SPACE COMMERCIALIZATION: ANALYSIS OF R&D INVESTMENTS WITH LONG TIME HORIZONS

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ABSTRACT

This paper presents an analysis of a typical hypothetical investment in an R&D project that leads first to a series of orbiting experiments launched by the NASA Shuttle, and later to a commercial production process carried out in space. The eventual profitability is quite large, recovering the total outlay in the first two years of commercial operation, with comparable profits continuing many more years into the future. However, there is an 8-year delay between inception of the R&D and realization of a profit stream. As a result, the Internal Rate of Return is only in the 30% range, which reduces this R&D program to being merely competitive with other corporate investment opportunities. When the risk of failure (inherent in any R&D project) is factored in, the space commercialization project becomes considerably less attractive. This paper analyzes the effects of alternate means of financing such a project, and comments on the differences in risk perceived by diverse investors. In order to investigate the viewpoint of an R&D Limited Partnership, the use of high leverage to finance the venture is modeled. Under certain circumstances, an RDLP may be an advantageous mechanism for investing in space commercialization.

I. INTRODUCTION

The prospect of space commercialization [1,2] is alluring because of the outstanding potential associated with exploring new fields. Yet industry is by no means stampeding to get aboard the Space Shuttle, despite the favorable terms offered by NASA. It is therefore appropriate to ask why this condition prevails [3,4].

Factors such as a lack of knowledge of what is feasible today constitute an obstacle to commercialization, and NASA is moving to alleviate that condition. Another major obstacle is the very long lead times associated with space ventures, and this leads directly into the theme of this paper. The fact is that, when examined by the standard financial-analysis methods commonly used today, most space commercialization investment opportunities do not look sufficiently attractive to secure the corporate commitment needed to persevere over a long gestation period. Entering a space-commercialization enterprise requires a CEO decision to start down a new path; a predisposition to apply financial analysis methods to future business opportunities in space will quite likely militate against such decisions.

How profitable does a space venture have to be in order to compete with other conventional investment opportunities? In order to provide a quantitative answer to this question, we have carried out a series of return-on-investment calculations for a typical hypothetical investment in an R&D program that leads to a new product produced in space. The investment provides a very generous stream of profits for 10 years or more. Nevertheless, the detailed analysis of the discounted after-tax cash flow associated with this investment reveals why the typical industrial investor has only limited enthusiasm for the opportunity to commercialize space.

It must be recognized at the outset that one single hypothetical example cannot possibly represent all the different possibilities. Still, the merit of this example is in showing how the perception of an industrial manager is affected by long lead times, so that even the most lucrative investments deflate to ordinary size when several years of front-end R&D is required before profits begin to accrue.

Section II of this paper describes the proposed investments. Section III presents the calculated Internal Rate of Return (IRR). Section IV shows how certain changes in financing and/or tax policy might alter the IRR. Section V briefly considers the effects of uncertainty. Section VI is a summary.

II. THE HYPOTHETICAL INVESTMENT

We assume a 21-year program that begins with 3 years of research, 5 more years of development, tests, initial shuttle flights and perfecting the process (the space equivalent of what on earth would be the pilot plant phase), and 13 additional years of profitable manufacturing of the product in space. This timetable is reasonable for a product that begins with a genuine breakthrough in technology and goes on to either create a new market or dominate an existing market.

The product envisioned by the research staff is a metal-matrix composite involving cobalt, manganese and tungsten, having exceptional strength and uniformity. Making it requires liquid tungsten (temperature 4000°K) to be contained for many minutes during production, in the absence of any magnetic fields. As such, no earthbound containment system is acceptable, and so the entire operation must be carried out in the weightlessness of orbit. (Readers more comfortable with pharmaceuticals or semiconductors can readily make the adjustment to apply the numbers in this case to examples drawn from their own fields of interest.)

