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# Cost And Business Analysis Module (CABAM)

## Final Report and User's Manual

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# Table of Contents

# 1. INTRODUCTION

## 1.1. The Importance of Early Economic Analysis

In the recent couple of decades, due to international competition, the US launchers lost a considerable amount of market share in the international space launch industry[1]. Increased international competition has continuously affected the US dominance to eventually place great pressure on future US space launch programs. To compete for future payload and passenger delivery markets, new launch vehicles must first be capable of reliably reaching a number of desired orbital destinations with customer-desired payload capacities. However, the ultimate success of a new launch vehicle program will depend on the launch price it is capable of offering it's customers. Extremely aggressive pricing strategies will be required for a new domestic launch service to compete with low-price international launchers. Low launch prices, then, naturally require a tight budget for the launch program economy. Therefore, budget constraints established by low-pricing requirements eventually place pressure on new launch vehicles to have unprecedentedly low Life Cycle Costs (LCC's).

Conventionally, economic aspects of a new launch system were analyzed after a 'finalized' design concept was reached. That is, a new launch vehicle was initially designed for the lowest launch weight, lowest empty weight, or minimum fuel approach ('design-for-performance'), and then the resulting design was passed to a cost analyst who would determine development and production costs (post-design evaluation). In some cases, operations and facilities costs would be included so that the LCC could be predicted. In even rarer cases, potential markets and revenue sources were considered so that a cash flow stream could be predicted. This last level of information, while rarely provided, comprises the minimum needed to evaluate the potential commercial business viability of a new launch service, thus minimizing the LCC and maximizing the profitability potential of the new launch vehicle program. However, the post design evaluation scheme is easily too late to recover unnecessary expenditures in Design Development Testing and Evaluation (DDTE) costs for various vehicle options. In general, 'design-to-cost' philosophies were accompanied with post-design evaluation where cost served as a constraint to the design process.

Unfortunately, for conventional design methods, the highest performance vehicle is seldom the lowest cost vehicle (or the most profitable). In fact, even the lowest development cost vehicle may not necessarily be the most attractive vehicle from a commercial business and profitability viewpoint. If the decision maker's objective is to produce a system with a high profitability and low financial risk, then there must be a way to estimate cost and business indicators early in the vehicle design process and a mechanism to feed cost and profit information back into the actual design process, so that appropriate design decisions are made as early as during the conceptual design phase. In such ways, budget overshoots and irrelevant expenses with the final concept can be minimized. Such a capability could change a 'design-for-performance' or a 'design-to-cost' principle into a more desirable 'design-for-business' principle within advanced design organizations[2].

Implementing a 'design for business' principle during the conceptual design phase has two requirements. First, a new design-oriented cost and business simulation model must be available. The model must be reasonably fast, accurate, robust, and be capable of operating on data of the detail typically available in the conceptual stage of design. Second, cost modeling and business simulation must be fully integrated into the conceptual design process. The business/cost analyst must also be knowledgeable in engineering aspects and become a full member of the design team. Then, each vehicle design cycle must include a prediction of key business indicators, and each design decision should be made with full knowledge of its impact on those indicators. Such efforts have been made in the Cost And Business Analysis Module (CABAM).

### *1.2. Overview and Capabilities*

CABAM was developed in response to the needs and benefits of early financial assessment in conceptual launch vehicle design. CABAM is a MS Excel based design tool for today's launch vehicle programs and is capable of handling launch systems of up to one first stage and two second stages. It requires only basic launch vehicle system definitions through component weights and a few important economic parameters such as tax rate and inflation rates as inputs. Therefore it allows economic assessment at the conceptual design stage. CABAM was developed in an integrated and coupled design architecture and, therefore, is the most effective when fully integrated into the design sequence. CABAM can also be utilized as a quick point design evaluator of an established design concept as well.

CABAM is a fiscal unit-based analysis tool. There have been important studies in launch vehicle economics in term of labor units such as man-hours (e.g. TRANSCOST[3]).

On the contrary, CABAM is based in US$ with standard fixed rate inflation. Reference dollars and then-year dollars are both utilized in CABAM and each dollar designations are marked throughout CABAM. CABAM is also a simulation tool requiring direct assumption inputs from the cost analyst. A simulation of a long term launch program is based on a set of main independent variables: launch prices for each target markets. Besides launch prices, assumption inputs range from tax rates to averaged salary for total work force. It is rather an art for the cost analyst to pick correct assumptions. Reference data and cost analysis experience should be used wherever possible. CABAM is also an annual figure-based analysis tool. Year-by-year LCC and revenue are kept to generate annual cash flows (cumulative and non-cumulative) as an output.

Running CABAM in a conceptual design phase of a launch vehicle development sequence can be beneficial for two main reasons. First, CABAM can be used as a quick evaluator of a launch vehicle program's Profit Generating Potential (PGP). PGP of a launch program is not solidly defined as a set of standard economics measures yet, but is rather a dynamic idea that incorporates many economic data from cost and revenue indicators. As many vehicle concepts and configurations arise within a conceptual design span, those which were only filtered by engineering intuition and performance calculations as a criteria can now be judged for their PGP. By eliminating various unfit design concepts on the basis of quick engineering and also by the associated financial data, one can add confidence to the design decisions and eventually the finalized vehicle concept. Next, CABAM can be integrated into the actual design loop for finalizing the final concept, where most of the other conventional disciplinary design tools are set up in an integrated design framework. CABAM mostly interacts with the weights and sizing department and as there are aerodynamics and propulsion analysts, an economics analyst can carefully study the concept and run CABAM. By integrating CABAM into the final design loop, vehicle and operations optimization for PGP is possible. This can ensure the success of new launch programs with the utmost confidence.

# 2. USING CABAM

## *2.1. Inputs and Outputs*

Understanding the variables of CABAM is crucial for using it to its fullest capabilities. Variables of CABAM can be divided in two different ways. One is by inputs and outputs and the other is by its level of involvement with the entire launch program. Inputs and outputs can be easily traced throughout CABAM. Most inputs have explanatory headings to help users. Outputs are arranged in easily distinguishable formats also. CABAM allows easy generation of custom output decks if necessary. Owing to its spreadsheet-based nature, standard outputs such as internal rate of return (IRR), net present value (NPV), break-even point (BEP), return on investment (ROI), maximum exposure, discounted cash flows, and optimized launch prices can be set up in a separate worksheet for easy reading. Currently, the standard outputs are located in a summary module where revenue and cost information are combined[2].

