Earth, Ocean & Space Environmental Operations Simulator

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Summary

The Earth, Ocean & Space Environmental Operations Simulator (EOS)^2 is the first Canadian University research facility that allows for a full range of physiology and, instrumentation and hardware testing in extreme Earth, ocean and space environments. The facility integrates the physiological monitoring expertise of the Aerospace Physiology Laboratory with the physical capabilities of the hypo/hyperbaric chamber (305 m sea water dive depth, 33.5 km altitude) at SFU. This chamber is unique in Canada and most probably one of a few chambers world wide with both diving and altitude capabilities. As a completely enclosed environmental system the hypo/hyperbaric chamber complex also provides a facility where real simulations of human activity in confined and isolated environments can be run. The Facility provides a unique research and teaching facility for the study of human physiology and performance and for the study hardware in extreme environments. It can provide a state-of-the-art scientific and technical training facility for both academic and industrial partners.

Introduction

The dive/altitude chamber complex (Figure 1) in Simon Fraser University's Department of Biomedical Physiology and Kinesiology was installed in 1981. This hypo-hyperbaric chamber complex had an original operating range of 305 metres sea water dive depth to 12,000 metres altitude with life support and environmental control systems. The Aerospace Physiology Laboratory (APL) was established in 1997 and contains equipment for measurement of a wide range of physiological variables. As part of the APL research program, in 2002 the altitude capabilities of the chamber was expanded so that altitudes comparable to that encountered with high performance aircraft (~110,000 ft) or equivalent to atmospheric pressure on Mars can be achieved. This is the only Canadian university research facility which allows a full range of aerospace physiology testing. The Earth, Ocean & Space Environmental Operations Simulator (EOS)^2 facility provides the infrastructure to facilitate research and development in critical areas for human-crewed exploration missions, including ISS, lunar, Lagrange-point, Near-Earth Asteroid, and Mars system (surface and moons) destinations.

Figure 1: *Altitude/dive chamber at SFU.*

The Facility

Hypo/hyperbaric chamber:

The dive/altitude chamber complex constructed to PVHO-1 (Pressure Vessel for Human Occupancy-1) standards was designed, fabricated and installed by Perry Ocean Engineering of Florida. The main features are outlined in Table 1. It consists of three interconnected chambers: entry lock, wet chamber and living chamber (Figure 2). The wet chamber is situated below the entrance lock and connected by a 0.75 metre diameter trunk. The design incorporates both internal and external doors. This accommodates separate pressurisation of each chamber, and evacuation of either the living chamber or the complete complex.

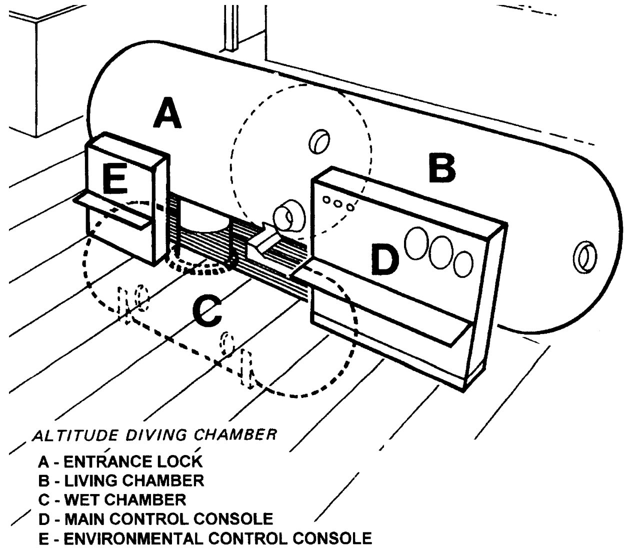

***Figure 2**: Dive/altitude chamber complex*

TABLE 1: HYPO-HYPERBARIC CHAMBER

DETAILS	ENTRY LOCK	MAIN CHAMBER	WET CHAMBER
Dimensions			
dia x length:	2.0 m x 2.4 m	2.0 m x 4.8 m	2.0 ax 3.6 m
Pressure			
(depth sea water)	305 m	305 m	305 m
Altitude			
(m elevation)	33,530 m	33,530 m	33,530 m
Access: 0.76 m			
to all chambers	3	1	1
pressure doors	external: 3	1	1
altitude doors	internal: 2	1	1
Medical lock		1	
dia x length		30 x 35 cm	
View ports	2	4	1
breathing masks			
mixed gas	8	8	
O_2 masks		8	
Lights	1	2	1
Fold-up bunks		4	
Data ports	4	5	
Gas sample port	1	1	
Internal power			
Diving	12V DC	12V DC	
Altitude	120 V AC	120 V AC	

Certification: PVHO-1; ASME Sect 8 Div 1; CSA draft standard

The main living chamber is outfitted to support a maximum of eight persons. It includes a 30 cm diameter medical lock, communications, fire detection and suppression system, four fold-up bunks, table and demand line breathing masks. Two independent breathing lines (BIBS) provide emergency and treatment gases: one line to supply special mixtures and one dedicated to oxygen. The oxygen is exhausted from the masks to an external dump. High pressure air is supplied to the system by means of two Bauer compressors. Air storage is provided by four 143 m^3 (5,060 cubic feet) cylinders at 26,700 kPa (3,000 psi). This allows air pressurisation of the chamber system to a maximum of 305 metres for wet or dry equipment testing.

