

Design Reviews: A Process Perspective for Improved Efficiency and Effectiveness

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Abstract. This paper documents and analyzes a typical design review process in the South African defense industry with the aim of improving the effectiveness and efficiency associated with design reviews. Process steps are scrutinized to identify behavioral and procedural actions that negatively impact on concluding successful design reviews. Poor design review culture and a few bad design review habits are highlighted with the aim that the lessons learnt will be of value to any organization in any environment conducting design reviews. The paper then goes on to suggest enhancements to ensure an improved design review process, as well as initiatives to foster a culture conducive to constructive reviews.

Introduction

Observation of and participation in design reviews undertaken in various organizations in the South African defense industry, showed that the design review process followed does not always optimally identify and address risks and design deficiencies. The focus is (at times) diverted from doing the right things right. This prompted some thought as to whether one can improve the process to ensure the conclusion of more successful design reviews. This paper details and explores poor design review culture and a few bad design review habits that have been observed over the years, with the aim that the lessons learned will be of value to any organization in any environment conducting design reviews. None of the identified pitfalls may seem “news” to the reader, but their consolidation in one place should be worthwhile. Knowing which pitfalls to look out for, avoiding the identified pitfalls and implementing the guidelines for improvement detailed in this paper will certainly contribute towards conducting streamlined, focused, effective and efficient design reviews.

The Design Review Process

The observation of these design review processes in at least 7 organizations over a 13 year period, both as client and contractor, led to the documenting of the following generic design review process. For readability the process is split between the internal design review (figure 1) and the external design review (figure 2).

