

## **Architecting in the Fourth Dimension Temporal Aspects of NAF and DoDAF**

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### **ABSTRACT**

*The capture of system structure, behaviour, configuration, interaction, and compliance is common practice in architectures. These are largely static views showing a specific configuration or behaviour at a specific instance in time. IEEE Std 610.12–1990 defines architecture as “the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.” (IEEE, 1990) Modelling this evolution or the temporal aspects in architecture frameworks such NAF (Nato Architecture Framework), MODAF (Ministry Of Defence Architecture Framework) or the Department of Defense Architecture Framework (DoDAF), was previously problematic. These architecture frameworks are based on the use of a 4 dimensional ontology such as IDEAS where the spatio-temporal extent of an element is a crucial concept. This is embodied in DoDAF 2 as well as the re-engineering effort of MODAF (MODEM: which provides an IDEAS foundation basis for MODAF). Time can now be dealt with to a much greater extent than previously. The challenge is to identify areas of architecture where time can be modelled and how to take best advantage of it. Also problematic is how to express these concepts without having to expose all the internal ontological relationships upon which MODEM and DoDAF are built. The Unified Profile for DoDAF and MODAF (UPDM) delivers an implementation of DoDAF 2.0 that provides a clear and concise way of expressing these concepts without requiring the user to become an expert in the DoDAF 2.0 “internal wiring” and detailed ontological concepts. Since MODEM was not available when UPDM 2.0 was finalised, MODEM is a requirement for UPDM 3.0. MODEM has also been accepted as the basis for an upgrade of NAF and will make its appearance as NAF version 4.0. This paper will examine the temporal concepts defined in NAF (MODEM) and DoDAF 2.0 and show how time can be effectively integrated into a model to express essential temporal concepts.*

## 1.0 INTRODUCTION

As William Shakespeare wrote in Julius Cesar, “Timing is everything.” (Shakespeare, 1613) Cummings (1922) noted humorously that “Time is what keeps everything from happening at once.” Philosophers have also mused on the concepts and flow of time for as long as human beings have roamed the planet. Time is no less important when building a military architecture framework. It is not sufficient to simply model the system configurations. It is necessary to show how a configuration will evolve over time, how the variations will differ, common components, additional and emergent behaviour, how a systems behaviour and capabilities change over time, etc. Some examples of the use of time are:

- Modeling a sequence of events for different scenarios
- Showing how a system changes over time and its different versions
- Showing how the use of a system can change over time as defined by different scenarios
- Capability modeling and how different systems support a capability over time
- Showing how a system supports multiple capabilities at different phases of its lifecycle
- Modeling system states to show time dependent behaviour as well as transitions and actions taken as a result of these transitions.
- Time dependent activity sequences
- Modeling processing time, latency, transport time etc.
- Scheduling deployment of systems over time
- Personnel deployment and competency assessment
- Data management lifecycles
- Integrating system acquisition cost, deployment cost etc. to show total cost of ownership.
- Modeling product variants
- Showing cost vs. time vs. capability
- Etc.

## 2.0 ARCHITECTURE FRAMEWORKS AND ONTOLOGIES

Arguably, the most widely used military enterprise architecture frameworks are the US Department of Defense (DoD) Architecture Framework (DoDAF), the British Ministry of Defence (MOD) Architecture Framework (MODAF) and the NATO Architecture Framework, (NAF). Military Architectural Frameworks such as DoDAF define a standard way to organize an enterprise architecture (EA) or systems architecture into complementary and consistent views. DoDAF was developed in the 1990s as the C4ISR architectural architecture framework. C4ISR v1.0 was released 7 June 1996, and was created in response to the passage of the Clinger-Cohen Act. It addressed the 1995 Deputy Secretary of Defense directive that a DoD-wide effort be undertaken to define and develop a better means and process for ensuring that C4ISR capabilities were interoperable and met the needs of the war fighter. C4ISR Architecture Framework v2.0 was released in December 1997.

**DoDAF Versions:** DoDAF v1.0 was released in August 2003. It broadened the applicability of architecture tenets and practices to all Mission Areas rather than just the C4ISR community. This document addressed usage, integrated architectures, DoD and Federal policies, value of architectures, architecture measures, DoD decision support processes, development techniques, and analytical techniques. The data format was expressed as CADM v1.01. (DoD, 2003) This was the start of the data-centric approach and placed emphasis on architecture data elements that comprise architecture products. DoDAF Version 1.5 was released in April

2007 as a stop-gap update, mainly concerned with SOA (Service oriented architecture) while awaiting a more complete approach based on IDEAS concepts (discussed later). (DoD, 2007a, 2007b, 2007c) On May 28, 2009 DoDAF v2.0 was approved by the Department of Defense. (DoDAF, 2010)

**DoDAF Views:** DoDAF 1.0 and 1.5 contained four basic views: the overarching All Views (AV), Operational View (OV), Systems View (SV), and the Technical Standards View (TV/StdV). Each view is aimed at different stakeholders, and it is possible to create cross references between the views. Although they were originally created for military systems, they are commonly used by the private, public and voluntary sectors around the world, to model complex organizations such as humanitarian relief organizations and public services such as FEMA. The goal is to improve planning, organization, procurement and management of these complex organizations. All major DoD weapons and information technology system procurements are now required to document their enterprise architectures using DoDAF.

**Evolution of MODAF/NAF:** MODAF kept compatibility with the core DoDAF viewpoints in order to facilitate interpretation of architectural information with the US military. However, MODAF v1.0 added two new viewpoints. The new elements were the Strategic and Acquisition Viewpoints. These were incorporated in DoDAF 2.0 and was there called the Capability (CV) and Project Views (PV). These were added to better contribute to MOD processes and lifecycles, specifically the analysis of the strategic issues and dependencies across the entire portfolio of available military capabilities within a given time frame. In MODAF v1.2, Service views were added to support the development of Service Orientated Architectures (SOA). These views, called SOV views in MODAF and SvcV views in DoDAF 2.0, were based on NAF 3. NAF 3.0 service views were however based completely on the MODAF 1.1 service views that were contained as part of the proposed package in MODAF.

**DM2:** DoDAF has a meta-model underpinning the framework, defining the types of modeling elements that can be used in each view and the relationships between them. DoDAF versions 1.0 thru 1.5 used the CADM meta-model, which was defined in IDEF1X (then later in UML) with an XML Schema derived from the resulting relational database. From version 2.0, DoDAF has adopted the IDEAS Group foundation ontology as the basis for its new meta-model. This new meta-model is called "DM2"; an acronym for "DoDAF Meta-Model".

### 2.1 IDEAS

IDEAS is the International Defense Enterprise Architecture Specification for exchange. DoDAF version 2.0 is based on the IDEAS ontology foundation. (IDEAS, 2012) The current versions of NAF and MODAF are influenced by IDEAS to some degree but are still UML profiles. An update to MODAF called MODEM has however been prepared which is based entirely on the IDEAS Foundation ontology. MODEM is by and large backward compatible to MODAF 1.2.004 and a large amount of documentation concerning MODEM has been produced. It has been published by the MOD as a replacement for MODAF and will be used as the basis for NAF version 4. The purpose of IDEAS is to develop a data exchange format for military Enterprise Architectures. This goal is to provide seamless sharing of architectures between the partner nations regardless of which modeling tool or repository they use. The initial scope for exchange is the architectural data required to support coalition operations planning:

- Systems – communications systems, networks, software applications, etc.
- Communications links between systems.
- Information specifications – the types of information (and their security classifications) that the communications architecture will handle.
- Platforms & facilities.
- System & operational functions (activities).

