Advance American Inventions

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Blog

A **blog** (a blend of the term ***web log***) is a type of website or part of a website. Blogs are usually maintained by an individual with regular entries of commentary, descriptions of events, or other material such as graphics or video. Entries are commonly displayed in reverse-chronological order. *Blog* can also be used as a verb, meaning *to maintain or add content to a blog*.

Most blogs are interactive, allowing visitors to leave comments and even message each other via widgets on the blogs and it is this interactivity that distinguishes them from other static websites.

Many blogs provide commentary or news on a particular subject; others function as more personal online diaries. A typical blog combines text, images, and links to other blogs, Web pages, and other media related to its topic. The ability of readers to leave comments in an interactive format is an important part of many blogs. Most blogs are primarily textual, although some focus on art (Art blog), photographs (photoblog), videos (video blogging), music (MP3 blog), and audio (podcasting). Microblogging is another type of blogging, featuring very short posts.

As of December 2007, blog search engine Technorati was tracking more than 112 million blogs.

History

The term "weblog" was coined by Jorn Barger on 17 December 1997. The short form, "blog," was coined by Peter Merholz, who jokingly broke the word *weblog* into the phrase *we blog* in the sidebar of his blog Peterme.com in April or May 1999. Shortly thereafter, Evan Williams at Pyra Labs used "blog" as both a noun and verb ("to blog," meaning "to edit one's weblog or to post to one's weblog") and devised the term "blogger" in connection with Pyra Labs' Blogger product, leading to the popularization of the terms.

Origins

Before blogging became popular, digital communities took many forms, including Usenet, commercial online services such as GEnie, BiX and the early CompuServe, e-mail lists and Bulletin Board Systems (BBS). In the 1990s, Internet forum software, created running conversations with "threads." Threads are topical connections between messages on a virtual "corkboard."

The modern blog evolved from the online diary, where people would keep a running account of their personal lives. Most such writers called themselves diarists, journalists, or journalers. Justin Hall, who began personal blogging in 1994 while a student at Swarthmore College, is generally recognized as one of the earliest bloggers, as is Jerry Pournelle. Dave Winer's Scripting News is also credited with being one of the oldest and longest running weblogs. Another early blog was Wearable Wireless Webcam, an online shared diary of a person's personal life combining text, video, and pictures transmitted live from a wearable computer and EyeTap device to a web site in 1994. This practice of semi-automated blogging with live video together with text was referred to as sousveillance, and such journals were also used as evidence in legal matters.

Early blogs were simply manually updated components of common Web sites. However, the evolution of tools to facilitate the production and maintenance of Web articles posted in reverse chronological order made the publishing process feasible to a much larger, less technical, population. Ultimately, this resulted in the distinct class of online publishing that produces blogs we recognize today. For instance, the use of some sort of browser-based software is now a typical aspect of "blogging". Blogs can be hosted by dedicated blog hosting services, or they can be run using blog software, or on regular web hosting services.

Some early bloggers, such as The Misanthropic Bitch, who began in 1997, actually referred to their online presence as a zine, before the term blog entered common usage.

Rise in popularity

After a slow start, blogging rapidly gained in popularity. Blog usage spread during 1999 and the years following, being further popularized by the near-simultaneous arrival of the first hosted blog tools:

- Bruce Ableson launched Open Diary in October 1998, which soon grew to thousands of online diaries. Open Diary innovated the reader comment, becoming the first blog community where readers could add comments to other writers' blog entries.
- Brad Fitzpatrick started LiveJournal in March 1999.
- Andrew Smales created Pitas.com in July 1999 as an easier alternative to maintaining a "news page" on a Web site, followed by Diaryland in September 1999, focusing more on a personal diary community.

- Evan Williams and Meg Hourihan (Pyra Labs) launched blogger.com in August 1999 (purchased by Google in February 2003)

Political impact

Since 2002, blogs have gained increasing notice and coverage for their role in breaking, shaping, and spinning news stories. The Iraq war saw bloggers taking measured and passionate points of view that go beyond the traditional left-right divide of the political spectrum.

Talking Points Memo

by joshua micah marshall

(December 6th, 2002 -- 3:20 PM EST // link)

Hard-hitting coverage? We report, you decide.

I've always thought that for all the jokes about age and longevity in office, the one line that really captures how long Strom Thurmond has been around is this: he ran for president against Harry Truman.

Do you really have to say any more than that?

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Of course, Thurmond ran as the presidential candidate on the "States-Rights Democrat" or "Dixiecrat" ticket -- a candidacy that was based *exclusively and explicitly upon the preservation of legalized segregation and opposition to voting rights and civil rights for blacks.*

There's a sort of agreement in Washington these days -- with Thurmond's retirement and hundredth birthday -- to sort of forget about all that unpleasantness.

