applications such as camcorders. Over the long term, such MPEG encoding may eventually supersede H.261. In any event, the high degree of similarity between MPEG and H.261 will likely result in decoders that accept both syntaxes. For a discussion of interoperability with ATM format, please see the transport layer discussion for more details.

8. EXTENSIBILITY AND MIGRATION PLAN

The Grand Alliance HDTV system is a starting point for HDTV, not a final solution that will be locked into place forever. As we face the problems of compatibly migrating from the past to the future, several important improvements should occur. First, the 59.94 Hz family of frame rates that are associated with NTSC should be increased to an exact 60 Hz family. The GA HDTV system plans ahead for this migration by ensuring that all HDTV receivers will be able to receive frame rates related to both 59.94 and 60 Hz. Second, as soon as compression technology and available channel capacity allow, a backward compatible migration to a ≈1000 line progressive scan and square pixel format at 60 Hz can occur. The GA HDTV system provides important extensibility that enables this migration[16]. Note that for non-broadcast uses this backward-compatible migration need not wait for broadcasters to find additional bandwidth; this migration could occur immediately with full backward compatibility with the installed base of GA HDTV receivers.

8.1 MIGRATION TO 60 HZ

The Grand Alliance HDTV system is designed so that all HDTV receivers will receive six temporal rates (60, 59.94, 30, 29.97, 24 and 23.976 Hz). Transmissions can thus initially operate at a temporal rates related to 59.94 Hz (including 29.97 and 23.976 Hz), which is the same as NTSC. This will allow economical transcoding between NTSC and HDTV, an important attribute during the initial simulcast period. In the long term 60 Hz has many advantages, but will require 1000/1001 frame rate conversion to interoperate with NTSC. All Grand Alliance HDTV receivers will be capable of temporal rates related to both 59.94 and 60 Hz, so broadcasters can "throw the switch" to begin broadcasting in 60 Hz (including 30 and 24 Hz) at the time of their choosing.

8.2 MIGRATION TO ≈1000 LINE PROGRESSIVE SCAN

The long term goal for picture format is full ≈1000 line progressive scan with square pixels at a 60 Hz frame rate. This level of performance is not currently feasible due to lack of sufficient channel capacity, currently about 18 Mbit/sec in a 6 MHz NTSC simulcast channel. Sending, for example, 1920 x 1080 x 60 (progressive scan) with 18 Mbits/sec gives a coding rate of 0.096 bits/pixel, which produces an unacceptably distorted picture using today's best compression technology.

---

[16] In accordance with PS-WP4 recommendation # 8.

However, the Grand Alliance believes that the goal of ≈1000 line progressive transmission can be achieved in the future by sending *enhancement* data that will complement the basic HDTV data stream. A new receiver would decode both data sets and combine them to create a full ≈1000 line progressively scanned image. Any of the several GA formats can provide a basis for enhancement encoding. There are several possible configurations, as shown in Figures 8.1 through 8.3:

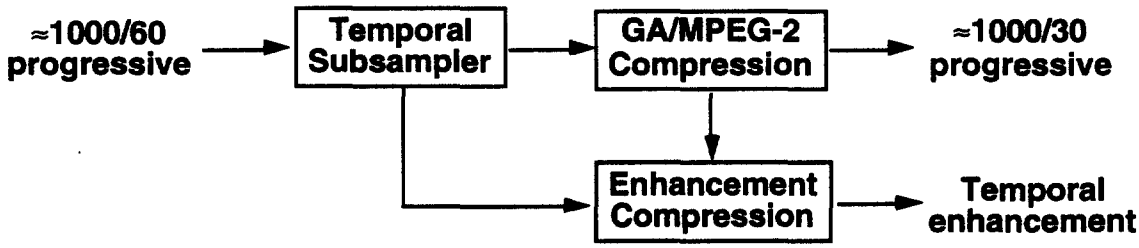

Figure 8.1. **≈1000/30 Progressive Enhancement**. Odd frames of ≈1000/60 progressive are compressed to create a standard GA ≈1000/30 progressive bit stream. The even frames and the locally reconstructed odd frames are used to create a bit stream that can be used to reconstruct the missing frames. See Section 7.9 "Temporal Scalability" in "Generic Coding of Moving Pictures and Associated Audio", Third Working Draft (New York), pp. 87-89.

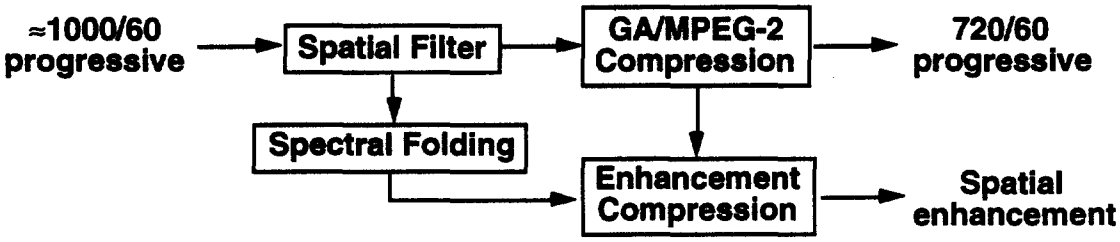

Figure 8.2. **720/60 Progressive Enhancement**. All frames of ≈1000/60 progressive are spatially filtered to create a 1280x720/60 picture format that is compressed to create a standard GA 720/60 progressive bit stream. The extra spatial information and the locally reconstructed 720/60 are used to create an enhancement bit stream that can be used to create a full ≈1000 line progressive image. See Section 7.7 "Spatial Scalability" in "Generic Coding of Moving Pictures and Associated Audio", Third Working Draft (New York), pp. 79-85.

