

THE PENNSYLVANIA STATE UNIVERSITY

The Graduate School

Great Valley Center

AN INTERNET2 PROGRAM

FOR

GEOLOGY EDUCATION

By

Jeffrey H. Schweriner

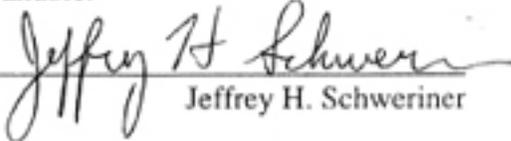
Submitted in Partial Fulfillment
of the Requirements
for the Degree of

MASTER OF SCIENCE IN INFORMATION SCIENCE

(June, 2001)

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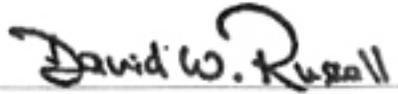

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ABSTRACT

The Internet2 is one of the most exciting initiatives in the world of information technology today. Introducing a new Internet2 program can be challenging – functionally, technically and fiscally. Remote classrooms, virtual laboratories and three-dimensional modeling using the Internet2 network are starting to be seen in disciplines such as music, medicine, and physics. Geology is an extremely visual discipline that requires visiting many locales, many visual aids, and three-dimensional visualization. It is natural to combine the high-bandwidth capabilities of the Internet2 with the visually intensive demands of geology education. The Internet2 is a natural extension of geology education as the Internet2 can help bring far away places to you.

This paper examines the requirements, both functionally and technically, of an Internet2 program for geology education and presents a potential model for other similar Internet2 applications. This paper may serve as a guide for geology departments wanting to move to the world of high-bandwidth by considering technical matters of the Internet2. Hence, the core audience for this paper is the educator familiar with geology, but perhaps unfamiliar with the Internet2 and its potential.

There is a secondary benefit to specifying an Internet2 program related to earth science education. One of the difficulties in specifying the needs of an Internet2 program is the language barrier between network engineers and professors who may be unfamiliar with cutting-edge technology. This paper attempts to "even the playing field", helping earth scientists understand the considerations of a high-bandwidth application. At the same time, it may raise awareness of common earth science educational goals for the university network administrator.

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*For my parents and sister
Who never stop believing in me and give me never-ending support*

*For my friends at work
Who helped give me a wonderful new career*

1 INTRODUCTION

1.1 Background

Internet use is becoming a way of life for the university student. One student may benefit from internet technology more than another, depending on the student's field of interest. Geology is such a discipline that can benefit more from high-bandwidth capabilities such as those available via the Internet2. But how can this powerful technology be exploited in a meaningful way? What 'edge' will this technology give students when they graduate and enter the working world?

In Section 1, limitations of the commodity Internet and an overview of the Internet2 are discussed. In Section 2, the special needs of geology education are examined and a rationale for an Internet2 program is built. In Section 3, an Internet2 program concept will be presented that seeks to bring geology students closer to remote locales. And in Section 4, the benefits of such a program are summarized and recommendations for getting started are given.

1.2 The Internet and the World Wide Web

1.2.1 The History of the Internet

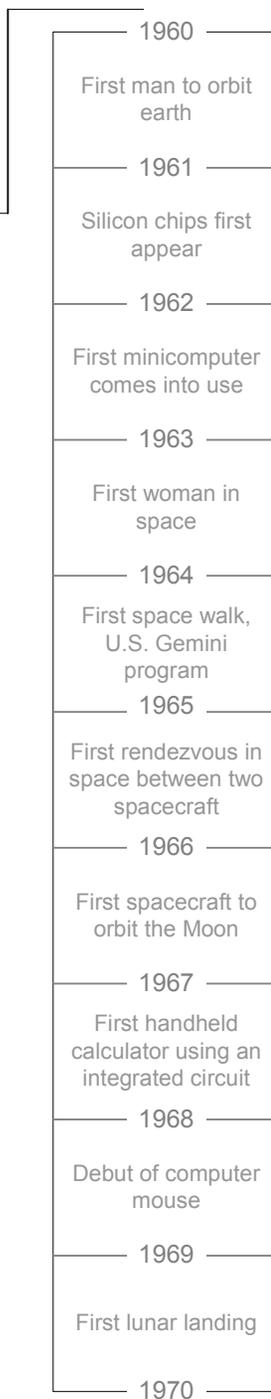
The growth of the Internet and the World Wide Web is a long, but fascinating story worth studying from both a technical and sociological point of view. For this paper however, I have chosen to highlight those points in the history of the Internet that are relevant to advancement in academic research, national and international connectivity, and key technical advancements, i.e., those areas that set the stage for Internet2 discussion. Figure 1 highlights these plus other great accomplishments in technology over the last four decades, creating the backdrop for Internet2-related achievements.

In **1957**, the Soviet Union launches Sputnik, the first artificial earth satellite. In response, the United States forms the Advanced Research Projects Agency (ARPA) within the Department of Defense (DoD) to establish US lead in science and technology applicable to the military.

In August **1962**, J.C.R. Licklider & W. Clark of MIT publishes "On-Line Man Computer Communication", a Galactic Network concept encompassing distributed social interactions.

In October **1966**, Lawrence G. Roberts of MIT publishes "Towards a Cooperative Network of Time-Shared Computers", which was the first ARPANET plan.

In **1969**, Univ of Michigan, Michigan State and Wayne State Univ establishes X.25-based Merit network for students, faculty, and alumni.



In July of **1961**, Leonard Kleinrock of MIT publishes "Information Flow in Large Communication Nets", the first paper on packet-switching theory.

In **1965**, ARPA sponsors a study on "cooperative network of time-sharing computers." As a result, TX-2 at MIT Lincoln Lab and AN/FSQ-32 at System Development Corporation (Santa Monica, CA) are directly linked (without packet switches) via a dedicated 1200 bits per second phone line; Digital Equipment Corporation (DEC) computer at ARPA was later added to form "The Experimental Network."

In **1969**, ARPANET is commissioned by DoD for research into networking .

1957 - 1970

FIGURE 1: SUMMARIZED HISTORY OF THE INTERNET HIGHLIGHTING ADVANCEMENTS IN ACADEMIC RESEARCH, NATIONAL AND INTERNATIONAL CONNECTIVITY AND KEY TECHNICAL ADVANCEMENTS.

SOURCE: CRINGELY; ZAKON

In March of **1970**, the ARPANET Host-Host protocol is first published:

C.S. Carr, S. Crocker, V.G. Cerf, "HOST-HOST Communication Protocol in the ARPA Network," in AFIPS Proceedings of SJCC.

In **1973**, first international connections to the ARPANET were established between University College of London (England) and NORSAR (Norway)

1970
AT&T introduces ESS#2 electronic switch
1971
TI releases 1st easily portable electronic calculator
1972
Intel introduces 1st commercial 8-bit microprocessor
1973
Skylab is placed in orbit.
1974
Intel releases an 8-bit chip that can access 64 KB
1975
Fiber optics trials begin in U.S. and Europe
1976
Mars space probes, NASA's Viking I and Viking II, launched
1977
Apple II personal computer released
1978
Atari 400 and 800 personal computers announced
1979
Dan Bricklin introduces Visicalc spreadsheet
1980

In July of **1970**, ALOHAnet, the first packet radio network developed by Norman Abramson at the University of Hawaii becomes operational. ALOHAnet was connected to the ARPANET in 1972.

In **1970**, ARPANET hosts start using Network Control Protocol (NCP), the first host-to-host protocol

In **1973**, Bob Metcalfe's Harvard PhD Thesis outlined idea for Ethernet. The concept is tested on Xerox PARC's Alto computers, and the first Ethernet network called the Alto Aloha System (May)

In **1979**, a meeting is held between University of Wisconsin, DARPA, National Science Foundation (NSF), and computer scientists from many universities to establish a Computer Science Department research computer network.

1970 - 1980

In **1981**, BITNET, the "Because It's Time NETwork", is started as a cooperative network at the City University of New York, with the first connection to Yale).

CSNET (Computer Science NETwork) is built to provide networking services (especially email) to university scientists with no access to ARPANET. CSNET later becomes known as the Computer and Science Network.

In **1982**, EUnet (European UNIX Network) is created by EUUG to provide email and USENET services, with original connections between the Netherlands, Denmark, Sweden, and UK

In **1984**, Domain Name System (DNS) is introduced. In the same year, Canada begins a one-year effort to network its universities. The NetNorth Network is connected to BITNET in Ithaca from Toronto.

In **1986**, NSFNET is created (backbone speed of 56Kbps)

The BARRNET (Bay Area Regional Research Network) is established using high speed links and became operational in **1987**.

In **1988**, NSFNET backbone upgrades to T1 (1.544Mbps)

In **1988**, countries connecting to NSFNET: Canada, Denmark, Finland, France, Iceland, Norway, Sweden

In **1988**, UCLA sponsors the Act One symposium to celebrate ARPANET's 20th anniversary and its decommissioning (August)

In **1988**, Countries connecting to NSFNET: Australia, Germany, Israel, Italy, Japan, Mexico, Netherlands, New Zealand, Puerto Rico, United Kingdom.

1980	Apple introduces the Apple III
1981	First space shuttle, Columbia, is launched
1982	Lotus 1-2-3 spreadsheet program announced
1983	Macintosh and Microsoft Windows 1.0 released
1984	Microsoft releases MS-DOS 3.0 for PCs
1985	Microsoft ships Windows 1.0
1986	Space Shuttle Challenger explodes
1987	Microsoft unveils Excel spreadsheet for Windows
1988	Internet Relay Chat invented
1989	ARPANET turned off
1990	

In **1982**, DCA and ARPA establishes the Transmission Control Protocol (TCP) and Internet Protocol (IP), as the protocol suite, commonly known as TCP/IP, for ARPANET. This leads to one of the first definitions of an "internet" as a connected set of networks, specifically those using TCP/IP, and "Internet" as connected TCP/IP internets. DoD declares TCP/IP suite to be standard for DoD .

In **1983**, ARPANET is split into ARPANET and MILNET; the latter became integrated with the Defense Data Network created the previous year. 68 of the 113 existing nodes went to MILNET

In **1985**, 100 years to the day of the last spike being driven on the cross-Canada railroad, the last Canadian university is connected to NetNorth in a one year effort to have coast-to-coast connectivity.

In **1986**, NSF establishes 5 super-computing centers to provide high-computing . This allowed an explosion of connections, especially from universities.

In **1987**, CERFnet (California Education and Research Federation network) founded by Susan Estrada.

In **1987**, number of hosts breaks 10,000 .

In **1989**, number of hosts breaks 100,000 .

First link between Australia and NSFNET via Hawaii on 23 June, **1989**.

