Why Open Source Software / Free Software (OSS/FS)? Look at the Numbers!

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This paper provides quantitative data that, in many cases, using open source software / free software is a reasonable or even superior approach to using their proprietary competition according to various measures. This paper's goal is to show that you should consider using OSS/FS when acquiring software. This paper examines market share, reliability, performance, scalability, security, and total cost of ownership. It also has sections on non-quantitative issues, unnecessary fears, OSS/FS on the desktop, usage reports, governments and OSS/FS, other sites providing related information, and ends with some conclusions. An appendix gives more background information about OSS/FS. You can view this paper at http://www.dwheeler.com/oss_fs_why.html (HTML format). Palm PDA users may wish to use Plucker to view this. A short briefing based on this paper is also available in PDF and Open Office Impress formats (for the latter, use Open Office Impress). Old archived copies and a list of changes are also available.

1. Introduction

Open Source Software / Free Software (OSS/FS) has risen to great prominence. Briefly, OSS/FS programs are programs whose licenses give users the freedom to run the program for any purpose, to study and modify the program, and to redistribute copies of either the original or modified program (without having to pay royalties to previous developers).

This goal of this paper is to show that you should consider using OSS/FS when you're looking for software, based on quantitative measures. Some sites provide a few anecdotes on why you should use OSS/FS, but for many that's not enough information to justify using OSS/FS. Instead, this paper emphasizes *quantitative* measures (such as experiments and market studies) on why using OSS/FS products is, in many circumstances, a reasonable or even superior approach. I should note that while I find much to like about OSS/FS, I'm not a rabid advocate; I use both proprietary and OSS/FS products myself. Vendors of proprietary products often work hard to find numbers to support their claims; this page provides a useful antidote of hard figures to aid in comparing proprietary products to OSS/FS.

Note that this paper's goal is *not* to show that all OSS/FS is better than all proprietary software. Certainly, there are many who believe this is true from ethical, moral, or social grounds, users *do* have control and flexibility advantages when they can modify and maintain their own software, and some countries perceive political advantages to not depending on a company from another country. However, no numbers could prove the broad claim that OSS/FS is always better. Instead, I'll simply compare commonly-used OSS/FS software with commonly-used proprietary software, to show that at least in certain situations and by certain measures, some OSS/FS software is at least as good or better than its proprietary competition. Of course, some OSS/FS software is technically poor, just as some proprietary software is technically poor, and even very good software may not fit your specific needs. But although most people understand the need to compare proprietary products before using them, many people fail to even consider OSS/FS products. This paper is intended to explain why acquirers should consider OSS/FS alternatives. This paper doesn't examine transition approaches, but it's worth noting that organizations can transition to OSS/FS in part or in stages, which for many is a more practical transition approach.

I'll emphasize the operating system (OS) known as GNU/Linux (which many abbreviate as "Linux") and the Apache web server, since these are some of the most visible OSS/FS projects. I'll also primarily compare OSS/FS software to Microsoft's products (such as Windows and IIS), since Windows has a significant market share and Microsoft is one of proprietary software's strongest proponents. I'll mention Unix systems in passing as well, though the situation with Unix is more complex; today's Unix systems include many OSS/FS components or software primarily derived from OSS/FS components. Thus, comparing proprietary Unix systems to OSS/FS systems (when examined as whole systems) is often not as clear-cut. This paper uses the term "Unix-like" to mean systems intentionally similar to Unix; both Unix and GNU/Linux are "Unix-like" systems. The most recent Apple Macintosh OS (MacOS OS X) presents the same kind of complications; older versions of MacOS were wholly proprietary, but Apple's OS has been redesigned so that it's now based on a Unix system with substantial contributions from OSS/FS programs. Indeed, Apple is now openly encouraging collaboration with OSS/FS developers.

Sometimes it's illegal to publicly criticize proprietary software, which does reduce the amount of information available. Many proprietary product licenses include clauses that forbid public criticism of the product without the vendor's permission. Obviously, there's no reason that such permission would be granted if a review is negative! As a result, reviewers may change their report so it can be published, or not report at all (they might not even *start* the evaluation). Some laws, such as UCITA (a law in Maryland and Virginia), specifically enforce these clauses forbidding free speech, and in many other locations the law is unclear - making researchers bear the risk that these clauses *might* be enforced. These legal risks do cause a chilling effect on researchers, and it's not a theoretical problem; these license clauses have already prevented some public critique. In spite of these legal tactics to prevent disclosure of data not controlled by a vendor, there is still a great deal of publicly available data, as this paper shows.

This paper omits or at least tries to warn about studies funded by a product's vendor. Remember that vendor-sponsored studies are often rigged (no matter who the vendor is) to make the vendor look good instead of being fair comparisons. Todd Bishop's January 27, 2004 article in the Seattle Post-Intelligencer Reporter discusses the serious problems when a vendor funds published research about itself. A study funder could directly pay someone and ask them to lie, but it's not necessary; a smart study funder can produce the results they wish without, strictly speaking, lying. For example, a study funder can make sure that the evaluation carefully defines a specific environment or extremely narrow question that shows a positive trait of their product (ignoring other, probably more important factors), require an odd measurement process that happens show off their product, seek unqualified or unscrupulous reviewers who will create positive results (without careful controls or even without doing the work!), create an unfairly different environment between the compared products (and not say so or obfuscate the point), require the reporter to omit any especially negative results, or even fund a large number of different studies and only allow the positive reports to appear in public. That doesn't mean that all vendor-funded studies are misleading, but many are, and there's no way to be sure which studies are actually valid. For example, Microsoft's "get the facts" campaign identifies many studies, but they're almost entirely vendor-funded! And Microsoft is by no means the only company that does this; many companies do this, and the concerns about vendor-funded studies applies equally to vendors of OSS/FS products. After a pair of vendor-funded studies were publicly lambasted, Forrester Research announced that it will no longer accept projects that involve paid-for, publicized product comparisons. One ad, based on a vendor-sponsored study, was found to be misleading by the UK Advertising Standards Authority (an independent, self-regulatory body), who formally adjudicated against the vendor. This example is important because the study was touted as being fair by an "independent" group, yet it was found unfair by an organization who examines advertisements; failing to meeting the standard for truth for an advertisement is a very low bar. I'm independent; I have received *no* funding of any kind to write this paper, and I have no financial reason to prefer OSS/FS or proprietary software.

This paper includes data over a series of years, not just the past year; all relevant data should be considered when making a decision, instead of arbitrarily ignoring older data. Note that the older data shows that OSS/FS has a history of many positive traits, as opposed to being a temporary phenomenon.

You can get a more detailed explanation of the terms "open source software" and "Free Software", as well as related information, from the appendix and my list of Open Source Software / Free Software (OSS/FS) references at http://www.dwheeler.com/oss_fs_refs.html. Note that those who use the term "open source software" tend to emphasize technical advantages of such software (such as better reliability and security), while those who use the term "Free Software" tend to emphasize freedom from control by another and/or ethical issues. The opposite of OSS/FS is "closed" or "proprietary" software. Software for which the source code that can be viewed, but cannot modified and redistributed without further limitation (e.g., "source viewable" or "open box" software, including "shared source" and "community" licenses), are not considered here since they don't meet the definition of OSS/FS. Many OSS/FS programs are commercial programs, so don't make the mistake of thinking OSS/FS is equivalent to "non-commercial" software (indeed, any article making this mistake should be ignored since it is obviously poorly researched). Almost no OSS/FS programs are in the "public domain" (which has a specific legal meaning), so avoid that term as well. Other alternative terms for OSS/FS software include "libre software" (where libre means free as in freedom), free-libre and open-source software (FLOS software or FLOSS), open source / Free Software (OS/FS), free / open source software (FOSS), open-source software (indeed, "open-source" is often used as a general adjective), "freed software," and even "public service software" (since often these software projects are designed to serve the public at large). OSS/FS is not "freeware"; freeware is usually defined as proprietary software given away without cost, and does not provide any right to examine, modify, or redistribute the source code. The most popular OSS/FS license is the General Public License (GPL); all software released under the GPL is OSS/FS, but not all OSS/FS software uses the GPL; nevertheless, some people do inaccurately use the term "GPL software" when they mean OSS/FS software.

This is a large paper, with many acronyms. A few of the most common acryonyms are:

Acronym	**Meaning**
GNU	GNU's Not Unix (a project to create an OSS/FS operating system)
GPL	General Public License (the most common OSS/FS license)
OS, OSes	Operating System, Operating Systems
OSS/FS	Open Source Software/Free Software

Below is data discussing market share, reliability, performance, scalability, security, and total cost of ownership. I close with a brief discussion of non-quantitative issues, unnecessary fears, OSS/FS on the desktop, usage reports, other sites providing related information, and conclusions. A closing appendix gives more background information about OSS/FS. Each section has many subsections or points. The non-quantitative issues section includes discussions about freedom from control by another (especially a single source), protection from licensing litigation, flexibility, social / moral / ethical issues, and innovation. The unnecessary fears section discusses issues such as support, legal rights, copyright infringement, abandonment, license unenforceability, GPL “infection”, economic non-viability, starving programmers, compatibility with capitalism, elimination of competition, elimination of “intellectual property”, unavailability of software, importance of source code access, an anti-Microsoft campaign, and what’s the catch. And the appendix discusses definitions of OSS/FS, motivations of developers and developing companies, history, licenses, OSS/FS project management approaches, and forking.

2. Market Share

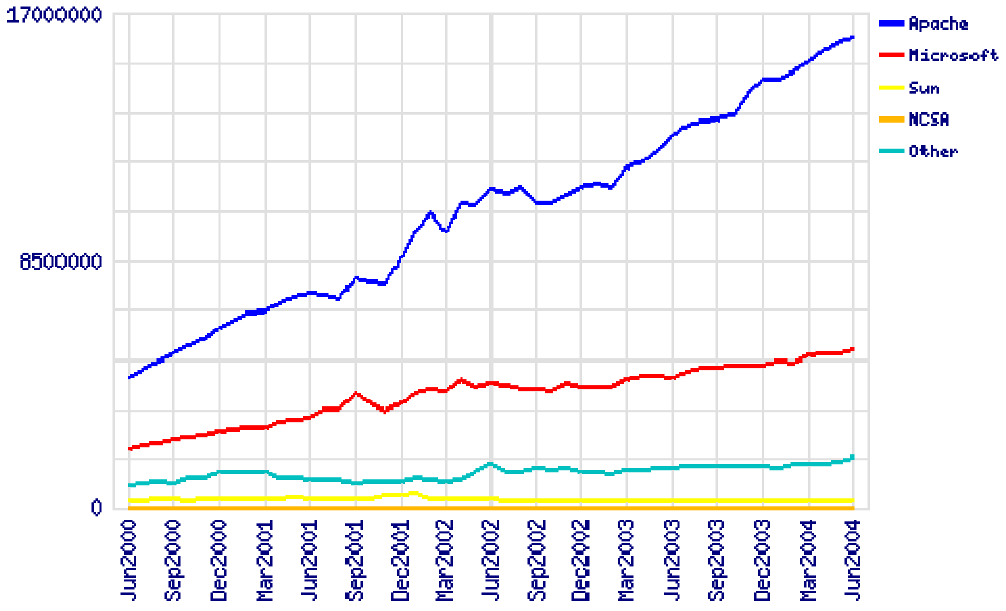
Many people think that a product is only a winner if it has significant market share. This is lemming-like, but there’s some rationale for this: products with big market shares get applications, trained users, and momentum that reduces future risk. Some writers argue against OSS/FS or GNU/Linux as “not being mainstream”, but if their use is widespread then such statements reflect the past, not the present. There’s excellent evidence that OSS/FS has significant market share in numerous markets:

1. **The most popular web server has always been OSS/FS since such data have been collected. For example, Apache is currently the #1 web server with over three times the market share of its next-ranked competitor.** Netcraft’s statistics on web servers have consistently shown Apache (an OSS/FS web server) dominating the public Internet web server market ever since Apache grew into the #1 web server in April 1996. Before that time, the NCSA web server (Apache’s ancestor) dominated the web from August 1995 through March 1996 - and it is also OSS/FS.

   Netcraft’s June 2004 survey polled all the web sites they could find (totaling 51,635,284 sites), and found that of all the sites they could find, counting by name, Apache had 67.22% of the market, Microsoft had 21.35%, Sun had 3.21%, and Zeus had 1.48%.

   However, many web sites have been created that are simply “placeholder” sites (i.e., their domain names have been reserved but they are not being used); such sites are termed “inactive.” Thus, since 2000, Netcraft has been separately counting “active” web sites. Netcraft’s count of only the active sites is a more relevant figure than counting all web sites, since the count of active sites shows the web server selected by those who choose to actually develop a web site. Apache does extremely well when counting active sites; in June 2004, Apache had 68.71% of the web server market, Microsoft had 23.08%, Zeus had 1.1%, and Sun had 0.77%. Here is the total market share (by number of active web sites):

Market Share for Active Web Servers, June 2000 - June 2004



Netcraft's September 2002 survey reported on websites based on their "IP address" instead of the host name; this has the effect of removing computers used to serve multiple sites and sites with multiple names. When counting by IP address, Apache has shown a slow increase from 51% at the start of 2001 to 54%, while Microsoft has been unchanged at 35%. Again, a clear majority.

CNet's "Apache zooms away from Microsoft's Web server" summed up the year 2003 noting that "Apache grew far more rapidly in 2003 than its nearest rival, Microsoft's Internet Information Services (IIS), according to a new survey--meaning that the open-source software remains by far the most widely used Web server on the Internet."

Apache's dominance in the web server market has been independently confirmed by Security Space - their report on web server market share published June 1, 2004 surveyed 14,820,541 web servers in May 2004 and found that Apache was #1 (70.99%%), with Microsoft IIS being #2 (22.12%%). E-soft also reports specifically on secure servers (web servers supporting SSL/TLS, such as e-commerce sites); while much closer, Apache still leads with 49.15% market share, as compared to Microsoft's 41.83%, Netscape/iPlanet's 2.58%, and Stronghold's 0.76%. Since Stronghold is a repackaging of Apache, Apache's real market share is at least 49.91%.

Obviously these figures fluctuate monthly; see Netcraft and E-soft for the latest survey figures.

2. **GNU/Linux is the #2 web serving OS on the public Internet (counting by physical machine), according to a study by Netcraft surveying March and June 2001.** Some of Netcraft's surveys have also included data on OSes; two 2001 surveys (their June 2001 and September 2001 surveys) found that GNU/Linux is the #2 OS for web servers when counting physical machines (and has been consistently gaining market share since February 1999). As Netcraft themselves point out, the usual Netcraft web server survey (discussed above) counts web server hostnames rather than physical computers, and so it doesn't measure such things as the installed

hardware base. Companies can run several thousand web sites on one computer, and most of the world’s web sites are located at hosting and co-location companies.

Therefore, Netcraft developed a technique that indicates the number of actual computers being used as Web servers, together with the OS and web server software used (by arranging many IP addresses to reply to Netcraft simultaneously and then analyzing the responses). This is a statistical approach, so many visits to the site are used over a month to build up sufficient certainty. In some cases, the OS detected is that of a “front” device rather than the web server actually performing the task. Still, Netcraft believes that the error margins world-wide are well within the order of plus or minus 10%, and this is in any case the best available data.

Before presenting the data, it’s important to explain Netcraft’s system for dating the data. Netcraft dates their information based on the web server surveys (not the publication date), and they only report OS summaries from an earlier month. Thus, the survey dated “June 2001” was published in July and covers OS survey results of March 2001, while the survey dated “September 2001” was published in October and covers the operating system survey results of June 2001.

Here’s a summary of Netcraft’s study results:

OS group	**Percentage (March)**	**Percentage (June)**	**Composition**
Windows	49.2%	49.6%	Windows 2000, NT4, NT3, Windows 95, Windows 98
[GNU/]Linux	28.5%	29.6%	[GNU/]Linux
Solaris	7.6%	7.1%	Solaris 2, Solaris 7, Solaris 8
BSD	6.3%	6.1%	BSDI BSD/OS, FreeBSD, NetBSD, OpenBSD
Other Unix	2.4%	2.2%	AIX, Compaq Tru64, HP-UX, IRIX, SCO Unix, SunOS 4 and others
Other non-Unix	2.5%	2.4%	MacOS, NetWare, proprietary IBM OSs
Unknown	3.6%	3.0%	not identified by Netcraft OS detector

Much depends on what you want to measure. Several of the BSDs (FreeBSD, NetBSD, and OpenBSD) are OSS/FS as well; so at least a part of the 6.1% for BSD should be added to GNU/Linux’s 29.6% to determine the percentage of OSS/FS OSes being used as web servers. Thus, it’s likely that approximately one-third of web serving computers use OSS/FS OSes. There are also regional differences, for example, GNU/Linux leads Windows in Germany, Hungary, the Czech Republic, and Poland.

Well-known web sites using OSS/FS include Google (GNU/Linux) and Yahoo (FreeBSD).

If you really want to know about the web server market breakdown of “Unix vs. Windows,” you can find that also in this study. All of the various Windows OSes are rolled into a single number (even Windows 95/98 and Windows 2000/NT4/NT3 are merged, although they are fundamentally very different systems). Merging all the Unix-like systems in a similar way produces a total of 44.8% for Unix-like systems (compared to Windows' 49.2%) in March 2001.

Note that these figures would probably be quite different if they were based on web addresses instead of physical computers; in such a case, the clear majority of web sites are hosted by Unix-like systems. As stated by Netcraft, "Although Apache running on various Unix systems runs more sites than Windows, Apache is heavily deployed at hosting companies and ISPs who strive to run as many sites as possible on one computer to save costs."

3. **GNU/Linux is the #1 server OS on the public Internet (counting by domain name), according to a 1999 survey of primarily European and educational sites.** The first study that I've found that examined GNU/Linux's market penetration is a survey by Zoebelein in April 1999. This survey found that, of the total number of servers deployed on the Internet in 1999 (running at least ftp, news, or http (WWW)) in a database of names they used, the #1 OS was GNU/Linux (at 28.5%), with others trailing. It's important to note that this survey, which is the first one that I've found to try to answer questions of market share, used existing databases of servers from the .edu (educational domain) and the RIPE database (which covers Europe , the Middle East, parts of Asia, and parts of Africa), so this isn't really a survey of "the whole Internet" (e.g., it omits ".com" and ".net"). This is a count by domain *name* (e.g., the text name you would type into a web browser for a location) instead of by physical computer, so what it's counting is different than the Netcraft June 2001 OS study. Also, this study counted servers providing ftp and news services (not just web servers).

   Here's how the various OSes fared in the study:

Operating System	Market Share	Composition
GNU/Linux	28.5%	GNU/Linux
Windows	24.4%	All Windows combined (including 95, 98, NT)
Sun	17.7%	Sun Solaris or SunOS
BSD	15.0%	BSD Family (FreeBSD, NetBSD, OpenBSD, BSDI, ...)
IRIX	5.3%	SGI IRIX

   A part of the BSD family is also OSS/FS, so the OSS/FS OS total is even higher; if over 2/3 of the BSDs are OSS/FS, then the total share of OSS/FS would be about 40%. Advocates of Unix-like systems will notice that the majority (around 66%) were running Unix-like systems, while only around 24% ran a Microsoft Windows variant.

4. **GNU/Linux was the #2 server OS sold in 1999, 2000, and 2001.** According to a June 2000 IDC survey of 1999 licenses, 24% of all servers (counting both Internet and intranet servers) installed in 1999 ran GNU/Linux. Windows NT came in first with 36%; all Unixes combined totaled 15%. Again, since some of the Unixes are OSS/FS systems (e.g., FreeBSD, OpenBSD, and NetBSD), the number of OSS/FS systems is actually larger than the GNU/Linux figures. Note that it all depends on what you want to count; 39% of all servers installed from this survey were Unix-like

(that's 24%+15%), so "Unix-like" servers were actually #1 in installed market share once you count GNU/Linux and Unix together.

IDC released a similar study on January 17, 2001 titled "Server Operating Environments: 2000 Year in Review". On the server, Windows accounted for 41% of new server OS sales in 2000, growing by 20% - but GNU/Linux accounted for 27% and grew even faster, by 24%. Other major Unixes had 13%.

IDC's 2002 report found that Linux held its own in 2001 at 25%. All of this is especially intriguing since GNU/Linux had 0.5% of the market in 1995, according to a Forbes quote of IDC. Data such as these (and the TCO data shown later) have inspired statements such as this one from IT-Director on November 12, 2001: "Linux on the desktop is still too early to call, but on the server it now looks to be unstoppable."

These measures do *not* measure all server systems installed that year; some Windows systems are not paid for (they're illegally pirated), and OSS/FS OSes such as GNU/Linux and the BSDs are often downloaded and installed on multiple systems (since it's legal and free to do so).

Note that a study published October 28, 2002 by the IT analyst company Butler Group concluded that on or before 2009, Linux and Microsoft's .Net will have fully penetrated the server OS market from file and print servers through to the mainframe.

5. **GNU/Linux and Windows systems (when Windows CE and XP are combined) are the leaders and essentially even in terms of developer use for future embedded projects, according to Evans Data Corporation (EDC).** Their Embedded Systems Developer Survey, fielded in July 2002, asked developers "For each of the following operating systems, please indicate whether you are targeting the OS on your current project or your next project." They collected data from 444 developers. Their results: 30.2% of embedded developers use or expect to use Linux, while 16.2% say they will use Windows CE and another 14.4% say they will use Windows XP Embedded. If the two Windows systems are combined, this gives Windows Embedded operating systems a statistically insignificant edge over Embedded Linux (at 30.6% vs. 30.2%). However, Embedded Linux has nearly double the growth rate, and combining two different Windows systems into a single value is somewhat misleading. Wind River's VxWorks embedded OS, the current embedded software market leader, "trails slightly behind Embedded Linux for current project use, and VxWorks' modest gain of just 2.9% for expected use in future projects drops it to a distant third place position, ending up with less than half the usage rate of the two neck-and-neck future project usage leaders (Windows Embedded and Embedded Linux)."
6. **An Evans Data survey published in November 2001 found that 48.1% of international developers and 39.6% of North Americans plan to target most of their applications to GNU/Linux. In October 2002, they found that 59% of developers expect to write Linux applications in the next year.** The November 2001 edition of the *Evans Data International Developer Survey Series* reported on in-depth interviews with over 400 developers representing over 70 countries, and found that when asked which OS they plan to target with most of their applications next year, 48.1% of international developers and 39.6% of North Americans stated that they plan to target most of their applications to GNU/Linux. This is surprising since only a year earlier less than a third of the international development community was writing GNU/Linux applications. The survey also found that 37.8% of the international development community and 33.7% of North American developers have

already written applications for GNU/Linux, and that over half of those surveyed have enough confidence in GNU/Linux to use it for mission-critical applications.

Evans Data conducted a survey in October 2002. In this survey, they reported “Linux continues to expand its user base. 59% of survey respondents expect to write Linux applications in the next year.”

7. **An Evans Data survey made public in February 2004 found that 1.1 million developers in North America were working on OSS/FS projects**. Evans Data’s North American Developer Population Study examined the number of software developers using various approaches. It found that more than 1.1 million developers in North America were spending at least some of their time working on Open Source development projects. That’s an extraordinarily large number of people, and it doesn’t even account for developers in other countries. Many only develop part-time, but that many people can develop a lot of software, and having a large number of people increases the likelihood of helpful insights and innovations in various OSS/FS projects.
8. **A 2004 InformationWeek survey found that 67% of companies use OSS/FS products, with another 16% expecting to use it in 2005; only 17% have no near-term plans to support OSS/FS products.** The November 1, 2004 InformationWeek article Open-Source Software Use Joins The Mix by Helen D’Antoni reported the results from InformationWeek Research, which measured adoption of “open-source architecture” and found that adoption is widespread. The survey also found other interesting results: “In general, companies don’t view open-source software as risky. It often functions alongside [proprietary] and internally developed software, and because of this acceptance, open-source code is being used more broadly. Its use is evolving as companies look for cost-effective ways to manage software expenses.” Of those companies using OSS/FS, they found that 42% of companies implement production database operations using OSS/FS, with 33% more considering it; only 25% are not using or considering OSS/FS for production database use.
9. **A Japanese survey found widespread use and support for GNU/Linux; overall use of GNU/Linux jumped from 35.5% in 2001 to 64.3% in 2002 of Japanese corporations, and GNU/Linux was the most popular platform for small projects.** The book Linux White Paper 2003 (published by Impress Corporation) surveys the use of GNU/Linux in Japan (it is an update to an earlier book, “Linux White Paper 2001-2002”). This is written in Japanese; here is a brief summary of its contents.

   The survey has two parts, user and vendor. In “Part I : User enterprise”, they surveyed 729 enterprises that use servers. In “Part II : Vendor enterprise”, they surveyed 276 vendor enterprises who supply server computers, including system integrators, software developers, IT service suppliers, and hardware resellers. The most interesting results are those that discuss the use of Linux servers in user enterprises, the support of Linux servers by vendors, and Linux server adoption in system integration projects.

   First, the use of Linux servers in user enterprises:

System	2002	2001
Linux server	64.3%	35.5%
Windows 2000 Server	59.9%	37.0%
Windows NT Server	64.3%	74.2%
Commercial Unix server	37.7%	31.2%

And specifically, here's the average use in 2002:

System	Ave. units	# samples
Linux server	13.4	N=429 (5.3 in 2001)
Windows 2000 Server	24.6	N=380
Windows NT Server	4.5	N=413
Commercial Unix server	6.9	N=233

Linux servers are the fastest growing category from last year. The average units of server per enterprise increased by 2.5-fold from 5.3 units to 13.4 units.

Second, note the support of GNU/Linux servers by vendors:

System	Year 2002 Support
Windows NT/2000 Server	66.7%
Linux server	49.3%
Commercial Unix server	38.0%

This is the rate of vendors that develop or sale products supporting Linux server; note that Linux is already a major OS when compared with its competitors. The reasons for supporting Linux server were also surveyed, which turn out to be different than the reasons in some other counties (for a contrast, see the European FLOSS report):

Increase of importance in the future	44.1%
Requirement from their customers	41.2%
Major OS in their market	38.2%
Free of licence fee	37.5%
Most reasonable OS for their purpose	36.0%
Open source	34.6%
High reliability	27.2%

Third, note the rate of Linux server adoption in system integration projects:

Project Size (Million Yen)	Linux		Win2000	Unix
	2002	2001	2002	2002
0-3	62.7%	65.7%	53.8%	15.4%
3-10	51.5%	53.7%	56.3%	37.1%
10-50	38.3%	48.9%	55.8%	55.8%
50-100	39.0%	20.0%	45.8%	74.6%
100+	24.4%	9.1%	51.1%	80.0%

Where 1 Million Yen = $8,000 US. GNU/Linux servers are No.1 (62.5%) in small projects less than 3,000,000 Yen ($24,000 US), and GNU/Linux has grown in larger projects more than 50,000,000 Yen ($400,000 US) from 20.0% to 39.0%. In projects over 100,000,000 Yen ($800,000 US), Linux is adopted by 24.4% of the projects

(mainly as a substitute for proprietary Unix systems). Note that many projects (especially large ones) use multiple platforms simultaneously, so the values need not total 100%.

Note that the Japanese Linux white paper 2003 found that 49.3% of IT solution vendors support Linux in Japan.

10. **The European FLOSS study found significant use of OSS/FS.** The large report Free/Libre and Open Source Software (FLOSS): Survey and Study, published in June 2002, examined many issues including the use of OSS/FS. This study found significant variance in the use of OSS/FS; 43.7% of German establishments reported using OSS/FS, 31.5% of British establishments reported using OSS/FS, while only 17.7% of Swedish establishments reported using OSS/FS. In addition, they found that OSS usage rates of larger establishments were larger than smaller establishments, and that OSS usage rates in the public sector were above average.
11. **Microsoft sponsored its own research to "prove" that GNU/Linux is not as widely used, but this research has been shown to be seriously flawed.** Microsoft sponsored a Gartner Dataquest report claiming only 8.6% of servers shipped in the U.S. during the third quarter of 2000 were Linux-based. However, it's worth noting that Microsoft (as the research sponsor) has every incentive to create low numbers, and these numbers are quite different from IDC's research in the same subject. IDC's Kusnetzky commented that the likely explanation is that Gartner used a very narrow definition of "shipped"; he thought the number was "quite reasonable" if it only surveyed new servers with Linux, "But our research is that this is not how most users get their Linux. We found that just 10 to 15 percent of Linux adoption comes from pre-installed machines... for every paid copy of Linux, there is a free copy that can be replicated 15 times." Note that it's quite difficult to buy a new x86 computer without a Microsoft OS (Microsoft's contracts with computer makers ensure this), but that doesn't mean that these OSes are used. Gartner claimed that it used interviews to counter this problem, but its final research results (when compared to known facts) suggest that Gartner did not really counter this effect. For example, Gartner states that Linux shipments in the supercomputer field were zero. In fact, Linux is widely used on commodity parallel clusters at many scientific sites, including many high-profile sites. Many of these systems were assembled in-house, showing that Gartner's method of defining a "shipment" does not appear to correlate to working installations. The Register's article, "No one's using Linux" (with its companion article "90% Windows..") discusses this further. In short, Microsoft-sponsored research has reported low numbers, but these numbers are quite suspect.
12. **Businesses plan to increase their use of GNU/Linux**. A Zona Research study found that over half of the large enterprise respondents expected increases of up to 25% in the number of GNU/Linux users in their firm, while nearly 20% expected increases of over 50%. In small companies, over one third felt that GNU/Linux usage would expand by 50%. The most important factors identified that drove these decisions were reliability, lower price, speed of applications, and scalability. Here are the numbers:

Expected GNU/Linux Use	Small Business	Midsize Business	Large Business	Total
50% increase	21.0%	16%	19.0%	19%
10-25% increase	30.5%	42%	56.5%	44%
No growth	45.5%	42%	24.5%	36%
Reduction	3.0%	0%	0%	1%

13. You can see more about this study in “The New Religion: Linux and Open Source” (ZDNet) and in InfoWorld’s February 5, 2001 article “Linux lights up enterprise: But concerns loom about OS vendor profitability.”
14. **The global top 1000 Internet Service Providers expect GNU/Linux use to increase by 154%, according to Idaya’s survey conducted January through March 2001.** A survey conducted by Idaya of the global top 1000 ISPs found that they expected GNU/Linux to grow a further 154% in 2001. Also, almost two thirds (64%) of ISPs consider the leading open source software meets the standard required for enterprise level applications, comparable with proprietary software. Idaya produces OSS/FS software, so keep that in mind as a potential bias.
15. **A 2002 European survey found that 49% of CIOs in financial services, retail, and the public sector expect to be using OSS/FS**. OpenForum Europe published in February 2002 a survey titled Market Opportunity Analysis For Open Source Software. Over three months CIOs and financial directors in financial services, retail and public sector were interviewed for this survey. In this survey, 37% of the CIOs stated that they were already using OSS/FS, and 49% expected to be using OSS/FS in the future. It is quite likely that even more companies are using OSS/FS but their CIOs are not aware of it. Perceived benefits cited included decreased costs in general (54%), lower software license cost (24%), better control over development (22%), and improved security (22%).
16. **IBM found a 30% growth in the number of enterprise-level applications for GNU/Linux in the six month period ending June 2001.** At one time, it was common to claim that “Not enough applications run under GNU/Linux” for enterprise-level use. However, IBM found there are over 2,300 GNU/Linux applications (an increase in 30% over 6 months) available from IBM and the industry’s top independent software vendors (ISVs). A Special report by Network Computing on Linux for the Enterprise discusses some of the strengths and weaknesses of GNU/Linux, and found many positive things to say about GNU/Linux for enterprise-class applications.
17. **Morgan Stanley found significant and growing use of GNU/Linux.** They surveyed 225 CIOs on August 2002, and among the respondents, 29% said they owned GNU/Linux servers, 8% did not but are formally considering buying them, and 17% of the CIOs said they neither owned nor were formally considering GNU/Linux servers but that they were informally considering them. The remainder (slightly less than half, or 46%) noted they didn’t own and weren’t considering GNU/Linux. For those that have recently purchased new GNU/Linux servers, 31% were adding capacity, 31% were replacing Windows systems, 24% were replacing Unix and 14% were replacing other OSes. It’s easier to transition to GNU/Linux from Unix than from Windows, so it’s intriguing that Windows was being replaced more often than Unix. CNet news commented on this study with additional commentary about open source vs. Microsoft.
18. **Revenue from sales of GNU/Linux-based server systems increased 90% in the fourth quarter of 2002 compared to the fourth quarter of 2001**. This 90% increase compared sharply with the 5% increase of server market revenue overall. This data was determined by Gartner Dataquest, and reported in C|Net.

    Sales of GNU/Linux servers increased 63% from 2001 to 2002. This is an increase from $1.3 billion to $2 billion, according to Gartner.

19. **A 2001 survey found that 46.6% of IT professionals were confident that their organizations could support GNU/Linux, a figure larger than any OS except Windows.** A TechRepublic Research survey titled *Benchmarks, Trends, and Forecasts: Linux Report* found that “support for Linux runs surprisingly deep” when it surveyed IT professionals and asked them how confidently their organizations

could support various OSes. Given Windows' market dominance on the desktop, it's not surprising that most were confident that their organizations could support various versions of Windows (for Windows NT the figure was 90.6%; for Windows 2000, 81.6%). However, GNU/Linux came in third, at 46.4%; about half of those surveyed responded that their organizations were already confident in their ability to support GNU/Linux! This is especially shocking because GNU/Linux beat other well-known products with longer histories including Unix (42.1%), Novell Netware (39.5%), Sun Solaris (25.7%), and Apple (13.6%). TechRepublic suggested that there are several possible reasons for this surprisingly large result:

- GNU/Linux is considered to be a rising technology; many IT professionals are already studying it and learning how to use it, assuming that it will be a marketable skill in the near future.
- Many IT professionals already use GNU/Linux at home, giving GNU/Linux an entree into professional organizations.
- Since GNU/Linux is similar to Unix, IT professionals who are proficient in Unix can easily pick up GNU/Linux.

TechRepublic suggests that IT executives should inventory their staff's skill sets, because they may discover that their organization can already support GNU/Linux if they aren't currently using it.

20. **Sendmail, an OSS/FS program, is the leading email server.** A survey between 2001-09-27 and 2001-10-03 by D.J. Bernstein of one million random IP addresses successfully connected to 958 SMTP (email) servers (such servers are also called mail transport agents, or MTAs). Bernstein found that Unix Sendmail had the largest market share (42% of all email servers), followed by Windows Microsoft Exchange (18%), Unix qmail (17%), Windows Ipswitch IMail (6%), Unix smap (2%), UNIX Postfix (formerly VMailer, 2%) and Unix Exim (1%). Note that Bernstein implements one of Sendmail's competitors (qmail), so he has a disincentive to identify Sendmail's large market share. Qmail is not OSS/FS, because modified derivatives of Qmail cannot be freely redistributed (without express permission by the author). Qmail *is* "source viewable," so some people are confused into believing that Qmail is OSS/FS. However, Sendmail, Postfix, and Exim *are* all OSS/FS. Indeed, not only is the leading program (Sendmail) OSS/FS, but that OSS/FS program has more than twice the installations of its nearest competition.
21. **A survey in the second quarter of 2000 found that 95% of all reverse-lookup domain name servers (DNS) used bind, an OSS/FS product.** The Internet is built from many mostly-invisible infrastructure components. This includes domain name servers (DNSs), which take human-readable machine names (like "yahoo.com") and translate them into numeric addresses. Publicly accessible machines also generally support "reverse lookups", which convert the numbers back to names; for historical reasons, this is implemented using the hidden "in-addr.arpa" domain. By surveying the in-addr domain, you can gain insight into how the whole Internet is supported. Bill Manning has surveyed the in-addr domain and found that 95% of all name servers (in 2q2000) performing this important Internet infrastructure task are some version of "bind." This includes all of the DNS root servers, which are critical for keeping the Internet functioning. Bind is an OSS/FS program.
22. **A survey in May 2004 found that over 75% of all DNS domains are serviced by an OSS/FS program.** Don Moore's DNS Server Survey completed May 23, 2004 surved DNS servers. He found that BIND (an OSS/FS program) serviced 70.105% of all domains, followed by TinyDNS (15.571%), Microsoft DNS Server (6.237%), MyDNS (2.792%), PowerDNS (1.964%), SimpleDNS Plus (1.25%), unknown (1.138%), and the Pliant DNS Server (0.277%), with many others trailing. Since BIND, MyDNS, PowerDNS, and Pliant are all OSS/FS, OSS/FS programs service

75.138% of all DNS domains. The figures are different if you count per-installation instead of per-domain, but OSS/FS still dominates. Counting per-platform, we have BIND (72.598%), Microsoft (21.711%), TinyDNS (2.587%), unknown (1.041%), Simple DNS Plus (0.922%), MyDNS (0.314%), PowerDNS (0.26%). Totalling BIND, MyDNS, and PowerDNS produces the trivially smaller figure of 73.172% supported by DNS. This difference in figures shows that about 3 out of 4 organizations choose the OSS/FS BIND when installing a DNS server, and the 1 in 4 who don't and then choose Microsoft tend to be those supporting fewer domains (otherwise the Microsoft count of domains would be larger). In any case, given the critical nature of DNS to the Internet, it's clear that OSS/FS is a critical part of it.

23. **PHP is the web's #1 Server-side Scripting Language.** PHP, a recursive acronym for "Hypertext Preprocessor", is an open source server-side scripting language designed for creating dynamic Web pages (e.g., such as e-commerce). As noted in a June 3, 2002 article, PHP recently surpassed Microsoft's ASP to become the most popular server-side Web scripting technology on the Internet, and was used by over 24% of the sites on the Internet. Of the 37.6 million web sites surveyed worldwide, PHP is running on over 9 million sites, and over the past two years PHP has averaged a 6.5% monthly growth rate.
24. **OpenSSH is the Internet's #1 implementation of the SSH security protocol.** The Secure Shell (SSH) protocol is widely used to securely connect to computers and control them remotely (using either a text or X-Windows graphical interface). On April 2002, a survey of 2.4 million Internet addresses found that OpenSSH, an OSS/FS implementation of SSH, was the #1 implementation, with 66.8% of the market; the proprietary "SSH" had 28.1%, Cisco had 0.4%, and others totaled 4.7%. You can see general information about the survey, or the specific SSH statistics for April 2002. It's also interesting to note that OpenSSH had less than 5% of the market in the third quarter of 2000, but its use steadily grew. By the fourth quarter of 2001, over half of all users of the SSH protocol were using OpenSSH, and its market share has continued to grow since.
25. **CMP TSG/Insight found that 41% of application development tools were OSS/FS, and VARBusiness found 20% of all companies using GNU/Linux.** VARBusiness reported in September 2003 on "The Rise of Linux". In the article, it reports a finding of CMP TSG/Insight: 41% of application development tools in use were OSS/FS, second only to Microsoft (76%) and leading Oracle (35%), IBM (26%), Sun (21%), and Borland (18%). They also reported their own finding that 20% of all companies they surveyed were GNU/Linux, presumably less than that of Microsoft, but twice that of Netware and Unix. Indeed, they note that GNU/Linux has transformed "from a curiosity to a core competency."
26. **A set of 2003 Gartner studies notes that the TCO of Linux (or OSS/FS) on the Desktop depends on your situation.** Gartner reported that that enterprises that installed Linux on client desktops would save $80 in hardware acquisition costs and an average of $74 per user per year on office automation software (assuming that StarOffice will be purchased instead of Microsoft Office). However, they also note that "lost productivity stemming from learning curves and compatibility can eat up direct-cost savings when moving to Linux on the desktop." A key issue is that many organizations have built or bought specialized applications that only run on Windows. Note that these studies primarily examine Linux vs. Windows on the client desktop, not other OSS/FS deployment options (such as moving to web-based applications using OSS/FS tools that work with any client operating system, or using OSS/FS applications on Windows). Gartner concludes that both Windows and GNU/Linux can have a lower TCO, depending on your circumstance, and that "before migrating your desktop computers to Linux, take inventory of your business applications and compare Linux to Windows in terms of total cost of ownership."
27. **MySQL's market share is growing faster than Windows'.** An Evans Data survey released in January 2004 found that the use of OSS/FS database MySQL grew 30%

over the year, vs. 6% for Microsoft's SQL Server and Access databases, according to a survey of 550 developers. Microsoft still has a far greater total market share in the database development market, but Evans Data reported that OSS/FS's "price and its ability to integrate with other software mesh well with the priorities of application developers" and that "Concerns over stability, expense and how well a database plays with others are leading a quickly growing number of...companies to seriously consider and implement an open source database solution." Evans Data noted that "We expect this trend to continue as the open source offerings are continually improved upon."

