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THE UK'S APPROACH TO VEHICLE SYSTEMS INTEGRATION AND MODEL BASED STANDARDISATION

Tony White
Ultra Electronics
Cheltenham
UK

Keith Smith
UK MOD
Bristol
UK

Chris Raistrick
Abstract Solutions
Guildford
UK

ABSTRACT

This paper reviews the UK Defence Standard 23-009 for Generic Vehicle Architecture (GVA), describes how the standard is being applied to the UK vehicle procurement programme, and the benefits expected from adopting the approach and standard. The expansion of the use of GVA to other countries will be discussed including the adoption of the fundamental approach by NATO/ 5 eyes countries

INTRODUCTION

Land platforms are typically in-service for many years and are subject to significant updates through life. Recent experience has highlighted the need to rapidly update platforms in response to new threats and scenarios. The traditional approach to platform design with standalone sub-systems results in costly and time-consuming upgrades and system integration. Bolt-on system approaches also proliferate the number of crew controls and displays along with duplication of infrastructure and services. This increases the size, weight, and power consumption of the mission system and components, makes it difficult to upgrade and update, and leads to a high cost of ownership through life.

Figure 1: Standalone Mission Sub-Systems

The GVA approach provides a standardized integration architecture with a standardized display and control point. It is based on established Systems Engineering principles to define a set of rules and constraints, based on open standards to realize cost effective integration (electronic, electrical and physical). GVA aims to constrain design solutions to the minimum

possible to realize the system integration and interworking goals. This allows system implementers maximum freedom to innovate.
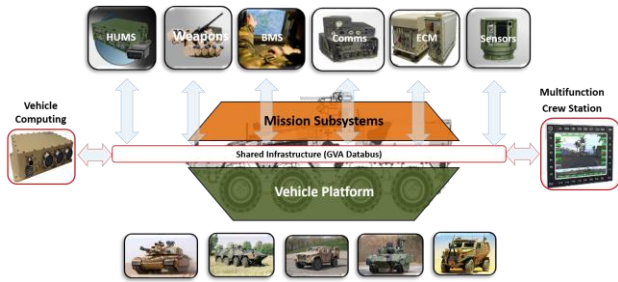

Figure 2: Integrated Mission Sub-Systems

In 2010, the UK MOD started application of the GVA Approach for all future land vehicle platform procurements, and current vehicle platform refurbishment and upgrade programs.

Land Open Systems (LOSA) Architecture

GVA is an integral part of the Land Open System Architecture (LOSA) which extended the GVA "Open Systems" principles to encompass soldier and base systems.
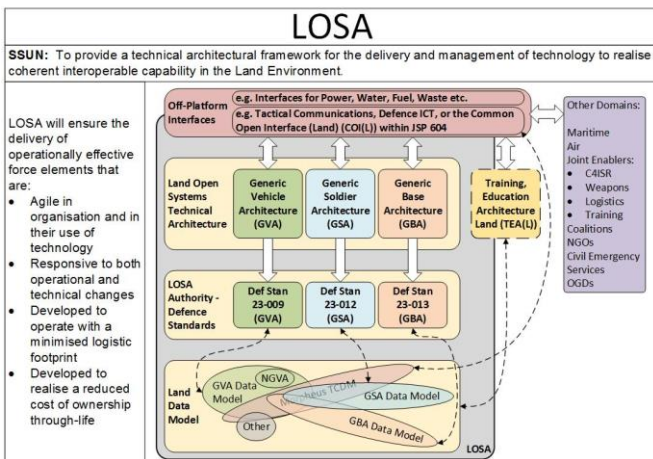
Figure 3: Land Open Systems Architecture

Each land platform type - vehicle, soldier or base - has an associated UK Defence Standard which outlines the approach, rules and technical standards to be applied. The standards referenced are either commercial standards or UK Defence standards such as the UK Defence Standard for Vetronics Infrastructure for Video over Ethernet (Defence Standard 00-082). Underpinning all three standards is the UK MOD standard for definition of the data interface requirements for logical functions and components called the Land Data Model (LDM). The LDM is fundamental to realization of system interoperability. It has been developed by the UK MOD but is freely available and released for re-use under the UK Open Government License.

