Development of High Definition Television

A Study in U.S.—Japan Trade Relations

Leland L. Johnson
The research described in this report was conducted in RAND's Center for U.S.-Japan Relations. The Center's research is supported by ten major U.S. and Japanese corporate sponsors. American sponsors include Boeing Commercial Aircraft, Citicorp, Motorola, United Airlines, and Xerox; Japanese sponsors are C. Itoh, IBM Japan, Kawasaki Heavy Industries, Minebea, and Toshiba.


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Leland L. Johnson

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Center for U.S.-Japan Relations

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- Provide "early warning" of potential conflicts and misunderstandings, and thereby forestall or alleviate them.
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To advance these objectives, the Center's research has been built around the broad theme of "U.S.-Japan Cooperation, Concerns, and Shared Leadership in the 1990s."

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PREFACE

This study examines the development of high definition television (HDTV) within the context of trade relations between the United States and Japan. For several reasons, the development of HDTV has been a source of both cooperation and conflict between the two countries. The purpose here is to examine these reasons and to suggest how the continued development of HDTV could affect each country's economic interests.

The research was supported by The RAND Center for U.S.-Japan Relations. Commensurate with the broad charter of the Center, the study is addressed to a wide audience—government agencies in the two countries and elsewhere, private firms in the worldwide electronics industry, consumer groups, and the academic research community.
SUMMARY

Nippon Hoso Kyokai (NHK) began basic research on high definition television (HDTV) in the early 1970s. This effort was motivated by (a) the perceived obsolescence of current world television standards, (b) the need to explore new market opportunities going beyond color television, and (c) consistency with Japan's industrial policy that emphasized development of high-technology industries as the foundation for expanding exports. By the mid-1970s, NHK had developed the "1125/60" HDTV program production standard that had potential to provide the basis for a single worldwide standard, in contrast to today's three incompatible television standards. As one result of the NHK-led effort, which involved numerous Japanese manufacturers, prototype HDTV equipment was demonstrated in the United States in 1981.

The United States showed little early interest in HDTV because (a) it would increase broadcasting costs without increasing advertising revenue, (b) cable television operators were preoccupied with expanding their markets with conventional television, and (c) no U.S. public organization had either the mission or the money for activities comparable to those of NHK.

After the HDTV hardware demonstrations, however, greater interest was expressed in the United States, culminating in the establishment of the Advanced Television Systems Committee (ATSC)—representing a wide range of U.S. television manufacturers, broadcasters, and others. The ATSC worked with NHK to promote the 1125/60 production standard. This cooperative effort arose because the United States particularly would benefit from a single worldwide standard, the 1125/60 approach seemed superior to alternatives, and cooperation was consistent with the U.S. free trade orientation. Backed by the ATSC, the U.S. Department of State urged at a 1986 meeting of the International Consultative Committee on Radio (CCIR) that the 1125/60 standard be adopted as a worldwide standard. However, opposition from European countries prevented the recommendation from being adopted, pending further study.

Despite this setback, the U.S. Society of Motion Picture and Television Engineers (SMPTE) continued work with the Japan Broadcast Television Association (BTA) to perfect the 1125/60 approach. These efforts led to the modified 1125/60 standard "SMPTE 240M" that was approved in 1988 by the American National Standards Institute (ANSI) as a voluntary consensus standard.
After the 1986 CCIR meeting, European countries—most notably, West Germany, France, and the United Kingdom—expedited development of a European standard within the “Eureka” program—a joint activity among numerous European countries directed to various R&D activities including HDTV. This work culminated in a “1250/50” standard in competition with the Japanese-led initiative.

Support in the United States for the 1125/60 approach has weakened because (a) European opposition makes adoption of a single worldwide standard less likely, (b) continuing technological advances have strengthened alternatives, and (c) concerns are becoming more widespread about Japanese inroads into the U.S. electronics market—a situation that might worsen with adoption of a Japanese-originated standard. An appeal to ANSI by Capital Cities/ABC was sustained in 1989, and ANSI withdrew its approval of SMPTE 240M as a voluntary consensus standard. Moreover, work is proceeding on a U.S.-based production standard that, some argue, would be more suitable for use in the United States than either the Japanese or the European approach.

The situation is further complicated by the fact that transmission standards must also be developed. The Japanese and European HDTV systems are designed for use with direct satellite broadcast, rather than terrestrial broadcast, because satellite broadcasting can more easily accommodate the large radio spectrum requirements for HDTV. Because prospects for direct satellite broadcasting in the United States are less clear, terrestrial broadcasting of HDTV is being emphasized. This is challenging because it requires about five times the information flow of a conventional television signal and, depending on technological advances, cannot be easily accommodated within the 6 MHz channels currently allocated to U.S. broadcasters.

Consequently, the U.S. Federal Communications Commission (FCC) is evaluating alternative transmission approaches proposed by U.S. and outside manufacturers and laboratories, including proposals by NHK. Decisions by the FCC, expected in 1993, will involve transmission for HDTV and perhaps also for other advanced forms of television (forms better than conventional television but not as good as HDTV).

Many uncertainties surround the development of HDTV. Estimates for HDTV receivers range from $600 to $3000 in early years, reflecting unknowns about receiver design and scale of output. The Japanese market will be particularly affected by the need to develop large flat screens—an area the Ministry of Industry and International Trade (MITI) is pursuing with a consortium of 12 Japanese firms in a seven-year $400 million program. Japan’s success in HDTV will depend on its gaining large foreign HDTV markets, especially in the United States. The United States market will depend on (a) decisions by the
FCC about transmission standards, for which NHK-developed proposals are among the many alternatives, and (b) decisions by program producers about which standards to select, where strong interest is being expressed in domestically designed standards rather than in the earlier Japan-U.S. cooperatively developed one.

Although it is easy to exaggerate the importance of HDTV to the future of the electronics industry, HDTV can have important spillovers to commercial and military markets. Flat screen displays, high-resolution pictures and graphics, and advanced integrated circuitry required for HDTV are examples of technologies applicable to computer workstations, displays for commercial and military command and control centers, and reconnaissance and surveillance. For example, the U.S. Air Force plans to replace 35 mm air reconnaissance cameras with videocameras, eliminating the logistics and time involved in processing film. The high resolution and bandwidth compression techniques for HDTV could play an important role in such electronics-based reconnaissance systems.

In light of the importance of HDTV, a number of U.S. initiatives have started or have been proposed, largely in response to continued heavy Japanese involvement in this field. Under a $30 million three-year budget, the U.S. Defense Advanced Research Projects Agency (DARPA) has selected eight firms to develop HDTV cathode ray tubes, projectors, flat panel displays, and display processors. Other proposals call for hundreds of millions of dollars (which is more comparable to expenditure levels in Japan) for HDTV-related R&D and commercialization. Exemptions of industry consortia from antitrust laws and a permanent tax credit for R&D expenditures are among the many other possibilities being considered.

Danger exists in assessing the competitiveness of the United States in terms of the problems faced in a single industry. The difficulty of encouraging the growth of a specific industry, such as HDTV, may be a symptom of more general national problems of competitiveness. If antitrust waivers, R&D tax credits, and other tools are to be used, it is probably better to make them broadly available rather than limiting them to HDTV. One report noted in this study correctly emphasizes the importance of economy-wide policies that "focus on increasing investment levels in physical plant, human, and knowledge capital."

Of key importance is the role played by multinational firms in television and in many other industries. This study illustrates how firms operate with manufacturing, R&D facilities, and ownership holdings scattered around the world. Identification of control and ownership is becoming increasingly difficult. As one report notes, "It is not clear why the product made in Mexico by a firm owned by U.S. citizens is a
U.S. product or a product made in the United States by a firm owned by foreigners is a foreign product." Issues relating to control are especially important because of concerns about potentially undue dependence by the United States on foreign sources for specialized computer chips and other electronic components—dependence that could affect both U.S. commercial and national security interests.

Much more study is needed to determine the significance of multinational firms particularly with respect to (a) the reasons for their behavior, (b) the effects of their activities on home and host countries, and (c) ways in which government control is exerted upon them. To summarize many of the questions that merit study: In what ways does it make a difference whether the headquarters of a multinational firm are located in New York City or Tokyo?

Other areas that deserve further study include analysis of (a) technical standards as nontariff trade barriers, where we need to know much more about how particular kinds of standards benefit firms in particular countries, and (b) the more specific potential impact of HDTV on commercial and military activities, to provide clearer guidance about appropriate government and industry sponsored R&D.
概要

日本放送協会(NHK)は、1970年代の初めに、高品位テレビ(HDTV)に関する基礎研究を始めた。この研究の動機は、(a)現行の世界のテレビジョン基準の明るな老朽化、(b)カラーテレビジョンを超えた新しい市場機会を探究する事の必要性、及び(c)輸出品増大の為の基盤としてハイテク産業の開発に非常に重きをおく日本の産業政策の一貫性であった。1970年代中頃には、NHKは“1125/60”HDTV番組製作方式を開発したが、それは潜在的には現行の互換性がない三つのテレビジョン標準方式と対照的に国際統一標準規格の為の基礎となる可能性を持つものであった。多数の日本の製造業者が携わった、こうしたNHK主導の努力の一つの成果として、1981年にアメリカ国内でプロトタイプHDTV装置がデモンストレーションされた。

(a)広告収入を増加させずに放映費を増加させる事になる、(b)有線テレビジョン経営者達が、現行のテレビジョンで市場拡張ができるという見通しをもっていた、(c)NHKに匹敵する程の種々の活動に対する使命感又は財力いづれかを持ち合っているアメリカの公的組織が一つもなかった事、が理由で、アメリカは、当初HDTVに殆ど関心を示さなかった。

しかし、HDTVの機械装置デモンストレーション後、アメリカにおいて強度の関心が表示され、広範囲のアメリカのテレビジョン製造業者、放送会社、その他を含む、米国次世代テレビシステム委員会(ATSC)が設立された。ATS Cは、1125/60製作標準規格推進の為NHKと共同研究した。この協同の研究が生じたのは、アメリカが国際統一標準規格により著しく利益を得るとと思われた事、1125/60方針が他の方法より優秀に思われた事、そして、協力がアメリカの自由貿易志向に調和したからである。ATSCの支持を受けて、アメリカ国務省、国際無線通信諮問委員会(CICIR)の1986年度会議において、1125/60方式を国際標準にするよう力説したが、ヨーロッパ諸国からの反対が、更に進んだ研究がなされまるまで、その採用を阻んだ。

挫折にも拘らず、米国映画テレビジョン技術者協会(SMPTE)は、日本放送テレビジョン協会(BTA)と共に1125/60方式完成に向けて開発研究を続けた。こうした努力が任意統一規格として1988年に米国国家基準協会(ANSI)より認可され修正1125/60方式“SMPTE240M”をもたらした。

1986年度CCIR会議の後、欧州諸国（特に西ドイツ、フランス、及び英国）は、多数の欧州諸国間でHDTVを含めた種々の研究開発活動を目指す共同作業である"Eureka"計画の範囲内で、欧州規格の開発を促進した。この研究は、日本が先導した発案に対抗して、“1250/50”標準規格に達したのである。

1125/60方式に対するアメリカの支持は、弱まってきた。というのは、(a)ヨーロッパ各国の反対が世界統一規格の導入を殆ど不可能にしている事、(b)継続している技術進歩が代替手段を強めた事、(c)アメリカのエレクトロニクス市場への日本の侵入に関する懸念が増々広がっている事＝即ち、日本で開発された
標準規格の導入により悪化するかも知れない事態のためである。Capital Cities / ABCによるANSIの訴えが、1989年に支持され、ANSIは、任意統一規格としてのSMPTE240Mの認可を取り消した。その上、日本方式又はヨーロッパ方式いずれよりもアメリカ国内の利用にはより適当であろうと若干数の人が主張する、アメリカ自体の製造規格に関する研究が始められている。

伝送方式もまた開発しなければならないという事実により、事態は、なお一層複雑になっている。衛星放送がHDTV用の広範な周波数帯を容易に受入る事が出来るため、日本及びヨーロッパのHDTV方式は、地上放送よりもむしろ衛星放送用に設計されている。アメリカ国内の衛星放送に対する見通しは、それほど明確ではないので、HDTVの地上放送が強調されている。これは、挑戦を要する事である。というのば、現行のテレビジョンの信号の約5倍の情報流出量を必要とし、技術進歩次第であるが、現在アメリカ放送界に関しては6メガヘルツの周波数帯域の範囲内に簡単に適用させる事が出来ないからである。

従って、米国連邦通信委員会(FC)は、アメリカ及びNHKも含めた外国の製造業者や研究所から提案されている他の伝送方式の評価を行っているところである。1983年には出されるFCによる決定は、HDTV用伝送及び、その他の先端方式テレビジョン(HDTVほど優秀ではないが現行テレビジョンより良い方式)用伝送を含むであろう。

多くの不確実性がHDTVの開発を取り巻いている。受像機のデザインや生産高の規模に関する未知の状態を反映して、HDTV受像機の見通しは、その初期年代において600 ドルから3000ドルの範囲にわたっている。日本市場は、大型の薄くて平たいスクリーンを開発する必要性に特に影響を受ける事であろう一方、通産省(MITI)が日本企業12社の連合と共同で4億ドルの7ヶ年計画に取り組んでいる領域である。HDTVにおける日本の成功は、大規模のHDTV外国市場、特にアメリカを獲得する事にかかっている。アメリカ市場は、(a) 他の代替手段とともにNHKが開発した提案も含んだ伝送方式に関するFCによる決断、(b) どの標準規格を採るかに関する番組製作者による決断、(ここでは初期の来年言出開発より先に国内で設計された基準への関心が強まっているが、次第であると思われる。

電子工学の将来の為にHDTVの重要性を通大視しがちであるが、HDTVは、商業及び軍事市場にも重要なスピーカー（平ィ外力）をもたらす可能性もある。平薄型スクリーン表示、高解像画質及び物影、そしてHDTVに必要な先端技術は、多機能パーソナルコンピューター、商業や軍の司令部及び管理統制本部、偵察及び監視の為に表示に応用出来るテクノロジーの例である。例えば、アメリカ空軍は、35mm航空偵察用カメラをフィルム常像の兵站業務と時間の削減する事になるビデオカメラと取り替える計画である。HDTVの高解像及び帯域圧縮技術は、このような電子工学を基盤とした監視システムにおいて重要な役割を果たす可能性がある。

