

## Developing the Scenario Assessment Tool

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### **ABSTRACT**

*Scenarios (as an undefined term) are the basis for much military training, war-gaming, planning, approaching some procurement issues and are similarly used by NGOs and other civil and commercial organisations. This could be with reference to disaster prevention or relief, or to determine the effect of potential legislation on a particular market. To be of any real value, for any application, a scenario must be “appropriate”. Our work has focussed on the identification of those components of an appropriate scenario, the relationship(s) between them, and of the individual items that may form each component. This work has enabled us to offer a generic scenario architecture – as the starting point for any scenario appraisal – and which, we believe, offers the basis for a generic scenario architecture (Whitworth et al, 2006). This led to the description of a process for the commissioning and employment of scenarios, effectively providing a VV&A function that is application independent. In the course of this work we have concluded that there are at least two basic forms of scenario (and, indeed, there may be more) that will need to be accommodated in any assessment tool to help formalise the VV&A process.*

### **1 INTRODUCTION**

What is this entity that we refer to as a scenario? For any meaningful discussion, we first have to define our topic in terms that can be related both to the topic, and to the nature of the discussion. It is often the case that a “scenario” is defined in terms that are domain specific:

*In film making, original idea for a film translated into a visually oriented text.*  
Encyclopedia Britannica, 2007

The US Defence Modelling and Simulation Office (DMSO), for example, offer four such definitions. The most generic in nature is:

*An outline or model of an expected or supposed sequence of events*  
Taken from [www.dictionnaire.com](http://www.dictionnaire.com)

Rather more specific and directed at the training domain is:

*An initial set of conditions and time line of significant events imposed on trainees or systems to achieve exercise objectives.*  
DMSO - 2006

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Neither of these can be seen as complete, or potentially generic, and this alternative was proposed in Whitworth et al (2006):

*A representation of the state, and present actions, of a set of animate and/or inanimate objects, so as to permit the exploration of, or reasoning about, their future state and the events that lead to it.*

It will be seen from this, that it is our assertion that the projection of current states into the future is at the heart of all scenarios, and they have been essential to war-gaming for almost two centuries. To discuss scenarios, we will initially use gaming as a baseline scenario application.

It is generally held that war-games, as we know them, were started at the US Navy Academy following the War of 1812 (also the first recorded use of “Blue” and “Red” as identifiers for friendly and opposing forces). This approach was developed (as “Kriegsspiel”), by the Prussian General Staff over the years from the 1820s to the Franco-Prussian War (1870-71) and then adopted by the General Staffs of most countries during the 20<sup>th</sup> Century. During the Cold War era, there was a transition toward the geo-political games that were used by all the major world powers to explore the effect of possible events and policy changes. Mandel (1977) holds that this was the case as early as 1961. In each of these cases, we suggest that there has been a scenario (to our definition above) that was the foundation for the game’s development and which formed the basis from which the game was played.

With the transition from the war-game to the more generalised geo-political game, it became apparent that gaming from a starting scenario was a practical - and usually low-cost - way of exploring possible futures. The armed forces of several countries increased their usage of scenarios from exploring strategies, via the development of tactics, and thence to scenarios for training at all levels of command. Indeed, it can be argued that the initial set-up for a sand-table exercise in the 1950s and ‘60s was a scenario. From this, if a scenario-based game would permit the possible development of new strategies and tactics, it should also permit the assessment of potential new equipments to be explored – hence Simulation Based Acquisition (SBA). The SBA approach would generally follow the line of “If we introduce a new [something], what effect will it have on the outcome of [xxxxx]?”.

In Whitworth et al (2006) we offered the example of a proposed long-range self-propelled artillery weapon. If a suitable model is employed in an appropriate combat scenario, it will enable not only the weapon effectiveness (fire rate, lethality etc) to be estimated, but will also allow some assessment of the logistic requirements (manning, ammunition supply, etc) of such a weapon when in use. Similarly, increasing the calibre of a tank main armament would potentially increase the lethality of a single round, but at the expense of being able to carry fewer rounds. This would then impact on both tactics and logistics. As the facility of scenario-based planning and prediction became more widely known, governments started to use the technique for addressing a wide range of disaster-management issues. As computing and display equipment improved, the cost of developing fresh scenarios increased, and the question of potential re-use became an issue.

