U.S. Microgravity Payload – 4

Microgravity Glovebox (MGBX)

Background

Many experiments planned for space require crew involvement, yet may contain substances that are irritating, potentially hazardous, or involve operations impractical in the cabin environment. To help resolve this situation, a Spacelab Glovebox was developed and flown on the First United States Microgravity Laboratory flight in July, 1992. The Spacelab Glovebox demonstrated it could provide a safe and user-friendly environment in which to conduct these experiments.

The Microgravity Glovebox (MGBX) was developed to provide this same capability in the Shuttle Middeck and aboard the Mir Space Station and International Space Station (ISS). It has flown on the Third United States Microgravity Payload (USMP-3) and several Mir missions, and has proven to be an excellent resource for conducting these type experiments in a cabin-air environment.

Objective and Procedures

The main objective of the MGBX is to provide an area of containment for experiments having substances that may present a risk to the crew or cabin environment. It also serves to protect experiment samples from the possibility of contamination from the cabin atmosphere when an experiment container must be opened.

Experiment containment is provided in the MGBX work area. The release of any materials into the cabin is prevented by door panels that securely seal and an internal air pressure that is maintained lower than cabin pressure. Astronauts then can handle the materials and the experiment instrument in a more protective environment for both the crew and the experiment sample.

With experiment procedures in hand, an astronaut is ready to begin experiment operations in the MGBX.

The MGBX provides power, filtration, illumination, data collection, and status sensing for gas, temperature, air pressure, and humidity. These and other requirements for each experiment are determined before flight.

Multiple experiments can be performed in the MGBX during a single mission. For each experiment, samples and the experiment instrument are packaged and stowed in the MGBX lockers. The experiment hardware is removed from stowage during flight and inserted through an outside door on the MGBX. The instrument can be bolted down or attached with magnets or Velcro™ if necessary; then the door is tightly sealed. Astronauts use the gloves inside the work area to complete the setup and loading of the hardware with samples after the door is sealed.

Experiment requirements usually call for a series of sessions for each type of experiment, each session containing several samples (for example, several samples of a combustion experiment during one session).

Setting up an experiment in the MGBX

Sample change-out, hardware manipulation or adjustment, and experiment operations continue in the work area until each session is concluded. Once completed, work area cleanup and experiment hardware and sample stowage begin. This same process will be followed for each of the experiment sessions.

Experiment operations proceed

Hardware and Operations

The major components of the MGBX consist of a Glovebox (GBX), a Video Drawer, and an Interface Frame that provide scientists with a complete system and area of containment for experiments. External video support equipment is used in addition to the MGBX video equipment, to further enhance MGBX science experiment operations.

The GBX includes a work area and an air management system. The interior of the work area is equipped with internal lighting and is coated with corrosion-resistant materials. The work area is visible through a clear viewing window on top and three front-loaded video port cameras, and is accessible through three removable door panels, and two glove ports. Two electrical feed-through connectors are also provided in the front door panel for any additional electrical and video operation requirements.

At the rear of the interior work area chamber is the air management system. It contains various filters, valves, and sensors which help to regulate filtration, temperature, humidity, gas, and air pressure in the work area.

The Video Drawer contains video/audio processing and recording systems. Experiments being processed in the GBX can be monitored from three camera angles. One of these three video signals can be simultaneously sent to the orbiter for immediate downlink to experimenters on the ground. The scientists are then viewing the experiment in real-time and may request modifications to experiment procedures to enhance the science return.

Video support equipment, external from the MGBX hardware, is included. Video cameras and monitors provide the crew and scientists with additional, different views of the science experiment in operation. An audio switch also allows the crew to add commentary to the video recording tape.

The Interface Frame attaches to the orbiter and houses the GBX and Video Drawer. It provides the basic functions of electrical power, control, and data collection.

On the USMP-4 mission, the MGBX will provide a safe and effective way to perform unique and important materials and combustion science investigations.

National Aeronautics and Space Administration

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U.S. Microgravity Payload – 4

Enclosed Laminar Flames (ELF) – A MGBX Investigation

Science Background

Combustion is the process of burning. More specifically, it is a rapid chemical reaction that consumes oxygen and releases energy. Combustion plays a key role in heating our homes, propulsion, global environmental warming, materials processing, hazardous waste disposal, as well as many other areas. Despite this, we have a limited understanding of many fundamental combustion processes.