But look at what Trent Lott said about that candidacy yesterday...

> I want to say this about my state: When Strom Thurmond ran for president we voted for him. We're proud of it. And if the rest of the country had of followed our lead we wouldn't of had all these problems over all these years, either.

Oh, what could have been!!! Just another example of the hubris now reigning among Capitol Hill Republicans.

-- Josh Marshall

On 6 December 2002, Josh Marshall's talkingpointsmemo.com blog called attention to U.S. Senator Lott's comments regarding Senator Thurmond. Senator Lott was eventually to resign his Senate leadership position over the matter.

An early milestone in the rise in importance of blogs came in 2002, when many bloggers focused on comments by U.S. Senate Majority Leader Trent Lott. Senator Lott, at a party honoring U.S. Senator Strom Thurmond, praised Senator Thurmond by suggesting that the United States would have been better off had Thurmond been elected president. Lott's critics saw these comments as a tacit approval of racial segregation, a policy advocated by Thurmond's 1948 presidential campaign. This view was reinforced by documents and recorded interviews dug up by bloggers. Though Lott's comments were made at a public event attended by the media, no major media organizations reported on his controversial comments until after blogs broke the story. Blogging helped to create a political crisis that forced Lott to step down as majority leader.

Similarly, blogs were among the driving forces behind the "Rathergate" scandal. To wit: (television journalist) Dan Rather presented documents (on the CBS show *60 Minutes*) that conflicted with accepted accounts of President Bush's military service record. Bloggers declared the documents to be forgeries and presented evidence and arguments in support of that view. Consequently, CBS apologized for what it said were inadequate reporting techniques. Many bloggers view this scandal as the advent of blogs' acceptance by the mass media, both as a news source and opinion and as means of applying political pressure.

The impact of these stories gave greater credibility to blogs as a medium of news dissemination. Though often seen as partisan gossips, bloggers sometimes lead the way in bringing key information to public light, with mainstream media having to follow their lead. More often, however, news blogs tend to react to material already published by the mainstream media. Meanwhile, an increasing number of experts blogged, making blogs a source of in-depth analysis.

Mainstream popularity

By 2004, the role of blogs became increasingly mainstream, as political consultants, news services, and candidates began using them as tools for outreach and opinion forming. Blogging was established by politicians and political candidates to express opinions on war and other issues and cemented blogs' role as a news source. Even politicians not actively campaigning, such as the UK's Labour Party's MP Tom Watson, began to blog to bond with constituents.

In January 2005, *Fortune* magazine listed eight bloggers that business people "could not ignore": Peter Rojas, Xeni Jardin, Ben Trott, Mena Trott, Jonathan Schwartz, Jason Goldman, Robert Scoble, and Jason Calacanis.

Israel's was among the first national governments to set up an official blog. Under David Saranga, the Israeli Ministry of Foreign Affairs became active in adopting Web 2.0 initiatives, including an official video blog and a political blog. The Foreign Ministry also held a microblogging press conference via Twitter about its war with Hamas, with Saranga answering questions from the public in common text-messaging abbreviations

during a live worldwide press conference. The questions and answers were later posted on IsraelPolitik, the country's official political blog.

The impact of blogging upon the mainstream media has also been acknowledged by governments. In 2009, the presence of the American journalism industry had declined to the point that several newspaper corporations were filing for bankruptcy, resulting in less direct competition between newspapers within the same circulation area. Discussion emerged as to whether the newspaper industry would benefit from a stimulus package by the federal government. President Barack Obama acknowledged the emerging influence of blogging upon society by saying "if the direction of the news is all blogosphere, all opinions, with no serious fact-checking, no serious attempts to put stories in context, that what you will end up getting is people shouting at each other across the void but not a lot of mutual understanding".

Types

There are many different types of blogs, differing not only in the type of content, but also in the way that content is delivered or written.

Personal blogs
: The personal blog, an ongoing diary or commentary by an individual, is the traditional, most common blog. Personal bloggers usually take pride in their blog posts, even if their blog is never read. Blogs often become more than a way to just communicate; they become a way to reflect on life, or works of art. Blogging can have a sentimental quality. Few personal blogs rise to fame and the mainstream, but some personal blogs quickly garner an extensive following. One type of personal blog, referred to as a microblog, is extremely detailed and seeks to capture a moment in time. Some sites, such as Twitter, allow bloggers to share thoughts and feelings instantaneously with friends and family, and are much faster than emailing or writing.

