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A Standardisation Concept for Non-Standard Development Projects

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Abstract. In many cases, organisation-wide process standardisation efforts are based on project specific experience. For an organisation with many similar projects running in parallel this is comparable easy. The project with the highest process quality enriched with some beneficial ideas from other projects may serve as a template for an organisation-wide systems engineering standard.

With decreasing similarity between projects it becomes increasingly difficult to define the best practice and even more to transfer it successfully from one project to another. Organisations working on projects with varying objectives, size and duration are considerably more challenged when they launch an organisation-wide process standardisation effort.

For this case, the process standardisation concept introduced here has been developed to pave the way for organisation-wide standardisation. On the basis of a detailed requirements analysis and an evaluation of existing methods and tools the essential features of this concept are described.

INTRODUCTION

A demand for an improved understanding of the engineering processes within system development organisations has grown due to increasing system complexity and the resulting problems and risks in managing such development programmes. The importance of the subject is illustrated by the various international standardisation efforts regarding life cycle management and process capability evaluation launched during the last decade. Examples for the definition of life cycle processes are ISO 15288 (ISO 2000), IEEE 1220 (IEEE 1998), and, specifically for civil aviation, SAE 4754 (SAE 1996). With respect to process capability evaluation the SPICE Project (Graydon et al. 1995) and the System Engineering Capability Maturity Model (Bate et al. 1995) are the most famous efforts.

The previous engineering experience with safety critical systems in the aerospace industry contributed to the basis for new system engineering standards and process capability evaluation models. However, these older concepts themselves have to be improved to cope with the higher complexity of newly designed aircraft systems and, as a consequence, the further increasing importance of process quality.

The route for improvement is mainly characterised by integrating existing practices for project planning, status reporting, configuration management, and process assurance with the development process definitions traditionally laid down in system development plans and similar documents. Expected benefits are an enhanced level of awareness within a development organisation as a prerequisite for achieving higher process capability levels and an enforced overall communication capability within the development organisation and with other parties involved.

To justify the effort, such improvements should be embedded within an organisation wide process standardisation concept.

Projects performed by an aircraft manufacturer are ranging from small technology and research projects over demonstrator aircraft to production aircraft development programmes. Organisation-wide standards are usually centred on production aircraft development programmes to satisfy customer needs effectively. However, such major development programmes are rarely running in parallel. Sometimes it takes years before a next programme is launched. In the meantime existing technologies may be enhanced, new technologies may have emerged, and experience from the previous programme may have disappeared together with the generation of engineers who were in charge of development before. Under this circumstances each major development programme may be categorised as a non-standard development project according to the title of this paper.

On the other hand it would not be wise to limit the process standardisation effort to major development programmes. Because process capabilities grow with practice and experience, engineers have to be continuously trained. For this purpose small projects may use process standards comparable to those applied in major development programmes, but no unjustifiable burden should be imposed to the smaller projects.

In the following paragraphs a process standardisation concept is described that has been developed to support the development of safety critical flight control systems for a company environment as described above.

REQUIREMENTS ANALYSIS

Adaptability. The standardisation concept should be adaptable with respect to project specific needs, compatibility with a wide range of development standards, and the existing organisational process capabilities.

Project Specific Customisation. An organisation-wide standardised process is required for the higher levels of the SPICE process model (Graydon et al. 1995) respectively the Capability Maturity Model (Bate et al. 1995). For non-standard projects this requirement inherits a potential to conflict with customer orientation, one of the common top goals of today's organisations.

This is especially true, if the customer has established detailed procedural requirements. However, even in the military sector the influence of detailed procedural contract requirements is fading since the so-called Perry Initiative has dropped procedural military standards in favour of common industrial standards (The Secretary of Defense 1994). Another conflict between an organisation-wide standardised process and customer satisfaction may result, if the standardised process is inadequate or inefficient for a particular non-standard project.

Conclusively, process standardisation should be driven from a customer perspective to ensure customer satisfaction, e. g. satisfaction with the performance of the delivered product. Thus, non-standard projects have to be dealt with on a case-by-case basis, and a concept for organisation-wide process standardisation should recognise the demand for project specific customisation capabilities.

