R&D PROJECT SELECTION: BEST PRACTICES FOR SUPPLIERS

By

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Submitted to the MIT Sloan School of Management and the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degrees of

Masters of Business Administration
AND
Master of Science in Mechanical Engineering

In conjunction with the Leaders for Global Operations Program at the
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Abstract

Successful research and development is critical in ensuring firms continue to meet customer needs and stay ahead of their competition. Hundreds of billions of dollars are spent every year on these R&D pursuits. It may seem logical that the more money a company spends on R&D, the more successful they will be. However, multiple studies have shown there is no significant correlation between a firm's R&D expenditures and its financial performance. The key to effective R&D is not how much a firm spends, but how well the money is spent.

There are two sides of doing R&D effectively—doing the right projects and doing projects right. This thesis focuses primarily on the first side, creating a process to help a company choose the best projects to pursue. A significant amount of literature exists in this area, however that literature mostly focuses on R&D performed at original equipment manufacturers (OEMs). For OEMs, R&D is the first step in a product development process where the company has the ultimate decision over the form their product takes.

This thesis expands on that literature to focus on R&D project selection for firms that act as suppliers to OEMs. Suppliers performing R&D are faced with significant additional challenges due to the OEM having final say over the product configuration. Suppliers have uncertainties about whether they are pursuing the right technology along with whether they will actually win business to utilize that technology. This fact often forces suppliers to adopt a conservative R&D strategy with a fairly secure likelihood of adoption over speculative R&D that might not come to fruition.

Because every company and every industry is different and has different priorities for their R&D activities, there is no single process that will work at every company to help them choose a better portfolio of R&D projects. Instead, this thesis presents a set of guidelines that can be used to help companies (especially suppliers with conservative R&D strategies) design their own process. Along with those guidelines, a case study is presented based on implementing an R&D project selection process at Spirit AeroSystems. The process that was implemented, along with problems encountered with that process and ideas for further improvements are discussed. Lessons learned from Spirit AeroSystems can further be utilized to help companies create better project selection processes.

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1 Introduction

1.1 Motivation

Research and development (R&D) is critically important to the prolonged success of any company. Successful R&D is the difference between leading a new wave of next-generation products and a slow decline into obscurity and bankruptcy. This should come as no surprise. In 2007, the one thousand public companies with the highest R&D expenditures spent a total of $492 Billion on R&D.[1] To put that number in context, that is approximately equivalent to the gross domestic product of Switzerland. [2]

Despite the vast sums of money being spent on R&D, there is no easy answer to the question of how a company should run its R&D organization. Ford spent more money on R&D than any other company from 2001 to 2005, despite that being a period when the company struggled with poor performance. Meanwhile, Toyota spent just two-thirds as much as Ford in 2001 as it established itself as an innovation leader in the automotive industry and stole away market share from Ford.[3] Despite passing Ford to become the top R&D spender in absolute numbers, Toyota still spends less as a percent of revenue (3.6% in 2007) than its rivals Ford (4.3%) and GM (4.5%).[1] (Note that these comparisons are not entirely fair, since it is at the company's discretion what counts as R&D spending.)

Numerous other examples exist of companies that far under-spend their competitors' R&D efforts while surpassing them in the output of those efforts. In fact, multiple studies have been conducted and discovered that no significant correlation exists between how much a company spends on R&D and how well that company performs[1] (see [1] and [3]). The key to effective R&D is not how much a firm spends, but how well the money is spent.

1.2 Problem Statement

Spirit AeroSystems is a world leader in the aerostructures industry. Spirit was created when Boeing sold its Wichita and Tulsa divisions to a private equity firm in 2005. Since becoming independent of Boeing, Spirit has sought to examine the ways in which its business is run and identify areas for improvement. One part of the business that Spirit has been working to improve over its four years of existence is the R&D organization.

[1] Based on primary measures of economic and firm success, such as profitability, growth, and shareholder return. There are other studies, however, that have shown R&D spending positively correlating with patents and share prices (at the firm level, see [32], [33], and [34]) and productivity (at a national level, see [35]).

As an independent supplier to Boeing and other manufacturers of aircraft, Spirit no longer has the visibility into the future product direction that it once had as a division of Boeing. This has created many new challenges. Spirit is seeking to improve their R&D processes given these new challenges. The first area that Spirit is addressing is finding a robust process to choose which R&D projects should be pursued and allocating budget to those projects accordingly.

1.3 Research Goals

This thesis is based on work conducted on-site at Spirit AeroSystems in Wichita, KS during an internship through MIT's Leaders for Global Operations program, from June through December 2009. The goal of the internship was to implement a new system by which Spirit could identify the R&D projects that it should fund in order to use its R&D budget as effectively as possible. This work required interacting with employees across almost every aspect of the company, within every business unit and representing many different job functions.

The author seeks not only to create a process to be used at Spirit, but based on the experiences had and lessons learned from implementing a project selection system at Spirit, the author also seeks to identify generally applicable guidelines for the most effective ways to allocate a company's R&D budget. While many of these ideas are appropriate for any company, the intent is to expand upon existing literature that is aimed at original equipment manufacturers (OEMs) by focusing on companies that act as suppliers to OEMs—that is, companies that do not make the ultimate decision about what form the final product will take, but instead have to act based on the decision of the OEM. These firms do, however, still have ultimate control over how they invest their R&D dollars.

The goal of this research is not to create a single process that will be successful when implemented at any firm. Instead, the goal is to create a set of guidelines that suppliers can utilize in developing a process that is unique and appropriate to their specific industry and situation.

1.4 Premise

There is no easy solution for how best to select a portfolio of R&D projects. Numerous alternatives are available for ways to score and judge which projects are the best. No one system is appropriate for every company. However, any firm which acts as a supplier should be able to more effectively spend their R&D dollars if they consider the following guidelines while creating their process.

- *Ensure that a strong link exists between R&D projects and corporate strategy (see § 3.4.1)*

- *Always listen to the voice of the customer (see §3.4.2 and 3.4.4.3)*
- *Create a continuous process that allows for projects to be started or ended at any time (see §3.4.4.1)*
- *Cross-train employees to allow for greater flexibility in which projects are pursued (see §3.4.4.2)*
- *When it is entirely unclear which technology will best serve future customer needs, hedge by pursuing both technologies until the customer's direction becomes clear (see §3.4.3)*
- *Do not be afraid to pursue some breakthrough technologies that, if successful, will drive the direction of the OEMs product (see §3.4.5)*

1.5 Outline of Thesis

This thesis seeks to provide the reader with a firm understanding of the challenges and best practices of R&D portfolio management and project selection, with a specific emphasis on supplier firms. It will also propose a new method for allocating a firm's R&D budget. Chapter 2 gives a background of established best practices to make R&D organizations within a company more effective. This discussion is based primarily on published research in the field, focused on OEMs. Chapter 3 introduces the challenges of performing R&D for companies that act as suppliers to OEMs. It then introduces a set of guidelines that supplier firms should consider as they create their own process for R&D project selection. Chapter 4 is a case study based on work performed at Spirit AeroSystems. The chapter begins with an introduction to Spirit and a look at its current R&D processes. An overview follows of work performed in an attempt to implement a new project selection process at Spirit based on the guidelines presented in Chapter 3. The discussion includes a look at the process as conceptualized, challenges associated with implementing this process, and recommendations for future improvements to be made at Spirit. Finally, Chapter 5 concludes the thesis by discussing opportunities for further research along with some closing remarks.

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2 Portfolio Management Best Practices

2.1 Introduction

A significant amount of literature exists on the topic of R&D portfolio management and best practices for project selection. This section gives a brief overview of some of the established best practices in the field.

2.2 Creating a Technology Roadmap

More and more firms are creating roadmaps to show the future direction of technology in their industry. Robert Galvin, the former chairman of Motorola, who was an early adopter of technology roadmaps, defines these roadmaps as "an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in the field."[4] Roadmaps typically contain a timeline of items such as markets, products, technologies, and R&D projects along with the link between those items (see Figure 1).

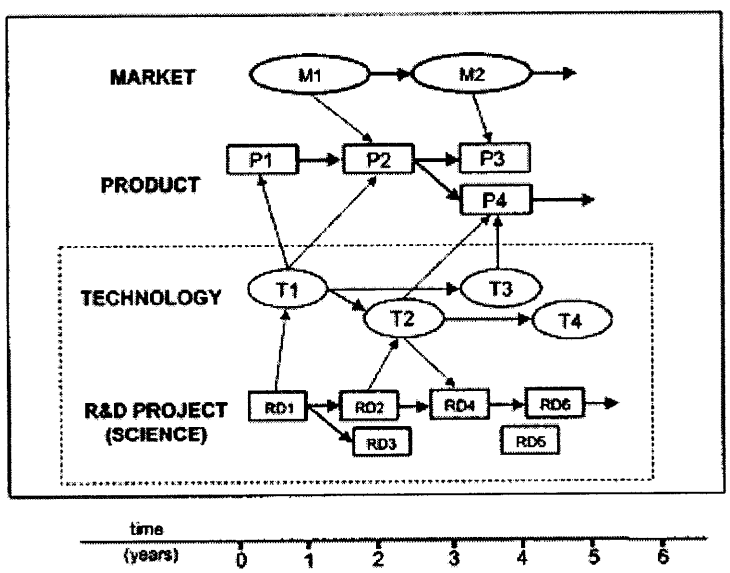


Figure 1 - Generic example of a technology roadmap [5]

Roadmaps are beneficial to an organization in a variety of ways. A summarized list of these benefits includes: [5]

- Developing a consensus amongst decision makers about what the firm's technology needs are
- Providing a mechanism to forecast technology developments

- Creating a framework to help plan and coordinate technology development cross-functionally and across multiple levels
- Aiding in the technology transfer process
- Creating an agenda for what technology to pursue at what time
- Ensuring a set of mutually supporting and synergistic activities

A significant amount of literature exists concerning various types of roadmaps and how to create these. Kostoff and Schaller consolidated the techniques into two general approaches: expert-based and computer-based.[5] Computer-based approaches use computational methods to comb through databases of papers, reports, letters, and emails to identify node and link attributes and create a network based on those attributes. Expert-based approaches typically involve a team of experts, potentially representing various technology working groups, conducting workshops in which they brainstorm ideas and come to a consensus on how those ideas can be represented as a roadmap.[4][5]

2.3 Key Objectives of R&D

Once a firm has established its technology roadmap, it still must choose which products to pursue and then manage that portfolio of products. Dr. Robert Cooper is renowned for his expertise in portfolio management. This section borrows heavily from his book, *Portfolio Management for New Products* [6], and a working paper of the same name ([7], available at http://www.prod-dev.com), to introduce the key objectives of performing R&D.

Cooper writes that there are four key goals in portfolio management:

- *Maximize portfolio value*
- *Ensure the portfolio is properly balanced*
- *Align the portfolio with corporate strategy*
- *Choose the proper number of projects within the portfolio*

2.3.1 Maximize Value

Maximizing the value of a portfolio is a rather simple concept in theory. However, it is much more difficult in practice. The idea is that projects should be selected which have the largest potential commercial worth. There are several tools that can be used to assess the value of projects.

Net Present Value (NPV)

Projects can be ranked by a simple net present value calculation. In the case of R&D projects that generate new products, this calculation should include expected revenue and costs of the new product. For projects that result in process improvements, calculations would include items such as investments, labor reductions, and material savings. These NPV calculations should be risk-adjusted to ensure a fair comparison of projects. While NPV calculations are an excellent way to value projects, they are difficult to use in practice, as many of the values needed for a proper NPV calculation are unknown in R&D projects.

Scoring Models

With a scoring model, decision makers rate each project using a set of criteria appropriate for their firm and industry. Projects can be distinguished across each criterion on a scale of 1-5 or 1-10. The various criteria can be weighted according to their importance, and then a weighted sum of the scores provides the total value for each project. A scoring model allows decision makers not only to include purely financial measurements, such as NPV, but also criteria such as strategic fit and synergies with current products. See §4.3.2.2 for an example scoring model as implemented at Spirit AeroSystems.

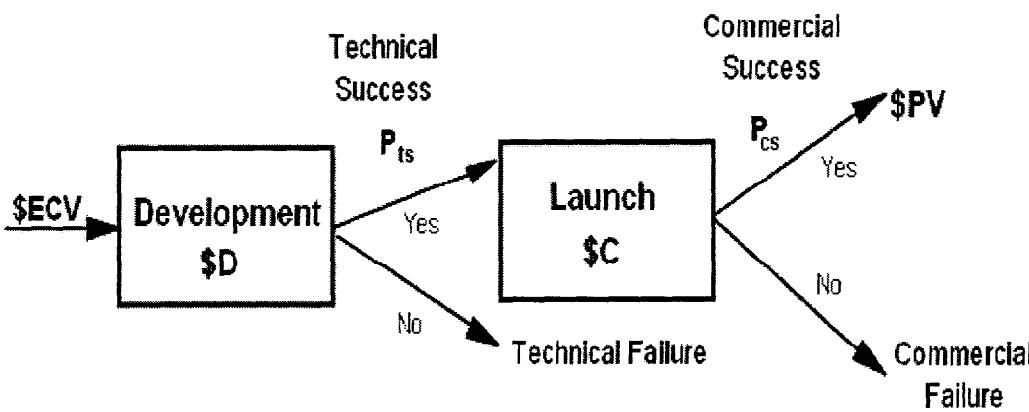
2.3.1.1 Real Options and Decision Trees

A more sophisticated method which can be used to determine the financial value of a project is known as real options theory. This theory is based on options as used in financial markets. However, options within R&D are significantly more difficult to evaluate due to the lack of information known about the R&D project.

Real options theory allows significantly more flexibility in managerial decisions. Instead of accounting for all of the costs which may be included in a project through development and implementation as is done with a simple NPV calculation, real options theory allows a manager to value a project based on the costs of developing to a certain point and then having the option to spend additional money on implementation. Real options theory gives credit for early project work which serves to provide information about future losses or benefits of a project.[8] Early project work can be thought of as a payment, or an option. Exiting the project at various points further on would be the equivalent of exercising the option.

The simplest view of real options theory is that at each stage of a project there are two options—continue the project or abandon it. In reality, there are essentially an infinite number of choices and an unlimited series of stages. As the number of choices increases, the mathematics becomes increasingly complicated. As a result, as elegant a theory as real options appears, it is not widely used in practice.[9] However, many researchers have proposed models for actually implementing real options theory (see [10] and [11]).

One of the simplest approximations of real options theory is discussed by Cooper. This is a basic decision-tree analysis which he calls Expected Commercial Value (ECV). Each decision stage has two outcomes along with a probability for those outcomes until the final stage is reached, which includes potential rewards. Figure 2 shows a simple ECV calculation.



$$ECV = [(PV * P_{cs} - C) * P_{ts} - D]$$

$ECV = Expected Commercial Value of the project

P_{ts} = Probability of Technical Success

P_{cs} = Probability of Commercial Success (given technical success)

$D = Development Costs remaining in the project

$C = Commercialization (Launch) Costs

$PV = Present Value of project's future earnings (discounted to today)

Figure 2 - Expected Commercial Value of a Project (borrowed from [7])

In addition to calculating the overall ECV, a decision tree is also a useful tool to determine different potential outcomes. The three outcomes possible in the simple decision tree shown in Figure 2 are as follows:

1. With probability $(1 - P_{ts})$, loss equals D

2. With probability $P_{ts}(1 - P_{cs})$, loss equals D + C
3. With probability $P_{ts}P_{cs}$, payoff is PV

2.3.2 Balance the Portfolio

Cooper's second key objective of portfolio management is achieving a balanced portfolio of projects. This balance applies to any number of criteria—target market, long term versus short term, high risk versus low risk, project type, technology, etc. The actual criteria that are necessary to balance are specific to the firm and industry. To achieve a proper balance, several graphical tools are typically used. These images are not decision tools, but are instead a convenient way to display the information and help to make informed decisions.

The first common tool is the bubble diagram. With this tool, a bubble is plotted on a chart with the two axes corresponding to two characteristics of the project. Common types of bubble diagrams are risk/reward, ease/attractiveness, and importance/ease. The size of the bubble also corresponds to a characteristic of the project, typically the budget needed to pursue that project. More sophisticated bubble diagrams use colors and patterns for the bubbles to code even more information into the diagram, such as project type or target market. Bubble diagrams can utilize some of the project valuation techniques discussed above to help display relevant information. For example, various criteria used in a scoring model can be displayed on the two axes of a chart.

Figure 3 shows a simple risk/reward bubble diagram. In this chart, the x-axis refers to the probability of success, or risk, of the project while the y-axis shows the net present value, or reward. The size of the bubbles displays the estimated development cost. From this chart, it is easy to see that the projects in the top right quadrant should definitely be pursued, since they correspond to low risk and high reward. In contrast, the projects in the lower left quadrant should not be pursued since they are high risk and low reward. The projects in the upper left and lower right quadrants are a little less clear, although it is easy to see how this type of chart can help achieve a balanced portfolio. (See Figure 21 for a bubble diagram of Spirit's 2010 R&D portfolio.)

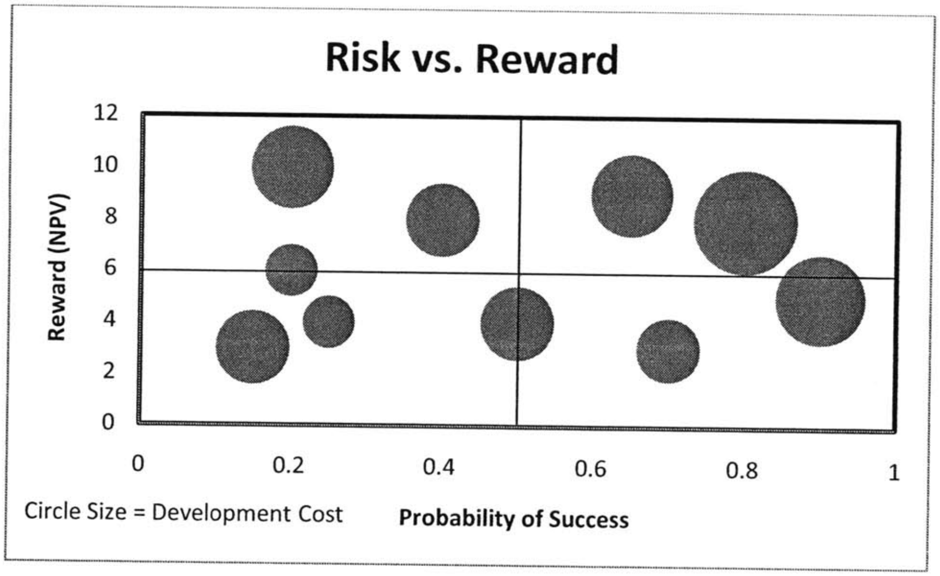


Figure 3 - Sample Risk vs. Reward Bubble Diagram

Another simple type of chart used to achieve a balanced portfolio is a simple pie chart. Pie charts can show a breakdown of projects across any number of criteria—market segment, project type, duration, product line, technology, etc. Figure 4 shows an example of a pie chart which displays the breakdown of a portfolio by project type. Decision makers can easily look at this chart to determine if the amount of spending on breakthrough technologies and each of the other project types is consistent with the strategic goals of the firm.

