A PROGRAMMATIC OVERVIEW OF THE DEVELOPMENT AND IMPLEMENTATION OF THE RICS

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ABSTRACT

The Range Instrumentation and Control System (RICS) is a network of personal computers (PCs), routers, and switches designed to transport time-space-position information (TSPI) and/or other data between multiple Test Sites and data reduction facilities. The typical use of RICS will be the transport of TSPI data from a System Under Test (SUT) to a Focus Site for real-time display and post-mission analysis of the data. This capability will be expanded to include the transport of telemetry (TM), video, and communications data via the RICS. This paper will discuss the overall hardware design of the RICS. It will further describe the programmatic issues encountered during the implementation phase of the RICS project. The paper will describe the initial design criteria, the selection of hardware to implement the design, problems encountered with the implementation of the hardware, solutions and workarounds to the problems encountered, and lessons learned during the entire process.

KEY WORDS

Real-Time, TSPI, RICS

INTRODUCTION

In 1995, Hurricane Opal struck the Gulf Coast of Florida. That portion of Eglin AFB called the Santa Rosa Island (SRI), was in Opal’s path and received significant damage to its infrastructure due to the hurricane's tidal surge. As a result, several Eglin test sites along the island were destroyed. Congressional funding was provided to restore or reconstitute the test capability on the SRI. Senior leadership at Air Armament Center (AAC) level decided that three new test sites and a 300-ft Open Air-Hardware In The Loop (OA-HITL) tower would be built to provide a premier test capability along the Gulf Coast, instead of just rebuilding the damaged or destroyed sites. This initiative was designated the SRI Reconstitution Program. The three test sites were named Focus Sites, since they would become the focal points for all data collection systems on SRI. Construction on the Focus Sites began in May 2000 and the sites were completed in May 2001. The OA-HITL Tower is still under construction and will be completed early in 2002.

The RICS program was created as a subprogram of the SRI Reconstitution Program. The initial intent of the RICS program was to provide a replacement for the antiquated Universal Data System (UDS), which is used for the data acquisition/recording/

transmission of a radar time-space-position information (TSPI) source. The data is transmitted via microwave back to the Central Control Facility (CCF) on Eglin Main Base. Additionally, the RICS will interface with the existing Range Slaving System (RSS). RSS data is utilized by other range systems for initial target acquisition and for pointing antennas/systems, which have no self-tracking capability. The RSS utilizes analog tone transmitter/receivers that communicate over telephone lines, similar in operation to the telephone modems used on PCs today. The RICS will provide an all digital and fiber optic interface to the RSS.

A team consisting of members from 96th Communications Group/SCW (software development), 46th Test Wing/TSD (hardware development), 46th Test Wing/TSR (program management/range facilities) was established to design and build the first RICS. Based on the potential capability of the RICS, the design was modified to include Telemetry, Voice Communications, and Video data. The initial design document reflecting the complete design was produced in Dec 1999 [1]. This document was modified several times to reflect the design being implemented today. As the design stands today, the RICS is a distributed network system that provides a variety of TSPI data to test sites distributed across the AAC test ranges. It can be used to pass TSPI data between any two RICS-capable sites or it can be expanded to include multiple RICS capable sites. Since all participating sites are RICS-capable, the data passed is standardized. Standardization leads to interoperability. Interoperability between systems, sites, and even test ranges is of vital importance to Department of Defense (DoD) testers in the 21st century. The RICS can provide that required interoperability. RICS team members have participated in recent meetings with the Foundation Initiative (FI) 2010 program, a DoD program aimed at standardizing data products and promoting interoperability between DoD ranges. The team has submitted several test cases, proposing that the RICS become a participant in the FI2010 test process at Eglin AFB.

INITIAL RICS NETWORK DESIGN

The original concept for the RICS, as mentioned earlier, was a replacement for the UDS. The primary reason for the replacement of the UDS system was obsolescence. Since radar data is still one of the primary TSPI sources on the AAC range, a new means of transporting AZ, EL and Range data was required to continue operations. To implement data transfer from a SUT, the Multicast User Datagram Protocol (UDP) [2] was selected. Although UDP does not guarantee the ordered-arrival or even the arrival of packets, tests showed that the system could meet and/or exceed the 10 Hz data rate of the existing UDS [3].

