The Wrong Kind of Lean:
Over-Commitment and Under-represented Skills on Technology Teams

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This paper reports on results from five companies in the aerospace and automotive industries to show that over-commitment of technical professionals and under-representation of key skills on technology development and transition teams seriously impairs team performance. The research finds that 40 percent of the projects studied were inadequately staffed, resulting in weaker team communications and alignment. Most importantly, the weak staffing on these teams is found to be associated with a doubling of project failure rate to reach full production. Those weakly staffed teams that did successfully insert technology into production systems were also much more likely than other teams to have development delays and late engineering changes. The conclusion suggests that the expense of project failure, delay and late engineering changes in these companies must greatly out-weigh the savings gained from reduced staffing costs, and that this problem is likely going to be found in other technology-intensive firms intent on seeing project budgets as a cost to be minimized rather than an investment to be maximized.

Pressing professionals to work at the limits of their capabilities is a widespread practice driven by the desire to minimize both project costs and cycle times. Recent experience in the aerospace industry suggests, however, that the drive to minimize staffing costs can lead to poor project performance. First there was the report that there had been sixty space launch failures worldwide in the 1990s. Among the reasons offered was the feeling that launch vehicle manufacturers had been stretching their experienced personnel across too many projects as they supported existing launcher fleets while developing, qualifying and ramping up to produce new systems.[1] Then came the very public failures of the Mars Climate Orbiter, the Wide-Field Infrared Explorer, the Mars Polar Lander and other NASA missions. In an analysis of the problems behind these events, reports pointed to several reasons including the view that NASA had taken on more tasks than it could manage well, and it had rushed projects to completion while being excessively concerned with holding down costs.[2]

Similarly, this study asks if "doing more with less" and "better, cheaper, faster" have been taken to the point of diminishing returns, but our concern is with a broad range of development projects. The success and failure rates of thousands of technology teams in

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private industry may not be reported on national television news, but these day-to-day successes and failures add up to determine the future value of technology-dependent corporations.[3] We will use data collected on 291 technology development and transition projects in the aerospace and automotive industries to explore whether the pressure to cut costs and spread technical staff more thinly has become counter-productive.

It should be stressed that the management of the companies with projects included in this study did not feel that they had ever gone too far in controlling staffing costs. These companies have been aggressively holding down costs, and their managers readily acknowledged that they have been pushing technical professionals to do a greater number of tasks under time pressure. They felt this stretching of resources and shrinking schedules had been unavoidable in the face of budget cuts, down-sizing and heightened competition. Yet the senior and middle managers we talked to felt almost without exception that they had in general given their teams the resources they needed. While mistakes had been made, we might best characterize their views as a sense that their teams had been provided "just enough" staffing. This paper reports on how well they were able to maintain that balance.

Lean Transition: Increasing the Value Stream of the Enterprise

LeanTEC, for Lean Transition of Emerging Industrial Capability, is a project jointly supported by the U.S. Air Force and The Boeing Company to determine why some technologies transitioned quickly and easily into production, and why others did not.[4] The first and most direct explanations were of course that the technologies were not ready or that the applications selected for them were not appropriate, but experienced managers looking over their technology portfolios felt that other forces must be at work that could be affected by management action. Boeing and the Air Force began cooperative research on the broad question of what management processes and practices were the major barriers to technology transition.

The organizing concept was "Lean" transition of technology, with a heavy emphasis on two principles. (1) Lean does not just mean the minimization of cost. The value of lean

effort is judged by its effect on the value stream of the enterprise. If, for example, cutting investment in some part of the development process can be shown to relate to sharp decline in project success, then budget-cutting is creating inefficiency and causing waste. (2) One must optimize the full range of that value stream, from technology identification and selection, through design, development, pre-production transition, production, testing, quality assurance and customer acceptance. Lower cost and more rapid development is important, but only if the resulting product or process was designed well, transitions easily into production, and serves its intended purpose.

This broad view of Lean led us to explore the staffing of cross-functional teams to see if they had the time and right skills to do effective technology development work. Here we will first show that roughly four out of every ten teams at each of four companies participating in our research were reported to be inadequately staffed by our functional definition. Then we will demonstrate that these weakly staffed teams have less effective internal team and cross-functional communications, and weaker team alignment internally and externally with the functional departments supporting the team. That result will be followed by further evidence that these same weak staffing practices relate to poor over-all project performance. The conclusion will suggest that project cost-cutting can reach the point where it costs the firm more both in dollars and cycle time than it is saving. That is, an excessive focus on near term cost savings has taken these companies beyond Lean to a loss of productivity.

