



# Technology Planning for Business Competitiveness

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13

A Guide to Developing  
Technology Roadmaps

August 2001



COMPETITIVE AUSTRALIA

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Technology Roadmaps

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The Emerging Industries Section would like to acknowledge the contributions of Geoffrey Nimmo (Industry Canada, Strategis); Rich Scheer and Jack Eisenhower (Energetics Inc, US); Professor Michael Radnor (Northwestern University, US); and Julie Glasgow, Louise Vickery, Catherine Farrell and Deborah Howard (Department of Industry, Science and Resources, Australia).

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ISR 2001/151

ISBN 0 642 72151 3

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# Purpose

## 1. Purpose — Delivering Benefits to Industry

This guide is intended for corporate executives and decision-makers, as well as business and research managers and policy and industry practitioners who are interested in strategic technology planning for enhancing business competitiveness.

Drawing on international best practice and Australia's growing experience in roadmapping, the guide provides a methodology for developing technology roadmaps. It contains practical tips and identifies success factors for developing high quality roadmaps, as well as pitfalls to avoid. It also includes examples of roadmaps and useful sources of information on technology roadmapping.

### 1.1 Introducing Technology Roadmapping

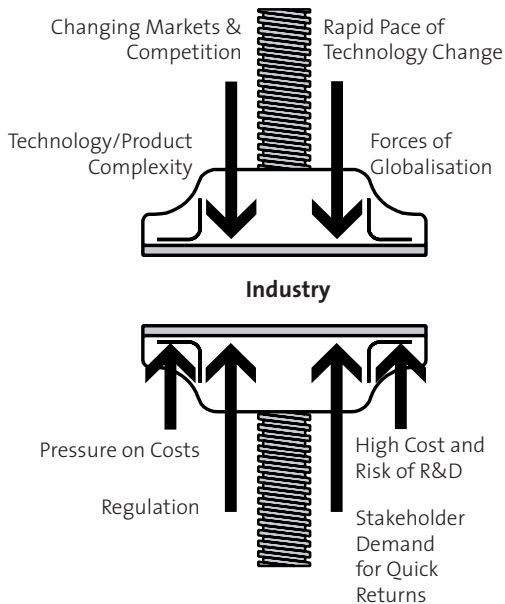
*“Industries that have technology roadmaps are moving to the next stage - joint technology initiatives that will prepare them to deliver what tomorrow's markets will demand.”*

**Industry Canada - Strategis<sup>1</sup>**

The key challenge for firms is to develop and sustain competitive advantage in a complex business environment. Markets and technologies are changing rapidly, cost pressures are increasing, customers are more demanding, and product life cycles and time-to-market are shrinking (see Figure 1). In this environment, firms need to focus on their future markets and use strategic technology planning to stay ahead of the game.

<sup>1</sup> Industry Canada - Strategis. Available from the World Wide Web at: [http://strategis.ic.gc.ca/sc\\_indps/trm/engdoc/homepage.html](http://strategis.ic.gc.ca/sc_indps/trm/engdoc/homepage.html)

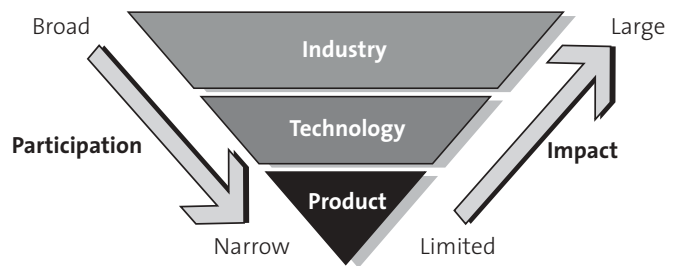
**Figure 1. Change, Complexity and Competition<sup>2</sup>**



Technology roadmapping is a comprehensive tool to help firms better understand their markets and make informed technology investment decisions. It is a planning process - led by industry - which can assist firms to identify their future product, service and technology needs and to evaluate and select the technology alternatives to meet them.

Technology Roadmapping can ensure that industry has access to the critical technologies needed to seize opportunities from the major market developments projected to occur over a 10 to 20 year timeframe. By providing strategies to access those technologies and by when, a technology roadmap can help firms and industries to position themselves better for the future.