Combustion in normal gravity creates buoyancy-induced flows (*convection*) through the production of hot gas, which is less dense than air. In a gravity environment, the hot gas is pushed up by the surrounding, denser air (a hot-air balloon provides a perfect example of this). As this gas rises, it creates movement–a flow–that promotes instabilities.

Research in microgravity permits a new range of combustion investigations and allows scientists to study processes masked by this buoyancy-driven convection during Earth-based combustion. Combustion research focuses on understanding the important hidden processes of ignition, flame spreading, and flame extinction that occur during combustion.

Understanding these processes will directly affect the efficiency of combustion operations in converting chemical energy to work or heat, and will create a more balanced ecology and healthy environment by the reduction of pollutants emitted during combustion. One such experiment, the Enclosed Laminar Flames Experiment (ELF), will be conducted in the Microgravity Glovebox (MGBX) during the USMP-4 mission.

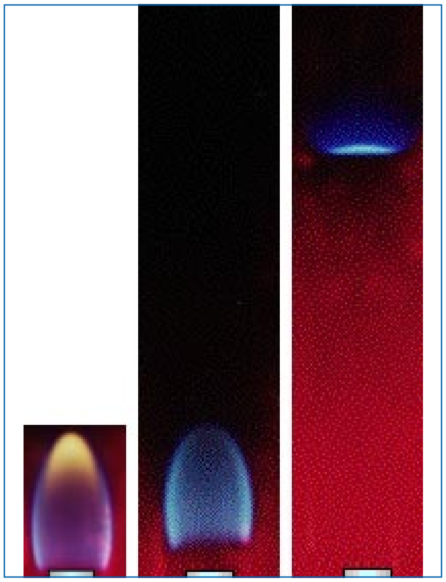
Objective and Procedures

The goal of the ELF investigation is to improve our fundamental understanding of the effects of the flow environment on flame stability. The ELF investigation will determine the effect of convective flows on the stability of laminar (non-turbulent), jet diffusion flames in a ducted, co-flow environment. The flame's stability refers to the position of its base, and ultimately its continued existence.

A microgravity combustion investigation showing the effects of a controlled, slow air flow on flame stability and smoke dissemination—without the buoyancy-induced flows found on Earth.

Enclosed diffusion flames are commonly found in combustion systems such as power plant combustors, gas turbine combustors, and jet engine afterburners. In these systems, the fuel is injected into a duct with a co-flowing or cross-flowing air stream. The diffusion flame is found at the surface where the fuel jet and oxygen meet, react, and consume each other. In combustors, this flame is anchored at the burner (i.e., fuel jet inlet) unless adverse conditions cause the flame to lift-off or blow-out. Investigations of burner stability study the lift-off, blowout, and reattachment of the flame.

Flame stability is strongly dependent on the fuel jet velocity. When this velocity is low, the flame anchors at the burner rim. When the velocity is increased, the flame base gradually moves downstream; but, as the velocity increases beyond a



Flame images with lifted flames captured during an Earth-based test that was conducted in a reduced-pressure environment to simulate the effects of bouyancy.

critical value, the flame base abruptly jumps downstream. When this "jump" occurs, the flame is said to have reached its lift-off condition. While lifted, the flame is not attached to the burner and it appears to float in midair. Flow conditions are such that the flame cannot be maintained at the burner rim despite the presence of both fuel and oxygen. So, when the fuel jet velocity is further increased, the flame will eventually extinguish at its blowout condition. In contrast, if the fuel jet velocity of a lifted flame is reduced, the flame base moves upstream and eventually returns to anchor (reattach) at the burner rim.

