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Concept for Determining the Focus of Technology Monitoring Activities

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***Abstract*—**Identification and selection of appropriate product and manufacturing technologies are key factors for competitiveness and market success of technology-based companies. Therefore, many companies perform technology intelligence (TI) activities to ensure the identification of evolving technologies at the right time. Technology monitoring is one of the three base activities of TI, besides scanning and scouting.

As the technological progress is accelerating, more and more technologies are being developed. Against the background of limited resources it is therefore necessary to focus TI activities. In this paper we propose a concept for defining appropriate search fields for technology monitoring. This limitation of search space leads to more concentrated monitoring activities. The concept will be introduced and demonstrated through an anonymized case study conducted within an industry project at the Fraunhofer Institute for Production Technology IPT.

The described concept provides a customized monitoring approach, which is suitable for use in technology-oriented companies. It is shown in this paper that the definition of search fields and search tasks are suitable methods to define topics of interest and thus to align monitoring activities. Current as well as planned product, production and material technologies and existing skills, capabilities and resources form the basis for derivation of relevant search areas. To further improve the concept of technology monitoring the proposed concept should be extended during future research e.g. by the definition of relevant monitoring parameters.

***Keywords*—**Monitoring radar, search field, technology intelligence, technology monitoring.

I. Introduction

THE deployment of innovative and good performing technologies is one of the most important aspects of corporate strategy for many companies [1], [2]. By applying leading and innovative technologies, competitiveness can be improved [3]-[6] e.g. by reducing manufacturing costs, enabling new product features [7] or improving product as well as production quality [8].

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It is challenging for companies to identify and select suitable technologies because of:

- the large amount of existing technologies,
- the accelerated technological and external change [9], [4],
- the huge number of future technologies, as well as
- the technology development which is difficult to assess since it is prone to large uncertainties and has many specific influencing factors [10]-[12].

Against this background more and more companies have to start or improve their technology management (TM) activities and also research in this field is increasing [13], [14].

TM includes all activities and tasks which are concerned with the planning of technology use and technology adoption regardless of whether it is a product or a production technology [15]. According to Gregory [16] identification, selection, acquisition, exploitation, and protection are among the task fields of TM. Based on the studies of Gregrory and of further authors Schuh et al. derive the basic activities of TM. These are: Technology forecasting, technology planning, technology development, technology exploitation, technology protection, and technology assessment [15], see Fig. 1.

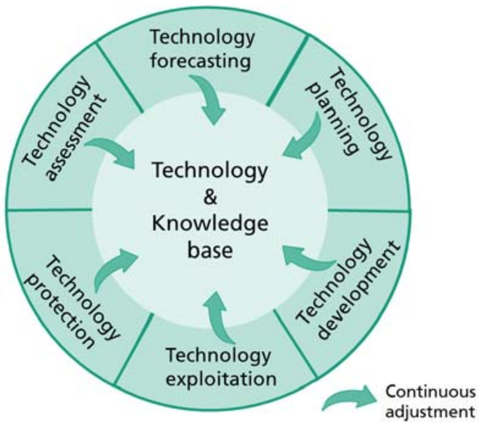

Fig. 1 Technology management activities (own representation according to [15])

A. Technology Intelligence

The desire of technology-driven companies is to discover recent technological developments and technologies as early as possible. In order to identify, evaluate and select the ones which are best suited for a specific company, technology intelligence (TI) activities have to be performed [7], [17].

TI is a main constituent of TM. It focuses mainly on the tasks technology identification and technology selection with the goal to derive and estimate opportunities and risks for a company associated with the introduction of a new, or the continuing use of an existing technology [18], [14]. As these findings form the basis for strategic decisions it is desired to create an extensive, transparent, and secure information base that enables the generation of a sustainable competitive advantage [19], [20]. This information base may be expanded through the analysis of (future) scenarios, which can be transferred to the technology strategy, and their associated impacts [21].

