THE STUDY OF BIOTECHNOLOGY AND BIOPROCESSING IN SPACE

Controlled-Environment Flight Hardware Selections Available from SHOT

SPACE HARDWARE OPTIMIZATION TECHNOLOGY, INC.

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HARDWARE CHOICES FOR THE STUDY OF BIOTECHNOLOGY AND BIOPROCESSING IN SPACE

Space Hardware Optimization Technology, Inc., (SHOT) has three existing pieces of equipment in its stable that could be used with or without modification for the automated study of cellular and molecular biotechnology. Furthermore, SHOT provides controlled-environment carriers for investigator-unique flight-qualified hardware.

BISEP PLATES.

Unmodified. The BISEP instrument is built around a pair of polycarbonate plates. Each plate has 22 cavities of about 0.5 mL volume each distributed around its periphery. These plates are clamped together at the center, and one rotates with respect to the other, so that the contents of cavities in one plate can be combined or mixed with the contents of cavities in the other plate. A pair of plates being filled with sample is shown in **Figure 1**. Any cavity may be interfaced with one, two or more opposing cavities at any time during flight, depending on experiment protocol. Magnetically driven mixing of the fluids is an available choice through SHOT's proprietary, flight-tested mixing method. Each pair of plates (22 samples) is inserted into a BISEP cassette along with another pair of plates, giving 44 samples per cassette. SHOT's thermally-controlled "ADSEP Processing Facility" automatically operates three cassettes simultaneously, giving 132 samples processed in parallel. **Figure 2** is a diagram showing a rotating plate inside a cassette and a cassette fitting into the processing facility (single mid-deck locker equivalent), which is also photographed in **Figure 3.** As illustrated in **Figure 4** the only crew tasks are the removing and inserting of cassettes; all other functions are automated. If an experiment cycle requires 1/2 a mission time, then two rounds of automatic processing (6 cassettes) would be possible giving 264 samples. This approach represents SHOT's highest present throughput mode.

Modifications. By placing 1 pair of plates in a cassette, fluid pumping in and out of cavities is possible. SHOT has developed this concept for its "ElecSep" product, and it has been tested in the laboratory. Approximately 15 samples, up to 2 mL each would be accommodated per cassette. In another modification, increased numbers of cavities can be made available at 0.5 mL per cavity or smaller if smaller individual sample volumes were desired. For example, about 100 specimens could be processed individually per plate if each specimen were to occupy about a 0.1 mL volume. In this modification, the BISEP plates would perform like a disk in a music box. If no processing (no transfer of material between plates) is required, then each pair of plates would accommodate 44 samples, and a cassette, 88 samples without modification. All samples can be mixed at any time. Provision can also be made for rotating the samples at about 1 RPM to maintain particles in suspension before launch or at higher rates for 0.1 – 1.0 g on orbit.

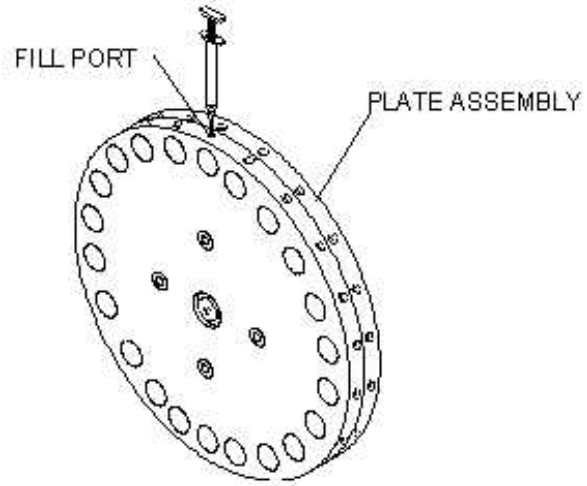

Figure 1. BISEP Plate Assembly showing addition of liquid sample through the fill port of one of the 22 cavities.

