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Line of Sight: A process for transferring science from the laboratory to the market place

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Abstract

Commercialization and transfer of technology from laboratories in academe, government, and industry has only met a fraction of its potential and is currently an art not a science. The *line of sight* approach, developed and in use at Sandia National Laboratories, is used to better understand commercialization and transfer of technology. The *line of sight* process integrates technology description, the dual process model of innovation and the product introduction model. The model, that the *line of sight* is based on, is presented and the application of the model to both disruptive and sustaining is illustrated. Work to date suggests that the differences between disruptive and sustaining technologies are critical to quantifying the level of risk and choosing the commercialization path. The applicability of the *line of sight* to both disruptive and sustaining technologies is key to the success of the model and approach.

Introduction

There are many success stories relating to the commercialization of technology (Morone, 1993). However, much of the science and technology developed in research labs is either not commercialized at all or does not reach its full commercialization potential. Many activities including precompetitive consortia (Arnold et al., 1998) and CRADAs (Rogers et al., 1998) have improved the quality of commercialization efforts. However, more needs to be done to encourage commercialization of innovation. The design and mapping of processes has assisted in the improvement of many tasks (Shostack 1984; Hammer and Champy, 1994). In R&D such models may seem simplistic. But specific

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This paper builds on the work on disruptive technologies of Walsh and Kirchhoff (1999) and the technology description work of Van Wyk (1988) and Linton and Walsh's (1999) application to specify a process for commercialization — the line of sight process. This *line of sight* process was developed with and is in use at Sandia National Laboratories. It has been determined that the two important characteristics of a candidate for commercialization is are (1) Is it disruptive or sustaining?, and (2) Is it science, technology or engineered product? Having stated the purpose and theoretical underpinnings of the *line of sight* process, the process will now be considered.

The First Phase of the *Line of Sight Process*

First, it is determined whether the candidate for commercialization is a disruptive or sustaining innovation. This distinction is important, since disruptive and sustaining innovations have different characteristics as commercialization candidates – irregardless of whether market pull or technology push is the commercialization mechanism (Walsh and Kirchhoff, 1999). These differences are summarized in figure 1.

