Summary results of the review include:

1. concensus that the GA proposal demonstrates significant commitment to interoperability through incorporation of concepts of major significance:
   a. all-digital implementation
   b. layered architecture
   c. header/descriptors
   d. packetized data structure
   e. MPEG-2 based video compression

2. two new criteria for interoperability were identified, recognizing interoperability requirements posed by compressed, digital program distribution ("compressed domain switching and insertion" and "method to insert overlay data ... ")

3. 1080 vertical line count received more support than 960

4. some areas were judged satisfactory contingent on further definition, analysis and/or specification:
   a. "viewer transparent channel re-allocation"
   b. "still/motion multi window transmission"
   c. "definition of one or more methods for providing 1080x1920x1:1x60Hz "target" ATV transmission format"
   d. "compressed domain insertions in data stream"
   e. "a method to insert (midstream) overlay data ..."
   f. "estimate cost of including both Musicam and Dolby implementations, and forward these results to the Audio Experts Group"

5. MPEG compatibility needs to be resolved without compromising US ATV - burden on GA to conform to MPEG-2 or demonstrate benefits of AC leak in which case GA would coordinate with US national body a new request to amend MPEG standard

6. need to verify conversion between transmission and display formats within acceptable quality limits in prototype testing

7. Persistence of interlace transmission (one of six formats) in the GA proposal sustains the debate on interoperability. Neither the interlace nor progressive scan advocates have generated sufficient justification or rationale to converge their positions and every proposed format in the GA proposal has supporters and detractors.

   Resolution of this issue would be desirable. The GA has agreed to work with those representing NII interests (and other electronic publishing applications interests) to define NII functional requirements so that they could be considered in the GA system definition. A working subgroup of the Joint Experts Group on Interoperability have agreed to initiate this work as soon as possible. This work must also be reflected in tests developed and implemented by SS-WP/2. The GA recognizes the need for future ATV systems to support (in a reasonable way) NII requirements and that they should not stand in the way of NII application access.

Attachment I

Joint Experts Group on Interoperability

S. Baron	NBC
J. Bellisio	Bellcore
T. DeYoung	ARPA
M. Haley	IBM
P. Hearty	ATEL
R. Hopkins	ATSC
B. Gerovac	Digital
D. LeGall	C-Cube Microsystems
M. Liebhold	Apple
R. Sanderson	Eastmank Kodak
C. Tanner	CableLabs

Grand Alliance

R. Keeler	AT&T
G. Reitmeier	Dave Sarnoff

Interoperbility Panel

W. Bailey	NCTA
D. Baylor	Hughes
J. Clark	Silicon Graphics
W. Connelly	Sony Pictures
T. DeFanti	U of I Chicago
G. Demos	DemoGraFX
P. Dodds	Inter. Multimedia
I. Dorros	Home
J. Flaherty	CBS
C. Fleischhauer	Library of Congress
J. Fuhrer	Hitachi
J. Hamalainen	Matsushita
G. Hannover	EIA/CEG
P. Heimbach	Viacom
R. Hummell	Walt Disney
N. Izenberg	Nemours
R. Kahn	Corp. NRI
R. Little	National Geo. Society
H. Miller	PBS
D. Monteith	Rogers Cablesystem
R. Myers	Hewlett-Packard
L. Roberts	US Dept. Education
W. Rossing	First Person
M. Schenker	Dow-Jones
A. Setos	FOX
L. Smarr	NCSA U of I
R. Stumpf	Universal City
M. Tsinberg	Toshiba
A. Uttendaele	ABC
W. Wedam	Sharp Elec.

