Model-Based Military Scenario Management for Defence Capability

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Abstract

Capability related work is a core area for Defence, and scenarios, in their many forms, are used in much of this work. This paper describes initial work towards the development of an information model that links scenario and capability related information, and the results of capability analysis and experimentation. The intention is to develop the information model so that it may serve as the basis for a Defence capability knowledge management system and hence as a means of integrating experimentation with Defence capability development.

1. Introduction

Work relating to Capability forms, without doubt, a core area of Defence activity and cuts across most of its major business areas. Within our definition of capability, we include concept development and experimentation, capability analysis, planning and development, planning with regard to the fundamental inputs to capability, capability acquisition and operation.

Scenarios, in their many forms, are central to much of the work concerning capabilities. They are for example used to: identify and prioritise capability gaps, as the basis for the development of a business case for acquisition of a particular capability and as a basis for contingency plans.

An immense amount of knowledge is generated throughout all these activities, but there is currently no means to capture and share this knowledge. This paper describes initial work towards the development of an information model intended to capture and represent scenario and capability related information. It is also intended to model the results of scenario "executions", including discussion forums, simulations, wargames and experimentation type information. The intention is to develop the model so that it may serve as the basis for a Defence capability knowledge management system and hence to support Defence's move towards a more rigorous capability development process.

2. Background

The Role and use of Scenarios in Defence

Scenarios are used in many core Defence business areas. These areas include capability analysis, planning and development and concept development and experimentation. They also serve as a basis for contingency planning and as an input for maintaining preparedness.

Work on capability analysis, planning, development and acquisition soaks up a substantial proportion of the available effort within the non-warfighting elements of the Defence. Capability is a core issue for Defence, given its impact on the structure and capacity of the current and future force.

Strategic planners first contribute to the conceptualization of required capabilities by the assessment of strategic imperatives and through the acceptance of Government endorsed strategic guidance. The definition of strategic scenarios is the outcome of this conceptualization. These scenarios illustrate the types of situations in which Australia might have to mount a military response in response to a threat to its national interest.

These strategic scenarios play an important role in capability development in two ways. They provide the context for capability analysis and planning as they define the likely roles that the Defence will need to fulfill, and hence the broad capability priorities that the individual and combined capabilities must satisfy (Defence 2002b). Drawing on inputs such as military strategy and operational concepts, capability planners use these scenarios as a framework for testing whether current and proposed capabilities will be adequate for the tasks that Defence may be required to undertake (Defence 2002b). These capability requirements are then prioritised in terms of their importance. Developments in both doctrine and technology also drive the capability development process.

Having used one or more strategic scenarios to identify a capability requirement, capability planners will develop operational scenarios in order to determine the operational requirements for a proposed capability in a solution independent manner (Defence 2002a). The operational scenarios are more detailed extensions of the strategic scenarios, often by detailing a force structure with equipped capabilities to be applied to achieve the particular mission. By extending the strategic scenarios, these extended operational scenarios are assured of having a strategic validity. Capability proposals are refined and developed through the exploration of scenarios. The resultant capability development proposals are argued on the basis that they will better position Defence to meet the challenges that the scenarios describe.

Defence also has an active program of experimentation underpinning its work in concept development, futures analysis and hence capability development. Within this broader experimentation framework, strategic and operational scenarios are used to define a context for a particular experiment or series of experiments (Defence 2003). In this context, the term *experiment* is intended to cover the gamut of analytical and experimental studies, from informal analysis, loosely constrained studies and tightly constrained experiments (experimental science)" (Ng 2003).

Scenarios are also used at the operational level of command. They are used as an input to the development of contingency plans, for the analysis of the preparedness of the force-in-being. However, the strategic scenarios, by definition, do not cover peacetime situations. Hence the scenarios are augmented with data from current operations. Work is also being undertaken to place the Defence program of major exercises on a more rigorous basis; the strategic and operational scenarios will represent some of the inputs that, in the future, will shape the Defence exercise program (Asenstorfer 2004).

Hence it can be seen that strategic and operational scenarios form a link between strategic planning, futures analysis, experimentation, capability development, force development, contingency planning and preparedness.

The Problem

The pervasiveness of scenario-related activities creates its own problems. As discussed, the term *scenario* is used in many ways and with many different senses throughout the department. The result is that the word has many shades of meaning. Nevertheless, it is noted that scenarios may be related to each other in different contexts of capability planning, analysis and development. Changes made to a specific scenario, in particular to an instantiated operational scenario, may impact upon other scenarios, depending on their relevance in the requirements of capabilities. The selection and creation of operational scenarios, for whatever purpose, like experimentation, simulation, exercise play or campaign planning, must be based on a proper understanding of the relations to and impact on other scenarios, and the capability constraints it might create for other scenarios.

Whilst a great deal of the knowledge is accumulated through each activity, nonetheless each area defines and manages their information and knowledge resources locally, in circumstances that often make their sharing problematic. There is no easy way for this knowledge and information to be accessed, collated, combined and analysed in its entirety in the context of the whole of Defence. In addition to the variety of scenarios, and their complicated use, their relationships with other core Defence concepts, like capability, platforms and systems, have made the level of knowledge complexity be far beyond what people could confidently deal with it individually. A systematically defined and well-established body of knowledge covering warfighting concepts and their successful use could become a major objective of Defence as it begins to tackle issues of knowledge management .