Some scenarios are written with re-use in mind. A scenario intended for (say) training Infantry recruits in Squad tactics will be constructed so as to achieve a specific set of training objectives, and will be re-used for each successive recruit intake. It will only be changed if and when doctrine and/or equipment is changed. Similarly, a scenario written for training a force for a specific mission will be used repeatedly until all elements of the force have “learned their parts”, and all potential problems have been identified and overcome. The example (above) of a scenario for SBA, might also involve re-use in order to compare the effect of changes to the specification of the proposed artillery piece.

Much of the preparation and evaluation for components of Network-Enabled Capability (NEC) and Network-Centric Operations (NCO) depends on scenario-based simulation and experimentation. Alberts, Hayes, Leedom, KirzI and Maxwell (2002) proposed ‘Campaigns of Experimentation’ as a way forward, an approach which will often require multiple consistent scenarios, and scenario re-use. Creation of a framework for scenario development will help to ensure that scenarios are created in a coherent manner, and are compatible.

Other scenarios are intended to be single use only. A scenario designed to test the integration and response of the emergency services in a single county, or region, is unlikely to be repeated. Lessons learned from one single use will be applied to those services, and a much-modified scenario will be subsequently employed to see if the lessons have been applied. Another single use for a scenario is as a preliminary step in the use of those architectural frameworks currently in use to give compatibility and interoperability. MODAF (UK), DoDAF (US) and NAF (NATO) all begin with a scenario (but we are not aware of any method for ensuring that the starting scenario is complete).

In the present context, the term “appropriate” is considered to mean the suitability of a scenario for its intended use, combined with the suitability of the intended use itself. As an example, a scenario written (say, in the 1980s) to test NATO Staff in their actions and processes in the event of an invasion of Western Europe, by Eastern Bloc forces through the Fulda Gap, will remain suitable (that is to say “appropriate”) at the Staff level, but will not be “appropriate” to the current European and NATO geo-political structure (given all the changes in NATO membership since then).

This paper will first consider the work currently available for reference in the field of scenarios, detailing the results of two literature reviews. It will then outline a systems approach to the identification of the generic components of a scenario. This approach has led first to the production of a component check-list, and then to the outline of a generic architecture for scenarios. Having covered the architecture and check-list, the method for mapping scenario to check-list will be outlined. This will lead to an outline of a scenario writing process that will enable the Validation, Verification and Accreditation (VV&A) process to be applied, and to tools for doing this. Finally, the future direction of this work will be covered.

## **2 INITIAL WORK ON SCENARIOS**

On commencing this project, two literature searches were undertaken on the Internet, in order to determine the extent of current activity in respect of scenarios.

The first search was carried out using the Copernic search engine (which eliminates the majority of duplicate references). It will not, however, eliminate different references to the same document, and these were removed manually. The following search terms were used:

**Scenarios, Scenario Development, Scenario Design, Scenario Construction,  
Scenario Testing, Scenario, VV&A, Scenario V&V,  
Military Scenario Validation, Military Scenario Verification**

The resulting hits could be categorised as falling into the following broad areas:

**Health, Environment, Military, HIS/SE, Finance, Other**

However, as noted above, some were manually rejected as being duplicate references to the same document, or because further inspection indicated their irrelevance. The search results are summarised below in Table 1:

## Literature Review on the Scenarios Theme

Table 1: Summary of First Stage Literature Review

Search Terms	<i>Categories</i>						
	Hits	Health	Environment	Military	HCI/SE	Finance	Other
Scenarios	44	2	11		7	1	3
Scenario Development	46		15	1	6	2	17
Scenario Design	40			(+1)	10	1	24 (+1)
Scenario Construction	49	5	4	3	8	2	8
Scenario Testing	45	4	4		18	2	3
Scenario VV&A	54			35	4	1	7
Scenario V&V	56		2	10	13	3	19
Scenario Military Validation	49	1		31	3		8
Scenario Military Verification	48			23	3		11
<b>Totals</b>	<b>431</b>	<b>12</b>	<b>38</b>	<b>103 (+1)</b>	<b>72</b>	<b>12</b>	<b>100 (+1)</b>

