Utilization of Internet Protocol-Based Voice Systems in Remote Payload Operations

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ABSTRACT

Due to limited crew availability to support science and the large number of experiments to be operated simultaneously, telescience is key to a successful International Space Station (ISS) science program. Crew, operations personnel at NASA centers, and researchers at universities and companies around the world must work closely together to perform scientific experiments on-board ISS. The deployment of reliable high-speed Internet Protocol (IP)-based networks promises to greatly enhance telescience capabilities. These networks are now being used to cost-effectively extend the reach of remote mission support systems. They reduce the need for dedicated leased lines and travel while improving distributed workgroup collaboration capabilities.

NASA has initiated use of Voice over Internet Protocol (VoIP) to supplement the existing mission voice communications system used by researchers at their remote sites. The Internet Voice Distribution System (IVoDS) connects remote researchers to mission support "loops" or conferences via NASA networks and Internet 2. Researchers use IVoDS software on personal computers to talk with operations personnel at NASA centers. IVoDS also has the capability, if authorized, to allow researchers to communicate with the ISS crew during experiment operations. IVoDS was developed by Marshall Space Flight Center with contractors AZ Technology, First Virtual Communications, Lockheed-Martin, and VoIP Group. IVoDS is currently undergoing field-testing with full deployment for up to 50 simultaneous users expected in 2002.

Research is being performed in parallel with IVoDS deployment for a next-generation system to qualitatively enhance communications among ISS operations personnel. In addition to the current voice capability, video and data/application-sharing capabilities are being investigated. IVoDS technology is also being considered for mission support systems for programs such as Space Launch Initiative and Homeland Defense.

1.0 INTRODUCTION

This paper will describe a new and innovative system for voice communications supporting International Space Station (ISS) payload operations. This system is Internet Voice Distribution System (IVoDS). An overview of IVoDS and current project status will be provided, as well as project experience with using Commercial-Off-The-Shelf (COTS) voice conferencing products.

POIC OVERVIEW

The Payload Operations and Integration Center (POIC) is located at Marshall Space Flight Center in Huntsville, AL. The POIC is an International Space Station (ISS) facility that manages the execution of on-orbit ISS payloads and payload support systems in coordination with the Mission Control Center in Houston (MCC-H), the distributed International Partner Payload Control Centers, Telescience Support Centers, and payload-unique facilities (NASA, 1999).

The POIC provides capabilities required by the POIC Cadre to manage and integrate payload operations. The POIC also provides capabilities required by individual payload users to operate and control their payloads and experiments. In addition to telemetry and command processing and video distribution, the POIC provides mission voice communication. The MSFC-developed POIC is the source of payload voice communications to all payload users.

The POIC voice communications system architecture is shown in Figure 1. The POIC supports over 100 simultaneous voice "loops" or conferences. Each conference may have dozens of participants distributed across North America. During normal operations, a user participates in several conferences simultaneously to monitor mission status. The existing circuit-switched telephony system and the new system both extend voice communications to remote payload user sites as shown in Figure 1.

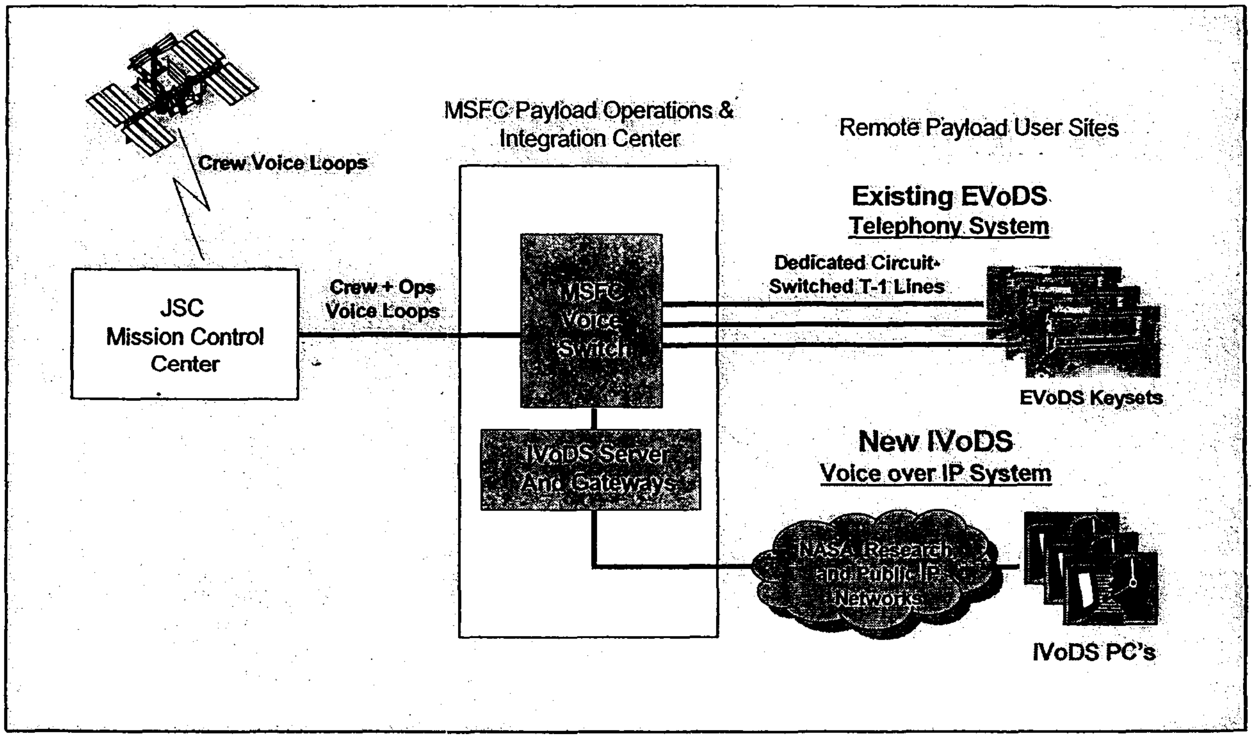

Figure 1. POIC Voice Communication System Architecture

ENHANCED HOSC SYSTEMS VOICE DISTRIBUTION SYSTEM (EVoDS)

EVoDS is the current voice distribution system that MSFC uses to provide voice communications to all POIC internal and remote users. The system allows for around the clock secure voice conferencing with the space station crew, operations personnel, and the remote payload users.

EVoDS is a telephony-based, circuit-switched system that provides voice loops extended from the POIC to remote payload user sites via dedicated fractional T-1 lines. The system is comprised of a central voice switch and user voice instruments known as key sets (Figure 2). The key sets allow the user to only select from up to 18 voice conferences without additional configuration. They allow talk capability in one conference at a time and they allow the user to access a regular phone line through the key set.

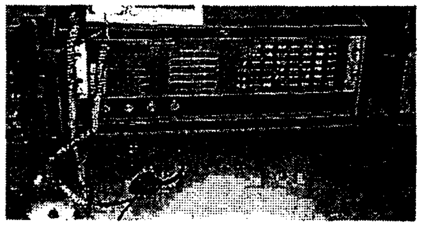

Figure 2. EVoDS Key set

RATIONALE FOR NEW VOICE SYSTEM FOR REMOTE USERS

The nature of NASA payload operations has changed over the past decade during the transition from Spacelab to Space Station. Two-week periods of intense operations during Shuttle missions have been replaced by continuous operations for International Space Station. Previously, most researchers traveled to the NASA centers to operate and monitor their experiments. Now they need to operate from their home sites. The number of remote POIC voice system users has increased to 50 short-term and 200 long-term. The result is a requirement for more telecommunications bandwidth for longer periods of time.

The current EVoDS system is very expensive to operate for the ISS program office. The leased circuit cost of each EVoDS session is approximately $9,000 a year and each key set costs $20,000 - $30,000. Maintenance cost for the EVoDS systems run about $37,000 per year. EVoDS has been implemented at a few remote sites during the early stages of payload operations as an interim solution. As the space station continues to grow and support more payload experiments there will be an increasing number of remote sites and International Partners that will require voice communications. The current system has been in place since the Spacelab missions from the early 90's and is nearing its end of life cycle. MSFC is planning to upgrade the EVoDS central system and the remote users' hardware will not be compatible with the new voice switch. The program office will no longer fund EVoDS and at this point the remote sites will have to incur the costs of leased circuits and voice equipment upgrades.

Realizing that this cost would be prohibitive for remote sites, MSFC sought a cost-effective alternative utilizing COTS equipment and recently deployed high speed, reliable Internets. The resulting Internet Voice Distribution System promises to be a cheaper alternative for our remote sites. IVoDS will run on a low-end PC costing $500 - $1,500. Bandwidth cost for using NASA Standard IP networks will be around $2,000/year. Table 1 compares the system costs per remote user. Based on 50 remote users, the return on investment for the new system is estimated to be two to three years.