Over-commitment

In preliminary discussions the LeanTEC research team had heard continuing complaints from technical professionals about a variety of management policies they believed had increased the responsibilities of their technical professionals to the point of hurting team effectiveness. A common opinion in organizations that had down-sized was that reductions in staff had not been followed by proportionate reductions in tasks, so that there was a drive to advance a large portfolio of projects at close to the old rate of progress with fewer people. In other organizations where there was less budgetary pressure, the sense of over-commitment was still strong. We continued to hear references

to "doing more with less," and the belief that under-staffing and rushing tasks of considerable complexity were leading to waste and error.

A survey at a global, multi-billion dollar firm we shall call Alpha also supported this view. Sixty technical professionals were asked to rank the importance of 49 barriers to technology transition in their company. The barrier list that was offered included such things as the difficulty of getting management funding, inadequate equipment budgets, time pressures, subcontractor problems, weak team leadership, and not enough training. The respondents were asked to rank these and other "barriers to successful development and application of new technologies" in their company on a scale from "not important at all" to the "most important" barriers.

For the most part, the barriers ranked as more important were those that almost any technical professional would focus on, those that put a concern for technology behind other priorities. For example, these managers at Alpha felt that management concentrated too much on cost and neglected opportunities to improve performance, and they thought management was too reluctant to pursue high risk/high pay-off technologies.

The surprise was that among the top ranked barriers at Alpha was, "Professionals are split across too many tasks and teams," our measure of over-commitment.[5] What made this result so striking was that the technical organization at Alpha was highly regarded, and it could point to significant and recent successes in advancing applied science in ways that had a concrete impact on the company's technological leadership and corporate profits. Alpha had been expected to serve as our benchmark of successful practice, not be the site of problems with over-committed staff.

Missing Key Skills

In addition to running teams at the edge so that the *average* team member is pressed to work on a larger number of tasks, we also found practices that led *key* technical professionals to be missing, or at least not adequately represented on development teams.

It is the nature of technology development that management is engaged in a difficult process of balancing the needs of teams against personnel costs. A very large number of diverse technical specialties are required for what are often very complex projects in the industries studied here. At one extreme, if you expect that only a few hours of work are needed to make an essential contribution, you probably would not commit a valuable professional to hundreds of hours of team meetings and discussions over a year or more. If the project is a high priority, and the skill in question will require many months of careful work, you would put that professional on the team. The difficulty lies between.

Good team leaders are expected to know when and how to find outside help, and integrate it into the team's process. But as the outside skill becomes more central to the team's progress, at what point do you want the specialist to become de facto or formally a part of the team, participating in its discussions of approaches and solutions? In periods when resources are scarce, managers will be more likely to err in the direction of leaving people off the team, and count on the team leader and informal mechanisms to fill the gaps.

Another concern that drives management assignment of skills is their scarcity. An organization may have some specialties with only one or two experts. If there are several projects that need significant contributions from, for example, a specialist on high speed machining of thin wall aluminum structures, how do you assign the time of what might be the one and only specialist with the necessary skills and experience? Or while a firm may have scores of projects that need assistance with design for manufacturing, there may only be a handful of Design for Manufacturing and Assembly engineers with the knowledge and experience to understand complex designs and solve assembly problems well in advance of going to production.

Whether the motivation for not putting skills on teams is cost or scarcity, the fact that some technical specialists do not participate in on-going team processes puts teams at some risk. Engagement is weaker because the resource professional does not accept responsibility for or identify with the team to the same degree. He or she may not give it enough priority to spend the time needed to help the team find the best design, and may

not be willing to take the time to help on an extended search for a solution. Detached from the team process, this specialist may also not feel committed to the team and its solution, and may not help when the team needs to win approval for its design from the functional departments and programs that will be affected.

In complex processes like technology development, the existence of even a small loss of engagement can have severe consequences. These teams must bring together diverse specialties with differing assumptions and professional experience unknown to the others. If the literature on knowledge management has taught us anything, it is that a great deal of critical information is tacit, unspoken and unobserved.[6] The premise of using a technical specialist as a background resource is that teams can ask questions and they will get a correct answers. When the resource specialist is not an active party to the discussions, however, answers may be given out of context because the specialist may not know that the question was not asked quite the right way. And of course the answer may make tacit assumptions that are never expressed and debated, creating potential problems later in the development process.

