Final Report

AVAILABILITY AND COST OF CONSUMER ADVANCED TELEVISION (ATV) TECHNOLOGY

HOME BOX OFFICE, INC.
New York, New York

July 26, 1988

BOOZ•ALLEN & HAMILTON INC.

FOREWORD

This study was undertaken by Booz, Allen & Hamilton Inc. for Home Box Office Inc. (HBO), and the report has subsequently been made publicly available by HBO.

This is an exploratory study of prospective technology, costs and prices of advanced television (ATV) receivers. Uncertainties about standards and timing of introduction made it inappropriate to undertake a costing based on a detailed engineering design at this time. The study is not based on detailed consumer electronics manufacturing data for three reasons:

- The client is a not a manufacturer
- Manufacturers generally appear to be still at the early stages of the design process for ATV
- Detailed cost data are considered by manufacturers to be competitively sensitive information

The study is based on general engineering and costing principles, and on interviews with component manufacturers. While the findings of the study are subject to considerable uncertainty, since actual design features and introduction timing may vary considerably from what we have assumed, we believe the study provides a sound general indication of the broad levels of prices and costs that should be expected.

TABLE OF CONTENT

I. INTRODUCTION

HBO HAS ASKED BOOZ, ALLEN TO ANALYZE THE PROSPECTIVE TECHNOLOGY, COSTS AND PRICES OF HOME RECEIVERS FOR THE INTRODUCTION OF ADVANCED TELEVISION* (ATV) SERVICES...

- To complement the extensive work on ATV that has already been carried out in-house by HBO
- To gain a better understanding of likely ATV receiver technology and the implications for rollout timescales, costs and market prices for receivers
- To compare proposed and currently used approaches to compression technology in video transmission as well as the implications for receiver cost/complexity

---

* We have adopted the FCC terminology of "Advanced Television (ATV)" instead of the term "High Definition Television (HDTV)," which is less general.

THE CHIEF FOCUS OF THE STUDY IS THE PROJECTION OF LIKELY ATV RECEIVER PRICES FROM A SCENARIO-DRIVEN COMPUTER MODEL BASED ON...

- Application of the experience curve to receiver block elements
- Technology affecting key receiver components
- Estimates of technological requirements of different approaches to ATV
- Consumer adoption scenarios in terms of introduction and penetration rate
- Estimates of the amortization of R&D
- Estimates of value added in manufacturing and the distribution chain to derive retail price from component costs

II. DESCRIPTION OF THE RECEIVER COST MODEL

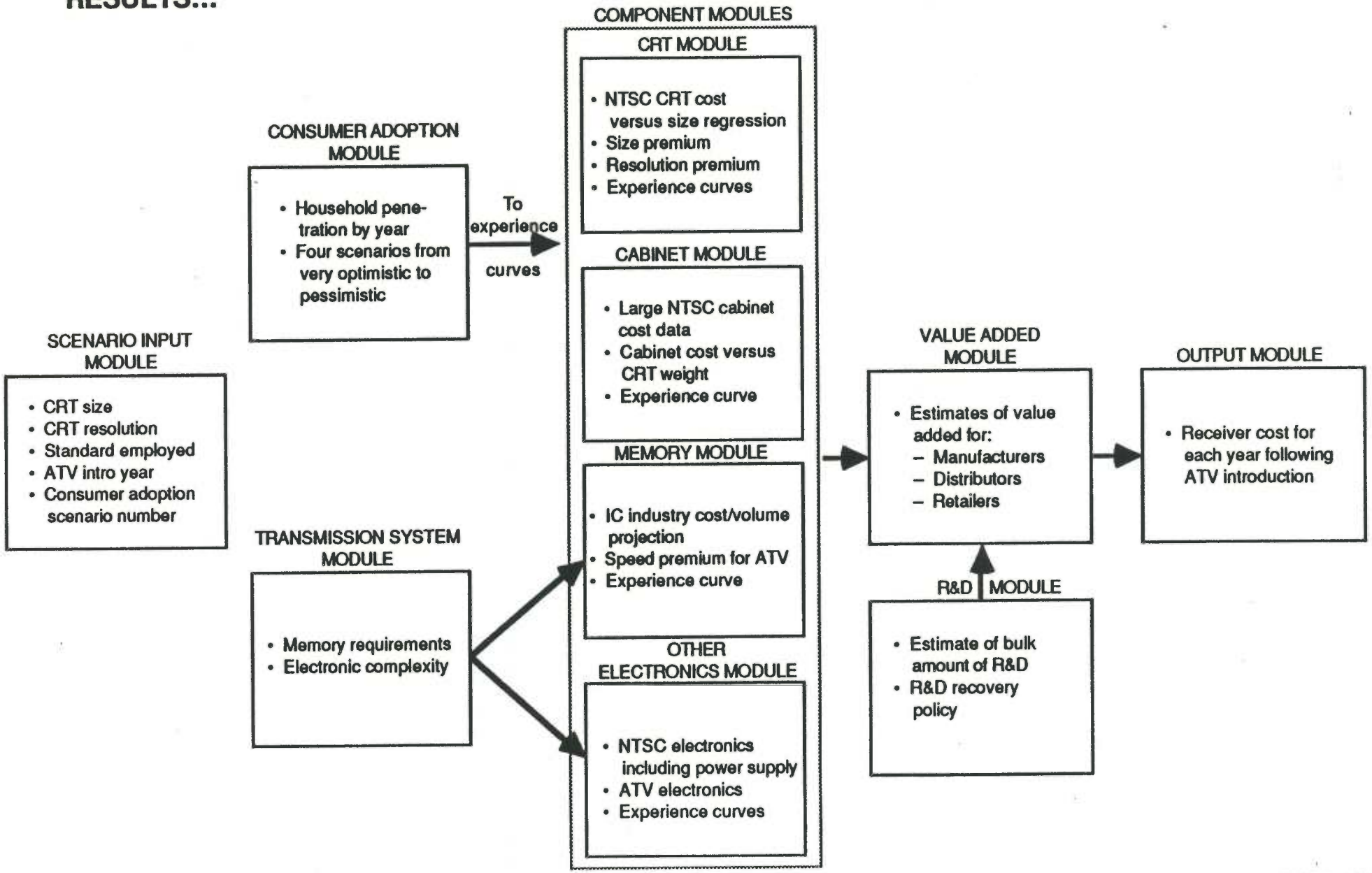
Overview...

THE ATV RECEIVER COST MODEL PROJECTS RETAIL PRICES BY BUILDING A CRT-BASED UNIT FROM THE GROUND UP...

	Year 1	Year 2	Year 3
Components costs			
CRT display			
Memory			
Other electronics			
Cabinet			
Subtotal			
R&D Costs			
Manufacturer value added			
Distributor value added			
Retail value added			
Retail List Price			

Overview...

THE MODEL IS STRUCTURED ACCORDING TO MODULES THAT ACCEPT SCENARIO PARAMETERS, PROJECT COSTS OF MAIN COMPONENTS, R&D, AND VALUE-ADDED AND GENERATES OUTPUT RESULTS...

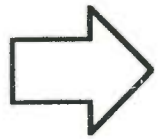


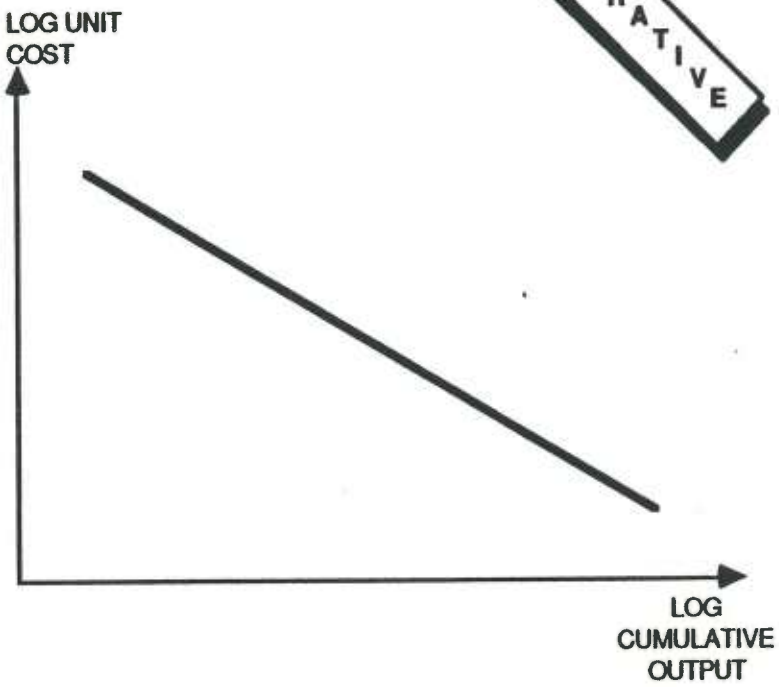
Overview...