Table 1. Estimated Costs per Remote User

Service	EVoDS Cost	IVoDS Cost
Network Bandwidth	$9,000/year	$2,000/year
Maintenance	$1,000/year	$1,800/year
Hardware	$25,000	$1,000

2.0 IVODS OVERVIEW

USE OF INTERNETS IN PAYLOAD OPERATIONS

In the past few years NASA has begun to use Internet Protocol-based communications in real-time payload operations systems in a limited way. Architectures that use "Space Internets" for the entire path from flight vehicles to remote user sites are still in the research phase (Foltz, 2001). However, several systems have been developed that use IP networks for part of the path, such as connections from NASA operations centers to remote user sites (Chamberlain, 1999). New systems such as the MSFC Telescience Resource Kit (Schneider, 2001) have focused on telemetry data and commanding. Experience and success with these telemetry data systems has spurred interest in IP-based live telemetry voice and video systems, which typically have very demanding timing requirements.

Voice over IP promises savings in bandwidth utilization and costs over circuit-switched telephony via use of:

- Silence suppression and audio compression codecs
- Existing IP-based local and wide area networks already available for data communications

Circuit-switched telephony time division multiplexing schemes require a constant 64 Kilobits per second (Kbps) channel per audio stream (Black, 2000). VoIP audio codecs such as G.723 are advertised at 6-8 Kbps but in our experience measure 16 Kbps. When encrypted, the audio bandwidth use doubles. In a mission operations environment, a conference may have long periods of silence between activities. Utilizing silence suppression, additional bandwidth can be saved. Assuming a 50% talk usage rate, which still provides reserve for bursts of activity, the allocated bandwidth is about ~20 Kbps per audio stream - less than one-third that used by circuit-switched telephony. In addition, our VoIP application requires 2 Kbps housekeeping data per client. A typical user connected to 8 conferences thus requires 20 *8 + 2 = ~162 Kbps of reserved bandwidth. These statistics are summarized in Table 2.

Table 2. Bandwidth Usage Comparison

Bandwidth	Circuit-switched Telephony	Voice over IP
Per active audio stream	64 Kbps	16 Kbps
Per active, encrypted audio stream	N/A	40 Kbps
During silent periods, no audio	64 Kbps	0 Kbps
Per 50% silent encrypted audio stream	64 Kbps	20 Kbps
Housekeeping traffic	N/A	2 Kbps/client

Additional cost savings are possible through data and voice bandwidth consolidation: carrying voice traffic on existing local- and wide-area networks already available for data communications. For the POIC application, many remote users have access to the Internet 2 Abilene network and use it to receive telemetry data. This high-speed link provides adequate bandwidth and reliability for IVoDS. At the remote user site, there must be sufficient bandwidth from the campus/corporate Internet 2 router to the researcher payload operations location. The bandwidth costs from the POIC to the NASA networks-Internet 2 access point are $2,000 per remote site per year. This compares with an average $9,000 annual leased circuit cost for dedicated bandwidth the entire distance from the POIC to the remote site.

RISK MITIGATION

Balancing the potential cost-savings of IVoDS are three primary risks:

- Security concerns
- Lack of Quality-of-Service (QoS) guarantees on existing utilized IP networks
- Early adoption of new technology

Utilizing networks shared by multiple organizations and applications introduces risks. NASA is very concerned with ensuring that its systems are secure, and that no risk is introduced to either the payload or the vehicle and its crew. This risk is mitigated by use of Virtual Private Networks (VPN), which are widely used in commercial and military applications. Both the POIC and remote sites conform to MSFC security requirements.

The NASA, Internet 2, and remote site networks do not currently allow for end-to-end QoS. Data, voice, and video traffic all have equal priority. A network may experience bursts of activity that result in lost voice packets. Several technical, operational, and test procedures help mitigate this risk. The audio codecs provide redundancy to minimize the effects of brief outages. NASA manages its networks for numbers of users and applications allowed while providing reserve bandwidth. The Internet 2 is closely managed and provides high-speed 2 Gigabit per second connections. The remote site is responsible for its QoS. Client simulators and audio-loading simulators are used to test the clients, servers, and networks for "worst-case" bandwidth usage. For example, a typical test will include 10 real users and 40 simulated users to reach the IVoDS 50-user limit. The simulators also helped reduce the costs of testing with real users and PC's.

VoIP technology is relatively new, with limited commercial use beginning in the late 1990's. As with any project that adopts "leading edge" technology and products, there is a technical risk associated with the ability to successfully design a system which meets all requirements. In addition, there is vendor and standards risk in the volatile VoIP market. This risk has been mitigated through development and testing of a prototype system and close cooperation with the vendors.

Feasibility of using VoIP for a voice conferencing system was demonstrated in 1998-1999. An educational program was developed that involved NASA National Educators Workshop teachers in 28 schools around the U.S. (Figure 3). Computers located in school science labs and classrooms were connected via the public Internet to the POIC. The prototype system worked consistently well for the 6-month test period. It also provided excellent VoIP experience and user interface design feedback. The voice quality was considered adequate, and became the standard against which to evaluate the operational system.

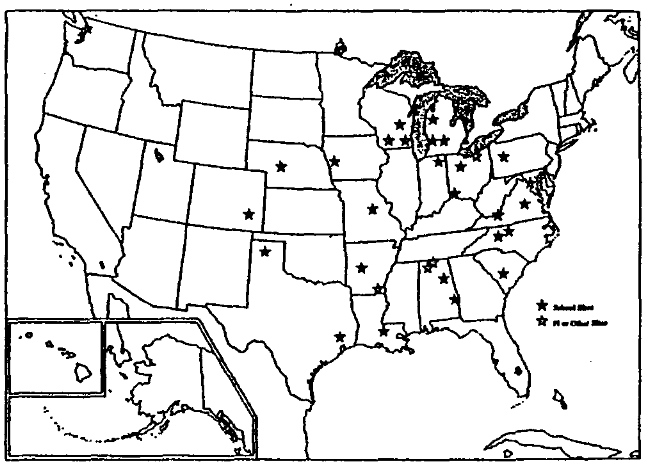

Figure 3. Remote School Sites for Prototype System

IVODS ARCHITECTURE

The IVoDS operational system includes three major components (Figure 4):

1. IVoDS user client PC's at remote sites
2. Internet Protocol network connections to the POIC
3. Voice, administrator, and encryption servers located in the POIC

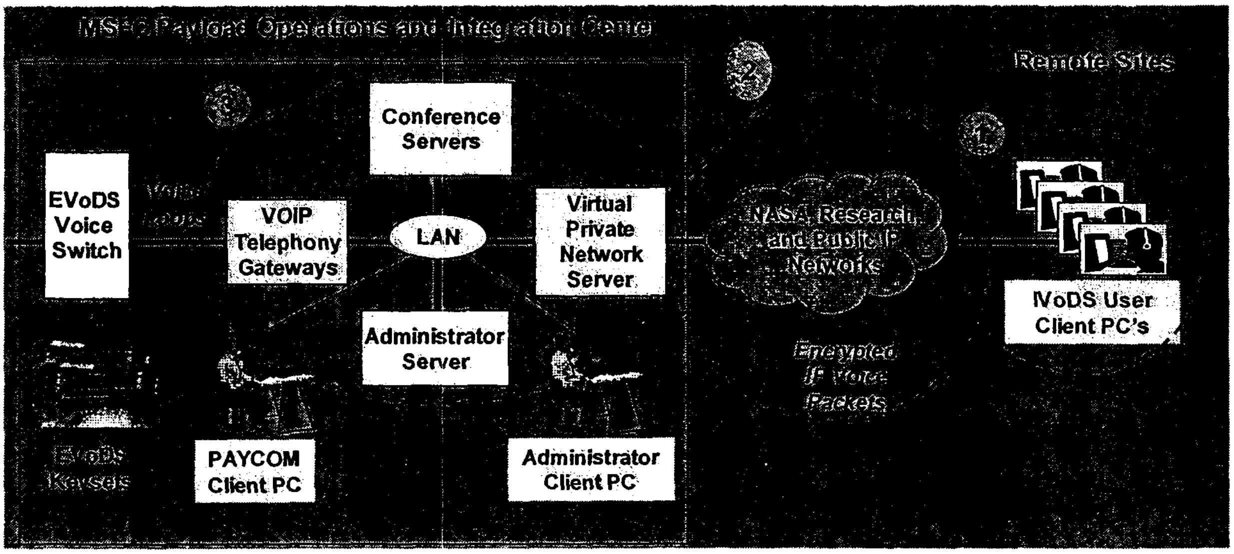

Figure 4. IVoDS Architecture

IVODS USER CLIENT PC'S

A remote user requires a low-end (e.g., 500 MHz) Windows NT/2000 personal computer with COTS sound card and headset (Figure 5). Internet Explorer and VPN software are required. The IVoDS client software is Web-based for easy installation and use. Central Processing Unit usage is minimal, approximately 2% per active stream. The IVoDS PC location is very mobile – anywhere on an internet that can access the POIC. Bandwidth of 40 Kbps per conference should be available.

