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Marco-parametrics; its unique capability and application

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Abstract

The Family of Advanced Cost Estimating Tools (FACET) has been used around the world as a macro-parametric cost model during the early stages of a project life cycle. It has been used to explore concept options, set early budgets and conduct independent cost estimates (ICE) with minimal information. With more than fifty system level cost models, covering space, land, sea and air domains, FACET has provided early and reliable conceptual costs since its inception in 1986.

FACET has a unique capability as it addresses the shortcoming of other parametric cost models through an interpretation of the performance requirements into a design. Taking both the performance and the design characteristics of a concept the model utilises Bayesian combination to seamlessly transition from performance based estimating to design based estimating. At the same time it will make initial observation on the risk of the concept design at an early project life cycle phase thus safeguarding against entry-ism or inadequate budgets.

Furthermore, FACET has the unique capability to combine three point estimate inputs and algorithm uncertainty. Considering both distributions and combining them is the only means of producing a true cost estimate that reflects the potential outcome of the parametric modelling.

This year sees an exciting new development as PRICE systems and QinetiQ have combined forces to deliver both sets of algorithms in the well-established TruePlanning cost modelling framework. It is now possible to access the best cost tool for the project life cycle in one easy to use interface giving you outstanding cost and schedule forecasting capability through a hybrid product breakdown structure of parametric cost models; either FACET, PRICE or both.

This paper will explore the development of this ultimate cost forecasting solution, its applications and benefits.

Keywords: macro-parametrics, micro-parametrics, cost model, FACET, TruePlanning.

Introduction

This paper will describe the integration of QinetiQ FACET parametrics cost model into the PRICE Systems cost framework. Furthermore, it will consider some applications of this combined capability.

QinetiQ was formed in July 2001, when the UK Ministry of Defence (MOD) split its Defence Evaluation and Research Agency (DERA) in two. The smaller portion of DERA, was rebranded Dstl (Defence Science & Technology Laboratory) and this remains part of the MOD. The larger part of DERA, including most of the non-nuclear testing and evaluation establishments, was renamed QinetiQ and prepared for privatisation. QinetiQ became a public private partnership in 2002 [1.].

As a people based business, our service offerings account for the majority of sales. In addition our products division provides technology-based solutions on a global basis including offices in Australia and Canada. Through their technical expertise, know-how and rigorous independent thinking, our engineers and scientists are uniquely placed to help customers meet challenges that define the modern world. These challenges include affordability and seeking value for money (VfM).

PRICE Systems was founded as an RCA business in 1975 and taken into private ownership in 1998. With headquarters in Mt. Laurel, New Jersey, USA and additional offices in DC, OH, VA, UK, France, Germany plus partner companies in China, S. Korea, Japan, Australia, Italy, Germany, and elsewhere. PRICE Systems have more than 350 customers and more than 12,000 project professionals trained worldwide [2.].

PRICE Systems improves their customers overall cost management by helping them to increase revenue and save money by empowering them with proven cost models and predictive cost analytics. Through this they become better estimators enabled to improve their bid success ratios, and achieve tremendous savings in analysing alternatives. They become confident in their cost, schedule, and risk estimates through the application of TruePlanning® software, PRICE Models, benchmark databases, integrated processes, and implementation services including PRICE University, instructor-led training on best estimating practices and mentoring and support for product implementation.

Macro- and micro-parametric cost modelling

When little data is available at the start of a project, parametric and analogous estimating methodologies are generally acknowledged to be the preferred approach as shown in Figure 1.

