Chapter 19
Integrated Approach to Maintenance and Capability Enhancement

Proposal of a Maintenance Dashboard Framework

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Abstract In the current climate, the industrial sector is increasingly characterised by longer product life cycles and asset availability demands. There is likely to be a reduction in the number of major acquisition projects in the future. This, combined with organisational changes and the fact that both governmental and commercial sectors are steering towards contracting for capability, has led to an internal shift in manufacturing centric companies. These traditional companies are now providing service offerings for their products, thereby reducing customer oriented risk. The services aspect includes the use of new technologies and methods for managing technical products over their life cycle and ensuring that customers' required capability and availability demands are met. This imposes new challenges on subsequent maintenance, repair and capability enhancement procedures. A framework for the development of a Maintenance Dashboard is proposed. The underlying purpose being to establish an approach that supports the decision-making process on whether to maintain, repair, upgrade or update a given asset. Through incorporating maintenance and capability enhancement, both facets are considered in their entirety as opposed to in isolation. The proposed framework aims to direct key asset status information at the various stakeholders involved while an asset is deemed 'active', thus aiding consistent decision-making which may ultimately be related to KPI management.

19.1 Introduction

The time between major platform acquisition projects in both the commercial and defence sector is increasing. Thus, there is a need to prepare for a potential 'ramp up' in the pace of technology insertion to enhance asset capability, as well

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considering robust maintenance management procedures as a means to sustain a working asset. This can be achieved through taking into consideration technological advances, allowing a response to both 'evolution and revolution in capability'. There is a requirement for open architectures which permit the incremental insertion of technology in a 'plug and play' manner. In order to enable this, platforms and systems need to be designed with adaptability in mind. New roles for existing systems are also defined in response to changing market requirements. Targeting those systems that need to be modular in nature requires specific identification of technologies which evolve rapidly. Alongside capability enhancement is the need to reliably predict system status. Prognostics is key to aiding both operational and support planning. Effective maintenance planning allows for improved fleet management and reduced support costs. The consideration of these factors sets the scene for the development of an integrated approach to maintenance and capability enhancement.

19.1.1 Retrospective Viewpoint

'We have now reached a crossroads. We are seeing a shift away from platform oriented programmes towards a capability-based approach, with corresponding implications for the demand required of the traditional defence base', A1.4 (MoD 2005). While this quote is taken from a defence perspective, it is equally applicable to the commercial world where companies such as Rolls-Royce have coined the phrase *Power By The Hour*® for their performance-based contracts.

The term capability is commonly used in a variety of contexts, and thus it is necessary to define the term in relation to the context in which it is being referenced. The UK Ministry of Defence (MoD) Acquisition Operating Framework (MoD 2009) describes Capability as the 'enduring ability to generate a desired outcome or effect, and is relative to the threat, physical environment and contributions of coalition partners'. The Oxford English Language Dictionary defines Capability to be 'the power or ability to do something'. Capability can thus be defined on a number of levels ranging from high-level operational viewpoints through to specific requirements, such as providing heating at a set temperature. For the purposes of future discussion, capability is considered from a platform/system perspective; 'the ability of a platform or system to deliver a specific requirement in support of an overall goal'.

Capability enhancement through the insertion of technology, either for the purposes of upgrade or update (discussed in Sect. 19.2), falls within capability management. At a simplified level, this would occur in response to an influencer. An influencer may be either an internal or external factor which must be taken into account if a given platform or system is to deliver the required effect. Influencers, at a strategic level, may comprise a number of factors including changing market requirements, threats, opportunities, environmental factors and/or internal policy changes. A further notable relationship occurs between capability management and technology management. Technology management (Shanks 2008) is key to the successful implementation of capability management since it involves developing an awareness of available and upcoming technologies, and can thus inform the decision-making process in any future integrated approach of the critical technologies available to meet a noted capability requirement.

Specific areas which require addressing in implementing an effective integrated approach, which includes capability-based planning, cover; requirements management, integration on two levels—technologies into systems and systems into platforms, and robust decision processes for determining potential solutions to previously identified capability requirements.

Capability management employs a top-down approach to its delivery. Key to the integrated approach towards maintenance and capability enhancement is a rigorous planning and requirements specification phase. Maintenance involves maintaining and securing systems in, or restoring them to, a state in which they can perform their required function or functions. One of the challenges for maintenance planning is to identify the actions for preventive maintenance and to ensure that necessary resources are available (Rosqvist et al. 2009). The role of maintenance has changed from simply being a repair solution to having an intrinsic role in through life management. To this end, models for predicting the remaining useful life of components or systems and prognostic methods for determining future system defects can be utilised (Jardine et al. 2006; Wang 2008b).

From the viewpoint of examining maintenance within through life management there are a number of issues which require consideration (Takata et al. 2004) and are key to any proposed integrated approach:

- Adaptation to changes in platform capability requirements during the life cycle.
- Adaptation to platform changes due to technology insertion.
- Integration of past and future maintenance information.