CENTRAL TO THE METHODOLOGY IS THE EXPERIENCE CURVE, THE GENERAL EMPIRICAL OBSERVATION THAT FOR EACH DOUBLING OF CUMULATIVE OUTPUT, UNIT COSTS FALL BY A CONSTANT PERCENTAGE...

For an experience curve of 0.8*, every doubling of cumulative output causes unit cost to fall by 20%

CUMULATIVE OUTPUT	UNIT COST
1	100
2	80
4	64
8	51
16	41

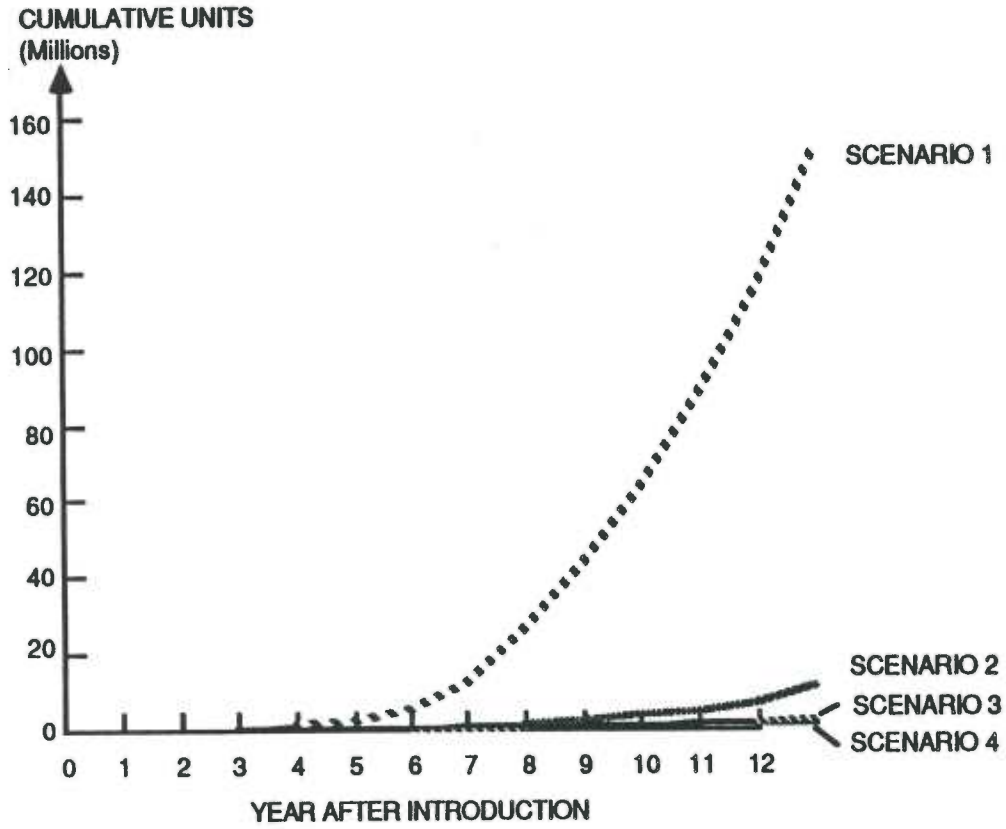




* Extensive research has shown that 0.8 is a typical value for general manufacturing. For instance, the experience slope for VCR manufacturing is 0.78.

Consumer Adoption...

THE CONSUMER ADOPTION MODULE PROVIDES FOUR SCENARIOS PROJECTING HOUSEHOLD PENETRATION AND CUMULATIVE UNITS OF ATV RECEIVERS SINCE INTRODUCTION AND SERVES AS AN INPUT TO THE EXPERIENCE CURVES...



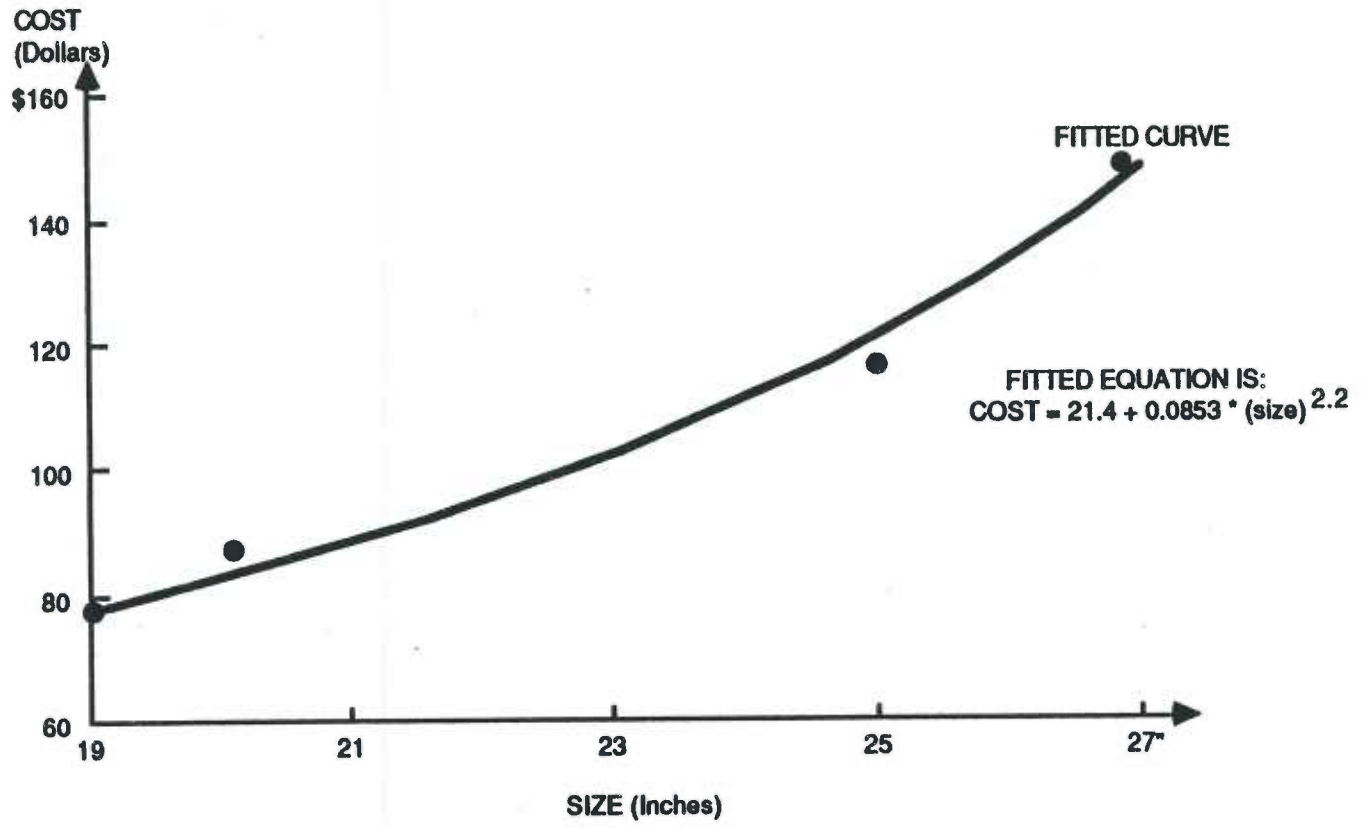
LEGEND	
Scenario 1	*Very Optimistic (CD)*
Scenario 2	*Optimistic (Color TV)*
Scenario 3	*Cautious Adoption*
Scenario 4	*Pessimistic*

CRT Module...

