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UNITED STATES AIR FORCE RESEARCH LABORATORY

INTERNET2: THE BACKBONE OF THE FUTURE

Christopher Barnes

Terresa E. Jackson

Air Force Research Laboratory
Warfighter Training Research Division
Information Systems Training Branch
2509 Kennedy Circle
Brooks AFB, TX 78235-5000

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AIR FORCE MATERIEL COMMAND
AIR FORCE RESEARCH LABORATORY
Human Effectiveness Directorate
Warfighter Training Research Division
6030 South Kent Street
Mesa AZ 85212-6061

NOTICES

CHISTOPHER M. BARNES, 2Lt, USAF
Project Scientist

DEE H. ANDREWS
Technical Advisor

CURTIS J. PAPKE, Colonel, USAF
Chief, Warfighter Training Research Division

Requests for copies of this report should be directed to:

Defense Technical Information Center
8725 John J. Kingman Road, Suite 0944
Ft. Belvoir, VA 22060-6
http://stinet.dtic.mil

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14. ABSTRACT
In 1994, the federal government proposed creating a second Internet that would surpass the one already in existence, primarily for the purpose of research. Out of it came the Next Generation Internet (NGI), a government lead project to advance and foster the creation of a better Internet. Internet2 was started in 1996, primarily by a collaboration of 34 universities throughout the US working together as the University Corporation for Advanced Internet Development (UCAID). Internet2 creators are doing the same thing that the people did when they created the original Internet, only going further down the road. But this time we have examples of what capabilities and effects Internet2 will bring about, and more will come about as time goes on. The possibilities it opens up in research, education, music, business, and every other form of information exchange and collaboration are incredible, but they are also fast becoming a reality. Eventually, the time will come when people use the example of Internet2 to justify even greater advances in Internet technology.

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INTERNET2: THE BACKBONE OF THE FUTURE

INTRODUCTION

Back in the 1970s, the predecessor of the current Internet was in its infancy. It was conceived as a research tool and received a lot of funding from the government. It took nearly three decades for it to go from what most researchers referred to as the “commodity Internet” to the one that millions of people are using right this second. University research and participation played a large role in its development. People didn’t realize what it was to eventually become, how it would be common for even a grade school child to log on, or unbelievably large volumes of business interactions to occur over the Internet.

After commercialization of the Internet in the 1990s, the originators of the Internet became more and more distressed at what had become of their wonderful tool. More people were logging on each day, and clogging up what had once been essentially exclusively theirs. According to Richard M. Stapleton (2000), “with the advent of commercial and individual use, the Internet has doubled in size and traffic has increased fourfold annually since 1988. Like any aging superhighway, traffic slowed, and the Web’s utility to the research community was compromised. It was time to reinvent the Net.”

So the cycle is going around again. In 1994, the federal government proposed creating a second Internet that would surpass the one already in existence, primarily for the purpose of research. Out of it came the Next Generation Internet (NGI), a government lead project to advance and foster the creation of a better Internet.

Internet2 was started in 1996, primarily by a collaboration of 34 Universities throughout the US working together as University Corporation for Advanced Internet Development (UCAID). According to the official Internet 2 website (UCAID, 2001):

> Internet2 is a consortium being led by over 180 universities working in partnership with industry and government to develop and deploy advanced network applications and technologies, accelerating the creation of tomorrow’s Internet. Internet2 is recreating the partnership among academia, industry and government that fostered today’s Internet in its infancy. The primary goals of Internet2 are to:
>
> - Create a leading edge network capability for the national research community
> - Enable revolutionary Internet applications
> - Ensure the rapid transfer of new network services and applications to the broader Internet community

UCAID has never directly received federal money. It has instead relied on the university members and corporations like Quest Communications International Inc., Cisco Systems Inc., and Nortel Networks Corporation. NGI is still largely government sponsored.

Internet2, which is led by UCAID and NGI, are separate entities, although they have essentially the same goals. They are not competing against each other; it’s more like they are working along parallel lines. While it sounds more like wasteful redundancy in their causes, it actually is beneficial for the advancement of the Internet. This way all of the big players can be involved: the government, universities, and industry. The government can help the new technology along without hampering those who can do it the best. Funding and creativity from different sources work synergistically with amazing results.

Reasons for its existence

Why should we bother with another Internet when the costs are extremely high, especially where maintenance and research are concerned? The Abilene backbone alone costs about $500 million to set up.

There are several important reasons. The most obvious of those is the capabilities. Internet2 will resemble the current Internet the same way a child's first tricycle resembles a Harley Davidson motorcycle. Outrageous speed, new applications, reliability, everything improved, enhanced, and advanced.

We are finding the current Internet to be a great educational tool. Students can access information for projects that they otherwise would not be able to. Schools with poor libraries can buffer their resources with Internet accessible computers. Some educational programs are now offered completely online.

As much as the Internet has been a boon to education, it falls short of what is possible. Internet2 is working on capabilities that can fully take advantage of distance connections. Currently, a student can download information for a college research project from a distant library, but they are primarily text-only information, with maybe a few pictures or low-resolution animations.

Imagine how much further things can be taken. A music major could download Bach's entire lifetime works, full digital quality, almost instantly. A fifth grader could download Dr. Martin Luther King's famous "I Have A Dream" speech not just written down as text but as video, at the same quality as today's digital video discs (DVDs).

Not just with education, Internet2 will improve just about every other realm where information is exchanged. An expert neurosurgeon will conference with another physician and patient thousands of miles away to ensure the most current and accurate medical information is put to use. A physicist at Harvard and a computer specialist at the University of Washington can conference on a new research project. An Air Force Airborne Warning and Control System (AWACS) simulator can work with an F-22 fighter aircraft simulator several states away. No longer hindered by low speeds or unreliable connections, people could come together from anywhere, to collaborate, exchange, interact, teach, and learn using any media they want.

When we created the original Internet, people had no concept of how important and widespread it would become. It could be said that they were fumbling in the dark with a new idea that they were trying to foster and implement. We are in a similar but more advantageous situation now, because we have the power of hindsight to guide us. Again, we are pushing the envelope and testing new grounds, but we can look at what the current Internet does for us and learn from that.

A newspaper article by Martha Woodall (2000) reads,

> “Why Internet2?” said Michael Palladino, Associate Vice President for Networking and Telecommunications at Penn. “So research institutions and other institutions… can collaborate and develop and use higher bandwidth applications without the commercial world and other getting in the way and clogging up the pipes.”

A quote from one of the originators of the Advanced Research Projects Agency Net (ARPAnet), the ancestor to the current Internet, comes to mind. In an article by Rory O’Conner (2000), George Strawn, deputy director at the National Science Foundation (NSF), says “If you raised the same question in 1974 – asked people working on ARPAnet, ‘Is the public investment in the [project] worth it?’ – I think they’d have had to dance a bit for you. And I think we’d have to dance a little bit for you today.”

As we grow into our computer age, we need more capacity and capabilities. Like any other developing organism, we have outgrown our current shell. We are bursting at the seams and straining to continue with what we have. We are ready for a bigger and better one.

