Making the most of scenarios through study-specific characterisation

Graham Mathieson, Will Grenham, Maj Gordon Miller (AAC)
Centre for Defence Analysis (Air Studies)

Abstract: The practice of military operational analysis in the UK depends heavily on using an appropriate range of scenarios consistent with Defence Planning Assumptions. This paper describes a method of scenario characterisation which aims to allow the analyst to determine which scenarios are appropriate for a particular study and how well a range of scenarios addresses the issues raised by that study. The paper also gives examples of recent studies which have used the method.

1. INTRODUCTION

The practice of military operational analysis (OA) in the UK requires the use of scenarios as the basis for generating justifiable recommendations. In the face of the uncertainties inherent in the post-Cold War environment, the MoD has approved a set of overarching scenarios for use in OA studies. These scenarios provide a broad range of possible future conflict situations which, taken together, provide a robust basis for OA aimed at supporting defence planning and procurement decision-making.

To achieve this robust basis it is necessary for studies to consider a range of different scenarios. Time and cost constraints, however, usually limit the number that can be included and make the selection of scenarios critical. This paper describes a method of study-specific scenario characterisation which can be used to select the most appropriate set of scenarios for a particular study and, in addition, to demonstrate that the chosen set is adequate for the purpose. The method can also be used to indicate where new scenarios need to be developed to fully address a particular study area.

Originally developed for a study into naval electronic warfare, the study-specific scenario characterisation has recently been used and further refined in studies of fixed wing offensive air, battlefield aviation, and air tactical communications. These studies, which are briefly described in an appendix to this paper, cover the effectiveness of command and control and information systems, the development of new tactics and system requirements analysis. This range illustrates the flexibility of the method and the paper discusses possible future development and applications.

2. STUDY-SPECIFIC SCENARIO CHARACTERISATION

Study-specific scenario characterisation seeks to identify which particular characteristics (or descriptive features) of scenarios are likely to have a significant impact on the results of a study. By focusing on scenarios in the context of the specific study question and using the scope of the study as a constraint, it is possible to identify a relatively small number of scenario characteristics which, taken together, will drive the answer to the study question. These scenario characteristics can be used to characterise existing scenarios, allowing them to be positioned within the problem space defined by the study question.

The scenario characteristics can be considered as axes on a multi-dimensional characterisation matrix (see Figure 1). Each axis is a variable feature of the scenario (such as terrain or state of hostilities) for which significant values can be defined. 'Significant' values are those for which the impact of the scenario characteristic is likely to be sufficiently different, when compared to that of other values, to create a distinct case for study. Values can be numeric or symbolic, they can represent points or ranges on a continuous scale or discrete conditions, and they can be either contiguous or disjoint.