The initial research phase leads to a go/no-go decision before embarking on major hardware expenditures. The costs are $150,000, $450,000 and $800,000 in the first 3 years. If the decision is made to go ahead, then in year 4, as spaceflight hardware begins to enter the picture, R&D costs total $2.6 million. Year 5 requires $5 million in R&D costs and $5 million in capital investment. Year 6 (when the first two launches occur) required $8 million in R&D costs and $12 million in capital investment. This concludes the R&D phase. A second go/no-go decision occurs at this point. If the initial space flight tests are successful, then the certainty of profitability downstream is assured, and so the decision is made to move forward with a major committment of capital and hardware construction.

As refinement of production moves forward, we hypothesize for year 7 a major input of capital equipment totaling $30 million, accompanied by engineering costs of $10 million. In year 8, with full scale production nearing readiness, additional capital requirements are only $10 million, but now there are $15 million in engineering costs.

The total face-value cost up to this point has been $57 million in capital expenditures, $17 million in R&D, and $25 million in engineering costs. Table I summarizes these expenditures. At this point the company has spent almost $100 million (over 8 years) but has not yet seen any profits.

TABLE I. CASH FLOW STREAMS ASSOCIATED WITH PRODUCTION OF NEW MATERIAL IN SPACE

YEAR	R&D COSTS	START-UP ENGINEERING	CAPITAL EXPENSES	PROFITS
1	$150,000			
2	450,000			
3	800,000			
4	2,600,000			
5	5,000,000		5,000,000	
6	8,000,000		12,000,000	
7		10,000,000	30,000,000	
8		15,000,000	10,000,000	
9		10,000,000		32,000,000
10		7,500,000		56,160,000
11		4,080,000		60,600,000
12		2,720,000		65,500,000
13		1,820,000		70,740,000
14		1,210,000		67,740,000
15		810,000		57,580,000
16		540,000		48,940,000
17		360,000		41,600,000
18		240,000		35,360,000
19		160,000		30,050,000
20		110,000		25,550,000
21		70,000		21,710,000

Once begun, the stream of profits is generous indeed. After a 6-month shakedown period, the process for making the metal-matrix composite is fully operational in space, and partway into year 9 a stream of profits begins to occur.* The product quality is so great that the corporation's marketing department estimates that the metal-matrix composite will capture 85% of the market for electric motor bearings, even at a high selling price. As a result, the total profit is expected to be $56 million per year in the first full year of operation. After that, profits are expected to escalate 8% per year for the next 4 years, owing to a combination of inflation and greater acceptance by customers.

* Over the next several years of profitable operations, engineering costs will decline steadily as bugs are worked out of the system: $10 million in year 9, $7.5 million in year 10, $4 million in year 11, and declining 33% annually thereafter.

Beyond this point, it is conservatively assumed that competitors will somehow enter the market, so that profits fall 15% per year for the following 8 years. Actually, it makes very little difference what the profits do in the out-years, because the discount rate reduces them to small fractions of their face value anyway. Thus long-range uncertainty is not disruptive of investment planning calculations done today. The profit stream is also presented in Table I.

This hypothetical case can be criticized on a variety of points. For example, no description has been given as to what the capital expenditures are for. Moreover, expenditures for working capital have been ignored, and perhaps some part of the engineering and start-up costs may be capitalized and then depreciated. Addressing these issues would clutter the example with details, and would detract from the point of the paper, which is that long lead times before profitability exert a very inhibiting effect upon R&D committments. Virtually all concepts whose goal is sustained processing of materials in space have such lead time associated with them. In this respect, the example is typical of space commercialization ventures.

III. INVESTMENT EVALUATION

In evaluating any proposed investment, a dollar received in the future must be discounted at an appropriate rate to determine its present value today. Beyond this, one can choose from a variety of evaluation indices, including the Net Present Value (NPV), Internal Rate of Return (IRR), Equivalent Rate of Return (EqRR), and profitability Index (PI). The Internal Rate of Return is that discount rate at which the net present value of initial outlays and later profits sums to exactly zero [5].

