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INTERIM PROGRESS SUMMARY AND DESCRIPTION OF
A-7 ALOFT SYSTEM

J. R. Ellis

Naval Electronics Laboratory Center
San Diego, California

1 January 1976

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A-7 ALOFT DEMONSTRATION



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Research and Development,
March 1974 through December 1975

Prepared for
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) International Business Machines, Federal Systems Division, Owego, New York, delivered the A-7 ALOFT system hardware to the Navy on 15 October 1975. An interim report of progress is presented together with a description of the ALOFT system design. Included are explanations of design tradeoffs that led to the components used by International Business Machines in the design of the system. A description of the tests conducted by the Naval Electronics Laboratory Center upon the ALOFT components is provided with a summary of the most significant test results. Graphic and written descriptions of the ALOFT system are included. The		

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test phases yet to be completed are summarized. The economic analysis, planned in parallel with the test phase of the project, is briefly described. A classification list of the original signals in the A-7 which have been converted from electrical to fiber-optic transmission is provided.

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OBJECTIVE

The A-7 Airborne Light Optical-Fiber Technology (ALOFT) Demonstration was established to confirm that fiber-optic technology is sufficiently practical and mature to be used in internal aircraft data-signal transmissions and to demonstrate the feasibility of a full A-7 system application.

RESULTS TO DATE

International Business Machines (IBM), Federal Systems Division, delivered A-7 ALOFT hardware to the Navy in October 1975 after demonstrating the capability of their subsystem with the A-7 Navigation and Weapon Delivery System (N/WDS) and the A-7 software. Testing of this hardware is in progress.

ADMINISTRATIVE INFORMATION

Work is being performed by the Air Systems Program Office, Naval Electronics Laboratory Center, for the Naval Air Systems Command under Program Element 63791N, Project F41X1, Task Area WF41X1001, and NELC Work Unit F228. The project was initiated in March 1974. The principal investigator is LCDR JR Ellis, USN. The A-7 Project Office of the Naval Weapons Center, China Lake, California, is supporting the ALOFT Project under the supervision of RJ Freedman. The Naval Air Test Center, Patuxent River, Maryland, is supporting the project with work being conducted by the Reliability and Maintainability Branch under the supervision of D Orwig. Under contract N00123-75-C-0262, portions of the work were performed by IBM, Federal Systems Division, Owego, New York. Ling-Temco-Vought (LTV), Vought Systems Division, Dallas, Texas, was issued contract N00123-75-C-2114 to design an installation plan and to perform ground-simulator testing. The author wishes to acknowledge the contributions to the generation of this report which were made by RD Harder, GM Holma, and TA Meador of the Naval Electronics Laboratory Center, R Betts and RC Clapper of IBM, and T Coleman and G Herring of LTV.

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BACKGROUND OF THE A-7 AIRBORNE LIGHT OPTICAL-FIBER TECHNOLOGY (ALOPT) DEMONSTRATION

Research and development work at the Naval Electronics Laboratory Center (NELC), San Diego, California, and throughout industry has demonstrated the feasibility and desirability of using fiber-optic technology in military communications systems. The properties of fiber optics should significantly reduce weight and space requirements, eliminate radio-frequency interference (rfi) and electromagnetic interference (emi), provide increased electromagnetic pulse-interference (emp) immunity, and alleviate electrical hazards and interface problems now plaguing the Navy in ships, aircraft, missiles, and other installations. The objectives of the ALOFT demonstration are to confirm that fiber-optic technology is sufficiently practical and mature for use in internal aircraft data-signal transmission and to demonstrate the feasibility of a full A-7 system application. This project will provide a definitive operational demonstration of the advantages of fiber optics over existing wire methods. It will also provide a meaningful, low-risk step toward development of a full-multiplex avionics data-bus system.

The manner in which a twisted-pair wire or coaxial-cable interface can be functionally replaced by a fiber-optic link is shown in figure 1. In the ALOFT demonstration, signal wiring in the navigation and weapons-delivery system (N/WDS) of a Navy A-7 aircraft is being replaced by electronic multiplexing circuits and fiber-optic interface circuits external to the existing avionics. Data will be exchanged optically over fiber-optic cables. The demonstration of the fiber-optic signal-multiplexing system is being conducted in three stages: laboratory simulation, ground flight-simulator testing, and a full flight test and

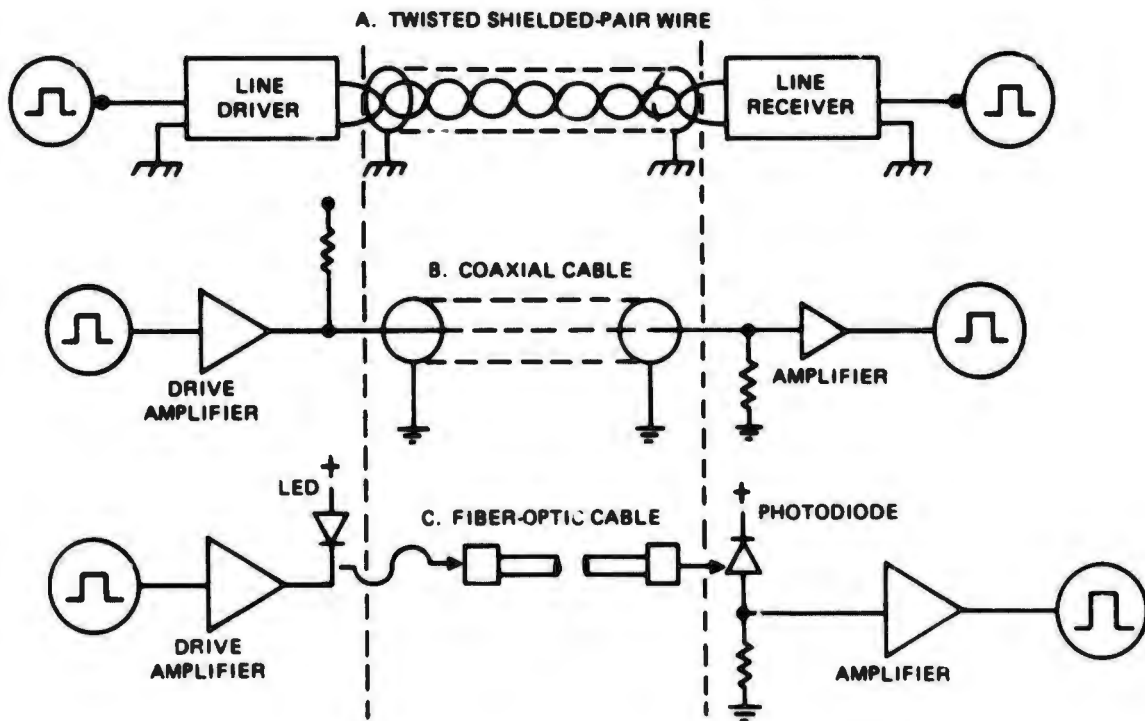
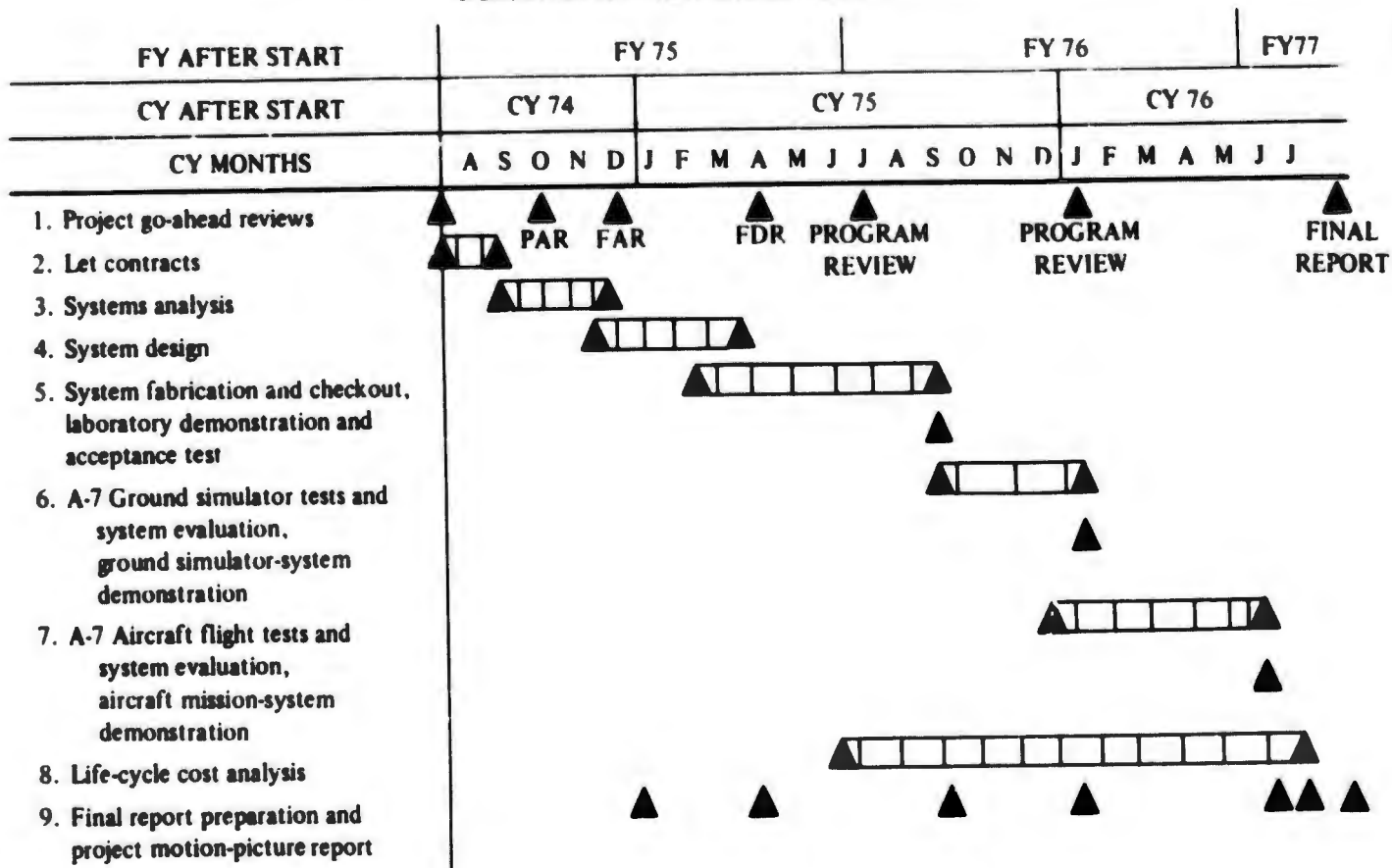


Figure 1. Typical interface systems.

evaluation of the total system. Definitive comparisons will be made of the original wiring and the improved fiber-optics system to show rfi and emi immunity, reduction in cable and connector complexity, reduction in the number and weight of cables, increased reliability, and lowered cost potentials.

The ALOFT project began during fiscal year 1974 when plans to conduct the demonstration were completed by NELC and were approved by the Naval Air Systems Command (NAVAIR). Initial project funding was received from NAVAIR in late March 1974 by an AIRTASK which assigned to NELC, as the lead laboratory, the responsibility for the execution of the A-7 ALOFT demonstration. A schedule of the two-year program, listing major tasks and milestones, is shown in table 1. A plan for the various contracting actions to be taken during the program was submitted to the Chief of Naval Material in a request for authority to negotiate. In April 1974, an approved decision and finding were received from the Secretary of the Navy. Procurement actions and contract negotiations were begun immediately and resulted in contracts being awarded, in August 1975, to International Business Machines (IBM), Federal Systems Division, Owego, New York, and to Ling-Temco-Vought (LTV), Vought Systems Division, Dallas, Texas. IBM was awarded a contract to develop, design, and fabricate an electronically multiplexed information-transfer subsystem for the A-7 N/WDS which would provide for communication over fiber-optic links between the A-7 tactical computer and peripheral avionics units. LTV was awarded an initial contract to design the installation plan to integrate the IBM hardware into an A-7 aircraft for a Navy flight test and evaluation. The LTV contract has since been amended to include a three-month ground test of the IBM hardware while it is installed in an avionics simulator of the

TABLE 1. AIRBORNE LIGHT OPTICAL-FIBER TECHNOLOGY (ALOFT) DEMONSTRATION MILESTONES.



A-7 N/WDS. The purposes of this ground test are to ensure the compatibility of the hardware and software of the A-7 N/WDS and to gather some environmental test data of the fiber-optic links before going into the flight-test phase.

IBM delivered the ALOFT hardware to the Navy in October 1975 after demonstrating the compatibility of their subsystem with the A-7 N/WDS and the Navy A-7 software. The Navy software, to be used in the ALOFT demonstration, was developed over the past year by the Naval Weapons Center (NWC), China Lake, California. NWC, in its role as the Navy agency responsible for the configuration management of the operational software for the A-7, was tasked by NELC to monitor the ALOFT design development by IBM and to adapt the Navy's software to the IBM ALOFT hardware design.

SYSTEM DESIGN CONSIDERATIONS

The IBM-designed interface subsystem interconnects the A-7 avionics units shown in figure 2. One hundred fifteen signals which were originally transmitted over a very dense, parallel interface, consisting of twisted-pair, three-wire, and coaxial cables, have been multiplexed on 13 channels of information. These 13 channels of information are transmitted via 13 fiber-optic cables and are consolidated into one optical connector in the computer interface. Such extensive point-to-point multiplexing was possible because of the wide bandwidth available with fiber-optic data links. Table 2 shows the different types of signals which make up the total signal population in the ALOFT configuration. The data rate achieved in the

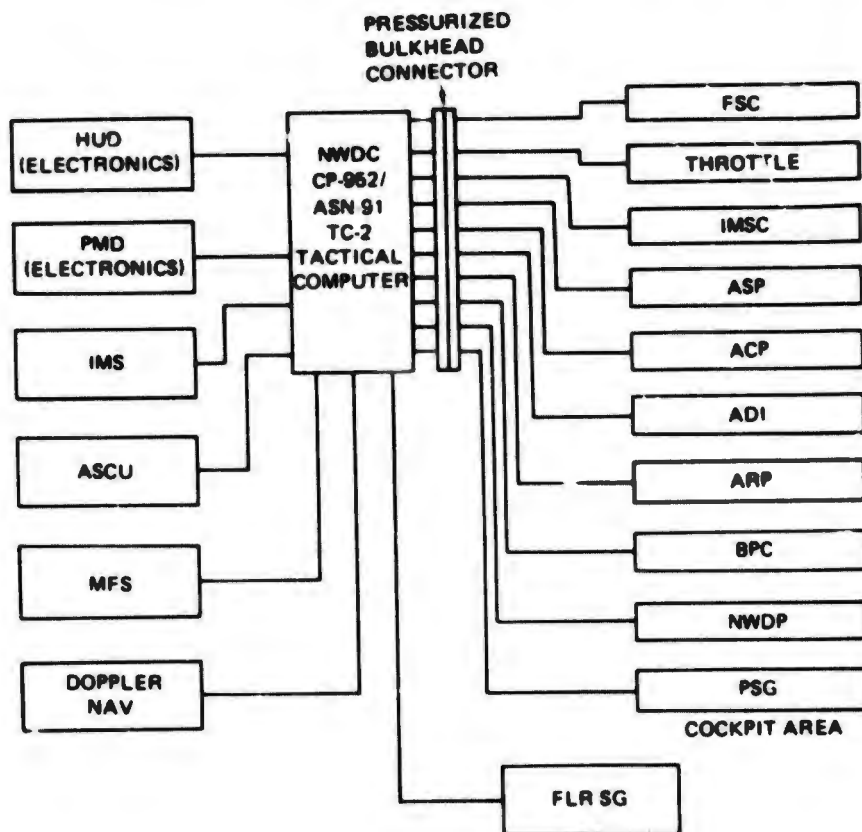


Figure 2. A-7 navigation and weapon-delivery system, electrical interface.

TABLE 2. ALOFT SIGNAL TYPES.

- Four 1 MHz
- Nineteen 50 kHz
- Forty-two 5-V discretes
- 27 switch closures
- Twelve 5-V pulse trains
- Eight 28-V discretes
- 2 analog (via A-D conversion)
- 1 analog (direct fiber-optic interface)

Total = 8 signal types and 115 signals

IBM design over the 13 fiber-optic data links is ten megabits per second, maximum. Time-division multiplexing is accomplished by Manchester coding of the sampled signals. (A list of the signals and their parameters which have been multiplexed is contained in appendix A.)

The IBM system analysis of the requirements for the fiber-optic interface led to the conclusion that, due to the small size of the system and the short distances involved for transmission, cumulative optical-insertion losses caused by coupling from light sources through bulkhead connectors and to the light detectors, represented a design consideration more important than cable attenuation. The maximum transmission distance required in the ALOFT configuration was determined to be 27 feet (8.23 meters). Some of the 13 fiber-optic links, however, required as many as five coupling points in the continuity of the optical signal from the light source to the detector. These were created by:

The connection of the fiber-optic cable to the light source;

The multiple-channel optical connector through the bulkhead of the computer;

The pressure-bulkhead connectors penetrating the pressure bulkhead between the unpressurized avionics compartment and the cockpit;

The bulkhead connector on the peripheral adapter units; and

The connector to the light detector.