- People & organizations.
- Architecture meta-data – who owns it, who was the architect, name, version, description, etc.

Before going further, it would be best to explain a few of the main concepts in the IDEAS foundation key objects. At the base of the IDEAS ontology is the “Thing”. There are three types of Things:

- Types (which are like sets),
- Tuples (ordered relationships), and
- Individuals (not persons, but Things that have spatial and temporal extent – spatio-temporal extent.)

Mereology is a collection of axiomatic first-order theories dealing with parts and their respective wholes. In contrast to set theory, which takes the set–member relationship as fundamental, the core notion of mereology is the part–whole relationship. Mereology is both an application of predicate logic and a branch of formal ontology. For further information see IDEAS (2012). The IDEAS foundation key objects are shown in Figure 1.

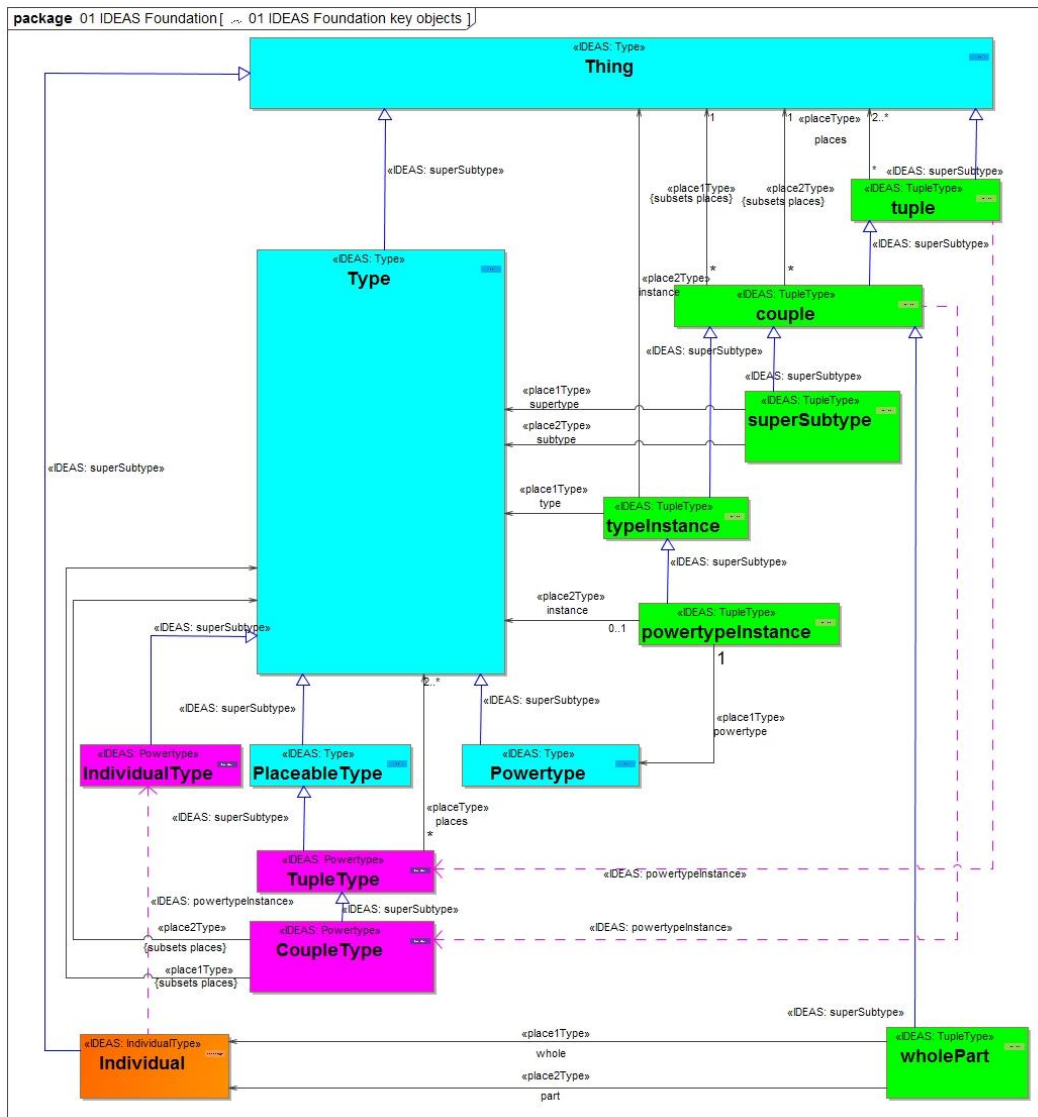


Figure 1: IDEAS Foundation key objects

### Foundation Objects:

None of these foundation properties found in Figure 1 are unusual; they are all used in everyday reasoning:

- Individuals, things that exist in 3D space and time, i.e., have spatial-temporal extent.
- Types, sets of things.
- Tuples, ordered relations between things, e.g., ordered pairs in 2D analytic geometry, rows in relational database tables, and subject-verb-object triples in Resource Description Framework.
- Whole-part; e.g., components of a service or system, parts of the data, materiel parts, subdivisions of an activity, and elements of a measure.
- Temporal whole-part; e.g., the states or phases of a performer, the increments of a capability or projects, the sequence of a process (activity).
- Super-subtype; e.g., a type of system or service, capability, materiel, organization, or condition.

### Higher level Objects:

These can then be used together to model kinds of things and their relationships. In enterprise architecture kinds of things are usually more interesting than individuals and these elements are therefore of great importance:

- BeforeAfter (IDEAS foundation element)
- BeforeAfterType (IDEAS foundation element)
- TemporalWholePart (IDEAS foundation element)
- TemporalWholePartType (IDEAS foundation element)
- Desired Effect (DM2 element)
- Work Streams (MODEM and DM2)
- Sequence of events in the form of sequence diagrams (MODEM)
- State modeling (MODEM)
- Milestones (MODEM)
- Etc.

There are a number of items above that are pure IDEAS elements. The fact that they are allowed for direct use in DM2 actually represents a problem since this places an awful lot of responsibility on the modeler. Although Milestones are part of MODEM/ MODAF, they are not part of the DM2 vocabulary. The closest that DM2 gets to this is by assuming that a kind of project contains a kind of activity that is assumed to be a milestone by the modeler.

#### 2.1.1 IDEAS examples

Since the main topic of this paper deals with timing concepts, a few examples that describe their use based on IDEAS foundation elements may be appropriate. Figure 2 shows a whole-part example while highlighting the temporal aspects. This simple example of a street crossing is an effective means to introduce these concepts.

