support the proposal is the hope that Europe will accept 60 Hz, rather than enthusiasm for the NHK system, as such. Presumably, this is also the rationale for its adoption by the State Department as the official position of the US.

This fall, the CCIR, the intergovernmental group that sets TV standards, considered such a proposal. Its advantages are clear. Equipment manufacturers, mainly Japanese, would be encouraged to market equipment, and its cost (and perhaps its price) would be lower because of standardization. TV and film producers would save money and gain convenience by going to all-video production methods.

Disadvantages to the proposed adoption are not easy to dismiss. All programs produced in NHK format must be converted for broadcast use, since there is no possibility at all that either the NTSC or PAL systems will be abandoned for regular broadcast use in the foreseeable future. Since the NHK system is 60 Hz, conversion to NTSC would be quite simple. A converter might cost $25-50K. Conversion to the 50-Hz PAL system would be a little more complicated than present-day PAL-NTSC conversion. Converters are expected to cost $200-250K and even then it is not assured that the quality of the conversion would be acceptable to meticulous European broadcasters. (In fairness, it should be noted that the motion artifacts associated with present-day 60-50 Hz converters are much less obvious than those always present in 24 fps films.) It is hard to see why they should go through this extra expense with no corresponding benefit.

Even accepting the quality of the conversion and ignoring the extra cost, the formal adoption of the NHK system would carry with it other and more far-reaching problems. If it were to be used for production only, the objections would not be overwhelming. It is production use as a foot in the door to broadcast use that most alarms the opponents, since it is in this application that the deficiencies are most critical. While Western proponents generally say that they have no intention of advocating NHK HDTV for any other purpose, this is not entirely true of the Japanese. For example, Kotaro Wakui, deputy director-general of NHK's network engineering branch, is quoted in *TV Digest* as stating that home video standards should be the same as production standards, and that a home video recorder is under development for the 1125-line system.

The NHK system is entirely analog, and the trend in professional TV equipment in recent years has been toward digital processing. It takes no advantage of modern signal processing ideas discussed above nor of advances in semiconductor technology that make such processing feasible. As a result, its system design is no more advanced than that of the 32-year old NTSC system. Its efficiency is about the same. What was barely tolerable for the 6-MHz NTSC channel, however, is intolerable for the NHK 20- to 30-

MHz channel. This wide bandwidth precludes the use of the system in existing TV channels and makes the associated equipment very expensive. It makes digitization especially costly, particularly the digital video tape recorder and digital special effects equipment, which many expect to figure prominently in future systems. The NHK system is certainly no better than NTSC with respect to motion rendition and flicker, and perhaps even worse, because the field of view is wider. Viewers generally do report less interline flicker with the NHK system than with NTSC, but this can only be true because the line structure is incompletely resolved or because of insufficient vertical resolution in the camera. In either case, it indicates even less efficient use of the channel capacity than NTSC.

If the NHK system is adopted now, the first effect is likely to be substantial capital investment by film/video producers in Japanese HDTV equipment. (It is doubtful that TV-only producers and broadcasters will buy much equipment, since they could not put it to profitable use.) The existence of this equipment and the associated investment will present a significant obstacle to the adoption of a more sophisticated system in the future. I believe that this will foreclose any opportunity for the US television industry to gain a meaningful share of the HDTV market. Admittedly, there is no guarantee that they will get much of the market in any case; but with a better system, on the scene several years from now, partly developed in the US, at least they will have a chance.

Of course, some may say that the Japanese deserve to dominate HDTV, since they alone were willing to make the investment to develop it to the present point. However, this situation is quite unlike that o Japanese cars, which American buyers prefer in devastating proportion because they perceive them to be superior to ours. The objections to the NHK system are not merely chauvinistic. Even in Japan, there is substantial support for compatible improvements in the NTSC system, rather than the use of the much wider bandwidth NHK system. A committee headed by the Ministry of Posts and Telecommunications, already working in this direction, is quoted in *Electronics* as pointing out that the HDTV signal cannot be broadcast in any terrestrial channel, and that sets smaller than 30″ (too large for Japanese homes), do not need 1125 lines resolution.

The deficiencies pointed out above in its system design are real. The potential for much better systems is not imaginary. The need to adopt the NHK system at this time is not overwhelming, and the likely results of its adoption, in my opinion, are serious and against the national interest.

