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Volume II

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With

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FINAL REPORT

PREPARED FOR:

NASA-LEWIS RESEARCH CENTER
CLEVELAND, OHIO 44135

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APPENDIX 2 TELECOMMUNICATIONS EVENTS

Event	Year	Probability
Numbers of television stations		
940	1980	1.00
1174	1985	1.00
1460	1990	1.00
1794	1995	1.00
2200	2000	1.00
3250	2010	1.00
4800	2020	1.00
7120	2030	1.00
10540	2040	1.00
Percent of households with Cable TV, if historical rate of market growth continues		
25%	1980	.95
50%	1994	.90
90%	2019	.80
99%	2040	.70
Numbers of Long Distance Calls (millions per day)		
61	1980	1.00
83	1985	1.00
113	1990	1.00
156	1995	1.00
216	2000	1.00
Percent of Telephone System using digital local loop		
10%	1988	.90
50%	1995	.80
90%	2002	.70
Percent of Long Distance Calls transmitted digitally		
10%	1980	.95
50%	1984	.90
90%	1994	.85
Percent of local loop installations using fiber optics		
10%	1981	1.00
50%	1985	1.00
90%	1997	1.00
Percent of long distance calls transmitted over fiber optics		
10%	1986	.90
50%	1990	.80
90%	1999	.70

Event	Year	Probability
Percent of Cable TV systems using fiber optics		
10%	1986	.90
50%	1990	.80
90%	2000	.70
Percent of Cable TV systems having a Fiber Optics return channel (from subscriber to head end)		
10%	1987	.90
50%	2001	.80
90%	2016	.70
Percent of Cable TV transmitted over telephone system fiber optics local loops		
10%	1985	.15
50%	1995	.10
90%	2004	.05
Percent of households having Video Disc (or equivalent video playback equipment)		
Using purchased video disc program materials		
10%	1990	.90
50%	1998	.75
90%	2006	.60
Using material recorded off the air		
10%	1989	.80
50%	1997	.70
90%	2005	.60
Percent of households with TV Games		
10%	1982	.95
50%	1987	.85
90%	1992	.75
Percent of households with CATV Games (interacting with hardware & software at head end)		
This development depends upon availability of return channels; see cross impacts for timing & probability		
Percent of Cable TV systems having a return channel (without fiber optics)		
10%	1990	.50
50%	2000	.40
90%	2010	.30
Electronic Stock Market	1985	.85
Electronic Check Clearing	1980	.85

Event	Year	Probability
Percent of Retail Sales using Point of Sale Electronic Funds Transfer		
10%	1983	.95
50%	1989	.90
90%	1995	.85
Numbers of Wideband (6 MHz) satellite channels available to U.S.		
600	1980	1.00
1100	1984	1.00
2000	1990	1.00
3700	2000	1.00
6000	2010	1.00
12300	Not possible without channel-expanding new technology;	
22000	see cross impacts for timing and probability	
Launch of 2000 Kilogram Satellite		
Overall probability 80%; if launched at all, probability is 0.03 in each of 1980 - 1984; 0.17 in each of 1985 - 1989.		
Launch of 6000 Kilogram Satellite		
Overall probability 60%; if launched at all, probability is 0.10 in each of 1990 - 1999.		
Launch of Orbital Platform (multiple antennas, multiple frequencies)	1986	.15
Launch of satellite with narrow spot beams		
Not possible until specific technology developments are available; see cross impacts for timing and probability		
Use of polarized beams to double transmission capacity at all frequencies	1985	.25
Digital Coding to increase channel capacity. Overall probability 50%; if available, probability is 0.10 in each of 1985 - 1994.		
Direct Broadcast, satellite to home		
10 channels	1995	.10
30 channels	2005	.10
60 channels	2015	.10

Event		Year	Probability
Special Broadcast TV, satellite to subscriber			
2000 channels	Two alternative schedules; see cross impacts for timing and probability		
6000 channels			
9000 channels			
13000 channels	Not possible without new technology; see cross impacts for timing and probability		
Percent of transportation (e.g., trains, trucks, taxis) using satellites for communication			
10%		1990	1.00
50%		1998	1.00
90%		2005	1.00
Special radio programming for professionals, satellite to subscriber. Percent of professionals using this service:			
10%	Three alternative schedules. See cross impacts for timing and probability		
50%			
90%			
Percent of professionals using Electronic Library services			
10%	Three alternative schedules. See cross impacts for timing and probability		
50%			
90%			
Special Household Applications. Percent of households using services:			
10%	Three alternative schedules. See cross impacts for timing and probability		
50%			
90%			
Percent of schools using Electronic Library services			
10%	Three alternative schedules. See cross impacts for timing and probability		
50%			
90%			
Computer Aided Instruction in schools			
Broadcast from satellite			
10%	Three alternative schedules, plus requirements for channel-expanding technologies. See cross impacts for timing and probability		
50%			
90%			
Using local computer			
10%	Three alternative schedules. See cross impacts for timing and probability		
50%			
90%			

Event	Year	Probability
Public Service applications, percent of maximum utilization		
10%	2006	.60
50%	2016	.60
90%	2025	.60
Business communications by satellite, percent of market		
10%	1993	.80
50%	2000	.80
90%	2007	.80
Videoconferencing, percent of market		
10% Three alternative schedules. See cross impacts		
50% for timing and probability		
90%		
Electronic Mail, percent of market		
10%	1985	.70
50%	1995	.60
90%	2005	.50

APPENDIX 3 CROSS IMPACTS

Event	Year	Probability
Number of television stations, if		
1) Cable TV has 50 and 90% market penetration		
2200	2006	1.00
3250	2016	1.00
4800	2025	1.00
7120	2031	1.00
2) Video cassette purchase events occur		
1460	1991	1.00
1794	1997	1.00
2200	2012	1.00
3250	2013	1.00
4800	2023	1.00
7120	2033	1.00
3) TV games exist		
1174	1988	1.00
1460	1995	1.00
1794	2000	1.00
2200	2006	1.00
3250	2016	1.00
4800	2027	1.00
7120	2037	1.00
4) Cable TV games exist		
1794	1996	1.00
2200	2004	1.00
3250	2015	1.00
4800	2026	1.00
7120	2037	1.00
Percent of households with Cable TV, if		
1) Under fast market penetration		
50%	1987	.90
90%	1998	.80
99%	2000	.70
2) Computer aided instruction for homeviewers through local computers at 50% market penetration occurs		
90%	2017	.90
99%	2035	.85

Event	Year	Probability
3) Computer aided instruction for homeviewers through local computers at 90% market penetration occurs		
90%	2018	.90
99%	2035	.85
4) Direct broadcast with 30 channels occurs		
90%	2000	.80
5) Direct broadcast with 60 channels occurs		
90%	2029	.80
99%	2040	.00
Numbers of long distance calls (millions per day), if business communications by satellites occur		
83	1986	1.00
113	1991	1.00
156	1996	1.00
216	2002	1.00
Percent of telephone system using digital local loop, if long distance calls transmitted digitally or local loop installations using fiber optics		
10%	1988	.95
50%	1995	.90
90%	2002	.85
Percent of telephone system using digital local loop, if point-of-sale electronic funds transfer is available		
10%	1987	.95
50%	1993	.95
90%	2001	.95
Percent of long distance calls transmitted digitally, if the electronic check clearing event occurs		
50%	1983	.95
90%	1992	.93
Percent of local loop installations using fiber optics, if		
1) digital local loops exist		
50%	1984	1.00
90%	1996	1.00
2) the fast market penetration occurs		
10%	1980	1.00
50%	1984	1.00
90%	1988	1.00

Event	Year	Probability
3) 10% of Cable TV or long distance calls are transmitted digitally		
50%	1987	1.00
90%	1996	1.00
4) 50% of Cable TV or long distance calls are transmitted digitally		
90%	1996	1.00
Percent of long distance calls transmitted over fiber optics, if		
1) long distance calls are transmitted digitally		
10%	1985	.95
50%	1988	.90
90%	1998	.85
2) local loop installations using fiber optics		
10%	1985	.95
50%	1989	.90
90%	1998	.85
3) the fast market penetration occurs		
10%	1985	.90
50%	1988	.80
90%	1992	.75
4) Cable TV systems using fiber optics		
10%	1985	.92
50%	1989	.85
90%	1998	.75
Percent of Cable TV systems using fiber optics, if		
1) local loop installations using fiber optics		
10%	1984	.95
50%	1989	.90
90%	1992	.85
2) 10% of long distance calls are transmitted over fiber optics		
50%	1989	.90
3) the same portion of long distance calls transmitted over fiber optics		
50%	1989	.90
90%	1999	.85
4) under the fast market penetration		
10%	1985	.90
50%	1988	.80
90%	1999	.70

Event	Year	Probability
5) 50% of Cable TV transmitted over telephone system fiber optics local loops		
90%	1995	0.00
6) 10% of computer aided instruction for homeviewer occurs		
10%	1986	.95
7) the same portion of Cable TV systems does not exist		
50%	1990	.00
90%	2000	.00

Percent of Cable TV systems having a fiber optics return channel, if

1) under the fast market penetration		
10%	1987	.90
50%	1995	.80
90%	2002	.70
2) the same portion of Cable TV return channel exists		
50%	2001	.90
90%	2016	.85
3) the same portion of Cable TV transmitted over telephone system fiber optics local loop		
10%	1985	.90
50%	1995	.80
90%	2004	.70
4) 10% of TV games exists		
10%	1987	.98
5) under fast Cable TV market penetration		
10%	1986	.90

Percent of Cable TV transmitted over telephone system fiber optics local loops, if

1) the same portion of CATV return cahnnel exists		
10%	1985	.08
50%	1995	.05
90%	2004	.03
2) the same portion of Cable TV having a fiber optics return channel		
10%	1985	.08
50%	1995	.05
90%	2004	.03

Event	Year	Probability
3) the same portion of local loop installations using fiber optics does not exist		
10%	1981	.00
50%	1985	.00
90%	1997	.00
4) the same portion of Cable TV systems using fiber optics does not exist		
10%	1985	.50
50%	1995	.45
90%	2004	.40
5) 50% of Cable TV systems using fiber optics exist		
90%	1990	.00
Percent of households having video disc and using purchased video disc program material, if		
1) numbers of TV stations follow the projected growth curve		
10%	1991	.90
50%	1999	.75
90%	2007	.65
2) numbers of TV stations do not follow the projected growth curve		
10%	1990	.95
50%	1998	.80
90%	2006	.65
3) the same portion of households having video disc using material recorded off the air		
10%	1990	.95
50%	1998	.85
90%	2006	.65
4) the same portion of TV games market exists		
10%	1992	.90
50%	2000	.75
90%	2008	.60
5) the same portion of Cable TV games market exists		
10%	1992	.90
50%	2000	.75
90%	2008	.60

Event	Year	Probability
Percent of households having video disc and using material recorded off the air, if		
1) numbers of TV stations follow the projected growth curve		
10%	1989	.85
50%	1997	.75
90%	2005	.65
2) numbers of TV stations does not follow the projected growth curve		
10%	1989	.70
50%	1997	.65
90%	2005	.55
Percent of households with Cable TV games, if		
1) the same portion of households, having video disc and using purchased video disc program material, exists		
10%	1993	.00
50%	2005	.00
90%	2026	.00
2) the same portion of Cable TV system having a return channel but without fiber optics		
10%	1992	.30
50%	1998	.30
90%	2012	.30
Percent of Cable TV systems having a return channel but without fiber optics, if		
1) 10% of computer aided instruction for homeviewers using local computers, exists		
10%	1990	.60
50%	2000	.50
2) 50% of computer aided instruction for home-viewers, using local computers, exists		
50%	2000	.60
90%	2010	.50
3) 90% of computer aided instruction for homeviewers using local computers, exists		
90%	2010	.60
Numbers of wideband (6MHz) satellite channels available to the U.S., if		
1) 2000 kilogram satellites exist		
2000	1982	1.00
3700	1985	1.00
6000	1988	1.00

Event	Year	Probability
2) any of spot beam, digital coding with a compression ratio of 4, or combinations of polarization and digital coding with a compression ratio of 2 or 3 is available		
3700	immediate	1.00
6000	immediate	1.00
12300	1999	1.00
22500	2008	1.00
3) any of polarization or digital coding with lower compression ratios (2 or 3) is available		
3700	immediate	1.00
6000	immediate	1.00
Launch of 6000 kilogram satellite, if		
1) orbital platform exists	1986	.00
2) 2000 channels special broadcast TV exist	1990-1999	.70
Launch of satellite with narrow spot beams, if		
1) 6000 kilogram satellites are in orbits	current	.85
2) orbital platforms are launched	current	.95
Direct broadcast (satellite to home), if		
1) Cable TV reaches 50% market penetration		
10 channels	1995	.05
30 channels	2005	.05
2) TV games at 50 or 90% market		
10 channels	1995	.07
3) Cable TV return channels exist		
10 channels	1995	.07
30 channels	2005	.07
60 channels	2015	.07
4) 2000 channels special broadcast TV exist		
10 channels	1995	.15
5) 6000 channels special broadcast TV exist		
30 channels	1997	.15
6) 9000 channels special broadcast TV exist		
60 channels	2003	.15

Event	Year	Probability
7) Video conferencing market reaches 10%		
10 channels	1995	.15
30 channels	2005	.15
8) Video conferencing market reaches 50%		
30 channels	2005	.15
9) Video conferencing market reaches 90%		
60 channels	2015	.15
Special broadcast TV (satellite to subscriber), if		
1) under a fast growth curve,		
2000 channels	1988	.90
6000 channels	1992	.85
9000 channels	1997	.80
13000 channels	2002	.75
2) under a slow growth curve,		
2000 channels	1988	.90
6000 channels	2000	.85
9000 channels	2010	.80
13000 channels	2020	.75
Percent of special radio programming for professionals (satellite to subscriber), if		
1) under early market penetration schedule		
10%	1982	.80
50%	1992	.80
90%	1997	.80
2) under mid market penetration schedule		
10%	1987	.80
50%	1992	.80
90%	1997	.80
3) under late market penetration schedule		
10%	1992	.80
50%	1997	.80
90%	2002	.80
Percent of transportation using satellites for communication, if		
1) under early market penetration schedule		
10%	1980	1.00
50%	1988	1.00
90%	1995	1.00

Event	Year	Probability
2) under mid market penetration schedule		
10%	1985	1.00
50%	1993	1.00
90%	2000	1.00
Percent of professionals using electronic library services, if		
1) under early market penetration schedule		
10%	1985	.60
50%	1995	.60
90%	2004	.60
2) under mid market penetration schedule		
10%	1990	.60
50%	1999	.60
90%	2009	.60
3) under late market penetration schedule		
10%	2000	.60
50%	2010	.60
90%	2019	.60
Percent of households using satellite communications service, if		
1) under early market penetration schedule		
10%	1985	.40
50%	1995	.40
90%	2005	.40
2) under mid market penetration schedule		
10%	1990	.40
50%	1999	.40
90%	2009	.40
3) under late market penetration schedule		
10%	1995	.40
50%	2005	.40
90%	2014	.40
Percent of schools using electronic library services, if		
1) under early market penetration schedule		
10%	1985	.60
50%	1993	.60
90%	2001	.60
2) under mid market penetration schedule		
10%	1990	.60
50%	1998	.60
90%	2005	.60

Event	Year	Probability
3) under late market penetration schedule		
10%	1995	.60
50%	2002	.60
90%	2010	.60
Percent of computer aided instruction in schools (broadcast from satellite or using local computer), if		
1) under early market penetration schedule		
10%	1985	.30
50%	1993	.30
90%	2001	.30
2) under mid market penetration schedule		
10%	1990	.30
50%	1998	.30
90%	2005	.30
3) under late market penetration schedule		
10%	1995	.30
50%	2002	.30
90%	2010	.30
4) the same portion of households, having video disc and using purchased video disc program material, exist		
10%	1997	.25
50%	2005	.25
90%	2014	.25
Public service applications (percent of maximum utilization), if		
1) under early market penetration schedule		
10%	1996	.60
50%	2006	.60
90%	2015	.60
2) under mid market penetration schedule		
10%	2001	.60
50%	2010	.60
90%	2020	.60
Business communications by satellite (percent of market), if		
1) under early market penetration schedule		
10%	1983	.80
50%	1990	.80
90%	1997	.80

Event	Year	Probability
2) under mid market penetration schedule		
10%	1988	.80
50%	1995	.80
90%	2005	.80
Video conferencing (percent of market), if		
1) under early market penetration schedule		
10%	1990	.10
50%	1995	.10
90%	2000	.10
2) under late market penetration schedule		
10%	2005	.10
50%	2010	.10
90%	2015	.10

APPENDIX 4

MARKET PENETRATION

4.1 INTRODUCTION

4.1.1 Description of Innovation Process

Product innovation is critical to survival and essential to growth both for companies within a free enterprise system and also countries in a world-wide context. The pace of technological advances, coupled with increased receptivity to progress and newness, is shortening the life cycles of established products and placing a premium on new products.

New product introduction comes not without large costs however, in terms of resources, time, and effort. In addition, the risk of product non-acceptance today remains at a very high level. Thus, the more that is known of the diffusion process the more the chances of success are maximized.

Diffusion is the process by which something spreads. Rural sociologists, educationalists, economists, communication researchers, and marketers among others have studied the diffusion of ideas, technologies, and products through various systems. Everett Rogers maintains a current bibliography of diffusion studies that now number in the thousands.[1]

The diffusion process as it relates to product innovations "refers to the percentage of potential adopters within a social system or market segment who adopt the product over time."[2] It is this process that the penetration study will examine and hope to quantify for the Product/Market Segments of interest.

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[1] Everett Rogers, DIFFUSION OF INNOVATIONS BIBLIOGRAPHY, Michigan State Center for the Study of Diffusion, East Lansing, Michigan.

[2] Thomas Robertson, INNOVATIVE BEHAVIOR AND COMMUNICATION (New York: Holt, Rinehart, and Winston, 1971), p. 30.

4.1.2 Definition of Product Area

The primary scope of the overall study is in the area of telecommunication innovations. These cover such products as telephone, teletype, radio, television, facsimile transmission, and other forms of similar communication as opposed to the physical transportation of bulk media such as via letters, books, magazines, newspapers, and others. Whenever possible, the penetration model for each market segment will be developed through study of the diffusion of previous telecommunication innovations through that segment. There are several limitations which may preclude this from always being possible.

First, the unavailability of secondary data on the diffusion of products through specific markets may make the use of them in this study difficult. Second, the collection of primary data for those areas where previous studies have not been done would be prohibitively expensive for the current study. And third, the time necessary for collection of data necessitates the use of secondary data whenever possible.

Because of the proceeding limitations surrogate innovations may have to be utilized in certain instances. When this is done every effort will be made to use those products for which a reasonable assumption can be made as to the similarity of their acceptance and acceptance of telecommunication devices.

4.1.3 Definition of Markets Covered

Those markets that appeared to have the largest potential for acception of telecommunication innovations were utilized. While every effort was made to be as specific as possible within a market and to use as complete a survey of the market as could be done, this was not always possible. Because of the general nature of telecommunication products much cross utilization is possible. Thus, sales of various products would provide no real clue as to their diffusion within various submarkets. Surveys of the markets themselves had to be used to obtain this data. While many times they were available, were quite good, and were complete, often they included other segments which were not desired or were done only on a small portion of the appropriate market. In these cases care was taken to utilize the best available data.

Sufficient data were found to develop at least some penetration model for eight markets. They were banks, general business establishments, hospitals, large manufacturing firms, municipal governments, professional people, wholesale organizations, and the consumer market. In addition, enough data were found to develop models for subsets of three of these markets. Within the bank market is a breakdown into small banks, medium banks, and large banks. Within municipal government is a breakdown into administration and police departments. And within the consumer market is a breakdown into household products and individual ones. Each of these markets and submarkets are described more fully in the market analysis section.

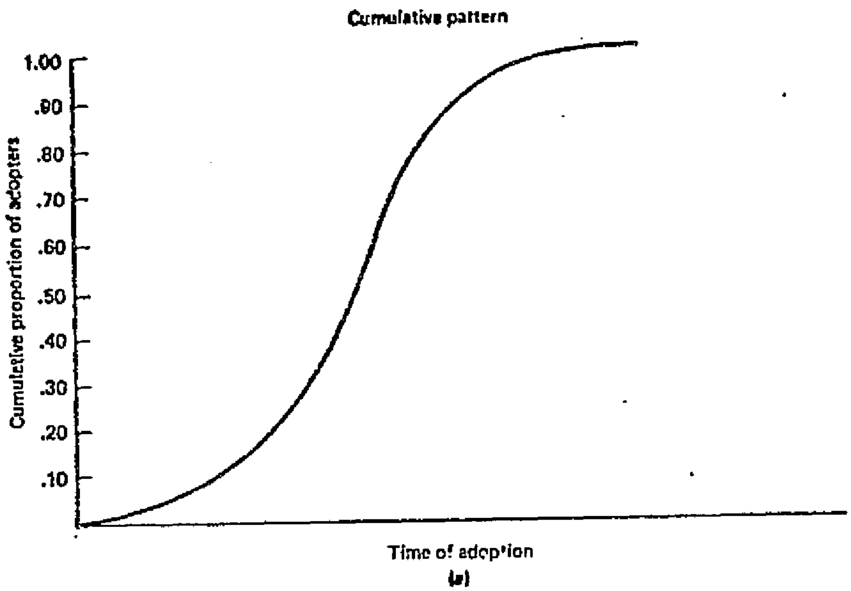
4.2 MEASUREMENT OF ADOPTION

4.2.1 Discussion of Models

The cumulative diffusion curve is generally considered to resemble an S-shaped growth pattern. Penetration is initially slow, then becomes quite rapid, and finally slows again as the last remnants of the old technology are crowded out, or the market is captured completely.

The primary reason for this type of curve is the propensity of most groups to contain only a few innovators willing to try a new product on its own merits. The majority of the group normally waits until the product has been tested by this early group and then follow suit. Rogers, among others, has found the distribution of adopters over time to be a fairly normal distribution.[1] The cumulative distribution function, when derived from such a normally distributed density function, tends to exhibit a logistic pattern, as described above. Figure (4.1) shows the generalized cumulative and noncumulative diffusion patterns.

Several mathematical functions have been utilized to describe the S diffusion growth curve. From the standpoint of goodness of fit, none of the



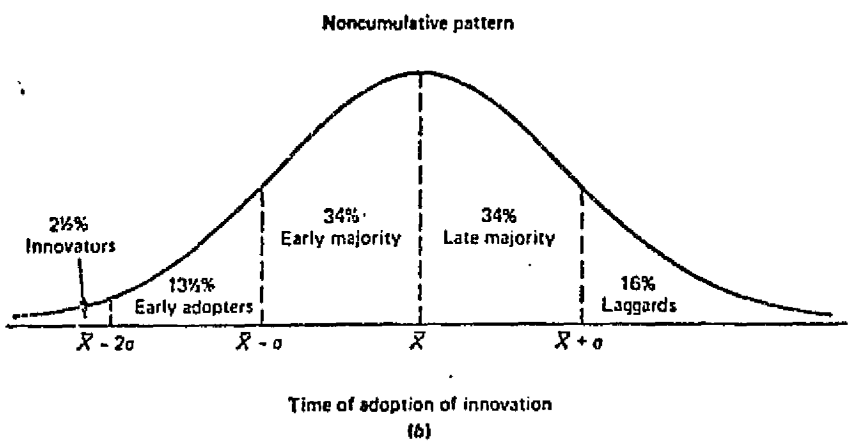


Figure 4.1 Generalized Cumulative and Noncumulative Diffusion Patterns

common formulas is noticeably superior to the others. In fact, when the commonly-used curves are plotted one on top of the other, it is difficult to tell them apart. One of the most familiar studies in this area was done by Mansfield, involving technological substitution.[3]

Mansfield exploited the mathematical convenience of the logistic curve in developing a model for the diffusion of innovations in various industries. He examined three innovations in each of four industries, and fitted logistic curves to the time history of market penetration for each of the 12 innovations. The parameter B for each fitted growth curve then was a direct measure of the rate of diffusion of the corresponding innovation. He then identified various parameters which might have an effect on the rate of diffusion, and included these in a regression model the purpose of which was to "predict" the B parameter. He found that with a satisfactory degree of accuracy, B could be predicted by a model which included a constant term (different for each industry), a term involving the capital investment required to adopt the innovation, and a term involving the profitability of the innovation. The profitability term entered with a positive sign, meaning that greater profitability hastened adoption; the investment term entered with a negative sign, indicating that greater investment need retarded diffusion. The industry-specific constant term represented a measure of the relative innovativeness of each of the four industries studied. He examined many other possible factors, and found that they had little or no effect upon rate of innovation. That is, in his model they had little power to predict the B parameter, as compared with investment and profitability. The end result of Mansfield's work was that a model had been developed which could predict the rate of diffusion of an innovation through an industry, when the investment required, and the profitability of that innovation, were known. In addition, his model required an industry-specific innovativeness coefficient, which could be determined only by fitting his model to several innovations in the industry of interest.

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[3] Edwin Mansfield, THE ECONOMICS OF TECHNOLOGICAL CHANGE (New York: Norton, 1968).

Several extensions to the original Mansfield model have been made in the years since Mansfield published his work. One of the most important extensions is that of Blackman[4]. Blackman, et. al. showed that the industry-specific innovativeness coefficient in Mansfield's model could be predicted from variables including R&D expenditures, value added, and ratio of Federal Reserve Board index. Thus with the availability of this result, it became possible to predict the rate of diffusion in an industry, knowing two characteristics of the innovation (required investment and profitability), and several characteristics of the industry in which the innovation was to be adopted. Blackman also showed that Mansfield's model could be extended to predict the penetration of several innovations into the household market, including appliances such as air conditioners.

The original proposal called for the use of a Mansfield type (or Blackman) model to be used in the penetration models. However, in trying to implement this several difficulties were encountered. First, some of the inputs needed to utilize these models could not be found. Cost data were sparse for most products and profitability data were found even less. And second, these models required an industry-specific term that could only be determined from analysis of several previous diffusions in that industry. Because most of the innovations were not industry-specific and also because some of the industries had only one innovation this could not be done conveniently.

4.2.2 Choice of Measuring Instrument

If one is not concerned about producing a specific penetration model for each submarket under consideration (which is possible using a cross impact approach) and makes the assumption of complete substitution or penetration (which is possible by defining a subset of a market as the appropriate target if necessary), then a simpler penetration can be taken by applying the Fisher-Pry Model. This is nothing more than a special case of

[4]A. Wade Blackman, et. al., "An Innovation Index Based on Factor Analysis", TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE, 4, 3, 1973.

the substitution model presented by Blackman. Blackman's model considers an upper limit of the market share that the new product can capture in the long run whereas in the Fisher-Pry model this upper limit is taken to be 100% substitution.[5] But by proper market definition this is always possible. The Fisher-Pry model is:[6]

$$F/1-F = \exp 2\alpha\ (t - t_o)$$

where:
- F = market share of a product at time t
- t = time
- t_o = time at which substitution is half complete
- 2α = slope of the regression line

Basically this model takes the line found by the Mansfield type model and reduces it simply to the slope of the regression line by limiting application to one market. This presents no problem in the present study since a separate model can be used for each market. Since the innovations are plotted directly, it eliminates the need for determination of an industry-specific term.

4.2.3 Description of Ten-fold times

The use of the Fisher-Pry model has several other advantages besides not needing industry determined coefficients. Foremost among them is the fact that as a result of calculating the diffusion rate over time, a single quantitative measure of adoption rate is determined. This is because the total competitive substitution process can be characterized by two parameters, T_o, the substitution midpoint, and ΔT, the time for the substitution to go from ten to ninety percent. That is, 2α is the rate constant that can be defined in terms of time, T, required for the substitute fraction,

$$F = \frac{\text{substitute}}{\text{total}},$$

to go from 0.1 to 0.9.[6]

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[5]M. Nawaz Sharif and Chowdhury Kabir, "A Generalized Model for Forecasting Technological Substitution", TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE, Vol. 8, No. 4, 1976.

[6]Robert Pry, "Forecasting the Diffusion of Technology", in TECHNOLOGY TRANSFER (NATO Advanced Study Institutes Series, 1977).

In practice, another constant related to 2α is used. If the ratio $F/(1 - F)$ is plotted on semi-logarithmic paper, it appears as a straight line, as can be seen by taking the logarithm of the equation defining the Fisher-Pry model. The time required for the ratio, $F/(1 - F)$, to increase by a factor of 10 is then related to α, but can be more directly connected with the $F/(1 - F)$ plot. This time, for the ratio to increase by a factor of 10, is referred to as the ten-fold time, and it characterizes the rate of market penetration. Thus by the use of this model, a single number adequately describes the market penetration process.

4.3 MARKET ANALYSIS

4.3.1 The Bank Market

The banking industry as a market for telecommunication innovations is very interesting from several respects. First, the sheer volume of information that banks have and must transmit is staggering. In the area of check processing alone, the Federal Reserve Board processed 11.4 billion checks and 5.9 billion "check images" through their system in 1975.[7] Second, the potential for innovations and services in the banking industry is very great. Teller machines, Point of Sale Systems, and Automated Clearing Houses are three such innovations that have been introduced in the recent past and show great promise of acceptance.[8] Third, the banking industry is very competitive, with about 1500 bank systems being large enough to aggressively adopt new innovations.

Sufficient data was obtained on three innovations whose adoption could be observed. These were the computer, cash dispensers, and auto-tellers. While not telecommunication devices per se, they are all involved with the processing of information and can be used to aid in the transmission of it. The acceptance of them should then be rather similar to acceptance of telecommunication innovations.

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[7] William Niblack, "Development of Electronic Funds Transfer Systems", in FEDERAL RESERVE BANK OF ST. LOUIS BULLETIN, Sept. 1976, p. 17.

[8] Ibid., p. 11.

Enough data was found on each of the three innovations so that acceptance was able to be observed by size of bank. They were broken down into small banks, less than $100 million deposits; medium banks, $100 to $500 million deposits; and large banks, over $500 million deposits. It was felt that this breakdown would be a more accurate representation of how the innovations actually diffused through the bank market.

Figure (4.2) gives the overall diffusion of computers through all size banks on semi-log graph paper. Table 4.1 breaks this diffusion down into the major bank groupings and Figure (4.3) shows it graphically. Several aspects become obvious in looking at these graphs. First, the Fisher-Pry Model discussed in the previous section represents the diffusion pattern quite well. Second, the pattern differs significantly depending on the size of the bank, with much faster adoption occurring in the larger banks. Finally, the difference in adoption of the computer between medium and large banks is one primarily of timing and not of rate, whereas the difference between small banks and the larger classes is one of both location and rate.

Because of the large number of banks in the small classification it was decided to break this category down further. As can be seen in Table 4.2 and Figure (4.4) the same pattern of adoption is found within this class as was found in the more aggregate case. There appears to be a definite relationship between the size of the bank and its adoption rate, with the banks in the 50 - 100 million dollar range approaching that of the medium sized banks.

Table 4.3 and Figure (4.5) show the penetration rate of cash dispensers into the various classes of banks. Table 4.4 and Figure (4.6) show the diffusion rate of auto-tellers into the various classes of banks. The cash dispenser is a limited function automatic device basically allowing withdrawals from the customers' accounts or advances similar to a loan. The auto-teller is a more sophisticated device allowing deposits, withdrawals, payments, transfers, and several other conveniences including in the case of on-line systems, immediate updating of the customers' accounts. A pattern very similar to that described for computer adoption is apparent. The exception here is the diffusion of the cash dispensers. Many of the larger banks were replacing or substituting the

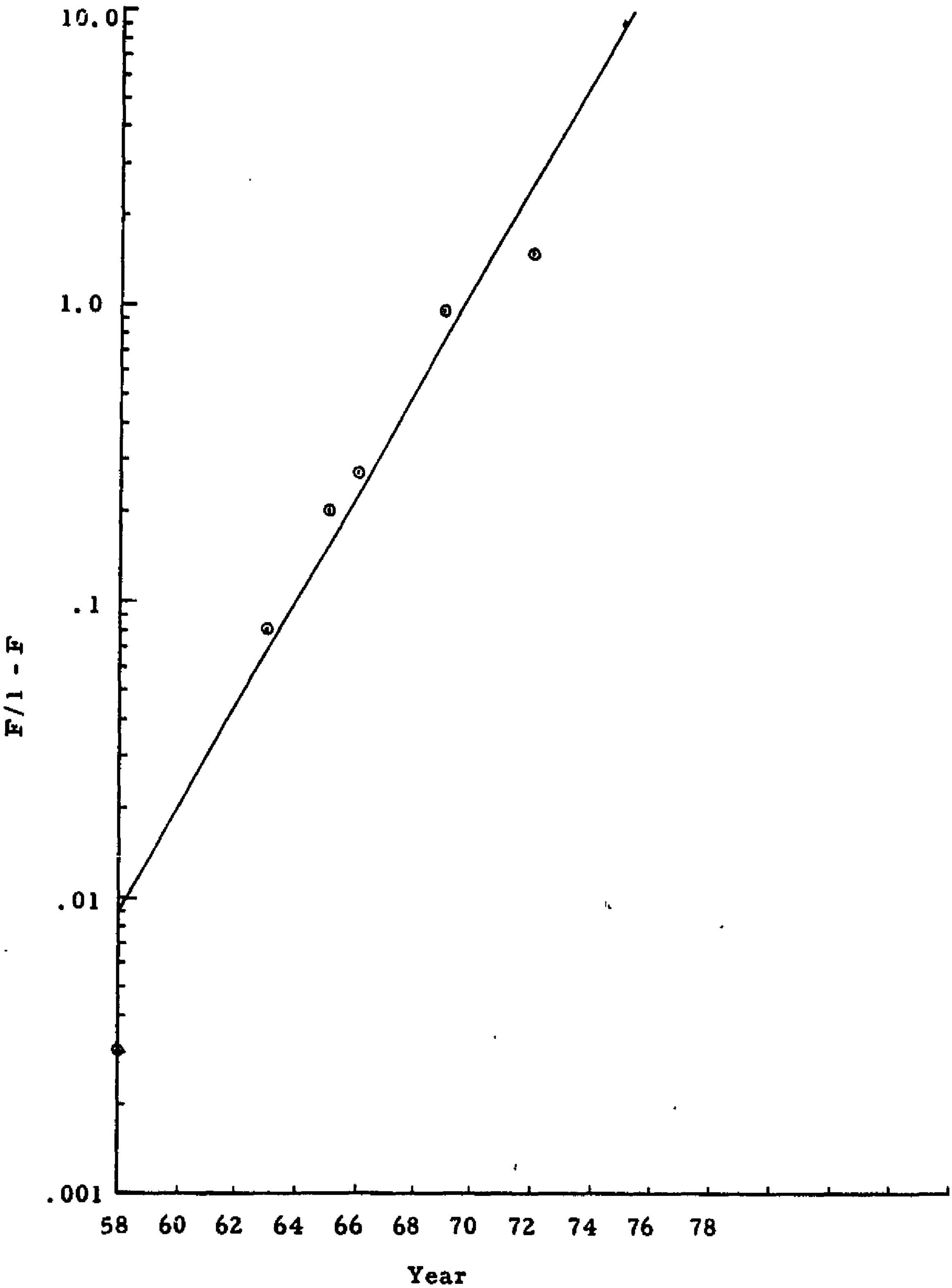

Figure 4.2 Penetration of Computers into Banks (All Sizes)

TABLE 4.1

DIFFUSION OF COMPUTERS THROUGH BANKS

	SIZE BANK					
	Small** (<$100 million)		Medium ($100-500 million)		Large (> $500 million)	
Year	Percent Saturation	F/1 - F	Percent Saturation	F/1 - F	Percent Saturation	F/1 - F
1974	85%	5.7	100%	---	100%	---
1971	54%	1.2	100%	---	100%	---
1970	48.5%	.93	100%	---	100%	---
1969	43%	.75	99%	99	100%	---
1968	37%	.59	99%	99	100%	---
1967	30%	.43	98%	49	100%	---
1966	20%	.25	95%	19	99%	99
1963	5.4%	.06	86%	6.1	92%	11.5
1958	.04%	.0004	8%	.09	30%	.43

*Sources: Issues of BANKING, 1963 through 1976.

**For years 1958-1971 data for small banks combined to give category.

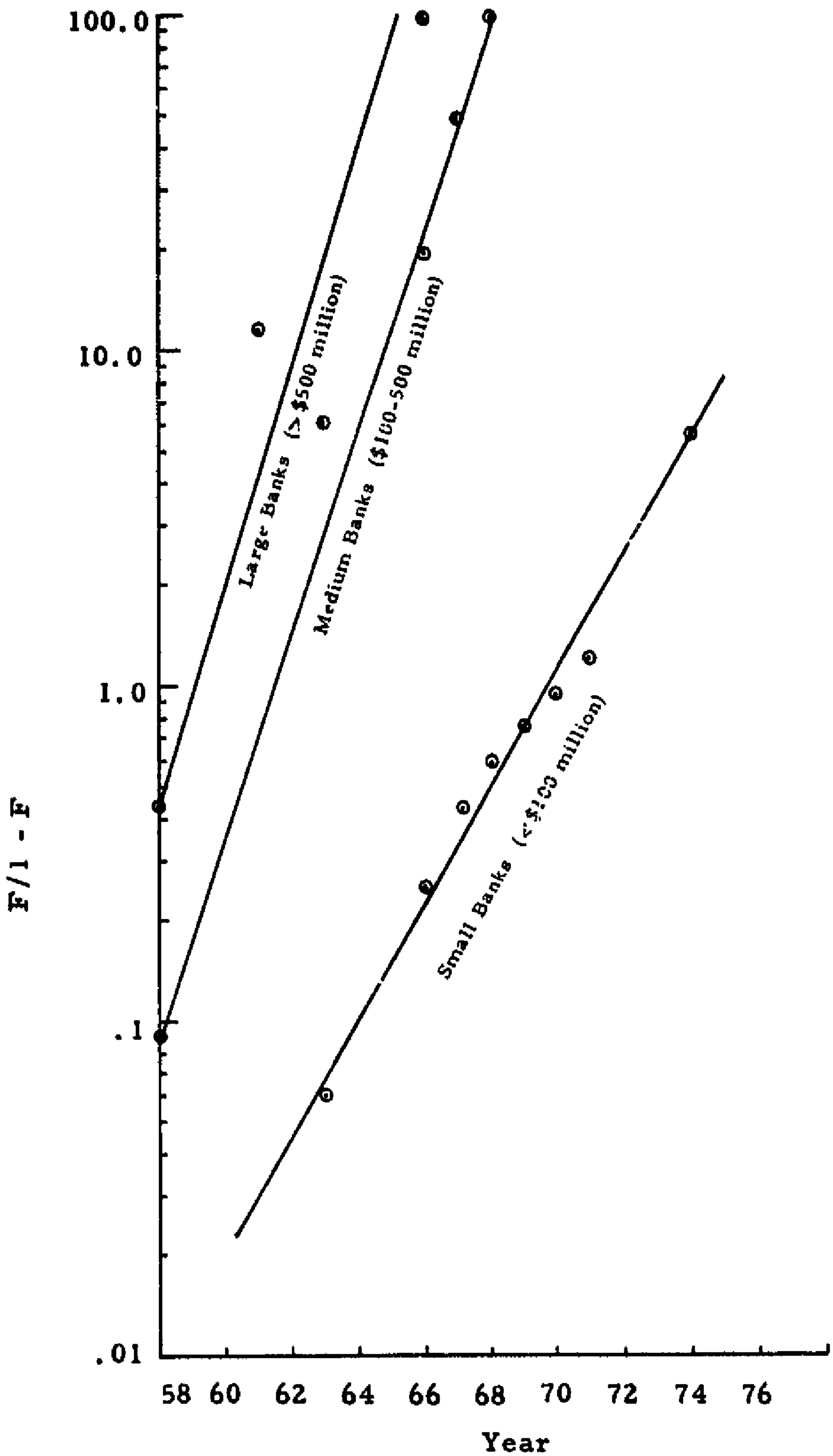

Figure 4.3 Diffusion of Computers Through Banks

TABLE 4.2

DIFFUSION OF COMPUTERS THROUGH SMALLER BANKS*

	BANK SIZE					
	< $10 Million		$10 - 50 Million		> $50 Million	
Year	Percent Saturation	F/1 - F	Percent Saturation	F/1 - F	Percent Saturation	F/1 - F
1971	43%	.75	84%	5.3	99%	99
1970	37%	.59	79%	3.8	98%	48
1969	31%	.45	74%	2.8	96%	24
1968	25%	.33	69%	2.2	95%	19
1967	19%	.23	57%	1.3	88%	7.3
1966	11%	.12	39%	.64	79%	3.8
1963	1%	.01	12%	.14	53%	1.1
1958	0	0	0	0	1%	.01

*Sources: Issues of BANKING, 1963 through 1976.

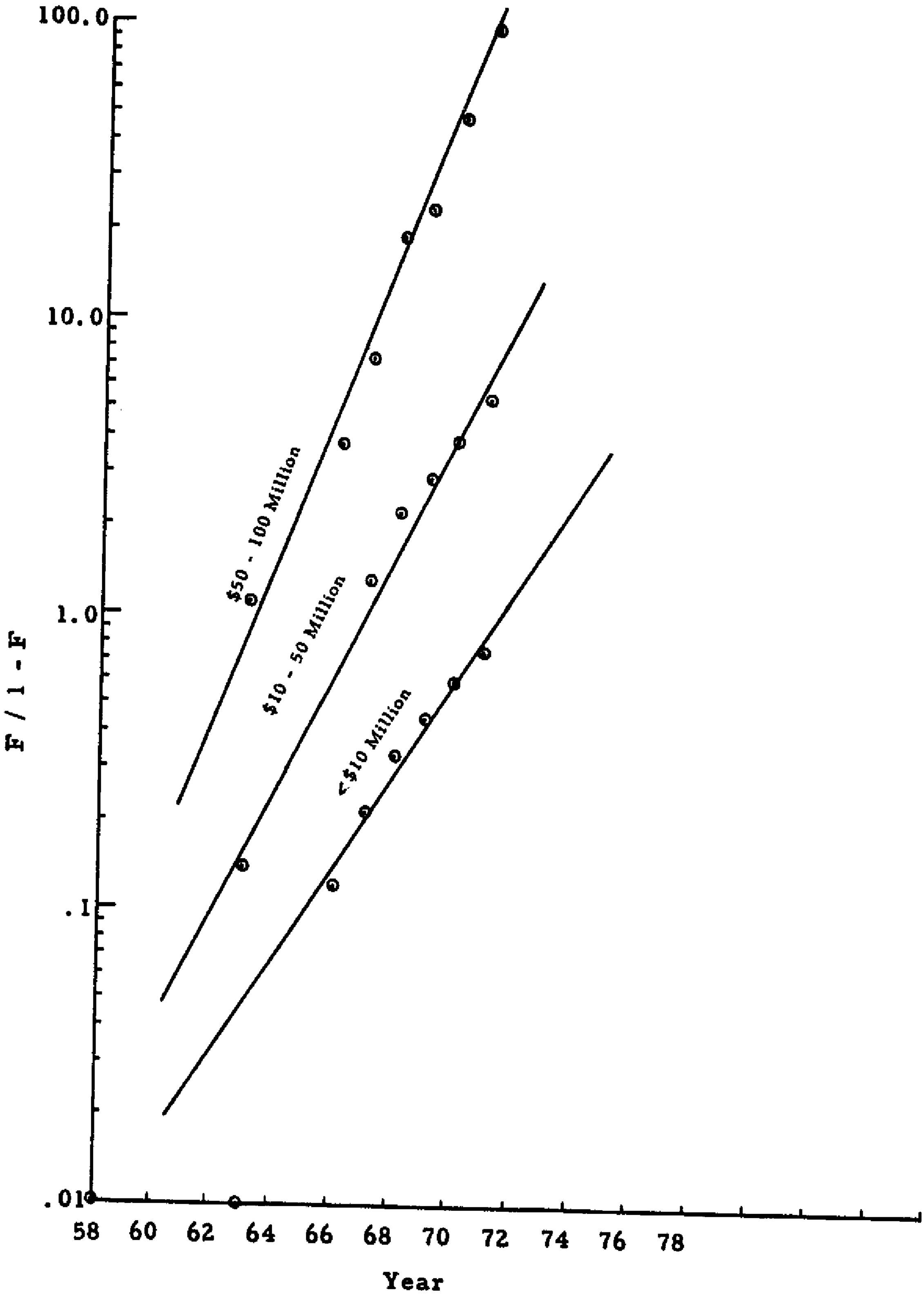

Figure 4.4 Diffusion of Computer Through Smaller Banks

TABLE 4.3

DIFFUSION OF CASH DISPENSERS THROUGH BANKS*

	BANK SIZE					
	Small (< $100 million)		Medium ($100-500 million)		Large (> $500 million)	
Year	Percent Saturation	F/1 - F	Percent Saturation	F/1 - F	Percent Saturation	F/1 - F
1976	9.7%	.11	29.2%	.41	44%	.79
1975	6.5%	.07	18.5%	.23	37.6%	.60
1974	4.9%	.05	15.0%	.18	32%	.47
1973	1%	.01	5.0%	.05	22%	.28

*Source: ABA 1976 STUDY ON BANK AUTOMATION, pp. 17-22.

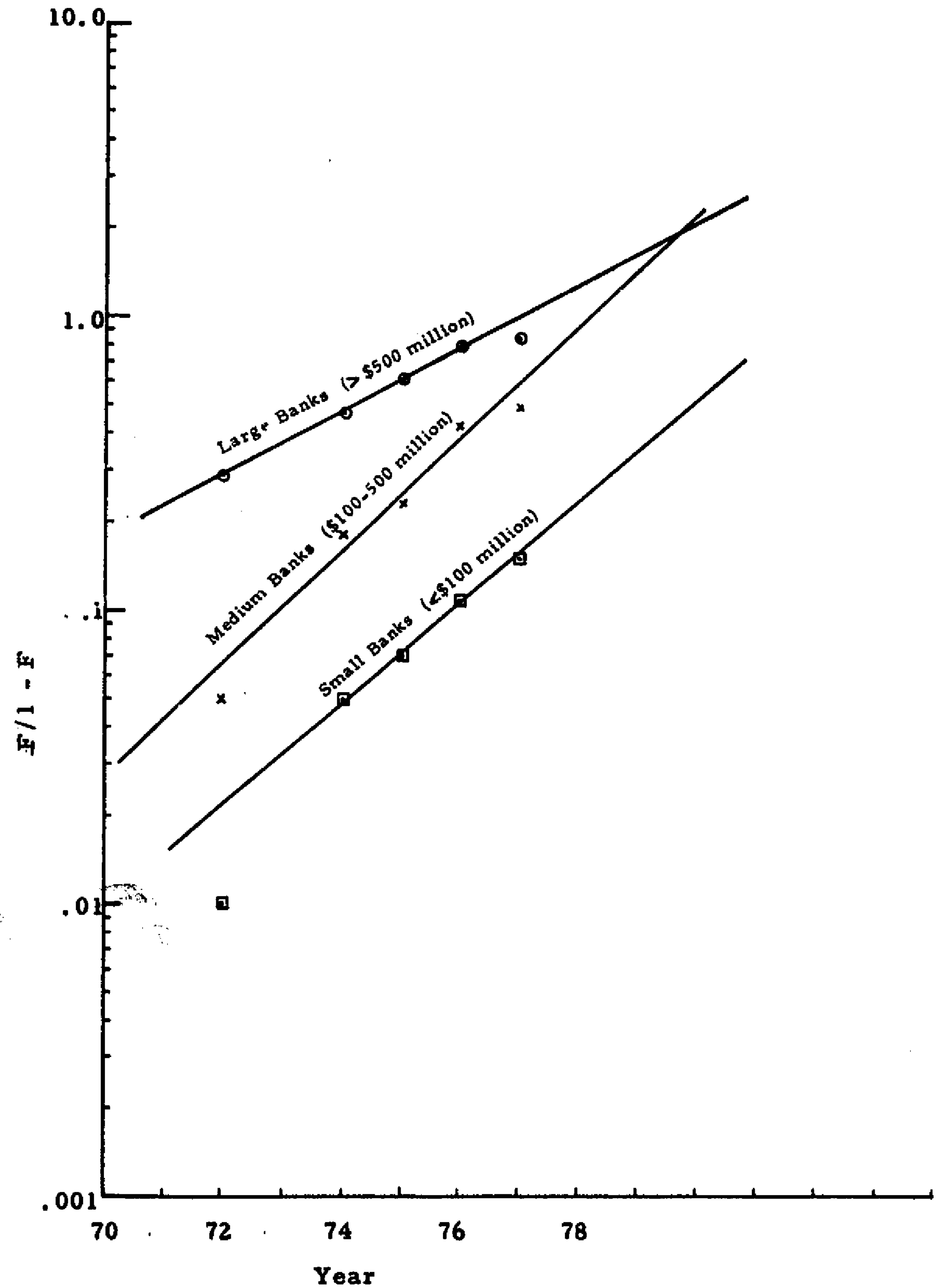

Figure 4.5 Penetration of Cash Dispensers into Banks

TABLE 4.4

DIFFUSION OF AUTO-TELLERS THROUGH BANKS*

	BANK SIZE					
	Small (< $100 million)		Medium ($100-500 million)		Large (> $500 million)	
Year	Percent Saturation	F/1 - F	Percent Saturation	F/1 - F	Percent Saturation	F/1 - F
1976	28.2%	.39	58.9%	1.43	76.7%	3.3
1975	19.5%	.24	41.6%	.71	64%	1.78
1974	15.5%	.18	33.7%	.51	51.5%	1.06
1973	1%	.01	2%	.02	10%	.11

*Source: ABA 1976 STUDY ON BANK AUTOMATION, pp. 17-22.

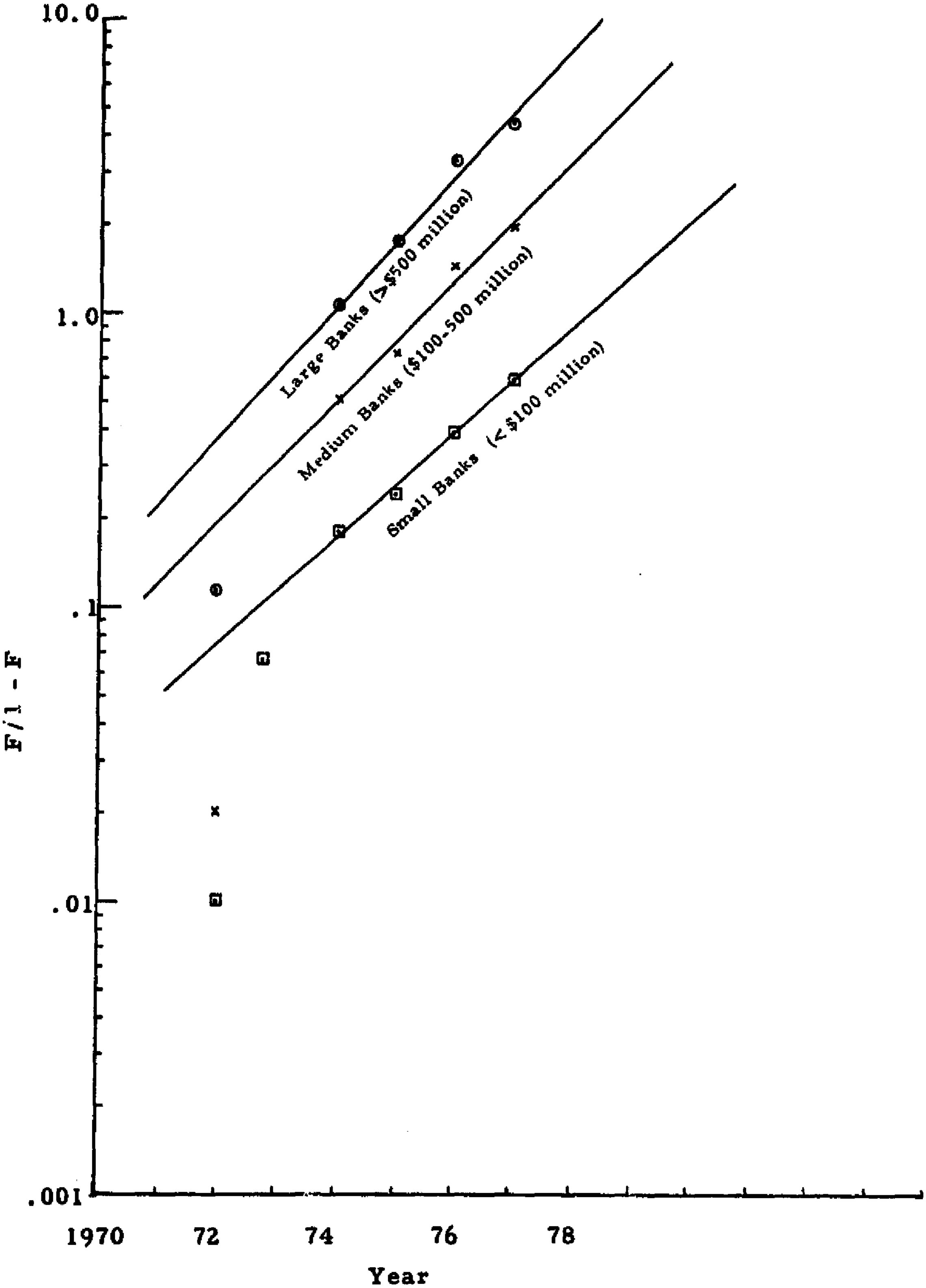

Figure 4.6 Penetration of Auto Tellers into Banks

more versatile auto-teller for the limited function cash dispenser before the cash dispenser was diffused through much of the segment. Thus the slope of adoption by the larger banks is artificially low.

4.3.2 General Business Market

The general business market is a very large, diverse group of organizations that conduct profit-making operations in the United States. The study concentrated on those organizations that were large enough to need some sort of an office structure to coordinate their activities and also were achieving sales revenue of about one million dollars or more annually. These criteria were chosen because it was felt that smaller firms would not be as likely to need or adopt innovations of the type studied. Also secondary data were much more readily available for the larger organizations. Even though the organization and size limitations were placed on this market, it is still such a diverse group that it is unlikely that some of the innovations would be applicable for the total group. In these cases an estimate of the appropriate subgroup was made.

The diffusion of seven innovations through this market was studied. Some of the innovations are very closely related to telecommunications. Others have the facility to be utilized with telecommunication devices. Still others were chosen because it was felt that acceptance of them would be very similar to acceptance of various telecommunication devices. The specific innovations that were studied were:

Computers - The total business market was used for the computer. The saturation level for the latest survey reached seventy-four percent. This probably would have been slightly higher but for the introduction of the next innovation, the mini-computer. The ten-fold time for the computer was about twelve years.

Mini-Computers - Again all businesses were used for diffusion of the mini-computer, even though saturation only reached about twenty-nine percent by 1975. Mini-computers are smaller, less expensive versions of the computer utilizing micro-components and allowing the user great flexibility in usage. They range from desk-top models to small freestanding units. Surveys seem to indicate that the mini-computer does not replace the computer but either expands the market to those organizations that could not afford the larger units, or allows for the organization to supplement their computer with one or several of these smaller units. Ten-fold time for the mini-computer was about seven years.

Data Terminals - Data terminals allow for distant usage of the computer. They probably are only applicable for those organizations having multiple facility usage of the computer or a need for hands-on capability by several groups within the organization. It was estimated that at most fifty percent of all general businesses would have such a need. Ten-fold time was about five and a half years.

CCTV and Videotape - Closed circuit television and videotape allow for the transmission and/or the recording and playing back over television equipment of messages or demonstrations desired by the organization. Examples of usage would be training presentations, sales demonstrations, security checks, and others. Usage would probably be limited to those organizations needing such security or large enough to need such an automated communication device. It was estimated on the basis of usage that about thirty percent of all businesses fall into this category. Ten-fold time was about seven years.

Optical Scanning - Optical scanning allows for the direct reading of symbols by a machine without the necessity of first manually transforming them via puched holes, magnetic characters, or similar methods. It is primarily used where large volumes of short messages or codes must be processed. It was estimated that only about twenty percent of all businesses would have such a use. Ten-fold time was about nine and a half years.

Electronic Calculators - These are a range of electronic computational devices used in various capacities in almost all businesses. Saturation in 1975 was about ninety-three percent. Ten-fold time was four and a half years.

FAC Equipment - Facsimile equipment allows for the direct point-to-point transmission of many types of written messages, graphs, or pictures, without first having to code them in any way. What is received is a picture of the message that was sent. Generally these are only used where an organization has multiple facilities needing quick written communication with each other. It was estimated that about twenty percent of all businesses had this need. Ten-fold time was four and a half years.

In observing the diffusion of innovations through general business organizations it appears as though they fall in two classes. The first one is a fairly rapid diffusion of four to six years ten-fold time. These are products that are relatively inexpensive, such as electronic caluclators, or ones that coordinate with existing products, such as data terminals. The other group of products are those having much slower diffusion rates. They are generally much more expensive, such as the computer, or ones having a less tangible return to the company such as videotape. Here the ten-fold times range from seven to twelve years. Thus, even though there is no uniform rate as was found in the bank market due to the diversity of the various businesses, it is possible to get some idea of product diffusion rate.

Table 4.5 and Figure (4.7) show diffusion of computers. Table 4.6 and Figure (4.8) show diffusion of mini-computers. Table 4.7 and Figures (4.9) and (4.10) show diffusion of data terminals. Table 4.8 and Figures (4.11) and (4.12) show diffusion of closed circuit TV. Table 4.9 and Figures (4.13) and (4.14) show diffusion of optical scanning equipment. Table 4.10 and Figure (4.15) show diffusion of electronic calculators. Table 4.11 and Figures (4.16) and (4.17) show diffusion of facsimile communications equipment.

4.3.3 Hospital Market

There is great potential for telecommunication devices in the health care field, but only one study could be found giving information on the rate of diffusion. It was on the diffusion of computers through hospitals in Texas. In spite of the limited data, the results were very favorable to application of the Fisher-Pry model. A twenty year study of adoption of the computer shows very little deviation from a straight line on semi log graph paper, as seen in Figure (4.18). The ten-fold time was about seven and a half years. Data are shown in Table 4.12.

4.3.4 Large Manufacturing Firms

Large manufacturing firms were singled out from general businesses for several reasons. First, they hold a unique place in our society with their great influence and huge resources. Second, because of their resources they are very often in the vanguard of adoption of innovations. Third, because of their size many innovations owe their later general adoption to the early diffusion through these firms.

TABLE 4.5

DIFFUSION OF COMPUTERS THROUGH GENERAL BUSINESS ESTABLISHMENTS *

Year	Percent Saturation	F/1 - F
1974	74%	2.8
1973	56%	1.3
1972	52%	1.1
1971	52%	1.1
1970	50%	1.0
1969	46%	.85
1968	43%	.75
1967	40%	.67
1965	38%	.60

*Sources: Issues of THE OFFICE, January 1965 through 1976.

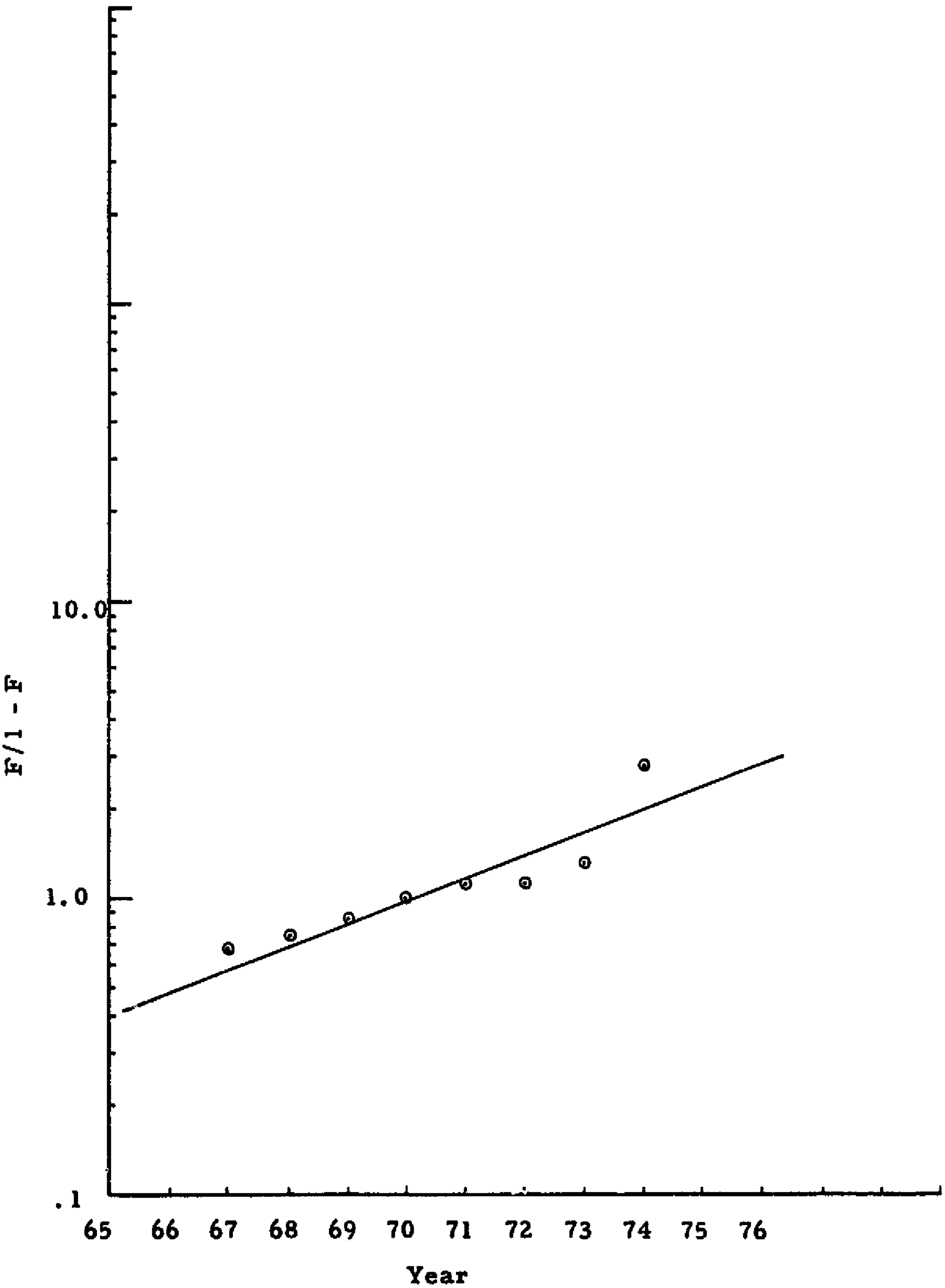

Figure 4.7 Diffusion of Computers Through General Business Establishments

TABLE 4.6

DIFFUSION OF MINI-COMPUTERS THROUGH GENERAL BUSINESS ESTABLISHMENTS*

Year	Percent Saturation	F/1 - F
1975	29%	.41
1974	27%	.37
1973	23%	.30
1972	13%	.15

*Sources: Issues of THE OFFICE, 1972 through 1976.

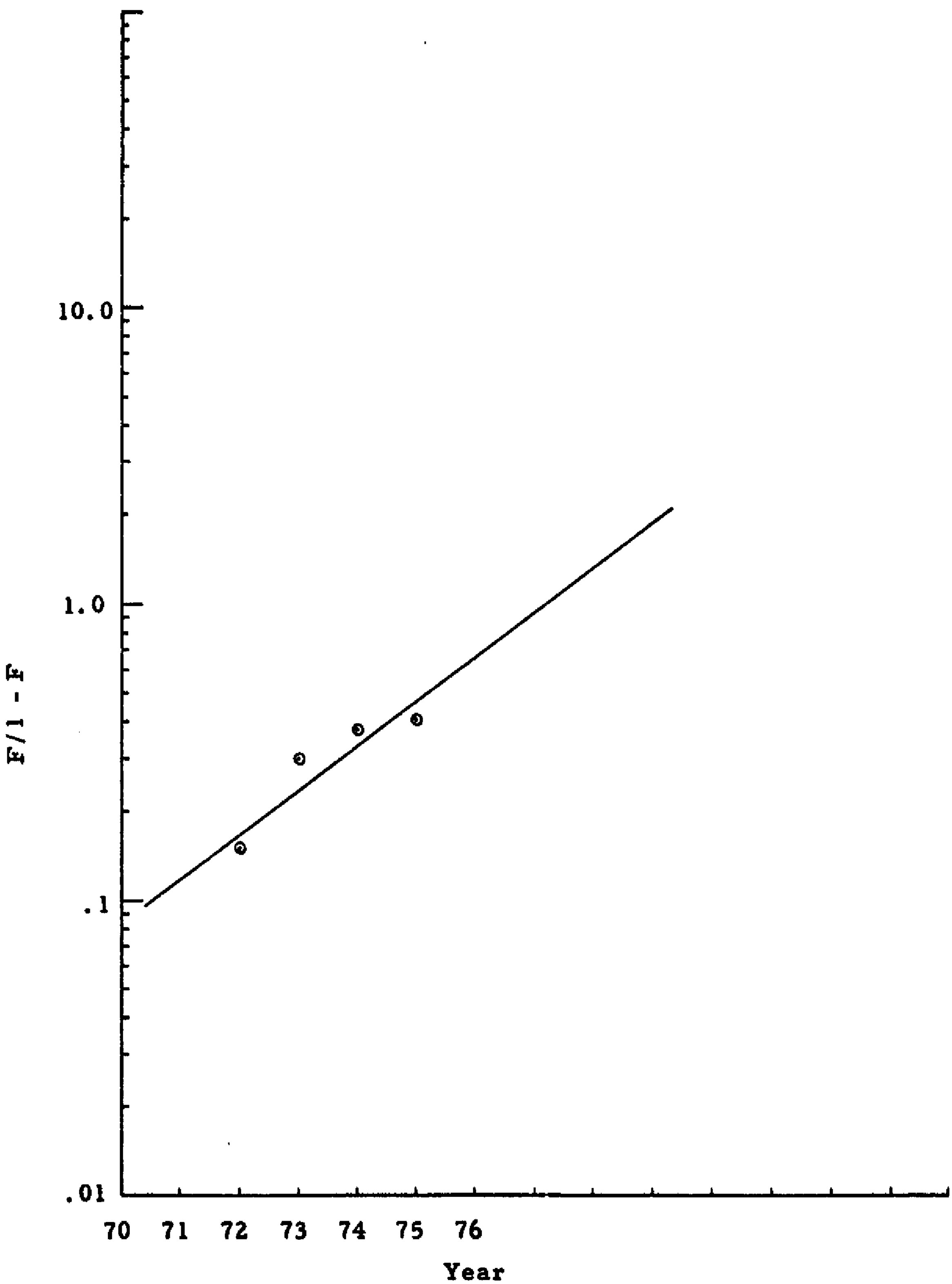

Figure 4.8 Diffusion of Mini-Computers Through General Businesses

TABLE 4.7

DIFFUSION OF DATA TERMINALS THROUGH GENERAL BUSINESS ESTABLISHMENTS*

Year	Percent Penetration	Percent Saturation**	F/1 - F
1975	39%	78%	3.5
1974	39%	78%	3.5
1973	26.5%	53%	1.1
1972	24%	48%	.92
1971	23%	46%	.85
1970	19%	38%	.61
1969	14%	28%	.39
1968	5%	10%	.11

*Sources: Issues of THE OFFICE, 1968 through 1976.