LOSA aims to provide increased operational effectiveness, opportunities for technology insertion and an improved acquisition process, through influencing the three key areas of commercial, technical and operational flexibility.
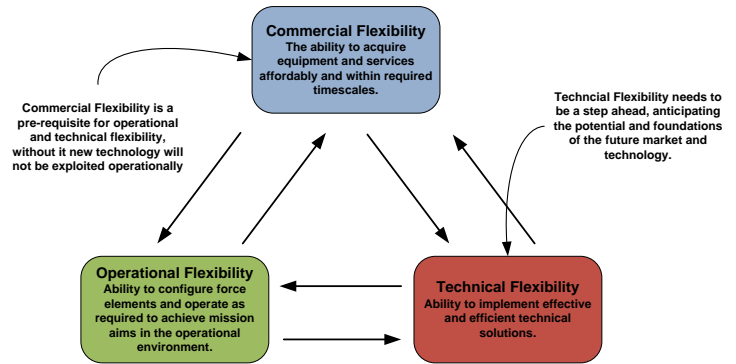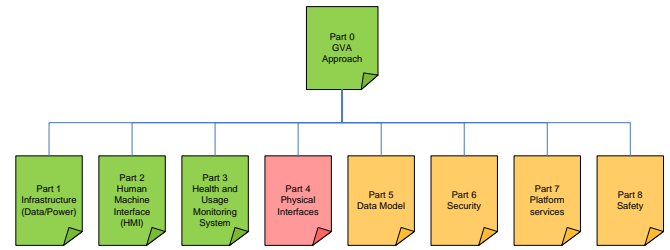

Figure 4: LOSA Key Areas

The primary objective is to improve operational effectiveness, but with changes to the commercial approach and the exploitation of new technologies, LOSA can also achieve a business benefit of reduced cost of acquisition and through life support.

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GVA Benefits

The benefits of applying an "Open Systems" approach as used by GVA are wide-ranging, but difficult to quantify and track. Figure ? shows a taxonomy of potential benefits at different levels of organization from the application of GVA. It results in a more integrated set of mission sub-systems using compliant electronic and power infrastructures.

As a result of GVA compliance, the brigade itself can become a more Interoperable Force Element, that is more able to work with others and share information that enables collaborative working, agile mission grouping, and effects synchronization.

Figure 5: Benefits Taxonomy

GVA Standard

Defence Standard 23-009 is the standard for GVA. It is published as a number of parts covering the areas to be standardized. The parts breakdown showing the coverage is shown in the figure below:

Figure 6: Defence Standard 23-009

The parts shown in green are issued and published and those in orange are still to be issued if required. The part in red was originally issued but has since been withdrawn. Work is ongoing to address requirements for security, particularly for the Electronic Architecture and there is research activity targeting the need for GVA safety requirements.

MOD GVA Application

The GVA approach has been applied since 2010 to UK MOD vehicle projects. The only one currently delivered and in service is the Foxhound protected mobility vehicle. Foxhound has been used on operations since 2011 in a number of locations. Other GVA-based vehicle projects are still in various stages of development and manufacture. These include Ajax, Warrior Capability Sustainment Programme (CSP), Challenger 2 Life Extension Project (CR2-LEP), Mechanised Infantry Vehicle (MIV), Multi-Role Vehicle-Protected (MRV-P), and the Future All Terrain Vehicle (F-ATV).

GVA International Expansion

Although the GVA approach originated in the UK the UK military market alone was insufficient for Industry to change their internal design approaches and products. To become successful GVA would have to become adopted by a much wider community. The UK had strong vehicle System Integration research programme and links with German vetronics research via a bi-lateral agreement. There was also close co-operation on

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vetronics standards via the Military Vetronics Association (MILVA) which has a Government and Industry membership. MILVA had been charged by NATO Land Capability Group – Land Engagement to develop a number of NATO Standards. MILVA made representations to LCG-LE to develop a NATO STANAG based on GVA. This was approved and NATO STANAG 4754 started to be developed in 2011.

