TECHNICAL REVIEWS: TORN BETWEEN KNOWLEDGE SHARING AND PROJECT ASSESSMENT*

Peter Putz[a]
David G. Bell[b]

[a,b]Research Institute for Advanced Computer Science,
NASA Ames Research Center, USA
[a] pputz@email.arc.nasa.gov
[b] dbell@email.arc.nasa.gov

Session A-2

Abstract

This paper presents initial findings from an ongoing research project studying the social and organizational practices of technical reviews at NASA. Technical reviews are a ubiquitous part of organizational life in most technical organizations, and one of the most consequential in terms of risk, innovation and knowledge management. We introduce a novel conceptual framework distinguishing formal, documentary reviews and informal, discursive reviews as two substantially different sets of practices. We show how each of these practices inhibit or facilitate effective knowledge sharing between project engineers and external experts. The paper also presents some initial empirical findings supporting this framework.

Keywords: technical reviews, documentary and discursive reviews, dysfunctional effects.

* This research was made possible through funds provided by the NASA Engineering for Complex Systems Program and by the Johannes Kepler University Linz, Austria. The interviews used for this analysis were conducted by Larry Chao, Irem Tumer and David Bell. Special thanks to Irem Tumer who enabled access for the interviews, and to Larry Chao who was the lead interviewer.

Technical Reviews: Torn Between Knowledge Sharing and Project Assessment*

Peter Putz and David G. Bell
Research Institute for Advanced Computer Science
NASA Ames Research Center, USA
{pputz, dbell}@email.arc.nasa.gov

Abstract

This paper presents initial findings from an ongoing research project studying the social and organizational practices of technical reviews at NASA. Technical reviews are a ubiquitous part of organizational life in most technical organizations, and one of the most consequential in terms of risk, innovation and knowledge management. We introduce a novel conceptual framework distinguishing formal, documentary reviews and informal, discursive reviews as two substantially different sets of practices. We show how each of these practices inhibit or facilitate effective knowledge sharing between project engineers and external experts. The paper also presents some initial empirical findings supporting this framework.

Keywords: technical reviews, documentary and discursive reviews, dysfunctional effects
Suggested track: A. Managing organizational knowledge and competence

1 Introduction

Technical reviews are a ubiquitous part of organizational life in most technical organizations, and one of the most consequential in terms of risk, innovation and knowledge management (Bell et al., 2002). In industry they are often used to support management decisions at phase gates, breaking up the over-arching product development processes into distinct “phases” (Clark and Fujimoto, 1991; Wheelwright and Clark, 1992). At NASA, a series of formal technical reviews are conducted across the mission lifecycle, including preliminary and critical design reviews in conceptual design as well as launch and flight readiness reviews in

* This research was made possible through funds provided by the NASA Engineering for Complex Systems Program and by the Johannes Kepler University Linz, Austria. The interviews used for this analysis were conducted by Larry Chao, Irem Tumer and David Bell. Special thanks to Irem Tumer who enabled access for the interviews, and to Larry Chao who was the lead interviewer.

mission operations. Additionally, less formal engineering peer reviews are often conducted as pre-cursors to formal reviews.

In most organizations reviews are designed to fulfill a multitude of purposes: reviews produce assessments which inform managerial decisions about continuation, modification or termination of a project; reviews "offer an opportunity to add value to the products and to the sharing of knowledge by inviting outside experts"; and reviews are a "tool for communication" among different contractors and stakeholders (NASA, 2002). However, from a behavioral perspective the various goals are inherently conflicted. In particular, there is a significant tension between knowledge sharing and project assessment. When assessments are conducted in order to hold individuals and groups accountable for success and failure, employees may begin to look out for themselves and "game" the system rather than focusing on common goals of knowledge sharing and risk mitigation.

Various studies at NASA criticize the inadequate practice of formal reviews (NASA, 2000). Most recently the report of the Columbia Accident Investigation Board provides a detailed analysis of flawed decisions making processes in the Flight Readiness Review (NASA, 2003). Feldman (2000), looking at the Challenger Flight Readiness Review found, that "conformity enforced by fear was a key factor in rendering the decision process dysfunctional". Some analyses of accidents provide specific examples where reviews could have mitigated risks (Vaughan, 1996), and other analyses have estimated that around 80% of post-launch problems/failures "possibly could have been identified in the design review" (Quinn, 1994).