**Notes:**

- Copernic Search Engine used to eliminates majority of duplications.
- Row and Column totals do not balance. Some instances were not duplicates but different references to the same item. Other items did not refer to “scenarios” as defined here.
- No instance was found of any scenario reference framework
- The (+1) refers to a hit which could have been placed in either category. It is not considered as statistically significant.
- The **Other** category includes a substantial number (around 40%) of “leisure war games” from 18<sup>th</sup> Century to Science Fiction

Taken from Whitworth et al (2006)

It will be noted that the “Military” category was the most popular by a very small margin. As a result of this, a further search was undertaken on the US DoD “Stinet” website (identified by the DoD as their major repository of military related documents). Table 2 (below) shows the search terms employed and the number of hits for each:

Table 2: Second stage literature review

Search Term	Hits
Scenario Design	18
Scenario Measurements	12
Scenario Composition	5
Scenario Components	2
Scenario Architecture	1
Scenario Assessment	0
Scenario Framework	0
Scenario Structure	0

Data taken from Whitworth et al (2006)

It will be seen that less than 40 hits were obtained in this search. Each hit was then individually reviewed for relevance to any domain that could be considered as “military”. In the most populated category (Scenario Design), almost all the hits related to PhD Theses on programming or software design. One must conclude that published activity relating to scenarios is – at best – minimal.

A further search, aimed at the production of a general-purpose bibliography, produced material that was predominantly related to Software Engineering, or Systems Engineering. From these searches, we conclude that published activity in the area of scenarios is domain specific, and is not concerned with scenarios in general. From the 2-stage literature review and the bibliography review, we conclude that there are no readily available examples or evidence of any work being carried out on the generic basis of scenarios. This would suggest that for many people, the generic DMSO definition listed at the beginning of this paper would be considered as sufficient.

From the search results, and the conclusions drawn from them (that there does not appear to be any work on a generic approach to scenarios), it was decided to take a Systems approach to the identification of the components of a scenario, and of the interactions between those components. This was considered to be the most suitable way of utilising the resources available and efficiently producing an initial view of the scenario domain.

### 3 A SYSTEMS APPROACH TO SCENARIOS

To determine the items that could be held to constitute a scenario, a number of separate scenarios were collected, and then analysed to determine their individual components. This approach generated a list of the “building blocks” used in scenario design.

As population of the list got under way, it became possible to assemble these components into a provisional architecture. From this it became possible to identify the relationships between components, the dependencies between components, then items which made up (or, in some instances, formed part of, or were conditional on, some of the components), and finally to identify where further components or items were potentially required. This approach brought out further interactions and dependencies, and

enabled the evolving architecture to be re-formulated into a check-list of components and items. Given a check-list, with a theoretical base, the next step was to determine if it was a tool that could be used in practice. This was seen as a way of moving toward the validation of the approach in general.

With the aid of the check-list, it was possible to review a sample set of scenarios, and to determine which of the components a given scenario actually used or contained. Using this approach, it was possible to determine that (for example) an apparently detailed and complete scenario contained only one component – with all the items present – but omitted all the other components which had earlier been identified as potentially necessary. This provided a measure of confidence that the architecture/check-list was an effective way of analysing a scenario. Due to the limited number of scenarios in our sample set, we would not consider that either the approach, or the check-list, had been fully validated, but rather that they appeared to show some merit. We then moved to testing the developed architecture/check-list against two detailed and well-known scenarios.

The first scenario was for a geo-political game (developed for senior White House staff during the Reagan Presidency) known as “Ivy League”. No description of this game has been officially published, but all details were “officially” leaked after the game scenario had been run, and full details were supplied to Allen (1987) for his comprehensive text on War Games.

