Capturing Tacit Knowledge for Spacecraft Operations in ESOC

Roberta Mugellesi Dow[1], Siegmar Pallaschke[2]
[1]European Space Agency
roberta.mugellesi.dow@esa.int
[2]Consultant
espall@t-online.com

Abstract

Within the past years, several activities were undertaken towards the introduction of a knowledge management system at ESOC, the European Space Operations Centre.

Now the knowledge management activities at ESOC are in a new phase where emphasis is put on knowledge capture. The paper describes the current knowledge management activities at ESOC specifically in knowledge capture and focuses on the developed and adopted methods and on the results obtained related to the process of knowledge capture using video-recording of experts. Furthermore it describes the steps which have been identified for the knowledge capture process: setting expectations and communication rules, structuring and conducting the interviews, preparing the list of questions to encourage the sharing of the tacit knowledge, reviewing the recorded material, etc.

1. Introduction

The European Space Operations Centre (ESOC) is located in Darmstadt, Germany and is an establishment of the European Space Agency (ESA). ESOC is responsible for the operations of the European satellites. These operations include the following major technical domains when considering only the ones directly linked to satellite operations:
- Set up of ground stations, its connection to ESOC, as well as the entire operations;
- Mission data systems covering all software and data aspects relevant for the preparation, control and operations of a space mission;
- Flight dynamics, navigation and space debris covering the celestial mechanics and the spacecraft dynamic part;
- Actual mission operations (spacecraft/ payload).

Knowledge management is not a new activity at ESOC. It has been done at unit/ project level as long as this establishment exists. However, knowledge management activities taking a more global view and going across the borders of departments have been conducted since the year 2003 [Ref.1,2]. The activities have been organised into four phases since then:

- preliminary study and investigation on knowledge management system including a review of already existing initiatives;
- a pilot project within the Flight Dynamics area (a technical domain within ESOC taking care of the orbit- and attitude aspects for the satellite operations) with respect to the questions of knowledge transfer and its barriers. This was performed with the help of the Fraunhofer Institute, Stuttgart, Germany during 2007.
- the definition of the ESOC knowledge management system was established with the support of Mercer, Italy during 2008.
- the introduction of knowledge capture procedures was conducted during 2009.

Knowledge management is not done for its own sake. The prime task of the knowledge management is to secure the gathered experience (Lessons Learned, Best Practice Workshops, Debriefings) and to make it available to the community of collaborators so that the proper knowledge is available at the appropriate places for the work process. In fact, it is a challenge to identify and to make available the knowledge, the experience and the competences so that other colleagues can benefit from it. This task becomes a real challenge especially for a larger organization with a complex structure in a multi-national environment. As ESOC is a multi-national organisation this aspect will be outlined in connection to the knowledge capture procedure.

2. Knowledge Management Processes

Knowledge management consists of several processes which all contribute to the successful functioning. There are for example six basic building blocks (definition, identification, acquisition, development, distribution, usage and preservation) plus two pragmatic ones (goal and evaluation). In a reduced and simplified form and leaving out the pragmatic ones the following are selected:
- **identification** (how to achieve transparency in the available knowledge)
An important prerequisite for the identification of knowledge is transparency which must be supported by the organisation. The goal is to maintain an overview of data, information and capabilities.
- **capture** (how to secure knowledge)
The term knowledge capture is used for two types, the continuous capture during the course of a project (lessons learned) and the one at specific points in time when staff are leaving their posts (expert debriefing). Certain knowledge and experience can only be passed on in personal conversations.
- **sharing** and usage (how to route the knowledge to the appropriate place and how to ensure the correct usage)
Knowledge sharing within the organization is an essential condition for its sustainable success. The process looks into the question of routing the knowledge to the appropriate place to ensure the proper distribution, helping people to get access to the knowledge base required for their work, encouraging them in use and reuse and training them the use of the KM tools. In addition to the optimal knowledge distribution one further aim is to make the isolated information and hidden experience available to the entire organisation. Willingness of the

employees to share their knowledge needs to be encouraged. Mature technologies ease the process.
- **preservation** (how to guard knowledge against losses)
The knowledge preservation and re-use process is essential to prevent reinventing the wheel time and again, from reiterating previous mistakes and enable the duplication of successes, thus fostering excellence and diminishing development costs. This process includes the selection, the storage and the regular actualisation of the relevant knowledge including documents and experience.
- the **organization** is of importance not only or the processes of identification, development and sharing but also for the sharing, capture and preservation.