**Figure 2. Types of Roadmaps<sup>3</sup>**



## 1.2 Different Approaches to Technology Roadmapping

Roadmaps can be developed at three broad levels of resolution: industry, technology and product (see Figure 2).

- **Industry roadmaps** define broader market goals that are applicable across an entire sector and provide focus for industry to identify and address market, regulatory and other barriers to growth and define a clear set of industry actions. *These are can be similar to Industry Action Agendas developed for various Australian industry sectors.*
- **Technology roadmaps** identify, evaluate and promote the development of collaborative projects within and between industries to fill technology gaps and/or capture technology related opportunities. *This guide focuses on this type of roadmapping.*
- **Product level** roadmaps provide business managers with a comprehensive, long range technology assessment of their future product needs. This type of roadmap provides a complete description of the product line, division or operating group of an organisation.

<sup>2</sup> Scheer, R, Presentation to the Department of Industry, Science and Resources, 18 May 2001.

<sup>3</sup> Scheer, R, Presentation to the Department of Industry, Science and Resources, 18 May 2001.

Technology Roadmaps can be either be forward or backward looking (see Box 1). Backward roadmapping, or 'customer needs' approach, is preferred by firms and industries that are market-driven and interact closely with customers. Industries that are largely technology-driven are more likely to use forward roadmapping, or a 'technology push' approach, and often set their own targets based on scientific knowledge.

*The proposed model outlined in Section 2 is based on a 'customer needs' market-driven approach.*

#### **Box 1. Customer Needs versus Technology Push**

*Backward Roadmapping* involves finding out how to reach a given target set by the marketplace. This could be a business goal, product, process, fulfilment of a legislative requirement or a technology.

*Forward Roadmapping* is the process of building upon existing technologies until new targets appear. It aims to evaluate the potential of a given technology by considering the possibilities for the satisfaction of future needs.

Participants can also employ different techniques to develop a roadmap. Roadmaps can be constructed by:

- drawing on the knowledge of experts (*expert-based approach*);
- engaging stakeholders from industry, government and research in workshops (*workshop-based approach*);  
or
- drawing on detailed information gathered through various information sources, such as journals and computer databases (computer-based approach) (see Box 2).

#### **Box 2. Approaches for Developing Technology Roadmaps**

*Expert based Approach:* A team of experts comes together to identify the structural relationships within the industry and specify the quantitative and qualitative attributes of the roadmap.

*Workshop based Approach:* This technique is used to engage a wider group of industry, research, academic, government and other stakeholders to draw on their knowledge and experiences.

*Computer Based Approach:* Large databases are scanned to identify research, technology, engineering and product areas of relevance. High-speed computers, intelligent algorithms and other modelling tools can assist to estimate and quantify the relative importance of these areas and to explore their relationships to other fields. This approach is in its infancy, as large textural databases and efficient information-extracting computational approaches have only begun to emerge.

*The proposed model outlined in Section 2 is a workshop based approach.*

### **1.3 International Use of Technology Roadmapping**

Technology roadmapping is widely used in a number of economies, such as the USA, Canada, Singapore and Korea. Box 3 identifies a selection of technology and other roadmaps that have been developed internationally.

### Box 3. Current Examples of Roadmaps

#### Industry Roadmaps

- Integrated Manufacturing Technology Roadmap (IMTR): a multiple sector map which defines technology goals that cut across all manufacturing sectors.
- Industry Canada (Strategis): Aircraft Design, Manufacturing, Repair and Overhaul; Aluminium; Electric Power; Medical Imaging.
- Office of Industrial Technologies “Industries of the Future” (US): Agriculture, Aluminium, Chemicals, Glass, Mining, Metalcasting, Petroleum, Steel.
- International Technology Roadmap for Semiconductors (US)

#### Technology Roadmaps

- Infocomm Technology Roadmap (Singapore).
- National Roadmap for Silicon Technology.

#### Product-Technology Roadmaps

- Motorola: roadmapping provides managers with comprehensive technology assessments required for a long range perspective of future product needs. Roadmap provides a complete description of the product line, division or operating group and encourages the use of structured tools in the planning and managing of the technological environment. It also outlines a framework for reviews of present activities and progress.
- Phillips Electronics: aim of roadmapping is better integration of business and technology strategy and improvement of the front end of product creation processes. With a five year focus, these roadmaps present products and technologies that are required to realise these products.

