REQUIREMENTS AND LIFE CYCLE MANAGEMENT FOR AN INTEGRATED PLATFORM MANAGEMENT SYSTEM

BY

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ABSTRACT

To address risks associated with procurement of effective Integrated Platform Management Systems the MoD, in conjunction with industry, has developed a number of processes to capture a complete and coherent set of functional requirements, and feed this information forward into the acquisition process to improve the chances of success. This article seeks to summarize and advocate these processes.

Introduction

Future platform procurement Integrated Project Teams (IPTs) are facing increasingly non-trivial challenges in attempting to satisfy the diverse requirements placed on them. User Requirements Documents (URDs) are influenced by a range of factors including:

- Environmental legislation.
- Maritime Platform Characteristics (MPC).
- Owners' requirements.
- Recoverability criteria.
- Safety legislation.
- The prevailing economic climate.

Increasingly IPTs are seeking to adopt solutions which make use of Commercial Off The Shelf (COTS) Programmable Electronic Systems (PES), or systems of systems.

Currently this tends to lead to the adoption of a number of independent PES, providing management systems for particular aspects of the platform functionality, with little consideration of user needs or interoperability. These can include:

- An integrated Bridge, communications/information management system.
- Waste management system.
- Combat management system.
- Power management system
- A Platform Management System (PMS).

Te latter system is often considered to be an enhanced Machinery Control And Surveillance System (MCAS) with added Damage Surveillance And Control (DSAC) functionality.

Inherent in this approach is the possibility that system integration is likely to be complex, and, that capability shortfalls may exist. These remain difficult to identify and quantify until build or acceptance. To address these factors the concept of an Integrated Platform Management System (IPMS) was derived, a system to:

- Act as an integrator between automated systems and users.
- To provide appropriate functionality and enable optimum use of the automated systems beneath it to maximize platform capability and chance of successful mission completion.

Central to this approach was recognition that platform management is a function, which has caused some confusion with the view of PMS described above. As such an IPMS has been, and continues to be, seen as a significant risk to platform programmes by IPTs and Prime Contractors alike.

Analysis of the risk associated with an IPMS identified the prevailing view that technological risk was not the main problem, rather it was one of management of the acquisition process to procure an IPMS fit for purpose [1]. Because of this a study team was formed, comprised of members from MoD and industry. The study was to develop and advocate a process for the lifecycle management of an IPMS, aligned with the MoD Acquisition Management System (AMS). This article will outline the process developed, and identify the key areas for future work to mitigate further the risk associated with developing an IPMS.

The body of work supporting this process development is beyond the scope of this article, but a useful overview of the principles advocated can be gained from a summary of the work in key areas, including:

- Functional definition.
- Requirements capture and generation.
- Risk management
- Integration and acceptance.

More information is available from our website.[2]

Functional Definition

The fundamental tenet of this work has been the need to define a complete, correct and unambiguous set of functional and non-functional requirements for the management, monitoring and control of the platform. This work has the specific focus of defining the scope of an IPMS, and not that of any another system e.g. a CMS. To avoid implying a certain IPMS implementation, the scope of an IPMS has not been closely bounded in this work. Because of this it is recognized that some functional activities identified may be embodied by systems other than an IPMS.

Functional Modelling

Functional modelling was used as a tool to identify the potential functionality of an IPMS, the objective being a complete and consistent list of all potential functionality. This was achieved by developing Unified Modelling Language (UML) Class diagrams.

This work produced a generic Functional Activity Matrix. At the highest level the functional activities of an IPMS are described as:

- Sense.
- Manage.
- Effect.

These high level activities were then decomposed to lower levels; the next lower level of the matrix defines an IPMS functional area or domain, which refers to a high level task in a domain area, e.g. 'Sense Platform internal environment.'[3]

Further decomposition of the matrix to lower levels provides increasingly refined and less abstract expressions of the activity, e.g. using the domain defined above a lower level activity would be 'Sense internal temperature'. Domain areas should be decomposed to the lowest level, which remains solution independent. However, this is a subjective decision. The ultimate value of the decomposition process is the relevance of the associated requirements. The current set of generic requirements has been produced to a level judged by the team to be solution independent, and hence remain applicable to the widest range of platforms. This is a complex process, which naturally produces extremely large data sets. To date these have been recorded using multiple spreadsheets, making it impractical to demonstrate them within this article.