1980 - 1990

In **1990**, ARPANET ceases to exist, but the world comes on-line (world.std.com), becoming the first commercial provider of Internet dial-up access

In **1991**, NSFNET backbone upgrades to T3 (44.736Mbps)

In **1992**, businesses and media begin taking notice of the Internet, as number of hosts break 1,000,000

In **1995**, NSFNET revert back to a research network. Main US backbone traffic now routes through interconnected network providers
The new NSFNET is born as NSF establishes the very high speed Backbone Network Service (vBNS)

Some of the Emerging Technologies in **1995** include JAVA, Virtual environments (VRML), Collaborative tools

1997, the 2000th RFC is published, "Internet Official Protocol Standards"

1990	Launch of the Hubble Space Telescope
1991	Gopher document retrieval system introduced
1992	Microsoft ships Windows 3.1
1993	Mosaic released
1994	First Virtual, the first online bank, is launched
1995	RealNetworks launches RealAudio streaming audio program
1996	Clinton signs Communications Decency Act
1997	Robotic explorer, Sojourner, lands on Mars
1998	Microsoft becomes world's most valuable company
1999	Intel announces the Pentium III processor
2000	

In **1991**, US High Performance Computing Act (Gore 1) establishes the National Research and Education Network (NREN)

In **1991**, NSFNET traffic passes 1 trillion bytes/month and 10 billion packets/month

In **1992**, the first MBONE audio multicast (March) and video multicast (November) .

In **1994**, NSFNET traffic passes 10 trillion bytes/month. Trans-European Research and Education Network Association (TERENA) is formed by the merger of RARE and EARN, with representatives from 38 countries as well as CERN and ECMWF. TERENA's aim is to "promote and participate in the development of a high quality international information and telecommunications infrastructure for the benefit of research and education" (October)

Sun launches JAVA on May 23, **1995**

In **1996**, MCI upgrades Internet backbone adding ~13,000 ports, bringing the effective speed from 155Mbps to 622Mbps.

Then, in **1999**, MCI/Worldcom, the vBNS provider for NSF, begins upgrading the US backbone to 2.5GBps. Abilene, the Internet2 network, reaches across the Atlantic and connects to NORDUnet and SURFnet

1990 - 2000

1.2.2 Problems with the Internet in 2000

1.2.2.1 Bandwidth and Speed

Two of the major problems with the commercial Internet now are bandwidth and speed. Simply put, heavy traffic being used for all different purposes on the commercial Internet makes it almost impossible to do any kind of meaningful research. Table 1 below provides estimates on the number of people online.

TABLE 1: ESTIMATES ON CURRENT INTERNET USAGE AS OF NOVEMBER 2000.
Source: Retrieved from World Wide Web April 26, 2001:
http://www.nua.net/surveys/how_many_online/index.html

Area	Number of people using the Internet (in millions)
Africa	3.11
Asia/Pacific	104.88
Europe	113.14
Middle East	2.40
Canada & USA	167.12
Latin America	16.45
<hr/>	
World Total	407.1 million

One factor that inhibits data transfer speed is the existence of multiple national backbones. It's possible for your information to travel a great distance even though you may be physically close to your data's destination (Kassabian, 1999).

1.2.2.2 Quality of Service

Another factor that inhibits research is that IPv4, the Internet protocol of today's commercial internet, does not support Quality of Service (QoS). QoS refers to the ability of a user to request and then expect a level of network performance. QoS is especially

critical to applications that are dependent on real-time video or audio activities (Kassabian, 1999). Refer to section 1.3.3.3 more information about Quality of Service.

1.2.2.3 Other Limitations

The TCP/IPv4 suite lacks support for *data integrity*, which refers to data being transmitted from one computer to another intact and free of errors. You can implement data integrity using error detection techniques such as *checksum* or *CRC* on top of the TCP/IPv4 protocols, but you cannot guarantee its existence because it is not native to the protocol. The TCP/IPv4 suite also cannot *ensure data privacy*.

There is also lack of native support for mobility of computers; to go beyond the local area network in which you are working you must renumber the interfaces. Renumbering interfaces refers to the need to manually assign new IP addresses for the network to which you want to log in. This can cause the user to lose active connections (Kassabian, 1999).

If these limitations of IPv4 aren't enough, the protocol will soon face *address exhaustion*. It was discovered in the 1990s that considering the rate of node growth, (computing devices attached to a network) over 10^9 possible addresses was not enough. 10^9 is the number of addresses allowed by the IPv4 system of 32 bits (4 octets). The addresses for the next generation internet protocol, IPv6, are made up of 128 bits (16 octets) and allow for over 10^{38} possible addresses – an enormous number.

1.3 Internet2

1.3.1 Overview

The Internet2 is a collaborative initiative of universities, in partnership with industry and government, to develop advanced Internet applications for research and higher education. The effort was formed in October of 1996 with 34 institutions. Currently, almost 200 academic institutions are Internet2 members.

A key goal of the Internet2 is to develop and demonstrate the next generation of network applications. Another primary goal is to facilitate and promote development of a next

generation infrastructure. More general information about Internet2 is available at <http://www.internet2.edu/html/faqs.html>.

The physical network of the Internet2 is made up of two major networks: the vBNS (Very High Backbone Network Service) and the Abilene network.

The Abilene network makes up the backbone of the Internet2 using 2.4 Gigabits per second (Gbps) IP circuits running over Synchronous Optical Network (SONET) facilities. Abilene has several industry partners: Routing and switching is accomplished with 12,000 Gigabit Switch Routers from Cisco Systems Inc. and Nortel SONET equipment; 10,000 miles of the Abilene fiber-optic cable has been donated by Qwest Communications International, Inc. for at least a three year contract. Figure 2 displays the wide-reaching Abilene and vBNS networks (Qwest, 2001).

Connectivity to the vBNS is a key component of the Next Generation Internet (NGI) initiative of The National Science Foundation (NSF). The NGI is sponsored by multiple agencies of the Federal government. There is much synergy between the NGI and Internet2 initiatives, as both programs are committed to developing revolutionary applications that require advanced networking capabilities. The available bandwidth for an application deployed over the vBNS (assuming 300 byte packets) is approximately 517 Megabits per second (Mbps) and 2072 Mbps for OC-12 and OC-48 respectively. (vBNS+, 2000).

1.3.2 How the Internet2 is Being Used Today

For the most part, the Internet2 is now being used by researchers to move large amounts of data in a reasonable amount of time, as well as providing uncongested links. These abilities are certainly valuable, but they represent a fraction of the capacity of the network's power. Currently, the big push in the Internet2 world is getting applications developed and the network certainly facilitates the design and testing of distributed applications. Universities are already starting to share resources, such as telescopes and electron microscopes, via their access to gigaPoPs (see Section 1.3.3.1).

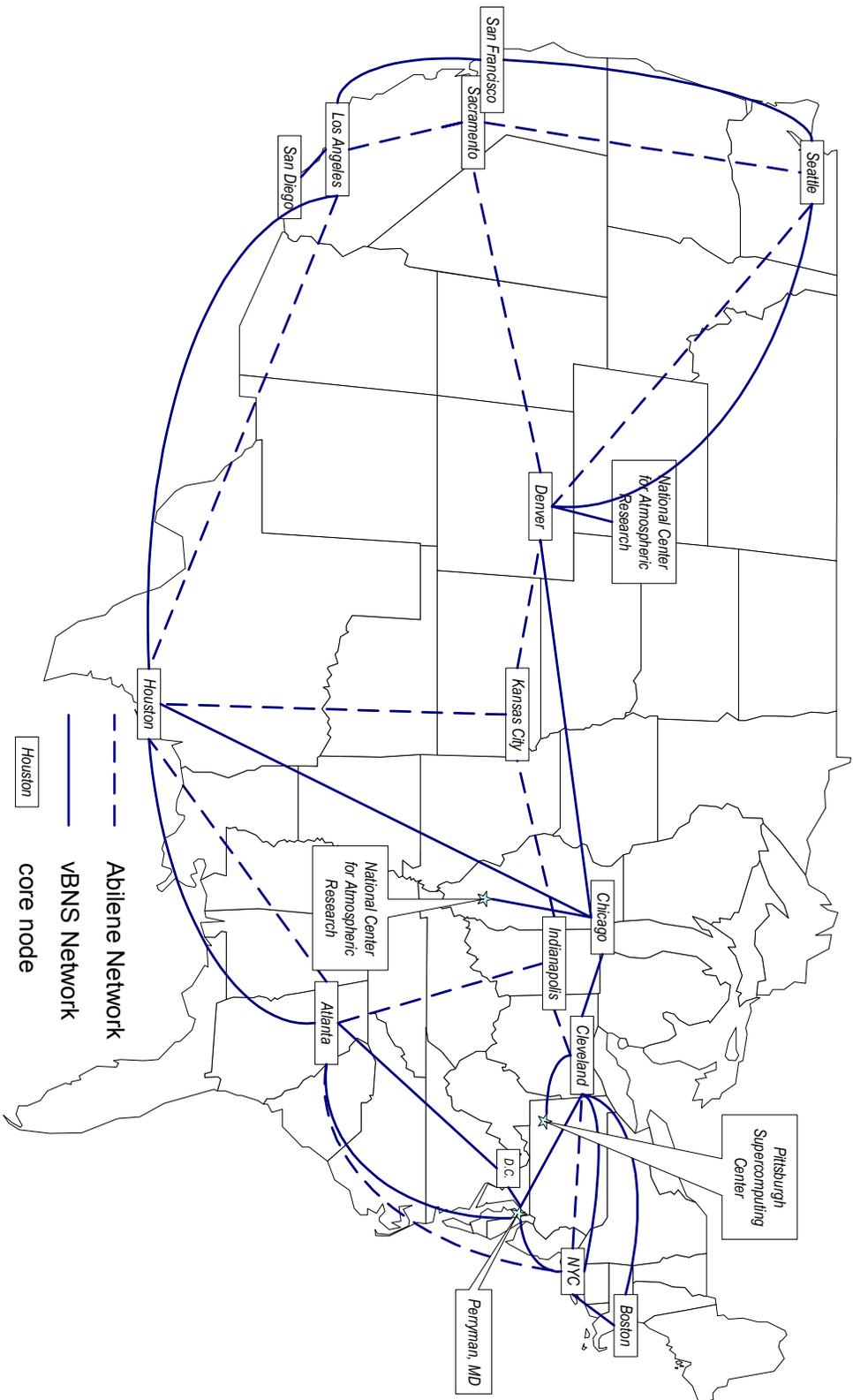


FIGURE 2: THE ABILENE AND VBNS NETWORKS
 SOURCE: [HTTP://WWW.INTERNET2.EDU/ABILENE/HTML/MAPS.HTML](http://www.internet2.edu/abilene/html/maps.html);
[HTTP://WWW.VBNS.NET/NETMAPS/BACKBONE.HTML](http://www.vbns.net/netmaps/backbone.html)

Internet2 applications are being developed in several key research areas such as digital libraries and tele-immersion (Internet2: Applications, 2000). The network is also contributing to the growth of distributed and distance learning technologies (Chinowsky, 1999). Some exciting examples of Internet2 application research are:

3-D Brain Mapping, which will allow real-time visualization of brain activity during visual and memory tasks, with the subject in a remote MRI scanner.