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**Technology roadmapping promotes enhanced collaboration, sharing of knowledge and reduces the risks of investing in technology.**

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*“We have been able to connect with technology partners who are doing similar long term, exploratory research and development and form collaborations, which have allowed this work to proceed more rapidly and successfully. Vision 2020 has helped to act as a focal point for companies interested in similar technology to join forces.”*

**Roger Day, Associate Director, Applications Research and Development, Praxair, Inc.**

The challenges of operating in the global business environment often mean that no single firm or industry has the resources to develop the full spectrum of technologies required. Through roadmapping, firms collaborate with research and government stakeholders, form new partnerships and develop creative solutions to the technology issues and research needs identified. By sharing pre-competitive technologies and knowledge, firms can leverage financial and intellectual resources to achieve market success.

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**Substantial benefits can accrue to individual firms which engage in roadmapping.**

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*“I figure that the ROI [return on investment] for the SIA (Semiconductor Industry Association) Roadmap is an astounding 640% per year (yes, I double-checked it, there is NO decimal point there). The net gain per cycle has been \$16B for the chip industry and \$5B for the equipment industry, while the cost was under \$50M.”*

**G. Dan Hutcheson<sup>4</sup>**

Technology roadmapping fits within a firm’s broad strategic planning and business development framework and provides a way to fill technology gaps and capture opportunities. By engaging in roadmapping, firms can:

- anticipate, respond more rapidly to changes in the business environment and ‘leap-frog’ competitors by staying at the forefront of technology;
- more efficiently align scarce resources to achieve company goals;

- quantify resource allocation to priority projects;
- leverage available investments, finance and other resources through coordinating R&D activities and networking;
- focus on longer term customer needs which allows radical innovation to build new competitive advantage and the development of next generation products and services;
- reduce risk of investing in technology through a more sophisticated understanding of technology needs;
- achieve better rates of return for shareholders through improved investment decision making;
- undertake holistic planning by developing a creative and flexible vision and linking technology strategy to business plans and commercialisation strategies; and
- communicate key strategic planning information to stakeholders.

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**Roadmapping can provide value to industry by provoking productive responses to the ‘triple bottom line’ - the interaction between economic, social and environmental drivers of growth.**

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Through the priorities identified in roadmaps, industry can pursue more advantageous collaborations and manage resources to address common technical problems. In particular, technology roadmapping:

- identifies the hard and soft technologies required to capture opportunities flowing from economic, social and environmental market drivers;
- identifies strategies by which industry can access technologies (eg. international science and technology collaboration, technology transfer and diffusion);
- improves industry’s ability to carry out research and apply new technology more cost effectively through collaborative R&D arrangements;

<sup>4</sup> Schaller, R.R. (1999), Technology Roadmaps: Implications for Innovation, Strategy, and Policy, Ph.D. Dissertation Proposal, US. p.16. Available from the World Wide Web at: <<http://www.iso.gmu.edu/~rschalle/rdmprop.htm>>

<sup>5</sup> Rycroft, R.W. and Kash, D.E. (Fall 1999) Innovation Policy for Complex Technologies, Issues in Science and Technology Online, p.8.

- promotes the accelerated demonstration, evaluation and implementation of new technologies and scientific breakthroughs that will address industry needs;
- identifies opportunities for technology showcasing to demonstrate applications and gain market access; and
- provides a shared vision for communication with, and education of, stakeholders.

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**Technology roadmaps can contribute to the policy aims of governments.**

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*“Government participation in the generation of industrial technology roadmaps is a particularly valuable way to gather intelligence regarding impending changes in innovation patterns. Roadmaps...generally represent a collective vision of the technological future that serves as a template for ways to integrate core capabilities, complementary assets, and learning in the context of rapid change.”*

**Robert W. Rycroft and D.E. Kash<sup>5</sup>**

Technology roadmaps can inform science and technology policy and program expenditure decisions across government and promote longer-term thinking on technology, innovation and R&D issues. They can also:

- influence major research and innovation funders to focus on the priorities identified in roadmaps;
- encourage a multi-disciplinary approach to resolve key non-technical barriers;
- increase technology transfer across sectors;
- foster industry cost sharing in government projects and encourage dissemination of technologies once developed;
- identify current national capabilities and gaps in knowledge infrastructure to deliver critical enabling technologies; and
- highlight areas of national expertise where there is potential for emerging industries to evolve.