After a number of years of work the majority of European governments and industry aligned behind a common approach resulting in the promulgation of STANAG 4754 in April 2018

Industry Perspective

UK MOD and industry have been working together to create GVA. This has resulted in an expert team of vehicle integrators and equipment manufactures coming together with the UK MOD technical teams to create a standard that everyone buys into.

Scale and Scope

GVA covers the Power, Data and Video architectures for fighting vehicles, defining the physical connectivity and data formats necessary for systems integration. Another huge benefit of GVA is that it defines the layout and location of key GVA functions that will be realized on a multi-function display.

Industry viewpoint

There are now several layers within the "GVA industry". The Platform prime has responsibility for delivering a GVA enabled vehicle but may not have the GVA know-how. This has created a market place for GVA integrators, who know about things like middleware. Finally the equipment or box manufactures find themselves producing equipment with GVA interfaces and so on. The benefits of the physical aspects of GVA

are well understood (the adoption of common connectors etc). Many equipment vendors now produce "GVA ready" hardware.

The challenge of producing a set of 'code' that complies with the LDM is made easy by the translation tools that UK MOD have made freely available.

Compliance

The GVA standard could be viewed as a set of design constraints that guides a platform integrator towards implementing an open architecture for power, data and video. As such, the standard has been written in carefully couched language, with uniquely identified requirements, tagged with a priority, a measure of performance, a justification of why the requirement exists and how to verify the requirement has been met.

It is expected that a program office could adjust/tailor the application of the GVA standard (for example, by only adopting the mandatory requirements) if necessary.

Victory/GVA contrast

Whilst on the face of it Victory and GVA have similar goals, there are some fundamental differences in the approach taken by both standards. Victory's published intent is to provide an architecture to support C4ISR/EW systems, whilst GVA has a wider remit across the whole of the platform. One of GVA's attributes is the common HMI. The benefit of this should not be underestimated in terms of providing a reduction in operational burden and a cross platform reduction in training.

The standards themselves are based upon worldwide open standards, making use of technologies such as Ethernet and TCP/IP. However, access to the Victory documentation itself is limited to US citizens working on US programs. This contrasts with GVA, which is freely available from the UK MOD standards website.

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In technical terms, Victory has a service-based network (referred to as the Victory Data Bus or VDB) whilst GVA uses a near real time Publish/Subscribe mechanism called Data Distribution Service (or DDS). Both have their merits but are different in terms of their implementation and would need a dedicated gateway to exchange information.

Model Driven Standardization – Land Data Model (LDM)

History

To achieve interoperable systems and components it is necessary to define the messaging between system components in a standardized way. In a GVA based system these standardized messages are transported across an open standardized infrastructure using a publish and subscribe messaging middleware conforming to the Data Distribution Service (DDS) Standard [1]. Around 2006, the UK MoD created a set of GVA DDS message models along with a translator to automatically convert the model into IDL for use with DDS. This was the early GVA Data Model Standard. The early models were created specific to DDS technology, their scope was limited, and the models immature. However, they were specified for implementation on the UK Ajax and Foxhound vehicle projects both of which operate with a DDS based electronic infrastructure.

Around 2012 it was agreed to transition the models from being vehicle and technology (DDS) specific and take a more abstract and technology agnostic approach to the modelling approach. Raising the level of abstraction of the models would mean a simpler set of models to maintain, models that were then not locked to a messaging technology solution, or to a particular application e.g. military vehicles.

Many of the of models would grow to become enduring, generic, and reusable across many different types of system promoting interoperability. This was really the birth point of the Land Data Model (LDM) concept as it is now.

The Land Data Model (LDM) is now a suite of tools and collection of models from which multiple standard reference models (e.g. The GVA Data Model) can be created. We no longer rely on industry to create new proprietary data models for each project. We can now contract for a solution that conforms to the LDM, which defines data exchanges required for certain capabilities, behavioral interactions across a system and common services essential for interoperability.