Capabilities

Speeds

Internet speeds are growing at a phenomenal rate (Table 1). It wasn’t too long ago that fastest modems were running under 10 kbps (kilobits per second). Currently, many people are using modems that are 28.8 kbps, or their phone lines won’t go any faster than that. The other conventional phone line users may be lucky enough to take full advantage of their 56K modems (56 kbps). Others are more fortunate in their Internet connections and have fiber optic connections. A standard T1 connection travels at about 1.5 (Mbps) megabits per second (1 megabit = 1000 kilobits), a significant jump over 56K modems. T3 connections conduct about 45 megabits per second, and are about the fastest you typically see on the current Internet.

The slowest Internet2 connection is an OC-3 connection, which can be obtained commercially through very high-speed backbone network service (vBNS). It connects at 155 megabits per second. The next step up would be an OC-12, connecting at 622 megabits per second. And finally, the fastest connection at this point is an OC-48, at 2.4 (Gbps) gigabits per second (1 gigabit = 1000 megabits). At this point the only place you will see this speed of connection is along one of the two backbones of Internet2, Abilene and vBNS. Eventually, it will grow more widespread.

Table 1 - Speed information

Connection	Speed	Bits per second
28.8 Modem	28.8 kbps	28 800
56K Modem	56 kbps	56 000
T1	1.5 mbps	1 500 000
T3	45 mbps	45 000 000
OC-3	155 mbps	155 000 000
OC-12	622 mbps	622 000 000
OC-48	2.4 gbps	2 400 000 000

For a quick comparison, a 2.4 gigabit connection is nearly 100,000 times faster than a 28.8 kbps connection that many people are still stuck with, and approximately 45,000 times faster than a 56K modem.

Richard Stapleton (2000) gives a great example,

> "Encyclopedia Britannica DVD 2000 Edition contains 4.5 gigabytes of data. If you connect from home at 56 kilobits per second, it would take you nearly eight (continuous) days to download EB. If you're at a research university, tied to today's Internet, your download time could be just under 14 minutes. On NGI's 100X test-bed, you're looking at about one-minute download time, and on a 1000X Web, the full EB can be yours in just 15 seconds."

While that example is based upon connections that NGI is developing, the numbers are about the same for Internet2 connections. An OC-3 connection is about the same speed as NGI's 100X, and an OC-48 is the same speed as NGI's 1000X Web. So an OC-48 connection, at 2.4 gigabits per second, could download the entire 4.5 gigabyte encyclopedia in 15 seconds as well.

Multicasting

One of the best known working groups in Internet2 is the Multicast working group, also known as Multicast Backbone (Mbone). Figure 1 depicts the official Internet2 site (UCAID, 2000),

> "Multicast is a set of technologies that enables efficient delivery of data to many locations on a network. In today's Internet, the dominant model of communication is "unicast" – the data source must create a separate copy of the data for each recipient. When there are many recipients, and when large amounts of data (e.g. streaming video) are being sent, unicast becomes prohibitively wasteful of bandwidth. The key behind multicast is to create each recipient's copy of each message at a point as close to that recipient as possible, thus minimizing the bandwidth consumed."

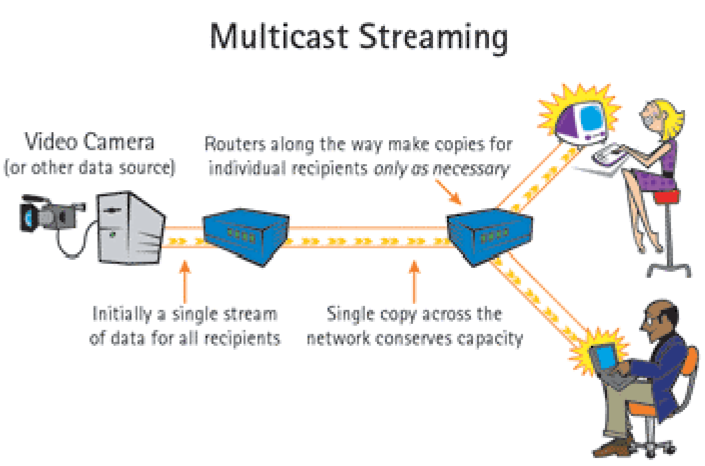

Figure 1. Multicast Streaming

So Internet2 is working to solve bandwidth problems not only by making connections faster, but smarter. The importance of multicasting will only grow as time goes on. It is especially crucial to distance learning applications, teleconferencing, or any other situation where large amounts of information are going to several sources and could potentially clog up the network.

A good analogy would be a coach who has to call every one of the 100 people on his football team to tell them that the game has been rescheduled. He could call each person individually, taking an enormous amount of time. If he was like the current Internet, he could get 100 phones and call all of the football players at once, tying up 100 phone lines. Or if he was multicasting, he could make one phone call, and it would be routed to each home in the most efficient way, using the least amount of phone lines necessary along the way.

Tele-immersion

According to the official Internet2 site (UCAID, 2001),

> "Tele-immersion enables users at geographically distributed sites to collaborate in real time in a shared simulated, hybrid environment as if they were in the same physical room.
>
> It is the ultimate synthesis of media technologies:
>
> - 3D environment scanning,
> - projective and display technologies,
> - tracking technologies
> - audio technologies
> - robotics and haptics
>
> and powerful networking. The considerable requirements for tele-immersion system, such as high bandwidth, low latency and low latency variation (jitter), make it one of the most challenging net applications.
>
> …Tele-immersive environments will therefore facilitate not only interaction between users themselves but also between users and computer-generated models and simulations. This will require expanding the boundaries of computer vision, tracking, display, and rendering technologies. As a result, all of this will enable users to achieve a compelling experience and it will lay the groundwork for a higher degree of their inclusion into the entire system."

Tele-immersion is still a relatively new and fluid field. Several different methods are being explored to find the best way to make conferencing and collaborating as real as possible, to make it as if the person you are speaking with is truly standing next to you. It also has many applications in modeling and simulation. A pilot can be totally immersed in the environment they are being trained in, as well as connected to an aircrew that is totally immersed in their own training environment thousands of miles away. Only Internet2 will have the capacity and capabilities to fully use these technologies. It is also further proof that Internet2 is more than just some engineers trying to make signals go faster. Reliability and stability are at least as important to this technology as speed.

Tele-immersion technologies are coming together from different sources to create a more believable virtual reality. Computers are being programmed to track an individual's movement in a room, as well as body posture and facial expressions. This information is send to another computer where a collaborator is, and that person sees the person being scanned in 3D. It compares to television the same way an old Intellivision video game system compares to the PlayStation 2.

This visual information can be conveyed to different sources and in different ways. One way was conceived by the University of North Carolina (UNC) at Chapel Hill, which they called the tele-cubicle, or *office of the future*. It involves stereo immersive desk surfaces and walls, onto which the 3D imagery is displayed. Their goal is that eventually everything could be projected onto, even a person standing in the way. Figure 2 is a picture that was made by UNC, and shows the telecubicle.

Figure 2. Tele-cubicle, Office of the Future

Internet2 conducted a demonstration in October of 2000 that sent real-time, 3D visual information across Internet2, with which the user on the other end could interact using a laser pointer. Looking at Figure 3, the Internet2 website shows us a picture of it.