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**Technology roadmapping differs from other technology planning - it is led by industry and driven by market needs.**

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Technology roadmapping can be confused with methods of technological forecasting, such as scenario planning, trend extrapolation and historical analogy. These approaches aim to make projections of technological capabilities and predict the invention and diffusion of technological innovations into the future.<sup>6</sup> Similarly, Technology Foresight aims to identify new areas of science and technology research over an extended period of time.

Roadmaps differ from these methods in one important respect. Unlike some methods where the end-point is forecast, the roadmap process starts with the end-point or vision clearly in mind and then traces the alternative technology paths to achieve it<sup>7</sup>. Roadmapping is a tool for companies to predict future market demands and to determine the technological processes and products required to satisfy them. This process is unique in that it encourages firms, R&D organisations, governments and industries to develop a shared vision of the future and explore the opportunities and pathways to achieve it.

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<sup>6</sup> Schaller, R.R. (1999), op.cit., p.9.

<sup>7</sup> Scheer, R, Presentation to Renewable Energy Technology Roadmap Workshops, Australia, May 2001.

# Model

## 2. A Model for Technology Roadmapping

This section provides a general checklist, based on different international approaches, that can be adapted for producing technology roadmaps for different industries. The approach that an industry takes to roadmapping will reflect the type of roadmap to be developed ie. the purpose of the document, the planning horizon and the level of detail needed. The nature of the industry, its degree of fragmentation, level of technological standardisation, extent of globalisation and the interactions and relationships within and between members of an industry's value chain will also be key determinants of the roadmapping approach.

### 2.1 Checklist for Technology Roadmapping Process

Figure 4 outlines the key steps or decision points in producing a technology roadmap.

**Figure 4. Producing a Technology Roadmap**



These are elaborated below:

### Step 1: Establish the need for and benefits of a technology roadmap

- This can be done by government in conjunction with industry or by industry itself, for example, as part of broader strategic policy and planning.

### Step 2: Identify an industry champion and leaders

- The role of the champion is to cultivate industry commitment and ownership of the process and lead the roadmap. A industry based *leaders' group* can be set up to support the work of the champion.

### Step 3: Identify resources for developing the roadmap

- Identify the resources needed - based on scope of the roadmap, its intended use, planning horizon and the level of technical detail.
- Industry leaders may work with governments to identify funding sources.
- Funding could be obtained from relevant government programs as well as cash and/or in-kind support from industry and other stakeholders.

### Step 4: Establish the process for developing the roadmap

- Agree on the approach and methodology for developing the roadmap. A consultant or other expert can be engaged to facilitate the roadmapping process.

There are different techniques, including an *expert based approach* to draw on the knowledge of a small group of experts, or a *workshop based approach* to engage a wider group of industry, government and research stakeholders (see Section 1.2). In this guide, the workshop based approach is proposed, using a customer needs approach to drive the roadmap.

- Develop a *Game Plan* which details how the roadmap will be produced. Box 5 in Section 3.3 provides an example Game Plan for conducting roadmap workshops.

- Establish the *Vision* and *Strategic Goals*<sup>8</sup>. (These could be developed as part of the roadmapping process or may already exist as a result of previous industry strategic planning processes).

The *vision* is a description of a desired future for a particular industry or activity in a given timeframe (eg. an industry Action Agenda). *Goals* are statements that are measurable and describe what needs to be done to achieve the vision<sup>9</sup>.

- Undertake a *stocktake of current and future technologies* based on key market drivers and demand. This list of technologies can be used as a reference document for the expert group or workshops.

One approach is to develop a *Critical Technologies List* which provides descriptions of current and potential processes and technologies required to design, manufacture and support future products and processes. Development of the list requires assessment of global activities, including use of and links with public sector research, training, technology transfer activities, etc.

Another document - *Forecast Market Drivers* - can also be developed as input for the roadmap. This identifies the vision, goals and anticipated market drivers.

### Step 5: Develop the Technology Roadmap

Through discussions with experts or roadmap workshops:

- *Confirm* the scope of the roadmap, vision and strategic goals.
- Identify the *technology barriers*<sup>10</sup> and *challenges*.
- Identify the *technology alternatives* for specific technology areas based on the critical product or service characteristics that are required to meet the anticipated market needs.
- *Prioritise* the technology alternatives according to their ability to overcome the barriers and meet the strategic goals and place them into short, medium and long term timeframes<sup>11</sup>.
- *Synthesise the technology roadmap* from discussions of the Working Groups (see Box 4).