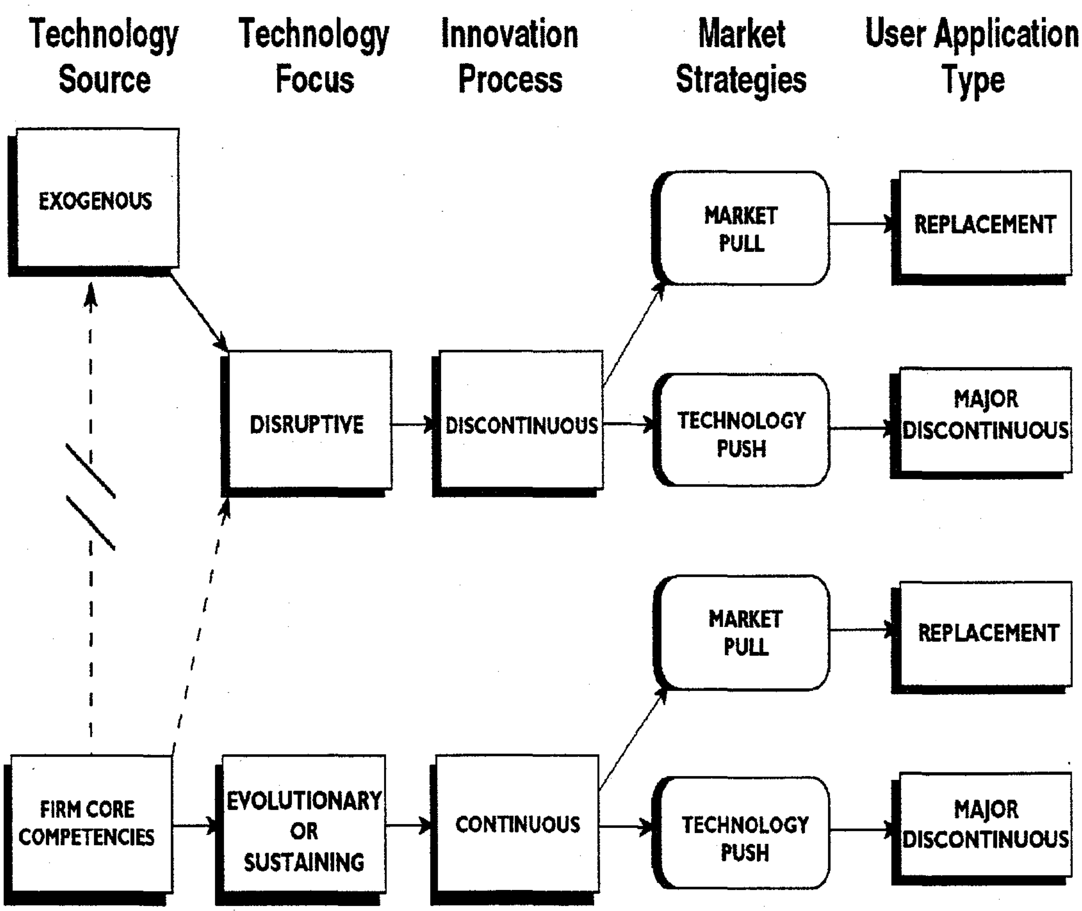

Figure 1: Commercialization Model for Disruptive and Sustaining Innovation (Walsh and Kirchhoff, 1999)

Next, the status of the commercialization candidate as a science, technology or engineered product is stated. Knowledge of a candidate's status for these two characteristics allows for a determination of the best commercialization strategy. If the candidate is a sustaining innovation then it will be of interest to established firms that will obtain incremental improvements from its use. However, disruptive innovations are competence destroying and as such are of interest to entreprenuerial and intrapreneurial firms that anticipate profit from the "creative destruction" (Schumpter, 1934) that is invoked by such innovations. The second characteristic, whether an innovation is science, technology, or engineered product suggests the amount of effort required before the product is ready for market. As the innovation moves from science towards engineered product the requirement for the investment of time and resources, prior to marketing, declines. Consequently, commercialization agents for innovations at a science stage must have a longer time line and more substantive financial resources. The relationship between these two sets of characteristics is summarized in figure 2.

By locating the candidate on the matrix in figure 2, we have a better understanding of the type of commercialization partner required. However, no insights may have yet been obtained on which industries or firms are suitable candidates. Nor are we able to provide a convincing business argument to why an organization would like to commercialize such an innovation. The process of technology assists in developing a business case to convince suitable firms that the innovation is worthy of their attention. Furthermore, technology description assists in determining which industries and organizations are suitable candidates for the commercialization process.

	Science	Technology	Engineered Product
Disruptive	• Entrepreneurial and intrapreneurial firms • Funds in research agreement • Three to five year working relation	• Entrepreneurial and intrapreneurial firms • Funds in research agreement • One to three year working relation	• Entrepreneurial and intrapreneurial firms • Licensing agreement
Sustaining	• Established firms • Funds in research agreement • Three to five year working relation	• Established firms • Funds in research agreement • One to three year working relation	• Established firms • Licensing agreement

Figure 2: Firm and relationship characteristics based on the nature of the innovation under consideration

The Role of Technology Description

Technology description provides a straight-forward standardized way of expressing the nature and benefit of a technology to non-experts. Technology description strives to produce a concise standard for communicating the essence of a technology. Technology description is briefly reviewed below.

Technology description involves reducing a new technology to as few and as simple a set of words as possible. In an effort to accomplish this, a series of standard questions have been developed. The questions asked in technology description serve as a minimum guideline of what needs to be known to understand what a technology is about. The technology description framework is based on the questions (Van Wyk, 1988) that follow.

(1) Function: What does the entity do?

The function of any technology can be described by one of three verbs and one of three nouns. The function is based on the major intended output of the technology. The verbs are *process, transport*, and *storage*. The nouns are *matter, energy,* and *information.* For example, a conveyor belt, an airplane, and a stage coach all transport matter.

(2) Performance: How well does it do it?

Performance describes how well a technology carries out its intended function. It is possible that the technology under consideration has performance characteristics that are unusual and important. If so, these performance characteristics must be stated. But there are four characteristics that are important in describing most technologies:

- Efficiency - Is the amount of output that is obtained from a specified quantity of input.
- Capacity- The definition of capacity depends on what type of activity one is referring to process, transport, or storage. In the case of processing, capacity refers to throughput. In the case of transport, capacity refers to distance traveled as a function of time. In the case of storage, capacity refers to the amount stored per unit mass or volume.
- Density - Is a measure of output offered by the technology in relationship to the amount of space required by the technology.
- Precision - Is a measure of the clarity or exactness of the output.

(3) Structure: How is it configured?

Structure is a description of the technology in terms of shape, size, and complexity. Complexity has been suggested as the most important aspect of describing a technology's structure (De Wet, 1992). The complexity of a technology describes how it fits in with other elements. Complexity can be described using the terms: material, component, product, or system. At the simplest level the technology could be a new *material*. The new technology could be a *component* or part that is used of existing materials in an existing product. The technology could be a new *product* that is made up of a series of existing components, but these components are configured in a novel way that offers a set of new or improved benefits. The technology could be a *system*, a series of products that are used together to offer a new set of benefits. For example, some firms take a series of existing pieces of equipment to make integrated work cells. The products may not be new, but the way in which the products work together is novel.

