# Seeking Information in Order to Produce Information: An Empirical Study at Hewlett Packard Labs

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**The essential characteristic of knowledge workers is that they use information to produce information subsequently. Hence, information seeking is a knowledge worker's central aspect of work life. In a corporate research laboratory environment, this is even more pronounced because the results produced are often in the form of more information, such as publications, tech reports, patent applications, or the embodiment of these into prototypes. The practices and expectations regarding information seeking and collaboration are fundamental to productive research in a corporate setting. To this end, a survey research project sampled researchers from selected labs of Hewlett Packard and Compaq Computer shortly after their merger. This survey examined researchers' usage of information sources, their preferred means of information seeking, and the types of information assets they produced. Findings indicated that participants relied heavily on the Internet and other Web-based resources, more so than on their colleagues inside the company. Participants chose which information resources to use based on the time it took them to track down the information as well as the authoritativeness of the sources. Most information assets were generated collaboratively by teams rather then by individuals. Findings suggested that behavior was affected by the unstable environment resulting from the merger and the process of integrating the two research organizations.**

## Introduction

Twenty-five years ago in a landmark book, Thomas Allen (1977) identified information as a key component in the innovation process: "Technology consumes information, transforms it, and produces a product in a form that can still be regarded as information bearing" (p. 2). Today, more firms recognize that intellectual capital has become the sine qua non of their enterprise as more and more of the economy flows towards "congealed knowledge" (Stewart, 1997, p.16). Information and the ability to find it effectively, as well as collaborating together once the relevant information has been found, are critical for innovation in organizations, especially in a research environment (Dinkelacker & Hirsh, 2002; Hirsh, 2000).

HP Laboratories is a world-wide amalgam of the research divisions of HP, Compaq, Digital Equipment Corporation, and Tandem Computers (following the HP/Compaq merger, and the earlier acquisition by Compaq of DEC and Tandem). With these acquisitions and merger, HP Labs became more geographically distributed than either premerger company's research organizations had been previously. Information seeking became yet more challenging following the merger as new people, new resources, new ways of working together, new tools for finding information, and new expectations regarding what to produce were all brought to the fore at once (Ernst & Vitt, 2000).

Irrespective of the shifts in market focus of the company, what was clear to all the researchers, however, was that their normal practice of conducting research and reporting their findings as publications or, at times, patent applications would continue. Instead, these shifts influenced the focus of their activities, leading to changes in information needs, or to alternate approaches to information seeking, such as diverse materials or different colleagues.

In order to assess the current state of practices and expectations regarding information seeking in the merged research labs, a survey research project was conducted over the summer of 2002. This study, part of an ongoing series of projects on "research on research and collaboration" (Dinkelacker & Hirsh, 2002; Hirsh, 2000), surveyed participants from select labs regarding their current information seeking and production practices, as well as their collaborative activities, and their expectations for future and/or better tools

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and techniques. This report presents the findings related to the sections of the survey exploring information-seeking behaviors and information asset production of R&D researchers in the newly merged corporation's advanced research division.

## Prior Research

In a discussion about the field of human information behavior, Wilson (2000, p. 49) defines information-seeking behavior as "the purposive seeking for information as a consequence of a need to satisfy some goal. In the course of seeking, the individual may interact with manual information systems (such as a newspaper or a library), or with computer-based systems (such as the World Wide Web)." The research reported herein explores information seeking in a research environment, specifically the information seeking of R&D researchers whose goal was often to seek information in order to produce information assets, such as patents and technical reports. Information seeking in this environment involved interaction with manual information systems and computer-based systems, as well as information gathered through information exchanges with colleagues.

### *Information-Seeking Behavior of Engineers and Scientists*

Numerous studies on information-seeking behaviors of scientists and engineers have been conducted over the past several decades. In an effort to understand and explain findings from these studies on the information-seeking behavior of scientists and engineers, researchers have developed different types of models, with some models focusing on identifying specific information-seeking activities including browsing, filtering, and extracting (e.g., Ellis & Haugan, 1997), and others taking a more holistic view by incorporating factors influencing the information-seeking process such as awareness, sources, and outcomes (e.g., Leckie, Pettigrew, & Sylvain, 1996). Additionally, some research on the information seeking of scientists and engineers has explored information-seeking behavior in different information-seeking contexts, such as current awareness, routine research needs, thorough literature searches, and research in a new or unfamiliar area (Quigley, Peck, Rutter, & Williams, 2002). Some of the consistent and emerging findings from this body of research include the following themes.

Research findings have made distinctions between the information-seeking behaviors of scientists and engineers (e.g., Allen, 1977; King, Casto, & Jones, 1994; Pinelli, 1991). For example, while engineers tend to work on specific technical problems that have a direct impact on the business success of their organizations, scientists tend to produce general conclusions with the aim of sharing their discoveries (Allen, 1977).

Scientists and engineers invest significant amounts of time on information-related activities. Research studies have found that engineers spend 40–66% of their time communicating and sharing information related to their work (King et al., 1994). A more recent study in an industrial research laboratory resulted in similar findings, with participants spending approximately 68% of their work week on information-related activities, supporting information needs, information seeking, and communication (Hirsh, 2000).

