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 signficant, 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.

<u>Videocassette Recorders</u> 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 televison 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.

Our purpose here is not to make a macroeconomic forecast for the nineties, but only to emphasize that general economic conditions have been, and will be, quite instrumental in the market performance of these product lines.

Home Computers It may be argued that home computers are evolving into a class of products quite dissimilar to ATV products and, for that reason, their respective market growth paths may be subject to entirely different market forces. Although home computers were in the beginning used in large measure for home entertainment purposes, recent developments suggest that other nonentertainment uses are coming to be more important. The hint for this development is found in software sales. Whereas game oriented software initially provided the bulk of software sales, in recent years utility programs for personal financial planning, tax preparation, word processing, a variety of educational tutorials, and programs designed for assorted specialized nonentertainment oriented purposes are among the most rapidly growing.

Sales of home computers have grown substantially but erratically in the past five years. Volume measured in the number of units sold peaked in 1984, but the value of dollar sales has continued to grow even though prices for "commodity" products have declined. Newer, more versatile and powerful models have been introduced. The average value of a sale has increased in the past five years, indicating that the composition of sales is shifting toward more technically robust and expensive units.

This development confirms the suspicion expressed earlier that the primary use of home computers is shifting, since utility programs frequently require more sophisticated hardware than many of the game programs used for home entertainment. In short, the growth path of home computers may be tracing two different product lines--the rise and flattening of video game machines and the birth/infancy of a market for more sophisticated applications.

Notwithstanding these bases for cautiously applying the home computer market experience to ATV products, the data, we believe, still have some relevance. First, the data show the willingness and ability of households to make fairly large expenditures on new consumer electronics products--even in a more or less volatile market being churned by price changes, new product introductions and uncertain product quality--in the context of a fairly immature set of supporting industries.

Despite all of this, there are now computers in about one in five US homes some twelve years after their introduction. Annual

sales have more than doubled since the 1% threshold was reached, which implies a CAGR in the neighborhood of 20%.

Audio Component Systems We have indicated that data tracking the early development of sales in this product line were difficult to interpret. Data describing sales behavior over the last decade are even less clear-cut. The 1978 sales peak of about 400,000 units was apparently not surpassed until 1984 when sales roughly quadrupled over the preceding year. This was a rather stagnant market until three years ago. After the great leap forward in 1984, sales grew a little over 50% in 1985, only to fall off again in 1986. It could very well be that the gains over the past three years are ephemeral, if the surge in sales represents the product of a temporary combination of very favorable macroeconomic forces, described earlier, rather than the beginning of a secular trend which is sustainable over a longer period of time.

Given the uncertainty suggested by the market history of audio component systems and the ambiguity involved in clearly defining the product for sales measurement purposes, we cannot comfortably infer from it much of value to our efforts to construct a plausible scenario for the development of ATV products.

Summary and Synthesis Taken together, the growth histories of these six selected consumer electronic product lines paint a somewhat dappled picture of possible growth paths for ATV products. Summary data are compiled in Table 9.

Optimists can find comfort in color TV receiver and VCR markets. Pessimists can find striking counterpoints in market histories of projection TVs and audio component systems. Those with a penchant for the middle road can find a fairly good candidate in the development of the home computer market. While we had no good reason to expect otherwise, there are some clear differences in the patterns emerging from the growth histories of these six product lines.

Despite the ambiguities and contradictions in the product histories, a couple of fairly consistent patterns are evident.

Four of the product lines--color TVs, VCRs, TVROs and home computers--share a strikingly common early product history, with each taking 6-8 years after introduction to achieve 1% US household penetration. We believe the product histories of audio component systems and projection TVs can each be written off as more or less *sui generis*. That is not to say, however, that we cannot easily conceive a set of economic, regulatory and political events which would result in a decade or more of

sluggish ATV consumer product sales which more or less track the experience of less successful consumer electronic product lines. But, more on that below.

TABLE 9
Diffusion Patterns: Household Penetration by Selected Consumer Electronics Products

	Audio Systems	Color TV	VCRs	TVROs	Home Comptr.	Projection TV
Years to 1% HH. Penetration	20	7	7-8	6-7	6-7	12-14
CAGR-Five Year Intervals						
0-5	flat	65%	60%	-	20%	-
5-10	30-40	10	-	-	-	-
10-15	-	10	-	-	-	-
15-20	-	7	-	-	-	-
20-25	-	9	-	-	-	-

Source: Base data from Electronic Market Data Book for selected years, EIA Marketing Services Department. Calculations and estimates by Author.

A second unlikely coincidence directly relevant to the future of ATV products is the near identity of the early growth patterns of color TV receivers and VCRs. This is an important consistency since these are the two consumer product lines most likely to be introduced in versions which embody ATV technologies. Each attained substantial household pentration in the decade following its introduction; and each grew at rates which resulted in tenfold increases in sales during the first five years after "take off".

IV. ATV PRODUCT GROWTH SCENARIOS

The task in this section is to interpret the growth histories reviewed previously in the specific context of potential markets for ATV products.

Although ATV products are at various stages of development and under the sponsorship of several different organizations,

only one company, NHK, has announced a firm production schedule. Indeed, only the NHK systems have been field tested under actual broadcast conditions. We are not able at this time to offer more than conjecture about the possible production schedules of the other contenders. Our impression is that the principals themselves are by no means firm in their expectations. For purposes of constructing the ATV consumer product market scenarios, we will assume that only NHK patent licensees will offer product at retail to US consumers within the next five years.

