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RESEARCH PROGRAM ON TOOLS FOR FUTURE MANNED SPACE FLIGHTS

Phase I - Final Report

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Report 66-24

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PHASE I FINAL REPORT

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Man System Integration Branch (RBM)
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Introduction

The major objectives of the research program developed by Raff Analytic Study Associates under NASW 1537 were to develop tool mitten concepts and work panels for possible use in extra vehicular activities (EVA) and to conduct a review of maintenance performance decrements resulting from weightlessness and pressure suit conditions.

The prime task under this work effort was to develop mock-ups of the tool concepts. The initial goal was to develop a mock-up but later efforts resulted in prototypes of two distinct multipurpose tools. The overall design concept for the tools was that the tool would offer suit-glove protection, permit rapid tool attachment accessibility, and offer greater mechanical advantage than conventional hand held power tools.

To better identify the specific approach in the tool development, Raff Associates has chosen to call the tool with the integral components, "The Tool Mitten" and the tool with the power source near the operator's elbow "The Space Mitten". The overall concept is designated as "The Space Tool Mitten" concept.

Tool Mitten

This multipurpose tool is capable of performing as an impact wrench, screwdriver, and drilling tool. It is

powered by means of a Black & Decker impact wrench that contains a half-inch drive and a pressure ring anvil. The handle and trigger for the Black & Decker tool were removed from its normal position and placed to the rear of the impact tool motor. The basic functions of the tool, that is, forward and reverse, remain as part of the tool capability.

The current tool is characterized by six tool attachments emplaced around the periphery of the forward well of the tool (See Figure 1). The tool attachment's outer surface has small channels that permit the tool attachments to spin about steel wire retainers when power is applied. The retaining wire that holds each tool attachment is firmly attached to clock spring material (metal strips) of a half-inch width. This material is of sufficient thickness to allow the tool attachments to be stored within the concentric wells and to travel in an arc out of the wells by the action of the clock spring. The attachments are easily mated to the anvil of the impact wrench.

It is envisioned that this tool would be used with the fully pressure suited astronaut while performing EVA maintenance and assembly tasks.

Space Mitten

The space mitten concept was initially conceived as a tool that would be an integral part of the astronaut's

suit. This particular feature would allow for bare hand or at least unpressurized glove operation of the space mitten. However, we now believe we will consider only "over the glove operations". A further feature of the space mitten is that it not only has forward and reverse speed features but also can be manually operated for forward and reverse torquing operations. Unfortunately, the T-shaped handle could not accomodate both ON-OFF and reverse switches. Thus, in the prototype, the reverse switch was located near the electric motor.

This tool is powered by a Craftsman impact wrench motor that is uniquely located near the elbow of the maintenance operator. This particular tool has a 3/8-inch chuck with a ball-bearing fitting that provides the necessary tension for the tool's attachments. It does not contain its own tool attachments. However, changing tool attachments is accomplished by the use of a tool cuff, to be described below (See Figure 2).

Tool Cuff

The tool cuff is a device for tool attachment storage for use with the space mitten (See Figure 2). The use of a cuff is an attempt to reduce or eliminate the need for a tool box separate from the working tool, and to avoid ever allowing the tool attachments to be free in space. Areas on the maintenance worker's leg and arm