The second scenario was the DARPA document known as “Fomblers Ford” (Gorman, 2000). This is a DARPA re-write of Swinton’s fictional classic “The Defence of Duffers Drift”. “Duffers Drift” was written immediately after the South African Wars (normally collectively referred to as the Boer War) as an instructional document for junior officers. The DARPA version was re-located in the Balkans of the early 1990s, using almost identical terrain features and force strengths, but with the equipment updated to be appropriate to the electronic age. It remained a guide for junior officers, but also served as an indication of the potential of modern equipment.

Application of the check-list appeared to indicate that (as earlier) some components would be found in all scenarios, but that not every component – and certainly not every item – would always be found in all scenarios. It is concluded from this analysis that there may well be more than one type of scenario, although conforming to a generally common architecture.

## 4 THE PROPOSED ARCHITECTURE

The proposed architecture is shown below (Figure 1). It must be emphasised that this is not intended to represent a flow chart or a process, but is purely a representation of those components, and items, which we have found in scenarios, together with an indication of the relationships and dependencies between them.

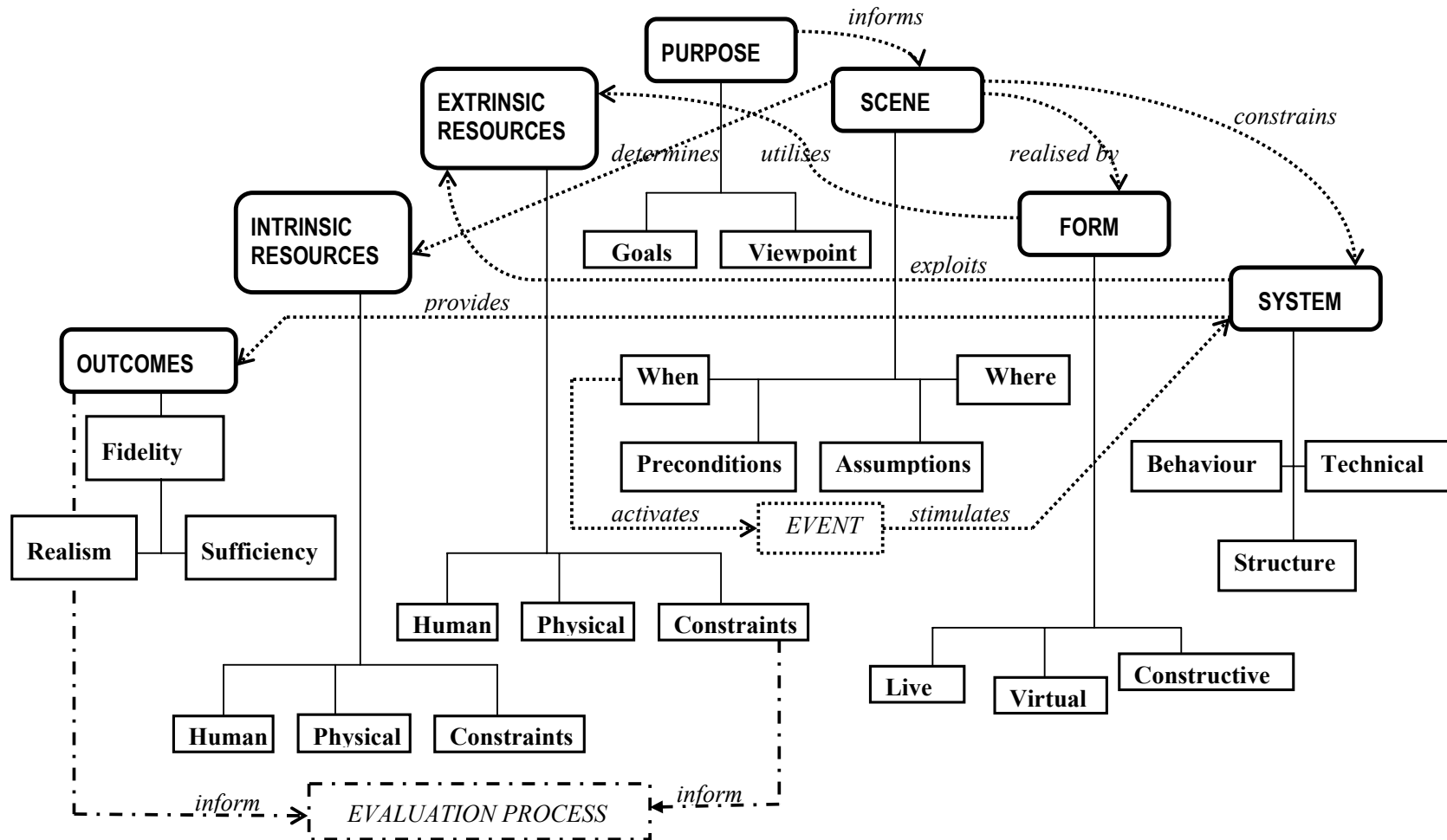
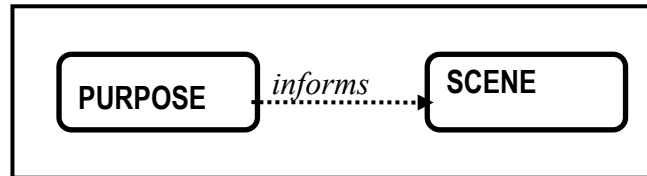


