HDTV

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Digital HDTV in America – The cutting edge

J.A. Flaherty (CBS)

While the European broadcast industry offers its wares to public scrutiny and invites viewers to define demand, the United States of America has preferred to play out its ATV/EDTV/HDTV battles in the privacy of the laboratories, under the arbitration of the Federal Communications Commission, and away from public gaze.

The FCC's aim is a radical one – the rapid introduction of all-digital terrestrial HDTV services, first in parallel with existing NTSC services (simulcast) and followed, within a relatively short time, by the withdrawal of NTSC, leaving the chosen digital HDTV system to stand alone.

Starting from over 20 candidate systems in 1989, the number of contenders has been whittled down to just five. Those five have much in common – but sufficient differences to ensure that there will be winners – and loosers – when the final choice is made in 1993.

1. The US HDTV goal

In the past year HDTV has continued its explosive development and growth toward becoming the television system of the 21st century. It was John Henry Cardinal Newman, founder of Dublin University which, by hosting the EBU's *HDTV Dublin Symposium and Workshops* has made its own contribution to these historic developments, who wrote in his 1863 *Apologia pro Vita Sua*, "Growth is the only evidence of life".

Thus, through the rapid growth of HDTV, we can conclude that HDTV is alive and well.

The lines that follow present, albeit less eloquently than Cardinal Newman, the 1992 American HDTV *Apologia pro Vita Sua*. Above all, this presentation will review the rapid progress being made in America's development of an all-digital terrestrial HDTV transmission system.

First it is important to realize that the HDTV situation in America is unlike that in any other part of the world. This difference in our HDTV development stems from America's underlying belief in growth through competition in a free and open market-place with a minimum of government interference. The freedom to create, to innovate, to profit, and even to fail with such innovations has always been the underpinning of American business.

Adapted from a paper delivered by the author at *HDTV Dublin*, September 1992.

In 1936, in a speech entitled "The future of radio and public interest, convenience, and necessity", RCA Chairman David Sarnoff said of television's development:

To bring television to the perfection needed for public service our work proceeds under high pressure at great cost and with encouraging technical results. Most foreign nations have been working with public funds. No such government subsidies, of course, have been available in the United States, and none have been asked. We are now entering advanced stages of our effort, and we believe that we have demonstrated again that private initiative can accomplish more in America than government subsidy can accomplish elsewhere.

Today, HDTV too, is a private sector initiative, without government subsidy or industrial policy, but with good cooperation and partnership on the part of the Federal Communications Commission (FCC).

From the outside, American democracy and its growth through competition may seem to be the art of running the circus from the monkey cage. But somehow order and innovation seem to emerge from the competitive chaos, and HDTV is no exception.

While all the world has been pursuing HDTV broadcasting via satellite and cable, abandoning terrestrial television, the United States has sought to solve the more difficult problem of broadcasting HDTV through the existing local terrestrial television stations.

At a meeting of the CBS Affiliates Board in January 1988, the author outlined the CBS viewpoint on the development of terrestrial HDTV systems. He explained, among other things, that:

Recognizing that VCRs, video discs, cable, and future DBS services will be able to deliver HDTV with fewer spectrum (or bandwidth) constraints than broadcasting, we must ensure that terrestrial broadcasters have a pre-eminent position in the HDTV landscape, however difficult that may seem today. We must achieve competitive parity at the outset and, equally important, we must maintain that parity as HDTV evolves and improves with time.

2. The contenders

In 1989 there were some 21 advanced television systems proposed by various American and international companies. It was as if America had said: *Anybody with a good idea, put up your hand.*

At that time, all 21 systems were analogue systems, 10 were enhanced systems, and 11 were high-definition systems. No digital proposals had yet been made, and none of the analogue systems had yet been reduced to hardware. Proponents were still extolling the virtues of "improved" and "enhanced" systems as well as "augmentation" and "simulcast" HDTV systems.

That same year, the CBS view on HDTV development and the CBS requirements for a terrestrial HDTV broadcasting system were outlined by the author as follows. They remain the same today.