**Percent Saturation based on estimate that the innovation is applicable to about 50% of business establishments.

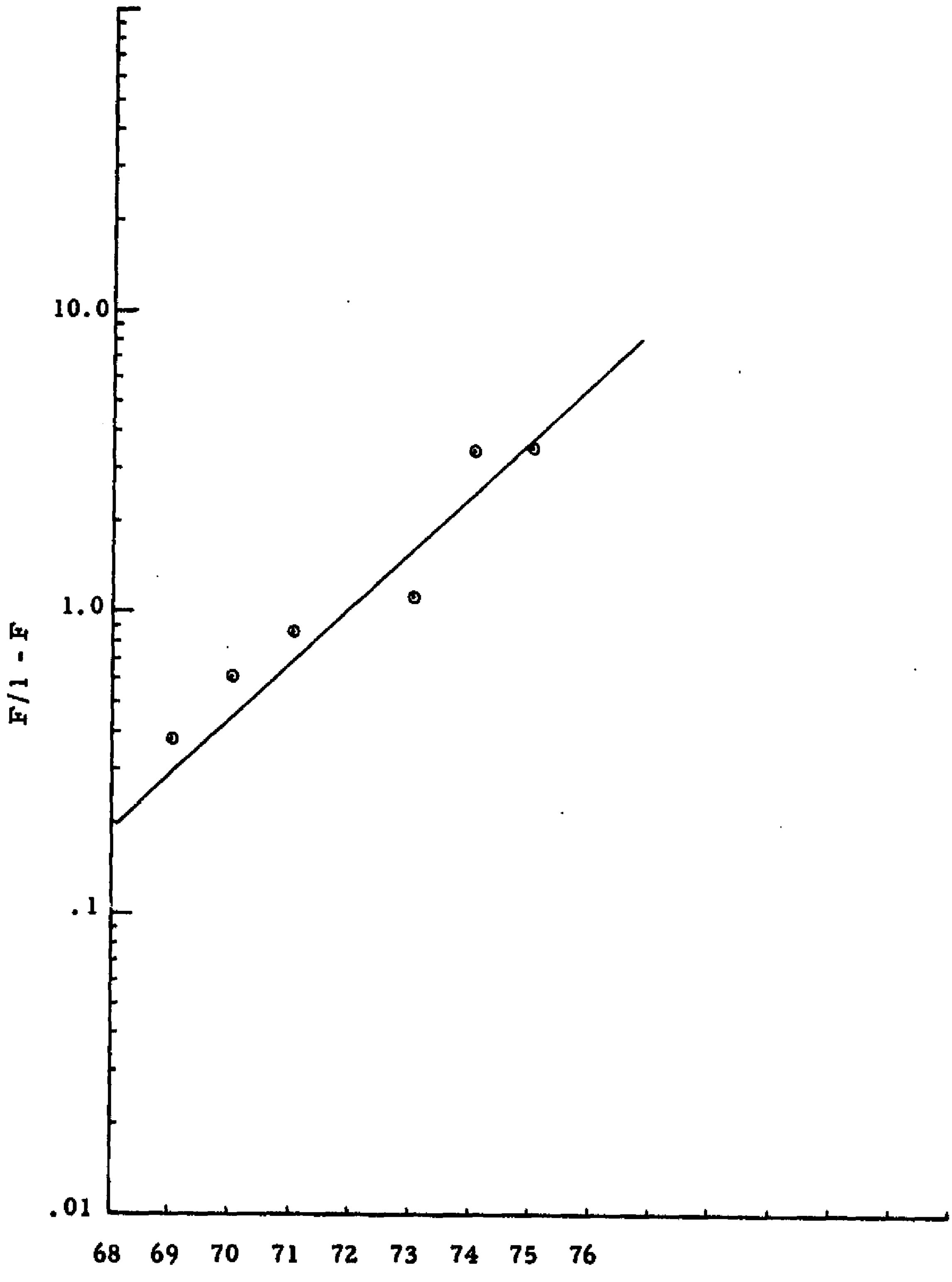

Figure 4.9 Diffusion of Data Terminals Through General Business Establishments

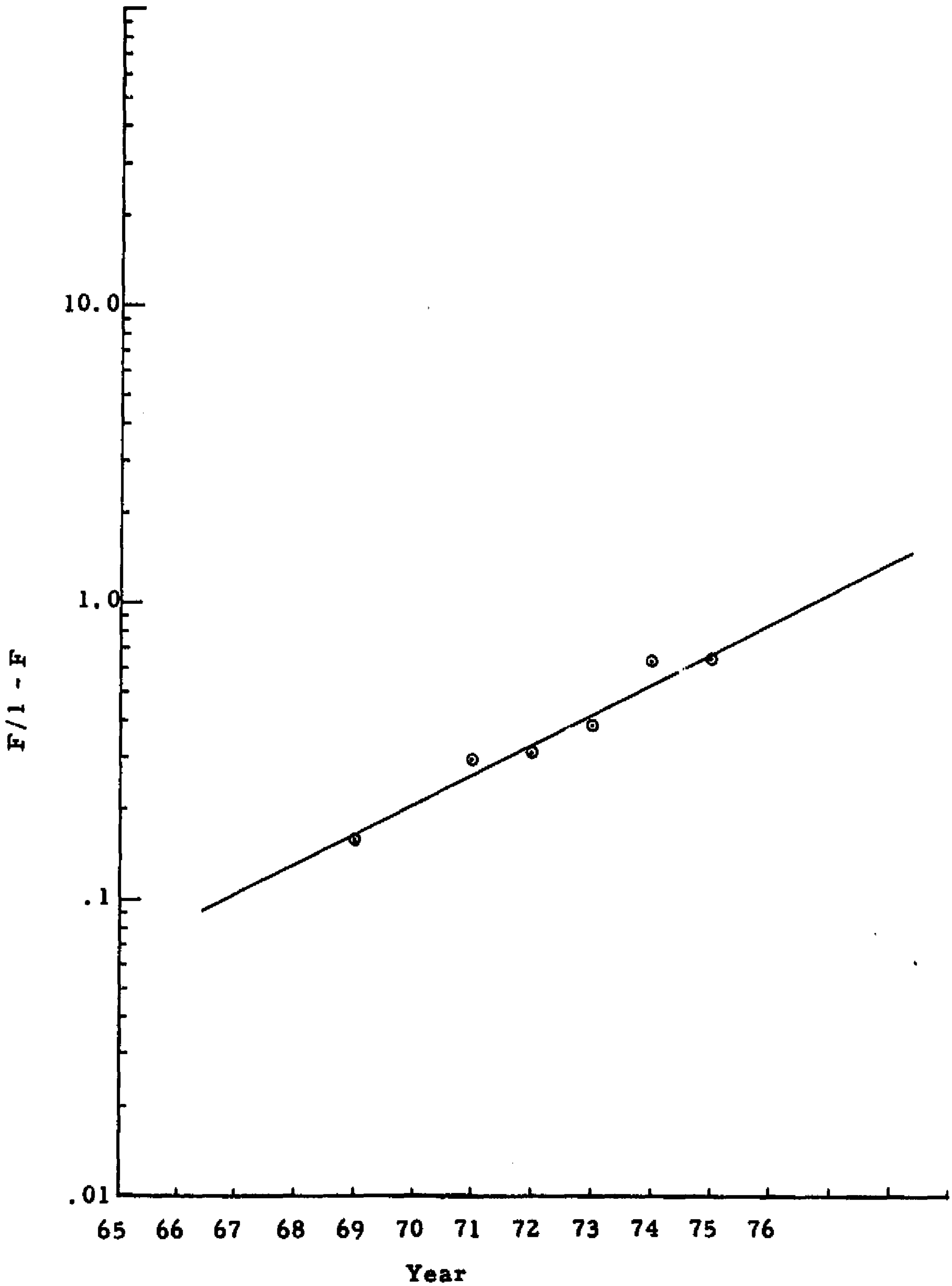

Figure 4.10 Penetration of Data Terminals into All General Businesses

TABLE 4.8

DIFFUSION OF CCTV AND VIDEOTAPE EQUIPMENT* THROUGH GENERAL BUSINESS ESTABLISHMENTS

Year	Percent Penetration	Percent Saturation**	F/1 - F
1975	21%	70%	2.33
1974	20%	67%	2.03
1973	18%	60%	1.5
1972	15%	50%	1.0
1971	13%	43%	.75
1969	11%	37%	.59
1967	6%	20%	.25

*Sources: Issues of THE OFFICE, 1967 through 1976.

**Percent Saturation based on the estimate that this innovation applicable to about 30% of business establishments.

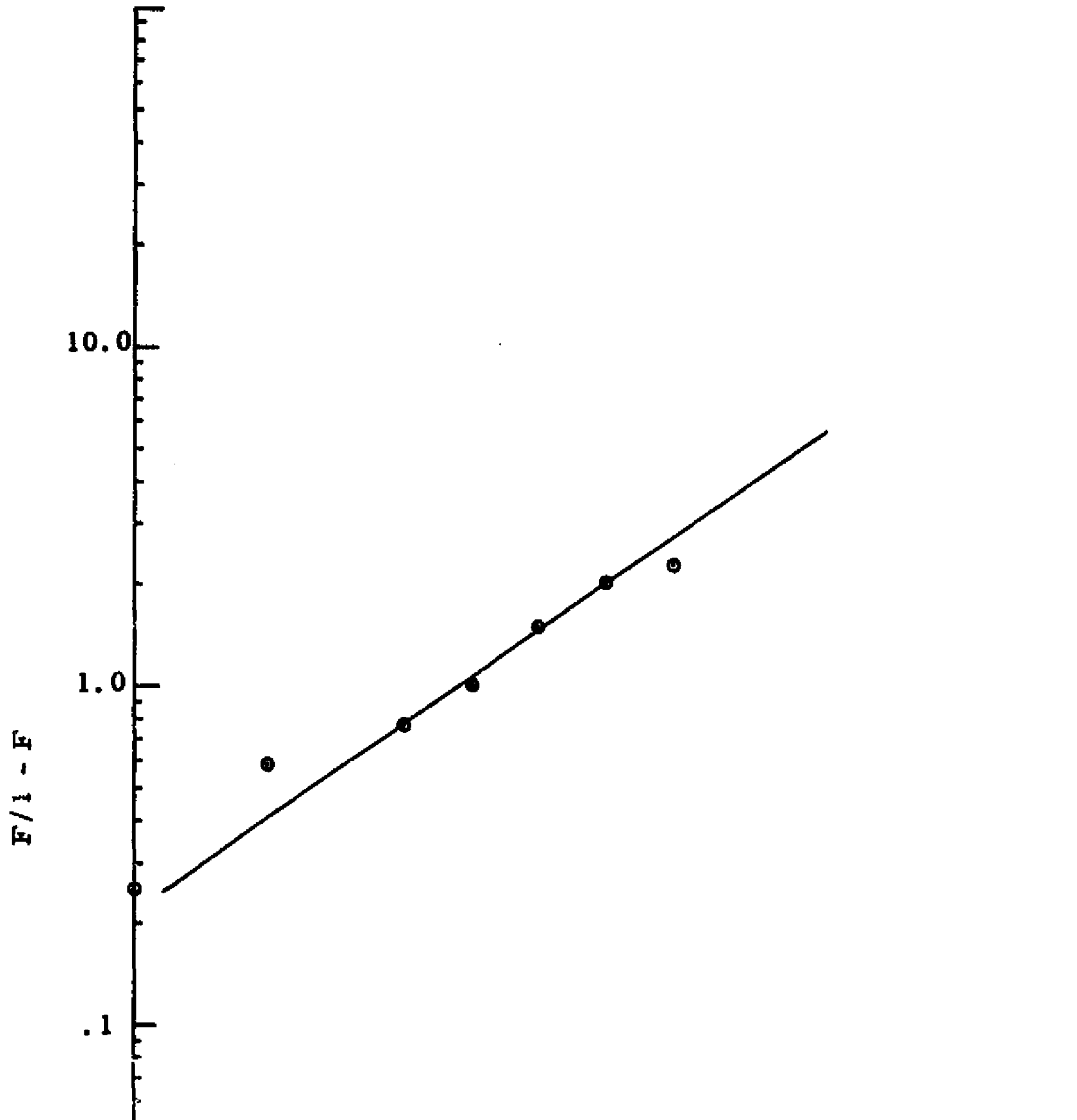

Figure 4.11 **Diffusion of CCTV and Videotape Equipment Through General Businesses**

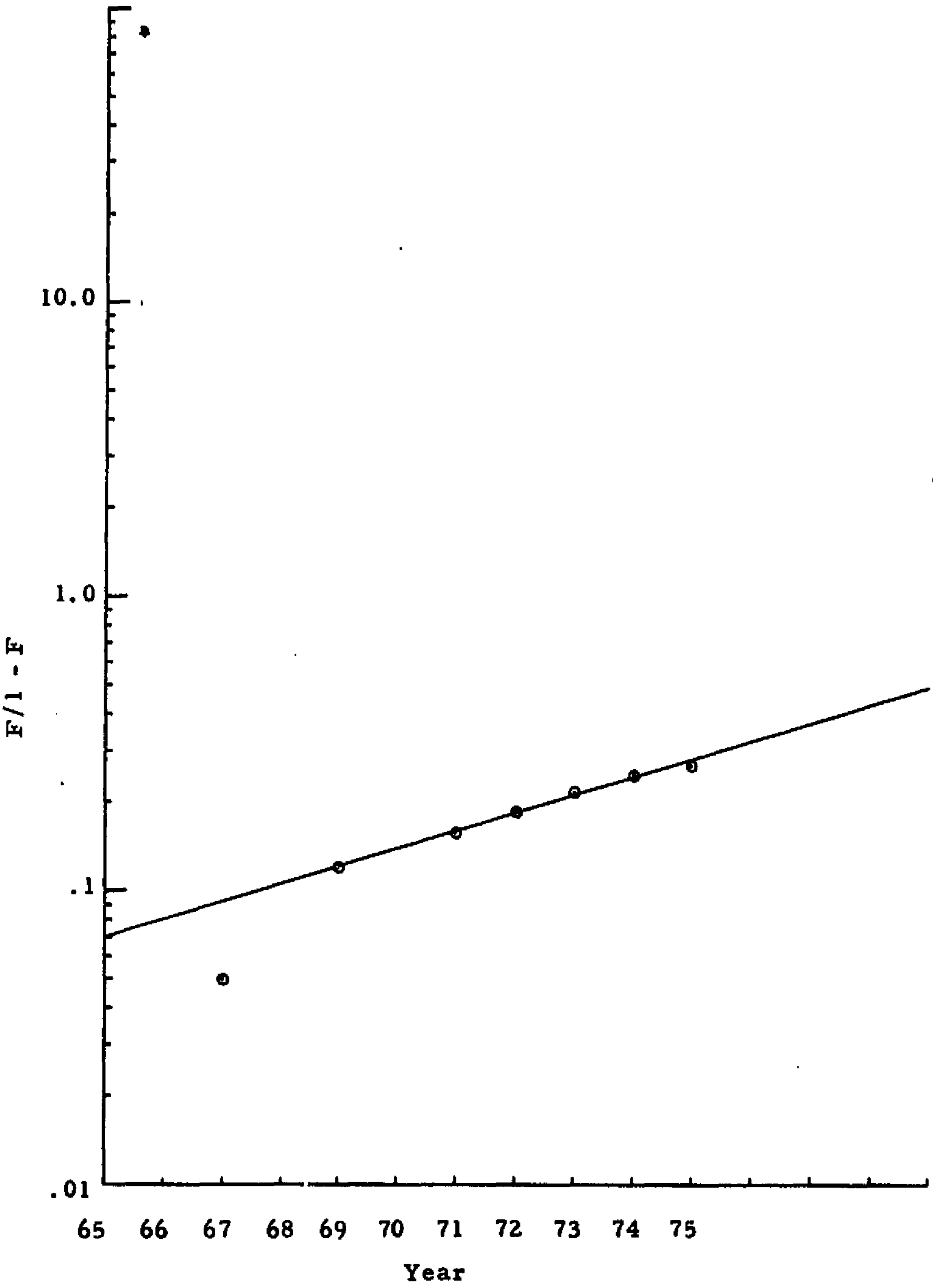

Figure 4.12 Penetration of Videotape into All General Businesses

TABLE 4.9

DIFFUSION OF OPTICAL SCANNING EQUIPMENT THROUGH GENERAL BUSINESS ESTABLISHMENTS*

Year	Percent Penetration	Percent Saturation**	F/1 - F
1975	13%	65%	1.86
1974	12%	60%	1.50
1973	9.5%	47.5%	.90
1972	9%	45%	.82
1971	9%	45%	.82
1969	6%	30%	.43
1967	5%	25%	.33

*Sources: Issues of THE OFFICE, 1967 through 1976.

**Percent Saturation based on estimate that innovation applicable to about 20% of business establishments.

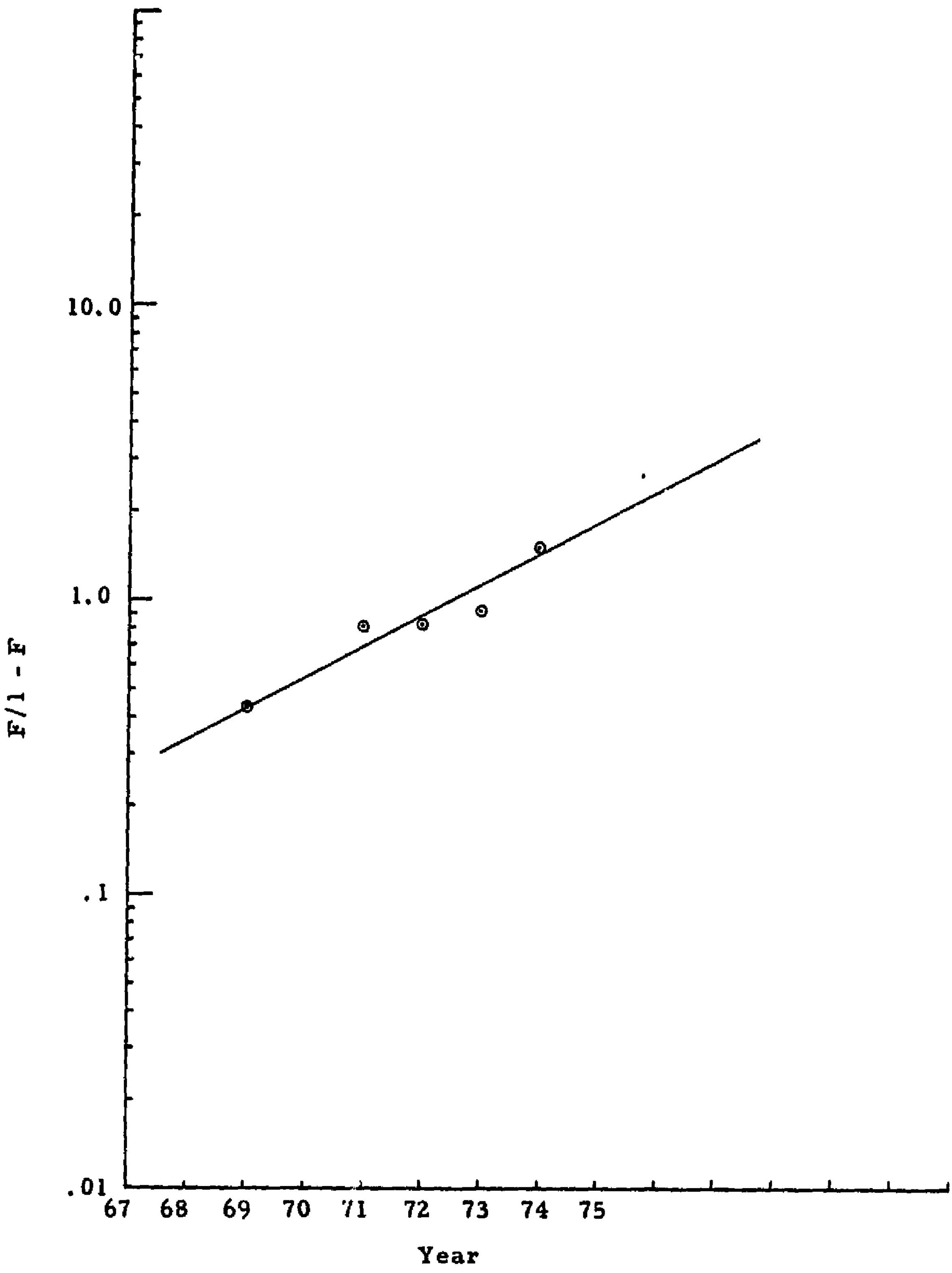

Figure 4.13 **Diffusion of Optical Scanning Equipment Through General Businesses**

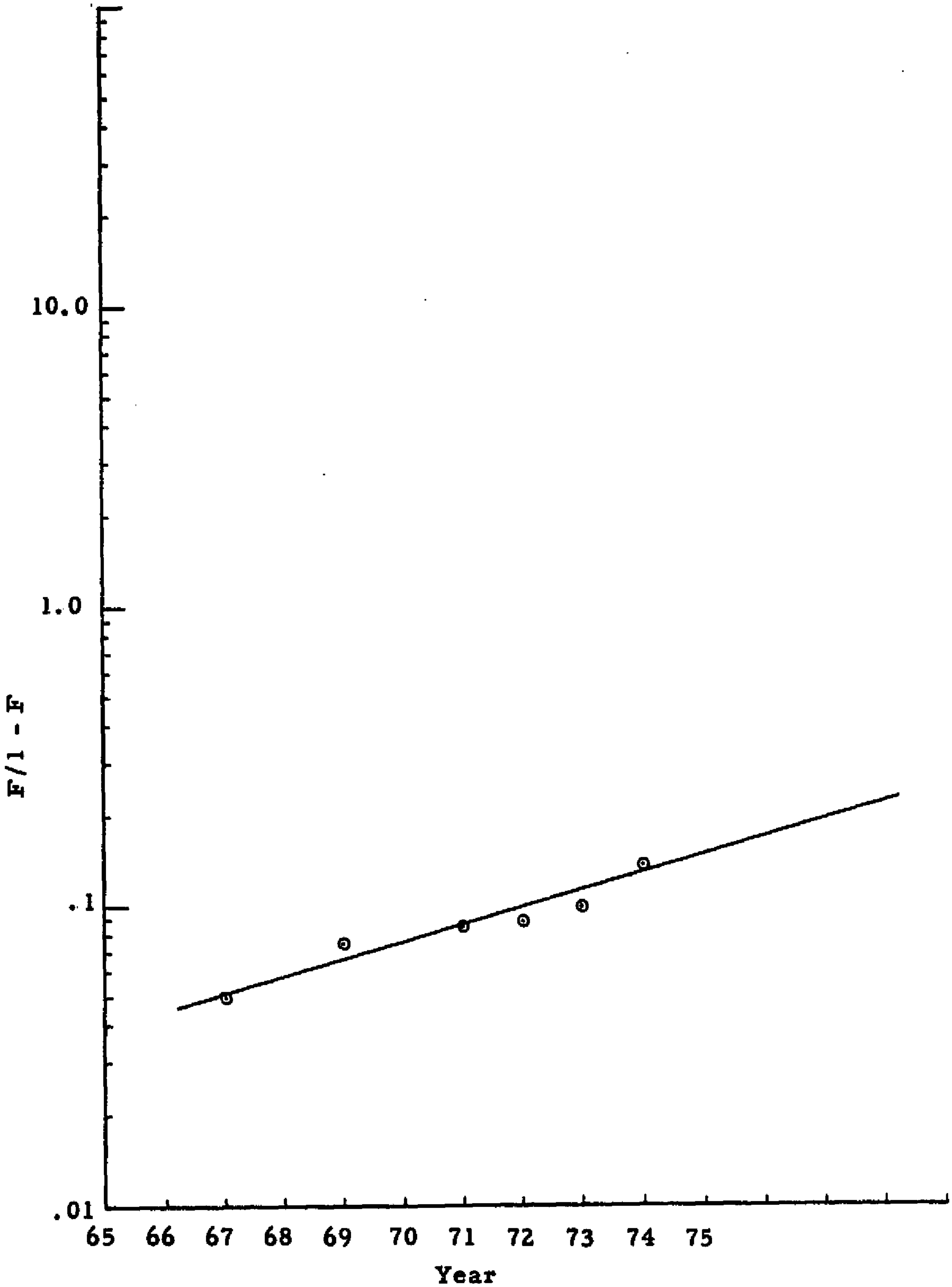

Figure 4.14 Penetration of Optical Scanning Equipment into All Businesses

TABLE 4.10

DIFFUSION OF ELECTRONIC CALCULATORS THROUGH GENERAL BUSINESS ESTABLISHMENTS*

Year	Percent Saturation	F/1 - F
1975	93%	13.3
1974	94%	15.7
1973	88%	7.3
1972	86%	6.1
1971	78%	3.5
1970	64%	1.8
1969	52%	1.1
1968	40%	.67
1967	28%	.39

*Source: Issues of THE OFFICE, 1967 through 1976.

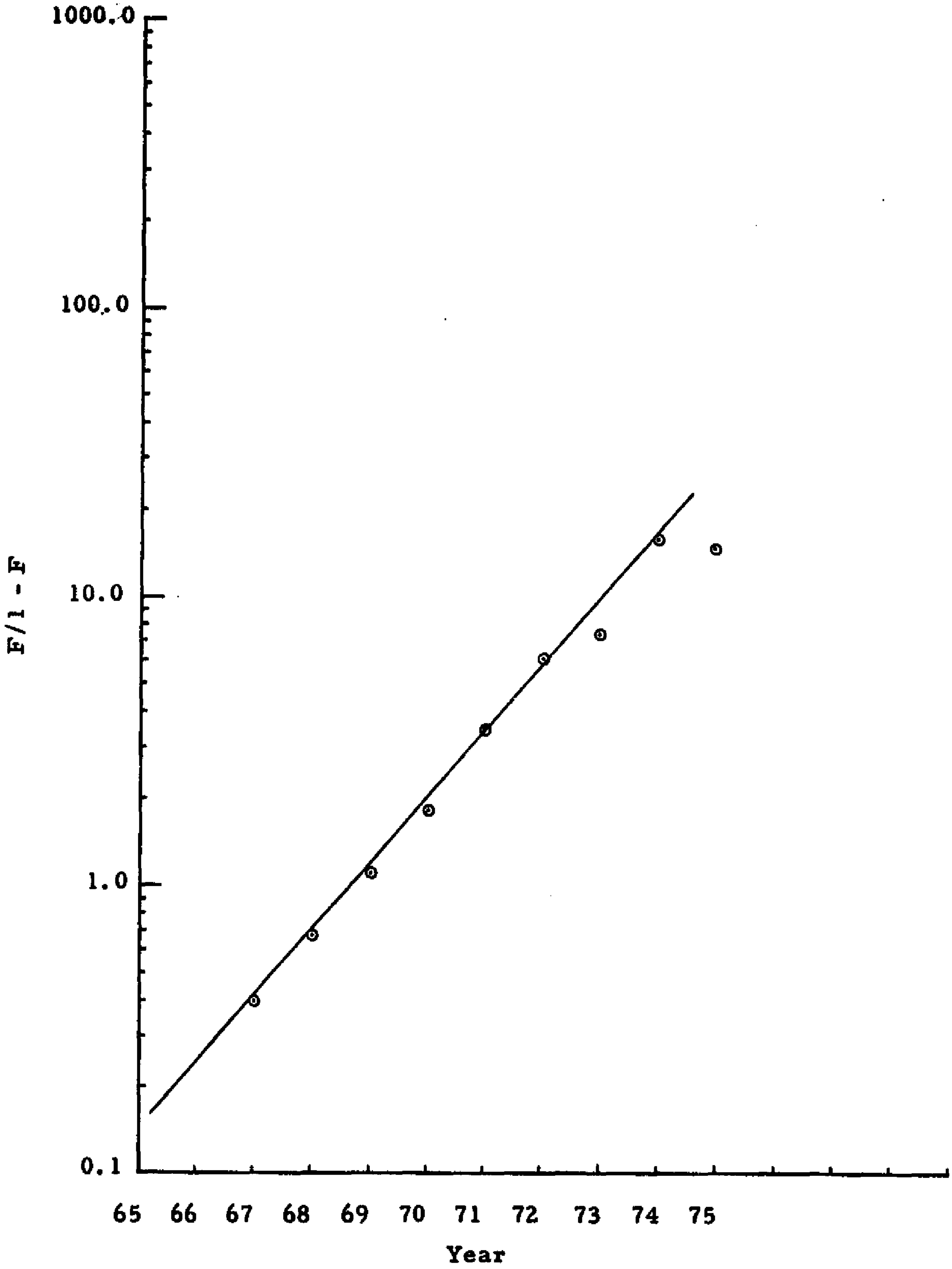

Figure 4.15 Diffusion of Electronic Calculators Through General Businesses

TABLE 4.11

DIFFUSION OF FACSIMILE COMMUNICATIONS EQUIPMENT THROUGH GENERAL BUSINESS ESTABLISHMENTS*

Year	Percent Penetration	Percent Saturation**	F/1 - F
1975	17%	85%	5.67
1974	17%	85%	5.67
1973	15%	75%	3.00
1972	11%	55%	1.22
1971	10%	50%	1.00
1970	8%	40%	.67
1969	5%	25%	.25

*Sources: Issues of THE OFFICE, 1969 through 1976.

**Percent Saturation based on estimate of applicability of innovation to about 20% of all business units.

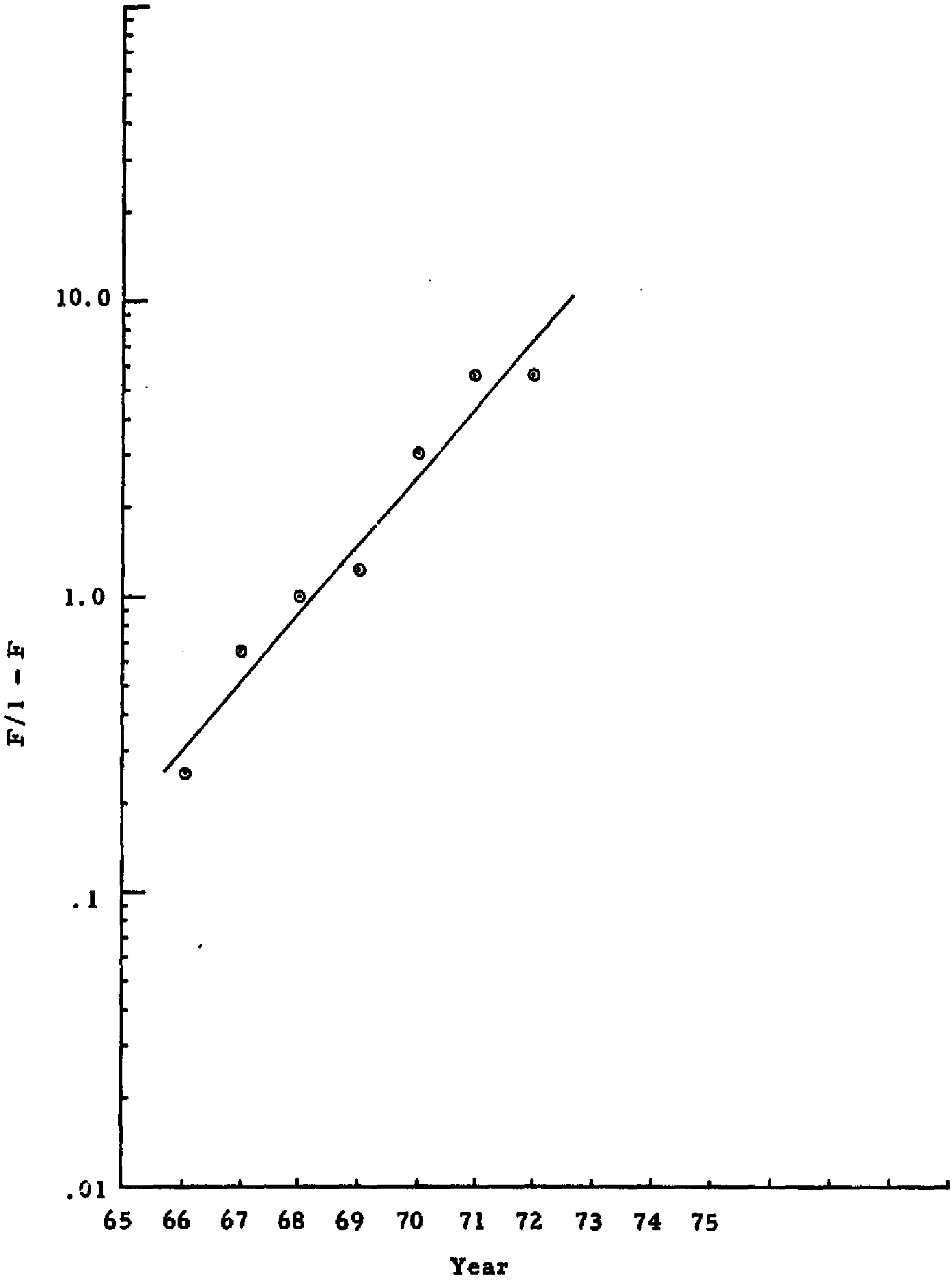

Figure 4.16 **Diffusion of FAC Communication Systems Through General Businesses**

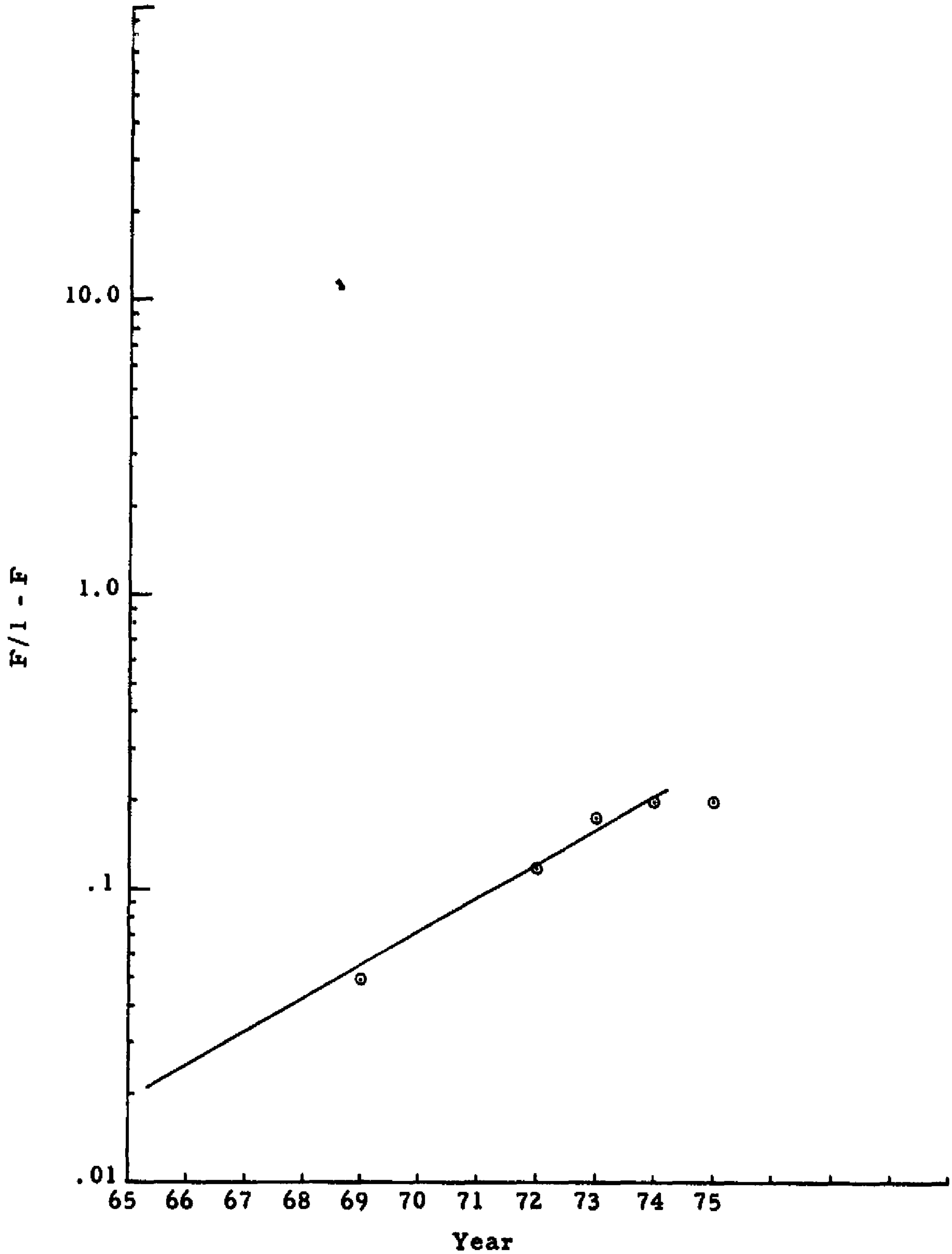

Figure 4.17 Penetration of FAC Communications Systems into All General Businesses

TABLE 4.12

DIFFUSION OF COMPUTERS THROUGH HOSPITALS*

Year	Cumulative Number	Percent Saturation	F/1 - F
1973	143	.300	.429
1972	128	.269	.368
1971	106	.223	.287
1970	75	.200	.250
1969	74	.155	.183
1968	55	.116	.131
1967	33	.069	.072
1966	22	.046	.048
1965	14	.029	.030
1964	11	.023	.023
1963	7	.015	.015
1962	6	.013	.013
1961	5	.010	.010
1960	4	.008	.008
1959	3	.006	.006
1956	2	.004	.004
1954	1	.002	.002

*Source: "Diffusion of Computers in Hospitals" a study done by Vjay Mahajan and Milton Schoeman on hospital adoption of computers in the state of Texas.

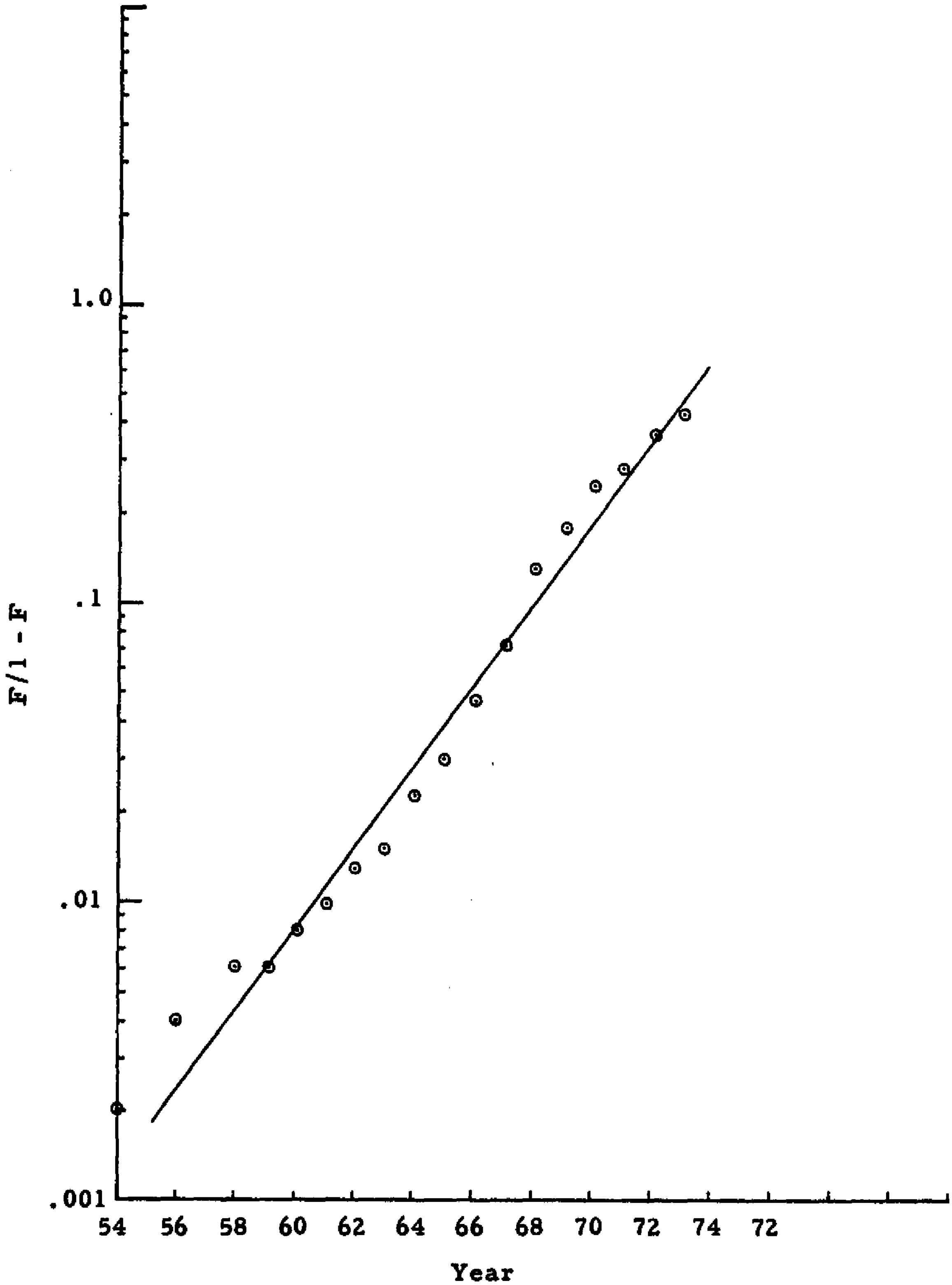

Figure 4.18 Diffusion of Computers Through Hospitals

Information was found on the adoption of three products through large manufacturing firms. In all three of the studies found, the large firms were defined as the five hundred largest manufacturing firms in terms of sales.

The computer had diffused through ninety-six percent of these large manufacturing firms by 1969. The ten-fold time for adoption was eight years. This contrasts with twelve years ten-fold time for all businesses.

Marketing Information Systems are a means of transmitting and coordinating information about the environment, competition, and cutomers to the firm in a systematic manner. By 1971 about seventy-one percent of the large firms had adopted the use of such a system. The ten-fold time for this innovation was nine and a half years.

Videotape systems were adopted by seventy-eight percent of large manufacturing firms by 1968. Unlike general businesses which took seven years for ten-fold adoption, large manufacturers adopted it in about two years.

Thus it can be seen that the adoption rate of innovations by large manufacturing firms was about fifty to one-hundred percent faster than businesses in general. The larger, complex, more expensive innovations took eight to ten years for their ten-fold time, while less expensive products diffused very quickly.

Diffusion of computers is shown in Table 4.13 and Figure (4.19). Diffusion of marketing information systems is shown in Table 4.14 and Figure (4.20). Diffusion of videotape equipment is shown in Table 4.15 and Figure (4.21).

4.3.5 Municipal Governments

Local governments provide a good potential market for many telecommunication devices. Not only must information be transmitted within each organization, but with today's increasing complexities, there is a great need to transmit much data between localities. They are also a good potential market because purchase of many of these capital goods can be subsidized through shared funds, thus minimizing much of the cost burden.

TABLE 4.13

DIFFUSION OF COMPUTERS THROUGH LARGE MANUFACTURING FIRMS*

Year	Percent Saturation	F/1 - F
1969	96%	24
1964	84%	5.2
1960	65%	1.85

*Sources: MANAGING WITH EDP, AMA Publication, 1965 and JOURNAL OF MARKETING RESEARCH, November 1969, p. 484.

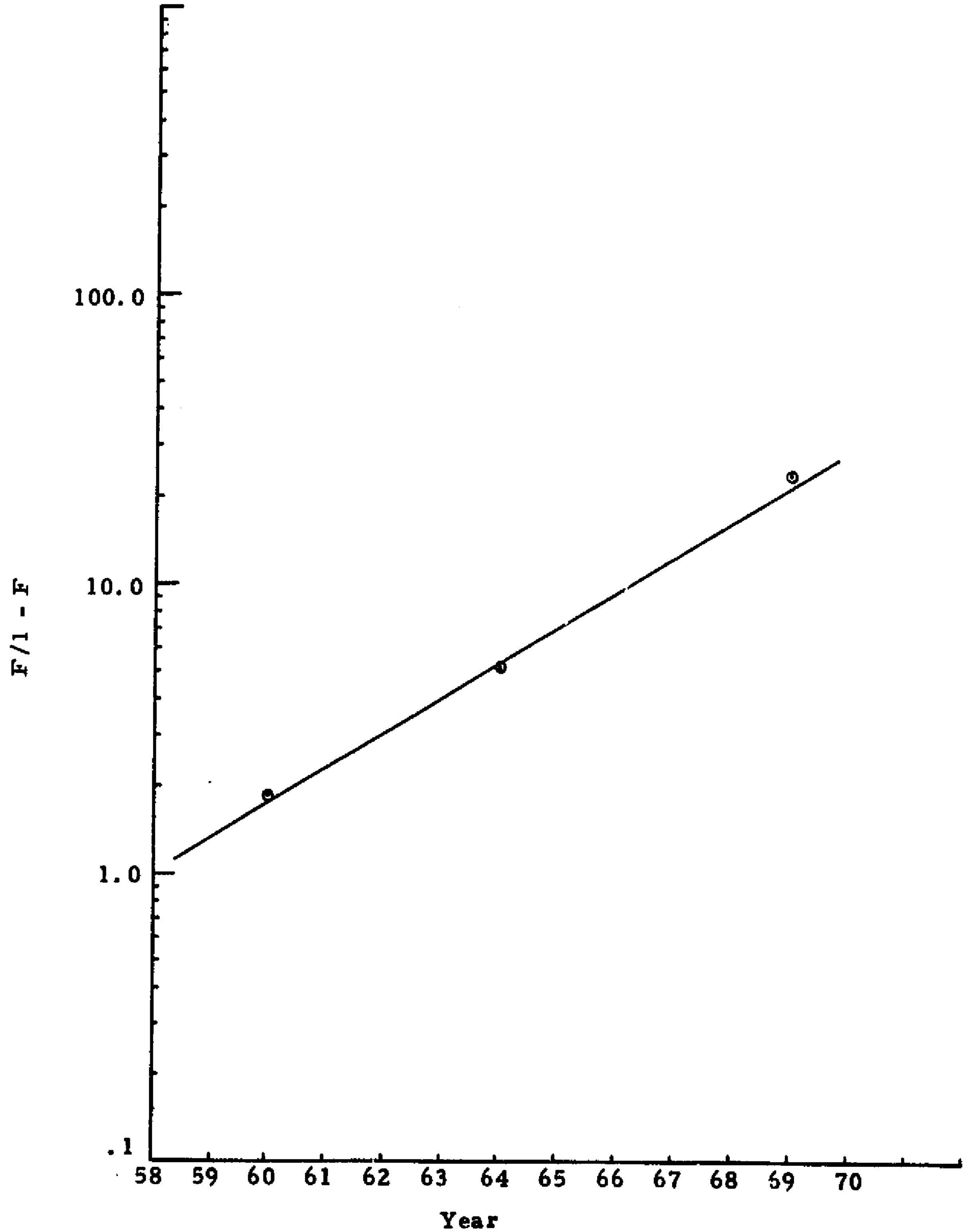

Figure 4.19 Diffusion of Computers Through Large Manufacturing Firms

TABLE 4.14

DIFFUSION OF MARKETING INFORMATION SYSTEMS THROUGH LARGE MANUFACTURING FIRMS*

Year	Percent Saturation	F/1 - F
1971	77%	3.3
1967	47%	.89
1960	16%	.19

*Sources: JOURNAL OF MARKETING RESEARCH, November 1969, p. 496 and PROCEEDINGS OF THE AMERICAN MARKETING ASSOCIATION, Fall 1971, p. 20.

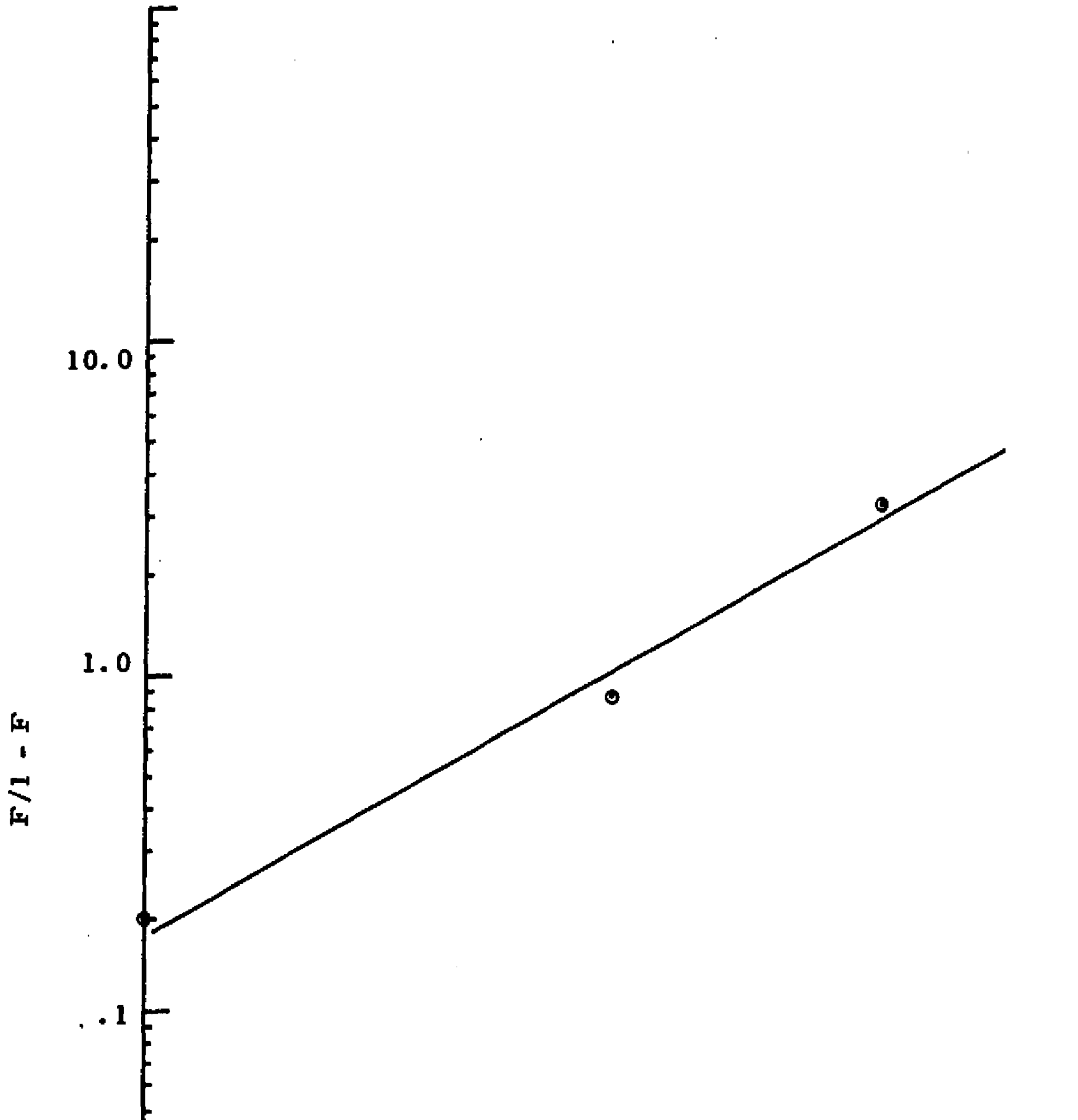

Figure 4.20 Diffusion of Marketing Information Systems Through Large Manufacturing Firms

TABLE 4.15

DIFFUSION OF VIDEOTAPE EQUIPMENT THROUGH LARGE MANUFACTURING FIRMS*

Year	Percent Saturation	F/1 - F
1968	78%	3.5
1967	51%	1.04
1965	10%	.11

*Source: THE USES OF VIDEO-TAPE IN TRAINING AND DEVELOPMENT, AMA Research Study 93.

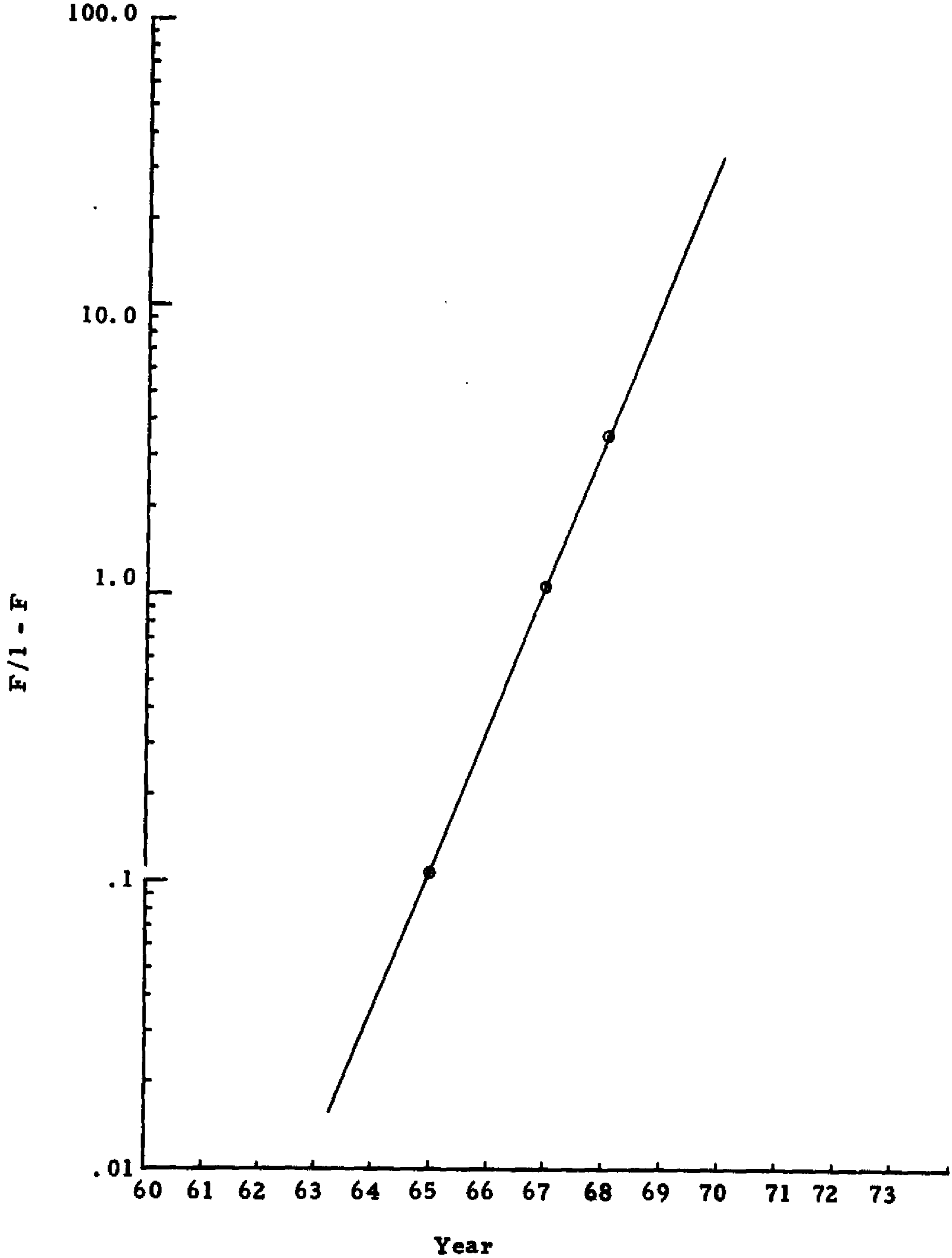

Figure 4.21 Penetration of Videotape Systems Through Large Manufacturing Firms

A study was found giving data on diffusion of three products through the administrative branch of municipal governments. While not telecommunication in nature they are electronic and provide for some transmission of information.

The computer traffic control equipment allows for flexible timing of light sequences depending on conditions. A computer analyzes the situation and varies the sequences to maximize traffic flow. By 1975 approximately forty-seven percent of municipal governments had such devices. The ten-fold time for this innovation was about nine and a half years.

Optically programmed traffic signals allow for changes in light patterns based on feedback that a sensor picks up. When traffic approaches a particular intersection this device can automatically manipulate the signal pattern to minimize traffic interference. By 1975 sixty-nine percent of the municipal governments used this device. The ten-fold time was about five years.

Pollution control can be facilitated when monitoring devices continually evaluate the environment and process this information. The electronic data signal and retrieval pollution control does this. By 1975 about thirty-seven percent of municipal governments used such a product. Ten-fold time was seven years.

In addition to the administrative branch of local governments, many other departments have need for the flow of information. Unfortunately only information on the diffusion of the computer through municipal police departments could be found. Saturation of these departments was fifty-six percent by 1974 with forecasted saturation of seventy-four percent by the end of 1977. The ten-fold time was twelve years.

Diffusion of computer traffic control is shown in Table 4.16 and Figure (4.22). Diffusion of optically programmed traffic signals is shown in Table 4.17 and Figure (4.23). Diffusion of electronic data signal and retrieval pollution control is shown in Table 4.18 and Figure (4.24). Diffusion of computers is shown in Table 4.19 and Figure (4.25).

TABLE 4.16

DIFFUSION OF COMPUTER TRAFFIC CONTROL THROUGH MUNICIPAL GOVERNMENTS*

Year	Percent Saturation	F/1 - F
1975	47%	.89
1970	20%	.25
1965	7%	.075
1960	4%	.04

*Source: Data extracted from graphs found in DIFFUSION OF INNOVATIONS IN MUNICIPAL GOVERNMENTS, Pennsylvania State University Institute for Research on Human Resources, June 1976, p. 4.

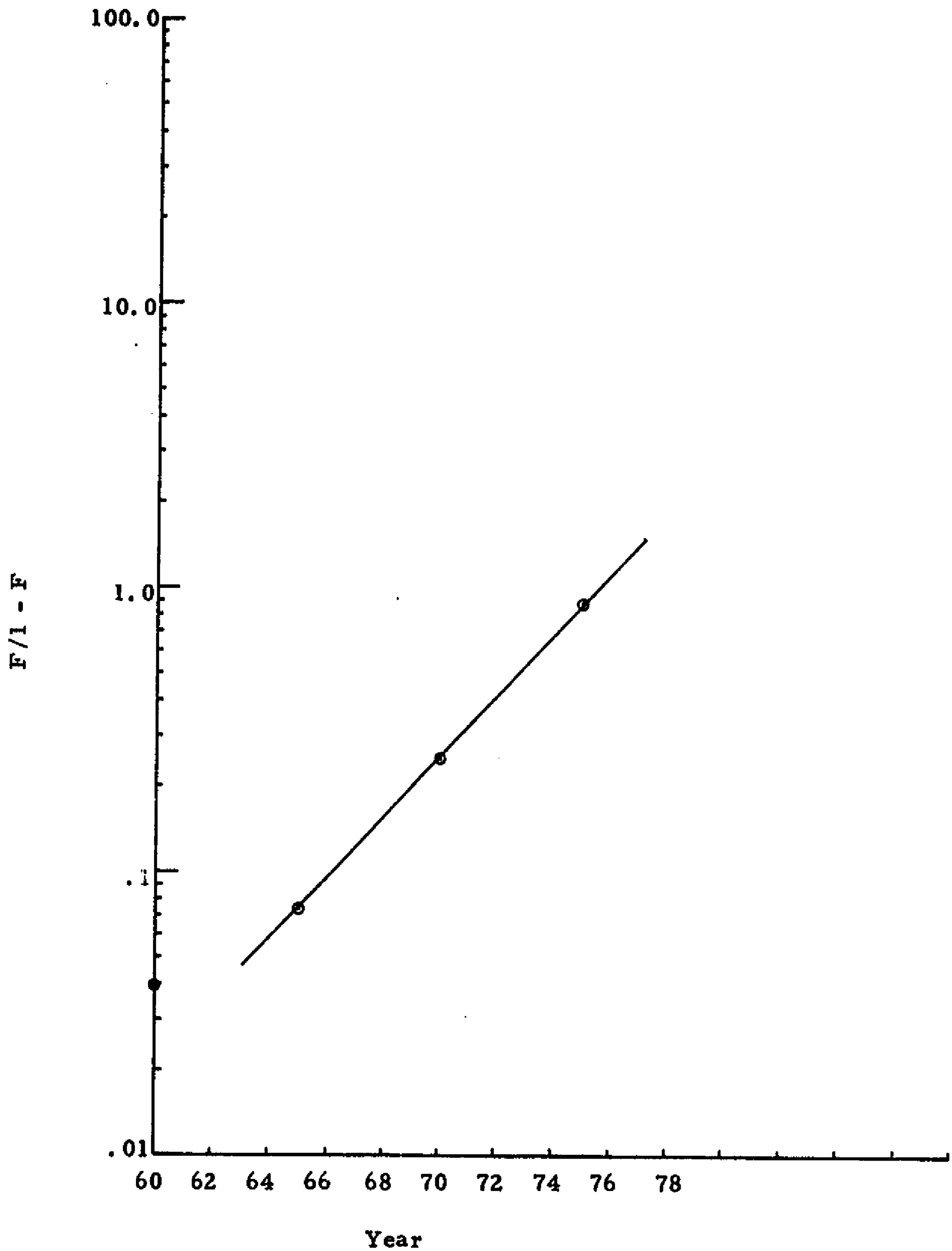

Figure 4.22 Diffusion of Computer Traffic Control Through Municipal Governments

TABLE 4.17

DIFFUSION OF OPTICALLY PROGRAMMED TRAFFIC SIGNALS THROUGH MUNICIPAL GOVERNMENTS*

Year	Percent Saturation	F/1 - F
1975	69%	2.22
1973	62%	1.63
1970	26%	.35
1968	7%	.075
1965	3%	.03

*Source: Data extracted from graphs found in DIFFUSION OF INNOVATIONS IN MUNICIPAL GOVERNMENTS, Pennsylvania State University Institute for Research on Human Resources, June 1976, p. 4.

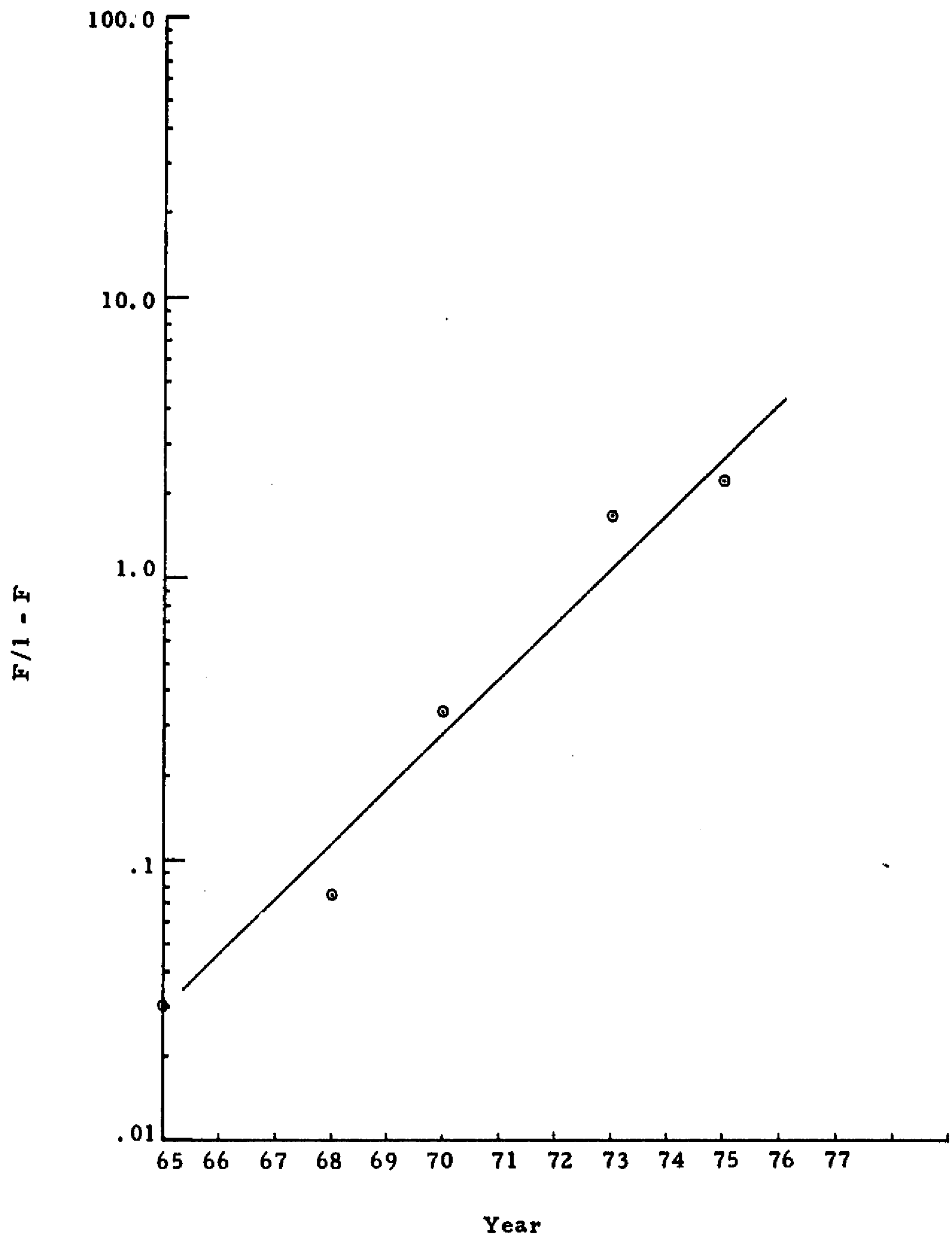

Figure 4.23 Diffusion of Optically Programmed Traffic Signals Through Municipal Governments

TABLE 4.18

DIFFUSION OF ELECTRONIC DATA SIGNAL AND RETRIEVAL POLLUTION CONTROL THROUGH MUNICIPAL GOVERNMENTS *

Year	Percent Saturation	F/1 - F
1975	37%	.59
1973	28%	.39
1970	12%	.14
1968	5%	.05
1965	3%	.03

*Source: Data extracted from graphs found in DIFFUSION OF INNOVATIONS IN MUNICIPAL GOVERNMENTS, Pennsylvania State University Institute for Research on Human Resources, June 1976, page 4.

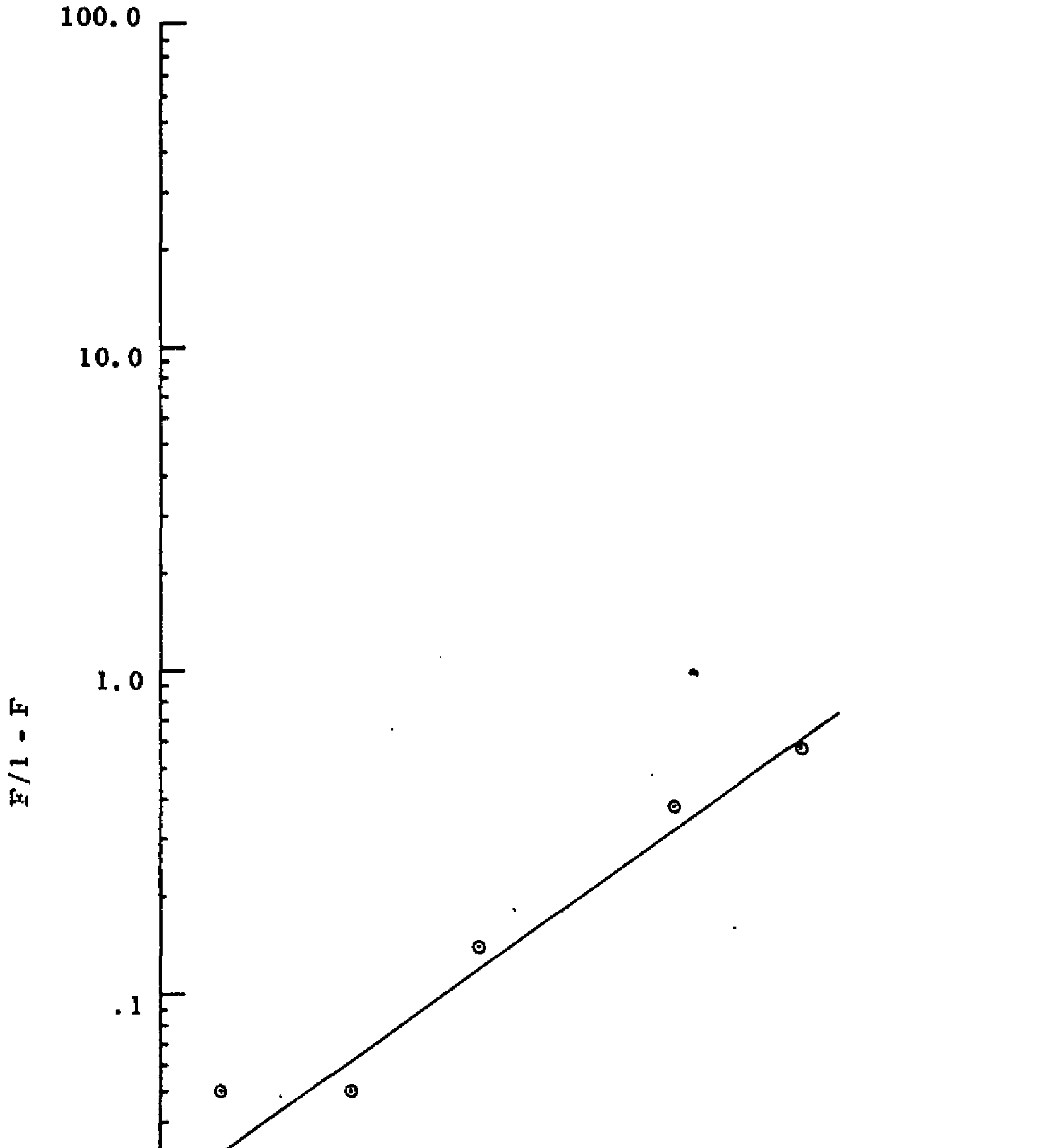

Figure 4.24 Diffusion of Electronic Data Signal and Retrieval Pollution Control Through Municipal Government

TABLE 4.19

DIFFUSION OF COMPUTER THROUGH MUNICIPAL POLICE DEPARTMENTS (CITIES OVER 25,000)*

Year	Percent Saturation	F/1 - F
1977 (forecast)	74%	2.8
1974	56%	1.3
1971	44%	.79
1967	40%	.66
1963	18%	.22
1960	9%	.1

*Sources: MUNICIPAL YEAR BOOK, International City Manager's Association, 1968 through 1975.

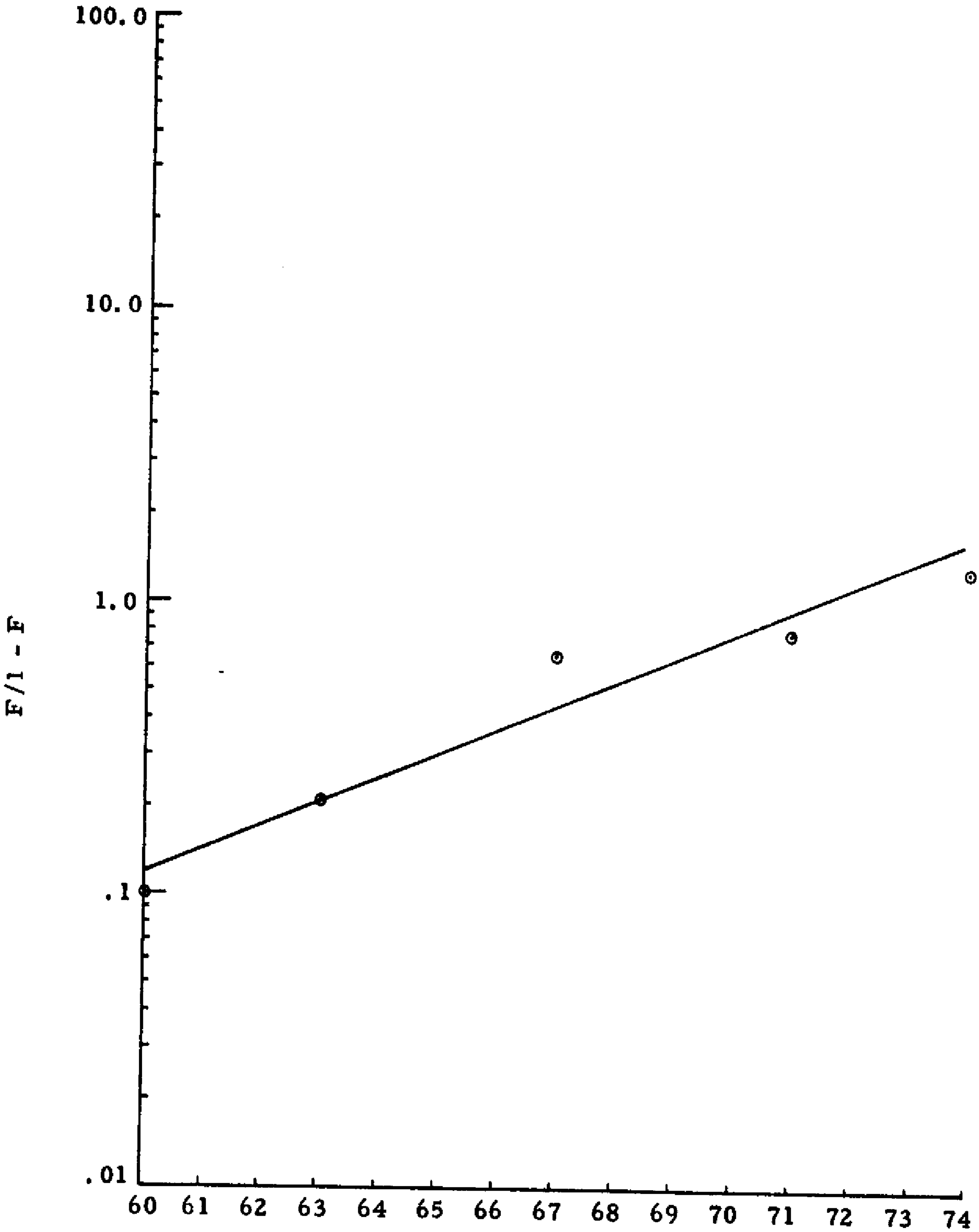

Figure 4.25 Use of Computer By Municipal Police Department (cities over 25,000 population)

4.3.6 Professional People

There is a large group of people working individually or in organizations, for which the flow of information is vital to the conduct of their business. They range from taxi fleets to doctors, with a common need to communicate. They differ in their needs as to form of communication, however, from complete messages to only signals. Information could be found on the diffusion of two communication products through these groups. The estimate of potential market size in each case was somewhat rough due to the ambiguous nature of the market, but it does allow for some idea of the adoption rate for these people.