Attachment II

Interoperability Review - Attendance List
[* = 6th Only, ** = 7th Only]

NAME	AFFILIATION	TELEPHONE/TELEFAX
Baron, Stan	NBC	212-664-7557/212-664/5219
Baylor, Dave	Direct-TV	310-535-5051/310-535-5224
Beasley, Roy*	Howard Univ.	202-806-1609
Bellisio, Jules	Bellcore	908-758-2959
Bretl, Wayne	Zenith	708-391-8386
Bronson, Barry	HP	415-857-3033
Cloutier, Leo*	Comsat	301-428-4080/301-428-9287
Connolly, William	Sony Pictures	310-280-6902/310-280-1866
DeFanti, Tom	Siggraph	312-996-3002
Demos, Garry	DemoGrafx	310-837-2985/310-837-1576
DeYoung, Tice	ARPA	703-696-226x/703-696-2202
Donahue, Joe	Thomson	202-872-0672/202-872-0674
Dorros, Irwin*	ACATS-Tech.Subc.	201-285-1266
Elliott, Dennis	Elliott Communic.	703-759-7456/703-759-6828
Fannon, Peter	ATTC	703-739-3850/703-739-3230
Fenimore, Charles*	NIST	301-975-2428
Fleischhauer, Carl	Library of Congress	202-707-6233
Fowler, Thomas*	MITRE	703-883-7912/703-883-5914
Fuhrer, Jack	Hitachi-Amer.	609-520-1320/609-520-8953
Gerovac, Branko	Digital	617-253-0669/617-489-5917
Godber, Alan	Consult.(ATTC)	908-846-4476/908-846-4476
Gravel, Arthur	Delta Info. Sys.	215-657-5270/215-657-5273
Greebe, C.A.A.J.**	Philips Labs	914-945-6102
Hack, David**	Library of Congress	202-707-7067/202-707-7000
Haley, Mike	IBM	914-894-4723/914-892-6799
Hamalainen, Jukka	Matsushita	609-386-5995
Hanover, George	EIA	202-457-4979/202-457-4985
Hearty, Paul	ATEL.CRC	613-592-1727/613-592-4398
Hopkins, Robert	ATSC	202-828-3130/202-828-3131
Hummel, Rob	Disney	818-754-7259
Hurst, Norm	DSRC	609-734-2925/609-734-2901
Izenberg, Neil	Nemours Found.	303-651-4049
Johnson, Clark**	DOHRS	612-377-2329/617-377-1704
Kahn, Robert	CNRI	703-620-8990
Kalil, Thomas**	White House	202-456-2801/202-456-2223
Keeler, Bob	AT&T	908-949-7982/908-949-5775
Lechner, Bernard*	Consultant	609-924-7545/609-924-7547
LeGall, Dedier	C-Cube	408-944-6353/908-944-6314
Liebhold, Michael	Apple	408-974-6025
Longbottom, Jeff**	ATTC	703-739-3850/703-739-3230
Maddocks, J.A.*	UTC	617-864-0201/617-864-5855
Meimed, Arthur*	Rand	202-244-9056
Misener, Paul	W.R.&F	202-828-7506/202-429-7049
Monteith, Don	Rogers Cable.	416-442-2845
Neil, Suzanne	MIT	617-253-4138/617-253-7326
Parulski, Ken*	Eastman-Kodak	716-477-4652
Patten, Tom**	Philips	202-962-8550/202-962-8560
Radwill, Bill	AT&T	908-221-5165/908-221-8484
Rast, Robert**	GI	619-535-2532/619-535-2486
Reitmeier, Glenn	DSRC	609-734-2523/609-734-2149
Roberts, Mike*	Educom	202-331-5347/202-872-4318
Rodgers, Quincy	GI	202-833-9700/202-466-3295
Sanderson, Robert	Eastman-Kodak	716-726-7763/716-7253-6284

Smarr, Larry	NCSA	217-244-0078
Solomon, Richard**	MIT	617-253-5159/413-267-5172
Sproull, Bob	Sun Microsystems	508-442-0353
Symes, Peter	GVG	916-478-3437/916-478-4195
Tanner, Craig	CableLabs	303-939-8500/303-939-9189
Tawil, Victor**	MSTV	202-462-4351/202-462-5335
Uyttendaele, Tony	CC/ABC	212-456-1227/212-456-6069
Van DeGrift, Craig	NIST	301-975-3828
Walsten, Douglas	NCSA	217-244-6390
Weaver, John	Liberty TV	212-864-4999/212-864-1771
Wedam, Werner	Sharp	201-529-8618/201-529-8425
Weitzner, Daniel*	Electronic Frontier	203-347-5400/203-393-5509
Widoff, Joe*	ATTC	703-739-3850/703-739-3230
Wiley, Dick*	Chairman, ACATS	202-429-7010
Zou, William	PBS	703-739-5475/703-739-8938

ATTACHMENT III
Joint Experts Group on Interoperability
Interoperability Review --- GA Proposal
Summary Report
October 6-7 1993

Report format note

Everywhere in this report summary, the agreed view of the Joint Experts Group on Interoperability is represented by the material within "square brackets" ([....]).

