ITEM LIFE CYCLES IN PRODUCT DATA MANAGEMENT: A CASE STUDY ON HOW TO IMPLEMENT A DESIGN DATA VALIDATION PROCESS

Bertrand Nicquevert[1,2,3] and Jean-François Boujut[3]
(1) CERN, Geneva, Switzerland (2) *Med*Austron, Austria (3) G-SCOP, Grenoble Institute of Technology, France

ABSTRACT

At the start of a new design project, product data management (PDM) system is one of the first to be implemented. Soon the design has to be shared, released or approved, either for prototyping or manufacturing, and the PDM system has to fulfil the not always explicit requirements of the users. This paper describes what has to be implemented at the early stage of a new design project in order to get an actual use of PDM. It is based on a real case study in 2010 for a new project in a new organisational structure, with new tools and new processes applying to new team members. The process of implementing and using a PDM system from an existing and well established software vendor is described, covering not only the classical title blocks for 2D drawings, but the release of 3D models and the relationship with the item approval. The proposed item-centric approach helps the designers, engineers and managers to make a proper distinction between the life cycle of the item and the life cycles of the CAD-entities that describe it, to assign the adequate status to these entities, depending on their maturity level, and to build up a common shared representation.

Keywords: Product data management, drawing title block, release and approval process, project management, item-centric system

1 INTRODUCTION: A DESIGN DATA MANAGEMENT PROJECT

Most modern design projects take into account the implementation of a product data management (PDM) system. When the design project is run within an existing organisation or a given company, the existing corporate system is of course used. Sometimes, however, design project starts outside of any pre-existing structure. This is of greatest interest from the academic point of view: the emergence of such an organisation better highlights the difficulties to be overcome than those met with the mere adaptation of an existing context.

The case studied in this paper belongs to this category. In this first section, we shall briefly describe the context of the overall project in which the design project takes place, and depict the organisation that was put in place around the existing PDM software. By contrast, it shows what areas are not covered, and delimits the area in which the design data management project (DDMP) had to be developed. However, describing the whole deployment of this information system goes beyond the scope of this paper. We shall focus on one of the many issues to be tackled in a DDMP: the process of design data validation.

The aim of this paper is to present the method used to approve design data and how it was developed. It is based on backgrounds on maturity of information, design spaces, intermediary objects and frames for cooperative actions. We demonstrate that the state of a document is not sufficient to manage the design data, and that the use of the item life cycle, not yet well spread amongst design teams, solves this lack and is of clear added-value for setting up a common representation of the data management process for the various stakeholders.

Our case study is hosted in *Med*Austron project. “*Med*Austron” stands for Medical Austrian Synchrotron. This is a large complex project, consisting mainly of a particle accelerator and several irradiation rooms in order to treat cancer tumors by protons and ion bombardment. It is composed of bending and focusing magnets, power converters, beam diagnostics devices, high vacuum system, as well as medical systems. All these components have to be installed, serviced and operated as a global system, ensuring the highest quality of beam with quite demanding safety issues. The MedAustron project benefits from a technical partnership with CERN, the well-known particle physics laboratory in Geneva, Switzerland. The principle of this partnership is to allow experienced staff from CERN to coach the younger members of MedAustron team during the design, procurement and commissioning phase, with the aim of letting them later operate the equipment autonomously. The project is due to deliver its first beam to irradiation rooms in 2014.

Given the constraint that the MedAustron project must run in full autonomy as soon as 2012 (start of the installation phase in the Austrian premises), the processes, software, tools and best practices of the CERN design offices could not be used directly for the project. In addition, the design effort being rather short – two to three years – it was out of question to proceed to specific developments around a PDM tool. Therefore the design and integration team had to face a challenging situation: around a software chosen and introduced by the project management upon basis of non-technical criteria, a brand new complete implementation of the design data management structure had to be launched in 2010, in parallel with running the design project itself. Implementing and customising the commercial software, defining the data model, inventing the rules to be applied, training designers, educating engineers, solving the relationships between all these entities, both human and digital, all this while producing real design data and managing them as the need arises. It is our belief that this situation is not a specific one, and that the lessons of this case study can be applied to any design project not hosted in a pre-existing organisation. This paper shows in addition that, contrarily to what can be thought, taking a software and using it 'out-of-the-box' is not a straightforward operation, and that it deserves specific care.

2 METHODOLOGICAL APPROACH

This paper is part of a wider research project whose aim is to conduct a qualitative multiple-case study, as categorised by Yin [1]. The question addressed is the role of the so-called technical manager in complex projects, either due to the complexity of the deliverable, or to the complexity of the organizational context, or both. This paper deals with one of these multiple-case studies, namely the implementation of a PDM system as introduced above. The other linked cases of our multiple-case study cover the field of space management in a particle physics experiment [2], of project management of mechanical parts design and procurement [3], and of flow management of heavy fragile magnets.

2.1 Our case study within the frame work of Design Research Methodology

In order to adapt the case study research to the field of design, we follow Blessing's Design Research Methodology (DRM) as articulated for instance in Bender et al. [4]. A first study on a given case is an a priori analysis called “Type I descriptive study”. Then, a “Prescriptive study” is derived from the lessons of this first descriptive study, which feeds a “Type II descriptive study”, this latter aims at analysing a posteriori the same case, where the differences with the first project are scrutinised.