These considerations led to stringent design requirements for all of the optical connectors to be used in the ALOFT system. A summary of these requirements is contained in table 3.

TABLE 3. ALOFT OPTICAL CONNECTOR REQUIREMENTS (IBM).

Specification – Initial Connector Specification

Multicontact rack and panel – IBM Drawing 74-366-16/74-366-17, five pairs from ITT Cannon

Optical loss – 3.0 dB, maximum (all tests)

Appropriate optical parameters as specified in relationship to MIL-C-83733

Single-contact terminals fabricated by IBM

Bulkhead single-contact terminals fabricated by NELC

Specification – Initial Fiber Terminating Specification

Terminal Parameters – internal mechanical

Bonding system – temperature, mechanical

Optical finish – Final polish

Electrical isolation requirements

OPTICAL CONNECTOR DESIGN REQUIREMENTS

COMPUTER CONNECTOR

The existing computer interface in the A-7 aircraft is through an electrical rack and panel utilizing nine, 101-pin, type DPKB101PF3F0, electrical connectors. By electrical pin count, only two of these electrical connectors would be functionally required to carry the original 115 parallel signals. In the original computer interface, however, the 115 signals were partitioned and distributed over nine of these electrical connectors along with power wires and spares. In the design of the ALOFT computer, IBM desired to retain the rack-and-panel interface approach for inherent system-maintainability advantages. For this reason, an IBM specification was written for an optical rack-and-panel interface connector in the ALOFT computer which would provide for 16 fiber-optic interfaces with a 3-dB, maximum, optical-insertion loss. This specification was reviewed with the connector industry and a contract resulted between IBM and International Telephone and Telegraph Company, Cannon Division (ITT-Cannon), Santa Ana, California, for a connector which not only accommodates these optical requirements but also provides 30, standard, number-12, electrical contacts in the same connector housing. This feature enables the hybrid use of the connector for optical-data transmission and electrical-power and signal transmission through the same rack-and-panel interface.

The connector has been proven in tests to meet all of the specified requirements: optical performance, mating and unmating, durability (up to 100 cycles), salt-spray resistance, fluid immersion, voltage breakdown, insulation, and contact retention.¹ Figure 3 shows the connector plug and receptacle (ITT-Cannon part number DPKB-48) in an unmated condition with five fiber-optic cables installed. The optical-alignment insert, which is removed by the T-handled tool shown in the figure, is removed for cable-pin insertion or

1. ITT-Cannon Test Report No 26-75, DPKB-48 Fiber-Optic Connector Optical Loss, RJ Sherrard, 7 February 1975.

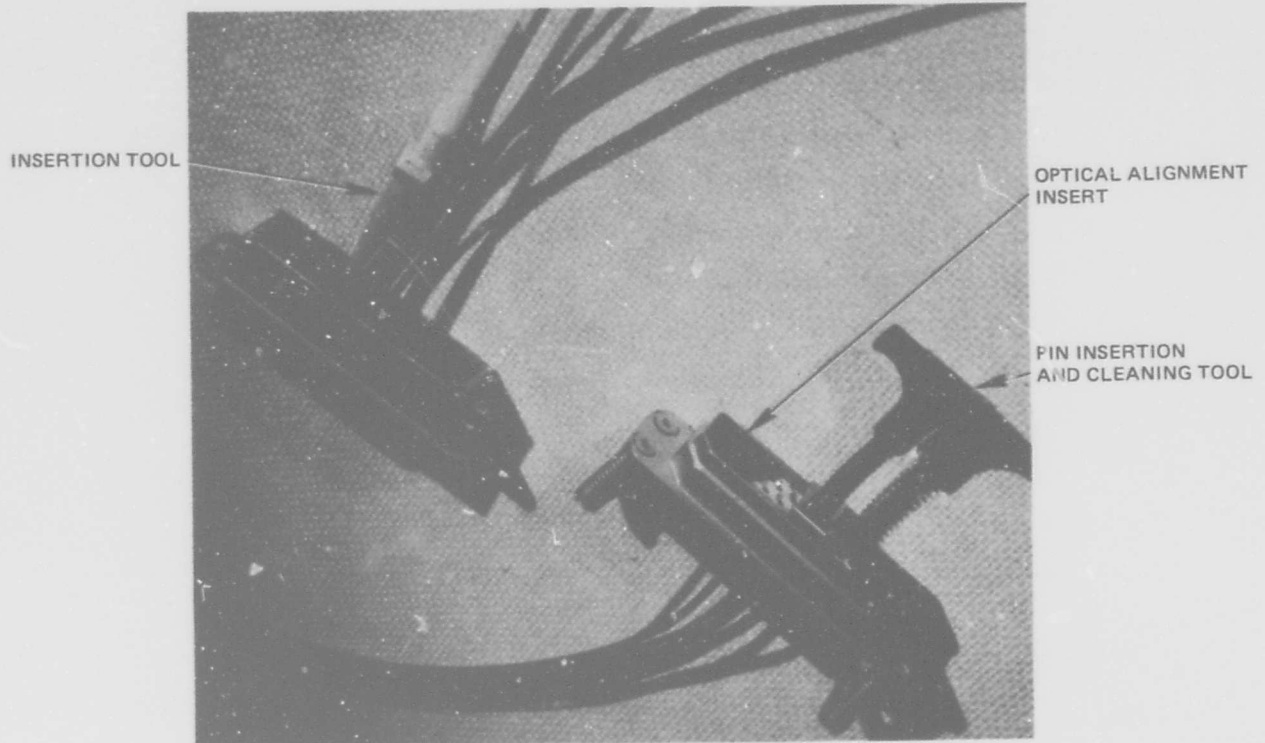


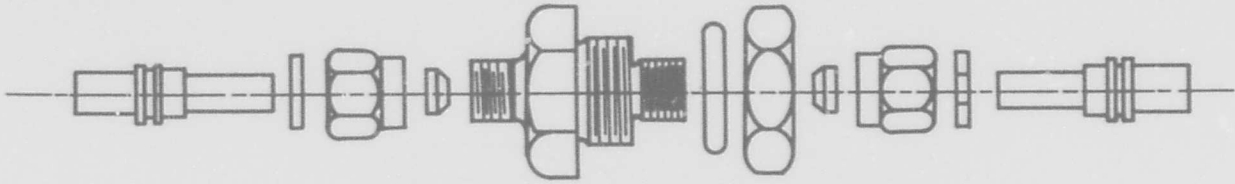
Figure 3. ITT-Cannon rack-and-panel fiber-optic connector (DPKB-48).

for cleaning of the optical surfaces. The terminated fiber-optic cables are inserted in the connector in a manner identical to that used for terminating electrical wires. Figure 3 also shows the insertion tool used in placing a fiber-optic cable into the connector shell.

PRESSURE-BULKHEAD CONNECTOR

Early in the design analysis of the ALOFT system, NELC recognized the need for an optical connector which could penetrate a bulkhead and maintain pressure integrity across the pressure-bulkhead interface. This connector would be used to penetrate the pressure bulkhead between the avionics compartment and the cockpit in the A-7 aircraft. Development of such an item was expected to require a long lead time. According to the IBM analysis, five fiber-optic cables would have to pass through the pressure bulkhead. NELC undertook to develop such a connector and designed the single-channel, fiber-optic, pressure-bulkhead connector shown in figure 4. When the design effort was started, it was anticipated that some of the optical-performance capabilities of this connector would have to be sacrificed to meet design parameters of pressure integrity, mechanical simplicity, and low cost. When the connector was constructed, however, it was found not only to meet all of the physical requirements but to provide the best optical coupling of any single-channel, fiber-optic connector developed to date.

The connector has a nominal throughput loss of 2.8 dB and a maximum loss of 3.0 dB with a designed pressure integrity up to 1000 psi. Since the bulkhead-pressure requirement of the A-7 aircraft is only 30 psi, the pressure integrity of this connector is more



1. HIGH-PRODUCTION, LOW-COST CONNECTOR
2. CABLE TERMINATION COST IS \$.97 EACH IN QUANTITIES OF 1000
3. CONNECTOR COST IS \$1.48 EACH IN QUANTITIES OF 1000
4. MEETS MIL-E-5400P, CLASS 2 REQUIREMENTS
5. PRESSURIZATION HAS BEEN TESTED TO 30 PSI AND CONNECTOR COULD BE USED UP TO 1000 PSI
6. OPTICAL LOSS IS 3 dB \pm 0.3 dB

Figure 4. Fiber-optic pressure-bulkhead connector.

than sufficient. The connector design has become the baseline for a proposed military-specification component and has been produced for the Navy on high-production machinery under a preproduction procurement with Sealectro Corporation, Mamaroneck, New York. The NELC-designed connectors produced by Sealectro have been fully tested and qualified by NELC to meet all requirements of the proposed specification. It is anticipated that additional production sources will be developed when the specification is finally approved. The connector design is easily manufactured and is, therefore, low in cost. The connector components shown in figure 4 (1 psi equals 6.894 kilopascal (kPa)) can be purchased for less than \$3.50.

LIGHT-SOURCE, DETECTOR, AND FIBER-TO-FIBER BUNDLE CONNECTORS

In their design approach for the ALOFT hardware, IBM determined the need for connectors to attach the fiber-optic cables to the light-emitting diode (LED) and photo-detector packages. The design of these connectors was undertaken by IBM and is described in figures 5 and 6 (1 inch equals 2.54 cm).

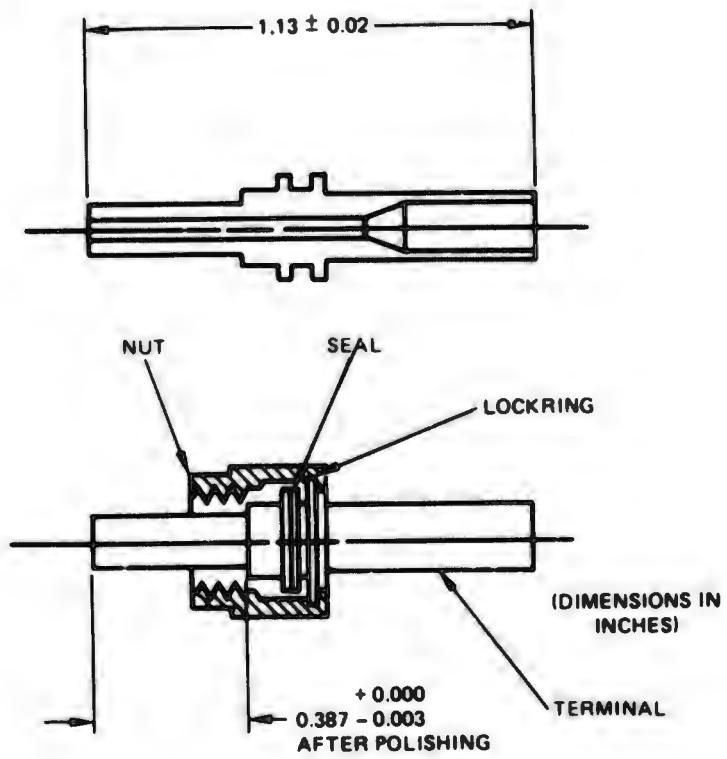


Figure 5. Fiber-optic steel terminal.

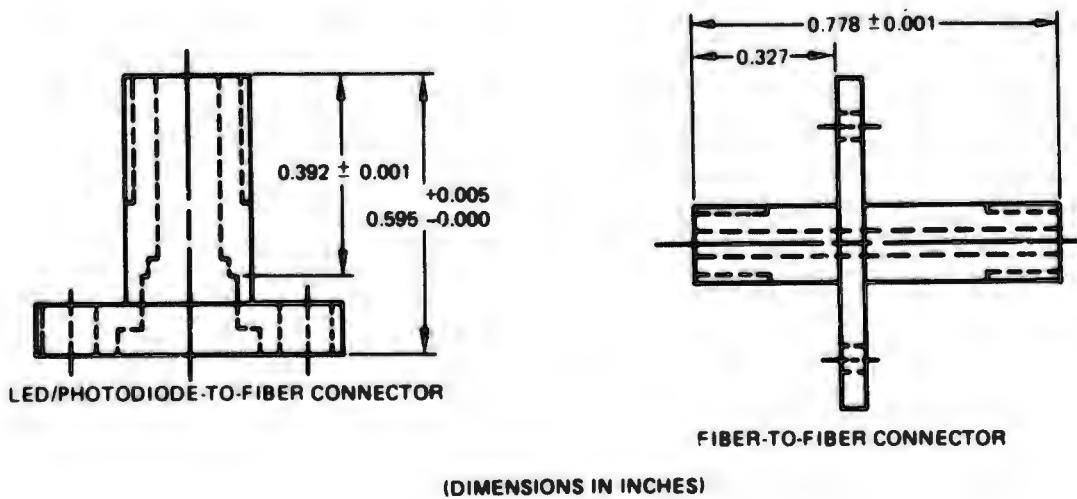


Figure 6. LED/photodiode-to-fiber and fiber-to-fiber connectors.

SYSTEM OPTICAL-LOSS AND CABLE REQUIREMENTS

The characteristics of available light sources and detectors allow an approximate 43-dB loss in transmission from source to detector. In the NELC specification, a margin of 7 dB would have to be allowed for splicing, and a goal of another 7 dB was established as additional margin for signal-to-noise and bit-error-rate protection. The remaining 29-dB transmission margin would be all that could be allowed for the fiber-optic cable and connectors. State-of-the-art bundle-to-bundle fiber-optic connectors were analyzed by IBM and NELC and the dB budget (table 4) was developed. IBM determined that the fiber-optic cable could have no more attenuation than 700 dB per kilometer. Because efficient coupling was so important, the cable specification was also evaluated by a computerized parametric analysis to determine the optimum cable configuration in terms of packing fraction, core-to-clad ratios, number of fibers, broken-fiber tolerance, and the like.² The results of this analysis were evaluated and are summarized in the specification for the fiber-optic cable contained in table 5. This specification was reviewed by various candidates in the fiber-optic cable industry who delivered samples of their products to IBM for evaluation. Evaluation of these samples led to the selection of VALTEC Corporation, Electro-Fiber-Optics Division, West Boylston, Massachusetts, as the supplier to IBM of the required cable.

TABLE 4. SYSTEM OPTICAL-LOSS BUDGET (IBM).

Loss mechanism	SYSTEM LOSS-ANALYSIS ALLOCATIONS (43 dB)		
	Achievable (dB)	Best available (dB)	Typical available (dB)
Input coupling	3.0	8.0	10.0
Output coupling	2.0	5.0	7.0
Fiber attenuation	10.0	11.0	14.0
Single connector	2.5	3.0	4.5
Multiple connector	3.0	4.5	6.0
Pressure connector	2.5	3.0	4.5
Required margin (2 splice)	7.0	7.0	7.0
Error margin (1 in 10 ⁸ bits)	7.0	7.0	7.0
System total	37.0	48.5	60.0

2. IBM Report No 75Z000436, Analysis and Selection of the Physical Parameters of an Optical-Fiber Bundle, RC Clapper and R Betts (prepared for presentation to the Electro-Optics '75 Conference, November 11-13 1975).

TABLE 4. (Continued)

ACTUAL ALOFT SYSTEM LOSSES

Loss mechanism	Best (dB)	Typical (dB)	Worst (dB)
Input coupling	4.40	5.50	7.00
Output coupling	4.40	5.50	6.70
Fiber attenuation	3.35	4.95	5.87
Single connector	2.80	3.00	3.20
Multiple connector	2.80	3.20	4.50
Pressure connector	2.80	3.00	3.20
Required margin (2 splice)	7.00	7.00	7.00
Error margin (1 in 10 ⁸ bits)	7.00	7.00	7.00
System total	34.55	39.15	44.47

TABLE 5. ALOFT FIBER-OPTIC CABLE SPECIFICATION (IBM).

Attenuation: 700 dB/km, maximum, 0.213 dB/foot

Number of fibers: 367 less 1% (4), analysis

Bundle diameter: 0.0465 inch, nominal (0.11811 cm)

Fiber diameter: 0.00215 inch, ± 3%, analysis (0.005461 cm)

Core area to total fiber area, ratio: 88% to 92%, analysis

Numerical aperture: 0.54 to 0.67

Jacketing: Mass Flex MF-62, 14 X 45 LTP-S/0.010/0.015

Low carbon-steel monocoil with PVC sheath

Number of allowable broken fibers in an unterminated bundle: 1% (4), analysis

Number of allowable broken fibers in a terminated bundle: 2% (7), analysis

Environmental test: NELC-MIL-T-5422, temperature and vibration

LIGHT-SOURCE AND DETECTOR REQUIREMENTS

Selection of the light source and detector for the ALOFT system was constrained by the availability of commercial LEDs and PIN diodes which meet the basic criteria shown in tables 6 and 7. After obtaining and evaluating samples from two candidate LED manufacturers and three candidate detector manufacturers, IBM selected the SPX-2231 LED made by Spectronics Incorporated, Richardson, Texas, and the HP-5082-4207 PIN diode made by Hewlett-Packard Corporation of Palo Alto, California.