Figure 5. IVoDS Users in the POIC

Before being allowed to connect to any conference, users must authenticate using a VPN, then login to IVoDS with a valid username/password. The IVoDS client main window (Figure 6) contains 8 rows of identical conference-related controls. Users can connect to 8 voice conferences and independently adjust volume and muting for each. The green/red LED's signify both connection status and talk activity. The column of "Talk" radio buttons assures users talk in only one conference at a time. While users talk and listen in the "talk" conference, they can still hear the other seven conferences.

Objective measures of voice quality are difficult to obtain. The quality of the IVoDS audio has been measured subjectively by users in a series of tests. Mean Opinion Scores (MOS) have consistently been greater than 4 using the scale in Table 3.

IP NETWORK CONNECTIONS TO POIC

The network path from the remote site to the POIC is the key factor in audio quality and reliability. For wide area access, research and education networks (REN) such as the NASA REN and the Internet 2 network are recommended. Most have acceptable use policies generally barring nonscience and public traffic. They are more centrally managed than the public Internet, thus minimizing latency and congestion problems.

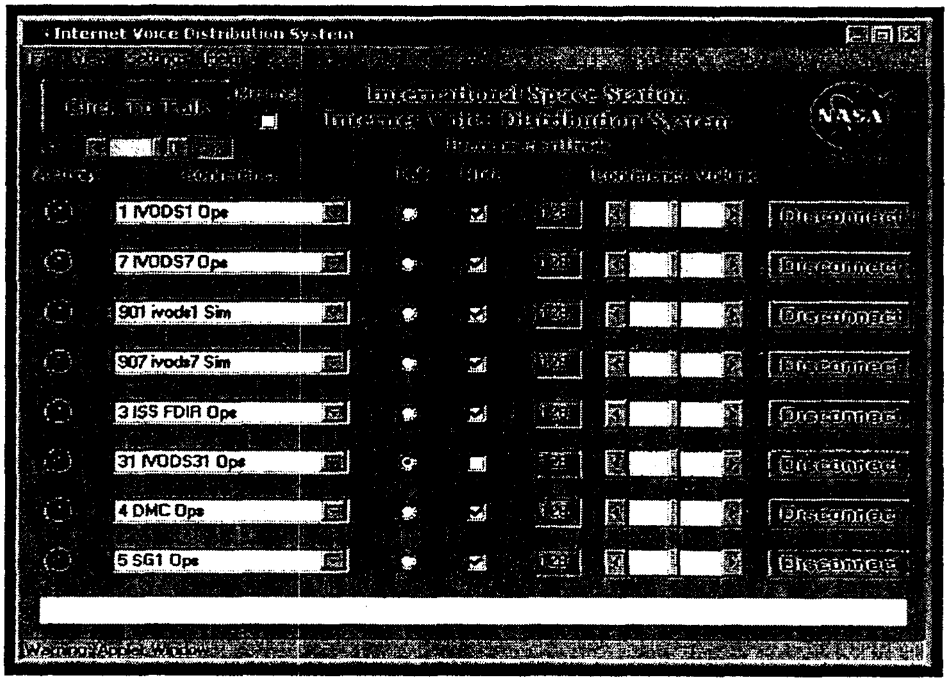

Figure 6. IVoDS User Interface

Table 3. Scale Used for Rating Audio Quality

Signal Strength	Readability
5 = Loud	5 = Clear
4 = Good	4 = With distortion
3 = Weak	3 = With background noise
2 = Barely Audible	2 = With fading but readable
1 = Noise	1 = Unreadable

Many IVoDS users are connected to the POIC via the Abilene network. Hundreds of universities, government agencies, and corporations are members (Figure 7). Abilene provides high-speed 2 Gigabit per second connections to its backbone. Utilization of existing IP networks avoids NASA involvement in remote site communications engineering and installations. However, point-to-point circuit/service is always an option if necessary. Remote sites with firewalls must open two ports required by the VPN.

The public Internet has also been used in IVoDS testing in the past 6 months. Audio quality has been very similar on the public Internet to that on Abilene. The main concern is congestion during busy Internet periods (e.g., early afternoon). The IVoDS developer uses a T-1 line to its Internet Service

Provider, with approximately 10 hops to the POIC via Atlanta and the Washington, D.C. area before entering the NASA network. This site experiences at most a few minutes per month of congestion that degrades audio.

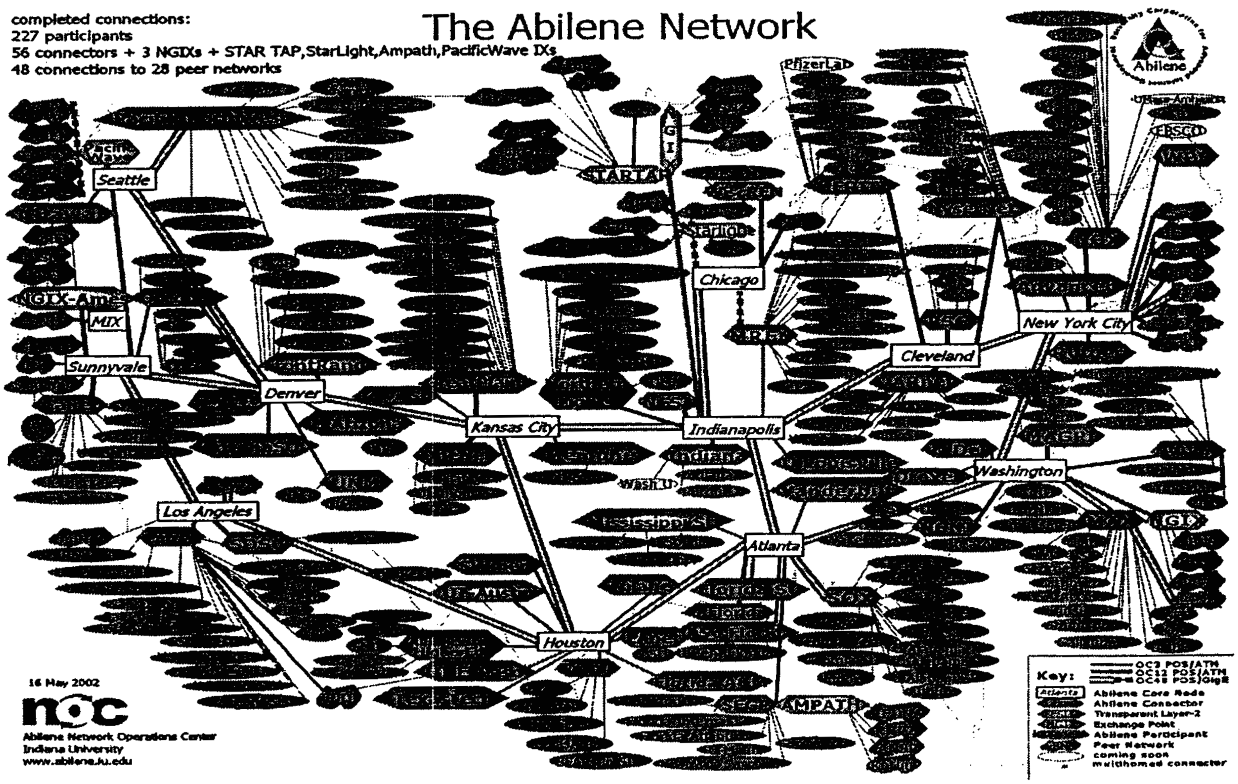

Figure 7. The Abilene Network Used by Many IVoDS Remote Sites

IVODS SERVERS

The core component of IVoDS is the conference server (Figure 4). It establishes H.323 connections with the clients, mixes the audio from all talkers, and sends the audio out to all listeners. The IVoDS software is built around the COTS conference server and web client toolkit produced by First Virtual Communications (FVC). These products are used extensively in the commercial market.

AZ Technology (AZTek), the prime contractor, developed the IVoDS-unique software to interface with and control the conference servers, maintain the user database, authenticate users, and control talk authority on Air/Space-to-Ground conferences. In addition, AZTek developed the multi-conference IVoDS client that provides the interface to the end-user.

