Innovation in Context™ (I²C):

Roadmap Planning for Science and Technology Based Entrepreneurs
Sharon C. Ballard, EnableVentures, Inc.
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ABSTRACT

Nascent ventures that learn and apply roadmap planning processes to gain technology intelligence (Boghani, Long, and Jonash 2008) generate stronger R&D proposals and increase funding success. This paper describes training that develops entrepreneurs’ skills in technology intelligence and monitoring by applying roadmap planning to gain and maintain situation awareness of their technology space. They learn to focus, plan, communicate, and position their innovations in context in proposals, business plans, and presentations. A top-down or systems engineering framework is used to consider, research, position, and monitor dependent, competitive, and internal science and technology forecasts. Trained entrepreneurs can gain and maintain situation awareness about their technology fields. They can better describe how their innovation advances state of the art, put innovations in the context of that art, and increase probability of funding; articulate the sustainable competitive advantage of products and business models, describe the value offered to customers, and increase probability of raising capital; and structure strategic alliances.

Introduction

Is it possible to teach technology intelligence and monitoring to science and technology entrepreneurs to help them to research, evaluate and position their innovations within their envisioned solution spaces before testing business models and writing business plans?

Technology intelligence is “the practice of capturing information about emerging technologies and trends and to deliver it in a usable form to decision makers. Establishing such a system can be challenging and requires the ability to evaluate large volumes of data and identify what is relevant and transfer it to those who need it ” (Lee et al. 2011). The traditional practices of roadmap planning, technology intelligence and monitoring, and situation awareness used by corporations, governments, and universities have been tailored for entrepreneurial training.

Entrepreneurs need technology intelligence to recognize and detect threats to their developments and identify opportunities in spaces where there is limited competition (Brown and O’Hare 2001; Fowler and Hammell 2011; Lopez-Ortega, Concepcion, and Viloria 2006; Mortara et al. 2009; Porter et al. 2007). Major corporations and large businesses use technology intelligence practices and tools1, but for entrepreneurs they are not available (propri-

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This tailored technology intelligence training for entrepreneurs has been in use since it was first developed in 1996. There is little research or literature published that addresses entrepreneurial training in or use of roadmap planning, technology intelligence and monitoring, or the adoption of situation awareness cognitive science techniques. There are recent engineering entrepreneurial education efforts applying quantitative patent claims to new problems (TRIZ) and to technology forecasting for small and medium sized enterprises (Savioz and Blum 2002; Schuh and Grawatsch 2003; Weaver, Kleinke, Lynch-Caris 2012). We found only one reference to applying technology forecasting and roadmap planning using intelligent agents for entrepreneurial training (Savioz and Blum 2002). Ventures pursuing federal R&D funds through the SBIR/STTR Program particularly benefit from this training; we have found that it is effective for ventures across all technologies, markets, and countries. We call this technology intelligence training Innovation in Context™ or I²C. The I²C curriculum is delivered within collegiate courses and as part of professional development workshops for commercialization training (we call it Supercoach® Entrepreneurial Training or SET). It is also delivered as part of SBIR/STTR Program training and as a stand-alone workshop or course.

This paper describes the topics covered within the training, what exercises make up the training, what challenges and anecdotal results have been achieved, and what future developments are being considered. Participants share how these trainings helped them demonstrate their knowledge of the state of the art (do they know what is the most recent or most advanced level of knowledge of a science or technology and can they compare it to their own invention in their innovation space), articulate how their innovations are different and better, how they consider and apply the pace of change of competing and dependent technologies over time, and how they are able to link their innovations to the value they deliver to customers and stakeholders.

How We Teach Technology Intelligence and Monitoring

Background
Technology intelligence and roadmap planning were first developed by Motorola, Inc. in the 1970s. Today, most corporations, governments, and universities practice roadmap planning to forecast science and technology and plan investment decisions. We incorporate roadmap planning in our training for entrepreneurs, and for instructors and coaches who want to help them. Our I²C roadmap plan training includes Intellectual Property (IP) Plans, Business Plans, Product Plans, and Resource Plans; how to tailor traditional roadmap
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planning for entrepreneurs and what resources and references we use for training and facilitation; what roadmap software tools are most useful; and how we designed our one-day workshops and more intensive five-week roadmap planning course with full roadmap facilitation for early-stage technology ventures. We teach I2C roadmap planning to faculty, instructors, and coaches who work with science-technology entrepreneurs and teach collegiate entrepreneurship courses.

