FASIP – Functional Analysis of System Implementation Parameters

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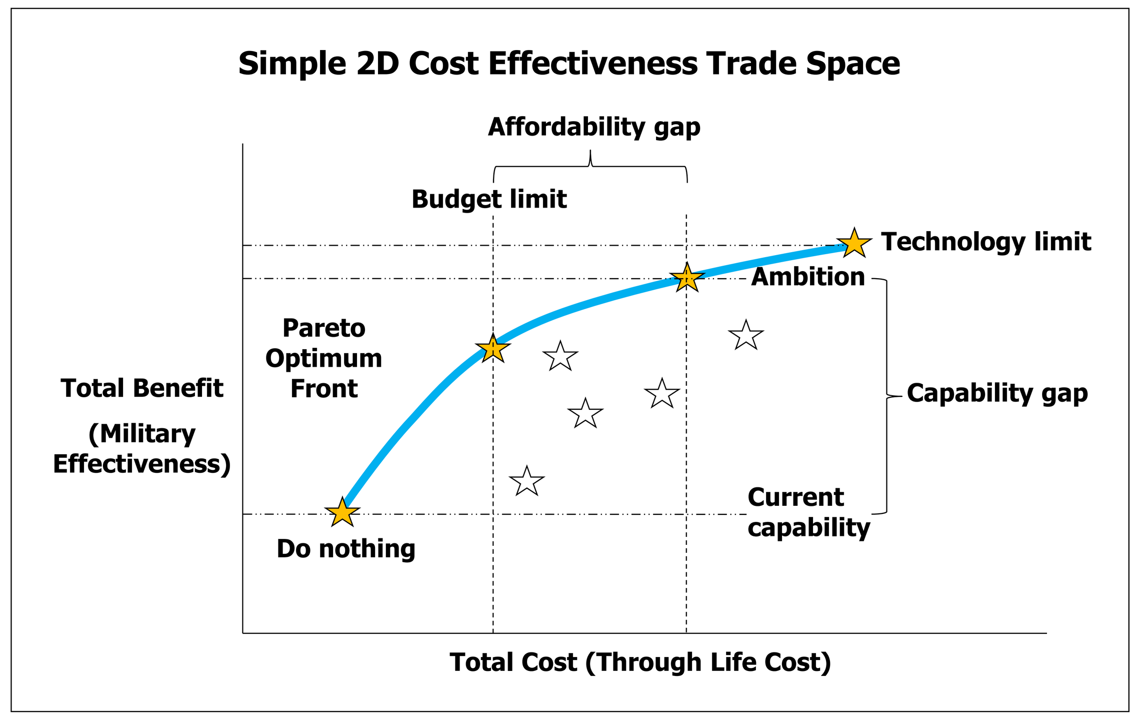
What is Cost Effectiveness

Cost effectiveness for military systems is best described as a comparison between the net overall costs and operational and other benefits offered by the system. If these quantities are kept separate then the issue of cost effectiveness is concerned with determining the best balance between them for any particular system user. In its simplest form a cost effectiveness plot of overall cost and benefit for multiple system options is shown below. An important characteristic of such plots is the presence of an optimum Pareto Front representing the best value solutions for a particular user. In todays environment of rapidly evolving technology and budget constraints ambitions in terms of capability have to be tempered by budget availability.



Developing Cost Effective Systems

In order to make Cost Effectiveness trade off decisions as early as possible in the concept stages of a project The following activities are required:

1. **Concept synthesis:-** to generate viable solutions quickly to the point that reasonable cost estimates can be made
2. **Operational analysis:-** to assess the military value of the solutions
3. **Multi criteria decision analysis:-** to make sense of the large amount of data generated by 1 and 2.

There is a therefore a need for a generalised high level system configuration modelling, assessment and ideally optimisation framework that can bring together all the above elements for feasibility studies across a wide range of systems. The FASIP methodology has been developed to provide this capability.