These studies identify the topic of technical design reviews as an important and novel research agenda. The task is to explore the social practice of reviews including their effects; most urgently – since this has not been done before: to study them empirically in situ, that is in the organizational context they take place. Our paper addresses this research space by establishing a conceptual framework that clearly distinguishes formal and informal reviews and presents an empirical study on the current social and organizational practices of technical reviews at NASA, identifying both functional and dysfunctional practices and their implications for knowledge sharing.

2 Conceptual Framework: Reviews Reconsidered as Social Practice

Reviews do not take place in isolation. The productivity of reviews is dependent on the organizational setting they are embedded in. And in turn reviews play a significant active role in creating and reproducing the very organizational structures they draw upon. This dynamic

interplay between situated activities and governing rules and structures has been called “structuration” (Giddens, 1984). Therefore a comprehensive social theory of reviews has to take into account the dynamic interplay between human interactions and organizational structures.

Reviews can be formally or informally organized, and can be vibrant places for knowledge sharing and the creation of innovative solutions. For example, at Xerox Corporation, the social practice that involved interactions with peers during formal reviews was described as the “fun” part of the product development process, and also reported to be one of the most valuable aspects of the process by members of program teams (Bell et.al, 2002). In this example, peers crossed departmental boundaries and shared experiences and insights as part of a formal process. A case at National Semiconductor provides an alternative example, where technical peers self-organized themselves to solicit advice from their peers and share their knowledge “apart from formal guidelines and processes” (Brown and Gray, 1995). In this case, the reviews of this “off-the-org-chart” community were so successful in innovating one of Nationals critical core technologies, that it was rewarded with special funds to develop novel chip designs and to build a specialized lab.

Reviews are venues where experts can share their knowledge but they are also structured to serve as “highly consequential moments of organizational accountability” (Bell et al., 2002). Recent developments in accounting theory provide a starting point for understanding the social practice of technical reviews as assessment practices. In the 1980’s, critical research began to study accounting "as a social and institutional practice, one that is intrinsic to, and constitutive of social relations, rather than derivative or secondary" (Miller, 1994). More recently, research has moved beyond a focus on formal assessment practices where specific forms of interactions are codified in legal or organizational rules and guidelines, and have also addressed on informal assessment practices (Jordan & Putz, 2003).

The present study applies and further develops a social practice framework of assessments which was recently introduced by Jordan and Putz (2003; forthcoming). It establishes a three-part typology that distinguishes two kinds of informal assessments – inherent and discursive assessments – from formal, documentary assessments (Table 1). The framework further shows, how an over-reliance on documentary assessment can lead to far-reaching dysfunctional effects on work practices, on corporate decision-making and on the structure and culture of organizations.

Table 1: Characteristics of Different Assessment Types (Jordan & Putz, forthcoming)

	Inherent Assessment	**Discursive Assessment**	**Documentary Assessment**
primary stakeholder	individual	team/social group	corporate entities
purpose	adjust individual conduct	align group-internal views	coordinate and control organizations
interaction	physical co-presence	physical and virtual co-presence	distance
mode of coordination	nonverbal monitoring	conversation	record production
locus of control	individual	group-internal	external
knowledge produced	tacit	implict/explicit	explicit
duration	ephemeral	short lived	enduring
emotional tone	affective	affective	objective

While this framework originally was developed to characterize a broad variety of formal and informal judgments, evaluations, measurements and metrics in educational and business settings, the present paper focuses specifically on technical reviews. It aims to explore an adapted and modified typology of discursive and documentary reviews and their respective functional and dysfunctional effects.

The following characterizations of discursive and documentary reviews serve as preliminary working definitions at the beginning of our research project which follows an inductive grounded theory approach (Glaser and Strauss, 1967).

Discursive technical reviews are conducted by and in the interest of peer experts in order to find the best solutions for the tasks at hand. The primary means of communication are verbal utterances. Assessments gain the character of 'social objects' that members of a work group or social community can refer to, negotiate about, and point to even at some temporal and spatial distance. Written notes and drawings are usually not distributed to anybody outside the group of participants. Discursive reviews are conducted in a flexible manner; process rules are kept at a minimum.

Documentary technical reviews are externally mandated; they are a formal requirement documented in official guidelines and protocols. Documentary reviews are heavily based on written symbolic representations frequently in the form of reports and viewgraphs. The written records are essentially "immutable mobiles" (Latour, 1986) that is, once they are produced, the content becomes stable, while the documents travel across organizational

boundaries and hierarchical layers. The participants of documentary reviews are typically chosen by an external authority and the review process is highly formalized.