Molecular Interactive Collaborative Environment, that will allow multiple users at different locations to examine and manipulate a shared 3-D representation of a macromolecule in a collaborative way and in real-time.

Arts and Humanities distribution, that links actors and musicians at two universities into a single musical presentation while audiences at both sites are able to see and hear the performance as a single show.

1.3.2.1 LearningWare Applications

LearningWare types of Internet2 applications refer to high-quality instructional software that can be widely distributed. Internet2 standards suggest that LearningWare be managed by an Instructional Management System (IMS). IMS is a network-based system, consisting of standards, whereby a traditional instructional process is designed by teachers, but managed by software. The system can be shared by teachers, students, and other information providers. The main difference between an IMS in place today using the commodity Internet and Internet2-based IMS, is the ability to distribute super-rich multimedia content with the latter.

What are the components of an Instructional Management System? One component is anytime availability learning that is a cross between a highly structured classroom environment, and the totally unstructured learning usually associated with web "surfing". Another component is access to a vast amount of potential instructional material for review or to be used in a course. Quality control by publishers or content collectors is another aspect of LearningWare IMS; the IMS will allow publishers to distribute their content to a wide-reaching audience. Another distinction of LearningWare is the broader

audience that authors can reach through an IMS. This distinction is a key benefit and selling point of LearningWare, as we'll see later (Internet2: LearningWare, 2000).

The education possibilities of LearningWare are endless. A shining example of these possibilities exist within music education. The network capabilities of the Internet2 removes limitations in accessing large quantities of streaming audio. More than that, LearningWare may allow students to interact with musicians far away. At an Internet2 Awareness Day at the University of Delaware, this author witnessed two musicians engaged in a musical demonstration and critique. However, one of the musicians was in another state! This jam session was made possible through a two-way audio/video connection via the Internet2. It would also be possible to store performances (audio or video or both) on a server to be called upon later for student review.

1.3.2.2 Virtual Laboratory Applications

An Internet2 Virtual Library may be described in terms of its hardware or software components.

- Virtual Laboratory hardware demands powerful computers that are able to handle large simulations and data crunching, such as those in supercomputing centers used by the National Science Foundation, the university community, or government R&D.
- Scientific instruments connected to the network will be considered a typical component of a Virtual Laboratory. Examples are a seismograph, an electron microscope, or astronomical instruments. A Virtual Library is also made up of custom software components used for data analysis, simulations, visualizations, and data reduction. Along with the software are large dynamic and distributed databases. These databases would contain application-specific information, such as experimental observations, initial conditions, boundary conditions, and customer requirements.

Tele-immersion is one of the most ambitious examples of a *collaboration tool*, another software component of Virtual Laboratories. “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.” (Internet2: tele-immersion, 2001). The *Cave5D/Virtual Director* application is a visualization of environmental data using tele-immersion and allows multiple users at several worldwide locations to participate in immersive virtual experiences.

1.3.3 Technical Aspects of the Internet2

1.3.3.1 GigaPoPs

A gigaPoP, or a Gigabit Capacity Point of Presence, is the interconnection point of access for several Internet2 regional members. It is a physically "secure and environmentally conditioned location" that contains networking hardware. Each gigaPoP may serve 5 to 12 or more Internet2 institutions. A university's physical location influences which gigaPoP they access.

It is suggested by the Internet2 Engineering Working Group that a gigaPoP operate with minimal onsite staff and operate under its own policies. There are two general types of gigaPoPs, Type I and Type II. A Type I gigaPoP is more simple, in that it serves only Internet2 members and routes IP traffic via one or two connections to other gigaPoPs. Type II gigaPoPs serve Internet2 members and other networks, such as government networks. These gigaPoPs may also route IP traffic to several gigaPoPs. This complexity requires a more complicated routing system and a higher level of security.

GigaPoPs will provide IP common bearer services (IPv4) and migrate to IPv6 with QoS as soon as practical. A *common bearer service* is simply basic information transport interface for communications among network applications. Figure 3 depicts the potential relationships between gigaPoPs and the institutions they serve.

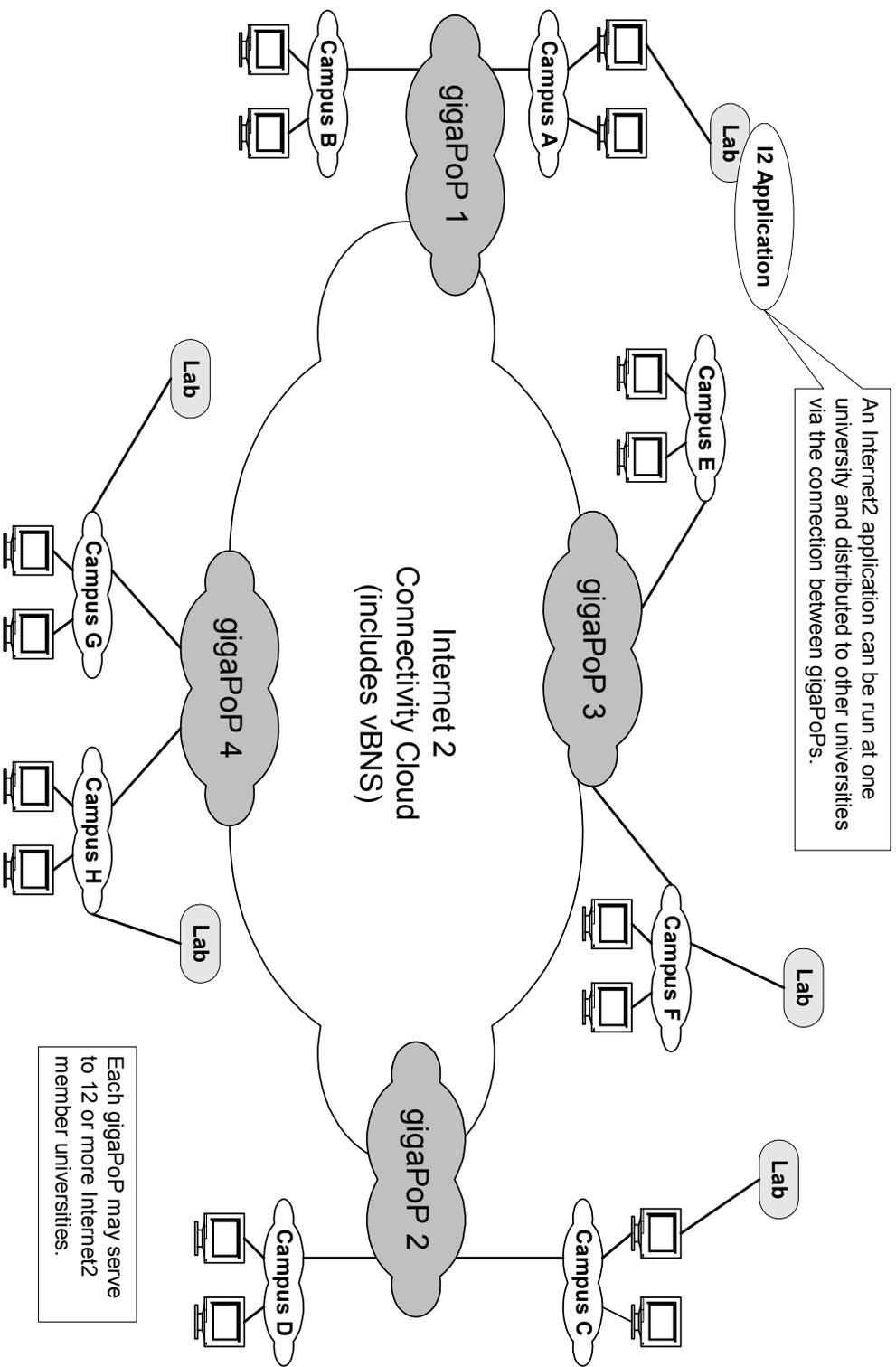


FIGURE 3: GIGAPOP DIAGRAM EXAMPLE
SOURCE: INTERNET2: PRELIMINARY ENGINEERING REPORT.

1.3.3.2 The IPv6 Protocol

As mentioned above, the current TCP/IPv4 protocol is lacking in some of the qualities needed for many Internet2 applications. Therefore, the Internet2 will take advantage of the developing IPv6 protocol, but will continue to service the current IPv4 protocol (Kassabian, 1999).

Unlike TCP/IPv4, IPv6 provides support for a minimum level of security and data integrity (Kassabian, 1999). IPv6 can authenticate IP traffic for security purposes, can fully or partially encrypt IP packets, and will allow developers to use strong cryptographic algorithms. Having this security at the internet protocol level can benefit "security aware" applications, as well as 'security ignorant' applications that don't take explicit advantage of security features" (Internet Engineering Task Force, 2000).

1.3.3.3 Quality of Service (QoS)

QoS is one of the most important aspects of the Internet2, as it provides the network with a guaranteed service level that is not available with the commodity Internet. With QoS, "[one] can request a guaranteed level of service and then expect that it will be provided if the request is granted" (Kassabian, 1999). Critical components of Internet2 QoS are made of the following:

Constant Bit Rate (Constant Variance)

Constant Bit Rate is an Asynchronous Transfer Mode (ATM) service that supports a constant or guaranteed rate for transport services such as video or voice, as well as circuit emulation. These require rigorous timing control and performance parameters.

Latency

Latency is the time delay between when the first bit of a packet is received and the last bit is forwarded. Achieving low latency is critical when you are talking about real-time applications involving video. With QoS, a user could specify that the gaps between packets should never be enough to cause an interruption in the video feed.

Throughput

Throughput is the amount of data to be transmitted in a specified time period. For example, a user might request that a Gigabit of data be transferred in one second.

Scheduled Capacity

A user could specify that their services be available during a certain time frame. This quality is especially critical when, for example, you are attempting to schedule university classes. This quality would allow a professor to schedule Internet2 access around her class time, not the other way around.

Loss Rate

Loss rate is the highest packet loss rate (number of packets lost / number of packets sent) that can be expected within a specified time interval.

Speed

Transmission speed is simply the data rate to be provided. With QoS, an average speed and tolerable boundaries may be set, as a user may need a connection with an absolute minimum data rate for a certain application. The user would also agree to not expect transmission greater than a certain bit rate.