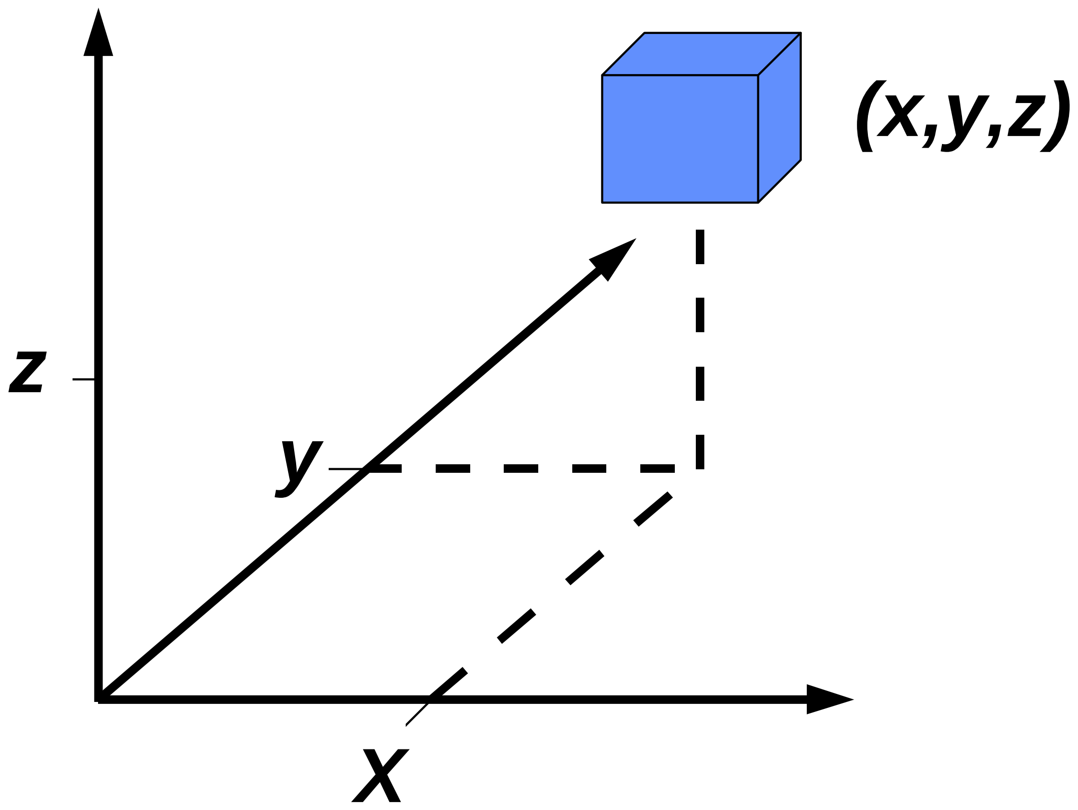

Figure 1: Scenario characterisation matrix

Once the characterisation matrix (axes and values) has been defined then it can be considered to define a set of significantly different cases for study where each 'case' is represented by a different combination of characteristic values. If the set of axes and values completely covers the problem domain implied by the study question then the characterisation matrix can be said to be complete, i.e. to define all significant cases for study. By implication, a study must seek to address all of these different cases if it is to completely explore the problem domain.

It is common for any one scenario to contain within it more than one combination of values and, therefore, to cover more than one case. Scenarios can, therefore, be viewed as 'blobs' which fill a definable 'volume' within the characterisation matrix. The extent to which a set of scenarios fills the characterisation matrix indicates how well the set addresses the problem domain and the space left unfilled indicates which aspects of the problem will not be covered. This is illustrated for a two dimensional matrix in figure 2.

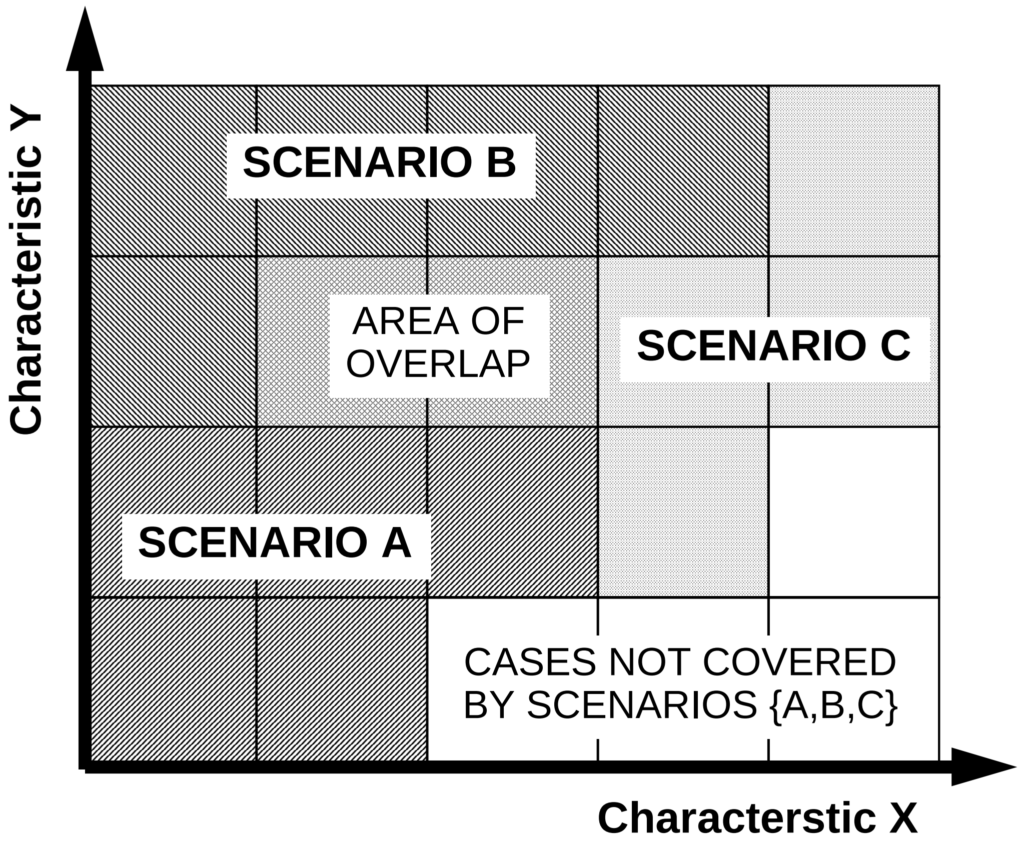

Figure 2: Illustration of scenarios as 'blobs' within a characterisation matrix in which each box represents a different case for study.

The extent to which the scenario characterisation matrix is filled is a metric for the effectiveness of a particular set of scenarios and can, therefore, be used as a basis for selecting the optimum scenario mix within a given cost constraint. Of course, not all combinations of characteristics will produce cases which need to be studied. Some combinations may, for example, be unlikely to occur or may describe cases which do not fall within the scope of the UK's defence requirements. For this reason, the there is a need for some post-production filtering of the matrix.

