

products embodying technologies developed abroad. These technologies are generally incompatible with the NTSC standard.

Most observers agree that several forms of improved definition television will be introduced in the US over the next decade and beyond. There are, however, enormous implications of different ways of getting from here to there. The transition from NTSC driven video to the next generation of video products and services might take several paths and proceed rapidly or slowly. There are immense economic stakes riding on the nature of the transition. Both the magnitude of economic activity and its distribution among international and US industry contenders will be determined by the direction and pace of the transition.

The purposes of this report are to analyze some potential economic impacts of the introduction of new video and related products into the US market and to assess in a preliminary way the implications for US economic development and other national goals. The overriding purpose is to set forth reasonable views of the market implications of advanced television (ATV) technologies, systems and products.

## **II. THE MARKET ENVIRONMENT FOR ATV PRODUCTS**

### **A. INTRODUCTION**

This section is intended to provide technological, economic and regulatory context within which ATV product markets will develop. It concludes with a broad scheme for classifying the economic impacts of the adoption and diffusion of new television technologies.

### **B. THE US CONSUMER ELECTRONICS MARKET**

Though ATV has no economic history, it is in a class of products and services, electronics and consumer electronics more specifically, about which we know quite a lot. Electronics constitute the technology of the post-war period and now represent the nation's largest industry--surpassing in sales the auto, chemical and steel industries. Over the last decade electronics industries in the aggregate posted compounded annual growth rates (CAGR) in excess of 13 percent. Consumer electronics growth surpassed even that rate.

By 1986 total sales of consumer electronics products in the US were nearly \$29 billion. This represents compound annual growth over the previous decade of about 15%. The consumer

electronics market in 1986 was roughly equally divided among four broad classes of products: television receivers, audio receiving equipment, video recording and playing apparatus, and assorted other related products--home computers and software, telephones and answering devices, receive-only earth stations, video game software and cartridges. Table 1 indicates some characteristics of the growth of consumer electronics products over the past decade.

TABLE 1  
Factory Sales of Consumer Electronics Products  
United States, 1976 - 1986  
(\$ Million)

<u>Product Line</u>	<u>1976</u>	<u>1981</u>	<u>1986</u>
Monochrome TV Receivers	495	505	328
Color TV Receivers	2,755	4,349	6,024
Projection TV		287	529
Video Cassette Recorders	65	1,127	5,258
Color Cameras		147	59
Video Disc Players		55	45
Audio Systems	489	720	1,370
Separate Audio Components	1,027	1,363	1,358
Home Radio	356	501	408
Portable Audio Tape Equipment	1,055	1,157	1,389
Car Audio	497	2,000	2,800
Blank Audio Cassettes		242	304
Blank Video Cassettes			1,480
Other		44	7,369
Total	6,739	12,497	28,721

Source: 1987 Electronic Market Data Book, EIA Marketing Services Department.

About half of the consumer electronics products available today have been introduced in the past ten years. Products proliferate and many fail. Rivals in the marketplace contend with both declining prices and better quality. One can buy a radio today for less than the price of a single vacuum tube seventy years ago. While the consumer price index has roughly tripled over the past twenty years, the prices of popular consumer electronics products (those that have been around that long) have been roughly constant and, in the case of television sets, have actually declined by about twenty percent. (See Table 2.)

**TABLE 2**  
**Consumer Price Index:**  
**Selected Products and Years**  
**(1967=100.0)**

<u>Year</u>	<u>Radios</u>	<u>Sound Equip*</u>	<u>Tape Recorders</u>	<u>TVs</u>	<u>CPI</u>
1967	100.0		100.0	100.0	100.0
1972	98.9		94.3	99.5	125.3
1977	105.0		95.1	101.7	181.5
1982		113.7		103.9	289.1
1983		111.8		100.3	298.4
1984		108.9		95.3	311.1
1985		105.2		88.6	322.2
1986		102.3		83.1	328.4

Source: U.S. Department of Labor

Note: \* A new series, sound equipment, combines radio and tape players from 1980 forward.

In short, the market environment within which new video products will be introduced is our largest, our most innovative, and, in several essential respects, our most dynamic.

### C. ADVANCED TELEVISION TECHNOLOGY AND SYSTEMS

Despite the obvious durability of the NTSC standards, they are, nevertheless, based on a very limited, some say primitive, set of technologies. Furthermore, the standards were adopted at a time when there was only one available signal or program distribution technology, i.e., terrestrial broadcasting. There are now several distribution media--coaxial cable, satellite distribution, videocassettes and videodiscs, and multipoint microwave distribution systems. The future, no doubt, augers even greater diversity in distribution, including systems relying mainly on optical fiber technologies.

NTSC systems are optimized, more or less, within constraints posed by analog signalling technologies, despite the fact that the world of electronic opportunity is increasingly digital.

Two specific developments, advances in signal processing and storage technologies, deserve mention in this context. Both derive from the development of semiconductors. Chips make it possible and increasingly inexpensive to distribute, process and store information--including digitized visual images. The quality of images captured and transmitted from space, moon walks and "close-ups" of missile sites, for example, suggest the expanding limits of image processing technologies. Digital compression techniques permit more effective use of the radio frequency spectrum in over-the-air transmissions, thereby allowing transmission of more information in the same bandwidth. "Smart" receivers with the ability to store and process video signals are now well within the reach of off-the-shelf semiconductor technologies.

