Variation in the hierarchy of welding production

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Abstract

Development of strategies for cost effective welding quality assurance is depending on knowledge from and communication between many functions in and supporters to the value chain of production of welded structures. Product development dimensions and estimates likelihood of failure, production monitors and develops process capability and quality/inspection assures measurement system accuracy and precision and estimates probability of detection. Their purpose is of course to avoid catastrophic failures on the field.

This investigation reveals that the view and language on risk-based inspection on welds not is the same between industries and not the same across different functions within the same industry. The consequence is that the underlying problem to welding inspection of inner faults not seems to be a technical issue in first-hand, instead development rather stall on difficulties on how to create overall consensus on how both root causes and risks with quality variation in the tolerance chain should be identified, assessed and mitigated. This displaces the issue from technical to managerial. This investigation supports an elevation of the issue in order to facilitate future interdisciplinary development to bridge horizontal and vertical fragmentation.

Three explaining concepts and one hypothesis on route cause are introduced:

- Concepts for elevated problem characterization are: <u>between industries</u> differences, <u>within industries</u> range of perspectives, and a <u>hierarchy of system levels</u> related to WHY WHAT and HOW.
- A hypothesis used for problem characterization is the difference between industries where NDT development is driven by the existence of public authority requirements and technical directions or not, which results in different prerequisites (will and need) to technically develop new NDT technology and procedures.

Introduction

The starting point for exploring the inspection strategy of inner welding errors[i] was a general uncertainty if the capacity of currently used non-destructive testing methods (NDT) can secure increasing demands of welding seam quality. In this investigation the complex of problems has been enlarged, characterized and discussed with a series of qualitative and quantitative investigations in order to propose a comprehensive picture of the problem that may serve as a base for further exploration.

The methodology used to tackle this problem was Six Sigma DMAIC. It stands for:

[i] WP6 – Inspection strategy for inner welding error

- Define: Characterization of the underlying problem through collection and analysis of qualitative and quantitative historical data with the purpose to validate or reformulate the problem statement and scope.
- Measure:
    - Securing that measurement system (MS) variability doesn't influence assessment of the processes monitored.
    - Process mapping, to identify process steps and input variables that influence the key performance indicator (KPI).
    - Sampling and measurements
- Analysis: Multi parameter exploration of the dependence between inputs and outputs.
- Improve: Parameter design of process and products in order to find the hidden improvements by changed settings that minimizes additional investments. Parameter design includes screening of influential factors (fractional design of experiments), full-factorial design of experiment to explore interactions and response surface methodology for optimization.
- Control: Correction and adjustment plans when process deviates from target.

The qualitative findings on problem characterization during define phase (D) is presented here. The successive statistical assessment of a welding process in production during phases MAIC is presented in a parallel paper[4].

An enlarged and elevated picture of the problem aroused during the problem characterization in the define phase in this project. It revealed a higher degree of complexity than expected that in its turn creates problems in the communications both within and between industries. And since the application of non-destructive testing for quality assessment and improvement is an interdisciplinary issue this findings is worth its own discussion and presentation in order to facilitate future work. In this paper some components to the overall picture are added and a hypothesis of the within and between industries problems is proposed. The purpose is to reformulate parts of the problem and add exploratory concepts that stimulates and facilitates communication that may help to bridge a fragmented welding community.

Characterization of the problem to create welding inspection strategies

The purpose of Six Sigma Define phase is to scope the problem area and to characterize the problem by collecting and organizing both historical qualitative and quantitative data. A main consideration is whether the cause is within the process defined or if it arises earlier in the chain of events. If the cause clearly origin earlier and beyond the control of the process developer, the task changes from 'find and eliminate causes of variation' to 'how should the process[ii] be improved and operated in order to reduce the influence of variation that not possible be eliminated'. This is extremely important to realize this difference; particularly with an interdisciplinary topic, when a group feels they suffer from lack of understanding of their problems from other functions in the value chain.

Scope

Primary scoping was done using the SIPOC-tool[1], Figure 1. The process "Preparation for RBI (risk based inspection)" is an immaterial information

[ii] or product, for that sake.

development process that starts when inspection is first contacted and stops when production starts. The main outputs for respective customer are (SIPOC right side):

- Design recommendations and risk evaluation for the value chain[iii]. The requirements from the value chain are for example: Product life estimates, producability, inspectability, cost effectiveness and risk vs. cost decision basis, etc.
- Testing procedure for the inspectors containing: Why (defect definition), What (testing method), How (procedure), Where (risk zones), When (sampling relative process capability), etc.
- Indication alarm procedure for production: What to do to bring process back to control, etc.