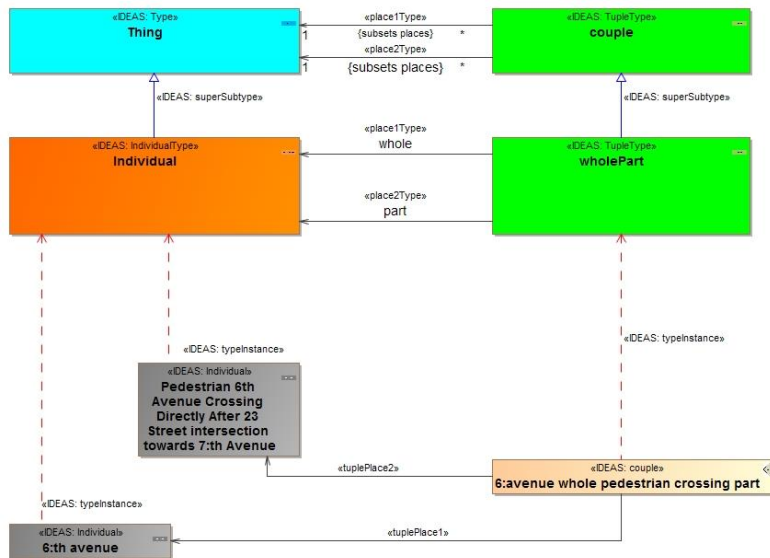


Figure 2: A wholePart example

The above example describes a simple wholePart relationship between an avenue and a crossing contained within it. It should come as no surprise that the set of all wholePart relationships should have an instance within it that is the relationship between 6:th avenue and its contained crossing. Both of these individuals have a defined spatio-temporal extent. The above example considers a spatial wholePart but there is actually a temporal wholePart inside this as well since it could be argued that the pedestrian crossing may not have been in existence all of the time that 6:th avenue was in existence. This means that if a completely spatial wholePart is being considered we are actually talking about 6:th avenue during the time interval where this crossing was a part of it. The wholePart relationship can contain both spatial as well as temporal wholeParts and the next example shown in Figure 3 deals with a wholePart that is completely temporal. IDEAS created a special subset of wholePart where completely temporal wholeParts can be dealt with.

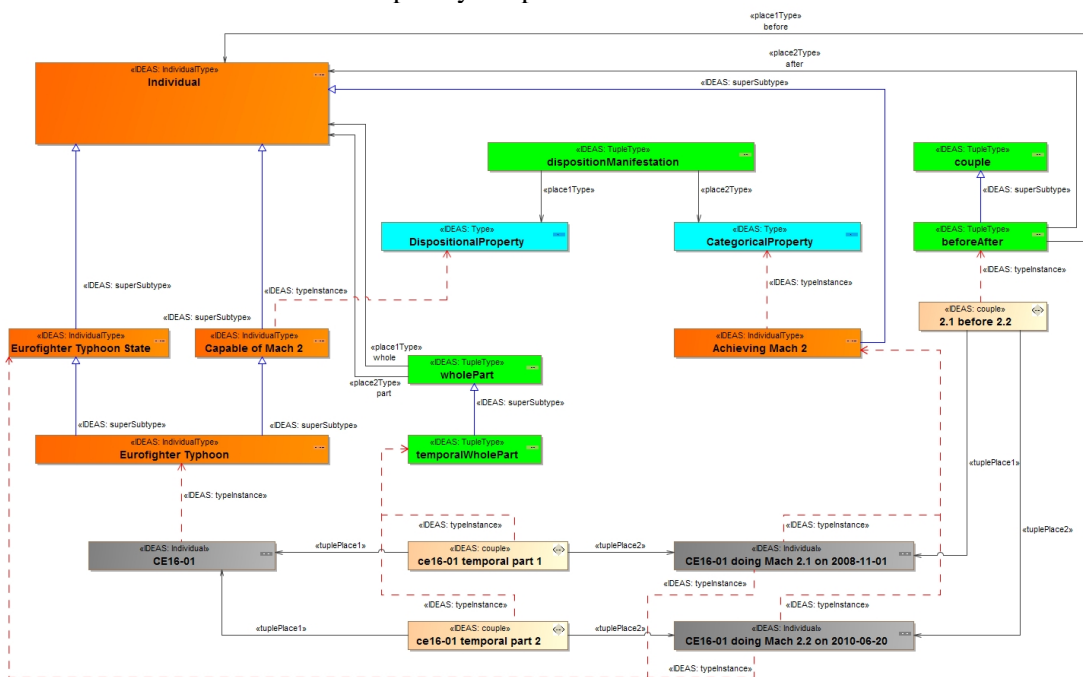
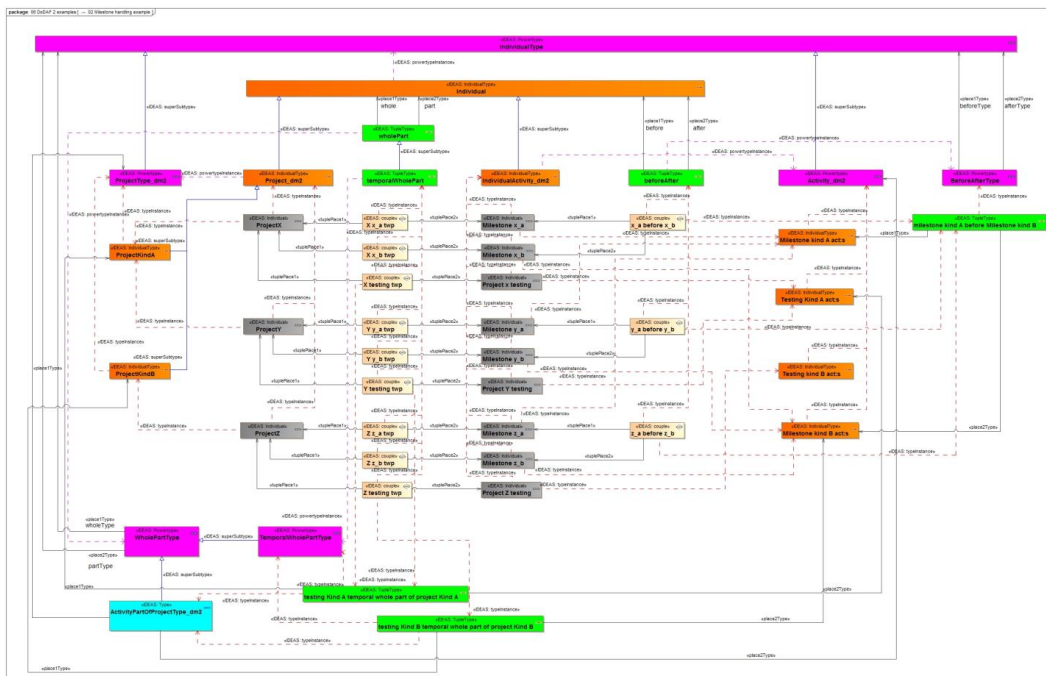


Figure 3: A temporalWholePart example

Eurofighter Typhoon is the set of all Eurofighter typhoon individuals from a whole-life perspective i.e. from the time it was commissioned until the time it was decommissioned. These instances are subset of the set of all possible states of Eurofighter Typhoon (i.e. temporal slices of the whole-life). It is also a subset of all things that are able to achieve a speed of Mach 2 and beyond. This is an example of a dispositional property, i.e. something that can be done. During a part of an individual Eurofighter’s life however it was actually doing Mach 2.0 and this time slice is a temporal part of the Eurofighter individual. It is therefore possible to construct a relationship between the two individuals that is an instance of temporalWholePart, a purely temporal wholePart. Note that there could be several instances of the Eurofighter achieving Mach 2 as indicated in the figure. The two time slices of the Eurofighter where it achieves a speed of 2 Mach or above are instances of the Eurofighter typhoon state set as well as the Achieving Mach 2 set. In order to further demonstrate a piece of temporal handling an instance of beforeAfter has been added. The instance of this set simply shows that 2.1 Mach was achieved before 2.2 Mach.

This starts to bring us into the area of time handling made possible by MODEM as well as DoDAF 2.

