N93-22172

# MICRO-VIDEO DISPLAY WITH OCULAR TRACKING AND INTERACTIVE VOICE CONTROL

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## ABSTRACT

In certain space-restricted environments, many of the benefits resulting from computer technology have been foregone because of the size, weight, inconvenience, and lack of mobility associated with existing computer interface devices. Accordingly, an effort to develop a highly miniaturized and "wearable" computer display and control interface device, referred to as the Sensory Integrated Data Interface (SIDI), is underway. The system incorporates a micro-video display that provides data display and ocular tracking on a lightweight headset. Software commands are implemented by conjunctive eye movement and voice commands of the operator. In this initial prototyping effort, various "off-the-shelf" components have been integrated into a desktop computer and with a customized menu-tree software application to demonstrate feasibility and conceptual capabilities. When fully developed as a customized system, the interface device will allow mobile, "hands-free" operation of portable computer equipment. It will thus allow integration of information technology applications into those restrictive environments, both military and industrial, that have not yet taken advantage of the computer revolution. This effort is Phase I of Small Business Innovative Research (SBIR) Topic #N90-331 sponsored by the Naval Undersea Warfare Center Division, Newport. The prime contractor is Foster-Miller, Inc. of Waltham, MA.

## INTRODUCTION

During the last decade, there has been a rapid development of technologies that support computer miniaturization. These technologies have significantly reduced computer workstation size and, at the same time, improved processor speed, memory capacity, and software utilization. It is interesting to note, however, that functional improvements in the interface devices for computers have been relatively few. With the exception of the computer mouse/trackball and new "pen-based" input devices, virtually all computer systems still rely on large and cumbersome interfaces, namely CRT/LCD screen displays and keyboards. There has been relatively little ergogenic improvement with these interfaces since their 1950s predecessors were introduced.

Unfortunately, many of the benefits associated with computer technology have been foregone because of this lack of appropriate interface devices. This is particularly true for certain space-restricted environments such as aircraft, submarines, and spacecraft. The disadvantages imposed by size, weight, and inconvenience of existing interfaces as well as the lack of mobility for the operators using them has resulted in the avoidance of "computer solutions."

The development effort described below seeks to solve this problem by integrating several new "off-the-shelf" technology products to produce a highly miniaturized, micro-video computer display and control system which incorporates both interactive ocular tracking and voice control. The goal is to create a "wearable" interface mounted on a portable headset. Further development will lead to the implementation of highly miniaturized, portable alternatives to currently used cathode-ray tube/liquid crystal display and keyboard control devices. The advantages of computer technology will thus become more accessible for space restricted and operator-mobile applications and environments.

## DISCUSSION

A number of emerging technologies are now available which can provide significant improvement for the human-to-computer interface. Singularly, each one of these technologies has the ability to provide improvement, but significant synergy is gained by combining them together into a single, integrated system. The technologies applied in this effort are those of micro-video displays, ocular tracking systems, and computer voice recognition. Based upon a capability verses cost analysis of commercially available products, as described in reference (1), the component subsystems described below were selected for use in this project. Since the interface concept relies on human sensory interaction, the system is referred to as the Sensory Integrated Data Interface (SIDI)

Once the component subsystems were selected, the effort consisted of assembling them into a functional interface. On an adjustable headset were mounted a micro-video display, an associated Infra-Red (IR) illumination source and video camera, and a microphone. The micro-video display presents computer data to the operator. Using eye-tracking hardware installed in a PC expansion slot, screen cursor movement is caused to follow eye movement. Software menu selections are then implemented by gaze-fixation timing and voice command. An analogy to the "point and click" functionality of a computer mouse can be drawn. The line-of-sight gaze is used to "point" to a menu option and the voice command "clicks on it" or activates the selected item.

Figure 1 illustrates how the components were assembled on an operator headset. Note that the display projector/eye-tracker is worn in a monocular arrangement in front of one eye. This allows the operator to access computer data while operating other equipment or performing other tasks. Note also that the use of the headset allows "hands-free" operation of the computer. Figure 2 illustrates a high level component integration scheme for the desktop computer. A customized software application was developed to demonstrate conceptual capabilities. As shown in Figure 3, it consists of a menu-tree listing of topics which the operator activates by gazing and, when ocular lock is achieved, initiates with a verbal command. Running underneath this application are the customized software device drivers for the system components.

