Technology Landscape Mapping

At the Heart of Open Innovation

Technology landscape maps can help organizations build awareness of strategic technologies and identify opportunities at the intersection of emerging technologies and customer needs.

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OVERVIEW: Open innovation efforts traditionally focus on sourcing external solutions against known needs. This approach, while helping the organization to close gaps in internal capabilities, has only limited impact on ideation and strategy. A broader awareness of technology and market trends can itself become a powerful source of new and differentiating ideas. Because of this, a systematic process for building technology awareness and articulating and disseminating knowledge within the organization is critical for enabling a collaborative cross-functional ideation process. This can be accomplished through systematic, proactive scouting and technology landscape maps, which, for a given technology domain, identify technology drivers, critical technology attributes, related existing and emerging technologies with their commercial readiness levels, and the opportunity space enabled by these technologies. We are sharing a new framework, with associated processes and tools that we developed at Kennametal. This process addresses a broader set of objectives than targeted technology searches and is versatile enough to be applied to any technology domain.

KEYWORDS: Technology scouting, Technology landscape map

Open innovation is a strategy whereby companies open their boundaries to the flow of information, ideas, capabilities, and resources in a quest to become more innovative (Chesbrough, Vanhaverbeke, and West 2006). Following successes at some leading global corporations (see, for instance, Huston and Sakkab 2006; Rohrbeck 2006; Monteiro 2008), this strategy has been widely adopted.

The publication of several open innovation process models in literature (for instance, Rohrbeck 2006; Monteiro 2008; Mortara et al. 2009; and Slowinski and Sagal 2010) has facilitated that adoption. One of the key initial steps in all of these is the systematic search for promising external technologies, broadly referred to as "technology scouting." Traditionally, these scouting efforts have focused on finding an external solution to a well-defined problem (Wolff 1992; Duberman

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Technology landscape maps depict the status of both internal and external technologies independently of internally defined needs.

1996; Huston and Sakkab 2006; Monteiro 2008). However, while focusing on defined needs is important, too tight a focus can limit the innovation process to executing on ideas based on available market information and on the needs customers are able to articulate today. This may be dangerous because technology as a whole follows a development path independent of an organization's internal knowledge of markets, customers, and unmet needs. Technology development drivers are often rooted in market insights remote from a company's immediate attention. Therefore, awareness of technology developments, when coupled with market awareness, can become a powerful source of new and differentiating ideas.

Kennametal's Innovation Ventures Group (IVG) has been looking for opportunities at this intersection of market needs and technology developments for the last few years. IVG's mission is to identify and develop new areas of growth for the company in the adjacent and white spaces. We found that relying on traditional product roadmaps was unlikely to generate white-space opportunities because their focus is on solving known customer and product needs. To accomplish our mission, we were forced to develop new processes to identify potential market disruptions that leverage our core technology competencies. Kennametal's marketing organization had a robust process for communicating trends in our target market spaces, called Market Area Perspectives. But the organization lacked a systematic approach for capturing and communicating technology trends and options.

We felt that the technology landscape concept, first introduced by Jay Paap (2010), was a good starting point for developing an approach for capturing and conveying technology trends and options. This concept, which implies the possibility of a "mapping" of the technology options in a particular technology domain, evolved from Paap's thinking about the importance of building the organization's knowledge and awareness of technologies that are valuable to the strategic areas in which the company intends to participate (Paap 2003). However, Paap's concept of the technology landscape had not been developed in a way that provides its definition, details on its structure, its key elements, or a methodology to build one. Recognizing that technology landscapes could be central to open innovation in the same way that market area plans guide business strategy, we developed a systematic framework, which we call the Technology Landscape Map (TLM), that puts the original concept to practice and allows for capturing emerging technologies in a way that can be connected to business opportunities. The technology landscape map is different from traditional technology or product roadmaps that describe major milestones in internal technology development to meet defined needs for new products (Phaal, Farrukh, and Probert 2004). Rather, technology landscape maps describe a wider territory, depicting the status of both internal and external technologies independently of internally defined needs. As Paap (2010) points out, information from a technology landscape can be used not only to inform sourcing, but also to guide ideation and technology strategy.