The characterisation of scenarios using the matrix can also be used to identify scenarios which are similar, from the point of view of the specific study question. Where two scenarios are shown to have the same set of characteristic values, then only one need be studied in detail and the answers can be read across to the other. If small differences exist then it may be possible to study small excursions in the detailed analysis of one scenario which will allow the results to be 'extrapolated' to another. The characterisation matrix will indicate which details of the scenario need to be varied in these excursions.

Similarly, where two scenarios 'bracket' a third in the characterisation matrix then it may be possible to 'interpolate' the answers from detailed analysis of the two to infer the likely answer for the third. Again, the matrix will indicate in which particular ways the scenarios differ and, therefore, what this 'interpolation' might mean.

In the general case, the number of potential scenario characteristics and characteristic values is enormous. It is for this reason that the matrix must be built anew for each specific study. By using the constraints imposed by a specific study question it has proved possible to limit the number of characteristics and values to a manageable range. The narrower the scope of the study then the smaller the matrix can be made and the easier becomes the job of filling it with a limited number of scenarios.

Table 1 lists some examples of scenario characteristics which have arisen out of an offensive air C3I study. These are grouped into overall headings such as "Geography", "Target", "Threat", "Own Force" and "Status". Each characteristic is defined by describing its impact on the study question (in this case "What is the impact of C3I on offensive air operations?"). In this particular study a total of 20 characteristics were defined. This is a typical value, although one study has defined as many as 107.

Category	Characteristic	Area of C3I & STAR impacted
Geography	Terrain	propagation of EM radiation
	Weather	STAR sensors and flight profiles
	Latitude	utilisation of satellites
Target	Target availability	need for timeliness of intelligence
	Location of target	support required, esp. STAR
Threat	Air defence	level of support required
Own Force	Force structure	infrastructure available
	Level of air activity	loading on air C3I system
Status	State of hostilities	ROE and FOA roles

Table 1 - Example scenario characteristics

The most recent use of study-specific scenario characterisation indicates that the technique will work equally well as a way of comparing and contrasting scenario 'vignettes'. Vignettes are small scale components of a scenario which are localised in time and space, such as an individual mission or combat engagement. Study-specific scenario characterisation offers the possibility that generic vignettes can be studied in detail and their results read across into a number of scenarios in which the vignette can be 'positioned' using the characterisation matrix.

Overall, then, the use of study specific scenario characterisation allows maximum use to be made of scarce analysis resources and the scenario coverage which these imply.

3. DEVELOPING THE CHARACTERISATION MATRIX

Experience in using the scenario characterisation method has indicated a number of useful 'rules of thumb' to be followed in deciding which characteristic axes and values to use.

Rule 1: Characteristics should have direct, relevant effects.
It is key to the success of the method that the characteristics chosen do not simply describe the scenario but, rather, that they describe some impact on the subject matter of the study. For example, the 'Latitude' characteristic in table 1 does not simply describe angular distance from the equator but, rather, it refers to the effect of latitude on satellite coverage. Therefore, the significant values of latitude in this case are not arbitrary divisions on a scale of 0-90 degrees but those angular ranges which have significantly different impacts on satellite coverage, i.e. inside or outside line of sight from geostationary orbits.

Rule 2 - Characteristics should be as independent as possible.
If characteristics are too closely correlated then it becomes difficult to disentangle the impacts of one from those of another. Consequently, it becomes almost impossible to assess whether the combined impact of any given combination of characteristic values, which constitute one case for study, will be significantly different from that of another combination or case. The ideal situation is that all characteristics are orthogonal, i.e. have independent impacts, so that one can be certain that any change in characteristic values on any subset of characteristics is likely to produce a change in overall impact on the subject of the study. This ideal is rarely possible, but it is worth striving towards. In some cases, where two characteristics cannot be disentangled, it may be appropriate to combine them into one, letting the values become value pairs.

Rule 3 - Characteristics should have few significant values (ideally < 5).
The product of the number of significant values across all of the characteristics is the number of significantly different cases for study. This has the potential to become an unmanageably large number

and efforts must, therefore, be made to limit the size of the matrix. In addition, experience suggests that forcing the analyst to define a small number of values for a characteristic tends to focus the mind and force values to be clearer and more distinct in their impacts rather than being just verbal catalogues or arbitrary scale divisions.

Rule 4 - Many simple characteristics are better than few complex ones.
One key to a useful characterisation matrix is that the mapping of characteristics onto impacts should be as straightforward as possible. This allows the analyst to compare and contrast different combinations of characteristic values more easily. If characteristics are too complex in their impacts then, as was the case with correlations, it will be difficult to assess whether two cases for study are different or the same in terms of their overall impact. This rule is, of course, in conflict with Rule 3 above in that it tends to increase the size of the characterisation matrix. To resolve this conflict Rules 5 and 6 should be applied vigorously!