Operational Modelling

The Strategic Defence Review (SDR)[4] identified the requirement to generate coherent Joint forces under unified Command, capable of achieving the UK Government's strategic objectives for military capability:

> "... to deliver appropriately motivated, manned, trained and equipped force packages, at the required level of readiness, and with the necessary support, sustainability and deployability, to achieve the full range of agreed military tasks."

British Maritime Doctrine[5] is concerned with the application of Maritime Power consistent with SDR, and defines the Operational Tasks/Roles (OT/R) of maritime force components.

Mapping Operational Tasks/ Roles to Functional Activity (FA)

Mapping the OT/R against the FA matrix and applying a weighting factor allows an assessment of the criticality of a given function against the operational task. This criticality assessment will guide the process of tailoring the generic requirements set to bound the scope of a platform specific IPMS solution.[6]

An important lesson learned during this process was that this approach could also be used retrospectively to evaluate legacy equipment, identifying current capability gaps or guiding a capability update process.

Requirements Generation

Defining the functionality of the system is only part of the process. From the derived functionality definition it is necessary to generate a set of requirements. This is a 2 stage process:

1. Generation of functional requirements from the functionality statements.
2. Attaching non-functional (performance) attributes to these requirements.[7]

For the output of this process to produce requirements statements a generic syntax and semantic were defined, along with the method of applying these to the functional requirements and attributes. This syntax was comprised of 5 elements:

(*a*) Subject.
The entity which fulfils the requirement.

(*b*) Contract.
How tightly the subject is bound to the requirement.

(*c*) Function.
The functional activity associated with the requirement.

(*d*) Target.
The operational context.

(e) Measurement.
Measure of the non-functional attribute.

Functional Requirements

The derivation of the functional requirements from the functional activity hierarchy is a relatively simple task. The syntax defined above is simply applied to the definitions of functional activity.[8]

Taking the example used above, the functional activity of Sense Platform Internal Temperature becomes the requirement statement: the system [subject] shall [contract] Sense Platform Internal Temperature [function]. This is illustrated further at (FIG.1).

		SUBJECT	THE SYSTEM
		CONTRACT	SHALL BE ABLE TO
FUNCTIONAL ACTIVITY	⟷	**FUNCTION**	SENSE
OPERATIONAL TASK	⟷	**TARGET**	INTERNAL TEMPERATURE
NON-FUNCTIONAL ATTRIBUTE	⟷	**MEASUREMENT**	CONTINUOUSLY

FIG.1 – FUNCTIONAL REQUIREMENT SYNTAX AND SEMANTIC

Non-functional Attributes

The identification of non-functional attributes is much more difficult. It is envisaged that the requirements derivation process will involve significant and continual input from the end-user, or Customer 2. In defining the non-functional attributes the input of a domain expert is vital.

There are many types of non-functional attribute, and they must all be considered for relevance against each of the functional requirements, and ultimately a value (or a range of values) included as an acceptance criterion.[9]

Research into previous requirements documentation identified a very large list of potential non-functional attributes. It was possible to categorize these into a smaller list of types:

Performance:

Timeliness, capacity, accuracy, concurrency, reliability, latency.

Engineering:

Sstandards, integration.

Global:

Upgradeability, survivability, induced environments, size, units, weight, human factors, tactical adaptability.

Commercial:

Cost.

All non-functional attributes must be measurable, and care must be taken to ensure that this is the case. Experience during generating the generic requirements set has shown that an attribute, which at first seems to be measurable, on further analysis may prove problematic or impossible to measure. Attributes must also be sufficiently constrained such that the measurements are meaningful, e.g. a suitable constraint in time to allow the attribute to be measured properly.

