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Effective System Engineering Peer Reviews

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Abstract

Effective and rigorous technical peer reviews provide quality to a product realization process. This paper proposes a five-step peer review process based on survey of the literature, experience with peer reviews, and pilot trials. Feedback was collected and integrated as lessons learned, resulting in a process that addresses key attributes of a peer review: roles & responsibilities; requirements; rigor; peer identification, independence, and external engagement; and follow-up actions. An idea for a tool is provided to assist with rigor level determination and scoping of the peer review. Use of this peer review process can yield consistent peer review practices surrounding peer review practices for product realization teams.

Background

Technical design reviews occur during the system engineering lifecycle. These reviews can be supported by peer reviews, which are deeper technical reviews by technical experts in the subject matter to be reviewed. Our experience suggests that there exists confusion between design and peer reviews. With the absence of a clear defined peer review process, this can contribute to the confusion. A corporate strategic milestone was defined to establish an engineering peer review process that will support successful execution of the engineering mission space and appropriately accommodates the need for review independence.

In investigating peer reviews for some of our major programs, two scenarios were identified. In the first scenario, the numbers of reviews and audits endured by project teams had become significant for high profile programs, such that shortcuts might be taken for peer reviews: i.) design reviews doubled as peer reviews or ii.) peers were invited to witness the design review and provide feedback (Air Force Space Command 2009). Peering deeply into focused technical issues is not effectively accomplished and the true benefit of a peer review might not be realized. In the second scenario in which peer reviews were held, no consistent approach existed as guidelines or tools to aid project teams tasked with undergoing peer reviews were lacking. Feedback was that peer reviews were beneficial; but that identification of peers was sometimes challenging, concern for independence was not always apparent, and follow-up to address review results was not always required. If peer reviews were required but follow-up was not required,

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commitment to the peer review could suffer, and the review itself could be treated as cosmetic (Chao et al. 2003) or box-checking.

Further investigation revealed that project teams did not always understand the qualities of a peer or the differences between a design review and a peer review. While these findings may not be widely applicable or new, it seemed worthy to investigate engineering peer review practices and guidance. A survey of the literature revealed the benefits of peer reviews and yielded peer review practices for journal publication selections and proposal decision making and some detailed guidance for technical peer reviews. We realized that we could make a contribution to the literature and the system engineering community through our work, which aimed to define key attributes of and to aid consistency in the peer review process.

The proposed process herein does not focus on selection of technologies or products to review but assumes a peer review will occur. The process is described in generic terms that hopefully are applicable to product realization teams. It may not vary significantly from what is being practiced by engineering organizations, but it attempts to create a common understanding of the difference between design and peer reviews, recommends a five-step process that captures important attributes of a peer review, and provides a tool that aids product teams in appreciating the need for a peer review. It focuses on some key attributes for a peer review:

- well-defined roles & responsibilities,
- minimum set of requirements to ensure consistency in peer review practices,
- appropriate rigor level undertaken to address depth and breadth of review material,
- proper peer identification, including need for independence and external engagement,
- and follow-up actions.

Terminology

Design Reviews. Design reviews are mandatory and conducted when the system under development meets a milestone or level of maturing during the product acquisition/realization process. Formalized design reviews have Entry and Exit Criteria and/or Acceptance Criteria. Lists of criteria for DoD reviews can be found in the literature (NRC 1997). Generically, the purpose of a design review is to:

- assure early broad technical input to systems and components to identify issues requiring special study;
- evaluate the proposed designs for completeness in meeting validated requirements, for adequate trade-off analysis against requirements, and for proof-of-concept in hardware;
- identify new equipment and facility needs for development, production, and testing;

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- identify areas where performance clarification or clarification of next assembly requirements is required;
- avoid late, disruptive, and schedule threatening design changes;
- provide a formal means for design and production agencies to jointly review design objectives and producibility of the system or component[12]; and
- judge the test program, manufacturing approach, and implementation of engineering disciplines necessary to develop the program and product for adequacy, sufficiency, and completeness.