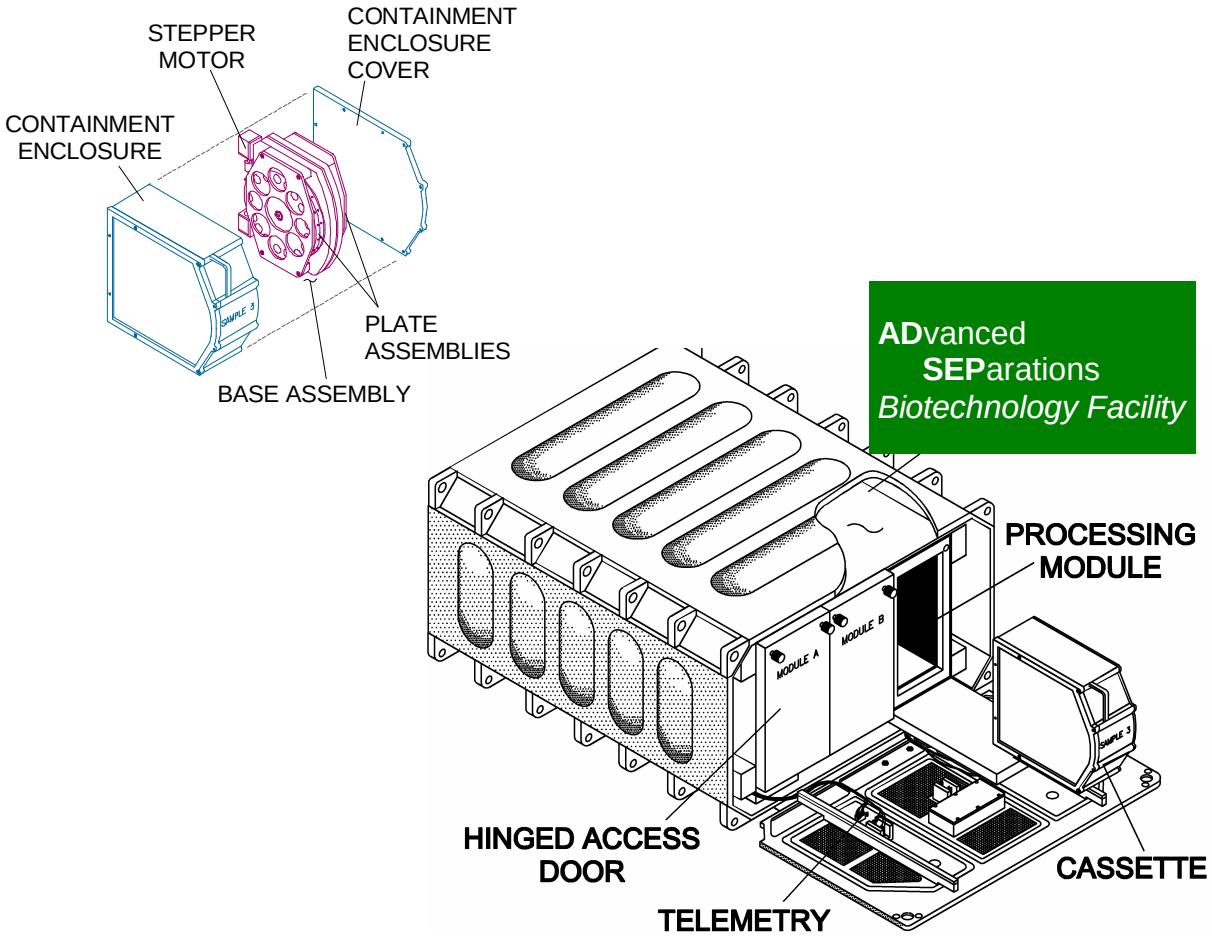

Figure 2. BISEP cassette and ADSEP biotechnology facility. Top: Two Plate Assemblies (Figure 1) with samples are assembled into SHOT's standard cassette envelope. Bottom: This cassette fits into one of three compartments in the ADSEP biotechnology facility, which fits a mid-deck locker. Three cassettes are processed independently and at independently controlled temperatures by the 16-bit computer at the back of the Facility.

Figure 3. Photograph of a closed cassette and of the ADSEP biotechnology facility.

Figure 4. Crew tasks consist only of removing cassettes and inserting cassettes. All other functions of the ADSEP biotechnology facility are automated.