There has been considerable work in technology intelligence and development of automated systems (Mortara et al. 2009), however there are few resources, research, tools, texts, or trade books specifically for entrepreneurs (Savioz and Blum 2002). This was the motivation for the development of entrepreneurial training curricula—to teach them how to gain insights that are provided by subject matter experts in established corporations, but are not affordably available to entrepreneurs. In a sense our training seeks to provide the surrogates for these experts.

Situational Awareness and Technology Intelligence Roadmap Plan Training

Entrepreneurs need to gain technology intelligence and continuously monitor their technology space in order to gain and maintain situational awareness regarding the state of their competitive landscape. They must be able to make technology trend forecasts for dependent and competitive technologies, as well as know how their own innovations fit in that technology landscape. They need to make sound investment decisions (investments are primarily in the form of time rather than capital), but they do not have the resources of corporations and governments. The cognitive science of situation awareness was originally developed to help soldiers make critical decisions in time-constrained environments when confronted with an over-abundance of uncertain or error-filled information that changes often; understand threats (competition) and capabilities; make plans and continuously monitor them; and respond to changing environments and communicate their decision-making reasoning to all stakeholders. We have adopted situation awareness advances, technology-product roadmap practices, and technology intelligence and monitoring methods for entrepreneurial training. Situation awareness employs methods for sensing the environment using various (often internet-based) sources of information, mining that information to extract pertinent content, assessing the extracted information for context and relevance, anticipating future changes, drawing conclusions based on that assessment, and communicating to others.

Prior to founding EVI, Ballard (1991) founded Reticular Systems, Inc., whose purpose was to design intelligent SA systems. Ballard recognized that technology intelligence training provides situational awareness for entrepreneurs, and her SA theories and innovations have influenced the design of the curriculum. The SET I2C curriculum is available via non-exclusive and exclusive license to educators with per copy price ranges from $10 to $50.

SET I2C teaches entrepreneurs to gain technologically intelligent SA using roadmaps by:
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- Sensing and mining: extracting information about interested technology (and business) environments.
- Assessing: integrating sensed and mined information with relevant internal knowledge to create a picture of the current situation.
- Predicting future events and perhaps re-planning (including temporal reasoning).
- Concluding and planning: using this picture to direct further perceptual exploration in a continual cycle.
- Communicating these pictures with others to gain resources or trigger desired actions.

Some of these SA functions are addressed by traditional business tools, such as Strength-Weaknesses-Opportunities-Threats (SWOT). However, they often do not consider landscape roadmaps, dependent or competitive technology roadmaps, and customer product-technology roadmaps. The entrepreneur's I²C roadmap is created considering these major SA functions. These are also the same functions in a classic and continuous SA system: recognition, assessment, prediction, planning, and communications. The SA functions work together to help the entrepreneur develop a situation state description, which often takes the form of a science-technology-product-market roadmap.

Technology Intelligence, Entrepreneurship Education, and Venture Success

Entrepreneurs struggle to communicate their innovations in context of the state of the art so that their audience can distinguish scientific merit and impact among proposed approaches2. Tunnel vision inhibits an entrepreneur's awareness of advances and pace of progress in related or dependent fields that have the potential to adversely affect his or her business plan. Typically an expert in a science or engineering discipline, they often suffer from tunnel vision; his/her focus is on one particular area of research3. However, most innovations are dependent upon advancements in underlying science and technology not often monitored by entrepreneurs. For example, a new venture from Duke University invented a new medical device to treat infantile jaundice. The entrepreneurs did not know or consider the pace of change for lighting technology roadmaps; during our training, they researched what technology experts forecasted, and they examined published vendor product roadmaps. As a result, they discovered a revolutionary way to make their product offering much more affordable and attractive, based on new lighting technology poised to be product-mature in time for their own adoption.

Technology intelligence roadmap training saves entrepreneurs time (Markley et al. 2007): not only faster “time to market” or improved “efficacy of building the business” or “decision making speed,” but the ability to quickly recognize whether an idea will not or cannot succeed as currently envisioned and

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2 Valley Ventures' Greg Adkin shared that they fund 1% of business plans received from qualified sources (Arizona State University Launch Prep Program, Sharon Ballard, lecturer, 2009); current SBIR success rates average 8% to 15% based on www.sbir.gov statistics.