In a previous demonstration by Internet2, Mary Lou Jepsen (2000) writes,

> "The 3-D display used in the Tele-immersion demo is actually just good old front projection with stereo glasses. The principle is not so different from the 3-D of the 1050s horror movies, although the glasses are actively shuttered LCDs.
>
> But what is really new is that the position of the user's head is tracked, in real-time, with the tracking grid of professor of computer science Henry Fuch's lab at the University of North Carolina, Chapel Hill.
>
> The tracking system is designed to acquire movement information over a large valume. A grid of LEDs are placed on the ceiling and a new type of opto-electronic sensor called the HiBall is a small unit that has six photodetectors and six lenses. Rather than simply providing each photodetector with its own lens, a given photodetector uses multiple lenses to achieve an overlapping record of LED locations. Build-in signal processing circuity is then able to extract

location and movement information with a latency of just one microsecond. The entire unit weighs only five ounces, making it easy to incorporate into a head-mounted display.

Figure 3. Tele-immersion in 3D

The addition of tracking and real-time scene acquisition with mulitiple cameras is compelling. The computer graphics rendering on top of this system is also new. The processing of all this information in real-time is the enabler for this technology.

Thinking of displays as communication systems rather than just output devices is where the power lies. In other words, advances in computer vision and computer graphics are allowing us to create really new forms of displays, using nearly the same hardware components as before, but with much better performance."

Another example of tele-immersive technology comes from Richard Stapleton (2000),

"Put on a pair of special glasses and enter “The Case” at the University of Illinois at Chicago’s Electronic Visualization Laboratory. Three-dimensional images of a table pop out at you. A computer tracks your movement, letting you walk around the table, viewing it from all sides. You can even get on your knees and peer under it. Auto designers already use caves to study new car designs. Unlike the old clay model, design changes can be as simple as a few mouse-clicks. The next Internet will tie caves together, letting designers in Germany, for instance, critique a sports car being displayed in Detroit."

So there are several methods displaying this information. Projections on special walls, rear- and front-projection monitors, and different head-mounted displays are all being researched, as well as tracking devices for people at every end of a connection. Using any of the multiple combination of these technologies, a user will be able to sit down at a virtual table in a conference with people from around the globe, turn their head to the left and right, and the scene will adjust properly to what they would see if they were at a live conference. They will watch the people in 3-D, and see everything from body posture to facial expression. Three-D sound could even be incorporated as well so the person hears the right voice coming from the right person.

Dual-SVGA head-mounted displays have been on the market since January using liquid crystal on silicon (LCOS) displays. Prices will drop over time and popularity will grow. The video gaming industry, a rapidly growing market, may eventually integrate this technology and expand the market further. Few people realize how much help the video display realm of technology will receive solely from the video gaming industry, which brought in more money last year than the movie industry.

Video and audio might not be the only media Internet2 uses. William Holstein (2000) states,

> "At the University of North Carolina-Chapel Hill, for example, scientists are learning how to transmit the sense of touch. The implication is that someday shoppers might be able to feel the fabric of an article of clothing they want to buy online. How does it work? Powerful 3-D devices collect data about an object and shoot it across Abilene. At the receiving end, an Intel-made controller converts the data and applies electronic force to the human finger in a way that replicates the original object. Scientists have demonstrated the technique for only tiny objects (atoms) so far, but it could be just a matter of time before more computing power allows it to handle the fabric of a dress, for example."

If the sensation of touch is integrated into the Internet, the possibilities for use are staggering, especially when used in conjunction with video and audio. One possibility could be virtual surgery practice for physicians, with full audio, visual, and touch sensational information. The doctor could not only peer into the heart but feel it at well.

Virtual Laboratories

The official Internet2 website (UCAID, 2001) states,

> "A Virtual Laboratory is a heterogeneous, distributed problem solving environment that enables a group of researchers located around the world to work together on a common set of projects. As with any other laboratory, the tools and techniques are specific to the domain of the research, but the basic infrastructure requirements are shared across disciplines. Although related to some of the applications of tele-immersion, the virtual laboratory does not assume a priori the need for a shared immersive environment."

Not everyone has access to top-notch laboratories. Some schools may have a high-level chemistry lab and a poor physics lab. Internet2 helps to level the playing field and allow people to collaborate online and in real-time with different laboratories. Imagine accessing brand new state-of-the-art National Aeronautical Space Administration (NASA) simulations for a project in a physics course. Or connecting with Boeing to model the flight of their line of the new F-22 fighter aircraft.

Neither of those is currently possible for most people. But this could eventually happen using Internet2 connections. Attempting to do either of those currently would be ugly, resulting in choppy, low-quality visuals, and delays that justify the nickname "World Wide Wait." But with the proper bandwidth and reliability, any person can have access to tools that are on the cutting edge of technology.

Another example is a weather forecasting system that uses information from scattered satellites, sensors, and computers that use highly complex simulations and models to predict the weather at different stages. As the weather is in constant motion, the information needs to be readily available in real time. This means that enormous delays due to transference of large amounts of detailed information need to be minimized as much as possible so the data won't lose its integrity along the way.

Digital Libraries

The Internet is seeping into every aspect of research already. Digital video and audio are very resource intensive in comparison to plain text or even text with pictures. If you want to download a video clip using the current Internet, even with a T1 connection you would have to settle for second-class quality as far as video quality, and there could be delays due to buffering and interruptions in the data stream.

Internet2 will be much more reliable and continuous in sending a digital video clip from one source to another, as well as obviously much quicker. A physician in Montana can view a recently recorded surgery technique in the highest video quality it can be recorded in, and he/she doesn't have to fly across the country or miss the information. The physician wouldn't even have to buy a high-end computer, as typical commercial off-the-shelf computers have either the capacity to play digital video or could with minor modifications.

The University of Illinois is digitizing its entire music library, and with a connection such as Internet2, that information could be accessed by anyone. Even a child in grade school who is just beginning to learn to play an instrument could access a masterpiece version of the song they are attempting to play.

Distributed Learning

Salas, Cannon-Bowers, and Kozlowski (1997) speak of how computer-based training has not yet been fully exploited. They provide arguments on how to improve the science and practice of training. Martinez and Bunderson (2000) write of how intentional web-based learning can result in high satisfaction and achievement. New possibilities are opening for uses of learning through a computer, more specifically distributed learning.

Distributed learning is exploding in the United States. People can even obtain graduate degrees in business without ever stepping foot in the classroom, or even the campus that the class originates from. We are learning more and more that the classroom is not so much as a physical place, but a way to learn. Currently, most distance learning programs are email-based. Email lists are assembled for the classes. The teacher emails lectures out to the students, and the students email homework and questions back to the teacher. Synchronous collaboration is also developing, where the students can watch and hear the instructor give a lecture live over the Internet, and can interact in real time.

These interactions are steps toward a growing field, and Internet2 can build upon them and facilitate future ones. With Internet2, an online classroom is possible, where everyone involved is represented in 3-D. Students could collaborate with the instructor or fellow students in real time, using any media they wish. Many people currently avoid distance learning because they feel it takes away human interaction involved in learning. But with this, they could not only see the other people, but observe their gestures, postures, and facial expressions. It doesn't cut down human interaction, it facilitates it by removing the hindrance of distance.