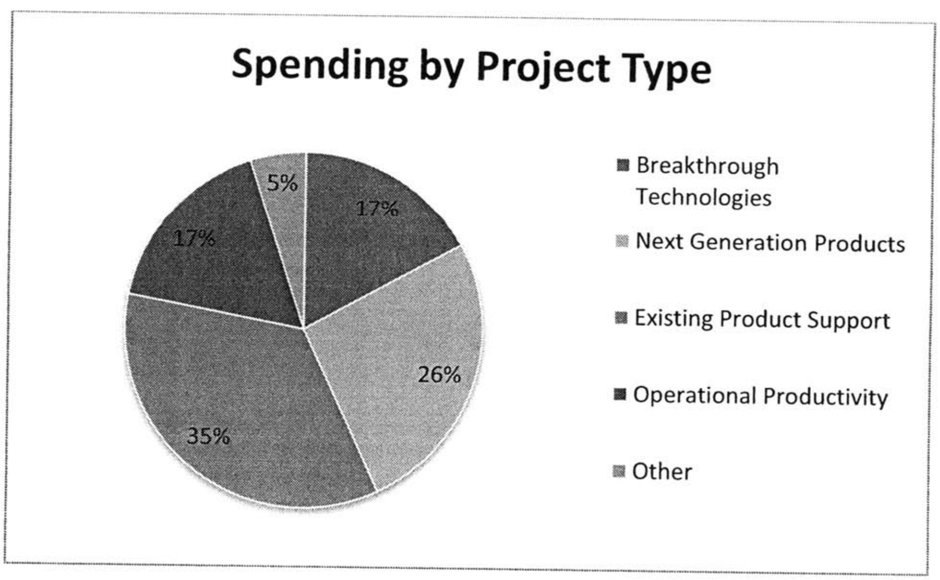


Figure 4 - Sample Pie Chart Showing Spending by Project Type

2.3.3 Strategic Alignment

Linking the portfolio to corporate strategy is an important factor of portfolio management. There are two main parts of this goal. The first is ensuring that each project is a strategic fit with the goals of the company. The second is choosing a complete portfolio of projects that not only fit the firm's strategy, but also reflect the strategic priorities. There are also two approaches to achieving strategic alignment of the portfolio—top-down or bottom-up.

The easiest way to accomplish a top-down approach is through strategic bucketing. With this approach, budget is set aside in buckets that align with strategic goals of the firm. For example, if a firm's strategic priorities involve moving into new market segments, then it might make sense to use buckets that correspond to the market segment targeted by each project. If a firm has a strategy to introduce breakthrough products into an existing market, then choosing buckets based on project type (as seen in Figure 4) makes more sense. Once budget has been assigned to buckets, projects are put into the appropriate buckets and are no longer compared against projects outside of their bucket.

The disadvantage of using strategic buckets is that a project which might have a higher NPV or a higher score in a scoring model might not be selected while a lower scoring project is selected, depending on the other projects in each bucket. On the plus side, scoring models tend not to select advanced technology projects due to their long-term payoffs and high risk, so strategic buckets are a way to ensure that type of project is pursued.[12]

In a bottom-up approach, strategy is built into the project selection tool. For example, when a scoring model is being used as the main project selection tool, one of the criteria can be how good of a strategic fit the project is. This type of approach works well for identifying whether or not a project is a strategic fit, but does not ensure that projects are appropriately allocated per the firm's strategic priorities.

Some of the problems associated with either a top-down or a bottom-up approach can be mitigated by creating a hybrid approach to strategic alignment. There are many different forms that a hybrid model could take. One hybrid model would be to create strategic buckets, as in the top-down approach, but instead of rigidly enforcing the buckets, instead assign target spending levels to each bucket. The bottom-up approach can then be used to compare all projects against each other regardless of which bucket they may have fallen into. Once the projects have been selected via the bottom-up approach, a review of how close the portfolio comes to matching the target spending levels can be performed. If necessary, funding can be moved around to meet target spending levels. This can result in lower scoring projects being funded, however it ensures that there is visibility into the relative scores of the projects. If a lower scoring project is funded, it is due to an active decision being made that the strategic priorities outweigh the scoring difference.

2.3.4 Proper Number of Projects

Choosing a portfolio of too many projects can result in a type of gridlock where none of the projects can move forward as employees struggle with switching between multiple projects and being unsure about the priority of each project. Pressure to dislodge the gridlock and move things forward can often result in taking shortcuts that may have an adverse affect on the outcomes of the projects. To avoid this situation, resource limits need to be in place from the start. Resources such as budget, number of employees, employee skill-set, facilities, and capital expenditures should all be considered. When using a scoring model to rank projects from best to worst, a line should be drawn and no further projects pursued once these resource limitations have been reached.

A more rigorous resource capacity analysis can be performed to deal with multiple resource constraints. In this type of analysis projects need to be listed out in a prioritized list with all resource needs identified. Adding up all the resources necessary can identify where the resource bottlenecks will be and which projects may need to be cut from the list. This type of analysis can also be useful in identifying any new talent acquisition that is necessary.

2.4 Project Selection Scoring Tools

A wealth of literature exists describing various ways that R&D projects can be ranked and prioritized. These methods typically fall into one of the following categories: [13][14]

- Unstructured peer review
- Scoring model (see §2.3.1)
- Mathematical programming, such as integer programming (IP) and linear programming (LP)
- Economic models, such as net present value (NPV) and internal rate of return (IRR) (see §2.3.1)
- Decision analysis, such as the analytic hierarchy process (AHP)

Henrickson and Traynor present an overview of R&D project selection literature with a brief description of each proposed technique [13]. Bitman and Sharif go a step further in selecting eight articles representing well-formulated ranking systems. They then break each system down into the following dimensions: perspectives, criteria, structure, model, and tools. [14]

Most project selection tools begin with criteria on which each project can be judged. These criteria can be optimized to identify the needs of the firm in which the prioritization is taking place. Generically speaking, some examples of these criteria are: relevance, attractiveness, risk, competitiveness, reasonableness, innovativeness, and return.[13][14] While it may be attractive to emphasize financial measures in these criteria, studies have shown that firms who avoid that temptation perform better over time.[14]

Once the criteria have been identified, two things must happen. First, each project must be evaluated against these criteria. The simplest way to do this evaluation is to create a project evaluation form, or scorecard. This scorecard should give explicit guidelines to the evaluators what various scores for each criterion represent. Peer or manager review of the scores should be performed to ensure fair and accurate scoring. Second, the relative importance of the various criteria must be determined. A pairwise comparison can be performed to assign weights to each criterion.[14]

Finally, after the scores and weightings have been determined, an algorithm must be generated to obtain a final score for each project. This algorithm will likely need to be customized to match the interests and needs of the firm. A weighted sum may work for some firms. However, there are limitations with purely additive algorithms when dealing with tradable criteria. Some studies suggest that tradable criteria should be added together while criteria that act independently should be multiplied. [13]

These frameworks are useful tools in creating a prioritized list of R&D projects. However, it should be recognized that they are only tools and have limitations. Project scoring tools should not replace all other activities in a firm's project ranking activity, but instead merely function as one aspect of a comprehensive process. [14] Indeed, despite a significant increase in the body of work describing various forms of project scoring tools, there has not been a significant increase in the adoption and use of these techniques. [15] This should serve as further evidence to maintain an appropriate level of human oversight when using project scoring tools as part of a project selection process.

2.5 Types of R&D Spending

The phrase "research and development" can mean many different things to different companies. Some typical types of R&D spending include:

- Breakthrough innovation
- Next generation products

- Existing product support
- Operational productivity improvements

Determining how best to allocate R&D budget across these categories is an essential, yet difficult decision for companies to make. Baumol finds that while the vast majority of R&D spending comes from a small number of very large companies, most revolutionary breakthroughs come from small entrepreneurial firms. The larger companies tend to be more successful with incremental innovation (e.g. Intel and their ever improving processors).[16] This suggests that larger firms, the ones who are likely to be making these R&D spending decisions, should focus on improving their existing products. On the other hand, the Research and Technology Executive Council conducted a recent study of its member companies and concluded that firms with above average spend in breakthrough innovation (not necessarily above average spend in their overall R&D budget, rather a higher proportion of spend on breakthrough innovation) had a 3% operating margin advantage over firms with below average spend.[17]

Ultimately, there is no breakdown of spending that will work for all firms. In their *Global Innovation 1000* study of the 1000 public companies with the highest R&D spending, Booz Allen Hamilton concludes that there is no "best innovation strategy." Instead, they find that the best innovation strategy for a given company is the one which best matches the firm's overall corporate strategy.[18] Firms must decide for themselves which breakdown of R&D spending is best for them. However, the varying academic opinions suggest that they should carefully consider how things like breakthrough innovation might ultimately benefit them despite not maximizing short term profits.

2.6 Project Execution Methods

Along with techniques for choosing the right portfolio of projects, a large body of literature exists which discusses techniques for properly executing on these projects. The following is a brief overview of some of these techniques.

2.6.1 Staged Product Development

Funding a project does not necessarily mean that money should be poured into it until its budget has been exhausted. Instead, a firm can put processes in place to ensure that the project is on track and is spending money in a constructive fashion. One method of doing this is creating milestones, or gates, at which the project will be reviewed to determine if it should continue to be funded. Cooper proposes that this gating process is a key driver of the portfolio management process. [6]

Staged product development is a framework for moving development projects from concept to launch (see Figure 5 for Cooper's trademarked approach to this). It consists of a series of stages, in which work is performed, followed by gates, at which the go/kill decisions are made. During each stage, work is performed and information is gathered cross-functionally to reduce key uncertainties and risks. Typically, costs increase as progress is made through the stages. The gates consist of a set of deliverables and criteria against which those deliverables are judged. Based on how well the project is performing, the output of each gate is a decision on whether to move the project to the next stage, kill the project completely, hold the project in its current stage, or recycle the project to be pursued at a later time. [19]

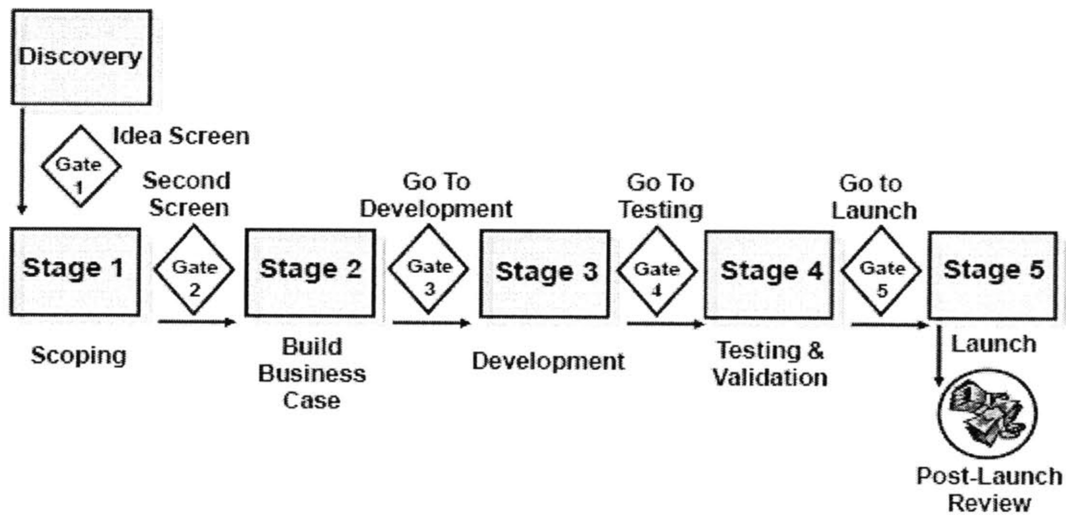


Figure 5 - An overview of a typical State-Gate process (borrowed from [19])

2.6.2 R&D Metrics

Knowing whether or not a particular R&D project, individuals within the R&D group, or the R&D organization as a whole is performing well requires defining metrics by which R&D effectiveness can be measured. Identifying what these metrics should be is not as straight-forward as identifying metrics in other areas, such as manufacturing. Various companies have identified hundreds of different metrics that are tracked within the R&D group. Some common metrics that firms use to measure R&D performance are percentage of sales from new products, total patents awarded, return on R&D expenditure, and new product success rate. Some commonly used metrics, such as deviation from schedule and variance from budget, are really more of a measure of the manager's prediction skills than of R&D effectiveness.[20]

Hauser proposes a three-tiered approach to measuring R&D effectiveness (see Figure 6). Tier 3 projects, which consist of applied engineering projects aimed at specific opportunities within the business units, are relatively easy to measure since they have clearly defined benefits. The bigger challenge is selecting the right projects, which should be based on project cost, benefits, and probability of success. Tier 2 projects, which are more developmental in nature and focused on creating core technological competencies, should focus on matching expertise with strategic direction. Both market-outcome metrics and effort-indicator metrics are commonly used on tier 2 projects. However, metrics indicating development effort should be weighed more heavily than metrics measuring market outcomes. Finally, tier 1 projects are focused on basic research. Metrics for tier 1 projects need to encourage staff to explore a broad range of ideas and technologies, suitably dubbed "research tourism." This suggests that metrics should be in place to reward researchers not only for creating and acting on new ideas, but also for identifying and working with useful ideas from outside the firm. [21]

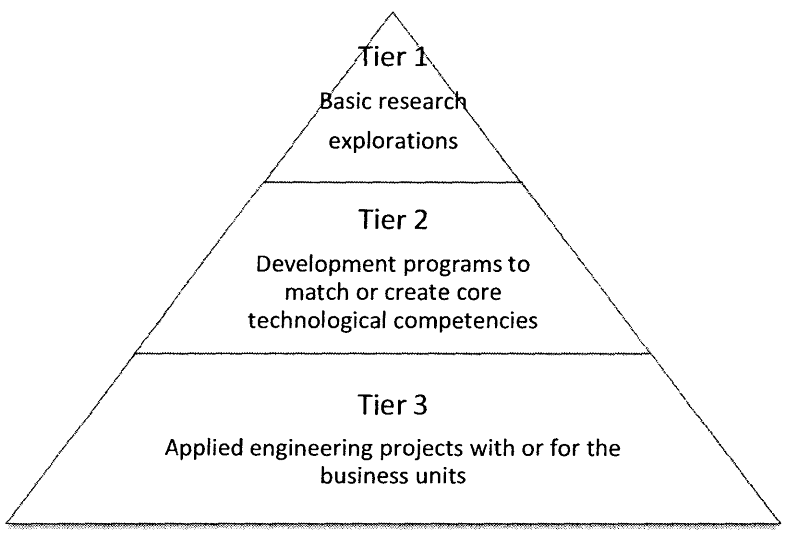


Figure 6 - Three tiers of R&D [21]

The three-tiered system leads to some common problems. Since tier 3 projects lend themselves to being funded directly by business units, projects which are short term, risk averse, and narrow in scope tend to be favored. Hauser proposes a system in which the projects receive corporate subsidies based on short-termism, risk-aversion, and concentration. Tier 1 projects focused on basic research can easily cause a firm to spend excessive resources on internal ideas. Metrics need to be carefully selected to ensure that adequate resources are dedicated to exploring external ideas.[22]

An analogous view of Hauser's three tiers is looking at R&D as three basic phases as shown in Figure 7, with tier 1 representing Basic Research, tier 2 representing Technology Development, and tier 3 representing Product Development. The metrics described by Hauser are still appropriate when considering the three-phase view.

Figure 7 - Three phases of R&D

2.7 Summary

This chapter provided an overview of various techniques and best practices for executing R&D as available in published literature. Technology roadmapping has been shown to be a very effective tool for R&D organizations and techniques for creating these roadmaps were introduced. Dr. Robert Coopers's keys to effective portfolio management—maximize value, balanced portfolio, strategic alignment, and choosing the right number of projects—were introduced and discussed. Most R&D organizations use some type of scoring project selection scoring tool. Various types of tools were presented and a generic scoring method was detailed out. Finally, other techniques that are useful for running R&D projects once the portfolio has been selected were introduced—specifically a gating method to ensure projects are progressing smoothly and a system for creating R&D effectiveness metrics.

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3 Portfolio Management for Suppliers

3.1 Overview

As discussed above, a large body of literature exists to offer suggestions for ways in which a firm should select its R&D projects and manage its R&D portfolio. The majority of this literature is aimed at original equipment manufacturers (OEMs). The literature looks at R&D as the first step of a product development process that ultimately results in a product being introduced to market. The firms at which the literature is targeted have complete discretion on what form their product takes and when and if they move forward with the product.

Firms that act as suppliers for OEMs are faced with additional challenges since they do not have as much visibility into the product's end customer and are often at the mercy of decisions made at the OEM level. This chapter will look at the goals of R&D from the supplier perspective, followed by a detailed look at the key challenges associated with supplier R&D. It will then offer a series of suggestions that suppliers should consider as they create their R&D project selection process.

3.2 Goals

There are three basic goals of performing R&D at the supplier level:

- Cut costs
- Win new business
- Execute on commitments

The first goal, cutting costs, is shared by suppliers and OEMs. Any firm will have a portion of their R&D expenditures focused on performing better on their current business. This includes things that directly translate to cost savings, such as reducing labor and cutting material costs, as well as other improvements to current business, such as quality, safety, and manufacturing productivity. These projects typically fall within Hauser's third tier. This goal could also be labeled as improving sustaining business, however the key goal for any firm engaged in these types of R&D activities is lowering their costs. Examples of this type of R&D are conducting research into new types of machine tools that can cut more quickly or developing automation equipment to remove a bottleneck in the manufacturing process.