The Kinect Example

The recent success of the Microsoft Kinect demonstrates the benefits of drawing connections between technology trends and market needs. Unlike competing gaming systems, Kinect allows players to interact with activity on the screen using their bodies, not handheld controllers. This breakthrough builds upon previous innovations in gaming controller design and other mapping and sensing technologies in fields like robotics and imaging. Although Microsoft developed several elements of the Kinect internally—including speech recognition and video capture technologies (Gates 2011)—a key enabler for the product appears to have been a 3D depth-sensing technology developed by an Israeli company called PrimeSense (Walker 2012). By combining PrimeSense's technology with their internal developments, Microsoft created a revolutionary motion-sensing device that enabled new gaming options and broadened participation to those unwilling or unable to use previous handheld controller designs.

In addition to its impact on video games, Kinect's low cost and ease of use enabled its application in other areas that benefited from motion sensing. Today, we see a wide range of Kinect uses; surgeons use a Kinect-based system to remotely move or zoom digital images of X-rays or CT scans in operating rooms, and Bloomingdales shoppers use the technology to "try on" clothes online in virtual dressing rooms. Many of these areas can be considered remote from Microsoft's current market and so escaped its immediate attention. In essence, Microsoft developed a technology (Kinect) targeted to the video game industry. Third parties made the connection between these attributes and unmet needs in other markets, creating new opportunities. The TLM methodology is a formalized approach to what was in the case of the Kinect an organic process. It can allow companies to identify new markets for technologies or, conversely, new technologies from other venues that can disrupt existing markets. Once these new markets and technologies are identified, the company can then choose which ones it wants to pursue.

The Microsoft Kinect exemplifies the disruptive potential at the intersection of emerging technologies and unmet—perhaps even still unrecognized—market needs. A comprehensive scouting effort that generates an understanding of the technology space beyond a company's immediate development drivers can enable opportunities in new application spaces not yet envisioned, by the company or even by the market. Generating such opportunities, however, requires a technology scouting program that is structured both to help procure outside solutions for current development programs and to provide a systematic view of the status and development trends in relevant technology domains. One way of achieving this systematic view—and the tool we adapted for the technology scouting program at Kennametal—is through technology landscape maps (TLMs).

The Technology Landscape Map

To put the TLM concept into practice, we developed a methodology that we have applied across multiple technology domains. This process addresses two key technology scouting needs: 1) implementing a systematic scouting approach to identify a broad set of technologies in a company's space that may be strategically important and 2) providing tools and a framework to capture this knowledge and communicate the findings in a way that facilitates technology sourcing and guides ideation and business strategy.

The core of this process is the TLM, which describes the state of a particular technology area as a whole. Any specific technology on the TLM is characterized by the attributes that describe its essence, its maturity, and the drivers for its development. To capture these apects, the TLM visually represents

1. Internal and external technology drivers that set the objectives for technology development,
2. Key technology attributes that are critical to achieving these objectives,
3. Existing and emerging technologies that exhibit these attributes,
4. The maturity levels of these technologies, and
5. The opportunity space enabled by these technologies.

These elements are captured via a chart that has three broad areas (Figure 1). The left side focuses on technology drivers—that is, the attributes in development by the technical community as a whole—while the middle area identifies the technology readiness levels of specific technologies and the right side identifies the opportunity spaces opened up by the technologies.

Technology Drivers and Their Attributes

The region on the left of the TLM shows the key groups of technology attributes that are the focus of development efforts. The attributes are grouped according to the technology driver that compels the development efforts. In our example, improving performance of coatings in metalworking is an important technology driver. Development efforts try to achieve this by improving a specific set of technology attributes: adhesion, coating quality, cost, and deposition rate. In the case of the Microsoft Kinect, the technology driver was improving the performance of user-interface controls with an underlying technology attribute of sensitive motion detection.