In this paper we choose the IRR, because it is the most popular index used by corporate finance departments. Typically, in today's economy, corporations seldom invest in projects with an IRR below about 30%, even though the cost of borrowing money is down around 15%. This is because "mandatory" investments (those needed to keep the company running) have the first priority for capital, regardless of their IRR. As a result, "discretionary" investments (including R&D and ventures into new markets) reside far down the list. For most companies, so many investments are available each year that total levels of investment are capped by cash flow limitations [6]. As we shall see, this condition beckons to third-party financiers to engage in joint ventures with companies whose ideas are stymied by such limitations.

As the discount rate increases, the significance of front-end expenditures is enhanced, and returns in later years fade into oblivion. Table II illustrates this point by tabulating the appropriate multiplying factors for several years for discount rates of 10, 20 and 30%. In year 8, for example, a dollar is worth 51 cents, 28 cents, and 16 cents. The manager concerned with "bottom-line performance" cannot realistically have a horizon longer than 5 years when choosing among investment opportunities that offer IRRs above 30%.

TABLE II. DISCOUNT FACTORS FOR CERTAIN RATES

d = rate, n = year number, $f = 1/(1+d)^{n-1}$

YEAR	10%	20%	30%
1	1.0	1.0	1.0
2	.909	.833	.769
3	.751	.694	.592
4	.683	.579	.455
5	.621	.482	.350
8	.513	.279	.159
10	.424	.194	.094
15	.263	.078	.025
20	.164	.031	.007
21	.149	.026	.005

Evaluation Indices other than IRR are more appropriate for projects that are lucrative but long term. The manager who is concerned with the long term realizes that the cost of capital* ultimately sets the hurdle rate, and computes the Net Present Value (NPV) of a long term project using that discount rate. This is the only way a long term project that requires continuing initial investment can survive the screening process.

Nevertheless, the IRR is still the index used by the great majority of American corporations when evaluating proposed R&D projects. Therefore it is the best choice to illuminate our understanding of corporate decision making. For the cash flows presented in Table I, the calculated IRR is 30.7%. Of course, this is the pre-tax IRR, which is only of significance to corporations that pay no taxes.

The after-tax IRR is calculated by including depreciation and tax credits, and by using a Federal tax rate of 46% with a state tax rate of 4%. The investment Tax Credit (ITC) is 10% of the capital expenses each year. Depreciation follows the ACRS rules for equipment (5-year schedule), but depreciation does not begin until year 8, at which time the entire $57 million capital investment is eligible. This set of conditions yields the dollar amounts presented in Table III. The after tax cash flow is discounted at whatever rate is necessary to give a NPV of zero, and this rate is the after tax IRR.

TABLE III. AFTER TAX CASH FLOW CALCULATION – FUNDING ALL FROM EQUITY – MILLIONS OF DOLLARS

Year	Pretax Cash Flow (from Table I)	Taxable Income	Tax Owed	Tax Credits	After Tax Cash Flow	Cumulative ATCF (Discounted at 27.8%)
1	-.15	-.15	-.07	0.	-.08	-.08
2	-.45	-.45	-.22	0.	-.24	-.26
3	-.80	-.08	-.38	0.	-.42	-.52
4	-2.60	-2.60	-1.25	0.	-1.35	-1.17
5	-10.00	-5.00	-2.40	0.50	-7.10	-3.83
6	-20.00	-8.00	-3.84	1.20	-14.96	-8.23
7	-40.00	-10.00	-4.80	3.00	-32.20	-15.64
8	-25.00	-26.40	-12.67	1.00	-11.33	-17.67
9	22.00	3.76	1.80	0.	20.20	-14.83
10	48.66	34.98	16.79	0.	31.87	-11.31
11	56.58	47.46	22.78	0.	33.80	-8.40
12	62.78	58.22	27.94	0.	34.83	-6.04
13	68.92	68.92	33.08	0.	35.84	-4.15
14	66.52	66.52	31.93	0.	34.59	-2.71
15	56.77	56.77	27.25	0.	29.52	-1.76
16	48.40	48.40	23.23	0.	25.17	-1.12
17	41.24	41.24	19.79	0.	21.44	-.69
18	35.12	35.12	16.86	0.	18.26	-.41
19	29.89	29.89	14.35	0.	15.55	-.22
20	25.44	25.44	12.21	0.	13.23	-.09
21	21.64	21.64	10.39	0.	11.25	-.01

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* A weighted average of the borrowing rate (15-16%) and the return expected on stockholder's equity (25-30%).