The second goal is specific to suppliers. While OEMs are trying to create products that they can sell and bring in new revenue, the supplier version of this goal is different. In a supplier R&D organization, technology is created in the hopes that it will be useful to a future OEM product and ultimately increase the likelihood of winning a bid to contribute to that product. These projects are primarily within Hauser's first and second tiers. In the aerostructures industry, developing new composite materials that would work for future composite aircraft designs would be an example of this type of project. The next section will examine the unique challenges in doing this type of R&D work.

A third type of R&D work also exists, common to all firms, to execute on commitments. This could either be some type of regulatory commitment, such as finding alternative chemical treatments to allow removal of a banned chemical, or program commitments that require developing new technology to execute on business that the firm has committed to delivering.

3.3 Key Challenges

The expected value of performing R&D work for an OEM is the value of that work if successful multiplied by the probability of success:

$$E(R\&D) = Payoff * P(success)$$

where

$$Payoff = Value\ of\ successful\ R\&D\ effort$$
$$P(success) = Probability\ of\ R\&D\ effort\ being\ successful$$

(Note that the value of a successful R&D effort is not always obvious, however for this exercise we will assume it can be determined.)

On the other hand, suppliers not only have to deal with the uncertainty of their R&D work being successful, but the uncertainty of not having control over the final product being released. This uncertainty comes in two parts—working on technology that is ultimately incorporated by the OEM into their product, and winning the contract to supply components for that OEM's product.

$$E(R\&D) = Payoff * P(success) * P(technology\_adopted\ ) * P(contract\_win)$$

where

$$P(technology\_adopted) = Probability\ that\ the\ OEM\ adopts\ the\ technology\ in\ question$$
$$P(contract\_win) = Probability\ that\ the\ supplier\ is\ awarded\ a\ contract\ to\ supply\ components$$

By definition, $P(technology\_adopted)$ and $P(contract\_win)$ must be less than one. The expected value of performing R&D is therefore at best equal and most likely less for suppliers than it is for OEMs. Suppliers have to deal with the added complexity of determining what R&D to pursue along with the knowledge that the expected value of their efforts can be, at best, equal to similar efforts being pursued by an OEM.

In order for it to make sense for a supplier to perform R&D and attempt to gain a competitive advantage over their competitors, they need $P(technology\_adopted)$ and $P(contract\_win)$ to be as close to one as possible, minimizing the R&D disadvantage that suppliers face compared to OEMs. The following section discusses techniques for accomplishing that.

3.4 Proposed Techniques

The techniques discussed in this section are intended to help a supplier choose a portfolio of R&D projects that uses its budget as efficiently as possible. These techniques can be implemented into the supplier's R&D project selection process, which will be unique to every company due to the complexities of running an R&D organization. Effective R&D at the supplier level can not only help to win business over a firm's competitors, it can also help a company form strategic partnerships with its OEM customers that will ensure winning business in the future.

Note that while these techniques are primarily aimed at suppliers, many of them could be useful for OEMs as well. However, given that most supplier firms tend not to be lead innovators, many of these techniques correspond to a conservative innovation strategy. Before implementing any of these techniques, effort should be made to establish the firm's innovation strategy and ensure that the techniques are in line with that strategy.

3.4.1 Strategic Focus

As discussed in §2.3, strategic alignment is one of the top priorities for any company's R&D portfolio management. However, with the additional uncertainties faced by supplier's R&D organizations, it becomes even more critical to ensure that every dollar spent on R&D is being spent wisely. The R&D group should lead the company in the direction it is going, not wander off in other directions that do not match the company's priorities. The worst case situation would be the R&D group investing money on a new technology while the company has no plans to bid on new projects that might utilize that technology.

Instead, every R&D project that is pursued should clearly map back to one of the firm's key strategic priorities. This can be ensured by using the framework shown in Figure 8 to identify technological gaps that need to be filled in order to execute on the firm's strategic priorities. As is shown in the figure, the highest level strategic priorities of the firm should drive key initiatives and ultimately the needs of the firm. Once these needs have been identified, R&D personnel can help to determine the manner in which technology can be used to help meet those needs. Comparing those required technologies against the firm's existing technology highlights technology gaps. These gaps should then drive which R&D projects are pursued.

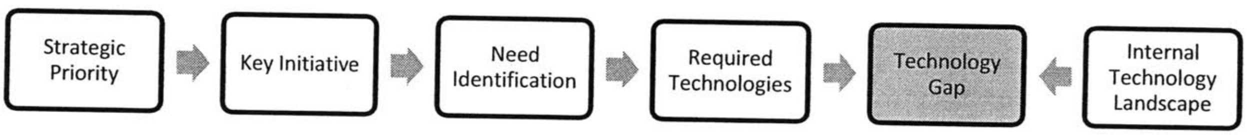

Figure 8 – Framework for flowing strategic priorities down to identify technology gaps

Along with driving R&D decisions, this framework can be expanded to create a firm's entire technology strategy. Technology gaps that are strategically important can be filled by executing internal R&D or pursuing alliances and partnerships. Less important gaps can be filled by purchasing the technology from other firms. Figure 9 shows an expanded version of Figure 8, developed in collaboration with Leaders for Global Operations fellow Michael Tajima during his internship at Spirit Europe, which describes how the technology gap leads to a make/buy decision for the firm to fill its technology gaps through means other than R&D.

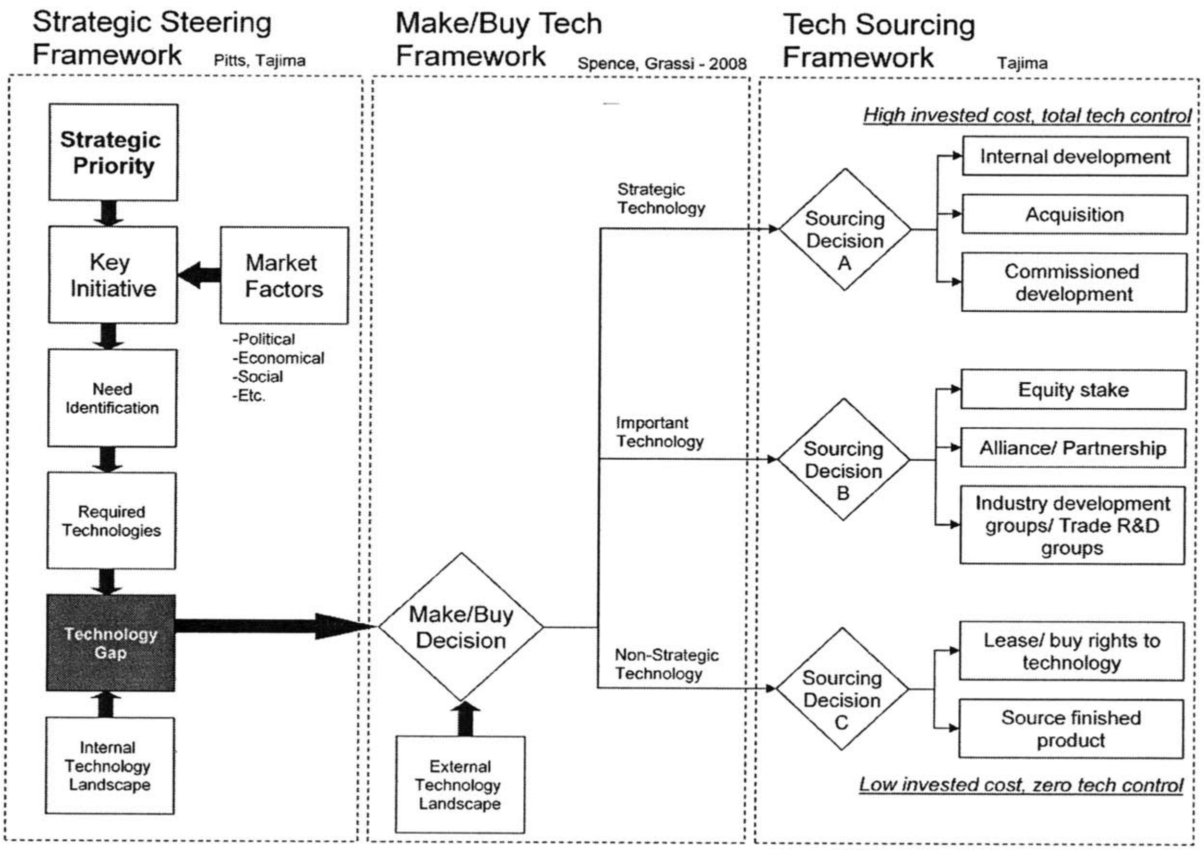

Figure 9 - Expanded strategic steering framework

3.4.2 Market Intelligence

Focusing on delivering products that the customer wants is a key to any firm's success. According to a study by Booz Allen Hamilton, customer focus is one of two keys to effective R&D (along with strategic alignment), much more important than the amount of money being spent on R&D.[18] Knowing what the customer wants is complicated for a supplier. A supplier must not only work with OEMs to deliver components that the OEM needs, but also anticipate those needs. In order to do this, a supplier's market intelligence efforts should not stop at their direct customers, but should also extend both to the product's end customer and to its competitors.

3.4.2.1 Direct Customers (OEMs)

Working with a direct customer is the easiest form of market intelligence. Because of the large number of interactions that occur between a supplier and its OEM customer, this market intelligence comes fairly easily. Suppliers need to take advantage of all of these interactions by working with their own employees to capture these informal conversations. For example, supplier and OEM engineers often work together when developing components for a new product. During these conversations, the supplier's engineering staff may pick up on some hints about the direction that the OEM is moving for their future products and product enhancements. All of this knowledge should be captured and documented so that the efforts of R&D are better informed.

Suppliers should also work to form partnerships with their customers. Establishing a company as a key contributor to several or all of an OEM's products and working to ensure those products are successful will help to move the firm from simply a supplier to a partner. That partnership will ensure that the firm is one which the OEM thinks of first when looking to source components in future products.

3.4.2.2 End Customers

A supplier should not be content with waiting to hear from OEMs what their future products will be. Instead, they should anticipate the direction of the industry and work to develop technology in advance to support that direction. Having technology in place when an OEM comes looking for suppliers will give a firm a huge advantage over its competitors.

In order to anticipate the direction of the industry, suppliers need to reach past their direct customers and speak with the end customer of the product. For example, in the aerostructures industry, the providers of aerostructures need to look past the aircraft OEMs and also look to the airlines that are ultimately buying and operating the aircraft and even to the individuals who are flying on those planes.

Gaining access to the end customer is not always easy. One approach to doing this would be conducting market research similar to what an OEM might do. This would involve approaching customers directly and asking the customer questions about their needs and expectations of future products. Another approach would be to leverage any existing communication that occurs between the firm and end customer. Aerostructures companies sometimes interact with airlines to provide spare parts and perform maintenance and repair work. During these interactions, the aerostructures company can try to learn more about what features the airlines are looking for in future aircraft. That knowledge can be used to direct R&D work towards developing technology that can be sold to OEMs and allow those OEMs to offer features that the end customer desires.

3.4.2.3 Competitors

A key component of market intelligence is being able to build a comprehensive landscape of the state of technology in a given industry. This landscape should include work being done by the firm in question along with technology being developed by the OEM customers of the firm. The landscape should also include other technology being developed, whether by university and government research agencies or at other firms in the industry.

This clear technology landscape allows the firm's R&D leaders and other executives to create a better and more comprehensive technology roadmap. When planning the direction of a firm's future research efforts, knowing the state of technology outside of the firm is incredibly useful. For instance, a technology that a competitor has a clear advantage in might not be worth pursuing at all. On the other hand, knowing that several competitors are all working on the early stages of similar technology is likely a good indicator that this is something a firm should pursue as well if it hopes to win future business in that area.

Once this technology landscape is known and a roadmap has been created, the decisions about which R&D projects to pursue are much better informed. These targeted and well-directed R&D efforts allow a supplier to spend its R&D dollars more effectively and not waste money on attempting to duplicate a technology that a competitor has a large advantage in creating or that another firm or researcher has already developed and is willing to license.

Building this technology landscape and learning about the research efforts of competitors is a very difficult thing to do. As with OEM market intelligence, much of this intelligence will have to come from informal interactions between the firms, not necessarily from the personnel tasked with market intelligence. Researchers at a firm who attend conferences and learn about technological advances must document and share those learnings. Supply chain personnel who learn from vendors about purchases made by their competitors must share that information. If all of these types of informal learnings are captured within a firm, market intelligence personnel can work to piece together some information and create a picture of the technology efforts of the firm's competitors.

3.4.3 Hedging

In some situations, it simply cannot be determined what technology an OEM's future products will utilize. In these cases, the supplier may to have hedge against the possibility of pursuing the wrong technology and pursue multiple technologies to some level. This is clearly not an efficient use of funds compared to only investing in the winning technology. However, in certain situations, it must be done to avoid the possibility of missing out on an entire generation of products. In practice, the winning technology is rarely known for sure in advance, so some level of hedging may often be necessary.

A current example of this in the aerostructures industry relates to the choice of materials for the next generation of single aisle aircraft. Several major aircraft manufacturers have released larger, twin aisle aircraft that have switched away from the traditional aluminum aircraft exterior to a composite material. At this time, it is unclear whether the composite material will also be a better choice for future single aisle aircraft, or if those aircraft will still be built of aluminum (or some combination of the two). Since nobody in the industry has an answer to this question yet, aerostructures suppliers are left without guidance on whether to pursue technologies related to metals or composites. In this situation, both types of technologies should be pursued in a limited fashion until it becomes clear which material aircraft OEMs will choose. Choosing the wrong material would likely result in not winning any business on the next generation of single aisle aircraft, which could be a catastrophic event for the firm.

3.4.4 Lean R&D

The principles of lean manufacturing have been successfully implemented across enough companies and industries that these principles are now a well accepted way to run a manufacturing line. With as much success as these concepts have had in improving manufacturing productivity, it is natural to wonder if they can also be applied to R&D organizations. Not only are the lean concepts proven to be effective, they are also known and accepted by many executives and thus could ease the difficulty of driving change when implementing them within R&D.

When considering how to implement lean principles within R&D, it is important to keep in mind the inherent differences between manufacturing and R&D. While lean attempts to eliminate all variability in manufacturing, R&D is by its very nature variable and thus reducing all variability would eliminate the value in doing R&D at all (although there is certainly bad variability that could be eliminated).[23]

The sections below describe ways that concepts from lean can be implemented within R&D, specifically to improve the project selection and portfolio management of the R&D organization. (For more concepts on how to apply lean to R&D in general, see [23].)

3.4.4.1 Continuous Process

As with a manufacturing environment, within R&D it also makes sense to move to smaller and smaller batch sizes and create a continuous process. Unfortunately, it is not immediately obvious what a "batch" is in the R&D world.

One type of R&D batch is the process by which new projects are funded. Some organizations run their project selection and funding process as an annual process to align with the firm's budget cycle. While this method may be convenient in terms of budget decisions, it is not conducive to effective R&D. This type of process causes several problems. First, it often misses issues or needs that arise mid-year since many companies operate in a fire-fighting mode and tend to only address the hottest issues at the time of the project selection process. Second, awarding projects a budget on an annual cycle can result in those projects being worked for a full year regardless of whether the project is still progressing and is the most deserving project to be funded. Third, and likely most common, many projects take longer than a year and are disrupted by having to reapply for funding every year. Instead, firms should move to a more continuous process where technology needs within the company are constantly being captured and the project portfolio is frequently evaluated to ensure the best mix of projects are being worked. This type of process requires additional work on the part of the R&D management to make a constantly evolving portfolio of projects fit into an annual budget, but the increased effectiveness of the portfolio should be well worth it.

Another way to consider batches within an R&D environment is to think of R&D's product as information.[23] R&D processes should be set up to get frequent and small batches of information. One way to do this is to conduct smaller and quicker experiments into multiple different solutions instead of going deep into solutions one at a time. Since perfect planning is simply not possible in R&D, conducting smaller experiments and getting smaller batches of information will help to reduce risk until a promising solution can be identified.

3.4.4.2 Employee Rotation and Cross-Training

Cross-training employees to allow for them to be moved between different roles is a common practice in manufacturing. This practice creates a more fluid workforce that can adapt to changing demand. It also increases worker productivity by keeping workers from getting bored from performing the same task day after day over years or decades.

Cross-training and rotating employees within R&D is considerably more challenging. Many of the skills required of R&D personnel take specialized education and years of on the job training to be thoroughly developed. However, with a little creativity by management and willingness to pick up new skills by employees, rotations can be created that still utilize the employees' skills. For example, an employee with mechanical design expertise who has been designing test stations could be rotated to design structures for new products. Coming up with effective rotations for R&D personnel can have multiple advantages, just as it does with manufacturing employees.

The first advantage is to keep employees from getting burnt out. In some situations, employees will just become bored of performing the same type of work, even if it is complicated work that requires creativity and ingenuity. In other situations, some R&D employees get assigned to new program work with challenging deadlines and aggressive schedules, while others work in core technology groups that tend to operate at a more leisurely pace. Rotating employees back and forth between these types of situations can help to keep the schedule pressure on the new programs from burning employees out while bringing some of the urgency learned in those scenarios back to the core technology groups to increase the output of those groups.

Another advantage to cross-training R&D staff is increasing flexibility, similar to what is experienced in the manufacturing world. Borrowing from the example in §3.4.3, we can look at the uncertainty in the aerostructures industry over whether future aircraft will be built of composites or metals. If half of a firm's R&D staff is specialized in composites and half in metals, as soon as that decision is made half of the staff becomes irrelevant. Instead, employees can be cross-trained in anticipation of that event. Materials specialists who have always worked with metal should set aside time to learn more about composite materials. Process experts who specialize in machining metal should begin to look at the new challenges that are encountered when working with composites. Similarly, the composites experts should spend time learning about metals and doing some work with metals. In this way, the R&D workforce becomes much more flexible so that if the aircraft OEMs announce decisions to work entirely with composites in the future, employees can be shifted to new projects to best address those needs.