Standards Compatibility. The standardisation concept should comply with multiple system engineering standards because no standard is likely to cover specific demands for all non-standard projects performed in an organisation adequately. A good example is the requirement for a dedicated safety assessment process in the aviation industry. The safety assessment process has to be performed independently from the other engineering processes (SAE 1996). Other system engineering standards that may be also applied by the same organisation for other projects put less emphasis on a dedicated safety assessment process (ISO 2000, IEEE 1998).

Organisational Process Capabilities. Even the best process standardisation concept cannot become effective if the people who have to apply it do not feel supported. Thus, a process standardisation concept should consider the existing process capabilities of an organisation. Lengthy and cumbersome introduction or transition phases should be avoided and a limited set of procedures and tools for which the organisation feels more or less already a demand should be extractable. However, the process capabilities of an organisation are not static. It is nearly the intention of any process standardisation concept to further improve process quality. The demand for a more comprehensive assistance in performing the processes will usually grow together with the process capabilities. As a consequence, the process standardisation concept should not establish a monolithic block of methods and procedures. Instead it should serve as a toolbox with a defined route to implement the available modules in a reasonable manner for further process improvements.

Project Awareness and Reporting. Higher process capability levels are characterised by an increasing awareness of the project status and the ability for fast recovery from deviations in order to minimise any adverse impact on project results. Awareness in this instance does not mean that there is somebody in the project organisation who has noticed a problem, or that a silent agreement on a potential risk exists within a group of people. To achieve good project awareness, deviations should be detectable as early as possible and a reporting scheme should exist to feed this information into the decision process respectively forward it to the responsibles who have the power to launch an adequate recovery action. Efficient reporting schemes are increasingly important with growing size and complexity of the project and of the organisational arrangement.

Ensuring project awareness is even more challenging for non-standard projects because decision makers on a company level will be less familiar with specific features of the particular project. Conclusively, the process standardisation concept should emphasise basic techniques to ensure good project awareness. In particular, the way the project framework is defined, the means organisation internal project awareness is provided, and the rules to make a project transparent to any other stakeholder should be considered.

Project Framework Definition. In general, the project framework comprises the organisational and personal arrangement as well as all process definitions down to a procedural level. The project framework is traditionally documented in several plans like development plans, configuration management plans etc. For non-standard projects the project framework will usually be project specific to a higher degree. To improve communication, the process standardisation concept should comprise the rules how project specific parts shall be defined and documented to ensure compatibility among projects. In addition, it should support the documentation of the project framework in the traditional style.

Project Organisation Internal Awareness. Reporting of real or anticipated deviations and the use of this information is frequently a sensitive area of the corporate culture. No process standardisation concept will lead to an immediate change of a corporate culture, but it should provide the means for effective reporting and should ensure transparency of the resulting recovery actions and the overall project status. The promises are to achieve rapid recovery after deviations become detectable and a harmonised view on the project status shared by all members of the project organisation.

Project Transparency to Stakeholders. In an ideal world, all stakeholders in a project may share the same detail of project status information as the members of the project organisation. Although such arrangements sometimes exist, usually stakeholders are provided with consolidated views on a project. Therefore, the process standardisation concept should consider specific demands for consolidated views within its overall reporting features.

Process Orientation. Process orientation is one of the terms stressed frequently during the last ten years. The term process orientation as understood here is only partly concerned with the description of detailed process definitions and their interaction. The resulting view on the project documented in development plans is usually almost static. They do not show how an incremental development with a stepwise integration of additionally functionality and the numerous feedbacks from subsequent life cycle processes is really brought alive. Although configuration management plans usually define some of the dynamic workflow elements to run and control a project, this seldom leads to a complete and consistent combined view. Taking both, the static process definitions and the dynamics of project management, into account, integrated management of all life cycle processes is achievable in a process oriented manner.

The process standardisation concept should segregate clearly between static process definitions and the dynamic workflow elements to run and control a project for good understandibility. Furthermore, it should ensure a complete and consistent implementation of process orientation as defined above.

Supported System Life Cycle Processes. Optimal acceptability of any procedure is achievable if those who have to take the effort do also profit from it equivalently. However, this optimum is not always achievable considering the nature of the various life cycle processes.