FASIP Methodology

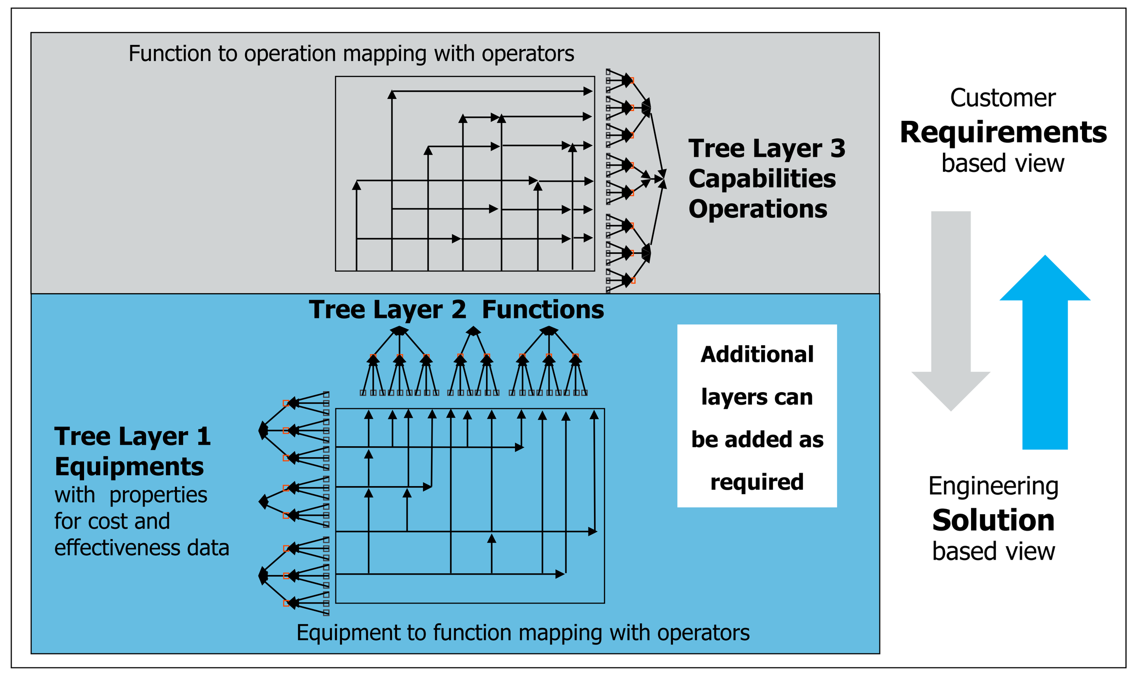
The FASIP approach is to take a high level view of the whole system by coupling together two opposite views

1. **Top Down :-** The user driven requirements based view of what a system is intended to deliver
2. **Bottom up:-** The engineering based view of how the system is reflecting the real world constraints and limitations that will exist, particularly if existing sub systems are to be utilised

These two views each consist of a data layer comprising a tree structure made up of items describing the important parameters of the view. So the top layer will typically comprise elements representing objectives or benefits to be provided by the system whist the lower layer will be made up of sub assemblies and equipment elements comprising potential solutions. Therefore in simple terms the upper layer is built around benefit elements whilst the lowest layer focuses on solutions and cost drivers. Properties describing attributes of the data items are passed through the data layers and from layer to layer. These attributes may include

- User priorities or objectives
- Benefits
- Measures of performance or effectiveness
- Cost elements

A complete model is likely to be constructed from multiple layers of tree structures with multiple system properties being passed up through the layers by means of links between the layers. The intermediate layers are used to understand the relationships between costs and benefits. They are typically comprised of system functions provided by different equipment elements and their connections to the upper levels will reflect the functions influence on operational benefit.



Methodology Evolution

In its original form the approach was essentially qualitative and was used to drive the initial concept design of what became the River Class Patrol Vessels based on the wider needs of Exclusive Economic Zone management by identifying how sub system elements influenced overall high level operational objectives (ref 1).

Over time quantitative analysis was added whereby properties were calculated as they moved through the data layers. Once the properties of interest at different layers could be evaluated for different selections of data items within the data trees Cost trade offs could be performed followed by optimisation of possible equipment combinations. This was used in support of the T26 Capability Decision Point process (ref 2).

More recent developments have allowed more data layers, more complex evaluations and mechanisms to automatically enforce item selection interdependencies. These extensions have been fully exploited in studies on force mixes within DSTL (ref 3).

Methodology Elements

Currently application of the FASIP approach involves the following capabilities and methods

- Construction of multiple interlinked **Data Tree Structures**
- Calculation of **Multiple System Properties** through model data tree layers and links
- Definition of a **Variety of Relationships** between properties of different data tree elements and layers, reflecting engineering dependency, redundancy etc.
- Generation of **New Properties** from existing
- **Selection of Subsets** of any data tree items for evaluation and sensitivity analyses
- Use of a range of **Calculation**, **Data Plotting** and **Output** formats
- Definition of alternative **Options** for data items within data tree structures
- Definition of **Property and Link Values** that can vary for different selections
- Performance of **Pareto Front Multi Variable Optimisation** to optimise selection of data item options and property and link values in complex trade spaces
- Definition of **Constraints** to be imposed on solutions
- Definition of **Rules** to be applied to choice and property/link values combinations, reflecting real world practicalities and engineering constraints
- Development of optimum solutions that are **Robust to Variations** in property values

Methodology Use

The objective of FASIP modelling is to understand the trade space of solutions that offer alternative balances between cost and effectiveness. This is necessary in order to find an acceptable compromise between bridging the capability and affordability gaps inherent in modern military system procurement. It is of course essential that any solutions selected can be shown to represent the best value for money i.e. lie on the optimum Pareto front of the potential system cost effectiveness trade space.

