Risk Management as an executive task in the construction of Wendelstein 7-X

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To manage all risks during construction, commissioning and later operation of complex fusion experiments like the stellarator W7-X it is necessary to have a thorough and highly efficient approach. It is an executive task of the upper management to anticipate, analyze and to build up a system of measures to prevent the occurrence of potential risks or to handle the risks in such a way to minimize the impact. Very good experience has been made with the introduction of a uniform quality management system which takes into account both the processes and the technology. The most important risks for the project and the decisions made to manage them are outlined briefly.

Keywords: Risk management, Quality, Assessment, Magnet system, Stellarator

1. Introduction

Wendelstein 7-X, the first numerically optimized stellarator, is presently under construction at the Max Planck Institut for Plasma Physics (IPP) in Greifswald (Germany) [1]. Construction, commissioning, and later operation of such an experiment represent unquestionably a very complex challenge in solving scientific, technical and organizational tasks.

In this relation the often quoted Murphy's Law in its well known reduction „Whatever can go wrong, will go wrong“ sounds for every project team like a bad omen. Indeed all project activities bear many process, management and technical risks. But is there a real chance to prevent the disaster of unconvincing technical solutions, and too expensive and too late projects?

Risk management is always also chance management. It is necessary to manage these risks in an anticipating and proactive manner to be successful with such a project. In the Wendelstein 7-X project this has been recognized early on.

Beginning with the identification and assessment of risks, priorities accordingly to their potential significance have been set and several measures have been introduced to handle the risks and minimize their impact. These activities are an integral part of the uniform quality management system which has been introduced for Wendelstein 7-X in 1999 [2] and which has been developed up to the DIN EN ISO 9001:2008 -certification by TÜV NORD CERT in 2009. This quality management system takes into account both the processes and the technical aspects.

2. Process risks

Process risks result from budgets, schedule, due dates, requirements in the specifications, fluctuation of specialized manpower, etc.

2.1 Budgets, Schedule and due dates

A very effective system has been introduced for the integrated budget and schedule planning and controlling of each subproject (IPT – Integrated Planning Tool). Only this extended planning and controlling of work packages on basis of detailed and linked work breakdown structures of all departments provides the chance to synchronize all the activities and due dates.

A clear structuring of the project in subprojects with a clear assignment of responsibilities is a basis for good project management in general. Therefore approximately 60 subprojects were defined to coordinate the activities in the construction phase of the W7 X peripheral systems for operational phase 1. For all these projects clear technical interfaces have been defined, individual work breakdown structures and budgets created. For risk prone processes contingencies where implemented from the beginning to provide corresponding planning reliability. These are both temporal and financial buffers; but often also a plan B for the case that an intended solution proves to be unrealizable.

Supported by a continuous reporting and decision process on a weekly basis it allows the project to react early and efficiently to deviations and turbulences.

2.2 Fluctuation of specialized manpower

Another risk to be not underestimated in a construction project like Wendelstein 7-X is the availability of very specialized staff. Different from standard operation of a research institution, different expertise is required urgently, but only for a limited period in time. Therefore it may be difficult to hire such specialized personnel or even replace them in case of fluctuations. The problems associated with this risk may strongly depend on the detailed situation of any project, and can therefore not be discussed in a general manner.

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3. Technical risks

Technical risks are present in all steps of the process from specification, design, material selection, manufacturing, assembly, testing up to the operation of the experiment.

To minimize the risks at W7-X all design- and development processes are subdivided into clearly defined steps: specification, concept-design, development-design, and detail-design. Each step ends with the corresponding formal review with mandatory checklists, presentation and discussion in technical coordination meetings, assessment by a design-review-board and release of documents. All assessments include, besides the scientific and technical aspects, a permanent monitoring of potential risks, budgets, and due dates. This allows for process control minimizing the risks.

A very important step, perhaps the most important step because of its long lasting impacts, is a clear and complete specification, beginning with the functional specification up to the technical specification for the manufacturing. The main risk is an over- as well as an under-specification. The demand for technically best and most innovative solutions is useless if the result is too expensive, comes too late or cannot be carried out. Otherwise a quick and cheap solution often does not fulfill the essential requirements.

After finding adequate solutions it is very important "to freeze" the results after the single design steps to guarantee a great reliability at the interfaces to other components.

It is a real challenge to define and specify requirements in specifications for call of tenders clearly. A reduced amount of requirements might lead to an unsatisfying result. Too many and/or unrealistic requirements might increase time and cost and, in case development or manufacturing cannot be fulfilled lead to a complete restart of the process with subsequent losses in time and costs.

In the W7-X project several specification templates for different grades of complexity help the engineers to generate complete and adequate specifications for external suppliers. All the specifications are reviewed not only by scientists or team leaders but also by project controllers and specialists for quality assurance. They check the schedules, the time buffers as well as the necessity of using certified material, qualification of manufacturing procedures and personnel and help to define necessary intermediate and final checks. The templates often allow that the manufacturer is allowed to make suggestions in the offers, based on his expertise in complicated methods. The risks of new qualification processes or the use of unfamiliar methods can be minimized by this. Often prototyping of the most important elements can help to recheck the specification in detail.