In May of 2000, Internet2 put on a demonstration at Networld+Interop's conference (http://www.key3media.com/interop/atlanta2000/). Larry Lange (2000) writes about it,

> "The Internet2 project is dedicated to high-performance applications," engineer Alex Latzko says excitedly, "and this is one of them." He points to a monitor which is playing a six-megabit streaming video of a Japanese drum ensemble flailing away energetically. "Is this broadcast quality or what?" ask Latzko, a proud smile on his face.
>
> He's right. The live feed and sharp picture showcasing Stanford University's "Taiko Drum Crew" is in real time – dynamic in both audio and video quality – with none of the herky-jerky video stream and mono audio response usually expected from an Internet multimedia event… Even more astonishing is that the concert is being played over a typical Pentium PC "souped up with only a $200 video MPEG decoder card, the same kind you use to view DVDs on your PC," says Latzko."

This is just an example of how we can use Internet2. If we take that same capability and apply it to distance learning, it becomes more realistic to learn over the Internet. And that isn't even with any 3-D or tracking technology, or any of the other tele-immersion that could make it so vivid.

A November 2000 news release by Internet2 and Optivision (UCAID, 2000) states,

> "Graduate Language Courses
> At the University of Nebraska's Kearney and Omaha campuses, enrollment in graduate-level foreign language courses, specifically German, had declined sufficiently to threaten the cancellation of these courses for the upcoming 2000-01 academic year. By offering such courses via the Internet2, the two campuses would be able to share resources, and provide Nebraska's students with a far greater selection of courses than they could offer individually."

So plans for implementation of Internet2 in distance learning are already in place. This is even more apparent when looking at Northwestern University. As part of their participation in Internet2, Northwestern has upgraded the network that links the dorms, allowing every dorm room to send and receive video. Koren Capozza (2000) states,

> "From the comfort of her dorm room, one Northwestern University student recently watched a Latin American soap opera in Spanish on her PC. When she did not understand a plot twist, the student paused the show and replayed the scene. At first glance, this may not seem like homework. But the TV program is course material assigned by the student's Spanish professor and made available online by Northwestern's pioneering digital-video network. After a $2 million upgrade this year, the university is now wired to deliver broadcase-quality online digital video to all of its 6,000 on-campus students… In the near future, Indiana University, the University of Washington and Yale may be the next to network dorms."

Another article that interviews the Vice President of Information Technology at Northwestern University is by Jeffrey R. Young (2000). The article questions Rahimi about specific kinds of video content they are planning to offer over the network. Rahimi responds,

> "I can give you a couple of examples. We have a course in marketing in which the faculty member uses short videos of television commercials that have been used over the past 30 or 40 years. It's displayed in a classroom setting. …That file of videos will be available on the network, so students can, in their dorm room, select a particular commercial they want and look at it. They don't have to be in a classroom to do that. … It will be on demand, so when the student is ready at 2 in the morning to work on the marketing course, the videos are there."

In the same article, Young asks Rahimi if the students could use the Internet to watch videos that teach language instead of going to the language lab. Rahimi answers, "That's correct. Your computer becomes everything – your language lab, your engineering workstation, your video-production center."

With Internet2, the same program for education can be implemented across the nation, or even the world. Northwestern is proving the advantages to having high-quality video instantly accessible to students. Their only drawback currently is that only the students who live on-campus are hooked up.

California is even creating the Digital California Project, sort of a statewide version of Northwestern University's networked dorms. According to a news release put out by Internet2 (UCAID 2000),

> "The Digital California Project, or DCP, provides the framework for a cohesive and seamless statewide advanced service network that reaches into each of the State's 58 counties. Once the network has been implemented, K-12 schools, districts, and county offices of education will be able to connect their networks to the DCP and gain access to rich content resources for teaching and learning, to prepare students with the basic knowledge and specific skills to inspire them to enter and be successful in higher education and in the 21st century workforce. …The enhanced infrastructure of the DCP will - - allow the students and teachers to collaborate with others outside the walls of the classroom, which will enrich teaching, learning and build skills that are increasingly sought by California employers. – Provide cost-effective methods for teachers to supplement the information that appears in textbooks and is taught to students.- Provide students with interactive learning opportunities and opportunities to hear and see information that can't be captured by printed text or would be too costly to try to visit in person.- Enable AP courses and other specialty courses to be delivered in a cost-effective manner in all geographical locations."

Now that a few groups have dipped their toes in the water, others are following them all of the way into the pool to join Internet2's rolling bandwagon. On March 8, 2001 Greg Wood, in Public Relations for the Internet2 project, put out a press release stating the following,

> "Washington, DC—March 08, 2001—Abilene, a nationwide Internet2® network, today announced state education networks in Michigan, Missouri, Oregon, Virginia and Washington will establish connectivity under a new policy that allows expanded access to the high-performance educational backbone. Partnerships with Internet2 universities and regional networking organizations will provide institutions such as elementary schools, secondary schools, community colleges, museums and libraries access to the national high-performance network….

Access to the high-performance backbone, leveraged by network upgrades at the state and local networks upgrades, will allow expanded use of applications that don't work well or at all on today's Internet. State networks in Indiana, Ohio, Oklahoma and Rhode Island are expected to be approved for access to Abilene in the near future. Access to Abilene is now available to educational organizations through partnerships with organizations with existing connections."

Not just beneficial for the students, Internet2 is also working on LearningWare, an Instructional Management System. This essentially tracks students in their distance learning, a standard program that can track the students through all of their coursework, even though the individual classes may be completely independent from each other. It will have capabilities as mundane as keeping track of which student has taken what course, to more difficult tasks such as how well students are doing in their course work. The official Internet2 site (UCAID, 2001) lists the capabilities it is working on:

- Establish learning objectives
- Locate and review (or create) learning
- Determine student skill or knowledge level
- Assign appropriate materials to students
- Provide student access to instructional components/modules
- Review/track students' progress and manage needed interventions
- Provide and manage student-instructor and student-student communications, both synchronous and asynchronous
- Evaluate student learning
- Report learning outcomes

These applications will be necessary as people use distance learning participation increases, and their records need to be tracked, organized and analyzed. As distance learning and Internet2 both grow, it becomes apparent that their future is ultimately intertwined, especially considering the fact that universities are the biggest players in the development of Internet2.

Remote Manipulation

The images that typically come to mind when people think of giant telescopes and astronomy are traveling up some huge mountain and sitting in the freezing cold in a dark observatory, trying to record some observations before the observer's fingers freeze off.

This is no longer necessary with Internet2 as now linked to South America. According to Florence Olsen (2000),

"Scientists will benefit from the new research link to Latin America in several ways. Astronomers, for example, will be able to use the Gemini South telescope in La Serena, Chile, "without having to travel to Chile," says Arthur S. Gloster, chief information officer at Florida International. Gemini South produces images that are among the sharpest available to space scientists."

A news release put out by Internet2 (UCAID, 2000) speaks of linking Internet2 to the Mauna Kea Observatories states the following,

"The University of Hawaii and the Association of Universities for Research in Astronomy (AURA), with support from the National Science Foundation, have connected eleven of the world's leading astronomical observatories to Internet2 networks via the Mauna Kea Observatories

> Communication Network (MKOCN). With a capacity of 45 million bits per second, the new link will dramatically expand the capacity of astronomers around the world to remotely use telescopes located on the Hawaii mountaintop. The connection, which is nearly one thousand times faster than a typical modem, expands access to telescopes situated on Mauna Kea in a variety of ways."