Corporate and organizational blogs
: A blog can be private, as in most cases, or it can be for business purposes. Blogs used internally to enhance the communication and culture in a corporation or externally for marketing, branding or public relations purposes are called corporate blogs. Similar blogs for clubs and societies are called club blogs, group blogs, or by similar names; typical use is to inform members and other interested parties of club and member activities.

By genre
: Some blogs focus on a particular subject, such as political blogs, travel blogs (also known as *travelogs*), house blogs, fashion blogs, project blogs, education blogs, niche blogs, classical music blogs, quizzing blogs and legal blogs (often referred to as a blawgs) or dreamlogs. Two common types of genre blogs are art blogs and music blogs. A blog featuring discussions especially about home and family is not uncommonly called a mom blog. While not a legitimate type of blog, one used for the sole purpose of spamming is known as a Splog.

By media type

A blog comprising videos is called a vlog, one comprising links is called a linklog, a site containing a portfolio of sketches is called a sketchblog or one comprising photos is called a photoblog. Blogs with shorter posts and mixed media types are called tumblelogs. Blogs that are written on typewriters and then scanned are called typecast or typecast blogs.

A rare type of blog hosted on the Gopher Protocol is known as a Phlog.

By device

Blogs can also be defined by which type of device is used to compose it. A blog written by a mobile device like a mobile phone or PDA could be called a moblog. One early blog was Wearable Wireless Webcam, an online shared diary of a person's personal life combining text, video, and pictures transmitted live from a wearable computer and EyeTap device to a web site. This practice of semi-automated blogging with live video together with text was referred to as sousveillance. Such journals have been used as evidence in legal matters.

Community and cataloging

The Blogosphere

The collective community of all blogs is known as the *blogosphere*. Since all blogs are on the internet by definition, they may be seen as interconnected and socially networked, through blogrolls, comments, linkbacks (refbacks, trackbacks or pingbacks) and backlinks. Discussions "in the blogosphere" are occasionally used by the media as a gauge of public opinion on various issues. Because new, untapped communities of bloggers can emerge in the space of a few years, Internet marketers pay close attention to "trends in the blogosphere".

BlogDay

BlogDay was created with the belief that bloggers should have one day dedicated to getting to know other bloggers from other countries and areas of interest. The designated date is August 31, because when written 3108, it resembles the word "Blog". On that day, bloggers recommend five new blogs to their visitors, so that readers discover new, previously unknown blogs.

Blog search engines

Several blog search engines are used to search blog contents, such as Bloglines, BlogScope, and Technorati. Technorati, which is among the most popular blog search engines, provides current information on both popular searches and tags used to categorize blog postings. The research community is working on going beyond simple keyword search, by inventing new ways to navigate through huge amounts of information present in the blogosphere, as demonstrated by projects like BlogScope.

Blogging communities and directories

Several online communities exist that connect people to blogs and bloggers to other bloggers, including BlogCatalog and MyBlogLog. Interest-specific blogging platforms are also available. For instance, Blogster has a sizable community of political bloggers among its members.

Blogging and advertising

It is common for blogs to feature advertisements either to financially benefit the blogger or to promote the blogger's favorite causes. The popularity of blogs has also given rise to "fake blogs" in which a company will create a fictional blog as a marketing tool to promote a product.

Popularity

Researchers have analyzed the dynamics of how blogs become popular. There are essentially two measures of this: popularity through citations, as well as popularity through affiliation (i.e. blogroll). The basic conclusion from studies of the structure of blogs is that while it takes time for a blog to become popular through blogrolls, permalinks can boost popularity more quickly, and are perhaps more indicative of popularity and authority than blogrolls, since they denote that people are actually reading the blog's content and deem it valuable or noteworthy in specific cases.

The blogdex project was launched by researchers in the MIT Media Lab to crawl the Web and gather data from thousands of blogs in order to investigate their social properties. It gathered this information for over 4 years, and autonomously tracked the most contagious information spreading in the blog community, ranking it by recency and popularity. It can therefore be considered the first instantiation of a memetracker. The project is no longer active, but a similar function is now served by tailrank.com.

Blogs are given rankings by Technorati based on the number of incoming links and Alexa Internet based on the Web hits of Alexa Toolbar users. In August 2006, Technorati found that the most linked-to blog on the internet was that of Chinese actress Xu Jinglei. Chinese media Xinhua reported that this blog received more than 50 million page views, claiming it to be the most popular blog in the world. Technorati rated Boing Boing to be the most-read group-written blog.

Blurring with the mass media

Many bloggers, particularly those engaged in participatory journalism, differentiate themselves from the mainstream media, while others are members of that media working through a different channel. Some institutions see blogging as a means of "getting around the filter" and pushing messages directly to the public. Some critics worry that bloggers respect neither copyright nor the role of the mass media in presenting society with credible news. Bloggers and other contributors to user-generated content are behind *Time* magazine naming their 2006 person of the year as "you".

