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Strategic Use of Information Technology - Google

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INTRODUCTION

Arguably the most popular search engine available today, Google is widely known for its unparalleled search engine technology, embodied in the web page ranking algorithm, PageRank[i] and running on an efficient distributed computer system. In fact, the verb "to Google" has ingrained itself in the vernacular as a synonym of "[performing] a web search."[1] The key to Google's success has been its strategic use of both software and hardware information technologies. The IT infrastructure behind the search engine includes huge storage databases and numerous server farms to produce significant computational processing power. These critical IT components are distributed across multiple independent computers that provide parallel computing resources. This architecture has allowed Google's business to reach a market capital over $100 billion and become one of the most respected and admirable companies in the world.

MARKET ENVIRONMENTS

Search Engine

Internet search engines were first developed in the early 1990s to facilitate the sharing of information among researchers. The original effort to develop a tool for information search occurred simultaneously across multiple universities is shown in Table 1. Although functionalities of these systems were very limited, they provided the foundation for future web-based search engines.

TABLE 1. Early Search Engines

Search Engine Name	University	Year	Inventor
Archie	McGill University	1990	Alan Emtage
Veronica	University of Nevada	1993	Many students
WWW Wanderer	Massachusetts Institute of Technology	1993	Matthew Gray

Source: Battelle, 2005.

Search Industry

During the 1990s, the Internet experienced exponential growth with thousands of new web pages being created daily. Online document search became the chief method of navigating the ever-expanding World Wide Web, as Internet users sought useful information among the largely disorganized pages. As a result, the online search industry was born.

Early web-based search engine had roots in university-based research, with the exception of AltaVista (Table 2). WebCrawler was known as the first search engine to perform full-text web search as opposed to searching library indices. In 1996, increased competition between search engines triggered the search engine size wars, as the companies competed to index the largest

[i] PageRank was named after co-founder Larry Page. The PageRank patent (U.S. Patent # 6,285,999), granted in 2001, and belongs to the trustees of Stanford University rather than Google with Larry Page as the inventor.

number of textual documents over the Internet. AltaVista was the first forefront search engine winner, becoming the most successful and widely adored search engine in the mid 1990s.

TABLE 2. Web-based Search Engines

Search Engine Name	University	Year	Inventor
WebCrawler	University of Washington	1994	Brian Pinkerton
AltaVista	Digital Equipment Corporation	1994	Louis Monier
Lycos	Carnegie Mellon University	1994	Michael Mauldin
Excite	Stanford University	1994	Six alumni
Inktomi	University of California at Berkeley	1996	Eric Brewer and Paul Gauthier
Google	Stanford University	1997	Sergey Brin and Larry Page

Source: Battelle, 2005.

Many start-up search engine companies were founded by technically brilliant academic researchers and graduate students. However, many of these founders were young, arrogant, and lacked business knowledge and experiences necessary to run a company. In addition, most of these start-up companies were impacted by the dot-com bubble and failed to remain operational. Some search companies tried to raise capital by going public, but failed on most occasions, as in the case for AltaVista. The majority of web-based search engine companies went through a series of acquisitions one after another, and some, such as Excite, Lycos, and AltaVista, were acquired by companies outside of the search industry. For example, Google's main competitor, Yahoo, acquired or licensed technology from a number of other search engine companies including AltaVista and Inktomi.

The lack of focus on core products in many search engine companies led to the decline of quality search results, driving users to hunt for better alternatives. Many found their way to Google.com because of the positive user experience. Google's popularity spread quickly by free advertising and by the word of mouth. Google was not the first company to enter the search industry, but it produced search results that were the most relevant to its users. The co-founders of Google had a vision of a distinguishing search engine from other platforms by providing fast, accurate and reliable search results. However, during the early stages, Google tried unsuccessfully to license its PageRank system to AltaVista, Excite, Yahoo, and other search engines. These companies were too focused on selling advertisements and were not interested in funding new "search" tools. Google then turned to other sources of capital, first from angel investors and later, venture capitalists. As the number of queries on Google.com grew, Google became a popular brand name that attracted additional investors.

Search Engine Market Share

Prior to the dot-com bubble in 2000, the search engine market was highly fragmented with fierce competition in the market space. However, after undergoing industry consolidation, the search engine industry was led by Yahoo, and followed by MSN, AOL, and Google. At the time, Google had less than 1% market share in 2000 but quickly gained momentum in 2001 and 2002. In 2001, Yahoo still led the search industry market share. Toward the end of 2002, Google surpassed Yahoo as the market leader in search engine, and has never looked back since,

claiming more than 50% of the market for the past three years (Table 3). As of 2006, major players in the search industry market include Google, Yahoo, and MSN, with Google maintaining its market dominance.

TABLE 3. Search Engine Market Share

Company	2004	2005	2006
Google	57.81%	63.16%	66.63%
Yahoo!	18.24%	16.51%	14.74%
MSN	13.83%	12.06%	10.92%
AOL	0.68%	3.81%	3.93%
Ask Jeeves	1.24%	1.13%	1.31%
Others	8.20%	3.33%	2.47%

Source: Netapplications.com, statistical data

GOOGLE'S BUSINESS MODEL AND STRATEGY

Business Model

Since its beginning as a research project from two Computer Science doctorate students at Stanford University, Google has continued to follow its mission "to organize the world's information and make it universally accessible and useful."[2] From Google's founding in 1997 until 2000, the company did not have a well-defined business model to generate revenues. In 2001, Google's two co-founders hired Eric Schmidt, the chairman and CEO of Novell and former CTO at Sun Microsystems, as the new CEO of Google to help drive the effort in creating a business model for Google.

With new management leadership, Google created a core business in online advertising, enabled by the millions of users using its search engine everyday. Revenue generation and profit growth in online advertising came from both Google's search engine homepage and partner websites that display Google sponsored advertisements. Google created a cost-per-click pricing scheme for sponsored advertisements such that advertisers only pay a base fee, and for the number of referrals to their site.

Equation for calculating Google's Revenue

$$\text{Revenues} = \text{Users} * \frac{\text{Queries}}{\text{User}} * \frac{\text{Ads}}{\text{Query}} * \frac{\text{Clicks}}{\text{Ad}} * \frac{\text{Revenue}}{\text{Click}}$$

Source: Varian, 2005.

From the metric above, Google's revenue is affected by three factors: quantity (users * queries/user * ads/query), quality (clicks/ads), and price (revenue/click). Quantity is dependent on the number of keywords, advertisers, and users. Quality is based on advertisements relevant to users and is determined by the click-through rate. Lastly, price is affected by the conversion

probability between the click-through rate and the consumers actually purchasing products or services on the advertiser's site.

The ability for advertisers to determine the value per click can be computed using Google's conversion tracking or internal tool to calculate online advertising retention rate. Furthermore, advertisers can bid on the maximum price they are willing to pay per click for their specific advertisements. Minimal value of the bid starts from $0.01 cost-per-click with an upper limit of $100. To control costs, advertisers can set an upper bound dollar limit they are willing to spend for online marketing. Once cost-per-click reaches the budget limit set by the advertiser, their advertisements are taken offline.

Business Strategy

Google is generally secretive about its business strategy, but it is evident that Google is building the foundation for all of its products and services under the central theme of leveraging advanced search technology and personalized advertising. For example, Google's popular web-based email service called GMail, allows users to store and search old emails rapidly using text search integrated into the email client and then placing sponsored advertisements on the side based upon email content a user is currently reading. The GMail client is also able to identify email contents in which it can link information onto Google Maps and track packages from UPS and USPS.

Existing search results are primarily textual-based. More advanced search technologies will allow users to search for other information besides textual data, such as multimedia content (e.g. audio, image, video). To maintain its reputation as a forefront technology leader and innovator, Google has been aggressively acquiring software start-up companies that can be easily integrated into its existing solutions, and can instantaneously gain visibility through Google's leverage. However, this strategy of growing through small acquisitions is also used by Yahoo, one of Google's major competitors, although the underlying methodology of the acquisitions is different. Yahoo's acquisitions have been focused on acquiring search technology companies having specialized search functionalities. For example, Yahoo acquired Inktomi, Overture, and Stata Labs to perform web search, locating advertiser key words, and retrieval of Yahoo email client, respectively. Yahoo has a group of search technologies for different products and services, while Google has only one search technology.