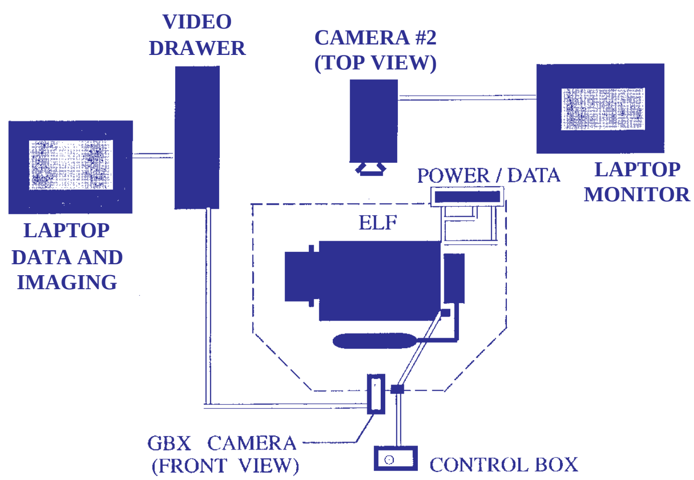
The air flow around the fuel jet can also significantly alter the lift-off, blowout, and reattachment of the flame. The effects of the air flow on the diffusion flame's stability in normal gravity, however, are often complicated by the presence of buoyant convection. Buoyant convection is strong enough in normal gravity flames that it dominates the flow field. In normal gravity testing, it is very difficult to tell the difference between the effects of the forced air flow from those of the buoyancy-induced flow. However, a comparison of normal gravity and microgravity flames provides a clear indication of the influence of forced and buoyant flows on the flame stability.

Hardware and Operations

The major hardware components are an experiment module, electrical cables, a control box, fuel bottles, and a set of ignitors.

The ELF module is a miniature, fan-driven wind tunnel, equipped with a gas supply system. A small nozzle, located on the duct's flow axis, has a thermocouple at its outlet to indicate extinction of the flame. The air velocity is measured by a hot-element anemometer, and the fuel flow is set with a mass flow controller. The duct is also equipped with a temperature rake, containing silicon carbide fibers and thermocouples. It can be positioned by the astronaut so that temperature measurements can be made at appropriate flow conditions. A hot-wire ignitor is activated by a lever on the ELF module.

The fuel flow, air velocity, rake position, fan voltage, and two temperatures are displayed for astronaut viewing on the module. Video imaging and data from the rake thermocouples is recorded by the MGBX video system. A second image of the flame will be recorded with a video camera through the top viewing window. During operations, the investigator team will monitor the downlinked data, so they can recommend appropriate conditions for subsequent tests. Having this capability will allow the ELF science team to further enhance the scientific return available after the combustion tests are conducted during USMP-4.



ELF GLOVEBOX SET-UP

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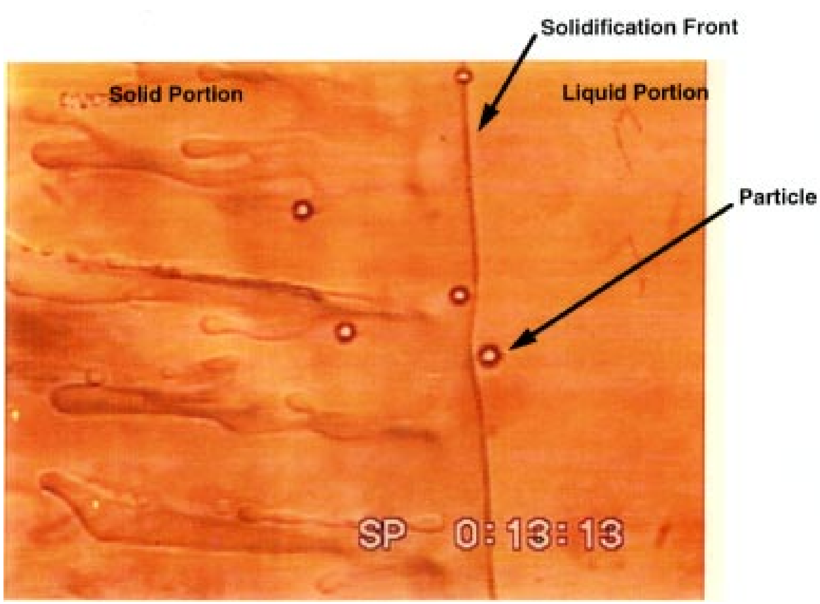
U.S. Microgravity Payload – 4

Particle Engulfment & Pushing by a Solid/ Liquid Interface (PEP) – A MGBX Investigation

Science Background

Composite materials are usually defined as a mixture of two or more materials which, when combined, form a new material with specific properties. The reason for developing such a combination is to take advantage of the properties of each of the component materials. The resulting composite material then has superior properties in terms of stiffness, strength, and strength-to-weight ratio.

Metal matrix composites, consisting of a combination of a metallic and a ceramic component, have widespread applications in the automotive and aerospace industries. Processing these type composites usually involves dispersing hard ceramic particles in a liquid metal and subsequently cooling (solidifying) the liquid metal. For the best combination of properties it is essential that a uniform dispersion of particles is obtained in the metal.



