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How do we know that a scenario is “appropriate”?

C2 Modelling and Simulation, C2 Analysis, C2 Experimentation

Ian R Whitworth, Steve Smith, Geoffrey Hone, Iain Macleod

Ian R Whitworth (POC)

Cranfield University at the Defence Academy of the United Kingdom

Cranfield University, Shrivenham, Swindon SN6 8LA, UK

+44 (0) 1793 785688

i.r.whitworth@cranfield.ac.uk (POC)
(s.j.smith; g.n.hone; i.Macleod; @cranfield.ac.uk)

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Cranfield University at the Defence Academy of the United Kingdom
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Abstract

Scenarios are the basis for all military planning, training, war-gaming, and the exploration of a wide range of geo-political potentialities. Scenarios are used in similar fashion by civil authorities, with particular reference to responses to natural and manmade disasters. To be of real benefit in any application, a scenario must be an "appropriate" scenario. Our research has been directed towards identification of those components of an appropriate scenario, the relationships between them, and of the individual items within each component. This work enables us to offer a basic scenario architecture – against which a scenario may be appraised – and which we believe may offer the basis for a generic scenario architecture. From this, we can now offer a process for the commissioning and employment of scenarios, which acts to provide a VV&A function in a manner similar to the VV&A process for simulations and their components. The future direction of this work will be directed at mapping a sufficient number of scenarios onto the basic architecture to distinguish different scenario types.

Introduction

What is a scenario? In order to discuss any topic in a meaningful way, it is first necessary to define that topic in terms that are fitting, and relevant – both to the topic, and to the nature of the discussion. All too frequently, a scenario is defined in terms that are domain specific. 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.dictionary.com

More specific, but clearly related to 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

Neither of these are complete, and we propose this alternative:

> ***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 that is at the heart of all scenarios, and they have been essential to war-gaming for almost two centuries. To discuss scenarios, we will use gaming as a baseline scenario application.

War games as we know them are generally considered to have started at the US Navy Academy following the War of 1812. Their use was revised by the Prussian General Staff some 50 years later (as "Kreigsspiel"), and adopted by the General Staffs of most countries over the last century. During the Cold War era (Mandel, 1977, suggests as early as 1961), war games evolved into the geo-political games used by all the major powers to explore the effect of possible events and policy changes. In all cases, we suggest that there has been a scenario (according to our definition above) as the base from which the game was developed, and which formed the basis for the game to be played.

As the war-game evolved into the general geo-political game, it became obvious that gaming from a starting scenario was a practical - and frequently low-cost - way of exploring possible futures. The armed forces of several countries moved from scenarios for exploring strategies, to those for exploring tactics, and then to scenarios for training all levels of command. If a scenario-based game would permit the possible development of new strategies and tactics, it would also permit the assessment of potential new equipments to be explored – otherwise Simulation Based Acquisition (SBA). This approach would generally follow the line of "If we introduce a new weapon/facility/etc, what effect will it have on the outcome of xxxxx?". Let us take 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. As 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 the cost of generating a scenario increased, the question of reuse arose.

Some scenarios are intended to be re-used. A scenario intended for (say) training Infantry recruits in Squad tactics will be designed (written) 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". The example (in the preceding paragraph) of a scenario for SBA, might also involve reuse 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, Kirzl and Maxwell (2002) suggest '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 is unlikely to be repeated. Lessons learned from one single use will be applied to those services, and a modified scenario will be subsequently employed to see if the lessons have been applied.

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. As an example, a scenario written to test NATO Staff in their action in the event of an invasion of Western Europe, by Eastern Bloc forces, through the Fulda Gap will remain suitable (appropriate) at the Staff level, but will not be appropriate to the current European and NATO geo-political structure (since much of the former Eastern Bloc is now part of NATO).

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

Current work in this domain

In order to gain some knowledge of the extent of current activity in respect of scenarios, two literature searches were undertaken on the Internet.