One of the fundamental measures of success for a system is the degree with which it meets its intended purpose. The eliciting of capability requirements (Nuseibeh and Easterbrook 2000) is vital to the successful implementation of a maintenance and capability enhancement decision process. Requirements Engineering has developed into a key stage in the overall systems engineering process (Stevens et al. 1998) with respect to interpreting and understanding user requirements and their successful transformation and implementation. Consequently, parallels may be drawn between knowledge enriched approaches (Ratchev et al. 2003) and the specific requirements of an integrated maintenance and capability enhancement approach.

Industry examples (Pagotto and Walker 2004; Rotor & Wing 2005; Aerosystems International 2003), indicate that maintenance management and capability enhancement programmes have been managed in isolation. Both governmental and commercial organisations across the world are now declaring that they are more likely to contract for capability rather than purchase specific products (MoD 2005). The priorities within acquisition projects are shifting towards procuring the capability to carry out an operation. From a customer perspective this offers reduced risk and support costs. This chapter proposes a framework which will allow maintenance and capability enhancement to be viewed in an integrated manner. These two aspects are embodied within the move towards servitization, especially where the capability being delivered is underpinned by data collection and information processing/analysis techniques. The framework forms the high-level architecture for a Maintenance Dashboard.

19.1.2 New Approach to Maintenance and Capability Enhancement

The reasoning behind the integrated approach stems from the fact that both preventive maintenance and capability enhancement techniques are based on the same fundamental comparison of capabilities. At a basic level, in the case of preventive maintenance, the performance of a capability enabling system fluctuates between design operating and actual values. When considering capability enhancement, the current system capabilities are compared with future and/or desired capabilities. Preventive maintenance and capability enhancement are thus two facets within the lifecycle of a system which can be addressed in an integrated approach and are considered to embody the decision-making process behind the proposed framework.

The majority of traditional manufacturing companies' customers face continuing budget pressure and as a consequence are implementing service methods which are better value for money while maintaining equipment availability levels. There is likely to be a reduction in the number of large acquisition projects in the future. This, combined with organisational and market changes, has led to an internal shift within traditional manufacturing companies from a manufacturing centric organisation to a service centric organisation concerned with establishing a service-based capability. Focus in this case is required in Enabling Through Life Capability and a systems engineering approach. Customer organisational changes have ultimately led to the manufacturer managing the risk. As such, customer emphasis has been refocused towards minimising the cost of ownership while maintaining high levels of equipment operability and functionality. Under the umbrella of 'refocused customer emphasis', practical linkages can be drawn between the potential outputs of the integrated approach in terms of asset status and asset performance indicators. An analysis of maintenance data in conjunction with capability enhancement information would enable clear reporting of asset status under the guidance of noted key performance indicators and measures.

The systems engineering approach (Stevens et al. 1998; MoD 2005) can be adapted from a support services perspective (Fig. 19.1). The top tier represents the customer, companies such as BAE Systems often perform the mid-tier integrator roles and, in conjunction with lower tier partners, produce a support service solution. Systems engineering provides an inter-disciplinary approach to problem