For our hypothetical example, the IRR is 27.8%. This is a very disappointing figure for an investment with such a high profit potential, but it must be recognized that, for example, the $33.8 million after-tax gain of year 11 is only worth $2.9 million in today's dollars when discounted at 27.8%. By contrast, the investor who calculates NPV with a fixed corporate discount rate of 15% would find that same $33.8 million contributing $8.4 million in today's dollars. Figure 1 displays the variation of after tax NPV of this project with increasing discount rate. The curve crosses the horizontal axis at the IRR, and the NPV changes from gain to loss there.

Because of the long waiting time for profits to begin flowing, the NPV of this project is quite volatile to changes in the discount rate. For projects with a much shorter time horizon, the NPV is less dependent upon later years, and hence less affected by discount rate. It is not difficult to construct a 5-year project with an IRR above 30% but a smaller NPV (at 20%) than this project's. The NPV line for the alternate project would then cross the curve of Figure 1 somewhere around 22 or 25%. If IRR were the main decision-criterion, the short-term project would be chosen; but if Profitability Index (PI) or NPV (at 20% opportunity cost of money) was used, the space-manufacturing project would win out.

IV. EFFECT OF CHANGES IN TAXES OR FINANCING

American space policy recognizes as a goal the desirability of encouraging the private sector to commercialize space [7]. Often it has been the custom to use the tax laws as an instrument of policy, so it is worth considering how potential investors looking at this space-commercialization project would respond to changes in tax law.

One such change occurred in 1981, when a 25% tax credit was offered to companies who increase their R&D expenditures in a year [8]. Our hypothetical case was first analyzed without that tax credit, which gave an IRR of 27.8%. When a 25% tax credit was given for the research expenses of the first 3 years, the IRR rose to 28.4%. This difference may seem inconsequential, but remember that the total spending in the first 3 years accumulated to only $1.4 million out of a $100 million project. The fact that this tax credit has any effect at all is because it occurs in the early years. Had a 25% credit been applied to the entire 6-year span of R&D, the effect would have been much greater.

Another possibility that is often discussed in Congress is the use of targeted tax credits [6]. For example, the law might be amended to provide an additional 10% tax credit for capital investments in space manufacturing. Our calculations indicate that such a change in tax law would increase the IRR by less than 2 percentage points, hardly enough to motivate a hesitant investor.

Alternate forms of financing now available in the private sector are likely to be more persuasive than government tax changes. Leveraging of investments is possible through a variety of new techniques. To model this, we considered the case in which $40 million out of the total of $57 million in capital costs was obtained from an external financing source. The $40 million is borrowed in the middle of year 7, at the rather high fixed interest rate of 20%, to be paid back uniformly over 8 years. An 8-year finance lease might be one example of such financing. It is incidentally assumed that this new debt will not adversely affect the corporation's bond rating or otherwise drive up its cost of borrowing. This is done to keep the example simple. Such "project financing" would not be typical of major corporations, but might represent the behavior of an R&D Limited Partnership (RDLP) formed explicitly for this venture.

Table IV shows the cash flow for this split-financed case. The presence of $820,000 monthly payments (part principal, part interest) beginning in the middle of year 7 reduce the operating cash flow in the early profitable years, but the very tiny capital outlays in years 7 and 8 compensate for this. Thus cash flow is smaller in each year 7-15 (i.e., less negative in 7 and 8, less positive thereafter). This causes a small pretax improvement, and a large after tax improvement. As a consequence of external financing, the IRR jumps up to 34.0%, compared to 28.4% in the unleveraged case. To investors with other options to choose from in the 30% IRR range, this difference may be significant.

