Framework for Concurrent Government/Commercial Value Generation in Space Programs

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Traditional aerospace programs have primarily concerned themselves with determining acquisition costs, and at times, life cycle cost, to the government for the program. Commercial interests were served by mandating an 8-10% fee for the developer on a cost-plus contract basis. As the commercial space industry expands, and opportunities for using non-traditional methods of system development and operation become more prevalent, different ways of determining the economic potential of a system are required. This paper will explore different operating scenarios that involve the cooperation of government and private industry. These scenarios range from a traditional all-government program, to ones in which government and private industry both incur some of the costs, to a completely commercial service bought by the government on a per flight basis. For these, a method of life cycle cost calculation is shown that involves determining the net present cost to the government of the operating scenario.

Nomenclature

D	=	Design, development, test, & evaluation (DDT&E) cost
P	=	Production cost
V	=	Variable operations cost
F_C	=	Fixed operations cost (Commercial)
F_G	=	Fixed operations cost (Government)
Y	=	Total years in the Program
i_G	=	Government discount rate
i_C	=	Commercial discount rate
C_G	=	Cost to government
C_C	=	Cost to commercial entity
M	=	Mission price
R	=	Revenue for commercial entity
N	=	Number of missions per year

I. Introduction

IN January of 2004, President Bush outlined his vision for space exploration. In it, he called for the development of a sustainable and affordable robotic and human presence in our solar system and beyond, with specific references to returning humans to the moon by 2020 and paving the way for landing humans on Mars. To achieve these goals, the plan calls for the development of innovative technologies, knowledge, and infrastructures both to explore and to support decisions about the destinations for human exploration; and promotion of international and commercial participation in exploration to further U.S. scientific, security, and economic interests. Further definition is given to the point of commercial participation, calling for a pursuit of commercial opportunities for providing transportation and other services supporting the International Space Station (ISS) and explorations beyond low Earth orbit (LEO).

For a truly sustainable presence in space, it may be argued that the commercialization aspect of the plan is the most important. Myriad proponents supporting space commercialization espouse that there will be an economic

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boom of new markets and private activity once a certain threshold of cost to orbit is achieved and once there is sufficient infrastructure in place for there to be something meaningful to do. However, getting to that point is the proverbial chicken and egg problem. The markets won't come until the technology is in place for the right price, and no one is going to spend significant capital to create the infrastructure and required technologies without a verified market. The "business" of human spaceflight has been strictly a governmental affair, mostly supported by a few aerospace industry giants under programs costing billions of dollars. These are public works programs paid for by taxpayers, not sustainable businesses earning a return on investment sufficient to justify the initial capital spending. And, they have been traditionally done in such a fashion that military or space agency goals are pursued without long term lifecycle costs being taken seriously into account, thus showing their cold war era legacy. More recently, largely because of the high costs of the space shuttle (even before the Columbia disaster of February, 2003), program costs have come under greater scrutiny. However, existing bureaucracies and fixed cost structures in both the government and the large prime contractors have limited the success of producing low cost space programs. The outcome of this has been a series of program cancellations as the true nature of the expense involved in these government programs becomes better known to the NASA leadership and to Congress.

The recent success of Burt Rutan's company, Scaled Composites, which captured the X-Prize last year with its Spaceship One flights, may be a disruptive event in the industry. This effort was funded by a single private investor to the tune of $25 million, and showed that enterprising small commercial companies can indeed play a significant role in the space industry as prime developers. New computer technologies have become available that allow for distributed and smaller workforces to accomplish what armies of engineers did in the past. These small companies employ "rapid prototyping" techniques, focusing on progressive hardware development, rather than protracted systems engineering studies, to do final requirements definition and system testing in stages of incremental design. These agile, lean companies work fast and cheap.