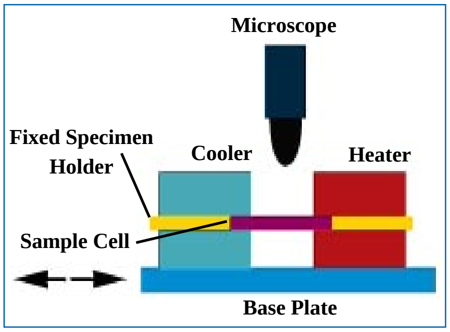
A video image of a moving solidification front

As the liquid metal solidifies, there is a band of solidifying liquid, a few atoms thick, between the solid and the liquid portion of the sample. This band is known as the solidification interface. As the interface moves (solidifies), particles are either pushed ahead of, or engulfed into, the solid material. The uniformity of the distribution of the ceramic particles depends primarily on the nature of interaction of this interface with the particles.

Results from ground-based investigations have been inconclusive in accurately understanding the physics of the problem. This is primarily due to the role of gravity-induced *convection* (flows or movements in a liquid or gas caused by gravity) and *sedimentation* (a separation of liquids, with heavier materials at the bottom and lighter materials at the top) which can significantly alter the nature of this interaction. The effects of convective flows prevent the study of other important processes, such as the dispersion of the particles. Hence, there is a necessity for performing such an investigation in a microgravity environment. The Microgravity Glovebox (MGBX) on USMP-4 gives the researchers this opportunity.

Objective and Procedures

The primary objective of this investigation is to obtain a fundamental understanding of the interaction between the interface and the particles and thereby propose methods and techniques for processing superior composite materials.



Internal sample configuration

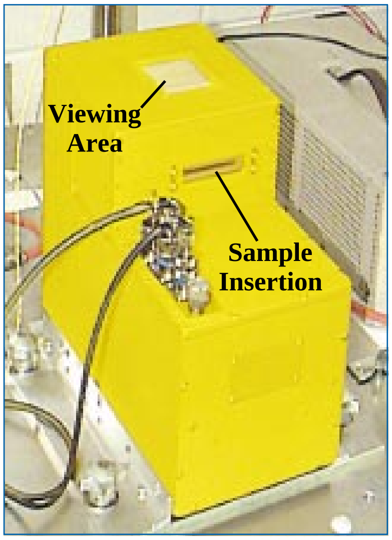
While performing experiments with a metallic sample, it is very difficult to view the nature of this interaction because metals are opaque (not transparent) to light. However, by using transparent materials such as organics it is possible to simulate the same factors that occur in real metallic systems. In this experiment, a mixture of transparent organic material (simulating the metal) and polystyrene or glass particles (simulating the ceramic particles) will be used.

For each investigative run, a crew member will insert a glass cell containing the sample mixture into a furnace placed in the MGBX facility. By moving the furnace at a controlled velocity, the solidification interface will be made to interact with particles of different sizes. The video image of this interaction will be downlinked to the science control center. This will allow scientists to analyze the results in real-time and make any desired changes to the conditions of the investigation. Temperature, particle size, and furnace velocity data obtained from the investigation will be used to develop a theoretical basis for processing real-world composite materials.