A simple project schedule diagram has been created to help explain the temporal aspects further and also includes discussions of higher level temporal elements and their use. Figure 4, apart from being unreadable looks extremely complicated. However, it is actually almost completely an explicit DoDAF 2 PV-2 model. It contains all of the DoDAF defined necessary elements for a PV-2 model. DoDAF 2 actually allows exactly 150 different optional element types as well for this view something that poses quite a challenge for any tool palette. It also contains some elements defined as optional for the view and some that a modeler is actually not allowed to use: notably Individual and IndividualType. These are used here since to exclude them would make it difficult to see where different elements point to. Figures 5, 6, 7, 8 and 9 detail Figure 4 in a more legible format. Figure 10 contains the MODEM equivalent of figure 4 and some discussions concerning the reason for the differences.



**Figure 4: A DoDAF PV-2 diagram**

As can be seen in Figure 5 there are:

- A set of Individual projects are contained in the example model and a set of example activities.
- Since milestones are not a part of the DoDAF vocabulary activities have been chosen instead and there are a few different individual milestones as well as a completely different type of activity (testing) associated with each individual project.

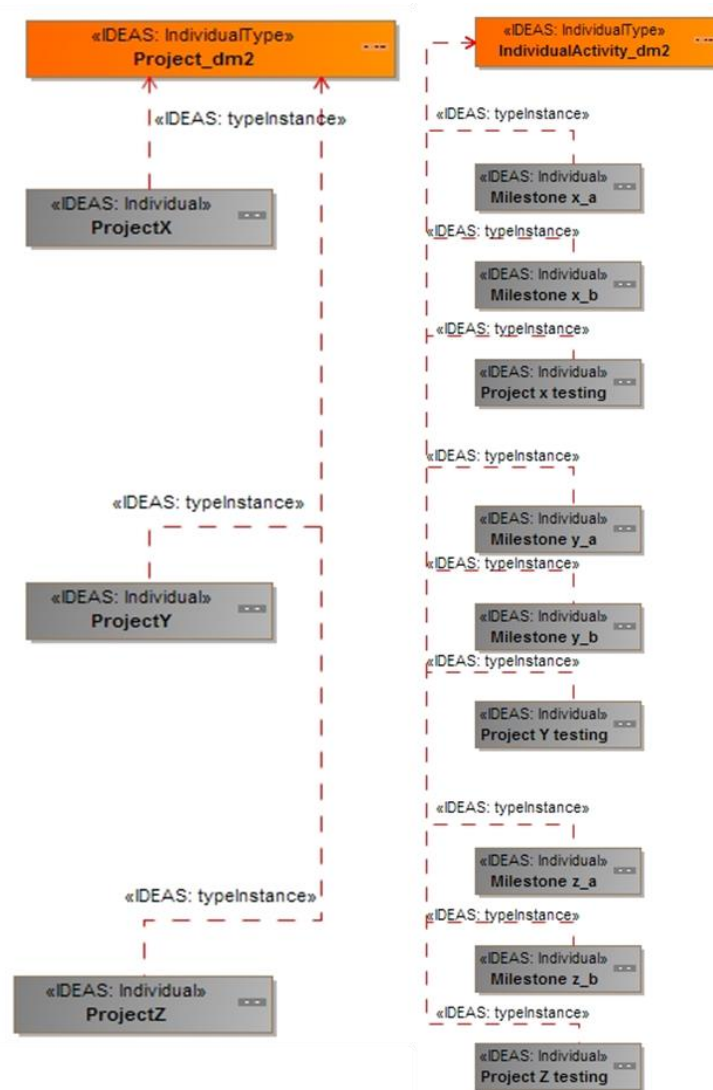


Figure 5: Projects and milestones



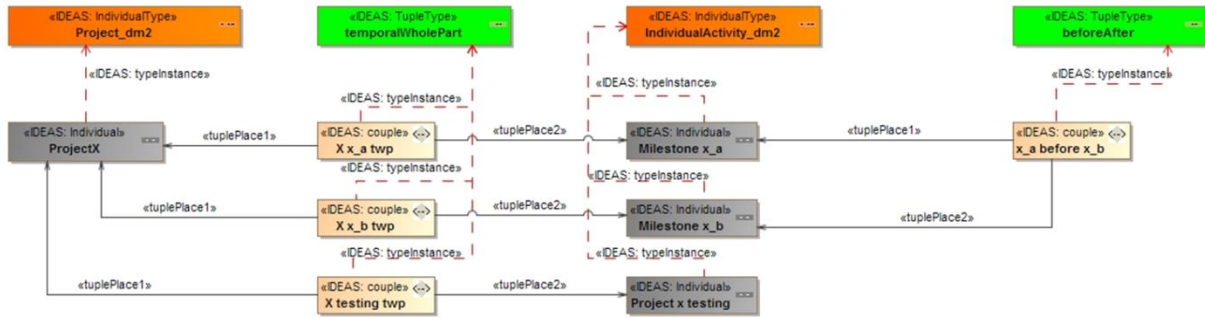


Figure 6: Temporal parts and beforeAfter

- The above shows project X with three different individual activities. Two of these are milestones and one is a testing activity.
- All three activities are temporal parts of the X project and before after is used to indicate that milestone a is before milestone b. Note that there is no indication of the time interval in between.

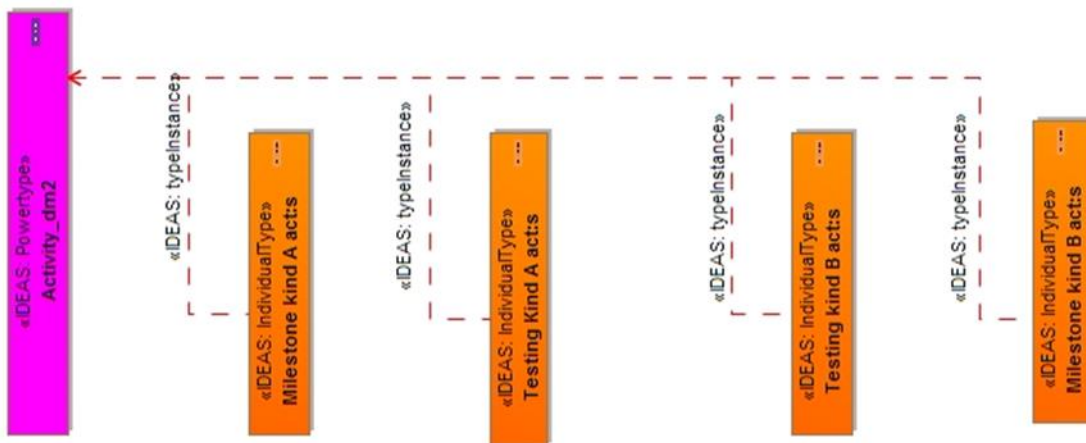


Figure 7: Activities

- Activity in DoDAF 2 is the set of all subsets of the set of all individual activities (it is a powertype) and therefore the four sets defined here are instances of the Activity\_dm2 set.
- Testing Kind A activities contain: Project x testing and Project y testing.
- Testing Kind B activities contain: Project z testing
- Milestone Kind A activities contain: Milestone x\_a, Milestone y\_a and Milestone z\_a
- Milestone Kind B activities contain: Milestone x\_b, Milestone y\_b and Milestone z\_b