Why Model Driven Standardization?

Using text documents to describe complex requirements and behaviour is fraught with risk of misinterpretation and misunderstanding, and the process of deriving lower level specifications from higher level textual specifications often leads to designing systems that do not perform as expected or originally intended. Errors are frequently only spotted way downstream in the development process and the cost to rectify and get the system to perform as required increases significantly.

There are real issues with using narrative text documents alone to specify requirements, they are:

- **monolithic**, and do not lend themselves to describing system concurrency (e.g. multiple operators, multiple resources);
- often **ambiguous** in a non-obvious way;
- often **inconsistent**, and not amenable to consistency checking;
- often **incomplete**, but hard to check for completeness;
- necessarily expressed at a **single level of detail**, and oriented to specific set of stakeholders;
- **hard to query** to extract information pertaining to relevant viewpoints (e.g. data view, function view, message view);

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- not amenable to **being transformed** automatically to into compliant deployment artefacts.

By contrast, a model provides a modular, coherent and precise means to organise and define a set of requirements. The model itself is typically expressed using an industry standard notation, such as the Unified Modelling Language (UML), that has well-defined semantics. Such models lend themselves to:

- **Precise and unambiguous** specification of rules and policies;
- Automated **consistency checking;**
- Exposing areas where the model **is incomplete**
- Automated **generation of standards documents,** each containing information relevant to specific set of stakeholders (customer, user, tester, platform integrator etc.);
- Automated **generation of standardized deployment artefacts**.

Model elements can, of course, be incorporated into classic defence standard (Def Stan) documents to improve rigour and clarity and reduce the risk of inconsistent realisation of the standard by different stakeholders.

Benefits of Model Driven Standardization – General

Specification of standards using the LDM approach yields a number of benefits, as outlined in the following subsections.

Longevity Through Platform Independence

The modules comprising the LDM are "Platform Independent Models" (PIMs). This means they fully describe the rules and policies to be standardized for that aspect of the system without prejudice to the technologies on which they will ultimately be deployed. This enables creation of

models with a longevity appropriate to the extended lifetimes, typically many decades, of the military systems derived from the models.

This contrasts with Platform Specific Models (PSMs), like the original GVA Data Models, that embed aspects of existing deployment technologies, such as the Data Distribution Service (DDS), and exhibit many undesirable characteristics, including:

- **Unnecessary complexity,** as they embed rules and policies pertaining to DDS as well as those pertaining to the system aspect under consideration**;**
- **Low portability,** as they embed assumptions about specific technologies that may be invalid when using other technologies. For example, DDS is based upon publish-subscribe message distribution, so models built for deployment on DDS are unlikely to be viable for technologies based upon event-response or database type transactions.

Portability through Model Translation

Any standardized rules and policies pertaining to the deployment technologies are captured separately and realized in model translators that guarantee compliance with those technology standards. This means that:

- The application models can evolve independently of technological considerations;
- Technology changes can be achieved, without affecting any application models, by development of new technology-specific model translators.

The PIMs can therefore be ported onto any technology platform, current or future, using appropriate model translators.

Compatible with Model Driven Development

Use of standardized models rather than documents enables standards, rules and policies (specifications and requirements) to be expressed in a machine readable unambiguous form that can form the basis of a Model Driven Development environment, and the models are:

- **Accessible** by multiple stakeholders**;**
- **Extendable** as requirements evolve and new capabilities and equipment types need to be integrated;
- **Reusable** on multiple technology platforms**;**
- **Rigorous** and unambiguous**;**
- **Consistent** across the entire architecture.

Model-based standardization enables the development of tools that help to automate and optimize the process of defining, building, reviewing and testing artefacts that are compliant with the standard.

The MoD can retain ownership of the translator tools, that convert its requirements into implementable code, preserving its capital investment, and provide them as government furnished software to all stakeholders wishing to adopt the standard. This reduces procurement cost by eliminating the need to develop such tools for each new contract; the GVA Model Translators fall into this category.