Over time with greater competition, an online advertising network may be commoditized and Google will need to develop new business models to entice new customers and enhance relationships with existing ones for customer lock-ins (Elgin, 2004). For existing customers, Google has Advanced Tools & Reporting to support sophisticated advertisers, and Google plans to tighten integration with other Google related products in advertising. Since Q4 of 2005, Google is offering Google Analytics as a free service. Google Analytics, formerly called Urchin, is a web-based service that provides log analysis and web statistics that lets advertisers know about their visitors and how they interact with their site. Google Analytics is integrated with AdWords and allows advertisers to optimize their keywords so they can better target resources for their marketing campaigns and deliver higher return on investment. This has served well for many small and medium size businesses using AdWords as the primary marketing tool for reaching to the customers.

Google has begun targeting its vertical sales in advertising to focus on Fortune 1,000 companies, where they have only captured one-forth of the market share.[3] Fortune 500 companies have not caught on as quickly using online marketing, and have relied more on traditional marketing techniques. However, according to a study conducted by Advertising Age, "Nearly half of the chief marketing officers at Fortune 500 companies said they plan to increase their online advertising budgets by 30% in 2006."[4] Out of the $250 billion dollar advertising industry in the United States alone, only $11 billion is spent online with about $5 billion attributed to search advertising where Google has 79% of the market share. To reach new markets faster, Google is expanding its advertising business beyond online marketing to other mediums, including radio and print. Google has already exhibited some efforts to diversify its advertising business by acquiring dMarc Broadcasting in January 2006, a company that develops a unique automated-radio–advertising-selling process between radio stations and advertisers (Perez, 2006). Google plans to integrate its AdWords platform with dMarc's software that automates the buying and placing of radio advertisements. Google is also experimenting with integrating its AdWords platform with print media by running classified advertisements for its AdWords customers through a limited trial in *PC Magazine*, *Maximum PC*, *Budget Living*, and the *Chicago Sun Times* (Hoover, 2006).

GOOGLE'S PRODUCTS AND SERVICES

Key Product and Services

Online advertising is Google's core product and accounts for 90% of the company's revenue. AdWords, a cost-per-click pricing scheme, was a result of Google's newly formed business model in online advertising. AdWords allows advertisers to pay Google once visitors click on an advertisement after entering a search query (Figure 1). Unlike other online marketing that use image and animated banners, these advertisements are text-based to maintain an uncluttered page design. This is a concept that Google's co-founders believe is essential for an enjoyable user search engine experience since most users typically want to find information and promptly leave the search results page. Increasing the covered audience is a complementary product called AdSense which involves placing targeted AdWords advertisements on Google's partner websites (Figure 2).

FIGURE 1. Google AdWords

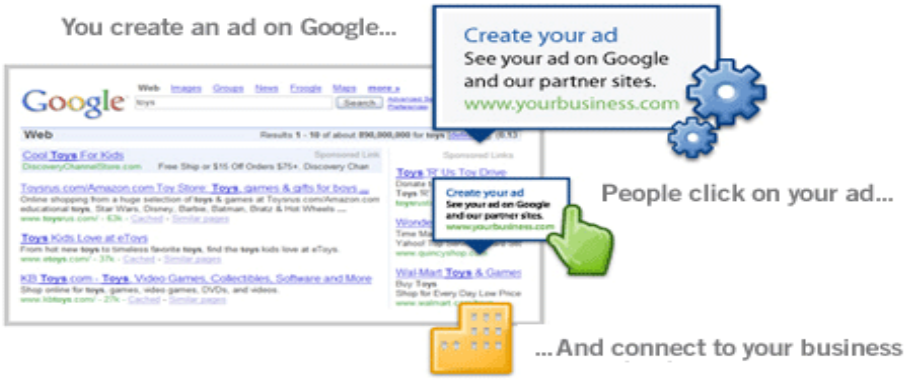
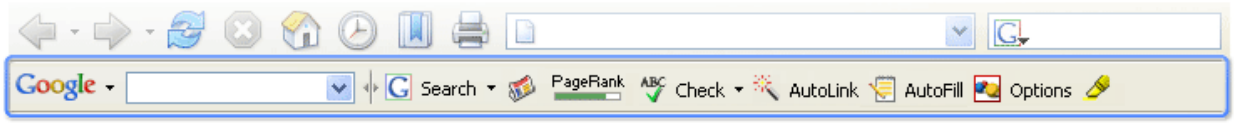


FIGURE 2. Google AdSense

FIGURE 3. Google Toolbar Plug-in for Web Browser



Other Google Products and Services

Besides online advertising services, Google leverages its search technology into a number of other search related services. One of these services is a product search website called Froogle. Froogle allows online shoppers the basis to search for product categories and brands, access to product reviews, and compare item prices. The use of search was further expanded beyond finding content on web pages to assist users to search for imagery information such as maps and satellite overlays through Google Earth. A similar concept was developed in a location-based service called Google Local in which users can search for nearby locations such as the closest coffee shop which will be labeled on a map displaying the shops in the surrounding area. Other search related services offered by Google that have gained popularity among users include an image search: Google Images, a searchable email client: GMail, a desktop file search tool: Google Desktop, and a web-based video streaming tool: Google Video. As the number of Google search queries increased, Google expanded their search accessibility by offering a Google search toolbar that users can download as a plug-in to many standard web browsers such as Internet Explorer and Mozilla Firefox (Figure 3). Many of the products and services Google develops depend on advertisements to generate revenues, but some such as Google Images, Google Earth, and Google SketchUp do not.

The only hardware equipment that Google sells to date is a standalone search product solution for the enterprise market. A listing of products and services offered by Google is shown in Table 4. The product offers corporate employees, partners, and customers to easily find information and product solutions through their internal networks. These products are known as Google Mini and Google Search Appliance, depending on the documents index capacity. Google pre-

installs its own search software and other customized software components in these hardware products. Google's bundling of software packages and hardware platform has alienated external hardware and software vendors the same services in other platform configurations.

TABLE 4. Other Notable Products and Services by Google

Product/Service Name	Description
Google Earth	Satellite imagery of geographical locations
Google Maps	View driving maps and directions
Google Local	Search for local businesses and shops
Google News	Search for news stories
Google Video	Search for TV programs and video clips
Google Desktop Search	Search for offline information stored on computers
Google Image Search	Search for images online
Google SketchUp	3-D model design tool
Google Checkout	Online payment processing service
Google Search Appliance	Enterprise search engine
GMail	Web-based email client
GTalk	Internet instant messaging and VoIP
Orkut	Online social network community
Froogle	Electronic shopper product search
Others: Google Page Creator, Google Analytics, Picasa, Blogger, Google Mobile, Google SMS, Google Finance, Google Groups, Google Scholar, Google Pack, Google Book Search, Google Code, Google Alerts, Google Calendar	

Source: Google website, listing of services and products

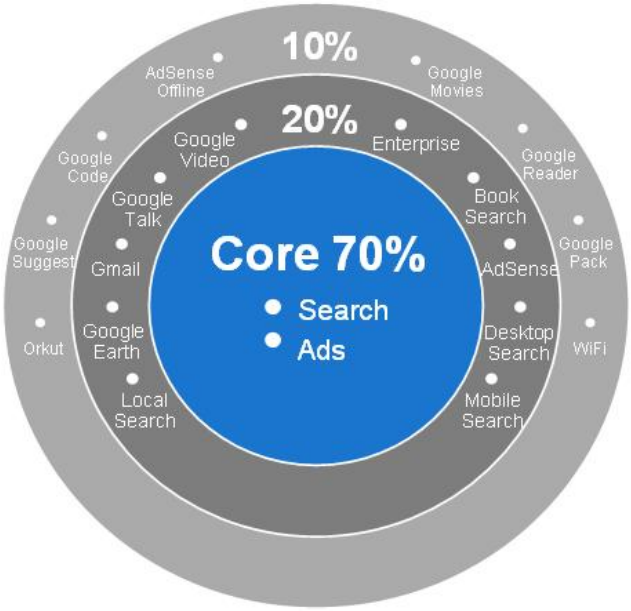
How Google Innovates

Google is a technology innovator that focuses on developing revolutionary ideas as well as complementary products and services. More than two-thirds of the company's employees are engineers and scientists. The company is a powerhouse of new technology innovations driven by software, and has a division unit called Google Labs which the company termed as an "engineer's playground."[5] Google Labs was developed since the early days of the company, and there is a place on the website to showcase new experimental products developed by Google employees. The product prototypes are available for anyone to download as beta version prior to commercial release. Unlike many engineering developments that never see daylight, this gives engineers a sense of satisfaction that their ideas turn into products that people can use.