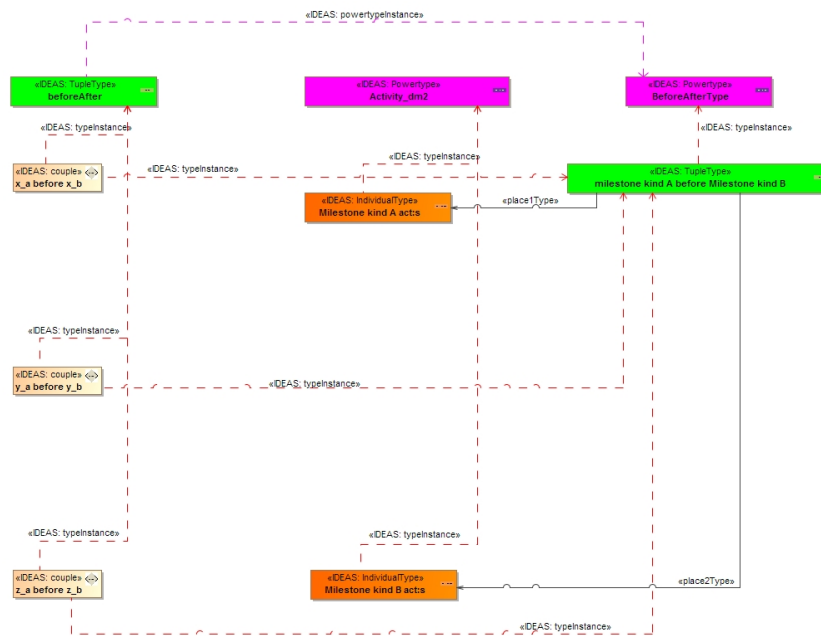


Figure 8: BeforeAfterType

- Since all instances within Milestone Kind A activities occur (i.e. end) before all instances within Milestone Kind B activities an instance of BeforeAfterType can be created in the form of the element *milestone Kind A before Milestone Kind B*.
- This element contains all of the before after relationships defined in the example.

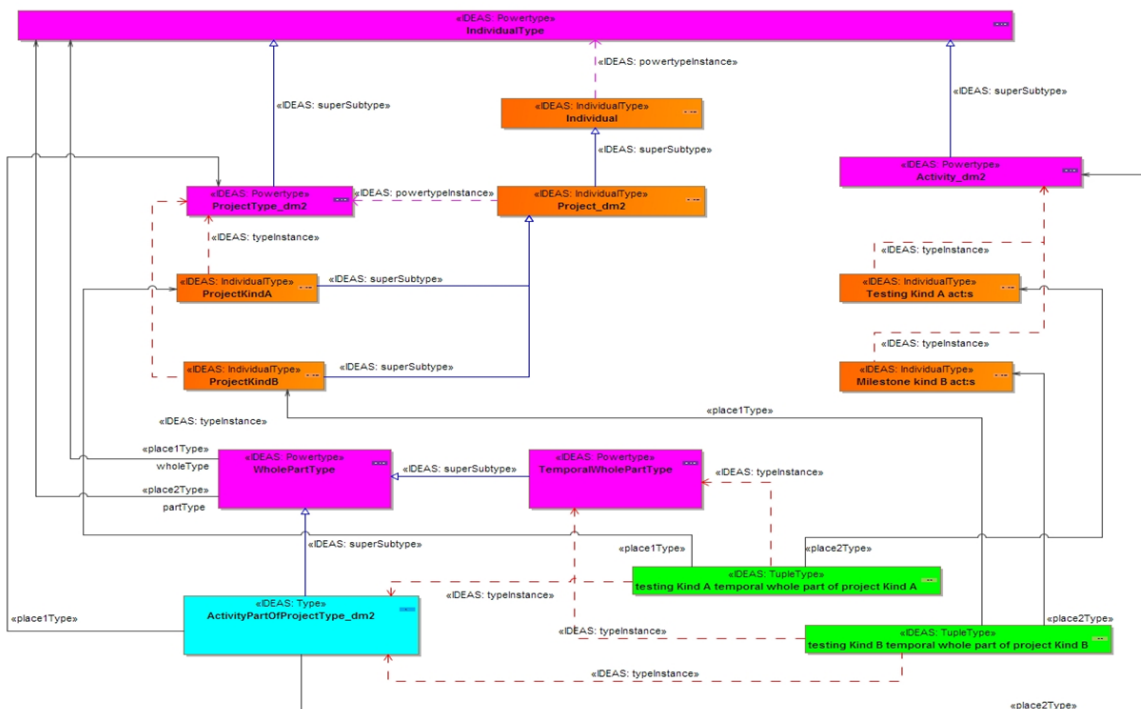


Figure 9: Temporal Whole Part Type

- As was shown previously, the testing activities can be combined into two distinct subsets that are instances of Activity (since it contains all possible subsets).
- This also means that instances of TemporalWholePartType can be created that contain the relationships that deal with temporal whole parts for testing Kind A and testing kind B.
- These in turn are instances of the DM2 element activityPartOfProjectType.

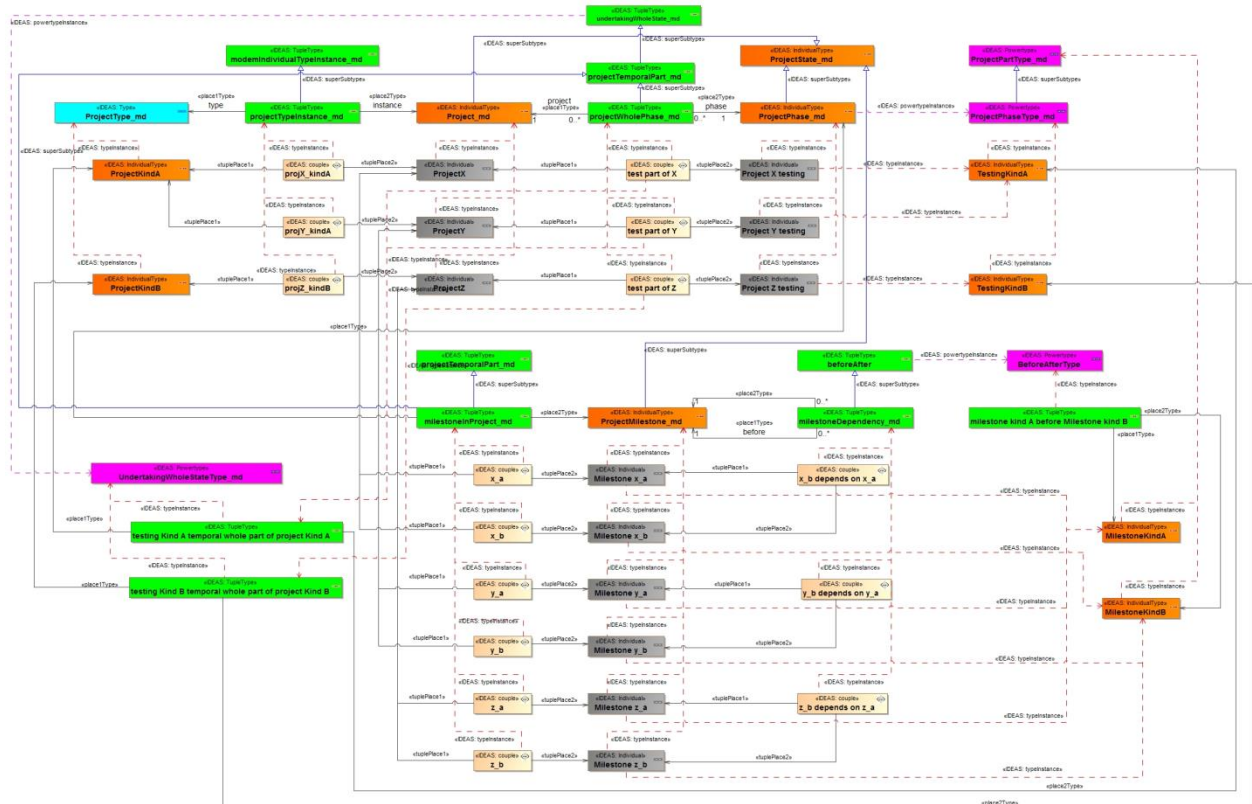


Figure 10: MODEM representation of the same data

As can be seen this differs somewhat from the representation using DM2, a detailed study will however reveal that the main difference is that DM2 makes use of IDEAS foundation elements directly to quite a large extent whereas MODEM does this much more sparingly if at all. There is considerable advantage in this since it implies that modeling is more constrained and regulated. In DM2 an attempt to constrain modelling is presented as a set of textual rules available in the DoDAF documentation. Allowing direct use of elements such as wholePart in DM2 makes it possible to consider a Country to be part of a Point. This kind of usage is constrained in DM2 by textual rules rather than by the model itself which is the case in MODEM.