For convenience, we placed these drivers into two zones. In the lower zone, the drivers focus on improvements in performance and cost elements in mature applications.

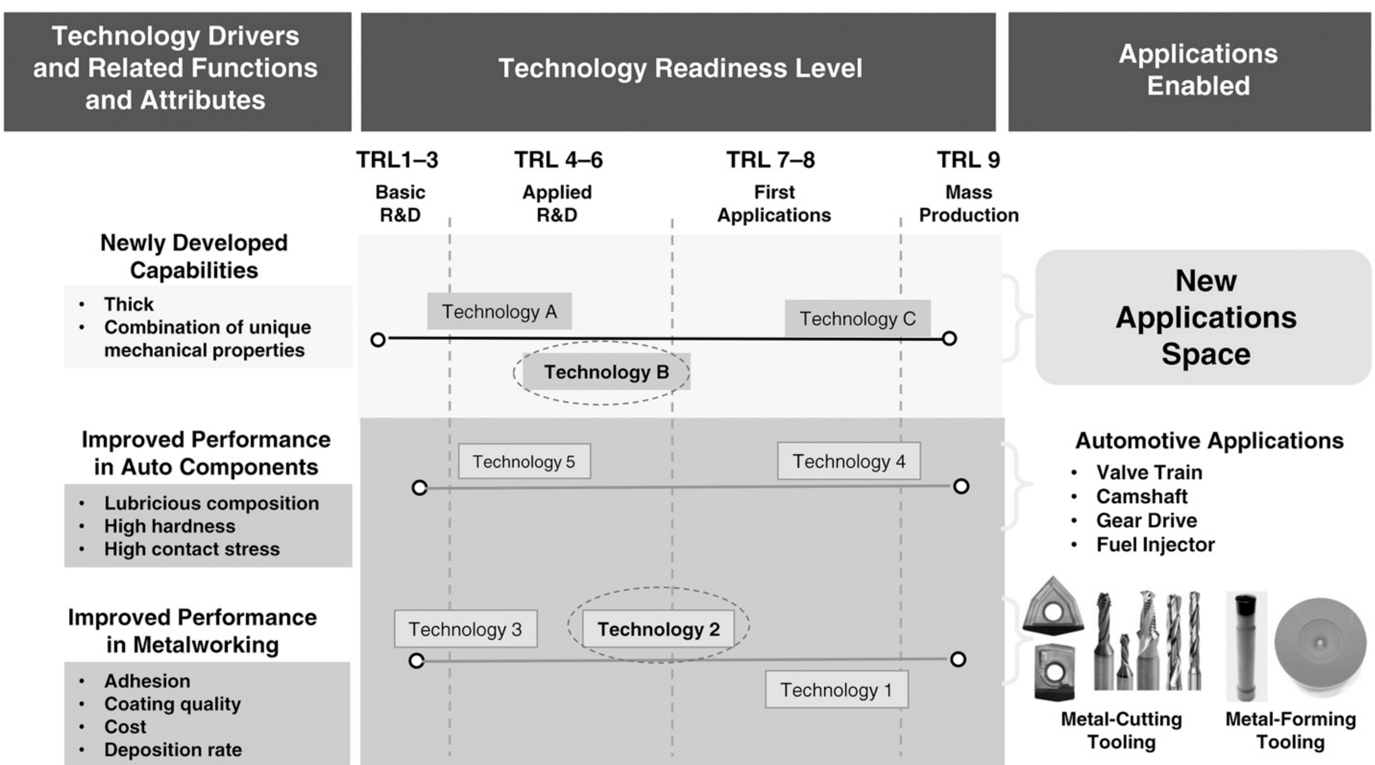


FIGURE 1. Example of a technology landscape map, based on a simplified version of a thin coatings TLM

By providing a comprehensive picture of the technology space, the TLM helps identify near-term technology applications and envision a long-term technology strategy.