Citizen's band radios, the rage of the electronics industry for the past several years, have been around as a two-way communication device for over two decades. Data prior to 1974 showed a very steady pattern of adoption leveling off at a little under 900,000 total adopters. This diffusion rate over a thirteen year period fit the Fisher-Pry model extremely well. The ten-fold time was four years.

Paging devices allow for transmission of either a "beep" indicating that a message is waiting for the individual or of the message itself. In either case, the intended market are those people for whom the time of reception of the message is very important, such as doctors, ambulance drivers, or law enforcement officers. There were over one half million of these units in use in 1975 or an estimated saturation of about twenty percent. The ten-fold time is about seven and one half years.

Diffusion of CB radios through the professional market is shown in Table 4.20 and Figure (4.26). Diffusion of paging devices is in Table 4.21 and Figure (4.27).

4.3.7 Wholesale Market

The distribution system in the United States is extremely complex. The pattern of product movements is very sophisticated and becoming more so every year. Wholesale organizations, those that handle movement of the product from the manufacturer through all steps with the exception of the

TABLE 4.20

DIFFUSION OF CB RADIOS THROUGH PROFESSIONAL MARKET*

Year	Cumulative Number	Percent Saturation**	F/1 - F
1968	867,600	96.4%	26.5
1967	847,800	94.2%	16.3
1966	794,700	88.3%	7.5
1965	743,400	82.6%	4.7
1964	680,400	75.6%	3.1
1963	441,000	49%	.97
1962	319,400	35.5%	.55
1961	202,500	22.5%	.29
1960	103,500	11.5%	.13
1959	49,500	5.5%	.057
1958	37,800	4.2%	.044

*Sources: Federal Communications Commission

**Estimate of saturation based on 900,000 total adoptions.

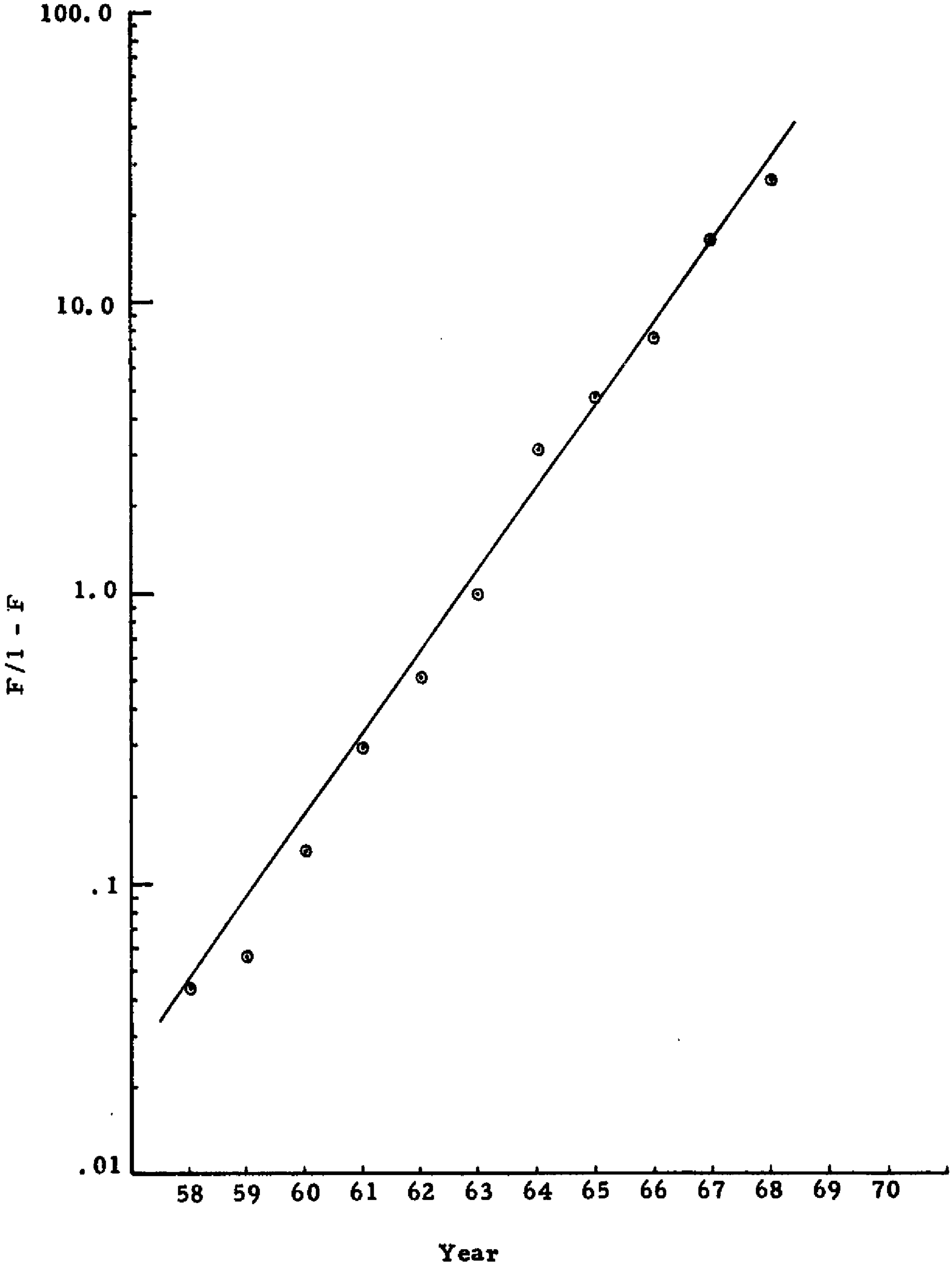

Figure 4.26 Diffusion of CB Radios Through Professional Market (900, 000 total adoptions)

TABLE 4.21

DIFFUSION OF PAGING DEVICES BY PROFESSIONAL PEOPLE*

Year	Number	Percent Saturation**	F/1 - F
1975	512,000	19,7%	.25
1974	403,000	15.5%	.18
1973	313,000	12.0%	.14
1972	240,000	9.2%	.10

*Source: George F. Mansur, "Paging," ELECTRONICS INDUSTRIES ASSOCIATION ANNUAL CONFERENCE PROCEEDINGS, 1976, p. 104.

**Percent Saturation based on a total potential market of 2.6 million users at today's prices of $16-23 for tone only and $22-30 for tone and voice.

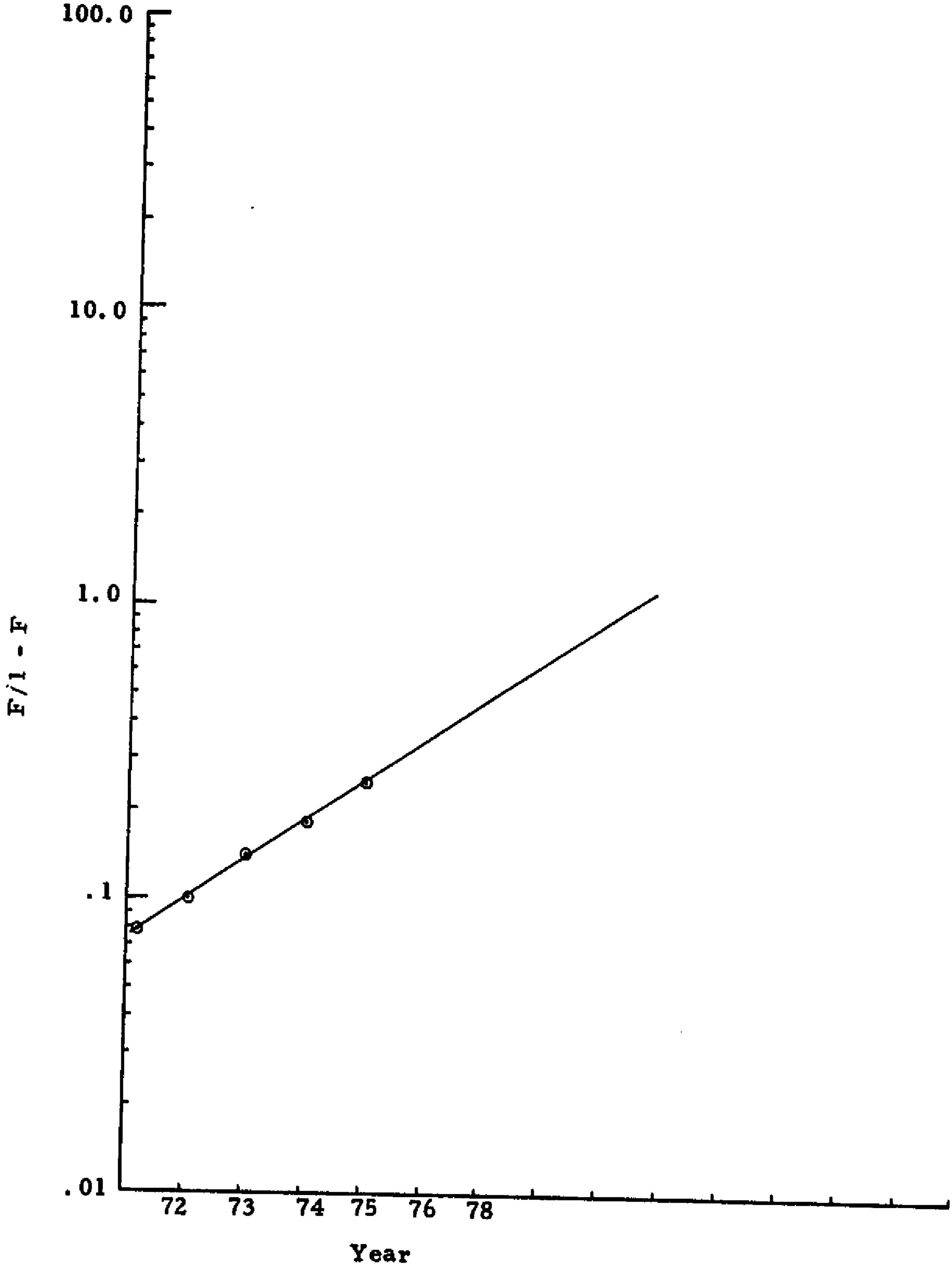

Figure 4.27 Penetration of Paging Devices By Professional People

consumer transaction, have an increasing need for transmission and processing of data in order to remain competitive. Thus they would be a potentially good market for many types of telecommunication innovations.

Unfortunately data on previous diffusions is very sparse and only information on the adoption rate of the computer could be found. By the end of 1975 about sixty-five percent of all wholesale organizations in the U.S. had adopted use of the computer. The ten-fold time was six and one half years. If this pattern were consistent over products it would put their adoption rate similar to large manufacturing firms instead of businesses in general. Diffusion of computers through wholesale firms is shown in Table 4.22 and Figure (4.28).

4.3.8 Consumer Market

By far the largest potential market for many new products is consumers themselves. With over one hundred fifty million people over eighteen years old and seventy-two million households, the potential is staggering. The diffusion rate through the consumer market has been studied by many people, but usually in terms of correlates of innovation or imitation, and not much in regards to the rate itself.

Of the seven products, electronic or communication in nature, for which data were found, all but one fit neatly into one of two groups. The first had ten-fold times of from two to three and one half years, and the second from eight to thirteen years. The first group were much more individually oriented. This group consisted of CB radios, two years; electronic calculators, three and one half years; and electronic digital watches, two years. Although data on these products are rather limited due to the newness of them, their patterns of adoption are remarkably similar.

The second group of products were those that were aimed more for household consumption rather than individual. They consisted of black and white television, eight and one half years; color television, eight years; and cable television, thirteen years. The one product that did not fit as

TABLE 4.22

DIFFUSION OF COMPUTER THROUGH WHOLESALE DISTRIBUTION ORGANIZATIONS*

Year	Percent Saturation	F/1 - F
1975	65%	1.85
1974	53%	1.12
1973	45%	.82
1972	38%	.61

*Source: 1975 and 1972 Year-End Studies of the National Association of Wholesaler-Distributors.

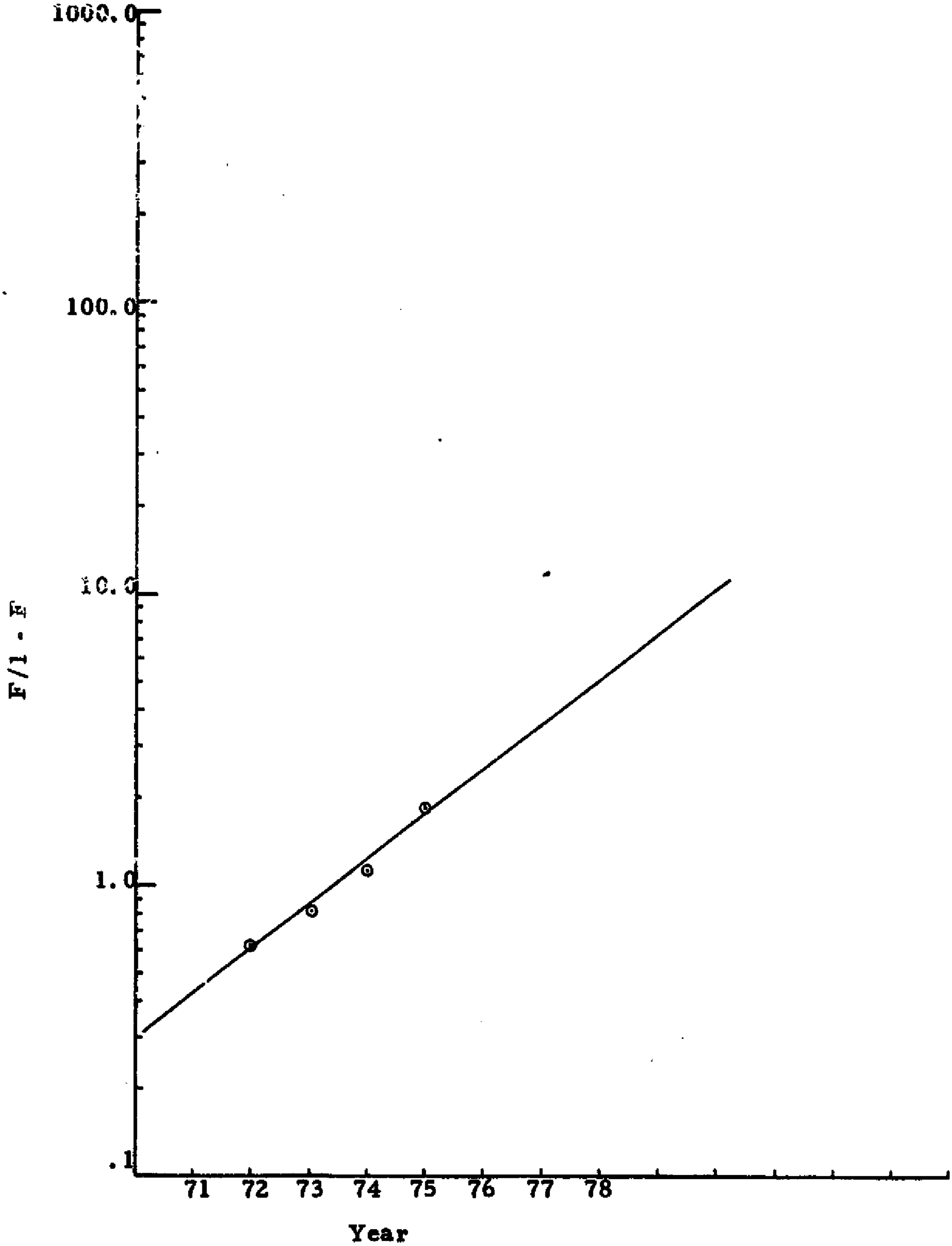

Figure 4.28 Diffusion of Computer Through Wholesale Distribution Organizations

well into either group was the tape recorder with a ten-fold time of five years. There are two possible explanations why it might fall in between the two groups. The first is that, although all the household group products could be purchased for individual consumption, the tape recorder has the greatest potential to be so. This is especially true of the portable ones. The second explanation is that the tape recorder was much less expensive than the other products in the household group.

In spite of the discrepancy of the tape recorders, the remaining consumer products have remarkably consistent adoption patterns. Diffusion of color television is shown in Table 4.23 and Figure (4.29). Diffusion of cable television is shown in Table 4.24 and Figure (4.30). Diffusion of tape recorders is shown in Table 4.25 and Figure (4.31). Diffusion of black and white television is shown in Table 4.26 and Figure (4.32). Diffusion of electronic calculators is shown in Table 4.27 and Figure (4.33). Diffusion of digital watches is shown in Table 4.28 and Figure (4.34).

4.4 SUMMARY

The study of the adoption of innovations is important both to firms introducing the innovations and also to the macroenvironment in which the innovations are introduced. This is especially true in the telecommunications field where the success of innovations affect not only the profits of companies involved but also have a great impact on the structure and behavior of the society itself.

This appendix has attempted to present a method for analyzing the diffusion of telecommunication innovations through those markets that appeared to be especially important for these innovations. A couple of general observations can be made as a result of this study.

First, a relatively simple model was successful in tracing the adoption of most of the innovations quite closely. This is especially true when measured against the needs of the cross-impact model itself. Two facets of special importance is the ability of the model to provide information or large numbers

TABLE 4.23

DIFFUSION OF COLOR TV THROUGH CONSUMER MARKET*

Year	Percent Saturation**	F/1 - F
1974	71.5%	2.50
1973	67.1%	2.03
1972	60.7%	1.54
1971	51.1%	1.04
1970	42.5%	.74
1969	38.2%	.61
1968	35.7%	.56
1967	26.2%	.35
1966	15.0%	.18
1965	9.5%	.1

*Sources: Issues of MERCHANDISING, March 1965 through 1975.

**Percent Saturation based on number of households in the U.S.

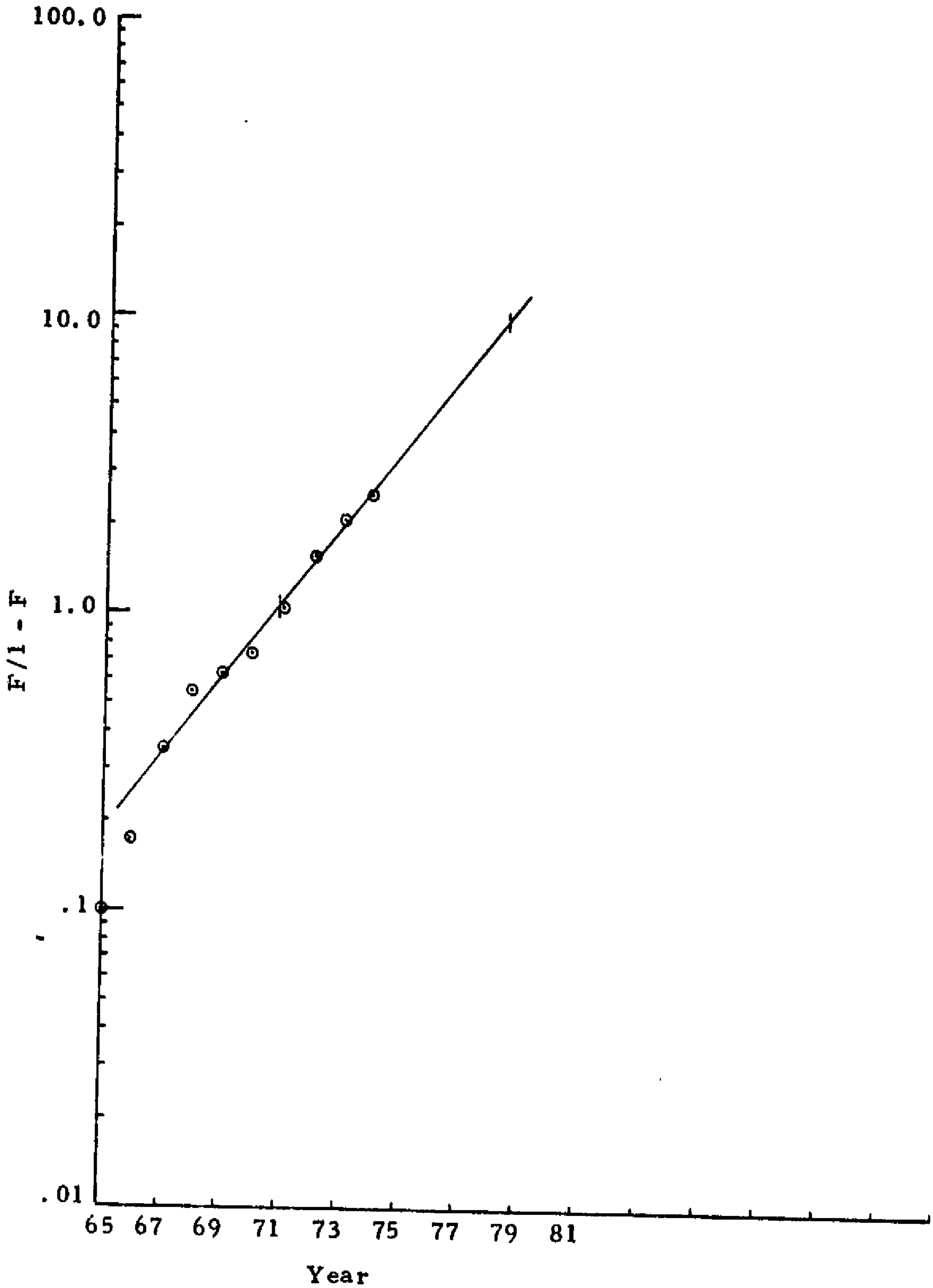

Figure 4.29 Penetration of Color TV Through Consumer Market

TABLE 4.24

DIFFUSION OF CABLE TV THROUGH CONSUMER MARKET*

Year	Number Of Homes (million)	Fraction Saturation**	F/1 - F
1955	.15	.005	.005
1960	.65	.014	.014
1962	.85	.016	.016
1963	.95	.017	.017
1964	1.1	.020	.020
1965	1.275	.024	.025
1966	1.575	.029	.030
1967	2.1	.038	.040
1968	2.8	.044	.046
1969	3.6	.061	.065
1970	4.5	.077	.083
1971	5.3	.088	.096
1972	6.0	.097	.1074
1973	7.3	.113	.1274
1974	8.7	.127	.1455
1975	10.8	.154	.182

*Sources: TV FACTBOOK and STATISTICAL ABSTRACTS OF THE UNITED STATES, 1975.

**Saturation based on total number of households.

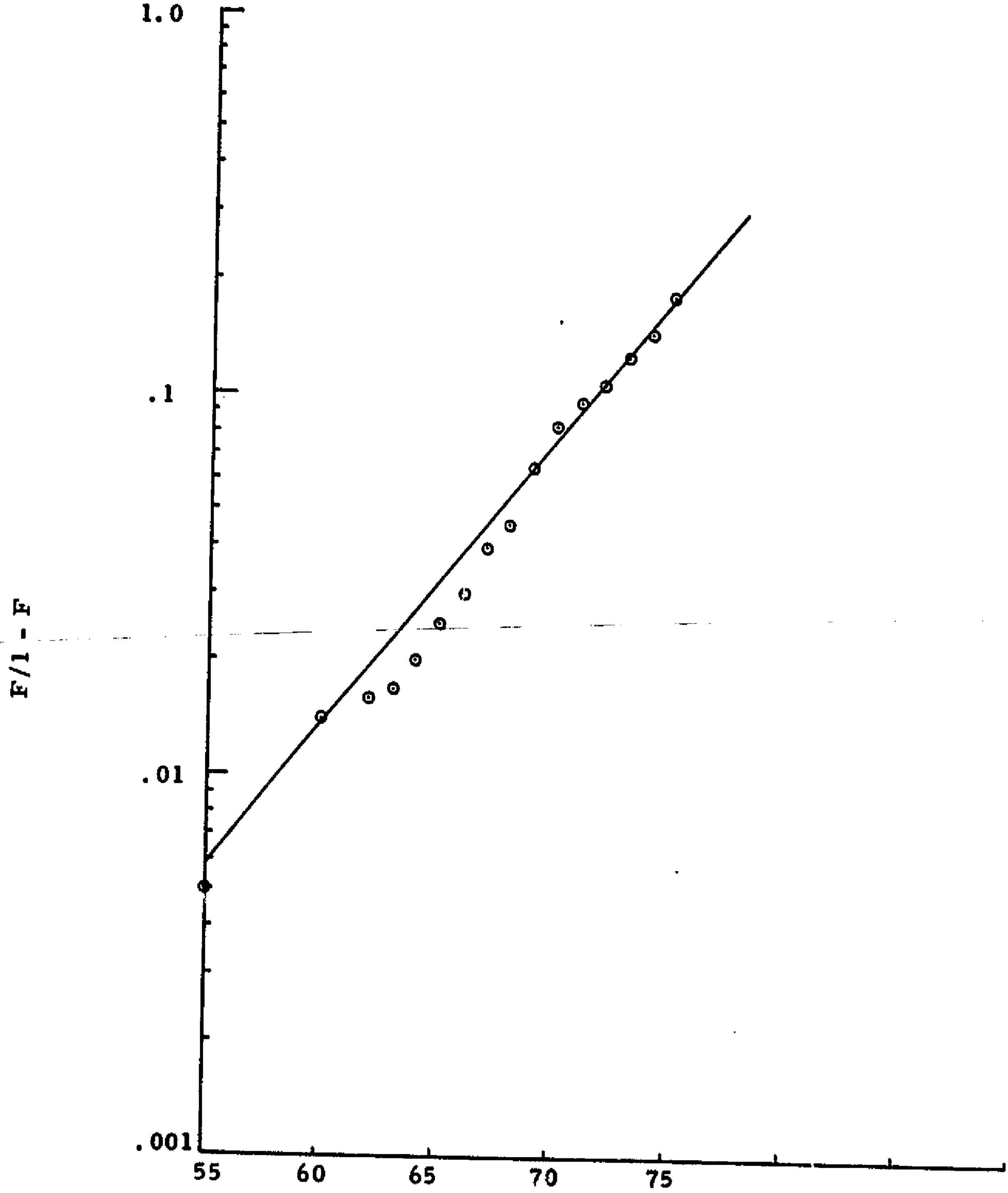

Figure 4.30 **Diffusion of Cable TV Through Consumer Market**

TABLE 4.25

DIFFUSION OF TAPE RECORDERS THROUGH CONSUMER MARKET*

Year	Cumulative Number (millions)	Percent Saturation**	F/1 - F
1969	34.5	55%	1.2
1968	27.6	45%	.82
1967	22.0	37%	.59
1966	17.4	30%	.43
1965	13.7	24%	.32
1964	9.9	18%	.22
1963	6.2	11%	.12
1962	3.3	6%	.06
1961	1.5	3%	.03
1960	.3	.5%	.005

*Sources: Issues of MERCHANDISING, March 1960 through 1969.

**Percent Saturation based on number of households in U.S.

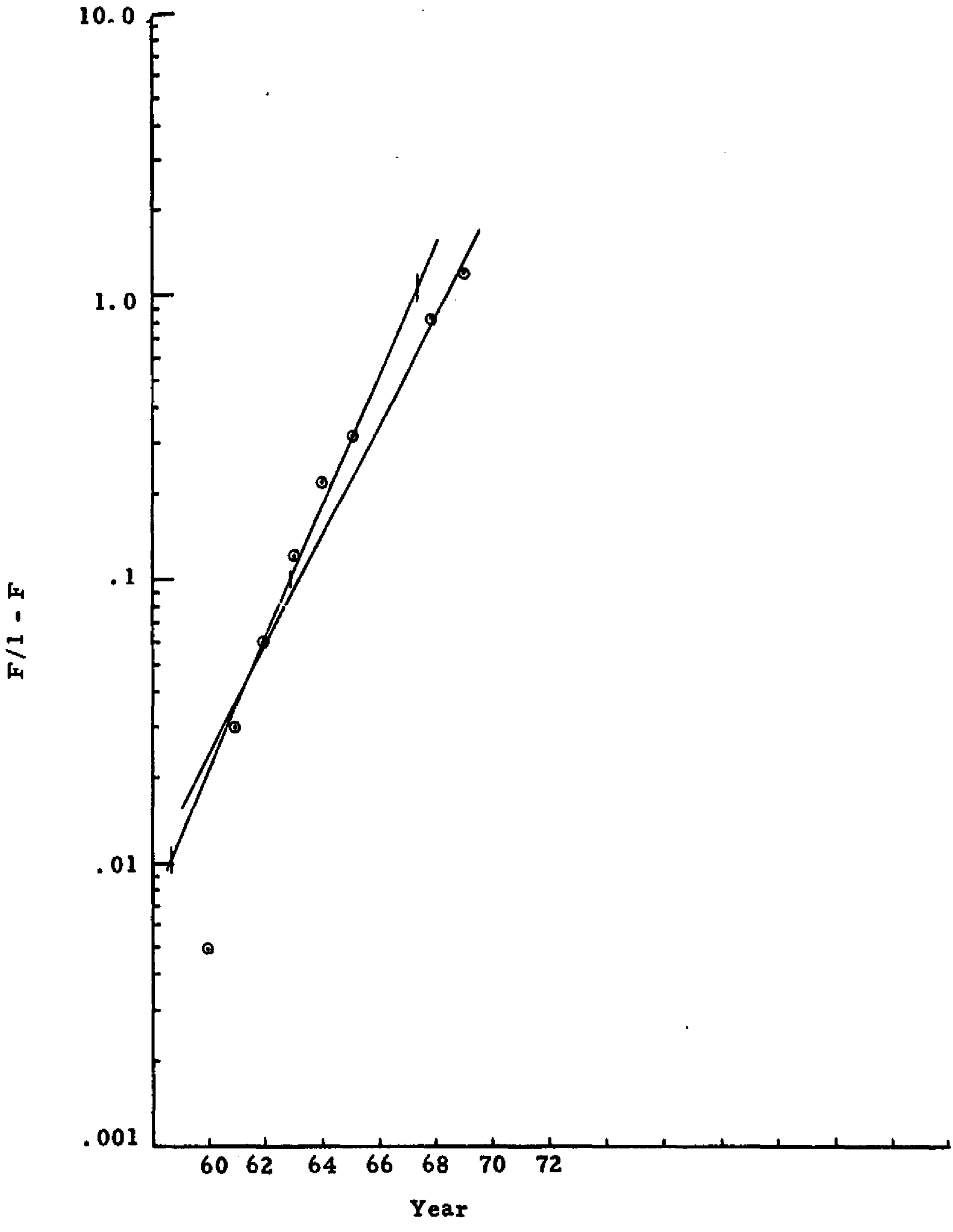

Figure 4.31 Penetration of Tape Recorders Into Consumer Market

TABLE 4.26

DIFFUSION OF BLACK AND WHITE TELEVISION THROUGH CONSUMER MARKET*

Year	Percent Saturation	F/1 - F
1970	96%	24
1968	95%	19
1966	94%	15.7
1964	93%	13.3
1962	90%	9
1960	88%	7.3
1954	80%	4
1953	66%	1.9
1952	54%	1.2
1951	42%	.72
1950	30%	.43
1949	11%	.12
1948	3%	.03
1947	.5%	.005

*Sources: Issues of ELECTRONIC INDUSTRIES, January 1948 through 1961 and 1976 ELECTRONIC MARKET DATA BOOK.

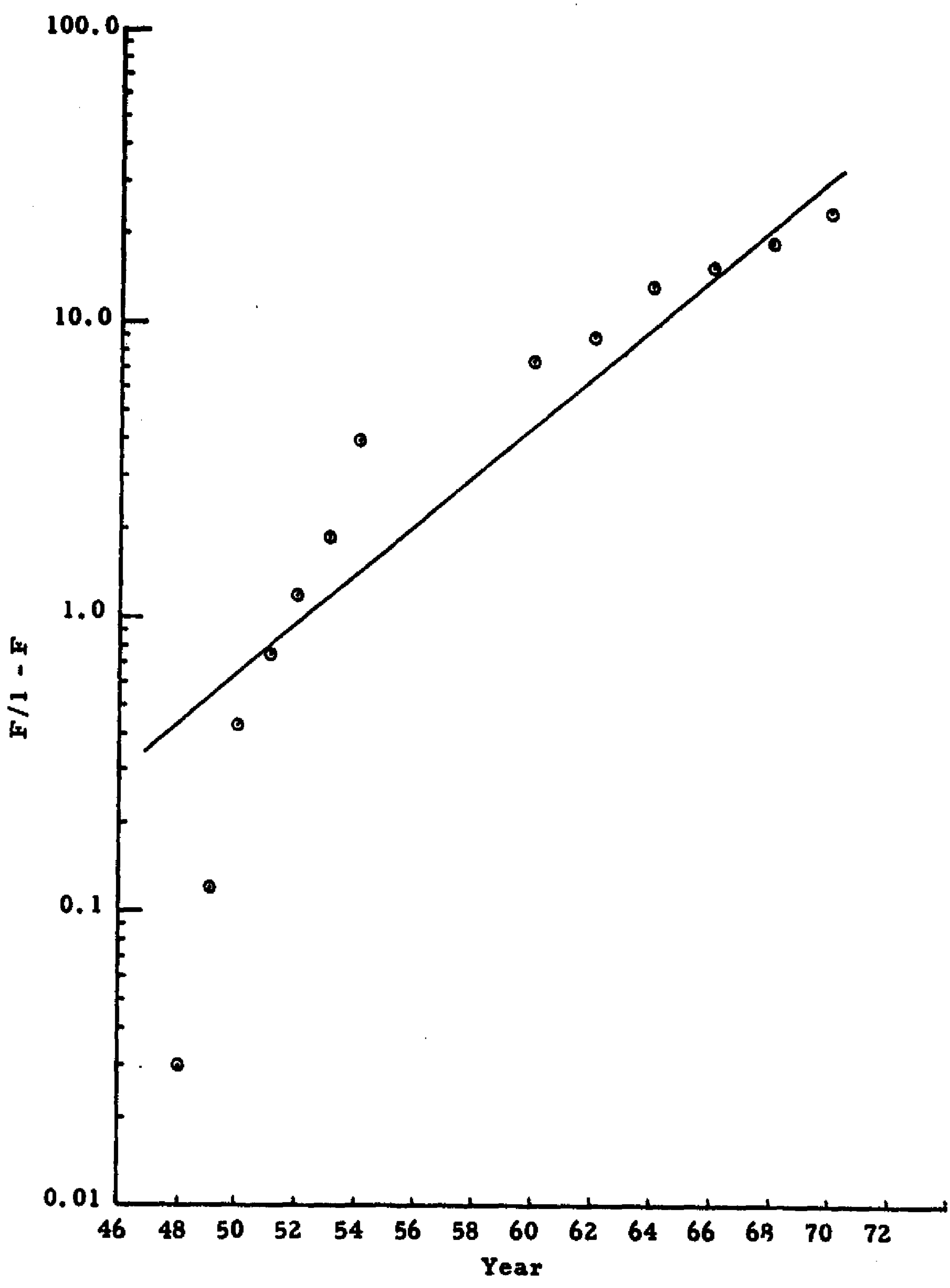

Figure 4.32 Diffusion of Black & White Television Through Consumer Market

TABLE 4.27

DIFFUSION OF ELECTRONIC CALCULATORS THROUGH CONSUMER MARKET*

Year	Cumulative Number (millions)	Percent Saturation**	F/1 - F
1975	50.9	35.8	.558
1974	32.5	22.9	.297
1973	18.2	12.8	.147
1972	6.0	4.2	.044

*Sources: Issues of MERCHANDISING, March 1972 through 1976.

**Based on population 18 years and older.

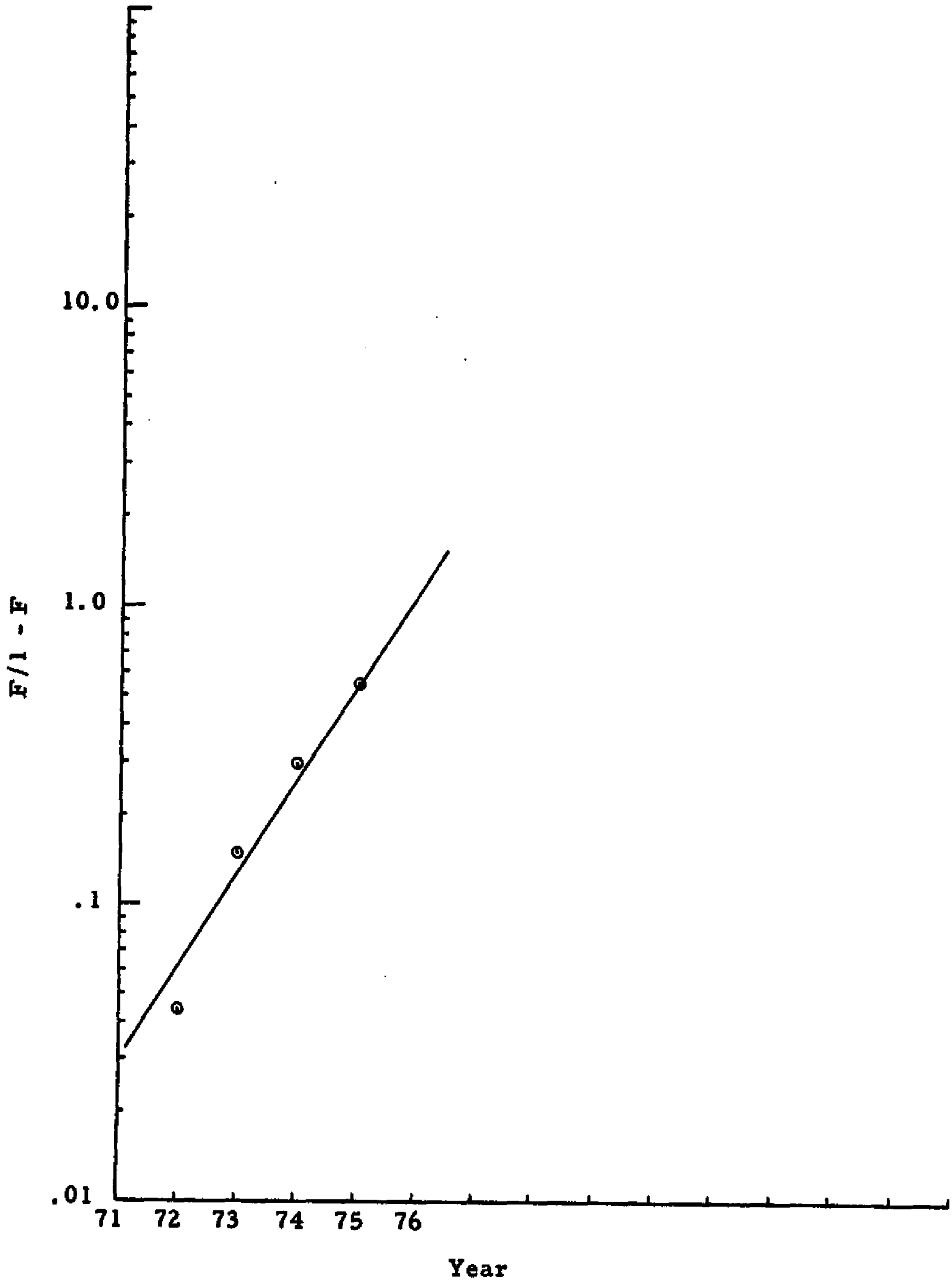

Figure 4.33 Diffusion of Electronic Calculators Through Consumer Market

TABLE 4.28

DIFFUSION OF DIGITAL WATCHES THROUGH CONSUMER MARKET*

Year	Cumulative Number (millions)	Percent Saturation**	F/1 - F
1976	13.28	9.35	.103
1975	3.77	2.65	.027
1974	1.007	.7	.007
1973	.340	.2	.002

*Sources: Issues of MERCHANDISING, March 1973 through 1976.

**Percent Saturation based on adult population.

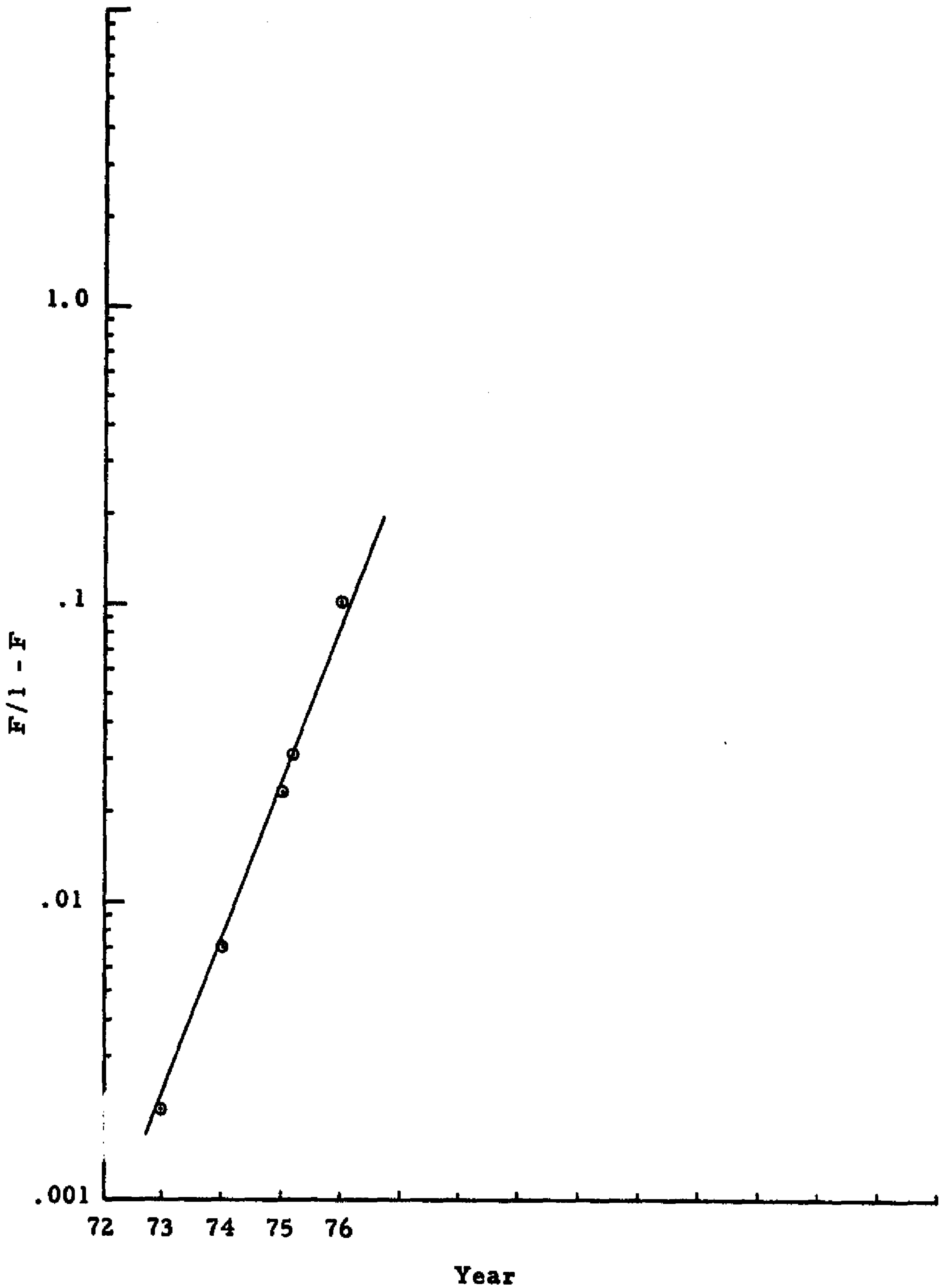

Figure 4.34 Diffusion of Digital Watches Through Consumer Market

of product/market cells at relatively low cost and also the ability of the model to provide specific events such as the 10, 50, or 90 percent penetration points.

Second, although the adoption rate for innovations differed considerably between markets, there was a high degree of internal consistency within the markets for many different products. This is even further emphasized when submarkets were utilized for several of the groups. This is very useful in analyzing future innovations. While one can not say for certain that a particular product will diffuse like previous ones, the comparative rates should give a good indication of the markets vis-a-vis each other.

The market penetration models developed in the appendix thus should be useful both in their ability to be incorporated in the overall cross-impact model and also as a study of the diffusion of products in the markets themselves.

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APPENDIX 5

PROJECTION OF HISTORICAL TRENDS IN TELECOMMUNICATIONS TECHNOLOGY

This appendix contains a detailed description of the development of predicted trends in telecommunications technology which were used as a basis for many of the events incorporated in the cross-impact forecast of satellite communications.

Trend projections in this appendix cover communication satellite characteristics, earth station characteristics, satellite communication cost elements, trends in special telecommunication services, broadcast service projections, and the substitution of electronics for paper-and-ink communications.

C. 2

5.1 PROJECTION OF COMMUNICATION SATELLITE TRENDS

Projections of technological progress in the component elements of communication satellites are at least partly dependent upon such basic factors as the numbers and the weights of the satellite systems. Therefore, the starting point for this portion of the forecast is the determination of historical trends in communication satellite numbers and weights and a projection of these trends to the year 2000.

The history of communication satellites covers at most a period of only 16 years. Therefore, the projection to the year 2000 makes the forecast almost two times longer than the historical base. In general, it would be preferred that the trend baselines be at least as long as the period of the forecast. Since a 25-year data base obviously does not exist, less confidence may be placed in the projections for the last decade of the century. Nevertheless, even in the later period, the trends do indicate the general capabilities which should be achieved, and provide a useful basis for updating the forecast as additional data becomes available with the passage of time.

A key feature of this forecast is the establishment of internal consistency among the trends, i.e., whenever a given physical relationship naturally exists among two or more trends, the projections will maintain that relationship. For example, the trends in numbers of satellites, total weight of satellites, and average weight of satellites have an obvious mathematical relationship, and any projection of these separate trends must logically reflect such a relationship. More complex relationships such as that between power source efficiency, radiated power, and satellite weight, require the same consideration for what might be termed "system trend budget balance". This point is stressed particularly for two reasons: (1) the requirement that separately projected trends should result in a logical overall outcome is often overlooked or ignored, and (2) the attempt to establish the required "system trend budget balance" will often disclose areas or components where technical progress is critical to the achievement of long-range goals.

The establishment of projected dates for the achievement of various levels of performance in communication satellite technology also provides material for the specification of events for the cross-impact matrix in subsequent portions of this assessment. Some of the overall aspects of the projection are also correlated with the projections of market penetration to establish relationships between that which is technically feasible and the probable market for such advances.

5.1.1 Projection of Communication Satellite Weight

The projection of the total weight of communication satellite systems in orbit and operational is a significant starting point, since it is an essential factor in the total capacity for communication which may be available. Obvious tradeoffs, of course, exist, since increased component efficiencies can lower the total weight required for a given amount of communication capability. However, in general, with a reasonable projection of total weight, it is likely that increased efficiencies will be used to expand communication capability for exploitation of expanding market potentials.

The historical data and trend of total U.S. communication satellite system weight in orbit and operational is included in Tables 5.1 and 5.2 and Figure 5.1.* The forecast trend for this weight is presented in Table 5.3 and Figure 5.1. The 1975 weight of 9,773 kg is projected to increase to approximately 67,600 kg by 2000, for an increase of nearly 700% or an average annual rate of 8% per year. This is conservative by comparison with the average annual rate of increase of nearly 40% per year during the period from 1962 to 1975, but is consistent with the pattern of a

*Experimental communications satellites have been omitted from these tables because, although very important to technological progress, their characteristics are anachronistic with respect to the primary operational stream.

TABLE 5.1

WEIGHT OF U.S. COMMUNICATION SATELLITES*
(ANNUAL VALUES)

Year	No. of Communication Satellites Launched			Total Weight Launched (kg)			Average Weight		Max. Weight
	During Yr.	Cum.	Oper. at Yr. End	During Yr.	Cum.	Oper. at Yr. End	Launched (kg)	Oper. at Yr. End	Launched (kg) During Yr.
1960	1	1	0	227	227	0	227	227	227
1962	2	3	2	155	382	155	78	78	78
1963	2	5	3	119	501	197	60	66	80
1964	2	7	5	117	618	314	59	63	78
1965	1	8	3	40	658	118	40	39	40
1966	1	9	4	322	980	440	322	110	322
1967	5	4	9	770	1750	1210	154	134	368
1968	2	16	11	522	2272	1732	261	157	368
1969	3	19	10	958	3230	2484	319	248	650
1970	2	21	11	308	3538	2704	154	246	154
1971	4	25	13	2510	6048	4804	628	370	732
1972	2	27	12	1464	7512	4727	732	394	732
1973	3	30	9	1852	9364	5088	617	565	732
1974	3	33	10	1882	11246	6662	627	666	732
1975	5	38	15	3111	14357	9773	622	651	795

*All satellite elements in each IDSCS launch are considered collectively as a single satellite.

TABLE 5.2

U.S. COMMUNICATION SATELLITES LIFE AND WEIGHT DATA*

(Page 1 of 2)

	Design or Timer Life in Years	Year Out	Life in Years	Orbit Wt. kg	Elect. Power Wt.** kg	Electronics Wt. kg	Attitude Control (wt. kg)	Structure (wt. kg)	Comm. subsys. (incl. in Electron. (wt. kg)
1960									
Courier 1b		1960	<1	227					
1962									
Telstar 1		1963	1	77					
Relay 1		1965	3	78					
1963									
Telstar 2		1965	2	80					
Syncom 2		1969	6	39	5.6	11.9	4.7	7.2	
1964									
Relay 2		1965	2	78					
Syncom 3		1969	5	39	5.6	11.9	4.7	7.2	
1965									
Intelsat 1		1969	4	40	6.5	12.2	3.1	7.9	8.5
1966									
IDCSP 1-7	6	1971	6	46(x7)	12	18		10	14 (ea)
1967									
Intelsat 2B(F-2)		1969	3	88	21.4	22.5	9.4	10.5	17.5
Intelsat 2C(F-3)		1970	3	88	21.4	22.5	9.4	10.5	17.5
Intelsat 2D(F-4)		1971	4	88	21.4	22.5	9.4	10.5	17.5
IDCSP 8-15	6	1972	5	46(x8)	12	18		10	14 (ea)
IDCSP 16-18	6	1973	6	46(x3)	12	18		10	14 (ea)
1968									
IDSCS 19-26	6	1973	6	46(x8)	12	18		10	14 (ea)
Intelsat 3F2	5	1973	5	154	29.6	40.5	8.3	26.5	

*Experimental & Passive Satellites Excluded
**Communication Subsystems, T/M, and Command
Sources: Astronautics & Aeronautics-May 1976, and TRW Space Log Series

TABLE 5.2

1969									
Intelsat 3F3	5	1973	5	154	29.6	40.5	8.3	26.5	
Intelsat 3F4	5	1973	5	154	29.6	40.5	8.3	26.5	
TACSAT 1		1972	4	650	132	140	78	300	86
1970									
Intelsat 3F6	5	1974	5	154	29.6	40.5	8.3	26.5	
Intelsat 3F7	5	1974	5	154	29.6	40.5	8.3	26.5	
1971									
Intelsat 4F2	7	1977	7	732	83	177	57	202	154
Intelsat 4F3	7	1978	7	732	83	177	57	202	154
DSCS-1		1972	1	523	137	137	119	130	101
DSCS-2		1973	2	523	137	137	119	130	101
1972									
Intelsat 4F4	7	1978	7	732	83	177	57	202	154
Intelsat 4F5	7	1979	7	732	83	177	57	202	154
1973									
Intelsat 4F7	7	1980	7	732	83	177	57	202	154
DSCS II F3	5	1978	5	560	142	142	124	135	106
DSCS II F4	5	1978	5	560	142	142	124	135	106
1974									
Intelsat 4F8	7	1981	7	732	83	177	57	202	154
WESTAR 1	7(est)	1980	7	575					
WESTAR 2	7(est)	1981	7	575					
1975									
Intelsat 4F1	7	1981	7	732	83	177	57	202	154
Intelsat 4AF1	7	1982	7	795					
RCA SATCOM 1	8	1983	8	464					
DSCS II F-7	5	1980	5	560	142	142	124	135	106
DSCS II F-8	5	1980	5	560	142	142	124	135	106

*Experimental & Passive Satellites Excluded
**Communication Subsystems, T/M, and Command

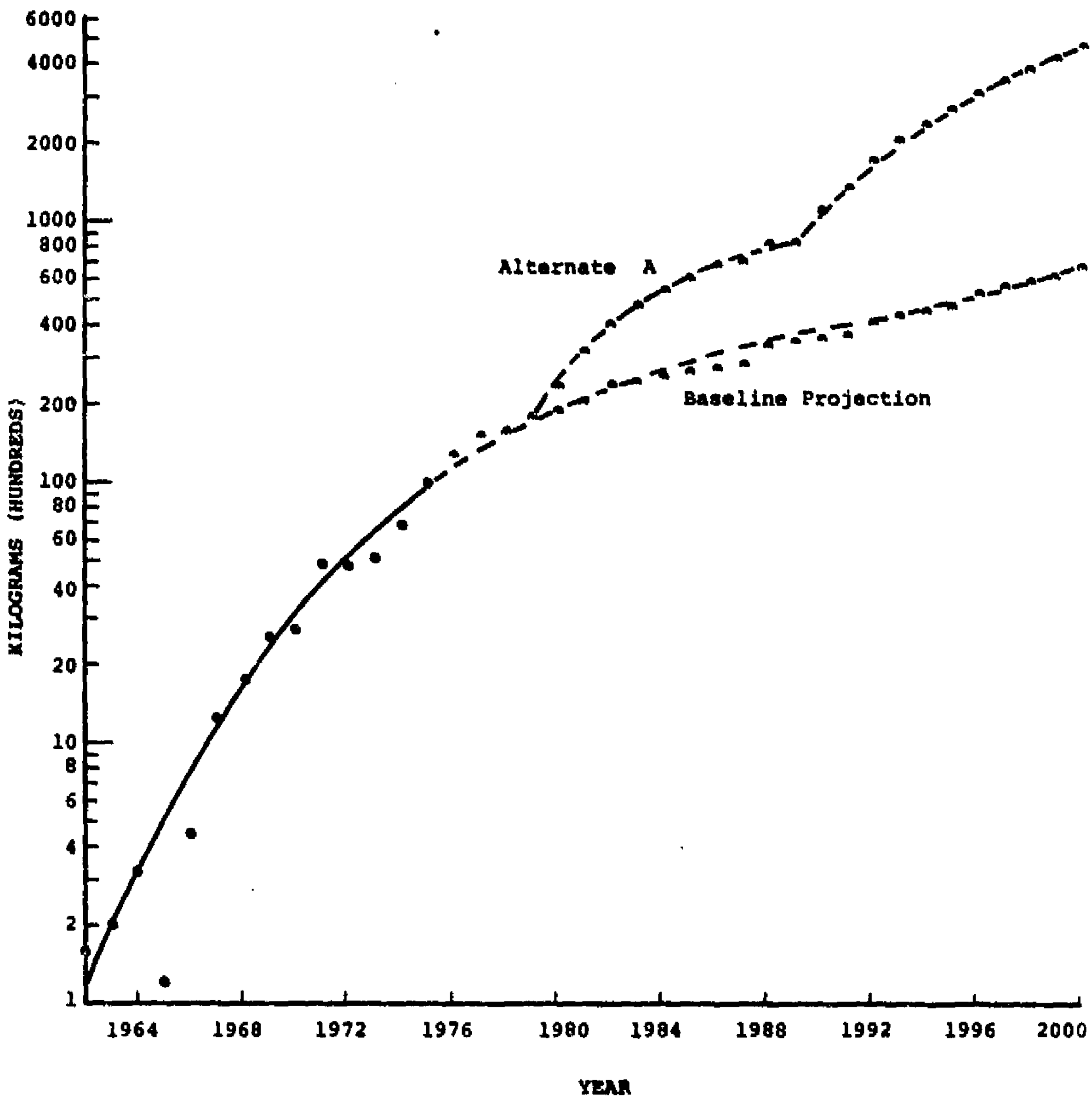

Figure 5.1. U.S. Communication Satellite Weight in Orbit and Operational (Kilograms)

TABLE 5.3

BASELINE PROJECTION OF U.S. COMMUNICATION SATELLITES

Year	No. of Communication Satellites Launched			Total Weight (kg) Launched			Average Weight (kg)	
	During Yr.	Cum.	Oper. at Yr. End *	During Yr.	Cum.	Oper. at Yr. End	Launched	Oper. at Yr. End
1975 (ref)	5	38	15	3111	14357	9773	622	651
1976	4	42	19	2960	17317	12733	740	670
1977	4	46	22	3020	20337	15021	755	683
1978	4	50	22	3060	23397	15497	765	704
1979	4	54	25	3100	26497	17865	775	715
1980	4	58	25	3140	29637	18578	785	743
1981	5	63	27	3975	33612	20514	795	760
1982	5	68	31	4000	37612	23719	800	765
1983	5	73	31	4025	41637	24320	805	785
1984	5	78	32	4050	45687	25350	810	792
1985	5	83	33	4075	49762	26365	815	799
1986	5	88	34	4100	53862	27365	820	805
1987	5	93	35	4125	57987	28350	825	810
1988	6	99	41	4980	62967	33330	830	813
1989	6	105	42	5010	67977	34365	835	818
1990	6	111	43	5040	73017	35405	840	823
1991	6	117	44	5070	78087	36450	845	828
1992	6	123	50	5100	83187	41550	850	831
1993	7	130	52	5985	89172	43485	855	836
1994	7	137	54	6020	95192	45430	860	841
1995	7	144	56	6055	101247	47385	865	846
1996	7	151	63	6090	107337	53475	870	849
1997	8	159	66	7000	114337	56350	875	854
1998	8	167	68	7040	121377	58410	880	859
1999	8	175	70	7080	128457	60480	885	864
2000	8	183	78	7120	135577	67600	890	867

$$\left[\frac{\text{Total Wt.}}{\text{Avg. Wt.}} = \text{No. of Satellites}\right]$$ for internally consistent projection

*Assuming projected lifetime for satellites launched after 1975.

decreasing rate of increase, as may be seen in Figure 5.1. The perturbations in the projected curve are the result of the calculations to establish internal consistency with the projections of the number of satellites and the average satellite weight which follow. They specifically result from assumptions regarding operating lifetime for each satellite, coupled with the known number of prior satellite launchings, and the projected number of satellite lauchings required to match with the projected number of satellites operational each year. The data and projected trend of satellite lifetime are depicted in Figure 5.2. Increases in satellite lifetime would (1) increase total operational satellite weight, (2) reduce the number of satellite launchings, (3) decrease average satellite weight, or (4) result in some combination of the preceding three. Since average satellite weight in the baseline forecast is projected to increase only slightly and since an annual increase in satellite launchings to meet specialized communication needs appears desirable, the most likely effect of increasing lifetime would be to increase total operational satellite weight (Option 1 above).

The number of satellites in orbit and operational is included in Tables 5.1 and 5.3 and Figure 5.3. The projected annual rate of increase is 6.8% which results in an increase from the 15 U.S. communication satellites operational in 1975 to 78 in 2000. These figures include both military and commercial satellites. [For the Initial Defense Satellite Communication System (IDSCS), all satellite elements in each system launch are considered collectively as a single satellite in these calculations.] Since the rate of increase decreased during the period from 1967 to 1975 (after an initially very rapid rate of increase), the projection may appear slightly optimistic. However, the potential for expanded applications for communication satellites justifies this steady rate of increase. If the rate of increase should decline, the most likely effect (maintaining internal consistency) would be a corresponding decline in the rate of increase of total communication satellite weight. (The primary effect on satellite technology

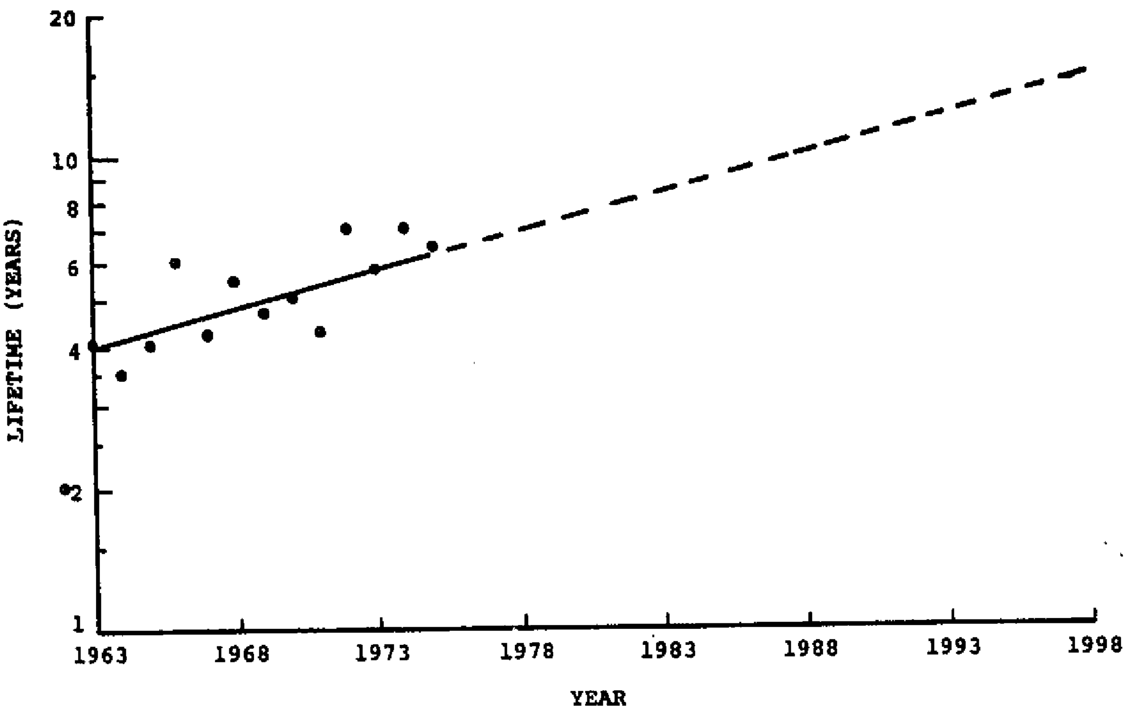

Figure 5.2. U.S. Communication Satellite Operational Lifetime (in Year of Launch)

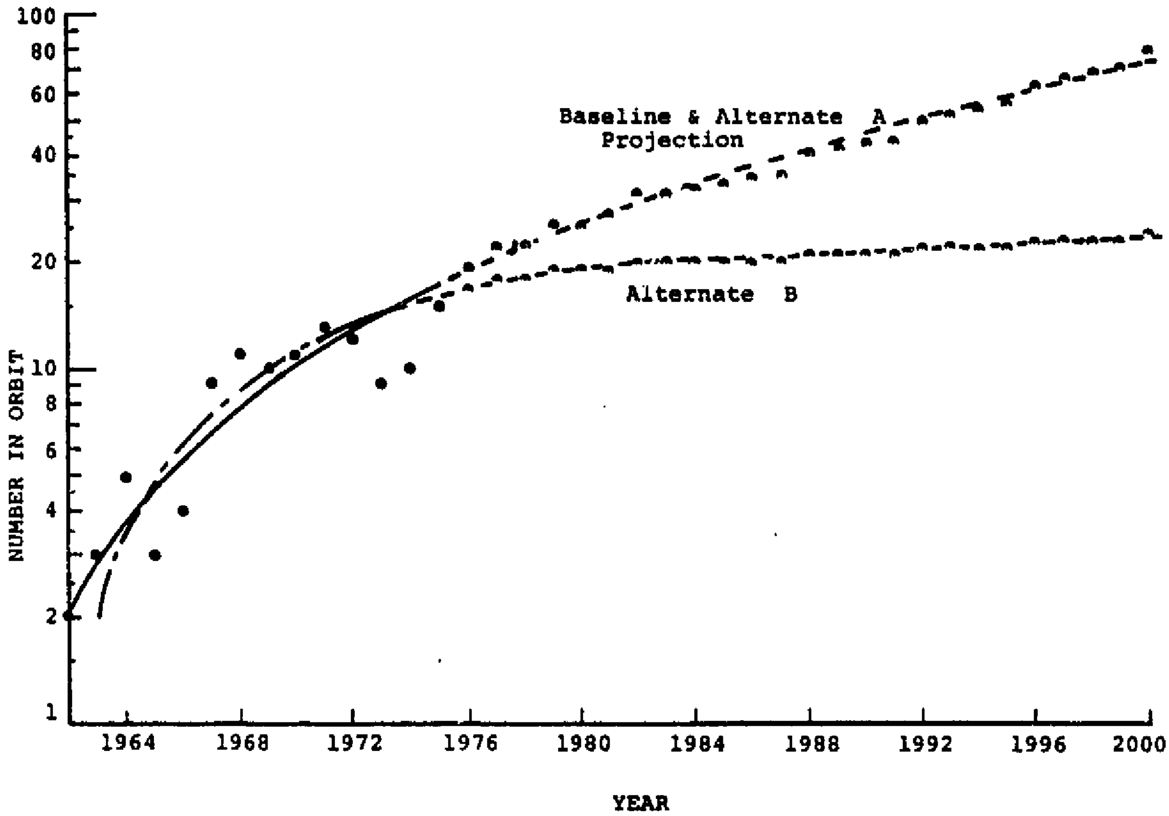

Figure 5.3. Number of U.S. Communication Satellites in Orbit and Operational at Year End

would result from the decreased rate of expansion in number of satellites and not from the second-order effect of lesser total satellite weight.)

Average satellite weight in orbit and operational can be projected directly from the two preceding items (total operational weight divided by number of operational satellites). This trend projection is presented in Tables 5.3, 5.4, and 5.5 and Figure 5.4.