NHK has announced plans to have available for worldwide distribution, under the terms of licensing agreements with eleven Japanese manufacturing firms, 100K MUSE receiver units in 1990; 500K units in 1991; and, to be able to satisfy retailer demand during 1992. Production is expected to reach 1.5 million units in 1992. According to NHK representatives, players of videocassettes and discs will also be available during that time frame. The expected quantity and timing of shipment of these products to dealers are, however, less clearly expressed by NHK.[10]

The availability of cassette and/or disc players is critical since, initially at least, there will very likely be little, if any, programming available from other distribution media--cable, satellite and over-the-air broadcasting. Supposing even that additional spectrum necessary to distribute MUSE and other ATV signals is made available by the FCC in Docket 87-268, there will be a substantial lag before an appreciable amount of programming will be available in ATV formats to US households. Although some compatible programming is available, in particular, feature films shot in 35mm formats, production of current programs will require substantial station investment in new studio equipment.

The upshot of all of this is that there are significant barriers to widespread and immediate acceptance and purchase of ATV products upon their being made available. Nevertheless, the barriers are not in essential respects qualitatively different from those confronted initially by color television receivers and VCRs. Yet, both product lines fairly quickly overcame both compatibility and program/signal scarcity much like those being considered here in the context of ATV products.

A. SCENARIO 1--SLUGGISH DIFFUSION

Earlier sections of this report cite a variety of technical, regulatory and market barriers to quick and widespread diffusion of ATV products. There is no good basis for supposing that the full, potentially adverse effects of these barriers will in fact

be realized. Similarly, there is insufficient reason for discounting completely such an outcome.

The fact is that a combination of regulatory delay and uncertainty, a sour economy, and a shift in consumer saving and buying patterns, for example, could seriously constrain market penetration rates. And, since there has been, to our knowledge, virtually no meaningful market research on consumer acceptance of these products in this country, it may be that consumer preferences for improved television images--though quite positive--are simply not strong enough to support the rather healthy household budget commitment required to obtain these products.

There are several ways to characterize a sluggish penetration scenario. Product introduction may be delayed, as in the case of AM stereo; the product may require several years to achieve the 1% market penetration threshold, as in the case of projection TV; the market may subsequently manifest slow growth like audio component systems, or erratic growth like home computers.

Even more pessimistically, the market may simply may not materialize, as was the case with picturephone, videotext, and a host of other failed consumer products. The high current visibility of ATV products could, in short, turn out to be much ado about very little.

Recognizing that several sluggish scenarios can be developed, the one characterized here is consistent with the following general conditions:

- Continuing uncertainty about spectrum constraints and receiver standards;
- Delay in R&D programs directed to competing technologies, systems and products;
- Periodic or prolonged domestic macroeconomic conditions involving some combination of slow growth, substantial government deficit reduction programs, flattening or declining real consumer spending and unfavorable employment conditions;
- High and rigid ATV product prices; and,
- Weak revealed household preferences for ATV products.

Should these illustrative conditions materialize, wholly or in part, it is quite conceivable that the one percent threshold would not be realized until well after the year 2000, and that subsequent growth would also be dampened. For example, 1% household penetration by the year 2003, fifteen years hence, would generate sales of slightly over one million units each of advanced VCRs and ATV receivers, thereby replicating the historic growth of projection TV sets.

Depending on the pattern of product prices over that period, the cumulative value of sales could be in the $3 to $5 billion range, as defined by hypothetical average product prices of $1500 for advanced VCRs and $2500 for ATV receivers.

Should ATV product sales languish in this fashion, there is little basis, a priori, for expecting any particular growth rate for subsequent periods. However, in keeping with the generally pessimistic outlook of this scenario, consider that 10% CAGR over the subsequent five year period would generate sales of 600,000 to 700,000 units of each product in the 2003-2008 time frame. Using the same set of hypothetical prices, this translates into an additional one to one-and-a-half billion dollars in revenue.

To summarize our "gloomy" scenario, a combination of adverse economic developments could severely repress household penetration of these technologies and result in tepid sales performance over the next 20 years. Under the very general conditions posited here, sales would be negligible over the next decade. Total sales in the $4 to $6.5 billion range might materialize, but the bulk of those would not be realized until after the turn of the century. These sales volumes are by no means trivial but, viewed in the context of 1986 sales of NTSC color receivers of over $6 billion, neither are they impressive.

B. SCENARIO 2--RAPID PRODUCT DIFFUSION

This scenario is more optimistic. It is consistent with more favorable economic conditions than those supporting Scenario 1. For ATV products to enjoy rapid diffusion among US households, both the economic and regulatory environments must be congenial. As indicated earlier, during the eighties US retailers have enjoyed unprecedented growth in sales of consumer electronic products.

In the past five years, sales of consumer electronics products have grown at a compound annual rate of nearly 20%. About 40% of those sales were accounted for by NTSC color receivers, a very mature product line, and conventional VCRs, which represent a very young product line. More importantly,

perhaps, is the fact that these are the product lines that the new technologies and systems seek to replace.

