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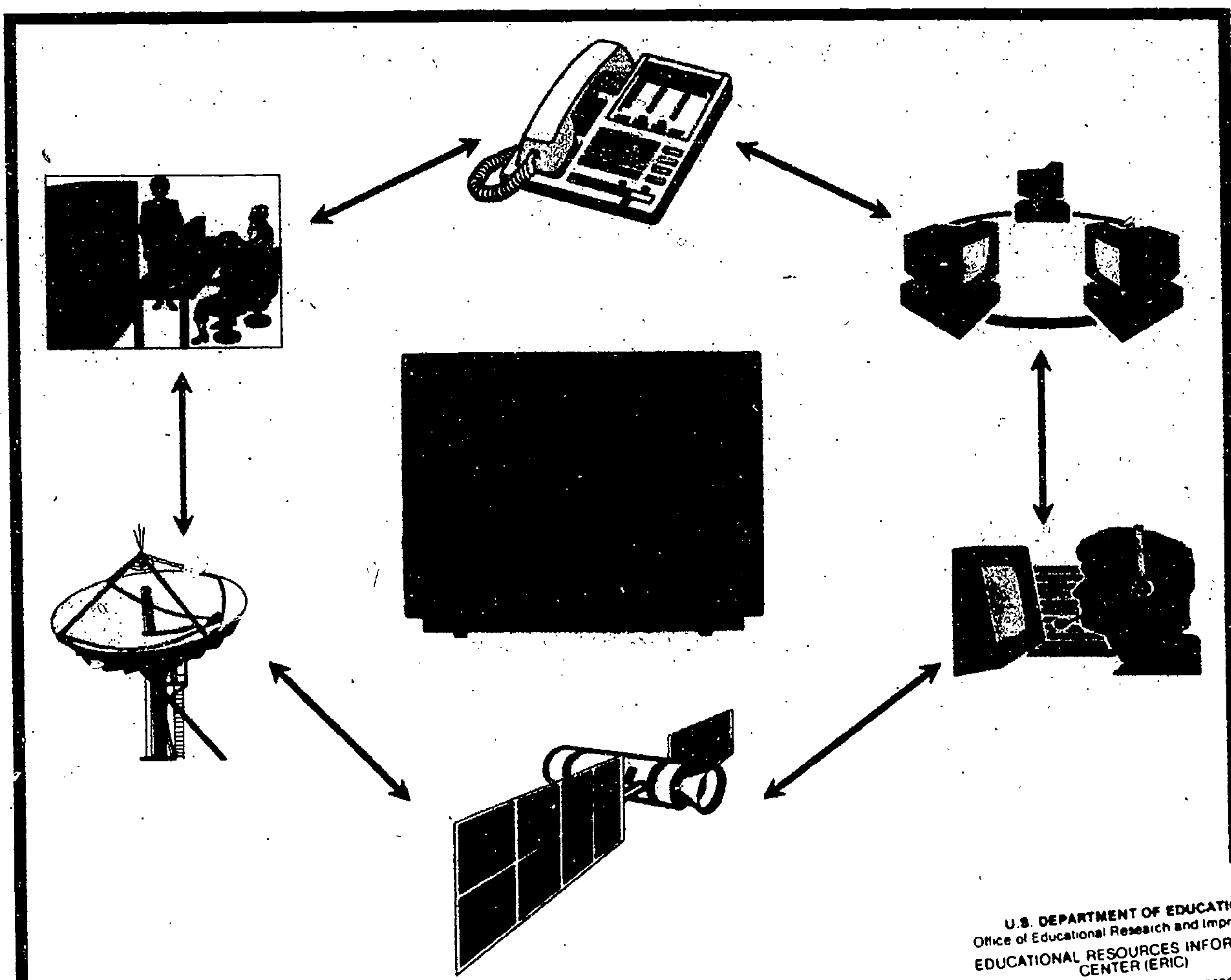
ABSTRACT

The National Information Infrastructure (NII) vision encompasses an infrastructure providing seamless, interactive, user driven access to the widest range of information. Video will play a key role in distribution of educational information, government data, manufacturing information, and access to health care data and services. The Technology Policy Working Group (TPWG) believes that with computers, television, and other digital devices working together seamlessly, a digital video infrastructure will be a central part of the infrastructure delivering the NII's benefits to the home and the workplace. Consequently, it should be U.S, policy to promote movement towards the creation and interoperability of this infrastructure. The Digital HDTV Grand Alliance's (GA) proposed standards represent a starting point in the creation of an architecture for communications and video standards. However, an overall advanced digital video architecture to address the full range of video in the NII does not yet exist. Delay in implementing the appropriate digital television infrastructure will propagate the current analog system that is incompatible with the NII vision. Consequently, TPWG recommends: (1) the Federal Government should fully support the Federal Communications Commission (FCC) Advisory Committee on Advanced Television Service (ACATS) process and the Grand Alliance's efforts to set an advanced digital television standard; and (2) the Federal Government should continue its working relationship with industry-led research and development efforts that are establishing an interoperative advanced digital video infrastructure. An appendix discusses technology challenges to an advanced digital video infrastructure. (Contains 14 references.) (MAS)

Advanced Digital Video and the National Information Infrastructure



Report of the Information Infrastructure Task Force Committee on Applications and Technology Technology Policy Working Group

ADVANCED RESEARCH PROJECTS AGENCY
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Dear Colleague:

Television is a fundamental element of the National Information Infrastructure (NII). To date, it has been solely a one-way communications medium. Digital technology advancements will permit video to be bi-directional in the not too distant future. Advanced video technology is being integrated into our NII to serve the communication and data distribution needs of many application areas such as entertainment, education, commerce, government, manufacturing, and health care.

