ENTITY MODEL BASED QUALITY MANAGEMENT: A FIRST STEP TOWARDS HIGH RELIABILITY ORGANIZATION MANAGEMENT

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ABSTRACT

A management system built upon a generic entity model is presented as an approach towards management systems for High Reliability Organizations (HRO). The entity model is derived from the Ground Systems and Operations standard of the European Cooperation for Space Standardization (ECSS).

DLR has launched a first application of the model in its Applied Remote Sensing Cluster, especially for the Center for Satellite based Crisis Information.

It is proposed that a management system built upon the entity model systematically enhances a significant number of HRO characteristics.

1. HIGH RELIABILITY ORGANIZATION

From Charles Perrow [1] we learned that in high risk industries accidents are normal events due to system inherent interactive complexity and tight coupling. Organizations who intend to improve safety of their operations should try to make their operations safer by viewing not only workplaces but also organizational and cultural conditions [2]. It turns out that there are High Reliablity Organizations (HRO), which seem more capable avoiding the pitfalls of life, being mindful, learning adequately and avoiding major catastrophes consistently for periods of time larger than to be expected by the risk involved. Weick and Sutcliffe [3] have argued that the success of HROs can be traced to the following five practices developing *mindfulness*:

(1) Preoccupation with failure
(2) Reluctance to simplify interpretations
(3) Sensitivity to operations
(4) Commitment to resilience
(5) Deference to expertise

The global challenges we face today, as shown in Figure 1, form a high risk environment in which all organizations interact collectively [4]. Last year's crisis has demonstrated the potential for crises spreading from one business sector into others. Everywhere, organizations were hit by unexpected risks. In the 1980´s it appeared reasonable to assume that complexity and coupling emerges from the specific high risk industry an organization was involved in. Today, it may emerge from the global challenges (see Figure 1) as well as from the risk already inherent in the system, as assumed in the 1980's. Thus it seems prudent to adopt the five practises developing *mindfulness* for all organizations. Tools need to be explored to help management practitioners to engineer mindfulness into business systems. The quality management system standard adopted world wide [5] may provide a starting point.

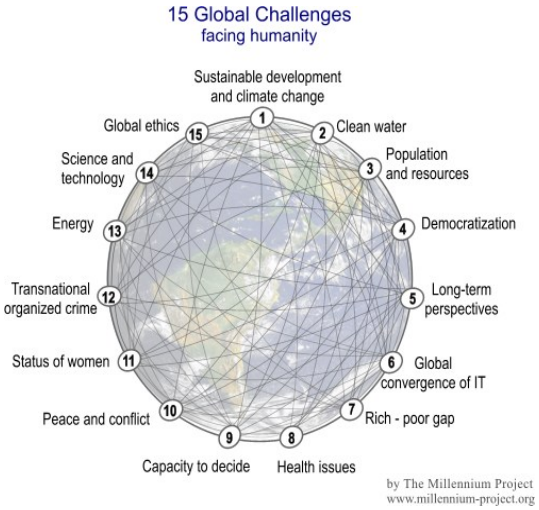

Figure 1 Global challenges

It is proposed that the generic entity model, which is being used in the field of quality management, may help to enhance mindfulness.

2. GENERIC ENTITY MODEL

2.1. Background

On the way to transform an organization into a High Reliability Organization, supporting structures have to be put in place and a suitable culture has to be developed and fostered. Hereby, focus is laid on work being of high complexity and significance: Work requires coordinated action by numerous technical components and operators; high precision is required; availability of service is mandatory at certain times. This characteristic applies for instance to satellite mission operations being performed at ground segments.

To deal with such challenges, adequate management instruments must be in place. In the context of this paper a two-tier management organization is assumed, distinguishing between a business management level and a product realization level. Here, focus is laid on product realization, both, to create a ground segment and to operate it. The term "product" refers to a generic product definition, being a defined output of a process. As such, a product may be software, system, data, information or operational service.

By addressing product realization with respect to ground segments, the Standard [6] of the European Cooperation for Space Standardization (ECSS) on Ground Systems and Operations introduces the concept of entities, as depicted in Figure 2.