Thus the goal-setting of TI is to identify, collect, select, evaluate, and prepare company-related information in time, so that the information can serve as the basis for the decision-making process of the management [20], [22]. Company-related in this context means that TI activities mainly focus on technologies that form the basis for the performance and the competitiveness of the company as well as promising substitution technologies. The scope of interest of TI is thus limited by the derivation of company-specific search fields and the determination of information needs within every search field. The procedure of search field definition will be elaborated on in chapter III.

Current challenges in the TI are the explosive rise of globally available information and knowledge [23]-[25], the simplified information access, e.g. via the Internet [24], [26], which leads to a huge amount of data that has to be processed, and the integration of different disciplines to new technology fields, e.g. mechatronics [27].

B. Technology Intelligence Procedures: Scanning, Monitoring, and Scouting

The basic activities in the field of TI are scanning, monitoring, and scouting. The decision which method should be used is mainly based on the level of detail and the width of the search task. In Fig. 2, the three activities are compared with each other regarding the features goal, search space and time horizon.

In literature, the terms scanning, monitoring and scouting are not uniformly defined. The following characterizations of scanning, monitoring and scouting are adopted from Wellensiek et al. [19].

Within *technology scanning* the environment is systematically searched for strong and weak signals [21], [27]. A filtering of the detected signals is not done at all or only at a very coarse level based on the specified search field structure. The goal is to identify all relevant signals for the company, including those that are not or only indirectly belonging to the current competencies of the company. The search space is thus very large or rather unlimited. The same applies to the time horizon.

Frequently, scanning is equated with an "outside-in"-perspective since it is mainly the business environment which is scanned for promising new technologies. Impacts of the identified signals and technologies for a company may be estimated by scenario analysis [21], [23].

Technology monitoring includes all search activities with a specified topic of interest. Therefore, only information directly belonging to the defined search fields is collected. The aim of monitoring activities is to systematically track technologies, their evolution over a certain time period, and related (technological) trends. As scanning these activities are usually executed over a longer period of time and the search space is quite large. However, monitoring has a much more limited focus compared to scanning since it is used for tracking and observing the trends identified in the scanning process [28], [29].

Because monitoring concentrates on the search fields which have been defined by a company it is also called the “inside-out” perspective.

Technology scouting is considered a special case of monitoring. It covers all, usually task-related, activities with a clearly defined search area. The goal is to obtain a detailed understanding of a technological search field or to answer a specific technological question. As the search task is defined clearly, scouting activities are executed with a limited time horizon and within a narrow search space.

II. Technology Monitoring

This section gives a brief review on monitoring theories with the aim to demonstrate the diversity of the conceptual understanding of monitoring.

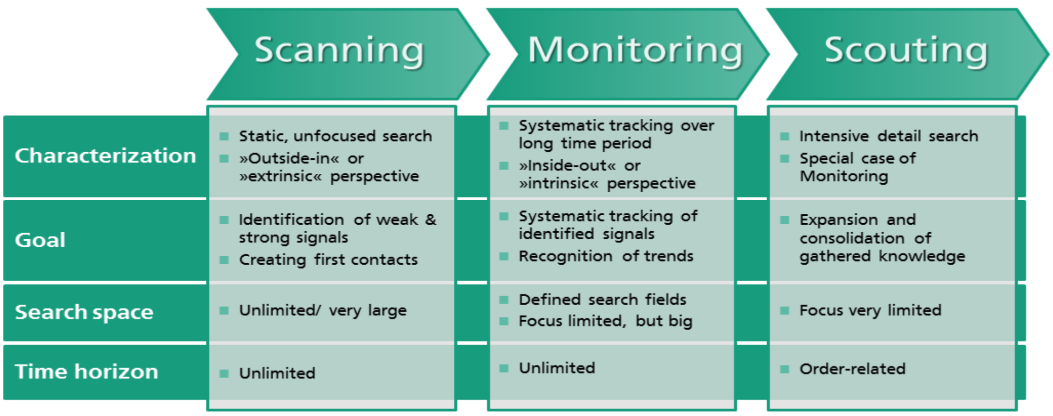

Fig. 2 Comparison of TI activities: scanning, monitoring, and scouting (own representation according to [19], [30])

A. Current Understanding

Monitoring is a term that is used widely and partly different in literature [18]. Often there is an overlap of the definitions of monitoring with other TM-related terms such as scanning, scouting, technology foresight, or technology intelligence.

