CRAFTING R&D PROJECT PORTFOLIOS

Appropriate management of three types of real options can produce a portfolio of projects that will deliver today's profits and tomorrow's growth.

Ian C. MacMillan and Rita Gunther McGrath

OVERVIEW *Uncertain, but promising, R&D projects should be treated as one of three types of real options, depending on their degree of technical and market uncertainty. Positioning options are designed to preserve a company's future right to compete in a highly uncertain technological arena. Scouting options are used to create information about customer needs and market conditions. Stepping-stone options provide a technological path forward for an organization's long-run technology strategy, while containing cost and risk as new knowledge is created. Corporations rarely distinguish between such options and product launches or line extensions, with the result that they are managed and valued inappropriately. The guidelines provided here can not only help determine the right category for individual R&D projects, but also enable designing a portfolio of projects that is consistent with a firm's technology strategy.*

Readers of *Research · Technology Management* are by now familiar with the argument that highly uncertain technology projects are better assessed by using options logic than by more conventional approaches, such as deriving their net present value (*1,2,3*). R&D projects can be viewed as the technological analogy of a financial options contract if they meet certain conditions. Provided that they represent a limited downside investment that gives a company a privileged position to create a commercial product at some point in the future, projects can have substantial potential value under uncertainty. This is so even if it isn't quite clear what that future asset is going to deliver in terms of profits or revenues at the time of the original investment.

Because so much of the value of highly uncertain projects lies in the future, it is hard to know when, or whether, they are going to pay off. This creates enormous stresses in the resource allocation process for most companies. Given finite resources, how can R&D managers choose between projects that have a near-term and quantifiable outcome and projects whose returns are

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hard to estimate and far-off in time? Particularly when resources are stretched thin, it is common for companies to focus too much on extending their existing technological bases, thus under-investing in the future.

It is also not unusual for all projects to be treated as though they were substantially the same, even when they have different levels and types of uncertainty and serve different strategic purposes. Such useful tools as stage-gate management processes don't really help resolve the fundamental question of what the whole portfolio of projects should look like for a given company.

Market and Technological Uncertainty

An important distinction that is seldom explicitly made with respect to R&D options is that their purpose and nature are not the same. Some options are taken out to preserve a company's opportunity to compete in some future and still unclear technological arena. Because these essentially position the company to make further moves, we call them positioning options. They are quite different from options in which one invests in order to learn about the market by probing or offering prototypes to potential early adopters (*4*). We call such options scouting options, because they help a company scout out potential opportunities. A final category of options are highly uncertain on both market and technological dimensions, but have the potential to open entirely new classes of opportunity for the firm. We call these options stepping-stone options because they represent steps toward a highly uncertain future. As their name suggests, when properly managed, they are contained investments that systematically build both market insight and technical competence to move a company forward without exposure to potentially catastrophic downside risks.

In highly unpredictable situations, smart companies have learned that the best way to make sure they are able to respond effectively to future challenges is to deploy patterns of options. Rather than making a single big bet on one means of access to an attractive opportunity, they have found that it makes more sense to fund a number of small ventures intended to capture market opportunity in different ways. Thus, established firms such as Intel and Microsoft might take multiple equity positions in startups pursuing similar solutions, research consortia supported by multiple firms might explore various alternative solutions, and joint ventures entered into by a wide variety of players might employ technology-sharing arrangements. Just as you might think of your company as a portfolio of businesses, there is a lot to be said for thinking of the initiatives you are pursuing within a given business as a portfolio of options.

This brings us to a point of departure for making the assessment of what your own R&D portfolio should look like. First, we develop a simple categorization scheme

Think of the initiatives you are pursuing within a given business as a portfolio of options.

for the three kinds of options (and also for less uncertain investments in enhancements and major platform launches). This categorization scheme is depicted in Figure 1, which provides a simplified structure for depicting your entire R&D portfolio at any given point in time. To map the portfolio, you next need to categorize all the projects you are currently working on into the five different types depicted in Figure 1. To do this, you need to assess the nature of the uncertainties faced in each project.

Is the issue one of determining whether the technology will work in the field, whether it will scale, whether complementary technologies will be ready in time or what the standards will be? These are issues of high technical uncertainty. Notice that they are very different questions than trying to figure out what need the technology really addresses, who will buy it at what price and in what frequency, and how best to get to that customer. These issues reflect market uncertainty.

A simple way to estimate the level of market uncertainty is to use the questionnaire in Table 1. Ideally, a multifunctional group comprising R&D, engineering, operations, marketing and sales would venture their opinions on those responses for which they are qualified. Discussing major differences between the responses of different team members helps highlight important information known to some but not others.

For each project, calculate the average of your scores and then assign each average according to the rule below:

Average less than 3:	Low market uncertainty
Average between 3 and 5:	Medium market uncertainty
Average 5 or more:	High market uncertainty

Next comes the assessment of technical uncertainty. Different issues, same idea: Ask yourselves how certain you are about each of the issues listed in Table 2.

As before, input from multiple functions is more valuable, and once again, people should not reply to sections that don't apply or that they don't know.