ATV CRT COSTS ARE MODELLED AS THE COST OF AN NTSC CRT PLUS PREMIA FOR LARGE SIZE AND HIGH RESOLUTION...

- Interviews of CRT manufacturers regarding cost of NTSC CRTs and subsequent regression analysis of size versus cost indicated:
  - CRT costs vary linearly with $(\text{size})^{2.2}$
  - There is a premium for both large size and high resolution
- The size premium is estimated by noting the difference in actual cost between large CRTs and the value predicted by the regression equation
- The resolution premium reflects the additional cost of adding higher resolution to current CRTs
  - For medium resolution (about 500 to 600 lines) the initial premium is 80% of the baseline NTSC cost
  - For high resolution (about 1,000 lines) the initial premium is 250% of the baseline NTSC cost

CURRENT NTSC CRT COSTS

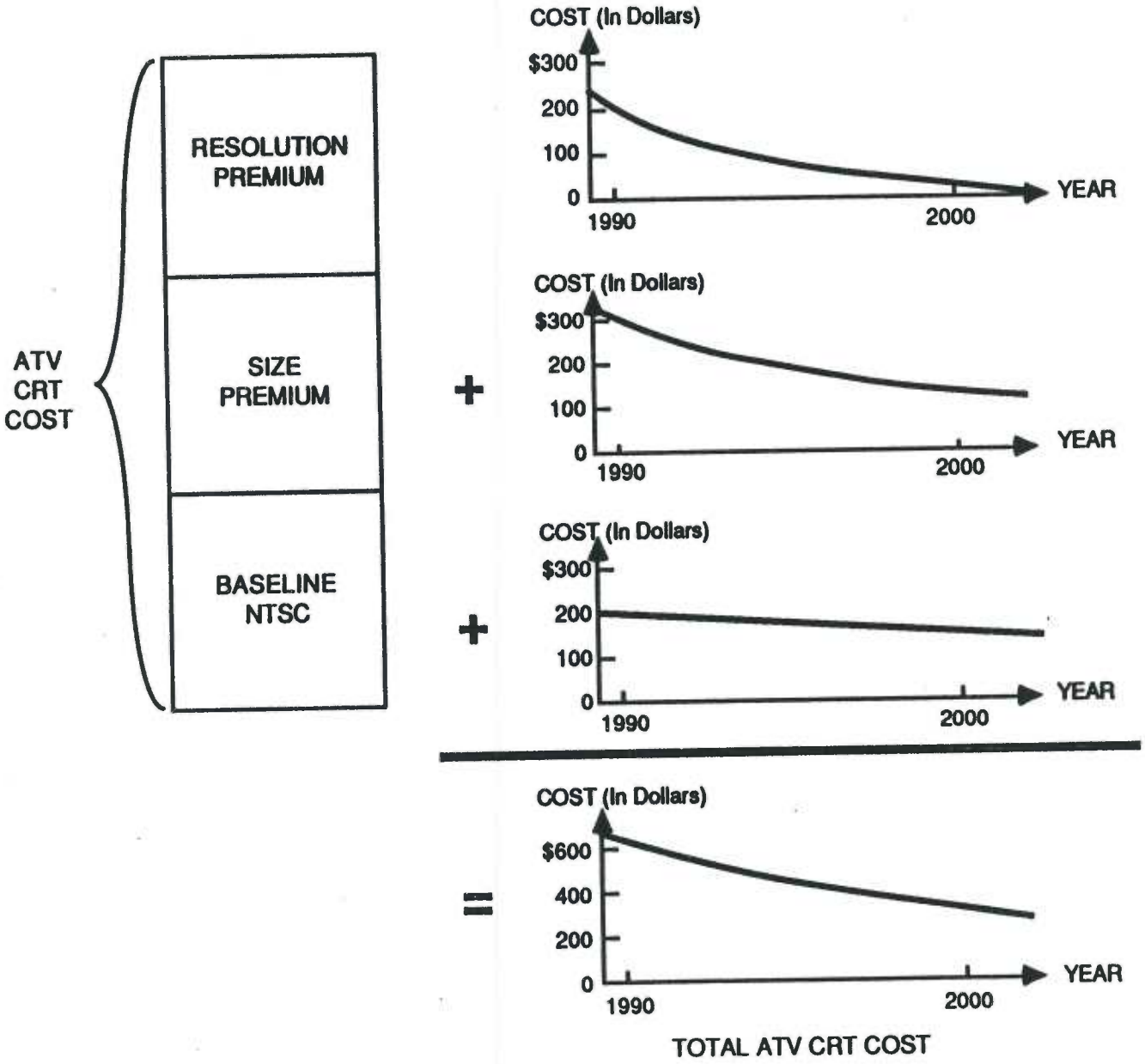


CRT Module...

EACH OF THE COMPONENTS OF CRT COSTS FOLLOWS A SEPARATE EXPERIENCE CURVE IN ORDER TO ARRIVE AT THE TOTAL CRT COST FOR EACH YEAR OF THE SCENARIO...

CRT Cost Components	Applicable Experience	Data Source	Experience Slope
. Baseline NTSC	NTSC CRTs	Historical NTSC production	0.8
. Size premium	Experience with large NTSC CRTs (>30 in) and ATV	Philips data on market for large CRTs and adoption scenario	0.8
. Resolution premium	ATV	Adoption scenario	0.8

ATV CRT COSTS ARE MODELLED AS THREE SEPARATE COMPONENTS...



Cabinet Module...

CABINET COSTS ARE BASED ON DISCUSSIONS WITH ZENITH AND OTHER INDUSTRY SOURCES...

- The main factor driving the cost of the cabinet is the size and the weight of the CRT
- For large CRT sizes, a good approximation is that the cost of the cabinet grows linearly with CRT weight
- Paper published by Matsushita engineers shows that CRT weight grows exponentially with size
- Experience curve used is that of NTSC

Memory Module...

MEMORY COSTS ARE BASED ON EXPERIENCE CURVE PARAMETERS AND VOLUME PROJECTIONS FROM AUTHORITATIVE SEMICONDUCTOR INDUSTRY SOURCES...

- The Integrated Circuit Engineering Corporation publishes an annual IC industry status report showing historical costs and volumes for memory on a per bit basis
  - Memory costs very closely conform to a 68% experience curve
  - Present memory costs are .77 millicents per bit ($62 per megabyte)
- Status report also publishes future volume projections so that experience curve can be used to derive implied future costs
- Memory costs used in the receiver model employ a speed premium
  - Interviews with TV industry sources indicate that ATV receivers will require faster than average memory
  - A two year cost premium was established - e.g., ATV memory costs for 1991 correspond to baseline costs in 1989

Other Electronics Module...

ATV ELECTRONICS COSTS ARE MODELLED AS THE COST OF BASIC NTSC COMPONENTS, PREMIA FOR HIGHER POWER AND BANDWIDTH REQUIREMENTS, AND COMPLETELY NEW ATV SIGNAL PROCESSING HARDWARE...

- Approach based on interviews with Motorola and National Semiconductor
- Current price of NTSC electronics is about $40
- High-power CRT deflection circuits and wide-bandwidth video amplifiers will add approximately $40 more
- Signal processing chips required for ATV will cost about $25 "at volume"; we have interpreted "at volume" as a cumulative production of 2 million
- Experience curve for NTSC is used for NTSC and basic enhancements; ATV semiconductor experience curve is used for new signal processing ICs

R&D Module...

R&D COSTS ARE DISTRIBUTED ACROSS RECEIVERS PRODUCED DURING THE TEN YEARS FOLLOWING INTRODUCTION...

- Bulk amount of R&D of $300 million is based on budgets for HDTV development of several organizations
  - NHK
  - David Sarnoff Research Center
  - Sony
  - Eureka project participants
- This bulk amount is recovered across 10 years
  - 80% is recovered equally across each set produced during these 10 years
  - 20% is recovered equally across each year of this period
- 80% * Bulk Amount / (cumulative production in first 10 years)
  + 20% * (Bulk Amount / 10) / (annual production in year x)
  = Total R&D cost per set in year x

Value Added Module...