28. **Internet Explorer is losing marketshare to OSS/FS web browsers**. Due to repeated security problems, in July 2004, Internet Explorer began to measurably lost market share. According to PC World, IE lost 1% of its market share in a single month. In the same time period Mozilla-based browser use increased by 26% (when compared to its previous share). IE was still far more widely used according to this July 2004 poll (94.73%), but IE hadn't lost market share in a long time, and it takes a significant event for that many people to change browsers.

    Later studies suggest that IE is continuing to lose significant market share, especially among leading-edge indicators such as the technically savvy and web developers. CNN found that among its CNET News.com readers, site visitors with OSS/FS browsers jumped up from 8% in January 2004 to 18% by September 2004. Statistics for Engadget.com, which has a technical audience, found that as of September 2004, only 57% used a MS browser and Firefox rapidly rose to 18%; w3schools (which explains web development) found a dramatic shift from July 2003 to September 2004 (more stats here), with IE dropping from 87.2% to 74.8% while Gecko-based browsers (including Netscape 7, Mozilla, and Firefox) rose from 7.2% to 19%. Chuck Upsdell has combined many data sources and estimates that, as of September 2004, IE has decreased from 94% to 84%, as users switch to other browser families (mainly Gecko), and that this downward trend likely to continue. Pundits such as PC Magazine's John C. Dvorak reported even more dramatic slides, with IE dropping to 50% share. By November 1, 2004, Ziff Davis revealed that IE had lost nearly another percent of the market in only 7 weeks. All of this is in spite of the some non-IE browsers will lie and use the same identification string as Internet Explorer, even though they aren't. Thus, these studies may be understating the actual share of non-IE browsers. And all of this is before the November 9, 2004 official initial release of the OSS/FS web browser Firefox. Grassroots efforts of the Spread Firefox marketing group and others seem to have been very effective at convincing people to try out Firefox.

Perhaps the simplest argument that GNU/Linux will have a significant market share is that Sun is modifying its Solaris product to run GNU/Linux applications, and IBM has already announced that GNU/Linux will be the successor of IBM's own AIX.

3. Reliability

There are a lot of anecdotal stories that OSS/FS is more reliable, but finally there is quantitative data confirming that mature OSS/FS programs are often more reliable:

1. **Equivalent OSS/FS applications are more reliable, according to the Fuzz study.** The paper "Fuzz Revisited" paper measured reliability by feeding programs random characters and determining which ones resisted crashing and freeze-ups. This approach is unlikely to find subtle failures, yet the study authors found that their approach still manages to find many errors in production software and is a useful tool

for finding software flaws. What's more, this approach is extremely fair and can broadly applied to any program, making it possible to compare different programs fairly.

OSS/FS had higher reliability by this measure. It states in section 2.3.1 that:

It is also interesting to compare results of testing the commercial systems to the results from testing "freeware" GNU and Linux. The seven commercial systems in the 1995 study have an average failure rate of 23%, while Linux has a failure rate of 9% and the GNU utilities have a failure rate of only 6%. It is reasonable to ask why a globally scattered group of programmers, with no formal testing support or software engineering standards can produce code that is more reliable (at least, by our measure) than commercially produced code. Even if you consider only the utilities that were available from GNU or Linux, the failure rates for these two systems are better than the other systems.

There is evidence that Windows applications have similar reliability to the proprietary Unix software (e.g., less reliable than the OSS/FS software). A later paper, "An Empirical Study of the Robustness of Windows NT Applications Using Random Testing", found that with Windows NT GUI applications, they could crash 21% of the applications they tested, hang an additional 24% of the applications, and could crash or hang *all* the tested applications when subjecting them to random Win32 messages. Thus, there's no evidence that proprietary Windows software is more reliable than OSS/FS by this measure. Yes, Windows has progressed since that time - but so have the OSS/FS programs.

Although this experiment was done in 1995, nothing that's happened since suggests that proprietary software has become much better than OSS/FS programs since then. Indeed, since 1995 there's been an increased interest and participation in OSS/FS, resulting in far more "eyeballs" examining and improving the reliability of OSS/FS programs.

The fuzz paper's authors found that proprietary software vendors generally didn't fix the problems identified in an earlier version of their paper, and found that concerning. In contrast, Scott Maxwell led an effort to remove every flaw identified in the OSS/FS software in the 1995 fuzz paper, and eventually fixed every flaw. Thus, the OSS/FS community's response shows why, at least in part, OSS/FS programs have such an edge in reliability; if problems are found, they're often fixed. Even more intriguingly, the person who spearheaded ensuring that these problems were fixed wasn't an original developer of the programs - a situation only possible with OSS/FS.

Now be careful: OSS/FS is not magic pixie dust; beta software of any kind is still buggy! However, the 1995 experiment measured mature OSS/FS to mature proprietary software, and the OSS/FS software was more reliable under this measure.

2. **IBM studies found GNU/Linux highly reliable.** IBM ran a series of extremely stressful tests for 30 and 60 days, and found that the Linux kernel and other core OS components -- including libraries, device drivers, file systems, networking, IPC, and memory management -- operated consistently and completed all the expected durations of runs with zero critical system failures. Linux system performance was not degraded during the long duration of the run, the Linux kernel properly scaled to use hardware resources (CPU, memory, disk) on SMP systems, the Linux system handled continuous full CPU load (over 99%) and high memory stress well, and the Linux system handled overloaded circumstances correctly. IBM declared that these

tests demonstrate that “the Linux kernel and other core OS components are reliable and stable ... and can provide a robust, enterprise-level environment for customers over long periods of time.”

3. **GNU/Linux is more reliable than Windows NT, according to a 10-month ZDnet experiment.** ZDnet ran a 10-month test for reliability to compare Caldera Systems OpenLinux, Red Hat Linux, and Microsoft’s Windows NT Server 4.0 with Service Pack 3. All three used identical (single-CPU) hardware, and network requests were sent to each server in parallel for standard Internet, file, and print services. The result: NT crashed an average of once every six weeks, each taking about 30 minutes to fix; that’s not bad, but neither GNU/Linux server *ever* went down. This ZDnet article also does a good job of identifying GNU/Linux weaknesses (e.g., desktop applications and massive SMP). Hopefully Windows has made improvements since this study - but the OSS/FS have certainly made improvements as well.
4. **GNU/Linux is more reliable than Windows NT, according to a one-year Bloor Research experiment.** Bloor Research had both OSes running on relatively old Pentium machines. During the one year test, GNU/Linux crashed once due to a hardware fault (disk problems), which took 4 hours to fix, giving it a measured availability of 99.95 percent. Windows NT crashed 68 times, caused by hardware problems (disk), memory (26 times), file management (8 times), and various odd problems (33 times). All this took 65 hours to fix, giving an availability of 99.26 percent. It’s intriguing that the only GNU/Linux problem and many of the Windows problems were hardware-related; it could be argued that the Windows hardware was worse, or it could be argued that GNU/Linux did a better job of avoiding and containing hardware failures. The file management failure is due to Windows, and the odd problems appear due to Windows too, indicating that GNU/Linux is far more reliable than Windows. GNet summarized this as saying “the winner here is clearly Linux.”
5. **A study by Reasoning found that the Linux kernel’s implementation of the TCP/IP Internet protocol stack had fewer defects than the equivalent stacks of several proprietary general-purpose operating systems, and equalled the best of the embedded operating systems.** As noted in their press release and C|Net, Reasoning’s study compared six implementations of TCP/IP, the fundamental protocols underlying the Internet. Besides the Linux kernel, three of the implementations were part of commercial general-purpose operating systems, and two were embedded in commercial telecommunications equipment. The Linux kernel primarily used as the kernel of a general-purpose operating system; it would be reasonable to expect that the embedded operating systems would have better reliability because of the need for reliability in that market. The study was not commissioned by any of the GNU/Linux vendors or companies who might be competing with GNU/Linux, and thus should be free of bias.

   The company used automated tools to look five kinds of defects in code: Memory leaks, null pointer dereferences, bad deallocations, out of bounds array access and uninitialized variables. Reasoning found 8 defects in 81,852 lines of Linux kernel source lines of code (SLOC), resulting in a defect density rate of 0.1 defects per KSLOC. In contrast, the three proprietary general-purpose operating systems (two of them versions of Unix) had between 0.6 and 0.7 defects/KSLOC; thus the Linux kernel had a smaller defect rate than all the competing general-purpose operating systems examined. The rates of the two embedded operating systems were 0.1 and 0.3 defects/KSLOC, thus, the Linux kernel had an defect rate better than one embedded operating system, and equivalent to another.

   One issue is that the tool detects issues that may not be true problems. For example, of those 8 defects, one was clearly a bug and had been separately detected and fixed by the developers, and 4 defects clearly had no effect on the running code. None of the defects found were security flaws. To counter this, they also tracked which problems were repaired by the developers of the various products. The Linux kernel did quite well by this measure as well: the Linux kernel had 1 repaired defect out of 81.9 KSLOC, while the proprietary implementations had 235 repaired defects out of 568 KSLOC. This means the Linux kernel had a repair defect rate of 0.013 defects/KSLOC, while the proprietary implementations had a repair defect rate of 0.41 defects/KSLOC.

CEO Scott Trappe explained this result by noting that the open source model encourages several behaviors that are uncommon in the development of commercial code. First, many users don't just report bugs, as they would do with [proprietary] software, but actually track them down to their root causes and fix them. Second, many developers are reviewing each other's code, if only because it is important to understand code before it can be changed or extended. It has long been known that peer review is the most effective way to find defects. Third, the open source model seems to encourage a meritocracy, in which programmers organize themselves around a project based on their contributions. The most effective programmers write the most crucial code, review the contributions of others, and decide which of these contributions make it into the next release. Fourth, open source projects don't face the same type of resource and time pressures that [proprietary] projects do. Open source projects are rarely developed against a fixed timeline, affording more opportunity for peer review and extensive beta testing before release.

This certainly doesn't prove that OSS/FS will always be the highest quality, but it clearly shows that OSS/FS can be of high quality.

6. **A similar study by Reasoning found that the MySQL database (a leading OSS/FS database) had fewer defects than a set of 200 proprietary programs used for comparison.** In a similar manner to the previous study, on December 15, 2003, Reasoning announced its analysis results comparing MySQL with various proprietary programs. MySQL had found 21 software defects in 236,000 source lines of code (SLOC), producing a defect density of 0.09 defects/KSLOC. Using a set of 200 recent proprietary projects (totalling 35 million SLOC), the same tools found a defect rate of 0.57 defects/KSLOC -- over six times the error rate. Again, not all defects are found by their tool, and this certainly doesn't prove that OSS/FS will always be the highest quality, but it clearly shows that OSS/FS can be of high quality.
7. **Sites using Microsoft's IIS web serving software have over double the time offline (on average) than sites using the Apache software, according to a 3-month Swiss evaluation.** These are the results of Syscontrol AG's analysis of website uptime (announced February 7, 2000) They measured over 100 popular Swiss web sites over a three-month period, checking from 4 different locations every 5 minutes (it'd be interesting to see what a larger sample would find!). You can see their report (in German), or a Babelfish (machine) translation of the report. Here's their set of published data on "average down-time (in hours in that month) for each type of server", plus a 3-month average that I've computed:

Downtime	Apache	Microsoft	Netscape	Other
September	5.21	10.41	3.85	8.72
October	2.66	8.39	2.80	12.05
November	1.83	14.28	3.39	6.85
Average	3.23	11.03	3.35	9.21

8. It’s hard not to notice that Apache (the OSS web server) had the best results over the three-month average (and with better results over time, too). Indeed, Apache’s worst month was better than Microsoft’s best month. The difference between Netscape and Apache is statistically insignificant - but this still shows that the freely-available OSS/FS solution (Apache) has a reliability at least as good as the most reliable proprietary solution.
9. The report does state that this might not be solely the fault of the software’s quality, and in particular it noted that several Microsoft IIS sites had short interruptions at the same time each day (suggesting regular restarts). However, this still begs the question - why did the IIS sites require so many regular restarts compared to the Apache sites? Every outage, even if preplanned, results in a service loss (and for e-commerce sites, a potential loss of sales). Presumably, IIS site owners who perform periodic restarts do so because they believe that doing so will improve their IIS systems’ overall reliability. Thus, even with pre-emptive efforts to keep the IIS systems reliable, the IIS systems are less reliable than the Apache-based systems which simply do not appear to require constant restarting.
10. **80% of the top ten most reliable hosting providers ran OSS/FS, according to Netcraft’s May 2004 survey** Netcraft’s May 2004 survey of the top ten most reliable hosting providers found 4 running GNU/Linux, 4 running FreeBSD, and only 2 running Microsoft Windows.
11. **OSS/FS did very well in a separate uptime study by Netcraft; as of August 3, 2001, of the 50 sites with the highest uptimes, 92% use Apache and 50% run on OSS/FS OSes.** Netcraft keeps a track of the 50 often-requested sites with the longest uptimes at http://uptime.netcraft.com. Looking at the August 3, 2001 uptime report, I found that 92% (46/50) of the sites use Apache; one site’s web server was unknown, and three others were not Apache. Of those three, only one reported to be Microsoft IIS, and that one instance is suspicious because its reported OS is BSD/OS (this apparent inconsistency can be explained in many ways, e.g., perhaps there is a front-end BSD/OS system that “masks” the IIS web site, or perhaps the web server is lying about its type to confuse attackers). In this snapshot, 50% (25/50) ran on an OSS/FS OS, and only Unix-like OSes had these large uptimes (no Windows systems were reported as having the best uptimes).

   As with all surveys, this one has weaknesses, as discussed in Netcraft’s Uptime FAQ. Their techniques for identifying web server and OSes can be fooled. Only systems for which Netcraft was sent many requests were included in the survey (so it’s not “every site in the world”). Any site that is requested through the “what’s that site running” query form at Netcraft.com is added to the set of sites that are routinely sampled; Netcraft doesn’t routinely monitor all 22 million sites it knows of for performance reasons. Many OSes don’t provide uptime information and thus can’t be included; this includes AIX, AS/400, Compaq Tru64, DG/UX, MacOS, NetWare, NT3/Windows 95, NT4/Windows 98, OS/2, OS/390, SCO UNIX, Sony NEWS-OS, SunOS 4, and VM. Thus, this uptime counter can only include systems running on BSD/OS, FreeBSD (but not the default configuration in versions 3 and later), recent versions of HP-UX, IRIX, GNU/Linux 2.1 kernel and later (except on Alpha processor based systems), MacOS X, recent versions of NetBSD/OpenBSD, Solaris 2.6 and later, and Windows 2000. Note that Windows NT systems cannot be included in this survey (because their uptimes couldn’t be counted). Windows 2000 systems’s data are included in the source source for this survey, but they have a different problem. Windows 2000 had little hope to be included in the August 2001 list, because the 50th system in the list had an uptime of 661 days, and Windows 2000 had only been launched about 17 months (about 510 days) earlier. Note that HP-UX, GNU/Linux (usually), Solaris and recent releases of FreeBSD cycle back to zero after 497 days, exactly as if the machine had been rebooted at that precise point. Thus it is not possible to see an HP-UX, GNU/Linux (usually), or Solaris system with an uptime measurement above 497 days, and in fact their uptimes can be misleading (they may be up for a long time, yet not show it). There is yet one other weakness: if a computer switches operating systems later, the long uptime is credited to the new OS. Still, this survey does compare Windows 2000, GNU/Linux (up to 497 days usually), FreeBSD, and several other OSes, and OSS/FS does quite well.

It could be argued that perhaps systems on the Internet that haven't been rebooted for such a long time might be insignificant, half-forgotten, systems. For example, it's possible that security patches aren't being regularly applied, so such long uptimes are not necessarily good things. However, a counter-argument is that Unix and Linux systems don't need to be rebooted as often for a security update, and this is a valuable attribute for a system to have. Even if you accepted that unproven claim, it's certainly true that there are half-forgotten Windows systems, too, and they didn't do so well. Also, only systems someone specifically asked for information about were included in the uptime survey, which would limit the number of insignificant or half-forgotten systems.

At the very least, Unix and Linux are able to quantitatively demonstrate longer uptimes than their Windows competitors can, so Unix and Linux have significantly better evidence of their reliability than Windows.

12. **An in-depth analysis (published in the Communications of the ACM) found good evidence that OSS/FS code quality appears to be at least equal and sometimes better than proprietary software.** The article "Open Source Software Development Should Strive for Even Greater Code Maintainability" by Ioannis Samoladas, Ioannis Stamelos, Lefteris Angelis, and Apostolos Oikonomou, was published by the highly-respected "Communications of the ACM" in October 2004 (pp. 83-87). They studied almost 6 million lines of code, tracking several programs over time, using the maintainability index (chosen by the Software Engineering Institute as the most suitable tool for measuring the maintainability of systems). Using their measurements, they concluded that OSS/FS "code quality appears to be at least equal and sometimes better than the quality of [closed source software] code implementing the same functionality." They conjectured that this "may be due to the motivation of skilled OSS programmers..." OSS/FS is no panacea; they also found that OSS/FS "code quality seems to suffer from the very same problems that have been observed in [closed source software] projects. Maintainability deterioration over time is a typical phenomenon... it is reasonable to expect similar beharior from the OSS projects as they age." But equal and sometimes better isn't a bad thing at all.
13. **A detailed study of two large programs (the Linux kernel and the Mozilla web browser) found evidence that OSS/FS development processes produce more modular designs.** Harvard Business School's "Exploring the Structure of Complex Software Designs: An Empirical Study of Open Source and Proprietary Code" by Alan MacCormack, John Rusnak, and Carliss Baldwin (Working Paper Number 05-016) reports research results that worked to see if OSS/FS programs tended to have better modularity than proprietary programs. It's generally accepted that there are important benefits to greater modularity, in particular, a more modular system tends to be more reliable and easier to change over time.

    They examined the Linux kernel (developed as an OSS/FS product), the original Mozilla web browser (developed as a proprietary product), and then the evolution of Mozilla after it became OSS/FS. They found "significant differences in their designs"; Linux possessed a more modular architecture than the original proprietary Mozilla, and the redesigned OSS/FS Mozilla had a more modular structure than both.

To measure design modularity, they used a technique called Design Structure Matrices (DSMs) that identified dependencies between different design elements (in this case, between files, where calling a function/method of another file creates a dependency). They used two different measures using DSMs, which produced agreeing results.

The first measure they computed is a simple one, called “change cost”. This measures the percentage of elements affected, on average, when a change is made to one element in the system. A smaller value is better, since as as this value gets larger, it’s becomes increasingly likely that a change made will impact a larger number of other components and have unintended consequences. This measure isn’t that sensitive to the size of a system (see their exhibit 7), though obviously as a program gets larger that percentage implies a larger number of components. When Mozilla was developed as a proprietary product, and initially released as OSS/FS, it had the large value of 17.35%. This means that if a given file is changed, on average, 17.35% of other files in system depend (directly or indirectly) on that file. After gaining some familiarity with the code, the OSS/FS developers decided to improve its design between 1998-10-08 and 1998-12-11. Once the redesign was complete, the change cost dramatically decreased down to 2.78%, as you can see:

Program	Change Cost
Mozilla-1998-04-08	17.35%
Mozilla-1998-10-08	18.00%
Mozilla-1998-12-11	2.78%
Mozilla-1999	3.80%
Linux-2.1.88	3.72%
Linux-2.1.105	5.16%

Change cost is a fairly crude measure, though; it doesn’t take into account the amount of dependency (measured, say, as the number of calls from one file to another), and it doesn’t take clustering into account (a good design should minimize the communication between clusters more than communication in general). Thus, they computed “coordination cost,” an estimated cost of communicating information between agents developing each cluster. This measure is strongly dependent on the size of the system - after all, it’s easier to coordinate smaller projects. Thus, to use this as a measure of the quality of a design compared to another project, the sizes must be similar (in this case, by the number of files). The numbers are unitless, but smaller costs are better. The researchers identified different circumstances with similar sizes, so that the numbers could be compared. The following table compares Mozilla 1998-04-08 (built almost entirely by proprietary means) and Mozilla 1998-12-11 (just after the redesign by OSS/FS developers) with Linux 2.1.105 (built by OSS/FS processes):

	Linux 2.1.105	Mozilla 1998-04-08	Mozilla 1998-12-11
Number of Source files	1678	1684	1508
Coordination Cost	20,918,992	30,537,703	10,234,903

> The paper computes numbers for several other cases, but yielding the same conclusion.
>
> It'd be easy to argue that kernels are fundamentally different than web browsers, but that can't be the right explanation. When Mozilla was released to the OSS/FS community, it was far worse by these measures, and the OSS/FS community actively and consciously worked to improve its modularity. The browser soon ended up with a significant and measurable improvement in modularity, better than the kernel's, without an obvious complete loss of functionality.
>
> It appears that at least part of the explanation is in the OSS/FS development environment. OSS/FS development is normally distributed worldwide, with little opportunity for face-to-fact communication, and with many people contributing only part-time. Thus, "this mode of organization was only possible given that the design structure, and specifically, the partitioning of design tasks, was loosely-coupled." In addition, the leadership of an OSS/FS project is incentivized to make architectural decisions that lead to modularity, since if they didn't, they wouldn't be able to attract enough co-developers: "Without such an architecture, there was little hope that other contributors could a) understand enough of the design to contribute in a meaningful way, and b) develop new features or fix existing defects without affecting many other parts of the design." Although not discussed in the paper, cultural norms may also be a factor; since the source code is reviewed by others, developers appear to actively disparage poor designs and praise highly modular designs.
>
> Again, this does not mean that OSS/FS programs are always more modular; but it does suggest that there is pressure to make modular programs in an OSS/FS project.

Damien Challet and Yann Le Du of the University of Oxford have written a paper titled *Closed source versus open source in a model of software bug dynamics*. In this paper they develop a model of software bug dynamics where users, programmers and maintainers interact through a given program. They then analyzed the model, and found that all other things being equal (such as number of users, programmers, and quality of programmers), "debugging in open source projects is always faster than in closed source projects."

Of course, there are many anecdotes about Windows reliability vs. Unix. For example, the Navy's "Smart Ship" program caused a complete failure of the USS Yorktown ship in September 1997. Whistle-blower Anthony DiGiorgio stated that Windows is "the source of the Yorktown's computer problems." Ron Redman, deputy technical director of the Fleet Introduction Division of the Aegis Program Executive Office, said "there have been numerous software failures associated with [Windows] NT aboard the Yorktown." Redman also said "Because of politics, some things are being forced on us that without political pressure we might not do, like Windows NT... If it were up to me I probably would not have used Windows NT in this particular application. If we used Unix, we would have a system that has less of a tendency to go down."

One problem with reliability measures is that it takes a long time to gather data on reliability in real-life circumstances. Thus, there's more data comparing older Windows editions to older GNU/Linux editions. The key is that these comparisons are fair, because they compare contemporaneous products. The available evidence suggests that OSS/FS has a significant edge in reliability, at least in many circumstances.

4. Performance

Comparing GNU/Linux and Microsoft Windows performance on equivalent hardware has a history of contentious claims and different results based on different assumptions. OSS/FS has at least shown that it's often competitive, and in many circumstances it beats the competition.

Performance benchmarks are very sensitive to the assumptions and environment, so the best benchmark is one you set up yourself to model your intended environment. Failing that, you should use unbiased measures, because it's so easy to create biased measures.

First, here are a few recent studies suggesting that some OSS/FS systems beat proprietary competitors in at least some circumstances:

1. **In 2002, TPC-C database measures found that a Linux based system was faster than a Windows 2000 based system.** More specifically, an HP ProLiant DL580 with 32 Intel Xeon 900MHz CPUs running Oracle 9i R2 Enterprise edition ran faster running on a stock Red Hat Linux Advanced Server than on Microsoft Windows 2000 Advanced Server. You can see the Linux and Windows reports; note that HP did not modify the Linux kernel to get these results.
2. **PC Magazine's November 2001 performance tests for file servers found that Linux with Samba significantly outperformed Windows 2000.** Their article Performance Tests: File Server Throughput and Response Times found that Linux with Samba significantly outperformed Windows 2000 Server when used as a file server for Microsoft's own network file protocols. This was true regardless of the number of simultaneous clients (they tested a range up to 30 clients), and it was true on the whole range on computers they used (Pentium II/233MHz with 128MiB RAM, Pentium III/550MHz with 256MiB RAM, and Pentium III/1GHz with 512MiB RAM, where MiB is 2^20 bytes). Indeed, as the machines became more capable the absolute difference grew more pronounced. On the fastest hardware while handling largest number of clients, GNU/Linux's throughput was about 130 MB/sec vs. Windows' 78 MB/sec (GNU/Linux was 78% faster).
3. **PC Magazine tested file server performance again in April 2002; Linux with Samba beat Windows 2000 again, but Samba then surpassed Windows 2000 by about 100% and can handle 4 times as many clients.** PC Magazine published another comparison of Samba and Windows (a summary is available electronically as "Samba runs rings around Win2000."). They noted that the later Samba software surpasses the performance of Windows 2000 by about 100 percent under benchmark tests, and found that Linux and Samba can handle four times as many client systems as Windows 2000 before performance begins to drop off. Jay White, IT manager at electronics firm BF Group, said that Samba is one of the most useful pieces of server software available for a mixed Windows and Linux environment. "Our Samba server has been online for 394 days so far. The total cost is the hardware plus 30 minutes of my time each year," he said. Mark Twells, IT coordinator at a large education facility, said, "We run six Samba servers on a variety of hardware [and] we have around 1,000 users."; this certainly excellent evidence of Samba's utility.
4. **In performance tests by Sys Admin magazine, GNU/Linux beat Solaris (on Intel), Windows 2000, and FreeBSD.** The article "Which OS is Fastest for High-Performance Network Applications?" in the July 2001 edition of *Sys Admin* magazine examined high-performance architectures and found that GNU/Linux beat its competition when compared with Solaris (on Intel), FreeBSD (an OSS/FS system), and Windows 2000. They intentionally ran the systems "out of the box" (untuned), except for increasing the number of simultaneous TCP/IP connections (which is necessary for testing multi-threaded and asynchronous applications). They used the latest versions of OSes and the exact same machine. They reported (by OS) the results of two different performance tests.

The FreeBSD developers complained about these tests, noting that FreeBSD by default emphasizes reliability (not speed) and that they expected anyone with a significant performance need would do some tuning first. Thus, Sys Admin's re-did the tests for FreeBSD after tuning FreeBSD. One change they made was switching to "asynchronous" mounting, which makes a system faster (though it increases the risk of data loss in a power failure) - this is the GNU/Linux default and easy to change in FreeBSD, so this was a very small and reasonable modification. However, they also made many other changes, for example, they found and compiled in 17 FreeBSD kernel patches and used various tuning commands. The other OSes weren't given the chance to "tune" like this, so comparing untuned OSes to a tuned FreeBSD isn't really fair.

In any case, here are their two performance tests:

1. Their "real-world" test measured how quickly large quantities of email could be sent using their email delivery server (MailEngine). Up to 100 simultaneous sends there was no difference, but as the number increased the systems began showing significant differences in their hourly email delivery speed. By 500 simultaneous sends GNU/Linux was clearly faster than all except FreeBSD-tuned, and GNU/Linux remained at the top. FreeBSD-tuned had similar performance to GNU/Linux when running 1000 or less simultaneous sends, but FreeBSD-tuned peaked around 1000-1500 simultaneous connections with a steady decline not suffered by GNU/Linux, and FreeBSD-tuned had trouble going beyond 3000 simultaneous connections. By 1500 simultaneous sends, GNU/Linux was sending 1.3 million emails/hour, while Solaris managed approximately 1 million, and Windows 2000 and FreeBSD-untuned were around 0.9 million.
2. Their "disk I/O test" created, wrote, and read back 10,000 identically-sized files in one directory, varying the size of the file instances. Here Solaris was the slowest, with FreeBSD-untuned the second-slowest. FreeBSD-tuned, Windows 2000, and GNU/Linux had similar speeds at the smaller file sizes (in some cases FreeBSD-tuned was faster, e.g., 8k and 16k file size), but when the file sizes got to 64k to 128k the OSes began to show significant performance differences; GNU/Linux was the fastest, then Windows 2000, then FreeBSD. At 128k, FreeBSD was 16% worse than Windows 2000, and 39% worse than GNU/Linux; all were faster than FreeBSD-untuned and Solaris. When totaling these times across file sizes, the results were GNU/Linux: 542 seconds, Windows 2000: 613 seconds, FreeBSD-tuned: 630 seconds, FreeBSD-untuned: 2398 seconds, and Solaris: 3990 seconds.

5. **GNU/Linux with TUX has produced better SPEC values than Windows/IIS in several cases, even when given inferior drive configurations.** One organization that tries to develop unbiased benchmarks is the SPEC Consortium, which develops and maintains a whole series of benchmarks. We can compare Microsoft Windows versus GNU/Linux by comparing SPECweb99 results (which measure web server performance) on identical hardware if both have undergone the same amount of performance optimization effort. Alas, things are not so simple; rarely are the same basic hardware platforms tested with both OSes, and even when that occurs, as of July 13, 2001 no exactly identical configurations have been tested (they differ in ways such as using a different number of hard drives, or including some faster hard drives). Using all results available by July 13, 2001, there were three hardware configurations, all from Dell, which ran both GNU/Linux (using the TUX web server/accelerator) and Windows (using IIS) on exactly the same underlying hardware. Here are the SPECweb99 results as of July 13, 2001 (larger is better), noting configuration differences:

System	Windows SPEC Result	Linux SPEC Result
Dell PowerEdge 4400/800, 2 800MHz Pentium III Xeon	1060 (IIS 5.0, 1 network controller)	2200 (TUX 1.0, 2 network controllers)
Dell PowerEdge 6400/700, 4 700MHz Pentium III Xeon	1598 (IIS 5.0, 7 9GB 10KRPM drives)	4200 (TUX 1.0, 5 9GB 10KRPM drives)
Dell PowerEdge 8450/700, 8 700MHz Pentium III Xeon	7300/NC (IIS 5.0, 1 9Gb 10KRPM and 8 16Gb 15KRPM drives) then 8001 (IIS 5.0, 7 9Gb 10KRPM and 1 18Gb 15KRPM drive)	7500 (TUX 2.0, 5 9Gb 10KRPM drives)

6. The first row (the PowerEdge 4400/800) doesn’t really prove anything. The IIS system has lower performance, but it only had one network controller and the TUX system has two - so while the TUX system had better performance, that could simply be because it had two network connections it could use.
7. The second entry (the PowerEdge 6400/700) certainly suggests that GNU/Linux plus TUX really is much better - the IIS system had two more disk drives available to it (which should increase performance), but the TUX system had over twice the IIS system’s performance.
8. The last entry for the PowerEdge 8450/700 is even more complex. First, the drives are different - the IIS systems had at least one drive that revolved more quickly than the TUX systems (which should give IIS higher performance overall, since the transfer speed is almost certainly higher). Also, there were more disk drives (which again should give IIS still higher performance). When I originally put this table together showing all data publicly available in April 2001 (covering the third quarter of 1999 through the first quarter of 2001), IIS 5.0 (on an 8-processor Dell PowerEdge 8450/700) had a SPECweb99 value of 7300. Since that time, Microsoft changed the availability of Microsoft SWC 3.0, and by SPECweb99 rules, this means that those test results are “not compliant” (NC). This is subtle; it’s not that the test itself was invalid, it’s that Microsoft changed what was available and used the SPEC Consortium’s own rules to invalidate a test (possibly because the test results were undesirable to Microsoft). A retest then occurred, with yet another disk drive configuration, at which point IIS produced a value of 8001. However, both of these figures are on clearly better hardware - and in one circumstance the better hardware didn’t do better.
9. Thus, in these configurations the GNU/Linux plus TUX system was given inferior hardware yet still sometimes won on performance. Since other factors may be involved, it’s hard to judge - there are pathological situations where “better hardware” can have worse performance, or there may be another factor not reported that had a more significant effect. Hopefully in the future there will be many head-to-head tests in a variety of identical configurations.
10. Note that TUX is intended to be used as a “web accelerator” for many circumstances, where it rapidly handles simple requests and then passes more complex queries to another server (usually Apache). I’ve quoted the TUX figures because they’re the recent performance figures I have available. As of this time I have no SPECweb99 figures or other recent performance measures for Apache on GNU/Linux, or for Apache and TUX together; I also don’t have TUX reliability figures. I expect that such measures will appear in the future.
11. **Low-level benchmarks by IBM found that GNU/Linux had better performance than Windows for pipes (an input/output mechanism), and also process and**

thread creation. Ed Bradford (manager of Microsoft Premier Support for IBM Software group) published in October 2001 the study *Pipes in Linux, Windows 2000, and Windows XP*. In this study he examined the the performance of pipes, a common low-level mechanism for communicating between program processes. He found the pipes in Red Hat 7.1 (with Linux kernel version 2.4.2) had a peak I/O rate of around 700 MB/sec, with a steady state at near 100 MB/sec for very large block sizes. In contrast, Windows 2000 peaked at 500 MB/sec, with a large block steady state of 80 MB/sec. Windows XP Professional (evaluation version) was especially disappointing; its peak I/O rate was only 120 MB/sec, with a stead state of 80 MB/sec, all on the same platform and all running a GUI.

In February 2002 he published *Managing processes and threads*, in which he compared the performance of Red Hat Linux 7.2, Windows 2000 Advanced Server (”Win2K”), and Windows XP Professional (”WinXP”), all on a Thinkpad 600X with 320MiB of memory. Linux managed to create over 10,000 threads/second, while Win2K didn’t quite manage 5,000 threads/second and WinXP only created 6,000 threads/second. In process creation, Linux managed 330 processes/second, while Win2K managed less than 200 processes/second and WinXP less than 160 processes/second.

12. **eWeek found in its tests that the OSS/FS program MySQL was quite comparable to the proprietary Oracle database program, and the pair outperformed other proprietary programs.** eWeek Labs/PC Labs compared several database packages and released the results on February 25, 2002. Comparable performance measures of database programs are actually quite rare. As they note, “database vendors routinely use no-benchmarking clauses in their license agreements to block publication of benchmarks of which they do not approve.” Indeed, to their knowledge, this is the first time a computer publication has published database benchmark results tested on the same hardware since PC Magazine did so in October 1993 (almost 9 years earlier). However, they took the risk and published the results examining five server databases: IBM’s DB2 7.2 with FixPack 5, Microsoft Corp.’s SQL Server 2000 Enterprise Edition with Service Pack 2, MySQL AB’s MySQL 4.0.1 Max, Oracle Corp.’s Oracle9i Enterprise Edition 9.0.1.1.1, and Sybase Inc.’s ASE (Adaptive Server Enterprise) 12.5.0.1. Their goal was to create a level playing field to determine which database performed best when used with a Java-based application server.

    The results? They found that overall Oracle9i and MySQL had the best performance and scalability; Oracle9i was slightly ahead of MySQL in most cases, but Oracle costs far more. “ASE, DB2, Oracle9i and MySQL finished in a dead heat up to about 550 Web users. At this point, ASE’s performance leveled off at 500 pages per second, about 100 pages per second less than Oracle9i’s and MySQL’s leveling-off point of about 600 pages per second. DB2’s performance dropped substantially, leveling off at 200 pages per second under high loads. Due to its significant JDBC (Java Database Connectivity) driver problems, Microsoft’s SQL Server was limited to about 200 pages per second for the entire test.”

    Naturally, “Manual tuning makes a huge difference with databases - in general, our final measured throughput was twice as fast as our initial out-of-the-box test runs.” In this case, they found that “SQL Server and MySQL were the easiest to tune, and Oracle9i was the most difficult because it has so many separate memory caches that can be adjusted.”

MySQL also demonstrated some significant innovation. Its performance was due primarily to its "query cache", a capability not included in any other database. If the text of a query has a byte-for-byte match with a cached query, MySQL can retrieve the results directly from its cache without compiling the query, getting locks or doing index accesses. Obviously, this technique is only effective for tables with few updates, but it certainly made an impact on this benchmark and is a helpful optimization for many situations. MySQL also supports different database engines on a table-by-table basis; no other tested database had this feature.

They also found that of the five databases they tested, only Oracle9i and MySQL were able to run their test application as originally written for 8 hours without problems. They had to work around various problems for all the others.

In this case, an OSS/FS program beat most of its proprietary competition in both performance and reliability (in terms of being able to run a correctly-written application without problems). A proprietary program (Oracle) beat it, but barely, and its competitor is far more expensive. It certainly is arguable that MySQL is (for this application) a comparable application worthy of consideration.

MySQL AB also reports other benchmark results comparing MySQL with other products; however, since they are not an independent lab, I'm not highlighting their results here.

13. **In February 2003, scientists broke the Internet2 Land Speed Record using GNU/Linux**. Scientists sent 6.7 GB of uncompressed data at 923 megabits per second in just 58 seconds from Sunnyvale, California, to Amsterdam - the equivalent of four hours of DVD-quality movies, using a transfer speed 3,500 times faster than a typical household broadband connection. The team used PCs running Debian GNU/Linux in Amsterdam and Red Hat Linux in Sunnyvale, California.
14. **Benchmarks comparing Sun Solaris x86 and GNU/Linux found many similarities, but GNU/Linux had double the performance in web operations.** Tony Bourke's October 2003 evaluation Sun Versus Linux: The x86 Smack-down gave a general review comparing Sun Solaris x86 and Red Hat Linux. He found that "Performance was overall similar for most of the metrics tested, perhaps with Linux in a very slight lead. However, with the web operations test (arguably the most important and relevant), Linux is a clear winner." He found that, given the same web serving programs and configuration, GNU/Linux supported over 2000 fetches/second while Solaris x86 supported less than 1000 fetches/second.

All OSes in active development are in a constant battle for performance improvements over their rivals. The history of comparing Windows and GNU/Linux helps put this in perspective:

1. **Ziff-Davis found that GNU/Linux with Apache beat Windows NT 4.0 with IIS by 16%-50% depending on the GNU/Linux distribution.** Ziff-Davis compared Linux and Windows NT's performance at web serving. They found that "Linux with Apache beats NT 4.0 with IIS, hands down. SuSE, the least effective Linux, is 16% faster than IIS, and Caldera, the leader, is 50% faster."
2. **Mindcraft released a report in April 1999 that claimed that Microsoft Windows NT Server 4.0 is 2.5 times faster than Linux (kernel 2.2) as a File Server and 3.7 times faster as a Web Server when running on a 4-CPU SMP system**. Several people and organizations, such Linux Weekly News (LWN) and Dan Kegel, identified serious problems with this study. An obvious issue was that NT was specially tuned by Microsoft's NT experts, at Microsoft, while GNU/Linux was not tuned at all. Another issue is that the price/performance wasn't considered (nor was

total expenditure kept constant - for the same amount of money, the GNU/Linux system could have had better hardware). Mindcraft claimed they asked for help, but they didn't use the documented methods for getting help nor did they purchase a support contract. Many were especially offended that even though this study was funded by Microsoft (one of the contestants) and held at their facility, neither Mindcraft's initial announcement nor its paper made any mention of this conflict-of-interest - and it could be easily claimed that their configuration was designed to put GNU/Linux at a disadvantage. Their configuration was somewhat bizarre - it assumed all web pages were static (typical big sites tend to use many dynamically generated pages) and that there were 100 or so clients connected via 100baseT (in 1999 a more typical situation would be that most clients are using slower 28.8 or 56 Kbps modems).

Careful examination of the benchmark did find some legitimate Linux kernel problems, however. These included a TCP bug, the lack of "wake one" semantics, and SMP bottlenecks (see Dan Kegel's pages for more information). The Linux kernel developers began working on the weaknesses identified by the benchmark.