3 Author Ballard's experiences writing SBIR proposals and coaching ventures pursuing SBIR funding and peer reviewers' comments on hundreds of such proposals since 1985.
pivot (Tice 2011) in a more promising direction. A time-saving example would be our infantile jaundice medical device entrepreneur, who saved months, maybe years, by learning of significant new lighting technology changes that would be available for his products. This new technology knowledge also reduced his manufacturing and direct material costs. The SET I2C training uses corporate, government, and industry association landscape roadmaps, customer and competitor product roadmaps, and traditional sources of knowledge such as patent databases, research, and publicly available reference databases to serve as surrogates for the subject matter experts that most start-up ventures lack.

Curriculum Description
The I2C exercises that form Session Two (of Eight Sessions) cover intellectual property (IP), technologies, and products. Each exercise is finalized in a one page slide or two, although there is a significant amount of work performed for each exercise. Entrepreneurs develop technology intelligence and roadmap plans; they can spend as much as five weeks to complete these exercises, depending upon availability of references, time available to dedicate to the process, and identification and availability of subject matter and industry experts that might be interviewed. For example, we encourage them to interview one or more roadmap creators to gain deeper insights into the roadmap forecasts.

These exercises help entrepreneurs to link dependent-internal and competitive technologies, products, markets, and resources (called layers in roadmap planning), and to link to their Profit & Loss, using timelines to indicate strategic activities' schedules. The training has been effective for all types of entrepreneurs, whether they are innovating new technologies or employing new technologies in traditional businesses. The SET I2C technology intelligence exercises are described in more detail below.

The Process for Technology Intelligence Roadmap Planning
The SET I2C Session Two exercises begin with the Sunflower, modified to include dependent technologies to be considered by the entrepreneur (Ryan 2002). This is our starting point for technology intelligence research. We then use the T-Plan (Phaal, Farrukh, and Probert 2001) approach that we have modified to facilitate the roadmap planning process; we start with the “what’s possible” layer–cataloging the internal, dependent, and competitive technologies and research. We then consider the external drivers (also called market drivers), or as Clayton Christensen writes, customers have “jobs they need to have done” that the entrepreneurs’ technologies could “apply for” (1997).
We use tools such as Mindjet MindManager® or free versions such as MindMeister®. The research is typically captured with these tools (e.g., file attachments, urls, images) but does not easily indicate timeframes, which must be done via a somewhat manual method (start and stop durations for each entry). However, some of these tools export to project planning tools or even Microsoft Excel®.
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**Table 1. SET I2C Process for Positioning Technologies and Products**

<table>
<thead>
<tr>
<th>Rob Ryan's Sunflower Exercise</th>
<th>Sensing, Mining, Assessing, Anticipating, Predicting</th>
<th>Planning and Communicating (or Handoff)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Core competencies identified</td>
<td>• Internal technologies assessment</td>
<td>• SWOT</td>
</tr>
<tr>
<td>• Products and markets envisioned</td>
<td>• External technologies assessment</td>
<td>• TRMs</td>
</tr>
<tr>
<td>• Key assumptions</td>
<td>• Dependent technologies assessment</td>
<td>• Quad Charts</td>
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<tr>
<td>• Dependent Technologies</td>
<td>• External market drivers</td>
<td>• Technology Readiness Levels</td>
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<td></td>
<td>• Internal business drivers</td>
<td>• Product simulations, models</td>
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<td>• Business plan presentations</td>
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<td></td>
<td></td>
<td>• R&amp;D proposals</td>
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**Identify Sources for Data Gathering**

We suggest how to generate and augment key words for searches, and how to identify internal sources of data as well as external access methods and limitations. We help entrepreneurs to establish a baseline list of sources for external references, access methods to those sources of references, and guide them in making a list of candidate key words to use for searches. We often engage reference librarians in courses to help entrepreneurs with search tips.

Resource lists of internal sources are created (including board members, advisors, other co-founders and employees, suppliers, and customers) as well as external sources such as government and industry association landscape roadmaps. The latter often elicit useful feedback from entrepreneurs. These roadmaps are available on the web or available at science and/or business libraries at universities, yet are seldom used or known by entrepreneurs. Many
are generated by the same agencies that new ventures are applying to as R&D customers. Another source of technology intelligence little used by technology entrepreneurs is prior awards to other small businesses, universities, and corporations.