Nosella et al. [18] define monitoring as a technique of TI, just as technology assessment and technology forecasting.

Monitoring is used to capture historical or current information on a technology or to estimate technological development [28]. According to Porter it includes the steps collecting, organizing and analyzing data [28].

Spath et al. [31] divide the monitoring process into four stages: identification, collection and assessment of relevant information followed by communication of monitoring results.

Bright [32] proposes monitoring to track the progress of innovation. He recommends the systematic monitoring of political, social and other influencing factors. He recommends four steps for monitoring: searching the environment for signals of technological change, identifying consequences, choosing parameters that should be further observed or tracked and presenting the data. Compared to the definitions of TI methods given in chapter I this approach provide a mixed form of scanning, monitoring and scouting.

Coates [29] sees monitoring as a method that helps to watch and keep up with current developments in a certain region of interest or for a particular purpose.

These definitions differ fundamentally in terms of goals and tasks of technology monitoring. In the present paper we define monitoring as a TI activity which includes acquisition of technological relevant information in a well-defined area, assessment regarding a certain purpose and communication of information over a long period of time [18], [19].

The main goals of technology monitoring can be summarized as follows [28], [29]:

- tracking of technological or socioeconomic trends,
- creation of an information basis on existing and developing technologies that helps to decide which ones are relevant for the company,
- assessment of the information in order to derive opportunities and threats for the company,
- establishment of a long-term oriented technology observation base which allows strategic planning of technology use and future product development.

This means, "monitoring provides the basis for most technology or socioeconomic forecasting" [28, p. 134]. Thus, it is of enormous importance for TM and it is necessary to implement monitoring in technology-based companies.

It was also shown by a benchmarking study of the Fraunhofer IPT on the topic TI that for good practice companies the ratio of directed search (monitoring and scouting) to undirected search (scanning) is larger, see Fig. 3.

As monitoring is a directed search with limited area of interest, search fields should be defined to align monitoring activities. This process is described in detail in chapter III. During planning of monitoring activities, the dimensions mentioned in Table I have to be specified [28]. After the search task has been characterized, clearly monitoring can be executed. An overview of possible methods for collecting, assessing and structuring of information is given in [31].

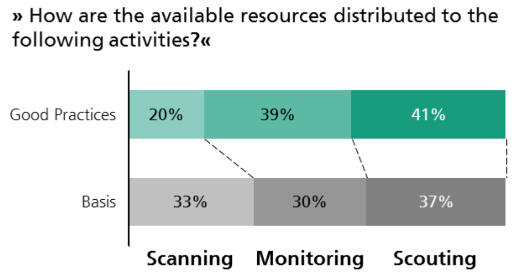

Fig. 3 Application of TI activities [33]

Current trends in technology monitoring are the increasing use of software tools [34], especially to intensify and speed up the search process, application of social media [31] and "Tech Mining". The latter describes the analysis of changing technologies with the help of text mining tools [24], [26].

TABLE I
DIMENSION OF MONITORING ACTIVITIES [28]

Dimension	Characteristic		
Time frame	Pre-implementation	Imminent decision	Post-decision
Monitoring process	One-time study	Ongoing monitoring	
Focus	Technological	Contextual	
Breadth	Macro	Micro	
Purpose	Choosing	Forecasting	
Develop-mental Stage	Established	Emerging technology	

B. Derivation of the Demand for an Adapted Technology Monitoring Procedure with Focus on Search Field Definition

As it was shown in Chapter II *A*, technology monitoring activities are based on explicitly defined topics of interest. This definition of search fields is necessary to limit the amount of relevant information [35]. Further information on search field definition can be found in [35]-[37]. The technology strategy, which defines the company's attitude towards application and development of technologies, and its competitive strategy serve as main input parameters for search field derivation [38].

