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AN EXPERIMENT IN REMOTE MANUFACTURING USING THE ADVANCED COMMUNICATIONS TECHNOLOGY SATELLITE

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1. Introduction

This final report describes the work done on contract NAGW-2345 of NASA Headquarters under the NRA-90-OSSA-7, by the Department of Electrical and Computer Engineering of the University of Kansas. The goal of the completed project "A Study of the Role of ACTS in Remote Manufacturing", was to develop an experiment in remote manufacturing that would use the capabilities of the ACTS satellite.

This report describes in detail a set of possible experiments that could be performed using the Advanced Communications Technology Satellite (ACTS), and which would perform remote manufacturing using a laser cutter and an integrated circuit testing machine. It will be shown that the design proposed is a feasible solution to the offered problem and that it takes into consideration the constraints that have been laid on the experiment. In addition, we have developed two more experiments that are included in this report: backup of rural telecommunication networks, and remote use of SAR data analysis for on-site collection of glacier scattering data in the Antarctic.

2. Experiments in Remote Manufacturing Using ACTS

2.1. Motivations for Remote Manufacturing

Recent advances in the manufacturing technology and industrial automation have made available sophisticated machines and instrumentations for manufacturing of high technology products. Although those machines are necessary to meet the increasing demand for high quality products and to maintain technological advancement in manufacturing, their use is very limited. Because of the cost and investment needed, installation of such machines is possible only at few very large manufacturing plants. An immediate solution to eliminate this restriction is through remote manufacturing, which will enable smaller manufacturing facilities to share expensive machines.

The use of remote manufacturing offers numerous technological, and economic benefits. Technological benefits are in the form of increased sophistication in the manufacturing process. The use of remote manufacturing will enhance modularity, flexibility, and automation at each level of the manufacturing hierarchy. Modularity is enhanced because the control and monitoring functions at each level have to be organized into well-defined sets of functions along with some specific sets of process variables and parameters that are essential for an operation. Enhanced flexibility is due to the possibility of cooperation among different machines in the remote manufacturing system. Increased automation results from the need to minimize the mechanical tasks performed by the local operator. Therefore, the use of remote manufacturing is also one step further toward the Factory of the Future which incorporates flexible and fully automated manufacturing systems.

Economic benefits from remote manufacturing are realized in the forms of optimal use of expensive machines, lower production cost, production volume enhancement, increase in productivity, and increase in product quality and reliability. The first benefit, optimal use of expensive machines, is quite obvious. High utilization of equipment through resource sharing will furthermore stimulate development of complex and powerful machines which would not be cost-effective otherwise. The second one, lower production cost is possible because a manufacturing plant doesn't have to buy or own all the machines it needs. Third, productivity is increased since a manufacturing plant can produce more items by using remote manufacturing facilities in addition to its own local facility, and since other facilities can also use its equipment remotely. Fourth, the increase in product quality and reliability follows from the capability to control the remote manufacturing process directly.

2.2. Motivations for Using Satellite-Based Communication Networks in Remote Manufacturing

Conceptually, any type of communication network can be used to implement remote manufacturing. However, the following factors have to be considered in practice in selecting the network: the rate of traffic to and from the machine, traffic sensitivity to transmission delay, area of coverage, and cost. The use of LAN, for example, is not feasible since the maximum distance covered by LAN is only a few miles. Fiber optic network is one good candidate since it can support high data rates with small propagation delay. Eventhough fiber optic communication systems are common among the telecommunication companies for long haul networks, high speed customer access to the fiber capacity is still rare. Installing fiber lines only for remote manufacturing is too expensive, especially for manufacturing facilities in a remote and isolated area.

Another reason for the superiority of satellite links in such situations is that traffic as generated here is not normally uniform. This applies to uniformity both in space and time. At certain times, individual locations might offer significantly larger traffic than at other times. By the same token, at certain other times, these locations may not need to be connected at all. Consequently, such non-uniform demand for capacity is well served by satellite until sufficient terrestrial services are available throughout the country to carry it. One other argument in favor of using satellite links is that it would then be possible to make use of the satellite link to communicate with locations away from the earth's surface, for example, space stations.

Furthermore, until such time as broadband Integrated Services Digital Networks (B-ISDNs) are a commercial reality in the user-world, satellite services must be used due to their inherent cost advantage.

Using a satellite link is thus the most feasible option. First, the new technology is already available in the ACTS system, which can support a high data transfer rate at T1 or T3 rates [Cass 1988; Coney et al. 1988; Nader and Campanella 1988]. Second, satellite communications can cover a very wide area including many isolated areas which are not reachable by other communication links because of natural limitations. A satellite may technically operate into any station within its antenna's view, which is approximately 42% of the earth's surface [Morgan and Gordon 1989]. Satellite link enables the simultaneous connection of more than two manufacturing sites. Furthermore, the use of satellite-based remote manufacturing makes it possible to extent remote manufacturing to places which are not suitable for human beings such as in space manufacturing.

In addition to the higher flexibility as described above, the use of satellite systems, as opposed to fiber-optic networks, can offer a significant economic benefit. Barnett described a detailed system design of the satellite system versus the fiber optic system for the 1990, 2000, and 2010 scenario. In all these cases, he shows that the satellite system can be more cost effective by at least an order of magnitude than the fiber optic alternative [Barnett 1988].

2.3. Architecture of a Remote Manufacturing System

The architecture of a manufacturing system describes the structure of the system. This structure is defined by a set of functions associated with each element and with each level in the system. A modular architecture provides a logical partition of the system such that implementation of one module is transparent to the other modules. Such an architecture makes the system scalable since any modification can be concentrated only at the corresponding functional levels or elements. Besides being modular, the architecture should also be flexible and fault tolerant [Schoeffler 1984]. Flexibility can be improved, for example by using software organization that permits engineers to configure almost any combination of modules into a node. To improve fault tolerant, the architecture should have redundant modules, which may include redundant data-highway interfaces, redundant I/O modules, and redundant controller modules. In the following, we will identify functional elements and functional levels which are pertinent to remote manufacturing.

2.3.1. Functional Elements

2.3.1.1. Remote Monitoring and Command Facilities

In remote manufacturing, the monitoring and command facilities, also called operator interfaces, replace the conventional process instrumentations in the machine room. Direct operation of actuators and analog controllers is now replaced by keyboard control functions, and numerous instruments indicating the process variables are replaced by a screen display device. The use of an operator interface not only supports remote manufacturing but also improves the quality of control and monitoring. Using this interface, the operator should be able to select for display the process variables or parameters of interest. And in the presence of disturbances, the interface should be able to automatically display any number of critical variables simultaneously.

We will discuss only briefly here some general concepts used in the display organization of the operator interface. Detailed specifications have been presented in [Lukas 1986, pp.158-216] and [Popovic and Bhatkar 1990, pp.91-112].

The display screen is subdivided into four areas: message area, overview area, main display area, and instruction area. The display menu is organized hierarchically from the most general to the most specific as follows: Plant Overview Display, Area Overview Display, Group Display, and Loop Display. Other important display options include alarm survey, which gives the operator chronological overview of the alarm status, and trend display, which allows analysis of the process behavior and anticipation of future alarm situations.

Although the structure of the display has been standardized, the final form of the display should be configurable by the users. For example, users should be able to implement their ideas in designing plant specific display panels. Thus, the system should provide primitive symbols which can be easily combined to create user-defined pictures.

