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Small Explorer Data System MIL-STD-1773 Fiber Optic Bus

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Small Explorer Data System MIL-STD-1773 Fiber Optic Bus

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Office of Management

Scientific and Technical
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1.0 INTRODUCTION

NASA's Goddard Space Flight Center (GSFC) recently has been developing a space flight data system called the Small Explorer Data System (SEDS) [1]. SEDS is a command and telemetry system with its components distributed around a dual-redundant bus. The distributed architecture allows for modularity and flexibility in designing a system from a few basic components for many different types of spacecraft. The computing power and memory required can be tailored for a given spacecraft. Standard interfaces and space flight versions of commercially available processors are employed to allow the use of inexpensive commercially available hardware and software in the design, development, test and integration of the system. This translates into major cost and schedule reductions not possible with the use of unique interfaces and processors requiring unique hardware and software support.

The bus used for SEDS is the MIL-STD-1773 fiber optic bus [2,3]. MIL-STD-1773 is the fiber optic version of the MIL-STD-1553 multiplexed data bus [4].

Since MIL-STD-1553 is well established in military avionics systems many one chip implementations of its protocol have been produced. All the functions of MIL-STD-1553 protocol have been incorporated into these one chip solutions. The interface to the user consists of data and handshaking lines. All the 1553 functions are hidden from the user. In addition, a large number of suppliers build generic test equipment for testing 1553 systems.

Advantages of the fiber optic bus over the electrical bus are lower power, lower weight and immunity from EMI/RFI. It does not radiate electrical or magnetic fields. It is a nonconductor so it cannot conduct electrical noise into or from a subsystem. This is particularly advantageous on a spacecraft with very sensitive instruments which are often susceptible to electrical interference. The fiber optics also provides a path to the much higher rate systems required in upcoming NASA missions.

In MIL-STD-1553 the bus side of the chip would go to an electrical transceiver and transformer circuit. For MIL-STD-1773 we have simply taken the bus side outputs of the chip and run them to a MIL-STD-1773 terminal. Thus all the benefits of the available 1553 chips are available to us and any other user. The use of this existing base of off-the-shelf products provides for significant cost and schedule savings over unique implementations.

2.0 MIL-STD-1773 BUS

The MIL-STD-1773 bus is the implementation of the MIL-STD-1553 protocol using fiber optics. MIL-STD-1773 addresses considerations peculiar to the fiber optic implementation as well as describing the protocol.

MIL-STD-1553 describes a system in which, in any given time period, there is one bus controller (BC) and up to 30 remote terminals (RT's). The bus controller, as the name indicates, controls all bus activity. Messages can be passed from BC to RT, RT to BC and RT to RT, but all these message transfers are initiated and controlled by the BC. This avoids the need for collision detection and avoidance. Since the BC controls all activity there are no collisions.

The 1553 standard describes three types of words. They are command, data and status. A command word contains information telling the RT what to do or how to configure itself. The data word allows for the transfer of data from BC to RT, RT to BC or RT to RT. All communications end with the RT providing a status word reflecting the status of the 1553 terminal. These words are all twenty (20) bits long. A detailed description of these words and the way in which they are used can be found in MIL-STD-1553.

Figure 1 shows the bus structure.

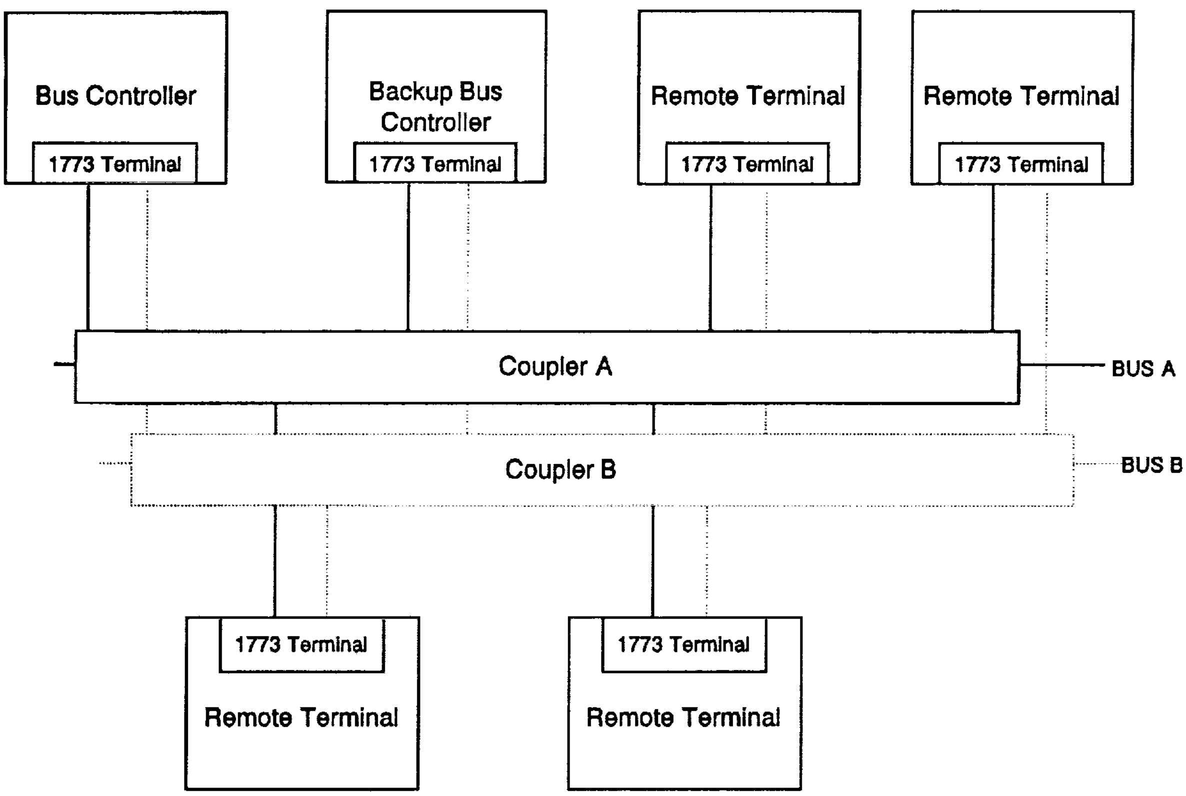

Figure 1. MIL-STD-1773 Bus

The bus is dual-redundant. Every box is attached to both bus A and bus B. The terminal supports this by also being dual-redundant. It allows a box to hook up to both buses. This also provides for complete cross-strapping of all subsystems. Since all boxes are on both buses, including the A and B boxes for a particular subsystem, it is possible to address one subsystem on bus A and another on bus