Over-commitment and Under-represented Skills at Four Companies

In a study of four additional companies, both over-commitment and quality of skill representation were explored by asking informants to react to statements about staffing of technology teams. Instead of asking them to draw a broad generalization about barriers in their company, in this second investigation they were asked to report on a variety of characteristics for a single, specific project that they knew well.[7] The wording about "Professionals were split across too many tasks and teams" was retained, but offered as an assertion that they should agree or disagree with. Similarly, an item was designed that sought to capture whether or not the varied key skills needed for a given team were present by asking informants to agree or disagree with the statement, "All the key skills were <u>not</u> represented on the team." The expectation was that responses to this statement would tap engagement through a sense of whether each specialty had been "represented," which is to say offered and supported in team processes. We hoped this sense of representation would bridge the fact that it matters less whether the person is formally on

the team or not, and depends more on whether all the key skills had a voice and a recognized place at the team's table.

Table 1

Staffing Practices at Four Companies

	RDS	Ajax	Century	SystCorp
Professionals split across too many tasks and teams				
Agree, somewhat or strongly	26.9% n=126	30.8% n=26	21.1% n=57	27.2% n=55
All key technical skills were NOT on team				
Agree, somewhat or strongly	31.5% n=130	33.3% n=21	34.5% n=61	33.3% n=57
Level of staffing practice				
Strong: Confident that all key skills were present and team was not over-committed*	14.2%	24.6%	12.7%	22.7%
Adequate: Limited belief that all key skills were present and team was not over-committed*	40.9%	31.6%	41.8%	27.3%
Weak: Felt that either the team lacked key skills and/or the team was over-committed	44.9%	43.9%	45.5%	50.0%
	100.0% n=127	100.0% n=57	100.0% n=55	100.0% n=22

Chi squares calculated for both sets of results using full table of data before the "somewhat" and "strongly" categories were combined. No statistically significant differences were found.

*Actual items were in the negative, so that a confident response is defined by Strongly Disagree responses to the items that all key skills were NOT on the team and the team was over-committed by being split across too many tasks and team. Adequate teams are those that informants Disagreed Somewhat with these items.

When we examined the results at the four companies, we learned that over-commitment and incomplete skills were a common condition, spread uniformly across the four companies included in this part of the research. RDS, Ajax, Century and SystCorp are names used to protect the identities of nationally recognized companies that together have research and development budgets that sum into the billions of dollars. The past staffing practices at these respected firms were reported to result in over-commitment for twenty to thirty percent of the projects reported on. When we add the "strongly agree" and "agree somewhat" responses, over-commitment was a characteristic of from 21.1% at Century to 30.8% of the project teams at Ajax. (See Table 1.)

We found even less variation across companies when we examined the completeness of the teams as measured by our second item about all key skills being represented. The practices at roughly a third of these projects are said to have been missing participation of key skills. That is, if we sum the two agreement categories for this statement, 31.5%, 33.3%, 34.5% and 33.3% of the teams respectively are said to have been missing key skills.

Necessary Conditions for Effective Cross-functional Team Staffing

One can relate these separate characteristics to project outcomes, but our view is that one should consider their combined effect. We propose that these elements of team staffing are both needed, in that if there is *either* over-commitment *or* missing skills, then team performance will be seriously impaired. Adequate staffing practice requires that both over-commitment and poor skill representation be avoided. If all the skills are present on a team, but the team members are so fragmented and over-committed that meetings are hard to hold and attention is limited, then one might expect the team to have a lower level of success. Similarly if the team members are in general not over-committed and they have substantial time to attend to the team's work, but critical skills are not adequately represented in team discussions, then the team is expected to have a higher probability of failure. Even a technology project "skunk works" with a dedicated team rich with resources will not be successful without the right knowledge and skills on the team.[8] High performance is expected only when the staffing of teams avoids both of these problems; low performance would be expected if either was a team characteristic.

This logic guides the combination of these two questions into a rough index of adequate staffing practice. If the person reporting on their team *disagreed strongly* on both questions, they were asserting with confidence that the team was not over-committed and they had all the key skills represented on the team. We characterize the 44 teams that had these characteristics as having "Strong" staffing practice. If they disagreed with both questions, but only disagreed somewhat with either or both of these questions, they would seem to be acknowledging that they held some reservations about the degree of

success the team had had in avoiding these problems. These team will be characterized as "Adequate."

The remaining "Weak" projects made up 42.2% of the projects in our study. The informants from these projects *agreed strongly* or *agreed somewhat* that either that key skills were missing or that the team members were over-committed. When we checked the results at each of the four companies, we found again that the pattern of weak staffing was more or less the same across the four firms (Table 1.)