1. *Deliver a fully competitive HDTV service.*
2. *Provide technical headroom to ensure future competitive parity*
3. *Preserve the value of existing television receivers with an NTSC simulcast or an NTSC compatible service.*
4. *Ensure the availability of spectrum required for terrestrial HDTV transmission.*

Each proponent pursued his system, and each spent money on its development and promotion. Nevertheless, in the course of study and development, many dropped out or were found wanting, and only one of the original proposals has survived as an analogue system. Today, there are five systems in contention, and of these five, four are all-digital systems, while one is a hybrid analogue/digital system. The competition continues in a "technical Olympics" as it were, to be the "Best of the Best".

Today, as shown in *Table 1*, there are five systems in contention. One is a hybrid analogue/digital system, and the other four are all-digital systems based on motion compensation using discrete cosine transform techniques.

- NHK's hybrid analogue/digital *Narrow MUSE* system employing frequency-split pulse-amplitude modulation.
- General Instrument's *DigiCipher* system employing digital DCT compression algorithms and 16 or 32-state quadrature-amplitude modulation (16/32-QAM).
- AT&T and Zenith with their *Digital Spectrum Compatible HDTV* (DSC-HDTV), employing progressive scanning, digital DCT compression algorithms and four-level vestigial-sideband modulation (4-VSB/2-VSB).

Proponent	System	Channel coding	Basic technology
NHK	Narrow-MUSE	Frequency-split modulation	Pulse-amplitude modulation
General Instrument (ATVA)	Digicipher	32-QAM or 16-QAM	Quadrature amplitude modulation
Zenith / AT&T	DSC-HDTV Digital spectrum compatible	4-VSB / 2-VSB	Multi-level vestigial sideband
Thomson / Philips / NBC / Sarnoff (ATRC)	AD-HDTV	Spectrally-shaped QAM	Quadrature amplitude modulation
General Instrument / MIT (ATVA)	CC-Digicipher (channel-compatible)	32-QAM or 16-QAM	Quadrature amplitude modulation

Table 1
American HDTV proponent systems

- Thomson, Philips, Sarnoff Labs and NBC with *Advanced Digital HDTV* (AD-HDTV) employing digital DCT compression algorithms and spectrally-shaped quadrature-amplitude modulation.
- General Instrument and Massechusets Institute of Technology (MIT) with *Channel Compatible DigiCipher* (CC-DigiCipher) employing progressive scanning, digital DCT compression algorithms and 16 or 32-state quadrature-amplitude modulation (16/32-QAM).

3. Selection - criteria and procedures

To move forward the process of providing HDTV service to the home, in 1987 the FCC sought private-sector advice and formed the Advisory Committee on Advanced Television Service (ACATS), charged to study the problems of the terrestrial broadcasting of HDTV, to test proposed systems, and to make recommendations for a single terrestrial HDTV transmission standard.

The work of the FCC Advisory Committee has progressed well over the last four years under the chairmanship of Mr. Richard E. Wiley, and has adapted to the rapidly-changing technology becoming available, and especially to advances in digital video compression and digital transmission techniques.

In April of 1990, FCC Chairman Sikes had announced:

...the Commission's intent is to select a simulcast high definition television standard that is compatible with the current 6 MHz channelization plan but employing new design principles independent of NTSC technology. We do not envision ... that the Commission would adopt an enhanced definition standard, if at all, prior to reaching a final decision on an HDTV standard, which ... will be made in the second quarter of 1993.

America had a goal - full terrestrial HDTV. And America had a target date - 1993.

In September of 1990, in its First Report and Order, the FCC decided:

We do not find it useful to give further consideration to systems that use additional spectrum to "augment" an existing 6-MHz television channel to provide NTSC compatible service.

Consistent with our goal of ensuring excellence in the ATV service, we intend to select a simulcast high definition television system.

A simulcast system also will be spectrum efficient and facilitate the implementation of the advanced television service. Such a system will transmit the increased information of an HDTV signal in the same 6-MHz channel space used in the current television channel plan.

By 1990, therefore, the FCC and the private-sector Advisory Committee had abandoned "enhanced" and "augmentation" systems from further consideration. They had focused further work on incompatible HDTV simulcast systems, frozen the broadcasting spectrum for three more years of testing, and ensured that complete and objective tests would be made on all proponent systems before the approval of any HDTV system.