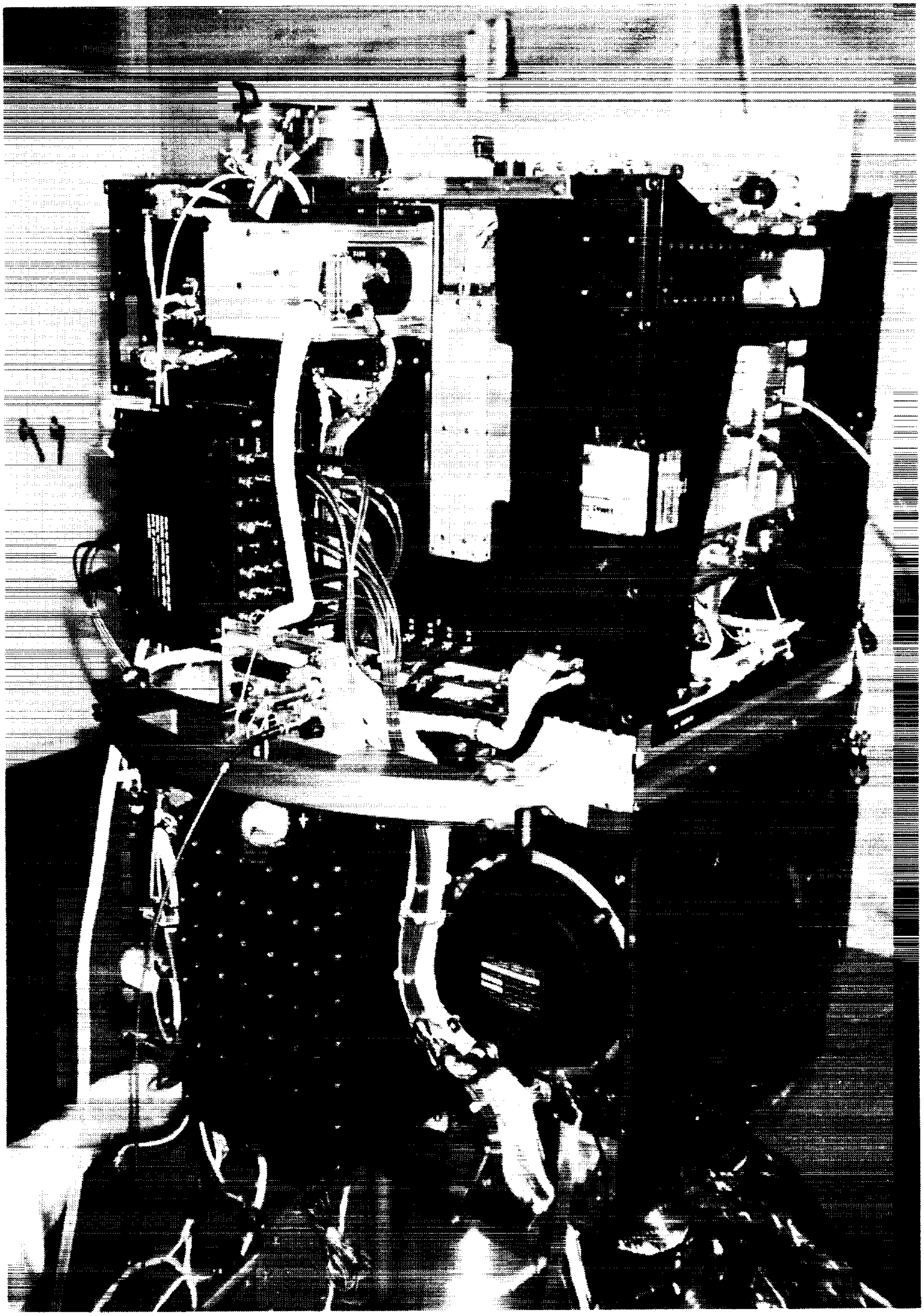

Figure 2. Photograph of SAMPEX spacecraft showing fiber optic couplers and cables.

B should that prove to be necessary. The dual-redundancy and cross-strapping of the system increase its reliability and flexibility.

The bus is created using fiber optic cables running to a star coupler. The star coupler takes any given input and sends it to all outputs. Therefore, any transmission from one station is received by all stations, as a bus requires.

3.0 MIL-STD-1773 BUS COMPONENTS

The 1773 terminal provides the method of converting a MIL-STD-1553 electrical signal into a MIL-STD-1773 optical signal and vice versa. It was developed under the auspices of the Small Explorer Project (SMEX) at GSFC.

The fiber optic cable used to create the 1773 bus is Brand-Rex OC1008. It has been tested at GSFC and is on the GSFC Preferred Parts List (PPL) [5].

A star coupler is used to connect the cables together to form the bus. The coupler is produced by Canstar. It is contained in an enclosure also built by Canstar.

The connectors are a type called SMA 905. This connector is similar to the SMA for electrical coaxial cables. Many vendors, including AMP and Amphenol, make these fiber optic SMAs. They are also on the GSFC PPL.

4.0 TERMINAL

4.1 Function

The MIL-STD-1773 terminal converts the electrical MIL-STD-1553 signals from a protocol chip like the United Technology Microelectronics Center (UTMC) BCRT [6] or the DDC 65612 [7] into the optical MIL-STD-1773 signal for transmission over the fiber optic bus. At the receiving end it takes the MIL-STD-1773 signal and converts it into the MIL-STD-1553 signal that the protocol chip expects. This process is illustrated in Figure 3.

The terminal is dual redundant. Each side is electrically and optically independent from the other. Each side has two connectors, one for receive and one for transmit. The terminal is thus designed to connect to both the prime and the redundant buses. The protocol chips mentioned above are internally redundant. This means that a complete MIL-STD-1773 interface can be constructed from one 1773 terminal and one protocol chip.

As part of the 1773 to 1553 conversion, the terminal includes the function to translate the 1773 bilevel bus to the 1553 trilevel bus. The source of the problem is that the 1773 bus has only two levels, on or off. However, the 1553 bus has three, positive voltage, negative voltage and zero. The zero voltage on the 1553 bus is used to indicate end-of-message. The 1773 terminal does the translation by waiting 2.5 microseconds after the apparent end of a message before causing its output to the protocol chip to go to a zero-voltage state.