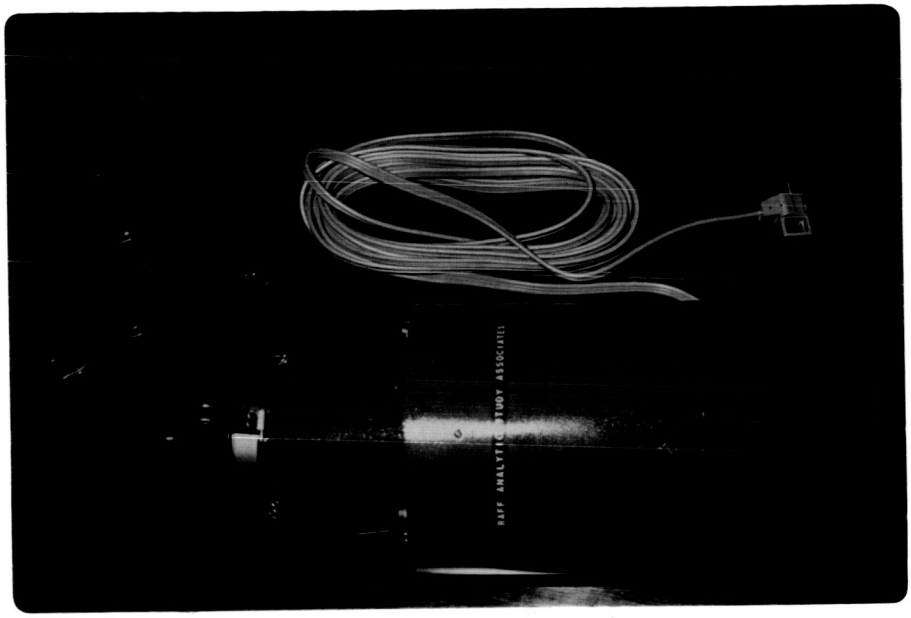

FIGURE 1

PROTOTYPE TOOL MITTEN AND

TOOL ATTACHMENTS

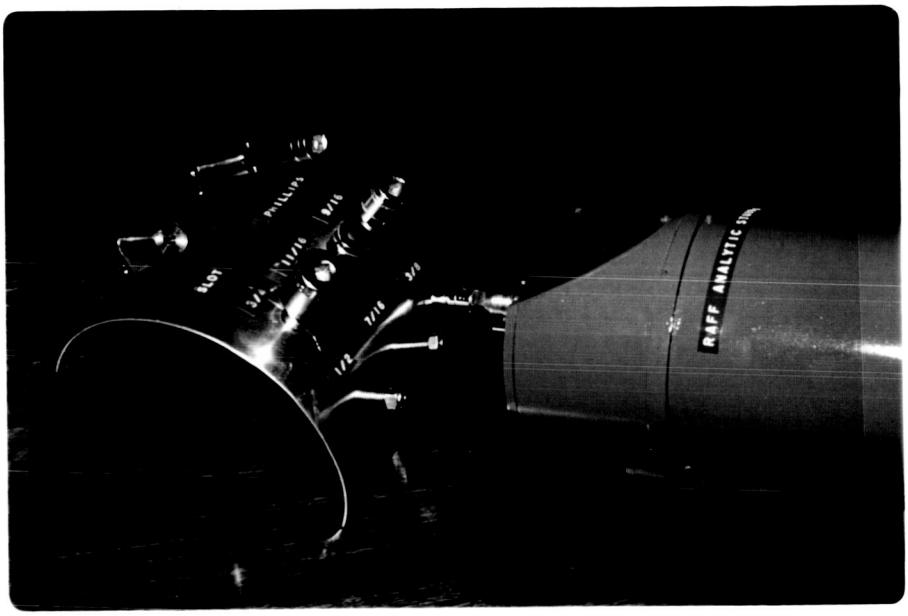

FIGURE 2

PROTOTYPE SPACE MITTEN AND

TOOL CUFF

have been considered as possible sites for fastening this device by means of velcro or other suitable bonding materials.

A holster has been developed that will be used to attach the tool cuff to the maintenance workers during the experimental trials, but this device would not be considered standard equipment for EVA activities. Our developmental effort is based more on the principle of operation rather than preferred locations of such tool cuffs.

The particular storage sites for impact wrench sockets are threaded, tapered studs that contain captured nuts at the small end of the taper. The captured nuts have been split longitudinally along their walls to allow them to expand as they are driven down by impact wrench sockets. The expansion of the nut causes a temporary bind between the nut and the interior wall of the socket. The removal of sockets involves the contraction of the nut, thereby freeing the socket from the nut. A retaining cap over the tapered stud keeps the nut on the stud.

The screwdriver storage sites (slotted and Phillips) are characterized by matching screwheads emplaced in small cylinders. As the screwheads are tightened, the turning

action of the screw causes the internal walls of the cylinder to contract, thereby holding the tool. The removal of screwdrivers merely allows the internal walls of the cylinder to relax, thereby releasing the tool.

Static Work Panel

The front surface of the work panel has a height of 12 inches and is 24 inches wide, and is made from 3/4-inch plyboard (See Figure 3). This panel is affixed to a 16 x 30 inch, 3/4-inch plyboard base, and supported by small triangular plyboard struts. Upon the surface of the work panel are four cutouts that will accept steel or aluminum plates of the following dimensions: 7 x 4 inch, 4 x 5 inch, 8 x 7 inch and 4 x 9 inch. The torquing plates contain embedded studs or nuts that will accomodate hex sockets of the following dimensions: 3/8, 7/16, 1/2, 11/16 and 3/4 inches. In addition, some removable plates can receiver either machine screws 6-32, 8-32 and 10-24 drill bits. The work panel is affixed to a stationary table by two C-clamps.