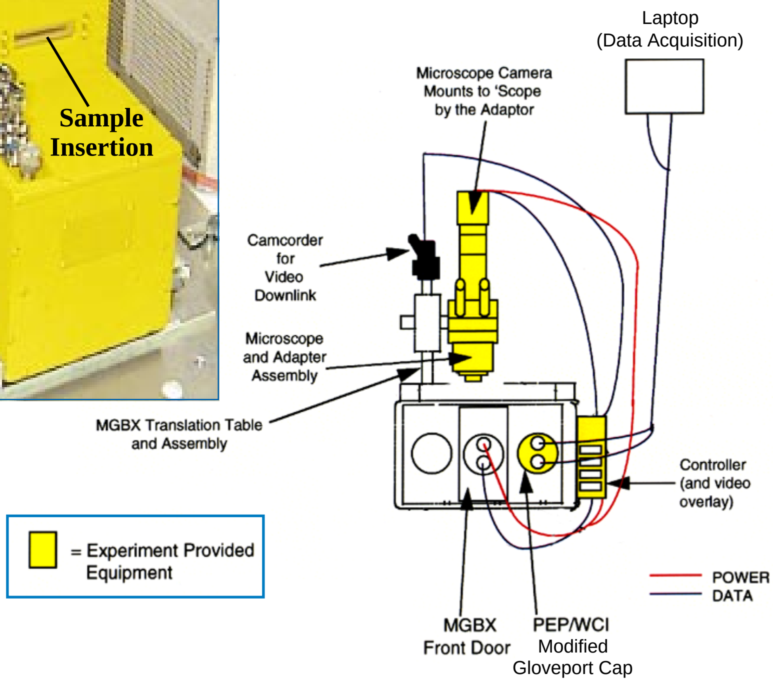
Hardware and Operations

The experiment hardware consists of a furnace with a hot and cold zone. By inserting the sample cell between these two zones, the solidification interface will be created. The furnace will then be moved across the sample at a predetermined velocity, using a stepper motor.

The resulting interaction of the interface with the particles will be viewed at a high magnification level, using a microscope placed over the sample cell. A video camera attached to the microscope will be used to record and downlink the experimental observations in real-time so that any changes may be made before the next sample run.



PEP GLOVEBOX SET-UP



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U.S. Microgravity Payload – 4

Wetting Characteristics of Immiscibles (WCI) – A MGBX Investigation

Science Background

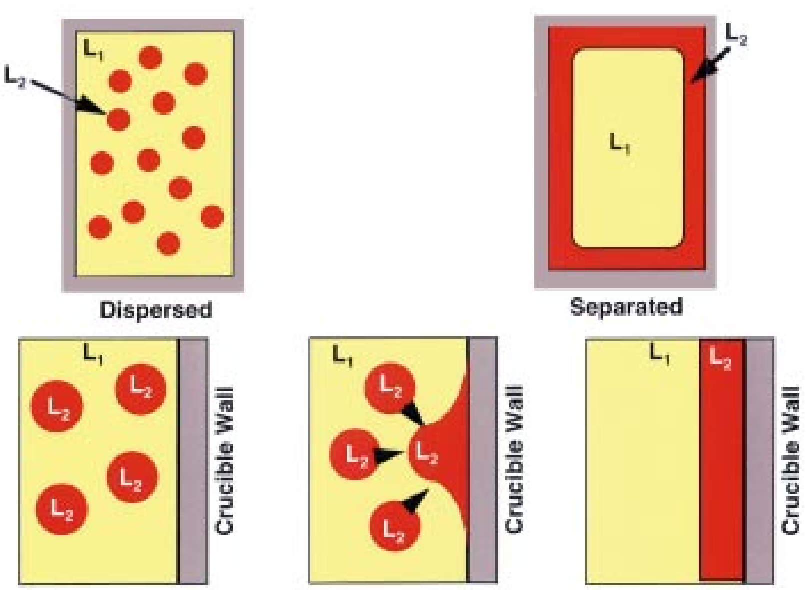
The Wetting Characteristics of Immiscibles (WCI) will be an investigation conducted in the Microgravity Glovebox (MGBX). WCI is an advanced study of the way immiscible liquids behave.

There are a large number of combinations of metals (alloys) which, when melted, form two liquids that do not mix; these non-mixing alloys are called immiscibles. When these combinations are processed on Earth, the heavier of the two liquids sinks to the bottom of the container. This separation of liquids is due to a common effect found in gravity known as *sedimentation.* This same gravity-induced behavior is also seen in other liquid systems, such as oil and water, where the water sinks to the bottom of a container.

Because of the many useful characteristics of these "immiscible alloys," there is great interest in producing combinations where the two liquids are uniformly distributed. Processing under low-gravity conditions can prevent the heavy liquid from sinking, but a new problem is encountered. One of the liquids tends to adhere to the walls of its container. This "wetting" of the container by one of the liquids again results in an undesirable, separated mixture.

The WCI investigation is designed to study ways in which to control this wetting behavior in order to produce more desirable structures. If the system can be controlled by processing in a microgravity environment, a better end product will be made.

With the availability of processing materials in space, provided by the USMP-4 mission, better materials can be developed in the absence of gravity which benefit us in many ways.