General comment

[Despite the limiting context of terrestrial(-only), HDTV(-only), a lot of progress has been made toward emerging/converging uses of ATV and NII.]

Assessment of GA Proposal vs. PS/WP-4 Recommendations

1. An all-digital implementation based on a layered architecture model [ok]

2. The use of universal headers and descriptors [acceptable --- MPEG h/d/ with hooks to a universal h/d -- registry to be defined and candidates exist]

3. Transmission of the signal in progressive scan format [still an issue since not all transmission formats are progressive]

4. Use of a flexible, packet data transport structure [ok]

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) [ok in principle, but needs detailed specification]

6. Ability to implement lower performance low-cost ATV receivers (comparable price/performance options to current NTSC receivers [not at early HD introduction although a cost/performance family is possible; base level cost is determined by electronics cost which is expected to decrease to acceptable levels by the time that NTSC is turned off]

7. Ability to implement low cost ATV consumer VCR [ok for compressed input]

8. System architecture and implementation that will allow improvements and extensions to be incorporated as technology advances while maintaining backward compatibility [ok via new packet types (at a minimum) given available data capacity]

9. Square pixels or at least the option to select square pixel presentation [square pixel formats included, e.g., 1280x720 and (recommended) 1080x1920, however, there is a question on how or whether 1080x1440 will be handled]

10. Compatibility with relevant international standards or commitment to this objective [actual and required level of conformance with MPEG-2 (video, audio, transport) /ATM /Internet protocols /etc. an issue]

11. Easily implementable and user-accessible "still/motion multi window transmission [feasible via multiplexed program streams; needs further requirements definition]

<u>New Criteria</u>

12. Compressed domain switching and insertions in data stream [mechanism in place; needs requirements, analysis, and specification]

13. A method to insert (midstream) overlay data that is not in the original picture; both modes: graphics created in receiver or inserted by local station (the tornado warning feature)

[needs requirements and definition --- receiver graphics are being addressed, in whole or in part, by the EIA Television Data Services Subcommittee]

Context (for ATV --- NII considerations)

1. ATV is happening: digital HDTV, digital SDTV,...

2. NII is happening: Internet, conferencing, radio,...

3. Desire exists and will increase for universal access (to information services in the public interest); but the market incentives are unclear

4. There is agreement on the goal of NII compatible consumer products, the discussion is on tactics of how we get there (market drive and technology) --- design of ATV should not inhibit earliest access to NII services. What design features of ATV would foster earliest access to NII services?

Recurring Issues (What do we do? How do we make it actionable?)

1. MPEG-2 Compatibility

   a. General
   [Endorse the ACATS Technical Subcommittee position: be compliant with MPEG-2 to the extent possible without compromising US HDTV requirements -- i.e., not defer to MPEG, not make gratuitous differences, document rationale for differences, encourage MPEG to adopt solutions to US HDTV requirements as needed.]

   b. Video --- AC leak
   [In view of the high degree of compatibility that the GA HDTV system has achieved with the emerging MPEG-2 standard, the remaining divergence appears as an undesirable obstacle to interoperability. Burden of proof is on the GA to demonstrate significant and consistent improvements with AC-Leak over solutions compliant with MPEG-2. Experiments should take

into account realistic conditions of random access of compressed data stream and critical source material. Should the experiment be favorable to AC leak, the GA will coordinate with the US national body on a new request to include the technique in an amendment to the standard to be produced in time for HDTV deployment.]

c. Audio

[Other Experts Groups are narrowing the audio standard choice to either the Musicam or Dolby approaches. There seems no clear interoperability rationale for selecting between these alternatives. The GA agrees to estimate the cost of including both the Musicam and Dolby implementations and will forward these results to the Audio Experts Group.]