By definition, the proposed standardisation concept for non-standard development projects cannot be focussed on the technical contents of a project, but concentrates on project management. Thus, project management processes are supported primarily, while all development processes should benefit due to improved project awareness and enhanced reporting resulting from a standardised project framework.

Following the definitions from ISO 15288 (ISO 2000), the proposed standardisation concept is suited to support the so called project processes. Because the risk management process is directed mainly to the development results, it is more concerned with the technical contents and is therefore an exception in the group of project processes. It benefits indirectly like the defined group of technical processes. The other project processes should be supported as detailed below.

Planning Process. The process standardisation concept should provide procedures to define project activities and to identify work packages in a process oriented manner in order to generate all required configuration items and deliverables. For the items defined, time and effort planning should be accomplished transparently.

Assessment Process. The process standardisation concept should support the assessment process by a versatile and comprehensive strategy for project status accounting that may be implemented easily.

Control Process. Again, the status accounting strategy should provide the backbone for efficient process control.

Decision Making Process. Like for the technical processes, the framework provided by the process standardisation concept should be helpful to control the decision making process, and to record any evaluation results and the final decisions. In case of non-technical decisions (e. g. compliance with schedule and budget), powerful status accounting capabilities should ensure adequate quality of the decisions made.

Configuration Management Process. Because the configuration management process provides services for all other processes, the process standardisation concept should consider easy access to these services in its framework. Thus, the effort spent for configuration management may be minimised accordingly.

METHODS AND TOOLS SURVEY

Methods Overview. During the last decades many methods have been proposed to support the business processes of an enterprise. Various tools have been developed to make a single method or a combination of methods applicable in a real world environment. Due to the advance in systems engineering and due to industrial competition the boundaries between the various tools respectively methods are fading. However, for this survey the following categorisation of project and enterprise management methods and tools may be sufficient (see Figure 1).

Process Modelling Systems. Process modelling systems focus on visualisation and documentation of business processes by describing inputs, outputs and activities as the main elements. Depending on the applied method and tool a more or less comprehensive view on the process is given including objectives, and organisational and product structures. Process modelling tools vary considerably regarding their functional capabilities. The scope extends from “simple” graphical visualisation possibilities to project scheduling support, and analysis and simulation functionality (Negele et al. 1999). Corresponding to the provided functional facilities several modelling techniques have been developed and enhanced. Notations used range from simple graphics to formal mathematical methods and executable specifications (Kawalek, P. 1997). A static view on functions and activities is provided by:

- IDEF0 (Information Definition Exchange Format)
- SADT (Structured Analysis and Design Technique)
- Activity Charts
- Role Activity Diagrams (RADs)
- State Transition Diagrams (STDs)

The specification of dynamic processes can be realised by Petri Nets. More advanced tools combine different views/models, like ARIS (“Architektur integrierter Informationssyteme”), which integrates organisational, informational and functional views, as well as a control perspective.

Workflow Management Systems. Described processes are automated by defining operational semantics. The process can be executed and controlled, while documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules. Workflow Management Systems are therefore limited by the process models they support. Highly repetitive tasks are easier maintained than ad-hoc kinds of processes where no principle can be defined. They also provide varying levels of monitoring and management reporting capabilities. Some are designed for complex decision making encapsulating rules and logic needed for decision support, while others focus on routines and recurring tasks incorporating greater detail about individual activities within the process (Benjamin et al 1999). Corresponding to the diversity of process modelling techniques, multiple approaches have been taken so far to support workflow formalisation: process algebra, state/activity-charts, Petri nets, etc.

Project Scheduling Systems. These systems focus on planning aspects when describing tasks and activities. In principal, three scheduling methods are applied: bar chart (also called Gantt chart) and two network diagram methods - Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM). Nowadays most available planning tools employ a mixture of these original methods to determine the

- critical path
- earliest possible time
- latest time for task initiation
- amount of buffer.

The performance of most scheduling tools is enlarged towards general project management capabilities by providing functionality for resource planning, cost control, status reporting and analytical forecasts.