As for major and minor inputs, the major ones, including submodule-specific internal inputs, are marked in red text throughout CABAM. These are user defined direct inputs which are spread out within CABAM and must be input entirely. Generally, overlooking anyone of these red direct inputs can have a large impact on the analysis results, since these red inputs define not only the launch vehicle, but the entire launch vehicle program. Minor variables are intermediate internal variables that are necessary for calculations in CABAM. Some of these can be essential in evaluating the PGP and must be identified as important output variables to be looked at after a simulation. As an example, for a particular concept which has a very high flight rate, mission-specific launch costs can be very important. Then the launch costs can be included in the main outputs to help the design team to observe and control launch costs.

It is important to be familiar with the variable structure of CABAM to use CABAM with confidence. However, understanding the nature and how they are associate with each other is more crucial. Since CABAM is spreadsheet based, the variables are marked in easily understandable words. What the variables mean and the role of each should be self-explanatory to users.

## 2.2. The Structure

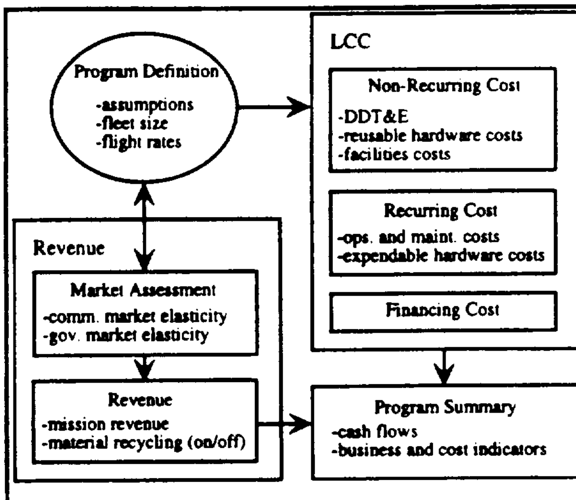


*Figure 1. Structure of CABAM*

CABAM has a modular structure due to its spreadsheet-based nature and also for unlimited flexibility. A representation of major modules and information flows are shown in Figure 1[2]. There are two major information flows in CABAM which are the revenue and cost. This is to simulate a common business economy where revenue and cost are separately dealt with. Revenue and cost for the launch business need not be directly connected unless via launch rates or flight rates. Revenue generation is represented by the pricing strategies and is also dependent on flight rates, but requires no cost information. For profit generation purposes, revenue needs to be above cost, yet in a diagnostic analysis that condition cannot be imposed as a constraint. Therefore, the element of profit is determined by pricing strategies via launch price optimization in CABAM. More on the launch price optimization will follow in the Post Simulation Analyses section. For cost information, flight rate dictates recurring cost. Indirectly, many other LCC components are affected by flight rates, but revenue information is not needed for cost assessment.

To look at the revenue stream in more detail, CABAM's eight market models must be discussed first. CABAM utilizes elastic market models to consider market capture. There are currently two sets of four markets modeled in CABAM. First set is for commercial launches and the other for government's launch purchases. This is to accommodate for different pricing strategies for two different parties. Each set includes Low-Earth Orbit (LEO) payload, LEO passenger (to ISS), Geo-Transfer Orbit (GTO) payload, and high speed global point-to-point (HS-PTP) delivery markets. These price-elastic market models define the total target market size and capturable market share and are linked to the program definition module via a lookup function which linearly interpolates for market data points as a function of launch prices. When a market size is defined from the interactions between program definition and market model modules, flight rate and required fleet size is defined in the program definition module. Guessed launch prices and flight rate combined with the program layout and operation schedule gives revenue generation in the summary module.

The cost stream of information is slightly more complicated since there are modules and submodules set up to follow an LCC breakdown. CABAM splits the LCC of a launch vehicle into nonrecurring, recurring and financing costs. Nonrecurring cost is comprised of the DDTE & TFU (note that theoretical first unit leads to reusable fleet hardware acquisition costs) and facilities costs submodules (separate worksheets) themselves. The DDTE & TFU submodule is where weights and technology information define the launch vehicle. Other representative vehicle design parameters such as payload capability and life span are input in program definition. Recurring cost is broken down into its constituents (e.g. airframe insurance, propellant, labor, and reusable hardware refurbishment) in the operations and maintenance submodule. Financing module incorporates a corporate bond scheme to generate capital for the launch program. Based on total nonrecurring cost, the cost analyst should assume a debt-to-equity ratio and annually issue bonds that have different maturity if necessary. After all LCC components are analyzed, they are assembled in the summary module.

## *2.3. Modules and Submodules*

As was mentioned before, CABAM has a modular structure. Since it is modular, expansions of analysis capabilities or modifications of existing estimation models are fairly simple. This added flexibility allows CABAM to be used for various launch vehicles, different target markets, different operation schedules, etc.

### 2.3.1. Program Definition

Program Definition is the main input module for CABAM. It includes all assumptions, internal parameters and program scheduling information. Therefore, program definition naturally contains the most number of direct inputs that are marked red. The time frame (span) of the program from program initiation to program termination are planned here. Operation schedule including projected initial operating capability (IOC), ramp-up period and steady state operation periods are all defined.

Program definition serves as the market share determining module also. Using commercial and government market elasticity modules as its database, it looks up the available market capture and overall estimated market size from each of the targeted markets (e.g. for launch programs only targeting LEO, only the LEO markets may be selected as target markets). This is done according to the guessed initial launch prices. After launch price determines market share, market share drives flight rate according to the launch