However, critics (including founder Burt Rutan himself) warn that Scaled's Tier One program was a sub-orbital demonstration and didn't require the tremendous thermal protection needed for an orbital re-entry. For this greater ambition, the technical credibility of these non-traditional companies comes into question, especially when talking about sending humans and/or mission critical supplies on board spacecraft developed by them. Also, cost becomes a much bigger issue. A similar program to send humans to orbit will not likely be on the order of $25 million, but rather several hundred million dollars. This is still an order of magnitude less than traditional programs are likely to cost, but perhaps outside the feasible funding region of a company using private investment capital. Banks and venture capital firms will by and large balk at a small company needing this kind of investment for what is perceived as a risky development program, while counting on an unproven, unsecured market that won't start earning revenue and offering returns for years to come, if at all. Angel investors are more tolerant of these things, but the industry can't count on billionaire benefactors to swoop in and provide what is arguably a critical national capability.

So, if these non-traditional efforts are to succeed, it is likely that the government must provide significant support. However, the government has a limited budget to spend as well. It needs to decide how best to spend those dollars. If there is a "must-have" capability, the government will tend to minimize its perceived risk by going with a known commodity. The general feeling is that while the traditional prime contractors may be expensive and slow, they will eventually produce a workable solution given enough time and money. But this single string approach has risks as well. Even if one discounts the billions spent over the last decade on cancelled space launch development programs, there are still billions to be potentially saved going forward if even one non-traditional program can succeed. These saved funds can be used on other research and development in support of the exploration goal. Also, some believe that a rapid-prototyping, simple vehicle approach is in fact safer than traditional giant programs that perform extensive analysis and incorporate many redundant systems, resulting in complex and potentially unwieldy systems. Finally, this country has spent approximately 5 of the last 19 years with no human spaceflight capability as the Shuttle fleet has been grounded following the Challenger and Columbia accidents. Having multiple options would seem to be a prudent, long overdue measure.

Thus, the key is to analyze the funding of these efforts from the perspective of a cooperative effort between government and commercial entities. There are several options on how the two work together, but in any case, both the needs of the government and those of the commercial company, which are distinctly different, must be met. This paper will look at the case for parallel funding of traditional and non-traditional programs from a government value perspective. It will then cover different operating scenarios for government/commercial programs. Finally, a mathematical method will be introduced that attempts to optimize the collective value in any of these scenarios, allowing for prudent decision-making in funding decisions.

II. The Value of a Parallel Non-Traditional Effort

Problems with cost overruns in the aerospace industry have been well documented and bemoaned by all parties involved, including the tax payer. Traditional space development programs conducted under government funding have been largely performed in a manner such that large prime contractors operate under a cost-plus contract basis with the government. Fees are typically designated by convention in the 8-10% range. This takes what would normally be a very risky proposition for the contractor and turns it into a virtually risk-free endeavor with a rate of return higher than "risk-free" government treasury bills. Unfortunately, the nature of these contracts and the resulting commercial-government interrelationship can lead to problems.

Primary among these is that there is no incentive for the contractor to reduce costs. While the percentage of profit is fixed, the absolute value of the net income is increased by increasing program costs. Some controls can be put in place with a "not to exceed" clause in the contract, but often this just means that sunk costs are not identified for what they are, and the contract is rewritten when the NTE level is reached so that the previous investment is not wasted. Award fee incentives have also been used to try to improve performance. Typically, though, the worst case is that the award fee goes to zero if the contractor performs very poorly, but profit is still maintained. Even programs that have negative award fee scales often simply cut into margin. Unless there is a fixed price aspect to the contract, there is little to no risk of actually losing money; only making less profit. This type of contracting worked in the cold war era when funding was not an issue and technological results were all that mattered, but things are a bit different today. Greater scrutiny on the cost of programs has led to (or at least contributed to) cancellations of at least three programs (X-33, Space Launch Initiative, and the Orbital Space Plane) in the last half decade. As these budgetary wastes gain more and more press, government entities strive to put stricter and stricter cost controls on the programs. Agencies mandate more and more reporting, oversight, and cost control methods; this is overhead which can often increase, rather than decrease actual costs, and pull key personnel away from doing engineering in order to prepare for reviews with the customer. During negotiations, government agencies or Congress may look at a contingency or management reserve, which is truly needed for dealing with "unknown unknowns," and see it as fluff in the budget and remove it. This reduces the flexibility of budget authority by the contractor, and inevitably leads to cost overruns during complex development programs, the costs of which cannot accurately be predicted.