Figure 1: Scenario Architecture

The architecture model shows relationships between components. The general nature of a relationship is represented by a line (an arrow) that joins two components. The precise nature of the relationship is shown by a label, written alongside the line, as shown in Figure 2 (below).

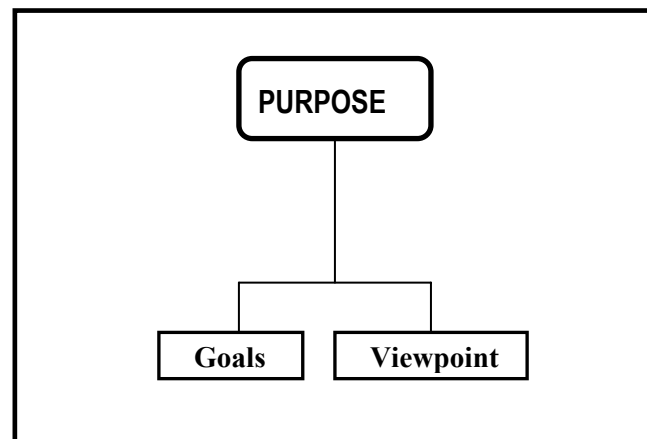


**Figure 2: Representing a Relationship**

Thus, the model in Figure 2 represents two components and their relationship is read as saying: “Purpose informs Scene”.

At this stage of the development of the architecture, the multiplicity (if any) of the relationship is not shown. Hence, the model contains no information on whether there is more than one purpose or more than one scene. The issue of multiplicity will be considered in future work, when the model is more mature.

The architecture model shows components made up of items. This relationship is one of aggregation and should be read as saying: “...is made up of ...”. Figure 3 (below) represents a component made up of two items. This relationship should be read as: “Purpose is made up of Goal and Viewpoint”.



**Figure 3: Representing Aggregation**

The architecture model given in Figure 1 is intended to show the generic structure of a scenario. Its aim is to provide a representation of all possible components, their constituent items and the relationships between them. In order to use the architecture, definitions are required for each component/item. The following definitions are proposed:

- Purpose:** the reason the scenario is required.
- Goal .. what is intended to be achieved.
- Viewpoint .. the position that values the goal



**Scene:** the context of the scenario

Where ..	the geographical place(s) the scenario unfolds
When ..	the events take place
Event ..	any input to the system that changes the system's state
Precondition ..	the initial state of the system, possibly as a result of a previous series of events.
Assumption ..	taken for granted as true

**Form:** how the scenario is realised

Live ..	real people, doing real things with real equipment
Virtual ..	real people, doing real things with simulated equipment
Constructive ..	simulated people, doing real things with simulated equipment