Development activity in this area typically focuses on improving existing attributes rather than adding new ones. In the upper zone, we identify a set of emerging technology features that could enable new applications. In this example, the set of new functional capabilities (that is, capabilities not normally associated with thin films) includes coating thickness significantly higher than can typically be achieved in an economical way and a combination of mechanical properties that cannot be achieved by tailoring the coating composition but require novel processing techniques. These combinations of attributes are grouped based on the applications they enable.

There can be multiple drivers identified in each zone. For instance, metalworking applications need improvements in coating adhesion, quality, cost, and deposition rate, whereas automotive applications require development of more lubricious coating compositions, coatings with high hardness, and coatings that can withstand high contact stress.

Technologies and Their Readiness Levels

The central region of the map shows the relevant technologies for each driver, arranged according to their technology readiness level. There are different approaches to identifying levels of technology maturity (see, for example, Mankins 1995; Rohrbeck 2006; US Department of Energy 2009). The primary purpose of identifying the readiness level is to recognize the type and amount of effort still required to convert a given technology into a commercial product.

Toward this end, we found it convenient to identify four levels of technology readiness: Basic R&D, Applied Research, First Applications, and Mass Production. This classification follows Rohrbeck's (2006) approach and shows some correlation with the Department of Energy's Technology Readiness Level (TRL) scale (US Department of Energy 2009): Basic R&D correlates generally to TRLs 1–3, Applied Research to TRLs 4–6, First Applications to TRLs 7–8, and Mass Production to TRL 9. In general, technologies in the first applications and mass production stages are those that can be considered for use in the near term, while technologies in the basic or applied research phases can be tracked for progress or may be considered as candidates for some form of joint development, depending on their perceived value to the company. In both cases, as we begin using the information developed by technology scouting to make investment decisions, understanding the relative value of the technologies identified in each category becomes important.

Opportunity Spaces

The right side of the map shows the groups of applications enabled by the new technology capabilities. This column ties together the applications, their corresponding drivers, and the relevant technologies in a simple visual outline. We found that the overall format of the TLM helps the scouting team to articulate to the business units the importance and competitive position of the technologies they have uncovered. As opposed to some other approaches proposed for visualizing the technology, such as the "radar screen" suggested by Rohrbeck (2006), our approach allows multiple technologies to be compared relatively easily. This format also shows how the technology fits within the company's current market space. Taken together with the information about its maturity level, this presentation helps to facilitate business unit–level discussions about the adoption of promising technologies.

By providing a comprehensive picture of the technology space, the TLM as we've structured it helped us identify technologies to consider for near-term applications and envision a technology strategy for the longer term.

Developing the TLM

Technology landscape development begins by defining the scouting domain. Some technology areas can be very broad (for instance, advanced ceramics), and typically should be divided into more specific subareas to make the scouting effort more focused and effective. Defining the right domain is an important step, and the scouting team should devote sufficient attention to this at the beginning of the process. A few examples of technology landscape domains we defined at Kennametal are thin-film coatings, thick coatings and claddings, wear ceramics, structural ceramics, powder processing, and powder metal injection molding.

Building a TLM is a four-step process:

1. Identify sources of information and prioritize them according to the objectives of the scouting effort.
2. Filter the technologies based on the technology drivers they address.
3. Prioritize the technologies based on their competitive position.
4. Build the technology landscape map to visualize the technology space.