The IVoDS servers are easily scalable by simply placing additional servers on-line and adding them to the Administrator's configuration. The quantity of voice servers is transparent to the end user. The servers can be co-located or distributed across remote sites, if required, to reduce network traffic between sites. The administrator server manages the users and conferences while coordinating the conference servers.

The gateways, developed by VoIP Group, convert audio between the telephony-based EVoDS voice switch and the H.323-based Conference Server. The gateways connect EVoDS users to IVoDS users in up to 96 conferences (e.g., Crew Air-to-Ground).

The VPN Servers provide high-speed user authentication and strong encryption utilizing a military standard. The VPN servers were integrated with IVoDS by the POIC facility operator, Lockheed-Martin.

3.0 DEVELOPMENT APPROACH: MODIFIED COTS

IVoDS could not be put together with COTS-only products. At the same time, for the voice solution to be cost effective, it could not be custom built. In addition to the difficulty in finding the right developer for this type of complex system, there would be limited marketability for the completed product. The unique system required a modified COTS approach. Our goal was well-defined custom-COTS interfaces utilizing standards and toolkits/Application Programming Interfaces (API). The resulting percentage of custom code was very low (Table 4).

Table 4. COTS vs Custom Percentages

IVoDS Component	% COTS
VPN Server	100
Conference Server	100
Administrator Server	80
Telephony Gateways	90
IVoDS User Client PC Hardware	100
IVoDS User Client PC Software	50

MSFC REQUIREMENTS DRIVE ENHANCEMENTS TO COTS PRODUCTS

The IVoDS requirements and NASA cooperation with vendors have lead to incorporation of IVoDS features into the COTS products. This benefits both NASA and the vendor. The vendor has a better product, while NASA is insured that enhancements are included in future COTS product releases, avoiding one-off, "step child" versions that don't get vendor attention. NASA is able to upgrade to new product releases. Enhancements were made to two key COTS products:

- VPN server
- FVC Conference Server and Web toolkit

Prior to IVoDS development, the POIC was already using VPN on a Sun platform for the telemetry and command ground processing system. The VPN requirement is to support 50 users, which equates to 16 Mbps (Megabits per second) of "worst case" bandwidth. Future expansion requires support for 200 users (64 Mbps). Like most commercial VPN's, the product had been optimized for data traffic, which utilizes large (~1500 byte) packets. It could process up to 80 Mbps utilizing the 1500-byte packet size. However, due to the small 100-byte size of voice packets and resulting large number of packets, the VPN could only process 3.2 Mbps of IVoDS audio, which equates to 10 users.

The VPN integrator Lockheed-Martin and the vendor investigated improving performance by running on a high-end server with a load-balancing solution. Around the same time that faster processors became available, the vendor released a new product on the Linux platform. Because they could access the source code for Linux, the vendor rewrote the driver for the Intel EtherExpress 1000 gigabit card. This improved performance to approximately 63 Mbps. This new driver is currently on the market. The VPN is now suitable for both high-speed data and audio processing.

MSFC and FVC experienced similar benefits integrating the FVC conference server into the IVoDS application. Reliability and performance of the conference server increased dramatically during the year-long development effort. MSFC requirements for the development of the IVoDS system have contributed to better COTS products being available on the market.

4.0 PROJECT STATUS AND POTENTIAL FUTURE ENHANCEMENTS

IVoDS was released to ISS Increment 5 remote users in May 2002. Shadow operations for that increment began in June. After running with IVoDS and EVoDS in parallel for three months, MSFC will hold an Operational Readiness Review. At that time, the decision will be made whether to utilize IVoDS as the primary system or run in shadow mode again for Increment 6. Initial success with IVoDS testing has encouraged other NASA centers and ISS International Partners including Italy and Canada to consider using IVoDS for voice hubs at their payload operations centers.

Outstanding IVoDS operational and maintenence issues include:

- Variable quality of some public Internet connections for remote users without research/science network access.
- Maintaining compatibility among new releases of COTS products.
- Maintaining good engineering support relationships among the customer, developers, and facility support contractor despite limited budgets.
- Addition of dynamic failover to the backup VPN server.

Research is being performed in parallel with IVoDS deployment for a next-generation system to take full advantage of the digital world - the personal computer and Internet Protocol networks - to qualitatively enhance communications among ISS operations personnel. In addition to the current voice capability, video and data/application-sharing capabilities are being investigated. Major obstacles being addressed include bandwidth limitations in existing unicast-based networks and strict security requirements. Techniques being investigated to reduce and overcome these obstacles include emerging audio-video protocols, network technology including multicast and quality-of-service, and faster, more secure encryption algorithms. IVoDS technology is also being considered for mission support systems for programs such as Space Launch Initiative and Homeland Defense.

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IVoDS
Internet Voice Distribution System

Space Ops 2002 Conference
Ground Segment Engineering And Architectures Session

October 9, 2002

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Information Technology Group
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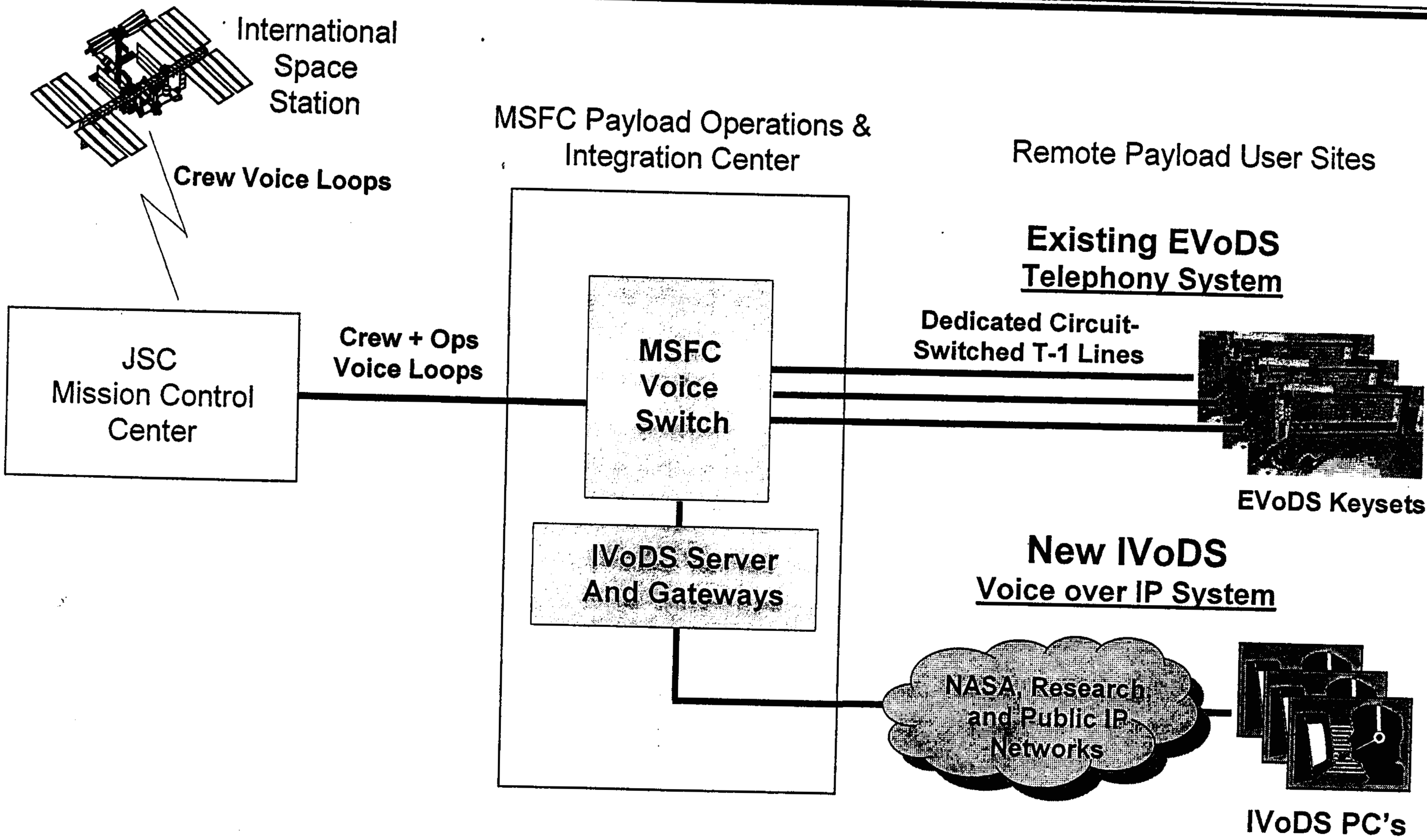
Purpose of Presentation