### Micro-Video Display

Data display for SIDI is provided by the "Private Eye" developed by Reflection Technology, Inc. The "Private Eye" uses a new proprietary technology which uniquely combines conventional semiconductor and optical techniques to create an image of a 12 inch monitor in a miniature package measuring only 1.1 inches X 1.2 inches X 3.2 inches. It weighs less than two ounces. The display uses emissive elements to provide a high definition, high contrast, and fast responding image viewable in bright daylight.

Worn in a monocular position in front of one eye, the unit interfaces with a PC computer via an interface card in an expansion slot. A virtual image of the computer CRT display is projected approximately 18 inches in front of the viewer's eye. The unit displays 720 X 280 pixels which can be formatted as 25 lines with 80 characters per line or can be used to show bit-mapped graphics. The monochrome image appears to float in space in front of the viewer with a quality and resolution matching that of a standard display. A lens system allows image focusing to accommodate viewing with or without eye glasses.

### Ocular Tracking System

The subsystem chosen to provide line-of-sight ocular tracking for the SIDI was the Eye Slaved Pointing (ESP) System from ISCAN, Inc. It is available as a PC compatible, turnkey eye movement monitoring system that serves as a hybrid interface device. Terminate and Stay Resident (TSR) software developed for the ESP is designed to substitute an operator's line-of-sight gaze for standard computer pointing devices. The system provides cursor positional data to software applications which permit or require a pointing device.

The eye-tracker functions by using a custom set of integrated circuits and tracking algorithms to lock on and track a point on the operator's eye in real-time. This is accomplished by measuring and tracking a low-level Infra-Red (IR) light beam reflected from the eye surface. A miniature IR video camera is used to acquire the pupil and corneal images needed by the tracking algorithms. The operator views a series of positional data points on a display to calibrate the tracking function for the display. From that point on, the tracking function converts eye movement into screen cursor movement. Since the display and eye-tracking camera are positionally coupled by the headset, movement of the head does not affect the tracking function. Both the ESP and Private Eye are mounted so as to be adjustable on the headset and allow variable positioning of the components for different operators.

### Voice Recognition Unit

The Voice Recognition Unit (VRU) chosen to provide voice control for the SIDI was the Voice Master from Covox, Inc. The system consists of a control unit, speaker, microphone, and software which can provide both speech recognition and generation capability for a computer using an available RS-232 port. The operator trains the system to accept specific voice commands which implement menu options once the ESP has achieved ocular lock on a menu option.

VRUs allow a computer to translate any spoken language into accurate, intelligent commands. It does so by breaking down a spoken command into its frequency components and then comparing those components with those of pre-stored commands. Most language requirements for a computer can be carried out with a relatively small vocabulary when combined with gaze-directed screen interaction. Within 10 - 15 minutes, an experienced operator can fully train the voice unit to recognize the required sets of alpha-numeric commands/inputs.

While voice input alone can be used to select items from a display menu, there are many situations where it does not perform well. For example, voice commands are poor for most interactions with graphic images, like pointing to a specific wire in a schematic or selecting a location to insert information in a text display. Even with text applications, voice interaction is difficult when selecting one item from a display which has many similar items, like a stock inventory sheet or a page of text. Eye-directed interaction in conjunction with voice commands handles these situations quickly and naturally.

### Software

A customized software application was developed to demonstrate functional and conceptual capabilities of the SIDI. The software consists of both the user application and the underlying TSR that handles hardware interrupts. As shown in Figure 3, the user application consists of a menu tree that allows the operator to access various types of documentation for submarine system and subsystem components. The operator makes a selection by gazing at a major topic item. When the SIDI achieves ocular lock-on, the selection flashes at the operator signifying that verbal commands can be initiated. Lock-on is achieved quickly enough so that the operator perceives that the system is operating concurrently with his thought processes. By giving various commands such as "ACCEPT", "UP", "DOWN", and "BACK" the operator can move around the menu to view desired data. The software was written in the C programming language with some in-line assembly code.