The main inputs to the process are listed to the left in the SIPOC. This preparation process is immaterial developing information. Some of the more important knowledge and information for this process come from three sources:

- Product development deliver information on what defects are dangerous where, i.e. the ‘Likelihood of Failure’
- Production deliver information on what the ‘Process capability C_{pk}’ is on the actual measures – defect type, occurrences per product zone and production facility.
- Inspection deliver information on what the ‘Probability of Detection POD’ is per testing method, defect type, location, orientation etc.

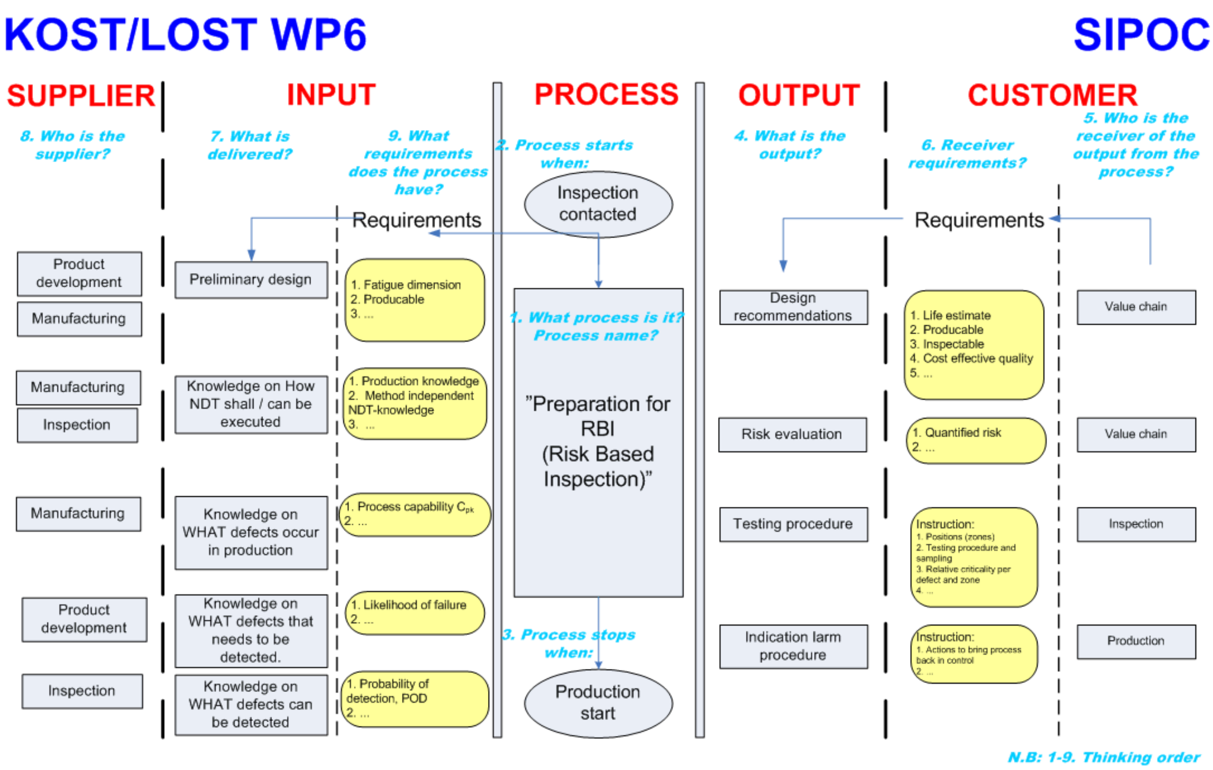

Figure 1: Primary scoping of the process "Preparation for RBI (Risk based Inspection)”

[iii] Value chain is considered to be the web of functions that design, build and deliver the final product.

Quantitative data – sampling and organizing

To learn and visualize what is already known, affinity-interrelationship analysis[2] was used to collect and organize quantitative data (verbal data). The 'risk-based inspection' community was sampled at two occasions:

- The first sampling: Between industries (Figure 2) was executed at a workshop at Chalmers Lindholmen (2008-02-06) with participants from vehicle and aero space manufacturing, inspection services (energy industry) and academia representing functions: engineering, manufacturing and inspection. Due to the origin of the issue in quality/inspection this workshop had a slight predominance in inspection. The group agreed that the following starting point captured the issue.