### 3.0 THE UNIFIED PROFILE FOR DODAF AND MODAF (UPDM)

The Unified Profile for DoDAF and MODAF, (UPDM) initiative was started by members of INCOSE, the OMG, the US Department of Defense, and the British Ministry of Defence. UPDM provides a consistent, standardized means to describe DoDAF and MODAF architectures in SysML/UML-based tools as well as a standard for interchange. The concepts found in the Systems Modeling Language (SysML) such as parametrics, blocks, complex ports, enhanced activity modeling, and cross-cutting constructs improve the state of the art for systems engineers and architects. The formal meta-model basis of UPDM also provides a basis for trade-off analysis, model execution, requirements traceability, and the transition to systems

development and implementation. It is important to stress that UPDM is not a new architecture framework. Instead, it provides a consistent, standardized means to describe DoDAF, MODAF and NAF architectures in UML-based tools as well as a standard for interchange (Hause, M.C., 2009), (OMG, 2005), (OMG, 2010), (OMG, 2009), (OMG, 2012), (DoDAF/DM2, 2010).

## 2.1 UPDM examples

The following section contains several examples of the use of UPDM to express temporal aspects of architectures. The set of concepts listed in the introduction cannot all be described due to the limitations of space for this paper. It is also worth noting that that list is a short subset of all the concepts that are possible to express in UPDM. Consequently we will touch on a demonstrative subset.

**Project Sequences:** The PV-2 model shown in Figure 4 and 10 has been redrawn using UPDM in Figure 11. It still shows 3 projects each with a set of milestones as well as additional information regarding organization, fielded systems, milestone and project sequences. The same information is shown but in a different manner.

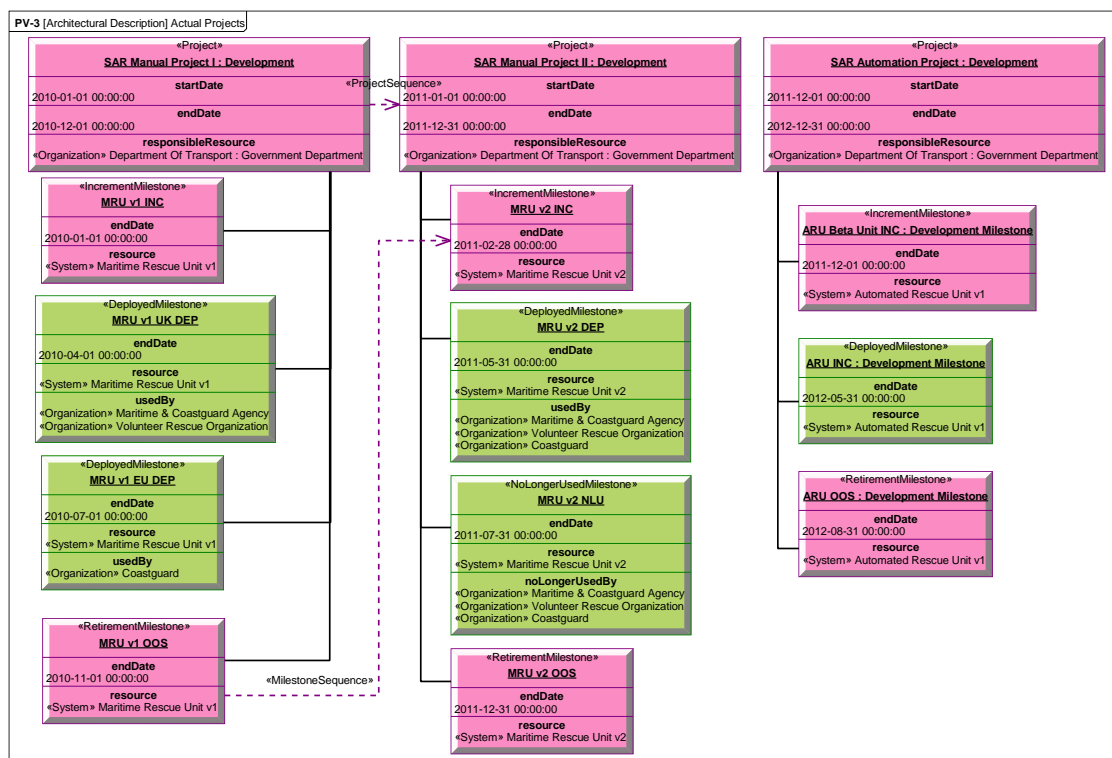


Figure 11: Project view in UPDM

**Systems Changing Over Time:** It is obvious that systems change over time for a variety of reasons. These include:

- System lifecycle of design, manufacture, deployment, maintenance, retirement
- Changes for mission-based configurations
- Changes due to maintenance

Taking the example of an aircraft, given all these changes is it the same aircraft because it has the same tail number, or is it a different aircraft and should we consider it so when creating an architecture? Figure 12 contains several SV-1 diagrams showing the evolution of an Intelligence Analysis (IA) system over time.

The acronym IMP refers to information (in any medium or form), material, or persons that can be collected and analyzed to produce intelligence. Starting from left to right, the initial IA system contains the IMP with Data Cleansing as well as a human Intelligence Analyst and Internal Comms System as well as interfaces between them. The central system groups the additional Data Fusion into an Intelligence Management system along with Data Cleansing. The final version adds Real-time Threat Analysis and an Intelligence Coordinator.

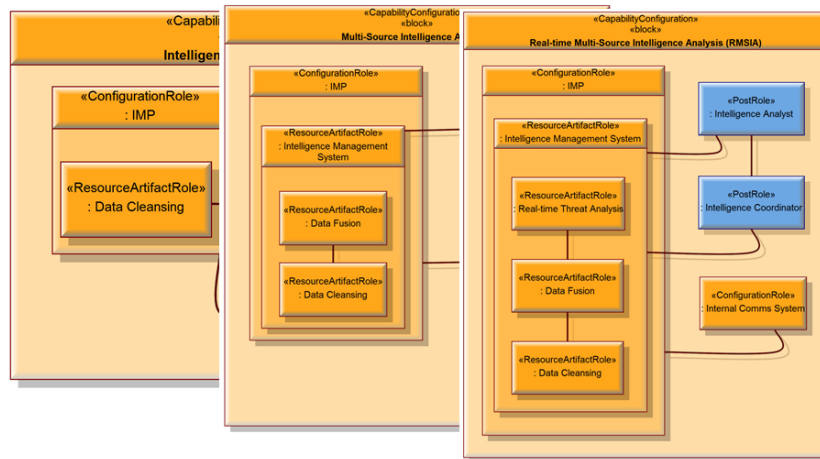


Figure 12: Intelligence analysis system configurations

**Scheduling System Deployment:** As mentioned earlier, the project view shown in Figure 6 also is used to show when systems are deployed over time. When linked to the capabilities, these can be used to show capability coverage as well as gaps using the CV-3 report. O’Shea et al (2012) expanded this view creating a Fit for Purpose view adding cost vs. budget, project dependencies, broken constraints, etc. as shown in Figure 13.