Of course all steps like material supply, qualifications tests at all points “of no return” during the manufacturing at suppliers as well as in the institute are carefully supervised by the responsible engineer and the inspectors of the quality assurance. That’s the only way to minimize the risks.

The same approach for the reduction of the technical risks at the assembly of W7-X led us to a unique process of planning all activities.

Quality Assurance and Assembly Plans (QAAP) are used as the central managing instrument to plan all the work and test steps for each assembly task.

They must be worked out very carefully and in detail. For all the essential work and test steps the necessary working instructions, drawings, welding and soldering procedures, technical guidelines, collision reports, test procedures, etc. must be given. "Points of no return" must be recognized. Corresponding examinations must be inserted at these points so that possible deviations can be corrected. Mistakes identified later have to be corrected with an appropriately higher effort. Not identified faults would endanger the function of the whole machine. For all these works and eventualities the corresponding resources must be included in the plans. For assembly sequences assessed as difficult or risky, special qualifications and tests are carried out beforehand. The knowledge gained in these steps reduces the risk considerably during the real assembly.

Of course the four-eyes principle is always used at the check of the working results to exclude a certain organizational or operational blindness consistently. The system of inspectors of the QM department, who normally have level 2 certificates acc. EN 473/SNT-TC-1A, and highly qualified and designated internal inspectors has been well established. [3].

4. Changes and Non Conformities

Despite of all carefulness during the design and fabrication of any component, modifications and quality deviations are unavoidable. Therefore, in all these processes potential risks have to be identified and assessed. E.g. all changes to technical specifications (change requests, CR) and all quality deviations (non conformity reports, NCR) during the manufacturing or the assembly process are subject to a formal assessment process evaluating possible effects on the later operation of W7-X.

All CR need mandatorily an assessment of their influence on the scientific goals, the properties of the component itself as well as on the schedule, costs, and quality aspects before release. The same assessment is required for all NCR. Both kinds of document are then submitted to all subdivisions for the examination to avoid disregarding possible cross effects on other components.

5. Risk assessment for later operation

The operational requirements and boundary conditions were defined in the W7-X system specification and the corresponding specifications of the subsystems. But there are potential risks that have to be analyzed with regards to possible restrictions or consequences. Therefore a central change/deviation data base in the project W7-X is used, in which all these issues are collected and assessed. All CR and NCR covering the entire process of specification, manufacturing and assembly as well as other documents like decisions of the Configuration Control Board and the W7-X-Board are subjected to a formal assessment process revaluating possible effects on the later operation of W7-X. Even blocking cards, which only document small deviations in quality and their elimination typically, are included.

All above mentioned documents are assigned to one or more related subsystems of W7-X like magnets, cryogenic supply, vacuum system, etc. in the same classification as used for the safety analysis. (fig. 1)

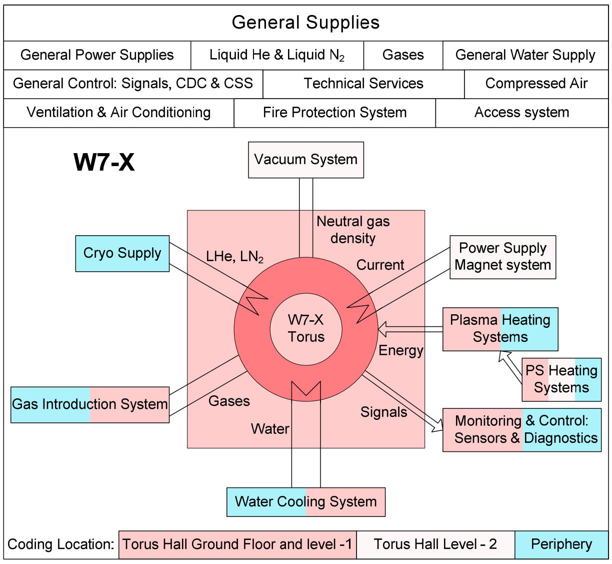

Fig.1 general supply subsystems

Major individual deviations and changes could lead to restrictions for single components or single operational modes. Sometimes the combination of several minor deviations can lead to a considerable risk resulting in a change of the operational limits of the machine. To discover these collateral dependencies, changes and deviations are linked to their subsystem through a KKS-number (power station designation system) as well as to a so called “problem area”. A problem area describes a certain system function of the W7-X machine which can be generated by a combination of different subsystems. Examples of problem areas are: “machine cooling H_2O”, “magnetic field”, “vacuum” and “structural integrity”. For example a component with a higher magnetic permeability than specified can influence the problem area “magnetic field” as well as “plasma”. Keywords from a fixed catalogue as shown in table 1 provide a condensed description of the changes/deviations and enlarge query options in the database for later trouble shooting. An example of use of keywords: A deviations concerns scratches on the front face of a vacuum flange. Here keywords such as “surface quality”, “vacuum capability” and “leakage rate” could be applied to describe the issue. Keywords thus describe the deviation/change whereas problem areas describe the system function which is affected by the deviation/change.