TABLE IV. AFTER TAX CASH FLOW CALCULATION – FUNDING INCLUDES $40 MILLION BORROWED CAPITAL – MILLIONS OF DOLLARS

Year	Pretax ≠ Cash Flow	Taxable Income	Tax Owed	Tax Credits*	After Tax Cash Flow	Cumulative ATCF (discounted at 34.0%)
1	-.15	-.15	-.07	.04	-.04	-.04
2	-.45	-.45	-.22	.11	-.12	-.13
3	-.80	-.80	-.38	.20	-.22	-.25
4	-2.60	-2.60	-1.25	.00	-1.35	-.81
5	-10.00	-5.00	-2.40	.50	-7.10	-3.01
6	-20.00	-8.00	-3.84	1.20	-14.96	-6.47
7	-14.95	-13.87	-6.66	4.00	-4.29	-7.21
8	-24.89	-34.50	-16.56	0.	-8.33	-8.29
9	12.11	-4.21	-2.02	0.	14.13	-6.93
10	38.77	27.95	13.42	0.	25.35	-5.11
11	46.68	41.52	19.93	0.	26.75	-3.68
12	52.88	53.55	25.71	0.	27.18	-2.60
13	59.03	65.74	31.56	0.	27.47	-1.78
14	56.63	64.83	31.12	0.	25.52	-1.22
15	51.82	56.57	27.15	0.	24.67	-.81
16	48.40	48.40	23.23	0.	25.17	-.50
17	41.24	41.24	19.79	0.	21.44	-.30
18	35.12	35.12	16.86	0.	18.26	-.17
19	29.89	29.89	14.35	0.	15.55	-.09
20	25.44	25.44	12.21	0.	13.23	-.04
21	21.64	21.64	10.39	0.	11.25	-.01

≠ Includes monthly payments of $.82 million in years 7-15

* Includes 25% R&D Credit for years 1-3.

The driving force that makes the leveraged investment more attractive is that money borrowed at 20% is earning a substantially higher rate. Every homeowner experiences the same advantage: when the house increases 10% in value, if it is 75% mortgaged, the homeowner's return on equity is 40%. The tax deductibility of interest payments mitigate the burden of the 20% interest rate for the RDLP or leveraged corporation.

Combinations of leveraging and government support enhance the attractiveness of the investment still further. For example, a 10% additional tax credit adds 4 percentage points to the IRR; and a government-subsidized loan at 10% instead of 20% adds 1.6 percentage points.

Table V collects and summarizes the several variations upon the original example. The essential point to be grasped from all this financial discussion is that there is an incentive for the leveraged investor (RDLPs, joint ventures, etc.) to participate in space commercialization. The same opportunity in space carries a disincentive to the equity-funded investor (or large corporation relying upon conventional IRR analysis) because of the exceptionally long lead times associated with R&D ventures in space.

TABLE V. IRR UNDER VARIOUS OPTIONS

BASE CASE	27.8%
with 25% tax credit on R&D portion	28.4%
Unconventional Financing	
2/3 of capital borrowed at 20%	34.0%
Subsidized Loan	
2/3 of capital borrowed at 10%	35.6%
Additional 10% tax credit	
All Equity Financing	29.6%
2/3 of capital borrowed at 20%	33.6%

V. RISK

So far, the example has treated the various cash flow items as fixed and certain, when in reality, the project is encumbered with considerable uncertainty. The cash flow is by no means definite, especially in later years. Risk goes both ways: profits may not materialize, or they may be greater than expectations, or hold up longer.

There are two points where a go/no-go decision is made, and we have only looked at the outcome when the decision is "go." Were the project to be stopped at either of those points, the total preceding expenditure would be lost. The estimated return on investment should be lowered in order to compensate for that possibility.

The proper treatment of risk is the subject of an extensive literature [9]. Here we only observe that the size of the corporation strongly influences their ability to bear risk. For a large company in which an R&D Expenditure of $1.4 million is small, the simple "expected value" method of predicting NPV is adequate. For a small company, the penalty for failure may be bankruptcy, in which case their perceived risk will be much higher and their approach far more hesitant.

