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AT&T

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July 30, 1992

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Ms. Donna Searcy
Secretary
Federal Communications Commission
1919 M Street, N.W. - Room 222
Washington, D. C. 20554

Re: Ex Parte Presentation
MM Docket 87-268

Dear Ms. Searcy:

On July 29, Tom Norris and I representing AT&T met with Commissioner Duggan, John Hollar, Michele Farquhar, and Linda Oliver to discuss HDTV, digital video standards, and other issues raised in the docket referenced above. The attached materials were discussed in our meeting.

Due to the late hour of the meeting, two copies of this Notice are being submitted to the Secretary of the FCC on the following business day in accordance with Section 1.1206(a)(1) of the Commission's Rules.

Sincerely,

Robert K. Graves

Attachments

Copy to:

Commissioner Duggan
J. Hollar
M. Farquhar
L. Oliver

No. of Copies rec'd 0+1
List A B C D E

# DIGITAL HDTV TECHNOLOGICAL BREAKTHROUGHS

- Video Compression
  - Motion Estimation
  - Human Perception-Based Coding
- Simulcast Spectrum Engineering
  - Digital Broadcast In Terrestrial Taboo Channels
  - Prevents Interference Into NTSC
  - Rejects Interference From NTSC
- Microelectronics
  - Specialized Digital Signal Processors
  - Relatively Simple Decoder

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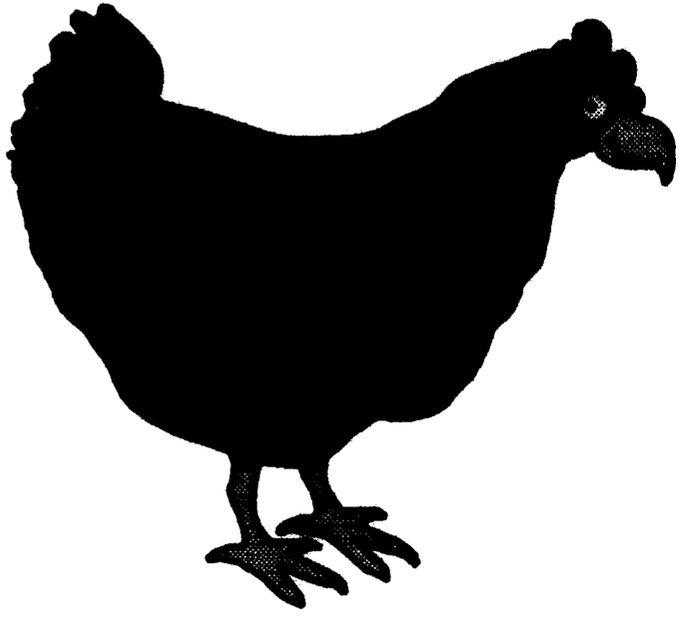
# HDTV PROMISES VIEWERS:

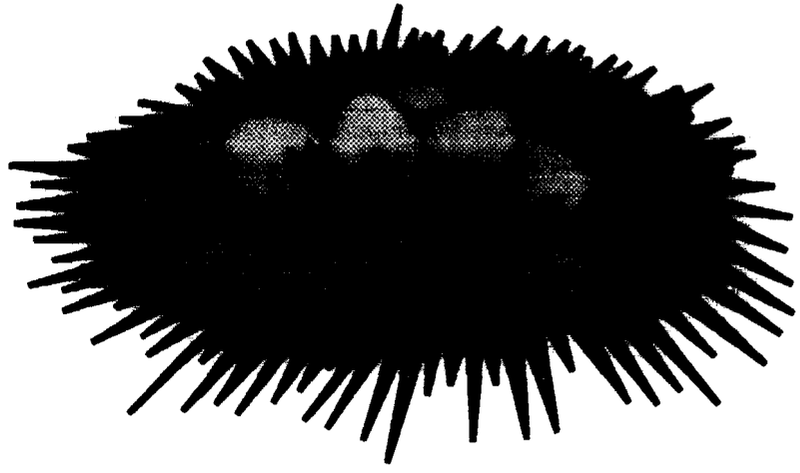
- Superb Pictures -- Movie Theater Quality
  - Free Of Interference, Snow And Ghosts
- Motion Rendition Without Artifacts
- Compact Disc Sound Quality
- Wider Aspect Ratio
- Larger Screen Sizes
- Potential Programming Innovations

But At What Cost? It All Depends . . .

