THE STUDY OF VERTEBRATE DEVELOPMENT AND PHYSIOLOGY IN SPACE

Controlled-Environment Flight Hardware Selections Available from SHOT, Inc.

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HARDWARE CHOICES FOR THE STUDY OF VERTEBRATE DEVELOPMENT AND PHYSIOLOGY IN SPACE

Through several NASA Ames Research Center SBIR contracts, Space Hardware Optimization Technology, Inc., (SHOT, Inc.) is producing three pieces of equipment that could be used with or without modification for the study of animal development and physiology. Furthermore, SHOT provides controlled-environment carriers for investigator-unique flight-qualified hardware.

AVIAN DEVELOPMENT FACILITY (ADF)

Unmodified. The unmodified ADF consists of 18 cylindrical sample (egg) holders on a carousel, as shown in **Figure 1**. In applications to vertebrate (avian) development, each cylinder holds one egg. 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 interior environment, very much as in the laboratory incubator setting. Whether for rotating the embryo 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. Chemical filtration of a sample can be achieved by rotating the carousel until the desired sample is at a chemical robot station. There are two carousels in the Facility, and they can be rotated independently of one another, thereby allowing important 1-g controls on orbit. The internal configuration is shown in the exploded view in **Figure 2.** The chemical robot then (typically) perforates the egg sample with a hypodermic needle and injects an additive, formalin fixative, for example. All functions are completely programmable (temperature, humidity, rotation rates, sampling and injections). The ADF internal computer provides downlinked data and performs uplinked commands. ADF flight hardware (see Figure 1) is currently scheduled to conduct initial flight experiments on UF-1 in October, 2001.

Modifications. Practically any vertebrate experiment that can be performed in a 25-mL volume can also 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. 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.

ADF 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.

SHOT's Services. SHOT serves the customer for the complete mission cycle for each piece of hardware 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.

Figure 1. Picture of SHOT's Avian Development Facility (ADF) showing 18 positions for holding samples. There is an identical carousel below (see Figure 2). 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.