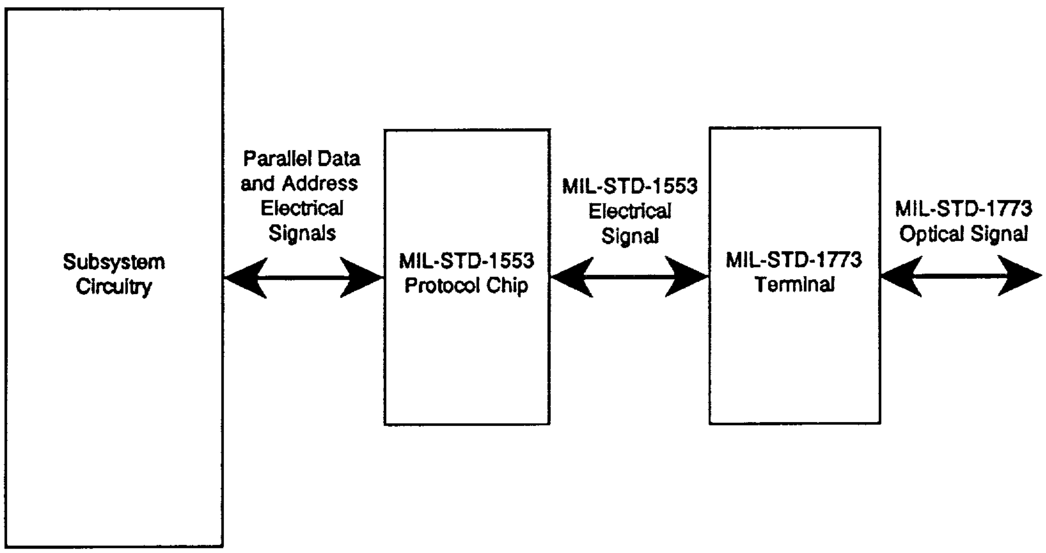

Figure 3. 1553 to 1773 Conversion

4.2 Electrical Specifications

Twenty (20) wires exit the back of the terminal. These consist of sixteen (16) 24-gauge wires, two shielded wires and two shield terminations. Ten (10) of these wires are for the A side of the terminal and ten (10) are for the B side. These provide the signal, power and ground interface to the 1773 terminal. A list of these wires with a description of the signal functions is in Table 1.

The 1773 terminal is designed to interface with any protocol chip. The SEDS uses the UTMC BCRT and the DDC 65612 protocol chips.

Those chips, like the UTMC BCRT, that can accept a unipolar signal from the 1773 terminal use only the RXD output of the terminal. This simplifies the interface because it eliminates the requirement for the 16-MHz clock.

Chips like the DDC 65612 protocol chip require the differential receive lines (RXDA, RXDAN, RXDB and RXDBN). In that case, the 16-MHz clock that is also required by the DDC chip is connected to the 1773 terminal as well as to the DDC 65612.

TABLE 1. MIL-STD-1773 Terminal Electrical Connections

PIN	SIGNAL	NOTES
20	CO_B	One bit of two-bit protocol chip interface select B
19	TXIN_B	Transmit Input B
18	TRINH_B	Transmit Inhibit B
17	+5VDC_B	+5 Volts Power B
16	CLOCK_B	16-MHz Clock B used with protocol chips like DDC 65612
15	CLOCK_B SHIELD	Shield termination for 16-MHz clock
14	RXDB	Receiver Output B
13	RXDBN	Receiver Output B Inverted used with protocol chips like DDC 65612
12	C1_B	One bit of two-bit protocol chip interface select B
11	GROUND_B	Ground B
10	CO_A	One bit of two-bit protocol chip interface select A
9	TXIN_A	Transmit Input A
8	TRINH_A	Transmit Inhibit A
7	+5VDC_A	+5 Volts Power A
6	CLOCK_A	16-MHz Clock A used with protocol chips like DDC 65612
5	CLOCK_A SHIELD	Shield termination for 16-MHz clock
4	RXDA	Receiver Output
3	RXDAN	Receiver Output A Inverted used with protocol chips like DDC 65612
2	C1_A	One bit of two-bit protocol chip interface select A
1	GROUND_A	Ground A

Figures 4 and 5 show how the 1773 terminal connects to the UTMC BCRT and the DDC 65612. The terminal only uses signals already required for the 1553 electrical transceiver or protocol chip. No additional signals are required to use the 1773 terminal.