# HDTV DEPLOYMENT: CHICKEN AND EGG



*Broadcasting*



*Receivers*

# MICROELECTRONICS MIRACLE

- Zenith/AT&T HDTV Receiver Requires Significant High-Speed Processing Power, Modest Memory

- AT&T's Task-Specific Digital Signal Processor Chips Operate At
  - 1-4 Billion Operations Per Second
  - 1000 Times Greater Than Typical PC

- Coding Algorithm Keeps Decoder Relatively Simple

- HDTV Receiver Will Require Just A Few Extra Chips

# WHAT CONSUMERS CAN EXPECT

- For Zenith/AT&T System, About $1000 Premium For Projection HDTV Sets
  - Premium Will Decrease As Volumes Build Up
- Rapid Adoption In "Giant-Screen" Segment
  - Benefits Most Apparent
  - Lower Percentage Price Premium
  - Half Of Current Giant-Screen Sales Would Yield 500,000 Sets Per Year
  - 1% Total Market Penetration Within Two Years
  - HD Will Stimulate Giant-Screen Sales
- Later Penetration To Smaller Screen Segments
  - Volume Cost Reductions
  - More Programming

# POSSIBLE PENETRATION SCENARIOS

- Black And White TV
- Color TV
- Stereo TV
- VCRs
- Camcorders
- Compact Discs

# Purpose and Overview

- Discuss relationships between FCC process for setting HDTV standards in U.S., and MPEG and other video standards
- These activities are not in conflict -- both reflect the evolution to digital technology
- AT&T projects address both MPEG and U.S. broadcast/entertainment television markets
  - Current MPEG-II efforts -- AT&T a leading contributor
  - High-performance algorithm for Zenith/AT&T HDTV system
  - High-performance HDTV-compatible algorithm responding to CableLabs low-bit-rate 525-line digital television RFP

# HDTV Compression

- Terrestrial/Cable/Satellite HDTV has special requirements
  - Different from multi-media computers
  - Different from video-conferencing/video-telephony
- Compression technology for different applications uses techniques from the same menu, e.g., motion compensation, DCT
- Customization for different applications can result in substantial performance improvements -- without sacrificing interoperability

# Terrestrial/Satellite/Cable HDTV Requirements

- Best picture quality consistent with 6 MHz bandwidth
- Simple, inexpensive decoder for HDTV receivers
- Quick recovery from scene, channel changes
- Robust transmission in taboo channels
- Coverage as good as NTSC
- VCR features
- Interoperability
  - digital
  - progressive scanning
  - square pixels
  - packet-like data format
- Real hardware; real transmission tests

# Other Digital Video Standards

- P*64 - established with international agreement
  - Motivation: interactive video telephony and conferencing
  - Symmetrical - low encoder and decoder cost
  - Minimal delay critical
- MPEG-I - established with international agreement
  - Motivation: interactivity with digital storage media (CD-ROM)
  - Incorporates VCR features
  - Asymmetrical - low decoder, reasonable encoder costs
- MPEG-II - requirements evolving, far from settled
  - Bit rates - 4 to 9 Mb/sec for 525-line or 625-line TV
  - AT&T Bell Laboratories is a leading MPEG contributor
  - Could be defined to be compatible with entertainment-oriented standards like HDTV standards resulting from FCC process

# Standards - Marketing Perspective

- Two distinct digital video market segments, based on distinct customer needs
  - Entertainment-oriented: broadcast, cable, satellite, fiber; HDTV and digital 525-line NTSC format
  - Telecommunications/computer/multi-media digital video
- Entertainment TV needs:
  - Picture quality in a television format
  - Interoperability among television delivery media
  - Access control for pay services
- Non-entertainment video needs:
  - Wide range of formats, performance levels
  - Flexible organization for creating, modifying, editing
- Common technology base for entertainment and non-entertainment segments
- Interoperability
  - Digital representation and processing can yield sufficient interoperability between market segments
  - Interconnections possible, driven by customer needs

# Summary

- FCC process for choosing HDTV standard is fair, open
- FCC Advisory Committee process has accelerated U.S. development, made U.S. digital technology a leader
- FCC should proceed to adopt HDTV standard optimized for U.S. television industry, in a non-disruptive evolution to digital technology
- MPEG is still being defined, may eventually encompass variations separately optimized for entertainment and other applications

AT&T Bell Laboratories

subject: **Multiple Digital Video Standards**

date: **July 14, 1992**

from: **R. E. Keeler**

*Executive Summary*


Rapid advances in digital video technology are creating opportunities for numerous video applications in traditional as well as non-traditional fields. Different formats and standards can emerge for different market segments, and the use of digital technology removes or reduces impediments to interconnections among formats, across industries and applications, so that market forces can determine how the applications evolve.