Determine Presentation Modes
Entrepreneurs have many visual representations to choose from, and many use much of the same data. The issue is how to best present that information to the target audience. We have them examine existing planning and communications models such as the variety of roadmap graphics, SWOT, Business Model Canvas, Quad Charts, and Opportunity Landscapes (Romito, Probert, and Farrukh 2007). We help the entrepreneur consider the variety of business and technology intelligence “reports” or outputs. Another consideration we include is that of Technology Readiness Levels (TRLs) for the technology intelligence gathered, as well as the maturity of internal inventions and innovations. The ideal is to provide graphical I2C views for the technology and business area of interest. We use several business plan formats, such as Business Model Canvas (Osterwalder and Pigneur 2010) and the Supercoach® Entrepreneurial Training’s One-Page Strategic Business Plan template to link to the I2C view. There are many formats for technology intelligence reports and roadmap graphical and tabular formats, as well as traditional business model formats that are important for them to learn about and consider.

Recent Training Results
In May 2012, a one-day roadmap planning workshop was held for the Center for Integrative Nanosciences at University of Arkansas-Little Rock for 18 researchers. This initial training was in preparation for a five-week process to generate four new applied sciences investment roadmaps that would lead to commercialization opportunities. Participant feedback was: a 100% score from 9 participants, a 90% score from 3 participants, an 88% score from 3 participants, and a 70% score from 3 participants. One new licensee venture has been launched and has received funding for two out of four SBIR proposals submitted.

Two-day SBIR roadmap planning training has been held annually since 2003 at Arizona State University (ASU) with entrepreneurs and faculty-led venture participants. Since 2008, ASU faculty and ASU-linked companies have been awarded more than 45 SBIR/STTR contracts and grants, amounting to more than $7 million.

The majority of critiques of the programs concerned lack of time to cover all that the participants wanted to explore. This is a common theme; once they learn that such roadmaps exist, the participants are anxious to spend time reading and reviewing them. This is not practical in a workshop or short course. Another area of criticism was about the difficulties of finding relevant roadmaps. This can be a challenge when the information resides within proprietary databases or sites, or in difficult to navigate government sites. Here is some longer feedback on the training:

The roadmapping exercises pushed us to learn new things about our technology, our competitors, and key leverage points in the industry.
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Kevin Dooley, ASU Professor, Department of Supply Chain Management, Distinguished Scholar, Dean’s Council of 100, W. P. Carey School of Business; Senior Advisor, The Sustainability Consortium, Arizona State University

When we signed up for the Technology Roadmapping class, we had a rough idea of the importance of the technology we had developed, where we were going, and what we needed to do to get there. However, the course really expanded our vision of the outside market influences and external events that needed to happen before we could turn our vision into reality. By the end of the course we had a much clearer vision as to how execute our business plan. This course was definitely time well spend for us.

—Ed Koeneman, Founder and CEO, Kinetic Muscles, Inc., Tempe, Arizona

The [NCIIA] program that I participated in was phenomenal in helping me understand the core framework of building a business. The introduction to roadmaps was essential, and a great tool for me in figuring out how to deal with the jumble of objectives I had floating around in my head. I created an Ecovative roadmap in 2007, last year when we moved to our new building I pulled it out for review. It turned out to be surprisingly accurate (albeit, needing to be time shifted by about 2 years). I still make roadmaps using this technique, and am thankful to have been introduced to it so early.

—Eben Bayer, CEO, Ecovative Design, Inc., Green Island, NY

Roadmapping...training was really helpful, but not because it necessarily resulted in the perfect path for your venture to take. In fact, given the early stage of these companies, it almost certainly did not; however, what it did do was present a process. It forced you to think differently about your business, evaluate assumptions, and make clear choices about direction. Having a plan, even if it’s not the perfect plan, is important for maintaining focus and understanding what’s working and what isn’t. Roadmapping helps make these choices deliberate and clear.

—Chris Leidel, COO, Therapeutic Systems, LLC, Amherst, MA

The technology roadmap planning process...has been a valuable asset for ArbSource, a biotechnology company developing wastewater treatment technology. Not only did it enable our team to structure our thoughts more readily in preparing the four Phase I SBIR proposals we have submitted to government agencies over the past eight months (with one already awarded), but it also helped define our competitive advantage over other players in the water treatment technology sector. ArbSource’s traction to date can most definitely be attributed in part to Ms. Ballard’s technology intelligence roadmapping tools.