Many mainstream journalists, meanwhile, write their own blogs — well over 300, according to CyberJournalist.net's J-blog list. The first known use of a blog on a news site was in August 1998, when Jonathan Dube of The Charlotte Observer published one chronicling Hurricane Bonnie.

Some bloggers have moved over to other media. The following bloggers (and others) have appeared on radio and television: Duncan Black (known widely by his pseudonym, Atrios), Glenn Reynolds (Instapundit), Markos Moulitsas Zúniga (Daily Kos), Alex Steffen (Worldchanging), Ana Marie Cox (Wonkette), Nate Silver (FiveThirtyEight.com), and Ezra Klein (Ezra Klein blog in *The American Prospect,* now in the *Washington Post*). In counterpoint, Hugh Hewitt exemplifies a mass-media personality who has moved in the other direction, adding to his reach in "old media" by being an influential blogger. Equally many established authors, for example Mitzi Szereto have started using Blogs to not only update fans on their current works but also to expand into new areas of writing.

Blogs have also had an influence on minority languages, bringing together scattered speakers and learners; this is particularly so with blogs in Gaelic languages. Minority language publishing (which may lack economic feasibility) can find its audience through inexpensive blogging.

There are many examples of bloggers who have published books based on their blogs, e.g., Salam Pax, Ellen Simonetti, Jessica Cutler, ScrappleFace. Blog-based books have been given the name blook. A prize for the best blog-based book was initiated in 2005, the Lulu Blooker Prize. However, success has been elusive offline, with many of these books not selling as well as their blogs. Only blogger Tucker Max made the New York Times Bestseller List. The book based on Julie Powell's blog "The Julie/Julia Project" was made into the film *Julie & Julia*, apparently the first to do so.

Consumer generated advertising in blogs

Consumer generated advertising is a relatively new and controversial development and it has created a new model of marketing communication from businesses to consumers. Among the various forms of advertising on blog, the most controversial are the sponsored posts. These are blog entries or posts and may be in the form of feedbacks, reviews, opinion, videos, etc. and usually contain a link back to the desired site using a keyword/s.

Blogs have led to some disintermediation and a breakdown of the traditional advertising model where companies can skip over the advertising agencies (previously the only interface with the customer) and contact the customers directly themselves. On the other hand, new companies specialised in blog advertising have been established, to take advantage of this new development as well.

However, there are many people who look negatively on this new development. Some believe that any form of commercial activity on blogs will destroy the blogosphere’s credibility.

Legal and social consequences

Blogging can result in a range of legal liabilities and other unforeseen consequences.

Defamation or liability

Several cases have been brought before the national courts against bloggers concerning issues of defamation or liability. U.S. payouts related to blogging totaled $17.4 million by 2009; in some cases these have been covered by umbrella insurance. The courts have returned with mixed verdicts. Internet Service Providers (ISPs), in general, are immune from liability for information that originates with third parties (U.S. Communications Decency Act and the EU Directive 2000/31/EC).

In *Doe v. Cahill*, the Delaware Supreme Court held that stringent standards had to be met to unmask the anonymous posts of bloggers and also took the unusual step of dismissing the libel case itself (as unfounded under American libel law) rather than referring it back to the trial court for reconsideration. In a bizarre twist, the Cahills were able to obtain the identity of John Doe, who turned out to be the person they suspected: the town's mayor, Councilman Cahill's political rival. The Cahills amended their original complaint, and the mayor settled the case rather than going to trial.

In January 2007, two prominent Malaysian political bloggers, Jeff Ooi and Ahiruddin Attan, were sued by pro-government newspaper, The New Straits Times Press (Malaysia) Berhad, Kalimullah bin Masheerul Hassan, Hishamuddin bin Aun and Brenden John a/l John Pereira over an alleged defamation. The plaintiff was supported by the Malaysian government. Following the suit, the Malaysian government proposed to "register" all bloggers in Malaysia in order to better control parties against their interest. This is the first such legal case against bloggers in the country.

In the United States, blogger Aaron Wall was sued by Traffic Power for defamation and publication of trade secrets in 2005. According to Wired Magazine, Traffic Power had been "banned from Google for allegedly rigging search engine results." Wall and other "white hat" search engine optimization consultants had exposed Traffic Power in what they claim was an effort to protect the public. The case was watched by many bloggers because it addressed the murky legal question of who is liable for comments posted on blogs. The case was dismissed for lack of personal jurisdiction, and Traffic Power failed to appeal within the allowed time.