Other findings suggest that engineers typically choose information based on its accessibility (King et al., 1994; Pinelli, 1991; Quigley et al., 2002). Fidel and Green (in press) suggest that the concept of "accessibility" has not been adequately defined in the literature, and has multiple dimensions. They found that when engineers were asked what they meant by accessibility, the most frequently mentioned factors were that it was a source they knew, it saved them time, and it was physically close to them.

Engineers prefer informal communication to more formal mechanisms of information seeking (King et al., 1994). Engineers tend to make more use of their own personal collections of knowledge, internal reports, and colleagues within their organizations than they do of the technical journal literature (Allen, 1977; Hertzum & Pejtersen, 2000; King et al., 1994; Pinelli, 1991). Networks among people persist irrespective of where they are currently employed. This fits the model of what's been called "micro-communities of knowledge" where people, who have worked together over time, become a "fused group" regardless of specific organizational membership or physical location (von Krogh, Ichijo, & Nonaka, 2000, p. 13). The conversations people have within these fused groups are an element of the informal communication commonplace in the research process.

Engineers rely extensively on information from colleagues. Engineers typically find that their colleagues provide them with the most relevant and context-specific information; their colleagues are also perceived as being easily accessible (Cool & Xie, 2000; Hertzum & Pejtersen, 2000; Leckie et al., 1996). Hirsh (2000) found that, typically, scientists and engineers approached colleagues within their organization first when they needed information. The persistence of social relations amongst colleagues in the work place is well known and widely studied. Brown and Duguid (2000) observed: "The demands of turning work that has been well supported by the local social systems into work produced without most or any of that system requires a commitment to transformation." (p. 8). In other words, the social relations amongst people, which in the research workplace means relations with colleagues, persist irrespective of whether the organizational context or tools are changing around them. Scientists and engineers whose primary activity is the creation of new information and intellectual property continue in this vein, and continue to rely on those familiar to them for information, insight, and critique. In such a context, researchers form their own communities, and as Stewart has observed: "A community of practice is voluntary, longer-lived, and has no specific "deliverable"

such as a report or a new product." He continues: "Organizational learning depends on these often invisible groups, but they're virtually immune to management in a conventional sense—indeed managing them can kill them" (Stewart, 1997, p. 97).

Studies of scientists and engineers in industrial settings have found that the most information-intensive stage occurs at the beginning of research projects when researchers explore new products and technologies (Ellis & Haugan, 1997; Hirsh, 1999). Collegial conversations, related to information seeking and information production, can be seen as falling into two categories: to "confirm" or to "create" knowledge (von Krogh et al., 2000: 128). Communication, a fundamental element of information seeking, is a consistent and fundamental activity of researchers.

The aforementioned findings are generated from research in relatively stable organizations. However, contemporary research environments are often in a state of flux. For example, research laboratories are increasingly being affected by business trends such as organizational downsizing, restructuring, and budget cuts. Some research suggests that the mere threat of future downsizing has a negative impact on innovation, specifically on people's willingness to take risks, make suggestions, and their work motivation (Bommer & Jalajas, 1999). For example, prior research suggests that acquisitions may negatively impact managerial commitment to innovation, resulting in a decreased willingness to allocate resources and champion technologies consistent with market opportunities (Hitt, Hoskisson, & Ireland, 1990). Understanding how information, as a key component of the innovation process, is sought and utilized within these settings during times of change will provide valuable insight about information-seeking and information production in rapidly changing environments.

### *Creation of Information Assets*

The essential activity of a research organization is the production of information. In other terms, this is the creation of information assets. The activity of producing information assets in a research environment fits Klein and Prusak's notion of intellectual capital: "Intellectual material that has been formalized, captured, and leveraged to produce a higher-valued asset" (1997, p. 1). As a term of art, these are designated as information assets and are tangible and material in nature; examples of information assets include technical reports, patent applications, and journal articles. Survey questions reported herein explicitly asked how various information sources were used for researchers to "get their work done." In a research setting, such "work" often leads to production of information assets. Senior managers in many types of organizations recognize the value of information assets, although they don't always have the time or resources to fully attend to them (Oppenheim, Stenson, & Wilson, 2002, p.26). However, in an organization such as HP Labs, information assets are at the forefront of researchers' productivity activities. In particular, researchers regularly write conference papers and journal articles, submit patent applications, and often develop prototypes as demonstrations of new ideas, mechanisms, and approaches. Each of these has some tangible form, even if that is electronic text, and these work products become identified as specific outcomes of an employee's efforts. As such, these are also investments that the employer (in this case HP but that could be any organization from which a researcher draws a salary) seeks to protect, and subsequently use as a source of benefit (Griffiths & King, 1991).

This benefit can be as specific as patents that protect a new product line, or as general as prestigious publications that enhance an organization's reputation and, in turn, draw talented researchers to seek employment. Some assets, such as prototypes that are an embodiment of design information, can lead to "new interactions between people that in turn create new value. The value of a prototype arises from how productively people interact around its iterations over time. Or, more simply, the value of prototyping arises from how people behave around prototypes" (Schrage, 2000, p. 15).