Enterprise Resource Planning (ERP) Systems. The origins of most Enterprise Resource Planning Systems (like SAP R/3) are cost accounting and finance. But today these systems support the entire spectrum of the enterprise operation that also includes business planning, contract management, production, and procurement. The flow of information concentrates on logistics data associated with parts, schedules, quantities, quality and costs. In other words, ERP Systems are integrated computer applications to plan and support the execution of business functions. In this way, they include project planning and workflow system functionality as basics, but provide enhanced capabilities with respect to capacity and production planning, and logistics in general.

Product Data and Document Management (PDDM) Systems. Today, Engineering Data Management (EDM), Product Data Management (PDM) and EDB (Engineering Database) are used simultaneously to describe the same idea: the management of product definition data in combination with the modelling of business processes (Allemann 1995). Data management focuses on retrieval and viewing of information, while classic configuration management capabilities are included as well, i.e.

- access control
- version management
- change management
- status accounting
- release generation
- archiving.

PDM Systems provide an integrated view of the product by relating its physical structure, functional structure, system architecture etc. Process or workflow management capabilities are included in PDDM Systems to support release, change or distribution processes during the entire product life cycle - from initial concept to product obsolescence.

Figure 1 shows the overlaps of all described systems. The main trends for integration are at the moment:

- Integration of Process Modelling Systems and Planning Systems (Negele et al. 1999)
- Integration of Workflow Management Systems and Process Modelling Systems (Gierhake 1998)
- Integration of ERP Systems and PDDM Systems (Bourke 1999)

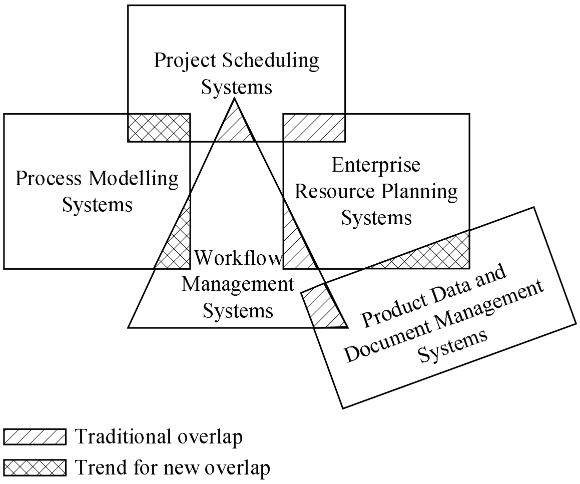

Figure 1. Overlaps of Systems

METHOD EVALUATION

The identified key systems and the underlying methods have been evaluated with respect to the analysed requirements for a process standardisation concept (see Figure 2). There may be particular exceptions of single systems regarding the evaluation result of the whole system category. But, since the variety of each system category is immense, an evaluation can only be brief in this context.

	Process Modeling Systems	Workflow Management Systems	Project Scheduling Systems	ERP Systems	PDDM Systems
Adaptability	++	+	++	+	+
Project Awareness and Reporting					
Project Framework Definition	++	+	-	-	+
Internal and External Awareness	-	+	++	++	+
Process Orientation	+	+	+	+	+
Supported System Life Cycle Processes	+	+	+	+	+

++: Requirement can be fulfilled +: Requirement can be partly fulfilled -: Requirement can not be fulfilled

Figure 2. Method Evaluation Summary

Adaptability. All systems are adaptable with respect to project specific customisation requirements and existing organisational process capabilities. Assuming that there is no request by a certain standard for the application of a particular method or tool, all systems can be regarded as adaptable to development standards in general. Even though, in any case the underlying methods may be more or less appropriate for specific projects, and the effort for customisation differs significantly between systems. It is quite clear that systems, like ERP Systems, PDDM Systems or Workflow Management Systems, which have an enterprise wide focus, require a lot of energy to be adapted to individual projects. This is also true, if the need for customisation has evolved in order to meet company process capabilities or to comply with certain standards.