## SIDI APPLICATIONS

There is a wide spectrum of applications for the SIDI or a SIDI derivative. They range from various consumer entertainment products to business applications to military documentation applications. Any current computer application that could benefit from operator mobility is a candidate SIDI application. Figure 4 illustrates an application for a technician performing a maintenance routine on a cruise missile using procedural documentation displayed by a SIDI system. A few of the many possible implementations that could be envisioned are as follows:

- Paperless technical manuals
- Equipment diagnostic/repair systems
- Personalized training systems
- Entertainment electronics
- Portable inventory management systems
- Procedural documentation in space-restricted areas
- Computer interface for the physically handicapped

## FUTURE WORK

The goal of this project was to prototype existing commercial off-the-shelf hardware to demonstrate the feasibility of the SIDI concept. That goal was achieved. A functional prototype system was developed that successfully allows hands-free operation of a computer. The next step, as described in reference (2), is to refine the concept by developing a more compact and optimized interface device that provides operator mobility, requires less hardware adjustment to accommodate different operators, and is compatible with commercial software applications.

To maximize operator mobility, it is proposed that the interface be developed to serve as a remote terminal served by a computer base station. The user module will contain the minimum amount of electronics required to drive the display, eye tracking camera, and microphone. The base station will provide all the intelligence for these components via a data link. The data link will be preferably an un-tethered technology, such as an Infra-Red (IR) spacial optical link, thereby providing the operator unrestricted movement.

To reduce the amount of component adjustment for each individual who operates the interface, the headset hardware will be miniaturized and integrated into a single, easy-to-use, composite unit. The hardware will be optimized for

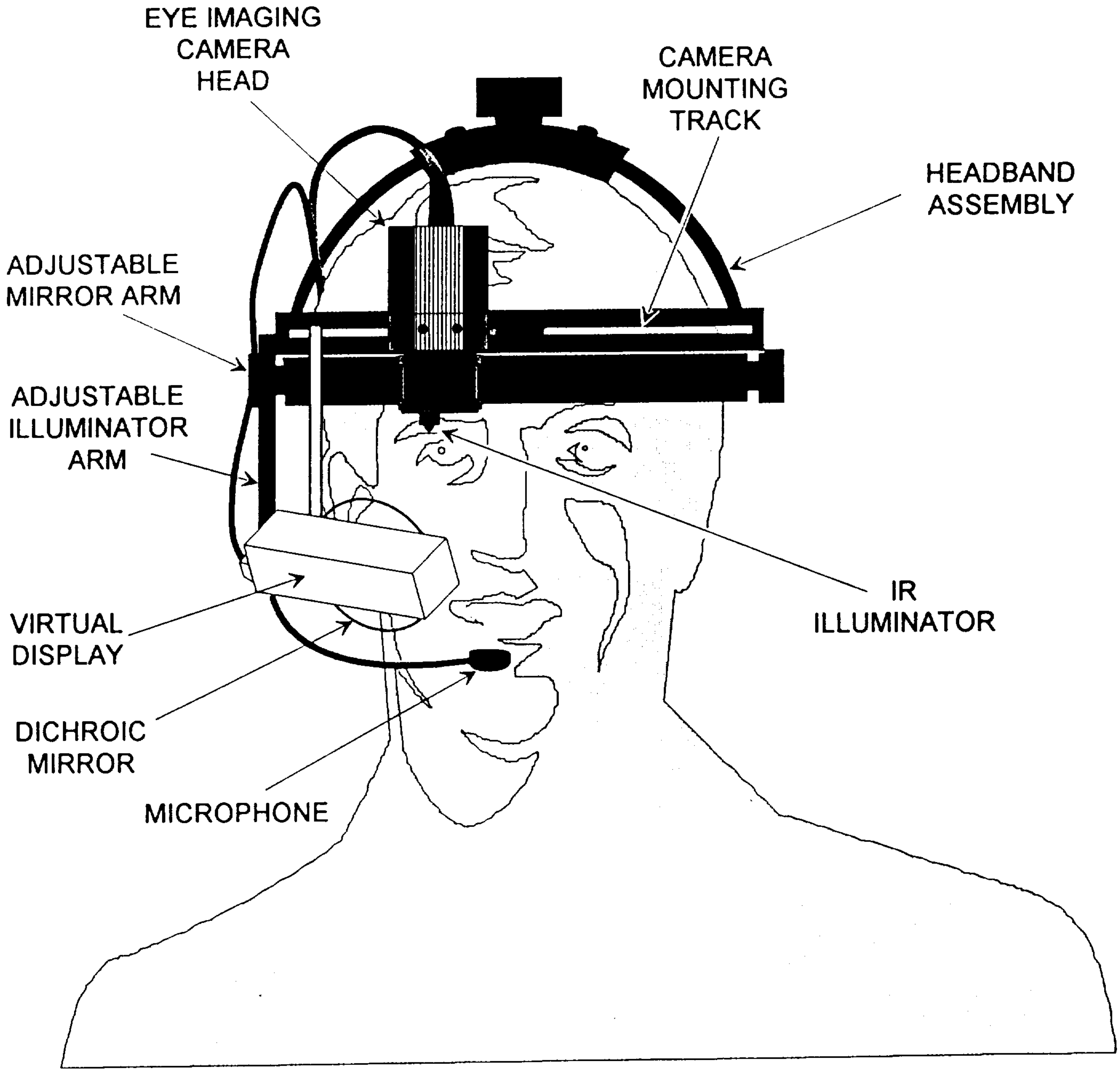
- Ease of alignment to obtain the eye image
- Ease of calibration to the user's eye
- Better tolerance to room lighting variations
- Better display resolution
- A separation of component functions to allow base station interaction