The Future of Television

Many upheavals may be in store for TV besides higher quality. The film theater may metamorphose

into a TV theater fed by a wideband link. Cable and the video cassette recorder have already made great changes in the means by which programs are produced and distributed. There is a real question as to how programs will be sent to homes in the future, and how they will be paid for. Fiberoptic cables or satellite transmission may be used to carry the signals direct to homes. Many proposals have been made for additional services, such as videotex and various interactive informational, transactional, and educational systems that would utilize television, video storage, and computer equipment now in use or that might be installed in the future. There appears to be a role in all this for a greatly improved television system so that at least some of these services could support productions of essentially perfect technical quality.

We are in the midst of a period of extraordinary creativity in every aspect of television system design. Research results indicate that a very attractive system can probably be developed that will require little, if any, increase in bandwidth. The worry expressed by some, that the absence of a quick agreement on a production standard will lead to a proliferation of proposals for new systems, is not at all a cause for concern. It rather demonstrates that knowledge is being acquired at a rapid rate. Adoption of any HDTV system at the present time, for any purpose, is therefore premature. It is likely to discourage investment in TV research and stretch out by many years the time it will take to achieve a truly superior system.

Glossary

ATSC. The Advanced Television Systems Committee. A US industrial group that has been developing voluntary standards for high-definition systems.

CCIR. International Consultative Commission on Radio. An intergovernmental standards-setting organization.

DBS. A system of transmitting TV programs directly to homes via satellites.

DVE. Digital Video Effects. A TV special effects systems that, in current systems, requires first digitizing the signal, then performing the desired process, and finally returning the signal to analog form.

EBU. The European Broadcasters' Union. The members are broadcasting authorities, mainly governmental. The EBU is in favor of MAC, but is considering the NHK system

as a production standard. It is very concerned about conversion from 60 to 50 Hz.

HDTV. High-definition television. 1000 lines or more.

MAC. Multiplexed analog components. A color TV transmission system in which three separate signals, usually luminance and two chrominance signals, are time-multiplexed for transmission.

NHK. The Japan Broadcasting Corporation. The main broadcaster in Japan with extensive research laboratories. NHK led the development of the 1125-line HDTV system.

NTSC. National Television System Committee. An American industry group that proposed monochrome TV standards in 1941 and color standards in 1953. Standard setting in the US is the prerogative of the Federal Communications Commission, which historically has preferred to adopt industry-initiated schemes. In colloquial usage, "NTSC" refers to the current US color TV transmission standards. NTSC is also used in Japan, Latin America, and some other places.

PAL. Phase alternation by line. The European color television system, using 625 lines, 25 frames, 50 fields. Used in most 50 Hz countries.

SECAM. The French color television system, also used in Eastern Europe. Uses a different method of modulating color information onto the color subcarrier.

SMPTE. Society of Motion Picture and Television Engineers. The principal American professional organization for the motion picture and TV industries. Has foreign members and branches. Studies proposals and sets standards for new TV systems.

UHF. Ultra high frequency. The spectral band that includes channels 14-69. All receivers sold in the US are required by law to include UHF capability.

VHF. Very high frequency. The spectral band that includes channels 2-13.

BOX ON THE SCANNING PRINCIPLE (Use a diagram or two here.)

The intensity (technically, irradiance) in the focal plane of the TV camera is a function of the space dimensions, x and y, as well as the time, t. I shall call this the *video function.* The TV system produces a version of this function on the surface of the picture tube or other display device. In order to do that, a *video signal* must be derived from the video function for transmission to the receiver. If we visualize the video function in a three-dimensional x,y,t space, this becomes a problem in sampling theory well understood by modern-day scientists. However, even without the aid of systems analysis, the idea of sampling by scanning was conceived no later than 1847 by Bain, and perhaps much earlier. In fact, a commercial facsimile system using the scanning principle was in service between Paris and Lyon around 1850.

Because of its relationship to the 3-d world, the video function has unique and important statistical properties. In mathematical terms, at each point in x,y,t space, the video function must be highly correlated. This is so because the function represents the projection, on a surface, of a collection of three-dimensional objects that are moving continuously in time. Thus the image of each point on the surfaces of these objects must trace a continuous path in x,y,t space, from the time it appears from behind some other object or from beyond the picture boundary, until it disappears from view. The direction of highest correlation is thus the direction of motion, and the intensity along this path, except for noise and perhaps for the effect of shadows, must be slowly and continuously changing. (In artificial intelligence circles, this phenomenon is called optical flow.) If the direction of motion is known, then many points along each flow line can be calculated from a relatively sparse sampling, thus permitting very accurate interpolation of intermediate frames.