HDTVの重要性にかんがみて、多数のアメリカの発案が、主にこの分野における日本の絶え間ない猛烈な取り組みに対応して、着手され成否は提案を
れている。3年間で3000万ドルの予算の下にアメリカ国防高等研究計画局（DA
RPA）は、企業8社をHDTVブラウン管、プロジェクト、平面パネル表示、
ディスプレイ処理装置の開発のために選出した。他の提案は、HDTVに関連する
研究開発及び商品化に（日本の支出レベルにもっと匹敵する）何億ドルも要求
している。現在、考えられている可能性の中には独占禁止法から企業撤退国の
免責及び研究開発被用の恒久的税額控除が含まれる。

单一産業の表面している問題点からアメリカの競争性を評価する事には危险
が存在する。HDTVのような特定の産業の成長を促進する事の難しさは、競争
力に関するもっと一般的な国全体の問題の側面であるのかもしれない。もし反
トラスト法の免責、研究開発税額控除、及びその他の手段が用いられれば、H
DTVだけに限定するよりむしろ広く一般に利用出来るようにする方が多分よい。この研究の中で注じた一つのレポートは、“物理的生産設備、人的資本、及
び知識資本に投資レベルを増大する事に重点を置く”一般的政策の重要性を正
しく強調している。

基本の重要点は、テレビジョン及びその他多くの産業の多国籍企業により果
されする役割である。この研究論文は、どのように企業が製造設施、研究開発
設備、及び世界中に提供している所有施設を経営するかを説明している。管
理と所有の識別は増々困難になっている。あるレポートが注目しているように、
“なぜアメリカ人所有の企業によりメキシコで造られた製品がアメリカ製品で
あり、又、外国人所有の企業によりアメリカで造られた製品が外国製品である
か”明確ではない。特殊なコンピューターチップ及びその他の電子部品に対
してアメリカの外国供給者への取引うべき適度の依存を、即ち、アメリカの商
業及び国家安全の両方の利益に影響を及ぼすような依存への懸念から、管理
に関する問題点は特に重要である。

多国籍企業の意義を決定する為に、特に(a)政策の行動の理由、(b)政策の活動
の本格それ 아니れ国への影響、及び(c)政策の結節点が政策に及ぼす手段、に関して
もっと多くの研究が必要である。研究に値する多数の論点を要約すると次のよ
うになる。すなわち多国籍企業の本拠がニューヨーク市に在るか東京に在るか
どうかがどのようにして相違を生じるのかである。

研究に値するその他の領域は、(a)非関税貿易障壁としての技術基準（そこで
は特定の国でどのように特定の種類の基準が企業のためになるかについてもっ
と多く知る必要がある）、(b)政府及び企業がスポンサーとなっている研究開発
についてより明確な指導をする為に、産業や軍事活動に与えるHDTVの明確な
潜在的影響の分析、を含んでいるのである。
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I. INTRODUCTION

The development of high definition television (HDTV) illustrates the nature and consequences of cooperation and conflict between the United States and Japan in a high-technology field. During the 1970s, Japan took the lead in HDTV development and this led to cooperative efforts between the two countries in the early 1980s. But for a variety of reasons, conflicts subsequently arose. Especially important are widely expressed concerns that the United States is losing its competitiveness in world markets for high-technology products, and that HDTV is but the latest example of this alleged weakness. Consequently, a number of initiatives are being explored to help the United States move forward independently in developing HDTV and related technologies. These initiatives may have long-term consequences for trade relations between the two countries.

HDTV AND ITS RELEVANCE TO U.S.-JAPAN RELATIONS

Before discussing why this particular technology is of interest to the RAND Center for U.S.-Japan Relations, four characteristics of HDTV will be described:

- It permits sharper pictures, similar to 35 mm photographs. This advantage leads some to predict that the future of photography lies in electronics, not film.
- Cameras and receivers are, in effect, computers because of the enormous amount of memory and microprocessing required to receive, transmit, and display the information involved. An HDTV signal involves about five times the information flow of a conventional television signal.
- The technology is used to best advantage with large flat screens where differences in resolution are most apparent to the viewer. The poster-size screen mounted on the wall is a future possibility.
- The technology has potential applications not only in residential but in commercial and military markets as well. Examples include graphics applications in computer workstations, displays in aircraft control towers, and terrestrial and space reconnaissance.
Many references are made to "advanced" television that may or may not involve HDTV. To avoid confusion it is important to distinguish among three forms of improvements in television technologies being pursued in the United States, Japan, and elsewhere.

- Improved-definition television (IDTV) is available in (relatively expensive) receivers already in retail stores. In these receivers the signal is digitized, processed, stored in memory, and displayed to improve picture quality. Use of these receivers, embodying only internal modifications, involves no change in broadcasting equipment or radio spectrum allocation.
- Enhanced-definition television (EDTV) involves further receiver improvements, including a wider screen, and perhaps more horizontal lines of resolution than currently used. But transmission would remain within the 6 MHz per channel allocated to broadcasters and much of today's broadcasting equipment would be unaffected.
- High definition television involves an increase in the number of lines of resolution, to perhaps twice that available today, to achieve picture quality comparable to that of 35 mm film, along with digital quality sound. These improvements would require more complex receivers, new program production and broadcasting equipment, and more radio spectrum space.¹

This study is concerned primarily with HDTV because it has generated controversy relevant to U.S.-Japan economic relations. However, because HDTV and EDTV are closely related in long-term R&D strategies, this study will treat aspects of EDTV where they affect the analysis.

The RAND Center for U.S.-Japan Relations is concerned about the development of HDTV because:

- It has been a source of both cooperation and conflict between the two countries. This case study is instructive for examining the reasons for this situation, especially in light of the implications for the future development of computer and other electronic technologies.
- It has been alleged that heavy U.S. involvement, requiring perhaps sustained government financial support, would (a) permit the United States to leapfrog the HDTV technologies already developed over many years in Japan, (b) strengthen

¹See the discussion of these three categories in U.S. Congressional Budget Office (1989), p. 2.
U.S. competitiveness more generally in the electronics and computer fields, and (c) contribute to U.S. national security.

- It illustrates the increasingly important role of multinational firms in U.S.-Japan relations—firms with R&D laboratories, manufacturing facilities, management centers, and shareholders scattered around the world.

THE IMPORTANCE OF TECHNICAL COMPATIBILITY STANDARDS

Because controversy about HDTV largely involves issues of technical compatibility standards, an understanding of these standards is vital. Standards in television and elsewhere are generally established through extensive deliberations by industry trade associations or other industry groups, with varying degrees of government involvement. These deliberations seek to identify from a wide range of alternatives the ones that seem most attractive in light of technical, economic, and other considerations. These alternatives are offered for consideration by particular industry representatives in these associations or by outsiders. The committee or other group then decides—typically after many meetings by working parties and demonstrations of hardware—the alternative that, overall, is deemed superior. The group then recommends this choice, either as a "voluntary consensus" standard to be adopted voluntarily by the industries affected, or as a mandatory standard to be enforced by a government agency.²

Table 1 displays elements of the three standards currently in place for conventional television, and three of the most important that have been proposed for HDTV. The National Television System Committee (NTSC) standard is used by the United States, Japan, Canada, Mexico, and 28 other countries.³ The number of scanning lines—525—affects the resolution or sharpness of the picture. The field rate—the number of "snapshots" taken by the camera per second—is designed to be nearly the same as the 60 Hz electric current used in the countries of adoption.⁴ The aspect ratio of 4:3 is the width to height ratio of the

²A salient characteristic of decision by committee is that the resulting standards are not necessarily socially optimal. For a detailed discussion with numerous cites to the literature, see Besen and Johnson (1986).

³This committee of industry representatives agreed to this standard for black and white broadcast television in 1941 and for color television in the early 1950s and successfully recommended that the standards be made mandatory with enforcement by the U.S. Federal Communications Commission (FCC).

⁴The field rate could have been set at 60 Hz, but for technical reasons that need not be discussed here the NTSC decided upon 59.94 Hz.
television screen. The SECAM (sequential color and memory) standard, adopted by France, the USSR, and about 40 other countries, has a greater number of lines than NTSC and a 50 Hz field rate for compatibility with the 50 Hz electric power of these countries. The PAL (phase alternate line) standard, used by West Germany and 62 other countries, is identical to SECAM in the characteristics listed in Table 1 but differs in other dimensions.5

Among the proposed HDTV standards, SMPTE 240M is of central importance in this study. Named for the U.S. Society of Motion Picture and Television Engineers that helped to refine the HDTV standard earlier developed in Japan and discussed in detail below, it specifies 1125 lines—more than twice that of NTSC—and a wider screen.

Other HDTV standards have been proposed. In the United States, the National Broadcasting Company (NBC) and others have proposed a 1050/59.94/16:9 system, with twice the number of lines as NTSC. Similarly, European interests have proposed a 1250/50/16:9 system, with twice the number of lines of PAL and SECAM.

The difference between conventional and HDTV standards, in terms of information transmission and processing rates, is the number of “pixels” (the smallest resolvable element of a television signal) that constitute the picture. A conventional 525-line system has about 480 visible lines per frame and about 640 visible pixels per line, totaling about 300,000 pixels. An 1125-line HDTV system would have perhaps 1080 visible lines and 1920 visible pixels per line for a total of about

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5For a discussion of the process by which these standards were developed and adopted, including analysis of political factors, see Crane (1979).
two million pixels—more than a sixfold increase over the requirements for conventional television.\(^6\)

It is important to distinguish between standards for producing programs and those for transmitting them (by over-the-air broadcasting or other means) to receivers, because they raise separate public policy issues discussed below. The role of production standards is illustrated by the question of how videotapes should be formatted for use with videocassette recorders—a question that gave rise to the competition between the Beta and VHS systems. The role of transmission standards is illustrated by the question of how the signal should be designed (e.g., should it use analog or digital techniques) to carry the program from the VCR to the input jack on the back of the TV receiver.

The figures in Table 1 relate to production standards. Alongside the currently used NTSC, SECAM, and PAL production standards are transmission standards required to assure satisfactory end-to-end service. In HDTV, as we shall see, compatibility between proposed transmission and production standards is controversial, exacerbated by the constraints of radio spectrum scarcity on over-the-air broadcasting.

**KEY ISSUES**

The development of HDTV raises several issues related to U.S.-Japan relations:

- What are the sources of cooperation and conflict in this area between the United States and Japan?
- What mechanisms exist for resolving conflicts within and between the two countries?
- How are Japan's R&D activities in this field, dating back to about 1970, likely to affect each country's welfare, including for the United States its international competitiveness and national security?
- How do the operations of multinational firms affect each country's interests?

\(^6\)For a discussion see Poynton (1990) and Frenkel (1989). In contrast, current workstations have between one million and 1.25 million pixels per frame—about half that required for HDTV.
PURPOSE AND ORGANIZATION OF THIS STUDY

This study seeks to:

• Provide the technical and institutional background necessary to understand the nature and significance of the issues surrounding the development of HDTV.

• Address the preceding issues by treating (a) the history of Japanese involvement in HDTV, (b) the U.S. and European response, (c) the nature of current Japanese, U.S., and European activities in this field, and (d) U.S. concerns about its international competitiveness and industrial policy.

• Outline possible directions for future research by the Center.

Section II treats the development of HDTV in Japan, exploring the reasons why early research in the area was started some 20 years ago, and how the effort was structured among the many Japanese entities that have participated. Section III describes the U.S. and European response, including the reasons for lack of early interest in the United States, how the United States subsequently became involved, and how events in Europe have affected HDTV development. Section IV treats HDTV within the context of Japanese and U.S. national interests. It assesses the factors that will affect the market for HDTV in the two countries in light of Japan’s head start in R&D, explores the concerns in the United States about its perceived loss of international competitiveness, and explores the important role played by multinational firms in affecting Japanese and U.S. interests—and those of many other countries as well. Section V draws conclusions framed in terms of the four issues listed above with respect to U.S.-Japan relations. Section VI suggests several directions for promising future research.
II. DEVELOPMENT OF HDTV IN JAPAN

THE ROLE OF NHK

NHK is Japan's public broadcasting corporation, which operates side by side with advertiser-supported commercial broadcasters. It is financed almost entirely from "receiving fees" paid by about 32 million households. These fees currently average 1090 yen (about $7) monthly per household for terrestrial television broadcast service and 2000 yen monthly for direct broadcast satellite service (described in detail below) combined with terrestrial broadcast. Total income in fiscal 1988 was 351.1 billion yen or about $2.4 billion.1

NHK devotes most of its revenues to the programming and operation of its domestic television and radio broadcasting stations. It also has a strong commitment to advancing broadcasting technology. Its "surveys and research for progress in broadcasting" amounted to 10.4 billion yen, or about $69 million, in 1988. This category involves R&D in satellite transmission systems, HDTV and other advanced television technologies, and other information delivery systems. These activities are supported largely by work in NHK's Science and Research Laboratories.

Several factors led NHK to initiate research on HDTV.

- Perceived obsolescence of NTSC, PAL, and SECAM standards. These standards were developed on early postwar technologies (and in the case of NTSC even prewar technologies). Many reasoned that it would be possible to design far superior standards given the revolutionary developments taking place in the computer field. High-resolution pictures were seen as one of many possible benefits.
- Success in penetrating color TV world markets. Japan had already successfully penetrated world television markets, especially in the United States. Prospects were good that Japan's market share would further expand (and, indeed, it did). But

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1This discussion of revenues and expenditures is taken from NHK (undated). This financial arrangement stands in contrast to that in the United States. The U.S. Public Broadcasting Service is financed by voluntary contributions from households and non-government organizations, plus support from federal, state, and local governments. NHK's financial arrangement is closer to that of the British Broadcasting Corporation (BBC), which levies a compulsory license fee on television receivers. The NHK system differs from that of the BBC in that the former is described as "voluntary," e.g., no fines are levied (although moral persuasion is applied) if the household refuses to pay.
the color television market, though large, would not be boundless. What would follow? The answer was HDTV—a development that, if successful, would open new markets while drawing on the expertise and commitment of NHK to explore and develop new technologies.