The attached report was prepared by the Technology Policy Working Group (TPWG) of the Committee on Applications and Technology (CAT) of the Information Infrastructure Task Force (IITF). Based on public hearings and the guidance of technology experts, the IITF believes that advanced digital video will be a major driver towards universal National Information Infrastructure (NII) access. With computers, televisions, and other digital devices working together seamlessly, a digital video infrastructure will be a central part of the infrastructure delivering the NII's benefits to the home and the workplace.

The report is intended for those interested in the NII. This includes U.S. industry, the general public, state and local governments, committees and working groups of the IITF, and other agencies and departments of our Government. We look forward to your comments.

Sincerely,

Duane A. Adams

Duane A. Adams
Chair, Technology Policy Working Group

DRAFT
FOR PUBLIC COMMENT

Advanced Digital Video and the National Information Infrastructure

Technology Policy Working Group
Committee on Applications and Technology
Information Infrastructure Task Force

February 15, 1995

Table of Contents

Acknowledgements

This report, prepared by the Technology Policy Working Group (TPWG) for the Committee on Applications and Technology (CAT) and the Information Infrastructure Task Force (IITF), summarizes a set of conclusions and recommendations synthesized from the contributions of many individuals drawn from industry, associations, academia, and government. Each of the individuals that contributed directly and indirectly to the references in the report are hereby acknowledged and their contributions are appreciated.

The TPWG's project, Advanced Digital Video and the National Information Infrastructure, was led by Dr. Howard Frank, Director of the Computer Systems Technology Office at the Advanced Research Project Agency (ARPA). The TPWG also acknowledges the significant efforts of the Program Committee of the ***Workshop on Advanced Digital Video in the National Information Infrastructure*** held on May 10-11, 1994. The Workshop was co-sponsored by the TPWG, the National Institute of Standards and Technology (NIST), the Electronics Industries Association, the Institute of Electrical and Electronic Engineers-USA, the Society of Motion Picture and Television Engineers, the Advanced Television Systems Committee, and the Cross-Industry Working Team. The Workshop brought together a wide array of experts and permitted an exhaustive sharing of the views held by the many academic, industry, and government participants.

Advanced Digital Video and the National Information Infrastructure

Executive Summary

The National Information Infrastructure (NII) vision encompasses an infrastructure providing seamless, interactive, user driven access to the widest range of information. The infrastructure will consist of many interconnected networks, including terrestrial and satellite broadcasting, cable television systems, wired and wireless telephone systems and computer networks.

The future NII will support many video rich applications spanning most segments of our economy. Video will play a key role in distribution of educational information, government data, manufacturing information, and access to health care data and services. Program delivery over interactive networks will permit cost-effective services such as video-on-demand and shopping at home. Electronic distribution will expose all students, even those in remote locations, to high-quality educational materials. Online medical records will permit immediate review by specialists and will simplify billing procedures.

The Technology Policy Working Group (TPWG) believes that advanced digital video will be a major driver towards universal NII access. With computers, televisions and other digital devices working together seamlessly, a digital video infrastructure will be a central part of the infrastructure delivering the NII's benefits to the home and the workplace. Consequently, it should be US policy to promote movement towards the creation and interoperabilty of this infrastructure.

Digital video is a relatively new technology, first appearing as video teleconferencing in the early 1980s. In 1987, the Federal Communications Commission (FCC) established the Advisory Committee on Advanced Television Service (ACATS) to recommend a terrestrial high-definition television (HDTV) standard. In 1991 and 1992, six systems were extensively tested to determine which should form the basis for the HDTV standard. The four all-digital systems proved clearly superior, and in May 1993, with the encouragement of the ACATS, seven companies announced formation of the Digital HDTV Grand Alliance (GA) to merge the four digital systems into a single "best of the best" system.

While entertainment television has been the principal video application of recent decades, new services promise to expand the use of video in many directions. Advanced video is a crucial technology policy issue. Despite many unifying

characteristics, the video infrastructure could develop along two separate paths: one based on interactive computing systems and the other built on entertainment-oriented digital television.

TPWG has concluded that video interoperability is a principal NII policy concern. Interoperability will enrich the NII because a greater range of services will be available to the average user. Consequently, industry will have better use of its investments because of the wider user base. Interoperability will create an environment that stimulates the invention of new applications. Building on the progress of current HDTV technology is an imperative.

The GA's proposal specifies methods to process, compress, and transmit advanced television images. Its proposed standards have gained acceptance in the broadcasting, cable and motion picture industries. It also has received support from members of the computer and communications industry, but some controversy remains over certain design choices.

To meet the goals of an open, interoperable NII, communications and video standards should fit within an architecture that is flexible, extensible, and simple. The GA proposal represents a starting point to create this architecture. However, an overall advanced digital video architecture to address the full range of video in the NII does not yet exist. There is a need for a long-term program involving government and industry to create this architecture.