THE VALUE ADDED MODULE APPLIES ESTIMATES OF VALUE ADDED BY MANUFACTURER, DISTRIBUTOR AND RETAILER IN BUILDING UP THE RETAIL PRICE FROM THE COST OF COMPONENTS AND R&D...

- Manufacturer value added of 100% of components costs is based on interviews with industry sources and analysis of NTSC prices
- Distribution and retail value added of 15% and 40% respectively are based on a recent EIA report on consumer electronics prepared by Arthur D. Little
  - These margins correspond to "suggested retail price"
  - We understand that in mature stage there could be heavy discounting but probably not in early stages of product life
- (Components cost * (1 + 100%) + R&D costs) * (1 + 15%) * (1 + 40%) = Retail Price

III. ATV RECEIVER COSTS

AS A MEANS OF STRUCTURING THE MODELLING PROCESS WE HAVE ADOPTED A BASELINE SCENARIO...

- **ATV introduction in 1991**
- **Consumer adoption based on optimistic (color-TV) scenario**
- **CRT size of 35 inches, medium resolution**
- **ATV transmission system: ACTV***
- **All dollar figures are current (1988) dollars**

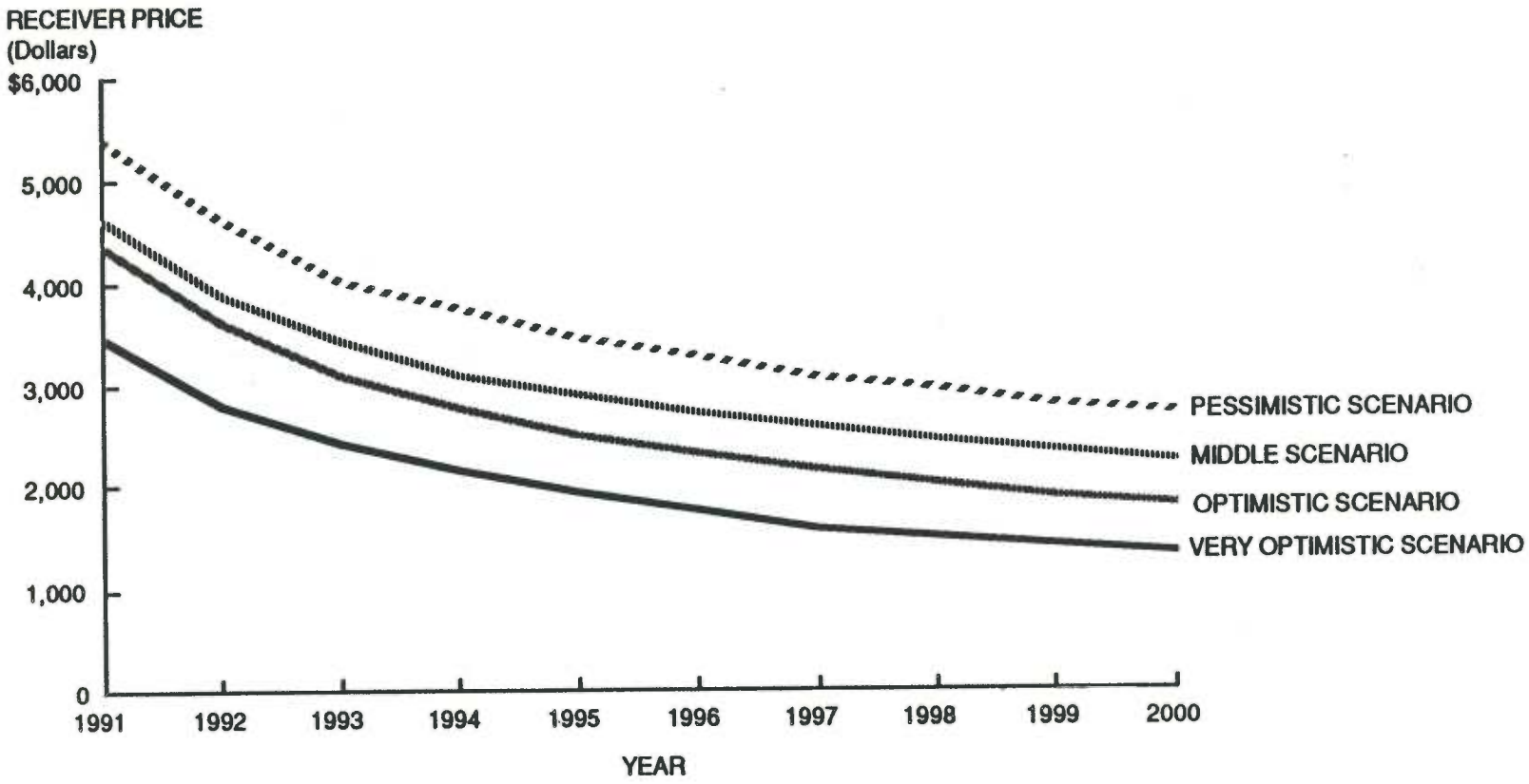
---

* Cost impact of other transmission systems is also addressed in this section.

FOR THIS BASELINE SCENARIO, INTRODUCTION PRICE IS APPROXIMATELY $4,300 FALLING TO $2,300 AFTER FIVE YEARS, WITH CRT COST BEING THE DRIVING COMPONENT COST...

	1991 $ COST	1992 $ COST	1993 $ COST	1994 $ COST	1995 $ COST	1996 $ COST
MANUFACTURING COSTS						
Component Costs:						
• CRT Display	670	592	540	497	462	432
• Memory	75	57	42	31	23	17
• Other Electronics	354	254	204	170	147	130
• Cabinet	121	118	114	111	108	105
SUBTOTAL	1,221	1,021	900	809	739	684
R&D COSTS	255	205	122	98	79	71
OTHER MANUFACTURING COSTS AND MARGIN	1,221	1,021	900	809	739	684
TOTAL FACTORY PRICE	2,697	2,248	1,922	1,717	1,558	1,438
DISTRIBUTION CHAIN MARKUP						
Distribution Markup	405	337	288	258	234	216
Retail Markup	1,240	1,034	884	790	717	661
RETAIL LIST PRICE	4,342	3,620	3,095	2,764	2,509	2,315

A FASTER ADOPTION LEADS TO LOWER PRICES FOR ATV RECEIVERS, BUT PRICES WILL FALL ANYWAY, EVEN IN A PESSIMISTIC SCENARIO, BECAUSE OF INDEPENDENT DEVELOPMENTS IN FIELDS SUCH AS SEMICONDUCTOR MEMORY AND LARGE CRTs...