Benefits of Model Driven Standardization – MoD Specific

In addition to the general benefits of model driven standardization outlined above, there are some MoD-specific benefits:

- Models such as the LDM **formalize the intellectual property for capability and system interoperability** in a standardized, reusable form suitable for use on current and future capabilities. They are platform independent, and can be deployed on a wide variety of military platforms, including maritime and airborne platforms where appropriate;
- Models **promote use of open standards** over vendor-owned and specific implementations;
- Models provide a **rigorous approach to defining contract requirements** for standardization during procurement;
- Models such as the LDM place **ownership and control** of critical land equipment data and messaging requirements in the hands of the MoD;
- Use of MoD owned, open models based on industry standards **facilitate wider competition** for platform and equipment upgrades;
- Models such as the LDM establish a **reusable blueprint for system integrators**;
- Models such as the LDM hold artefacts that define all system data exchanges required to **integrate systems of all types** used in the land environment and potentially beyond;
- The LDM and associated model translators are highly reusable, long-life assets that can be provided to contractors as government furnished information and software. This means that the cost of developing the models and translators is incurred once only, which helps to **reduce cost of acquisition** for all systems in which they are specified.

OMG Model Driven Architecture (MDA) Approach – Land Data Model

The LDM approach captures the complex requirement into a formalized model and from that

model, deployment artefacts can be automatically generated with some associated LDM translator tools. In the case of GVA the LDM has a translator that takes the UML model and automatically creates IDL for use in a GVA based DDS publish and subscribe deployment.

The LDM toolset uses the principles of the Object Management Group (OMG). Model Driven Architecture Standard (MDA). MDA is an approach to software design, development and implementation. MDA provides guidelines for structuring software specifications that are expressed as models.

The UK has adopted MDA for the LDM. We have developed a specific methodology [3] for creation of models that populate the LDM, and a suite of translators that can transform the models into the Interface Definition Language code needed for use in a DDS development environment.

System implementations that are based on the standardized IDL from the LDM will by design be natively highly interoperable.

The MDA part of the GVA process involves the creation of Platform Independent Models (which are stored in the LDM repository), an automated translation from PIM to Platform Specific Model (PSM), which in turn is translated into an Interface Definition Language (IDL) representation of the PSM.
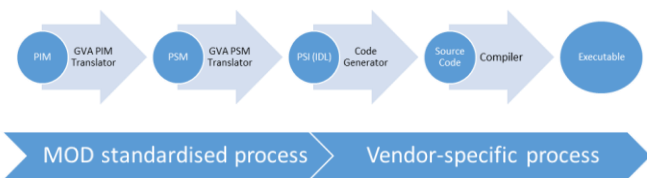

Figure 7 – LDM MDA Process

The process and methodology used conforms to the MDA industry standard as mentioned earlier.

The LDM components are themselves represented using mainstream industry standards. The standards used for the LDM are summarized in Fig ? and include:

- **UML (Unified Modelling Language)**, the industry standard notation for system and software models. Flexibility is provided through stereotypes and tags, which allow it to be tailored for use in specialised areas such as standardisation.
- **IDL (Interface Definition Language)**, a software language used to define interfaces in a language and machine independent way, allowing the specification of interfaces between components written in different languages, and possibly executing on different machines.
- **XML (Extensible Markup Language),** a markup language from the World Wide Web Consortium (W3C), that defines a set of rules for encoding documents in a format that is both human and machine readable.
- **XSD (XML Schema Definition),** from the World Wide Web Consortium (W3C), specifies how to formally describe the elements in an Extensible Markup Language (XML) document.
- **DDS (Data Distribution Service)** for real-time systems is an Object Management Group (OMG) machine-to-machine (sometimes called middleware) standard that aims to enable scalable, real-time, dependable, high-performance and interoperable data exchanges using a publish–subscribe pattern.