However, not all enterprises perform strategic technology planning nor do all companies have a distinctly specified technology or competitive strategy. In some cases the existing technology strategy is not formulated on an appropriate level of detail to derive monitoring activities. Therefore, it is necessary to adapt the technology monitoring procedure of

[38] in order to allow firms, to which the before mentioned points apply, to conduct a systematic technology monitoring which is based on well-defined search fields. Accurately described search fields are also important against the background of optimized resource utilization. Through the differentiation between relevant and non-relevant topics as well as an unambiguous specification of the information-demand unnecessary work can be avoided.

In literature the definition and selection of search fields have been insufficiently addressed by practical means. In addition the needs of companies which do not have explicitly defined technology strategies have not been addressed.

Because of the identified gap in prior research and the requests from industry partners of the Department Technology Management of the Fraunhofer Institute for Production Technology IPT, we suggest an adapted concept for search field definition during technology monitoring.

III. Concept for Search Field Derivation for Technology Monitoring

The concept presented here is based primarily on [38], which describes a concept to increase the efficiency of TI by the derivation of search fields and strategies, which are adapted to the corporate strategy. In the following it is shown how this concept can be modified against the background of the deficiencies described in chapter IIB. An application of the proposed approach can be found in Chapter IV. In future research as well as industry projects a larger number of case studies within companies from various business areas should be conducted to test the concept adequately.

The concept described in this chapter focuses on the derivation of information demand from an “inside-out”-perspective, the so called search field definition. Other aspects of technology monitoring such as selection of information sources or technology assessment are not addressed.

A. Structuring of the Technological Basis

In the first step the technological capabilities and competencies of a company, business unit or similar is analyzed. This is necessary to demarcate the focus of the monitoring activities. For this purpose, a morphological box has proved to be useful [39]. Based on experience from industry projects we propose the following classification criteria for the manufacturing sector:

- Products (Which products do the company/ business unit have?)
- Product & production processes (Which processes can be realized with these products? Which processes are conducted during production?)
- Materials (Which materials are used within these processes?)
- Technologies (Which technologies or subcategories exist in the company/ business area?)
- Software (Which (specialized) software is used?)
- Hardware (Out of which components does your equipment consist?)
- Resources (Which specific resources exist in your company?)
- Capabilities (Which technology-related capabilities does your staff have? Which capabilities result from your technological basis?)
- Boundary conditions (Are there any boundary conditions, e.g. corporate strategy?)

The morphological box should be filled in carefully as it forms the basis for all further steps. Therefore, it is recommended to ask internal experts from different disciplines such as research & development or marketing to obtain a complete overview. As monitoring includes examining current as well as future technologies, both existing and planned activities have to be added to the morphological box.

B. Deriving of Relevant Technology Fields

Secondly, relevant technology fields have to be derived from the technological basis. The goal-setting of technology field definition should be to define them adequately so that they can be used at the same time as search fields in the technology monitoring radar (see chapter IIC). For this reason, they should satisfy the requirements posed on search fields. They have to be precise, focused, and unambiguous but at the same time abstract enough to have the largest possible solution space. Furthermore technology fields should contain a sufficient number of sub-segments and related technologies, be independent from one another, and be described in a way that a common strategic orientation can be named. In addition, all technology fields have to be defined on an equivalent level of abstraction.

To streamline technology field definition we propose a two-step approach. In the first step, the recorded technological basis (see Chapter III *A*) is clustered into object level, functional level, technological level, and miscellaneous. Thus, the previously documented information is accumulated. The contemplation is made from different points of view under the consideration of the questions stated in Fig. 4.

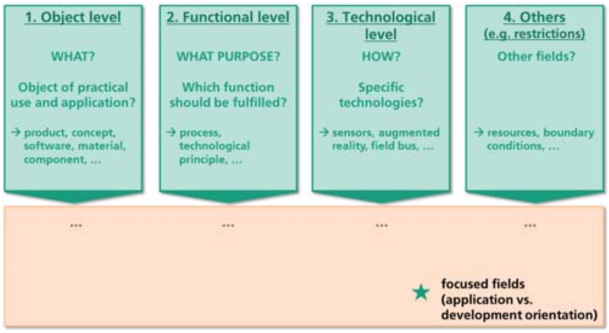

Fig. 4 Scheme for deriving technology fields

In the next step, correlating clusters are combined to technology fields. During this step it is decided whether the technology field is looked at from an object, functional or technological perspective. In addition, the abstraction level of the search fields is defined.