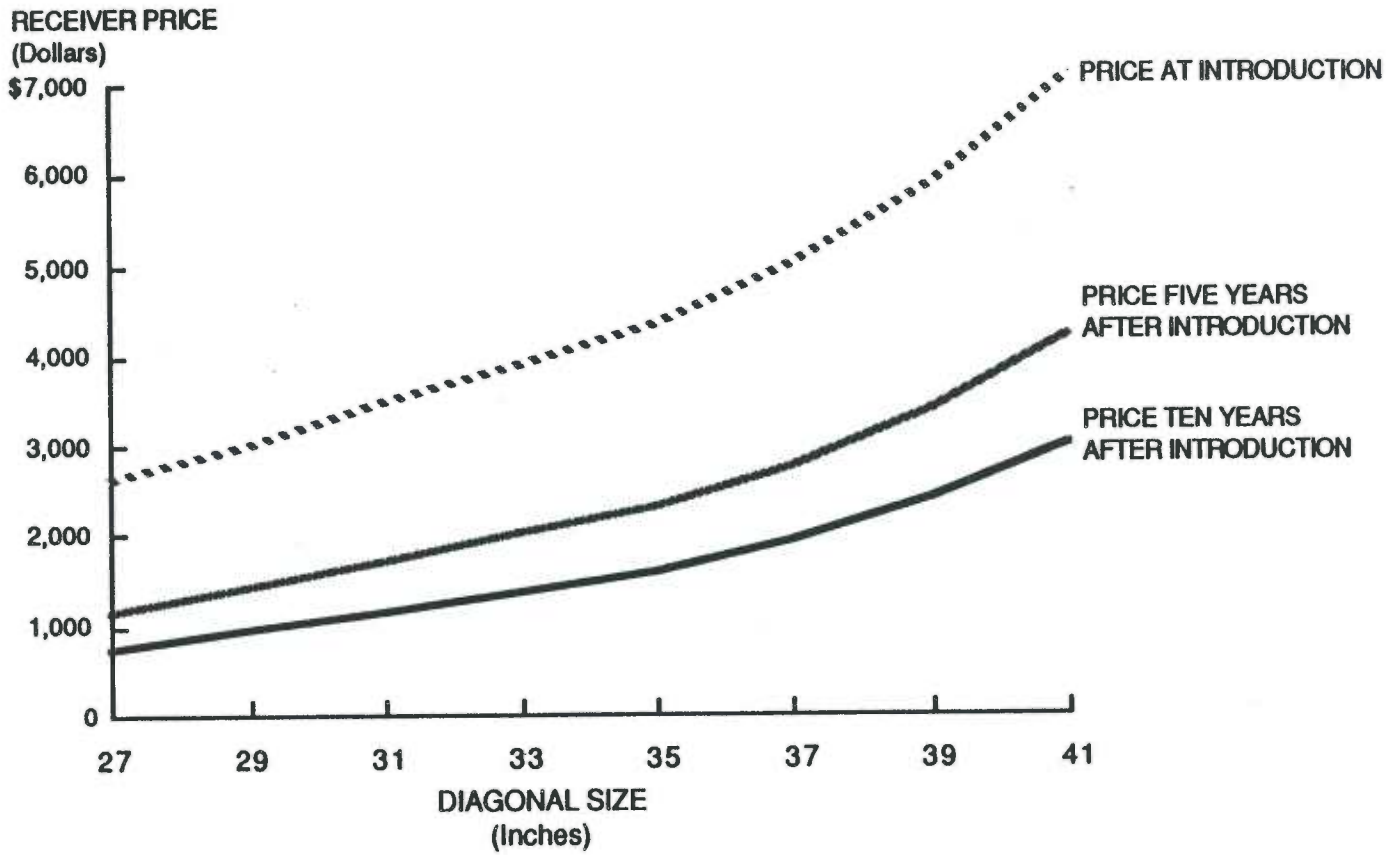
Note: All prices are given for a 35" medium resolution ACTV receiver introduced in 1991.

BECAUSE OF THESE INDEPENDENT DEVELOPMENTS, LATER INTRODUCTION MEANS LOWER INTRODUCTION PRICES...

Year of Introduction	Price at Introduction ($)
1990	4,598
1991	4,342
1992	4,148
1993	3,987
1994	3,857
1995	3,750

Note: All prices are given for a 35" medium resolution ACTV receiver, 30,000 units being produced during the first year.

CRT SIZE IS A DRIVING FACTOR FOR THE PRICE OF THE RECEIVER...



Note: All prices are given for a medium resolution ACTV receiver, introduced in 1991, and assuming optimistic scenario.

HOWEVER, THERE IS ONLY LIMITED FREEDOM IN FIXING THE CRT SIZE...

- Size has to be large enough to exploit advantages of ATV
  - The higher resolution of ATV can only be perceived if the viewing angle is wide enough
  - Because of aspect ratio variation, a 33" diagonal ATV CRT has only the same height as a 27" diagonal NTSC CRT
- Very large CRTs are still in very early development
  - The first 41" CRT TV set was introduced by Matsushita in July 1987 at a price of $13,000
  - The weight of the CRT grows exponentially with its diagonal size and rapidly becomes a problem

...THEREFORE, A SIZE OF 31 TO 35 INCH CRT SEEMS LIKELY FOR THE INTRODUCTION OF ATV. WE HAVE ALSO CONSIDERED ALTERNATIVE FORMS OF DISPLAY TO THE EXTENT FEASIBLE AND WILL COMMENT ON THOSE

CRT RESOLUTION IS ALSO A MAJOR FACTOR, MAINLY DURING THE FIRST YEARS AFTER INTRODUCTION...

	Medium Resolution (500-600 TVL/PH) Full Resolution of ACTV	High Resolution (1,000 TVL/PH) Full Resolution of MUSE
Introduction price	$4,342	$5,483
5 years after introduction	$2,315	$2,741
10 years after introduction	$1,613	$1,811

Note: All prices are given for a 35" ACTV receiver, assuming the optimistic scenario and introduction in 1991.

FIRST ATV GENERATION WILL PROBABLY CONSIST OF MEDIUM RESOLUTION RECEIVERS, EVEN IF THE TRANSMISSION SYSTEM PROVIDES HIGH RESOLUTION...

- For most ATV purchasers, the cost premium of high resolution versus medium resolution will not be justified

- There is a precedent for early hardware not exploiting the full capabilities of the transmission system - it took 35 years for NTSC receivers to accurately perform chrominance/luminance separation

STANDARD ADOPTED ALSO HAS AN INFLUENCE ON RECEIVER COST, BUT THIS INFLUENCE IS LIMITED AND ONLY LASTS A FEW YEARS...

	Medium Complexity Electronics No Memory (e.g., HDB-MAC)	High Complexity Electronics 2 Mbytes Memory (e.g., Del Rey)
Introduction Price	$3,682	$4,402
5 years after introduction	$2,183	$2,329
10 years after introduction	$1,580	$1,617

Notes:
- All prices are given for a 35" medium resolution receiver, assuming the optimistic scenario and introduction in 1991.
- For electronics complexity and memory requirement of other transmission systems, see Appendix B.

...HOWEVER, INDIRECT EFFECT DUE TO INFLUENCE OF CHOSEN STANDARD ON ADOPTION SCENARIO SHOULD ALSO BE TAKEN INTO ACCOUNT

ATV COULD ALSO COME THROUGH REAR PROJECTION RECEIVERS...

- Experts' opinion vary as to whether first ATV receivers will be CRT or projection based
  - Projection receivers use no shadow mask and therefore require fewer modifications to move to higher resolution
  - However, there are still some problems to be overcome with projection technology
    - Insufficient brightness
    - Need for sophisticated devices for heat dissipation
    - Insufficient contrast ratio
- Most experts think that after a few years, most ATV receivers will be projectors
  - To really take advantage of ATV, large screen sizes are required
  - For large sizes, projection technology is less expensive

IN A LONGER TERM, SEVERAL NEW DISPLAY TECHNOLOGIES COULD BE ADOPTED...

. **Liquid Crystal Display**

- Sharp has demonstrated a 14" direct view LCD
- Sharp and Comtrex International have each demonstrated LCD projectors, but resolution remains low
- Technology needs to acquire capability of higher resolution and larger size

. **Light Valve Projector**

- GE/Eidophore technology is successful but extremely expensive
- New developments, such as the active-matrix solid-state driver chip proposed by Glenn, could lead to lower prices but are still in their early stages

. **Plasma Display**

- Research is progressing, notably at NHK
- Many problems have to be overcome, such as low luminous efficiency, limited resolution, and high cost

...DEVELOPMENTS IN THESE TECHNOLOGIES COULD HAVE A MAJOR EFFECT ON PRICES OF ATV RECEIVERS. HOWEVER, ACTUAL COMMERCIAL POTENTIAL IS STILL UNKNOWN

SOME GENERAL FINDINGS EMERGE FROM THE MODEL...

- At least initially, receivers will be expensive, on the order of $4,300 for a 35 inch medium resolution receiver

- The primary factor affecting cost is display technology

  - Improvements/cost reductions with large, high resolution CRTs
  - Improvements/cost reduction in CRT-based rear projectors
  - Development in alternative technologies

- ATV transmission system employed doesn't appear at this point to have the major impact on receiver cost

- Assuming the optimistic scenario and a 35" medium resolution receiver, price falls to approximately $2,300 five years after introduction (-47% compared to initial price) and $1,600 ten years after introduction (-63% compared to initial price)

ALTHOUGH THE DETAILS OF THE IMPLIED RECEIVER COST/COMPLEXITY FOR TRANSMISSION SYSTEMS ARE NOT YET KNOWN, INTERVIEWS WITH SEMICONDUCTOR MANUFACTURERS SUGGEST THAT MULTIPLE-STANDARD CAPABILITY WILL NOT SIGNIFICANTLY AFFECT RECEIVER COST...