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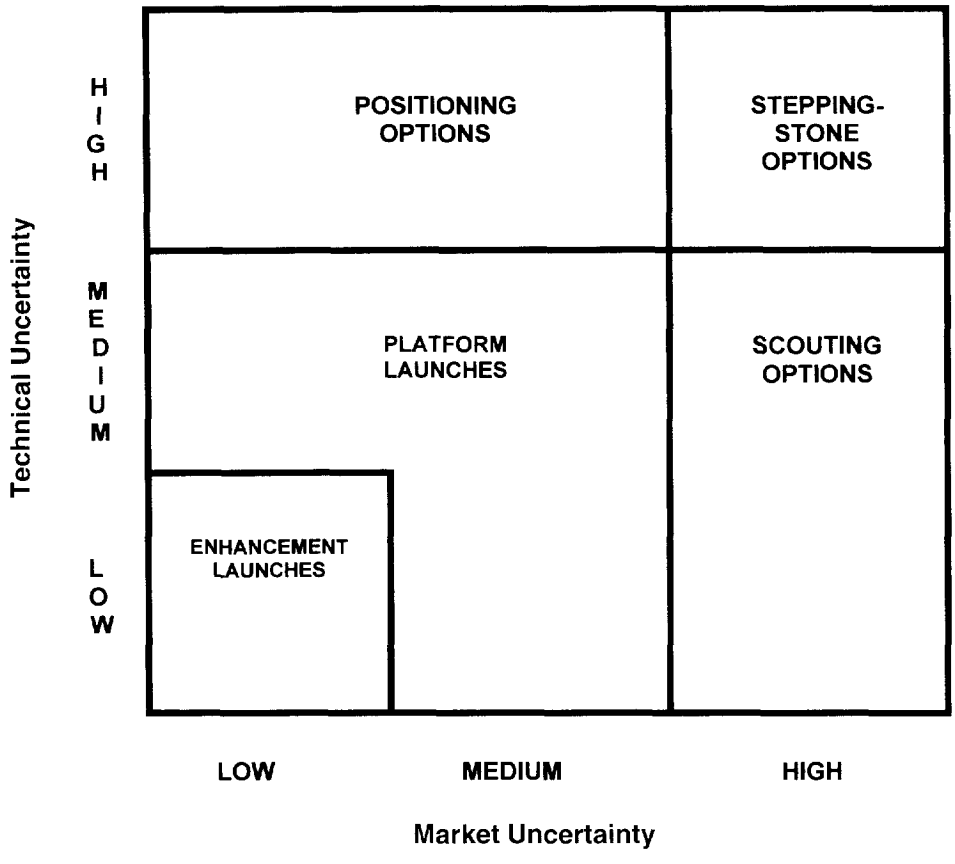

Figure 1.—There are five types of R&D projects, depending on the degree of technical and market uncertainty.

As before, for each project, calculate the average of your scores and assign each average according to the rule below:

Average less than 3:	Low technical uncertainty
Average between 3 and 5:	Medium technical uncertainty
Average 5 or more:	High technical uncertainty

These procedures are deliberately a little rough-and-ready because, in highly uncertain situations, you need an inexpensive, quick means of structuring the decisions you need to make. We have found simple tools such as those we recommend here to be far superior to more elegant ones that serve mostly to take up shelf space in an untouched binder. With scores in hand, you are now ready to categorize each of your projects into one of five types: positioning options, scouting options, stepping-stone options, launches, or enhancements.

Positioning Options

Positioning options represent cases in which the level of technical uncertainty is high but you have some confidence that you know which markets and segments you eventually want to serve. Your uncertainty may stem from a lack of knowledge with respect to the feasibility of a major technical development step, from the lack of confidence that a particular technology trajectory is feasible, the lack of confidence as to which of several alternative technology trajectories to follow, the lack of a dominant design or standard, or from issues such as the regulatory acceptability of certain technologies. Because the major uncertainties have to do with alternative technological solutions, the idea is to take a minimal number of positions to hedge against making a single wrong bet, thus containing the damage done if any one position does not work out.

Positioning projects are most appropriate under two conditions. First is when you are uncertain what the trajectory of development of a technology is likely to be, so you make small "initiating" projects that you use to uncover that trajectory. Second is when there are several competing technologies that could satisfy a predictably high-potential market demand, but it is not yet clear which technology will dominate. You can't afford to pursue all technologies aggressively—this would be too expensive, yet you cannot afford to end up losing the market by betting on the wrong technology.

Consider mobile telephony in the United States. As of this writing, there are four or more different communi-

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Table 1.—Evaluating Market Uncertainty

How certain is YOUR TEAM of the following? Score on scale of 1 (certain) to 7 (highly uncertain).*
Market demand for future products using the fruits of the project
Total future revenues from these products
The stability of the revenue stream generated
Extent to which you will be able to obtain needed support from distributors and suppliers
Extent to which premium pricing can be expected
Extent to which premium pricing can be sustained
The speed with which products will be accepted in the market
The speed with which products will be approved by necessary regulatory bodies
Who the major competitors will be
The probability that competitors will rapidly imitate us
The probability of other technologies matching our offerings
The probability of having our technology blocked by others
Whether the technology has the potential to be licensed
Degree to which we will have to constantly change designs
The degree to which parallel technologies will be needed
Whether such parallel technologies will be available in time
Degree to which technical specifications will be required in the industry
Degree to which technical specifications will be standardized in the industry
The probability of profits being disrupted by third-party intervention (governments, distribution channels, labor unions, etc.)