Rule 5 - Make maximum use of any study constraints available
The method described in this paper is *study-specific* scenario characterisation. The essence of the technique is to use the scope of a specific study question to determine which scenario characteristics and which values of those characteristics are significant. This principle can be taken further by using any and all constraints of the specific study to further refine the characterisation matrix. For example, if the study concerns a platform or system which will not be widely deployed or will be deployed only in limited circumstances, then there will be an implied geographical constraint which can be used to limit the matrix. Similarly, if the study concerns only one aspect of operations, such as command and control, then impacts on other aspects, such as weapon effectiveness, can be ignored for the purposes of scenario characterisation.

Rule 6 - Be pragmatic!
Study-specific scenario characterisation is a tool to make studies more cost effective. There is a limit, therefore, on how much effort it is worth spending to create and refine the characterisation matrix. Also, it is highly unlikely that an ideal matrix of simple, perfectly orthogonal characteristics with a few independent values will be achievable for any real study. Compromises will be needed between simplicity and abstractness and between completeness and usefulness. At times the debates arising from such compromises can verge on the philosophical and a pragmatic approach is essential to success.

Using the above rules of thumb, the process for creating a characterisation matrix is as follows:

a) Identify the set of characteristics which best captures the impacts of scenarios on the specific study problem. This is usually an iterative process of creation and refinement and requires considerable input from subject matter experts.
b) For each characteristic define a small number of significant values representing significantly different impact regimes.
c) Remove from consideration any cases which involve unrealistic or irrelevant combinations of characteristic values. These may be combinations which are:
    - intrinsically unrealistic because, for example, they imply a situation which is internally inconsistent or extremely unlikely to arise;
    - inconsistent with overarching defence requirements;
    - not likely to generate an overall effect which is relevant to the study question (such a case may arise because of the application of rule 6 above!).
d) Once the characterisation matrix has been reduced as far as reasonably possible then an initial, qualitative analysis of the likely impacts of the various remaining combinations can be done to identify groups of combinations which have similar overall impacts. It is likely to be within such groupings that the results from one case for study can be re-used in others.
e) Finally, it is important to record the remaining correlations within the characteristics and values of the matrix. Knowledge of these correlations will avoid unnecessary analysis of value combinations which are unlikely to occur.

4. PROGRESSIVE ANALYSIS USING THE MATRIX

Once the study-specific scenario characterisation matrix has been created it is possible to go directly on to characterising existing scenarios and selecting those best matching the study problem based on maximising matrix coverage. However, another approach is possible. Each different combination of characteristic values within the matrix represents a significantly different case for study. Depending on the nature of the study question it is possible that many of the combinations will produce trivial answers, or answers which can be determined by simple qualitative reasoning rather than full-blown quantitative modelling.

Assuming that time and cost constraints mean that detailed analysis must be restricted to a very few cases, it may be more cost effective to sacrifice some of the detailed analysis in favour of providing a broad qualitative analysis across the whole of the matrix. The purpose of this qualitative analysis would be to identify those cases in which ‘obvious’ answers could be derived. It can also be used to identify where some cases are more or less extreme than others or whether two cases ‘bracket’ a third. These results will allow a number of cases to be ruled out of the set requiring detailed analysis and will also provide the understanding needed to extrapolate and interpolate the results of detailed analysis to cover more cases.

This initial analysis can be taken a stage further. Since the reasoning on which the scenario characterisation matrix was based identifies the impacts of the scenario on the study question it should be possible to identify those cases where the answer can be calculated using fairly crude models or other analysis tools, or where only a smaller part of the problem needs to be explored. This could free up scarce detailed analysis resources to concentrate only on those cases which really need them.

Typically, in studies where the number of scenarios analysed in depth is limited, those chosen are the scenarios which are deemed most ‘important’ from a general operations perspective. For many studies, particularly C3I studies, this does not guarantee that the chosen scenarios will effectively or efficiently exercise the specific study problem. However, using the progressive analysis approach outlined here, detailed analysis will be reserved for those cases which present the most ‘interesting’ or difficult analysis problems. The resultant optimisation in the application of scarce analysis resources will improve the coverage achieved by the study and this can be monitored by measuring how many of the cases for study defined by the characterisation matrix have been addressed.

Finally, the ‘gaps’ left in the scenario characterisation matrix, once all analysed cases have been struck out, indicate which aspects of the problem have not been addressed and this gives a coherent and objective justification for specific excursions from existing scenarios or, as a last resort, the commissioning of entirely new scenarios.

5. SUMMARY

Study-specific scenario characterisation offers a method for optimising the use of scenarios in operational analysis and requirements capture studies. The method uses the constraints of a specific study to determine which set of existing scenarios best covers the problem domain and provides evidence to support the case for developing new scenarios if required. The method also offers a progressive analysis technique which allows a broader spectrum of cases to be included in a study by optimising the application of detailed analysis resources to those cases which really need them.

The method outlined in this paper provides a significantly more structured and rigorous approach to scenario selection than has hitherto been available. Although the method still requires extensive use of military and technical judgement, it provides a clearly auditable framework within which that judgement is exercised and, thus, can provide greater confidence in the soundness of the choices made. The method can also provide robust justifications for the expense of generating new scenarios where this is shown to be necessary.