2. Interlace and Progressive vs. Progressive-only

[Persistence of interlace transmission in the ATV proposal sustains the debate on interoperability. However, neither the interlace nor progressive scan advocates have generated sufficient justification or rationale to converge their positions and every (GA) proposed format has supporters and detractors.

Some NII advocates desire proscan-only in transmission (in order to promote deployment of proscan displays), so that all ATV receivers could serve as NII displays, and so that these could benefit from economies of scale based on a common set of standards. Even greater economies of scale could be achieved through joint adoption of standards across industries (including the computer industry). Some others advocate that consumers should be able to purchase ATV receivers without paying a premium for NII display functionality which they may not need or desire or (NII) functionality that they may fulfill by using a separate computer system. Both economic assertions need validation.

This may (or already is) a public policy issue if the consume TV is to be the NII terminal.]

3. Multiple formats, benefit vs. cos

   a. [Every format in the GA proposal has supporters (and detractors)]

   b. Conversion between multiple formats
      [Conversion from all transmission formats to all proposed GA display formats must be verified in prototype testing to be within acceptable quality limits (limits need definition, demonstration, and verification). In particular, verify typical-case cost effective and performance effective transmission (1920x1080I, 1280x720P, 1920x1080P/24) to display (1920x1080I, 1280x720P, 1920x1080P/60)]

   c. Interoperation among formats, e.g., mixed format editing
      [as in b. above]

4. Square Pixels

   a. Required for "1000 line format"? 24/30/60?

   b. Coding or filtering?
      [consensus for square sample distribution]

5. 1080 vs. 960
   [more support for 1080 than 960]

6. Migration Path

   a. Definition of terms
      ["Migration" may be a misleading term. It is important that provision be made for 1080x1920x1:1x60Hz. Initial receivers may not perform beyond their initial parameters.]

   b. Target
      [There is common support for 1080x1920x1:1x60Hz as the future ATV target. The GA must define one or more technically viable migration paths to this target from any initial HDTV offering.]

c. What are the migration path objectives [Should encompass NII.]

7. Other

a. The Joint Experts Group on Interoperability is grateful for the contributions from the Intreoperability Panel and others. Additional points may be included in the attached submitted reports that have not been fully analyzed.

Attachment IV

Presentations and/or documented inputs to the Interoperability Review

L. Smarr	NCTA
R. Hopkins	(For TI)
K. Parulski	Kodak
T. DeYoung	ARPA
N. Izenberg	Nemours Foundation
W. Connolly	Sony
B. Bronson	HP
R. Sproul	SUN
G. Demos	DemoGraFX
J. DeFanti	Siggraph
R. Hummel	Disney
V. Kemper	Amer. Society of Cinematographers
R. Kahn	CNRI
S. Baron	NBC
M. Liebhold	Apple
D. LeGall	C-Cube
J. Fuhrer	Hitachi
C. Tanner	CableLabs
J. Hamalainen	Matsushita
M. Haley	IBM
J. Bellisio	Bellcore
D. Weltzner	Electronic Fronties Foundation
P. Symes	Grass Valley Group
R. Hopkins	ATSC
C. Fleischhauer	Library of Congress
D. Baylor	Direc TV
M. Schenker	Dow Jones
G. Hanover	EIA
W. Schreiber	MIT (Retired)
R. Buddenberg	Consultant
H. Donahue	Ohio State University
C. Birkmaier	PCUBED
W. Bretl	Zenith
D. Staelin	MIT - Lincoln Laboratory

Dr. Larry Smarr
Director, National Center for Supercomputing Applications
University of Illinois at Urbana-Champaign

Position:

The rapid convergence of networking, television, video games, and telephone is leading to the requirement for a standardized "window into information space". The interoperability between computer screens and televisions is a critical technology to support this effort to build a National Information Infrastructure.

In this regard, I are very excited about the formation of the Grand Alliance proposed standard. However, I believe that the standard should have as a minimum PROGRESSIVE SCAN and SQUARE PIXELS.