This paper belongs to this last category. It is based on a “Type I descriptive study” extracting some key success factors out of the example of the implementation of a PDM tool in a large research organisation [5]. The part devoted to the Prescriptive study is based on frameworks established by Lécaille on design spaces and traceability [6], Blanco on maturity of information [7], and Boujut on the frames for cooperative actions [8], and completed by the learnings of our Type I descriptive study [5]: proceed by a doing/learning strategy, and get a sufficiently high level of decisional power and wide range of skills in the hands of the leader(s) of the data management project.

The case we address deals with the effective implementation of a PDM system. After a presentation of the context, we focus on one crucial dimension of the implementation process of the management system of design (or engineering) data, how to deal with the validation of these data. Our research question is: *How is the validation process established, as a way to share information throughout the project, and how to make the adequate level of representation of this validation process appear.*

Our answer is that, in order to improve the approval process, it is crucial to properly identify the validated entity and the aim of the approval process itself at a given time: the design data cannot be approved as such, but only for a given phase of the project, and in strong conjunction with the approval of the item they are supposed to describe (the item being seen as an element class, a pattern for a given product).

In a more general way, according to the work on design method development as in Teegavarapu et al. [9], we may even consider the implementation of the approval as a design process itself, of an organisational nature. The particular position of one of the authors is detailed in the next section. It gives access to data from inside of the project of implementation of the PDM tool, for which he has held a leading position since early 2010. All this work constitutes action research, following the recommendations of Avison et al. [10], taking into account the complexity of the systemic modelling as conceptualised by Avenier [11].

2.2 An adequate decisional perimeter

The first author of this paper is in charge of the work package “integration” of the project. Amongst many other things, he is in charge of the design office, and the definition and implementation of the overall strategy for the management of data falls within his scope of supply. It is defined in an internal document, “Job Description of the MedAustron Integration work package leader”:

- *Supervise CAD application environment implementation, establish storage environment for engineering data with access rights, and implement approval process with versioning*
- *Implement workflows for teams involved related to integration and design work*
- *As part of the design coordination task: technical document preparation for evaluation, approval, tender, production (and follow-ups) for all MedAustron work packages*

This part of the work package is a project in itself, called “Design data management project” (DDMP). This project is included within a much wider work package, comprising overall integration of the MedAustron project, design studies, and installation coordination. As a consequence, within the framework of this work package, most of the key stakeholders are included: designers themselves, some engineers, and computer scientists in charge of CAD and PDM implementation. The work package holder, being a member of the project management board, is well located to discuss and “sell” the solutions to his peers from other work packages and to the project management. His decisional perimeter is therefore well placed for an efficient implementation of the proposed solutions.

3 THE ONLY VISIBLE PART OF THE DESIGN DATA MANAGEMENT PROCESS: THE TITLE BLOCK

In this section, the first step of the DDMP is reported. It consists of the formalisation process of a shared representation: the drawing title block. In this first step, the information choice and sorting were thought to be a sufficiently practical solution to answer the question: How do I trace the drawing status, once printed on paper? The selection of fields to be shown is described, as well as the somehow classical dynamic process of drawing approval, and a new improved layout of title block is proposed, aiming at supporting the PDM functionalities and easing a common understanding between the various stakeholders. Limits to this model are finally emphasised.

3.1 The title block as a classical support for CAD documents metadata

A technical drawing must contain a title block (i.e. a legend) that allows its identification in a database. According to ISO standard 7200:2004 [14], it is a table-like form, composed of various rectangular fields. It should contain at least three fields that provide the following information: the drawing identification number, the drawing title, and the drawing owner. Most of the time, the title block provides some other fields for additional information. Standards, while giving some precise prescriptions to follow, actually leave a lot of freedom (see Figure 1). During the MedAustron DDMP, one of the very first required steps was to define the layout for the MedAustron title block. Following the standards, there is a very limited amount of information required, and their order is not defined. Moreover, it has to contain the drawing number, whose format and scheme had to be defined as well.

3.2 Drawing numbering scheme and naming convention: beyond breakdown structures, towards meaningless convention

One of the recurrent questions at the beginning of a data management project is the drawing numbering scheme, and the naming strategy of objects. Quite often, the naming convention is PBS-oriented, following the Product Breakdown Structure. However, there may be various contradictions between PBS, ABS (Assembly Breakdown Structure), and even OBS (Organisational Breakdown Structure) or other kinds of breakdowns [15]. Giving a PBS-oriented name to an object means classifying it only along one given BOM-structure. There are two major problems linked to this strategy. First, if the same object has to be re-used in another assembly, then its name would have to change even if the design is exactly the same. And second, how to name a super-assembly of objects, and how to ensure the link between PBS and ABS.

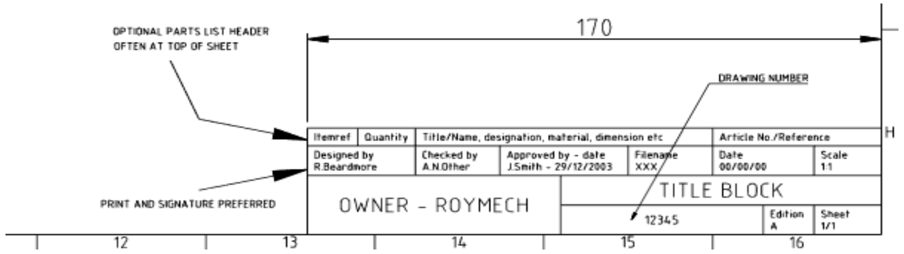


Figure 1: Typical example of a title block (from http://www.roymech.co.uk)