3. **PC Week confirmed that Windows did indeed do better in this less probable configuration.** In June 30, 1999, Mindcraft released their Open Benchmark in conjunction with PC Week. While this didn't excuse Mindcraft's biases, it did make a convincing case that there were legitimate problems in the Linux kernel and Apache that made GNU/Linux a poorer-performing product in this somewhat improbable configuration (serving static web pages to clients with high-speed connections). Note that this configuration was considerably different than Ziff-Davis's, so the benchmarks don't necessarily conflict; it's merely that different assumptions can produce different results (as I've already stressed).
4. **The German magazine c't found that web sites with NT was better at static content and dual network connections, but GNU/Linux was better for sites with dynamic content and single connections.** Their article *Mixed Double: Linux and NT as Web Server on the Test Bed* examined Windows NT with IIS against GNU/Linux (kernel 2.2.9) with Apache on a machine with four Pentium II Xeon CPUs. They found that the performance winner depended on the situation (by now that should not be a surprise). If the web server primarily served static web pages through two high-performance network cards, NT's performance was better. However, they also noted that in sophisticated web sites this result didn't apply, because such sites tend to have primarily dynamic content, and that few sites had this kind of dual-network connection (when only one network board was available, GNU/Linux generally had an edge). They concluded that "Mindcraft's result can't be transferred to situations with mainly dynamic contents - the common case in nearly every sophisticated web site... In the web server areas most relevant for practical use, Linux and Apache are already ahead by at least one nose. If the pages don't come directly from the system's main memory, the situation is even reverted to favor Linux and Apache: Here, the OpenSource movement's prime products leave their commercial competitors from Redmond way behind." See their paper for more figures and background.
5. **Network Computing found that GNU/Linux with Samba ran at essentially the same speed as Windows for file serving.** In their article "Is it Time for Linux", Network Computing compared Red Hat Linux v5.2 running Samba 2.0.3 against Microsoft Windows NT Server Enterprise Edition on a Pentium II-based HP NetServer LPr, stressing the machine with multiple reads and writes of small, medium and large files over the course of several hours.

   For file serving, they discovered only "negligible performance differences between the two for average workloads... [and] depending on the degree of tuning performed on each installation, either system could be made to surpass the other slightly in terms of file-sharing performance." Red Hat Linux slightly outperformed NT on file writes, while NT edged out Red Hat Linux on massive reads. Note that their configuration was primarily network-limited; they stated "At no point were we able to push the CPUs much over 50-percent utilization-the single NIC, full duplex 100BASE-T environment wouldn't allow it."

They also noted that "examining the cost difference between the two licenses brings this testing into an entirely new light... the potential savings on licenses alone is eye-opening. For example, based on the average street price of $30 for a Windows NT client license, 100 licenses would cost around $3,000, plus the cost of an NT server license (around $600). Compare this to the price of a Red Hat Linux CD, or perhaps even a free download, and the savings starts to approach the cost of a low-end workgroup server. Scale that up to a few thousand clients and you begin to see the savings skyrocket." See this paper's section on total cost of ownership.

6. **The Linux developers' various efforts to improve performance appear to have paid off.** In June 2000, Dell measured the various SPECweb99 values noted above.

There are other benchmarks available, but I've discounted them on various grounds:

1. A more recent set of articles from eWeek on June 2001, shows some eye-popping performance numbers for GNU/Linux with TUX. However, although they compare it to Microsoft IIS, they don't include Microsoft's SWC (Scalable Web Cache), Microsoft's response to TUX - and omitting it makes this comparison less balanced. You can read more at "Tux: Built for Speed", "Smart Coding pays off Big", and Kegel's detailed remarks.
2. The ZDNet article *Take that! Linux beats MS in benchmark test*, loudly trumpeted that GNU/Linux was the May 2001 performance leader in the TPC-H decision support (database) benchmark ("100Gb" category). However, this result should not be taken very seriously; the hardware that Linux ran on was more powerful than that of the runner-up (Windows 2000). Frankly, the more surprising fact than its top score (which can be easily explained by the hardware) is its mere measurement at all with this benchmark - traditionally only Microsoft's numbers are reported for this benchmark at this range. For more information, see the TPC results.

More information on various benchmarks is available from Kegel's NT vs. Linux Server Benchmark Comparisons, SPEC, and the dmoz entry on benchmarking.

Remember, in benchmarking, everything depends on the configuration and assumptions that you make. Many systems are constrained by network bandwidth; in such circumstances buying a faster computer won't help at all. Even when network bandwidth isn't the limitation, much depends on what the products are designed to do. Neither Windows nor GNU/Linux do well in large-scale symmetric multiprocessing (SMP) shared memory configurations, e.g., for 64-way CPUs with shared memory. On the other hand, if you want massive distributed non-shared memory, GNU/Linux does quite well, since you can buy more CPUs with a given amount of money. If massive distribution can't help you and you need very high performance, Windows isn't even in the race; today Windows 2000 only runs on Intel x86 compatible chips, while GNU/Linux runs on much higher performance processors as well as the x86.

5. Scalability

Which brings us to the topic of scalability, a simple term with multiple meanings:

1. **GNU/Linux and NetBSD (both OSS/FS) support a wider range of hardware platforms and performance than any other OS.** Many people mean by "scalability" to answer the question, "can you use the same software system for both small and large projects?" Often the implied issue is that you'd like to start with a modest system, but have the ability to grow the system as needs demand without costly modifications. Here OSS/FS is unbeatable; because many people can identify scalability problems, and because its source code can be optimized for its platform, the scalability of many OSS/FS products is amazing. Let's specifically look at GNU/Linux. GNU/Linux works on PDAs (including the Agenda VR3), obsolete hardware (so you needn't throw the hardware away), common modern PC hardware, over a dozen different chipsets (not just Intel x86s), mainframes, massive clusters, and a number of supercomputers. There's even a prototype implementation of GNU/Linux on a wrist watch, And GNU/Linux runs on a vast number of different CPU chips, including the x86, Intel Itanium, ARM, Alpha, IBM AS/400 (midrange), SPARC, MIPS, 68k, and Power PC. Another OS that widely scales to many other hardware platforms is NetBSD.

   GNU/Linux is widely used for massive parallel processing; a common approach for doing this is the Beowulf architecture. Sandia's "CPlant" runs on a set of systems running GNU/Linux, and it's the forty-second most powerful computer in the world as of June 2001 (number 42 on the TOP 500 Supercomputer list, June 2001). Lawrence Livermore National Laboratory's "Thunder" is based on Linux, and a May 2004 report states that it delivers 19.94 teraflops, making it the most powerful computer in North America (and the second fastest on earth). IBM announced in October 2002 that GNU/Linux will be the main OS for IBM's "Blue Gene" family of supercomputers. IBM plans for the Blue Gene family to eventually perform perform a quadrillion calculations per second (one petaflop). Blue Gene/L, the first member of the family due in 2004 or 2005, will contain 65,000 processors, 16 trillion bytes of memory, and be able to perform 200 trillion calculations per second.

   Thus, you can buy a small GNU/Linux or NetBSD system and grow it as your needs grow; indeed, you can replace small hardware with massively parallel or extremely high-speed processors or very different CPU architectures without switching OSes. Windows CE/ME/NT scales down to small platforms, but not to large ones, and it only works on x86 systems. Many Unix systems (such as Solaris) scale well to specific large platforms but not as well to distributed or small platforms. These OSS/FS systems are some of the most scalable programs around.

2. **OSS/FS development processes can scale to develop large software systems.** At one time it was common to ask if the OSS/FS process is "scalable," that is, if OSS/FS processes could really develop large-scale systems. Bill Gates' 1976 "Open Letter to Hobbyists" asked rhetorically, "Who can afford to do professional work for nothing? What hobbyist can put three man-years into programming, finding all bugs, documenting his product, and distribute it for free?" He presumed these were unanswerable questions - but he was wrong. See my reports estimating GNU/Linux's size. For Red Hat Linux 6.2, I found the size to be over 17 million source lines of code (SLOC). Implemented traditionally it would have taken 4,500 person-years and over $600 million to implement this distribution. For Red Hat Linux 7.1, I found it to have over 30 million SLOC, representing 8,000 person-years or $1 billion (a "Gigabuck"). Most developers ascribe to the design principle that components should be divided into smaller components where practical - a practice also applied to GNU/Linux - but some components aren't easily divided, and thus some components are quite large themselves (e.g., over 2 million lines of code for the kernel, mostly in device drivers). By October 2002, Sourceforge.net announced that it had surpassed

500,000 registered users and supported almost 50,000 OSS/FS projects - and a vast number of OSS/FS projects don't use SourceForge. Thus, it's no longer reasonable to argue that OSS/FS cannot scale to develop large systems -- because it clearly can.

6. Security

Quantitatively measuring security is very difficult. However, here are a few attempts to do so, and they suggest that OSS/FS is often superior to proprietary systems, at least in some cases. I'll concentrate on comparing OSS/FS to Windows systems, since as noted above other proprietary systems are increasingly including OSS/FS components (making comparisons more difficult).

1. **J.S. Wurzler Underwriting Managers' "hacker insurance" costs 5-15% more if Windows is used instead of Unix or GNU/Linux for Internet operation.** At least one insurance company has indicated that Windows NT is less secure than Unix or GNU/Linux systems, resulting in higher premiums for Windows-based systems. It's often difficult to find out when a company has been successfully cracked; companies often don't want to divulge such information to the public for a variety of reasons. Indeed, if consumers or business partners lost trust in a company, the resulting loss might be much greater than the original attack. However, insurance companies that insure against cracking can require that they get such information (as a condition of coverage), and can compute future premiums based on that knowledge. According to Cnet, Okemos, Mich.-based J.S. Wurzler Underwriting Managers, one of the earliest agencies to offer "hacker insurance" (and thus more likely to have historical data for premium calculation), has begun charging its clients anywhere from 5 to 15 percent more if they use Microsoft's Windows NT software instead of Unix or GNU/Linux for their Internet operations. Walter Kopf, senior vice president of underwriting, said that "We have found out that the possibility for loss is greater using the NT system." He also said the decision is based on findings from hundreds of security assessments the company has done on their small and midsize business clients over the past couple of years.
2. **Most defaced web sites are hosted by Windows, and Windows sites are disproportionately defaced more often than explained by its market share.** Another way to look at security is to look at the OS used by defaced web sites, and compare them to their market share. A "defaced" web site is a site that has been broken into and has its content changed (usually in a fairly obvious way, since subtle modifications are often not reported). The advantage of this measure is that unlike other kinds of security break-ins (which are often "hushed up"), it's often very difficult for victims to hide the fact that they've been successfully attacked. Historically, this information was maintained by Attrition.org. A summary can be found in James Middleton's article, with the actual data found in Attrition.org's web site. Attrition.org's data showed that 59% of defaced systems ran Windows, 21% Linux, 8% Solaris, 6% BSD, and 6% all others in the period of August 1999 through December 2000. Thus, Windows systems have had nearly 3 times as many defacements as GNU/Linux systems. This would make sense if there were 3 times as many Windows systems, but no matter which figures you use, that's simply not true.

   Of course, not all sites are broken through their web server and OS - many are broken through exposed passwords, bad web application programming, and so on. But if this is so, why is there such a big difference in the number of defacements based on the OS? No doubt some other reasons could be put forward (this data only shows a correlation not a cause), but this certainly suggests that OSS/FS can have better security.

Attrition.org has decided to abandon keeping track of this information due to the difficulty of keeping up with the sheer volume of broken sites, and it appeared that tracking this information wouldn't be possible. However, defaced.alldas.de has decided to perform this valuable service. Their recent reports show that this trend has continued; on July 12, 2001, they report that 66.09% of defaced sites ran Windows, compared to 17.01% for GNU/Linux, out of 20,260 defaced websites.

3. **The Bugtraq vulnerability database suggests that the least vulnerable OS is OSS/FS, and that all the OSS/FS OSes in its study were less vulnerable than Windows in 1999-2000, unless you counted every GNU/Linux vulnerability multiple times.** One approach to examining security is to use a vulnerability database; an analysis of one database is the Bugtraq Vulnerability Database Statistics page. As of September 17, 2000, here are the total number of vulnerabilities for some leading OSes:

OS	1997	1998	1999	2000
Debian GNU/Linux	2	2	30	20
OpenBSD	1	2	4	7
Red Hat Linux	5	10	41	40
Solaris	24	31	34	9
Windows NT/2000	4	7	99	85

4. You shouldn't take these numbers very seriously. Some vulnerabilities are more important than others (some may provide little if exploited or only be vulnerable in unlikely circumstances), and some vulnerabilities are being actively exploited (while others have already been fixed before exploitation). OSS/FS OSes tend to include many applications that are usually sold separately in proprietary systems (including Windows and Solaris). For example, Red Hat 7.1 includes two relational database systems, two word processors, two spreadsheet programs, two web servers, and many text editors. In addition, in the open source world, vulnerabilities are discussed publicly, so vulnerabilities may be identified for software still in development (e.g., "beta" software). Those with small market shares are likely to have less analysis. The "small market share" comment won't work with GNU/Linux, since GNU/Linux is the #1 or #2 server OS (depending on how you count them). Still, this clearly shows that the three OSS/FS OSs listed (Debian GNU/Linux, OpenBSD, and Red Hat Linux) did much better by this measure than Windows in 1999 and (so far) in 2000. Even if a bizarre GNU/Linux distribution was created explicitly to duplicate all vulnerabilities present in any major GNU/Linux distribution, this intentionally bad GNU/Linux distribution would still do better than Windows (it would have 88 vulnerabilities in 1999, vs. 99 in Windows). The best results were for OpenBSD, an OSS/FS OS that for years has been specifically focused on security. It could be argued that its smaller number of vulnerabilities is because of its rarer deployment, but the simplest explanation is that OpenBSD has focused strongly on security - and achieved it better than the rest.
5. This data is partly of interest because various reporters make the same mistake: counting the same vulnerability multiple times. One journalist, Fred Moody, failed to understand his data sources - he used these figures to try to show show that GNU/Linux had worse security. He took these numbers and then added the GNU/Linux ones so each Linux vulnerability was counted at least twice (once for every distribution it applied to plus one more). By using these nonsensical figures he declared that GNU/Linux was worse than anything. If you read his article, you also

must read the rebuttal by the manager of the Microsoft Focus Area at SecurityFocus to understand why the journalist's article was so wrong.

6. In 2002, another journalist (James Middleton) made the same mistake, apparently not learning from prior work. Middleton counted the same Linux vulnerability up to *four* times. What's bizarre is that he even reported the individual numbers showing that specific Linux systems were actually *more* secure by using Bugtraq's vulnerability list through August 2001, and somehow he didn't realize what it meant. He noted that Windows NT/2000 suffered 42 vulnerabilities, while Mandrake Linux 7.2 notched up 33 vulnerabilities, Red Hat Linux 7.0 suffered 28, Mandrake 7.1 had 27 and Debian 2.2 had 26. In short, all of the GNU/Linux distributions had significantly fewer vulnerabilities by this count. It's not fully clear what was being considered as being "in" the OS in this case, which makes a difference. There are some hints that vulnerabilities in some Windows-based products (such as Exchange) were not counted, while vulnerabilities in GNU/Linux products with the same functionality (e.g., sendmail) *were* counted. It also appears that many of the Windows attacks were more dangerous (which were often attacks that could be invoked by remote attackers and were actively exploited), as compared to the GNU/Linux ones (which were often attacks that could only be invoked by local users and were not actively exploited at the time). I would appreciate links to someone who's analyzed these issues more carefully. The funny thing is that given all these errors, the paper gives evidence that the GNU/Linux distributions were *more* secure.
7. The September 30, 2002 VNUnet.com article "Honeymoon over for Linux Users", claims that there are more "Linux bugs" than "Microsoft bugs." It quotes X-Force (the US-based monitoring group of security software firm Internet Security Systems), and summarizes by saying that in 2001 the centre found 149 bugs in Microsoft software compared to 309 for Linux, and in 2002 485 Linux bugs were found compared to Microsoft's 202. However, Linux Weekly News discovered and reported serious flaws in these figures:
    1. "Each distribution is counted independently. The same vulnerability in five distributions will count as five separate vulnerabilities. This practice drastically overstates the number of reported Linux problems.
    2. Linux vulnerabilities include those in applications (i.e. PostgreSQL) which are not part of a standard Windows system.
    3. Most Linux vulnerabilities are found through code audits and similar efforts; they are patched and reported before any exploits happen. Any Windows bugs found through similar audits are fixed silently and do not appear in these counts.

    Indeed, assuming that the vulnerabilities were only counted three times (and thus dividing by only 3) would show Linux as having a better result, never mind the fact that there are more than 3 Linux distributions and the other factors noted by Linux Weekly News.

Indeed, as noted in Bruce Schneier's Crypto-gram of September 15, 2000, vulnerabilities are affected by other things such as how many attackers exploit the vulnerability, the speed at which a fix is released by a vendor, and the speed at which they're applied by administrators. Nobody's system is invincible.

A more recent analysis by John McCormick in Tech Republic compared Windows and Linux vulnerabilities using numbers through September 2001. This is an interesting analysis, showing that although Windows NT lead in the number of vulnerabilities in 2000, using the 2001 numbers through September 2001, Windows 2000 had moved to the "middle of the pack" (with some Linux systems having more, and others having fewer, vulnerabilities). However, it appears that in these numbers, bugs in Linux applications have been counted with Linux, while bugs in Windows applications haven't - and if that's so, this isn't really a fair comparison. As noted above, typical Linux distributions bundle many applications that are separately purchased from Microsoft.

8. **Red Hat (an OSS/FS vendor) responded more rapidly than Microsoft or Sun to advisories; Sun had fewer advisories to respond to yet took the longest to respond.** Another data point is that SecurityPortal has compiled a list of the time it takes for vendors to respond to vulnerabilities. They concluded that:

   How did our contestants [fare]? Red Hat had the best score, with 348 recess days on 31 advisories, for an average of 11.23 days from bug to patch. Microsoft had 982 recess days on 61 advisories, averaging 16.10 days from bug to patch. Sun proved itself to be very slow, although having only 8 advisories it accumulated 716 recess days, a whopping three months to fix each bug on average.

   Their table of data for 1999 is as shown:

   1999 Advisory Analysis

Vendor	Total Days, Hacker Recess	Total Advisories	Recess Days/Advisory
Red Hat	348	31	11.23
Microsoft	982	61	16.10
Sun	716	8	89.50

   Clearly this table uses a different method for counting security problems than the prior table. Of the three noted here, Sun's Solaris had the fewest vulnerabilities, but it took by far the longest to fix security problems identified. Red Hat was the fastest at fixing security problems, and placed in the middle of these three in number of vulnerabilities. It's worth noting that the OpenBSD OS (which is OSS/FS) had fewer reported vulnerabilities than all of these. Clearly, having a proprietary OS doesn't mean you're more secure - Microsoft had the largest number of security advisories, by far, using either counting method.

   More recent examples seem to confirm this; on September 30, 2002, eWeek Labs' article "Open Source Quicker at Fixing Flaws" listed specific examples of more rapid response. This article can be paraphrased as follows: In June 2002, a serious flaw was found in the Apache Web server; the Apache Software Foundation made a patch available two days after the Web server hole was announced. In September 2002, a flaw was announced in OpenSSL and a patch was available the same day. In contrast, a serious flaw was found in Windows XP that made it possible to delete files on a system using a URL; Microsoft quietly fixed this problem in Windows XP Service Pack 1 without notifying users of the problem. A more direct comparison can be seen in how Microsoft and the KDE Project responded to an SSL (Secure Sockets Layer) vulnerability that made the Internet Explorer and Konqueror browsers, respectively, potential tools for stealing data such as credit card information. The day the SSL vulnerability was announced, KDE provided a patch. Later that week, Microsoft posted a memo on its TechNet site basically downplaying the problem. The article Linux Security Holes Opened and Closed makes the same argument: OSS/FS systems fix problems more rapidly, reducing the time available for attackers to exploit them.

   In an August 18, 2004 interview, Symantec's chief technology officer Robert Clyde argued that proprietary vendors were more reliable for fixing problems within a fixed timescale, and that he didn't know of a single vendor who would sit on a vulnerability. Yet the day before (August 17), an eWeek article revealed that Oracle waited 8 months to fix a vulnerability. And Microsoft waited 9 months to fix a critical IE vulnerability (and only fixed it after it was being actively exploited in 2004). Proprietary vendors are certainly not winning prizes for reliably and rapidly fixing security vulnerabilities.

9. **A 2002 survey of developers found that GNU/Linux systems are relatively immune from attacks from outsiders.** Evans Data Corp.'s Spring 2002 Linux Developer Survey surveyed over 400 GNU/Linux developers, and found that Linux systems are relatively immune from attacks from outsiders. Even though computer attacks have almost doubled annually since 1988 (according to CERT), 78% of the respondents to the GNU/Linux developers survey have never experienced an unwanted intrusion and 94% have operated virus-free. Clearly, the survey shows that GNU/Linux "doesn't get broken into very often and is even less frequently targeted by viruses," according to Jeff Child (Evans Data Corp.'s Linux Analyst); and claims that "Linux systems are relatively immune from attacks from outsiders." Child notes that it's much harder to hack a knowledgeable owner's system (and most Linux developers have hands-on, technical knowledge) and that because there are fewer desktop GNU/Linux systems there are fewer viruses being created to attack GNU/Linux. The developers being surveyed attributed the low incidence of attacks to the Open Source Software (OSS) environment; "more than 84% of Linux developers believe that Linux is inherently more secure than software not created in an OSS environment," and they ranked "Linux's security roughly comparable in security to Solaris and AIX ... and above any of the Windows platforms by a significant margin."
10. **Apache has a better security record than Microsoft's IIS, as measured by reports of serious vulnerabilities.** Eweek's July 20, 2001 article "Apache avoids most security woes" examined security advisories dating back to Apache 1.0. They found that Apache's last serious security problem (one where remote attackers could run arbitrary code on the server) was announced in January 1997. A group of less serious problems (including a buffer overflow in the server's logresolve utility) was announced and fixed in January 1998 with Apache 1.2.5. In the three and a half years since then, Apache's only remote security problems have been a handful of denial-of-service and information leakage problems (where attackers can see files or directory listings they shouldn't).

    In contrast, in the article "IT bugs out over IIS security," eWeek determined that Microsoft has issued 21 security bulletins for IIS from January 2000 through June 2001. Determining what this number means is a little difficult, and the article doesn't discuss these complexities, so I examined these bulletins to find their true significance. Not all of the bulletins have the same significance, so just stating that there were "21 bulletins" doesn't give the whole picture. However, it's clear that several of these bulletins discuss dangerous vulnerabilities that allow an external user to gain control over the system. I count 5 bulletins on such highly dangerous vulnerabilities for IIS 5.0 (in the period from January 2000 through June 2001), and prior to that time, I count 3 such bulletins for IIS 4.0 (in the period of June 1998 through December 1999). Feel free to examine the bulletins yourself; they are MS01-033, MS01-026, MS01-025, MS01-023, MS00-086, MS99-025, MS99-019, and MS99-003. The Code Red worm, for example, exploited a vast number of IIS sites through the vulnerabilities identified in the June 2001 security bulletin MS01-033.

    In short, by totaling the number of reports of dangerous vulnerabilities (that allow attackers to execute arbitrary code), I find a total of 8 bulletins for IIS from June 1998 through June 2001, while Apache had zero such vulnerabilities for that time period.

Apache's last such report was in January 1998, and that one affected the log analyzer not the web server itself. As was noted above, the last such dangerous vulnerability in Apache itself was announced in January 1997.

It's time-consuming to do this kind of analysis, so I haven't repeated the effort more recently. However, it's worth noting eWeek's April 10, 2002 article noting that ten more IIS flaws have been found in IIS Server 4.0, 5.0, and 5.1, some of which would allow attackers to crash the IIS service or allow the attacker to run whatever code he chooses.

Even this doesn't give the full story, however; a vulnerability in IIS tends to be far more dangerous than an equivalent vulnerability in Apache, because Apache wisely follows the good security practice of "least privilege." IIS is designed so that anyone who takes over IIS can take over the *whole system*, performing actions such as reading, modifying, or erasing any file on the system. In contrast, Apache is installed with very few privileges by default, so even taking over Apache gives attackers relatively few privileges. For example, cracking Apache does not give attackers the right to modify or erase most files. This is still not good, of course, and an attacker may be able to find another vulnerability to give them unlimited access, but an Apache system presents more challenges to an attacker than IIS.

The article claims there are four reasons for Apache's strong security, and three of these reasons are simply good security practices. Apache installs very few server extensions by default (a "minimalist" approach), all server components run as a non-privileged user (supporting "least privilege" as noted above), and all configuration settings are centralized (making it easy for administrators to know what's going on). However, the article also claims that one of the main reasons Apache is more secure than IIS is that its "source code for core server files is well-scrutinized," a task that is made much easier by being OSS/FS, and it could be argued that OSS/FS encourages the other good security practices.

Simple vulnerability notice counts are an inadequate metric for security. A vendor could intentionally release fewer bulletins - but since Apache's code and its security is publicly discussed, it seems very unlikely that Apache is deliberately underreporting security vulnerabilities. Fewer vulnerability notices could result if the product isn't well scrutinized or is rarely used - but this simply isn't true for Apache. Even the trend line isn't encouraging - using the months of the bulletins (2/99, 6/99, 7/99, 11/00, three in 5/01, and 6/01), I find the time in months between new major IIS vulnerability announcements to be 4, 1, 18, 6, 0, 0, 1, and 3 as of September 2001; this compares to 12 and 44 as of September 2001 for Apache. Given these trends, it looks like IIS's security is slowly improving, but it has little likelihood of meeting Apache's security in the near future. Indeed, these vulnerability counts are corroborated by other measures such as the web site defacement rates.

The issue here isn't whether or not a given program is invincible (what nonsense!) - the issue is which is more likely to resist future attacks, based on past performance. It's clear that the OSS/FS Apache has much a better security record than the proprietary IIS, so much so that Gartner Group decided to make an unusual recommendation (described below).

11. **IIS was attacked 1,400 times more frequently than Apache in 2001, and Windows was attacked more than all versions of Unix.** SecurityFocus co-founder and CEO Arthur Wong reported an analysis of the various vulnerabilities and attacks (based on SecurityFocus's data) in the February 2002 article *RSA: Security in 2002*

worse than 2001, exec says. IIS was attacked 17 million times, but Apache was attacked only 12,000 times. This is a stunning comparison, since there are about twice as many Apache systems on the Internet. In 2001, Windows systems were attacked 31 million times, while Unix systems were attacked 22 million times. See the article for more information.

12. **The Gartner Group is recommending that businesses switch from Microsoft IIS to Apache or iPlanet due to IIS's poor security track record, noting that enterprises had spent $1.2 billion simply fixing Code Red (IIS-related) vulnerabilities by July 2001.** Microsoft's IIS has such a bad security record that in September 2001, Gartner Group announced a recommendation that "businesses hit by both Code Red and Nimda immediately investigate alternatives to IIS, including moving Web applications to Web server software from other vendors such as iPlanet and Apache. Although those Web servers have required some security patches, they have much better security records than IIS and are not under active attack by the vast number of virus and worm writers." Microsoft is sometimes a Gartner Group customer, so this announcement is especially surprising.

    In a background document by Gartner, they discuss Code Red's impacts further. By July 2001, Computer Economics (a research firm) estimated that enterprises worldwide had spent $1.2 billion fixing vulnerabilities in their IT systems that Code Red could exploit (remember, Code Red is designed to only attack IIS systems; systems such as Apache are immune). To be fair, Gartner correctly noted that the problem is not just that IIS has vulnerabilities; part of the problem is that enterprises using IIS are not keeping their IT security up to date, and Gartner openly wondered why this was the case. However, Gartner also asked the question, "why do Microsoft's software products continue to provide easily exploited openings for such attacks?" This was prescient, since soon after this the "Nimba" attack surfaced which attacked IIS, Microsoft Outlook, and other Microsoft products.

    A brief aside is in order here. Microsoft spokesman Jim Desler tried to counter Gartner's recommendation, trying to label it as "extreme" and saying that "serious security vulnerabilities have been found in all Web server products and platforms.. this is an industry-wide challenge." While true, this isn't the whole truth. As Gartner points out, "IIS has a lot more security vulnerabilities than other products and requires more care and feeding." It makes sense to select the product with the best security track record, even if no product has a perfect record.

13. **The majority of the most serious security problems only apply to Microsoft's products, and not to OSS/FS products, as suggested by the CERT/CC's "most frequent, high-impact types of security incidents and vulnerabilities" and the ICAT database.** Some security vulnerabilities are more important than others, for a variety of reasons. Thus, some analysis centers try to determine what's "most important," and their results suggest that OSS/FS just doesn't have as many vulnerabilities.

    The CERT Coordination Center (CERT/CC) is federally funded to study security vulnerabilities and perform related activities such as publishing security alerts. I sampled their list of "current activity" of the most frequent, high-impact security incidents and vulnerabilities on September 24, 2001, and found yet more evidence that Microsoft's products have poor security compared to others (including OSS/FS). Four of the six most important security vulnerabilities were specific to Microsoft: W32/Nimda, W32/Sircam, cache corruption on Microsoft DNS servers, and "Code Red" related activities. Only one of the six items primarily affected non-Microsoft products (a buffer overflow in telnetd); while this vulnerability is important, it's worth noting that many open source systems (such as Red Hat 7.1) normally don't enable this service (telnet) in the first place and thus are less likely to be vulnerable. The sixth item ("scans and probes") is a general note that there is a great deal of scanning and probing on the Internet, and that there are many potential vulnerabilities in all systems. Thus, 4 of 6 issues are high-impact vulnerabilities are specific to Microsoft, 1 of 6 are vulnerabilities primarily affecting Unix-like systems (including OSS/FS OSes), and 1 of 6 is a general notice about scanning. Again, it's not that OSS/FS products never have security vulnerabilities - but they seem to have fewer of them.

The ICAT system provides a searchable index and ranking for the vulnerabilities cross-references by CVE. I sampled its top ten list on December 19, 2001; this top ten list is defined by the number of requests made for a vulnerability in ICAT (and including only vulnerabilities within the last year). In this case, 8 of the top 10 vulnerabilities only affect proprietary systems (in all cases, Windows). Only 2 of 10 affect OSS/FS systems (#6, CAN-2001-0001, a weakness in PHP-Nuke 4.4, and #8, CVE-2001-0013, a new vulnerability found in an old version of BIND - BIND 4). Obviously, by itself this doesn't prove that there are fewer serious vulnerabilities in OSS/FS programs, but it is suggestive of it.

An analysis of security reports by Nicholas Petreley found that a much larger percentage of Windows vulnerabilities are critical compared to Red Hat Linux. In October 2004, Nicholas Petreley's paper "Security Report: Windows vs Linux" (available in HTML or PDF) found that Windows vulnerabilities are far more likely to be serious than vulnerabilities in Red Hat Linux. He examined the 40 most recent patches/vulnerabilities listed for Microsoft Windows Server 2003 vs. Red Hat Enterprise Linux AS v.3, as reported by each vendor's website. He then used a metric to score their severity, and by that measure, 50% of the Windows vulnerabilities are critical, compared to 10% being critical in Red Hat.

There's an interesting twist here; Microsoft claims that certain vulnerabilities aren't as serious as long as an administrator doesn't change certain settings. But as Petreley notes, "it is nearly inconceivable that anyone who uses Windows Server 2003 will leave the [Windows Server 2003] settings ... unchanged. These settings make the Internet Explorer browser nearly useless to the server administrator who wants to perform any browser-based administrative tasks, download updates, etc. To lower the severity rank based on the assumption that Windows Server 2003 users will leave these default settings as they are is a fantasy, at best." Also, Microsoft presumes that "Users" are never "Administrators", a very doubtful assumption on a Microsoft Windows server. If you accept these implausible claims, the percentage drops to 40%, which is still larger than Red Hat's. Microsoft assigns its own criticality levels (Red Hat doesn't), but even using Microsoft's reporting level things are worse; 38% of the patched programs are rated as Critical by Microsoft.

He also did some analysis of the CERT database; while that analysis was more limited, that still suggested that Linux vulnerabilities tended to be less severe.

The article goes on to argue against what it terms "myths." Petreley also argues that the reason for this difference is that Linux-based systems have a far better design for security than Windows systems. His design argument makes four statements: Linux-based systems are based on a long history of well fleshed-out multi-user design, they are modular by design (not monolithic), they are not constrained by an RPC model (that unnecessarily enables external control of internal functions), and Linux servers are ideally designed for headless non-local administration.

This study didn’t try to determine how many critical vulnerabilities there have been overall in the same period, which is a weakness of the study. And Petreley is certainly an advocate of GNU/Linux systems. Still, this report makes a plausible case that there is a difference in design and/or development process that makes GNU/Linux vulnerabilities less severe than Microsoft Windows vulnerabilies.

14. **Computer viruses are overwhelmingly more prevalent on Windows than any other system.** Virus infection has been a major cost to users of Microsoft Windows. The LoveLetter virus alone is estimated to have cost $960 million in direct costs and $7.7 billion in lost productivity, and the anti-virus software industry sales total nearly $1 billion annually. Dr Nic Peeling and Dr Julian Satchell’s *Analysis of the Impact of Open Source Software* includes an analysis of the various data sources for virus counts, noting the disproportionate vulnerability of Windows systems. Here is what they said:

    The numbers differ in detail, but all sources agree that computer viruses are overwhelmingly more prevalent on Windows than any other system. There are about 60,000 viruses known for Windows, 40 or so for the Macintosh, about 5 for commercial Unix versions, and perhaps 40 for Linux. Most of the Windows viruses are not important, but many hundreds have caused widespread damage. Two or three of the Macintosh viruses were widespread enough to be of importance. None of the Unix or Linux viruses became widespread - most were confined to the laboratory.

    Many have noted that one reason Windows is attacked more often is simply because there are so many Windows systems in use. Windows is an attractive target for virus writers simply because it is in such widespread use. For a virus to spread, it must transmit itself to other susceptible computers; on average, each infection must cause at least one more. The ubiquity of Windows machines makes it easier for this threshold to be reached.

    There may be a darker reason: there are many who do not like Microsoft’s business practices, and perhaps this contributes to the problem. Some of Microsoft’s business practices have been proven in court to be illegal, but the U.S. government appears unwilling to effectively punish or stop those practices. Some computer literate people may be taking their frustration out on users of Microsoft’s product. This is absolutely wrong, and in most countries illegal. It is extremely unethical to attack an innocent user of a Microsoft product simply because of Microsoft’s policies, and I condemn such behavior. At this point, although this has been speculated many times, I have not found any evidence that this is a widespread motivator for actual attacks. On the other hand, if you are choosing products, do you really want to choose the product whom people may have a vendetta against?

    However, the reasons given above don’t explain the disproportionate vulnerability of Microsoft’s products. A simpler explanation, and one that is easily proven, is that Microsoft has made many design choices over the years in Microsoft’s products that are fundamentally less secure, and this has made their products a much easier target than many other systems. Examples include executing start-up macros in Word, executing attachments in Outlook, and the lack of write protection on system directories in Windows 3.1/95/98. This may be because Microsoft has assumed that customers will buy their products whether or not Microsoft secures them. After all, until recently there’s been little competition, so there was no need to spend money on “invisible” attributes such as security. It’s also possible that Microsoft is still trying to adjust to an Internet-based world; the Internet would not have developed as it has without Unix-like systems, which have supported the Internet standards for decades, while for many years Microsoft ignored the Internet and then suddenly had to play "catch-up" in the early 1990s. Microsoft has sometimes claimed that they can't secure their products because they want to ensure that their products are "easy to use". While it's true that some security features can make a product harder to use, usually a secured product can be just as easy to use if the security features are carefully designed into the product. Besides, what's so easy to use about a system that must be reformatted and reinstalled every few months because yet another virus got in? But for whatever the reason, it's demonstrably true that Microsoft's designers have in the past made decisions that made their products' security much weaker than other systems.

In contrast, while it's possible to write a virus for OSS/FS OSes, their design makes it more difficult for viruses to spread... showing that Microsoft's design decisions were not inevitable. It appears that OSS/FS developers tend to select design choices that limit the damage of viruses, perhaps in part because their code is subject to public inspection and comment. For example, OSS/FS programs generally do not support start-up macros nor execution of mail attachments that can be controlled by attackers. Also, leading OSS/FS OSes (such as GNU/Linux and the *BSDs) have always had write protection on system directories. Another discussion on why viruses don't seem to significantly affect OSS/FS systems is available from Roaring Penguin. OSS/FS systems are *not* immune to malicious code, but they are certainly more resistant.

15. **Surveys report that GNU/Linux systems experience fewer viruses and successful cracks.** In July 2004, Evans Data's Summer 2004 Linux Development Survey reported that 92% of their Linux systems have never been infected with a virus, and 78% that their Linux systems have never been cracked (called "hacked" in the report). This contrasts with their Spring 2004 survey, where only 40% non-Linux users reported no security breach; indeed, 32% non-Linux users experienced three or more breaches.
16. **According to a June 2004 study by Sandvine, 80% of all spam is sent by infected Windows PCs.** 80% of all spam comes from computers contaminated with Trojan horse infections, according to a study by network management firm Sandvine. Trojans and worms with backdoor components turn infected PCs into drones in vast networks of compromised zombie PCs.

    Sandvine identified subscribers bypassing their home mail servers and contacting many mail servers within a short period of time over sustained periods - i.e., spammers. It also looked at SMTP error messages returned to clarify the total volume of spam. They then compared this with the messages passing through the service provider's mail system.

    Sandvine's preliminary analysis has shown that the most active Trojans for spamming purposes are the Migmaf and SoBig variants; note that these are Windows-only attacks. Indeed, since almost all successful trojans and worms are those that attack Windows systems, it appears that this problem is essentially due to Windows systems.

17. **National Cyber Security Alliance's study of May 2003 reported that 91% of Broadband users have spyware on their home computers running proprietary operating systems; in contrast, there's no evidence of that this is an issue for OSS/FS systems.** America Online, Inc. conducted a study for the National Cyber Security Alliance. Its results, "Fast and Present Danger: In-Home Study on Broadband Security among American Consumers" (May 2003) produces some interesting results, in particular, they found that "91% of Broadband Users Have Spyware Lurking on Home Computers". Their study method did not appear to permit

collection of data from OSS/FS systems, and spyware systems are essentially nonexistent on OSS/FS systems anyway.

18. **Microsoft has had far more vulnerabilities than anyone else, according to SecurityTracker**. The paper SecurityTracker Statistics (March 2002) analyzes vulnerabilities from April 2001 through March 2002. They identified 1595 vulnerability reports, covering 1175 products from 700 vendors. Their analysis found that Microsoft had more vulnerabilities than anyone else (187, or 11.7% of all vulnerabilities), and more than four times the next vendor. The next largest were Sun (42, 2.6% of the total), HP (40, 2.5%), and IBM (40, 2.5%). Solely OSS/FS vendors did much better: the Apache Software Foundation had 13 (0.8% of the total), and Red Hat had 10 (0.6% of the total). It can be argued that Microsoft sells more kinds of software than most other vendors, but this is nevertheless an astonishingly large number of vulnerabilities. The gap between Microsoft and everyone else widened during the second half of the year, which is even scarier.
19. **In late June 2004, the U.S. Department of Homeland Security's Computer Emergency Readiness Team (CERT) recommended using browsers other than Microsoft Corp.'s Internet Explorer (IE) for security reasons. Microsoft had failed to patch a critical vulnerability for 9 months, and IE was being actively exploited in horrendous ways. Customers then rushed to download Mozilla and Mozilla Firebird, popular OSS/FS alternatives, to replace IE. This was a good idea, since 4 more serious IE vulnerabilities were soon admitted, and the technologically savvy began to switch in droves to OSS/FS browsers.** The U.S. CERT warned that the Microsoft browser (IE) cannot protect against vulnerabilities, and there were dangerous active attacks exploiting them. A team of crackers (supposedly Russia-based) exploited Microsoft IE vulnerabilities by also exploiting other vulnerabilities in Microsoft's IIS. The crackers broke into IIS sites and inserted malicious code that IE users would download if they viewed an IIS site they'd broken into. The IE users who visited those sites (who legitimately trusted these sites) would have their IE program exploited, which then compromised their system. As a result, many IE users had keystroke information stolen from them. It's hoped the purpose was to steal credit card numbers, though passwords and other sensitive data could have been stolen too (e.g., to drain people's bank accounts or steal extremely private data). By June 25, 2004, this active attack was publicly known, but a fix to IE wasn't available until July 2, 7 days later. Even worse, ZDNet found that Microsoft had failed to fix this critical known IE vulnerability for nearly nine months. And even after a 9-month lead time, ComputerWorld learned that the patch doesn't address another closely related vulnerability.

    Nine months is a shamefully long time; 2-30 days is the expected time by most security practitioners, since every day a known exploit is unfixed is another day that attackers can exploit it, and attackers often know and exploit attacks that the vendor claims are secret. This is long after Microsoft loudly announced (in 2002) that it would pay much more attention to security; certainly in this case users were left unprotected for a long time. Even more tellingly, at the same time (June 28, 2004), Microsoft's Bill Gates told Australians that while other operating system vendors took 90-100 days to release a security patch, Microsoft had this time "down to less than 48 hours." Gates assured attendees that the Internet Explorer attack was new, but later analysis has shown otherwise. Clearly Microsoft admits that long delays in security patches are a bad thing, but it nevertheless still commits them.