Semiconductor technology has made possible a broad range of multipurpose, multifunctional receiver designs which were scarcely dreamed of at the time the NTSC standards were institutionalized. These new designs will avail users better sound and image quality, but also promise the potential for greater interaction within and among groups of users, receivers and program sources.

Advanced television is a constellation of technologies which combine to make possible several striking improvements in television picture and sound quality when compared to that which is currently available. Visual characteristics comparable to 35 millimeter film quality accompanied by compact disk quality stereo sound have been demonstrated.

A survey of the literature describing various advanced television systems under development yields a richly diverse array of technical improvements.<sup>1</sup> Depending on how one defines a "system", the type of improvements one includes, and when the count is taken, there appear to be about a dozen systems now under development or serious study. The systems vary in several dimensions. Some are channel compatible; some are receiver compatible; and, some are neither.

There is also significant variation among the different systems with respect to receiver complexity, aspect ratios, as well as line, frame and field resolution. System performance can be measured against several technical benchmarks: resolution, lines, frames/second, fields/second, signal to noise ratio and so forth. However, the hedonic performance of the various systems is very much a matter of personal judgment based on personal perceptions and individual preferences.<sup>2</sup>

High Definition Television (HDTV) is the most advanced of a trio of technology clusters, as defined by a classification

scheme adopted by the Advanced Television Systems Committee (ATSC). The ATSC taxonomy includes:

- Improved NTSC Systems
- Enhanced 525 Line Systems
- HDTV Systems

Each of these systems improves on one or more of the key visual/aural characteristics of NTSC television: horizontal and vertical resolution as defined by the number of video "lines" in the signal, color fidelity and picture sharpness, the ratio of picture width to picture height (the "aspect" ratio), sound fidelity, motion rendition and others. The visual image is further improved by the elimination of certain "artifacts" or imperfections in image rendition; for example, backward spinning wagon wheels and bluish-red smudges on an American flag.

Improved NTSC Systems By definition, these operate wholly within the current broadcast technical standards. Improvements are made possible by "combing" interspersed signals at both the transmitter and the receiver; by converting to progressive from interlaced scanning through the use of a memory device in the receiver; and, by interspersing more video information throughout the normal six megahertz channel. The combined effect of these and numerous other technical improvements is to double (roughly) the amount of visual information displayed while reducing some of the picture imperfections of traditional systems. These systems are generally compatible with both existing channel allocations and the embedded receiver base.

Enhanced 525 Line Systems These systems could, theoretically at least, incorporate many of the techniques available for upgrading NTSC systems. In addition, through a form of time divided, multiplexed packet transmission, signal quality and information quantity are appreciably enhanced. One such system is now being marketed and used in Australia for satellite transmissions. This and several other systems rely on multiplexed analog components (hence the name MAC). These systems generally require a signal converter to make them compatible with standard receivers. MAC systems generally require more than 6 MHz for transmission. B-MAC can be compressed into a standard channel, albeit with significant degradation of image quality. MAC systems are potentially compatible with other transmission or distribution media--cable, satellite, discs, cassettes, etc. The MAC approach is being developed primarily in Western Europe.

HDTV Systems There are several HDTV systems under development, but the most widely publicized effort in this class is the Japanese Broadcasting System (NHK) family of technologies,

systems and products. The result of almost two decades of development, the NHK system is the only one for which supporting products are now available on the market. Studio production equipment manufactured to NHK specifications is now being used in this country and those specifications appear to have become the de facto standard in this country and Canada.

NHK demonstrated a transmission system in 1981. It explores the limits of analog technology and was originally intended for use with direct broadcast satellites. The prototype system required 30 megahertz of bandwidth for transmission, but in 1984 a reduced bandwidth version, called MUSE, was introduced. Transmission of the MUSE format is incompatible with the current 6 megahertz standard. The MUSE signal can be displayed, with some sacrifice in quality, on conventional NTSC sets coupled to a special converter.

Home video equipment embodying the NHK technology, according to NHK representatives, is scheduled to be introduced into this country in 1990 with the planned shipment to US dealers of television receivers, videocassette players and disc players.<sup>3</sup>

#### D. BASIC DETERMINANTS OF MARKET DEVELOPMENT

Product Availability Despite the inevitability of the introduction of new video products and their eventual widespread acceptance by users, the timing and technical configurations of new products is still very much up in the air. As indicated above, there is wide dispersion among various systems in technical and performance dimensions. But, there is also fairly sobering uncertainty about when different products may actually be made available. Only NHK has announced an initial production schedule. Other systems have not yet been field tested. All are still subject to a bewildering array of technical and economic questions which bear heavily on the rate at which production engineering and product specification can be tailored to comply with user needs and market demand.

Central to the fundamental question of availability is the speed and content of resolution of a complex web of technical, economic, and geopolitical public policy issues related to the conditions for, and the impact of, the introduction of ATV products. Although the Federal Communications Commission (FCC) will provide an important forum for airing the contentions of interest groups, and is obliged by current law to decide questions of television spectrum use, both the Executive Branch and the Congress will very likely play key roles in any final determinations on the pivotal questions.

MM Docket No. 87-268 Responding to a petition filed by terrestrial broadcasting interests, the FCC issued late last year a Notice of Inquiry soliciting views and data on a broad reaching set of questions raised by the different potential applications of ATV technology.<sup>4</sup> The complexity of the issues raised discourages easy generalization or simple summary. However, the breadth, depth and intensity of the subsequent responses by large and diverse economic interests signal unmistakably the magnitude and ubiquity of the stakes involved.