System assessment and optimisation is typically performed with three data layers as follows

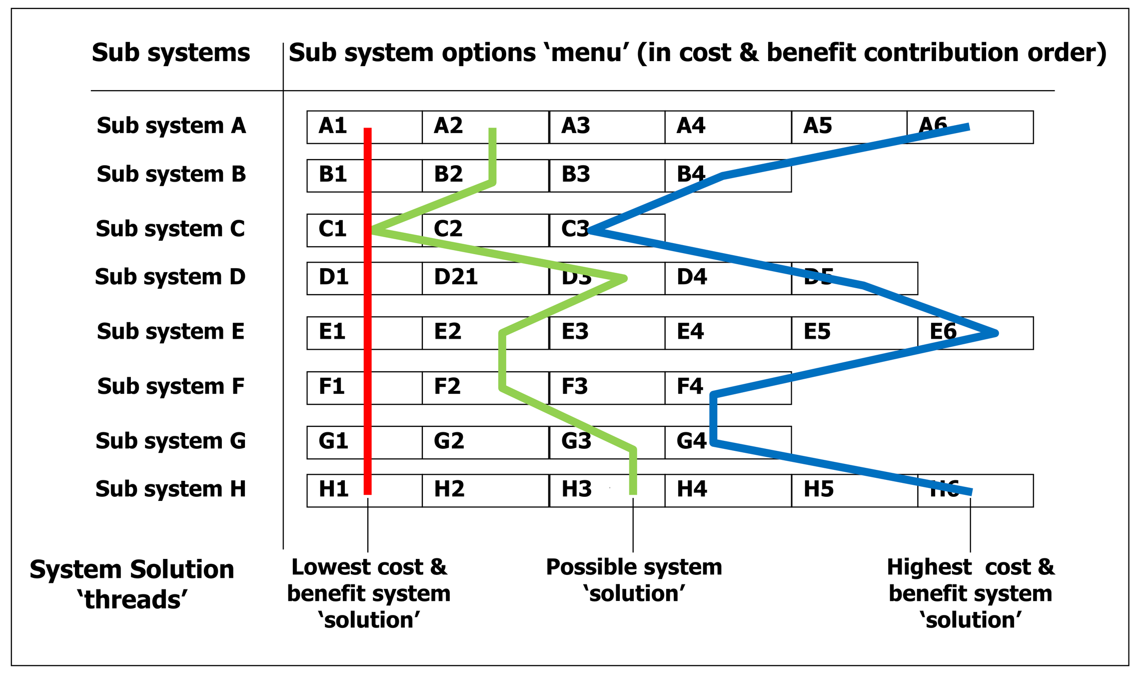
1. **Operations :-** The stakeholder view of the system, characterised by stakeholder value defined by Measures of Effectiveness or preferences. The discipline of Multi Attribute Value Theory (MAVT) is likely to be the source of tree structure and data values
2. **Functions :-** Effectively Measures of Performance derived from the Equipments
3. **Equipments :-** Individual elements and sub assemblies with associated costs etc.

Engineering design practicalities dominates the lower data layers whilst Operational analysis will inform the generation of data for the middle and upper layers.

System Optimisation

If cost and benefit contributions are defined as functions of each data item, property and link value option then the Pareto front comprising the data item selections and values giving the most favourable total cost effectiveness ratio can be identified using various algorithms

1. **Stepwise Search :-** For 2 D optimisations of simple linear models with no discontinuities, a rapid stepwise search approach may be used
2. **Genetic Algorithm:-** Applicable to multi variable non linear models with multiple constraints and option interdependencies



Optimisation Refinements

Optimisation requires the automation of the complexities involved in selecting viable sub system combinations considering issues of equipment dependence and compatibility etc. This can be achieved by automating the application of rules used by designers in developing viable systems