From the trend of total weight in orbit and operational established in Figure 5.1, the total weight of communication satellites placed in orbit each year may be projected by adding to the increase in total weight each year, the weight necessary to replace satellites which cease operations that year. The result of this calculation of tht total weight of communication satellites to be launched each year is presented in Tables 5.3 and 5.4 and Figure 5.5. From the launch weight total of 3,111 kg in 1975, the annual launch weight total is projected to more than double by 2000, to 7,120 kg, or an average annual increase of 3.4%. (The stepwise increase indicated by the data points stems from the increases in number of satellites launched, which are made in whole numbers of satellites.) Although annual total launch weight is a derived calculation in this projection in order to establish internal consistency, it could have been projected independently, although with less precision in view of the variation of this quantity during the historical period. The 3.4% rate projected is much lower than the average rate of 26% from 1962 to 1975, and is conservative in that sense. However, the 3.4% rate has been selected for the baseline projection to reflect a pattern common to many new technologies in which a rapid early rate of exploitation is followed by a period of slower steady increase. Variation in the trend of annual total satellite launch weight resulting either from an increase in the number of satellites launched or from an increase in average satellite weight, would, of course, increase total weight in orbit. A reasonably conceivable upper limit to annual total communication satellite launch weight would be a

TABLE 5.4

ALTERNATE A PROJECTION OF U.S. COMMUNICATION SATELLITES
(Two-Step Increase in Satellite Weight)

Year	No. of Communication Satellites		Total Weight (kg)			Average Weight (kg)	
	Launched During Yr.*	Oper. at Yr. End*	Launched During Yr.	Launched Cum.	Oper. at Yr. End	Launched During Yr.	Oper. at Yr. End
1975(ref)	5	15	3111	14357	9773	622	651
1976	4	19	2960	17317	12733	740	670
1977	4	22	3020	20337	15021	755	683
1978	4	22	3060	23397	15497	765	704
1979	4	25	3100	26500**	17865	775	715
1980	4	25	8000	34500	23438	2000	939
1981	5	27	10000	44500	31399	2000	1163
1982	5	31	10000	54500	40604	2000	1310
1983	5	31	10000	64500	47180	2000	1522
1984	5	32	10000	74500	54160	2000	1693
1985	5	33	10000	84500	61100	2000	1852
1986	5	34	10000	94500	68000	2000	2000
1987	5	35	10000	104500	70000	2000	2000
1988	6	41	12000	116500	82000	2000	2000
1989	6	42	12000	128500	84000	2000	2000
1990	6	43	36000	164500	110000	6000	2558
1991	6	44	36000	200500	136000	6000	3091
1992	6	50	36000	236500	172000	6000	3440
1993	7	52	42000	278500	204000	6000	3923
1994	7	54	42000	320500	236000	6000	4370
1995	7	56	42000	362500	268000	6000	4786
1996	7	63	42000	404500	310000	6000	4921
1997	8	66	48000	452500	348000	6000	5273
1998	8	68	48000	500500	384000	6000	5647
1999	8	70	48000	548500	420000	6000	6000
2000	8	78	48000	596500	468000	6000	6000

*Same as Table 5.3
**Rounded Value

TABLE 5.5

ALTERNATE B PROJECTION OF U.S. COMMUNICATION SATELLITES
(Two-Step Increase in Satellite Weight, With Corresponding Lower Number of Operational Satellites)

Year	No. of Communication Satellites			Total Weight (kg)			Average Weight (kg)	
	Launched			Launched			Launched	Oper. at Yr. End
	During Yr.	Cum.	Oper. at Yr. End	During Yr.	Cum.	Oper. at Yr. End		
1975(ref)	5	38	15	3111	14357	9773	622	651
1976	2	40	17	1480	15837	11253	740	662
1977	2	42	18	1510	17347	12031	755	668
1978	4	46	18	3060	20407	12507	765	695
1979	2	48	19	1550	21957	13325	775	701
1980	4	52	19	8000	29957	18898	2000	995
1981	3	55	19	6000	36000*	22859	2000	1203
1982	2	57	20	4000	40000	26064	2000	1303
1983	3	60	20	6000	46000	30120	2000	1506
1984	2	62	20	4000	50000	32610	2000	1631
1985	4	66	20	8000	58000	37550	2000	1878
1986	2	68	20	4000	62000	40000	2000	2000
1987	4	72	20	8000	70000	40000	2000	2000
1988	1	73	21	2000	72000	42000	2000	2000
1989	3	76	21	6000	78000	42000	2000	2000
1990	2	78	21	12000	90000	50000	6000	2281
1991	3	81	21	18000	108000	62000	6000	2952
1992	1	82	22	6000	114000	68000	6000	3091
1993	2	84	22	12000	126000	76000	6000	3455
1994	4	88	22	24000	150000	92000	6000	4182
1995	2	90	22	12000	162000	100000	6000	4545
1996	1	91	23	6000	168000	106000	6000	4609
1997	4	95	23	24000	192000	122000	6000	5304
1998	1	96	23	6000	198000	126000	6000	5478
1999	3	99	23	18000	216000	138000	6000	6000
2000	1	100	24	6000	222000	144000	6000	6000

*Rounded value

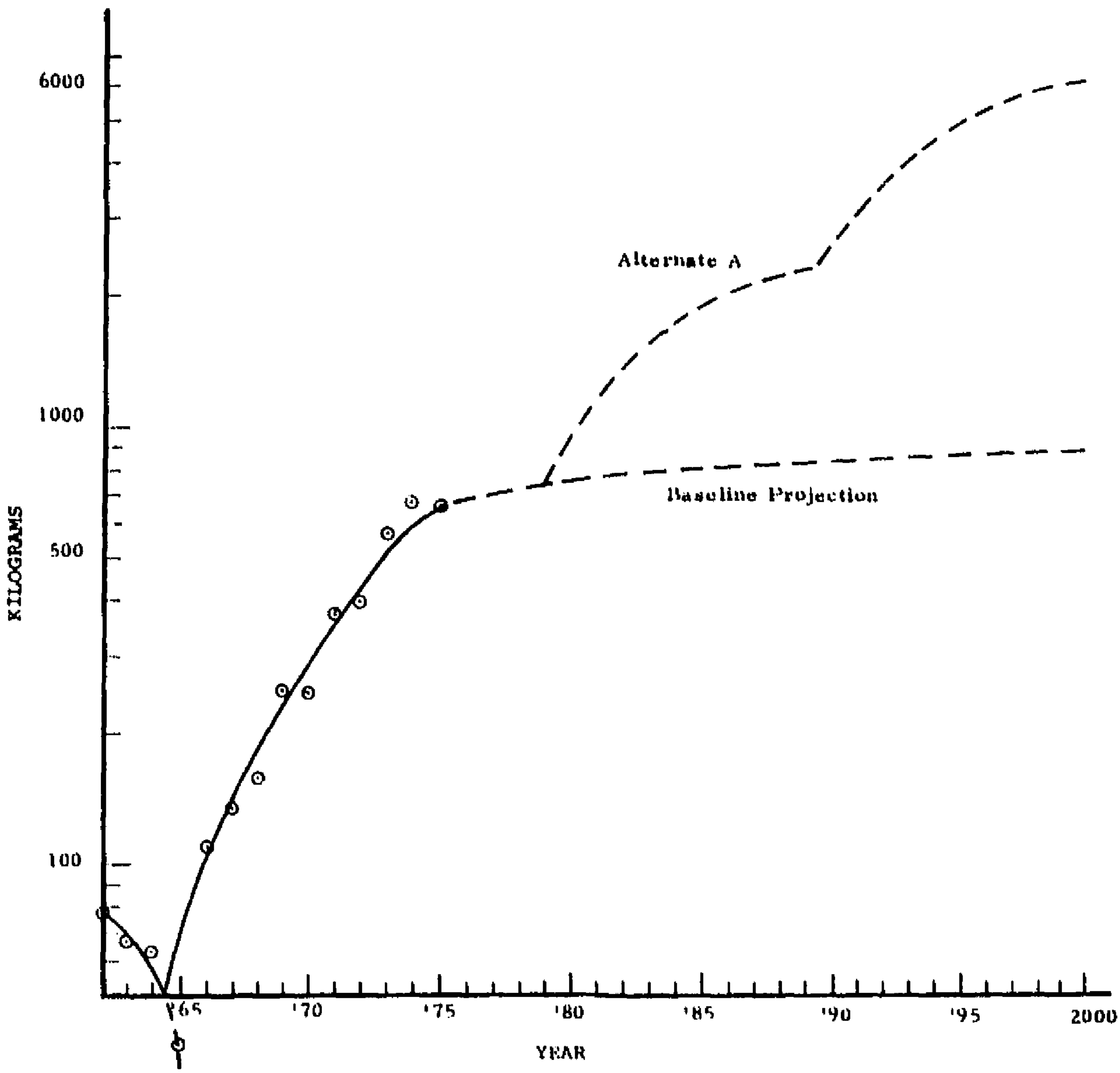

Figure 5.4. Average Weight of U.S. Communication Satellites in Orbit and Operational (Kilograms)

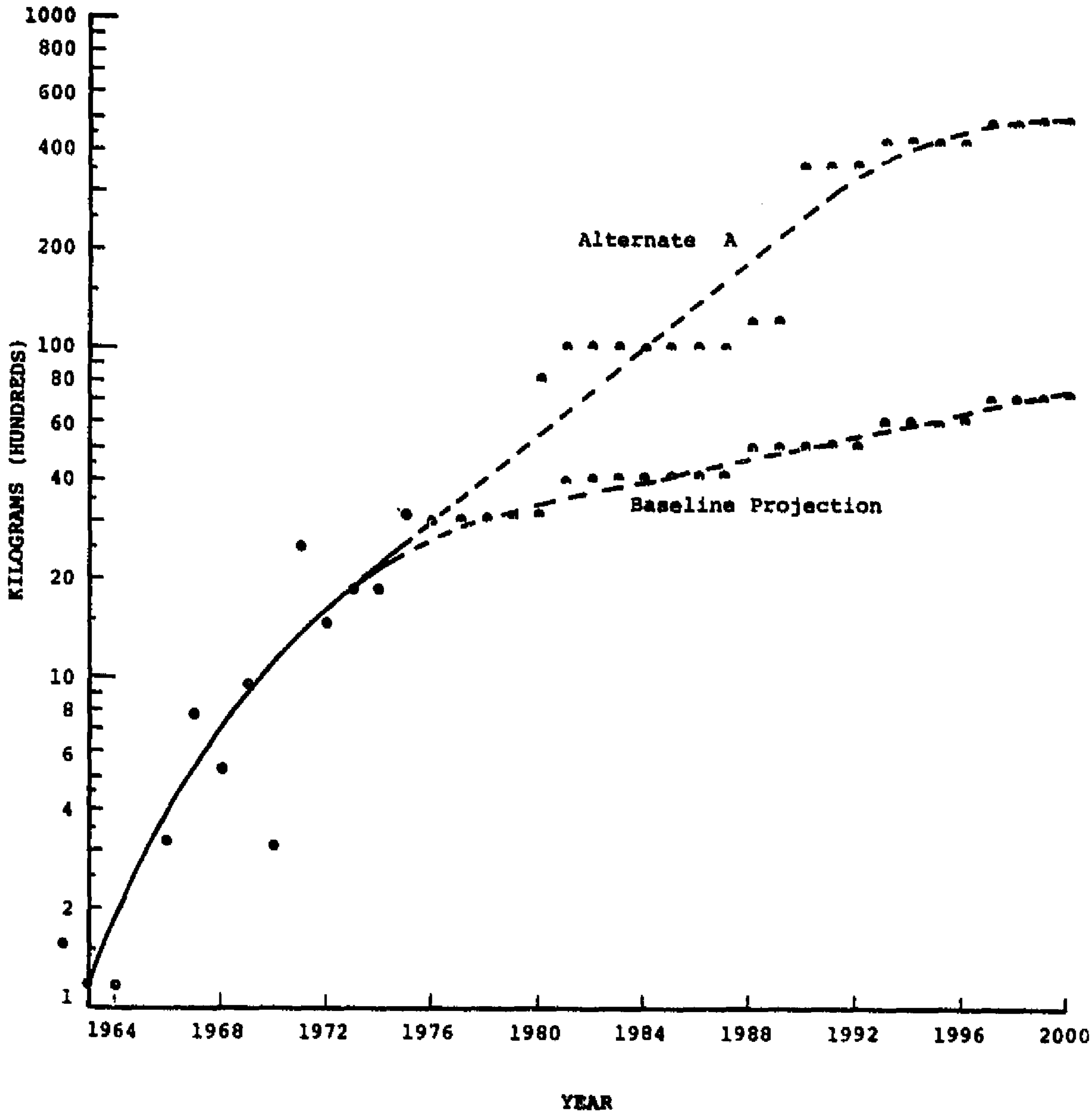

Figure 5.5. Total Weight of U.S. Communication Satellites Launched During Each Year (Kilograms)

16.4% annual rate of increase, shown by the curve identified as Alternate A in Figure 5.5. This would lead to an annual launch weight total of 48,000 kg in 2000, more than 15 times larger than the 1975 total of 3,111 kg. This would lead to a total weight in orbit of 468,000 kg in 2000, which is consistent with a reasonably conceivable upper limit for total weight (it may be noted that this is nearly seven times the basic projection of total weight of 67,600 kg in 2000). Comparisons of these alternate projections with the baseline projections are shown in Figures 5.1 and 5.5.

The projected number of satellite launches each year was made consistent with the number in orbit and operational by combining the number of satellites ceasing operation each year (i.e., requiring replacement) with the number of additional satellites required to obtain the increase in total number operational each year. The number of satellite launches obtained in this manner is shown in Table 5.3 and Figure 5.6. From an average of three communication satellite launches per year in the early 1970's, this projection indicates an average of eight by 2000, or an increase of 4% per year, although the increase is made in steps of whole numbers of satellites. This is consistent with the projected rate of increase in total communication satellite weight placed in orbit. A greater rate of increase in number of communication satellite launches would logically result in a greater rate of increase in total launch weight. This would suggest an upper limit of 54 launches per year in 2000 (based on the 48,000 kg total launch weight of Alternate A and an average satellite weight of 890 kg in the year 2000). However, it seems more likely that the upper limit on launch weight would be approached as a result of increasing weight per satellite, as will be discussed later.

Average weight of each satellite launched may now be projected as a consequential calculation, i.e., total weight added in orbit each year, divided by the number of launches in that year. The results of this calculation are given in Table 5.3 and Figure

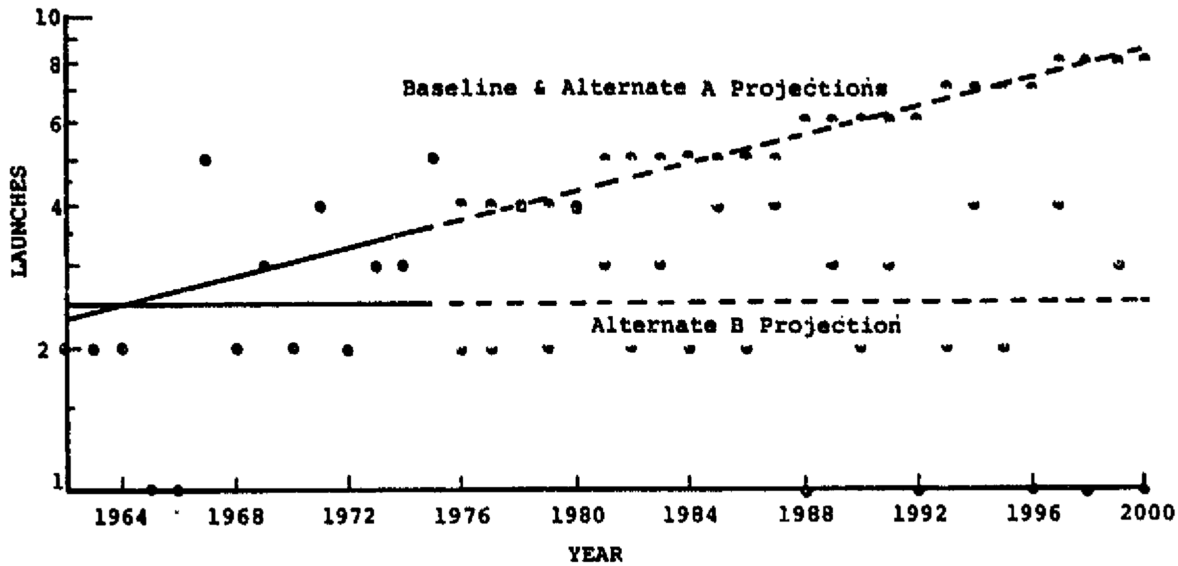

Figure 5.6. Number of Successful U.S. Communication Satellite Launches Each Year

5.7. The projection indicates only marginal increases in communication satellite weight over the remainder of the century. This, of course, does not imply any lack of technical capability to build and launch much heavier satellites, since other satellites of one and two orders-of-magnitude larger have been successfully launched, and larger communication satellites could easily be built with current technology. Rather, the trend in this decade and the pattern of the forecast developed thus far both appear to indicate a direction of progress in communication satellite capability toward more satellites of approximately 700 to 800 kg rather than toward larger satellites. It also may be inferred, although not from this data alone, that recent gains in technology have been used to increase performance while maintaining satellite weight nearly constant. With the above in mind, the projection indicates that average satellite weight will increase from the present average of 622 kg to about 890 kg by 2000. Using the baseline forecast of numbers of communications satellites, any increase in weight beyond this projection would increase total annual launch weights and total operational satellite weights toward the upper limits previously noted. For example, the upper limit of 48,000 kg (total satellite weight launched in 2000) divided among eight satellites would indicate an average satellite weight of 6,000 kg. This upper limit possibility leads toward an alternate forecast for average satellite weights as follows. It may be noted from the data in Table 5.3 and from the corresponding presentation in Figure 5.7 that satellite size has tended to increase in steps rather than in continuous progression. The first level averaged about 74 kg during the period 1962 to 1965. The second period from 1966 to 1970 had two separate categories, one averaging 154 kg and the other 320 kg, for a collective average of 237 kg. The third period from 1971 to 1975 averaged about 670 kg. Matching this pattern of approximate tripling of weight for each major step with the upper limit of 6,000 kg in 2000 suggests the possibility of two more major steps, the first to 2,000 kg between 1980 and 1988 and the second to 6,000 kg between 1990 and 2000, noted as Alternate Projections A and B in Figure 5.7.

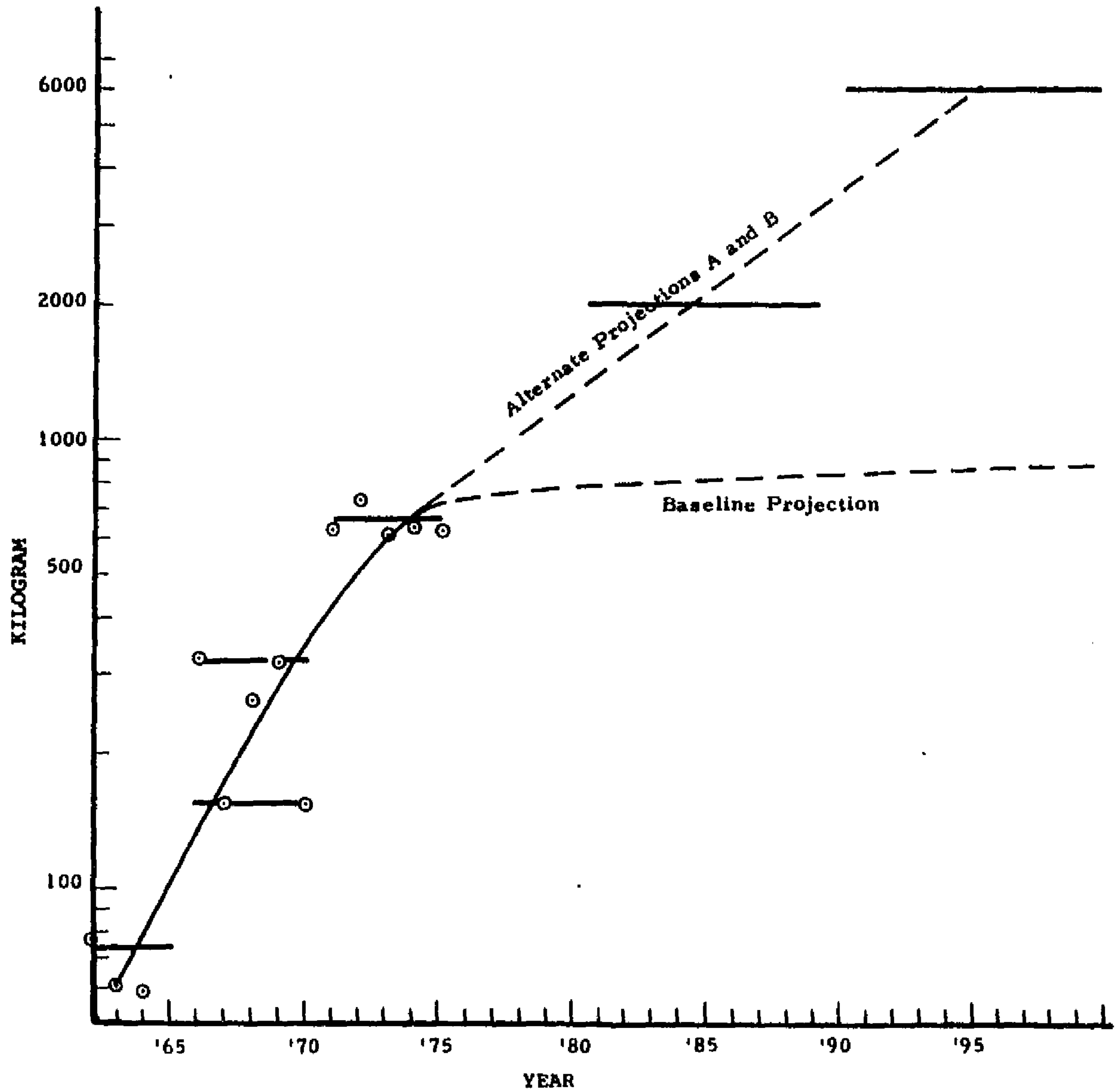

Figure 5.7. Average Weight of U.S. Communication Satellites Launched during Each Year (Kilograms)

Summarizing these projections, two major conclusions may be reached. The first, or Baseline forecast, assumes that only minor increases in communication satellite weight will occur between now and the year 2000, and that the annual number of communication satellite launches will increase to eight by 2000. The second, or Alternate A forecast, assumes that satellite weights will increase in two steps, first to 2,000 kg in 1980, and then to 6,000 kg in 1990, with the annual number of satellite launches increasing to eight in 2000, as in the baseline forecast. An alternate minor conclusion, derived by combining these two for an Alternate B forecast, is that satellite weights will increase as in Alternate A and that the average number of satellite launches will be reduced to meet the baseline projection of total satellite launch weight. This would result in an average of two launches per year in the decade from 1990 to 2000 (a slight decrease from the present average). The higher average launch weights are dominant in the calculation of total operational weight so that this forecast produces a greater satellite weight in orbit in the 1988 and 2000 periods, than the baseline forecast. The alternate forecasts are tabulated in Tables 5.4 and 5.5. Key reference points are noted in Table 5.6 for further development of the communications satellite technology forecast.

It should be noted that the above projections of future numbers and weights of communications satellites cannot be reached directly and solely from the historical pattern of annual launch numbers and weights. The scatter of data on annual launch numbers in particular provides no basis for selection of a forecasting model for projection. The key factors which introduce sufficient regularity of data to fit a logical pattern of development are the trends of operational communication satellite numbers and weights. Since these two operational parameters represent a first-order approximation of balance between technological capability and communications market demand, it is reasonable that they provide the basis for the projections from which the forecasts of annual launch weights, satellite numbers, and average satellite weights

TABLE 5.6

SUMMARY TABULATION
SATELLITE LAUNCH AND OPERATIONAL FORECASTS

Year	Reference	Number	Average Weight kg	Total Weight kg
	Launch Forecasts			
	Baseline*	8	880	7,000
2000	Alt. A	8	6,000	48,000
	Alt. B	1 to 4	6,000	7,000 to 24,000
	Baseline	6	800	5,000
1988	Alt. A	6	2,000	12,000
	Alt. B	1 to 4	2,000	2,000 to 8,000
1975	Actual*	5	600	3,000
	Operational Forecasts			
	Baseline*	80	880	70,000
2000	Alt. A	80	6,000	480,000
	Alt. B	24	6,000	140,000
	Baseline	40	800	32,000
1988	Alt. A	40	2,000	80,000
	Alt. B	20	2,000	40,000
1975	Actual*	15	600	9,000

*Data approximated from Tables 5.1 and 5.3, separately for each column, for easier comparisons.

were developed. However, even the regularity of the data for operational numbers and weights was insufficient to complete the forecast, and the iterative approach involving these two parameters with annual launch numbers and weights was necessary to establish an internally consistant set of trends as discussed earlier.

5.1.2 Projection of Design Trends and Technology Advances for Communication Satellites

The three forecasts of possible satellite weights and numbers may now be used as a basis in projection of design trends and technology advances for the major elements of communication satellites. The significant differences in projected numbers and weights will result in differences in technological paths which might be pursued. To the extent that the different paths provide equal or complementary communication capabilities, each of the possible paths will be included in the forecast. Selection of the best or most likely pattern of technological progress will then depend upon the relative likelihood of successful exploitation of each path in terms of potential for improvement and probability of achievement of the required advances. It is, of course, possible that a single pattern of technological development will support all of the forecasts of weights and numbers equally well, thus placing the resolution of this portion of the forecast in the domain of market requirements. It is also possible in this situation that a mixture of both the larger and the smaller satellites will develop to meet differing demands. None of the above situations invalidate the basic forecasts, which provide probable boundaries and primary directions as a starting point for future communication satellite design characteristics. Also, although it may appear that the continued branching of options at each succeeding component level would produce an unwieldy set of technology forecasts, the best options at successively lower levels will often feed back to eliminate one or more branches at the higher levels. Thus, the end result will produce a forecast of a limited number of key technologies which are integral and necessary to the achievement of the overall pattern of communication satellite development which is forecast.

5.1.2.1 Projections of Satellite Primary Power

Available power for broadcast transmissions is a key element of satellite capability and is the next element in this projection. The primary source of power has been an array of N-P solar cells. No change to another primary power source, i.e., nonsolar, is projected for this forecast. The historical data and projected trends of power from the solar arrays are given in Table 5.7. The historical data provided no basis for projection of trends in available power in terms of either power per unit of electric power weight or power per unit of solar cell area, i.e., no increase in efficiency of the solar cell arrays was achieved during the historical period. Likewise, no correlation nor trend was established relating electrical power to orbit weight. The most regularly behaved historical data for satellite power is the trend of total satellite power in orbit and operational. Since projections of this quantity may readily be related to the total weight of satellite systems in orbit and operational, this quantity was selected as the basis for projecting satellite power trends. The original projection of this trend, assuming no major change in the concept of satellite solar power arrays is shown in Table 5.7 and Figure 5.8. From this projection, and using the numbers and weights of satellites previously projected, average electric power per satellite and electric power per kilogram of orbital weight can be calculated, as also shown in Table 5.7. It may be noted that the latter quantity shows a slight increase with time, a trend which could not be inferred directly from the historical data on power per kilogram of orbital weight for individual satellites. Calculation of this projected average power of satellites launched each year, as shown in Table 5.7 and Figure 5.9, provides the next step of the forecast.

However, the projection up to this point fails to take into account the major change in solar array design concept, from arrays on the cylindrical surface of the satellite to deployable, flat, and continuously sun-oriented arrays. This

TABLE 5.7

U.S. COMMUNICATION SATELLITE PRIMARY POWER TRENDS FOR BASELINE PROJECTION*

Year	Total Electric Power			No. of Communication Satellites			Aver. DC Electric Power in Watts		DC Power/Orbit wt. Baseline Projection Watts/kg	
	Launched		Oper at Year End	Launched		Oper. at Year End	Launched	Oper. at Year End	Launched	Oper. at Year End
	During Yr.	Cum.		During Yr.	Cum.					
1963	29	29	29	1	1	1	29	29		
1964	29	58	58	1	2	2	29	29		
1965	45	103	103	1	3	3	45	34		
1966			103			3		34		
1967	300	403	403	3	6	6	100	67		
1968	178	581	581	1	7	7	178	83		
1969	1336	1917	1714	3	10	6	445	286		
1970	356	2273	1970	2	12	7	178	281		
1971	2208	4481	4078	4	16	10	552	408		
1972	1138	5619	3701	2	18	10	569	370		
1973	1639	7258	4271	3	21	9	546	475		
1974	1169	8427	5084	3	24	10	390	508		
1975	3009	11436	8093	5	29	15	602	540	.97	.83
1976	2547	13983	10640	4	33	19	637	560	.86	.84
1977	2909	16892	12980	4	37	22	727	590	.96	.86
1978	2868	19760	13640	4	41	22	717	620	.94	.88
1979	2929	22689	16000	4	45	25	732	640	.94	.90
1980	2839	25528	16900	4	49	25	710	676	.90	.91
1981	3650	29178	19112	5	54	27	730	708	.92	.93
1982	3963	33141	22475	5	59	31	792	725	.99	.95
1983	3937	37078	23095	5	64	31	787	745	.98	.95
1984	4134	41212	24320	5	69	32	827	760	1.02	.96
1985	4123	45335	25575	5	74	33	825	775	1.01	.97
1986	4214	49549	26860	5	79	34	843	790	1.03	.98
1987	4250	53799	28271	5	84	35	850	808	1.03	1.00
1988	5349	59148	33620	6	90	41	892	820	1.07	1.01
1989	5400	64540	35370	6	96	42	900	842	1.08	1.03
1990	5573	70121	36980	6	102	43	929	860	1.11	1.04
1991	5677	75798	38720	6	108	44	946	880	1.12	1.06
1992	6000	81798	44720	6	114	50	1000	894	1.18	1.08
1993	7254	89052	47840	7	121	52	1036	920	1.21	1.10
1994	7300	96352	51017	7	128	54	1043	945	1.21	1.12
1995	7400	103752	54203	7	135	56	1057	968	1.22	1.14
1996	7537	111289	61740	7	142	63	1077	980	1.24	1.15
1997	8800	120089	66290	8	150	66	1100	1004	1.26	1.18
1998	8900	128989	69841	8	158	68	1113	1027	1.26	1.20
1999	9059	138048	73500	8	166	70	1132	1050	1.28	1.21
2000	9180	147228	82680	8	174	78	1148	1060	1.29	1.22

*Nine satellites omitted, five in period prior to 1965 because of insufficient data, and four IDCSP satellites because of difference in character. This projection assumes that all satellites are spin-stablized, with solar cell arrays on the cylindrical surface of the satellite.

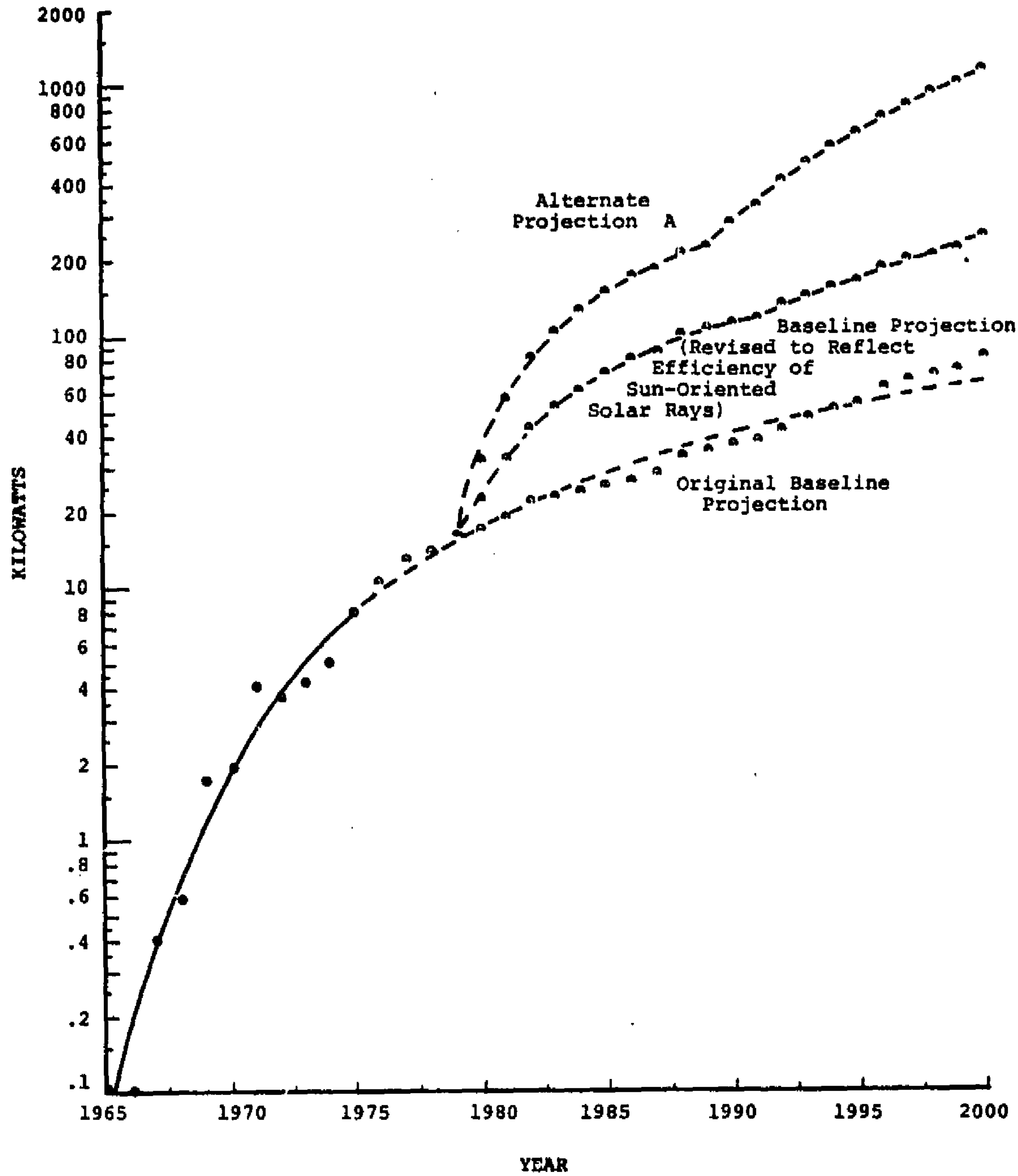

Figure 5.8. U.S. Communication Satellite Total Electric Power in Orbit and Operational

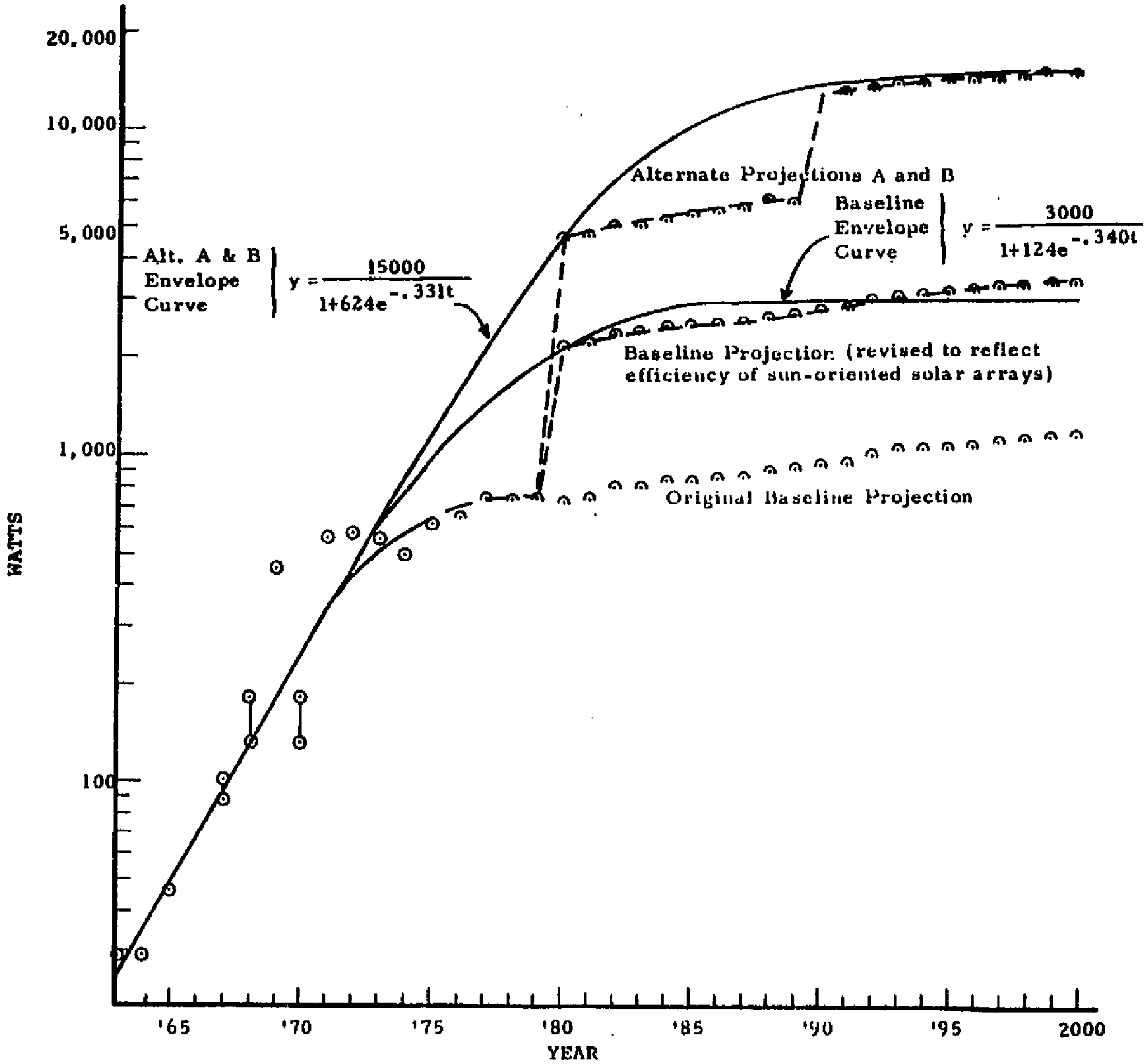

Figure 5.9. Average Power of U.S. Communication Satellites Launched Each Year

change, already in use on the NASA-Lewis Communications Technology Satellite, and planned for next-generation commercial satellites, increases the efficiency of the solar collector system by at least a factor of three. Therefore, assuming that the newer form of solar array will be used on all communication satellies from 1980 on, the original baseline projection for average power of each satellite launched is multiplied by three in 1980 and thereafter. This revised baseline projection is shown in Table 5.8 and Figure 5.9 and is used to recalculate total power in orbit, average power in orbit, and total power launched each year, as tabulated in Table 5.8 and plotted in Figures 5.8, 5.10, and 5.11.

Total operational satellite power (assuming sun-oriented solar arrays) is projected to increase at an average annual rate of nearly 15% during the next 25 years, reaching a total of 250 kilowatts in orbit in the year 2000. This is highly conservative compared to the rate of 55% per year for the period 1965 to 1975 but is consistent with the trend of decreasing rate of increase during the last few years.

The larger satellites of Alternate Projections A and B described previously reasonably should be accompanied by corresponding increases in satellite power. As will be shown subsequently, increases in satellite weight have resulted in an increasing fraction of total satellite weight being allocated to structure. Therefore, to calculate projected levels of power for Alternates A and B, the amount of satellite weight utilized to provide electrical power was decreased proportionately to the decrease in total weight remaining after subtracting that portion allocated to satellite structure. The calculations of these projections for Alternates A and B are shown in Table 5.9 and Figures 5.8, 5.9, 5.10, and 5.11.

The projections in Figure 5.8 of total power in orbit with the greater satellite weights of Alternate A reaches just over one megawatt in the year 2000, about four times larger than the baseline projection and more than 100 times greater than

TABLE 5.8

U.S. COMMUNICATION SATELLITE PRIMARY POWER TRENDS FOR BASELINE PROJECTION* (USING SUN-ORIENTED SOLAR ARRAYS AFTER 1979)

Year	Total Electric Power (Watts)			No. of Communication Satellites			Aver. DC Electric Power in Watts**		DC Power/Orbit wt. Baseline Projection Watts/kg Orbital Wt.	
	Launched		Oper at Year End	Launched		Oper. at Year End	Launched	Oper. at Year End	Launched	Oper. at Year End
	During Yr.	Cum.		During Yr.	Cum.					
1963	29	29	29	1	1	1	29	29		
1964	29	58	58	1	2	2	29	29		
1965	45	103	103	1	3	3	45	34		
1966			103			3		34		
1967	300	403	403	3	6	6	100	67		
1968	178	581	581	1	7	7	178	83		
1969	1336	1917	1714	3	10	6	445	286		
1970	356	2273	1970	2	12	7	178	281		
1971	2208	4481	4078	4	16	10	552	408		
1972	1138	5619	3701	2	18	10	569	370		
1973	1639	7258	4271	3	21	9	546	475		
1974	1169	8427	5084	3	24	10	390	508		
1975	3009	11436	8093	5	29	15	602	540	.97	.83
1976	2547	13983	10640	4	33	19	637	560	.86	.84
1977	2909	16892	12980	4	37	22	727	590	.96	.86
1978	2868	19760	13640	4	41	22	717	620	.94	.88
1979	2929	22689	16000	4	45	25	732	640	.94	.90
1980	8520	31209	22581	4	49	25	2130	903	2.71	1.21
1981	10950	42159	32094	5	54	27	2190	1189	2.75	1.56
1982	11880	54039	43374	5	59	31	2376	1399	2.97	1.83
1983	11755	65794	51812	5	64	31	2351	1671	2.92	2.13
1984	12405	78199	61308	5	69	32	2481	1916	3.06	2.42
1985	12375	90574	70815	5	74	33	2475	2146	3.04	2.68
1986	12645	103219	80531	5	79	34	2529	2369	3.08	2.94
1987	12750	115696	84761	5	84	35	2550	2422	3.09	2.99
1988	16056	132025	100817	6	90	41	2676	2459	3.22	3.02
1989	16200	148225	106067	6	96	42	2700	2525	3.23	3.09
1990	16722	164947	110909	6	102	43	2787	2579	3.32	3.13
1991	17028	181975	116182	6	108	44	2838	2640	3.36	3.19
1992	18000	199975	134182	6	114	50	3000	2684	3.53	3.23
1993	21756	221731	143533	7	121	52	3108	2760	3.64	3.30
1994	21903	243634	153061	7	128	54	3129	2834	3.64	3.37
1995	22197	265831	162613	7	135	56	3171	2904	3.67	3.43
1996	22617	288498	185230	7	142	63	3231	2940	3.71	3.46
1997	26400	314848	198880	8	150	66	3300	3013	3.77	3.53
1998	26712	341560	209536	8	158	68	3339	3081	3.79	3.59
1999	27168	368728	220504	8	166	70	3396	3150	3.84	3.65
2000	27552	396280	248056	8	174	78	3444	3180	3.87	3.67

*Nine satellites omitted, five in period prior to 1965 because of insufficient data, and four IDCSP satellites because of difference in character.

**Projection based on trend of average power, multiplied by factor of 3 after 1979, as a result of assuming tripled solar array efficiency brought about through deployable arrays aimed continuously in direction of the sun.

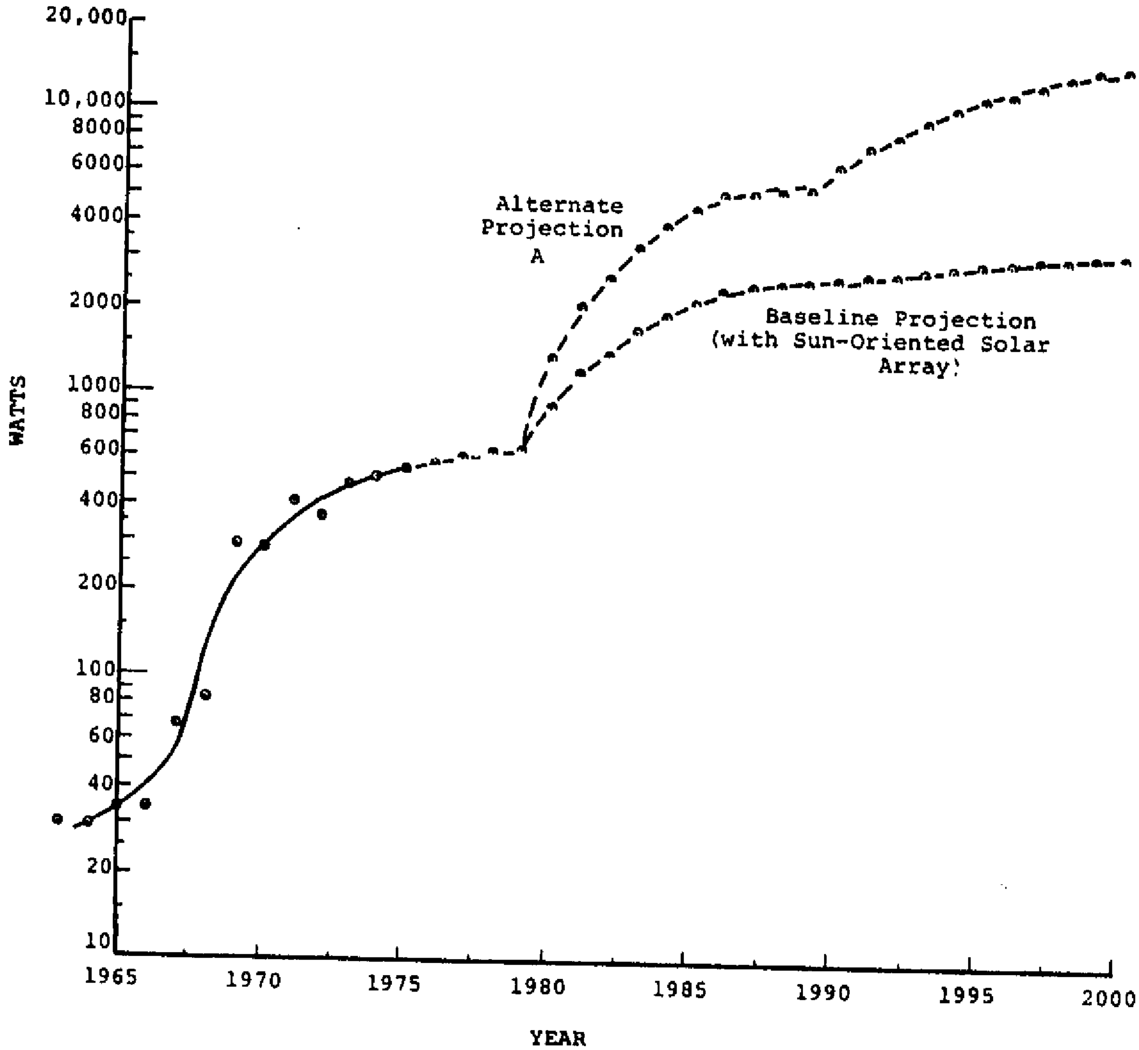

Figure 5.10. Average Power of U.S. Communication Satellites in Orbit and Operational

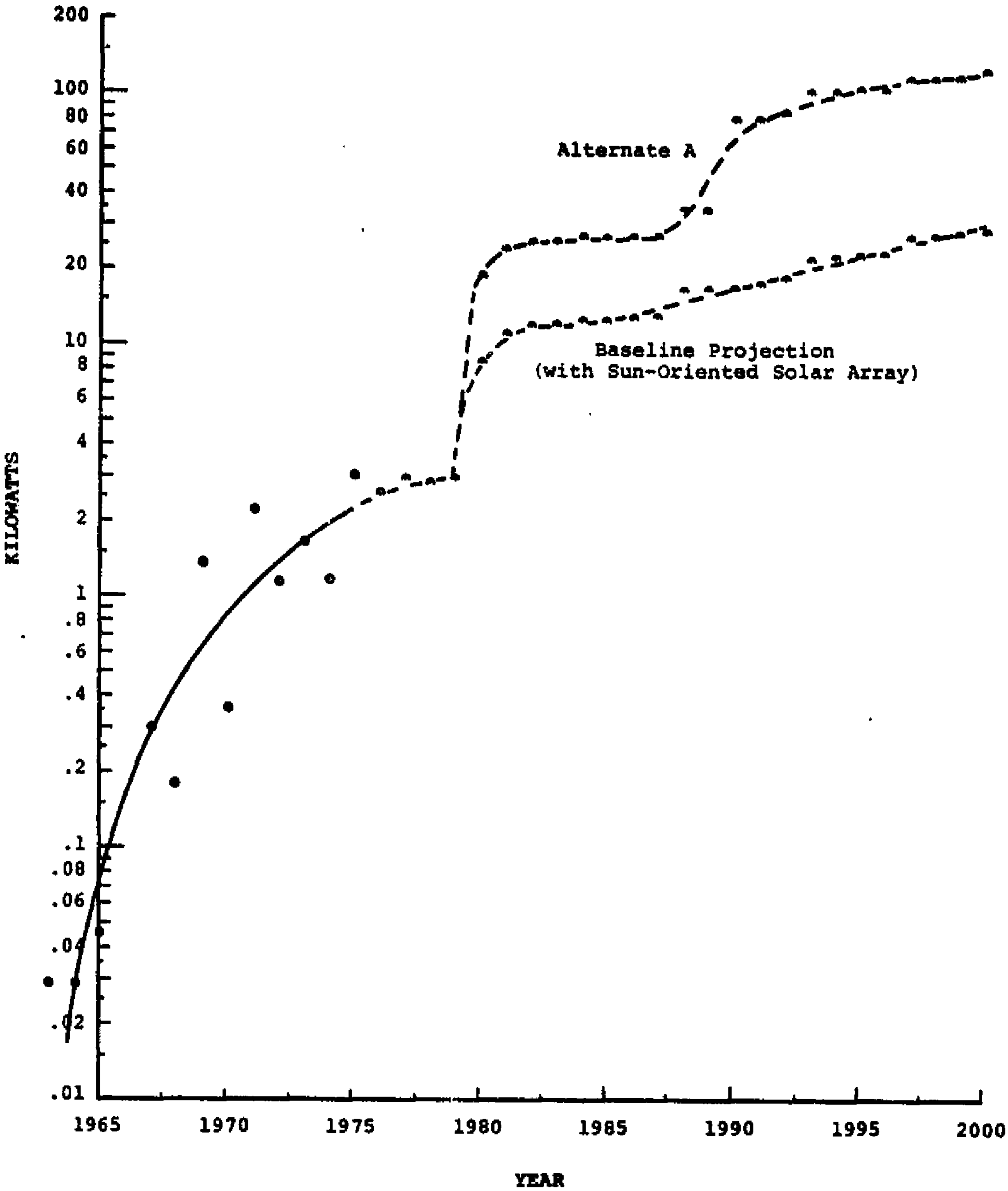

Figure 5.11. Total Power of U.S. Communication Satellites Launched During Each Year

TABLE 5.9

U.S. COMMUNICATION SATELLITE PRIMARY POWER TRENDS FOR ALTERNATES A AND B PROJECTIONS

Year	Alt. A & B Average Electric Power (watts)		Alt. A Total Electric Power (watts)	
	Launched	Oper. at Year End	Launched	Oper. at Year End
1975	602	540		
1976	637	563	2548	10697
1977	725	587	2900	12914
1978	719	620	2876	13640
1979	732	644	2916	16100
1980	4661	1312	18644	32805
1981	4730	2037	23650	55017
1982	5108	2579	25540	79957
1983	5022	3282	25110	101750
1984	5263	3911	26315	125156
1985	5229	4498	26145	148433
1986	5298	5059	26490	172007
1987	5315	5141	26575	179938
1988	5538	5199	33228	213166
1989	5556	5306	33336	222852
1990	12948	6395	77688	275000
1991	13104	7466	78624	328514
1992	13767	8222	82602	411116
1993	14196	9311	99372	484173
1994	14196	10322	99372	557400
1995	14313	11270	100191	631101
1996	14469	11625	101283	732384
1997	14703	12476	117624	823433
1998	14781	13360	118248	908453
1999	14976	14213	119808	994925
2000	15093	14303	120744	1115669

*** Calculation as follows:
Baseline Watts per kg,
times Orbit Weight,
times

$$\left[\frac{\text{1-Str. Wt. Fract. Alt. A}}{\text{1-Str. Wt. Fract. Base 1975}}\right]$$

1975 to 1979 [ ] = 1

1980 to 1989 [ ] = $\frac{1-.38}{1-.28}$ = .86

1990 to 2000 [ ] = $\frac{1-.53}{1-.28}$ = .65

present power in orbit. This is a reasonably conceivable upper limit and one which would be achieved with an average annual increase of 22%, which is somewhat lower than the more recent historical rate of increase.

Alternate A average satellite power appears in Figure 5.9 as a two-step increase consistent with the similar increases in satellite weight. Also shown on this figure are "envelope curve" projections representing the smooth curves which just touch the maximum points of each major step increase in satellite power. These curves, frequently discussed in the literature on technological forecasting,* are of value here primarily in indicating upper limits which might be achieved if the increases in average power should occur at different times or for different reasons than indicated by the primary forecast. The baseline projection indicates attainment of average satellite powers of 3.5 kilowatt by 2000, compared to the present 0.6 kilowatt level, most of which increase would come in one step to more than 2 kilowatts in 1979 or 1980. Alternates A and B would increase power in two major steps, to about 5 kw in 1980 (as the combined result of the tripling of satellite weight and the design change to sun-oriented arrays), and to about 15 kw in 1990 (as the result of increased satellite weight).

If satellite power does not increase in accordance with these projections, i.e., if average power per satellite remains below one kilowatt, then other consequences may be forecast. For example, greater satellite weight fractions will be available for other purposes, more advances in antenna technology may be required or may occur to offset the need for increased power, and/or requirements may be directed toward more satellites in the smaller size range, leading away from Alternates A and B.

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*e.g., "Technological Forecasting for Industry and Government"; James R. Bright, 1968, Prentice-Hall, Englewood, New Jersey; Pages 77-94; Chapter by Robert U. Ayres.

Average power in orbit and operational, plotted on Figure 5.10, shows the pattern which will prevail using sun-oriented solar cell arrays. The baseline projection shows the increase in power which will result if satellite size increases only marginally, while the Alternate A projection indicates the average power available with the larger satellites. Figure 5.11, showing the total power for satellites launched each year, dramatizes the sharp increase in power made available through the use of sun-oriented arrays. Even with the smaller satellites of the baseline projection, more than ten kilowatts of new communications broadcast power would be added each year during the 1980's and two to three times that amount during the 1990's. The larger satellites of Alternate A would add 20 to 30 kw each year during the 1980's and around 100 kw per year during the 1990's.

The projection of solar cell array area plotted in Figure 5.12 is consistent with the power levels of the preceding figures and is based on the assumption of 40 watts per square meter of solar cell array for cylindrical arrays and 120 watts per square meter for sun-oriented flat panel arrays. These values are consistent with the absence of any trend of improvement in the efficiency of individual solar cells, i.e., all significant power increases have been made simply by an equivalent increase in the number of cells and the configuration change to sun-oriented flat panels. Any potential which might exist for improving individual solar cell efficiency would obviously permit either higher power levels or reduce the fraction of orbital mass required for solar energy collection.

The satellite primary electric power forecasts are summarized in Table 5.10. As shown by the approximate figures in this table, the average power of satellites launched each year should increase by a factor of six during the next 25 years, to 3.6 kilowatts per satellite, in the baseline projection. This would provide 30 kw of additional satellite broadcast power each year around the year 2000. About four times these amounts of power would be provided by the larger satellites of Alternate

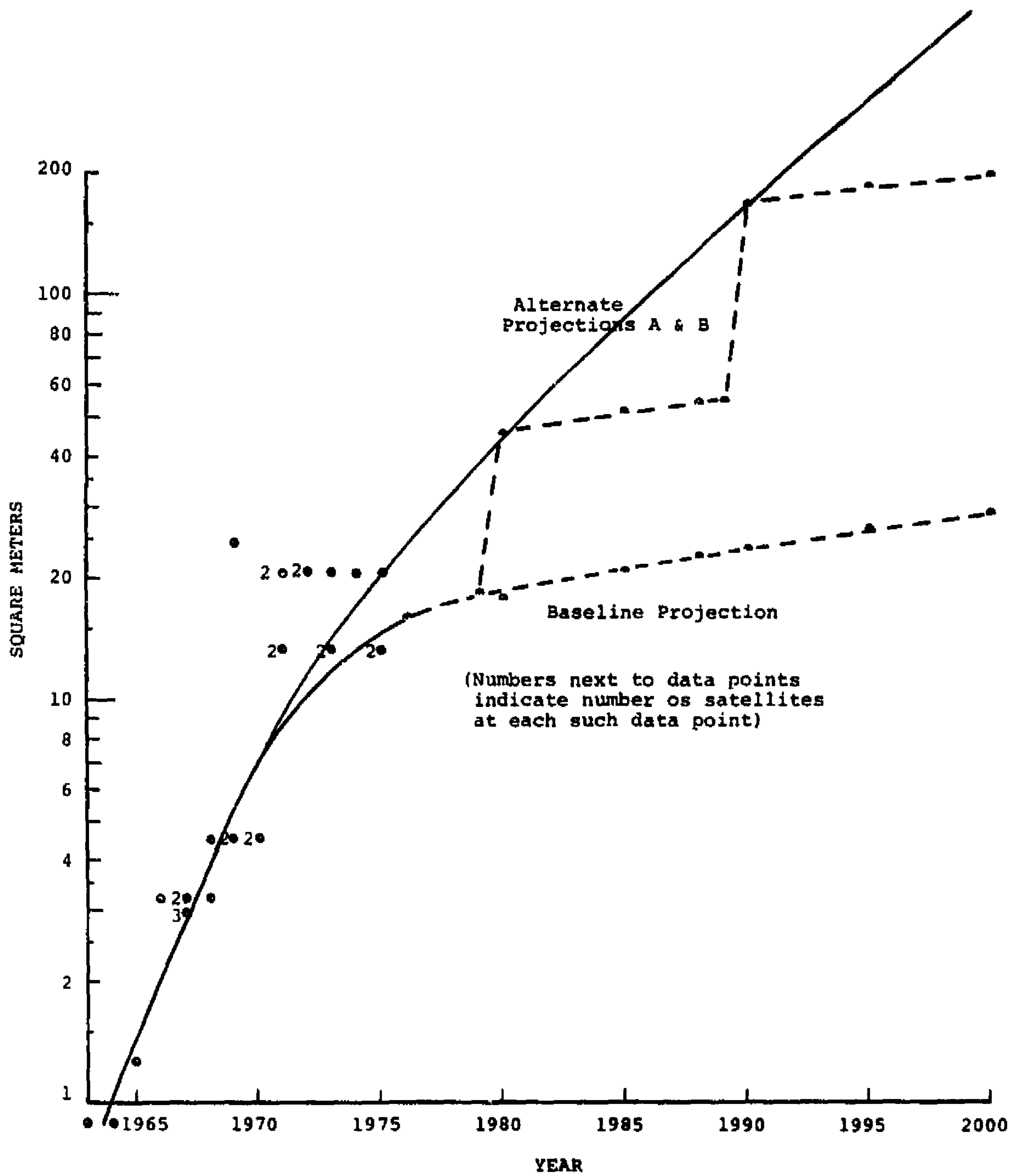

Figure 5.12. U.S. Communication Satellite Solar Cell Area Per Satellite

TABLE 5.10

SUMMARY OF SATELLITE PRIMARY POWER FORECASTS*

Year	Reference	Number	Average Power Kilowatts	Total Power Kilowatts
	Launch Forecasts			
	Baseline	8	3.6	30
2000	Alt. A	8	15	120
	Alt. B	1 to 4	15	15 to 60
	Baseline	6	2.5	15
1988	Alt. A	6	5	30
	Alt. B	1 to 4	5	5 to 20
1975	Actual	5	0.6	3
	Operational Forecasts			
	Baseline	80	3.2	250
2000	Alt. A	80	14	1100
	Alt. B	24	14	330
	Baseline	40	2.5	100
1988	Alt. A	40	5	200
	Alt. B	20	5	100
1975	Actual	15	0.54	8

*Data approximated from Tables 5.8 and 5.9, separately for each column, for easier comparisons.

Projection A. Total operational power would increase from the current 8 kw to 100 kw by 1988 and to 250 kw by 2000 in the Baseline increasing by a factor of 30. Alternate A would provide 1100 kw, an increase of more than two orders-of-magnitude, which is reasonably equivalent to the two orders-of-magnitude increase from 1965 to 1975.

5.1.2.2 Projection of Satellite Weight Fractions

The fraction of satellite weight required for its basic structure is a significant element in satellite design and is a particularly important consideration with respect to projections of major increases in satellite size. A regression analysis of communication satellite weight versus total orbital weight, as shown in Figure 5.13, indicates a very regular increase in the structural weight fraction as satellite size increases. Aircraft designers have long noted a similar increase and have used the term "square-cube law" to reflect the nature of the increase in structural weight fraction. Using a similar mathematical expression, satellite structural weight has increased in proportion to the 2.61 power of the square root of the fraction of increased orbital weight divided by the initial orbital weight. This expression is given in Figure 5.13 and is equivalent to a "square-2.61 power law" for satellite structural weight increases. Although the change of satellite design approach from spin-stabilized satellites to three-axis stabilized systems with deployable solar arrays might be expected to alter this relationship, the evidence to date does not reflect a change in this relationship. Specifically, the CTS Satellite, with a spacecraft usable weight in orbit of 347.1 kg, has a basic structural weight of 55.1 kg plus a flexible solar array structure of 46.3 kg (not including the solar array blankets themselves), for a total structural weight of 101.4 kg. As shown in Figure 5.13, this structural weight is slightly higher than the trend line for structural weight increase, which would support the projection shown. Although allocations of weight may be shifted from one function to another, it seems reasonable to allocate the structural weight of deployable arrays, and the supporting structure for antennas, to the structural weight account, which would support the projection shown in Figure

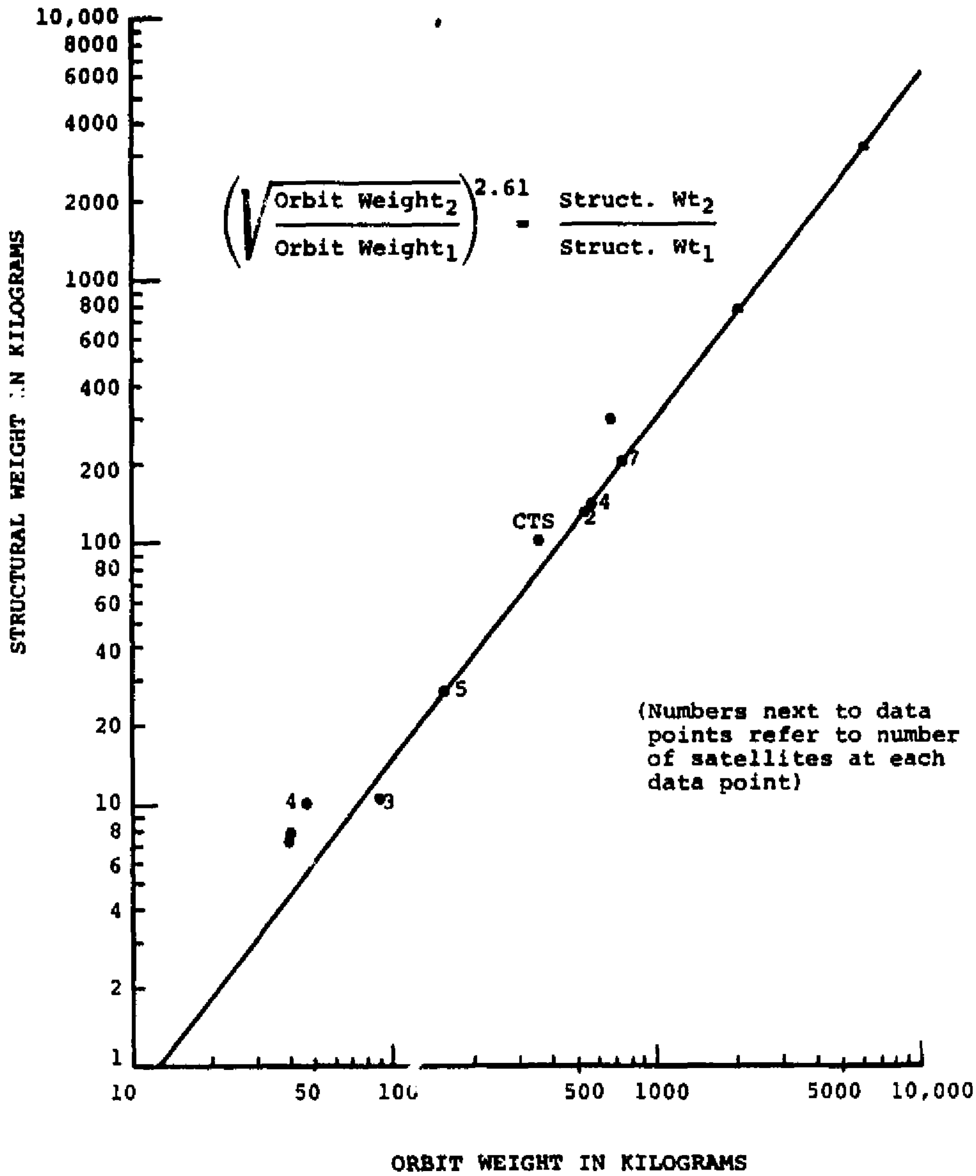

Figure 5.13. U.S. Communication Satellite Structural Weight Versus Orbit Weight

5.13. Of course, efforts to reduce structural weight may alter this trend in the future, but until evidence from actual designs provides justification for a change, the trend line provides a useful estimate of satellite structural weight fraction. More importantly, it provides a target against which progress might be measured. It is also worth noting that concurrent efforts to improve functional weight efficiency of all other components will tend to maintain the trend line.

Projection of this well-established trend to the 2000 kg and 6000 kg satellites of Alternate A indicates structural weight fraction increases from the current 25% to 38% for the 2000 kg satellite in the 1980's and to 53% for the 6000 kg satellite of the 1990's as indicated in Table 5.11. This clearly indicates the potential value of research on satellite structural design to limit the increasing proportion of weight devoted to nonfunctioning structure. This factor assumes added importance when consideration is given to the requirement for extra apogee motor and propellant weight to place the heavier satellites in synchronous orbit.

5.1.2.3 Projections of Satellite Broadcast Power

The satellite power projections may be combined with data from the power-consuming components of the satellites to provide a forecast of probable developments in those components. This approach also leads to consistent projections of broadcast power, which is directly related to proposals for various satellite uses.

The sum of effective Isotropic Radiated Power (EIRP) per satellite is a measure of broadcast power and was chosen as a forecasting parameter primarily because it provides a reasonably uniform trend for projection. The regression of EIRP versus total satellite power availability shown in Figure 5.14 is extrapolated and combined with the forecasts of total power to obtain projections of broadcast power. Granted that some fraction of total satellite power is used for other functions, it is assumed for this projection that such other

TABLE 5.11

PROJECTION OF STRUCTURAL WEIGHT VERSUS ORBIT WEIGHT

Year	Reference	Orbit Wt. kg	Struct. Wt. kg	Struct. Fraction of Orbit Weight
1975	Actual Average	622	158	.254
1980	Baseline	785	221	.282
	Alt. A & B	2000	761	.381
1988	Baseline	830	238	.286
	Alt. A & B	2000	761	.381
1990	Baseline	840	242	.288
	Alt. A & B	6000	3193	.532
2000	Baseline	867	262	.294
	Alt. A & B	6000	3193	.532

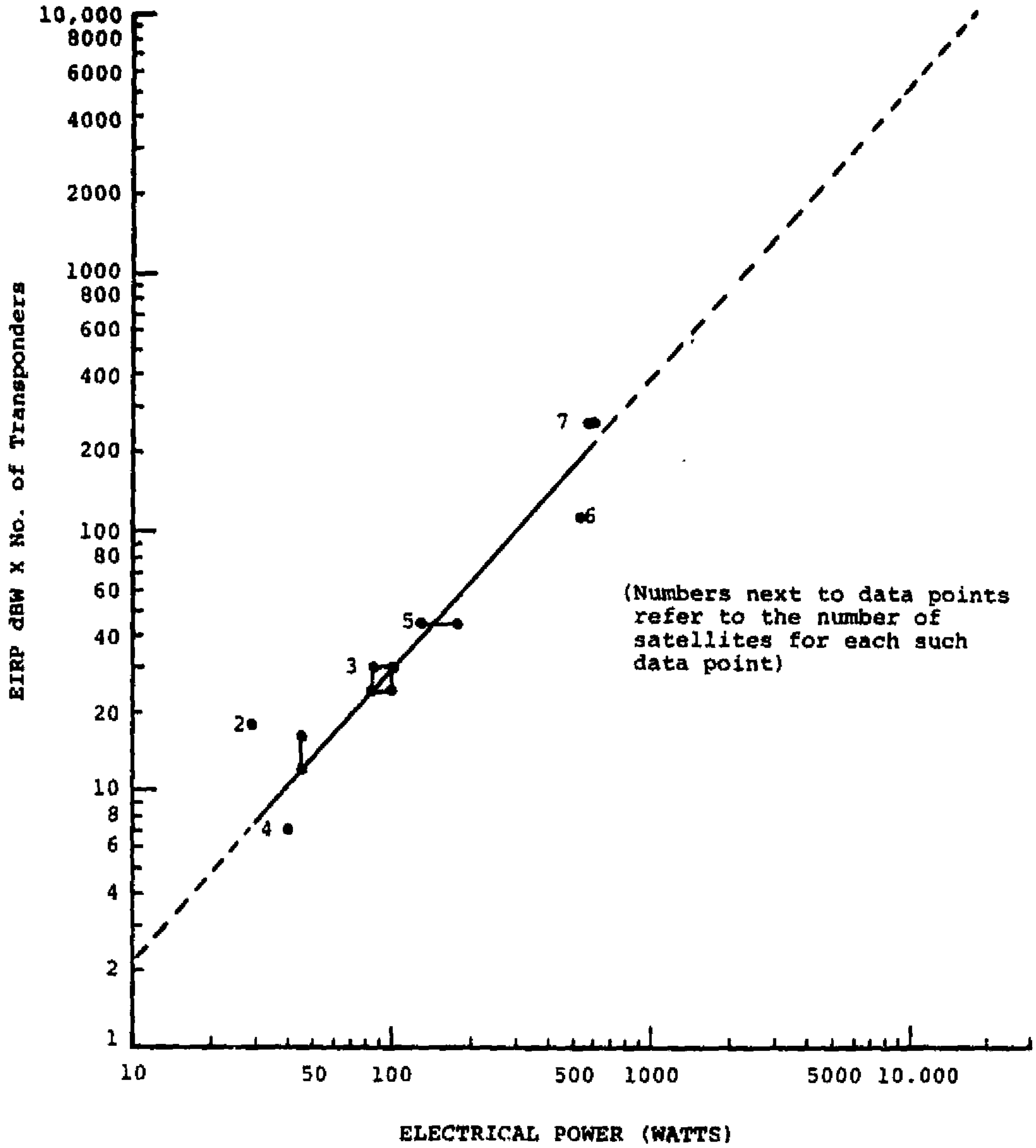

Figure 5.14. Regression of Wide-Beam EIRP Versus Satellite Power

uses constitute a relatively constant fraction of total power requirements. It is further assumed that design for these uses will continue to minimize this fraction so that the projections of EIRP will be conservative.

Projection of EIRP using the Baseline and Alternatives "A" and "B" forecasts of total power is shown in Figure 5.15. Since EIRP for wide beam (17°) channels is limited to approximately 33 dBW for C-Band (60-70 dBW in millimeter bands) by international agreements on terrestial flux density, [1] and since satellite development is in the direction of multiple spot-beam antennas to concentrate satellite tramsmitted power over separate small areas of the earth's surface, [2,3] the total rf power will be used primarily to increase the number of wide-band transponder channels per satellite. The trend of EIRP per channel for wide-beam and spot-beam channels is shown in Figure 5.16. The Pearl Curve approach [4] was selected to project the trend of EIRP per channel, because the previously cited references clearly imply growth of these characteristics toward upper limits. In the near future, C-Band is likely to dominate and therefore delay the rate of EIRP increase shown by the upper curve of Figure 5.16. On the other hand, the use of the 12 gigahertz frequency on Intelsat V, and a general trend in demand for higher EIRP, tend to support the spot-beam curve.