2.3.1.2. Communication Link

In assessing the communication requirements, one important step is to identify the set of functions that will be implemented on the communication line. Following [Lukas 1986, p. 115], these functions include:

1. Transmission of control variables between local control units (LCU) in the system.
2. Transmission of process variables, control variables, and alarm status information from the LCUs to the high-level human interfaces and to the low-level human interfaces in the system.
3. Communication of set-point commands, operating modes, and control variables from the high-level computing devices and human interface devices to the LCUs for the purpose of supervisory control.
4. Downloading of control system configurations, tuning parameters and user programs from the high-level human interfaces to the LCUs.
5. Transmission of information from the data input/output units to the high-level computing devices for purposes of data acquisition or transfer.

6. Transfer of large blocks of data (e.g. console displays, historical trends and logs, or large data bases), programs or control configurations from one high-level computing device or human interface to another.
7. Transferring voice and video images.

When process data and other control variables must be transmitted over the network, it is important to consider the problem of limiting response delays under heavy load. Heavy load is due primarily to the fast scan rate, which is often necessary to provide fast response to a process event. Schoeffler proposed the use of exception processing of process signals in the heavy load situation. In this approach, two additional parameters, T_{min} and exception band, are associated with every point data. T_{min} specifies the minimum time between samples reported across the communication network, while exception band is a limiting quantity, below which a new value is used only for the local control algorithm. A new value is sent over the network to the appropriate destination only if it is needed or if it exceeds the exception band. Using a combination of T_{min} and exception band, the sampling rate can be set as high as necessary to permit fast detection of events, while overloading of the network can be prevented [Schoeffler 1984].

Another problem is to guarantee that under heavy load, real-time information can be transmitted immediately across the network. Real-time information, such as for synchronization among the computer controlled machines, are necessary for the proper operation of the system. Huang and Smith proposed a two-level message transmission algorithm to solve this problem. This algorithm uses LAN arbitration to handle exception process. Exception occurs when the network is occupied by the non-emergent message (second level data) when first level data arrive [Huang and Smith 1990].

2.3.2. Functional Levels

In an automated manufacturing system, the implementation is organized hierarchically such that the lowest level implements the most time-critical functions which have to interface directly to the instruments. From the lowest level manufacturing hierarchy includes sensor level, machine level, and cell level. In extending this hierarchical organization to remote manufacturing, the network should be organized accordingly to support the requirements from each level. We will summarize below some networking requirements that should be considered at each level. A complete discussion of this has been presented in [Pimentel 1990, pp.532-552].

2.3.2.1. Network Requirements at the Sensor Level

- ability to handle very short messages in an efficient manner
- ability to handle periodic and aperiodic traffic
- bounded and sometimes fixed response times
- no single point of failure
- adequate error control mechanisms
- short geographical coverage and limited I/O
- low network interface cost
- no bandwidth constraints
- appropriate signaling with adequate time content.

2.3.2.2. Network Requirements at the Machine Level

- ability to handle fairly short messages in an efficient manner
- ability to handle discrete event traffic
- machine resource management
- bounded response times
- no single point of failure
- good error control mechanisms
- limited geographical coverage
- relatively low network interface cost
- no bandwidth constraints
- adequate timing content
- prioritized messages
- message deadline

2.3.2.3. Network Requirements at the Cell Level

- ability to handle fairly short and long messages in an efficient manner
- ability to handle discrete event traffic
- cell resource management
- no single point of failure
- excellent error control mechanisms

- not so limited geographical coverage
- bandwidth constraints
- adequate timing content
- real-time environment
- global time structure
- prioritized messages
- message deadline
- reliable message transfer

2.4. What is ACTS

This section presents a brief description of the ACTS satellite, the nature of its mission and some of the key technologies that are expected to be validated through its deployment.

ACTS is an acronym derived from the Advanced Communications Technology Satellite, a NASA sponsored communications satellite scheduled for launch in early 1993. It is an endeavor by NASA to uphold the primary goal of its Communications program: to maintain the continued competitiveness of the US Satellite Communications Industry in the international market. In this context, the ACTS is a prototype satellite defining relevant satellite communication systems contributing to the improvement of services to the public.

The mission statement of the ACTS program falls within two distinct categories: the ACTS flight program and the ACTS experiments program. Together, they place the overall objective of the ACTS program within the established goals of the NASA Communications Program. The mission of the ACTS flight program is to support the continued leadership of the US in the world satellite communications market by flight testing high-risk technologies that are outside the capabilities of private sponsorship and to use these technologies in an experiment program. The mission of the ACTS experiments program is to stimulate the commercial use of ACTS and ACTS-like technologies by demonstrating technical feasibility and applications through the development of suitable experiments for the ACTS spacecraft and communications payload.

The ACTS system is divided into the flight and the ground segments. The flight segment consists of the communications package and the spacecraft bus. The bus is to be parked in geosynchronous orbit at 100 degrees west longitude. The ground segment consists of the NASA ground station at NASA's Lewis Research Center, a spacecraft control center at General Electric's East Windsor facility, and the experimenters terminals.

Key technologies to be validated as a part of the ACTS program include the following :

Multibeam Antennas: The use of electronically hopping multiple spot-beam antennas has been designed with the idea of a rapidly reconfigurable hopping beam to serve users equipped with small aperture terminals at their premises. Replacing the existing single shaped beams of most satellites with the hopping beam of the ACTS results in a savings of almost 20 dB more in antenna gain patterns. The ACTS provides three types of spot beams - stationary, electronically hopping and mechanically steered. The effect of these multi-beam antennae is to increase the utilization of the system capacity. As the beam can be hopped within the Time-Division-Multiple-Access frame, traffic from multiple locations can be picked up and the system's capacity matched efficiently to non-uniform demand.

Multibeam technology requires inter-beam communications, and to provide this, the ACTS operates in either the baseband processor mode or the microwave switch matrix mode.

Baseband Processor: The baseband processor mode, or the Onboard Stored Baseband Switched TDMA (OSBS/TDMA) mode requires storage and regeneration of the signals received by the satellite. The baseband processor demodulates and stores the signals from each of the two hopping beams. A switch then routes data from input to output storage locations and thus provides connectivity between the uplink and the downlink beams. The data is subsequently read out, coded (if needed), modulated and transmitted on the downlink beam.

In this mode, the beam used for the uplink looks down for a certain period upon a user location that has requested capacity. All bursts received from that location within the TDMA frame of 1 ms is sequentially stored in an uplink memory after decoding (if necessary) and demodulation. Beam dwell time can be dynamically allocated to account for non-uniform demand. Then, within the next dwell time, the beam looks upon another user-location and receives bursts from there. This process is carried on until the end of the TDMA frame.

At the beginning of the second TDMA frame, the data stored in the uplink memory are transferred to another operating in a ping-pong fashion. This is the switch input memory. The baseband switch then reconfigures the bursts from the first frame into the appropriate groups for the downlink and puts them into the switch output memory. At the start of the third frame, the switch output memory is transferred to the downlink memory, acting also in a ping-pong fashion. From there, it is coded again (if needed), modulated on the downlink and transmitted.

The baseband processor is dynamically reconfigurable in order to establish changes in message routing. This switching is possible on a word-by-word basis, where a word is a 64 kilobit channel. The modulation used is in serial minimum shift keying (SMSK). Error correcting coding is possible to counteract rain-fades - forward error correction (FEC) is used with a convolutional encoding rate of 1/2 and constraint length 5.

Microwave Switch Matrix: The other mode of operation is the microwave switch matrix or the satellite switched TDMA (SS/TDMA) mode. It is normally used with the three stationary beams. As no onboard regeneration of signals is required, ground stations are free to use any kind of modulation techniques that they desire.

The microwave switch matrix can dynamically route uplink and downlink beams in any combination of matrix patterns (switch state). Point-to-point or broadcast transmission is possible with the switch, but no traffic reconfiguration is possible in this mode. This switch is most efficient in routing high-volume traffic.