BOX ON COLOR

Newton discovered that the sensation of color depends on the spectral distribution of light, i.e., on the amount of energy at each visible wavelength. However, colors can be matched, or reproduced, by a suitable additive mixture of only three primary lights, the best set being narrow-band red, green, and blue. A color TV tube mixes colors in this way. Paint or dye mixtures, as used in color film and printing, are more complicated

because the physical situation is quite different. Such mixtures are called subtractive. The best set of dye primaries comprises cyan (blue-green), magenta, and yellow, the complementary colors to the primaries used for additive mixtures.

When color standards were first adopted in the US in 1951, a very simple field-sequential system promoted by CBS was chosen. Equal-resolution red, green, and blue images were transmitted in succession by means of rotating color wheels in front of camera and receiver. To fit this signal into the 6-MHz channel, the resolution and frame rate were reduced. The system was incompatible with the then-existing monochrome system, and lasted only two years.

In the NTSC system, the RGB components are transformed, by a change of coordinate system in color space, into luminance and two Cartesian chrominance components. At the transmitter, the latter are modulated onto a subcarrier near the top of the luminance band. The resulting composite signal is sent to the receiver where it is separated (demodulated) into components, several design measures having been taken in an effort to make it possible to perform the demodulation accurately. The amplitude of the subcarrier depends on the amount of color in the picture and is zero for neutral colors. Furthermore, the phase of this subcarrier is chosen so that it cancels out on successive frames. The subcarrier frequency is chosen so that the spectral lines used for color are interleaved with those used for luminance. These measures reduce, but do not eliminate, the interference between the chrominance and luminance signals. Some modern receivers use so-called "comb filters" to improve the separation, but only very expensive three-dimensional filtering at both transmitter and receiver would eliminate luminance/chrominance interference completely. These are the considerations that led to the development of the MAC systems.

TAB

Summary of Oral and Written Testimony
before the Markey Committee, October 8, 1987

William F. Schreiber
Professor of Electrical Engineering
Director, Advanced Television Research Program
Massachusetts Institute of Technology

(The opinions herein are those of the author only)

Advanced Television Systems

This testimony discusses the various ways in which the benefits of advanced television technology can be brought to the public, both from a public policy point of view and from the standpoint of technology. The effects on the TV distribution system and on domestic industry are also considered. The principal points made are as follows:

1. The Japanese have developed a high-definition TV system called "NHK" that has about twice the vertical and horizontal resolution and a wider picture than the "NTSC" system used in the US. It requires the equivalent of 5 normal TV channels, but is not seriously proposed as a *transmission* standard.

2. The governments of Japan and the US, alone among major countries, have proposed the adoption of the NHK system as a *production* and *program interchange* standard by the international community.

3. Europeans have refused to adopt this standard, and have embarked on the large and well funded *Eureka* project to develop their own system.

4. A bandwidth-compressed version of NHK, called "Muse," of somewhat lower quality, has been demonstrated for transmission. It takes 1 1/2 to 2 channels and is noncompatible with existing receivers.

5. Use of the NHK or Muse systems poses serious hazards for the US TV distribution system. There are also many technological objections. Their adoption would probably exclude American manufacturers from both the professional equipment and TV receiver markets.

6. Many superior alternatives exist or have been proposed: 1- or 2-channel compatible systems with improved quality on special receivers, noncompatible systems in one channel, and flexible systems that can continue to be improved over time. It is agreed among American interests that service to existing receivers must be continued.

7. There is no urgency to adopt any system at the present time, especially when so much progress is being made in developing systems that are more efficient than NHK and Muse, and more suited to American requirements.

Oral Testimony before the Markey Committee, October 8, 1987

William F. Schreiber
Professor of Electrical Engineering
Massachusetts Institute of Technology

(Speaking for himself only)

My name is William F. Schreiber. For 40 years, my main professional interest has been imaging systems. For 28 years, I have been a faculty member at MIT, where I am professor of electrical engineering. For the past 4 years, I have been Director of MIT's Advanced Television Research Program, the only TV research and development program jointly sponsored within the American TV industry. Our basic mission is to find out how to make better television systems. Since it is impossible to summarize in 5 minutes what we have learned in 4 years, I shall have to make a series of unqualified statements. I have submitted additional material and shall be glad to provide the committee any further information it desires. The opinions I shall express are mine only.

