INTRODUCTION

The VA Prosthetics Center Research and Development effort is organized along a time axis based on when clinically useful results from each project are expected. Each Project, supervised by a manager, may conduct research, development, and evaluation in prosthetics, orthotics or other areas. In one Project, Advanced Systems, for example, where results are not expected to reach clinical practice for several years, the scope of work includes lower-limb prosthetics, upper-limb orthotics, and spinal-cord-injury devices.

This paper has been organized to match the order of workshops scheduled for this Conference. Our work is described below in the following sequence: A. Lower-Limb Prosthetics, B. Upper-Limb Prosthetics, C. Orthotics, and D. Spinal Cord Injury.

A. LOWER-LIMB PROSTHETICS

1. VAPC Above-Knee Endoskeletal Structures

The evaluation of the “Multiplex” prosthesis through the VA Interstation Testing Program continues to point out the inadequacies of the cosmetic treatment of the above-knee endoskeletal prostheses, although the mechanical system is sound. The one-piece cosmetic cover has been temporarily replaced with the Hydra-Cadence knee cap and socket attachment plate to avoid further delay in clinical use of the Multiplex prosthesis. Several hundred models are being fabricated to phase them into production for our field distribution system.
2. Composite Endoskeletal Structures

Through a contractual arrangement with the Aircraft Division of Northrop Corp., Hawthorne, California, we are developing a plastic (graphite fiber-epoxy) composite endoskeletal prosthesis. It is in fact a fairly faithful replica of the multiplex designed to meet the Veterans Administration requirement that most fluid-knee controls, as well as a mechanical friction system, be accommodated by a single structure. It is however, lighter than the metal multiplex and may permit better dimension standardization.

3. Weber-Watkins Rotator for Lower-Limb Prostheses

Designed to permit axial rotation of the shank relative to the foot, several models of this device have been fitted to patients. Initial reactions of both the above-knee and below-knee patients were quite positive. Most reported that, they experienced more “freedom,” i.e., the ability to move with less restrictions. The frequent adjustment, excessive noise, and slightly substandard cosmesis have been improved. It is now on contract. Patient reaction to the device will be monitored for a period of 1 year.

4. UC-BL Four-Bar Linkage Polycentric Knee

The University of California at Berkeley, California, has a new swing-and stance-control knee mechanism developed at the Biomechanics Laboratory by C.W. Radcliffe and L.W. Lamoreux. The stance portion of the knee is controlled by a mechanical four-bar polycentric linkage system. Swing phase is controlled by a pneumatic piston-cylinder system.

Several models are being evaluated by VA Prosthetic Center. Initial reactions of patients currently wearing them have been quite positive.

5. UC-BL Shank Torque Absorber

The VAPC is evaluating a torque absorber device for lower-limb prostheses developed by the University of California at Berkeley. This relatively lightweight, tubular design permits control of the ranges of transverse rotation and adjustment of the resistance to rotation. Fifty units have been ordered for field tests and clinical evaluations.

6. Graphite Fiber Composite Keel for SACH Feet

Models of a newly designed SACH foot keel are being fabricated for us by Northrop Aircraft Corporation of California of a lightweight graphite-epoxy composite. This material is potentially superior to wood as it is stronger, impervious to water, and dimensionally more stable. The keel is shaped better to distribute reaction force generated in the
compressible sections of the foot, an area of potential failure in conventional SACH feet. The new keel accommodates a split plug to facilitate attachment through the bottom of the foot and to permit alignment changes to be made in the foot attitude following completion of the appliance.

7. Machine Forming of Plastic Sockets

Prosthetic sockets for above-knee and below-knee are being vacuum-formed of Acrylonitrile-Butadiene-Styrene (ABS) sheets using a new portable system recently purchased from Orthomedics, Inc., of Downey, California. The plastic sheet mounted in a metal frame is heated in a conventional oven and placed, by hand, over the forming model. The advantages of this system over the commercial production vacuum systems are the comparatively small size of the unit, portability, low initial cost, and capability of the heated plastic sheet to be manipulated by hand to take advantage of the “drape” when indicated. Average molding time of approximately 10 minutes is required for forming a socket. Above-knee sockets are more easily drawn than below-knee sockets, due to the pronounced conical shape of the thigh stump. Difficulties previously encountered in maintaining critical anterior-posterior dimensions of the below-knee socket have been overcome by the use of a device which provides clamping pressures over the patellar-tendon and popliteal aspects of the socket. Suitable bonding between the plastic socket and the shank is now possible.