1.3.4 Capabilities of the Internet2

There have been some amazing demonstrations in the past twelve months of the capabilities of the Internet2 – demonstrations that make one think of *Star Trek* where information flows on demand and as easily as tap water. One popular example of this is that theoretically the Internet2 has the capacity to send the entire library of Congress from one coast to the other in under a minute. Figure 4 compares Internet2 bandwidth capacity expectations to that of other entities.

In one recent Internet2 land-speed contest, a team used the High Speed Connectivity Consortium (HSCC) Network (a sub-project within the Internet2 initiative) to send 8.4

gigabytes of data (the equivalent of about 6,000 full floppy discs) from Redmond, Washington to Arlington, Virginia (a distance of 5,626 Km) in 81 seconds at a transfer rate of over 830 megabits per second.

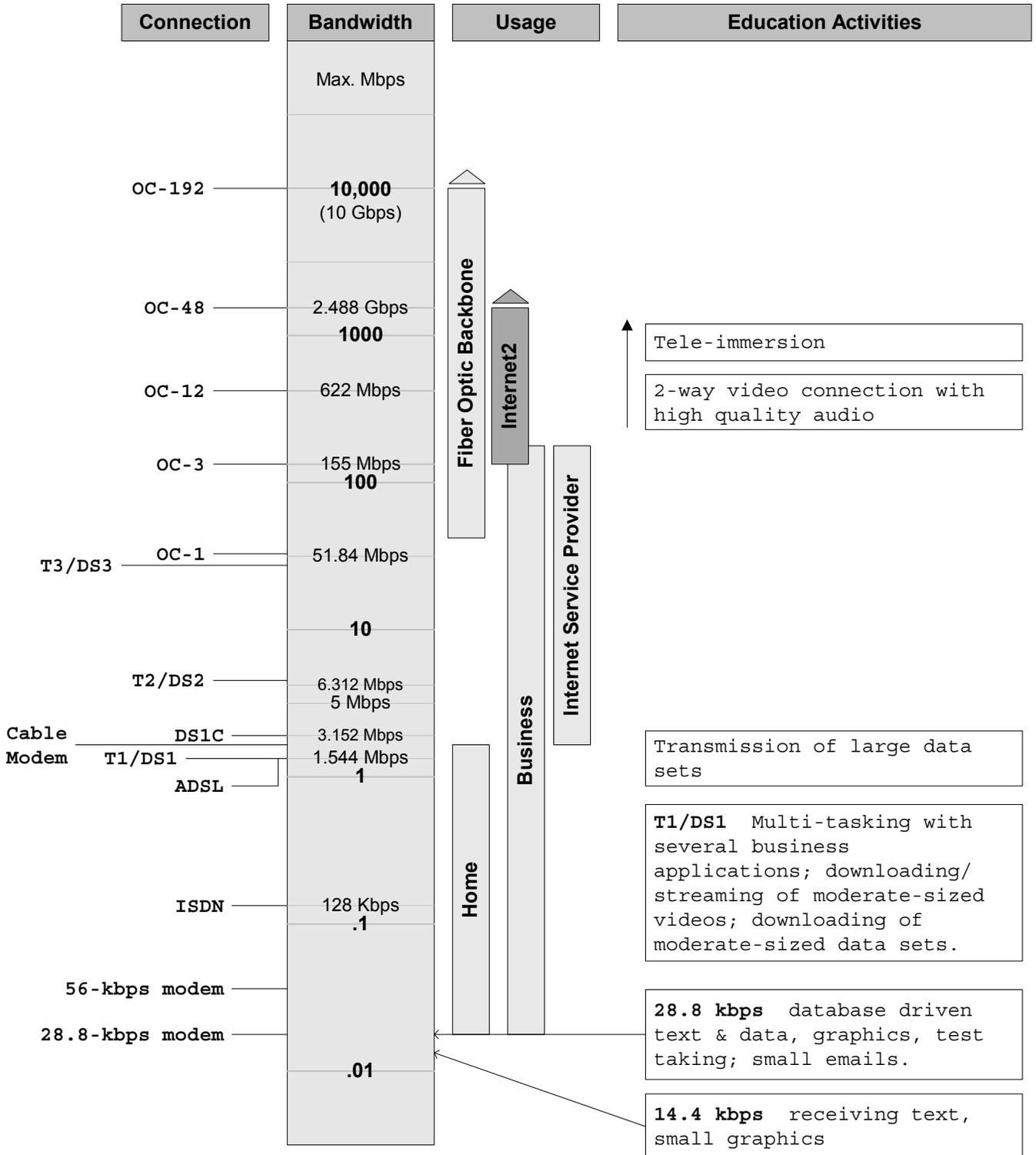


FIGURE 4: INTERNET2 CAPACITY
 SOURCE: [HTTP://WWW.BANDWIDTH.COM](http://www.bandwidth.com)

2 DEVELOPMENT

2.1 Education via the Web

2.1.1 The State of Online Distance Education Today

The need for education and training beyond secondary school is increasing, and this must continue throughout a worker's life. In the United States, it is estimated that college enrollment will increase by over 15 percent by the year 2010 (United States Department of Education, 2000).

Online distance education is thriving today. It is also a political issue, as politicians see online education as a way to deliver quality education to the many who could not easily get access to it otherwise. Online education is well suited for lifelong learning, for lifelong learners often include non-traditional learners such as older people and single working parents who may have limited access to a classroom setting.

Online education is being used to conduct a wide variety of courses, by academia and by for-profit companies. For example, New York University offers courses, degrees and certificate programs in management, systems, and information technologies in their *Virtual College* program. *Stanford Online* offers graduate level engineering courses, degrees and certificate programs. Companies like DeVry, ITT Education Services, and the Apollo Group have made online training a significant part of their overall programs.

The president of the University of Utah, Dr. J. Bernard Machen, spoke about online education at his inauguration speech. He stated that the virtual university seemed to him "most appropriate for the job skills component of education." Dr. Machen went on to say that the virtual university "limits the broader, more interactive aspects of a university education... Learning about the different professions and academic disciplines available at the University of Utah requires personal involvement, and that is only available on our campus and it can only be experienced by being here" (Harris, 1999).

This is put eloquently and this author believes, on target. The Internet2 should be envisioned as yet another productivity tool to provide a richer experience, not for

replacement of education standards. And as we'll see in Section 3, a geology education with its visual nature, fits with this perfectly.

2.1.2 Problems

2.1.2.1 Quality

Quality, namely speed, is not a problem for most of the low-tech (predominantly text-based) online education programs. When graphics are added to the mix, research from Stanford University indicates that pictures must consistently download in 10 seconds or less for the program to be worthwhile. There is a significant difference in the tolerability of slow downloads for occasional surfing versus using the Internet to really learn something. In a study conducted at Stanford, 2000 learners from 110 countries participated in an online course. Almost a third of these people dropped out due to quality of service issues. This course illustrated the vast differences in quality of service from country to country. In another online course at Stanford directed towards engineering professionals in the Silicon Valley area, quality of service was, not surprisingly, a significant factor (Harris, 1999). Although faster home connections such as cable modems are becoming more common, the “last mile” problem of dial-up access via analog phone lines continues to hamper productivity.

2.1.2.2 Location to Participate

We all see the growing popularity of the Internet. It seems that not having Internet access is the exception. However, when considering access to online training, an often overlooked factor is access to a quiet, productive place to learn. Any effective education, online or otherwise, requires concentration. Online education demands an uninterrupted phone line, which most homes still do not have. Feedback from students at Stanford indicate that having a proper setting to pursue online learning remains a significant issue to consider (Harris, 1999).

2.2 The Special Needs of Geology Education

2.2.1 Visiting Many Different Environments

Geology education has special needs. Math is math wherever you study it, but geology is different. Geology education at the university level may often be biased towards the region of the country. Volcanology 101, while popular at the University of Hawaii, will not likely be taken at the University of Delaware. Similarly, coastal plain geology, popular at the University of Florida, may not be stressed at the University of Kansas.

Figure 5 depicts the major physiographic regions of the United States, along with several Internet2 university members. This demonstrates the varying exposures that a student may have, depending on their school. A wide-reaching information source could allow for a broader array of geological experiences for the student. This is necessary in today's global economy, as today's geologists may find themselves having to work far from their alma mater, whether involved in petroleum exploration or environmental clean-up.

Everyone in business today must be prepared to be mobile. The more exposure to various geological regions in the country and the world, the more well-rounded and marketable the new geology graduate will be. Overlain on the physiographic regions of Figure 5 is the powerful Internet2 Abilene network. This juxtaposition demonstrates that the country's broadband capabilities reach each geologic corner.

Quality geology education requires more hands-on fieldwork experience than most other disciplines. Most institutions are limited to examining regions within reasonable driving distance. During this author's undergraduate experience at the University of Delaware, our field trips focused on southern Delaware, central eastern Pennsylvania, and northern New Jersey. I took advantage of a unique opportunity to visit Wyoming and Montana during a summer at geology field camp, however I recently learned that this class has been canceled due to the high cost of coordinating the effort.