Also, in an effort to exert greater control and to focus the effort, the contracting agency will issue more and more stringent requirements that are often technologically focused, rather than goal-oriented, and dependent on debatable metrics. While some of these requirements may be unavoidable in light of mission goals, this can often greatly and unnecessarily restrict or eliminate innovation on the part of the contractor (e.g. "the contractor will produce a vertical takeoff, horizontal landing rocket that can carry 4 people per flight to orbit 3 times per year at less than $10,000 per pound" is more constraining than "the contractor will provide the capability to bring 12 people to orbit per year for less than $100M in annual costs"). Of course, the worst offense is the changing of requirements in the middle of the program. Traditional programs use a heavy up-front systems engineering effort to optimize the system design to a set of requirements and then allocate budget. Change orders in the middle of the program require going back to this stage and the ripple effects throughout the interfaces in the system can be devastating to schedule and budget as existing work must be scrapped and redone.

Finally, as Adam Smith told us in the 18th century, the "invisible hand" of market forces will tend to bring prices to a stable equilibrium. However, when barriers to entry are so high, and government intervention determines the market and sets up a monopoly or oligopoly, this can't work. There is inadequate competition (often none) as the government will usually down-select at some point in a development program. So contractors bid low on their cost distribution estimate (not necessarily fraudulently, but aggressively) to win the contract. This leads to higher risk and almost assures higher than bid program costs. By the time the true hardware production gets under way, and certainly by the operational phase, there is no countervailing market force to control those rising costs.

These problems have been documented before, and there's no easy fix. The existing infrastructure of the government and the prime aerospace industry contractors can't be easily abandoned as they are national resources. To date, there is no proven alternative to producing these complex systems. New methods of contracting and development, i.e. rapid prototyping under other transactions agreements (OTAs) with small, lean companies offer the promise to lead to lower costs in the future. As argued above, it is unlikely that private investment will be able to fund these non-traditional companies alone due to the perceived risk and length of time until returns are realized. The government must continue to be the primary investor. It is often perceived as too risky a proposition to fund them outright over proven methods if the capability is critical. However there is room for a side bet.

For example, there are many areas in which a successful non-traditional earth to orbit (ETO) launch capability development program may provide savings to NASA. Among these are:

- The non-traditional systems will likely be cheaper to operate if successful than traditionally developed ETO systems. That portion of the CEV budget may be directed towards in-space activities, particularly if the non-traditional program is completed ahead of the traditional effort.
- A separate ETO program might free up the traditional CEV development to focus on earth orbit to the surface of the moon. CEVs could be launched uncrewed. This would allow the CEV to be smaller, thus reducing development and production costs of the CEV, as well as reducing launch vehicle costs. It also could eliminate the impending need to man-rate EELVs, which will likely be expensive.
- A non-traditional program opens the way for commercial operating practices, thus allowing NASA to focus its personnel on exploration rather than operations and also to take advantage of commercial efficiencies.
- Non-traditional systems might very well cost less than Soyuz launches, which aside from the positive political aspects of not being dependent on foreign countries for launches during the gap between Shuttle retirement and the CEV coming online, would provide cost savings.

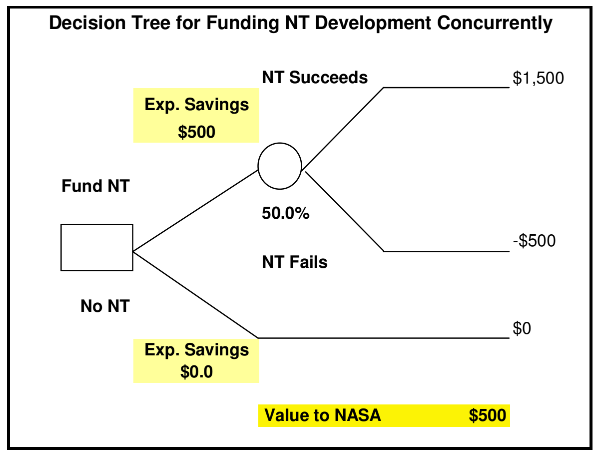

Figure 1: Non-Traditional Funding Decision Tree

It is easy to imagine these potential savings running into the billions considering the budget line of the existing traditional CEV program. Of course, this assumes that the non-traditional program is successful. If not, the government may still get some transferable research or technology, but at worst, be out the cost of the non-traditional program. Thus, the perceived probability of success of the non-traditional ETO program is the key financial variable for the decision makers. By using a simple decision tree to calculate the expected value of funding the non-traditional system, and assuming a modest $1.5 billion in potential savings, a $500 million development cost, and only a 50% probability of success of the non-traditional program, it can be shown that