Irrespective of the case, information assets are a central result of research activities in a commercial research lab, and it is the nature of limited budget and finite resources that the production of information assets is an ever present aspect of performance reviews, and, as such, managers (and researchers) are quite attentive to the assets produced. Also, people in commercial environments are often organized as teams and frequently the output of a team is a joint project as indicated by papers or patents by multiple authors. As a result, this research was also concerned with those information assets that were produced by those in the research sample either by individuals or by teams.

## Research Questions

A combination of quantitative and qualitative questions were used to assess the general state of information seeking and collaboration in the newly merged research labs. Although there was an underlying dynamic of new tools, new information sources, new tasks, and, most importantly, new expectations, the process of conducting research by a population of experienced researchers continued. This was because prior to the merger that joined the two research organizations, each had been operating as a research environment for many years previously. Taken together, this emergent situation led to the following research questions related to information-seeking and information production.

- Q#1: What types of information resources were used by R&D researchers?
- Q#2: What factors influenced their selection of information resources?
- Q#3: What approaches were used in the production of new information assets?

## Method

A Web-based survey instrument was distributed to approximately 180 labs researchers over the summer of 2002.

TABLE 1. Use of company library resources by percentage of participants.

| Information resource | Keeping current (%) | Routine research info needs (%) | Thorough literature searches (%) | Exploring new or unfamiliar areas (%) |
|---|---|---|---|---|
| Visit library in person | 19 (32) | 20 (33) | 20 (33) | 20 (33) |
| Use library Web services | 26 (43) | 31 (52) | 32 (53) | 22 (37) |
| Consult with research analysts | 4 (7) | 5 (8) | 11 (18) | 8 (13) |
| Subscribe to alerting services (like ETOC) | 7 (12) | 10 (17) | 2 (3) | 1 (2) |
| Read electronic newsletters delivered via e-mail | 24 (40) | 17 (28) | 1 (2) | 14 (23) |

*Note.* n = 60.

The targeted participants represented a range of disciplines including individuals who are scientists, engineers, mathematicians, and their various sub-disciplines. The survey contained a variety of closed-ended and open-ended questions designed to elicit responses regarding information seeking and the production of information assets, their perceptions of the organizational factors that impacted them, and their suggestions for improvement. Where possible, questions were designed to be conformable with related themes extant in the literature.

### *Environment*

Hewlett-Packard Laboratories provides the centralized R&D for the Hewlett-Packard Company, with main research facilities in Palo Alto, CA, Cambridge, MA, and Bristol, England. Smaller labs are located in various other countries including the United States, France, India, Israel, Japan, and Spain. HP offers physical libraries and extensive Web-based library services and provides these library services to employees worldwide. Also, the largest capacity computer networks are among Palo Alto, Cambridge, and Bristol, with lesser levels of bandwidth service to the other locations.

### *Participants*

A total of 60 people responded to this study representing a 33.3% response rate. Participants were drawn from six representative labs from both pre-merger Compaq Labs and pre-merger HP Labs. In specific terms, several Labs from Compaq were being merged together with various Labs from HP. For this sample, three pre-merger Compaq Labs and three pre-merger HP labs were selected as targets for this study. A Web survey was developed, and invitations to participate were e-mailed to a sample frame of researchers located in six specific labs, geographically spanning Palo Alto, CA, Bristol, England, and Cambridge, MA. The sample was explicitly designed to examine the information seeking of individuals who had previously been in distinct companies because each organization had its own approaches and resources. A greater proportion of the final sample was from pre-merger HP (65%) as compared to pre-merger Compaq (30%) due in part to the larger size of the pre-merger HP Labs. Company policy prohibits disclosing the specific number of employees in the Labs, or their distribution geographically.

Participants consisted primarily of individual contributors (82%) with the balance being managers (13%). Most of the participants were located at labs in Palo Alto, CA (77%), with additional participants located in Cambridge, MA (10%), and Bristol, England (7%), and other scattered locations. The average length of time that participants worked at HP Labs/Compaq Labs and at the HP/Compaq company was generally slightly over 2 years, with about one half of the participants having worked at their respective companies less than 5 years and the other half greater than 5 years; approximately one-fifth of the participants worked more than 10 years at their respective pre-merger company.

## Results

Questions in the Web-based survey that were related to information-seeking and information-producing behaviors in the newly merged corporation were analyzed.

### *Q#1: What Types of Information Resources Are Used by R&D Researchers?*

Research involves the use of information from a wide variety of sources in order to:

- stay abreast of current research developments,
- meet everyday information needs,
- conduct searches on specific topics,
- understand historical findings, and
- pursue information on fresh areas of interest.

Participants were asked to indicate how they typically used various sources and services in their work. Since participants were allowed to select more than one type of use for each situation, percentages are thus not constrained to 100%. This approach to evaluating information usage was modified from a framework put forth by Quigley et al. (2002). Survey data on how participants consulted personal collections such as books, journals, and reprints were lost in the data collection process. Follow-up research will include this important information resource.