The emerging digital standards include high-definition television (HDTV), digital forms of NTSC (in the U.S.), video telephony, and multi-media business video. These different applications reflect different customer needs, and represent different market segments. Advances in digital video technology allow performance to be optimized separately for the distinct market applications, while taking advantage of common developments. The underlying digital video technology relies on a common base of semiconductor and processing elements, and modern digital communications techniques, and progress in those fields is continuing rapidly. New standards need to allow for future advances which cannot be predicted, but which will allow for important extensions to performance without rendering the new standards obsolete.

The HDTV requirements for the terrestrial broadcast/cable/satellite applications include the constraint to a 6 MHz transmission bandwidth and requirements related to the needs of an entertainment-oriented market. Additionally, the cable industry has requested proposals for digital television that would provide multiple television programs within a single 6 MHz channel.

The P*64 compression algorithms, designated as H.261, are the subject of international agreement under the CCITT, and they focus on video telephony, with a requirement for minimum processing delay. The MPEG-I (Moving Picture Experts Group) standard, under the auspices of the ISO, addresses digital video for digital storage media (like CD-ROM) and multi-media applications. The requirements include easily implemented VCR functions, and inexpensive decoders.

The MPEG-II standard is still evolving, and is intended to extend the performance of multi-media applications above the 4 Mb/sec range, with corresponding improvements in picture quality. MPEG-II will allow "profiles" to be defined for various applications and formats, such as CCITT/ATM, broadcast CCIR 601, and HDTV.

The digital video applications can be thought of as concentrated in two broad market segments: the entertainment-oriented broadcast/cable /satellite market, and the telecommunications/computer/multi-media/business video market. The second broad segment obviously consists of several different important groupings, but they are similar in having more need for interconnection across industries, across computer applications, and among differing formats than the entertainment segment. This segment also deals with images in a wide range of formats, while the entertainment segment delivers pictures to a consumer television format that is more or less standardized, and needs interoperability primarily among different transport media.

Work underway in SMPTE (Society of Motion Picture and Television Engineers) on headers and descriptors can provide a basis for tying the various digital video implementations together, while allowing for customization. Digital video representation and the interoperability facilitated by headers and descriptors will minimize the risk of technological dead ends and will foster innovation. As a result, the different emerging standards for digital video are not in conflict. A digital video standard optimized for the U.S. HDTV market will make possible a non-disruptive evolution to digital technology in U.S. consumer television, and international standards like MPEG can incorporate broadcast television requirements as they evolve.

# *Memorandum*

## I. Introduction

The purpose of this memo is to discuss the relationships among established and emerging digital video standards, and to put them into a perspective that includes the FCC Advisory Committee process for selecting an HDTV standard for the U. S. The memo shows that the various digital video standards are not in conflict, and that they properly address the needs of different market applications, while retaining a powerful capacity for interoperability.

AT&T, in particular, is a leading participant in digital video standards activities for video telephony (including video teleconferencing), for multi-media business video applications, and for broadcast/entertainment digital television in both NTSC (i.e., 525-line, the current U.S. format) and HDTV formats. (AT&T's international video interests include the 625-line systems, and the CCIR 601 standard.) Our partnership with Zenith has resulted in a prototype HDTV system that has completed tests at the Advanced Television Test Center. On April 2, AT&T announced a chip-set that implements P*64 and MPEG-I algorithms.[1] AT&T has also recently demonstrated compression technology for NTSC that will allow multiple television programs to be carried in a single 6 MHz television transmission channel. Our efforts in all these fields persuade us that it is important to optimize performance for the different requirements of distinct market applications by customizing the compression methods, while at the same time maximizing common development and interoperability. Since these standards, and new algorithms still in the research stage, all rely on common semiconductor and algorithmic elements, economical customized implementations are feasible. Furthermore, the digital representation of video signals, along with embedded identification and descriptive information, will facilitate interconnections and interoperability among different digital video applications as dictated by market forces.

## II. Digital Video Compression

Video compression techniques have been developed over the last two decades, and are still the subject of very active and productive research. Standards chosen now must allow for the likely substantial advances in compression technology that are yet to come, and that cannot be predicted. On the other hand, we should not hesitate, just because research is ongoing, to establish a new television standard that will bring an excellent

1. The P*64 standard for video telephony has been developed under the auspices of the CCITT (International Committee on Telegraph and Telephones), and the MPEG (Moving Picture Experts Group) standards, initially for digital storage media, have been developed under the auspices of the International Organization for Standardization (ISO).

level of performance, comparable to watching movies in a theater, to the television viewing public.