3.4.4.3 Pull System

Factories that fully embrace lean principles typically see reduced levels of inventory and work in progress (WIP). Less inventory and WIP frees up cash to allow the company's executives more flexibility in running the business. A big reason for the reduction in inventory and WIP is moving from a "push" system to a "pull" system. In a push system, materials are received from a vendor at a pre-specified rate and pushed into component build, components are built and pushed into subassemblies which are in turn built and pushed into final assembly which are built and pushed into a warehouse. If demand for the product goes down, inventory levels build up. If a bottleneck emerges in the manufacturing process, WIP builds up behind the bottleneck.

A pull system, on the other hand, is one where work is only performed when there is a pull for it. When a customer orders the product, a final assembly is pulled. In order to build the final assembly, subassemblies and components have to be pulled, which will in turn result in materials being pulled from vendors. By operating in this manner, if demand drops or a bottleneck emerges, inventory and WIP do not build up as in the push system.

In an R&D environment, technology projects are WIP and the technology solutions are inventory. Pushing out technology that not does clearly address a need of the company is just as bad as any manufacturing push system. The result is personnel and equipment tied up working on developing that technology. Once a solution is reached, the technology essentially sits on a shelf until a use for that technology can be found.

Instead, R&D can be run as a pull system. The needs of the company—whether they are immediate operational needs or longer-term business development needs—can be used to pull technology out of R&D. Once the technology is developed, it can immediately be put to use through shop floor implementation or by being incorporated into new designs by engineering. This way, technology solutions never have to sit on a shelf waiting to find a need. The money and effort spent on R&D would be much more effective if none of the developed technology ends up as inventory, sitting on a shelf waiting for an opportunity to be implemented.

Implementing a pull system should not imply that a firm only works on operational improvements and ignores breakthrough technology (as described in §2.5), or even that technology cannot be used to drive some business decisions. Depending on the firm's innovation strategy and overall corporate strategy, breakthrough technology should still be pursued. In these situations, the technology pull comes from the long term strategic vision of the company. For example, it probably would not make sense for R&D staff at an aerostructures firm to research jet engines and begin development of a jet engine. However, if the firm had a goal of winning more future nacelle business, it might make sense for the R&D team to partner with one or more jet engine manufacturers and work with those companies to identify ways that future nacelle designs can be improved to better work with future jet engines. This R&D work could still lead to technology that would guide the firm's future nacelle development, but it would be much less likely to result in new technology ending up on a shelf as compared to pursuing projects that do not match the firm's strategic goals.

In practice, it is difficult if not impossible to predict the outcome of longer-term, more innovative R&D projects. As you move up from Hauser's third tier projects to the second and first tier, the project outcomes become increasingly uncertain. This uncertainty makes it difficult to pull breakthrough technology. As discussed in the example above, even if a pull system cannot be used to pull out the exact technology, the subject of the research should still be pulled by the needs of the company. This will help to ensure that the outcomes of the research are technologies more likely to be implemented into future products of the firm.

3.4.4.4 Faster Feedback and Improved Use of Metrics

A common tool within lean manufacturing is using metrics to track performance and both displaying and using those metrics to immediately know when problems arise. Many factories have displays on the shop floor showing how many units have been produced that shift, what the defect rate is, and other metrics. Both workers and supervisors can see these displays to immediately know how well they are performing and if there might be problems that need to be addressed.

Similarly, metrics can be used within R&D to track how well the R&D organization is performing. Some example of these metrics are discussed in §2.6.2. It is not enough to simply collect data and track these metrics. They should be used in an analogous fashion to the display on the shop floor. The metrics should be posted in such a fashion that all R&D employees can see them and quickly know how effective their individual projects are as well as the R&D organization as a whole. One way to display these metrics would be a simple stoplight chart as shown in Figure 10, which could be implemented as an R&D dashboard that all R&D personnel see on their computers. Longer term metrics such as percent of sales from new products could not be displayed in this way, but short-term metrics such as schedule and budget can be tracked nearly in real-time.

	Schedule	Budget	Sponsorship	Collaborations
Project 1	Green	Red	Green	Yellow
Project 2	Yellow	Green	Green	Green
Project 3	Yellow	Yellow	Green	Red

Figure 10 - Example stoplight chart

Creating and displaying the metrics is useful, but to really improve R&D efficacy, they must be acted upon. Projects that have begun to stagnate or are no longer moving in a direction that is a strategic fit for the company should be cancelled and their budget reallocated to better projects. The metrics and subsequent feedback loop should be used as a tool to help achieve the continuous process described in §3.4.4.1.

3.4.5 Driving OEM Decisions

The best possible scenario for R&D performed at the supplier level is that the technology developed is so successful that it drives the OEM to make product decisions to incorporate that technology. This can be illustrated by continuing with the example of metal or composite fuselages for the next generation of single aisle aircraft. An aerostructures supplier might someday create technology that allows composite aerostructures to be manufactured quickly and at lower costs than metal with better performance. This type of technology would likely be enough to drive aircraft manufacturers to choose composites for their next single aisle aircraft.

Moving forward with R&D in the hopes of eventually affecting the OEM's product decisions is incredibly risky. Since the OEM also has final say in what the product is, they can always choose not to use technology even if it does produce a superior product. Also, since the supplier may only have visibility into a small piece of the product, technology that appears to make the piece better may not be superior when viewing the product as a whole. If the OEM decides not to incorporate this technology, then all of the money spent developing it will have gone to waste (unless the technology can be incorporated into one of the OEM's competitor's products).

The supplier's corporate strategy should guide how much of the R&D portfolio is spent on breakthrough innovation that could be used to drive the OEM's decisions. Successful breakthrough innovations will lead to considerable success for the firm and can even change entire industries. However, because of the high risk of these types of projects, suppliers should proceed cautiously with this type of work and will likely want to only invest a small portion of their R&D budget into these breakthrough projects.

3.5 Summary

This chapter examined R&D portfolio management as it pertains specifically to suppliers. The goals of R&D being conducted at the supplier level are somewhat different than the more traditional goals of OEM conducted R&D. Suppliers also face additional challenges to their R&D efforts due to their lack of control over whether or not their technology will ultimately be adopted into a product. The chapter then proposed a number of techniques that suppliers can incorporate into their R&D processes to increase the effectiveness of R&D. These techniques include ensuring a strong strategic alignment of R&D projects with corporate priorities, using market intelligence to drive R&D decisions, hedging by pursuing multiple technologies in instances where the future of the product is unclear, borrowing techniques from lean manufacturing to use in the R&D organization, and performing a limited amount of work on breakthrough projects that could ultimately drive the decisions of OEMs.

4 Case Study - Portfolio Management at Spirit AeroSystems

4.1 Company Background

4.1.1 History/Background

On a recent Friday morning, a group of Spirit new hires were welcomed to the company by Steve Turkle, Director of Logistics, with the statement, "Spirit is a four year old company with eighty years of history." This simple statement provides a significant amount of insight into Spirit's history.

Spirit AeroSystems's roots can be traced back to 1927 when Stearman Aircraft Company moved its operations to Wichita, KS. Stearman was bought by United Aircraft and Transportation Company in 1929. In 1934, United was forced to separate its airline and manufacturing divisions and thus the Boeing Airplane Company was launched as an independent company. The Stearman facility officially became known as the Wichita Division of the Boeing Company in 1941 and operated under that name for more than 60 years.[24] An investor group, led by the Onex Corporation, purchased Boeing's Wichita division, which included facilities in Tulsa and McAlester, Oklahoma and, in 2005, Spirit AeroSystems was created. The aerostructures division of BAE Systems in the United Kingdom was acquired in 2006, creating Spirit AeroSystems (Europe) Limited and giving Spirit a global footprint. After an IPO event in 2006, Spirit now operates as a public company.[25]

Today, Spirit is a $4.1 billion company and the largest tier 1 supplier in the aerostructures market, with 16% of the $23.7 billion share of market held by tier 1 suppliers, twice that of its closest competitor.[26] A summary of Spirit's facilities can be seen in Table 1.

Table 1 - Summary of Spirit facilities (adapted from [27])

Site	Square Feet	Employees	Main Products
Current Facilities			
Wichita, KS	11.1 million	11,000	Fuselages, struts, nacelles
Tulsa, OK	1.9 million	1,800	Control surfaces, wing structures
McAlester, OK	135,000	300	Detail parts supplier to Tulsa
Prestwick, Scotland	1.1 million	1000	Leading and trailing wing edges
New facilities[2]			

[2] Number of employees refers to projected Phase 1 numbers, square footage may still be under construction

Kinston, NC	596,000	800	Composite manufacturing and assembly
Subang, Malaysia	242,000	450	Composite manufacturing and assembly

Spirit's manufacturing capabilities include many different aerostructure components, including fuselages, nacelles, pylons, wing structures, and empennages. Spirit supplies some portion of every Boeing production aircraft, most notably the majority of the airframe for the B737 and the nose section for the B787. Spirit is also the largest supplier to Airbus, producing parts for the A320, A330, A340, A380, and A350 XWB aircraft. Additionally, Spirit has moved into the business jet markets, winning programs with Gulfstream, Hawker, and Cessna, as well as recently entering the military business by winning a composite cabin package for the Sikorsky CH-53K helicopter and working with Boeing on the P-8A program.[25]

Spirit is organized into three main business segments—Fuselage Systems, Propulsion Systems (comprised mostly of pylons and nacelles), and Wing Systems. Figure 11 shows 2008 revenue and income by business segment.

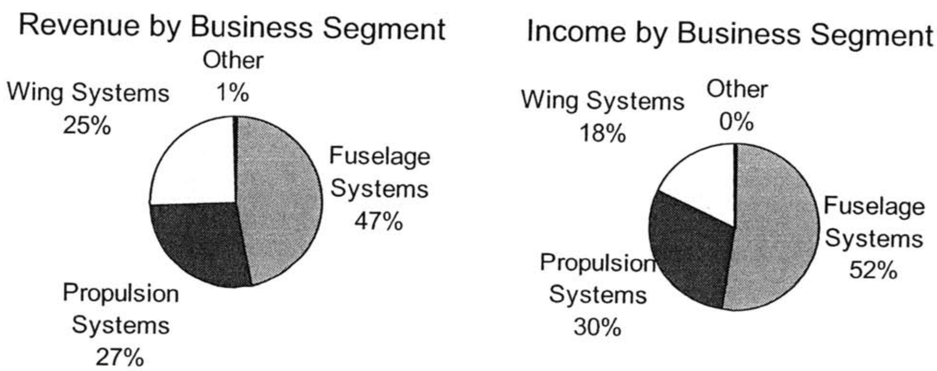

Figure 11 - Revenue and Income by Business Segment [25]

4.1.2 Culture

After spending nearly seventy years with most of its facilities owned and operated by Boeing, it should not be a surprise to find out that much of the Boeing culture remains. While all of the official signage has dutifully been changed from Boeing to Spirit, the Boeing logo can still be seen on polo shirts, lanyards, mouse pads, coffee mugs, and many other items throughout the facility. Even the transition away from all Boeing computing systems was only completed in 2009, more than four years after divesture. The workforce tends toward long tenure, with many having worked their entire careers for Boeing and Spirit. As of June 30, 2009, the average age of the Wichita workforce is 47 years. Examining the tenure of the workforce also sheds some light on the difficulty in shedding the Boeing culture. Of all the employees at the Wichita location, 67.5% have been with the company longer than 5 years—that is, they worked for the company at least one year before the Boeing Wichita division was spun off into Spirit. Of those employees, 68.6% have been with the company more than twenty years. The average employee has been with Spirit nearly 16 years. Not only did the majority of Spirit's employees spend at least some time as part of Boeing, learning the Boeing way of doing things, many of those employees worked for Boeing for a very long time and became very accustomed to Boeing's practices. Figure 12 shows the complete picture of the tenure breakdown of Spirit's Wichita workforce.

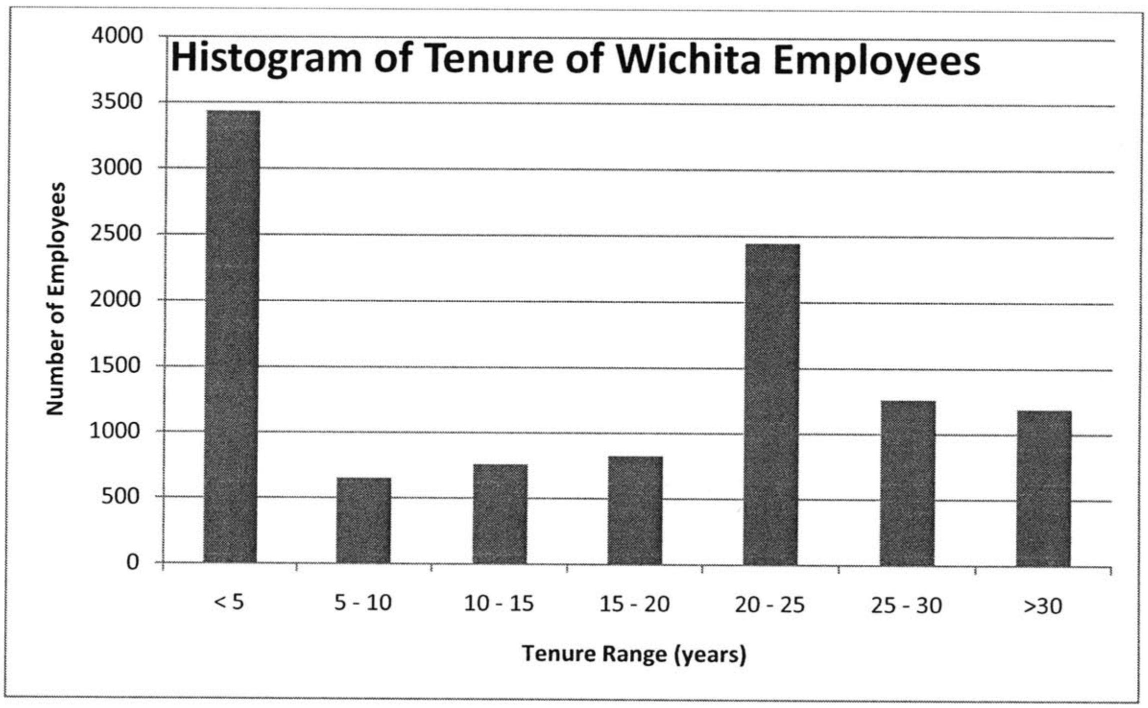

Figure 12 - Histogram of employee tenure at Spirit's Wichita location

Making the shift from being a division of Boeing to a stand-alone company requires massive changes within the organization. Spirit is no longer a cost center for Boeing, designing and making whichever components the executives in Seattle decide to send to Wichita or Tulsa. Instead, Spirit now stands alone with its own profit and loss responsibilities. Many functions that were performed at other Boeing locations—IT, sales and marketing, and advanced research to name a few—now have to be developed in

Wichita. The leadership team in Wichita, who had gotten very good at making parts of airplanes for Boeing, now faces the additional challenge of having to think strategically about the future direction of the company instead of just focusing on tactical day-to-day decisions to drive down costs and meet schedules.

Because of, or perhaps in spite of this, Spirit is a company that is fiercely looking to establish its own identity. One of the main strategic objectives is to win more business from companies other than Boeing (Boeing currently represents 85% of Spirit's business [25]). Several external executives were brought in to bring a non-Boeing legacy perspective to the executive team. Spirit branding can be seen throughout the facility. Yet the quest to completely break free from Boeing is an ongoing battle that will continue to challenge Spirit for many years to come.

4.1.3 R&D At Spirit

4.1.3.1 History

As with every other function at Spirit, the research and development (R&D) group has been heavily influenced by their days of representing R&D for Boeing's Wichita Division. Boeing Commercial conducts most of its R&D out of its headquarters near Seattle, WA, with some advanced technology being developed at Phantom Works in St. Louis, MO.[28] R&D money sent to manufacturing cost centers, such as Wichita and Tulsa, was designated primarily for manufacturing research and development (MR&D). MR&D focuses on process improvements to improve current programs through lower costs, higher quality, or higher throughput. R&D was very closely tied in with operations, with personnel spending a large amount of time on the factory floor. Projects were identified and selected based on the current needs of the various programs. Very little R&D targeted at new products or advanced technology was done at Boeing's Wichita Division.

After the divesture in 2005, Spirit recognized that R&D meant more than the shop support type work that had been done in the past. An advanced research group was set up to begin looking at new technologies. The R&D group began to look at longer term projects that would enable future program wins, instead of just saving money today. A large push was made to begin generating Spirit-owned intellectual property. As with the company in general, managers who had been very good at solving short-term, tactical type problems were faced with the challenges of thinking strategically about the most effective way to allocate their budget across various types of projects.

4.1.3.2 Organizational Structure

R&D organizations tend to be structured in one of two ways:

- Centralized—The R&D group reports up through a support function leader, typically the Chief Technical Officer (CTO) or a Vice President of R&D. Business units can request work be done in their area. The work is funded directly by the corporation and then charged back to the business unit, either directly or indirectly.
- Decentralized—Each business unit has its own R&D group which it funds itself. Some collaboration may still occur across R&D groups, but they ultimately are responsible to their own business unit.

Spirit's R&D organization (see Figure 13) is neither of these, but is instead somewhat of a hybrid. While hybrid organizations are not uncommon, a typical hybrid has centralized groups focused on core technologies while groups within the business units focus on applying technology to their specific area. Spirit has a core R&D group, known as Technology Development, which reports up through the CTO and represents slightly less than half of the R&D staff. This group does not focus exclusively on technologies though. While some of the managers carry technology responsibilities (e.g. Chemical Processes and Metals), others have responsibility to support a specific business unit (Fuselage Technology Development and Propulsion Technology Development). There are two other main R&D groups. The Fuselage MR&D group, within the Fuselage business unit, is nearly as large as the Technology Development group. While some of the Fuselage MR&D group focuses exclusively on operational needs within its business unit, other subgroups actually focus on technologies and do considerable amounts of work outside of the Fuselage business unit (e.g. Automation and Non-Destructive Inspection). The third major R&D group, A350 R&D, exists within the Aerostructures business unit and supports the development of the A350 program. This group focuses entirely on the A350 program and pulls heavily on resources from the other R&D groups. Additionally, a Chief Scientist Office (CSO) exists to keep up to date on academic research and future technological possibilities, and an R&D group exists within Spirit Europe although it acts fairly independently of other R&D activities.