Integrated Product Teams and Staffing Practice

The finding that four out of every ten projects had one or the other of these poor staffing practices is a high level of what we consider to be inadequate staffing. One might ask if this staffing practice is inadvertent and unrecognized, or if it is part of a considered strategy. It is possible that these companies set up some teams with a higher priority and staff them well, while leaving the other projects to struggle for the resources they need. This second group could include seed projects, investments in competency building or other projects that have less immediate need to produce results. It would be useful to know how staffing in practice relates to formal team establishment and assignments.

While we do not have detailed information about staffing histories, we did ask if the teams our informants were reporting on had been set up as an Integrated Product Team, or IPT. Like management in many industries and corporations, executives in the companies being studied had come to appreciate the logic of concurrent engineering, its potential for cutting cycle times, and the key role of having formally-established cross-functional technology development teams. In the 1990s, a common designation of such workgroups in these industries was the IPT or often IPDT, for Integrated Product Development Team. Formal rules were issued governing the creation of such teams and their activities, and for a period of time that included the work of many of the teams studied in this research, IPT-designation was a seriously considered organizational decision.

Of course any team should be set up with the various skills it needs to do its work, but one might expect that management would be much more concerned with giving IPTs the resources to pay for and keep the different special skills they need. Equally important, many IPTs are set up to work on high priority projects, and we would expect them to be somewhat better staffed. Does this explain the differences we found, with perhaps the IPTs being well staffed and others not?

We asked our informants, yes or no, was the project team they were reporting on an IPT? This left it to the informant to determine the meaning of that term in their particular companies. Over 70% said their projects were IPTs, and we can group the projects by their answers to compare IPTs and non-IPTs to see how they were implemented in practice relative to our index. As shown in Table 2, we first found that IPTs at the four companies were less likely to be weakly staffed. At RDS, 63.0% of the non-IPTs were weakly staffed, compared to 40.4% of the IPTs. Similar patterns were also found at Century, SystCorp and Ajax. Around two out of three, 61.5% of the non- IPTs at Century and 66.7 % of those at SystCorp, were over-committed and/or missing key skills, substantially more than the 38.6% and 37.5% of the IPTs that were weakly staffed. (The small number of projects at Ajax limits any conclusions on this point.)

But these difference do not account for the high level of weak staffing in general because when the IPTs are separated out, we find that they are still far more weakly staffed than should be expected. Looking just at the IPTs in Table 2, we find that 40.4% of IPTs at RDS, 38.6% at Century, and 37.5% at SystCorp failed to meet our test of staffing practice. Looking at all four companies, there are 201 projects that were identified as IPTs. Of that number, 80 or a remarkable four out of ten IPTs (39.8%) were inadequately staffed based on our index.

Table 2

Integrated Product Teams and Staffing in Practice at Four Firms

At RDS:	Integrated Product Team? Yes	No
Adequacy of staffing practices		
Strong staffing practice: not over-committed or missing key skills	16.2%	3.7%
Adequate: agree somewhat team not over-committed/missing skills	43.4%	33.3%
Weak staffing: teams were over-committed and/or missing skills	40.4%	63.0%
	100.0%	100.0%
Kendall's tau b = -.196, significant at .014.	n=99	n=27

At Century:	Integrated Product Team? Yes	No
Adequacy of staffing practices		
Strong staffing practice: not over-committed or missing key skills	25.0%	23.1%
Adequate: agree somewhat team not over-committed/missing skills	36.4%	15.4%
Weak staffing: teams were over-committed and/or missing skills	38.6%	61.5%
	100.0%	100.0%
Kendall's tau b = -.135, not significant.	n=44	n=13

At SystCorp:	Integrated Product Team? Yes	No
Adequacy of staffing practices		
Strong staffing practice: not over-committed or missing key skills	15.0%	6.7%
Adequate: agree somewhat team not over-committed/missing skills	47.5%	26.7%
Weak staffing: teams were over-committed and/or missing skills	37.5%	66.7%
	100.0%	100.0%
Kendall tau b = -.243, significant at .05.n=40	n=15	

At Ajax:	Integrated Product Team? Yes	No
Adequacy of staffing-in-practice		
Strong staffing practice: not over-committed or missing key skills	27.8%	0.0%
Adequate: agree somewhat team not over-committed/missing skills	27.8%	25.0%
Weak staffing: teams were over-committed and/or missing skills	44.4%	75.0%
	100.0%	100.0%
Kendall tau b = -.259, not significant.	n=18	n=4

Relating Staffing Practice to Internal Team Processes

The first area to explore is whether weak staffing practices affect team behavior, both in general and more specifically for cross-boundary communications with people on and off the team from various functional departments. Several questions were asked to get at whether the team had been able to meet and discuss their work. The question about team meetings asked for their agreement with the statement that team members had been "committed and available for meetings." When the three levels of staffing were compared on this question, the proportion that strongly agreed to this item showed a dramatic trend. Those agreeing strongly – saying yes, the team members were committed and available – rises from 24.1% of the weakly staffed team, to 41.7% of the Adequate teams up to 65.1% of the well-staffed teams (see Table 3.)

