TECHNOLOGY MANAGEMENT VIA A SET OF DYNAMICALLY LINKED ROADMAPS

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Abstract- The three fundamental types of information/knowledge needed to support a best-in-class technology management capability are: 1) the business, marketing and customer requirements driving your business; 2) the decision planning needed to frame the strategic direction of your company; and 3) the roadmaps that identify the decision alternatives (business scenarios) over time. Today, most companies are focusing on one or two of these essential ingredients, leaving a major gap in their ability to understand how change will impact their business in what is now an explosive period of technological and sociological change. They need to better leverage their strategic knowledge in order to dramatically improve their technology management capability. However, this knowledge is either missing, localized to a few experts, hidden in documents, or is untrustworthy since it is out of date, of questionable quality or has no clear accountable source.

This paper will describe work that Motorola Labs is pioneering in providing an integrated, strategic decision-making, requirements management, and roadmapping process. To make this process realizable within a large enterprise, a set of methods and tools have been developed to support the process. While this paper will focus on technology management, this approach can and is being applied across other processes such as strategy development, research management, system architecture and platform development as well as market and product planning.

I. INTRODUCTION

Motorola has been using a well-defined technology planning process for over a decade [1], tracking the key elements of business and product planning strategy. At technology intensive companies, it is critical that engineering, business, and marketing teams work together to create technology-based solutions that address real needs in the marketplace. Companies with “best practices” in technology planning have established a structured process and fostered involvement between R&D and the business and marketing teams [2]. In mid-1994, Motorola’s Land Mobile Products Sector (LMPS) Research began to investigate what it would take to dramatically improve the requirements management capability of the LMPS software development organizations. What was discovered from this research was that requirements management was not possible without decision management. Each decision ties the incoming set of requirements to a derived set of requirements that are created to support the alternative(s) chosen in the decision making process. It was further discovered that dramatic improvement in time to market cannot be supported by “document-based” processes. Documents are inefficient containers for the information and knowledge created by key business and engineering processes. As a result of our research, the Motorola Technology Roadmap process was expanded to include many types of roadmaps. This broader set of roadmaps can be connected to decision alternatives, creating an integrated, linked, set of decisions, requirements and roadmaps. This lays a foundation for dramatically increasing our ability to effectively manage the business and to provide solutions to the market place in shorter and shorter timeframes [3].

Leadership demands that engineers, marketing, and managers can share a common view of this information and learn as well as add knowledge as they build relationships between key planning elements (business requirements, key decisions, technologies, capabilities, product releases, features,

Fig. 1. The Essentials.
etc.) [10]. Redundant, outdated, inaccurate or missing information simply cannot be tolerated.

To summarize this work, Motorola discovered that dramatic improvement required focusing on value added content, held as information / knowledge. The essential elements that needed to be captured were a connected set of decisions, requirements and roadmaps (see Fig. 1).

This paper will cover the following topics. Section II will include additional discussion of the problems we believe exist in current technology management practice. Since roadmapping is not in broad use, Section III will describe what a roadmap is, and how to interpret one using an example. Section IV will cover a portion of the solution set Motorola is working on to address the problems described in Section II. Section V will finish with our current status and conclusions.

II. KEY PROBLEMS

Achieving a dynamic roadmap planning and tracking capability is a critical goal for any high technology company that wishes to survive in the future. Based on discussions with individuals from other Fortune 500 companies, the following list of problems identifies some of the common barriers to successful enterprise-wide technology management. This list highlights in many cases, the strategic knowledge that is missing, but critical for dramatic improvement to be possible.

A. Missing, Incorrect or Misleading Information / Knowledge

- Necessary requirements, decision, or roadmap information is nonexistent.
- Information needed by the enterprise is maintained by local domain experts, and not easily available for broader leverage.
- Competitor, supplier and industry trend information is not available to drive decision making and roadmapping.
- Information is hidden in documents.
- Information is untrustworthy since it is out of date, of questionable quality or has no clear accountable source.
- No pre-planning of key decisions and analysis; no knowledge gathering templates exist to ensure that the right information is available.
- Information is unstructured, hard to navigate or to observe trends, and often redundant.
- Inconsistent use of information between organizations (different organizations using copies of the same information, which have since diverged).
- No routine knowledge capture - therefore too costly to gather the information when the need for it is recognized. This leads to many business decisions being made with missing information (e.g., Competitive, supplier and industry trend information).