The validity of the derived requirements with respect to the URD can be tracked and assessed systematically, using the mapping of URD to SRD, and OT/R and FA, shown at (FIG.2).

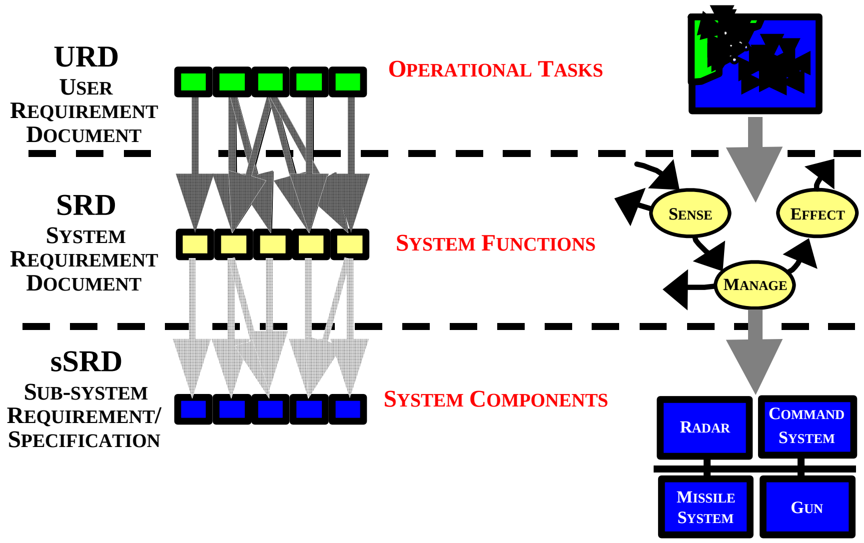

FIG.2 – MAPPING BETWEEN ENTITIES

Global Issues

The work thus far would only consider the non-functional attributes of individual functions of the IPMS. When generating a full set of IPMS system requirements that the non-functional attributes of the IPMS system as a whole (robustness, human factors, security etc.) must be considered.

In particular human factors must be given due consideration. The considerable use made of PES means that the platform becomes one system of inter-linked PES and crew, working together to complete the mission. Mission success will be dependent on the safe and effective performance of the crew as a critical component of the platform system; to achieve this a human-centred approach to designing system elements will be needed, with due consideration to the Human Machine Interface (HMI) of the PES, in our case the IPMS.

Scenario Based Analysis

Scenario based analysis is a method of introducing an element of real world operational considerations, adding a behavioural perspective to the structural perspective already presented. Scenario based analysis also provides an intuitive means of tailoring and validating the functional areas identified in the criticality analysis as being mission critical to platform capabilities. Functional modelling creates a list of functional activities, while the scenario based analysis validates the derived requirements set, and can identify any gaps by fitting the derived activities into a simulated operational environment.

For each scenario there are 3 steps to the analysis. Firstly a domain expert generates a scenario script, outlining the necessary activities in a time-based sequence, as they would occur in a ‘real world’ event. Working together the domain expert and a systems modeller would then match the scenario script to the functional activities.

Two models were then generated from each scenario script, both using the UML notation: an Activity Model and a Sequence Diagram. The Activity Diagram shows a system's operation by breaking the process into a sequence of activities. These activities are allocated to sub-systems responsible for their execution, and the control indicated by appropriate linkages.

In a similar manner Sequence Diagrams seek to represent the time between activities taking place and the information flow between sub-systems.

Such a scenario based analysis, using 8 distinct scenarios, has just been used to support the MARS project, and the results will be used to validate the SRD to be produced later in 2005.

The scenario based analysis enables the evaluation of the relevance of the FA set in a specific Operational context.

Assurance and Capability Management

The Defence Procurement Agency (DPA) uses a software tool to manage project requirements and develop SRDs.[10] This tool, the Dynamic Object Orientated Requirements System (DOORS), is a powerful relational database. The data from scenarios, URD, SRD, and sSRD are entered as functional models of the requirements sets. Additional models to provide guidance explaining constraints imposed and why decisions were taken can be added in support of the requirements models.