(4) Size: How big is it?

Size gives an indication of the physical dimensions of the technology. The easiest way to express size is in meters (metric), since it lends its design works well with an expression of sizes of different orders of magnitude.

(5) Material: what is it made of?

The general class of the material that the technology is made of is stated. This is important since knowledge of the material implies certain properties and manufacturing techniques. The recommended material classifications are metals, polymers, ceramics, glasses, and composites. In some cases, the technological advance maybe a material having a property that is not normally associated with it (like plastics that conduct electricity). In this case, the unusual property has been stated elsewhere (usually as part of the performance characteristics).

The role of technology description is different for sustaining and disruptive technologies. With sustaining technologies the function is obvious, therefore, the function can be stated and the technology can be characterized. However, with disruptive technology the function is not yet defined. Consequently, interesting characteristics are described and potential functions of these characteristics are identified. Having stated that there is a difference between sustaining and disruptive technologies the *line of sight* process will be identified for each.

Line of Sight for Sustaining Technologies

Having stated that the direction be taken with sustaining technology is more obvious, we will consider it first. The *line of sight process* consists of the following steps:
(1) Complete technical description
(2) State a list of industries that have technical trajectories that may benefit from the technology description given.
(3) Research the industries through examination of websites and trademagazines to obtain a better understanding of the potential fit between the industry and the candidate innovation.
(4) Make contact with industry associations and/or experts and obtain their input on what the likely potential of the candidate innovation is and how you should go about finding potential commercialization candidates.

(5) Submit articles/news releases to industry information sources (trade magazines and newsletters), make presentations (at conferences and tradeshows).
(6) Use steps 4 and 5 above to identify potential commercialization candidates. Initial meetings are held at trade shows to allow for a number of meetings over a short period of time, and limited expense, with a number of organizations.
(7) Based on the meetings in step 6, a decision is made which candidate(s) is/are best suited for commercialization.

An example is now given to demonstrate the process. Software has been developed through the cooperation of SNL with organizations in the ceramic powder compaction industry (Keller et al., 1998). The software models the stress and density gradients of compacted parts. It is believed that this software could bring benefit to other industries with little or no modification.

The software is identified as an engineered product that is a sustaining technology. Consequently, a commercialization partner will (as shown in figure 2 and 3) license it to use, in the case of compaction of powders. Uses associated to the compaction of fluids, with some modification and testing (technology) are also possible. Consequently, firms already established in their respective industries are candidates for licensing agreements (see figure 3). And funds-in agreements (see figure 3) should be sought with established firms in industries that can use this technology with some further development.

	Basic Science	Applied Science	Engineered
Disruptive			
Sustaining		Non-powder compaction applications • Established firms • Funds in research agreement • One to three year working relation	Powder compaction applications • Established firms • Licensing agreement

Figure 3: Firm and relationship characteristics for *optimization of design and process software*

The technical description of powder compaction software follows:
Function: Process Information (see figure 4)

Capability:
Time-to-market – saving of 3 to 12 weeks
New product cost reduction – $1,000 to $10,000 on product that generates revenue of $50 to $100,000/year

Defect reduction – Up to 50% of compaction related defects – could be 2.5% of ceramic components
Reduction in processing (through near-net shape design) – save up to 25% of manufacturing cost

Size: Not applicable

Structure: Product

Material: Not applicable

Additional information: Identify flaws in product design through simulation of process and provision of information on stress and fill characteristics. Able to demonstrate to customers why a specific design is advantageous/disadvantageous. Able to train people faster on design and manufacture of parts (currently years of experience are required to understand which designs will have manufacturing problems and why).

Associated costs:
Characterization of materials (fixed cost) – up to $30,000 and 5 weeks time. In large volumes could be reduced to $5,000 to $10,000.
Analysis of design (variable cost) – several minutes.

	Process	Store	Transport
Energy			
Information	Compaction Software		
Matter			

Figure 4: Location of ceramic powder compaction software on technology description matrix

This information is used to support discussions with trade associations and potential commercialization partners. The information is also the basis for presentations and articles, to support the commercialization process regarding this innovation. Having considered the line of sight process for a sustaining innovation, we will now examine how it is applied to analyze a disruptive innovation.