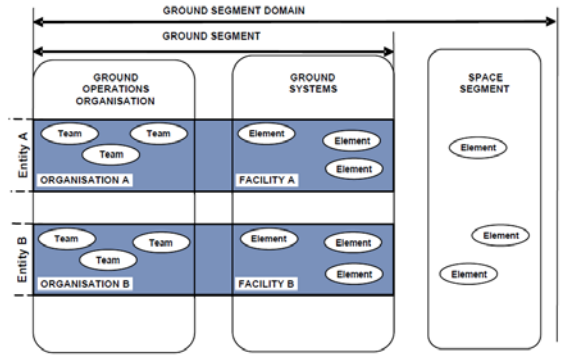

Figure 2 Introduction of entities as per ECSS

A ground segment consists of two domains: Ground Systems and Ground Operations Organization. The combination of an operations organization and its corresponding supporting facility constitutes an entity. This functional segmentation of a ground segment into entities forms the basis of the generic entity model, which now serves as a powerful management instrument in the field of product realization. Within product realization emphasis is laid on operational services.

2.2. Entity Model

As a starting point the model [7] requires that entities are embedded in a business organization. Assuming a two-tier management organization entities are placed in the product realization level as illustrated in Figure 3.

Figure 3 Entities in a 2-tier management organization

Entities are operated in a framework of business management processes, here categorized as Top Management, Resource Management, Quality Management and Project Management. Seen from a technical point of view, however, entities are fully autonomous processing units with a given functionality, defined processes and defined products. They communicate among each other and with the external world solely by exchanging products.

An entity is supported by a facility, forming the basis for operational entity processes. A facility shall be described in the same way as an entity. Thus, a facility is an entity named facility. However, while an entity is described on entity level zero, a facility is described on entity level minus one, see Figure 4.

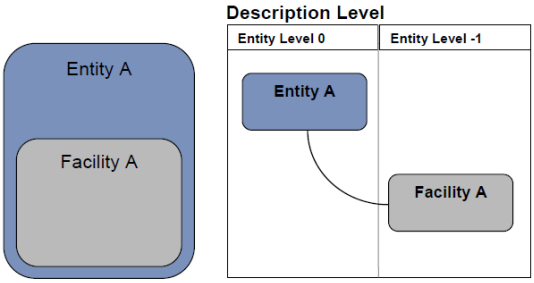

Figure 4 Entity decomposition: facility as sub-entity on description level -1

Entities are described using MindMap diagrams, according to Figure 5. Elements of description are:

- Entity Identification: Defining functionality & purpose as well as roles & responsibilities
- Product In: Listing requirements and products needed to start production
- Process: Identifying product realization processes carried out by personnel and sorted by Management, Engineering and Operations
- Product Out: Listing products created
- Facility: Naming the embedded facility to be described on the next lower level

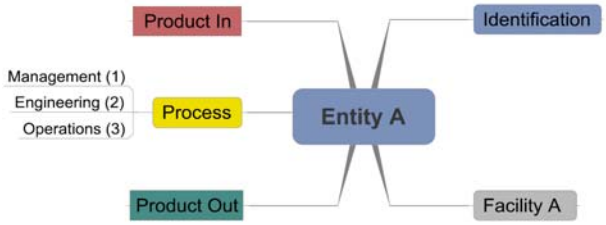

Figure 5 MindMap diagram of an entity

Facilities are also described using MindMap diagrams, see Figure 6. Elements of description are the same as for Entities, namely

- Facility Identification: Defining functionality & purpose as well as roles & responsibilities

- Product In: Listing requirements and products needed by the facility
- Process: Identifying processes carried out by personnel to make and keep the facility ready for operations, such as Facility Design, Implementation & Test, Facility Configuration, Technical Verification & Validation, Facility Maintenance
- Product Out: “Facility ready for Operations”
- Facility Element: Naming facility elements to be further described on the next lower level, if needed

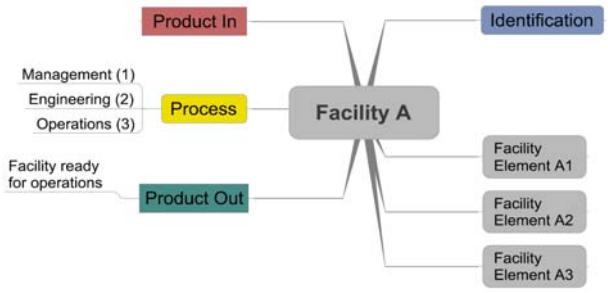

Figure 6 MindMap diagram of a facility

An entity or facility houses a number of processes. To limit complexity, no more than six processes are recommended per entity or facility. A process description represents the “as-is” state rather than the “as-be” state. Its structure repeats the Entity MindMap structure, see Figure 7. The structure is self-explaining, both in color and content. Emphasis is laid on dense process descriptions (simple, comprehensive, true) as well as on precise and unique product definitions. Facility processes make use of the same description structure.

