1   INTRODUCTION

Since the introduction of the term 'technology roadmap' by Sandia National laboratories in 1997 (Garcia and Bray, 1997), technology and product roadmapping are now standard procedures in most companies (Eppinger and Ulrich, 1995). Many companies keep product and technology roadmaps constantly updated and use them to guide decisions as to which products and technologies should be selected and funded for the next phase of product development (Phaal et al., 2001).

1.1 Background on product roadmap

Product roadmaps are used to keep a company's product strategies up to date and to predict upcoming market trends through visualization of past, current and future product line-ups over time. Cooper and Edgett (2010) define the product roadmap as a canvas that lays out the major initiatives and platforms a business will deal with in the future. As one process example, Vähäniitty et al. (2002) propose a four-step process of creating and updating product roadmaps; defining strategic mission and vision, scanning the environment, revising the product vision, and estimating a product life cycle and evaluating development efforts.

1.2 Background on technology roadmap

Cooper and Edgett (2010) and Phaal et al. (2004) define the technology roadmap as a strategic plan for the business's expected technology development or acquisition that is relevant to their existing product line-ups. Creax, a consulting firm (2014) that supports companies with technological innovation, develops roadmaps for technological trends based on patent innovations over the last several decades. Rinne (2004) adds visualization elements to the roadmap by connecting arrows between markets, products, and technologies. Rinne has also attempted to differentiate various roadmapping methods: virtual innovation, innovation factories, and several patterns of co-evolution of technologies, products, and markets.

1.3 Market uncertainty

Despite the mature application of roadmapping processes in industry, increasing uncertainties, rapid changes, and complexities in market environments are forcing companies to question the validity of strategies that differentiate their products and services solely by their features as specified by roadmaps based on linear technology evolutions. Design/experience-driven approaches have been proposed to connect market forces with product innovations. Bertola and Teixeira (2003) argue implementation of design as a knowledge agent in organizations to promote innovation. Shelby et al. (2012) present an example of partnership failures due to a technology only driven approach by arguing that understanding needs and/or building trust of end users are crucial market success factors. An et al. (2008) propose integrated product-service roadmaps with Quality Functional Deployment (QFD) to push the role of design research in forecasting products and services in the near and/or long term future. A scenario-based technology roadmap is presented by Geschka and Hahnenwald (2013). In this example, a technology roadmap is not influenced merely by technology evolutions, but by external circumstances such as market, societal, and economic factors. Many industrial firms are struggling with finding operational methods for employing effective implementation.

   While product and technology roadmaps have been well-formalized in terms of their structures, methodologies, and frameworks, design roadmaps have not been explicitly explored nor studied from either an academic or industry practice standpoint. Our research questions arise from discovery of incomplete design implementations into the roadmapping processes. Based on our preliminary research, we have found that quite a few lead companies keep some form of a design roadmap within their organization. However their design roadmaps appear to be mostly sub-sets of product and technology roadmaps that have not been fully implemented in a way to achieve strategic business goals on a long-term basis (Hunsaker, 2014; Watermark Consulting, 2012). In this paper we investigate challenges and opportunities of the roadmapping process and define a design roadmap as a first step.

2 RESEARCH METHODOLOGY

The goal of this research is to answer two key research questions. (1) What are the types of roadmaps used in industry and who has ownership of the process? (2) What are the challenges and opportunities for integrated design roadmapping in the future?

2.1 Pilot interviews

Six in-depth pilot interviews were conducted to understand general usage of the roadmapping process in industry. Interviewees with at least five years of work experience from business, marketing, design and research and development were included in the study. Throughout the preliminary research, interview scripts were refined and edited based on prior comments and feedback.