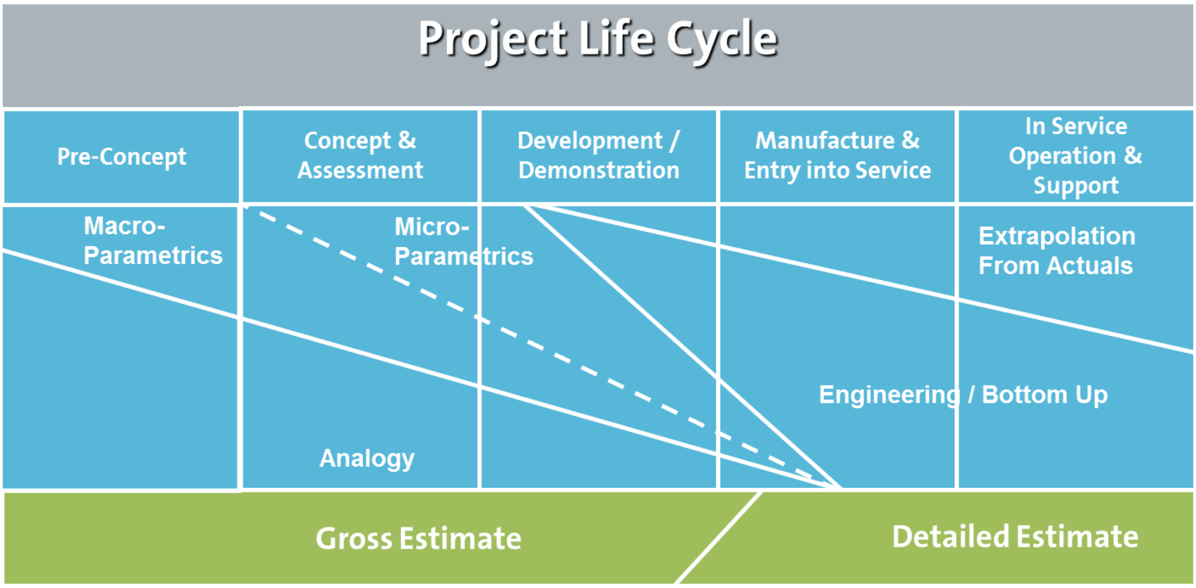

Figure 1: Types of cost forecasting methodologies across the life cycle.

This International Cost Estimating and Analysis Association (ICEAA) diagram [3.] has been developed to extend the project life cycle backwards to early decisions and the parametric methodology has been split into two sub-elements. We have identified two types of parametric cost model as defined in Table 1.

Table 1: Characteristics of parametric models

Classification	Model focus	Mathematics	Cost drivers
Marco-parametrics	Platform / system	Multiple specific models	Few platform specific parameters
Micro-parametrics	Technology / Line Replaceable Unit	Single universal model	Many universal parameters

QinetiQ has developed a macro-parametric cost model called Family of Advanced Cost Estimating Tools (FACET) [3.]. FACET has a life cycle cost (LCC) capability that makes it well-suited to the creation of cost forecasts at an early genesis stage in the project life cycle. This is complementary to the TruePlanning cost models which includes micro-parametric tools, such as hardware, software and information technology models, with the ability to produce more detailed cost forecasting results.

True FACET internal research and development

QinetiQ has funded an internal research and development project (IRAD) to port the FACET algorithms into the PRICE Systems TruePlanning cost framework [5.]. The FACET and PRICE System models complement each other providing suitable parametric capability depending upon the maturity of the project life cycle.

A software development contract and licensing agreement took some time to negotiate, but at the conclusion both parties were ready to start the implementation in earnest. We adopted an incremental approach to the development and QinetiQ provided the FACET algorithms for a single model. PRICE Systems quickly implemented this complete Infantry Fighting Vehicle

(IFV) cost object together with framework tailoring. The QinetiQ team began a test schedule and found the implementation to be satisfactory; providing identical results to the original FACET implementation. This triggered the second increment when the algorithms for more than fifty cost models were delivered for implementation. Around Christmas 2016 the TruePlanning framework and True FACET catalogue was delivered for testing. Following structured testing the product was accepted and the final increment invoked. This included the peripheral items essential to a commercial product; the help systems, the training material, licensing and so forth.

It is recognized that this "final product" is not really final. The True FACET models will receive maintenance, updates and upgrades in future to ensure that they remain current and reflective of emerging technologies. The number of cost objects will also grow: we already have ideas around a number of system types that need adding.

Overview of the True FACET White Paper

There is a database of historical information that is common to all parametric cost models. Typically the database will include national and international projects, but there have only been a limited number of defense projects through history.

Frank Freiman, the acknowledged "founding father" of parametrics looked at this database and saw different technologies; welding steel, riveting aluminum, composites and so forth. His research led to one universal model with numerous independent variables (over seventy) to represent the future platform cost estimates in the parametric models, at the micro- and the macro-levels. The difference between micro and macro-parametrics is the different approach to the cost research, as shown in Figure 2.

The macro-parametric cost research at QinetiQ considered the database as numerous platform or system types. This research led to numerous (currently 50+) parametric models each with a few platform-specific independent cost drivers to be populated.