Project Awareness and Reporting. Regarding this requirement, the support of a static project framework definition has to be distinguished from the capability of the evaluated systems to enhance the internal or external project awareness. Process Modelling Systems are suitable to establish a project framework definition and its documentation. But, they are very limited with respect to status accounting and dynamic project awareness. Project Scheduling Systems and ERP Systems are the opposite. They focus on the assessment of the project status with respect to time and cost control, but are restricted in supporting a generic overview of the project framework. Workflow Systems and PDDM Systems provide functionalities somewhere in between. They can be used for project framework definition to some extent, as well as for status accounting and reporting. But, in any case the other systems concerned provide more capabilities regarding both aspects.

Process Orientation. None of the identified systems is based on a method, which clearly differentiates between static process definitions and dynamic workflow aspects. PDDM Systems comply in a way to the concept of static and dynamic processes by their configuration management capabilities. For baseline definition they distinguish between incremental product changes that constitute the elements of the dynamic workflow and the baseline documentation itself which is part of the static process. The other considered systems allow to map static processes as well as dynamic processes in the same way. The applied methods do not segregate between a dynamic workflow model and a static process map. Accordingly, both process types can be generated, but a distinction between them is not explicitly made. This results in a limited capability to integrate both process types in a clear and transparent way.

Supported System Life Cycle Processes. Evaluating the identified systems with respect to their support of system life cycle processes, it becomes apparent that all of them support different individual project processes to some extend. For example, Project Scheduling Systems have capabilities regarding planning processes and control processes, and PDDM Systems are used for configuration control obviously. Decision Making Processes and Assessment Processes are supported by the considered systems as they store and handle the data, which is used as basis for those processes or to manage them. However, none of the considered systems provides support to all individual inter-linked project processes to facilitate in this way an integrated view on all of them.

Summary. None of the evaluated systems provides the methods to meet all requirements for the envisaged standardisation concept. The deficiencies are manifold and cannot be allocated to a certain requirement. Even though, the requirements for adaptability, process orientation and support of system life cycle processes are more or less met by all identified systems. Regarding the capabilities of the systems, Workflow Management Systems and PDDM Systems provide functionalities in all requirement areas, but not to a sufficient extend.

PROPOSED PROCESS STANDARDISATION CONCEPT BASICS

Process Standardisation Approach. Starting point for the proposed approach to process standardisation is the customer and his satisfaction with the delivered Product. On an engineering level, this is equivalent to the features and the performance of the envisaged system (see Figure 3). At least a rough understanding of the system functions and their decomposition is required when a project is launched. For safety critical applications, the criticality level of the system's functions and of the system's sub-systems and components has to be determined. In addition, clarity should be available by which technologies the system will be implemented.

In a second step, the processes required to develop the system are defined statically. The objectives of each process should be clarified and the process should be refined to a number of sub-processes and basic activities. The inputs and outputs should be identified. Assumed that a process contributes significantly to the definition of the product, the inputs and outputs should be essential for a complete description of a system release and may be subjected to continuous updates in case of changes to the system definition. Personal responsibilities should be assigned. Finally, standards, procedures, methods, and tools have to be identified that are used by the particular process. Although processes from successful projects may serve as a template for new projects, the standardisation concept per se should not impose any unnecessary constraints.

On the lowest level, a set of basic rules regarding project and configuration control, time and resource planning as well as status accounting should be defined. All this may be named basic workflow definition. The basic workflow definition is not directly dependent from the system definition, and should be invariant with respect to the specific characteristics of a project.

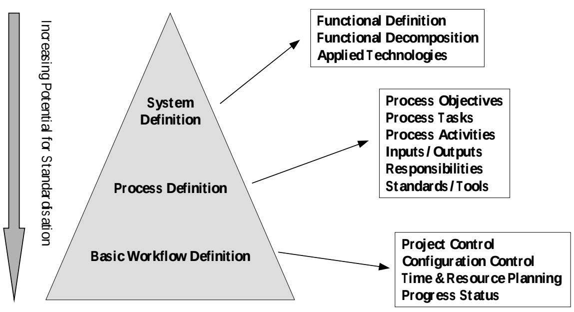

Figure 3.
Process Standardisation Approach

Main Standardisation Concept Characteristics. The proposed standardisation concept consists of a documentation standard for process definition called process definition model and a fully featured basic workflow element called the basic workflow model. The process definition model fulfils the following purposes:

- establishing organisation-wide common documentation rules for process descriptions
- generation of project plans (Development Plan, Configuration Management Plan etc.) in a standardised format
- mapping of process definitions to a basic workflow for a defined work package

The basic workflow model comprises a simple project independent workflow scheme usable for ad-hoc activities as well as more or less complex processes defined according to the process definition model. On the basic workflow level project and configuration management functions are hosted including:

- time and resource planning capabilities
- recording of actual achievements and the effort spent
- progress status monitoring
- comparison between time schedule and actual achievements
- comparison of the actual effort against the planned effort and the available budget

Proposed Tool Architecture. A tool architecture (see Figure 4) implementing the process standardisation concept should consist of a common data repository and several graphical user interfaces for process definition and basic workflow management. The data repository should comprise all data required for navigation between process definitions and the basic workflow, and all project management data including planning information and actual achievements. It is not necessarily required that all descriptions are stored in the repository. Preferably, the repository should refer to information details stored elsewhere.

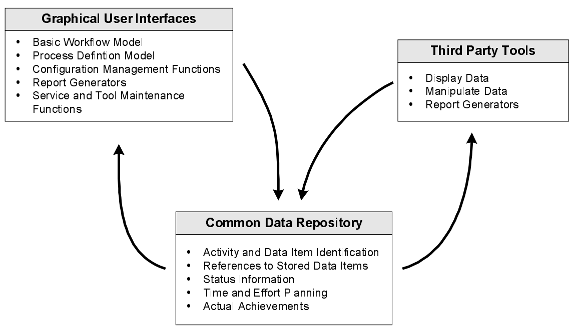

Figure 4. Proposed Tool Architecture

The tool should offer inherent input and output capabilities to display and manipulate all data stored in the repository. However, other management tools may be integrated as report generators and for data manipulation as convenient.

THE PROCESS DEFINITION MODEL

General Considerations. Process modelling systems may rely on a recursive refinement structure with the same attributes, or a static hierarchy featuring pre-named levels and specific attributes on each level. A mixture of both principles is also possible.

The process definition model chosen for the proposed standardisation concept is of the second kind for the following reasons:

- A limited number of hierarchical levels enforces a simpler project breakdown structure.
- The intended interpretation of the nodes and links may be defined differently on each hierarchical level to cope better with real world situations (e. g. strong transition criteria on higher levels, weaker transition criteria on lower levels).
- For searching a particular piece of information, it is clearly defined to which level the corresponding attribute belongs.

These features enhance the overall transparency and understandibility paired with a remarkable degree of similarity regarding the representation of non-standard development projects.

Project Breakdown Structure. Figure 5 shows the project breakdown structure of the process definition model. The top node represents the whole project.

For complex development efforts, the project may be broken down to sub-projects. Each sub-project comprises a group of processes that are interconnected and that are manageable separately from other processes. Examples are two subsequent development phases each adding new functionality to a system, or an assurance process that may be performed independently from the development process.

Below the sub-project level, individual processes are defined. In this instance, the term process is used for a set of linked activities providing a significant contribution to the system under development. Consequently, the outputs of a process have to be referenced by the system release documentation. In other words, they are work products that have to be under strict configuration control. The interconnections of processes represent the work product flows respectively the flow of work product increments. Associated with these interconnections are strict transition criteria. A process can only be entered, if the maturity of the input work products is declared to be sufficient.

Processes should be refined to sub-processes. Sub-processes are more or less a pure means to structure processes.

On the lowest level, process activities have to be defined. A process activity comprises a single entity like the generation of a change or a change review. The process internal interconnections between process activities define a logical dependency without pre-defined transition criteria. It is the process activity level that may be mapped to the activity categories defined by the basic workflow model.

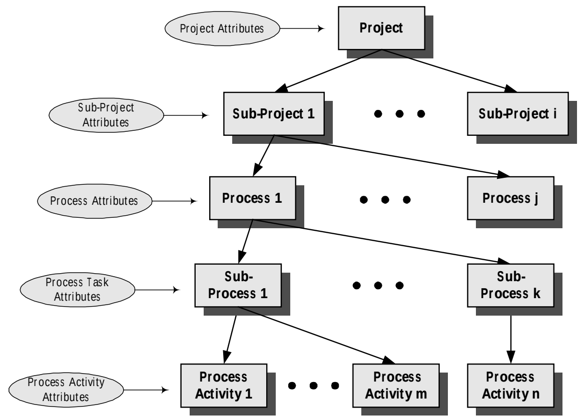

Figure 5. Project Breakdown Structure

THE BASIC WORKFLOW MODEL

Overview. The basic workflow model features a simple and generalised workflow template. The template is at least appropriate for managing system development projects, but may also be adequate for other project types.