    The U.S. CERT took the unusual step of noting that a useful solution would be to stop using IE and use another program instead. SANS made a similar announcement, noting that one solution would be to stop using IE. OSS/FS programs sometimes have vulnerabilities too, but it's rare that they last so long. More importantly, users of

OSS/FS programs can always fund to have a repair created and implemented quickly if it is important to them, and can have that fix reviewed and shared with others worldwide. Proprietary users have no such options; proprietary users are completely dependent on the proprietary vendor for making any emergency repairs, and for more reacting more responsibly than this. Downloads of Mozilla and Mozilla's Firefox dramatically increased in late June 2004, presumably as a response to this serious problem in IE. Downloads of Mozilla and Firefox browsers hit an all-time high on July 1, 2004, from the usual 100,000 or so downloads on a normal day to more than 200,000 in one day. Mozilla argues that IE is in general less secure, in part because Microsoft's ActiveX technologies, IE's tight integration into the Microsoft operating system, and IE's weak default security settings make IE easier to exploit than its competition. Even the U.S. CERT notes that IE includes many design decisions that make it an especially easy web browser to exploit. In contrast, every change made to Mozilla applications is first peer reviewed by at least two engineers who are familiar with the code and overall architecture of the system before the new code is allowed into the product. The product then goes through automated tests and evaluations, and then Mozilla users and the development community are invited to review the impact of each change by downloading the test builds that are produced two or three times a day. All source code is available for review by anyone.

This problem was so significant that it was noted in many different media and technology analysis sites. USA Today noted in 2004 that "Using Microsoft's Internet Explorer Web browser to surf the Internet has become a marked risk -- even with the latest security patches installed." The New York Times noted in 2004 that concerns about Internet Explorer's security vulnerabilities have dented its market share, and that the US CERT recommendation to consider other browsers was an unusual step. The Inquirer reported that the "US Government warns against Internet Explorer", noting that the US Government's tone essentially pleaded for "users to stop using Microsoft's Internet Explorer". Netcraft suggested that this may mean that the browser wars will recommence. Netcraft noted that one major difference is that this attack was different because of its extreme gravity: "victims of [these] attacks might conceivably lose their life savings. Some people now perceive Internet Explorer and Internet Banking as a potentially lethal cocktail that must not be mixed, with insiders in the banking industry urging their families to switch if not operating systems, then at least browsers, while conversely some internet banking customers have adapted to the threat by forgoing convenience and moving funds back into accounts which require traditional telephone and fax instructions." Netcraft also noted that there is now "a serious alternative to Internet Explorer available on Windows" and that "this [combination of loss of confidence and a viable alternative] is an extremely dangerous situation for Microsoft. The phishing threats and the growing professional chorus of disapproval for Internet Explorer provide Windows users with very good reasons to turn elsewhere, even if only temporarily. But [OSS/FS] Firefox is so good that many will want to stay with it. And once they have tasted the power and freedom of open source, maybe they will be tempted to try 'just one more program'."

Indeed, the security problems of IE have caused IE to lose marketshare, ceding marketshare to OSS/FS browsers.

As if to prove the point of how differently security vulnerabilities are handled, a vulnerability was found soon after that affected Mozilla and Firefox when running on Windows (though it was actually another Windows vulnerability). In contrast with IE, the security fix was delivered extremely rapidly. The initial notice of this vulnerability was on July 7, it was fixed the same day, and the configuration change was released to all in one day - with no known compromises to any system. The

Mozilla project has more information about the security issue, and you can even read the detailed discussions between the finders and developers. What's especially interesting is that it's not even a vulnerability in the OSS/FS programs; it's a vulnerability in Windows itself. The problem is the Windows maintains a registry of secure programs that accept URLs, but the list provided by Microsoft includes an application known to be insecure (the shell: URL). Windows XP Service Pack 1 was supposed to have closed this hole, but it didn't. Thus, the Mozilla project had to create a patch to compensate for Windows' insecurity, but explicitly disabling it on Windows. It appears that other Microsoft products, such as MSN Messenger and Word, are affected by this vulnerability in Windows. And it appears that Mozilla is continuing to be proactive in its security; they have already added new features to make attacks against the browser even more difficult.

After all that, on July 13, 2004, Secunia reported four more extremely critical vulnerabilities in IE. The only solutions at the time were to disable active scripting or use another product. It's unlikely that these additional vulnerabilities will improve IE's reputation.

20. **According to a Network Security evaluation, an OSS/FS vulnerability scanner (Nessus) was found to be the best (most effective).** On January 8, 2001, Network Computing's article *Vulnerability Assessment Scanners*. reported an evaluation of nine network scanning tools, most of them proprietary. In their evaluation, Network Computing set up demonstration systems with 17 of the most common and critical vulnerabilities; they then used the various network scanning tools to see how effectively each of the tools detected these vulnerabilities. Sadly, not one product detected all vulnerabilities; the best scanner was the OSS/FS program Nessus Security Scanner, which found 15 of the 17 (which also received their top total score); the next best was a proprietary scanner which only found 13.5 out of 17.

    In their words,

    Some of us were a bit skeptical of the open-source Nessus project's thoroughness until [Nessus] discovered the greatest number of vulnerabilities. That's a hard fact to argue with, and we are now eating our words ... [Nessus] got the highest overall score simply because it did more things right than the other products.

    I agree with the authors that ideally a network vulnerability scanner should find every well-known vulnerability, and that "even one hole is too many." Still, perfection is rare in the real world. More importantly, a vulnerability scanner should only be part of the process to secure an organization - it shouldn't be the sole activity. Still, this evaluation suggests that an organization will be *more* secure, not less secure, by using an OSS/FS program. It could be argued that this simply shows that this OSS/FS program had more functionality - not more security - but in this case, the product's sole functionality was to improve security.

Security is notoriously hard to measure, and many reports that attempt to do so end up with interesting information that's hard to interpret or use. And some reports come from sources whose reliability is widely questioned. On November 2, 2004, mi2g reported on successful digital breaches against permanently connected computers worldwide. They concluded that BSDs (which are usually OSS/FS) and Apple's computers had the fewest security breaches; on the surface, that sounds positive for OSS/FS. They also reported that GNU/Linux systems had the most breaches, followed by Windows. That result sounds mixed, but digging deeper it turns out that this ranking is artificial, based on artificial definitions. Their default definition for a security breach only included manual attacks and ignored malware (viruses, worms, and

Trojans). Yet malware is one of the dominant security problems for Windows users, and only Windows users! After all, why bother with a manual attack when completely automated attacks against broad collections of computers will do more? When they include malware in their calculations for all system breaches, "including the impact of MyDoom, NetSky, SoBig, Klez and Sasser, Windows has become the most breached computing environment in the world accounting for most of the productivity losses associated with malware - virus, worm and trojan - proliferation." Even without malware, in governments "the most breached Operating System for online systems has now become Windows (57.74%) followed by Linux (31.76%) and then BSD and Mac OS X together (1.74%)" (a reversal of their previous rankings). But while these results are interesting, there are significant problems in interpreting what these results actually *mean*:

1. Ignoring malware in the main report is hard to justify, though to be fair the report does clearly state this assumption and explains how the results would change with a different definition. But most users want to be protected from *all* attacks, automated or not, and it's especially hard to justify this assumption since malware is a leading attack on only one of the systems.
2. None of these statistics, at least what's publicly posted, seem to take market share into account, or control sampling in general. If 2 of 100 type A machines are broken into, and 1 of 1 type B machines are broken into, type A may have twice as many break-ins, but that's irrelevant to most users; what's more interesting is noticing that 98% of the type A machines were unbreached, while 0% of the type B machines were unbreached! Besides, what you really want to know is not raw numbers like this, but the probability that a given system will be breached (given various criteria such security configuration and as if you're relatively up-to-date on patches). That information doesn't appear to be available from the public information provided.

Checking the source (mi2g) yields decidedly mixed reports, too. mi2g clearly states that it has no financial interest in Apple. I always search for financial links in research reports, and that's a good sign at least. However, The Register, the full disclosure mailing list, attrition.org, Vmyths, and Yahoo! News provide a number of troubling reports about the quality and validity of mi2g's reports. Many of these reports suggest that these figures are made up, and cannot be relied on at all. Hopefully in the future I can gain a better understanding of the situation; I know nothing more than what I reference above. But for now, I'm mentioning both sides (mi2g's results and the concerns many number of people have raised about them), so that those who have heard about these results will know about the controversies and limitations surrounding this data. I'm not including mi2g results in my major list of studies, given the limitations and current questions surrounding them.

One serious problem in making secure software is that there are strong economic disincentives for proprietary vendors to make their software secure. For example, if vendors make their software more secure, they would often fail to be "first" in a given market; this often means that they will lose that market. Since it is extremely difficult for customers to distinguish proprietary software with strong security from those with poor security, the poor products tend to eliminate the good ones (after all, they're cheaper to develop and thus cost less). Governments have other disincentives as well. For a discussion of some of the economic disincentives for secure software, see *Why Information Security is Hard - an Economic Perspective* by Ross Anderson (Proceedings of the Annual Computer Security Applications Conference (ACSAC), December 2001, pp. 358-365). It's not clear that OSS/FS always avoids these disincentives, but it appears in at least some cases it does. For example, OSS/FS source code is public, so the difference in security is far more visible than in proprietary products.

One of the most dangerous security problems with proprietary software is that if intentionally malicious code is snuck into it, such code is extremely difficult to find. Few proprietary vendors have other developers examine *all* code in great detail - their testing processes are designed to catch mistakes (not malice) and often don't look at the code at all. In contrast, malicious code can be found by anyone when the source code is publicly available, and with OSS/FS, there are incentives for arbitrary people to review it (such as to add new features or perform a security review of a product they intend to use). Thus, someone inserting malicious code to an OSS/FS project runs a far greater risk of detection. Here are two examples, one confirmed, one not confirmed:

1. Some time between 1992 and 1994, Borland inserted an intentional "back door" into their database server, "InterBase", as a secret username and fixed password. This back door allowed any local or remote user to manipulate any database object and install arbitrary programs, and in some cases could lead to controlling the machine as "root". This vulnerability stayed in the product for at least 6 years - no one else could review the product, and Borland had no incentive to remove the vulnerability. Then Borland released its source code on July 2000 as an OSS/FS project. The "Firebird" project began working with the source code, and uncovered this serious security problem with InterBase in December 2000 (only 5 months after release). By January 2001 the CERT announced the existence of this back door as CERT advisory CA-2001-01. What's discouraging is that the backdoor can be easily found simply by looking at an ASCII dump of the program (a common cracker trick), so it's quite possible that this vulnerability was exploited many times in the intervening years. Once this problem was found by open source developers reviewing the code, it was patched quickly.
2. Mohammad Afroze Abdul Razzak, arrested by Mumbai (Bombay) police Oct. 2, 2001, claims that Osama bin Laden's Al Qaeda network were able to gain employment at Microsoft and attempted to plant "trojans, trapdoors, and bugs in Windows XP." This was reported to Ravi Visvesvaraya Prasad, a New Delhi information systems and telecommunication consultant, and then reported by the Washington Post's Newsbytes division. This claim has not been confirmed; indeed, I'm somewhat skeptical. The problem, however, is that this is impossible to disprove. Even if this particular case isn't true, note that this threat is unfortunately a credible threat to proprietary software, because very few of its users can review the code. This is far less dangerous to OSS/FS software, due to the worldwide review that's possible (including the ability to see the changes made in each version).

Bruce Perens, in "Open sourcers wear the white hats", makes the interesting claim that most of the people reviewing proprietary products looking for security flaws (aside from one or two paid reviewers) are "black hats," outsiders who disassemble the code or try various types of invalid input in search of a flaw that they can exploit (and not report). There is simply little incentive, and many roadblocks, for someone to search for security flaws simply to improve someone else's proprietary product. "Only a black hat would disassemble code to look for security flaws. You won't get any 'white hats' doing this for the purpose of [just] closing the flaws." In contrast, he thinks many open source developers *do* have such an incentive. This article slightly overstates the case; there are other incentives (such as fame) that can motivate a few people to review some other company's proprietary product for security. Still, it has a point; even formal reviews often only look at designs (not code), proprietary code is often either unreviewed or poorly reviewed, and there are many cases (including the entire OpenBSD system) where legions of developers review open source code for security issues. As he notes, "open source has a lot of 'white hats' looking at the source. They often do find security bugs while working on other aspects of the code, and the bugs are reported and closed."

OSS/FS programs can be evaluated using the formal security evaluations required by some government agencies, such as the Common Criteria (ISO Standard 15408) and NIST FIPS 140, One complication has been that many governments have assumed that vendors would pay for such evaluations on their own. This assumption is a poor match for many OSS/FS projects, whose business models typically require that users who want a particular improvement (such as an evaluation) pay for that improvement (in money or effort). This doesn't make formal security evaluations of OSS/FS projects impossible, but it may require that customers change their approach to performing evaluations in some cases. In particular, customers will need to not assume that vendors will do evaluations 'for free.' Part of the problem is that many organizations' acquisition strategies were defined before OSS/FS became prevalent, and have not yet been adjusted to the widespread presence of OSS/FS. Some OSS/FS programs have multiple project sites, so an organization must select exactly what project to evaluate, but that's not really change; evaluations of proprietary programs must select a specific version too.

Here are several reports on OSS/FS program evaluations:

1. The U.S. NIAP Validated Products List shows that Novell's SuSE Linux Enterprise Server V8 successfully passed a Common Criteria EAL3+ evaluation against the Controlled Access Protection Profile (CAPP) in January 2004. Novell hopes to reach EAL 4 by the end of 2004 (consistent with earlier reports).
2. Red Hat Enterprise Linux 3 passed an EAL2 evaluation in February 2004. Various reports in IT Security and by Red Hat state that in August 2004 Red Hat Enterprise Linux 3 was successfully against the Common Criteria EAL 3+ and the Controlled Access Protection Profile (though it hasn't appeared in the Validated Products List yet). Red Hat also reports that they are working to complete an EAL 4 evaluation.
3. Mandrakesoft and others have won a 1 million Euro three-year contract to help create a highly secure Linux based solution for the French Ministry of Defense that meets Common Criteria Evaluation Assurance Level (EAL) 5.
4. Trusted Computer Solutions Inc. of Herndon, Va., expects to begin beta-testing Trusted Linux this fall and seek Common Criteria certification at EAL 4 to meet not only the Controlled Access Protection Profile (CAPP), but the additional requirements of the Labeled Security Protection Profile, the Role-based Access Control Protection Profile, and the requirements of Director of Central Intelligence Directive 6/3.
5. The IBM Crypto for C (ICC) library received a FIPS 140-2 level 1 certificate #384 in 2004, and it uses the cryptographic library provided by OSS/FS OpenSSL.
6. The OSS/FS cryptographic library OpenSSL is being evaluated itself using the FIPS 140 evaluation process. The OpenSSL FAQ provides more information on an effort to evaluate OpenSSL sponsored by HP and the Defense Medical Logistics Standard Support program.

Some other interesting data about security can be found in Google Facts/Statistics question about computer security and loss of data.

The "Alexis de Tocqueville Institute" (ADTI) published a white paper called "Opening the Open Source Debate" that purported to examine OSS/FS issues. Unfortunately, ADTI makes many wrong, specious, and poorly-argued claims about OSS/FS, including some related to security. Wired (in its article Did MS Pay for Open-Source Scare?) made some startling discoveries about ADTI; after querying, they found that "a Microsoft spokesman confirmed that Microsoft provides funding to the Alexis de Tocqueville Institution... Microsoft did not respond to requests for comment on whether the company directly sponsored the debate paper. De Tocqueville Institute president Ken Brown and chairman Gregory Fossedal refused to comment on whether Microsoft sponsored the report." Politech found additional suspicious information about ADTI, and UPI reported that ADTI receives a significant portion of its funding from the Microsoft Corp, and thus it essentially lobbies in favor of issues important to Microsoft. ADTI apparently has a history of creating "independent" results that are apparently paid for by corporations (e.g., see the Smoke Free for Health article about ADTI's pro-tobacco-lobby papers). Reputable authors clearly identify any potential conflict of interest, even if it's incidental; ADTI did not.

The ADTI paper makes many errors and draws unwarranted conclusions. I'll just note a few examples of the paper's problems that aren't as widely noted elsewhere: incorrect or incomplete quotations, rewriting web browser history, and cleverly omitting the most important data in one of their charts:

- The ADTI "quotes" me several times in the paper, but in some cases claims I said something I never said, and in others places them out of context by intentionally omitting important things that I said. ADTI originally claimed that I said that "without licensing the source code in a multilicense format, (referring to other more permissive licenses), it is impossible for GPL to work for a proprietary business model." But I *never said this*. In fact, I specifically noted to ADTI that Microsoft sells a GPL'ed product (a fact I'd already publicly published). Instead of removing the statement, ADTI later made up a statement and claimed that I said it. What I really said was more nuanced: "without licensing the source code in a multilicense format [GPL and other licenses], the GPL does not permit certain kinds of uses in proprietary business models." The words are similar, but this is a much narrower statement. In particular, ADTI's Brown was essentially trying to claim that the GPL was essentially incompatible with business, even though this wasn't true, I told them it wasn't true, and even provided them with examples. ADTI also claims I said that "today I would be confident that the number [of GPL software] has probably grown to 80%;" I only said that I believed the number was probably larger than 50%, but since I couldn't remember the exact figures offhand, I told them to examine my papers - a trivial search which ADTI did not do (if they had, they'd notice that I'd recently published that 71.85% of Freshmeat's software packages were covered by the GPL). More intriguing are the omissions. For example, I explained to ADTI the GPL license (which they did not understand, even though they were attacking it); ADTI seems to think that the GPL requires public release of code, but it does not. The GPL only requires that those who receive the binary executable receive the source code. This is crucial, because it means you can still keep "secrets" in GPL'ed code, in spite of ADTI's implied assertion otherwise. Besides, there's anecdotal evidence that the government uses most GPL'ed code as-is, in which case these issues don't apply - the GPL permits arbitrary use and redistribution of unmodified copies.
- For a second example, the ADTI paper rewrites the history of web browsers in an attempt to make its claims; it bases much on the claim that Mosaic was an open source web browser, but it never was; modified versions of the Unix version could only be used non-commercially without a separate license (OSS/FS must be usable commercially), and the Mac and Windows licenses were even more restrictive. It also completely omits the heavily publicized move of Netscape to OSS/FS in 1998, clearly the most important event in web browser history relating to OSS/FS. I specifically mentioned these problems to ADTI before they published their paper, but ADTI was not willing to fix their paper to meet the facts.
- Switching to the third example, ADTI includes a chart of showing source lines of code (SLOC) for various programs; it even references my paper More than a Gigabuck while noting that the Linux kernel is over 2 million SLOC. The same chart also reports that Windows XP is 30 million SLOC, an interesting statement since to my knowledge this value has not been made public (ADTI has *not* revealed their source, but has confirmed to me that they really meant Windows XP). But note the

invalid comparison - ADTI reports on the Linux kernel (a small part of an OS), and Windows XP (a whole OS), but not on an whole OSS/FS OS. ADTI willfully ignores my paper's abstract and main point, which reported that the whole Red Hat Linux 7.1 distribution is *also* 30 million SLOC; by omitting the most important data, ADTI gives false impressions. But these are merely the tip of the iceberg; the paper's flaws are so numerous, and discussing the flaws in its conclusions require so much effort, that a serious rebuttal would require writing a whole separate paper.

Thus, I recommend that anyone who reads the ADTI paper also examine the detailed rebuttals available from many different sources, since these rebuttals expose the paper's numerous flaws. Rebuttals are available from John Viega and Bob Fleck of Secure Software (Viega is a respected security expert), Juliao Duartenn (Director of the Security Skill Center, Oblog Software, SA), Roaring Penguin's David Skoll (via the Register), Ken Ambrose (via LWN), and Leon Brooks. Anthony Awtrey analyzed the changes made in the published editions of the ADTI paper. Operating system expert Andrew Tanenbaum responded to ADTI's later claim that Torvalds stole Linux, and found that ADTI's Ken Brown "doesn't have a clue what he is talking about," was "confused about patents, copyrights, and trademarks," failed to even do basic research (he failed to consider original sources and didn't bother to read the major works on his subjects), and wrote "patent nonsense." In short, ADTI's paper is a highly biased and poorly researched "report."

All of this is unfortunate, because the real Alexis de Tocqueville strongly approved of the OSS/FS's underlying approaches. Alexis de Tocqueville remarked on the extraordinary success in the United States of voluntary community associations to do many tasks, and viewed them extremely favorably. He found such associations to be remarkably effective.

There are other non-quantitative discussions on OSS/FS and security. The October 2002 paper *Open Source Digital Forensics Tools: The Legal Argument* by Brian Carrier notes that to enter scientific evidence into a United States court, a forensics tool must be reliable and relevant as determined through the "Daubert" guidelines. The paper examines then those guidelines and argues that "open source tools may more clearly and comprehensively meet the [forensics] guidelines than closed source tools." Stacey Quandt's "Linux and Windows security compared" compares Windows and GNU/Linux security qualitatively; she concludes that they're comparable in network security/protocols, deployment and operations, and trusted computing; Linux is superior in base security, application security, and open standards. The only area where Windows was ahead was in assurance, because an EAL4 Common Criteria evaluation has been completed for Windows; an EAL3 evaluation for a GNU/Linux has completed, but an EAL4 evaluation for a GNU/Linux is in process but not yet complete. Since an EAL4 GNU/Linux evaluation is expected to complete by around the end of 2004, this doesn't appear to be a long-lasting advantage for Windows.

Many security experts have stated that OSS/FS has advantages over the security of proprietary software, including Whitfield Diffie (co-inventor of public key cryptography), Bruce Schneier (expert on cryptography and computer security), Vincent Rijmen (a developer of the Advanced Encryption Standard (AES)), Elias Levy (Aleph1, the former moderator of the popular security discussion group Bugtraq). John Viega (author of a book on secure programming), and Peter Neumann. This doesn't guarantee that a particular OSS/FS program is more secure than a particular proprietary product - merely that there are some fundamental security advantages to easing public review.

In contrast, Microsoft's Jim Allchin disclosed under oath in court testimony that some Microsoft code was so flawed it could not be safely disclosed to the public. Yet more recently, Microsoft announced its "Government Security Program" to allow governments to view most source code (though not all code, and they cannot change and freely redistribute the results). Indeed, Reuters reported a survey by Forrester Research Inc. that found that most computer security experts at major companies do not think Microsoft Corporation's products are secure; 77% said security was a top concern when using Windows. The primary problem reported was that patches were not implemented, because "administrators lacked both the confidence that a patch won't bring down a production system and the tools and time to validate Microsoft's avalanche of patches."

Now it should be obvious from these figures that OSS/FS systems are not magically invincible from security flaws. Indeed, some have argued that making the source code available gives attackers an advantage (because they have more information to make an attack). While OSS/FS gives attackers more information, this ignores opposing forces: having the source code also gives the defenders more information (because they can also examine its original source code), and in addition, the defenders can improve the code. More importantly, the necessary information for breaking into a program is in the binary executable of the program; disassemblers and decompilers can quickly extract whatever information is needed from executables to break into a program, so hiding the source code isn't all that helpful for preventing attacks against attackers who are willing to use such programs. Even if source code were required (it's not), source code can often be acquired by attackers, either by simply asking for it (in exchange for funds) or by acquiring the source code itself by attack. Again, it is *not* true that proprietary programs are always more secure, or that OSS/FS is always more secure, because there are many factors at work. For example, a well-configured and well-maintained system, of any kind, will almost always be far more secure than a poorly configured and unmaintained system of any kind. For a longer description of these issues, see my discussion on open source and security (part of my book on writing secure software). However, from these figures, it appears that OSS/FS systems are in many cases *better* - not just equal - in their resistance to attacks as compared to proprietary software.

7. Total Cost of Ownership (TCO)

Total cost of ownership (TCO) is an important measure; it doesn't matter if a product starts out cheaply if it costs you more down the line. However, TCO is extremely sensitive to the set of assumptions you make.

Indeed, whatever product you use or support, you can probably find a study to show it has the lowest TCO for some circumstance. Not surprisingly, both Microsoft and Sun provide studies showing that their products have the lowest TCO. Xephon has a study determining that mainframes are the cheapest per-user (due to centralized control) at £3450 per user per year; Centralized Unix cost £7350 per user per year, and a decentralized PC environment costs £10850 per user per year. Xephon appears to be a mainframe-based consultancy, though, and would want the results to come out this way. There are indeed situations where applying a mainframe makes sense.. but as we'll see in a moment, you can use OSS/FS in such environments too.

In short, what has a smaller TCO depends on your needs and your environment. First, identify what the requirements are, including the types of applications. You must then determine the architectural options that meet these requirements. For example, GNU/Linux systems can be implemented as independent client systems with a few common servers, just like most Windows systems are. But there are many architectural alternatives, such as using X-Windows terminals (programs run on a central server (so the client systems can be extremely low-end "throw-away" systems), clustering (where tasks can be divided among many computers), or use Stateless Linux (programs run locally on the computer, but since nothing is stored locally, anyone can log into any computer later).

Then, to determine TCO you must identify all the important cost drivers (the "cost model") and estimate their costs. Don't forget "hidden" costs, such as administration costs, upgrade costs, technical support, end-user operation costs, and so on. Computer Sciences Corporation' study "Open Source: Open for Business" (pp. 39-43) identifies the TCO factors that it believes are most important for evaluating OSS/FS with proprietary software: hardware costs (including purchase price and hardware maintenance), direct software costs (including purchase price and support and maintenance), indirect software costs (especially administration of licenses), staffing costs, support costs, and downtime (CSC claims that the "modularity of Linux can allow a very lean build to be deployed, which in turn can enable more stability...").

OSS/FS has many strong cost advantages in various categories that, in many cases, will result in its having the smallest TCO:

1. **OSS/FS costs less to initially acquire.** OSS/FS costs much less to get initially. OSS/FS isn't free in the monetary sense, because the "free" in "free software" refers to freedom, not price. This distinction is usually summarized as "free speech, not free beer". Merrill Lynch executive Robert Lefkowitz found what may be a better way to describe it: "We like to think of it as 'free as in market.'"

   OSS/FS isn't cost-free, because you'll still spend money for paper documentation, support, training, system administration, and so on, just as you do with proprietary systems. In many cases, the actual programs in OSS/FS distributions can be acquired freely by downloading them (linux.org provides some pointers on how to get distributions). However, most people (especially beginners and those without high-speed Internet connections) will want to pay a small fee to a distributor for a nicely integrated package with CD-ROMs, paper documentation, and support. Even so, OSS/FS costs far less to acquire.

   For example, examine the price differences when trying to configure a server, such as public web server or an intranet file and email server, in which you'd like to use C++ and an RDBMS. This is simply an example; different missions would involve different components. Using the prices from "Global Computing Supplies" (Suwanee, GA), September 2000, rounded to the nearest dollar, here is a quick summary of the purchasing costs:

	Microsoft Windows 2000	Red Hat Linux
Operating System	$1510 (25 client)	$29 (standard), $76 deluxe, $156 professional (all unlimited)
Email Server	$1300 (10 client)	included (unlimited)
RDBMS Server	$2100 (10 CALs)	included (unlimited)
C++ Development	$500	included

   Basically, Microsoft Windows 2000 (25 client) costs $1510; their email server Microsoft Exchange (10-client access) costs $1300, their RDBMS server SQL Server 2000 costs $2100 (with 10 CALs), and their C++ development suite Visual C++ 6.0 costs $500. Red Hat Linux 6.2 (a widely-used GNU/Linux distribution) costs $29 for standard (90 days email-based installation support), $76 for deluxe (above plus 30 days telephone installation support), or $156 for professional (above plus SSL support for encrypting web traffic); in all cases it includes all of these functionalities (web server, email server, database server, C++, and much more). A public web server with Windows 2000 and an RDBMS might cost $3610 ($1510+$2100) vs. Red Hat Linux's $156, while an intranet server with Windows 2000 and an email server might cost $2810 ($1510+$1300) vs. Red Hat Linux's $76.

Both packages have functionality the other doesn't have. The GNU/Linux system always comes with an unlimited number of licenses; the number of clients you'll actually use depends on your requirements. However, this certainly shows that no matter what, Microsoft's server products cost thousands of dollars more per server than the equivalent GNU/Linux system.

For another in-depth analysis comparing the initial costs GNU/Linux with Windows, see *Linux vs. Windows: The Bottom Line* by Cybersource Pty Ltd. Here's a summary of their analysis (in 2001 U.S. dollars):

	Microsoft Solution	OSS/FS (GNU/Linux) Solution	Savings by using GNU/Linux
Company A (50 users)	$69,987	$80	$69,907
Company B (100 users)	$136,734	$80	$136,654
Company C (250 users)	$282,974	$80	$282,894

Consulting Times found that as the number of mailboxes got large, the three-year TCO for mainframes with GNU/Linux became in many cases quite compelling. For 50,000 mailboxes, an Exchange/Intel solution cost $5.4 million, while the Linux/IBM(G6) solution cost $3.3 million. For 5,000 mailboxes, Exchange/Intel cost $1.6 million, while Groupware on IFL cost $362,890. For yet another study, see the Cost Comparison from jimmo.com. Obviously, the price difference depends on exactly what functions you need for a given task, but for many common situations, GNU/Linux costs far less to acquire.

2. **Upgrade/maintenance costs are typically far less.** Long-term upgrade costs are far less for OSS/FS systems. For example, upgrading a Microsoft system will typically cost around half the original purchase. What's worse, you are essentially at their mercy for long-term pricing, because there is only one supplier (see *Microsoft Turns the Screws*). In contrast, the GNU/Linux systems can be downloaded (free), or simply re-purchased (generally for less than $100), and the single upgrade be used on every system. This doesn't include technical support, but the technical support can be competed (a situation that's not practical for proprietary software). An anti-trust lawyer would say that OSS/FS technical support is "contestable." In short, if you don't like your GNU/Linux supplier (e.g., they've become too costly), you can switch.
3. **OSS/FS does not impose license management costs and avoids nearly all licensing litigation risks.** Proprietary vendors make money from the sale of licenses, and are imposing increasingly complex mechanisms on consumers to manage these licenses. Customers who cannot later prove than they paid for every installed copy of proprietary software (e.g., due to copying by an employee or losing the license paperwork) risk stiff penalties. In short: by using proprietary software, you run the risk of having the vendor sue you.

To counter these risks, organizations must keep careful track of license purchases. This means that organizations must impose strict software license tracking processes, purchase costly tracking programs, and pay for people to keep track of these licenses and perform occasional audits.

In contrast, there's no license management or litigation risk in using OSS/FS software. Some OSS/FS software do have legal requirements if you modify the program or embed the program in other programs, but proprietary software usually forbids modifying the program and often also imposes licensing requirements for embedding a program (e.g., royalty payments). Thus, software developers must examine what components they're employing to understand their ramifications, but this would be true for both OSS/FS and proprietary programs. See the licensing litigation discussion later in this paper for more about licensing costs and risks.

4. **OSS/FS can often use older hardware more efficiently than proprietary systems, yielding smaller hardware costs and sometimes eliminating the need for new hardware.** OSS/FS runs faster on faster hardware, of course, but many OSS/FS programs can use older hardware more efficiently than proprietary systems, resulting in lower hardware costs - and in some cases requiring no new costs (because "discarded" systems can suddenly be used again). For example, the minimum requirements for Microsoft Windows 2000 Server (according to Microsoft) are a Pentium-compatible CPU (133 MHz or higher), 128 MiB of RAM minimum (with 256MiB the "recommended minimum"), and a 2 GB hard drive with at least 1.0 GB free. According to Red Hat, Red Hat Linux 7.1 (a common distribution of GNU/Linux) requires at a minimum an i486 (Pentium-class recommended), 32MiB RAM (64MiB recommended), and 650MB hard disk space (1.2 GB recommended).

   In Scientific American's August 2001 issue, the article The Do-It-Yourself Supercomputer discusses how the researchers built a powerful computing platform with many discarded computers and GNU/Linux. The result was dubbed the "Stone Soupercomputer"; by May 2001 it contained 133 nodes, with a theoretical peak performance of 1.2 gigaflops.

5. **When used as an application server based system, the total costs for hardware drop by orders of magnitude**. Many people make the mistake of deploying OSS/FS workstations (such as GNU/Linux or the *BSDs) the same way they would deploy Windows systems. Although it's possible, this is an unnecessarily costly approach if they're installing a set of workstations for typical productivity applications (e.g., word processing, spreadsheets, etc. for an office), For many, a better approach is to provide each user with a very old GNU/Linux-based machine which is merely a graphics display (an "X terminal"), and then run the actual applications on an "application server" that is shared by all the users. See How to create a Linux-based network of computers for peanuts for more information about this. With this application server approach, workstations can cost about $30 each (using "obsolete" machines), a server (shared by many users) can cost about $1000 each, and nearly all system administration is centralized (reducing administration costs). A nice side-effect of this approach is that users can use any workstation just by logging in. A more detailed discussion of this approach is given in Paul Murphy's article, *Total cost of ownership series revisited*. Linux Style: Windows PCs vs. X Terminals: A Cost Comparison describes how the Mark O. Hatfield Library at Willamette University has used networked X terminals in its public and staff computing environments since 1995. The 15-year cost of 25 Linux systems in this environment is estimated to be $41,359 versus a 15-year cost of $100,000 to $155,000 for Windows PCs serving the same

function. This is how the City of Largo, Florida, and many other organizations use GNU/Linux.

6. **As the number of systems and hardware performance increases, this difference in initial and upgrade costs becomes even more substantial.** As the number of servers increases, proprietary solutions become increasingly costly. First, many proprietary systems (including Microsoft) sell per-client licenses; this means that even if your hardware can support more clients, you'll must pay more to actually use the hardware you've purchased. Secondly, if you want to use more computers, you must pay for more licenses in proprietary systems. In contrast, for most GNU/Linux distributions, you can install as many copies as you like for no additional fee, and there's no performance limit built into the software. There may be a fee for additional support, but you can go to competing vendors for this support.

   According to Network World Fusion News, Linux is increasingly being used in healthcare, finance, banking, and retail due to its cost advantages when large numbers of identical sites and servers are built. According to their calculations for a 2,000 site deployment, SCO UnixWare would cost $9 million, Windows would cost $8 million, and Red Hat Linux costs $180.

7. **There are many other factors; their effect varies on what you're trying to do.** There are many other factors in TCO, but it's difficult to categorize their effects in general, and it's generally difficult to find justifiable numbers for these other effects. Windows advocates claim that system administrators are cheaper and easier to find than Unix/Linux administrators, while GNU/Linux and Unix advocates argue that fewer such administrators are needed (because administration is easier to automate and the systems are more reliable to start with). Various reports have mentioned this (a Red Hat executive stated that one Wall Street bank has one administrator for 800 machines), quantitative studies are beginning to back this claim that fewer administrators are needed. Some GNU/Linux advocates have told me that GNU/Linux lends itself to hosting multiple services on one server in cases where Windows installations must use multiple servers. License compliance administration can be costly for proprietary systems (e.g., time spent by staff to purchase CALS, keep track of licenses, and undergo audits) - a cost that simply isn't relevant to OSS/FS.
8. **Cybersource's 2002 study found TCO savings of 24% to 34% when using OSS/FS instead of Microsoft's proprietary approach.** Cybersource's "Linux vs. Windows: Total Cost of Ownership Comparison" modeled an organization with 250 computer-using staff, an appropriate number of workstations, servers, with Internet connectivity, an e-business system, network cabling and hardware, standard software, and salaries for IT professionals to establish and support this infrastructure and technology. Using existing hardware and infrastructure, they found a three-year savings of 34.26% ($251,393 U.S. dollars) when using the "Linux/Open Source Solution" instead of the proprietary "Microsoft solution". When new hardware and infrastructure were purchased, the savings were 24.69%. Note that this study is a follow-on of their earlier study; a commentary is available at Linux Journal. It could be argued that this was merely a paper study, but they claim that they've seen significant savings in their consulting work. In any case, TCO savings have been reported by real organizations, corroborating these results, as discussed below.
9. **An Italian study in 2002 found GNU/Linux to have a TCO 34.84% less than Windows.** The full study is in Italian; you can try to read an automatically-generated translation.
10. **For many circumstances, the total cost savings can be substantial. For example, real-world savings exceeding $250,000 *per year* were reported by 32% of the Chief Technical Officers (CTOs) surveyed in a 2001 InfoWorld survey; 60% of**

these CTOs saved over $50,000 annually. The August 27, 2001 InfoWorld (pages 49-50) reported on a survey of 40 CTOs who were members of the InfoWorld CTO network. In this survey, 32% using OSS reported savings greater than $250,000; 12% reported savings between 100,001 and $250,000; and 16% reported saving between $50,001 and $100,000. Indeed, only 8% reported annual savings less than $10,000 (so 92% were saving $10,000 or more annually). A chief benefit of OSS, according to 93% of the CTOs, was reduced cost of application development or acquisition; 72% said that a chief benefit was reduced development or implementation time (multiple answers were allowed). The CTOs reported using or planning to use OSS for web servers (65%), server OSes (63%), web-application servers (45%), application development testing (45%), and desktop OS (38%), among other uses. InfoWorld summarized it this way: "in early 2000, it seemed as if no one was using open-source software for business-critical tasks... a vast majority of today's corporate IT executives are now using or plan to use OSS OSes and web servers for their enterprise applications."

11. **The Robert Frances Group's July 2002 study found the TCO of GNU/Linux is roughly 40% (less than half) that of Microsoft Windows and only 14% that of Sun Microsystem's Solaris.** The Robert Frances Group (RFG), in Westport, Conn., studied actual costs at production deployments of Web servers running on GNU/Linux with Apache, Microsoft Windows with IIS, and Sun Solaris with Apache at 14 Global 2000 enterprises. These are *real* deployments where, if the web server goes down, money is lost - not minor prototype sites. Their TCO analysis was based on the software purchase price, hardware purchase and maintenance prices, software maintenance and upgrade prices, and administrative costs. To make the numbers comparable, these figures were were scaled to a "processing unit" able to handle 100,000 hits per day; see the study for more information. They determined that over three years a (scaled) GNU/Linux deployment cost $74,475, a Windows deployment cost $190,662, and a Solaris deployment cost $534,020. Thus, the cost of running GNU/Linux is roughly 40% that of Microsoft Windows and only 14% that of Sun Microsystem's Solaris.

    This report also found that GNU/Linux and Solaris had smaller administrative costs than Windows. Although Windows system administrators cost less individually, each Linux or Solaris administrator could administrate many more machines, making Windows administration much more costly. The study also revealed that Windows administrators spent twice as much time patching systems and dealing with other security-related issues than did Solaris or GNU/Linux administrators.

    RFG also examined some areas that were difficult to monetize. In the end, they concluded that "Overall, given its low cost and flexible licensing requirements, lack of proprietary vendor goals, high level of security, and general stability and usability, Linux is worth considering for most types of server deployments."

12. **Netproject reported that the TCO with Linux on the desktop was 35% that of Microsoft Windows (a 65% savings).** Netproject's Cost of Ownership report found a very significant savings, and it reported the following causes:
    - The elimination of license fees for both the system software and office software;
    - Elimination of vendor churn that forces unnecessary software updates;
    - Reduction in the number of software security updates;
    - No need for anti-virus software for Linux computers [anti-virus software for Linux is only needed to check for viruses that run on Microsoft PCs];
    - Reduction in the number of support staff.

13. **A majority of InternetWeek Newsbreak subscribers from companies with over $5 million in revenues reported that OSS/FS software costs substantially less than proprietary software**.

    A survey was by TheOpenEnterprise.com (a joint editorial effort between InternetWeek.com and InformationWeek) of individuals with management responsibility for IT and software specifically in companies with over $5 million in revenue. In this survey, 39% said "open source/standards-based software" costs 25% to 50% less than proprietary software, while 27% (over 1 in 4) said it' costs 50% to 75% less. In context, it appears their phrase was intended to mean the same (or similar) thing as the term OSS/FS in this paper, since in many cases they simply use the term "open-source." As they note, "Would your CFO react favorably to a 50-75% reduction in software costs?"