Identify

Technology development takes place in a technology ecosystem, a global technical community that consists of a number of interacting organizations, including academic, government, and industrial research labs; industrial consortia; small and large corporations and start-ups; and customers and suppliers (Huston and Sakkab 2006). Kennametal's technology ecosystem consists of government labs, start-ups and small businesses, industrial labs, and academic institutions (Figure 2). Interactions between these organizations are

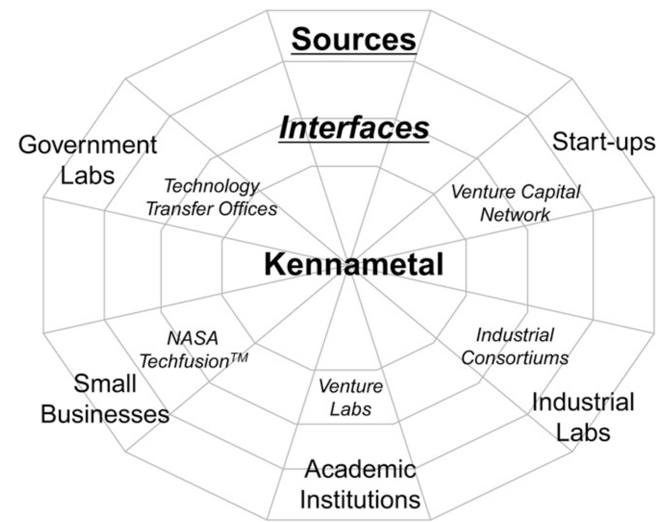


FIGURE 2. Kennametal's technology ecosystem

complex, and information on new and emerging technologies can reside within the individual members of the technology ecosystem or be shared through local and global technical organizations and societies. In order to tap into this large pool of sources, it is critically important to establish effective interfaces, or pathways for the exchange of information between the scouting team and the technology ecosystem.

Interfaces can include a number of channels, such as technology transfer offices at universities and government labs, university incubators (for instance, Pennsylvania State University's Lion Launch Pad and USA and SPARK Business Accelerator, both affiliated with University of Michigan at Ann Arbor), and industrial consortiums. Other interfaces include specific technology search organizations (such as NineSigma, NASA TecFusion) or industry and academia consultants who help integrate information from multiple sources. As it is impractical to cover all the information sources, it is important to focus the scouting effort on sources that are most likely to lead to commercially viable technologies. In this regard, we found it was useful to express the goals for the scouting effort along five common objectives:

1. Increase our fundamental knowledge in core technologies.
2. Source technologies for defined needs/gaps.
3. Identify development trends relevant to our core business among suppliers and competitors.
4. Identify next-generation technology in its early stages.
5. Connect with the global technical community.

The team should prioritize its objectives based on business priorities and then match them with the sources most likely to yield technologies of interest. To help establish this match, we categorized the sources into a manageable number of groups, which we then prioritized based on the weight assigned to the objectives a particular group could fulfill (Table 1). This framework helps create a rationale for selecting sources to scout and also promotes diversification in the scouting effort, encouraging the team not to limit engagement to sources team members are familiar with.

Filter

Paap and Katz, in their 2004 paper on "anticipating disruptive innovation," emphasize that a key reason new technologies replace current ones is that customers' needs change, and new technologies fulfill these new needs better than existing ones can. They conclude that "while you cannot predict the future, you can anticipate the change and prepare for it by focusing on the drivers of the technology" (Paap and Katz 2004, 22). Along these lines, asking questions about which product attributes need to be improved and why can help uncover the technology drivers. Understanding the technology drivers in turn allows us to predict the changes these new attributes will enable, thus leading to disruptions and new opportunity creation. In the Kinect example, understanding the driver to improve user-interface controls and corresponding attributes (like sensitive motion detection) allowed Microsoft to think more broadly about the technology potential. Therefore, it is important that scouting efforts deliver an understanding of both the technology attributes and its drivers.