Once a transfer protocol had been selected, the basic design of the network needed to be documented. Figure 1 shows the basic design of the fiber network that the RICS uses to pass data. The design has remained relatively unchanged since the initial concept. As can seen from the figure, the network consists of a single mode fiber backbone, which connects the Focus Sites to the CCF.

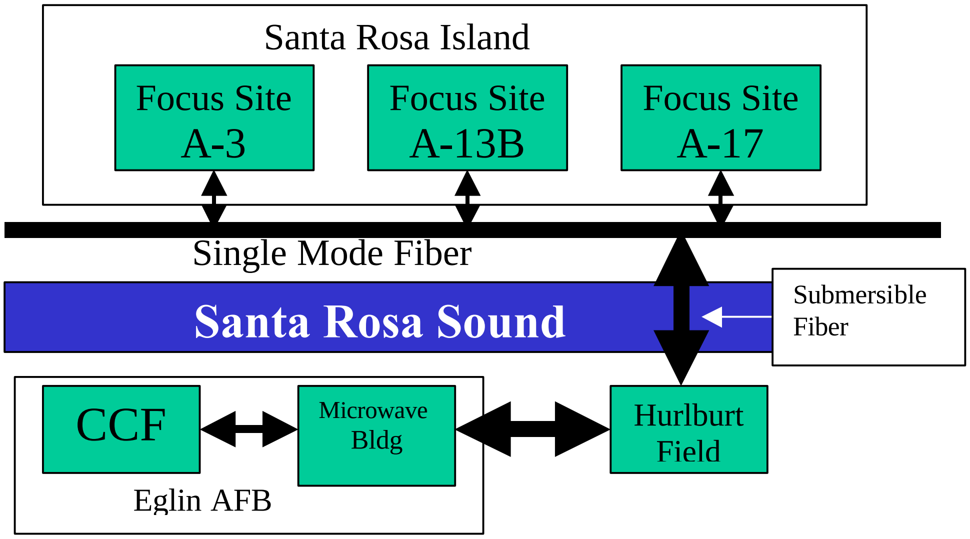

Figure 1. Basic Network Design for RICS [3]

The Focus Sites are spaced along the coast of the Santa Rosa Island, which is separated from the mainland by the Santa Rosa Sound. The fiber originates in the microwave building, which is the focal point for all fiber connections on the AAC range. The main fiber bundle (indicated by thick lines) runs from the microwave building approximately 8 miles to nearby Hurlburt Field, under the Santa Rosa Sound, and then along the length of Santa Rosa Island. The main fiber bundle provides 48 single mode fiber pairs to the Santa Rosa Island. As the main bundle travels down the Island, multiple pairs of fiber are split off the main bundle to service the three Focus Sites and other test sites. The CCF is connected to the microwave building by several, single mode fiber pairs. This connection completes the connectivity between the CCF and the Focus Sites.

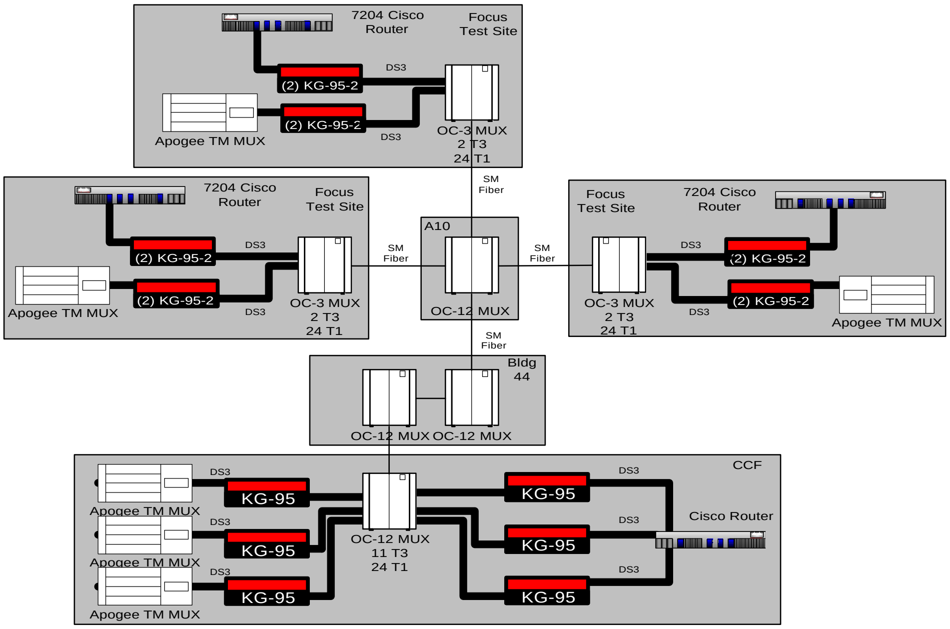

Figure 2. The Initial Network Design for RICS [4]