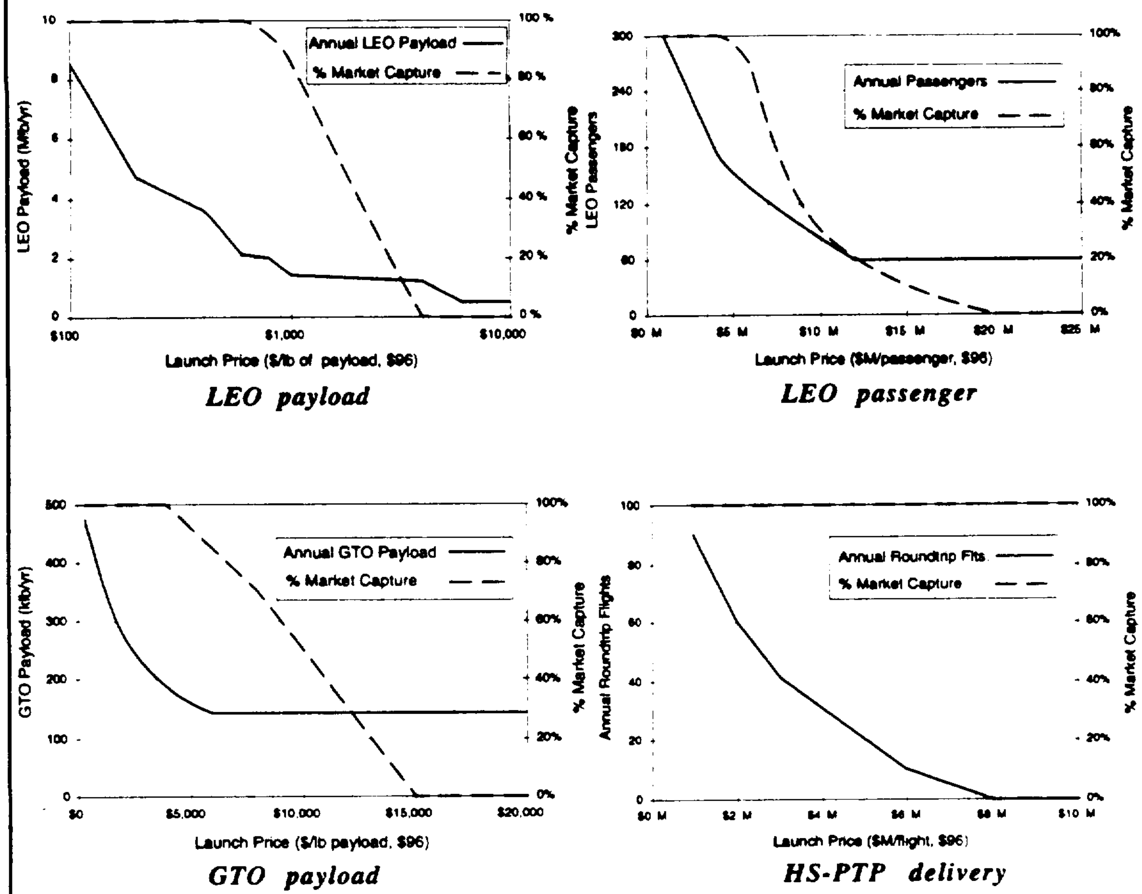


***Figure 2. Sample Market Elasticity Models***

vehicle's defined payload capabilities to each market. Then flight rate and defined airframe life span determines fleet size. This is another major role of the program definition module.

### 2.3.2. Market Models

In CABAM's program definition module, separate launch prices for government and commercial payloads are accounted for. Therefore, separate sets of market elasticity curves are needed. CABAM has two market models, commercial and government, of four markets each which are LEO payload, LEO passenger (to ISS, international space station), GTO payload and high speed global point-to-point delivery markets. These market projections were based on the NASA's CSTS[4]. Tabularized data points and linearly interpolated in-between regions comprise each markets. Figure 2 shows the four markets for commercial launches as an example[5]. Market size predictions can be changed directly from the tables that define the market elasticity curves by the user if desired.

When a launch program serves a fixed-price payload customer such as a constellation deployment, market elasticity is not used. In such cases, where there is a fixed element in price involved, a separate deck in the program definition module should be provided for the flight rates, fleet requirements, etc. for the fixed-price portion of the market capture.

### 2.3.3. DDTE & TFU

DDTE & TFU is where the vehicle definition is made via weights and the DDTE and TFU costs are assessed. CABAM's model for this task is based on subsystem weight-based cost estimation relationships (CER's) that were sourced in part from data within NASA's unrestricted release version of NASCOM database II[6]. DDTE & TFU includes a common weight breakdown structure that is shown in Figure 3. Currently, CER's for the level 1 breakdown are available. If CER's for subsystems of level 2 or level 3 become available, they can be easily entered following the formula structure that is in place for level 1 subsystems. The propulsion system is treated separately since it is commonly acquired separately from the airframe subsystems. Often, propulsion systems can be purchased from another vendor, also. Currently, weight breakdown structure and CER's are provided for up to three main vehicle stages. Then a launch vehicle concept with up to three stages or any combinations below three can be assessed by CABAM.

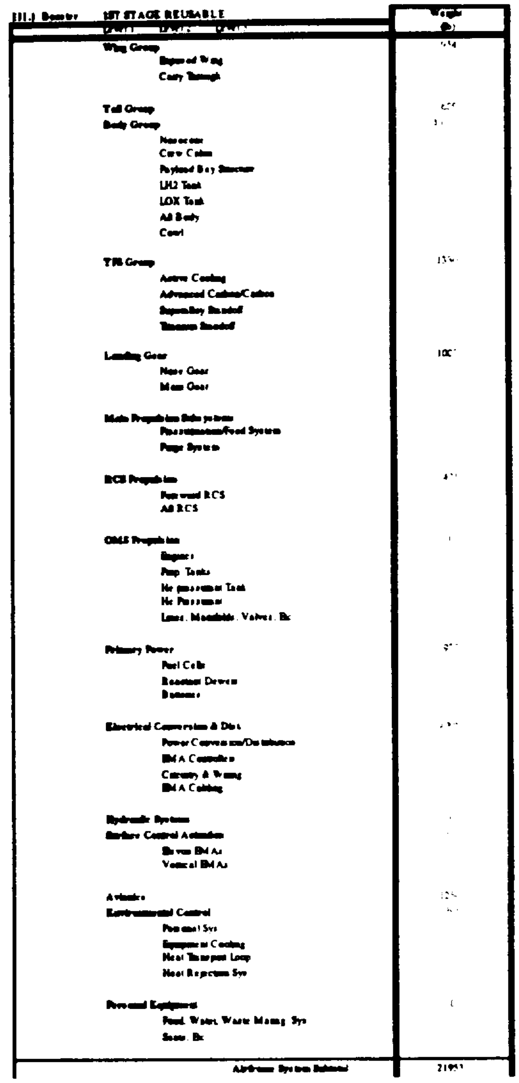

***Figure 3. Sample Airframe Systems Weight Breakdown Structure***

### 2.3.4. Facility

Facilities cost of construction (CoF) in CABAM is currently simply a user input from an off-line calculation. That is, facilities for each of the stages are given a cost allowance. The user can specify the spread of facilities expenditures in detail if there are such strategies, yet the facilities cost estimation is made only as a stage-specific cost allotment. For more specific facilities such as a Magnetic Levitation Launch Facility, any outside cost of construction data that is available can be easily incorporated into the facility submodule[7].

### 2.3.5. Nonrecurring Cost

Nonrecurring cost is a summation of the DDTE, reusable hardware acquisition and facilities costs. The sum of DDTE costs are taken from the DDTE & TFU module and then applied over a program spread of up to the planned IOC. A reusable hardware acquisition schedule is prescribed from the program definition module and the TFU costs are from the DDTE & TFU module in reusable systems. Implementation of learning and rate effects are built into this module and the user specifies the learning and rate effects through a percentage amount. This percentage amount is what the cost will be reduced to every time the units of manufactured systems are doubled. Facilities cost is arranged in an annual basis from the facility module itself. The sum of two are represented in an annual spread in nonrecurring cost module. The breakdown is available in a pie chart as part of a standard output as shown in Figure 4.