We are talking today about money - and jobs. Although the direct social value of TV depends on programming, it is a large industry with important economic effects. High definition is the next milestone. The technological choices we make will have a profound impact on all companies delivering TV to consumers. These choices will also determine whether the billions of dollars of professional and consumer equipment will *surely* come from abroad or *may* come, in part, from US manufacturers. The US consumer electronics market is about $24 billion, with 85% in foreign hands. The governments of the United States and Japan, alone among major nations, favor the adoption of the Japanese-developed "NHK" system. There are many technological objections to this system; its adoption will assure that virtually no HDTV equipment will be American. If "Muse," the compressed version of NHK, is used for cassettes or for transmission, the broadcast and cable industries may be seriously and adversely affected.

There are many possible paths to HDTV. All of them *must* continue to serve the 120 million or so receivers in the hands of the public. Terrestrial broadcasters favor a receiver-compatible HDTV system using no more channels than today's standard "NTSC" system. Cable companies are not so restricted, but would still prefer to use no more than one channel for any new system.

At present, we do not know how to provide true HDTV imagery within a single channel in a manner fully compatible with today's receivers. HDTV thus requires the use of extra channels, at least for an interim period during which NTSC service is maintained. The NHK system, for example, requires five standard channels. By making certain compromises, this has been compressed to one and one-half or two channels in the Muse system. Thus this method, including existing service, would require 2 1/2 or 3 channels.

Other proposals call for combining one NTSC channel with an "augmentation" channel, producing high-definition images on special receivers that use both channels. Such systems can surely be made to work. However, they tie up the extra channels permanently, in the same way as Muse.

Our work at MIT, as well as that done elsewhere, leads me to believe that there are other scenarios that are feasible, both technologically and commercially. For example, by making some tradeoffs with respect to image reproduction on NTSC receivers, it would be possible to provide, within one channel, substantially enhanced viewing on special receivers, even if not quite up to "true" HDTV. I also believe that it is possible to achieve true HDTV within a single independent channel. Such a system could be used by cable companies, such as Home Box Office.

An important part of these two proposals is the concept of the "open-architecture, smart" receiver, capable of being improved in an evolutionary manner as our knowledge of the image-transmission process improves, and as improved components become available. Ready interfacing with computers, VCR's, video games, and the forthcoming electronic still cameras and recorders would provide mutual support for other industries. Manufacturing plug-in hardware or software modules for millions of such receivers is an ideal business for the many ingenious small-scale electronics companies that have done so well in the personal computer market. The prospect of providing the receivers themselves might well spark a resurgence of interest in consumer electronics by large American companies.

It is clear that there are many alternative ways to make the benefits of advanced television systems available to the public, without at the same time causing serious damage to the existing TV industry. There is no pressing need to choose *any* system, for any purpose, at this time.

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Glossary

HDTV. High-definition television. About twice the resolution of NTSC horizontally and vertically, and a wider aspect ratio.

NTSC. National Television System Committee. The present US television system.

pel, pixel. Picture element - the unit of resolution in an electronic image.

NHK. Japan Broadcasting System

Muse. The compressed version of the NHK HDTV system. Requires 1.5 to 2 standard channels.

Written Extension of Oral Testimony
before the Markey Committee, October 8, 1987

William F. Schreiber
Professor of Electrical Engineering
Director, Advanced Television Research Program
Massachusetts Institute of Technology

(The opinions herein are those of the author only)

Advanced Television Systems

We are now witnessing, within the American television industry, a curious phenomenon. A substantial number of TV professionals, primarily through SMPTE and ATSC, are working diligently to iron out all the details so that the NHK system will become the worldwide *de jure (or de facto)* standard for TV production and program interchange. Although Muse, the bandwidth-reduced version of NHK that has been proposed for transmission, is officially not on the agenda of these bodies, NHK and Muse are cousins, in my opinion. The adoption of the former makes the use of the latter inevitable. If NHK is adopted, then, in all probability, the Muse system will become the worldwide high-definition distribution standard.

The members of these committees are ostensibly working on specific details, such as signal descriptions, sampling frequencies, "square pixels," colorimetry etc. Much of the work is of excellent quality and would be relevant to any HDTV system. However, the principal effect of these efforts is to help propagate a particular system that the world community, through its authorized agency, the CCIR, refused to accept in 1986, and whose adoption would be detrimental to the interests of many of the participants and their employers.