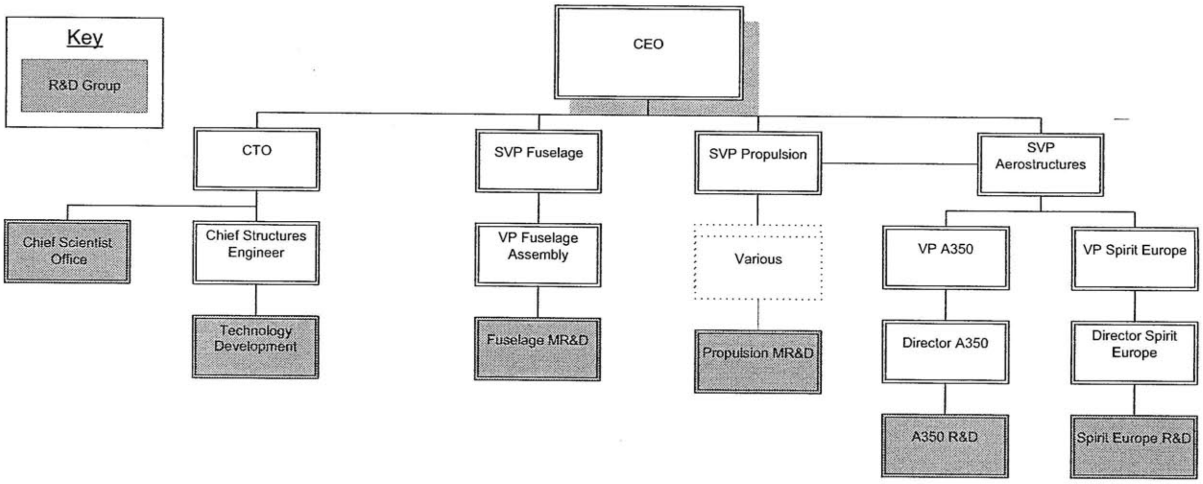

Figure 13 - Spirit Organizational Chart (only R&D related areas shown)

The overall complexity of the system further complicates matters. While some funding comes directly from the business units for short term "shop support" projects that R&D personnel support, all of the true R&D work is funded through one central pot of money allocated by the Director of Technology Development. Managers who report up through four different representatives to the executive council must all work together to decide how to divide a single budget allocated for R&D.

4.2 Industry Background

4.2.1 Background

The aerostructures industry supplies structures to aircraft manufacturers. These structures are primarily fuselages, wings, empennages, and nacelles. In 2008, the overall market was $35.9B, although a large percentage of that work is done in-house by the aircraft manufacturers themselves. A recent industry study found 136 companies as externally supplying aerostructures at any notable volumes. Of these, fifty are tier 1 suppliers, supplying directly to the aircraft manufacturer, and eight, including Spirit, are known as Super Tier 1 supplier, who have design and build capabilities and are engaged in risk sharing partnerships with aircraft manufacturers.[26] Figure 14 shows the market share held by various tier 1 suppliers.

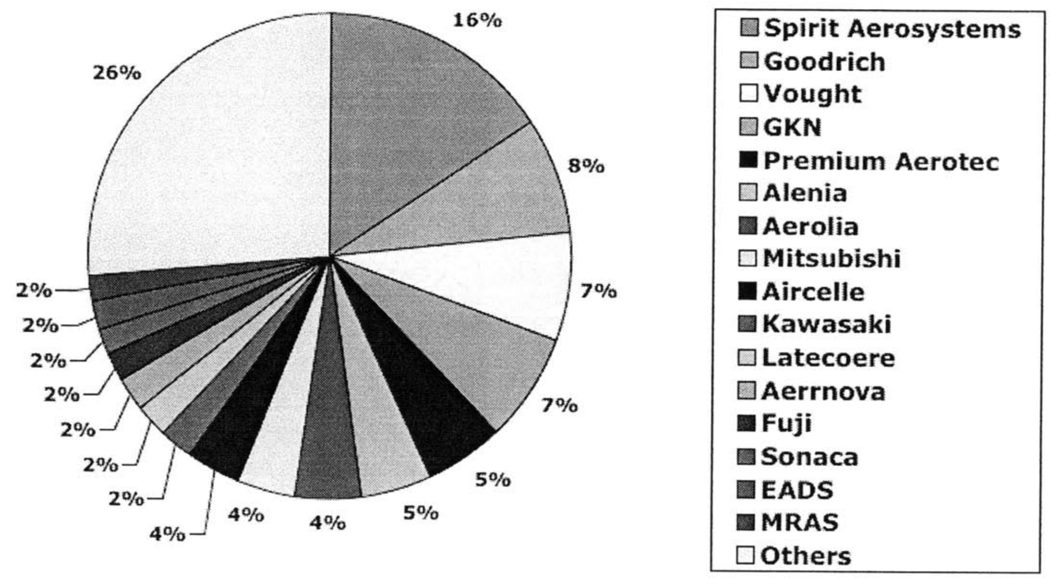

Figure 14 - Market share of tier 1 aerostructures suppliers [26]

The customers for these aerostructures suppliers are aircraft manufacturers. The largest share of the market, 45%, is one hundred plus seat commercial jets.[26] Within the commercial jet market, only two major players exist—Boeing and Airbus. A breakdown of the aerostructures market by type of aircraft manufacturer can be seen in Figure 15.

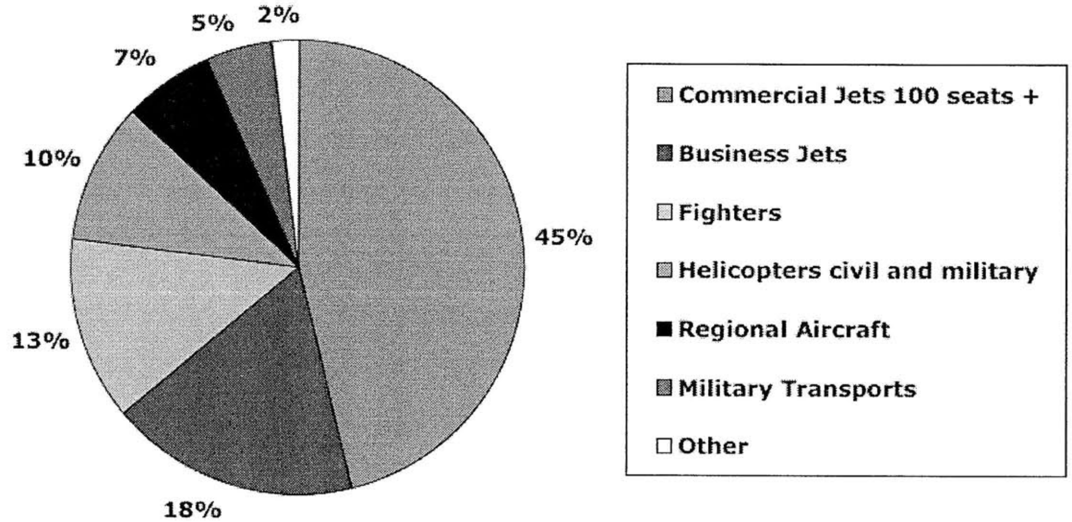

Figure 15 –Breakdown of aerostructures market by aircraft type [26]

4.2.2 Industry Specific Challenges

Boeing delivered the first 737 on December 28, 1967.[29] More than forty years later, on April 16, 2009, the 6000th Boeing 737 was delivered.[30] In fact, current estimates by industry analysts are that the replacement airplane for the 737 will not be introduced until around 2020, resulting in a total lifespan of more than sixty years for this remarkable plane.[26] Granted, there have been many redesigns and refreshes along the way, but the fact remains that lifecycles in the commercial aircraft market are incredibly long.

These long lifecycles present a unique set of challenges to R&D organizations. In consumer goods industries where lifecycles tend to be one to two years, missing a new technology trend means falling a year or two behind the competitor's technology. In the commercial aircraft market, missing a trend in technology can easily result in falling ten or more years behind. To make matters worse, as a supplier to aircraft manufacturers, many contracts are for the life of the product. Missing a technological advance and not winning a program could mean getting locked out of that program for a lifespan that could last sixty years, as in the case of the 737.

There are other challenges to performing R&D in this industry as well. For one, the market is dominated by two manufacturers—Boeing and Airbus. If a supplier invests money in developing a technology that neither of these companies is interested in, that development goes to waste. Also, the capital expenditures required in this industry are enormous. Getting the tooling and equipment required to prove or disprove a new technology can cost millions of dollars. Vought, another aerostructures supplier, recently had to sell its 787 facilities to Boeing. After investing $540 million in capital and inventory for their facility, Vought was no longer able to support the financial demands of a program that has yet to deliver an airplane and deliver payment to its suppliers (Boeing paid $580 million for the facility and forgave $422 million in advance payments).[31] A company has to be very sure that a technology is the right one to pursue before investing millions of dollars in capital to prove it. However, as in Vought's case, even if a company has the right technology, the expenses can still be too large to endure.

4.3 Spirit's Existing Project Selection Process

4.3.1 Historical Process

Starting out as Boeing's Wichita division and continuing into the first few years of Spirit, the R&D budget was allocated in blocks to managers. Each manager was then able to choose which projects he or she deemed the most important to be working on and assign their resources accordingly. This system was extremely flexible in allowing managers to adapt to an ever-changing business environment; however it provided little oversight into specific projects that were being worked. The process also lacked global oversight of the portfolio to ensure an efficient portfolio with no duplicated effort. In an effort to add more accountability and oversight to the process, the 2009 R&D planning process[3] attempted to centrally allocate budget at the project level for the first time.

4.3.2 2009 R&D Planning

A flowchart of the 2009 R&D planning process can be found in Figure 16. Key portions of the process are explained below.

[3] The R&D planning process typically runs the last several months of the preceding year. For example, the 2009 planning process ran from September through December, 2008.

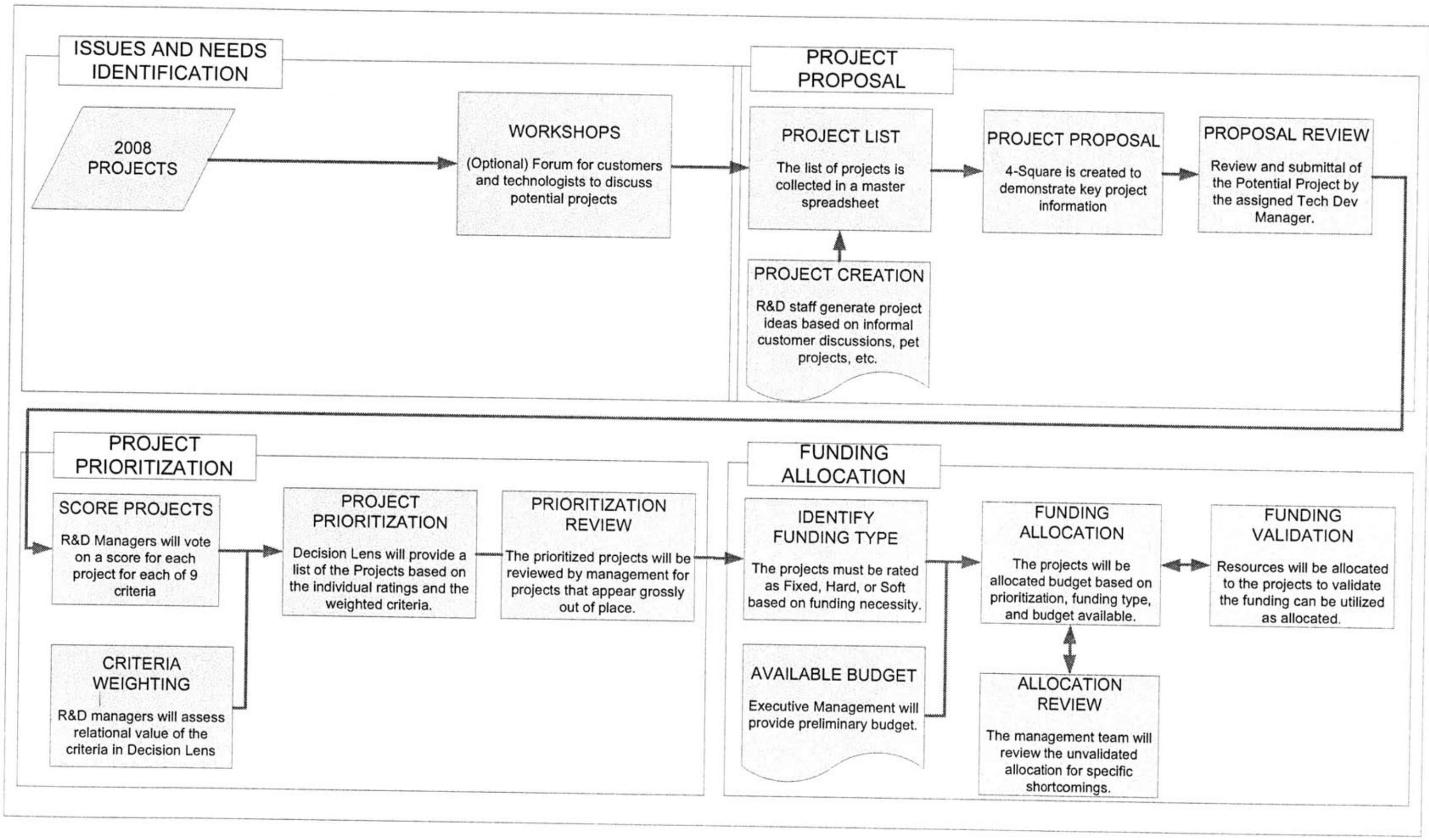

Figure 16 - 2009 R&D planning process

4.3.2.1 *Project Generation*

The 2009 planning process did not include any formal process for generating project ideas. Instead, different R&D groups used different methods. Some groups used cross-functional workshops to gather ideas. At these workshops, key personnel from operations, engineering, marketing, and R&D would sit in a room together to discuss what projects should be pursued in the future. Other groups sent out surveys to various operations personnel to get their input.

By far the most common method of obtaining input from non-R&D personnel was through informal channels. Most of the R&D staff knows the operations employees with whom they deal and are embedded enough to know what the latest problems are within operations. In a survey conducted as part of this project regarding the 2009 planning process, 75% of non-R&D personnel reported that their needs were gathered through informal channels, compared to only 10% who attended workshops and 25% who responded to a survey. Note that these results do not include the 41% of respondents who reported that their needs were not collected, as they may have been intentionally omitted due to not being in a function that could provide useful input to R&D planning.

R&D employees ultimately came up with a list of projects that they themselves determined to be useful to the company. No formal method existed to verify that these projects related to an actual business need. In the same survey, only 51% of R&D personnel reported being involved in generating project ideas. The generation of projects tended to be done primarily by the more experienced R&D staff. Many projects were carryovers from previous years or reflected individual priorities of various employees.

4.3.2.2 *Project Prioritization*

A major step was taken in 2009 when all of the projects from various segments of the R&D organization were compared against one another for funding. With the help of a software package called Decision Lens, a scoring method was used in evaluating the projects. Each project received a ranking on nine different categories:

- Product Performance
- Product Lifecycle Cost
- Project Risk
- Intellectual Property
- Business Impact

- Sponsorship
- Environment, Health, and Safety Impact
- Process Benefit
- Technology Enabler Impact

Each criterion was then given a weighting and a weighted sum of the scores of the nine criteria determined the final value of the project. To determine the weightings, Decision Lens uses a pairwise-comparison algorithm. The criteria are put up two at a time and the user determines which is more important. Decision Lens uses that input to generate the weightings. In this case, the R&D managers all met and voted on which criteria were more important.

In an attempt to obtain a fair scoring for each project, the R&D managers met to discuss each project and then voted on a score for each project's nine criteria. However, with over 160 projects being submitted for review, and each project needing to be ranked on nine different criteria, the time burden was enormous. This process lasted more than 15 hours, spread across several weeks. With meetings happening at many different times, a different subset of the managers was available each time and thus consistency in the voting was not guaranteed. The end result was a list of project scores that no one fully trusted. Since many managers did not know all of the details of each project and were afraid to vote either strongly for or against a project, the scores all clustered towards average with minimal differentiation between projects. This clustering towards average carried through to the weighted scores seen in Figure 17 (which is somewhat expected due to the orthogonal nature of some of the criteria). As can be seen in the figure, the scores are bunched around the average value of 0.415. The standard deviation is only 0.114 and the 20th and 80th percentiles are 0.334 and 0.512 respectively.

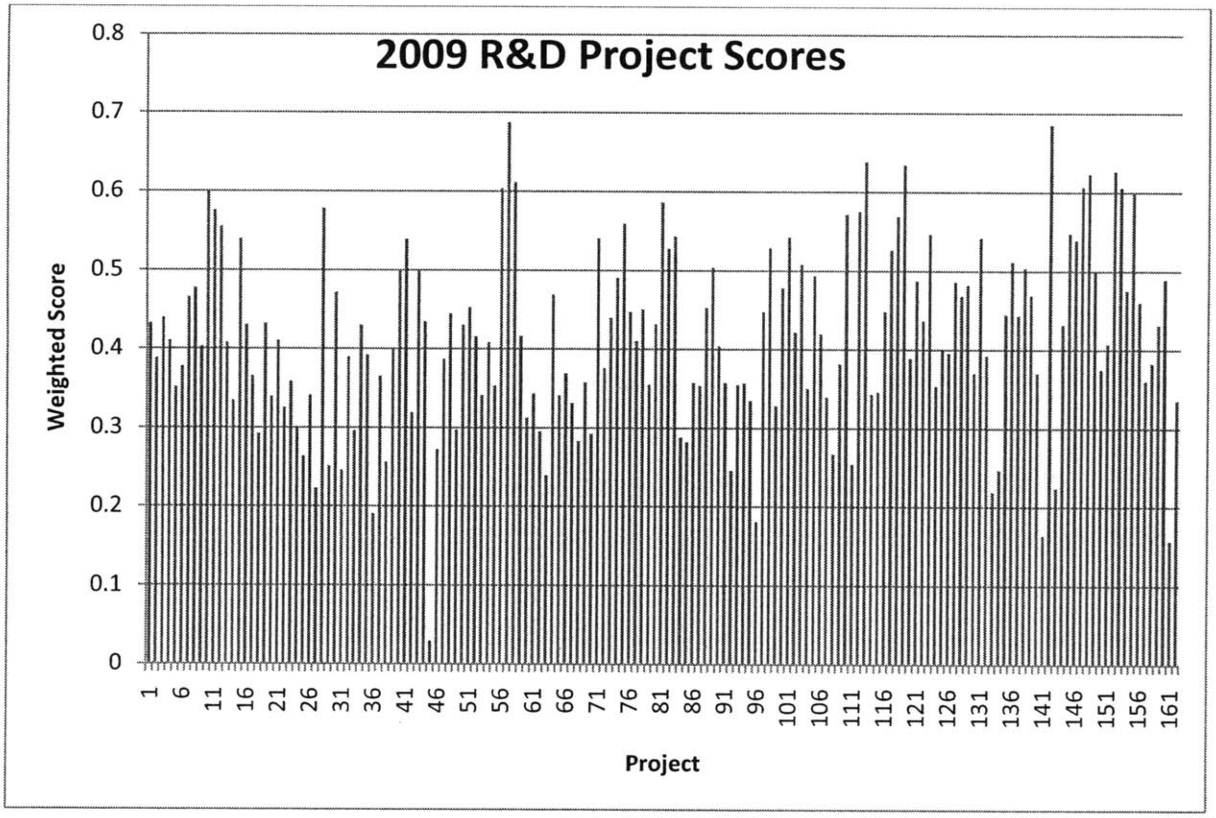

Figure 17 - Plot of total scores for 2009 R&D project submittals

Along with the project scores, estimated budgets are input into Decision Lens for each project. Decision Lens uses an integer programming method to choose the set of projects which results in the maximum total value for the portfolio.