One of the most important characteristic for Google's innovative thinking is attributed to its work atmosphere. Unlike a typical corporate environment, Google's headquarters in Mountain View, called the Googleplex, is reminiscent of a college campus, and operate like a graduate school atmosphere with numerous guest speakers everyday and where open mind is encouraged. Other technology companies have previously tried to mimic a similar university culture but Google goes a long way in providing flexibility, openness, and fun workplace for its employees. To minimize management from getting into the way of the engineers, Google adopts a very flat organizational structure.

Google engineer Joe Beda praised the positive atmosphere inside the Google headquarters: "The intrapersonal environment at Google is very energizing. When someone comes up with a new idea, the most common response is excitement and a brainstorming session." [6] Google implemented a 20 percent rule in which engineers spend 80% of their time at work on Google's core products, and the freedom to dedicate the remaining 20% of their working time on any "pet projects." The 20 percent rule was a way of encouraging innovation at Google. Adopting the philosophy of 20 percent rule has enabled the engineers at Google to develop a number of products including Froogle, Google News, Google Finance, Orkut, and GTalk. In 2005, the company changed this policy slightly with a 70/20/10 rule, where 70% of time is spent on search and advertising, 20% on a work-related product, and 10% on other ideas. Google's product framework following this work policy is shown in Figure 4 below. Following the principles from management guru Peter Drucker that "knowledge workers believe they are paid to be effective," Google employees are provided with free laundry services, free gourmet food, barbers, massages, gym, commuting buses with Wi-Fi access, as well as on-site oil changes, car washes, and physician doctors.

FIGURE 4. Google 70/20/10 Product Framework



Source: Google Analyst Day, slide presentation, March 2006.

Acquisition and Incorporation of Companies

Google is very aggressive in acquiring innovative technologies and ideas. For the past five years, Google has acquired over 25 technology companies (Table 5). Google has subsequently transformed many of these technologies acquired from the buyouts into Google products and services such as Google Earth and Google Analytics (Table 5, Derived Google Services).

TABLE 5. Companies Acquired by Google[ii]

Company	Technology	Date Acquired	Derived Google Services
Deja	Usenet Search Services	February 2001	Google Groups
Outride Inc	Personalized Internet Search	February 2003	Personalized Internet Search
Pyra Labs	Blogging	February 2003	Blogger.com
Neotonic Software	E-Mail Customer Support	April 2003	E-mail Groups, GMail
Applied Symantics	Online Advertising	April 2003	AdSense, AdWatch
Kaltix	Personalized Internet Search	September 2003	Google Personal
Genius Labs	Blogging Entity	October 2003	Blogger.com
Sprinks	Paid Advertising	October 2003	AdSense and AdWords
Ignite Logic	Web Templates	April 2004	*
Picasa	Photo Management Software	July 2004	Picasa/Blogger
Where 2 Technologies	Internet Mapping	August 2004	*
Keyhole	Satellite Imagery	October 2004	Google Maps/Google Earth
Zipdash	Mobile GPS Traffic Updates	December 2004	Google Ride Finder
Urchin Software	Web Analytics	March 2005	Google Analytics
Dodgeball	Mobile Social Networking	May 2005	Google Mobile/Google SMS
Reqwireless	Wireless Software	June 2005	*
Akwan IT	Distributed Data Processing	July 2005	*
Android Inc	Mobile Phone Software	August 2005	Google Mobile/Google SMS
dMarc Broadcasting	Radio Advertising	January 2006	*
Measure Map	Blogging Analytics	February 2006	Google Analytics
Writely	Web-based Word Processing	March 2006	*
"@"Last Software	3-D Design Tool Maker	March 2006	*
2Web Technologies	Web Spreadsheet	June 2006	Google Spreadsheet
Neven Vision	Biometric Identification	August 2006	*
JotSpot	Wiki Host Site	October 2006	*
YouTube	Internet Video	November 2006	*
Endoxon	Internet and Mobile Mapping	December 2006	*
Adscape	Video Game Advertising	February 2007	*

Source: Various news sources

Acquisition of People

Likewise, Google is among the most active high-tech company in the footprint for hiring top engineering talents. During the technology bust, Google seized opportunity to hire bright technologists and focused on doing what they do best: search. Google co-founders Brin and Page had their pick of talents since they were hiring while everyone else was firing (Vise, 2005). Google's revenue did not grow rapidly at first, but its employee brainpower was. Instead of paying these engineers high salaries, Google offered them mediocre pay but generous stock options. Many of these individuals hired by Google were either inventors of successful technologies or technical leads for a division of their former employer.

The knowledge and skills from these talents were difficult to replace and in some cases, irreplaceable. A high profile example of this to date was when a former Microsoft Vice President and academic professor, Kai-Fu Lee left Microsoft to work for Google. Lee was known as an industry expert in speech recognition and played a pivotal role in driving

[ii] * Denotes unidentifiable derived Google services

Microsoft's China strategy. Microsoft feared this was not only a loss of talent, but a leakage of critical confidential information which resulted in a legal battle against Google for a one year non-competitive agreement signed by Lee. The case was settled between Microsoft and Google with the court judge placing a temporary restraining order for the type of projects Lee can work on at Google. Lee effectively started working for Google without further delay.

Various news surfacing in the technology industry estimates that over 100 former Microsoft employees to date have left their former employers and opted-out to work for Google instead. If this estimated figure is fairly accurate, approximately 1.76% of Google's total employee pool would be ex-Microsoft workers.[iii] Among the complaints, these former Microsoft employees criticized that there were duplicate efforts within the company and more time spent on maintaining software at Microsoft instead of innovating new product ideas. Google has hired many notable technologists which include technology industry legends and young guru programmers (Table 6).

Working at Google is not only attractive in the industry, but is equally enticing from many of those in academia. In fact, many university professors have opted out from their academic career track of getting tenureship to work for Google. For example, in December 2005, Andrew Moore, Professor of Computer Science at Carnegie Mellon University and an expert in data mining and artificial intelligence, decided to join Google and lead Google's new Pittsburgh engineering office.[7]

To ensure the quality of its workers at Google, the employment screening process has become one of most rigorous among all technology companies, comparable to Microsoft, and perhaps even more difficult. Applicants are asked to solve complex technical questions from at least half a dozen interviewers. Google is very careful in their recruiting and their hiring process is based on a committee hearing everyone's feedback (Schmidt & Varian, 2005). An entire interview process at Google can take several months before a decision is made.

[iii] As of December 31st, 2005, there are 5,680 full-time employees. Calculation for 1.76% (~100 / 5680).