The University of Pennsylvania is also working on exploring virtual microscopy, linking electron microscopes to the Web. So scientists everywhere will have access to some of the world's most advanced research equipment without having to leave their offices. These same principles could be applied to other equipment as well, such as particle accelerators, medical scanning equipment, and others.

Music

An impressive example of the power of collaboration Internet2 offers is with music. Not only will people be able to download music from Indiana University's digital music library, but people will be able to use Internet2 for other music purposes. A website by the Oklahoma University School of Music deals completely with teaching music with Advanced Network Videoconferencing (http://music.ou.edu/internet2/).

A news release by Internet2 and Optivision (UCAID, 2000) states,

> "Palo Alto, Calif., November 6, 2000 - Optivision® Inc., a leading provider of networked streaming video products, today announced the successful completion of the first ever multi-location music video recording session using real-time streaming video over Internet2® networks. Linking five major university campuses with its plug-and-play live streaming video servers and receivers, Optivision participated in a real-time music video recording session between musicians located thousands of miles apart, which included world-class professionals from groups that back major performers, such as Stevie Wonder, Aretha Franklin, N Sync, Christina Aguilera and CeCe Winans. Profiled and broadcast on CNN on Saturday, November 4th at 1:30 p.m. EST, the national event showcased the immediately deployable communications power that the Internet2 infrastructure will bring to thousands of universities."

With Internet2, musicians can collaborate just as scientists can for research. With real-time interaction, a person can conduct an orchestra from thousands of miles away, even if the parts of the orchestra are scattered throughout the country. This requires not only high-speed connections to send the digital audio, but one that flows continuously without delays and jitters.

Other Components

Abilene

Named after the railhead in Abilene, KS, that opened the West for settlement, Abilene is one of the two major network backbones of Internet2. It is independent from the other, vBNS, but linked with it. According to the official Internet2 website (UCAID, 2000),

> "Abilene is an advanced backbone network that supports the development and deployment of the new applications being developed within the Internet2 community. Abilene connects regional network aggregation points, called gigaPoPs, to support the work of Internet2 universities as they develop advanced Internet applications. Abilene complements other high-performance research networks."

It is primarily funded by Qwest, Cisco Systems, Nortel Networks, and Indiana University. As one of the backbones of Internet2, Abilene, along with vBNS, is where the fastest connections can be found, including the 0C-48 connection at 2.4 gigbits per second. It is also capable of native multicasting.

Though both networks are equally important to Internet2, Abilene manages to get a bit more press than its sister backbone. It links nearly 180 research facilities, and has been proven to be very reliable.

UCAID and Qwest are about three years into their five-year contract, which has arranged for Qwest to build and maintain Abilene. No contracts have been drawn up yet for when the current one ends, but everyone involved indicates intentions for Abilene to remain a research network and not immediately be sold to the public.

vBNS

The vBNS is the other major network backbone of Internet2, and is just as capable as Abilene, as shown in aspects such as speed, reliability, and native multicasting. According to the vBNS website (vBNS, 2000),

> "vBNS+ is a network that supports high-performance, high-bandwidth applications. Originating in 1995 as the vBNS, vBNS+ is the product of a five-year cooperative agreement between MCI Worldcom and the National Science Foundation. Now Business can experience the same unparalleled speed, performance and reliability enjoyed by the Supercomputer Centers, Research Organizations and Academic Institutions that were part of the vBNS."

vBNS+ may be the first step toward getting Internet2 technology out to the general population. Anyone can purchase an OC-3 connection to vBNS+, although the price is still hefty ($21,600/month). It is still used by Internet2, but commercial businesses can start to connect to it. Although it was probably commercialized solely to recover some of the expenses associated with it, it has the unintentional effect of becoming sort of a halfway house. It isn't too difficult to imagine Abilene remaining as the research network in years to come, leaving the universities their own playground, and vBNS+ becoming the source for high-speed connections for the Average Joe. While most people are probably not willing to pay such a large sum of money each month even for such a supreme product as vBNS+ offers, as the price comes down, more people will connect to it.

The vBNS + website (vBNS, 2000) shown in Figure 4, depicts its connections as of 12/31/2000.

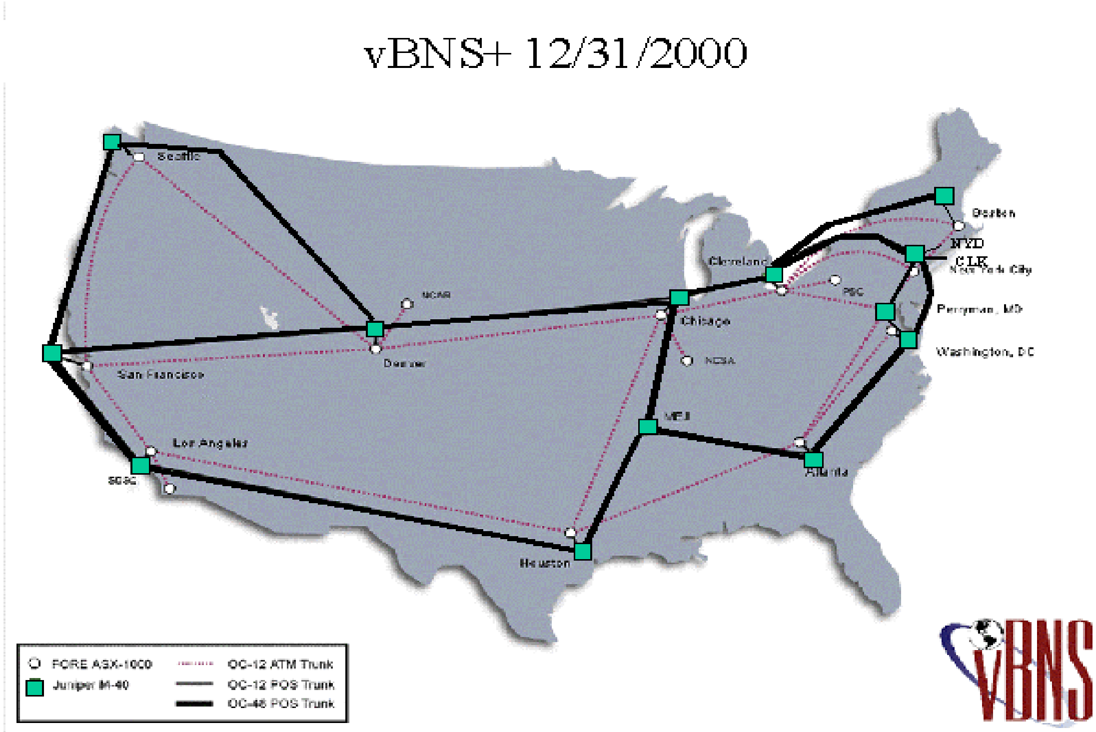

Figure 4. vBNS connections

Qbone/Quality of Service/Priority Packeting

On the current Internet, every bit of information has the same priority as any other. For example, a rural emergency room doctor videoconferencing with a group of specialists at the University of Washington School of Medicine about a time critical illness may be interrupted and delayed by an email from John Doe to his buddy about a joke that he heard the other day.

The QoS working group, short for Quality of Service (otherwise known as Qbone, short for Quality of Service Backbone) has made priority packeting a central concern of theirs. The goal is to prevent the delay of time critical data that is due to high traffic of data that is not time critical. This would be accomplished by labeling the time critical data as higher priority and ensuring that it is sent first. It works sort of like a real post office, where you can send something through overnight delivery, or choose a lower class. Along with Middleware, QoS is an excellent example showing that Internet2 isn't only about faster connections, but better connections and better implementation of those connections as well.