Entity Name & Entity Path

Entity Name:	E.Name of Sub-Entity (E.xxx)
Entity Path:	E.Name of Main Entity (E.xxx) - E.Name of Sub-Entity (E.xxx)

Process Identification

Process Name	Process Name
Process ID	QMH-CAF-E.xxx-E.xxx-EP##
Process Manager	

Purpose of Process

Text

Product In

- Process input 1
- Process input 2
- ....

Process

- Action 1
- Action 2
- ...

Product Out

- Process output 1 (Product 1: ID, Name)
- Process output 2 (Product 2: ID, Name)
- ....

Figure 7 Process description structure

Starting from an entity on level zero, the depth of description may be further enhanced by creating and describing entities on level minus one. Further refinement of description leads to entity clusters as depicted in Figure 8. The resulting entity cluster can be understood as a self-similar evolution of the originating entity on level zero. Entities on level zero mainly contain high-level processes, such as Customer Relations or Document Management and often they do not have a facility of their own. Going deeper in the entity cluster, processes become more specific and facilities are commonly used, however, not displayed in Figure 8.

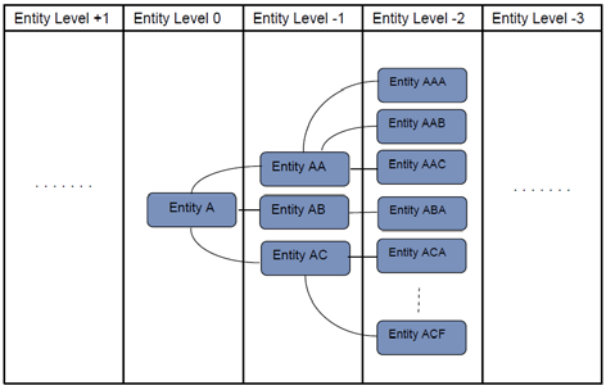

Figure 8 Entity cluster

Entities and entity clusters, respectively, reflect the function tree (function decomposition) of the ground segment; facilities reflect the product tree (system decomposition) of the ground segment.

Connection lines between entities (see Figure 8) symbolize the exchange of products showing the main product flow. However, they do not represent fixed product delivery chains. On each level, products may also be directly delivered to other entities or to external customers, thus forming networks of interaction, which are scenario or use case driven. This principle also applies to facilities.

The benefit of forming entity clusters is the creation of process hierarchies together with the refinement of processes, roles and responsibilities. Moreover, internal products become “visible”, which would not be seen on a top level description only. As a consequence, internal products are rigorously defined and managed (e.g. by product description and configuration management), hereby becoming marketable. Other benefits are:

- Common understanding of functionalities and work flows
- Manageability of the process extent within an entity
- Special treatment of critical processes
- Possibility to activate an entity (or sub-entity) as independent profit unit
- Possibility to replace an entity (or sub-entity) through purchase of external products

- Knowledge preservation through detailed description
- Knowledge provision through easy navigation

As indicated in Figure 8, there is also room to organize processes on a higher level of abstraction, e.g. by combining two entity clusters on level plus one.

Entities are not tied to disciplinary boundaries of a company organization. On the contrary, they are instruments of the operational organization. To this end, entities may span across organizational units and different sites; decision-making authority resides with the experts on site, where the work is done.

On all levels, entities are managed by Entity Managers, who are supported by Facility Managers, Process Managers and Operators.

The Entity Manager is responsible for product and service provision of the entity; he acts as quality manager on entity level. His tasks include:
- Resource planning
- Operations coordination
- Document management
- Configuration management
- Relations management to line management and customers
- Supplier management
- Product assurance

Processes are defined, described and maintained by Process Managers. They are responsible for
- Process verification, validation and roll-out
- Operator training
- Process improvement

Beyond formal non-conformance management, a culture is fostered within entities to consider failures in a larger context. Failure with undetected root cause is considered as Major Event to be reported to the next level of decision.

3. ENTITY MODEL APPLICATION

Applications of the model have been realized in the satellite ground segment domain, such as software development, data reception, data processing and data archiving as well as in the domain of user services, such as airborne remote sensing and crisis information. The latter is used as an example.

3.1. Center for Satellite based Crisis Information

The Center for Satellite Based Crisis Information (ZKI) is a service of DLR's German Remote Sensing Data Center (DFD). Its function is the rapid acquisition, processing and analysis of satellite data and the provision of satellite-based information products (mainly maps) on natural and environmental disasters for humanitarian relief activities, as well as in the context of civil security. The analyses are tailored to meet the specific requirements of national and international political bodies as well as humanitarian relief organizations.