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C. Definition and Structuring of Search Fields

If the technology fields have been defined according to the requirements stated in chapter IIIB the focused fields can serve as search fields. In order to avoid misinterpretations a definition of each search field should be added.

The identified search fields can be visualized by a monitoring radar, see Fig. 5 [23]. This monitoring radar puts relevant technology fields on view, assigns technologies to the technology fields, and displays the technology readiness level (TRL) via concentric circles [31]. For a definition of the TRL levels see [40]. A short description is also given in Fig. 10. As the TRL defines the maturity of a certain technology it is a general, not a company-specific information. Furthermore it is possible to include information on the company-specific relevance of a technology into the monitoring radar.

The main function of a monitoring radar is the structured representation of technology fields, subfields, and optionally also technologies. Further advantageous properties of such a radar include:

- an integrated presentation of existing and upcoming technologies,
- its signaling effect as all employees can identify the relevant technological search fields of the company on the first view and
- the clear positioning of technologies into a certain field.

In addition, a technology monitoring radar can serve as communication instrument within a company. In this way it helps to form awareness of application possibilities of existing and new technologies and thus it gives impulses for the generation of new product ideas or new product functions.

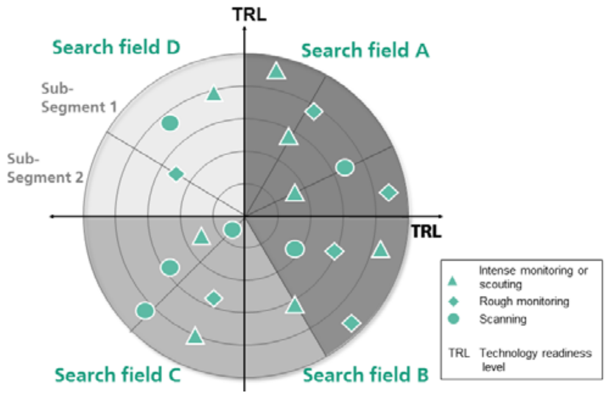

Fig. 5 Technology radar for representation of search fields

Furthermore, the radar can represent the search fields for scanning and scouting. Usually scanning should rather be employed for the undirected search within a complete search field, due to the width of the search space. In contrast, investigations for detailed information onto a single sub-segment or a particular technology are typically covered through scouting activities. Monitoring activities should be used in accordance with search tasks that lie between scanning and scouting. Whether it is appropriate to use scanning, monitoring, or scouting is dependent upon the strategic importance of the search field as well as the needed width and depth of information. Furthermore, it depends on the company-specific importance of the technology field/ technology.

After the search fields for the monitoring radar have been chosen, the sub-segments are defined. These serve as a further structuring criterion for the technologies which are added in the next step. The relevant technologies are assigned to each sub-segment and placed in the radar according to their TRL.

The integration of the TRL into the technology radar is recommended because it signals the development phase of a technology at the first glance. This is important against that background that TI activities change during development life cycle [41]. For a technology with a high TRL they are for example focused on problem solving such as reduction of manufacturing costs [41]. In addition, the TRL helps to determine information sources. During basic technology research scientific literature has to be used and for a mature technology already existing products and product documentations can serve as information sources [41].

As a last step the company-specific attractiveness of the technology has to be assessed. Various evaluation methods exist for this purpose. As shown in Fig. 6 we propose an evaluation based on technology potential and market potential.