There is a common base of technology for digital video, and it includes advances in the miniaturization, speed, power and cost effectiveness of semiconductors; advances in processing algorithms; and advances in digital communications. These technologies are making possible the realization of advanced image systems for a very wide range of applications. The applications include video telephony and teleconferencing, multi-media interactions and presentations, broadcast and entertainment television, educational television, medical imaging and many others.

This paper examines the requirements for several different video applications, and discusses the way the needs of different market applications are met by customizing the compression architectures, which all draw on the same menu of compression techniques.

**A. HDTV Compression**

The HDTV systems for the terrestrial broadcast/cable/satellite applications have requirements that are different from those for multi-media or video conferencing and video telephony. For the broadcast/entertainment market, the following are important:

a. Best picture quality consistent with 6 MHz bandwidth

b. Simple, inexpensive decoder for HDTV receivers

c. Quick recovery at receiver from channel changes

d. Quick recovery of picture after scene changes

e. Robust transmission in taboo channels

f. Coverage as good as NTSC

g. VCR compatibility

h. Interoperability, especially among common transmission media and with computer applications

i. Extensibility to new features as needed by the market

The FCC's Advisory Committee process further required submission of working hardware prototypes for testing, which has caused the HDTV proponents to focus on the realistic practical implications of the many tradeoffs necessary in satisfying the broadcast HDTV requirements.

It is notable that the four all-digital HDTV proposals before the FCC, while differing greatly in specific choices, have some important processing and transmission techniques in common. These common techniques include:

a. Motion-compensated predictive coding

b. Block-oriented spatial transforms (specifically, Discrete Cosine Transforms, or DCTs)

c. Adaptive quantization of transform coefficients

d. Entropy coding of data to be transmitted

e. Transmission buffers with feedback to adaptively control the compression

f. Multiple-bits-per-symbol modulation, with efficient synchronization

g. Low power RF transmission

The specific details of system architectures and parameter choices selected by proponents, even with many general techniques in common, may lead to substantial performance differences. For example, Zenith and AT&T believe their choice of a very robust transmission scheme that has extended range for the most important data, combined with an adaptive compression algorithm that is based on a sophisticated model of the human visual system, yields the best performance for the HDTV requirements.

Among the building blocks of the Zenith-AT&T system is an extremely efficient vector quantization method for representing the adaptively encoded discrete-cosine-transform coefficients, which makes possible very high picture quality for a given bit rate. This method allows great flexibility in locally adapting to the fine structure like texture and edges within the images, according to a model of human perception capabilities (i.e., information that humans can't perceive need not be sent). A forward analysis technique allows for an adaptive response to scene changes or other unpredictable motion in the image. The use of progressive scanning not only results in a superior picture, without interlace artifacts, but it makes possible high-quality format conversions that would be seriously degraded or difficult to achieve for interlaced systems. This is because an interlaced format leads to added complexity in de-interlacing and motion prediction. Thus, interoperability and extensibility[2] to other applications with different formats are facilitated.

2. While interoperability refers in general to a capability for interconnections among applications in various realms such as different transport media, different industries, different geographical areas, *extensibility* refers to the ability to make future improvements in performance within a common framework while retaining at least partial compatibility with systems belonging to the common framework.

All of the digital systems that use spatial transforms can achieve a degree of scalability[3] by selecting a subset of transform coefficients (like lower frequency DCT coefficients) for decoding at the receiver. Also, a layered coding architecture can be employed to extend any of the digital compression techniques to higher quality compression. However, the relatively inexpensive decoder now planned for the Zenith-AT&T system may make it more economical to decode the entire signal before scaling the non-interlaced received images (for use in inexpensive small-format receivers, for example). None of the HDTV systems proposed for the FCC, nor the P*64 or MPEG standards, provide for the kind of scalability in which many different performance levels are associated with different subsets of the compressed data stream.

The FCC's testing and evaluation process provides an objective way of determining the relative performances of the proposed HDTV systems. The selection of an advanced television system will thus reflect both the optimizations and tradeoffs for each system, and the comparative results among the systems tested.