*Do not answer where you do not know.

Table 2.—Evaluating Technical Uncertainty

How certain is YOUR MANAGEMENT TEAM of the following? Score on scale of 1 (certain) to 7 (highly uncertain).*
The time it will take to complete development
The type of skills needed for development
The availability of necessary skills
The cost of staffing those skills
The type of equipment needed for development
The availability of equipment needed
The cost of equipment that is needed
The systems needed for development
The availability of systems needed
The cost of systems needed
The raw materials that will be needed
The availability of needed raw materials
The cost of raw materials
Total costs of development
The infrastructure that needs to be created
Our ability to access necessary complementary technologies
The cost of access to needed complementary technologies
The technology barriers we will face
Our ability to overcome technology barriers we will face
The cost to overcome technology barriers
The required level of product quality
Required levels of support and service
How much production capacity will be needed
The commitment level of senior management

cation standards and massive uncertainty about which will ultimately become *the* standard. The plausible scenarios include: (1) a lock-in on one of the three standards, (2) preservation of the current multistandard system, and (3) the emergence of some new standard or way of communicating that makes the current mobile concept obsolete. Given such uncertainty, a sensible route for an R&D program to take might be to make modest investments that will prepare the firm for pursuing any of the three scenarios. We see this, of course, in practice, as telecom companies engage in a vast array of mergers, acquisitions of smaller firms and joint ventures and alliances with larger firms while also aggressively lobbying regulatory agencies and making investments in the development of standards.

The two reasons to select a positioning option are therefore to generate knowledge that tells you whether a particular technology trajectory is possible and/or to buy time, flexibility and capability to pursue the best course of action once it becomes clear.

Ideally, positioning options are low-cost probes of alternative technological directions, such as experimental programs to probe the potential to develop a new technology. If pursuing several alternatives starts to look expensive, it may be possible to lay off the risk via cross-licensing or technology access deals, joint ventures for commercialization of new technologies, or joint marketing agreements. Of course, if money is no object, one can be a lot more aggressive in staking out positioning options. AT&T for instance, has spent billions of dollars on capturing attractive positions, acquiring cable companies such as Tele-Communications and MediaOne in 1998/1999, entering joint venture agreements with British Telecom and Japan Telecom, and setting up deals with Microsoft for set-top box software. Whatever happens in the telecommunications industry, AT&T is likely to have some options in its portfolio that will position it to participate. "Guidelines for Managing Your Options," next page, provides guidelines for managing positioning option projects.

Scouting Options

Scouting options are used when you are confident you can develop the technology but you are not sure which combination of attributes the market will eventually prefer. The core questions you seek to answer with scouting projects concern how future markets will be segmented and what would be the way to develop technology applications for these emerging segments. The guiding principle is to get some prototype offering into the hands of customers in order to get feedback on their reactions to its features.

Scouting options allow you to explore new terrain from your current technology base, gathering information on

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Guidelines for Managing Your Options

Managing Positioning Options

1. Identify the major problems that the proposed technology could solve.

2. Develop the major scenarios that would make a positioning investment worthwhile, looking at the number and scale of the major problems that will be solved by the solution that the proposed project will enable. Build a convincing argument to show why taking one or more positioning options is called for.

3. Identify the full array of possible technological solutions that have potential to provide solutions to the problems.

4. Identify all the alternative technological bases that need to be covered in case the proposed positioning play does not work out.

5. Assess whether these other bases can be covered by taking options with other players—by means of alliances, joint ventures, cross-licensing agreements.

6. Make sure that you are not over-investing in this position—be sure you are covering alternative positions.

7. Using a planning approach along the lines of stage-gating, clearly identify what technical results need to be accomplished and what data you will use to track results.

8. Identify which data will be tracked to monitor the progress of competing technical solutions. Put in place a rigorous intelligence system to capture, interpret and make decisions based on these data.

9. Specify clearly which data you will use to let the option expire by discontinuing. This is critical—projects that are not accomplishing target outcomes or are losing out to competing technologies must be shut down so as to deploy resources, particularly talent, to other projects.

10. Make sure that a system is in place to ensure that information from steps 7, 8 and 9 is delivered in a timely way to a person with authority to decide whether to continue the option(s) or to let them expire by discontinuing one or more.

11. This person must be in a position to make an objective decision to continue or shut down—it is very difficult for the person in charge of an option to discontinue it.

Managing Scouting Options

1. Identify as many applications as you can of the technology.

2. Use these to identify possible major markets and assemble small experimental probes deliberately designed to capture data about the market's reaction to the product.

3. Insist on design parsimony—spend as little as possible to gather specific information about the reaction of the scouted market.

4. Specify a clear business model—what the value added of the technology will be that will generate revenues and drive profits.

5. Specify how you will be using the scouting option to test the validity of the business model.

6. Ruthlessly reject proposals that suggest you develop the whole business to determine whether there is market demand or where no business model is proposed. The initial business model is seldom the final one, but the option needs to continuously test both the initial and evolving models for validity.

7. Specify the major assumptions about the market and the business model and decide where you can test the assumptions during the scouting option.