- Electronics themselves do not appear to be the major cost driver of ATV receivers
- Semiconductor manufacturers have already gained some multiple-standard experience through dual capability PAL/NTSC chip set
- Memories and microprocessing capabilities will be shared among different transmission systems

...THE ACTUAL RAMIFICATIONS OF MULTIPLE STANDARDS WILL BECOME CLEARER IN THE COMING MONTHS AS SYSTEMS PROPONENTS FLESH OUT THEIR ELECTRONIC COMPLEXITY AND SEMICONDUCTOR MANUFACTURERS DEVELOP DETAILED PROJECTIONS

TELEVISION MANUFACTURERS ARE OPPOSED TO THE IDEA OF MULTIPLE STANDARDS IN GENERAL AND "OPEN ARCHITECTURE" IN PARTICULAR...

- Through participation in the Electronics Industries Association (EIA), manufacturers have taken the position of supporting one common standard

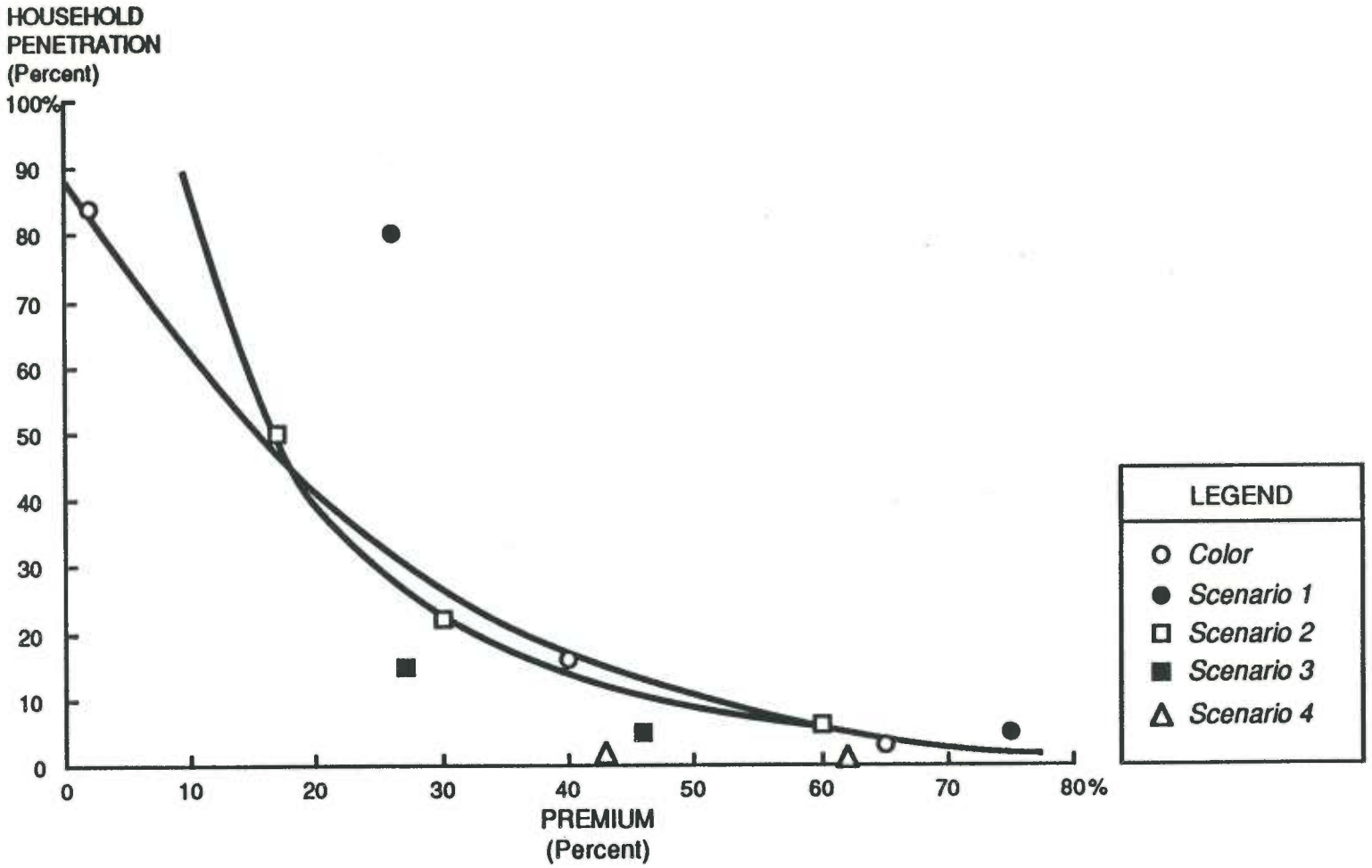
  - Initial EIA meeting took place June 7, 1988
  - Representatives from
    - Thomson
    - David Sarnoff Research Center
    - Matsushita/Panasonic
    - Toshiba America
    - Zenith
    - Mitsubishi

- EIA letter to FCC chairman Patrick dated June 30, 1988 argues against open architecture:

  - Will delay ATV introduction
  - Will increase receiver cost/complexity
  - Will raise safety concerns
  - Will cause consumer confusion

...HOWEVER, TV MANUFACTURERS DO NOT OPPOSE STANDARD INTERFACES THAT ALLOW ACCESS TO "KEY POINTS IN THE SIGNAL PATH"

CONSIDERING THE "OPTIMISTIC" SCENARIO, ATV PREMIA ARE COMPARABLE TO PREMIA PEOPLE PAID FOR COLOR TELEVISION...



Color premium: Color compared to 1953 Black & White.
ATV premium: ATV (medium resolution 35" ACTV receiver introduced in 1991) compared to 1991 27" NTSC.

SOME IMPLICATIONS CAN BE DRAWN FROM THE MODEL...

- If consumers value ATV relative to NTSC as they did color relative to black and white, then "optimistic" scenario is plausible with respect to price elasticity
- Receiver cost should not be the determining factor in selection of standard
- Use of multiple standards does not seem to have a major impact on receiver cost
- Cost implications of "open architecture" is a more open question.
  Manufacturers are definitely opposed

IV. COMPRESSION TECHNOLOGY

OUR STUDY OF VIDEO COMPRESSION TECHNIQUES IS BUILT UPON A SURVEY OF TECHNICAL LITERATURE AS WELL AS INTERVIEWS WITH ATV TRANSMISSION SYSTEM PROPONENTS AND MAJOR RESEARCH LABS...