Let us give an example. A dipole magnet is made of three parts: the magnetic device, the vacuum chamber, and the support. According to the PBS defined by the project naming convention (defined in an internal project document “Naming convention of the MedAustron accelerator complex”), the magnetic part has a code MBHC – standing for “Magnetic Bending Horizontal with C-shape yoke”. And the vacuum chamber is called VCEA – standing for “Vacuum Chamber Elliptic Aperture”. Because the function is defined by the magnetic part, the whole assembly is usually called “the magnet”. But how to name the assembly? Should it be magnet oriented, or vacuum oriented? And how to call the supports, which in addition are used for other devices than this magnet? The PBS is more a kind of FBS (Functional Breakdown Structure), widely inspired by the definition of the accelerator complex following the requirements of the beam optics. When a given assembly spreads over several work packages, the PBS no longer operates, because it conflicts with the OBS. The naming convention has to deal with this limitation. This is the reason for the choice of a “meaningless” numbering scheme; meaningless in the sense that the meaning is not given in the name itself. The number acts only as a unique identifier, all the other information is then managed in and by the PDM system. The prefix designates the project: a two-letter prefix, MA for MedAustron. The remaining part of the name is a seven-digit running number, automatically assigned by the CAD and PDM management system. A typical name is therefore MA-1234567. This number is the number of the item, and the item structure is managed by the PDM system. A drawing describing an item therefore holds the same number as the item it is assigned to, with file extension suffix depending on the CAD software.

3.3 Fields of a title block reflecting the initial approval process

The initial approval process of a drawing was assumed by the project team to be made of four usual linear phases – preparation, quality control check, engineering release, and approval. The drawing is first created by a designer or a draftsman, starting from a 3D model. The drawing is then submitted to a checker, whose role is to check the quality of execution of the drawing (respect of standards of representation and of tolerancing). Once checked, it is transmitted to the engineer in charge, whose role is to validate that the solution expressed by the drawing fits correctly the functional requirement. And finally, the project leader (or equivalent) releases the drawing for manufacturing. This initial model was used to create the layout for the title block.

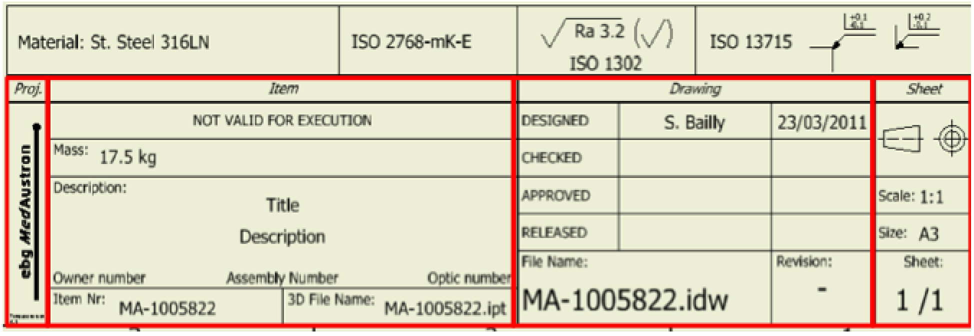
Four pairs of fields show in the title block the release steps of this process on the drawing sheets themselves (with one minor constraint: all sheets of the same drawings follow the same life cycle). These four pairs of fields are: name of the designer and date of the start of the design; name of the checker and date of the check; name of the person responsible for the release and date of the release; and at last, name of the approval leader and date of the approval. This last phase triggers the change of the status stamp “Not valid for execution”.

3.4 Title block layout

The drawing is seen here as an intermediary object [16]. The concept of intermediary object introduced in design studies field by Jeantet [17], and adapted to the framework of mechanical design by Boujut and Blanco [8], was built “to inform the notion that those artefacts are simultaneous representation of the future product and mediation through different actors”. As artefacts, they need to be identified, hence the question of the naming described above (they are “equipped”, according to the proposal of Lécaille [6]). As mediating objects, their identification must contain a state indicating their degree of maturity. For a drawing, all the information is contained in the title block.

The layout of the title block is not defined in standards, and there is a huge diversity in title block layouts from various companies or organisations. The main drawback of “typical” title blocks as described in section 3.1 is that they mix various levels of meaning. Some fields of information relate to the drawing itself – that is, to its printed copy; some others deal with the 2D document – that is, the electronic file produced by the CAD software. Others refer to the item – that is, to the type of object under design. Consequently, what is approved when a drawing is approved? For which reason, and at which project phase? With the introduction of PDM software, new questions arise, and the overall question of how to define drawings metadata must be revisited.

For the MedAustron DDMP, an opportunity was given to design the layout from scratch, taking these questions into account. The strategy defined by the work package holder was to use this title block as a tool to set up a representation of the underlying design data management. The layout as shown in Figure 2 clearly makes a distinction between four areas: project, item, drawing file, paper sheet.



Material: St. Steel 316LN
ISO 2768-mK-E
Ra 3.2
ISO 1302
ISO 13715
Proj.
ebg MedAustron
Item
NOT VALID FOR EXECUTION
Mass: 17.5 kg
Description: Title Description
Owner number
Assembly Number
Optic number
Item Nr: MA-1005822
3D File Name: MA-1005822.ipt
Drawing
DESIGNED S. Bailly 23/03/2011
CHECKED
APPROVED
RELEASED
File Name: MA-1005822.idw
Revision: -
Sheet
Scale: 1:1
Size: A3
Sheet: 1 /1

Figure 2: Overall layout of the proposed title block

The first area at left is the identification of the project (or the company). The three others deal respectively with the item (and 3D master file), the 2D file, and the sheet. The nature of these four entities is very different and it is useful to have separate columns. The project or company is of organisational nature, and the title block only needs to refer to it. The item is a managed object that has generic characteristics. This is the "element class", to which a physical real element – the final product – belongs. The 3D file is a CAD-produced file, which gives a (spatial) geometrical representation of the item. The 2D file is another CAD-produced file, derived from the 3D file, which gives a standardised projected geometrical representation of the item; it consists of several sheets – a folder of sheets. The sheet itself is another expression of the 2D file; it is the contractual document, and the only one that can be printed as another physical object, on paper.