TABLE 6. Respected Individuals Hired by Google

Top Talents Hired	Previous Positions Held
Vint Cerf	Senior VP at Worldcom, also known as the Father of Internet
Kai-Fu Lee	VP at Microsoft, lead Microsoft China Research Lab, VP of Apple
Adam Bosworth	BEA and Microsoft, pivotal role in Internet Explorer
Joe Beda	Lead of Avalon team at Microsoft
Mark Lucovsky	Microsoft, pivotal role in Windows operating system
Meir Brand	Microsoft and AOL executive
Louis Monier	Director at EBay, founder of AltaVista search engine
Udi Manber	CEO of Amazon spin-off A9 online search, Chief Scientist at Yahoo
Rob Pike	Scientist from Bell Labs, worked on operating systems
Peter Norvig	scientists at NASA, Junglee, SUN Microsystems Labs
Joshua Bloch	Java coder guru from SUN Microsystems
Guido van Rossum	Inventor of Python programming language
Cedric Beust	Weblogic developer at BEA Systems
Darin Fisher	Firefox developer
Ben Goodger	Firefox developer
Brian Rydner	Mozilla developer
Mike Pinkerton	Lead Camino developer open source project
Sean Egan	Lead Gaim developer open source project
Dr. Larry Brilliant	Award-winning physician
Andy Hertzfeld	Apple Computer's original Macintosh development team
Elliot Schrage	Business and Foreign Policy at the Council on Foreign Relations
Andrew W. Moore	Carnegie Mellon University Professor of Computer Science and Robotics
Alan Davidson	Associate Director for Advocacy Group Center for Democracy & Technology
Nikesh Arora	Chief Marketing Officer at T-Mobile
Johnny Chou	President of UTStarcom China operations
Joerg Heilig	Director of Engineering at SUN Microsystems
Hal Varian	Consultant for Google, Management Professor at UC Berkeley
Wray Buntine	Consultant for Google, Senior Research Scientist at Helsinki Institute of IT

Source: Various news sources

Strategic Partners and Alliances

As a formidable player in search technology, Google has gained respect and visibility in the technology industry. It is without surprise that other technology companies are considering partnering or forming business alliances that can leverage synergies with Google's search expertise. Interestingly, companies that have been competing with Microsoft in some market sectors seem to be partners with Google, as in the case for America Online and SUN Microsystems. In late 2005, Google invested $1 billion in AOL for a 5% stake (Mills, 2005). The partnership enables AOL to use Google's search engine power while Google receives rights to sell additional sponsored advertisement through AOL's user network. An unconfirmed article from News.com reports that up to 10% of Google's advertising revenue came from AOL (Olsen & Mills, 2005).

In a joint R&D collaboration, Google has partnered with NASA where Google applies its search technology on terabytes of incoming data to Earth from various NASA space projects. For the project, Google agreed to supply capital to build a new R&D facility in Mountain View that will occupy both Google and NASA engineers (Lewis & Fox, 2005). To expand the enterprise search business, Google has partnered with BearingPoint, formerly KPMG consulting. Google

endorses customized Google Search Appliance hardware, and Google Desktop software that BearingPoint can offer its customers a new enterprise search solution. Google has already trained over 100 BearingPoint IT professionals to facilitate the technology consulting firm (Regan, 2006).

Perhaps the most important of all partnerships is between Google and SUN Microsystems. In the joint effort, Google is hiring engineers to assist on the OpenOffice project, an open source office suite that SUN Microsystems supports. In addition to the collaboration, Google has deep historical relationships with SUN Microsystems; Google's CEO, Eric Schmidt, and the company's first angel investor, Andy Bechtolsheim, are both co-founders of SUN Microsystems. A summary of the strategic alliances Google has formed with these technology companies is shown in Table 7.

TABLE 7. Strategic Google Partners and Alliances

Company	Collaboration Efforts	Date
NASA	R&D; Google provide funding for a new joint R&D center	September 2005
SUN Microsystems	OpenOffice, an open source office suite	October 2005
America Online	AOL adopts Google's search engine; Google advertises in AOL network	December 2005
Bearing Point	Enterprise search technology services with unstructured data	February 2006

Source: Various news sources

INFORMATION TECHNOLOGY AT GOOGLE

The focus of information technology at Google for both software and hardware is speed and cost. These two metrics are valued more than any other criteria such as reliability of machines or high-performance enterprise computing hardware. Ultimately, the result must transform a response time of user query using Google's search engine to be completed within a one second time-frame. Started in Larry Page's dormitory room, the information technology at Google has transformed into a full-blown large cluster PC network that functions similar to a computing grid.[iv] Even though information technology infrastructure has changed dramatically over the years, the model of IT use at Google has stayed the same. This model follows the original principles adopted by the co-founders of building a prototype system that uses commodity hardware and intelligent software. The shift of computer industry with PCs becoming commodity electronic hardware over the years has worked in favor of Google's IT strategy in getting the best cost performance ratio (Patterson & Hennessy, 2004). Thus, instead of purchasing the latest microprocessors, Google IT performs calculations to look for the best value of processing power per dollar and purchasing many PCs that are only a few months old in the market, but at a much lower discounted price. This is suitable for Google because the framework of their search engine is built around parallelizing many user query requests across multiple machines and if more

[iv] Computing grid is an emerging model in technology that provides higher scientific computations through the use of many networked computer systems, thereby imitating supercomputer processing capabilities.

processing is required, the system can simply increase more machines to serve even greater user requests. The overall price per performance is more important than individual peak performances, and this enables Google to achieve superior speed at a fraction of the cost rather than using a few, but expensive high-end server systems. The end equation for Google's IT in selecting machines is calculated by the cost per query, and is derived by the sum of capital expenses and operating costs divided by performance. For accuracy, the calculation takes into inherent effects due to hardware depreciation and maintenance repairs. At the data centers, the primary cost factor is capital expenditure credited to hardware, followed by personnel and hosting costs (Barozzo, et al., 2003).

FIGURE 5. Equation for Calculating IT Cost at Google

$$\frac{\text{Cost}}{\text{Query}} = \frac{\text{Capital Expense} + \text{Operating Cost}}{\text{Performance}}$$

Source: Barroso, et al, 2003.

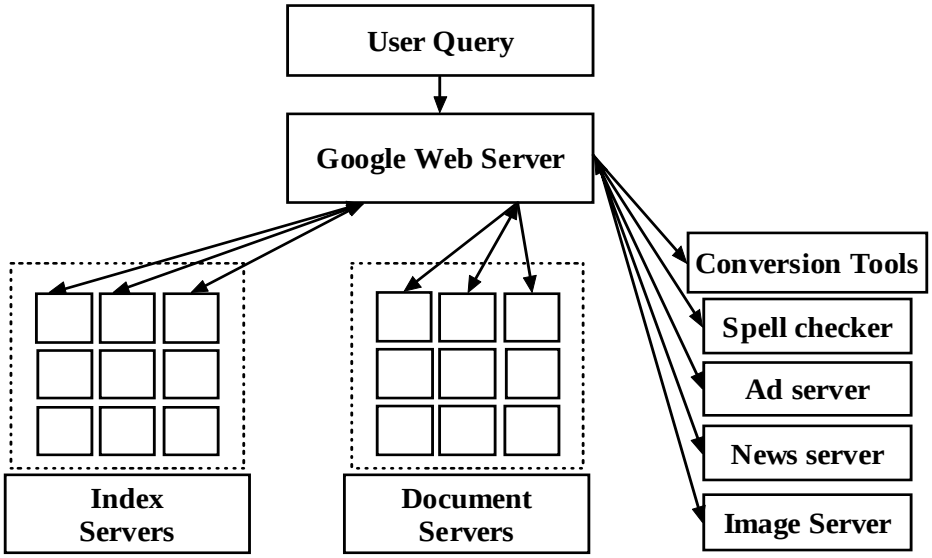
To address the reliability problem with commodity PCs, Google solves the issue mainly in software by implementing reliability and redundancy functionality in its architecture. Similar to reducing operational costs in hardware, Google adopts numerous open-source software solutions with available software functionalities and libraries. In many instances, when Google uses a particular open-source project rigorously, the company would hire active developers from the open source project and bring them on board. For example, lead software architect and guru programmers for open source projects such as Mozilla Firefox, Camino, and Gaim have joined Google in the past two years (Table 6). The software engineering process at Google focuses highly on programmer productivity with developers responsible for writing software. A separate team takes the responsibility of making the software distributed and run in parallel. Even an increased productivity of a few percent in programming time can result in thousands of dollars in savings. The CFO of Google, George Reyes, describes "Revenue per employee [as] a key metric. Google's revenue per employee is double that of its competitors, a comparison of $1.44 million per head versus $700,000 per head for rivals."[8]

Software Technology

A large portion of IT at Google depends on complex software components and architecture design. Generally, a search engine is a program that helps find information stored on a computer system. Three important steps in software technology are essential for developing a web-based search engine. These operations are web page crawling, indexing, and searching. The non-stop "web crawler" collects documents from the web. The information is stored in a searchable index, and a metric for finding desired result is computed based upon user query. One of Google's co-founders, Sergey Brin, wrote a web crawler to find and store web page indexes that later became Googlebot, while Larry Page, Google's other co-founder, came up with a unique technique to calculate web page relevance called PageRank. [9]

When user sends a search query to the Google web server, the text query gets extracted by an intelligent parser that correspondingly executes other ancillary tasks such as spell-checking to ensure the query is a valid entry prior to performing the actual search. Index servers first map the query word to a list of documents and assign relevance scores for each document. When this phase is done, the document servers then fetch each document from disk to extract the title and other relevant keyword snippets from the web page. Replication of data is necessary to ensure fast performance and reliability. Google has stored multiple copies of web content across many clusters. Load balancing is an important characteristic to perform all of the operations described above. Once the result for a search lookup is determined, a web page response is generated and displayed on the web browser as output. Along with document and index servers for web search, Google has other servers including images, news, and advertising as shown in Figure 6.