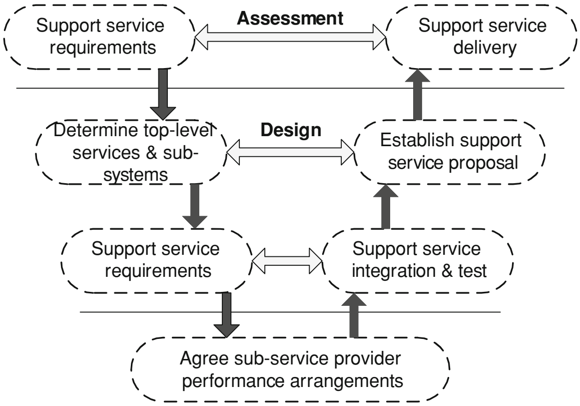

Fig. 19.1 System Service 'V' Diagram

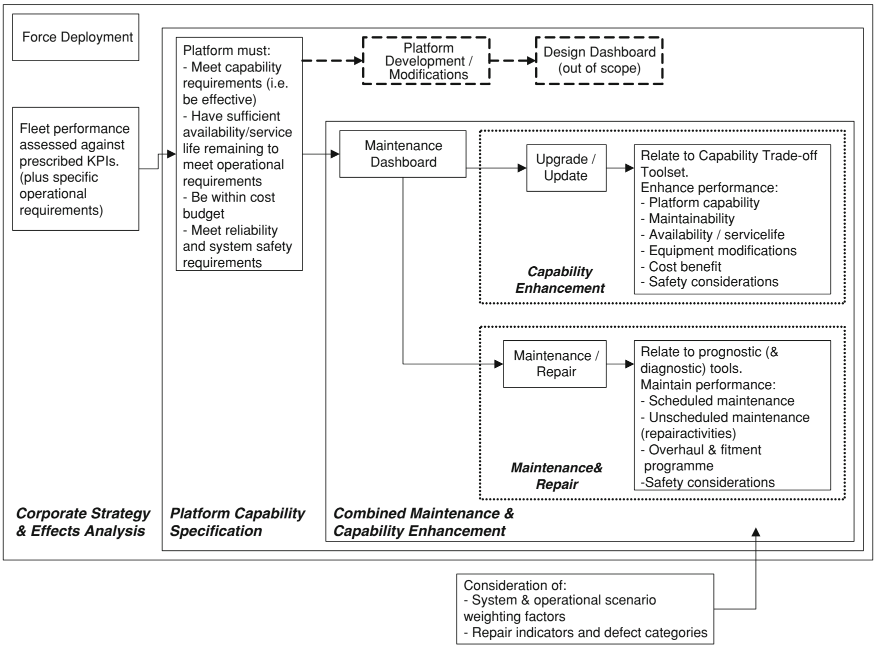

Fig. 19.2 Service requirements for an integrated approach towards maintenance and capability enhancement

solving and is the backbone to delivering the end aim. The end aim being to create a support service structure which satisfies the defined customer requirements while remaining within cost and schedule constraints. An industrial consultation conducted by the Engineering and Physical Sciences Research Council (EPSRC 2009) noted product life-cycle as one of the key manufacturing research challenges, with emphasis placed on providing a whole systems approach towards servitization.

The proposal of a Maintenance Dashboard is directly aimed at extending product life cycles and contributes towards the creation of a support service structure. Extensions to product life cycles are achievable through lengthening the 'useful phase' of the product, where the 'useful phase' is defined as the period during which the product has a functional value. It is proposed that this may be realised through a balanced integrated strategy towards preventive maintenance and product modifications. In this case, modifications cover system adaptations due to changing capability requirements, thereby conducted via capability enhancement. In order to increase product life, the application and addition of new technologies is imperative as a means to ensure the possibility of permanent upgrading. Figure 19.2 illustrates the specific service requirements of importance in developing an integrated approach within the context of the System Service 'V' Diagram.

19.2 Development and Integration of Preventive Maintenance and Capability Enhancement

The concept behind the Maintenance Dashboard is discussed in the following section. The main principle being a *decision process which involves assessing platform capability requirements alongside information retrieved from both preventive maintenance and capability enhancement trade-off programmes*; the aim being to provide an indication of platform status. In this manner it is possible to specify, for example, whether a particular sub-system requires maintenance due to a predicted defect or, if due to capability trade-off information, upgrade should take place at the next maintenance opportunity. *The decision process thus acts to integrate preventive maintenance and capability enhancement and may be viewed as a maintenance management assistance tool.* Maintenance planning, with regard to the ordering of parts and organisation of resources, can be managed in conjunction with optimising maintenance activities associated with scheduled maintenance and repair tasks or system upgrade.

In Sect. 19.1 it was noted that the Maintenance Dashboard proposal could be related to the design of sustainable product life cycles. Sustainable manufacturing for the next generation is also focused on enhancing use-productivity in the total product life cycle (Selinger et al. 2008). Sustainability, from a technological point of view, can thus be viewed to be associated with ensuring the 'useful phase' of a product's life is extended. Figure 19.3 has been adapted (Nieman et al. 2009) to represent the design of sustainable product life cycles from the perspective of creating a support service structure.

The three central boxes illustrate that the success of the proposed Maintenance Dashboard is reliant on service requirements, information and the customer. From a holistic point of view the Maintenance Dashboard supports life cycle management; within the framework the asset status is modelled and evaluated according to available data. The solution proposed by the dashboard with respect to maintain,

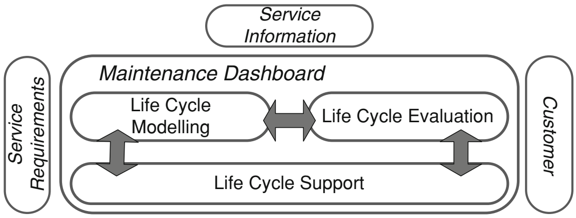

Fig. 19.3 Sustainable product life cycle—support service perspective

repair, upgrade and update is arrived at through a decision process that optimises the required asset capabilities against a known scenario.

19.2.1 Methodological Design Progression

The proposed framework for the Maintenance Dashboard is adapted from the precedent set by the reference architecture for the CommonKADS system (Schreiber et al. 1994; 2000; Kingston 1998). The CommonKADS methodology is a collection of structured methods for building knowledge-based systems (KBS); permitting a structured, detailed analysis of knowledge-intensive tasks and processes.

In brief, CommonKADS is a methodology for KBS development which proposes the creation of different models between which implicit links are identified. The models are thus both related to each other and depend on each other. The methodology comprises six key models of which the design model is the main element of regard in relation to the development of a framework for the Maintenance Dashboard. The model proposed in this chapter comprises the technical design process of the Dashboard.

The technical design consists of three main stages. Generic descriptions of the stages are summarised for reference. Section 19.2.3 describes the stages with specific reference to the Maintenance Dashboard in greater detail.