- Consistency with Japan’s industrial policy. Moving ahead with HDTV was fully consistent with Japan’s policy—embodied in the activities of the Ministry of International Trade and Industry (MITI) and other organizations—to develop its high-technology industries as the base for expanding exports.

As shown in Fig. 1, NHK started its HDTV work with basic research into the relationship between human perceptions and picture characteristics. It addressed such questions as: What aspect ratio of the screen is best, taking into account the information content of various televised activities? What is the relationship between the number of scanning lines and human perception about the quality of the picture? What are the best viewing angles and distances for various shapes and sizes of screens?

By the mid-1970s its studies had shown that the number of lines should exceed 1000 (for a resolution comparable to that of 35 mm film), and that wider aspect ratio screens than those in use today (in the neighborhood of 4.33:3 in contrast to 4:3) would add significantly to viewer satisfaction. Moreover, NHK came upon a particularly attractive number—1125 lines. In addition to affording high resolution in HDTV applications, it had potential to provide a basis for relatively easy conversion to existing standards. That is, a videotape shot at 1125 lines could, with simple conversion devices, be played on NSTC,

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>NHK initiates research</td>
</tr>
<tr>
<td>1974-75</td>
<td>Focus on 1125/60 as potential world standard</td>
</tr>
<tr>
<td>1981</td>
<td>Prototypes: NHK coordinates competition among</td>
</tr>
<tr>
<td>1983</td>
<td>Standards development with U.S. industry groups</td>
</tr>
<tr>
<td>Today</td>
<td>Product development and sales</td>
</tr>
</tbody>
</table>

Fig. 1—Japan’s HDTV R&D program
SECAM, or PAL studio equipment to transmit a conventional picture to existing receivers.

The relationship between the 1125 proposal and current standards is shown in Table 2, where the number of scanning lines converts to a lower level of “active” lines.\(^2\) The ratios of active lines shown in the last column are relatively simple integer relationships, which facilitate conversion to 525-line and 625-line television systems. In contrast, the 1050/59.94 proposal for the United States (listed in Table 1) has 966 active lines, twice as many as NTSC. But to downconvert programming from that standard to PAL/SECAM, which have 575 active lines, would involve a ratio of 966/575 or 42/25—requiring greater hardware complexity.\(^3\)

**A POTENTIAL WORLDWIDE PROGRAM PRODUCTION STANDARD**

Consequently, the 1125-line approach had the potential to provide the basis for a worldwide production standard. A program recorded at 1125 lines could be downconverted with all existing broadcasting systems for reception as conventional television. At the same time the program could be distributed worldwide and received on HDTV receivers (with a suitable transmission system) at much higher resolution, if all other countries also adopted the 1125 standard.

**Table 2**

**CONVERSION OF NHK 1125 STANDARD TO CURRENT STANDARDS**

<table>
<thead>
<tr>
<th>Total Lines</th>
<th>Total Active Lines</th>
<th>Down Conversion</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1125—NHK</td>
<td>1035</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>525—NTSC</td>
<td>485</td>
<td>1035/483</td>
<td>15/7</td>
</tr>
<tr>
<td>625—SECAM, PAL</td>
<td>575</td>
<td>1035/575</td>
<td>9/5</td>
</tr>
</tbody>
</table>

\(^2\)The “active” lines are used to carry the actual picture. The remaining lines are used for synchronization and auxiliary signals. A comprehensive glossary of technical terms is contained in Ampex (1989).

\(^3\)For a discussion see HDTV 1125/60 Group (1989), pp. 9–12. Others argue, however, that conversion from 1125/60 to NTSC cannot be made without degrading picture quality. See, for example, U.S. Congress (1988b), pp. 106–107.
Today the de facto worldwide program standard is 35 mm film, which can easily be used on all current broadcasting systems. In contrast, a 525-line videotape cannot feasibly be shown in Europe. A single worldwide standard for videotape would be advantageous because production costs with tape are lower in many cases than for film, and tape is more adaptable to inclusion of computer-generated special effects.\(^4\)

The prospect of a worldwide standard was all the more appealing to NHK, and to Japanese manufacturers, since success would open the market to cameras, other studio equipment, and receivers. NHK continued its efforts, in collaboration with manufacturers, to perfect the production standard and associated equipment during the second half of the 1980s. NHK engaged in what might be called "coordinated competition," where it assigned particular R&D tasks to one or more manufacturers. Fierce competition emerged among manufacturers in performing these tasks, while NHK sought to orchestrate the effort to avoid needless duplication.\(^5\) In 1981, more than 10 years after NHK had started its basic research, Japanese manufacturers demonstrated a prototype system in San Francisco and Washington, D.C.

The Ministry of Posts and Telecommunication (MPT) has also been active in HDTV. In addition to supporting the standard-setting process discussed below, it promotes the technology by sponsoring demonstrations. The MPT supported heavy promotion of HDTV in 1988 during the Seoul Olympic games, which could be watched on 208 prototype HDTV sets at 81 locations. Current MPT promotions include demonstrations held at trade fairs throughout Japan.\(^6\)

HDTV studio equipment is now being marketed and a number of programs have already been produced at the 1125/60 standard.\(^7\) Even if no other countries adopt this production standard, these programs can be transmitted (presumably with relatively simple conversion devices and at acceptable quality) on NTSC, PAL, and SECAM equipment used for conventional broadcast.\(^8\)

\(^{4}\)One source estimates that production costs would be 15 percent lower for HDTV tape than for 35 mm film (U.S. Congress, 1989a, p. 147). Another advantage of videotape is instant replay, which aids in quick decisions about the need for reshooting, a feature not possible with film because of the time required for chemical processing.

\(^{5}\)Unfortunately, documentation is scanty about how this approach to coordinated competition was designed or how well it has worked. For a discussion and cites to the literature including Japanese sources, see U.S. Office of Technology Assessment (1990).


\(^{7}\)For example, Sony has developed a relatively small HDTV camera that in quantity production might cost $75,000. The company developed an HDTV videodisc player and by late 1989 had sold 40 of them at a retail price of $25,000 (Jurgen, 1989, p. 27).

\(^{8}\)Estimates of the R&D costs incurred by NHK and Japanese manufacturers vary widely. One source estimates NHK's costs at $10 million over a 17-year period. Another source estimates $200 million to $300 million for NHK and Japanese manufacturers
CURRENT AND PLANNED HDTV TRANSMISSION

As noted above, the high information rates required for HDTV call for more spectrum space than is required for conventional broadcast. With bandwidth compression techniques, radio spectrum requirements can be reduced. But compression taken to high levels reduces reception quality and adds to costs and equipment complexity. In response to this challenge, NHK is developing a family of standards—called MUSE—for transmission of HDTV signals in addition to its 1125/60 production standard. One MUSE system—MUSE-6—is usable with the 6 MHz of radio spectrum currently allocated to terrestrial television broadcasters in Japan and the United States, and the system is compatible with NTSC receivers. But the quality of reception is uncertain.

Another system—Narrow MUSE—fits within a 6 MHz channel but would be usable only with HDTV receivers. Both MUSE-6 and Narrow MUSE have been offered by NHK for consideration by the FCC for use in the United States, as discussed below.

Another MUSE system—MUSE E—uses 9 MHz for better quality. This bandwidth is too great to fit into today's terrestrial television spectrum allocations, but the system will be suitable for satellite use.

The magnitude of the transmission problem is illustrated by the decisions already made in Japan that will dictate the nature of its television system into the foreseeable future. Current plans call for HDTV to be transmitted only by satellite, because much more spectrum space is available on satellites than in terrestrial broadcasting. Currently, one hour daily of HDTV is being transmitted experimentally on one of the two channels that NHK now operates on the nation's BS-2

together (U.S. Congress, 1988b, pp. 178–179). Yet another source estimates the “value” of NHK’s contributions at $500 million, while “private spending” has been “as much as $400 million” (U.S. National Telecommunications and Information Administration, 1989, p. 21). In a personal interview with a knowledgeable person, the author was told that NHK has spent about $150 million, and private industry about $700 million, on all forms of advanced television.

A leading possibility for reducing bandwidth requirements is to retransmit only the portions of the picture that change from image to image. The extent to which this approach is feasible depends on the amount of change from image to image. For example, greater bandwidth reductions are feasible with head-and-shoulder coverage than with football game coverage.

MUSE stands for “Multiple Sub-Nyquist Encoding,” the process by which the 22 MHz baseband NHK studio system is compressed to a lower bandwidth.

The amount of spectrum available for satellite use depends on agreements by bodies within the International Telecommunications Union. Although more spectrum space is available for satellites (within the K bands especially) than for terrestrial broadcast, transmission quality at high frequencies is more affected by rain and other weather conditions than is the case at the lower frequencies used by terrestrial broadcasters.
satellite. The HDTV channel width is 27 MHz, more than four times that of the conventional 6 MHz signal. This satellite, which carries standard NTSC programs, requires use of an antenna dish of about one-half meter in diameter with associated electronics at the receiving location.

Published data are not available about the percentage of Japanese households that receive conventional direct broadcast satellite signals. But the author has been told in interviews that the figure is less than 10 percent.

The experimental HDTV signal cannot be received on conventional television sets, although technological developments may permit conventional sets (perhaps with a converter) to display a picture as good as NTSC quality. As of late 1989, HDTV programming could be seen only on prototype HDTV receivers in about 90 locations throughout the country.¹²

Plans call for HDTV service to be expanded to eight hours per day, using the 9 MHz MUSE transmission standard when a larger satellite is launched during the early 1990s. Although MITI expects a huge market for satellite-transmitted HDTV, no receivers are yet available for household use. MITI and NHK are orchestrating production of HDTV receivers with nine Japanese manufacturers. Initial selling prices may not be determined until late 1990 and, according to one report, could be anywhere from $4,000 to $24,000, with NHK's goal being $4,000.¹³

Into the foreseeable future, terrestrial broadcasting stations owned by NHK and the commercial broadcasters will be limited to EDTV—improved versions of NTSC transmission and reception. In the first generation of improvements, receivers will be marketed with circuitry to enhance signal quality—most notably the use of ghost cancelling techniques to remedy one of the most common reception problems.¹⁴ A second generation, several years away, will add other improvements—including the 16:9 aspect ratio screen in common with HDTV. Both generations will continue with the 525-line signal.

Two other possibilities exist for delivering HDTV programs. First, videotape, discs, and players could be designed to handle the greater bandwidths required by HDTV. Japanese manufacturers are working on these technologies, but no tape- or disc-based system is yet being

¹³Ibid.
¹⁴As of late 1989 receivers were on sale from Sony, Panasonic, and NEC at prices ranging from $21,000 for a 42-inch diagonal screen to $3,000 for a set with a 27-inch screen (Jurgen, 1989, p. 28).
marketed. Second, cable television systems, using coaxial cable and fiber optic transmission, are less bandwidth-constrained than terrestrial broadcasting for handling HDTV. But cable television is in its infancy in Japan. Only a few percent of Japanese households are currently passed by cable systems. In contrast, more than 80 percent of U.S. households are passed by cable, and more than 50 percent of U.S. households subscribe.

THE ORGANIZATION OF STANDARD-SETTING

The key organization for the development of high definition television in Japan is the High Definition Television Committee within the Broadcasting Technology Association (BTA). The BTA, established in 1985, is organized for voluntary development of broadcasting standards as discussed in Sec. I. The BTA is supported by the MPT similar to the way that the FCC supports standard-setting activities in the United States, discussed in Sec. III. As shown in Fig. 2, the HDTV Committee consists of NHK, seven commercial broadcasting companies, and 13 electronics manufacturers.

This composition of membership is typical of standard-setting bodies in television and in the hundreds of other fields in which technical standards are developed. In all such cases, the standard-setting body seeks inputs from the many groups that would be affected by the adoption of the standards in question. Usually, these inputs are obtained by including representatives of these groups as participants in the numerous working party and committee meetings needed to achieve a consensus about adoption of specific recommendations.

The HDTV Committee draws up the plan for development with the approval of MPT and the members carry out their research for joint development based on this plan. The HDTV Committee covers the major areas of concern discussed in this report—studio standards, under which the 1125/60 system was approved, and the transmission standards subcommittee involved with the MUSE family of transmission standards. The HDTV Committee is within the satellite broadcasting section of the BTA, reflecting the fact that HDTV in Japan is planned as a satellite broadcasting system rather than a terrestrially based one. In parallel with HDTV is the work on EDTV that involves the TV section, shown in Fig. 2, including the Ghost Cancel Committee

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For example, Toshiba is reported to have developed a MUSE-based VCR using a VHS one-half-inch size cassette with three hours of recording time (Jurgen, 1989, p. 27).
Fig. 2—Standard-setting committees in Japan

whose work focuses on the first generation of terrestrially based advanced television, discussed above.\textsuperscript{16} Other groups shown in Fig. 2 provide further inputs into the decisionmaking process.

\textsuperscript{16}Much of the discussion in this subsection is taken from Broadcast Technology Association (1987), pp. 29–31.
III. THE U.S. AND EUROPEAN RESPONSE

LACK OF EARLY U.S. INVOLVEMENT

In contrast to the Japanese experience, little U.S. interest was expressed in HDTV during the 1970s for several reasons. First, commercial broadcasters had no incentive to support technological advances that would only add to their costs without also increasing their revenues. Because U.S. television viewing is near saturation levels, HDTV cannot be expected to significantly add to total viewing. Since advertising revenues are tied to viewing levels, these revenues would not likely be much affected by HDTV.¹ However, HDTV would add to costs. For example, the technology requires more radio spectrum space, which would increase the costs of transmitting equipment and antennas—if, indeed, the additional radio spectrum space were available at all, as discussed below.