We expect these definitions to be changed and refined as we collect more empirical data from multiple case studies (Eisenhardt, 1989; Yin, 1984). The strengths of building conceptual models in an inductive way is the likelihood of generating novel theoretical constructs, that are relevant, empirically valid, and easily testable. The new theoretical model emerges as closely as possible to the systematically gathered empirical data.

3 Initial Findings

In this section we present some initial findings from interviews with project managers conducted in 2003 at a major NASA facility in California.

3.1 Documentary Review Practices

> *"Okay, for reviews we had 8.2 kg of documents, we employed 117 reviewers so far, we had 14 reviews, the cost of reviewers were $ 208,000 they reviewed 528 items of ISO compliance elements, we complied with 221 design principles and we had 21 versions of the requirements documents based on different reviewers, and we produced 1325 charts for different reviews." NASA Project Manager, 2003*

The very nature of documentary assessment is the production of written accounts, with stable records produced for external distribution. This feature is one of the reasons why documentary reviews can become dysfunctional. In the following section we show that dysfunctional effects include flawed–yet highly persistent–data, euphemistic language that obfuscates reality, suboptimal resource allocation, and the proliferation of a restrictive organizational culture.

One project manager describes that reviews conducted in the early design phases of a project are prone to the presentation of flawed data and false estimations: "... people tend to put down on viewgraphs things that are just simply untrue because they are based on early wrong assumptions." This problem is a very serious one, since false numbers presented and documented in early reviews do not get corrected later on, even against the better knowledge of engineers involved. The reason for this persistence is a commitment made in public to statements that are documented in writing. Here is a vivid description of this social dynamic:

"I found a lot of problems with the current review system, okay? Number one is the fact that people ask to have reviews very early. And what it does is because there is a whole series of reviews and the idea is: oh yeah, we have to have reviews from the beginnings, so they don't go in the wrong direction, okay? Unfortunately what it does is that engineers have a tendency to produce viewgraphs with some thoughts they do have very early. And then these viewgraphs, because something is in writing and it's on the viewgraph and it's been reviewed, somehow it gets some notoriety. Well, it may be based on completely unrealistic assumptions. Especially I have a beef with early cost estimates. Because you know, if I ask you to build this table, how much you gonna spend, okay? And you don't have the time to figure out if it is Formica or if it's plywood and you didn't have time to ask me enough questions what I am gonna use it for and if you can carry it through the doors, how wide it is. But on the viewgraph you put 327 dollars. And the problem I notice with these early reviews is that, you know, this becomes 327 dollars and carries these 327 dollars for a long time and it will never become 2000 dollars because then you feel like, oh, you didn't know what you were talking about and why there is this big change, even though it's actually a better number, right? And I think that a lot of cost problems that we encounter is due to this early, you know, on one hand they think it's good to do it early, but I think there's also a problem with this approach. You do it early and then you never double or triple that amount because you look stupid or incompetent."

Changes in how work is actually carried out often occur as people adjust to the assessment procedures. While intended to increase productivity and quality in education and business, what often occurs is the opposite. Employees tend to make their work look good in compliance with the established and highly visible requirements sacrificing other objects and long-term goals. These adaptations often make the process as a whole more cumbersome and more expensive.

In the long run false cost estimations and too optimistic technical descriptions may lead to wrong resource allocation and to a suboptimal division of labor. If for example in a larger project a subsystem is presented as unproblematic, straightforward solution while in reality it involves challenging questions, the subsystem might not get the financial and human resources necessary. And that is exactly what happened in the second example.

"We usually spend a whole day describing things and there's different people from different subsystems presenting things and people are just tired and it takes a long time and there's the chairman of the board and he says, come on, next, we are 37

> minutes late, come on, we gotta get going, okay? For example I had an experiment were this new technology was an inflatable antenna, okay? And so we kept on reviewing the inflatable part, the Mylar, the deployment mechanism, all of these things. We ended up at the last minute, working out 600k additional for a box. Because the box was misdesigned. Well, the box was in every review, but here the result is new stuff. And the guy would come out and it was just one guy, and he'd say I did find aluminum – yeah, good, good – and I calculated a lots – good, good – nobody wanted to pay attention to this and spend the time and nobody finally reviewed it. And there was only one engineer in the company and he ended up making mistakes. Nobody has ever reviewed this even though we had all these NASA reviews."