  The starting point: *What are the biggest problems translating drawing requirements to actual testing?*

  The group concluded: *Communication problems and insufficient NDT legitimacy is of greatest importance*. The most important concepts identified was:
    - o Communication flow in organizations doesn't work
    - o Ignorance about HOW NDT is done
    - o RBI-investigation not accomplished

  Another interesting concept identified on NDT ignorance was also 'ignorance about WHY NDT is done'. It represents another aspect of 'ignorance' that probably would need its own treatment. And the basic problem 'to do it right from the start' and make an estimate of how cost effective testing is done (lower right corner) was identified as a symptom of other problems.

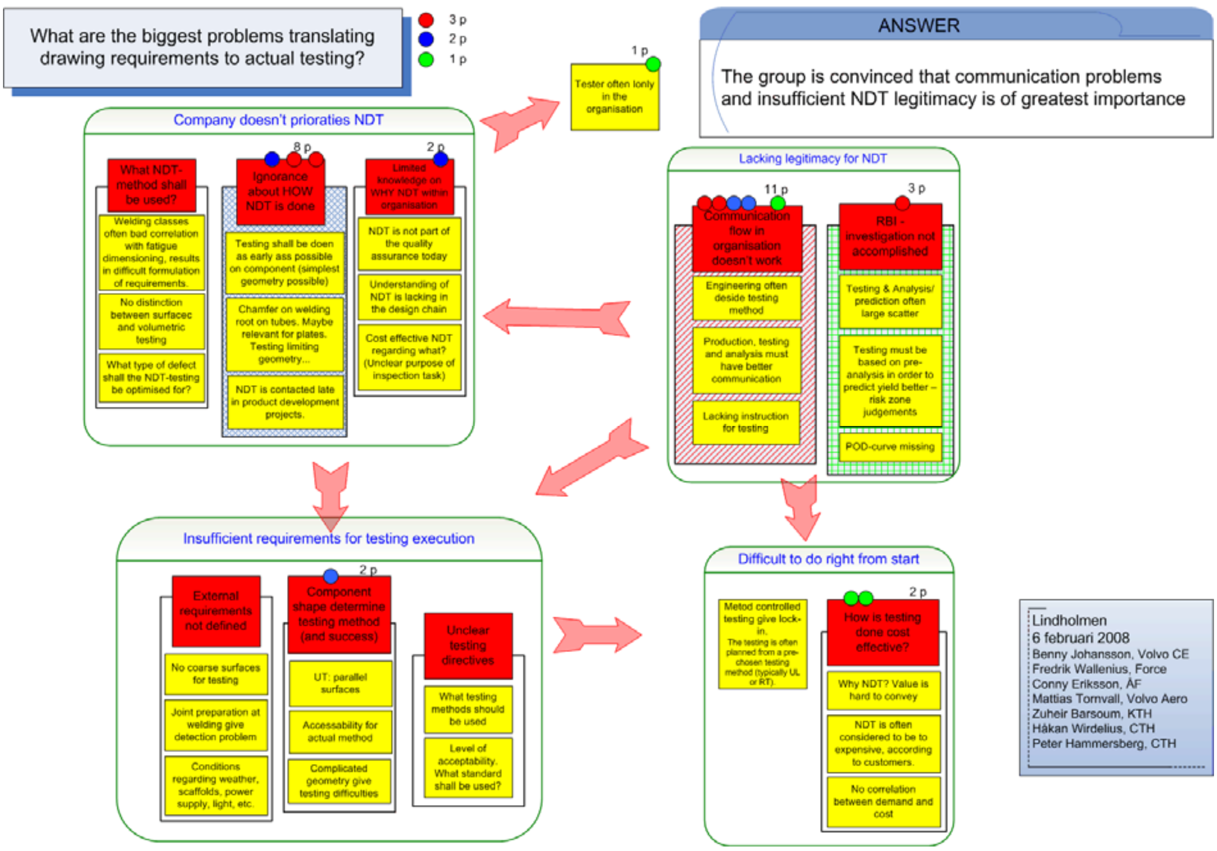

Figure 2: Affinity-interrelationship analysis between industries regarding risk based inspection.