1. System Architecture Design: The general architecture of the Maintenance Dashboard is specified.
2. Identification of Implementation Platform: The constraints with respect to the implementation platform are identified i.e., environment in which the Maintenance Dashboard is set.
3. Specification of Architecture Components and Application: The individual architectural components of the dashboard are defined in greater detail, in particular the interfaces between components. All knowledge-based information is then mapped onto the system architecture. This includes tasks to be performed (i.e., aim of dashboard), knowledge bases, associated inferences and decision process mechanisms. The application specific sections within the architecture are also specified.

Table 19.1 Maintenance dashboard solution definitions

Decision	Function
Maintain	Conduct scheduled maintenance according to prescribed maintenance plan
Repair	Conduct unscheduled maintenance (and indirect capability enhancement if upgraded technology spares used) through the replacement of faulty system components
Upgrade	Conduct capability enhancement through the replacement of systems or components containing newer technologies capable of increased functionality (also taking into account component replacement as parts near end of life)
Update	Conduct scheduled maintenance to maintain system capability through the replacement of obsolete components

19.2.2 Decision Process

The principal aim of the decision process is to provide a means for comparing current and future required capabilities in order to determine if the platform (or constituent systems) requires maintaining, repairing, upgrading or updating. The decision process thus presents a solution that indicates whether the maintenance and/or capability enhancement route should be followed. This gives rise to one of four solutions; maintain, repair, upgrade or update. The definitions assumed for each of these terms are detailed in Table 19.1.

Taking into account factors raised in Requirements Engineering, the decision process adopts a three-phase evolutionary approach:

1. Identification: Identification of specific capabilities (either individually or collectively) to be taken into account. This phase also involves defining the system/platform capability requirements (i.e., requirements elicitation).
2. Analysis: The majority of the analysis phase involves developing, refining and evaluating all possible solutions to the given capability requirements from (1) above. The decisions which govern whether a system should be maintained or upgraded depend on, in brief; (i) the obsolescence attributes of the technology in question that provide the capability, (ii) the ‘utility’ (e.g., performance) realised to the system or platform by changing the technology and (iii) associated capability priorities.
3. Solution: Determination of the best solution for meeting the required capability(s) identified in (1).

19.2.3 Development of a Maintenance Dashboard Framework

The first stage, as noted in the design process, involves defining the structural framework (architecture) of the Maintenance Dashboard. There are three main components identified in the reference architecture. If the framework for the

Maintenance Dashboard were to be viewed as a system, then these components would comprise the principal sub-systems. The three sub-systems are termed Controller, Views and Application Model (Gamma et al. 1995). The framework also structures the information flow from requirements elicitation through the three major components, thereby delivering a solution.

The *Controller* represents an integral "command and control" centre which handles external information (i.e., User Input) in order to activate application functions. The input requirements model is composed from two data streams obtained through requirements elicitation: (i) current system capability levels, and (ii) required system capability levels. The integration of preventive maintenance techniques and capability ranking data provide the system status with regard to (i) maintenance schedule, (ii) urgent actions to be addressed e.g., component failure, (iii) failure profiles and (iv) technology insertion programmes.

The *Application Model* specifies the functions and data that together deliver the functionality of the dashboard application. Additionally it contains the reasoning functions, including information and knowledge structures, which give rise to the decision approach. It primarily contains the elements that realise a solution from the functions and data specified during analysis.

Within the dashboard application, the *View* allows static and dynamic information from the application to be available. Utilising information from the decision process, the View delivers the output. This comprises one of four options; (i) Maintain system (according to maintenance plan), (ii) Initiate repair strategy, (iii) Update or (iv) Upgrade.

Figure 19.4 illustrates the formation of the structural framework for the Maintenance Dashboard based on the reference architecture (Schreiber et al. 2000). Detailed component functional information specific to the Maintenance Dashboard framework is expanded under Sect. 19.2.3.1, where the architecture components are specified as per Stage 3 of the design process.

The platform specification phase (design process Stage 2) involved in developing the Maintenance Dashboard further is twofold; (i) specification of the asset (e.g., aircraft) and (ii) specification of the computational infrastructure which will support the Maintenance Dashboard. From a theoretical and concept generating perspective, the design process behind the development of the framework for the Maintenance Dashboard can be conducted independently of the computational implementation platform.

19.2.3.1 Specification of Architecture Components and Application

The final stage in the design process involves defining the three major components (Controller, Application Model, Views (Gamma et al. 1995)) in the proposed Maintenance Dashboard framework. In addition, the interfaces between the components and application specific facets of the framework are also identified. The main purpose of this stage is to decompose the knowledge base into 'chunks of information' which may be then used to determine a solution to the system status query. In the case of the Maintenance Dashboard, functional decomposition

