

THE FOUNDATION  
**COMMERCIAL  
SPACE REPORT**



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Gary C. Hudson, Editor

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Dear Subscriber:

August

This month's Report is a special guest article by Dr. Michael Hyson of Cal Tech. Dr. Hyson is a neuro-biologist currently working on new teleoperator technologies and applications. He is presently attending a month long work-shop on Robotics being hosted by Santa Clara University.

Sincerely,

A handwritten signature in black ink, appearing to read "Gary C. Hudson". The signature is fluid and cursive, with a long horizontal stroke extending to the right.

Gary C. Hudson

Recent Developments in Space Manufacturing Technology

Teleoperators, Legged Locomotion, and

The Space Activity Suit

Introduction

Several technologies of great relevance to the operation of space manufacturing facilities have recently been unearthed from some of the early days of NASA research. All are in the public domain but have received little attention. This article is an attempt to briefly outline three of these: Master-Slave Teleoperators, Legged Locomotion and the Space Activity Suit (aka "the skin suit"). The potential exists that these techniques could give great flexibility to space operations without great lead times for development and without sophisticated automation that might delay our early entry into space, while at the same time leaving our options open for later automation and robotic techniques as they become available.

Teleoperators

A teleoperator is a device that allows action or observation at

a distant site by a human operator. There are many forms of teleoperator with different design philosophies ranging from the "Waldo's" used in nuclear reactors to free flying teleoperators that do jobs from changing modules in satellites to boosting an aging Skylab to a permanent orbit (Alas, this project was cancelled due to internal NASA political factors and overall indecision about whether Skylab should be saved). Here we will discuss Master-Slave and display concepts that apply to any manned teleoperation.

In 1958, William Bradley, while working on helicopter head-up displays, developed a TV camera mounted on an operators head which displayed the view from a remote camera to the operator as if it were at infinity, or through a pair of binoculars. It was black and white, with no stereo vision involved. The key difference was that the remote camera rotated to match the subject's head motion. This gave the operator a strong sense of "being at " the remote site. As an example, Bradley drove a pick up truck through the desert at a range of ten miles. He was shocked when he removed the helmet and found himself back in the laboratory. This demonstrates the remarkable ability of th human brain to project sensory information and interpret it as being events external to the user. The advantage of matching the human to the machine in this manner is that the coupling is tighter, and intuitive judgement and "feel" that are mostly unconscious are available for dexterous operations.

Another key component of teleoperator technology is the bilateral force reflecting Master-Slave manipulator. These devices are arms with seven degrees of freedom and jointed in a way similar to the human arm. The operator inserts his hands in a glove or sleeve-like arrangement on the master end and moves his arm in a natural manner to make the slave arm at the remote site move. Existing manipulators have very simple hands, allowing a pinch grip much like a pair of pliers. The two key concepts involved are "kinematic similarity" and bidirectional rate servoing of the arms. Kinematic similarity means that the arms behave and bend in ways compatible to the human arm, although this does not mean that it must have the same joint structure as the human arm. This similarity allows a good intuitive feel by the operator of what he should do to make the slave arm move in the correct way. Bilateral rate servoing means that rate errors developed at either the master or the slave end of the teleoperator link are fed back to both the master and slave ends for correction. The details are at once obvious but difficult to describe in this space. Suffice it to say that if the remote arm encounters an obstacle, this makes the master end harder to move. Thus one has "feel", much like power steering gives one some sense of the road while giving a power assist.

Coupling the head mounted and slave camera system with good manipulators will allow dexterous manipulation at distances only limited by the speed of light and the delay times tolerated by the operator. He will have a strong feeling of "telepresence", (to use Marvin Minsky's term) and be able to perform almost any task a man could do while there. Distances of 10,000 miles present a 1/10 second time delay which is the maximum distance that presents no special problems to the operator. Operation on the Moon from the Earth would involve a three second delay.

This is frustratingly slow but the Russians were able to drive a Lunakod rover with little difficulty. For Low Earth Orbital operations, by men on Earth, the system is ideal. With current manipulators, it takes a man using a box of tools at the slave end about twice as long to complete a task as it would if he were there himself. If better hands were developed, there would be little difference between the teleoperation and the man's actual presence.

The implications for both space and earth activities are obvious. To mention a few, one could service satellites given free flying propulsion units. One could buy a NASA Space Shuttle and operate it as a remotely piloted vehicle at vastly reduced cost, since no men would be aboard and a higher risk could be accepted, since only the hardware would be lost in the event of failure.

### Legged Locomotion

For movement of teleoperated devices around on planetary surfaces, with rough terrain, or on asteroids, where there is little gravity, a legged walking vehicle is ideal. While we are a long way from the walking tanks in Star Wars, we do know how to build useful walkers. A typical example is the six-legged device developed by Robert McGhee at Ohio State University. It is a prototype device to be sure, powered by Black and Decker drill motors through worm gears. It walks very well over some obstacles, climbs stairs and walks in all directions and turns in its own length. A space rated device, teleoperated from earth, could explore the poles and permanently shadowed areas of the moon in order to find possible water or other volatiles so valuable for space industrial operations. Development of such devices may become important for future operations.

### The Skin Suit

There are now two successful ways to protect a man from vacuum, one is to put him in a pressurized enclosure, either a shell or a pressure suit, or you can give him a very tight form fitting leotard-like garment made of an elastic material something like Spandex. In the first case, the non-porous suit cancels the cooling result of sweating. This requires heavy, elaborate cooling methods such as the water filled cooling garment in the Apollo suits. Water is then boiled from the backpack into space to cool the man.

If the suit is porous, the man can simply sweat. Then all you need is a helmet and oxygen system to provide oxygen at a pressure equal to the applied pressure of the elastic suit. Now it so happens that one Paul Webb and Associates, of Yellow Springs, Ohio built and tested such suits for NASA and successfully kept a suited man at 80,000 feet equivalent altitude for three hours and at 20mm Hg equivalent pressure for several five minute periods. He could have gone to full vacuum for several hours, but the concept of the elastic suit so unnerved the

altitude chamber people that they would not let the test continue longer, even though there was no problem.

The suit was constructed of six layers of elastic and provided a counter pressure to the skin of 3.5-4 pounds per square inch. This is sufficient to prevent bubble formation in the body and to prevent the bends and other vacuum effects. The major problem was that it was hard to zipper shut a single layer that provided all the pressure. If a powered zipper or pneumatic closure device were developed, a double or single layer suit would work fine.

The major advantage to the suit, besides its sweat cooling of the body, is that it is much easier to move in such a suit, only 1.5 times the normal energy used for walking. This is roughly twice as good as an Apollo suit. In addition, the gloves were so pliable, you could pick up coins from a table.

The appearance of the man in the suit is like a man in a skin diving wet suit with a goldfish bowl on his head! Straight out of Buck Rogers, and it has been tested, it is real, and it works! Improvements in energy cost, fit, comfort and safety are very possible, Paul Webb would be happy to continue the work if opportunities arose, but NASA is not interested. Why?? They are conservative and suffer from a "not invented here" syndrome.

Enough for now. But it does seem that buried in NASA reports are many solutions to the problems of space industry that were brought to the point of prototype and dropped. Resurrecting these ideas may allow a new scenario that will allow profitable use of space at a very small cost compared to earlier NASA ventures.

Sincerely,

*M. T. Hyson*

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