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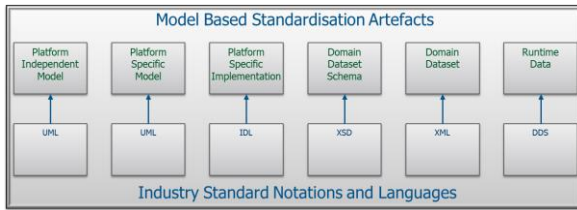
Figure 8 – Industry Standards Used in the LDM

What is Standardized in the LDM?

The move to using models to describe the requirements is a fundamental shift from a document centric approach. The intent is to define and specify adherence to a model in the contract rather than a document against which we can assess and accept a delivered system or component. The LDM uses a subset of UML and currently standardizes:

1. The **data items** to be provided (modelled as UML classes)
2. The **set of values and units** to be used for each data item (modelled as data types)
3. The **messages** to be supported (modelled as operations in a UML class)
4. The **modes** to be supported (modelled as UML state diagrams)
5. The set of **standard services** required by any LDM compliant deployment (modelled as mandatory service domains that embed standardised data and operations)
6. The **message protocols** to be supported by standard services (modelled as state machines and sequence diagrams)
7. The **configuration data** values to be used when realising data driven domains.

LDM Standardization Artefacts

The primary artefacts of MDA used for LDM standardization, illustrated in Figure . In summary, they are:

- **Use Case Models** to specify actors and use cases, and the dependencies between them. These represent the standardised set of capabilities that support human roles, equipment types and external systems;
- **A Domain Model** (represented as a UML package diagram) for the overall architecture, showing the domains and their dependencies. Each domain represents a subject matter, or system aspect, for which standardised rules and policies are defined;
- **Interaction Models** (represented as UML sequence diagrams) to show LDM components and their message level interactions. These show the standardised message protocols to be used by all system components to enable reliable interoperability;
- **Class Models**, one per domain to show the classes, attributes and associations in each domain. These specify the standardised data items to be provided by, and used by any system components using data pertaining to each domain;
- **State Models** to show the states and transitions for relevant classes. These specify a standardised set of modes for equipment items and services and show when certain mode-dependent messages are valid.
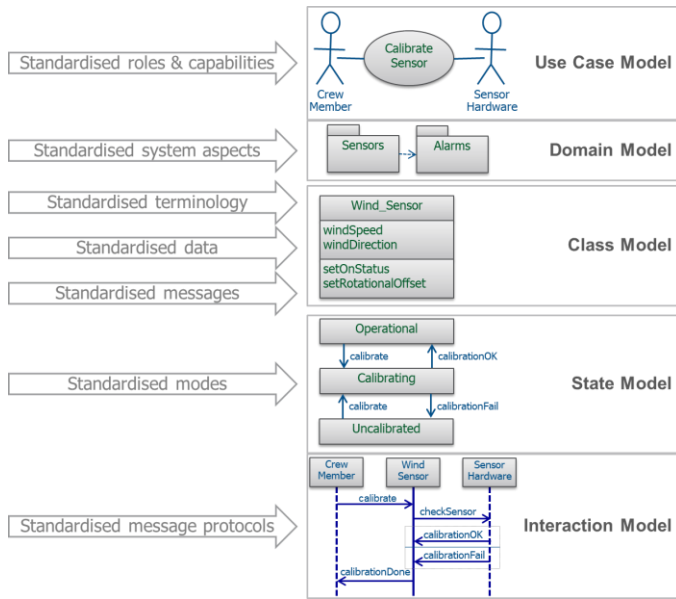
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Figure 9 – LDM Standardisation Components

LDM Reference Model Build Sets

The separate LDM domains must operate together as pairs or groupings to deliver whole system functions. For example, data exchanges associated with alarms linked to a laser warning might involve the Alarms, Laser Warning, Navigation Reference, and Mount domains. When combined, domain groupings form interconnected model hierarchies. A prescribed set of interconnected models is termed a Reference Model Build Set (RMBS). For instance, the GVA Data Model is a RMBS of models relevant to vehicle applications.

The RMBS provides the set of module versions to be used as the basis for development of an LDM compliant system. For each deployed system, the developers will create a Deployed System Build Set (DSBS) based upon the specified RMBS. The DSBS may incorporate additional modules, representing capabilities of the deployed system that extend beyond those standardized in the LDM.