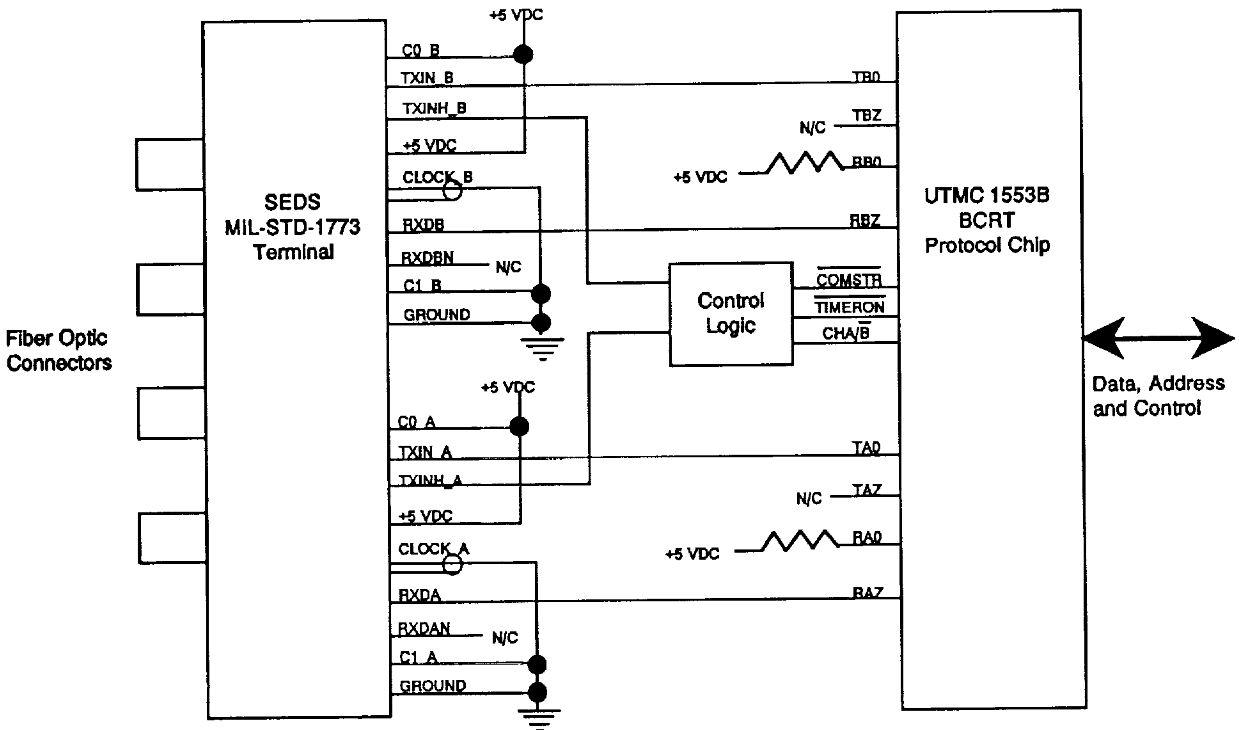

Figure 4. MIL-STD-1773 Terminal to UTMC BCRT Electrical Connections

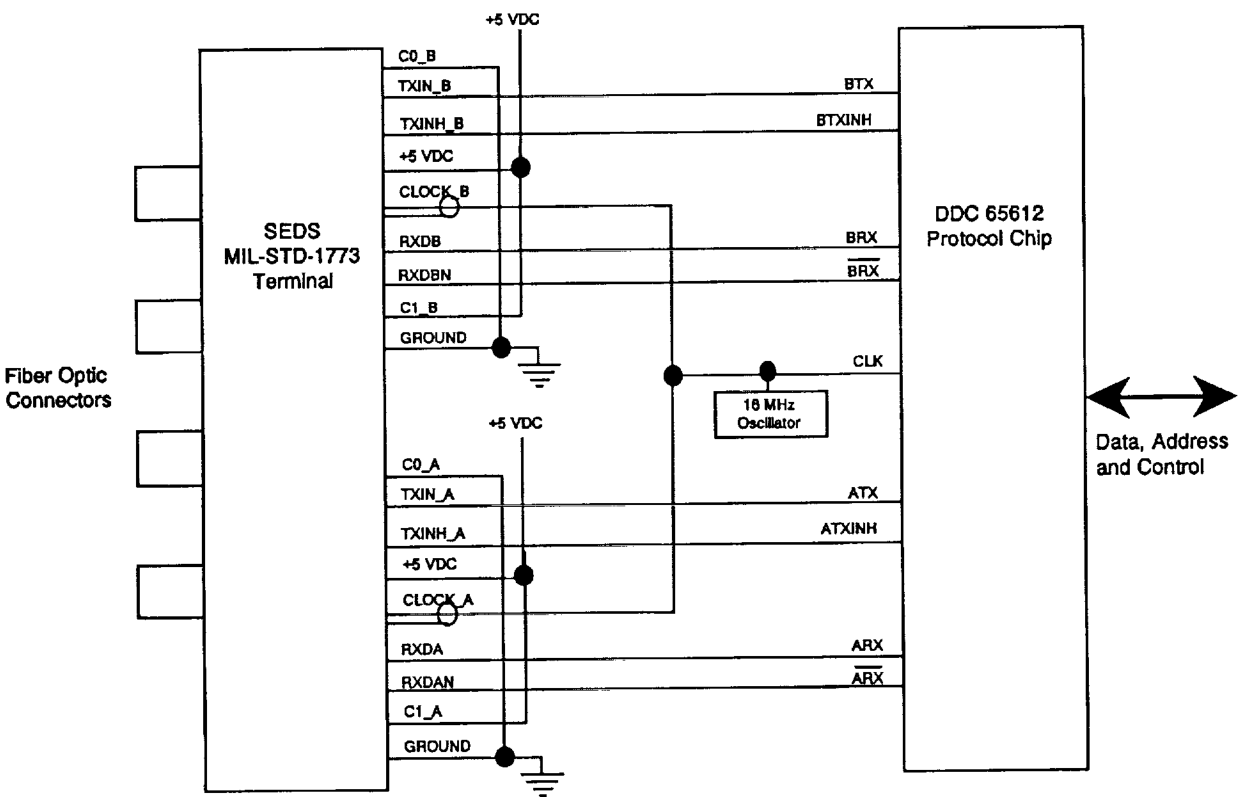

Figure 5. MIL-STD-1773 Terminal to DDC 65612 Electrical Connections

The wires C0 and C1 are used to select the interface, UTMC-type or 65612-type. A one is +5 volts DC, a zero is ground.

TABLE 2. Protocol Chip Selection

Mode	C0	C1
UTMC BCRT	1	0
DDC 65612	0	1

In either case, no new signals are required for the 1773 terminals that are not already required by the protocol chip or by the 1553 transceiver.

4.2.1 <u>Signals</u>

The signal characteristics of the terminal are described in Table 3.

TABLE 3. MIL-STD-1773 Terminal Signal Characteristics

Item	Description
Type	TTL differential
Coding	Manchester

The terminal uses TTL signals to be compatible with the available 1553 protocol chips. The Manchester coding is a requirement of MIL-STD-1773 and MIL-STD-1553.

4.2.2 <u>Power</u>

The power requirements of the terminal are summarized in Table 4.

TABLE 4. MIL-STD-1773 Terminal Power Requirements

Item	Description
Voltage	+5 volts +/- 10%
Ripple	100 mV maximum
Average power during standby mode	300 mW
Power during transmit mode (maximum)	450 mW

Standby mode means that the terminal is listening to the bus, rather than transmitting. Standby mode is the most common mode for a terminal to be in. Transmit mode means that the terminal is transmitting.

An important fact about the MIL-STD-1773 bus is that only one terminal can be transmitting at any time. This means that the power required by a complete MIL-STD-1773 bus is:

$$P_{bus}=[P_{standby}(N-1)]+P_{transmit}$$

where:

P_{bus}= *total power of bus components*
$P_{standby}$= *terminal power during standby mode*
$N_{terminals}$= *number of terminals*
$P_{transmit}$= *terminal power during transmit mode*

The first term is the power consumed by all the terminals in standby mode. The second term is the power consumed by the transmitting terminal.

For SEDS there are sixteen possible terminals on the bus. So:

$$P_{bus}=[300mW(16-1)]+450mW$$
$$=4.95Watts$$

This is the maximum total power that the 1773 terminals are consuming at any given time.

4.2.3 Ground

There are two grounds, one for each side of the unit. Signal ground is isolated from chassis within the unit.

4.3 Optical Specifications

The optical characteristics of the terminal are summarized in Table 5.