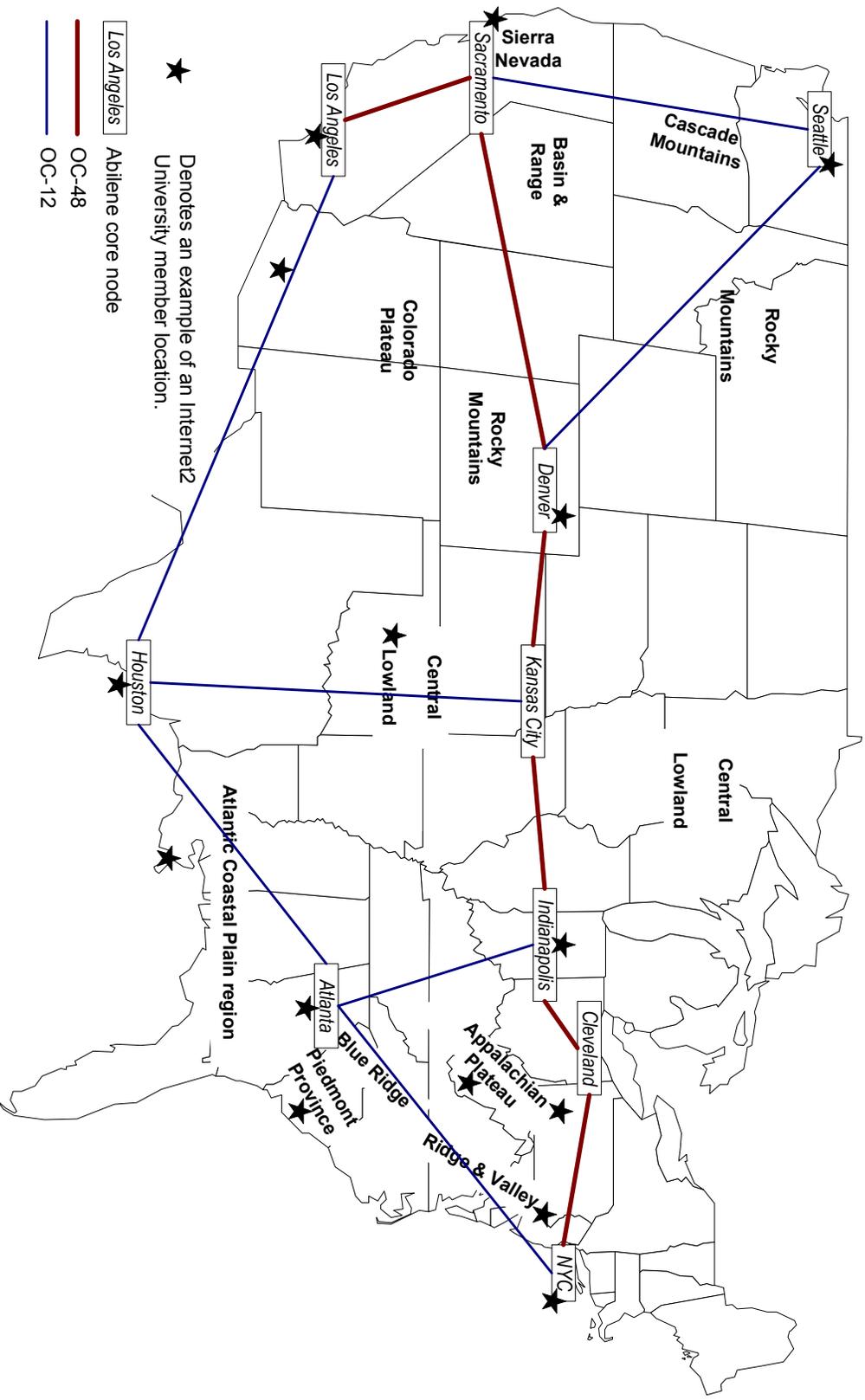


FIGURE 5: PHYSIOGRAPHIC REGIONS OF US OVERLAIN ON THE ABILENE NETWORK
 SOURCE: [HTTP://WWW.INTERNET2.EDU/ABILENE/HTML/MAPS.HTML](http://www.internet2.edu/abilene/html/maps.html), MARCH 1990; PRESS & SEEVER, EARTH, 1986

Stephen Hurst states that "trips to diverse geological settings over the course of a geologist's career provide breadth of experience and depth of understanding of the geologic processes of the earth." The computer also allows students to visit places that would normally be off limits (Hurst, 1998). This author had the privilege of participating in Volcanology at the University of Hawaii through an undergraduate student exchange program. The course was taught by the state Volcanologist, who had access to areas the average tourist did not, such as off-limit areas on the Big Island. This was a rare experience. Hurst imagines that with computer simulations, it would even be possible to visit places even more remote, like the moon or mid-Atlantic ridge! Could students someday have this kind of access to all the geologic regions of the world?

2.2.2 Numerous Visual Aids

Geology education has a unique set of classroom materials in addition to the usual class notes. Paper materials include topographic maps, geologic maps, aerial photographs and drilling logs. Other visual aids include high-resolution photographs, laboratory rock and mineral specimens, petrology charts, and hydrogeologic contour maps.

2.2.3 Thinking in 3-D

Geological education teaches you to think in three dimensions in many sub-disciplines such as structural geology and stratigraphy, hydrogeology, petrology, mineralogy and crystallography. The computer is a natural extension of pencil and paper (often folded paper) for the geology student. However, to share three-dimensional data in real time across distances requires powerful computers and a high-bandwidth network.

2.2.4 Laboratory Instruments

At the heart of the geology classroom is the geology lab where theories and observations are applied. Geology students may have several tools at their disposal depending on the institution – the petrography microscope, seismometer, x-ray fluorescence spectrometers, scanning electron microscopes and others. These tools seem especially appropriate for web access (Argast, 1998). Argast demonstrated that a diffractometer can be controlled

using a browser. Despite the cost, Argast also believes that web accessible devices can impact geological research and teaching in several ways –

1. Sharing of resources among institutions, resulting in an overall cost savings. Internet protocols may also allow exposure to underdeveloped countries that cannot afford the cost of specialty research devices.
2. More fluidity and interactivity in the classroom setting. Moving back and forth from lecture to a web accessible device can be more exciting for the student.
3. The ability for high school students and even younger children to visit the university environment and take part in experiments.
4. Accelerated collaboration in research among separate institutions through real-time data exchange.

2.3 Geology and the Internet: What has been done?

2.3.1 Classroom Materials Online

There are countless college level courses, in geology and other disciplines, which use the commodity Internet to distribute and archive class materials. Most students find this an efficient way to obtain critical class information during off-hours.

2.3.2 Virtual Field Trips

In the past, bringing other geological regions to the student has been attempted in several ways. Slide shows with hand-held rock specimens are a traditional and easy way for students to visit other geologic locales. The Geological Society of America and the Open University in the United Kingdom have prepared videotapes of field trips. This type of experience lacks an interactive element, limiting the student's ability to extract and analyze data.

Field trips are planned journeys that are designed to illustrate geological relationships. The value of field trips is the interpretation of data collected at several scales and locations. Professor Stephen Hurst designed a series of geologic case studies using

visualization techniques and traditional laboratory materials. Hurst makes the case for *virtual* field trips, noting that a computerized field trip enhances teaching by making more data available and gives the student more control of the data (Hurst, 1998).

Hurst's project involved the formation of three case studies that combine state-of-the-art technology with traditional teaching materials. Each study incorporated the following steps:

1. Familiarization of the area using several sources that may have included satellite imagery, aerial photos, topographic maps, limited geologic data and rock samples.
2. Formation of a hypothesis about the area and proposals for testing the hypothesis.
3. Gathering of additional information such as earthquake data, geochemical data, and more.
4. Analysis of the data and refinement of existing or formulation of new hypothesis.

According to Hurst, the students learned the most when they created the field trip themselves! Although this was a time-intensive exercise, students benefited by learning additional skills such as some programming techniques and data handling (Hurst, 1998). Would it not be an incredible learning and social experience to have a group of students in one region of the country present their virtual field trip to a group of students in another region?

2.3.3 Virtual Earthquake

There are some excellent examples of online geology experiences with meaningful interactivity, though they are all limited by capabilities of the commodity Internet. *Virtual Earthquake* is an online learning entity that allows students to discover how the Richter magnitudes of epicenters are determined. Gary Novak at California State University developed the Virtual Earthquake application as a model for other online geology labs. The application allows students to measure data on-screen and submit these variables to the server. Usability studies on the program were positive – students and instructors alike

rated the program high and stated unanimously that similar online courses would be welcomed.

Novak cited low quality of service, support and sustainability as disadvantages of applications such as Virtual Earthquake (Novak, 1999).

2.3.4 The UND Geology Explorer Project

The Geology Explorer project is an online initiative at the University of North Dakota that allows students to visit a virtual geologic environment. With Geology Explorer, multiple users can visit a virtual planet and perform simple experiments. The first version of the program, while text-based, is goal oriented, and strives to have the user think like a geologist. There are more than 50 environments described on the virtual world (called Planet Ort), complete with 100 rock and mineral types, 200 explorative features (outcrops, veins, etc.) and many instruments at the student's disposal (Geology Explorer Project Details, 2000).

The Geology Explorer project is extremely significant. It is a comprehensive attempt to bring different environments closer to the geologist using a computer network. Although Geology Explorer is low in visual experience at the present time, there is much interaction and problem solving within a session.

2.4 What's Needed: Part LearningWare, Part Virtual Laboratory

The key advantage of the Internet2 is being able to push large amounts of data to various locations quickly. Unlike videotapes, CD-ROMs, or the commodity Internet, the Internet2 has the capabilities of providing a rich, real-time educational experience.

2.4.1 LearningWare

The Internet2 has shown that interaction between two people in separate locations via Internet protocols is possible and the ability to bring far-away places closer to the student will always be key to a geology student's experience. This has already been demonstrated at the Seattle Community College District (SCCD). A geology instructor at SCCD used a television news van and a gigaPoP connection to bring a fault line 20 miles from his

classroom to his students. (The fault line area did not allow for all of the students to visit). Instructor Joseph Hull notes the high cost of traditional field trips as a reason to make them virtual. He also notes the difficulty in coordinating trips and the fact that field trips may exclude students with disabilities. Hull views virtual field trips as enhancing a course, not replacing traditional field trips (Carnevale, 1999).

2.4.2 Virtual Laboratory

As mentioned earlier, in addition to paper materials the geology student relies heavily on visual aids. How can network-driven materials provide an adequate, or even better experience?

Laboratory specimens are good examples. While no computer screen can take the place of holding a rock or mineral specimen in your hands, high-resolution photographs can provide information on color and color patterns (banding), shape and crystal structure, and size if photographed next to a common object for scale.

Rocks in thin section are necessary for petrologic conclusions about an area. There are several advantages to viewing rocks in thin section on a monitor rather than a microscope. Certainly fewer microscopes are needed because several students can view the image at the same time, which also saves in microscope maintenance. Often professors will have a class view a thin section image on a large monitor anyway. In addition, students can print the image out for reference later. Of course, monitors must allow for a high enough resolution to view rocks in thin section. Monitors that display at least 1000 x 1500 lines of resolution are recommended for examining details (Wong, 1999). Also, using a network connection, it is possible to view the thin sections of another university!

The idea of viewing geological aids on a computer monitor via a network connection can also be applied to fossils, field notes, geologic and topographic maps, and reference material. Internet protocols provide an ideal platform for the development of digital libraries, especially where there is potential for a large number of requests and wide distribution is required. This is contrary to the use of digital libraries in the health care

field for example, where a PAC or Picture Archiving & Communication System is often used to provide services to a limited number of image workstations. In the healthcare industry, quick access to medical images is essential for diagnosis or clinical review (Wong, 1999).

2.5 The University Network Environment

The university networking environment is often a mixed-bag of architectures, protocols, and physical wiring. This is simply due to the size, age and complexity of the typical university. While it would be impossible to characterize every university, a relatively robust environment was examined in this study, based on the recent state of one particular distinguished Internet2 university.

2.5.1 Typical University Network Environments

Many universities have a place of central routing. Individual buildings may be connected over fiber cable at approximately 10 Megabits per second (Mbps) or more. There may be thousands of end stations ranging from small printers to large workstations (Kassabian, 1999).

Many universities have remote campuses outside the fiber distance. For these locations, 1.5 Mbps T1 lines or 128 Kilobits per second (Kbps) ISDN lines may suffice. Figure 6 depicts some characteristics of a large university's network.

2.5.2 Remote Access

Just as in the business world, remote access to the university network is becoming commonplace and often a necessity. Most universities will support Point-to-Point Protocol (PPP) for dial-up access. This type of access is dependent upon the speed of your PC's modem and the 'last mile' of digital access to your home, often times an analog phone line.