Maintenance Task Cylinder

The maintenance task cylinder is 24 inches in diameter and 21 inches in height. (See Figure 4). It is a partial cylinder because of the 19 x 19 inch cutout that

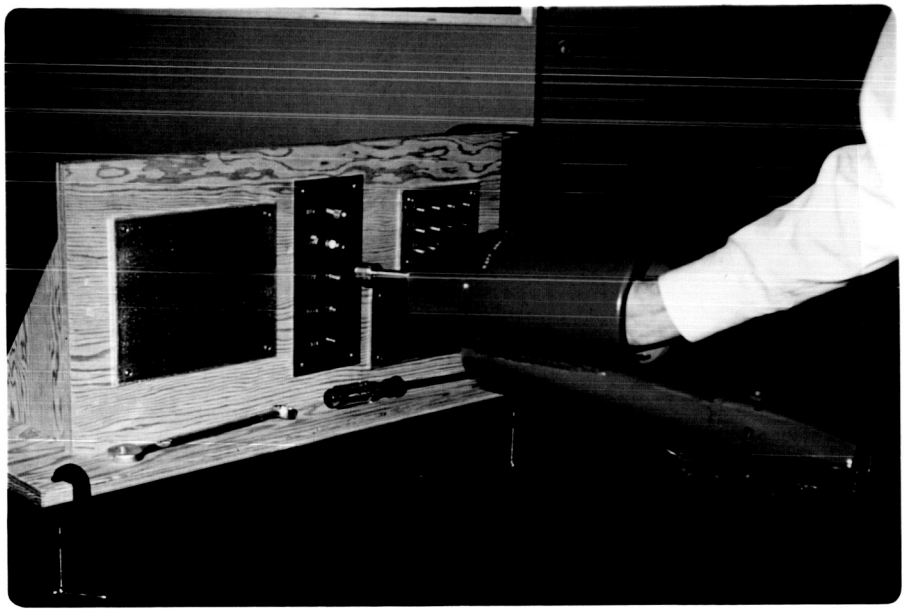

FIGURE 3

PROTOTYPE SPACE MITTEN AND

WORK PANEL

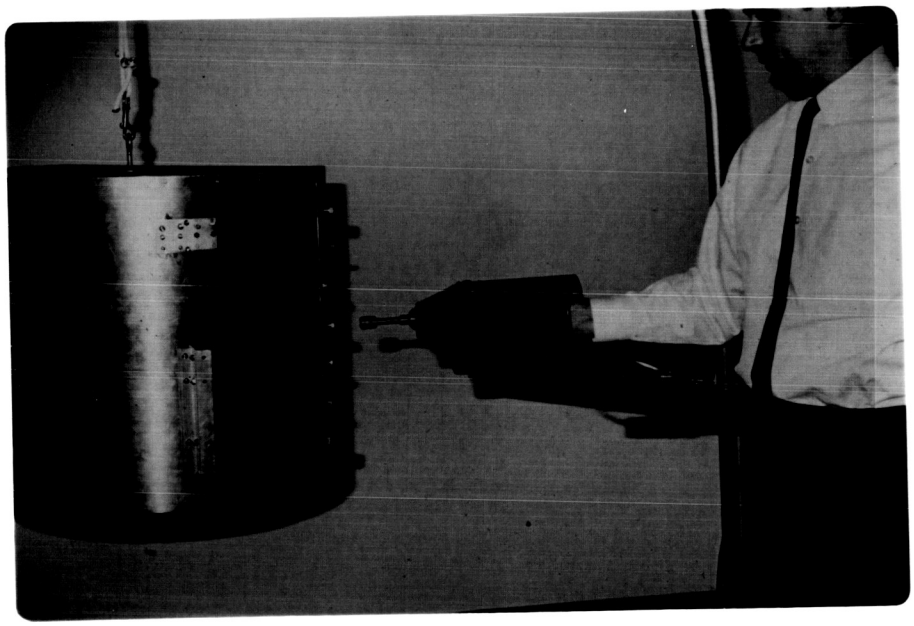

FIGURE 4

PROTOTYPE SPACE MITTEN AND

MAINTENANCE TASK CYLINDER

constitutes the access task area. This area has an overall depth of approximately 12 inches. The exterior surface of the cylinder contains two 19½ x 1½ inch steel plates. There are studs on one of these plates that will accept nuts to be torqued with the following hex socket sizes: 3/8, 7/16, 1/2, 9/16, 11/16, 3/4 and 15/16 inches. The other plate contains welded nuts that will accept bolt heads that are compatible with the above wrench sizes. The spacing between studs or nuts, as measured from each center, is approximately 2-1/2 inches.

The 4 x 4 inch machine screw plate will accept 6-32, 8-32, and 10-24 machine screws. We are currently using Phillips slotted and Allen heads for the 10-24 machine screws. There is also a 6 x 6 inch plate that will be used in metal drilling tasks. Also, there is a pair of 8-inch angle irons, with 1-inch faces, that are bolted to the cylinder. The pair of angle irons is to be used in serial task performance experiments. It is planned that spacecraft components or similar compartments can be affixed on the surface or in the access task area for space maintenance simulation.