#### Box 4. Content of a Roadmap

A draft roadmap should:

- analyse and synthesise technological trends, markets and challenges. This includes determining how markets will evolve over the medium to long term and research needed to address a particular technology issue;
- identify the key technologies and skill competencies in which local industry has a competitive advantage;
- identify key opportunities for technological innovation;
- identify barriers relating to technology and technology uptake in the industry;
- discuss the critical success factors (ie. if not met, will cause the roadmap to fail);
- provide specific, quantifiable performance targets to inform the implementation plan;
- define the actions required to develop and commercialise the technologies identified;
- map out a logical, prioritised sequence of technology acquisition and/or diffusion. This requires an assessment of the ability of firms to adopt and adapt these technologies; and
- identify appropriate roles for public and private partners in the process.

The draft roadmap should be circulated to all participants for feedback and amendment, as required.

#### Step 6: Implement and Review the Technology Roadmap

- Industry to develop implementation plans, using the information in the roadmap to inform investment decisions.
- Develop a strategy for regular reviews and update of the technology roadmap.

<sup>8</sup> For example, if long term R&D opportunities are of interest, this must be reflected in the vision. In contrast, a shorter timeframe will tend to dictate that the vision could best be achieved through systems integration and product development using an existing portfolio of technologies.

<sup>9</sup> Scheer, R, Presentation to Renewable Energy Technology Roadmap Workshops, Australia, May 2001.

<sup>10</sup> Barriers are knowledge gaps. These are the scientific, technical or other issues that prevent the strategic goals being achieved today (Scheer).

<sup>11</sup> These are the set of activities that need to be done to overcome the barriers, accomplish the goals, and achieve the vision. The priorities reveal the relative importance of the various R&D activities to achieving the goals and the vision (Scheer, R, Presentation to Renewable Energy Technology Roadmap Workshops, Australia, May 2001).

# Key Elements

## 3. Key Elements of Technology Roadmapping

### 3.1 Parties to the Roadmapping Process

Technology roadmapping is designed to create an alliance of industry, academia, technology researchers and specialists, educators, government and other stakeholders to focus resources on addressing technology issues and identifying solutions to deliver what future markets will demand. The process is led by industry, with out-reach to experts to provide facts and data for decision making.

Engaging high profile individuals who are acknowledged for their capacity to perform in the role of *industry champion* can have a major influence on the success of a roadmap. Such individuals should play a leading role in the design and implementation of the process and be visible at roadmapping events.

An industry based *leaders group* can be established to support the work of the champion. Its role is to provide front-end guidance and, at appropriate milestones, to assess the direction of the work, provide insight and promote the roadmap both within the sector and externally.

Depending on the breadth and detail of the roadmap, a *facilitator* can be engaged to coordinate the roadmapping process and have responsibility for preparing the roadmap. For example, a facilitator could coordinate consultations with experts, conduct workshops and facilitate meetings of the leaders group in writing the roadmap. Additional secretariat support during this process may also be necessary.

### 3.2 Strategic Visioning

*“Roadmaps communicate visions, attract resources from business and government, stimulate investigations and monitor progress. They become the inventory of possibilities for a particular field...”*

**J. Galvin, Chairman and CEO, Motorola.**

Visions and strategic goals are paramount to effective roadmapping. Bold business and market-based visions and goals set by corporate executives are essential to effective roadmaps. They define where the industry wants to be by when, the measures for success, and whether it has been achieved.

Strategic visioning has the potential to disrupt linear technology thinking and drive innovative solutions and technology breakthroughs. By bridging the gap between the present and the future, market based visions and goals can assist firms to focus on how to get from where they are now to where they want to be in the future. Developing and articulating this sense of direction is critical to effective technology roadmapping.

If the vision is to establish commitment, then it must be realistic, credible and easily understood. The process should involve a wide range of people with diverse ideas and backgrounds to stimulate creativity. For effective roadmapping, this means engaging corporate leadership at an early stage in order to create enthusiasm and commitment to the process, the outcomes and the implementation.