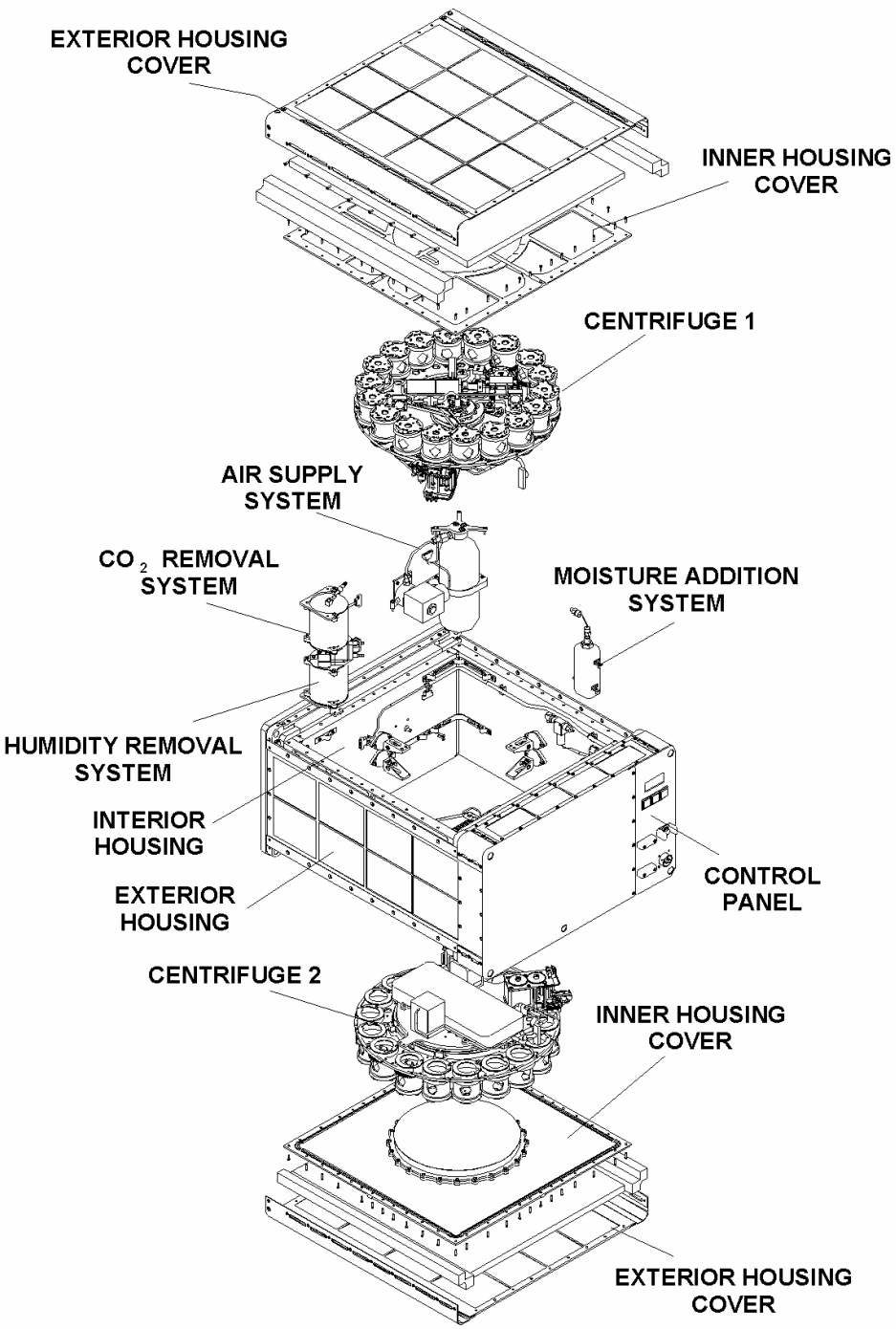

Figure 2. Exploded view of ADF showing upper and lower carousels, insulation and avionics layer, and internal mechanisms.

AVIAN HATCHLING HABITAT (AHH)

The Avian Hatchling Habitat will serve as a brooder for freshly hatched quail chicks from, for example, eggs incubated in the ADF. Its technology is suitable as a component for studying the "egg-to-egg" cycle in reduced gravity or for poultry husbandry on deep space missions. A rendering of the AHH is shown in **Figure 3**.

Figure 3. Exterior view of the Avian Hatchling Habitat

Significant Features. A list of the significant features of the AHH follows:

- Programmable internal temperature control suitable for high-viability brooding
- Water and food delivery adapted to avian feeding habits with minimum wastage
- Water system accurately measures consumption
- Waste management system for the unique waste products of birds and their odors
- Controlled, programmable levels of illumination
- Video monitoring and recording system provides both day and night high-resolution imaging for animal viewing; transparent scroll mechanism provides lens protection and assures clear views
- Configurable cage arrangements: from one single large brooder volume to 12 individual cells for hatchlings or 6 cells for adults
- Forced-air system provides control for oxygen, carbon dioxide, and relative humidity as required to maintain the health of the animals.

ADVANCED ANIMAL HABITAT (AAH-C)

The Advanced Animal Habitat (-Centrifuge) provides controlled-environment housing for laboratory rodents. Its modular design will be suitable, initially, for group-housed adult rats or (with an insert) group-housed adult mice. Further modifications will accommodate individually housed adult rats or mice at all phases of their life cycle and, eventually, animals equipped with advanced biotelemetry systems. The external geometry and interfaces are designed to allow controlled operation of the Habitat on the space shuttle during transit or orbital missions, on the International Space Station in the Habitat Holding Racks and, most significantly, on the ISS Life Sciences Centrifuge. A rendering of the external appearance of the AAH-C is shown in **Figure 4**.