TABLE 2. Use of Internet/intranet resources by percentage of participants.

| Information resource | Keeping current (%) | Routine research info needs (%) | Thorough literature searches (%) | Exploring new or unfamiliar areas (%) |
|---|---|---|---|---|
| Use items from WWW (external Web sites) | 51 (85) | 49 (82) | 42 (70) | 46 (77) |
| Use items from HP's/Compaq's intranet | 19 (32) | 21 (35) | 8 (13) | 20 (33) |
| Read online news/discussion groups | 29 (48) | 20 (33) | 7 (12) | 22 (37) |
| Use Web search engine (Google) | 48 (80) | 51 (85) | 46 (77) | 47 (78) |

*Note.* n = 60.

Table 1 presents the ways that participants used their library resources. As shown in Table 1, participants utilized their company library to accomplish a range of information tasks, with responses evenly distributed across all categories of use. Of the library services investigated in the survey, participants indicated heaviest use of library Web services. Over 50% of the participants used library Web services for resolving routine research-related information needs and performing thorough searches of the literature.

Participants in the study who consulted with library research analysts did so primarily for help in performing comprehensive literature searches. Subscriptions to alerting services, like the "Electronic Table of Contents" service, were maintained mostly for routine information needs. Not surprisingly, participants read electronic newsletters that were delivered to participants' e-mail inboxes to keep current in areas of interest. Overall, participants indicated a lower level of usage of library services as compared to general Internet resources. It is possible that some participants were using various library-provided Web-based services or indexed sites without realizing it.

Table 2 presents the ways participants made use of Internet/intranet resources to address different types of information needs. Participants made heaviest use of the Internet, by using items from the World Wide Web and conducting searches on Web search engines to address all categories of information needs. Anywhere from 70 to 85% of participants indicated use of the Internet to meet their information needs. Approximately one-third of the participants used items from the company's intranet to address their information needs, with the lowest use of this information resource for thorough literature searches. Reading online news and discussion groups were used most frequently by approximately half of the participants to help them keep current in areas of interest.

Table 3 displays circumstances under which participants consulted with colleagues or other information resources to meet their information needs. Approximately half of the participants indicated turning to their colleagues *outside* of the company to help keep current. Colleagues, both those inside and outside the company, were consulted by about one-third of the participants in matters related to both new and unfamiliar topic areas, as well as routine information needs. Sources from standards bodies were used across all information need categories, with the heaviest use of these information resources being used for keeping current.

Looking across the previous three tables, Table 4 was constructed to highlight the top five information resources based on the percentages of participants selecting the information resource to address a particular information need. As can be seen in Table 4, the top two information resources used, regardless of information need, were the usage of items from the World Wide Web that may have been bookmarked or otherwise previously known to the participants, or located from Web search engines like Google. Other information resources that were selected as useful for more than one information need included: using library Web services, consulting colleagues outside of the company, consulting sources from standards bodies, and reading online news/discussion groups. Library Web services rated in the top five information resources for all categories, except for keeping current. Half the participants indicated that they read online news and discussion groups to keep current; some of the online news services mentioned by participants may have been accessed through the library portal site. Sources from standards bodies played a promi-

TABLE 3. Consultation with colleagues and use of other information resources by percentage of participants.

| Information resource | Keeping current (%) | Routine research info needs (%) | Thorough literature searches (%) | Exploring new or unfamiliar areas (%) |
|---|---|---|---|---|
| Consult HP colleagues outside of Labs but within company | 15 (25) | 17 (28) | 5 (8) | 19 (32) |
| Consult colleagues outside of company | 29 (48) | 19 (32) | 12 (20) | 24 (40) |
| Consult sources from standards bodies | 29 (48) | 26 (43) | 25 (42) | 20 (33) |
| Other | 4 (7) | 4 (7) | 3 (5) | 5 (8) |

*Note.* n = 60.

TABLE 4. Top 5 information resources for each information need.

| Ranking | Keeping current | Routine research info needs | Thorough literature searches | Exploring new or unfamiliar areas |
|---|---|---|---|---|
| 1 | Use items from WWW (external Web sites) (85%) | Use Web search engine (e.g., Google) (85%) | Use Web search engine (e.g. Google) (77%) | Use Web search engine (e.g., Google) (78%) |
| 2 | Use Web search engine (e.g., Google) (80%) | Use items from WWW (external Web sites) (82%) | Use items from WWW (external Web sites) (70%) | Use items from WWW (external Web sites) (77%) |
| 3 | Consult colleagues outside of company (48%) | Use library Web services (52%) | Use library Web services (53%) | Consult colleagues outside of company (40%) |
| 4 | Consult sources from standards bodies (48%) | Consult sources from standards bodies (43%) | Consult sources from standards bodies (42%) | Use library Web services (37%) |
| 5 | Read online news/discussion groups (48%) | Use items from HP's/Compaq's intranet (35%) | Visit library in person (33%) | Read online news/discussion groups (37%) |

nent role in all information need categories except for exploring new or unfamiliar areas; standards are critical to technology development and researchers require the latest information about standards specifications.