The access task area has a 5/8-inch stud in a removable plate that will be used to evaluate the amount of depth and area necessary for maintenance operators when

using different tools for the same task. The "egg crate" divider inserts will permit work area depths of 6, 9 and 12 inches. An insert for a particular depth will accomodate 8 x 8, 12 x 12, or 16 x 16 inch access areas.

This cylinder is normally suspended from three 1-1/4 inch diameter conduit pipes that form a triangular 7-1/2 foot structure by means of several lengths of nylon ropes and a 9-inch metal spring. The metal spring and adjustable nylon rope allow for varying the distance of the maintenance task cylinder from the floor. Thus, the task cylinder allows for a reasonably unstable task area that will simulate, to a limited degree, the dynamics of structures in space.

Performance Decrements Study

The purpose of the performance decrement paper was to review the decrements in performance associated with maintenance workers activities as a result of various spacesuit environments and under simulated weightlessness conditions. The approach was to treat pressurization and weightlessness conditions as independent variables, and to consider the manipulation of Purdue Pegboard pins, the performance of maintenance tasks involving tools, the performance of maintenance assembly operations, and the application of force as dependent or performance variables. In order to make the studies comparable, it was necessary to

regard maintenance performance under shirtsleeve and/or frictional conditions as optimal performance, and to regard performance under frictionless conditions, or within a space suit environment as the comparison (experimental) conditions. Performance under the experimental conditions was typically less than optimal and the resultant loss was called "performance decrement", (Johnson, 1967).

Studies selected for the review have been categorized under four major headings. The first collection of papers pertained to the performance of subjects participating in Purdue Pegboard tasks under various pressure suit conditions. These tasks have been used considerably in psychomotor and manual dexterity studies and are considered quite representative of maintenance task requirements. The second major category of papers pertained to the actual operation of tools by maintenance workers under conditions of weightlessness or within the pressure-suited environment. These studies were selected on the basis of the currently known maintenance tasks requirements likely to be encountered for future space programs. The next category involved an evaluation of space related activities that were performed under reduced-g conditions, and space suited conditions. These studies were included to get an indication of gross performance decrement as a result of the two major independent variables, pressurization and weightlessness. The last major category of studies related to the

application of manual force under frictionless and pressure-suited conditions. The application of manual forces are within the realm of the types of activities the maintenance worker will experience in outer space.

The review reflected the efforts of investigators during the 1960's to increase the maintenance efficiency of astronauts while performing extra-vehicular activities in a rather hostile environment.

Recommendations

The major recommendation resulting from the efforts during this contract is that experimental trials be conducted with these space tool mittens. Apparently this recommendation has become a reality through the recent award of the second phase of the research effort. Based upon the tools and task devices developed to date, only preliminary recommendations can be made on redesign and modifications.

It seems highly possible that the tool mitten can be reduced in overall diameter and in weight. The prototype tool mitten was built largely with off-the-shelf components and has become somewhat large. It is firmly believed that it will be possible to devise a production model of this tool that is approximately one-third less in overall diameter. The weight of the tool can easily be reduced by proper selection of metals.

The space mitten, as a production model should contain both ON-OFF and forward and reverse switches as integral parts of the T-handle. The manual mode for this tool for production models should be developed for ratchet action. Further, any production models of this tool should be lighter in weight.

The tool cuff seems to offer a great deal of promise. It seems reasonable to suspect that a tool cuff developed along these lines with the capability of multiple location features on the maintenance operator's suit would be quite desirable. Further, the retaining components on the tool cuff could be attached to swivels in order to allow the maintenance operator greater flexibility in storing and removing tool attachments.

Work panel and task cylinder development seems adequate to date. These devices have been designed in order to allow rather rapid substitution of components, nuts, bolts and other task devices.

A few recommendations can be made concerning the specific report on performance decrement. Future attempts to review performance decrements as a function of various independent variables could be aided immensely if authors made available their complete data and experimental designs to prospective reviewers. Further, such data would be more valuable if researchers made greater use of available performance measures, such as precise time measures and the

use of measurement gauges, for example, torque meters.

Maintenance performance data are currently being generated by NASA and contractor personnel related to weightlessness and pressure-suited conditions. Some means for relating these current efforts with the present document will be needed in the future.

Conclusions

The end of the first phase of a planned three phase research program suggests that the products developed are, in fact, valid concepts for serious consideration for EVA use. The devices have been deomonstrated before a number of NASA personnel and contractor personnel and it appears that the devices have created some interest within the research community. Further, experimental investigations and human engineering tests must be conducted before definitive recommendations and conclusions can be made.

References

Johnson, L. B., A Review of Maintenance Perform- and Decrements Resulting from Weightlessness and Pressure Suit Conditions, Kaff Analytic Study Associates Report No. 66-23, 27 February 1967.