Engineers' and scientists' identification with their work is very common; in fact, it is usually a necessary ingredient for success, and accounts for the enormous amount of time and energy we are willing to spend to get something to work right in spite of obstacles. Thus we often tend to lose sight of the overall objective. People who have spent their entire professional lives making beautiful pictures want them for their own sake. The spectacular images we have seen from the NHK system inspired many of us to work very hard to get them into every living room. The Japanese deserve a lot of credit for their foresightedness and, particularly, their willingness to spend a considerable amount of money, beginning in 1970, to show that better television pictures can be ours if we want them.

It behooves us to remember, however, that the quest for high definition and the resulting controversy about which system, if any, should be adopted, is an aspect of a vigorous commercial competition. In this competition, we have already lost most of our consumer electronics industry and a large part of the professional TV equipment market. If Muse is established in this country via VCR's, it poses a significant threat to both the broadcast and cable TV industries. If Muse or the wide-band NHK system is adopted for either terrestrial broadcasting or satellite transmission,

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a complete realignment of those services will ensue, with unknown consequences. If NHK is adopted as a production standard, it will be hard to avoid any of these developments.

While many Americans seem oblivious to this situation, Europeans are not. Europe has begun, through its well funded *Eureka* project, to work toward alternative solutions more in accord with its own vision of the future. Among other things, this eliminates the possibility of a worldwide program interchange standard, one of the reasons given by many otherwise uncommitted professionals to support the NHK system. It is time for the US to look to its own interests.

Opposition to the NHK system need not, and should not, be based primarily on short-term market considerations. HDTV, properly conceived and introduced, presents the possibility of becoming a large new industry, bringing satisfaction to the public and profits to most of the present players. We should all welcome it. What is needed is a sound long-term solution - a way of introducing advanced television systems that will permit orderly growth and in which existing providers of equipment and services will have a chance to participate successfully. A poorly conceived system will grow only slowly, reducing the benefits to all concerned. This is equally important for the Japanese, who, in all likelihood, will eventually supply a large part of the hardware for any new system.

NHK and Muse as New Systems: The Correct Choice?

The desirable features of a new system are not hard to describe. The system must be thought out well enough to last 30 or 40 years, taking advantage of improvements in technology now on hand and that are likely to occur in the near future. It certainly must not be out of date when first put into service. It must use minimum bandwidth for whatever image quality is obtained. This is necessary for economical recordability and because spectrum conservation is important for all users and not just TV. Minimum bandwidth also facilitates digitization, which is needed to take advantage of the many processes that are better carried out numerically. Finally, since any new system must exist side by side with film, NTSC, PAL, and SECAM for many years, easy defect-free transcodability is required.

The NHK production system and the Muse distribution system do not meet any of these requirements. For all the remarkable progress made in cameras, displays, and recorders, the system concepts are fatally out of date. NHK is simply a scaled-up version of the existing analog systems, with all their shortcomings except composite video. It takes no advantage of the enormous progress in cheap and powerful integrated circuits. Worst of all, it makes inefficient use of excessive bandwidth. As a result, it is very expensive for the broadcaster, and presents nearly insuperable problems in transmission. While it could be used as a studio standard, it has no special advantages for this purpose over any other possible high-definition system, except that it is available. Its use of interlace is probably a disadvantage.

Muse is more advanced. It does use some newer concepts in signal processing and is much less bandwidth-greedy. (Nearly half of the bandwidth savings come from reduced spatial resolution and an equal amount comes from some blurring of moving objects; many in the industry do not regard it as high definition at all.) It inherently requires a sophisticated receiver, but so would almost any other acceptable system. However, as it is based on the NHK system, it shares many of its system concepts. In addition, the use of subsampling for bandwidth compression makes the signal highly vulnerable to common analog channel distortions such as multipath. If

we could clean up our analog broadcasting and cable channels to make them good enough for Muse, we would get much higher quality on NTSC, as seen on home receivers, without any changes at all in system design.

Receiver-Compatible Systems

Terrestrial broadcasters, who see a major threat to their audience share from HDTV delivered to the home via high-definition VCR's and special receivers that can also display NTSC, hope for the development of a one-channel *receiver-compatible* system. In such a system, the transmitted signal would be modified in such a way that existing receivers would display pictures no worse than at present and special receivers would show "high-definition" images. This is intended to permit the broadcasters to continue to serve their present viewers as they move into improved systems, and to compete with HD cassettes.