2.2 Semi-structured interviews

Based on the pilot interviews discussed in the previous section, the research team performed thirty-five interviews with professionals at eighteen companies in the San Francisco Bay Area to understand how various types of roadmaps are used and developed within current industry settings. Semi-structured Interviews were useful as they followed more or less the themes outlined but allowed room to explore additional topics that were also relevant to both the interviewee and the interviewer. They gave participants more flexibility in answering the questions in-depth, depending on their own organizational structure. Participants in a one-week long Executive Product Management Program at UC Berkeley's Haas School of Business composed the primary subjects and were interviewed in November 2013 and March 2014. Other subjects were from local companies in the San Francisco Bay Area, interviewed from August 2013 to November 2014. Table 1 provides the number of participants interviewed by company sector and job function.

- *Interviews with product managers* Product managers are usually in charge of product roadmaps in their organization. Product managers, marketers, portfolio managers, service managers, business directors are included in this category. Sixteen product managers were interviewed in this study.
- *Interviews with technology managers* Technology managers lead or play a major role in a technology development team and usually manage technology roadmaps. We interviewed seven technology managers in this study.
- *Interviews with designers* Designers and design researchers lead or play a substantial role in design teams and typically manage the design process in various ways within a firm. We interviewed twelve designers in this study.

Table 1. Summary of interview participants

	Product Managers	**Technology Managers**	**Designers**
Number of participants	16	7	12
Company categories	*Network, Communication & Information, Security Solutions, Software, E-commerce, Financial Solution, Online Education, Internet, Home Automation*	*Network, Software, Camera, Sound Technologies, Security Solutions, Consumer Electronics*	*Software, Consumer Electronics, Computer software & hardware, Glass & Ceramic Materials*

3 DATA ANALYSIS

Grounded Theory (Glaser 1992; Strauss and Corbin 1998) was used to analyze our interview data and refine our analyses. We analyzed the data by creating transcriptions, highlighting main responses, interpreting and extracting keywords and key quotes. Three researchers worked independently and the results and insights were discussed and merged into one compiled document once the individual analyses were completed. We aimed to understand typical uses of roadmapping processes, and better understand how they were created and refined. Practitioners and researchers use the term, *roadmapping,* differently depending on how and where it is implemented within an organization.

Similarly, the unit using roadmapping varies from macro levels, such as for strategic planning within a company, to micro levels within teams, groups, projects, or even at an individual level. In this research, the unit of analysis was at the team, group, or project level within a firm. Where possible, we also analysed data at the organizational level in order to relate the roadmapping process to the organization structure and as a medium to connect cross-disciplinary or cross-organizational efforts.

3.1 Descriptive summary

By analysing 35 interview transcripts, we synthesized responses to our key research questions. In this paper, we categorized responses by the respondent's role in a company. Quotes are provided as examples to illustrate pertinent points, coded by the role of the respondent within the company (D-designer, P-product manager, T-technology manager).

3.1.1 Types of roadmap in use

All the product and technology managers responded that they keep technology-product roadmaps in a regular manner. A few designers answered that they keep design roadmaps, but they tend to be subsets of technology-product roadmaps.

Product Roadmaps: A product roadmap shows a company's vision and holistic plan that includes aspects of business strategy, engineering, marketing, etc. From the interviews, we found that companies generally maintain two types of product roadmaps: one for internal use and the other for external use. Internal product roadmaps map out a detailed long-term strategy whereas external roadmaps show business partners and customers general directions for the company.

Technology Roadmaps: A technology roadmap is mainly for internal stakeholders. It gives a detailed plan for technology development. Usually technology roadmaps are derived from product roadmaps; but companies whose innovations are heavily technology-driven find that their technology roadmaps have a relatively larger influence on product roadmaps than those that are design-driven.

Design Roadmaps: Seventy-five percent of designers interviewed answered that they kept some sort of design roadmap. These current design roadmaps in use mostly showed design trends and were loosely organized and tended to be subsets of technology-product roadmaps.

3.1.2 Uses of roadmaps

Internal collaboration: Eighty percent of our research participants answered that the primary purpose of their roadmaps was for internal communication. They were used to align the product development processes among multiple teams in a company. One technical manager explained that good communication with internal stakeholders was necessary to make decisions.