Second, cable television operators, who potentially could compete with HDTV program broadcasters, were preoccupied with fighting other battles. During the 1970s they were competing intensely among themselves to obtain municipal franchises required to provide service. Moreover, they were struggling to gain permission under favorable terms from the FCC to retransmit signals from distant broadcasting stations and to carry pay television.²

Third, equipment manufacturers were concerned about maintaining their domestic market share against the intrusion of foreign—most notably Japanese—imports. Rather than undertaking R&D activities that might have long-term payoffs in expanding their exports, U.S. firms focused on the difficult immediate situation at home.³

Fourth, and most important, no public institution in the United States plays the role of those in Japan in funding and in other ways promoting technological advance. Especially, there was no single organization with funding comparable to that of NHK in broadcasting. The U.S. Public Broadcasting Service (PBS) has only paltry resources

¹However, the composition of programs may change because some programs are more effectively shown on HDTV than others. The effect of the potential change in program composition on overall broadcaster revenues is unclear.

²Pay television involves a subscriber payment on a per channel basis (generally for special movie channels). “Basic” service involves a payment for a bundle of channels (including signals from broadcasting stations and cable television networks).

³The behavior of U.S. firms during that period is discussed in MIT Commission on Industrial Productivity (1989).
compared to NHK. Nor does it have a strong role in promoting technological advance. Major U.S. R&D laboratories were owned by equipment manufacturers and broadcasters who, as noted above, did not share NHK’s interest in HDTV. In principle, a U.S. government agency could have performed this task. But none had the authority or the funding of the sort that could match NHK’s efforts. Indeed, any such action by a government agency would surely have been judged a gross intrusion in the role of the private sector.

The MPT and the FCC have similar roles in overseeing the standard-setting process. But the demonstrations of HDTV sponsored by the MPT go far beyond the mandate of the FCC. The FCC has a broad interest in encouraging technological advance, but it does not have the funds or the authority to single out and promote use of any particular technology. Similarly, a 12-firm consortium organized by MITI to engage in a $400 million effort on flat screen technology, discussed in Sec. IV, goes beyond the role of any U.S. government agency in orchestrating private sector efforts.

At the same time, the early work in Japan on HDTV and the hardware demonstrations in 1981 sparked interest in the United States. It was becoming clear that the NTSC system would be succeeded by more advanced forms of television, whether developed in Japan or elsewhere, and that early planning within the United States was necessary.

Consequently, in 1982 the Joint Committee on Inter-Society Coordination (JCIC) established the Advanced Television Systems Committee (ATSC) to coordinate and develop voluntary national technical standards for advanced television systems. The ATSC was also charged with recommending to the U.S. Department of State U.S. positions on technical standards to be presented to the International Radio Consultative Committee (CCIR). ATSC’s membership includes television networks, terrestrial and satellite broadcasters, cable television operators, television manufacturers, educational institutions, and motion picture producers.

At about the time that the ATSC was established, the nine regional broadcasting unions agreed on the objective of achieving a single world standard.

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4The PBS has about 50 percent of the revenues of NHK, yet has to cover 20 times the area with radio and television signals (Corporation for Public Broadcasting, 1989, p. 18).

5The JCIC consists of a group of industry associations—the Electronic Industries Association, the Institute of Electrical and Electronic Engineers, the National Cable Television Association, and the Society of Motion Picture and Television Engineers. All are charter members of the ATSC.

6A more detailed account of ATSC’s activities is included in ATSC (1988).
production standard for HDTV, for the reasons discussed above. That objective, issued in 1983 at the unions' meeting in Algiers, remains in force today.

COOPERATION WITH JAPAN

An obvious contender for consideration by the ATSC was the 1125/60 standard that had been developed to the prototype stage in Japan. Of course, there were possible alternatives to this standard. In particular, a good deal of debate arose about the relative merits of interlaced scanning (employed by the 1125/60 system as well as by NTSC, SECAM, and PAL) and progressive scanning. Progressive scanning produces a better picture, for a given number of scanning lines, but requires perhaps twice the bandwidth of an interlaced system. Much debate has focused on whether recent and foreseeable technological advances shifts the overall advantage in favor of progressive scan.

Within the context of this and other debates, the ATSC proceeded to evaluate and help refine the 1125/60 approach. At its request, the SMPTE formed a working group to draft a proposed standard, in cooperation with NHK and BTA. After months of debate at various meetings, a strong enough consensus emerged to support a recommendation by ATSC to the U.S. State Department to propose worldwide adoption of the 1125/60 standard. This proposal was made by the Department of State to the CCIR Plenary Assembly, which met in Dubrovnik in May 1986.

To be sure, some U.S. groups had reservations about this step but were willing to support the ATSC recommendation in the interests of achieving a single worldwide standard.

Although RCA and NBC had proposed an alternative progressively scanned system that we believe to have superior technical and opera-

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8With interlace, two vertical scans or fields are required to compose one frame or complete picture. Each field contains half the total number of scanning lines. One field provides every other line of the frame and the second field is superimposed to fill in the other lines. A progressive scan system contains all the scanning lines in a single field, which constitutes the complete picture. For a good tutorial on these and other technical aspects of television, see Hopkins (1987).
tional merits over the interlaced system, we would like to assure you that, in the interest of achieving a single worldwide standard based on a 60-Hz field rate, we will support the recommendation of the ATSC.9

ABC, Inc., was in a similar position. “Even though ABC believes that there are unanswered questions surrounding HDTV and that further studies may be needed, ABC is continuing to support the recommendation of the ATSC standard based on a 60 Hz field rate.”10

This period, through mid-1986, might be termed a time of “close cooperation” between the United States and Japan. Several reasons can be adduced for this cooperative activity.

- **The United States had a strong interest in a single worldwide standard.** It is a net exporter of television programming and a single standard for videotape would help to maintain or expand markets. Consequently, U.S. program producers were generally strong supporters of the goals of ATSC.11
- **There was no clearly superior alternative to the Japanese-initiated proposal.** Much of the debate among engineers and others about the merits of alternatives hinged on questions of what would be feasible in light of assumptions about future technological advance. The NHK-led proposal showed concretely what could be achieved with technologies already (or nearly) at hand. For near-term adoption of a worldwide standard, there was no alternative that could convincingly be demonstrated as superior.
- **U.S. support was consistent with its free trade philosophy.** Why not take advantage of Japan’s lead by “importing” the technology rather than incurring the cost and time required for developing a new one? An affirmative answer was all the easier, since an alternative technology might provide a less satisfactory basis for a worldwide standard.

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11Foreign sales have accounted for about half of the total revenues from U.S. motion pictures and television programs during the last 20 years. The U.S. trade surplus for these entertainment products exceeds $1 billion annually (U.S. Congress, 1989a, p. 140).
DEVELOPMENT OF HDTV IN EUROPE

European Opposition to the U.S. Position

A watershed in this history is marked by the 1986 Dubrovnik meeting where the CCIR declined to adopt the U.S.-Japan position. Rather, it voted to postpone a decision on worldwide standards to the next Plenary session scheduled for May 1990. This outcome was a consequence of strong opposition by European countries to the 1125/60 proposal. During the deliberations of the ATSC and the SMPTE, European countries expressed their reservations, and the issue came to a head at the Dubrovnik meeting.

A leading objection was the alleged incompatibility of the 60 Hz specification with the 50 Hz electrical current prevalent in European countries. However, fairly simple conversion devices can be employed to ensure compatibility. Indeed, Japan itself uses both 60 Hz and 50 Hz electric power—a situation that did not deter NHK from adopting the 60 Hz specification.

More fundamental was the reluctance to accept a Japanese-developed standard that might place European manufacturers at a disadvantage. This motivation is clearly expressed by the Commission of the European Communities (CEC):

In May 1986 Europe united and succeeded in obtaining from the CCIR—which was poised to adopt a Japanese-American standard—a four year period in which to demonstrate the validity of its alternative proposal. The Japanese-American proposal would have greatly diminished Europe’s possibilities to develop its audiovisual and electronic industries.12

The Eureka Program

After the Dubrovnik meeting Europe moved rapidly to develop standards of its own. The work proceeded within the framework of “Eureka”—a most notable R&D institution. Eureka was established in 1985 to facilitate transnational cooperative R&D among firms and research institutes within its 19 European member countries. Relying on a “bottom-up” approach, Eureka serves as a clearinghouse to bring together proposals from individual entities for collaborative work. It does not fund projects itself but depends on whatever financial arrangements are established by collaborators.

The organization of Eureka, briefly, is as follows: A Conference of Ministers, consisting of members of governments of participating countries and the CEC, develops the substance, structure, and goals of Eureka and assesses the results. “High Representatives” of each Eureka member nation assist the Conference of Ministers in carrying out its tasks. National Coordinators in each country and the CEC serve as the channels through which project proposals pass. The Secretariat gathers and disseminates information on projects and proposals received by the National Coordinators and facilitates contacts among potential partners.\textsuperscript{13}

By mid-1988, more than 210 projects had been announced, involving some 900 entities. One of these projects—"Eureka-95"—involves the development of HDTV. The HDTV initiative has been supported primarily by Bosch (Germany), Philips (Netherlands), Thomson (France), and Thorn-EMI (United Kingdom). A production standard with 1250 lines, 50 Hz, and progressive scan (instead of interlace) has been demonstrated. Varying estimates of R&D costs have appeared in the literature, including one of $400 million in funding from government and industry over a four-year period.\textsuperscript{14}

This development has been widely hailed in Europe as a successful response to the perceived threat from Japan. In the words of the CEC:

\begin{quote}
The threat of an HDTV standard of Japanese origin being imposed on the world against the interests of Europe has receded; the European conceptual work on systems and research and development efforts on hardware are proceeding satisfactorily; and Pan-European solidarity on compatibility and evolution has been consolidated.\textsuperscript{15}
\end{quote}

The CEC further proposes as an objective,

\begin{quote}
to ensure that the European proposal based on the parameters: 1250 lines, 50 frames per second progressive scanning, is adopted as the single world standard for the origination and exchange of HDTV programme material.\textsuperscript{16}
\end{quote}

As in Japan, the European approach to HDTV is through use of direct satellite broadcast. Transmission standards have been developed—called HD-MAC for high definition, multiplexed analog-component—and were demonstrated for the first time in England in

\textsuperscript{13}Information in the subsection draws heavily from Eureka (1988).
\textsuperscript{14}Jurgen (1989), p. 28. Another source depicts the effort as “a 180 million dollar crash program for HDTV” (U.S. Congress, 1989a, p. 294).
\textsuperscript{15}Commission of the European Communities (1989), p. 5.
\textsuperscript{16}Ibid., p. 7 (italics added).
1988. Experimental HD-MAC broadcasts are planned for 1991 and full service is planned for the mid-1990s.\textsuperscript{17}

COOPERATION AND CONFLICT

For a variety of reasons, U.S. support for the 1125/60 approach has weakened since the Dubrovnik CCIR meeting in 1986. First, European opposition to 1125/60 makes adoption of the standard more difficult in the United States. During early U.S. deliberations, some had reservations about the Japanese approach but were willing to support it if doing so meant adoption of a single worldwide standard. With that outcome becoming less likely, a separate U.S. approach became more attractive.\textsuperscript{18}

Second, the Japanese approach faced an increasing number of alternatives as technological advance continued. The Eureka-95 efforts, as well as continuing developments in the United States (discussed below), forced reconsideration of the early support for 1125/60 that had been based in part on the hardware demonstration in 1981. Progressive scan looks more feasible now than it did in 1981. Moreover, recently developed proposed improvements to the NTSC standard could support an "advanced television system" that might be acceptable, on an interim basis, allowing more time for development of an HDTV standard. Eventually, an HDTV system might be perfected using sophisticated digital processing that would go well beyond present-day Japanese-developed technology.

Third, some concerns relate to various issues of international trade, U.S. competitiveness, and national security.

- The large persistent trade deficit makes it harder than otherwise to support a Japanese standard where adoption would confer advantages on Japanese firms, exacerbating trade pressures. Erosion of the electronics market is widely viewed as particularly threatening to the United States in high-technology industries. Figure 3 shows the crossover point in 1983 and the deficit that has since persisted. Moreover, the electronics deficit arises primarily in trading relations with Japan. Figure 4


\textsuperscript{18}While supporting the ATSC position at the Dubrovnik CCIR meeting, RCA stated at the time that "In the event that final worldwide agreement on this specific system [1125/60] is not reached during the current CCIR Study Period, we intend to reopen the issue of progressive scan both for a U.S. National Standard and for the U.S. position during the next CCIR cycle" (Letter, Frederick to Dougan, op. cit.).
Fig. 3—Imports, exports, and balance of trade for electronic products, United States

shows a steadily increasing deficit with Japan, while the United States maintained a surplus with the rest of the world.

- The loss of the consumer electronics market makes the Japanese lead in HDTV a particularly sensitive issue. Essentially all VCRs, radios, and digital equipment are imported. The situation for television receivers is depicted in Fig. 5. Japanese firms hold nearly 50 percent of the market; the only U.S.-owned firm—Zenith—has about 12 percent. No less important, well-known U.S. names are now on the television receivers of foreign-owned firms. After acquiring RCA in 1985, GE sold the consumer electronics portion of GE/RCA in 1987 to Thomson, owned by the French government. Other U.S. television operations have been acquired by Philips. Zenith is left as the only U.S.-owned television manufacturing company.\(^{19}\)

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\(^{19}\)As one authority puts it, "This [the David Sarnoff Research Center], the most important consumer electronics laboratory in the U.S., and the home of many historic developments including color TV, was given away to SRI as a consequence of the
The diminished role of U.S. R&D laboratories, reflecting in part the loss of consumer electronics markets, has generated concern about the potentially weaker U.S. role in the world economy. In 1985, RCA closed its Broadcast Systems Division that had operated for 66 years. In 1986 CBS closed its Technology Center in Stamford, Connecticut. In 1988, General Electric, the parent of NBC/RCA, donated its David Sarnoff Research Center, which was founded in 1942, to Stanford Research Institute International (SRI International). It now operates as a contract research center, possibly putting it in a more vulnerable position than the one it enjoyed as part of RCA. Only Zenith and SRI International have major U.S.-owned facilities for television R&D.