### 3.3 Game Plan for the Roadmap: Workshop-based Approach

*What steps are planned to ensure that an effective and manageable number of the right individuals attend the workshop? What approach is planned to achieve commonality and consistency among workshops so the results can be aggregated in a logical and transparent manner?<sup>12</sup>*

**Rich Scheer, US Energetics.**

Through effective planning and preparations, the answers to these types of questions will become apparent - constructing a *Game Plan* for the roadmap is an effective means to do this. Before convening roadmap activities, especially workshops, time must be spent in advance to prepare participants for the event, to prepare the facilities and logistics during the event, and to prepare for follow up and implementation.

A Game Plan can convey information at different levels for a range of roadmap players:

- To the facilitators and planners of roadmapping activities, a Game Plan will be a detailed strategy for conducting the roadmapping workshop(s). It should describe the method of facilitation to be employed, the composition and organisation of participant break-out groups, timing of the workshop agenda, etc.
- For workshop participants, a summary of the Game Plan will provide background information about the purpose and method of technology roadmapping, clarify the role of the leaders group, describe the workshop structure and explain what is expected of participants. This should be widely circulated prior to the workshop activities.

An example of a Game Plan is outlined in Box 5.

<sup>12</sup> Scheer, R. *ibid.*

### Box 5. Example of a Game Plan for a Technology Roadmap

A Game Plan should include:

#### 1. Purpose of the Workshop

eg. “To identify research priorities and technology acquisition and diffusion strategies to be incorporated into a Technology Roadmap that will provide a long-term strategy for attaining specific industry goals.”

#### 2. Background Information to the Roadmap

Clarify the role of the leaders group

Outline the workshop structure - eg. point out that participants will be engaged in structured brainstorming sessions and that critical analysis will be used to identify issues and build consensus on technology alternatives.

#### 3. Workshop Preparation

Invite participants to bring to the workshop their personal experience when considering the major issues, barriers and potential solutions to the technology developments identified.

#### 4. Follow-up

Advise participants that a draft report on the workshop discussions and results will be circulated to individuals for review and comment. (In follow-up, additional information may be sought to clarify points and provide technical insight, although consensus results of the workshop will not be changed).

Advise participants that a final Technology Roadmap document will be circulated to relevant parties (once all comments are received and processed).

#### 5. Additional Information (Appendices)

Preliminary list of participants

List of individual members on the leaders group (draft) Strategic Goals

Logistics information for workshop attendance

Preliminary workshop agenda

Key tips for practitioners to consider in designing and conducting roadmapping workshops include:

- **Allocate sufficient time and resources in advance of the workshop to develop a Game Plan and to identify and invite people who are key to the success of the workshop(s).**

At least 30 days advance notice should be allowed to ensure that the key decision-makers participate and that they have a sound understanding of the roadmapping methodology and what it will mean for their own organisation. Devoting time to recruit the right people to the workshop(s) will ultimately be rewarded in the quality of the ideas raised.

A further 30 to 60 days is usually required in advance to identify potential participants, form the leaders group and develop a Game Plan. If support from facilitators is required, then planning must begin at an even earlier stage. During this time, the leaders group should identify the draft strategic goals and market drivers in preparation for the workshops.

- **Create a workshop environment that is conducive to creative thinking and to spur participants to share their ideas for the future.**

Workshop design and structure is critical to ensure that the technological depth and breadth intended is achieved. The quality and experience of facilitators are key success factors for roadmap workshops. For a diverse industry, specific workshops according to technology or business specialisation will allow greater depth of assessment of technical issues.

- **Allow adequate time in workshop sessions for participants to determine technological categories, explore issues and priority items in sufficient depth, and identify cross-cutting themes and next steps.**

It is important not to cover too many technologies and pose too many questions for a single day's workshop. For any given roadmap, it may be preferable to allow one to two days for the workshop.

- **Emphasise that the results of the workshop(s) will provide major technical input to the development of the Roadmap.** (Additional technical information and analysis can be added where necessary).

Results from the workshops must be carefully aggregated to ensure that suggestions from participants are captured and that they fit together into a coherent roadmap document. A user-driven network may assist with follow up and implementation.

A suggested workshop format and process is outlined in Box 6.

### Box 6. Workshop Format and Process - an example

#### Format and Scope

Workshops should bring together technical and marketing experts from industry and related organisations to identify research, development, and marketing needs and priorities through interactive discussion. Participants may consider research, development, and market solutions that address short-term (0-3 years), mid-term (3-10 years), and long-term (beyond 10 years) industry needs.