FIGURE 6. Google Search Query Architecture



Similar to other search engines, Google has more than 150 criteria to determine relevancy of a web page. However, PageRank is the most essential criterion for accurate results, and is the core technology that differentiates Google's search engine from its competitors.[10] PageRank uses a family of algorithms that calculates the ratio of the number of outgoing vs. ingoing links to a web page, and assigns numerical weight for the indexed web pages (to intuitively understand how PageRank works, see Appendix One). Calculating outgoing and ingoing links may seem to be a trivial operation, but the technique becomes computationally demanding and difficult as Google needs to analyze billions of web pages, perform calculations, and assign a ranking score for all of the web pages collected. The fundamental mathematical formula used by PageRank has been published by the Google co-founders through academic research papers and various web postings that contain discussions on the topic. However, competitors are still not able to imitate a search engine using the PageRank concept as efficiently as Google since numerous optimizations in the mathematical algorithm are necessary to calculate large-scale web pages along with other software tools for creating efficient and scalable distributed system.

During the late 1990s, Google realized that a major problem with search engines in the foreseen future was scale. The quality of search results depend not only on the methodology used for ranking web pages, but on quantity or amount of data sets the system is able to process. Intuitively, the larger set of information coverage, the better. In 1997, a research paper published by Brin and Page describes the important problem of achieving scale as "Storage space must be used efficiently to store indices...indexing system must process hundreds of gigabytes of data efficiently. Queries must be handled quickly, at a rate of hundreds to thousands per second" (Brin & Page, 1997). Achieving scale is critical for the ever increasing computational capacity demanded by many of Google's products and services, led by the search engine. Jeff Dean, a Google Fellow, says, "At Google, everything is about scale."[11] To address the scalability issue, an efficient file system capable of maintaining terabytes of data across multiple storage locations is needed to store all of the collected indexes for calculating and retrieving user queries. Optimizations in data extraction utilities were developed to speed up processing large data sets. Eventually, this led to two important software developments internally at Google: the creation of a new file system called Google File System and a data processing tool known as MapReduce.

The Google File System (GFS) is a scalable distributed file system designed and developed internally that suits the need of large data-intensive applications. GFS was implemented based on observations of application need for concurrently accessing several large gigabyte-size data files across terabytes of storage disks spread over thousands of machines (Ghemawat, et al., 2003). Individual files are broken up into fixed size chucks and assigned a unique identifier label for later retrieval. Permissions for data access are set to "read-only." Only when a "write operation" is needed as in the case of storing a new file, specific permissions are then granted by the master server.[12]

Google uses MapReduce, a programming tool developed in C++ that implements parallel computations for large data sets greater than one terabyte.[v] As described by Jeff Dean, one of the main architects behind MapReduce, "The run-time system takes care of the details of partitioning the input data, scheduling the program's execution across a set of machines, handling machine failures, and managing the required inter-machine communication. This enables programmers without any experience in parallel and distributed systems to easily utilize the resources of a large distributed system" (Dean & Ghemawat, 2004). Within Google, MapReduce has been used by its programmers in a wide variety of applications including web access log statistics and document clustering.[13]

A major portion of software engineering practices at Google is focused on writing code and developing new software web-based applications rather than traditional standalone applications that run on local machines. Following the theme of speed in its search engines, these applications need to run quickly and efficiently. In particular, many web-based applications offered in Google's products and services use an innovative software design methodology known as Asynchronous JavaScript and XML (AJAX). AJAX is a web development technique for creating interactive web-based applications while refreshing the page, and has been used in a number of Google products including GMail, Google Earth, and Google Finance. Sergey Brin

[v] A "terabyte" is a unit of computer storage totaling 2^{40} bytes and is equivalent to 1,024 gigabytes. The terminology of "Map" and "Reduce" traces roots from concepts in functional programming languages.

has confidence in his company's expertise in AJAX technologies and its ability to overcome technical difficulties internally: "[our] company has had good experience with AJAX. There are important technical challenges to overcome with some technologies but no impediments that can't be overcome…For the performance-critical areas, the company uses its own internal solutions" (Mills, 2006b). The primary operating system used by Google engineers is based on the Linux platform. In particular Ubuntu Linux distribution is popular within Google.

Technology Infrastructure

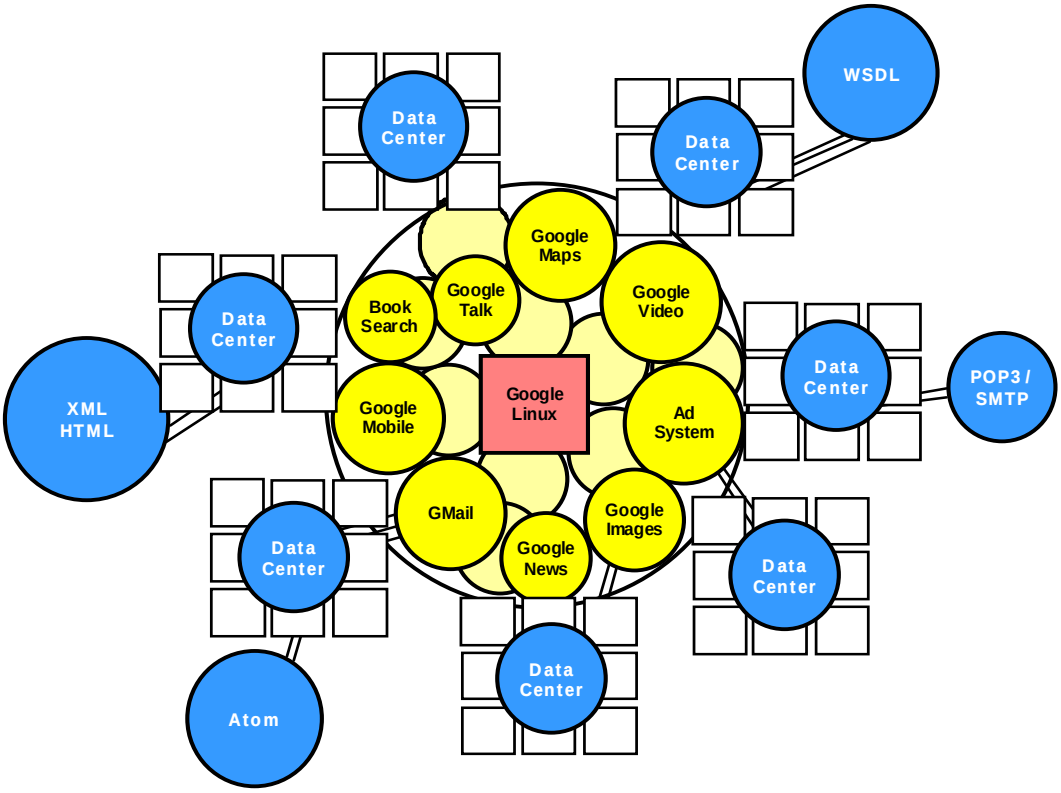
Delivering fast search results not only requires software optimizations, but also a lot of hardware computing power to do the task. Google uses typical Intel x86-based PCs to function as servers. The benefits of falling prices in commodity PCs, increasing computing processing power, increasing storage capacity, and other component upgrades are major cost-saving advantages for Google's IT. The computational framework for delivering high-performance computing at Google is made possible by using low-cost hardware. In order to save software costs and to allow the commodity PCs to function together in a distributed manner, machines at the data centers run customized versions of the Linux operating system. Google has researchers within the company to measure performance benchmarks by taking empirical measurements to calculate complex hardware metrics such as CPU execution time and clock cycles per instruction.