Time pressure is one of the factors why unmet requirements and safety hazards remain unnoticed. However, there are also reasons why the presenting engineers tend to make their work look good rather than pointing out the more problematic issues.

When evaluation data gain high visibility within a larger organization, new levels of accountability emerge. When reputation and perceived competency is at stake employees look out for themselves to avoid recrimination rather than focusing on shared goals. There arises a temptation to focus on short-term success, and to deny responsibility for failure. As a consequence one may see mistrust, competitiveness, passing-the-buck behavior, and what is known in the workplace as a “cover-your-ass” attitude (Putz and Jordan, 2004). Some organizational theorists (e.g. Gittell, 2000) have argued that quantitative performance measurements inevitably generate some level of dysfunctional behavior since they tend to operate with a relatively low level of trust.

In a restrictive organizational culture undesired facts tend to be hidden through the use of euphemistic language. A project manager claims that exactly this is the case at NASA "And there's also the agency's stigma on, you know, I had a failure, I had a problem and I have to talk about it. Well, how come you didn't catch it? So people tend to use very euphemistic language."

As mentioned above, Feldman (2000) has shown that the NASA Marshall Center Board Flight Readiness Review for the Challenger Space Shuttle enforced conformity by fear. A restrictive culture not only appears during operations, but also during the preceding research and development phases. Two statements from different project managers at NASA illustrate how formal reviews in engineering design can yield a defensive and restrictive culture:

> "Reviews are actually a game. They are high stakes. The goal of the project manager is to get through the review as much as it is to root out problems."

"So I am saying a lot of the times if you look at the reviews you look what's on the agenda, who is involved, you know what's their expertise, what's covered, time, how many charts – it's all right. But the psychology is all wrong. Because, you know, if I ask you, let's say: You know, you guys been - you know management consensus - you guys been doing this for what: three months? You know, what have you accomplished? Okay? Well, you know, so I'm gonna get uh 5 more days and you'll make a presentation, we'll critique it. Well, that immediately sets up that two sides of a barricade, unfortunately. What you gonna be doing is: give me your presentation. And you in a sense, you know, you work for a solid presentation. And you put all your thoughts and your efforts into this and then you'll be sitting here, you know, checking it out, you know, leaning back in your chairs and you in a sense, you wanna look smart. You wanna prove that you have thought of everything. And we, we prove you wrong. Right. And that's I think is a bad psychology. Because that's the two sides prosecution and defense. And it's where we are not truly as a team looking at improving things."

Drawing attention to the problematic sides of documentary reviews is not to be misunderstood as an argument against the use of formal reviews per se. There is no doubt that documentary reviews are necessary and beneficial. However, we need to significantly improve our knowledge about unintended, dysfunctional effects in order to establish a more accurate understanding of their characteristics as social practices embedded in organizational structures and rules.

3.2 Discursive Review Practices

> *“Before I was a project manager I never liked reviews. And I vowed that if I'll become a project manager I'll completely do it differently. Because I don't like the psychology of the reviews. I think that it's, uh the way we conduct reviews, it's kind of like our judicial system. You know, where there is a prosecution and defense. It's not truly looking for the truth. It's kind of like, it's either one side is trying to defend itself and the other side is trying to zap on them.” NASA Project Manager, 2003*

NASA project managers know from their own experiences of the tricky downsides of documentary reviews. And therefore, some of them have developed their own ways of conducting additional informal peer reviews which are at the core discursive assessments. One of their most salient features is that they avoid the production of written records. Rather

they remain verbal communications among a few subject matter experts. It is the project team or the local group of engineers responsible for a subsystem that is in control of the peer reviews.

The following three statements vividly describe the substantial difference between documentary and discursive reviews. The first statement draws a clear connection between purely verbal group-endogenous evaluations and the avoidance of dysfunctional commitments to early and often wrong cost estimations. The second one highlights the open-ended nature of discursive reviews which allows for in depth knowledge-sharing and out-of-the-box-thinking. The third excerpt explains the importance of keeping the number of people involved small, once again in order to avoid the production of written records.