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

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

The resulting hits were found to fall into into the following broad areas of:

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

or were manually rejected as effectively being duplicates, or because further inspection indicated their irrelevance. A summary is given below in Table 1:

Literature Review on the Scenarios Theme

		Categories					
Search Terms	**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**
Totals	**431**	**12**	**38**	**103 (+1)**	**72**	**12**	**100 (+1)**

Table 1: Summary of First Stage Literature Review

Notes:

- Search Engine used was Copernic. This takes in 10 other search engines and eliminates most of the duplications.
- Column and row totals do not "sum out". Some items were not duplicates but different references to the same item. Other items did not refer to "scenarios" as we use the word.
- No instance was found of anyone who had produced, or who was attempting to produce, a scenario reference framework.
- The (1) refers to a hit which could have been placed in either category. As such, it is not statistically significant.
- The **Other** category includes a substantial number (around 40%) of "leisure war games" from 18th Century to Science Fiction

It will be noted that the "Military" category is the most popular by a very narrow margin. As a result of this, a further search was undertaken of the US DoD "Stinet" website. This is considered by the DoD to be the major repository of military related documents. The table below (Table 2) shows the search terms used and the number of hits for each term:

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

Table 2: Second stage literature review

It will be seen that only a very small number of hits were obtained. Each of these hits was then individually reviewed for relevance to any military domain. In the "Scenario Design" category, almost all hits were from PhD Theses on programming or software design. It seems clear that published activity in the present research area is – at best – minimal.

A separate search, which was expected to produce a general-purpose bibliography, produced material that was over 90% related to Software Engineering, or Systems Engineering. It seems clear from these searches, that any published activity in the area of scenarios is domain specific, rather than being concerned with scenarios in general. From the 2-stage review and the bibliography review, it would appear that there are no readily available examples or evidence of any work being carried out on the generic basis of scenarios. Thus, that for the many people, the vague definition listed at the beginning of this report would be sufficient.

As a result of the searches, and the conclusion drawn from them that there is apparently no work on a generic approach to scenarios, it was decided to take a Systems approach (as being the most inclusive) to the identification of the components of a scenario, and of the interactions between those components.

A Systems Approach to Scenarios

In order to determine the items that could be said to constitute a scenario, a number of scenarios were collected, and were then analysed to determine their individual components. This method produced a list of the "building materials" 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 to identify items which made up (or, in some instances, formed part of) some of the components, and to identify where further components or items were potentially required. This approach brought out further interactions and

dependencies, and enabled the developed provisional architecture to be re-formulated into a checklist of components and items.

Given a checklist, 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 checklist, 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/checklist was an effective way of analysing a scenario. Given the limited number of scenarios in our sample set, we would not consider that either the approach, or the checklist, had been fully validated; we would consider that they appear to show some merit. We then moved to testing the developed architecture/checklist against two detailed and well-known scenarios.

The first was a geo-political game developed for senior White house staff during the Reagan Presidency, known as Ivy League. A description of this game has not 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 was the DARPA document known as "Fomblers Ford" (Gorman, 2000). This is a DARPA re-write of Swinton's classic "The Defence of Duffers Drift". Duffers Drift was written immediately after the South African Wars (normally 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, with the equipment updated to that appropriate to the electronic age, but remained a guide for junior officers, as well as being an indication of the potential of modern equipment.

These tests appear to indicate that (as had been found earlier) some components will be found in all scenarios, but that not every component – and not every item – will be found in all scenarios. Given this, it is considered that there may well be more than one type of scenario, built to a generally common architecture.

The proposed Architecture

The proposed architecture is shown below. 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.

