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Technical Order Library in Orbit

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TECHNICAL ORDER LIBRARY IN ORBIT
(TECHNICAL ANALYSIS)

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SUMMARY:

This paper is a follow-on technical analysis of "The Technical Order Library in Orbit",[1] a paper written by Mr. Rene M. Winz, Titan I Technical Writing Chief, and presented to our Denver Division and corporate management last summer. In his paper, Mr. Winz proposed three alternate methods of providing technical order support to a manned orbital space station. These were: ground station-to-space station, orbiting data station, and on-board technical orders (in microform). His conclusion recommended the ground station-to-space station approach.

Mr. Moravec and I have elected to expand on all three of the philosophies and present possible methods of accomplishing; data storage, transmission, receipt, and display; not only for manned orbital space stations, but also for manned space vehicles.

NEED FOR A LIBRARY:

With the advent of manned orbiting space stations and space vehicles, more and more emphasis is placed on the reliability of the vehicle. Generally, space experts agree that the chance for survivability of a space mission could be maximized by in-flight maintenance. Back-up systems and redundancy can help; however, there would be a space and weight limitation to redundancy. A significant increase in the morale of the crew could be obtained if they have the self-contained ability to maintain, detect and repair malfunctioning equipment.

Due to the quantity and complexity of the equipment required on board the station or vehicle, information for proper operation would be required in addition to that of maintenance and repair. Since it would not be practical to store spares at the chassis or black box level, our Technical Publications Department has estimated that the necessary technical manuals required for maintenance at the piece part level of the type of systems that might be utilized in a space vehicle would require a library that would weigh approximately 300 pounds in bound manual form. The weight and volume of this information could be reduced by utilization of methods such as micro-filming and video-audio transmission and tape recording.

REQUIREMENTS OF A LIBRARY:

Since the library would be used primarily in case of trouble, information must be available with a minimum of time involved. This would require an efficient indexing system in conjunction with a speedy method for sorting out the required data. The library would have to be capable of being updated or changed rapidly and have extremely high reliability. Means of displaying the information to several areas within the space vehicle simultaneously would also be a desireable capability.

LOCATION OF THE LIBRARY:

There are several approaches to the problem of maintaining a library for a space station or vehicle. These are as follows:

1. It could be maintained in a ground station or stations.

2. It could be maintained in an orbiting satellite.

3. It could be maintained on board the vehicle.

1. GROUND STATION LIBRARY:

A complete library could easily be maintained on the ground and stored for rapid search and retrieval in a Mechanized Data[2] system such as FASTI or A-VIS.

Fast Access to Systems Technical Information, FASTI,[3] was developed by General Dynamics/Astronautics for the Atlas Weapon System. FASTI is a program covering the preparation, retrieval and display of technical data. With FASTI, maintenance personnel can isolate a malfunction in 15 minutes, compared with five hours required with ordinary troubleshooting methods - a time saving of 95%.

The preparation phase corresponds to the creation of a troubleshooting chart by a technical writer. Time and function oriented logic diagrams are developed for each circuit. These are then translated into Boolean algebra equations for use in an IBM 7094 computer. The computer does the decision making by comparing normal indications with those for malfunctions by actually failing a component in Boolean algebra.

The output of the computer includes a sequential print-out of the most logical causes for each malfunction.

Standard Recordak microfilm retrieval and display equipment is used. When a system indicator reveals a malfunction, the corresponding microfilm index number is determined by the operator. This index number is inserted into the Recordak machine by the operator through a pushbutton command keyboard. The microfilm record related to the malfunction is displayed on the screen. If desired, the operator may obtain a print of the display. If the malfunction is not identified in the first display, it calls forth the index number of another display which corresponds to the next most logical level for the malfunction. This procedure is continued until the malfunction is located.

A-VIS is an experiment in the area of mechanized retrieval being conducted by the Army Materiel Command. This experiment is a follow-on feasibility study (MODAPS)[4] resulting from an earlier investigation conducted by Bell Telephone Laboratories and Western Electric Company. The study indicates the definite feasibility of developing an automated information system featuring audio-visual concepts in support of requirements for operation and maintenance data.