The expected value method is relatively simple: here the cash flow in each year is multiplied by the probability that the project is still ongoing in that year. The resulting NPV or IRR is the expected value of the NPV or IRR. Referring to our example, suppose that the probability is 1/2 that the first R&E hurdle will be overcome, and hence the project will proceed beyond 3 years. Assume further that at the second go/no-go point, the decision is made to go ahead. But then let the probability be only 1/2 that the profits will materialize as predicted – this corresponds to a cautious guess about the market share that can be captured with the new space-produced alloy. To represent this, the cash flows in Table I would be revised by multiplying the first 3 values by 1, all subsequent costs by 1/2, and all the profits by 1/4. The expected value of the NPV can be termed the "utility" of the investment [10]. Obviously the expected value of any index of performance will decline sharply.

We have modeled this "expected value" case and calculated the after tax IRR to be 15.7%, a precipitous drop from the "sure-thing" figure of 28.4%. If the investment is leveraged as described in the preceding section, Table III has to be similarly revised and the resulting after tax IRR is 17.6%, down from 34%. For such a return, borrowing at 20% becomes of questionable value. However, given the freedom to bail out after 3 years with only a $1.4 million loss, the question posed to either investor by these expected value calculations is "Am I willing to invest $1.4 million to reach that first decision point?" For such an R&D-level decision, an expected return of 15-18% is not too bad.

When a company cannot afford to lose big, they are not likely to enter into a project such as this. Consider a medium-sized company in which a $1.4 million R&D loss is tolerable, but a $34 million loss (the total cost of reaching the second go/no-go decision point) is not. Assume the company's survival is seriously threatened by such a loss. In that case, the weighted value of the various outcomes will greatly distort their outlook on this project. The utility of the expenditures in years 4 through 6 will be so large and negative that the utility of the entire project (the weighted expected value of the NPV) will be negative. Thus for this company the proper decision at the outset is not to pursue the project.

Down-side risk is not the only kind of uncertainty; the possibility of some major scientific breakthrough is equally important. Yet very few business investors give any weight to concepts like the value to future generations. Such very long term risks and rewards belong to the entire society.

Finding ways to encourage medium-sized companies to take risks puts us at once into questions of public policy [4]. Such avenues as loan guarantees, research grants, and free flight opportunities offered by NASA, all fall within that category. Here it suffices to note that the weighted value of risk is an extra disincentive to all but very large corporations.

VI. SUMMARY

By following a single hypothetical example through a series of variations, we have described how different potential investors might look at the opportunity to participate in space commercialization. The viewpoints represented include those of large and small, equity-based and leveraged investors.

The example itself is fairly typical of commercial opportunities in space. The chief characteristics are a steadily increasing requirement for capital infusion over an 8-year period, followed by a very generous stream of profits running another decade or more beyond. There is a decision point at 3 years, at the conclusion of laboratory R&D; and another at 6 years, following 2 initial space flights.

Many companies compute the Internal Rate of Return (IRR) enroute to evaluating an investment opportunity, and this has been done here. The IRR is constrained from becoming very large by the long lead time for profits; the value of distant dollars is reduced to insignificance as the IRR nears 30%. For this project, the Net Present Value (NPV) responds sharply to changes in the discount rate, as shown in Figure 1.

Changes in government tax policy have been analyzed as well. The new R&D tax credit is not important, because R&D is a small fraction of the total project cost. An additional 10% tax credit for capital invested in space ventures is not persuasive, either. However, creative new financial coalitions, such as RDLPs, may be able to take advantage of leveraging to facilitate venturing into space.

The uncertainty of R&D directed towards space must not be minimized. Large companies can afford to take risks of the magnitude of a space venture; medium and small firms cannot. The advantage of RDLPs is particularly noteworthy here: on the one hand, a total loss is acceptable if unpleasant; and on the other, the partners can leverage their individual investment shares. Uncertainty and leverage together increase the volatility of return-on-investment, but RDLP investors are cognizant of that and willingly accept risk.

Certain recommendations are implicit in the results of these calculations. First, industrial leaders should take an imaginative and long-range view when considering space investments, and calculate the NPV of projects instead of the IRR. For its part, NASA should maintain its outstanding record of reliability for the Shuttle, resist delays vigorously, and move swiftly to accommodate companies getting ready to fly.