The work described in O’Shea (2012) applies a UPDM-based architecture development approach to capture capability development information with an emphasis on developing a fit-for-purpose visualization to support decision-making. This work includes the development of prototype visualization software to facilitate decision-support from architectural models. Users have the ability to shift projects on the timeline to determine the impact on overall budget as well as to ensure that costs for fiscal periods are not exceeded. Shifting the timeline will also affect equipment availability, thus impacting the ability to deliver essential capabilities. Without the use of this tool, the work would largely be done by hand or by using multiple disconnected data sources. Finally, the use of the UPDM repository will allow architects to further develop integrated architectures within the same repository rather than creating multiple disconnected models. Sections of the model can be extracted to form the basis of the development of architectures that support the required capabilities. This provides continuity throughout the development lifecycle.

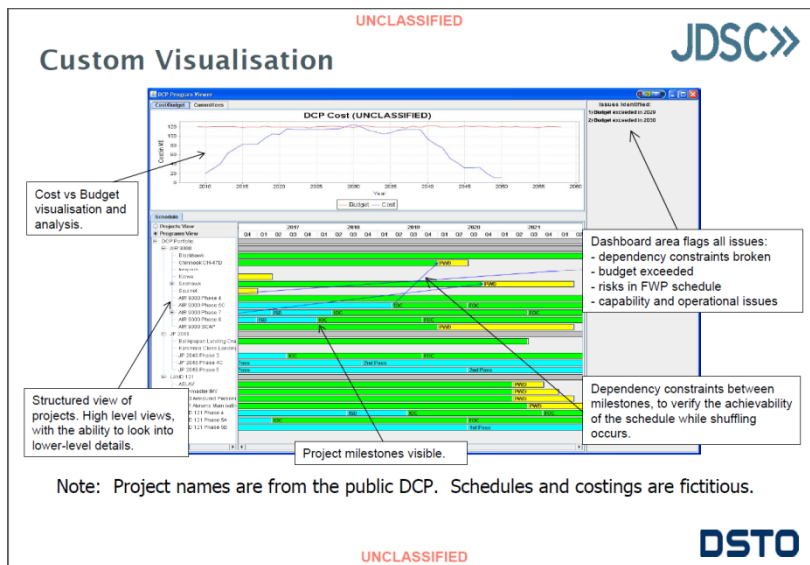


Figure 13: Project time vs. Cost vs. Capability

**Event and Interaction Sequences:** The OV-6c can be used to describe operational activity sequence and timing that traces the actions in a scenario or critical sequence of events. The SV-10c provides a time-ordered examination of the system data elements exchanged between participating systems (external and internal), system functions, or human roles as a result of a particular scenario. Each event-trace diagram should have an accompanying description that defines the particular scenario or situation. Each SV-10c in the Systems and Services View may reflect system-specific aspects or refinements of critical sequences of events described in the Operational View. An example SV-10c is shown in Figure 14.

The diagram is owned by the system context. The elements shown are parts of this system. The interactions (horizontal flows) are those already defined in the in the SV-1 and SV-2. Time progresses from the top to the bottom of the diagram. Additional timing information has been added such as transmission latency and processing duration. Timing constraints are shown as vertical arrows on the left of the diagram. Static analysis can be done by collating the timing information on these diagrams into spreadsheets for numerical analysis. This provides architects with the ability to evaluate the performance of potential variant architectures. As the interactions are limited to those available in the configuration, consistency is built into the model. Simulation of behavioral portions of the model can be used to verify timing and behavior of the model for trade-off analysis and requirements specification. Having run the simulation, the timing information can be displayed on the sequence diagram, allowing the architect to evaluate alternate solutions.

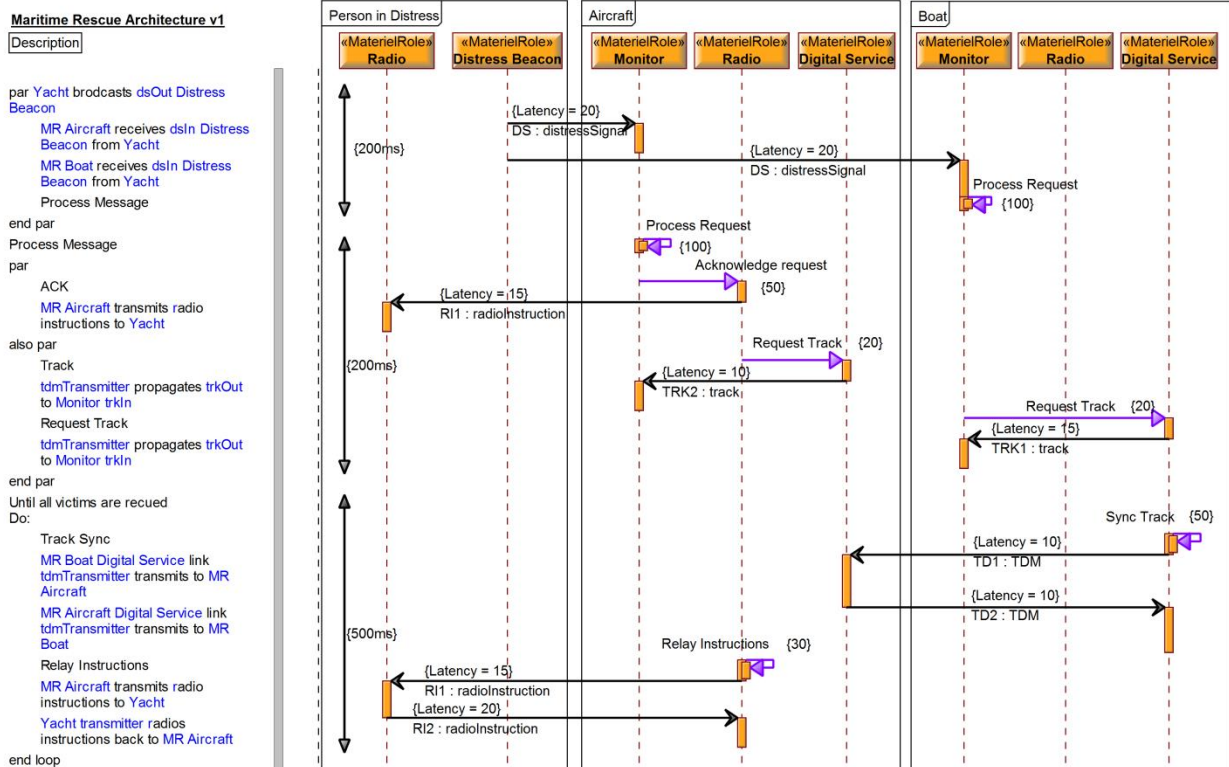


Figure 14: Event sequence diagram.