8. Ensure that you have plans to scout in markets that are different from your current segments and that you are

its most attractive application. Scouting options differ from positioning options in that they extend your evolving technologies into application arenas that could allow you to capture significant market opportunities. The primary reason for selecting a scouting option is to learn.

It can not be stressed enough that these options should be consciously managed as scouts—that is, they are meant to be *small* investments made without expecting an immediate payoff. You use them to learn, to gather information. The idea is to send out your scouts using the smallest possible fixed investment or sunk cost and to then redirect your efforts after you find the most promising path.

Scouting is an area in which large companies often make mistakes that small entrepreneurial companies avoid, simply because the large firms have more money to spend. Redirection becomes much more difficult when you load yourself down with heavy fixed costs or massive sunk investment. Even fabulously well-researched and technically brilliant new products can disappoint in the marketplace. Not investing enough in scouting has been deadly for many technology-push kinds of ventures, such as the original launch of the Iridium world phone concept, which consumed over $7 billion to produce clunky, expensive phones that businesspeople could not use indoors.

It is crucial not to assume that you know what the customer wants. Your team of scientists and engineers should be encouraged to go out and actually talk to, and observe, the customers using the current products or prototypes before deciding on the direction of development of applications. See "Guidelines," above.

Stepping-Stone Options

Stepping-stone options commence with small exploratory forays into less challenging market niches and use

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scouting not only for lead users but for the mass market as well.

9. As soon as responses are garnered from lead users, push them hard to establish why they adopted the offering so as to tease out where the real applications are.

10. Identify which data will be tracked to monitor the progress of competing technical solutions. Put in place a rigorous intelligence system to capture, interpret, and make decisions based on these data.

11. Specify clearly which data you will use to let the option expire by discontinuing. This is critical—projects that are not delivering target outcomes, or are losing out to competing technologies, must be shut down so as to deploy resources, particularly talent, to other projects.

12. Make sure that a system is in place to ensure that information from steps 7, 9, 10, and 11 is delivered in a timely way to a person with the authority to decide whether to continue the option(s) or to let them expire by discontinuing one or more.

13. This person must be in a position to make an objective decision to continue or shut down—it is very difficult for the person in charge of an option to discontinue it.

Managing Stepping-Stone Options

1. Identify several early possible applications of the technology that do not challenge the technology too much.

2. Use these to identify a possible early, non-demanding market—even a small market—that will genuinely benefit from what you are proposing to offer.

3. Assemble small experimental probes deliberately designed to (a) capture data about the market's reaction to the product and (b) learn how to apply capability of the technology.

4. Insist on design parsimony—spend as little as possible to gather specific information about the useful features of the technology and the reaction of the experimental market.

5. Develop a program whereby you stage and sequence the project in a way that redirects the program toward unfolding opportunities.

6. Develop clear metrics that, rather than measure revenues and profits, initially measure learning progress. This is done by specifying at each stage which assumptions about markets and the technologies capabilities will be tested.

7. Ensure that rather than conventional measures of success, evidence of learning is used to assess progress.

8. At each stage, assess what has been learned, then design the next stage by selecting a more challenging technology requirement for a larger, more demanding market.

9. Define, and be alert for, indicators that a major opportunity is opening up.

10. Identify which data will be tracked to monitor the progress of competing technical solutions. Put in place a rigorous intelligence system to capture, interpret and make decisions based on these data.

11. Specify clearly which data you will use to let the option expire by discontinuing. This is critical—projects that are not accomplishing target outcomes or are losing out to competing technologies must be shut down so as to deploy resources, particularly talent, to other projects.

12. Make sure that a system is in place to ensure that information from steps 7, 8 and 9 is delivered in a timely way to a person with authority to decide on whether to continue the option(s) or let them expire by discontinuing one or more.

13. This person must be in a position to make an objective decision to continue or shut down—it is very difficult for the person in charge of an option to discontinue it.

the experience gained there as stepping-stones to build technologies in increasingly challenging and attractive market arenas discovered as you go. Investments in stepping-stones are thus made as a series of deliberately staged and sequenced real options.

Managing such investments calls for the kind of discipline used by venture capitalists, in which funding decisions are made only when key milestones are reached and a great many assumptions have been tested. As each milestone is reached, you have the opportunity to stop further development or to sell, trade, license, or otherwise attempt to gain some returns on investments in technological and market development to that point. The idea is to keep each successive round of investment to an absolute minimum, to reassess the project frequently, and to be willing to redirect it.

With stepping-stone options, the organization has a lot of learning to do on both market and technical dimensions. You should not necessarily expect to make profits from these early forays. They are your sacrificial products, and you need to prepare yourself for the fact that they are unlikely to be successful right off the bat. The idea is to follow Silicon Valley's famous principle for learning: "Fail fast, fail cheap, try again."

The primary difference between stepping-stone and scouting options is that scouting options involve technology that your R&D people are confident can be developed. Stepping-stone options focus on the creation of a new technological competence base in what seem to be irresistibly attractive opportunities. As this competence base develops, the new skills are used to progressively enter specialized sub-fields or new niche markets. This is done deliberately to develop experience and generate cash flow, sometimes with no intention of remaining in the early markets once the competence is sufficiently well developed. In this way, you can make deliberately parsimonious resource allocations designed

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to pursue carefully selected and increasingly challenging opportunities, with the objective of developing a new competence along an increasingly sophisticated trajectory and deploying it in unfolding markets.