When considering state-of-the-art technologies, two of the major drivers are typically performance and cost. Technologies in this category tend to be more relevant to existing applications and, consequently, closer to the needs of the core business. In other cases, we identified major drivers that will likely lead to entirely new technology attributes. These new attributes can enable new functions and therefore lead to new applications and entirely new business platforms that

TABLE 1. Template for selecting sources to engage based on scouting objectives

	Objectives for Scouting Effort					
Source	**Knowledge in Core**	**Technology Sourcing**	**Recognized Trends**	**Early Trends**	**Global Outreach**	**Priority***
University/Research Partners						
Vendor Alliances						
Start-ups						
Small Businesses						
Government Labs						
Industry Consortiums						

Shaded boxes in objectives columns indicate that information from the source will address that particular objective.
** Net priority of the sources is calculated based on the weight the scouting team assigns to each objective.*

do not exist today. Asking the question "why are things being developed?" and identifying the major drivers behind the technology development builds insight into the needs being addressed, some of which we may not be aware of.

Understanding the technology drivers and attributes also helps to identify patterns and major groupings when the scouting team is faced with a large number of technologies. In constructing the thin coatings map, we identified more than 25 relevant technologies that were enhancements to existing state-of-the-art coating technologies. We identified key drivers for each technology and then compared the attributes of the new technologies with those of the state-of-the art technologies on two major dimensions: performance and commercial viability (Figure 3). Once the key attributes were identified, a number of established approaches could be used to compare how the new technologies fared against the benchmark.

Based on this characterization, we found that most of the 25 technologies could be grouped into as few as five categories, where technologies in each category targeted improvement of the same subset of attributes. However, some technologies (Technologies A and B in the example) added an entirely new combination of capabilities to an existing technology. These technologies were typically developed by innovators who saw an emerging need that the state-of-the art technologies could not address satisfactorily. The enhancements that these innovators pursued were typically driven by emerging applications, where gaps in the current state-of-the-art technologies prevented them from materializing. In some other instances, inventors had discovered a new capability and were in the process of identifying the right applications. Once the technologies were categorized, we could compare the technologies within each category to identify the most promising ones for more detailed evaluation. This process is described below.

Prioritize

Once the technologies and their attributes have been ranked, this information can be used to narrow the field of candidates to the critical few technologies that are attractive for particular applications. At Kennametal, we were interested in two kinds of technologies: technologies that can help deliver next-generation performance in existing applications and technologies that can help create new opportunities. For next-generation performance in metalworking, experts identified a need for technologies that offered a combination of better adhesion, coating quality, oxidation resistance, and coating deposition rate at a lower cost than the current state-of-the-art technology.

In contrast, new opportunities were enabled by technologies that delivered new attributes that current technologies lacked while retaining some of the attractive features of the current state of the art (adhesion and coating quality, for example). These new technologies presented some challenge to our ranking system. Identifying the right combination of attributes required to meet a particular need is crucial for ranking different technologies. Such identification is relatively easy for existing applications, but it may be difficult when reviewing technologies for new applications. In this case, we found it useful to identify a starting set of attributes in consultation with the technology developers and other technology experts and then further refining them based on insights

		Development Driver(s)	Technical Attributes							Commercial Viability			
			Adhesion	Quality	Oxidation Resistance	Deposition Temperature	Thickness	Toughness	Complex Shapes	Coating Rate	Coating Cost	Scalable	TRL
	State-of-the-art												
Improve Existing Capabilities	Technology 1	Quality	++	+	o	o	o	o	o	o	o	o	7–8
	Technology 2	Adhesion, Quality Cost	++	+	+	o	+	o	o	+	+	o	6–7
	....												
Add New Capabilities	Technology A	Thickness, new properties	o	+	o	+	++	+	+	+	+	+	3–4
	Technology B	Thickness, new properties	o	o	-	+	++	++	++	+	+	o	4–5

o comparable to benchmark + better than benchmark
– inferior to benchmark ++ much better than benchmark

FIGURE 3. Comparison of identified emergent technologies with current state-of-the-art technologies

from cross-functional ideation discussions. This process identified an initial set of applications that can benefit from those attributes.