TABLE 6. ALOFT LED REQUIREMENTS (IBM).

Initial Requirements

Material: gallium arsenide, 910 nm wavelength
Power output: 1 mW at 50 mA, minimum
Numerical aperture: 25 degrees, maximum
Physical aperture: 0.050 inch, maximum (0.127 cm)

Packaging Requirements

Temperature shock: -65°C to 85°C , less than 5 minutes
Hermetically sealed
Maximum package profile: TO-18 can with lens

Optical Requirements

Must include reflector
Can include index matching
Can include special chip form factor
Can include lens

Spectronics SPX-2231 Parameters

1.4 mW at 50 mA
NA 15°
Physical aperture: 0.050 inch (0.127 cm)
Light risetime: 15 ns
Wavelength: 910 nm
Modified TO-48 package
Hermetically sealed
Isolated chip
Reflector design

TABLE 7. AVOFT PIN PHOTODIODE REQUIREMENTS (IBM).

Initial Requirements

Silicon PIN photodiode
Risetime: less than 10 ns
Reverse operating voltage: 5V, typical, 15V, maximum
Minimum active area: 0.040 diameter (0.1016 cm)
Sensitivity: 0.5 A/W, minimum, at 910 nm
May have guard ring to reduce leakage

Packaging Requirements

Maximum component profile: TO-18
Temperature: -65°C to +85°C
Temperature shock: -65°C to 85°C in less than 5 minutes
Must have hermetic seal
Preference for isolated can

Optical Requirements

May use lens
Attempt to minimize coupling loss

Hewlett Packard HP-5885-4207

Silicon PIN photodiode	Isolated can
Risetime: 1 ns	5.5-dB coupling
Reverse operating voltage:	5V/200, maximum
Active Area:	0.040 diameter (0.1016 cm)
Sensitivity:	0.5 A/W at 910 nm
TO-18 Hermetic-seal package	

Others

RCA-C-30807
Spectronics SPX-2232

CIRCUIT DESIGNS

ELECTRO-OPTICAL CIRCUITS

IBM designed the fiber-optic interfaces into the ALOFT system with discrete transmitter and receiver circuits. There are 12 digital optical links and one analog optical link in the ALOFT configuration between the computer and the peripherals. Circuits used by IBM for the digital transmitters and receivers and the one analog transmitter and receiver are shown in figures 7 through 10.

MULTIPLEX/DEMULTIPLEX CIRCUITS

IBM used a time-division multiplexing (TDM) system with Manchester coding for the parallel-to-serial conversion of the 114 digital signals into 12 serial-data channels. The circuits used for this purpose are shown in figures 11 and 12.

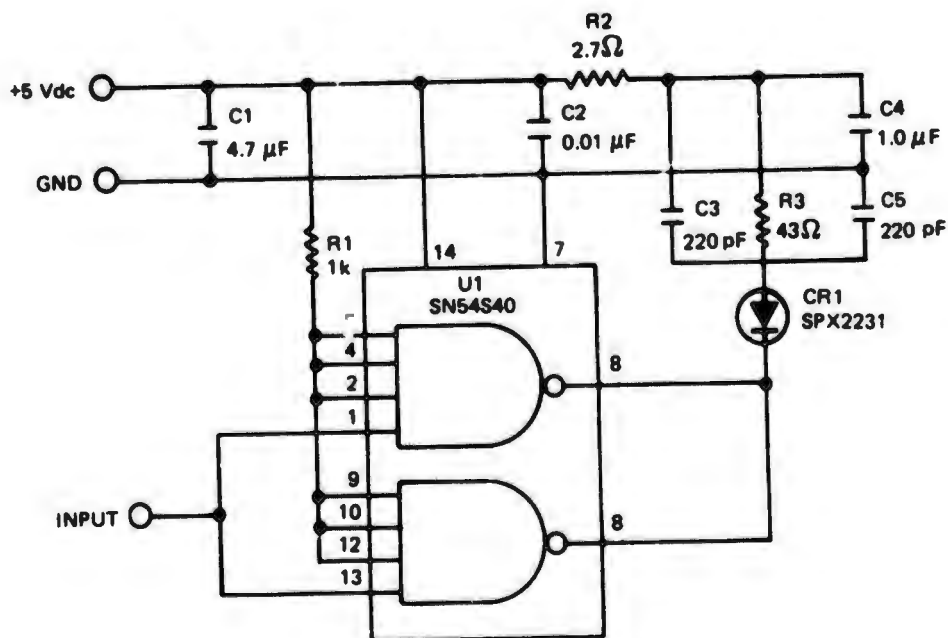


Figure 7. ALOFT digital transmitter schematic.

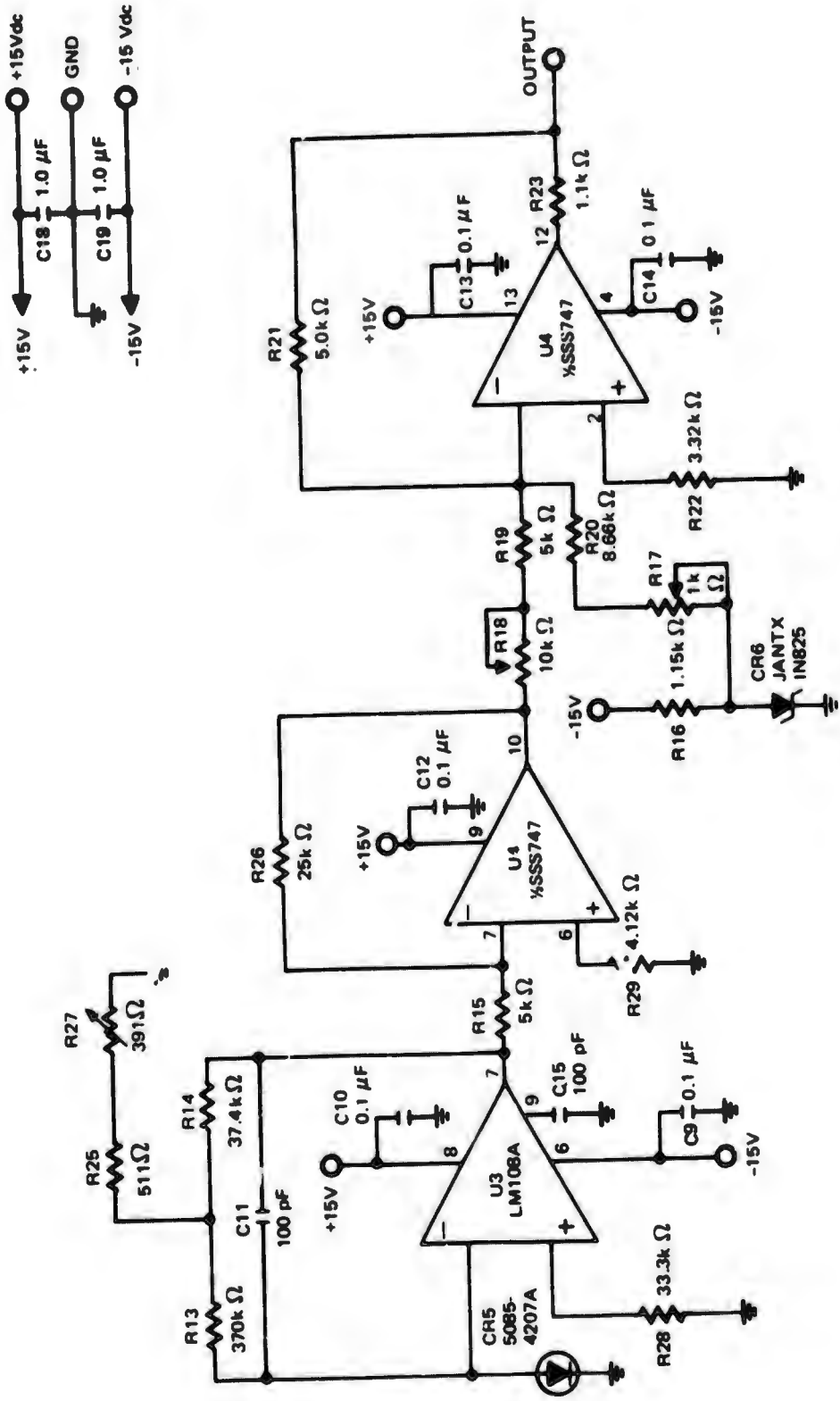


Figure 10. ALOFT analog receiver schematic.

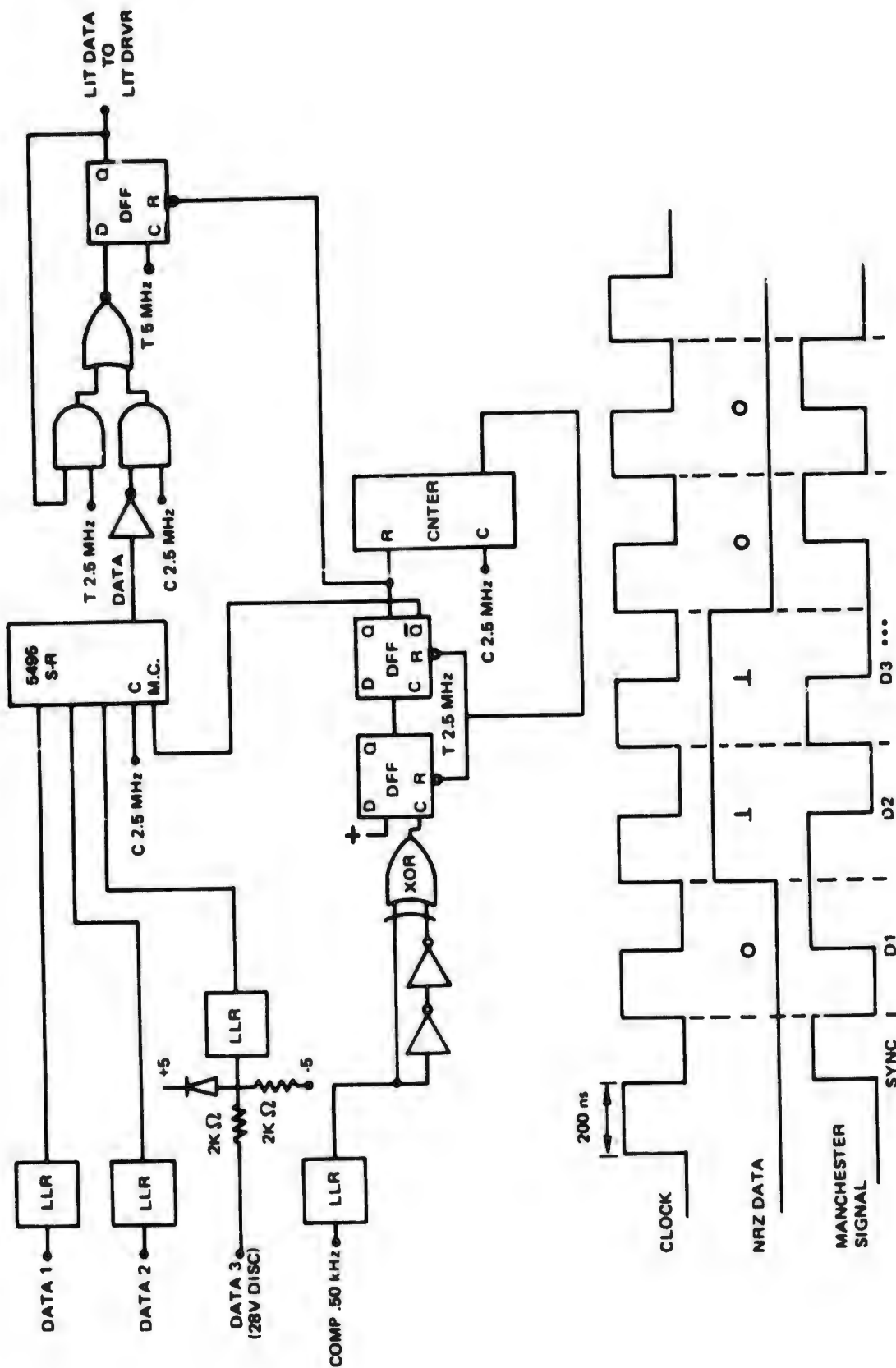


Figure 11. Typical 50-kHz channel multiplexer and Manchester encoder.

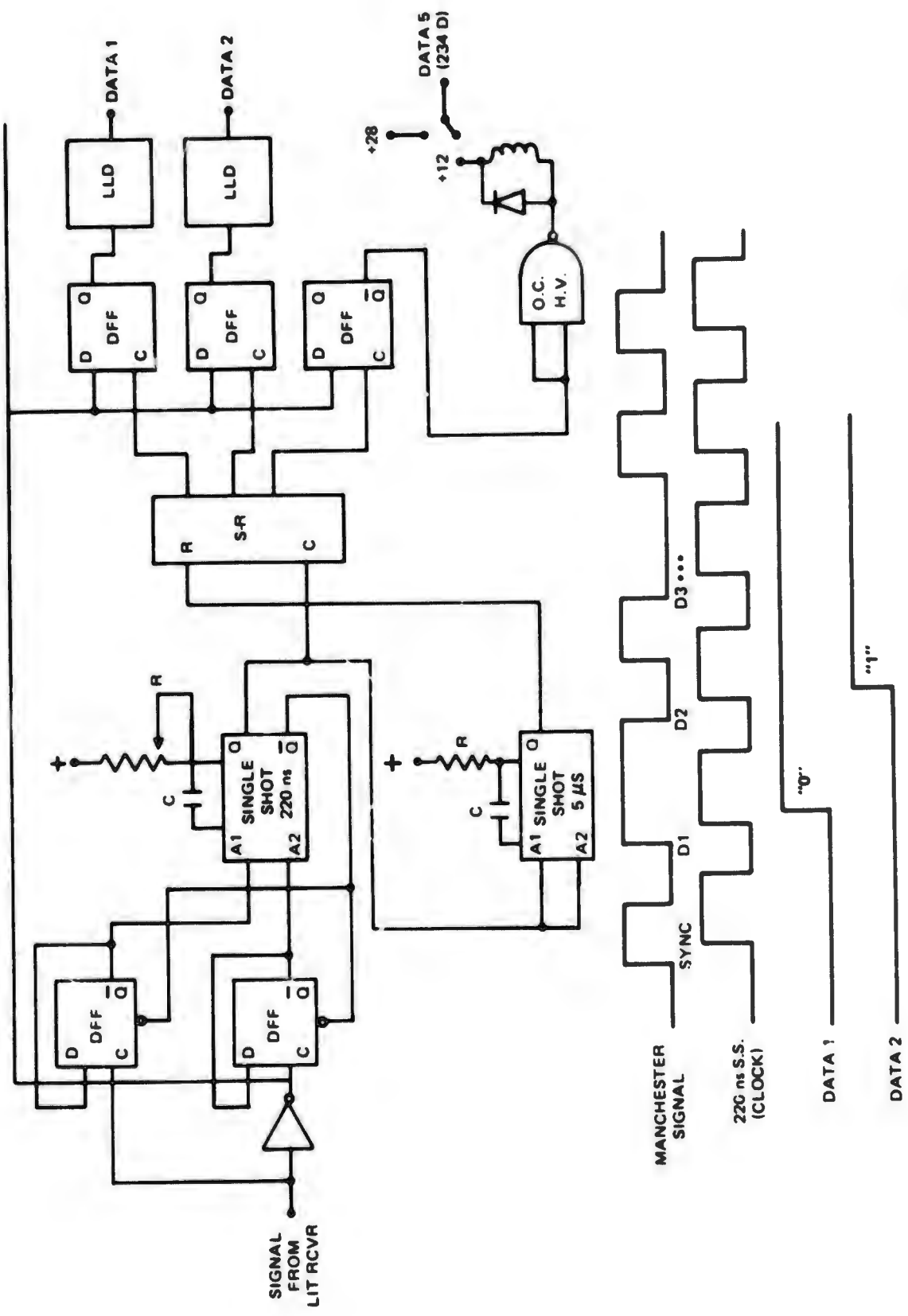


Figure 12. Typical 50-kHz channel demultiplexer and Manchester decoder.