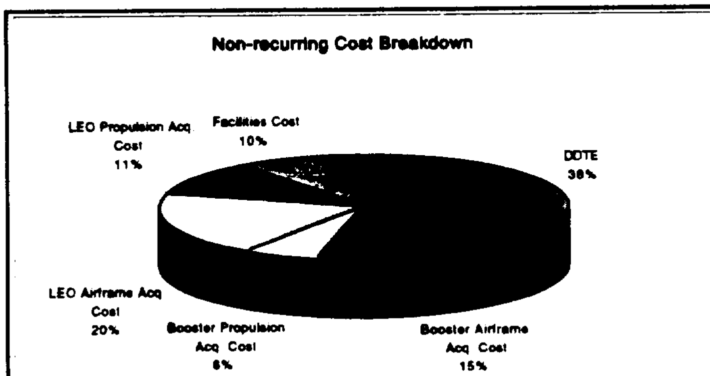


*Figure 4. Nonrecurring Cost Breakdown*

### 2.3.6. Financing

CABAM's launch program modeling provides for the capital generation scheme and associated costs in the financing module. The baseline financing strategy is to issue corporate bonds to gain capital for the program span before the IOC. The amount for financing is specified by the user as a debt-to-equity ratio applied to the total program nonrecurring cost. In a tables for each year, the user specifies the terms and amounts of total bond issuing. Interest is accrued as incurred financing costs. Payment schemes for

| Max. # of Launches/yr. | # of Ground Crew |
|---|---|
| 20 | 40 |
| 60 | 80 |
| 100 | 110 |
| 140 | 150 |
| 200 | 240 |
| 330 | 350 |
| 450 | 500 |
| 600 | 600 |

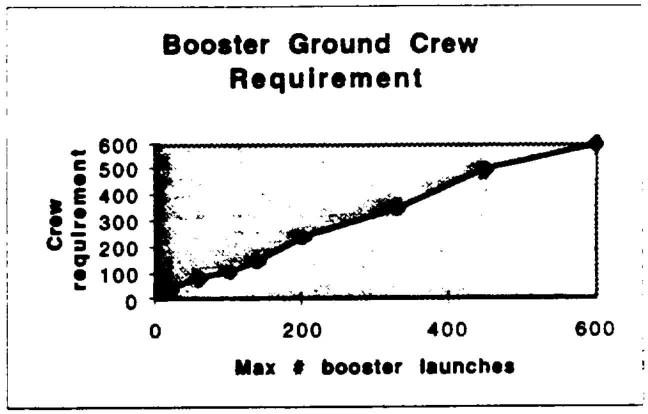


***Figure 5. Work Crew Estimation in Operations and Maintenance Module***

the interest and the premium are specifiable through careful revisions of the currently implemented strategy

### 2.3.7. Operations & Maintenance

After the nonrecurring costs are calculated, recurring cost calculation starts with the operations and maintenance submodule. This submodule includes propellant, averaged associated labor and reusable hardware refurbishment costs[8]. Propellant cost is calculated from a direct input of propellant weights. Currently, propellants are based on LOX and LH2, but different varieties can be easily accommodated for on a "purchase" dollars per lb. basis. Averaged labor costs are based an averaged encumbered salary for the entire work crew (i.e. the average cost of one man-year). The amount can be directly input by the user. The issue of the number of work crew is resolved through a built in step-function. The relationship between flight rates and required number of work crew is a non-continuous one. A sample crew size vs. flight rate graph is shown in Figure 5. The table defining the relationship is a user input. The per flight hardware refurbishment cost for reusable systems is determined by estimating the weight of reusable hardware replaced after each flight. This hardware is tpyically LRU's (line replacement units), but should also include costs associated with maintaining spares and inventory. Averaged cost per pound of replacement hardware is estimated and combined with the weight to calculate the cost of refurbishment per flight. Aerospace hardware typically costs $10,000 per pound. The three operations and maintenance cost constituents are summed on both a per flight and an annual basis.

### 2.3.8. Recurring Cost

The recurring cost module brings operations and maintenance, expandable system acquisition and airframe insurance costs together. Operations and maintenance costs are from the Operations and Maintenance module. Expendable system acquisition is calculated in the recurring cost module based on any expendable stage TFU costs from the DDTE & TFU module. Learning and rate effects are imposed for repeated system manufacturing as with the reusable systems. The production schedule is specified in the program schedule included in the program definition module. Airframe replacement insurance is based on expected losses per flight in dollars. For each mission, the total launch system's TFU cost is multiplied by the expected launch "unreliability" (failure rate) from the program definition to calculate a base amount that each mission should charged to account for airframe replacement cost. In addition to this base amount, an insurance premium is imposed and this premium is directly input by the user in percentage of the base amount. A pie chart is generated for each of the constituents of recurring cost.

### 2.3.9. Summary Module

In the summary module, the annual revenue generation is calculated and is combined with the annual nonrecurring, financing and recurring costs (components of the LCC) for calculating the annual before-tax cost flow of the launch program. This module also redisplays various key parameters of the launch program from various modules as a summary of the launch program. Revenue is calculated from annual flight rates for each mission type based on the user selected launch prices (price per pound of payload). The launch prices could be the guess or trial values or the optimized values depending on the stage of the analysis. After the total revenue and total costs are combined as the annual net cash, taxes are imposed and appropriate investment tax credits are given. Annual inflation is then calculated so that annual cash amounts are available in both reference year dollars and then year dollars (inflation adjusted). An annual after-tax cash flow diagram and cumulative after-tax cash flow diagram is generated as part of the standard output. Refer to a sample in Figure 6.