Finally, to preclude the need for customized software applications, the output of the eye tracking system will be modified to reflect standard computer mouse and trackball conventions. This will allow the use of standard software interface environments.

## REFERENCES


1. Kendrick, W. K. "Component Survey and System Definition Report," NAV-9371, Contract N66604-91-C-0936, Foster-Miller, Inc. March 25, 1992.

2. Nappi, B. "Sensory Integrated Data Interface (SIDI)," Small Business Innovative Research (SBIR) Phase II Proposal, Foster-Miller, Inc. August 21, 1992.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CAMERA
HEAD
CAMERA
MOUNTING
TRACK
HEADBAND
ASSEMBLY
ADJUSTABLE
MIRROR ARM
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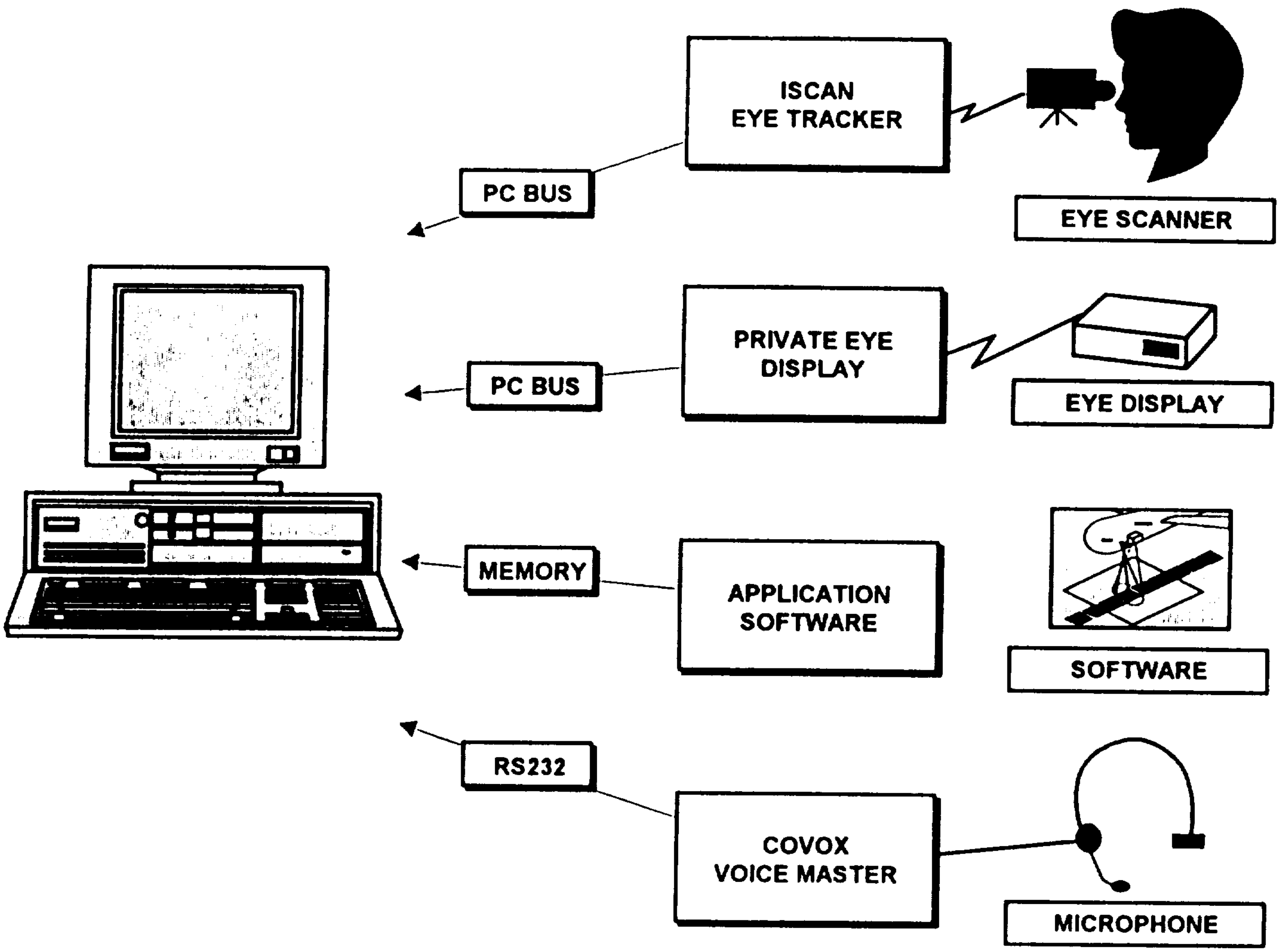
ARM
IR
ILLUMINATOR
VIRTUAL
DISPLAY
DICHROIC
MIRROR
MICROPHONE

FIGURE 1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PC BUS
EYE SCANNER
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MEMORY
APPLICATION
SOFTWARE
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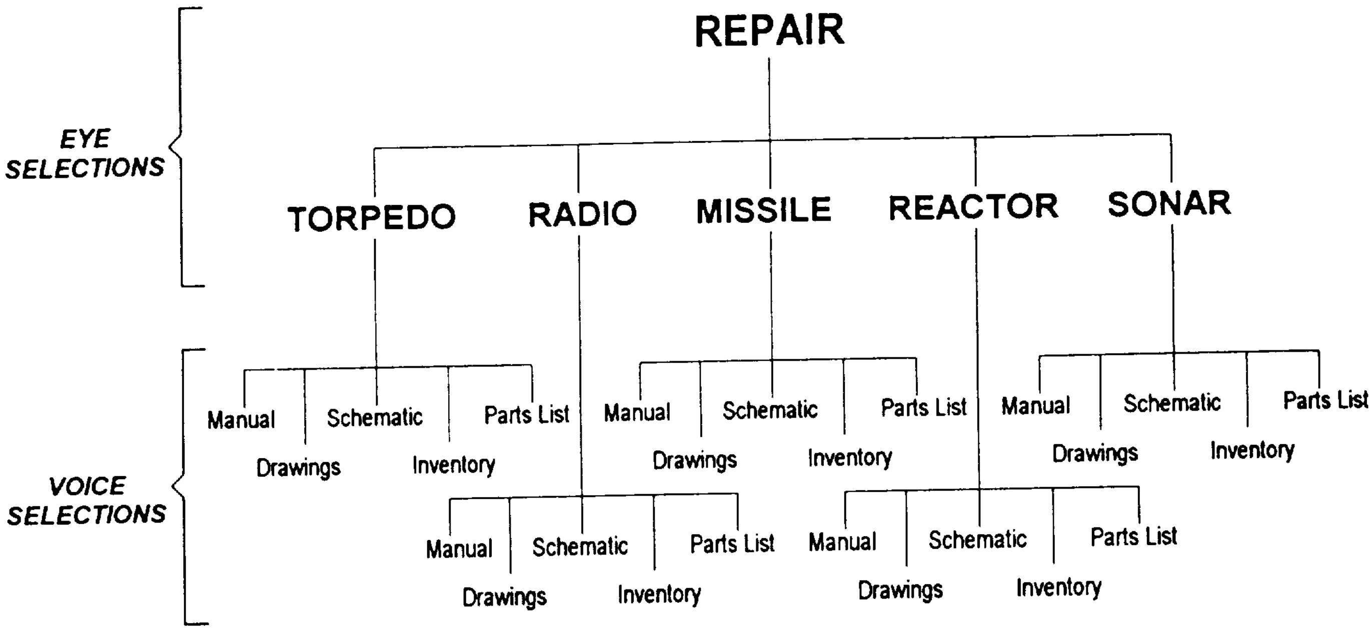
RS232
COVOX
VOICE MASTER
MICROPHONE