3. Knowledge Capture Methodology

3.1 Overview of Knowledge Capture Methods

It would be nice if one could compare the knowledge capture and its transfer from one staff to the other with an ordinary removal where one packs the documents into boxes, moves them to the new place and puts them into the new racks in a well defined order. Of course, the transfer of knowledge between staff cannot be compared with an ordinary removal. The transfer of knowledge is extensive and complex. A further point could be mentioned. Within an ordinary removal things are destroyed or things get lost. This holds for the knowledge transfer as well. Estimates say that about one third of the experience accumulated within the many years of service will not be transferred, it will be lost. As the transfer of knowledge between staff is extensive and complex, it has to be carried out in a thorough way.

Solutions for avoiding knowledge losses at the departure of employees can be anticipated. Knowledge share is an essential sign of a knowledge-based enterprise. Organized exchange of views, tandem-concepts, mentoring systems, documentation and archiving of project knowledge and knowledge of experience in data bank systems are examples of successful knowledge management processes which would ease the situation at change-over of employees. Of course, generous hand-over periods would help as well. For most of the methods listed above it can be seen that this process requires verbal communication. The transfer of experience in a verbal form should be preferred compared to the written one. Verbal communication creates contact and nearness which are essential for the passing on of experience. Experiences are best exchanged in the personal conversation.

The term 'Knowledge Capture' is normally used for two types of processes. On one hand there is the continuous knowledge capture and transfer during the course of a project, where methods like communities of practice, mentoring, master-student (sempai-kohai), project tandems, lessons learnt or documentation standards are used. On the other hand there is the knowledge capture and transfer at specific points in time when staff members are leaving their posts such as change of position within organization, leaving the organization or retirement. In these cases knowledge capture describes the methods for catching the critical knowledge by helping the people to articulate and making explicit their knowledge for later sharing. For this capturing process three steps are quoted:
- coverage analysis to identify where unique knowledge exists;
- structured interviews following an interview manual;
- extended overlap in case of staff departure.

Knowledge capture is required at different stages/ levels such as within project or when staff is leaving the post, either change of position within organization, leaving the organization or retirement. Although emphasis put on staff leaving, a more global view on knowledge capture is given in here. The procedure for the knowledge capture has to be well structured in order to make sure that the broad spectrum of the knowledge of the leaving staff is systematically scanned. All relevant subjects have to be covered in a systematic approach and not by pure chance.

The willingness to cooperate of all participating members is the prerequisite for the successful conduct of this knowledge capture procedure.

The procedure for knowledge capture for leaving staff as outlined in the subsequent chapter is based primarily on the following references:

a) Rosetta Knowledge Management Video Approach (2003) [Ref.1]
The Rosetta mission is a long duration mission, with seven years of pre-launch development, a launch in 2004 and twelve years of post-launch operations. In order to maintain the expertise for both the operations and the engineering a Rosetta Knowledge System (ROKSY) has been developed during the year 2002/3. ROKSY is located at ESOC and will be maintained throughout the mission duration.

b) Leaving Experts: Experience captured by Talks (Hartmut Krause in How Knowledge by Experience can be retold, Papst Science Publisher, 2005, [Ref.5])

The company Siemens AG has introduced (in cooperation with some other enterprises) a Leaving Expert Debriefing Process in order to reduce the loss in knowledge and experience when staff are leaving their posts. The debriefing is a kind of workshop with a duration of about 0.5 days. The leaving expert describes his duties and their dependencies with emphasis on the methods applied, the information flow, the contact persons and the outstanding actions. He explains from his point of view the required specialized and organizational know-how. He also outlines what he would do differently with the knowledge of today. The participants of this workshop are the members of his group. The chair of the debriefing would be the superior.

c) A Colleague leaves, where will the knowledge remain? (Benno Ackermann in [Ref.6, Jan. 2009])

This paper describes the three phases for the knowledge capture as applied at Credit Suisse.

They are:

- Identification;
- Transfer methods: non moderated methods for simple cases, moderated methods for the more complex cases (Story-telling, SWOT-visualization, Best u. Worst Practices, Case-based Walkthroughs). The abbreviation SWOT stands for Strength, Weakness, Opportunities and Threats;
- Transfer/ Communication.
Ackermann quotes the following advantages for a knowledge capture process, where in fact all participants would benefit:

- Advantages from the point of the enterprise: Preservation of the knowledge of experience; no inefficient or unnecessarily long hand-over periods; efficient transfer of projects; transparency in functions and processes; recognition of improvement possibilities, closure of gaps between vision and actual work.
- Advantages for the successor: efficient and shorter hand-over; fast increase of decisive competence; maintaining the personal network of the predecessor,
- Advantage for the staff leaving: working report refers to actual projects, skills and abilities; esteem and motivation by interest in the performed work; support of the career planning by more transparency in fields of knowledge and functions.