A-VIS consists of a shoulder height console with an automated slide projector, a synchronized magnetic tape, and a pair of earphones. The aural instructions provide the user with step-by-step instructions while the projector displays an illustration of the operation. Changes to data are made by substituting a new tape and replacing slides in the film chip magazine.

A-VIS is designed to provide rapid retrieval and display of maintenance data including schematics, checklists, troubleshooting instructions, adjustments and other related data. It also provides automation of certain maintenance functions such as reporting unsatisfactory equipment, recording data obtained during periodic checks, and requisitioning spare parts.

The information system consists of two rear projection viewers, a mechanized film-chip magazine with a capacity of 10,240 microfilm chips, and automated data collection units. The operations console has two film-chip magazines; an "A" screen magazine for regular page size projections, and a "B" screen magazine for large foldout type illustrations, each having individual push-button controls. The film cartridge transport unit is mechanically positioned in the projector for vertical and horizontal movement. The console also has a hard copy capability so it does not tie up the machine.

When the need for information would be required by the space vehicle, the vehicle would transmit a specific code number or numbers to the library corresponding to an indexing system for the technical areas covered. The signal received at the ground library would be decoded and sent through the memory unit of the computer which in turn would sort out the requested data and transmit it back to the requesting vehicle or station in the form of a video-audio signal.

Basically no audio conversation would be required with the ground crew, unless additional information not contained within the library would be needed. If necessary, a pre-recorded audio tape within the library similar to that in "A-VIS" could be transmitted along with the video signal. In addition, should it be necessary, a live video-audio conference could be arranged between the vehicle crew and engineering specialists on earth.

The information received in the vehicle could be viewed directly on a master and slave monitors of a closed circuit TV system and simultaneously tape recorded for future reference, allowing it to be played back through the TV system as required. Thus, personnel would receive the most up-to-date instructions for correcting the problem with a minimum of preoccupation. A recorder with a "stop tape" capability would be utilized to greatly increase the storage capacity of printed data. The "stop tape" feature would allow one frame to be viewed at a time, making it possible to record a different page of text or illustration on each frame. The tape transport would be stopped and the individual frame scanned by a revolving head, transmitting the image to a master and/or slave monitor screens for viewing.

By using slow scan TV, with a scanning rate of 1/2 frame per second, and retaining the same resolution as commercial TV, a conventional video tape recorder could be slowed down to have a recording time 60 times longer than present off-the-shelf units.

An audio warning system, such as the one used on the B-58 Hustler should also be considered in the vehicle. As problems occur, a pre-recorded audio tape describing the corrective steps to repair the malfunction would be automatically played over the PA system. If more than one failure occurs, the corrective action for the incidence of primary importance would be played first. Once corrective action has been taken, the tape playback would advance to the next major failure.

The vehicle closed circuit TV system would be quite an asset in conjunction with the audio warning system. By placing TV monitors in hazardous or remote areas such as the exterior of the vehicle, or fuel areas, monitoring could be accomplished without exposing the crew to unnecessary dangers.

Depending upon the mission of the space vehicle, the transmission requirements for communications between the vehicle and the ground station could be quite complex. Since the position would be constantly changing between the ground station and the space station or vehicle, active communication relay satellites and/or additional ground stations would be required to maintain constant communications. The air-to-ground communications would be the weakest link in the library system and thus must be extremely reliable. This could be accomplished with redundant and/or easily repairable equipment.

Due to the possibility of failures in the vehicle power supply or in the communications system itself, a small library would have to be maintained on the vehicle. This library should be independent of the communication and display systems and the vehicle power supply which are commonly used as part of the master library system. This "emergency" library would contain data concerning the power supply, communications, and abort systems stored on 16mm film. The viewer could be hand held or case mounted[5] and contain its own light source and battery supply. A redundant power source in the airborne transmitter and receiver should also be considered.