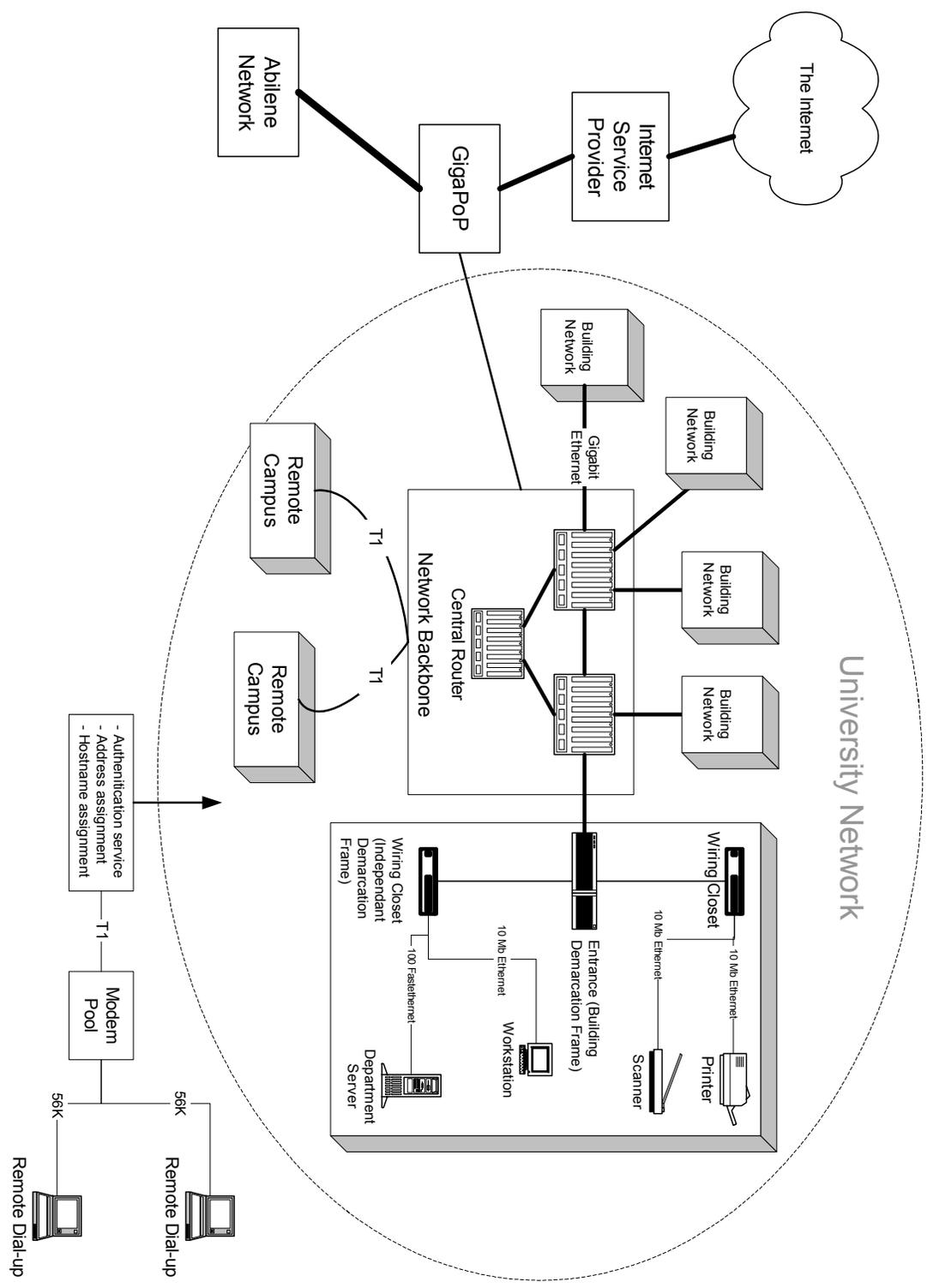


FIGURE 6: EXAMPLE OF A UNIVERSITY NETWORK
SOURCE: KASSABIAN, 1999

2.5.3 Protocols

Not surprisingly, TCP/IPv4 is the dominant protocol on the university campus today. Non-IP protocol suites may also be found at the university, such as AppleTalk and IPX. AppleTalk is an inexpensive LAN architecture built into all Apple Macintosh computers and laser printers. IPX is short for Internetwork Packet Exchange, a connectionless networking packet protocol used by the Novell NetWare operating systems.

(*Connectionless* refers to network protocols in which a host can send a message without establishing a connection with the recipient. The host puts the message with the destination address onto the network and hopes that it arrives. *Connection-oriented* protocols require a channel to be established between the sender and receiver before any messages are transmitted.)

Often times *tunneling* of non-IP protocols is supported. Tunneling is "the transmitting of data structured in one protocol format within the format of another protocol. Tunneling allows other types of transmission streams within the prevailing protocol" (Kassabian, 1999).

2.5.4 Physical Wiring

Kassabian describes networking at the University of Pennsylvania as a utility, "as fundamental as electricity and water." But at Penn and many other universities there is much wiring work to be done. While it is impossible to make assumptions about the infrastructure of all universities, it is probably safe to say that there exists a mixed bag of wiring at any given university. Wiring can vary from building to building depending on the age of the structure and will reflect the standards that were in place at the time.

Migrating to the next generation university infrastructure can be costly in equipment and in training staff in new technology. However, these costs may be unavoidable for universities to remain competitive.

3 RESULTS – AN INTERNET2 PROGRAM FOR GEOLOGY STUDENTS

3.1 Program Objective

So, what is the best way to harness the networking power of the Internet2 for the geology student? A program objective can be stated in the following way:

A **program** whereby geology department faculty and students at **different universities** in **different physiographic regions** of the country can **share regional information** about their locale through lectures, field notes, and supplemental information, by way of **real-time digital video** and a **shared database**.

This program, which we'll call *GeoNet*, requires that each participating Internet2 university (at least two in different physiographic regions) make certain regional lectures and supporting data available on the Internet2 network for the other participating university(s) to use. Using internet technology will allow geology students to explore their world further, giving them a richer academic experience and making them more marketable when they graduate.

Figure 7 depicts the overall GeoNet program and the relationships between the various entities at a high level.

Whenever specifying any software, it is necessary to state the functional requirements upfront. In specifying an Internet2 program for geology students, the following requirements should hold true; i.e., faculty will want to keep these ideas in mind when implementing an Internet2 initiative at their institution.

- The program must serve to replicate the live geology classroom and *complement* the geology lab environment.
- The program must strive to obtain the same level of engagement and responsibility from the student as would a live classroom.
- The program must provide a real-time experience with a high quality of service.

- The program must be flexible to allow for future improvements.
- The program must serve to uphold basic principles of geology, and physical science education wherever possible.

In the next section, functional requirements and a high-level design for GeoNet are suggested.

3.2 Functional Requirements

Figure 8 depicts the high-level navigational flow and Figures 9a and 9b suggest a user interface concept for the application. The elements of the navigational flow are described below.

3.2.1 Lecture Hall

This critical element of the program consists of scheduled lecture presentations or field trips from another Internet2 university via a two-way video/audio network connection. The events are viewed on an oversized screen in a lecture hall room.

3.2.1.1 Scheduling Lectures

It is critical to maintain a schedule of what will be presented in the Lecture Hall, including - topic, time, and any necessary abstracts. This schedule should be maintained by the respective department administrator via a simple administration tool. The schedule could be viewed by each participating geology department.

3.2.1.2 Supporting Articles

Articles that support the lectures should be made available in the program. The articles would be uploaded by the respective department administrator or the lecture's instructor via a simple administration tool. It is recommended that the articles be available as attachments stored in Portable Document Format (PDF). It may be difficult to obtain articles in electronic form depending on the article's age, but there is a simple work-around to this: faxing a hard-copy of an article to an eFax™ number, and then receiving the eFax and converting it to PDF form is a simple, quick and reliable method for

converting hard-copy documents to electronic form. The only disadvantage to this method is a slight degradation in quality.