It also shows the long-term vision the people running Internet2 have. It would be easy to overlook an issue such as this, especially with Internet2's current capacity. It is hard to imagine this new Supernetwork being clogged up, but engineers and programmers have already planned for it and will continue to take issues such as this into account.

Middleware

Middleware is another example of issues Internet2 deals with aside from solely speed. According to the official Internet2 website (UCAID, 2001),

> "Middleware, or "glue," is a layer of software between the network and the applications. This software provides services such as identification, authentication, authorization, directories, and security. In today's Internet, applications usually have to provide these services themselves, which leads to competing and incompatible standards. By promoting standardization and interoperability, middleware will make advanced network applications much easier to use. The Internet2 Middleware Initiative (I2-MI) is working toward deployment of core middleware services at Internet2 universities."

Another page at the same website (UCAID, 2001) states, "A popular definition of middleware that reflects this diversity of interests is "the intersection of the stuff that network engineers don't want to do with the stuff that applications developers don't want to do."

Middleware will become increasingly important as time goes on. Sort of a buffer, or diplomat between programs, it will help Internet2 run more smoothly. With all of the different machines, applications, programs, and networks hooked together, this is no small task. But Middleware will make them all speak the same language and work together.

IPv6

Currently, the Internet uses Internet Protocol version 4. Internet2 recently upgraded itself to Internet Protocol version 6 (IPv6). The biggest reason for this is a problem the current Internet is coming up against. Everything connected to the Internet has to have its own identification number. Computers, cell phones, pagers, everything. As more people connect with more devices, we are running out of addresses.

An article by Dawn Bushaus (2000) states,

> "IP version 6's primary advantage over IP version 4, which is used in the commercial Internet today, is its bigger address pool. Specifically, it increases address space from 32 to 128 bits, dramatically increasing the size of the pool and enhancing security. Globally, as more phones become IP-based and the number of other IP devices grows, the IP address crunch is going to get worse, says MCI WorldCom's Wilder."

Internet2 nips this problem in the bud by using IPv6, knowing that the number and types of devices hooked up to the Internet is going to skyrocket.

gigaPoP

The neurons in the central nervous system of Internet2 are referred to as gigaPoPs. They send the information in packet bursts to each other, and the data is reassembled into what it was originally. Internet2 consists of dozens of these gigaPoPs connected to each other by fiber optics. The website of the Pacific/Northwest Gigapop (Pacific/Northwest Gigapop, 1999) writes the following about its gigaPoP,

> "a 'one-stop shopping' connection point that provides exceedingly cost-effective access to the major national commodity Internet Service Provider's (ISPs) as well as to 'aggregation pools' and mechanisms that ensure alternate data paths, data paths with especially high quality, end-to-end performance for specific applications, and links to partners."

ARENA

The official Internet2 website (UCAID, 2001) tells us the following,

> "ARENA, the Advanced Research and Education Network Atlas, is a project to prepare and maintain an on-line Atlas of maps of Research and Education Networks for the use of Internet2 members, and other researchers and engineers in the larger R&E (Research and Education) community. ARENA will include Internet2 Backbones (vBNS and Abilene); U.S. Federal Agency Networks; gigaPoPs; and National Research Networks (NRNs) outside of the United States."

With the bastardization of different networks, speeds of connections, and routes, it will become necessary to have a current map of these connections. This way in the future someone in Tacoma, WA, will know if they can connect to an air force base in San Antonio, TX at 2.4 gbps, or if they will be at a slower connection. For its current purposes, it would more likely be a college in Washington trying to collaborate with a college in Texas. The connections of Internet2 will quickly become far more complex than a map of every single road and street in the entire United States. ARENA fills the need of keeping track of them.

Security

The current Internet has many security problems. There is an abundance of information that people don't want others to have that is passing across the Internet, and there are people trying to get that information. It becomes even more critical when one looks at confidentiality of information in conjunction with the government or Department of Defense. The problem is that the Internet was built to exchange information, not to protect it. It is a constant battle to try to keep walls around protected information, while other people constantly erode those same walls away.

Internet2 is being designed with security in mind. Authentication, authorization, and security issues in general are high on the priority list of Internet2 creators. With security being implicated from the very beginning of its creation, Internet2 will be much more protected than the current Internet.

Who is participating

Universities

Internet2 University Participants:

Arizona State University
Auburn University
Baylor College of Medicine
Baylor University
Boston University
Brigham Young University
California Institute of Technology
California State University, Hayward
California State University System
Carnegie Mellon University
Case Western Reserve University
Clemson University
College of William and Mary
Colorado State University
Columbia University
Cornell University

Dartmouth College
Drexel University
Duke University
East Carolina University
Emory University
Florida A & M University
Florida Atlantic University
Florida International Univ. Florida St. Univ.
Gallaudet University
George Mason University
George Washington University
Georgetown University
Georgia Institute of Technology
Georgia State University
Harvard University
Idaho State University
Indiana State Universtiy, Bloomington
Iowa State University
Jackson State University
Johns Hopkins University
Kansas State University
Kent State University
Lehigh University
Louisiana State University
Massachusetts Institute of Technology
Medical University of South Carolina
Michigan State University
Michigan Technological University
Mississippi State University
Montana State University, Bozeman
New Jersey Institute of Technology
New Mexico State University
New York University
North Carolina State University
North Dakota State University
Northeastern University
Northwestern University
Ohio State University
Ohio University
Oklahoma State University
Old Dominion University
Oregon Graduate Institute of Science & Technology
Oregon Health Sciences University
Oregon State University
Pennsylvania State University Main
Portland State University
Princeton University
Purdue University Main Campus
Rensselear Polytechnic Institute
Rice University
Rochester Institute of Technology
Rutgers University
Seton Hall University
South Dakota School of Mines & Technology
South Dakota State University
Southern Illinois State University
Southern Methodist University
Stanford University
State University of New York, Stony Brook
Stephen F. Austin State University
Syracuse University
Texas A & M University
Texas Christian University
Texas Tech University
Tufts University
Tulane University
University at Buffalo, SUNY
University of Akron
University of Alabama
University of Alabama, Birmingham
University of Alabama, Huntsville
University of Alaska
University of Arizona
University of Arkansas
University of Arkansas at Little Rock
University of Arkansas for Medical Sciences
University of California, Berkeley
University of California, Davis
University of California, Irvine
University of California, Los Angeles
University of California, Office of the President
University of California, Riverside
University of California, San Diego
University of California, San Francisco
University of California, Santa Barbara
University of California, Santa Cruz
University of Central Florida
University of Chicago
University of Cincinnati