Ka Band Components: The ACTS will be key to opening up the Ka band (20/30 GHz) for communications. The opportunity to tap this portion of the spectrum, which has been relatively unused should prove to be of great interest. However, excessive fade degradation in this band will prove to be a considerable challenge to developing the ground and flight terminal hardware. As expanding the link margin to combat this fading is expensive, the ACTS uses an adaptive technique whereby only terminals experiencing fade are provided additional protection.

Rain-fade Compensation: One of the key ACTS technologies to be verified in the program is the dynamic rain-fade compensation. In essence, the satellite senses changes in the uplink and downlink signal levels, compares them to preset levels and institutes measures to prevent loss of data under fade conditions. This involves the invoking of a convolutional forward error correcting code of rate 1/2 and constraint length 5. Simultaneously, the burst rate is decreased to half the original burst rate. However, the beam dwell time is increased in order to compensate and user throughput is not affected. The 10 dB gain afforded by the combination of the encoding and burst-rate reduction coupled with the 5 dB clear-sky margin results in a 15 dB fade margin for the affected terminals.

The ground segment of the ACTS program includes the Master Control Station, the NASA ground station and the user traffic terminals. The Network Management Center at NASA's Lewis Research Center in Cleveland, Ohio, will be responsible for controlling the SS/TDMA network on the ACTS. Another Master Control Station will be used to control the traffic on the OSBS/TDMA network. Its responsibilities include responding to user demand for capacity, handling requests for fade protection, providing burst time plans for the baseband processor and to manage the overall network.

The Lewis Research Center will also house one OSBS/TDMA station and one SS/TDMA station being built by NASA. Some terrestrial interface equipment including T1 lines and 6Mbps RS-442 ports will also be located at this Ground Station.

User terminals are being designed and built by Harris Corp. These are designated as the LBR 2 ground terminals and will consist of one 1.2/2.4 meterdiameter antenna and feed assembly, as well as an indoor unit consisting of the modem processor and the terrestrial interface equipment (TIE). It will use an uncoded uplink rate of 27.5 Mbps, uncoded downlink rate of 110 Mbps, coded uplink at 13.8 Mbps and coded downlink at 55 Mbps. As discussed earlier, serial minimum shift keying will be employed for the modulation and access to the satellite will be Time Division Multiple Access with Demand Assigned Multiple Access (TDMA/DAMA). The terrestrial interface will consist of central office type telephony interfaces allowing standard user interfaces to be plugged in. Effective throughput on the LBR 2 terminals will be 1.792 Mbps (or T1 + (4) 64 Kbps).

2.5. A Remote Manufacturing Experiment Using ACTS

2.5.1. Scope of the Experiment

"Remote Manufacturing Using the ACTS" is an experiment to be conducted by the University of Kansas in collaboration with the National Aeronautics and Space Administration (NASA) and NCR Corporation. At the conceptual level, voice, video and process data from certain manufacturing and testing facilities of NCR Corp. are to be linked using the ACTS communications technology to a remote site (Lawrence), where the data is analyzed and responsive action taken. Full connectivity between the two sites is used to ensure that machine programming and control can be achieved from the remote location itself.

This experiment is deemed to be of strategic importance to the long-term interests of US industry, primarily because of the verification of remote process control, be it in design, manufacturing or testing phases. Such capability is desired by industry with a view to increasing productivity, utilizing process capacity and other reasons expanded upon in the following sections.

The experiment falls into two segments - one is the institution of the communication link between the target location and the remote site, the other is to generate control systems adequate to download, control and generally oversee the operation of the process from the remote site. The former involves precisely networking the various machines that are to be controlled with the remote location so that data transfer from remote to target and vice-versa is possible. This also involves the simultaneous transmission and reception of audio/video signals together with the process data so that the results of applying control signals to the process is relayed to the remote site not only in terms of feedback from the process but also by sight and sound.

This report will focus on the communications segment of the experiment. A detailed picture of the hardware and software components necessary to implement the communication link between the target and the remote sites will be presented. Furthermore, it will be shown that the design so proposed is a feasible solution to the offered problem and that it takes into consideration the constraints that have been laid on the experiment.

2.5.2 Experiment Sites

Principal sites involved in the execution of this experiment are the Center for Research at the University of Kansas, NCR Corporation's Component Evaluation Test Center (NCR-CETC) and Peripheral Products Division (NCR-PPD), both at Wichita, Kansas. NCR-PPD and NCR-CETC will act as the target sites for the experiment, since the machines associated with the experiment are located there. The remote site from which these machines will be monitored and controlled will be at The University of Kansas campus.

Also associated with the experiment will be NASA's master control station (MCS) at the Lewis Research Center (NASA-LeRC) in Cleveland, Ohio, which is responsible for the overall traffic control of the OSBS/TDMA network of the ACTS. This location will be involved in the call setup, tear-down and intermediate reconfigurations necessary for undisrupted communications between the remote and target sites to be accomplished.

2.5.3. Manufacturing Facilities Involved

The NCR-PPD facility is situated in Wichita, Kansas. The process sited there that is of interest to this experiment is the Laser Cutting process. This consists of a precision cutting instrument using laser technology to aid in the manufacture of precision metal products. The laser cutter that is installed is model 180.2 LK/LW manufactured by TRUMPF Industries. The process is as follows: a control file containing the commands and other process variables necessary to operate the machine (such as reference coordinates, laser power, beam intensity and so forth) is downloaded into the controller and the appropriate blank placed in position within the machine. Acting under the directions of the controller, and hence the downloaded operations file, the cutter then begins the process of cutting the blank to the specifications required. During this process, the control variables are monitored on an operations terminal and any deviation from the required dimensions will need to be acknowledged and prompt action taken.

The scope of this experiment includes the downloading of the control file from the remote location, monitoring the changes in the laser operational variables and viewing/talking to the human operator at the site from the remote location. The forward signal path will be the downloading of the control file. Feedback is provided by data from the process used to monitor the operation of the laser and additional feedback in the form of the human audio/video communications is also to be provided.

The machine itself is already connected to an ethernet segment from which the control file can be downloaded. Feedback from the laser can be made available from a 4800 baud modem that will be installed within the laser housing. In order to convert this serial data into ethernet packets, it is necessary for suitable software to be written at the University. Once this is done, connectivity to the ethernet LAN will be able to provide access to the process and this is precisely what is achieved with the system design presented.

Software required for analyzing the variables from the laser can either be written at Lawrence or can be obtained from TRUMPF Industries on a non-disclosure basis.

The situation at NCR-CETC is more complex than the simple case presented above. Here, the machine involved is a Trillium Arraymaster, a chip-testing machine manufactured by Trillium Inc. This machine consists of a DSP 80A controller within the machine which acts as the test-processor and server, an Apollo DN3000 workstation that is used as the computational node and other peripheral equipment such as an oscilloscope to view the signals generated during the testing process. The DSP 80A test-processor contains the run-time software. The DN3000 terminal is used for program editing and debugging, contains the menu-driver and the graphics display, thereby serving the test system management and compilation functions. The Apollo workstation and the DSP 80A controller are connected through an IEEE 796 or Multibus interface. Other workstations are also connected through a 12 Mbps coax token-ring LAN running the Apollo Domain protocol. The TEK 11400 oscilloscope runs off a DOS-based platform and TEK software is used to transmit the images frame by frame over a 2400 baud modem.