Natural events like earthquakes or floods are happening unexpectedly showing different impacts, depending on the characteristics of the affected geographic region and the distribution of population. Quick reaction is crucial in disasters, thus 24/7 service has to be available and the quality of data products must be high. To streamline activities and to continuously ensure high level service quality, ZKI has been ISO 9001 certified. For managing its processes the generic entity model has been chosen.

Upon request, the typical work flow for the provision of satellite-based information products is shown in Figure 9. It consists of six main steps, namely mobilization, data acquisition, preprocessing, image analysis and map production with subsequent dissemination.

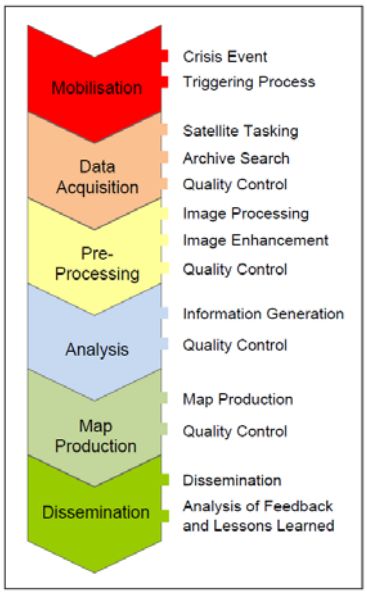

Figure 9 Typical workflow

3.2. Entity cluster of ZKI

Processes needed to implement the above workflow are listed in the ZKI entity cluster, shown in Figure 10.

The ZKI entity cluster consists of an entity on level zero, named Entity Center for Satellite Based Crisis Information (E.ZKI), two sub-entities on level minus one, named Entity Rapid Mapping (E.RM) and Entity Fire Monitoring (E.FM) as well as one facility, named Facility ZKI (F.ZKI).

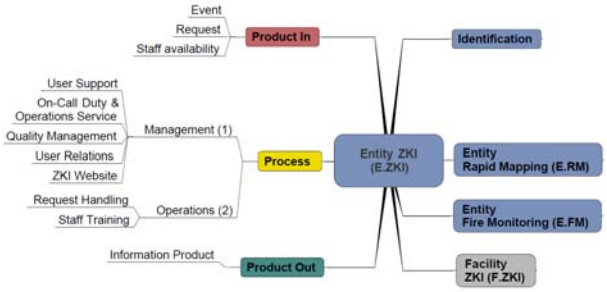

Figure 10 ZKI entity cluster

The Entity Center for Satellite Based Crisis Information (E.ZKI) describes general operational and managerial tasks including communication to users. As an example, mobilization (step one of the shown workflow) refers to the entity processes Management of On-Call Duty & Operations Service and to Request Handling.

The Entity Rapid Mapping (E.RM) handles all processes needed for steps two to six of the workflow, as shown in Figure 11. The first level process descriptions (i.e. Data Provision, Preprocessing, Image Analysis and Map Production) contain a high level decision support tree giving advice to the operator on how to proceed for a certain application or with a specific data set in line with the particular objectives of the activation. First level processes branch into second level processes giving detailed work instructions.

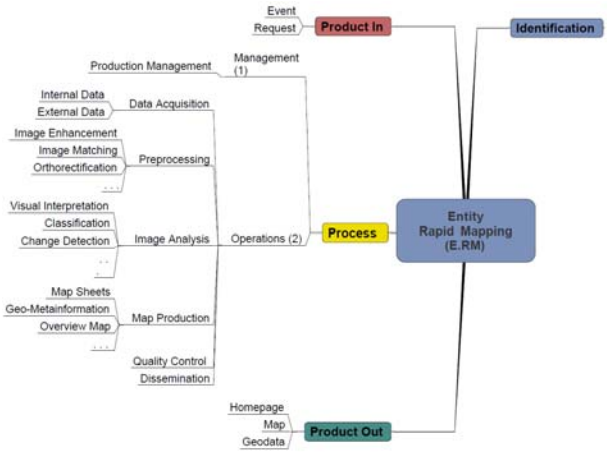

Figure 11 Sub-entity Rapid Mapping

The workflow diagram in conjunction with the entity MindMaps help to understand and handle the complex work environment.

Outputs of each process are handled as final products and have to pass quality control. For intermediate products, being passed from one process to another, quality control is done in form of quick checks conducted by small teams, thus, cultivating communication between team members. Quality control of products for dissemination to the user is formalized through check lists.

3.3. Developing mindfulness

Usually disasters happen unexpectedly. Nevertheless, ZKI has to react promptly and reliably. Besides technical competencies and structures, a culture of mindfulness has to be developed to cope with the unexpected. ZKI has implemented the following measures:

Disasters and risk areas are continuously tracked and monitored worldwide to work proactively and to respond immediately to requests from humanitarian relief organizations or from the International Charter – Space and Major Disasters (http://www.disasterscharter.org/). These efforts make unexpected events more expected.