- Describe an innovative and cost-effective voice communications system
  - Internet Voice Distribution System (IVoDS)
  - Supports International Space Station (ISS) payload operations
- Provide Overview of IVoDS Architecture
- Share Lessons Learned
  - COTS, Standards, Customization for Unique Requirements
  - MSFC's Influence on Marketable Products
- Review Project Status
  - Potential Future Enhancements
  - Technology Transfer To Other Applications

Payload Operations and Integration Center (POIC) Background

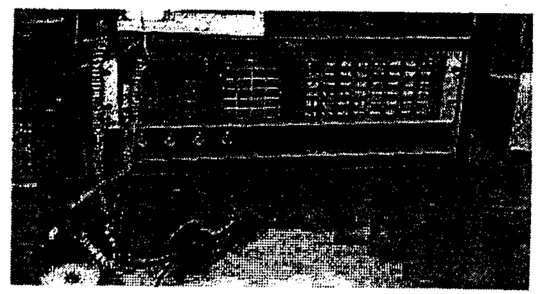
- Ground support facility that manages the execution of on-orbit ISS payloads and payload support systems in coordination with:
  - Mission Control Center in Houston
  - Distributed International Partner Payload Control Centers
  - Telescience Support Centers
  - Payload-unique facilities at universities, corporations, etc.
- Primary ISS users:
  - Internal POIC Cadre: management and integration of payload operations
  - Remote payload users: remote site operation and control of payloads and experiments
- Primary ISS services:
  - Telemetry and command processing
  - External data communication interfaces
  - Video distribution
  - **Voice communications**

POIC Voice Communications System Architecture



Enhanced Huntsville Operations Support Center Voice Distribution System (EVoDS)

- Existing system providing voice communications to all POIC internal and remote users
  - Secure 24x7 voice conferencing system connecting Space Station crew, operations personnel, and remote payload users
  - Telephony-based, circuit-switched system
- Consists of central voice switch and user voice instruments or "keysets"
- Voice loops extended from POIC to remote payload user sites via dedicated T-1 lines
- Keyset features
  - Allows user to only select from up to 64 voice loops without additional configuration
  - Talk on one loop using handset with push to talk button
  - Able to access regular phone line through key set

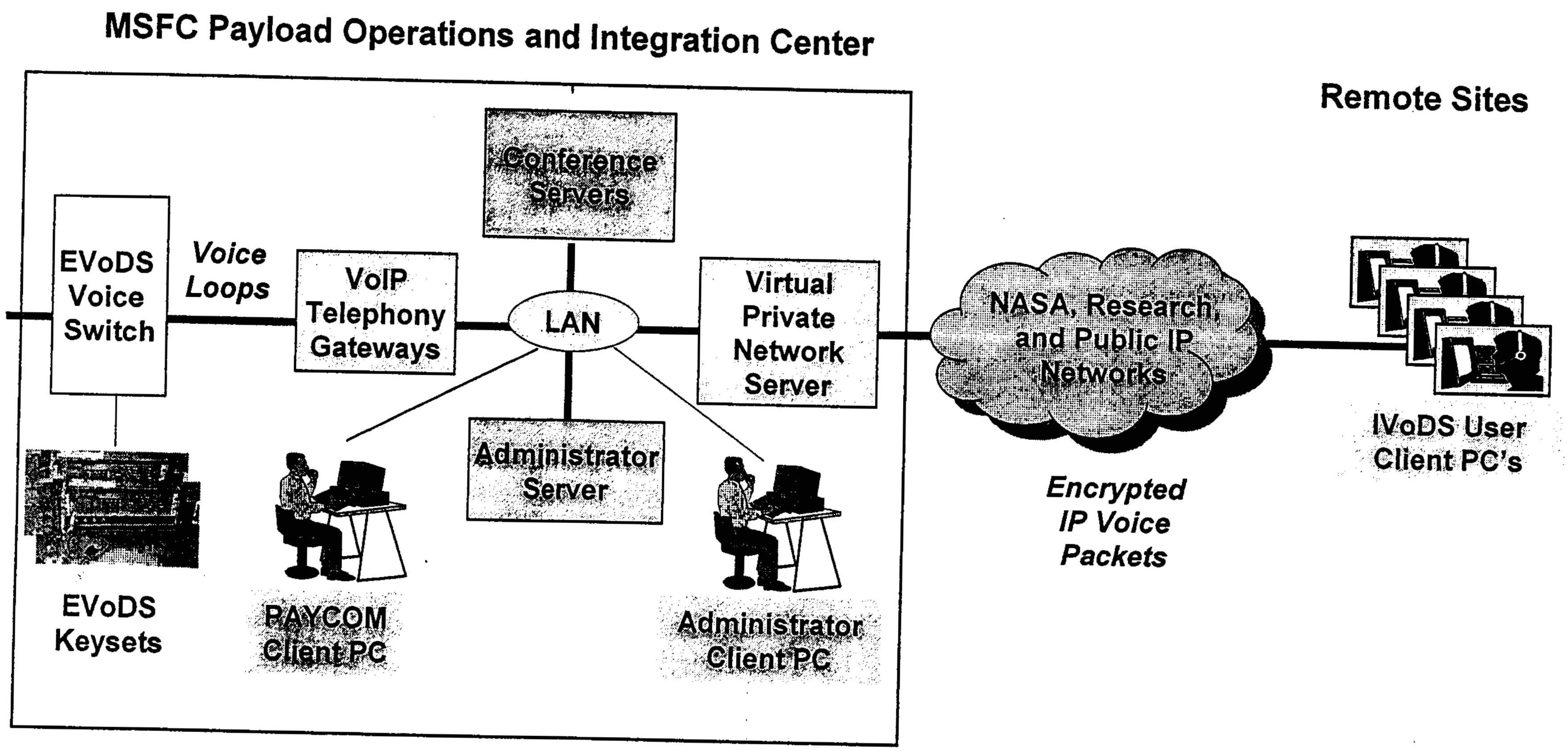


Rationale for New Voice System for Remote Users

- EVoDS is expensive for remote sites
  - Custom keyset, headset, and communications equipment
  - T-1 leased line to remote site
- EVoDS is nearing end-of-life (utilized for 12 years)
- Large number of remote users
  - Initial support for 50 remote users
  - Expansion to 200 remote users
  - Potential additional remote voice hub sites (e.g., European Space Agency)
- Seeking cost-effective alternative utilizing:
  - Commercial-off-the-Shelf (COTS) voice equipment
  - Existing high-speed, reliable internets
- Estimated costs per user (50-user system):

Service	EVoDS Cost	IVoDS Cost
Network Bandwidth	$9,000/year	$2,000/year
Maintenance	$1,000/year	$1,800/year
Hardware	$25,000	$1,000

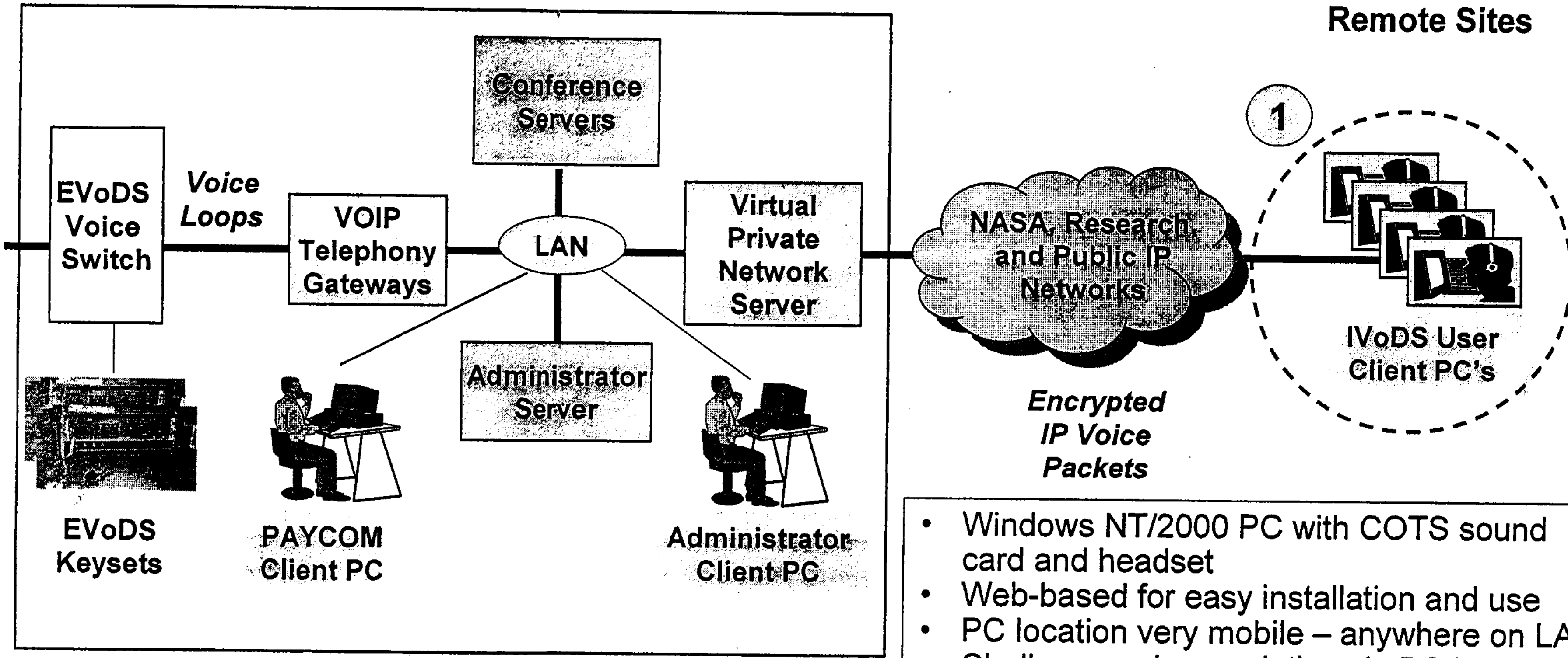
Internet Voice Distribution System (IVoDS) Architecture