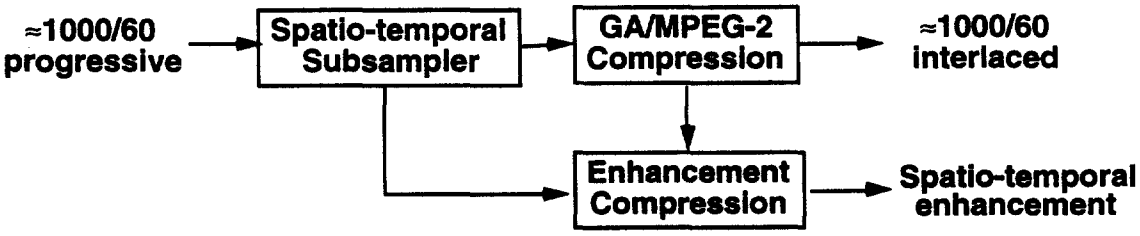

Figure 8.3. **≈1000/60 Interlaced Enhancement**. The ≈1000/60 progressive input is vertically and temporally subsampled to create a ≈1000/60 Interlaced image that is compressed to create a standard GA ≈1000/60 Interlaced bit stream. The other-parity interlaced image and the locally reconstructed ≈1000/60 Interlaced are used to create an enhancement bit stream that can be used to create a full ≈1000 line progressive image. See Section 7.9 "Temporal Scalability" in "Generic Coding of Moving Pictures and Associated Audio", Third Working Draft (New York), pp. 87-89.

In all enhancement scenarios the enhancement compression algorithm may be based on MPEG, or it may be some as-yet-undiscovered system that will be defined as an extension to the Grand Alliance syntax. The beauty of the packetized data transport approach is that it allows extensions to completely unforeseen technologies.

Backwards compatibility, that is, not disrupting service to older HDTV receivers, can be achieved by using the Grand Alliance packet level extensibility. By defining a new packet service identifier to carry the enhancement data, older receivers would simply ignore these packets and continue to reconstruct images from packet types it understands. New receivers would process both types of packet streams to create a full ≈1000 line progressive display.

Figure 8.4. **New Enhancement Services added at the packet level.** Because every packet has a Packet ID header/descriptor, new services may easily be added simply by defining a new Service ID and multiplexing the new packets into the packet stream. This approach is inherently backward compatible since receivers ignore service types they cannot process.

However, although it is fairly clear how to implement the syntax of a backwards compatible ≈1000 line progressive extension to the Grand Alliance HDTV System, it is not so clear where to find the required added bandwidth. Several possibilities exist: as NTSC service is phased out, perhaps those channels may be used to send the enhancement data, or perhaps it is possible to simply increase the power of the HDTV transmitter as HDTV-into-NTSC interference becomes less significant as NTSC stations "turn off". A somewhat less likely possibility is that compression efficiency improvements will be made within the MPEG syntax that would free-up 40-60% of the bit rate currently used.

The Grand Alliance HDTV System has been designed with extensibility in mind, so that it may provide service for many years, incorporating new technologies as they become available.

9. SUMMARY

The Grand Alliance has crafted an HDTV system designed to provide a high degree of interoperability, despite the presence of numerous conflicting goals. In addition, we believe that the GA HDTV system meets all of the PS-WP4 interoperability recommendations, as summarized below:

1. *An all-digital implementation based on a layered architecture model* is fundamental to the design of the GA HDTV system.

2. *The use of universal headers and descriptors (as agreed by industry standards group)* has been achieved by adopting the MPEG-2 header/descriptor structures at the compression layer (to support multiple formats and frame rate) and at the transport layer (to provide flexibility and extensibility).

3. *Transmission of the signal in progressive scan format* is provided for five all-progressive format and frame rate combinations. The sixth format/frame rate combination always encodes full frames of an interlaced source, but allows block-by-block adaptation of the coding, per MPEG-2.

4. *Use of a flexible, packet data transport structure* is implemented by the GA/MPEG-2 transport layer.

5. *Viewer transparent channel re-allocation (limited picture and sound while most of the channel capacity is devoted to data transmission for conditional access addressing or other purposes)* is provided by the multiplexing capabilities of the GA/MPEG-2 transport.

6. *Ability to implement lower performance low-cost ATV receivers (comparable price/performance options to current NTSC receivers)* is enabled by the fundamental nature of digital video compression and transmission, which decouples the display from the transmitted system and gives receiver manufacturers the flexibility to use different displays in different market segments.

7. *Ability to implement low cost ATV consumer VCR* is enabled by the low ≈18 Mbps data rate of the GA HDTV system.