Thus, America would adopt an incompatible simulcast, full HDTV, terrestrial service! There would be no half-way measures taken in America!

The private broadcasting, cable, and consumer electronics industries established a private-sector laboratory, the Advanced Television Test Center (ATTC), to conduct the objective laboratory tests of each proposed HDTV system. This laboratory under the direction of Mr. Peter Fannon, has a staff of twenty professionals plus five additional persons from the Cable Labs. The total cost for the three years of testing is US$17 million with an investment of US$9.2 million in capital equipment

including that from the Cable Labs. No government funding was requested nor was it offered!

The objective testing and evaluation of the five proponent systems are being conducted exclusively in this laboratory. The subjective viewer testing is being conducted in Canada by the Canadian Advanced Television Evaluation Laboratory (ATEL).

The objective testing started last year, with each system allotted a seven-week test period for its evaluation.

By the end of August 1992, four of the five HDTV systems had completed objective laboratory tests and "expert viewer" psychophysical tests at the ATTC; three of the systems had completed their "non-expert" psychophysical tests at the Advanced Television Evaluation Lab (ATEL) in Canada; and further testing was continuing apace.

The FCC released its second Notice of Proposed Rule Making, or NPRM, in November of last year, and this notice proposed how the HDTV service would be defined, the time schedule for its implementation, and for the replacement of the NTSC service.

This second FCC NPRM stated:

In keeping with our goal of expediting delivery of advanced television service to the American public, we propose to limit the period of time during which existing broadcasters would have the right to apply for a particular HDTV channel. ... We note that preliminary information appears to indicate that a three-year application and a two-year construction period will permit broadcasters sufficient time to begin transmission in HDTV in the vast majority of cases.

We envision HDTV ... will eventually replace existing NTSC. In order to make a smooth transition to this technology, we earlier decided to permit delivery of advanced television on a separate 6-MHz (simulcast) channel. In order to continue to promote spectrum efficiency, we intend to require broadcasters to "convert" entirely to HDTV - i.e., to surrender one 6 MHz frequency and broadcast only in HDTV once HDTV becomes the prevalent medium.

America will move quickly and will become an all-HDTV nation!

4. Time-scales and regulation

At the last FCC Advisory Committee meeting in April of this year the Committee's Fifth Interim Report was issued. That report included a revised test and report schedule.

The Narrow MUSE system of NHK, the DigiCipher system of General Instrument, the DSC-HDTV system of AT&T and Zenith, and the AD-HDTV system of Thomson, Philips, Sarnoff and NBC have completed their ATTC lab tests. The CC-Digicipher system of General Instrument and MIT is in the ATTC Lab at the beginning of September 1992. The test report on the Narrow Muse system has been issued, and the DigiCipher report will be issued very soon.

The final ATTC test report is scheduled to be sent to the last proponent on October 16, and the final Canadian ATEL test report will be finished on October 8, 1992. After data analysis and the completion of all but the last chapter of the Advisory Committee report, a working party will adopt the report by December 4, 1992. The final chapter of the report making the system recommendation will be prepared in February 1993 by a "Special Panel" appointed by the Advisory Committee. The final report will be adopted by the Advisory Committee in March 1993 and transmitted to the FCC for action.

Mr. Joseph Flaherty *received his degree in physics from the University of Rockhurst, Kansas, in 1952. After service in the US Signal Corps, he joined CBS as a television design engineer and became Vice-President and General Manager of CBS Engineering and Development in 1967, a position he held until his promotion to his present position as CBS Senior Vice-President, Technology, in 1990.*

Mr. Flaherty has been responsible for many innovations in the television industry, including electronic news-gathering, electronic cinematography, off-line video-tape editing, one-inch video-tape, Plumbicon cameras and the miniature colour camera. He was responsible for opening the HDTV debate in the United States in 1981, and has been an influential figure in this field ever since.