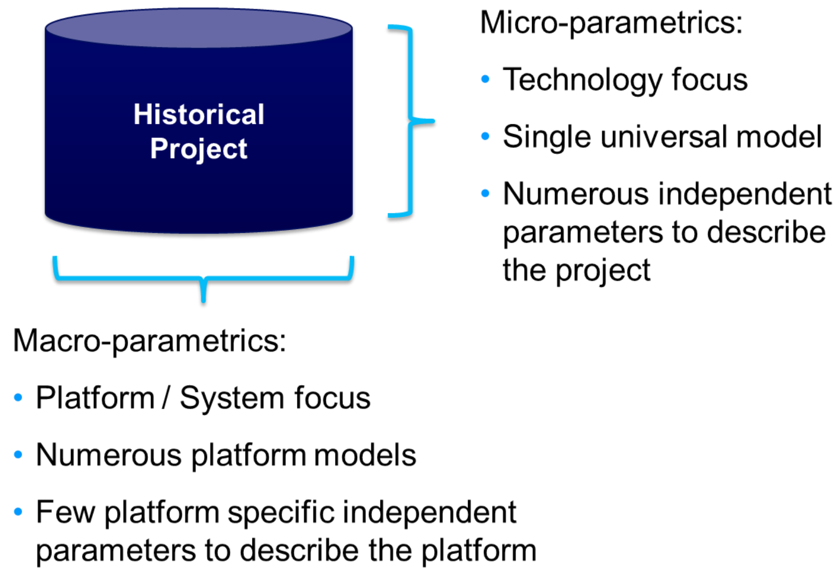

Figure 2: One database: two cost research methods

The True FACET cost model calculates the total life cycle cost (LCC) of a system from a top-down view using the following equation:

$$LCC_n = D_n + PI_n + P_n + C_n + M_n$$

Where:

D_n = the Development cost
PI_n = the Production investment cost
P_n = the Production cost
C_n = the Crew cost and
M_n = the Maintenance cost

It is typical in parametric cost models for the cost drivers to be size (for example weight or SLOC), complexity (for example Technology or functional complexity) and productivity relative to average industry (for example tooling or processes) [6.]. The True FACET model cost drivers are Design (DE_n), Performance (PE_n) and Technology year (T_n).

Research, development, test and evaluation cost algorithm

As shown in Figure 3, the True FACET system has input for both performance and design. The performance requirements are translated through sizing rules to create a nominal design. This is compared mathematically with the user design inputs. If the inputted design details have a wide tolerance band, as is the case at the start of a project, the underlying algorithm within True FACET will interpret this as a user who is uncertain of the design of their finished system. True FACET will hence discriminate against the user entered design parameters, and generate an output that is aligned to the nominal design derived from the entered performance parameters. True FACET effectively forecasts, for the required level of performance, what the user should be expecting in terms of a design. True FACET alerts the user that this has happened, and advises the user as to the design parameters that they should be expecting to meet their performance requirements.

As the project life cycle progresses and the tolerance on the design parameters progressively reduces to certainty the estimate then has bias towards the design inputs. The True FACET model will signal initial observations regarding this comparison and highlight any technical risks if the performance derived design and design inputs are seriously misaligned.

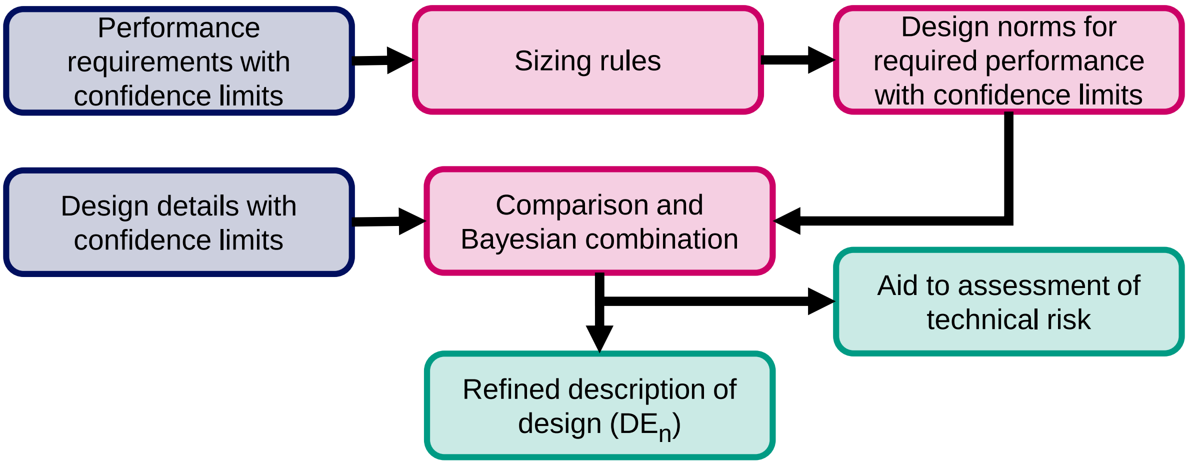

Figure 3: True FACET estimating process with the application of Bayesian approach