In a nutshell, the FCC is seeking information upon which to base an evaluation of the various costs and benefits to its constituencies of potential changes in the NTSC standards. These costs and benefits have several dimensions.

Several of the ATV proposed systems would require use of additional bandwidth in the frequency spectrum--bandwidth which has valuable alternative uses and which is coveted by several other potential users. Some systems are incompatible with the installed base of NTSC receivers now being used in U.S. homes. Both prices and the performance of new ATV products will be significantly affected by the details of any change in the current NTSC specifications. The list of corporate participants reads like a "Who's Who" of U.S. telecommunications with several new entries--domestic and foreign--rounding out the roster of players with a significant economic or other interest in the content of any new standards and frequency assignments.

The outcome of this proceeding and of processes within the Administration and the Congress will have an inestimable effect on the ultimate character of both the supply and demand for ATV products. Despite the FCC's clear intention and desire to resolve the key issues fully and quickly, the history of similarly momentous FCC proceedings demands its due. The National Telecommunications and Information Administration has suggested that the FCC should declare its intention to establish a broadcast transmission standard during 1991. (See Appendix A.) As a practical matter, we expect that several regulatory questions with significant economic impact on the ATV market may linger well into the next decade.

Production Costs and Prices The principal goal for potential suppliers of HDTV products is to earn a return on total investment which exceeds the cost of capital used up in the process; in short, to make profits. That objective implies that prices in the long run must exceed unit total costs.

Suppliers will have substantial discretion in pricing. Pricing strategies for all emerging industries are complex and there are no hard and fast rules to follow. Differing institutional constraints (product familiarity, expected strategy

of rivals and the nature of government imposed technical constraints) render them different for each emerging industry.<sup>5</sup>

The pricing problem is particularly vexing for ATV pioneers. There is almost baffling strategic uncertainty and every reason to believe that different suppliers will adopt different pricing strategies. Successful strategies will be emulated to the extent possible as failing approaches are scrapped. The prospects are for a very dynamic pricing environment.

Historical experience with other emerging industries/product lines and scattered other available information permit us to sketch out the broad characteristics of a general pricing scenario. These general considerations are most helpful in developing the bounds of secular price trends. They are considerably less so in making point estimates of prices for particular products on some particular future date.

Pricing considerations are important to the present analysis for two reasons. Prices will influence the rate of penetration of ATV products and the value of the market which does evolve. Secularly declining prices imply faster product diffusion. Prices are also instrumental in giving signals to suppliers about potential profits in the market, while also providing a benchmark for measuring the economic activity associated with the introduction of the technology.

In the long run, prices will likely settle in the vicinity of unit costs. Entry of new firms and the appearance of new and differentiated products will tend to suppress prices if they appear to be significantly above unit costs. Exit of incumbents and contraction of supply will force prices upward toward cost if it falls below. These are the tendencies in workably competitive markets; and we expect that the ATV market will qualify in this respect.

Each product line that ultimately reaches the end user will be responsible, in principle at least, for covering the costs occasioned to bring it to market. At this point it is not clear what product configurations will emerge. Nevertheless, whatever products materialize will be responsible over the product life cycle for covering the aggregate of three broad classes of costs: sunk costs, fixed costs and variable costs.

Sunk costs are all those expenditures made and obligations incurred prior to commencing production. In the present case, they are, for the most part, the result of expenditures for research, development, and related activities. Every supplier will incur such costs, although not the same amount or over the same time period.

The magnitude of sunk costs incurred to date is not clear, and even less is known about how much will be spent in the future on the various contending systems. Detailed information is held quite closely and public disclosures are not always completely reliable. The financial commitment made to develop the NHK family of technologies and products appears to be well in excess of \$500 million to date. The EUREKA HDTV program of the European Community has been funded at 200 million ECUs. Total R&D expenditures to date in the US private sector appear to be on the order of \$70 million.<sup>6</sup>

Suppliers have wide latitude in recovering these costs by allocating them over different products in different markets over the life cycle of several product lines. In absolute terms, ATV sunk costs impress as being quite substantial. But, depending on the eventual size and scope of the market for products embodying these technologies, they may on average represent fairly small additions to the delivered price of final products. For example, \$200 million spread over the US installed base of TVRO earth stations would lift the cost of an antenna by about \$100, or about 5% of its average value. Higher penetration of ATV products, to the extent it occurs, will proportionally reduce the average burden of research and development costs on final product prices.

The real significance of sunk costs is less in how to recover them through the price structure than in whether they can be recovered at all. This uncertainty constitutes a significant barrier to firms considering entry. Several promising ATV developmental approaches may never overcome this hurdle.

High volume consumer markets can amortize large sunk costs with nominal markups. The problem arises when large markets do not develop. Recognition of this fact leads to an expectation that introductory prices for new ATV products will be designed to permit fairly rapid market penetration and will not reflect much concern for recovering sunk costs in the short run.

The second category of costs, unlike the first, is incurred in the process of commencing and carrying out actual production of finished product. These fixed costs are incurred, in part, prior to actual production and, in part, concurrently with production runs. They are, as the name implies, independent of volume for a plant of given capacity. They will increase as plant capacity is expanded and as more plants are added. Fixed costs bear a strong resemblance to popular notions of "overhead" costs--rent, interest, contractual labor obligations, long term commitments for utilities, and the like. Assuming that ATV products will not require processes substantially different from those being used to produce NTSC compatible products, there should be little change in the relative burden of fixed costs on product prices.