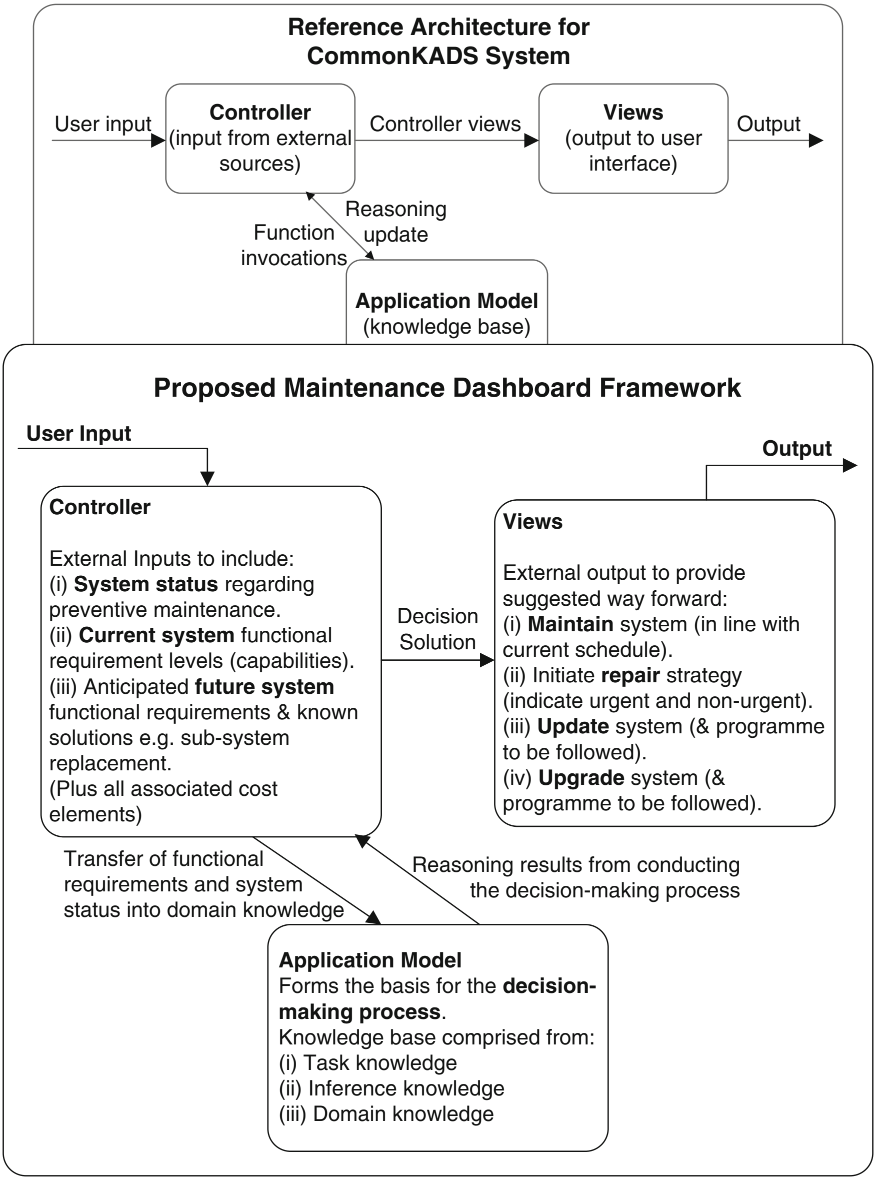

Fig. 19.4 Proposed maintenance dashboard framework

is employed; inferences between knowledge elements are preserved according to their functionality. The framework component of most importance, with regard to the functionality of the Maintenance Dashboard, is the Application Model. The Application Model embodies the decision process which ultimately determines the solution with reference to maintain, repair, upgrade or update.

Under the third stage of the design process the application specific sections of the framework are also defined. The proposed Maintenance Dashboard framework is not platform dependent and thus fully adaptable since the decision process is performed based on the data held within the knowledge base. The processes contained within the framework are however scenario dependent. Therefore, the Maintenance Dashboard is only applicable within the remit of determining platform status (maintain, repair, upgrade or update) based on the current and required platform (and/or system) capability levels. The processes and scenario-related information are changeable, and thus the Maintenance Dashboard can be adjusted to cover a variation in situation if the 'maintain-repair-upgrade-update' scenario-related decision approach is inappropriate (i.e., to cover a change in requirements to the desired output for assisting decision support). The Maintenance Dashboard framework components are summarised:

The *Controller* represents an integral "command and control" centre which handles both external and internal information (e.g., user input) in order to activate application functions. Within the Maintenance Dashboard framework the controller represents the central information hub and its function is threefold:

1. The principal purpose of the Maintenance Dashboard is to provide the platform status with regard to maintain, repair, upgrade or update. Related information (e.g., operational defect data, system concessions, alterations and additions system operational priority ratings) is input into the Controller component to aid this task. This data is then transferred to the Application Model for analytical purposes and comprises data streams on (i) current system capability levels, (ii) required system capability levels, (iii) preventive maintenance results (prognostics, failure profiles), (iv) urgent actions to be addressed (e.g., failure/imminent failure) and (v) capability trade-off ranking results taking technology insertion into consideration (capability enhancement route).
2. The Controller component informs the Application Model when to conduct analysis. The Controller thus initiates the first task that is necessary in order to determine the status of the asset (and associated systems).
3. The results from the Application Model are relayed to the Controller. The Controller 'handles' this information and transfers the solution of the analysis conducted by the Application Model to the View Component. The Controller also retrieves all data from the Application Model with regard to the analysis reasoning process. The added handling of this data provides traceability of information and permits clear reporting routes, if applicable.