The TPWG believes that rapid implementation of advanced digital television is critical to building the future video rich NII. Delay in implementing the appropriate digital television infrastructure will propagate the current analog system that is incompatible with the NII vision. Consequently, TPWG recommends:

- **Recommendation 1: The Federal Government should fully support the FCC ACATS process and the Grand Alliance's efforts to set an advanced digital television standard.**

The TPWG has concluded that the ACATS/GA proposal for HDTV is the best available alternative. It is superior to continuing the current analog system or incrementally deploying a system that involves digitizing today's television signals, but not changing the fundamental picture formats and other technical parameters of the current broadcasting infrastructure.

Implementing advanced digital television is but one step in the process to create the video rich NII. Additional efforts by industry and government are required. Federal agencies such as the National Institute of Standards and Technology (NIST), the Federal Communications Commission (FCC), and the National Telecommunications and Information Administration (NTIA) should coordinate with the private sector in establishing appropriate technical standards. Research and development (R&D) activities, which are necessary for these agencies to execute their responsibilities warrant appropriate investment of Federal funds. In addition, R&D investments which benefit agency mission requirements, such as affordable high resolution display and transmission systems for defense capabilities, are also appropriate. For example, sponsorship of R&D which serves a dual-use purpose and which enables affordability in government systems by leveraging mass consumer market-based common standards items can provide high returns on Federal investments. In addition, applications which have a universal benefit to society such as in education and health care need to be considered.

- **Recommendation 2: The Federal Government should continue its working relationship with industry-led research and development efforts that are establishing an interoperable advanced digital video infrastructure.**

  This program should focus on and consider implementation of the recommendations of the May 10-11, *1994, Workshop on Advanced Digital Video in the National Information Infrastructure.*

  Companies participating in the program should demonstrate a commitment to commercialize the results of the program.

The R&D program should identify key interfaces and interconnection points, promote interoperable systems components, communications networks, video servers, information appliances and demonstrate pilot applications. In addition, it should address one- and two-way communications, multicast video services, internetworking cable, satellite, broadcast, common carrier, and packaged media. Companies participating in the program should develop migration paths to phase in new technology with existing systems. Industrial participants should also define paths to commercialization of the R&D so that funded activities result in products and services.

Introduction

The NII vision encompasses an infrastructure providing seamless, interactive, user access for a wide range of information.[1] The NII is an amalgam of information networks, appliances, and services. It is being built, owned, and run by the private sector with thousands of companies providing products and services. The future NII will consist of many interconnected networks, including terrestrial and satellite broadcasting, cable television networks, wired and wireless telephone systems and commercial computer network services. Computer systems, televisions, telephones, and other devices will all have expanding capabilities to serve as "information appliances" on the NII. Digital libraries, information services, and databases will provide information content.

Video in the NII will appear in many ways. Today's pervasive NII video application is entertainment with broadcasting and cable television as the predominant delivery mechanisms. Rapidly developing multimedia computer technology is driving video into the business and education environments. Tomorrow's NII will consist of numerous video-rich applications spanning most segments of our economy.

NII applications will include distribution of entertainment programming, educational information, government data, manufacturing information, and access to health care services. Digital program delivery over interactive networks will permit cost-effective services such as video-on-demand and shopping at home. Electronic distribution of educational material will expose all students, even those in remote locations, to high-quality educational materials.

Digital video will facilitate business and public access to government reports, weather information, and other scientific data. Electronic "blueprints" and rapid communication between manufacturers and their suppliers will improve manufacturing productivity. Telemedicine will enable remote patient examination and diagnosis. On-line medical records will permit immediate review by specialists and simplify billing procedures.[2]

Technology Policy Working Group Project

United States industry has embarked on a path towards a digital television infrastructure that could be a major NII driver. This is creating an opportunity to capture significant benefits for industry, the consumer, and US competitiveness if the technology is interoperable with other elements of the NII. Interoperability means that the considerable investments to be made by the broadcasting industry would promote more rapid development of NII infrastructure. Also, broadcasters and other content distributors will use computing and communications industry NII investments.

Digital video includes many types of image and multimedia communications including the next generation of television. Industry and government are presently completing a process to establish standards for the next television generation that is commonly termed "high definition digital television." Besides providing superior transmission and resolution characteristics, digital video is superior to its analog predecessor because of its ability to manipulate, compress and store images. These capabilities, if properly implemented, will allow the worlds of entertainment and information services to interact. Market research has shown that entertainment can be a key to consumer acceptance of advanced information services. This research suggests that for information services to be accepted readily by consumers, home computing and home entertainment should be interoperable.[2,3]

The TPWG believes that advanced digital video will be a major driver towards universal access to the NII. With computers, televisions and other digital devices working seamlessly together, digital video infrastructure will become part of the core infrastructure for delivering the benefits of the NII to the home and the workplace. Consequently, it should be US policy to promote movement towards an interoperable digital video infrastructure.

To achieve interoperability, questions relating to the method of preparing a video signal for transmission, the technology employed to broadcast the signal over the airwaves, cable or fiber and the methods proposed to display an image on a video monitor must be addressed. While many of these technical issues are esoteric, the potential implications to the NII are not.