### *Q#2: What Factors Influenced Their Selection of Information Resources?*

Participants were asked to rate how six factors influenced their selection of which information resources to use (Table 5). While all of the factors presented to the participants were ranked fairly high, the two most salient factors in selecting information resources were: (1) the time it took to track down the information; and, (2) the authoritativeness of the information resource (i.e., it gives the most reliable, complete information). Ninety-one percent (91%) and 86%, respectively, of the participants identified these factors as significantly or very useful. The least important factor in selecting an information resource was how familiar it was, that is, that the participant had used the information resource previously and had been satisfied with it. Nearly 60% of the participants identified this factor as being significantly or very useful in choosing which information resource to use.

### *Q#3: What Approaches Were Used in the Production of New Information Assets?*

Intellectual assets are typically generated as a result of work completed in a research project. Participants in this study reported generating various types of intellectual property in their most recent research project. Results are presented first in terms of whether information assets were produced as a result of individual or team efforts and second in terms of thematic perceptions of information asset production from a series of open-ended questions.

#### *Information Assets Production by Individuals and Teams*

As seen in Table 6, participants reported producing more intellectual property collaboratively as a team rather than as individuals. This is most evident with invention disclosures and conference papers. For invention disclosures, respondents reported that 75% were produced by their teams as compared with 50% by individuals. Similarly for conference papers, 72% said these were produced by a team as compared with 45% by individuals. While the numbers were closer, the same pattern was evident with refereed publications (45% by teams to 33% by individuals, respec-

TABLE 5. Factors influencing selection of information resources.

| Factor | Not at all | Somewhat | Moderately | Significantly | Very useful | Mean, median, mode |
|---|---|---|---|---|---|---|
| Least TIME to track down | 0 | 29 (4%) | 3 (6%) | 22 (41%) | 27 (50%) | 4.37, 4.5, 5 |
| Most CONVENIENT at time/place of my choosing | 0 | 1 (2%) | 7 (13%) | 24 (44%) | 22 (41%) | 4.24, 4, 4 |
| Most CURRENT I need the most up-to-date info possible | 0 | 2 (4%) | 12 (22%) | 23 (43%) | 17 (31%) | 4.02, 4, 4 |
| Most AUTHORITATIVE, gives the most reliable, complete information | 0 | 1 (2%) | 6 (12%) | 21 (41%) | 23 (45%) | 4.29, 4, 5 |
| Most FAMILIAR, "tried and true," has worked for me in the past | 1 (2%) | 7 (13%) | 14 (26%) | 24 (44%) | 8 (15%) | 3.57, 4, 4 |
| Most RELIABLY available, no waits or hassles | 0 | 2 (4%) | 10 (20%) | 26 (51%) | 13 (26%) | 3.98, 4, 4 |

*Note.* n = 60.

TABLE 6. Information assets by production method.

| Intellectual property | Individually produced [% (no.)] | Team produced [% (no.)] |
|---|---|---|
| Invention disclosures | 50 (30) | 75 (45) |
| Technical reports | 52 (31) | 60 (36) |
| Conference papers | 45 (27) | 72 (43) |
| Patents | 48 (29) | 58 (35) |
| Publications (refereed journals) | 33 (20) | 45 (27) |
| Publications (trade magazines) | 13 (8) | 8 (5) |
| Books/chapters | 25 (15) | 12 (7) |
| Internal presentations (e.g., for product groups) | 58 (35) | 58 (35) |
| Software code | 55 (33) | 68 (41) |
| Hardware designs | 17 (10) | 20 (12) |
| White papers (e.g., for product groups) | 20 (12) | 33 (20) |
| Other | 5 (3) | 7 (4) |

*Note.* n = 60, multiple responses allowed.

tively), software code (68 to 55%, respectively), patents (58 to 48%, respectively), technical reports (60 to 52%, respectively), and white papers (33 to 20%, respectively).

The predominant information asset that was reported as being more often produced by individuals as compared to teams were book chapters (25% by individuals to 12% by teams). Participants also reported producing articles for trade magazines slightly more as individuals than as a team (13% by individuals to 8% by teams). An equal number of participants indicated that internal presentations, such as those for product groups, were produced as a result of individual and team efforts.

Overall, the findings underscore that information asset production in this commercial research environment is predominantly a collaborative event and that while individuals may seek information and communicate with various colleagues, the production of information assets is typically a team action.

### *Thematic Perceptions of Information Asset Production*

Participants were asked various open-ended questions about how they thought the company's current activities regarding information seeking and information production could be improved. These questions covered various topics related to information seeking, production of information assets and prototypes, perceived barriers to publication, and the like. Here is a summary of their responses.

When asked how the company's ability to generate intellectual property could be improved, the common themes that emerged are detailed below.

- *Improving cross-lab interactions and related tools:* For example, participants commented on the need to reduce the feeling of "compartmentalization by territory/turf." One participant suggested using internal [electronic] discussion groups as a way to achieve this. Specifically, "Internal newsgroups/discussion groups on specific research areas could help us locate other researchers in remote locations who are interested in similar problems. Currently, we need to rely on word-of-mouth."
- *Giving credit and recognition where it is due:* Several participants mentioned the importance of reward and recognition for intellectual property contributions by individuals and teams. For example, one participant said: "The largest improvement would result from special recognition of unusually valuable IP." Another person indicated: "Yes, but politics is a factor in such a big organization; people have to feel that everybody will get credit where credit is due."
- *Establishing a filtering process that focuses on IP quality instead of quantity:* Several participants raised concerns about how to filter intellectual property in the research labs environment—separating out "the really good ones from the unimportant ones"— so that the intellectual property generated demonstrates "real value" for the company. One participant expressed this concern by saying: "I have seen at times that many low-quality patents are proposed, and these can fill up the pipe and delay important patent applications from being filed. I think that it is very important to focus on quality of patents, and not quantity." Another participant also argued the importance of focusing on generating quality intellectual property, stating: "Eliminate IP quotas, e.g., turn all good invention disclosures into patents instead of making the selection process political (driven by quotas)."