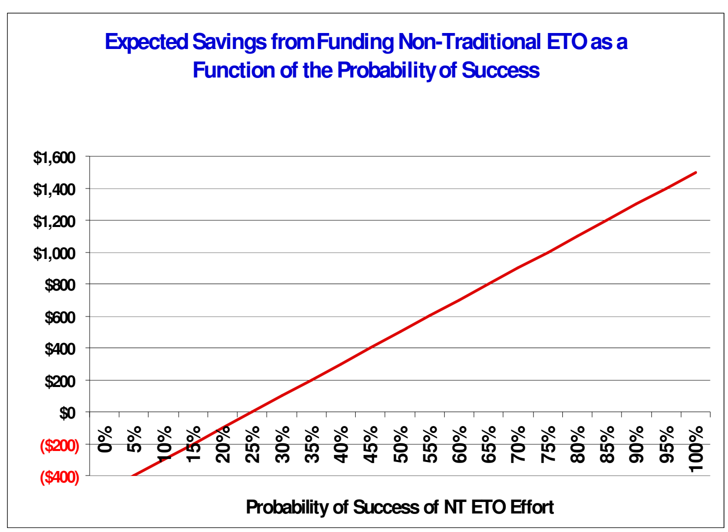

Figure 2: Sensitivity of Non-Traditional Concurrent Funding Value Probability of Success

the option of taking advantage of the non-traditional program is sizable at $500 million. With these assumptions, the probability of success would have to be only 25% to make it a bad bet for the government.

The key is to find a way that commercial and government entities can work together to optimize the economics of the system as a whole.

III. A Variety of Joint Operating Scenarios

Assuming that the government wants to work with the private enterprise, the question is what is the nature of that relationship? One simple way to define the options is to determine who pays for what in each scenario. Aerospace programs can be divided into three distinct life cycle phases: DDT&E (Development, Design, Test, & Evaluation), Production, and Operations. One end of the spectrum is the traditional program in which the government pays for all phases, and owns leadership and assets at all phases from DDT&E through operations. The other end of the spectrum is the commercial-only case, in which the government is merely a customer to a service that consists of a system developed, manufactured, and operated by a commercial entity. Each of these scenarios implies a different level of risk to the commercial entity and any private investment dollars. The level of risk implies a commercial discount rate, which is the required rate of return of the venture for a company to pursue the program in lieu of other opportunities. This changes based on the amount of risk bought down by the government in each scenario.

For use in the analysis presented later, four simple scenarios which assume NASA as a guaranteed customer to only one commercial entity are defined below. Of course, more complicated models are possible in which there are different contractors in different phases. In those, the goal remains the same: provide sufficient value to all parties involved. Also, it is important to note that all of the programs will be subject to changes in risk level depending on the specific provisions in whatever contract mechanism is used (e.g. government oversight/reporting requirements, commercial use rights, etc.).

Option A: Government Program

In this scenario, the government pays for everything; DDT&E, Production, and Operations. Any phase of the program managed by a commercial operator will be charged at cost with some fixed fee. Commercial discount rate is irrelevant as the fee is written into the contract.

Option B: Commercial Operation

Here, the government pays for DDT&E and Production of NASA-unique system hardware which is then commercially operated (e.g. the United Space Alliance with the Space Shuttle). As the scenario is used in this model, a service price is charged to NASA by the commercial operator. This price is set at a level such that it will cover operational costs, but needn't worry about recouping investment from development and production phases (typically referred to in the aerospace industry as amortizing development costs). Operational costs include fixed annual operating costs (direct and indirect personnel costs, building utilities and maintenance, etc.) and variable costs that are incurred on a per flight basis (fuel, expendables, etc.). The discount rate for this scenario is assumed to be 10% since this is akin to the standard government contracting method with a guaranteed customer, and no at-risk hardware development takes place.