After all assessment calculations are complete for the program, some analytic data are generated on the total LCC, revenue, DDTE, reusable system acquisition and expandable system acquisition. Those figures are divided into their major constituents for relative comparison. Typical business metric include net present value (NPV, after-tax cash flow summed to year one assuming a user inputted discount rate), internal rate of return (IRR, the value of discount rate that makes NPV zero), breakeven point (BEP, the

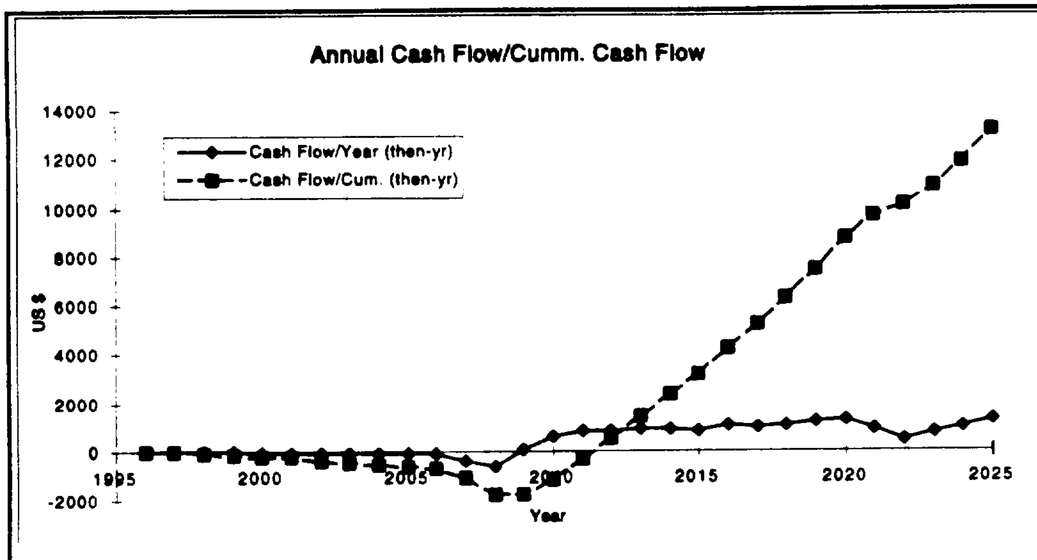


*Figure 6. Sample Cash Flows*

date in which cumulative cash flow returns to zero in then-year dollars), and maximum exposure (the most negative cumulative cask flow in then-year dollars). Also, there are market specific cost and revenue generation comparisons based on the recurring costs provided for measuring the profitability of each mission.

### 2.3.10. Add-on Modules

Since CABAM's cost estimation models are limited in the level of detail, additional submodules can be written and linked into CABAM when there are more extensive cost information available. Previously mentioned MLLF is a good example of such case. By supplementing additional cost information, CABAM can become more and more powerful. However, users should be cautioned to fully understand the current CABAM before linking additional modules in.

It should also be mentioned that the capabilities of CABAM can be enhanced further by utilizing the Visual Basic programming language built into MS Excel. One experimental use of this coding capability was to implement a launch price optimization scheme. A coarse grid search was set up in Visual Basic for searching the combinations of launch prices for an optimum. Even though it requires much more time than MS Excel's 'Solver' (a gradient-based optimizer), a more complete evaluation of the launch price combination space was possible. Solver tends to be 'trapped' in a local minimum if the user does not have a good idea of the region of optimum launch prices. Note that there is significant interaction between launch prices to each market since each price affects market size, flight rates, fleet size, etc. This, combined with the inherent nature of the entire business simulation model itself in CABAM which is highly non-smooth, proved Solver alone to be insufficient for the launch price optimization task. When a coarse grid search was used for identifying the general region of optimum launch prices, only then Solver was able to pick a good answer.

# 3. QUICK ANALYSIS PROCEDURE

For quickly reconfiguring and executing CABAM, there can be a standard procedure to follow. For the completeness of reconfiguring CABAM, since misdefining any of the launch vehicle or program schedule will still give an answer that is wrong, all of the necessary steps are listed for careful following. From preconceptual studies of the launch vehicle and its missions, a preliminary weight breakdown structure, payload and orbit capabilities for market selection, program time span and IOC are required data to have before initiating a cost and business analysis in CABAM.

## *3.1. General Program Definition*

It is easy to start with the launch vehicle definition when configuring CABAM for a new launch vehicle program. First, enter the level 1 weights in the DDTE & TFU submodule for each stage. Vehicle level 1 weights are entered without a dry weight margin since a separate cost margin is provided in CABAM. 20% is a representative cost margin usesd in CABAM. Then in program definition, enter the information in the first section, Ground Rules and Assumptions, entirely. This section includes sensitive economic assumptions such as tax rate, inflation rate, etc. Careful estimations are needed for these numbers. The honeymoon period represents a period from the IOC where the government is expected to pay a slight premium over the normal government launch prices for assisting a successful launch program initiation. The payload inefficiency variable models the lost payload carrying capability due to multiple manifesting of several paylaods on a single flight. While the CABAM market models assume only a total mass delivered to a certain segment, it is assumed that there will be a variety of discrete payloads. With a fixed payload bay shape, there will generally be a loss of carryable payload weight due to different shapes of payload items. This is a rather sensitive figure since it directly influences flight rate.

Next, in the fourth section of program definition, the fleet is defined. Airframe and propulsion system life spans require system knowledge to estimate. From the preliminary concept, enter the number of propulsion system required for each airframe of the stages. Replacement engine purchase sets are usually the same number as the original systems. Then, enter the estimated expected failure rates in the fifth section in program definition. The numbers are expected to be quite low. In the sixth section of program definition, enter the guess values for launch prices. Government and commercial missions are separate in CABAM. In the last section, estimate the government contribution expected.

The last two areas that define the launch vehicle program are associated facilities and operations and maintenance parameters. In the facilities submodule, directly input the stage system associated facilities cost. These figures are in a per site basis and the number of sites are linked to the first section in the program definition module. The operations and maintenance submodule contains many direct inputs. In the first section of this submodule, propellant weights are entered with the propellant unit costs in dollars per lb. Then, average annual encumbered salary for the work and launch crew are estimated. Note that this is on an annual, not an hourly basis. The manpower requirements table is the next input area where the relationship with the flight rates are defined. Enter the estimated manpower requirements for the booster stage since it serves as a reference to other stage systems. Remember that this is not a continuous function since the launch program cannot hire two more personnel for a two flights per year increase. Next, in the same section, estimate the refurbished hardware for reusable stage systems only in percentages of dry weights for each stage systems. Then estimate the averaged cost per lb. of the refurbishment hardware. Remember that this section is mission based. Lastly, for this submodule, enter the rate effect parameters in the third section. Usual numbers are above 85%.

### 3.2. Market Definition

From the preconceptual studies, a launch vehicle program must have target markets. LEO payload, LEO passenger, GTO payload and global high speed point-to-point delivery markets are available in CABAM. When a target market or a combination of markets is chosen by entering the payload capabilities in the third section of the program definition module, the appropriate amount of market capture is automatically assessed by a built-in table look up function in the program definitions module. The market models are in the government and commercial market submodules and can be modified with external market projections. Each submodule holds a set of the four markets mentioned.