#### Workshop Structure

Workshops comprise separate sessions spread over the duration of the workshop. Depending on the number of participants, the core of the agenda should be a series of professionally facilitated break-out sessions, one for each technology area. Sessions could include:

*Plenary Session* covering overview of the roadmap process, vision for the industry and directions, and strategic goals described. Presentations might also include additional issues for the industry (eg. finance and marketing). Panel discussions can be valuable at this stage of the workshop.

The Plenary session should also include instructions for the break-out groups and a description of the workshop process and expectations.

*Break-out Sessions:* Participants should be divided into smaller groups (no more than 15 people per break-out group) that meet separately to address technology and market issues related to the industry. Composition of groups should be aligned with the objectives of the workshop and the nature of the industry.

Break-out sessions should take place concurrently and follow the same format. A suggested format is:

- Review draft strategic goals;
- Identify key challenges that must be overcome to accomplish goals;
- Explore potential solutions to address these needs and objectives;
- Prioritise technology options according to their ability to meet the strategic goals and place into near and long-term time frames;
- Analyse highest priority options to determine their potential impact on the goals; and
- Clarify respective roles of industry, government, researchers and other stakeholders to help accelerate implementation strategies.

*Tip:* Posting notes on a display board is one way to capture participants' ideas, eliminate duplicates and organise actions into categories. Participants can prioritise ideas with votes recorded by small coloured stickers.

Questions for discussion with participants must be specific to provide focus during the break-out sessions. Defined questions also help with integrating the results of all workshops. Suggested questions include:

- How do the industry's vision and strategic goals relate to markets and applications? Do the goals need to be modified?

- What technology challenges (eg. scientific/technical, institutional, and market barriers) stand in the way of achieving the goals?
- What technology is needed to overcome these barriers? Which of these needs require attention in the short-term (0-3 years), mid-term (3-10 years), and long-term (>10 years)? Discuss and rank possible initiatives that could overcome these barriers.
- For the top 5 actions identified, what needs to be done, by when, and by whom to achieve the industry's strategic vision?
- When are returns expected from the technology, research and diffusion activities identified?
- What will each participant do tomorrow?

- How do we take these ideas and move forward?  
There is no need to wait until the document is available before implementation can begin.

*Summary Session:* All workshop participants convene to hear concise summaries of the results of each break-out group. Participants should discuss the findings of each group, identify common themes, note cross-cutting needs, suggest next steps and propose opportunities for collaboration. After each presentation group members should field questions and engage in a discussion of the findings and next steps.

Before adjourning, the facilitator can pose questions to the participants to capture their final thoughts on the roadmapping workshop. eg. Were there any surprises? Anything important left out of discussions? What were the cross-cutting themes?

From international experience, organising and conducting workshops and developing a technology roadmap can typically require at least six months. The completion of a roadmap document, however, will depend on factors such as:

- the extent to which the market and technology analysis has been completed prior to the workshops;
- the group or organisation responsible for drafting the roadmap; and
- the level of technical detail that is included in the roadmap, including its planning horizons and objectives.

## Case Study 1 The Semiconductor Industry

*“Faster than expected advances in lithography technology have pushed ahead the latest draft version of the SIA Semiconductor Tech Roadmap by 2 years. That means that the next chip generation - incorporating a 0.18 micron feature size - will be launched in 1999 instead of early in the 21st century.”*

**Robertson, J. (1999), “Semiconductor Roadmap Accelerates”, Semiconductor Business News, CMP Media Inc. July 1997.**

In 1992 the US Semiconductor Industry Association (SIA) coordinated the first National Technology Roadmap for Semiconductors. In 1999, the roadmapping process was expanded to bring together international players in the semiconductor industry, including experts from Europe, Japan, Korea and Taiwan. The Roadmap identified the technological challenges and needs facing the semiconductor industry over a 15 year period.

The product focus of the roadmap was semiconductors. While the industry competed on semiconductor designs and the products that used them, semiconductor

manufacturing technology was the basis on which the industry could cooperate. The roadmap identified 11 technical areas, developing technology roadmaps for each area (eg. lithography) and sub-area (eg. exposure technology). Technology alternatives were identified for each area and sub-area, with technology driver performance projected for various points in time.