Within the dashboard application, the *View* allows static and dynamic information from the application function to be available. In brief, the View realises the presentation of the Maintenance Dashboard purpose to the users. All data presented by the View is transferred from the central information hub (Controller). The View simply acts as an interface between the decision process and the end user. The solution output comprises one of four options; (i) Maintain system, (ii) Initiate repair strategy, (iii) Update system and (iv) Upgrade system.

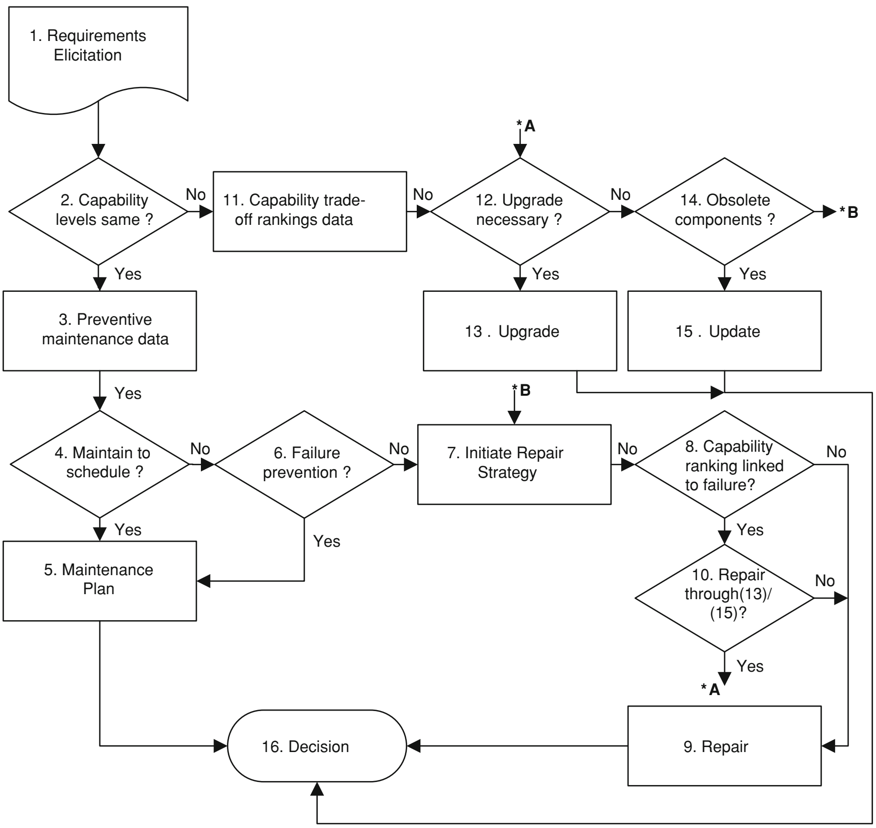

Fig. 19.5 Representation of application model component decision algorithm

The *Application Model* specifies the functions and data that together deliver the functionality of the Maintenance Dashboard. The Application Model knowledge base is formed from the data streams input into the Controller component as well as the reasoning functions behind the decision approach. The Application Model therefore contains the elements necessary for realising a solution. Within the Maintenance Dashboard framework the Application Model provides the user with decision support and assistance in determining the asset status relative to the 'maintain-repair-upgrade-update' scenario-related decision algorithm. The task initiated by the Controller component results in the commencement of the decision process. This task defines a single operation; conduct a comparison of current capability levels with required capability levels. The execution of the task invokes the decision algorithm (simplified illustration presented in Fig. 19.5), which in turn results in the initiation of specific decision tasks (represented by ◇).

In performing the decision process, data is sought from the knowledge base. This includes the current system status obtained from preventive maintenance techniques, system specific technology insertion programme data retrieved from

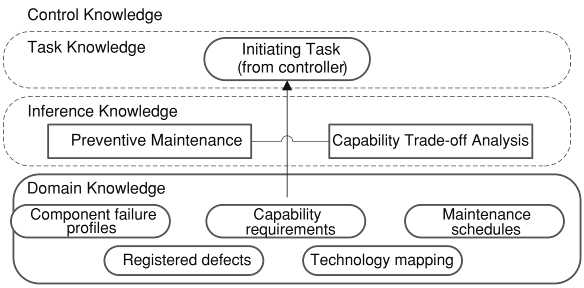

Fig. 19.6 Knowledge base 'snap-shot' (requirements mapping illustration)

capability ranking procedures and associated inferences between the variables contained in the data bases and the decision tasks. A 'snap-shot' of an example knowledge base structure is illustrated in Fig. 19.6.

Control Knowledge defines both the content and structure of the task and inference specific data: (i) *Task Knowledge* is defined by a key goal and describes the decomposition process involved in the decision algorithm (decision tasks referenced in Application Model). (ii) *Inference Knowledge* describes the inference steps that are to be followed in completing the key goal (task) through utilising information obtained from capability ranking procedures for example.