14. **A report by *Research and Markets* found a number of caes where deploying open source software resulted in significant savings.** The report Saving Cash: A Comparison of Open Source and Proprietary Software (Oct 2004, 95 pages) on OSS/FS in Germany shows significant saving potentials through the deployment of open source software for different company sizes. The study found that the risk for users on account of copyright or patent violations is minimal. A set of interviews were used to create a detailed TCO model, and they perform calculations with typical case studies. Warning: This is an expensive report.
15. **Many organizations report significant savings when using OSS/FS.** Here are a few examples of specific organizations saving money through OSS/FS:
    a. The analysis *Linux as a Replacement for Windows 2000* compares Red Hat Linux 7.1 to Windows 2000; in this customer's case, using Linux instead of Windows 2000 saved $10,000. The reviewer came from a Windows/DOS background, and after performing an intensive hands-on Linux project lasting several months, determined that "you will be stunned by the bang for the buck that ... open source software offers."
    b. Intel's IT Vice President, Doug Busch, reported savings of $200 million by replacing costly Unix servers with cheaper servers running GNU/Linux.
    c. Amazon.com was able to cut $17 million in technology expenses in a single quarter, largely due to a switch to Linux. Amazon spent $54 million on technology and content expenses in its third quarter (ending Sept. 30), compared with $71 million in the year-ago quarter, and executives expected that technology costs as a portion of net sales would decrease by 20% this year.
    d. The city of Largo, Florida reports a savings of $1 million per year using GNU/Linux and "thin clients."
    e. Dell offers a savings of 21% when using GNU/Linux. Dell computer has a dedicated hosting service, such as their D-2800 offering. This service offers a respectable system (Pentium 850, 256MiB, 20GB, 21GB/month bandwidth) in two configurations: Red Hat Linux 7.1 for $189/month, and Windows 2000 for $239/month. Thus, with identical hardware and bandwidth provision, the GNU/Linux system is 21% cheaper. This is especially interesting because Dell is not out to prove which system is better; as a business, they've just figured out competitive prices at which they can offer their services.
    f. An independent report in Denmark concluded that if the political goals for using the Internet to improve the public sector are to be fulfilled, it would be $500 million cheaper over the next 10 years to use OSS/FS instead of Microsoft software (my thanks to Poul-Henning Kamp, who translated the conclusions).

There are many other reports from those who have switched to OSS/FS systems; see the usage reports section for more information.

16. **Even Microsoft has admitted that its products are more costly than GNU/Linux.** For some time Microsoft has tried to convince users that its products are somehow less costly. However, as documented in Var Business and The Register, Microsoft CEO Steve Ballmer in 2002 admitted that Microsoft has not "figured out how to be lower-priced than Linux. For us as a company, we're going through a whole new world of thinking." The Register summarizes Microsoft's new approach as saying that "it costs more because it's worth more"; whether this is true is rather debatable in many cases, but at least it's a more sensible argument. However, Microsoft has gone back to trying to claim that they cost less, so the detail in this section is still needed.
17. **A Microsoft-sponsored study claims that Windows is cheaper than Linux, but this has been debunked as a general claim.** The Microsoft-sponsored study (available from Microsoft) compared Windows 2000 to Linux; it stated that Linux had lower TCO for webserving, and Windows 2000 had a lower TCO for network infrastructure, print serving, file serving and security applications (note: the "David Wheeler" quoted in InfoWorld is not the author of this paper). I will give credit here: unlike the Mindcraft reports sponsored by Microsoft, this TCO report clearly states that it was sponsored by Microsoft, and I appreciate that.

    It's important to examine the assumptions of any TCO study, to see if its assumptions could apply to many other situations - and it is easily argued that they don't. Joe Barr discusses some of the problems in this TCO study. These include assuming that the operating system is never upgraded in a 5-year period, using an older operating system Microsoft is transitioning *from*, and not using the current Enterprise license agreement (which many organizations find they must use). Costs that are not included in the study include legal advice costs (when signing large-scale agreements), purchase and maintenance of a software license inventory system (which you'll generally need even with Enterprise agreements), costs if you are audited, cost of insurance and liability incidents (if a proof of purchase is misplaced, you might need to pay the $151,000 per-incident liability), and paying multiple times for the same product (a side-effect of many Enterprise license agreements).

    Barr concludes with: "TCO is like fine wine: it doesn't travel well. What may be true in one situation is reversed in another. What gets trumpeted as a universal truth ('Windows is cheaper than Linux') may or may not be true in a specific case, but it is most certainly false when claimed universally." Since the TCO of a system depends on its application, and Microsoft as sponsor could specifically set all of the parameters, the conclusions of the report were easily predicted.

18. **Another Microsoft-sponsored study claims that Microsoft's toolsuite with .NET is cheaper than using GNU/Linux with J2EE.** This Giga Research study sponsored by Microsoft compared the costs incurred by five large and medium-size companies that used J2EE (Java 2 Enterprise Edition) with the costs incurred by seven large and medium-size companies that used .Net applications to develop Web portal applications. For large corporations, the cost of using Microsoft products (for development and deployment plus three years of maintenance) was 28% less than for J2EE/Linux. For medium-size companies, the Microsoft products were 25% cheaper.

    However, once again, the TCO values all hinge on the assumptions made. As CIO.com points out, the Microsoft-based solution was cheaper primarily because the GNU/Linux systems were configured using extremely expensive proprietary products

> such as those from Oracle (for the database system) and BEA (for the development system).
>
> A company can certainly choose to use these particular products when developing with GNU/Linux, but not all organizations will choose to do so. Indeed, the acronym “LAMP” (Linux, Apache, MySQL, and PHP/Python/Perl) was coined because that combination is extremely popular when creating web portal applications. MySQL and PostgreSQL are popular OSS/FS database programs; PHP, Python, and Perl are popular OSS/FS development languages (and tie easily into the rest of the development suite provided by OSS/FS operating systems). An obvious question to ask is, “Why were extremely common configurations (such as LAMP) omitted in this Microsoft-funded study?” CIO.com reports Giga’s answer: “Microsoft didn’t ask them [to] look at any such companies.”
>
> Again, I give credit to Giga for clearly reporting who funded the study. Indeed, if your situation closely matches Giga’s study, your costs might be very similar. But it would be a mistake to conclude that different situations would necessarily have the same results.

You may also want to see MITRE Corporation’s business case study of OSS, which considered military systems.

Most of these items assume that users will use the software unmodified, but even if the OSS/FS software doesn’t do everything required, that is not necessarily the end of the story. One of the main hallmarks of OSS/FS software is that it can be modified by users. Thus, any true TCO comparison should consider not just the products that fully meet the requirements, but the existing options that with some modifications could meet the requirements. It may be cheaper to start with an existing OSS/FS program, and improve it, than to start with a proprietary program that has all of the necessary functionality. Obviously, the total TCO including such costs varies considerably depending on the circumstances.

Brendan Scott (a lawyer specializing in IT and telecommunications law) argues that the long run TCO of OSS/FS must be lower than proprietary software. Scott’s paper makes some interesting points, for example, “TCO is often referred to as the total cost of ‘ownership’... [but] ‘ownership’ of software as a concept is anathema to proprietary software, the fundamental assumptions of which revolve around ownership of the software by the vendor. ... The user [of proprietary software] will, at best, have some form of (often extremely restrictive) license. Indeed, some might argue that a significant (and often uncosted) component of the cost of ‘ownership’ of proprietary software is that users don’t own it at all.” The paper also presents arguments as to why GPL-like free software gives better TCO results than other OSS/FS licenses. Scott concludes that “Customers attempting to evaluate a free software v. proprietary solution can confine their investigation to an evaluation of the ability of the packages to meet the customer’s needs, and may presume that the long run TCO will favor the free software package. Further, because the licensing costs are additional dead weight costs, a customer ought to also prefer a free software solution with functionality shortfalls where those shortfalls can be overcome for less than the licensing cost for the proprietary solution.”

Microsoft’s first TCO study comparing Windows to Solaris (mentioned earlier) is not a useful starting point for estimating your own TCO. Their study reported the average TCO at sites using Microsoft products compared to the average TCO at sites using Sun systems, but although the Microsoft systems cost 37% less to own, the Solaris systems handled larger databases, more demanding applications, 63% more concurrent connections, and 243% more hits per day. In other words, the Microsoft systems that did less work cost less than systems that did more work. This is not a useful starting point if you’re using TCO to help determine which system to buy - to make a valid comparison by TCO, you must compare the TCOs of systems that meet your requirements. A two-part analysis by Thomas Pfau (see part 1 and part 2) identifies this and many other flaws in the study.

There are some studies that emphasize Unix-like systems, not OSS/FS, which claim that that there are at least some circumstances where Unix-like systems are less costly than Windows. A Strategic Comparison of Windows vs. Unix by Paul Murphy is one such paper. It appears that many of these arguments would also apply to OSS/FS systems, since many of them are Unix-like.

Be sure that you actually compute your own TCO; don’t just accept a vendor’s word for it, and in particular, don’t just accept a vendor’s claims for the TCO of its competitors. In 2004 Newham council chose Microsoft products over a mixed solution, reporting that their selected solution had a lower TCO according to an independent study. Yet when the reports were made public in September 2004, it was discovered that it was *Microsoft* who created the cost figures of switching to their competitor - not an independent source at all. Any vendor (open or closed) can tell you why their competitor costs more money, if you naïvely let them.

Again, it’s TCO that matters, not just certain cost categories. However, given these large differences in certain categories, in many situations OSS/FS has a smaller TCO than proprietary systems. At one time it was claimed that OSS/FS installation took more time, but nowadays OSS/FS systems can be purchased pre-installed and automatic installers result in equivalent installation labor. Some claim that system administration costs are higher, but studies like Sun’s suggest than in many cases the system administration costs are lower, not higher, for Unix-like systems (at least Sun’s). For example, on Unix-like systems it tends to be easier to automate tasks (because you can, but do not need, to use a GUI) - thus over time many manual tasks can be automated (reducing TCO). Retraining costs can be significant - but now that GNU/Linux has modern GUI desktop environments, there’s anecdotal evidence that this cost is actually quite small. I’ve yet to see serious studies quantitatively evaluating this issue, but anecdotally, I’ve observed that people familiar with other systems are generally able to sit down and use modern GNU/Linux GUIs without any training at all. In short, it’s often hard to show that a proprietary solution’s purported advantages really help offset their demonstrably larger costs in other categories when there’s a competing mature OSS/FS product for the given function.

Factors that need to be included in a TCO analysis is switching costs; most people remember to include the costs of switching *to* something, but forget to include the extremely important costs of switching *away* from it later. As noted in ???, Linux Adoption in the Public Sector: An Economic Analysis by Hal R. Varian and Carl Shapiro (University of California, Berkeley; 1 December 2003), “a system that will be difficult to switch away from in the future, in part because the lock-in associated with using such a system[,] will reduce their future bargaining power with their vendor. Vendors always have some incentive to make it difficult for users to switch to alternatives, while the users will generally want to preserve their flexibility. From the user’s viewpoint, it is particularly important to make sure that file formats, data, system calls, APIs, interfaces, communication standards, and the like are well enough documented that it is easy to move data and programs from one vendor to another.” Obviously, someone who elects to use a proprietary program that locks them into that specific program will almost certainly pay much higher prices in future updates, because the vendor can exploit the user’s difficulty in changing.

Clearly, if one product is significantly more productive than another where it’s used, it’s worth paying more for it. However, it’s clear that at least for major office tasks, GNU/Linux systems are about as usable as Windows systems. For example, one usability study comparing

GNU/Linux to Microsoft Windows XP found that it was almost as easy to perform most major office tasks using GNULinux as with Windows: “Linux users, for example, needed 44.5 minutes to perform a set of tasks, compared with 41.2 minutes required by the XP users. Furthermore, 80% of the Linux users believed that they needed only one week to become as competent with the new system as with their existing one, compared with 85% of the XP users.” The detailed report (in German) is also available.

Does this mean that OSS/FS always have the lowest TCO? No! As I’ve repeatedly noted, it depends on its use. But the notion that OSS/FS *always* has the larger TCO is simply wrong.

8. Non-Quantitative Issues

In fairness, I must note that not all issues can be quantitatively measured, and to many they are the most important issues. The issues important to many include freedom from control by another (especially a single source), protection from licensing litigation, flexibility, social / moral / ethical issues, and innovation.

1. **OSS/FS protects its users from the risks and disadvantages of single source solutions.** While “free software” advocates use the term “freedom,” and some businesses emphasize different terms such as “free market”, “multiple sources”, “alternate supply channels”, and “the necessity of multiple vendors”, the issue is the same: users do not want to be held hostage by any one vendor. Businesses often prefer to buy products in which there is a large set of competing suppliers, because it reduces their risk; they can always switch to another supplier if they’re not satisfied, the supplier raises their prices substantially, or the original supplier goes out of business. This translates into an effect on the products themselves: if customers can easily choose and switch between competing products, the products’ prices go down and their quality goes up. Conversely, if there is a near or real monopoly for a given product, over time the vendor will continuously raise the cost to use the product and limit its uses to those that benefit the monopolist. Users who are unwilling to leave single source solutions often pay dearly later as their single source raises their costs.

   For example, many organizations have chosen to use Microsoft’s products exclusively, and Microsoft is trying to exploit this through its new “Microsoft Licensing 6.0 Program.” The TIC/Sunbelt Software Microsoft Licensing Survey Results (covering March 2002) reports the impact on customers of this new licensing scheme. 80% had a negative view of the new licensing scheme, noting, for example, that the new costs for software assurance (25% of list for server and 29% of list for clients) are the highest in the industry. Of those who had done a cost analysis, an overwhelming 90% say their costs will increase if they migrate to 6.0, and 76% said their costs would increase from 20% to 300% from what they are paying now under their current 4.0 and 5.0 Microsoft Licensing plans. This survey found that 36% of corporate enterprises don’t have the funds to upgrade to the Microsoft Licensing 6.0 Program. Half indicated that the new agreement would almost certainly delay their migration initiatives to new Microsoft client, server and Office productivity platforms, and 38% say they are actively seeking alternatives to Microsoft products. In New Zealand a Commerce Commission Complaint has been filed claiming that Microsoft’s pricing regime is anti-competitive. Craig Horrocks notes that the Software Assurance approach does not assure that the purchaser receives anything for the money; it merely buys the right to upgrade to any version Microsoft releases in the covered period. Microsoft may levy further charges on a release, and the contract does not obligate Microsoft to deliver anything in the time period.

There are increasing concerns about Microsoft's latest releases of Windows. Michael Jennings argues in *Windows XP Shows the Direction Microsoft is Going* that Microsoft users are increasingly incurring invasion of privacy, intentionally crippled yet necessary services, and other problems.

More generally, defining an organization's "architecture" as being whatever one vendor provides is sometimes called "Vendor Lock-in" or "Pottersville", and this "solution" is a well-known AntiPattern (an AntiPattern is a "solution" that has more problems than it solves).

Having only one vendor completely control a market is dangerous from the viewpoint of costs (since the customer then has no effective control over costs), and it also raises a security concern: the *monoculture vulnerability*. In biology, it is dangerous to depend on one crop strain, because any disease can cause the whole crop to fail. Similarly, one proprietary vendor who completely controls a market creates a uniformity that is far easier to massively attack. OSS/FS programs provide an alternative implementation, and even when one dominant OSS/FS program exists, because they can be changed (because the source code is available) at least some implementations are likely to be more resistant to attack.

Historically, proprietary vendors eventually lose to vendors selling products available from multiple sources, even when their proprietary technology is (at the moment) better. Sony's Betamax format lost to VHS in the videotape market, IBM's microchannel architecture lost to ISA in the PC architecture market, and Sun's NeWS lost to X-windows in the networking graphics market, all because customers prefer the reduced risk (and eventually reduced costs) of non-proprietary products. This is sometimes called "commodification", a term disparaged by proprietary vendors and loved by users. Since users spend the money, users eventually find someone who will provide what they want, and then the other suppliers discover that they must follow or give up the market area.

With OSS/FS, users can choose between distributors, and if a supplier abandons them they can switch to another supplier. As a result, suppliers will be forced to provide good quality products and services for relatively low prices, because users can switch if they don't. Users can even band together and maintain the product themselves (this is how the Apache project was founded), making it possible for groups of users to protect themselves from abandonment.

The article Commentary from a new user: Linux is an experience, not an operating system, describes freedom this way:

"As I worked in Linux... the word 'free' took on a far greater meaning. As the advocates of the Open Source and Free Software movements put it, free means freedom. Yes, as a humble user of Linux, I am experiencing freedom and pride in using a world-class operating system.

Linux is not only an operating system. It embodies a myriad of concepts about how the world of computers and software should be. This is an operating system designed by the world, meant for the world. Everyone who is interested in Linux, can develop, share and use it. People can contribute their best in programming, documenting or in any aspect of their choice. What a novel concept!

Free in Linux spells freedom -- freedom to use Linux, freedom to use the code, freedom to tweak and improve it. Not being a programmer, I still can be happy about many things. For me, freedom has meant that my operating system is transparent, and there are no hidden codes at work in my computer. Nothing about Linux is hidden from me. ... I've gained more control over my computer for the first time in my life."

2. **OSS/FS protects its users from licensing litigation and management costs.** Proprietary vendors make money from the sale of licenses, and are imposing increasingly complex mechanisms on consumers to manage these licenses. For example, Microsoft's Windows XP requires product activation - a scheme that means that an accumulation of hardware changes requires a new activation code. A license no longer gives unlimited rights to reinstall - if you have hardware trouble, you may end up being forced to re-buy your product. Indeed, for a variety of reasons, businesses are finding that they must buy the same proprietary software more than once.

   Proprietary vendors also litigate against those who don't comply with their complex licensing management requirements, creating increased legal risks for users. For example, the Business Software Alliance (BSA) is a proprietary software industry organization sponsored by Microsoft, Macromedia, and Autodesk, and spends considerable time searching for and punishing companies who cannot prove they are complying. As noted in the SF Gate (Feb. 7, 2002), the BSA encourages disgruntled employees to call the BSA if they know of any license violations. "If the company refuses to settle or if the BSA feels the company is criminally negligent and deliberately ripping off software, the organization may decide to get a little nastier and organize a raid: The BSA makes its case in front of a federal court in the company's district and applies for a court order. If the order is granted, the BSA can legally storm the company's offices, accompanied by U.S. marshals, to search for unregistered software."

   Software Licensing by Andrew Grygus discusses the risks and costs of proprietary licensing schemes in more detail. According to their article, "the maximum penalty is $150,000 per license deficiency; typically, this is negotiated down, and a company found deficient at around $8,000 will pay a penalty of around $85,000 (and must buy the $8,000 in software too)." For example, information services for the city of Virginia Beach, VA were practically shut down for over a month and 5 employees (1/4th of their staff) had to be dedicated to put its licensing in order to answer a random audit demand by Microsoft, at a cost of over $80,000. Eventually the city was fined $129,000 for missing licenses the city had probably paid for but couldn't match to paperwork. Temple University had to pay $100,000 to the BSA, in spite of strong policies forbidding unauthorized copying.

   To counter these risks, organizations must keep careful track of license purchases. This means that organizations must impose strict software license tracking processes, purchase costly tracking programs, and pay for people to keep track of these licenses and perform occasional audits.

   A related problem is that companies using proprietary software must, in many cases, get permission from their software vendors to sell a business unit that uses the proprietary software, or face legal action. For example, Microsoft has filed objections to Kmart's proposed $8.4 million sale of Bluelight.com to United Online Inc., citing software licensing as one of their concerns. Microsoft stated that "The licenses that debtors (Kmart) have of Microsoft's products are licenses of copyrighted materials and, therefore, may not be assumed or assigned with[out] Microsoft's consent." Whether or not this is a risk depends on the licensing scheme used; in many cases it appears that the legal "right of first sale" doctrine cannot be applied (for example, there are many different licensing schemes for Windows, so the same action with Windows may be legal or not depending on the licensing scheme used to acquire it).

In contrast, OSS/FS users have no fear of litigation from the use and copying of OSS/FS. Licensing issues do come up when OSS/FS software is modified and then redistributed, but to be fair, proprietary software essentially forbids this action (so it's a completely new right). Even in this circumstance, redistributing modified OSS/FS software generally requires following only a few simple rules (depending on the license), such as giving credit to previous developers and releasing modifications under the same license as the original program.

One intriguing example is the musical instrument company Ernie Ball, described in *World Trade*, May 2002. A disgruntled ex-employee turned them into the Business Software Alliance (BSA); who then arranged to have them raided by armed Federal Marshals. Ernie Ball was completely shut down for a day, and then was required to not touch any data other than what is minimally needed to run their business. After the investigation was completed, Ernie Ball was found to be noncompliant by 8%; Ball argued that it was "nearly impossible to be totally compliant" by their rules, and felt that they were treated unfairly. The company ended up paying a $90,000 settlement, $35,000 of which were Microsoft's legal fees. Ball then decided at that moment his company would become "Microsoft free." In one year he converted to a Linux-based network and UNIX "mainframe" using Sun's StarOffice (Sun's proprietary cousin to OpenOffice); he now has no Microsoft products at all, and much of the software is OSS/FS or based on OSS/FS products.

3. **OSS/FS has greater flexibility.** OSS/FS users can tailor the product as necessary to meet their needs in ways not possible without source code. Users can tailor the product themselves, or hire whoever they think can solve the problem (including the original developer). Some have claimed that this creates the "danger of forking," that is, of multiple incompatible versions of a product. This is "dangerous" only to those who think competition is evil - we have multiple versions of cars as well. And in practice, the high cost of maintaining software yourself has resulted in a process in which the change is contributed back to the community. If it's not contributed (e.g., it solves a problem that needed solving but only for a specialized situation), then it's still a win for the user - because it solved a user's problem which would have been unsolved otherwise.

   For example, in 1998 Microsoft decided against developing an Icelandic version of Windows 95 because the limited size of the market couldn't justify the cost. Without the source code, the Islandic people had little recourse. However, OSS/FS programs can be modified, so Icelandic support was immediately added to them, without any need for negotiation with a vendor. In contrast, in July 2004, Welch support for in the OSS/FS OpenOffice.org became available, the first complete office environment available in Welsh. Users never know when they will have a specialized need not anticipated by their vendor; being able to change the source code makes it possible to support those unanticipated needs.

4. **Many believe that there are social, moral, or ethical imperatives for using OSS/FS**. The Free Software Foundation has a set of papers describing their philosophy, i.e., why they believe Free Software is an ethical imperatives. These lengthy documents explain themselves in depth, so there's little need to describe them further here.
5. **There is ample evidence that OSS/FS encourages, not quashes, innovation.** Innovation is a strength, not a liability, for OSS/FS. InformationWeek's survey of

business-technology professionals “Open-Source Software Use Joins The Mix”, published in November 2004, found that OSS/FS “is believed to create more opportunities for innovation than commercial or proprietary software.” Nearly 60% of the companies with annual revenue of $100 million or more stated that OSS/FS creates more opportunities for innovation. Small businesses (less than $100 million), where much innovation takes place, agreed even more strongly; “almost three-quarters report open-source software readily promotes more opportunities for IT innovation.” This is consistent with previous surveys of expectations. The February 2001 research paper Distributed Knowledge and the Global Organization of Software Development by Anca Metiu and Bruce Kogut (The Wharton School, University of Pennsylvania) reports on field observations of companies in four countries. They state that, “the open development model opens up the ability to contribute to innovation on a global basis. It recognizes that the distribution of natural intelligence does not correspond to the monopolization of innovation by the richest firms or richest countries. It is this gap between the distribution of ability and the distribution of opportunity that the web will force companies to recognize, and to realign their development strategies. For the young engineer in India, China, or Israel - who cannot or does not want to come to the Silicon Valley, or the Research Triangle, or Munich - is increasingly able to contribute to world innovation.” In 2000, a Forrester Research study interviewed 2,500 IT managers and found that 84% of them forecast that open source software would be the spark behind major innovations throughout the industry

It’s not just business people and observers of them; software developers themselves report that OSS/FS projects are often innovative. According to the BCG study of OSS/FS developers, 61.7% of surveyed developers stated that their OSS/FS project was either their most creative effort or was equally as creative as their most creative experience. Eric S. Raymond’s widely-read essay The Cathedral and the Bazaar describes one case of this happening in his project, fetchmail. He had been developing a product to do one job, when a user proposed an approach that changed the entire nature of his project. In Raymond’s words, “I realized almost immediately that a reliable implementation of this feature would make [a significant portion of the project] obsolete.” He found that “Often, the most striking and innovative solutions come from realizing that your concept of the problem was wrong” and that “the next best thing to having good ideas is recognizing good ideas from your users. Sometimes the latter is better.” Clearly, OSS/FS enables interaction between developers and users that can encourage innovation.

This is not a new phenomenon; many key software-related innovations have been OSS/FS projects. For example, Tim Berners-Lee, inventor of the World Wide Web, stated in December 2001 that “A very significant factor [in widening the Web’s use beyond scientific research] was that the software was all (what we now call) open source. It spread fast, and could be improved fast - and it could be installed within government and large industry without having to go through a procurement process.” The Internet’s critical protocols, such as TCP/IP, have been developed and matured through the use of OSS/FS. The Firefox web browser has some very interesting innovations, such as live bookbooks (making RSS feeds look just like bookmark folders, and enabling simple subscription), as well as incorporating innovations from other browsers such as tabbed browsing and pop-up blocking. Indeed, many people are working hard to create new innovations for the next version of Firefox.

Leading innovation expert Professor Eric von Hippel is the head of the management of innovation and entrepreneurship group at the Massachusetts Institute of Technology (MIT) Sloan School of Management. He has studied in detail how innovation works, including how it works in the development of OSS/FS programs.

His studies suggest that OSS/FS can significantly enable innovation. In the interview Something for nothing of von Hippel and Karim Lakhani, they report that “Apache and other open-source programs are examples of user-to-user innovation systems.” von Hippel explained that “Users may or may not be direct customers of the manufacturer. They may be in different industries or segments of the marketplace, but they are out in the field trying to do something, grappling with real-world needs and concerns. Lead users are an innovative subset of the user community displaying two characteristics with respect to a product, process or service. They face general needs in a marketplace but face them months or years before the rest of the marketplace encounters them. Since existing companies can’t customize solutions good enough for them, lead users go out there, patch things together and develop their own solutions. They expect to benefit significantly by obtaining solutions to their needs. When those needs are evolving rapidly, as is the case in many high-technology product categories, only users at the front of the trend will have experience today with tomorrow’s needs and solutions. Companies interested in developing functionally novel breakthroughs... will want to find out how to track lead users down and learn from what they have developed...” He closes noting that, “We believe Apache and open source are terrific examples of the lead user innovation process that can take teams and companies in directions they wouldn’t have otherwise imagined.” von Hippel has elsewhere noted that in certain industries approximately 80% of new developments are customer based; vendors ignore customers at their peril. For more information on this work relating to OSS/FS, innovation, and user interaction, see Nik Franke and Eric von Hippel’s Satisfying Heterogeneous User Needs via Innovation Toolkits: The Case of Apache Security Software, Karim Lakhani and Eric von Hippel’s How Open Source Software Works: Free User to User Assistance, Eric von Hippel’s Horizontal innovation networks- by and for users, Eric von Hippel and Georg von Krogh’s Exploring the Open Source Software Phenomenon: Issues for Organization Science (which proposes that OSS/FS development is a compound innovation model, containing elements of both private investment and collective action), and Eric von Hippel’s Open Source Shows the Way - Innovation By and For Users - No Manufacturer Required.

Other academics who study innovation have come to similar conclusions. Joachim Henkel (at Germany’s University of Munich, Institute for Innovation Research) wrote the paper ”The Jukebox Mode of Innovation - a Model of Commercial Open Source Development”. In it, he creates a model of innovation in software, and finds that “free revealing of innovations is a profit-maximizing strategy... a regime with compulsory revealing [e.g., copylefting licenses] can lead to higher product qualities and higher profits than a proprietary regime”. Tzu-Ying Chan and Jen-Fang Lee (at Taiwan’s National Cheng Chi Univerity of Technology & Innovation Management) wrote ”A Comparative Study of Online User Communities Involvement In Product Innovation and Development”, which identified a number of different types of online user communities. They discussed in particular the “user product collaboration innovation community”, noting that firms must play a supporting/complementary role for effective inteactions with this community, a role very different from its interactions with many other kinds of communities.

Yuwei Lin’s PhD thesis (at the UK’s University of York, Science and Technologies Studies Unit, Department of Sociology), Hacking Practices and Software Development: A Social Worlds Analysis of ICT Innovation and the Role of Free/Libre Open Source Software examines the social world of OSS/FS developers and its implications. Its major findings are (I quote but use American spelling):

1. As a community of open source practices, the FLOSS social world allows diverse actors to engage in the innovation process and therefore contains more innovation resources than other relatively conventional software models.
2. The strategic collaboration between the public (i.e., the free software community) and the private (i.e., infomration technologies corporations) sectors symbolizes a pattern of hybrid innovation that entails complex communications and networks.
3. Tacit knowledge anchored in everyday experiences is peculiarly valued in a community-based innovation system where social networking and information sharing are undergoing vigorously.
4. The development of FLOSS democratizes [the] software innovation process and allows lay people to develop their understanding and knowledge of a shared problem/issue, especially through the web, to challenge established views on the issue.

On September 14, 2004, *The Economist* (a highly respected magazine) awarded Linus Torvalds an award for innovation, specifically as someone driving the most financially successful breakthrough in computing, for his work on the Linux kernel. His citation declares that this OSS/FS project “created a huge following, eventually attracting big industry players such as Oracle, IBM, Intel, Netscape and others. It also spawned several new software companies, including Red Hat, SUSE LINUX and Turbolinux. Today, there are hundreds of millions of copies of Linux running on servers, desktop computers, network equipment and in embedded devices worldwide.”

This history of innovation shouldn’t be surprising; OSS/FS approaches are based on the scientific method, allowing anyone to make improvements or add innovative techniques and then make them immediately available to the public. Eric Raymond has made a strong case for why innovation is more likely, not less likely, in OSS/FS projects.

In public, Microsoft has long asserted that OSS/FS cannot innovate, or at least cannot innovate as well as Microsoft can. At first, the argument seems reasonable: why would anyone innovate if they (or at least their company) couldn’t exclusively receive all the financial benefits? But while the argument seems logical, it turns out to be untrue. In February 2003, Microsoft’s Bill Gates admitted that many developers are building innovative capabilities using OSS/FS systems. Microsoft’s own secret research (later leaked as “Halloween I”) found that “Research/teaching projects on top of Linux are easily ‘disseminated’ due to the wide availability of Linux source. In particular, this often means that new research ideas are first implemented and available on Linux before they are available / incorporated into other platforms.” In contrast, when examining the most important software innovations, it’s quickly discovered that Microsoft invented no key innovations, nor was Microsoft the first implementor of any of them. In fact, there is significant evidence that Microsoft is not an innovator at all. Thus the arguments, while sounding logical, ignore how innovation really occurs and what researchers say are necessary. Innovation requires that researchers be able publish and discuss their work, and that leading-edge users be able to modify and integrate components in novel ways; OSS/FS supports these requirements for innovation very well.

If proprietary approaches were better for research, then you would expect that to be documented in the research community. However, the opposite is true; the paper “NT Religious Wars: Why Are DARPA Researchers Afraid of Windows NT?” found that, in spite of strong pressure by paying customers, computer science researchers strongly resisted basing research on Microsoft Windows. Reasons given were: developers believe Windows is terrible, Windows really is terrible, Microsoft's highly restrictive non-disclosure agreements are at odds with researcher agendas, and there is no clear technology transition path for OS and network research products built on Windows. This last problem is especially interesting: you'd think that if you could improve a popular product, the improvement would get to users more quickly. But innovation doesn't work this way usually; most research creates prototypes that aren't products by themselves, and requires signficant interaction between many people before the idea comes to fruition. In proprietary products, usually only the vendor can distribute changes, and publishing the detailed source code explaining the work is prohibited, stifling research. In contrast, NSA's Security-Enhanced Linux (SELinux) project could simply take GNU/Linux code, modify it however they liked to try out new concepts, and publish all the results for *anyone* to productize. In contrast, if an innovation requires the cooperation of a proprietary vendor, it may not happen at all. HP developed new technology for choking off the spread of viruses, but although HP got it to work well in its labs using systems like Linux, they couldn't duplicate the capability on Windows systems because "we [HP] don't own Windows." Stanford Law School professor Lawrence Lessig (the "special master" in Microsoft's antitrust trial) noted that "Microsoft was using its power to protect itself against new innovation" and that Microsoft's practices generally threaten technical innovation - not promote it.

The claim that OSS/FS quashes innovation is demonstrably false. There are reports from IT managers that OSS/FS encourages innovation, reports from developers that OSS/FS encourages innovation, and a demonstrated history of innovation by OSS/FS (such as in the development of the Internet and World Wide Web). In contrast, Microsoft's failure to demonstrate major innovations itself, there is dissatisfaction by researchers and others about Microsoft's proprietary approaches, and Microsoft's own research found that new research ideas are often first implemented and available on OSS/FS.

This doesn't mean that having or using OSS/FS automatically provides innovation, and certainly proprietary developers can innovate as well. And remember that innovation is not as important as utility; new is not always better! But clearly OSS/FS does not impede innovation; the evidence suggests that in many situations OSS/FS *is* innovative, and some evidence suggests that OSS/FS may actively aid innovation.

While I cannot quantitatively measure these issues well, these issues are actually the most important issues to many.

9. Unnecessary Fears

Some avoid OSS/FS, not due to the issues noted earlier, but due to unnecessary fears of OSS/FS. Let's counter some of them:

1. **Is proprietary software fundamentally better supported than OSS/FS? No.** There are actually two kinds of support for OSS/FS: traditional paid-for support and informal community support. There are many organizations who provide traditional support for a fee; since these can be competed (an option not available for proprietary software), you can often get an excellent price for support. Again, an anti-trust lawyer would say that OSS/FS support is "contestable." For example, many GNU/Linux distributions include installation support when you purchase their distribution, and for

a fee they'll provide additional levels of support. There are many independent organizations that provide traditional support for a fee as well. The article 'Team'work Pays Off for Linux evaluated four different technical support services for GNU/Linux systems, and found that "responsiveness was not a problem with any of the participants" and that "No vendor failed to solve the problems we threw at it." It's very important to understand that OSS/FS support can be competed separately from the software product; in proprietary products, support is essentially tied to purchase of a usage license.

For example, the Gartner Group reports that "By 2005, warranties and additional maintenance for at least the 100 most-popular open-source software products will be offered by commercial software vendors, service providers, or insurance companies (0.7 probability). In the meantime, users can minimize any 'fitness for purpose' risks through evaluation and testing, and by only using production releases of well-known, mature products from reputable distributors." Indeed, this prediction seems nearly certain, since it's been happening and accelerating for years.

As an alternative, you can also get unpaid support from the general community of users and developers through newsgroups, mailing lists, web sites, and other electronic forums. While this kind of support is non-traditional, many have been very satisfied with it. Indeed, in 1997 InfoWorld awarded the "Best Technical Support" award to the "Linux User Community," beating all proprietary software vendors' technical support. Many believe this is a side-effect of the Internet's pervasiveness - increasingly users and developers are directly communicating with each other and finding such approaches to be more effective than the alternatives (for more on this business philosophy, see The Cluetrain Manifesto). Using this non-traditional approach effectively for support requires following certain rules; for information on these rules, consult "How to ask smart questions" and How to Report Bugs Effectively. But note that there's a choice; using OSS/FS does not require you to use non-traditional support (and follow its rules), so those who want guaranteed traditional support can pay for it just as they would for proprietary software.

2. **Does proprietary software give users more legal rights than OSS/FS? No.** Some have commented that "with OSS/FS you give up your right to sue if things go wrong." The obvious retort is that essentially all proprietary software licenses *also* forbid lawsuits - so this isn't different at all! Anyone who thinks that they can sue Microsoft or other shrink-wrap proprietary vendors when things go wrong is simply fooling themselves. In any case, most users aren't interested in suing vendors - they want working systems. See "A Senior Microsoft Attorney Looks at Open-Source Licensing", where Bryan Pfaffenberger argues that "With open-source software... you are, in principle, walking into the deal with your eyes wide open. You know what you're getting, and if you don't, you can find someone who does. Open-source licenses enable the community of users to inspect the code for flaws and to trade knowledge about such flaws, which they most assuredly do. Such licenses allow users to create derivative versions of the code that repair potentially hazardous problems the author couldn't foresee. They let users determine whether the program contains adequate safeguards against safety or security risks. In contrast, the wealthy software firms pushing UCITA are asking us to buy closed-source code that may well contain flaws, and even outright hazards attributable to corporate negligence - but they won't let us see the code, let alone modify it. You don't know what you're getting." Finally, if the software goes wrong and it's very important, you can fix it yourself or pay to have it fixed; this option greatly reduces risk, and this option doesn't exist for proprietary software.

There is a another legal difference that's not often mentioned. Many proprietary programs require that users permit software license audits and pay huge fees if the organization can't prove that every use is licensed. So in some cases, if you use proprietary software, the biggest legal difference is that the *vendors get to sue you*.

3. **Aren't OSS/FS programs simply plagerized proprietary programs? No.** A programmer who has access to the source code of one program *could* illegally take that code and submit it to another related program. There are good reasons to believe this has happened many times in proprietary programs; since few people can view the source code of two different proprietary programs, some programmers may do it in the (plausible) belief that they won't be caught. However, it's unlikely that a programmer would copy code from a proprietary program to an OSS/FS program without permission, because (1) the worldwide visibility of most OSS/FS source code would make it easy for a proprietary vendor to detect the violation, and (2) the clear record of exactly who submitted the plagerized code would make it easy to prosecute that lawbreaking programmer.

   A proprietary company could conceivably conspire to insert such code to try to discredit their OSS/FS competitor. But the risk of tracing such an attack back to the conspirator is very great; the developer who does it is likely to talk and/or other evidence may provide a trace back to the conspirators. Alternatively, a proprietary company can *claim* that such an event has happened, without doing it, and then use the false claim to spread fear, uncertainty, and doubt. But in that case, eventually the case will fall apart due to lack of evidence.

   A few years ago The SCO Group, Inc., began claiming that the Linux kernel contained millions of lines of its copyrighted code, and sued several companies including IBM. SCO has vocally supported several lawsuits, funded at least in part by Microsoft (via Baystar and a license purchase with no evidence that it will be used). Yet after repeatedly being ordered by a court to produce its evidence, SCO has yet to produce any evidence that code owned by SCO has been copied into the Linux kernel. Indeed, it's not even clear that SCO owns the code it claims to own (it's in dispute with Novell on this point). In addition, Open Source Risk Management (OSRM) did a detailed code analysis, and certified in April 2004 that the Linux kernel is free of copyright infringement. SCO claims that its contracts with IBM give it ownership over IBM-developed code, but previous documents relating to this contract inherited by SCO (such as newletter explanations from AT&T and a previous court case involving BSD) give extremely strong evidence that this is not true. More information on the SCO vs. IBM case can be found at Groklaw.net.

   In 2004 Ken Brown, President of Microsoft-funded ADTI, claimed that Linus Torvalds didn't write Linux, and in particular claimed that Torvalds stole much of his code from Minix. Yet it turns out that ADTI had previously hired Alexey Toptygin to find copying between Minix and Linux using automated tools, and Toptygin found that no code was copied from Minux to Linux or from Linux to Minux. Andrew Tanenbaum, the author of Minix, strongly refuted Brown's unsubstantiated claims in a statement, follow-up, and rebuttal. For example, Tanenbaum stated that "[Linus Torvalds] wrote Linux himself and deserves the credit." Tanenbaum also discredited Brown's claim that no one person could write a basic kernel; Tanenbaum noted that there are "six people I know of who (re)wrote UNIX [and] all did it independently." Other reports find many reasons to believe that ADTI's claims are false; for example, the Associated Press noted that Recent attacks on Linux come from dubious source.

There are a vast number of OSS/FS programs, almost none of which are involved in any dispute. No reasonable evidence has surfaced to justify the most publicized claims (of SCO and ADTI); these claims can be easily explained as attempts by a vendor to stall a competitor through the courts (see the terms barratry and vexatious litigation) and unfounded claims. There may be some cases, but given the widespread visibility of OSS/FS source code, and the lack of plausible cases, they must be extremely rare. Thus, there is strong evidence that people really are (legally) developing OSS/FS programs, and not simply copying program source code illegally from proprietary programs.