Internet Voice Distribution System (IVoDS)
Overview

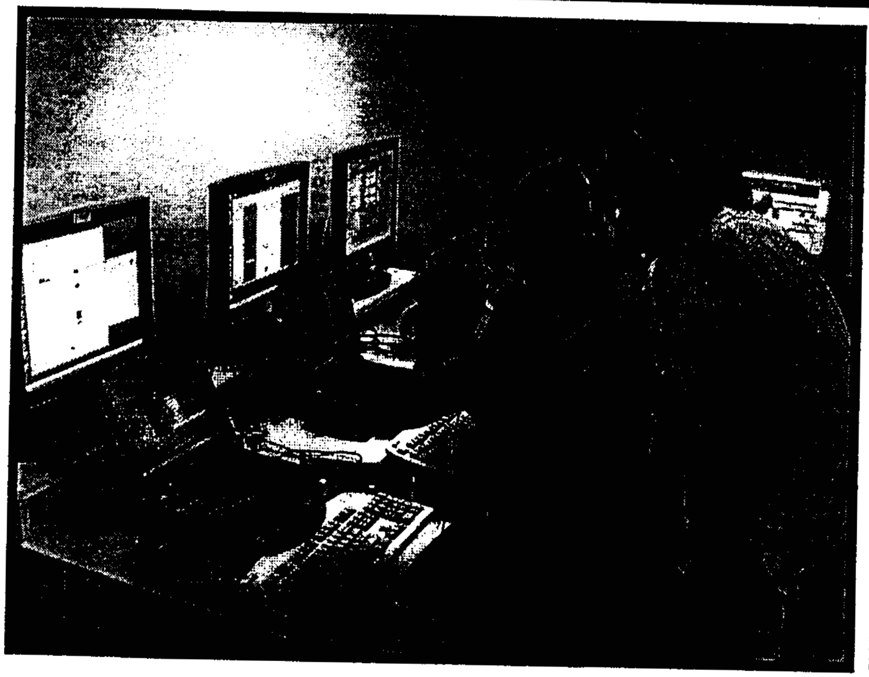
- Extends the existing telephony-based EVoDS voice switch utilizing Voice over Internet Protocol (VoIP) technology
- Remote users located at NASA centers, universities, and companies throughout North America
- Three major components:
  1. IVoDS user client PC's at remote sites
  2. Internet Protocol network connections to the POIC
  3. Voice, administrator, and encryption servers located in the POIC

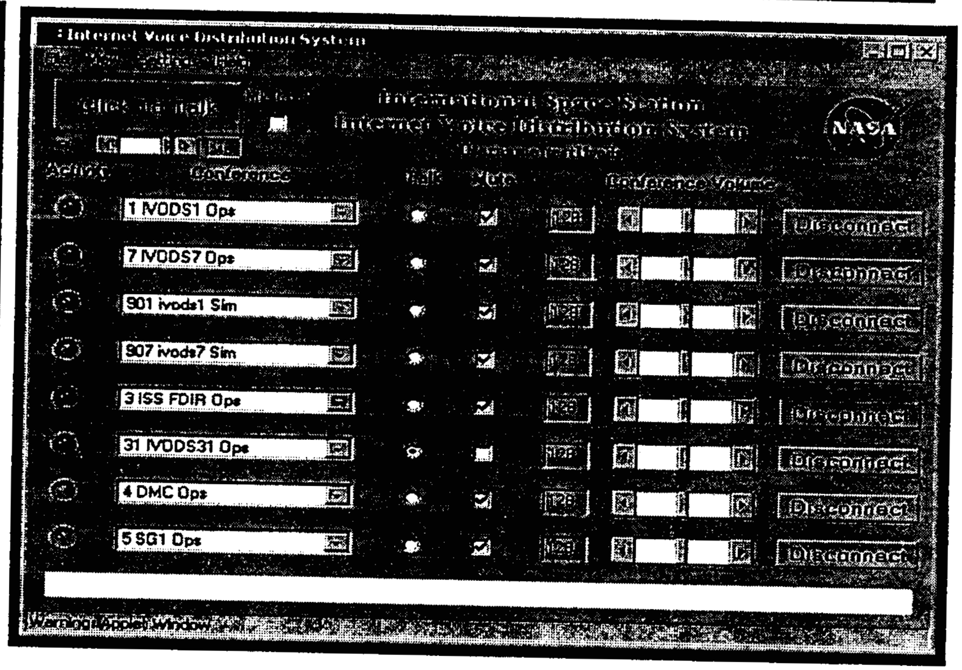
IVoDS User Client



- Windows NT/2000 PC with COTS sound card and headset
- Web-based for easy installation and use
- PC location very mobile – anywhere on LAN
- Challenge: minor variations in PC hardware and software configurations at remote sites