Whereas the reference b) proposes a kind of workshop (called expert debriefing), the other ones recommend interviews (moderated or unmoderated). It should be mentioned that many more references could be found for this topic, however, only one example has been selected for b) and c).

For completeness some further explanations are added for the comparison of both methods. The expert debriefing is a kind of forum/workshop in order to allow the expert to explain his specialized knowledge for a selected range of topics to a larger group of participants. Of course, the assistance of a moderator would help to facilitate to express the underlying expertise. In essence, the goal of the expert debriefing is twofold, the expression of the underlying expertise in a verbal interaction with the audience and the recognition of the expert's merits.

The interviews would be applied for the description of complex subjects. Obviously they have to be video-recorded. The participation of the interviews would be very limited, i.e. the expert, the moderator and the IT member.

The table below provides an overview of the methods with respect to their goals and applicability. It has to be added, that there is no basic difference for the overall structure of the procedure with respect to the preparation and its conduct.

	Expert Debriefing	Interview
Type	Workshop	Script
Audience	Larger group of experts/colleagues within knowledge area	Interview team only
Interaction	Face-to-face interaction with audience	No direct interaction, interview script to be followed
Moderation	Required	Depending on the subject
Recognition of merit	Direct in public	Indirect

The methodology for knowledge capture within the running projects is to some extent similar to the one for leaving staff members. Knowledge capture could be achieved with the help of Lessons Learned procedures. Enhanced Lessons Learned Workshops should be conducted at certain milestones but at least towards the end of the project. At the end of a project most of the members are leaving their posts in order to take up new duties. Hence there is a significant similarity for the knowledge capture for the departing staff members and for the running projects.

3.2 Description of Knowledge Capture Course

The references listed in the previous chapter quoted the following three steps:
- Identification of knowledge subjects
- Transfer of knowledge
- Documentation.

Of course, an additional step dedicated to the preparation of the interviews could be inserted between the steps 1 and 2. The detailed description of the knowledge capture procedure can be found in reference [Ref.4]. It consists of:
- Step 1: Review of status with an inquiry. The objective is to assess the important knowledge subjects of the leaving staff as well as the knowledge demand required by the group and the successor. For the identification of the essential knowledge items to be captured different viewpoints should be adopted in addition to the chronological review of the projects supported. The quality aspects could be the other viewpoints such as best and worst practices, contribution of the success and mistakes leading to a possible failure.
- Step 2: Plan for debriefing and interview. This includes the sequence of knowledge subjects for the debriefing / interviews and its structure.
- Step 3: Conduct of Debriefing / Interviews with the goal to capture the tacit knowledge and to facilitate its documentation. The various viewpoints mentioned for the first step above has to be adopted for the conduct of the expert debriefing and the interviews as well.
- Step4: Documentation of tacit knowledge

Some further explanations have to be added to the actual knowledge capture step (#3), the range of application of the various possible options are described in the following paragraphs.

The references related to the Expert Debriefing consider this option as mandatory for leaving experts, not only to provide the expertise to a larger audience but also as a sign of appreciation of the achievements of the leaving expert. The status as expert will be emphasized through this method.

The selection of the interview option (with or without moderator, with or without video recording) clearly depends on the complexity of the subject to be handled as well as the usefulness of the moderation and the recording. Some further explanations are given for these three items, i.e. moderation, recording and complexity.

Moderated methods for knowledge capture are useful for complex subjects of knowledge and expertise. It can be assumed that the leaving expert has a magnitude of knowledge, ideas, perceptions and expertise which he is not always aware of. Hence a good guidance through the discussion and explanations facilitate a deeper assessment/ examination/review of the subject and can bring to light implicit knowledge. There are various methods available for the knowledge transfer from implicit to explicit (Story-telling, SWOT-visualization, Best u. Worst Practices, Case-based Walkthroughs) and the skill of the moderator lies in the selection of the most appropriate method for the given situation.

Non-moderated methods are useful for less complex knowledge subjects as user knowledge of applications.

Video-recording could be used for the documentation of the interviews. Audio-visual means are a valuable complement within the preservation methods for knowledge as more senses are involved for the explanation and the understanding of the complex subject.

The level of the complexity of the subject could be derived from the criticality and coverage figures collected within the Appraisal. The criticality figure is based on the role, the speed of change and the market availability. Obviously, the lower the criticality figure is the less important becomes the interview subject. A similar relation holds for the coverage figure. The higher the number of available experts is, the less important the interview subject becomes.