In 2009, a controversial and landmark decision by The Hon. Mr Justice Eady refused to grant an order to protect the anonymity of Richard Horton.

In 2009, NDTV issued a legal notice to Indian blogger Chetan Kunte for "abusive free speech" regarding a blog post criticizing their coverage of the Mumbai attacks. The blogger unconditionally withdrew his post, replacing it with legal undertaking and an admission that his post had been "defamatory and untrue" which resulted in several Indian bloggers criticizing NDTV for trying to silence critics.

Employment

Employees who blog about elements of their place of employment can begin to affect the brand recognition of their employer. In general, attempts by employee bloggers to protect themselves by maintaining anonymity have proved ineffective.

Delta Air Lines fired flight attendant Ellen Simonetti because she posted photographs of herself in uniform on an airplane and because of comments posted on her blog "Queen of Sky: Diary of a Flight Attendant" which the employer deemed inappropriate. This case highlighted the issue of personal blogging and freedom of expression versus employer rights and responsibilities, and so it received wide media attention. Simonetti took legal action against the airline for "wrongful termination, defamation of character and lost future wages". The suit was postponed while Delta was in bankruptcy proceedings (court docket).

In early 2006, Erik Ringmar, a tenured senior lecturer at the London School of Economics, was ordered by the convenor of his department to "take down and destroy" his blog in which he discussed the quality of education at the school.

Mark Cuban, owner of the Dallas Mavericks, was fined during the 2006 NBA playoffs for criticizing NBA officials on the court and in his blog.

Mark Jen was terminated in 2005 after 10 days of employment as an Assistant Product Manager at Google for discussing corporate secrets on his personal blog, then called 99zeros and hosted on the Google-owned Blogger service. He blogged about unreleased products and company finances a week before the company's earnings announcement. He was fired two days after he complied with his employer's request to remove the sensitive material from his blog.

In India, blogger Gaurav Sabnis resigned from IBM after his posts exposing the false claims of a management school, IIPM, led to management of IIPM threatening to burn their IBM laptops as a sign of protest against him.

Jessica Cutler, aka "The Washingtonienne", blogged about her sex life while employed as a congressional assistant. After the blog was discovered and she was fired, she wrote a novel based on her experiences and blog: *The Washingtonienne: A Novel*. Cutler is presently being sued by one of her former lovers in a case that could establish the extent to which bloggers are obligated to protect the privacy of their real life associates.

Catherine Sanderson, a.k.a. Petite Anglaise, lost her job in Paris at a British accountancy firm because of blogging. Although given in the blog in a fairly anonymous manner, some of the descriptions of the firm and some of its people were less than flattering. Sanderson later won a compensation claim case against the British firm, however.

On the other hand, Penelope Trunk wrote an upbeat article in the *Boston Globe* back in 2006, entitled "Blogs 'essential' to a good career". She was one of the first journalists to

point out that a large portion of bloggers are professionals and that a well-written blog can help attract employers.

Political dangers

Blogging can sometimes have unforeseen consequences in politically sensitive areas. Blogs are much harder to control than broadcast or even print media. As a result, totalitarian and authoritarian regimes often seek to suppress blogs and/or to punish those who maintain them.

In Singapore, two ethnic Chinese were imprisoned under the country's anti-sedition law for posting anti-Muslim remarks in their blogs.

Egyptian blogger Kareem Amer was charged with insulting the Egyptian president Hosni Mubarak and an Islamic institution through his blog. It is the first time in the history of Egypt that a blogger was prosecuted. After a brief trial session that took place in Alexandria, the blogger was found guilty and sentenced to prison terms of three years for insulting Islam and inciting sedition, and one year for insulting Mubarak.

Egyptian blogger Abdel Monem Mahmoud was arrested in April 2007 for anti-government writings in his blog. Monem is a member of the banned Muslim Brotherhood.

After expressing opinions in his personal blog about the state of the Sudanese armed forces, Jan Pronk, United Nations Special Representative for the Sudan, was given three days notice to leave Sudan. The Sudanese army had demanded his deportation.

In Myanmar, Nay Phone Latt, a blogger, was sentenced to 20 years in jail for posting a cartoon critical of head of state Than Shwe.

Personal safety

One consequence of blogging is the possibility of attacks or threats against the blogger, sometimes without apparent reason. Kathy Sierra, author of the innocuous blog Creating Passionate Users, was the target of such vicious threats and misogynistic insults that she canceled her keynote speech at a technology conference in San Diego, fearing for her safety. While a blogger's anonymity is often tenuous, Internet trolls who would attack a blogger with threats or insults can be emboldened by anonymity. Sierra and supporters initiated an online discussion aimed at countering abusive online behavior and developed a blogger's code of conduct.