In the early stages as a research project, Google's data center drew on Stanford University's computing resources or equipment donated by the industry. When Google was downloading web pages from the Internet, Stanford University was generous in lending huge chunks of network bandwidth for the project. In fact, there were numerous occasions when Google's network bandwidth usage took all of the university's network capacity and shut down the entire campus network (Battelle, 2005). When Google transcended from a research project to a commercial product, it had to look for outside data center vendors.

To gather all of the old and new documents collected from the web, Google runs a large number of server farms in the data centers. These data centers are located at different regions within the United States and around the world. Some estimate that Google has more than two dozen data centers across the world to date. Many of the data centers are served by different network service providers to reduce catastrophic downtime.[20]

A main data center hub is located in the Silicon Valley which serves California, while the other major data center is located in Virginia, which is connected to the data centers in Europe (Vise & Malseed, 2005). The computing framework in Figure 7 shows that individual data centers serve users in proximity areas.

FIGURE 7. Google Computing Framework

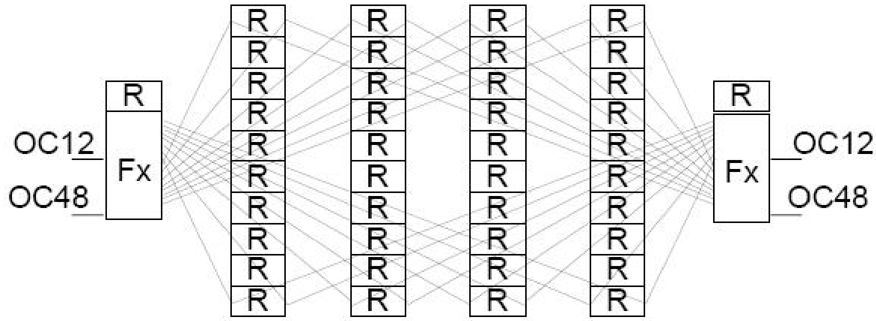


Source: Arnold, 2005.

Although it is difficult to know the configuration of Google's data center today, historical information is available for discussion. As of 2000, Google had over 6,000 processors with disk storage reaching the one petabyte milestone, likely one of the highest storage networks in the private industry, and comparable to supercomputer research center sites in the U.S.[vi] In addition, a data center has minimally 40 racks with each rack containing 80 PCs. To support connectivity between PCs, each PC has at least two Gigabit/sec Ethernet interfaces that are individually connected to two high capacity Cisco switches (Figure 8) (Patterson & Hennessy, 2004).

[vi] A "petabyte" is a unit of computer storage totaling 2^{50} bytes and is equivalent to 1,024 terabytes.

FIGURE 8. Google Data Center PC Cluster [vii]



Source: Patterson & Hennessy, 2004.

In a normal scenario, Google upgrades machines in its data center every two to three months, mainly to increase processing power and storage capacity. By far, most of the computing resource utilization in its data centers derive from the search engine's persistent web crawler, and less so on the millions of daily user query computations. To handle the workload, Google's IT infrastructure is believed to have 100,000+ PCs as of April 2004 and as many as 250,000 PCs by the end of 2004 (Ferguson, 2005). Some estimate that these numbers may double roughly every nine months as the search engine continues to crawl, index, and search the billions of new web pages. Having more machines to maintain may seem to burden the IT department, but in fact the issue is not very problematic since thousands of servers in each data center have identical configurations.

Although using "white box" hardware helps Google reduce costs, it comes with its drawbacks. Commodity PCs are less reliable and more prone to problems. A number of PCs are rebooted on a daily basis due to either software or hardware failures. Hardware attributes about one-tenth of the failures and about two to three percent of the PCs need to be replaced per year. DRAM accounts for 95% of all failures (Vise & Malseed, 2005). However, Google takes extreme precautions for these failures and have developed mechanisms to allow fault-tolerance in their distributed system. For example, to overcome rack or data center failure, Google's customized Linux operating system has the ability to automatically replicate data files across different storage devices to at least three other data center locations (Arnold, 2005).

Another major drawback with PCs is higher power usage than typical commercial data centers since they use suboptimal power supplies with relatively simple packaging and cooling devices. Energy efficiency is critical to Google's IT operation due to high power consumption. The purchasing of hardware contributes largely to the IT costs at Google. However, the power costs of running these servers may become an increasing concern since it requires a huge amount of power consumption (Shankland, 2005). While cost per MBit/second is decreasing, cost per kilowatt hour is increasing. To address this issue, Google has made it a priority to purchase machines that offer the best watts per unit of performance. Some of the other major issues in

[vii] The data center diagram as of 2000. OC12 and OC48 are fiber optic lines that support network link speed of 622 Mbit and 2.4Gbit. Fx = network switches, R = racks that contain stacks of PCs.

data center operations include heat generated by racks, and lack of network management tools to monitor all hardware failures automatically. Google works alongside with third party data centers to improve server racks, cooling devices such as fans, placement of cables, and optimal data center layouts. Some of these components are custom-built specifically to solve the heating problem.

Both software and hardware play an important role in Google's information technology. In software, high-performance is vital, while in hardware cost reduction is crucial (Table 8). The use of software and hardware IT at Google is inherently strategic to the company's success in delivering products and services that are fast and accurate. Beyond the importance of PageRank technology, software and hardware practices at Google are likewise worthy differentiators from other competitors that are unable to replicate the process.

TABLE 8. Google's Software and Hardware IT Strategy [viii]

Software (high performance)	Hardware (cost reduction)
▪ Google Linux Operating System	▪ Commodity PC and PC Components
▪ Google File System	▪ Use Standardized Devices
▪ MapReduce Libraries	▪ PC Clusters
▪ Programming Models	▪ Automatic Backups
▪ Intelligent System	▪ Geographic Distribution
▪ Replication and Redundancy	▪ Co-location Sites

FIRM GROWTH

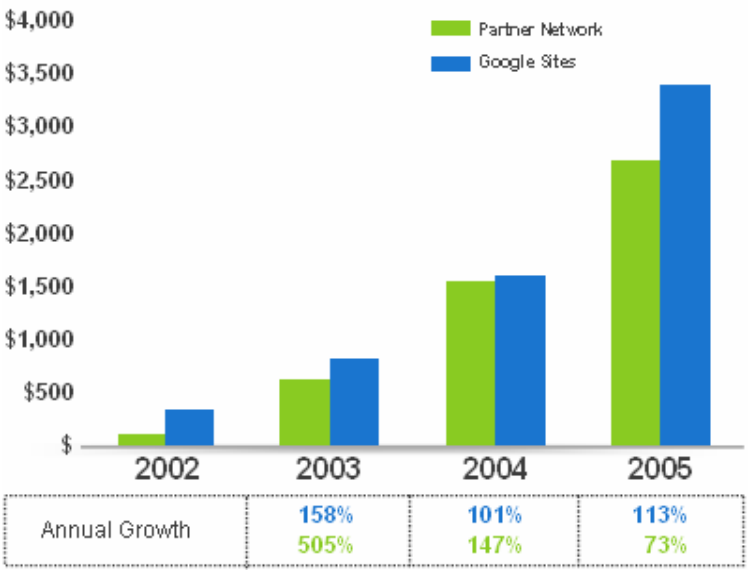
Financial Performance

Google was first funded by angel investors that include corporate executives and retired technologists. The first capital for Google occurred on August 1998 in the amount of $100,000 from Andy Bechtolsheim, a co-founder of SUN Microsystems. Shortly thereafter in September 1998, Google raised another $1 million from other private investors including David Cheriton from Netscape and Amazon executive, Ram Shriram (Rivlin, 2004). In early 1999, Google went through a round of venture capital funding, raising $25 million from Sequoia Capital, Kleiner Perkins Caufield & Byers (KPCB), and a few private investors. When news spread that Google received funding from the prestigious venture capital firms, many technologists and investors in Silicon Valley took a closer look at Google.