—Mark Sholin - Founder and CEO, ArbSource, Phoenix, AZ

I have been lucky to receive...coaching guidance while turning my invention to innovation. I use to be a researcher and teacher at university...technology intelligence training gave me new ways of thinking about my technology and business. You did not replace me, you extended my abilities. You pointed out weak points...and helped to maintain and develop good ones. Nowadays I run an international technology company having product development projects
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In June 2012, the NSF sought input on technology intelligence: “[t]ransformative approaches and innovative technologies are needed for heterogeneous data to be integrated, made interoperable, explored and re-purposed by researchers in disparate fields and for myriad uses across institutional, disciplinary, spatial and temporal boundaries” (National Science Foundation 2012). Science and technology entrepreneurs face the same challenges that the NSF identified in their call for comments.

—Mr. Mika Laitinen, Managing Director, Magnasense Technologies Oy

The technology roadmap session...introduced the topic of technology intelligence by saying, ‘How can your company be successful in 5 years if the technology your product is based on becomes outdated?’ Looking in the marketplace, it is very apparent which companies have poor technology intelligence. They are the ones at the end of their rope—and will shortly have to terminate entire product lines—whereas the companies with good technology intelligence continually have success in the marketplace. As an entrepreneur and advocate of disruptive technology, I use [these] practices to not only keep up with the state of the art, but define it. Through good technology intelligence, I am able introduce my disruptive technology at the point of highest impact, and displace my competition. Talk about a competitive advantage; my competition is planning to develop a technology next year when my product is shipping with it today. Thanks!

—Marc Groom, CEO

Conclusion

Roadmap planning and technology intelligence is typically not taught in traditional engineering and science college courses – it was developed by industry for industry. SET I2C technology intelligence roadmap plan training provides exercises that enable first-time entrepreneurs to uncover the context-specific information they need if they are to shape viable business concepts and differentiate their innovations in context of the state of the art. Intellectual property and related protections are considered early; without this consideration, entrepreneurs can accidentally violate patent positions, such as mistakenly make an offer to sell, or move before considering trade secret vs. patent protection or other methods of IP safety. We use a top-down systems engineering approach to business planning and technology intelligence training, with holistic exercises in the first session. Deceptively simple exercises force entrepreneurs to consider the silos of business areas, such as marketing, sales, finance, and product development, and how they are interrelated and interdependent. The only roadmap planning “textbook,” T-Plan, advocates the traditional approach of “market-led” or market driven requirements; ours is more “technology-informed.” We first consider “what is possible” and then move to consider marketplace pain, being careful to understand what customers are challenged by in their businesses and not expecting them to know what is technically or scientifically the state of the art in potential solution spaces. We learned that technology intelligence and roadmap planning has the most resistance from non-technology entrepreneurs, even when their businesses might benefit from technology intelligence monitoring and application (Markley et al. 2007).

In June 2012, the NSF sought input on technology intelligence: “[t]ransformative approaches and innovative technologies are needed for heterogeneous data to be integrated, made interoperable, explored and re-purposed by researchers in disparate fields and for myriad uses across institutional, disciplinary, spatial and temporal boundaries” (National Science Foundation 2012). Science and technology entrepreneurs face the same challenges that the NSF identified in their call for comments.
In September 2011, the NSF invested $10M in a five-year program from the Stanford Technology Ventures Program (STVP), with the NCIIA, to launch a national center for teaching innovation and entrepreneurship in engineering. The NSF's investment addresses the increasing interest in entrepreneurship for engineers and scientists. With STVP's leadership in preparing students as entrepreneurs and NCIIA's university network, nearly 350 US engineering schools are within the program scope, tapping into innovative education across this network.

But there is still much to do. The SET I2C training can help these entrepreneurs gain competitive technical intelligence to position inventions and innovations in context of the state of the art, communicate how they are different and better, and to differentiate themselves in the marketplace with their products. We are now turning our attention to new education tools to increase automation of technology intelligence and for self-paced and collaborative learning. We are also preparing a new, stand-alone technology intelligence e-book that incorporates the exercises from Session Two described above. This will give instructors a new tool to teach technology intelligence using an SA-inspired roadmap planning approach proven to be useful after over a decade of global use.

**References**

Association for the Advancement of Artificial Intelligence (AAAI) Workshop Agendas, 26th AAAI Conference on AI (AAAI-12), to be held July 22-23, Toronto, Ontario, Canada.


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