Behavior

The **Blogger's Code of Conduct** is a proposal by Tim O'Reilly for **bloggers** to enforce civility on their blogs by being civil themselves and moderating comments on their blog. The code was proposed due to threats made to blogger Kathy Sierra. The idea of the code

was first reported by BBC News, who quoted O'Reilly saying, "I do think we need some code of conduct around what is acceptable behaviour, I would hope that it doesn't come through any kind of regulation it would come through self-regulation."

O'Reilly and others came up with a list of seven proposed ideas:

1. Take responsibility not just for your own words, but for the comments you allow on your blog.
2. Label your tolerance level for abusive comments.
3. Consider eliminating anonymous comments.
4. Ignore the trolls.
5. Take the conversation offline, and talk directly, or find an intermediary who can do so.
6. If you know someone who is behaving badly, tell them so.
7. Don't say anything online that you wouldn't say in person.

Chapter- 2

Global Positioning System

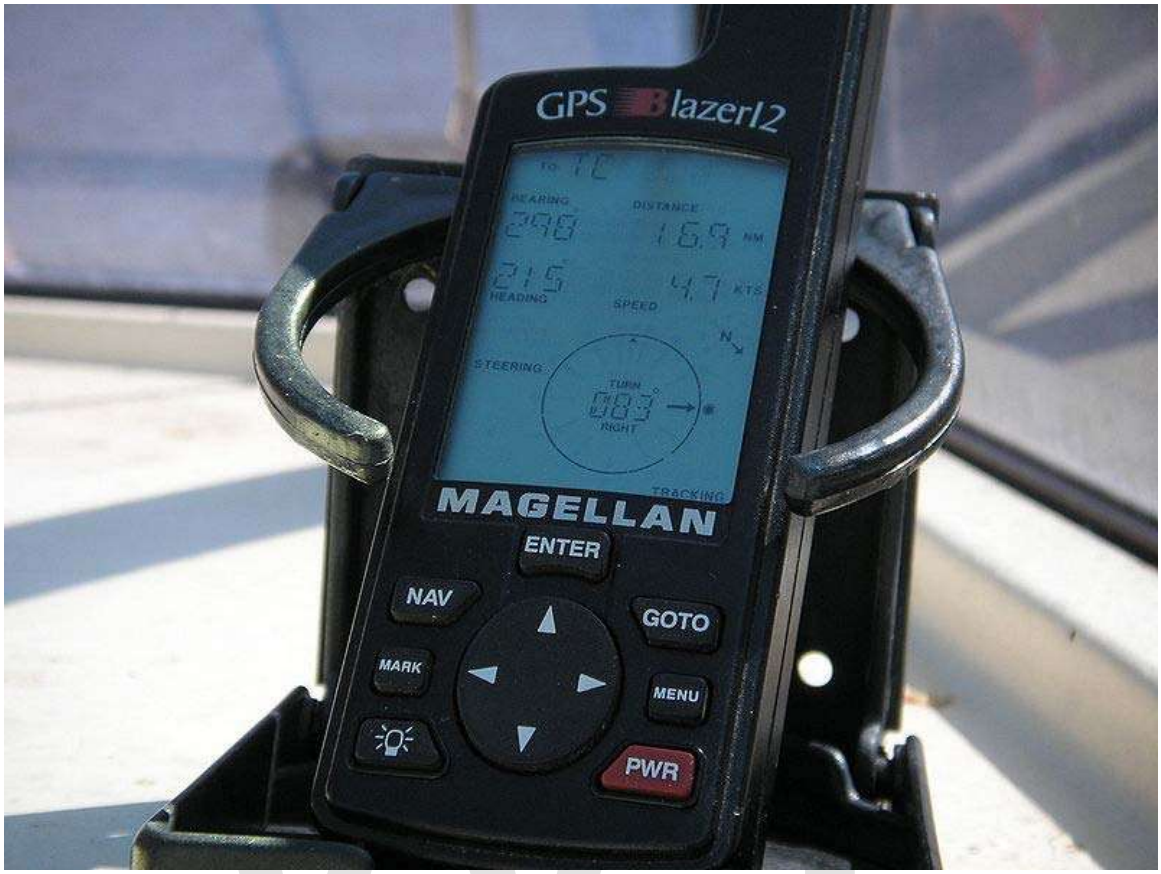
The **Global Positioning System** (**GPS**) is a space-based global navigation satellite system (GNSS) that provides reliable location and time information in all weather and at all times and anywhere on or near the Earth when and where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the United States government and is freely accessible by anyone with a GPS receiver.

GPS was created and realized by the U.S. Department of Defense (USDOD) and was originally run with 24 satellites. It was established in 1973 to overcome the limitations of previous navigation systems.