- The second sampling: Within industries (Figure 3) was held in a workshop at construction equipment manufacturer Volvo CE in Skövde (2008-12-15) with representatives from engineering, production and quality/inspection. The group decided from the following topic:
  The starting point: *What are the biggest problems to control our welding processes towards new welding classification?*
  The group concluded: The problem origin in *insufficient inter disciplinary co-operation*. The most important concepts identified was:
  - o Interdisciplinary cooperation is missing
  - o Securing competence level for personnel within operations
  - o Control strategy is missing – when, how and where

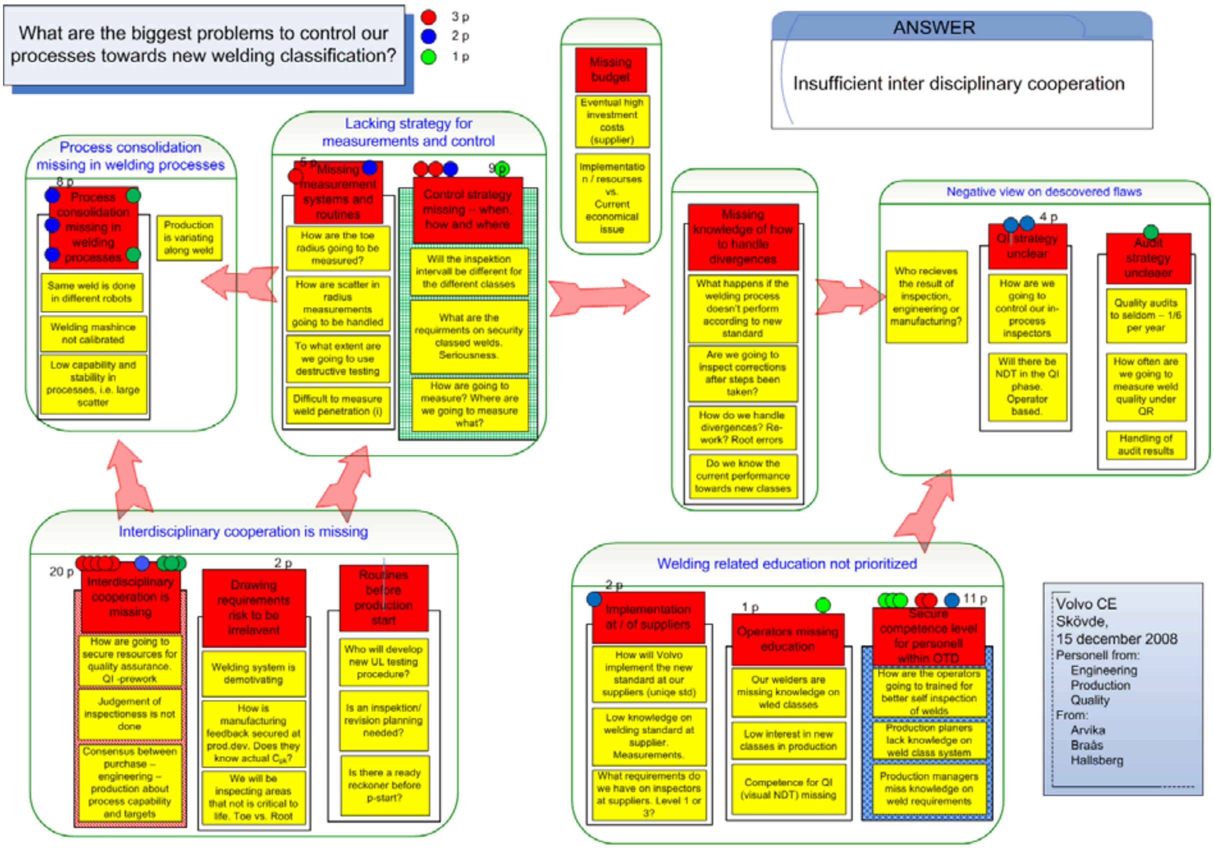

Figure 3: AI-analysis with different functions from one organization representing vehicle manufacturing

Observations of differences between industries

The AI-analysis above have lead to further considerations of what factors make a difference between industries and one of the most obvious observed is difference regarding technical requirements from the authorities. Within Aero and Nuclear sector the technical requirements on inspection from the authorities are clear, whereas manufacturing industry mainly is driven by self-induced demands to avoid warranty campaigns and production stop:

- Within Aero and Nuclear are authority requirements heavy and clear – driven by an extremely high price for catastrophic failures. This leads to:
  - o Imperative development of procedures and qualified technology
  - o Cost is thereby a natural part of the total mass of costs