The True FACET model calculates the research, development, test and evaluation (RDT&E) cost (D_n) for the system *(n)* as a function of the following parameters:

$$D_n = \int(DE_n, PE_n,\ T_n, Nat_n, Nvar_n)$$

Where:

DE_n = the Design parameters
PE_n = the Performance parameter
T_n = the Technology Year
Nat_n = the number of participating nations in the project
$Nvar_n$ = the number of variants to be developed concurrently with the basic design

This function is combined in a mathematical form with a number of constants and coefficient parameters which are derived from statistical analyses of past projects. The impact on the development cost of a programme involving multiple nations is shown in Figure 4.

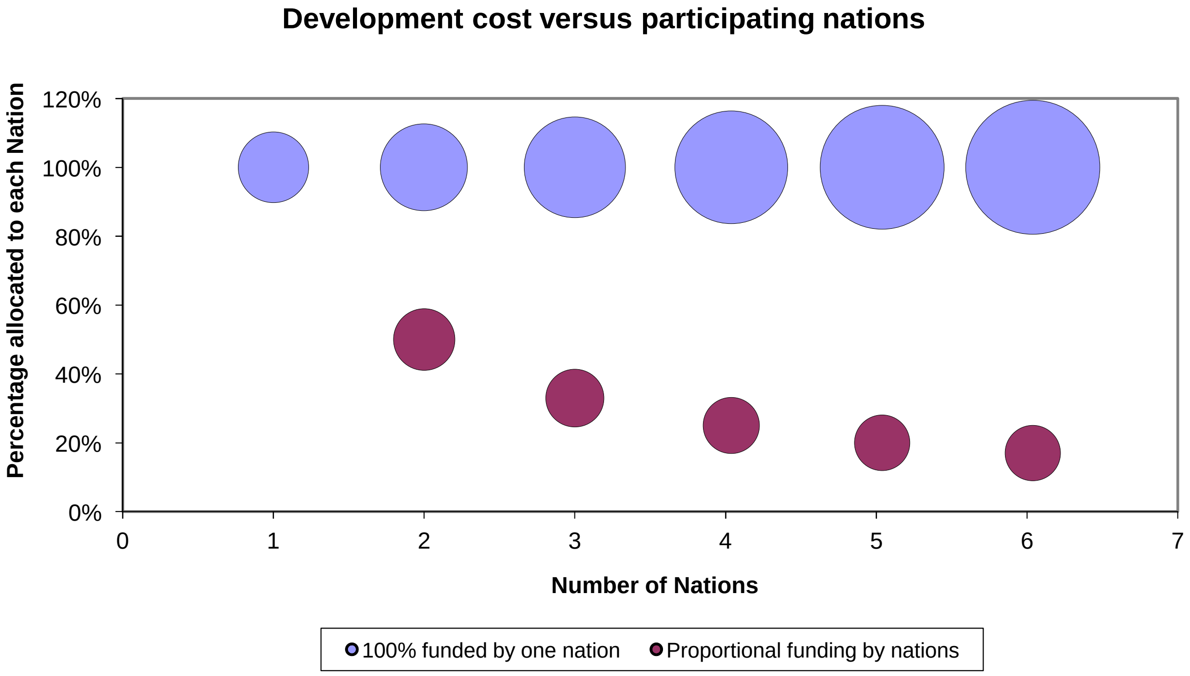

Figure 4: Impact of multiple nations

While the total cost burden (indicated by the blue circles) associated with the development activities increases with the number of participating nations, this is offset by the fact that each individual nation bears only a fraction of the total project development cost (indicated by the red circles). The individual contribution should be less than the total burden for a single nation project, but this is dependent on the workshare agreement.

Production cost algorithm

The model calculates the Production cost (P_n) for the system *(n)* as a function of the following parameters:

$$P_n = \int(DE_n, PE_n, T_n, Q_{ref}, R_{ref})$$

Where:

DE_n	= the Design parameters
PE_n	= the Performance parameters
T_n	= the Technology Year
Q_{ref}	= the reference quantity in the project
R_{ref}	= the reference production rate in the project

Again this function is combined in a mathematical form with a number of constants and coefficient parameters which are derived from statistical analyses of past projects. The influence of acquiring a batch of systems from progressively larger production runs is shown in Figure 5.