Whether or not performance of the domestic and world economies will support continuation of secular consumer spending patterns on electronics products is outside the scope of the study. If it does, even approximately, the growth paths of NTSC color TV receivers and VCRs may be replicated by kindred products embodying ATV technologies. That eventuality summarizes, in a nutshell, the conditions underlying this scenario.

More specifically, this scenario also requires:

- Timely and decisive regulatory action respecting receiver standards and spectrum limitations;
- Accelerated R&D programs leading to product diversity and active price competition;
- Sufficient sales in the first ten years to avail producers the opportunity to exploit scale and learning economies; and,
- Rapid development of high quality, moderately priced, compatible program supply sources.

Should these conditions materialize, the historic path of their NTSC predecessors may well provide a reasonable template for the future growth of similar ATV products. Scenario 2 is based on the following assumptions: one per cent household penetration 7-8 years after introduction, 60% CAGR for the five years following, and steady, if unspectactular, growth thereafter of 10% per year, driven by product replacements, production cost and price reductions and significant, but unspecified, product improvements.

ATV Receiver Growth Scenario Table 10 incorporates these conditions and summarizes the results for color TV receivers. Beginning in 1987 with 1 million units sold and growing them at 60% for each of the next five years yields sales of about 10.5 million units by 2002. Simultaneously growing current households at 1.5% per year and then taking the ratio with the illustrative installed base suggests nearly 25% household penetration in 2002, some twelve years after the introduction of ATV compatible receivers. If sales were to grow subsequently at an average rate of 10% for each of the next five years, the household penetration would exceed 90% some two decades after introduction and the

installed base would accumulate to over 100 million units, even after allowing for replacement of aging units.

TABLE 10
Product Development Scenario:
ATV Compatible Receivers
(000,000 units)

Year	Annual Sales (units)	Cumulative Sales (units)	Household Penetration (%)
1997	1.0	1.0	1.0
1998	1.6	2.6	1.5
1999	2.6	5.2	4.8
2000	4.1	9.3	8.5
2001	6.6	15.9	14.4
2002	10.5	26.4	23.5
2003	11.5	37.9	33.2
2004	12.7	50.6	43.7
2005	14.0	64.6	54.9
2006	15.4	80.0	67.0
2007	16.9	96.9	80.0
2008	18.6	115.9	93.9

VCR Growth Scenario The growth path of VCRs using ATV technologies is subject to uncertainties even beyond those permeating the color TV scenario sketched out above. During the early years of ATV product availability, it appears that VCRs will most likely be an indispensable complement to TV receivers, without which the receiver will have little value. The bulk of the early programming will come from existing libraries or 35mm film which will be processed electronically to make it compatible with the ATV format.

The VCR will very likely be the first medium available for distributing ATV programming and, for a while, it may well be the only one of any consequence for most US households. The cable, terrestrial broadcast, and satellite industries will have an incentive to reconfigure their respective distribution systems only when there appears to be sufficient household demand to warrant undertaking the necessary investments. However, significant community demand for cable or out of the air programming should materialize when the installed ATV compatible base of TV receivers reaches some substantial level of household penetration. And, whatever that level of penetration might be, it can only be supported by high levels of early VCR sales as necessary adjuncts to receivers.

Thus, for the first few years, VCR sales and sales of a new generation of ATV cassettes should track very closely the installation of receivers. For how long this will persist is an open question which will be resolved only by the rate at which the other distribution media adjust their systems to the ATV distribution format.

Early availability of compatible programming over other media will sever the one to one nexus between receivers and VCRs by increasing the value of stand-alone receivers and reducing the scarcity value of VCRs as a distribution medium. The future potential interplay of these industries and the strategic options of the players are fascinating but beyond our limits to explore here.

TABLE 11
Product Development Scenario:
Videocassette Recorders
(000,000 units)

Year	Annual Sales (units)	Cumulative Sales (units)	HH Penetration (%)
1997	1.0	1.0	1.0
1998	1.6	2.6	2.4
1999	2.6	5.2	4.8
2000	4.1	9.3	8.5
2001	6.6	15.9	14.4
2002	10.5	26.4	23.5
2003	9.2	35.6	31.2
2004	10.2	45.8	39.5
2005	11.2	57.0	48.5
2006	9.2	66.2	55.4
2007	10.1	76.3	63.0
2008	11.2	87.5	71.1

For purposes of this scenario, we will characterize VCRs and receivers as necessary complements, or technologically "tied" products, for the first five years after introduction with equal unit sales in each year. After 2002 when about a quarter of US households may, according to this scenario, own an ATV compatible receiver, there may be sufficient programming available from other media to begin to break the VCR/receiver bond. Thereafter, the scenario characterizes VCR unit sales each year falling to 80% of receiver unit sales for three years, then to 60% for the final three years of the scenario.

The sales and household penetration implications of these characterizations are presented in Table 11. VCR sales track receiver sales until 2002, achieve nearly 25% household penetration, then begin a new, basically flat, growth period which boosts penetration to about 70% (compared to 94% for receivers) in twenty years after take off.

Combined Market Value of Product Scenarios Table 12 combines the results of the two product line scenarios and values unit sales by applying a range of hypothetical product prices.