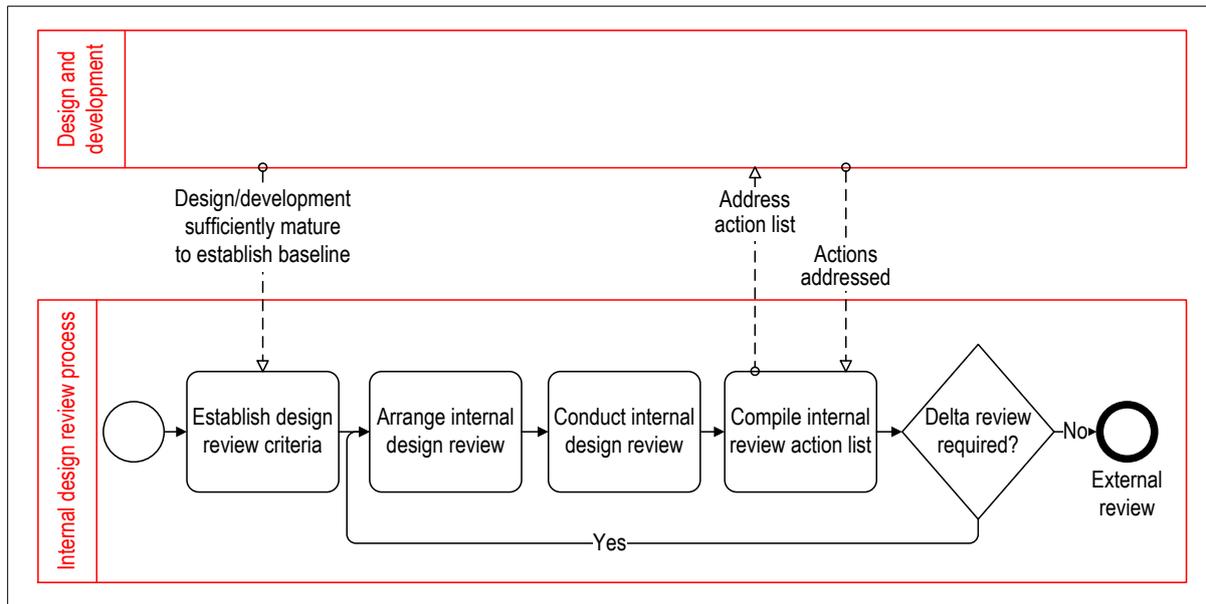


Figure 1. Generic internal design review process

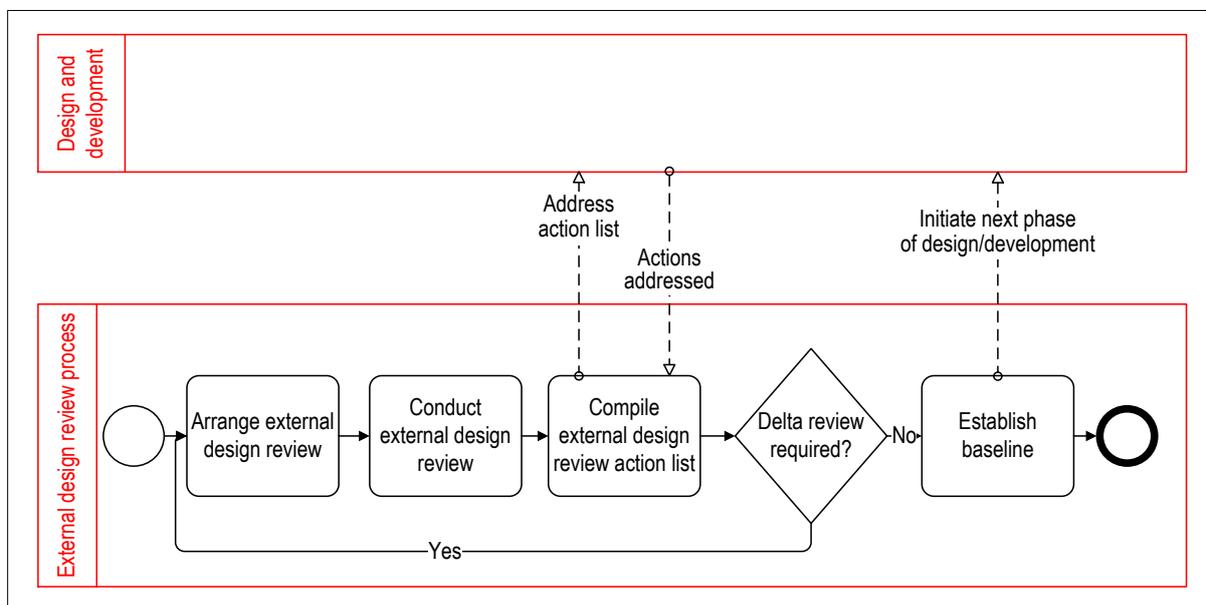


Figure 2. Generic external design review

Even though an individual organization's design review process may have variations on this generic process, it can be argued that the same or at least similar problems will be experienced during the preparation for and execution of design reviews. The nature of the problems identified in my experience correlates to those problems and areas for improvement identified in the available literature on design reviews e.g. understanding the purpose of the decision gate (Haskins 2011); ensuring that the design and associated data package is technically mature and ready for review (Gilb 2004; Gilb 2007); understanding the customer, his knowledge of and insight into the design and his expectations (both functional and from a quality perspective) (Armstrong 2004; Wyman 1994); selection of the design review team and assigning clear roles and responsibilities (Zonnenshain and Tavory 2006); etc. The design review woes experienced in the South African defense industry are therefore not unique and any organization undertaking a review process could potentially benefit from this paper.

Addressing Both “Efficiency” And “Effectiveness”

Before getting into the process deficiencies and proposed improvement strategies, the concept of efficiency vs. effectiveness is recapped. The question whether to improve efficiency or effectiveness is often asked and debated at length; as such it is of value to look at the definition of both terms to decide what the aim of any proposed process improvements should be.

Efficiency is the extent to which an activity achieves its goal whilst minimizing resource usage or in simpler terms “*doing the thing right*“ (Harvey 2012).

Effectiveness is the extent to which an activity fulfills its intended purpose or function or simply put “*doing the **right** thing*“ (Harvey 2012).

From personal experience, management or contract driven design reviews may focus on the efficiency of the creating system and divert attention away from the real intent of a design review. This focus is better suited to a contract “gate” review where the focus is on stakeholder and sponsor risk management. Such reviews should be managed in accordance with project management principles, looking at budget, schedule and the design-to specification. Whilst, also in my experience, engineering driven design reviews may focus on the effectiveness of the end product or created system in isolation of the needs or constraints of the creating system. This leads to long action item lists which include multiple items which cannot be implemented due to the constraints of the contract or creating systems. In both cases the focus of improvement is inappropriately limited to either efficiency or effectiveness improvements whilst neglecting the other, and the resulting effects may in all likelihood be undesirable.