The minimum configuration for the Apollo workstation is a DN3000 terminal with at least 4 Mb of main memory. Additionally, Winchester drives with at least 70 Mb of storage are required. As can be expected, the data rates associated with the Trillium Arraymaster are quite large. The machine is capable of being configured for up to 256 full I/O pins with a maximum of 6 timing markers per pin and 7 reference levels per pin. Currently, it has been configured to test only chips with a maximum of 150 pins. Control programs to execute tests of such magnitude will necessarily be large. So, too, will the process data being generated by the machine. The following table shows the extent of data requirements to operate the Arraymaster.

Input (control) file size:

Control Pattern Memory	4Kb per pin x 150 pins (max) = 600 Kb (max)
Data Pattern Memory	256 Kb to 1 Mb per pin = 150 Mb (max)

Output from the Arraymaster:

Response Log Memory	4Kb pass/fail or float/fail memory per pin per second= 600Kbps (max)

Unlike the laser cutter associated with NCR-PPD, the Arraymaster controller is capable of both download and control (D&C) capabilities. Using this feature, the remote location can operate the machine, analyze the process information and adjust variables within the controller program for the next iteration. Execution can be suspended, variables altered, continued and, if necessary, aborted from the remote location without the presence of a human operator at the target site. Therefore, true remote process control can be achieved with this machine.

The site at the University of Kansas comprises of many different types of workstations and other computers running on an ethernet backbone. In particular, Apollo DN10000 terminals available can be used to control the process of the Arraymaster. The laser cutter control file, being a data file, can be written on any editor, while the TRUMPF in-house software for the diagnostic analysis of the laser, if acquired, will need to work off a DOS platform running DOS 2.3 or higher with 512 Kb of main memory, CGA card and two drives. On the other hand, the analysis can be performed on the same computer that the control file is written on if the software is developed at Lawrence.

2.5.4. Experiment Configuration

The objective of the experiment is to link the two target locations, NCR-PPD and NCR-CETC to the remote location, Lawrence. To test the performance of the satellite under heavy loads and to provide a realistic experiment scenario[1], we will link all of the locations simultaneously.

To decide on the location of the T1 VSAT terminal at the remote sites we evaluated the amount of data being transmitted at each target site and chose NCR-CETC, since the aggregate traffic out of this node is approximately 988 Kbps. In comparison, the NCR-PPD site has a traffic volume of only 388 Kbps.

Land-line based connections between the two locations were considered at first. A cable or fiber ethernet interconnect between the segments at the two sites could be installed. The data from the laser cutter may then be routed to the ethernet at NCR-CETC and pulled off at the ethernet itself or transferred to the token-ring through the existing network interface and taken from there. However, three reasons against this strategy could be advanced : this would still leave the audio/video signals from the codec at NCR-PPD to be dealt with, the cost of laying new fiber/cable between the two buildings would be prohibitively high, and the ex-

[1] If a company in the future is involved in remote manufacturing operations it is expected that it will try to put as many remote operations as possible through the same communications link.

perimental nature of the situation did not warrant any permanent connection of this type.

Leased lines utilizing Frame-relay or X.25 connections were then considered. While this would be a cheap solution, the question of the video connection still remained. Also, X.25, the cheapest method of transmission supports only up to 64 Kbps using the router that has been considered. This would result in a bottleneck at this location for the data transfer.

The recent emergence of radio connections for ethernet LANs prompted the choice of the next alternative for the interconnect, a radio link between the two buildings. Line-of-sight conditions exist between them and radio would be an answer for almost every argument that has been offered against the other methods of interconnection. Such a radio connection can be leased fairly cheaply ($2000 per month) for the short time that the experiment needs to be conducted, additional equipment for the video codec transmission can be added on without degradation in performance of the ethernet interconnect, sufficient bandwidth is available to make use of the relatively high speed of ethernet (10 Mbps) and the connection is not permanent in nature. Some additional factors also suggest that the radio interconnect be preferred over the other alternatives that are considered: to make the facilities a future feasible reality we want to stress a modular design for the communications system. At the same time, system diversity need also be considered; a prototype system such as this design should be versatile, in the sense of being capable of handling a wide variety of network types. For this reason, a radio link between the two target sites has been deemed the optimal choice. Some of the technical characteristics of the microwave link are presented in the following.

With the link between NCR-PPD and NCR-CETC being defined, the second phase of the system, the link between NCR-CETC and Lawrence needs to be addressed. The crucial part of this link is the T1 VSAT. This terminal is central to the entire design. The terminal is equipped with central office type telephone equipment interfaces. Consequently, it can handle a T1 line, synchronous data, asynchronous data and a number of other telephone-type connections. The ability to incorporate T1 lines and that of asynchronous data is particularly useful and is used as a key element of the design.

The basic premise of the next step in the design is to convert these ethernet and token-ring packet data into synchronous serial data that can be time-division multiplexed onto a T1 line. This T1 line can then be connected to the T1 VSAT. A multiprotocol, multimedia router featuring concurrent bridging and routing is used to implement this phase of the design.

At this site (NCR-CETC), a number of different types of data need to be multiplexed over the single T1 line. The types of data that are to be so treated are:

1) Ethernet packets from NCR-PPD to be accessed from the ethernet LAN at NCR-CETC.
2) Token-ring packets from the Arraymaster machine at NCR-CETC.
3) The video signal from the codec at NCR-PPD.
4) The video signal from the codec at NCR-CETC.
5) The 2400 baud modem information from the oscilloscope allied with the Arraymaster.

In order to multiplex all this information into a synchronous serial format, a gateway router from cisco Systems is proposed. This router is capable of assimilating all the signals from the ethernet, token-ring and the video signals together and putting it out on a T1 compatible line. This line is then connected to the T1 VSAT terrestrial interface equipment. The 2400 baud modem is connected directly to the T1 VSAT, into the asynchronous data terminal using a standard RS-232c serial interface.

After careful consideration of the various alternatives discussed in the preceding , the following design has been determined to be the best suited to attain the objectives of the required system. Figure 1 illustrates the configuration for interconnection between the three sites.

Data from the ethernet at NCR-PPD is accessed through a transceiver and is connected to the ethernet at NCR-CETC through the radio (microwave) interconnect. At this point, an MGS router from cisco Systems is used to concentrate data from the ethernet and the token-ring networks into a T1 line. This T1 line is connected directly to the LBR-2 VSAT terminal for the ACTS. At the same time, the output of the TEK11400 oscilloscope is also presented to the LBR-2 terminal through the asynchronous data terminal. This data is also multiplexed into the T1 output of the VSAT terminal.

At the remote site, the data transmitted over the ACTS is received by the LBR-2 terminal. The data is then split into two components, the oscilloscope data is taken directly from the LBR-2 and the T1 line is fed into another MGS router. Token-ring and ethernet packets are then put into the ethernet at the remote site, from where they are used by the appropriate terminals to process and deliver information about the state of the machines.

Downloading control files is not time-sensitive, in the sense that the timing of reception of the data in the file is not quite so critical to the entire process as that of the process information from the target to the remote location. Therefore, the size of the control file and the time it takes to transfer this file is not of importance. What is probably critical is the available capacity of the system to handle peak data flow from the machines to the remote site.

Process data from the laser cutter at NCR-PPD is available at 4.8 Kbps. Added to this is the audio/video data rate of 384 Kbps, amounting to a total of 388.8 Kbps of offered traffic to the LBR-2 terminal. At NCR-CETC, the Arraymaster offers a maximum traffic of 600 Kbps, combined with 384 Kbps for the video information and added to 2.4 Kbps of the oscilloscope information. The total traffic offered to the ACTS is thus calculated to be 1.3752 Mbps, quite well within the support offered by the LBR-2 terminal.