Research to improve NTSC within the 6-MHz channel, usually called EDTV (extended-definition TV), has been carried out in a number of places, such as Hitachi and Matsushita. Proposals and demonstrations have been made by others, including Faroudja and Iredale in the US, and significant work has been done in Europe. NBC has just announced a system developed at the David Sarnoff Research Laboratories, the former laboratory of RCA.[1]

Our own MIT laboratory has such a system under consideration. Many of these schemes result in worthwhile quality improvements, even if not up to the level represented by the wideband NHK system.

It is perfectly clear that the present audience must continue to be served via NTSC transmissions to existing receivers for many years to come. That being the case, extra channels must be used if "true" high-definition broadcasting is to be introduced. One way to do this is to use an NTSC channel, for compatibility, together with an augmentation signal occupying an additional channel, or perhaps only one-half a channel, that would be combined in special receivers with the NTSC transmission, to display high-definition images. Such systems have been proposed by Glenn and by North American Philips and certainly could be developed. A second way to accomplish this is to use a completely independent high-definition transmission in the second channel, in which case the same or different programs could be transmitted through the NTSC and the high-definition channels, at the option of the broadcaster. The most prominent contender for such service is Muse, which itself will require at least one and one-half, and in all likelihood, two channels. Even with this extra bandwidth, Muse suffers at present from the multipath problem mentioned above. The experimental Muse transmissions earlier this year in Washington confirmed this difficulty.

None of these three possible routes to the TV system of the future has clear sailing. The one-channel receiver-compatible method may well be the most practical interim solution. However, it probably will not have good enough performance to serve as the very high quality system that we would all like ultimately to see. The two-channel compatible scheme, while it can achieve adequate quality, at least doubles the bandwidth consumption forever. The noncompatible approach has even higher bandwidth consumption and is potentially very disruptive of existing

[1]The NBC/Sarnoff system was demonstrated for the first time at the HDTV Symposium in Ottawa this week. The pictures were very good and the demonstration evoked a great deal of interest.

services.

Channel-Compatible Systems

After having studied this problem at MIT for the past four years as director of the Advanced Television Research Program, I believe that there is another approach that is much more attractive in the long run.

An important goal is obtaining maximum quality within the allowable spectrum. This will be greatly facilitated by eventually abandoning NTSC. With existing receivers serviced by one of the proposed backward-compatible EDTV schemes, by one of the 2-channel systems, or by completely separate transmissions, it would then be feasible to design a totally new system that does not have to be be decodable by NTSC receivers. Such a system could take advantage of much of the truly significant knowledge about image transmission that we have gained in the 35 years since the birth of NTSC. Of at least equal significance, it could also utilize cheap and powerful signal-processing and memory chips of the kind developed for computers.

Without the receiver-compatibility requirement, I am convinced that it is possible to develop a system with image quality comparable to, and eventually much superior to, that of Muse, without the multipath problem, and fitting within a single 6-MHz channel. (Of course, even better quality could be obtained with 2 or 3 channels; the goal is to do "HDTV" in one channel, if possible.) Such *channel-compatibility* is highly desirable as it avoids the wholesale realignment of channel assignments, a practical and regulatory nightmare.

From the market standpoint, this approach has a great deal of flexibility. When the same programs are transmitted via NTSC and on the one-channel HDTV system, we have functional equivalence to other two-channel compatible systems, such as that of Philips. When different programs are transmitted, we have functional equivalence to NTSC plus Muse, but with less bandwidth. If the market so decrees, such a two-tier service could be maintained permanently. On the other hand, if the market overwhelmingly prefers high definition for all programming, NTSC can be slowly phased out, as contemplated in the recent FCC Notice of Inquiry. The public would then have an all-HD system very economical of spectrum space and without any reallocation of channels.

The technological reasonableness of the channel-compatible approach is clear by comparison with NTSC. After all, the latter, remarkable as it was at the time, was conceived with two important constraints. One is that it used the signal transmission ideas of the day, and had to be compatible with the monochrome system selected in 1941. Another is that it had to be designed around a very simple-minded receiver, which was the best that could economically be achieved in 1953. Simply by avoiding the inefficiencies due to vestigial-sideband transmission, the separate sound carrier, and the retrace intervals, efficiency (picture elements per second per unit bandwidth) can be increased by about 65%. By using a progressive-scan display, an improvement in vertical resolution of about 40% can be obtained. In a system that does not have to adhere to pre-existing scanning standards and that uses a sophisticated receiver, further improvement is possible by assigning channel capacity appropriately to the various signal components, as done, to some extent, in the Philips system. With the right kind of receiver architecture, even further improvement is possible in an evolutionary manner after the system is in place.