Domain Knowledge contains the concepts, relationships and facts that are required in order to reason a given application domain. For example, in cases where preventive maintenance techniques are used to describe inference steps, system failure profiles are contained within domain knowledge.

19.2.4 Maintenance Dashboard Application: Asset Status

The framework developed to integrate preventive maintenance and capability enhancement is realised through the representation of a Maintenance Dashboard. The Maintenance Dashboard illustrates the functionality of the decision approach and is structured to relay asset status information to the service provider at system, platform and fleet levels (Fig. 19.7). A generalised schematic representation of the Maintenance Dashboard, based on the structural framework illustrated in Fig. 19.4, is presented in Fig. 19.7. An example of application of the Maintenance Dashboard is illustrated in Fig. 19.8. In the given example, the dashboard is linked to an overall support service offering by relating it to the defined Ministry of Defence Defence Lines of Development.

At the highest level (Fleet/Class) the Dashboard offers a single overview representation of all of the assets and their availability for a particular scenario and duration. This availability is determined based on the status of the key systems required for that particular scenario. The platform level (Asset/Warship) illustrates the status of the asset systems (i.e., fully operational or issue identified) and

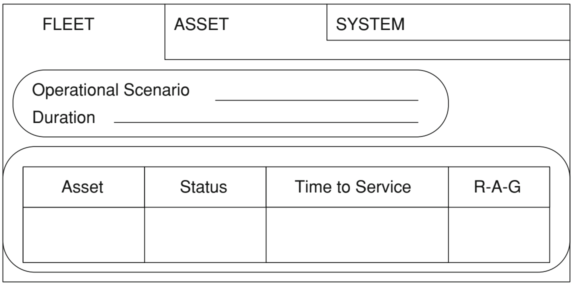

Fig. 19.7 Maintenance dashboard—generalised schematic representation

Fig. 19.8 Maintenance dashboard—an example application

associated priority for reparative action. Relevant capability enhancement programmes are noted and information relating to enhancement options, cycle time and fitment opportunities are detailed.

The decision support process (application model) summates this data into a single operational capability level representation for instant service information acquisition. The system level of the Dashboard provides similar analysis utilising a greater degree of detail with regard to scheduled maintenance, unscheduled maintenance, current and required system capabilities. The outputs from the Maintenance Dashboard feed directly into maintenance planning decision support. This is a significant component in the delivery of a service support offering and directly links to the implementation of service methods as noted in Sect. 19.1.2.

19.3 Maintenance Dashboard and Services Transition

Servitization is noted to involve the innovation of an organisation's capabilities and processes so that it can better create mutual value. This is specific to the relationship between customer and supplier, through a shift from selling products to selling associated systems (Ng et al. 2010b). Consequently, service information and related decision support tools, such as the proposed Maintenance Dashboard, are instrumental to the successful delivery of a support service offering.

Popular advice to manufacturing based companies has been that 'in order to remain competitive they should move up the value chain and focus on delivering knowledge-intensive products and services' (Baines et al. 2007; Hewitt 2002). Occurring in conjunction is that fact that governments are now declaring that they will contract for capability (Neely 2009) and, as such, the support service aspect is outsourced to the supplier. From a supplier perspective, servitization may be viewed as a way in which sales revenue can be increased, whilst from a customer perspective, servitization offers reduced risk and improves the way in which costs and budgets may be set.

Servitization involves the use of the new technologies as well as methods for managing technical products (i.e., asset) over their life cycle. Service science is interdisciplinary and focuses on service as a system of interacting parts that include people, technology and business (Demirkan et al. 2008). Within this environment, product life can be evaluated. The Maintenance Dashboard proposal is aimed at extending the 'useful phase' of a product's life. This 'useful phase' being defined as the period during which a product performs a particular function (in the context of this chapter, meets a given capability). This extension is achievable through conducting preventive maintenance and modifications, where modifications involve capability enhancement. To enable product longevity, the option for permanent upgrading and updating must remain viable. The Maintenance Dashboard provides an option for initiating a balanced strategy with regard to maintenance and capability enhancement and thus better serves to increase the 'added value' of the product during its 'useful phase' in the life cycle. The solution retrieved from the Maintenance Dashboard is of specific relevance to the different management levels within a business/organisation. Figure 19.9 illustrates the information flow.

1. Corporate with regard to business strategy; this may relate to budgetary control for example.
2. Operational and tactical assessment of working scenarios/missions, required fleet capabilities and determining the 'most sensible time' to conduct asset maintenance, repair, upgrade or update.
3. Equipment management from the perspectives of those involved in maintenance management and logistics planning (resources, spares, and work-space).