The use of genetic algorithms allows the optimisation process to be extended to

- Include constraints on properties of interest
- Incorporation of rules on data item and value option combinations. Rules needed include
  - Equipment A **never with** equipment B
  - Equipment A **always with** equipment B
  - Equipment A **needs** equipment B
  - Equipment A **needed** by equipment B
  - If all of equipment A, B and C are present then **need** equipment D
  - Equipment A **needed** if all of equipment B, C and D are present
  - If one of equipment A, B or C are present then **need** equipment D
  - Equipment A **needed** if any of equipment B, C or D are present
  - Equipment A **needs** one of equipment B, C or D
  - Equipment A, B or C **needed** if equipment D is present
- Generate fronts that are robust to variations in individual data item property values. Typically such robustness could be developed by the use of Monte Carlo runs during functional evaluations to determine probable rather than nominal outcomes. This is very time consuming. However by allowing the data to vary during the population evolutionary process, and incorporating suitable measures into the population optimum identification process at each generation, this can be performed much more rapidly. Typically a time overhead of times two as opposed to the factor of hundreds needed by a traditional Monte Carlo approach.

References

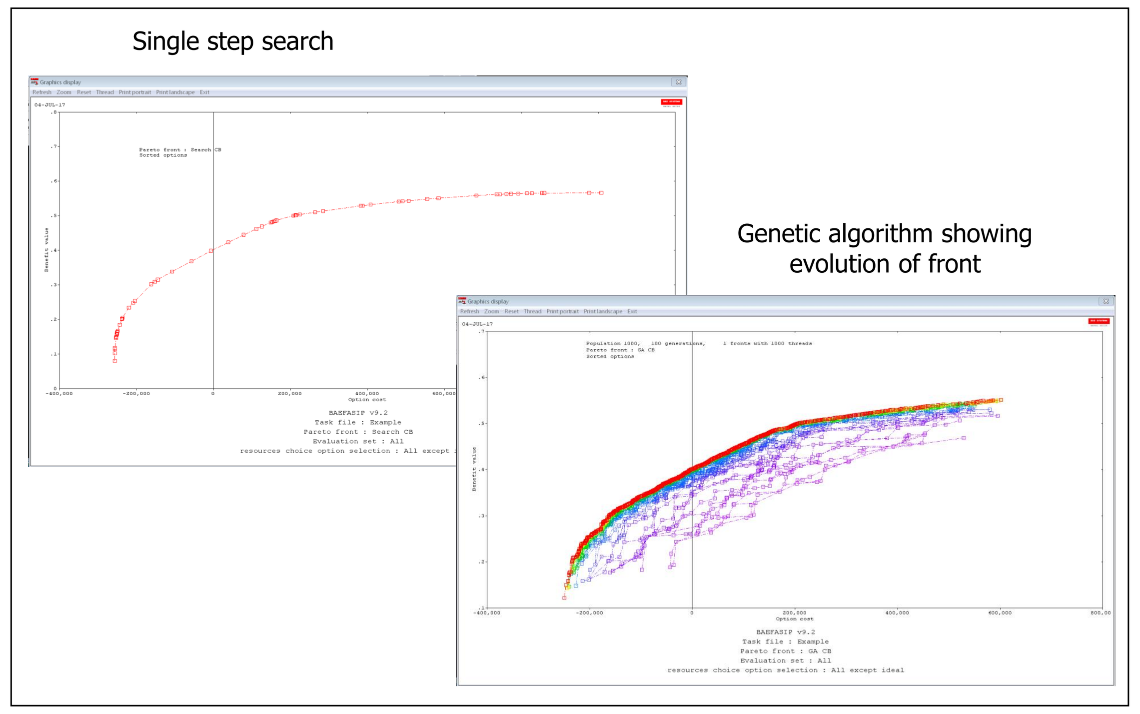
1) Courts, M., Brown, P., Tucker, P., Maxwell, A., Andrew, D., & Searle, G. (2004). Vessels for Civilian Authority Support in the EEZ. *SURV 6*. London: RINA.
2) Courts, M., Brittain, R., Lamble, A., & Osborne, N. (2012). Warship Trade Space Exploration: Challenges and Approaches. *The Systems Engineering Conference*. London: RINA.
3) Brett C., Courts M. (2017), Combatant Design and Fleet Mix Assessment and Optimisation Using BAEFASIP. ISMOR34