Other suggestions for improving the company's ability to generate IP included creating a "more open atmosphere for ideas," "giving a vision to follow," and changing the role of senior scientists to serve as "real tutors in a department, a lab, and the whole HP Labs."

These themes reflect the underlying notion that the power of the social network prevails irrespective of the quality (or lack thereof) of the available information-seeking and retrieval tools. Considering the social process of two research organizations merging together, certain tools and techniques were differentially familiar with distinct premerger groups. At the present time, it is unknown whether the sense of "compartmentalization" derived from the organizational dynamics of melding the groups, or pointed to deeper issues specifically related to the available tools and how widely known they were.

In another question, respondents were asked what might improve their ability to contribute to scientific breakthroughs. Their general themes are listed below.

- *Providing more support for risk-taking:* Participants repeatedly mentioned the need for greater support and rewards for risk-takers. "Invest more in hiring breakthrough thinkers (if that's what you want). Then be prepared to give them lots of rope." Another encouraged that the company "have a better tolerance of risk."
- *Articulating a greater long-term view and vision:* Some remarks were "Think further out, too much of what we do is on heavily-trod ground." "Realize it takes four to five years to get to the cutting edge in any area." "Employ and develop good people and give them the time and space to generate world-class competence in important areas." Another simply said: "set a vision."

In line with the notion of producing information assets, an open-ended question asked respondents about how to improve the capacity to generate prototypes and demonstrations. The responses reflected these themes.

- *Enhancing rewards and recognition programs:* Participants frequently mentioned the importance of rewarding and recognizing people who invested their time and applied their expertise to implementing prototypes and demonstrations. For example, one participant said: "Reward prototypes and demonstrations as much as publications." Another said "achieve a better balance between understanding and demonstrations; frequently the relevance of demonstrations is not well communicated or understood." One summarized this well by saying: "Recognize and reward people/groups that actually get things to work. But at the same time, it is very important to distinguish between novel and/or very difficult prototypes and demos and very simple demos. By rewarding simple demos it may make people who spend a lot of sweat developing real complex demos not feel very happy."
- *Providing software expertise:* Participants discussed the importance of having a software team available to help with the technical implementation of prototypes and demonstrations. For example, one person suggested having a "team of programmers that could help those of us who can design but not implement well, or training so we can help ourselves." Another offered a similar suggestion: have "a pool of professional software developers." Some people felt that it was critical for the technical implementation work to be recognized and rewarded. For example, one person said: "Allow and support technical non-research staff in the project groups [at the] same pay and status." Another person said: "Employ a grade of technical assistants into research projects and measure them on their contributions to research communication rather than research publication."

From the perspective of a new organization being formed, these are particularly poignant points. Underlying the comments is a notion of a different method or priority of resource allocations, recognition and reward, than had been in place prior to the merger. Nevertheless, the remarks did underscore the necessity of recognizing individual and team efforts for complicated and demanding work, and also having the technical resources available to round out a team, perhaps on a temporary basis, to complete an informative demo.

Respondents were also asked several open-ended questions regarding how new projects were generated. When asked specifically about how the process of generating patent applications by themselves or their teams could be improved, they highlighted a few consistent themes.

- *Maintaining consistent relationships with patent attorneys:* Respondents repeatedly mentioned the value of having enduring relationships with attorneys instead of having to start fresh every time. For example, one said: "Work with the same attorney each time since each seems to have different rules to follow."
- *Involving patent attorneys in research teams:* One cogently said: "get a more aggressive team of patent attorneys and have them pro-actively work with project teams to pull out the patentable core at the earliest possible moment." Another said "have a technically savvy patent attorney [who] would read our technical reports and sit down with us and suggest potential patent opportunities letting the researchers generate the applications results in many lost opportunities as most researchers don't recognize what is patentable."
- *Accelerating the patent filing process:* Several participants felt: "The patent review process should be speeded up." One way this process could be accelerated is to get a "quicker response from the patent lawyers who are preparing the patent applications." One participant summed it up this way: "I feel it is very important in today's climate to be able to file a patent as early as possible. I think having a short invention disclosure to filing time is very important. Also, I think there are many little things that can be done that help the patents get through the patent office faster. I think it is worth while spending the little extra effort and a few extra days to take care of them . . . as [then] the patent may be granted six months or a year earlier."

Whereas these remarks reflect the situation of the merging companies, the underlying emphasis on establishing ongoing relationships with the patent attorneys, and working with attorneys who have some familiarity with the technical areas, is a useful theme. This would thereby make it easier for the researchers and attorneys to meet on common intellectual ground irrespective of the technology, the company, or the researchers.