The Process Towards an Advanced Digital Video Infrastructure

In 1987, the FCC established an Advisory Committee on Advanced Television Service (ACATS) to gain private sector advice regarding the establishment of standards for HDTV. The FCC asked ACATS to make a recommendation for a terrestrial standard. Initially, many companies and consortia proposed analog systems so that by 1989 there were twenty such proposals. In 1990, after the FCC established the goal of simulcasting full HDTV in a single 6 MHz channel, a movement to digital systems began. By mid 1991, six systems—four digital and two analog—remained as viable contenders. These systems underwent extensive testing in 1991 and 1992.[4]

Following testing, ACATS decided in February 1993 to limit further consideration to the four all-digital systems—two proposed by General Instrument and MIT; one proposed by Zenith Electronics and AT&T; and one proposed by David Sarnoff Research Center, North American Philips, Thomson Consumer Electronics, and the National Broadcasting Company. The Advisory Committee decided that none of these systems had demonstrated sufficient superiority to be recommended as the US standard. The

Committee ordered another round of tests to evaluate improvements to the individual systems.

At its February 1993 meeting ACATS adopted a resolution encouraging the digital HDTV groups to merge the four digital systems by combining the best features of each into a single "best of the best" system. In May 1993, the seven companies involved announced the formation of the Digital HDTV Grand Alliance (GA) to create such a system.

Many challenges faced the GA.[5] North American National Television Systems Committee (NTSC) television operates in television channel bandwidths of 6 MHz to support a video signal bandwidth of 4.2 MHz plus audio channels. Because of radio spectrum crowding, the FCC constrained HDTV to use the same 6 MHz channel bandwidths and to use existing television broadcast allocations, including many "taboo" allocations that are currently unusable for NTSC broadcasting because excessive interference into other existing NTSC stations would result. The simultaneous requirements of providing full HDTV in 6 MHz bandwidth, HDTV service area comparable to NTSC and low interference into existing NTSC service have been major factors in many of the GA's design choices for picture formats, video compression, transport processes, and transmission schemes. (Production, display or consumer interface standards are out of both ACATS' and the GA's scope.)

While television is primarily a consumer product, the business use of video expanded in the 1980's when compression technology improved to the point where video transmission over high-speed data lines became economically viable. Initially, teleconferencing equipment cost hundreds of thousands of dollars and circuit costs could exceed a thousand dollars per hour. More recently, prices for equipment have plummeted to $5 to 10 thousand for a desk-top system (including the personal computer). Combined with the dramatic drop in communications costs, costs per hour of use have also plunged. As a result, the use of video conferencing systems has grown rapidly. Video is also appearing as an educational tool[6] in medicine[7] and "narrow casting" of specialized conferences.[8]

Experimental technology promised to expand the use of video in many directions. Worldwide multicast video broadcasts over the Internet involving hundreds or even thousands of computers now take place on a daily basis. The multicast backbone (MBONE) experimental system connects 900 networks in 24 countries over the Internet.[8] With this technology, an Internet user can "tune in" on a conference. Examples include broadcasts of the UC Irvine Pancreatic Islet Symposium, broadcasts of NASA space shuttle launches, and informal interactive multicasts of Internet Engineering Task Force conferences.[8]

The 6 MHz HDTV standard requires use of compression techniques which, when pushed to the limit, reduces video and audio information carrying capacity, reduces quality, and introduces distortions. Bandwidth transmission capacities are increasing dramatically as fiber moves closer to the home. Some have questioned the desirability of a limiting 6 MHz HDTV standard to accommodate a short-term frequency scarcity in one video delivery method.

While no one can predict the ultimate role of video in the NII, it seems clear that future applications are limited only by the imagination of the application developers, the accessibility of these applications to potential users and the capabilities and restrictions of the enabling infrastructure.

Interoperability—A Critical Technology Policy Issue

TPWG has concluded that interoperability is a principal policy concern. Interoperability will enrich the NII because of the greater range of services will be available to the average user resulting in the enhanced asset utilization of industry investment when applied to a wider user base. Business will benefit from the integration of computing, entertainment, and communications, because such integration creates an environment in which the invention of new applications and services will be stimulated.

Without interoperabilty, traditional broadcasting could become an increasingly isolated industry, able to deliver entertainment products in essentially a single direction but lacking the capabilities to participate in two-way information transfer or the interactive video applications envisioned by NII futurists. This prospect is a serious concern, because broadcasting is an important part of the economy and a crucial communications medium with more televisions in US homes than telephones.[9] Recognizing the important convergence of digital HDTV with computers and communications, three of the ten evaluation criteria used by ACATS focused on interoperability related issues, and extensive reviews of these considerations have been performed as part of the public process.

Despite many common characteristics, advanced digital video could develop along two paths—one based on interactive computing systems and the other built on entertainment-oriented digital television. Some argue that the "separate but equal" approach is appropriate because computing and entertainment meet different needs and have different technical requirements. For example, today's entertainment systems use bright large-screen displays for multiple viewers at a distance from the display. Computer systems usually have higher resolution (but lower brightness) small-screen displays for nearby viewing by a single viewer.

These distinctions are important in the current environment, but future applications could require large, high resolution/bright screens for activities ranging from business and medicine to more advanced simulated training, rehearsal, and educational experiences termed "virtual reality." History demonstrates that it is nearly impossible to predict how enabling technologies are applied in the long term. Market forces rather than *a priori* contentions will determine which view will predominate. However, given economic realities, investments needed to promote interoperability may need to be encouraged to permit capabilities of an interoperable computing-television environment.