B. Disconnected Information / Knowledge

- Decision results and rationale related to strategic technology management is either not captured or if captured, not able to be easily found or leveraged.
- Business, user, market, and other key requirements are not connected or tied to the decisions and roadmaps they support.
- Since information is disconnected, the impact of change can only be accomplished assembling a set of experts with the hope that they will re-discover all of the implicit connections needed to assess the impact of change.
- Information prepared for quarterly or annual review only and not used as the basis for on-going decision-making and roadmap planning.
- Roadmap elements are not tied to actual product plans and product requirements.

These problems are just the tip of the iceberg, but are a good starting place. As discussed in the next section, Motorola “architected” a “connected” solution and began piloting portions of these processes, methods and tools with a broad set of organizations and roles. Through a commercial tools partner, we were able to pilot the use of this approach with companies outside of Motorola as well.

III. INTERPRETING A ROADMAP

Fig. 2 shows the elements of a composite roadmap, where more than one type of roadmap is shown on a single page. A roadmap provides a simple, yet powerful visualization of a forecast. This forecast can be in a number of key areas, such as technology, capability, parameter, feature, product, platform, system, environment, threat and business opportunity. While Fig. 2 is an example of a Motorola style roadmap, other Fortune 500 companies have adopted similar roadmapping approaches. An industry consortium, MATI II [4], has been formed to share roadmapping best practices across a diverse set of industries.
Each roadmap is based on a consistent structure (hierarchy, tree) of information. The top levels of the roadmap structure, Areas and Categories, represent your organization's model or logical grouping of one of the roadmap areas described above (e.g., capabilities, technologies, products, etc.). This model should be fairly stable over time, i.e. rooted in the real world domains that are critical to your business. This logical grouping should work for forecasting your competitors and suppliers as well as your own company. On a typical roadmap, the Area appears at the top of the roadmap as its title. Categories are arranged as blocks on the left-hand side.

Beside each Category are its child Scenario Sets made up of individual Scenarios (roadmap rows) or evolutionary threads of technologies, capabilities, etc. These "mini" roadmap scenarios are not to be confused with "scenario planning" scenarios. Those involved in scenario planning, can actually create "high-level" scenarios by linking a number of elements from these "mini" scenarios to create a number of named scenario planning scenarios.

Scenarios contain one or more Elements, represented by "bars" arranged by their start and end dates. These Elements are the heart of the roadmap planning process, wherein most of the analysis is performed and forecast data stored.

A roadmap may contain Categories composed of different types of Elements. For example, a composite roadmap may include categories of Technologies and categories of Products. Within each Category, all of the Element bars must have the same time context, an attribute that defines the meaning of the bar’s time period. The first time context is “development” in which the bar signifies that work on that element starts on the left side of the bar and is completed by the right side of the bar. The second time context is “availability,” in which the left side of the bar signifies the beginning of that Element being available for use or shipment, and the right side of the bar indicating it is no longer available. A development roadmap represents work to be performed (research projects); an availability roadmap represents the states that are achieved upon completion of such work (improved capabilities in technology X).

The series of Elements in each Scenario (row) represent the forecast of how one Element will supplant or replace another as the preferred alternative in any time period. The most common scenario is a simple replacement of one Element by a new and better successor. However, scenarios may merge or split as well (e.g., Fig. 2 shows scenarios 2 and 3 merging in the year 2002).

The color of each Element is driven by the value assigned to an attribute, Commitment Level.

Fig. 2. The component pieces of a roadmap

Note: These "mini" scenarios are not to be confused with "scenario planning" scenarios. See text for details.
Commitment Level represents the degree of confidence that that item will be achieved in the time period shown. It is a subjective measure of the risk associated with deploying the element in the forecast period. As such, Commitment Level generally indicates whether sufficient investment is committed and being applied to mature the capability, technology, etc.