  - WHY (NDT) is clear and the central discussion mainly regards technical limitations of the measurement systems (including gauge performance and human factors within inspection)
  - Important drivers are such as:
    - High component and cost for temporary deregistration
    - Lowest possible share false calls
    - Recurrent inspection and detection, characterization and size determination of cracks and flaws
    - Operation induced crack growth (fatigue, SCC, …)
    - Qualified technology only (verified by third part)
    - Extremely high quality requirements
- Within manufacturing industry the main drivers for the development of inspection are to:
  - Avoid major warranty campaigns demanded from market side and management. This leads to:
    - Indirect savings (by non-aroused costs often in organizational accounts elsewhere) shall motivate local factory investment
    - Long term development of technology and procedures are constantly questioned locally.
  - Avoid production stop demanded by production management leads to direct cost in the factory that drives development of process control and fast, short term feedback. This leads to:
    - A need of another type of information or another type of wrapping of NDT-information than quality principles demands.
    - This tend to build conflicting prioritization of who the customer to inspection really is, resulting in unclear directives and reluctance to drive long term development and fragmentation between production and quality.

Discussion

Between industries problems

The two samples of qualitative data from the AI-analysis and the observations on differences authority requirements lead to the conclusion that different industries and different functions do not think and talk the same way about risk-based inspection. In Figure 4 and Figure 5 the consequences of the difference <u>between industries</u> are generalized. The triangle in the center of the figures visualizes the organization as a hierarchical system with three levels. System level 1 (HOW) contains the separate physical functions: product development, production inspection and all other main functions of the organization. System level 2 (WHAT) represents the value chain, the immaterial web of functions that actually produce the welded structures. System level 3 (WHY) represents the stakeholders, mainly management and owners, responsible for long term profitability.