Such developments have caused much angst about the apparent decline of U.S. competitiveness. Frustration and emotion have spilled

GE/RCA takeover. It is currently doing work on HDTV, partially financed by Thomson, the French company that bought the GE and RCA consumer-electronics divisions" (Schreiber, 1989, p. 16).
over to HDTV developments, with the cooperative activities by the United States and Japan subject to severe criticism. In other words of one prominent participant in HDTV research:

I am convinced that the principal motive behind pushing the NHK system is, and the main effect of adopting it would be, to advance Japanese economic interests to the detriment of our own. There is no reason whatsoever for the U.S. to be a party to inflicting this damage on itself.\textsuperscript{20}

Despite mounting concerns about U.S.-Japan collaborative efforts, SMPTE continued to work with BTA to refine the 1125/60 proposal which was officially adopted by SMPTE in 1987 and given the name

\textsuperscript{20}Ibid., p. 6. The author continues in a footnote, “There is, of course, nothing wrong with foreign countries pursuing policies to advance their own interests. What is foolish is for the U.S. to fail to recognize this, and to assume that such proposals have been put forward solely for the benefits of mankind.”
SMPTE 240M. As a result of this work, substantial changes were made in the original proposed standard, with mainly the 1125 lines and 60 Hz parameters remaining unchanged. Some of the major comparisons between the original Japanese proposal and the SMPTE 240M standard are shown in Table 3.

In early 1988 the full membership of the ATSC approved the SMPTE 240M standard. The vote exceeded the two-thirds majority required by the ATSC Charter for adoption of a standard, and eliminating the votes of ATSC members that are foreign-owned would not have changed the outcome of the vote.22

In 1988, SMPTE submitted the standard to the American National Standards Institute (ANSI) for approval as a national standard.23 After a demonstration that the voting and other procedures set down by ANSI had been followed and that a consensus had been achieved in accordance with ANSI criteria, ANSI approved the standard in early 1989.

Table 3

<table>
<thead>
<tr>
<th>COMPARISONS OF PROPOSED STANDARDS</th>
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<tr>
<td></td>
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<tr>
<td>Image Parameters</td>
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<td></td>
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<tr>
<td>Total number of lines</td>
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<tr>
<td>Number of active lines</td>
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<tr>
<td>Field rate</td>
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<tr>
<td>Interlace</td>
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<td>Aspect ratio</td>
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<tr>
<td>Luminance</td>
</tr>
<tr>
<td>Color difference #1</td>
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<tr>
<td>Color difference #2</td>
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21One participant noted that "The formal alliance of the SMPTE/BTA had been highly successful in producing the basic HDTV production standard of which our two countries can be most proud" (letter from Richard Stumpf, Chairman of the Working Group on High Definition Electronic Production, to the Broadcast Television Association, August 19, 1988).


23ANSI does not itself develop standards but sets down administrative procedures for voting, handling dissents, and achieving consensus. The applicant seeking approval of a proposed standard must document that these procedures have been followed. Telecommunications is only one of dozens of areas in which standards carry the ANSI approval.
At the same time, opposition to the standard became more vocal. Capital Cities/ABC appealed to ANSI to withdraw its approval of SMPTE 240M. The basis for the appeal was that “SMPTE 240M has not achieved consensus among the directly and materially affected interests and that it is unsuitable for national use.”\(^{24}\) The Appeals Board of ANSI upheld the appeal and withdrew approval of SMPTE 240 on grounds that the standard “lacked current consensus based on the latest information presented.”\(^{25}\)

The ATSC was also under pressure to withdraw its support for the 1125/60 approach. In response, in April 1989 the Executive Committee of the ATSC formally withdrew its advocacy for early adoption of the SMPTE 240M production standard as a world standard.

While continuing to support the objective of a single worldwide production standard, ATSC recommended to the Department of State that it seek to delay adoption of a single standard at the CCIR Extraordinary Meeting in May 1989. The meeting resulted in (a) no selection of a single worldwide standard at that time, (b) documentation of both 1250/50 and 1125/60 as “candidates” for a future worldwide single standard, and (c) establishment of a study program for the concepts of a “common image format” (CIF) and of a “common data rate” to facilitate agreement on as many parameters as possible among competing program standards.\(^{26}\)

Considerable progress has been made in resolving differences within a common image format. In May 1990 the CCIR Plenary Assembly approved 23 parameter values that constitute a television picture. These include, for example, the 16:9 aspect ratio screen, and the precise definitions of basic colors (red, blue, and green) “for the first time in the history of television production.”\(^{27}\)

But differences between scanning lines (e.g., 1125 compared with 1250) and frame rate (e.g., 60 Hz compared with 50 Hz) are yet to be resolved. One approach favored by some in the United States and elsewhere would call for 1080 active lines (in contrast to the 1035 active lines of the SMPTE 240M standard), and 1920 samples per picture width, which would result in square rather than rectangular pixels on a

\(^{24}\)Capital Cities/ABC (1989), p. 1. Among its objections was that “the number of entities publically opposing adoption of SMPTE 240M is substantial and has grown considerably since Capital Cities/ABC’s initial appeal of ANSI’s decision” (p. 3).

\(^{25}\)American National Standards Institute (1989), p. 1. ANSI had earlier denied an appeal made by Capital Cities/ABC in 1988, at the time ANSI was considering the approval of SMPTE 240M. After Capital Cities/ABC requested a rehearing in 1989, based in part on additional evidence, ANSI sustained the appeal.


\(^{27}\)Advanced Television Systems Committee (1990).
16:9 screen. This characteristic is important because square pixels would facilitate use of HDTV technologies for computer displays. But agreement within the CCIR is not yet in sight.

CONTROVERSY ABOUT U.S. BROADCAST TRANSMISSION

Controversy exists not only about production standards but about the transmission standards that would be best for the United States, in light of alternatives in various stages of development. Moreover, issues about transmission standards and production standards cannot be treated in isolation.

How can one be confident that the production standards will be compatible with a transmission standard that is yet to be determined? Deciding the production standard first also creates the danger that the production standard will "drive" the transmission standard and result in a less than optimum solution for the American television system. A premature decision on a production standard might also disadvantage U.S. manufacturers seeking to enter this market.

The FCC is under time pressure to make decisions about radio spectrum use for EDTV and HPTV. Portions of the UHF band currently allocated but unused by television broadcasters are being strenuously sought by mobile radio and other users who face severe shortages with their current spectrum allocations. In response, the FCC launched an inquiry in 1987 to address the technical, economic, legal, and policy issues related to advanced television. It also established the Advisory Committee on Advanced Television Service to assist the Commission in making its decisions. The Advisory Committee members represent diverse viewpoints, including those of the television broadcasting networks and stations, equipment manufacturers, and cable television systems.

After examining voluminous files of material provided by interested parties and recommendations of the Advisory Committee, the FCC has decided that any advanced television program transmitted by a broadcasting station must be receivable on existing sets. That is, the receiver must be able to display the program (without a special

28For a discussion of the deliberations surrounding this approach, see Broadcasting, "High Definition Gets High Visibility at SMPTE," February 5, 1990, pp. 62-64.
29For a discussion of the importance of square pixels for computer displays, see Poynton (1990).
converter) at a quality comparable to that provided by the NTSC standard.\footnote{U.S. FCC (1988).}

In principle, a number of transmission approaches would ensure this compatibility. First, under the EDTV approach, an improved NTSC signal of 6 MHz could be designed for compatibility with existing sets while showing better reception (but not as good as HDTV) on new, specially designed sets. This approach would be similar to that being developed in Japan for terrestrial broadcasters, as discussed in Sec. II. A second possibility—the "augmentation" approach—involves a basic 6 MHz signal compatible with existing sets, with information needed to boost the first signal to HDTV being broadcast on a second channel. Third, under the "simulcast" approach, the station would transmit an NTSC 6 MHz signal compatible with existing sets and a separate signal for HDTV receivers. This approach is especially attractive because if NTSC receivers are eventually replaced by HDTV receivers, broadcast of the NTSC signal can be discontinued and the spectrum space could be reallocated to other uses.

A number of proponents are seeking to have their systems selected by the FCC. A list current in late 1989, shown in Table 4, is useful in illustrating the process by which alternatives are being narrowed down, as discussed below. As shown in Table 4, NHK is proposing its MUSE systems in competition with those offered by other proponents. Thus, the scope of U.S.-Japan relationships regarding HDTV extends not only to production standards—1125/60 or something else—but to transmission standards as well.

The alternatives for both EDTV and HDTV are to be tested under simulated field conditions by the Advanced Television Test Center (ATTC) established in 1988 by the National Association of Broadcasters, commercial television networks, and other groups. The FCC hopes for a final decision based on inputs from the ATTC, the Advisory Committee, and other groups in 1993.

Complicating the FCC's decision-making process are the rapid developments in transmission technologies that are forcing some proponents out of the race, adding new ones, and leading to mergers of some proponents' interests into development of a common system.\footnote{As this report was going to press General Instrument submitted its DigiCipher digital video compression system for the FCC's evaluation as the standard for HDTV broadcasting. For a discussion of digital video compression, see Broadcasting, June 11, 1990, pp. 68-71.}

Philips, Thomson, and RCA announced in early 1990 that they were joining forces in a new Advanced Television Research Consortium (ATRC). The partnership will combine the efforts of the three co-
Table 4
FCC TESTING PROGRAM: ADVANCED TV COMPETITORS

<table>
<thead>
<tr>
<th>Proponent</th>
<th>System</th>
<th>Type</th>
</tr>
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<tbody>
<tr>
<td>Faroudja Production Services, Inc.</td>
<td>Super NTSC</td>
<td>Enhanced NTSC</td>
</tr>
<tr>
<td>Sarnoff Research Center, NBC, Thomson</td>
<td>ACTV-I</td>
<td>Enhanced NTSC</td>
</tr>
<tr>
<td>Sarnoff Research Center, NBC, Thomson</td>
<td>ACTV-II</td>
<td>Simulcast</td>
</tr>
<tr>
<td>NHK</td>
<td>Narrow MUSE</td>
<td>Simulcast</td>
</tr>
<tr>
<td>NHK</td>
<td>MUSE 6</td>
<td>Enhanced NTSC</td>
</tr>
<tr>
<td>Zenith</td>
<td>Spectrum compatible</td>
<td>Simulcast</td>
</tr>
<tr>
<td>Philips</td>
<td>HDS-NA</td>
<td>Augmentation</td>
</tr>
<tr>
<td>Massachusetts Institute of Technology</td>
<td>Channel compatible</td>
<td>Simulcast</td>
</tr>
</tbody>
</table>


sponsors of the Advanced Compatible Television (ACTV) systems—NBC, the David Sarnoff Research Center, and Thomson Consumer Electronics—with the sponsor of the High Definition System for North America (HDS-NA)—North American Philips.  

This combination will use simulcast (rather than augmentation) as the favored transmission system and will probably use an 1050/59.59 production standard.

Not surprisingly, the partnership has raised controversy:

Observers pointed out that the merger is dominated by European interests associated with the Eureka system, and said that the lowered line resolution (1,050) of the production standard adopted by the new group is below the Japanese (1,125) and the European (1,250) proposals and, if adopted, would put the U.S. at a permanent disadvantage.  

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34As of mid-1988, the sponsors had spent $45 million on the ACTV system, and another $30 million was estimated to be required to perfect the system (U.S. Congress, 1989b, p. 160).

Moreover, the FCC has announced that it will not pick an EDTV standard before it decides on an HDTV standard. In doing so, it hopes to stimulate the development of a “full blown" HDTV system rather than encouraging the development of an EDTV system as an interim step toward HDTV.\textsuperscript{36} With these developments, the leading alternatives are the ATRC approach backed by certain U.S. and European interests, Narrow MUSE backed by NHK, the Zenith approach,\textsuperscript{37} and the MIT proposal. Other mergers may take place, or some proponents may drop out, while new proponents may emerge.

**WHAT IF THE U.S.-JAPAN PROPOSAL HAD BEEN ADOPTED AS A WORLD STANDARD?**

Finally, it is instructive to consider the likely consequences had the U.S.-Japan proposal for the 1125/60 production standard been approved in 1986 by CCIR as a single worldwide production standard. This outcome would have occurred if the European community had not been so strongly concerned with technical aspects, such as the 50 Hz versus 60 Hz specification, and if it had been unwilling to spend a good deal of R&D on HDTV, as it has within Eureka 95.

While this counterfactual scenario is necessarily conjectural, it is nevertheless worth exploring to illustrate how the nature and timing of standard-setting can have both positive and negative effects.

Adoption of the U.S.-Japan proposal would probably have expedited the development of HDTV. But the question would remain as to whether the path of HDTV development in that case would have been more beneficial than the path that is, in fact, being taken.

For three reasons, worldwide adoption in 1986 of the 1125/60 standard would likely have expedited development of HDTV. First, with the program production standard defined, manufacturers of receivers, studio equipment, and other hardware would have faced less uncertainty. They would have been able to move more quickly in design, fabrication, and sales. This situation would have differentially benefited Japanese manufacturers who hold patents relating to 1125/60 technology.

Second, more HDTV programs would probably have been produced since 1986 for both experimentation and eventual commercial


\textsuperscript{37} The Zenith approach is tied to a recommended program production standard involving progressive scanning with 787.5 lines and 59.94 frames/sec, in contrast to the interlace 1050/59.94 approach by the ATRC partnership. For a given quality of reception, fewer lines are needed for progressive than for interlaced scanning.
exhibition. This growing inventory of programming would have had a positive feedback on manufacturing to further stimulate hardware development. This situation would have differentially benefited U.S. program producers.

Third, the FCC's evaluation of alternative transmission techniques would have been facilitated. The performance of a transmission standard depends on the nature of the program format used as an input. With these inputs clearly defined, all prospective transmission proponents would have started on common ground in exploring the best alternatives for transmitting the signal over the air, by cable television, and by satellite. With no common format defined, the FCC has faced a controversy about the appropriate inputs to assure comparability in the testing of transmission alternatives.38

At the same time, the question would remain about whether the 1125/60 standard is indeed better than other approaches. We simply do not know which of the many program production possibilities will turn out to provide the best combination of cost and technical performance—taking into account commercial and military applications as well as the residential television market. Conceivably, constraining proponents of alternative transmission systems to working with the 1125/60 production standard would have foreclosed identification and development of a superior program standard. In the history of standard-setting, cases have arisen where a standard is adopted quickly but also prematurely. In other cases, a standard appropriate to the technology and market at hand is adopted but is superseded by a superior approach in later decades. This situation raises the question of whether it is better to adopt the standard, knowing that it may later be superseded, or not to adopt the standard and wait for the better one.39

39For an expanded discussion, emphasizing factors that lead standard-setting toward or away from social optimality, see Besen and Johnson (1986).
IV. HDTV AND NATIONAL INTERESTS

In light of the events recounted above, questions arise about how development of HDTV will affect the interests of Japan and the United States. What is the likely importance of HDTV in each country's domestic and foreign television markets? What will be the role of European firms? Should the U.S. government support development of HDTV, in light of concerns about loss of U.S. competitiveness in high-technology areas and the possible uses of HDTV technologies for commercial and military purposes? What roles do multinational firms play in the answers to these questions?