Study-specific scenario characterisation has been successfully used in a range of studies including command and control effectiveness, tactics development and system requirements capture.

APPENDIX: SCENARIO CHARACTERISATION CASE STUDIES

This appendix gives brief descriptions of the use of study-specific scenario characterisation in four different case-studies. Each has highlighted a different aspect of the method and each has contributed to its development. The four studies are:

1. The impact of C3I on offensive air operations;
2. The requirement for an Aviation Command and Control System;
3. Optimum warfighting doctrine for the attack helicopter; and
4. Air tactical communication requirements.

CASE STUDY 1 - OFFENSIVE AIR C3I

The objective of this study was to assess which aspects of surveillance, target acquisition and reconnaissance (STAR) and command, control, communications and intelligence (C3I) were likely to impact on the procurement and operation of a future offensive aircraft (FOA).

A number of future military settings in which the FOA might operate were identified. Each scenario was then analysed, and characterised through the identification of aspects which will impact on air C3I.

The main aims of the characterisation were to examine the significance of the characteristics, and to identify key scenarios for further more detailed analysis.

The analysis was conducted in six steps:

Step 1: Selecting scenario characteristics: Twenty scenario characteristics were identified as having an impact on air C^3I. The final list is shown in table A-1.

Force structure	GIS cover	Red air defence threat
State of hostilities	FOA operational role	Red C3I capability
Air Situation	FOA sortie rate	Red threat to blue C3I
Latitude	Target availability	Blue AWACS cover
Terrain	Target location	Blue SEAD
Culture	Target density	Blue air activity
Weather	Target signature	

Table A-1 : Scenario characteristics selected for offensive air C3I study

Each of these characteristics was closely defined and for each a small set of significant values was also closely defined. Examples of characteristic values chosen are shown in table A-2.

Characteristic	**Example values**
Force structure	NATO, Alliance (with US), Alliance (without US), UK Alone
State of hostilities	OOTW, TTW, War
Latitude	Above 76 degrees, Below 76 degrees
Target location	Close to FLOT, Within stand-off surveillance cover, Within penetrating recce cover, Beyond penetrating recce cover

Table A-2 : Examples of characteristic values for air C3I study

In the process of selecting scenario characteristics a number of possibilities were considered and rejected through application of the ‘rules-of-thumb’ defined in the main section of this paper. These characteristics were undoubtedly features of scenarios which would have significant impacts on

C3I. However, consideration of their impacts indicated that they were too diverse for them to act as well-formed characteristics.

Warning time, for example, impacted on the level of infrastructure available in theatre, the air situation (whether air superiority was established), blue SEAD, etc. Warning time was also highly correlated with a number of other characteristics. Because each of these impacts could be covered by one of the other characteristics it was decided that warning time was not needed in the matrix. However, because it was clearly an important feature of scenarios, a new category of 'omnibus' scenario characteristics was introduced for this study.

An omnibus characteristic was defined as one whose impacts are fully represented by a set of other characteristics. Omnibus characteristics did not form part of the matrix but were used to represent some residual correlations between characteristics and as a route to establishing which characteristics values apply to any given scenario. This concept was much more fully developed in Case Study 4.

Step 2: Scenarios in which a FOA might operate: A range of possible scenarios in which a FOA might be required to operate was identified and the possible roles for the FOA within those scenarios were examined. The scenarios covered general war/regional conflict and peace support operations.

Step 3: The Significance of the Characteristics in Scenarios: Values were ascribed to the characteristics in each scenario and an assessment was made of the significance of each characteristic in the light of the value attributed to it in each scenario.

Step 4: Consider other possible scenarios: For the purposes of the study there was a need to think more widely than the scenarios typically used in OA studies. A number of possible alternative scenarios was characterised using the characterisation matrix, including war scenarios and operations other than war.

Step 5: Critical Scenario Characteristics: The fifth step was to draw conclusions about critical scenario characteristics. An analysis of the influence of scenario characteristics in already agreed scenarios in Step 3, and in others identified in Step 4 above, suggested a number of characteristics were likely to be more dominant than the others.

Step 6: Key Scenarios for Detailed Analysis: The final step was to identify key scenarios for detailed analysis. The key scenarios for future C3I study could be considered to be those in which the critical characteristics are least favourable.

Scenario selection is a largely subjective task. The use of the characterisation matrix allowed a clearer and more rigorous choice to be made and provided a valuable audit trail to justify that choice. For this study, the necessary and sufficient set of scenarios for future C3I studies into the FOA was identified. The matrix also allowed the implications of changes to scenarios to be quickly assessed.

Although the Scenario Characterisation study was conducted within a rigid framework, it nevertheless remains a subjective technique. The problem of subjectivity could be limited by using a wide range of military personnel and analysts when producing the matrix. Constructing the matrix in the first place was the critical activity and it is anticipated that it will evolve over time as it is subject to broader military and analytical scrutiny.