COMPONENT SELECTION CRITERIA

Additional information describing the considerations in the selection of components for the ALOFT system can be obtained by reference to other NELC reports.³

COMPONENT TESTS

The purpose of the component tests conducted by NELC was to assure that the fiber-optic components would survive the installation process and perform adequately under the environmental conditions of the A-7 aircraft.⁴

The fiber-optic cables and pressure-bulkhead connectors were tested through the following tests from MIL-T-5422F to meet the requirements of MIL-E-5400P, Class 2:

Temperature/Altitude test

Vibration test

Shock test

Humidity test

Salt-fog test

Thermal-shock test

The components were also tested to the following mechanical and optical tests:

Cable optical loss

Connector optical loss

Cable tensile test

Cable bend-radius test

Connector-cable retention test

Connector durability test

A data link, identical to the A-7 ALOFT interface and combining the highest optical attenuation and greatest digital modulation rate, was subjected to the following tests under operating and nonoperating conditions:

Temperature/Altitude as defined in MIL-E-5400P, Class 2, operation;

Temperature extremes as defined in the LTV Report,⁴ Table I; and

Temperature/Shock as defined in MIL-E-5400P, Class 2, nonoperation.

In the operational tests, system peak-to-peak transition jitter and transmitter high-level dc output were monitored. It was found that jitter ranged from eight percent at room temperature to 34 percent at 85 degrees C.

The nonoperational temperature/shock tests had no discernible effect upon the physical integrity of any of the link components nor upon their later operation.

3. Naval Electronics Laboratory Center NELC Technical Document 426, Fiber-Optic Components for the A-7 ALOFT Demonstration, TA Meador, 11 April 1975.

4. LTV Report 2-50360/4R-5738, Environmental Definition Analysis Report, JH Rigby, 23 September 1974.

The test results indicated that the fiber-optic components should survive their installation aboard the A-7 aircraft. The tests also demonstrated that the fiber-optic components will not degrade the N/WDS performance when exposed to the A-7 environment. Further details of the tests performed by NELC and the detailed results can be found in other NELC reports.^{5, 6}

SYSTEM INTEGRATION DESIGN

The LEDs and photo-detectors, together with their respective transmitter and receiver circuits, were mounted on the electro-optic (E/O) circuit cards. In the computer, separate cards were used for the transmitter and receiver circuits. The E/O transmitter circuit card in the computer contains six separate LEDs and the transmitter-channel circuits (figure 13). Another similar card contains the seven photodiodes and the E/O receiver-channel circuits (not shown). Short lengths of fiber-optic cables were connected to the LED and photodiode mounting fixtures through specially designed IBM connectors. These 13 short-length cables were then routed internally from the computer to the bulkhead where they were mated with the ITT-Cannon rack-and-panel optical connector for external transmission (figure 14).

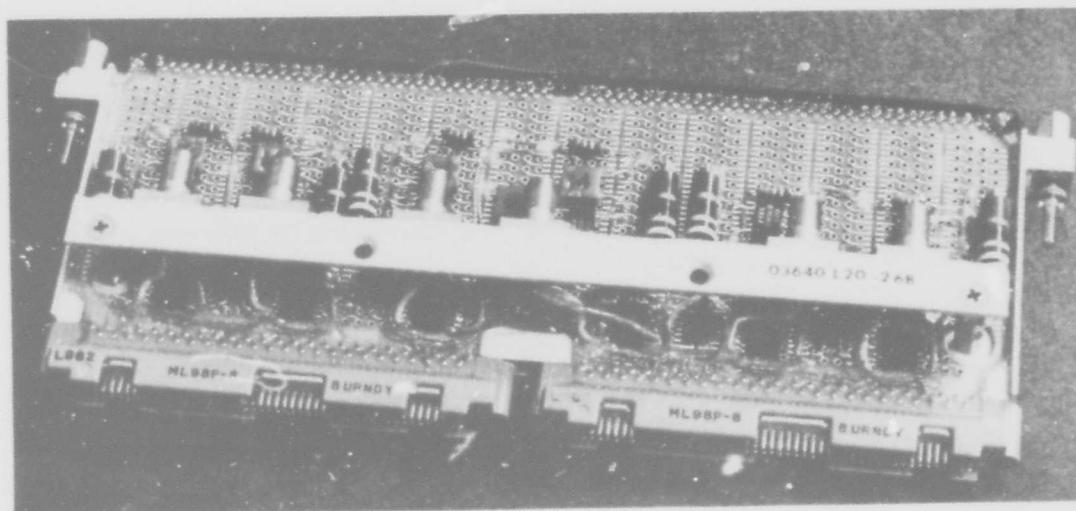
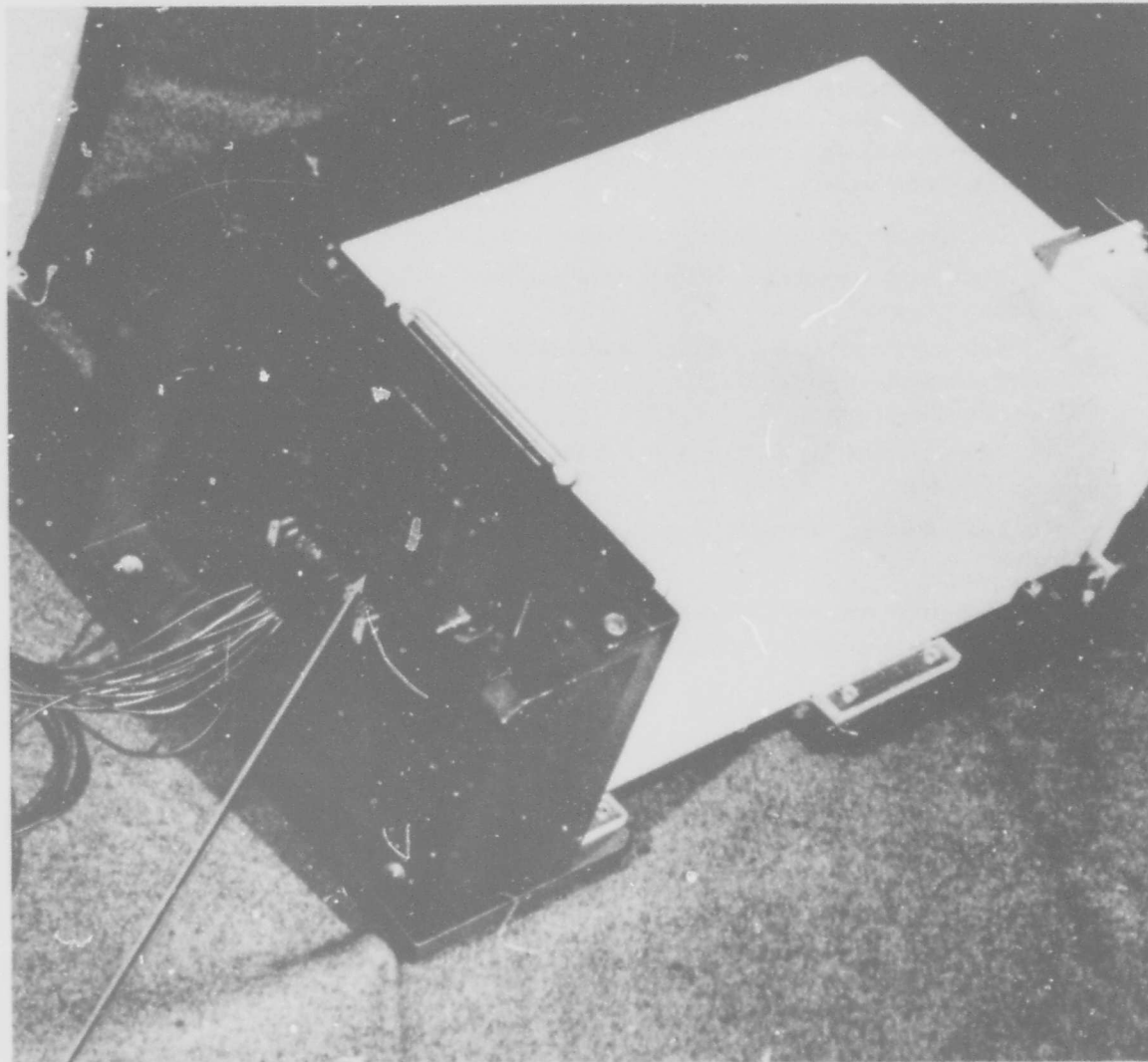


Figure 13. LED mounting on the transmitter circuit card in the ALOFT computer.

5. Naval Electronics Laboratory Center NELC Technical Document 418, A-7 ALOFT Hardware Requirements Environmental Analysis, GM Holma, 1 April 1975.
6. Naval Electronics Laboratory Center NELC Technical Document 460, ALOFT Fiber-Optic Component Tests, GM Holma and TA Meador (in preparation).



COMPUTER OPTICAL
INTERFACE

Figure 14. ALOFT computer optical interface.

External adapter units had to be used with the peripheral avionics to implement the fiber-optic interface. This was necessary because program restraints did not permit the re-design of any of the avionics units (other than the computer) because of the low level of funding available for the demonstration and because all of the avionics assets used during the demonstration were operational hardware items which had to be retained in a standard configuration to maintain the Navy's limited inventory.

IBM partitioned the interface, at the peripheral end from the computer, into five aircraft areas containing peripheral avionics and designed adapters for each of these areas (figure 15). These were:

Cockpit-area adapter, servicing all control sets, displays and avionics in the cockpit;

Right-hand avionics bay adapter, servicing the Doppler avionics and the projected-map display avionics;

Left-hand avionics bay adapter, servicing the master function-switch relay panel (MFS), the heads-up display (HUD) avionics, the inertial measurement unit (IMU), and the IMU adapter power supply;

Armament-station control unit (ASCU) adapter, servicing the ASCU in the left-hand avionics bay; and

Mid-equipment bay adapter, servicing the forward-looking radar (FLR) sweep generator.

Since there was not enough space inside the adapter units to install separate transmitter and receiver cards (as was done in the computer), transmitter and receiver circuits,

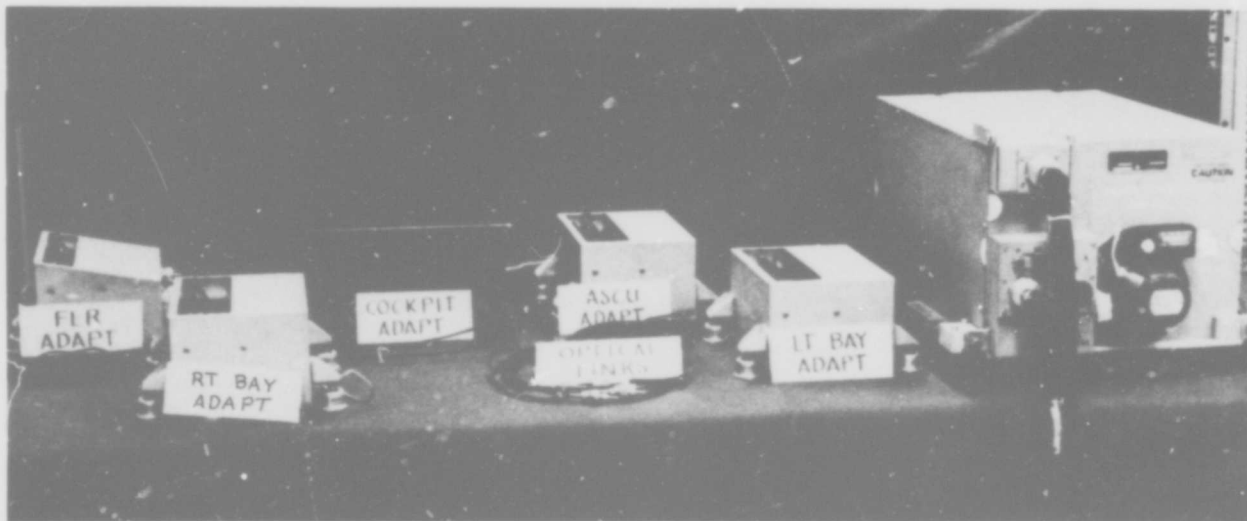


Figure 15. The ALOFT computer and peripheral E/O adapter units.

with their respective LEDs and photodiodes, were mounted on the same circuit card (figure 16). To achieve cross-channel isolation from radiated-noise interference, receiver- and transmitter-circuit layouts were spatially dispersed on each card. Each of the photodetectors and their respective pre-amplifier circuits were covered by a grounded shield which further increased the isolation of cross-coupled noise from the sensitive receiver circuit. Conductive-noise isolation between the transmitter and receiver circuits was achieved on the same circuit card by strong circuit decoupling from the common power supply.

For the purposes of the demonstration, interfacing between the peripheral adapter units and the peripheral avionics was accomplished by short electrical adapter cables. Since the peripheral interface obviously is not representative of the optimum design of a fiber-optic interface system, the majority of the efforts in the ALOFT demonstration, both in terms of design attention and intended testing, was devoted to the computer. With minor modifications, the ALOFT computer design could be made very representative of future production designs for the input/output (I/O) sections of computers which desire to make use of a point-to-point fiber-optic interface. It is interesting to note that the IBM design purposely provided for a means of reconfiguring the I/O of the ALOFT computer for either a fiber-optic or electrical signal interface, or vice versa, in only two hours of shop time. Extensive use of this feature is planned during the field testing of the ALOFT computer in order to compare the features of the electrical-versus-optical interfaces.

The multiplexing/demultiplexing circuitry in the ALOFT computer and in the adapter units consists of logic flat-packs mounted on circuit-card assemblies which interface with the parallel signals coming to and from the input-output section of the avionics unit by means of a plug-in page assembly (figure 17). The 13 serial-data channels, generated by the

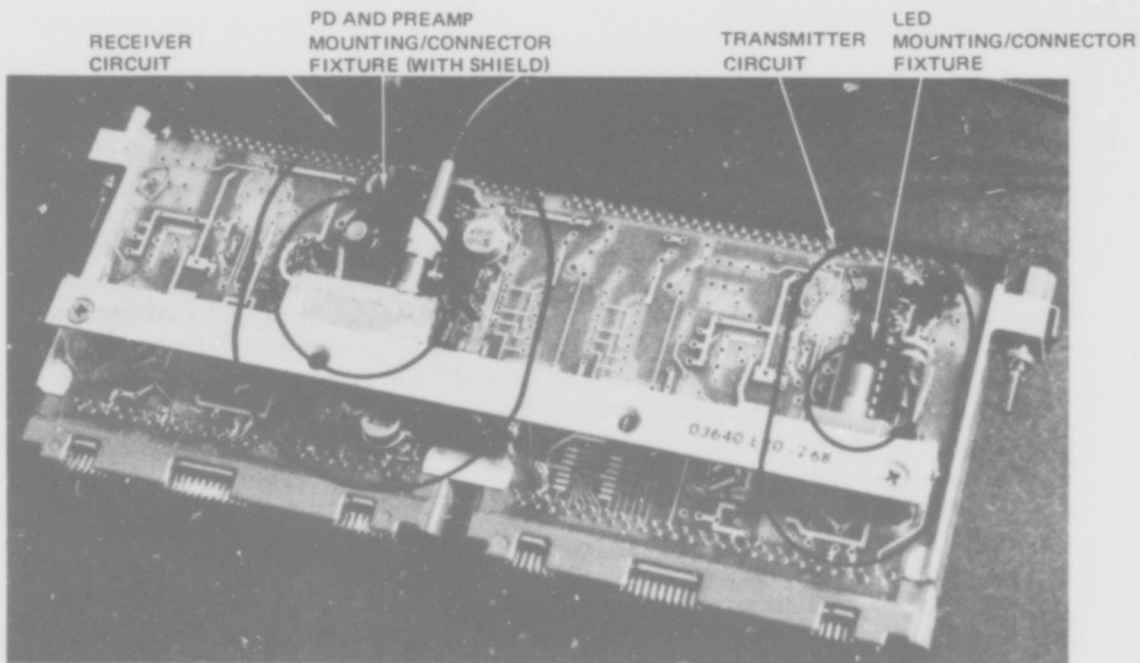


Figure 16. LED and detector mounting on transmitter/receiver circuit board used in ALOFT area adapters.