The Video Path

Video interoperability is a difficult technical topic concerning several technical questions. These questions are complex because video is used in many ways. In broadcast television, video is sent over a one-way path from camera and originating station to the television receiver. In other applications such as in a medical consultation, the path may be two-way with image capture and transport taking place at both ends. In still other applications such as teleconferencing or collaborative planning, there could be many senders and receivers.

When television was first introduced, all elements from image capture to transmission to display were "tightly coupled." Captured images were immediately transmitted and displayed. The original NTSC television broadcasting system, was designed so that the basic parameters at the camera and at the television set were the same. Camera and television images were broken up into 525 picture scanned lines of various shades of gray. A new picture was transmitted every 1/30th of a second.

Video information, just like motion picture film, is displayed a frame at a time. The frames must be shown at a rate to fool the eye into perceiving them as continuous motion. A rate of about 30 updates per second is marginally sufficient to provide smooth motion. However, at this rate some picture images appear to flutter or flicker.

In the initial NTSC television system, the transmission bandwidth required to transmit a flicker free continuous image exceeded the capabilities of the technology. Therefore, the required bandwidth was reduced by "interlacing" partial images rather than progressively displaying many complete frames per second. (These methods are called interlace scanning and progressive scanning, respectively.) In interlacing, each frame is divided into two parts; each contains half of the picture. One part contains the *even* scanning lines; the other contains the *odd* scanning lines. On each update, alternate partial images are displayed. This "refresh" rate of 60 half images per second eliminates flicker and provides smooth motion.

Regardless of its scanning method or delivery means, a digital image must pass through a series of stages from inception to display. The stages include:

Image Capture/Generation: The image is captured by a sensor such as a television camera or is generated by an electronic device such as a computer.

Processing: The volume of information in the raw image may be too large to be sent through an affordable transmission channel. Therefore, the data must be compressed to reduce its volume in such a way that the picture can be reconstructed without unacceptable degradation at the receiver.

Storage: The compressed data is stored until it is ready for transport or display.

Transport: The data representing the image is prepared for transmission. Each component of a video program such as picture, sound channels and associated data is separately organized into packets of data. Address and descriptive information is included in each packet. Packets for the program are combined with packets for other programs and services into a single bit stream for transmission. The bit stream is then broadcast over-the-air, or transmitted through a data communications network, a coaxial cable, or an optical fiber. The means of transmission depends on the characteristics of the medium. Protection against loss or corruption of the signal is provided by adding extra bits to the data stream.

Processing, Storage and Display: After the image is received, the earlier steps are reversed. The bits that were added to aid in transmission are removed. Programs are unbundled. The video, audio and data streams for each program are separated. The data stream containing the images may be stored until ready for display. The images are then decompressed and formatted for display on a television, computer monitor, or other appliance.

Towards an Interoperable NII

In May 1994, the TPWG cosponsored a Workshop on Advanced Digital Video and the NII to examine technical issues associated with advanced video. The purpose of the workshop was to:

- define a vision of the role of advanced digital video within the NII,
- identify the architectural, scaling, and performance issues in realizing this vision, and
- recommend the research, experiments, and steps to be taken to resolve these issues.

The workshop was attended by approximately 180 industry, government, and academic representatives. It consisted of talks, breakout sessions, and group discussions by experts in information services, broadcasting, computing, consumer electronics, and government policy. It was cosponsored by the TPWG, the National Institute of Standards and Technology, the Electronics Industries Association, the Institute of Electrical and Electronics Engineers - USA, the Society of Motion Picture and Television Engineers, the Advanced Television Systems Committee, and the Cross-Industry Working Team.

There was broad, cross-industry agreement on a variety of issues. The group concluded that the United States should move forward on HDTV as quickly as possible because it is a powerful driving force for the development of NII applications. The workshop attendees endorsed the GA proposal for HDTV as the best available alternative. The group viewed the GA system as greatly superior to either continuing the current analog system or incrementally deploying a system that involves digitizing NTSC signals. The "digital NTSC" alternative would enable several digital programs to be compressed into a broadcast channel, but would propagate interlaced transmission indefinitely. This would continue the division between entertainment television and the computer/communications technologies, and would be detrimental to the long-term prospects of an interoperable NII.

One of the primary image quality considerations for high resolution images is the choice of interlace or progressive scanning for display. The GA's proposal includes six picture formats which support various degrees of picture definition and transmission frame rates. Five of these use progressive scanning. One of these formats uses the interlace method because of its ability to offer higher vertical resolution than the progressive-scan mode, given the bandwidth constraint of the 6 MHz channel.

The choice of interlace scanning is controversial because nearly all computer displays use progressive techniques where the entire image is displayed each frame. Interlace images do not allow the same resolution for text and graphics as do progressively coded images. However, in contrast to television, there is no single computer display standard. Nearly all agree that progressive scanning in the transmission standard offers the superior long term approach. There is no consensus about how to get to the long term, although under consideration are several possible approaches which include the give-back of the analog NTSC channels to allow transmission of more bits at higher power without interference.