These basic definitions can appear straightforward; our experience shows, however, that there is a confusion between these various levels of ontological status. Clarifying this confusion is required in order to elicit exactly the meaning of release procedures. The column "Sheet" shows physical properties of the paper sheet (format, scale). The physical properties of the item (weight) are given in the column "Item", as well as the item life cycle stamp (here in Figure 2, "Not valid for execution"). This layout contributes to this clarification, and introducing this kind of distinction between fields of various nature improved the understanding of the life cycle process in the project. However, this was not sufficient to lead to a satisfactory use, and the next section is devoted to the challenges to overcome, their origin and the way they were solved.

4 FROM TITLE BLOCKS TO LIFE CYCLES: THE ITEM AS A KEY INTERMEDIARY OBJECT FOR A COMMON REPRESENTATION

At this stage of the DDMP, the design office users were able to produce drawings with title blocks. The next question was: How to map properties between the title blocks and the CAD software. In this section, the focus is on the necessary operations which are required to go from theory to real practice, in the real world of real production of data. How to make it so that the system is not only usable, but really *used*; used at all phases of the life cycle, from creation to diffusion of design data, including all necessary collective elaboration, verification and validation phases; and used by all stakeholders, from designers to external manufacturing companies, including engineers and project managers.

4.1 Limitations of the title block

The aim of the new title block layout was to get a tool to make a clear distinction between the item and its representation(s). The life cycle of the item is not the life cycle of its representation(s). The printed drawing is the only physical place where the item status is visible. Hence a regular confusion that this new title block layout was aiming at reducing. This was not the case, due to some limitations.

The first limitation comes from data mapping: the definition of the metadata and life cycle scheme was not the same between CAD and PDM software, title block and actual process. The team in charge of system configuration had to deal with synchronising, when not even recreating all these fields.

The second limitation is the difficulty in producing BOMs (bills of material) directly from the CAD breakdown structure. On Figure 2, above the title block itself, a representation of the BOM is visible, seen as a list of parts with position number (first column), title and quantities, and reference to the item number (last column). The next question is therefore again how to link the information appearing in or above the title block with the fields managed by the Product Data Management system.

The third limitation was the effort for the users to take in hand the overall process of design data management. Users were "lost in translation". Concepts were new, names of metadata were not equivalent from one place to another, etc. And they were not even convinced of the need of a PDM: in the initial phase when implementation of a management system goes together with production of data, and not all features are working, managing data appears somehow as a useless extra task.

Every aspect of the project had to be improved in order to get a working data management environment: the tools, the users' training, the process and procedures. The solution was therefore an overwhelming strategy to clarify concepts, configure and synchronise the tools, promote the use of the item as central concept, model the business process to be implemented, and then define the rights and train all users throughout the overall project. The remaining part of this section reports some issues.

4.2 Clarification of underlying concepts, and prescriptions for PDM features

The data management process is made of several phases. The release of a drawing is the procedure of verification and validation leading from the preparation of a drawing in the private space of the designer to its publication in the more open space of the project. The approval of a drawing is then the procedure through which the manufacturing of the element, as physical object corresponding to an item, is allowed. The drawing is then made public outside the project.

This definition is based on some concepts that need to be explained. Data are prepared, discussed and managed in various working spaces, following various steps of a life cycle. During these steps the data get higher degrees of maturity which are endorsed by a state. We consider that the maturity is not an absolute property, and that data validity does not exist *per se*, but *for* something. That is to say, the data validity is not an intrinsic property of the data, but depends on the step of the design project. We claim that the *status*, the validity of given data, is a combination of its *state* (as seen as its degree of maturity) and of the information on the *step* (the phase of corresponding *item* life cycle).

Working spaces and information maturity

In 2003, Lécaille proposed the concept of design spaces ([6] p. 166): "*A design space corresponds to the moment when the need to keep an object for oneself or not emerges, to convince oneself or other stakeholders of what is represented, to have to coordinate or to request approval of others. In connection with these actions, the design spaces indicate the frame of possible exchanges of the given objects.*" Three design spaces are initially introduced: personal, collective, and project. In order to increase their degree of maturity, the intermediary object needs to cross these various spaces. Grebici

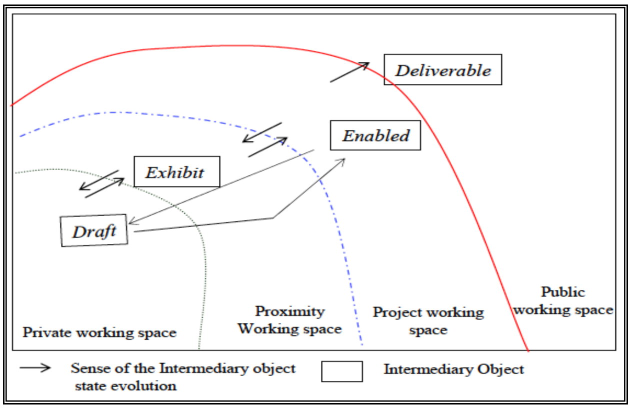


Figure 3: Theoretical model of the maturity evolution of an intermediary object during a design phase (according to [18], derived from [6])

et al. [18] later extended the concept by speaking of working spaces (*private*, *proximity* and *project*), and adding a fourth one (*public*). The Figure 3 gives a graphical representation of these various spaces. Each time a border is crossed, the intermediary object is *equipped* in order to bear an additional state, from *draft* (in private space) to *deliverable* (in public space), passing by *exhibit* (in proximity space) and *enabled* (in project space).