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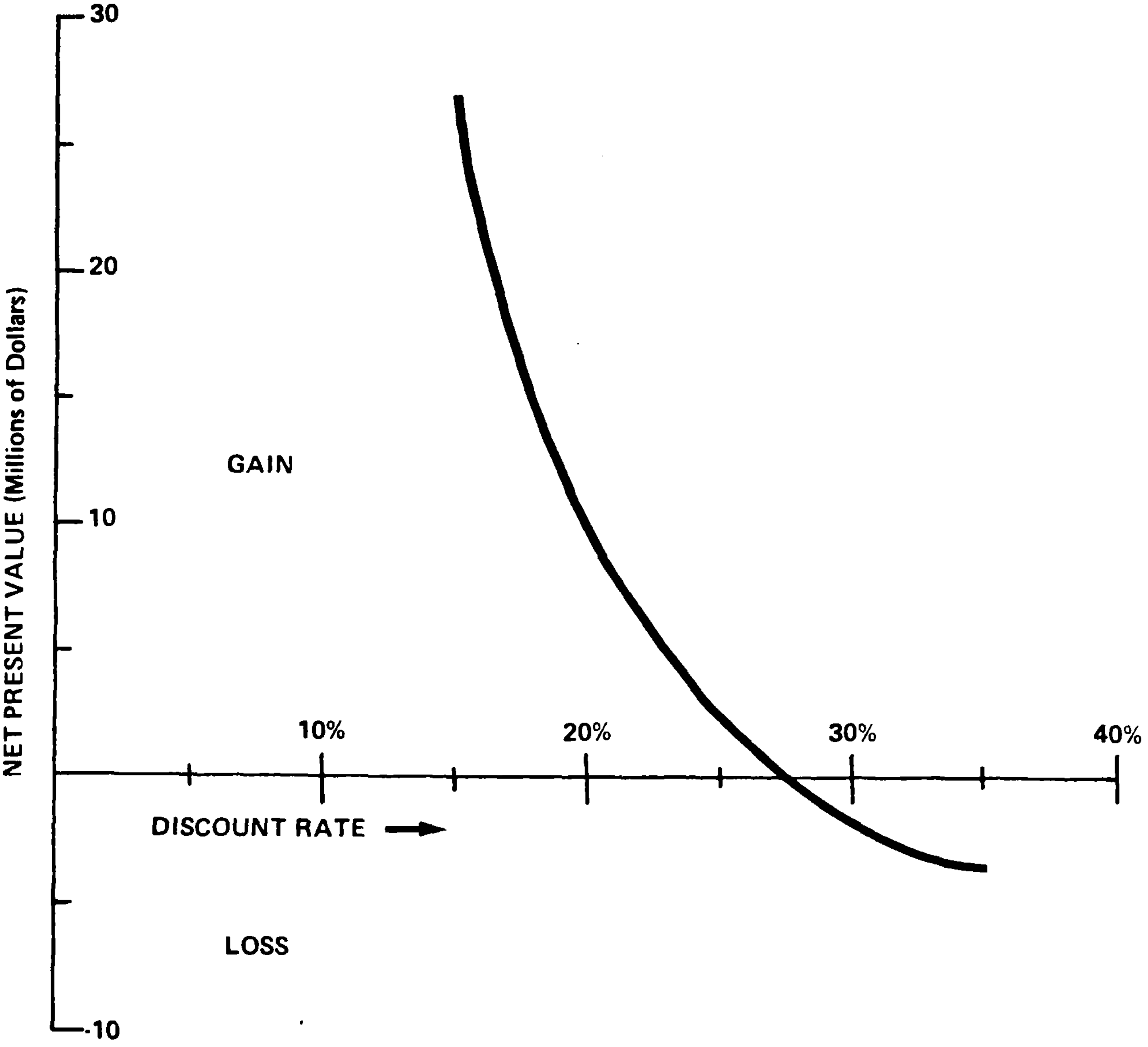

Figure 1 EFFECT OF DISCOUNT RATE ON NPV