Unlike many start-up companies that were greatly impacted by the dot-com bubble, Google grew slowly, yet steadily, with positive cash flow. Google began to generate robust advertising revenues in 2002, mainly through google.com. By 2003 and 2004, the company achieved over 100% annual growth in advertising revenues from both its Google site and partner network (Figure 9). Google maintained very healthy revenue growth from 2002 to 2005 with over $6 billion in revenues by the end of fiscal year 2005 (Figure 10).

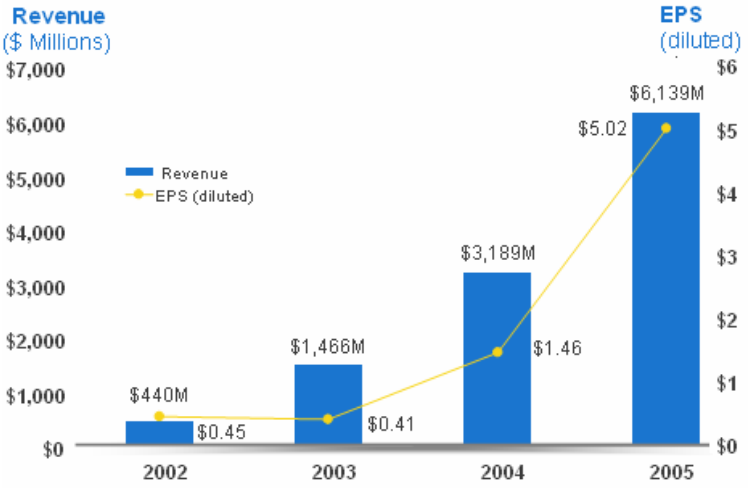
[viii] This table is a modified version of a software/hardware fusion diagram from reference[33].

FIGURE 9. Advertising Revenues



Source: Google Analyst Day, slide presentation, March 2006.

FIGURE 10. Revenue Growth



Source: Google Analyst Day, slide presentation, March 2006.

For several years, Google enjoyed being a private company without having to disclose financial and other information to the public. However, in April 2004 Google filed with the SEC to become public later that summer to raise $2.7 billion in order to reward its employees and investors. However, the IPO process took an unconventional Dutch-auction method where normal individual investors along with financial institutions can participate in purchasing Google IPO shares online. Besides not following the typical Wall Street IPO process, remarkably, Google sold only Class A shares while its management retained all Class B shares, in which Class B shares has ten times more voting rights. This essentially means that the Google management team retains majority control of the company and its board of directors when the company becomes public.

Prior to the IPO, Google received a lot of media attention and created a website solely discussing the event.[ix] On August 13th, 2004, Google went public on the Nasdaq Stock Market under the symbol GOOG with a selling price set at $85 per share. At the close of the IPO, Google raised $1.67 billion from the public. As of 2006, Google's stock price was around $300 to $500 per share. Many investors have complained that Google's stock has become too expensive to purchase, at least from the number value perspective. The Google management does not believe in stock splits to lower cost of their stock price while increasing the number of shares. In fact, Brin and Page have quoted billionaire investor, Warren Buffet, as their role model and would like Google to follow the same financial methodology that was set for Berkshire Hathaway holding company on the opposition of stock splits (Mills, 2006a).

Global Expansion

The international markets are critical for many technology companies in expanding new business opportunities and generating more revenues. Similarly, this principle is reminiscent in Google's case, as the international markets contribute from 30% to 40% of the company's total revenues every quarter for the past two years.[4] In order to tap into the international market, Google's search engine has been translated to allow multi-language search capabilities, while maintaining its philosophy of objective and unbiased search results (Brin, 2001). The strong international markets for Google include the United Kingdom, Western Europe, Japan, Canada, and Australia. Google has transformed from a start-up firm to a multi-national corporation; however, the majority of its employees are still based in the Mountain View headquarters. Google has international presence in all continents of the world other than Africa and Antarctica. However, the location of its international employee base is divided into two primary groups: engineering and product development team, and a sales force team (Table 9). Google offers customer interfaces in over 40 different languages and close to 50 different currency exchanges to date.

TABLE 9. Google International Locations

Continent	Engineering and Product Developments	Sales Force
North America	U.S. - Mountain View, CA (Headquarter), Kirkland, WA, Phoenix, AZ, Pittsburgh, PA, New York, NY, Santa Monica, CA, Others - Waterloo, Canada	U.S. – 14 different sites Others - Toronto, Canada, Montreal, Canada Mexico City, Mexico
South America	Belo Horizonte, Brazil	Sao Paulo, Brazil
Asia	India - Bangalore, Hyderabad Others - Beijing, China, Tokyo, Japan, Taipei, Taiwan	India - Hyderabad, Delhi, Mumbai, India Others - Tokyo, Japan, Seoul, Korea, Hong Kong, China
Europe	London, U.K., Munich, Germany, Trondheim, Norway, Zurich, Switzerland	Copenhagen, Denmark, Paris, France, Hamburg, Germany, Amsterdam, Netherlands, Madrid, Spain, Stockholm, Sweden, Zurich, Switzerland, Istanbul, Turkey, London, UK, Manchester, UK, Tel Aviv, Israel, Dublin, Ireland, Milan, Italy, Rome, Italy
Australia	None	Melbourne, Sydney

Source: Various news sources

[ix] The website on Google's Initial Public Offering, http://www.ipogoogle.org/

THREATS AND CHALLENGES

Business Risks

Google is vulnerable in various aspects. Weak customer lock-in, eroding public trust, lawsuits, and too much dependence on search advertising are risks that the company faces. Google's stock price has been viewed as overvalued by many financial analysts and resulted in a recent decline. Google has almost twice as many search advertising click-through as its nearest competitor; however, they lack maturity and customer lock-in that Yahoo possesses. Yahoo has the advantage of having over 141 million customer profiles that can be integrated with their search engine to customize search results tailored for individual interests. Google only began subscribing customers via GMail and its personalized homepage for users.

The competitive threat from Microsoft is foreboding. Microsoft is expected to aggressively compete head to head with Google by leveraging its Windows monopoly to win the search market. Microsoft's search engine will be embedded into the core of Microsoft's next-generation operating system, Windows Vista. At a technology conference in March 2006, Neil Holloway, Microsoft President for Europe, Middle East and Africa indicates, "What we're saying is that in six months' time we'll be more relevant in the U.S. market place than Google" (Reuters, 2006a). Only time will tell whether Microsoft is able to compete successfully in the search market, Microsoft certainly has scale, industry influence, and capital. They can quickly ramp up using its $7 billion plus budget in R&D annually. Steve Ballmer, CEO of Microsoft, has acknowledged that in recent years Microsoft has not been spending enough R&D in the area of search technology, and has promised to put a big emphasis on it in the future (Linn, 2004). Microsoft is known to setup a R&D center on search technology in Mountain View, California. While Yahoo and Microsoft's MSN are leading the assault as large companies in search engines, there are many new start-ups in the search industry that specialize in niche search capabilities (Table 10). Larry Ellison, CEO of Oracle, has claimed that Oracle will be filling the gap in enterprise search business, a market that Google has not penetrated rigorously (Reuters, 2006b).

In order for Google to stay ahead of its competitors, it must broaden its horizons. "Google needs to make that leap into display advertising," says Charlene Li, a Forrester Research analyst. "Right now, their advertising base is really comprised of direct marketers, not traditional brand marketers, and they really don't have the expertise and credibility that Microsoft and Yahoo and AOL have in that area" (Elgin, 2004). Google is beginning to diversify its revenue stream by branching into different areas of advertising. Google Video, a pay-for-video service allows content owners to charge fees for users to watch programs on their PCs. Content include NBA basketball games, music videos, news, and CBS prime-time shows. Google's acquisition of dMarc is also evidence of its efforts to expand its customer base to attract the offline customers as well, specifically through the radio broadcast medium.