Due to the low confidence of the scores input into Decision Lens, the resultant prioritized list of projects received significant manual overrides. Some of the R&D managers chose to move around the money that Decision Lens had allocated to projects in their group to other projects which they deemed more valuable. The end result was budgeting not unlike in previous years. However, even after some money was moved around, budget was still assigned and tracked at the individual project level, which was a key step in increasing the accountability and visibility of R&D activities.

4.3.2.3 Executive Review

The 2009 R&D planning process was run entirely within the R&D organization. No executive input was requested or submitted as the process proceeded. It was not until the entire process had been completed and a portfolio of projects selected that the portfolio was taken to the Executive Council for review. At that time, an overview of the portfolio was shown to the Executive Council and several members expressed concerns over a few details.

As a result, some of the budget had to be moved around to different projects. While the 2009 budget for R&D had been finalized, the spend plan had to be reworked in the first few months of 2009 as the R&D managers worked to reallocate spending on projects per the Executive Council recommendations.

4.3.2.4 E-Notebook

In 2009, a major improvement was put into place after it was decided that a better tool was needed for tracking the R&D portfolio. This decision led to the development of an in-house software solution known as "E-Notebook." E-Notebook tracks every R&D project and provides a quick and easy way to get visibility into a project's status in terms of progress, budget, or many other attributes (creating a dashboard much like what is described in §3.4.4.4. It also was a significant step in getting information on projects being pursued across multiple different branches that exist within Spirit's R&D all located in one place so that the entire portfolio is visible in one location. E-Notebook was not created until after the 2009 portfolio had already been selected, so in 2009 it was only used as a tool for project visibility and tracking.

4.4 Improving the 2010 R&D Planning Process

4.4.1 Overview

The attempt to improve Spirit's 2010 R&D planning process was performed as part of a Leaders for Global Operations (LGO) internship, conducted June through December, 2009. Due to the time constraints, a complete overhaul of the process was not possible. Instead, improvements upon the existing process were made. Several key objectives lay behind the improvements that were made. These key objectives are based on Spirit's R&D strategy which, as a supplier, tends towards the conservative side. Discussing the pros and cons of this strategy is beyond the scope of this research and will not be discussed here. The key objectives are as follows:

- *Standardize the process* – As mentioned in §4.1.3.2, Spirit's R&D organization is spread across multiple areas of the company. In the past, the different groups have not all generated projects in the same way. The 2010 planning attempted to create a one company R&D mentality.
- *Increase strategic alignment of portfolio* – Executive oversight in the past happened merely as a review after the entire portfolio had been selected. The new method aims to have executive

input guide the process to ensure that the R&D portfolio is well aligned with the strategic goals of the company.

- *Eliminate technology for the sake of technology* – The 2010 process aims to directly tie every project to a customer need, whether it is an internal or external customer or a long or short term need. This will help to ensure that R&D personnel are not pursuing pet projects or projects that do not have value for the company, along with creating awareness outside of the R&D community that customer needs are driving the actions of R&D.
- *Ease burden on managers for project ranking* – The 2009 process required hours upon hours of the managers' time to vote on ranking criteria for the various projects. The new process is intended to find a better method for ranking the projects.
- *Choose the right number of projects* – As discussed in §2.3.4, pursuing the proper number of projects is a key to effective R&D portfolio management. Spirit's 2009 portfolio included a large enough number of projects that it became burdensome to evaluate and track every project. Correcting this requires creating a uniform definition of what a project is and implementing that definition across the organization, followed by a robust process for screening and narrowing down the funded list of projects.

4.4.2 The 2010 Planning Process

A flowchart of the 2010 R&D planning process can be found in Figure 18. By comparing this with the 2009 flowchart, it is clear to see that most of the improvements were made in the issues and needs identification portion of the process. However significant improvements were also made to the proposal and prioritization stages as well. Key portions of the improved process are explained below.

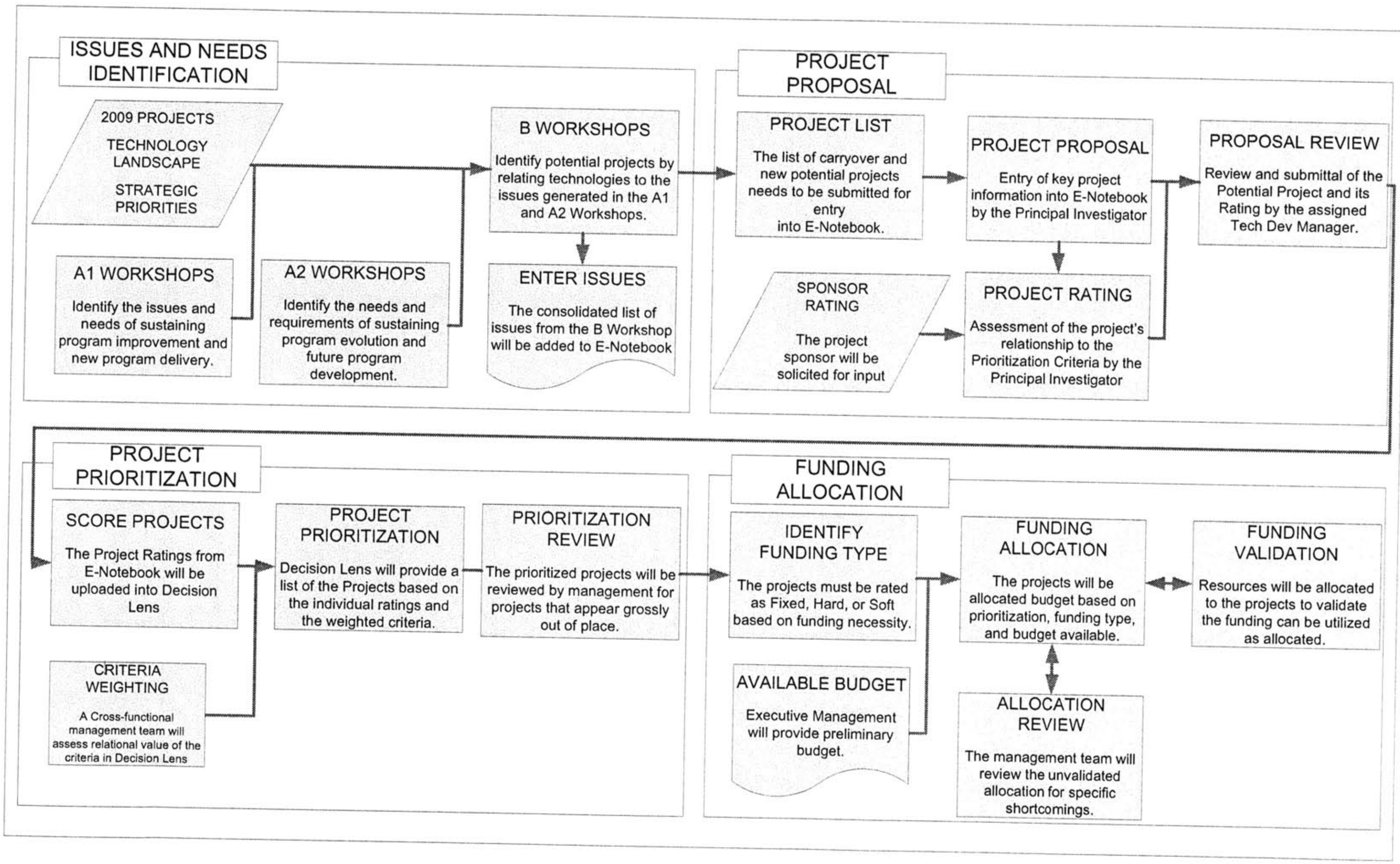

Figure 18 - 2010 R&D process planning

4.4.2.1 Collecting Issues

Creating a uniform system for collecting the needs and issues of the customers of R&D was critical for standardizing the project selection process across the organization, ensuring that the R&D portfolio accurately reflects the strategic needs of the company, and eliminating technology for the sake of technology.

To ensure that the needs of the business were accurately captured, a system of workshops was created based on the workshops that had been used in previous project planning exercises and that many employees were comfortable with. Workshops in previous years had focused on creating ideas for projects. Employees from operations, engineering, R&D, and other functions all met together in one meeting to generate project ideas. For the 2010 process, this was broken up into two rounds of workshops. The first round, or "A", workshops were to focus on collecting the needs, requirements, and issues of various customers of R&D. The second round, or "B", workshops, were to be used for R&D staff to create ideas for how technology could be created and applied to solve the needs collected during the A workshops. Figure 19 shows a diagram of the workshop process. Referring back to the process conceptualized in Figure 8, the A workshops represent the "Needs Identification" stage and the B workshops both identify "Required Technologies" and where a "Technology Gap" exists.

The A workshops were further broken down into two different types, known as "A1" and "A2" workshops. The A1 workshops are used for collecting shorter-term, operational needs of the company. These workshops were attended by factory managers and used to ask those managers what issues are preventing them from being more effective in producing product. Since the A1 workshops were focused on operational needs, they were organized by the various shops located within the factory (ten in total). Examples of A1 workshops are composite fabrication or twin aisle fuselage assembly.

The A2 workshops are aimed at longer-term needs of the company, both large-scale change to existing business and creating technology that would allow the company to win future business. Attendees at the A2 workshops were personnel from sales and marketing and business development functions, along with senior operations personnel who have more of a forward looking perspective than that of the factory floor managers. The A2 workshops asked participants what their vision of the future state of the company is and what needs and requirements exist to achieve that vision. The A2 workshops were organized by major product lines, such as metallic fuselage or wing (six in total).

The functionality of E-Notebook was also expanded to support the needs collection activity. A module was added to E-Notebook to allow anyone to enter a need or issue that they have, which is captured and is visible to R&D personnel to evaluate opportunities for technology solutions to those needs.

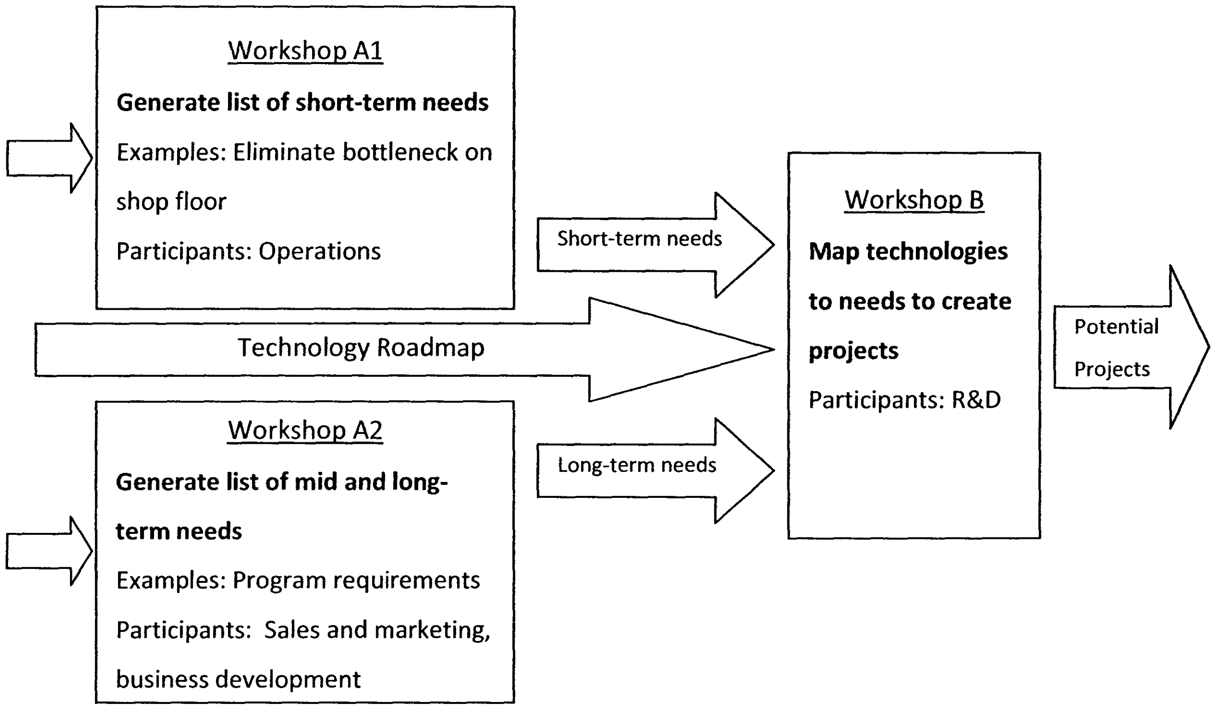

Figure 19 - Diagram of workshop process used to collect needs and generate project ideas

4.4.2.2 Project Generation

The workshop system created to collect customer needs also led to project generation. The B workshops, as shown in Figure 19, are designed to gather technologists together to brainstorm technology solutions to the customer needs collected during the A workshops. The attendees of the B workshops represent the various R&D departments at Spirit and also include experts of all relevant technologies. The B workshops are organized by major product lines, similar to the A2 workshops. Needs gathered during the A1 and A2 workshops flow into the appropriate B workshops.

A hypothetical example scenario of how needs and projects flow through this workshop process would be as follows. During an A1 workshop session looking at composite fuselage fabrication, a shop floor manager mentions that he is having trouble meeting his production rates because of the time consuming inspection required of each part. During an A2 workshop session, the director of a major composite fuselage program states that early indications from her customer indicate rates will be increasing by fifty percent over the next two years. These two separate needs, along with many others, would flow into a B workshop focused on composite fuselage. Attendees at the workshop would not only include key technologists in composite fuselage technology, but also experts in areas such as inspection and automation. While there may be temporary solutions that could help the shop floor manager meet his rates, the need gathered during the A2 workshop about a rate increase makes it clear that a better solution must be found. During a quick brainstorm on the issue, the inspection and automation experts come up with an idea for a robotic inspection setup that could dramatically increase the throughput of the inspection step of the manufacturing process. That idea is captured and later assigned to someone to expand into a full project proposal.

Creating project concepts during the workshop process is just part of the project generation process. Once a concept has been created, someone must then expand that idea into a full project proposal. This process is facilitated and standardized through additional functionality added to E-Notebook. A module was created within E-Notebook for project proposals. Each project is entered into E-Notebook and assigned to a manger and principal investigator (PI). The PI can then go into E-Notebook and fill out the necessary information—items such as the goals of the projects, key deliverables in a high level timeline, and a projected budget. At that time, the PI is also required to tie the project back to at least one need that has been documented in the needs area of E-Notebook. This eliminates the possibility of R&D personnel inventing a need just to pursue a pet project of theirs and allows R&D management to document the customer provided needs that their project portfolio is addressing.

Collecting project proposals in E-Notebook also provides a uniform format in which all proposals can be displayed. E-Notebook can generate reports showing the key information for each project. No longer do the different branches of R&D use different types of reports to summarize their projects.

4.4.2.3 Project Prioritization

The prioritization process used in 2009 worked fairly well and is supported by current literature on scoring models as discussed in §2.4. The major problem with the 2009 process was the overwhelming burden it put on the managers to score each project across nine different categories. Additionally, it was desired to obtain customer input into the prioritization process.

To begin with, the criteria used in 2009 were evaluated. It was decided that they could be edited down from nine to the following six criteria:

- Intellectual Property Potential

- Financial Impact
- Product Performance
- Risk
- Environmental Health and Safety Impact
- Sponsorship

Despite reducing the number of criteria down to six, scoring every project submittal across all six criteria would still be a large amount of work. Thus it was decided to have the PI responsible for the project proposal provide scores and a manager review those scores. In order to make the scores less subjective, worksheets were created with three to four questions for each criterion. The PI simply has to select an answer to each question. Each answer corresponds to a value. The values for each question within a given criterion are then combined together to automatically calculate a score for that criterion. The complete set of worksheets for evaluating the six criteria can be found in Appendix 1 (however the values and formulas for calculating the scores are withheld due to their proprietary nature).

Along with reducing the burden of scoring projects, the 2010 process improvements also sought to increase customer involvement in the project prioritization process. This was done in two key ways. The first area is the manner in which weights are assigned to each of the criteria. In the past, a pairwise comparison exercise was performed by R&D managers to assign these weights. The 2010 process instead used key leaders from various areas of the company representing R&D's customers to perform the pairwise comparison. In this way, the customers themselves decided what was most important to them when evaluating potential projects and weights were assigned accordingly. The second area of increased customer involvement is the sponsorship criterion. In the past, R&D managers voted on how strong the sponsorship was for a given project. For 2010, each project had to have a sponsor assigned and the sponsor himself was responsible for filling out a worksheet that generated a sponsorship score.