Mr. Flaherty's many contributions to broadcasting have been honoured by the world's leading broadcasting societies and institutions, and he has been awarded the French Légion d'Honneur, the French Ordre des Arts et des Lettres. He is a frequent lecturer on television technology and has published many articles in the television field.

In May 1992, in its Second Report and Order for implementing the HDTV service, the Commission decided to make a block allotment of frequencies for HDTV, and broadcasters will have the first option on these frequencies. However the license application period for the HDTV channel has been changed from three to two years, and the construction period has been increased from two to three years - less time to apply, more time to build, but still five years total.

In its third Notice of Proposed Rule Making the FCC proposed to transition broadcasting to an all HDTV service, and to require broadcasters to surrender one of their two paired channels in 15 years from the date on which an HDTV standard is set or a final table of HDTV channel allotments is effective. At this time the NTSC service would be abandoned, but this schedule will be reviewed in 1998.

In its latest Notice of Proposed Rule Making issued on August 14 1992, the Commission proposed four broad HDTV (channel) allotment objectives for the implementation of HDTV.

- *To accommodate all existing NTSC stations, e.g., provide a second channel for HDTV service for all existing broadcasters;*
- *To maximize the service areas of all HDTV stations to the extent possible, and ensure all HDTV stations have a minimum service area of at least 85-90 km (55 miles) from the station's transmitter;*
- *To allot all HDTV channels to UHF spectrum; and*
- *To prefer HDTV allotments in situations where a choice must be made between providing greater service area for a new HDTV allotment or additional protection for an existing NTSC allotment.*

Thus, the FCC is finalizing the regulatory procedures and rules that will govern HDTV terrestrial broadcasting. When the Advisory Committee recommendation for an HDTV system is made early in 1993, over-the-air field tests will follow to confirm the choice. The final FCC action on the HDTV standard, including the system decision, the spectrum allotment plan, and a channel assignment plan will occur in the latter half of 1993.

Chairman Sikes is determined that the FCC shall select a standard in 1993, and, in an address to the Conference of Maximum Service Telecasters, he stated:

If we intend to maintain broadcasting as a strong competitor - and assure strong local television - we need to keep to our schedule. In a high technology world, second best is just not good enough. And in a video marketplace where broadcasting's competitors are relatively unaffected by the government's standards selection process, we cannot afford to delay.

The US strategy for the introduction of an advanced television service is therefore based on the provision of a true high-definition service, transmitted terrestrially to the home. This approach will preserve the uniquely American feature of localism in broadcasting.

Based on the FCC plan, the existing broadcasters will have the first option on the new HDTV channels, despite the fact that many consider this a "great broadcaster giveaway". However, the application time for the license and the construction time to build the HDTV facility will be limited. Those broadcasters who do not opt to go ahead, may not have a second chance, as the HDTV channels will be made available to other potential HDTV broadcasters and/or to other users such as the land mobile service.

Since the FCC intends to transition broadcasting to an all-HDTV service, and plans to require broadcasters to surrender one of their two channels and to abandon the NTSC service, it is not clear what will happen to those stations who do not apply for, and construct the second HDTV channel.

No one knows how long it will take for HDTV to become the "prevalent" broadcast system and for the FCC to abandon NTSC, but when Europe made such a transition from 405 and 819 lines to 625 lines in 1965, the simulcast of both the old and new channels lasted for twenty-five years. Nevertheless, the simulcast did end, and the VHF channels were reassigned to other services.

Moreover, the European transition took place at a time of vacuum-tube receivers and a limited number of programme services. It does not seem likely that the transition could take longer now. The question is: how much less time will it take in today's competitive media environment - ten years, the FCC's fifteen years, or longer?