User requirements for information are often very specific and hard to meet. Results depend on data availability and quality, weather conditions, disaster evolution and field information. For example, problems occur if satellite images can not be made available quick enough by providers. In order to prepare for the unexpected, networks have been built up with satellite providers to work together on this problem. Data of new sensors and new methods are constantly integrated and tested in the ZKI workflow, feedback from users and products of other rapid mapping providers are being analyzed and included into updated versions of process descriptions.

Another step towards mindfulness has been made by implementing the above entity model. Its structure is of such a nature, that processes are not bound to fixed process chains. Processes can be combined in a modular way through exchange of products without prohibiting alternative solutions. Herewith operations gain a high degree of resilience.

Supported by the entity model, responsibilities are assigned on all levels empowering experts with decision making authority. In case of doubt or conflict the last decision on how to combine process chains or on how to deviate from standard procedures rests with the responsible operator or expert.

Shift changeover is done with a short but intensive handover discussion that is structured into the topics Activation Management, Geoinformation and Image Interpretation. For each topic there is one expert per shift who has the responsibility to handover to the subsequent expert.

All process descriptions are put together in form of a handbook called Standard Operation Procedure (SOP), of which every team member has a personal copy. This gives staff the possibility to add personal notes and

comments to process descriptions, which in turn helps to obtain sensible input for the regular update and improvement of techniques and workflow.

Internal trainings are organized at a minimum of once a month, depending on the training needs or engagement of team members. For each process described in the SOP the process manager is the declared expert in the particular field. He is responsible for the training and is also the contact person for problems that may occur.

One source of input for improvement is the handover discussion. It was a learning process to see the necessity to ask questions and to discuss, both, technical issues and personal matters. In addition, a simple and efficient procedure is set up to compile workflow records, which allows reconstructing single steps after activations.

Another source of input for improvement is the preoccupation with failure. Team spirit is important. It turned out that a good working atmosphere is essential for the willingness to be preoccupied with failure. Regular team meetings offer a platform to address and discuss problems and failures. Action items derived from the discussions and from lessons learned are immediately worked on during non-activation phases, while being on standby.

From the above, it becomes clear that ZKI has certain characteristics of a High Reliability Organization. The team is widely prepared to deal with unexpected events and is used to work concentrated and with high performance under stressful conditions. Each of the five practices to develop mindfulness, listed in chapter 1, is applied to some extent.

4. AUDITING MINDFULNESS

To verify the statement that the application of the generic entity model helps to put an organization on the pathway to mindfulness, the mindfulness audit defined by Weick and Sutcliffe [3] was conducted within DLR. Four organizational units were asked to do a self-assessment; all of them are ISO 9001 certified. While unit 1 is part of a department without operational activities, units 2, 3 and 4 are all part of the same department, having extensive operational activities. Unit 1 is not using the entity model and is not intending to do so in future. Units 2 and 3 are using the entity model and unit 4 is a candidate for applying the model in the near future.

Each of the five common practices developing mindfulness have been evaluated and scored on the basis of the questionnaires from Weick and Sutcliffe [3]. The results have been averaged and normalized per practice. The level of achievement towards mindfulness is divided into the value ranges low, moderate and high. Achievements of the four organizational units are shown in Figure 12.

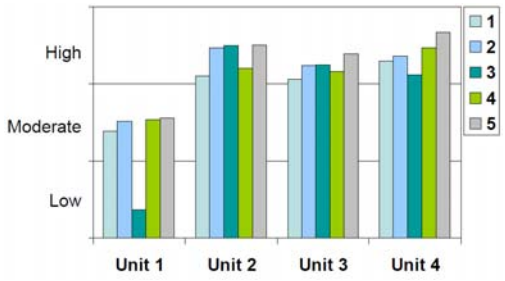

Figure 12 Audit results

1 Preoccupation with failure, 2 Reluctance to simplify interpretations, 3 Sensitivity to operations, 4 Commitment to resilience, 5 Deference to expertise

Achievements of unit 1 are moderate with low scoring in sensitivity to operations, which does not come as a surprise. Achievements of the more operational units 2, 3 and 4 are all high, without distinct difference between those already using the entity model and the one not yet using the model. Summerizing the results it appears that management culture and the existance of operations did strongly influence the self-assessments. The entity model seems to rather have a supporting role than a key role. To obtain further evidence one should compare audit results of organizational units before implementing the entity model and again after having worked with it for a certain period of time.

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