Services. SHOT serves the customer for the complete mission cycle for each cassette that is to be flown on an orbital flight. This covers the following elements:

- Providing a hardware prototype to the investigator's laboratory approximately 11 months before launch, on loan for up to 2 months (or to the point of satisfactory operation).
- Providing flight or flight-equivalent hardware to the investigator's laboratory approximately 6 months before launch, on loan for up to 2 months (or to the point of satisfactory operation).
- Performing all paperwork and meeting milestones to qualify the experiment for flight technically: meeting safety/containment requirements and attending all reviews.
- Working with the investigator(s) at the launch site to build up the payload and arranging handover (usually late-loading) to launch officials.
- Monitoring the payload during the flight, using SHOT's data downlink and command uplink capabilities when these are consistent with the spacecraft's communication system.
- Collecting and returning the payload during post-landing recovery operations.
- Modifying the existing hardware or building new hardware to fit the experimenter's needs.

CELLCULT

Unmodified. The current flight-tested CELLCULT cassette contains a single 50-mL bioreactor with many options: rotation (or not) at a few RPM, perfusion, oxygenation and timed sampling. This reactor system is suitable for cells of all types and aquatic organisms. It can also serve as a large-scale crystallization reactor or emulsion polymerization reactor. Any kind of aqueous suspension can be placed in the reactor vessel. Clean medium is fed by peristaltic pump to the reactor vessel from a fresh-medium storage bag at a rate specified by the experimenter. The fluid within the vessel can be circulated via external loop for oxygenation or exchange with any other gas. Up to six samples of the supernatant or unfiltered culture, can be collected during the flight. The time at which such collections are made is completely open to the experimenter, as the process is totally automated. The plumbing diagram of the CELLCULT system is shown in **Figure 5**, and the entire assembly, inside SHOT's standard cassette housing, is shown in **Figure 6**.

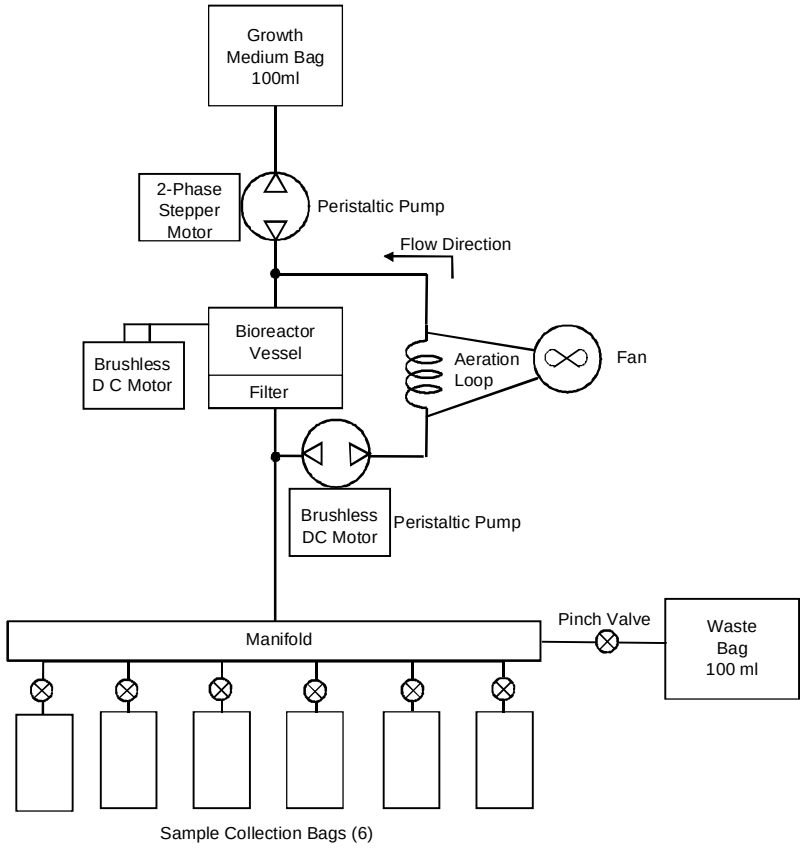

Figure 5. Plumbing diagram of the CELLCULT system showing the reactor vessel, perfusion system, aeration loop and sampling manifold.