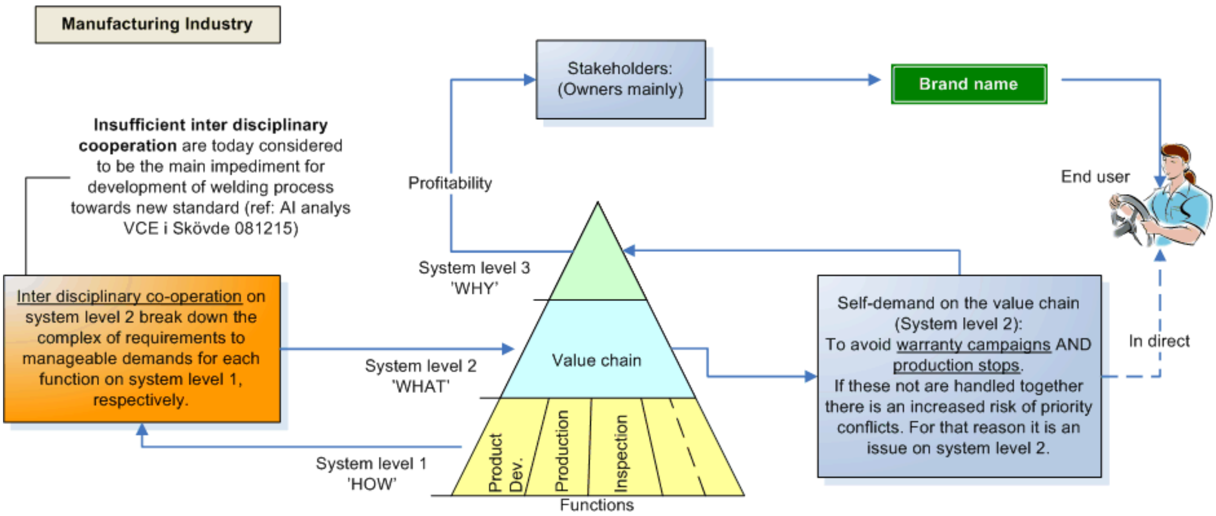

Figure 4: Problem description and driving forces in manufacturing industry

The self-demand on the value chain (to avoid warranty campaigns and production stop) within manufacturing industry (blue text box to the right in Figure 4), originate in the stakeholders requirement of overall and long term profitability. It directly has an effect on the brand name and end user community. A failing product at a single end-user will of cause influence the will in the organization to avoid shipment of bad products in directly, but the real driver is to avoid multimillion warranty campaigns. The requirement to avoid production stop also descends from the stakeholders at system level 3 but through the production managers. Bluntly put the market director worry about warranty campaigns and production management worry about production stop. The problem identified with the AI-analysis from within industries (Figure 3) that *'insufficient interdisciplinary cooperation'* concretizes that there is a lack of a 'physical' actor, which would be the natural counterpart to carry the <u>combined requirement</u> to avoid warranty campaigns AND production stop on system level 2. There is no concrete function that can weigh system level 1 characteristics together to meet the overall demand. The risk is high when the responsibility is put on any of the parallel system level 1 functions (product development, production or quality/inspection) that it lead to ineffective and costly sub-optimizations. Minimal number of defects in critical areas is common requirement from product development that may be unrealistically expensive for production and impossible to guarantee for quality/inspection, for example. All functions support long term profitability, but from their perspective. Many times with system level 1 conflicts.

On the other hand, with clear technical requirements from the authorities (Figure 5), the situation is simplified. Clear technical requirements are directed directly towards the system level 1 functions in their language and terms. That is, the requirement to, for example, to test with a certain method at a certain position for a certain defect, is met by a natural 'physical' counterpart that can carry this requirement and apply for means through the normal budget route, which can be done because it is already part of the picture that it must be done. Fewer questions asked.

A natural consequence, in the latter case, is that the discussion is about technical limitations and HOW instead of the diffuser discussion on WHY that the former from manufacturing industry is suffering from. It ends up in a cultural conflict; technically advanced discussions within the authority requirement driven community are of limited interest in the manufacturing community since the discussion is on whether or not to use NDT and if there are alternatives. And vice versa is the delicate discussion in manufacturing about balancing market director requirement to avoid warranty campaigns to the production director requirement of cost down production of limited interest in communities where there is no option to avoid the NDT investment if one wants to deliver at all.

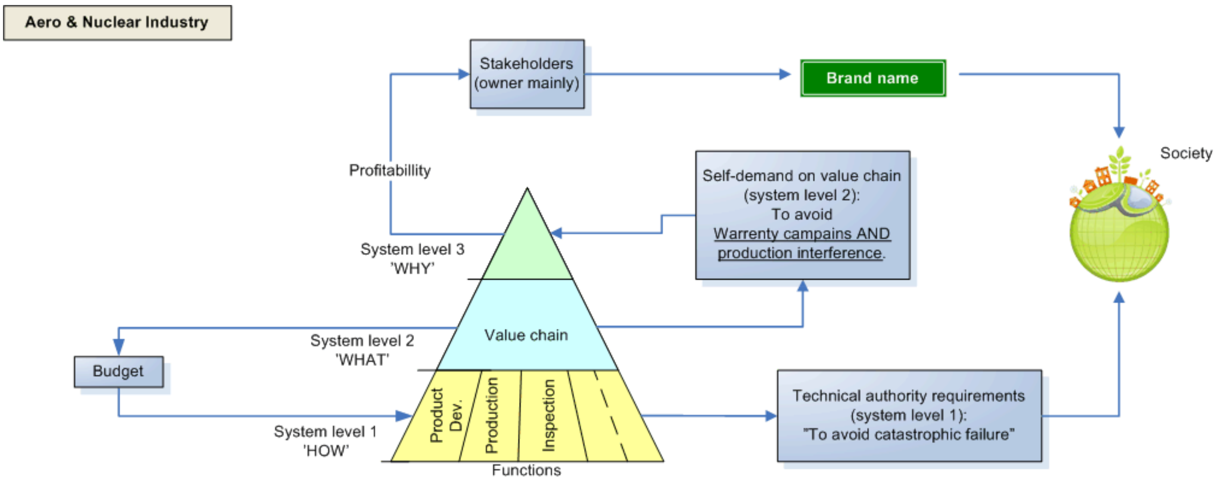

Figure 5: Problem hypothesis and driving forces in aero & nuclear industries

Within industries problems

Further exploration of the AI-analyses in Figure 2 and Figure 3 reveals differences between the system level 1 functions in their approach to robustness and how to reach reliability. The traditionally separated functions for product development, production and quality/inspection think and talk about variations differently.
The variation within the own function overshadow the significance of other variation. For example, product development are concerned that different defects differently serious at different positions, zones, likelihood of failure. Production are concerned that same settings on the welding process bring different result on different places on the product and from different production equipments, resulting in varying process capability. And for quality/inspection will different methods, equipment and procedures give different detectability for the same defect on different positions.