> "So anyways, the bottom line is that what I decided to do, is do peer reviews and I'll have some comment to you doing peer reviews correctly. But the peer reviews–I insist on getting these peer reviews from the very beginning. And the psychology I change. You know, we get together in a room and I go to the engineers in the room and we chat about it. I don't let people write anything down for a long time. I insist that they don't. They don't send me emails. We talk about it. We talk about it for a long time. And that's to prevent this 327 dollars kind of problem, right? And we talked about it and I am telling you tested this on different subsystems, just as a test. On subsystems where I asked people to write down the numbers, they evolved only maybe 30 percents. On subsystems where we only talked, they evolved up to 400 percent. You know I didn't do it for a 3000 elements, so it's not a statistical sample, but there is something in it."

> "Okay, the difference to me is: The formal review is when there is a chairman, there is a panel, and there are viewgraphs presented and there is a package and that has the objective of the reviews, success criteria for the review and at the end the panel convenes and decides, will they successfully pass the review, if the objectives are met and what is the outcome of the review. That's formal. To me a peer review on the other hand is when we get together for all the subsystems–I've done this for subsystems. Where I say, okay we have two engineers that are experienced from previous missions and they talk to this engineer and no viewgraphs, he just looks into his files, pulls out stuff, they ask questions and then they maybe get together the next day discuss it more, it's two hours and two hours the next day maybe. And they kind of start try getting an impression. There isn’t in there anything that that person prepares for. So they can ask about different things."

"[Conducting reviews in a conference room] changes the psychology and you can not reach out for materials. So it has to be conducted in the office. And I noticed that if there's three or more peer reviewers then there is not enough dialog going on, because there is not enough time to ask questions and more. So just like here: I wanna show you what I have here. Well the two of you then see it, he saw it. You didn't see it because you know you have to pull in, you have to look at it, I have to show it to you, or I have to have four copies. If I make copies I better put you know a more formal material. You see where we are going? Now, if only the two of you are here, I can show it to you and both of you can look at it and you know what's on it. So I think the best peer reviews are you know never more than three people. Never more then three people. The best things are two on two, one on two. That are the best interactions."

The next dialog is initiated by the interviewers who want to know if an electronic directory of peer reviews would be of help. However the project manager remains skeptical towards any kind of written documents or standardization even regarding the administrative matters of peer reviews. There are various reasons for that: the avoidance of externally available and consequential judgments on individuals is one, keeping responsibility and control for planning and execution of reviews local is another one.

Project manager: Well, to tell you the truth, such a list will never be created. Because you are putting judgment on people. Who is an expert who isn't an expert and who'd wanna make such a list? And the list will become outdated and people are not available. So what you do is, you know you want an expert in avionics, you call the manager of that particular section. You have to just know.

Interviewer: So what do you think of having a more permanent sort of review office or people who are dedicated reviewers? Where we can know where to find them and we know what they are experts on

Project Manager: Well, I'll tell you - well, there is a process like [Review Process Manager] for example, you know he is a process owner for the reviews at JPL and there are people, who are in an office and we have project support people who can help you with costs, they are cost reviewers and you know, ISO reviewers and design principle reviewers, so there is that. And you use them. But, you can't let it become, you just go to the review office, because then there may be a tendency: okay, I'd been at the review office, and they'd sent some guys and they'd reviewed it. Instead of putting more thought into this: what do you really need out of the review? Do you need a rubber stamp? Do you need some smart people to share some

general comments? Or what do you really think, can go wrong? And then you have to penetrate these things."

Informal discursive peer reviews are substantially different from formal reviews. However they are not mutually exclusive or competitive alternatives. If used with creativity these two kinds can be combined to improve the quality of formal reviews. In the following paragraph a project manager describes how a documentary System Review can be enhanced by utilizing the results of peer reviews:

> "[...] what I found is that this [System Review] is the area where you have to have overlap between the peer groups. So the actual System Review takes place in a formal review. This is I ask the leads of these different peer groups to come to the formal review and then it's four hours not three days. Where everybody is really burned out and tired. And then we have peer group reports, just real reports, this is what the problem was with this subsystem and this is a problem with this subsystem and then everybody stays and participates in the discussion of the system. Because you have to got all the subsystems to discuss the system implications. So the system has peer group and also has a discussion at the formal review."

4 Conclusions

Initial findings from interviews with project managers and document analyses show undesired and dysfunctional consequences of formal documentary reviews, and in-depth knowledge sharing and out-of-the box thinking of informal discursive assessments.