B. ORTHOTICS

1. ORTHO-WALK Orthosis

VAPC is evaluating this pneumatic “suit” which enables paraplegics with relatively high lesion levels to stand when the suit is inflated. Other physiological benefits are also attributed to the suit. Some 35 suits are being evaluated in seven different clinics in collaboration with CPRD. VAPC is independently evaluating an additional 30 suits using almost identical procedures.

2. Liberson Functional Electrical Stimulation

Many years ago Dr. Vladimir Liberson, now a VAPC consultant, designed an electrical nerve stimulator employing a bimodal stimulation signal train and surface electrodes for stimulating both the peroneal and tibial nerves and is expected to prevent the eversion often associated with dorsiflexion when a single electrode system is used to stimulate the peroneal alone. The required equipment is being modernized for use in clinical trials with hemiplegic patients at Castle Point, New York.
3. Externally Powered Orthoses

Some conventional orthoses are being modified by the addition of power sources; either control switches or EMG systems. Several ball-bearing arm supports have been reworked to permit the standard VA-powered elbow to lift and lower a quadriplegic's arm. These wheelchair-mounted devices are presently being tested at Castle Point. A brachial-plexus elbow-hand orthoses that utilizes a single muscle control site to raise the arm and move the fingers is being tested.

4. Remote Manipulator

A remote manipulator with seven degrees of freedom has been designed. The device is wheelchair mountable and provides a sphere of operation 2½ meters in diameter, centered adjacent to either armrest. It can move a 2 kg load through a major chord in 2 seconds. The patient controls the device either by verbal commands, by head motion, or by any residual function. The terminal device itself is similar to the VAPC powered hook, but in addition to prehension, provides the equivalent of wrist flexion-extension, adduction-abduction, and rotation. The control logic is primarily input (joystick position) to velocity. When the patient moves his head to the right the terminal device moves to the right at a velocity related to the patient's head position and independent of the previous terminal device position. Another control system which recognizes spoken speech is being fabricated. Verbal commands—up, down, slower, faster, stop, etc., will result in the desired operation. A joint NASA-VAPC effort on a continuing basis is being undertaken to advance this development. Jet Propulsion Laboratories, Pasadena, California, will coordinate the effort.

5. Polypropylene Knee Orthosis with Supra-Patellar Suspension Strap

This knee orthosis consists essentially of a calf band and a thigh band connected by knee joints. Similar to a knee cage, it employs a supra-patellar suspension strap to eliminate the need for attachment to the shoe. It provides improved cosmesis, lighter weight, and improved convenience since the shoe does not have to be altered.

C. UPPER-LIMB PROSTHETICS

1. VAPC Free-Swing Electric Elbow

The commercially available VAPC electric elbow has been fitted with an external forearm release mechanism designed by AMBRDL. It permits the elbow to swing freely when it is fully extended and locks automatically when driven toward flexion. Both the external AMBRDL
device and the VAPC-designed internal free-swing components are being evaluated.

2. VAPC Hook

The VA-powered hook is in a final design stage. Work is underway to permit the system to operate on far smaller energy sources. Both the output prehension force and position are monitored and compared to the desired EMG information. This feedback is used to instantaneously stop the energy flow when the monitored parameter matches the EMG command. Voluntarily halting the energy flow requires hundreds of milliseconds and accounts for the major energy expenditure in these systems.

3. VAPC Hand

a. The VA switch-controlled hand has been modified to detect stall conditions and to automatically stop the power, thereby conserving energy.

b. The VA EMG hand is being modified with a feedback system similar to the VAPC hook to permit a patient to directly sense finger prehension force and finger position.