Once the scores for each project and the criteria weightings were collected, the process was essentially the same as in 2009. These numbers, along with budget projections were input into a software package called Decision Lens. Each project has a requested budget along with a minimum budget at which it still makes sense to pursue the project. Decision Lens decides whether or not to fund the project and, if funded, whether at the minimum or full requested level so as to maximize the total score of the funded projects for a given budget level.

Because of the change to have people more familiar with the projects score each project, a larger range of scores resulted which provided better differentiation between the projects than was seen in 2009. The standard deviation increased from 0.115 to 0.149 and the range between the 20th and 80th percentile increased from 0.178 to 0.252. Table 2 shows a summary of the scoring data for the proposed projects for 2009 and 2010 and Figure 20 shows the scores of each 2010 project proposal.

Table 2 - Summary of scoring data for 2009 and 2010 project proposals

	Average	Standard Deviation	20th Percentile	80th Percentile
2009 Proposals	0.415	0.115	0.334	0.512
2010 Proposals	0.455	0.149	0.322	0.574

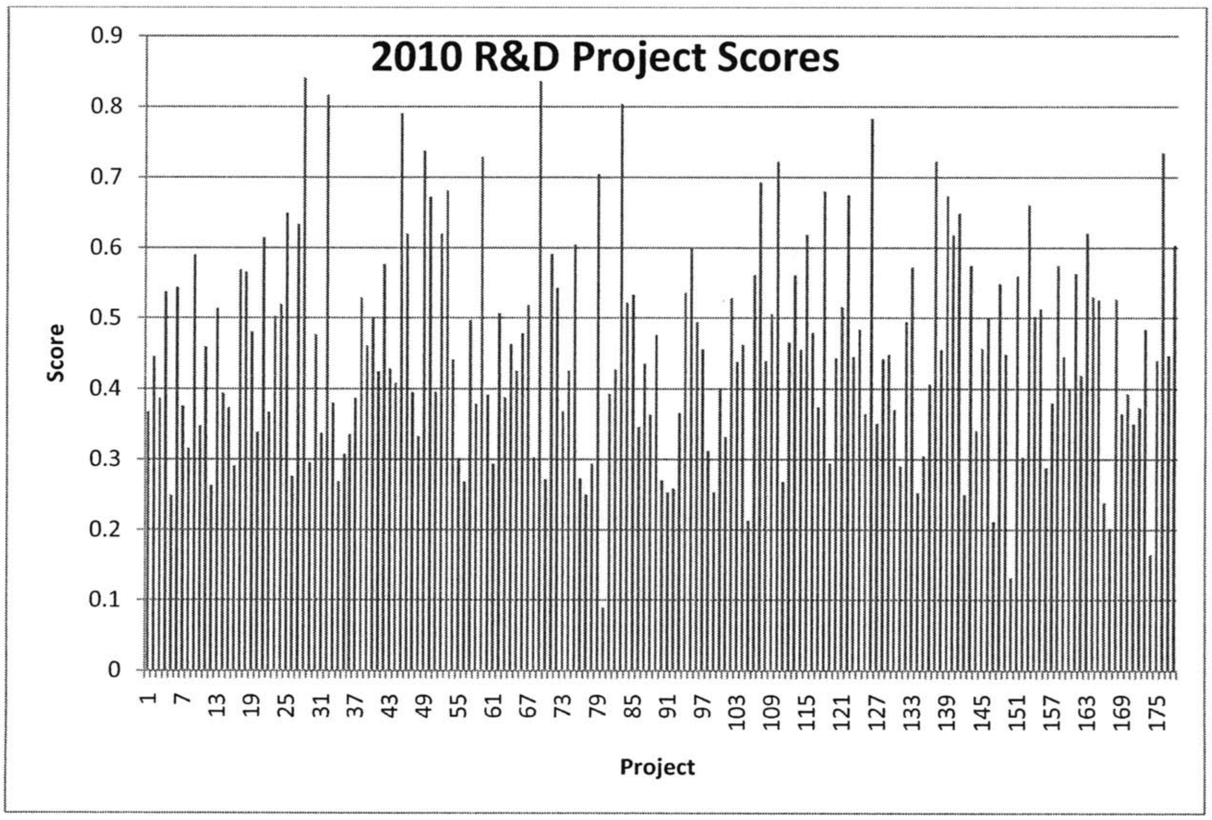

Figure 20 - Plot of total scores for 2010 R&D project submittals

In addition to using Decision Lens to choose the portfolio of funded projects, bubble diagrams (as discussed in §2.3.2) were used as a visualization of the portfolio. Projects were broken down into three key types or "buckets":

- Winning future programs
- Delivering on existing programs

- Improving sustaining programs

Each bucket was assigned a target spending level to ensure the portfolio aligned with the wishes of R&D management. A risk versus reward bubble chart of Spirit's 2010 portfolio, shown in Figure 21, allows manager to visualize the portfolio and verify that the results from Decision Lens are providing the portfolio that they expect.

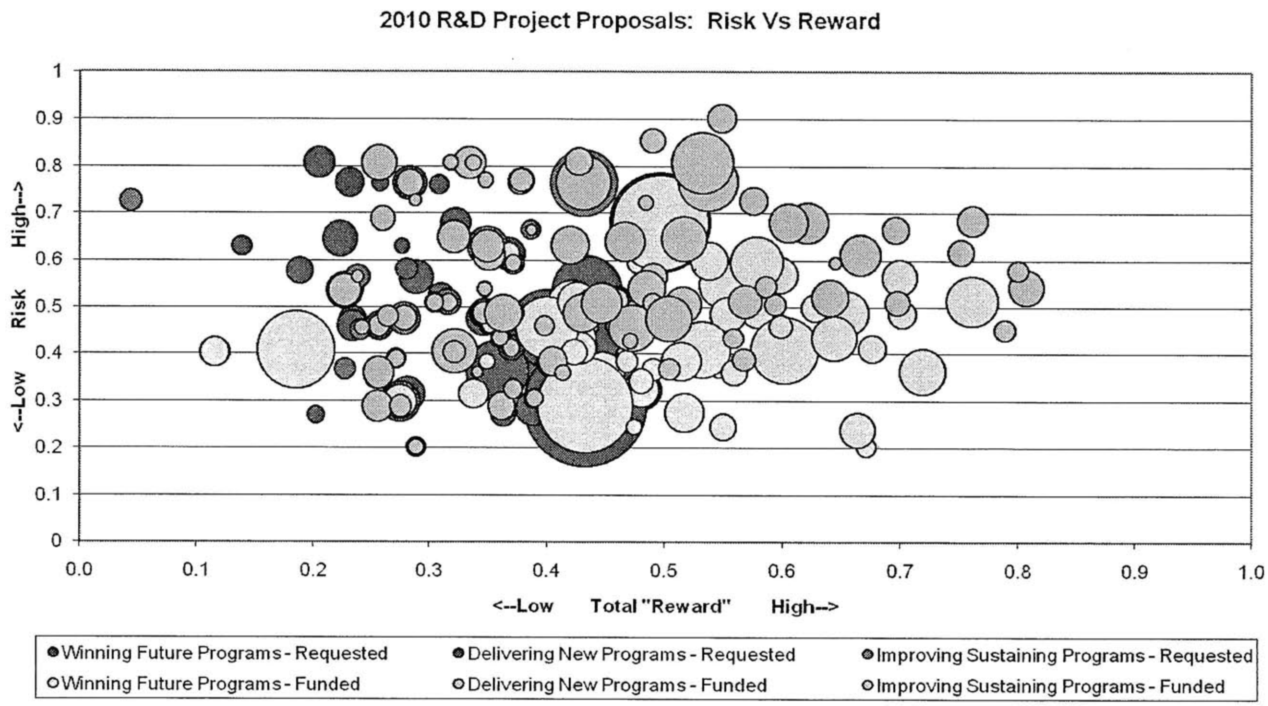

Figure 21 - Bubble chart of risk versus reward of Spirit's 2010 R&D portfolio

4.4.2.4 Executive Oversight

One of the key areas identified for improvement in the 2010 project selection process was to increase the amount of executive participation early on in the process to ensure strong alignment between the R&D portfolio and the strategic priorities of the company. A significant amount of work was put into creating a framework for how this process would work (as shown in Figure 8). However, time restrictions prevented the process from being formally run. As mentioned earlier, the 2010 process jumped into the framework at the Needs Identification stage. Strategic priorities and key initiatives were driving the needs that were collected during the workshop process, however they were not formally captured.

While the framework was not implemented at Spirit's headquarters, progress was made in using the framework at Spirit Europe as a trial for full implementation in the future. Due to the relatively small size and independent nature of Spirit Europe, it was an ideal location for this type of trial implementation. Spirit Europe's R&D staff met with local executives to document the strategic priorities of the division and flow those down into key initiatives. Once the key initiatives were identified, workshops were conducted in a similar fashion to the main Spirit process to flow those into needs and eventually ideas for potential projects. Results of the trial in Spirit Europe are quite promising and indicate that this type of framework can help to ensure R&D projects are well aligned with strategic priorities.

4.5 Challenges

As with any change to the status quo, a large number of challenges were encountered when attempting to implement a new R&D project selection process. This section explains some of those key challenges.

4.5.1 Resistance to Change

Resistance to change is human nature. That is amplified at Spirit by the complicated organizational structure that results in groups from multiple different divisions of the company all vying for a central pot of R&D funding. Many managers and employees agree to the changes in principle, but are still hesitant to execute on the changes because they are concerned that their piece of the funding pie might be reduced or eliminated. Additionally, some resistance is based on employees being fearful of the changes resulting in more work for them to do when they are already overworked.

This resistance to change resulted in many portions of the 2010 project selection process not being run according to plan and reverting back to the old way of doing things. For example, less than half of the workshops for capturing needs and generating projects were actually run. Instead, the informal methods from the past were used to generate many of the project proposals.

4.5.2 Strategic Thinking

Due to Spirit's history as simply being a cost center for Boeing, having to think about long-term, strategic issues is a relatively new concept. As the company's strategic plan grows and matures, this strategy needs to flow down to the R&D organization and help guide the decisions made within R&D. One way to accomplish this would be to implement the framework discussed in §3.4.1. The trial implementation of this framework at Spirit Europe showed promising results and suggests it can be successfully used in the future. A mature corporate strategy being used to guide R&D investment decisions will be a key step in ensuring that the R&D budget is spent as effectively as possible.

4.5.3 Finding the "Right" Formula

One of the most difficult parts of using a scoring model to prioritize R&D projects, as was implemented at Spirit, is to create a formula that accurately reflects the needs of the company and prioritizes the projects accordingly. This formula would ideally combine the scores of each criterion in such a way that both the relative importance of the criteria as well as the relationship between each criterion is captured. Many papers have been written which describe a formula that worked for one company or in one situation (see [13] for an example), but no formula will work universally. The process put into place at Spirit is complicated further by using worksheets to identify the scores for each criterion in the first place. The worksheets use those own formulas that need to produce accurate scores for each criterion before the final formula can go to work combining the scores appropriately.

The worksheets and formula implemented at Spirit were the result of working with key members of the R&D organization to best reflect the needs of the company. Several iterations were used to eventually reach the final formula. As early project proposals were submitted, the formula was evaluated to ensure that the results were consistent with management expectations and changes were made as necessary. The final list of projects was reviewed and approved by R&D management to make certain that the formula provided reasonable results.

The best check of how well the formula worked will be to assess the efficacy of the portfolio that it produced after some time has passed. Evaluating the projects that the formula deemed to be high priority against how well those projects actually performed should provide valuable insight. This insight can be used to refine the worksheets and formula used in future years to ensure that they produce the best possible portfolio of projects.

4.5.4 Defining What "R&D Project" Means

At first glance, defining what constitutes a project seems trivial. However, it is not as straightforward as it seems. This is further complicated by an organization like Spirit's with R&D personnel working in many different areas. Upon reviewing lists of project proposals from different managers, it becomes clear that what one defines as a project, another would have rolled up as one of several deliverables in a higher-level project. Spirit had 170 project proposals for the 2009 selection process with requested budgets ranging in size by more than two orders of magnitude. With that large a range of projects, it is nearly impossible to compare them side by side.

For the 2010 selection process, efforts were made to provide guidelines for the approximate budget size and scope of a project. The hope was that the scoring model could evaluate projects more fairly when comparing two projects with similar funding requests instead of comparing the range of projects encountered in 2009. However, as this effort was not made a priority, the list of project proposals received was similar to what was seen the previous year. The number of proposals actually increased slightly to 178 with requested budgets still varying by more than two orders of magnitude.

The range of project size forced changes to be made to the scoring model to attempt to accommodate the larger projects. Otherwise, the default linear optimization used by Decision Lens would fund all of the smaller projects first since more total projects with a higher total score would result. The large number of projects is a burden on the project selection process, but also on the management of these projects throughout the year. Getting a more accurate and consistent definition of a project across the entire R&D organization and reducing the number of funded projects will be essential for ensuring high performance of Spirit's R&D in the future.

4.5.5 Getting the Attention of Executives

One of the priorities of the improvements being made to the 2010 project selection process was to get more executive input early on in the process. The hope was to avoid the problems encountered during planning for 2009 when the executives did not see the list of funded projects until the entire process had been run. When they objected to some of the budget splits, a lot of work was wasted in having to repeat earlier work and reallocate that budget.

Despite efforts being made during 2010 planning to bring the project selection process to the executive committee throughout the process, no progress was made. Spirit, as a company, needs to determine how much of a priority R&D is and allocate the time of its executives accordingly.

4.6 Recommendations for Future Improvements

Large strides have been made over the past few years in improving the process with which Spirit chooses its portfolio of R&D projects and how the R&D organization is run in general. This section provides recommendations for further improvements that can be made, based on observations made during time spent on-site working with Spirit employees.

4.6.1 Use Lean Principles

Spirit's R&D could benefit greatly by borrowing some of the concepts already used in its factories to create a lean R&D process, as described in §3.4.4. Some specific ways to apply the lean concepts are described below.

4.6.1.1 Continuous Process

R&D project selection at Spirit is run as an annual process. Only urgent new business needs result in projects being added mid-year. Instead, the R&D portfolio should be continuously evaluated and adjusted. Needs from customers should be collected year round, instead of once a year in a workshop process, and potential projects for addressing those needs identified on a frequent basis. If a new project is identified that is determined to be higher impact than one that is currently funded, budget should be shifted accordingly. No longer should a project sit in a stagnant fashion for a year just because it received funding at the start of that year. The portfolio of projects that best meets the needs of the company should be worked at all times and adjusted to reflect the company's needs as they change.

One option for implementing this in an interim fashion would be to hold a sizable percentage of the budget as a management reserve when initially allocating budget. That reserve can then be used to fund high value projects mid-year. While this option would allow for new projects to be funded, it would not help to ensure stagnating projects have their budgets taken away and reallocated to more deserving projects.

4.6.1.2 Pull System

Significant progress was made in implementing a pull system within R&D. Every project proposal for 2010 had to be tied back to a documented customer need within E-Notebook. As well as this process worked on paper, some liberties were taken. Some needs were entered after the project had already been created, especially for carryover projects from previous years. Some projects were tied back to needs that they might not fully address or that they might not be the best solution for. However, a tool is now in place to help create a pull system. Following the process and using the tools that were created will help to ensure that future projects are truly pulled from customer needs.

4.6.1.3 Rotation System

Creating a rotation system within Sprit's R&D organization can accomplish multiple objectives. First, it will allow a balance between employees who are working under tight deadlines on program related R&D

from getting burnt out while helping to bring an enhanced sense of urgency to the core R&D functions. Second, as employees rotate through different roles, they will acquire new skills that will allow for improved flexibility in future R&D activities. Finally, employees who move across different parts of the R&D organization will gain an appreciation for work that is being performed in other areas and no longer fight so hard to keep any of their funding from being reallocated to those areas.

4.6.1.4 *Metrics and Feedback*

Identifying metrics that can be tracked and properly reflect the effectiveness of a given R&D project and R&D as a whole is not a simple task. However, with a powerful tool like E-Notebook in place, tracking these metrics becomes much easier. Spirit should more aggressively follow some of the metrics that are already available through E-Notebook, such as adherence to schedule and budget, and add functionality to track new metrics. These metrics should not only be tracked, but should be used to identify low performing projects and quickly eliminate those projects and move their budget to more deserving efforts.

This increased use of metrics will require breaking projects down into something similar to the three tiers proposed by Hauser in §2.6.2. The near real-time metrics that can be tracked within E-Notebook are most valuable for evaluating tier 3 projects. For early stage research that falls more in Hauser's tier 1, metrics such as those proposed by Hauser to reward research tourism will need to be implemented.

4.6.2 Initiative System

As discussed in §4.5.4, defining what exactly a project is has been a challenge for Spirit. Additionally, the large number of projects is a burden for both selecting and managing projects. Managers also complain about the lack of flexibility they have compared to previous years to adjust to changing business needs since their entire budget is tied to specific projects.

One way to mitigate this problem is to move to a system where budget is no longer assigned to specific projects. Instead, key initiatives can be created and receive funding. These initiatives would be actionable items that allow for goals to be clearly defined. Examples of initiatives at Spirit could be *Lower the cost of composite tooling* or *Reduce sustaining costs to the 787 program*. Once an initiative receives funding, a manger would then be assigned and tasked with choosing the specific projects, or actions, that need to be performed to meet the goals of that initiative.

Since tracking budget at the project level has been a valuable improvement for Spirit in recent years, the manager responsible for a given initiative would still need to allocate his or her budget down to the project level, but would have some amount of discretion in doing so. Once the budget is allocated, both project and initiative level budgets could be tracked in E-Notebook. The manager could decide to move budget between projects after it is allocated, but would first need to justify that decision to the Director of R&D and receive approval.

4.6.3 Incentive Structures

Spirit has struggled with employees across various parts of the R&D organization fighting to always get as much funding as possible for their particular function, regardless of how critical other budget requests are. While it makes sense for the company as a whole to fund the most critical projects regardless of which groups they come from, individual employees are concerned about losing funding compared to the past and possibly being deemed expendable.

The rotation system described above can help with responding to budget being allocated to different groups from year to year, but a new type of incentive system would help to get employee buy-in. An incentive structure could be created where employees are compensated based on the successes of R&D as a whole, solidifying the one-company R&D attitude. With this type of incentive system, employees would actively seek to allocate budget to the most deserving projects so that R&D would perform better and the employees would receive higher levels of compensation as a result.