Figure 6. Photograph of CELLCULT bioreactor system integrated into SHOT's standard ADSEP cassette envelope. The gasket around the outer edge provides one of the two or three levels of safety containment.

Modifications. Planned modifications include microscopic observation, video monitoring, pH monitoring and/or control, oxygen monitoring and/or control, up to 12 rotating reactors at about 10 mL each, and varied approaches to gas exchange, sample collection and perfusion..

Services. SHOT's service arrangements for CELLCULT cassettes are identical to those for BISEP cassettes.

AVIAN DEVELOPMENT FACILITY (ADF)

Unmodified. The unmodified ADF consists of 20 cylindrical sample holders on a carousel, as shown in **Figure 7**. In applications to vertebrate (avian) development, each cylinder holds one egg. However, practically any experiment that can be performed in a 25-mL volume can be accommodated in ADF. It is anticipated that each 25 mL cylinder would contain several specimens, and all the specimens in a given cylinder would be treated identically, but each cylindrical container could be treated individually. Since the interior of the locker that houses the ADF is a humidified, gas-controlled atmosphere, the specimen containers can be in equilibrium with the locker environment, very much as in the laboratory incubator setting. Whether for mixing or for g-level control, each cylinder can be rotated on its own axis, and the carousel can be rotated at a desirable speed for g-level control as well as slower rotation for processing. Sample processing is achieved by rotating the carousel until the desired sample is at a chemical robot station. The chemical robot then (typically) perforates the sample container with a hypodermic needle and injects an additive, formalin fixative, for example.

Modifications. A necessary step for any non-egg experiment in the ADF is the design and production of specimen containers. The operating program of ADF is already sufficiently flexible that reprogramming the robotics software may be all that is necessary to accommodate a new protocol.

Services. The ADF can only be flown as an integrated mid-deck locker equivalent. A typical single, multi-sample experiment would probably (but not completely necessarily) require exclusive use of the payload. If necessary, a means of combining similar multisample experiments simultaneously could be found.

THERMAL CARRIERS

Unmodified. Irrespective of the experimental machinery contained in a mid-deck locker experiment, temperature and environmental control are vital to any space experiment. SHOT excels in mid-deck thermal carrier design and construction. The ADSEP Processing Facility (Figure 3) and the ADF (Figure 7), excellent cases in point, are joined by TCF-3 (Thermal Carrier Facility-3) shown in **Figure 8,**

Figure 7. Picture of SHOT's Avian Development Facility (ADF) showing 18 positions for holding samples. There is an identical carousel below. The two carousels rotate independently and are served by a chemical robot that injects reagent solutions into one sample at a time on a predetermined program or by remote control. Each sample holder also rotates independently of carousel rotation.

Figure 8. Photograph of SHOT-developed thermal carrier "TCF-3". TCF-3 is compatible with space shuttle and space station racks and can operate automated internal experiment hardware while providing a programmed temperature profile.

which are generic thermal carriers supporting a wide range of temperatures and payload devices. They include computers for operating experimental apparati as well as controlling internal temperature and humidity. ADF and the CELLCULT cassettes also have some capacity to control atmospheric composition as well as temperature and humidity. Furthermore, three CELLCULT cassettes can be operated simultaneously at three different temperatures in the ADSEP processing facility (Figure 2).

Modifications. SHOT's thermal carriers are intentionally versatile, so two broad categories of modifications, already accounted for, are usually sufficient. Existing computer software is programmable to adapt the carriers to any internal experiment, and NASA-approved shelving is customized to immobilize internal payloads and to help isolate them from vibrations.

Glossary

ADF	"Avian Development Facility" multisample avian egg incubator with two independently spinning carousels capable of providing a 1g control group in space. Can also accommodate cylindrical cultivation vessels carrying cells, insects, fish, plants/spores, etc.
ADSEP	"ADdvanced SEParations biotechnology facility" refers to single-locker equivalent facility that accommodates several different types of experiments simultaneously.
BISEP	BIphasic SEParator for multisample contacting in space. Can accommodate 0.5 mL samples in rotating contactor plates.
CELLCULT	Cassette with SHOT's cylindrical reactor vessel and peripherals.

Further Information

Visit SHOT's Web site at www.SHOT.com
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