The aim is thus to *do the right things right* and the focus should thus be on both efficiency- and effectiveness improvement.

Is The Design / Development Sufficiently Mature?

When should the design review process be initiated? Is it at the point where technical maturity is sufficient to ensure a meaningful outcome of the review process (event driven) or is at a predetermined point on the schedule (schedule driven)? Underlying to this question is the integrity vs. cash flow debate. The earlier you commence with formal design reviews, such as during the bid process, the greater the impact of the review on efficiency and effectiveness.

A bias towards cash flow. Yes, it an undisputed fact that cash is king and that no project can survive without the required funding and associated cash flow. However, in every project there should be a balance between business, funding and integrity. This view is supported by the INCOSE Systems Engineering Handbook v. 3.2.2 (Haskins 2011) and it stresses that system integrity mandates all three of these aspect to be in balance and given equal emphasis at decision gate reviews. Personal experience has shown that the project manager has cash flow on his/her agenda, whilst the systems engineer champions integrity. Literature (Jackson 2012, 40) also suggests that program managers are focused on “organizational strategy say profitability”, whilst systems engineers are focused on “high technical quality”. This disparity between the two parties has the result that “work often costs more, takes longer and provides a suboptimal solution” (Langley, Robitaille and Thomas 2011, 25).

In the ideal world the organization will foster and encourage both agendas to succeed in balance with one another. In the real world, however some organizations are structured in such a manner that only one of the two are rewarded, leading to an automatic and potentially

disastrous conflict. The argument is often that cash flow is measurable within a realistic timeframe whereas technical success may only be evident long after product fielding. Add to this a situation where the systems engineer reports to and is subservient to the project manager and you have a problem heading your way. This leads to the short term achievement of payment milestones at the long term cost of technical integrity. It creates risk instead of abating it and ultimately leads to dissatisfied customers, projects failing and/or costing far more than they should.

Closely related to this pitfall of design review culture detailed above, is a culture and environment where revisiting requirements or design, reconsidering project activities or terminating a project is not tolerated. An example of this is the development of a handheld device, which at the embodiment of the first prototype proved to be everything but handheld. After rigorous ergonomic evaluation and heated debate, the project manager simply insisted in continuing with the development as it was felt that it was too late (i.e. my schedule and my cash flow are at risk) to make changes and that any changes would just distract the contractor. Valid arguments. One just has to wonder whether the customer, who required a handheld device will be satisfied with a brick. The issue never even made it to a design review agenda. If the project allows for only one decision at a gate, namely forward/proceed and no deviations or detours are allowed, it creates the perfect environment for project failure.

When design reviews are initiated based solely as a result of schedule and cash flow planning, one is at risk of hearing comments such as *“this is a relatively new concept”* (surprise expressed by the design team as a result of focusing on a specific deliverable and neglecting to take a holistic view of the system, thus ignoring the required concept of operations when implementing a specific element of the design – consequently there is resistance and an inability to show compliance to implicit contractual requirements), *“those loose wires (on a wiring diagram) are an indication that there may be a project slip”*, *“this was all hashed together rather quickly”* or *“it’s all that we could think of at this stage”* from designers who are trying to defend their designs. The result? At best – a delta review (which ultimately has a negative impact on schedule and resulting cash flow). At worst – an inferior baseline that “will be fixed later” (naturally still within the original planned schedule). It leads to demotivated design teams and ultimately to disillusioned customers who have to pay more for systems that they receive (much) later than planned.

To all project managers out there who have an unbalanced bias towards cashflow: consider the technical aspects and maturity of the design under consideration before forcing a design review. This focus may decrease the chances of identifying technical problems through the review, necessitating the implementation of problem fixes at a later stage and thus increasing project cost. A slip now may well be detrimental to short term timescales and cashflow, but will in all likelihood prove beneficial in the long run.