Like sunk costs, the burden of fixed costs on final product prices is sensitive to production volumes that can be absorbed by the end user market. Unlike sunk costs, however, none have yet been incurred. And, they will only be incurred in the main when market signals from users appear to justify building large amounts of productive capacity. Fixed costs per unit can be expected to decline as production economies are realized at higher market penetration rates.

Costs in the third category vary more or less directly with the level of production, once minimum levels of output are attained. Materials costs are a large component, but wages, inventory carrying costs, distribution costs, and those associated with sales and marketing are also important. The limited evidence available indicates that these variable costs will account for about three-quarters of the market price of ATV products. Secular reductions in the average burden of variable costs on product price is likely to draw prices down over time. Technological advances affecting components, product design and production processes are also likely, if history is an adequate guide, to provide for secular decline in average variable costs and a consequent downward pressure on product prices.

Demand In principle, consumer demand for ATV products will depend on price, quality, the quality and price of closely related goods/services (substitutes or complements), buyers' income, and buyers' expectations about each of the foregoing. Although these factors by no means exhaust the considerations underlying individual decisions to purchase, they represent a common core of factors which have been successful in "explaining" aggregate consumer behavior.

In practice, these buyer and product/service characteristics appear to have been quite instrumental in determining the rate at which electronics products embodying new technology have succeeded in the marketplace. For example, sales of radios and monochrome television receivers increased as prices fell, as their quality improved, as the number of broadcast transmitters increased and as signal quality and program diversity improved. The importance of the availability of complementary goods is clear from the pattern of growth of audiocassettes and videocassettes, which have closely tracked the growth of companion player/recorders. Similarly, the demand for home computers has been stimulated by the proliferation of diverse, high quality software, and vice-versa.

Since consumer electronics products may be regarded loosely as leisure goods, as opposed to one of the necessities of life, we would expect sales and penetration to be sensitive to the levels of national income and employment and to the business cycle more generally. Although there are classes of "inferior" goods whose use increases as income declines or expectations turn

negative (potatoes, do-it-yourself kits, and used cars are common examples), consumer electronics generally do not qualify. To the contrary, the steady growth in sales of color television receivers, for example, has been interrupted only by general economic recession. Aggregate sales of radio sets and monochrome television receivers have followed the same general pattern. The evidence generally indicates that demand for new ATV products will be very sensitive to income levels and expectations.

The broad principles of market demand have generally found clear expression in other consumer electronics markets; and we will look to them for guidance in making assumptions to provide the basis for our ATV product market development scenarios.

#### E. THE GLOBAL MARKET--A SIMPLE TAXONOMY OF ECONOMIC EFFECTS

The uncertainties described above will be gradually resolved by time, regulatory and political cycles, and more detailed study of the evolution of this market as events yield more information. Although the character of the market for ATV products will be influenced by the resolution of these uncertainties, for now about all we can do is to note them and be appropriately cautious in developing a view of the future.

The economic activity likely to be generated will take numerous forms. It is helpful to classify this activity into descriptive categories: time, location and type of product or service. Economic activity will not materialize completely or instantaneously; it will not appear and grow at the same rate in different parts of the world or in different geographic submarkets; nor will the impact be realized uniformly across different product/service lines. Both "primary" and "secondary" (i.e., supporting, complementary, or induced) activity will be generated.

Thus, aggregate economic activity generated by the development of ATV products can be visualized in four dimensions: geographic area, sector of end product use, the nature of the activity generated and time. Although the distinctions have a certain intuitive appeal, they are more or less arbitrary and adopted largely for expository and analytical convenience.

The location of economic activity can be divided into four geographic trading areas--the domestic market, our principal Western trading partners, Japan, and the rest of the world. These trading areas represent both potential buyers and potential producers.

Secondly, the market in a particular trading area can usefully be subdivided further into three sectors: households,

businesses, and government. For reasons that will shortly become clear, this is a particularly helpful way to think about the market for ATV products, especially in the US.

Next, within trading areas and for each end user product, the economic activity generated can be distinguished according to whether the activity is directly the result of the production of the end product (that is, a primary activity), or an economic activity which is inspired by the production, sale and/or use of the primary product. For example, the diffusion of ATV products will require inputs from upstream industries such as electronic components and the materials for such components. Similarly, the growth of ATV sales may be accompanied by the growth of specialized maintenance, repair and service activities; or, by other types of complementary products, comparable to cassettes and discs using the current generation of technology.

Finally, the market has a time dimension. This requires recognition of the fact that economic activity will begin at different times and grow at different rates in different subsectors.

A full explication of the development of global markets for ATV products over, say, the next twenty years would require examination of 480 data points (20 years times 4 trading areas times 3 user sectors times 2 kinds of economic activity). That is clearly beyond the scope of this paper. Obviously, and fortunately, not every data point has the same expected weight. Moreover, some are likely to be inconsequential from a domestic policy perspective. The likely incidence of economic activity is quite concentrated in this four dimensional matrix for reasons that are discussed further below.

### III. THE US MARKET FOR SELECTED CONSUMER ELECTRONIC PRODUCTS

#### A. INTRODUCTION

The analysis of this and subsequent sections attempts to construct scenarios describing, in a rough sort of way, the boundaries within which the economic activity generated by ATV products can reasonably be expected to fall. Thus, the analysis should be regarded as a description of what could happen, rather than a forecast, projection or prediction of what will happen.

The reasons for being tentative about the future of ATV products are well-grounded in the present and in the past. ATV products have a short but rich technological and geopolitical history. There is no economic history--no data trails--to project; there are no established sets of economic relationships from which to derive a prediction; and, we are not divinely

inspired to prophesy. Much of the technology is still in a very early experimental stage; some of the technology is still being developed; and, while there is some product available today, even the most optimistic planners expect a lag of three to five years before product is available to even a modest subset of the potential US consumer market.