Once the key set of attributes is identified, the methodology can be used to identify promising technologies. However, we found it useful to use a customized spider chart to conduct the comparisons (Figure 4). A feature of this chart is that, unlike in a standard spider chart, we do not use the same ranking scale for all the attributes; instead, we use the actual values of the attribute whenever possible. For instance, the actual temperature scale is used for the oxidation limit. In addition, the scale is oriented in such a way that the attractive value is on the outside. This ensures that the technology having the best combination of the attributes occupies the greatest area on the chart.

For the sake of simplicity, only one technology from the performance improvement category (Technology 2) and one from the "adding new capabilities" category (Technology B) are shown on these spider charts. These serve to highlight some typical observations regarding these two kinds of technologies. In our example, Technology B does improve on some attributes of importance to existing applications (Figure 4a). However, it is no match for the significant improvements that Technology 2 provides over the current state-of-the-art technology. In contrast, while Technology 2 shows improvements on some attributes that help with performance, the improvements are not sizeable enough to enable new opportunities; Technology B, however, provides significant improvements on some of these attributes while being comparable to the current technology in others (Figure 4b). Some technologies may provide improvements that are useful in both categories; these would be highly attractive.

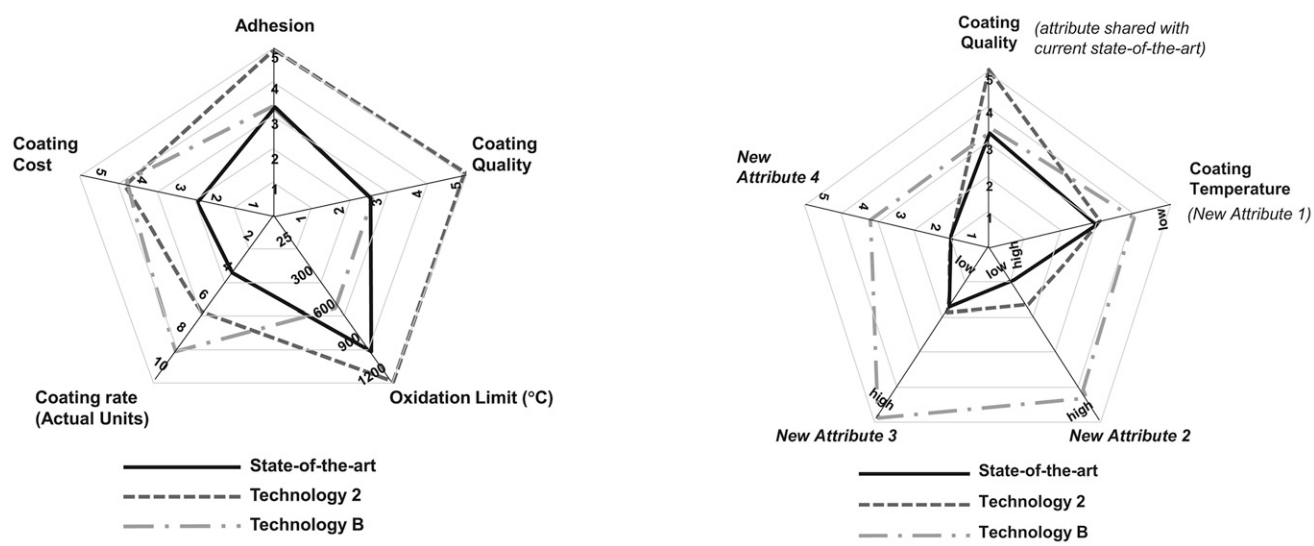
We found that summarizing the technology capabilities on a spider chart makes it easier to engage a diverse audience of internal experts and, more importantly, customers, leading to new product opportunities. The new product opportunities that were identified through this process frequently turned out to be more attractive (in terms of the business potential for Kennametal) than those applications for which the technologies were initially developed.