IVoDS User Client

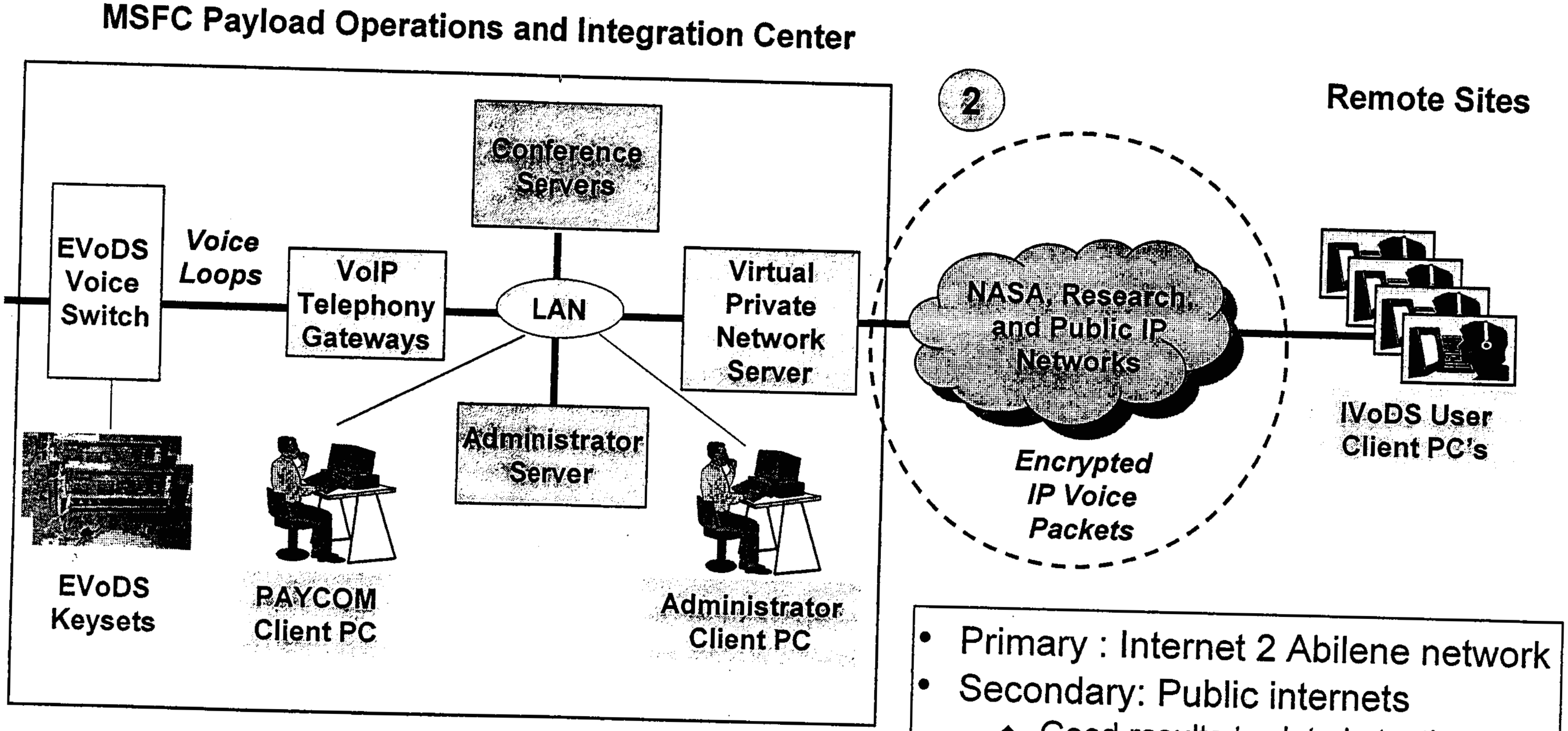




Capabilities

- Monitor 8 conferences simultaneously, talk on one
- User selects from authorized subset of available voice conferences
- Volume control/mute for individual conferences
- Assign talk and monitor privileges per user
- Show lighted talk traffic per conference
- Talk to crew on Space (Air) to Ground if enabled by PAYCOM

IP Network Connections to POIC

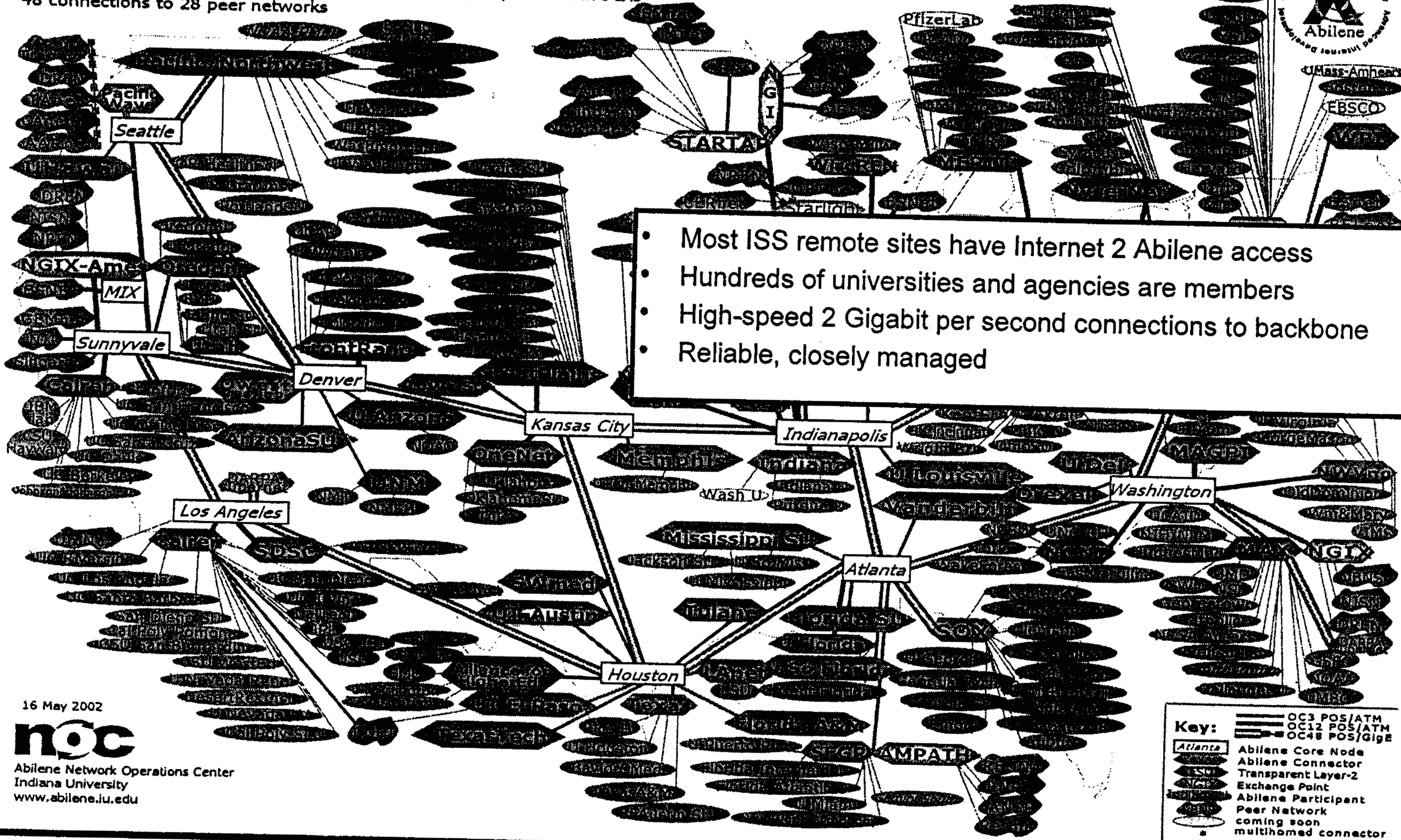


- Primary : Internet 2 Abilene network
- Secondary: Public internets
  - Good results to-date in testing
  - Depends on path, congestion

IP Network Connections to POIC

completed connections:
227 participants
56 connectors + 3 NGIXs + STAR TAP,StarLight,Ampath,PacificWave IXs
48 connections to 28 peer networks

The Abilene Network

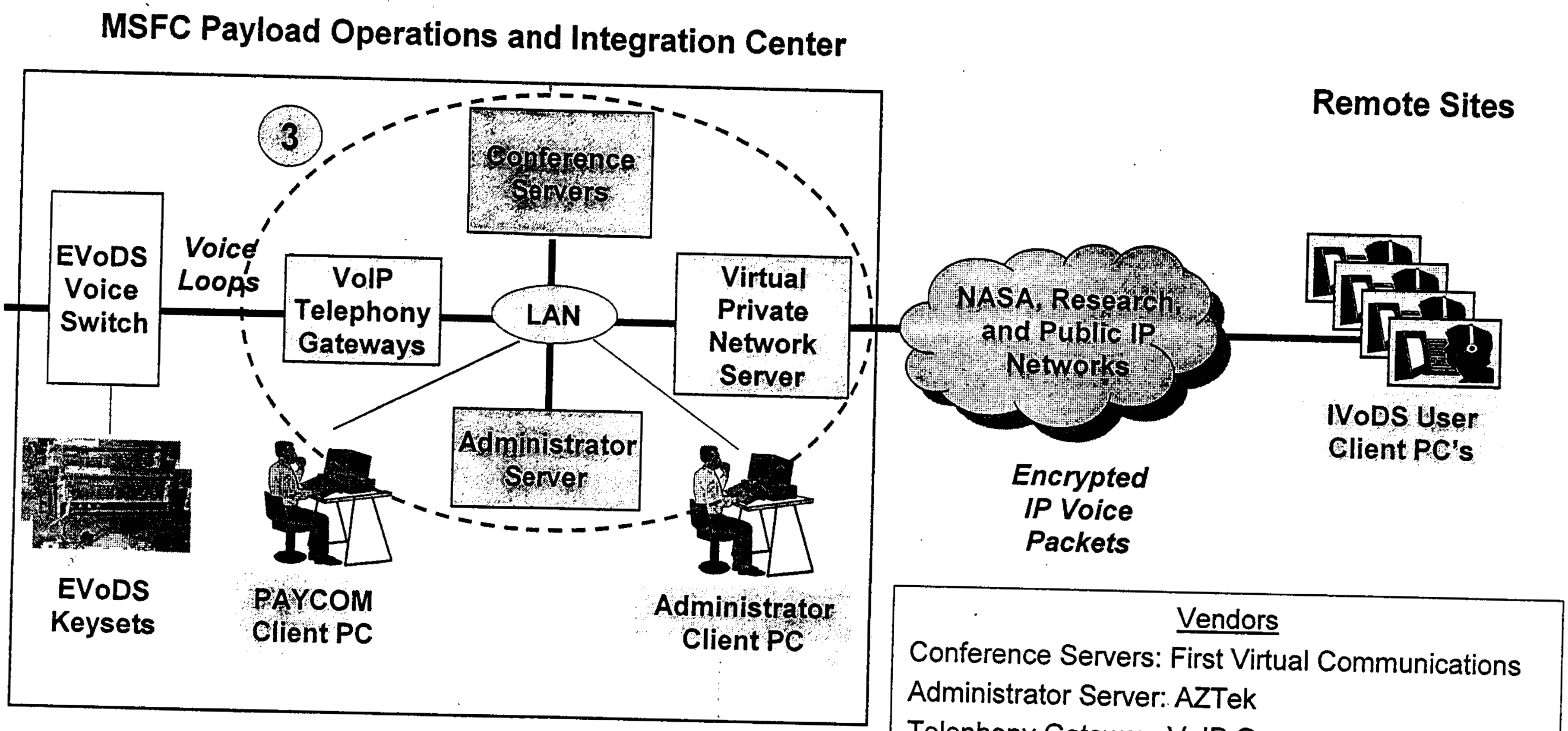


- Most ISS remote sites have Internet 2 Abilene access
- Hundreds of universities and agencies are members
- High-speed 2 Gigabit per second connections to backbone
- Reliable, closely managed