TABLE 12
Market Value of Scenario Growth Paths
(000,000 units, $000,000,000)

Year	Cumulative Sales Receivers			Cumulative Sales VCRs			Total Value of Sales	
	Units	Value High	Value Low	Units	Value High	Value Low	Value High	Value Low
1997	1.0	$.8	$.4	1.0	$.6	$.3	$1.4	$.7
1998	2.6	2.0	1.0	2.6	1.5	.75	3.5	1.7
1999	5.2	4.2	2.1	5.2	3.1	1.5	7.3	3.6
2000	9.3	7.4	3.7	9.3	5.6	2.8	13.0	6.5
2001	15.9	12.7	6.4	15.9	9.5	4.8	22.2	11.1
2002	26.4	21.0	11.5	26.4	15.8	7.9	36.8	19.4
2003	37.9	30.3	15.6	35.6	21.4	10.7	51.7	25.3
2004	50.6	40.5	20.2	45.8	27.4	13.7	67.9	33.9
2005	64.6	51.6	25.8	57.0	34.2	17.1	85.8	42.9
2006	80.0	64.0	32.0	66.2	39.7	19.8	103.7	51.8
2007	96.9	77.5	38.7	76.3	45.8	22.9	123.3	66.6
2008	115.5	92.4	46.2	87.5	52.5	26.2	144.9	72.4

The relationship between product prices and the rate of household penetration is one of mutual interaction. Cause and effect goes in both directions. Recalling our earlier discussion of demand, production costs and pricing policies, it is clear that prices must come down substantially if the sales volumes and penetration rates depicted here are to be realized. The market scenarios give up any claim to realization without substantial decline in the $3,000 introductory prices expected for each product.

Trends in both component technologies and production technologies support expectations that prices will decline precipitously over time. Further, the technological and economic

histories of microelectronics based industries give every reason to expect that VCR and receiver functions, along with others perhaps, will be merged into a single piece of equipment priced below the total of the stand-alone prices. One can easily imagine numerous other developments which will have a bearing on product specifications, costs, quality and price--all of which will shape the willingness of households to replace NTSC equipment.

The long and short of it is that specifying prices for these products a decade from now is pretty much guesswork. For purposes of illustration Table 12 is calculated for a "high" value and a "low" value. Receiver sales are valued on average at $800 and $400 per unit and VCR sales at $600 and $300. All dollars are current. These average values are well below the introductory prices now being quoted. Introductory prices must come down for the scenario penetration rates to be attained.

The dollar values contained in Table 12 clearly reflect the fact that unit sales were developed without regard to product price, a practice which is clearly inconsistent with expected and historic consumer behavior. Specifically, the scenario suggests that unit sales will be the same in each time period under both the high and low price assumptions. There is no reason to believe that product demand will exhibit that kind of price inelasticity. Thus, the range in total market valuations based on the high and low set of product prices is overstated by a factor which varies with product price elasticities, since unit sales would surely be higher (lower) when prices are lower (higher). Adjusting quantities for the different assumed price levels would change the "naive" sales figures in Table 12 which simply ignore the unknown price elasticity effects.

It is important to be as clear as possible about this assumed set of prices as they affect the market valuation of sales. We are aware of market valuation estimates that assume product prices in the neighborhood of $1500 for an ATV receiver. The penetration rates derived in this scenario are very likely unattainable if product prices substantially lower than that are not achieved.

Moreover, since the demand for these products is likely to be price "elastic" (in a technical economic sense), lower prices imply higher total sales revenue, since a relatively small percentage reduction in price will, given the definition of "elasticity", stimulate a greater percentage increase in the number of units sold. Thus, the boost in revenue from greater volume should exceed the negative revenue impact of lower prices so that, on balance, the net effect of a price reduction is to increase the value of sales.

Is this scenario realistic? It is not if one is looking for point estimates of market sales data for these products in the future. It also goes without saying that the further into the future we look, the less confidence we can have that underlying forces have been either captured or accurately represented in their potential impact.

This scenario is as realistic as the key assumptions which underlie it. We believe that those assumptions are not unreasonable; nevertheless, it is useful to review them in a summary fashion. Proceeding from the more general to the more specific, they include:

- Healthy world and domestic economies;
- High levels of consumer spending on electronics products;
- Favorable product development and pricing trends;
- Timely and decisive resolution of critical receiver standards and spectrum questions;
- Vigorous competition among several product sources and technological systems;
- Reasonable replication of market histories of other US consumer electronic product lines--particularly VCRs and color TV receivers; and,
- Widespread availability of compatible ATV software.

Realization of these necessary conditions would permit ATV compatible receivers and VCRs to reach $3-4B in sales within a decade and to top $50B within the next fifteen years, if the "high" value totals in Table 12 for the years 1998 and 2003 accurately embody the forces which will drive this market.

Of course, the interested and arithmetically inclined reader can easily create other quite reasonable scenarios by simply changing the assumptions and working out the results. Two key assumptions are that it will take seven years to reach 1% household penetration and that the market will grow at 60% CAGR for the first five years thereafter. These standards were met by both color TV receivers and VCRs in the marketplace, but they are indeed ambitious. They can be achieved in ATV product markets in the future only if the necessary conditions spelled out above generally prevail.