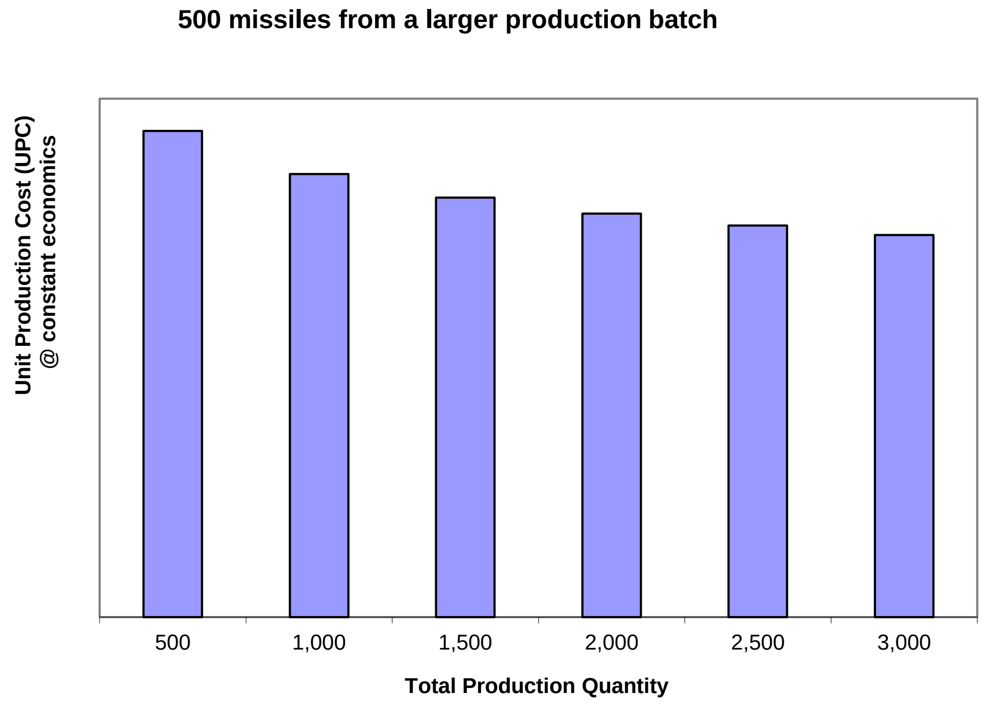

Figure 5: The effects of large scale manufacture

It can be seen that taking a lot or batch from part of a larger production run has the impact of reducing the unit production cost. This naturally only holds true if the remaining production items are sold as foreign military sales (FMS) or another funding stream.

The model calculates the Maintenance cost (M_n) for the system (*n)* as a function of the follows parameters:

$$M_n = \int(DE_n, PE_n, T_n, Act\ \ )$$

Where:

DE_n	= the Design parameters

PE_n = the Performance parameters
T_n = the Technology Year
Act = the activity or operating tempo of the system

Again this function is combined in a mathematical form with a number of constants and coefficient parameters which are derived from statistical analyses of past projects. The operating tempo of the system's use is an influence on the maintenance costs, if the system is constantly stored in an environmentally controlled warehouse to preserve it and is never used, it will never fail or require maintenance. Conversely, if it is used for training purposes 24 hours of the day, 7 days per week, then the likelihood of there being failures and the need for maintenance will increase dramatically.

True FACET

With the implementation of True FACET in the TruePlanning cost framework it is possible to generate a host of different cost estimates. The initial list of cost objects are shown in Figure 6.