The basic workflow model may be used in conjunction with the process definition model or on a stand-alone basis. However, the stand-alone mode is only recommended for the control of simple projects or ad-hoc activities.

To commence any work the basic workflow defines a trigger. Triggers are named by the generic term 'product report' (see Figure 6). In the real world product reports may range from requests for embodiment of intended functional increments to problem reports raised during development or a later life cycle for notification of any observed deviation.

The basic workflow model comprises six activity categories. Three of these are concerned with generating development results while the other three are dedicated assurance activities. Each of the generation activities is followed by an associated assurance activity. Thus, the basic workflow model enforces quality control of all development results, but does not imply any assumptions on the contents of the assurance activity.

One activity pair, consisting of a 'product evaluation' and at least one 'product evaluation review', comprise the 'evaluation and concept life cycle'. The evaluation and concept life cycle is not directly concerned with changing the contents of a work product. Instead, it covers all preparatory work performed prior to the generation of an actual change including evaluation of optional alternative solutions for a given requirement, relevance of a problem report etc.

The actual change is defined and incorporated into an existing work product baseline by the 'change generation and implementation life cycle'. Within this life cycle a distinction is made between the definition of the change and the baseline incorporation for the following reasons:

- A work product may consist of more than one configuration item and a generated change may lead to updates of more than one of these configuration items.
- Several changes may be bundled to create a new version of a configuration item.
- An approved change may be set valid to commence changes to subsequent work products without being incorporated into the baseline.
- The incorporation of several changes into a work product baseline may have to follow a certain embodiment sequence.

So called 'project and configuration control boards' should control all workflow activities associated with a product report. Project and configuration control boards are defined on the sub-project level according to the process definition model. As a guideline, the responsibles for the processes of a sub-project should be members of the particular project and configuration control board.

The last element of Figure 6 to be explained is the 'product library'. The product library is concerned

- with storage and identification of all data items,
- with building releases, and
- with maintaining all data in the product library during their specified life cycle.

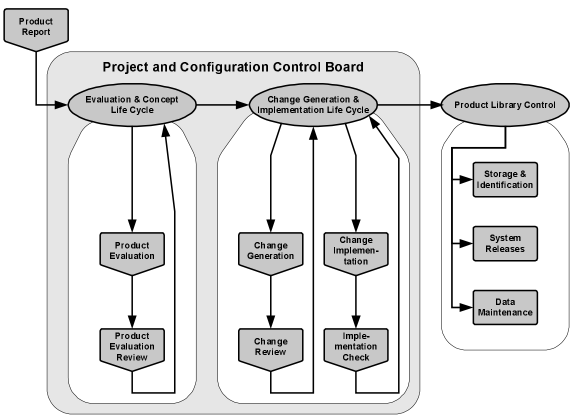

Figure 6. Basic Workflow Model

The product library may be actually implemented by a product data management system or any other suitable configuration management tool.

Basic Workflow Sub-Models. The basic workflow model is organised in a core model and various sub-models. This segregation is introduced for the benefit of a tool that implements the basic workflow model.

The core model provides the means to identify the item and to hold basic descriptive information. The core model alone offers nearly no project management capabilities. To be useful one or more sub-models have to be invoked.

The data access model provides the means to get the data items referenced in the repository. The core model and the data access model together define the main configuration management framework of the basic workflow model. All other sub-models address certain more or less independent project management aspects.

The state progress model defines the possible states for product reports and all activity categories. A tool that implements the basic workflow model should store the current date if the state of an item is changed.