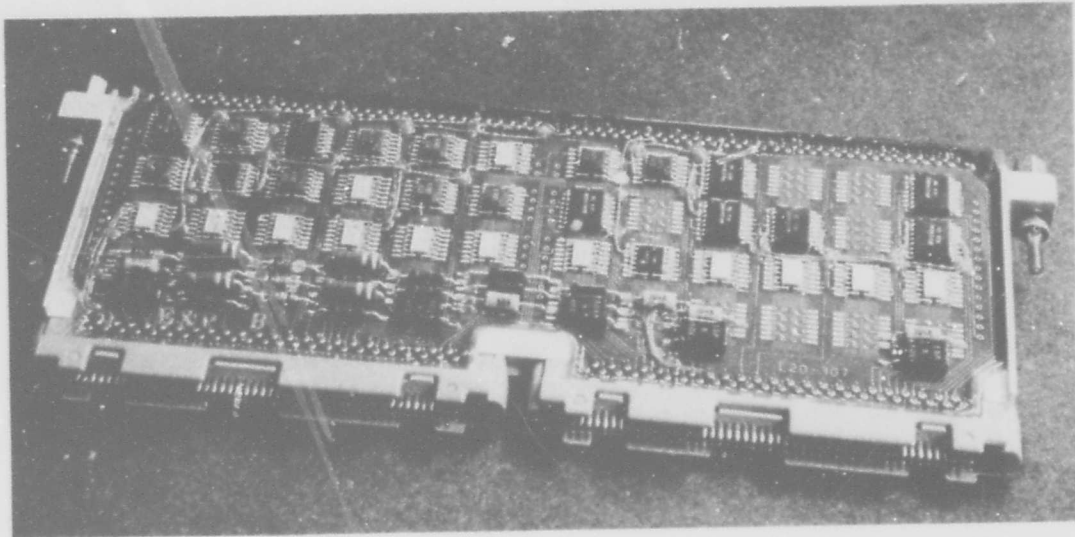


Figure 17. ALOFT multiplexer/demultiplexer circuit card and page assembly.

mux/demux cards in the computer, are fed back electrically through the card connector plug to a common electrical back-panel interface to the adjacent E/O circuit cards where E/O conversion takes place. The E/O converted serial-data channel is then optically transmitted via the fiber-optic cables for external transmission.

The A-7 N/WDS configuration with the ALOFT interface subsystem installed is shown in figure 18. The thin-lined blocks are avionics units which are already integral parts of the N/WDS avionics system of the A-7 aircraft. The block labeled "MODIFIED NWDS" is the A-7 tactical computer as modified by IBM into the ALOFT computer. Dashed lines depict the 13 fiber-optic cables carrying the 115 TDM signals across the interface between the computer and the adapter units. The bold-lined blocks are the ALOFT adapter units which provide optical-to-electrical conversion and multiplexing/demultiplexing of the 115 signals on the peripheral end of the interfaces. The dot-dashed lines are representative of the electrical adapter cables which interface the serviced avionics to the geographic area adapters. The manner in which the 115 signals are multiplexed and apportioned across the 13 channels is shown in table 8.

It should be noted (figure 18) that seven of the 13 fiber-optic cables are routed through the liquid-oxygen (LOX) and aft mid-equipment compartments, the latter serving as the ammunition-storage location for the A-7 20-mm cannon. Both of these compartments are defined as hazardous-cargo areas. For this reason, when LTV designed the A-7 aircraft all wiring had to be routed around and away from these two areas. In the original electrical installation, the N/WDS interface from the computer to the cockpit was routed to the opposite side of the aircraft and thence forward to the cockpit to avoid the hazardous areas.

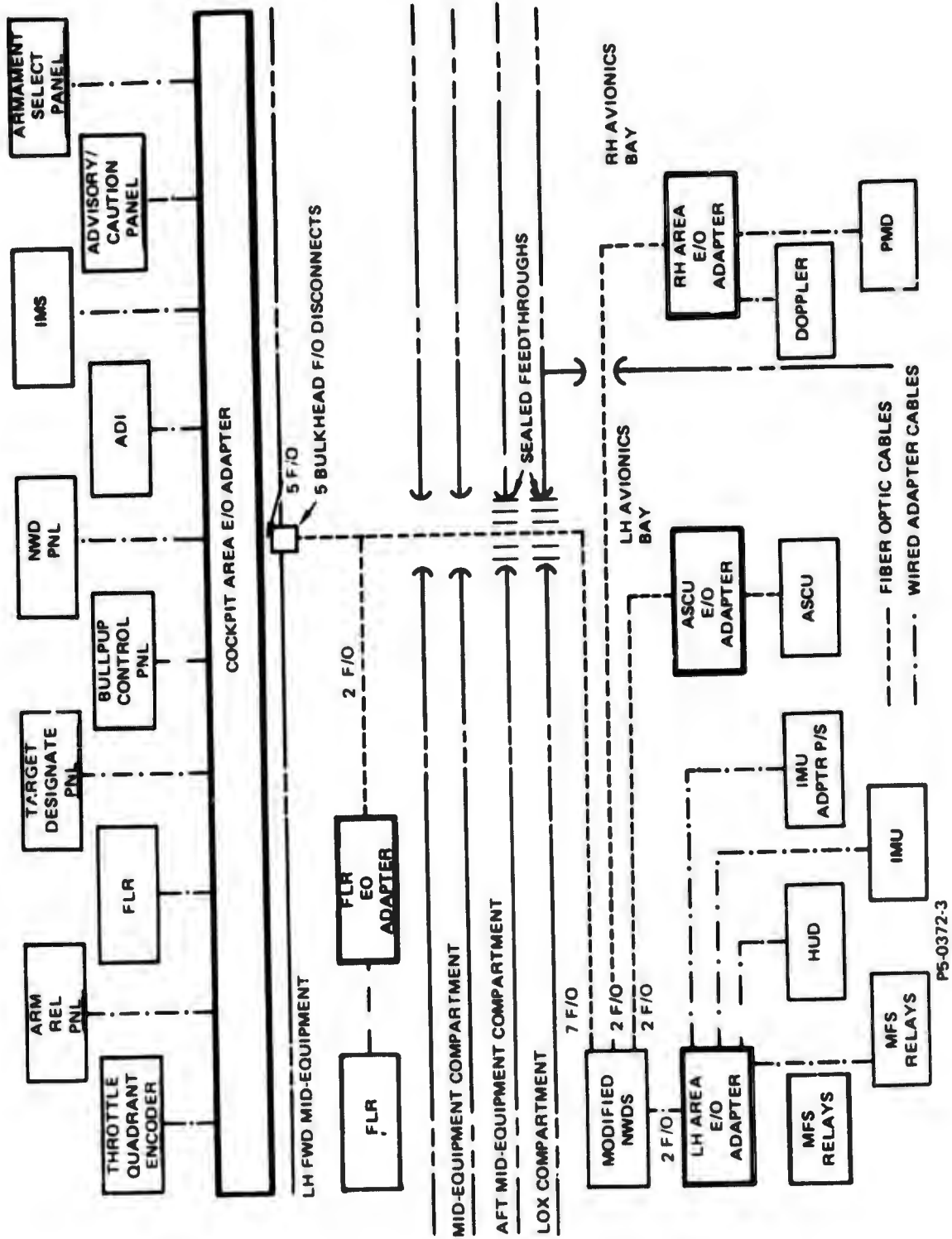


Figure 18. ALOFT system general arrangement.

TABLE 8. ALOFT SIGNALS, MULTIPLEXING PARTITIONING.

ALOFT Adapter	Optical Signals	Signal Types
Computer	6 out, 7 in	All signals below
Right bay	1 out 1 in	5,50 kHz 3,50 kHz
Left bay	1 out 1 in	4,50 kHz, 4 pulse trains, 11 discretes 6 pulse trains, 2,5-V discretes, 5 switch closures
ASCU	1 in 1 out	17,5-V discretes 2,5-V discretes
FLR sweep generator	1 in 1 out	3,50 kHz 3,50 kHz, 2,28-V discretes
Cockpit area	1 out 1 in 1 out 1 in 1 out	3,1 MHz 6 control 1,1 MHz 2,5-V discretes 4,28-V discretes 22 switch closures 2,5-V pulse trains 2,5-V discretes 2,28-V discretes 2 ±4-V analog (via A/D) 1 direct analog (+2.5V)

Five feet of wiring harness were required over the length needed if a straight shot through the hazardous area had been used. This points up one of the design constraints of aircraft battle-damage survivability for electrical interface systems. Obviously, fiber optics does not have to deal with these design constraints and can, thus, offer possible design, weight, and performance tradeoffs in the design of systems containing hazardous-cargo compartments.

ALOFT SYSTEM DELIVERED-HARDWARE DESCRIPTION

Figure 15 shows the IBM hardware delivered to the Navy. The largest unit is the A-7 tactical computer which was modified into the ALOFT computer by IBM. It is connected to the five peripheral adapter units through the 13 fiber-optic cables shown coiled between the units. These cables constitute 224 lineal feet of fiber-optic cable. Table 9 is a side-by-side comparison of the 13 fiber-optic cables with the wiring interface they functionally displace in the aircraft. Figure 19 shows this same comparison in visual form. The savings in weight and bulk are obvious.

It should be noted that the conversion of the A-7 computer to the ALOFT computer design reduced the weight of the computer by five pounds, maintained the same physical size, and added only five watts to the computer power consumption. This increase in power consumption could be overcome in a next-generation design which could be dedicated to fiber optics. Since it was desired that the ALOFT computer retain the capability to use the

TABLE 9. SIDE-BY-SIDE COMPARISON,
FIBER-OPTIC AND ELECTRICAL CABLES.

	Wire	Fiber Optics
Number of wires/cables	302	13
Total length	1890 ft (576.07 m)	224 ft (68.27 m)
Total cables & connectors weight	31.9 lb (14.45 kg)	2.7 lb (1.2 kg)
Total cables & connectors cost	\$1.63k	\$1.03k

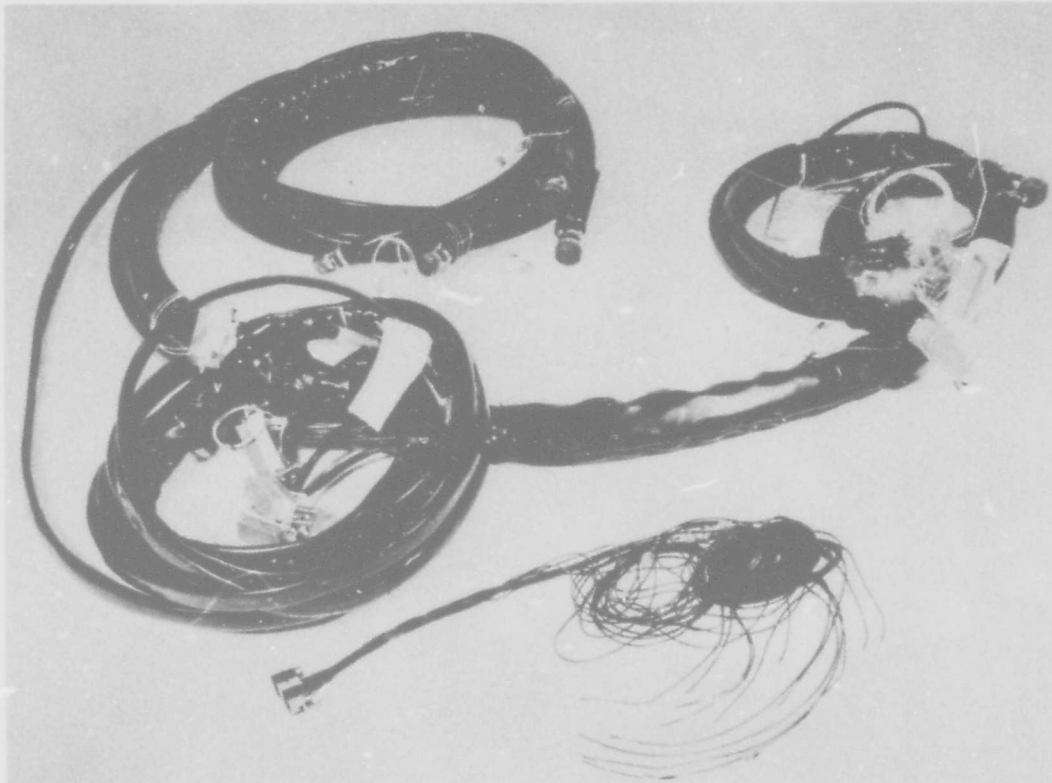


Figure 19. Side-by-side comparison of the amount of copper wiring displaced in the A-7 by the 13 fiber-optic cables in the ALOFT system.

original A-7 electrical interface, if so configured, the original electrical input-output circuits were left intact. Most of the excess power consumption (over and above the ALOFT computer consumption) is caused by these circuits even when they are not being used. Any future design would remove this redundant circuitry since it would not be required if all external communications were to make use of the optical interface.

A comparison of the reduction in bulk, weight, and material costs achieved by the ALOFT wiring configuration in displacing the original electrical wiring and connectors in the A-7 N/WDS is shown in tables 10 and 11. The avionics components are shown in their relative locations on the A-7 aircraft in figure 20. The major reductions in bulk and cost of the A-7 fiber-optic installation over the bulk and cost of the electrical installation have been achieved by time division-multiplexing (TDM) circuits and fiber-optic interfaces. Although most of these reductions are due to TDM, it is the wide bandwidth capability of the fiber-optic data links which enables the number of cables to be reduced to only thirteen. A 12-to-1 weight-reduction ratio has been achieved.

TABLE 10. A-7 ALOFT DISPLACED WIRES AND CONNECTORS.*

Component	Type	Required Quantity	\$ Cost/Unit	Total Cost	Unit Weight	Total Weight (Pounds)
Coaxial cable	RG-179B/U	222 ft	\$ 0.1045/ft	\$ 23.20	0.0170 lb/ft	3.77
Wire, unshielded	M22754/16-22	222 ft	0.0228/ft	5.06	0.00368 lb/ft	0.82
Wire, shielded	M27500A22/TE1T14	456 ft	0.0882/ft	40.22	0.0088 lb/ft	4.01
2 wires, shielded	M27500A22/TE2T14	192 ft	0.1405/ft	26.98	0.0169 lb/ft	3.24
3 wires, shielded	M27500A22/TE3T14	24 ft	0.1700/ft	4.08	0.0206 lb/ft	.49
Wire, 2 shields	M27500A22/TE1V14	543 ft	0.1285/ft	69.74	0.0188 lb/ft	10.21
2 wires, 2 shields	M27500A22/TE2V14	231 ft	0.2314/ft	53.44	0.0319 lb/ft	7.37
Connector, plug (212 Contacts)	CVC6092 - IN	2 each	30.79 each	61.58	.72 lb each	1.44
Connector, receptacle (212 Contacts)	CVC6093 - IN	2 each	32.81 each	65.62	.64 lb each	1.28
Cost of terminating above and testing final harness	Labor	42 hr	20.00/hr	1 280.00		2.00**
Cost/Weight totals				\$1 629.92		31.89

NOTES:

*These connectors are not actually replaced by the ALOFT components, but an approximately equal number of contacts (424) are idle in the sub-systems involved after ALOFT modification. In actuality, these 424 signal contacts are normally distributed over 9 of these types of connectors along with power wires in the original computer interface configuration.

**This additional approximate weight is generated by the termination, potting and harnessing materials.

1 foot = 0.3048 meter

1 pound = 0.4536 kilogram

TABLE 11. A-7 ALOFT FIBER-OPTIC CABLES AND CONNECTORS.

Component	Type	Required Quantity	\$ Cost/ Unit	Total Cost	Unit Weight	Total Weight (Pounds)
Fiber-optic cable	Valtec (IBM P/N L20-262-1)	224 ft	\$ 2.50/ft	\$ 562.50	1.3 lb/100 ft	2.91
	*Valtec (P/N L20-262-2)	224 ft	2.00/ft	448.00	0.68 lb/100 ft	1.52
Single-channel bulkhead Connectors	IBM (P/N L20-242)	13 ea	2.50 each	32.50	0.0297 lb each	0.386
Single-channel pressure-bulkhead connectors	NELC (P/N 6507)	5 ea	3.50 each	17.50	0.0499 lb each	0.250
Multichannel bulkhead (rack-panel) connector	ITT Cannon (P/N DBK-4B)	1 ea	\$294.05 each (+ \$500.00 setup)	294.05	0.559 lb each	0.559
Cost of terminating, polishing and testing final harness	Labor	12 hr	20.00 hr	240.00		
Cost/Weight totals				<u>\$1 032.05**</u>		<u>2.715**</u>

NOTES:

*The first listed fiber-optic cable was the cable selected by IBM for their delivery of the ALOFT system. The second listed cable is the alternative set of cables being procured by NELC in time for the flight test. The new cable has the same optical properties, but utilizes a new lightweight, nonconductive, Hytrej jacket in lieu of the PVC-jacketed, steel Monocoil, for protective packaging.