8. *System architecture and implementation that will allow improvements and extensions to be incorporated as technology advances while maintaining backward compatibility* is achieved by the extensibility attributes of the transport layer, which ensure that "enhancement data" can be compatibly introduced. In addition, the multiple format

approach of the GA HDTV system allows backward-compatible enhancement to be based on any of the initial formats.

9. *Square pixels or at least the option to select square pixel presentation* is provided through the use of multiple formats, specified through the GA/MPEG-2 Sequence Header. As of this writing, all formats have square pixels.

10. *Compatibility with relevant international standards or commitment to this objective* is achieved by the high degree of compatibility that the GA HDTV system has achieved with the International Standards Organization (ISO) MPEG-2 draft standard.

Thus, the GA HDTV system provides for the practical delivery of HDTV to consumers within the FCC-mandated 6 MHz simulcast channel, and at the same time forms the basis for new services and applications through its outstanding interoperability.

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10. *Compatibility with relevant international standards or commitment to this objective* is achieved by the high degree of compatibility that the GA HDTV system has achieved with the International Standards Organization (ISO) MPEG-2 draft standard.

11. *Easily implementable and user-accessible "still/motion multi-window transmission"* is provided by the multiplexing capabilities of the GA/MPEG-2 transport

Thus, the GA HDTV system provides for the practical delivery of HDTV to consumers within the FCC-mandated 6 MHz simulcast channel, and at the same time forms the basis for new services and applications through its outstanding interoperability.

ERRATA PAGE FOR

"INTEROPERABILITY ASPECTS OF THE GRAND ALLIANCE HDTV SYSTEM"

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October 5, 1993

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Mr. Richard E. Wiley
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Texas Instruments is strongly committed to the promotion of International Standards in the field of Information Technology. In particular, the MPEG-2 standard now under development by ISO/IEC JTC 1/SC 29/WG 11 shows great promise for interoperability in the area of digital video and associated audio.

While this standard is not yet complete, it is anticipated that the work will reach the Draft International Standard stage by March of 1994, and be an International Standard by October of 1994.

Texas Instruments believes that it is mandatory (and in the best interest of the United States and the data compression industry in general) that the new US standard for digital television fully conform to the final MPEG-2 International Standard. Only if this is done can we achieve the goal of interchanging program bitstreams with other MPEG-2 conforming systems from other countries

Texas Instruments also recognizes the need for and supports the goal of having available in the MPEG-2 standard an audio encoding layer that could replace or supplement the audio encoding that is currently defined in the WG11 Working Draft, and TI is fully supportive of efforts to include this in the final standard.

Regards,

Clyde R. Camp, P.E.
Director of Standards

cc: Dr. Robert Hopkins, Chair, Scanning Format/Compression Expert Group
Dr. Joseph A. Flaherty, Co-Chair, Technical Subgroup
Dr. Irwin Dorros, Co-Chair, Technical Subgroup
Mr. Craig Tanner, Chair, Transport Expert Group
Dr. Robert Sanderson, Chair, Interoperability Expert Group
Mr. James Gaspar, Chair, Audio Expert Group

The
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Center for Biomedical Communication

October 4, 1993

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Michael Liebhold, Vice Chairman
Joint Expert Group on Interoperability
Advisory Committee on Advanced Television Systems
Apple Computer
20525 Mariani Avenue
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Cupertino, CA 95014

Dear Mr. Liebhold,

Thank you for inviting my comments regarding the development of high resolution television and imaging systems. As you know, as a practicing physician, producer of educational videoprograms, and director of a multistate telemedicine system now in formation, I have been most interested in the healthcare applications of any proposed high-resolution imaging and broadcast system.

The nation is struggling with how to achieve medical care which is equitable, cost-effective, and high-quality. As healthcare providers, we must find ways to better diagnose, record and communicate our findings, and motivate and educate the public. The use of high resolution medical imagery will be part of the way by which our national healthcare goals will be met.

The varied uses of high resolution medical images by the healthcare profession are becoming increasingly important. The number and types of applications using such images are rapidly multiplying with no end in sight. Any development of new widespread technologies in this area must take into account present and future medical applications. In addition, with the increasingly important role that Telemedicine will play nationally, the use of medical images suitable for accurate diagnosis and treatment is an absolute necessity.

Please allow me, then, to offer these rather brief comments regarding the needs of healthcare providers with regard to imaging, cameras, and display devices.

Current uses of medical imagery

Radiology

Where medical imaging at one time consisted only of radiographs (X-rays), now there is an impressive array of applications. These medical images are

stored on, and retrieved from, a number of different media. It is clear that inthe near future, many of these images will be electronically stored, transmitted, retrieved, compared, indexed, and manipulated in ways which will dramatically enhance healthcare providers' ability to diagnose and treat illness. Many of these varied forms of imagery also will be combined with other medical data, such as electronic medical records, to form a seamless whole.

As we consider present and future medical imagery, certain characteristics become vitally important for the ability to gather and produced them.

Resolution is of prime concern. Accurate diagnoses will likely depend on the consulting clinician or pathologist being able to visualize the finest possible detail - which means the greatest possible amount of information. The finer or greater the resolution, the higher the potential accuracy in many circumstances.