A design review is customer focused, whereby the customer's objectives serve as a guide for the contracting agent from program definition through end item (system) development, assuring the program's health and readiness at logical transition points in the development effort, providing a method for the program team to determine progress achieved to date, and facilitating contractor and contracting agent concurrence on technical progress.[14] Attendance for a design review includes project customers and stakeholders, management, and staff. If the design team extends beyond the agency, staff and managers from other design and production agencies may be in attendance.

Peer Reviews. An engineering peer review can be a resource for a product team to find potential defects, design weaknesses, or implementation flaws as early as possible in the development process. A peer review tends to fall along the lines of improving quality, aiding decision-making, ascertaining that objectives and/or requirements are being met, and/or providing validation. Such reviews, conducted by a team of peers, bring the product team a broad experience base and lessons-learned from previous missions, without which design oversight can be missed (Haag-Heitman and George 2011; JISC et al. 2011). The goal(s) of peer review processes may be to:

- verify whether the work satisfies the specifications,
- identify any deviations from the standards,
- ensure sound engineering rigor has been practiced,
- ascertain that the science underlying the technology is well-understood,
- identify good practices and strengths exhibited by the design, and/or
- provide suggestions for improvements.

Attendees of a peer review are members of the Product Team and the Peer Review Panel; customers and other stakeholders and preferably Product Team Management are not present.

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A peer review has two characteristics i.) the peer should be someone that is of equal standing, have technical expertise[1] in the subject matter to be reviewed, and be independent of the work being reviewed; and ii.) the review should consist of a critical appraisal and should exercise or involve careful judgment or judicious evaluation. We identify two categories of peer reviews.

Reactive or Challenge Peer Review.

A Responsive or Challenge review may be requested, such that the Product Team must respond because some issue or aspect of the program or product is being criticized or challenged. The peer review helps guide decision making or assures confidence on the issue. A Requestor may be internal or external to the agency and may be management, a customer, or Federal Program Manager (FPM); but, the Requestor must be a valid stakeholder as understood by the Product Team and Management. Challenge reviews will always require a high level of rigor.

Proactive Peer Review.

Proactive peer reviews are self-initiated by the Product Team or its immediate Management as a quality measure. Low, Medium, and High levels of rigor for a Proactive peer review may be needed based on the level of need for the review. This will be developed in detail below.

Proposed Peer Review Process

A systematic peer review process with five major steps is being proposed:

1. determine need and scope of review;
2. determine rigor level;
3. plan review details;
4. hold review; and
5. ensure observations are resolved.

[1] Although a team of peers might be convened to review programmatic issues such as cost and schedule, the focus of this effort is technical peer reviews.

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Figure 1. Peer Review Process Flow

Roles & Responsibilities

To accomplish these steps and their associated activities, roles and responsibilities for the peer review have been identified as shown in Table 1. These roles were identified to ensure the key attributes sought in peer reviews.

Table 1: Summary of Peer Review Roles

Roles	Functions
Requestor/Sponsor	Requests review
Product Team Management	Ensures accountability
Product Team	Supports Panel activities
Steward	Administers review
Coordinator	Helps administers review (optional)
Panel Chair	Leads review
Peer Review Panel	Performs review
Scribe	Takes technical notes (optional)
Technical Writer	Assists with output documents (optional)

The Requestor, who may be the Product Team or its Management or some other entity, requests the peer review. In the case of a Reactive peer review, if the Requestor is outside of the agency or corporation, a Sponsor who is internal must be identified. This Sponsor must be independent of the Product Management Team to prevent any appearance of bias. The Sponsor interfaces with the Requestor and Product Team Management to communicate peer review scope, assure funding for the review, and communicate peer review completion and results.