Some computer technologists argue that no interlace should be used in future digital televisions. These interlace opponents are concerned that the existence of the interlace format in the transmission standard will impede the development of televisions with progressive displays. They believe that because interlace displays cost much less than progressive displays, interlace scanning could drive out the other modes causing the entire system to sink to the lowest common denominator. Equally strong counter arguments are made by some individuals in the entertainment industry. They contend that because computers and televisions are used differently, there is no need to have compatible display standards, especially since current computer displays are considerably more expensive than interlace televisions. The interlace proponents believe that requiring all digital televisions to have progressive capabilities will increase cost and, therefore, slow the acceptance of digital television. The GA approach allows receivers to be built with either progressive or interlaced displays and they anticipate that both types will be produced, thereby enabling the market to determine the ultimate conclusion and to evolve over time.

There will be continued controversy and disagreement over the desirability of including an interlaced video format within the GA system. Some believe that an all progressive system is the only acceptable choice. Because transmission of film-sourced material occupies 60-70% of the prime-time schedule, the Workshop concluded that the anxiety level would be reduced if the major broadcasting networks broadcast film-sourced material in the progressive format. The theory is that if progressive scan material is in the channel, competition in the receiver design will assure that the customers will get an opportunity to choose sets that display progressive material with high quality. This approach is supported by the GA and the major networks who are planning to broadcast film in progressive formats, in accordance with GA technical specifications.[11,12]

To meet the goals of an open, interoperable NII, communications and video standards should fit within an architecture that is flexible, extensible, and simple. While the GA proposal represents a starting point, an overall advanced video architecture does not yet exist. The Workshop participants identified the need for a long-term program involving government and industry to:

- facilitate interface standards,
- fund research and development in interoperable systems, and
- establish pilot programs to apply advanced video technology in education, health care, and other areas of national importance.

Digital video technology is rapidly developing and change and migration will be the normal environment. The video system will evolve to be a service-rich, multimedia information environment. To enable this environment, additional advanced digital video standards must be developed that complement and are interoperable with the US HDTV transmission standard. Standards should include both one- and two-way communications, provision for multicast video services, and internetworking of cable, satellite, broadcast, common carrier, and packaged media.

The effort should address the interconnection and interoperability of digital appliances and devices, digital networks and channels, software and programs, and third-party services. Defining standards requires identifying long-lived "reference points" for physical and logical points of attachment, such as status and control management protocols, channel end points, coding within channels, channel address space naming, naming protocols for items transmitted over the network, media-specific data formats, and connection points for third-party services supporting network management.[10]

Rather than mandate a single standard at each reference point, industry should adopt a flexible architecture that assumes that the interfaces are constantly evolving and that most reference points will be realized by a variety of detailed standards. An important requirement for NII interoperability is that a publicly documented interface be made available at each reference point. Market forces will then drive the implementation of converters and convergence of standards to facilitate interoperability.

Technology Policy Working Group Recommendations

The TPWG believes that rapid implementation of advanced digital television is critical to building the future video-rich NII. Delay in implementing the appropriate digital television infrastructure will propagate the current analog system that is incompatible with the NII vision. Consequently, the TPWG recommends:

- **Recommendation 1: The Federal Government should fully support the FCC ACATS process and the Grand Alliance's efforts to set** an **advanced digital television standard.**

The TPWG has concluded that the ACATS/GA proposal for HDTV is the best available alternative. The GA system is superior to continuing the current analog system or incrementally deploying a system which involves digitizing NTSC signals. Consistent with the established FCC process, US policy should be to encourage the rapid approval and deployment of a ACATS/GA based advanced digital television infrastructure.

Implementing advanced digital television is but one step in the process to create the video-rich NII. Additional efforts by industry and government are required. Federal agencies such as the National Institute of Standards and Technology, the Federal Communications Commission, and the National Telecommunications and Information Administration should coordinate with the private sector in establishing appropriate technical standards. Research and development (R&D) activities which are necessary for these agencies to execute their responsibilities warrant appropriate investment of Federal funds. In addition, R&D investments which benefit agency mission requirements, such as affordable high resolution display and transmission systems for defense capabilities, are also appropriate. For example, sponsorship of R&D which serves a dual-use purpose and which enables affordability in government systems by leveraging mass consumer market-based common standards items can provide high returns on Federal investments. In addition, applications which have a universal benefit to society such as in education and health care need to be considered.

- **Recommendation 2: The Federal Government should continue its working relationship with industry-led research and development efforts that are establishing an interoperable advanced digital video infrastructure.**

  This program should focus on and consider implementation of the recommendations of the May 10-11, *1994, Workshop on Advanced Digital Video in the National Information Infrastructure.*

  Companies participating in the program should demonstrate a commitment to commercialize the results of the program.

The R&D program should identify key interfaces and interconnection points, promote interoperable systems components, communications networks, video servers, information appliances and demonstrate pilot applications. In addition, it should address one- and two-way communications, multicast video services, internetworking cable, satellite, broadcast, common carrier, and packaged media. Companies participating in the program should develop migration paths to phase in new technology with existing systems. Industrial participants should also define paths to commercialization of the R&D so that funded activities result in products and services.

GA members along with other key representatives of the broadcasting, cable, computing, and communications industries have expressed interest in participating in such a program.[11,13] As examples of specific activities, the participants could develop and support interoperability test beds to develop and demonstrate multimedia capabilities. The test beds would integrate transport systems such as ATM, broadcast, and the Internet. Applications could demonstrate coverage, transmission, and display of live and filmed programs in progressive and interlaced modes for display on digital televisions and computer monitors. Additional advanced digital video standards must be developed. The recommended program should support this effort but industry must take the lead.