C. COMMERCIAL/INDUSTRIAL AND GOVERNMENT APPLICATIONS

The market for ATV products will be driven by entertainment applications of the technology in the home, as indeed are current R&D programs and production plans. Even modest penetration of 90M US households will generate sales well beyond the levels likely to be attained by sales to government, commercial and industrial users. The reason is the magnitude of the US consumer sector, its buying power and its appetite for entertainment related electronic products. Thus, the sheer size of the U.S. consumer market dwarfs any other subset in the market classification developed above and may, in fact, compare not unfavorably with all of the others taken together.

To illustrate, the revenues generated if 7% of U.S. households spent $1,500 each on ATV products would amount to about $9 billion.

Total Defense Department procurement by 1990 is expected to be on the order of $80 billion.[11] Defense is the principal potential government user of ATV products, yet it is difficult to imagine a scenario in which as much as one or two percent of the Department's total procurement would be allocated to expenditures on these ATV products. Even those levels would generate relatively small revenues compared to the hypothetical household spending of $9 billion posited above. Thus, DOD would have to spend over one percent of each year's procurement budget on ATV related products over the next decade to approximate the level of economic activity associated with seven percent of US households spending $1,500 each.

Looking at spending by DOD from a different angle, the Defense Department is currently spending about $6 billion annually on research, development, testing, and evaluation in <u>all</u> categories of electronics <u>and</u> communications.

The potential for industrial and commercial uses also pales in comparison to potential household demand. In 1986 the total value of all shipments of graphics displays, special purpose graphics terminals and computer monitors (CRTs) was a little over $2 billion. CAT scanner sales were about a half billion dollars. While total spending on all types of electromedical equipment exceeded $5 billion, over 95% of those expenditures can be eliminated as completely insulated from the availability of new ATV products.

This is not to say that government and commercial uses of ATV products will be inconsequential. Rather, we expect that

entertainment oriented uses of such products will simply overwhelm commercial applications in the foreseeable future.

Some commercial applications are specifically entertainment oriented. These types of products will promote and be promoted by the development of consumer products oriented applications. Studio production equipment, large segments of broadcast transmission equipment, electronic equipment in cable distribution systems and a variety of other NTSC compatible gear will have to be replaced if and when those standards are changed.

Recent testimony before the House Subcommittee on Telecommunications and Finance of the Committee on Energy and Commerce is helpful in estimating the potential value of this market segment. The principals of the New York Institute of Technology estimated the cost to a broadcast station owner of converting to a standard other than NTSC. They placed the cost at $4.5 million per station, or about $6 billion if all current stations were to convert.[12] This is by no means a negligible market, but it assumes less importance when placed in some additional perspective.

First, station owners are not going to convert until household penetration of equipment is substantial, or until the growth path of home entertainment devices is unmistakably clear. Secondly, the smaller the station the greater the burden of the additional investment and the lower the expected return from converting. The economics of small market broadcasting may not support these levels of investment. Finally, the estimated cost per station to convert to a new ATV standard does not reflect the potential for significant production economies if huge demand were to materialize in a relatively short period of time.

Our search for applications of ATV technologies outside of the entertainment field turned up several pockets of interest and potential demand for specialized commercial applications. These include:

-Medical diagnostic applications;

-Retail telemerchandising applications;

-Teleconferencing applications;

-Industrial quality control;

-Various training and simulation devices; and

-Various CAD/CAM applications.

We are unable to estimate the total potential value of markets for these applications without substantial further

analysis. It is quite possible, though, that the dominant industrial uses of the technology will be in entirely new applications which have yet to be identified. It is humbling in this context to recall that an early forecast of total US computer sales proclaimed total potential demand to be "no more than a dozen".[13]

To summarize, commercial and governmental applications, though by no means inconsequential, are not, on the surface at least, sufficiently robust to qualify as much more than a marginal adjunct to the consumer market. The most likely prospect is that there will be numerous special applications of the technology customized for particular nonentertainment uses. This is not to imply that these markets should or will be ignored. For purposes of this analysis, however, our summary review of non-household applications suggests that the market for ATV products will be dominated by the rate of product adoption by households.

D. OTHER ECONOMIC EFFECTS OF ATV DIFFUSION

The discussion thus far has been directed toward establishing the market value potential for the sale of ATV products to households, commercial/industrial concerns and government. Whatever those sales might amount to in time, they do not exhaust or fully characterize the economic activity likely to be induced by the introduction of ATV products in either the short or the long run. The purpose of this section is to elaborate on the direct impact of ATV product sales and to explore a range of indirect effects of ATV market development.

The scenario results were expressed in terms of potential dollar sales of ATV products under different economic conditions. These final sales reflect the summation of incremental market values added by agents at various stages in the upstream production chain. The value of assorted materials, components, capital, labor and managerial resources "used up" in prior production processes are reflected, albeit anonymously, in the final sales price. At each intermediate stage of production required by the demand for final ATV products jobs are created, taxable income created, profits earned and wealth accumulated.

It requires immense effort to identify and quantify the various strands in this web of economic activity. Fortunately, some work has already been done which begins to unravel some of the key relationships.

Employment Effects ATV sales will create jobs both here and abroad. The split will be determined by the ability of US

producers to compete successfully. The best analysis available for understanding the domestic employment implications is contained in a study performed for the Consumer Electronics Group of the Electronics Industries Association by Arthur D. Little, Inc.[14] Based on extensive research, personal interviews and the use of a Department of Commerce "input-output" model of the economy, the study was able to identify and quantify a variety of economic impacts originating with domestic production of consumer electronics products.