In this respect, foretelling the economic activity associated with the application of ATV technologies may be likened somewhat to efforts to foresee the development of private, commercial and defense aviation (and supporting industries) three to four years after the Wright Brothers' successful trials at Kitty Hawk.

## B. METHODOLOGY

Since there is no market history of any consequence for ATV products, we are left to infer a potential growth path indirectly from the history of other product innovations. This approach draws comfort from the fact that household penetration rates of new consumer electronics products share common elements with diffusion patterns of innovations more generally.

Stages of New Product Diffusion Casual empiricism confirms that new products, like new processes or ideas, are not universally adopted immediately following their introduction.<sup>7</sup> Unlike hula hoops, most new or substantially improved products are adopted slowly in the beginning, then take off after some critical mass has been reached, only to taper off after a relatively high level of market penetration has been achieved. Some, of course, never take off, but the successful ones commonly follow a "diagonal S" shaped growth path which reflects three distinct stages of growth--the innovation stage, an imitation stage and a period of maturation during which sales flatten, decline or disappear.

The innovation stage embraces the early period after a new product is introduced. The product is new; consumers are not familiar with the product; distribution networks are not fully developed so that the product is not everywhere accessible in the market; a few venturesome buyers experiment; and, the product may be improved or repriced in reaction to early consumer responses. With the passage of time, sales begin to gather momentum fueled from a variety of sources: improved distribution networks, better consumer information about the product, development of supporting products or services and the evolution of a product track record. Of course, many products never escape this stage and die here.

The imitation stage commences when sufficient favorable product information emanates from the market to both buyers and sellers. Consumers have become aware of key product characteristics through contact with pioneering buyers. Alternative suppliers glean valuable information about the potential of the market. New suppliers enter and vie for market share through product differentiation and/or price competition. This stimulates demand and, as sales grow, production costs and prices decline further as a result of economies of scale, learning curve effects and market rivalry.

Eventually the market matures. Firms may drop out of the market or be absorbed by rivals. Prices stabilize. High penetration rates among potential buyers have been achieved and sales to first time buyers begin to yield to replacement sales as the market driver. The product may become standardized and sell pretty much as a commodity. Absent some new stimulus, the market stabilizes with modest or zero growth. New product or process innovations may either rejuvenate the market or sound its death knell.

Growth Path for ATV Consumer Products The cycle described here is by no means universal. It does, however, describe in a very general way some of the important forces that come into play and influence the market development of new products. More to the point, though, we expect consumer ATV products to follow this general pattern, although not necessarily in all its details.

Our method for describing the potential growth path for ATV products will rely on the history of other innovations in consumer electronic products. It goes without saying that markets for ATV products may not follow either the general pattern described above or the pattern for selected consumer electronics described below. These products may suffer the fate of other heralded innovations, like the "picturephone", quadraphonic stereo sound systems, or AM stereo, and not escape stage one. These products may languish like teleconferencing, two-way cable television, videotext or direct satellite broadcasting. Or, the development of the market may be long deferred as a result of regulatory indecision and inaction, as in the case of cellular telephone equipment and services.

While any of these scenarios is quite possible, the special circumstances which led to such dismal market performance are not clearly inherent in these technologies and, it appears, are in several essential respects avoidable. This conclusion, combined with the phenomenal market success of other home entertainment products like color receivers and VCRs impels us to develop the more optimistic scenarios based on more successful product and service lines. At a minimum, the result will be to develop some reasonable upper and lower bounds for the future of ATV market activity. Thus our scenarios may be bounded by two types of

errors: underestimating a successful product innovation or grossly overestimating a "dud".

In what follows, we will describe the growth paths traced by selected consumer electronic products for which adequate history and data are available. For each product we will establish the date of its introduction into the consumer market; estimate the length of time required to reach an arbitrarily determined threshold penetration rate (thereby measuring the innovation stage); then, quantify subsequent growth over various time periods as a means of describing subsequent stages of the product cycle.

### C. STAGE 1--THE INNOVATION STAGE

We have identified six consumer electronics product lines for which reasonably good data are available and which appear to share some important common characteristics with potential ATV products. These products are: color television receivers, videocassette recorders, "home" computers, television receive-only earth stations (TVROs), large screen/projection televisions and audio stereo component systems. Each of these products was, during the early years of its availability, sold primarily to consumers to be used for home entertainment purposes. Furthermore, each required a substantial consumer outlay as measured by product price as a percentage of family income.

Growth rates based on low initial sales levels are not very meaningful since small incremental growth, measured in dollars, will translate into high relative growth, measured in percentage terms. Thus, in describing the first stage of development of these product lines, it is necessary to establish a benchmark to identify the end point of Stage 1 and the beginning of the next. Selection of this turning point is pretty much a matter of judgment.

After experimenting with different benchmark specifications, calculating the implied subsequent growth path, and comparing the results for consistency, we will use 1% penetration of households as the threshold from which subsequent growth is measured and as the breakpoint between the first two stages.<sup>8</sup> This approach permits the use of physical units of sales, rather than dollar measures, and simplifies the analysis by eliminating the need to account for changes in dollar measures brought about by product price changes, product specification changes, and changes in the value of the dollar.