Guidelines for technical maturity. If the balance between business, funding and technical integrity can be achieved, the question of what constitutes technical maturity or integrity still remains. It is proposed (Gilb 2004; Gilb 2007) that the design is not ready for review if the specifications are unclear or if you are “unclear whether a design is mandatory (a design constraint, which is a ‘requirement’) or optional (one of many possible design solutions)”. It is therefore important to ensure that all specifications are clear and unambiguously stated, understood and implemented before proceeding with the design review. Comprehensive quality assurance should have been undertaken on both the specifications and resulting designs before the design review can be convened.

Proper change-, requirements- and risk management during the execution of design and development activities contribute to technical maturity and subsequently to design review success. It is imperative that any changes made during design and development (an identified deficiency or a requirement change) be properly linked to a customer need and the requirement designed to meet that need. This will enable the project team to show evidence of why decisions were made.

Prepare For The Design Review

What is your standard? With the cancellation of MIL-STD-1521B Military Standard (for Technical Reviews and Audits for Systems, Equipments, and Computer Software (US Department of Defense 1985) (at least in local design and development of South African Defense systems) the question has been raised as to what specification should guide the planning and execution of design reviews. It has become a point of debate and contention as to what standard(s) should be contractually prescribed as it is argued that MIL-STD-1521B is outdated and invalid i.e. no longer effective or efficient. The South African Defense domain therefore faces a challenge to either formally mandate MIL-STD-1521B, embrace an alternative standard such as IEC 61160 Design Review (IEC 2005) or to develop a local South African military standard. In the absence of such guidance, South African developers are faced with the decision to at least embrace some form of standard (even if it is developed in-house) into company policies and procedures to contribute to the efficiency and effectiveness of the company design review process.

In my opinion, South African companies undertaking defense developments should develop their own, unique processes and procedures based on a standard such as IEC 61150, tailored within the context of the South African Department of Defence's (DOD's) Policy, Process and Procedure for the Acquisition of Armaments - DAP 1000 (South African Department of Defence 2010), the South African Military Standard for Program Baselines (RMSS 2007) and guidelines available in literature such as the INCOSE handbook (Haskins 2011).

Ensuring the data package is ready. Preparation is key to the successful completion of the design review. At the outset it is imperative to set the objectives or criteria for the specific review. This can be achieved by means of design review checklists and/or compliance matrixes. Research has shown that this facilitates the identification of more problems (Ostergaard et al. 2005, 183) and a more comprehensive (Sater-Black and Iverson 1994) and systematic (Pahl and Beitz 1996) review of the design. Even though it is advisable to use a generic checklist or compliance matrix as the basis for determining these criteria, it is important to use these generics as a guideline only and not as a one size fits all. Tailoring of guidelines should be mandatory. It is vital to assign the right team to do the tailoring. It seems obvious that the systems engineer and lead designer should be included in such a team, but the contribution to the tailoring efficiency that can be contributed by representatives from quality and specialist areas such as logistics, test and evaluation, as well as technical documentation should not be overlooked. It is also beneficial to involve the client in the tailoring process to ensure "understanding and acceptance of the benefits and associated risks" (Richstein, Nolte and Pfarr 2004) of the tailoring decisions. If the right team is not assigned to the tailoring, the result may be a loss in efficiency due to the difference in perspectives. But, a balance should be maintained and the team size and span should be limited to avoid a situation where there are simply too many role players or sub-teams.

The generic checklists or compliance matrixes should also take into account where the design

under consideration is in the development cycle i.e. a single, prescriptive 150 page checklist for all design reviews will prove to be both inefficient and ineffective. Tailoring requires an understanding of key stakeholder considerations and should ensure that stakeholder interests are addressed (Richstein, Nolte and Pfarr 2004) without compromising on design quality. The checklist or compliance matrix typically addresses conformance to requirements as stated in specifications and highlights issues/implications associated with the design (e.g. cost and risk) (Pahl and Beitz 1996; Sater-Black and Iverson 1994).