FIGURE 2


REPAIR
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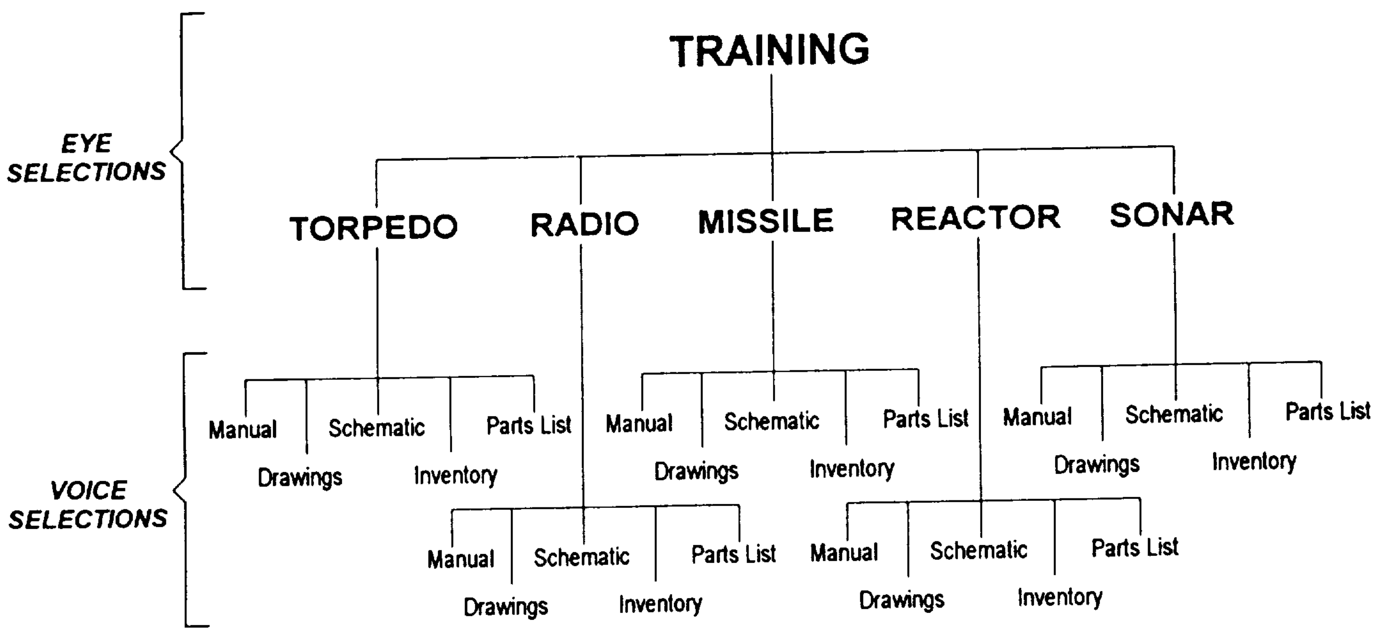
TRAINING
EYE SELECTIONS
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Schematic
Inventory
Parts List