CASE STUDY 2 - AVIATION COMMAND AND CONTROL SYSTEM

The objective of this study was to establish the requirements for an Aviation Command and Control System (ACCS) including a quantitative justification, where possible. The study used task and information analysis techniques to elicit requirements from military experts and mission modelling to quantify the military value of the information services provided by an ACCS. Both of these activities require scenarios and scenario characterisation was used to select suitable cases for study.

In developing the characterisation matrix for this study the matrix used for offensive air C3I was taken as an initial “strawman”. Some of the characteristics could be read across almost unchanged but, in general, at least some re-definition of values was needed to adapt to the constraints of the new study. Force structure, for example, was retained as a characteristic but the values relevant to battlefield aviation CIS were more local structures at division and regiment level rather than multi-national alliance structures. This reflects the more localised nature of aviation operations over air activity - a constraint which was used to refine the scenario characterisation matrix.

In other cases, more radical changes to the “strawman” were required. In the air C3I study a group of geographical characteristics were defined including terrain, culture and weather. The impacts of terrain and weather were principally on lines of sight and propagation conditions for sensing and communications. The impact of culture was principally as a background for imaging. When these impacts were considered in the aviation context it was realised that they did not apply in quite the same way.

Because helicopters, particularly attack helicopters, tend to operate very close to the ground, their lines of sight are much more affected by micro terrain and by culture than by macro terrain. When one is hiding behind a tree it doesn’t much matter whether the tree is on a flat plain or on the side of a mountain. In fact it doesn’t much matter whether it is a tree or a building. Therefore, terrain and culture were rejected as characteristics and replaced by the more direct ‘line of sight conditions’.

Weather conditions had been defined for fixed wing air largely in relation to cloud cover. For low level operations rain and fog are more relevant as having impacts on propagation. However, micro culture (including the presence of buildings) and terrain also have impacts on propagation and, therefore, a more direct characteristic ‘propagation conditions’ was chosen.

Choosing the more direct characteristics of ‘line of sight’ and ‘propagation conditions’ made the task of characterising individual scenarios more difficult, since a longer reasoning process was required to establish which values of these characteristics were implied by the terrain, culture and weather condition defined by the scenario. This tendency to move complexity towards the assignment of characteristic values and away from the interpretation of those values once assigned was seen as a good thing. As was concluded in Case Study 1, the generation of the characterisation matrix is essentially a judgmental activity. However, the application of the matrix to compare and contrast specific scenarios can be made much more objective provided the characterisation matrix approaches the ideals of orthogonality and directness of impact.

The characteristics finally chosen for the aviation CIS study are shown in table A-3.

Force structure	Mission co-ordination requirements
Integrity of blue non-aviation C3I	Sortie rate
Operational logistics	Target constancy over time and space
Line of sight	Target acquisition requirements
Propagation conditions	Target distinctiveness
Terrain data	Enemy air defences
	EW environment

Table A-3 : Characteristics selected for aviation CIS study

The matrix was used to select scenarios for use in Task Analysis. The selection allowed scenarios based on certain wargame outputs to be used with confidence whilst other game-based scenarios were shown to add nothing extra. The characterisation also indicated clearly some areas where the chosen scenarios did not address the whole problem and excursion cases would need to be considered.

Study-specific scenario characterisation proved effective in this study in that it gave robust evidence to support the choice of some scenarios, and the exclusion of others. The method also gave clear indications of deficiencies in the chosen scenario set.

CASE STUDY 3 - ATTACK HELICOPTER TACTICS AND DOCTRINE

This ongoing study seeks to address the optimum warfighting tactical doctrine for the attack helicopter (AH) within an all arms context. The aim is to make a systematic evaluation of the method of employment of the specific AH selected for the Army (the Westland AH64) in order to optimise operational effectiveness.

The nature of AH implies that it is capable of being deployed in a variety of ways across a spectrum of conflict - from warfighting to OOTW. Thus a number of scenarios have to be utilised in order to conduct the study.

The perceived difficulty was to ensure that a suitable robust selection of scenarios was created that would provide the means by which a balanced results could be achieved. The study-specific scenario characterisation method was therefore applied to the process of creating and selecting scenarios.

Scenario characterisation matrices from the previous two studies were used as a starting point for discussion. These were examined by subject matter experts in order to determine their applicability to the study question. This process resulted in some of these previous characteristics being retained, although with modified definitions, and some being dropped in favour of entirely new characteristics.

A key aspect of the matrix development was the identification of the lowest level of characteristic that impacted on the tactics employed by AH. Aspects of AH itself that could cause changes in tactics - such as weapon load - were deemed not to be scenario characteristics and were not included in the scenario characterisation matrix.

As the characterisation process progressed it became clear that there were distinct levels that the characterisation was passing through. In order to portray a clear picture of the process, for briefing purposes, these levels were portrayed diagramatically using Ishikawa charts (cause and effect ‘herring-bone’ diagrams). An example chart showing the level 1 characteristics is reproduced at figure A-1. At this level 26 characteristics are defined. At level 2 a total of 107 characteristics are defined.