The situation where a design review data package is distributed for external review without a completed checklist should be avoided. This reflects even more negatively on the design team when enquiries by the client reveal that no checklist exists. It becomes downright ugly when the client is consulted only at this point as to what criteria to include in such a checklist. Preparation for the design review (even the internal design review) should include interaction with the client to ensure agreement on the design review criteria.

It is however, essential that the design review, reviews the design. Cash flow motivated reviews tend to focus on reviewing the compliance matrix and making sure that all the boxes are checked. Such reviews generally neglect to review the design underlying the compliance matrix. The risk is thus that critical design flaws will not be identified nor addressed, even though all the right boxes were ticked in the compliance matrix. Reviewers should review the design (including the underlying specifications i.e. the requirements as detailed in the higher level specification(s), as well as the requirements detailed in the specific element specification(s)) and check the completed compliance matrix against their review of the design.

It is important to remember that the “real purpose of design reviews is not to approve the design as correct, but to uncover specific risks and ignorance” (Gilb 2004; Gilb 2007). The purpose is thus not to rubber stamp the design, establish the baseline and move forward from there. The view should rather be that the design under consideration is good enough with its associated risks exposed sufficiently for the development process to continue. This ensures that design(er)s don’t fail, but rather identify ways to improve. It eradicates a culture where the design review is merely a (painful) gate to pass and instills it as an opportunity for adding value and finding meaningful ways to manage risks.

Select the review team. It is important to identify and select a competent, well balanced design review team for both internal and external design reviews. Reviewers should be technically capable and have sufficient experience to objectively provide constructive inputs on the design and documentation package presented. Even though it is undesirable to assign responsibility disproportionate to experience, it may be meaningful to involve a limited number of junior staff in the review, as it is an opportunity to learn from more experienced reviewers. However, senior staff should not delegate juniors to attend a review on their behalf, sending the junior along with the senior’s marked-up documentation pack – it reflects poorly on both parties when a junior engineer provides feedback and when further clarification is required has to confess that they themselves are not quite sure what is meant by the specific comment.

Consideration should be given to including a member/s on the design review team that are not intimately familiar with the design to ensure objectivity in identifying risks and areas for improvement. Roles and responsibilities should be assigned well in advance of the review, making sure that the assigned responsibilities map to role player capabilities. There should be consistency between the design organization’s role players for both the internal and the external review. The identification of client role players for the external review requires close

coordination with the client and no assumptions should be made on which client representatives to invite.

It is also very important to ensure that reviewers have the required decision making responsibility, authority and accountability to accept/reject decisions about the design and to ensure that any required corrective actions are implemented (Sater-Black and Iverson 1994).

It is necessary to ensure that the design review team comprises of members representative of all applicable disciplines, including the “-ilities”, as well as stakeholders throughout the subsequent life-cycle phases such as manufacturing, maintainability, training, supply chain, etc.

Setting the scene. Having a “dry-run” for the design review may go a long way toward avoiding nasty surprises at the actual review meeting. It serves as a final check to ensure that unnecessary ambiguity does not exist and that all aspects required for consideration are sufficiently addressed. It may be worthwhile to involve key client role players in such a dry-run to ensure that the client is orientated and to obtain buy-in. It is, however, important to schedule this meeting well before the actual review to allow sufficient time to address any outstanding issues prior to review meeting.

Evolutionary design reviews. When dealing with complex systems, it is advisable to conduct sub-system reviews, building up to a system review that deals with the design from an integrative perspective. This strategy will improve efficiency as it avoids attempting to review huge piles of design documentation over a short period. Involving clients in the evolutionary review process will have the added benefit of avoiding the situation where lengthy explanations and orientations are required to get the client up to speed. This sentiment is echoed in the recommendation by Sater-Black and Iverson (1994) that “a series of well-planned meetings will also provide more comprehensive coverage than a single lengthy meeting”.