We shall shortly embark on a project to demonstrate whether 1-channel HDTV can be made to work. If successful, it is the intention of MIT and the sponsors to offer this system to any and all users with at most nominal royalties.

The Open-Architecture Smart Receiver

The design of an entirely new system at the present time can take advantage of television receiver capabilities made possible by the enormous progress in integrated circuits of the past two decades. For about the same price as the first color receivers, a highly flexible unit could be designed, not only capable of squeezing maximum quality from whatever signal is transmitted, but one that could adapt itself, under the control of a small amount of digital information transmitted along with the picture signal, to the signal format. The latter, in turn, could be adapted to the characteristics of the particular program material. For example, fast-moving sports scenes could be shot at high frame rates for optimum motion rendition, while slowly moving images that emphasize fine detail could be rendered at lower frame rates. In both cases, the display, as distinct from the transmission, would operate at both high resolution and high frame rate, for flicker-free reproduction without visible line structure.

A programmable receiver of this nature could, at little additional cost, receive signals in a variety of formats, including, of course, NTSC. (Some multistandard receivers are already available in Europe.) This means that, as our knowledge increases, improvements could be introduced at the transmitter without making receivers obsolete.

Another valuable feature of a truly modern receiver is that it could be organized in much the same way as a personal computer. This means that it would be possible to plug in hardware and software modules designed and produced by third parties for enhancing and/or adding capabilities. Easy interfacing to computers, cable, VCR's, video games, various proposed interactive services, and, perhaps most important of all, electronic still photographic equipment, could readily be provided.

Conclusion

From all this, it is obvious that we are in the midst of a true renaissance in visual communications systems. With the knowledge now available and with the hardware we now know how to build, there are many alternative ways to provide the American people with a vastly improved television system. This can be done without placing at risk the elaborate existing structure for delivering programs to the public. The hope for a worldwide standard based on the NHK system has been dashed by the European decision to follow a separate path.

The original NHK system was devised more than ten years ago, and it is now widely considered to be impractical and wasteful as a broadcast standard. Muse modifies the original system and does improve its efficiency, but with what we know today, we can do much better than either of these systems in terms of image quality for a given channel capacity.

From a technical standpoint, I can see no reason to accept these standards when there are substantially better alternatives available. From an economic standpoint, there is no reason to accept inferior standards that effectively exclude American industry from participation in future TV manufacturing. I therefore suggest that the adoption of the NHK production system or the Muse transmission system at this time as any kind of standard, *de jure* or *de facto*, is against the

public interest.

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The opinions expressed in this note are those of the author and not of MIT or the members of the Center for Advanced Television Studies.

Glossary

SMPTE. Society of Motion Picture and Television Engineers

ATSC. Advanced Television System Committee

NHK. Japan Broadcasting Company. Colloquially used to mean the 1125-line HDTV system developed by NHK.

Pixel, pel. Picture element. The smallest unit of resolution on the screen.

HDTV. High-definition television

CCIR. The international body that sets TV and radio emission standards.

VCR. Video cassette recorders used by consumers.

Muse. The bandwidth-reduced version of the NHK HDTV system

Multipath. A transmission defect in which two or more signals, with different delay, arrive at a receiving antenna. Causes "ghosts."

NTSC. National Television System Committee. Colloquially used to mean the present US color television system.

PAL. The color TV system used in Western Europe and most 50-Hz countries.

SECAM. The color TV system used in France and Eastern Europe

EDTV. Enhanced definition television system. Refers to systems better than NTSC but not as good as NHK.

6-MHz. The bandwidth of a standard TV channel.

Transcode. To convert a TV signal from one standard to another.

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Federal Communications Commission
Office of the Secretary

Nov. 17, 1987

The Broadcasting Technology Association (BTA) hereby responds with the following comments to the Notice of Inquiry, MM Docket No. 87-268 (August 20, 1987) of the Federal Communications Commission.

Broadcasting Technology Association, Japan

Tamotsu Ohmura

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Executive Managing Director