There is a pressing need for Defence to, firstly, engineer scenario and capability knowledge through systematically defining concepts and their relations, and secondly, to develop a knowledge management environment that can help capture, manage, and make accessible knowledge from these diverse activities. In the short to medium term, taking a narrower, scenario and capability-focused perspective may make the development of such a knowledge management environment more practicable.

Objectives of Scenario Based Knowledge Management

A scenario based knowledge management environment should provide support for capability concept development, analysis and planning. It should allow a user to pose, and then answer, the following questions:

- How can Defence plan and evaluate their capabilities in multiple operational scenarios?
- How many scenarios can Defence cope with, in parallel, at a given level of capability?
- How can Defence analyse conflicts, shortage or gaps of capabilities in coping with multiple scenarios?
- How can Defence analyse impact and consequence of the change to an instantiated operational scenarios to other scenarios due to the constraints of capability requirements shared among those scenarios?
- How can Defence Information Environment information flows be examined in different warfighting contexts?

The ideal system would integrate with other capability related information, such as projects, systems and architectures, and other capability related systems. Such a system, together with the provision of suitable analytical tools, would be a further step towards moving Defence towards a more rigorous capability based planning framework[1].

3. DAIM and SIM

This paper describes initial work towards the development of an information model, the Scenario Information Model (SIM), designed to support the management of scenario related information. SIM forms one component of the Defence Architecture Information Model (DAIM). DAIM is intended to serve as an information model to enable the implementation of a capability-centred enterprise architecture library and a knowledge-rich architecture practice and systems engineering support environment. DAIM provides definitions for the principal concepts that underpin Defence's work. It defines concepts for systems, architectures, projects and documents, and through SIM, for scenarios, capabilities, effects, experimentation and analysis outcomes.

DAIM and SIM define concepts and information entities in an object-oriented and tool-independent fashion. Concepts are modelled as one or more classes within a taxonomy, through a capability and architecture based ontology (that is, their attributes, the methods by which they interact with other objects, and their relations with other objects) and by their meta-data.

DAIM and SIM give a high priority to representing and managing the relations between classes and their objects. As well as helping to define its semantics, an object's relations also define a context for that object. The context of an instance of one class will help to differentiate it from another instance of the same class, and also provide a richer explanation for its current situation or state. An ability to visualise an object's context will be an important aspect for a concept demonstrator that will be based on DAIM and SIM.

Capturing the relations between objects can also be seen as addressing an important knowledge management issue. By modelling relations, SIM is intended to represent critical Defence knowledge such as, for example, dependency and traceability relations between scenarios, capabilities and their associated concepts.

An Alternative to CADM

The United States Department of Defence (DoD) has developed a C4ISR Core Architecture Data Model (CADM), as a formal model of architecture products, structures, and their interrelationships, to support its DoD Architecture Framework (DODAF) (Software Productivity Consortium 2003). CADM was initially developed by selecting core entities from the most important and useful features of existing architecture data models. CADM defines 25 entities (such as Architecture, System, Missions, Mission-Area, Capability, Task, Action, Organisation and Document) their subtypes and their attributes. It has become the de facto standard for the development of architecture tools within the DoD.

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[1] According to Davis, P. K. (2003), the term *capability-based planning* has been used in the 2001 Department of Defense Quadrennial Defense Review (Rumsfeld, D. (2001)) as the desired framework for force planning.

There are several reasons why DAIM is being developed as an alternative to CADM. DAIM intends to model the architecture / system / scenario and capability domain to a far greater level of granularity than does CADM. It is intended to expand the scope of DAIM beyond that of CADM, to include Defence business processes for architecture and capability development. SIM and DAIM are also intended to act as a basis for an information repository for capability concept development, analysis planning and experimentation.

4. The Scenario Information Model

Scenario Based Capability Analysis – A Use Case

It is hoped that SIM can be developed to be the basis of a knowledge rich environment that can support capability concept development, analysis and planning. A use case, shown in Figure 1, has been developed to explore this idea and, in turn, to shape the initial development of SIM.

In this use case, the adequacy of a capability for either the force-in-being or the future-force is explored. A user selects one or more scenarios. He or she has the option of examining how that specific combination of scenarios has been 'played' in the past, The user can examine the capabilities and concepts of operations that had been used, together with their resultant outcomes.

The user then selects an applied force (that is, units together with a command structure) to achieve a desired set of capabilities. This capability set should include the one or more capabilities that are to be evaluated. The user finally develops a concept of operations (CONOPS) as a means of evaluating the capabilities being analysed.