The design was then expanded to include specifications for hardware. Figure 2 shows the initial design for the RICS data and Telemetry data. Not shown in this initial drawing is the third DS3 connection that provides all of the communications capability at the Focus Sites. DS3 is a standard commonly used to transport high-speed data over copper wire (carried by a T3 line at 44.736 Mbps) [5]. The design for the communications system was added a year later. The figure shows the RICS to be a network of routers designed to pass information freely between two sites or multiple sites. The basic backbone of the network is built upon Alcatel's OC MUX technology. This setup provides a SONET fiber ring with maximum data rates at the OC-12 level or 622.08 Mbps [6]. SONET is a physical transmission vehicle that is capable of transmissions in the gigabit range [6]. Each of the Focus Sites is outfitted with an OC-3 MUX, which has a maximum data rate of 155.52 Mbps [6]. By today's standards, these data rates may seem a little slow, but the basic design can be modified to accommodate any data rate the user may wish. One approach would be the use of Gigabit Ethernet, which was not available at the time of the initial RICS design. In fact, the routers listed in Figure 2 have the ability to support Gigabit Ethernet with a simple card swap. Since the design utilizes commercial off-the-shelf (COTS) hardware, it can be expanded with new technology to fit future requirements for higher data rates. The initial RICS design, shown in Figure 2, shows a Cisco 7204 router used to pass the RICS data. The design has been changed to 7206 routers at the Focus Sites. By changing the router chassis, additional DS3 data pipes can be added to the RICS by simply adding additional cards. The RICS now has a little room for growth in the future.

It should be noted that the telemetry (TM) does not actually pass through a router in the design shown in Figure 2. The Pulse Code Modulation (PCM) data, from the telemetry receiver/bit sync, is fed into an Apogee multiplexer. The telemetry data is then converted to DS3 data and it is passed through the SONET backbone to another multiplexer at the site receiving the data. Typically, the CCF will be the recipient of the TM data for reduction/analysis/display, but the Focus Sites will have the ability to receive and display the TM data with a PC-based decommutation system. Reduction and analysis of the TM data will still be accomplished at the CCF. This portion of the RICS design may be significantly changed in the future to incorporate the new features of PC-based decommutation systems. Most PC-based decommutators provide Ethernet support for the networked exchange of telemetry data. By using a series of networked decommutators (one at each Focus Site and one at CCF), the RICS could freely pass telemetry data between multiple test sites. Since the data would have already passed through the decommutation system, it would be available to the user in raw or formatted form, ready for immediate use in strip charts or display. Obviously, the TM data would now be in unencrypted form (necessary to pass TM data through a decommutator) and the advanced RICS design would need to provide security for classified data.

The current RICS design uses KG-95 Encryption/Decryption units to provide security for the RICS. The KG-95 is designed to take in clear DS3 data and output encrypted DS3 data. Conversely, the KG-95 can take in encrypted DS3 data and output clear DS3 data.

Figure 2 shows the required placement of the KG-95 units that maintain a secure link between the Focus Sites and CCF.

Figure 3 is a block diagram of the physical layout of the Focus Sites. Not all of the Focus Sites have two test pads, but the diagram illustrates the basic layout of the site. The RICS is installed in the control building. A multi-pair bundle (single mode) is tapped from the main SRI fiber bundle and interfaced into the RICS. Multi-mode fiber is run from the test pads to the control building and it is connected to the RICS. The test pads are reinforced concrete slabs (30' X 30') with tie downs for a large System Under Test (SUT). The SUT can be a radar, TM pedestal, or another large system needed for testing. The customer secures the SUT to the test pad and hooks into the RICS via a Data Interface Adapter (DIA). The DIA is a PC-based system that provides a multitude of electrical interfaces to the SUT, which allows the SUT to become a participant in the RICS network. As the figure indicates, multiple DIAs can be supported by a single RICS. The total number of DIAs that can be added is dependent upon the overall bandwidth of the system. As discussed earlier, the RICS bandwidth can be increased by the addition of technologically advanced hardware as it becomes available. Care must be taken to account for the bandwidth of the overall system, which includes the SONET backbone.