The study reports 1983 US employment and domestic value added (net of imported goods) by category of consumer electronics products. Taking the ratio of these study estimates yields a crude estimate of the average relationship between the value of domestic content and employment. Column 1 in Table 13 displays the results of this reorganization of the A. D. Little data for selected product categories.

TABLE 13

Employment and Multiplier Effects of
ATV Product Sales Growth

Product Line	Value Added per Worker	Value Added Multiplier	Employment Multiplier
Color TV Receivers	$28,000	2.8	2.8
Videocassette Recorders	27,000	2.0	2.0
Video Tape	28,000	3.4	3.2
Other Video Products	27,000	2.4	2.4
All Consumer Electronics	27,000	2.7	2.7

Source: Arthur D. Little, Inc.

The interpretation of the numbers is straightforward. On average in 1983, sales of consumer electronics products valued by end users at $27-28,000 required the creation of one job. Alternatively, this implies that every $1B worth of value added created by US consumer electronics suppliers is associated with about 35,000 US jobs. These jobs are scattered throughout the economy--manufacturing, service, utilities, trade and transportation, for example. They represent the direct employment created in the electronic products production chain.

Multiplier Effects The income and employment impacts of the activity are not exhausted by direct sales and direct employment. Workers employed in electronics and supporting industries, investors there, and others deriving income in those sectors will use the proceeds to buy other goods. Suppliers of those goods

will hire other workers, buy other goods, and so on. There is, then, a secondary "multiplier" effect which will magnify the domestic income and employment impact of increased production of ATV products. This multiplier will generate a substantial stream of indirect or secondary income and employment effects.

Multipliers derived from the Arthur D. Little, Inc. study are also displayed in Table 13. The value-added and employment multipliers were each about 2.8 in 1983 according to that study. This means that for each job or dollar of income generated directly by domestic production of consumer electronics and complementary goods/services, an additional 1.8 jobs or dollars will be generated indirectly. A. D. Little estimates that the total of direct and indirect activity will be 2.8 times the amount generated in the first instance.

It may be helpful to put these effects in the context of the scenario for ATV consumer product sales developed above. We will use the years 1998 and 2003, ten and fifteen years hence, to illustrate. From Table 10 we read ATV compatible receiver (unit) sales in those years as 1.6 million and 11.5 million units, respectively. Assuming each unit sells for $600, direct value added is $960 million in 1998 and $6.9 billion in 2003. The Arthur D. Little "value added to jobs ratio" described above ($1 billion value added means 35,000 jobs) implies that this level of ATV receiver sales would would be associated with over 240,000 jobs in 2003 and 35,000 jobs in 1998. Similar calculations using data on VCR sales from Table 11 are possible, as are calculations for other years.

These income and employment impacts assume that the entire value added in the production of these products is the result of economic activity in the US, i.e., there are no imported components or materials and no offshore fabrication, for example. It further assumes that production processes will not become less labor intensive between now and then. Although neither of these assumptions is likely to be realized, the exercise still graphically illustrates the powerful direct employment impact this technology could have on the domestic economy.

Taking into account the induced income and employment effect of these sales requires, according to A. D. Little estimates, increasing the direct income and employment effects by a factor of 2.8. Continuing with the VCR example and performing the arithmetic yields $2.7 billion in (direct plus indirect) sales and almost 100,000 jobs by 1998. Bear in mind that total employment in 1986 for <u>all</u> US consumer electronic industries was about 63,000.

Again, we want to emphasize that we are not forecasting these levels of income and employment impacts. They rest on a series of assumptions and calculations which, for a variety of

reasons, may ultimately prove to be in error. Nevertheless, the arithmetic is very instructive, for it demonstrates the economic forces which may be mobilized, or lost, as a result of the development of ATV systems and products.

Fiscal and Trade Impacts The income and employment effects of the level of ATV related economic activity suggested in the foregoing scenarios would create substantial pressures on the current balances in both the US trade and fiscal accounts. Full exploration of the effects of those pressures is beyond the purposes of this study, but even a superficial analysis indicates the enormous potential leverage of ATV market development on the twin deficits.

In 1986 the US posted a trade deficit of almost $17 billion in the electronic products account, of which $14.5 billion (85%) originated in consumer electronics products alone. Factory sales of TV receivers and VCRs to dealers in the US were roughly $12 billion, the overwhelming bulk of which were imported. Total US exports of consumer electronics products in 1986 were about $1.2 billion, while exports of electronic parts were in the neighborhood of $2.7 billion.[15]

These data confirm that home video products are a major source of the deficit and, consequently, a line of business where some potentially remedial steps might generate substantial payoffs. That is the good news. The bad news is that the trade account could be dramatically worsened if US households do not have a domestic option for ATV products and instead satisfy their entire demand for these products from sources abroad.

To get a rough idea of the relative importance of the potential market for ATV products in the context of the current trade balance, refer back to Table 12. The mid-point of the range of cumulative value-added between 1997 and 2003 is $38 billion, which is about $6 billion a year on average. That is roughly half of the the 1986 deficit in the trade accounts generated by imported NTSC receivers and VCRs. We hasten to caution that these calculations are based on a long list of assumptions, not all of which have not been explicitly stated or justified in this report. The calculations are intended, nevertheless, to illustrate a general conclusion which is all but unassailable, namely, that the market potential for ATV products in this country implies dramatic potential effects on the balance of trade.