The set of scenarios is then run in some way, perhaps as discussion forum, a wargame or as part of an experiment. The results are fed back into the Exercise / Wargame database. Such analyses can be run many times. This ability to store and retrieve the result of scenario evaluations potentially represents a substantial improvement on the current system in terms of capturing and sharing information. It should allow users to systematically explore the scenario and capability spaces. Using this data, users can evaluate the adequacy of a capability, extant or proposed, identify any gaps in the capability under evaluation and identify new capability requirements. They could also examine and compare collections of capabilities, either to examine capability sets as system-of-systems, or to prioritise between required capabilities. These results are stored within the Analytical Outcomes and Capability Requirements databases.

Subsequently, as a result of many capability evaluations, analysts draw conclusions regarding existing capability shortfalls or gaps, requirements for new capabilities and priorities between competing capabilities.

The Scenario Information Model – the UML Model

SIM broadly represents strategic and operational scenarios, military capabilities, both current and future, experimentation outcomes and their relationships. In this context, scenarios typically describe a conflict situation, an opposing force, a military setting, a theatre of operations and the events leading up to the conflict situation. They specify the international setting and the attitudes of allies, allies of the enemy and neutrals.

They also detail the political aims of the Australian government and its military strategic objectives.

Within SIM, the base class is named Abstract Scenario[2], which defines the principal attributes for the scenario classes. In practice, scenarios may be broken up into one or more phases. For example, a scenario focusing on evicting an enemy from an overseas territory may have phases representing the build up, the establishment of sea and air dominance, lodgement, the tactical battle and the post battle phase. Hence the Abstract Scenario class has two subclasses: Scenario and Scenario Phase, where a Scenario is comprised of one or more Scenario Phases.

The Scenario class has three subclasses: Strategic Scenarios, Strategically Derived Operational Scenarios, and Operational Scenarios; these latter two classes represent instantiated operational scenarios Strategic Scenarios represent strategically endorsed scenarios. Australia has a collection of government endorsed strategic scenarios which are high-level descriptions of situations, with a brief history of preceding events and their context. Together they represent the totality of possible situations where it is believed that the defence of a country might be required to mount a military response. Hence all these strategic scenarios, taken together, in principle largely define a country 's overall defence requirements. This aggregation of Strategic Scenarios is represented by the Strategically Endorsed Scenarios class, of which there is a single instance.

Strategically Derived Operational Scenarios are reference scenarios that have been extended from Strategic Scenarios, to provide sufficient detail for rigorous evaluation and descriptions of defence operation resolutions against the Strategic Scenarios. The descriptions include the requirements for and use of capabilities. Operational Scenarios represent scenarios that typically take place in a peacetime environment. Most recent many military operations would fall under this last category (Asenstorfer 2004). One must be careful when altering these scenarios. Changes made to instantiated operational scenarios require overall analysis of possible impact on other scenarios because their requirements on platforms and capabilities will constrain the availability of these for other instantiated operational scenarios.

Modern defence capability analysis requires an ability to examine and evaluate its current and planned capabilities and systems and their joint operations, not only in terms of a single scenario but also in terms of multiple simultaneous scenarios. Through using SIM, users will be able to combine one or more scenarios into an instance of the Scenario Evaluation Set class, potentially allowing users to plan and evaluate Defence's capabilities when coping with multiple simultaneous scenarios. A Scenario Evaluation Set will present a context where scenarios and capabilities can be jointly examined. Scenarios are "played" in some sense, perhaps in a discussion forum, a wargame or simulation, an exercise or a series of experiments. A Scenario Play is an "execution" of a scenario that may require more detailed descriptions on configuration and operation of capability and systems. Different types of Scenario Plays are represented by subclasses. The results from playing a Scenario Evaluation Set are stored as instances of a Scenario Play subclass.

[2] All DAIM classes are subclasses of a DAIM Base Object class. It's attributes include a class name as well as some meta-data. For this reason, none of the SIM classes have a name attribute.

As Scenarios are composed of Scenario Phases, so are Scenario Play instances composed of one or more Scenario Play Phases. Each instance of a Scenario Phase has a corresponding instance of the Scenario Play Phase class.

There are also classes representing the participants in the Scenario Evaluation Set, representing both countries and non-state actors, the events that take place and the areas in which the theatre or theatres are located.

SIM has been modelled in the Unified Modelling Language. The above-mentioned classes and their relationships are shown in Figure 2.

To analyse a Scenario Evaluation Set, a user needs to determine the force that will be assembled, their organisation and their concept of operation. These concepts are represented within the SIM. There are representations of the force required to defeat a supposed enemy, named the Applied Force class. An Applied Force is a collection of Units, which in turn may have Platforms which are organic to the Unit. Units provide Capabilities and Capabilities produce Effects. Capabilities also satisfy Capability Requirements.

Units are assembled to form Mission Capability Packages which are utilised by the Applied Force to achieve its mission. The concept of operations for an Applied Force is broken down to become the concept of operations for its component Mission Capability Packages.

The combined Mission Capability Packages provide the Required Effects necessary for the Applied Force to achieve its mission. By doing so, the Required Effects are intended also to satisfy the military strategic objectives and political directions that are specified in the Scenario Evaluation Set. These classes and their relationships are shown in Figure 3.