Table 3
Staffing Practices and Team Process

	Adequacy of Staffing Practice		
	Weak	Adequate	Strong
Members committed and available			
Disagree strongly or somewhat	19.5%	8.4%	4.7%
Agree somewhat	56.4%	50.0%	30.2%
Strongly agree	24.1%	41.6%	65.1%
	100.0%	100.0%	100.0%
	n=108	n=96	n=43

Kendall's tau b = .287, significant at the .0005 level.

	Adequacy of Staffing Practice		
	Weak	Adequate	Strong
Hard to have informal discussion			
Strongly disagree	23.9%	44.7%	76.6%
Disagree somewhat	49.5%	41.7%	14.0%
Agree somewhat or strongly	6.6%	13.6%	9.4%
	100.0%	100.0%	100.0%
	n=109	n=138	n=43

Kendall's tau b = -.317, significant at the .0005 level.

Informal social meetings were probed with the statement that it had been "hard to get together for informal discussions." Again one can see the trend clearly by considering the strongest positive answer, which is to disagree strongly that it was hard to get together. The disagreement, indicating an ease of informal discussion, went from 23.9% of the weakly staffed teams to 44.7% of the Adequate teams, topped by 76.6% of the well-staffed projects. Adequate staffing and meeting availability are very highly correlated.

One might argue that this result shows that good staffing is an essential enabler of team process, but we believe it to be more accurate to use these results as a validity check on our measure of adequate staffing. A judgement about whether members were on "too many tasks and teams" or "missing key skills" is likely to be strongly influenced by recollections of how hard it was to assemble the right people to work on a problem. From that perspective, over-commitment and problems of supporting informal and formal team processes are different aspects of the same phenomenon.

Staffing and Cross-Functional Team Communications

A central purpose of a cross-functional team is to anticipate and work on problems that would otherwise appear later in the development process. It would seem to follow that it is important that professionals on a development project have the opportunity to work with others concerned with the application that is involved and the subsequent transition of the product or process design into production.

To learn about the nature of different team work processes, we asked the informants on the projects to report on how frequently they engaged in different activities such as visits to the shop floor, asking whether each activity had occurred never, once or twice, several or many times. To learn more about cross-functional work, the series of questions went on to specify that they should answer about the frequency of activities only when both the development team and – across an important functional boundary [9] -- professionals from Production and/or the Program (the inside customer that would have to accept the project

results) were involved. For our purpose here, two questions in this series seem particularly relevant: how often there were joint planning meetings, and the frequency of unscheduled conversations between development personnel on one hand and Program and production groups on the other.

Table 4
Staffing Practices and Cross-Boundary Communications

	Adequacy of Staffing Practice		
	Weak	Adequate	Strong
Joint planning meetings			
Never	8.3%	4.1%	4.9%
Once or twice, several times	60.2%	54.7%	41.5%
Many times	31.5%	41.2%	53.7%
	100.0%	100.0%	100.0%
	n=108	n=97	n=41

Kendall's tau b = .155, significant at the .005 level.

	Adequacy of Staffing Practice		
	Weak	Adequate	Strong
Unscheduled discussions			
Never	0.9%	0.0%	2.4%
Once or twice, several times	42.5%	27.2%	16.7%
Many times	56.6%	72.8%	80.9%
	100.0%	100.0%	100.0%
	n=113	n=99	n=42

Kendall's tau b = .191, significant at the .001 level.

As might be expected, better staffed teams were much better at cross-functional communications (Table 4) While only 31.5% of the weakly staffed teams are reported to have met "many times" with Programs and production, the Adequate teams worked with these other communities 41.2% of the time. Comparing the well staffed teams with the weak ones, 53.7% of the good teams had many joint planning meetings.

Similarly, the teams that had the right skills and were not so over-committed were much more likely to have unscheduled discussions with Programs and production. Given the complexity of many of these projects and the substantial amount of detailed coordination that was required, it is appropriate to find that informal cross-functional communications is higher than the frequency of more formal meetings. Among the weakly staffed teams,

56.6% worked many times with Programs and production. By contrast, 72.8% of the Adequate teams and 80.9% of the good teams had unscheduled conversations many times with those that would have to accept and implement their technology designs. The weakly staffed teams were much less likely to engage in either formal or informal communications activities.