Radiographic film, for example, has extremely high resolution. Transferring those images to be read remotely requires a high resolution display. While this display does not necessarily need the degree of resolution afforded by radiographic film, a megapel display is desirable.

Typical matrix sizes of an X-ray (plain radiograph), using a high resolution monitor for that purpose, is up to a 2560 X 2048 matrix. For MRIs it is 256 X 256, and for CAT scans: 512 X 512. MRI, CT computers preserve 12 bits (4096 levels) of contrast for each location in the display matrix.

Radiologist, as a rule, require a high degree of resolution for final interpretation of plain films. "What is required For primary interpretation of digitized plain radiographs, it is generally agreed that a full data-set of at least 2048 X 2048 matrix size must be available for display by a monitor." (From: Arenson RL, Chakraborty DP et al: The digital imaging workstation. Radiology 176:303-315, 1990.)

Some non-radiologist clinicians contend, however, that such a high degree of resolution is not necessary for the vast majority of films. A one megapel or less display is commonly used.

Currently, high resolution scanners are used to scan in an x-ray that needs to be seen remotely, the data file is downloaded (often over phone lines) and the image reconstructed over the high resolution progressively scanned monitor at the consultation site. Under this circumstance, the physicians involved can not discuss the image with any real time indications to each other (like pointing) because there is no current camera capable of scanning the original x-ray real time in high resolution.

Not only would a high resolution camera/monitor allow this sort of real time consultation, but it would allow this image to be attached to the chart, and to be manipulated in various ways that would enhance the information.

Ultrasound is used in prenatal/fetal ultrasound, and for visualizing abdominal and pelvic contents (anywhere with hollow viscus), and for cardiac ultrasound. Also ultrasound is used for blood flow studies, such as venous/arterial flow dopplers. Images seen on the monitor are saved and replayed on videotape over an NTSC monitor. Improved capture and display of medical imagery will likely lead to better diagnostic capability.

Intraoperative diagnosis

What is true for radiologic images is equally true for other medical applications, such as intraoperative camera use and pathology specimen use. Intraoperative use is primarily through a variety of rigid and flexible scopes. Currently, the use of standard NTSC cameras with endoscopes is increasingly common. These currently have a CCD chip embedded at their ends, or carry images through glass fiber which are displayed (on television monitors) and collected on VTRs.

These live images from the interior of the gastrointestinal, genitourinary or respiratory tracts are invaluable for making diagnoses and treating in the least invasive way possible. Again, however,under current methods, the images scanned are collected and displayed using interlace technology with its many drawbacks regarding inferior resolution, color accuracy, image instability, summing effects, etc.

Furthermore, as we look toward the future certain issues would be best left open for the moment - such as the ultimate degree of resolution possible. It's easy to imagine, for example, that a future endoscopic camera may have "dialable" resolution. In effect, this camera pressed against a bowel wall lesion might be able to dial up a resolution/magnification equivalent to a microscope - further enhancing our ability to make diagnoses with the least possible surgical invasion whenever feasible. (The ability to provider greater resolution and to magnify are distinct, yet highly related).

The whole concept of "dialability" of imaging devices could open new vistas in medicine. There could be a variety of circumstances where the clinician would find it advantageous to be able to select varying degrees of resolution, color control, depth of field, contrast, individual still frames, speed, etc. There are circumstances where the ability to select for (or eliminate) certain light frequency patterns likely would yield valuable diagnostic information.

One issue that should be dealt with is whether there will be a quivering motion artifact on any future standards. The quivering artifact seen with current NTSC, particularly problematic for medical diagnostic applications.

Cameras and playback devices, of course, have other applications in medicine such as real-time sonography (eg, echocardiograms). To the extent that resolution can be improved and captured still images made free of this quivering effect, the medical applications that will use them will improve.

Pathology

Medical imagery is an important part of pathology. Recording of microscopic images of pathologic specimens (such as a bowel lesion biopsy) requires fine resolution (and has required a still camera), Besides the use of visible light, fluorescent tagging of specific antibodies may be used with specimens in an attempt to better identify a pathogenic agent. In both these cases, high resolution cameras will prove useful. Obviously, artifacts must be absent to the extent possible.

Near future uses of medical imagery

Telemedicine

One increasingly important medical application is Telemedicine, the real-time collection and sharing of patient-related images. These include images gathered through specially configured diagnostic instruments, such as otoscopes or stethoscopes. These images are used for distant consultation whereby patients in remote areas can be seen by specialists in a central facility.

At least 30 systems exist in varying states in the US, using a variety of configurations and bandwidths. National savings that can be achieved annually through the use of Telemedicine are estimated by an Arthur D. Little study in the hundreds of millions.

Telemedicine has the potential to allow us to share precious diagnostic resources more equitably and at lower costs. It will allow for distance education and improve the retention of healthcare providers in hard to place locations - and not just in remote rural areas, but in inner cities where improved healthcare is so important.

Record Integration

Here again, as data and medical records come to the desktop, the issue of interoperability is vital. Eventually (in the not-too-distant-future) the many image and data sources in medicine will be united in an electronic medical chart at the medical workstation. This will consolidate the myriad separate locations the clinician has to search to get all of the information related to their patients.