TABLE 10. Start-up Search Firms

Company Name	Search Techniques
A2B	Location Search
Accoona	Artificial Intelligence/Semantic Search
Blinkx	Media and Implicit Search
Gravee	Social Search
Grokker	Enterprise Search
Kosmix	Health Search
Nexidia	Media Search
PageBull	Visual Search
PubSub	Weblog and Newsgroup Search
Riya	Photo Search
Simplyhired	Job Search
SurfWax	Targeted Search
Teoma	Clustering Categorization
Transparensee Systems	Relevant Matching
Trulia	Real Estate Search
Truveo	Video Search
Vast	Classified Search
Vivisimo	Clustering Categorization
Wisenut	Vertical Category Search

Source: Various news sources

Then, there are political, copyright, and privacy issues that Google constantly deals with. Google has been the subject of much debate at GMail's release, as the correlation between GMail and Google's search poses enormous privacy risks. A California state senator proposed a law to ban advertising function where Google sponsored ads is displayed based on keywords found in an email read. Privacy advocates addressed the danger of having personal email retained in Google's servers even after being deleted by the user explicitly.[14] However, many critics are triggered by public reaction to information stored on external computers that sometimes fall into the wrong hands. Computer users should be aware of the perils they potentially face and should not expect more privacy in an email than sending a telegram or postcard. Google also faced an onslaught of lawsuits, especially over the past 18 months (LaPlante, 2006). There have been numerous occasions when Google's AdWords customers had to pay for clicks that turned out to be fraudulent or manipulated in some way. Other threats include allegations of stolen source code in their Orkut software; "Google bombing" where some users deliberately undermine the effectiveness of the PageRank algorithm by changing site linkages to web pages to gain ranking scores; and copyright law violations for digitizing books without the permission of copyright holders in the Google Book Search initiative. These issues still remain controversial and some are still being fought in court.

Current and Future Perspectives

Google has already started initiatives to target radio, print media, and other media advertising. GTalk, Google's advertisement-free instant messaging and Internet telephony application may become an appealing option as well. The company is looking to advance its VoIP services with potential for GTalk to become an advertisement-supported voice-calling product, integrating

phone number and Web searches into the interface. Among new products, Google is planning to release the GDrive, an online disk storage drive for users. In addition, there is evidence that Google is moving into telecommunications business as the company has been interested in buying dark fibers nationwide owned by various telecom service providers.[x] Google placed a job listing seeking telecom expertise who could procure dark fiber for the company. It is rare for companies to buy sizable amounts of cable unless they have huge data demands (e.g. banks), but it may be an attempt for Google to further cut down costs in network usage in the future (Hansen, 2005). Other future product speculations include a Google web browser. Google has also expressed interest in the wireless market space and has formed partnerships with mobile phone vendors Samsung and China Mobile.

At the 2006 Consumer Electronics Show in Las Vegas, Page announced Google's plans to distribute a consumer software bundle called Google Pack. Google Pack is the answer to Page's frustration that new home computers do not come with enough easy-to-use applications. It contains Google software including Google Desktop, GTalk, anti-virus, anti-spyware, FireFox browser, and Adobe Reader. Dell Computer is considering using GooglePack as part of its pre-installed software packages for selling new PCs.

In 2006, Google released the 802.11 Wi-Fi initiatives in the San Francisco area. A Wi-Fi VPN client called Google Secure Access allows all San Francisco's residents wireless Internet access. Supplying free Wi-Fi is a major step of making information more available and to get people onto the Internet more easily, a significant move to ubiquitous, affordable Internet access. Furthermore, Google invest in wireless start-up companies that are developing Wi-Fi community networks including FON and Meraki.

Google is partnering with other companies to invest approximately $100 million to develop broadband Internet over power lines. Network computer maker Wyse Technology says there were speculations about a $200 Google-branded PC that would likely be marketed in China and India through local telecommunication companies. The only relevant source of information to support the claim is Google's funding support of the one laptop per child (OLPC) non-profit association dedicated to research and development of cheap laptop computer for children in developing markets. The initiatives potentially allow more users access to educational information over the Internet, benefiting society and increasing the standard of living around the world.

CONCLUSION

In only a short period of time, Google has become a dominant player in search technology and a formidable threat to many other technology firms in various industry sectors including advertising, standard software, web application development, and telecommunication networks. Behind the scenes, the use of information technology has been strategic and critical for Google's search engine success and other Google products and services. A variety of advanced concepts in computer science have been applied to many of Google's products and services ranging from topics in distributed systems, machine learning, software architecture, and communications

[x] Dark fiber refers to fiber optic cable that is already laid out, but is not in use and involves huge operational cost.

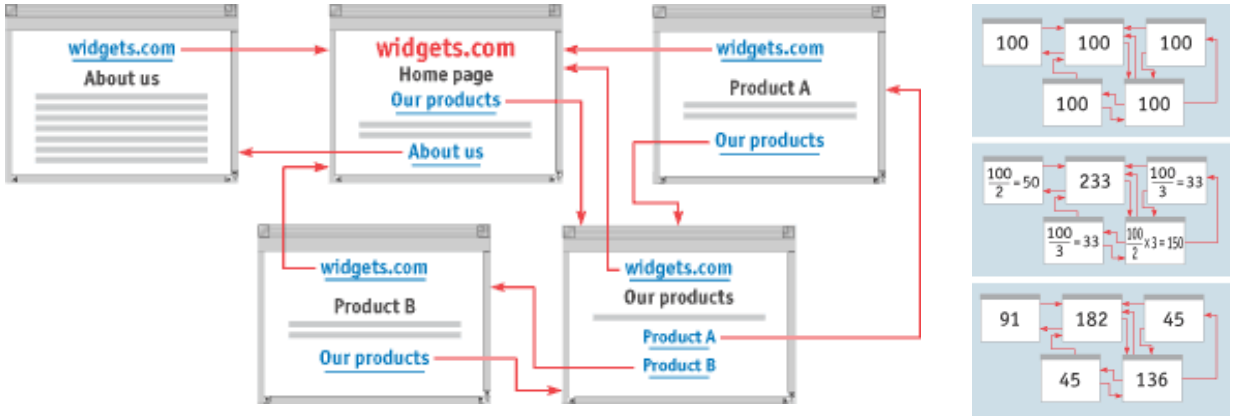
networks. Google's vision of applying advanced computing concepts and innovative ideas has allowed the company to stay as a forefront leader. However, there are even greater challenges for Google as it matures into a multi-national corporation. How will Google be able to enter international markets where information dissemination is highly regulated and controlled by the foreign governments? Can Google continue to sustain its rapid growth while continue to hold on its unique work culture? With the massive amount of information collected on a daily basis, will Google invade privacy concerns? Will Google be able to maintain its technology leadership as competition gets even more intense? And how real is the threat from Microsoft as it claims to defend itself and compete rigorously with Google in the search market? The story behind Google is only a start. Only time will tell Google's destiny. Many futurists predict that Google may perhaps become the most important technology company this decade, similar to how Microsoft and Intel have changed the technology industry in the past.

APPENDIX 1 – Page Rank Algorithm

PageRank Sample Calculation

- Initially, assign all five pages the same score (a non-zero number, in this case 100).
- Each page's score is determined by the sum of a number, calculated by the score of the linking page(s) divided by the number of outgoing link(s). For example, the "About us" page has one incoming link (from "Home page"). Initially, "Home page" has a score of 100 and contains two outgoing links. Hence, the new score for "About us" page is 50, calculated by 100 (score of "Home page") divided by two (number of "Home page" outgoing links). Calculation for the more complicated "Home page" is: 100/1 + 100/2 + 100/2 + 100/3 = 233
- When scores for all five pages are recalculated, the process is repeated using the new scores assigned (in this case: 50, 233, 33, 33, 150). The process is repeated over and over again until the scores convergences, and this number is the final scores that will go into ranking system (in this case: 91,182,45,45,136)

FIGURE 11. PageRank Calculation



Source: The Economist, 2004.

PageRank Toolbar

- PageRank is also displayed in the Google toolbar (Figure 3) that can be plug-in to standard web browsers. However, rather than showing actual PageRank calculation, the toolbar uses a range from 1 to 10 for showing page relevance using a logarithmic scale.

TABLE 11. PageRank Toolbar Bar Translation

Toolbar PageRank (log base 10) PageRank	**Real PageRank**
0	0 to 10
1	100 to 1,000
2	1,000 to 10,000
3	10,000 to 100,000
4	100,000+

Source: Rogers, n.d.

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