The levels of economic activity associated with potential domestic value-added in the production of ATV products will generate taxable national income earned by both corporations and households. Further, by increasing domestic employment, domestic production of these products will tend to dampen employment

sensitive federal, state and local government expenditures. A full analysis is beyond the scope of this report. However, a crude indication of the relative impact of ATV related value-added is suggested by the fact that federal tax receipts are running at a rate of about a quarter of national income. While we are not able to quantify reliably the potential fiscal effects of the ATV penetration scenario, they are clearly both positive and too large to ignore.

E. THE MARKET OUTSIDE THE US

Western Europe The potential European market for ATV products has such substantial economic appeal and offers so much political and cultural opportunity that industry and governments have joined in a concerted effort to stake out an early claim by agreeing on common European ATV equipment and transmission standards. The EUREKA project, by any standard measure, has been very successful. The European Economic Community has adopted the MAC standard for direct broadcast satellite transmission while maintaining compatibility with existing receivers and protecting, at least in the short term, the value of investment in equipment engineered to PAL or SECAM standards. The MAC systems being installed in Europe today can easily accomodate migration to HDTV and the plans are to do so beginning in 1992.

The European MAC system will offer at the margin substantially greater value-added to European consumers. The system is engineered to provide a data channel; to provide the opportunity for viewers to choose whatever language they desire for commentary or sound "dubbing" of films; and to provide several stereo audio signals. The system will also be compatible with existing cable television distribution systems.

Given the close economic linkages across the North Atlantic, European and US consumers will be subject to many of the same economic forces described earlier in the development of the US household scenarios. Thus, the rate at which the European market develops is also quite dependent on general economic conditions over the next decade and beyond.

Our approach to describing the European ATV market potential is to compare current European patterns of spending on electronic products to US spending and to use those relations as the basis for making inferences about possible market development rates in Europe.

Table 14 permits comparison of spending on selected electronic products categories in the US and in Western Europe. Roughly 75% of European sales are generated in West Germany, the

U.K., France and Italy. The data indicate that the European market has recently been about half the US market in major categories of spending on electronic products.

TABLE 14
Comparative Spending on Selected
Electronics Products (1986):
US and Western Europe

Product Class	Europe	US
Total Electronics Sales ($B)	97	198
Consumer Electronics Sales ($B)	15	29
Video Equipment Sales ($B)	8.6	17.7
Television Receivers (000,000 units)	16.0	22.0
Videocassette Recorders (000,000 units)	7.8	13.5

Source: 1987 Electronic Market Data Book: EIA Marketing Services Department for US data; and, Yearbook of World Electronics Data--1988--Western Europe, Volume 1, BENN Electronics

The exception to that pattern is spending on TV receivers. The relative strength of European receiver sales may reflect in part the fact that TV sets are less ubiquitous in Europe (around 35% population penetration) than in the US (50% population penetration). Thus, more European sales are probably to households without a TV than is the case in the US where about 98% of all households have at least one set. Secondly, we expect that the strength of VCR sales may lift the demand for receivers in Western Europe to a much greater extent than in the US, due to differences in the availability of alternative distribution media and programming.

The foregoing suggests that ATV products may well achieve faster diffusion and higher growth in Western Europe than in the US. For present purposes we will assume that the sales over time in Europe will at least match the US growth rate, but on a base

that is only one-half as large. Using that rule of thumb and applying it to the optimistic US scenario developed above, the resulting European scenario suggests a market for ATV receivers and VCRs in the neighborhood of $25 billion by the year 2003. That is about three times the amount spent on video equipment in Western Europe in 1986 and implies that such spending will grow at about eight percent a year, a rate which is by no means unreasonable in view of the substantial value added for consumers by the MAC technology.

Japan There are about 31 million television sets registered in Japan according to recent estimates. Since registration requires payment of a receiver tax, there may be more actually in use. Sales in the past three years alone sum to about 15 million units. Penetration of TV receivers in Japan is significantly less (254 sets per 1,000 population) than in the US or Western Europe. Almost 17 million VCRs have been sold to Japanese consumers in the past three years. Sales for the next three years have been projected to be closer to 18 million.[16]

In view of the progress made in Japan in virtually every aspect which is required to hasten the introduction and growth of ATV products, there is every reason to expect that product diffusion and market development there will exceed the rates suggested above for the US and, probably, Western Europe. Government and broad segments of the Japanese electronics industries are united in their efforts to meet a commonly accepted schedule for making compatible product and program distribution media available. This reflects a strong, clear and unified national commitment to promote the technology within both domestic markets and abroad. And, of course, NHK has a demonstrated technology and a well-defined production schedule. These conditions contrast sharply with the technological, regulatory, political and economic uncertainties cited above as characterizing the US environment.

Under any conceivable timetable for resolving the uncertainties in the US and making available US produced ATV products, NHK and their manufacturing licensees will have an enormous headstart in the Japanese market. Moreover, this experience will very likely be leveraged to great advantage in other world markets and in the US in particular.