Taken together, users will be able to evaluate scenarios and Scenario Evaluation Sets many times, with a different mix of forces, capabilities, concepts of operations and effects. Previous evaluations will be accessible, stored in the subtypes of the Scenario Play class. These subtypes can be indexed in terms of scenarios, military capability packages exercised and their concept of operations.

The results of these capability evaluations are stored in the Analytical Outcomes class for future reference, and to support proposals for capability acquisitions and upgrades. In turn, from the Analytical Outcomes class, it may be possible to identify derive capability gaps, identify and prioritise capability requirements. These potential analytical outcomes are represented as subclasses of the Analytical Outcomes class. The Analytical Outcomes class hierarchy is shown in Figure 4.

The classes representing units, capabilities, platforms and effects serve as important links to the other DAIM packages. For examples, there are relationships between capabilities and projects, as projects are the mechanism by which capabilities are acquired and upgraded. Capabilities, platforms and projects will have links to their respective architecture products packages. Platforms will be linked to the systems from which they are composed. These broader representations, together with the

representations within the SIM, should provide the basis for a knowledge management environment supporting both capability development and an improved architecture practice.

The assembling, integration, configuration and operation of defence capabilities and systems in various operational scenarios and their associated scenario plays can be graphically represented as an operational view of architecture, simply called as OV. Both US DoD Architecture Framework (DODAF) and ADO Architecture Framework define a number of OVs as part of a required architecture product set for capabilities and systems. The complicated relations between capabilities and systems are conceptually defined and described in various OVs and system views, another type of DODAF architecture product.

A Strategic scenario, together with its corresponding Scenario Play, or an instantiated operational scenario, presents a use case of a capability or system in relation to other capabilities and systems. Therefore, its associated OVs, developed for capability planning, requirements study or acquisition, must meet the deployment requirements described in all operational scenarios or scenario plays that may use the capability or system. Planning and defining an operational scenario or a scenario play, on the other hand, must select those capabilities and systems of which OVs can support the required assembling, configuration and operation.

5. Capabilities Based Planning

The State of Australian Capability Planning

The move towards capability based planning in Defence is very recent. Between 1986 and 1996 for example, there was no identified threat, essentially one accepted scenario and no attempt to identify capability gaps or requirements. Decisions were made by consensus between small numbers of key players. Consequently, capabilities were changed or expanded only incrementally and there was minimal change in force structure. (Dunn 2003)

The situation changed significantly between 1996 and 2000, in response to a change of government, broadening priorities and a number of reorganisations. However, the strategic and planning environment remained confused, with many strategic concepts and constructs being used but none finding long-term acceptance. (Dunn 2003)

Within the space of a few short years, the processes surrounding capability have matured significantly. Defence White Papers[3] and regular strategic updates provide a strategic context. There is a defined and evolving capability development process embedded within a developing capability planning framework. The processes and mechanisms supporting acquisition continue to be refined. Australian doctrine continues to progress and there is a growing emphasis on capability development and experimentation.

However, problems remain. There are still too many conflicting processes, and there remains a lack of suitable analytical tools (Dunn 2003). Requirements are often excessively prescriptive, the functional linkages and dependencies between related capabilities are generally not recognised, and managing capability plans whilst

[3] The most recent was published in 2000.

remaining within financial guidance remains a most taxing challenge (Brown 2003). A recent review[4] was critical of the current capability development system, stating that it fails to give adequate advice and information to enable decision makers to make strategic decisions on an informed basis.

The Complexities of Capability Planning

Developing defence capabilities is a complex multi-dimensional problem. When planning and acquiring capabilities, there is a need to:

- identify the strategic circumstances in which Australia is likely to find itself, over a time frame extending to perhaps thirty years; changing political direction
- identify gaps in current capabilities
- balance current and future capabilities
- balance equipment acquisitions with changes to other fundamental inputs to capability
- plan for long procurement lead times
- take advantage of evolving technology and doctrine
- maintain interoperability with allies and potential coalition partners
- remain within a tight financial framework

Taking all these factors into consideration, Defence decision makers need to determine: (Brown 2003)

- what are the current gaps in capability;
- which enhancements or new capabilities are essential;
- what is achievable now;
- what should be achievable in the future;
- what are the risks of any gaps between the two, and
- what are the options for reducing the gap, in order of costs and risks.

In turn, what Government requires is advice that focuses on: (Kinniard 2003)

- the potential plausible military situations where Australia might be required to mount a military response;
- the implications in terms of capability requirements, force structure and preparedness;
- plausible options on how these capability requirements might be met;
- and how the resultant capabilities might be acquired and sustained at an acceptable cost. Where necessary, advice may also be required on what capabilities may need to be retired to achieve the budgetary requirement.

Capability-Based Planning

As has been stated, the American Department of Defense is moving to a capabilities-based planning framework (CBP) as its mandated framework for force planning. Davis (2003) offers one approach to CBP. He defines CBP as “planning, under uncertainty, to provide capabilities suitable for a wide range of modern-day challenges and circumstances, while working within an economic framework.”