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[1] J.E. Kiegler, et al., "Momentum Wheel Three-Axis Attitude Control for Synchronous Communication Satellites", AIAA Progress in Astronautics and Aeronautics, Communication Satellite Technology, Vol. 33, The MIT Press, Cambridge, Mass., 1974.

[2] H.J. Meyerhoff, "Power Balancing in Multibeam Satellites", AIAA Progress in Astronautics and Aeronautics, Communication Satellite Developments: Systems, Vol. 41, The MIT Press, Cambridge, Mass., 1976.

[3] W.G. Schmidt, "Satellite-Switched TDMA: Transponder Switched or Beam Switched?", AIAA Progress in Astronautics and Aeronautics, Communication Satellite Developments: Systems, Vol. 41, The MIT Press, Cambridge, Mass., 1976.

[4] Joseph P. Martino, "Technological Forecasting for Decision Making", American Elsevier, New York, NY, 1972, pp. 111-113.

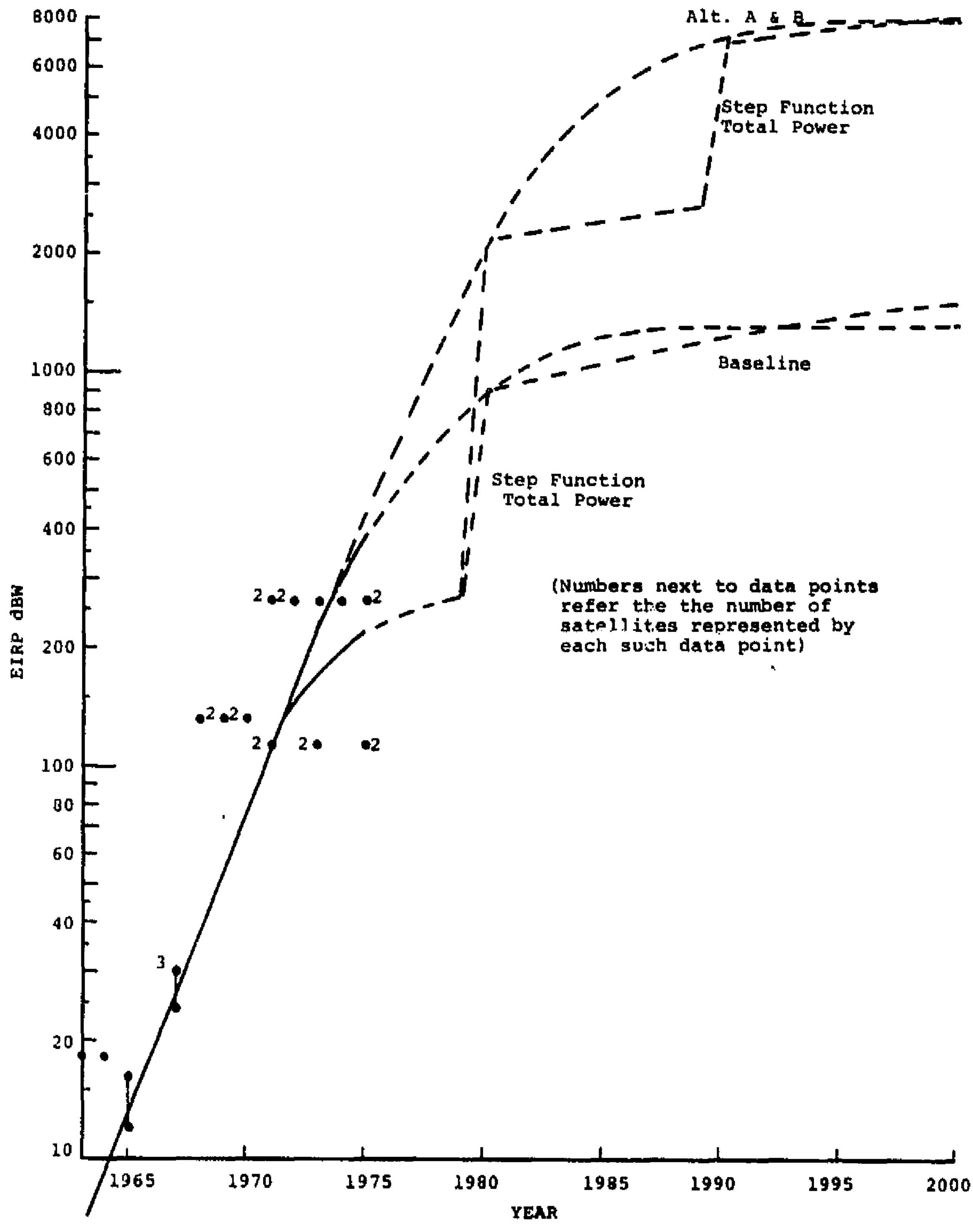

Figure 5.15. Total EIRP Per Satellite Launched (Global Beam 17°)

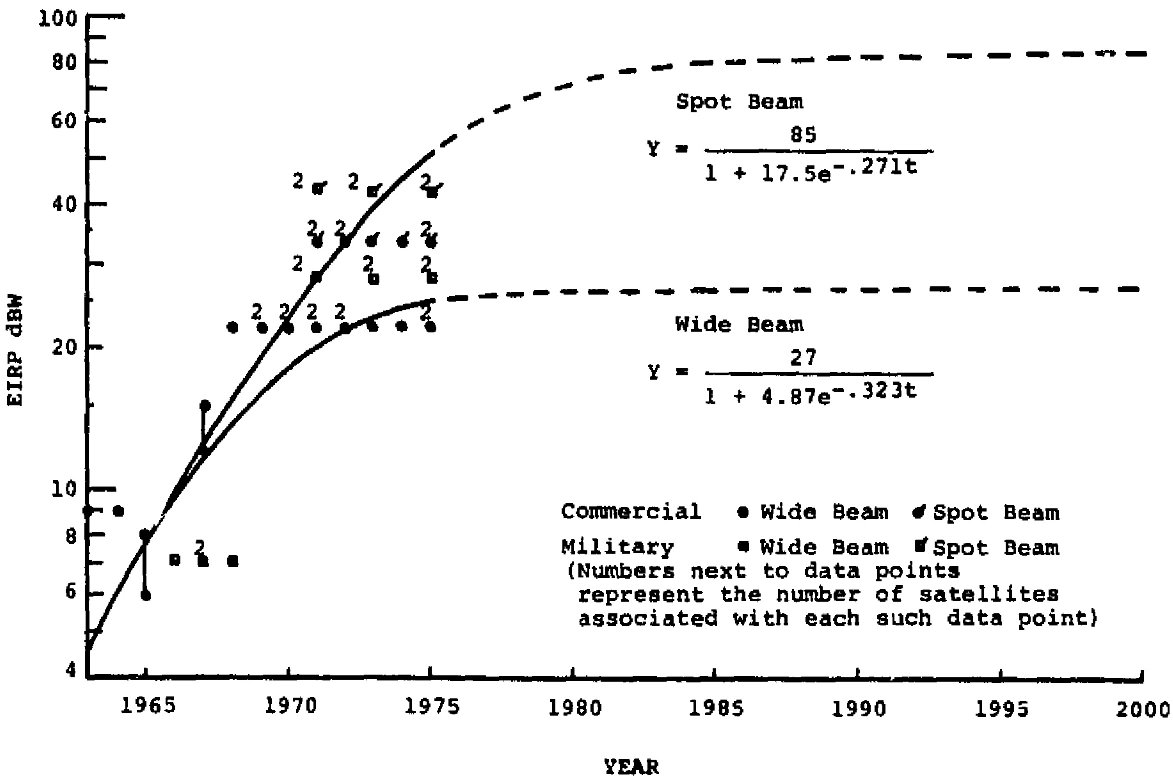

Figure 5.16. Effective Isotropic Radiated Power (EIRP) Per Channel

The Pearl Curve for the wide-beam transponder channels provides the basis for projection of the number of channels per satellite since the total radiated power in the spot-beam channels is equivalent to the radiated power of the wide-beam channels, given equivalence in other factors. The projected number of channels per satellite, derived from total EIRP and EIRP per wide-beam channel, is shown by Figure 5.17. The Baseline projection will provide 36 to 48 channels (for simultaneous operation) per satellite in the period from 1980 to 2000. The larger satellites of Alternates A and B will permit 84 to 96 channels in the period 1980 to 1990, and 240 to 288 channels from 1990 to 2000. At 750 duplex voice-grade channels per transponder, the Baseline projection would provide 27,000 to 36,000 simultaneous voice-grade channels per satellite from 1980 to 2000, while Alternates A and B will provide 63,000 to 72,000 such channels from 1980 to 1990 and 180,000 to 216,000 from 1990 to 2000. Since traveling-wave-tube-amplifiers (TWTA) have been, and are expected to remain, a primary component in the wide-band-transponder channels, the characteristics of TWTA'a compatible with the projected input and output power levels are of interest in this forecast. Regression of the total TWTA rated output per satellite versus satellite power, as presented in Figure 5.18, provides the basis for a forecast of total TWTA output derived from the projections of total satellite power. This forecast of total TWTA rated output power per satellite is given in Figure 5.19. Total TWTA output should range from 560 to 1000 watts in the period 1980 to 2000 for the Baseline projection, 1500 to 1900 watts between 1980 and 1990, and 5400 to 6400 watts between 1990 and 2000 for Alternates A and B.

The projection of TWTA output per wide-band channel may be derived using the number of channels calculated from the relationship of total EIRP and EIRP per channel (previously cited) to divide total TWTA output per satellite. The results of this calculation are shown in Figure 5.20. The basic conclusion apparent in this figure is that TWTA output required per channel will level out at approximately 18 watts for the

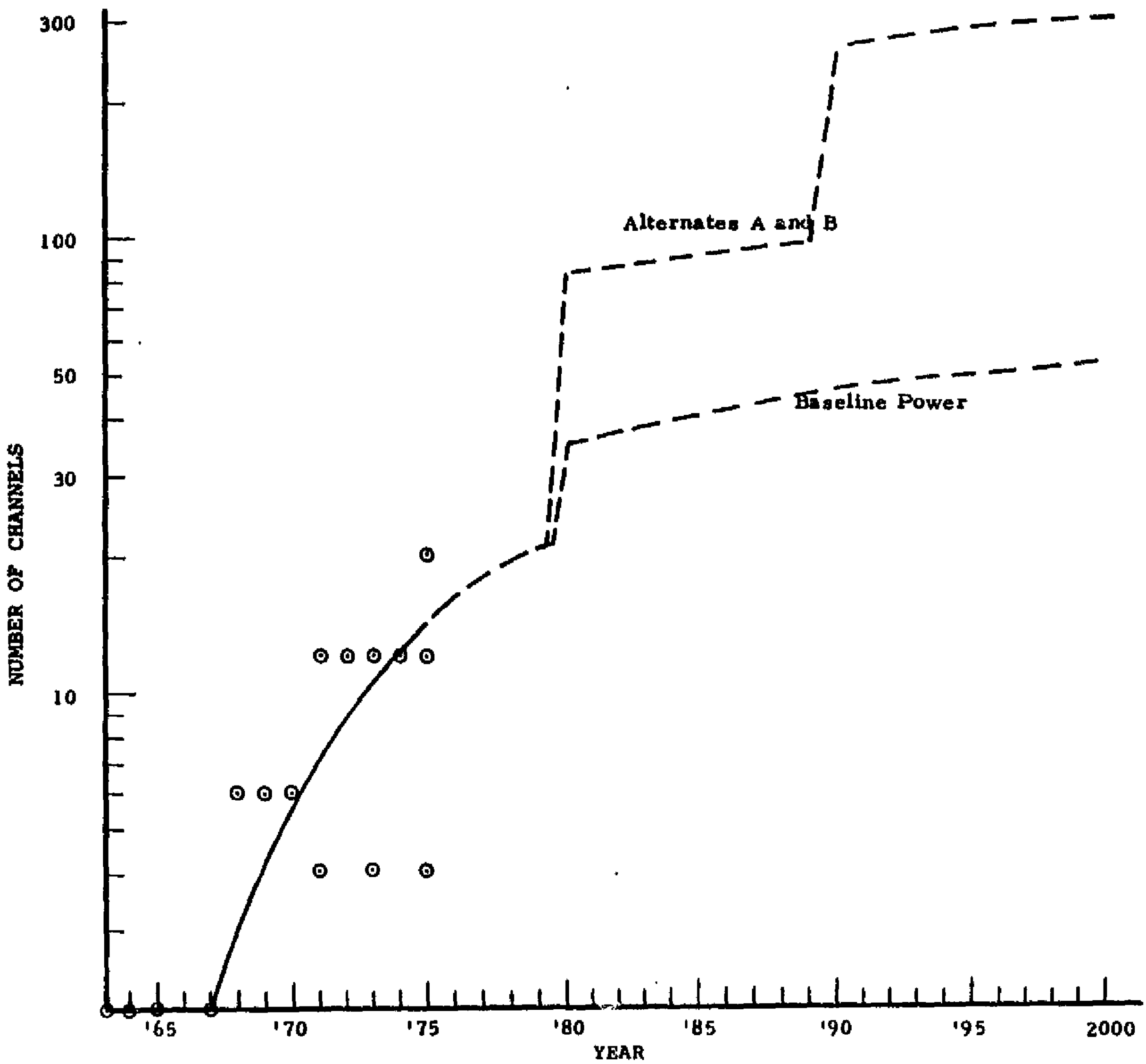

Figure 5.17. Number of Wide-Band Channels per Satellite

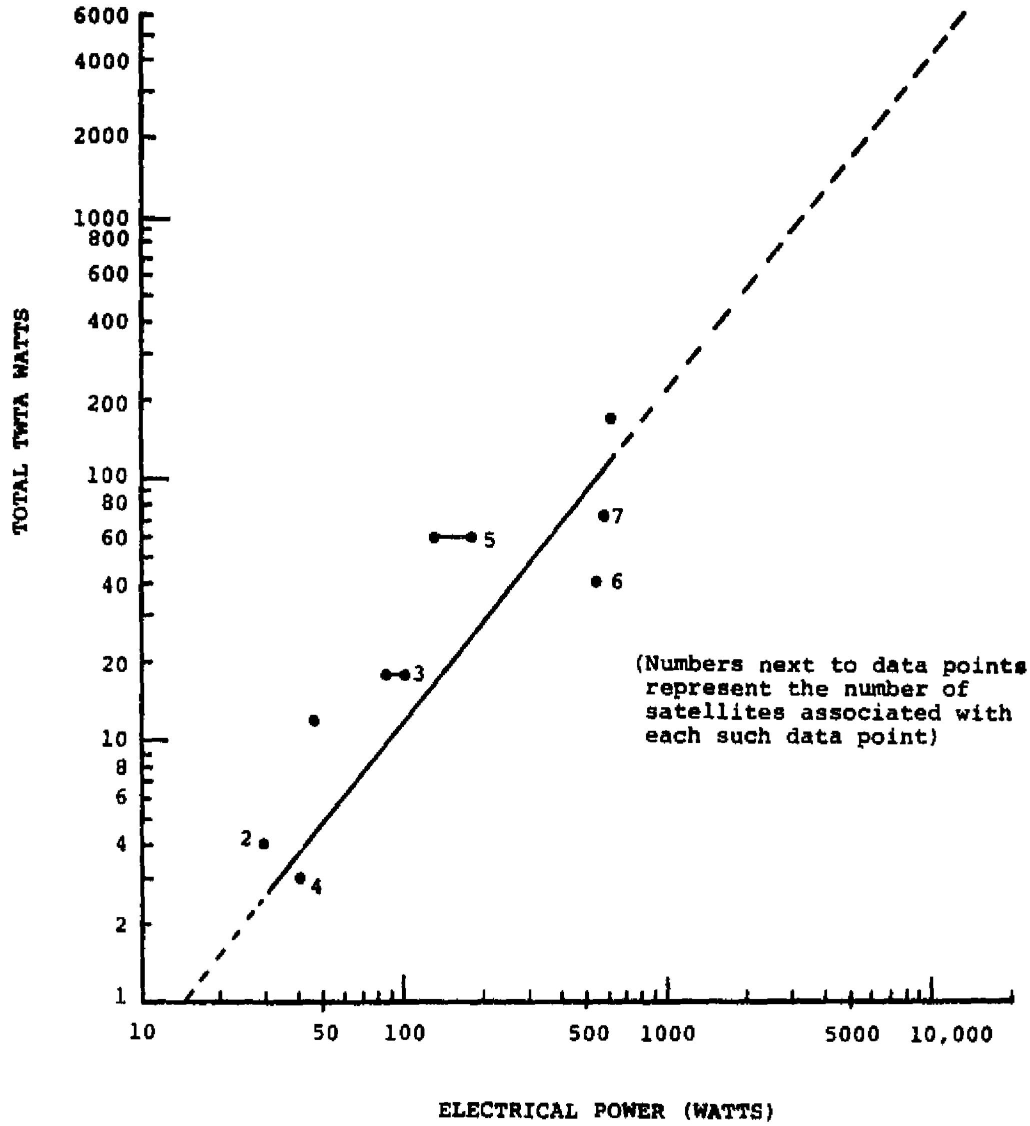

Figure 5.18. Total TWTA Power Versus Satellite Power

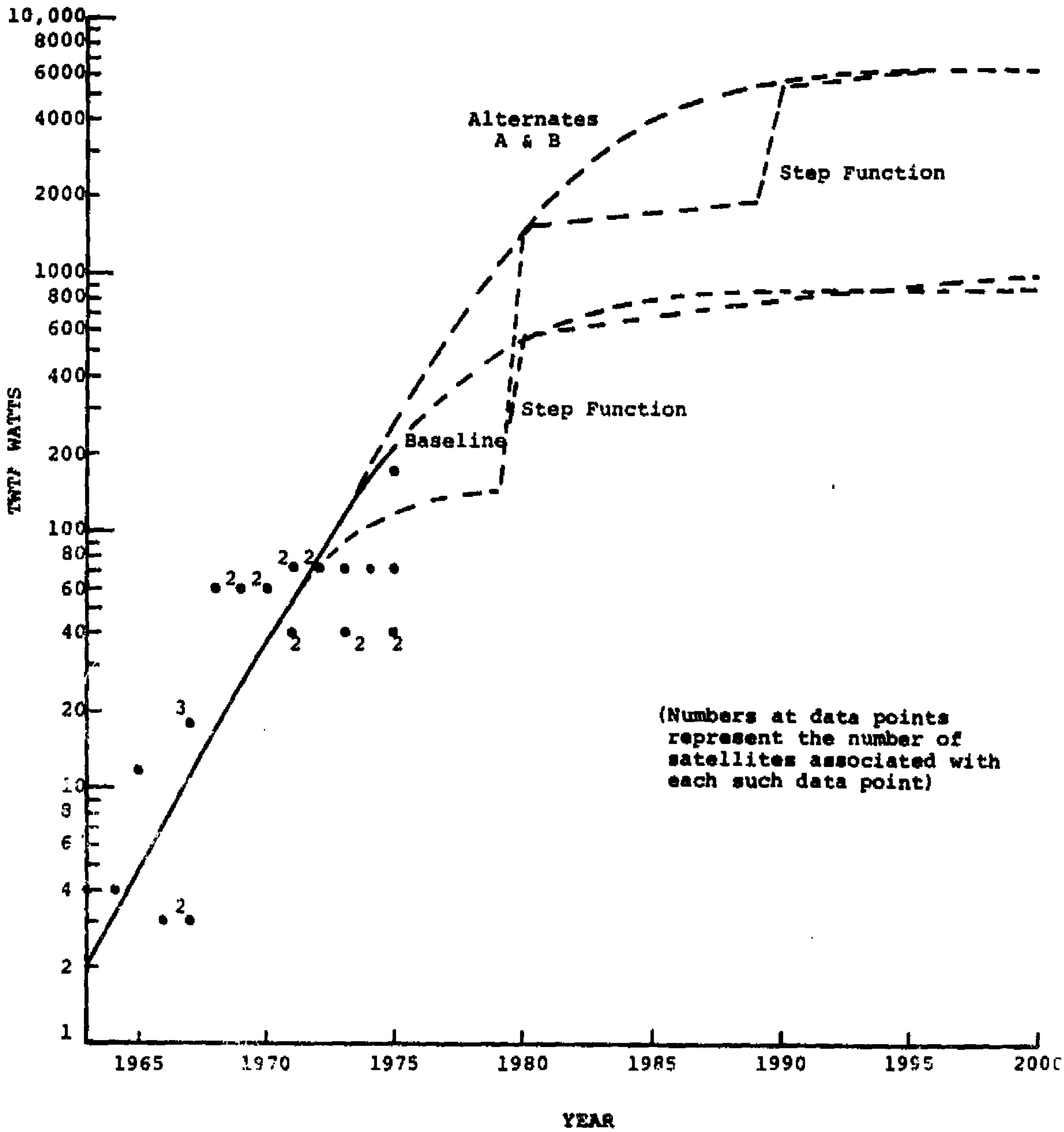

Figure 5.19. Total TWTA Rated Power Per Satellite

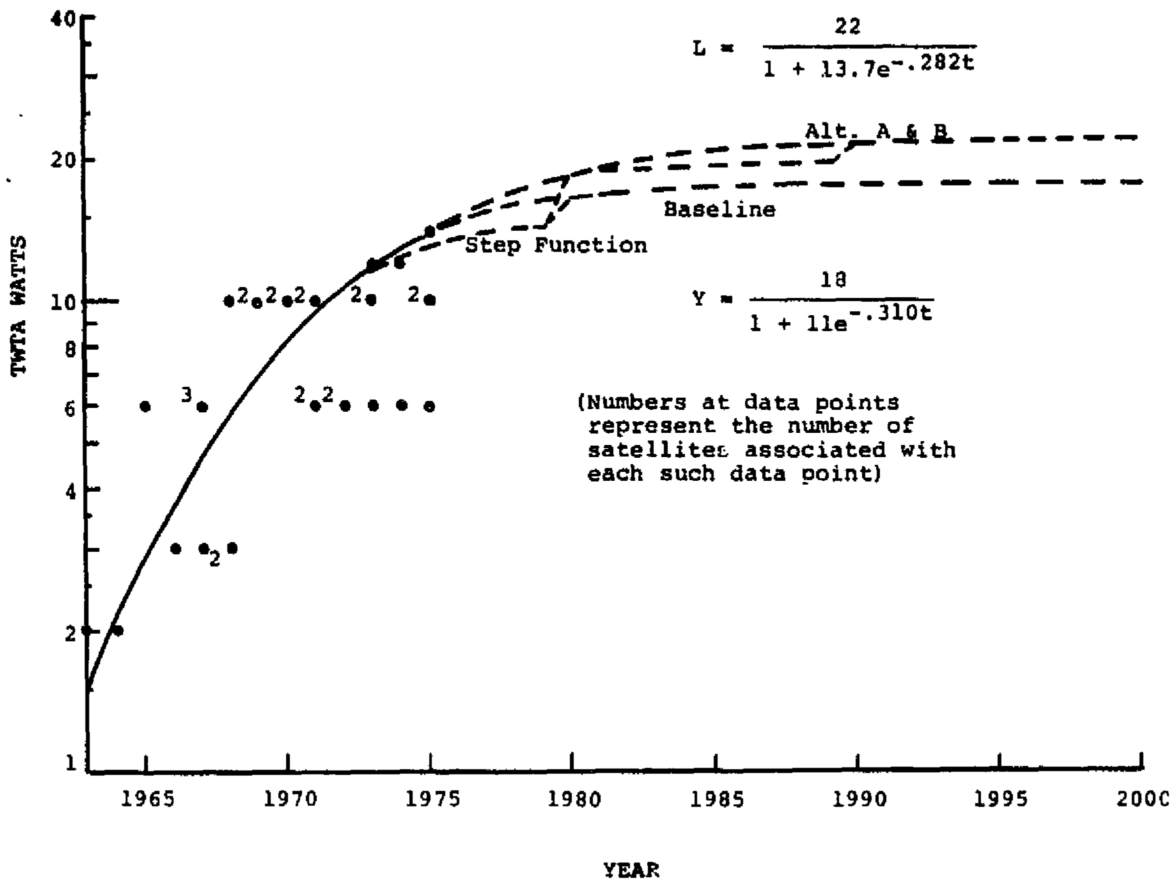

Figure 5.20. TWTA Rated Power Per Channel

Baseline projection and about 22 watts for Alternates "A" and "B". The approximate Pearl curve growth formulas for these two forecasts are shown in the figure. Both values are easily within the reach of current technology, since 20-watt TWTA's have demonstrated practicality in the DSCSII satellites. The implication for research in this area is that effort should be directed toward greater efficiency and reliability within currently attainable power levels.

Transmitting antenna gain projections are shown in Figure 5.21. Since antenna gain is basically a measure of beam width, it is reasonable that wide-beam antenna gain should level off in the region of 20 dB for 11.5° beam width, which is adequate for coverage of major continental areas. Since this is easily attainable with current technology, the potential for improvement in spot-beam antennas is of greater interest. The projection for spot-beam antenna gain assumes an upper limit of 70 dB. This limit is equivalent to a beam width of 0.036°, or a 22 Km spot-beam diameter at the earth's surface, which would approximate the area coverage required for most major cities. A 10-meter diameter parabolic antenna would be required to achieve this 70 dB antenna gain. Since this is an order-of-magnitude larger than current communication satellite antennas, it is obvious that new approaches to antenna design would be required to achieve such capability. In addition, solutions to the problems associated with multibeam spacecraft antennas which are implied by such narrow beams are of great significance. Analysis of such problems is beyond the scope of this study, but include requirements for side-lobe suppression, interference protection, intermodulation interference, and cross-talk reduction. [5,6]

[5] K.G. Schroeder, "Characteristics and Applications of Multibeam Spacecraft Antennas", AIAA Progress in Astronautics and Aeronautics: Communications Satellite Technology", Vol. 33, The MIT Press, Cambridge, Mass., 1974, pp. 503-532.

[6] J.L. Dicks and M.P. Brown, Jr., "Intelsat IVA Satellite Transmission Design", AIAA Progress in Astronautics and Aeronautics: Communication Satellite Developments: Systems", Vol. 41, The MIT Press, Cambridge, Mass., 1976, pp. 247-272.

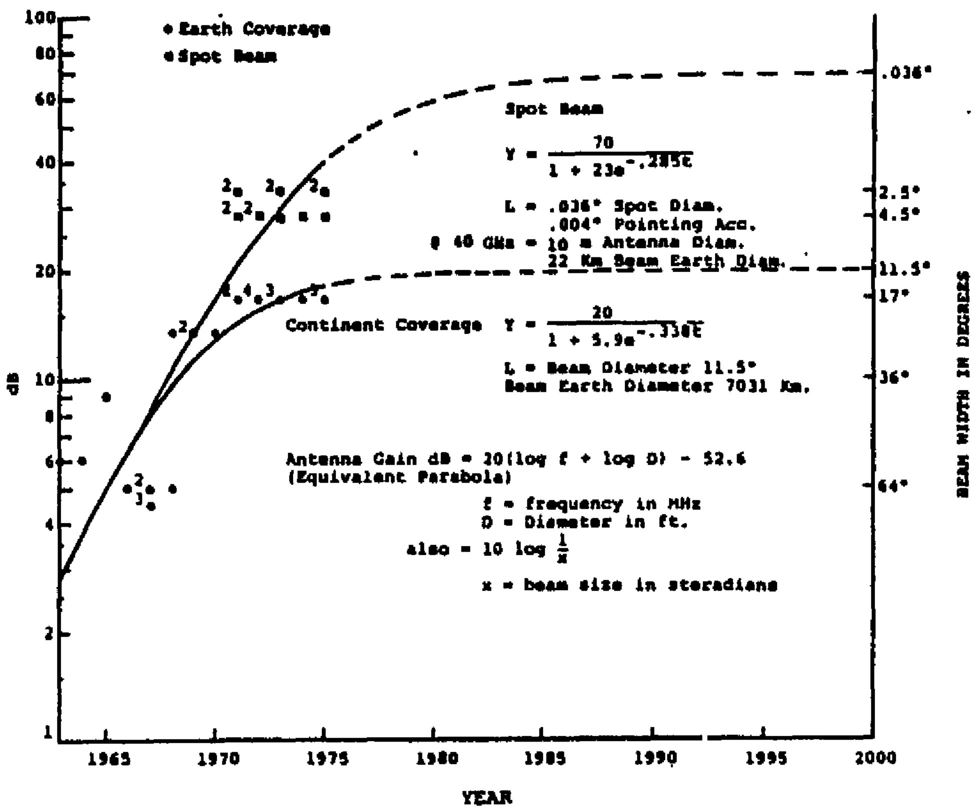

Figure 5.21. Transmitting Antenna Gain

Spot-beams of such narrow diameter also require extreme pointing accuracies. If pointing accuracies of the order of one-tenth of the angular dimensions of the beam are required, the 0.036° beam limit would imply pointing accuracies of 0.004°. Antenna pointing through closed-loop ground control from the illuminated area, using rf interferometry with ground stations providing the control signals is one possible solution to meet such requirements.[7] Assuming the upper limit of 70 dB antenna as a practical upper limit in terms of minimum desirable earth spot diameter leads to the Pearl curve projection shown for spot-beam antenna gain shown in Figure 5.21. If this projection is fulfilled, 60 dB gain antennas should be available in the period 1980 to 1990, and the 70 dB limit should be approached during the decade 1990 to 2000. The 60 dB gain antennas would provide a beam diameter of 0.115°, equal to a 71 km spot-beam diameter on the earth's surface. The parabolic antenna diameter for such a beam would be 3.3 meters, or about 3 times larger than the Intelsat IV spot-beam antennas. Small earth stations, operating below 4 GHz, would require larger antennas, ranging upward of 11 meters in diameter, with a tradeoff of decrease in antenna size and corresponding increase in beamwidth for lower frequencies.

Although it is not inconceivable that the Baseline size satellites could be designed to accommodate these larger spot-beam antennas, it seems more likely that the larger antennas would be associated with the satellite sizes of Alternates A and E.

Other elements of communication satellites whose patterns of development might be forecast include satellite body stabilization systems, high-speed electronic switching systems, apogee motors, energy storage systems, and satellite control systems. Forecasts in these technologies have not been included in

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[7] W.L. Pritchard and P.L. Bargellini, "Trends in Technology for Communication Satellites", Astronautics and Aeronautics, Vol. 10, No. 4., April 1972, pp. 36-42.

this study in order to make time available for projections of earth-station technology and competitive communications technologies on a basis matching the projection of major communication satellite parameters.

5.1.2.4 Projection of Satellite Wide-Band Channel Capacity

The projection of the average number of transponder channels per satellite launched, together with the prior projections of satellites launched and satellites phasing out enables a calculated projection of the number of wide-band channels which may be expected to be operational each year. For the Baseline projection, this calculation indicates an increase from the 160 such channels in 1975, to 512 channels in 1980, 1310 in 1985, 2005 in 1990, and 3822 in the year 2000. The average annual rate of growth would be 14% starting at 23% in the early years and slowing to 7% near the end of the century, which rates are conservative in comparison with the 1965-1975 annual rate of growth of approximately 40% per year. Alternate A would provide an increase from 160 wide-channels to over 1000 in 1980, 4300 in 1985, 9400 in 1990, and over 22,000 in 2000. This is equivalent to an overall annual average growth of 22%, although the projection indicates a continuance of the 1965-1975 rate for the next ten years, slowing to 9% in the last decade. Alternate B, with fewer of the larger satellites, provides total channel capacities roughly half-way between the Baseline and Alternate A.

The projections, as shown in Figure 5.22, are based on the envelope curve of the power projection. If instead the number of channels is based on the assumption of step function increases in power as a result of the change to sun-oriented solar arrays and the two step increases in satellite size, then the end results (year 2000) are the same, but the 1980 and 1990 projections are reduced by 40-50%.

The historical data and the projections of the satellite characteristics discussed in the preceding paragraphs are tabulated in Tables 5.12, 5.13, 5.14, and 5.15.

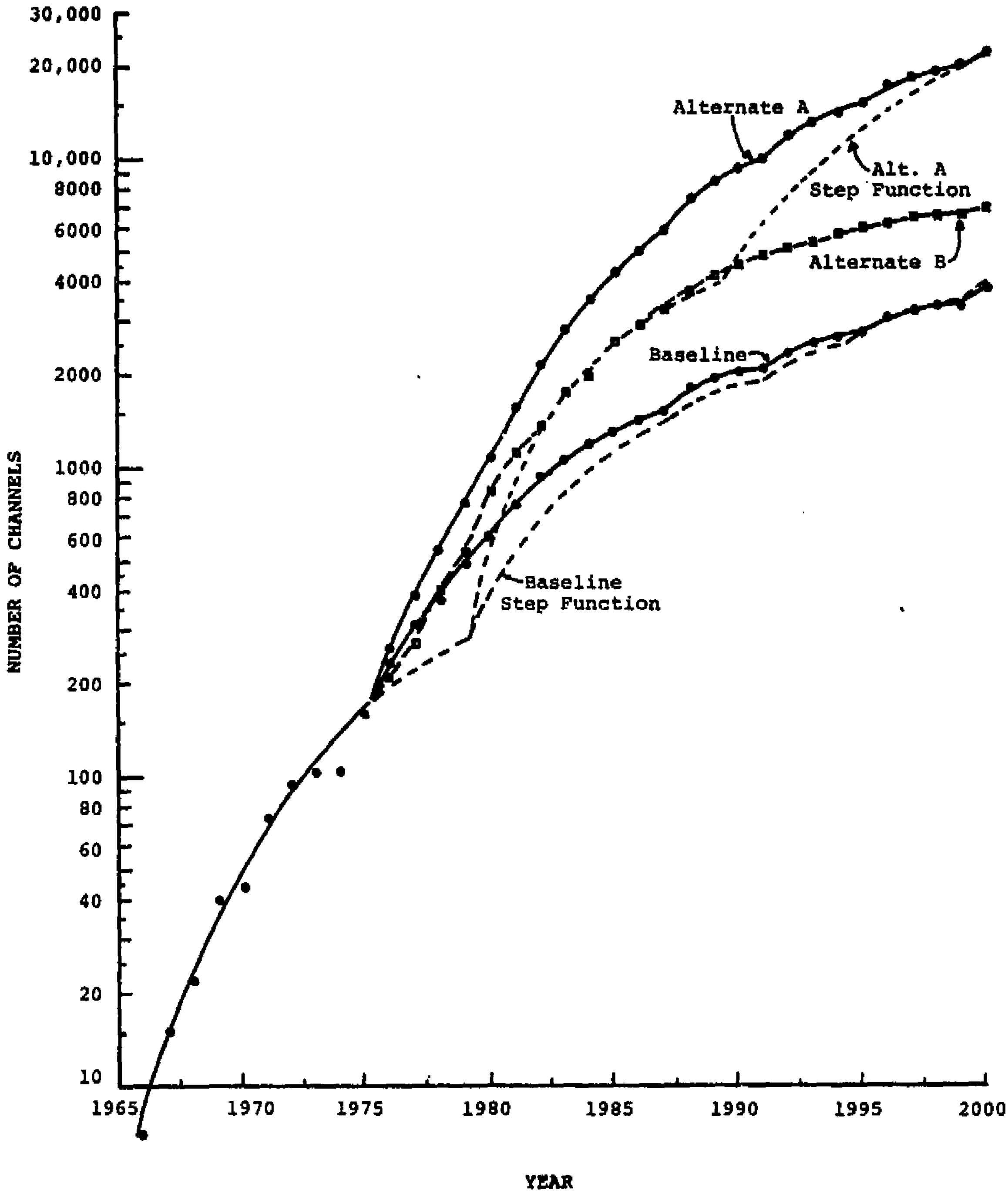

Figure 5.22. Number of Wide-Band Transponder Channels in Operation

TABLE 5.12

HISTORICAL DATA - COMMUNICATIONS SATELLITE POWER AND COMMUNICATION SUBSYSTEM CHARACTERISTICS

	Number Launched	Elect. Power Watts	No. of Wide-Band Transponder Channels	Total EIRP dBW	Total TWTA Rated Power Watts	Transmitting Antenna Gain dB: Wide-Beam	Transmitting Antenna Gain dB: Spot-Beam	Equivalent Number of Voice-Grade Channels
1963								
Syncom 2	1	29	2	18	4	6	-	240
1964								
Syncom 3	1	29	2	18	4	6	-	240
1965								
Intelsat 1	1	45	2	12-16	12	9	-	240
1966								
*IDCSP 1-7	1	40	1	7	3	5	-	
1967								
Intelsat 2	3	85-100	2	24-30	18	4.5	-	240
*IDCSP 8-18	2	40	1	7	3		-	
1968								
*IDSCS 19-26	1	40	1	7	3	5	-	
Intelsat 3	1	130-178	6	132	60	13.5	-	1200
1969								
Intelsat 3	2	130-178	6	132	60	13.5	-	1200
TACSAT 1	1	980						
1970								
Intelsat 3	2	130-178	6	132	60	13.5	-	1200
1971								
Intelsat 4	2	569	12	264	74	16.7	28.1	6K-9K
DSCS-II	2	535	4	112	40	16.8	33	
1972								
Intelsat 4	2	569	12	264	72	16.7	28.1	6K-9K
1973								
Intelsat 4	1	569	12	264	72	16.7	28.1	6K-9K
DSCS-II	2	535	4	112	40	16.8	33	
1974								
Intelsat 4	1	569	12	264	72	16.7	28.1	6K-9K
Westar	2	300+	12					7.2K
1975								
Intelsat 4	1	569	12	264	72	16.7	28.1	6K-9K
Intelsat 4A	1	600	12**		170			14K
RCA SATCOM	1	770	24					
DSCS-II	2	535	4	112	40	16.8	33	

*Each IDCSP Launch Group considered as a single satellite for statistical purposes, but with characteristics listed for a single satellite within the group.

**Switching arrangement permits 20 channels.

TABLE 5.13

BASELINE PROJECTIONS - COMMUNICATIONS SATELLITE POWER AND COMMUNICATION SUBSYSTEM CHARACTERISTICS

Year	Average Satellite Power* Watts	Total EIRP dBW	EIRP per Wide-Beam Channel dBW	No. of Wide-Beam Channels per Satellite	Total TWTA Rated Power Watts	TWTA Rated Power per Channel Watts	Wide-Beam Transmitting Antenna Gain dB	Spot-Beam Transmitting Antenna Gain dB	Calculations Using Step-Function Satellite Power Projection: Aver. Satellite Power Watts	Total EIRP dBW	No. of Wide-Beam Channels per Satellite	Total TWTA Rated Power Watts
1963	24	6	4.6	1	2	1.5						
1964	35	9	6.0	1	3.2	2.1	3.8	3.8				
1965	49	13	7.6	2	4.9	2.9	5.0	5.0				
1966	67	19	9.6	2	7.2	3.6	6.4	6.5				
1967	93	27	11.6	2	11.0	4.7	7.9	8.3				
1968	130	40	14.0	3	16.7	5.8	9.6	10.8				
1969	180	56	16.0	4	25	7.1	11.3	13.7				
1970	240	78	18.0	4	36	8.3	12.9	17.0				
1971	340	116	20.0	6	56	9.6	14.3	21.2				
1972	470	170	21.6	8	86	10.9	15.6	25	420	146	7	73
1973	620	230	23.0	10	120	12.0	16.7	30	500	180	8	90
1974	790	300	24.0	12	160	12.8	17.5	35	560	200	8	105
1975	970	370	25.0	15	220	14.9	18.2	40	600	220	9	116
1976	1200	480	25.6	19	280	14.9	18.7	45	640	235	9	124
1977	1400	560	25.9	22	340	15.7			670	250	10	132
1978	1650	680	26.2	26	410				700	260	10	140
1979	1900	800	26.4	30	490				730	270	10	148
1980	2150	920	26.6	35	570	16.5	19.6	59	2150	920	35	570
1981	2350	1020	26.7	38	650				2200			
1982	2500	1080	26.8	40	700				2300			
1983	2600	1140	26.9	42	740				2400			
1984	2700	1200	27	44	770				2450			
1985	2800	1250	"	46	800	17.3			2500	1080	40	700
1986	2900	1280	"	47	830				2525			
1987	2925	1290	"	48	840				2550			
1988	2950	1300	"	48	850				2675			
1989	2975	1310	"	48	860				2700			
1990	3000	1320	"	49	870	17.8	20	69	2800	1250	46	800
1991	"	"	"	"	"				2840			
1992	"	"	"	"	"				3000			
1993	"	"	"	"	"				3100			
1994	"	"	"	"	"				3130			
1995	"	"	"	"	"				3200	1400	52	920
1996	"	"	"	"	"				3230			
1997	"	"	"	"	"				3300			
1998	"	"	"	"	"				3340			
1999	"	"	"	"	"	17.8	20	70	3400	1530	57	1000

*From Envelope Curve of Figure 5.9

TABLE 5.14

ALTERNATES A & B PROJECTIONS COMMUNICATIONS SATELLITE POWER AND COMMUNICATION SUBSYSTEM CHARACTERISTICS

	ENVELOPE CURVE						STEP FUNCTION			
Year	Average Satellite Power Watts	Total EIRP dBW	EIRP per Wide-Beam Channel dBW	No. of Wide-Beam Channels per Satellite	Total TWTA Rated Power Watts	TWTA Rated Power per Channel Watts	Aver. Satellite Power Watts	Total EIRP dBW	No. of Wide-Beam Channels per Satellite	Total TWTA Rated Power Watts
1975	970	370	25.0	15	250	14.9	600	220	9	116
1979	3700	1700	26.4	64	1120	17.4	730	270	10	148
1980	4700	2200	26.6	83	1520	18.3	4700	2200	83	1520
1985	10200	5200	27	193	4000	20.8	5200	2450	91	1750
1989	13200	7000	27	259	5500	21.2	5600	2650	98	1900
1990	13700	7200	27	267	5800	21.6	13000	6800	252	5400
1995	15000	8000	27	296	6400	21.6	14500	7700	285	6200
2000	15000	8000	27	296	6400	21.6	15000	8000	296	6400

TABLE 5.15

PROJECTION OF NUMBER OF OPERATIONAL WIDE-BAND TRANSPONDER CHANNELS

Year	Baseline Envelope*	Baseline Step Function Power	Alternate A Envelope*	Alternate A Step Function Power	Alternate B Envelope*
1963	2				
1964	4				
1965	6				
1966	7				
1967	15				
1968	22				
1969	40				
1970	44				
1971	74				
1972	95				
1973	104				
1974	104				
1975	160				
1976	236	196	264	196	212
1977	312	224	389	224	270
1978	384	232	541	232	422
1979	492	260	779	260	538
1980	612	380	1097	572	850
1981	766	520	1586	961	1129
1982	942	685	2197	1372	1359
1983	1076	839	2838	1781	1754
1984	1184	970	3524	2167	2000
1985	1310	1130	4305	2582	2588
1986	1425	1295	5124	3007	2890
1987	1525	1365	5942	3150	3478
1988	1813	1623	7408	3732	3722
1989	1911	1707	8437	3895	4184
1990	2005	1798	9404	4972	4464
1991	2089	1890	10303	6087	4839
1992	2383	2178	11989	7707	5120
1993	2500	2326	13134	9182	5350
1994	2619	2476	14192	10687	5734
1995	2727	2635	15189	12217	5896
1996	3070	3006	17261	14233	6192
1997	3222	3228	18479	16078	6456
1998	3226	3410	19383	17832	6508
1999	3430	3594	20197	19596	6619
2000	3822	4050	22565	21964	6915

*Using Envelope Curve of Power Projection

The Baseline projection appears to stabilize at a 5% growth rate from 1985 to 2000. Thus, assuming that this growth rate will gradually slow, a further projection of the Baseline may be made out to the year 2040. Using a 5% growth rate for 2001 to 2010, 4% for 2011-2030, and 3% for 2031 to 2040, results in the following projection.

Year	No. of Channels	Year	No. of Channels
2000	3822	2021	9583
2001	4013	2022	9966
2002	4214	2023	10365
2003	4424	2024	10779
2004	4646	2025	11210
2005	4877	2026	11659
2006	5121	2027	12125
2007	5877	2028	12610
2008	5646	2029	13115
2009	5928	2030	13639
2010	6224	2031	14048
2011	6473	2032	14470
2012	6732	2033	14904
2013	7002	2034	15351
2014	7282	2035	15811
2015	7573	2036	16286
2016	7876	2037	16774
2017	8191	2038	17277
2018	8519	2039	17796
2019	8860	2040	18330
2020	9214		

5.1.3 Summary of Communication Satellite Trends

The sets of internally consistent forecasts may now be summarized to present an overall picture of possible communication satellite developments over the next 24 years. These will be combined later with similar projections of ground station characteristics to provide an estimate of future communication system capabilities based on the use of satellites.

Three general paths for future communication satellite development emerge from the projections. The Baseline scenario represents a conservative development picture with a series of small incremental improvements in satellite characteristics. The cumulative effect of such improvements, nevertheless, offers a substantial increase in overall satellite communication systems capabilities. This scenario should be regarded as the minimum expectation for communication satellites. In this Baseline projection, satellite size will increase only marginally, which may easily be achieved with slight increases in present launch vehicle and apogee motor capabilities. Average satellite size, measured in terms of weight, should reach 900 kg. Solar power is expected to be the primary power source, and will increase by a factor of three over the earlier spin stablized satellites as a result of the use of solar arrays which are continuously oriented toward the sun. Although no other major improvements are projected, continuing small improvements in energy collection, storage, and management techniques, coupled with the small increases in satellite size, should nearly double the power gain obtained from the shift to sun-oriented arrays. Thus, average satellite power shluld reach 3-1/2 kw by the end of the century, compared with 1975 levels averaging little more than half a kolowatt. This increase in power will support a projected increase in the number of wide-band transponder channels to about 48 channels per satellite by the end of the period. Most of this increase will come early in the period, averaging 36 channels per satellite in the early 1980's. Annual launch rates will gradually increase from an average of four per year to eight per year in the late 1990's. This, coupled with an increase in satellite lifetime to ten years, will produce a five-fold increase in the number of satellites operational by the year 2000. The increase will go from 25 satellites in 1980 to over 75 in 2000. Total power of all communication satellites in operation will increase 30 times over current levels which provides one measure of the increase in available capability.

The total number of wide-band transponder channels available is projected to increase from 600 in 1980 to nearly 4000 by the year 2000. This will provide the equivalent of one million voice grade channels by 1985 and three million such channels by the end of the century. The several features of satellite technology development associated with this capability have been discussed previously and will not be repeated here, since the most significant feature of this Baseline projection is the increase in the number of wide-band channels available.

The second path represents a bolder projection of satellite development, but follows a pattern consistent with prior developments in communication satellite capability and remains within reasonable constraints of technical feasibility. This forecast, referred to as Alternate A, is primarily characterized by two major step increases in satellite size, coupled with the same increase in the number of satellites as forecast in the Baseline scenario. The first step increase in satellite size, to 2000 Kg in 1980, is achievable with current launch vehicle capabilities. [8] The second step increase, to 6000 kg in 1990, is technically feasible. These weights should permit average satellite power of about 5 kw in the 1980's and 12 to 15 kw in the 1990's.

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[8] Atlas F, with Fairchild Stage Vehicle System, 3265 kg synchronous-transfer orbit capability.

At least 100 wide-band channels per satellite should be available in the 1980's and close to 300 in the 1990's, six times more than in the Baseline forecast. The net result, with the same number of satellites, is that Alternate A will provide the equivalent of three million voice-grade channels by 1985 and seventeen million by 2000. This scenario represents the most plausible upper limit for satellite capability during the forecast period.

Alternate B describes a third scenario for communication satellite capa' ·lity. Individual satellite capability is projected as being identical with Alternate A. However, the number of satellite launches each year is reduced so that the total weight placed in orbit approximates that occuring in the Baseline forecast. The fewer large satellites provide capability (measured in voice-channel capacity) lying between the Baseline projection and Alternate A, i.e., two million channels by 1985 and over five million by 2000, approximately twice the Baseline values. These projections are summarized in Table 5.16.

The larger satellites of Alternates A and B have greater implications for communication satellite research and development than do those of the Baseline forecast. In addition to the requirement for larger launch vehicles and apogee motors, these satellites expand the range of technical options for increasing communication satellite capabilities. In particular, larger satellites enhance the potential for multiple spot-beam systems, with attendant implications for narrow-beam antenna technology, switching techniques, and pointing methods.

The Baseline and Alternate A projections bound the likely capabilities for meeting communication market demand and total system cost, while the larger satellites forecast for Alternates A and B provide the upper limits for communication satellite R&D.

TABLE 5.16

SUMMARY TABULATION OF PROJECTED BROADCAST SATELLITE CHARACTERISTICS

	Per Satellite Launched During Year					Satellite in Orbit and Operational			
Year	Aver. Wt. Kg	Aver. Power Kw	Aver. Total TWTA Power Watts	No. of Wide-Band Channels	No. of Satellite	Total Wt. Metric Tons	Total Power Kw	Total No. of Wide-Band Channels*	Equiv. Voice-Grade Channel Capacity
1975	622	0.6	220	15	15	10	8	160	120K
					BASELINE PROJECTION				
1980	785	2.1	570	35	25	19	23	600	450K
1985	815	2.5	800	46	33	26	71	1300	975K
1990	840	2.9	870	49	43	35	111	2000	1.9M
2000	890	3.4	870	49	78	68	248	3800	2.9M
2040								18300	14M
					ALTERNATE A				
1980	2000	4.7	1520	83	25	23	33	1100	825K
1985	2000	5.2	4000	193	33	61	148	4300	3.2M
1990	6000	12	5800	267	43	110	275	9400	7.0M
2000	6000	15	6400	296	78	468	1116	22500	17M
					ALTERNATE B				
1980	2000	4.7	1520	83	19	19	--	800	600K
1985	2000	5.2	4000	193	20	38	--	2600	2.0K
1990	6000	12	5800	267	21	50	--	4400	3.3M
2000	6000	15	6000	296	24	144	--	6900	5.2M

* Rounded to Nearest 100

5.2 PROJECTION OF TRENDS IN SATELLITE COMMUNICATION EARTH STATIONS

The major directions of change in earth station technology for satellite communications have been toward smaller antennas, reduced costs, and reduction in the land-line interconnection system for satellite signal distribution. The history of this technology is too brief to provide a basis for extrapolation of trends from the scattered data available. However, the data which is available provides an adequate basis for determination of probable antenna sizes to meet various service requirements, and also furnishes a starting point for cost projections using production "learning curves". Reduction in the land-line interconnection system is directly associated with the trend toward smaller antennas and reduced earth-station costs, with a consequent transfer of increasing amounts of communication traffic from land-lines to satellite transmissions, to avoid land-line network costs.

5.2.1 Earth Terminal Costs Versus Antenna Size

Data relating earth-terminal costs to antenna size and G/T are presented in Table 5.17. Five of the data sets represent reported actual costs, while the remaining two are derived from calculations of earth-terminal costs by Petrick and Abrahamson.[10] Although this does not provide an extensive data base, it does have sufficient consistency to provide a basis for reasonable extrapolation of costs, as will be shown later. Estimates of earth-terminal costs on a more detailed basis, which will be available upon completion of a NASA-Lewis funded study contract with the Fairchild Company, may be used to confirm or correct these costs in subsequent use of the cross impact model.

Earth terminal costs tend to be associated with antenna size, not only in terms of the antenna itself, but also in terms of

[10]G.P. Petrick and C.M. Abrahamson, "Economic Considerations for Low-Capacity SHF Satellite Communications Earth Terminals", Communication Satellite Developments: Technology, Vol. 42, Progress in Astronautics and Aeronautics, The MIT Press, 1976.

TABLE 5.17

EARTH TERMINAL COSTS

Earth-Terminal Identification	Antenna Diam. Meters	Antenna Area Sq. M	G/T dB/°K	Cost $	Year	Reference
Intelsat Standard	27	572	41	2000K	1971	1
Algerian System	11	95	32	500K	1975	2
Philippine Domestic	10	78.5	(31)	200K	1976	3
PBS-165	10	78.5	(31)	150K	1978	4
COMSAT DICOM	4.6	15.6	21	150K	1973	1
Min. Cost G/T 23	3.7	10.7	23	37K (31K)	1974	5
Min. Cost G/T 14	2.4	4.7	14	22K (16K)	1974	5

Reference 1: "Small Earth Terminals", Edelson, Aeronautics & Astronautics, June 1973, Page 45.

Reference 2: "Algerian Domestic System", Bairi, Communication Satellite Developments: Systems; Progress in Astronautics and Aeronautics, Vol. 41, Page 276.

Reference 3: "Philippine Domestic System", Cheadle, Communication Satellite Developments: Systems; Progress in Astronautics and Aeronautics, Vol. 41, Page 40.

Reference 4: "PBS Connecting TV Network Via Westar", Aviation Week, March 8, 1976, Page 16.

Reference 5: "Economic Considerations for Earth Terminals", Petrick & Abrahamson, Communication Satellite Developments: Technology; Progress in Astronautics and Aeronautics, Vol. 42, Pages 153 & 157.

Reference See Text.

transmitter and receiver costs. It is axiomatic that total terminal costs will be optimized in actual systems, so that it may be inferred that terminal costs will follow established patterns in the absence of major advances in technology. Following this assumption, the earth terminal costs for the antenna areas shown in Table 5.17 are plotted in Figure 5.23. These data support a formula for approximate earth terminal cost as follows:

$$\text{Earth Terminal Cost, } E_c \text{ (in dollars)} = 3600 \times \text{antenna area (in sq m)}.$$

For example, an earth terminal with a 3.2 meter diameter antenna should cost on the order of $30,000. Associated with this figure are assumptions of a production quantity of at least 100 units, and capability for TV reception plus two-way voice communication. A 0.6 meter diameter earth terminal, capable of two-way voice communication should cost approximately $1000, given a production quantity of between 100 and 1000 units.

The antenna, feed, and mount costs represent a significant fraction (15% to 40%) of total earth terminal costs, and since these costs logically may be expected to be a function of antenna size, a separate estimate of such costs may be made. Petrick and Abrahamson [11] offer a formula for minimum cost as follows:

$$\text{Antenna Cost } (\$10^3) = 1 + 0.8D + 0.016D^2, \text{ with diameter given in feet.}$$

This formula gives reasonable estimates for antenna diameters of about 10 meters ($44,000), but gives costs which are much higher than currently quoted prices for antennas in the 2- to 3-meter diameter range. For example, verbal quotes from the Prodelin Corporation indicate prices of $2600 for a 1.83-meter antenna system (receive only), $4200 for a 3-meter system (receive only), and $5100 for a 3-meter receive and transmit antenna system. The Petrick-Abrahamson formula gives a cost of $6400 for the 1.83-meter system,

[11] op. cit.

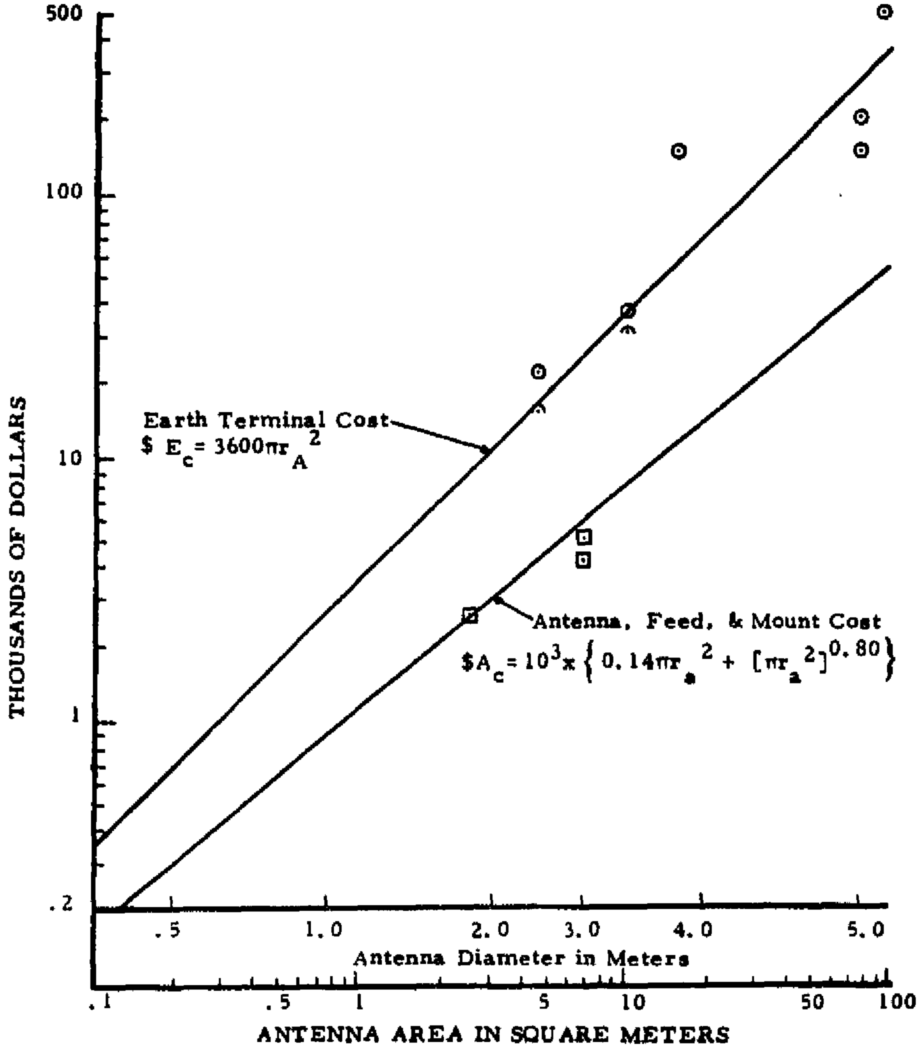

Figure 5.23. Earth Terminal Costs Versus Antenna Size

and \$10,600 for the 3-meter system, i.e., from 2 to 2-1/2 times more than currently quoted prices in these sizes. At the lower end of antenna size, if the total earth terminal cost of \$1000 is accepted for a 0.6-meter diameter system, as given in Figure 5.23, it seems reasonable that antenna system costs should be held to not more than 40% of the total, or \$400.

Using the above sets of values for antenna system costs, i.e., the Petrick-Abrahamson figure for a 10-meter antenna, Prodelin quotes for the 1.83- and 3-meter systems, and the lower-bound figure for the 0.6-meter antenna, a curve for antenna systems costs may be established as shown in Figure 5.23. The formula for antenna systems costs in accordance with this curve is as follows:

$$\text{Antenna System Cost, } A_c \text{ (in dollars)} = 10^3 \times \left\{ 0.14 \times \text{antenna area} + [\text{antenna area}]^{0.8} \right\}$$

with antenna area given in square meters.

Reestablishing total earth terminal costs by replacing the original antenna costs in the Petrick-Abrahamson data in Table 5.17 with costs according to the above formula, gives lowered costs for the Minimum Cost G/T 23 and G/T 14 terminals of \$31,000 and \$16,000, respectively. These revised estimates are shown by the half-circle data points on Figure 5.23.

5.2.2 Earth Terminal Costs Versus G/T Ratio

Since antenna size, by itself, is not a measure of earth terminal performance, even though it is a practical consideration in both cost and performance estimates, it is desirable to express performance in terms of earth station receiver sensitivity.

The principal parameter used to characterize the sensitivity of an earth station receiver is the gain-to-noise temperature ratio, G/T. G/T is a function of the antenna gain, G, and the system noise temperature, T_s. The gain of a parabolic dish antenna is a function of antenna diameter, frequency, and antenna efficiency, as given by [12]

[12] Future Communications Systems Via Satellite Utilizing Low-Cost Earth Stations, July 1968, Appendix J Staff Paper 2, President's Task Force on Communications Policy.

$$G = 108\eta D^2 f^2 \quad (5\text{-}1)$$

where

η = antenna efficiency,

D = antenna diameter (m), and

f = operating frequency (GHz);

or $$G(dB) = 10 \log_{10} G = 10 \log_{10} 108 + \log_{10}\eta + 2 \log_{10} D + 2 \log_{10} f \ , \quad (5\text{-}2)$$

therefore,

$$G(dB) = 20.3 \text{ dB} + 10 \log_{10}\eta + 20 \log_{10} D + 20 \log_{10} f. \quad (5\text{-}3)$$

The system noise temperature, T_s, of a ground station receiver includes preamplifier noise, feed noise, elevation angle noise, indigenous noise, etc. The system noise temperature in terms of dB is given by the equation:

$$T_s(dB) = 10 \log_{10} T_s(°K) \quad . \quad (5\text{-}4)$$

The ground station G/T can be obtained by combining the equations for G and T:

$$G/T(dB) = G(dB) - T_s(dB) \quad (5\text{-}5)$$

$$G/T(dB) = 20.3 + 10 \log_{10}\eta + 20 \log_{10} D + 20 \log_{10} f - 10 \log_{10} T_s \ . \quad (5\text{-}6)$$

Information concerning G/T values for existing earth stations is presented in Tables 5.18 and 5.19. The G/T values from Table 5.18 have been plotted as a function of antenna diameter in Figure 5.24. To provide a means of relating antenna size, G/T values, and cost, a single curve has been fitted to this data. The curve follows the equation

$$G/T(dB) = A + 20 \log_{10} D \quad (5\text{-}7)$$

where A is a constant that is given by

$$A = 20.3 + 10 \log_{10}\eta + 20 \log_{10} f - 10 \log T_s \quad . \quad (5\text{-}8)$$

TABLE 5.18

EARTH TERMINAL RECEIVER CHARACTERISTICS

Ground Station Identification	Satellite System	D(m)	G/T (dB)	G(dB)	T_{sys} (°K)	f(GHz)
US 0.6 m	CTS	0.6	4	35	900	12
AN/ASC-18	DSCS	0.84	7	-	-	7.9-8.4
One-Meter CTS	CTS	1.0	5.2	-	-	12
US 1.2 Meter	CTS	1.2	10	40	900	12
AN/SSC-6	DSCS	1.82	15	-	-	7.9-8.4
S-IA (DTS)	DSCS	1.82	17.5	-	-	7.9-8.4
DSCS Trans	DSCS	1.92	16	-	-	7.9-8.4
Two-Meter CTS	CTS	2.13	16.6	-	-	12
"Min. Cost, Single Thread"	Anal.	2.44	14	43.0	794	7.9-8.4
AN/TSC-85	DSCS	2.44	17	-	-	7.9-8.4
AN/MSC-59	DSCS	2.44	17	-	-	7.9-8.4
AN/TSC-86	DSCS	2.44	18	-	-	7.9-8.4
AN/WSC-2	DSCS	2.44	18	-	-	7.9-8.4
Three-Meter Transportable	CTS	3.0	22	-	-	12
US Three-Meter	CTS	3.0	18	48	900	12
COMSAT DICOM	Intelsat	4.6	21	-	-	12
Cleveland NASA	CTS	4.9	23.5	52.5	800	12
SC-IA (DTS)	DSCS	5.5	26	-	-	7.9-8.4
AN/TSC-54	DSCS	5.5	26.5	-	-	7.9-8.4
AN/TSC-86	DSCS	6.1	27	-	-	7.9-8.4
Min. Cost, Single Thread	Anal.	6.7	23	52	794	7.9-8.4
ANIK HS333	Canad. TELSAT	9.0	26 @4 GHz	48.5	160	4
Nine-Meter Ottawa	CTS	9.0	32.9	-	-	12
VET Terminal	Intelsat	9.8	30	50.4	-	--
NSA	DSCS	10.0	31	-	-	7.9-8.4
SC-2 (DTS)	DSCS	10.7	31	-	-	7.9-8.4
Algerian Sta.	Alger.	11.0	31.7	-	-	4
AN/MSC-46	DSCS	12.2	34	-	-	7.9-8.4
AN/MSC-61	DSCS	12.2	34	-	-	7.9-8.4
US/USSR Link	US/USSR	18.3	31	53.6	95	3.4-3.9
AN/FSC-9	DSCS	18.3	37	-	-	7.9-8.4
AN/MSC-60	DSCS	18.3	39	-	-	7.9-8.4
Intelsat Stand.	Intelsat	26-30	40.7	-	50	--

TABLE 5.19

EARTH TERMINAL REFERENCES

Ground Station Identification	Satellite System	D(m)	Reference	Page Nos.
US 0.6 m	CTS	0.6	1	VII 16
AN/ASC-18	DSCS	0.84	2	320
One-Meter CTS	CTS	1.0	1	VII 12-14
US 1.2 Meter	CTS	1.2	1	VII 16
AN/SSC-6	DSCS	1.82	2	320
S-IA (DTS)	DSCS	1.82	2	320
DSCS Trans	DSCS	1.92	2	320
Two-Meter CTS	CTS	2.13	1	VII 9-12
"Min. Cost, Single Thread"	Anal.	2.44	3	145-166
AN/TSC-85	DSCS	2.44	2	320
AN/MSC-59	DSCS	2.44	2	320
AN/TSC-86	DSCS	2.44	2	320
AN/WSC-2	DSCS	2.44	2	320
Three-Meter Transportable	CTS	3.0	1	VII 4-9
US Three-Meter	CTS	3.0	1	VII 16
COMSAT DICOM	Intelsat	4.6	4	44-45
Cleveland NASA	CTS	4.9	1	VII 17-24
SC-IA (DTS)	DSCS	5.5	2	320
AN/TSC-54	DSCS	5.5	2	320
AN/TSC-86	DSCS	6.1	2	320
Min. Cost, Single Thread	Anal.	6.7	3	145-166
ANIK HS333	Canad. TELSAT	9.0	1	167-180
Nine-Meter Ottawa	CTS	9.0	1	VII 2-4
VET Terminal	Intelsat	9.8	5	230
NSA	DSCS	10.0	2	320
SC-2 (DTS)	DSCS	10.7	2	320
Algerian Sta.	Alger.	11.0	2	273-284
AN/MSC-46	DSCS	12.2	2	320
AN/MSC-61	DSCS	12.2	2	320
US/USSR Link	US/USSR	18.3	3	115-143
AN/FSC-9	DSCS	18.3	2	320
AN/MSC-60	DSCS	18.3	2	320
Intelsat Stand.	Intelsat	26-30	4	44-45

Reference 1:

CTS Reference Book; NASA TM X-71824; 15 Oct 75; Lewis Research Center, Cleveland, Ohio; Editors: J. G. Kennard and A. W. Nice.

Reference 2:

Communications Satellite Developments: Systems; Progress in Aeronautics and Astronautics; Vol. 41, 1976; Editors: G. E. LaVean & W. G. Schmidt.

Reference 3:

Communications Satellite Developments: Technology; Progress in Aeronautics and Astronautics; Vol. 42, 1976, Editors: G. E. LaVean & W. G. Schmidt.

Reference 4:

"Small Earth Terminals for Satellite Communications", B. L. Edelson, Astronautics and Aeronautics, June 1973.

Reference 5:

"An Unattended Earth Terminal for Satellite Communications", L. Pollak and W. Sones. COMSAT Technical Review, Vol. 4, No. 2, Fall 1974 (Reprinted in Satellite Communications Systems; I. Kadar, Editor; AIAA Selected Reprint Series; Vol. XVIII; January 1976.

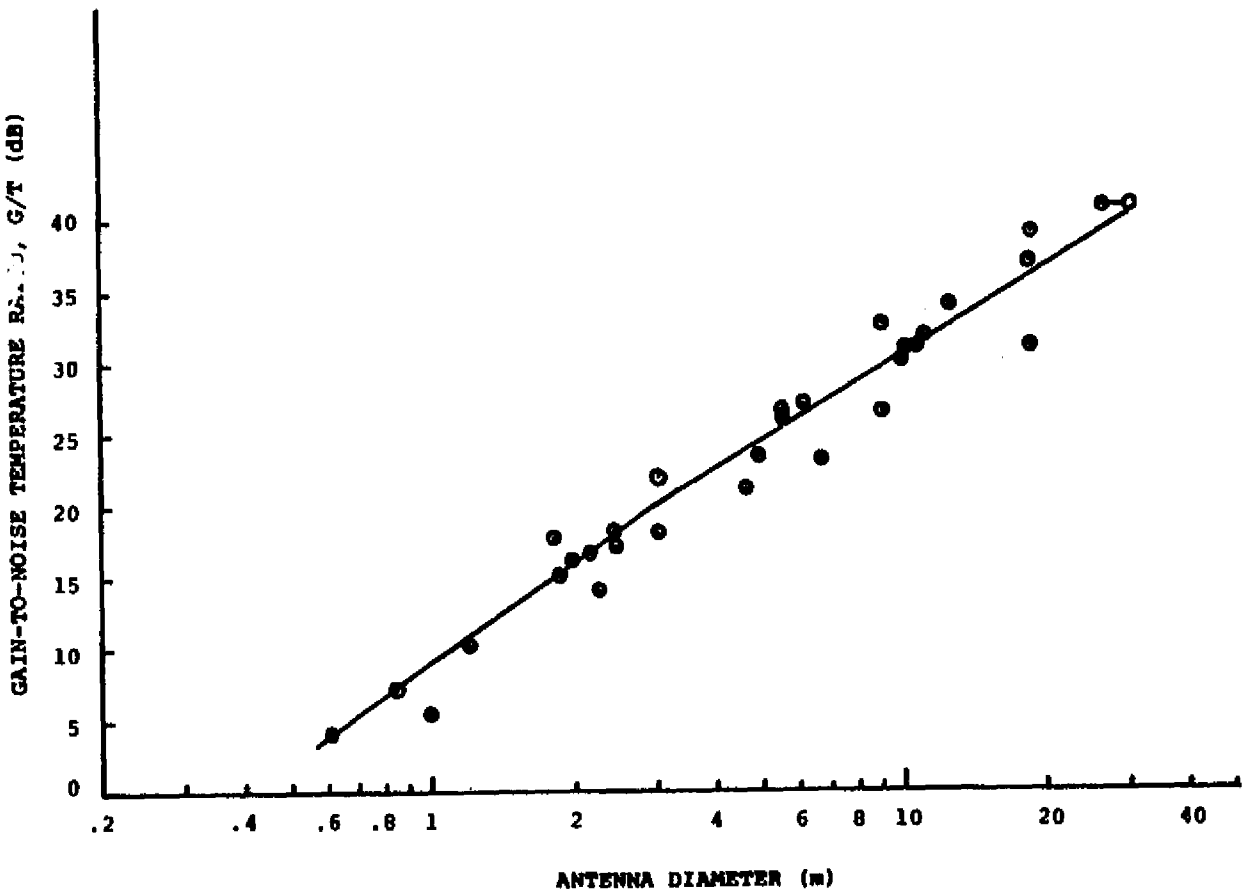

Figure 5.24. Gain-To-Noise Temperature Ratio Versus Antenna Diameter

From D = 3.0 m to D = 20 m, the curve selected to fit the data requires that A = 10.6 dB. Although the parameters that influence A vary from one ground station example to the next, a set of reasonable values could result in a 10.6 dB magnitude for A. For example, if

$f = 8.15$ GHz,

$\eta = 0.57$, and

$T_s = 354°K$, then

$$A = 20.3 - 2.4 + 18.2 - 25.5 = 10.6 \text{ dB} . \quad (5\text{-}9)$$

For smaller antenna sizes, parameter values corresponding to higher frequency operation (12 GHz), and a higher system noise temperature (900°K), in conjunction with antenna efficiency that drops off as antenna size is reduced results in a better fit of the available data, as presented in Table 5.20. The parameter values of f, η, and T_s listed in Table 5.20, which provide a single curve to fit the data, were arbitrarily selected. Any number of combinations of f, η, and T_s could provide a equally good fit.