The critical system requirements identified by the US semiconductor industry included smaller size, lower cost and power dissipation for portable equipment. As an example of goals, it projected feature size between 1992 and 2007 as declining in three-year increments from 0.5 to 0.1 microns. Technology drivers in the lithography area that related to feature size included overlay, resolution, and device size. The lithography area was further broken down into exposure technology; mask writing; inspection, repair, processing, and metrology; and resist, track and metrology.

(Source: Semiconductor Industry Association, (1999), *International Technology Roadmap for Semiconductors*, SEMATECH, US)

# Checklist

## 4. Creating a High Quality Roadmap – a Checklist

### 4.1 Features of High Quality Maps

Factors for constructing a high quality roadmap include:

- Management Commitment - the most important factor for success is the commitment of senior industry executives with decision making authority for the roadmap. The embedding of rewards and incentives to encourage bottom-up support for roadmaps is also important.
- Effectiveness of Leaders Group - the leaders group sets the boundaries and constraints on the roadmap scope. It also determines the structure of the working groups and has influence over the final roadmap design.
- Competence of Roadmap Participants - competence and objectivity of the participants is important. Expertise should cover the multiple research, technology and product areas that are related to the science or technology area being considered.<sup>13</sup>
- Industry Driven - to be successful, a roadmap must have a clear sense of purpose and ownership. Despite the often substantial contribution of governments, universities and consortia to industry roadmaps, they are most successful when industry driven.
- Disciplinary Breadth of Participants – working group participants should not be limited to disciplines related only to the present technology area (which tends to reinforce the status quo and commit development along very narrow lines). Participation can be broadened to disciplines and technologies that have the potential to introduce innovations.
- Cost and Commitment - the major contributor to total costs is the time of the individuals involved in developing and reviewing the roadmap. The costs and commitment required from participants to the process should not be underestimated, but the potential gains are substantial.
- High Ethical Standards - these must be employed to avoid the potential, for example, of technical fraud, betraying confidential information and unduly profiting from access to privileged information.

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<sup>13</sup> Schaller, R.R. op. cit. p.11.

- Implementation and Review - implementation is critical to capitalise on the roadmapping process. It requires updating and revisiting to reflect changing market demands, the maturing of new technologies and shifts in technology focus. A roadmap will always be a work in progress.

### Case Study 2 Lucent Technologies

Technology roadmapping has proven highly rewarding for the global firm Lucent Technologies, uncovering many common technology needs throughout the corporation.

Through a top level review of multiple wireless communications product-technology roadmaps, managers discovered that all the individual roadmaps addressed the need for battery and antenna technologies. With this information, the corporate technology office was able to recommend sharing and consolidation of R&D, supply-line and other common resources.

(Source: Kostoff, R.N, & Schaller, R.R. (1999), *Science and Technology Roadmaps*, IEEE Transactions on Engineering Management:US. p.7.)

## 4.2 Avoiding the Pitfalls

The experience of participants in roadmapping exercises provides valuable feedback for enhancing the chances of success of future roadmaps. Experience suggests that the following factors need to be addressed in preparing for workshops:

- Show participants how roadmap activities will achieve the vision, industry goals and also improve the bottom lines of individual players;
- Gain commitment from senior industry executives and government policy makers;
- Implement a strategy for integrating results across workshops;
- Implement a marketing strategy for increasing awareness and participation beyond the workshop delegates;

- Include actionable items and use metrics to track progress to the roadmap goals;
- Use public recognition to acknowledge and reward achievement of key milestones; and
- Remember a workshop is not a roadmap - pay attention to implementation strategies, follow-up and the need to regularly review and update the resulting roadmap document.

### Box 7. Secrets of Successful Roadmaps

The following have been identified as contributing significantly to the development of successful technology roadmaps.

#### In the process:

- include the right people;
- begin to build partnerships;
- design a manageable process; and
- carefully plan a review cycle.

#### In the Roadmap itself:

- be strategic, clear and easy to follow;
- show relationships among research activities;
- quantify research benefits and set performance targets and measures;
- provide broad recognition of competing technologies;
- develop a realistic picture of non-technical barriers;
- ensure a realistic view of long development lead times;
- include consumer and world economic trend information;
- draw from other disciplines to develop a sufficiently broad outlook; and
- make greater use of visual/graphic maps over text and tables.

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