Use of model-based standards enables the adoption, voluntary or mandated, of a standardized model-based deployment process based around the standards models. Although the LDM includes only small amounts of behavior definition (enough to enable interoperability), it is possible to take the LDM and extend it to include behavior for developing a compliant system. This enables easier compliance checking and can reduce the cost and time required to realize a compliant system. Figure ? shows an example process based upon taking the LDM as the core system architecture and extending it with additional data and behavior to specify a complete system.
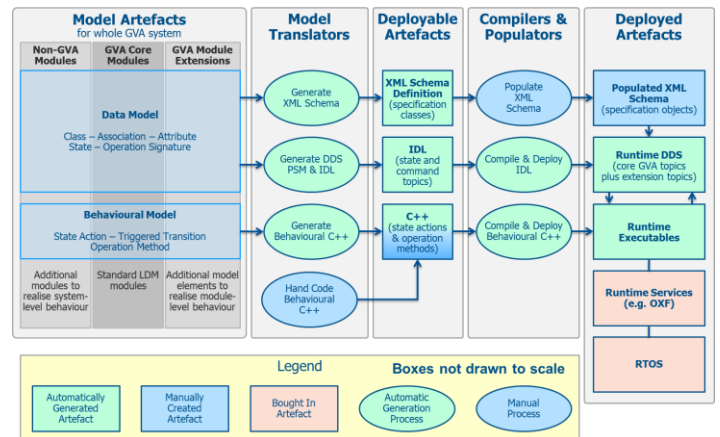

Figure 10 – Example LDM Development and Deployment Process

LDM Environment

The LDM and all its artefacts are accessible worldwide through internet access at landopensystems.mod.uk. Registration is required but access is not usually limited.

For management of the LDM models, all Reference Model Build Sets, and other artefacts there is an Apache Subversion repository and linked access to a change control tool called Trac.

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Changes to the models and other artefacts in the Subversion repository are strictly controlled. But all artefacts are available for checkout and reuse including model translators. The models themselves are all held as IBM Rational Rhapsody models in the repository and can be accessed remotely with a Subversion client.

Within the LDM environment, the Alfresco platform is used for document storage, collaboration and communication. It provides access to key information and documents and is partitioned into several "sites" for different business areas. For instance, there is a site for GVA, LDM, Generic Base Architecture etc. These sites can be access controlled to subsets of the whole registered community.

This paper has just scratched the surface of the LDM and its application within GVA. In the Alfresco platform you can find documents that will provide a more full and detailed description of the LDM modelling approach. Perhaps the key document is the LDM Methodology Description Document which covers all the modelling rules and policies needed to create LDM compliant models and explains why the models are constructed in the way they are.

The document can be found on the Alfresco platform [3]

Broader than vehicle use

The Land Data Model, as the name suggests has application beyond the Generic Vehicle Architecture, and is being extended to accommodate the requirements for soldier systems (defined in Generic Soldier Architecture standard) and Bases (defined in Generic Base Architecture standard).

In addition. the UK MOD team responsible for Morpheus, the new military communications system, are also looking to exploit the LDM where appropriate.

Conclusions

GVA has been widely adopted globally, both by NATO and some Five Eyes countries. Key to the success of GVA is the creation of the Land Data Model, which forms the blueprint for platform interoperability.

Adopting a model-based approach has seen benefits for all stakeholders, both in industry and the MOD.

The true value of such an approach will truly be realized in future upgrades and technology insertions, where model-based development will serve to reduce integration time and cost, bringing solutions to the war fighter when they needed.

REFERENCES

[1]Data Distribution Standard, http://portals.omg.org/dds/

[2]Model Driven Architecture Standard, https://www.omg.org/mda/

[3].Alfresco - Land Open Systems site

https://landopensystems.mod.uk/share/page/site/land-data-model/document-details?nodeRef=workspace://SpacesStore/05c049a6-13bc-4be9-b671-8d42f38bb5a4