"You have to talk to a lot of different people. You understand the market, you understand your customer, then you have an idea of what's needed in the product. But then you need to talk to engineers to make sure that there's the technology to help it."(T-7)

Internally, roadmaps were also used to make technological alignments since there are multiple engineering teams in a company, such as software and hardware teams. A technology manager from a hardware company explained it was necessary for the engineers to use roadmaps to collaborate well:

"For us, there are many independencies, so it [roadmap] helps get alignment. Because they [engineers] have to do a lot of integration or testing, planning, to make sure things align between hardware and software. So its primary purpose is alignment." (T-5)

External communication: We found that 56% of product managers use product roadmaps to communicate with external stakeholders whereas only 14% of technology managers do so. Product managers use external product roadmaps to gain feedback about their business plans from key business partners and customers. Another motivation to share product roadmaps with customers is to increase competency. Large companies may lack agility because of their size. One of the product managers at a multinational company explained that they use roadmaps as a marketing strategy to inform customers which features the company is committed to develop in the near future:

"[A] roadmap is used as a competitive weapon. Competitors might come up with features that we don't have. Eventually we are doing certain things, but some features may not be covered today. So, the primary purpose of roadmap of our company is to document what we will be doing for the next 18 months…and the customers can make plans and purchase decisions based on that roadmap." (T-4)

Future prediction: Companies use roadmaps to predict future markets and plan for products in advance so that they can make effective business strategies (Günther et al., 2013). They use roadmaps to derive actionable items to reach desirable states in future markets. One technical manager explained that a roadmap shows the necessary steps needed to reach the company's goal, and the company uses it to evaluate its current state:

"So product roadmapping is important because it gives you two things. First, it tells you the direction in which the company needs to go. So you have a checkpoint and you have a report, you evaluate that and you figure out whether you are on the right track or not." (T-1)

Resource allocation: Once executive decision makers set the company's vision, product and technical managers prioritize plans based on the predicted impact on revenues and customer satisfaction and growth. The key players in the roadmapping process allocate resources based on their priorities. We found out that 57% of technical managers use their roadmaps primarily for resource allocation while only 38% of product managers do. Since technologies take time to develop, technical managers need to select and invest in the most appropriate technologies in advance.

3.1.3 Frequency of Updates

Interviewees emphasized the necessity of updating roadmaps on a regular basis to *"keep them alive"* because markets change fast today. The majority (66%) of our research participants revised their roadmaps quarterly. We found out that the frequency of a company's decision-making process also affects roadmap update frequency. The company updates roadmaps to revise their core product concepts, features, and experience revisions. Also, the update frequency depends largely on a product lifecycle. Hardware companies are less likely to update their roadmaps frequently because their product lifecycle is relatively long (T-5). On the other hand, software companies are likely to update their roadmaps frequently because of short product release cycles (T-3). A company may also update its roadmap if there is a change in its fiscal plan that will influence resource allocations (T-2). Table 2 summarizes the number of participants in each functional category that responded to key roadmapping issues.

Table 2. Summary of descriptive research on roadmap in use

Primary-code	Sub-code	Product Manager	Technology Manager	Designer
Types of roadmap	Product Roadmap	12	6	6
	Technology Roadmap	6	7	6
	Design Roadmap	0	0	9
Frequency of roadmap updates	Less than a quarter – 6 weeks	2		
	Quarterly	11		
	Longer than quarterly	4		
Purpose of roadmap	Future Prediction	6	4	3
	Internal Collaboration	10	6	3
	External Communication	9	1	0
	Resource Allocation	6	4	1
Issues on roadmapping process	Lack of feedback loop from users	1	0	3
	Ineffectiveness in predicting future	3	1	0
	Communication conflict	6	3	0
	Plan not followed	1	2	4
	Feature driven	3	2	3
	Ambiguity and confusion	4	2	0
	Lack of agility	1	0	2

*The total number of respondents in the table excludes interviewees who either were not asked or declined to answer specific question.

4 ROADMAPPING CHALLENGES

From our interviews we have identified several uses for roadmaps in industry. We then analysed and categorized the challenges that most of our test bed participants encountered while working with roadmaps.