Color Television Receivers Of the six product lines examined here, color television receivers have the longest, and in many ways, the most interesting history.<sup>9</sup> Color sets were

first introduced in 1954 after years under development and discussion of appropriate technical standards. Early growth was modest for a variety of reasons, not the least of which was the paucity of color signals being transmitted by local broadcasters, whose facilities were engineered to accomodate black and white signal origination.

Also instrumental in the early development of color TV penetration was the fact that the first six years following the product's introduction were punctuated by three years of general economic recession--one year of moderate recession and two years of more severe general economic conditions. Sales of consumer durables are generally sensitive to general economic conditions; and, sales of consumer electronics appear to be particularly sensitive.

TABLE 3  
Color Receiver Sales  
(000,000 units)

<u>Year</u>	<u>Sales</u>	<u>Cumulative Sales</u>
1953	0	0
1958	.1	.2
1963	.8	1.8
1968	5.0	10.8
1973	10.0	60.4
1978	10.7	103.2
1983	14.0	163.0
1984	17.2	180.0
1985	16.9	197.0
1986	19.0	216.1

Source: 1987 Electronic Market Data Book, EIA Marketing Services Department.

For these and other reasons, sales of color TV sets languished until the fourth quarter of 1961, a year after the close of the 1959 recession, and did not really "take off" until 1962. Thus, it took about 8 years for sales of color receivers to reach the 1% household penetration threshold. Summary data are included in Table 3.

Videocassette Recorders VCRs were first introduced in this country in 1975. Roughly half of US homes now have a VCR, a fact which testifies to the very rapid US household adoption of this

technology and product line. Well over 80% of the installed VCR base has apparently been manufactured in the past five years. Consumer uncertainty about the relative values of VHS and Beta formats dampened early sales as did a brief and mild recession beginning in mid-1978. For many years cassettes were not readily available in all locales and, where they were available, the selections were neither diverse nor expansive.

The best estimate available suggests that about 4.5 million units were imported between 1975 and 1982. Most of these remained in dealer inventories or elsewhere in the distribution pipeline. Accounting for these differences between imports and consumer sales, it appears that 1% household penetration was probably reached sometime during 1981 or 1982--some 6 or 7 years after VCRs were first introduced. (See Table 4.)

**TABLE 4**  
**Videocassette Recorder Factory Sales**  
 (000 units, \$000,000 value)

<u>Year</u>	<u>Units</u>	<u>Value</u>
1976	30	-
1977	250	\$ 180
1978	415	325
1979	488	388
1980	802	620
1981	1,471	1,126
1982	2,020	1,303
1983	4,127	2,162
1984	7,881	3,585
1985	11,786	4,738
1986	13,533	5,257

Source: 1987 Electronic Market Data Book, EIA Marketing Services Department

Television Receive-Only Earth Stations Penetration of TVROs has been fairly erratic since their introduction into the marketplace. Uncertainty as to the lawfulness of taking pay television signals off the air and the future availability of unscrambled signals undoubtedly discouraged many potential buyers. The decision of major satellite program distributors to scramble their signals and the inaccessibility of decoders in some areas may have dampened the growth of TVROs.

It is difficult to date the introduction of TVROs for consumer use. Receive only earth stations were in commercial use long before higher powered, and otherwise more advanced, satellites permitted design and use of smaller, lower priced versions suitable for household entertainment purposes.

Although the Niemann-Marcus Christmas catalog touted a very expensive model in 1977 or 1978, only a handful of TVROs were installed before 1980. By 1981 there were between 5,000 and 20,000 installations, many of which were at commercial establishments--hotels, motels, neighborhood bars and the like. It appears that about 1 million units were sold to US dealers during 1981 and 1982. Many, of course, remained in dealer inventories. Thus, the limited information available suggests that 1% household penetration may have been reached in 1986 or 1987, some six or seven years after the "introduction" of TVROs into the consumer market.

In one very important respect, however, the "years to 1% household penetration" measure substantially underestimates the diffusion rate among "eligible" households. Because of space and zoning limitations in urban and suburban locations, the effective market for TVROs has been predominantly in rural areas. If the market were redefined to reflect those realities, the first stage would be a couple of years shorter and the current penetration would be several points higher. The weight of these observations is not, however, sufficient to alter the ATV product scenarios developed below.

**Projection Television Receivers** Large screen projection color televisions have been available in the US for about a decade. To date, however, total sales to US dealers have been somewhere between 1.5 and 2 million units. A large but unknown percentage of these have been purchased for use in commercial establishments rather than in households. Taking that into account and assuming a 3 to 1 inventory to sales ratio indicates that the 1% penetration rate has not yet been reached. At current rates of sales growth, the 1% threshold probably will not be reached for another three or four years. This implies that it may take this product line twelve to fourteen years to reach the threshold.

**Home Computers** These were first available in 1975, when about 500 were sold. Sales reached 100,000 units in 1978. The proliferation of videogames and other hobbyist oriented software began to lift personal computer sales dramatically. Prices declined and the range of product available increased to broaden consumer choice. Recent sales history is summarized in Table 5. By 1982, sales to US dealers were in the neighborhood of 2 million units. It appears that the first stage of the product

cycle for home computers was completed in the 1981-1982 time frame, or about six to seven years after the product line was first introduced into the marketplace.