4. **Does OSS/FS expose you to greater risk of abandonment? No.** Businesses go out of business, and individuals lose interest in products, in both the proprietary and OSS/FS world. A major difference, however, is that all OSS/FS programs are automatically in escrow - that is, if their original developer stops supporting the product, any person or group can step forward to support it instead. This has been repeatedly demonstrated in OSS/FS. For example, the GIMP is a bitmapped graphical editor that was abandoned by its original developers (what's worse, they abandoned it before its initial release and failed to arrange for anyone else to succeed them). Nevertheless, even in this worst-case situation, after a period of time other users came forward and continued its development. As another example, NCSA abandoned its web server "httpd", so some of its users banded together to maintain it - its results became Apache, the world's most popular web server.
5. **Are OSS/FS licenses enforceable? In particular, is the GPL enforceable?** Almost all OSS/FS programs are released under some sort of license, and the most popular license is the GPL. A few competitors have claimed, in the past, that these licenses -- in particular the GPL -- are unenforceable. But legal scholars and lawyers who look into the issue generally scoff at such arguments. Eben Moglen's article Enforcing the GNU GPL describes why the GPL is so easy to enforce -- and why he's been able to enforce the GPL dozens of times without even going to court. At the time, he stated that "We do not find ourselves taking the GPL to court because no one has yet been willing to risk contesting it with us there."

   In 2004, the GPL was tested in court and found valid. On 14 April 2004, a three-judge panel in German Munich court granted a preliminary injunction to stop distribution of a Sitecom product that was derived from the GPL, yet failed to comply with the GPL. (see also the French article La licence GPL sur un logiciel libre n'est pas une demi-licence!). Soon afterwords, Sitecom Chief Executive Pim Schoenenberger said the company made changes to comply with the GPL. The preliminary injunction was later confirmed on July 23, 2004, along with a significant judgement. John Ferrell of law firm Carr & Ferrell declared that this German decision lends weight to the GPL, and that it "reinforces the essential obligations of the GPL by requiring that if you adopt and distribute GPL code, you must include the GPL license terms and provide source code to users," just as its license requires.

   The license requirements for common OSS/FS licenses are actually easy to comply with, but there is significant evidence that those terms *are* enforceable. Which is good news for OSS/FS users; clear, simple, and consistent requirements make it easy to understand what to do. For developers who depend on licenses like the GPL to keep the code available for improvement, this is also good news.

6. **Will unintentionally including GPL code in proprietary code force the rest of the product to be GPL'ed? No, though you can choose to do so.** The GPL, like most licenses for proprietary software libraries, grants you the right to use code only under certain conditions. Many proprietary libraries require that you pay a fee for each

copy, or a large fee for unlimited use. The GPL requires no fee, but it does require that if you include the GPL code as part of your code, you need to release the rest of the code under the GPL to obey the license.

So what happens if you are developing a proprietary product, and one of your developers includes GPL code directly into the product without your knowledge? Once that happens, you have three (not one) options: (1) release the rest under the GPL, (2) remove the GPL'ed code, or (3) arrange for the GPL'ed code to be released to you under a compatible license (this typically involves a fee, and some projects will not be willing to do this). This is not a good situation to be in; make sure that your developers know that they must *not* steal code, but must instead ensure that the licenses of any software they include in your program (either open source software or proprietary software) is compatible with your licenses.

There are many ways of proprietary and GPL programs can work together, but it must be carefully done to obey the licenses. The Linux kernel is GPL'ed, but proprietary applications can run on top of it without any limitations at all. The gcc compiler is GPL'ed, but proprietary applications can be compiled using it.

Indeed, there are a large number of misconceptions about the GPL, more than can be covered here. For more information about the GPL, a useful source is the Frequently Asked Questions about the GNU GPL from the Free Software Foundation (the authors of the GPL).

7. **Is OSS/FS economically viable? Yes.** There are companies that are making money on OSS/FS, or using OSS/FS to support their money-making activities. Many papers have been written about how to make money using OSS/FS, such as Eric S. Raymond's "The Magic Cauldron" and Donald K. Rosenberg's "How to make money with open-source software." An IT Manager's Journal article from May 2004 describes seven business strategies using open source software. OSS/FS isn't compatible with some business models, but OSS/FS is certainly compatible with or supports other models. Capitalism does *not* guarantee that businesses can remain unchanged in changing environments.

   For example, HP reported in January 2003 that it had annual sales of $2 billion linked to GNU/Linux. IBM reported in 2002 that they had already made almost all of their $1 billion investment in Linux back in only one year - i.e., as profit. James Boyle's response "Give me liberty and give me death?" makes the extraordinary observation that "IBM now earns more from what it calls 'Linux-related revenues' than it does from traditional patent licensing, and IBM is the largest patent holder in the world."

   The Financial Times Story "Could Linux dethrone the software king?" from January 21, 2003 analyzes some of the financial issues of OSS/FS.

   Joel Spolsky's "Strategy Letter V" notes that "most of the companies spending big money to develop open source software are doing it because it's a good business strategy for them." His argument is based on microeconomics, in particular, that every product in the marketplace has substitutes and complements. A substitute is another product you might buy if the first product is too costly, while a complement is a product that you usually buy together with another product. Since demand for a product increases when the prices of its complements decrease, smart companies try to commoditize their products' complements. For example, an automobile manufacturer may invest to reduce the cost of gas refinement - because if gas is cheaper, they'll sell more cars. For many companies, such as computer hardware makers and service organizations, supporting an OSS/FS product turns a complementary product into a commodity - resulting in more sales (and money) for them.

Although many OSS/FS projects originally started with an individual working in their spare time, and there are many OSS/FS projects which can still be described that way, the “major” widely-used projects tend to no longer work that way. Instead, most major OSS/FS projects have large corporate backing with significant funds applied to them. This shift has been noted for years, and is discussed in papers such as Brian Elliott Finley’s paper *Corporate Open Source Collaboration?*.

Also, looking only at companies making money from OSS/FS misses critical issues, because that analysis looks only at the supply side and not the demand side. Consumers are saving lots of money and gaining many other benefits by using OSS/FS, so there is a strong economic basis for its success. Anyone who is saving money will fight to keep the savings, and it’s often cheaper for consumers to work together to pay for small improvements in an OSS/FS product than to keep paying and re-paying for a proprietary product. A proprietary vendor may have trouble competing with a similar OSS/FS product, because the OSS/FS product is probably much cheaper and frees the user from control by the vendor. For many, money is still involved - but it’s money saved, not money directly acquired as profit. Some OSS/FS vendors have done poorly financially - but many proprietary vendors have also done poorly too. Luckily for consumers, OSS/FS products are not tied to a particular vendor’s financial situation as much as proprietary products are.

Fundamentally, software is economically different than physical goods; it is infinitely replicable, it costs essentially nothing to reproduce, and it can be developed by thousands of programmers working together with little investment (driving the per-person development costs down to very small amounts). It is also durable (in theory, it can be used forever) and nonrival (users can use the same software without interfering with each other, a situation not true of physical property). Thus, the marginal cost of deploying a copy of a software package quickly approaches zero. This explains how Microsoft got so rich so quickly (by selling a product that costs nearly nothing to replicate), and why many OSS/FS developers can afford to give software away. See “Open Source-onomics: Examining some pseudo-economic arguments about Open Source” by Ganesh Prasad, which counters “several myths about the economics of Open Source.” People are already experimenting with applying OSS/FS concepts to other intellectual works, and it isn’t known how well OSS/FS concepts will apply to other fields. However, it is clear that making economic decisions based on analogies between software and physical objects is not sensible, because software has many economic characteristics that are different from physical objects.

8. **Will OSS/FS destroy the software industry? Won’t programmers starve if many programs become OSS/FS? No.** It’s certainly possible that many OSS/FS products will eliminate their proprietary competition, but that’s the nature of competition. If OSS/FS approaches pose a significant threat to proprietary development approaches, then proprietary vendors must either find ways to compete or join the OSS/FS movement. No one mourns the loss of buggy whip manufacturers, who were driven out of business by a superior approach to transportation (cars). Heinlein noted that no one is guaranteed protection against change in Life-Line (1939): “There has grown up in the minds of certain groups in this country the notion that because a man or a corporation has made a profit out of the public for a number of years, the government and the courts are charged with the duty of guaranteeing such profit in the future,

even in the face of changing circumstances and contrary public interest. This strange doctrine is not supported by statute nor common law. Neither individuals nor corporations have any right to come into court and ask that the clock of history be stopped, or turned back, for their private benefit. “

Eric Raymond’s “The Magic Cauldron” describes many ways to make money with OSS/FS. One particularly interesting note is that there is evidence that 95% of all software is not developed for sale. For the vast majority of software, organizations must pay developers to create it anyway. Thus, even if OSS/FS eliminated all shrink-wrapped programs, it would only eliminate 5% of the existing software development jobs. And, since the OSS/FS programs would be less expensive, other tasks could employ developers that are currently too expensive, so widespread OSS/FS development would not harm the ability of developers to make a living.

OSS/FS doesn’t require that software developers work for free; many OSS/FS products are developed or improved by employees (whose job is to do so) and/or by contract work (who contract to make specific improvements in OSS/FS products). If an organization must have a new capability added to an OSS/FS program, they must find someone to add it... and generally, that will mean paying a developer to develop the addition. The difference is that, in this model, the cost is paid for development of those specific changes to the software, and not for making copies of the software. Since copying bits is essentially a zero-cost operation today, this means that this model of payment more accurately reflects the actual costs (since in software almost all costs are in development, not in copying).

Indeed, there has been a recent shift in OSS/FS away from volunteer programmers and towards paid development by experienced developers. Again, see Ganesh Prasad’s article for more information. Brian Elliott Finley’s article “Corporate Open Source Collaboration?” stated that “Now corporate America is getting involved in the development process. This seems to be a common trend amongst individuals, and now corporations, as they move into the Open Source world. That is that they start out as a user, but when their needs outstrip existing software, they migrate from being mere users to being developers. This is a good thing, but it makes for a slightly different slant on some of the dynamics of the process.” AOL decided to spin off the Mozilla project as a separate organization; not only does the separate organization employ several full-time employees, but other organizations have worked to hire Mozilla workers. Fundamentally, paying sotware developers is similar to paying for proprietary licenses, except you only have to pay for improvements (instead of paying for each copy), so many organizations appear to have found that it’s worthwhile. The Boston Consulting Group/OSDN Hacker Survey (January 31, 2002) surveyed users of SourceForge and found that 33.8% of the OSS/FS developers were writing OSS code for “work functionality” (i.e., it was something they did as part of their employment). It also provided quantitative evidence that OSS/FS developers are experienced; it found that OSS/FS developers had an average age of 30 and that they averaged 11 years of programming experience.

In 2004, Government Computer News reported in July 2004 on a presentation by Andrew Morton, who leads maintenance of the the Linux kernel in its stable form, and confirmed the trend towards paid OSS/FS developers. Morton spoke at a meeting sponsored by the Forum on Technology and Innovation, to address technology-related issues, held by Sen. John Ensign (R-Nev.), Sen. Ron Wyden (D- Ore.) and the Council on Competitiveness. Morton noted that “People’s stereotype [of the typical Linux developer] is of a male computer geek working in his basement writing code in his spare time, purely for the love of his craft. Such people were a significant force up until about five years ago ...” but contributions from such enthusiasts, “is waning... Instead, most Linux kernel code is now generated by corporate programmers.” Morton noted that “About 1,000 developers contribute changes to Linux on a regular basis... Of those 1,000 developers, about 100 are paid to work on Linux by their employers. And those 100 have contributed about 37,000 of the last 38,000 changes made to the operating system.” The article later notes “Even though anyone can submit changes, rarely does good code come from just anyone. Morton noted that it is rare that a significant change would be submitted from someone who is completely unknown to the core developers. And all submitted code is inspected by other members of the group, so it is unlikely some malicious function may be secretly embedded in Linux... Far from being a project with a vast numbers of contributors, about half of those 37,000 changes are made by core developer team of about 20 individuals, Morton said.” The September 3, 2004 article Peace, love and paychecks gives one of many examples of this trend. Network Appliance (NetApp) pays significant money to one of the Linux lieutenants (Myklebust), as well as developing code for Linux, for a very simple reason: money. “What’s in it for [NetApp] is sales; it can sell into the Linux market. This is not about philanthropy. There is plenty of mutual benefit going on here,” says Peter Honeyman. The article notes that “Big companies pick up the tab for Linux development because the system helps them sell hardware and consulting services. HP claims $2.5 billion in Linux-related revenue in 2003, while IBM claims $2 billion. Red Hat, which distributes a version of the Linux operating system, generated $125 million in revenues last fiscal year and carries a market value of $2.3 billion. Last year sales of Linux servers grew 48% to $3.3 billion, and by 2008 Linux server sales could approach $10 billion, according to market researcher IDC.” NetApp earned $152 million on sales of $1.2 billion, its Linux payoff is significant. Linux now contains bits of code written by NetApp’s programmers, so that NetApp works particularly well with Linux. As a result, “it has won business it wouldn’t have otherwise at Oracle, Pixar, Southwest Airlines, ConocoPhillips and Weta Digital, the effects studio behind Lord of the Rings.”

Corporate support of OSS/FS projects is not a new phenomenon. The X window system began in 1984 as a cooperative effort between MIT and Digital Equipment Corporation (DEC), and by 1988 a non-profit vendor consortium had been established to support it. The Apache web server began in 1995, based on previous NCSA work) were developed by consortias of companies from their very beginnings, and other popular OSS/FS projects like MySQL, Zope, and Qt have had strong backing from a specific commercial company for years. But now there is more corporate acceptance in using OSS/FS processes to gain results, and more understanding of how to do so. And as more OSS/FS projects gain in maturity, it is more likely that some project will intersect with a given company’s needs.

It seems unlikely that so many developers would choose to support an approach that would destroy their own industry, and there are a large number of OSS/FS developers. On January 28, 2003, Sourceforge.net all by itself reported that it had 555,314 registered users on its OSS/FS development site, and many of the largest OSS/FS projects are *not* hosted by Sourceforge.net (including the Linux kernel, the gcc compilation system, the X-Windows GUI system, the Apache web server, the Mozilla web browser, and the Open Office document management suite). Unfortunately, there seems to be no data to determine the number of OSS/FS developers worldwide, but it is likely to be at least a million people and possibly many, many more.

OSS/FS enables inexperienced developers to gain experience and credibility, while enabling organizations to find the developers they need (and will then pay to develop more software). Often organizations will find the developers they need by looking at the OSS/FS projects they depend on (or on related projects). Thus, lead developers of an OSS/FS project are more likely to be hired by organizations when those organizations need an extension or support for that project's program. This gives both hope and incentive to inexperienced developers; if they start a new project, or visibly contribute to a project, they're more likely to be hired to do additional work. Other developers can more easily evaluate that developer's work (since the code is available for all to see), and the inexperienced developer gains experience by interacting with other developers. This isn't just speculation; one of Netscape's presenters at FOSDEM 2002 was originally a volunteer contributor to Netscape's Mozilla project; his contributions led Netscape to offer him a job (which he accepted).

Of course, OSS/FS certainly has an impact on the software industry, but in many ways it appears quite positive, especially for customers. Since customers are the ones directly funding the specific improvements they actually want (using money and/or developer time), market forces push OSS/FS developers directly towards making the improvements users actually want. Proprietary vendors try to identify customer needs using marketing departments, but there's little evidence that marketing departments are as effective as customers themselves at identifying customer needs. In OSS/FS development, customers demonstrate which capabilities are most important to them, directly, by determining what they'll fund. Another contrast is that proprietary developers' funding motivations are not always aligned with customers' motivations. Proprietary development has strong financial incentives to prevent the use of competing products, to prevent interoperation with competing products, and to prevent access to copies (unless specifically authorized by the vendor). Thus, once a proprietary product becomes widely used, its vendor sometimees devotes increasing efforts to prevent use, interoperation, and copying, instead of improving capabilities actually desired by customers and even if those mechanisms interfere with customer needs. This trend is obvious over the decades of the software industry; dongles, undocumented and constantly changing data protocols and data formats, copy-protected media, and software registration mechanisms which interfere with customer needs are all symptoms of this difference in motivation. Note that an OSS/FS developer loses nothing if their customer later switches to a competing product (whether OSS/FS or proprietary), so an OSS/FS developer has no incentive to insert such mechanisms.

Karen Shaeffer has written an interesting piece, Prospering in the Open Source Software Era, which discusses what she views to be the effects of OSS/FS. For example, OSS/fS has the disruptive effect of commoditizing what used to be proprietary property and it invites innovation (as compared to proprietary software which constrained creativity). She thinks the big winners will be end users and the software developers, because "the value of software no longer resides in the code base - it resides in the developers who can quickly adapt and extend the existing open source code to enable businesses to realize their objectives concerned with emerging opportunities. This commoditization of source code represents a quantum step forward in business process efficiency - bringing the developers with the expertise into the business groups who have the innovating ideas."

9. **Is OSS/FS compatible with Capitalism? Yes.** Years ago some tried to label OSS/FS as "communistic" or "socialistic" (i.e., anti-capitalist), but that rhetoric has failed. One article explaining why OSS/FS and capitalism are compatible is Ganesh Prasad's *How Does the Capitalist View Open Source?*. This paper shows that OSS/FS is quite consistent with capitalism: it increases wealth without violating principles of property ownership or free will. The developer of the Linux kernel, Linus Torvalds, noted that

U.S. copyright law specifically notes the exchange of copyrighted material as financial gain. US Code, Title 17 (copyrights), Chapter 1, Section 101: “Definitions” says that, “The term ‘financial gain’ includes receipt, or expectation of receipt, of anything of value, including the receipt of other copyrighted works.” He notes that this is part of the very fundamentals of copyright law. What’s more, he notes that the GPL license (the most popular OSS/FS license) “is designed so that people receive the value of other people’s copyrighted works in return [for] their own contributions. That is the fundamental idea of the whole license - everything else is just legal fluff... the notion that the GPL has, of ‘exchange of receipt of copyrighted works,’ is actually explicitly encoded in U.S. copyright law. It’s not just a crazy idea that some lefty Commie hippie dreamed up...” See also the previous information on economic viability and starving programmers for more.

10. **If only OSS/FS programs exist in a software category, will that completely eliminate competition? No.** Oddly enough, OSS/FS programs sometimes compete with each other in a given functional area. The text editors emacs (primarily GNU emacs) and vi (primarily vim) have dueled for decades. Sendmail is still a popular program for delivering email, but it has competition from other OSS/FS programs such as Postfix and Exim. The desktop environments GNOME and KDE compete with each other, as do the OS kernels of Linux and the BSDs. Generally, competing OSS/FS projects must distinguish themselves from each other to succeed (e.g., through user interface philosophies, design approaches, characteristics like security, licensing strategies, and so on), but of course that’s true for competing proprietary programs too. Also, competing OSS/FS programs generally try to stay compatible with each other (because their customers demand it) and sometimes even help each other with technical problems. For example, freedesktop.org provides a forum to encourage cooperation among open source desktops for the X Window System (such as KDE and GNOME), and is part of the Free Standards Group which tries to accelerate the use and acceptance of open source technologies through the development, application and promotion of standards. In addition, even if there is one product, multiple organizations can compete for maintenance and support (e.g., GNU/Linux distributors do this). Thus, even if OSS/FS eliminates all proprietary programs in a given category, that would still not eliminate competition.
11. **Is OSS/FS a “destroyer of intellectual property”? No.** It’s true that Microsoft’s Jim Allchin has claimed that OSS is an intellectual-property destroyer and that it’s somehow “un-American”. But you can use OSS/FS products (e.g., a word processor) to develop private and proprietary information, and you can keep the information as confidential and proprietary as you want. What you can’t do is use someone else’s material in a way forbidden by law... and this is true for all software, not just OSS/FS.

    One interesting case is the “General Public License” (GPL), the most common OSS/FS license. Software covered by the GPL can be modified, and the modified code can be used in house without obligations. If you release that modified software, you must include an offer for the source code under the same GPL license. Basically, the GPL creates a consortium; anyone can use and modify the program, but anyone who releases the program (modified or not) must satisfy the restrictions in the GPL that prevent the program and its derivatives from becoming proprietary. Since the GPL is a legal document, it can be hard for some to understand. Here is one less legal summary (posted on Slashdot):

    This software contains the intellectual property of several people. Intellectual property is a valuable resource, and you cannot expect to be able to use someone else’s intellectual property in your own work for free. Many businesses and individuals are willing to trade their intellectual property in exchange for something of value; usually money. For example, in return for a sum of money, you might be granted the right to incorporate code from someone’s software program into your own.

The developers of this software are willing to trade you the right to use their intellectual property in exchange for something of value. However, instead of money, the developers are willing to trade you the right to freely incorporate their code into your software in exchange for the right to freely incorporate your code [which incorporates their code] into theirs. This exchange is to be done by way of and under the terms of the GPL. If you do not think that this is a fair bargain, you are free to decline and to develop your own code or purchase it from someone else. You will still be allowed to use the software, which is awfully nice of the developers, since you probably didn’t pay them a penny for it in the first place.

Microsoft complains that the GPL does not allow them to take such code and make changes that it can keep proprietary, but this is hypocritical. Microsoft doesn’t normally allow others to make and distribute changes to Microsoft software *at all*, so the GPL grants far *more* rights to customers than Microsoft does.

In some cases Microsoft will release source code under its “shared source” license, but that license (which is not OSS/FS) is far more restrictive. For example, it prohibits distributing software in source or object form for commercial purposes under any circumstances. Examining Microsoft’s shared source license also shows that it has even more stringent restrictions on intellectual property rights. For example, it states that “if you sue anyone over patents that you think may apply to the Software for a person’s use of the Software, your license to the Software ends automatically,” and “the patent rights Microsoft is licensing only apply to the Software, not to any derivatives you make.” A longer analysis of this license and the problems it causes developers is provided by Bernhard Rosenkraenzer (bero). The FSF has also posted a press release on why they believe the GPL protects software freedoms.

It’s true that organizations that modify and release GPL’ed software must yield any patent and copyright rights for those additions they release, but such organizations do so voluntarily (no one can *force* anyone to modify GPL code) and with full knowledge (all GPL’ed software comes with a license clearly stating this). And such grants only apply to those modifications; organizations can hold other unrelated rights if they wish to do so, or develop their own software instead. Since organizations can’t make such changes at all to proprietary software in most circumstances, and generally can’t redistribute changes in the few cases where they *can* make changes, this is a fair exchange, and organizations get far more rights with the GPL than with proprietary licenses (including the “shared source” license). If organizations don’t like the GPL license, they can always create their own code, which was the only option even before GPL’ed code became available.

Although the GPL is sometimes called a “virus” by proprietary vendors (particularly by Microsoft) due to the way it encourages others to also use the GPL license, it’s only fair to note that many proprietary products and licenses also have virus-like effects. Many proprietary products with proprietary data formats or protocols have “network effects,” that is, once many users begin to use that product, that group puts others who don’t use the same product at a disadvantage. For example, once some users pick a particular product such as a proprietary OS or word processor, it becomes increasingly difficult for other users to use a different product. Over time this enforced use of a particular proprietary product also spreads like a virus.

Certainly many technologists and companies don't think that the GPL will destroy their businesses. Many seem too busy mocking Microsoft's claims instead (for an example, see John Lettice's June 2001 article " Gates: GPL will eat your economy, but BSD's cool"). After all, *Microsoft sells a product with GPL'ed components*, and still manages to hold intellectual property (see below).

Perhaps Microsoft means the GPL "destroys" intellectual property because the owners of competing software may be driven out of business. If so, this is hypocritical; Microsoft has driven many companies out of business, or bought them up at fractions of their original price. Indeed, sometimes the techniques that Microsoft used have later been proven in court to be illegal. In contrast, there is excellent evidence that the GPL is on very solid legal ground. "Destruction" of one organization by another through legal competition is quite normal in capitalistic economies.

The GPL does not "destroy" intellectual property; instead, it creates a level playing field where people can contribute improvements voluntarily to a common project without having them "stolen" by others. You could think of the GPL as creating a consortium; no one is required to aid the consortium, but those who do must play by its rules. The various motivations for joining the consortium vary considerably (see the article License to FUD), but that's true for any other consortium too. It's understandable that Microsoft would want to take this consortium's results and take sole ownership of derivative works, but there's no reason to believe that a world where the GPL cannot be used is really in consumers' best interests.

The argument is even more specious for non-GPL'ed code. Microsoft at one time protested about open source software, but indeed, they are a key user of open source software; key portions of Microsoft Windows (including much of their Internet interfacing software) and Microsoft Office (such as compression routines) include open source software. In 2004, Microsoft released an installation tool, WiX, as open source software on SourceForge.

12. **Is there really a lot of OSS/FS software? Yes.** Freshmeat.net counts over 21,000 software branches of OSS/FS software as of October 2002. Sourceforge.net hosts 55,424 OSS/FS projects all by itself (as of January 28, 2003). The dmoz list of just OS counts 114 OSS/FS OSes; this includes old systems (re-enabling their support), experiments, and specialized projects. There's little reason to believe that this counts *all* OSS/FS software, but it certainly indicates there's a large amount of it. These projects vary in value and quality, of course, just as proprietary programs do, but all of these OSS/FS projects can be the basis of future work.
13. **Is having the ability to view and change source code really valuable/important for many people? Surprisingly, yes.** It's certainly true that few people need *direct* access to source code; only developers or code reviewers need the ability to access and change code. But not having access to how your computer is controlled is still a significant problem. Bob Young of Red Hat uses the analogy of having your car's hood welded shut to explain why even non-technical users need access to the source code. Here is his explanation, in his own words:

    Open source gives the user the benefit of control over the technology the user is investing in... The best analogy that illustrates this benefit is with the way we buy cars. Just ask the question, "Would you buy a car with the hood welded shut?" and we all answer an emphatic "No." So ask the follow-up question, "What do you know about modern internal-combustion engines?" and the answer for most of us is, "Not much."

We demand the ability to open the hood of our cars because it gives us, the consumer, control over the product we've bought and takes it away from the vendor. We can take the car back to the dealer; if he does a good job, doesn't overcharge us and adds the features we need, we may keep taking it back to that dealer. But if he overcharges us, won't fix the problem we are having or refuses to install that musical horn we always wanted -- well, there are 10,000 other car-repair companies that would be happy to have our business.

In the proprietary software business, the customer has no control over the technology he is building his business around. If his vendor overcharges him, refuses to fix the bug that causes his system to crash or chooses not to introduce the feature that the customer needs, the customer has no choice. This lack of control results in high cost, low reliability and lots of frustration.

To developers, source code is critical. Source code isn't necessary to break the security of most systems, but to really fix problems or add new features it's quite difficult without it. Microsoft's Bill Gates has often claimed that most developers don't need access to OS source code, but Graham Lea's article "Bill Gates' roots in the trashcans of history" exposes that Gates actually extracted OS source code himself from other companies by digging through their trash cans. Mr. Gates said, "I'd skip out on athletics and go down to this computer center. We were moving ahead very rapidly: Basic, FORTRAN, LISP, PDP-10 machine language, digging out the OS listings from the trash and studying those." If source code access isn't needed by developers, why did *he* need it?

See also the discussion on the greater flexibility of OSS/FS.

14. **Is OSS/FS really just an anti-Microsoft campaign? No.** Certainly there are people who support OSS/FS who are also against Microsoft, but it'd be a mistake to view OSS/FS as simply anti-Microsoft. Microsoft already uses OSS/FS software in its own applications; Windows' implementation of the basic Internet protocols (TCP/IP) was derived from OSS/FS code, and its Office suite depends on the OSS/FS compression library "zlib." Microsoft could, at any time, release programs such as its OSes as OSS/FS, take an existing OSS/FS OS and release it, or provide applications for OSS/FS systems. There is no licensing agreement that prevents this. Indeed, OSS/FS leaders often note that they are not against Microsoft per se, just some of its current business practices, and many have repeatedly asked Microsoft to join them (e.g., see Free Software Leaders Stand Together).

    In many cases OSS/FS is developed with and for Microsoft technology. On June 21, 2002, SourceForge listed 831 projects that use Visual Basic (a Microsoft proprietary technology) and 241 using C# (a language that originated from Microsoft). A whopping 8867 projects are listed as working in Windows. This strongly suggests that there are many OSS/FS developers who are not "anti-Microsoft."

    Microsoft says it's primarily opposed to the GPL, *but Microsoft sells a product with GPL'ed components*. Microsoft's Windows Services for Unix includes Interix, an environment which can run UNIX-based applications and scripts on the Window NT and Windows 2000 OSes. There's nothing wrong with this; clearly, there are a lot of Unix applications, and since Microsoft wants to sell its OSes, Microsoft decided to sell a way to run Unix applications on its own products. But many of the components of Interix are covered by the GPL, such as gcc and g++ (for compiling C and C++ programs). (Microsoft seems to keep moving information about this; here is a stable copy). The problem is not what Microsoft is doing; as far as I can tell, they're following both the letter and the spirit of the law in this product. The problem is that Microsoft says no one should use the GPL, and that no one can make money using the GPL, while simultaneously making money using the GPL. Bradley Kuhn (of the FSF) bluntly said, “It’s hypocritical for them to benefit from GPL software and criticize it at the same time.” Microsoft executives are certainly aware of this use of the GPL; Microsoft Senior Vice President Craig Mundie specifically acknowledged this use of GPL software when he was questioned on it. Kelly McNeill noted this dichotomy between claims and actions in the June 22, 2001 story “Microsoft Exposed with GPL’d Software!” A more detailed description about this use of the GPL by Microsoft is given in The Standard on June 27, 2001. Perhaps in the future Microsoft will try to remove many of these GPL’ed components so that this embarrassing state of affairs won’t continue. But even if these components are removed in the future, this doesn’t change the fact that Microsoft has managed to sell products that include GPL-covered code without losing any of its own intellectual property rights.

That being said, there are certainly many people who are encouraging specific OSS/FS products (such as Linux) so that there will be a viable competition to Microsoft, or who are using the existence of a competitor to obtain the best deal from Microsoft for their organization. This is nothing unusual - customers *want* to have competition for their business, and they usually have it in most other areas of business. Certainly there is a thriving competing market for computer hardware, which has resulted in many advantages for customers. The New York Times’ position is that “More than two dozen countries - including Germany and China - have begun to encourage governmental agencies to use such “open source” software ... Government units abroad and in the United States and individual computer users should look for ways to support Linux and Linux-based products. The competition it offers helps everyone.”

15. **I’ve always assumed there’s no free lunch; isn’t there some catch?** If there is an OSS/FS product that meets your needs, there really isn’t a catch. Perhaps the only catch is misunderstanding the term “free.” The GPL includes this (haiku) text: “When we speak of free software, we are referring to freedom, not price.” I.E., OSS/FS is not necessarily cost-free. In practice, it’s still often a bargain.

    Naturally, if you want services besides the software itself (such as guaranteed support, training, and so on), you must pay for those things just like you would for proprietary software. If you want to affect the future direction of the software - especially if you must have the software changed in some way to fit it to your needs - then you must invest to create those specific modifications. Typically these investments involve hiring someone to make those changes, possibly sharing the cost with others who also need the change. Note that you only need to pay to change the software - you don’t need to pay for permission to use the software, or a per-copy fee, only the actual cost of the changes.

    For example, when IBM wanted to join the Apache group, IBM discovered there really was no mechanism to pay in money. IBM soon realized that the primary “currency” in OSS/FS is software code, so IBM turned the money into code and all turned out very well.

    This also leads to interesting effects that explains why many OSS/FS projects start small for years, then suddenly leap into a mode where they have a rapidly increasing functionality and user size. For any application, there is a minimum level of acceptable functionality; below this, there will be very few users. If that minimum level is large enough, this creates an effect similar to an “energy barrier” in physics;

the barrier can be large enough that most users are not willing to pay for the initial development of the project. However, at some point, someone may decide to begin the “hopeless” project anyway. The initial work may take a while, because the initial work is large and there are few who will help. However, once a minimum level of functionality is reached, a few users will start to use it, and a few of them may be willing to help (e.g., because they want the project to succeed or because they have specialized needs). At some point in this growth, it is like passing an energy barrier; the process begins to become self-sustaining and exponentially increasing. As the functionality increases, the number of potential users begins to increase rapidly, until suddenly the project is sufficiently usable for many users. A percentage of the userbase will decide to add new features, and as the userbase grows, so do the number of developers. As this repeats, there is an explosion in the program’s capabilities.

10. OSS/FS on the desktop: Client computing

OSS/FS programs are have been competing for many years in the server market, and are now well-established in that market. OSS/FS programs have been competing for several years in the embedded markets, and have already begun to significantly penetrate those markets as well.

In contrast, OSS/FS programs currently have only a small client (desktop and laptop) market share. This is unsurprising; OSS/FS only began to become viable for client computing in 2002, and it takes time for any software to mature, be evaluated, and be deployed. Since OSS/FS is a brand new contender in the client market, it has only begun penetrating into that market. However, there are reasons to think that OSS/FS use on client systems will grow significantly in the future.

A few definitions are necessary first, before examining the issue in more depth. Many users’ only direct experience with computers is through their desktop or laptop computers running “basic client applications” such as a web browser, email reader, word processor, spreadsheet, and presentation software (the last three together are often called an “office suite”), possibly with additional client applications, and all of these must have a graphical user interface and be supported by an underlying graphical environment. Such computers are often called “client” computers (even if they are not using the technical approach called the “client-server model”). Another term also used is the “desktop”, even if the computer is not on a desk.

However, the small market share should not be surprising, because viable OSS/FS client applications only became available in 2002. As a practical matter, client systems must be compatible with the market leader, for example, the office suite must be able to read and write documents in the Microsoft Office formats. Before 2002 the available OSS/FS products could not do this well, and thus were unsuitable for most circumstances. Clearly, OSS/FS client applications cannot be considered unless they are already available.

One point less understood is that OSS/FS operating systems (like GNU/Linux) could not really compete with proprietary operating systems on the client until OSS/FS basic client applications and environment were available. Clearly, few users can even consider buying a client system without basic client applications, since that system won’t meet their fundamental requirements. There have been proprietary basic client applications for GNU/Linux for several years, but they didn’t really make GNU/Linux viable for client applications. The reason is that a GNU/Linux system combined with proprietary basic client applications still lacks the freedoms and low cost of purely OSS/FS systems, and the combination of GNU/Linux plus proprietary client applications has to compete with established proprietary systems which have many more applications available to them. This doesn't mean that GNU/Linux can't support proprietary programs; certainly some people *will* buy proprietary basic client applications, and many people have already decided to buy many other kinds of proprietary applications and run them on a GNU/Linux system. However, few will find that a GNU/Linux system with proprietary basic client applications has an advantage over its competition. After all, the result is still proprietary, and since there are fewer desktop applications of any kind on GNU/Linux, many capabilities have been lost, little has been gained, and the switching costs will dwarf those minute gains. There is also the problem of transition. Many organizations will find it too traumatic to immediately switch all client systems to an OSS/FS operating system; it is often much easier to slowly switch to OSS/FS basic client applications on the pre-existing proprietary operating system, and then switch operating systems once users are familiar with the basic client applications. Thus, the recent availability of OSS/FS basic client applications has suddenly made OSS/FS operating systems (like GNU/Linux) far more viable on the client.

First, let's look at the available market share figures. According to the June 2000 IDC survey of 1999 licenses for client machines, GNU/Linux had 80% as many client shipments in 1999 as Apple's MacOS (5.0% for Mac OS, 4.1% for GNU/Linux). More recent figures in 2002 suggest that GNU/Linux has 1.7% of the client OS market. Clearly, the market share is small at this early stage. Obviously, while this shows that there are many users (because there are so many client systems), this is still small compared to Microsoft's effective monopoly on the client OS market. IDC reported that Windows systems (when they are all combined) accounted for 92% of the client operating systems sold.

However, there are many factors that suggest that the situation is changing: OSS/FS basic client software is now available, there's increasing evidence of their effectiveness, Microsoft is raising prices, and organizations (including governments) want open systems:

1. *OSS/FS basic client software is available.* Back in 1997 I forecast that GNU/Linux would be "ready for the desktop" in 2002-2003 (5 years later). My forecast appears correct; OSS/FS applications and environments matured in 2002 where they are finally functionally competitive on the client. In 2002, Mozilla finally released version 1.0 of their suite (including a web browser, email reader, and other tools), and the first reasonably usable version of Open Office, the first practically useful OSS/FS office suite, was released in 2002 as well. Desktop environments matured as well; in 2002 both the GNOME and KDE projects released capable, more mature versions of their desktop environments. In addition the WINE product (a product that allows OSS/FS systems to run Windows programs) was finally able to run Microsoft Office 97, suggesting that although WINE is still immature, it may be sufficient to run some Windows applications developed internally by some organizations.

   There are other plausible alternatives for client applications as well, such as Evolution (an excellent mail reader), Abiword (a lighter-weight but less capable word processor which also released its version 1.0 in 2002), Gnumeric (a spreadsheet), and KOffice (an office suite).

   However, I will emphasize Mozilla and Open Office, for two reasons. First, they also run on Microsoft Windows, which makes it much it easier to transition users from competitors (this enables users to migrate a step at a time, instead of making one massive change). Second, they are full-featured, including compatibility with Microsoft's products; many users want to use fully-featured products since they don't want to switch programs just to get a certain feature. In short, it looks like there are now several OSS/FS products that have begun to rival their proprietary competitors in both usability and in the functionality that people need, including some very capable programs.

2. *There is increasing evidence of OSS/FS client software effectiveness.* The MOXIE study of January 2003 randomly acquired 100 documents from the Internet in the Microsoft Office word processor, spreadsheet, and presentation software formats. Their leading OSS/FS contender, Open Office version 1.0.1, did well; it was able to successfully use 97%, 98%, and 94% of the documents (of the respective formats). The study concluded that “the current state of interoperability is reasonably good, although there is significant room for improvement.” Since that time, the Open Office developers have specifically worked to improve interoperability with Microsoft Office, and it’s reasonable to expect that the figures are significantly higher now.
3. *Microsoft has raised its prices.* Microsoft is changing many of its practices, resulting in increasing costs to its customers. It has changed its licensing so that one copy of Windows cannot be used for both home and office. Microsoft has switched its largest customers to a subscription-based approach (called “Licensing 6”), greatly increasing the costs to its customers. TIC/Sunbelt Software Microsoft Licensing Survey Results (covering March 2002) reports the impact on customers of this new licensing scheme. 80% had a negative view of the new licensing scheme, noting, for example, that the new costs for software assurance (25% of list for server and 29% of list for clients) are the highest in the industry. Of those who had done a cost analysis, an overwhelming 90% say their costs will increase if they migrate to 6.0, and 76% said their costs would increase from 20% to 300% from what they are paying now under their current 4.0 and 5.0 Microsoft Licensing plans. Indeed, 38% of those surveyed said that they are actively seeking alternatives to Microsoft products. Licensing 6.0 can also significantly harm organizations trying to sell off a part of its operations. The program requires accelerated software maintenance payments when the computers that are covered under the license are sold off - but Microsoft is no longer obligated to provide maintenance even if the contract is fully paid.

   Gartner’s review of Star Office (Sun’s variant of Open Office) also noted that Microsoft’s recent licensing policies may accelerate moving away from Microsoft. As Gartner notes, “This [new license program] has engendered a lot of resentment among Microsoft’s customers, and Gartner has experienced a marked increase in the number of clients inquiring about alternatives to Microsoft’s Office suite... enterprises are realizing that the majority of their users are consumers or light producers of information, and that these users do not require all of the advanced features of each new version of Office... unless Microsoft makes significant concessions in its new office licensing policies, Sun’s StarOffice will gain at least 10 percent market share at the expense of Microsoft Office by year-end 2004 (0.6 probability).” They also note that “Because of these licensing policies, by year-end 2003, more than 50 percent of enterprises will have an official strategy that mixes versions of office automation products - i.e., between multiple Microsoft Office versions or vendor products (0.7 probability).”

4. *Organizations (including governments) want open systems.* Organizations, including governments, do not want to be locked into products and services from a single vendor. Multiple vendors mean competition between suppliers, generally driving down costs and increasing quality. See the separate section on governments and OSS/FS.

There are some interesting hints that GNU/Linux is already starting to gain on the client. Some organizations, such as TrustCommerce and the city of Largo, Florida, report that they’ve successfully transitioned to using Linux on the desktop.

Many organizations have found a number of useful processes for making this transition practical. Many start by replacing applications (and not the operating system underneath) with OSS/FS replacements. For example, they might switch to Mozilla as a web browser and email reader, OpenOffice.org for an office suite. Organizations can also move their infrastructure to web-based solutions that don't care about the client operating system. Eventually, they can start replacing operating systems (typically to a GNU/Linux distribution), but still using various mechanisms to run Microsoft Windows applications on them. Various products allow users to run Microsoft Windows applications on GNU/Linux, including Windows application servers, Wine, win4lin, VMWare, and so on.

There's already some evidence that others anticipate this; Richard Thwaite, director of IT for Ford Europe, stated in 2001 that an open source desktop is their goal, and that they expect the industry to eventually go there (he controls 33,000 desktops, so this would not be a trivial move). It could be argued that this is just a ploy for negotiation with Microsoft - but such ploys only work if they're credible.