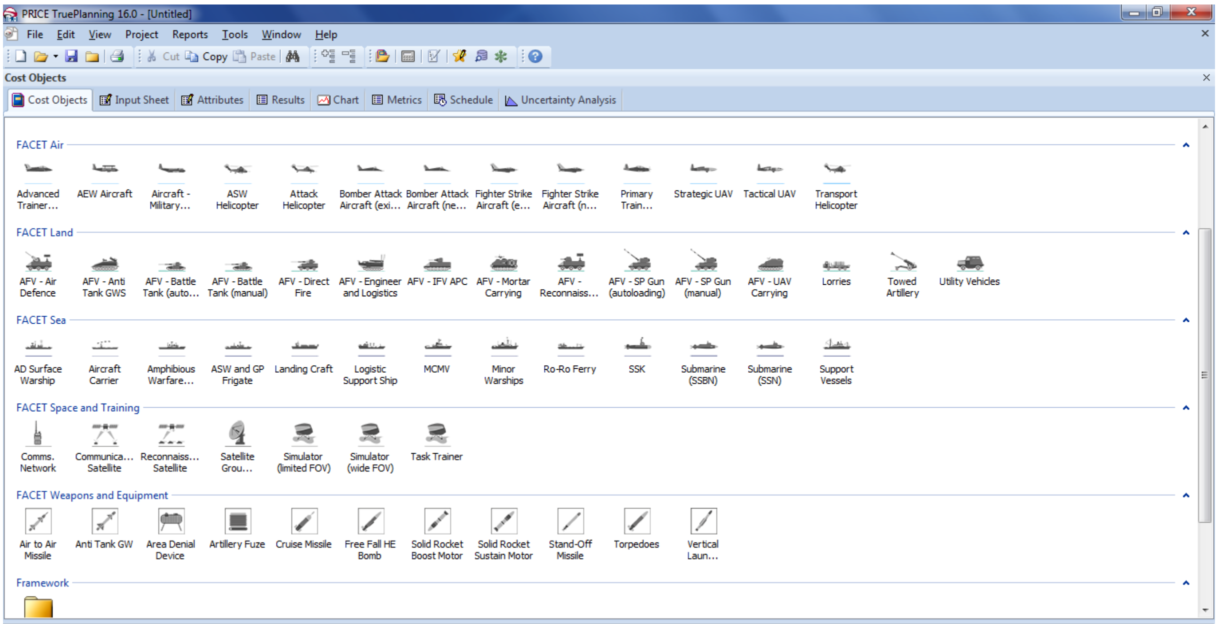

Figure 6: Screenshot of the True FACET catalogue

The True FACET cost objects benefit from the intuitive graphical user interface (GUI) of the TruePlanning cost framework. Due to the adoption of the activity based costing (ABC) construct, with activities and resources, all the standard graphical and tabular outputs are accessible. This makes the adoption of True FACET quick and easy for the existing clients of the TruePlanning system as little training is necessary, just time focusing on the understanding of the True FACET parameters allowing more time to apply the models.

Applications of True FACET

In a mature cost estimating organization there is a recognized need for data, tools, people and processes [7.]. True FACET has the ability to enhance the maturity of a cost estimating organization as a tool with multiple applications. Due to the macro-parametric nature of the True FACET model the applications align themselves to the early phases of a project life cycle and high level analysis, for example, the balance of investment (BOI). True FACET enables you to consider high level policy and strategic questions to influence the shape and size of the current and future armed forces: the ability to ask 'big picture' questions, for example: "*Is the army too big?*" or "*What is the spend profile if we delay the introduction of a new capability?"*

It enables you to consider the cost effects of strategic policy changes, for example: "*Are there cost savings from merging elements of the services?*" or "*What would the services cost if all the rotary-wing fleet were in a separate service?*" As a programmatic view, True FACET enables the consideration of changes of acquisition strategy or political policy, for example: "*How is the budget influenced by a pure sovereign manufacturing policy?"* or "*What is the impact of an Anglo-American procurement?*"

Figure 7 shows a simple example of a force structure with a variety of elements [8.]. Through the global or specific change of the input parameters it will be possible to consider the impact of those questions on the cost profile.