Currently, the disparate places where images, data, lab results, notes, ECG, demographic information are placed (or often misplaced), have a harmful effect. Duplicated lab tests cost the nation hundreds of millions. The ability to consistently unite these data will have a dramatically positive effect on patient care, and reduce of costs substantially.

It is likely that within the near future, many of these medical images and databases will be brought into the home for personal use and education. Current NTSC monitors makes the display of print or detailed material impractical for the reasons outlined above.

Color accuracy is required for accurate diagnosis. Any imaging, transmission, and display system must be able to accurately and consistently reproduce the color of the image scanned. Current television standards fail miserably at this, and future systems must be designed to overcome this problem.

Not all diagnostic imagery requires real-time capture. An example of this might be taping a slowly changing pathology specimen. Others circumstances may require capturing motion accurately, such as with a movement disorder. The ideal system might allow for certain viewer choices, such as "dialable" resolution versus speed.

Home care, monitoring, and education

Not all, perhaps not even most, medically related imagery will be shuttling between medical records, laboratories, or offices. They will be delivered into the home.

One example of the importance of bringing high resolution images into the home concerns home-monitoring of ill or technologically dependent (eg, ventilator dependent) individuals. Real-time health data and monitoring will undoubtedly travel over cable or other ground lines into the home to allow interactive monitoring by family care providers. Such systems, which again require stable and high resolution images, have the potential to allow more care on an outpatient basis. This will bring the locus of control back into the home while dramatically lowering the costs of healthcare.

A number of projects nationwide are in development which suggest some of the future direction of how high resolution imagery will be brought into the home, such as the innovative work being done by Dr. Linda Harris in the Office of Disease Prevention and Health Promotion (US Department of Health and Human Services). Dr. Harris' project is the creation of an interactive social services workstation which allows the user to access a variety of community resources, many of which have written text accompanying them.

Joe Henderson, M.D. at Dartmouth Medical School is creating a vast interactive media server which will provide real-time education concerning healthcare issues. This will become a standard in health education for consumer and professional. Henderson's configuration, too, benefits from a broadcast and display method which will allow the joining of text and image.

The proper approach, it would seem, would be to create a standard that unites technical and home displays for a whole host of obvious reasons. It seems clear that, in the near future, imagery collected from a variety of sources, recorded on a variety of media will be united and brought into the home. Many of these images will include healthcare related ones, used in a wide variety of ways including for diagnosis, record keeping and education.

To summarize, then, there are a number of characteristics of cameras and monitors that will have great effect on medical applications.

- *Resolution.* For a number of applications, the better the possible resolution the more accurate the diagnosis. We would want potentially extremely high resolution, which is dialable, and open to improvement as technology evolves.

- *Image stability.* Must be free of quivering artifacts seen with current television technology. Along with resolution this characteristic can be objectively evaluated using standardized images looking for the ability to distinguish between fine parallel lines, etc.

- *Correct color.* Color is extremely important for medical diagnosis. Images can not smear or average color; they must reflect reality, be accurate and self-correcting. This too can be objectively evaluated.

  Ability of the viewer to select certain light/frequency patterns may be useful.

- *Selectability.* Should allow for selectable trade-offs, such as dialable speed vs. resolution, etc. For example, in evaluation of movement disorders, the ability to capture a motion and play it back slower can be a helpful diagnostic tool. In other cases, such as the evaluation of a skin rash,

greater resolution is more important than the ability to distinguish rapid motion.

- *Interoperability.* Imagery collected by various means and stored on various media must be usable together, and viewable (along with fine text) in an interactive environment.

- *Flexibility.* Whatever standards are adapted must take into account that new and improving methods of collecting and manipulating visual data will continue to develop in the years to come. Standards should be left as open and adaptable as possible - and not, in effect, hinder future advances in technologies and applications.

Medical technologies involving the creation, manipulation, interpretation, and transport of healthcare-related images are evolving rapidly. These technologies will enhance our understanding and have the potential to reduce the amount of invasive procedures, hospitalization, travel, and costs.

As medical imagery becomes part of a world of resources that includes education the ever-shrinking distinction between technical imagery and consumer imagery will become virtually non-existent. This is a wonderful opportunity to think ahead on this issue, and I thank you for allowing me to participate in the important deliberations of the Advisory Committee on Advanced Television Systems.

Please do not hesitate to call on me if I can be of any further help in your work.

Sincerely yours,

Neil Izenberg, M.D., FAAP
Director, Nemours Foundation Center for Biomedical Communication
Alfred I duPont Institute Children's Hospital
Associate Professor of Pediatrics
Jefferson Medical College

Applications for High Resolution Healthcare Images: Present and Near Future

Neil Izenberg, M.D., FAAP
The Nemours Foundation

1. [redacted]

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6. [redacted]

Need to consider:

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mayo

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Applications for High Resolution Medical Images: Present and Near Future

Desirable Characteristics

- *Resolution.* For a number of applications, the better the possible resolution, the greater the potential for diagnostic accuracy. We would want potentially high resolution, which is dialable, and open to improvement as technology evolves.