4.1 Ineffectiveness in predicting future

The primary purpose stated by interviewees for roadmaps was to predict future markets and opportunities. Previous research also highlights roadmaps' strength in business forecasting (Kappel, 2001). However, due to rapid technological progress as well as swiftly shifting consumer needs, it has become extremely difficult to predict future markets (Günther et al., 2013). Therefore traditional roadmaps that depend heavily on technological progress have become less and less reliable in predicting changes in recent years.

From our research, we also found that the difficulty in forecasting was problematic to many key players in the roadmapping process. In practice, business executions easily deviate from the roadmaps because companies need to react or respond to events that roadmaps fail to predict previously. As one respondent mentioned:

"Over time, the market dynamics have become even more dynamic. The sine wave is getting tighter and tighter. For me, even predicting what I'm going to produce in six months is very difficult. We invested a tremendous amount of time on roadmapping, but we never ended up producing what we targeted for this, even the second year, much less the third year." (T-3)

Roadmaps are expected to present products that will be competitive in the future market so that companies can select appropriate technologies to develop (Phaal et al., 2013). Relying on roadmaps with inaccurate market forecasts poses a high risk to companies because they may not develop products that satisfy rising consumer needs. Therefore effective consumer needs prediction is crucial to developing appealing products. Companies need to direct their engineering departments to develop technologies before they can introduce new products in the market. If the companies invest in technologies for products that will no longer meet upcoming consumer needs, those investments may be wasted as a result.

4.2 Lack of feedback loop from research on end-users

In recent years there is movement in the new product development process to take in more customer insights to develop products that meet customers' needs. However we found out that customer feedback is not effectively incorporated into the roadmapping process.

"There is not a good feedback loop from the consumer side to us." (P-2)

This interviewee explained that there are several intermediaries between the company and their end users. Retailers sometimes overly influence the roadmap and mislead companies into producing what the retailers want to sell instead of what consumers want. Although the company may receive access to a full range of market data and customer analyses at significant levels, customer feedback and insights may be filtered and distorted as the number of stakeholders between the end users and the decision-makers increases. As a result the key players in the roadmapping process face challenges in capturing latent user needs. Our interviewees highlighted the lack of effective methodologies to extract insights from customers.

"Although we regularly conduct user tests, there hasn't been user's reaction that's strong enough to make change on our direction, it's more towards incremental changes in features, small pieces." (D-10)

"It's very hard to figure out the process of how to extract the information I want from my customers and apply to roadmapping." (T-7)

It is difficult to simply take in UX researchers' insights from user experience analysis into the business strategy because those researchers often *"do not understand business constraints in which the company operates"* (T-4). Roschuni et al. (2013) define this sort of tension between the designers and business decision makers as *inertia*. Similarly, we found that current roadmapping processes face challenges in the inability for key players to define the best use of the UX research.

4.3 Over-dependence on feature-driven roadmapping processes

Nearly every roadmapping process that the interviewees described was technology-driven. Technology-driven roadmaps are relatively straightforward for companies because they can keep adding new features to products based on technological progress in any specific time frame. From a marketing perspective, adding new features to appeal to consumers may be a valid strategy even though those new features may not effectively solve customer pain points. Our respondents described their concerns about the feature-driven roadmapping process:

"Every year, we need to have different marketing points, which means that we don't have solid good features but keep adding other features into it...because we need to market it differently...so we are not building what's the most important, I think that that's an issue." (D-3)

"Sometimes [new features] are harmful to customers... But because of that sales pressure, my organization will often bend to that pressure and doing something that is only beneficial to one customer. Very incremental [progress] and sometimes harmful to other customers." (T-4)

Even though feature-driven approaches have been effective in the past, we require more radical innovations to respond to shifting consumer preferences. Moreover, if a company simply adds features based on technological progress, the product may deviate from the most significant user needs. In our interview, a few respondents answered that their teams are aware of this shortcoming of feature-driven roadmapping.