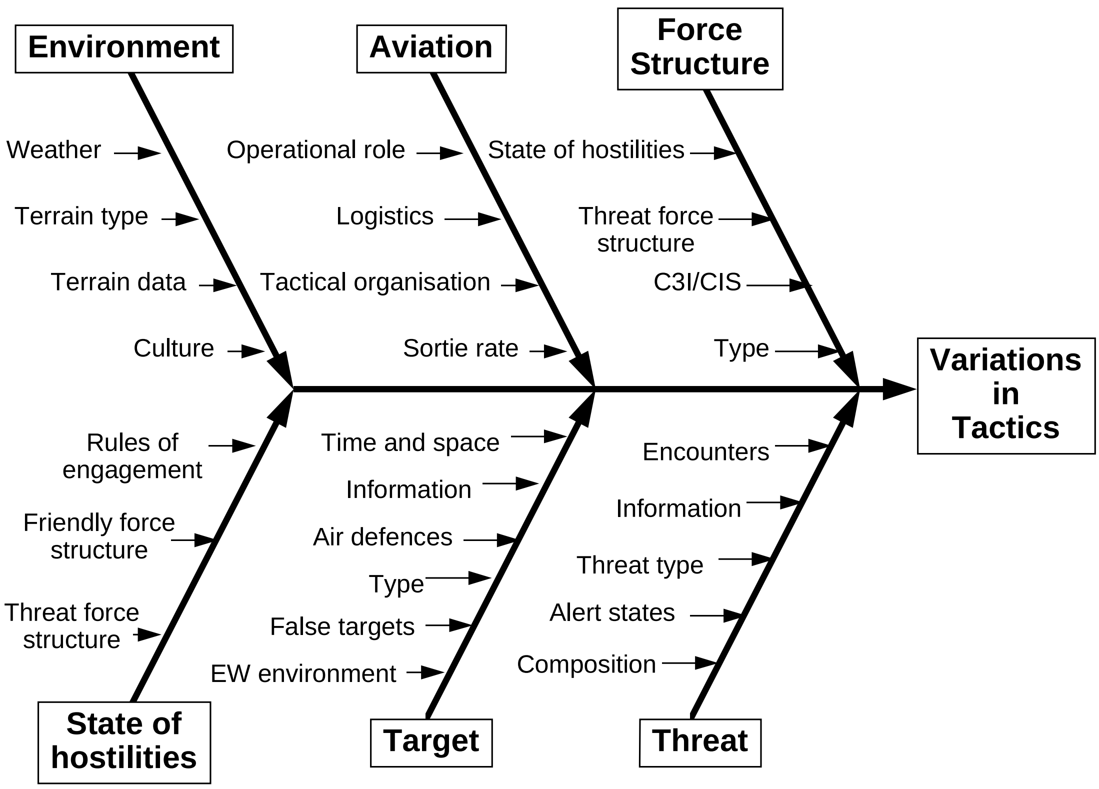

Figure A-1 : Ishikawa chart showing level 1 characteristics for AH Tactics study

The study-specific scenario characterisation method enabled the study team to identify a vast range of scenario aspects that required to be addressed in the study. The recording of discussions regarding each characteristic created an audit trail of the reasons for including or discarding each characteristic and thus provided the study customer with documentation explaining how and why the scenarios were selected.

The process has provided a means by which the scenarios that will be selected will provide a suitable spread of situations in which to examine AH tactical doctrine. There is, therefore, a greater level of confidence in the robustness of the results than otherwise might be expected form conventional scenario selection methods.

Of all the case studies this one produced by far the largest characterisation matrix. This is partly due to the broader nature of the study question, providing fewer constraints with which to filter the matrix. However, it is also the case that, in this study, the process of generating scenario characteristics was explicitly used as vehicle for initial problem analysis. It remains to be seen how effectively such a large matrix can be used for scenario selection.

CASE STUDY 4 - AIR TACTICAL COMMUNICATIONS REQUIREMENTS

This case study has only recently begun the process of study-specific scenario characterisation but is included here because it has already raised some interesting issues. The study is intended to aid in the selection of scenarios for a major programme of requirements analysis for air tactical communications.

The rules-of-thumb for scenario characterisation encourage the definition of characteristics which have direct and relatively simple effects. In the case of tactical communications it has been recognised that scenario impacts fall into two fairly distinct categories - direct physical effects and indirect organisational effects.

Direct physical effects, such as the impact of terrain on lines of sight, had already been fairly well covered in the offensive air C3I study (Case study 1 above). These physical effects tend to show up most clearly in consideration of individual, point-to-point communications and, therefore, on individual communications bearers.

Less direct effects arise from the operation of the air C3I. For example, the size and complexity of the air component in an operation will impact on the requirements for communications organisation such as networks and the interconnectivity they provide. However the indirectness of these impacts make them unsuitable to form the axes of a scenario characterisation matrix. It has proved necessary, therefore, to look beyond those characteristics which describe C3I impacts with only indirect effects on communications towards the more localised direct causes of those effects.