Respondents were asked how the process of generating research publications by themselves or by their teams could be improved. These are the themes they reported.

- *Implementing a quick approval process:* It is typical in any commercial organization that all materials publicly distributed must go through an approval process. At times, this can take longer than desired. For example, one respondent said: "[have] electronic signoff instead of paperwork it's hard to meet everyone's deadlines all stacked against each other in a row." Another said "faster approvals by management."
- *Allocating time/priorities for paper writing:* Aligning time spent on work projects with organizational priorities is critical in an industrial R&D laboratory. Given the need to align with organizational priorities, participants sought to find the right balance between time spent on research and time spent on producing quality research publications. As several participants expressed, it takes time to write a high-quality research paper, but it is time well spent because it is an essential part of the research process. For example, one participant said: "Make it clear that HP Labs considers it prestigious to have papers with its name on it I'd love to hear where publications rank on our priority list." Another said " . . . a manager should understand that writing a paper is also part of research activities which needs time." Similarly, another participant said: "Publications take a long time to prepare; there is no management support for this." One cogently said: "Research publications should be recognized as important. However, quality is very important once again. It is often easier to have many low-quality publications in many conferences than a single high-quality publication."

Continuing the thread related to production of information assets, an open-ended question asked respondents what could be done to make it easier to publish more than they currently do. Consistent with their earlier remarks, they echoed the following themes.

- *Easing the ties to patent filings:* One stated this clearly as follows: "It is not practical to wait until the patent is filed before submitting to a conference or a journal. How about expediting things in some way. Many companies allow preliminary patents to be filed at the time the publication is submitted for review, which then allows the company one year to figure out whether or not they want to file for real and to get the application done." Another said "We need clear rules about publication and patents."
- *Having a technical editor:* Several respondents mentioned simply having a technical editor. Another suggested having "writers to help ghostwrite articles for trade magazines; this isn't work I should be spending my time on but is important for some projects."

Overall, the respondents' remarks conveyed several general notions that call forth certain organizational factors, notably resources and allocations, recognition and reward, management support of distinct efforts that, in essence, are determinant incentives, and time allowances so researchers can more effectively pursue certain outcomes (e.g., prototypes, patent filings, or publications).

## Discussion

In this examination of information-seeking and information production of R&D researchers, several findings emerge.

First, information seeking was dominated by use of the Internet. Participants relied most heavily on Web-based information resources, such as items from the World Wide Web and items found by using Web search engines like Google. Between 70 to 85% of the participants indicated use of these resources to address all four types of information needs examined in this study: keeping current, completing routine research information needs, conducting thorough literature searches, and exploring new or unfamiliar areas. Recent research has shown that information gathering was the main kind of activity on the Web performed by knowledge workers (Sellen, Murphy, & Shaw, 2002).

One of the reasons that participants relied so heavily on Internet resources may be due to the organizational nature of the new HP Labs. Both HP and Compaq were global companies with contributors around the world. Much of our work with colleagues happens via e-mail and it is not unusual for documents, including collaborative works in progress, to be posted on Web sites for others to access (Dinkelacker & Hirsh, 2002). Similarly, the combination of the labs led to entirely new organizational reporting structures where the personnel of certain departments were widely dispersed, perhaps in different countries. This, in turn, has led many of the Lab's researchers to use their computers as a primary means of communication, and, in turn, to use the Internet both as a vehicle for that as well as a convenient gateway to information that is readily available to them.

Corporate Library Web services were used by more than half of the participants to perform routine and thorough searches for information. Currently, the HP Global Library and Information Services portal provides direct Web access to approximately 50 distinct business and technology electronic services, as well as news alerting services and consulting services. These findings suggest a continued need to enhance the availability and functionality of information made available on the corporate library's portal.

Standards Bodies are also of significant importance to these researchers for several reasons. Especially in the engineering and computer science disciplines, much work is done in reference to existing standards and activities to expand them or work towards the adoption of new standards. Also, organizational incentives exist for Labs' employees (namely, researchers) to participate on standards bodies to both advocate promising new areas of research as well as raise a voice where proposed standards may prove to be detrimental to their employer's current directions. Consequently, researchers are attentive to the information sources available through standards bodies, many of which are only available over the World Wide Web.

Second, while participants frequently consulted with colleagues outside of the company, specifically when they explored new or unfamiliar areas (40%) and when they were keeping current in fields of interest (48%), participants did not as often turn to their colleagues inside the company to assist them with their information needs. This finding deviates from other studies of information-seeking behavior of engineers and scientists that generally find that familiar colleagues are not only one of the most important sources of information, but usually the first place that engineers go to when they need information (Allen, 1977; Hirsh, 2000; Pinelli,1991).

Participants in this study may not have relied as heavily on their colleagues within the company due to the changing and unstable environment resulting from the recent merging of two research cultures. During this study, which occurred soon after the merger was officially consummated, the organizational dynamics of the research environment were changing rapidly. Due to the newly merged corporation, each organization within the company was in the midst of performing layoffs and reorganizing their projects. As a result, duties, resources, and expectations were all in a state of dramatic flux, and people were uneasy about the changes that were taking place within the research labs, about their own future in the changing organization, and about their colleagues' future as well. This may explain why participants in this study did not rely extensively on their own colleagues within the company, and instead turned to seemingly more stable relationships outside of the company and to other information resources (e.g., the Internet). They did this despite research findings suggesting competitive mis-

trust of external colleagues by corporate engineers in the aerospace industry (Cool & Xie, 2000), albeit the case in point is a computer and imaging company.