TABLE 5. MIL-STD-1773 Terminal Optical Characteristics

Item	Description
Optical connector	SMA 905
Optical wavelength	850 nm ± 40 nm
Fiber size to be used	100/140 μm
Coding	Manchester
Receiver optical sensitivity (with 100/140 micron fiber)	-34 dBm (0.4 μW) maximum -30 dBm (1.0 μW) typical
Transmitter optical output power (with 100/140 micron fiber)	-9.4 dBm (116 μW) minimum -8.4 dBm (145 μW) typical

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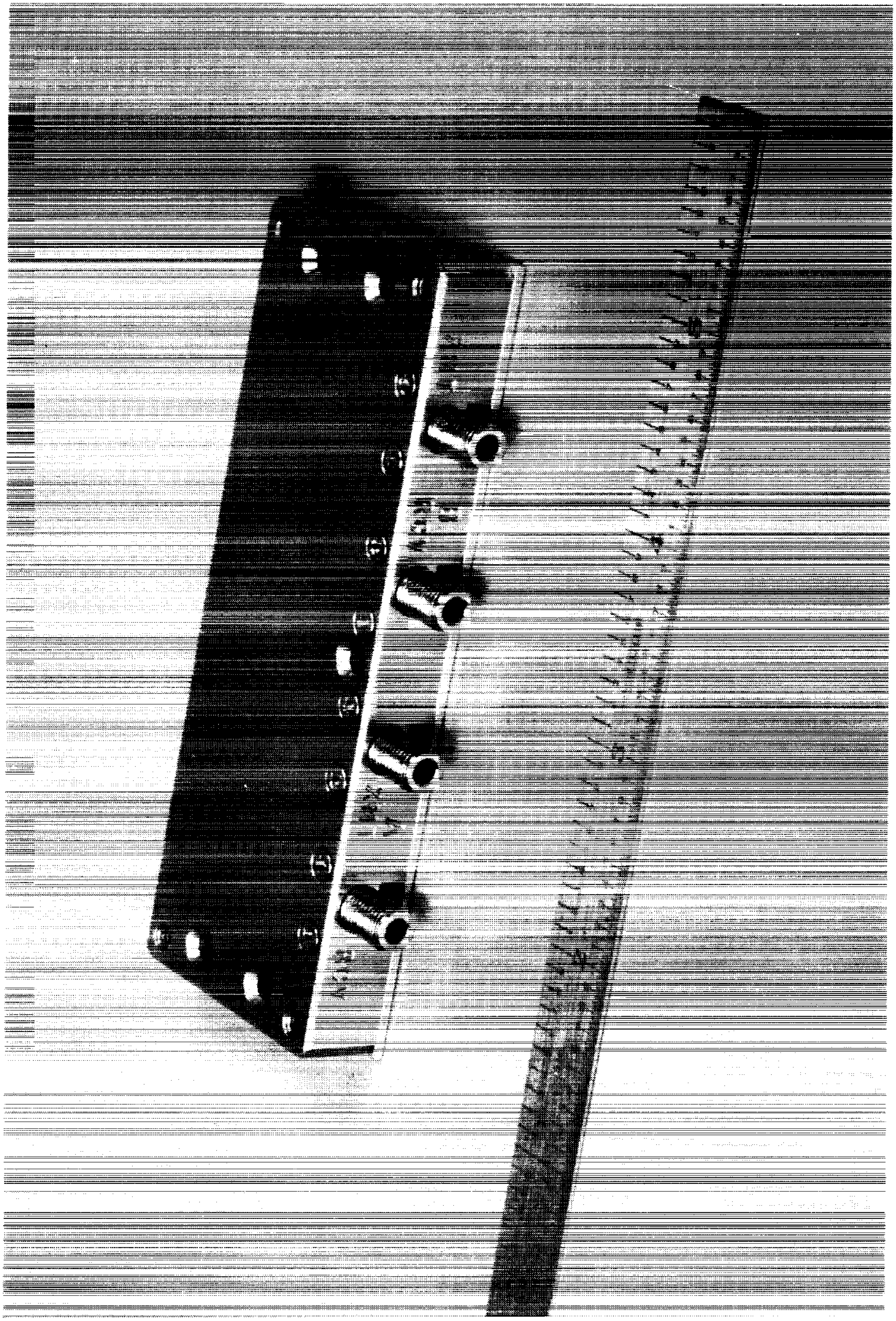

Figure 6. Photograph of MIL-STD-1773 Terminal

The SMA 905 connector and the 100/140 μm Corning fiber are on the GSFC PPL. The wavelength of 850 nm was chosen because optical devices operating at that wavelength are easily obtainable. The coding is a requirement of both MIL-STD-1553 and of MIL-STD-1773.

The optical sensitivity and output power are functions of the size of fiber used. As the fiber diameter increases, so does the amount of light coupled. This means that a specification for coupled power or sensitivity must include the fiber diameter.

4.4 Mechanical Specifications

The terminal's size is 4 x 1.5 x 0.47 inches (10.2 x 3.8 x 1.2 cm). It weighs 0.23 pound (105 grams).

4.5 Parts/Materials

The terminal consists of two Honeywell integrated receivers [8] in low-profile SMA PCB mount packages (part number HFR 3801-002), two Honeywell integrated transmitters [9] in low profile SMA PCB mount packages (part number HFT 4811-014), two LSI ASICs and various resistors and capacitors. The integrated receiver includes a PIN diode (the HFD 3000 base component) for sensing the light and the receiver circuitry necessary to convert the PIN diode current response to a TTL voltage level. The integrated transmitter contains an LED (the HFE 4010 base component) to send the light signal and the transmitter circuitry necessary to convert TTL signals to the LED's drive currents. These devices are being screened per MIL-STD-883 Class B.

The LSI ASIC is used to convert the 1773 bilevel bus to the 1553 trilevel bus as was described in section 4.1.

5.0 STAR COUPLER

5.1 Function

The coupler provides the central point to which all fiber optic cables are connected. It and the fiber are the physical medium through which the light travels.

The coupler used in this system is a fused biconical taper star coupler. It is made by laying fibers parallel to each other, stripping off the buffer material at a point, twisting them around each other at that point, pulling them and heating them. The fibers fuse. The fused area is then enclosed in a small case which allows the fibers to exit as pigtails.

The coupler being used is a 16 x 16 coupler. It has sixteen inputs and sixteen outputs. This means that sixteen fibers were fused together in this way. Light entering a given fiber travels through the fused area and is divided into sixteen equal parts which exit through all the sixteen fibers on the other end.