### 3.3. Program Scheduling

For scheduling the various pre-operation and operation events, start with scheduling the launch operations and systems acquisition from the seventh section in the program definition module. Mark the IOC first. Then, fill in the commercial and government flight rates in the appropriate rows in percentiles of the maximum flight rates. Zero is for no flights and one is for full operation of launches. The production plan is controlled by the formulas in the production plan table in the same section. Currently, all reusable vehicle acquisition is set up to spread over the operation period. Expendable stage systems are acquired the year before use. These acquisition schedules also drive the associated costs. Therefore careful planning is required for avoiding concentrated expenditure. Different schemes of stage systems acquisition can be implemented after careful revision of the formulas.

Next, the DDTE cost and facilities cost needs a schedule for expenditure. DDTE cost expenditure is controlled in the nonrecurring cost module and the facilities cost is controlled in the facility submodule. Again maximum spreading is important and considerations for timely readiness before the IOC is another factor.

Another scheduling concern at this stage of configuring CABAM is vehicle recycling. After complete usage, precious body materials can be 'scrapped' and recycled. This is a toggle option in CABAM and is in the sixth section of the summary module. The number of operational units remaining at the end of the program span is specified and the material deterioration factor is input in percentages of the body, wing and tail structural weights. If this option is not desired, typing a zero in the toggle box will delete the option of vehicle salvaging. However, this option adds a noticeable jump in revenue at the end of the program span. This is also the only other source of revenue for the launch program besides launch revenues.

### 3.4. Financing Scheduling

Scheduling for financing the initial investment capital is done in the financing module and the program definition module as well. The program definition module contains a financing parameters block in the second section. Debt-to-equity ratio, average annual interest rate and late charge penalty rates are specified. These numbers are extremely sensitive since it involves a great amount of capital. Payment span is also input in this section.

In the financing module, enter the bond terms for each year's bond issue. The bond terms must not exceed the program span. Depending on the specified debt-to-equity ratio and the amount of nonrecurring cost incurred each year, the principle amounts for bond issue is determined. Therefore, there are no bonds issued on years well into the steady state operation years where no more nonrecurring cost is incurred by the launch vehicle program.

If MS Excel is in auto-calculation mode, standard output variables such as IRR, NPV, maximum exposure, BEP, and return on investment should all be calculated by this point. Before relying on those output values, check for any error cells in all the modules and submodules. Throughout CABAM, the formulas are written so that the output cells will return errors if there are any errors in all the modules and submodules, yet it should become a habit to check for any slips. If there are errors, use MS Excel's auditing tools to trace the origin of errors. Another common error can be found in MS Excel's IRR function. This function requires a guess value to start and for some IRR values, an error will return. Try different negative and positive IRR values as guesses. Through experience, it was found that for extremely negative IRR values (beyond -15%), there will always be an error value returned.

# 4. Post Simulation Analyses

The true value of using CABAM as a decision aid can be shown through the post simulation analyses as follows.

## 4.1. Launch Price Optimization

It should be understood that for a given launch vehicle program, the revenue, flight rates, and therefore fleet size, acquisition costs, and operating costs all follow from the selection of price points within each market. It is unlikely that the true potential of profitability of the program (e.g. maximum IRR) will result from the intial guesses used to establish the initial business simulation. The maximum potential for profitability of a launch vehicle program must be measured via launch price optimization.

It was mentioned before that a combination of a coarse grid search and MS Excel's Solver can be a way of optimizing launch prices. However, there is another method that promises better possibilities. For Macintosh computers, there is a built-in scripting function called Applescript. Using it to call CABAM itself and executing different input values from a remote workstation class terminal with UNIX has been demonstrated for integrating CABAM into a series of design codes architecture. It has also been found that during the remote execution, a command for executing a 'canned' optimizer with CABAM is possible. This is the currently desired optimization method. Details of this method is still under research.

## 4.2. 1-D Trade studies

To account for the dynamic nature of such a large business program over a long period of time, and the risk associated with it, a series of trade studies are necessary after a point execution is conducted with CABAM. Since, after an initial run, all the parameters are fully configured for the particular launch vehicle program, the trade variables can be studied. For example, if a series of good national economy years are expected, the interest rate that the corporate bonds promise may be insufficient to attract enough investors for generating the capital for nonrecurring cost. Vice versa, it would be possible to promise lower interest rate for the bonds if the industry's reliability becomes well advertised to the investors. These possible fluctuations can be studied by varying the interest rate in CABAM. Typical 1-D trade studies are:

1) launch price sweeps to study IRR behavior,
2) fluctuations in average salary for the work crew,
3) fluctuations in inflation,
4) fluctuations in airframe insurance premium...

Sample charts generated for 1-D trade studies for various launch vehicle programs are provided in the Appendix. Multi-dimensional trade studies can be set up using MS Excel's Solver, yet a more reliable method for conducting it is with grid searches in Visual Basic or by linking a standard grid generation code in an UNIX environment.

Combinations of these 1-D trade studies can build business scenarios for further forecasting. Within reasonable probability, maximum and minimum profitability scenarios can be generated after collecting a series of 1-D trade study results.

### *4.3. The PGP Envelope and Results*

In most cases, IRR, BEP and maximum exposure are the most important indicators to consider for a given launch program. However, from the program management's point of view, a PGP envelope can be of great value. The PGP envelope is the maximum and minimum possible cumulative cash flows from the associated business scenarios. Each scenario has IRR, BEP and maximum exposure associated with them, yet a graphical representation of the 'ball park' can be shown in the PGP envelope. A sample is shown in Figure 7.