Each roadmap includes a multi-period time scale. The time scale represents the "Planning Horizon" for this type of element. This is commonly 2, 5, 10, or 15 years. The time scale is broken into a near term segment (viewed at one year intervals) and a far term or long-range segment shown as a single interval. This approach supports the common "Rolling Wave" method of planning in which greater detail and precision is applied to near term elements.

While much more can be said about the breadth of the roadmap visualization, for the purpose of this paper, the focus will now shift to describing a simple example of a connected set of roadmaps.

IV. IMPROVED TECHNOLOGY MANAGEMENT - AN EXAMPLE

This section describes some of the solutions that Motorola Labs has been investigating in the area of Technology Management. As postulated in the opening sections of this paper, this research has indicated that dramatic improvement can be enabled via a set of integrated processes, methods and tools that support creating and leveraging knowledge via a connected set of decisions, roadmaps and requirements.

A. Integrated Decisions and Roadmaps

The Roadmap Planning process supports and needs to be intimately tied to key business decisions. These decisions may be organized as a Decision Network as shown in Fig. 3 (the rectangles represent decisions). For any business, the Decision Network will have two main branches, a Core Competency branch (decisions about the capabilities and strengths that the company will build around) and a Market branch (decisions about the customers and markets the company will serve and the products they will offer).

A roadmap may be thought of as a compact method of summarizing and communicating the results of a key business decision. For example, in Fig. 3, the output of the decision, "Select Market Capture Strategy" may be illustrated by a business opportunity roadmap. The preferred alternative for the decision, "Select Product Release Strategy" may
be captured as a multi-generation product roadmap. The business Decision Network view in Fig. 3 highlights the Technology Push vs. Market Pull relationships between a family of typical roadmaps. Depending on the needs of the organization or the market, this integrated set of decisions, roadmaps and requirements can assist them in planning using a push, pull or balanced push/pull approach. While Fig. 3, does not explicitly indicate how requirements get connected, they in fact are intimately tied to the decisions that created them and those downstream decisions that consume them. In addition, requirements tend to be connected to specific elements within appropriate roadmaps (e.g., a Feature element on a Feature roadmap may be linked to twenty product requirements that defines its scope).

An organization that desires to achieve effective and comprehensive use of roadmapping should promote a “One Roadmap” vision. This vision does not imply a single, very large roadmap. Rather, it signifies that an integrated set of roadmaps have been used as a focal point to align goals and strategies across the organization.

Strategic alignment may occur in two dimensions. First, roadmap linkages may be used to align strategies within a business unit "end-to-end" across all parts of the research-to-product value chain. Second, roadmap linkages may be built between business units to capture commitments for technology, capability and product sharing and reuse.

One of the benefits of this approach is the ability to support the rapid analysis of the impact of change. Once the organization has produced a connected set of decisions, requirements and roadmaps, impact analysis can be very focused. If a feature for a specific product was proposed to be dropped or delayed, the organization can assess the impact of that change prior to making it. This sidesteps the common mistake, where the change is made based on discussing it with a limited set of experts or managers, only to find out later that the person who knew that particular feature was critical to a new opportunity was missing from the discussion. Gap analysis is also supported by looking at the white spaces in your organization’s roadmaps or by comparing your roadmaps with those you have created to describe your competitors or suppliers.

A common approach to roadmap planning and decision-making facilitates communication across the organization. This approach features a common language, information/knowledge infrastructure, methods, and tools. Within Motorola, this approach represents several years of evolution and continues to improve due to the interactive feedback we continue to receive from the real users of the methods and tools. This feedback contributes to a true learning organization approach [7] we have adopted in the area of roadmapping, decision-making, and requirements management.

Fig. 4 shows a populated example of a composite
roadmap for a non-Motorola example; the Gasoline Dispensing System. While this style of roadmap can show evolution of specific scenarios over time, this roadmap view does not readily show the connections made between element bars on one or more diagrams. This is where automated tool support is valuable, by assisting in the creation, display and exploration of those connections as well as adding key planning data to each element. Fig. 5 shows an example of visualizing the dependency relationships that are hidden behind the circled items in Fig. 4. It shows that an Eastern European Opportunity requires a product called “GDS 3.0,” which requires a set of technologies and factory capabilities to be made available for it to be possible. This view can be enhanced to show the commitment level of each of these elements to further assess what it would take to support this opportunity.