V. IMPLICATIONS FOR THE MICROELECTRONICS INDUSTRY

The electronics industries make up a vast complex with numerous and frequently subtle linkages among their parts. Observers have likened the structure of these industries to an integrated fabric, a food chain, a seamless web or a pyramid with

semiconductor materials and manufacturing equipment/processes at the apex, which is the residence of the technological wherewithal for providing a broad range of commercial and consumer product applications.

The decline of US leadership in this important sector is amply documented. Several large scale research efforts and numerous technical papers have addressed and attempted to isolate its causes and consequences.[17] Our purpose here is decidedly more modest and the discussion will focus on the general nature of the linkages between the consumer electronics sector and the broader set of electronics industries, particularly the semiconductor industry.

The consensus view is disturbing. Loss of leadership in semiconductor production will breed dependency and lack of competitiveness in a broad array of downstream information industry product lines. Integrated circuitry has become as ubiquitous as energy as a necessary input into industrial and commercial processes. Indeed, it is almost impossible to find a line of commerce that does not rely in important respects on products and services embodying microelectronics technology. Factory automation, instrumentation, military hardware and systems, retailing, banking, as well as a great variety of consumer goods are increasingly driven by the information processing and storage capabilities of semiconductor technology.

The Office of Technology Assessment concluded a massive study of US competitiveness in electronics with the observation that, "[I]f there is any single industry whose technological progress and competitiveness are critical to the economic growth and national security of the United States, it is electronics."[18]

A similar view was expressed in a study originally prepared for the Joint Economic Committee of the US Congress: "For the foreseeable future, the relative economic strength of all advanced industrial economies will rest in part on their capacity to develop and apply semiconductor technology to product design and production processes."[19]

Nor is this view limited to US experts. The President of a major Italian electronics firm observed in 1986 that, "[A]s soon as the leading role of an enterprise in the development of semiconductors is lost, it becomes dependent upon the supplier of base technology and is degraded to being a dealer in electronic systems produced by others; and, when it no longer has command over semiconductor technology, it loses control over its own industrial fate."[20]

There is little dispute about the key role to be played by this technology in the development of national economies. The question of greatest interest here, however, centers on the

potential contribution of large scale participation in the manufacture of ATV products to the development of the domestic semiconductor industry. To put it differently, it is clear that semiconductors will be important to ATV product development, but how important will the production of ATV products be to the future development of the semiconductor industry? In what follows we will attempt to sketch the broad outlines of an answer.

One of the more striking historical changes in the semiconductor market is the transformation of its major user base. The semiconductor market in this country initially was driven almost exclusively by government demand for defense and space applications. Growth in commercial and industrial uses quickly outstripped government demand in the sixties and early seventies, so that by 1978 government purchases accounted for only about one-tenth of total sales of semiconductors in the US. The truly high growth sector in the past decade has been neither government nor the commercial sector, even though together they continue to command a high percentage of semiconductor output.

Consumer electronics applications, which were negligible in 1970, accounted for over 30% of total world consumption of integrated circuits by 1984. Much of the early demand was for use in watches, calculators, handheld games, and assorted toys. More recently, however, some of the more advanced product lines, including VCRs and limited intelligence TV receivers, have accounted for a growing share of total integrated circuit use.

Notwithstanding these worldwide trends, the share of the output of the US semiconductor industry destined for consumer electronics products has declined significantly during the past five years. Our best estimate, based on discussions with several industry experts, is that about 5-6% of US semiconductor output was incorporated into consumer products in 1986. In sharp contrast, almost one-third of Japanese semiconductors were shipped to, and used by, the consumer electronics sector in that year.

The ATV systems and products now under development will very likely lead to quantum increases in the demand for signal processing and storage capability, which in turn will require incorporation of several fairly sophisticated chips. Different system designs will have different requirements and both spectrum availability and receiver design standards will influence the amount of intelligence required in these consumer products. But, almost any conceivable outcome will boost demand for integrated circuitry substantially. For example, to convert a MUSE signal to make it compatible with NTSC receivers requires a converter consisting of four circuit boards, which will in the future be composed of five VLSI chips.

If the recent past is prologue, firms which capture substantial shares of the US consumer electronics market will tend to manufacture those products using components which they, or their close affiliates, manufacture. Put differently, it is doubtful that US imports of ATV products will include much in the way of US value-added components, including semiconductors. A recent estimate indicates that Japan accounts for about 40% of world consumption of semiconductors, much of which is incorporated into consumer electronics products, while less than 10% of Japanese consumption of semiconductors is of US origin.

A chain of reasoning which clearly demonstrates some of the more important linkages under consideration here appears in the Report of the Defense Science Board Task Force on Defense Semiconductor Dependency.[21] This Report, which provided much of the impetus for the SEMATECH consortium, concluded:

- US military forces depend heavily on technological superiority to win;
- Electronics is the technology that can be leveraged most highly;
- Semiconductors are the key to leadership in electronics;
- Competitive, high-volume production is the key to leadership in semiconductors;
- High-volume production is supported by the commercial market;
- Leadership in commercial volume production is being lost by the US semiconductor industry;
- Semiconductor technology leadership, which in this field is closely coupled to manufacturing leadership, will soon reside abroad;
- US Defense will soon depend on foreign sources for state-of-the-art technology in semiconductors. The Task Force views this as an unacceptable situation.[22]

There are other important synergies between semiconductor materials and manufacturing processes, the level of semiconductor sales, and downstream activities like manufacture of ATV