One technical development which could tend to shorten the simulcast time, is a consumer-quality HDTV-to-NTSC transcoder board that could be added, as a converter, to existing NTSC receivers and might be integrated into new NTSC receivers, especially those with small screens. In this way, NTSC broadcasts could be dropped after HDTV

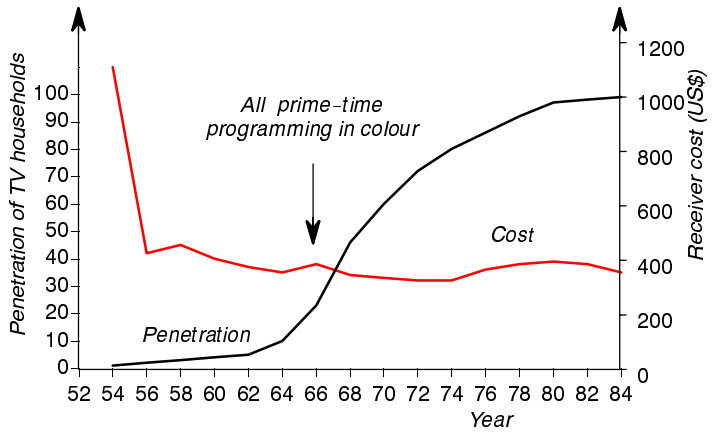

Figure 1
Comparison of cost and penetration of colour television receivers in the US

receivers reach a majority market penetration, but less than 100% penetration, and thus, before replacment of the "last" NTSC receiver in use.

5. HDTV production? - 7300 hours per annum

The final conversion to all HDTV will ultimately depend on the penetration of HDTV receivers in American homes. This, in turn, will depend on the cost and availability of HDTV receivers. A ready supply of reasonably-priced HDTV receivers will depend on the demand, and demand will depend on programmes. Programmes! That is what it is all about, because people watch programmes, not technology!

Fig. 1 shows that when colour television came to the United States in 1955, colour receiver prices were high and penetration was low. During the next seven years the price of receivers declined by more than 50% yet the penetration did not increase. It was only in 1964, when all three commercial television networks began broadcasting their prime time evening programmes in colour that receiver sales began a dramatic increase.

Here again, in HDTV production, the American situation is completely different from that elsewhere in the world. Primetime television programmes on the three commercial networks in America have been produced in high-definition for thirty years. Indeed, up to 70% of all primetime programs have been, and are, produced in high definition - namely 35-mm film.

Thus, notwithstanding the fact that not one frame of this high-definition has ever been delivered to the home, "primetime" drama, adventure, mystery, and series production in America is, and has always been, a high-definition reality.

With this massive base, the Hollywood film industry now provides 85% of the world's exports of cinema and television programmes, for broadcasting, cable, cinema, DBS, and home video.

This is a unique American experience. In most areas of the world 35-mm film means cinema. In the United States it largely means television. There is nearly ten times more 35-mm film production for television than there is for the cinema in America. Today, in Hollywood, there are approximately 800 hours of 35-mm cinema production per year, but 7300 hours of 35-mm television production.

The machine that drives this production effort is huge. The 7300 hours of television programming that Hollywood produces annually for broadcasting, cable, and home video, requires 36000 production days, and occupies more than 200 stages.

Thus, unlike other regions of the world, which must begin high-definition programme production with a large investment in electronic production equipment, the US networks can convert up to 70% of their primetime programming shot on high-definition 35-mm film to wide-screen high-definition display, at little or no additional cost, by merely deciding to do so.

No expensive conversion of existing studios is required initially. Programmes will be shot on the same film using the same cameras as are already used today to shoot normal television programmes. Thus, a large proportion of the programme schedule can be broadcast without an initial investment in electronic high-definition studio equipment.

This base of HDTV programming will probably be sufficient to accelerate the sales of HDTV receivers and increase the rate of HDTV receiver penetration.

6. Hello to the 21st century!

At this year's NAB HDTV World Conference the author said:

Today America leads the world in high-definition transmission technology overall and is the only nation placing the highest priority on terrestrial high-definition transmission. High-definition has been here for ten years. That was the decade of development and demonstration. Today we are

in the second decade. This will be the decade of decision and change.

In his 1931 New Year's greeting to the American people, Dr. Albert Einstein said:

I feel that you are justified in looking into the future with true assurance, because you have a mode of living in which we find the joy of life and the joy of work harmoniously combined. Added to this is the spirit of ambition which pervades your very being and seems to make the day's work like a happy child at play.

Thanks to that ambition and much hard work, American terrestrial broadcasters can now look with assurance toward a place in the competitive, multi-media landscape of 21st century television!