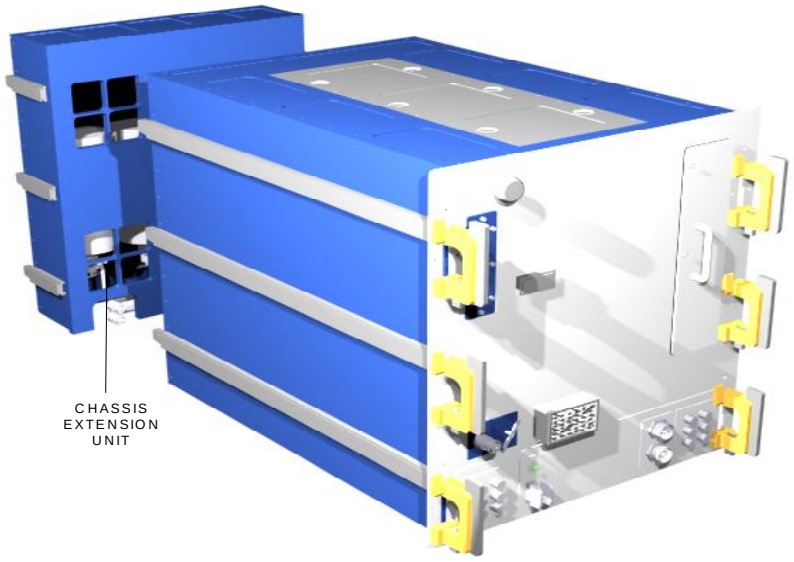

Figure 4. Advanced Animal Habitat-Centrifuge. Rendering of the exterior of the current design illustrates double locker configuration that will fit within the envelope of the ISS Life Sciences Centrifuge. The front panel includes access to food modules and inlets and outlets for front-panel connectors on ISS double racks.

AAH-C Features. The following is a list of the most significant features of the AAH-C:

- Provides a complete biological research environment for housing rodents for long-duration operation on the International Space Station (ISS), or short-duration operation on Shuttle Middeck
- Internally modularized and reconfigurable – capable of accommodating mice or rats from weanlings to adults
- Designed for operation in the ISS Habitat Holding Rack (microgravity environment), in the Centrifuge Rotor (selectable acceleration environment form 0.1 to 2.0g), and at the Life Sciences Glovebox (experimental procedures and unique manipulations)

- Modular food delivery system provides on-demand solid nourishment (foodbars) to the animals while minimizing wastage. Automatically advances food (exposing segment for consumption)
- Water delivery system dispenses potable water on demand via lixits fed from pressurized reservoirs
- Waste management system collects, contains and processes urine, feces, dander, loose fur, glandular secretions, food particles, water (potable and condensate)
  - Prevents animal access to waste products and protects them from harmful volatiles produced from decomposing waste
  - Prevents malodorous, harmful gaseous and particulate materials from entering the crew environment
- Lighting system provides control of light levels in the specimen chamber
  - Programmable to provide day and night cycles
  - Provides uniform light to entire cage and incorporates both "white light" and infrared LEDs to enable monitoring of animal activity and behavior at all times
- Video monitoring system provides both day and night high-resolution imaging for animal viewing. Incorporates a scrolling mechanism that provides a continuous clear mylar viewing surface
- Environmental control system provides control of airflow and temperature within the habitat, and monitoring and regulation of relative humidity and carbon dioxide
- Control and data handling system monitors all habitat sensors, commands and controls all system functions, and stores all required data.

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 ADF (Figure 1), an excellent case in point, is joined by safety-approved "CLIMATE" and its successor TCF-3 (Thermal Carrier Facility-3) shown in **Figure 5,** which are generic thermal crriers supporting a wide range of temperatures and payload devices. They include computers for operating experimental apparati as well as controlling internal temperature and humidity. SHOT's thermal carriers are intentionally versatile, so two broad categories of modifications are built-in. 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.

Figure 5. 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.

Glossary

ADF	"Avian Development Facility" multisample avian egg incubator. Can also accommodate cylindrical cultivation vessels.
AAH-C	“Advance Animal Habitat-Centrifuge” rodent housing facility that fits into the ISS Life Sciences Centrifuge and other carriers
AAH	“Avian Hatchling Habitat” avian chick housing facility for ISS
TCF-3	“Thermal Carrier Facility-3” single mid-deck locker equivalent container for computer controlled experiments in a thermally controlled environment
ISS	International Space Station