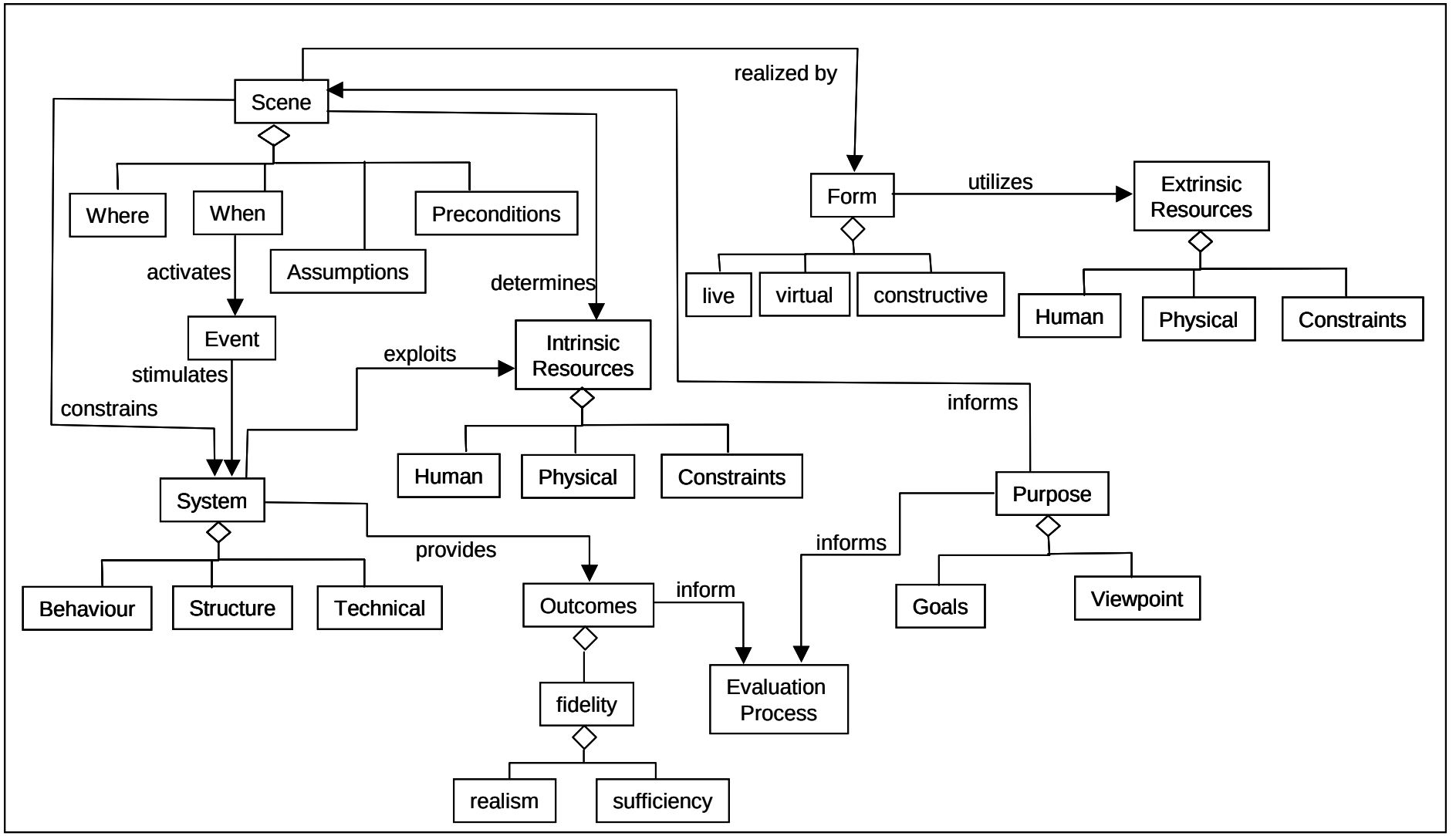

Figure 1: Proposed Architecture

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

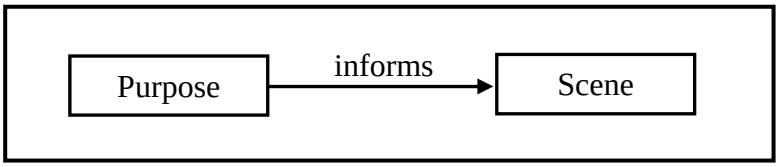

Figure 2 Representing a Relationship

Thus, the model in Figure 2 represents two components and their relationship and 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 is shown diagrammatically by a diamond shape. This relationship is read as saying: “ …is made up of …”.