For example, a relevant characteristic used in previous C3I studies was Force Structure. This referred to the type of coalition involved and had values such as UK only, NATO, US-led coalition, etc. The impact of this characteristic has at least two main strands, affecting:

a. the composition of the force in terms of the available ORBAT;

b. the likely command structure and, hence, the IER.

These impacts, in turn, are likely to affect the communications requirement in a number of ways including, for example:

- types and capacities of communications systems available;
- loading and interoperability requirements;
- complexity of networking required.

Each of these impacts on communications are also likely to be affected by other scenario characteristics, such as theatre of operations (and hence available infrastructure), nature of operations (hence mix of missions) and intensity of conflict.

In the face of this complexity and indirectness it became clear that, unlike previous applications of the method, a simple scenario characterisation matrix would not be possible for this study. On the one hand, there was a set of obvious or 'naturalistic' scenario characteristics, such as force structure and nature of operations, whose values could be determined for any given scenario in a relatively straightforward way. The impacts of these naturalistic characteristics on communications, however, was diverse and complex and such a matrix would not, therefore, satisfy the rules-of-thumb identified in main text of this paper.

On the other hand, it was possible to identify characteristics which had direct and reasonably orthogonal impacts such as loading or availability of ground-based infrastructure. These characteristics would certainly satisfy the criteria for a useable matrix, but the process of determining what values should apply to any given scenario would be difficult and obscure.

To resolve this dilemma it proved necessary to create a multi-step characterisation process as illustrated in figure A-2. In this schema, the 'naturalistic' characteristics are those for which it is relatively easy to identify the characteristic value which should apply to a given scenario. The direct characteristics are those which satisfy the criteria for a well-formed matrix, i.e. they should ideally be orthogonal and have direct impacts. In a number of cases there was a need to invoke intermediate characteristics representing the indirect mechanisms whereby some natrualistic characteristics impacted on direct characteristics. For example, force structure impacted on communications loading via organisationally driven IER.

Since the orthogonality rule only applies to the direct characteristics, it was possible to allow a greater degree of correlation and influence between the naturalistic characteristics, as illustrated in figure A-2. It is important to record these correlations.

This process of working through obvious, but indirect causes of impact towards perhaps less obvious but more direct causes is important. For the scenario characterisation matrix to be useful in scenario selection it has to be possible to determine whether or not two scenarios are different in their impacts on the study question.

With a well formed characterisation matrix the fact that two scenarios are characterised by different value sets means, by definition, that they will have different impacts because each of the characteristics are orthogonal and each of the values significantly different. However, if the matrix has characteristics which have many indirect effects then it is much harder to determine if two different values sets will have cumulative impacts.

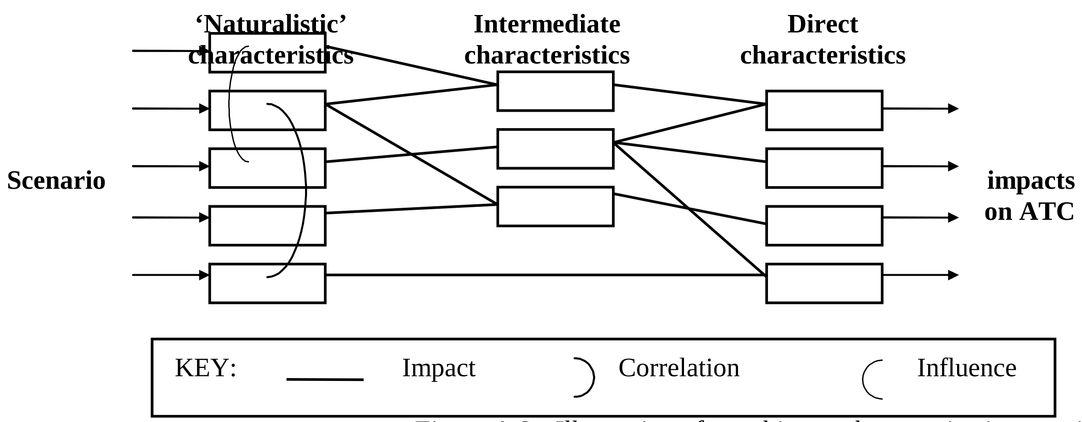

Figure A-2 : Illustration of a multi-step characterisation matrix

Another aspect of scenario characterisation which arises in the communications requirements study is the question of the level of scenario. To determine the whole range of communication system requirements it is necessary to analyse scenarios both in breadth and in depth. This implies a need to select not only between overall scenarios but also to select localised vignettes within those scenarios in which to analyse detailed requirements. The study is, therefore, developing two characterisation matrices - one for each of these tasks. It is anticipated that the matrix for choosing vignettes will be heavily influenced by direct physical characteristics whilst that for comparing overall scenarios will be biased more towards the ‘organisational’ characteristics discussed above.