Using this curve (Figure 5.24) to transform the earth terminal cost versus antenna size to earth terminal cost versus G/T provides results approximated by the curve shown in Figure 5.25. The formula for earth terminal cost versus G/T with this transformation is as follows:

$$\text{Earth Terminal Cost, } E_c = 0.4e^{0.214\ G/T} . \quad (5\text{-}10)$$

Earth terminal costs versus G/T for the data points in Table 5.18, plotted on Figure 5.25 are reasonably consistent with this curve, given the cost variabilities associated with amount of channel equipment, redundency, quantity produced, and manufacturer. The utility of this approximation lies in its indication of probable cost ranges for given values of the important single parameter of G/T, and in its indication of relative costs for various values of G/T, given equivalence of other factors. For example, a terminal

TABLE 5.20

DATA FOR BEST FIT OF G/T VERSUS D

Antenna Diameter D (m)	Gain-to Noise Temp. G/T (dB)	Gain G (dB)	System Noise Temp. T_s (°K)	Antenna Efficiency η	Frequency f (GHz)	A (dB)*
0.6	4.0	33.5	900°K	.40	12	8.4
1.0	9.0	38.5	900°K	.46	12	9.0
1.5	13.2	42.7	900°K	.54	12	9.7
2.0	16.0	45.5	900°K	.57	12	10.0
3.0	20.1	45.6	354°K	.57	8.15	10.6
9.0	29.7	55.2	354°K	.57	8.15	10.6
20.0	36.6	62.1	354°K	.57	8.15	10.6

$*A = 20.3 + 10 \log \eta + 20 \log f - 10 \log T_s$

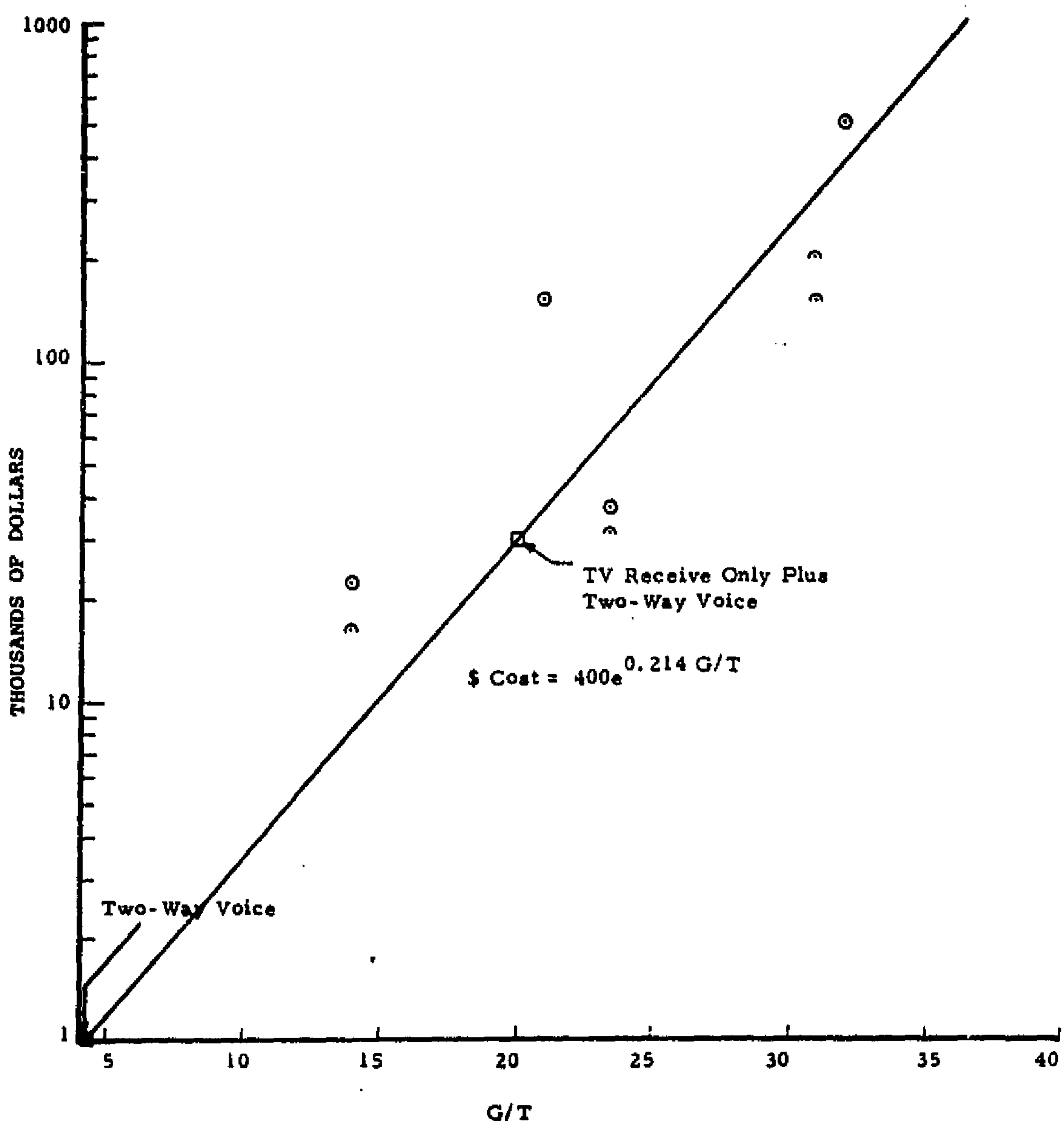

Figure 5.25. Earth Terminal G/T Versus Cost

for TV receive-only, plus two-way voice, at a nominal 20 G/T should cost approximately $30,000. A two-way voice earth station with a G/T of 4.5 should cost about $1000.

5.2.3 Earth Terminal Cost Projections

The economies of quantity production may reasonably be expected to lower earth terminal costs. A projection of expectations for lowered costs may be made using the conventional "learning curve" approach.* For this projection, a 90% learning curve was selected, which is quite conservative in comparison with the 80% learning curves usually associated with production of electronic equipment. That is, it might reasonably be expected that earth station costs would come down more rapidly than indicated by the 90% learning curve projection.

Figure 5.26 portrays earth terminal costs for a typical TV receive, two-way voice, terminal, and for a typical two-way voice terminal under various conditions. The initial cost basis for one-channel** TV receive terminals, taken from Figure 5.23 and 5.25 as presented and discussed previously, is assumed to be $30,000 for a production quantity of 100 units. A cumulative production quantity of 10,000 units on a 90% learning curve should lower this cost to $15,000 for the 10,000th unit. Since this cost would still exceed a reasonable outlay for a single-family installation, the alternate possibility of a terminal for large apartment complexes may be considered. Such a terminal, whose costs are also shown on Figure 5.26, would be an 11-channel TV receiver, capable of receiving 11 channels simultaneously and distributing the channel signals to individual TV sets for channel selection at the set, in a manner similar to current cable TV. Initial costs for this added capability are conservatively assumed to be $2000 for each added channel at the terminal, giving an initial cost of $50,000 for such a terminal.

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*Learning curve percentages indicate the percentage of initial cost associated with each doubling of the initial quantity, i.e., a 90% curve indicates a 10% cost reduction each time the production quantity is doubled.

**"One-channel" refers to a terminal which is capable of receiving only one channel at a time, although various channel frequencies may be selected.

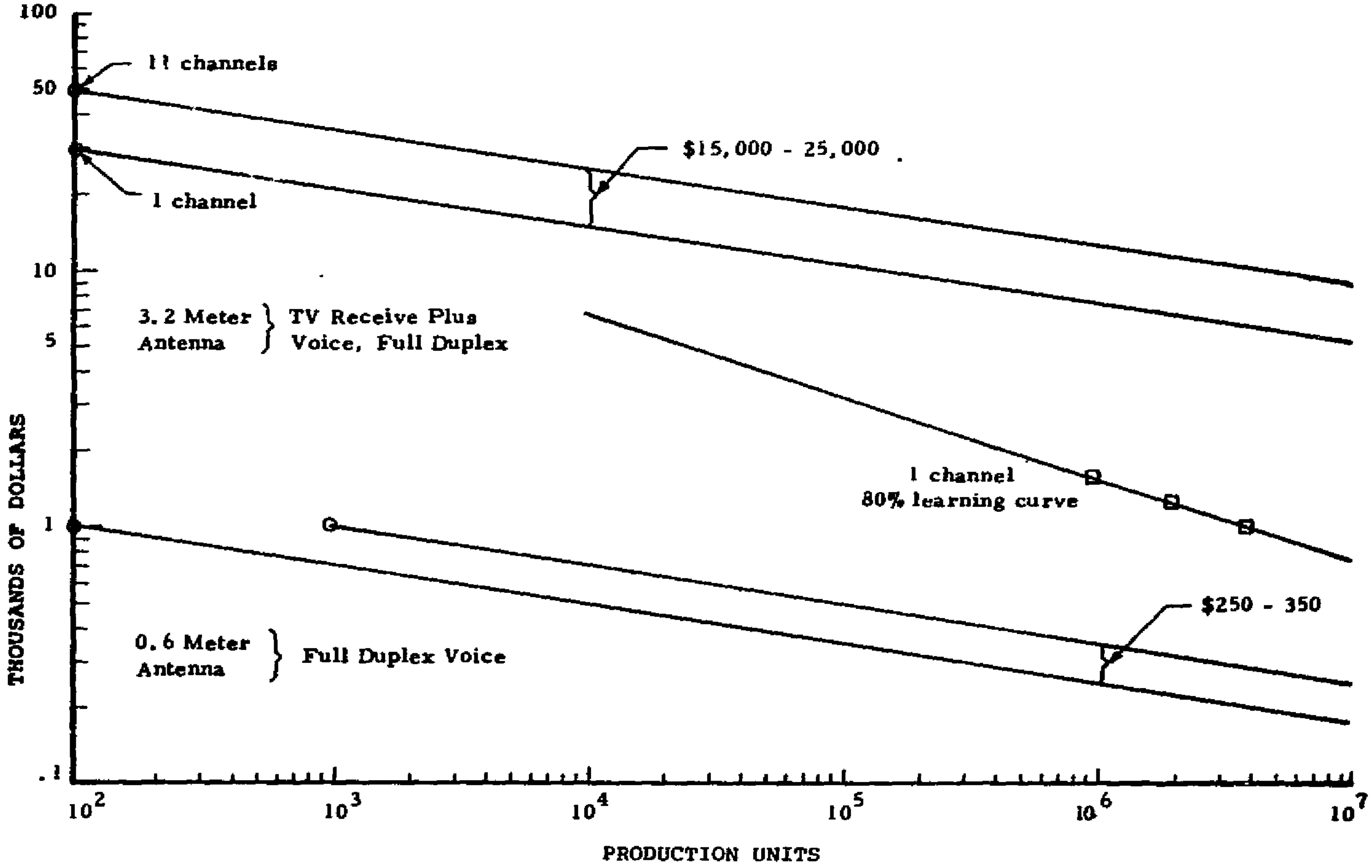

Figure 5.26. Earth Terminal Production Costs with 90% Learning Curves

With cumulative production of 10,000 units, the 10,000th unit would cost approximately $25,000. Assuming a market of 10,000 apartment complexes each with 80 or more apartments units, this price would permit an acceptable rate of return-on-investment at revenue rates competitive with cable TV.

A tunable, one-channel-at-a-time, TV receiver, plus two-way voice, for individual installations, would require production of one-million units on an 80% learning curve to lower the cost of such a unit to $1600. This quantity and cost is a reasonably close match for that portion of the farm market with annual sales of $20,000 or more per year.*

Two-way voice communication using 0.6-meter antenna earth stations at an initial cost of $1000 (as indicated by Figures 5.23 and 5.25 and accompanying discussion) would reach unit costs of $250 to $350 at the one-millionth unit on a 90% learning curve, as shown on Figure 5.26.

Advances in earth station technology will be primarily in the realm of reducing costs coupled with a feedback relationship between expanded use and reduced costs. That is, cost reductions will expand markets which in turn will further reduce costs through quantity production. Antenna technology should develop in the direction of fiberglass and plastic parabolic reflectors and/or alternative antenna configurations for lower-cost earth stations in the 5 to 23 G/T range for direct service to the user. For TV reception, higher performance/lower cost room temperature parametric amplifiers offer alternate routes to meet the requirement for low-cost, low-noise amplifiers. For voice transmission, the technology requirements should be in the direction of major cost

* 1974	Farms with sales of			
	$20K-39K	$40K-99K	$100K +	Total
No. of Farms	588,000	355,000	115,000	1,058,000
Income per Farm	$16K	$26K	$94K	

Source: Statistical Abstract of the United States, 1975.

reductions in solid-state amplifiers or TWT's in the 5 to 20 watt range. Fixed or manually pointed antennas appear essential to achieve the projected cost levels. Technology for all other earth-station components appears to be in-hand at acceptable costs.

5.3 PROJECTION OF COST TRENDS IN SATELLITE COMMUNICATION

In addition to the earth station cost trends presented in Subsection 5.2, cost trends for other major elements of satellite communication systems have been developed. These projections are presented in the following paragraphs.

5.3.1 Projection of Leasing Costs for Wide-Band Transponder Channels

The first of these projections is a learning curve* projection of leasing costs for wide-band transponder channels, as shown in Figure 5.27 and Table 5.21. The data for Intelsat leasing costs offers strong support for a 77% learning curve, which is reasonably consistent with the general experience factor in the electronic industry. Current data for various satellite systems indicates a wide scatter in wide-band transponder leasing costs, reflecting various pricing policies. There is evidence which indicates some cross-subsidization of full transponder costs by charges for primary-line circuits. This may result from the fact that leased-land-line service is currently high enough to provide a pricing margin for satellite transmission which permits a charge

*The data used for total number of wide-band channels is not the cumulative total for all communication satellites launched because of accounting difficulties. Instead, the number of operational channels at each point in time is used as a surrogate for the cumulative total. This surrogate is useful for the purpose of projecting leasing costs since it has a consistent relationship to the cumulative total. The rapid increase in total number of operational channels with passage of time results in the cumulative total being only slightly larger than the total number operational at any time. As long as the incremental increases are reasonably regular, the principle of learning curve cost decrease will apply, and projections may be made with confidence. The rate of cost decrease for the learning curve will be slightly greater, i.e., the percentage figure will be smaller, but the values for cost reduction will be accurately reflected with reference to the total number of operational channels.

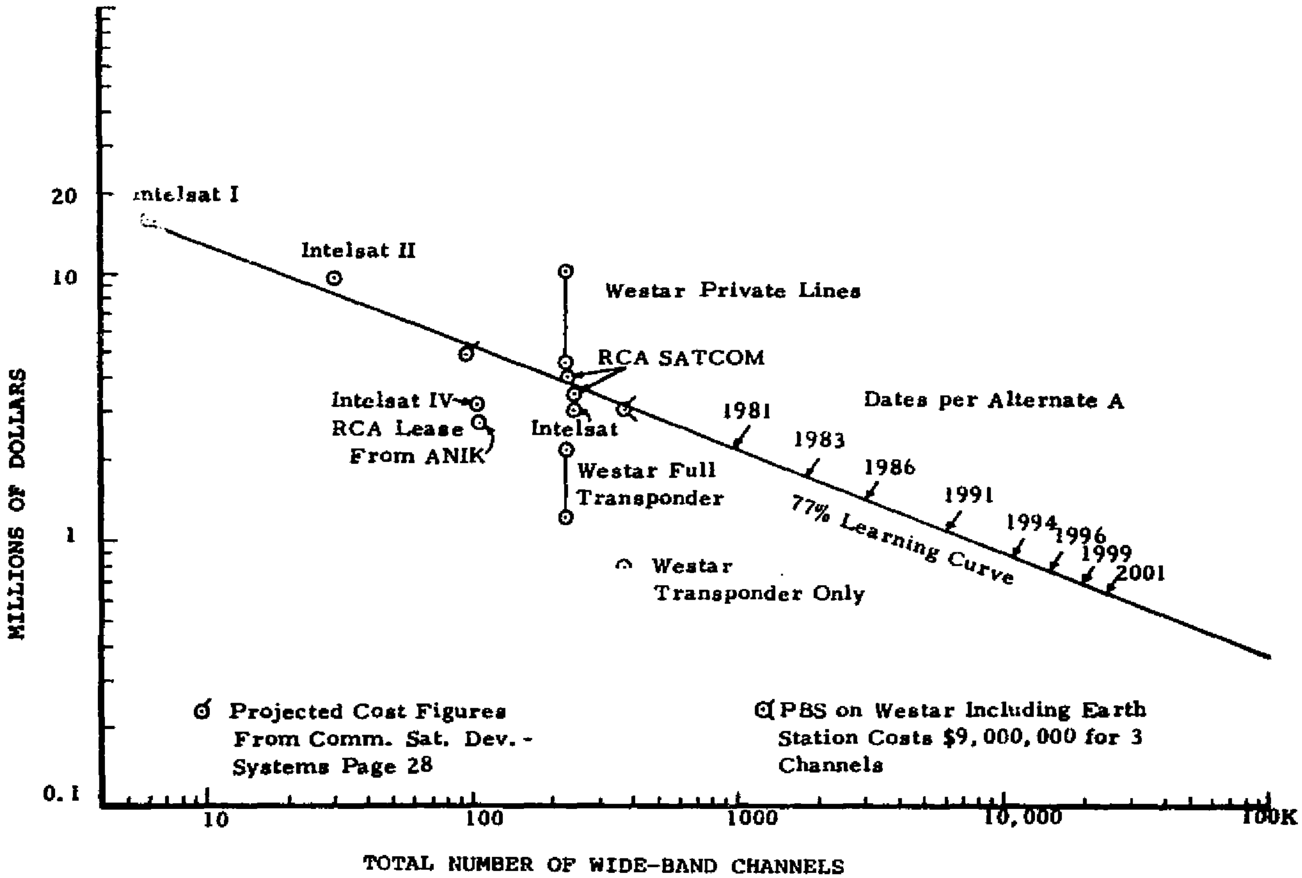

Figure 5.27. Learning Curve Projection of Leasing Cost Per Wide-Band Transponder Channel Versus Number of Operatioal Channels

TABLE 5.21

LEASING COSTS PER WIDE-BAND TRANSPONDER CHANNEL

Year	Total Number of Operational Wide-Band Channels[1]	Leasing Cost Millions of Dollars	Associated Satellite Systems
1965	6	15.8 (2)	Intelsat I
1967-70	15-44	9.6 (2)	Intelsat II and III
1971	74	6.0 (2)	Intelsat III
1972	95	5.2 (2)	Intelsat III and IV
1973	104	4.4 (2)	Intelsat III and IV
1974	104	3.24 (2)	Intelsat IV
1974	104	(2.7) (4)	Anik (RCA Lease)
1975	160	(1.7) (4)	Westar
1975-79	160-260	3.0 (5)	Intelsat
1976	196	1.2-2.17 (6)	Westar
1976	196	3.4-4.1 (7)	RCA SATCOM
1977	224	4.5-10 (8)	Westar
1978	232	3.0 (9) (0.8) (9)	PBS-Westar
1979	260	3.8 (2)	Intelsat

(1) See footnote in text, data taken from Table 5.15

(2) Communication Satellite Developments: Systems, page 27-28

(3) Communication Satellite Developments: Systems, page 276

(4) Frost & Sullivan 221 VIII 32

(5) Aviation Week, July 21, 1975, page 39

(6) K.A. Polcyn, PRC Information Sciences Company

(7) Forecasting International Inc., Draft Report, Table B-18

(8) Dayton Daily News, January 12, 1977, page 27, et al.

(9) Aviation Week, March 8, 1976, page 16

( ) Transponder Only

for satellite leased-line service which exceeds actual costs. The total evidence suggests that the 77% learning curve is conservative, i.e., that leasing costs may decrease at an even greater rate. The costs for transponder lease only, i.e., with earth terminal costs and distribution costs borne by the user, indicate an extremely rapid learning curve. However, the number of data points for full-transponder lease costs is insufficient to support any conclusion in this regard, other than that the transponder costs may constitute a decreasing fraction of the total communication costs.

The learning curve projection may be combined with the projections of total numbers of wide-band channels to give cost projections versus time, as shown in Figure 5.28 and Table 5.22. Most long-range projections of leasing costs have inherently assumed continuing exponential rates of decrease until some point at which the forecaster felt a leveling off would occur. Such forecasts have also tended to ignore the usual relationship between quantitative increase in capacity (with time) and cost reductions, i.e., the learning curve experience factor. As may be noted from Figure 5.28, the current scatter of leasing cost data would make the selection of an accurate exponential rate for leasing cost reduction very problematical. However, by combining the learning curve from Figure 5.27 with the Baseline and Alternate A projections of numbers of wide-band transponder channels, projections of leasing costs can be obtained which appear reasonably consistent with current data and intuitive expectations. These curves, as given in Figure 5.28, indicate a drop in leasing costs per transponder (with associated earth systems) to \$1.3 million by the year 2000 with the marginal increases in satellite size assumed for in the Baseline projection. The larger satellites of Alternate A would result in annual leasing costs decreasing to about \$700,000 per complete wide-band transponder channel by 2000.

One approach to a forecast of leasing costs, using an exponential rate for cost reduction could be the fitting of an

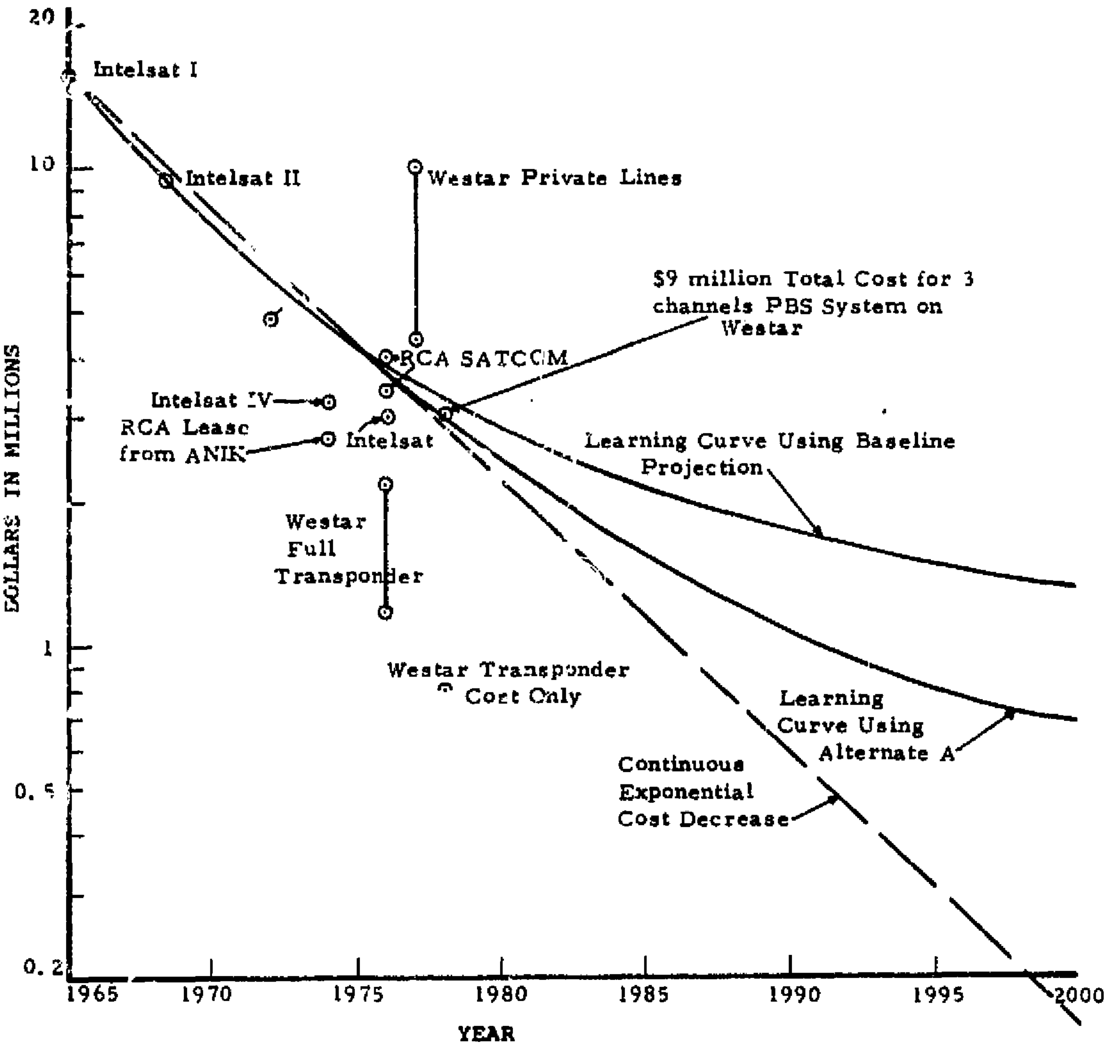

Figure 5.28. Cost per Wide-Band Transponder Channel - Including Associated Earth Systems

TABLE 5.22

WIDE-BAND TRANSPONDER LEASING COSTS VERSUS YEAR

Year	Baseline No. of Channels *	Baseline Cost $M	Alternate A No. of Channels *	Alternate A Cost $M
1965	6	15.8		
1967	15	11.0		
1969	40	7.5		
1971	74	5.8		
1973	104	5.2		
1975	160	4.4		
1977	224	3.8	224	3.8
1980	380	3.2	572	2.7
1985	1130	2.1	2582	1.5
1990	1798	1.7	4972	1.2
1995	2635	1.5	12,217	.83
2000	4050	1.3	21,964	.68

*From Table 5.15

exponential "envelope curve" [13] tangent to the curves of Figure 5.28. Although not plotted on this figure (in order to retain simplicity in the figure), the exponential envelope using the Baseline projection would forecast a leasing cost of $700,000 in 2000, and using the Alternate A projection would give a cost of about $300,000 in 2000.

If the satellite transponder portion of the cost remains at about 40% of the total leasing cost, then for the Baseline case such costs might range from $300,000 to $500,000, and for Alternate A, from $150,000 to $260,000 in the year 2000. These projections are sketched in Figure 5.29 for later comparison with projections of satellite costs.

Combining the projections of leasing costs per wide-band channel with the projections for numbers of channels, projections of total revenues may be obtained, both for the total system and for the satellite portion of the system. These projections are given in Figure 5.30 and Table 5.23. For comparison purposes, it may be noted that projected total system revenues for the year 2000 of $5.27 billion (Baseline) and $14.5 billion (Alternate A) are 20% and 57%, respectively, of the 1973 revenues of the U.S. domestic telephone system ($25.5 billion).

5.3.2 Satellite Segment Cost Projections

Projections of satellite segment costs can be determined on this basis of data available for costs associated with past and present commercial communications satellites. The satellite segment costs are herein defined as the sum of the cost of launching and the cost of the satellite itself. Trend information has been developed for cost-per-unit-mass of the satellite segment for subsequent calculation of cost-per-channel through the year 2000. This determination has been accomplished through the use of trend projections of channels per satellite and mass per satellite developed in Subsection 5.1 of this report.

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[13] Robert U. Ayres, "Technological Forecasting", McGraw-Hill, New York, 1969, pp. 102-105

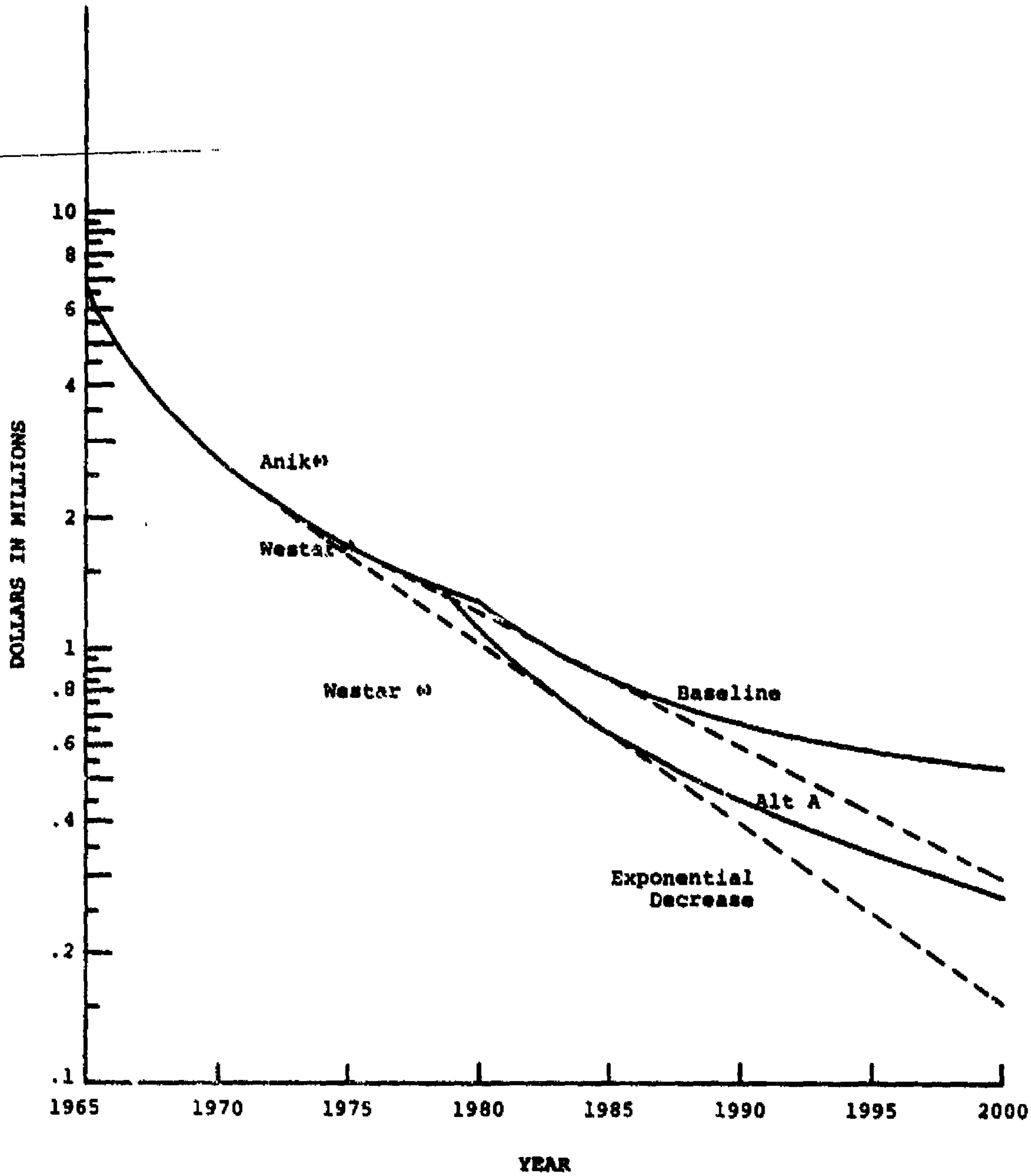

Figure 5.29. Projection of Leasing Costs for Wide-Band Transponder Channels Satellite Portion Only

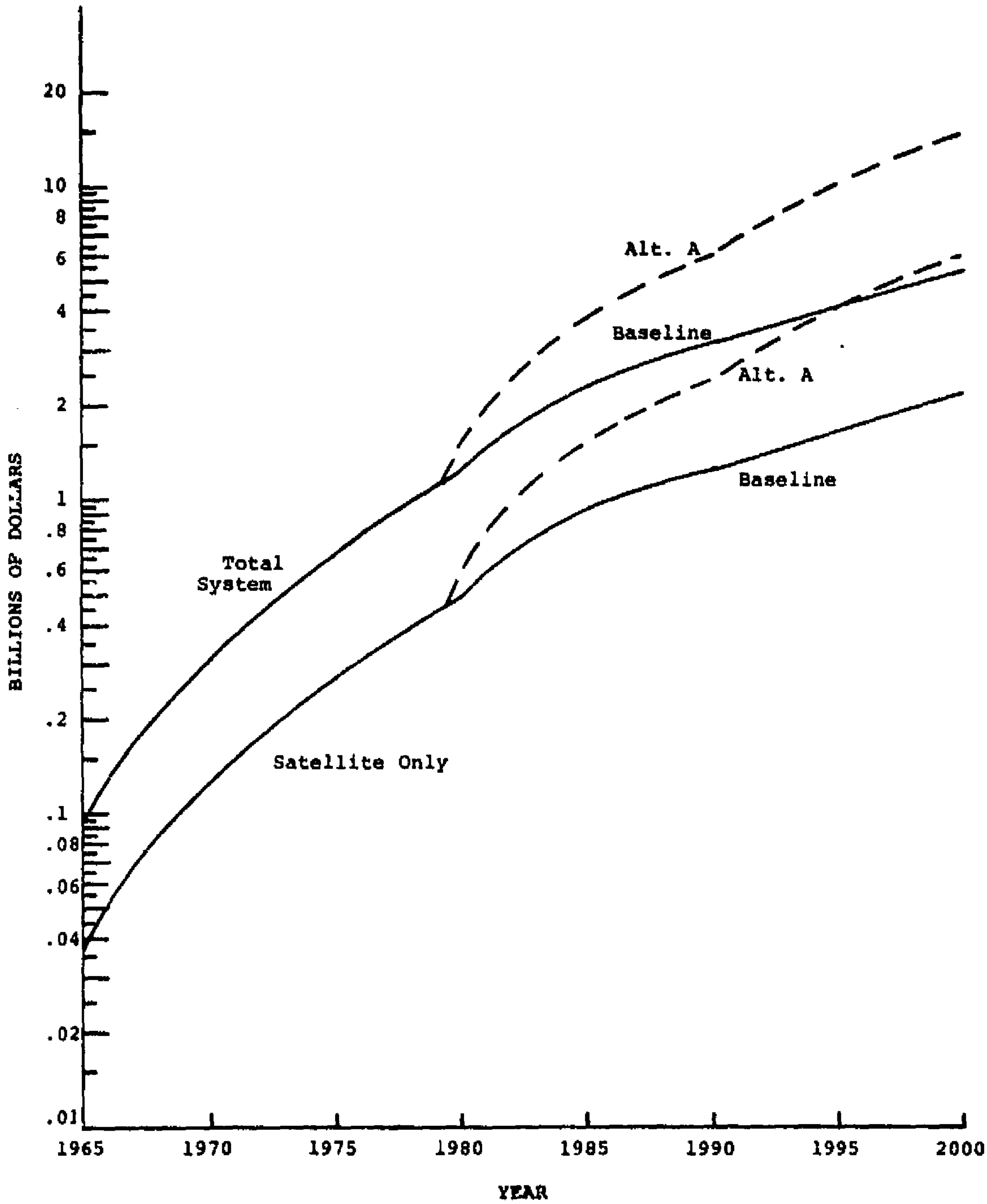

Figure 5.30. Total Annual Revenue from Satellite Communication Systems

TABLE 5.23

TOTAL ANNUAL REVENUE FROM SATELLITE COMMUNICATION SYSTEMS

	Baseline				Alternate A			
			Total Annual Leasing Revenue				Total Annual Leasing Revenue	
Year	No. of Channels	Annual Leasing Revenue Per Channel ($M)	System ($B)	Satellite Only ($B)	No. of Channels	Annual Leasing Revenue Per Channel ($M)	System ($B)	Satellite Only ($B)
1965	6	15.8	.095	.038				
1970	44	6.9	.304	.122				
1975	160	4.4	.704	.282				
1980	380	3.2	1.22	.488	572	2.7	1.54	.616
1985	1130	2.1	2.37	.948	2582	1.5	3.87	1.55
1990	1798	1.7	3.06	1.22	4972	1.2	5.97	2.39
1995	2635	1.5	3.95	1.58	12217	.83	10.14	4.06
2000	4050	1.3	5.27	2.11	21964	.66	14.5	5.80

5.3.2.1 Satellite Segment Costs per Unit Mass Projections

The cost per unit mass data associated with launch and satellite hardware for past, present, and near-future satellites and launch vehicles of the Intelsat series is listed in Table 5.24. To establish a basis for projection of satellite segments costs over the next 25 years with only the limited amount of data available, this cost per unit mass for the commercial satellites were plotted against cumulative communication satellite mass launched (with the cumulative mass being that associated with the year that the first satellite of a given series was launched, see Tables 5.3 and 5.4) as illustrated in Figures 5.31, 5.32, and 5.33, which cover launch costs, satellite costs, and the sum of launch and satellites costs, respectively. A learning curve was fit to each of the three data plots to establish a basis for trend projections to the year 2000.

The data points for launch cost per unit mass versus cumulative communication satellite mass launched, Figure 5.31, can be fit with reasonable agreement with a learning curve of 75%. Such a value compares favorably to learning curves of approximately 80% frequently encountered in the aerospace industry. In a similar manner, a learning curve of 85% was obtained for the cost of the satellite per unit mass (Figure 5.32) and a learning curve of 80% was found to fit reasonably to the sum of launch and satellite costs (Figure 5.33).

The data for launch cost-per-unit-mass for commercial communication satellites is plotted in Figure 5.34, using data points for projected costs obtained from Figure 5.31, to provide launch cost-per-unit-mass trend projections to the year 2000. Two trend lines are presented, one based on the baseline projections and the others for the Alternate A projections (see Subparagraph 5.1.1). Both are derived from the same 75% learning curve of Figure 5.31. The results indicate that the cost-per-unit-mass of the larger Alternate A satellites will decrease at a more rapid rate than the cost-per-unit-mass of the Baseline satellites, with values

TABLE 5.24

INTELSAT SATELLITES: SATELLITE SEGMENT COSTS

Satellite	Launch Vehicle	First Launch of Series (Year)	Satellite Mass (kg)	Launch Cost ($M)	Satellite Cost ($M)	Launch & Satellite Cost ($M)	Wide-Band Channels	Voice Channels	Launch Cost/ Unit Mass ($K/kg)	Satellite Cost/ Unit Mass ($K/kg)	Launch & Satellite Cost/Unit Mass ($K/kg)	V/C (kg)
Intelsat I	Thor-Agena D	1965	40.0[a]	4.4	3.0[b]	7.4[b]	2[a]	240[a]	110.0	75.0	185.0	66
Intelsat II	Thor-Agena D	1966	88.3[a]	4.5	2.7[b]	7.2[b]	2[a]	240[a]	50.9	30.6	81.5	2.7
Intelsat III	Thor-Agena D	1968	154[a]	5.7[a]	6.0[b]	11.7[b]	6[illegible]	1200[a]	37.0	39.0	76.0	7.8
Intelsat IV	Atlas-Centaur	1971	732[a]	20.4	10.0[b]	30.4[b]	12[a]	6000-9000[a]	27.9	13.7	41.6	82 - 12.3
Intelsat IVA	Atlas-Centaur	1975	795[a]	24.9[b]	19.0[b]	43.9	20[a]	14,000	31.3	23.9	55.2	17.6
Intelsat V	Atlas-Centaur	est. 1978	est. 1134-1723[b]		est. 20-35[b]					est. 17.6-20.3		
	Space Shuttle*	est. 1980	454, 998, 2268[b]	7.7, 15.1, 25.9[b]					16.9, 15.1, 11.4			

[a] TRW Space Log Series & Astronautics & Aeronautics, May 1976.

[b] Personal Communication, S. Stevenson, NASA-Lewis

*One 2268 kg satellite @ 25.9 $M/satellite; Two 998 kg satellites per launch @ 15.1 $M/satellite; Four 454 kg satellites per launch @ 7.7 $M/satellite

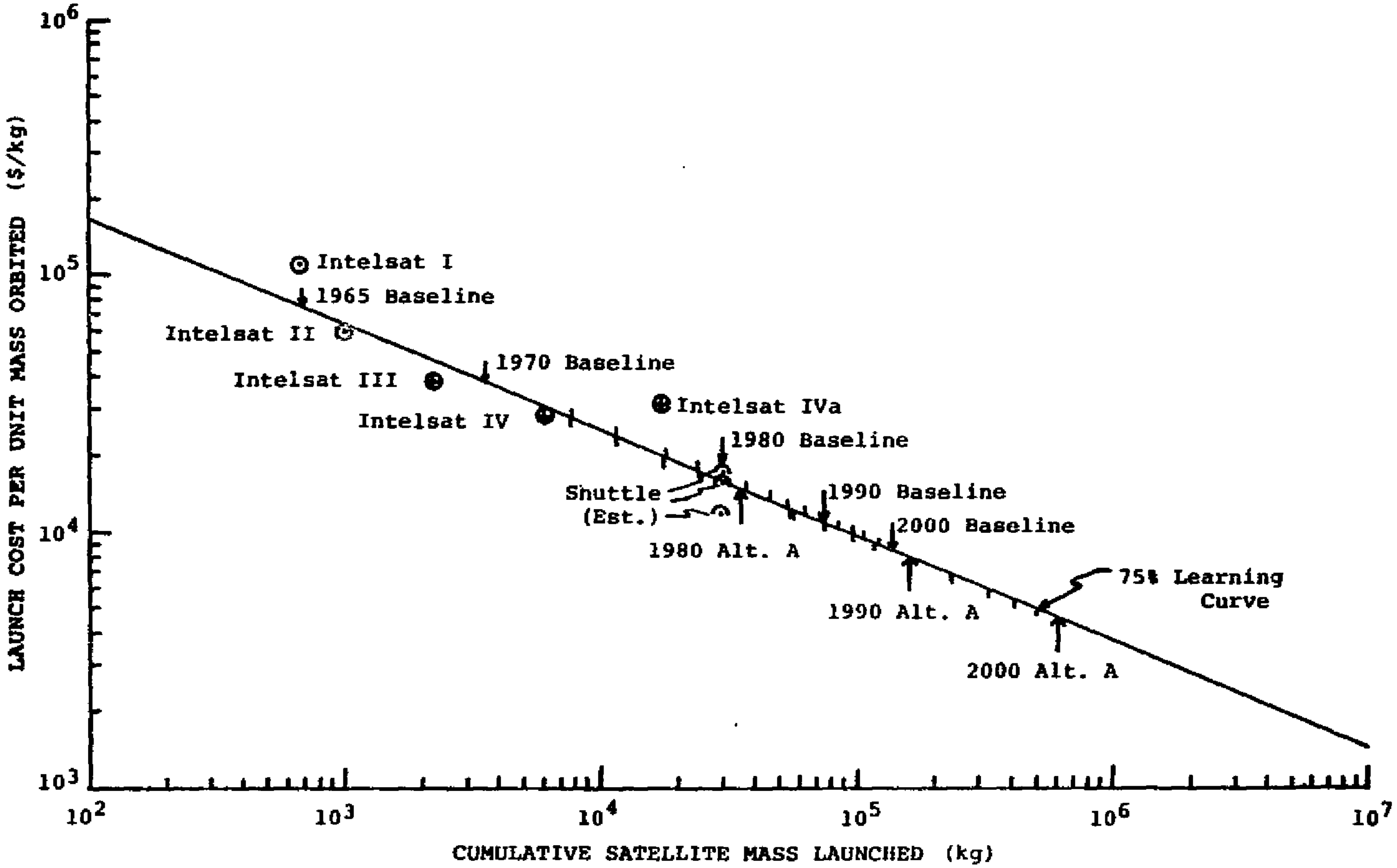

Figure 5.31. Launch Cost per Unit Mass Orbited Versus Cumulative Mass Orbited

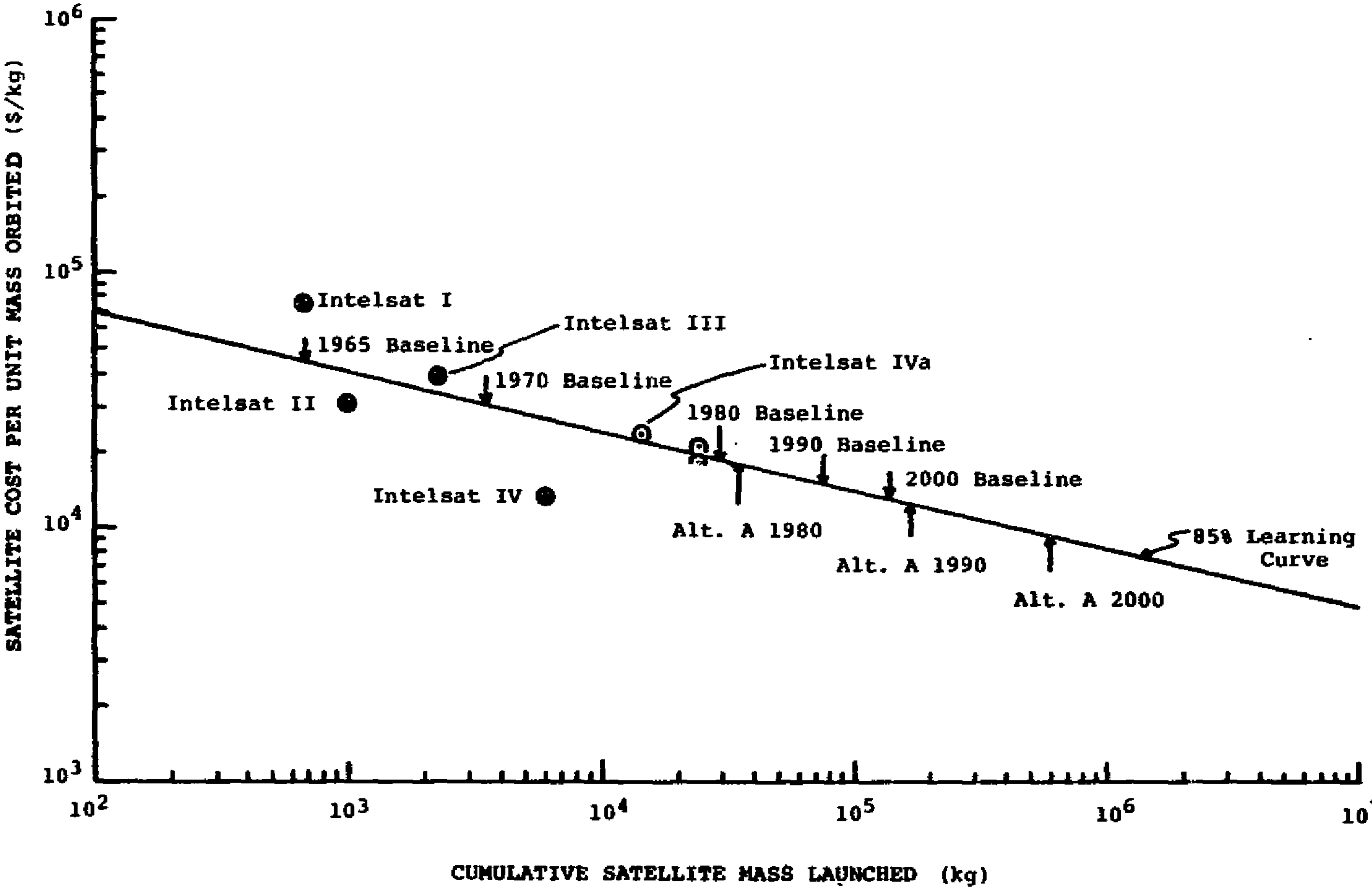

Figure 5.32. Satellite Cost per Unit Mass Orbited Versus Cumulative Mass Orbited

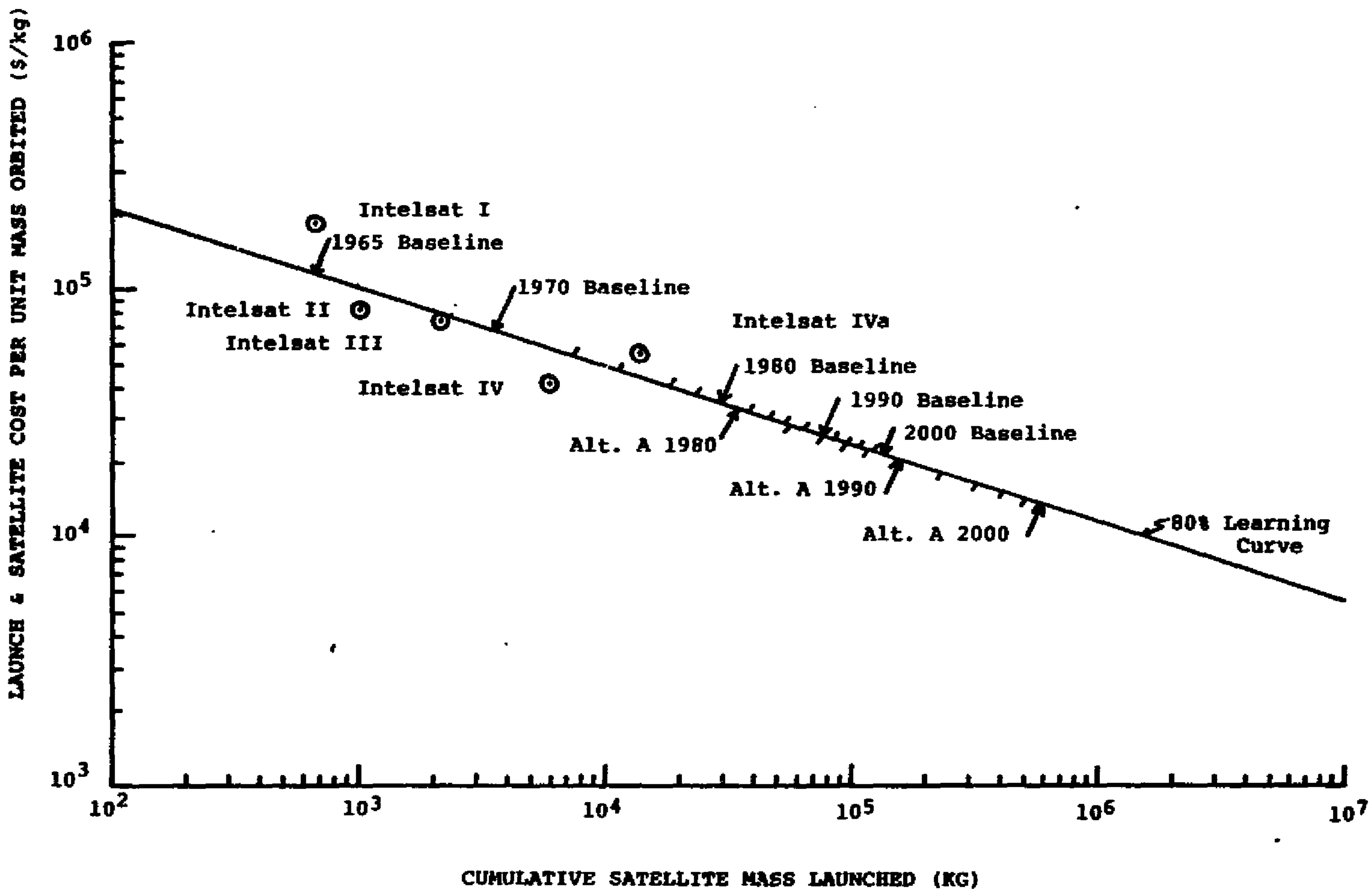

Figure 5.33. Cost of Satellite and Launch per Unit Mass Orbited Versus Cumulative Mass Launched

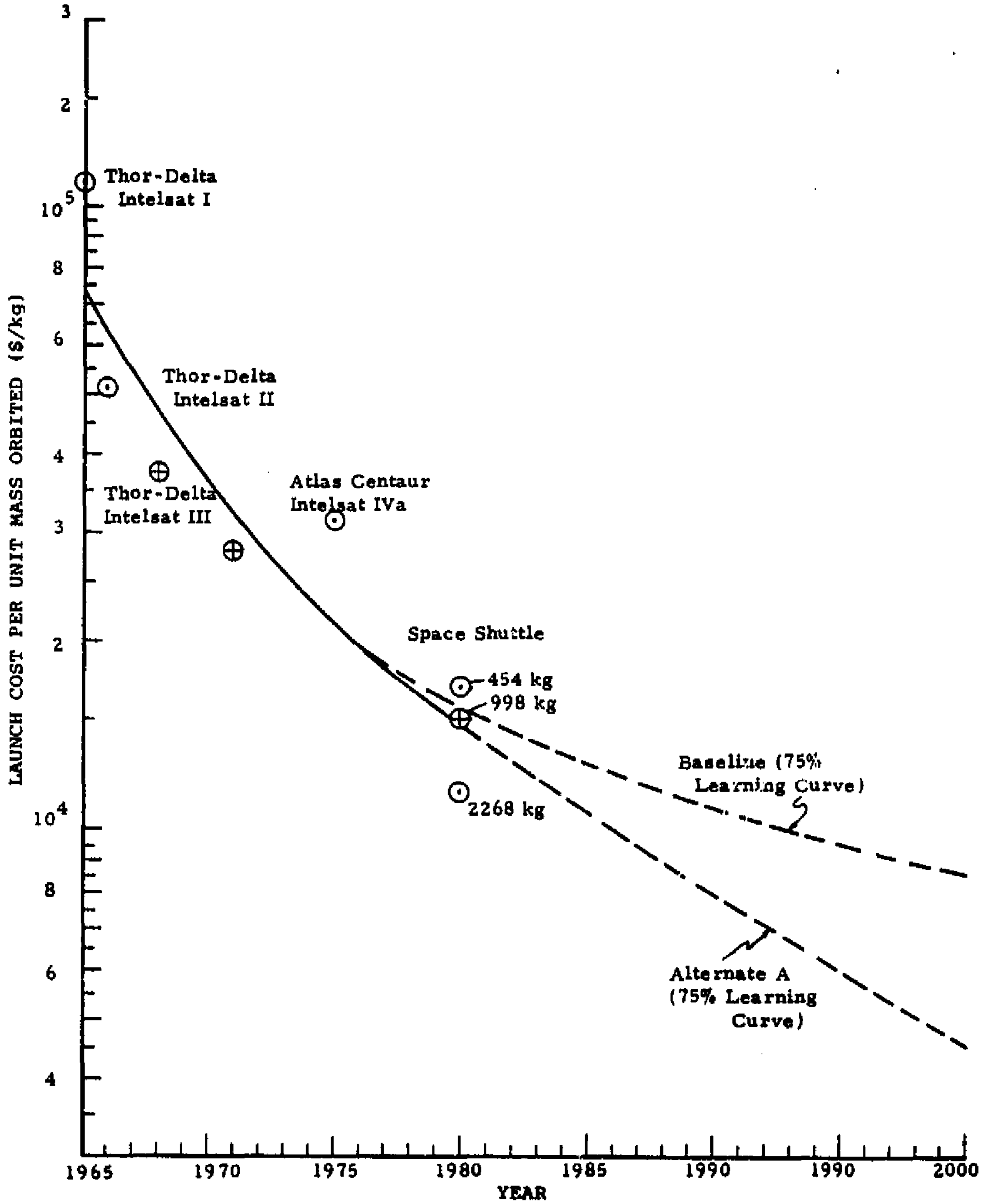

Figure 5.34. Trends for Launch Cost per Unit Mass

$4,500/kg for Alternate A satellites and $8,400/kg for Baseline satellites by the year 2000. Other values are listed in Tables 5.25 and 5.26.

Through a similar approach, the cost-per-unit-mass trends for satellites and for combined launch and satellite were derived and plotted in Figures 5.35 and 5.36. Selected values are listed in Tables 5.25 and 5.26. Baseline projections indicate satellite cost-per-unit-mass values of $13,100/kg for the satellite and $21,500/kg for the combined satellite and launch for the year 2000. Alternate A projections indicate cost-per-unit-mass values of $9,000/kg and $13,600/kg for the year 2000.

5.3.2.2 Wide-Band Channel Costs per Unit Satellite Mass Projections

Having established a projection for satellite segment costs per unit satellite mass, the next step to derive trends for the cost of voice and wide-band channels per unit mass of satellite. Information on trends for the average weight of satellites launched were presented in Subsection 5.1.1 in Figure 5.7 and Table 5.3. Information on the trends for the number of wide-band, wide-beam channels per satellite is presented in Figure 5.17 and Tables 5.13 and 5.14. The trend for communication channels per kilogram of satellite mass was developed by dividing the number of channels per satellite by the average mass per satellite for each year in the projection (see Figure 5.37). The step function nature of the trend lines is due to step function increases in mass and number of channels in 1979-80 and 1989-90 (see Figures 5.7 and 5.17). The slight downward step in Alternates A and B channels/kg in 1989-90 are the result of a projected step increase in mass that exceeds the relative magnitude of the increase in channel capacity. The trends indicate that the Baseline satellite would have a slightly larger number of channels per unit mass than the Alternates A and B satellites through the period 1980 to 2000, with each attaining a peak value in the year 2000. The Baseline satellite, in 2000, would have 48 voice channels per kilogram (0.064 wide-band channels/kg, at 750 voice channels per wide-band channel) and the Alternates A

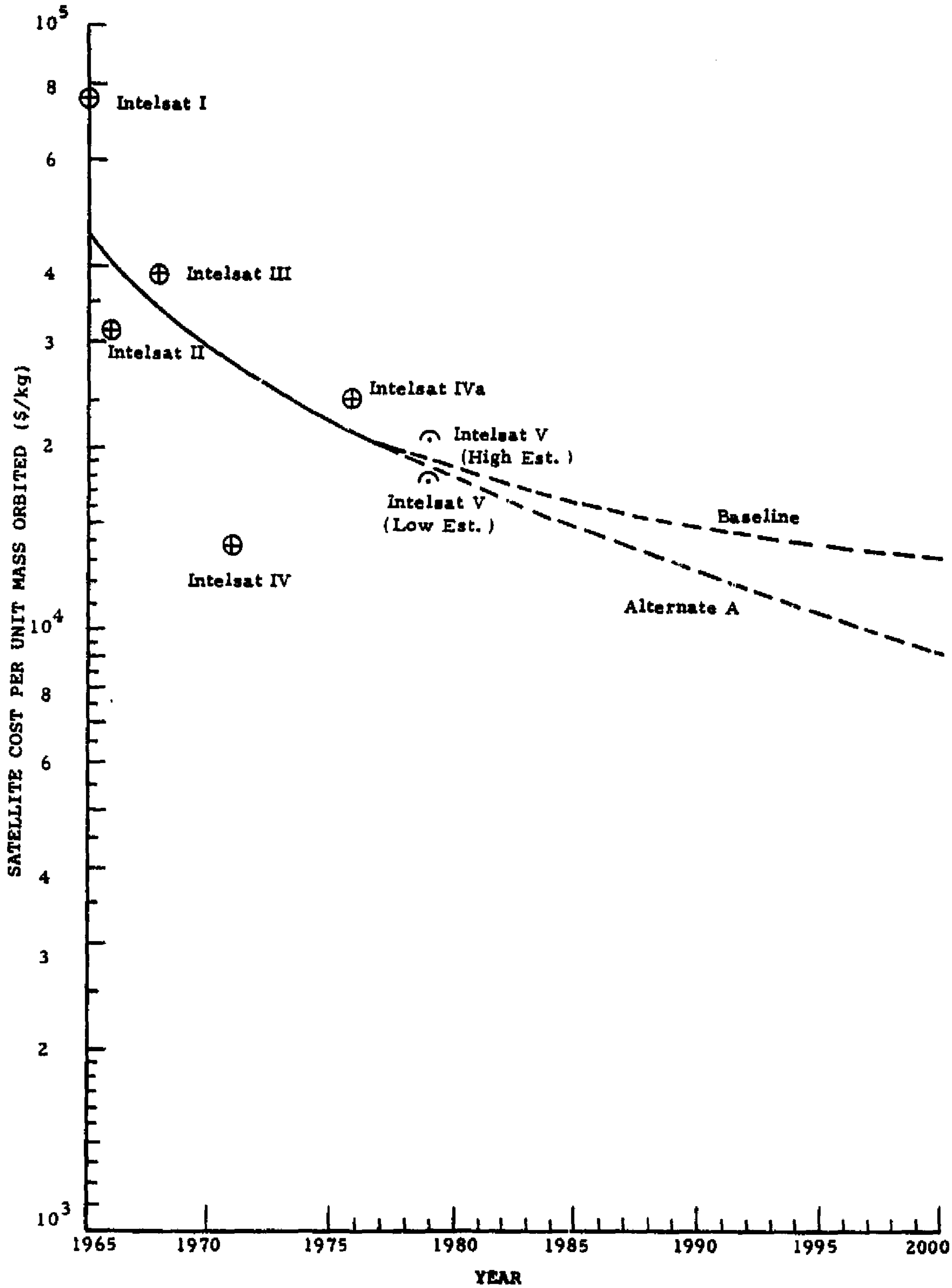

Figure 5.35. Trends for Satellite Cost per Unit Mass

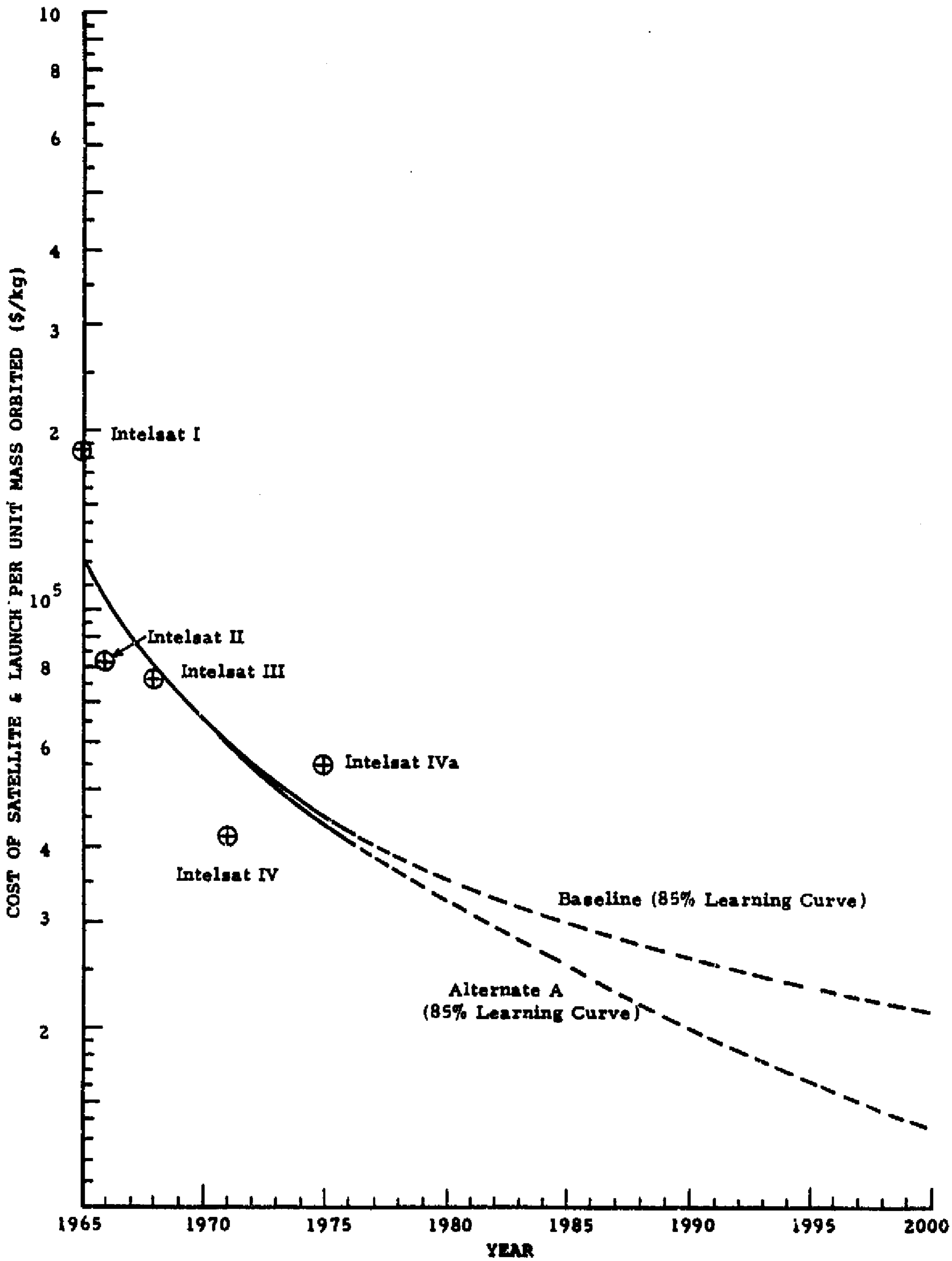

Figure 5.36. Trends for Satellite Plus Launch Cost per Unit Mass

TABLE 5.25

BASELINE SATELLITE COST TREND PROJECTIONS

Year	Satellite Average Weight Launched (kg) Baseline	(kg) Alt. A&B	Cost Per Unit Mass: Launch ($K/kg)	Satellite ($K/kg)	Launch & Satellite ($K/kg)	Cost Per Satellite Launched: Launch ($M)	Satellite ($M)	Launch & Satellite ($M)
1965	104		75	45	120	7.8	4.7	12.5
	116		63	41.0	104			
			54.5	37.0	91.5			
			47.5	34.0	81.5			
			4 .5	31.1	72.6			
1970	350		36.5	29.0	65.5	12.8	10.1	22.9
			32.2	27.1	59.3			
			28.6	25.6	54.2			
	590		26.0	24.4	50.4	15.3	14.4	29.7
	670		23.2	23.0	46.2	15.5	15.4	30.9
1975	720		21.2	22.0	43.2	15.3	15.8	31.1
	740	740	19.8	21.1	40.6	14.7	15.9	30.6
	755	755	18.8	20.4	39.2	14.2	15.4	29.6
	765	765						
	775	775						
1980	785	2000	16.0	18.6	34.6	12.6	14.6	27.2
	795	2000						
	800	2000						
	805	2000						
	810	2000						
1985	815	2000	12.8	16.5	29.3	10.4	13.4	23.8
	820	2000						
	825	2000						
	830	2000						
	835	2000						
1990	840	6000	11.0	14.8	25.8	9.2	12.5	21.7
	845	6000						
	850	6000						
	855	6000						
	860	6000						
1995	865	6000	9.5	14.0	23.5	8.2	12.1	20.3
	870	6000						
	875	6000						
	880	6000						
	885	6000						
2000	890	6000	8.4	13.1	21.5	7.5	11.6	19.1

TABLE 5.26

ALTERNATE A SATELLITE SEGMENT COST TREND PROJECTION

Year	Satellite Average Weight Launched (kg) Baseline	(kg) Alt.' A&B	Cost Per Unit Mass: Launch ($K/kg)	Satellite ($K/kg)	Launch & Satellite ($K/kg)	Cost Per Satellite Launched: Launch ($M)	Satellite ($M)	Launch & Satellite ($M)
1965	104		75	45	120	7.8	4.7	12.5
	116		63	41.0	104			
			54.5	37.0	91.5			
			47.5	34.0	81.5			
			41.5	31.1	72.6			
1970	350		36.5	29.0	65.5	12.8	10.1	22.9
			32.2	27.1	59.3			
			28.6	25.6	54.2			
	590		26.0	24.4	50.4	15.3	14.4	29.7
	670		23.2	23.0	46.2	15.5	15.4	30.9
1975	720		21.2	22.0	43.2	15.3	15.8	31.1
	740	740	19.5	21.1	40.6	14.4	15.6	30.0
	755	755	17.9	20.1	38.0	13.5	15.2	28.7
	765	765	16.6	19.2	35.8	12.7	14.7	27.4
	775	775	15.6	18.6	34.2	12.1	14.4	26.5
1980	785	2000	14.7	17.9	32.6	29.4	35.8	65.2
	795	2000						
	800	2000						
	805	2000						
	810	2000						
1985	815	2000	10.6	14.8	25.4	21.2	29.6	50.8
	820	2000						
	825	2000						
	830	2000						
	835	2000						
1990	840	6000	8.0	12.5	20.5	48.0	15.0	123.0
	845	6000						
	850	6000						
	855	6000						
	860	6000						
1995	865	6000	5.9	10.7	16.6	35.4	64.2	99.6
	870	6000						
	875	6000						
	880	6000						
	885	6000						
2000	890	6000	4.50	9.1	13.6	27.0	54.6	81.6

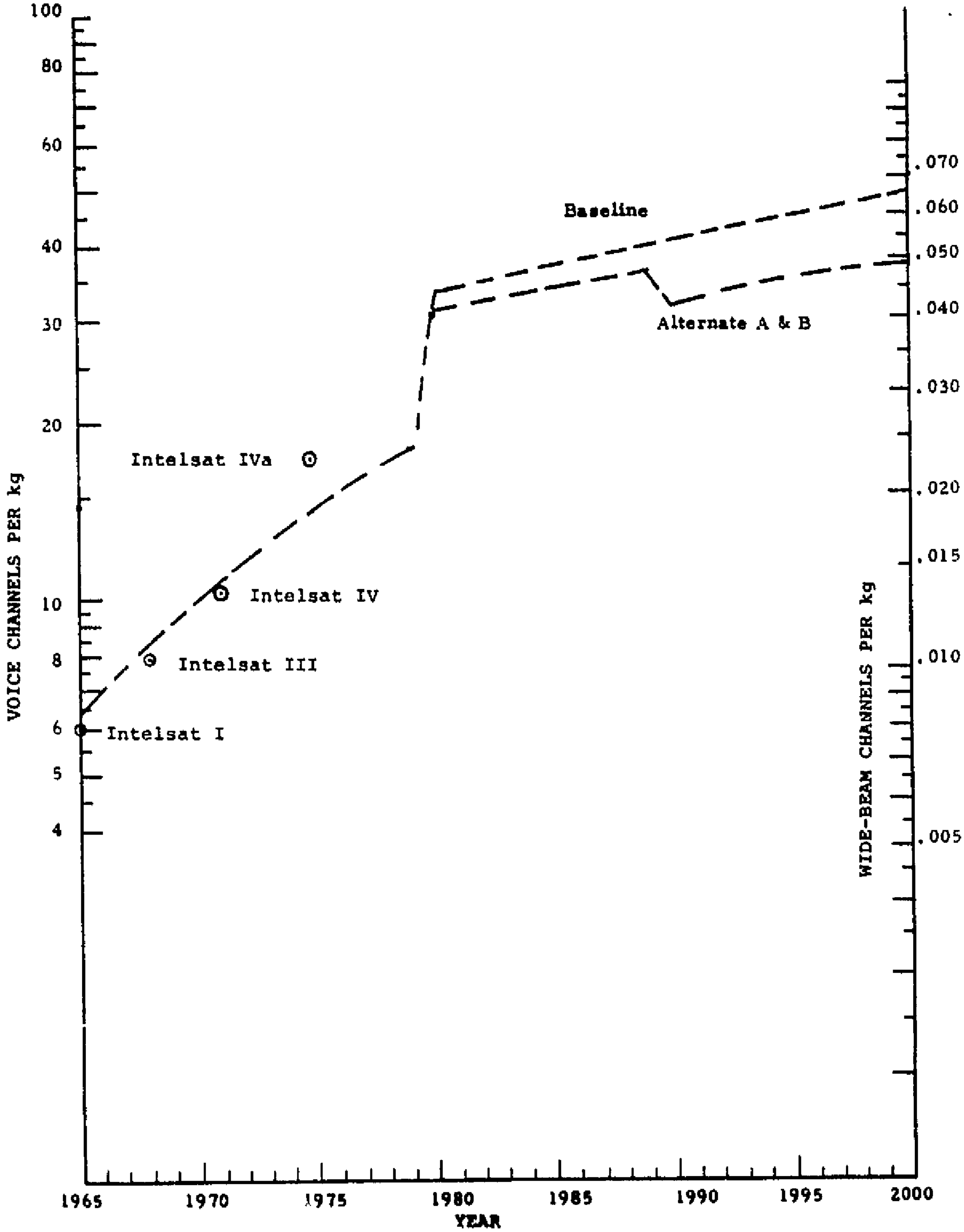

Figure 5.37. Trend for Communication Channels per Unit Satellite Mass

and B satellites would have 37 voice channels per kilogram (0.049 wide-band channels/kg). Such a projection follows from the projection that the larger satellites will have a higher nonpayload weight fraction (see Subparagraph 5.1.2.2).