4. Multi-Cultural Aspects

Knowledge capture has to focus on the tacit component (and less on the explicit part) of the knowledge. Explicit knowledge can be expressed in a formal language and can be kept in form of documents, user manuals and other types of reports. Tacit knowledge refers to skills and experiences which have been gathered through the execution of activities and its critical review over years of practice. The repetitive execution of activities leads to an improved knowledge and understanding.

Experience strongly relates to the procedural knowledge. In particular experience helps to grasp situations, to derive associations, to recall action patterns, to judge feasible solutions and to take decisions.

With respect to knowledge capture and the multi-cultural aspects it makes sense to distinguish between specialized knowledge and knowledge by experience (also called empirical knowledge). Specialized knowledge can be described and understood in many languages and hence the multi-cultural aspect could be ignored. However, empirical knowledge is based on experience and this is very individual. Empirical knowledge is acquired through learning-by-doing plus the resulting understanding. This presupposes special knowledge on the one hand and individual assessment of the occurrence on the other. The occurrence has to be judged as self-relevant in order to be considered as experience. Here the cultural background is of importance.

For illustration the analysis performed by Geert Hofstede (born 1928, retired professor at university of Maastricht, expert for culture-science), known as the 5D-model, is quoted here. Hofstede's study [Ref. 7] demonstrates that national and regional cultural groupings affect the behavior of societies and organizations. Hofstede found five (initially four) dimensions of culture in his study of national work related values. They are:
- Low vs. high power distance (PD)- This dimension measures how much the less powerful members of organizations accept that power is distributed unequally. In cultures with low power distance, people expect and accept power relations that are more consultative or democratic. In cultures with high power distance, the less powerful accept power relations that are autocratic or paternalistic. Subordinates acknowledge the power of others based on their formal, hierarchical positions.
- Individualism vs. collectivism (ID)- This dimension measures how much members of the culture define themselves apart from their group memberships.
- Masculinity vs. femininity (MA)- This dimension measures the value placed on traditionally male or female values. Another interpretation of this dimension is that in 'M' cultures, the differences between gender roles are more dramatic and less fluid than in 'F' cultures.
- Low vs. high uncertainty avoidance (UA)-This dimension measures how much members of a society attempt to cope with anxiety by minimizing uncertainty. In cultures with high uncertainty avoidance, people prefer explicit rules and formally structured activities. In cultures with low uncertainty avoidance, people prefer implicit or flexible rules or guidelines and informal activities.
- Long vs. short term orientation – This dimension describes a society's "time horizon," or the importance attached to the future versus the past and present. This fifth dimension was implemented later.

The cultural differences describe averages or tendencies and not characteristics of individuals and hence a country's scores should not be interpreted as deterministic. But, to some extent it could be envisaged that the interpretation of occasions with respect to its recognition as experience could vary significantly between members of these two countries. Analogous to the different interpretation of occasions as experience, the scope and the importance of empirical knowledge and its applicability will also be judged differently.

5. Concluding Remarks

Knowledge management has been acknowledged at ESOC to guarantee reliable and efficient execution of the responsibilities of the centre. The two most important driving factors for the introduction of knowledge management in ESOC are the efficiency and the decrease of risks.

The knowledge capture methodology has to consider this cultural aspect in the interpretation of empirical knowledge. The selection of the empirical knowledge topics for the capture event has to take into account not only the dimensions of projects and collaborators but also the perspectives of culture and nation.

6. References

[1] A Knowledge Management Initiative in ESA/ESOC, R.Mugellesi-Dow et al., IAC-04-IAA.4.9.2.06, October 2004 (also published in Journal of Knowledge Management, Vol 10, No 2, 2006)
[2] Overview of the Knowledge Management System in ESA/ESOC, R.Mugellesi-Dow et al., IAC-07-D5.1.02, September 2007 (also published in Acta Astronautica, Vol 63, Number 1-4, 2008)
[3] Simplicity: A pragmatic Approach for Knowledge Management, IAC-08-D5.2.8, September 2008
[4] Capturing Tacit Knowledge for Spacecraft Operations in ESOC, IAC-09-D5.2.3, October 2009
[5] Hartmut Krause, Leaving Experts: Experience captured by Talks (in: How Knowledge by Experience can be retold, Papst Science Publisher, 2005)
[6] Wissensmanagment, Journal Benno Ackermann, A Colleague leaves, where will the knowledge remain?, Jan. 2009

[7] Hofstede, Geert, Culture's Consequences: comparing values, behaviors, institutions, and organizations across nations (2nd ed.). Thousand Oaks, CA: SAGE Publications, 2001