TABLE 5  
Home Computer Factory Sales  
(000,000 units, \$000,000 value)

<u>Year</u>	<u>Units</u>	<u>Value</u>
1982	2.0	1,300
1983	4.8	1,950
1984	5.1	2,250
1985	4.1	2,050
1986	3.8	2,890

Source: 1987 Electronic Market Data Book: EIA  
Marketing Services Department

Audio Stereo Component Systems It is difficult to track the development of these systems, because they are not in fact a single product line. Components include receivers, tuners, amplifiers, speakers, turntables, headsets and a variety of accessories. There is no requirement that the components be combined by all users in the same way or purchased together as a single unit. Indeed, those features give users great flexibility and appear to be one of the strongest attractions of component systems. Systems can be individually tailored and upgraded, or otherwise enhanced, on a piecemeal basis as new components become available in the market and/or household budgets permit.

System components were individually available on a limited basis to aficionados in the fifties and somewhat more widely during the sixties. But, component sales barely dented the commanding market position of combination units until the mid-eighties. Throughout the seventies, it appears that combination systems outsold component systems on the order of 10 to 1. The real impetus to sales of component systems came with the availability of inexpensive audio tape equipment, which provided both a substitute for and a complement to the traditional combination "player" component--the turntable.

On the basis of limited and somewhat ambiguous data, our best guess is that the 1% penetration threshold was reached

sometime around 1976--about two decades after component systems first became available to US consumers. (See Table 6)

TABLE 6  
Audio Component System Factory Sales  
(000 units, \$000,000 value)

<u>Year</u>	<u>Units</u>	<u>Value</u>
Pre '76	900	-
1976	245	-
1977	300	-
1978	414	-
1979	394	-
1980	178	80
1981	200	89
1982	319	144
1983	403	178
1984	1,540	729
1985	2,335	1,046
1986	2,158	1,050

Source: 1987 Electronic Market Data Book: EIA  
Marketing Services Department

Summary Table 7 brings together the early sales history of our set of six consumer electronic products by presenting estimates of how long it took each product line to reach the 1% household penetration threshold. Projection television and audio component systems stand apart from the cluster embracing the other product lines. A variety of reasons can be advanced for the relatively poor market performance of projection TVs. They are bulky and require large viewing areas for maximum visual performance. They are also still rather "pricey" a decade after their introduction, although models embodying different technologies are beginning to address both of those problems. The history of audio component systems sales also falls well outside the norm for the sample. Since we are not sure what is actually being measured by the data, there does not appear to be sufficient reason to assign much weight to this product history.

What is more striking than the exceptional cases of projection TV audio component systems is the tight cluster of initial market development times for the other four product lines. These early diffusion rates are remarkably similar and tentatively suggest a consistent pattern of consumer response to new, home entertainment related electronic devices.

TABLE 7  
Years to Achieve 1% U.S. Household  
Penetration for Selected Consumer  
Electronic Products

<u>Product</u>	<u>Time Interval</u> (years)
Color TV Receivers	8
Videocassette Recorders	7-8
TV Receive Only Antennas	6-7
Home Computers	6-7
Projection TV Receivers	12-14
Audio Component Systems	20

#### D. STAGE II--GROWTH AND IMITATION

In this section we will explore further the historical growth path of selected consumer electronics products. The eligible set of products has diminished, however, due to the fact that two of the selected product lines are quite immature. As indicated above, sales of TVROs and projection television receivers are still fairly modest and clearly have not broken out of the first stage of diffusion. Their immaturity is only partially attributable to their relative youth. The fact is, owing to several forces operating in those markets, they may never take off.

For present purposes, the key question is whether ATV products will mimic the more or less tepid market performance of TVROs and projection TV, or emulate more nearly the growth experience of the more successful lines. Put differently, are the factors accounting for the growth patterns of TVROs and projection TVs likely to hinder the growth of ATV products as well?

The residential TVRO market has been predominantly driven by demand for television signals in areas not served by cable television. The decision of program distributors to scramble

those signals reduced the value of the earth station to all users and, for those with adequate reception of terrestrial signals, scrambling did not leave much residual value for an earth station. Until decoders are made more readily available at modest expense, the market may well continue to languish with additional sales limited mainly to households without access to cable or strong terrestrial signals; or to those with a very strong preference for specialized program signals, religious broadcasts for example. Continuing reductions in average "dish" prices will, however, stimulate residential installations.

In the context of the potential demand for ATV products, the TVRO experience sends out a clear signal for caution. Growth will be quite dependent on the availability, quality, and diversity of compatible programming. Improved visual images are important, but consumers apparently may not support the expense of ATV products on that basis alone, particularly if they are restricted in their program choices.

The implications of the projection TV market for ATV products are rather more opaque. While there are now three different technologies available, the popularity of rear projection models points to the simple "bulk" of combination units as a barrier to wider consumer acceptance. Related, of course, is the fact that the distance required between the viewer and the screen to minimize annoying visual distortions is larger than the available viewing areas in most US homes.

Finally, the sluggish national economy in 1982 significantly dampened sales in both 1982 and 1983, thereby suppressing the growth of the installed base and the opportunity for potential buyers to observe a receiver outside of dealer showrooms. This opportunity has been important in the diffusion patterns of other consumer durables, since it is a valuable source of consumer information about new products, and because it feeds the incentive of more conservative buyers to emulate pioneers.

Whatever the reasons for the failure of these two product lines to take off, the other four have grown quite remarkably since reaching the 1% threshold of household penetration.

Color Television Receivers After the 7-8 year introductory period, consumer purchases escalated rapidly and, in the first five years thereafter, sales doubled every fifteen months.