The relatively short distance between the two remote sites offers the potential for the two ethernet LANs in these sites to be connected over a short-haul microwave link. Recent developments in this field make this an attractive proposition for this application. Commercially available links operate over K band and provide about 20 MHz of bandwidth. With a conversion of 1 bit-per-Hertz, a 10 Mbps ethernet link as well as a T1 line are supported. Consequently, ethernet packets as well as additional synchronous serial signals can be sent over the

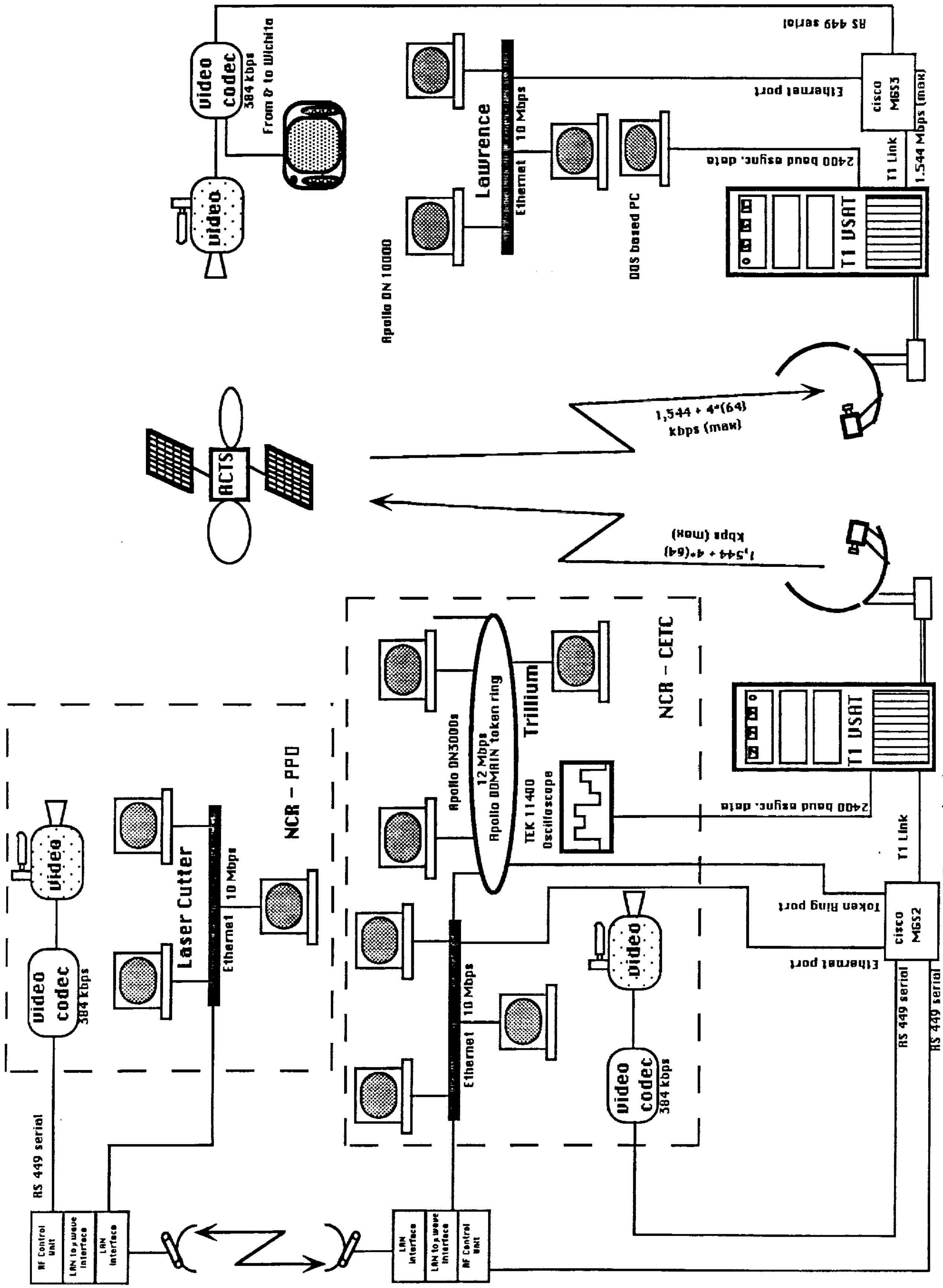

Figure 1: Equipment configuration of Remote Manufacturing experiment

unit. The units themselves comprise an 18 or 23 MHz duplex microwave RF unit, an antenna from one to four feet in diameter, a microwave control unit, an ethernet to microwave interface and an ethernet retiming device. Such units offer link availabilities in the order of 99.999 percent, matching, if not exceeding telephone link reliability.

A comparative study of the routers/bridges available commercially indicates that the best price to performance ratio is achieved by the set of modular multiprotocol, multimedia routers with concurrent bridging and routing functions offered by cisco Systems. Among those offered by cisco, the one best suited to the objectives of the experiment is the MGS system hub internetworking device.

The MGS is capable of supporting up to 11 network and serial interfaces, thereby acting as a backbone for reliable internetworking in multivendor environments. For example, it is capable of internetworking multiple ethernets running different protocols (Novell IPX, TCP/IP, Appletalk etc.) and a Token-ring running SNA (or DOMAIN etc.). These networks can also be connected to other networks over synchronous serial lines at T1/E1 rates and up to 4Mbps

The MGS features a 30 MHz 68020 CPU and asymmetrical processing architecture including 16 MIPS RISC-like processors. The system bus works at 160 Mbps. A wide variety of routing protocols such as the Routing Information Protocol (RIP), the Exterior Gateway Protocol (EGP), OSI End System Intermediate System (OSI-ESIS) and cisco's own Interior Gateway Routing Protocol (IGRP) are supported.

The modular architecture of the MGS offers the user the ability to plug different cards into the card-slots to custom fit the MGS to any specific application. A wide variety of interfaces are also supported to make this a truly "plug-and-play" system. The router also allows setting up access control lists to restrict the transmission to specified hosts and networks, and in some environments, the type of packets that need to be access limited may be specified by subprotocol type. On other distinguishing feature of the MGS is the ability to prioritize traffic up to four different priority levels, based on packet/protocol type and/or host or workstation address.

Two MGS routers are required for the communication system being designed. One is to be located at NCR-CETC to connect the various machines to the LBR 2 terminal and the other at the remote site to perform the same function. The MGS at NCR-CETC needs to be configured with a 4/16 Mbit switchable token-ring card, an ethernet and two high-speed serial multiport communications interface (MCI) card, as well as another high-speed serial-port communications interface (SCI) card. The token-ring port is connected to the token ring on which the Arraymaster workstation is resident, the ethernet port is connected to the local ethernet, in order to access data from the laser cutter at NCR-PPD, two high-speed serial connects are used to access the video signals from both the codecs and the final high-speed serial port is connected to the LBR 2 terminal which acts as the backbone here

The configuration of the remote location is identical to the one at the target location except for the absence of the token-ring interface card. Consequently, the ethernet port can be connected to the ethernet LAN, two of the serial interfaces can be used to connect the video codecs and the third serial interface can be used to connect to the LBR 2 terminal.

In order to facilitate the implementation of remote manufacturing, it is deemed necessary to offer audio/video connectivity between the target and remote locations. Such a connection enables users at both ends to view the process visually, rather than conceptually as is possible with data connections alone. Especially the remote use of the Trillium tester requires audio/video connection since the remote engineers need to be able to talk to the local testing engineer and to view the handling of the chips.

Currently, there is no audio/video connectivity between the remote and target locations. This situation is advantageous in light of the fact that a new system installed can be tailored to fit the circumstances of its use. However, it also adds to the cost of the equipment to be acquired and consequently, the choice of the system need conform to the limitations on its cost, too. It should be noted that this part of the design is similar in nature to implementing a video conferencing unit between the target and remote locations.