University of Colorado, Denver
University of Connecticut
University of Delaware
University of Florida
University of Georgia
University of Hawaii
University of Houston
University of Idaho
University of Illinois, Chicago
University of Illinois, Urbana-Champaign
University of Iowa
University of Kansas
University of Kentucky
University of Louisville
University of Maine
University of Maryland, Baltimore County
University of Maryland, College Park
University of Massachusetts
University of Memphis
University of Miami
University of Michigan, Ann Arbor
University of Minnesota, Twin Cities
University of Mississippi
University of Missouri, Columbia
University of Missouri, Kansas City
University of Missouri, St. Louis
University of Montana
University of Nebraska
University of Nevada, Las Vegas
University of Nevada, Reno
University of New Hampshire
University of New Mexico Main
University of North Carolina, Chapel Hill
University of North Dakota
University of North Texas
University of Notre Dame
University of Oklahoma, Norman
University of Oregon
University of Pennsylvania
University of Pittsburgh
University of Puerto Rico
University of Rhode Island
University of Rochester
University of South Carolina, Columbia
University of South Dakota
University of South Florida
University of Southern California
University of Southern Mississippi
University of Tennessee
University of Texas, Arlington
University of Texas, Austin
University of Texas, Dallas
University of Texas, El Paso
University of Texas Southwestern Medical Center at Dallas
University of Tulsa
University of Utah
University of Vermont
University of Virginia
University of Washington
University of Wisconsin, Madison
University of Wisconsin, Milwaukee
University of Wyoming
Utah State University
Vanderbilt University
Virginia Commonwealth University
Virginia Polytechnic Institute
Wake Forest University
Washington State University
Washington University, Saint Louis
Wayne State University
West Virginia University
Western Michigan University
Worcester Polytechnic Institute
Wright State University
Yale University

Corporations

Internet2 Corporate Partners:

3Com
Advanced Network & Services
Alcatel
AT&T
Cisco Systems
WorldCom

Internet2 Corporate Sponsors:

Bell South
Baltimore Technologies
Cable & Wireless
Compaq Computer
Ericsson
Foundry Networks
Litton Network Access Systems
NEES Communications, Inc.
Novell

Internet2 Corporate Members:

Akamai Technologies
Apple Computer
AppliedTheory Communications, Inc.
Asta Networks
Bell & Howell Information & Learning
Blackboard, Inc.
Boeing Phantom Works
C-SPAN
Centro Studi E Laboratori Telecumunicazioni
Community of Science
Deutsche Telekom
Digital Bitcasting Corp.
EBSCO Information Services
Eli Lilly Corporation
Fujitsu Laboratories
Global Crossing
Hitachi
Impstat Fiber Networks
J.P. Morgan
Johnson & Johnson
Juniper Networks
Media Station, Inc.
Medschool.com
Motorola Labs
Multicast Technologies, Inc.
NEC Corporation
Nippon Telegraph and Telephone
Nokia Research Center
Optivision
Pacific Internet Exchange Corporation
PaineWebber Incorporated
RADVision
SeaChange International
SFI/Advanced Internet Fund
Siemens
Source Software Institute
Sprint
Sun Microsystems
Tachyon.net
Telecordia Technologies
Telebeam, Inc.
Teleglobe
TeraBeam Networks
The Hartford Financial Services Group, Inc.
Verizon Communications
Williams Communications Group
WorldPort Communications, Inc.
zUniversity.com

Internet2 Affiliate Members with Collaboration Site Status:

Alliance for Higher Education
Association of Universities for Research in Astronomy
European Center for Nuclear Research (CERN)
Earth Resources Observations Systems (EROS) Data Center
Howard Hughes Medical Institute
Jet Propulsion Laboratories
NASA – Goddard Space Flight Center
NASA - Marshall Space Flight Center
National Institutes of Health
National Oceanic and Atmospheric Administration – Boulder
National Oceanic and Atmospheric Administration – DC
National Science Foundation
Southwest Research Institute
University Corporation for Atmospheric Research

Affiliate Members:

Alabama Supercomputing Authority
Army Systems Engineering Office
Bradley University
Department of Management Services
DePaul University
Desert Research Institute
EDUCAUSE
Ellemtel Utvecklings AB
Environmental Research Institute of Michigan
WVNet.edu
Fraunhofer Center for Research in Computer Graphics, Inc.
Illinois State University
Indiana Higher Education Telecommunication System
LANet
MCNC
Merit Network, Inc.
New World Symphony
NYSERNET, Inc.
OARNet
OneNet
PeachNet
Southeastern Universities Research Association
State University System of Florida
State University of New York
Survivors of the Shoah-Visual History Foundation
University of Missouri System
University of North Carolina, General Administration

Government Agencies

National Science Foundation
Department of Energy
Defense Advanced Research Projects Agency
National Aeronautics & Space Administration
Department of Defense
National Institutes of Health
National Institute of Standards and Technology

Costs

Abilene and vBNS each cost approximately $500 million to set up. The vBNS connections at OC-3 speeds can be leased for $21,600/month. OC-12 connections are approximately three times that much.

The Internet2 information site (UCAID, 2001) states that universities contributing to Internet2 have contributed over $80 million per year, while corporate members have contributed over $30 million during the span of the project. Other reports have estimated that different sources have contributed over $300 million per year after everything is calculated.

Air Force Applications

DMT-Rnet

The following information on the Distributed Mission Training Research Network (DMT-Rnet) program was provided by Mr. Jeffrey Whitmore in an interview on 13 Feb 01 and Dr. Linda Elliott on 14 Feb 01,

> "The United States Air Force is positioned to take full advantage of Internet2 capabilities. Here at Brooks AFB, researchers are involved in two major programs grounded in I-2 technology. One example of this is focused on investigations and enhancement of operational expert training

through Distributed Mission Training (DMT). The DMT-Rnet project will establish an I-2 based network for collaborative research and training via distributed PC-based systems. Another area of research which is growing exponentially is the Advanced Distributed Learning (ADL) project, another "umbrella" topic of research which integrates numerous multidiscipline projects. Both DMT and ADL projects are national in scope, with headquarters in Washington, D.C.

DMT enables highly realistic mission rehearsal based on networks of high-fidelity simulations which immerse the personnel in virtual battlespace scenarios. Because these simulations strive for maximum realism, they must run in classified mode within its own network, thus restricting data analysis and publication. In order to enable systematic investigations in unclassified mode, the DMT-Rnet project will establish the infrastructure to conduct investigations of operational performance using less costly PC-based systems. These systems will also enable cost-effective distributed training using internet access. DMT is very definitely a hot topic at this time. Much work has been accomplished to enable people in different simulators to be able to interact and train together independent of distance."

DMT-Rnet capitalizes on advanced distance learning technologies and PC-based software systems, and can go a slightly different direction from past DMT programs. The primary goal is not necessarily to put people in the different consoles and train them for operational duties. DMT-Rnet is for training *research* purposes. Instead of real-world training, the main focus is on the next level up, researching the best ways to train people for these jobs. A later goal is to possibly integrate DMT-Rnet technology into training to give the trainee a broader vision of what they are doing, but the primary objective is still to research on the training itself.

There are two contracting companies that have created Airborne Warning and Control System (AWACS) simulators for the purpose of Cognitive Task Analysis. Aptima's Dynamic Distributed Decision (DDD)-making process and 21st Century's Weapons Director Intelligent Agent Assistant are low-fidelity simulators as far as transferability to operational Air Force procedures and processes. This means that they cost much less and have lower hardware requirements and such. But they are high fidelity when it comes to the cognitive processes performed by the people working in an AWACS in the operational Air Force.

These simulators really fit the bill because they don't cost very much, they are high fidelity when it comes to cognitive task analyses (CTA), and they don't require the actual people who work on an AWACS for their subjects. The expensive and valuable training that real AWACS operators receive doesn't have to be tied up for these research projects. Any person can be shown how to operate these simulations and can be used as a subject, saving the Air Force resources that it can't afford to squander.