The TLM is a living document that needs periodic updating by the scouting team to capture significant changes.

Map

While the comparison table and spider charts are useful in understanding the capabilities of the new technologies, they do not give a simple, overall view of what the technologies are about and what applications they are enabling. The TLM gives this high-level view, placing the technologies on a map according to the type of innovation they represent (core or new opportunity), relevant drivers and their corresponding set of attributes, their technology readiness level, and the application spaces they enable.

The TLM is a living document that needs periodic updating by the scouting team to capture significant changes. Each member of the scouting team should monitor one or more of the scouting interfaces selected during the landscape-building process, and the team leader should facilitate a process to capture new information and update the TLM. It is not always necessary, or even advisable, to reengage the entire network established during the "identify" stage. Some sources may have proven to be ineffective, while others were very effective. In addition, it is typically not practical to have



A. Combination of attributes critical for improving performance in existing applications

B. Combination of attributes necessary for enabling new applications

FIGURE 4. Spider charts to facilitate comparison of technology attributes

a fully dedicated scouting team for every technology domain. Therefore, to ensure that the scouting activity delivers business value, it is important to conduct a periodic review and refocus resources accordingly.

Operationalizing the Technology Landscaping Process

For technology scouting in the core, Kennametal has adopted Slowinski and Sagal's (2010) open innovation model, which proposes four phases: Want, Find, Get, Manage (WFGM). The TLM framework is used in the Want and Find phases of the model. It expands the focus of the scouting effort from well-defined core needs to a systematic understanding of the related technology space for strategic purposes.

Challenges associated with implementing this disciplined process are typical of any change exercise. The process, for example, requires changing how the R&D team approaches interactions with the outside technical community. It also requires spending more time in the beginning to better articulate scouting objectives and make sure a broader organizational perspective is covered, balancing the priorities of various businesses as well as both short- and long-term goals. Achieving this balance will usually rely on a team-based process that engages experts from different parts of the organization as well as members from different functions, as opposed to relying on the opinions of a few individuals or a narrow group of experts. Broadening the scouting network and ensuring diverse technology sources will help overcome the habit of repeatedly going to the same sources.

The TLM delivered several important benefits for our organization. Since it provided a good summary of technology status, it was useful in driving strategic decisions through product-technology roadmaps and long-range business planning. Additionally, the visual nature and simple outline of the TLM made it an effective framework to drive cross-functional collaboration between technology and business teams.

We have successfully implemented this process with several teams and used it across multiple domains related to our core and adjacent technology spaces. It has improved our ability to identify strategically important technologies, including those that can be disruptive to our core as well as those enabling new business opportunities. It has also generated critical input into a few major development platforms that include both organic growth and merger and acquisition strategies. Two ongoing M&A projects have grown directly out of our TLM efforts, as well as the capitalization of an entirely new organic growth platform. These successes increased the process's visibility and helped build support for this approach in the broader organization.

Currently, we are working toward a more formal integration of technology landscaping with other internal organization processes such as product roadmapping and staged, gated product development.

The visual nature and simple outline of the TLM made it an effective framework to drive cross-functional collaboration between technology and business teams.

Conclusion

Technology scouting has a profound effect on at least three areas of open innovation: 1) identifying external sources of solutions for known problems, 2) providing input into the development of a technology strategy that balances investment in internal technology development with partnerships and acquisition of external technology, and 3) providing important information that enables the generation of new product and business ideas. The benefits of this approach can be realized across technology domains from consumer electronics to advanced wear-protective coatings.

Technology scouting needs to follow a systematic approach so that useful information on emerging technologies can be easily extracted and put in the context of existing customer needs and developing market trends. Our approach has shown that TLMs can be used effectively by cross-functional ideation teams to help identify disruptions and opportunities at the intersection of the market needs and technology options. And, without this clear framework for communicating technology options to the business units, technology scouting will not effectively impact overall strategy.

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