**Totals reflect weight and cost of the newer Valtec cable.

1 foot = 0.3048 meter

1 pound = 0.4536 kilogram

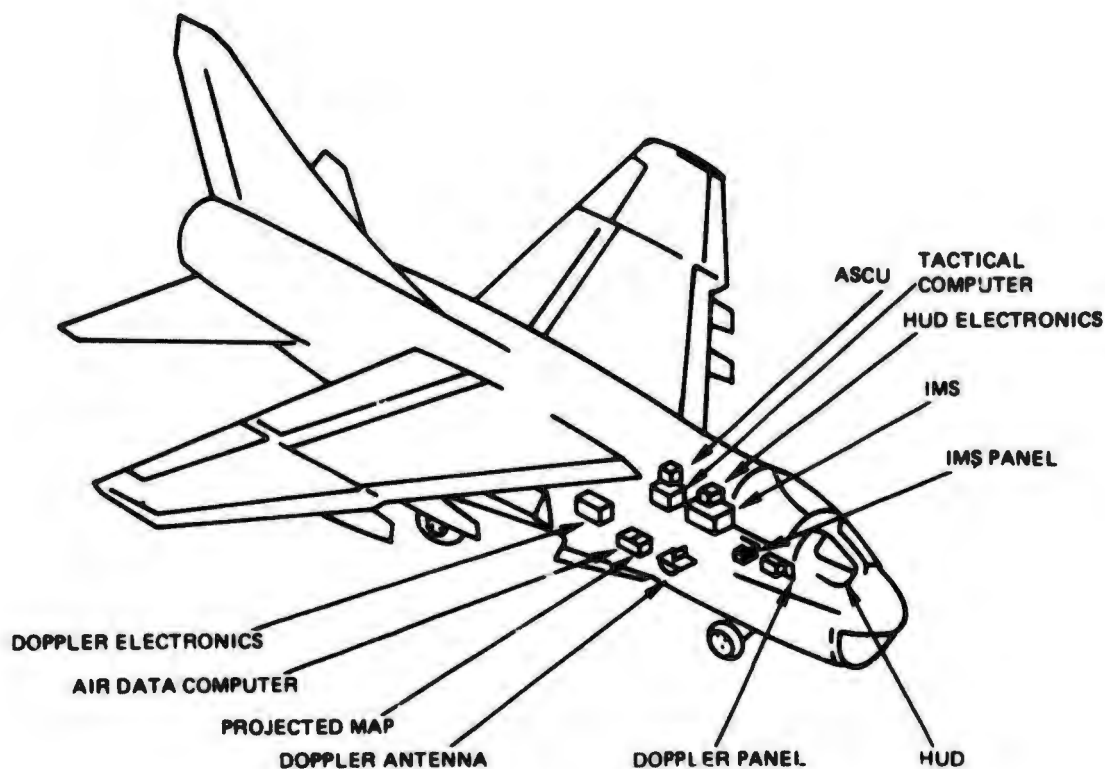


Figure 20. Orientation of avionics components aboard the A-7 aircraft.

ALOFT PROGRAM FUTURE PLANS

A-7 AVIONICS GROUND-SIMULATOR PHASE

The ALOFT system is presently being installed in the A-7 avionics "hot mock-up simulator" at LTV. Initially, the system will undergo certain performance tests to validate functional performance of the ALOFT system with the A-7 hardware.⁷ At the completion of the performance tests, environmental tests over the actual ranges of temperature, altitude, and vibration, normally experienced aboard the A-7, will be performed using an environmental test chamber which LTV has located next to the "hot mock-up" simulator. Some electromagnetic interference (emi) testing in accordance with MIL-STD-461/462 will also be performed. These tests were concluded in December 1975 with a major demonstration of the A-7 simulator while the ALOFT system is still installed. This demonstration, to be given by LTV, will provide an opportunity for interested parties to observe, at first hand, how the fiber-optic interface subsystem is integrated into the A-7 N/WDS avionics and how the A-7 N/WDS avionics perform in a simulated flight exercise of the ALOFT-modified N/WDS.

7. Naval Electronics Laboratory Center NELC Technical Document TD-438, A-7 ALOFT Demonstration Master Test Plan, RD Harder, 7 July 1975.

FLIGHT-TEST PHASE

Upon completion of the ground-simulator tests at LTV, the ALOFT system will be shipped to the Naval Weapons Center (NWC), China Lake, California. Preparations are already underway at NWC to conduct a six-month flight test and evaluation of the ALOFT system commencing in January 1976. A flight-test plan for the ALOFT program was published by NWC in November 1975. It outlines the detailed tests to be performed.⁸ NWC personnel, with support from LTV and NELC, will install the ALOFT hardware in A-7C BUNO 156782 which has been designated the ALOFT test aircraft by the NAVAIR Test and Evaluation Coordinator at Patuxent River, Maryland. IBM is under contract to provide all maintenance and logistics support for the ALOFT-peculiar hardware during both the NWC flight-test phase and the earlier LTV ground-simulator phase. The flight-test program has an objective of 50 to 100 flight hours, including navigation system-accuracy flights and weapon delivery-accuracy flights to validate the functional performance of the ALOFT system against a previously known baseline of the original copper-wired N/WDS. Upon completion of the flight-test phase, NWC and NELC will conduct an in-depth analysis of the test data. The results and conclusions will then be published in a final project report to be released in October 1976.

A reliability and maintainability evaluation will be conducted on the maintenance, logistics, and repair-action data collected during the flight-test phase. In this evaluation, the R and M Branch, Strike Aircraft Test Directorate, Naval Air Test Center, Patuxent River, Maryland, will be comparing the collected data on the ALOFT system to baseline data on the standard A-7 N/WDS under similar operating tempos. This evaluation will greatly aid in the assessment of the impact of fiber-optic interface systems on the reliability and maintainability of future avionics systems and will enable determination of the improvements required in field-test equipment and packaging designs for fiber-optic systems while they are still in development.

ECONOMIC ANALYSIS

In parallel to the test phases of the ALOFT demonstration program, an economic analysis is being conducted, as a joint effort, by NELC and the Naval Postgraduate School, Monterey, California, to determine the projected life-cycle cost tradeoffs between fiber-optic and alternative avionics-interface mediums such as coaxial cable.⁹ As part of this analysis, a contract is planned for fiscal year 1976 which will attempt to price the tradeoffs between the use of fiber optics and coaxial cable to meet the increasingly difficult performance requirements being placed upon avionics systems. Examples of these requirements are:

Data bandwidths which have increased from between 125 and 500 kHz in 1960 to between 1 and 5 MHz in 1975 and which are expected to go to 10 MHz and higher by 1980;

8. Naval Weapons Center Technical Note 404-216, A-7 ALOFT Demonstration Flight-Test Plan, RR Bruckman and JD Ross, 30 September 1975.

9. Naval Electronics Laboratory Center NELC Technical Document TD-435, A-7 ALOFT Economic Analysis Development Concept, JR Ellis, LCDR USN, and RA Greenwell, 7 July 1975.

The need for the avionics system to operate in a nuclear environment, including the electromagnetic-pulse phenomena (emp), without the weight penalties of increased shielding:
and

The need for improved electromagnetic compatibility (emc) and emi/rfi noise immunity as the sensitivity and bit-error rate requirements of avionics systems go ever lower and the data bandwidth goes higher.

To date, two study efforts have been completed by the Naval Postgraduate School in support of the economic analysis. One defines a conceptual approach to the problem of predicting the costs of an emerging technology.¹⁰ The other develops the costing methodology and defines a recommended cost model for comparing an aircraft fiber-optic interface to a coaxial cable system.¹¹

SUMMARY

The results of the A-7 ALOFT flight-test demonstration, the conclusions to be drawn, and the economic analysis should do much to answer, in quantitative terms, the questions presently being posed by avionics-system designers in the Department of Defense and in industry as to the capabilities and operational potentials of fiber-optic data communications. If the results are favorable, the ALOFT demonstration should pave the way for a multitude of advanced-development systems with which to apply this valuable new technology in such fields as point-to-point communication interfaces, avionics data-bus systems, and fly-by-optic control systems.

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10. Naval Postgraduate School Thesis, An Approach to the Estimation of Life Cycle Costs of a Fiber Optic Application in Military Aircraft, JM McGrath and KR Michna, September 1975.
 11. Naval Postgraduate School Thesis, The A-7 ALOFT Cost Model: A Study of High Technology Cost Estimating, RL Johnson and EW Knobloch, December 1975.

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2. IBM Report No 75Z000436, Analysis and Selection of the Physical Parameters of an Optical-Fiber Bundle, RC Clapper and R Betts (prepared for presentation to the Electro-Optics '75 Conference, November 11-13 1975).
3. Naval Electronics Laboratory Center Technical Document 426, Fiber-Optic Components for the A-7 ALOFT Demonstration, TA Meador, 11 April 1975.
4. LTV Report 2-50360/4R-5738, Environmental Definition Analysis Report, JH Rigby, 23 September 1974.
5. Naval Electronics Laboratory Center Technical Document 418, A-7 ALOFT Hardware Requirements Environmental Analysis, GM Holma, 1 April 1975.
6. Naval Electronics Laboratory Center NELC Technical Document 460, ALOFT Fiber-Optic Component Tests, GM Holma and TA Meador (in preparation).
7. Naval Electronics Laboratory Center Technical Document 438, A-7 ALOFT Demonstration Master Test Plan, RD Harder, 7 July 1975.
8. Naval Weapons Center Technical Note 404-216, A-7 ALOFT Demonstration Flight-Test Plan, RR Bruckman and JD Ross, 30 September 1975.
9. Naval Electronics Laboratory Center Technical Document 435, A-7 ALOFT Economic Analysis Development Concept, JR Ellis LCDR USN and RA Greenwell, 7 July 1975.
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11. Naval Postgraduate School Thesis, The A-7 ALOFT Cost Model: A Study of High Technology Cost Estimating, RL Johnson and EW Knobloch, December 1975.

**APPENDIX A:
A-7 ALOFT INTERFACE REPORT AND SIGNAL LIST**

TABLE A1. A7E OPTICAL SYSTEM SIGNAL LIST (ASCU ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
ARMAMENT STATION CONTROL UNIT	WEAPON TYPE 80	5V DISCRETE	TO	W.T. 80 J6-1 0V=1	LLR
	WEAPON TYPE 40	5V DISCRETE	TO	RETURN J6-2 W.T. 40 J6-3 0V=1	LLR
	WEAPON TYPE 20	5V DISCRETE	TO	RETURN J6-4 W.T. 20 J6-5 0V=1	LLR
	WEAPON TYPE 10	5V DISCRETE	TO	RETURN J6-6 W.T. 10 J6-7 0V=1	LLR
	WEAPON TYPE 8	5V DISCRETE	TO	RETURN J6-8 W.T. 8 J6-9 0V=1	LLR
	WEAPON TYPE 4	5V DISCRETE	TO	RETURN J6-10 W.T. 4 J6-11 0V=1	LLR
	WEAPON TYPE 2	5V DISCRETE	TO	RETURN J6-12 W.T. 2 J6-13 0V=1	LLR
	WEAPON TYPE 1	5V DISCRETE	TO	RETURN J6-14 W.T. 1 J6-20 0V=1	LLR
	STATION 1 READY	5V DISCRETE	TO	RETURN J6-21 S1R J6-22 0V=1	LLR
	STATION 2 READY	5V DISCRETE	TO	RETURN J6-23 S2R J6-24 0V=1	LLR
	STATION 3 READY	5V DISCRETE	TO	RETURN J6-25 S3R J6-26 0V=1	LLR
	STATION 6 READY	5V DISCRETE	TO	RETURN J6-27 S6R J6-28 0V=1	LLR
	STATION 7 READY	5V DISCRETE	TO	RETURN J6-29 S7R J6-30 0V=1	LLR
	STATION 8 READY	5V DISCRETE	TU	RETURN J6-31 S8R J6-32 0V=1	LLR
	GUNS SELECTED	5V DISCRETE	TO	RETURN J6-33 G.S. J6-42 0V=1	LLR
	MULTIPLE LOADING	5V DISCRETE	TO	RETURN J6-43 M.L. J6-44 0V=1	LLR
	RELEASE ENABLE	5V DISCRETE	TO	RETURN J6-45 R.E. J6-46 5V=1	DER
	BOMB RELEASE	5V DISCRETE	FROM	RETURN J6-47 B.R. J6-48 5V=1	LLD
	FIRE READY	5V DISCRETE	FROM	RETURN J6-49 F.R. J6-50 5V=1 RETURN J6-51	LLD

TABLE A2. A7E OPTICAL SYSTEM SIGNAL LIST (LEFT BAY ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
INERTIAL MEASUREMENT SET	GYRO TORQUING X	5V PULSE TRAIN	FROM	GYROX J8-10 5V=1	LLD
	GYRO TORQUING Y	5V PULSE TRAIN	FROM	Return J8-11 GYROY J8-12 5V=1	LLD
	GYRO TORQUING Z	5V PULSE TRAIN	FROM	RETURN J8-13 GYROZ J8-29 5V=1	LLD
	SAMPLE CLOCK	5V 200 pps	FROM	RETURN J8-30 SAMP. C. J8-31 0V=1	LLD
	SCALE FACTOR CHANGE	5V DISCRETE	FROM	RETURN J8-32 S.F.C. J8-3 5V=1	LLD
	AZIMUTH SLEW	5V DISCRETE	FROM	RETURN J8-4 A.Z.S. J8-20 5V=1	LLD
	AZIMUTH SLEW SENSE	5V DISCRETE	FROM	RETURN J8-21 A.Z.S.S. J8-22 5V=1	LLD
	LATITUDE 70°	5V DISCRETE	FROM	RETURN J8-23 LAT 70 J8-24 5V=1	LLD
	COMPUTER FAILED	5V DISCRETE	FROM	RETURN J8-25 C.F. J8-40 5V=1	LLD
	COMPUTER CONTROL MODE	5V DISCRETE	FROM	RETURN J8-41 C.C.M. J8-42 5V=1	LLD
	AUTO CALIBRATE	5V DISCRETE	FROM	RETURN J8-43 AUTO. C. J8-44 0V=1	LLD
	X SLEW	5V DISCRETE	FROM	RETURN J8-45 X.S. J8-61 5V=1	LLD
	X SLEW SENSE	5V DISCRETE	FROM	RETURN J8-62 X.S.S. J8-63 5V=1	LLD
	Y SLEW	5V DISCRETE	FROM	RETURN J8-64 Y.S. J8-65 5V=1	LLD
	Y SLEW SENSE	5V DISCRETE	FROM	RETURN J8-66 Y.S.S. J8-81 5V=1	LLD
	EAST VELOCITY POSITIVE	5V PULSE TRAIN	TO	RETURN J8-82 E.V.P. J8-51 5V=1	LLR
	EAST VELOCITY NEGATIVE	5V PULSE TRAIN	TO	RETURN J8-52 E.V.N. J8-53 5V=1	LLR
	NORTH VELOCITY POSITIVE	5V PULSE TRAIN	TO	RETURN J8-74 N.V.P. J8-70 5V=1	LLR

TABLE A.3. A7E OPTICAL SYSTEM SIGNAL LIST (LEFT BAY ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
INERTIAL MEASUREMENT SET	NORTH VELOCITY	5V PULSE TRAIN	TO	N.V.N. J8-72 5V=1	LLR
	NEGATIVE VERTICAL VELOCITY	5V PULSE TRAIN	TO	RETURN J8-73	LLR
	POSITIVE VERTICAL VELOCITY	5V PULSE TRAIN	TO	V.V.P. J8-92 5V=1	LLR
	NEGATIVE VERTICAL VELOCITY	5V PULSE TRAIN	TO	RETURN J8-93	LLR
	IMS READY	SV DISCRETE	TO	V.V.N. J8-94 5V=1	LLR
	IMS FAIL	SV DISCRETE	TO	RETURN J8-95	LLR
	AUTO CALIBRATION MODE	SWITCH CLOSURE	TO	I.M.S.R. J8-85 5V=1	LLR
	NORMAL MODE	SWITCH CLOSURE	TO	RETURN J8-86	LLR
	OFFSET MODE	SWITCH CLOSURE	TO	I.M.S.F. J8-83 5V=1	LLR
	RADAR/BOMB	SWITCH CLOSURE	TO	RETURN J8-84	LLR
MASTER SELECTION SWITCH	NAVIGATION/BOMB	SWITCH CLOSURE	TO	A.C.M. J8-90 SHRT=OPN	SER
	DATA OUT	50 KHZ DIGITAL	FROM	RETURN J8-91 SHRT=1	SER
	ADDRESS OUT	50 KHZ DIGITAL	FROM	N.M. J9-20 SHRT=OPN	SER
	READY OUT	50 KHZ DIGITAL	FROM	RETURN J9-21 SHRT=1	SER
	SERIAL CLOCK	50 KHZ DIGITAL	FROM	O.M. J9-22 SHRT=1	SER
	DATA COMMON	GND	TO	RETURN J9-23	SER
				R/B J9-24 SHRT=1	SER
				RETURN J9-25	SER
				N/B J9-33 SHRT=1	SER
				RETURN J9-34	SER
HUD ELECTRONICS			FROM	TRUE J8-16 0V=1	LLD
			FROM	COMP. J8-17 5V=1	(DIFF)
			FROM	TRUE J8-36 5V=1	LLD
			FROM	COMP. J8-37	(DIFF)
			FROM	TRUE J8-57 5V=1	LLD
			FROM	COMP. J8-58	(DIFF)
			FROM	TRUE J8-78 5V=1	LLD
		TO	COMP. J8-79	(DIFF)	
			J8-96	(DIFF)	