The airborne and ground receiver sensitivity and transmitter output will be dependent on bandwidth, airborne power source available, antenna gain, and distance. Based on the limitations of the vehicle, airborne communications would be restricted to the amount of transmitted power output and the antenna configuration as compared to the ground station. With the great distances involved in space travel and because of the "hole in the sky" for radio transmission (1 to 10 gigacycles)*, ground stations such as Telstar's Andover, Maine station, elaborate antenna and tracking systems would be required for reception of the signals transmitted from the space vehicle. Because of the lower antenna gain on the vehicle, the ground station must transmit a high power output. The Andover station transmits RF at 2 kilowatts as compared to the received signal of approximately 1 picowatt.+ The satellite transmitter output would be approximately 2 watts with the received signal at about 1 nanowatt.**

For transmission beyond the earth's atmosphere, the carrier frequencies are somewhat limited to a band between 1 and 10 gigacycles. Below 1 gigacycle (1 KMC), cosmic noise increases in amplitude thus reducing the usable signal-to-noise ratio. Above 10 gigacycles (10 KMC), galactic noise and water vapor absorption increase RF attenuation and thus reduce the usable signal-to-noise ratio.

The communication system bandwidth, operating within the range of the above-mentioned frequencies, would be dependent upon the type of modulation that would be used. The airborne receiver need only detect the video and audio transmission from the library, whether it be from the ground or another satellite. By using a slow scan TV system which transmits and receives one frame every 2 seconds, the bandwidth would be 150 kilocycles per second.

* 1 gigacycle = 10^9 cycles per second

+ 1 picowatt = 10^{-12} watts

**1 nanowatt = 10^{-9} watts

The audio bandwidth in turn, would be about 4 kilocycles per second. Utilizing AM single side band modulation, the airborne receiver bandwidth could be as narrow as 160 kilocycles per second. The type of coding, such as binary or selective tone frequencies that could be used with the library indexing systems airborne transmitter also affect the bandwidth.

Each space mission will require its own study to determine the characteristics peculiar to it and the necessary design paramiters required to do the job.

Due to the earth's rotation, several ground stations would be required to maintain constant communication with the space vehicle. However, it would not be necessary to have a complete library at every ground station. These stations could communicate with a central library by means of landlines, microwave repeaters, or relay via satellite repeaters. Communications between the vehicle and earth could also be relayed via orbiting communications satellites instead of multiple ground stations. (See Figure 1)

If no library were involved with the space vehicle, the communication system might consist only of an audio link. However, since television is used in the previous example, the addition of a camera in the vehicle could be used for monitoring critical functions and transmitting this information back to earth for further and immediate evaluation and assistance from engineering and scientific specialist teams. During extended trips, the TV communications systems could also be used for leisure time entertainment such as televised mail or pictures of the crew members and their families along with audio exchange of information.

2. <u>ORBITING SATELLITE LIBRARY:</u>

A second method of supporting a library for a space vehicle would be to place it in an orbit around the earth or some other planet. The space vehicle would be similarly equipped as in the previous example to communicate with the satellite. However, in this instance the satellite's library storage, retrieval and transmission equipment would be completely automated. By appropriate orbital orientation of the library with respect to the space vehicle, the distance for transmission between the two could be controlled to a degree, easing the problem of the propagation requirements. In order for the vehicle to keep in constant communications with the satellite and the satellite maintain constant communications with earth, several satellites would be required. We must realize that the increase of components would result in decreased system reliability.

The ground station must communicate with the satellite for updating of the library in addition to relaying of any communications with the vehicle. As mentioned earlier, the communications equipment on the vehicle and satellite are not as powerful or sensitive as those on the ground. Because of the distances involved for space missions, active relay satellites could be required at various orbiting distances. Since the satellite would be unmanned and the equipment automated, the repair capability would be limited and fully dependent upon redundant components. (See Figure 2)

3. <u>ON BOARD LIBRARY:</u>

As mentioned earlier, a complete library with all the necessary manuals in bulk form on board the vehicle would be impractical because of the volume required. Also, thumbing through them looking for the required information