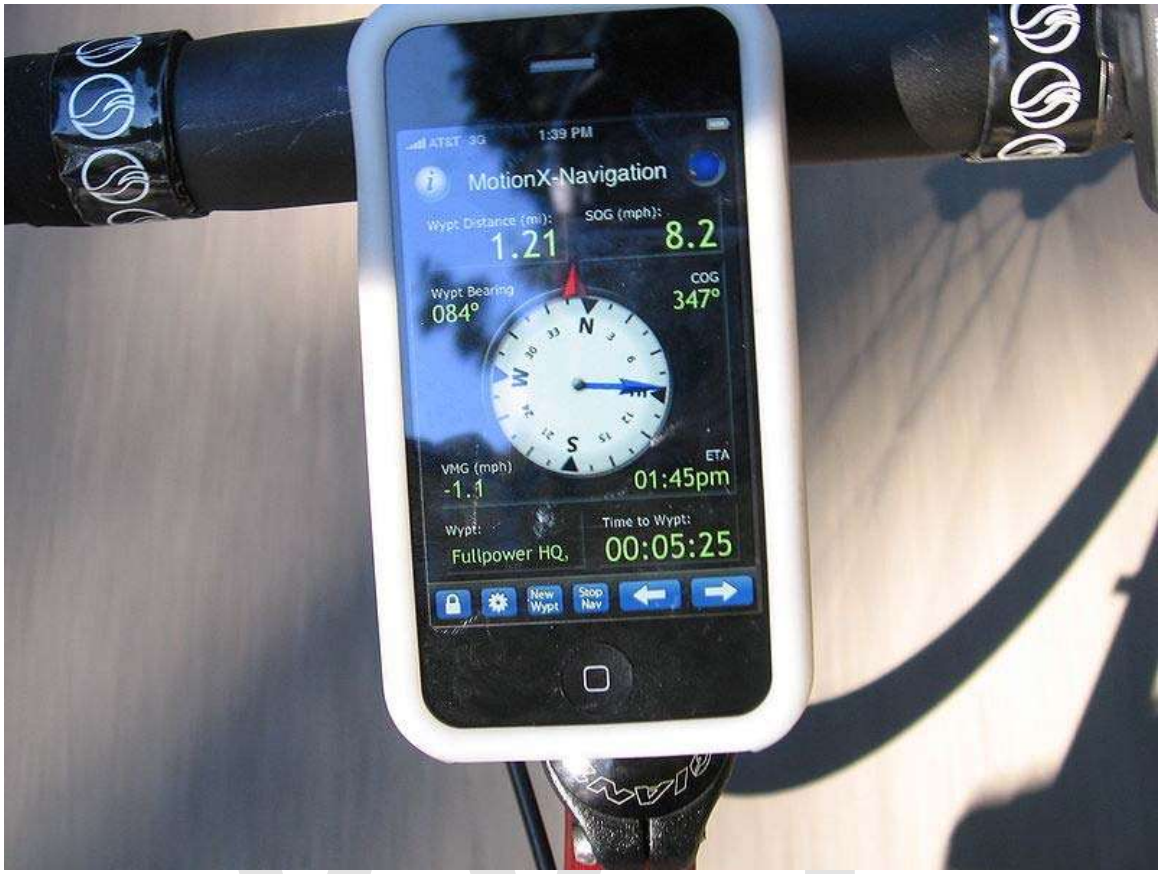
In addition to GPS other systems are in use or under development. The Russian GLObal NAvigation Satellite System (GLONASS) was for use by the Russian military only until 2007. There are also the planned Chinese Compass navigation system and Galileo positioning system of the European Union (EU).

Automotive navigation system in a taxicab

Artist's conception of GPS Block II-F satellite in orbit



Civilian GPS receiver ("GPS navigation device") in a marine application



GPS receivers are now integrated in many mobile phones.

History

The design of GPS is based partly on similar ground-based radio navigation systems, such as LORAN and the Decca Navigator developed in the early 1940s, and used during World War II. In 1956 Friedwardt Winterberg proposed a test of general relativity using accurate atomic clocks placed in orbit in artificial satellites. To achieve accuracy requirements, GPS uses principles of general relativity to correct the satellites' atomic clocks. Additional inspiration for GPS came when the Soviet Union launched the first man-made satellite, Sputnik in 1957. A team of U.S. scientists led by Dr. Richard B. Kershner were monitoring Sputnik's radio transmissions. They discovered that, because of the Doppler effect, the frequency of the signal being transmitted by Sputnik was higher as the satellite approached, and lower as it continued away from them. They realized that because they knew their exact location on the globe, they could pinpoint where the satellite was along its orbit by measuring the Doppler distortion.