We have rejected the option of using a turnkey system since, although these systems offer a large number of advanced services and features, their price makes them unrealistic for an experimental set-up. We have instead selected to build up a system that will perform just the services that are required of it for the purposes of the experiment to be conducted. Such a solution will help to minimize the cost of the video communications subsystem.

Advanced Video Technologies Inc. and Concept Communications are two vendors who offer codec boards for purposes of creating such a system. While acquisition of these boards is a cheaper solution to acquiring turnkey systems, additional expenses will arise to buy monitors, cameras and PCs to create an entire system.

After careful consideration of the alternatives available, it has been decided that the objectives of the experiment would be met without undue expenses by purchasing video codec boards and creating the system from constituents rather than acquiring turnkey systems. In particular, Concept Communications' IMAGE 30 seems to be an outstanding choice for the basic video codec boards.

The IMAGE 30 is a pair of PC expansion boards, one board being a video processor and the other being an audio processor. Both are required in order to maintain video/audio synchronization over satellite links, such as the environment of the present experiment. These boards can be plugged into the expansion slots of any IBM PC, XT, AT, or compatible. Transmission can occur at user-selectable bandwidths ranging from 54 to 384 Kbps; the larger the bandwidth used, the better the video quality. The audio board digitizes 3.7 KHz sound into 32 Kbps data and mixes it into the video data stream to create adequate synchronization.

Other superior qualities of the IMAGE 30 which merit its choice for the video system are enumerated below:

1) Full motion video with 256x200 resolution enhance the received picture quality.
2) Graphics overlay using standard CGA input provides 512x400 pixels resolution.
3) Compatibility with standard video cameras and monitors; IMAGE30 provides RGB input/output as well as NTSC compatible composite video input and out-

put ports. Multiple inputs and outputs are possible, including VCRs and video printers.

4) Standard RS 422/449 communications port.
5) Windows function generates four windows on a single monitor screen to view different inputs on the same screen.

The ability of the IMAGE 30 to split the screen into windows can be used to view the received signals from both the target locations on the same screen.

2.5.5. Equipment and Costs

Table 1: Component Costs for NCR-CETC Site

Quantity	Item	Unit Price	Cost
Router			
1	MGS/3	9,275	9,275
1	4/16Mb token ring attachment	5,950	5,950
1	1E2T ethernet & 2 serial	4,100	4,100
1	1T High speed serial	2,625	2,625
3	RS 449 DTE applique	150	450
	Total		22,400
	(Minus 30% University discount)		*-6,720*
	Cost for Router		**15,680**
Video Conferencing System			
1	Codec board	8,000	8,000
1	IBM compatible PC	3,000	3,000
1	Monitor	700	700
1	Camera	1,000	1,000
1	Other (cables, etc.)	250	250
	Cost for Video Conferencing System		**12,950**
Other			
1	Cabling and Miscellaneous		**1,000**
Total Equipment Costs for NCR-CETC Site			**29,630**

Table 2: Component Costs for NCR-PPD Site

Quantity	Item	Unit Price	Cost
Interconnect			
1	Modem for data acquisition	500	500
2	Lease of radio interconnect	2,000	4,000

	(2 months)		
	Cost for Interconnect		**4,500**
Video Conferencing System			
1	Codec board	8,000	8,000
1	IBM compatible PC	3,000	3,000
1	Monitor	700	700
1	Camera	1,000	1,000
1	Other (cables, etc.)	250	250
	Cost for Video Conferencing System		**12,950**
Other			
1	IBM compatible PC for digital oscill.	3,000	3,000
1	Cabling and Miscellaneous	1,000	1,000
	Total Other		**4,000**
Total Equipment Costs for NCR-PPD Site			**21,450**

Table 3: Component Costs for Lawrence Site

Quantity	*Item*	*Unit Price*	*Cost*
Router			
1	MGS/3	9,275	9,275
1	1E2T ethernet & 2 serial	4,100	4,100
1	1T High speed serial	2,625	2,625
3	RS 449 DTE applique	150	450
	Total		16,450
	(Minus 30% University discount)		*-4,935*
	Cost for Router		**11,515**
Video Conferencing System			
1	Codec board	8,000	8,000
1	IBM compatible PC	3,000	3,000
1	Monitor	700	700
1	Camera	1,000	1,000
1	Other (cables, etc.)	250	250
	Cost for Video Conferencing System		**12,950**
Other			
1	Cabling and Miscellaneous		**1,000**
Total Equipment Costs for Lawrence Site			**25,465**

2.6. Future Benefits and Extensions of Satellite-Based Remote Manufacturing

The design presented in the preceding sections can be used as a prototype for other similar applications. Due to the modularity of design and the upgradable features of the equipment used, adapting this prototype for use in other experiments or actual links should not pose a problem. Modularity allows for different hardware cards to be filled in for ones that need to be replaced in other situations, while the wide range of software support available with the vendors increases the likelihood that equipment can be custom-tailored to any situation.

As a result of this design, full interconnectivity between the networks at the target and the remote sites has been established. Any user on the terminal at the remote site will have all functions of the machines available right at the terminal console itself, thus paving the way for true remote process control. In this experiment, remote testing and/or manufacturing will be established as feasible technology.

Applications of this communications link design can be extended to any number of situations. Some of the foreseeable applications for it are outlined below:

• Remote design, manufacture and testing: With the technology from this design providing the capability of extending the control console of machines to a user operating from a remote location, the stage has been set for users to utilize sophisticated, high-technology equipment to aid them in industrial design. This potential is a significant gain for users of highly sophisticated computer aided design (CAD) technology. Similarly, expensive manufacturing equipment may be operated directly by the very users of the product, so that the resultant product fits the intended application or satisfies the particular need.

• Collaboration: Through the verification of remote process control technology, and of the communication system proposed here, hands-on collaboration between individuals or agencies in geographically distant locations is made possible. Significant savings can accrue through this process, considerably enhancing productivity.

• Voice/video transmission: The communication system that has been proposed also contains the elements of a typical video conferencing system. The use of voice and video to enhance the process representation at the remote users terminals results in significant advantages. For one, fault and crisis conditions can be managed more effectively if the user at the remote location can see and hear what is going on at the target location. For another, reaction times to control inputs is reduced - often the user does not have to wait for the data from the process to be analyzed and displayed in order to take some action.

• Remote design: The proposed experiment sets forth the foundations for remote design, which is a feasible alternative to remedy the losses incurred in bringing team members from diverse locations together. Through interactive voice/video/data communications, it will now be possible for these members to discuss, design and see the result of each individual's input to the process. Since the CAD program can be accessed by all the members, wherever their location, immediate feedback on the progress of the design is possible. This ability will be prized by firms currently losing productivity as a result of shuttling team members to and fro. By extension, this process can also be used in the manufacturing and testing phases of the design process. Knowledge from individuals or agencies with varying specialties in manufacturing processes can now be tapped without going to great expense. While the manufacturing division goes to work in turning out prototypes, the design team can also be online and assist. Last-minute design ideas can also be incorporated without a great deal of expense. After this process, prototype testing can be instituted with all the pertinent team members present. Interactive testing can lead to multiple inputs from different members of the team so that the final product is defect free. This is an additional competitive advantage when the product is ready to be introduced.