Table 1
Problem areas and keywords

Problem area	Keywords for changes/ deviations
Activation	Design space
Machine cooling H_2O	Design
Machine cooling He	Electrical resistance
Machine cooling N_2	EMC
Electrical isolation	Electrical grounding
Magnetic field	Geometry
Plasma	HV resistance
Electric power supply	Instrumentation
Structural integrity	none
Thermal insulation	Cobalt content
Vacuum	Collision
	Leakage rate
	Material properties
	Surface quality
	Permeability
	Position
	Crack initiation
	Cleanliness
	Weld seam quality
	Material changes
	Operational Phase 1 (uncooled divertor)
	Operational Phase 2 (High heat flux divertor)
	Vacuum capability
	Procedure

During the risk assessment, each change or deviation is assessed regarding probability and consequences as per DIN EN 61511-3 (table 2). The combination of probability and consequence results in a risk classification as shown in table 2. This classification of risks describes only the additional risk on top of the risks as inherently present in the reference design.

Table 2
Risk classes and their interpretation acc. DIN EN 61511-3 used for W7-X

Probability	Consequences				
	Catastrophic	Critical	Low	Negligible	No
Frequent	3	3	3	2	
Probable	3	3	2	2	
Incidental	3	2	2	2	
Low	2	2	2	1	
Improbable	2	1	1	1	
Incredible	2	1	1	1	
No					0

Risk class	Interpretation
0	Riskless, nominal conditions have been established
1	Negligible risk
2	Unwanted risk which only can be tolerated, if a risk reduction is impracticable, or if the costs for it are in rough discrepancy to the reached improvement.
3	Intolerable risk

Afterwards all changes and deviations and their risks must be assessed regarding their possible restrictions for later operation of W7-X as shown in table 3.

Table 3
Classification of Operational Limits

Grade of restrictions	Interpretation
0	No restrictions
1	Restricted operation, no monitoring
2	Restricted operation, monitoring necessary

Because of the late installation of the central data base in 2009 a backlog of older changes and deviations has to be assessed. But due to the good documentation base in W7-X assessing this backlog will, although time consuming, not be a problem.

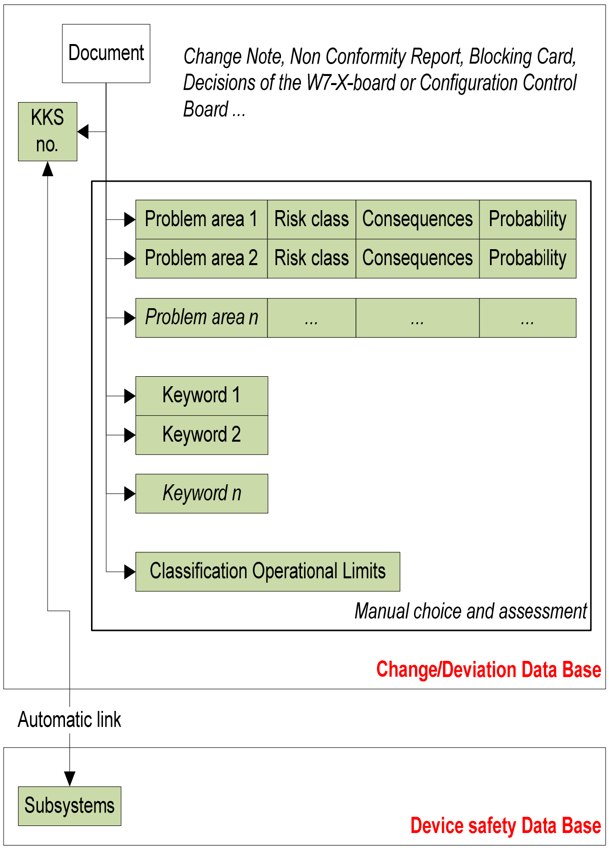

Fig.2 features assigned to every item in the change/deviation database as a basis for efficient query functions

All the additional information as linked to each item (change note, NCR, decision proposal etc.) in the database supports the definition of safe operational limits for W7-X. However this assessment cannot be carried out automatically in the database. Each subsystem must be evaluated by a team of specialists. But the features of the linked data bases are a good basis for efficient query functions to support these evaluations. Till now approx. a fifth of all NCR and CR were assessed. Approx. 900 risks were identified, which, however, do not lead to restrictions for the later operation.

In addition it provides a useful tool when trouble shooting in the later commissioning and operation phase of the subsystems of the machine to minimize effort and to supervise the potential risks adequately. (fig. 2)

Acknowledgment

All work as described above was done in close cooperation between the departments of W7-X, the assembly staff, project control and the QM-department. The good collaboration between these various partner, sometimes under strong time pressure, is gratefully acknowledged.

References

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