	Option A (Government Program)	Option B (Commercial Operation)	Option C (Commercial Ownership)	Option D (Commercial Program)
DDT&E	Government	Government	Government	Commercial
Production	Government	Government	Commercial	Commercial
Operations	Government	Commercial	Commercial	Commercial
Commercial Discount Rate	N/A	10%	20%	30%

Figure 3: Operating Scenario Summary

Option C: Commercial Ownership

In this scenario, the government pays for DDT&E. A commercial entity pays for production, owns all the assets, and incurs all operational costs, in turn charging a price to NASA set at a level to cover all of these costs. The commercial entity is free to use all assets for any customers (although NASA might have negotiated first refusal rights due to the DDT&E investment – again, it depends on the details of the contract). A 20% discount rate is assumed here since a capital outlay is necessary for the production cost, but the commercial entity still has an anchor tenant in NASA, keeping the risk down.

Option D: Commercial Program

In this scenario, the commercial entity pays for everything. The government pays only a price for service. In general, this option looks infeasible from the outset due to the nature of these programs, which commercial investors would view as extremely risky. The capital would probably not be available without some buy-down of the risk by the government. Here a 30% discount rate is assumed (it likely could be 50% or more) since a large capital outlay is necessary long before revenues appear.

IV. Framework for Measuring Options

To analyze each of these options from the government perspective, a total lifecycle cost must be determined. The method of estimation is different depending on the scenario. For the all-government case, the calculation is simple as all costs are incurred by the government. Acquisition cost is DDT&E and production costs. Incremental cost/mission is just the variable operations cost. Total annual cost (during the operational phase) is the fixed operational cost + variable operations cost * number of missions. Total cost is a sum of total annual cost over the entire length of the program, including all phases (DDT&E, Production, Operations, and Retirement).

The commercial scenarios are a little more interesting. Both government and commercial needs must be met simultaneously. To have a feasible business case, commercial net present value (NPV) must be >= $0. This means that the required return on investment for the perceived level of risk is being met or exceeded. Assuming the costs are what they are, NPV can be increased by increasing the revenue for the service provider. If the number of missions is fixed, the revenue can only be increased by increasing the mission price. This is a variable over which the service provider has control. As the mission price goes up, the customer's costs also go up. The method used here is to determine the best possible cost to the government given the cost assumptions by optimizing mission price such that NPV=0. This gives the best deal to the government while still allowing the commercial service provider to meet his return requirements. Note that depending on which scenario is employed, the government and commercial service provider will each carry different elements of the cost which must then be accounted for in the NPC/NPV calculations. Figure 4 shows the calculations of the various metrics used to compare programs.

	Government Operation Scenario (Option A)	Commercial Operation Scenarios (Options B, C, & D)
Cost/Mission	V	M
Total Cost (Net Present Cost)	$NPC = \sum_{y=1}^{Y} \frac{G_y}{(1+i_G)^y}$	
Commercial Net Present Value (NPV)	N/A	$NPV = \sum_{y=1}^{Y} \frac{R_y - C_y}{(1+i_C)^y}$
Commercial Revenue	N/A	$R = MN$

Figure 4: Calculation of metrics

where:

V = Variable operations cost
M = Mission price
NPC = Net Present Cost (the net present value of the program to the government)
Y = Total years in the Program
G_y = Cost to the government in year y

i_G	=	Government discount rate
NPV	=	Commercial Net Present Value
R_y	=	Revenue for the commercial entity in year y
C_y	=	Cost for the commercial entity in year y
i_C	=	Commercial discount rate
N	=	Number of missions per year

For any given year, the government (G) and commercial (C) costs are determined as shown in Figure 5 for each scenario.