• National Resource Centers: Another possible application of the remote manufacturing methodology is in the establishment of national resource centers. With the extremely high investment capital required to acquire and operate sophisticated machinery, it is not always possible for smaller firms to obtain these machines. Consequently, even though these machines may be necessary for continued presence in the product market, their use is being limited by the cost barrier to acquisition. Smaller firms also generally do not require the use of the entire capacity of these machines, which are by nature, of a large size. One of the ways in which this barrier can be overcome is to form *resource centers*, in which a number of firms establish a co-operative and procure these machines. The right to use these machines can be made available to the member firms on a time-sharing basis. This discussion is also equally applicable to educational institutions, which can opt for this resource sharing as a means of offering better services to the students. At a higher level, the government can set up these national resource centers for equipment and other services where the investment potential is so great as to preclude direct investment by corporations. This is similar to the goal of the NASA Communications Division, which seeks to improve benefits to users by investing in high-risk technology and prove their commercial viability.

3. Other Experiments Using ACTS

In addition to planning in detail the experiment in Remote Manufacturing using the ACTS, we have designed two more experiments that could show the effectiveness and applicability of ACTS in a corporate and in a scientific application.

3.1. Rural Telecommunications Systems Backup

Diverse connectivity of telecommunications resources needed to improve system reliability is difficult to obtain in remote rural areas, e.g., central and western Kansas. The cost of installing multiple connections to switching nodes and cellular towers is high. Furthermore there are frequent service outages between cell sites and their associated switching centers. A solution to this problem may be found in satellite technology evolving from NASA's Advanced Technology Communications Satellite (ACTS) program. Several elements of this program combine to make future satellite technology attractive for increasing the diversity and thus the reliability of remote or rural telecommunications resources. ACTS operates with carrier frequencies of 20/30 GHz, reducing the size of the ground antennas. The use of these carrier frequencies also allows for the transmission of higher rate (bandwidth) signals; T1 rates and higher are possible. ACTS also uses a scanning spot beam that can be positioned over a relatively small site of interest. Concentrating the field of view of this beam can reduce the transmit power needed for the ground stations.

A possible future system then could have sparse terrestrial connectivity with diversity provided by a high bandwidth, small, low power (low cost) ground stations that can carry traffic when network failures occur. In the event of a network failure bandwidth would be provided on demand by the satellite system. The system would position its scanning spot beam over the needed site, collecting the traffic and switching it onto a fixed beam down link to another node where the traffic would reenter the terrestrial network.

This scheme has several potential advantages. Primarily it offers the potential for a cost effective method to increase the reliability of rural telecommunications systems. The satellite capacity would only be used and paid for on a demand basis. It is expected that a relatively small base fee would be charged for access to this kind of service. Coverage of the remote area would be provided by a scanning spot beam, reducing the power requirement of the system. Also the scanning beam would be a resource shared by other users, again reducing its cost. A specialized and centralized node would be used to collect all rerouted traffic further reducing the complexity and cost of the system and its management.

Essentially, today's satellite backup of high capacity trans-Atlantic and trans-Pacific fiber connections would be implemented on a distributed and smaller scale using the proposed system.

The above arguments indicate that there is potential for the commercial development of satellite technology to support remote and rural telecommunications services. Research is needed to further explore this potential. We are proposing a research program of analysis and experimentation designed at determining the feasibility of this use of satellite technology. The ACTS experiments program provides an ideal mechanism to perform this research. ACTS has the capabilities described above. NASA is developing ground stations with standard telephony T1 interfaces that will be used as part of these experiments. We suggest an experiment connecting a remote cellular site in Western Kansas to a switching node in the Kansas City area spot beam using the T1 capability of ACTS. As part of this effort an analysis would be conducted of the relative merits of the technology considering both cost and technical feasibility. Prototype software would be developed to provide signaling and possibly continuous customer service in the event of a network failure. For example, after a failure event occurred affected customers would hear a message like, "There has been a network failure; please hold for your call to be reconnected". The information concerning ongoing calls would be used to re-establish the connection through the backup node.

A joint University/industry ACTS experiment will be conducted to address the potential of using ACTS to increase the reliability of rural telecommunications systems. The Kansas Independent Network Inc. (KINI) will work with the University of Kansas to demonstrate the technical feasibility of using satellite technology to backup rural telecommunications systems.

KINI has a target of having 43 cell sites and five switches with link lengths of 20 mi. or more commonplace. With 25 cell sites currently on line KINI is experiencing about one link failure per week. Line cuts, lightning, and human error are common causes for these outages. Further it may take hours to reestablish a connection to a remote cell site. The current situation leads to both lost revenue and customer dissatisfaction.

There are several alternatives for solving this reliability problem. Redundant land links can be installed. This is an expensive solution. Redundant radio links can be used. Terrain considerations may require repeaters again leading to an expensive solution. For the reasons outlined above KINI and the University of Kansas intend to team to explore the use of ACTS like technology to improve system reliability.

For ACTS like technology to be successfully applied to this problem several issues must be resolved. The voice quality of the alternate satellite link must be satisfactory. Signaling protocols must be developed to support the application. The complexity of the management of such a backup facility must be considered. Most importantly, the technology must be proven to be cost effective relative to the other possible solutions. We have developed the following tasks:

Before performing the experiments we will develop and implement the required re-routing mechanism, protocols, and network management procedures needed to support this application. Next, we will integrate the ACTS T1 VSAT, the developed protocols, and management tools with KINI facilities, i.e., select the sites for the experiment and insure that proper interface mechanisms are in place. KINI has agreed to give us night access (between 12:00 am and 4:00 am CST) to its live network to perform backup experiments. Next, we will use the ACTS to test the re-routing mechanisms, protocols, and management tools. Various failure scenarios will then be executed and the effectiveness of the technology and its quality of service evaluated. Finally, using the results of the experiment, and with the help of KINI we will develop a cost/performance analysis for this backup service and compare it to other technologies.

3.2. Remote Scattering Data Collection in the Antarctic

Spaceborne synthetic aperture radar (SAR) will play an important role in measuring the behavior of the Antarctic ice sheet. SAR images will be collected over Antarctica to aid in developing an understanding of the effects of global warming on the ice sheets. This understanding will evolve through the investigation of the ice mass balance and surface ice features. These and other parameters of the ice will be estimated from spaceborne SAR sensor data. Radio echo sounding techniques and radar altimeters have successfully measured the thickness and surface elevations of ice sheets. However, little research has been conducted on estimating such characteristics of sheet ice using spaceborne SAR data. SAR can likely provide information on surface roughness, snow accumulation, ablation rates, and ice motion as well as information on the history of the ice and augment information on its stress patterns. Such knowledge is important for ice research.

To effectively utilize the SAR data to be collected requires the development of techniques for extracting useful geophysical information from the SAR data. A collaboration between microwave engineers and glaciologist is needed to develop scattering electromagnetic models of sheet ice and subsurface features. Inhomogeneities in the ice cause refraction of the electromagnetic energy that can degrade the SAR performance, the nature of this effect is unknown.

The University of Kansas Radar Systems and Remote Sensing Laboratory (RSL) has been active in studying the microwave response from ice for many years, including several Arctic and Antarctic experiments involving University of Kansas faculty and students. The ultimate goal of their research is to relate surface and subsurface ice features to SAR image characteristics through understanding the fundamental microwave mechanism. This relationship would then be used by glaciologist to learn more about the ice sheets and their behavior. Researchers from RSL have extensive experience in conducting microwave scattering experiments in the Antarctic. RSL currently has support from NASA through the NASA Graduate Student Researchers program to work on this problem.

