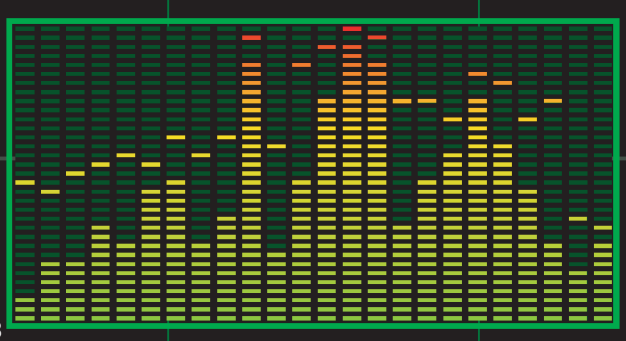
selecting successful systems

Dr **Jay Mandelbaum** explains how the US Department of Defense uses systems engineering to achieve successful system acquisitions



According to the International Council on Systems Engineering: 'Systems engineering is an interdisciplinary approach and means to enable the realisation of successful systems.' Systems engineering activities allow the development of a system that satisfies customer requirements within a set of constraints. These activities progressively build on each other in a logical way to determine the entire technical solution.

Systems engineering technical reviews (SETRs) are designed to determine whether the system is ready to enter the next stage of development. These reviews are event-driven, multi-disciplinary and organised around detailed checklists that are used to assess both technical progress and technical risk.

The US Department of Defense relies heavily on systems engineering processes and quality engineering makes important contributions to them.

Quality engineers identify process-based technical risks that affect the technical solution. Best practices include:

- the early involvement of quality engineering personnel in product realisation processes to ensure that they are implemented correctly
- creating conditions to encourage the entire workforce to focus on product and process quality along with cost, schedule and performance
- developing strong links between quality management and the systems engineering technical reviews

Quality and systems engineering

Within the US Department of Defense, quality management has two principal interactions with systems engineering processes.

First, product quality is a systems engineering design consideration. Design engineering efforts lead to a producible and testable product only if that product is designed with consideration for the manufacturing process capability. To achieve high product quality, the manufacturing process must be designed so that it can be in statistical control over an extended period of time and varying conditions. The design specifications must also be aligned with manufacturing process capabilities.

The Defense Acquisition Guidebook has a more detailed definition. It has been developed for both government members of the acquisition community and its industry partners to provide discretionary best practices that should be tailored to the needs of each system acquisition. For more information on this visit http://akss.dau.mil/DAG

The second interaction between quality management and systems engineering is related to processes. While system engineers develop, manage and execute technical processes, quality engineers independently assess if those processes are working as designed. This is especially important for the determination of technical risk during the SETRs since process carelessness leads to technical risk. Quality engineers, therefore, seek to identify process-based technical risks that affect the technical solution.

In particular, quality engineers identify potential risks that can be mitigated. For example, the inappropriate application of technical processes and/or inadequate procedures may lead to ill-defined requirements, a breakdown in requirements flow down or uneconomically producible designs. Similarly, ineffective supplier management processes may result in the selection of suppliers with inadequate capabilities or decreasing leverage with subtiers.

Process-based technical risks can be prevalent. Figure 1 shows the results of an analysis by Northrop Grumman Space Technology of design escapes. Root cause analysis showed that 82 per cent of the design errors (escapes) were attributed to 'no

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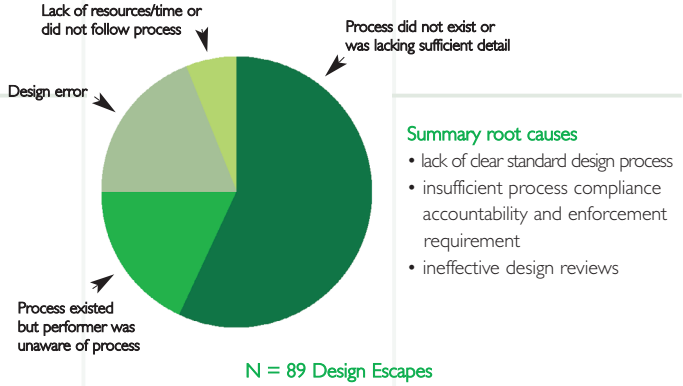
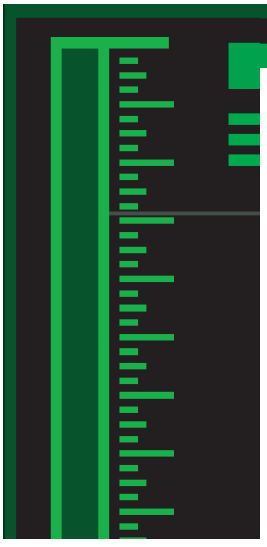
Figure 1: Illustration of the prevalence of process-based technical risks