The Steward is a key role that oversees all peer review activities and ensures the independence of the peer review, so that the credibility of the review is not questioned. This role must be filled by someone who is outside the management chain of the Product Team. The Steward determines the rigor level of the review, aids in identifying independent Peer Review Panel membership and chair with qualifications appropriate to the needs of the review, and is responsible for all communications. In the case that the scope is not provided or adequately defined, the Steward works to define or refine the scope for greatest understanding and benefit to all involved.

Product Team Management acts as the entity ensuring accountability by the Product Team to the Panel's feedback.

The Panel and its Chair perform the peer review with the Steward in attendance. The Steward may act as the Chair and always acts as the entity that keeps the review focused and orderly.

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The other roles, such as Scribe, Technical Writer, and Coordinator, are optional; however, the role of the Coordinator was found to be highly useful in a series of pilot peer reviews used to develop this process. Scribes, if used, must have a technical background, so that notes containing acronyms, technical jargon, and technical context are accurately captured.

Review Activities

The proposed peer review process steps and corresponding activities are listed below. Several activities, containing the word "*shall*", are recommended as core requirements necessary for meeting the intent of this peer review process.

Table 2: Summary of Peer Review Process

Process Step	Activity	Definition of Activity
Step 1: Determine Need & Scope of Review	1	The Requestor identifies the need for a peer review. If the Requestor is external, a Sponsor is identified who performs the Requestor functions in the Peer Review process. The Requestor relays the request to the Product Team Management.
	2	The Requestor/Sponsor *shall* assign an independent Steward for the peer review.
	3	As part of assuring no bias, the Steward and Requestor must agree to the scope of the peer review.
	4	The Requestor must document the review request to the Steward and the Product Team.
Step 2: Determine Rigor Level	5	The Product Team Management *shall* use the rigor guidelines (or tool) to determine the rigor level.
	6	The Steward and Product Team Management *shall* agree on objectives, scope, and rigor level of the review.
Step 3: Determine Review Details for Panel Selection and Review Logistics	7	The Steward and Product Team Management *shall* agree to the Peer Review Panel selection.
	8	The Steward and Requestor *shall* agree to the rigor level and panel selection.
	9	The Steward *shall* coordinate peer review logistics, adhering to the intent of the rigor level guidelines.
	10	The Steward *shall* hold peer review coordination meeting(s) to initiate activities.
Step 4: Hold Review	11	The Panel Chair and Panel perform review activities.
	12	The Product Team supports the Peer Review Panel activities.
	13	The Panel Chair finalizes the review activities, including out-briefing and documentation of the review process and observations.
	14	The Panel Chair presents the observations to the Steward.

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	15	The Steward presents the observations to the Requestor and Sponsor.
Step 5: Ensure Observations are Resolved	16	The Product Team must follow-up on review output, including generation of necessary action items to address observations.
	17	The Product Management Team must ensure all action items are documented, tracked, and resolved.
	18	The Product Management Team *shall* issue an official resolution memo reporting on path forward to resolve observations and action items.

As with roles, some of the steps have been specifically designed to meet important key attributes of a peer review. Steps 5 & 6 ensure appropriate rigor in the peer review. Steps 7 & 8 ensure appropriate level of external participation, if needed, in the review. Steps 16-18 ensure follow-up to the review including documenting resolution of peer review observations[2].

Rigor and Scope Determination

For Proactive peer reviews, Steps 5, 6, 8, and 9 require determination of a rigor level for the peer review. The rigor level directs the depth and intensity practiced in reviewing the material as well as by the numbers and of peers serving on the panel. Levels of rigor guidelines were established by considering the likelihood for problems to be encountered by the Product Team, such as maturity and complexity of proposed or chosen technologies and methodologies, foundation of knowledge underlying scientific and/or engineering basis, understanding of lifecycle requirements, and levels of readiness, experience, and expertise within the Product Team. The consequences, if those problems were realized, also factored into the rigor level determination.

A Rigor Level Tool was developed in Microsoft Excel to enable a disciplined and consistent approach to determining peer review rigor level. The input to the tool contained three categories.

Technical Issues.