Undesired, dysfunctional effects of documentary reviews fall into three categories: a) inaccurate numbers and euphemistic language, b) changing work processes and resource allocation to the detriment of over-all project goals and c) establishing a restrictive culture, where interactions are framed as prosecution versus defense situation. The results indicate that dysfunctional effects are tightly connected to the very nature of documentary assessments: production of written, i.e. stable records, extended distribution, context stripping, openness for mis-interpretation and the fact that it is usually imposed from the outside.

Some project managers are very aware of the limitations of documentary reviews. Therefore some of them developed their own ways of conducting additional informal peer reviews which are at the core discursive assessments. One of their most salient features is the lack of written records which is deliberately avoided. Rather they are conducted as verbal communications among only a few subject matter experts. This setting avoids the above-

mentioned dysfunctional effects of documentary reviews and allows for in depth knowledge sharing between project engineers and external experts. Discursive peer reviews facilitate the communication within communities of subject matter experts and allow individual project engineers to learn from more experienced colleagues.

The initial findings show that formal documentary reviews are prone to dysfunctional effects not seen with discursive reviews. If this holds true, NASA and other organizations need to reconsider their current management policies which focus almost exclusively on documentary assessments. In fact at NASA the recent accidents have even reinforced this tendency towards formal, documentary reviews. However, these findings indicate that what is needed, is not more of the same but a balanced approach which combines documentary and discursive reviews in a smart and novel way.

5 References

Bell, David G., Susan Newman and Nelson P. Repenning (2002). Process, Practices and Politics: Understanding the Relationship Between Documentation, Deployment and Daily Work, The Academy of Management 2002 Conference. Organization and Management Theory Division.:

Brown, John Seely and Estee Solomon Gray (1995). The People Are the Company. Fast Company 1, 78-82

Clark, Kim B and Takahiro Fujimoto (1991). Product Development Performance: Strategy, Organization, and Management in the World Auto Industry. Harvard Business School Press: Boston, MA

Eisenhardt, Kathleen M. (1989). Building theories from case study research. Academy of Management Review 14, 532-550

Feldman, Steven P. (2000). Micro Matters: The Aesthetics of Power in NASA's Flight Readiness Review. Journal of Applied Behavioral Science 36, 474-490

Giddens, Anthony (1984). The constitution of society: outline of the theory of structuration. Polity Press: Cambridge

Gittell, Jody H. (2000). Paradox of Coordination and Control. California Management Review 42, 101-117

Glaser, Barney G and Anselm L Strauss (1967). The discovery of grounded theory: Strategies of qualitative research. Wiedenfeld and Nicholson: London

Jordan, Brigitte and Peter Putz (2003). Thinking Assessment. Practicing Anthropology 25, 37-41

Jordan, Brigitte and Peter Putz (forthcoming). Assessment as practice: notes on measurement, tests and targets. Human Organization

Latour, Bruno (1986). Visualization and cognition: thinking with eyes and hands. Knowledge and Society: Studies in the Sociology of Cultures Past and Present 6, 1-40

Miller, Peter (1994). Accounting as Social and Institutional Practice: An Introduction. In Anthony G. Hopwood, Peter Miller (Eds.), Accounting as Social and Institutional Practice, 1-39. Cambridge University Press: Cambridge

National Aeronautics and Space Administration (2000). Enhancing Mission Success - A Framework for the Future. A Report by the NASA Chief Engineer and the NASA Integrated Action Team:

National Aeronautics and Space Administration (2002). NPG 7120.5B: NASA Program and Project Management Processes and Requirements

National Aeronautics and Space Administration (2003). Columbia Accident Investigation Board: Report Volume I. CAIB: Arlington, VA

Putz, Peter and Brigitte Jordan (2004). "Cover-your-ass" - zum Umgang mit formalen und informalen Bewertungen in Organisationen. In Bernd Hackl, Georg Hans Neuweg (Eds.), Zur Professionalisierung pädagogischen Handelns. Beiträge aus der Sektion Lehrerbildung und Lehrerbildungsforschung in der ÖFEB, 151-176. Lit Verlag: Münster

Quinn, James D. (1994). Flight P/FRs and the Design Review Process. NASA Jet Propulsion Laboratory: Pasadena, CA

Vaughan, Diane (1996). The Challenger launch decision: risky technology, culture, and deviance at NASA. University of Chicago Press: Chicago

Wheelwright, S. and Kim B Clark (1992). Revolutionizing Product Development: Quantum Leaps in Speed, Efficiency and Quality. The Free Press: New York

Yin, Robert K (1984). Case study research. Sage Publications: Beverly Hill, CA