We see the PDM role as a keeper of tracks for these back-and-forth border crossings (who was the “customs officer”, when the “passport” validation was done, by incrementing which revision index). The limit of this model is that it applies to the state of the intermediary object. We do not think that there is a fully bidirectional equivalence between the state and the position in the working space. During the design loops that occur as long as the intermediary object is open to modifications, it is rather true. But at he last stage it is considered as a completely frozen (so-called “closed”) intermediary object. Yet once the last border (between project and public spaces) has been crossed, a deliverable can still evolve, and restart (with a new revision number) a new life cycle. In between, something has evolved: this is the item status, which has increased by a new step and will keep it for ever in its own life cycle. Hence our proposal to enrich this theoretical model.

Spaces, maturities and life cycles: how to link them together

We make the proposal that the status of a design data is made of the double information on its state (maturity) and on the life cycle step of the corresponding item. The circulation of intermediary objects between the first three various spaces is tracked by changing the state. Within each space, activities occur: design, or verification. Crossing borders are validation activities. Crossing the last border adds a new dimension: not only are the data validated, but also the life cycle step of the item that they are assigned to. Hence our proposal that:

Status (validity of data) = State (degree of maturity) + Step (phase of item life cycle)

Coming back to the title block, it can be seen that the state is indicated by the number of release steps that are filled, and that the step is given by the stamp “Valid for execution”, all this being done for a given revision index. The only missing information is the revision index of the item. Fortunately, knowing the revision index of the drawing, this information is available from the PDM itself.

This enriched status gives all indication to define the position of an item in the working spaces. We can see it as a kind of “*hypercompass”* in an extended space, the product/process/project space.

4.3 Actual implementation: from theory to action

Design data static and dynamic mapping

Each category of object has its own metadata to describe its name, state. CAD and PDM keep a good link between 3D models and 2D drawings. It is less simple when items are introduced. And the various words used for the same concepts, or mismatches between concepts, trigger misunderstandings and difficulties for users to get to a common representation of the actual underlying design data management process. Table 1 gives an overview of the correspondences to be established between the various fields and concepts, starting from the title block established in the previous section.

At that stage of the DDMP, due to these various mismatches, it was not possible to map directly the CAD/PDM fields into the title block, the tools were not working together. Anyway users were confused between “released” and “approved” states, or even “checked” and “approved”. The content and limitation of each verification phase was unclear. Designers were lost regarding the rules and procedures to follow: when does a new revision number need to be taken; when do they trigger the change from “Work in progress” into “For review” (draft drawing submitted for check – a non-existing step in PDM); how and when do they create a BOM; etc. The difficulty was to synchronise all these fields and names between users' cognitive representation (concepts), CAD tool (database fields), PDM tool (and its own data model), drawing and title block (as intermediary object), and business process (as guideline for users).

It can be seen that, in the column “Data state in PDM”, there is by default no change of state from “approved” (Eng approved) to “released” (Mfg approved) data. Hence the importance of introducing a link between the data life cycle and the item life cycle to fully get the “released” state.

Table 1. Various fields to map and concepts to reconcile

Title block state	*CAD/PDM field*	*Role allowed to proceed with border crossing validation*	*Role name in PDM*	*Data state in PDM after "border crossing" validation*	*Maturity state (according to [18])*	*Design space (according to [18]) after border crossing*
Created	Created by	Designer	Engineer design	Work in progress	Draft	Private
[submitted] – not shown	*[submitted by] – not defined*	Designer	Engineer design	For review	Exhibit	Proximity in design office
Checked	Controlled by	Head of design office	Checker	For review	Exhibit	Proximity in work package
Approved	Eng. Approved by	Work Package engineer	Engineer approver	Released	Enabled	Project
Released	Mfg Approved by	Project leader	Manufacturer approver	Released	Deliverable	Public

4.4 Item life cycle management

Data validation process and management of revisions

This link between the data and the item life cycles is introduced in the management process by imposing that the release of a document can only happen at the time of release of the item. Figure 4, issued from the DDMP, is a trial to represent this link. It shows the coordination of data life cycle phases with item life cycle phase (the little box after the name shows the revision number): no data is fully released, but only approved in a first step. The release procedure of any data is synchronised with the release of the corresponding item. Further revisions of data are linked to further revisions of items through an ECR (Engineering Change Request) procedure.

Many possibilities arise. The co-existence of various statuses of different revisions of the same document can be ensured: for instance, one being in the state "released" for an item in the life cycle step "for prototyping"; another one being in the state "approved" for an item in the life cycle step "preparation of the market survey"; and a third one being in the state "work in progress" for the item in the life cycle step "final manufacturing". Configuration management is at hand!