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Appendix
Technology Challenges to an Advanced Digital Video Infrastructure

Even though digital technology is well established, its application to video is relatively new. Creating a digital video infrastructure is not a routine or inexpensive process. It consists of a variety of R&D and deployment considerations at each step along the video path.

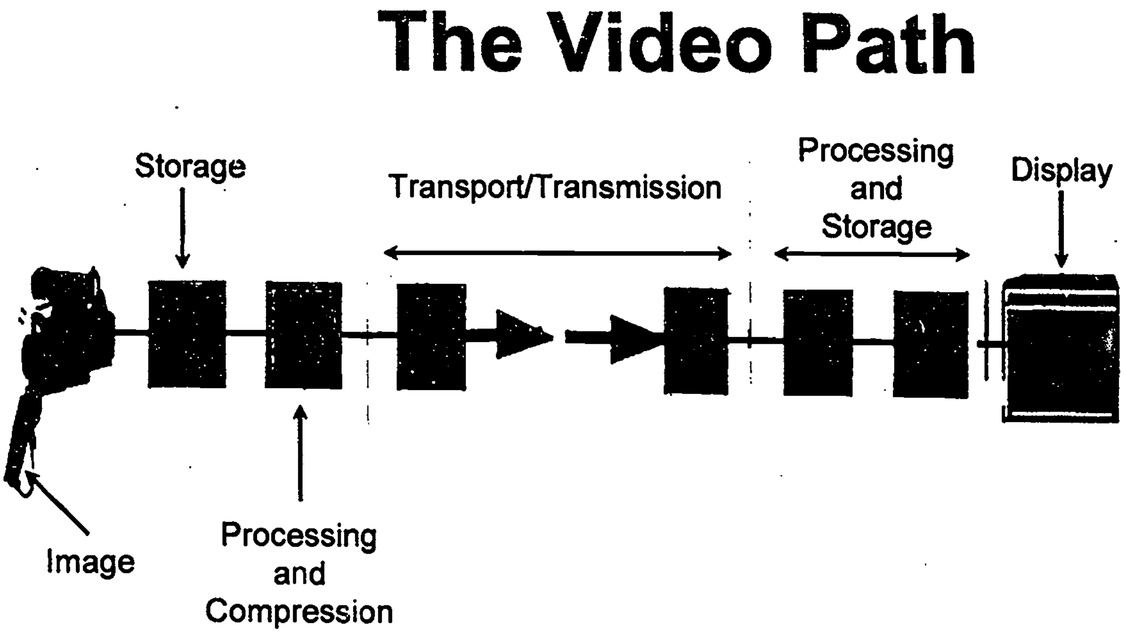

Image Capture/Generation: The quality of video is limited by the production source—the camera or the generating computer. Although production and display are separable, the quality of video is constrained by the best resolution and noise level provided by the production process.

The scanning process for NTSC has traditionally been interlaced because of the reduced bandwidth requirements for the handling and storage of camera generated signals. Nearly all of today's video cameras use interlaced scanning, and the availability of interlaced HDTV production equipment is an additional factor in the interlaced-progressive controversy. There are few progressive cameras and this technology is relatively immature when compared to its interlace competitor. This will require additional technology development and commercialization.

Storage at the Image Capture Site: Analog storage technology is highly developed. Professional VCR recording technology is more widespread and cost effective than digital tape recorders which are more demanding. To store a comparable volume of uncompressed high quality video requires many gigabytes of storage and at present is much more expensive than the professional analog equipment used by broadcasters or other program originators. Research and technology development are required to develop cost effective digital video storage devices for consumers.

Processing and Compression: Digital video generates very high data rates. As an example, a 525-line progressive scan camera demonstrated[2] for commercial high definition digital television generates a 405 Mbps data stream. A 720-line progressive scan camera, as required for one of the high definition modes in the GA system, generates a data stream at 885 Mbps. These data rates must be compressed to a level supportable within 6 MHz broadcast channels (about 20 Mbps). The Grand Alliance recommends compliance with a compression standard, called "MPEG-2," developed by the "Moving Pictures Experts Group" of the International Standards Organization (ISO). Because the standard is not yet complete, there currently are no full implementations. Further, compression technology is developing rapidly. Therefore, future improvements both within the scope of the MPEG-2 standard, as well as the development of new approaches, can be expected. System architecture must allow technology upgrades and replacements as technology advances.

Transport and Transmission: The GA has also adopted the MPEG-2 packet structure which was designed to meet television performance requirements and constraints. The packet structure is similar and related to, but not identical to, the "ATM" standard being introduced into the computer/communications world. Further work to provide architectural flexibility is required so that the transport method used can be changed to meet the needs of the application and the application providers. Future generations of the advanced television system should have open interfaces to provide this flexibility.

Technical approaches exist for mapping advanced digital video streams into the computer and communications world and to handle applications where video and audio time synchronization are crucial. Further technology development is required and industry agreements are needed. Current video experiments are also being performed on the Internet to examine multicasting techniques and the use of multiple service classes to handle applications with different timing requirements. Overall architecture and standards for the full range of advanced digital video applications remains open to research and standards activities.