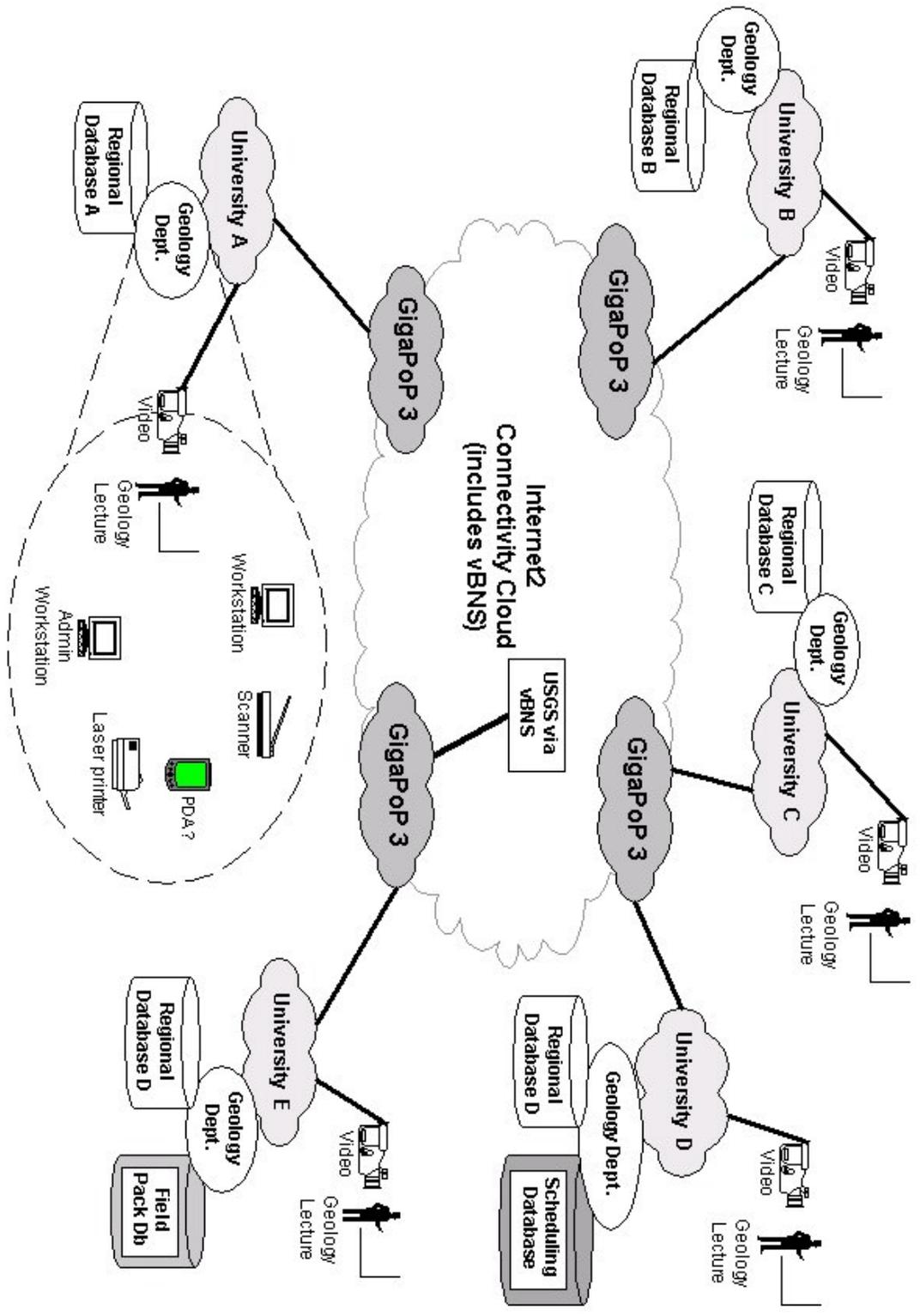


FIGURE 7: OVERVIEW OF THE GEONET PROGRAM

GeONet Gateway @ The University of Oregon

Region Database

- Appalachian Plateau
- Region Overview
- @ University of West Virginia
- Current Research
- Online Lecture Schedule
- Regional Geologic Maps
- Regional Topographic Maps
- Faculty and Students
- Geology Club Information
- Atlantic Coastal Plain region
- Basin & Range
- Blue Ridge
- Cascade Mountains
- Central Lowland
- Colorado Plateau
- Piedmont Province
- Ridge & Valley
- Rocky Mountains
- Sierra Nevada

SEARCH

Topic Keyword

Lecture Hall



Presentation Slide

Oregon Basalts

1 of 12

↔



Lecture Running Time: 00:23

[Make New Connection](#)

[Break Current Connection](#)

[Audio Controls](#)

[Video Controls](#)

[Help](#)

Field Pack

- [Metric-SI Conversions](#)
- [Units of Measure](#)
- [Dictionary of Geologic Terms](#)
- [Geochemistry Handbook](#)
- [Rock & Mineral Handbook](#)
- [Paleontology Database](#)
- [MyFieldNotes](#)

Now Showing

- Volcanology 101 Lecture 4
- Measuring Seismic Activity
- University of Washington
- Professor Joseph Bloggs
- 1000-1050 PST
- [Go to Main Scheduling Interface](#)

Supporting Info for Current Lecture

- [Thompson, *Volcanology of the Western States*, 1998](#)
- [Parker, *Geophysics of Washington State*](#)

FIGURE 9A: APPLICATION INTERFACE CONCEPT

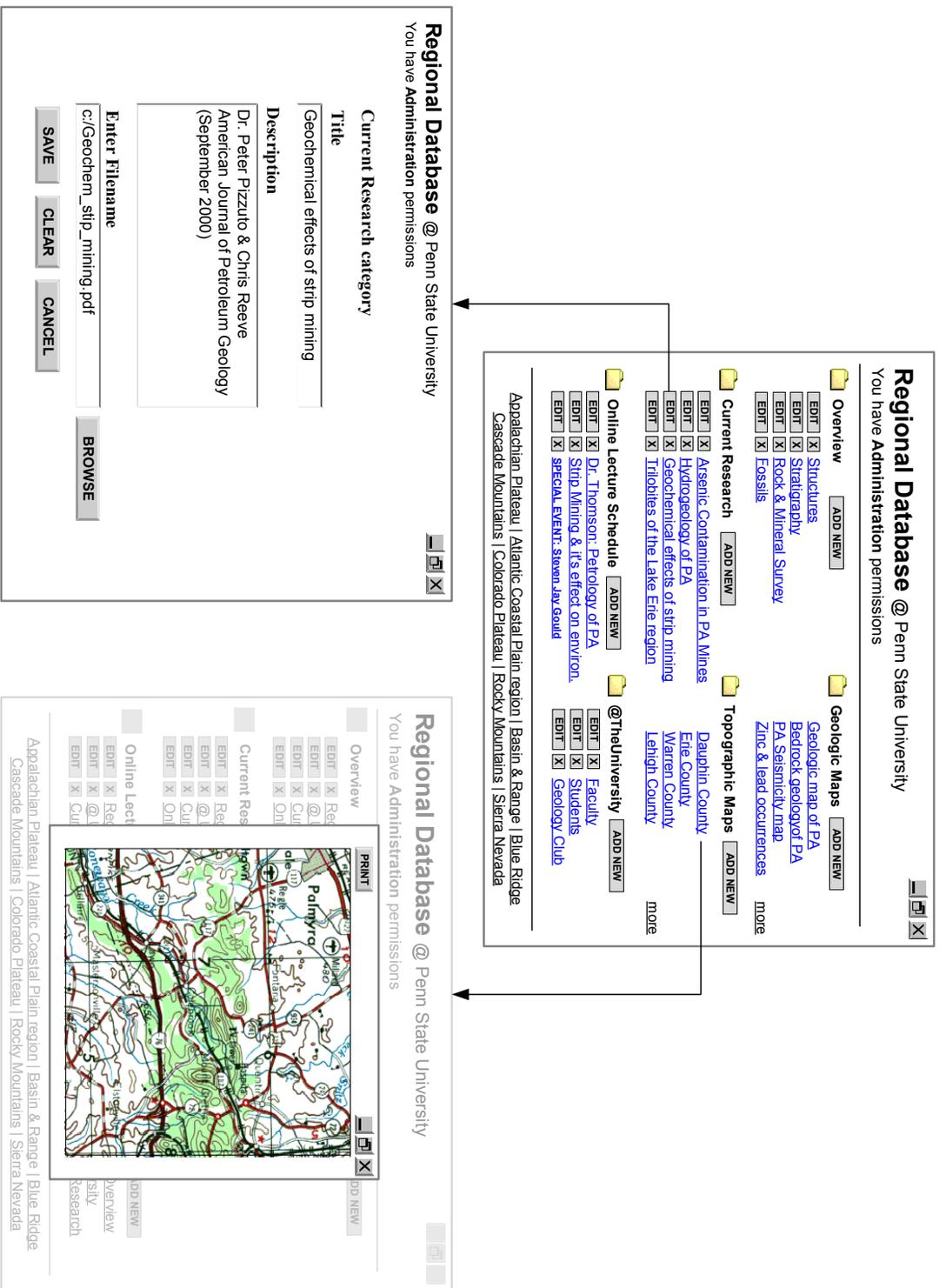


FIGURE 9B: APPLICATION INTERFACE CONCEPT (REGIONAL DATABASE ADMIN TOOL)

3.2.1.3 Lecture Archive

The Lecture Archive allows a department to record and save lectures for future viewing. It is not practical or necessary to record every lecture given, but special events like guest lecturers may be considered. This can be considered a future enhancement to GeoNet, as the resources needed to store lectures (hard-disk space, administration time, etc.) may outweigh the added value to the program.

3.2.2 Region Database

The Region Database contains comprehensive information about each region. This database can be a living and breathing collection of research, notes, hypothesis, and photographs. It's important to give each university department the freedom to organize their information in a way they see fit. Therefore, document attachments (Word or PDF), rather than ASCII text in database fields, may be preferable. Formats such as Word also make it easier to note special symbols and scientific characters. The documents could be uploaded by the respective department administrator via a simple administration tool.

3.2.3 Field Pack

The Field Pack section of the program serves to assist the geology student with traditional supplemental information. This section would be common to all participating departments. Each part of the Field Pack could be the responsibility of one of the participating departments and shared by all. The exception is the MyFieldNotes (3.2.3.6), which are students' own observations and hypotheses.

3.2.3.1 Geologic Maps

Geologic maps are vital to a student's understanding of a locale. Ideally, each department could tap into the United States Geological Survey (USGS) repository of geologic maps, allowing access to the maps in some standard viewing format. This is a good example of where a government agency could partner with the Internet2 community.

3.2.3.2 Topographic Maps

Access to topographic maps is critical as well. Currently, topographic maps are available off-the-shelf in CD-ROM form. It would be simple enough to have these live within a database on a server to be downloaded and printed out. This is a good example of where an outside publisher could deliver it's content through a partnership with a university or group of universities.

3.2.3.3 Rock & Mineral/Paleontology Database

This is a simple informational database with complete descriptions and hi-resolution photographs. Again, this feature is an opportunity for an outside publisher of a rock and mineral text or paleontology text to deliver it's content on this system through a partnership with a group of universities.

3.2.3.4 Charts and Tables

Having handy conversion charts (US-Metric-SI) and units of measure tables are also critical. Reference charts are good examples of information that could be easily downloaded from GeoNet and stored (synchronized) with a personal device such as a Personal Digital Assistant (PDA). See section 3.2.3.6, MyFieldNotes.

3.2.3.5 Dictionary of Geologic Terms

This is a third example of where an outside publisher could deliver it's content via another medium. It would also be interesting to translate this into other languages! Other references are possible of course, such as a Handbook of Geochemistry.

3.2.3.6 MyFieldNotes

As mentioned above, MyFieldNotes consists of the individual student's own observations and hypotheses. Field notes can be stored in simple text (ASCII) form. Although field notes are usually a personal record, there may be instances where students can benefit from the collections of others; an option for MyFieldNotes would be to allow the student to set permissions for his/her notes, either private or public.

A means of inputting for electronic field notes is an option to consider. The idea of capturing personal notes is not new in academia and industry. PDAs such as the Palm Pilot are enormously popular in business. They allow employees to make personal notes, receive email, synchronize their calendar with a PC, and store files. A Digital Field Notebook is a geologist's tool of the future, allowing the user to capture real-time data like a laptop, but having the ruggedness of a traditional notebook. There are such items available today, such as the Xenus 810-E Tablet product, a hand-held electronic notebook. Devices like this are not only incredibly powerful and extremely durable, but they also have optional docking stations as well. At present, these items are too expensive for most students to purchase, but sharing one or two department devices among students may be reasonable.

3.3 Technical Requirements

There is a difficulty in specifying technical requirements for a program like GeoNet in that technology standards are always evolving and capabilities always increasing – especially with regards to digital video. There are many initiatives within Internet2 and the private sector on bringing digital video more efficiently and cost-effectively to the user, and the latest information should be consulted before committing to one setup type. Table 2 provides a summary of the technical considerations for GeoNet.

Many departments of a single university, considering the high cost of digital video, would undoubtedly share an Internet2 videoconferencing setup. Chances are that more popular or more life-enhancing disciplines with greater performance needs than geology, will set the standard.