There are other sources of information on OSS/FS or GNU/Linux for clients. Desktoplinux.com is a web site devoted to the use of GNU/Linux on the desktop; they state that "We believe Linux is ready *now* for widespread use as a desktop OS, and we have created this website to help spread the word and accelerate the transition to a more open desktop, one that offers greater freedom and choice for both personal and business users."

Bart Decrem's Desktop Linux Technology & Market Overview, funded by Mitch Kapor, gives a detailed analysis and prognostication of GNU/Linux on the desktop. Paul Murphy discusses transitioning large companies to Linux and Intel ("Lintel") on the desktop, and concludes that one of the biggest risks is trying to copy a Windows architecture instead of exploiting the different capabilities GNU/Linux offers.

Indeed, it appears that many users are considering such a transition. ZDNet published survey results on August 22, 2002, which asked "Would your company switch its desktop PCs from Windows to Linux if Windows apps could run on Linux?" Of the more than 15,000 respondents, 58% said they'd switch immediately; another 25% said they'd consider dumping Windows in favor of Linux within a year. While all such surveys must be taken with a grain of salt, still, these are not the kind of responses you would see from users happy with their current situation. They also noted that ZDNet Australia found that 55% of the surveyed IT managers were considering switching from Microsoft products. Most people do not expect that this transition, if it happens, will happen quickly: it is difficult to change that many systems. But the fact that it's being considered at all is very intriguing. A number of opinion pieces, such as Charlie Demerjian's "The IT industry is shifting away from Microsoft" argue that there a major IT industry shift toward OSS/FS is already occurring, across the board.

Many analysts believe Microsoft has extended Windows 98 support because it's worried that Windows 98 users might switch to GNU/Linux.

11. Usage Reports

There are many reports from various users who have switched to OSS/FS; here are a sample that you may find useful. This is *not* an exhaustive list, nor can it be.

As discussed earlier, the City of Largo, Florida supports 900 city employees using GNU/Linux, saving about $1 million a year. A BusinessWeek online article notes that Mindbridge shifted their 300-employee intranet software company from Microsoft server products and Sun Solaris to GNU/Linux; after experiencing a few minor glitches, their Chief

Operating Officer and founder Scott Testa says they now couldn't be happier, and summarizes that "...we're saving hundreds of thousands of dollars between support contracts, upgrade contracts, and hardware." Amazon.com saved millions of dollars by switching to GNU/Linux. Oracle's Chairman and CEO, Larry Ellison, said that Oracle will switch to GNU/Linux to run the bulk of its business applications no later than summer 2002, replacing three Unix servers. A travel application service provider saved $170,000 in software costs during the first six months of using GNU/Linux (for both servers and the desktop); it also saved on hardware and reported that administration is cheaper too. CRN's Test Center found that a GNU/Linux-based network (with a server and 5 workstations) cost 93% less in software than a Windows-based network, and found it to be quite capable. The article *Linux as a Replacement for Windows 2000* determined that "Red Hat Linux 7.1 can be used as an alternative to Windows 2000... You will be stunned by the bang for the buck that Linux bundled free 'open source' software offers."

Educational organizations have found OSS/FS software useful. The K12 Linux Terminal Server Project has set up many computer labs in the U.S. Northwest in elementary, middle, and high schools. For example, St. Mary's School is a 450-student Pre-K through 8th grade school in Rockledge, Florida that applying GNU/Linux using their approach. Their examples show that kids don't find GNU/Linux that hard to use and quite able to support educational goals. For example, third graders put together simple web pages about their favorite Saints using a variety of OSS/FS programs: they logged into GNU/Linux systems, typed the initial content using Mozilla Composer (an OSS/FS web page editor), drew pictures of the Saints using The Gimp (an OSS/FS drawing program), and shared the results with Windows users using Samba. The page *Why should open source software be used in schools?* gives various examples of educational organizations who have used OSS/FS programs, as well as linking to various general documents on why educational organizations should use OSS/FS. The letter from the Kochi Free Software Users' Group to the Government of Kerala and others also summarizes some of the issues, especially why governments should specify standards (and not products) for educational use. The Faculty Senate of the University at Buffalo, State University of New York, approved a resolution strongly supporting the use of OSS/FS instead of proprietary software. The Northwest Educational Technology Consortium has an interest set of information on OSS/FS on its website, in the section Making Decisions About Open Source Software (OSS) for K-12.

Many financial organizations use OSS/FS. Online brokerage E*Trade is moving its computer systems to IBM servers running GNU/Linux, citing cost savings and performance as reasons for switching to GNU/Linux (the same article also notes that clothing retailer L.L. Bean and financial services giant Salomon Smith Barney are switching to GNU/Linux as well). Merrill Lynch is switching to GNU/Linux company-wide, and are hoping to save tens of millions of dollars annually within three to five years. Adam Wiggins reports on TrustCommerce's successful transition to Linux on the desktop. An April 22, 2002 report on ZDNet, titled "More foreign banks switching to Linux", stated that New Zealand's TSB bank "has become the latest institution to adopt the open-source Linux OS. According to reports, the bank is to move all its branches to the Linux platform... in Europe, BP and Banca Commerciale Italiana feature among the big companies that have moved to Linux. According to IBM, as many as 15 banks in central London are running Linux clusters." They also mentioned that "Korean Air, which now does all its ticketing on Linux, and motorhome manufacturer Winnebago, are high-profile examples." The Federal Aviation Air Traffic Control System Command Center in Herndon, Virginia is currently installing a system to support 2,000 concurrent users on Red Hat Linux. The system, known as the National Log, will act as a central clearinghouse database for users in air traffic centers across the country. ComputerWorld reported in October 2002 an increasing use of GNU/Linux on Wall Street - Merrill Lynch reports that a majority of new projects are interested in GNU/Linux, for example, and the article references a TowerGroup (of Needham, MA) estimate that GNU/Linux is currently deployed on 7% of all servers in North American brokerage firms. TowerGroup also forecasts that GNU/Linux use will grow at an annual rate of 22% in the securities server market between 2002 and 2005, outpacing growth in Windows 2000, NT and Unix deployments.

Some organizations are deploying GNU/Linux widely at the point of sale. Many retailer cash registers are switching to GNU/Linux, according to Information Week (”Cash Registers are Ringing up Sales with Linux” by Dan Orzech, December 4, 2000, Issue 815); on September 26, 2002, The Economist noted that “Linux is fast catching on among retailers.” According to Bob Young (founder of Red Hat), BP (the petroleum company) is putting 3,000 Linux servers at gas stations. Zumiez is installing open-source software on the PCs at all its retail locations, and expects that this will cut its technology budget between $250,000 and $500,000 a year; note that this includes using Evolution for email, Mozilla for web browsing (to eliminate the need for printed brochures and training manuals), and an open source spreadsheet program. Sherwin-Williams, the number one U.S. paint maker, plans to convert its computers and cash registers (not including back office support systems) in over 2,500 stores to GNU/Linux and has hired IBM to do the job; this effort involves 9,700 NetVista desktop personal computers,

OSS/FS is also prominent in Hollywood. Back in 1996, when GNU/Linux was considered by some to be a risk, Digital Domain used GNU/Linux to generate many images in *Titanic*. After that, it burst into prominence as many others began using it, so much so that a February 2002 article in IEEE Computer stated that “it is making rapid progress toward becoming the dominant OS in ... motion pictures.” “Shrek” and “Lord of the Rings” used GNU/Linux to power their server farms, and now DreamWorks SKG has switched to using GNU/Linux exclusively on both the front and back ends for rendering its movies. Industrial Light & Magic converted its workstations and renderfarm to Linux in 2001 while it was working on Star Wars Episode II. They stated that “We thought converting to Linux would be a lot harder than it was” (from their SGI IRIX machines). They also found that the Linux systems are 5 times faster than their old machines, enabling them to produce much higher quality results. They also use Python extensively (an OSS/FS language), as well as a number of in-house and proprietary tools. Disney is also shifting to GNU/Linux for film animation.

Many remote imaging systems use GNU/Linux. When a remote imaging system was placed at the North Pole, reporters noted that the Linux mascot was a penguin and announced that Penguins invade the North Pole.

There are many large-scale systems. In October 2002, Chrysler Group announced it’s using a Linux cluster computer for crash simulation testing and analysis in an effort to make safer cars and trucks. Their configuration uses 108 workstations, each with 2 processors, so the system uses 216 computers all running Red Hat Linux, and expect to improve simulation performance by 20% while saving about 40% in costs.

OSS/FS is widely used by Internet-based companies. Google uses over 6,000 GNU/Linux servers. Yahoo! is increasing its already-massive use of OSS/FS. Yahoo claims it is the “World’s most trafficked Internet destination,” justified based on Nielsen/NetRatings of August 2002. Yahoo had 201 million unique users, 93 million active registered users, over 4500 servers, and over 1.5 billion pageviews a day. Yahoo noted that OSS/FS already runs their business (e.g., Perl, Apache, FreeBSD, and gcc), and they’ve recently decided to move from their proprietary in-house languages to PHP (an OSS/FS language). Afilias has switched the registration database for the .org Internet domain from the proprietary Oracle to the OSS/FS PostgreSQL database program; .org is the fifth largest top-level domain, with more than 2.4 million registered domain names.

Bloor Research announced in November 2002 that they believe GNU/Linux is ready to support large enterprise applications (i.e., it’s “enterprise ready”). They reached this conclusion after examining its scalability, availability, reliability, security, manageability, flexibility, and server consolidation characteristics, They concluded that “Linux now scales well on Intel hardware, and by taking advantage of failover extensions from Linux distributors and Grid suppliers, high availability can be achieved. Linux is proven to be reliable, especially for dedicated applications, and its open source nature ensures that it is at least as secure as its rivals.” Only 3 years earlier Bloor had said GNU/Linux wasn’t ready.

Librarians have also found many advantages to OSS/FS.

One interesting usage story is the story of James Burgett’s Alameda County Computer Resource Center, one of the largest non-profit computer recycling centers in the United States. Its plant processes 200 tons of equipment a month in its 38,000-square-foot warehouse. It has given thousands of refurbished computers to disadvantaged people all over the world, including as human rights organizations in Guatemala, the hard-up Russian space program, schools, and orphanages. All of the machines have GNU/Linux installed on them.

Indeed, for well-established products like GNU/Linux, very strong cases can be made for considering them. On October 18, 2002, Forrester Research reported that “Linux is now ready for prime time.” They stated that “CIOs have many new reasons to be confident that they’ll get quality Linux support from their largest application vendors and systems integrators,” referencing Amazon, Oracle, Sun, and IBM, among others who have made commitments that increase confidence that GNU/Linux is ready for deployment.

Indeed, these uses are becoming so widespread that Microsoft admits that OSS/FS competition may force Microsoft to lower its prices, at least in the server market. Microsoft noted this in its 10-Q quarterly filing, stating that “To the extent the open source model gains increasing market acceptance, sales of the company’s products may decline, the company may have to reduce the prices it charges for its products, and revenues and operating margins may consequently decline.”

Summaries of government use in various countries are available from Infoworld and IDG.

Several organizations collect reports of OSS/FS use, and these might be useful sources for more information. Linux International has a set of Linux case studies/success stories. Mandrakesoft maintains a site recording the experiences of business users of the Mandrake distribution. Red Hat provides some similar information. Opensource.org includes some case studies.

The Dravis Group LLC published in April 2003 *Open Source Software: Case Studies Examining its Use*, examining several specific use cases in depth. Their study of several different organizations deploying OSS/FS concluded the following:

1. Cost is a significant factor driving adoption of open source software.
2. Control and flexibility are considered benefits as well.
3. Implementation of open solutions is evolutionary, not revolutionary.
4. Open source extends across the entire software stack.
5. Product support is not a significant concern.
6. Open source is not a magic solution.
7. Open standards may be more important than open source.

12. Governments and OSS/FS

Practically all governments use OSS/FS, and many have policies or are considering policies related to OSS/FS. Motivations vary; for many governments, the overriding rationale for consideration of OSS/FS is to reduce costs. Others have a more nuanced view, considering a variety of factors that a commercial firm would also consider such as reliability, performance, and so on. Some governments also consider OSS/FS for other reasons, such as industrial policy (trying to encourage local companies who can train, support, and tailor products), transparency of government (OSS/FS enables complete review of exactly what is done and what data is stored), and longevity of records (OSS/FS reveals exactly how data is stored). Few governments want their government computing infrastructure -- or their country's infrastructure -- completely controlled by any one company. In many cases, the company is foreign (or at least not local), which adds additional concerns in some cases.

The Center for Strategic and International Studies developed a 2004 survey of the OSS/FS positions of various governments worldwide. The Open Source and Industry Alliance (OSAIA)'s "Roundup of Selected OSS Legislative Activity WorldWide" (aka Policy Tracker) surveys government OSS policies in 2003 and 2004. The widely-cited Free/Libre and Open Source Software (FLOSS): Survey and Study includes a great deal of information about public sector use of OSS/FS. An older but broad survey was published in 2001 by CNet. More information about governments and OSS/FS can be found at the Center of Open Source and Government (eGovOS) web site.

A New York Times article noted that "More than two dozen countries in Asia, Europe and Latin America, including China and Germany, are now encouraging their government agencies to use 'open source' software" Robert Kramer of CompTIA (Computer Technology Industry Association) says that political leaders everywhere from California to Zambia are considering legislating a preference for Open Source software use; he counted at least 70 active proposals for software procurement policies that prefer OSS/FS in 24 countries as of October 2002. There are certainly debates on the value of OSS/FS preferences (even a few OSS/FS advocates like Bruce Perens don't support mandating a government preference for OSS/FS), but clearly this demonstrates significant positive interest in OSS/FS from various governments.

Tony Stanco's presentation "On Open Source Procurement Policies" briefly describes why he believes governments should consider OSS/FS. Ralph Nader's Consumer Project on Technology gives reasons he believes the U.S. government should encourage OSS/FS. The paper Linux Adoption in the Public Sector: An Economic Analysis by Hal R. Varian and Carl Shapiro (University of California, Berkeley; 1 December 2003) makes several interesting points about OSS/FS. This paper uses some odd terminology, for example, it uses the term "commercial software" where it means "closed source software" (this poor terminology choice makes the paper's discussion on commercial open source software unnecessarily difficult to understand). But once its terminology is understood, it makes some interesting points. It notes that:

1. "The Linux operating system has achieved a 'critical mass' sufficient to assure users that it will be available and improved for years to come, reducing the risk to users and to software developers.
2. ... users adopting Linux are less likely to face "lock-in" than those adopting proprietary platform software, and they retain greater control over their own computing environments. These benefits are especially salient in complex computing environments ... as often occurs in the public sector.
3. Open source software, such as Linux, typically uses open interfaces [that] typically lead to a larger, more robust, and more innovative industry and therefore software with open interfaces should be preferred by public sector officials, as long as it offers comparable quality to proprietary alternatives.

4. Because Linux is open source platform software, adoption of Linux can help spur the development of a country's software sector, in part by promoting the training of programmers that enables them to develop applications that run on the Linux platform. The adoption of the Linux platform may well promote the economic development of commercial software to run in that environment.
5. Fears that the licensing terms associated with Linux discourage the development of commercial software are misplaced... we expect mixed computing environments involving open source software and commercial software, that employ both open and proprietary interfaces, to flourish in the years ahead.

Many countries favor or are considering favoring OSS/FS in some way, such as Peru, the UK, and Taiwan.

The following sections describe some government actions in the United States, Europe, and elsewhere. There is also a section on some attempts or perceived attempts to prevent government consideration of OSS/FS. However, this information is by no means complete; this is simply a sample of some of the ongoing activities.

12.1 United States

There are many government users of OSS/FS in the United States, and a variety of related policies, studies, and recommendations. This includes departments and agencies of the federal government, as well as state and local governments. Many have advocated additional use or changes in approach. A summary of some of this information is below.

The U.S. federal government has a formal policy of neutrality, that is, OSS/FS and proprietary software must be considered using the same criteria, as noted in Office of Management and Budget memorandum M-04-16 of July 1, 2004. This mirrors the earlier 2003 OSS/FS policy of the U.S. Department of Defense, which clearly states that OSS/FS and proprietary are both acceptable but must follow the same rules. Both also note that the license requirements for OSS/FS are different than proprietary software, so acquirers should make sure they understand the license requirements since they may be different from what they're used to.

The (U.S.) President's Information Technology Advisory Committee (PITAC)'s report, the *Recommendations of the Panel on Open Source Software For High End Computing*, recommends that the U.S. "Federal government should encourage the development of open source software as an alternate path for software development for high end computing." See the separate discussion on MITRE Corporation's business case study of OSS (which emphasized use by the U.S. government, especially the U.S. military).

A NASA technical report describes in detail an approach for NASA to release some of its software as open source software.

The U.S. National Imagery and Mapping Agency (NIMA) National Technical Alliance, through the National Center for Applied Technology (NCAT) consortium, funded the Open Source Prototype Research (OSPR) project. Under the OSPR project ImageLinks Inc., Tybrin Inc., Kodak Inc., and Florida Institute of Technology (Florida Tech) performed evaluations of open source software development practices and demonstrated the technological advantages of Open Source Software. The OSPR final report includes those evaluations, a survey, and various related documents; these are actually rather extensive. The final report concludes:

Open Source Software development is a paradigm shift and has enormous potential for addressing government needs. Substantial technology leverage and cost savings can be achieved with this approach. The primary challenge will be in establishing an organizational structure that is able to employ OSS methodology...

The paper Open Source and These United States by C. Justin Seiferth summarizes that:

The Department of Defense can realize significant gains by the formal adoption, support and use of open licensed systems. We can lower costs and improve the quality of our systems and the speed at which they are developed. Open Licensing can improve the morale and retention of Airmen and improve our ability to defend the nation. These benefits are accessible at any point in the acquisition cycle and even benefit deployed and operational systems. Open Licensing can reduce acquisition, development, maintenance and support costs and increased interoperability among our own systems and those of our Allies.
NetAction has proposed more OSS/FS use and encouragement by the government; see The Origins and Future of Open Source Software by Nathan Newman and The Case for Government Promotion of Open Source Software by Mitch Stoltz for their arguments.

More recently, The U.S. Department of Defense Information Systems Agency (DISA) has certified Linux distributor Red Hat's Advanced Server operating system as a "Common Operating Environment" (COE), meaning the server product meets the agency's software security and interoperability specification.

U.S. state governments have widely used OSS/FS too. The Center for Digital Government's 2003 "Best of the Web" awards named the top 5 state web sites as Utah, Maine, Indiana, Washington, and Arkansas. Four of the five winning state web sites use OSS/FS programs to implement their site. The only state in the top five not using OSS/FS was Washington - Microsoft's home state.

Some states, such as Massachusetts, have a formal policy encouraging the use of open standards. It is often easier to deploy OSS/FS, if you choose to do so, if you're already using open standards; it's much more difficult to change to either a proprietary or OSS/FS product if you're stuck using proprietary standards.

A report from the state of California urges that "the state should more extensively consider use of open source software, stating that OSS/FS "can in many cases provide the same functionality as closed source software at a much lower total cost of ownership".

California's Air Resources Board (ARB) has had a great deal of experience with OSS/FS; their web page on ARB's Open Source Initiatives provides much more information.

Stanislaus County has saved significant amounts of money through smart migration to OSS/FS programs like Linux and JBoss. Richard Robinson, the director of strategic business technology (not the county's CEO), once worked at Accenture (Anderson Consulting) and has been working hard to identify the county's needs and meet them. In two years, he's reduced costs in his department by 30-65% depending on how you measure it. In 2002, 2% of the county's servers used Linux; by 2004, 25% use Linux, and next year that's expected to increase to 33%.

12.2 Europe

The Interchange of Data between Administrations (IDA) programme is managed by the European Commission, with a mission to "coordinate the establishment of Trans-European telematic networks between administrations." IDA has developed a vast amount of OSS/FS information, including an extraordinary amount of information specific to Europe. IDA's

Open Source Observatory provides a great deal of OSS/FS background information, OSS/FS news, European OSS/FS case studies, OSS/FS events (both European and abroad), and other material. IDA also provides The IDA Open Source Migration Guidelines to describe how to migrate from proprietary programs to OSS/FS programs. The authors state that “There are many reasons for Administrations to migrate to OSS. These include: the need for open standards for e-Government; the level of security that OSS provides; the elimination of forced change; the cost of OSS. All these benefits result in far lower [Information Technology] costs.” Another paper of interest to governments considering OSS/FS is Paul Dravis’ “Open Source Software: Perspectives for Development”, developed for the World Bank Group. The Consortium for Open Source in the Public Administration aims to analyze the effects of introducing open data standards and Open Source software for personal productivity and document management in European public administrations.

In 2002 an independent study was published by the European Commission. Titled ”Pooling Open Source Software”, and financed by the Commission’s Interchange of Data between Administrations (IDA) programme, it recommends creating a clearinghouse to which administrations could “donate” software for re-use. This facility would concentrate on applications specific to the needs of the public sector. More specifically, the study suggests that software developed for and owned by public administrations should be issued under an open source license, and states that sharing software developed for administrations could lead to across-the-board improvements in efficiency of the European public sector.

In October 2002, the European Commission awarded Netproject a pilot contract valued at EUR250,000 to examine deployment of OSS/FS in government departments.

As reported in the *Washington Post* on November 3, 2002, Luis Millan Vazquez de Miguel, the minister of education, science and technology in a western region of Spain called Extremadura, is heading the launch of a government campaign to convert all the area’s computer systems (in government offices, businesses and homes) from the Windows operating system to GNU/Linux. Vazquez de Miguel said over 10,000 desktop machines have already been switched, with 100,000 more scheduled for conversion in the next year. The regional government paid a local company $180,000 to create a set of freely available software, and invested in a development center that is creating customized software. “So far, the government has produced 150,000 discs with the software, and it is distributing them in schools, electronics stores, community centers and as inserts in newspapers. It has even taken out TV commercials about the benefits of free software.” The Post also discussed some of the reasons some governments are turning to OSS/FS. “Among the touchiest issues that Microsoft faces outside the United States is the uneasiness some countries have expressed about allowing an American company to dominate the software industry in their country. ‘Non-U.S. governments in particular view open source as a way to break the stranglehold against Microsoft. If Microsoft owns everything their countries, their own companies can’t get a foothold in the software industry,’ said Ted Schadler, an analyst for Forrester Research Inc.” Some Spanish government systems and those belonging to the telecommunications company Telefonica recently were shifted to Linux partly because of security concerns. In Florence, legislators talked of breaking the ‘the computer science subjection of the Italian state to Microsoft.’ “

Germany intends to increase its use of OSS/FS. IBM signed a Linux deal with Germany; Germany’s Interior Minister, Otto Schilly, said the move would help cut costs, improve security in the nation’s computer networks, and lower dependence on any one supplier.

Munich, Germany (the third largest German city) has decided to migrate all of its 14,000 computers in public administration to GNU/Linux and other OSS/FS office applications, dropping Microsoft’s Windows in the process. USA Today gives a detailed discussion of how this decision was made. Here's more information about the Munich approach. The GNU/Linux system bid had a somewhat higher cost than the lowest cost Microsoft bid, but when looking at the details, the claim that Microsoft was lower cost appears misleading -- Microsoft's bid was significantly different than the GNU/Linux bid. For example, in Microsoft's bid, the Windows systems wouldn't be upgraded for 6 years. Who doesn't upgrade for 6 years? If Munich had agreed to that in 1998, in 2004 they'd still be running only Windows 98 and NT 4.0. Also, in Microsoft's low bid, many systems would only get the word processor Word, not a full office suite (GNU/Linux systems typically come with complete office application suites at no additional cost, important for people who suddenly need to read presentations and spreadsheets). Also, some have noted that many of the costs for the GNU/Linux approach can be viewed as a "removing Microsoft" cost rather than the cost of using GNU/Linux per se; delaying the switch could have made the cost of switching later even larger due to increased lock-in. It's likely, however, that this decision was made with a long-term view of many issues, not solely by cost.

Finnish MPs are encouraging the use of GNU/Linux in government systems.

Statskontoret, the Swedish Agency for Public Management, has performed a feasibility study on free and open source software and came to very positive conclusions (see the report in English or Swedish).

On October 10, 2002, the Danish Board of Technology released a report about the economic potential in using Open Source software in the public administration. The report showed a potential savings of 3.7 billion Danish Kroners (500 million Euros) over four years. A pilot project in the Hanstholm municipality determined that switching the office suite from Microsoft Office to OpenOffice.org and StarOffice did not increase their number of problems and that each user only needed 1 to 1.5 hours of training to learn the new office suite. The municipality will now use OpenOffice.org and StarOffice on all workplaces (200 in all) and will save 300,000 Danish Kroners (about 40,000 Euros) each year in license fees. They will still use Microsoft Windows as their OS. You may want to see the Danish government's report on OSS/FS.

In July 2002, UK Government published a policy on the use of Open Source Software. This policy had the following points:

1. UK Government will consider OSS solutions alongside proprietary ones in IT procurements. Contracts will be awarded on a value for money basis.
2. UK Government will only use products for interoperability that support open standards and specifications in all future IT developments.
3. UK Government will seek to avoid lock-in to proprietary IT products and services.
4. UK Government will consider obtaining full rights to bespoke software code or customisations of COTS (Commercial Off The Shelf) software it procures wherever this achieves best value for money.
5. UK Government will explore further the possibilities of using OSS as the default exploitation route for Government funded R&D software.

As follow-on work, the United Kingdom's Office of Government Commerce (OGC) performed "proof of concept" trials of Open Source Software (OSS) in a range of public bodies. In October 2004 summarized its key findings taking into account information from elsewhere. Their Government Open Source Software Trials Final Report is publicly available, and has some very interesting things to say. A brief news article describes the report. The report concludes that:

- *Viability of OSS:* Open Source software is a viable and credible alternative to proprietary software for infrastructure implementations, and for meeting the requirements of the majority of desktop users;
- *Obstacles to implementation:* The main obstacles to widespread implementation of Open Source software are: for desktop applications, the current lack of complex functionality which can affect ease of migration and interoperability for some organisations; and for business applications, the lack of Open Source products to compete with large-scale proprietary enterprise-level products; no significant obstacles were noted for the adoption of Open Source in infrastructure developments;
- *Costs and benefits:* Adoption of Open Source software can generate significant savings in hardware and software costs for infrastructure implementation, and reduce the licensing costs and hardware refresh requirements for desktop implementation;
- *Lessons learned:* Adoption of Open Source, particularly for the desktop, requires investment in planning, training of users, development of skills for implementation and support, and detailed consideration of migration and interoperability issues.

The UK report recommended that public sector bodies should:

1. examine carefully the technical and business case for implementation of Open Source software and the role which OSS could play in current and future projects, working with their outsourced IT providers where appropriate;
2. review the potential for server consolidation, comparing the benefits of OSS with proprietary solutions;
3. consider the potential costs and benefits of migration to an OSS desktop for transaction users, (potentially in conjunction with use of “thin client” architecture solutions);
4. identify the role of open standards in future IS/IT strategy and policy, in conformance with the e-Government Interoperability Framework (eGIF);
5. consider requirements for the development of skills in Open Source development, deployment and operation within the organisation, and review the availability of such skills in their outsourced IT service providers;
6. review their current infrastructure and applications - in collaboration with their outsourced IT providers where relevant - well in advance of any planned procurement or renewal, and determine whether current technologies and IT policies inhibit future choice; and if so consider what steps may be necessary to prevent future “lock in”;
7. consider the benefits of incremental change by diversifying OSS use beyond the server platform to products like Email, LDAP, Web and internet Browser.

12.3 Other Countries

A Linux Journal article notes many interesting international experiments and approaches, for example, Pakistan plans to install 50,000 low cost computers in schools and colleges all over Pakistan using GNU/Linux. A June 14, 2002 article in PC World also lists actions various governments are taking.

The Korean government announced that it plans to buy 120,000 copies of Hancom Linux Deluxe this year, enough to switch 23% of its installed base of Microsoft users to open source equivalents; by standardizing on GNU/Linux and HancomOffice, the Korean government expects savings of 80% compared with buying Microsoft products (HancomOffice isn’t OSS/FS, but GNU/Linux is). Taiwan is starting a national plan to jump-start the development and use of OSS/FS.

Peru has even been contemplating passing a law requiring the use of OSS/FS for public administration (government); rationale for doing so, besides saving money, include supporting “Free access to public information by the citizen, Permanence of public data, and the Security of the State and citizens.” Dr. Edgar David Villanueva Nuñez (a Peruvian Congressman) has written an interesting letter supporting this law. Marc Hedlund written has a brief description of the letter; an English translation is available (from GNU in Peru, UK’s “The Register”, and Linux Today); there is a longer discussion of this available at Slashdot. Whether or not this law passes, it is an interesting development.

Sun Microsystems has announced a deal with China to provide one million Linux desktops, and mentioned that China “has pledged to deploy 200 million copies of open standards-based desktop software”.

South Africa’s government departments are being officially encouraged to stop using (expensive) proprietary software, and to OSS/FS instead. This is according to a January 15, 2003 announcement by Mojalefa Moseki, chief information office with the State Information Technology Agency (Sita). South Africa plans to save 3 billion Rands a year (approximately $338 million USD), increase spending on software that stays in their country, and increase programming skill inside the country. Soutch Africa reports that its small-scale introductions have already saved them 10 million Rands (approximately $1.1 million USD). More information is available at Tectonic (see also South African minister outlines OSS plans). The state of Oregon is considering an OSS/FS bill as well. Japan has earmarked 1 billion yen for a project to boost operating systems other than Microsoft Windows - it is expected to be based on OSS/FS, particularly Linux, and both South Korea and China are coordinating with Japan on it. In December 2003, Israel’s government suspended purchases of new versions of Microsoft office software and began actively encouraging the development of an open-source alternatives (especially Open Office). Indian President A.P.J. Abdul Kalam called for his country’s military to use OSS/FS to ward off cybersecurity threats; as supreme commander of the Indian armed forces, this is a directive he can implement.

Brendan Scott’s Research Report: Open Source and the IT Trade Deficit of July 2004 found that in just Australia, the costs of just the closed source operating system were causing an Australian trade deficit of $430 million per year.

There have been many discussions about the advantages of OSS/FS in less developed countries. Heinz and Heinz argue in their paper Proprietary Software and Less-Developed Countries - The Argentine Case that the way proprietary software is brought to market has deep and perverse negative consequences regarding the chances of growth for less developed countries. Danny Yee’s Free Software as Appropriate Technology argues that Free Software is an appropriate technology for developing countries, using simple but clear analogies. *Free as in Education: Significance of the Free/Libre and Open Source Software for Developing Countries*, commissioned by the Finnish Ministry for Foreign Affairs, examines the significance of OSS/FS and related concepts; their FLOSS for Development website identifies other analyses of OSS/FS to support their goal, “To find out if and how Free/Libre and Open Source software is useful for developing countries in their efforts to achieve overall development, including bridging the digital divide.”

12.4 Countering Government Use of OSS/FS

Many proprietary companies compete with OSS/FS products. The rise of competition in IT markets, particularly in places where there hadn’t been competition before, has had the general beneficial effect of lowering the costs of software to governments. Even simply *threatening* to use a different supplier is often enough to gain concessions from all vendors, and since governments are large customers, they often gain large concessions. And of course all companies work to provide information on their products that puts them in the best possible light. Competing in terms of technical capabilities, cost, support, and so on is a normal part of government acquisition, and not further considered here.

However, there have been some efforts (or at least perceived efforts) to prevent government use of OSS/FS, or forbid use of the most common OSS/FS license (the GPL). Generally these efforts have not had much success.

As described in “Geek activism” forces Congress to reconsider Open Source, in 2002 a letter from the U.S. Congress unrelated to OSS/FS was modified by Representative Adam Smith from Washington state. Smith’s largest campaign donation source is Microsoft Corporation. The modifications added statements strongly discouraging the use of the GPL. The letter was originally signed by 67 Congressmen, but as an Associated Press piece notes, “Smith’s attack on open-source drew an angry response from one of the original authors of the letter, Rep. Tom Davis, R-Va., chairman of the House Government Reform subcommittee on technology and procurement policy. “We had no knowledge about that letter that twisted this position into a debate over the open source GPL issues,” said Melissa Wojciak, staff director of the subcommittee. Wojciak added that Davis supports government funding of open-source projects.” At the end, “Many staffers of the 67 Congressman who signed are now claiming they didn’t know what they were signing and the letter has been withdrawn.” Information Week also picked up the story. Also in 2002, the Washington Post reported in 2002 that there had been an aggressive lobbying effort to squelch use of OSS/FS in the the U.S. Department of Defense. The effort didn’t work; the DoD released an official policy of neutrality.

So many governments have begun officially requiring that OSS/FS options be considered, or enacting preferences for OSS/FS, that Microsoft has sponsored an organization called the Initiative for Software Choice. Many observers believe the real purpose of this organization is to prevent governments from considering the advantages or disadvantages of a software license when they procure software, to prevent governments from requiring consideration of OSS/FS products, and to encourage the use of standards that inhibit the use of OSS/FS. Indeed, Microsoft has invested large sums of money to lobby against OSS/FS, according to CIO magazine.

An opposing group, founded by Bruce Perens, is Sincere Choice.org, which advocates that there be a “fair, competitive market for computer software, both proprietary and Open Source.” Bruce Perens has published an article discussing why he believes “Software Choice” is not what it first appears to be.

This doesn’t mean that governments always choose OSS/FS; quite the contrary. Indeed, most governments are quite conservative in their application of OSS/FS implementations. Articles such as Linux in Government: In Spite of Endorsements, Government Linux Projects Still Treading Water and Not So Fast, Linux discuss some of the roadblocks and reasons governments don’t use OSS/FS in various situations.

Interestingly, OSS/FS has forced Microsoft to be more open with its code to various governments. Bloomberg’s January 14, 2003 article “Microsoft Has New Plan to Share Code With Government” announces that Microsoft Corporation “will expand sharing of the code underlying its Windows programs to help governments and agencies such as Russia and the North Atlantic Treaty Organization (NATO) improve computer security.” It notes that “Microsoft is facing competition from the Linux operating system, which lets customers view and modify its source code. In the government sector in particular, Microsoft has lost contracts to Linux, analysts said. More than 20 countries are looking at legislative proposals that mandate considering or using Linux in government computers... [and Microsoft has] begun to make the code available to governments, as well as key customers and partners, in an effort to compete with Linux.”

13. Other Information

Here are some other related information sources:

1. There are several general information sites about OSS/FS or Unix that might be of interest, such as the Free Software Foundation (FSF), the Open Source Initiative website, and the Linux.org site. George Mason University's Exploring and Collecting History Online (ECHO) project has a useful collection in its material on A Free and Open History of Free and Open Source Software, and the Massachusetts Institute of Technology (MIT)'s Free / Open Source Research Community website also maintains a useful collection of research papers. An older paper is John Kirch's paper, *Microsoft Windows NT Server 4.0 versus UNIX*. (also archived at the Internet Archives). The book *The Cathedral and the Bazaar* by Eric Raymond examines OSS/FS development processes and issues. A useful collection of many OSS/FS writings, including the essay *The Cathedral and the Bazaar*, is in the Open Source Reader. Peter Wayner's book Free For All: How Linux and the Free Software Movement Undercut the High-tech Titans describes the history and rise of OSS/FS, and includes interviews with many key leaders; the book can be either downloaded electronically without fee or purchased as a hardcover book. Ganesh C. Prasad has published The Practical Manager's Guide to Linux. Dan Kegel's "The Case for Linux in Universities" discusses why students need exposure to GNU/Linux at universities (and thus why universities should support and encourage this). The paper Our Open Source / Free Software Future: It's Just a Matter of Time argues that within the next few years, the standard de-facto OS that nearly everyone uses, as well as much of the commodity software in widespread use, will be OSS/FS. You can see a collection of general information about OSS/FS at my web page listing OSS/FS references.
2. MITRE Corporation has examined the application of OSS/FS to military systems. Their July 2001 report, A Business Case Study of Open Source Software, concludes that "open source methods and products are well worth considering seriously in a wide range of government applications, particularly if they are applied with care and a solid understanding of the risks they entail. OSS encourages significant software development and code re-use, can provide important economic benefits, and has the potential for especially large direct and indirect cost savings for military systems that require large deployments of costly software products." They also recommend following the following steps to determine whether to use OSS or proprietary products: assess the supporting OSS developer community, examine the market, conduct a specific analysis of benefits and risks, compare the long-term costs, and choose your strategy. MITRE has received a Leadership Award from the non-profit Potomac Forum for showing that OSS can provide substantial advantages over proprietary software, particularly when reliability and long-term support are key requirements.

   After that, in the Washington Post article *Open-source Fight Flares at Pentagon*, it was reported that "Microsoft Corp. is aggressively lobbying the Pentagon to squelch its growing use of freely distributed computer software and switch to proprietary systems such as those sold by the software giant, according to officials familiar with the campaign..." But the effort backfired.

   MITRE Corporation report, presumably in response to such efforts, prepared a second report at the request of the Department of Defense (DoD) Defense Information Systems Agency (DISA). The report was titled "Use of Free and Open Source Software in the US Dept. of Defense" and was originally dated May 10, 2002, publicly released on October 28, 2002, and was updated slightly in 2003. This report concluded that OSS/FS use in the DoD is widespread and should be expanded. This MITRE report concluded that "banning [OSS/FS] would have immediate, broad, and strongly negative impacts on the ability of many sensitive and security-focused DoD groups to defend against cyberattacks." The report also found that the GPL so dominates in DoD applications that a ban on just the GPL would have the same strongly negative impacts as banning all OSS/FS. MITRE noted that OSS/FS "plays a far more critical role in the DoD than has been generally recognized." In a two-week survey period MITRE identified a total of 115 FOSS applications and 251 examples of their use. MITRE concluded that "Neither the survey nor the analysis supports the premise that banning or seriously restricting [OSS/FS] would benefit DoD security or defensive capabilities. To the contrary, the combination of an ambiguous status and largely ungrounded fears that it cannot be used with other types of software are keeping [OSS/FS] from reaching optimal levels of use." It short, MITRE found that OSS/FS is widely used, and should be even more widely used. On May 28, 2003, the DoD issued a formal memo placing OSS/FS on a level playing field with proprietary software, without imposing any additional barriers beyond those already leveled on its software.

The Post article also noted that "at the Census Bureau, programmers used open-source software to launch a Web site for obtaining federal statistics for $47,000, bureau officials said. It would have cost $358,000 if proprietary software were used."

3. The European Free/Libre and Open Source Software (FLOSS): Survey and Study is a large multi-part report examining OSS/FS from a number of different vantage points. The report is divided into the following (besides its summary and raw data):
   - Part I: Use of Open Source Software in Firms and Public Institutions,
   - Part II: Firms' Open Source Activities: Motivations and Policy Implications
   - Part II B: Open Source Software in the Public Sector: Policy within the European Union
   - Part III: Basics of Open Source Software Markets and Business Models
   - Part IV: Survey of Developers
   - Part V: Source Code Survey
4. Computer Sciences Corporation (CSC) released in 2004 the large paper *Open Source: Open for Business* reporting many advantages to employing OSS/FS.
5. Microsoft has been trying to claim that open source is somehow dangerous, and indeed is its leading critic, yet the Wall Street Journal's Lee Gomes found that "Microsoft Uses Open-Source Code Despite Denying Use of such Software." Here are some interesting quotes from his article:

   ... But Microsoft's statements Friday suggest the company has itself been taking advantage of the very technology it has insisted would bring dire consequences to others. "I am appalled at the way Microsoft bashes open source on the one hand, while depending on it for its business on the other," said Marshall Kirk McKusick, a leader of the FreeBSD development team.

   More recently Microsoft has targeted the GPL license rather than all OSS/FS licenses, claiming that the GPL is somehow anti-commercial. But this claim lacks evidence, given the many commercial companies (e.g., IBM, Sun, and Red Hat) who are using the GPL. Also, see this paper's earlier note that Microsoft itself makes money by selling a product with GPL'ed components. The same article closes with this statement:

   In its campaign against open-source, Microsoft has been unable to come up with examples of companies being harmed by it. One reason, said Eric von Hippel, a

Massachusetts Institute of Technology professor who heads up a research effort in the field, is that virtually all the available evidence suggests that open source is “a huge advantage” to companies. “They are able to build on a common standard that is not owned by anyone,” he said. “With Windows, Microsoft owns them.”

Other related articles include Bruce Peren’s comments, Ganesh Prasad’s *How Does the Capitalist View Open Source?*, and the open letter *Free Software Leaders Stand Together*.