Today there is no clearly expressed strategy and methodology how to balance these variations. Earlier there was little awareness or at least concern with these variations, since they were hidden by over dimensioning and broad margins. But the overall aim with the project to increased performance for the load carrying structures will bring a significantly tougher comprehensive thinking when it comes to identification, assessment and mitigation of variations if it is going to be cost effective. How are the complex web of influencing product, process and inspection parameters set in order to minimize output variations <u>without</u> narrowing specification limits and automatically increase cost?

Comprehensive picture

In Figure 6 the picture is summarized. Differences between and within industries are expressed with the hierarchical thought model: WHY, WHAT and HOW[3]. To the left is the between industries problems visualized. And to the right is the within industries problems between internal functions. Many times (HOW) are the only base for the common language used across functions and industries. It naturally limits the discussions and means to communicate on problems, causes and solutions on a higher level. Even if the same technology is used in different industries and the way of expressing the technology limitations are the same and HOW to use it – sensor performance, detectors, sources, noise, contrast, resolution etc – it does not mean that WHY it is used and WHAT is done with it are expressed the same way. It takes long time before messages are conveyed and understood in the same way. Before concepts generally are understood and grasped the same way the communication is full of misunderstanding.

One particularly clear example of this misunderstanding frequently occurring is when 'cost-effective NDT' is used on the HOW-level (system level 1). What does it mean really (and in relation to what and why)? Each function and stakeholder has their own unspoken interpretation easily assumed to be a general aim for all others too.

Even if there is no great surprise that these differences occurs it is very important to reveal them and to make concepts of the difference part of the daily life in these communities to increase awareness and to facilitate development of mutual benefits and bridge fragmentation.

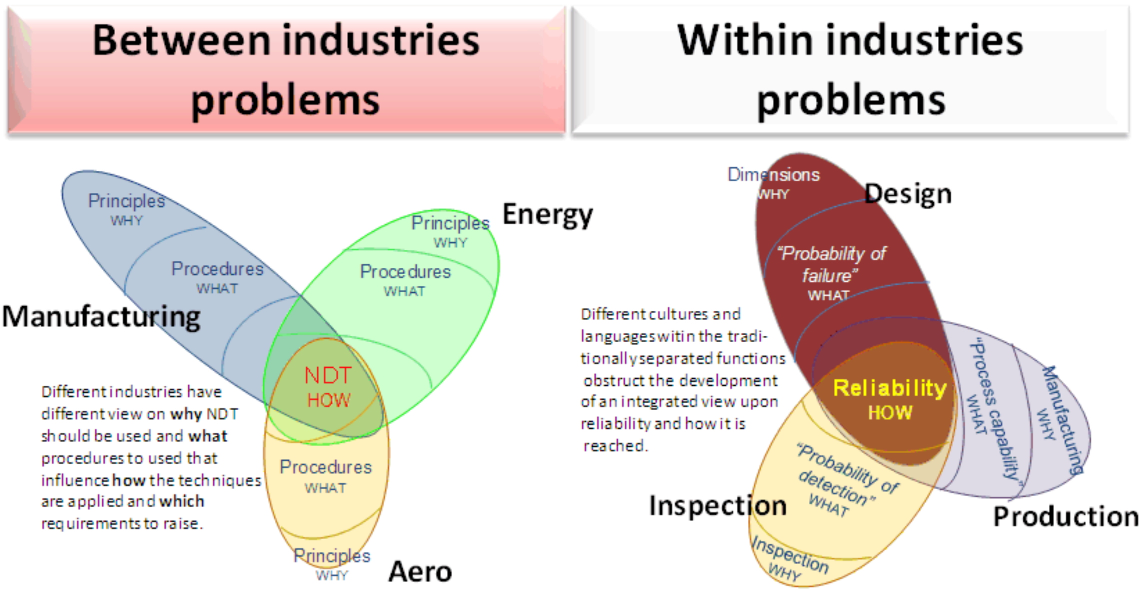

Figure 6: Summary of between and within industry problems regarding NDT and reliability using the hierarchal thinking model of why, what & how.

Conclusions

The views and languages of NDT is not the same between industries and between functions within different industries. These differences need to be clarified and explored in order to develop cost-effective NDT with the right technology level at the right place. The first step in an elevated discussion bridging fragmentation is to define common concepts that may be used to explore the problem.

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