The end users of NII include not only personal computer, workstation, and supercomputer users, but also the emerging markets of small business, industrial corporations, K-12 and college education, and particularly digital libraries. The home market inself will be using these multimedia digital libraries over both cable tv and fiber within the next 12 months. This vast market will benefit enormously by a single digital image standard.

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TEXAS INSTRUMENTS

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October 5, 1993

Mr. Richard E. Wiley
Chair, ACATS
Wiley, Rein & Fielding
1776 K. Street, NW
Washington, DC 20006

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

Proposal for an Explicit 1080x1920, 1:1, 24 Hz HDTV format

Kenneth A. Parulski
Representing: Motion Picture and Television Imaging Division
Eastman Kodak Company, 4/81 Kodak Park, Rochester NY 14650-2015

Eastman Kodak Company supports the explicit inclusion in the U.S. terrestrial HDTV standard of a high line-count, progressively scanned, square pixel, 24 Hz image source format[1]. Specifically, we favor the use of 1080 active lines, consistent with the recommendations of the (FCC) Advisory Committee on Advanced Television Service, to maximize compatibility with the anticipated television production standard as well as to encourage development of an international HDTV image format agreement.

Abundant, ultra-high definition source material exists at 24 Hz in the form of filmed programming. To optimize both the efficiency of the intraframe compression used for post-production and the efficiency of the motion-compensated interframe coding used for distribution, the system should adapt to the source frame rate[2]. It appears technically feasible to deliver a 1080x1920, 1:1, 24 Hz format using the GA system design at U.S. HDTV service initiation. This 24 Hz source format provides 49.8 million luminance pixels / sec. The 720x1280, 1:1, 60 Hz format proposed by the GA provides 55.3 million luminance pixels / sec. The 960x1728, 2:1, 60 Hz format proposed by the GA provides 49.8 million luminance pixels / sec. Note that the proposed 24 Hz format rate equals the lower of these two GA 60 Hz rates.

To implement this proposal, all compression encoders must be designed to directly accept the 24 Hz format as one allowable input format. The quantizers used to code the DCT coefficients of the motion compensated residuals, in the 24 Hz mode, should be specifically optimized for motion picture film material. All receivers must be capable of receiving this 24 Hz format, although they could convert to a different format for the final display, if desired. If all receivers are designed to accept a 1080x1920, 1:1 format from the initiation of HDTV service, the migration path to a 60 Hz version of this format will be simplified. The 1080x1920, 1:1, 24 Hz format would provide superior spatial resolution for film originated material, compared to other 24 Hz formats suggested by the GA. It would also allow more efficient and effective image processing during post-production, since there would be no required scanning standard conversions between the telecine output and the GA compression encoder input. A 1080x1920, 1:1 format is also ideal for still images and computer graphics.

HD Telecines capable of producing this 24 Hz format have been demonstrated and will soon be commercially available. Kodak also believes that it is feasible to develop and manufacture CCD-based, progressively scanned, square pixel cameras, initially at 30 Hz, and ultimately at 60 Hz. Kodak presently manufactures a progressive scan, square pixel, 1000x1000, 30 Hz sensor[3], and is marketing a monochrome industrial camera using this sensor. Kodak has recently developed an interlaced 1080x1920, 2:1, 60 Hz image sensor[4], which is available as an off-the-shelf product[5]. The sensor was designed using interlaced readout so that it could be interfaced to commercially available HDTV recorders and displays. However, a 30 Hz progressive scan version of this sensor, using existing technology and offering similar performance specifications, could be developed immediately if there was a commercial need. Although a 60 Hz version of this sensor requires improved technology, Kodak believes that a 1080x1920, 1:1, 60 Hz camera could be developed before significant market penetration of consumer HDTV receivers occurs.

References

1. "Considerations for an Explicit, 1080x1920, 1:1, 24 Hz, HDTV Format", Letter from Henri Petit, Vice President, Motion Picture and Television Imaging, Eastman Kodak Company, October 5, 1993.
2. Parulski, K. A., et. al., "Source-Adaptive Encoding Options for HDTV and NTSC", SMPTE *Journal*, 101:674-683, Oct. 1992.
3. Steven, E. G., et. al., "A 1-Megapixel, Progressive-Scan Image Sensor with Antiblooming Control and Lag-Free Operation, *IEEE Trans. on Electron Devices*, 38:981-988, May 1991.
4. Nichols, D. N., "Single-Chip Color HDTV Image Sensor with Two Polysilicon Levels and with WSi_x Lightshield Used for Strapping Vertical Gates", *IEDM Tech. Dig.*, pp. 101-104, Dec. 1992.
5. Kodak KAI-2090CM Image Sensor Specifications, July 1993.