Checking Inferences about Knowledge Processes and Alignment

The data also enable a check on our earlier argument on how and why over-commitment and missing skills would be expected to hurt team performance. It was argued above that participation in team processes would create involvement and commitment to the team, and consequently greater buy-in to team solutions. If so, one would expect the team to be better able to resolve their differences internally and not require outside authority to force compromise. A question used to measure this aspect of team engagement is how often the teams had to go to management "for help to resolve team differences." Table 5 shows that 61.0% of the well-staffed teams "never" went to management for this kind of help, compared to 34.8% of the weakly staffed teams, with Adequate teams falling between. In addition, when the well staffed teams did go to management for help, they generally (29.3%) had to do so only "once or twice. Note that when you combine the frequencies of "several times" and "many times," 33.9% -- one out of every three -- of the weakly staffed teams had to go for outside help with some frequency. For well staffed teams, 9.7% or less than one out of ten needed management support to bring about closure. Better staffed teams are far less likely to have to go to management to assist them resolve internal problems.

Another suggestion in our discussion of team processes was that if key skills are not represented, some functional specialists are not engaged in the process. This lack of engagement was argued to have two negative consequences. First because of weak representation from that specialty, the team will not get the advice and assistance it needs to understand that specialty's problems and constraints. The more likely outcome is that the team's solution will run into very real problems when it seeks approval for its

solution. Second, without participation and buy-in from the department's representative, specialists may be less willing to take up the cause of the team and argue that their departments should accept team solutions. Either way, weak staffing would then be expected to relate to problems with departmental acceptance.

Table 5
Staffing Practices and Team Alignment

Frequency of needing management to resolve team differences	Adequacy of Development Team Staffing: Weak	Adequate	Strong
Never	34.8%	44.1%	61.0%
Once or twice, several times	56.3%	51.6%	36.6%
Many times	8.9%	4.3%	2.4%
	100.0%	100.0%	100.0%
	n=112	n=93	n=41

Kendall's tau b = -.186, significant at the .001 level.

Effort required because departments rejected team ideas	Adequacy of Development Team Staffing: Weak	Adequate	Strong
None, not a problem	43.0%	52.2%	62.0%
Very minor, minor effort	23.7%	25.5%	26.1%
Significant or major effort	33.3%	22.3%	11.9%
	100.0%	100.0%	100.0%
	n=114	n=94	n=42

Kendall's tau b = -.155, significant at the .003 level.

To assess how teams operated at this boundary with the departments, we included a survey item about departmental resistance in a battery of questions about problems that had arisen on the projects being studied. The question started by asking whether a problem had come up. If the problem did occur on a particular project, the informant was then asked to judge how much effort the team invested in solving the problem. The second part of Table 5 shows that well-staffed teams were more likely to avoid the problem of having their ideas rejected by departments, with 62.0% reporting no, the problem did not appear. For the weakly-staffed teams, only 43.0% avoided problems

with departments rejecting team ideas, with the Adequate teams falling between at 52.2%.

Staffing Practice and Project Outcomes

Having shown the relationships between the quality of staffing practices and team processes, it remains to show the net effect of staffing adequacy on project outcomes. One key outcome question used in this study asked informants, "Was the technology inserted into a production system?" While memories might not be clear on smaller issues, we thought this central outcome would be a straightforward question of fact. On the other hand, many of the informants had been on the team they were reporting on, and had invested time and energy into trying to make the project a success. Knowing that participants might then be reluctant to simply say the project had been abandoned, they were offered other ways of saying that the project had not been less than fully successful. They could say that there had been no insertion but that the technology was "on the shelf for future use, " or that "ideas and parts of the technology" had been inserted. This technique allows the informant to say something positive about less successful projects to lessen the likelihood that the last option, that the technology was fully inserted, would be checked for weaker projects.

Table 6
Staffing Practice and Project Success
(For all projects)

	Adequacy of Development Team Staffing		
Insertion of Technology into production systems	Weak	Adequate	Strong
Technology abandoned, put on shelf or only ideas/part of technology inserted	43.6%	34.0%	20.0%
Technology was fully inserted	56.4%	66.0%	80.0%
	100.0%	100.0%	100.0%
Tau b = .161, signif. at the .006 level.	n=110	n=94	n=40

When we related our measure of adequate staffing to the important project outcome of moving the technology into full production, we found a positive relationship. Four out of five, 80.0%, of the strongly staffed teams were successful in fully inserting the technology they were working with, compared to 56.4% of the weakly staffed teams. The Adequate teams fell between with 66.0% achieving insertion into production. (Table 6.)