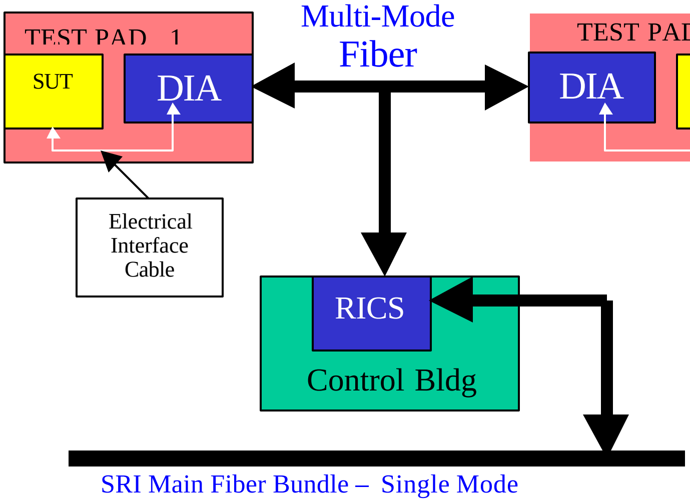

Figure 3. Focus Site Layout

PRESENT RICS DESIGN

This section covers the RICS design as it is documented today. Figure 4 below shows the system design for each of the Focus Sites. The original RICS design documentation did not include a detailed specification for the communications system. Figure 4 shows a detailed breakdown of the communications system used for the RICS. The addition of the communications system utilizes the remaining DS3 data pipe available on the OC-3. The DS3 line is connected to a T1 channel bank, which provides up to 24 T1 lines. The T1 line provides a 1.54 Mbps data pipe [4]. The communications system is a COTS solution from CSTI-Motorola and it utilizes T1 lines to digitally pass voice across the network. Figure 4 shows several units marked AP or Access Panel. The APs are touch screen panels containing software menus to control all aspects of communications to include telephones, radios, and voice nets. A switch located in the microwave building is responsible for the transfer of data between the APs. Voice data from the microphone of one AP position is digitized, sent via T1/SONET to the microwave building, routed through the communications switch to another T1/SONET connection, and the digitized voice is transported to a different AP position (same or different Focus Site).

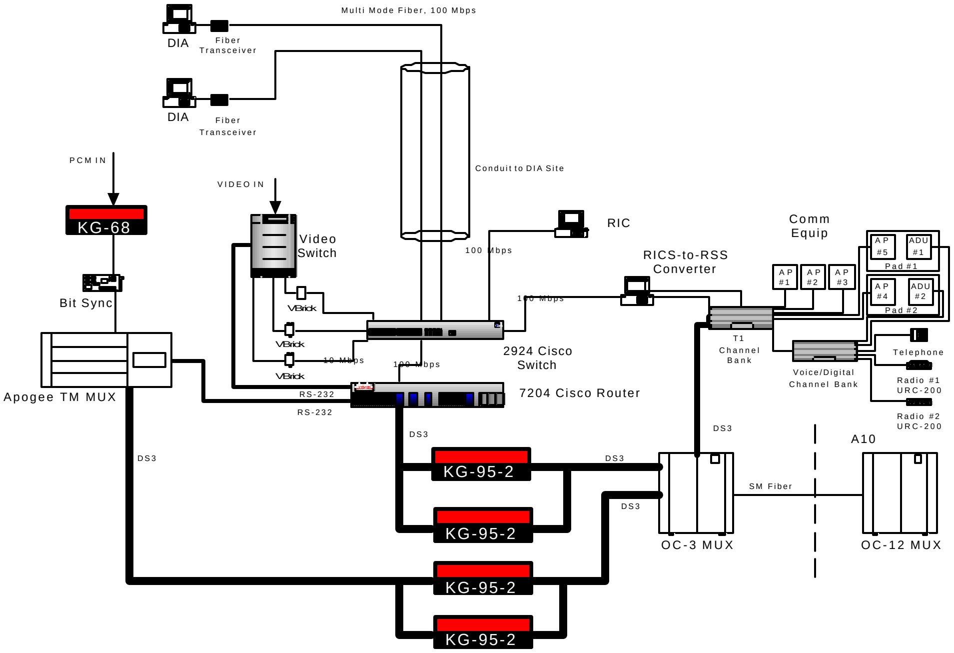

Figure 4. Focus Site System Design [4]