	G	*C*
Option A	$G = D + P + F_G + VN$	*N/A*
Option B	$G = D + P + MN$	$C = F_C + VN$
Option C	$G = D + MN$	$C = P + F_C + VN$
Option D	$G = MN$	$C = D + P + F_C + VN$

Figure 5: Calculation of government and commercial total costs in any given year

where:

G	=	Cost to government
C	=	Cost to commercial entity
D	=	Design, development, test, & evaluation (DDT&E) cost
P	=	Production cost
F_G	=	Fixed operations cost (Government)
V	=	Variable operations cost
F_C	=	Fixed operations cost (Commercial)

There are a few things to note about these metrics. First for Option A, the commercial entity perspective is not shown because there is no need to calculate a price as the fee is written into the contract. The formulae for NPV and NPC direct the analyst to lay out a stream of estimated cash flows for each of the scenarios over the length of the program (from development through operations), and then perform a discounted cash flow analysis at the appropriate discount rate. Different phases of the program may have costs in certain years and none in others. For example, DDT&E will proceed for a number of years at a high level until the first unit is complete. Then, the Production phase begins in earnest (assuming the program is selected). Finally, the Operational phase occurs. There will be overlap between these phases, but in any year, the program cash flow values are a sum of these phases.

NPV is a calculation that allows differing streams of cash flows over different time frames to be converted into present year dollars for comparison. The conversion uses a discount rate to account for the time value of money (a dollar today is worth more than a dollar tomorrow since that dollar can be invested at some interest rate). Since the government doesn't have a revenue side (at least not within the confines of NASA), we talk in terms of Net Present Cost (NPC). The discount rate used for the NPC calculation is the 10 year risk-free rate identified by OMB (recently set at 4.6%). For the commercial entity, NPV is discounted according to risk of the investment, which determines the required rate of return (greater risk requires greater reward = higher discount rate).

The goal is to find a scenario that allows for Concurrent Value. Concurrent Value is defined as one in which both the government and the commercial entity find value. This is the proverbial "win-win situation." In order for there to be concurrent value, there are two conditions that must be met simultaneously for a given set of input assumptions:

1. Government Net Present Cost (NPC) must be better than the alternative ($GV = NPC_{option\ 1} - NPC_{option\ 2}$). This provides positive value to the government, or GV > $0

2. Commercial Net Present Value (NPV) > $0

For the government side of the equation, value must be defined in comparison to an alternative. In the example that follows, the Commercial Operation Scenario (Option B) is compared to the Government Program Scenario (Option A). GV is positive if NPC for Option B is less than NPC for Option A. In Option B, the commercial operator charges a price to the Government for each mission. Price is the primary decision variable in this problem. As mission price goes up, so do commercial profits (NPV), but government costs (NPC) and subsequently government value (GV) go down. If there is a mission price that yields both positive NPV and GV, then there is a feasible region for achieving Concurrent Value. The wider the range of mission prices that allow this in the financial projections, the larger the chance that there can be successful negotiations between the government and the commercial entity (assuming, of course, that there is a desire for the system in the first place because it meets requirements).

The following three figures show different feasibility regions based on different underlying cost structures of Options A and B. The feasible region is defined along the X axis (mission price) where simultaneously the NPV line rises above the NPV=0 line, and the GV line rises above the NPC of Government Program line. Figure 6 shows a cost structure such that there is a wide range of mission prices that can provide concurrent value. Figure 7 shows a small feasible region, which provides only a marginal opportunity for delivering concurrent value. In this case, if some small change in the underlying cost estimate or the required commercial discount rate, the program may lose its viability. Figure 8 shows a situation in which there is no feasible region. The government's alternative is good enough in comparison to the operating scenario that there is no mission price that provides concurrent value. The government shouldn't invest unless there is a compelling non-financial need for the service. The commercial entity, meanwhile, should go back and re-evaluate their service plan in order to try to reduce costs or risks.