Before concluding that our definition of adequate staffing affects the probability of insertion, however, there is an alternative explanation to be considered. If a project loses priority or runs into what appear to be fatal technical problems, team members in an over-committed environment will be tempted to pay less and less attention to projects in trouble, and invest time in those that are doing well. Is the relationship between poor staffing and project failure simply a result of team members deserting unsuccessful projects?

To deal with this problem of interpretation, we can study the outcomes for only those projects that were successful in inserting at least some aspect of the developed technology into production, whether it is ideas and a part of the technology that were inserted or insertion in full. If we look only at these more successful projects in isolation, we will have by definition dropped out most if not all the projects that were dealing with failed technologies, as well as those projects that were abandoned by management. If relationships are again found between staffing practice, it is unlikely to be because the projects were being deserted.

We can now examine the relationship between staffing practice and two other outcomes that were asked about, whether the project was on time or delayed, and whether after production began there had been late engineering changes. This will inform us about whether staffing practice explains variation in the quality of successful insertion, and help to validate or create doubt about the finding just presented that staffing is a major explanation for project success.

Project Delay in Transitioning Technology. While there is widespread pressure to make development processes go faster, managers sometimes forget that we are essentially asking technology teams to do creative invention on a tight schedule. One might expect projects to take longer than expected when dealing with new technology applications for systems and sub-systems with hundreds or often many thousands of parts. We asked about delay focusing on the phase of the transition process marked by production acceptance when most of the risk should have been taken out of the technology. The question was, after the project had been accepted for production, whether the transition to production went, "as quickly as it should have?" Informants were given the option to say there had been no delay, or to check a rough range of the number of months involved in the delay.

The results (Table 7) show that project delay is also related to staffing practices. Teams with good staffing substantially out-performed the others, with 60.0% transitioning their projects to production without any delay. Of the Adequate teams, 48.4% encountered no delays, and only 36.5% of the weakly staffed were early or on time.

Late Engineering Changes after Full Production Begins. Late engineering changes are a particularly good indication of poor team processes. If someone discovers a problem with technology or a design applying that technology after full production has ramped up, it is almost always a problem the team failed to anticipate. However impossible it is to anticipate some problems, on balance effective teams should have this outcome less often. We asked whether once production had started, had there been additional engineering changes and how severe were they?

When the answers to this question were related to the quality of team processes, we again find that missing skills and over-commitment together relate strongly to team effectiveness. Of the well staffed teams, 92.0% avoided late engineering changes. Again the performance of the Adequate teams is lower, with 85.2% avoided such changes, and

for the projects with weakly staffed teams, only 65.6% avoided additional late changes in designs and processes.

Table 7

Staffing Practice and Project Outcomes

(Only for 166 projects that had partial or full technology insertion into Production)

A. Delay Going to Production	Adequacy of Development Team Staffing: Weak	Adequate	Strong
Delayed	63.5%	51.6%	40.0%
No delay	36.5%	48.4%	60.0%
	100.0%	100.0%	100.0%
Tau b = .160, signif. at the .019 level.	n=74	n=62	n=30

B. Late Engineering Changes after Project in Production	Adequacy of Development Team Staffing: Weak	Adequate	Strong
Significant, or many serious changes	34.4%	14.8%	8.0%
None or only minor changes	65.6%	85.2%	92.0%
	100.0%	100.0%	100.0%
Tau b = .246, signif. at the .001 level.	n=64	n=61	n=25

We can now revisit our finding that successful insertion into technology is related to project failure. Team staffing is associated with other team outcomes when we have controlled for the effects of technology failure and project cancellation. It follows then that the effects of weak staffing are also more likely to flow in the direction of increasing project failure, and other explanations can be set aside. The conclusions are therefore (1) over-commitment and/or under-representation of key skills are associated with major increases in failure to transition projects into production, and (2) of those that do reach production, inadequate staffing is linked to increased delay and a very high increase in late engineering changes.

Conclusions and Discussion

The first general conclusion to be drawn from these results is that trying to staff each team with "just enough" people and skills implies that – absent perfect knowledge -- mistakes will be made. Of course if this research has any impact on future practice, it

will not be because we have found that problems can result from over-extending technical professionals. Presumably everyone familiar with technology-driven industries knows this fact, and persists in doing it out of conviction that the attendant costs are not great and/or that it is a price of doing business in down-sized, faster-cycle, and highly competitive industries.