In addition to the APs, the communications system supports an Analog Distribution Unit (ADU). The ADU is an analog communications panel that only provides voice nets, which is ideal for testers operating a SUT out on a test pad. The tester selects the voice net with a rotary switch located on the front of the ADU. Since the ADU is an analog system, it will not accept T1 data. The ADU is connected to the communications switch in the microwave building via an analog (4 wire) input to the voice/digital channel bank. The voice channel bank then converts the analog input to a digital word. The digital words from ADU's, telephone and radio inputs are multiplexed together to form a DS1 data stream. The DS1 data is sent to the T1 channel bank for shipment to the microwave building. In the microwave building, the DS1 data is converted back to analog. The analog data is then processed by a 4 wire analog card; located in the communications switch. Once the data is inside the communications switch, it can be sent in digital/analog form to any of the participating APs or ADUs. The digital interface provides significant flexibility by allowing the user to create a different communications menu for each type of mission to be supported. From a single AP, the user can control voice net, radios, and telephones with a simple touch on the APs screen.

Figure 4 illustrates how video data is inserted and transported with the RICS. Up to 8 video inputs, in standard NTSC (National Television System Committee) format, are fed into a video switch. The video switch output is routed to one of three Video Bricks

(Vbrick), which digitize the analog NTSC data. Additionally, the video switch output is routed to video monitors in the RICS console (not shown in Figure 4). The Vbrick converts the analog NTSC video into MPEG video. The digital MPEG video is passed through the 2924 switch, into the 7206 router (note the router has been changed from a 7204 to a 7206), where it is routed to either CCF or another Focus Site. Since the video switch has a RS-232 link to the router, the router can remotely control the video switch. Therefore, the video switch can be remotely controlled from any location that has a RICS. Video can be passed from one Focus Site to another for merging video displays. This provides a significant amount of flexibility by allowing the tester to distribute cameras across multiple Focus Sites and view all the video at a single RICS console. Experiments in the laboratory did show some latency problems with the Vbricks. When the video is passed from one Vbrick to another Vbrick, there is less than a half second latency. This minimal latency is due to the fact that the MPEG video is simply passed between two Vbricks without attempting to display the digital MPEG video. In other words, the video goes in one end as NTSC and it comes out on the other end as NTSC. The Vbricks have simply acted as a "pass through" for the analog data. The latency problem occurs when the NTSC video is converted to MPEG on one end and the system attempts to display the MPEG video on a SVGA computer monitor on the other end. In this case, the video was delayed by at least three seconds, an unacceptable eternity in many real-time test applications. The problem appears to be in the third party software provided with the Vbrick. The code would have to be optimized to be useful for real-time testing. Recent developments in this technology may solve the latency problem, but the RICS program has not yet tested the latest Vbricks.

The 7206 router is the centerpiece of the RICS design for the Focus Sites. First, the router is responsible for directing control commands to the video and telemetry sections of the RICS. Second, the router directs the flow of UDP messages between the DIA and the RICS computer (labeled RIC in Figure 4). Third, the router directs slaving data to the RSS system via the RICS-to-RSS computer. Finally, the router provides the main I/O port for the data collected by the DIAs at the Focus Site.

The telemetry portion of the RICS design contains a TM receiver (not shown in Figure 4), KG-68 decryptor, bit synchronizer, TM multiplexer, and a PC based decommutator (not shown in Figure 4). Once the PCM stream has been received and decrypted, it can be passed to the TM multiplexer and/or the decommutator. The decommutator is PC-based and it supports a distributed network of data. The feedback path for the decommutator is a 100 Mbps Ethernet connection to the 2924 switch. If the data is passed to the multiplexer, it simply passes directly to another multiplexer at the other end of the SONET connection, where it is converted back to a PCM stream.

The DIA portion of the RICS design is perhaps the most significant effort undertaken during the implementation of the RICS program. The DIA provides an electrical/logical interface to legacy systems that cannot provide an Ethernet connection, which is required to interface to the RICS. The DIA is a rack-mounted PC with multiple interface cards. Figure 5 illustrates the basic design as it stands today. The DIA is a combination of COTS hardware and Government Furnished Equipment (GFE). The GFE portion of the hardware was designed locally at Eglin AFB. Additionally, the software for the DIA is GFE and it was also developed locally at Eglin AFB. The basic Operating System (OS) for the DIA is VxWorks. This OS was selected for its ability to provide excellent real-time control of the computer and interface cards.