Source: Presented by Lisa Kohl; Vice President, Northrop Grumman Space Technology; at the Lean Aerospace Initiative Plenary Conference; 23-24 March 2004.



'The later these risks are identified in the acquisition process, the greater the cost of corrective action and the greater the delays in schedule'

Case study

Reviews of the overall project

The Department of Defense has modified its SETR checklists to include early emphasis on quality assurance policy and procedure documentation, quality assurance organisation and personnel, the completeness and adequacy of quality planning, and manufacturer and supplier quality control.

System requirements review

This is the first SETR after programme initiation. Checklist questions are designed to determine that the prime contractor's quality management system is in place, a quality plan is tailored for the programme, the authority of the personnel performing quality functions is established and organisational responsibilities are agreed upon. Questions also verify that planning has begun for industrial base capacity assessments, supplier selection and manufacturing control.

Systems functional review

Checklist questions substantiate that a corrective action system is in place to analyse data on trends and deficiencies in processes, product and work performance to prevent nonconforming products. The questions also determine that a process is in place to assure that the relationship between key characteristics and operational safety requirements is verified. In addition, the questions confirm that there is a process for examining performance requirements and risk at the subsystem level to assure all work affecting product quality is documented in a clear and complete manner.

Preliminary design review

By the time this stage occurs, the questions confirm that much more has been accomplished. Plans for qualification testing to support programme requirements should be prepared. Process capability and quality metrics should be identified and estimated. The supplier management programme should be in place and the prime contractor's responsibilities established for controlling and recording design and other changes originating with suppliers. Documentation necessary to produce articles in conformance with design should be specified and a variability reduction programme plan documented.

Reviews with the prime contractor

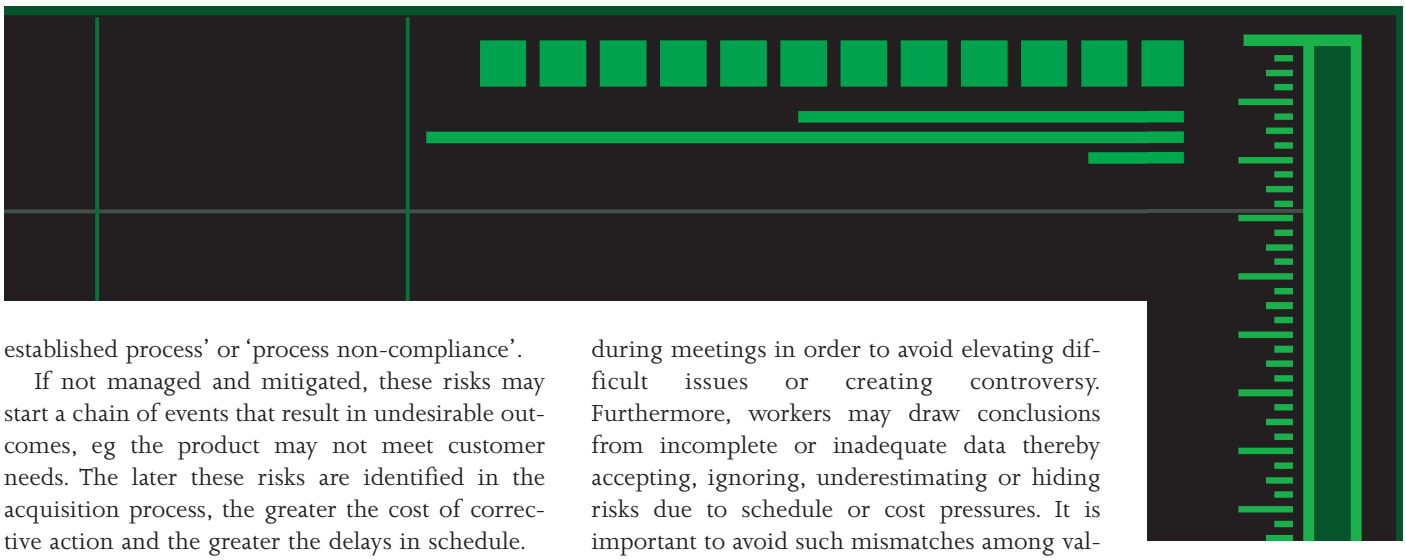
These reviews are conducted between the Department and its prime contractor. The contractor conducts similar technical reviews at the major subsystem level with its principal suppliers. Quality personnel from the contractor should also pose questions to their supplier counterparts in parallel with the subsystem SETR and the questions should be designed to elicit discussion, not just a 'yes' or 'no' answer. An early version of this process was successfully used by the Boeing Company for its Poseidon, multi-mission maritime aircraft program, for the US Navy.