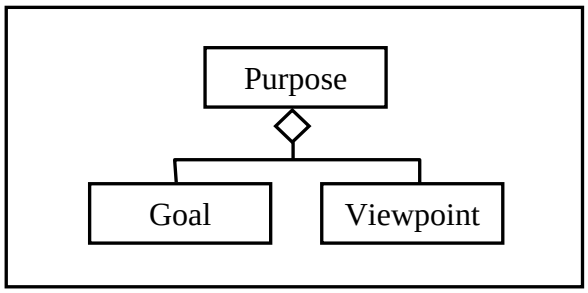

Figure 3 Representing Aggregation

Figure 3, therefore, represents a component made up of two items. This relationship should be read as: “Purpose is made up of Goal and Viewpoint”.

The architecture model shown 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 items and relationships. 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 organized 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, it became clear that there is a strong need for a general set of standard descriptors for any discussion of scenarios

Mapping Scenario to Architecture

The checklist was cast in a form that permitted 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 some 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 the 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 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 - those components that will allow it to meet its purpose. A scenario must therefore be purpose-oriented, and from this we can offer the following proposition:

1. Any scenario must have a declared purpose

If the purpose-oriented nature of a scenario (in the previous paragraph) 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 our second proposition:

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

A Process for Scenario Employment

It follows from the need for purpose that no scenario is developed in a vacuum. Some person or organization must have identified the need for a scenario, someone must have authorised its generation, someone must have written it, someone must have assessed its suitability. We have considered this as a process, and particularly as a process with the appropriate constraints and feedbacks to ensure that the finished scenario satisfies the basic requirements of Validation, Verification and Accreditation (VV&A) that would be applied to any simulation. This process is illustrated in Figure 4 (below).

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

Have we built the right product?
Have we built the product right?
Does it do what we wanted it to do?

However, it must be stressed that the answers do not necessarily come in that order, nor are they usually expressed in a succinct form.