By contractual arrangement with Rancho Los Amigos, two VA hands are being modified in preparation for fitting two patients.

The hands will be controlled by means of standard surface electrodes and will provide force and position feedback by means of implanted electrodes placed against the scleral nerve. These electrodes are connected transcutaneously to the prostheses by means of the Rancho Autofeed Carbon buttons.

4. Johns Hopkins Applied Physics Laboratory Prosthesis

VAPC is evaluating six units of this electrically powered upper-limb prosthetic unit. It is designed to flex the elbow by means of a torque motor and, when the elbow is locked, to open a rubberband or spring-loaded terminal device. It is controllable either myoelectrically (three units) or by means of position transducers (three units). Fittings are being made at VAPC, Northwestern University, and Duke University.

D. SPINAL-CORD-INJURED PATIENT

VAPC has devoted a heavy portion of its total Research and Development capability to devices for the spinal-cord-injured patient. No less than nine active Research and Development projects are being conducted. A tenth project is devoted to the hemiplegic. For brevity they are classified under three major headings.
1. Mobility Aids

a. *Adaptive Automotive Equipment Standards*

VAPC is writing what we expect to be a final version of Standards and Specifications for Automotive Aids (Adaptive Equipment). These are principally hand controls to enable paraplegics and partial quadriplegics to operate automobiles and vans. These Standards are based on a year-long evaluation program of every known hand control. The evaluation included engineering analyses, simulated testing, and road testing by paralyzed veterans. This project has also led to the development of a continuous compliance testing program for these devices.

b. *Electro-Hydraulic Automotive Hand Control System*

This system is under development with controls mounted on the wheel to avoid problems of mechanical linkages to brakes and gas pedals, and to completely bypass firewall and dashboard.

c. *Hold Down System for Van Passenger in Wheelchair*

We are developing a semi-automatic mechanical locking system to safely retain a wheelchair with a passenger aboard while he is riding as a passenger in a van.

d. *Vans*

We are evaluating eight different van configurations consisting of different types of entry-exit systems and driving control systems designed for use by spinal-cord-injured patients. Driving control system, seating, entry-exit systems, and safety features are being evaluated with a view toward developing minimum standards of safety, function, and economy. Design analyses on the safety of each of these features of vans are being conducted at VAPC. In a collaborative effort the College of Engineering at Texas A&M is conducting safety and strength tests. In general the worst features of all currently available vans are the seating arrangements for both driver and passenger.

e. *Wheelchairs*


2. Environmental Control Systems

a. *Hospital Environmental Control Systems*

VAPC development of pneumatically actuated environmental control systems for hospital use is now considered complete. Several hundred units, evaluated in clinical service, have been found highly reliable and extremely effective. The basic component is commercially available.

b. *Home Environmental Control Systems*

Now under active development, the VAPC home environmental control system is fundamentally similar to the hospital type which is now
commercially available. It offers a greater number of channels for control of a somewhat different array of appliances than the hospital controller. The present model is being deployed in patients' homes where, in addition to the usual package of appliances (TV's, radios, tapes, lights, fans, etc.), it is also being used to operate front door surveillance systems, telephones, and certain reading devices. Further experience is necessary before the most appropriate set of appliances for home use can be determined.

c. Telemetry for Environmental Controls

Although a minor inconvenience in the hospital ward, wiring of appliances in a number of homes may interfere with decor and may present a physical hazard. But most important, the home living patient is more highly mobile than the hospital patient, and a ward-wired system required him to remain relatively static. For this reason VAPC has developed an RF link between the pneumatic actuator and the controller, eliminating the wiring. This effectively liberates the patient from the controller and all the appliances it operates. Three units are being prepared for evaluation in patients' homes. We are considering using the telemetric pneumatic actuator to control several controllers, each of which operates a different array of components in various areas of the home.