**Extrinsic Resource:** resource used and consumed by executing the **scenario**

Human ..	persons working on the scenario
Physical ..	the non-human components of the scenario
Constraint ..	limitations applied to the human and physical resources

**System:** the set of relating objects that achieves the needs of its stakeholders.

Behaviour ..	how the system moves from state to state due to events acting upon it
Structure ..	how the system's objects are organised with respect to one another
Technical ..	the measures of performance of system objects

**Intrinsic Resource:** resource used and consumed by the **system**

Human ..	persons working in the system
Physical ..	the non-human components of the system
Constraint ..	limitations applied to the human and physical resources

**Outcomes:** the state of system attributes (that can be measured, or assessed)

Fidelity ..	the faithfulness of the results.
Realism ..	correspondence with facts as they are.
Sufficiency ..	completeness of results with respect to the viewpoint

In defining the components above, the conclusion was reached that there is a strong need for an accepted set of standard descriptors for any discussion of scenarios.

## 5 MAPPING SCENARIO TO ARCHITECTURE

The check-list was formatted so as to permit identification of the way in which the component requirement was met, together with the location of that component within the scenario. It was determined that, while any given scenario did not have to contain all the identified components, some components were essential to any scenario. One apparent problem related to scenarios which seemed to lack a stated purpose. A number of these were examined, and it was concluded that a purpose was necessary (and was usually obvious), but that such purpose was not always stated as part of the scenario itself. The extent to which a purpose may be removed from the actual scenario has not yet been determined, but for the work in hand it is considered that this should not exceed two removes. Thus, Document A may state the purpose of a scenario, while Document B may both refer to Document A, and also authorise the generation of a scenario (which then becomes Document C). This could (typically) arise in the case of the Infantry Squad training mentioned in the introduction.

It seems clear from, the foregoing discussion, that a scenario requires - as a minimum - such components as will allow it to meet its purpose. A scenario must therefore be purpose-oriented, and from this we have developed this proposition:

### **1. Any scenario must have a declared purpose**

If the purpose-oriented nature of a scenario is accepted, then it follows that any scenario must also have an architecture that will allow it to meet its purpose. Hence any two (or indeed more) scenarios may have differing architectures (component sets) provided they meet their respective purposes, but they will each require all components necessary to achieve those purposes. This leads us to offer a second proposition:

### **2. Any scenario must contain all components necessary to meet the declared purpose**

Further, since several documents may be involved, we offer a third proposition:

### **3. These do not have to be in one document (provided that there is traceability)**

## **6 A PROCESS FOR SCENARIO EMPLOYMENT**

If we accept the need for purpose, it follows that no scenario is developed in a vacuum. The need for a scenario must have been identified by some person or organization, somebody must have authorised its generation, someone else must have written it, and yet another person must have assessed its suitability. We have considered this in process terms, and particularly as a process with the appropriate constraints and feedbacks to ensure that the finished scenario satisfies the basic requirements of VV&A that would be applied to any synthetic environment. This process is illustrated in Figure 4 (below).

A simplistic view of VV&A is that it asks three questions:

- Have we built the right product?
- Have we built the product right?
- Will it do what we want it to do?

In everyday life, however, it must be stressed that the answers do not necessarily come in the above order, expressed in such a succinct form.