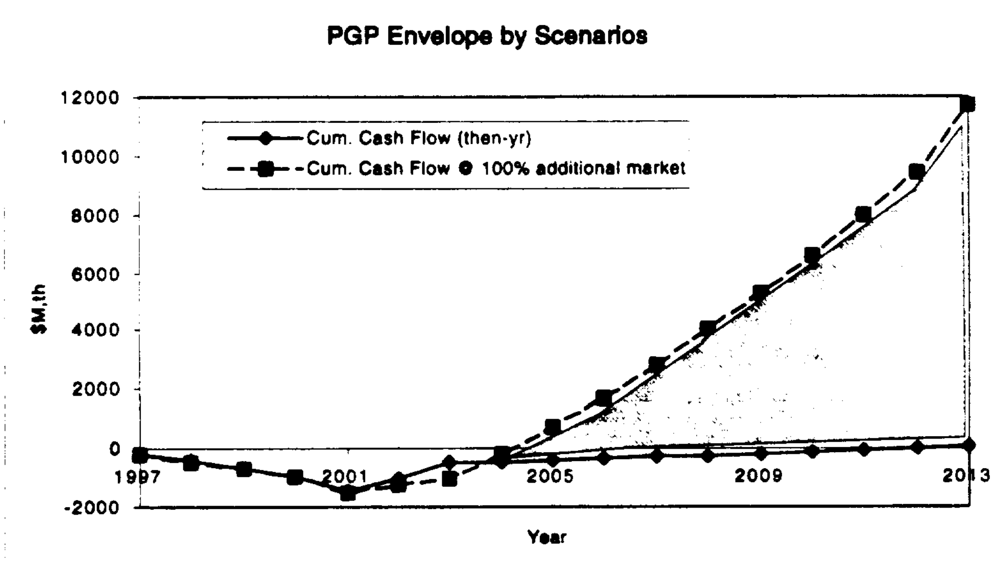


*Figure 7. Sample PGP Envelope*

Additional information that can be of interest should be included as a part of economic assessment results. For example, recurring cost per lb. of payload for each mission, the margin between revenue and recurring cost for each mission and LCC breakdowns are valuable information that are readily available or easily obtainable information with CABAM. The element of risk is tremendous in all-inclusive economic assessments as with CABAM and the user should be aware of a certain degree of conservativeness that is necessary in conducting an analysis with CABAM.