d. Voice Actuation of Environmental Controls

As the number and complexity of appliances and machines that a patient may operate increases and as the functions available in a particular device increase, switch-type control systems become less effective. A seven-degree of freedom manipulator, for example, is quite difficult to control by means of switches when the operator (patient) has so little information in terms of arm or hand movements. Almost all patients retain most of their speech patterns. We are therefore developing several approaches to control devices which respond to spoken speech. One project is being carried on in-house at VAPC. Another approach is being taken in collaboration with Army Medical Biomechanical Research and Development Laboratories. A third effort is being made on contract with the University of California at Santa Barbara.

e. Scope System

We have also taken steps to purchase the SCOPE system, which is one of the few commercially available speech recognition systems.

f. Communication Devices

A small number of spinal-cord-injured patients have secondary pathologies which prevent them from speaking with sufficient effect to communicate. We are evaluating several devices for nonvocal communication including the Cybertype, Possum typewriter, View Comm, etc. Experience gained during these evaluations are providing the basis for
design concepts to develop devices for use in schools and social environments. This project is not aimed at temporary loss of speech like the aphasia of the hemiplegic. It is directed more toward other neurological pathologies.

g. Reading Machines

Quadriplegics and others without the use of their arms are unable to read because they cannot manipulate written material. VAPC has developed a microfiche reading device which is controllable by means of the VAPC environmental controller. The unit is also independently controllable by a pneumatic switch. Also being investigated for this purpose are microfilm techniques and video tape. All of the above require processing of the written material from its original source to another form: microfiche, microfilm, and video tape. We are also sponsoring the development of a machine to enable a patient to read certain classes of written material, i.e., books, magazines, or newspapers, directly. We are considering proposals to fabricate a machine which scans by video camera written material placed on a viewing stage by an attendant. The patient, however, can control the focus of the camera, read from a bedside TV monitor, and use a page turner.

3. Patient Handling Devices

a. Beds

(1) We are conducting a program to evaluate various kinds of beds for spinal-cord-injured patients including the Royalaire, the Gaymar, the Stoke-Mandeville and the Hess Rotary Bed. The Nelson Bed, also being evaluated, is a device whose central portion converts into an armchair-type seat enabling the patient to sit up independently.

(2) Under development, at Rancho Los Amigos Hospital, is a mobile bed to enable a patient independently to reconfigure a portion of his bed into a “wheelchair” and to travel short distances depending upon the way he is dressed and the weather.

b. Lifts

Under evaluation are several newer types of patient lifts. The Mercy Lift fits over the entire bed, enabling a nurse or attendant to change the bed linen or to transport the patient as in a stretcher. The original unit was rather large for hospital corridors and elevators and is currently being redesigned. Also under evaluation is the Mobilizer, a device designed to enable one attendant to move a patient from the bed to a gurney or stretcher and to replace him in the bed.

c. Cushions

In collaboration with Dr. George Van B. Cochran, N.Y.S. Rehabilitation Hospital (now known as Helen Hayes Hospital), West Haverstraw, New York, we have developed an objective method for evaluating and
grading the utility of load-absorbing materials. An interim report recently published in BPR 10-20 details the findings on 26 cushions. These results are being validated by clinical followup prior to developing test standards.

d. Baths

(1) The Aurora Century Bath Lift is being evaluated in several hospitals. A patient is placed either in a wheelchair or in a contoured seat placed on a wheelchair and moved to the bath. The contoured seat, a low one for low lesion levels and a high backed version for higher lesion levels, attaches to a vertical hydraulic lift mounted on one end of the bath tub. Once the seat is firmly attached and the patient strapped in it, the attendant simply actuates the lift which raises the patient some 6 ft. in the air, rotates him 180 deg. and sets him down on a seat built into the tub. The water temperature is variable and whirlpool accessories are available. The patient is lifted out, dried, and returned to his bed.

(2) Under development is a different bath configuration in which a patient is moved, perhaps by means of a Mobilizer, to a special gurney which is rolled into a freestanding bath very much like a dishwasher. With the patient horizontal, shower heads within the unit bathe the patient whose face is protected by a curtain that hangs down around his neck. It is planned to install dry air blowers within the unit so that the patient may be dried before removal.