Arrange Design Reviews (Internal And External)

Allow sufficient review time: Design reviews should be arranged well in advance of the actual date. It should be appreciated that this is a time consuming processes and, should effective results be required, sufficient time should be granted for reviewers to efficiently review the design. Distributing mountains of design documentation a week prior to a review will only elicit comments such as “I spent all night looking at your documents and I still don’t know what you’re trying to achieve”. Unfortunately, ensuring that the reviewers have adequate preparation time, still does not ensure that attendees arrive at a design review prepared or even sure of the purpose of the meeting (Armstrong 2004). It is also important to ensure that complete data package be distributed to the entire design review team, thus ensuring that the information becomes shared to facilitate relevant discussions and more thorough problem identification (Wetmore, Summers and Greenstein 2010, 124-125). In addition to the data package clear, concise guidance on the purpose and intended outcome of the review must be distributed to the team. This should also address the application of the checklist or compliance matrix to the design and required outcome of the meeting.

It should also be ensured that the actual review meeting is scheduled for an appropriate length of time and that the review team is all committed to being available for the entire scheduled duration. Key role players leaving early to attend another meeting or to catch a flight may be detrimental to achieving the objectives of the design review.

Allow for objectivity: When arranging the design review, it may be prudent to include attendee(s) who are not familiar with the design. The design team and to an extent even the client, have become familiar with the design during the development process. In addition, developers take pride in their developments and may feel the need to defend their designs at the cost of improvement. This familiarity and developer pride sometimes breed content and comfort with the design, removing the ability to review objectively and potentially introducing ineffectiveness into the design review process. Including someone who can take an objective view of the design may find it easier to spot risks and areas for improvement. It is, however, important to assign this role to someone whom the design team respects and whose inputs will be taken seriously. The objective reviewer should thus be acknowledged as an authority in the field under consideration to facilitate a fruitful exchange of ideas with the design team. It is important to guard against nominating an existing stakeholder to fulfill this role as it could have an adverse effect on objectivity.

Clarify roles and responsibilities: The “who should do what” at the review meeting i.e. who chairs the meeting, who is the secretary, who makes the required presentations and who attends should be clarified well in advance of the meeting. It is also important to know who the client representative will be and what their respective roles are. In the case of defense clients it’s important to ensure that all contractor review attendees have been sufficiently briefed on the correct protocol to observe. A temptation may be to assign the role of secretary to a project administrator or personal assistant, but it should be kept in mind that the discussions are likely to be of a highly technical nature and, if you want useful (effective and efficient minutes) it imperative to allocate someone to this role who is familiar and comfortable enough with the technical discussions to accurately capture the minutes. In addition, assigning the roles and responsibilities should not only focus on technical competence, but should also make provision for the softer skills required in dealing with a meeting of this nature. It is, for example, *imperative* that the chairman be adept at conflict resolution.

Conduct Design Review (Internal And External)

Provide the context: Because not everyone knows why they’re there – clarify the purpose of each design review – even if the project has progressed in the development cycle and previous reviews were conducted (Armstrong 2004).

Take all reviews seriously: Designers and developers like creating stuff. They are not naturally inclined to wasting valuable design time in boring meetings. A culture can easily exist where the design team views especially the internal review as a nuisance – often arriving late, unprepared, not at all or sending the most junior delegate, because they did not have any time to “waste” at an internal meeting that will just be “repeated” at the external review. The design review becomes a box to tick because that’s what an ISO company does or what the contract demands. Organizationally a culture should be fostered, especially by senior executive, where all review meetings are cherished as an opportunity not only to showcase design achievements, but to gather constructive inputs for addressing risks and improving designs. Management’s stance should never be that “they (the designers) have to come and defend their design”, but should rather be treated as an opportunity to ensure the “we have produced the best design possible”. Improved efficiency and effectiveness in the design review process may therefore require well planned and meticulously executed change management initiative(s) to foster the appropriate review process culture.

If taken seriously and the purpose is to be achieved, the review meeting “should not be an

informal management meeting to collect unfocussed opinions under pressure” (Gilb 2004; Gilb 2007). Rather, it should be a well-planned, focused meeting where a prepared and competent design review team works together to identify risk and improve the design.

Execute to achieve the objective: Well run (effective and efficient) design reviews focus on achieving the objectives of the review without digressing into mud throwing and blaming (criticizing designers) or embarking on a re-design session. All inputs should be valued and tolerated, but the focus should always remain on risk identification and improvement of the design, whilst meeting the cost and schedule targets.