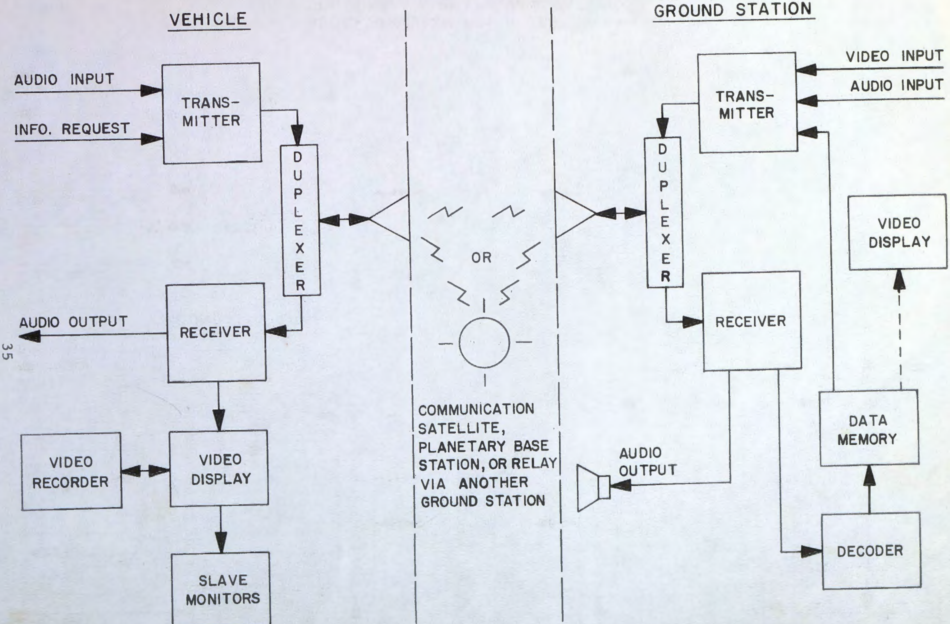

FIGURE I-BLOCK DIAGRAM FOR A SYSTEM WHICH CONTAINS A LIBRARY IN A GROUND STATION

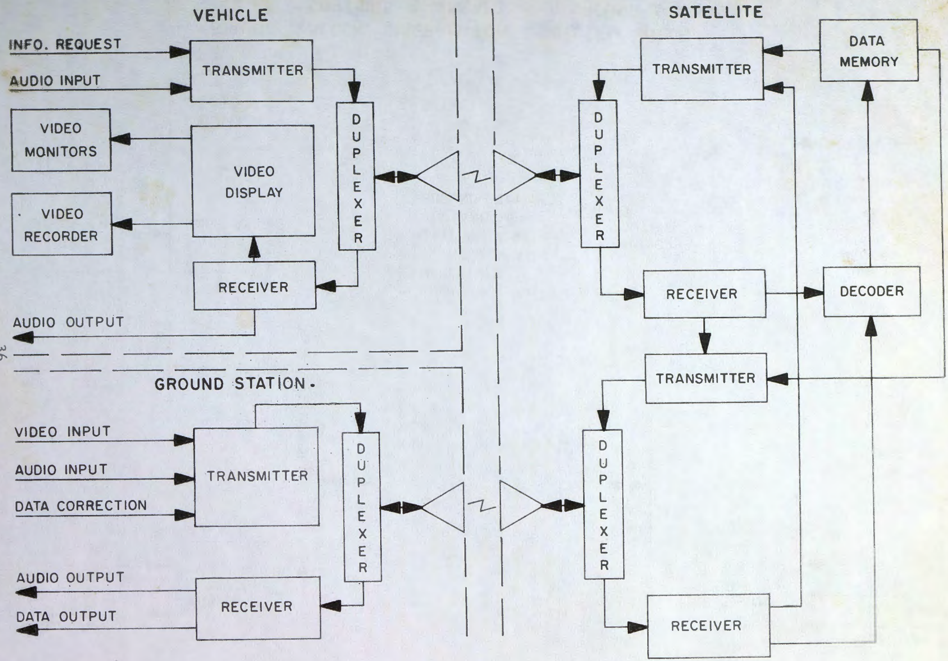

FIGURE 2 – BLOCK DIAGRAM FOR A SYSTEM WHICH CONTAINS A LIBRARY IN A SATELLITE

would be quite time consuming. These problems would be alleviated considerably by the utilization of microfilm or photochromic micro images[6] (Micro Dot) for storage of the T.O. library.

The National Cash Register Company, Hawthorne, California, has developed a device employing a new technique for the storage and dissemination of micro-documents. The technique, known as photochromic micro images (Micro-Dot) makes it possible to make tremendous reductions ultimately recorded on high definition film. Linear reductions of 200:1 make it possible to record a 300-page book within a square inch of film. Expressed in another way, the end item is a photochromic plate 3 x 5 inches capable of recording 2,625 micro-images. With photochromic micro images an entire set of Titan II technical manuals, involving approximately 21,000 pages, could be recorded on 10 3 x 5 cards which could easily fit in a shirt pocket.