The sixteen inputs and sixteen outputs of the coupler are terminated in SMA 905 connectors that are mounted on the coupler housing wall. The coupler housing is an aluminum case that contains the coupler and its pigtails. The housing is used to provide mechanical strength and ease of connection to the coupler. If weight or space is unavailable for the coupler housing then the coupler itself can be protected by a tougher enclosure around the fusion point and the exiting fibers protected with a tough sheathing. Then, no aluminum housing is required.

Some of the important parameters for the coupler are its size, the transmission loss caused by the division of the input light into the outputs and the consistency of that division between outputs.

5.2 Electrical Specifications

The coupler is passive. It has no electrical system requirements.

5.3 Optical Specifications

The coupler optical specifications are summarized in Table 6.

TABLE 6. Coupler Optical Characteristics

Item	Description
Coupler Manufacturer	Canstar
Ports	16 x 16 (16 inputs and 16 outputs)
Connectors	AMP SMA 905 Part No. 501348-2
Fiber Manufacturer and Type	Corning ISDF-1508
Fiber diameter	100 μm core 140 μm cladding
Fiber material	Glass
Fiber index type	Graded index
Fiber mode	Multimode
Numerical Aperture	0.29
Maximum Insertion Loss	-16.0 dB
Insertion Loss Spread (Maximum to Minimum)	4.0 dB

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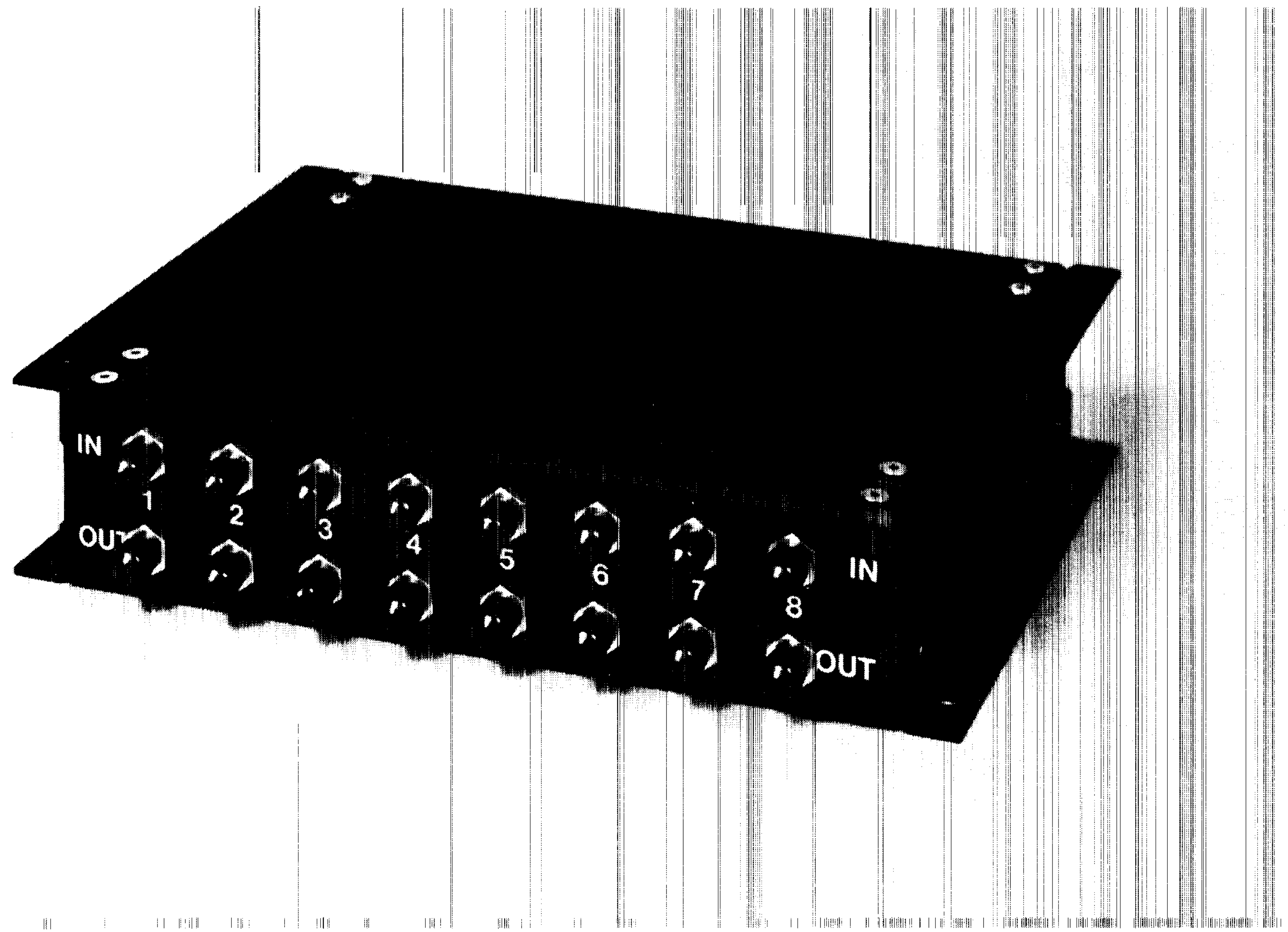

Figure 7. Photograph of 16 x 16 Star Coupler (half of connectors are on other side of box)

The number of ports on the coupler determines how many subsystems can be handled on the bus.

Numerical aperture is a measure of the light-gathering ability of a fiber. It also is a measure of the spreading of light from a source and the acceptance of light by a detector. It is a very important parameter used in matching fibers, sources and detectors. This is discussed in more detail in Section 7.1, Loss Budget.

The loss budget analysis of a system requires consideration of the insertion loss of a coupler, the insertion loss spread of the coupler, the connector losses, the fiber losses, the power output of the transmitters and the sensitivity of the receivers. A large part of the loss is determined by the size of the coupler. A 16 x 16 coupler is the maximum size that can be handled using the 1773 terminal described above.

The SMA 905 connectors the fiber are the only ones currently on the GSFC PPL. Both the fiber and connectors have been tested at GSFC [8].

5.4 Mechanical Specifications

The coupler housing is 6.75 x 5.5 x 1.48 inches (17.2 x 14.0 x 3.8 cm). The coupler (in its housing) weighs 1.62 pounds (737 grams).

5.5 Parts/Materials

The coupler box consists of fiber, the fiber buffering on the pigtails from the coupler, the coupler enclosure and connectors.