The Sanyo Corporation, for example, used this approach to pursue the solar cell business. When energy conversion from light to electricity was in its early stages and hugely inefficient, instead of investing to crack high-level applications like solar panels for factory heating, Sanyo initially invested in low-end applications for known niche markets in which conversion efficiency was irrelevant. For instance, by focusing on light cells for wrist watches and calculators, the company generated modest cash flows while resolving considerable technical uncertainty with respect to cell construction and conversion efficiency. This created an initial technological competence which, as it evolves, is taking Sanyo along a trajectory of increasing technical sophistication in higher-end applications of light-to-energy conversion.

In a similar vein, 3M's movement into its optical business did not start with a massive launch into high-end optical applications. Instead, 3M started by using a simple technology for building "louvers" in glass that prevented light from penetrating at certain angles. This was tested first in applications like protecting valuable paintings from direct sunlight, to securing computer screens from nearby viewers. As new small markets were penetrated, the technology skills improved and diversified, and bigger and bigger markets were uncovered, so that today the optical products business is a major contributor to both growth and profits.

One point that bears mention: to the extent that you fix early on a particular design or feature set, you are limiting your future flexibility. Try, if you can, to pursue new designs and applications in a modular way, so that as new information comes in you can change your design plans. "Guidelines for Managing Your Options" contains guidelines for managing a stepping-stone venture.

Launches

Options are unnecessary when the R&D project is not saddled with high uncertainty—with moderate to low uncertainties, it makes more sense to undertake an outright launch. Intel, for instance, would have been crazy to use any strategy other than an outright launch for each next-generation chip for the bulk of its x86-to-Pentium lines. Why? Because for these products, the company's uncertainty with respect to market demand was low (Intel is a dominant player, people wanted those speedy processors, and manufacturers wanted to put them in the next generation PC's). Also, technical uncertainty was moderate as well.

In fact, there are as many examples of situations in which a launch is the preferred alternative to a more cautious options strategy. Cases in point include Gillette's longtime strategy in selling razors (always be the first to market with the most sophisticated shaving technology), most pharmaceutical companies' market entry for approved new drugs, and Texas Instruments' plunge into all manner of digital signal processing applications.

We categorize launches into two types: enhancements and platform launches. Enhancements represent improvements in existing products and services and are basically incremental improvements on an existing business model where both technical and market uncertainty are low. Enhancements make existing offerings better, cheaper, easier to use, or improve them in some other way. On the other hand, platform launches are moderately uncertain and require more substantial investments. These are launches that are intended to create a substantial new base of business or basis of competitiveness for the firm.

Following Wheelwright and Clark (*5*), some launches create new product or service platforms from which you can build a substantial future business. The primary goal of a platform launch is to establish your company in a strong technological position with a target market that you think will respond favorably to what you have to offer. It is worthwhile, as you are doing the R&D work associated with platform launches, to think through what follow-on and enhancement launches may need to come later. To the extent that you can develop your technology in such a way that customers have a natural path to either migrate to your next-generation product or to buy a greater variety of products from you, growth prospects for the project will be better.

Platform launches provide the basis for next-generation advantages and are therefore critical to the company's medium-term competitiveness.

Enhancements represent R&D projects based on highly certain technology and directed to well-known markets, and that are critical for continuing support from those customers who are delivering the majority of the firm's current cash flows. These development projects basically enhance or deliver variations on an existing platform—and continuously improve your company's current offering relative to competitors. These critical projects are often not regarded as "sexy" enough by the R&D people and consequently can be seriously neglected unless management applies pressure to include them in the portfolio.

Assembling a Strategic R&D Portfolio

Trading off between shorter-term but surer, and longer-term and uncertain projects is always problematic for the R&D leader. A second common complaint is that project ideas come one at a time, and unpredictably, while budgets and plans are assembled all at once at specific

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time points. This can, over time, create a lack of alignment between both the strategy of the company and its available resources. All too often, the R&D group finds that it is totally over-committed in terms of projects, without a clear sense of what its priorities should be.

We suggest that one way to try to create alignment between budgets, strategies, available resources, and projects is to use the simple portfolio depicted in Figure 1 to take strategic control of the flow of projects. The core concept is to let your strategy and available resources guide your choice of how much emphasis to put on each of the categories. There is no cookbook for how best to do this. In general, though, you want to craft a project portfolio that suits the strategic environments in which you will have to compete. Thus, if you are in a fast-moving, highly uncertain industry, you will want to weight the proportion of resources in your portfolio more heavily toward options. If you are in a relatively stable or capital-intensive industry, you should probably be investing a greater percentage of project resources in platforms. Thus, it makes perfect sense for companies like Intel and Hewlett-Packard to invest substantially in options, such as equity investments in small entrepreneurial companies with interesting technology. It makes equally good sense for a company like Boeing to place its emphasis on platforms, such as its successful introduction of the 777 line of aircraft.

An approach that we have found powerful is to look at the pace of technology change and the nature of R&D in your business and then decide what you consider to be a competitive mix of projects by allocating different, strategically decided, proportions of your resources to each type of R&D project. We show an example in Figure 2.