Having determined the number of channels per kilogram (Figure 5.37) and the combined cost of satellite and launch per kilogram (Figure 5.36), a trend projection of the cost per channel for both Baseline and Alternates A and B satellites can be obtained. The cost trends are plotted in Figure 5.38 include cost per coice channel and cost per wide-band channel. The projections indicate that the cost per voice channel for Baseline satellite in the year 2000 would be \$500/kg and that for Alternates A and B satellites would be \$365/kg. Alternates A and B costs-per-channel for the 1980 to 2000 time period are slightly lower than those for the Baseline satellite because the cost-per-unit-mass advantage (Figure 5.36) outweighs the disadvantages of lower values of channels per unit mass (Figure 5.37).

5.3.2.3 Satellite Segment Cost Projections Summary

To summarize the satellite segment cost trend analyses, the cost per satellite for launch, satellite only, and combined launch and satellite costs were determined on a per-satellite trends of Subparagraph 5.1.1 which were based on a larger number of communications satellites drawn from military as well as commercial series (Figure 5.7 and Table 5.2). In general, the broader series of satellites demonstrated a shallower rate-of-growth in mass during the 1965 to 1975 time period than did the Intelsat series. Thus, when combined with the rate of growth of cost-per-unit-mass of satellites based on the Intelsat series, the relative rate of cost growth for the years 1965 to 1974 depicted by the smooth curves in Figures 5.39, 5.40, and 5.41 appears shallower than that implied by the Intelsat data points.

The step-function nature of the trend lines at the 1979-80 and 1989-90 follow from the step-function nature of the manner in which such satellites have been projected to be placed

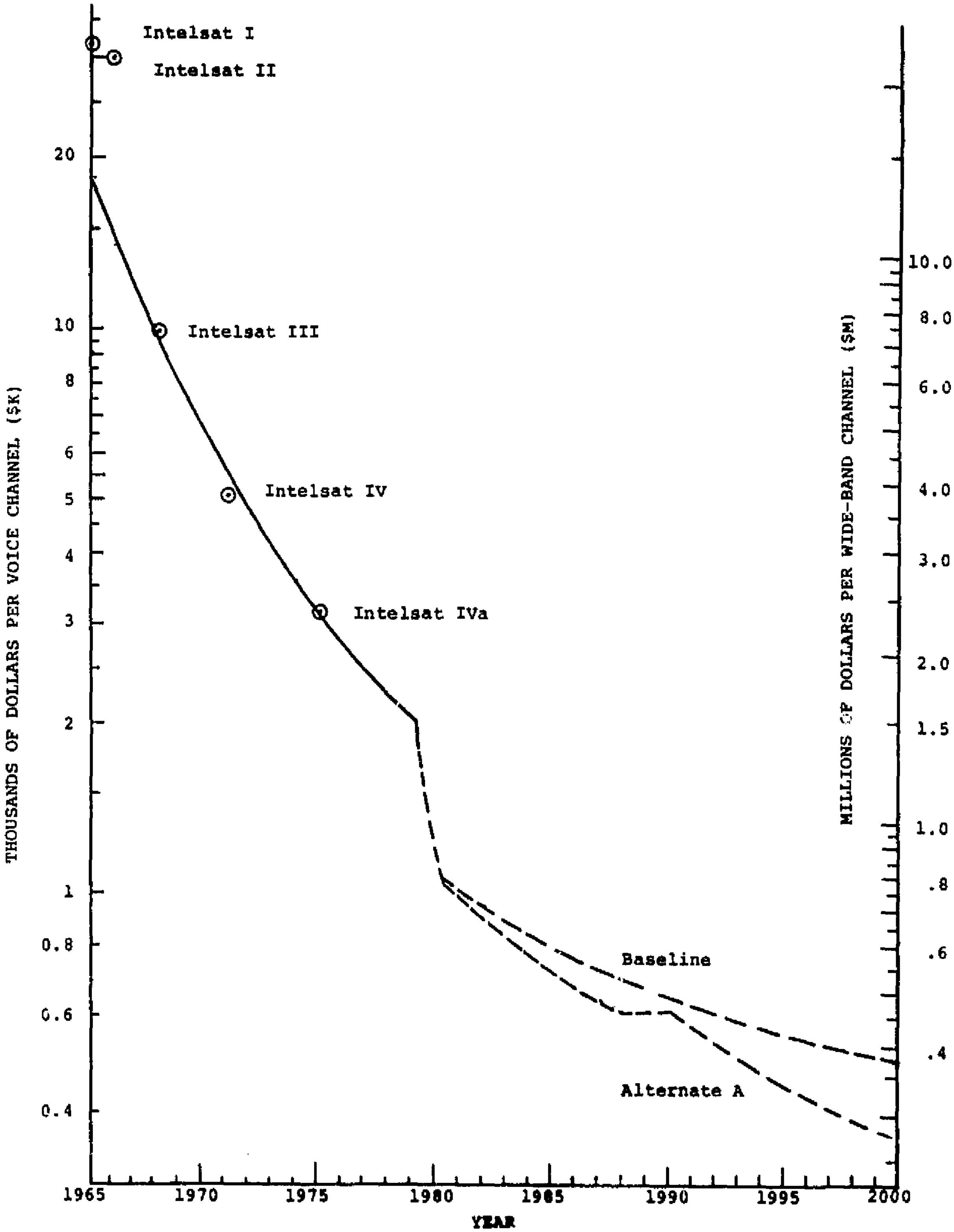

Figure 5.38. Satellite Segment Costs per Channel

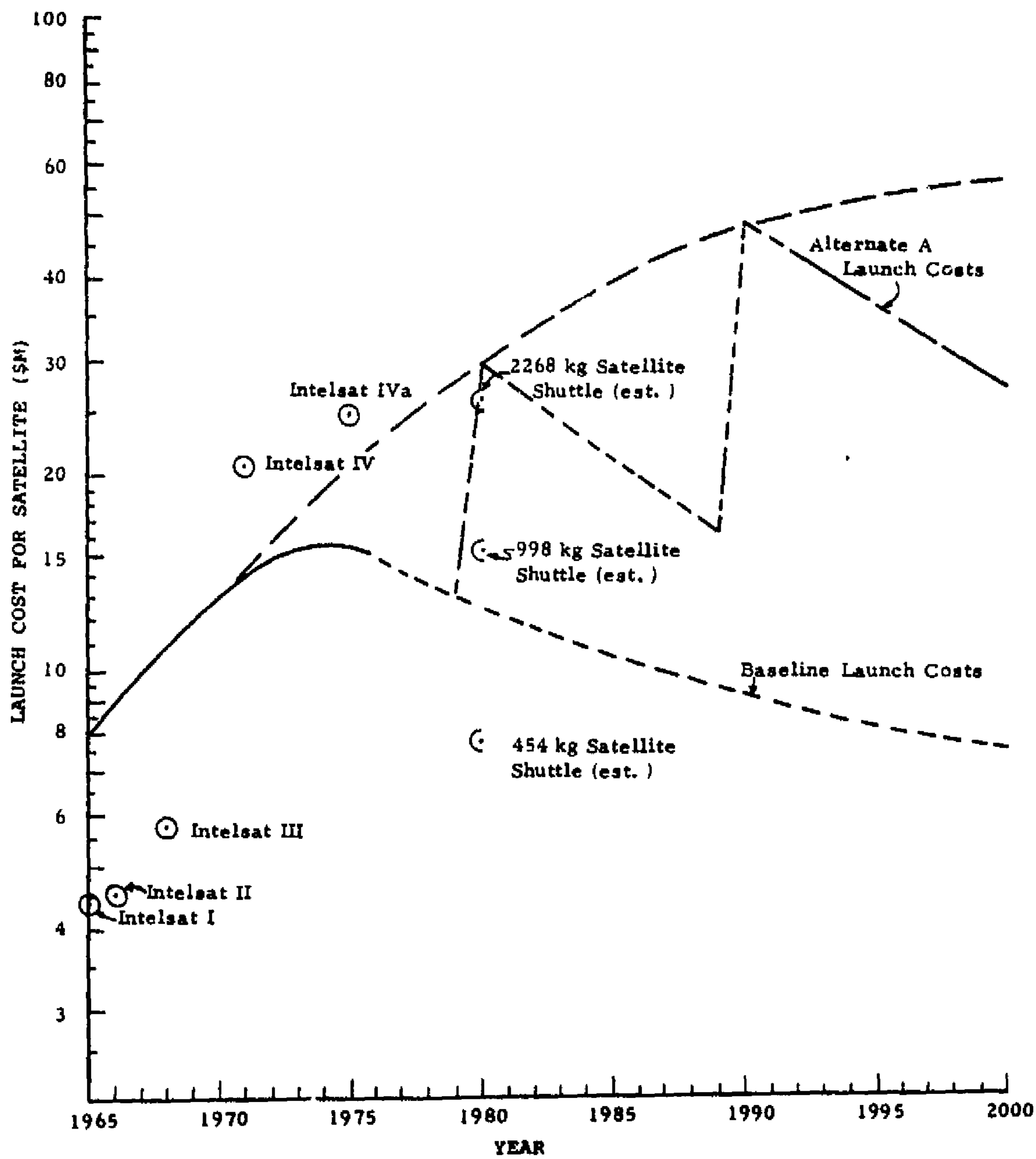

Figure 5.39. Trend of Launch Costs per Satellite

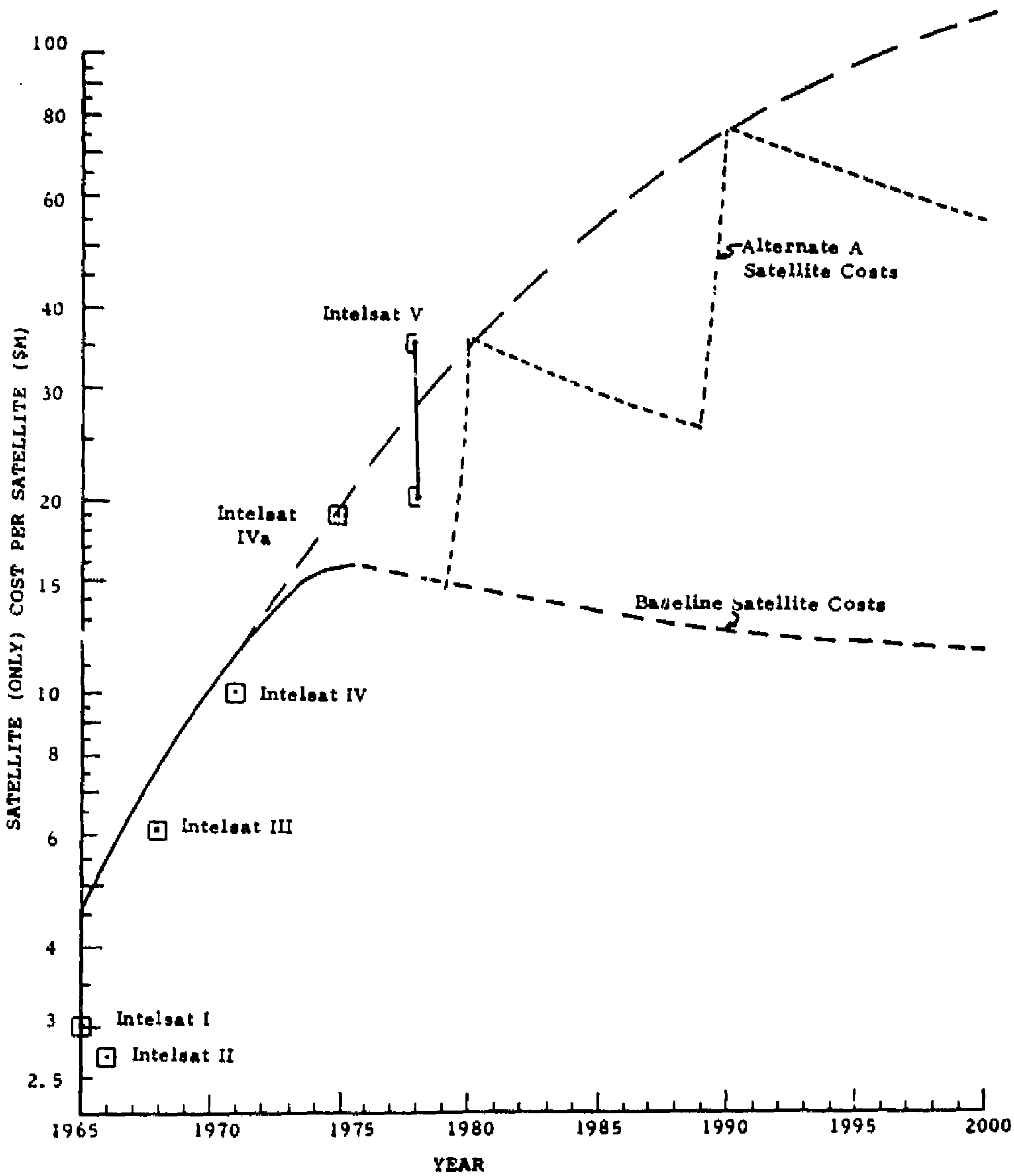

Figure 5.40. Trend of Satellite Costs (Satellite Only)

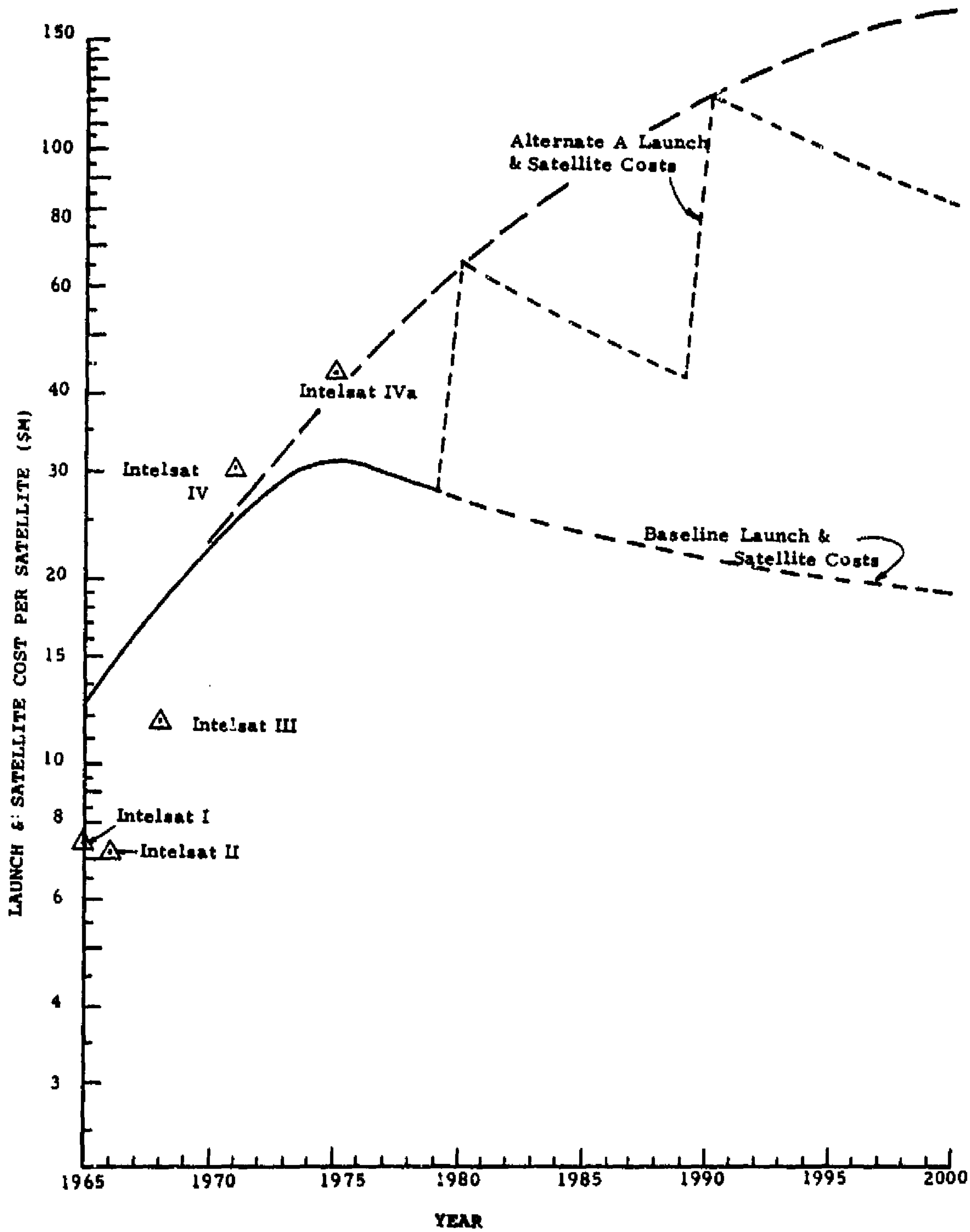

Figure 5.41. Trend of Total Cost of Launch and Satellite per Satellite

in operation. The first series of the larger Alternates A and B satellites which were projected for introduction in the 1980 to 1989 time period were forecast to have a constant mass of 2000 kg over that period. Then, in 1990, larger 6000 kg Alternates A and B satellites were projected for introduction and were forecast to be continued in use at that size through the year 2000 (see Table 5.4 of Subparagraph 5.1.1). An envelope curve can be fit to the maximum value points for the step function. It is reasonable to expect that, should a different sequence of step-functions occur, but still in the trend pattern for mass growth projected for Alternates A and B satellites, the peak-points would still fall on the envelope curve. Indeed, it would appear that costs for Intelsat IV, IVa, and V satellites fall close to the envelope curve.

5.3.3 Correlation Analysis of Leasing Cost and Satellite Segment Cost Projection

The independently derived projections of satellite investment costs (satellite plus launch costs) and leasing costs per wide-band channel in the preceding paragraphs may be combined to give a cross-check for internal consistency in the following manner. The projected investment costs from Figure 5.38 for the Baseline Case and for Alternate A are sufficiently close that a mean line between the two should give a reasonable value for investment cost per channel. This mean line would begin at $750,000 per channel in 1980, decreasing at 4.5% per annum to $300,000 in the year 2000, as shown on Figure 5.38. Assuming the satellite lifetimes previously projected of 7 years in 1980, increasing by 2 years in every 5, to 15 years in 2000, and providing for an average annual return-on-investment of 30%, the total cash flow required per channel may be projected. The "present value" of the cash flow at time of launch may be determined by discounting at the rate of 9% per year over the lifetime of the satellite. The 9% rate is approximately equal to recent "prime rates" for corporate borrowing. This total discounted cash flow required per channel at the time of launch is shown by the upper curve of Figure 5.42. For example, a satellite launched in 1985 is projected to cost $600,000 per channel in orbit.

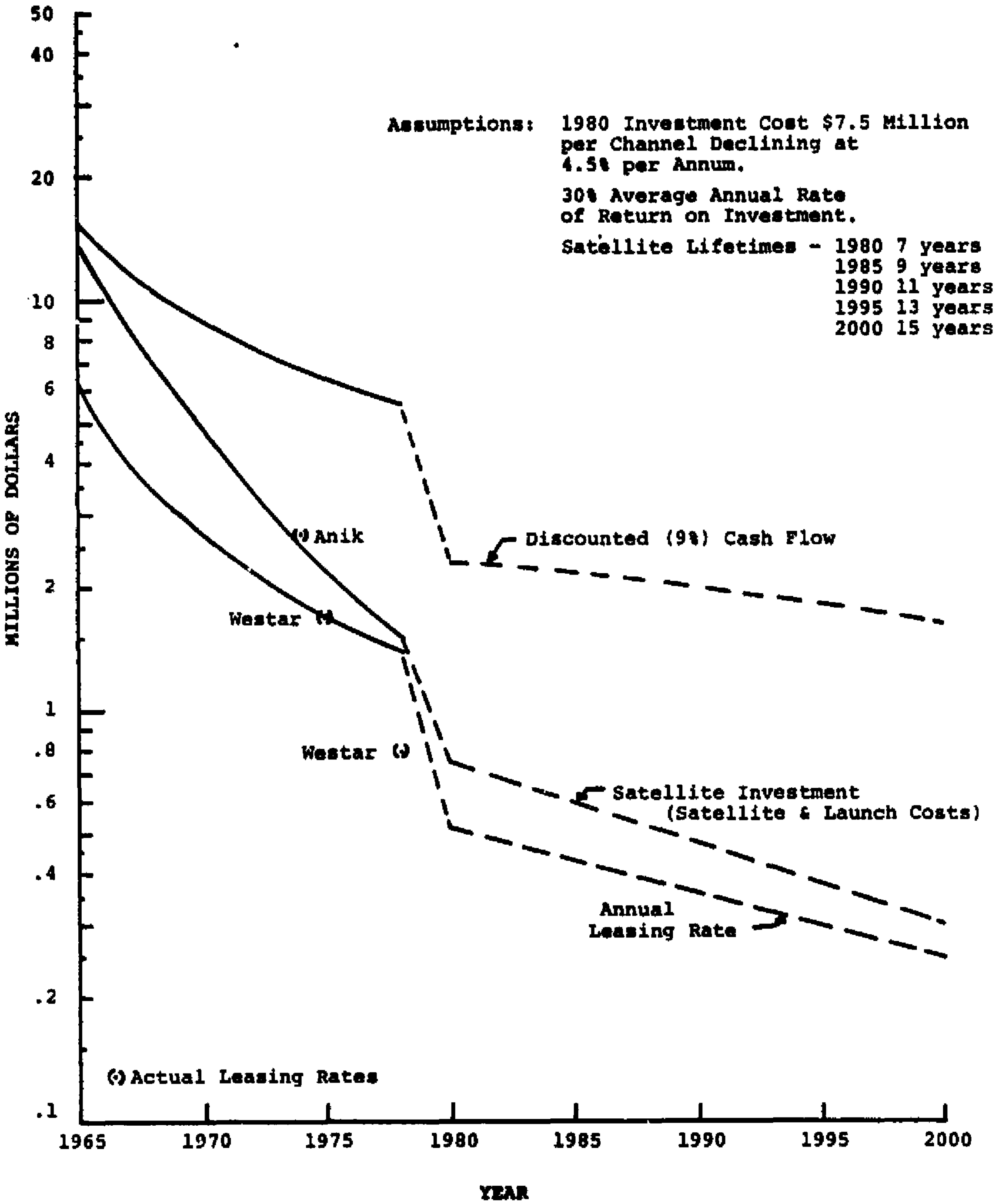

Figure 5.42. Projection of Annual Leasing Rates per Wide-Band Channel - 1980 to 2000

The total discounted cash flow per channel from this satellite during its 9-year lifetime would have to be $2.2 million to provide a 30% average annual rate-of-return.

Next, projecting a 3.2% decline per year in leasing rates (consistent with the reduction in subsequent satellite investment costs), the annual leasing rates required to provide this cash flow may be determined. These leasing rates are shown by the lower curve of Figure 5.42. For example, a satellite launched in 1985 would require an initial annual leasing rate of $430,000, declining to $340,000 in the last year of its 9-year life, to provide the $2,200,000 discounted cash flow for a 30% rate of return. If newer satellites should be introduced during the 9-year lifetime, at lower investment costs than projected in Figure 5.42, the net result would be to reduce the rate-of-return for the older satellites.

It should be noted that any satellite-associated costs incurred on earth, such as monitoring satellite performance and positioning and costs of marketing and managing satellite channel leasing must be deducted from the 30% gross margin discussed above. Since actual margins and pricing decisions are determined by a number of factors, including detailed risk analysis, it is not implied that the data in Figure 5.42, and this discussion, are indicators of the precise relationships which will exist between leasing rates, investment costs, and financial returns. Rather, as stated at the beginning of this discussion, the intent is to show that the independently derived forecasts of leasing rates and satellite investment are consistent with each other in the "real-world" market sense. The leasing rates projected in Figure 5.42 are higher in 1980 for both the Baseline Case and Alternate A than required for a 30% rate-of-return. Therefore, these rates may be considered conservative, allowing a margin either for satellite costs greater than projected in Figure 5.42, or a reduction in leasing rates to the values shown in Figure 5.42. By the end of the century, both the exponential envelopes for leasing rates in the Baseline Case and the projected curve for Alternate A are close to the 30% rate-of-return, and represent consistent real-world expectations. Data associated with the preceding discussion is presented in Tables 5.27, 5.28, 5.29, and 5.30.

The connection between satellite investment costs and leasing rates in forecasts must be emphasized. If other projections indicate a lesser rate of satellite cost reduction (or lesser capability per satellite), then annual leasing costs must also come down more slowly. On the other hand, given effective competition in this area, greater reductions in satellite costs should result in correspondingly greater decreases in annual leasing rates.

Some overall comparisons may be made to indicate the consistency of this data with similar calculations for other areas. The Alternate A satellite in 1985 with 193 wide-band channels would cost $104 million dollars (in orbit) and at an initial annual leasing rate of $570,000 per channel would generate a discounted cash flow of $560 million during its lifetime of 9 years, giving a 49% rate-of-return. In comparison, a 747 airplane at an average passenger-mile rate of 10¢, and 240 million annual passenger miles produces a total revenue of $24 million of which $16 million is required for operating expenses, giving a gross return of $8 million annually, for a discounted cash flow of approximately $60 million over a 20-year lifetime. A purchase cost of $30 million for the 747 airplane would produce a 5% rate-of-return. Increasing the average load factor from 50% to 70% would provide an 18% rate-of-return. This comparison would appear to indicate that the projected leasing rates for satellite channels are conservatively high, if the total satellite channel capacity is utilized. In any event, the projections of leasing rates and satellite costs appear to produce results of the correct order-of-magnitude and relationship in comparison with the air transport example. Total annual revenue from satellite leasing may be compared with other communication media revenues for an order-of-magnitude comparison. The projected Alternate A 2582 wide-band channels in 1985, at an annual leasing rate of $430,000, would give a total annual revenue of $1.11 billion. This compares with 1974 gross revenues of $12.8 billion for

TABLE 5.27

INTERNALLY CONSISTENT PROJECTION OF LEASING RATES VERSUS INVESTMENT PER WIDE-BAND CHANNELS

Year	Satellite Life Time (t) Yrs	Invest.[1] Cost/ Channel in Year of Launch $ M	$1 + r \times t$[2]	Total Rev.[3]	Leasing[4] Rate at Beginning of Years of Launch $ M
1980	7	0.75	3.1	2.33	0.52
1985	9	0.60	3.7	2.22	0.43
1990	11	0.475	4.3	2.04	0.36
1995	13	0.38	4.9	1.86	0.30
2000	15	0.30	5.5	1.65	0.25

(1) Exponential decline in leasing rate, at rate between Baseline and Alternate A, starting at $750,000 in 1980, and declining at rate of 4.5% per year.

(2) r = rate of return, 30% per year

(3) Total Revenue = Investment x (1 + r x t)

(4) Leasing Revenue = $\sum$ Leasing $\text{Rate}_i \times 0.91^i$

i = years following launch,
i in year of launch = 1
0.91 represents cash flow discounted at rate of 9% per year, compounded annually.

TABLE 5.28

LEASING REVENUE CALCULATIONS FOR TABLE 5.27

Year	Leasing[1] Rate $M	Leasing Revenue[2] 1980	1985	1990	1995	2000[3]
1980	.52	.47				
1981	.50	.42				
1982	.49	.37				
1983	.47	.32				
1984	.45	.28				
1985	.43	.25	.39			
1986	.42	.21	.35			
1987	.40	Σ = 2.33	.30			
1988	.39		.27			
1989	.37		.23			
1990	.36		.21	.33		
1991	.35		.18	.29		
1992	.33		.16	.25		
1993	.32		.14	.22		
1994	.31		Σ = 2.23	.19		
1995	.30			.17	.27	
1996	.29			.15	.24	
1997	.28			.13	.21	
1998	.27			.12	.19	
1999	.26			.10	.16	
2000	.25			.088	.14	.23
2001	.24			Σ = 2.04	.12	.20
2002	.23				.11	.17
2003	.22				.095	.15
2004	.21				.082	.13
2005	.21				.074	.12
2006	.20				.064	.10
2007	.19				.055	.089
2008	.19				Σ = 1.81	.082
2009	.18					.070
2010	.17					.060
2011	.17					.054
2012	.16					.046
2013	.16					.043
2014	.15					.036
						Σ = 1.58

(1) Leasing Rate at beginning of year.

(2) Leasing Revenue per year on basis of rate at beginning of year, discounted at rate of 9% per year, compounded annually from date of Launch, computed at end of each year.

Σ represents total discounted cash flow over life of satellite.

(3) Year of Satellite Launching.

Discount Factor[2]

Yrs After Launch	$.91^{(t)}$
1	.91
2	.83
3	.75
4	.69
5	.62
6	.57
7	.52
8	.47
9	.43
10	.39
11	.35
12	.32
13	.29
14	.27
15	.24

TABLE 5.29

PROJECTION OF LEASING RATES FOR WIDE-BAND CHANNELS

	BASELINE				ALTERNATE A		
Year	Sat. Life Yrs.	Total* Life Rev. / Channel $M	Invest Cost/ Channel in Year of Launch $M	Annual** Return on Invest. %	Total* Life Rev. / Channel $M	Invest Cost/ Channel in Year of Launch $M	Annual** Return on Invest. %
1965	4	15.4	13.9	2.7			
1970	5	8.8	4.8	17			
1975	6	6.4	2.3	30			
1980	7	5.0	0.8	75	4.0	0.8	57
1985	9	4.2	0.6	67	2.9	0.54	49
1990	11	3.9	0.5	62	2.32	0.47	36
1995	13	3.8	0.42	62	1.95	0.34	36
2000	15	3.9	0.39	62	1.67	0.27	35

*Total Discounted Cash Flow for Satellite Portion Only, Based on Figure 5.29, using Revenue at beginning of each year, discounted at rate of 9% per year, compounded annually (Prime Rate for Long-Term Commercial Loans)

** $\left(\frac{\text{Total Revenue - Investment}}{\text{Sat. Life x Investment}}\right)$ = Annual Rate of Return

TABLE 5.30

LEASING RATE CALCULATIONS FOR TABLE 5.29

Year	BASELINE LEASING REVENUES[2] Leasing[1] Rate	1965	1970	1975	1980	1985	1990	1995	2000[3]	ALT. A LEASING REVENUES[2] Leasing[1] Rate	1980	1985	1990	1995	2000[3]
1965	6.3	5.7													
1966	5.0	4.2													
1967	4.1	3.1													
1968	3.5	2.4													
1969	3.0	15.4													
1970	2.7		2.6												
1971	2.4		2.0												
1972	2.2		1.7												
1973	2.0		1.4												
1974	1.8		1.1												
1975	1.7		8.8	1.5											
1976	1.6			1.3											
1977	1.5			1.1											
1978	1.4			.97											
1979	1.32			.82											
1980	1.28			.73	1.16					1.08	.98				
1981	1.13			6.42	.94					.95	.78				
1982	1.04				.78					.84	.63				
1983	.96				.66					.76	.52				
1984	.90				.56					.69	.43				
1985	.84				.48	.76				.63	.36	.57			
1986	.80				.42	.66				.58	.30	.48			
1987	.76				5.00	.57				.54	4.00	.41			
1988	.72					.50				.50		.35			
1989	.69					.43				.47		.29			
1990	.66					.38	.60			.44		.25	.40		
1991	.64					.33	.53			.41		.21	.34		
1992	.62					.29	.47			.39		.18	.29		
1993	.60					.26	.41			.37		.16	.26		
1994	.59					4.18	.37			.35		2.90	.22		
1995	.58						.33	.53		.33			.19	.30	
1996	.56						.29	.46		.31			.16	.26	
1997	.55						.26	.41		.30			.14	.23	
1998	.54						.23	.37		.29			.12	.20	
1999	.53						.21	.33		.27			.11	.17	
2000	.52						.18	.30	.47	.26			.09	.15	.24
2001	.52						3.88	.27	.43	.25			2.32	.13	.21
2002	.51							.24	.38	.24				.11	.18
2003	.51							.22	.35	.23				.10	.16
2004	.50							.20	.31	.22				.09	.14
2005	.50							.18	.29	.22				.08	.13
2006	.50							.16	.26	.21				.07	.11
2007	.50							.15	.24	.20				.06	.09
2008	.50							2.82	.22	.19				1.95	.08
2009	.50								.20	.19					.07
2010	.49								.17	.18					.06
2011	.49								.16	.18					.06
2012	.49								.14	.17					.05
2013	.49								.13	.17					.05
2014	.49								.12	.16					.04
2015	.49								3.87						1.67

Note: (1) Leasing Rate at Beginning of Year
(2) Leasing Revenue per Year (as in Table 5.28)
(3) Year of Satellite Launching

toll telephones, $3.5 billion for TV, and $1.7 billion for radio. These figures are not directly comparable since no measure of relative capacity is included; however, they do indicate that the total revenue projected for communication satellite operations is conservatively low with respect to current expenditures by the consuming public for communication in these other media.

The cost projections reported in this section meet the tests of realism, internal consistency, continuation of established patterns, and likelihood that the factors creating the historical patterns will continue to influence the future. The projections of satellite launch costs are conservatively high; probably enough so to offset possible understatement of the costs of the satellites themselves. Projected leasing costs per channel are conservatively high, also permitting some leeway for satellite costs to exceed the projected levels. Technological improvement which will aid in cost reduction are generally implicit in the projection. However, any improvements in channel capacity which will permit materially greater signal capacity for a given bandwidth will tend to reduce costs below those projected.

5.4 PROJECTION OF SPECIAL TELECOMMUNICATIONS SERVICE

Radio telecommunications services for aviation, marine operations, public safety activities, and industrial use have each followed a common pattern of increase in the amount of service provided, measured in terms of numbers of operating stations. Based on the assumption that satellite services can capture portions of these markets, it is projected that growth in satellite usage for these services will follow the characteristic pattern of the growth in radio services.

Characteristics postulated for each of the four telecommunications areas listed above, relevant to the possible uses of satellites for communication are as follows.

5.4.1 Marine Operations

Fixed stations will transmit video information and data on weather, marine traffic, navigation hazards, harbor conditions, shipping documentation, and possibly personal contact exchange (e.g., family information to sailors), to ships at sea. Distances involved make satellite communication the only possible means for providing such services. Because of the value of such services, it is projected that the number of fixed stations offering such services using satellite transmission will eventually be as large as the current number of fixed marine radio stations. Estimates of satellite channel capacity required for any given number of fixed stations are dependent on the amount of real-time video-transmission required versus intermittent transmissions, and on the number of separate transmissions to individual ships versus broadcast services. These estimates are included in that portion of this report which projects satellite channel demand. Mobile marine stations using satellite transmission are estimated to increase to a number which is equal to 20% of the current number of mobile marine radio units. This is equal to the merchant vessel proportion of current marine units, and assumes that the number of merchant marine vessels will remain approximately constant, and that most pleasure boats will not utilize satellite communication. These mobile stations will have TV receive-only and voice/data transmit and receive capability.

5.4.2 Aviation Operations

Fixed stations will transmit video information on weather, air traffic, airport conditions, and traffic control instructions. It is projected that the number of fixed stations offering such video services through satellite transmission will eventually reach 40% of the current number of aviation radio stations, on the basis that such a number will be adequate to meet the needs of airlines and the business sector of general aviation. Airborne stations using satellite communications are projected to increase to 20% of the current number of aviation radio units, equivalent to 30% of all aircraft. These airborne units will be TV receive-only, with voice/data transmit and receive capability.

5.4.3 Public Safety Activities

This category includes police activity, fire-fighting, emergency ambulance service, and disaster-related activities. It is postulated that ultimate growth in the number of public safety stations having TV and voice/data transmit capabilities using satellites will reach 10% of the current number of public service radio stations. This estimate is based on expansion of centralized services in metropolitan areas beyond the limits of fully effective line-of-sight service plus equivalent service to large nonmetropolitan areas, and on recognition of the additional utility provided by several types of video service. Receive-only TV plus voice/data transceiver capability is projected to reach 5% of the current number of mobile radio stations of this type, i.e. most units will continue to have radio voice communications only.

5.4.4 Industrial Use

Fixed industrial stations with TV plus voice/data transmission are expected to reach a number equal to 5% of the current number of industrial radio stations. This usage is expected to come from such installations as off-shore oil platforms, other remote operations, and centralized control of wide-spread industrial activities. Mobile industrial stations with TV receive only plus voice/data transceivers are estimated to number ultimately 2% of the current number of mobile industrial radio units. In addition to these mobile stations, it is projected that 8% of the land transport units (10,000 trains plus 7% of the motor freight trucks) will have this capability.

5.4.5 Projections of Special Telecommunication Services

These projections of upper limits of numbers of stations in the future, based on current levels of radio stations, is predicted on the fact that the pattern of radio usage has reached, or is approaching saturation in each market, and that a similar pattern will prevail in usage of the satellite capability postulated.

The growth patterns for special services radio stations are shown in Figures 5.43 and 5.44. Data for these figures is from "Historical Statistics of the United States, Part 2". This data also forms the basis for projection of the numbers of special services stations estimated to use satellite transmissions for communication, in accordance with the postulates noted above.

For the purposes of the projection, three assumptions apply: (a) that the patterns for increase in numbers of radio stations for special services will be repeated when satellite communications begin to provide service in the same markets; (b) that the year 1981, for satellite services, will be equivalent to the year 1951 for radio stations, and that the pattern of increase will follow year-by-year, e.g., satellite year 1990 will be equivalent to radio year 1960; and (c) that summation of the numbers of stations projected for each service in each year will give a reasonable indication of the total numbers of stations involved with satellite communications, with the principle of compensating errors operating to smooth the pattern of increase and minimize the effect of errors in the separate projections for each service.

The tabulation of data for fixed, or land, stations is presented in Table 5.31. The ratios of projected stations using satellite transmissions to radio stations for each service, as noted in preceding paragraphs, result in approximately equal numbers of fixed stations for each service. Thus, if the argument is made that one or more of the projected services will not use satellite communications, the projection of total market demand may be reduced by 1/4 of the total for each market eliminated. To calculate the satellite channel capacity which the special service fixed station TV transmissions will require, the following approximations were used:

Service	Transmission Rate	No. of Channels Per Station
Marine	2 frames per second around-the-clock operation	.067

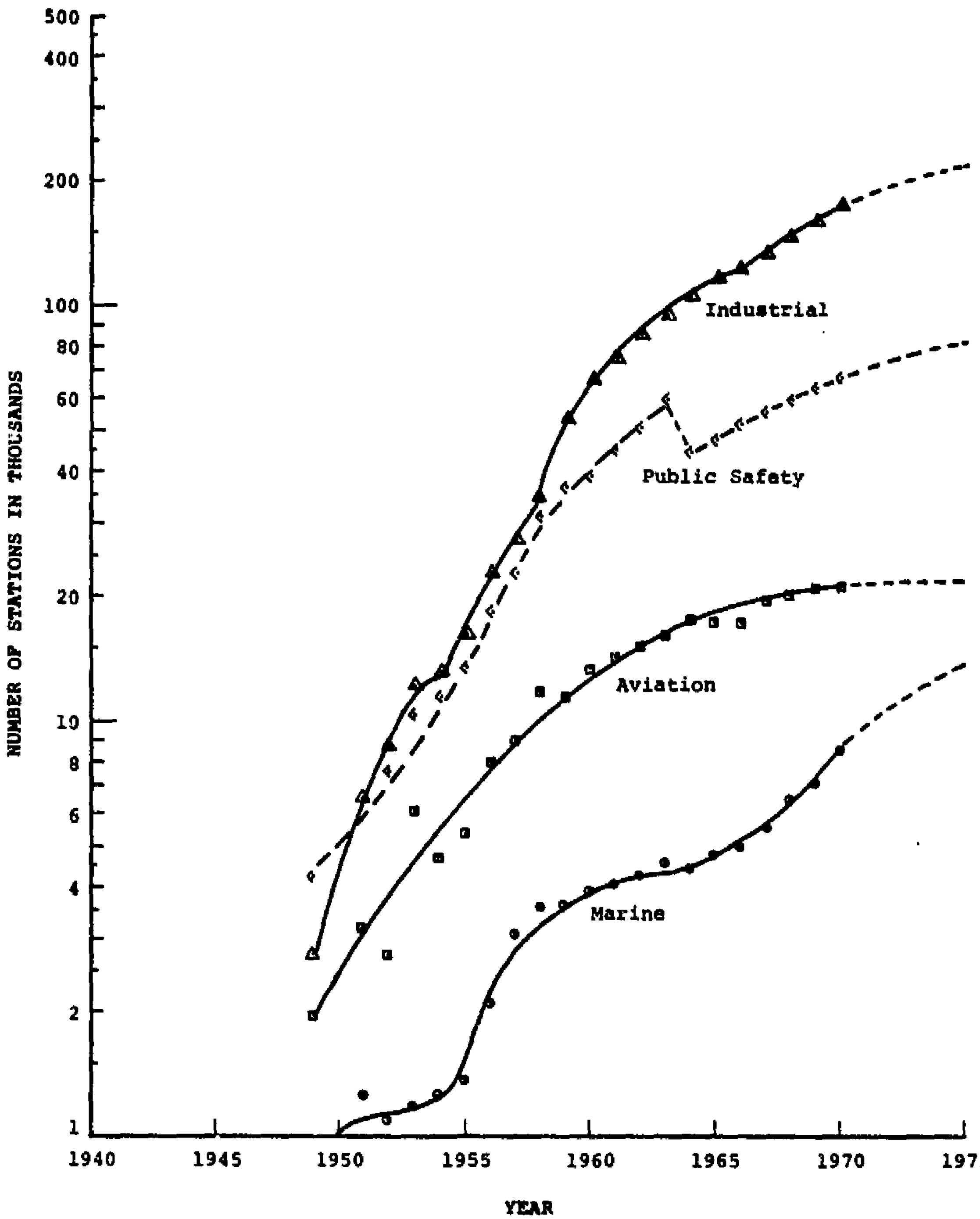

Figure 5.43. Fixed Radio Stations for Special Communication Services (Source: "Historical Statistics of the United States")

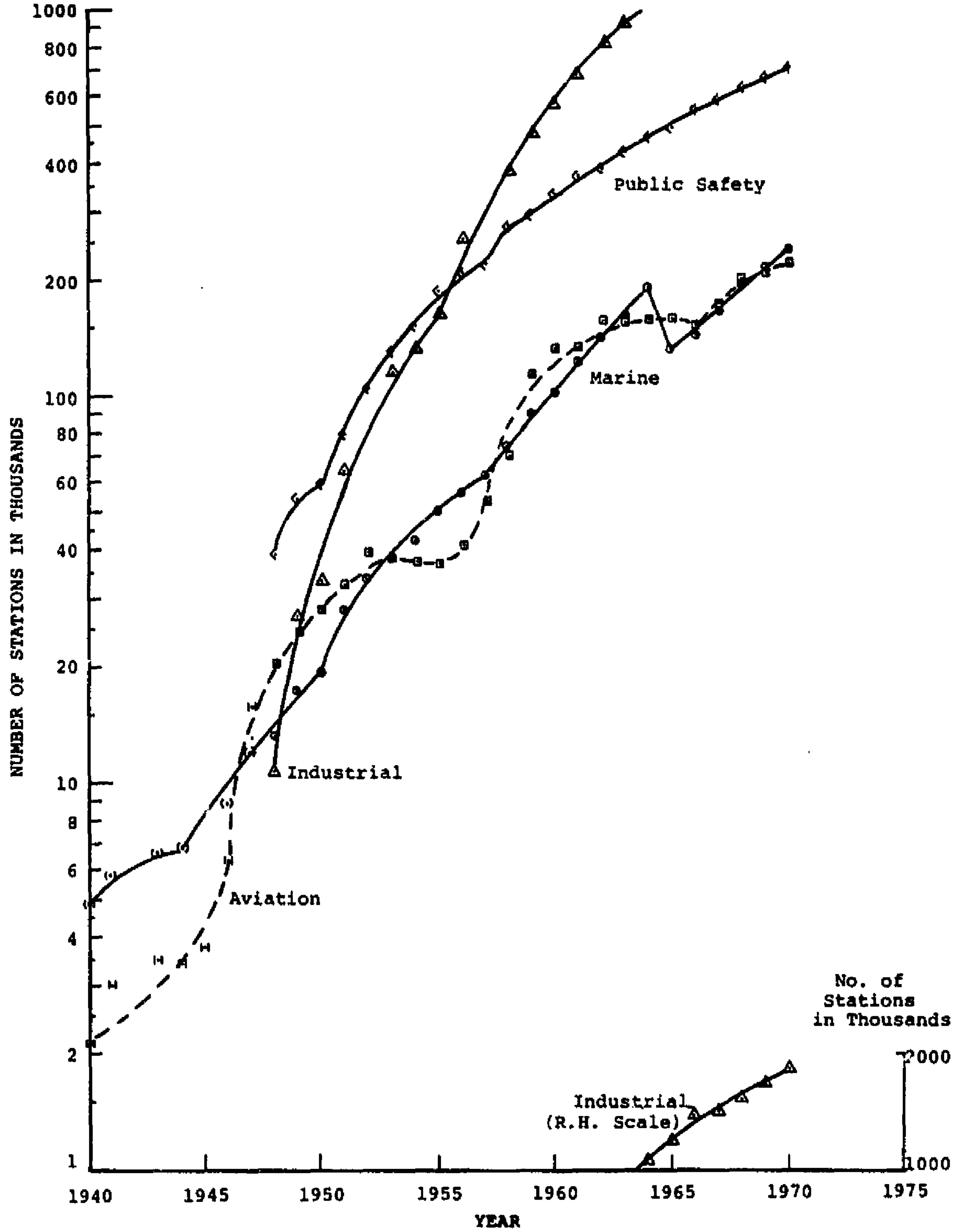

Figure 5.44. Mobile Radio Stations for Special Communications Services (Source: "Historical Statistics of the United States")

TABLE 5.31

PROJECTIONS OF NUMBERS OF LAND (FIXED) STATIONS FOR SPECIAL COMMUNICATIONS SERVICES AND ASSOCIATED SATELLITE CHANNEL CAPACITY REQUIREMENTS

Equivalent Radio Year	No. of Stations in Thousands					TV Channel Capacity Demand (0.4 x Total No. of Stations)	Satellite Year
	Marine	Aviation	Public Safety	Industrial	Total		
1951	1.27	1.27	.66	.32	3.52	1,410	1980
2	1.10	1.09	.77	.43	3.39	1,360	2
3	1.17	2.46	1.03	.60	5.26	2,100	3
4	1.25	1.86	1.17	.70	4.98	2,000	4
5	1.39	2.15	1.37	.80	5.71	2,280	5
6	2.1	3.2	1.9	1.1	8.3	3,320	6
7	3.1	3.6	2.4	1.4	10.5	4,200	7
8	3.6	4.8	3.1	1.7	13.2	5,280	8
9	3.6	4.6	3.7	2.7	14.6	5,840	9
1960	3.9	5.4	3.9	3.3	16.5	6,600	1990
1	4.0	5.8	4.6	3.8	18.2	7,280	1
2	4.1	6.1	5.2	4.4	19.8	7,920	2
3	4.6	6.4	6.0	4.8	21.8	8,720	3
4	4.4	7.1	4.5	5.3	21.3	8,520	4
5	4.7	7.0	4.9	5.9	22.5	9,000	5
6	5.0	6.9	5.2	6.3	23.4	9,360	6
7	5.6	7.8	5.6	6.9	25.9	10,360	7
8	6.5	8.0	6.0	7.5	28.0	11,200	8
9	7.1	8.4	6.5	8.2	30.2	12,080	9
1970	8.6	8.6	6.9	8.9	33.0	13,200	2000

Assumptions used to establish number of stations:

Marine - number of stations transmitting TV will equal 100% total no. of radio stations
Aviation - " " " " " " 40% " " "
Public Safety - " " " " " 10% " " "
Industrial - " " " " " " 5% " " "

Service	Transmission Rate	No. of Channels Per Station
Aviation	10 frames per second around-the clock operation	.333
Public Safety	0.1 channel per day health 0.9 channel per day police	1.0
Industrial	2 frames per second, peak-to-average load ratio = 3	0.20
Average for all	(assumes each service has approximately 1/4 of the total number of stations)	0.4

Therefore, multiplication of the projected total number of special service stations by 0.4 will provide the forecast of satellite channel demand for special service TV broadcasts in these markets, as shown in Table 5.31. Graphical indication of the projected pattern of increase in numbers of special services stations is shown by Figure 5.45.

The tabulation of data for mobile stations is given in Table 5.32. The ratios of stations using satellite transmissions to radio stations, for each service, as previously noted, result in approximately equal numbers of mobile stations for each service. Therefore, similarly to the projection for fixed stations, the elimination of any one service would reduce the total market by 20%. Calculation of the channel capacity required to support the voice/data transmission of the mobile stations (in addition to the TV receive-only requirement) is based on the following approximation:

> Each mobile unit will be transmitting 10% of the time (six minutes per hour), with a peak-to-average ratio of three, and each voice/data channel will require 0.00133 of wide-band channel capacity, so that 3/10 x 0.00133, or 0.0004, times the number of mobile stations will give the number of wide-band channels required.

The number of channels required for this voice/data service is small in comparison with the TV requirement, so that the more significant element of this projection is the number of

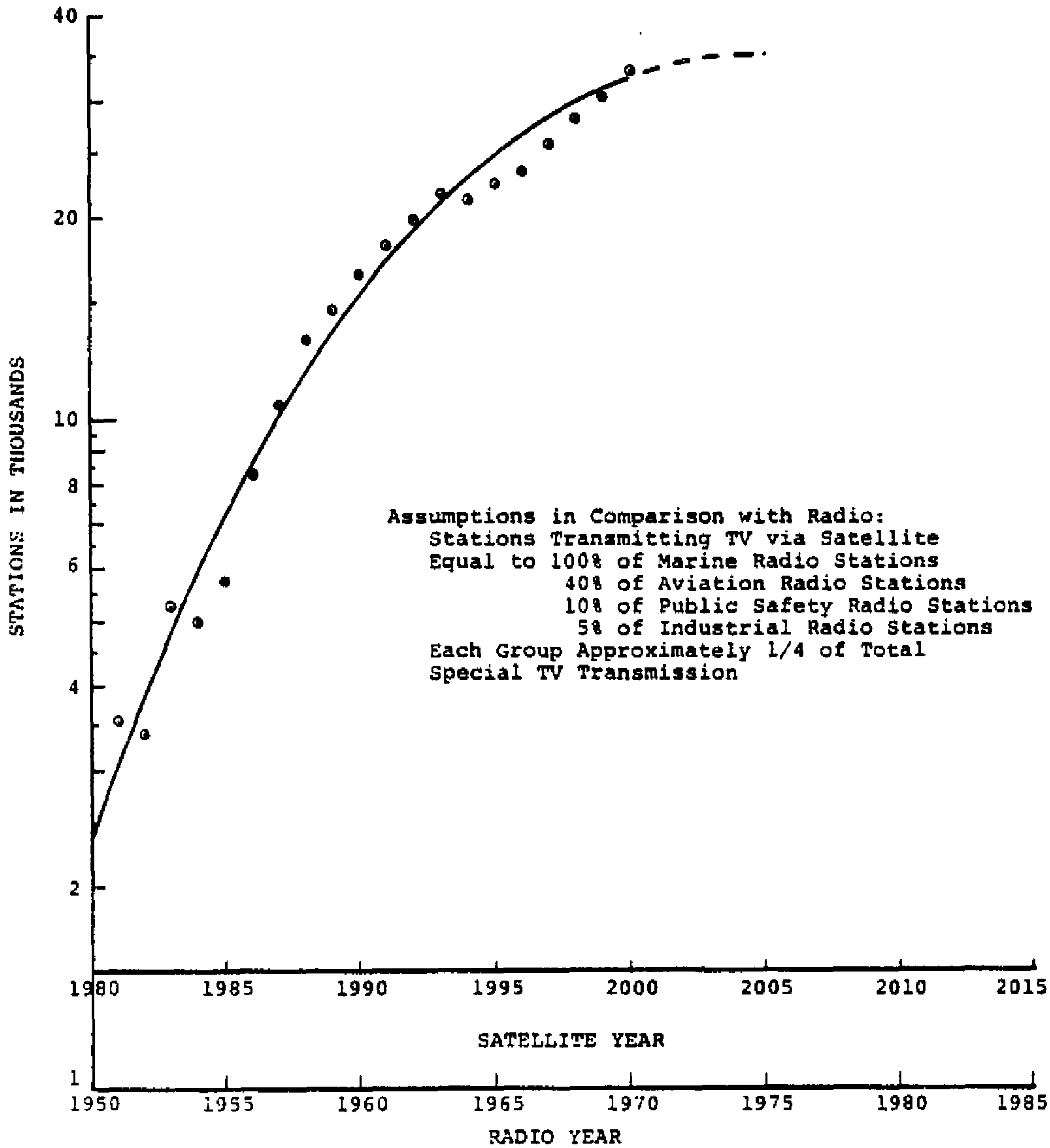

Figure 5.45. Composite Special Land Stations Projection--Based on Historical Pattern of Special Radio Services Growth

TABLE 5.32

PROJECTIONS OF NUMBERS OF MOBILE STATIONS
FOR SPECIAL COMMUNICATION SERVICES AND
ASSOCIATED SATELLITE WIDE-BAND CHANNEL CAPACITY REQUIREMENTS

Equivalent Radio Year	No. of Mobile Stations in Thousands						Wide-Band Channels Req.	Satellite Year
	Marine	Aviation	Public Safety	Industrial	Land Freight*	Total		
1951	5.6	6.6	4.0	1.3	6.0	23.5	9.4	1981
2	6.8	7.8	5.3	1.6	7.4	29	11.6	2
3	7.5	7.6	6.6	2.3	8.8	33	13.2	3
4	8.5	7.5	7.7	2.6	10.6	37	14.8	4
5	10	7.3	9.4	3.3	12	42	16.8	5
6	11	8.1	10.4	5.0	19	54	21.6	6
7	12	10.7	11	5.9	24	64	25.6	7
8	15	13.9	14	7.6	27	76	30.4	8
9	18	22.3	15	9.6	34	99	39.6	9
1960	21	26	17	11	20	95	38.0	1990
1	25	26	19	14	26	110	44.0	1
2	29	31	19	16	28	123	49.2	2
3	32	31	22	19	30	134	53.6	3
4	38	31	23	21	30	143	57.2	4
5	27	32	25	24	32	140	56.0	5
6	29	30	27	25	34	145	58.0	6
7	34	35	29	28	37	163	65.2	7
8	39	41	31	31	40	182	72.8	8
9	44	42	33	34	42	195	78.0	9
1970	48	44	35	37	44	208	83.2	2000

*10,000 train units (1/3 of locomotives); 34,000 trucks (7% of trucks)

Assumptions used to establish number of stations:
Marine - number of stations using satellite transmission will equal 20% of total no. of mobile radio stations
Aviation - " " " " " " " 20% " " " "
Public Safety " " " " " " " 5% " " " "
Industrial - " " " " " " " 2% " " " "

mobile receivers projected. Graphical indication of the projected pattern of increase in numbers of mobile special services stations is presented in Figure 5.46.

In summary, the total number of special services fixed stations using satellite transmission is projected to equal 12% of the number of fixed radio stations for these services, reaching 33,000 stations in the year 2000. The total number of mobile stations using satellite transmissions is expected to equal 7% of the number of mobile radio stations, reaching 208,000 in the year 2000. Television transmissions are projected to require 13,200 wide-band channels by the year 2000, with voice/data transmissions requiring an additional 83 wide-band channels, for special services for marine, aviation, public safety, and industrial operations.

5.5 PROJECTION OF INCREASE IN BROADCAST SERVICES

The increases in various broadcast services may be examined to discern patterns which might be repeated in the growth of similar satellite services. Such patterns are presented and discussed in the following paragraphs. Data for these services was obtained from the "Historical Statistics of the United States" and the "Statistical Abstract of the United States".

5.5.1 Commercial AM Broadcast Services

The patterns of increase in this category are shown in Figure 5.47. It may be noted that the very rapid initial growth slowed markedly and then fell below the trend line ultimately established from 1947 to 1974. Although the short fall from 1930 to 1946 is attributable to the depression and World War II influences, the initial overshoot and leveling in the 1923 to 1930 period strongly resembles dynamic overshoot in a lightly damped system.

5.5.2 Commercial FM Broadcast Services

The FM pattern shown in Figure 5.48 is a close replica of the AM growth pattern, following 22 years later. The characteristic of dynamic overshoot is evidenced even more markedly. This may have been the result of World War II constraints on use of available

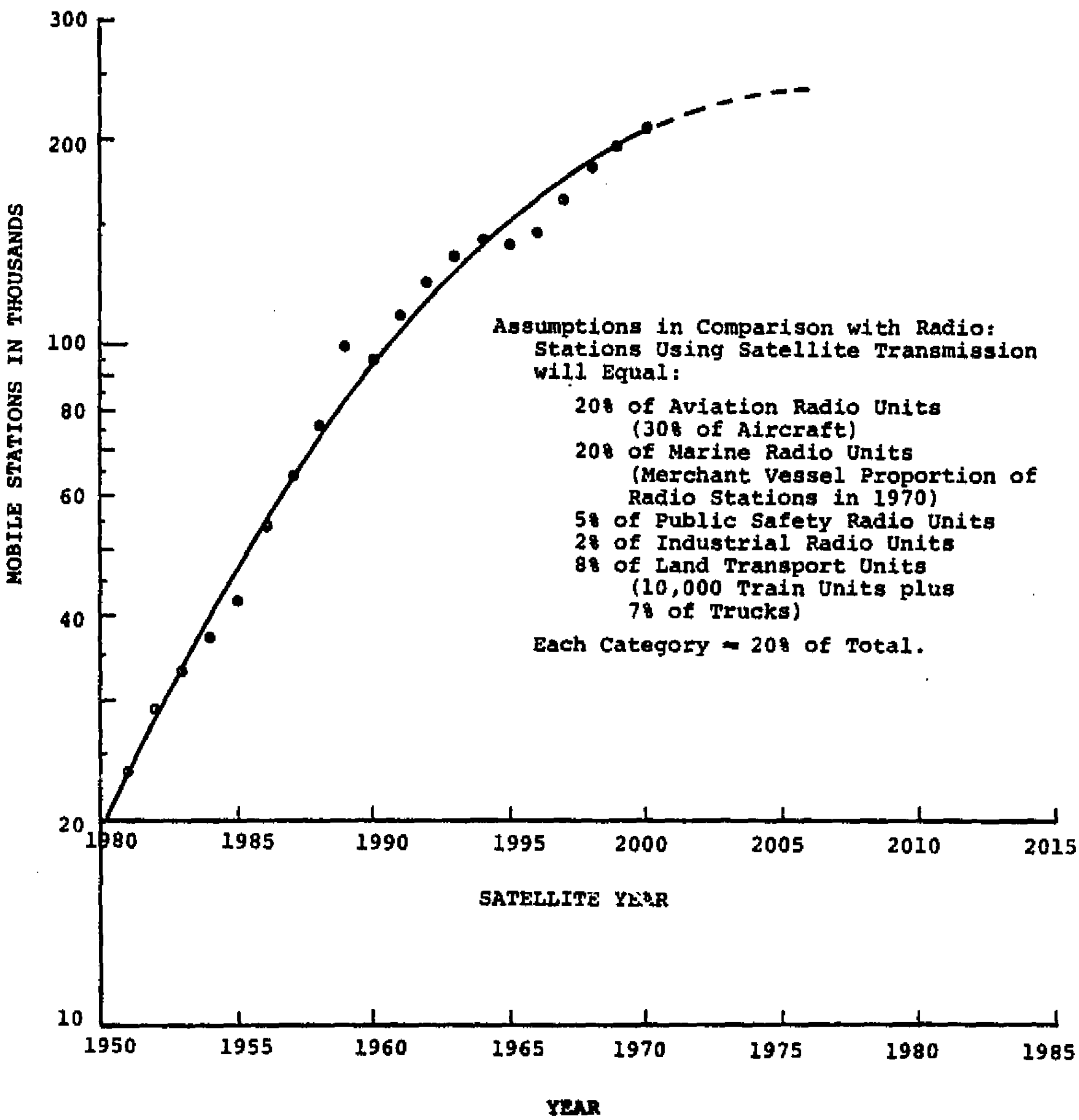

Figure 5.46. Composite Special Mobile Stations Projection--Based on Historical Pattern of Special Radio Services Growth for Voice and Data

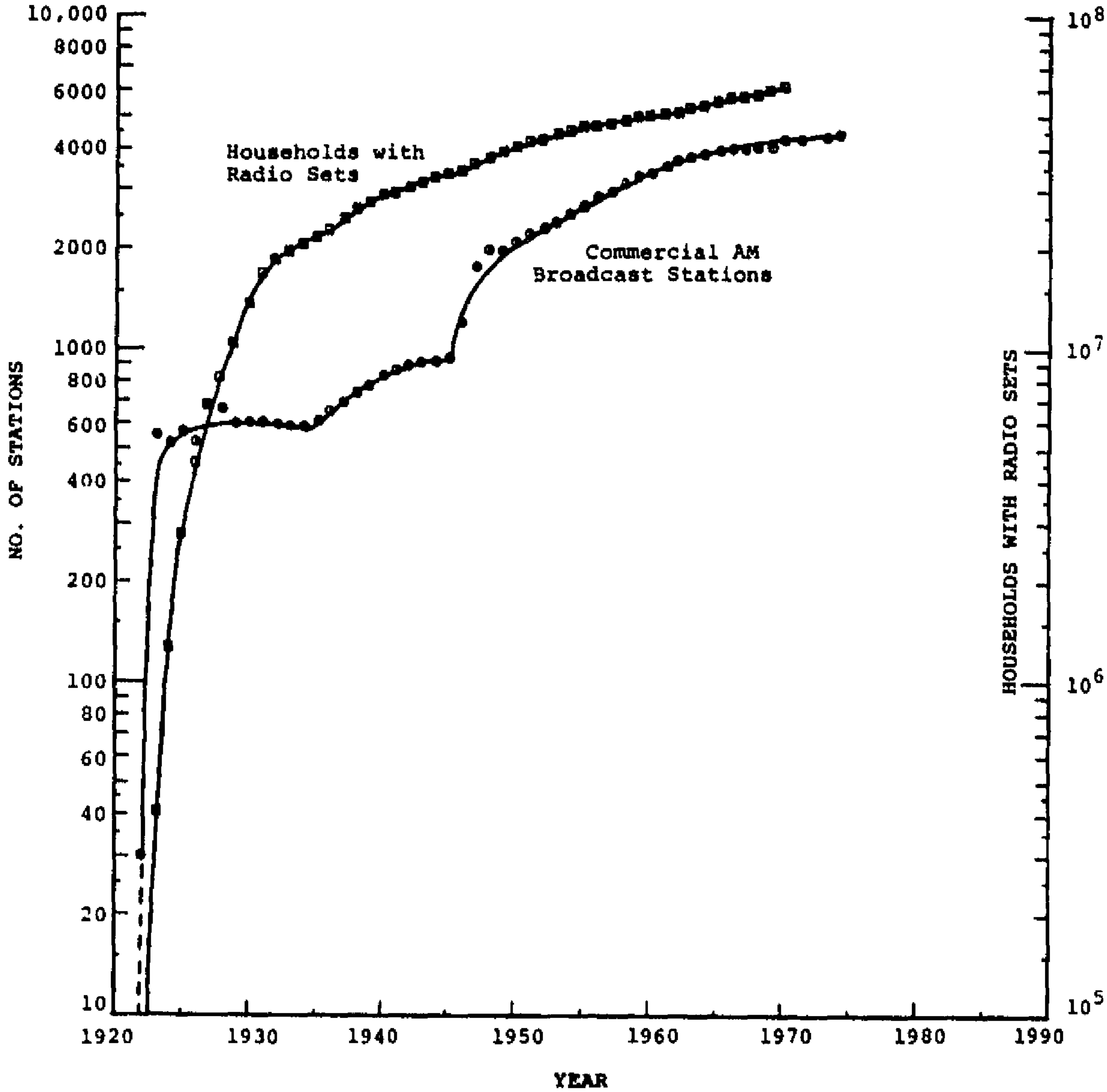

Figure 5.47. Commercial AM Broadcast Services

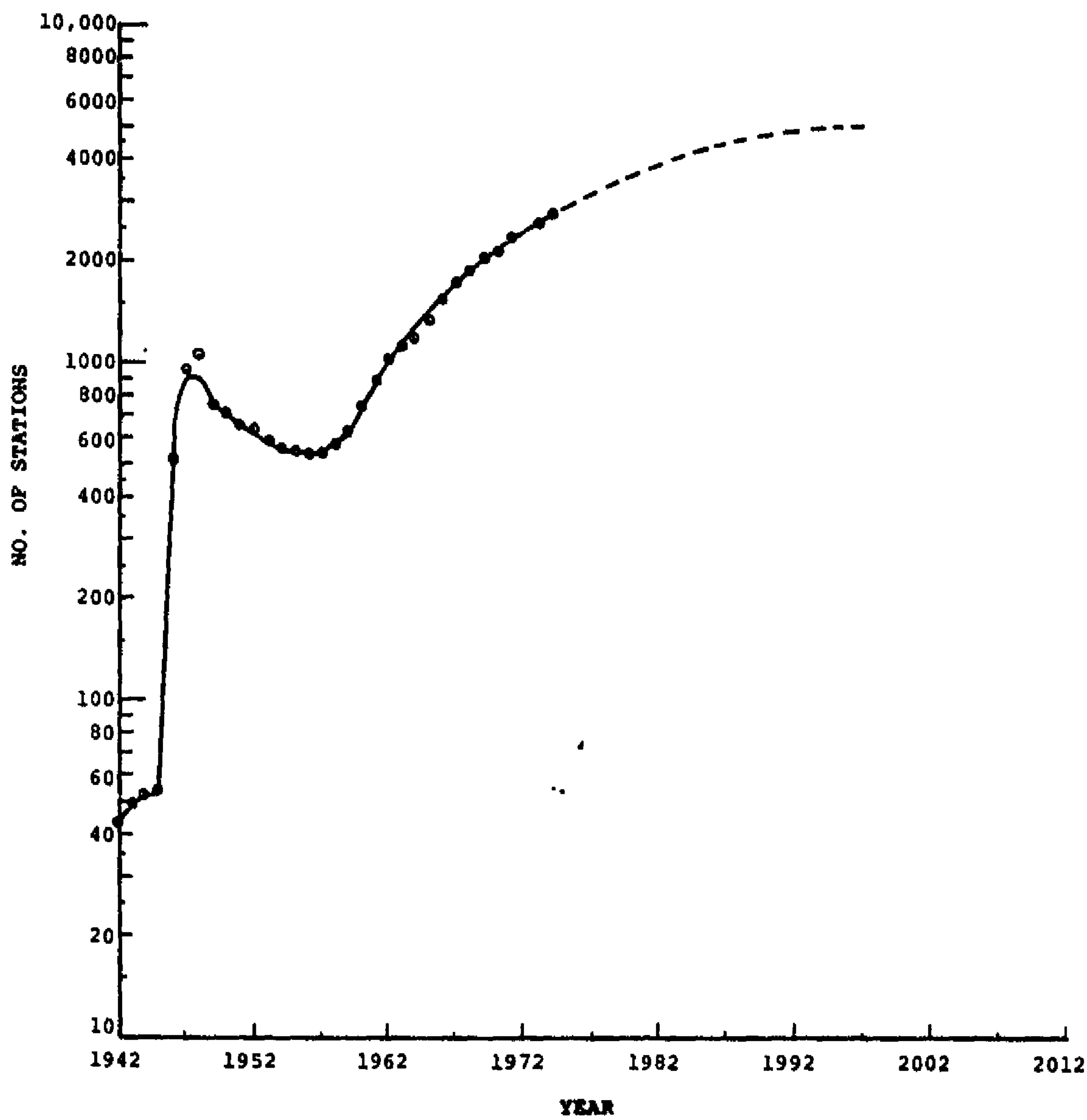

Figure 5.48. Commercial FM Broadcast Stations

technology, leading to extremely rapid overexpansion when those constraints were removed.