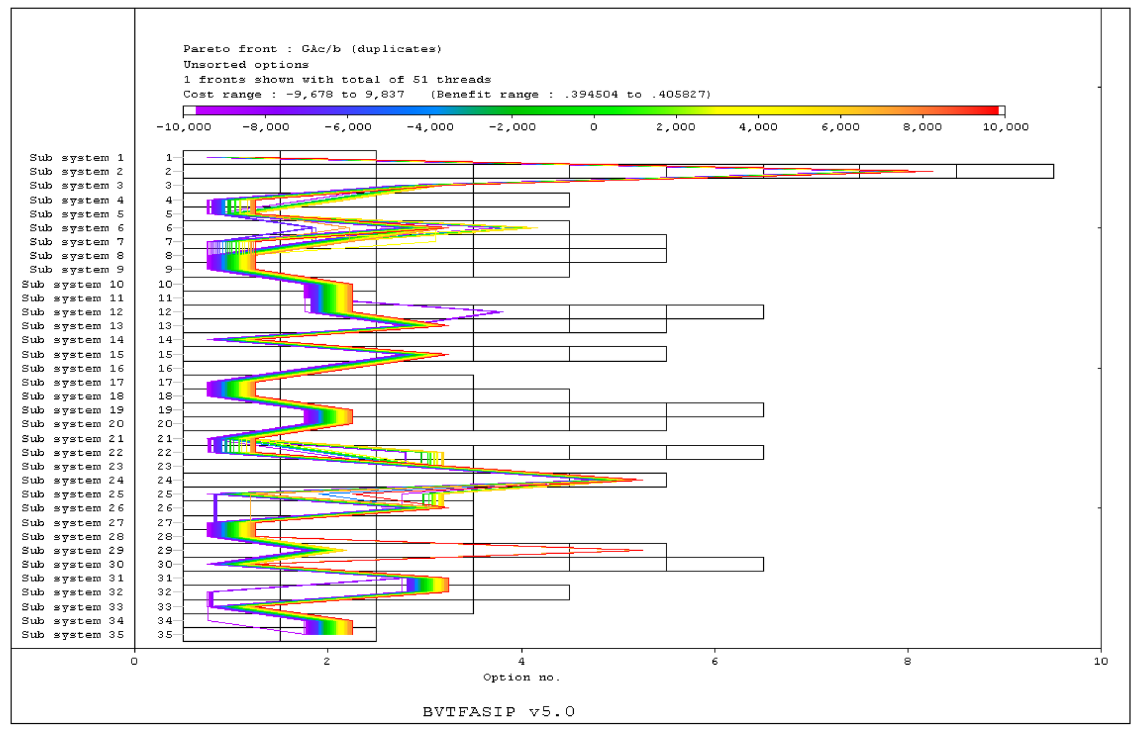
Example Results from FASIP Analysis

The approach has been used successfully on problems involving

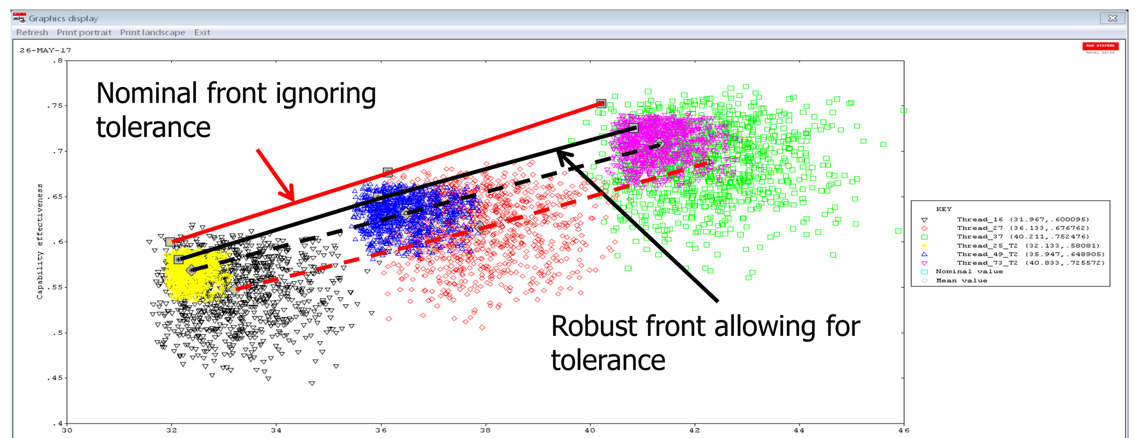
- System assessment and optimisation of sub system selections
- Force mix studies

Example Cost Benefit Pareto fronts results and optimum sub system option selections from a ship sub system option feasibility are shown below





An illustration of how optimum system solutions can be generated that are robust to triangular distributions of data value probability for some risky options is shown below



The robust front (black) looks as though it is worse than the nominal front (red), however in reality when tolerances are considered it is likely to be better?

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