The final part of the structure is assurance models, which complement the requirements models. These models will contain the validation/acceptance statements associated with the requirements, and ultimately they will be used to write tests that will prove system requirements have been met.

Once the models are populated links are created between the statements in the various models. These links provide project traceability. An acceptance statement can be followed back through the links to the original User Requirement and Operational Task to which it is associated. Through this dependent link structure the models can be checked to see that all requirements will be satisfied, providing a level of assurance that the requirements set is complete and consistent.

These models are also a powerful tool for managing capability trade offs and changes. It is quickly possible to trace the impact of a change, e.g. observing the impact on platform capability of a change in system functionality of IPMS.

Integration

Integration can be defined as achieving effective interoperability of system elements through management and co-ordination of design effort. For an IPMS this will need to include effective interoperability with all the other management and control systems with which IPMS has functional links, e.g. CMS. The integration task will be fundamental to the successful delivery of the Military Capability needed from the platform, through the IPMS.

It is hoped that the DOORS models for requirements can be used to explore and model the functional interfaces between different systems. Work to inform the integration process is the next priority for PMS Studies. Identifying these functional interfaces at the requirements stage will highlight potential conflicts and demonstrate areas which will need to be the main effort with respect to integration of the distinct systems.

Acceptance Strategy

The proscribed syntax and semantic for deriving the requirements statements provides an essential link between the requirement and its associated measurable attribute, which if subjected to scenario based analysis will already have been subject to (albeit qualitative only) evaluation in an operational context.

Acceptance is defined in a number of ways. For our purposes a suitable definition is found on the AMS website:[11]

> "Acceptance is a process ... to confirm that the user's needs for Military Capability (MC) have been met by the systems supplied."

Acceptance has traditionally been associated with the end of manufacturing. In the modern acquisition strategy acceptance takes place at all phases of a contract, and in a number of guises.

There are 2 key milestones defined for acceptance under AMS. They are:

1. System Acceptance.

   The point at which the requisite equipment capability is confirmed as achieved.

2. In Service Date

   The point at which the other components of Military Capability (e.g. trained manpower) are confirmed to have been integrated with the new system so as to achieve a useable Military Capability.

Acceptance is reviewed at both these milestones. Early in the project life cycle an acceptance strategy will need to be developed to identify how to meet the above milestones, and used to inform an Integrated Test Evaluation and Acceptance Plan (ITEAP). The ITEAP is a key part of the acquisition process up to In Service declaration.

The acceptance criteria required for this process are derived from the URD, and detailed in the SRD. In this context, the importance of the non-functional attribute definition in the requirements capture process can be seen. If the requirements capture process is rigorous then it will feed forward and drive the acceptance process planning, and inform the acceptance tasks as they happen.

Whole Life Cycle Risk Management

Our work has shown that the application of SMART Acquisition principles to IPMS projects is still developing. Risk Management is a part of the AMS, which identifies the need to maintain a balance between Demand Risk (requirements) and Supply Risk (capability delivery).[12] Technology intensive projects like an IPMS procurement can bring particular issues such as Technology or System Readiness Levels (TRL, SRL) to the fore.

Risk Management is a through life activity, applied throughout the project life cycle. Therefore Risk Management must be applied within the context on the Through Life Management Plan (TLMP). A Risk Management strategy needs to be developed in the context of the overall project objectives, demonstrating that Risk Management aligns with the project TLMP. A Risk Opportunity Management Plan (ROMP) can then describe how risk is to be managed within the project, the goal being the reduction of risk to an acceptable level.

The MoD risk framework recognizes 3 types of risk:

- Project.
- Technical.

Corporate.

Without addressing the whole subject of risk definition and management here, it is worth considering 2 sub-sets of technical risk:

- Technology risk.

  Relates specifically to the uncertainties associated with advancements in science and engineering capabilities that impact upon the project. The pace of change of COTS technology is such that it must be considered; there may be 2 or 3 step changes in technology over the timescale from Concept to Demonstration phases.