Several people in the Warfighter Training Research Division of the Air Force Research Laboratory (AFRL/HEA) at Brooks Air Force Base, TX, including Dr. Sam Schiflett and Captain Ed McCormick, are working on creating a Command and Control Training Research (C2TR) project that would create a Synthetic Task Environment of a Time Critical Targeting Cell (TCTC). The TCTC is part of the CAOC-Forward, which is the forward station of a deployable control center.

Essentially, the TCTC is the brain for time-critical targets. Different positions in the TCTC find, organize, assess, and prioritize different targets, decide what to do with each target and when, and then give orders to each of the people who will implement their decisions. An example would be a TCTC out in a hostile desert. It would find an enemy MIG, gather information about it, determine that it should be destroyed, and then send out orders to specific fighters to destroy it. This Synthetic Task Environment (STE) would be located at Brooks AFB.

Brooks AFB has an F-16 simulator called FPASS that can be hooked up to a DMT network. New Mexico State University has a Unmanned Aerial Vehicle (UAV) simulator that could do the same. New Mexico State University is also working on implementing Distributed Interactive Simulator (DIS) Protocol for the Air Force. This would enable these different simulators that speak different proprietary languages to communicate with each other.

Put this all together and what does it mean? Researchers at Brooks AFB are doing just that, and working to create a simulated war that could be used for research purposes. It means that a DDD (AWACS like simulator) stationed at Brooks AFB in San Antonio, TX can be hooked up with another DDD station at Aptima in Boston, MA, and others in different locations. These AWACS simulators can send their data to the TCTC Synthetic Task Environment, located at Brooks AFB. People in the simulated TCTC can manipulate the information received from the simulated AWACS, send orders to the simulated UAV at New Mexico State University to go check out a particular area and send orders to the FPASS F-16 simulator at Brooks AFB to go destroy a specific target.

Just as in the simulated weapons director programs, intelligent agents can be inserted in different parts of the process. Any of the individual pieces of the synthetic battlefield can be operated by an intelligent agent. Intelligent agents can also work in several roles, working together. Someone running the DDD can receive information from a human doing a simulation in a UAV, an intelligent agent simulating an AWACS, and send orders out to a four-ship of F-16 simulators, occupied by two humans and two intelligent agents. These F-16 simulators could have an air battle with MIGs that are controlled by another intelligent agent. This way any number of a large number of combinations of information exchanges can be examined.

As the technology progresses, in the future almost any factor will be controllable in this simulated battlefield. Weather, integrity of communications, information warfare, forces other than the Air Force, whatever the creators think of could all be set to exact specifications. Situations could be manipulated to reflect real-world conditions, or new ones that nobody has ever seen.

As the pieces fall together, Dr. Schiflett is working to get the whole interaction of simulators going in early 2003. This would enable researchers to look at each simulated station individually as well as the interactions and exchanges of information between them. No longer will we have to set up our command and control based solely on how some people think things should be done. We will have empirical data to rely on to inform the process and aid in optimization.

This entire DMT-Rnet is made possible by Internet2. Without the speed and reliability of Internet2's connections, there would be too many delays, interruptions, and other problems plaguing the project. Even now Aptima is using Internet2 connections in development of its DDD.

CONCLUSION

Internet2 is coming to life, whether some people view it as necessary or not. It has already proven its capabilities and continues to amaze people at its various demonstrations. As before when the Internet was created, people weren't sure if it was a good way to spend their money. Eventually, Internet2 will explode across the country and around the world.

We are just beginning to explore the capabilities that will be possible with connections of the speed and quality Internet2 is developing. Tele-immersion is just one example of how far we can take things, and what new options we will have. It will pay for itself many times over in travel savings alone once people really start using it. Computer-based training (CBT) is growing as people realize the savings they get, and Internet2 is like (CBT) on steroids.

As industry, academia, and government agencies are starting to realize what can be accomplished with Internet2, they are joining in a hurry and trying to get in on the action while the project is still fairly young. What was once 30 or so universities has become 180, with more continuing to join. Corporations are putting large amounts of funding toward Internet2 to realize a tremendous return on investment. Educators are excited over the potential, and even with their low budgets are make connecting to Internet2 a priority, as evidenced by the growing numbers of education networks hooking up to Internet2.

Richard Stapleton (2000) speaks on the future possibilities of the Internet,

> "Convergence of services for one" says (Internet2 spokesman Greg Wood). "Television, radio, telephone; these and more will all be coming to us over the Net." I-2's Van Houweling predicts that within three years, people will be routinely watching TV on the Internet. And the Web will quickly be a collaborative tool. Experiments with 3-D virtual worlds and virtual laboratories foretell scenarios ranging from collaboration on medical procedures to virtual family reunions. "Today's Web is used primarily to reach out for information," Van Houweling says. "Tomorrow's Internet will be used to reach out to people and work with them."

One thing is certain, Internet2 is going to take the Internet further than people expect, and will continue to surprise people with its capabilities and uses. Which brings back a previous statement from the beginning of the paper by Rory O'Conner (2000) quoting George Strawn as saying, "If you raised the same question in 1974 – asked people working on ARPAnet, 'Is the public investment in the [project] worth it?' – I think they'd have had to dance a bit for you. And I think we'd have to dance a little bit for you today."

Internet2 creators are doing the same thing that the people did when they created the original Internet, only going faurther down the road. But this time we have previous examples of what capabilities and effects Internet2 will bring about, and more will come about as time goes on. The possibilities it opens up in research, education, music, business, and every other form of information exchange and collaboration are incredible, but they are also fast becoming a reality. Eventually, the time will come when people use the example of Internet2 to justify even greater advances in Internet technology.

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Networld+Interop's conference
(http://www.key3media.com/interop/atlanta2000/)

Oklahoma University School of Music Advanced Network Videoconferencing
(http://music.ou.edu/internet2/)

LIST OF ACRONYMS

ADL	Advanced Distributed Learning
ARENA	Advanced Research and Education Network Atlas
ARPAnet	Advanced Research Project Agency Network
AURA	Association of Universities for Research in Astronomy
AWACS	Airborne Warning and Control System
CAOC	Combined Air Operations Center
C2TR	Command and Control Training Research
CTA	Cognitive task analyses
DDD	Dynamic Distributed Decision
DIS	Distributed Interactive Simulator
DMT Rnet	Distributed Mission Training Research Network
DVD	digital video disc
Gbps	gigabits
gigaPoP	gigabit Point of Presence
IPv6	Internet Protocol version 6
kbps	kilobits per second
LCD	liquid crystal display
LCOS	liquid crystal on silicon
LED	light emitting diode
Mbps	megabits
Mbone	Multicast backbone
MKOCN	Mauna Kea Observatories Communication Network
NASA	National Aeronautical Space Administration
NRN	National Research Network
NSF	National Science Foundation
NGI	Next Generation Internet
QoS	Quality of service or Qbone
SVGA	Super Video Graphics Adapter
TCTC	Time Critical Targeting Cell
UAV	Unmanned Aerial Vehicle
UCAID	University Corporation for Advanced Internet Development
UNC	University of North Carolina
vBNS	very high-speed backbone network service