# 5. ACKNOWLEDGMENTS

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# 7. APPENDIX

Sample Charts from 1-D Trade Studies

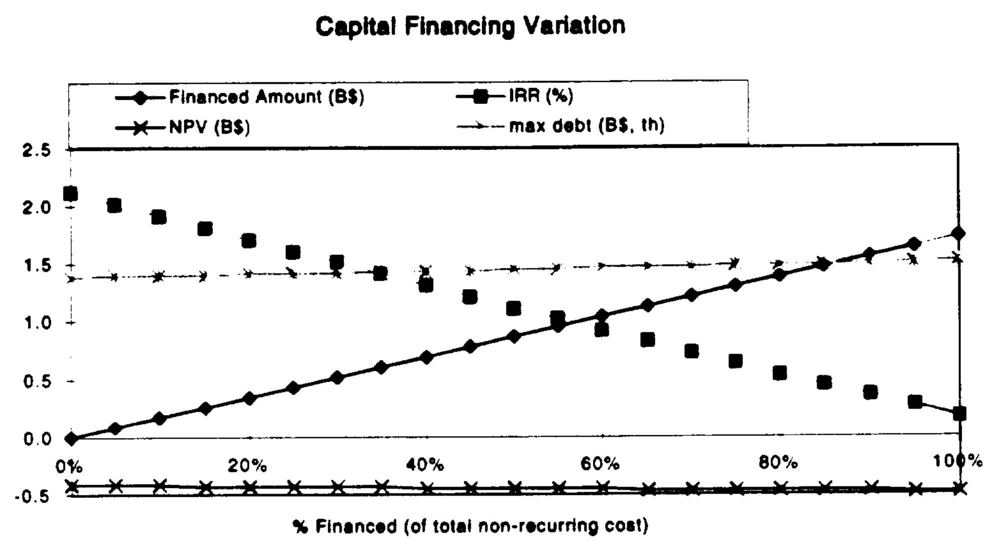


*Figure 8. Capital Financing Variation Study*

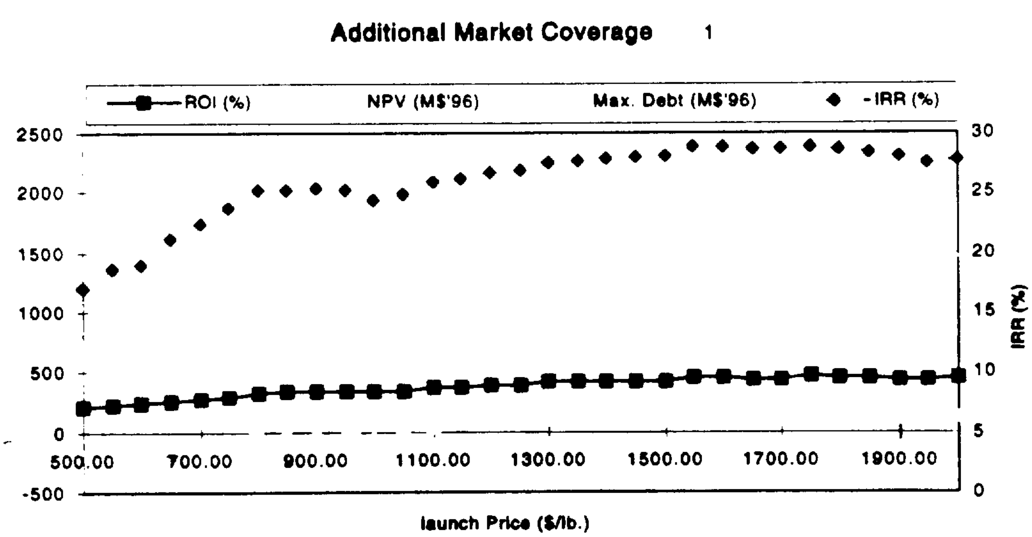


*Figure 9. 100% Market Expansion Study*

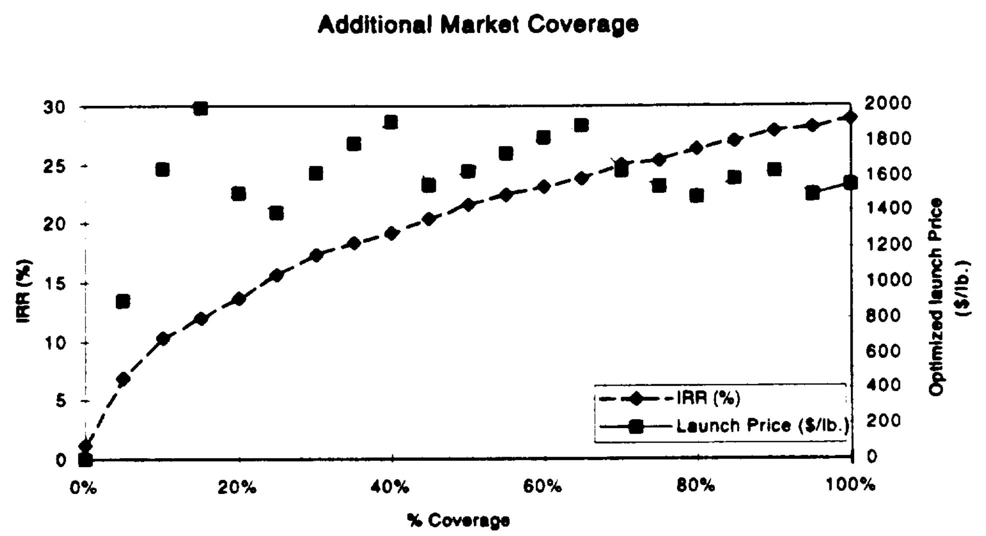


*Figure 10. Market Expansion Variation Study*

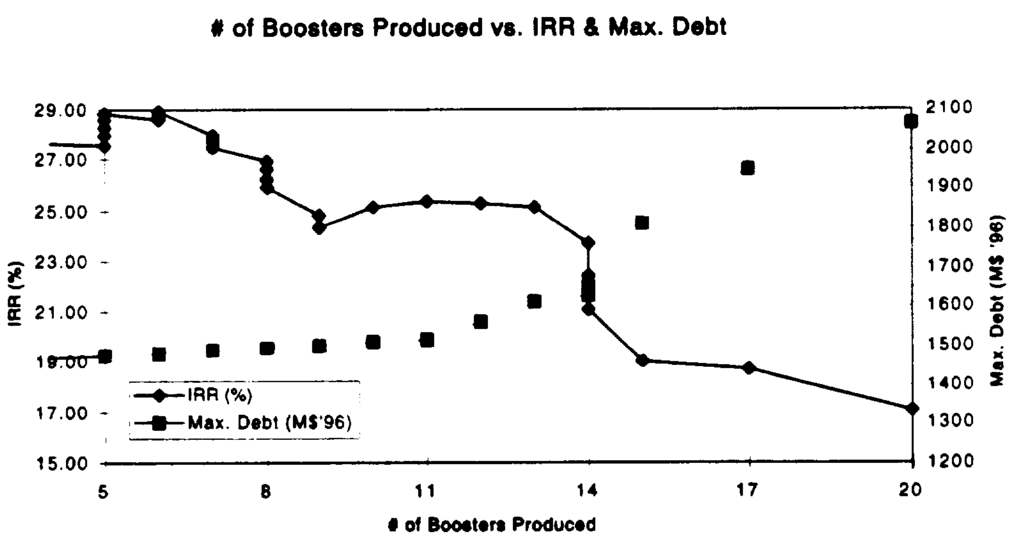


*Figure 11. Market Expansion &Booster Production Study*

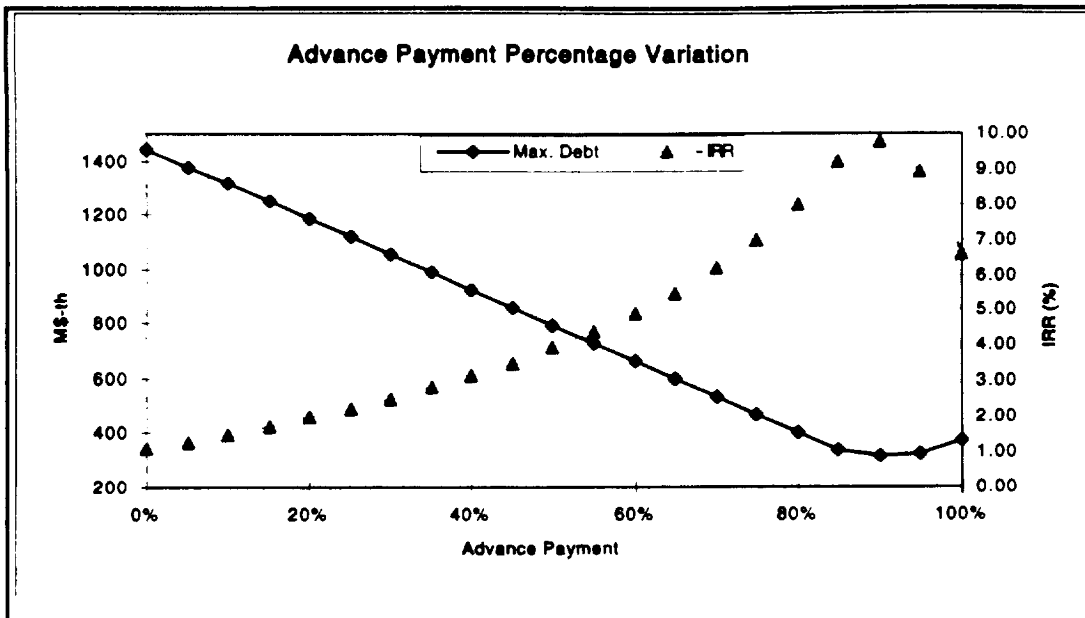


*Figure 12. Advance Payments Variation Study*

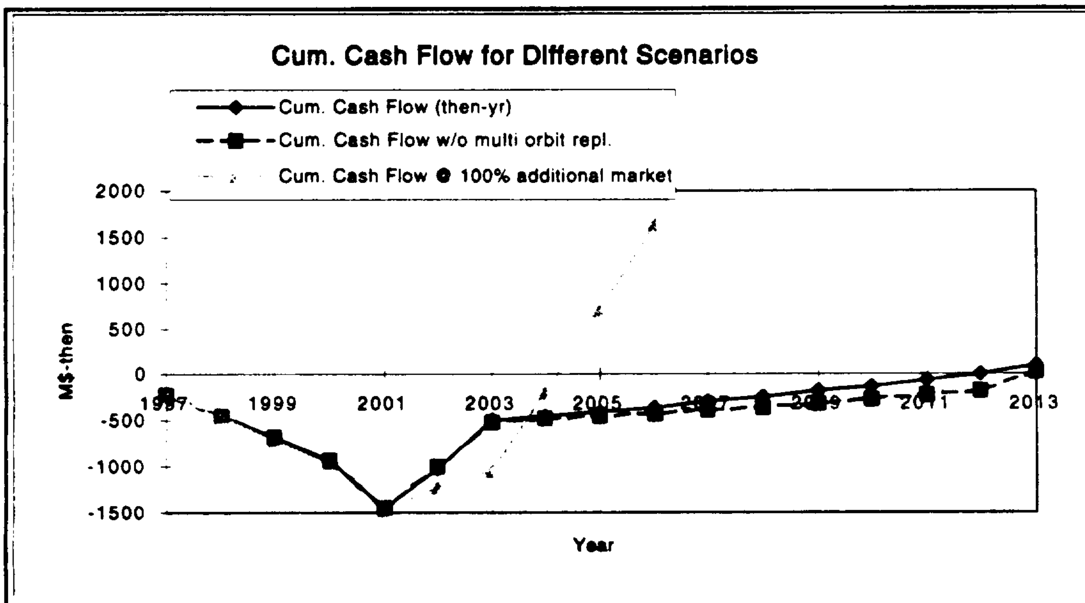


*Figure 13. Business Scenario Comparison*