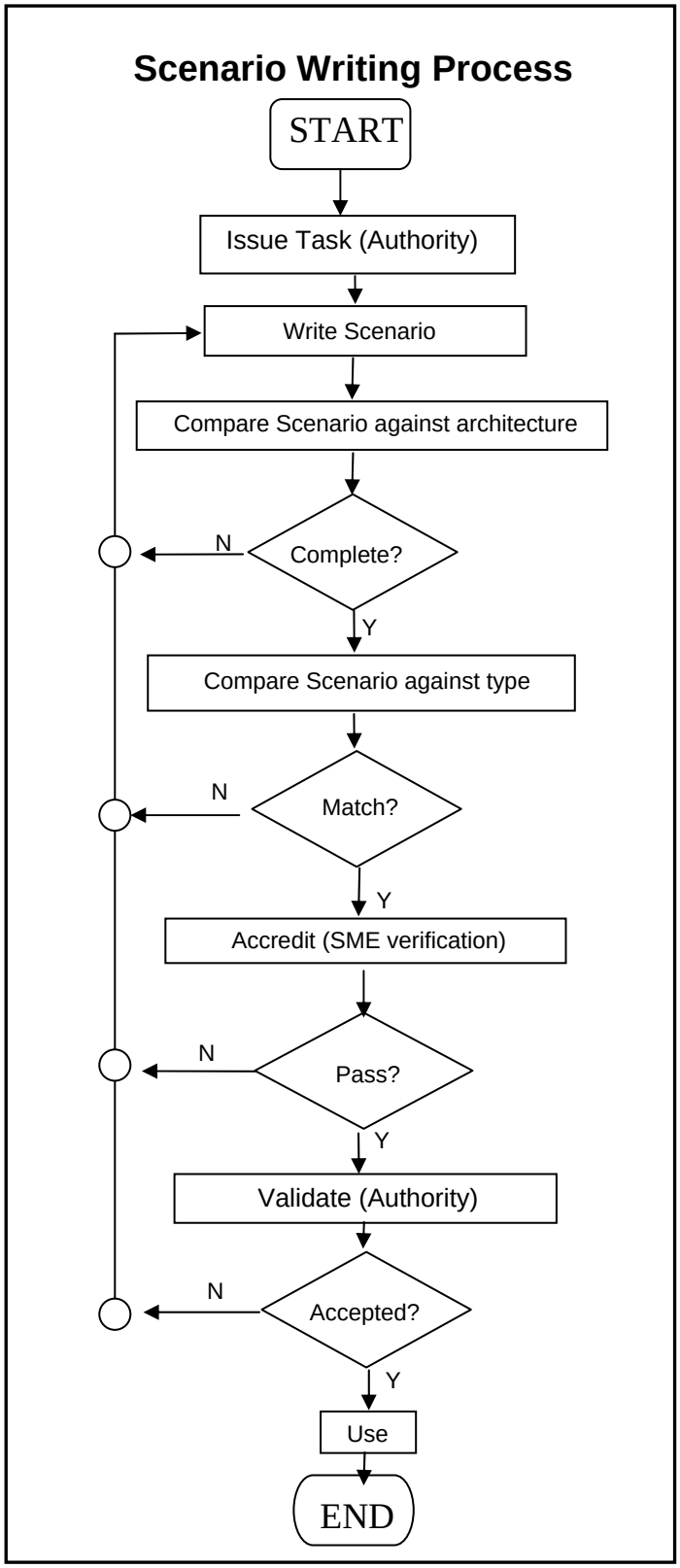

Figure 4: Scenario writing process

If one follows the flowchart from the point at which the generation of a scenario is authorised – the START - it will be seen that the written scenario reaches the point where it is checked for completeness. Here, the scenario is checked to see that all essential components are in place, using the checklist given above. This stage – by asking if the drafted scenario is complete - seeks a positive answer to the question: "*Have we built the product right*?". A negative answer will cause the scenario to be modified until the positive answer is attained.

The complete 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 accreditation of the scenario as appropriate for its intended use. From here, the original Authority - which authorised the scenario generation - can accept or reject the product.

While this process can account for the *ab initio* development of a scenario, it will also serve to enable the reuse of one generated previously. Such an existing scenario can be injected into the process as the completion of the 'Write' stage. As a previous product, it will only have been complete in terms of a previous requirement, and it must then 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 should – on no 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 or current developments (e.g. CREWS-SAVRE, Kaos, RETH, GRAIL, etc) while some are a decade old (the DARPA Advanced Simulation Technology Thrust (ASTT) program funded work at the University of Central Florida, for example). These tools are always domain specific. Several tools are intended to write scenarios for hobby war-games, others are for financial modelling; as far as we could establish, none of these have a generic basis.

Future Work

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

Development of a formal 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 a stand-alone topic, although it may well be logical to proceed in the order shown above.

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, probably three types and possibly four. Any move forward in this respect will be contingent on the development and validation of a formal tool, and this will require access to a reasonable number of scenarios. At the present time, we are considering how to develop our checklist into a tool that is fast,

accurate and user-friendly. This may require the production of custom software, or may perhaps be viable as an extension to existing commercial software.

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". This should lead to a general classification system for scenarios which is architecture-based, rather than domain dependent.

Production of these first two items 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 … …"

rather than 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.

Conclusions

There is substantial evidence of tools to assist in the writing of scenarios, but these all seem to be domain dependent. There is no readily available evidence relating to work on the generic basis of scenarios, or of work on tools/methods for the assessment of a scenario on a generic basis. It is believed that the approach outlined here will, to some degree, overcome this. There does not, as yet, appear to be any standardisation in the terms used to describe, or to discuss, a scenario. Whilst the component definitions offered here may help in this direction, we feel 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.

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Duffer's Drift was originally published in 1907. The copyright lapsed and for about 12 months, in 1992, Swinton's original text was available for public download from the US Army training website, using the 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.