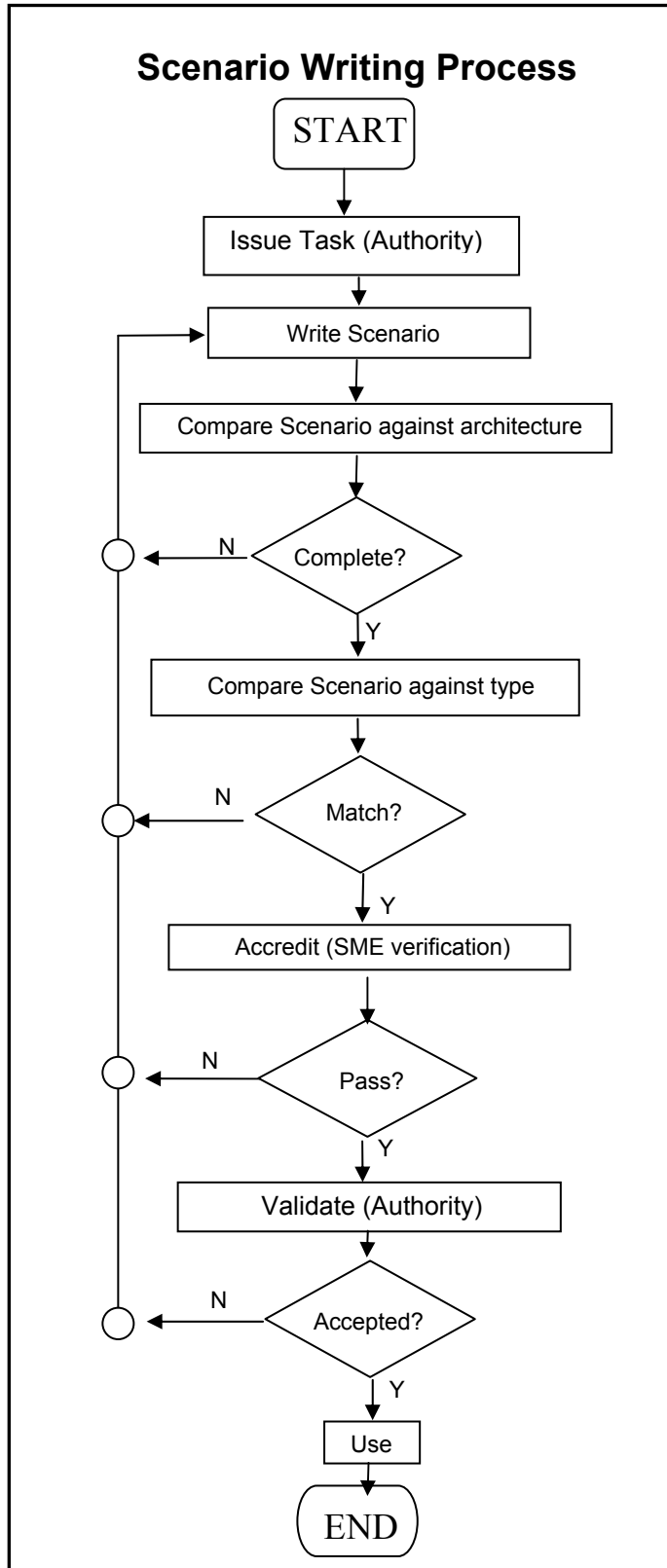


Figure 4: Scenario writing process

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Following the flowchart (Figure 4) from the point at which the generation of a scenario is authorised – the START - it will be seen that the written scenario reaches a point where it is checked for completeness. Here, the scenario is checked to see that all essential components are in place, using the check-list above (in paper or electronic form). This, by asking if the drafted scenario is complete, seeks an affirmative answer to the question: “*Have we built the product right?*”. A negative answer would require the scenario to be modified until the positive answer is attained.

When completed, the scenario can then be checked to see that it matches the original requirement: thus requiring a positive answer to “*Have we built the right product?*”. A “Yes” at this stage will require the scenario to be passed on to a suitable Subject Matter Expert (SME) who is competent to rule on the fitness for purpose of the scenario, or “*Does it do what we wanted it to do?*”. This enables the initial acceptance/accreditation of the scenario as appropriate for its intended use. From here, the original Authority – that which authorised the scenario generation - can accept or reject the product.

As described, this process relates to the development of a scenario from the beginning. It will, however, also serve to enable the re-use of one that has been generated previously. Any existing scenario can enter into the process as at the completion of the ‘Write’ stage. As a previous product, it will only have been deemed complete in terms of some previous requirement, and thus it must pass all the steps before it can be accredited for use in the new requirement. This can be viewed as a parallel to the way in which standard models may be used in a number of simulations, but only after the VV&A process has been completed.