**B. Digital 525-Line TV for Cable and Other Broadcast Applications**

The cable industry in the U.S. has requested proposals for digital television compression systems, and AT&T has proposed for those applications a variation of the Zenith/AT&T HDTV algorithm that is appropriately scaled in format and adjusted to handle an NTSC-format interlaced video signal. The result is a compression algorithm with outstanding performance in the 1.5 Mb/sec, 3 Mb/sec, 5 Mb/sec and 7 Mb/sec range for 525-line broadcast/entertainment television. This algorithm is compatible with the Zenith-AT&T system for HDTV, so that a decoder could be configured to receive either HDTV or 525-line television.

**C. Other Digital Video Standards**

In addition to significant and practical work on proprietary methods of video compression for specific applications, there has also been international agreement on certain digital video compression standards, and that work is continuing.

**1. P*64 Algorithms**

The P*64 compression algorithms, designated as H.261, are the subject of international agreement under the auspices of the CCITT.

This standard was motivated by the needs of interactive video telephony and video conferencing. The requirements of this market application include a symmetry between coder and decoder in terms of cost and complexity, and a need for minimum processing delay (less than 150 msec each way). Picture quality is important, but the applications do not generally involve the range of motion and scene changes expected for broadcast and

3. *Scalability* means that the image data representation allows for functionally different performance levels. The idea is that a common data stream can serve the needs of various end users whose requirements may differ.

entertainment television. In the decoder, where improved picture quality might result from processing over many picture frames, the delay criterion requires an algorithm that minimizes multiple-frame processing.

The P*64 standard is relatively open and extensible, being intended for integer multiples of 64 kb/sec transmission up to about 2 Mb/sec, although the algorithms could be used at higher speeds as well. Parameters within the P*64 standard can be chosen to optimize performance for specific applications. The algorithms with different parameters will produce different compressed bit streams. (That is, a lower rate H.261 bit-stream will not generally be a subset of a higher rate H.261 bit stream produced with different parameters.)

**2. MPEG-I**

The MPEG-I standard (MPEG stands for Moving Picture Experts Group) has been established with international agreement under the auspices of the ISO (International Organization for Standardization). The goal, different from the P*64 standard, was to address the requirements for multi-media applications and interactivity with digital storage media in particular, such as CD-ROM. Among the requirements were the inclusion of easily implemented VCR features like fast forward and reverse searching, full-quality stop motion and slow motion. An asymmetry between coder and decoder costs is needed, because of a need for low decoder costs and "reasonable" encoder costs. The decoder must be inexpensive for consumer decoding of mass-distributed video on pre-recorded storage media like CD-ROM. The video formats considered were those associated with CCIR Recommendation 601, which supports digital moving images (525-line and 625-line) that can be stored in compressed form on affordable storage media.

Like the P*64 standard, the MPEG-I standard includes many parameters that can be changed to fit particular applications. Also like the P*64 standard, the bit streams resulting from different parameter choices within the MPEG-I syntax will be different, and not interchangeable.

**3. MPEG-II**

The MPEG-II standard could in general extend the performance for multi-media applications to higher bit rates, and initial attention has focused on the above-4 Mb/sec range for 525-line video. However, the requirements for MPEG-II are still evolving, and therefore the standard is far from settled.

AT&T Bell Laboratories is a leading contributor to the MPEG-II activities which are currently the subject of intensive worldwide investigation. At recent tests in Kurihama, Japan, the Bell Labs algorithm proposed for MPEG-II was one of the best in terms of picture quality, among more than 30 submissions. The Bell Labs submission was aimed at maximum picture quality for the given bit rate, consistent with economical implementation. Systems that concentrated on a simple scalability attribute dependent on frequency scaling did not perform well.

Since the underlying techniques for compression are common among HDTV and other digital video standards, the possibility of including HDTV requirements (and the algorithms that optimize performance for HDTV) within the MPEG-II standard (or some subsequent MPEG standard) has been considered. The goals of maximum interoperability and extensibility could be served by including requirements tailored to the broadcast/entertainment HDTV market within the MPEG requirements. This would mean that MPEG would recognize different subsets of requirements for different market applications. Applications that do not need all the features related to all requirements could be implemented with sufficient hooks to retain an adequate level of interoperability. In this way, future video systems could retain the commonality of adhering to a single family, while allowing customization with different sets of requirements for different market applications.

**D. Interoperability from a Marketing Perspective**

For the FCC's Advisory Committee process, at least two distinct market segments are apparent, based on distinct customer needs. These market segments are:

1. The entertainment-oriented broadcast/cable/satellite markets for HDTV (and digital 525/625-line TV).
2. The telecommunications/computer/multi-media/business video digital video markets.