3.3.1 Network Requirements

3.3.1.1 Speed

Minimum data rate requirements for GeoNet would be decided based on the needs of the Lecture Hall feature, the part of the program with the highest bandwidth requirements. There has been much success with the CAMVision-2 Education Node system by Litton Network Access Systems for broadcasting lectures. It is recommended that this system

connects to a network capability of 100 Mb Ethernet via TCP/IP. This system offers a barely noticeable delay of 100-250 ms and is easy to operate and set-up. The cost of a system like this is approximately \$50,000.

3.3.1.2 Security

There can be many tiers of security for a program such as GeoNet. First, gigaPoPs have high level security in place based on their nature. Second, the program can be subject to the university security measures already in place, i.e., the university firewall. In addition, each student using the program could also be set up with an individual username (social security number or Student ID) and password.

Moving forward, the use of IPv6 will provide further security opportunities, but elaborate security measure such as data encryption would probably not be necessary due to the non-sensitive nature of the content.

3.3.2 Workstation and Physical Space Considerations

For use of the regional database, initially two or three workstations would probably be sufficient for the average size geology undergraduate and graduate collective (one workstation for administration purposes and one or two for student use). As in anything else, let demand influence supply and add on as needed. For the user workstations, 300 MHz or greater Pentium PCs should be sufficient.

There are physical space considerations as well, such as a classroom to hold two-way video lectures. An average size classroom for about 50 students and a large video screen should be sufficient for an average geology department.

TABLE 2: TECHNICAL ENVIRONMENT AND PHYSICAL SPACE CONSIDERATIONS

Lecture Hall	
Network	<ul style="list-style-type: none"> - connection to Internet2 - ≥ 100Mb Ethernet connection (w/ standard Category 5 Ethernet cable) - isolated subnet - all routers locked in full duplex
Hardware Needs	<p>Recommend CAMVision-2 Education Node system by Litton Network Access Systems</p> <p>System uses MPEG-2 codec (100 to 1 compression), offering broadcast quality video and CD quality sound (44.1 kHz sampling rate; 16-bit sampling width). Codec yields constant bit rate encoding of 1.5 to 15.8 Mbps and can be played at 30 frames per sec.</p> <p><u>System includes</u></p> <ul style="list-style-type: none"> - 32" Television Monitor - Computer Monitor, Keyboard and Mouse - Video Camera - Boundary Microphone - Video Cart
Room Size	Average size lecture room. Additional speakers optional.
Screen Size	32" television monitor is part of system, but 46" projection television screen would be optimal
Regional Database/Fieldpack workstations	
Hardware Needs	Pentium ≥ 300 MHz PCs running Win NT 17" monitors Printer (for map print-outs) Scanner (optional) PDA input (optional)
Power requirements	One standard power outlet (110V) per workstation, with surge protection

3.4 Development & Testing Considerations

The software specifics of GeoNet are beyond the scope of this paper, but a major benefit of a program such as this is that the workload can be shared among university departments. Also, at this point in Internet2 application development, there are many synergies to exploit.

When launching any software, sufficient testing; launching software with bugs can be devastating to the early success of any new program. Consider the testing methodologies presented in the Appendix.

4 SUMMARY AND RECOMMENDATIONS

4.1 Benefits Summary

The future is here. Just as in popular science fiction, where citizens can call up almost any information they desire at a nearby monitor, we are seeing dramatic advances in the ability to move large amounts of data around the country and the world. Next generation internets is an initiative that is being embraced across the nation and beyond – and it is now easier to get started through Internet2 meetings, workshops, and Awareness Days.

4.1.1 Summary of Student Benefits

Benefits of the program described herein for the geology student are strong:

- A choice of more geology courses with local expertise.
- Greater exposure to regions other than that of the student's own university.
- The opportunity to interact with a greater number of students and professors.
- The potential opportunity to visit some unique places like mines, volcanoes, research vessels, or fault lines.

4.1.2 Summary of Professor Benefits

The benefits for the professor are equally compelling:

- A greater exposure to different theories, opinions and work-related experiences via a better connection to other researchers.
- An exposure to a wider student audience, thereby offering a more satisfying personal and professional experience.
- The ability to reach a broader array of students and a new kind of collaboration in the classroom.

- Further collaboration with other professors.

4.1.3 Summary of University Benefits

Finally, the university can benefit tremendously in the following ways:

- The ability to offer richer experiences is a great selling point for recruitment. Work-study programs at schools like Drexel University have given students a tremendous advantage over their fellow job seekers upon graduation. For the student, the opportunity to meet with others outside of the immediate college atmosphere is of great value. Utilizing the capabilities of the Internet2, students can become involved in activities of other universities and possibly government agencies like the USGS or EPA.
- The acquisition of an online library of lectures and data, which can be a shared resource.
- The sharing of costs between other universities. These might include costs of guest lecturers, materials, computer time and power.

4.2 Recommendations

4.2.1 Analyze Current Information System

It is important to know where you are before you know where you are going. Write an audit (or have a graduate student do it) on the current state of general computer and Internet use within the department. Be sure to include technical information in the audit.

4.2.2 Make Connections

Talk to other university staff and gain an understanding of the institution's Internet2 capabilities and limitations. Attending Internet2 Awareness Days is an excellent way to do this. At these events, you can make contacts with key Internet2 people and see how other universities are engaged. For more information about Internet2 Awareness days, visit <http://www.internet2.edu/html/contact.html>.

Also, make use of the outside contacts of your fellow professors and talk to geology departments at other Internet2 member universities. Share your vision with theirs.

4.2.3 Develop a Department Education & Technology Charter

Where do you want to be in two Years? Five Years? Ten Years? A document such as an Education and Technology Charter, shown in Table 3, can help create the foundation for where your department is headed. It is important to not let technology guide you – remember that technology is only a tool and extension of your educational practices. Document in the charter what you're trying to accomplish and allow it to reflect immediate and long-term goals. If high-bandwidth capabilities fit within your department's goals, does it fit within the university's goals? First and foremost, obtain department level commitment (Butler, Distance Education, 1998).

University of Great Valley Geology Department Education & IT Charter	Spring 2001
Educational Statement of Excellence	Our Department offers undergraduate and graduate degrees that emphasize opportunities for education and research in the laboratory and the field. We offer BA and BS degrees in geology, with possible concentrations in hydrogeology or geochemistry. We collaborate in the College of Arts and Science's environmental science BS degree program. Our MS and PhD graduate program focuses on two areas that represent our research interests: ocean geophysics and mineralogy.
Short-term IT Goals (next two semesters)	It is our short-term goal to have class materials online for each undergraduate course. This material will include class contact and schedule information, syllabi, and assignments. Class notes will be at the discretion of the professor.
Intermediate IT Goals (next two years)	It is our intermediate goal to develop at least one Internet2 application that relates to faculty level research. This will allow us to 1) demonstrate our research interests, 2) demonstrate our commitment to IT, 3) migrate to our long-term goals.
Long-term IT Goals (next five years)	It is our long-term goal to regularly collaborate with at least one other fellow Internet2 member. We would like our undergraduate students to benefit from the experience of a department in a different geophysical region of the country.
Brief statement regarding department's current use of information technology (beyond normal University use)	The department's current use of information technology is manifested in – <ol style="list-style-type: none"> 1) Limited online materials for some courses 2) LAN connection with the university oceanography institute 3) The PlanetFrontier online project
Brief statement regarding University's intermediate high-bandwidth goals	The University is an Internet2 member. Currently the University's high bandwidth goal is to have at least one Internet2 application running for each academic department.
Department high-bandwidth vision statement	The Department seeks to have educational excellence and high-bandwidth IT work together seamlessly to create the richest possible experience for the student. Educational excellence will always be considered first.

TABLE 3: GEOLOGY DEPARTMENT EDUCATION & IT CHARTER SAMPLE

4.2.4 Be Realistic and Start Simply

As is often said, Rome was not built in a day. As quickly as IT moves in the business world, academia moves at a slower pace and this must be realized. Use of the web is exploding, but not at an equal pace in academia (Butler, *The Internet - A Catalyst for Change*, 1998). Expand on your academic World Wide Web sites by offering additional features such as field trip photos or a 'featured locale of the month'. Show other universities what your department is doing.

Be sure to get students involved; ask them what they would like to see. If you haven't done so already, you may want to create a simple online seminar with another university for a credit or two. If you currently are not digital at all, start collecting information in electronic form. You may want to create one completely electronic project within the department and do a survey of it's usefulness at the conclusion.

The world of high-bandwidth is an exciting one, but there are many obstacles to overcome – physical, spatial, logistical, financial, and also mental. However, it is clear that high-powered networks are the future and higher education and the physical sciences will guide that future.

APPENDIX

Software Testing Methodologies Overview

Functionality Testing

Functionality is concerned with what works and how it works; i.e., how functional is the application and does it conform to the software specifications. Three types of functionality testing are:

Reliability Testing

Reliability testing is based on how well an application handles failures, data integrity and safety and security.

Scenario Testing

A test technique that combines a series of simple tests that may individually produce no bugs, but collectively may produce a variety of problems.

Specification-Based Testing

Specification testing ensures that the application adheres to the requirements outlined in software specifications.

Editorial Testing

During editorial testing a series of tests are performed to ensure proper grammar, spelling, punctuation and syntax. Image and text layout is also under consideration during editorial testing.

Usability Testing

Usability testing verifies that the software has the following attributes:

Understandability

The design is consistent with the standards set forth in a design document, dependencies between internal, external and shared components are well understood, and technical documentation is accessible, well-organized, specific, and detailed.

Suitability

The purpose of the software is well understood, the users of the software are well understood, and the environment in which the software will be used is understood.

Regression Testing

Regression testing is an important part of the overall testing effort. This step includes automated testing that involves writing and debugging automation test scripts. Manual regression testing is also performed where the inputs are varied. Exact keystrokes and configurations can help to reveal any new bugs as a new build is released to quality assurance.

User Acceptance Testing

User Acceptance testing is also a key part in the testing process. Two phases of user acceptance testing are Alpha Testing and Beta Testing. At these key milestones, the application is reviewed in-depth with the person who has to sign off on the software.

Alpha Testing

Alpha Testing is held at the conclusion of development. Software in the Alpha phase has only minimal testing, so it may have bugs. The main goal for this testing phase is to ensure that the software that was built to spec and meets with the end user's expectations. Changes can be suggested, and these will be evaluated to determine their impact on budget and schedule.

Beta Testing

Beta Testing is held at the conclusion of the Alpha testing phase. Software in Beta phase should be fully functional and bug-free. As this review often initiates additional changes, the software cannot yet be considered as ready for final release.

Bug Reporting Procedures

Bugs can be defined as a concern about the quality of the application. There are primarily two types of bugs: problems and suggestions. Each of these bug types requires written documentation to communicate the nature of their occurrence. A bug report should have the following sections: Title, Severity, Description, Steps to Reproduce, Actual Result, Expected Result.

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