While the state progress model records the actual achievements, the time planning model offers the capabilities to establish a time schedule. Baseline as well as updated planning dates should be retained by the time planning model. The time planning model comprises the functional capabilities to cope with the following two conflicting requirements. On the one hand, time planning is intended to be process and not budget oriented. On the other hand, a time schedule should be established quite early although some activities may not be defined completely. The time planning model and the state progress model together provide the status accounting functionality with respect to time planning.

The effort-planning model comprises the means for baseline and updated effort planning as well as for recording the actual effort spent. Like the time planning model, the effort-planning model has to address the conflicting requirements stated above.

More detailed effort planning capabilities are provided by the resource allocation model. This sub-model allows effort allocation and recording for individuals.

The resource allocation model is the only sub-model that requires the invocation of another one. A project organisation may select the sub-models appropriate for its process capabilities and should omit those that do not boost efficiency, but are currently more a burden. The remaining sub-models may be subsequently invoked when the process capabilities have adequately matured. Various improvement strategies may be followed dependent from the goals of the organisation and particular project needs.

Formal and Informal Life Cycle Data. The life cycle data generated during development may be basically categorised as formal or informal. These terms have been introduced to express fundamental differences regarding the purpose and the validity scope of the data. Formal life cycle data

- comprise all work products that together establish a complete description of the developed system
- are the building blocks system releases are derived from
- have to be baselined and incrementally updated to provide a true description of all system releases and the development progress
- have to be retained for the whole system life cycle

Informal life cycle data cover all other data generated that do not fulfil the criteria stated above for formal life cycle data. In particular, informal life cycle data

- are not necessarily related to a specific work product, but to an activity category of the basic workflow model
- are not required for a complete system description, but are of value to track the involvement of system features and therefore support system understanding
- may inherit a limited validity scope for their direct context only.

According to Figure 7, work products constitute the top-level formal life cycle data category. A work product may consist of several items that are taken under configuration control separately. For example, the work product source code may comprise several files configured independently from each other. As another example, a system development plan may be split in the configuration items main body, organisation chart and time schedule for convenience to address different update cycles of the particular contents. Finally, configuration items may exist in several versions for the initial version and later updates. Work products, configuration items and versions are related in a one-to-many tree structure.

In real world projects, informal life cycle data may be more or less well structured. To enforce project transparency with respect to the technical contents the proposed standardisation concept defines informal life cycle data types in accordance with product reports and the six activity categories of the basic workflow model. In addition, the validity scope of all informal life cycle data follows a simple rule. The data is valid in a product report context only. However, if the scope has to be widened this has to be stated explicitly.

The relations between the informal life cycle data types are as followed:

A product report may require more than one product evaluation. Each comment and response sheet is handled as a separate data item. Thus, product reports, product evaluations and product evaluation reviews are arranged in a hierarchical tree structure.

A change request may be caused by more than one product report. Because a product report may lead to changes to more than one work product and an individual change request can only be related to one work product, product reports and change requests are connected by a many-to-many relationship.

Implementations are linked to versions by a one-to-one relation. Because more than one change request may be incorporated for a version update, change requests and implementations are connected by many-to-many relations.

The relations between change requests and change reviews as well as between implementations and implementation checks are equivalent to the relation between product evaluations and product evaluation reviews.

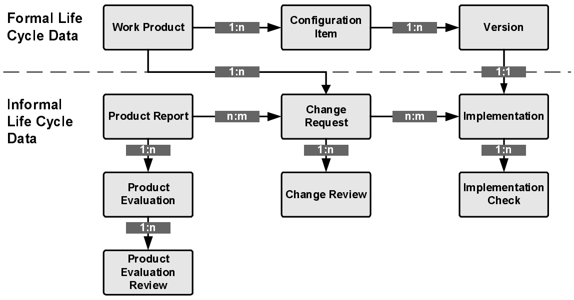

Figure 7.
Formal and Informal Life Cycle Data

CONCLUSION

The proposed standardisation concept demonstrates that the various requirements from the requirements analysis can be fulfilled in an integrated and project oriented way.

To validate the concept further, the basic workflow model has been implemented as a database application. This implementation is used on a trial basis in a major development programme. From the experience gained, a better understanding of reasonable user modes, adequate reporting features and efficient process improvement strategies is expected. A future publication may report on the findings.

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