"I do think a lot of organizations are feature-driven, and I think it happens a lot with internal tools as well" (P-15)

"We're trying to shift from feature roadmaps to outcome, customer outcomes. Okay, so we might say we're going to solve these five customer problems in the next six months." (T-3)

5   ROADMAPPING OPPORTUNITIES

By analysing the major challenges, we have identified several opportunities to improve the existing roadmapping process.

5.1 Experience-driven roadmapping opportunities

Purchasing decisions for consumer products are no longer driven entirely by product or service features. Rather the holistic experience around the product or service is becoming more dominant in today's market. Many participants in our research address this point in similar ways. They exemplify several usages of design implementations in their organizations particularly during the roadmapping process. One example is a software company who credits *design DNA* as a key driver of innovation to the entire organization. In this company, they develop a roadmap based on outcomes rather than features as described in the previous session.

"We try to be very vague in terms of how at first, and we don't try feature-driven roadmaps, but outcomes of features." (T-2)

Recent efforts to bring experience design in as an essential part of the roadmapping process, either beforehand or simultaneously, has the potential to improve the traditional feature-driven technology or product roadmapping processes.

5.2 Increase ownership of designers in the roadmapping process

Despite the fact that a majority of interviewees argued that they wanted to bring more design aspects into the roadmapping processes, they actually did not have detailed execution plans to do so. While designers answered that they already used or were aware of product, technology and design roadmaps

in their work, the number of product and technology managers who were aware of these design roadmaps is relatively low. The contradiction in what product managers and technology managers perceive of as design roadmaps and what they have actually been using reveals an opportunity for improving the direct application of design into the roadmapping process. We believe that increased ownership of designers into this process will be essential to take this opportunity.

"This is like a customer experience group or a user design experience group, but they are not, they are not part of the product team or haven't been part of our product team traditionally. I think, probably their engagement would help us better solve the right problem." (T-6)

5.3 Preparing for the future using an iterative roadmapping process

We advocate for a more agile and iterative roadmapping processes to incorporate rapid changing market conditions. One interviewee (T-3) explicitly emphasized the need for an iterative design roadmapping process. Due to increasingly more complicated and unpredictable market conditions, his/her company has decided not to initiate roadmaps until a certain level of feasibility has been met and market acceptance achieved. This interviewee comments:

"After iteration of parallel prototyping processes, we select the most compelling one among many to put on their roadmap." (T-3)

Designers point out that the *"plan not followed"* can be the highest missed opportunity in the existing process (33%). They would like roadmapping to be more flexible and iterative so that it can react better to market changes. Also, they wanted to include key overarching experiences into new product/service roadmaps using a highly iterative design-oriented internal process for new concepts. One respondent comments:

"Leverage that expertise, build a hypothesis & test it. Don't sit down and do a bunch of research unless you don't know what the question is. If you know what the question is and you don't know the answer, then start with an answer. And work it back, much faster. Much faster process." (T-4)

6 DESIGN ROADMAP EXAMPLE

Whereas product and technology roadmaps are frequently used in industry, the design roadmap appears to currently have limited use. In fact, none of the product managers mentioned the use of design roadmaps when they were interviewed on different types of roadmap usage. A few designers responded that they keep design roadmaps, but only as a minor part of product development. However, they commented they would be highly valued if tightly coupled with product and technology roadmaps and used by product and technology managers. This motivation provides an opportunity to better define a framework for design roadmapping based on insights from our interviews.

We define the design roadmap as a canvas that reflects expected core design elements acquired throughout various types of design activities relevant to users and customers. Our proposed design roadmapping process includes these aggregated design elements aligned in accordance to the target *core experiences*, *outcomes*, and *key user needs* associated with products, services or systems along an evolving time frame.