Line of Sight for Disruptive Technologies

The *line of sight process* consists of the following steps:
(1) List the separate forms or characteristics that will be considered for the innovation, for each of the forms the following steps are now completed.
(2) Complete technical description

(3) Consider what industries or applications could benefit from the technology description given.
(4) Make contact with industry associations and/or experts and obtain their input on what the likely potential of the candidate innovation is and how you should go about finding potential commercialization candidates.
(5) Submit articles/news releases to industry information sources (trade magazines and newsletters), make presentations (at conferences and tradeshows).
(6) Use steps 4 and 5 above to identify potential development candidates. Initial meetings are held at trade shows to allow for a number of meetings over a short period of time, and limited expense, with a number of organizations.
(7) Based on the meetings in step 6, a decision is made which candidate(s) is/are best suited for development.

An example is now given to demonstrate the process. A way to produce self-assembled nanostructured materials has been developed by a research team at SNL (Lu et al., 1999). The process is repeatable and controllable in a laboratory environment. The process appears to be scalable and can be set up as either a batch or continuous process.

Nanostructure materials are a disruptive technology. Nanostructure materials have the potential to destroy the advantages of established firms' technical competencies. Consequently, the applications of innovations are not as apparent as for sustaining technologies. The technology is still at the science stage. Based on the characteristics of the technology (see figures 2 and 5), funds in research agreement with a duration of between one and five years should be sought with entrepreneurial and intrapreneurial firms.

	Science	Technology	Engineered Product
Disruptive	• Entrepreneurial and intrapreneurial firms • Funds in research agreement • Three to five year working relation	• Entrepreneurial and intrapreneurial firms • Funds in research agreement • One to three year working relation	
Sustaining			

Figure 5: Firm and relationship characteristics based on the nature of the science and technology under consideration

Since a disruptive technology is under examination, products are expected to be replacements for existing products (Walsh and Kichhoff, 1999). The products will be adopted for industries and applications in which the nanostructure materials provide an order of magnitude improvement in a critical performance characteristic. As new products are developed, the knowledge of the characteristics of the technology, capabilities of the technology, and the manufacturing process increase. This may lead to a major continuous innovation pushed on the market by the characteristics of the technology (Walsh and Kichhoff, 1999).

In the case of a disruptive technology, the applications are not apparent. Technology description in this case is used to identify possible applications that depend on specific characteristics of the technology. The self-assembled nanostructure materials can be made to have a variety of different forms. These forms include:

- Non-porous coating
- Porous coating with controlled pore size
- Porous coating with reactive pores
- Non-porous spheres with selected material inside
- Porous sphere with selected material inside (controlled pore size)
- Porous sphere with reactive pores
- Sphere that will selectively bind to ions or proteins
- Spherical composite – Soccer ball shape (a ball comprised of smaller balls)

The process is now demonstrated for one of the eight forms identified above — self-assembled nanostructure materials in the form of a non-porous coating.

	Process	Store	Transport
Energy			
Information			
Matter		Coating	

Figure 6: Location of non-porous coating self-assembled nanostructure materials on technology description matrix

Capability: 1 micron inert non-porous barrier
Variable Cost- $0.004 for coating of 1 m x 1m surface (approximately .02 g of materials required for a micron thick coating of a 1 m x 1 m surface)
Materials costs are about $40 for 270 g
Fixed Cost – Under $10,000 (process can be batch or continuous)

Size: 1 micron thick

Structure: material

Material: ceramic, amorphous

Application: Potential substitute for currently used coatings.

This market should be pursued immediately, since the application will require little development work and the potential market is large. Presentations at the upcoming trade conference and an application's oriented article are recommended. In addition, information should be submitted to industry association newsletters.

It has been demonstrated that the line-of-sight process is applicable for the analysis of the commercialization potential of both a disruptive and sustaining technology. Given this information the type of firms that are potential partners and the type and form of commitment are identified. Further testing is required to extend the validity of this model past face validity. Information is also available at the end of the technical description to present the business that underlies the innovation.

Conclusions and Implications

To date the line-of-sight process has assisted Sandia personnel in identifying and acting on commercialization opportunities. As a consequence, it can be stated that the line-of-sight process has face validity. Additional time and experience is required to establish the validity of this method.

Need to understand whether the disruptive/sustaining dichotomy is sufficient for determining the steps for the analysis of the commercialization targets for an innovation. If other technical characteristics are critical to the application of the line-of-sight procedure, this results in either a failure of the framework or the users avoiding failure by modifying the framework. Consequently, it is important that the analysis of failed applications be conducted to determine whether these applications are unique in terms of one or more technical characteristics.

Process has provided a framework that assists in identifying potential partnerships. Intent is for the process to act as a standing plan for commercialization. It is acknowledged that luck will still play a part in the process of commercialization, the researchers and transfer agents suggest that "luck favors the prepared."

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