**State-Based Specification:** The SV-10b state diagram is a graphical method of describing a system (or system function) response to various events by changing its state. The diagram basically represents the sets of events to which the systems in the architecture will respond (by taking an action to move to a new state) as a function of its current state. Each transition specifies an event and an action. Guard conditions including timing information can be added to these transitions to specify time-based transitions. The before-after concept described earlier is the underlying mechanism for the transitions. This is called a directed relationship in that it shows the transition from one state to another as shown in Figure 15.

Another aspect of UPDM is the ability to show the interaction of more than just data. Energy, people, systems, organizations, etc. can be shown to be exchanged (or travel) between systems. This provides the ability to create architectures for logistics among other applications. The example shown in Figure 10 shows a simplified case management lifecycle for the delivery of a parcel. It shows the various states of the parcel, activities that can be performed on the parcel while in that state, valid transitions to other states, error conditions, and how the processing of the parcel changes in relation to its state. The SV-10b is normally used to show the state-based behaviour of a system.

The state machines shown above can be executed in UPDM tools. Timing constraints can be added to the transitions as well as embedded in the operations and activities of the state machine to demonstrate the behavior of the owning entity including time based behavior. By executing this state machine in conjunction with others in the model, the architect can perform behavioral and timing analysis of the architecture. This provides a means of performance based trade-off analysis.

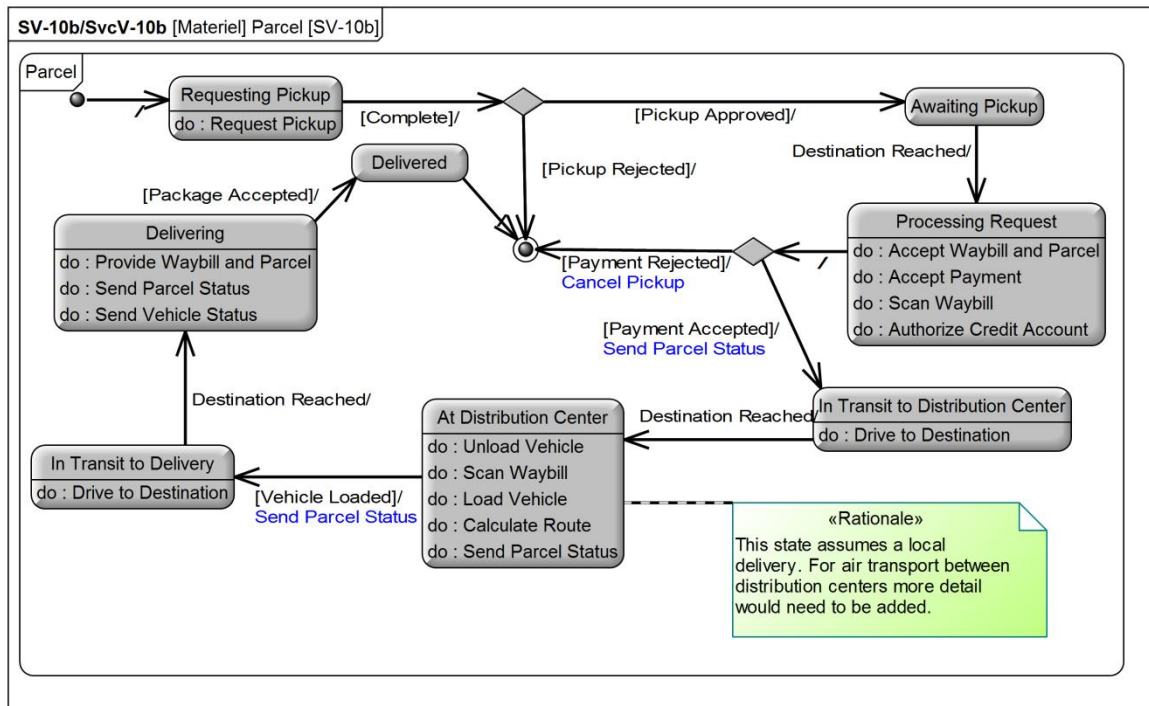


Figure 15: Case management lifecycle using a state transition diagram.

## 4.0 CONCLUSION

Military architecture frameworks are powerful tools for enabling architects to define, design, plan, and implement enterprise architectures. The latest versions of frameworks such as MODEM and DoDAF 2.0 are based on the ontological concepts in the IDEAS foundation objects. These concepts provide the detail necessary to express temporal concepts in precise and testable ways. Using tools implementing the UPDM standard, architects now have the tools to build the complex models needed to manage both government and industrial enterprises. UPDM tools provide the means to develop these architectures in a far more useable format. This paper has described examples of these concepts using UPDM. There are numerous other examples and it is hoped that these can be explored in future papers.

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## **6.0 BIOGRAPHY**

**Lars-Olof Kihlström** was tasked to aid the UK during the finalization work of the NATO architecture framework version 3 based on MODAF. Lars-Olof was asked to act as a modeling expert by the Swedish armed forces in the IDEAS group where the UK, USA, Canada and Australia is creating an ontology for architecture information that will enable the different architecture frameworks to exchange architecture information. He was also responsible for MODAF framework usage guidance description creation. Lars-Olof is a member of the architectural core of the UPDM 2.0 submission team responsible for development of the UPDM 2.0 submission. Presentations at the Enterprise Architecture conference in London concerning the use of SOA in NAF and the handling of the MODAF Learning Portal has also been held together with the Swedish Armed forces in 2008 and 2009. The Presentation concerning SOA has also been held at the DoD architecture conference in Orlando Florida. He has been project manager for the creation of MODEM where MODAF was re-engineered in order to base it completely on the IDEAS Foundation and remove its reliance on a UML profile. This work was conducted in a small expert team composed of Lars-Olof, Ian Bailey and Chris Partridge.

**Matthew Hause** is Atego's Chief Consulting Engineer, the co-chair of the UPDM group and a member of the OMG SysML specification team. He has been developing multi-national complex systems for almost 35 years. He started out working in the power systems industry and has been involved in military command and control systems, process control, communications, SCADA, distributed control, and many other areas of technical and real-time systems. His roles have varied from project manager to developer. His role at Atego includes mentoring, sales presentations, standards development and training courses. He has written a series of white papers on architectural modeling, project management, systems engineering, model-based engineering, human factors, safety critical systems development, virtual team management, systems development, and software development with UML, SysML and Architectural Frameworks such as DoDAF and MODAF. He has been a regular presenter at INCOSE, the IEEE, BCS, the IET, the OMG, DoD Enterprise Architecture and many other conferences.

**Prof Jon Holt** is an internationally-published and recognised expert in the field of system engineering. His main area of interest is the application of systems modelling to all aspects of system engineering. Jon's areas of expertise include: UML and SysML for system engineering, process modelling, standards compliance, requirements engineering, life cycle modelling, enterprise architectures, architectural frameworks and competency assessment. Jon is an international award-winning author and public speaker in the field of applied systems engineering and research. He has authored nine books on systems engineering. His books cover the application of UML and SysML to systems engineering, process modelling, enterprise architectures and competency assessment. Jon is active in the IET via their Professional Networks and the BCS as a member of the Learned Society. He is a Fellow of both the IET and the BCS and is a Chartered Engineer and Chartered IT Professional. Jon was the founder-director of Brass Bullet Ltd, a systems engineering consultancy and training company for over 12 years, until it was acquired in 2009. He is currently the Global Head of Systems Engineering for Atego, the leading independent provider of tools and capability for systems engineering. Jon is also a Professor of Systems Engineering at the UK Defence Academy, where he is involved with teaching and research.