Digital video can be transmitted from the production source to the viewer's display over many media. Television transmission imposes severe demands on the broadcast channel and transmission scheme. Video transmission paths may be one- or two-way and may pass through many different networks. In some cases, entirely different kinds of transmission schemes may be required. This will require a higher degree of modularity than is currently available.

Storage at the Receiver Site: Upon reception, the signal may be stored and processed later or processing might take place before storage. In either event, analog video storage is cheap and widely available. Consumer-level digital storage devices are currently more costly and less abundant. Multi-media CD-ROMS are practical consumer products that offer many advanced capabilities but they must be connected to personal computers. The technology does not yet allow digital recording at acceptable consumer pricing levels (a few hundred dollars). Even though the cost of personal computers has dropped dramatically, their use in future digital video applications will require greater storage capabilities at significantly lower costs to be competitive with analog technology. Industry is currently developing a digital consumer VCR standard that will be capable of recording both NTSC and HDTV, targeting a $1000 price in the 1996-97 time frame. Besides hardware costs, other challenges include a variety of software issues such as the structure of the future video storage "server," its location in the video system, the development of video data bases, and overall system performance.

Processing: Today's home or office can have many electronic entry points such as broadcast television, CATV, wireless, cable, telephony, one or more radio paths for AM and FM, a paging channel and possibly a cellular telephone path. Direct broadcast television satellite services are also being inaugurated. As the NII evolves, there will be many uses for these media. Dedicating any one medium to a single purpose may be counterproductive, because one capability may be shared with another capability to be most useful.[14] For example, over the air broadcasting is inherently unidirectional. Even relatively straight forward interactive services such as home shopping would require the use of a different communication service for the response path.

Today, a typical home can have several televisions. The future home will have multiple devices—some specialized to applications such as entertainment and others filling more general purposes. The typical future video system will contain displays connected to a control processor that handles transport, compression, conversion from one format to another, and possibly security. The user will be able to interface with a variety of appliances such as a joy stick for games, a VCR, a laser disk player, and other digital sources. Connected to the control electronics will also be external network interfaces such as cable, wireless (satellite, microwave or cellular), and terrestrial networks such as CATV and telephone systems. Cameras and sensors for entertainment, control, or security purposes may also be attached.

Eventually, the processing system in the home will become a high performance local distribution system. To reach this point, the system will have to be low enough in cost and high enough in performance to replace the dedicated systems that currently exist.

A natural point of departure for the evolution of such a system will be the set-top box that currently serves as the cable television controller. This device will ultimately become a home network router and gateway to external NII services and security point.[14] The exact course of this development will affect NII interoperability.

Display: The HDTV proposed standard changes the display screen aspect ration from the traditional 4-wide to 3-high to the ratio of 16-wide to 9-high. It is recognized that there is some controversy around this new proposed screen dimension and it is another factor that must be considered in interoperability design requirements.

One of the primary considerations in image quality for high resolution, high definition images, is the choice of interlace or progressive scanning for display. The GA's proposal for the US HDTV transmission standard includes six picture formats which support various degrees of picture definition. Five of the six picture formats use progressive scanning while the sixth uses interlace. Transmission of standard 24 frame per second motion pictures film is always performed in progressive scan formats. The transmission of fast action material requiring a higher 60 Hz temporal scanning rate for smooth motion rendition can be performed with either progressive scan at lower picture definition or interlaced scan at the highest picture definition.

The interlace format is included because for certain television applications, such as sports, require very high frame rates to render rapid movement without judder (objectional strobing) or blurring. The data rates available in a simulcast broadcast television channel are insufficient to simultaneously support both the highest frame rate and the greatest degree of picture resolution using the best current compression technology. The GA included an interlace format because interlace transmits only half of the picture at a time (either the even or odd lines) and the data rates required are, therefore, halved for the same degree of picture definition. This reduction in data rate impacts both the required channel capacity and the performance level of receiver electronics. While interlacing creates certain picture artifacts, it allows twice the resolution (either in picture detail or in frame rate) than progressive scan at the same data rate. Since each of the HDTV formats must be highly compressed using MPEG-2, even progressive scan formats can exhibit compression artifacts such as noise and blockiness that can occur in fast moving areas of the picture.

The choice of interlace scanning as a picture format has been proven to be controversial because it is seen as less compatible with computer display technology. The approaches adopted by the computer manufacturers to display images are different from those used predominantly by the television industry (some progressive scan display TV receivers are, in fact, available today). Nearly all computer displays use progressive techniques where the entire image is displayed on each frame. In contrast to television, there is no single computer display standard. Refresh rates on computer displays range from 60 - 75 or more frames per second. Therefore, on the one hand, displaying television images on computer monitors requires using video boards which add expense and complexity and potentially undesirable picture flaws. Displaying computer images on interlaced television displays (whether NTSC or HDTV) can lead to unacceptable results because they can not display high quality text or graphics with acceptable fidelity.

The interlace/progressive debate has stirred many strong opinions with some computer industry representatives arguing vehemently that interlace should not be used in future digital televisions. The interlace opponents are concerned that the existence of the interlace transmission format will drive out the other formats causing the entire system to sink to a common denominator which is incompatible with text and graphics. Equally passionate arguments by some in the entertainment industry contend that because computers and televisions are used differently, there is no need to adopt the same display standards, especially since current computer displays are considerably more expensive than comparably sized interlace televisions. Nearly all agree that progressive scan is superior and should be a long-term goal.