6. Indeed, many who have analyzed general information technology (IT) trends or Microsoft’s actions have concluded that strongly depending on Microsoft’s products is now a dangerous strategy. 2003 And Beyond by Andrew Grygus examines the IT industry from a small business point of view, and identifies a large number of dangers from depending on a Microsoft-based infrastructure. Fundamentally, Microsoft is working hard to increase customer dependency, and charges exorbitantly once the customer cannot practically switch.
7. Microsoft inadvertently advocated OSS/FS in leaked documents called the ”Halloween” documents. The original first two Halloween documents found that OSS/FS was far more effective than they wished to admit. Halloween 7 gives results of one of their surveys, again, with many positive comments about OSS/FS.
8. Another leaked internal Microsoft document is Converting a UNIX .COM Site to Windows (by David Brooks). This document describes lessons learned when converting Hotmail from the OSS/FS FreeBSD to Microsoft Windows after Microsoft purchased Hotmail, including advantages and disadvantages of each approach, and ends up identifying a large number of advantages of their competition. For example, it noted that “entrepreneurs in the startup world are generally familiar with one version of UNIX (usually through college education), and training in one easily converts to another.” An article in The Register summarizes many of the advantages of the Unix approach given in the paper.
9. Several documents were written to counter Microsoft’s statements such as those in Microsoft’s “Linux Myths”. This includes LWN’s response and Jamin Philip Gray’s response, and the FUD-counter site. The shared source page argues that Microsoft’s “shared source” idea is inferior to open source. Richard Stallman’s *The GNU GPL and the American Way* counters the amusing claim by Microsoft that the GPL was “un-American.” The letter Free Software Leaders Stand Together argues against the statements by Craig Mundie. You can find many general sites about Microsoft, including Cloweth’s site.
10. In a story full of ironies, Microsoft and Unisys teamed up in a well-funded marketing campaign against Unix, in part to try to revive Unisys’ sagging sales of Windows-based products. The 18-month, $25 million campaign, dubbed “We have the Way Out,” specifically attacked the Unix offerings of Sun, IBM, and Hewlett-Packard, but since the major OSS/FS OSes are Unix or Unix-like, it attacks them as well. In a delicious irony, it was revealed that the anti-Unix campaign website is powered by Unix software - in this case, FreeBSD (an OSS/FS version of Unix) and the OSS/FS Web server Apache. Once this was publicly revealed, Microsoft and Unisys quickly switched to a Windows-based system.. and then the website failed to operate at all for several days. If *that* wasn’t enough, Andrew Orlowski reported in *The Register* a further analysis of this website, noting that port 3306 was open on their website - a port primarily used by MySQL and Postgres. In other words, it appears that their anti-Unix site was still using OSS/FS software (not Microsoft’s own database) that is primarily deployed on Unix-like systems. Even their original imagery turns out to have had serious problems; the campaign’s original graphic showed a floor almost wholly covered in mauve paint (Sun Microsystem’s color), and the alternative offered was to jump through a window. Many literate readers will recognize this symbol (the

act of throwing out through, or of being thrown out of, a window) as *defenestration*, a way of killing rulers and also a popular way of inviting kings to commit suicide in 17th century Europe. In other words, this imagery suggests that you should use the window[s] to commit suicide (!). Leon Brooks then analyzed the site further - and found that the "way out" site used JSP (a technology fathered by Sun, Unix specialists). He also found that the site violated many standards; the site's content failed the W3C validation suites (Microsoft is a member of the W3C), and uses a Windows-only character set that is not only non-standard, but actively conflicts with an important international standard (and ironically one which Microsoft is actively promoting). If using only Windows is so wonderful, why can't the advocacy site conform to international standards? The real problem here, of course, is that trying to convince people that Unix is to be avoided at all costs - while using Unix and then having serious problems when trying to use an alternative - is both ironic and somewhat hypocritical.

11. "How Big Blue Fell For Linux" is an article on how IBM transitioned to becoming a major backer. IBM announced that it planned to invest $1 Billion in GNU/Linux in 2001 *all by itself* (see the IBM annual report). In 2002 IBM reported that they had already made almost all of the money back; I and others are a little skeptical of these claims, but it's clear that IBM has significantly invested in GNU/Linux and seem to be pleased with the results (for an example, see their Linux-only mainframe). This is not just a friendly gesture, of course; companies like IBM view OSS/FS software as a competitive advantage, because OSS/FS frees them from control by another organization, and it also enables customers to switch to IBM products and services (who were formerly locked into competitor's products). Thankfully, this is a good deal for consumers too. In 2002, IBM had 250 employees working full time to improve Linux.
12. For a scientifically unworthy but really funny look at what people who *use* the various OSes say, take a look at the Operating System Sucks-Rules-O-Meter. It counts how many web pages make statements like "Linux rocks". It's really barely an opinion poll, but if nothing else it's great for a laugh.
13. There have been several academic studies of OSS/FS. For example, "A Framework for Open Source Projects" (a Master Thesis in Computer Science by Gregor J. Rothfuss) describes a framework for describing Open Source projects, introducing notions of actors, roles, areas, processes and tools, and depicts their interrelationships. The goal was to provide a conceptual foundation and a help for organizing and managing Open Source projects.
14. Several studies examine developers (instead of the programs they write), including "A Quantitative Profile of a Community of Open Source Linux Developers", Herman, Hertel and Niedner's study (based on questionnaires), and the Who Is Doing It (WIDI) study. The European Free/Libre and Open Source Software Survey (FLOSS) has a large amount of information on developers. The paper Two Case Studies of Open Source Software Development: Apache and Mozilla examines two major open source projects, the Apache web server and the Mozilla browser, and using archives (such as source code change history and problem reports) they quantify aspects of developer participation, core team size, code ownership, productivity, defect density, and problem resolution intervals for these projects. The Boston Consulting Group/OSDN Hacker Survey (release 0.73, July 21, 2002) made some interesting observations by sampling SourceForge users. For example, it gives evidence that open source developers can be divided into four groups (based on their motivations for writing OSS/FS software):
    a. Believers (19%): believe source code should be open.
    b. Learning and Fun (29%): for non-work needs and intellectual stimulation.
    c. Hobbyists (27%): need the code for a non-work reason.
    d. Professionals (25%): for work needs and professional status.

Journalists sometimes like to romanticize OSS/FS developers as being mostly teenage boys with little experience, but the survey didn't support that view. The study found that the open source developers surveyed are mostly experienced professionals, having an average of 11 years of programming experience; the average age was 28.

The paper "Altruistic individuals, selfish firms? The structure of motivation in Open Source Software" by Andrea Bonaccorsi and Cristina Rossi (First Monday, January 2004) discusses a 2002 survey of 146 Italian firms supplying OSS/FS, and compared that with surveys of individual programmers. It found significant differences between motivations of individuals and firms, with firms emphasizing economic and technological reasons. The top reasons (in order) of OSS/FS-supplying firms were (1) because OSS allows small enterprises to afford innovation, (2) because contributions and feedback from the Free Software community are very useful in fixing bugs and improving software, (3) because of the reliability and quality of OSS, (4) because the firm wants to be independent of the price and licence policies of large software companies, and (5) because we agree with the values of the Free Software movement.

15. If you determine that you wish to start an OSS/FS project, there are some documents available to aid you. This includes the *Free Software Project Management HOWTO* and *Software Release Practice HOWTO*. You should also read *The Cathedral and the Bazaar*.
16. Other evaluations include the Gartner Group and GNet evaluations.

For general information on OSS/FS, see my list of Open Source Software / Free Software (OSS/FS) references at http://www.dwheeler.com/oss_fs_refs.html

14. Conclusions

OSS/FS has significant market share in many markets, is often the most reliable software, and in many cases has the best performance. OSS/FS scales, both in problem size and project size. OSS/FS software often has far better security, perhaps due to the possibility of worldwide review. Total cost of ownership for OSS/FS is often far less than proprietary software, especially as the number of platforms increases. These statements are not merely opinions; these effects can be shown *quantitatively*, using a wide variety of measures. This doesn't even consider other issues that are hard to measure, such as freedom from control by a single source, freedom from licensing management (with its accompanying risk of audit and litigation), Organizations can transition to OSS/FS in part or in stages, which for many is a far more practical transition approach.

Realizing these potential OSS/FS benefits may require approaching problems in a different way. This might include using thin clients, deploying a solution by adding a feature to an OSS/FS product, and understanding the differences between the proprietary and OSS/FS models. Acquisition processes may need to change to include specifically identifying OSS/FS alternatives, since simply putting out a "request for proposal" may not yield all the viable candidates. OSS/FS products are not the best technical choice in all cases, of course; even organizations which strongly prefer OSS/FS generally have some sort of waiver process for proprietary programs. However, it's clear that considering OSS/FS alternatives can be beneficial.

Of course, before deploying any program you need to evaluate how well it meets your needs, and some organizations do not know how to evaluate OSS/FS programs. If this describes your circumstance, you may wish to look at the companion articles *How to Evaluate OSS/FS Programs* and the *Generally Recognized as Mature (GRAM) list*.

OSS/FS options should be carefully considered any time software or computer hardware is needed. Organizations should ensure that their policies encourage, and not discourage, examining OSS/FS approaches when they need software.

Appendix A. About Open Source Software / Free Software (OSS/FS)

This appendix gives more information about open source software / free software (OSS/FS): definitions (of source code, free software, open source software, and various movements), motivations of developers, history, license types, management approaches, and forking.

A.1 Definitions

There are official definitions for the terms “Free Software” (as the term is used in this text) and “open source software”. However, understanding a few fundamentals about computer software is necessary before these definitions make sense. Software developers create computer programs by writing text, called “source code,” in a specialized language. This source code is often mechanically translated into a format that the computer can run. As long as the program doesn’t need to be changed (say, to support new requirements or be used on a newer computer), users don’t necessarily need the source code. However, changing what the program does usually requires possession and permission to change the source code. In other words, whoever legally controls the source code controls what the program can and cannot do. Users without source code often cannot have the program changed to do what they want or have it ported to a different kind of computer.

The next two sections give the official definitions of Free Software and Open Source Software (though in practice, the two definitions are essentially the same thing); I then discuss some related defintions, and contrast the terms “Free Software” and “Open Source Software”.

A.1.1 Definition of Free Software

OSS/FS programs have existed since digital computers were invented, but beginning in the 1980s, people began to try capture the concept in words. The two main definitions used are the “free software definition” (for free software) and the “open source definition” (for open source software). Software meeting one definition usually meets the other as well. Since the term “free software” came first, we’ll examine its definition first.

The Free Software Definition is published by Richard Stallman’s Free Software Foundation. Here is the key text of that definition:

“Free software” is a matter of liberty, not price. To understand the concept, you should think of “free” as in “free speech,” not as in “free beer.” Free software is a matter of the users’ freedom to run, copy, distribute, study, change and improve the software. More precisely, it refers to four kinds of freedom, for the users of the software:

- The freedom to run the program, for any purpose (freedom 0).
- The freedom to study how the program works, and adapt it to your needs (freedom 1). Access to the source code is a precondition for this.
- The freedom to redistribute copies so you can help your neighbor (freedom 2).

- The freedom to improve the program, and release your improvements to the public, so that the whole community benefits. (freedom 3). Access to the source code is a precondition for this.

A program is free software if users have all of these freedoms. Thus, you should be free to redistribute copies, either with or without modifications, either gratis or charging a fee for distribution, to anyone anywhere. Being free to do these things means (among other things) that you do not have to ask or pay for permission. You should also have the freedom to make modifications and use them privately in your own work or play, without even mentioning that they exist. If you do publish your changes, you should not be required to notify anyone in particular, or in any particular way. The freedom to use a program means the freedom for any kind of person or organization to use it on any kind of computer system, for any kind of overall job, and without being required to communicate subsequently with the developer or any other specific entity.

The text defining "free software" is actually much longer, explaining further the approach. It notes that "Free software does not mean non-commercial. A free program must be available for commercial use, commercial development, and commercial distribution. Commercial development of free software is no longer unusual; such free commercial software is very important."

A.1.2 The Open Source Definition

Open source software is officially defined by the open source definition:

Open source doesn't just mean access to the source code. The distribution terms of open-source software must comply with the following criteria:

1. Free Redistribution

The license shall not restrict any party from selling or giving away the software as a component of an aggregate software distribution containing programs from several different sources. The license shall not require a royalty or other fee for such sale.

2. Source Code

The program must include source code, and must allow distribution in source code as well as compiled form. Where some form of a product is not distributed with source code, there must be a well-publicized means of obtaining the source code for no more than a reasonable reproduction cost preferably, downloading via the Internet without charge. The source code must be the preferred form in which a programmer would modify the program. Deliberately obfuscated source code is not allowed. Intermediate forms such as the output of a preprocessor or translator are not allowed.

3. Derived Works

The license must allow modifications and derived works, and must allow them to be distributed under the same terms as the license of the original software.

4. Integrity of The Author's Source Code

The license may restrict source-code from being distributed in modified form *only* if the license allows the distribution of "patch files" with the source code for the purpose of modifying the program at build time. The license must explicitly permit distribution of software built from modified source code. The license may require derived works to carry a different name or version number from the original software.

5. No Discrimination Against Persons or Groups

The license must not discriminate against any person or group of persons.

6. No Discrimination Against Fields of Endeavor

The license must not restrict anyone from making use of the program in a specific field of endeavor. For example, it may not restrict the program from being used in a business, or from being used for genetic research.

7. Distribution of License

The rights attached to the program must apply to all to whom the program is redistributed without the need for execution of an additional license by those parties.

8. License Must Not Be Specific to a Product

The rights attached to the program must not depend on the program's being part of a particular software distribution. If the program is extracted from that distribution and used or distributed within the terms of the program's license, all parties to whom the program is redistributed should have the same rights as those that are granted in conjunction with the original software distribution.

9. The License Must Not Restrict Other Software

The license must not place restrictions on other software that is distributed along with the licensed software. For example, the license must not insist that all other programs distributed on the same medium must be open-source software.

10. No provision of the license may be predicated on any individual technology or style of interface.

A.1.3 Other Related Definitions and License Issues

The Open Source Definition was actually derived from the Debian Free Software Guidelines (DFSG); those original guidelines are still maintained and used by the widely-used and influential Debian project. Thus, the Debian guidelines are nearly identical to the Open Source Definition, yet Debian tends to use the term "Free Software" in its materials.

In addition, the debian-legal mailing list discusses licensing issues in great depth, in an effort to evaluate licenses based on the freedoms they grant or do not grant. The DFSG and Software License FAQ states that "The DFSG is not a contract. This means that if you think you've found a loophole in the DFSG then you don't quite understand how this works. The DFSG is a potentially imperfect attempt to express what free software means to Debian."

The DFSG and Software License FAQ also defines three additional "tests" used on the debian-legal mailing list to help them evaluate whether or not a license is "Free" (as in freedom). These tests aren't the final word, but because they're described as scenarios, they are sometimes easier for people to understand (and I quote the Debian FAQ here):

1. **The Desert Island test**. Imagine a castaway on a desert island with a solar-powered computer. This would make it impossible to fulfill any requirement to make changes publicly available or to send patches to some particular place. This holds even if such requirements are only upon request, as the castaway might be able to receive messages but be unable to send them. To be Free, software must be modifiable by this unfortunate castaway, who must also be able to legally share modifications with friends on the island.
2. **The Dissident test**. Consider a dissident in a totalitarian state who wishes to share a modified bit of software with fellow dissidents, but does not wish to reveal the identity of the modifier, or directly reveal the modifications themselves, or even possession of the program, to the government. Any requirement for sending source modifications to anyone other than the recipient of the modified binary - in fact any forced distribution at all, beyond giving source to those who receive a copy of the binary - would put the dissident in danger. For Debian to consider software Free it must not require any such excess distribution.
3. **The Tentacles of Evil test**. Imagine that the author is hired by a large evil corporation and, now in their thrall, attempts to do the worst to the users of the program: to make their lives miserable, to make them stop using the program, to expose them to legal liability, to make the program non-Free, to discover their secrets, etc. The same can happen to a corporation bought out by a larger corporation bent on destroying Free software in order to maintain its monopoly and extend its evil empire. The license cannot allow even the author to take away the required freedoms!

And there are practical issues that arise too:

1. **GPL compatibility is very desirable.** The GPL is by far the most popular OSS/FS license. Thus, a license that isn’t compatible with the GPL causes many practical problems, because the vast amount of GPL software can’t be combined with it. Choosing a GPL-compatible license (such as the BSD-new, MIT/X, LGPL, or GPL license) is often the safest course. See my paper for more information on why selecting a GPL-compatible license is important for OSS/FS projects.
2. **Choice-of-law and choice-of-venue requirements are very undesirable.** Many developers strongly object to licenses that specify that the licensee must agree to be judged by the laws of a specific jurisdiction and/or be judged at a specific location. This was a key problem, for example, for the older Python licenses. The problem is that choice-of-law and choice-of-venue requirements create superfluous incompatibilities with any other licenses with choice-of-law and/or choice-of-venue restrictions. A goal of OSS/FS licenses is to allow software to be combined and modified in new, innovative ways, and such statements interfere with that goal.
3. **Advertizing clauses are very undesirable.** Some old licenses, like the old BSD license, required that credit be given to developers in certain ways, e.g., whenever a product is advertized. When there’s only one developer, that doesn’t sound too bad. But imagine what happens as more developers get involved -- suddenly each advertisement has to individually list (say) 20,000 people! These kinds of licenses don’t scale well as more people become involved, and major OSS/FS projects can involve large numbers of developers.

A technical discussion examining the freedom of a license might compare the license against the Free Software Definition (all four freedoms), the Open Source Definition (every point) and/or the Debian Free Software Guidelines, and the tests (scenarios) above, as well as considering practical concerns like the ones above. An example of such analysis is Mark Shewmaker’s August 2004 examination of the Microsoft Royalty Free Sender ID Patent License.

A.1.4 Open Source Movement and Free Software Movement

As a practical matter, the definitions given above for free software and open source software are essentially the same. Software meeting the criteria for one generally end up meeting the other definition as well; indeed, those who established the term “open source” describe their approach as marketing approach to Free Software. However, to some people, the *connotations* and motives are different between the two terms.

Some people who prefer to use the term “free software” intend to emphasize that software should always meet such criteria for ethical, moral, or social reasons, emphasizing that these should be the rights of every software user. Such people may identify themselves as members of the “free software movement”. Richard Stallman is a leader of this group; his arguments are given in his article Why “Free Software” is better than “Open Source”

Some people are not persuaded by these arguments, or may believe the arguments but do not think that they are effective arguments for convincing others. Instead, they prefer to argue the value of OSS/FS on other grounds, such as cost, security, or reliability. Many of these people will prefer to use the term “open source software”, and some may identify themselves as part of the “open source movement”. Eric Raymond was one of the original instigators of the name “open source” and is widely regarded as a leader of this group.

Is the “free software movement” a subset of the “open source movement”? That depends on how the “open source movement” is defined. If the “open source movement” is a general term describing anyone who supports OSS or FS for whatever reason, then the “free software movement” is indeed a subset of the “open source movement”. However, some leaders of the open source movement (such as Eric Raymond) specifically recommend *not* discussing user freedoms, and since this is the central principle of the free software movement, the two movements are considered separate groups by many.

The Free/Libre and Open Source Software Survey (FLOSS), part IV, summarizes a survey of OSS/FS developers (primarily European developers), and specifically examined these terms. In this study, 48.0% identified themselves as part of the “Free Software”, community, 32.6% identified themselves as part of the “open source” community, and 13.4% stated that they did not care. A slight majority (52.9%) claimed that the movements different in principle, but the work is the same, while 29.7% argued that the movements were fundamentally different, and 17.3% do not care at all about the differences. After examining the data, the surveyers determined that OSS/FS developers could be divided into six groups:

1. developers who assign themselves to the Free Software community and who see fundamental differences between the two communities (18%).
2. developers who consider themselves as part of the Open Source community and who perceive fundamental differences between the two communities (9%).
3. developers who assign themselves to the Free Software community and who perceive only principle differences between the two communities, but consider work in the two communities the same (26%).
4. developers who assign themselves to the Open Source community and see principle, but no fundamental differences between the two communities (17%).
5. developers who assign themselves to either the Free Software or the Open Source Software community, but are not bothered by differences between the two communities (9%).
6. developers who do not care to which community they belong (20%).

This difference in terminology and motivation can make it more difficult for authors of articles on OSS/FS (like this one). The motivations of the different movements may be different, but since practice the developers usually work together, it's very useful to have a common term that covers all groups. Some authors choose to use one of the terms (such as OSS). Other authors use some other term merging the two motivations, but as of this time there is no single merged term used by everyone. This article uses the merged term OSS/FS.

A.2 Motivations

This leads to a more general and oft-asked question: "Why do developers contribute to OSS/FS projects?" The short answer is that there are many different motivations.

The Boston Consulting Group/OSDN Hacker Survey (release 0.73, July 21, 2002) made some interesting observations by sampling SourceForge users. The top motivations given for participating in OSS/FS development were as follows:

1. intellectually stimulating (44.9%)
2. improves skill (41.3%)
3. work functionality (33.8%)
4. code should be open (33.1%)
5. non-work functionality (29.7%)
6. obligation from use (28.5%)

By examining these motivations, they concluded that open source developers could be divided into four groups (based on their primary motivations for writing OSS/FS software):

a. Believers (19%): believe source code should be open.
b. Learning and Fun (29%): for non-work needs and intellectual stimulation.
c. Hobbyists (27%): need the code for a non-work reason.
d. Professionals (25%): for work needs and professional status.

Part IV of the Free/Libre and Open Source Software Survey (FLOSS), mentioned above, also examined individual developer motivations, and found a variety of motivations.

Many businesses contribute to OSS/FS development, and their motivations also vary. Many companies develop OSS/FS to sell support - by giving away the product, they expect to get far more support contracts. Joel Spolsky's "Strategy Letter V" notes that "most of the companies spending big money to develop open source software are doing it because it's a good business strategy for them." His argument is based on microeconomics, in particular, that every product in the marketplace has substitutes and complements. A substitute is another product you might buy if the first product is too costly, while a complement is a product that you usually buy together with another product. Since demand for a product increases when the prices of its complements decrease, smart companies try to commoditize their products' complements. For many companies, supporting an OSS/FS product turns a complementary product into a commodity, resulting in more sales (and money) for them.

One widely-read essay discussing commercial motivations is Eric Raymond's The Magic Cauldron. The European Free/Libre and Open Source Software (FLOSS): Survey and Study has additional statistics on the motivations of individuals and corporations who develop OSS/FS.

A.3 History

In the early days of computing (approximately 1945 to 1975), computer programs were often shared among developers, just as OSS/FS practitioners do now. An important during this time period was the ARPAnet (the early form of the Internet). Another critical development was the operating system Unix, developed by AT&T researchers, and distributed as source code (with modification rights) for a nominal fee. Indeed, the interfaces for Unix eventually became the basis of the POSIX suite of standards. However, as years progressed, and especially in the 1970s and 1980s, software developers increasingly closed off their software source code from users. This included the Unix system itself; many had grown accustomed to the freedom of having the Unix source code, but AT&T suddenly increased fees and limited distribution, making it impossible for many users to change the software they used and share those modifications with others.

Richard Stallman, a researcher at the MIT Artificial Intelligence Lab, found this closing of software source code intolerable. In 1984 he started the GNU project to develop a complete Unix-like operating system which would be Free Software (free as in freedom, not as in price, as described above). In 1985, Stallman established the Free Software Foundation (FSF) to work to preserve, protect and promote Free Software; the FSF then became the primary organizational sponsor of the GNU Project. The GNU project developed many important software programs, including the GNU C compiler (gcc) and the text editor emacs. A major legal innovation by Stallman was the GNU General Public Licence (GPL), a widely popular OSS/FS software license. However, the GNU project was stymied in its efforts to develop the “kernel” of the operating system. The GNU project was following the advice of academics to use a “microkernel architecture,” and was finding it difficult to develop a strong kernel using this architecture. Without a kernel, the GNU project could not fulfill their goal.

Meanwhile, the University of California at Berkeley had had a long relationship with AT&T’s Unix operating system, and Berkeley had ended up rewriting many Unix components. Keith Bostic solicited many people to rewrite the remaining key utilities from scratch, and eventually managed to create a nearly-complete system whose source code could be freely released to the public without restriction. The omissions were quickly filled, and soon a number of operating systems were developed based on this effort. Unfortunately, these operating systems were held under a cloud of concern from lawsuits and counter-lawsuits for a number of years. Another issue was that since the BSD licenses permitted companies to take the code and make it proprietary, companies such as Sun and BSDI did so - continuously siphoning developers from the openly sharable code, and often not contributing back to the publicly available code. Finally, the projects that developed these operating systems tended to be small groups of people who gained a reputation for rarely accepting the contributions by others (this reputation is unfair, but nevertheless the perception did become widespread). The descendants of this effort include the capable operating systems NetBSD, OpenBSD, and FreeBSD, as a group called the *BSDs. However, while they are both used and respected, and proprietary variants of these (such as Apple Mac OS X) are thriving, another OSS/FS effort quickly gained the limelight and much more market share.

In 1991, Linus Torvalds began developing a small operating system kernel called “Linux”, at first primarily for learning about the Intel 80386 chip. Unlike the BSD efforts, Torvalds eventually settled on the GPL license, which forced competing companies working on the kernel code to work together. Advocates of the *BSDs dispute that this is an advantage, but even today, major Linux distributions hire key kernel developers to work together on common code, in contrast to the corresponding commercial companies to the *BSDs which often do not share their improvements to a common program. Torvalds made a number of design decisions that in retrospect were remarkably wise: using a traditional monolithic kernel design (instead of the “microkernel approach” that slowed the GNU project), using the the Intel 386 line as the primary focus, working to support user requests (such as “dual booting”), and supporting hardware that was technically poor but widely used. And finally, Torvalds stumbled into a development process rather different from traditional approaches by exploiting the Internet. Torvalds’ new process looked rather different than more traditional approaches. He publicly released new versions extremely often (sometimes more than once a day, allowing quick identification when regressions occurred), and he quickly delegated areas to a large group of developers (instead of sticking to a very small number of developers). Instead of depending on rigid standards, rapid feedback on small increments and Darwinian competition were used to increase quality.

When the Linux kernel was combined with the already-developed GNU operating system components and some components from other places (such as from the BSD systems), the resulting operating system was surprisingly stable and capable. Such systems were called GNU/Linux systems or simply Linux systems. Note that there is a common misconception in the media that needs to be countered here: Linus Torvalds never developed the so-called "Linux operating system". Torvalds was the lead developer of the Linux kernel, but the kernel is only one of many pieces of an operating system; most of the GNU/Linux operating system was developed by the GNU project and by other related projects.

In 1996, Eric Raymond realized that Torvalds had stumbled upon a whole new style of development, combining the sharing possibilities of OSS/FS with the speed of the Internet into a new development process. His essay The Cathedral and the Bazaar identifies that process, in a way that others could try to emulate the approach. The essay was highly influential, and in particular convinced Netscape to switch to an OSS/FS approach for its next generation web browser (the road for Netscape was bumpy, but ultimately successful).

In spring of 1997, a group of leaders in the Free Software community gathered, including Eric Raymond, Tim O'Reilly, and Larry Wall. They were concerned that the term "Free Software" was too confusing and unhelpful (for example, many incorrectly thought that the issue was having no cost). The group coined the term "open source" as an alternative term, and Bruce Perens developed the initial version of the "open source definition" to define the term. The term "open source" is now very widely used, but not universally so; Richard Stallman (head of the FSF) never accepted it, and even Bruce Perens switched back to using the term "Free Software" because Perens felt that there needed to be more emphasis on user freedom.

Major Unix server applications (such as the OSS/FS Apache web server) were easily moved to GNU/Linux or the *BSDs, since they all essentially implemented the POSIX standards. As a result, GNU/Linux and the *BSDs rapidly gained significant market share in the server market. A number of major initiatives began to fill in gaps to create completely OSS/FS modern operating systems, including graphical toolkits, desktop environments, and major desktop applications. In 2002, the first user-ready versions of capable and critical desktop applications (Mozilla for web browsing and Open Office for an office suite) were announced.

You can learn more about the history of OSS/FS from material such as *Open Sources: Voices from the Open Source Revolution* and *Free for All: How Linux and the Free Software Movement Undercut the High-Tech Titans* by Peter Wayner,

A.4 Licenses

There are dozens of OSS/FS licenses, but the vast majority of OSS/FS software uses one of the four major licenses: the GNU General Public License (GPL), the GNU Lesser (or Library) General Public License (LGPL), the MIT (aka X11) license, and the BSD-new license. Indeed the Open Source Initiative refers to these four licenses as the classic open source licenses. The GPL and LGPL are termed "copylefting" licenses (also called "protective" licenses), that is, these licenses are designed to prevent (protect) the code from becoming proprietary. Here is a short description of these licenses:

1. The GPL allows anyone to use the program and modify it, but prevents code from becoming proprietary once distributed and it also forbids proprietary programs from "linking" to it.
2. The MIT and BSD-new licenses let anyone do almost anything with the code except sue the authors. One minor complication: there are actually two "BSD" licenses, sometimes called "BSD-old" and "BSD-new"; new programs should use BSD-new instead of BSD-old.
3. The LGPL is a compromise between the GPL and the MIT/BSD-new approaches, and was originally intended for code libraries. Like the GPL, LGPL-licensed software cannot be changed and made proprietary, but the LGPL does permit proprietary programs to link to the library, like the MIT/BSD-new licenses.

Note that all of these licenses (the GPL, MIT, BSD-new, and LGPL) permit the commercial sale and the commercial use of the software, and many such programs as sold and used that way. See Perens' paper for more information comparing these licenses.

The most popular OSS/FS license by far is the GPL. For example, Freshmeat.net reported on April 4, 2002 that 71.85% of the 25,286 software branches (packages) it tracked are GPL-licensed (the next two most popular were LGPL, 4.47%, and the BSD licenses, 4.17%). Sourceforge.net reported on April 4, 2002 that the GPL accounted for 73% of the 23,651 "open source" projects it hosted (next most popular were the LGPL, 10%, and the BSD licenses, 7%). In my paper More than a Gigabuck: Estimating GNU/Linux's Size, I found that Red Hat Linux, one of the most popular GNU/Linux distributions, had over 30 million physical source lines of code in version 7.1, and that 50.36% of the lines of code were licensed solely under the GPL (the next most common were the MIT license, 8.28%, and the LGPL, 7.64%). If you consider the lines that are dual licensed (licensed under both the GPL and another license, allowing users and developers to pick the license to use), the total lines of code under the GPL accounts for 55.3% of the total. My paper on GPL compatibility discusses these figures further, and discusses why, if you choose to develop OSS/FS code, you should strongly consider using a licensing approach that is compatible with the GPL.

A.5 Management Approaches

There is no single approach to managing an OSS/FS project, just as there is no single approach to managing proprietary projects. Management approaches are strongly influenced by the size and scope of the project, as well as the leadership styles of those managing the project.

The Cathedral and the Bazaar argues for a particular style of development, termed the "bazaar" style. In this approach, there are a large number of small, incremental releases, and a large number of developers can send in patches for proposed improvements. The releases need to compile and run (to some extent), so that developers can test and improve them. Not all OSS/FS projects work this way, but many do.

It is useful to examine the management approaches of successful projects to identify approaches that may work elsewhere. Here are a few:

1. *Linux kernel*. The Linux kernel's development process is based on a hierarchy of four levels: ordinary developers, maintainers, trusted lieutenants, and the benevolent dictator. Ordinary developers can propose changes, but usually they submit their proposals to a maintainer of a particular component of the kernel; the maintainers then send their sets up to a trusted lieutenants, who then sends it up to the benevolent dictator (currently Linus Torvalds). At each stage testing can take place. The

benevolent dictator writes code and issues general direction, but his primary job is to be the integrator and arbiter of changes. Development releases are made often; after the development has stabilized, a “stable” branch is created with a separate maintainer of the branch. Linux distributions then take the stable branch, test it further, and select the “best” version of the stable branch.

2. *Apache*. The Apache web server project, in contrast, is run by a group. At the top is the “Apache HTTP Server Project Management Committee (PMC)” a group of volunteers who are responsible for managing the Apache HTTP Server Project. Membership in the Apache PMC is by invitation only and must be approved by consensus of the active Apache PMC members. Membership can be revoked by a unanimous vote of all the active PMC members other than the member in question. Most changes are approved by consensus.

   An action item requiring consensus approval must receive at least 3 binding +1 votes and no vetos (a “-1” vote). An action item requiring majority approval must receive at least 3 binding +1 votes and more +1 votes than -1 votes (i.e., a majority with a minimum quorum of three positive votes).

   Ideas must be review-then-commit; patches can be commit-then-review. With a commit-then-review process, they trust that the developer doing the commit has a high degree of confidence in the change. Doubtful changes, new features, and large-scale overhauls need to be discussed before being committed to a repository.

   See the Apache Voting Rules for more detailed information.

3. *Perl*. Perl was originally developed by Larry Wall, but he no longer wishes to have to always have the job of integrating patches. Thus, there is a notional “patch pumpkin” that must be acquired to change Perl. In Moody’s *Rebel Code*, Wall explains that “we have essentially a chief integrator who is called the pumpkin holder.” Moody adds that this “integration involves taking the approved patches and adding them into the main Perl source code.” Larry Wall, as original developer, can veto any change. More information about the patch pumpkin (as it has currently evolved) is available from perl.com.
4. *Sourceforge-based Applications*. Many OSS/FS projects are supported by SourceForge, which includes the CVS tool for configuration management. Typically, those who have write access to the repository simply make their updates; others who do not have such access post their requests or patches to the bug tracking database (or mailing list) and ask one of those with write access to include it. There are typically only a few people with direct write access, so conflicts are rare and CVS supports resolving the occasional conflict.

A.6 Forking

A *fork* is a competing project based on a version of the pre-existing project’s source code. All OSS/FS projects can be “forked”; the ability to create a fork is fundamental to the definition of OSS/FS.

Simply creating or releasing a variant of a project’s code does not normally create a fork. Indeed, releasing variants for experimentation is considered normal in a typical OSS/FS development process. Many OSS/FS projects (such as the Linux kernel development project) intentionally have “fly-offs” (also called “bake-offs”) where different developers implement different competing approaches; the results are compared and the approach that produces the best results (the “winner”) is accepted by the project. These “fly-offs” are often discussed in evolutionary terms, e.g., the “winning mutation” is accepted into the project and the alternatives are abandoned as “evolutionary dead ends”. Since all parties intend for the “best” approach to accepted by the project, and for the other approaches to be abandoned, these are not forks. What is different about a fork is intent: the person(s) creating the fork intend for the fork to replace or compete with the original project they are forking.

Creating a fork is a major and emotional event in the OSS/FS community. It similar to a call for a “vote of no confidence” in a parliament, or a call for a labor strike in a labor dispute. Those creating the fork are essentially stating that they believe the project’s current leadership is ineffective, and are asking developers to vote against the project leadership by abandoning the original project and switching to their fork. Those who are creating the fork must argue why other developers should support their fork; common reasons given include a belief that changes are not being accepted fast enough, that changes are happening too quickly for users to absorb them, that the project governance is too closed to outsiders, that the licensing approach is hampering development, or that the project’s technical direction is fundamentally incorrect.

Most attempts to create forks are ignored, for there must be a strong reason for developers to consider switching to a competing project. Developers usually resist supporting OSS/FS forks: they divide effort that would be more effective when combined, they make support and further development more difficult, and they require developers to discuss project governance rather than improving the project’s products. Developers can attempt to support both projects, but this is usually impractical over time as the projects diverge. Eric Raymond, in *Homesteading the Noosphere*, argues that a prime motivation in OSS/FS development is reputation gain through the use of a gift culture, and that forking significantly interferes with this motivation.

Some historical examples of major forks may help give perspective, showing that often forks “lose” while other times they “win” against the original project:

1. *glibc vs. libc*. When the Linux kernel was first being developed, the kernel developers took the FSF’s GNU C library (now called glibc) and created their own fork of it (called libc). Both were licensed under the LGPL. At the time, the Linux kernel developers thought that the FSF’s development process for the C library was too slow and not responding to their needs. Thus, they created a forked version of GNU libc version 1.07.4 (which had been released February 17, 1994). In this case, however, the original GNU C library project (led by the FSF) surpassed the forked project over time. Over the next few years the original glibc increasingly offered far better standards conformance, multithreading, higher performance, and more features than the forked libc project. Elliot Lee briefly describes this history. In this case, the fork was abandoned after several years; in 1997 through 1998 nearly all GNU/Linux systems switched from libc back to glibc.
2. *gcc vs. egcs*. The GNU Compiler Collection (gcc) is a collection of important compilers, including a C++ compiler; the main compilers are licensed under the GPL. In 1997, there were disagreements over the development approach and slow development speed of gcc. In particular, many were dissatisfied with the FSF-appointed gcc maintainer, who was very slow to accept changes. Cygnus (headed by Michael Tiemann) decided to create a fork of the project named egcs, and invited others to join. Egcs worked at an accelerated pace, and soon surpassed the original gcc project. In April 1997 the rift was healed; the FSF agreed to switch to using the egcs code for gcc, and the egcs project agreed to dissolve itself and take over the original gcc project. In this case, the fork ended with the forking project’s results “taking over” the original project.

3. *Free86 vs. X.org*. The XFree86 project historically led development of a popular X server. An X server is a critical component for implementing a graphical user interface in a typical Unix-like system. The XFree86 project traditionally licensed the vast majority of its code used the simple "MIT/X" open source license that is GPL-compatible. The XFree86 president, David Dawes, decided to change the XFree86 license to one that wasn't GPL-compatible and had many practical problems. This proposed license change caused a serious uproar, but the project leader refused to listen to those complaints. For example, Jim Gettys, a well-respected developer and co-founder of X, strongly opposed this change to the XFree86 license, even though he's not a strong advocate of the GPL. Richard Stallman politely asked that something be worked out. But the project leader wouldn't budge, so the users and some of the developers forked the project, creating a new project at X.org based on the previous version. An article at Linux Today and a discussion at Freedesktop.org show that the leading distributors, including Red Hat, Debian, SuSE, Gentoo, Mandrake, and OpenBSD, are switching or plan to switch from XFree86 to X.org. Since the XFree86 folks wouldn't switch to a GPL-compatible license, the X.Org Foundation (formed January 2004) announced its own version of X on April 6, 2004. The X.Org foundation version was immediately endorsed by Novell's SUSE, Red Hat, HP, TrollTech, and FSF Europe among others. Very soon, nearly all developers and users had abandoned XFree86. You can see more information in my cautionary tale about XFree86. This is a case where a project leader attempted to make an extremely unpopular licensing change, causing a mass exodus of its uses and developers. Note how similar this process was to a vote of no confidence; the leader was unwilling to listen to his customers and developers, so his customers and developers established a project where their needs would be met.

Too many forks can be a serious problem for all of the related projects. In fact, one of the main reasons that Unix systems lost significant market share compared to Windows was because of the excessive number of Unix forks. Bob Young states this quite clearly in this essay "Giving it Away", and also suggests why this is unlikely to be a problem in copylefted OSS/FS software:

The primary difference between [GNU/Linux and Unix] is that Unix is just another proprietary binary-only ... OS [operating system]. The problem with a proprietary binary-only OS that is available from multiple suppliers is that those suppliers have short-term marketing pressures to keep whatever innovations they make to the OS to themselves for the benefit of their customers exclusively. Over time these "proprietary innovations" to each version of the Unix OS cause the various Unixes to differ substantially from each other. This occurs when the other vendors do not have access to the source code of the innovation and the license the Unix vendors use prohibit the use of that innovation even if everyone else involved in Unix wanted to use the same innovation. In Linux the pressures are the reverse. If one Linux supplier adopts an innovation that becomes popular in the market, the other Linux vendors will immediately adopt that innovation. This is because they have access to the source code of that innovation and it comes under a license that allows them to use it.

Note that the copylefting licenses (such as the GPL and LGPL) permit forks, but greatly reduce any monetary incentive to create a fork. Thus, the project's software licensing approach impacts the likelihood of its forking.

The ability to create a fork is important in OSS/FS development, for the same reason that the ability to call for a vote of no confidence or a labor strike is important. Fundamentally, the ability to create a fork forces project leaders to pay attention to their constituencies. Even if an OSS/FS project completely dominates its market niche, there is always a potential competitor to that project: a fork of the project. Often, the threat of a fork is enough to cause project leaders to pay attention to some issues they had ignored before, should those issues actually be important. In the end, forking is an escape valve that allows those who are dissatisfied with the project's current leadership to show whether or not their alternative is better.

About the Author

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