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[4] Kinniard, M., Early, L., Schofield, W. (2003). Defence Procurement Review, Department of Defence. cited in Dunn, M. (2004). Case Study - Australia's Application of Capability Planning. R. Gori. Canberra, Australia.

A key element of Davis's approach is an analytical framework with three components (Davis 2003) His framework requires:

- a thorough understanding of capability requirements
- an assessment of capability options at the level of mission or operation
- an ability to choose between capability levels and amongst capability options in an integrative portfolio framework that considers other factors (eg, force management), different types of risk and economic limitations.

Davis states that "serious capabilities planning and operations require the concreteness that comes with considering specific scenarios – either real or credibly constructed." This requirement for credible scenarios allows for capability options to be assessed in terms of missions or operations.

In the context of his paper, Davis relates several interesting concepts. He argues the need for a "scenario space" for each critical scenario. It would contain information such as the politico-military context, key objectives and strategies, the size, character and nominal capabilities of the suggested forces, their effectiveness, relevant environmental details and other critical assumptions. (Davis 2003) He stresses the importance of a "design space". In his words "a design space … is essential to good design. It is what allows the designer to move from broad motions to something concrete and to identify the myriad issues that must be addressed." (Davis 2003) He then talks of the importance of understanding the "requirements space" as a means of dealing with the uncertainty inherent in the capability process. His design and requirement spaces must be addressed and evaluated many times, "at multiple levels and in numerous components of effort." (Davis 2003)

Essentially, Davis argues for the capability process to be conducted on a highly rigorous basis, based on a range of plausible scenarios representing strategic and operational requirements. Capability developers then need to explore the scenario, design and requirements spaces, iteratively and recursively, so as to develop and understand capability requirements, develop options, examine trade-offs and factor in budgetary considerations. These considerations need to be related to a complementary CD&E framework.

Davis argues cogently that his approach would greatly enhance a capabilities-based approach to force development; Nonetheless, Davis warns that there is no truly rigorous way to perform force development "without doing violence to the strategic issues". (Davis 2003)

It is argued in this paper that Defence can not generate the advise that the Australian Government requires without the development of a knowledge rich environment to support all aspects of capability conceptualisation, analysis, development and planning. It is further argued that SIM offers a potential first step towards the development of such a knowledge rich environment.

6. Future Work

The discussion regarding military scenario management, presented in this paper. is just a starting point of a journey for the Defence to moving towards better engineering warfighting knowledge management and integrating it with capability planning and development knowledge. Following the development of SIM/DAIM, our effort will

mainly focus on helping the ADO to develop a Defence Enterprise Architecture Library (DEAL) that will hold all knowledge and architecture information covering from scenarios, capabilities, systems, architecture products and projects. The knowledge and architecture information will be captured and managed in an object-oriented fashion such that each real world entity of scenarios, capability, systems, projects and architecture can be presented and visualised with its full context in terms of its artefacts and relations to others.

Engineering warfighting knowledge through introducing the military scenario management is a complicated task that has the potential to impact upon many defence business areas from force development, capability planning and analysis to military operation planning and control. The main outcome of the knowledge engineering effort is a well-structured and systematically managed body of knowledge that can be viewed as a defence capability knowledge management system. It can also server as a foundation for developing knowledge-based applications to automate or semi-automate some scenario and capability related processes and activities, such as rule-based reasoning and checking of scenario and capability gaps or conflicts, and rule-based scenario generation for simulations and experimentations.

7. Conclusion

In this paper, it has been argued that despite many improvements in Australia's capability development process in the recent past, many problems remain. This is unsurprising, given the immense complexities that underlie the process. The Australian Government has recently clearly articulated its requirements regarding capability advice. Consequently, Defence has recently been radically restructured in order to try and satisfy these requirements. Nonetheless, without improved analytical tools and databases, it remains difficult to envisage that Defence will be able to satisfy the Australian Government's requirements regarding capability advice.

The United States Department of Defense is adopting a capabilities-based planning framework as its mandated framework for force planning. Davis (2003) has suggested an approach to support this framework. It is based on the development of critical scenarios, and hence the systematic exploration of the corresponding scenario space, design space and requirements space.

It is the thrust of this paper that these processes would be well served by the development of a suitable information management system, and that SIM is a potential candidate to meet these requirements. SIM is intended to support the individual processes of concept development, experimentation, capability analysis and development, and to tie them together in some meaningful way that supports traceability between assumptions, scenarios and derived results. More work is required before SIM reaches the desired level of maturity. In addition, the required improvement in Australia's capability development processes will require the development of sophisticated analytical tools and databases. SIM, however, promises to provide a rigorous information model to support their development.

Acknowledgements

The authors would like to thank:

- Norman Ferguson and Martin Hamilton, of Codarra Advanced Systems, for their contribution to developing DAIM;

- Michael Isgro and Fung Wong of Swinburne University for their contributions to both developing DAIM and the DAIM concept demonstrator;
- Daniel Hall and Elizabeth Newton-Smith of the Defence Science and Technology Organisation, for their help and support.