THE NATURE OF UNCERTAINTIES

We must recognize the uncertainties in the development and commercialization of this technology. Many have asked how much HDTV receivers are likely to cost, initially and over time. The varying estimates underline the uncertainties involved. Figure 6 shows the wide range of estimates made by several U.S. sources. The range, from about $600 to $3000 in early years, reflects two factors.

Receiver Design

In the United States much will depend on the transmission standards adopted by the FCC for both EDTV and HDTV. Depending on the success of EDTV, the commercialization of HDTV could be either expedited during the 1990s or postponed to the next century. The longer commercialization is postponed, presumably the lower would be the costs of receivers because of intervening technological advances. Receiver design could also be affected by use of alternative delivery modes—most notably use of videotape and discs with HDTV capability, direct broadcast satellites, and cable television—which would bypass the FCC's deliberations about radio spectrum use for terrestrial broadcast. At the same time, uncertainty exists about the economic viability of these alternative delivery modes for delivering HDTV, as elaborated on below.
Fig. 6—Projected price of high definition television receivers

The Scale of Output

Even with design fixed, unit costs will depend on the volume of sales in both domestic and foreign markets. Thus, the unit costs for Japanese manufacturers will depend on the size of both their domestic and their foreign markets. Especially, the size of the U.S. market will be of key importance to Japanese manufacturers where uncertainty is magnified by European penetration of the U.S. market. The wide range of estimates of sales in the United States, shown in Fig. 7, illustrates the uncertainty about the size of the U.S. market. Of course, sales levels shown in Fig. 7 depend on prices shown in Fig. 6, but a demand curve relating sales to prices cannot be satisfactorily estimated on the basis of current evidence.¹

¹Some maintain that the real price of HDTV receivers during the 1990s will be no greater than was the price of color television sets during their introduction in the 1950s. If so, they reason, the market for HDTV receivers could be quite large—comparable to that for color receivers. But this argument ignores the possibility that the incremental value to consumers of HDTV relative to color TV may be quite different from the incremental value of color TV relative to black and white. It also ignores the fact that some alternatives for consumer television-related purchases (e.g., VCRs, large-screen conven-
THE JAPANESE MARKET

In light of these uncertainties, what is the likely size of the Japanese domestic market? In response, recall from Sec. II that HDTV is currently planned as a satellite-based system. Expanded satellite broadcasting is planned for 1990, after earlier experimental activities with prototype receivers. The market for HDTV will depend on several factors:

- Development of large flat screens. The improved picture quality of HDTV is most easily appreciated on large screens. But use of large-screen television is difficult in the small living quarters typical of Japanese households. Widespread use of HDTV may, therefore, depend on development of large wall-mounted flat

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tional receivers, and high-capacity cable television) were not available at the time color sets were introduced. Three alternatives could compete with sales of HDTV sets.
screens. But their commercialization is further down the road than that of cathode ray tubes (in large cabinets), which have already been successfully demonstrated for HDTV. In response to this need, MITI has formed a consortium of 12 companies. They have committed $400 million to be spent over seven years to develop the technologies needed for a one square meter HDTV active-matrix, liquid crystal display.\(^2\)

- **Compatibility with NTSC signals.** HDTV receivers would need to be compatible with NTSC signals (that is, display NTSC signals at NTSC picture quality). Otherwise the consumer would need an NTSC receiver as well as the HDTV receiver to have access to the wide range of programming that, during the foreseeable future, would continue to be available only on NTSC signals.

- **Cost of satellite receiving equipment.** In addition to conventional television antennas to receive terrestrial broadcast, consumers would have to procure satellite dishes and associated electronics capable of handling HDTV signals. The willingness of consumers to do so would depend on cost.

- **Receiving fees for HDTV service.** As noted above, NHK has set a monthly receiving fee of 2000 yen for its NTSC satellite and terrestrial broadcasts, compared with 1090 yen for terrestrial broadcasts alone. Presumably, a yet higher fee would be set for HDTV satellite broadcasts. The size of this fee could affect the willingness of households to sign up for the new service.\(^3\)

It is probably safe to conclude that the success of HDTV in the Japanese domestic market will depend on Japan's success in gaining large foreign HDTV markets, especially in the United States. For the larger these foreign markets, the lower the receiver costs because of learning curve effects and manufacturing economies of large-scale production.

**THE U.S. MARKET**

The prospects for direct satellite broadcasting are dimmer in the United States than in Japan because of the greater competition from cable, which passes more than 80 percent of U.S. homes, and the less mountainous terrain that facilitates good reception with terrestrial broadcasting.


\(^3\)Perhaps a household willing to pay the high price of an HDTV receiver would not be deterred either by the NHK receiving fee or by the need for satellite receiving equipment. If so, the considerations of key importance would remain the cost of HDTV receivers and the prospects for developing wall-mounted flat displays.
As an alternative, a videotape or disc-based system could be developed, avoiding entirely the use of over-the-air radio spectrum. But this would require a new generation of relatively complex players and large new videotape and disc inventories, in addition to the cost of the receivers. This approach might be attractive for specialized markets such as for business applications, theaters, and other public viewing centers. But widespread residential use is more problematical.

Cable television systems could carry HDTV signals, but not without some difficulty. Signals wider than 6 MHz would require replacement of existing set-top converters. Moreover, the "robustness" of the signal on cable (i.e., its ability to withstand quality degradation as it passes down the cable) depends on the technical characteristics of the signal. Expressed differently, cable systems cannot carry with equal ease all of the signal formats shown in Table 4.4

The FCC's decisions in the early 1990s will play a critical role in dictating the requirements for HDTV receivers, as well as for studio and other supporting equipment.

Japanese manufacturers would be favorably positioned if the FCC selected a MUSE transmission standard. But stiff competition arises from other proponents. Regardless of which system is selected, however, Japanese receiver manufacturers would probably retain a large U.S. market share. That is, they could successfully design to whatever standards are selected, albeit with royalty payments to outside patent holders.

More important is the disparity among proposed production standards. Support is strong in the United States for the 1050/59.94 standard and for progressive scan, in contrast to the earlier Japanese-American sponsorship of SMPTE 240M with interlace scan. The joint activities of NBC, Philips, and Thomson will probably take advantage of the research activities within Eureka-95 where progressive scanning has been emphasized. Were the FCC to select a non-MUSE transmission standard or a program production standard different from 1125/60, Japanese manufacturers would be disadvantaged.

Although the United States has lost the bulk of the consumer electronics market, it remains a major producer of studio and other professional electronics. U.S. professional equipment manufacturers supply more than 50 percent of the world market, which exceeds $3 billion a year. Moreover, as one supplier observes, "It is here that advanced technology is developed first—not in consumer electronics. And it is

4For this reason, the cable television industry participates in activities of the FCC's Advisory Committee on Advanced Television Service to evaluate alternative transmission formats. See National Cable Television Association (1987), p. 8.
here that HDTV technology will be spun off to other industries.\textsuperscript{5} In light of the large U.S. presence in the professional market, Japanese professional equipment suppliers would likely be more severely disadvantaged than those in consumer electronic markets, were the United States to adopt its own production standard and a non-MUSE transmission standard.

**U.S. COMPETITIVENESS AND R&D INITIATIVES**

In addition to the important role of standard-setting, initiatives are under way, or being proposed, in the United States to strengthen its position in the HDTV field. These initiatives are potentially significant not only for the consumer electronic market but, perhaps more important, for broader commercial and military applications. As one U.S. Congressman concludes:

HDTV is going to require increasingly sophisticated chips and semiconductors. HDTV also is likely to cause technological advancements in photonics, fiber optics, microprocessing and other related industries. If foreign competitors control HDTV, they will have a major advantage in developing these other new technologies, causing a further erosion in America's ability to remain competitive in electronics. And if there is one industry that is undeniably critical to the economic stability of this nation it is the electronics industry.\textsuperscript{6}

In response to concerns about U.S. competitiveness, a number of legislative activities are being pursued within the U.S. Congress, although nothing has yet been enacted into law. Perhaps the most notable is "The High Definition Competitiveness Act of 1989," a bill that would

provide appropriate incentives in the tax code to stimulate HDTV research, development, and pilot manufacturing by domestic industries. Next, it would change current antitrust laws to allow cooperative efforts and joint ventures by domestic companies to engage in HDTV-related research, development and manufacturing. The legislation would also encourage government participation and shared funding (up to $100 million a year for five years to be at least matched by industry) to facilitate and coordinate joint venture and cooperative industry efforts in HDTV development . . . the bill would increase funding to the FCC to speed the adoption of a transmission

\textsuperscript{5}Ampex (1989), p. 9.

\textsuperscript{6}Markey (1989).
standard, an essential component to the rapid development for an HDTV manufacturing industry.\textsuperscript{7}

Another proposal has been made by the American Electronics Association (AEA) representing a large group of U.S.-owned firms in the electronics field. It has proposed a plan involving about $1.3 billion in government funding tied to the proposed formation of the "ATV Corporation"—an industry-led body that, with government support, "would monitor and guide development of a U.S.-based ATV [advanced television] industry and support component industries, emphasizing weak or threatened sectors."\textsuperscript{8} Under the AEA plan, $500 million in government guaranteed loans and $500 million of direct government loans would be made available to participants in the ATV partnership to manufacture and market advanced television products.

Another initiative has been undertaken by DARPA in the U.S. Department of Defense under a three-year $30 million budget. (The AEA recommends that DARPA's budget for this initiative be increased to $100 million a year.) In 1988 DARPA requested proposals for improving high-definition video technology, including lower cost and more effective displays. Out of the more than 80 proposals it received by late 1989 it has selected eight to develop HDTV cathode ray tubes, projectors, flat panel displays, and display processors.\textsuperscript{9}

Such an initiative is not new in the sense that DARPA has sought to develop advanced display systems for many years. The new aspect of this initiative is its emphasis on the relationship between defense and civilian electronics needs, with the goal of encouraging development of "dual use" technologies. However, DARPA's involvement in HDTV has been highly controversial. The issue remains about what role, if any, the military should play in developing technologies that would have commercial uses rather than primarily military ones.\textsuperscript{10}

The activities described above have arisen out of, and fuel, the controversy about the importance of HDTV in consumer electronics, commercial applications, and military spillovers. Some assert that U.S. leadership in HDTV is critical. As one U.S. Congressman emphasizes:

The United States has no choice but to develop its own HDTV industry if it is to remain on the industrial cutting-edge. HDTV is

\textsuperscript{7}Ritter (1989).
\textsuperscript{8}American Electronics Association (1989).
\textsuperscript{9}Broadcasting, November 6, 1989, p. 78.
\textsuperscript{10}For a description of the controversy in the United States about the role of government, and DARPA in particular, in the development of HDTV, see Wall Street Journal, June 6, 1990, p. 1.
important not only as a huge market in and of itself, but because it will drive technology developments in dozens of components like chips and lenses, which are critical to our success in other industries. We will not long remain a world leader in giant industries such as computers and automobiles—which will see 30% of their cost comprised of electronics by the year 2000—if we are not competitive in HDTV development.\textsuperscript{11}

In contrast, another report concludes that under the most optimistic forecasts of HDTV sales, this new industry would constitute only a small portion of the world semiconductor and broader electronics market, so that it could not be expected to be a major driving force in shaping the future of electronics.\textsuperscript{12}

The truth is probably somewhere in the middle. Although HDTV will surely remain only a small portion of the electronics industry, it will nevertheless have a substantial role to play going far beyond simply improving television pictures in the living room. Consider the following possibilities.

Flat Screen Displays

Sustained R\&D for residential use of flat screens may lead to lower cost and more feasible displays in other applications, ranging in computers from lap-top units to workstations, along with large-scale displays in other commercial and military installations. Conversely, R\&D directed to display technology for commercial and military markets may also spill over to the residential consumer market. The MITI-led consortium of 12 firms discussed above may give Japan a lead in such applications.

Advanced Integrated Circuitry

HDTV could become an important factor in integrated circuit technology because of the advanced circuitry it requires.

HDTV receivers will require more video memory, faster digital signal and video image processors, and more complex analog/digital hybrid circuits than NTSC receivers. Some of these circuit techniques will have uses outside consumer electronics. Video memories and video image processors will be important components in computers and computer workstations. Faster digital signal processors and

\textsuperscript{11}Levine (1989), p. 534.

\textsuperscript{12}U.S. Congressional Budget Office (1989), p. 19. The report observes that “the world electronics sector grew by $34 billion in 1988 to reach $461 billion . . . not only is this sector more than 15 times larger than the [projected] HDTV market, but also its annual growth is almost double that projected for the HDTV market.”
Military Applications

The U.S. Department of Defense is reported to have a wide range of needs where development of HDTV would be relevant.

For its broad range of video applications in battle management, command and control, training and simulation, and intelligence analysis, DOD needs high-definition, low-cost, dynamic multimedia displays for presentation of motion video, real-time graphics, maps and photographs. Such video technology is used in fighter airplane cockpits, command centers, training simulators, and analysis groups. For example, the Air Force plans to replace 35-millimeter air-reconnaissance cameras with video cameras, thus eliminating the logistics and time lags involved in processing film. The Navy wants to put remote-video conference facilities in all its ships and shore commands by the year 2000.14

The technology may also be applicable to video-controlled guided weapons, to increase their accuracy and the range of conditions under which they can be used. One report notes how the technology could be applied to “electro-optically guided weapons, such as the AGM-65 Maverick and AGM-62 Walleye ‘smart’ bombs, since each carries a miniature TV sensor in its nose which is locked on to a point of high contrast on the target.”15

U.S. R&D Strategy

In light of the above possibilities, and controversy about the appropriate U.S. response, the relationships among technologies merit emphasis. HDTV is only one link within the many two-way relationships among technologies in the electronics field. Advances in HDTV technologies may stimulate advances in computer chips. But advances in computer chips, reflecting the needs of the computer industry, can also spill back to the benefit of HDTV. Advances in screen technology stimulated by the needs of residential users would have applications elsewhere, while advances stimulated by commercial and military needs may be applicable to the residential market.