In the spring of 1963, NCR successfully demonstrated the feasibility of Micro-Dot under a contract with the Navy Bureau of Supplies and Accounts, Long Beach, California.

A drawback to this would be that information could not be conveniently updated. Corrected information would have to be transmitted to the vehicle and new films made and corrections spliced into existing film. This would require other items such as cameras, chemicals, projectors, editor/splicers, etc., in addition to the vehicle communications equipment.

Let us assume that a problem occurs, corrective information would be obtained from the "On Board" library, and displayed on a projector or similar device. Several groups of people may require this information simultaneously at different locations in the vehicle. Reproducing and delivering this data could be accomplished with the closed circuit TV system mentioned earlier or by using machines such as Verifax, Recordak, Polaroid, etc., to make hard print-out copies. However, storage of photographic papers, chemicals, and film on board the vehicle would pose an additional problem.

The major advantage to this system would be that all of the basic library information would be self-contained within the vehicle and not basically dependent on an external source. (See Figure 3)

In the event of a failure in the power system on the vehicle, the video recording and playback equipment and audio warning systems should have their own secondary power source.

CONCLUSION:

One of the main considerations for determining the type of library system would be the qualifications of the people on board the vehicle. In the beginning, manned space shot crews will consist of two or three astronauts whose primary function will be piloting of the vehicle and various life science experiments. The repair of malfunctioning equipment could be considered as secondary. These people probably would not be trained electronic or mechanical engineers, chemists, or technicians who would be familiar with all the equipment on board. Therefore, they might have to rely upon others to expedite repairs. Consequently Approach Number 1, having the library on the ground, would be the most workable. A small library would still have to be maintained on board; however, technical assistance from the designers and scientists on the ground would be feasable and advantageous.

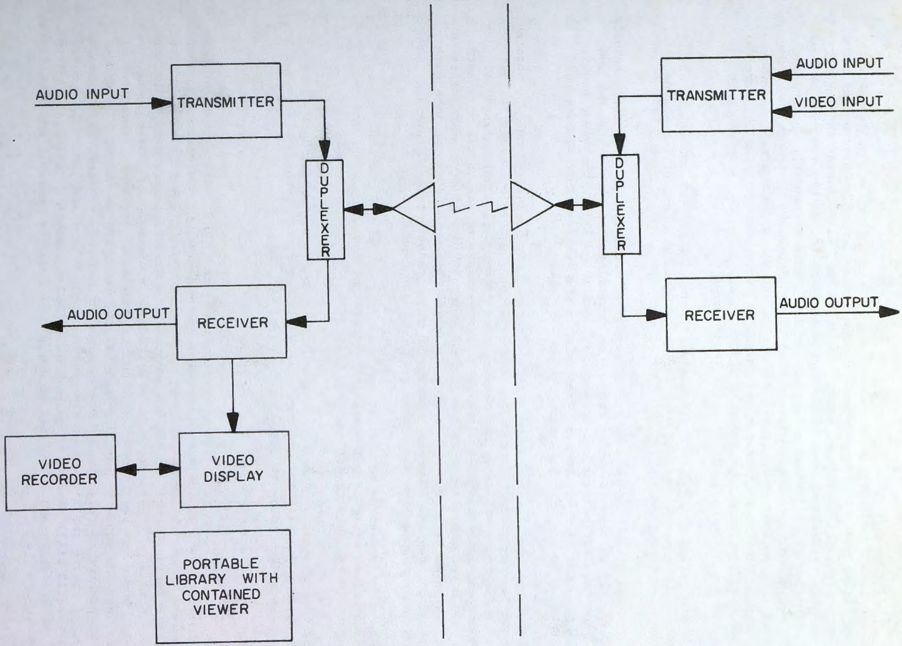

FIGURE 3—BLOCK DIAGRAM FOR A SYSTEM WHICH CONTAINS AN ON BOARD LIBRARY

The frequency, power output, receiver sensitivity, and other RF characteristics of the communications system would be determined after a careful study was made of the flight plan, time duration, size of required library, etc., for the manned vehicle or station.

It should be noted that most of the items to be employed in this analysis are not new items that are pushing the "state of the art" but are almost all available off-the-shelf.

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