Under technical issues are seven topical areas relevant to various parts of the product lifecycle (see Table 3). The user is to enter answers or concern levels from the limited option set: No/No Concern, Minor Concern; Medium Concern; Yes/High Concern. If the user needs more information in order to respond, hyperlinks take the user to tables with detail to guide them.

In addition to aiding in determination of rigor level, these topical areas also guide the Steward and Product Team in determining the scope of the review. For example if requirements

[2] Note the use of the term "observations" is intentional as peer review results are not deemed an issue until follow-up is deemed necessary by the Product Team or its Management. The term "finding" is avoided because of its connotation in the realm of audits.

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and functional or performance concerns along with complexity in design or process rate as High Concerns, then the peer review should be scoped to focus on these topics.

Table 3: Technical Issues for Rigor Level Determination

Technical Issues (Click Cell to Obtain More Information)	**Please Enter Answer/ Concern Level**
Are there requirements of concern? Are there functional or performance areas of concern?	Yes/High Concern
Is there new technology that is being used? Is the design approach new? Are there Customer Returns or history of issues on legacy design or process?	Minor Concern
Are there any new process approaches? Are there major process changes? Have there been materials changes?	Medium Concern
Is the necessary information for the design or process difficult to obtain?	No/No Concern
Is the design or process highly complex?	Yes/High Concern
Are there qualification concerns?	No/No Concern
Are there high-risk components included in the design? Is the design or process highly dependent on other things being achieved?	No/No Concern

Programmatic Issues.

The user is asked to respond to questions on programmatic aspects of the project (see Table 4). While this peer review process is focused on technical reviews, lessons learned showed that product teams struggled with product realization when programmatic factors were present.

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Table 4: Programmatic Issues for Rigor Level Determination

Programmatic Issues (Click Cell to Obtain More Information)	Please Enter Answer/ Concern Level
Is the level of experience of design team of concern?	No/No Concern
Is anything on a critical path?	No/No Concern
Is the funding or funding profile of concern?	No/No Concern
Are there conditions of Program, program obstacles, or program constraints (i.e., use COTS, provide commonality, really long lifetime….) that are of concern?	No/No Concern
Is the program sufficiently ready?	No/No Concern

System Impact or Consequence.

Our risk based approach to rigor level determination used system impact as part of the decision making process. Questions are shown in Table 5; answers were limited to Negligible; Low/Minor; Moderate/Major; or High/Critical. Details on impact and perspective in which to frame questions are provided as shown in Table 6 to aid the user.

Table 5: System Impact Issues for Rigor Level Determination

System Impact* (Click Cell to Obtain More Information)	Please Enter Answer/ Concern Level
Are there concerns about stakeholder perceptions, political and/or social factors, if the design does fails or does not meet its performance requirements?	High/Critical
What is the time impact if design cannot be realized when needed?	Moderate/Major
What is the cost impact if design cannot be realized when needed?	Low/Minor

**Note: If design in used in multiple systems, please consult with all system owners.*

Table 6: Guidance for Answering System Impact Issues for Rigor Level Determination

Impact	Negligible	Low/Minor	Moderate/Major	High/Critical*

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Are there concerns about stakeholder perceptions, political and/or social factors, if the design fails or does not meet its performance requirements?	Unaffected	Minor on over all mission and program	Major on overall mission and program Question competency through requirement of rigorous oversight and/or halt program	Critical on over all mission and program Public alarm Failure of national security
Perspective	Contingency can be managed within Org.	Contingency can be managed within the Program	Contingency can be managed within agency, corporation, or by customer	Congress gets a call

Note: The reader may think the High/Critical entries are a bit dramatic, yet for national security systems these situations can be real.