The process discussed above must not – on any account – be confused with the detailed process of writing the scenario. There are several tools which will take a set of specifications and write a detailed scenario from them. Some of these are recent (even current) developments (e.g. CREWS-SAVRE, GRAIL, Kaos, RETH, etc) while some are a decade old (the DARPA Advanced Simulation Technology Thrust (ASTT) program funded work in this area at the University of Central Florida, for example). These tools always appear to be domain specific. Several tools are intended to write scenarios for use in hobby war-games, others are intended for financial modelling; as far as we could establish, none of these have a generic basis.

## 7 FUTURE WORK

We see several interwoven strands to the future of this work:

- Development of a formal software tool for scenario architecture assessment
- Scenario type identification
- Improving the process for extracting and categorising the scenario structure

None of these three strands can be seen as independent of the others. The tool development is in progress, but the “flat paper” version of the check-list is ready for use now, and collaboration would be welcome. Note that the paper check-list is designed so that sensitive information need not be passed on; the software version will incorporate the full range of protective markings (as do our other software tools).

We believe that we have a method by which the architecture of a scenario can be assessed. Sufficient evidence has now been collected to indicate that there are certainly two generic scenario types, and possibly three to four. Any move forward in this respect will be contingent on the development and validation of the formal tool, and this will require access to a reasonable number of scenarios. At the present time, we are working to turn our check-list into a computer-based tool that is fast, accurate and

user-friendly. This could be done as an extension to existing commercial software (possibly as a spreadsheet overlay) but we consider that the production of custom software (sharing an interface with the other software tools which we have produced) will offer greater benefits.

Given the tool, it will then be necessary to apply it to a substantial number of scenarios (possibly between 50 and 100) to produce enough raw data, and will also require the development of an approach to the representation of that data so that each scenario can be “typed”. We believe that this will lead to a general classification system for scenarios which is architecture-based, rather than domain dependent.

Development of the tool and subsequent derivation of scenario types will lead toward a standardised approach to categorising the architecture (as basic structure) of a scenario. The end product envisaged is an approach where a scenario can be categorised at the time of authorisation:

**“A Type 2 scenario is required for ... ..”**

as opposed to simply being able to make a *post hoc* statement that:

**“This is a Type 2 scenario ...”**

Just as simulation components are built to Object Models having a standard format, it is believed that this approach will lead to standardisation in scenario architectures, without imposing any restriction on the detail design.

## **8 CONCLUSIONS**

There is substantial evidence of tools to assist in the writing of scenarios, but these all appear to be domain specific. We have found no readily available evidence relating to work on a generic base for scenarios, or of work on tools/methods for a formal assessment of a scenario on any generic basis. We believe that the approach outlined here will, to some degree, obviate this apparent problem. There does not, as at time of writing, seem to be any standardisation in the terms used to describe, or even to discuss, a scenario. The component definitions offered here may help in this regard, but we would argue that the matter should be addressed more formally.

There is some limited evidence that scenarios can be categorised into a small number of domain independent, and application independent types, but more research is needed before this can be confirmed. It is hoped that the approach outlined here will aid in this respect.

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Whitworth, I., Smith, S.J., Hone, G., and Macleod, I. (2006) How do we know that a scenario is “appropriate”? Proceedings of the 11<sup>th</sup> International Command and Control Research and Technology Symposium: Coalition Command and Control in the Networked Era. held at Cambridge UK. Washington DC: The DoD-CCRP. (on CD-ROM)

Duffer’s Drift was originally published in 1907. The copyright lapsed and for a period of about 12 months, in 1992, Swinton’s original text was available for public download from the US Army URL: <http://www.adtdl.army.mil/cgi-bin/atdl.dll/misc/duffers-drift/duffers-drift.htm>

The work has since been reprinted, acquired a new copyright, and is now only available commercially (the US Army website mentioned above is now “access by account only”). DARPA continue to make “Fomblers Ford” freely available.

The work of which this product is part was initiated by the Research Director, CBD/Human Sciences. Any views expressed are those of the author(s) and do not necessarily represent those of MOD or any other UK government department.