- *Image stability.* Must be free of quivering artifacts seen with current television technology. Along with resolution this characteristic should be objectively evaluated using standardized images looking for the ability to distinguish between fine parallel lines, etc.

- *Correct color.* Color is extremely important for medical diagnosis. Images can not "smear" or have color "averaged."; they must reflect reality, be accurate and self-correcting. This too can be objectively evaluated.

  Ultimately the ability to for the viewer to select for, or against, selected light/frequency patterns may be useful for certain diagnostic work.

- *Selectability.* Should allow for selectable trade-offs, such as dialable speed vs. resolution, etc.

- *Interoperability.* Imagery collected in various means and stored on various media must be usable together, and viewable (along with fine text) in an interactive environment.

- *Flexibility.* Whatever standards are adapted must take into account that new and improving methods of collecting and manipulating visual data will continue to develop in the years to come. Standards should be left as open and adaptable as possible - and not, in effect, hinder future advances in technologies and applications.

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October 4, 1993

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4 October 1993

Mr. Robert L. Sanderson
Chairman

Mr. Michael Liebhold
Vice-Chairman

Joint Experts Group on Interoperability
Advisory Committee on Advanced Television Systems

Dear Sirs:

The following is in response to the Sept. 30 Interim Report from the Grand Alliance, entitled "Interoperability Aspects of the Grand Alliance HDTV System," and the accompanying slide set, both of which were distributed for review prior to the upcoming Interoperability Review meetings in Washington this week. Again, let me express my regrets at being unable to attend these meetings, but I am sure that Mr. Barry Bronson from HP Laboratories will do a better job than I could at this time in representing our positions.

The documents provided contain some very encouraging proposals, particularly in the areas of transport and compression interoperability. These proposals represent a significant step forward from those seen earlier, and certainly show serious consideration of these aspects of the future HDTV standard. However, there is at least one part of this report which is cause for serious concern, and that is what is being called here "picture layer interoperability."

As the GA report itself notes, what is being discussed is a transmission standard – not a production standard, and not a display standard. However, while it is true that production, transmission, and display are decoupled in a digital system. we cannot neglect the impact that standards in any of these areas will have on the other two. They are decoupled, but cannot be considered unrelated. This is especially true from the perspective of those of us in the computer industry, who may reasonably expect to provide systems which must exhibit interoperability with all three of these areas. Several papers have already been published which outline the concerns of our industry; among these, I would like to specifically mention "HDTV: Technical Issues of Special Importance to the Computer Industry" from Apple Computer's Advanced Technology Group, and "The Need for a Specific, Benchmarked Migration Path to an Interoperable ATV System," a white paper prepared by the Computer and Business Equipment Manufacturers Association (CBEMA). These papers do an excellent job of summarizing the general concerns of our industry.

I would like to concern myself here, though, with several very specific proposals in the areas of frame rates and spatial formats, and the arguments which have been presented for each. One of

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the most striking aspects of the GA report is the proposal to include a very large set of permissible formats and frame rates in the transmission standard. While the use of a hierarchy of related formats and rates has been one of the cornerstones of all recommendations for an interoperable system, this is not the approach being taken here. There are instead multiple unrelated formats and temporal rates, including both interlaced and progressively-scanned formats and rates based on both 60.00 Hz and 59.94 Hz rates. This is not in the interests of either interoperability or an acceptable international television standard, and there is no justification presented for many of these choices. In the following sections, I will address some of these issues separately and in greater detail.

1. The Choice of Frame Rates

The Grand Alliance is proposing that the transmission standard permit both 24, 30 and 60 Hz rates and the "NTSC-compatible" family of 23.97, 29.97. and 59.94 Hz. The reasons given for the use of the 59.94 Hz group are supposedly better compatibility with NTSC during the expected simulcast period, including both use of existing NTSC source and the display of NTSC transmissions on an HDTV receiver. This is a very unwieldy proposal, as it will be very difficult for a single set of hardware (as will be expected of the computer industry) to simultaneously support both sets to the necessary degree of accuracy. Further, there is really no compelling reason for choosing this path:

- Using 59.94 and related rates to maintain compatibility NTSC source is unnecessary for several reasons. First, the majority of prime-time programming -- the source from which HDTV might be expected to draw most heavily from past material -- is, by the GA report's own admission, originally shot on film, not NTSC video. Surely the use of this material by HDTV will best come from the use of the original film footage, at the 24 or 30 Hz modes already included in the GA proposal. What NTSC video remains unavailable in any but the NTSC format can simply be converted into 30 or 60 Hz HDTV by duplicating one field out of every 1000, something which can be done at scene cuts or other points in the original which will not result in a visible artifact. Requiring 59.94 Hz transmission, and supposedly therefore HDTV production at this rate, further does not do away with the problem of the final transition to 60 Hz. Instead, it makes it even more difficult, as we could reasonably expect that in the future we would also then have a sizable archive of 59.94 Hz HDTV material in addition to the existing NTSC stores.