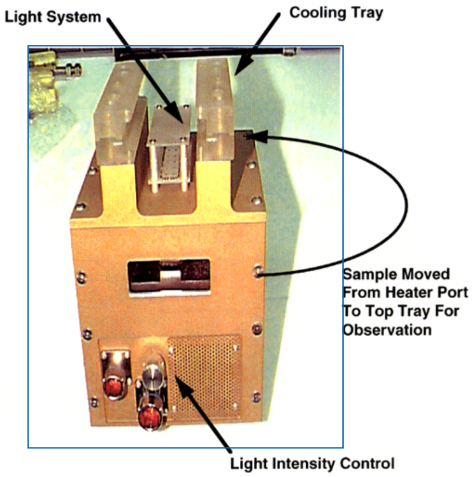
L_2 Migrates To Crucible Wall Due To Wetting

"Wetting" of the container walls still occurs, even in microgravity. Investigations such as WCI should help solve this mystery.

L_1 – Liquid 1
L_2 – Liquid 2

Objective and Procedures

WCI will use transparent materials to simulate a molten metal so the scientists can actually see how the liquids interact with each other—and to the container they are in. The scientist leading the experiment, Dr. Barry Andrews, has used these materials for experiments on Earth, trying to understand how these factors work together.

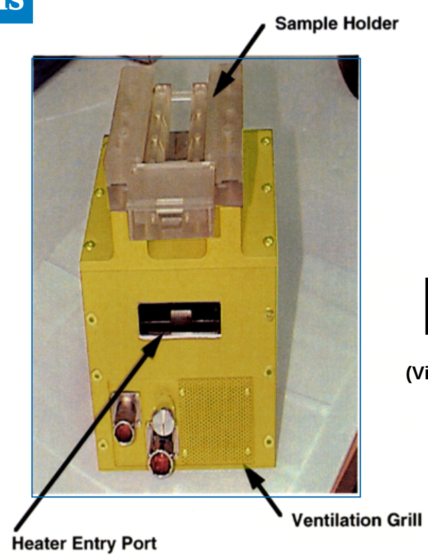


There will be ten samples prepared to go on the USMP-4 flight. When the astronauts set up the experiment in the MGBX, a microscope and video camera will allow the scientists back on Earth to study the behavior and composition of the materials.

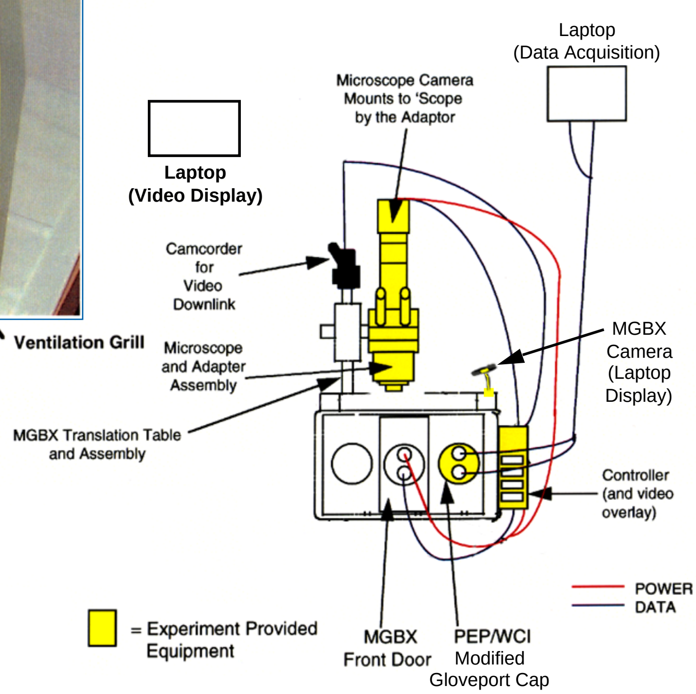
What will happen is that each sample will be heated and then cooled. It is during the cooling step that the scientists and astronauts will watch the sample very closely to see where immiscible droplets form and the steps involved in the separation process.

Hardware and Operations

WCI consists of a heater module for one step of the experiment, and cooling rails for the second step. The sample will be heated to melt the materials to form liquids, then placed upon the rails. Then, a microscope and video camera will be used to observe what happens to the materials. Back on Earth, the video images and tapes will be studied to see how the molten materials behaved during cooling. This will help the scientists further understand how to prepare and mix the materials used to make alloy metals for specialized items useful to mankind.



WCI GLOVEBOX SET-UP



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