As an example of a framework for a design roadmap in a real-world situation, we illustrate one associated with Sproutel's products, Jerry the Bear, (Sproutel.com, 2015). Sproutel is a relatively new start-up whose mission is to improve the healthcare of children with chronic diseases by promoting healthy lifestyles early in life. Sproutel is passionate about achieving innovation through a human-centred design approach. *Jerry the Bear* is their first product – a cuddly bear that serves as a "best friend" who measures glucose levels and gives advice to kids with type 1 diabetes. In Sproutel's example design roadmap (Figure 1), the top layer represents the evolution of core experiences in each phase of the anticipated product development. The middle layer is primary user needs extracted from their own design research based on observations, interviews, and ethnographic research. The lowest layer represents the anticipated core outcomes including a specific user's benefit from using their product/service. The design roadmap, coupled with a technology and product roadmap, shows the progression from the beta version, to the final version and finally to the *Jerry the Bear* platform. Figure 1 shows their integrated roadmapping process where design iterations begin with the design roadmap: Identifying underlying vision based on desired *core experiences*, *primary user needs*, and

outcomes, which are in accordance with technologies associated with Sproutel's functions/features on technology and product roadmaps.

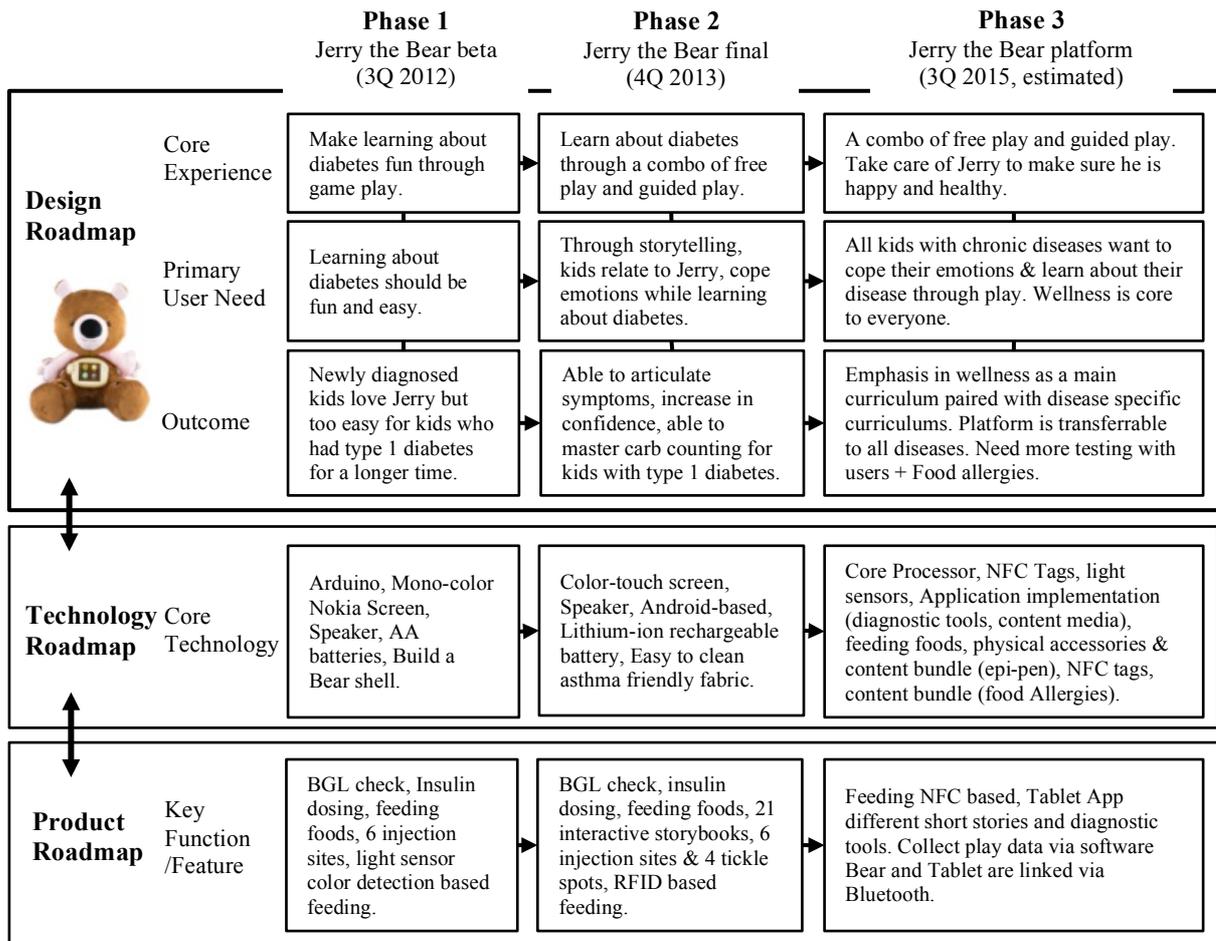|		**Phase 1** Jerry the Bear beta (3Q 2012)	**Phase 2** Jerry the Bear final (4Q 2013)	**Phase 3** Jerry the Bear platform (3Q 2015, estimated)
Design Roadmap	Core Experience	Make learning about diabetes fun through game play.	Learn about diabetes through a combo of free play and guided play.	A combo of free play and guided play. Take care of Jerry to make sure he is happy and healthy.
	Primary User Need	Learning about diabetes should be fun and easy.	Through storytelling, kids relate to Jerry, cope emotions while learning about diabetes.	All kids with chronic diseases want to cope their emotions & learn about their disease through play. Wellness is core to everyone.
	Outcome	Newly diagnosed kids love Jerry but too easy for kids who had type 1 diabetes for a longer time.	Able to articulate symptoms, increase in confidence, able to master carb counting for kids with type 1 diabetes.	Emphasis in wellness as a main curriculum paired with disease specific curriculums. Platform is transferrable to all diseases. Need more testing with users + Food allergies.
Technology Roadmap	Core Technology	Arduino, Mono-color Nokia Screen, Speaker, AA batteries, Build a Bear shell.	Color-touch screen, Speaker, Android-based, Lithium-ion rechargeable battery, Easy to clean asthma friendly fabric.	Core Processor, NFC Tags, light sensors, Application implementation (diagnostic tools, content media), feeding foods, physical accessories & content bundle (epi-pen), NFC tags, content bundle (food Allergies).
Product Roadmap	Key Function /Feature	BGL check, Insulin dosing, feeding foods, 6 injection sites, light sensor color detection based feeding.	BGL check, insulin dosing, feeding foods, 21 interactive storybooks, 6 injection sites & 4 tickle spots, RFID based feeding.	Feeding NFC based, Tablet App different short stories and diagnostic tools. Collect play data via software Bear and Tablet are linked via Bluetooth.