The initial idea was to drive all design data approval processes through the ECR/ECO (Engineering Change Order) PDM built-in procedure. This is a feature which helps to manage data during the process of design change and revision. Unfortunately, it appears so far that the complexity of such a procedure (which can apply at the same time to several design data and to several items) is high, and the PDM tool is neither linked to the items nor mapped to the database fields of the data themselves. It goes beyond the scope of this paper to further detail the implementation.

Looking back to the title block, the amount of information to be managed is greater and greater, and the wish could be to remove from it all non-necessary information. The usual "revision tables" were not implemented. What is needed (apart from data on paper sheet) is the identifier (number) and the revision index. Even the stamp might be removed! But this would be a too-high loss of information. Anyway, the social acceptance of such an extreme solution is not high enough: users would feel lost without this redundancy and immediate availability of status, not forgetting the requirement to be permanently on-line (but are we so far from this?).

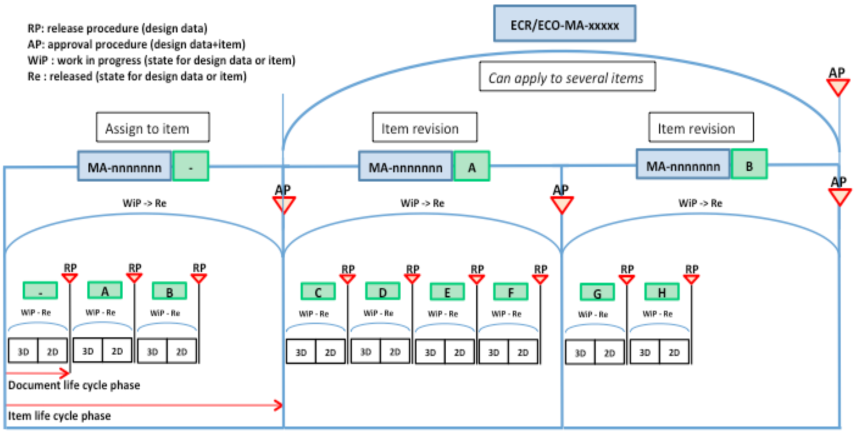


Figure 4: Articulation between design data life cycle and item life cycle

Verification and validation process, design loop and process modeling

Figure 5 gives an overview of the overall process of design data management. It is a simplified view of a full process using BPMN (Business Process Management Notation). The main roles are identified in the four lines of actions (pool lanes): Designer, Checker, Engineer approver, Manufacturing approver. This model is the basis for showing in practice the concept of work spaces and border crossing: work spaces (superimposed to the BPM in Figure 5) are more or less equivalent to the lanes; and border crossings are directly visible and represented by the actions named “Properties to change”.
Behind these roles can stand either one single actor, or a whole group of people involved in the corresponding action. A distinction must be made between two kinds of activity [19]: *verification* activities, happening within a given working space – and for which more than one actor can be involved, allowing multiple points of view in the process; and *validation* activity (a single-actor action), which marks the end of the verification phase, and therefore allows and triggers what we called “border crossing”. In practice, validation of course happens after the verification phase, but the design and verification phases are not sequential, and non-linear. A loop occurs, that we call “design loop”, which cannot be prescribed as a workflow: inside this loop, it is essential for the sake of fluidity of information flow that the design/verification activities not be tracked by the PDM and be let free to stakeholders. This *ad hoc* working space is represented in our BPM by a specific zone which spreads over several lanes. This proposal of extension of the BPM notation is explained in Bailly et al. [20].

What does “release an item” mean

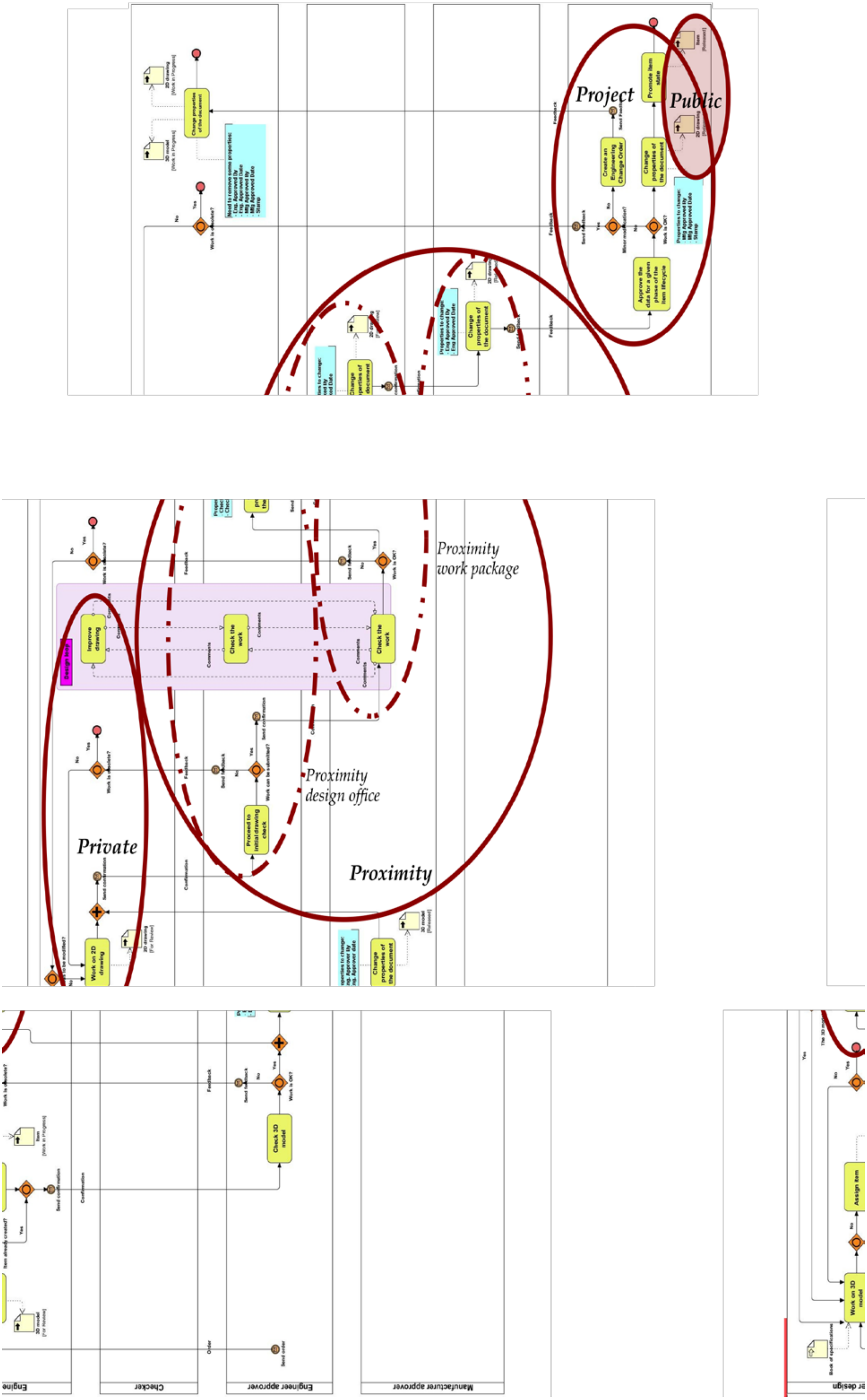
Releasing an item is not as simple as releasing a document. It imposes amongst other conditions that all subitems are either already released or part of the same release procedure; and that all design data (3D model “master”, and main 2D drawing) are previously released. But above all, the process of releasing an item is no longer a simple operation of design data management. This is a project management action, which extends well beyond the framework of the product design. This is one element of what we propose to call product/project integration (see below).