The growth of color TV sales has been remarkably steady over the product's life. The general growth path has been interrupted only by periodic economic recession. In 1986 US consumers spent more than eight billion dollars on color receivers alone. Over the 30 odd years since color television was first introduced, US consumers have purchased almost 220 million sets. Roughly 100

million of these have been sold in the last five years, clearly indicating that the market has not come close to saturation, despite the fact that about 92% of US homes now contain at least one color set.

Between 1962, when 1% household penetration was first reached, and the latest year for which data are available, units sold grew at a compound annual rate (CAGR) of over sixteen percent--from about 400,000 units to well over 19 million units in 1986.

Sixteen percent CAGR over a twenty-five period is remarkable by almost any standard but, taken by itself, that growth rate does not adequately describe the historic path of color TV sales. The twenty-five year average growth rate is distorted by a purely statistical phenomenon which is endemic to most growth rate calculations. As mentioned above, a given absolute gain in sales will look relatively larger in the early years of a product's life than later. Thus, a fuller picture of color TV growth can be described by examining growth over different intervals of the product's history.

TABLE 8  
Color TV Sales Growth Rates for  
Selected Intervals  
(nearest %)

	<u>Actual CAGR</u>	<u>Smoothed CAGR</u>
<u>Eight Year Intervals</u>		
1962-1970	37	40
1970-1978	9	7
1978-1986	5	8
<u>Five Year Intervals</u>		
1962-1967	65	65
1967-1972	10	10
1972-1977	10	10
1977-1982	5	7
1982-Present	11	9

Note: Since 1970 and 1982 were recession years in which sales declined, the data were smoothed by use of a simple average of the values for years before and after the years of decline.

The size of the time segment chosen is arbitrary. Two years are not very interesting and fifteen masks a lot of interesting variation. Table 8 shows growth for two intermediate intervals-- five year and eight year time segments after 1962, the 1% threshold date. These numbers give more definition to the color TV growth path. Two rates for each interval are included in the table--one is the actual rate and the other, in parentheses, is calculated after the data were "smoothed" to take out the distorting effects of the 1970 and 1982 recessions, each of which fell on one of the interval endpoints.

We believe the most useful information, for present purposes, is reflected by the data grouped in five year intervals after adjusting for the 1982 recession. Both the five and eight year groupings show dramatic growth following 1% penetration, followed by solid but slower growth in subsequent time periods. Both breakdowns show growth surging in the mid-eighties when the general model of product diffusion creates the expectation that growth would continue, diminish, flatten or become negative.

Several sources for the unexpected strength of this market have been advanced. The average service life of a color set has been estimated to be on the order of seven years. This means that the replacement market alone will be about 15% of the installed base each year. Estimates of the installed base vary, but the most commonly cited figures center around 125 million units. Thus, replacement of aging units will support sales of around 19 million units this year. And, since the installed base has been growing, replacements alone will fuel sales growth for the next few years. Of course replacement can be deferred, but that rate depends on several factors, including maintenance and repair costs, but more important determinants relate to product prices, qualities and the level of household income. (The ability of consumers to defer replacement of aging NTSC sets may provide a source of liquidity for sales of ATV products.)

There is little doubt that the major source of strong color receiver sales in the mid-eighties has been attributable to the strong impetus to consumer spending generated by general macroeconomic conditions in the past five years. Growing real income, relatively stable prices, declining costs for consumer credit, high employment rates, and very importantly, the strength of the dollar in world currency markets have all contributed to generally strong US markets for consumer durables.

The strength of the dollar has probably been the single most important factor underlying the surge of color receiver sales in the past five years. The increased value of the dollar has been largely responsible for the fact that the television receiver (all types including black and white) component of the consumer price index declined by over twenty-three percent from 1981 to 1986, while the consumer price index as a whole was increasing by

over 18%. Thus, receivers were not only getting cheaper relative to other goods and services, their prices actually declined by almost a quarter over the five year period.

It is also significant, we believe, that some of the solid state components of receivers have become less expensive in all currencies; and, that new manufacturing "process" technologies using workers from previously underutilized offshore labor pools have contributed to the more efficient and less costly production of all consumer electronics products, including color television receivers.

Lest we stray too far from the main focus of this paper, we should emphasize that these sources for recent growth in the sales of color receivers are not guaranteed to recur in ways that will assure a similar impact on ATV products. Although history does sometimes repeat itself, it can be argued that the confluence of forces described above is very unlikely to recur during the life cycle of ATV products. Thus, the growth path of ATV products may well be less steep in the out years than our experience with color TVs might indicate.

Videocassette Recorders Earlier analysis indicated that VCRs reached the 1% penetration threshold in 1981 or 1982. In either event the time interval since is quite narrow, thereby making pretty lean the data for characterizing the post-threshold growth path.

By 1986 factory sales to US dealers had reached more than 13 million units, valued at over \$5 billion. Not all of these sales to dealers have reached US households. The best available estimate has it that about half of US households now contain a VCR. Thus, in about thirteen years, VCR sales have gone from zero to 50% household penetration. Over the four year interval 1982 to 1986, VCR unit sales grew almost sevenfold, or at a CAGR of better than 60%, thereby describing an "early take-off" growth path remarkably similar to that of color television receivers.

Caution is warranted, however, before inferring that ATV products will enjoy similar success in the domestic marketplace. The quite favorable confluence of macroeconomic forces described above in the context of the market for color TVs have come to bear with equal force in the domestic market for VCRs. Although an equally congenial economic environment may well materialize during the late nineties when ATV products are expected to be at a similar stage in the market development cycle, it is just as conceivable, and likely, that economic forces in the aggregate will be somewhat less hospitable to growth in consumer electronics products.