Here is the key point: After you have determined the mix of projects you need to support your strategy and how many projects you can support, similar projects compete *only* against other similar projects, and *only* for the percentage budget and staff allocated to that category of project. Let's say that you have decided to allocate 15 percent of your available resources to positioning projects. Any new candidate for acquiring resources that is a positioning project should compete *only* against all the other positioning projects for those 15 percent of resources, and not compete against any other type of project. In other words it should not compete at all against other kinds of options or against launches or

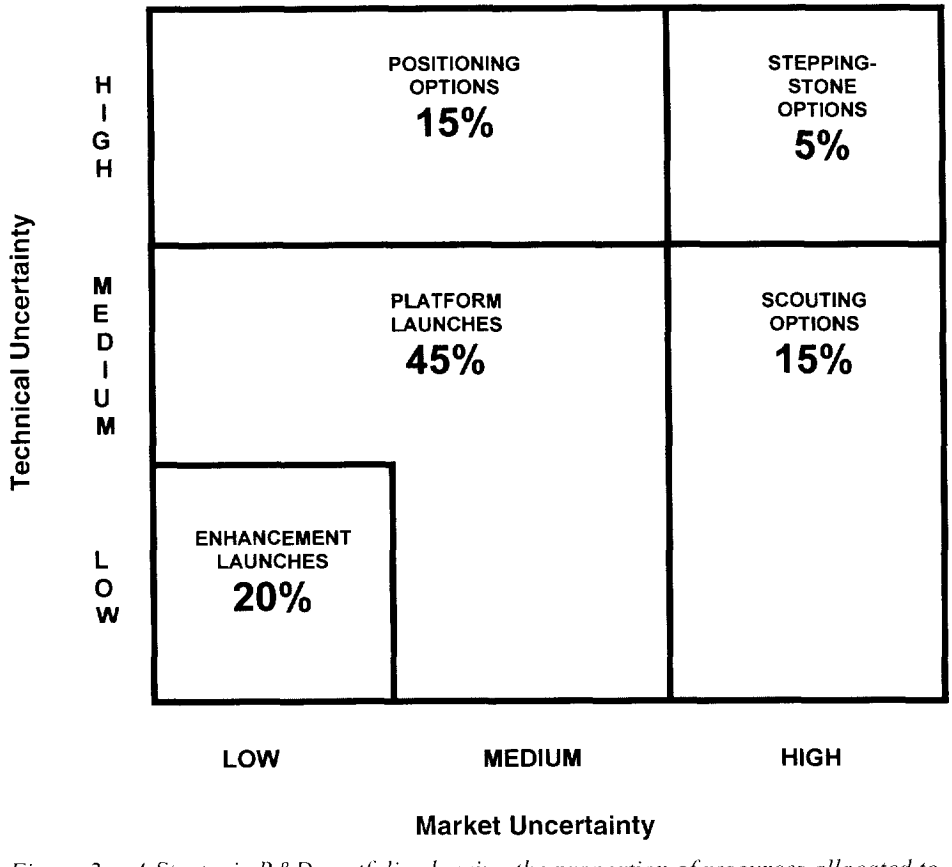

Figure 2.—A Strategic R&D portfolio showing the proportion of resources allocated to each type of project.

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enhancements. This ensures that you will pick only the very best positioning projects for your portfolio. More importantly, it gets you out of the constant tug of war between projects intended to produce short-term results, and projects that you know are important for the long term.

The strategic choice is thus how many of your resources you will put into each category. Within a category, the best projects should compete against one another for consideration.

Allocating resources is a process that in our experience most companies undertake with a fair amount of iteration. A fruitful place to start is by getting a handle on what the portfolio of projects (and ongoing businesses) looks like for you at the moment. Next, you need to determine whether you have the financial and human resource capacity to handle your existing portfolio of businesses and those new initiatives you wish to start. If you are out of capacity, you have two choices: find more resources, or cut back on what you are doing.

As part of this process, you will need to also assess (at least roughly) not only what mix of project types are needed to support your strategy but also how many you are realistically able to undertake. Most companies, for instance, would be hard pressed to start many platform launches simultaneously—they are terribly draining for the organization.

The first step in sorting out what your ideal portfolio should look like is thus figuring out what your actual portfolio looks like today. Because everything new you want to do will add to the work people are already doing, you need to look both at your portfolio of new ideas and at the portfolio of work already in the pipeline. In our experience, most firms chase many more projects and ideas than they can execute successfully.

Building the Portfolio

To show how this works, we illustrate the process with a project we worked on for a medical devices manufacturer. We began by listing all the projects currently underway in the company. We then worked with the senior executive team to categorize them into the five portfolio categories (positioning option, scouting option, stepping-stone option, platform launch, or enhancement). Next, we estimated the effort (roughly in full-time, equivalent person-months) that would be required to bring each project to the next budget period, at which stage the portfolio would be re-evaluated. This gave us a picture of where the company was spending its energy today. On top of this, we loaded in all the new initiatives the senior executive team indicated they were considering undertaking within the next two years, and what resources it would take to get to the next budget period. Finally, we mapped the results onto a chart similar to Figure 1.