Figure 1. A simplified schematic example of an integrated design, technology, and product roadmap: Sproutel's Jerry the Bear

7 CONCLUSIONS AND FUTURE RESEARCH

In this paper we have evaluated product and technology roadmap use cases associated with consumer product companies with product development facilities located within the U.S. San Francisco Bay Area. Thirty-five interviews were analyzed and synthesized. We summarized our findings, and investigated challenges and opportunities associated with the current models. We have identified the potential opportunity of integrating design research in a way that serves to provide meaningful insights to the roadmapping process. We recommend three opportunity areas as design principles for the design roadmapping process: (1) move away from feature-driven to experience-driven approaches, (2) increase the ownership of designers within the process, and (3) shift the paradigm away from future prediction to that of future preparation. The primary purpose of the creation of design roadmaps is to advocate their usage on par with technology and product roadmaps. Figure 1 depicts a schematic illustration of our research direction to map all three roadmaps together for the integration of key elements with the example of *Jerry the Bear* from Sproutel.

The preliminary feedback from our industry collaborators for our integrated roadmapping framework has been quite positive. In the future, the authors plan to further develop it by:

1. Analyzing data by company sector and job function, along with other sector criteria.
2. Formalizing and structuring the proposed design roadmap's architecture, attribute and elements.
3. Applying our integrated design roadmap model to real-world case studies with a number of consumer electronics companies in the U.S. San Francisco Bay Area.

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