Given these relationships, it is probably unwise to focus government legislation and other support narrowly on HDTV. If antitrust waivers are

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14Hack (1990), p. 4.
important to private consortia activities, they should be made broadly available to the semiconductor and other industries within the electronics field, and perhaps elsewhere as well. Similarly, if permanent R&D tax credits would, in fact, stimulate socially useful R&D spending, it would make little sense to restrict them to HDTV.

A recent report on the semiconductor industry recommends a wide range of strategies, involving business environment, trade policy, and education, for promoting U.S. leadership in this field.\textsuperscript{16} Many of these strategies would also encourage a strong U.S. presence in the HDTV industry. While evaluation of these recommendations lies beyond the scope of the present study, they are noted here as examples of approaches that should be kept in mind in considering how the United States should respond to the challenges posed by HDTV.

More generally, one must understand that concerns about competitiveness that the United States faces are different from the concerns facing a particular industry. A single industry, such as HDTV, may have characteristics that are symptomatic of more general problems of competitiveness. These more general problems are more appropriately addressed by economy-wide policies than those that focus on the single industry. The recommendations of one study are probably right in emphasizing that "economy-wide policies should focus on increasing investment levels in physical plant, human, and knowledge capital."\textsuperscript{17}

THE OPERATIONS OF MULTINATIONAL FIRMS

So far, we have referred to "domestic" and "foreign" firms as if they were national monoliths. But this is far from an accurate depiction. The increasingly global character of business enterprise is making identification of "ownership" and "control" more difficult—a situation highly relevant to concerns about the growth of foreign economic interests in the United States.

As a case in point, Fig. 5 fails to show that most color television sets are assembled in the United States. For example, Sony manufactures more than a million picture tubes annually in San Diego for use in North and South America and Asia. The San Diego plant is one of seven Sony factories in the United States. Matsushita Electric Industrial is undertaking a "global localization" approach, under which some 69 overseas factories are being rearranged to supply "four major poles"—North American, Europe, Japan, and the rest of Asia, with regional headquarters established in New Jersey, England, and

\textsuperscript{16}National Advisory Committee on Semiconductors (1989).
\textsuperscript{17}Electronic Industries Association (1989).
Singapore.\textsuperscript{18} More generally, at least 19 companies make television sets in the United States in 29 facilities. Television tubes, the most expensive part of the set, are manufactured in seven facilities. Some companies are exporting color TV sets and picture tubes manufactured in the United States.\textsuperscript{19} Almost all television sets larger than 20 inches are manufactured in the United States, albeit predominantly by foreign firms, with the average domestic content being about 70 percent for color television receivers produced in the United States.\textsuperscript{20} At the same time, Zenith, the only remaining U.S.-owned firm, assembles many of its sets in Mexico.

A substantial amount of funding by foreign firms is directed to R&D activities in the United States. North American Philips conducts research on advanced television for the United States at its facilities in Briar Cliff, New York. Thompson, through its acquisition of the RCA consumer electronic activities in Indianapolis, is supporting research on advanced television there and at the David Sarnoff Research Center in Princeton, New Jersey. General Electric, NBC, and NBC affiliates also contribute to funding of the Sarnoff facility.\textsuperscript{21} Sony operates its Advanced Technology Center in San Jose, California, one of its three U.S. R&D facilities. Designs that have come out of this center “have led to professional tape products that are manufactured by Sony Magnetic Products of America in Dothan, Alabama, and other products made in Sony’s Fort Lauderdale factory.”\textsuperscript{22} Hitachi has research centers in San Francisco and Detroit (as well as in Dublin and Cambridge in Europe), and any patents or other intellectual property generated by these centers are retained by the local companies.\textsuperscript{23}

Moreover, such firms have shareholders scattered around the world, along with subsidiaries that exercise varying degrees of managerial control.

How does one determine where “control” is located, given the worldwide nature of these operations? By the geographical location of headquarters? The citizenship of members of the board of directors? How does one define a domestic or foreign-based firm? Facing these issues, one report notes that “it is not clear why the product made in Mexico

\textsuperscript{18} The Multinational, ‘Eastern Style,’ ” The Economist, June 24, 1989, p. 64.

\textsuperscript{19} U.S. Congress (1988b), p. 396.

\textsuperscript{20} Electronic Industries Association (1989), p. 37. The characteristics of 26 television manufacturing plants in the United States are listed on pp. 39–41 in that study. At the same time, most skill-intensive subassemblies are produced offshore.

\textsuperscript{21} Ibid., pp. 397–398.

\textsuperscript{22} Connolly (1989), p. 15. An interesting detailed account of Japanese R&D activities in the United States is provided by Herbert (1989).

\textsuperscript{23} The Economist, June 24, 1988, p. 63.
by a firm owned by U.S. citizens is a U.S. product, while a product made in the United States by a firm owned by foreigners is a foreign product.” As a solution, the report resorts to defining U.S.-based firms as “firms owned by U.S. citizens, while foreign based firms have foreign ownership.” But use of this criterion only highlights the nature of the problem. What is the difference between, say, 70 percent and 30 percent U.S. ownership in terms of control, benefits of multinational operations to host countries, international trade flows, and other considerations?

Issues relating to control are especially important because of concerns about potentially undue dependence by the United States on foreign sources for specialized computer chips and other electronic components—a dependence that could affect both U.S. commercial and national security interests.

With respect to commercial interests, one can imagine a situation where foreign firms have such strong control over critical electronic components that they have monopoly power in sales to U.S. consumers. In this case the United States would be harmed by the flow of excess profits to outsiders. This situation of foreign-held monopoly is more serious that that of monopoly in the hands of domestic firms in that in the latter case, the excess profits are transfer payments contained within the domestic economy so that the economy, as a whole, would not necessarily suffer a loss.

However, monopoly pricing would require that these foreign producer firms collude in a cartel-like arrangement. Generally speaking, these arrangements are harder to enforce, the greater is the number of producer firms having the bottleneck technology. Moreover, enforcement would likely be more difficult if these firms were themselves located in several countries (e.g., in Europe as well as in Japan).

As globalization of business activity expands, the distinction between “domestic” and “foreign” loses meaning. For example, a multinational firm, nominally owned and controlled by foreign interests, could use its excess profits from monopoly pricing to fund R&D in a laboratory in the domestic economy (e.g., “foreign” funding of R&D in the Sarnoff facility). Moreover, to the extent that shareholders of the multinational firm live in the domestic economy, dividends would be

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25 This statement follows from the fact that, on grounds of economic efficiency, economists do not distinguish between a given increment of producer surplus (excess profit) and an equal loss of consumer surplus (resulting from higher prices). However, if the producers are in another country, the transfer could harm the country within which consumers are located. Moreover, monopoly pricing causes an “allocative” economic loss resulting from the failure to equate price with marginal cost. This allocative loss arises regardless of whether buyers and sellers are in separate countries.
retained there. More generally, the multinational firm may have a strong interest in not harming the host economy. Its subsidiaries in the United States may depend for their success on other U.S. firms that could be disadvantaged by the monopoly pricing of the multinational parent. As markets, ownership, and operations of the multinational firm become more diffuse, the effects of its behavior become increasingly difficult to categorize by domestic and foreign labels and its interests become increasingly less tied to those of any single country—including the one in which it is nominally “owned.”

NATIONAL SECURITY INTERESTS

In addition to commercial considerations, how would dependence of the United States on foreign sources affect its national security? Four possibilities are worth noting: First, the foreign country might not side with the United States in a war that could last long enough to require U.S. military hardware, whose manufacture would be impeded by the unavailability of the critical inputs from the foreign country. Second, the foreign country might oppose some action by the United States (e.g., deployment of a controversial weapon) and withhold supplies of critical inputs to U.S. producers. Third, the country might withhold critical inputs from American defense (and other) contractors until the inputs had been incorporated in the foreign country’s export products—a case where the foreign country’s commercial interests would handicap U.S. military preparedness. Fourth, the foreign country, over the opposition of the United States, could sell to a country unfriendly to the United States.

The key question is whether the foreign country has the degree of control, implied by the above possibilities, over a multinational firm based in that country. The more the firm’s operations are globally dispersed, the harder would be the task of the government in exerting control to serve its foreign policy interests.

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26A more general proposition is that the greater the asset holdings of foreigners in a country, the greater the interest of these foreigners in maintaining a strong economy in that country.

27These possibilities draw heavily from the discussion by Carter (1989), pp. 251–252.
V. CONCLUSIONS

Conclusions can best be categorized in terms of the four issues raised in Sec. I. These involve the nature and sources of cooperation and conflict between the United States and Japan, the mechanisms for conflict resolution, the significance of Japan's head start in the development of HDTV, and the importance of multinational firms.

COOPERATION AND CONFLICT IN U.S.-JAPAN TRADE RELATIONS

This study concludes that there have been three principal sources of cooperation:

- **Advantages of a single worldwide production standard.** These advantages have particular appeal in the United States, whose well developed television and movie program export sector would benefit.

- **Lack of strong competing alternatives to NHK's 1125/60 approach.** While alternatives were demonstrated on paper and in computer simulations, Japanese manufacturers were able to demonstrate with actual hardware the workings of the 1125/60 standard.

- **U.S. free market orientation.** This orientation encouraged adoption of standards based on cost and performance considerations rather than on country of origin.

This study also identifies several sources of conflict.

- **Continuing technological advance.** The R&D conducted in Europe as part of Eureka-95, as well as developments in the United States, led to alternatives that seemed more attractive than at the time the Japanese-based HDTV system was demonstrated in 1981. Especially, there is growing pressure to adopt a progressive scan approach. Possibilities are also being explored for sophisticated digital processing that would (in the long term) leapfrog earlier Japanese efforts.

- **Uncertainty about U.S. transmission standards.** In contrast to the situation in Japan, where a satellite-based system is being planned for HDTV, interest in the United States has focused on terrestrial transmission. The need for greater bandwidth
compression and other factors raises questions about the compatibility of alternative production standards, including 1125/60, with whatever transmission standard is adopted in the United States.

- **Concerns about U.S. competitiveness.** The deficit in the electronics trade balance, largely attributable to trade with Japan, has fueled concerns about U.S. loss of competitiveness, the importance of electronics as a strategic industry, and the need for the United States to take independent action as a remedy.

- **European actions.** European opposition to the Japanese-led initiative has encouraged a shift in U.S. interest toward alternatives.

**MECHANISMS FOR CONFLICT RESOLUTION**

These mechanisms can be divided into two categories—those designed to resolve domestic conflict and those designed to resolve conflicts among countries.

**Domestic**

- **Public agencies.** In both Japan and the United States, public agencies play key roles. Coordinating the activities of Japanese manufacturers, NHK helped to reduce conflict in the development of production and transmission standards. The MPT and the FCC play important roles in organizing and monitoring standard-setting activities. A good example is the current work of the FCC’s decisionmaking process for selecting transmission standards, based on assessment of conflicting evidence.

- **Domestic standard-setting bodies.** The BTA and the SMPTE are leading examples of bodies established expressly to deal with conflict resolution. During the mid-1980s the SMPTE sponsored numerous meetings where conflicting points of view were expressed and evaluated. While it did not eliminate controversy or lead to unanimity of opinion, it perfected the SMPTE 240M standard that was recommended successfully (at the time) to ANSI as a voluntary consensus standard.

- **Agreements among private firms.** Firms that originally have differences in views sometimes find it advantageous to resolve their conflicts by agreeing to coordinated action. A good example is the recent agreement among NBC, Philips, and Thompson to join forces in developing an HDTV transmission standard to be considered by the FCC for the United States.
International

- *The International Consultative Committee for Radio.* The CCIR seeks to achieve agreement among the dozens of nations that participate in its deliberations. Although a single worldwide production standard for HDTV has not emerged from CCIR deliberations, it provides an effective international forum for resolution of some issues. For example, the agreements on parameters within a common image format represent a step forward in achieving worldwide cooperation in the development of HDTV production standards.

- *Operations of multinational firms.* Conflict is reduced to the extent that these firms organize their activities in ways that more clearly benefit host as well as home countries. For example, the capture of nearly 50 percent of the U.S. receiver market by Japanese firms would surely have generated more conflict with the United States if these firms did not assemble the bulk of these sets in the United States.

SIGNIFICANCE OF JAPAN’S EARLY LEAD IN HDTV

This issue can best be considered separately for Japan and the United States.

Japan

- *The future of direct satellite broadcasting.* The success of HDTV as currently planned in Japan will depend critically on how many households subscribe to HDTV satellite service. Subscription will be affected by the cost of HDTV receivers, the development of large flat screens, the costs of satellite receiving equipment, and the fees levied by NHK for HDTV broadcasts.

- *Manufacturers’ response to foreign standards.* The FCC’s decision about transmission standards will determine the nature of receiver design for both EDTV and the follow-on HDTV. A decision in favor of a MUSE-based transmission standard would more favorably affect Japanese manufacturers than would a decision, say, in favor of the NBC/Thompson/Philips proposal. It is not clear whether the early work in Japan on production standards will particularly benefit manufacturers of
receivers whose design is affected by transmission standards as well as production standards.

- Commercial and military markets. Whether Japan's early R&D will confer advantages in commercial and military markets will depend on how widely the 1125/60 production standard is adopted. The prospects were brighter in the mid-1980s than they are today.

United States

- Consumer electronics. Because the United States has already lost most of its consumer electronics market, it is not clear whether the adoption of any particular production and transmission standards would revive the industry in the sense that U.S.-owned firms would emerge to play a dominant role. Most likely, the industry will be dominated by multinational firms—European, Japanese, and U.S.