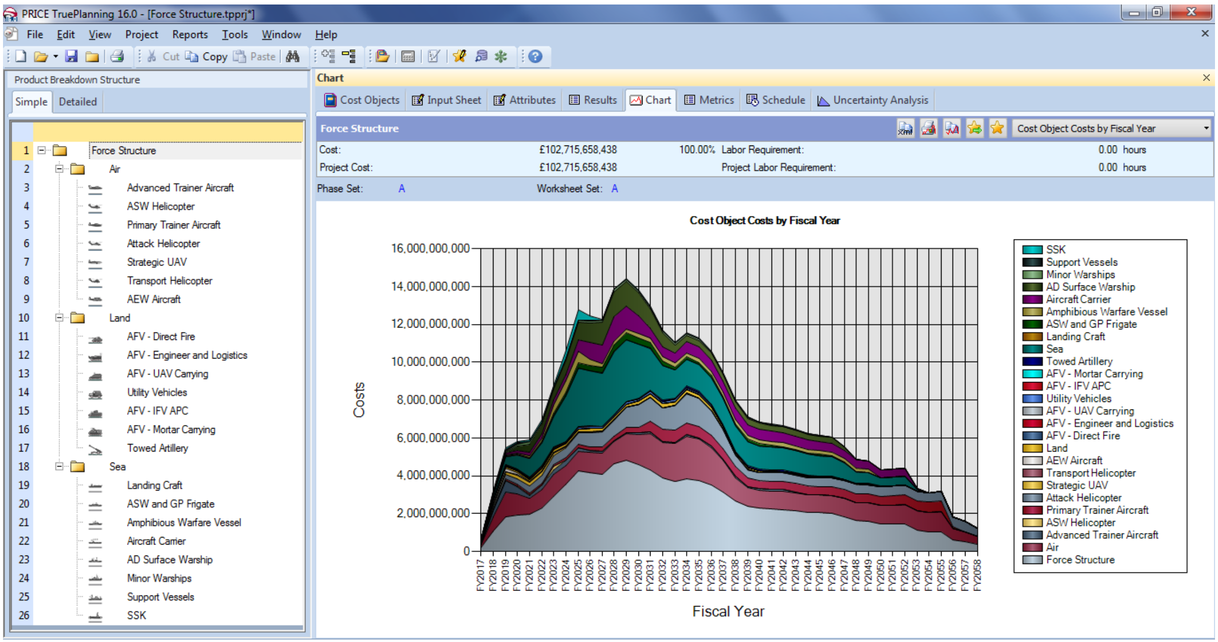

Figure 7: Balance of Investment (BOI) application

Due to the limited data required to populate the True FACET models at an early stage of a project, it is possible to set realistic budgets. This might seem obvious, but setting sufficient budget for the acquisition and support of a capability will help ensure a legacy, exemplar project that avoids cancellation.

Avoid setting unrealistic budgets early at the genesis stage of a project by guessing the budget needed. For example, a statement such as: "*I'm sure I read an article that these things cost X million*" needs to be a statement of the past. Although establishing a project is seen as a real career enhancement, if the project funding is not enough, as shown in Figure 8, at each approval gate, review or business case the possibility of cancellation increases and your reputation diminishes.

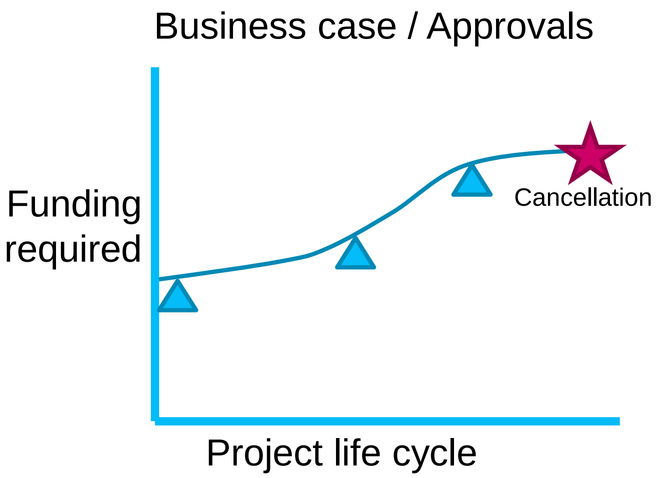

Figure 8: The need to set early realistic budgets

Unrealistic budgets threaten the project at later stages due to the lack of realistic funding, inevitably there is a conversation "*We need to discuss a fleet that is 70% of our need due to funding constraints or cancel the project*". Based on limited information True FACET is able to provide realistic life cycle cost estimates early in the project life cycle to avoid unrealistic funding constraints and budget squeezes in later life.

True FACET enables you to quickly explore the costs associated with viable systems that can satisfy the capability statement or performance need with realistic designs; early analysis of alternatives. During the initial period of the project life cycle there are the opportunities for project decisions to influence the life cycle cost at minimum expense to the overall project, as shown in Figure 9.