What is new is the recognition that this kind of organizational environment can foster serious and fundamental weakness among a surprising number of teams, and the magnitude of the consequence. The finding presented here is that well respected companies have adopted policies that impair as many as 40% of their project teams. Management in these companies know that these teams are being pushed hard, but some feel this is a sign of good (which is to say, tough) management. Even so, they are surprised to learn how extensive the weak staffing practices have become.

The most important result of this research may be specific to the companies being studied, but it seems clear that the cost of these staffing practices is far, far higher than anyone suspected. We have found that if you create technology development teams with over-committed professionals and/or teams that don't ensure the active participation of key skills in on-going team processes, you hurt those teams severely. Table 6 suggests that a 20% failure rate of not achieving full insertion into production for well staffed team jumps to 44% for poorly staffed teams. Failure to reach production more than doubles.

In Table 7, we discussed the differences in terms of comparative success, and the differences were substantial. If you again turn the results around and focus on failure rates, the findings are more dramatic. Taking just the case of late engineering changes in the companies studied here, 8.0% of the well staffed teams ran into that problem. The rate of late engineering changes on weakly staffed teams at 34.4% is over four times higher. Given that late engineering changes can sometimes be enormously expensive, this difference alone would lead us to wonder if weak staffing practices are costing more than they could possibly be saving in personnel costs. Add that finding to the more than doubling of project failure, and perhaps it is time to reconsider just how aggressive we should be when trying to do more with less.

We should stress that we would not expect differences this extreme in all industries. These findings are for industries engaged in product development that requires both the advancement of new technologies and their subsequent insertion into large and often very complex product systems. For teams not so dependent on advanced technologies and working on comparatively simple products, the differences might be more modest. But if a problem can become this severe in several companies without its importance being recognized or addressed, it could be an unrecognized problem hurting research, development and technology transition almost anywhere.

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[1] The results of the investigation and opinions about launch failures by the Aerospace Corporation were reported in Aviation Week & Space Technology, April 1999.

[2] Los Angeles Times, Tuesday, March 14, 2000, pp. A3 and A20. One should also note the enormous success of other NASA programs of equal or greater challenge, like the launch of the Chandra X-ray observatory and the global 3-D maps received from the Mars Global surveyor.

[3] Shona L. Brown and Kathleen M. Eisenstadt, "Product Development: Past Research, Present Findings, and Future Directions," Academy of Management Review, 20 (1995) 2, 343-378. Or see the views in C.B. Schoohoven, K.M. Eisenhardt, & K. Lymna, "Speeding Products to Market: Waiting time to first product introduction in new firms," Administrative Science Quarterly, 35 (1990) 177-207, arguing that product development is a critical means for reinventing the firm.

[4] LeanTEC is supported by Cooperative Research Agreement F33615-97-2-5153, administered by the U.S. Air Force Research Laboratory, Wright-Patterson AFB.

[5] With 7 as the ranking of "most important" and 4 as "average importance," too many tasks and teams had an average score of 5.44 followed by 5.41 for "Management only cares about cost savings." Tied for third were "Unwillingness to invest in breakthrough technologies" and "Teams don't have enough authority and resources" at 5.20.

[6] See perhaps the most widely cited source of this view, Ikujiro Nonaka and Hirotaka Takeuchi, The Knowledge Creating Company (New York, NY: Oxford University Press, 1995.)

[7] The reliability of reporting historical project data can be low. These data were collected in a careful process where knowledgeable engineers were selected to report on a single project they knew well on self-administered forms. The surveys were completed in small group sessions, and the participants were given a charge number to cover the one to two hours it took to complete the instrument. Among other reliability checks, a question was asked about how well each respondent remembered the details of the project. Answers to this memory question were related to project outcomes and other questions to see if there was any positive or negative memory bias. The authors' best judgement is that, while the data used here can be assumed to have a relatively high level of random error, we found no evidence of systematic bias error that could explain the findings presented here.

[8] Art Single and William M. Spurgeon, "Creating and Commercializing Innovation Inside a Skunk Works," Research-Technology Management, 39 (No 1), January-February 1996. They also stress that the major project successes they reviewed at Ford suffered no lack for resources and no red tape, certainly the polar opposite of the closely managed finances of projects today.

[9] This particularly boundary was the focus of the questions because high quality communications between design and manufacturing is a particularly important cross-functional need. See Daniel E. Whitney, "Manufacturing by Design," Harvard Business Review, July-August 1988.