- Commercial and military markets. Production standards could have a substantial impact on commercial video equipment markets where the United States continues to play a major role. The issue remains about whether U.S. government support, especially the involvement of DARPA, would improve spillover effects to and from military applications.

- R&D strategies. In response to Japan's early lead in HDTV, there is danger in targeting R&D strategies too narrowly on HDTV. Because of two-way relationships among technologies, tools such as antitrust waivers and permanent R&D tax credits should be made more generally available, if they are to be used at all.

THE ROLE OF MULTINATIONAL FIRMS

This study illustrates the major role of multinational firms in the television industry—their dominance in U.S. television receiver manufacture, their involvement in the FCC's deliberations about transmission standards illustrated by the recent NBC/Philips/Thomson agreement, and their HDTV R&D in Europe, Japan, and the United States. However, the study raises more questions than it answers in emphasizing how the concepts of national ownership and control are becoming increasingly murky. This topic deserves much more study, as elaborated on below.
VI. PROMISING DIRECTIONS FOR FUTURE RESEARCH

The preceding analysis raises many questions, only some of which have been answered. Three major areas of future research are suggested by this study.

THE EFFECTS OF MULTINATIONAL FIRMS

One of the most interesting aspects of this study is the role played by multinational firms. Although this study concentrates on only HDTV and related high-technology areas, multinational firms are prominent elsewhere.

As a basis for crafting wise public policy, we need to know much more about these firms in at least three areas: (a) the reasons for their behavior, (b) the effects of their activities on both home and host countries, and (c) ways in which government control is exerted upon them.

With respect to behavior, a number of questions arise. Why do firms decide to locate some of their R&D activities in foreign countries? In what ways do these outside R&D activities differ from those at home? One possibility is that particular types of R&D are best performed in countries where other firms, universities, and other entities are performing complementary work. Conceivably, such relationships could explain decisions to locate in the San Francisco Bay area and in the Northeast. Patent laws in particular countries could also favor or discourage locating there. The availability of certain skilled labor and other specialized resources is another possibility.

Similarly, what underlies decisions to locate manufacturing facilities and management centers in foreign countries? The cost of labor, tax treatment, and market proximity immediately come to mind. A better understanding is needed of how such factors affect the timing of decisions and the geographical composition of the firm’s manufacturing and management resources.

The effects of these various activities on host countries is also of concern. Foreign-owned assembly plants are sometimes referred to, almost contemptuously, as “screwdriver” plants. Is the implication of such a reference correct that these operations employ mostly cheap, unskilled labor, and confer rather little benefit on the host country? How do the labor mix and other inputs into the firm’s assembly
operations in foreign countries compare with those in the firm’s home country?

How do R&D activities benefit the host country where, presumably, high-skilled professionals are employed? How are patent rights and other protections of intellectual property arranged for inventions in R&D facilities in the host country in comparison with protections in the firm’s home country? More generally, how do the benefits from R&D in host countries compare to the benefits from R&D activities in the home country?

Questions also arise about the differential benefits between home and host countries of geographically dispersed management centers. To what extent, and in what ways, do foreign subsidiary operations exercise autonomy? How does this division of management responsibilities benefit host and home countries?

How do the personnel policies of foreign-based firms differ from those of domestic firms? For example, do local citizens face fewer opportunities for advancement in foreign-based firms? Are transfers to company headquarters or other overseas management centers common? How do personnel policies affect the competitive position of the foreign-based firm?

Questions about how control of the firm is exercised is of key importance, as noted in Sec. IV, because of the sensitivity in the United States to foreign control of assets. How does government control of domestic firms differ from its control over foreign-based multinationals? How may a foreign-based multinational, either seeking its own objectives or being within the control of the home government, operate in ways detrimental to either the home or host country? In what ways does the geographical location of the headquarters make a difference? Does the citizenship of members of Boards of Directors play a notable role in determining the degree of control that can be exercised by home and host governments?

A question that summarizes much of the above is: In what ways does it make a difference whether a firm’s headquarters are located in Tokyo or in New York City?

STANDARDS AS NONTARIFF TRADE BARRIERS

It is generally assumed that the foreign adoption of standards benefits the country in which the standards are developed. It has been alleged, for example, that difficulties facing Japanese television manufacturers in exporting to Europe arise from Europe’s use of SECAM and PAL standards. Indeed, the rationale of Europe’s
adopting these standards was the desire to erect nontariff trade barriers.\textsuperscript{1} Refusal of European firms to adopt the 1125/60 production standard and the MUSE transmission standards for HDTV stems at least in part from the desire to protect domestic industry. At the same time, the fact that the NTSC standard was developed in the United States has been far from an insuperable barrier to Japanese penetration of the U.S. television market.

We need a better understanding of how technical standards serve as nontariff trade barriers. Perhaps much depends on the nature of the standards in question, where some involve strong patent protection and others do not. Moreover, standards may confer protection only for a limited time, depending on the lifetimes of key patents. Use of some standards may exploit the comparative advantages of certain countries, putting them in the lead as a consequence of the widespread adoption of these standards. Our improved knowledge of how standards (depending on their characteristics) affect international trade and comparative benefits among countries would improve our ability to assess the consequences of adopting alternative standards.

THE COMMERCIAL AND MILITARY USES OF HDTV

Although many assertions have been made about the importance of HDTV to the electronics industry and to national welfare, there has been little careful assessment of the evidence. This study suggests a close potential interaction between HDTV and the computer industry. An example is use of high-resolution displays in computer workstations at geographically dispersed locations connected by telecommunications links. More knowledge is needed to develop R&D strategies (by firms and by governments) to most effectively exploit the synergies between the two.

HDTV may also have important military applications only hinted at in this study. Conversely, developments of reconnaissance and surveillance technologies within the military sphere could have favorable spillovers to the commercial development of HDTV. However, barriers imposed by national security classifications and other restrictions on information flow could hinder the exploitation of interactions between the commercial and military sectors. Improved understanding of the potential interactions could aid in the design of effective cooperative R&D strategies involving the United States, Japan, and other countries.

\textsuperscript{1}One observer concludes that “When Europe chose not to adopt NTSC, opting for PAL and various versions of PAL, it restricted competition. But it also eliminated manufacturing economies. As a result, European consumers pay anywhere from 50 to 100 percent more for TV sets than Americans do” (Connolly, 1989, pp. 12–13).
Appendix

GLOSSARY OF HDTV TERMS

1050/59.94, 1125/60, 1250/50, 1375/50, etc. The number of scan lines followed by the field rate of various HDTV system proposals.

Active line. The lines used to carry the actual picture. For example, 483 out of the 525 lines in NTSC television are active lines. The remaining lines are used for synchronizing and auxiliary signals.

Alternative media. The delivery of electronic television programs by means other than traditional ground-based broadcasting, such as cable, fiber-optics, DBS, VCR, and video disc.

Artifact. An audio or video impairment or defect that can be produced during the processing or transmission of a signal.

Aspect ratio. The ratio of picture width to picture height. The ratio for conventional TV is 4:3, whereas the proposed ratio for HDTV is 16:9, closer to the aspect ratio of 35 mm movies.

ATV (advanced television). A generic term used to refer to all transmission proposals offering improved performance.

Bandwidth. The frequency, measured in megahertz, required to contain a television signal or other electronic signal.

Bandwidth compression. The method of reducing the bandwidth required to transmit an electronic signal.

Bit rate. The data rate (number of bits of data transferred per second) in a digital signal. The digital equivalent of bandwidth.

Bit-rate reduction. A method of reducing or compressing the data rate of a digital signal, whereby data are removed with the least possible picture impairment.

Broadcast television. TV programming delivered according to government-authorized standards (NTSC, PAL, SECAM, etc.) normally by licensed terrestrial broadcast or cable rebroadcast.


Channel. The amount of spectrum (radio frequency) required for a television signal.

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1This glossary is reproduced by permission of The Ampex Corporation from its publication Everyone's Talking about HDTV, But What Are the Facts? Redwood City, California, 1989.
Chrominance. The color part of a television signal. (See also luminance and composite.)

Clear-Vision. The Japanese name for their EDTV system.

Cochannel interference. Distortion or interference on one TV channel caused by simultaneous broadcasts on an adjacent channel.

Compatibility. The ability of present TV sets to receive new types of signals but display them in the old way—in much the same way that black-and-white TVs could receive, but not display, color signals when color TV first came out. (Actually, the NTSC color system was not fully compatible with the black-and-white because adding color caused some degradation to the black-and-white picture.)

Component. A television system in which the luminance and two or three color signals (chrominance) are kept separate from one another.

Composite. A color television signal containing both luminance and encoded chrominance information.

Cross-color. An unwanted color signal, or artifact in the composite, that results when a luminance signal has the same frequency range of a signal in the encoded color subcarrier.

DBS (direct broadcast satellite). A method of delivering a TV signal or other electronic signal directly to the home via a stationary-orbit satellite.

Decode. To convert from an encoded or combined multiple-part signal to its individual parts.

Delivery standard. (See transmission standard.)

EDTV (extended- or enhanced-definition television). A form of ATV that provides better resolution than conventional TV but not as good as HDTV. Also referred to as IDTV (improved-definition).

Emission. The broadcast or transmission of a television signal or other radio frequency signal.

Encode. To convert the components of a color signal into a single combined television signal such as NTSC, PAL, or SECAM.

ETV (enhanced television). An improvement of the standard NTSC, PAL, or SECAM signal usually accomplished in the TV set with internal processing.

Field. The alternate lines that compose one-half of a frame, or a complete television picture. (See interlaced scan.)

Field rate. The rate at which each field of a TV picture is changed or refreshed. The NTSC field rate is 59.94 cycles per second. The PAL/SECAM field rate is 50 cycles per second.
Frame. One complete television picture or scan.

Frame rate. The rate at which the complete TV picture is changed or refreshed. The NTSC frame rate is 29.97 cycles per second. The PAL/SECAM frame rate is 25 cycles per second.

Frame store. The storage of one complete TV picture or frame.

Fukinuki hole. A gap in the energy spectrum of a TV signal used for imbedded information to improve resolution. Named for the Japanese engineer who made the discovery.

HD-MAC (high definition multiplexed analog component). An HDTV television system intended for DBS delivery in Europe.

HD-NTSC. A wide-screen, 900-line ATV system proposed by the Del Rey Group.

HDTV (high definition television). A television system with twice the vertical resolution and twice the horizontal resolution of conventional TV. It also features a wide-screen display and high-fidelity stereo sound of CD quality.

Hi-Vision. The Japanese name for their HDTV system.

IDTV (improved-definition television). (See EDTV.)

Interlaced scan. The method of interleaving TV fields so that the complete picture can be displayed without flicker, using a lower total bandwidth than needed for progressive scan.

Line rate. The number of scan lines per second (the number of scan lines per frame times the frame rate).

Line-rate conversion. Converting from one TV line rate or system to another.

Luminance. The monochrome, or black-and-white, part of a TV signal. (See also chrominance and composite.)

MAC (multiplexed analog components). A method that uses studio component video signals but multiplexes them in time to fit them into a single channel for DBS.

Multipath distortion. Picture distortion caused when a TV antenna receives a reflected or unwanted signal in addition to the direct signal from the broadcaster. (Also called ghosting.)

MUSE (multiple sub-Nyquist sampling encoding). An HDTV delivery method, a form of bandwidth compression, developed by NHK specifically for DBS. (See also MAC.)

NTSC (National Television Systems Committee). The industry group that defined the current FCC-approved color television system.

PAL (phase alternating line). The type of TV system used in most European countries, the People’s Republic of China, and Australia.
Pixel. The smallest resolvable element of a TV signal.

Post-production. The process of editing and embellishing tape or film footage into the final viewable product. Electronic post-production is that which uses only electronic means to arrive at the final product.

Presentation. The process of showing the finished film or TV program.

Production. The process of creating the rough and unedited film or videotape from a script.

Production equipment. The equipment used in the production and post-production of TV programming—devices such as cameras, recorders, switchers, and titling generators.

Production standard. A set of technical specifications used to create the images for original programming. This studio standard usually uses higher performance criteria than needed for transmission. (See delivery standard.)

Progressive scan. A TV picture that does not use interlaced fields and is thereby complete in one scan. Each field has an identical line structure and can be electronically produced from an interlaced source.

Raster. The periodic electronic structure made up of scan lines used to create a TV frame.

Resolution. A measure of the finest image element that can be seen in a TV picture. (See also sharpness.)

Resolving power. The ability to reproduce the finest detail of an image.

RGB. The primary additive television colors—red, green, and blue.

Scanning. See interface scan and progressive scan.

Scanning lines. The horizontal lines, caused by electron beam traces, that make up a TV picture.

SECAM (sequential encoded color amplitude modulation). The TV system used in France, the Soviet Union, and other Eurasian and African countries.

Sharpness. The visual perception of resolution.

Spatial. Pertaining to two-dimensional space, as in a single television frame. (See also temporal.)

Spectrum. The continuous range of radio frequencies, such as those allocated to UHF TV channels or FM radio.

Standards conversion. To change from one TV format such as NTSC to another such as PAL.

Subcarrier. A frequency embedded in the spectrum of a signal to carry additional or separate information.
Super NTSC. An improved and compatible NTSC system developed by Faroudja Laboratories.

Taboo channels. FCC-designated TV channels, which are adjacent to active channels within a given geographic area and would cause cochannel interference if they were used.

Temporal. The sequence of time. Spatio-temporal in TV terms would be the passage of frames through time. (See also spatial.)

Terrestrial broadcast. TV signals delivered by ground-based transmitter to an audience within a specified geographic area.

Transcoding. Converting from one encoded format to another, as in transcoding from NTSC to PAL.

Transmitter. The device used to deliver an electronic signal.

Transmission. Delivery of an electronic signal by emission or cable.

Transmission standard. A set of agreed-upon rules for transmitting signals to the home. (Not to be confused with production standards, which usually have a higher bandwidth.)

UHF (ultra high frequency). The TV frequency band of 470 to 590 megahertz. (See also VHF.)

Vertical blanking interval. The period of time required for the electron scan to return from the bottom to the top of a TV display.

VHF (very high frequency). The television frequency band of 54 to 216 megahertz. (See also UHF.)
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