TABLE A.4. A7E OPTICAL SYSTEM SIGNAL LIST (COCKPIT AREA ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
NAVIGATION WEAPON DELIVERY PANEL	DATA IN	1 MHZ DIGITAL	TO	TRUE J7-101 0V=1	DER
	SELF TEST	5V DISCRETE	TO	COMP. J7-100 5V=1	SER
	NAV/WD INTERRUPT	5V DISCRETE	TO	RETURN J7-90	LLR
	DATA OUT	1 MHZ DIGITAL	FROM	N/W. 1. J7-91 0V=1 RETURN J7-92	LLD
	ADDRESS 1	5V DISCRETE	FROM	TRUE J7-60 0V=1	(DIFF) LLD
	ADDRESS 2	5V DISCRETE	FROM	COM. J7-59	LLD
	ADDRESS 3	5V DISCRETE	FROM	ADD. 1 J7-14 0V=1	LLD
	ADDRESS 4	5V DISCRETE	FROM	RETURN J7-15	LLD
	READ	5V DISCRETE	FROM	ADD. 2 J7-34 0V=1	LLD
	WRITE	5V DISCRETE	FROM	RETURN J7-35	LLD
	SHIFT CLOCK	1 MHZ DIGITAL	FROM	ADD. 3 J7-55 0V=1	LLD
	TIMING CLOCK	1 MHZ DIGITAL	FROM	RETURN J7-56	LLD
	RESET DELAY	5V DISCRETE	FROM	ADD. 4 J7-74 0V=1	LLD
	BOMB FALL LINE 1	5V PULSE	TO	RETURN J7-75	LLR
	BOMB FALL LINE 2	5V PULSE	TO	READ J7-76 0V=1	LLR
	BOMB HIGH DRAG	28VDC DISCRETE	TO	RETURN J7-77	HVR
ARMAMENT SELECT PANEL	NORMAL MODE	SWITCH CLOSURE	TO	WRITE J7-94 0V=1	SER
	INERTIAL MODE	SWITCH CLOSURE	TO	RETURN J7-95	SER
	MAGNETIC SLAVE	SWITCH CLOSURE	TO	TRUE J7-19 0V=1	SER
	GRID MODE	SWITCH CLOSURE	TO	COMP. J7-18	SER
THROTTLE	RESET DELAY	5V DISCRETE	FROM	TRUE J7-39 0V=1	(DIFF) LLD
	BOMB FALL LINE 1	5V PULSE	TO	COMP. J7-38	(DIFF) LLD
	BOMB FALL LINE 2	5V PULSE	TO	R.S. J7-96 0V=1	LLD
	BOMB HIGH DRAG	28VDC DISCRETE	TO	RETURN J7-97	LLR
	NORMAL MODE	SWITCH CLOSURE	TO	B.F.L. 1 J7-42 0V=1	LLR
	INERTIAL MODE	SWITCH CLOSURE	TO	RETURN J7-43	LLR
	MAGNETIC SLAVE	SWITCH CLOSURE	TO	B.F.L. 2 J7-53 0V=1	HVR
	GRID MODE	SWITCH CLOSURE	TO	RETURN J7-54	HVR
				J9-45 28V=1	HVR
				N.M. J8-47 SHRT=OPN	SER
IMS CONTROLLER			TO	RETURN J8-48 SHRT=1	SER
			TO	I.M. J8-49 SHRT=1	SER
			TO	RETURN J8-50	SER
			TO	M.S. J8-88 SHRT=1	SER
			RETURN J8-89	SER	
			G.M. J8-68 SHRT=1	SER	
			RETURN J8-69	SER	

TABLE A5. A7E OPTICAL SYSTEM SIGNAL LIST (COCKPIT AREA ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
ARMAMENT RELEASE PANEL	GROUND ALIGN MODE	SWITCH CLOSURE	TO	G.A.M. J8-27 SHRT=OPN	SER
	WEAPON QUAN. 80	SWITCH CLOSURE	TO	RETURN J8-28 SHRT=1	SER
	WEAPON QUAN. 40	SWITCH CLOSURE	TO	W.Q. 80 J7-7 SHRT=OPN	SER
	WEAPON QUAN. 20	SWITCH CLOSURE	TO	RETURN J7-8 SHRT=1	SER
	WEAPON QUAN. 10	SWITCH CLOSURE	TO	W.Q. 40 J7-9 SHRT=1	SER
	WEAPON QUAN. 8	SWITCH CLOSURE	TO	RETURN J7-10	SER
	WEAPON QUAN. 4	SWITCH CLOSURE	TO	W.Q. 20 J7-11 SHRT=1	SER
	WEAPON QUAN. 2	SWITCH CLOSURE	TO	RETURN J7-12	SER
	WEAPON QUAN. 1	SWITCH CLOSURE	TO	W.Q. 10 J7-24 SHRT=1	SER
	WEAPON SPACING 800	SWITCH CLOSURE	TO	RETURN J7-25	SER
	WEAPON SPACING 400	SWITCH CLOSURE	TO	W.Q. 8 J7-26 SHRT=1	SER
	WEAPON SPACING 200	SWITCH CLOSURE	TO	RETURN J7-27	SER
	WEAPON SPACING 100	SWITCH CLOSURE	TO	W.Q. 4 J7-28 SHRT=1	SER
	WEAPON SPACING 80	SWITCH CLOSURE	TO	RETURN J7-29	SER
	WEAPON SPACING 40	SWITCH CLOSURE	TO	W.Q. 2 J7-30 SHRT=1	SER
	WEAPON SPACING 20	SWITCH CLOSURE	TO	RETURN J7-31	SER
	WEAPON SPACING 10	SWITCH CLOSURE	TO	W.Q. 1 J7-44 SHRT=1	SER
	PAIRS SELECTED	SWITCH CLOSURE	TO	RETURN J7-45	SER
	PAIRS INT. COMMON WEAPONS QUAN. COMMON	GND GND	FROM	W.S. 800 J7-46 SHRT=1 RETURN J7-47 W.S. 400 J7-48 SHRT=1 RETURN J7-49 W.S. 200 J7-50 SHRT=1 RETURN J7-51 W.S. 100 J7-32 SHRT=1 RETURN J7-52 W.S. 80 J7-65 SHRT=1 RETURN J7-66 W.S. 40 J7-67 SHRT=OPN RETURN J7-68 SHRT=1 W.S. 20 J7-69 SHRT=OPN RETURN J7-70 SHRT=1 W.S. 10 J7-71 SHRT=OPN RETURN J7-72 SHRT=1 P.S. J7-85 SHRT=OPN RETURN J7-86 SHRT=1 J7-47 J7-8	SER

TABLE A6. A7E OPTICAL SYSTEM SIGNAL LIST (COCKPIT AREA ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
ATTITUDE DIRECTION INDICATOR	COMPUTER RELIABLE	5V DISCRETE	FROM	COMP. REL. J7-5 5V=1	LLD
PILOT STICK GRIP	STEERING ERROR	±2.5V ANALOG	FROM	HI J4-81	HVR
BULLPUP CONTROL STICK	TGT. DESIG. NOT	28 VDC DISCRETE	TO	LO J4-82	
	AZIMUTH RATE	±4VDC ANALOG	TO	J4-2	10 MEG
	+4V REF	ANALOG	TO	J4-1	
	-4V REF	ANALOG	TO	J4-3	10 MEG
	ELEVATION RATE	±4VDC ANALOG	TO	J4-5	
	BPC POT CNTR TAP	GND	TO	J4-10	
	CURSOR ENABLE	28VDC DISCRETE	FROM	J9-41 28V=1	HVD
FLR CONTROL SET	ANTENNA SLAVE	28 VDC DISCRETE	FROM	J9-43 28V=1	HVD
ADVISORY CAUTION PNL	COMPUTER FAIL	28V DISCRETE	FROM	J7-20	HVD
	IMU NOT ALIGNED	28V DISCRETE	FROM	J7-61	HVD

TABLE A7. A7E OPTICAL SYSTEM SIGNAL LIST (FLR ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type
FLR SWEEP GENERATOR	CHANNEL CLOCK	50 KHZ DIGITAL	FROM	TRUE J9-4 0V=1	LLD
	DATA OUT	50 KHZ DIGITAL	FROM	COMP J9-5 5V=1	(DIFF) LLD
	ADDRESS OUT	50 KHZ DIGITAL	FROM	TRUE J9-6 0V=1	(DIFF) LLD
	READY OUT	50 KHZ DIGITAL	FROM	COMP J9-7 5V=1	(DIFF) LLD
	COMPUTER RELIABLE DATA IN	28VDC DISCRETE 50 KHZ DIGITAL	FROM TO	TRUE J9-16 0V=1	(DIFF) LLD
	ADDRESS IN	50 KHZ DIGITAL	TO	TRUE J9-17 5V=1	LLD
	READY IN	50 KHZ DIGITAL	TO	TRUE J9-27 0V=1	(DIFF) LLD
	AGR TEST DATA COMMON	28 VDC DISCRETE GND	FROM TO	COMP J9-28 5V=1 J9-31 28V=1	HVD
				TRUE J9-8 0V=1	DER
				COMP J9-9 5V=1	DER
				TRUE J9-18 0V=1	DER
				COMP J9-19 5V=1	DER
				TRUE J9-29 0V=1	DER
			COMP J9-30 5V=1 J9-12 28V=1 J9-38	HVD	

TABLE A8. A7E OPTICAL SYSTEM SIGNAL LIST (RIGHT BAY ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Computer Pin Assignment	Computer Circuit Type	
DOPPLER RADAR ELECTRONICS	DATA IN	50 KHZ DIGITAL	TO	TRUE J8-18	DER	
	ADDRESS IN	50 KHZ DIGITAL	TO	COMP J8-19	DER	
	READY IN	50 KHZ DIGITAL	TO	TRUE J8-38 COMP J8-39	DER	
PROJECTED MAP ELECTRONICS UNIT	SERIAL CLOCK	50 KHZ DIGITAL	FROM	TRUE J8-59 COMP J8-60	L'D (DIFF)	
	DATA OUT	50 KHZ DIGITAL	FROM	TRUE J8-100 COMP J8-101	LLD (DIFF)	
	ADDRESS OUT	50 KHZ DIGITAL	FROM	TRUE J8-54 0V=1 COMP J8-75 5V=1	LLD (DIFF)	
	READY OUT	50 KHZ DIGITAL	FROM	TRUE J8-46 5V=1 COMP J8-67	LLD (DIFF)	
	CLOCK OUT	50 KHZ DIGITAL	FROM	TRUE J8-07 5V=1 COMP J8-26	LLD (DIFF)	
	DATA COMMON	GND	GND	FROM	TRUE J8-14 5V=1 COMP J8-33	LLD (DIFF)
				FROM	J8-96	

TABLE A9. A7E OPTICAL SYSTEM SIGNAL LIST (ASCU ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
ARMAMENT STATION CONTROL UNIT	WEAPON TYPE 80	5V DISCRETE	TO	W.T. 80 J-308 P2-125 RETURN	J4-45	LLR
	WEAPON TYPE 40	5V DISCRETE	TO	W.T. 40 J-308 P2-124 RETURN	J4-46	LLR
	WEAPON TYPE 20	5V DISCRETE	TO	W.T. 20 J-308 P2-123 RETURN	J4-44	LLR
	WEAPON TYPE 10	5V DISCRETE	TO	W.T. 10 J-308 P2-122 RETURN	J4-34	LLR
	WEAPON TYPE 8	5V DISCRETE	TO	W.T. 8 J-308 P2-115 RETURN	J4-35	LLR
	WEAPON TYPE 4	5V DISCRETE	TO	W.T. 4 J-308 P2-114 RETURN	J4-36	LLR
	WEAPON TYPE 2	5V DISCRETE	TO	W.T. 2 J-308 P2-113 RETURN	J4-37	LLR
	WEAPON TYPE 1	5V DISCRETE	TO	W.T. 1 J-308 P2-112 RETURN	J4-32	LLR
	STATION 1 READY	5V DISCRETE	TO	S.1 R. J-308 P2-134 RETURN	J4-33	LLR
	STATION 2 READY	5V DISCRETE	TO	S.2 R. J-308 P2-135 RETURN	J4-30	LLR
	STATION 3 READY	5V DISCRETE	TO	S.3 R. J-308 P2-136 RETURN	J4-31	LLR
	STATION 6 READY	5V DISCRETE	TO	S.6 R. J-308 P2-137 RETURN	J4-22	LLR
	STATION 7 READY	5V DISCRETE	TO	S.7 R. J-308 P2-138 RETURN	J4-18	LLR
	STATION 8 READY	5V DISCRETE	TO	S.8 R. J-308 P2-139 RETURN	J4-19	LLR
	GUNS SELECTED	5V DISCRETE	TO	G.S. J-308 P2-126 RETURN	J4-16	LLR
	MULTIPLE LOADING	5V DISCRETE	TO	M.L. J-308 P2-116 RETURN	J4-17	LLR
	RELEASE ENABLE	5V DISCRETE	TO	R.E. J-308 P2-141 RETURN	J4-14	LLR
	BOMB RELEASE	5V DISCRETE	FROM	B.R. J-308 P2-143 RETURN	J4-15	LLR
	FIRE READY	5V DISCRETE	FROM	F.R. J-308 P2-142 RETURN	J4-5	LLR
	CHASSIS GND				J4-6	LLR
					J4-12	LLR
				J4-13	LLR	
				J4-3	DER	
				J4-4	LLD	
				J4-49	LLD	
				J4-50	LLD	
				J4-47	LLD	
				J4-48	LLD	
				J4-51	LLD	

TABLE A.10. A7E OPTICAL SYSTEM SIGNAL LIST (LEFT BAY ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
HUD ELECTRONICS	DATA COMMON DATA OUT	GND	TO	P3050 2J1-47	J4-65	LLD
		50 KHZ DIGITAL	FROM	P3050 TRUE 2J1-17	J4-31	(DIFF)
	ADDRESS OUT	50 KHZ DIGITAL	FROM	P3050 COMP 2J1-16	J4-32	LLD (DIFF)
		50 KHZ DIGITAL	FROM	P3050 TRUE 2J1-32	J4-29	LLD (DIFF)
	READY OUT	50 KHZ DIGITAL	FROM	P3050 COMP 2J1-30	J4-15	LLD (DIFF)
		50 KHZ DIGITAL	FROM	P3050 TRUE 2J1-5	J4-16	LLD (DIFF)
	SERIAL CLOCK	50 KHZ DIGITAL	FROM	P3050 COMP 2J1-4	J4-70	LLD (DIFF)
		5V PULSE TRAIN	FROM	P3050 TRUE 2J1-12	J4-71	LLD (DIFF)
	GYRO TORQUING X	5V PULSE TRAIN	FROM	P3050 COMP 2J1-26	J4-45	LLD (DIFF)
		5V PULSE TRAIN	FROM	P3096 G.T.X. 1J1-12	J4-46	LLD (DIFF)
INERTIAL MEASUREMENT SET	GYRO TORQUING Y	5V PULSE TRAIN	FROM	P3096 RETURN 1J1-31	J4-63	(DIFF)
		5V PULSE TRAIN	FROM	P3096 G.T.Y. 1J1-49	J4-64	LLD
	GYRO TORQUING Z	5V PULSE TRAIN	FROM	P3096 RETURN 1J1-52	J4-61	(DIFF)
		5V PULSE TRAIN	FROM	P3096 G.T.Z. 1J1-28	J4-62	LLD
	SAMPLE CLOCK	5V 200 PPS	FROM	P3096 RETURN 1J1-53	J4-41	(DIFF)
		5V DISCRETE	FROM	P3096 SC 1J1-4	J4-42	LLD
	SCALE FACTOR CHANGE	5V DISCRETE	FROM	P3096 RETURN 1J1-15	J4-17	(DIFF)
		5V DISCRETE	FROM	P3045 S.F.C. 2J5-16	J4-18	LLD
	AZIMUTH SLEW	5V DISCRETE	FROM	P3045 RETURN 2J5-36	J4-72	(DIFF)
		5V DISCRETE	FROM	P3045 A.S. 2J5-17	J4-73	LLD
AZIMUTH SLEW SENSE	5V DISCRETE	FROM	P3045 RETURN 2J5-36	J4-74	(DIFF)	
	5V DISCRETE	FROM	P3045 A.S.S. 2J5-18	J4-75	LLD	
LATITUDE 70°	5V DISCRETE	FROM	P3045 RETURN 2J5-37	J4-25	(DIFF)	
	5V DISCRETE	FROM	P3045 L. 70 2J5-20	J4-26	LLD	
COMPUTER FAILED	5V DISCRETE	FROM	P3045 RETURN 2J5-21	J4-21	(DIFF)	
	5V DISCRETE	FROM	P3045 C.F. 2J5-19	J4-22	LLD	
COMPUTER CONTROL MODE	5V DISCRETE	FROM	P3045 RETURN 2J5-21	J4-78	(DIFF)	
	5V DISCRETE	FROM	P3045 C.C.M. 2J5-15	J4-79	LLD (DIFF)	
				P3045 RETURN 2J5-36		LLD (DIFF)