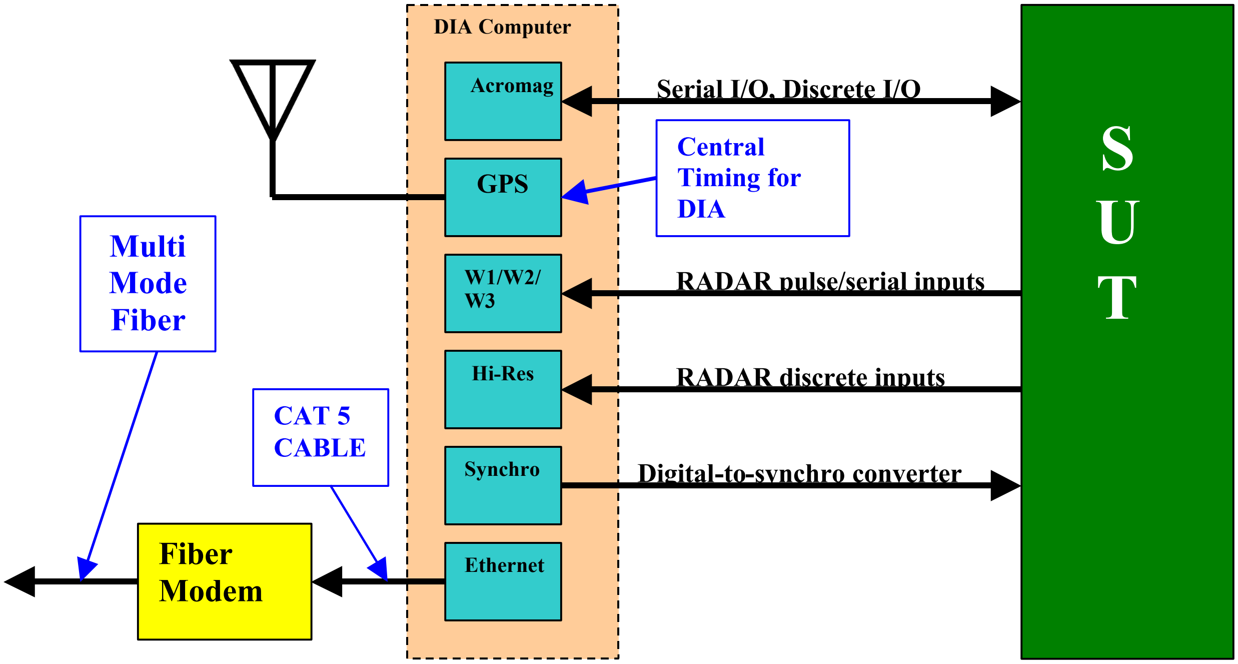

Figure 5. Current DIA Design

Figure 5 illustrates the layout of the cards in the DIA chassis. The Acromag card is a basic I/O card, which provides multiple serial I/O ports and multiple discrete input lines. The discrete input lines have opto-isolators for protection. This COTS card serves as a generic I/O card. The GPS receiver card is COTS hardware that provides the central timing for the DIA. All timing is based upon or referenced to the GPS time. The W1/W2/W3 card, designed and fabricated by design engineers in the 46th Test Wing/TSD, is the hardware that receives pulses and serial words from various legacy radar systems. The pulses and serial words are then converted to radar AZ, EL, and range TSPI parameters. The W1/W2/W3 card is system specific and it is not intended for use as a generic capability. The Hi-Res card is GFE hardware that samples discrete inputs. The difference between the Acromag and the Hi-Res discrete input capability is simply a matter of sample rates. The Hi-Res card samples discrete data at a faster rate than the Acromag. Again, the Hi-Res card is system specific, designed to capture data characterized by a high rate of change and it is not intended for use as a generic capability. The Synchronizer card is GFE hardware that provides a generic digital-to-synchro converter. The card has plug-in modules to support a range of synchronizers, depending on the application. The primary purpose of the Synchronizer card is to provide slaving from other TSPI sources (radar, GPS, etc.). The last card shown in figure 5 is the Ethernet card. This card is COTS hardware that provides a 100 Mbps connection to the RICS. As shown in Figure 5, a fiber modem is used to provide the final connection between the DIA and the multi-mode fiber. The fiber is then connected to the 2924 switch, as shown in Figure 4.