Another explanation is that participants may have perceived "not knowing" as a risky behavior during this uncertain period, and chosen to ask those who were external to their organization for help instead. In addition, it is reasonable to expect that the nature of relationships were changing rapidly at this time as the types of research initiatives and the direction of the newly-merged company itself was becoming more refined. One possible consequence of this is that the relationships upon which researchers had previously relied were now also undergoing great changes as people were reassigned or redirected to new areas of inquiry. As a result, their previous colleagues were not necessarily the ones who were most closely affiliated with their new/current information needs. A follow-up study is planned to assess the stability of these findings.

Third, researchers in this study were found to select information resources most frequently on the basis of two factors: the amount of time it takes to track down information and the authoritativeness of the information resource. Research studies have repeatedly found that accessibility, based on the "principle of least effort," is the most common criterion applied by engineers in their selection of information resources (King et al., 1994). While the amount of time it takes to track down an information resource can be considered a dimension of accessibility (most closely related to Fidel & Green's "saves time" factor), the authoritativeness of the resource has more to do with the quality of the information. These dimensions also suggest the importance of the filtering role that libraries play with regard to selecting quality information resources. A recent study by Fidel and Green (in press) also found that some quality dimensions, such as "can give data that meets the needs of the project," were frequently mentioned in their study of engineers. Research has shown that with regard to the Web, information quality is a notable factor. Knowledge workers tend to "return to a small handful of trusted sites (as opposed to doing keyword searches), and spend considerable time assessing the quality of information on an unknown site" (Hyams & Sellen, 2003, p. 12). Furthermore, when only the Web is considered as an information source, they found that more often than not people used familiar resources and tools in their information-gathering tasks (p. 30).

Fourth, and perhaps expected, the findings indicated that most information assets, especially those related to refereed papers, patents, patent disclosures, and software code, were produced predominantly by teams as compared with individuals. In contrast, book chapters were the only information asset that was typically created more often by individual researchers.

It is worth noting, perhaps anecdotally, that the combined company's research labs has a strong emphasis on the creation of information assets and intellectual property, especially patents and writings that are typically termed "defensive publications." Each of these requires definitive information, historical antecedents, explication of prior art, and as narrow a construction as can be crafted in order to accurately describe inventions and clearly establish defensive boundaries around other research endeavors. As a consequence of this focus, authoritativeness is centrally important to practitioners engaged in these activities.

Also, as mentioned previously, this study occurred during a significant merger and the research portfolios of the combined labs were undergoing refinement in two ways. First, certain domains of inquiry were being streamlined and focused on market opportunities that presented themselves to the newly combined firm. Second, other researchers were taking this as an opportunity to engage in new areas of exploratory research to identify fresh areas of intellectual property for the company to explore.

When asked via open-ended questions about their information-seeking and -producing activities, researchers indicated that their ability to produce intellectual property could be improved by having better "filters" to discern quality from quantity in the production of information assets and to ensure that "credit" be given where "credit is due." Others pointed to the value of cross-lab interactions, and having tools that would enhance communication and information sharing across space and time. It was also pointed out that in terms of patent disclosures and filing, the process could be improved by more stable relationships amongst patent attorneys and researchers such that they were more familiar with the attorneys and could work with the same ones on a recurring basis, and that things could be made to move with more alacrity. In terms of increasing the number of publications that could be produced, respondents called for a quicker internal approval process as well as having their management recognize that writing takes time and needs to be factored into assignment loads.

## Conclusions

This report presented partial findings from a larger study on research-related information and collaborative behaviors in an ongoing worldwide research division of a major global corporation, focusing on information-seeking and information-producing behaviors of research scientists and engineers.

Findings suggested that the information-seeking behavior of the respondents was impacted by the dynamic environment and refinements in focus resulting from the recently completed merger, which resulted in the integration of two research organizations. One indication of this was the limited reliance of researchers on their colleagues within the company as a source of information, choosing instead to consult with colleagues outside the company and other information resources. Other findings included a heavy reliance on the Internet and other Web-based resources for information to address a range of information needs. Participants made their selections of which information resources to use based on how little time it took them to track

down the information (a dimension of accessibility) and the authoritativeness of the source.

As would be expected in a commercial research environment, most intellectual assets were produced as a result of team activities. Irrespective of the impact of the merger, the creation of intellectual assets is typically a time-consuming process; many of the assets to which respondents were referring were thus from a period prior to the merger. It is reasonable to think that with the ongoing emphasis on team work in such settings, the merger would hardly impact the focus of team productivity, but the timing of the survey happened so closely to the completed merger that future research must revisit this topic in the context of the newly formed research labs organization.

Future work includes additional investigations into HP Labs information and collaborative behaviors and how information is sought and used in order to produce information assets and intellectual property. A follow-up study a year after the original data collection is planned.

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