COMPRESSION INTERVIEWS

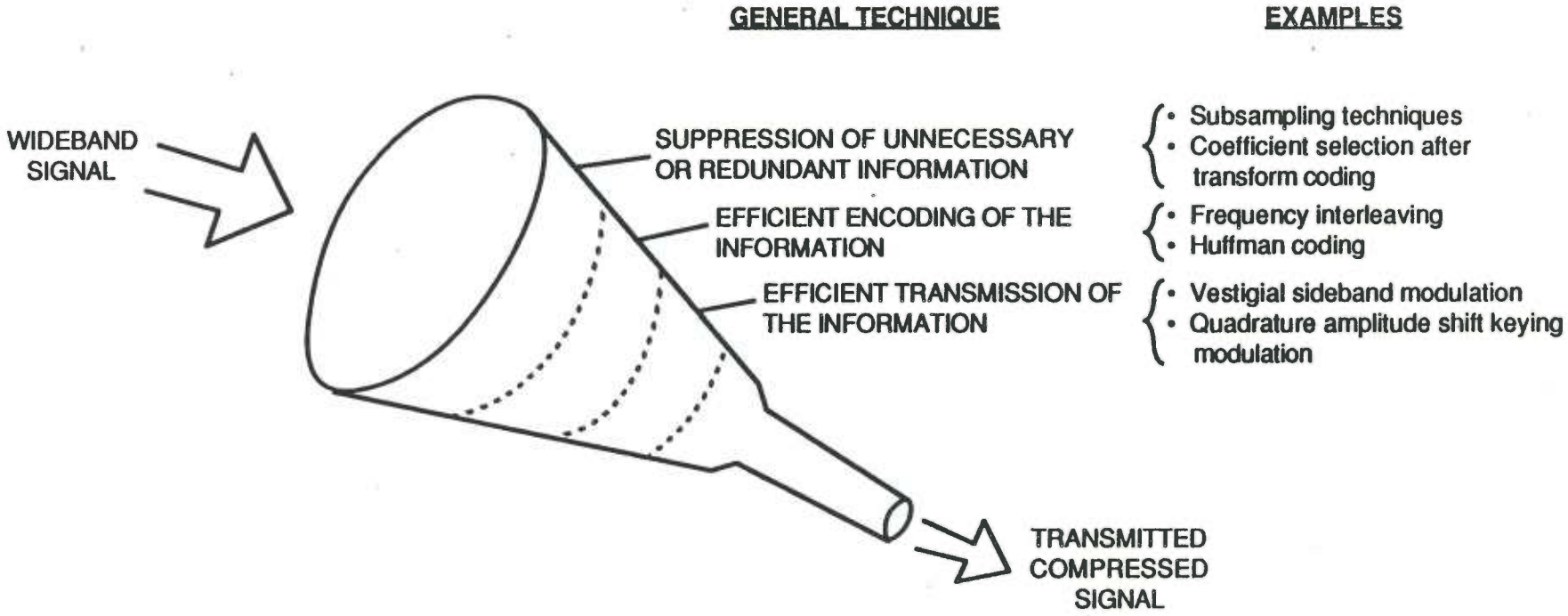
Organization	Contact
Faroudja Labs	Ron Zimbrick
David Sarnoff Research Center	Jack Fuhrer
Del Rey Group	Richard Iredale
New York Institute of Technology	William Glenn
North American Philips	Mr. Greebe
Scientific Atlanta	Keith Lucas
MIT	William Schreiber
Bell Labs	Ted Rzeszewski
Bell Core	Hugo Gaggioni

COMPRESSION IS INHERENTLY AN IMPERFECT PROCESS AND THEREFORE IMPLIES TRADEOFFS...

- **Spatial resolution versus temporal resolution**
- **Compression technique efficiency versus required receiver complexity**
- **Quality of reception on a dedicated receiver versus compatibility**
- **Compression technique efficiency versus noise immunity**

...THESE TRADEOFFS CAN HAVE MAJOR EFFECTS ON PERCEIVED SIGNAL QUALITY AS WELL AS RECEIVER COST/COMPLEXITY

THREE GENERAL TECHNIQUES CAN BE EMPLOYED IN COMPRESSING A WIDEBAND SIGNAL FOR MOST EFFICIENT TRANSMISSION...



THE GENERAL COMPRESSION TECHNIQUE UNIVERSALLY EMPLOYED BY ATV TRANSMISSION SYSTEMS IS THAT OF SUPPRESSION OF UNNECESSARY OR REDUNDANT INFORMATION...

SPECIFIC TECHNIQUE	EFFECT	MOTIVATION	USE	SYSTEMS
Two-dimensional Prefiltering	Reduced Diagonal Resolution	The Visual System Has Less Resolution In The Diagonal Orientation Than In The Horizontal And Vertical Directions	Frequency Interleaving Of Additional Information	HDB-MAC
Three-dimensional Prefiltering	Some Resolution Reduction	A Diamond-Shaped Spatio-Temporal Frequency Response Is The Best Fit To The Visual System	Frequency Interleaving Of Additional Information	ACTV
			Sub-Nyquist Sampling Without Aliasing Problems	Del Rey Narrow MUSE/MUSE
Diagonal Sampling	Reduced Diagonal Resolution	The Visual System Has Less Resolution In The Diagonal Orientation Than In The Horizontal And Vertical Directions	Diagonally Sampled Information Can Be Transmitted With A Reduced Bandwidth	Vista
Transmission Of Several Spatio-Temporal Components Approximating A Diamond-Shaped Frequency Response	Some Resolution Reduction	A Diamond-Shaped Spatio-Temporal Frequency Response Is The Best Fit To The Visual System	No Bandwidth Is Wasted For Noncritical Information	HDNTSC/HDMAC 60 MIT-RC MIT-CC
Predictive Coding Of A Bandlimited Helper Signal	Slightly Jagged Diagonal Edges On Moving Objects	This Artifact Is Not Too Annoying	Enhanced Vertical Resolution Can Be Transmitted With A Reduced Bandwidth	ACTV HDNTSC/HDMAC 60 HDB-MAC
Temporal Subsampling Of High Resolution Details	Slight Flicker For High Resolution Details	The Visual System Has A Poor Temporal Resolution For High Resolution Details	Enhanced Spatial Resolution Can Be Transmitted With A Reduced Bandwidth	Vista HDNTSC/HDMAC 60 MIT-RC MIT-CC
Dot Interlace	Some Blurring For Moving Portions Of The Picture	Tradeoff Between Temporal And Spatial Resolution	Higher Resolution Can Be Transmitted For Static Portions Of The Picture Without Additional Bandwidth	Del Rey Narrow MUSE/MUSE
Several Transmission Modes	Some Blurring For Moving Portions Of The Picture	Tradeoff Between Temporal And Spatial Resolution	Information Considered As The Most Important, Depending On The Degree Of Motion, Is Transmitted	MUSE 6/MUSE 9 Narrow MUSE/MUSE MIT-CC

OTHER TECHNIQUES ARE BASED ON AN OPTIMAL USE OF THE AVAILABLE BANDWIDTH THROUGH EFFICIENT ENCODING AND/OR EFFICIENT TRANSMISSION...

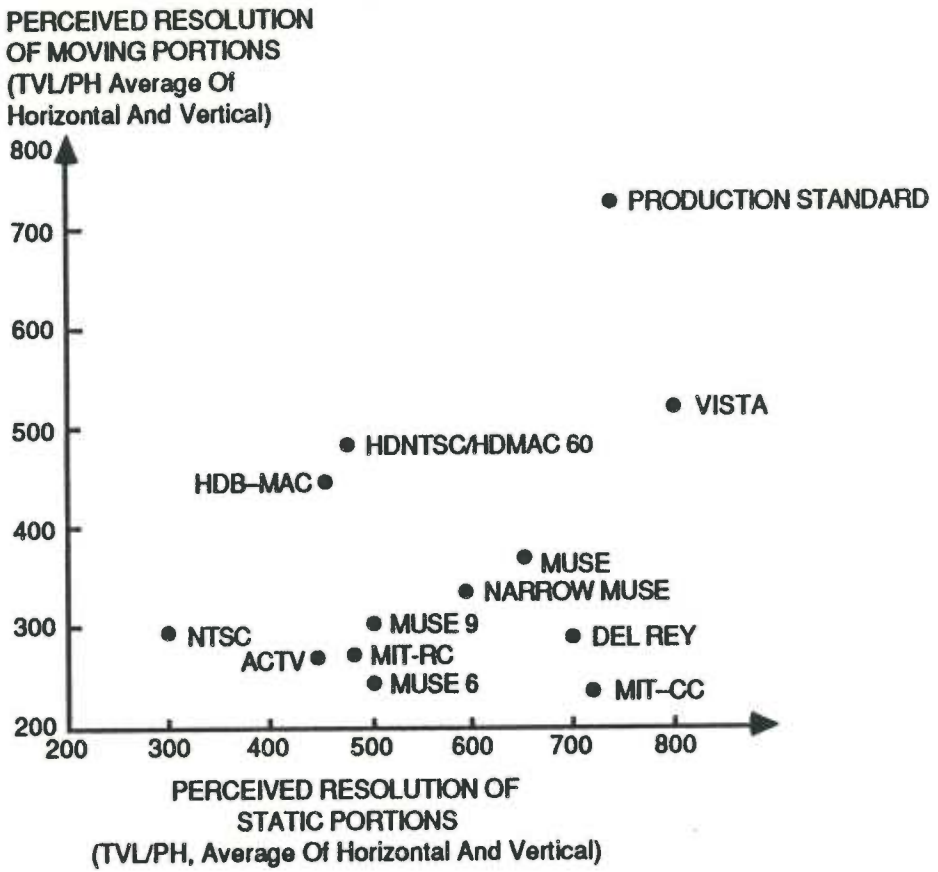
- Shortening or invading of the horizontal blanking period
  - All noncompatible systems have a shorter horizontal blanking period (HDMAC60, HDB-MAC, MIT-CC, MUSE)
  - Some compatible systems invade the NTSC horizontal blanking period (ACTV, DEL REY, VISTA)
- Use of dark bands
  - Some compatible systems use dark bands at top and bottom of the screen to allow wider aspect ratio
  - Additional information can be transmitted during the period corresponding to these dark bands (DEL REY, MIT-RC, MUSE6/MUSE9)
- Quadrature modulation
  - Addition of a second carrier, in quadrature with the main carrier (ACTV)
  - Double-sideband quadrature modulation (MIT-CC)

MOST ATV TRANSMISSION SYSTEMS USE A COMBINATION OF COMPRESSION TECHNIQUES...