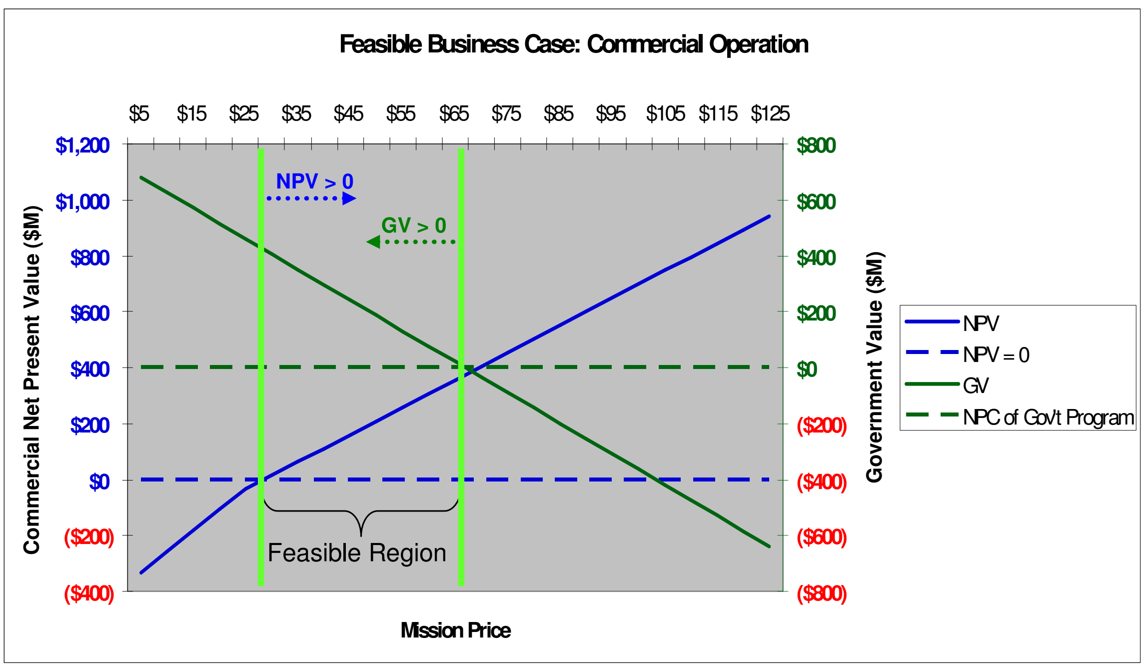

Figure 6: Large Feasible Region - Clear opportunity for Concurrent Value

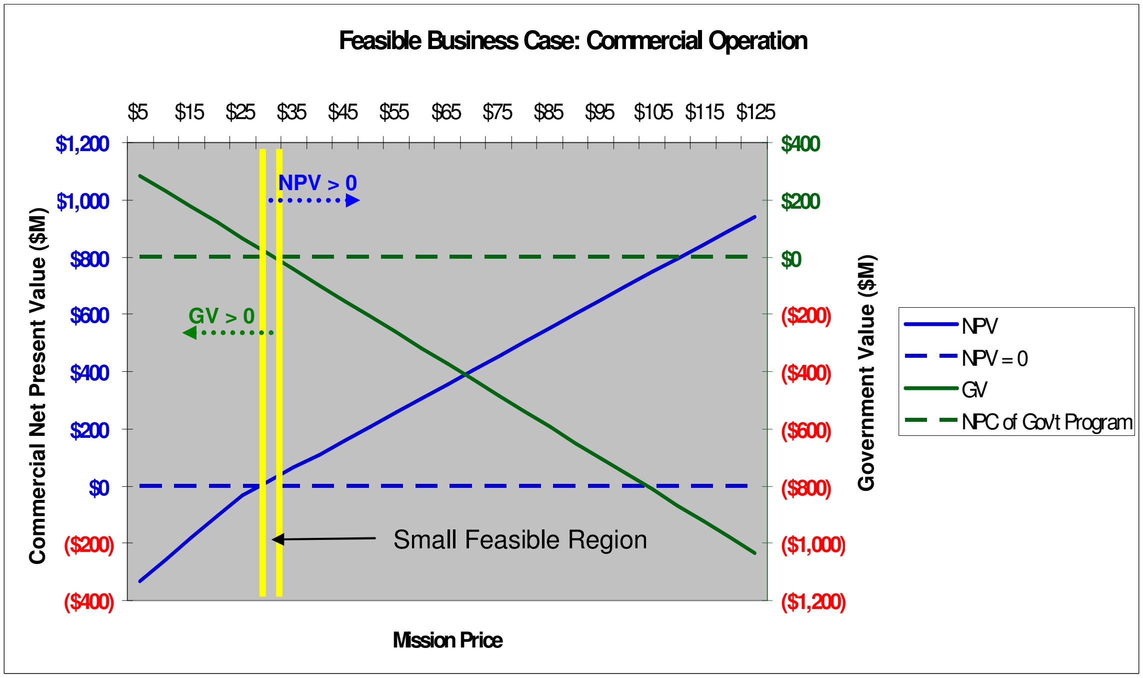

Figure 7: Small Feasible Region - Marginal opportunity for Concurrent Value

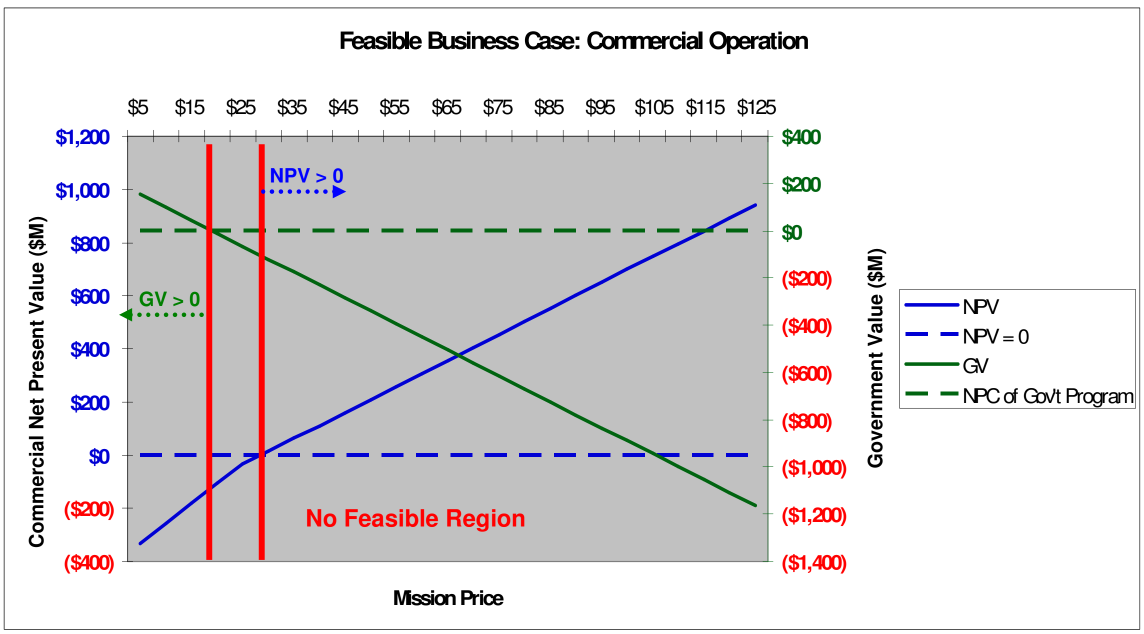

Figure 8: No Feasible Region - Cost structure must change for Concurrent Value

V. Conclusion

This paper has discussed the value to the government of pursuing cooperative relationships with non-traditional aerospace developers. It is unlikely that commercial investment capital alone will enable these potentially innovative systems. However, it can easily be shown that there is positive expected value to the government in paying for the option of having these entities provide alternative space systems. Given that there is value to funding the program, the question is how. The paper briefly discusses different operating scenarios that can be considered as a way for government and commercial entities to work together. They each have different risks associated with them. A Government Program (Option A) is standard fare and is used as the control. A fully Commercial Program (Option D) is high risk, and capital is unlikely to be available without some support from the government. In the other two scenarios, the government buys down the risk and takes advantage of efficiencies that can be provided by commercial practices. Finally, the notion of concurrent value was put forth to describe a framework that can be used by both commercial and government entities in evaluating the various cooperative operating scenarios. An example is shown in which flights are guaranteed to the commercial contractor in the operational phase, thus making mission price the key variable. The key point is that there must be value for both sides when evaluating the stream of cash flows. This paper looks at a specific set of scenarios that assume a single lead contractor for the relevant phases and some form of guaranteed flight rate in the operational phase. Future efforts can examine more complex operating structures in which more than two entities must find concurrent value.

Acknowledgments

The author thanks Livingston Holder for his valuable contributions and support.