Empirical mathematics underlies the final rigor level determination; the specific detail provided here resulted from Senior Program Managers' input. Our formula was constructed by counting the number of each entry for technical and programmatic issues and using a power law aggregation in base 11:

$$MinC = total\ number\ of\ Minor\ Concerns$$

$$MedC = total\ number\ of\ Medium\ Concerns$$

$$HighC = total\ number\ of\ Yes/High\ Concerns$$

$$|Likelihood| = \sqrt[2]{(MinC)^2 + (11 * MedC)^2 + (121 * HighC)^2}$$

Likelihood score is scaled as follows:

$$If\ |Likelihood|\ is:$$

$$\geq 363\ then\ Likelihood = 5;$$

$$else\ if\ \ |Likelihood| < 363\ and\ \geq 242, then\ Likelihood = 4;$$

$$else\ if\ \ |Likelihood|\ < 242\ and\ \geq 88, then\ Likelihood = 3;$$

$$else\ if\ \ |Likelihood|\ < 88\ and\ \geq 11, then\ Likelihood = 2;$$

$$else\ Likelihood = 1.$$

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A similar approach was taken for Consequence determination. First, the number of entries of a given consequence level is tallied:

$$LowCon = total\ number\ of\ Low\ Minor\ Consequence$$

$$ModCon = total\ number\ of\ Moderate\ Major\ Consequence$$

$$CritCon = total\ number\ of\ High\ Critical\ Consequence$$

Then, using a power law aggregation, the norm of Consequence is obtained:

$$|Consequence| = \sqrt[2]{(2 * LowCon)^2 + (6 * ModCon)^2 + (16 * CritCon)^2}$$

And finally, Consequence score is scaled as follows:

$$If\ |Consequence|\ is:$$

$$\geq 48\ then\ Consequence = 5;$$

$$else\ if\ \ |Consequence| < 48\ and\ \geq 32, then\ Consequence = 4;$$

$$else\ if\ \ |Consequence|\ < 32\ and\ \geq 16, then\ Consequence = 3;$$

$$else\ if\ \ |Consequence|\ < 16\ and\ \geq 7, then\ Consequence = 2;$$

$$else\ Consequence = 1.$$

The above entries in Tables 3, 4, & 5 yield a Likelihood of Problems value of 4 and a Consequence value of 3. From Figure 2, the user finds the intersection of these colored by yellow and red meaning the peer review rigor should be medium or high. In this case a judgment needs to be made by the Steward in agreement with the Product Team Management.

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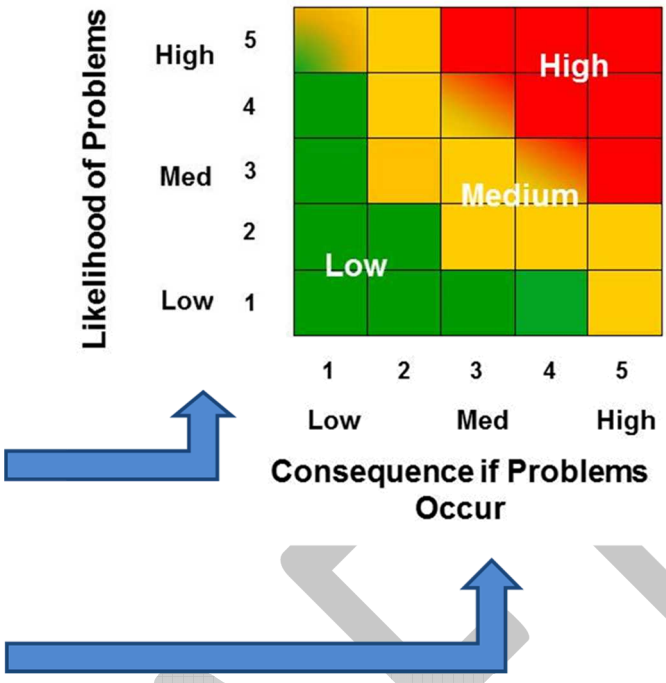

Figure 2. Final Rigor Level Determination

All of the above can be tailored to suit organizational needs and experiences. The important features are that rigor level guidelines generate consistency across programs, and that the Product Team, its Management, and the Steward provide a structured method of communicating and decision-making. Our experience revealed that Product Teams tended to be overly optimistic of their product realization process and erred low in rigor level determination. When Stewards worked through the tool with the Product Team and its Management, the resulting rigor level often increased. This communication enabled the Product Team to buy into the need for a peer review.