5 CONCLUSIONS BASED ON LESSONS LEARNED FROM THE CASE STUDY

The case we addressed deals with the effective implementation of a PDM system based on an existing software. We mainly focused on the management process of the design data. Our research question was then: *How is the validation process established, and how to make the adequate level of representation of this validation process appear?* We suggest that the status of data is a combination of their state and of the step reached by the item they describe. A model of the process is proposed, underlining the concepts of working spaces and border crossing procedures as a theoretical framework of actual implementation. As a conclusion, we extract some key success factors for a DDMP and open some perspectives on how to proceed to get an improved product/project integration.

5.1 Some key success factors of the MedAustron design data management project

Two key factors are emphasised: the decisional perimeter and management strategy, and the use of process modelling. The work package “Integration” described in the introduction contains all necessary teams and skills below the same project organisation – designers and engineers, computer


Project
Public
Proximity
work package
Proximity
design office
Private
Proximity
Engineer
Checker
Engineer approver
Manufacturer approver

scientists, project managers – for the full life cycle and integration process, from beam optics to installation and non-conformities. This provides a short chain of command and an efficient steering loop. It was therefore possible and easy to adopt a doing/learning strategy: the DDMP developed in close conjunction to the needs and requests of the design project itself, offering a very short feedback loop on both the tools, the procedures and the understanding of the concepts by all users.

The use of BPM (Business Process Modelling) was very fruitful. It allowed one to define the various roles – and even create a new role: data manager. It helped in identifying the phases of sequential and parallel work and the associated workflow, as well as the non-sequential complex design loop. This is a very powerful tool quite useful in formalising, sharing and building-up a common picture amongst all stakeholders.

5.2 Perspectives

The developed process described above is the support and the most visible tool for the convergence of the design process and its link with the project management tools. It is based on the use of the item, which is a concept coming from the ERP world. The BOM (bill of material) seen as a tree of items is one of the main links between these three worlds: design, project, production.

The introduction of the concept of item as a central pivot is the first step towards a global product/production/project integration. Throughout the PDM and the CAD tools, the design handles virtual artificial objects describing the item. Throughout the ERP and the MRP (manufacturing resource planning) tools, the production handles real objects, which instantiate the item. Throughout the PLM and project planning tools, the project handles overall activities over time. With an item-centric view, it is possible to reconcile these various ways at looking at the same object. This is for instance the case with geometrical integration: the item is both carrying the requirements of the users and the spatial envelope (amount of space with interfaces) attributed top-down by the project; the 3D model coming bottom-up from the design; and the manufacturing drawings which are the requirements for production. We are working on an overall global piloting tool based on this hybrid item-centric method, which would help the project management to get an integrated view of these three dimensions, and provide a full product/process/project integration

ACKNOWLEDGEMENTS

The first author thanks S. Bailly for having prepared the Business Process Models; F. Luiz for the title block template design; and both for being real active members of the MedAustron DDMP. Thanks as well to all MAID members for feedback and participation in the doing/learning process, and to M. Benedikt (MedAustron project leader) for having given him a free hand. Finally, thanks to R. Saban and S. Baird (CERN Engineering department head) for their support and understanding; and to S. Chemli (CERN configuration management team) for endless discussions.

Both authors thank P. Lécaille for his friendly advices and exchange of ideas.

REFERENCES

[1] R. Yin, *Case study research : design and methods*, 4th ed, Los Angeles: Sage Publications, 2009.

