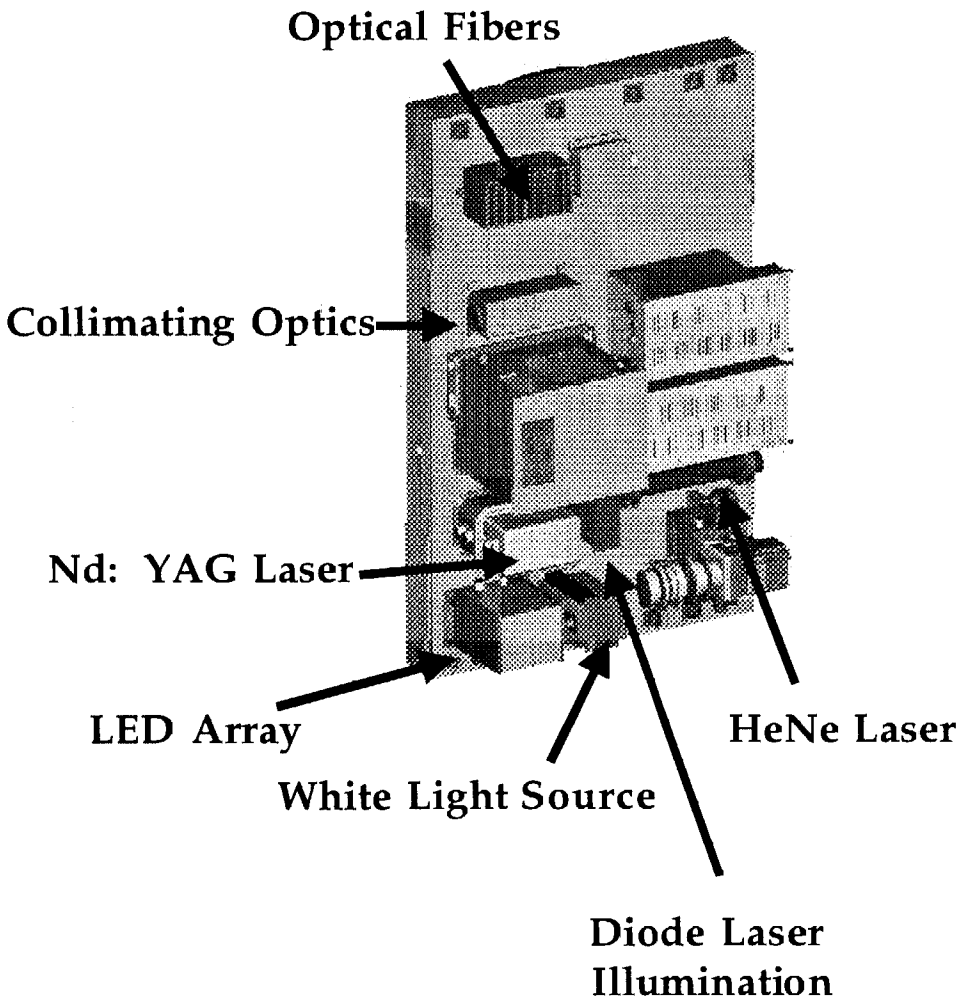
Rotating bench for ease of access to back of bench

Internal Rail Design
- High accuracy positioning, 2mm and 2 degrees point to point
- Flatness <0.5mm
- Quick connect interface for easy crew operations
- Standard Optics Hole mounting also available for PI use

GRC Microgravity Science Program

Fluids and Combustion Facility

FIR Laser & Illumination Packages



Nd: YAG Laser
- 532nm Wavelength, solid state laser
- > 50mW Power to PI hardware
- Coherence Length ~30m

HeNe Laser
- 633nm Wavelength
- single mode, 1mW Power
- Polarization ratio 500:1

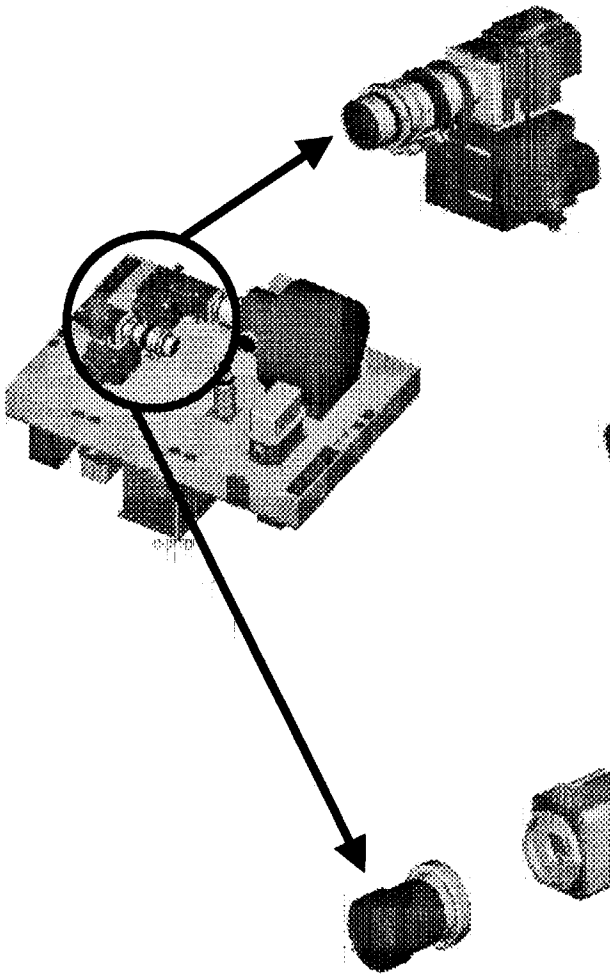
Laser Diodes
- 680 nm, 10mW and 780 nm, 15mW
- Supplemental laser diode drive available for PI hardware

LED Array
- 150mm x 150mm, 640nm illumination strobing capability, variable intensity

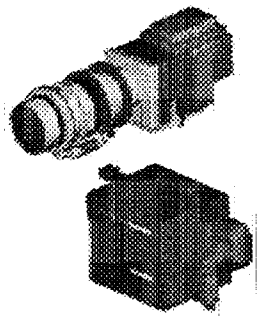
Collimating Optics
- 2.5 mm beam, <1.5 milliradians divergence
- 50mm beam, <0.8 milliradians divergence

White Light Source
- 140mm x 140mm fiber weave panel
- Highly uniform intensity

FIR Cameras and Lenses



High Resolution Camera, with modular design



Color Camera Body and interchangeable lens

- **High Speed Cameras**
  - 1024 x 1024 12-bit pixels up to 30 fps
- **High Resolution Microscopic Camera**
  - 8x magnification for 1 mm x 1mm field, 3 micrometer resolution
- **Color Camera**
  - 484x768 pixels
  - 3 chip design for individual R,G,B readout
  - C-mount lens for interchangeability
- **Ultra- High Speed Camera (Generation II)**
  - 1000 fps w/ significant longer duration and higher resolution
  - Enhanced Image Processing & Storage Unit
- **Macroscopic Zoom Lens**
  - 19mm - 100mm Fields of View (FOV)
- **Microscopic Lens**
  - 200um x 200um FOV - 18mm x 18mm FOV