In this example, the adequacy of a capability for either the force-in-being or the future-force is explored. A user selects one or more scenarios, an applied force (units and a set of capabilities) and a concept of operations (CONOPS) as a means of evaluating one or more capabilities. A user has the option of examining the capabilities and CONOPS used previously for the selected scenario. The scenario is then run in some way, perhaps as discussion forum or as a wargame. The results are fed back into the appropriate databases within the DAIM.

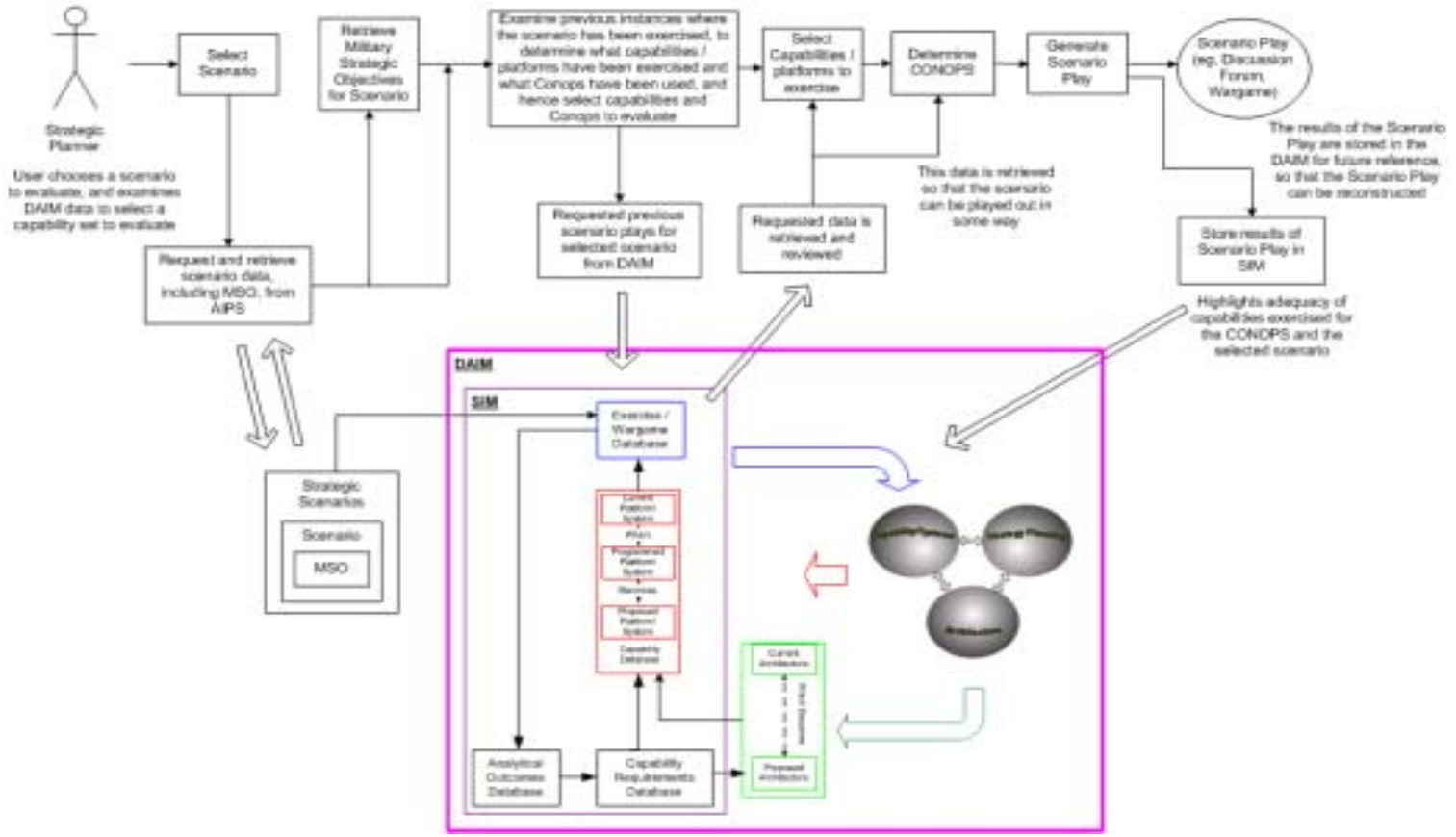

Figure 1: Use Case for Scenario Based Capability Analysis

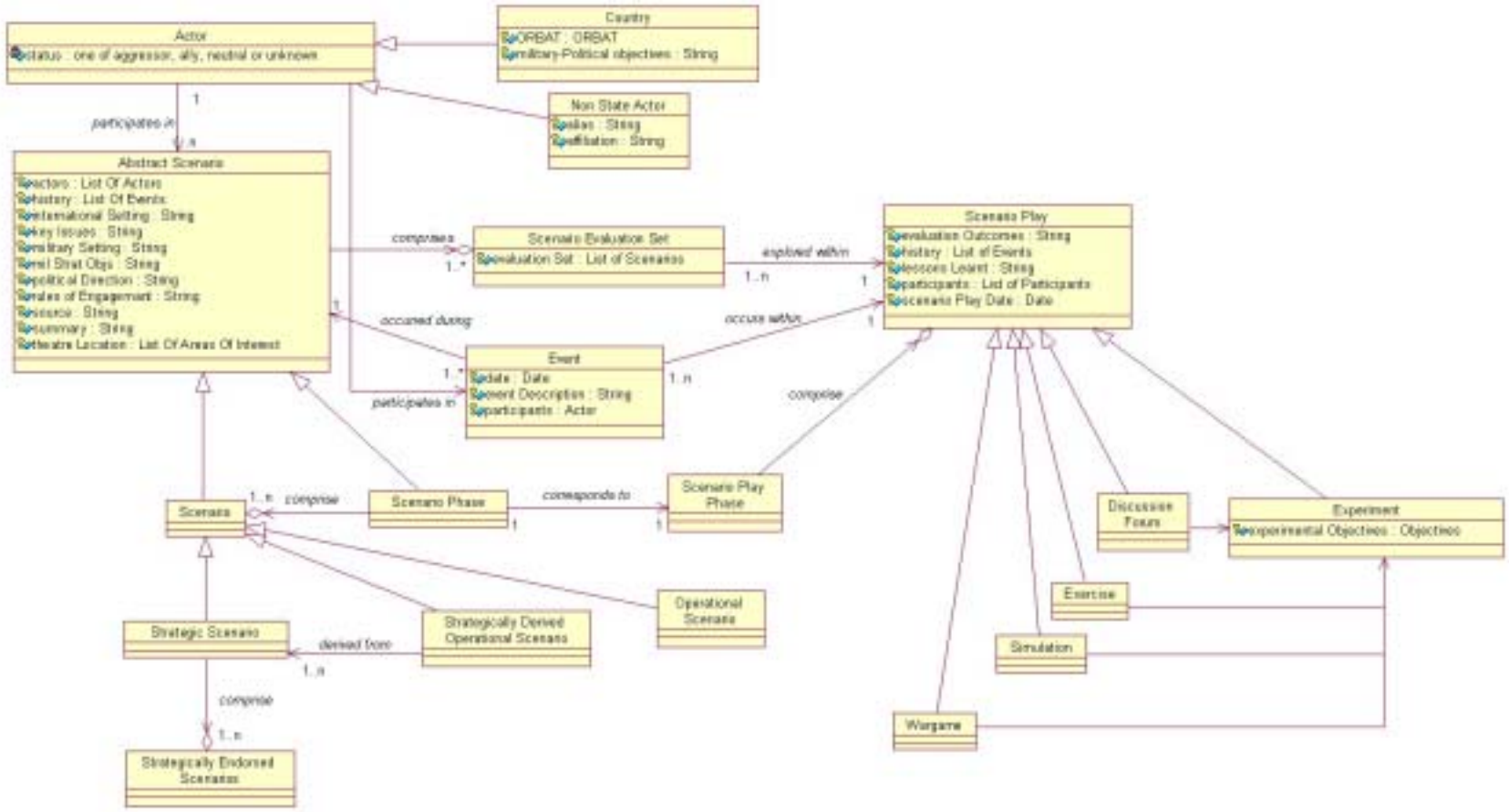