We show the results in Figure 3. Each circle in the figure represents a project. The size of the circle represents the (roughly) estimated revenue benefits expected, and the number in the circle represents the number of person-months currently budgeted for ongoing projects in the next year. Blank circles represent projects that were on the list, but to which no resources had been allocated at the time we did the mapping. The idea was to try to get everything that was or could be consuming R&D time and energy mapped in a way that allowed people to identify the totality of what was going on.

This visualization exercise was a revelation. After comparing demand for man-hours with available scientist/engineer resources, it became crystal clear that the company was pursuing many more projects than people thought it was or should. In particular, by trying to

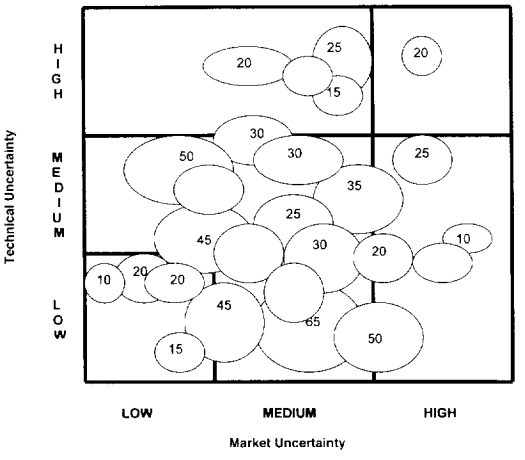

Figure 3.—Initial portfolio of Medical Devices Corporation.

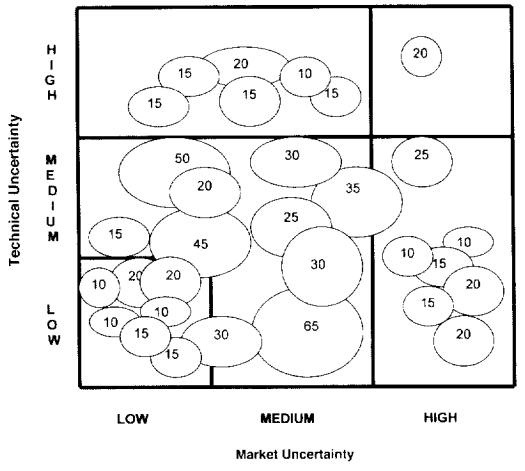

Figure 4.—Revised portfolio of Medical Devices Corporation.

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engage in many highly demanding platform launches at the same time, the company was unlikely to do justice to its portfolio of options. Time and talent needed for options investments were being siphoned away to shorter-term platform launches. Furthermore, enhancements to satisfy the firm's customers were simply not being allocated the necessary resources because many of these were still on the drawing board and competing for the same scarce design and engineering talent as the major platform launches. (This happens often—scientists are more interested in the "hot" platform projects than the simple enhancements).

In short, the company was doing both too much and too little. The results of over-commitment to large platform programs meant that project deadlines perpetually slipped, promises of enhancements to key customers were often broken, and people were beginning to feel burned out.

It is not unusual for the usual process through which companies take on projects to lead them to discover later that they lack the resources to do justice to everything on their plates. In particular, when managers have not clearly thought through which projects will be needed to support their needs to either build new platforms or learn through options, the different kinds of projects compete with each other and confusion results. It is also typical of companies that have not matched their strategy to available resources. A far wiser approach is to pursue a few well-run projects than to chase a grab-bag of forever-behind-schedule and over-budget initiatives.

If you do a similar exercise, you will now be able to determine whether there is any rhyme or reason to the projects that you currently have on the drawing board.

The next thing we did was to decide what the appropriate percentage of resources should be for each project category. Our medical devices client, after considering the pressure from current customers for enhancements and the paucity of options that it was pursuing, decided to reallocate its resources. The company put several major platform launches on hold for later development, and reassigned staff and budget to more enhancements (which require relatively less resources), and to an increased number of options. After considerable, and sometimes heated discussion, our medical devices client redrew its original portfolio to reflect the projects in Figure 4.

The goal of this piece of the opportunity selection process is to ensure that the key people available are not hopelessly overloaded with projects. Part of the challenge is to match desired effort with your carrying capacity for projects. Though part of the puzzle is obviously capital budget allocations, most companies seem to have a much higher awareness of the rules by which capital and assets are allocated than they do about how skilled people should be spending their time. R&D managers and CTOs need to focus on the allocation of skills and talents they will need to cope with the demands of current businesses, to run successful launches, and to manage options.

Most firms chase many more projects and ideas than they can execute successfully.

If you are willing to begin with some educated guesses as to how people are going to allocate their time, the process of figuring out how much your organization can handle is pretty straightforward. Start by making rough estimates of the number of different kinds of people who will be needed to work on the projects you have identified in your version of Figure 4 in the course of the next year, as shown in Table 3. We like to break it up in six-month chunks but you may prefer shorter or longer periods. There is no need for precision; you need only estimate in broad terms to see the scope of the human resource challenge that you face. This table allows you to map out how many, and what kind of staff you will need to do everything you want to do within the timeframe specified.

The next step is to consider how many and what kind of skilled people you already have. If your business is anything like our exemplar firm, or indeed like most of the companies we have worked with, you will find that the projects you have committed to complete represent well over 100 percent of your carrying capacity. This can have surprising effects on the length of time each project takes to complete. For instance, imagine a project that will take a skilled software developer six months to complete. The lead time to completion if this person is working full-time on the project is six months. Divide this person's time between four projects, however, and most of the time, three out of the four are not getting any attention and the lead time to completion of all four projects is two years! Delays like this can be deadly in a world where speed matters.