It is clear from the previous discussion that the second segment itself is divided among different types of applications, with different requirements responding to different sets of customer needs. However, from the point of view of the process of selecting an HDTV standard for the U.S. television market, we can lump the "others" into a single segment.

The different market segments have different needs related to interoperability. For the broadcast/entertainment segment, picture quality must be delivered to a consumer television viewing format, and that format is more or less common to all of the displays. Consumers watch movies, news, sports, sit-coms, and do not do significant cut-and-paste editing requiring bit-mapped images, and do not watch spread sheets. In the non-entertainment segment, a wide range of formats will be appropriate, with greatly varying needs for performance, quality, and resolution.

The interoperability that is most important for the broadcast entertainment segment is for interconnection among television delivery media; that is, among terrestrial broadcast, cable, satellite, and fiber transmission systems. For the non-entertainment segment, interoperability is important on many levels besides the transport media, with interconnections across industries, across computer applications, and among different formats playing a large role in the use of the images.

While the non-entertainment segment has needs for a flexible organization for creating, modifying, and editing images, sometimes with a precision editing capability based on bit-mapped images and sub-images, the broadcast/entertainment segment needs access control for pay services, but has less need for sophisticated manipulation of images (after they are created). An illustration of the potential for cross-industry interoperability is the television production process; in composing moving images for television and film, very sophisticated image processing is often used for such processing steps as image creation and manipulation and colorization.

The fact that the image systems under consideration all have a common technology base in semiconductors, compression algorithm techniques, and communications techniques, and most importantly that they rely on digital image representation, leads to an opportunity to facilitate interoperability among all the various digital video applications in separate market segments, while optimizing performance for each application. The digital nature of the signals means that all systems can reliably be expected to have the same material (signals, objects, representations) to process. Further, the ease of manipulating, transporting and storing digital information is increasing along with the speed, power and economy of semiconductors.

**1. Headers and Descriptors**

The very important work within SMPTE (Society of Motion Picture and Television Engineers) on headers and descriptors has provided a basis for tying together the various digital video implementations in a sensible way that allows customization for different applications, but provides the hooks for interconnections where needed. For example, headers and descriptors could indicate the image format for origination, and a history of the coding algorithms used for compression. Details of colorimetry and camera settings are information that may be desirable to maintain, but in such a way that most users can ignore it.

Interconnections between the entertainment and non-entertainment segments will doubtless be important in the future, but they are sparse at present.

In the broadcast/entertainment segment, where bandwidth is limited and receiver costs must be minimized, we foresee a relatively small set of headers and descriptors that identify the signal data streams and provide hooks for interoperability as needed. Applications in the non-entertainment segment will in general have need for more elaborate headers and descriptors, commensurate with the greater need for flexibility and ability to manipulate images. A key point is that when program material from the entertainment segment is connected to the non-entertainment applications, it must be possible to enrich the headers and descriptors to satisfy the needs of the multi-media or other applications. And when programming from the non-entertainment segment connects to the broadcast/entertainment segment, the scaled-down headers and descriptors must retain sufficient information for a useful level of interaction in the new environment.

It should be noted that the many-faceted non-entertainment video market will involve large numbers of interconnections within that market segment. There are significant, but more restricted interconnections among parts of the broadcast/entertainment segment.

Digital representation and processing, with headers and descriptors that can be extended and enriched as needed, allow market forces to determine the kind and amount of interoperability that are implemented for digital video applications. This interoperability means there will be less risk of technological dead ends within digital video, and will foster innovation of diverse video applications.

**III. Summary**

The FCC process for testing HDTV systems and selecting a new standard for U.S. television is a fair and open process which should lead to selection of a standard that will be good for the U.S. public. The FCC's requirement of working hardware prototypes for testing has led the remaining proponents to consider carefully the practical implications of design tradeoffs, and this has caused an acceleration of HDTV developments.

Numerous digital video standards have been announced, and more will be forthcoming, that properly address distinct market applications. This is desirable, and does not mean the different standards are in conflict. The risk of unacceptable difficulty in interconnections among the different video standards is avoided by providing "hooks" in the form of headers and descriptors that will be embedded in at least a minimal form in all advanced video applications.

A digital video standard optimized for the U.S. HDTV market will enable a non-disruptive evolution to digital technology in U.S. consumer television. Such a standard could be incorporated within the ISO's MPEG framework if an appropriate set of requirements or "profile" for the broadcast entertainment television industry is defined for MPEG.

Robt E Keeler

**R. E. Keeler**