FIGURE 3

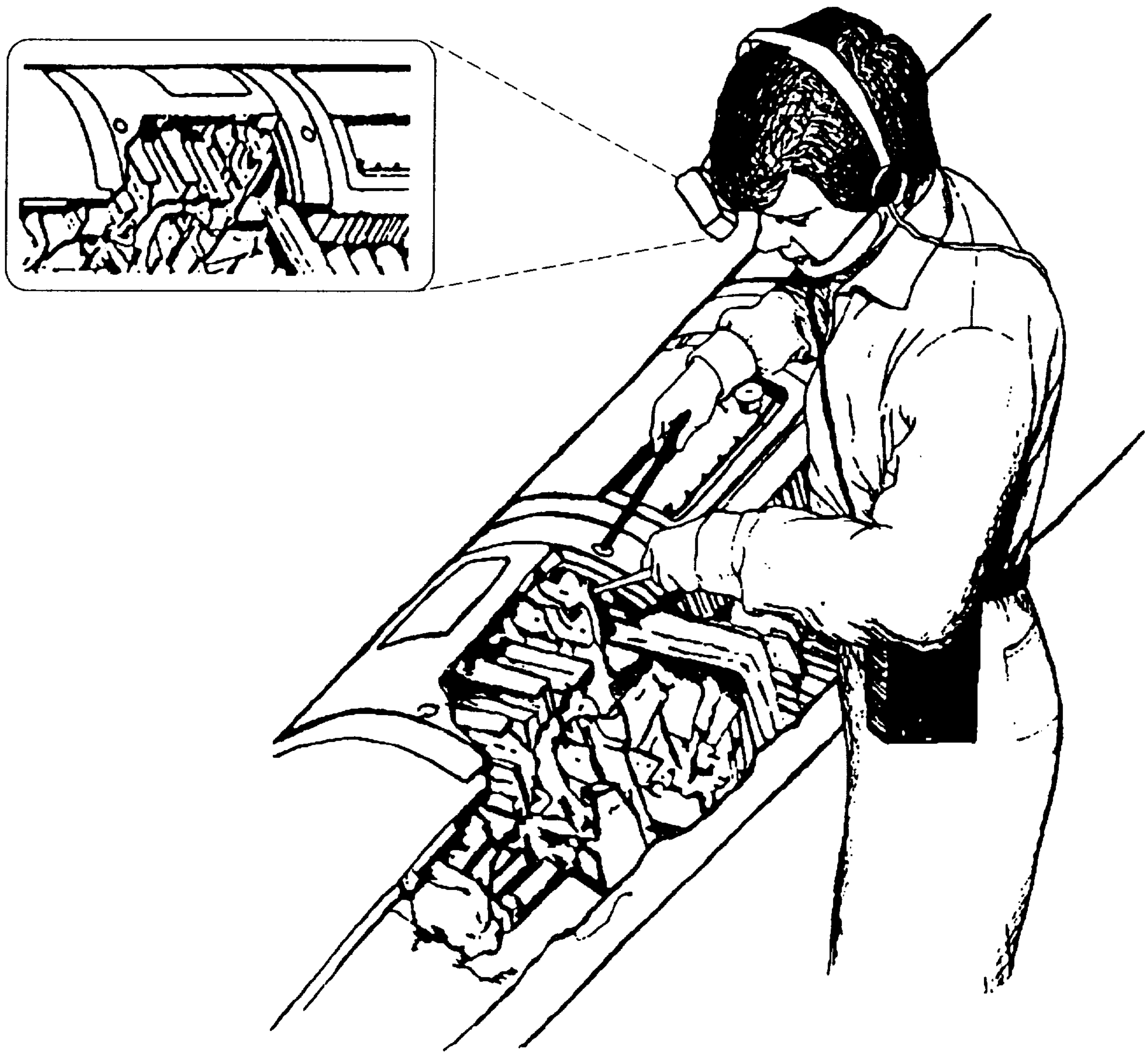

FIGURE 4 234