DATA FLOW IN THE RICS

A discussion of the flow of data is necessary to provide insight into the overall capabilities of the RICS. Figure 6 shows the client/server relationship between the DIA and the RICS computers. The server represents the DIA and the clients represent the RICS computers (note: the RIC computer represents the RICS computer in Figure 4).

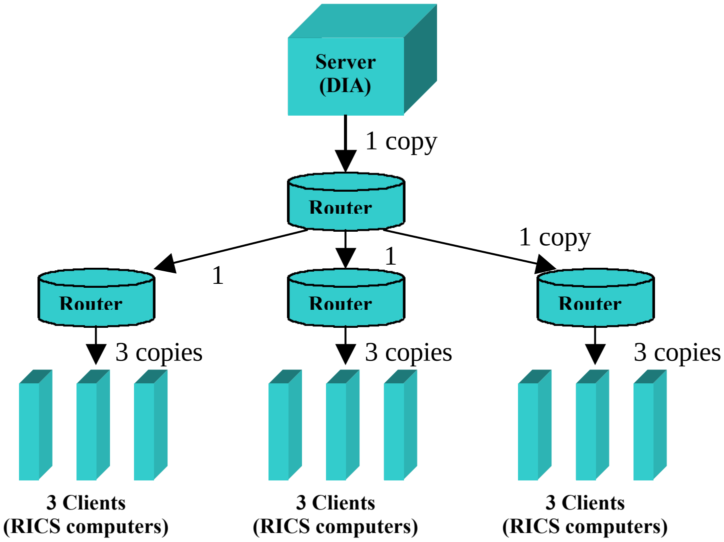

Figure 6. Multicast UDP in the RICS [3]

An individual RICS computer (client) signals the DIA (server) to send information over the network. Since RICS utilizes multicast UDP, the UDP packet is broadcast over the network. All the routers on the network receive the UDP packet and they pass multiple copies on to each of the computers on their respective networks. At first glance, it might appear that the clients would be overloaded by a steady stream of packets that are not of interest to every client. This would be true if every client listened to every packet that the network produced. The actual process allows each client to effectively “listen” to specific packets from specific servers. The question remains, which client controls the flow of the packets? A client assumes control of a server to direct the packet flow. The client now commands the packets to be transmitted from the server, but other clients can “listen” to the packets. This allows other clients to receive the transmitted packets in a “read only” manner. Therefore, the client can take control of a single or multiple servers and the client can “listen” to a single or multiple servers.

The RICS utilizes multiple software packages to provide the orderly flow of data on the network. VxWorks is used for the DIA operating system. C++ was used to create the driver/application for each of the cards in Figure 5. A Component Object Request Brokering Architecture (CORBA) software module was compiled with the C++ application to provide a CORBA object capability in the DIA. With this CORBA configuration, the server exposes necessary objects to the client and the object location is transparent to the client [3]. On the opposite side of the network, the RICS computer uses the Windows 2000 operating system. Java was used to create the Graphical User Interface (GUI) for the RICS. The Java software creates the necessary reference application to access the CORBA object that is resident on the DIA. The GUI provides all the necessary controls to direct the flow of data. Since it is a Windows-based application, the "look and feel" of the GUI is very intuitive.

CONCLUSIONS

Although this paper is not an exhaustive discussion of the RICS, it is intended to provide a general overview of the design and capabilities of the RICS. During the execution of the RICS program, there were several lessons learned. The first lesson learned was that the design should be transcribed to paper as early as possible, which is a basic premise to systems engineering design. The communications system for the RICS was not added until late in the design process which resulted in schedule delays during the search for an applicable communications system. The second lesson is that regular structured meetings must be held between the members of the entire design team. The RICS design team has met every two weeks for the last three years. The meetings have been invaluable in coordinating the efforts between the various organizations involved and the meetings have provided a forum for discussion on design changes, thereby significantly reducing risk to the overall success of the program. The last lesson was the proper identification and allocation of funds resulting in a detailed financial plan. The plan should define funding for each year and it should identify the items to be purchased during that year as well as identify the areas of accomplishment for each year. A detailed financial plan helps identify problem areas coming up in the schedule and it helps the program manager identify shortfalls in funding “up front and early”. All lessons learned reiterated the basic programmatic rules governing cost, schedule, and performance for the successful completion of a program.

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