[2] B. Nicquevert, “Intégrer un détecteur de physique des particules dans sa caverne ou Les défis de la gestion d’espace autour de repères multiples dans des grands projets innovants,” in *Repères et Espace(s). De la pluralité à la polysémie*, Sous la direction de Barbara Aiosa, Faïza Naït-Bouda et Marie Thévenon., Grenoble: Presses universitaires de Grenoble, 2010, p. 139-146.

[3] B. Nicquevert, S. Yami, M. Nordberg, et M. Boisot, “From Russia With Love: A Contributing Country Perspective, chapter 9,” in *Collisions and Collaboration: Managing Big Learning from Small Events in the ATLAS Experiment at the LHC*, Boisot M., Nordberg M., Yami S. & Nicquevert B. (Eds)., Oxford: Oxford University Press, under press, 2011.

[4] B. Bender, T. Reinicke, T. Wünsche, et L. Blessing, “Application of methods from social sciences in design research,” presented at the Design 2002, Dubrovnik, 2002.

[5] B. Nicquevert, J. Boujut, et S. Yami, “Design process modelling and complexity: which key success factors for the implementation of a PDM tool?,” presented at the Design 2010, Dubrovnik, 2010.

[6] P. Lécaille, “La trace habilitée, une ethnographie des espaces de conception dans un bureau d'études mécaniques: l'échange et l'équipement des objets grapho-numériques entre outils et acteurs de la conception,” Thèse de doctorat, INP Grenoble, 2003.

[7] E. Blanco, K. Grebici, et D. Rieu, “A unified framework to manage information maturity in design process,” *International Journal of Product Development*, vol. 4, n°. 3, p. 255, 2007.

[8] J. Boujut et E. Blanco, “Intermediary Objects as a Means to Foster Co-operation in Engineering Design,” *Computer Supported Cooperative Work (CSCW)*, vol. 12, n°. 2, p. 205-219, Juin. 2003.

[9] S. Teegavarapu, J. D. Summers, et G. M. Mocko, “Design method development: a case study and survey,” presented at the Tools and methods of competitive engineering : proceedings of the Seventh international symposium on tools and methods of competitive engineering - TMCE 2008, Izmir, Turkey, 2008.

[10] D. Avison, F. Lau, M. Myers, et P. A. Nielsen, “Action research: making academic research relevant,” *Communications of the ACM*, vol. 42, n°. 1, p. 94–97, 1999.

[11] M. J. Avenier, “Designing a Collective Undertaking and Systemic Modelling: Potentially Fertile Concepts,” presented at the 5th European Systems Science Congress, Crete, p. 14–19, 2002.

[12] *ISO 5457:1999 – Technical product documentation -- Sizes and layout of drawing sheets*. 1999.

[13] L. Najman, O. Gibot, et S. Berche, “Indexing technical drawings using title block structure recognition,” in *Document Analysis and Recognition, 2001. Proceedings. Sixth International Conference on*, p. 587–591, 2002.

[14] *ISO 7200:2004 – Technical product documentation - Data fields in title blocks and document headers*. 2004.

[15] A. P. Hameri et P. Nitter, “Engineering data management through different breakdown structures in a large-scale project,” *International Journal of Project Management*, vol. 20, n°. 5, p. 375–384, 2002.

[16] O. Lavoisy et D. Vinck, “Le dessin comme objet intermédiaire de l'entreprise,” 2000. [Online]. Available: http://halshs.archives-ouvertes.fr/hal-00261643/. [Accessed: 15-Jan-2011].

[17] A. Jeantet, “Les objets intermédiaires dans la conception. Eléments pour une sociologie des processus de conception (Intermediary objects in design: Elements for a sociology of design),” *Sociologie du travail*, vol. 40, n°. 3, p. 291–316, 1998.

[18] K. Grebici, D. Rieu, et E. Blanco, “Les objets intermédiaires dans les activités d’ingénierie collaborative.,” *Actes du XXIIIème Congrès INFORSID, Grenoble, France*, p. 24–27, 2005.

[19] V. Chapurlat et C. Braesch, “Verification, validation, qualification and certification of enterprise models: Statements and opportunities,” *Computers in Industry*, vol. 59, n°. 7, p. 711–721, 2008.

[20] Bailly, C. Braesch, et B. Nicquevert, “How to represent with BPM notation simultaneous and interlinked activities spreading over several lanes: a proposal based on a case-study in a design office,” submitted to BPM 2011, 9th International Conference on Business Process Management, Clermont-Ferrand, 2011.

Contact: B. Nicquevert
CERN – Engineering department
Route de Meyrin
1211 Geneva 23
Switzerland
Tel +41 22 767 60 83
Fax +41 22 766 90 45
Bertrand.nicquevert@cern.ch

B. Nicquevert is a project engineer at CERN, Switzerland. He was in charge of mechanical integration of the ATLAS detector at the Large Hadron Collider, and took part of the installation coordination of this accelerator. He is now coordinating the design, integration and installation of the *Med*Austron project, an accelerator for hadrontherapy currently under construction in Austria. He is also preparing a Ph. D. in Industrial Engineering at Grenoble Institute of Technology.

J.-F. Boujut is professor of engineering design at Grenoble Institute of Technology in the Industrial Engineering school. He earned his Ph. D. in 1993 and his Habilitation in 2001. His research interest is on design communication and collaborative aspects of innovative design including tools for managing informal information and sharing knowledge. He teaches creativity and innovation methods and collaborative engineering aspects.