There is an opportunity to apply the capabilities of ACTS to assist the RSL researchers in their science mission. We are proposing to use ACTS to provide near real-time feedback to RSL researchers. The experiment would consist of SAR image collection of Antarctic ice, SAR image processing performed at Fairbanks, Alaska in the SAR data processing center, transmission of the SAR images directly to the University of Kansas using ACTS, SAR image analysis performed at the University of Kansas, transmission of the results of the image analysis to Antarctic field experimenters using ACTS, and feedback of microwave scattering field data to the University of Kansas using ACTS. The rapid distribution of information in this experiment will enable RSL researchers to rapidly correlate SAR image and ice features; further the attention of the field party can be focused on areas of interest based on the analysis of recent SAR images. The ACTS system would allow rapid interaction between on campus researchers and the field team, increasing amount of the knowledge that can be obtained for each experiment. Further the communications aspects of this experiment provides a mechanism to test EOS/DIS concepts using ACTS.

The effectiveness of the microwave scattering experiments will be increased by using ACTS to provide rapid communications of research data during the field experiments. Three ground sites will be involved in the communications process. The spaceborne SAR will collect the raw SAR signals, and these signals will be processed at the Fairbanks, Alaska SAR processing facility. Large SAR data sets covering the ground experiments sites will be rapidly processed in Alaska and then transferred to the University of Kansas through ACTS. A quick turnaround of SAR images is critical for this project. RSL will then apply algorithms to estimate the geophysical features from these data. Features of specific interest will be communicated to the RSL researches in the field through ACTS. Ground scattering data will also be transmitted to RSL researchers through ACTS. The field team will then be able to collect ground truth for those features of interest. Sites of specific interest will be identified by the RSL researchers and communicated to the field team through ACTS; ground truth and local scattering data for these sites will then be collected by the field team and communicated back to Kansas. These data will be used to further understand microwave scattering from ice.

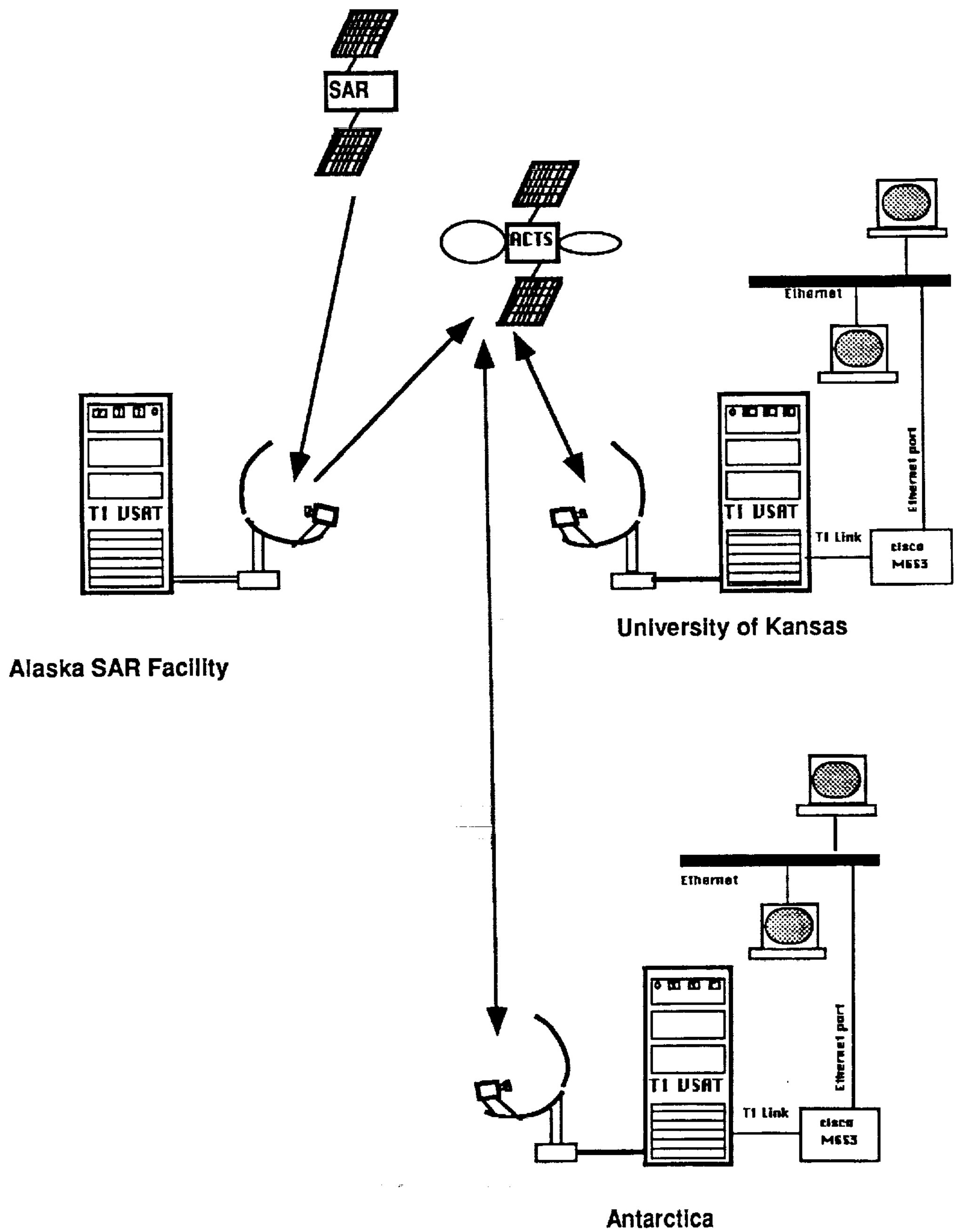

Figure 2: Experiment configuration for Remote Collection of Antarctic Scattering Data using the ACTS.

The communications network providing the above conductivity is based on the ACTS T1 ground terminal. A cost effective way of interconnecting existing ground computing facilities using the ACTS T1 terminal will be to employ Ethernet to T1 gateways. Note most computing facilities have Ethernets and commercial Ethernet to T1 gateways are available, some specifically designed to be used over satellites. In addition, Ethernet connectivity for workstations and PC's is very common. Thus three Ethernet to T1 gateways will be required in this experiment. Some specialized hardware and software may be required to format the information for the various sites. The communications network is shown in Figure 2.

The following tables summarize the components that will be needed for the experiment and the expected costs:

Table 1: Component Costs for Antarctic Site

	Quantity	*Item*	*Unit Price*	*Cost*
Router				
	1	MGS/3	9,275	9,275
	1	1E2T ethernet & 2 serial	4,100	4,100
	1	1T High speed serial	2,625	2,625
	3	RS 449 DTE applique	150	450
		Total		16,450
		(Minus 30% University discount)		*4,935*
		Cost for Router		**11,515**
Video Conferencing System				
	1	Codec board	8,000	8,000
	1	IBM compatible PC	3,000	3,000
	1	Monitor	700	700
	1	Camera	1,000	1,000
	1	Other (cables, etc.)	250	250
		Cost for Video Conferencing System		**12,950**
Other				
	1	Cabling and Miscellaneous		1,000
Total Equipment Costs for Antarctic Site				**25,465**

Table 2: Component Costs for Lawrence Site

	Quantity	*Item*	*Unit Price*	*Cost*
Router				
	1	MGS/3	9,275	9,275
	1	1E2T ethernet & 2 serial	4,100	4,100
	1	1T High speed serial	2,625	2,625
	3	RS 449 DTE applique	150	450
		Total		16,450

	(Minus 30% University discount)		*-4,935*
	Cost for Router		**11,515**
Video Conferencing System			
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1	IBM compatible PC	3,000	3,000
1	Camera	1,000	1,000
1	Other (cables, etc.)	250	250
	Cost for Video Conferencing System		**12,950**
Other			
1	Cabling and Miscellaneous		**1,000**
Total Equipment Costs for Lawrence Site			**25,465**

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