16 May 2002

noc
Abilene Network Operations Center
Indiana University
www.abilene.iu.edu

IVoDS Servers



Vendors

Conference Servers: First Virtual Communications
Administrator Server: AZTek
Telephony Gateway: VoIP Group

IVoDS Servers

- Virtual Private Network (VPN) Server
  - Provides user authentication and strong encryption
  - Connects to VPN client on remote IVoDS PC
- Conference Servers
  - Host conferences to which clients connect. Provide mixing of incoming audio streams and output of mixed stream to clients
  - Servers can be chained to scale processing power required
- Administrator Server
  - Manages the users and conferences, controls Conference Servers
- Telephony Gateways
  - Convert EVoDS telephony traffic to IP packets

Design: Mixing COTS and Custom Components

- System design options:
  1. COTS-only products. Not possible – IVoDS-unique requirements.
  2. Build "from scratch". Difficultly finding right developer for complex system with limited marketability. Expensive.
  3. **Modified COTS.** IVoDS approach taken. Systems integrator selects component vendors who will modify their COTS products to meet requirements.
- Goals: 100% COTS. When custom code required, well-defined custom-COTS interfaces utilizing standards and toolkits/ Application Programming Interfaces (API)
- Results - estimated percentage of COTS vs. custom code:

IVoDS Component	% COTS
VPN Server	100
Conference Server	100
Administrator Server	80
Telephony Gateways	90
IVoDS User Client PC Hardware	100
IVoDS User Client PC Software	50

Lessons Learned: "Modified COTS" Approach

- Suggestions for customer:
  - Require close systems integrator and operations organization communications during systems development to minimize long-term maintenance costs
  - Modified COTS products invariably require long-term engineering support from the vendor
    - Make an agreement up-front on fixed or per-hour fees
  - Insure rights to licenses, source code, designs, etc.
    - Require delivery of source code in event COTS vendor discontinues support for product. "Third-party escrow" is most secure method but expensive.
- Suggestions for system integrator:
  - Clearly define role of COTS in subcontracts and purchase agreements with vendors
    - Even if not "required", have customer review and approve all subcontracts and purchase agreements that impact long-term maintenance.
  - Utilize toolkits/API's for custom-COTS interfaces
  - Utilize standards to extent possible
  - Identify second sources for COTS products when possible
- Suggestions for COTS vendors
  - Define modified-COTS product descriptions, part #'s, special configurations, and ordering information in a price list that can be used by customer procurement and vendor sales organizations for future purchases and maintenance

MSFC's Requirements Driving COTS Changes

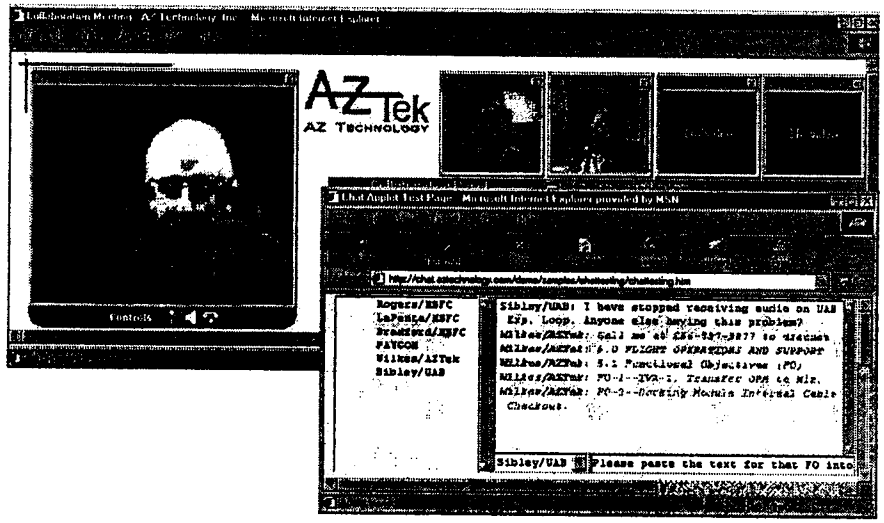
- Goal: insure enhancements are included in future COTS product releases
  - Avoid "one off", "step child" version that doesn't get COTS vendor attention
  - Be able to upgrade to/benefit from new releases
- Virtual private networks
  - Challenge: COTS VPN's are optimized for large packet, non-time sensitive traffic. Small voice packet size causes performance problems.
  - VPN vendor rewrote the driver for the Intel EtherExpress 1000 card
  - IVoDS requirements helped drive a better product which is now on the market
- First Virtual Communications - Voice servers and client toolkit
  - Challenge: COTS conferencing products are designed for business use. User participates in only one conference at a time, not eight.
  - FVC enhancements: client toolkit, support for multiple conference streaming
  - IVoDS requirements drove:
    - CUWeb Client 2.0 toolkit release
    - Conference Server Version 6 voice performance improvements

Project Status

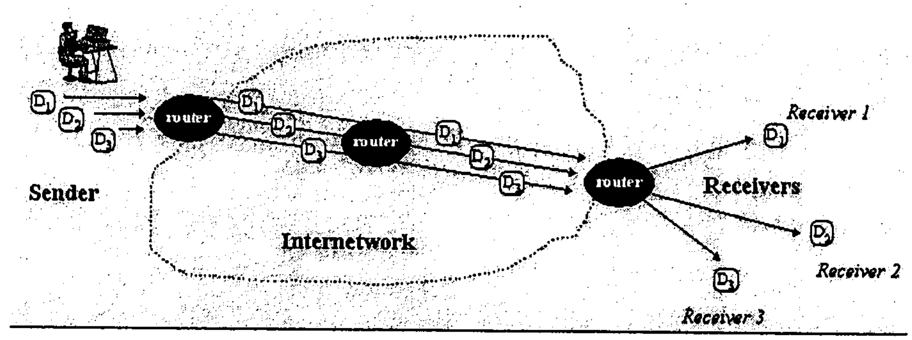
- Deployment
  - IVoDS was released to ISS Increment 5 remote users in May 2002
  - Shadow Operations for Increment 5 for 3 months
    - Parallel operation of EVoDS and IVoDS at remote sites
- Schedule
  - Operational Readiness Review 8/15/2002
  - Fully Operational for Increment 6 10/2002
- Outstanding Issues
  - Variable quality of some public Internet connections for remote users without research/science network access
  - No dynamic failover to backup VPN
    - Check Point and FVC are working compatibility of releases
  - Maintaining compatibility among new releases of COTS products

Potential IVoDS Future Enhancements

- Short-term:
  - ◆ Additional real-time collaboration capabilities:
    - Video teleconferencing
    - Instant messaging
    - Application sharing
- Long-term:
  - ◆ IP multicast transmission
  - ◆ Guaranteed quality-of-service
  - ◆ VoIP industry trends, standards



Future IVoDS: video, instant messaging,...



Unicast: one talker + three listeners = three redundant streams

Technology Transfer To Other Applications

- Voice hubs for other NASA centers and ISS International Partners
  - Italy: ASI
  - European Space Agency
  - Canada
- IVoDS is Not Just for Space Station
  - Use of Internet Protocol networks/devices provides great flexibility for voice/video applications
  - Software-based architecture allows enhancements for special requirements not possible with hardware-based voice systems
- Space Launch Initiative test site communications (NASA)
  - Mobile: laptops, wireless IP network
- Emergency response systems (AZTek, Lockheed-Martin)
  - Integrate voice/video communications from a variety of vendor systems and organizations (e.g., local police, state police, FBI)

Summary

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