4.6.4 Organizational Structure

Many of the challenges and problems surrounding Spirit's attempts to improve its R&D organization relate back to the organizational structure of R&D at Spirit. This structure was discussed in detail in §4.1.3.2 and shown in Figure 13. The main problem is that R&D personnel report up through three different representatives to the executive committee. As seen in Figure 22, the R&D group underneath the Chief Technology Officer (CTO) includes core R&D functions such as chemicals and advanced research, but also includes groups focused on technology applications within the Propulsion and Fuselage business units. In contrast, some core R&D functions, such as non-destructive inspection (NDI) and automation report up through the Fuselage business unit. Further problems are encountered with overlap between the scope of some groups, such as composite fuselage technology development, which is done underneath the CTO as well as within both the Fuselage and Aerostructures business units.

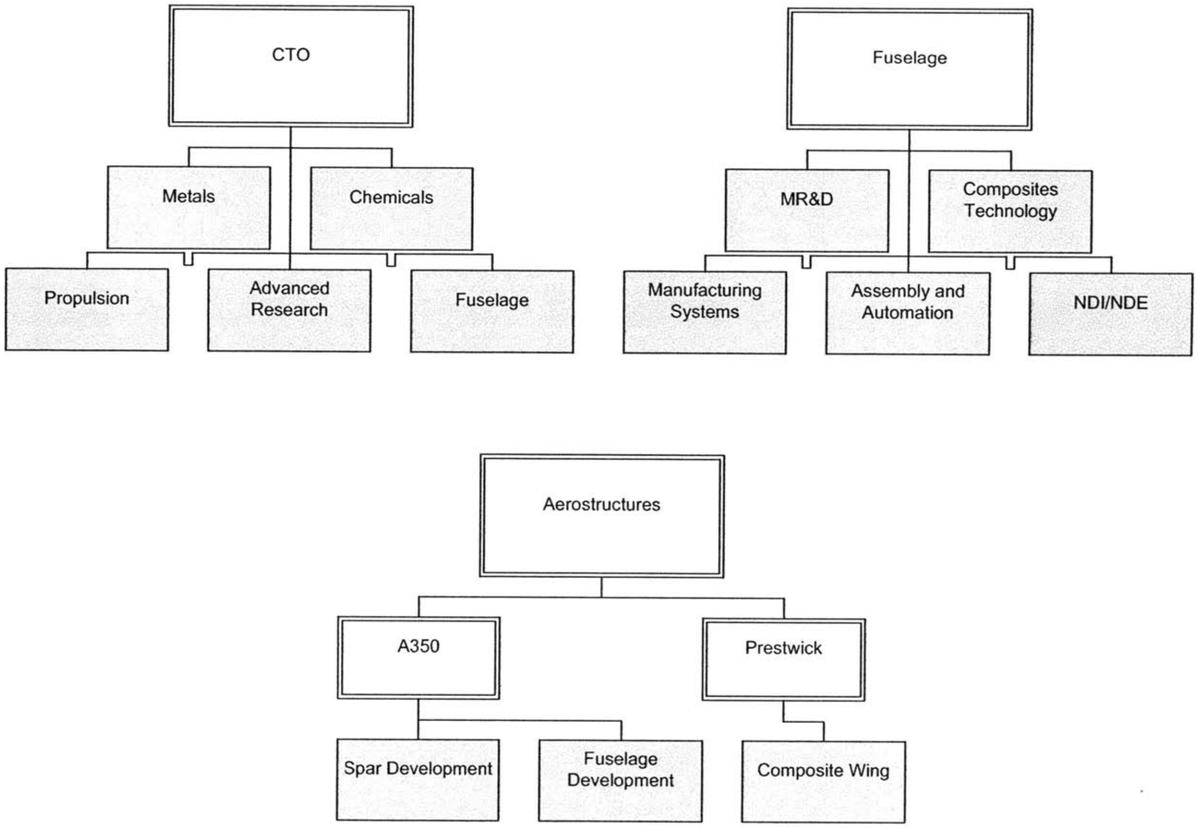

Figure 22 - Cartoon of current Spirit R&D organization

To create a more effective R&D organization and eliminate some of the power struggles that currently exist, Spirit needs to move to a true hybrid organizational structure as shown in Figure 23. The core technology development area underneath the CTO should house all of the groups focused on technology—things like chemical, NDI, automation, and advanced research. The R&D groups in each business unit should focus on application of technology. Employees may have to move around or deal with some temporary soft-line reporting assignment as they apply technology to different programs, but the overall effectiveness would be greatly improved. Any redundancies in function would be eliminated and each group would know exactly what its goal is and how it can help the company succeed.

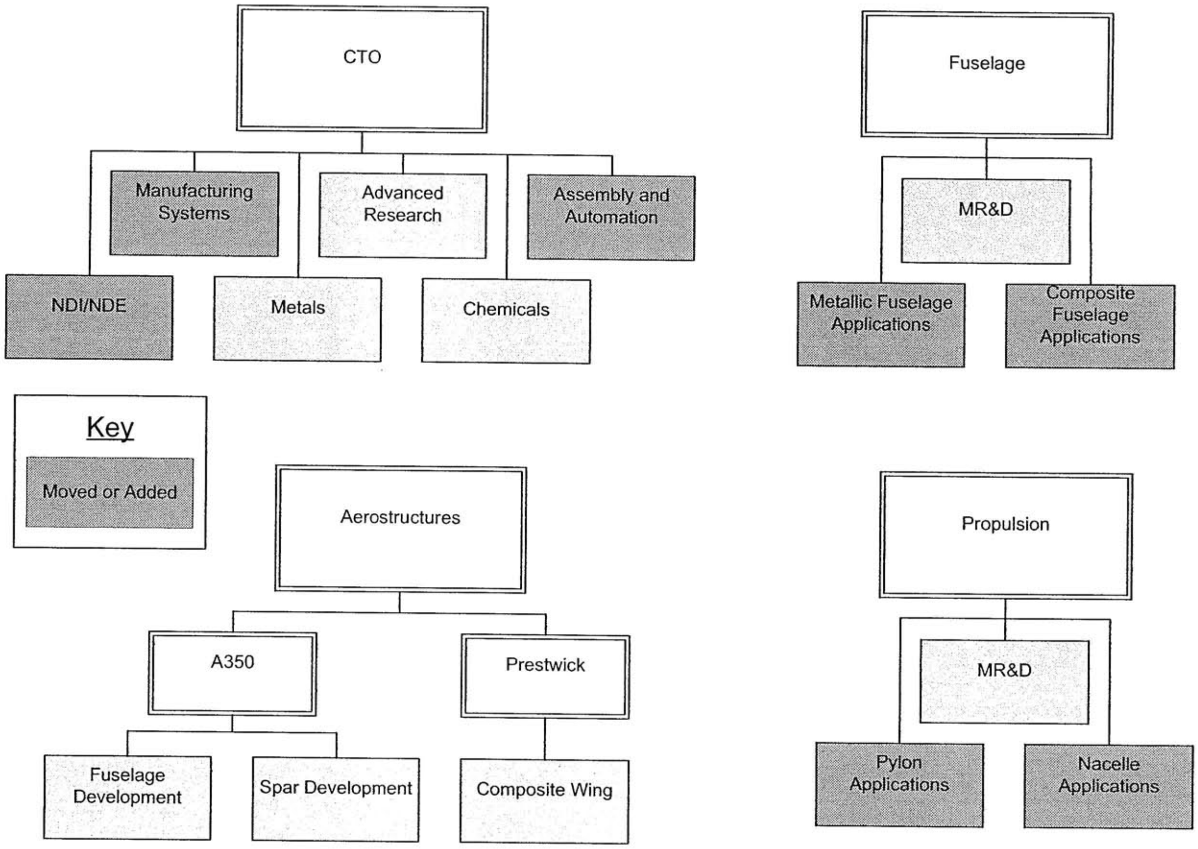

Figure 23 - Proposed future organization of Spirit R&D

4.6.5 Summary

Spirit's R&D project planning process has been constantly evolving and improving since Spirit became a company in 2005. As a supplier to major aircraft manufacturers, Spirit is faced with the challenges of performing R&D as a supplier (as discussed in §3.3), as well as some additional industry specific challenges. Spirit also faces issues of its own because of its history as a former Boeing site and the resultant culture. The author spent six months working on-site in an effort to further evolve the project planning process, help create the best possible portfolio of R&D projects for 2010, and offer suggestions for further improvements. This chapter documents the existing state of Spirit's process upon the author's arrival, the improvements made to the 2010 process along with challenges faced in the process, and a number of suggestions for ways to further improve R&D at Spirit.

5 Conclusion

5.1 Key Findings

During the course of this research effort, a significant amount of learning occurred, both tangentially and directly related to the topic. Many of these learnings can be generalized into useful information for any firm looking to change their R&D selection process. These key findings are summarized below:

Implementing change is extremely difficult. During the author's research at Spirit AeroSystems, roughly half of the project was spent studying the organization and creating an improved process and half was spent attempting to implement that process. While the process that was created is arguably quite good and has the potential to have a positive impact on the company, the implementation of that process did not go smoothly. Several more months could have been dedicated to implementing the process and likely still not completely accomplished that task. Realistically, when working with any established firm, a 50/50 breakdown between process creation and implementation may not be appropriate. Instead, something on the order of a 70/30 or even 80/20 breakdown in favor of the implementation portion of the project may be suitable. Additionally, dedicating time either before or at the beginning of the implementation period to gain buy-in might have cut down on the overall implementation time.

Aligning R&D projects and initiatives with key strategic goals is critical. This sentiment can be found again and again in the literature, but it was even more apparent when working with Spirit's R&D team to choose their project portfolio. One part of this goal that may often be overlooked is that the R&D team cannot accomplish this task alone, but instead needs the help of the firm's executives to lay out those strategic goals and work with R&D management to determine how R&D can help achieve them. The R&D team can do a significant amount of work trying to interpret the firm's strategy and figure out how R&D can help meet those goals, but without the executive team dedicating some time to the R&D portfolio planning process, the portfolio will not be as well aligned with the firm's strategic goals.

A well-defined innovation strategy is important. This thesis frequently discusses customer needs being used to pull technology from R&D and eliminate pursuing technology for the sake of technology. While this is generally true, the extent to which a firm focuses on this should be consistent with the innovation strategy that it has in place. The innovation strategy can lay out issues like how much of the firm's portfolio should be spent on breakthrough innovation versus operational improvements. A firm's innovation strategy should be closely aligned with the overall corporate strategy and can be used to help guide many important R&D policy decisions that are often made in the moment without completely considering the full implications of those decisions.

Market intelligence is a useful complement to R&D. While it is easy to think of R&D employees as sitting locked in a lab oblivious to the outside world, it is incredibly valuable for those employees to be well informed of both technology developments across the industry and the ever-changing needs of the end customer. Knowing all of these things is incredibly difficult. A good market intelligence group can be a valuable asset to the R&D team by working to learn these things. For a supplier firm, the market intelligence group can work to learn not only the needs of the OEM customer, but also reach past the OEM to discover the needs of the end customer. The market intelligence group can also help R&D keep informed on technological developments at other firms in the industry and even within academia. All of this information can help the R&D organization to create a better technology roadmap which will lead to better technology strategy and ultimately a more successful R&D effort.

Never underestimate the value of good tools. Much of the success in implementing process changes at Spirit can be tied back to the E-Notebook tool in place there. A good tool such as E-Notebook can help to ensure the process is being run according to plan. Once a tool like that is in place, any process changes can be driven by changing the tool itself. Personnel can be informed of process changes, but the updates to the tool ensure that the new process is followed.

5.2 Opportunities for Future Work

There are several potential areas to continue the research discussed in this document and build on the findings. The first area would be to continue the work begun at Spirit AeroSystems. This would involve continuing to implement the future changes described in §4.6 and improve upon the existing project selection process. Metrics should also be implemented that allow the effectiveness of the R&D portfolio to be measured and improvements documented as changes are made. A multi-year study that documented the effects on Spirit's business over time as improvements are made to its R&D process would be informative and beneficial as well.

Along with continuing the work at Spirit, there are also opportunities to expand this research to other firms. Using the hypothesis that no single process will work at every firm but that the guidelines presented in this document can aid firms in building their own process, process changes should be implemented at firms to verify that these guidelines work at other firms and in other industries. Metrics can also be put into place at these firms to track and verify the success of any changes that are implemented.

Finally, based on additional work performed at Spirit and at other firms, the guidelines and suggestions presented in this document should be revisited. Any new findings for techniques or processes that help firms to improve their R&D project selection process and increase the overall effectiveness of their R&D organization should be captured and described in follow-up efforts.

5.3 Closing Remarks

R&D project selection and portfolio management is not a simple task. There is no one size fits all solution to the problem that can be implemented at any firm to increase the effectiveness of its R&D dollars. Industry and firm-specific challenges are such that each firm must customize its process to match the firm's priorities and ensure that R&D spending goes towards the best projects for the firm. Suppliers are faced with additional challenges in performing R&D and have to work even harder to ensure that their R&D dollars are spent as efficiently as possible.

While there is no magic bullet that will solve every firm's problems, there are general guidelines that can be used to help guide the creation of a new process. These guidelines, presented in chapter 3, are not a perfect answer either, but they at least provide a place to start when coming up with ideas for how to improve a firm's process. While many of these ideas may be appropriate for the R&D function at any firm, they are aimed specifically at suppliers. Along with taking into account the additional uncertainties faced by suppliers, these guidelines assume the suppliers have a conservative R&D strategy—a strategy that emphasizes projects from Hauser's third tier and does not lead the firm to engage in a significant amount of basic research. This approach will not always be the appropriate R&D strategy for all firms or even for all suppliers, but it was appropriate to implement at Spirit during the trial discussed in this thesis.

When it comes to R&D process design, what is really important, more than any technique for measuring a project's value or algorithm for comparing different projects, is simply a firm's realization that their current process is not as effective as it could be. This realization, along with a willingness to change, will drive more improvements to the R&D organization than any one method or process change.

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Appendix 1 – Worksheets Used for Determining Project Scores

Intellectual Property Potential

1 Will the project generate IP for the company?

Yes
No
Maybe

2 What is the value of the potential IP?

Significant
Above Average
Average
Below Average
Low

3 Will external collaboration be a part of the project?

Yes
No
Maybe

Financial Impact (Short Term Projects Only)

(Inputs allows for rough NPV calculation)

1 What is the primary program for the project?

2 How many hours are saved per unit?

3 How much money is saved per unit on non-labor costs?

4 How much money is saved per unit on quality improvements?

5 What is the one-time non-recurring cost avoidance?

6 What is the anticipated year of implementation?

Financial Impact (Long Term Projects Only)

1 What is the starting TRL level of the project?

2 What is the projected ending TRL level of the project?

3 What year will the projected ending TRL level be reached?

4 What is the primary product and program for the project?

5 What is the projected impact of the technology on the program?

Required for program delivery
Required for program win
Significantly increases likelihood for program win
Increases likelihood for program win
Minimal impact for program win
No impact

Product Performance

(These questions are industry specific)

1 How will the technology affect future product weight?

The technology will significantly affect the weight of an end-item product
The technology will have an effect on an end-item product
The technology will have an effect on a sub-assembly
The technology will have an effect on a detail part
The technology will have no effect on the weight

2 How will the technology affect future product noise levels?

The technology will have a significant effect on the exterior noise level
The technology will have a significant effect on the interior noise level
The technology will have an effect on the exterior noise level
The technology will have an effect on the interior noise level
The technology will have a minor effect on the noise level
The technology will have no effect on the noise level

3 How will the technology affect the initial purchase cost from an OEM?

The technology will significantly affect the purchase price of an end-item product
The technology will have an effect on the purchase price of an end-item product
The technology will have an effect on the purchase price of a sub-assembly
The technology will have an effect on the purchase price of a detail part
The technology will have no effect on the purchase price

4 How will the technology affect the interval or cost of standard repairs?

Significant
Above Average
Average
Below Average
Low
None

Risk

(These questions are industry specific)

1 What is the current TRL (technology readiness level)?

2 Rate your confidence on project completion within scheduled timeframe?

High probability of completing on schedule
Slight chance of schedule overrun
Unknown variables with schedule uncertainty
Many unknown variables with significant schedule uncertainty

3 Is the technology current accepted by the aerospace industry?

Currently used within Industry
Currently being pursued within the Industry
Currently used in a related Industry
Currently unknown use or technology

4 What is the known level of activity in this technology outside the company?

There is no effort outside of the company in this area
Others in industry or academia may be working in this area
Others in industry or academia have worked in this area
A known patent exists

Environmental Health and Safety Impact

1 What is the environmental impact of the project?

Required to meet a released environmental regulation
Required to meet an anticipated environmental regulation
Directly improves the environment
Indirectly improves the environment through monitoring and testing
Provides minimal improvement to the environment
Does not impact the Spirit environment

2 How confident in the proposed solution are you?

Required to meet a released safety and health regulation
Required to meet an anticipated safety and health regulation
Directly improves the safety of our workforce
Indirectly improves the safety or our workforce through monitoring
Provides minimal improvement to the safety of our workforce
Does not impact workforce safety

3 What is the ergonomic impact of the project?

Addresses operation with recorded lost work day case
Addresses operation with recorded injury cases
Directly improves ergonomics conditions

Indirectly improves ergonomic conditions through monitoring and testing
Provides minimal improvement in ergonomics
Does not impact ergonomics

Sponsorship

1 How vital are the issues associated with the project?

Short term projects only
Issue could potentially halt production
Issue is seriously affecting production
Issue has a noticeable impact on production
Issue is a nuisance
Issue does not affect production

Long term projects only
Requirement is essential to multiple future programs
Requirement is essential to a single future program
Requirement is an important concern for future programs
Requirement is a general concern for future programs
Requirement is a minimal concern for future programs

2 How confident in the proposed solution are you?

Confident and completely behind the approach
Behind the approach
Not confident, but will back approach
Not confident and will not back approach

3 What is the likelihood of implementation of a successful solution?

It will be implemented
Very likely to be implemented
Should be implemented
Significant hurdles to overcome
This will not be implemented

4 How widespread is the impact of the solution?

Vital to a single operation
Vital to a single line
Vital to a value stream
Vital to a business unit
Vital to entire company

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