During human occupancy one storage cylinder is dedicated to driving the fire suppression system. Sprinklers are controlled by a tracking pressure regulator and cover the entrance lock and main chambers with a deluge of 6.8 L s^{-1} from a high pressure reservoir. Control of all three chambers is provided from a central console with voice and television monitoring. The console provides independent system control to each chamber. In case of a line malfunction, the chamber controls have cross-connections to allow isolation of any component. All through-hull penetrations have internal and external shut-off valves. Atmospheric monitoring of each chamber is provided at the control console. The ambient conditions within the chambers are controlled by an Environmental Control System developed by the Nova Scotia Research Foundation. The system consists of two loops, serving the wet and dry chambers respectively. These control ambient air purity and temperature in all units of the chamber complex and also provide temperature control and filtration of water in the wet chamber.

For hardware testing, the bunks and other non-essential items can be removed from the chamber to provide a larger volume for the test hardware. Single components must be less than 0.76 m (30”) in diameter and assembled systems must be less than 2.0 m (78”) in diameter (See Table 1 for specs). Through the treatment gas console various gas mixtures can be introduced into the chamber and continuously monitored, allowing for the simulation of a wide variety of atmospheres including Mars pressure and atmospheric gas content.

Aerospace Physiology Laboratory:

The Aerospace Physiology Laboratory (APL) contains equipment for measurement of a wide range of physiological variables. These include the capability for non-invasive: blood pressure (BP); electrocardiograms (ECG); breath-by-breath respiratory gas exchange; blood gases; and Doppler ultrasound blood flow. The laboratory also contains a respiratory feedback control system as well as exercise testing equipment. This system is capable of making changes to respiratory gases breath-by-breath and can be used to test the effects of various atmospheric gas conditions on human performance.

A custom computer controlled hydraulic breathing machine is also available. This device is capable of simulating human ventilatory function over a wide range of pressures. A range of tidal volumes, respiratory frequencies and gases can be programmed into the device to test a wide variety of commercial and experimental breathing apparatus.

The Earth, Ocean & Space Environmental Operations Simulator (EOS)^2:

The research devices in the APL can be integrated with the hyper/hypobaric chamber and configured to be accessible for on-line remote observation with network/internet access. Specialized connectors can be inserted to link data collection devices resident outside the chamber with their respective sensors inside and allow for multi-signal data collection and processing. Wireless communication is also possible. This facility provides a unique research and teaching facility for hardware testing and development and the study of human physiology and performance (such as the effects of diving, altitude, temperature, humidity and environmental gases) in extreme environments.

At present our team includes Andrew Blaber an expert in the area of Aerospace Physiology in the Department of Biomedical Physiology and Kinesiology, Simon Fraser University and Stephen Braham, also at Simon Fraser University who is Chief Engineer of the NASA Haughton-Mars Project, Haughton Crater, Devon Island, Canada, and lead of the Deep Space Operations, Computing an Communications and Exploration Systems Operations Centre projects. It is possible to have the research devices in the facility accessible for on-line remote observation and interaction with network/internet access. This will enable both remote science and build infrastructure for Participatory Exploration. The facility has video monitors and voice communication devices that will be integrated into the computer network system so that two-way communication with video, voice and data will be possible via the internet, as well as the usual e-mail and text communication. In long duration studies (e.g. involving extended stays in the chamber) the computer components will allow subjects greater access to and from the outside world.

Conclusions

The hypo/hyperbaric chamber is unique in Canada and most probably one of a few chambers world wide with both diving and altitude capabilities. In the areas of space related research we are able to investigate the physiological effects related to astronaut EVA (30,000 ft altitude pressure, pure oxygen), including decompression sickness research, and human-machine interface. As well we can assess hardware under Mars conditions including Mars EVA equipment. As a completely enclosed environmental system the hypo/hyperbaric chamber complex also provides a facility where real simulations of a Mars Habitat can be run. The participants are isolated and communicate via an audio, video and data link (over which realistic time delays and signal problems can be simulated). Through computer control of the onboard systems, various scenarios such as air pressure leaks and EVA's can be performed with continuous monitoring of hardware and astronaut physiology. We provide, on a service contract basis High Altitude Indoctrination (Physiologic Training) for private and professional pilots, and flight training schools.

These are only a few of the activities that are possible or presently underway in this facility. Any person, group, or company interested in using the facility is asked to contact the authors.