In the process of planning and then allocating your human resource needs, it is important not to overload. Putting together a table like Table 4 will help you begin to flesh out realistic allocations of time for people to

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Table 3.—Estimating Approximate R&D Human Resource Demand

Key Contribution	Project 1: Jan–June	Project 1: July–Dec	Project 1: Total	Project 2: Jan–June	Project 2: July–Dec	Etc.	All Projects Jan–Dec
Development staff	1	1	2	1	—	—	5
Engineering staff	1	2	3	2	1	—	6
Software staff	—	1	1	2	2	—	6
Marketing staff	—	1	1	—	2	—	4
And so on . . .							

Table 4.—How You Might Depict Key R&D Human Resource Allocations

	Functional Contribution	% Time on Current Business	% Time on Project 1	% Time on Project 2	And So On . . .	% Total Time (Maximum 90%)
Person 1	Development	0	90	0		90
Person 2	Development	0	0	80		80
Person 3	Engineering	60	20	10		90
Person 4	Marketing	70	20	0		90
Person 5	Marketing	75	0	15		90
And so on . . .						

pursue new ventures and to conduct their current, ongoing business. We strongly recommend that no more than 90 percent of an employee's time be pre-allocated. The built-in slack allows for contingencies and breathing space for creativity as well as for the networking that is the heart's blood of entrepreneurial organizations.

It may seem trivial to account for employee time to this degree, but it is absolutely vital, particularly if you plan to take on a number of projects with different time demands, different levels of uncertainty, and different requirements from the people you are working with. This much being said, don't get trapped into micro-allocating people's time. Allocating man-months is sufficient for most projects of any strategic significance. Regularly reviewing a chart like this can also clear up a lot of misunderstandings. Absent information about how many other projects colleagues are working on, it is easy to misinterpret absences or exhaustion as a lack of commitment.

After you have made a realistic assessment of the human resources required for each project, you can further adjust your portfolio of opportunities to accommodate this assessment. The effort to group projects by type really pays off here. You have already given some thought as to what an ideal portfolio of projects would look like for your firm. Now you can be specific about the number of each kind of project you want and have the resources to pursue.

In the company we were advising, we suggested that managers cut back the number of projects in their portfolio mix to include only one stepping-stone project, the nine most important platform launches, eight enhancement launches, six positioning options, and seven low-budget scouting options. This project load did not exceed the capacity of the organization. At the same time, it accommodated the firm's need to generate growth through platform launches, to meet the enhancement needs of current customers, and to support a number of positioning options that would allow it to react swiftly should technology suddenly shift in certain arenas.

We did not suggest that they completely kill off other good projects. Most of those could be deferred without undue damage, so they were kept in an "opportunity register" for future use should resources or opportunity emerge. You can also consider spinning off projects you don't have the capacity to handle, either through joint venture or other mechanisms (such as licensing).

Making comparisons within each category of launch or option allows you to make project tradeoffs without having to worry about trading off between the different categories—that is a separate decision that gets made when you determine how many projects you want in each category. This can be a big relief, as it is common corporate practice to put people in the position of having to choose between an essential enhancement launch (a short-term goal) and a stepping-stone that is thought to be crucial to the firm's future viability (a long-term goal). Using the categories, and your target number of projects within each category, you can compare launches to launches and scouts to scouts and pursue only those ventures that are really attractive.

You must also make a realistic assessment of what else is going on in your corporate environment. If your company is in the midst of a major reorganization, merger, business crisis, or other significant change, the

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amount of time and attention people will have for new initiatives will be limited.

Taking Action

The action steps that follow are meant to get you started on the concepts and processes discussed in this article. Feel free to elaborate in a way that works for your company.

1. For each R&D project in your portfolio, assess the market and technical uncertainty using the questions in Tables 1 and 2.

2. Decide on what proportion of your resources you will allocate to each of the different kinds of initiatives you might want to take: positioning options, scouting options, stepping-stone options, platform launches, and enhancement launches, along the lines of Figure 2. The greater the uncertainty and amount of change in your arenas, the more resources you should allocate to options as a proportion of your overall portfolio (think of this as your initial rule of thumb—you can adjust it later as warranted by experience).

3. Assign each R&D project to one of the portfolio categories. You can use your scores from Tables 1 and 2 to do the allocations. Estimate the number of man-months to the next budget period for each of them. Chart the projects in a format similar to that in Figure 3.

4. Determine the carrying capacity of your organization for new initiatives and older ones, using the technique demonstrated in Table 3.

5. If you have more projects than capacity, consider which should be postponed or dropped. Your objective is to manage your portfolio of projects so that they fall within the carrying capacity of your organization.

Don't get trapped into micro-allocating people's time.

Compare projects within a category to other projects within that category (for instance, launches to launches).

6. Assign specific responsibilities to specific people and make a record of them in a figure like Figure 4, so there will be no future confusion as to who is supposed to do what.

7. Make it a point to regularly review capacity, the portfolio of opportunities, and the match of people to projects. ◆

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