	ACTV DSRC	HD-NTSC DEL REY	MIT-RC MIT	MUSE 6/ MUSE 9 NHK	VISTA NYIT	HDNTSC NAP	MIT-CC MIT	HDB-MAC SA	HDMAC 60 NAP	MUSE/ Narrow MUSE NHK
Two-Dimensional Prefiltering								●		
Three-Dimensional Prefiltering	Interleaving Of Additional Information	Sub-Nyquist Sampling								Sub-Nyquist Sampling
Diagonal Sampling					●					
Transmission Of Several Spatio-Temporal Components				●		●			●	●
Predictive Coding	●					●		●	●	
Temporal Subsampling			●		●	Optional (Or Suppression Of These Details)	●		Optional (Or Suppression Of These Details)	
Dot Interlace		●								With Motion Compensation
Several Transmission Modes				●			●			●
Use Of The Horizontal Blanking Period	●	●			●	For The Augmentation Channel	●	●	●	●
Use Of Dark Bands		●	●	●						
Quadrature Modulation	●						●			

HOXOF S002

THESE COMPRESSION TECHNIQUES IMPLY VARIOUS TRADEOFFS BETWEEN THE RESOLUTION OF STATIC AND MOVING PORTIONS OF THE PICTURE...



Note: Information based on interviews and recently published specifications not independently verified.

HOWEVER, RESOLUTION IS ONLY ONE OF THE FEATURES WHICH HAVE TO BE TAKEN INTO ACCOUNT WHEN CONSIDERING AN ATV TRANSMISSION SYSTEM...

	1 CHANNEL COMPATIBLE			2 CHANNEL COMPATIBLE		1 CHANNEL INCOMPATIBLE			
	ACTV DSRC	HD-NTSC DEL REY	MIT-RC MIT	VISTA NYIT	HDNTSC NAP	MIT-CC MIT	HDB-MAC SA	HDMAC 60 NAP	MUSE NHK
Aspect Ratio	5:3 (Should Be Changed to 16:9)	5:3	16:9	5:3	16:9	16:9	16:9	16:9	16:9
Bandwidth	6 MHz (RF)	6 MHz (RF)	6 MHz (RF)	6+6 MHz Or 6+3MHz (RF)	6+4 MHz (RF)	6 MHz (RF)	10.7 MHz (Baseband)	9.5 MHz (Baseband)	8.1 MHz (Baseband)
Reception On An NTSC Receiver (Compatibility)	◕	◒	◕	●	●	○	○	○	○
Resolution Of Static Portions	◒	●	◒	●	◒	●	◒	◒	●
Handling Of Motion	○	○	○	◒	●	◕	●	●	◒
Color Resolution	○	○	○	●	◒	●	◒	◒	●
Sound And Data	○	◒	○	◒	◕	◕	●	◕	●
Estimated Noise Immunity	○	◕	◒	◒	◒	◕	◒	◒	◕
Estimated Mulitpath And Micro-Reflection Immunity	◕	◒	◒	◒	◒	◕	◒	◕	◕
State Of Development	◕	○	○	◒	◒	○	◒	◕	●

... MORE INFORMATION ON THESE SYTEMS AS WELL AS ON OTHER SYSTEMS DEVELOPED BY NHK CAN BE FOUND IN APPENDIX A

FILM AND CABLE FRIENDLINESS OF THE ATV TRANSMISSION SYSTEMS ARE ALSO VERY IMPORTANT FOR HBO...

. **Film friendliness**

- **MIT-CC is the only system which is really film friendly, as it uses frame rates which are multiples of 12Hz**

- **For all other systems, frame rate conversion is necessary**

  .. **Most proponents envision using three to two pull down, as for NTSC encoding**
  .. **However, it's also possible to do some temporal interpolation, which would enhance the motion rendition**

. **Cable friendliness**

- **Systems using only 6MHz are easier to transmit via cable**

- **Interview with Glenn suggests that some cable plants use the horizontal blanking period to transmit some scrambling information. This could be a problem for systems that "invade" the horizontal blanking period (ACTV, Del Rey, Vista)**

- **Ghost cancellors should be available in a few years to avoid the problem of microreflection**

Model Assumptions...

NTSC PENETRATION MODULE

- CAGR for NTSC is 9.5%
- Annual volume peaks at 40 million
- Each new ATV set sold cannibalizes sales of two NTSC sets

Model Assumptions...

TRANSMISSION SYSTEMS MODULE

- Aspect ratio and resolution associated with each transmission system are only given for information but are not used by the model
  - It is assumed that any "adopted" transmission system will have an aspect ratio of 16:9
  - CRT display resolution chosen by the model user can be different from transmission system resolution capability
- Memory required and electronics complexity result from interviews as well as scan of the literature

Model Assumptions...

TRANSMISSION SYSTEMS MODULE

Transmission System	Memory Required (Mb)	Electronics Complexity
ACTV	1.6	High
DEL REY	2.0	High
MIT-RC	2.0	High
VISTA	1.0	High
HDNTSC/HDMAC 60	0.0	Medium
HDB-MAC	0.0	Medium
MIT-CC	2.0	High
MUSE6	1.0	High
MUSE9	1.0	High
NARROW MUSE	1.0	High
MUSE	1.0	High

Model Assumptions...

CRT MODULE

- Baseline cost
  - Grows with $(size)^{2.2}$
  - Adjustment is made to take into account new aspect ratio
- Large size premium is a percentage of baseline cost, depending on the size of the CRT
- Resolution premium is also a percentage of baseline cost
  - 80% for medium resolution
  - 250% for high resolution
- Experience curves

	Baseline	Size Premium	Resolution Premium
Experience Curve	NTSC	Large Size CRT	ATV
Experience Slope	.8	.8	.8
Cumulative Experience Required	240 million	1.34 million	30,000

Model Assumptions...

MEMORY MODULE

- CAGR for bit volume after 1991 = 66%
- Experience slope: 68%
- Cost of speedy memory in year X = cost of standard memory in year X-2

Model Assumptions...

OTHER ELECTRONICS MODULE

- Cost of medium complexity ATV signal processing is half of full complexity
- Experience curves:

	Basic NTSC Hardware	Basic Enhancements	ATV Signal Processing
Experience Curve	NTSC	NTSC	ATV
Experience Slope	.8	.8	.68
Cumulative Experience Required	240 million	240 million	2 million
Cost Corresponding To That Cumulative Experience	$65	$40	$25

Model Assumptions...

CABINET MODULE

- Cost of large-size cabinets grows linearly with the weight of the CRT
- An adjustment is made to take into account new aspect ratio
- Applicable experience curve is NTSC

Model Assumptions...

VALUE ADDED MODULE

- Manufacturing value added: 100% of components costs
- Distribution value added: 15%
- Retail value added: 40%

Model Assumptions...

R&D MODULE

- Bulk amount of R&D: 300 million dollars
- Number of years to recover R&D: 10
- Percentage of bulk amount which is to be recovered equally across each set produced during these 10 years: 80%
- Percentage of bulk amount which is to be recovered equally across each year of this period: 20%
- 80% * 300 million / (cumulative production in first 10 years)
  + 20% * (300 million / 10) / (annual production in year x)
  = Total R&D cost per set in year x