Figure 2: Scenario Information Model – Scenarios and Scenario Play

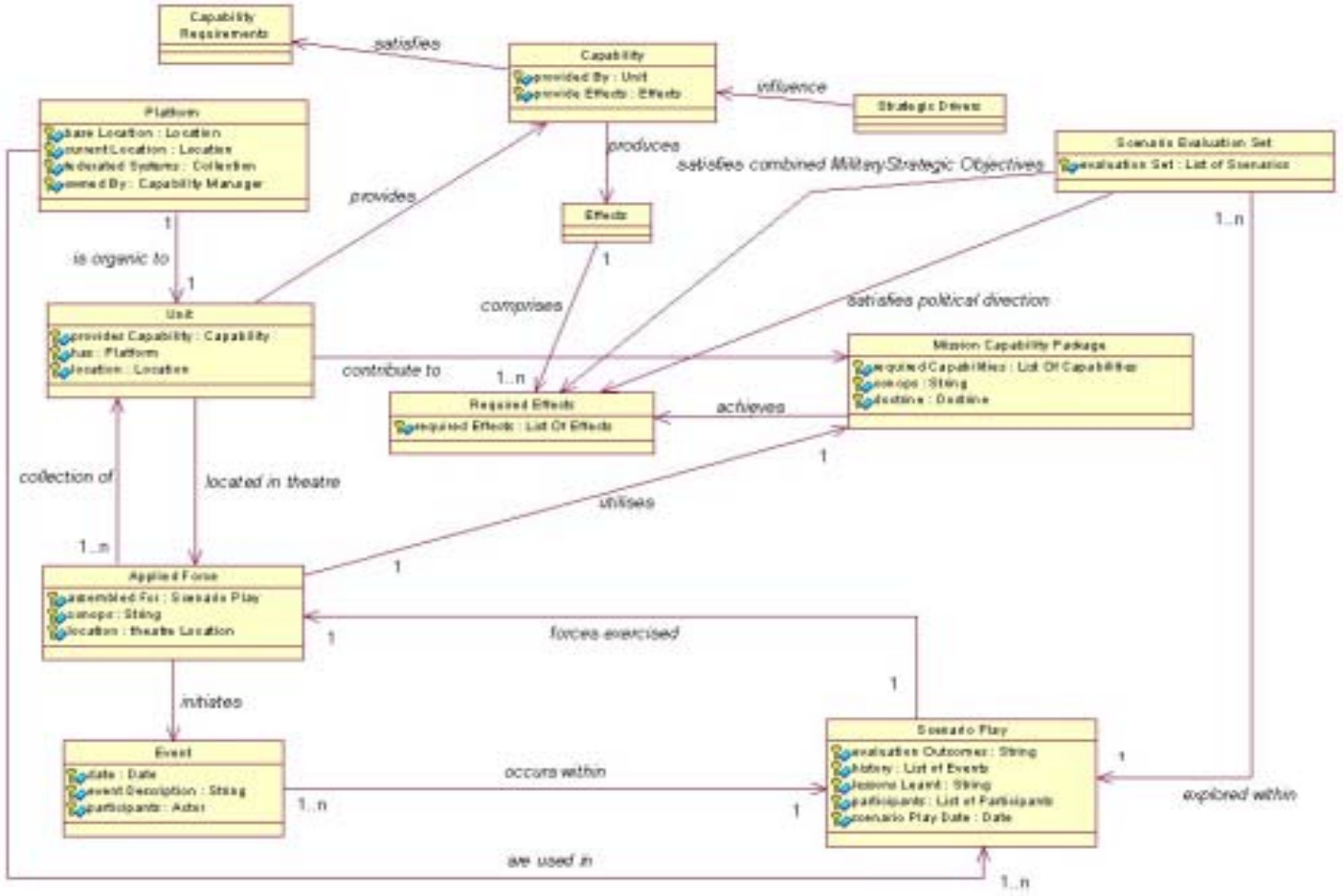

Figure 3: Scenario Information Model – Applied Force, Units, Capabilities, Platforms and Effects

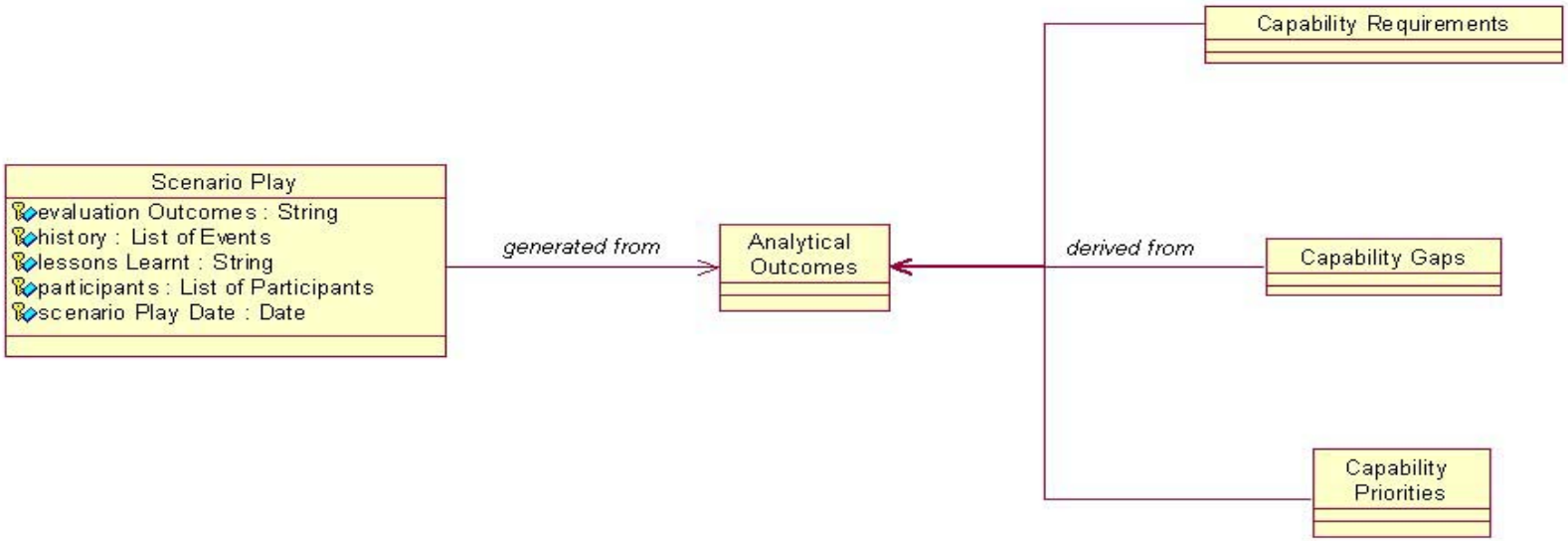

Figure 4: Scenario Information Model – Analytical Outcomes

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