TABLE A11. A7E OPTICAL SYSTEM SIGNAL LIST (LEFT BAY ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
INERTIAL MEASUREMENT SET	AUTO CALIBRATE	5V DISCRETE	FROM	P3045 A.C. 2J5-26	J4-76	LLD
	X SLEW	5V DISCRETE	FROM	P3045 RETURN 2J5-37	J4-77	LLD
	X SLEW SENSE	5V DISCRETE	FROM	P3096 X.S. 1J1-27	J4-7	LLD
	Y SLEW	5V DISCRETE	FROM	P3096 RETURN 1J1-30	J4-8	LLD
	Y SLEW SENSE	5V DISCRETE	FROM	P3096 X.S.S. 1J1-1	J4-3	LLD
	EAST VELOCITY POSITIVE	5V PULSE TRAIN	TO	P3096 RETURN 1J1-5	J4-4	LLD
	EAST VELOCITY NEGATIVE	5V PULSE TRAIN	TO	P3096 Y.S. 1J1-47	J4-33	LLD
	NORTH VELOCITY POSITIVE	5V PULSE TRAIN	TO	P3096 RETURN 1J1-51	J4-34	LLD
	NORTH VELOCITY NEGATIVE	5V PULSE TRAIN	TO	P3096 Y.S.S. 1J1-45	J4-37	LLD
	VERTICAL VELOCITY POSITIVE	5V PULSE TRAIN	TO	P3096 RETURN 1J1-14	J4-38	LLR
	VERTICAL VELOCITY NEGATIVE	5V PULSE TRAIN	TO	P3096 E.V.P. 1J1-54	J4-47	LLR
	IMS READY	5V DISCRETE	TO	P3096 RETURN 1J1-16	J4-48	LLR
	IMS FAIL	5V DISCRETE	TO	P3096 E.V.N. 1J1-6	J4-5	LLR
	AUTO CALIBRATION MODE	SWITCH CLOSURE	TO	P3096 RETURN 1J1-32	J4-6	LLR
	NORMAL MODE	SWITCH CLOSURE	TO	P3096 N.V.P. 1J1-56	J4-43	LLR
	OFFSET MODE	SWITCH CLOSURE	TO	P3096 RETURN 1J1-17	J4-44	LLR
	RADAR/BOMB	SWITCH CLOSURE	TO	P3096 N.V.N. 1J1-34	J4-35	LLR
NAVIGATION/BOMB	SWITCH CLOSURE	TO	P3096 RETURN 1J1-18	J4-36	LLR	
CHASSIS GND	CHASSIS GND		P3096 V.V.P. 1J1-36	J4-39	LLR	
CHASSIS GND	CHASSIS GND		P3096 RETURN 1J1-8	J4-40	LLR	
			P3096 V.V.N. 1J1-59	J4-1	LLR	
			P3096 RETURN 1J1-19	J4-2	LLR	
			P3045 I.R. 2J5-22	J4-53	LLR	
			P3045 RETURN 2J5-28	J4-54	LLR	
			P3045 I.F. 2J5-23	J4-49	LLR	
			P3045 RETURN 2J5-28	J4-50	LLR	
			P3045 A.C.M. 2J5-13	J4-57	SER	
			P3045 RETURN 2J5-14	J4-58	SER	
			P3064 N.M. J1-40	J4-51	SER	
			P3064 RETURN J1-38	J4-52	SER	
			P3065 O.M. J1-5	J4-27	SER	
			P3065 RETURN J1-6	J4-28	SER	
			P3064 R.B. J1-15	J4-23	SER	
			P3064 RETURN J1-16	J4024	SER	
			P3064 N.B. J1-25	J4-19	SER	
			P3064 RETURN J1-43	J4-20	SER	
				J1-68	SER	
				J4-67	SER	

TABLE A12. A7E OPTICAL SYSTEM SIGNAL LIST (COCKPIT AREA ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
NAVIGATION WEAPON DELIVERY PANEL	DATA IN	1 MHZ DIGITAL	TO	P2042 TRUE 2J3-24	J4-65	DER
	SELF TEST	5V DISCRETE	TO	P2042 COMP 2J3-25	J4-66	LLR
	NAVI WD INTERRUPT DATA OUT	5V DISCRETE	TO	P2042 S.T. 2J3-29	J4-23	LLR
				P2042 SHIELD 2J3-30	J4-24	LLR
				P2042 N.W.I. 2J3-27	J4-27	LLR
				P2042 RETURN 2J3-28	J4-28	LLR
				P2042 TRUE 2J3-1	J4-31	LLD
				P2042 COMP 2J3-2	J4-32	(DIFF)
				P2042 ADD 1 2J3-14	J4-49	LLD
				P2042 RETURN 2J3-15	J4-50	LLD
				P2042 ADD 2 2J3-16	J4-51	LLD
				P2042 RETURN 2J3-17	J4-52	LLD
				P2042 ADD 3 2J3-18	J4-53	LLD
				P2042 RETURN 2J3-19	J4-54	LLD
			P2042 ADD 4 2J3-20	J4-55	LLD	
			P2042 RETURN 2J3-21	J4-56	LLD	
			P2042 READ 2J3-12	J4-57	LLD	
			P2042 RETURN 2J3-13	J4-58	LLD	
			P2042 WRITE 2J3-10	J4-59	LLD	
			P2042 RETURN 2J3-11	J4-60	LLD	
			P2042 TRUE 2J3-5	J4-15	LJD	
			P2042 COMP 2J3-4	J4-16	(DIFF)	
			P2042 TRUE 2J3-8	J4-67	LLD (DIFF)	
			P2042 COMP 2J3-7	J4-68	LLD	
			P2042 R.D. 2J3-22	J4-9	LLD	
			P2042 RETURN 2J3-23	J4-10	LLR	
			P255 BFL1 J11-32	J4-1	LLR	
			P255 RETURN J11-33	J4-2	LLR	
			P255 BFL2 J11-34	J4-5	LLR	
			P255 RETURN J11-35	J4-6	HVR	
			J264 P1-48	J4-74	HVR	
THROTTLE	BOMB FALL LINE 1	5V PULSE	TO	P2045 N.M. 3J1-7	J4-79	SER
	BOMB FALL LINE 2	5V PULSE	TO	P2045 RETURN 3J1-8	J4-80	SER
	BOMB HIGH DRAG	28 VDC DISCRETE	TO	P2045 I.M. 3J1-5	J4-75	SER
ARMAMENT	NORMAL MODE	SWITCH CLOSURE	TO	P2045 RETURN 3J1-6	J4-76	SER
	INERTIAL MODE	SWITCH CLOSURE	TO	P2045 M.S. 3J1-9	J4-25	SER
	MAGNETIC SLAVE	SWITCH CLOSURE	TO	P2045 RETURN 3J1-10	J4-26	SER

TABLE A13. A7E OPTICAL SYSTEM SIGNAL LIST (COCKPIT AREA).

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
IMS CONTROLLER	GRID MODE	SWITCH CLOSURE	TO	P2045 G.M. 3J1-11	J4-21	SER
	GROUND ALIGN	SWITCH CLOSURE	TO	P2045 RETURN 3J1-12	J4-22	SER
ARMAMENT RELEASE PANEL	WEAPON QUAN. 80	SWITCH CLOSURE	TO	P2045 G.A. 3J1-3	J4-17	SER
	WEAPON QUAN. 40	SWITCH CLOSURE	TO	P2045 RETURN 3J1-4	J4-18	SER
	WEAPON QUAN. 20	SWITCH CLOSURE	TO	J202 W.Q. 80 P1-2	J4-63	SER
	WEAPON QUAN. 10	SWITCH CLOSURE	TO	J202 RETURN P1-64	J4-45	SER
	WEAPON QUAN. 8	SWITCH CLOSURE	TO	J202 W.Q. 40 P1-41	J4-61	SER
	WEAPON QUAN. 4	SWITCH CLOSURE	TO	J202 RETURN P1-46	J4-41	SER
	WEAPON QUAN. 2	SWITCH CLOSURE	TO	J202 W.Q. 20 P1-40	J4-37	SER
	WEAPON QUAN. 1	SWITCH CLOSURE	TO	J202 RETURN P1-62	J4-7	SER
	WEAPON SPACING 800	SWITCH CLOSURE	TO	J202 W.Q. 10 P1-39	J4-33	SER
	WEAPON SPACING 400	SWITCH CLOSURE	TO	J202 RETURN P1-42	J4-3	SER
	WEAPON SPACING 200	SWITCH CLOSURE	TO	J202 W.Q. 8 P1-33	J4-47	SER
	WEAPON SPACING 100	SWITCH CLOSURE	TO	J202 RETURN P1-38	J4-43	SER
	WEAPON SPACING 80	SWITCH CLOSURE	TO	J202 W.Q. 4 P1-32	J4-39	SER
	WEAPON SPACING 40	SWITCH CLOSURE	TO	J202 RETURN P1-8	J4-35	SER
	WEAPON SPACING 20	SWITCH CLOSURE	TO	J202 W.Q. 2 P1-18	J4-30	SER
	WEAPON SPACING 10	SWITCH CLOSURE	TO	J202 RETURN P1-34	J4-29	SER
PAIRS SELECTED	SWITCH CLOSURE	TO	J202 W.Q. 1 P1-17	J4-11	SER	
PAIRS INT. COMMON	SWITCH CLOSURE	TO	J202 RETURN P1-4	J4-12	SER	
WEAPONS QUAN. COMMON	SWITCH CLOSURE	TO	J202 W.S. 800 P1-30	J4-19	SER	
	SWITCH CLOSURE	TO	J202 RETURN P1-48	J4-93	SER	
	SWITCH CLOSURE	TO	J202 W.S. 400 P1-29	J4-92	SER	
	SWITCH CLOSURE	TO	J202 RETURN P1-44			
	SWITCH CLOSURE	TO	J202 W.S. 200 P1-28			
	SWITCH CLOSURE	TO	J202 RETURN P1-40			
	SWITCH CLOSURE	TO	J202 W.S. 100 P1-27			
	SWITCH CLOSURE	TO	J202 RETURN P1-36			
	SWITCH CLOSURE	TO	J202 W.S. 80 P1-16			
	SWITCH CLOSURE	TO	J202 RETURN P1-95			
	SWITCH CLOSURE	TO	J202 W.S. 40 P1-15			
	SWITCH CLOSURE	TO	J202 RETURN P1-94			
	SWITCH CLOSURE	TO	J202 W.S. 20 P1-14			
	SWITCH CLOSURE	TO	J202 RETURN P1-97			
	SWITCH CLOSURE	TO	J202 W.S. 10 P1-13			
	SWITCH CLOSURE	TO	J202 RETURN P1-96			
	SWITCH CLOSURE	TO	J202 P.S. P1-11			
	SWITCH CLOSURE	TO	J202 P.I.C. P1-12			
	GND	FROM	J202 W.Q.C. P1-31			
	GND	FROM				

TABLE A14. A7E OPTICAL SYSTEM SIGNAL LIST (COCKPIT AREA ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
ATTITUDE DIRECTION INDICATOR	COMPUTER RELIABLE	5V DISCRETE	FROM	P272 C.R. J-8	J4-78	LLD
	STEERING ERROR	±2.5 ANALOG	FROM	RETURN J-9 P272 ±J1-12 J1-13	J4-125 J4-71 J4-72	DIRECT ANALOG E/O
AUTO-NAV	COMPUTER RELIABLE STEERING ERROR	5V DISCRETE		AIRPLANE SWITCHING MATRIX	J4-85	AMPLIFIER
		±2.5V ANALOG			J4-83	
		28V DISCRETE			J4-84	
		CHASSIS GND			J4-86	
		CHASSIS GND			J4-128	
		CHASSIS GND			J4-127	
		CHASSIS GND			J4-126	
		CHASSIS GND			J4-125	
		CHASSIS GND			J4-124	
		CHASSIS GND			J4-123	
PILOT STICK GRIP BULLPUP CONTROL STICK	TGT. DESIG. NOT +4V REF -4V REF AZIMUTH RATE ELEVATION RATE BPC POT CNTR TAP CURSOR ENABLE ANTENNA SLAVE	28VDC DISCRETE	TO	J502 PS-13 (P221-33)	J4-73	HVR
		ANALOG		J201 P-G	J4-87	A-D
		ANALOG		J201 P-E	J4-88	A-D
		±4VDC ANALOG	TO	J201 P-H	J4-89	A-D
		±4VDC ANALOG	TO	J201 P-E	J4-90	A-D
		GND		J201 P-J	J4-91	A-D
		28VDC DISCRETE	FROM	P2025 SJ1-h (P211-95)	J4-13	HVD
		28VDC DISCRETE	FROM	P2025 SJ1-i (P211-95)	J4-14	HVD
		28V DISCRETE	FROM	P263 J1-6	J4-77	HVD
		28V DISCRETE	FROM	P220 J1-15	J4-81	HVD
FLR CONTROL SET						
ADVISORY CAUTION PNL	COMPUTER FAIL IMU NOT ALIGNED					

TABLE A.15. A7E OPTICAL SYSTEM SIGNAL LIST (FLR ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type
FLR SWEEP GENERATOR	CHANNEL CLOCK	50 KHZ DIGITAL	FROM	P240 TRUE 6J6-f	J4-4	LLD (DIFF)
	DATA OUT	50 KHZ DIGITAL	FROM	P240 COMP 6J6-g	J4-5	LLD
	ADDRESS OUT	50 KHZ DIGITAL	FROM	P240 TRUE 6J6-a	J4-20	LLD (DIFF)
	READY OUT	50 KHZ DIGITAL	FROM	P240 COMP 6J6-b	J4-21	LLD (DIFF)
	COMPUTER RELIABLE DATA IN	28VDC DISCRETE 50 KHZ DIGITAL	FROM TO	P240 TRUE 6J6-c P240 TRUE 6J6-d	J4-14 J4-15	LLD (DIFF)
	ADDRESS IN	50 KHZ DIGITAL	TO	P240 COMP 6J6-i	J4-10	LLD (DIFF)
	READY IN	50 KHZ DIGITAL	TO	P240 COMP 6J6-j	J4-11	HVD
	AGR TEST DATA COMMON	28V DISCRETE GND CHASSIS GND CHASSIS GND	FROM TO	P240 6J6-g P240 TRUE 6J6-m P240 COMP 6J6-n P240 TRUE 6J6-p P240 COMP 6J6-q P240 TRUE 6J6-t P240 COMP 6J6-u P240 6J6-v P240 6J6-h	J4-24 J4-18 J4-19 J4-16 J4-17 J4-22 J4-23 J4-28 J4-12 J4-30 J4-31	DER DER DER DER DER DER DER HVD

TABLE A16. A7E OPTICAL SYSTEM SIGNAL LIST (RIGHT BAY ADAPTER).

Unit	Signal Name	Signal Type	To/From Comp	Unit Pin Assignment	Unit Adapter Pin Assignment	Unit Adapter Circuit Type	
DOPPLER RADAR ELECTRONICS	DATA IN	50 KHZ DIGITAL	TO	P3052 TRUE 2J3-4	J4-18	DER	
	ADDRESS IN	50 KHZ DIGITAL	TO	P3052 COMP 2J3-5	J4-19	DER	
	READY IN	50 KHZ DIGITAL	TO	P3052 TRUE 2J3-6	J4-16	DER	
	SERIAL CLOCK	DATA OUT	50 KHZ DIGITAL	FROM	P3052 COMP 2J3-7	J4-17	DER
					P3052 TRUE 2J3-12	J4-22	LLD
					P3052 COMP 2J3-15	J4-23	(DIFF)
	PROJECTED MAP ELECTRONICS	DATA OUT	50 KHZ DIGITAL	FROM	P3052 TRUE 2J3-20	J4-4	LLD
P3052 COMP 2J3-22					J4-5	(DIFF)	
P3104 TRUE 1J1-15					J4-20	LLD	
P3104 COMP 1J1-16					J4-21	(DIFF)	
UNIT					ADDRESS OUT	50 KHZ DIGITAL	FROM
	P3104 COMP 1J1-33	J4-15	(DIFF)				
	P3104 TRUE 1J1-55	J4-10	LLD				
	P3104 COMP 1J1-56	J4-11	(DIFF)				
	CLOCK OUT	DATA COMMON	50 KHZ DIGITAL	FROM			
P3104 COMP 1J1-31					J4-7	(DIFF)	
P3104 1J1-54					J4-12		
		GND	FROM		J4-30		
		CHASSIS GND			J4-31		
		CHASSIS GND					

TABLE A17. A7E OPTICAL SYSTEM SIGNAL LIST (ALL ADAPTERS).

Signal Name	Signal Type	Unit Adapter Pin Assignment
A Ph. 400 Hz	115V	J1-A
B Ph. 400 Hz	115V	J1-B
C Ph. 400 Hz	115V	J1-C
A Ph. 400 Hz	115V	J1-F
B Ph. 400 Hz	115V	J1-G
C Ph. 400 Hz	115V	J1-H
+28V FOR RELAYS	28V	J1-D
+28V RETURN	GND	J1-K
SHIELD PICK UP		J1-E
SAFETY GND		J1-J