6.0 CABLE

6.1 Function

The fiber optic cables provide the interconnection between the subsystems and the coupler. The cables consist of a glass fiber surrounded by various protective coatings and sheaths.

6.2 Electrical Specifications

The fiber optic cable has no electrical requirements.

6.3 Optical Specifications

The cable optical characteristics are given in Table 7. The fiber used in the cables is the same fiber as that used in the coupler.

TABLE 7. Cable Optical Characteristics

Item	Description
Cable Manufacturer and Type	Brand-Rex OC1008
Fiber Manufacturer and Type	Corning ISDF-1508
Fiber Size	100 μm core 140 μm cladding
Fiber material	Glass
Fiber index type	Graded
Fiber mode	Multimode
Numerical aperture	0.29

6.4 Mechanical Specifications

The cable weighs 7.75 grams/meter.

The Brand-Rex OC1008 cable has a 2 inch bend radius. The bend radius specifies how tightly the cable can be bent. In this case it can be bent into a circle of 2-inch radius. Bending further than this produces a slight increase in attenuation and stresses the fiber. Cables can be purchased with as little as a 0.5-inch bend radius.

6.5 Parts/Materials

The cable consists of the fiber, a buffer coating and various layers of protective sheathing. It has been tested successfully at GSFC for space-based applications [10].

7.0 SYSTEM DESIGN

7.1 Loss Budget

The implementation of a fiber optic communications system on a spacecraft differs in some significant ways from other types of implementations, notably from telecommunications systems. The most significant difference is the much smaller distances involved in spacecraft systems. A large spacecraft may have cable runs of, at most, 50 feet. This is insignificant when compared to the miles that telephone cables can run. The impact of this is that the loss in the cable itself is a small part of the overall system loss. Most of the loss is in the connectors and coupler. The required dynamic range for the transmitter/receiver pair is 20.5 db. Table 8 summarizes this information.

TABLE 8. Typical Power Budget Calculations (dB)

Component	Maximum Loss	Minimum Loss	Typical Loss
Transmitter to Cable	1.5	0.4	0.6
Star Coupler	16.0	10.4	12.6
Cable to Receiver	1.5	0.4	0.6
Power Margin (EOL)	1.5	0.0	0.0
Total	**20.50**	**11.20**	**13.80**

The transmitter-to-cable loss is the total loss due to inefficiencies in coupling light from the transmitter into the cable. Connection losses like these are variable, depending on several factors.

Factors intrinsic to the fiber itself are the concentricity of the core in the cladding, the ellipticity of the core and NA mismatch. Intrinsic factors are normally outside the direct control of a system designer.

Extrinsic factors include lateral displacement of the fibers within a connector, end separation of the fibers, angular misalignment of the fibers and poor surface polish. Careful construction of the cable by an experienced technician using quality tools is the best way to minimize these losses. These tools are readily available in termination kits from many vendors. However, some losses will occur and must be included in the loss budget.

The coupler loss consists primarily of splitting loss, loss in the connectors and loss within the coupler itself. The splitting loss is due to the splitting of one input signal into, in this case, 16 output signals.

$$L_{splitting} = -10LOG\left(\frac{1}{N_{ports}}\right)$$

where:

$$L_{splitting} = \text{splitting loss}$$
$$N_{ports} = \text{number of ports}$$

So for a 16 x 16 coupler (16 ports):

$$L_{splitting} = -10LOG\left(\frac{1}{16}\right)$$
$$= 12dB(typical)$$

The worst-case internal coupler losses are 2 dB and the worst-case connector losses are another 2 dB (1 dB in and 1 dB out). This drives the worst-case total coupler loss of 16 dB.

The cable-to-receiver losses are of the same type as the transmitter-to-cable losses.

There is one source of loss that needs additional explanation: Numerical Aperture (NA) mismatch. NA measures the light-gathering ability of a fiber. It equals the sine of the acceptance angle. Therefore, as the acceptance angle increases the NA increases.

If the NA of a source is greater than that of the fiber, then NA mismatch losses will result. If the NA of a detector is less than that of the fiber, then NA mismatch loss will result. If two fibers with different NAs are connected together, NA mismatch loss will occur when the light signal travels in the direction of high NA to low NA. The reason is the same for all these cases; the light is lost going from a part with a larger angle of acceptance (high NA) to a part with a smaller angle of acceptance. Light is emitted from one part in a cone larger than the other part can accept.

7.2 Bandwidth

The bandwidth of this system is limited by the integrated transmitter and receiver. They are both rated at 10 MHz. That is enough to handle the 2-MHz MIL-STD-1773 signalling rate. The couplers, cables and connectors do not limit the bandwidth in this system.

8.0 RELIABILITY

The following table summarizes the SEDS MIL-STD-1773 data bus reliability calculations.

The reliability of the fiber optic bus is very high because of to its low parts count, including the electronic parts in the 1773 terminal, and its redundancy.

TABLE 9. Reliability Calculations

Failure Rate Source	MIL-HDBK-217E
Environmental Condition	SF (space flight)
Base Reference Temperature	50 °C
Stress Level	30%
Part Quality IC Semiconductor Passive Parts	 B JAN R

Failure Rate (side A or B)	0.22437×10^{-6} F/hour
Predicted MTBF (side A or B)	4,556,923 hours
Reliability over 3 years	0.994120
Reliability at 1 of 2 Redundancy over 3 years	0.999965
MTBF at 1 of 2 Redundancy over 3 years	750.84 million hours

9.0 TESTING

9.1 Qualification

Four 1773 terminals and two couplers have been qualification tested as follows. The fiber will be tested on the spacecraft.

1. Full Functional Test

2. Thermal Vacuum: 8 cycles; 4-hour soaks at each level; -30 to +60 degrees Celsius. The DUTs were powered during the entire test. Full functional tests were run during each 4-hour soak.

3. Random Vibration: Scout qualification levels as specified in Table 10.

TABLE 10. Vibration Qualification Levels

Frequency (Hz)	Levels
20-375	0.04 g^2/Hz
375-800	+5 dB/octave
800-2000	0.12 g^2/Hz

4. Full Functional Test

9.2 Acceptance

All flight units (1773 terminals and couplers) have been acceptance tested as follows.

1. Full Functional Test

2. Thermal Vacuum: 2 cycles; 4-hour soaks at each level; -20 to +50 degrees Celsius. The DUTs were powered during the entire test. Full functional tests were run during each 4-hour soak.