"Film mode" format recommendation

Abundant ATV source material exists at 24 Hz

- **Format parameters**
  - 24 frames per second
  - Progressive scanning
  - Square pixels
  - 1080 lines x 1920 pixels per line
  - 49.8 million luminance pixels / sec
- **System requirements**
  - All compression encoders would directly accept this format as one allowable input format
  - Encoder quantizers used for the film mode would be optimized for motion picture film material
  - All receivers would be capable of decoding this format
  - Display format decided by the receiver manufacturer
- **Reasons for including this format in the GA system**
  - Provides higher image quality for motion picture film, the source of most initial ATV programs
  - Facilitates efficient intraframe compression during post-production and interframe compression during delivery
  - Allows post-production processing and storage to operate more efficiently for 24 Hz sources
  - Helps ensure receivers will migrate to the final 1080 x 1920, 60 Hz, progressive scan format
- **Other sources could use the 1080 line x 1920 pixel format**
  - Progressive scan, square pixel, high resolution format is ideal for still images and computer graphics
  - If desired, electronic cameras could be developed immediately using 30 Hz progressive scanning
  - Future electronic cameras could use 60 Hz progressive scanning

ARPA HDS COMMENTS & CONCERNS

- DoD is an interested party to HDTV proceedings only as it impacts issues such as the capture, transmission, switching, analysis and display of high quality text (e.g. manuals), maps and intelligence imagery. DoD's perspective is that of a user.

- Military competitiveness means "winning the information war". Being on the leading edge of the information integration revolution is a necessary part of winning the information war. If HDTV standards can accelerate the information revolution in the United States, DoD is a very interested party. (And in such a case, is one of very many such parties.)

- DoD must be able to win the information war "any time, anywhere." US leadership in HDTV standards setting, if done right and soon, can plausibly lead to one worldwide standard. From a social good perspective, economies of scale will help disadvantaged people in the US and around the world become part of the information age.

- From a military perspective, a single progressively scanned HDTV standard adopted worldwide will make the information technology components of the "any time, anywhere" force more affordable, simplify logistics for US forces in other countries, and increase the ability of US forces to the use the infrastructure of host countries

- One of the key advances in information technology that will be occurring over the next decade is the convergence of video, computing and telecommunications

- The choice of forward-looking US HDTV standards can hurry the day of this oft-predicted convergence, helping maintain the US edge in information technology

- While there are many detailed technical considerations, the central technical <u>requirement</u> for DoD interest in HDTV is:

Interoperability with computer systems

Which requires:

- Digital
- Progressive scan-square pixels
- Header/Descriptors

While progressive scan-square pixels are included in the GA proposal, as we understand them to date, there is included in there an interlace-round pixel option as an "interim" standard for transmission. Our concerns are:

1. Interlace may not be "interim" but it is intermediate. i.e. it does not seem to bring us closer to the sort of system that would meet our needs.
2. We understand the path from interlace to proscan for cameras and TVs, but do not understand this for the transmission channel. We have a suspicion that an "interim" solution would delay the right solution.

- Given DoD's needs in this area, and if HDTV is more than an entertainment delivery system, DoD is willing to partake in some testing of HDTV systems with respect to their performance on maps, manuals, and images. These applications were completely outside the scope of the test cases used to date.
- If involved in testing, DoD would look for cost sharing arrangements with other interested parties with similar requirements, such as the computer and information industries.

The
NEMOURS
FOUNDATION

Center for Biomedical Communication

October 4, 1993

Michael Liebhold, Vice Chairman
Joint Expert Group on Interoperability
Advisory Committee on Advanced Television Systems
Apple Computer
20525 Mariani Avenue
MS-301-4L
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

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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.

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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.

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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,

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