- Requirements risk.

  Is an emergent area of understanding in Requirements Management. It is not yet a formal subset of technical risk, but the risks arising from poorly defined, incomplete or changing requirements cannot be ignored in the future.

As with many elements in these processes, consideration of these issues early in a project will allow visibility of issues and appropriate action to be taken.

Exploitation

All of this work is of little use without an exploitation route. Both the CVF and MARS project teams have been engaged as stakeholders through the working groups, and both are keen to take onboard the principles and process advocated.

New Platforms/Ships

MARS has recently used the generic requirements set and conducted a scenario based analysis of the functional activities of a tailored IPMS. This work was then modelled in UML to provide the requirements set, which will be used to validate the SRD before Main Gate approval. With the requirements data populated in a DOORS database the project team now has a resource which they can interrogate to demonstrate assurance of requirements, and should it become necessary, inform any cost/capability analysis.

Legacy Platforms

Whilst the process advocated by the study team has focused on new platforms, it can also be applied to legacy platforms, e.g. LPD PMS. This can help evaluate correctness and completeness of existing requirements, and/or an already chosen architecture. Existing requirements can be evaluated against the generic syntax and semantic, and the derivation process with non-functional requirements used to validate the scope of the requirements sets satisfies the Operational Tasks/Roles. The chosen architecture can be evaluated analytically or against operational criteria. Such work could validate the existing system, and may identify capability gaps. This approach has been tested and found to be successful, against a platform supplied by one of the study team industry member companies.

Such management of legacy capability is an increasingly important area of consideration within the DLO, particularly as platforms are considered for life extension or capability update, e.g. Type 23 Frigate Mid-life Capability Upgrade. The ability to use this process retrospectively should allow informed decisions to be made regarding existing capability gaps. It should also allow more informed debate over cost/capability trade offs in any update programmes.

Comparable Work

The work of the study team has been focused towards maritime platforms for UK MoD, but the extensive use of PES in the wider maritime community has come to the attention of the Classification Societies and standards organizations. Indeed, the International Standards Organization (ISO) has drafted ISO 17894, which will advocate a similar approach and process for the design of PES for use in the maritime environment; this standard is currently in the ISO approvals process prior to possible publication.

Whilst derived from the Maritime domain, the work on generic requirements would be equally applicable to projects in the Land and Air domains as well.

Conclusions

The successful acquisition of an IPMS is seen by DPA platform IPTs and contractors as a significant risk to programmes. To mitigate against this risk a study team was formed to investigate and advocate a process for improving IPMS procurement.

The fundamental conclusion of this work has been that successful acquisition of an IPMS can be achieved only if it is underpinned by a complete, correct and unambiguous set of functional and non-functional requirements.

Process guidance has been developed to aid IPMS requirements generation. Operational Tasks/Roles can be mapped against IPMS functionality to identify an appropriate system boundary. An analytical process for deriving functional requirements and non-functional attributes can be supported by a qualitative analysis of functions based upon operational scenarios. The development of non-functional attributes is seen to be the key, and most difficult element in this process.

The management of these requirements in the DOORS database system allows for validation of the completeness of the requirements set, and also allows considerable interrogation of the data for the implications of any changes in requirements or functionality, providing auditable links to the original Operational Task.

Interrogation of DOORS requirements data should also allow early identification of the key functional interfaces between disparate platform systems, allowing the targeting of project effort to the points of greatest need.

The complete requirement set thus generated will naturally feed forward to inform the acceptance strategy, defining acceptance criteria and aiding development of suitable test procedures.

Although no new risk management strategies have been identified, risk management is an important element of the TLMP. This work has highlighted the emergence of requirement risk as an important consideration in the risk management strategy.

Aligned with the doctrine of the AMS, the work of the study team is already being adopted by DPA platform IPTs, and has shown promise for application to capability management in legacy platforms.

The processes advocated by the study team are broadly comparable with similar work in the wider maritime community, and when considering generic requirements, are equally applicable to work in any domain.

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