Compile Action Lists

Action lists should be clear, concise, assign responsibilities and allocate realistic target dates. The target date should be mutually agreed between the design team and the client and should not be driven by cash flow. The design review therefore aims to address technical issues and any contractual issues should be resolved at a project/contract management forum.

Track Assigned Action Items

It is advisable that a mechanism be put in place to formally monitor and track progress on actions items. The next time, following the review, the action list is checked should not be the next review meeting. Progress on resolving review actions should be made visible to the client. It is also important to agree the exit criteria (i.e. when is the action sufficiently addressed to proceed) and associated means of compliance for each action with the client as early as possible.

In the long term it is also desirable that the organization and other projects benefit from lessons learned at design reviews and the resulting action items. It is, therefore, advisable that a mechanism be implemented to ensure this benefit. Ideally this should be through the organization’s knowledge management initiatives and should be a continuous activity instilled in organizational culture, spanning wider than just the lessons learned from a design review.

Is A Delta Review Required?

The significance of the items on the action item list with respect to their impact on the design and the specifications (both parent and children) will dictate whether a delta review is required after embodiment. In all cases this is a judgment call which could be made easier by a rule-set included in the engineering change process. The decision needs to include both the engineering and project management perspectives and should not exclude client consultation. The critical element is that the engineering change process should be followed meticulously to embody any action items.

Establish The Baseline

The review process can only be completed once the baseline is formally established. The key consideration in this activity, to ensure effectiveness and efficiency, is to meticulously follow configuration management principles. It is imperative that a formal process and system be instituted in the organization and that the process is adhered to. A culture where piles of approved design documentation are stored in an individual’s office should not be tolerated. Nor should there be multiple iterations of documents with no revision status floating around.

Conclusions

The major contributors hampering design review success in the South African defense industry are:

- designs that are not sufficiently mature as a result of an over emphasis on achieving contractual / schedule milestones at the cost of technical integrity
- a design review culture where the purpose of the review is to defend the design or to tick a box, but not test the integrity of the design; and
- in the absence of a well-structured process and guidelines (as presented in this paper), the strongest personality tends to dominate and may unduly influence the outcome.

Further factors negatively impacting on design review success, are:

- underestimating and/or neglecting the preparation required for effective and efficient design reviews; and
- a lack of discipline to complete the process (post review meeting) – tracking action items, documenting and distributing lessons learned, as well as properly establishing the baseline.

When seeking opportunities to enhance the effectiveness and efficiency of the design review process, it is important to focus on the real purpose of the review (Gilb 2004; Gilb 2007), namely on identifying and addressing risk, as well as improving the design. It is suggested that the following actions be implemented to ensure that these objectives are achieved:

- avoid reviews as a mechanism to achieve cash flow, rather ensure that there is a balance in achieving technical, timescale and financial goals;
- foster a culture where the review process is treated as an opportunity to showcase the design / development work and to gather constructive inputs for improvement and risk identification;
- publish the purpose and intended outcome(s) of the design review well in advance of the review meeting along with the data package. Ensure that a focused, but comprehensive checklist is used as an aid to evaluating the integrity of the design;
- take all reviews seriously, focusing on achieving the objectives of the review;
- develop good design review habits (ensure that all requirements are properly interpreted and translated into the design prior to declaring the design ready for review, ensure that there is a process for design reviews and that it is followed, prepare well for design reviews, conduct the review efficiently and effectively, and ensure that the process is completed by establishing the baseline under configuration control);
- ensure comprehensive client interaction, making sure that client stakeholder's expectations are understood and met; and
- instill a culture where lessons learned are documented and distributed to enable projects to continuously learn from each other.

These are in all likelihood not symptoms unique to the South African defense industry and any organization should benefit from implementing the suggested actions.

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Biography

Ms. Young is a Systems Engineer, holding a Master's degree in Industrial Engineering from the University of Pretoria in South Africa. She has 19 years' experience and has been working as a systems engineer and program manager in the South African defense industry / sector for a period of 13 years, being involved in a number of major defense acquisition programs during this time – most notably the communications upgrade of a medium transport helicopter and the

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