- The use of 59.94 Hz also does not simplify either HDTV receiver design or the display of NTSC transmissions on HDTV receivers (or vice-versa, via an external converter feeding an existing NTSC receiver). Per the GA report, the HDTV receiver would now be expected to handle both the 24/30/60 family of rates and 23.97/29/97/59.94 -- which cannot help but complicate the design, particularly in the area of maintaining accurate timing, over a single-family solution. Given the fact that the HDTV receiver must include a large frame buffer and circuitry for performing spatial and simple rate conversions, and much better solution would be to simply allow the receiver to perform the deinterlacing and field duplication mentioned above. Conversely, a converter for the display of HDTV transmissions on an NTSC receiver will essentially be the "front end" of an HDTV receiver, and can therefore reasonably be expected to perform a frame drop to display 60 Hz source at 59.94. (It must already have the needed memory, etc., as it will have to handle the 24 and 30 fps modes of HDTV.) Actually, such a conversion may not be needed -- the majority of current NTSC receivers will likely work quite well with HDTV converted to a 60.00 Hz NTSC-like signal.

- The GA report implies that HDTV receiver standards and computer display standards will remain completed unrelated, owing to a supposed need for the HDTV receiver display to

operate at a line rate which is some multiple of the current NTSC rate, and due to the belief that the computer display industry does not have any suitable display standards anyway. Both of these are in error. Taking the latter first: it is certainly true that in the past, there were no true standards in the computer–display industry, and the timings which were in use were not selected for compatibility or interoperability. This is rapidly changing; the computer industry has recognized the need for compatible standard timings, and has developed such standards. The Video Electronics Standards Association (VESA) is a industry group to which I am currently HP's representative, and I can assure you that format and timing standards are a very important aspect of that group's activities. In fact, a set of standards for several related computer display formats (640 x 480, 800 x 600, 1024 x 768, and 1280 x 1024) were recently developed for 75.00 Hz refresh, specifically to address the need for display standards which were interoperable with existing and expected future video standards. One might even argue that the approach being taken here – developing standards for a set of related formats and rates – is exactly what is needed in HDTV.

Basing HDTV receivers on integer multiples of the NTSC line rate is unnecessary; as discussed above, there are other ways to achieve NTSC compatibility without tying the receiver to this past standard. For true interoperability, we might instead propose that the HDTV display standards be developed in cooperation with computer–display groups such as VESA and similar groups from other concerned industries.

- The GA report also completely ignores the issue of acceptability of this proposal as a worldwide standard. Surely, if any of the arguments regarding NTSC compatibility are valid, they will remain valid when considering the potential use of such a standard in areas currently using the 50 Hz PAL or SECAM standards. In keeping the 59.94 Hz rate family, the GA has taken a major step away from such worldwide acceptance.

2. The Choice of Spatial and Scanning Formats

The GA report present a bewildering array of spatial and scanning options: the expected 1280 x 720 and 1920 x 1080, plus 1440 x 1080 and 1728 x 960. All but the 1280 x 720 format are being considered for initial use as 2:1 interlaced. It is true that the final selection of the 1000+ line format, according to this report, has not yet been made. However, several aspects of the formats being considered are of great concern:

- The 1440 x 1080 and 1728 x 960 formats should be viewed as unacceptable for several reasons. First, neither of these is simply related to either of the other two, while 1280 x 720 and 1920 x 1080 have a very usable 2:3 relationship. Further, the pixel aspect ratio of the 1440 x 1080 proposal is non–square, and has no compelling reason which would justify this step away from full interoperability. Both of these come from relationships to the NTSC format; 1728 x 960 by doubling the line count, and 1440 x 1080 by doubling the number of pixels in the horizontal dimension from a supposed 720 x 480 digitized version of NTSC. Neither of these features is necessary; as discussed above, maintaining an integer multiple of NTSC lines is not required, given the spatial conversion capabilities which must already be a part of any HDTV receiver or convertor. Further, the 720 x 480 digitization of NTSC (on which the 1440 format is based) is non–square, and represents a horizontal resolution which is beyond the capability of broadcast NTSC. It would be better from an interoperability point of view to assume that NTSC is digitized as 640 x 480, which is square and which is already in widespread use as a standard display format

- All of the >1000 line formats are discussed in terms of their use in an interlaced scanning mode at the time HDTV is first introduced. Interlaced operation is certainly not desirable from

the standpoint of maximizing interoperability, and has no compelling reason which would justify even its initial use. The arguments presented in favor of interlaced formats have to do with the impracticality of full-rate progressive scan cameras and displays. However, none of these arguments justify the use of an interlaced transmission standard, as follows.

An interlaced transmission would supposedly allow a high-resolution, high-end receiver which would de-interlace the transmitted image for display. It is also argued that the interlaced transmission would permit a less expensive receiver using interlaced display. However:

1. The interlaced transmission has ALREADY given up vertical resolution which cannot be restored simply by deinterlacing in the receiver. In the case of an interlaced receiver, the effective vertical resolution will be comparable to that obtained with the proposed 720-line progressive-scan display, but with poorer motion rendition and the usual interlace artifacts.