Based in part on those experiences, the Department has developed a broad set of approximately 100 tailorable questions for use on all of its programmes. These tailorable questions are organised around the ISO 9001 product realisation process.

Questions have been developed for systems engineering, software engineering, integrated product definition, product support, test engineering, supplier management and procurement, manufacturing engineering and manufacturing product.

Example questions

- describe/evaluate the verification plans for 'non-tooling' concepts (eg determinant assembly, self locating parts etc)
- describe/evaluate how verification is accomplished
- describe/evaluate how to integrate the verification requirements into the work instructions
- describe/evaluate the process that identifies key characteristics (ie the features of a material, process, or part whose variation has a significant influence on product fit, performance, service life, or producibility)



established process' or 'process non-compliance'.

If not managed and mitigated, these risks may start a chain of events that result in undesirable outcomes, eg the product may not meet customer needs. The later these risks are identified in the acquisition process, the greater the cost of corrective action and the greater the delays in schedule.

For example, process defects discovered well before production may be easily corrected while product defects discovered in production or testing may lead to expensive and time-consuming rework.

Product failures discovered in the field may even lead to degraded mission effectiveness or mishaps. Early identification, management and mitigation of important process-based risks to a program produce less expensive and less disruptive preventive actions that break the chain of events leading to more serious consequences.

Reducing risk

Quality engineering personnel need to be involved early in product realisation processes. Such involvement entails the systematic use of a process-based quality management system and improves outcomes by ensuring that the processes are implemented correctly.

It also enables a better understanding of requirements, an evaluation of processes in terms of value added and the improvement of process performance based on objective measurements. Delaying involvement until production or until there are problems is a mistake.

Another best practice is for management to encourage the entire workforce to focus on quality along with cost, schedule and performance. Ideally, values, beliefs and behaviors will also be aligned to achieve high quality.

But while values often reflect quality goals, beliefs and behaviours may not. For example, a value codified in policy may be 'nothing goes out the door if it's not done right'. Yet people may believe they should not ask penetrating questions during meetings in order to avoid elevating difficult issues or creating controversy. Furthermore, workers may draw conclusions from incomplete or inadequate data thereby accepting, ignoring, underestimating or hiding risks due to schedule or cost pressures. It is important to avoid such mismatches among values, beliefs and behaviours.

As part of its focus on quality, the Department of Defense encourages industry to apply effective practices, and the Department follows best practices consistent with its oversight responsibilities. Key areas for this focus on quality at system acquisition programme startup include:

- establishing the product or project budget for quality engineering activities
- placing responsibility for product and process quality in the programme
- assigning personnel with adequate skills for assessing product and process quality to the project
- analysing requirements for product and process quality and mitigating associated risks
- establishing the project's strategy for achieving product and process quality

Other important areas for this focus on quality throughout the lifecycle include:

- management's use of data on product and process quality
- contractor's approach for continuous process improvement
- contractor's approach for preventive and corrective action
- contractor's approach for achieving customer satisfaction qw

Dr Jay Mandelbaum joined the Institute for Defense Analyses (IDA) as a research staff member in April 2004. He received his MS and DSc in operations research from the George Washington University in 1976 and 1982 respectively.