B. Supporting Tools

While process and methods have been our primary focus, tools are crucial enablers for these processes and methods. Below are described the current tools that support and enable this methodology for information-based roadmap planning integrated with requirements and decision management.

1) 1st Generation

Motorola has specified and co-developed with Quality Systems and Software (QSS) a number of first generation knowledge capture and visualization tools that leverage the information and relationships within an object database which implements an information/ knowledge architecture [3], [5], [6]. Motorola’s commercial partner introduced a roadmap planning tool called VisionMap (initially called TechPlan) and a decision making tool called DecisionLink in early 1998. VisionMap & DecisionLink are briefly described below:

- **DecisionLink™**: Decisions are the primary creators and consumers of requirements and are the source of most, if not all, significant product development information. This tool has the capability to maintain the essential object, attributes, links, and link attributes that drive the decision-making process. There are specific views to support common structured decision-making techniques. These include decision networks; evaluation matrices; requirements to decision traceability; decision summary management views, as well as complete decision summary RTF exported reports.

- **VisionMap™**: The intent of this tool and methodology is to leverage the “Best Practices” of strategic roadmap planning. This tool supports a single repository for essential technology data (at the appropriate level for your organization) using an efficient, well-defined information structure. This tool acts as a process enabler, providing greater consistency and flexibility in the use of technology information. In addition, it provides a specific visualization of planning information in the form of
“roadmaps” and allows for on-line impact analysis and filtering.

2) Second Generation
Motorola Labs is currently working on a second generation set of tools that incorporate what was learned from piloting the first generation tools. The primary goal of the second generation is to address scalability within large enterprises and to create a web-enabled set of tools that further improve ease of use and provide additional analysis and visualization capabilities. Contact the author if you have interest in this work.

V. STATUS AND CONCLUSIONS
Since the activities supporting the information / knowledge architecture, that underlie this work are largely methods based, a key factor in deployment has been the development of a training workshop. The "Roadmap Planning Workshop," is available both inside and outside of Motorola. This is where the participants use their own information to create a set of strategic roadmaps in a facilitated working session [8]. Motorola is also having great success in improved decision making via the companion decision making methods workshops [9] that support the use and rollout of the DecisionLink tool.

Through the presentation of the workshop to various project teams within Motorola, along with direct coaching and the operational support of a technology planning rollout team, the Technology Planning process and VisionMap tool have been successfully deployed by a large number of pilot teams. Furthermore, this approach was selected for use across Motorola and is now in the process of being rolled out across the entire corporation worldwide.

Information-based strategic roadmap planning has already demonstrated tremendous value within Motorola. During a recent company-wide reorganization, the business and engineering teams were able to re-assess the technology portfolio of two groups that were in the process of being merged (~2000 technologies). This re-assessment would normally have taken twenty to thirty days, but was accomplished in three days since both of the groups involved had their portfolios within the VisionMap database and had a common understanding of the process and methods that were used to define the roadmaps.

It is critical that companies master the skills required for true technology management in order to remain competitive in the years to come. This requires organizations to take the next step in process maturity by enhancing their ability to plan for and manage change. With the aid of integrated roadmaps, decisions and requirements, a well-defined set of processes and methods, a supporting training curriculum that is workshop oriented, and commercial tools to facilitate deployment, a business organization can achieve these goals.

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REFERENCES
BIOGRAPHY

Gary DeGregorio is a Member of the Technical Staff and is leading the Requirements and Decision Management project within the Software & System Engineering Laboratory of Motorola Labs. He has worked in the area of systems and software engineering process, methods, and tool applied research for over 15 years, focusing on system requirements and decision management, knowledge/information architectures, as well as strategic technology and product planning methods and tools. Gary is an Associate of the Motorola Science Advisory Board, an award for technical achievement. Gary started his career at Motorola in 1977. He earned a BSEE and MSEE at the University of Illinois, Champaign. Gary is a member of the IEEE, the IEEE Engineering Management Society, the ACM and the International Council on Systems Engineering (INCOSE). Gary can be contacted at Gary.DeGregorio@Motorola.com.