In the context of the Core Integrative Framework (CIF) (Ng et al. Introduction chapter) for complex engineering service systems, the Maintenance

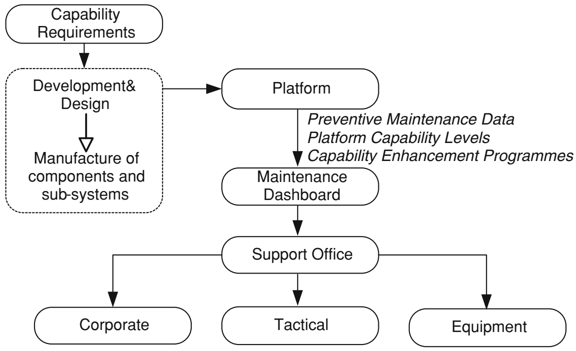

Fig. 19.9 Information flow from maintenance dashboard

Dashboard fits within transformations (a) and (b). These transformations cover transforming materials and equipment and transforming information. Ng et al. document that if a customer were to consider contracts from an outcome based perspective then value is likely to be added through the adoption of all three transformations noted in the CIF. The 'mutual value' referenced in the definition of servitization is thus delivered through the interactions between the three transformations of information, materials and equipment and people. The Maintenance Dashboard proposal does not dovetail with 'transforming people', however the decision support provided by the dashboard may be used to, in effect, persuade the adoption of different mindsets. The proposed Maintenance Dashboard is able to provide support for day-to-day operations conducted under the service paradigm plus address longer-term strategic perspectives from a technical point of view. This serves to combine technical asset considerations and interdependencies with the strategy challenges that may be faced through the analysis of information. A simplified representation of the information interactions between transformations (a) and (b), with reference to the Maintenance Dashboard, is depicted in Fig. 19.2.

19.4 Concluding Remarks

'The quality and shelf-life of current technical products is no longer determined by wear and attrition but by being technically out of date' (Niemann et al. 2009). Current, and future, strategies for achieving maximum product utilisation are required to consider longer-term planning for product life-cycles. The concept behind life-cycle management aims to optimise product performance. This covers the three main phases within a product life-cycle; (i) manufacture, including design and development, (ii) usage and (iii) disposal/recycling. The Maintenance Dashboard framework is directly aimed at extending product life cycles and aiding the associated planning process. Extensions to product life cycles are achievable through lengthening the 'useful phase' of the product. Within the Maintenance Dashboard this is realised through a balanced integrated strategy towards preventive maintenance and capability enhancement. Through incorporating maintenance and capability enhancement data, both facets are considered in their entirety as opposed to in isolation. As a result, the proposed framework takes into account the various stakeholders involved during the 'useful phase' of the product's life-cycle as illustrated by Fig. 19.9. This entails directing asset status information at the required level to the various stakeholders. For example, an engineering director is likely to place greater emphasis on knowing the high-level status of the fleet under his control, i.e., understand *x* out of *y* assets are active and their respective status with regard to downtime relative to maintenance programmes and planned modifications. An engineering manager however will be interested in the details behind planned maintenance programmes and their effect on items such as concessions.

The framework supports the analysis involved in implementing an integrated maintenance and capability enhancement approach. The structural framework architecture provides a concise representation of the processes involved in determining the status of an asset with regard to maintain, repair, upgrade or update; while the knowledge base for the decision process is suitably customisable dependent on the platform and related systems under consideration.

It has been reported (Neely 2009) that new business models for manufacturers have implications for operations management frameworks and philosophies. This is of particular relevance to situations where the delivery of an operational capability is underpinned by the data collection and information analysis techniques. The decision process associated with the Maintenance Dashboard is initiated by a single task; comparison of current and required capabilities (assumed from a platform/system perspective). The Dashboard is dependent on the results obtained from asset maintenance information and capability trade-off analyses. These, in turn, are dependent on the data that can be retrieved from the asset and planners.

The provision of service support is gaining in importance as more organisations move towards capability and performance-based contracts. There are an increasing number of reasons for traditional manufacturing companies of high value complex systems to include services into their product offerings. This list is by no means exhaustive, however reasons include facilitating the sale of high value products, further strengthening customer relationships and addressing business growth and demand requirements. With the introduction of service contracts customers are far more likely to expect integrated service solutions i.e., goods and services integrated into customer specific packages (Davies 2003; Brax 2005). A service provision should offer value to both the customer and manufacturer. It is postulated that the Maintenance Dashboard may form part of a higher-level Integrated Support Service Dashboard and that the creation of a dashboard hierarchy would enable increased planning of maintenance activities alongside other functions.

19.5 Chapter Summary Questions

This chapter has brought to the forefront the consideration that service information and related decision support tools can be instrumental in the successful delivery of a support service offering. The services aspect of a support offering can be said to include the use of new technologies and methods for managing products over their life cycle, while also ensuring that the customer's required capability and availability demands are met. This drives the following questions:

- What process can be followed to ensure the service provider is able to consider maintenance and capability enhancement in their entirety as opposed to in isolation?
- How can these facets be structured into a framework for an integrated approach towards a decision-making mechanism?
- Within the transition to services, do the outputs from the integrated approach encourage the appropriate distribution and analysis of decision support results? Are these results suitably directed at the three levels depicted within the framework (i.e., fleet, asset, system)?

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