3. Random Vibration: Component Workmanship Levels as specified in Table 11.

TABLE 11. Vibration Acceptance Levels

Frequency (Hz)	Levels
20	0.01 g^2/Hz
20-160	+3 dB/octave
160-250	0.08 g^2/Hz
250-2000	-3 dB/octave
2000	0.01 g^2/Hz

4. Full Functional Test

9.3 Box Level

The terminals have also undergone qualification and acceptance testing as parts of the individual electronic boxes.

10.0 CONTAMINATION

The optical connectors must be kept clean and covered at all times. The system relies on the coupling of light between its components. That coupling can be substantially reduced if the connectors get dirty. Caps are available which fit over the connectors or the central post which contains the fiber. These should be used whenever the connectors are not mated. Cleaning and inspection with a fiber microscope should occur immediately prior to connection.

11.0 RADIATION

11.1 Test Characterization

The components in the MIL-STD-1773 Bus have been characterized for degradational effects from the harsh space radiation environment. This includes the effects from total dose, protons, and heavy ions. The total dose requirement on the system is specified as 100 krad.

11.2 Total Dose Tolerances

The total dose hardness levels are summarized in Table 12.

TABLE 12. Total Dose Hardness Levels

Component	Total Dose Tolerance
Terminal - Digital IC	200 Krad
Terminal - Receiver/Transmitter	1 Mrad
F.O. Cable / Coupler	100 Krad

11.3 Heavy Ion Effects

The heavy ion test effects are summarized in Table 13. No latchup has been seen on any set of tests.

TABLE 13. Heavy Ion Effects

Component	LET Threshold in MeV x cm^2/mg	SAMPEX SEU RATE (Upper Bound)
Terminal - Digital IC	34	2.7 E-4 per mission
Terminal - Receiver	>1.5	475 per mission
Terminal - Transmitter	>13.5	1.19 E-2 per mission
F.O. Cable / Coupler	N.A.	N.A.[1]

11.4 Proton Effects

The proton test effects are summarized in Table 14. Total dose effects seen in these tests have been negligible.

TABLE 14. Proton Effects

Component	SAMPEX SEU Rate (Upper Bound)
Optical Terminal	< 1 E4 upsets/mission
F.O. Cable / Coupler	N.A.

The Digital IC has not been tested for proton effects, since it is relatively insensitive to SEUs compared to the transmitter and receiver.

11.5 System Performance

Overall, the total dose characteristics exceed the 100 krad requirement, while the SEU and BER effects from protons and heavy ions are summarized in Table 15.

[1]NOTE: Luminescence may occur, but the large majority of these events will be outside of the spectral range of the transmitter/receiver pair.

TABLE 15. System Radiation Effects Summary

System Components	SEU Rate for SAMPEX (Upper Bound)	BER for SAMPEX[2]
2 Star Couplers F.O. Cables Terminals	< 1 E4 upsets/mission	4.2 E-10 errors/bit

12.0 ERROR HANDLING

Errors due to irradiation are dominated by the effects due to protons. The result of proton irradiation is single bit errors on the bus. Every 20 bit MIL-STD-1553/1773 word has a single bit reserved for odd parity. A single bit error in a word causes a parity error which is detected by the receiving device and flagged as an error. The bus controller responds to the error by retransmitting the word.

Multiple bit errors are caused by heavy ion irradiation. These are extremely uncommon. However, if they occur they result in an illegal word on the bus. The reason is that the bus uses a Manchester encoded signal. This means that the ones and zeros on the bus are represented by transitions, not levels. The nature of a heavy ion induced error is to suppress these transitions. Therefore, multiple bit errors are detected and the bus controller responds by retransmitting the word.

13.0 HERITAGE

The terminal has been designed, developed, fabricated and tested for GSFC's SMEX program by SCI of Huntsville, Alabama. It is an integral part of the Small Explorer Data System (SEDS) which is being proposed for many spacecraft. Currently, it will fly on a SMEX mission called SAMPEX in 1992. It also will be flown on the Tropical Rainfall Measuring Mission (TRMM) observatory and the X Ray Timing Explorer (XTE).

The fiber and the coupler will also fly on the SAMPEX, TRMM and XTE missions. The fiber has been tested at GSFC and is on the GSFC Preferred Parts List. These tests included thermal vacuum cycling, outgassing, vibration, shock and radiation testing. The coupler has undergone thermal vacuum cycling and vibration testing at SCI as indicated in the Testing section, above. It also will undergo those tests at the spacecraft level. The fiber used in the coupler is the same as that tested in the cable, so the radiation testing done on the cable applies to the coupler.

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[2]This is based on an assumed SAMPEX bus traffic rate of 20 kbps.

14.0 CONTACTS

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16.0 ACRONYMS

ASIC	Application Specific Integrated Circuit
BCRT	Bus Controller Remote Terminal
BER	Bit Error Rate
dB	Decibel
dBm	Decibel referenced to 1 milliwatt
DDC	Data Devices Corporation
DUT	Device Under Test
EMI	Electromagnetic Interference
EOL	End Of Life
GSFC	Goddard Space Flight Center
IC	Integrated Circuit
ILC	company name
kbps	kilo bits per second
krad	kilorad
LSI	company name
MeV	Megavolts
MHz	Megahertz
MIL-HDBK	Military Handbook
MIL-STD	Military Standard
Mrad	Megarad
MTBF	Mean Time Between Failures
mV	millivolts
mW	milliwatts
NA	Numerical Aperture
PPL	Preferred Parts List
RFI	Radio Frequency Interference
RT	Remote Terminal
SAMPEX	Solar Anomalous Magnetospheric Particle Explorer
SEDS	Small Explorer Data System
SEU	Single Event Upset
SMEX	Small Explorer
TRMM	Tropical Rainfall Measuring Mission
TTL	Transistor Transistor Logic
UTMC	United Technologies Microelectronics Center
XTE	X-Ray Timing Explorer

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13. ABSTRACT *(Maximum 200 words)*

This technical paper describes the MIL-STD-1773 Fiber Optic Data Bus as implemented in the Goddard Space Flight Center (GSFC) Small Explorer Data System (SEDS) for the Small Explorer program. It provides an overview of the SEDS MIL-STD-1773 bus components system design considerations, reliability figures, acceptance and qualification testing requirements, radiation requirements and tests, error handling considerations, and component heritage. The first mission using the bus will launch in June of 1992.

14. SUBJECT TERMS

MIL-STD-1773, MIL-STD-1553, SEDS, Fiber Optic(s), Radiation, Coupler, Fiber Optic Cable

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