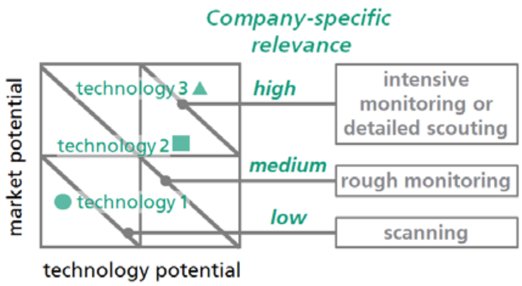

Fig. 6 Technology assessment based on technology and market potential

D. Definition of Search Tasks

It is advisable to document the desire of performing a previously defined TI activity and the information requirement in a search request. In this request the search field's or respectively the sub-segment's or the technology's name and a corresponding description should be included. Furthermore, it should contain information on the desired strategic positioning, the target of the search task, and subordinate specific search tasks. All these points define the search strategy, the evaluation logic for the collected information, and the communication strategy of the obtained results.

Making a rough definition of the strategic positioning is necessary at this point since it directly impacts the search task specifications. For instance, a search field in which a performance leadership is to be achieved and at the same time the claim is to be first in the market requires a much more intense search with the aim to obtain exclusive information than a search field in which the pure presence (the application of technologies already established on the market) is desired. In Fig. 7 an example for a search task structure is given.

Search Field Name/ Segment Name	
Technology Position	Start position: Target position:
Search Task Target	Target and purpose of the expected results …
Specific Search Task	Orientation of search Specific description Specific sources, observation fields, etc. …

Search Field/ Segment description	
Procedure	Responsiblity Time and financial budget Intensity and frequency …
Assessment	Prognosis/ analysis/ selection Specific criteria …
Communi-cation	Documentation/ storage …
Linking/ Others	Linking with other search fields …

Fig. 7 Proposed structure and content of a search task

IV. Application of the Proposed Concept in a Case Study

As proof for its applicability the developed concept was used in an industrial case study. The results for the business area "laser" are presented in the following. For reasons of confidentiality these can however only be partially reproduced.

A. Structuring of the Technological Basis of the Business Area Laser

For the derivation of the orientation of monitoring activities for the investigated business area its technological basis was recorded and structured in a first step. An excerpt of the results is shown in Fig. 9. Achieving (near perfect) completeness is a particular challenge in this step. But an extensive definition of the technological basis is necessary in order to define appropriate technology fields during the next step. The assignment to an appropriate classification criterion is of subordinate importance. The morphological box is mainly intended to support the acquisition of a complete data set.

B. Derivation of Relevant Technological Search Fields

In the first step of technology field definition, clusters were deduced from the technological basis. In Fig. 8 this is illustrated with an example. The different materials mentioned in the technological basis such as paper, foil or metal were clustered into "laser-processable material". Viewed from a functional perspective this could be described as laser material processing. This cluster contained in turn the processes marking and cutting. Laser process simulation and laser regulations also belonged to this group of clusters. As for the company in our case study the functional level was of major interest, the technology field laser processing with regard to laser-processable materials was defined.

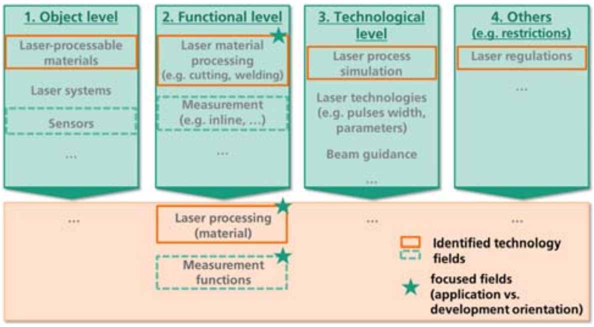

Fig. 8 Definition of relevant technology fields

A. Definition and Structuring of Search Fields

The technology fields can be transferred into the monitoring radar as search field if they were defined properly. As a first search field we chose laser processing (material), see Fig. 8. Then each search field was divided into sub-segments. Afterwards technologies were added to the monitoring radar. In the given example, certain functions which can be realized with laser processing were listed in the radar instead of technologies since we used a functional perspective. After the TRL and the company-specific attractiveness were defined the technology radar was completed. In Fig. 10 an excerpt from this radar is given.