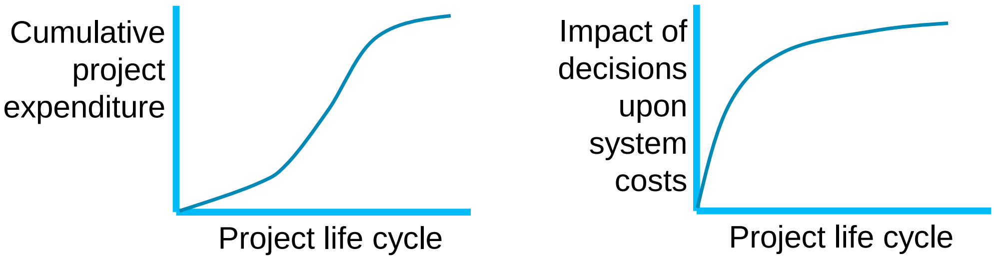

Figure 9: Early consideration of the analysis of alternatives

When in the pre-concept phase of a project, one should not have to guess at the best design solution, for example: "*let's make it a wheeled vehicle*". Once the project is approved and started any changes to the systems requirements or the systems designs are huge, for example "*it should have had tracks, can we discuss the options?*" Based on limited information True FACET is able to provide realistic cost estimates across a number of competing designs early in the project life cycle to avoid inappropriate expensive design decisions needing to be corrected in later life.

Finally, True FACET can support the comparison of different design options in terms of affordability and cost effectiveness through optimization of system designs, see Figure 10.

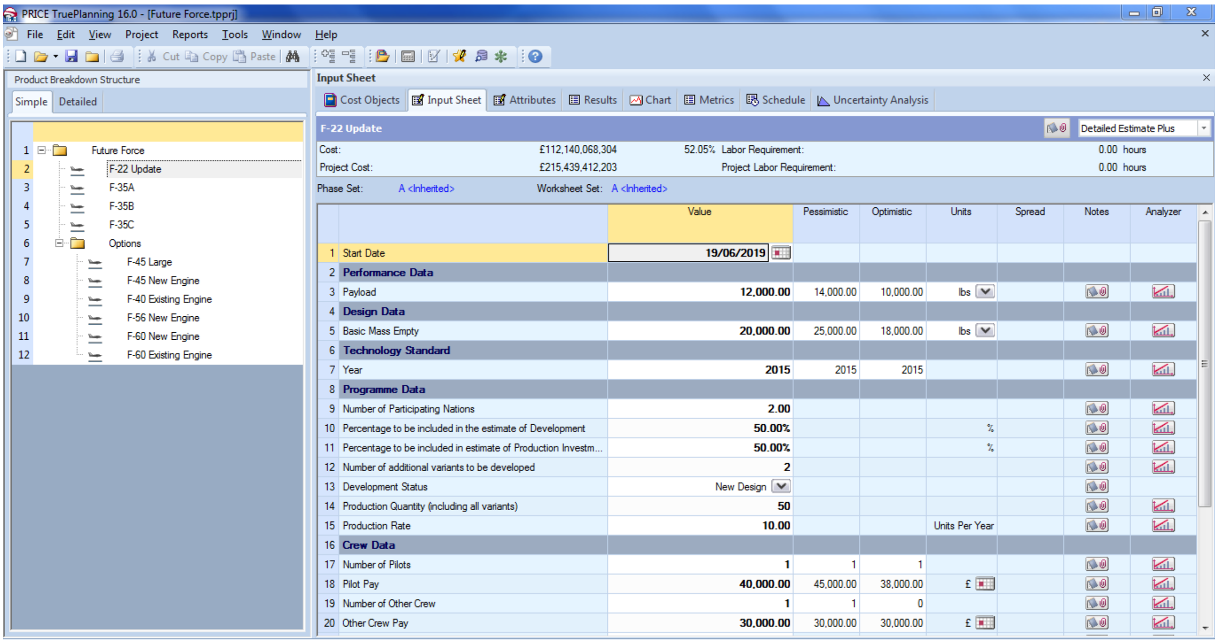

Figure 10: Optimization of system designs

True FACET has the ability to rapidly generate the life cycle cost across multiple platform options that include:

- Research, Develop Test and Evaluation (RDT&E)
- Production Investment (PI)
- Total Manufacture
- Unit production cost (UPC)
- Crew
- Non-crew or maintenance

This capability makes the early down selection of all alternative options possible in a quick and easy to use cost forecasting environment.

Conclusion

This paper has examined some of the challenges of cost forecasting complex projects. Business processes demand that projects have costs generated for them early when there is little information available. The combination of the FACET algorithms and the TruePlanning cost framework provides an excellent through life estimating capability.

Marco-parametric estimating is useful early in a project and has a number of applications, including, but not limited to:

- Balance of Investments
- Realistic budget setting
- Analysis of alternatives
- Optimising the Systems design

With TruePlanning it is now possible to utilise the FACET macro-parametric cost model and hardware, software and IT micro-parametric cost models seamlessly within a single framework saving time and money on training and cost forecasting.

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