2. Even if the full 1920 x 1080 resolution COULD be restored in the receiver, there will be no display capable of adequately displaying the resulting image. Horizontal sweep rate issues aside, there simply isn't going to be any tube suitable for such display in consumer equipment. It is important to note that in comparisons between proposed 720-line progressive and ~1000-line interlaced receivers, the CRT and video amplifier is assumed the same for each, and would not be capable of the full 1920 x 1080 resolution in any case. If a low-cost consumer receiver is desired, we might consider the possibility of a 720-line interlaced set; interlaced display is always simple to achieve from a progressive transmission, and such a display would be even less expensive than the 1000-line interlaced units proposed so far. A 720-line interlaced receiver would not, as some have claimed, have any problems in dealing with an NTSC transmission. Again, given the memory, etc., which is already required of such a receiver, reception of NTSC at 240 active lines per field will be readily achieved by a 1.5:1 upconversion to the 360-active-line fields used in the interlaced HDTV receiver.

3. If we grant that both the sweep rate cost and tube issues could be solved simply by throwing enough money at them (I am willing to consider this as a VERY high-end receiver), this would still be expected to represent a very small share of the market for the foreseeable future - certainly not reason enough to take the interoperability hit that permitting interlaced transmission would cause. We must also note that, at expected display sizes and viewing distances, the image quality of a true 1000+ line display (if one were available) would not be significantly better than that of a 720-line display.

4. There is already a 1920 x 1080 x 24 film mode proposed, and a 1280 x 720 progressively scanned receiver would have to be capable of displaying transmissions using this mode. Therefore, the ability to handle 1920 x 1080 information is already a part of the system. I have heard no arguments which suggest that a deinterlaced 1000-line interlaced transmission, displayed on what we might reasonably expect for a high-end consumer tube, is going to look significantly better than 1920 x 1080 x 24 feeding a 1280 x 720 x 60 progressive-scan display. Of course, the hypothetical high-end proscan receiver might reasonably be expected to be bought by the same people who are the market for laser disc, etc., today - those who want high-quality movies. 1920 x 1080 at either 24 or 30 fps with progressive scan would work very well with their 60 Hz (or even higher!) progressive displays, and such a receiver would certainly be capable of handling the 1280 x 720 x 60 progressive transmission expected for sports and other motion-critical programming.

Arguments for an interlaced transmission format based on the need for interlaced cameras are also in error. The GA report assumes that the HDTV receiver will be capable of handling all proposed formats; this implies that, for a 720–line progressive–scan display, a simple, economical, and effective method of deinterlacing such a transmission will be available. However, if such a technique is available, then it more properly belongs at the point of program origination, prior to encoding and transmission, in order to keep the overall system cost down and to maximize performance. If deinterlacing cannot be achieved with high quality at a sufficiently low cost for use in consumer receivers, then it most certainly belongs in the production area – not in the consumer display. In either case, the transmission standard remains fully progressive for the best interoperability, and the task of the consumer receiver/display is simplified for lower cost. There is simply no justification whatsoever for the use of interlacing in the transmission standard.

3. The Need for a Scalable Hierarchy of Formats and Rates

Many sources, most notably the report from the SMPTE Task Force on Digital Image Architectures (published in Sept., 1992), have called for the establishment of a hierarchy of related formats and rates which would provide for easy scaling and conversion among its members. Adopting such a strategy of considering the format and rate set as a whole is, in my opinion, essential to meeting the goals of interoperability, scalibility, and extensibility for the HDTV standard. The GA proposal fails to do this; not only are the formats and rates being considered often unrelated, but there is the implication that the initial HDTV transmissions will use an "interim" standard, to be later discarded in favor of the ultimate 1920 x 1080 x 60 goal. This is an unrealistic approach. We should assume that the initial transmissions will be made using a set of formats and rates which IS a part of an overall hierarchy, and that they will continue to be used even after the more difficult members of that hierarchy become practical to use. To design a system using the assumption of a temporary "interim" set of formats does nothing to enhance either interoperability or backwards/forwards compatibility. Indeed, as noted earlier, this makes the compatibility issues more difficult to deal with. It forces a second conversion to an unrelated "final" standard at a later date – after considerable material may be expected to have been produced using the "interim" standard. We should therefore insist on an approach which is based on a complete hierarchy, with a clear path showing how all members of that hierarchy can be introduced and used.

The sensible hierarchy, based on what we know of the GA proposals so far, would seem to be at least the following (all progressively scanned):

24 fps: 1280 x 720, 1920 x 1080

30 fps: 1280 x 720, 1920 x 1080

60 fps: 1280 x 720 only (until 1920 x 1080 practical).

(I am disappointed that so far, there has been little discussion of lower–end formats (say, 640 x 360 or 854 x 480, depending on whether or not the 3:2 scaling of the above is kept), and/or the option for transmitting even higher resolution still imagery at reduced frame rates.)

As I said at the beginning of this letter, I am encouraged by many of the steps taken by the Grand Alliance in this proposal, and feel that we are definitely converging to a truly interoperable HDTV standard, one which will see widespread use in many industries around the world. But I would ask that this panel and the Alliance carefully consider these issues, and address them in a manner consistent with developing the best possible standard for all concerned.

Sincerely,

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cc: Mr. Barry Bronson, HP Laboratories