Object	products	cutting tool machine, laser measuring, laser marking, …
	components/ hardware	3D-laser, laser source, laser sensor, optical components,
	software	ablation software, laser control software, simulation software, …
	materials	paper, foil, ceramics, metals, metal powder, …
	capabilities	expertise in process design e.g. perforation, laser system qualification, laser process development, …
Function	product processes	marking, cutting, measuring, cleaning, …
	production processes	ablation, welding, deposition welding, …
Techno-logy	technologies	short pulse, ultra short pulse, long pulse, …
Others	resources	laser labs (test facility), experts, cooperation with laser source suppliers, university cooperation, …
	boundary conditions	workpiece (rotation) manipulation system, fume - safety regulations, …

Currently used
Planned in future

Fig. 9 Structuring of the company's technological basis regarding "laser"

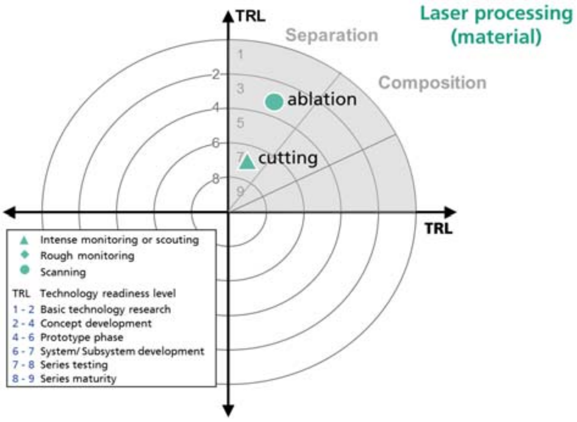

Fig. 10 Excerpt from the monitoring radar "laser"

V. Discussion of the Proposed Concept

The overall aim of the presented research was to deduce a technology monitoring concept, which is specially adapted on the needs of firms that have no or only an inadequate technology strategy and that thus could only use existing monitoring approaches at great resource expenditure. Besides, it was aimed at developing a concept that can easily be used in a practical context. The main benefit is that companies that have not yet defined a technology strategy can use the proposed concept or the definition of the focus of their technology monitoring activities.

A. Practical Implications and Limitations

Due to the fact that this research focusses on practical applicability it is of direct relevance for industrial praxis. The proposed concept simplifies the implementation of TI with the focus on technology monitoring. The introduction of the adapted technology monitoring approach allows companies that do not have an explicitly formulated technology strategy or that have no detailed overview of their core technologies to define search fields for TI based on their technological basis and their capabilities. The company-specific information demand in each search field can be further specified with the help of search tasks.

The easy applicability of the proposed concept was shown in a case study. As a consequence of the low amount of required theoretical knowledge for applying this concept the barrier to use technology monitoring is reduced and a larger number of companies are enabled to benefit from its advantages. Furthermore, the concept contributes to an increased efficiency of technology monitoring.

The suggested approach enables firms to answer the majority of monitoring-related questions e.g.:

- Which technologies will be important for our products in the future?
- How should monitoring activities be designed?
- How should relevant technologies be structured?
- How can areas of interest for TI be visualized?

The monitoring radar which is the outcome of the proposed method can be used to structure and visualize search fields. The radar can be extended through the addition of strong and weak signals that have been identified by scanning [10]. Furthermore, it can be used as a communication instrument within a company [25] to increase the awareness of existing technologies.

B. Research Implications and Limitations

In this paper we proposed a concept for determining the focus of monitoring activities. Thus the presented research concentrates on creating a concept which is easy to implement. In literature this point has not yet been addressed sufficiently. In addition, the detailed description of search field derivation and representation expands existing research.

As demonstrated in the case study the aim of good practical feasibility was achieved. The proposed approach makes companies capable of setting up a structured technology monitoring against the background of a non-existing technology strategy. In order to further proof the concept the range of case studies should be extended.

Since the presented research concentrates on developing a concept with good practical feasibility it neglects other important variables such as resource optimization, definition of technological parameters to be monitored or translating monitoring results into managerial actions. As these points are only insufficiently addressed so far they should be taken into account for further research. Furthermore, the "outside-in" perspective could be integrated into the proposed approach.

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