Planning the Review at the Appropriate Rigor Level

The Steward is responsible for planning and executing the peer review. The details of planning and holding the review will not be described herein. Recommendations are that planning occur at least 2 months or more in advance of formal review meetings, Panel Members be identified in this timeframe so their calendars accommodate the review time, guidelines and expectations for both the Panel and the Product Team be set and communicated in initiation meetings, and review material be sent in advance of the formal meetings. For High and Medium level reviews, a pre-brief of program information should be given to the Panel at least 1 week in advance of the formal meetings.

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Table 7 recommends the size of a Panel, varying from two to eight persons based on rigor level. A lead Product Engineer from a similar product, experienced engineers, and subject matter experts (SMEs) in fields of science, testing, and modeling & simulation should be considered. External peers provide independence of thought and different perspectives. For Low levels of rigor, the recommendation for inclusion of external (to agency or corporation) reviewers was optional; expediency may not allow. However, for Medium rigor reviews, external reviewers were recommended; for High rigor, required.

Table 7. Suggested Panel and Review Attributes by Levels of Rigor

Rigor Level	**Panel Size**	**Depth**	**Reviewers**
High	4-8	Review Panel may perform their own analysis/ investigation or ask for additional analysis to be performed; review may take several months	External Required
Medium	4-6	Opportunity for review team to ask for additional analysis and information; review may take several weeks	External Recommended
Low	2-4	Review team is not expected to perform homework or assign Product Team homework; review completed within 1 day	External Optional

A variety of methods can be used for the actual review; they will not be addressed herein. The depth of review at a minimum is a review of documents and presentations provided by the Product Team; the intensity of review activities can increase dramatically beyond a Low rigor review (see Table 7). The recommended output and timeline for a review vary by rigor level as shown in Table 8.

The rigor guidelines serve as a standard for the peer review process and act as a starting point to communicate a consistent expectation. They are not intended to appear as overly prescriptive or universally applicable. The length of the review, the amount of material covered, the qualifications of the Panel, and/or the level of detail to which a topic is covered all factor into the rigor level of a review. Due to time constraints, project size, security or classification, and other limitations, it may not be possible to meet the guidelines but their intent can be honored and met through other means. In the event that factors influence the ability to adhere to the guidelines, tailoring should be allowed. If undertaken, tailoring should be for success of the peer review and its objectives.

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Table 8. Suggested Peer Review Output by Levels of Rigor

High	Medium	Low
Formal report • Within 2-3 weeks of review • Reviewed prior to external release for Reactive review	Formal report • Within 2-3 weeks of review	Report, by request
Out brief • Perform dry-run within 2 weeks • Brief Product Team and Product Team Management within 3 weeks • Conduct formal out briefing with Sponsor	Out brief • To Product Team within 2-3 weeks • To Sponsor after briefing Product Team	Out brief • At end of review with Product Team and Sponsor
Resolution Memo • Within 4-8 weeks of receipt of final report	Resolution Memo • Within 4-8 weeks of receipt of final report	Resolution Memo • Within 4-8 weeks of out brief

Concluding Remarks

The process was piloted on 3 development programs that have provided validation of the process. The tool was integral to scope the review topics and impresses on the minds of those being reviewed a risk level that they had not previously appreciated. The process presented a methodology to tailor the parameters to meet the scope of their project and organizational needs. Effective peer reviews for system engineering teams can be realized when roles & responsibilities are defined, independence and attention to audience are practiced, and a consistent method for determining rigor is developed and then applied to the planning and execution of peer reviews. This paper provides a methodology that can be adopted and tailored to suit the needs of product realization teams. A risk-based approach that considers fundamental elements of a product lifecycle and technical and programmatic issues that can confound a project team helps guide the scope and level of rigor for a Proactive peer review.

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Biography

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