5.5.3 Commercial TV Broadcast Stations

Commercial TV broadcasting evidenced two dynamic overshoots, the first from 1946 to 1950, and the second from 1953 to 1961, as shown in Figure 5.49. From 1953 to 1974, the number of TV stations matches almost exactly the pattern of increase in number of AM radio stations during the period from 1923 to 1944. An apparent anomaly exists if the previous argument is accepted that the depression and World War II caused the slow growth in radio from 1920 to 1944, since no equivalent influence existed during the period of 1960 to 1974 to slow the growth of TV. If, in spite of this problem of explanation, TV continued to follow the pattern of increase in numbers of AM stations, then an upward jump in number of TV stations should occur during 1977 to 1979, increasing from the current number of 700 stations to between 1400 to 2000 stations. Two elements appear necessary if this increase is to take place. First, the expansion must take place in the UHF band which is not now heavily used. Second, additional programming must be provided at costs compatible with advertising revenues available. The additional programs may come either from new networks or from local programming. In this connection, it may be argued that the TV audience rating systems have depressed growth in TV as much as the Great Depression and World War II depressed growth in radio.

5.5.4 Cable TV Systems

The growth of cable TV also evidences dynamic overshoot, although to a lesser extent than the previous examples, as shown in Figure 5.50. The lesser overshoot may be the result of the combined effects of greater capital investment required, the necessity for community charters, and constraints imposed by the FCC on early expansion of this service. It appears that this service will continue to increase to saturation of the market of urban places larger than 2500 population near the end of this century.

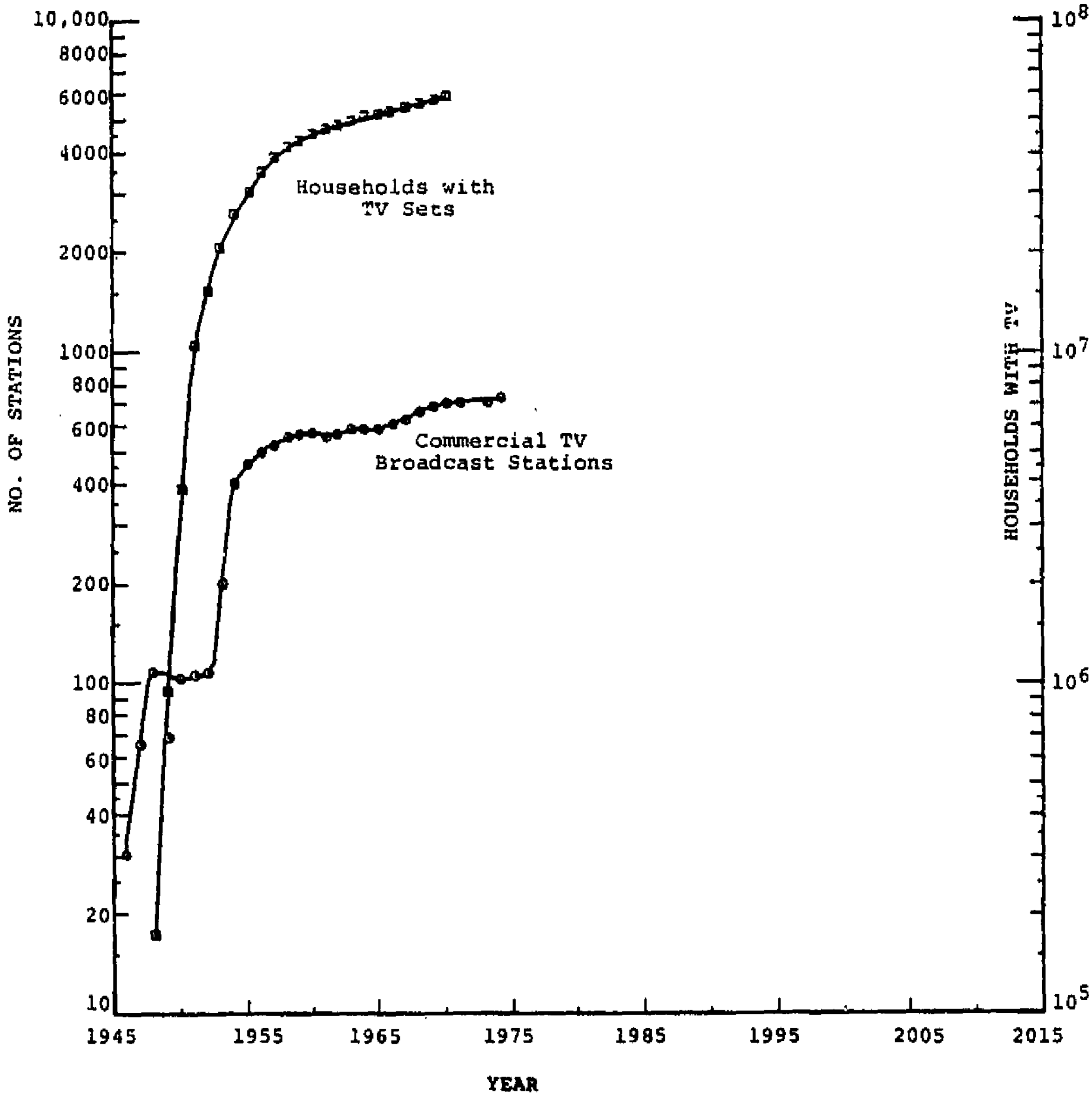

Figure 5.49. Commercial TV Broadcast Services

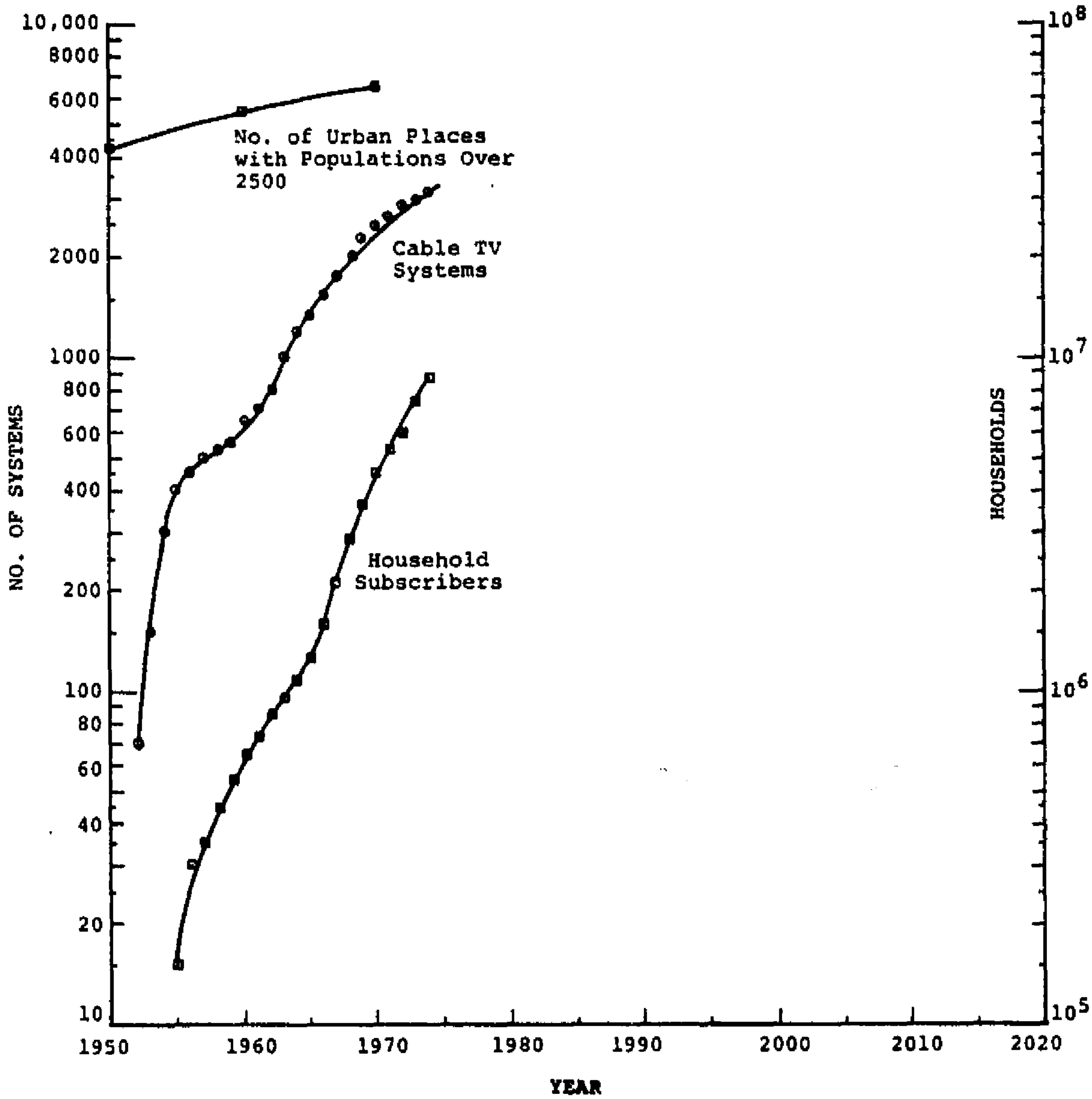

Figure 5.50. Cable TV Systems

5.5.5 Education TV Stations

Data for this service is shown in Figure 5.51. The pattern of increase for this service shows only minimal evidence of the dynamic overshoot characteristic. This may be attributed to the absence of the profit motive which ordinarily operates to encourage rapid exploitation of new markets resulting in overexpansion and subsequent retrenchment. The growth pattern is otherwise similar to that for cable TV. If the number of institutions of higher learning is taken as a surrogate for potential market size (in lieu of a better measure), further expansion may be projected to follow the curve shown on the figure, reaching a fivefold increase in the current number of stations in the 1990's, i.e., about 1200 stations.

5.5.6 Projections of Broadcast Services

The characteristics of the dynamic overshoot for commercial AM, FM, TV, and cable TV are markedly similar. For AM and FM, the time from initial rise to a pronounced first minimum was 12 years, for commerical TV with two successive overshoots, the combined time to the second minimum was 13 years, and for cable TV with a weak overshoot, the comparable period was 7 years. Allowing for the World War II constraint on increases in commercial AM broadcast stations, the time required for the pattern to damp to steady growth was nearly 20 years in all four of these situations. This consistency of behavior provides a useful basis for examination of influences which might lead to, or prevent, similar overexpansion and subsequent retrenchment in total communication satellite capacity.

Comparison of these growth patterns with the projected increases in number of wide-band transponder channels, as previously given in Figure 5.22, is shown in Figure 5.52. In this figure, the growth in total number of earth-based TV systems from 1946 to 1974 is compared with the increase in numbers of satellite wide-band channels for an equivalent 28-year period from 1969 to 1997.* If

*The earth-based TV systems are defined herein to include the numbers of commercial TV stations, plus educational TV stations, and the numbers of cable TV systems.

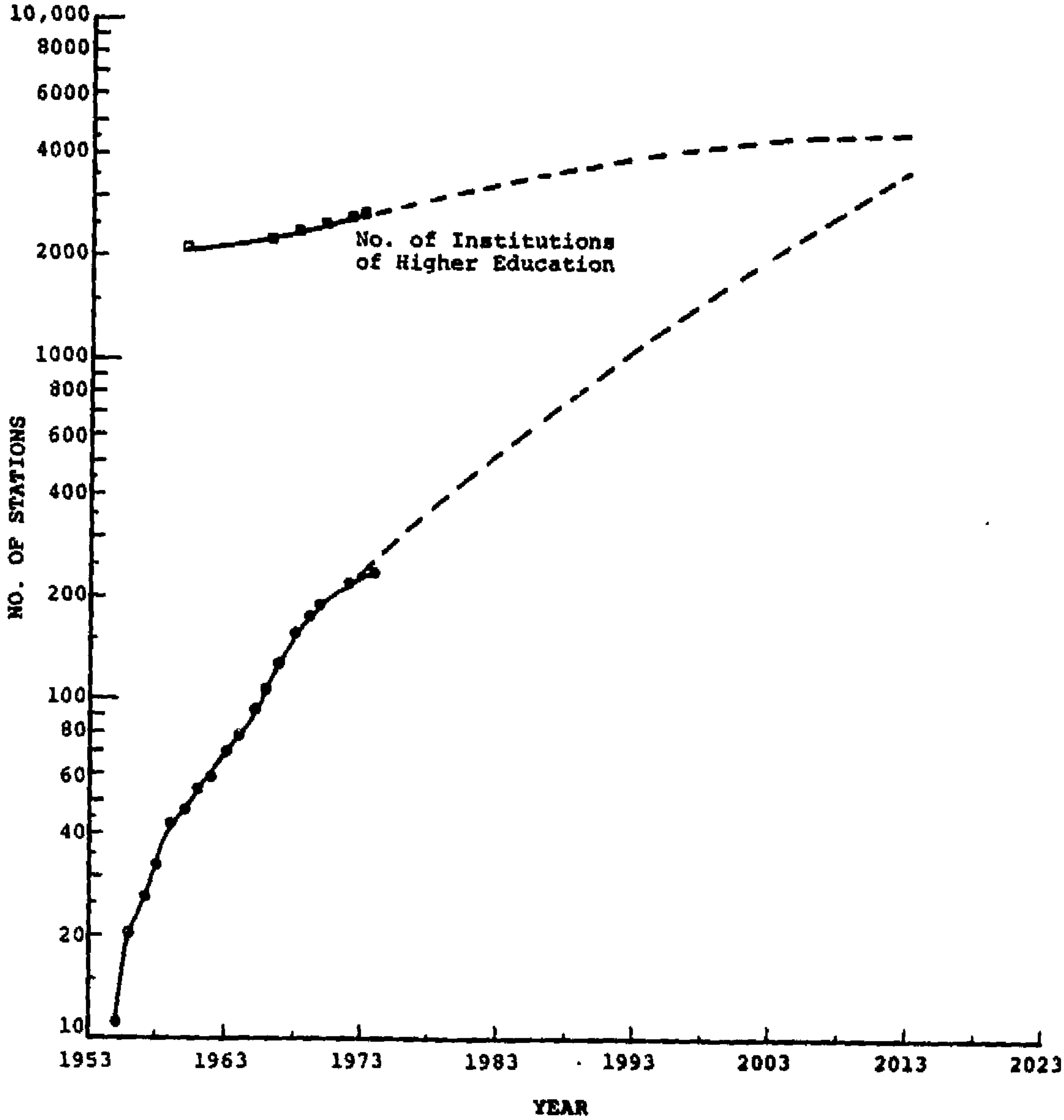

Figure 5.51. Educational TV Stations

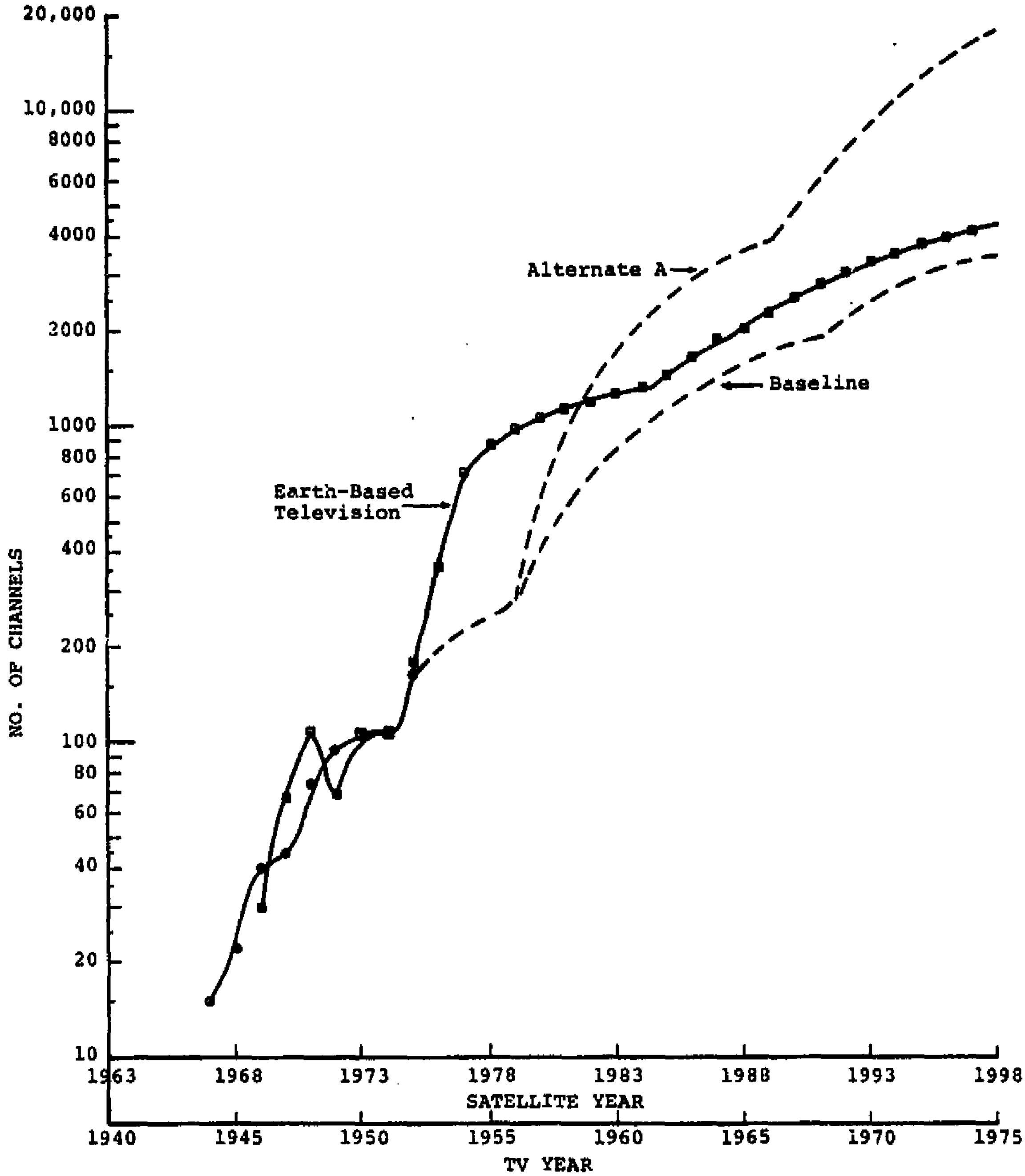

Figure 5.52. Comparison of Projections of Numbers of Satellite Wide-Band Channels Versus Historical Increase in Numbers of TV Systems (Cable plus Broadcast)

it were to be assumed that satellite use would be restricted solely to broadcast functions, then the Baseline projection given in Figure 5.22 (and as repeated in Figure 5.52) is conservative in comparison with the actual increase in numbers of earth-based TV systems.

This comparison, of course, does not address the issue of the size of the total market for broadcast services, nor the degree to which satellites might substitute for the earth-based broadcast systems. Except for the fact that growth in cable TV was coincident with a slow-down in growth of commercial TV stations, there is little evidence that any of the broadcast systems depressed growth in the other systems. Therefore, it might be argued that growth in satellite broadcasting will proceed in accordance with the trends projected, regardless of the degree of substitution for other services and independently of the total market sum of such services. The cross-impact portion of the study offers further exploitation of this issue.

The Alternate A projection, also repeated in Figure 5.52, exceeds the growth pattern of earth-based television at approximately the halfway point in the period, i.e., in 1982 on the satellite time scale. Therefore, it may be postulated that the additional increases in capacity projected in Alternate A will be associated with services other than commercial and general educational broadcast activities. Since this projected additional capacity is nearly three times larger than the general broadcast segment, it is apparent that fulfillment of the Alternate A projection will depend heavily upon the generation of such additional services, e.g., telephone communications, data transfer, and special communication services.

5.6 SUBSTITUTION OF ELECTRONICS FOR PAPER AND INK IN COMMUNICATIONS

One way of providing a bench-mark against which various projections in the communications market may be tested is the construction of an overall estimate of the total communications market, and the relative shares of this market which will be satisfied by various technologies. This portion of the report constitutes a "first cut" at this approach, which may be used as a basis for testing the concept and as a guard against gross errors in projecting total communications volume in terms of resources available for communication.

Except for face-to-face communication, it may be stated categorically that two technologies constitute the total communications market, i.e., communication is effected either through hard-copy, principally paper-and-ink, or through electronic devices. Although either process may use elements of the other, the primary determinant for this analysis is based on expenditures attributed to the transmission media. In practice this determination is easier than might be expected, since data is available to construct the actual expenditures for most such transmissions. For example, that portion of newspaper expenditures attributable to electronic transmission will appear in telephone and telegraph revenues. Although some degree of "double-counting" may occur, this should not materially affect the result in terms of the purpose for which this estimate is intended, i.e., to provide protection against gross errors in estimating potential markets. The basis for this assertion may become clearer to the reader as the various elements of the estimate are presented and discussed in the following paragraphs. Data for this analysis was taken from tables in the "Historical Statistics of the United States" and from the "Statistical Abstract of the United States".

The hard-copy, or paper-and-ink, market is defined herein to include expenditures for postal service (less parcel post), the total receipts of the newspaper, book, and periodical publishing industry, and expenditures for motion picture entertainment (does not include television payments to motion picture industry). The electronic market is defined to include total domestic telegraph, telephone, and broadcast revenues, plus consumer expenditures for radio and television receivers and phonographs. (The overstatement implicit by the inclusion of phonographs is offset to an unknown extent by the understatement resulting from exclusion of special services radio communication equipment. It is believed that this variance is not of sufficient magnitude to affect the use of the data for the purpose stated.)

Figure 5.53 presents the trends of U.S. expenditures for communications as defined above. Except for the period from 1920 to 1945, these trends have been very regular. The sharp surge in 1920 may be attributed to the influence of World War I in raising national aspirations, while the depression of the 1930's, followed by the constraints of World War II, returned the levels of expenditure to the long-term trends. It is of interest to note that even before the advent of the telephone, the telegraph had captured a significant portion of the communications market in terms of dollar volume, although the comparative "bit" volumes of information transmitted were grossly weighted in favor of paper-based communication.

Viewing electronic communications as a substitute for paper-based communications which is theoretically capable of completely replacing hard-copy transmission, the techniques of substitution analysis may be used to forecast future market proportions for each of the two media.[14] If the fraction of the market captured by electron-based media is divided by the fraction retained by the hard-copy media, the plot shown in Figure 5.54 may be obtained. If the trend of the first 70 years had continued, electronic transmission would by now have 82% of the market, i.e., the straight line from $f_e/f_p = 0.1$ in 1860, extending through the point $f_e/f_p = 1.0$ in 1930, would reach $f_e/f_p = 4.5$ in 1976, which is equal to 82% of the total market. However, the depression of the 1930's coincided with a precipitous drop in the electronic share of the market. This drop may also have been accelerated by diversion of electronic technology toward preparations for war in lieu of equivalent efforts on television which was effectively postponed until after World War II. This drop had a permanent effect on the trend, so that "hard-copy" media retained more than half the total market until 1951. If the current, well-established substitution trend is continued,

[13] H.A. Linstone and D. Sakal, "Technological Substitution, Forecasting Techniques and Applications", American-Elsevier Publishing Company, New York, 1976.

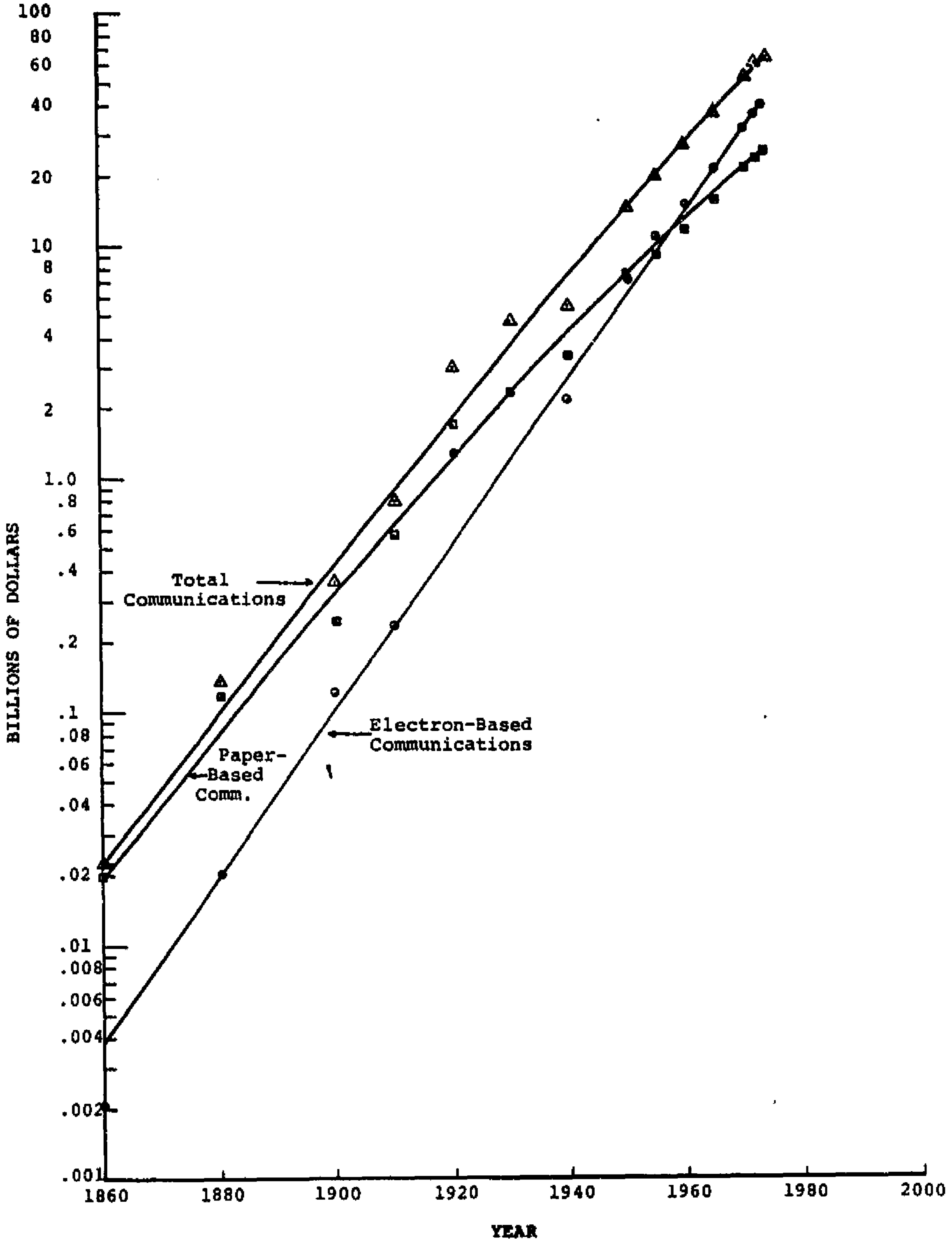

Figure 5.53. Communications Expenditures

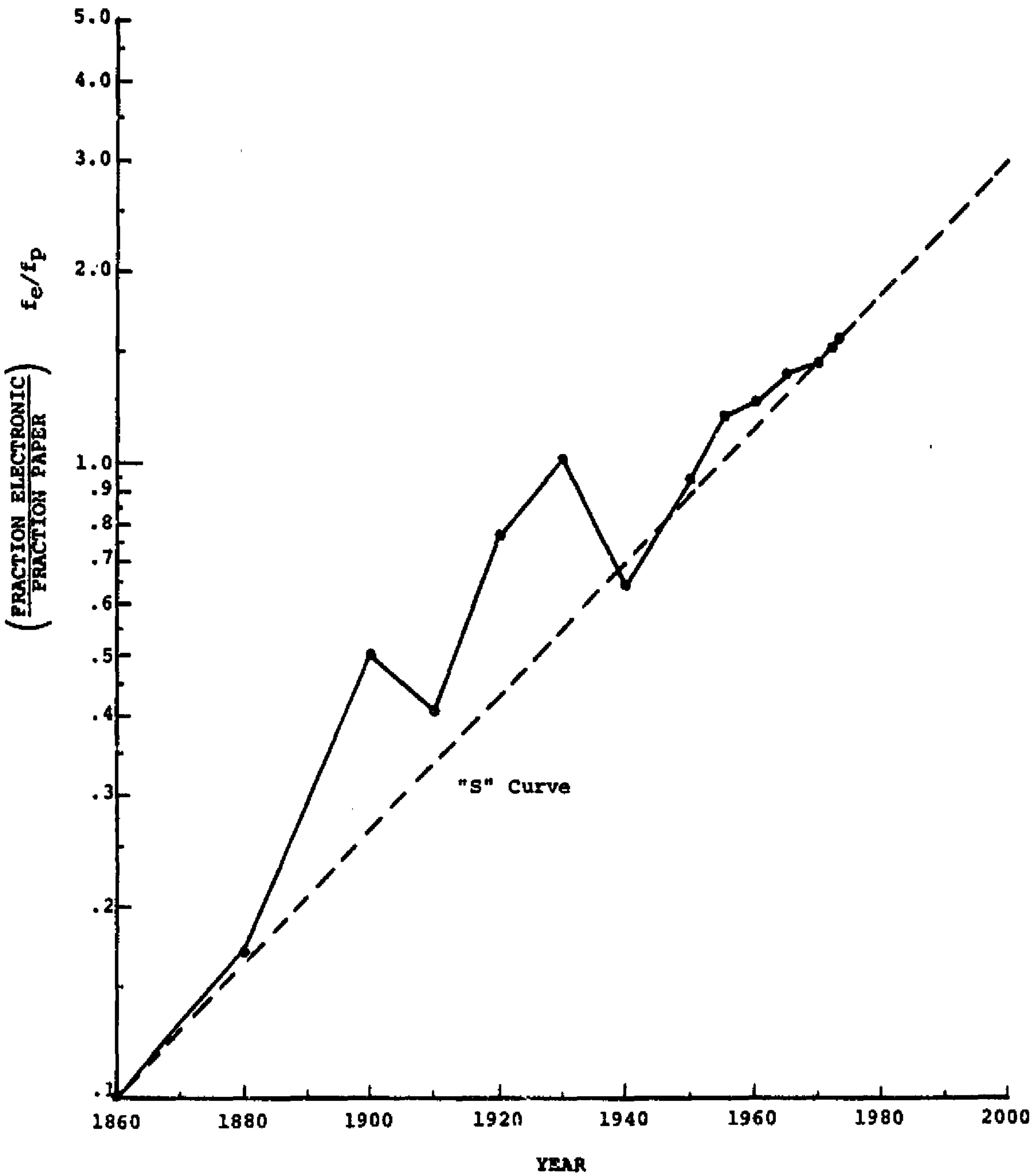

Figure 5.54. Substitution of Electron-Based Media for "Paper-Based" or "Hard-Copy" Media

the electron-based media should capture 75% of the market by the year 2000, as indicated by the extension of the trend to f_e/f_p = 3.0 in that year. This data is plotted in the more conventional percentage terms in Figure 5.55, together with the typical "S" curve resulting from the transformation of the straight line from Figure 5.54, where the inflection point of the "S" curve occurs at the 50% point in the 1950's.

Further insight into the development of the total communications market may be gained from the data plotted in Figure 5.56. In this figure, the total expenditures for communication are plotted in terms of percentages of GNP, Personal Income, and Personal Consumption Expenditures. These percentages show a steady increase in communications expenditures from 0.44% of GNP to 5% of GNP in 1930, with similar increases of the percentages referenced to Personal Income and Personal Consumption Expenditures. Apparently the 5% figure represents a de facto concurrence that this amount is close to the maximum that the public desires to spend on communication since this figure has held reasonably constant during the past 45 years, as shown in the figure.

This 5% figure has, therefore, been used in conjunction with a projection of GNP growth to $6,700 billion by the year 2000 (measured in current dollars), to obtain an estimate of total expenditures, reaching $335 billion in the year 2000, is shown in Figure 5.57. The 5% level may be considered conservative in view of the fact that any significant use of communication to replace transportation now used to obtain face-to-face communication, should increase this figure. The possibility of such a shift is enhanced by the fact that transportation is highly energy-intensive, especially in comparison with the low-energy-intensive characteristics of the communication media.

The GNP projection is consistent with the long-term trend, however, any significant reduction in the GNP estimates will produce equivalent reductions in the trends shown in Figure 5.57. Given the above considerations, and using the market share projections

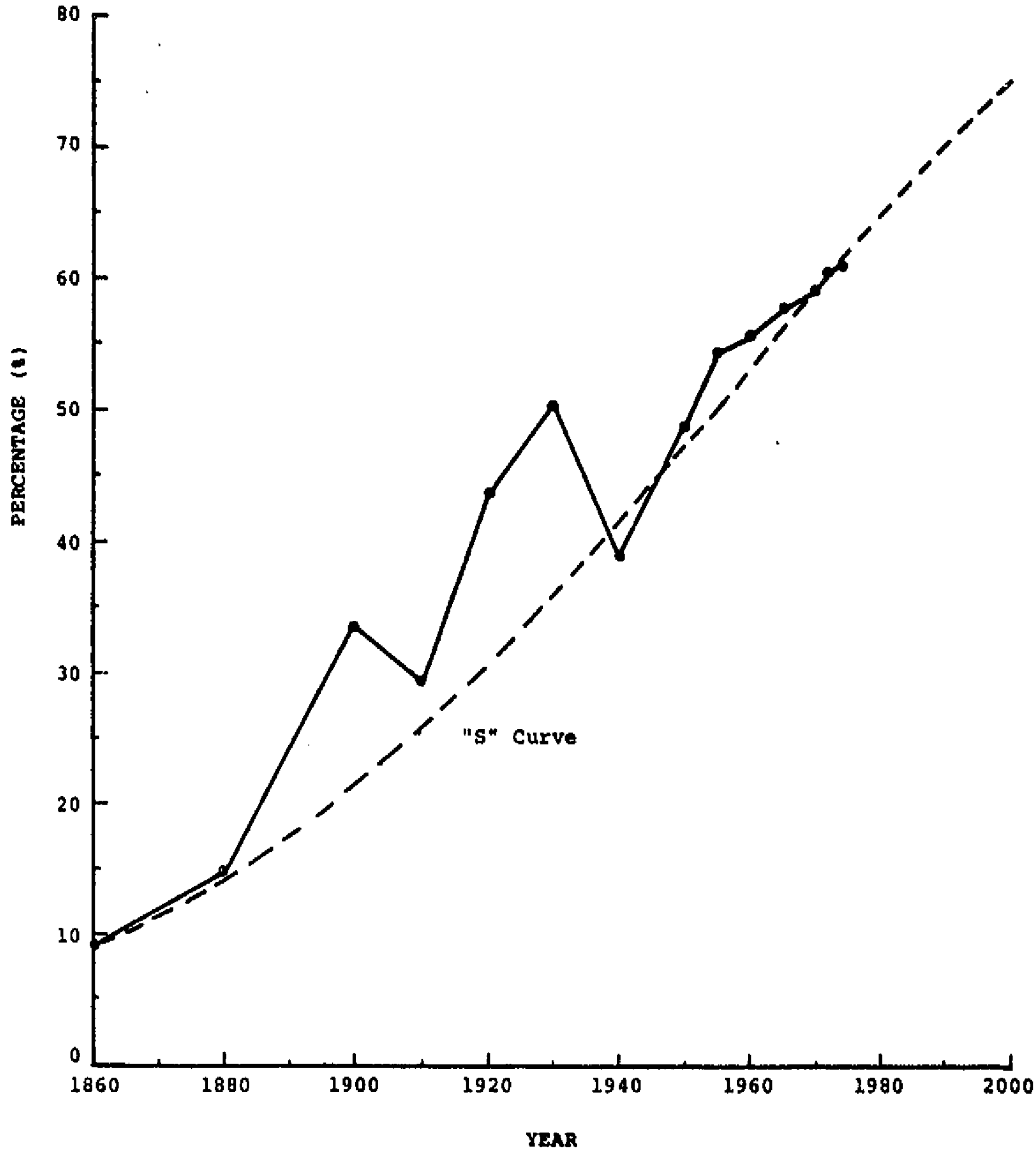

Figure 5.55. Market Shares for Electron-Based Communication Versus "Paper-Based", or "Hard-Copy" Communication

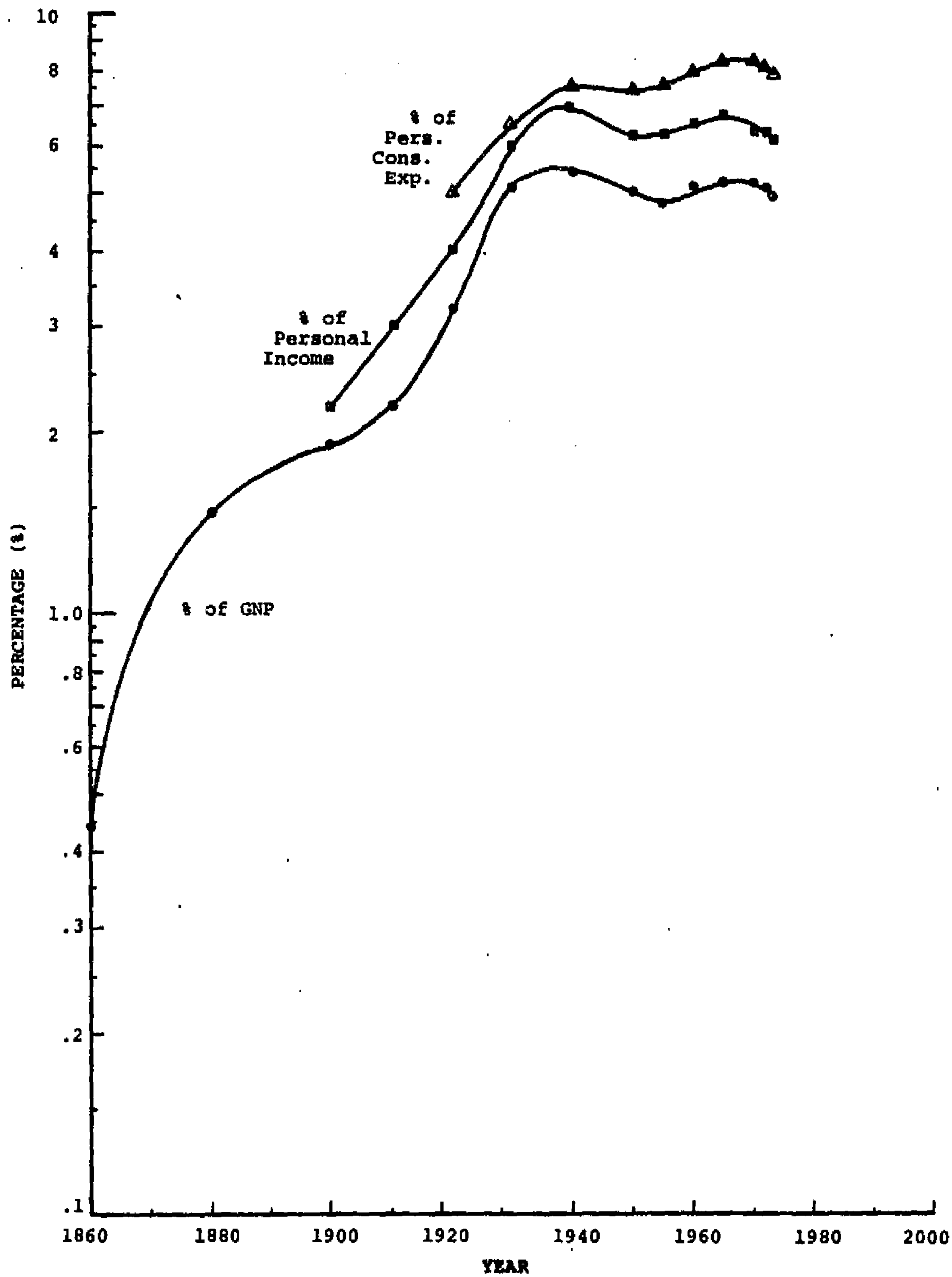

Figure 5.56. Communications Percentages

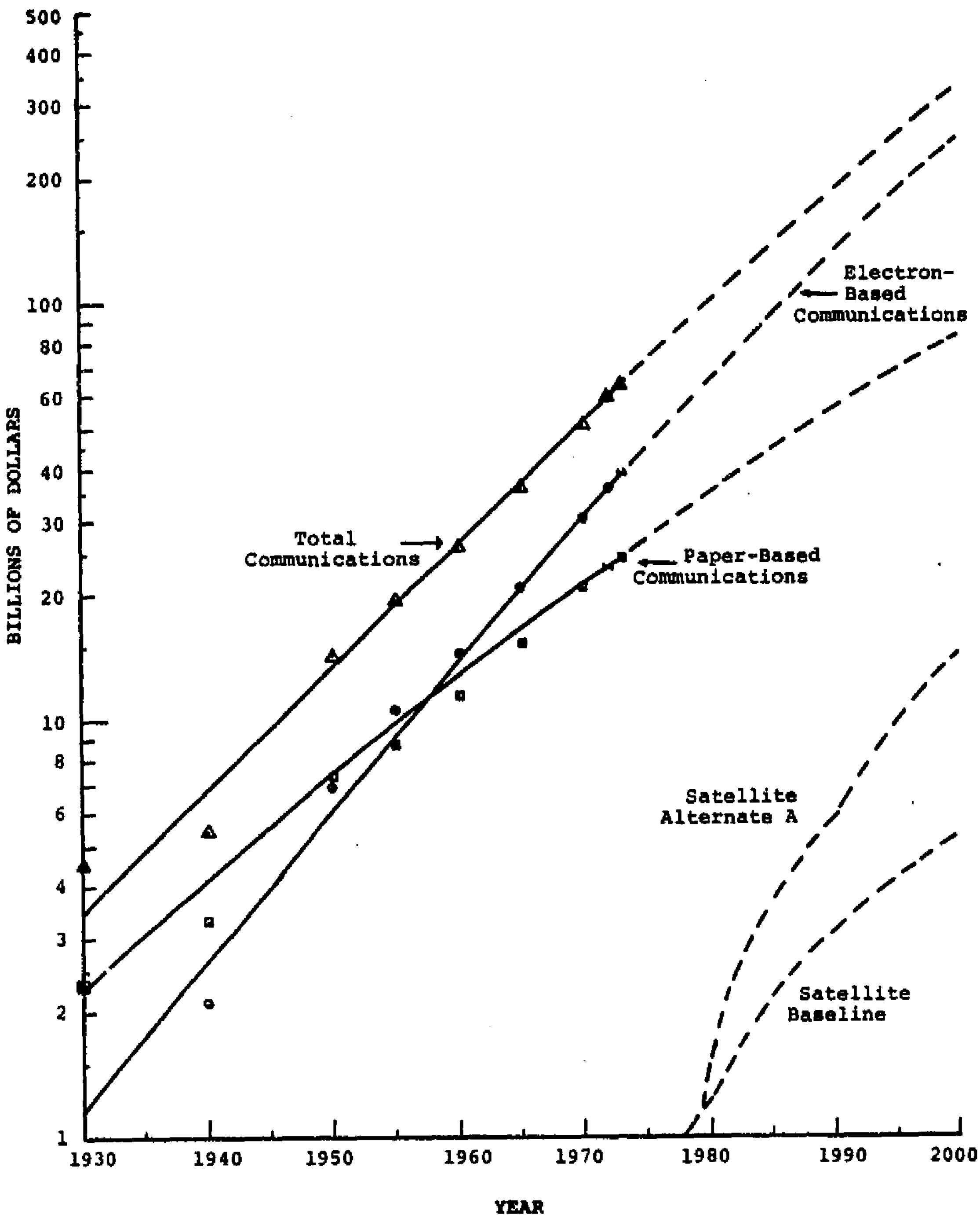

Figure 5.57. Projection of Communications Expenditures

indicated in Figures 5.54 and 5.55, the electron-based communications market should reach $250 billion in the year 2000. Paper-based communications, even though losing another 14% of the market (down to 25% of the total) will still expand from $25 billion to $84 billion by 2000. (Since this is expressed in current dollars, it may be noted that a 5% annual inflation rate would result in no real growth in this market, i.e., the $84 billion would be equivalent to $23 billion in 1975 dollars.)

For the primary purpose of this analysis, the projections of satellite annual revenue trends may now be compared with the projections of the total electron-based communications market. The data from Figure 5.30 (also expressed in current dollars) is repeated on Figure 5.57 for this comparison. The Baseline projection of $5.3 billion in 2000 for satellite revenues is only 2.1% of the projection for electron-based communication expenditures, and thus indicates extreme conservatism in this estimate. The Alternate A projection of $14 billion is less than 6% of the total electron-based communication projection and is thus also a conservative estimate. At $14 billion, this projection is only 35% of the current $40 billion level of expenditures for electron-based communications, so that even in the unlikely event of zero real growth in the total, the substitution of satellites in lieu of other transmission media should occur in a reasonably orderly manner.

In summary, the projections of annual satellite revenues developed in the preceding portions of this report meet the test of reasonableness in comparison with projections of total communications market expenditures. Even rather large errors in underestimating satellite costs and overestimating market size would not invalidate the projections of numbers of satellite channels supportable by the market. For example, a 100% increase in satellite costs combined with a 50% reduction in market size would result in the high Alternate A projection requiring only 22% of the total communication market expenditures. However, none of the above discussion should be taken as an indication that satellite operations will actually penetrate the market to the extent shown, since many other factors will govern the extent of market capture. The effects of such other factors are treated in the cross impact modeling described elsewhere in this report. This analysis is solely for the purpose of indicating that the projections of numbers of operational satellite channels and the costs thereof, are within the bounds of reasonable expectations from the standpoint of probable national expenditures for communications.

APPENDIX 6

PROJECTIONS OF ECONOMIC VARIABLES

Projections of five basic economic and communications industry variables were constructed for the period 1976 to 2000. Multiple regression techniques were employed in most of the projections. The communications variables were estimated using equations developed by Houthakker and Taylor (1) which were modified in some instances.

A. GROSS NATIONAL PRODUCT PER CAPITA (1975 DOLLARS).

1. Estimate of Gross National Product.

   a. It is assumed that GNP will reach the full employment level (4% rate of unemployment) in 1980. The balance of the projection estimates a 3.3% annual rate of growth in the full employment GNP.

   b. The assumption of full employment by 1980 is based, in part, on the stated objectives of U.S. economic policymakers.

   c. The assumption of a 3.3% annual growth rate is an extension of the 1975-85 forecast of the Bureau of Labor Statistics (2). This forecast is primarily based on estimates of labor force and labor productivity. Therefore, it is essentially a forecast of growth in the economy's ability to produce, rather than a projection of aggregate demand.

   d. The decision to forecast growth, rather than cyclical activity, is based on the transitory nature of business cycles.

   e. The forecast assumes a 6% real growth rate in 1976 and 7.2% per year from 1977-80, in order to reach full employment at that time.

   f. The projected GNP is shown in Table 5.

2. Conversion to 1975 Dollars.

The conversion to 1975 dollars utilized the implicit GNP price deflator (3, 4).

3. Population Estimate.

The population estimates are based on the U. S. Bureau of the Census, Series E projections (5). The Series E estimate uses a replacement birth rate, 2.1 births per woman. This results in an annual rate of increase in the population of .95%. This is the same series employed in the Bureas of Labor Statistics GNP estimates. The estimate is shown in Table 5.

B. LONG DISTANCE TELEPHONE CALLS PER CAPITA.

Forecasted values for the period 1976-2000 were generated by applying multiple regression analyses to the historical data for 1938-1974, with the war years (1942-45) excluded. Two estimating equations were used, the first involving both per capita income and the rate for long distance calls, the second per capita income only. The equations are:

$$\ln X_1 = -9.24071 + 1.58729 \ln X_2 - .35213 \ln X_{14} \qquad \text{(a)}$$

$$R^2 = .9550$$

$$S_e = .12832$$

$$\ln X_1 = -14.8749 + 2.28076 \ln X_2$$

$$R^2 = .9502$$

$$S_e = .13286$$

where:

$\ln X_1$ = natural logarithm of long distance telephone calls per capita

$\ln X_2$ = natural logarithm of GNP per captia in 1958 dollars ln X_{14} = natural logarithm of the long distance rate for a three minute call from New York to Chicago in constant dollars.

The variables employed are those used by Taylor (1). However, Taylor used the long distance rate in current, rather than in constant dollars. (Equations for C, D, and E come from the same source.)

1. Long Distance Telephone Calls Per Capita.

   Historical data from Historical Statistics of the U. S. (3) and the current Statistical Abstract (6). Historical data is shown in Table 2 and projections in Table 6.

2. GNP Per Capita (see A, above).

   The appropriate historical data appears in Table 1 and projections in Table 5.

3. Long Distance Rate for a Three Minute Call (New York to Chicago).

   a. Historical data from sources (3) and (6), see Table 2.
   b. Constant dollar conversion utilized the implicit GNP deflator as shown in Table 1.
   c. Projections for 1976 to 2000 assume that the real rate remains constant. Projections are in Table 6.

C. RADIO AND TELEVISION REVENUES (MILLIONS OF 1975 DOLLARS).

Forecasted values for the period 1976-2000 were generated by applying multiple regression techniques to historical data for 1947-70.

The estimating equation is :

$$X_4 = -2271.5 + 4.78582\ X_5 + .14198\ X_6$$

$$R^2 = .9943$$

$$S_e = 121.38779$$

where:

X_4 = radio and television broadcasting revenues in millions of 1975 dollars

X_5 = gross corporate product in billions of 1975 dollars

X_6 = total advertising expenditures in millions of 1975 dollars.

1. Radio and Television Revenues.

Historical data from (3) and converted to 1975 dollars by using the implicit GNP deflator. The historical data appears in Table 3 and projections in Table 6.

2. Gross Corporate Product.

a. Projections are based on the following equation:

$$X_5 = -75.22 + .66042\, X_{11}$$

$$R^2 = .9991$$

$$S_e = 6.14584$$

where:

X_5 = gross corporate product in billions of 1975 dollars

X_{11} = gross national product in billions of 1975 dollars.

b. For estimates of GNP, see A, above.

c. Historical data on Gross Corporate Product is for 1947-75 from (3) and updated from (4), see Table 3. Projections are in Table 6.

3. Advertising Expenditures.

a. Historical data from source (3), see Table 3.

b. Projections for 1976-2000 assume a 4% annual rate of increase. This is consistent with the average increase of 7% in current dollars from 1947-74 and the Bureau of Labor Statistics assumption of a 3% annual rate of inflation. Projections appear in Table 6.

c. Advertising expenditures were converted to 1975 dollars by using the implicit GNP deflator. Projections are in Table 6.

D. CHANGE IN PER CAPITA CONSUMER EXPENDITURES FOR TELEPHONE AND TELEGRAPH (1975 DOLLARS).

Projections utilized multiple regression techniques for data covering the period 1930-75 (1942-46 excluded). Variables in the following equation are in 1958 dollars, with the dependent variable subsequently converted into 1975 dollars.

$$X_7 = -1.11774 + .01581\, X_8 + .00767\, X_9 - 3.25893\, X_{10}$$

$$R^2 = .8001$$

$$S_e = .60944$$

where:

X_7 = change in per capita consumer expenditures for telephone and telegraph in 1958 dollars

X_8 = change in total personal consumption expenditures in billions of 1958 dollars

X_9 = personal consumption expenditures in the previous year in billions of 1958 dollars

X_{10} = change in relative price of telephone and telegraph.

1. Change in Per Capita Consumer Expenditures for Telephone and Telegraph.

   a. Historical data is from (7) and updated by (4). See Table 4.

   b. The data was converted from 1958 to 1975 dollars by using the implicit price deflator for consumer expenditures on telephone and telegraph (7, 4). The projections are shown in Table 7.

2. Change in Total Personal Consumption Expenditures.

   a. Historical data is from (7) and (4). See Table 4.

b. Personal Consumption Expenditures are projected to increase at the same rate as real GNP as shown in Table 7.

3. Personal Consumption Expenditures in the Previous Year (see above).

4. Change in Relative Price of Telephone and Telegraph.

a. The relative price of telephone and telegraph is the implicit price deflator for this service divided by the deflator for personal consumption expenditures. Historical data is from (7) and (4) and is shown in Table 4.

b. Based on historical trend, this variable is projected to fall .01 each year. Projections are in Table 7.

E. PER CAPITA CONSUMER EXPENDITURES ON RADIO AND TELEVISION RECEIVERS (1975 DOLLARS).

Projections utilized multiple regression techniques for the period 1930-75 (excluding 1942-46). Variables in the following equation are in 1958 dollars, with the dependent variable subsequently converted to 1975 dollars.

$$X_{12} = -1.47 + .06274\,X_8 + .00901\,X_9 + .99155\,X_{13}$$

$$R^2 = .9947$$

$$S_e = 1.43578$$

where:

X_{12} = per capita consumer expenditures on radio and TV receivers in 1958 dollars

X_8 = change in total personal consumption expenditures in billions of 1958 dollars

X_9 = total personal consumption expenditures in previous year in billions of 1958 dollars

X_{13} = per capita consumer expenditures on radio and TV receivers in the previous year in 1958 dollars.

1. Per Capita Consumer Expenditures on Radio and Television Receivers.

   a. Historical data is from (7) and (4) as shown in Table 4.

   b. Conversion from 1958 to 1975 dollars utilized the implicit deflator for consumer expenditures for radio and TV receivers. The projections appear in Table 7.

2. Change in Total Personal Consumption Expenditures (see D-2).

3. Total Personal Consumption Expenditures in Previous Year (see D-3).

4. Per Capita Consumer Expenditures on Radio and TV Receivers in Previous Year (see E-1).

   Projections are in Table 7.

TABLE 6.1

HISTORICAL DATA

	GNP 1975 $'s Billions	GNP 1958 $'s Billions	GNP Deflator 1975=100	GNP Deflator 1958=100	Population Thousands	GNP Per Capita 1958 $'s
1929		203.6		50.6	121167	1671
1930		183.5		49.3	123077	1490
1931		169.3		44.8	124040	1364
1932		144.2		40.2	124840	1154
1933		141.5		39.3	125579	1126
1934		154.3		42.2	126374	1220
1935		169.5		42.6	127250	1331
1936		193.0		42.7	128053	1506
1937		203.2		44.5	128825	1576
1938		192.9		43.9	129825	1484
1939		209.4		43.2	130880	1598
1940		227.2		43.9	132127	1720
1941		263.7		47.2	133402	1977
1942		297.8		53.0	134860	2208
1943		337.1		56.8	136739	2465
1944		361.3		58.2	138397	2611
1945		355.2		59.7	139928	2538
1946		312.6		66.7	141389	2211
1947	576.0	309.9	40.1	74.6	144126	2150
1948	601.7	323.7	42.8	79.6	146631	2208
1949	602.4	324.1	42.6	79.1	149188	2172
1950	660.4	355.3	43.1	80.2	151684	2342
1951	712.6	383.4	46.1	85.6	154287	2485
1952	734.4	395.1	47.1	87.5	156954	2517
1953	767.3	412.8	47.5	88.3	159565	2587
1954	756.5	407.0	48.2	89.6	162391	2506
1955	814.1	438.0	48.4	90.0	165275	2650
1956	829.2	446.1	50.6	94.0	168221	2652
1957	841.1	452.5	52.4	97.5	171274	2642
1958	831.4	447.3	53.8	100.0	174141	2659
1959	884.6	475.9	54.7	101.6	177830	2688
1960	906.5	487.7	55.6	103.3	180671	2699
1961	924.2	497.2	56.3	104.6	183691	2706
1962	984.8	529.8	56.9	105.8	186538	2840
1963	1024.2	551.0	57.7	107.2	189242	2912
1964	1080.1	581.1	58.5	108.8	191889	3028
1965	1148.3	617.8	59.7	110.9	194303	3180
1966	1223.2	658.1	61.3	113.9	196550	3348
1967	1255.0	675.2	63.3	117.6	198712	3398
1968	1313.4	706.6	65.8	122.3	200706	3521
1969	1348.7	725.6	69.0	128.2	202677	3580
1970	1342.9	722.5	72.7	135.2	204879	3555
1971	1386.6	746.0	76.1	141.4	207053	3603
1972	1468.2	789.9	78.6	146.1	208846	3782
1973	1559.9	839.2	83.0	154.3	210410	3988
1974	1526.0	821.0	91.6	170.2	211909	3874
1975	1516.0	834.5	100.0	185.9	213466	3909

TABLE 6.2

HISTORICAL DATA

	Total Long Distance Calls, Millions	Long Distance Calls Per Capita	Rate For 3 Minute Call N. Y. -Chicago 1958 $'s
1938	1048	8.07	5.01
1939	1095	8.37	5.09
1940	1150	8.71	4.33
1941	1201	9.00	3.71
1942	1318	9.77	3.30
1943	1508	11.03	3.08
1944	1632	11.79	3.01
1945	1803	12.89	2.93
1946	2051	14.51	2.36
1947	2186	15.17	2.08
1948	2245	15.31	1.95
1949	2274	15.24	1.96
1950	2263	14.92	1.93
1951	2299	14.90	1.81
1952	2373	15.12	1.71
1953	2920	18.30	1.70
1954	2993	18.43	1.67
1955	3212	19.43	1.67
1956	3468	20.62	1.60
1957	3687	21.53	1.54
1958	3833	22.01	1.50
1959	4161	23.40	1.48
1960	4417	24.45	1.40
1961	4599	25.04	1.39
1962	4891	26.22	1.37
1963	5183	27.39	1.35
1964	5658	29.49	1.33
1965	6205	31.94	1.26
1966	6826	34.73	1.23
1967	7410	37.29	1.19
1968	8030	40.01	1.06
1969	9125	45.02	1.01
1970	9855	48.10	.96
1971	10585	51.12	.74
1972	12045	57.67	.72
1973	13505	64.18	.75
1974	14235	67.18	.68

TABLE 6.3

HISTORICAL DATA

	Radio & TV Revenues Millions 1975 $'s	Gross Corporate Product Billions 1975 $'s	Advertising Expenditures Millions 1975 $'s
1947	912.7	309.5	10632
1948	972.0	332.2	11365
1949	1051.6	326.5	12211
1950	1273.8	365.7	13248
1951	1483.7	392.2	13939
1952	1683.7	402.1	15193
1953	1911.6	427.4	16326
1954	2161.8	416.0	16938
1955	2473.1	466.1	18996
1956	2719.4	476.3	19575
1957	2782.4	481.9	19678
1958	2882.9	460.2	19149
1959	3144.4	508.8	20576
1960	3178.1	523.4	21460
1961	3378.3	530.7	21039
1962	3713.5	572.6	21759
1963	3928.9	600.2	22716
1964	4294.0	638.8	24197
1965	4619.8	686.4	25553
1966	5016.3	735.7	27194
1967	5026.9	750.7	26645
1968	5386.1	795.9	27549
1969	5828.1	826.2	28235
1970	5426.4	814.9	26960
1971		837.9	27385
1972		901.9	29428
1973		955.7	30217
1974		933.0	28985
1975		911.0	

TABLE 6.4

HISTORICAL DATA

	Consumer Expenditures For Telephone & Telegraph Per Capita 1958 $'s	Change In Per Capita Expenditures For Telephone & Telegraph 1958 $'s	Personal Consumption Expenditures Billions 1958 $'s	Change In Personal Consumption Expenditures Billions 1958 $'s	Implicit Price Deflator For Personal Consumption Expenditures	Implicit Deflator Expenditures For Telephone & Telegraph	Relative Price Of Telephone & Telegraph	Change In Relative Price Of Telephone & Telegraph	Personal Expenditures For Radio & TV Receivers Per Capita 1958 $'s
1929	7.08		139.6		55.3	66.3	1.20		4.75
1930	7.02	- .06	130.4	- 9.2	53.6	66.8	1.25	.05	5.56
1931	6.67	- .35	126.2	- 4.2	47.9	67.0	1.40	.15	4.07
1932	5.76	- .91	114.9	-11.3	42.3	67.0	1.58	.18	3.09
1933	5.19	- .57	112.8	- 2.1	40.6	66.9	1.65	.07	2.45
1934	5.32	.13	118.0	5.2	43.5	65.9	1.52	- .13	2.67
1935	5.66	.32	125.5	7.5	44.4	65.5	1.48	- .04	2.92
1936	6.12	.46	156.4	30.9	44.7	65.2	1.46	- .02	3.91
1937	6.54	.42	143.0	-13.4	46.5	64.3	1.38	- .08	4.40
1938	6.48	- .04	152.2	9.2	45.6	64.4	1.41	.03	3.98
1939	6.84	.36	148.2	- 4.0	45.1	64.3	1.43	.02	5.09
1940	7.24	.40	155.7	7.5	45.5	64.3	1.41	- .02	5.86
1941	8.05	.81	165.5	9.8	48.7	64.7	1.33	- .08	6.93
1942	8.97	.92	161.5	- 4.0	54.8	68.2	1.25	- .08	6.00
1943	10.12	1.15	165.8	4.3	59.9	70.3	1.17	- .08	3.72
1944	10.73	.61	171.3	5.5	63.2	72.5	1.15	- .02	2.63
1945	11.55	.82	183.0	11.7	65.4	73.6	1.13	- .02	2.87
1946	12.38	.83	203.4	20.4	70.5	73.6	1.04	- .09	9.12
1947	12.76	.38	206.3	2.9	77.9	74.8	.96	- .08	9.08
1948	13.59	.83	210.9	4.6	82.3	78.6	.96	0	8.71
1949	14.15	.56	216.4	5.5	81.7	82.0	1.00	.04	9.36
1950	14.52	.37	230.5	14.1	82.9	88.2	1.06	.06	13.38
1951	15.61	1.09	233.3	2.8	88.6	90.1	1.02	- .04	12.27
1952	16.52	.91	239.4	6.1	90.5	93.4	1.03	.01	13.79
1953	17.39	.87	250.8	11.4	91.7	96.7	1.06	.03	15.43
1954	18.04	.65	255.7	4.9	92.5	95.2	1.03	- .03	16.89
1955	19.68	1.62	274.2	18.2	92.8	94.1	1.01	- .02	18.39
1956	20.84	1.16	281.3	7.1	94.8	95.3	1.01	0	18.46
1957	21.94	1.10	288.1	6.8	97.7	97.1	.99	- .02	16.81
1958	22.35	.41	290.1	2.0	100.0	100.0	1.00	.01	16.29
1959	23.04	.69	307.2	17.1	101.3	102.2	1.01	.01	18.27
1960	24.00	1.04	316.1	8.9	102.9	103.8	1.01	0	17.97
1961	25.22	1.16	322.6	6.5	103.9	104.1	1.00	- .01	19.05
1962	26.27	1.05	338.5	15.9	104.9	104.1	.99	- 01	20.46
1963	27.91	1.64	353.4	14.9	106.1	104.3	.98	- .01	23.45
1964	29.55	1.64	373.6	20.2	107.4	104.3	.97	- .01	27.96
1965	32.16	.61	397.7	24.1	108.8	102.8	.95	- .07	31.68
1966	34.89	2.73	418.2	20.5	111.5	100.7	.90	- .05	37.37
1967	37.16	2.27	430.1	11.9	114.4	102.0	.89	- .01	39.83
1968	39.93	2.77	452.9	22.8	118.4	102.0	.86	- .03	41.29
1969	43.43	3.50	469.1	16.2	123.5	103.3	.84	- .02	43.66
1970	46.05	2.62	477.5	8.4	129.3	104.7	.81	- .03	49.06
1971	47.37	1.32	496.4	18.9	134.4	110.2	.82	.01	49.58
1972	51.00	3.63	527.3	30.9	138.2	116.3	.84	.02	55.09
1973	55.97	4.97	552.1	24.8	145.9	119.2	.82	- .02	61.47
1974	58.31	2.34	546.2	- 5.9	162.5	124.3	.77	- .05	64.26
1975	62.99	4.68	557.6	11.4	174.6	128.4	.74	- .03	67.93

TABLE 6.5

PROJECTIONS

	GNP 1975 $'s Billions	Population Thousands	GNP Per Capita 1958 $'s	GNP Per Capita 1975 $'s
1976	1606.9	215,957	4003	7441
1977	1722.5	218,009	4251	7901
1978	1846.7	220,080	4514	8391
1979	1979.6	222,171	4794	8910
1980	2129.6	224,132	5112	9502
1981	2200.0	226,373	5228	9719
1982	2272.5	228,637	5347	9939
1983	2346.1	230,923	5466	10160
1984	2423.6	233,233	5591	10391
1985	2499.4	235,701	5705	10604
1986	2582.0	237,840	5841	10856
1987	2667.1	240,001	5979	11113
1988	2755.2	242,183	6121	11377
1989	2846.1	244,386	6266	11643
1990	2940.0	246,639	6413	11920
1991	3037.0	248,612	6572	12216
1992	3137.2	250,601	6735	12519
1993	3240.7	252,605	6903	12829
1994	3347.6	254,626	7073	13147
1995	3458.2	256,015	7267	13508
1996	3572.3	257,551	7462	13870
1997	3690.2	259,196	7660	14237
1998	3811.9	260,750	7865	14619
1999	3937.7	262,415	8073	15006
2000	4067.7	264,430	8276	15383

TABLE 6.6

PROJECTIONS

	Long Distance Telephone Calls Per Capita (a)	Radio & TV Revenues 1975 $'s Millions	Gross Corporate Product 1975 $'s Billions	Advertising Expenditures 1975 $'s Millions	Long Distance Telephone Calls Per Capita (b)
1976	58.05	6,898.44	986.01	31350	57.03
1977	63.86	7,441.84	1062.35	32604	65.41
1978	70.25	8,019.56	1144.38	33908	75.01
1979	77.29	8,632.27	1232.15	35265	86.04
1980	85.58	9,306.55	1331.21	36675	99.61
1981	88.69	9,737.32	1377.70	38142	104.84
1982	91.91	10,183.13	1425.58	39668	110.37
1983	95.18	10,641.09	1474.19	41255	116.05
1984	98.66	11,120.30	1525.37	42905	122.19
1985	101.87	11,603.51	1575.43	44621	127.95
1986	105.75	12,118.01	1629.98	46406	135.01
1987	109.75	12,650.54	1686.19	48262	142.40
1988	113.91	13,203.14	1744.37	50193	150.23
1989	118.23	13,775.39	1804.40	52200	158.47
1990	122.66	14,368.61	1866.41	54288	167.07
1991	127.52	14,983.62	1930.48	56460	176.67
1992	132.58	15,620.89	1996.65	58718	186.82
1993	137.86	16,281.51	2065.00	61067	197.62
1994	143.29	16,966.25	2135.60	63510	208.90
1995	149.58	17,676.43	2208.64	66050	222.20
1996	156.00	18,412.20	2284.00	68692	236.03
1997	162.63	19,174.99	2361.86	71440	250.56
1998	169.59	19,965.26	2442.23	74297	266.11
1999	176.76	20,784.88	2525.32	77269	282.44
2000	183.87	21,634.60	2611.17	80360	298.90

TABLE 6.7

PROJECTIONS

	Change In Per Capita Consumer Expenditures For Telephone & Telegraph 1958 $'s	Consumer Expenditures For Telephone & Telegraph Per Capita 1975 $'s	Personal Consumption Expenditures Billions 1958 $'s	Change In Personal Consumption Expenditures Billions 1958 $'s	Consumer Expenditures On Radio & TV Receivers Per Capita 1975 $'s
1976	3.5443	85.42	579.9	22.3	72.60
1977	3.9129	90.46	614.7	34.8	77.94
1978	4.3094	95.99	657.7	43.0	84.07
1979	4.6883	102.00	703.8	46.1	90.74
1980	5.1051	108.56	753.9	50.1	98.02
1981	5.0910	115.10	778.8	24.9	104.10
1982	5.2946	121.90	804.5	25.7	110.41
1983	5.5044	128.96	831.0	26.5	116.95
1984	5.7235	136.31	858.5	27.5	123.74
1985	5.9628	143.97	887.8	29.3	130.84
1986	6.1875	151.91	917.1	29.3	138.13
1987	6.4281	160.17	947.4	30.3	145.69
1988	6.6779	168.74	978.8	31.4	153.54
1989	6.9298	177.64	1010.9	32.1	161.63
1990	7.1966	186.89	1044.3	33.4	170.05
1991	7.4686	196.46	1078.7	34.4	178.75
1992	7.7513	206.43	1114.3	35.6	187.77
1993	8.0434	216.75	1151.1	36.8	197.11
1994	8.3446	227.46	1189.1	38.0	206.76
1995	8.6551	238.58	1228.3	39.2	216.76
1996	8.9779	250.11	1268.9	40.6	227.12
1997	9.3083	262.06	1310.7	41.8	237.84
1998	9.6526	274.45	1354.0	43.3	284.94
1999	10.0068	287.30	1398.7	44.7	260.42
2000	10.3717	300.62	1444.8	46.1	272.29

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