The first satellite navigation system, Transit, used by the United States Navy, was first successfully tested in 1960. It used a constellation of five satellites and could provide a navigational fix approximately once per hour. In 1967, the U.S. Navy developed the Timation satellite that proved the ability to place accurate clocks in space, a technology required by GPS. In the 1970s, the ground-based Omega Navigation System, based on phase comparison of signal transmission from pairs of stations, became the first worldwide radio navigation system. Limitations of these systems drove the need for a more universal navigation solution with greater accuracy.

While there were wide needs for accurate navigation in military and civilian sectors, almost none of those were seen as justification for the billions of dollars it would cost in research, development, deployment, and operation for a constellation of navigation satellites. During the Cold War arms race, the nuclear threat to the existence of the

United States was the one need that did justify this cost in the view of the US Congress. This deterrent effect is why GPS was funded. The nuclear triad consisted of the US Navy's submarine-launched ballistic missiles (SLBMs) along with the US Air Force's strategic bombers and intercontinental ballistic missiles (ICBMs). Considered vital to the nuclear deterrence posture, accurate determination of the SLBM launch position was a force multiplier.

Precise navigation would enable US submarines to get an accurate fix of their positions prior to launching their SLBMs. The US Air Force with two-thirds of the nuclear triad also had requirements for a more accurate and reliable navigation system. The Navy and Air Force were developing their own technologies in parallel to solve what was essentially the same problem. To increase the survivability of ICBMs, there was a proposal to use mobile launch platforms so the need to fix the launch position had similarity to the SLBM situation.

In 1960, the Air Force proposed a radio-navigation system called MOSAIC (Mobile System for Accurate ICBM Control) that was essentially a 3-D LORAN. A follow-on study called Project 57 was worked in 1963 and it was "in this study that the GPS concept was born." That same year the concept was pursued as Project 621B, which had "many of the attributes that you now see in GPS" and promised increased accuracy for Air Force bombers as well as ICBMs. Updates from the Navy Transit system were too slow for the high speeds of Air Force operation. The Navy Research Laboratory continued advancements with their Timation (Time Navigation) satellites, first launched in 1967, and with the third one in 1974 carrying the first atomic clock into orbit.

With these parallel developments in the 1960s, it was realized that a superior system could be developed by synthesizing the best technologies from 621B, Transit, Timation, and SECOR in a multi-service program.

During Labor Day weekend in 1973, a meeting of about 12 military officers at the Pentagon discussed the creation of a *Defense Navigation Satellite System (DNSS)*. It was at this meeting that "the real synthesis that became GPS was created." Later that year, the DNSS program was named *Navstar*. With the individual satellites being associated with the name Navstar (as with the predecessors Transit and Timation), a more fully encompassing name was used to identify the constellation of Navstar satellites, *Navstar-GPS*, which was later shortened simply to GPS.

After Korean Air Lines Flight 007, carrying 269 people, was shot down in 1983 after straying into the USSR's prohibited airspace, in the vicinity of Sakhalin and Moneron Islands, President Ronald Reagan issued a directive making GPS freely available for civilian use, once it was sufficiently developed, as a common good. The first satellite was launched in 1989, and the 24th satellite was launched in 1994.

Initially, the highest quality signal was reserved for military use, and the signal available for civilian use was intentionally degraded ("Selective Availability", SA). This changed with US President Bill Clinton ordering Selective Availability turned off at midnight

May 1, 2000, improving the precision of civilian GPS from 100 meters (about 300 feet) to 20 meters (about 65 feet). The US military by then had the ability to deny GPS service to potential adversaries on a regional basis.

GPS is owned and operated by the US Government as a national resource. Department of Defense (USDOD) is the steward of GPS. *Interagency GPS Executive Board (IGEB)* oversaw GPS policy matters from 1996 to 2004. After that the *National Space-Based Positioning, Navigation and Timing Executive Committee* was established by presidential directive in 2004 to advise and coordinate federal departments and agencies on matters concerning the GPS and related systems. The executive committee is chaired jointly by the deputy secretaries of defense and transportation. Its membership includes equivalent-level officials from the departments of state, commerce, and homeland security, the joint chiefs of staff, and NASA. Components of the executive office of the president participate as observers to the executive committee, and the FCC chairman participates as a liaison.

USDOD is required by law to "maintain a Standard Positioning Service (as defined in the federal radio navigation plan and the standard positioning service signal specification) that will be available on a continuous, worldwide basis," and "develop measures to prevent hostile use of GPS and its augmentations without unduly disrupting or degrading civilian uses."

Timeline and modernization

Summary of satellites

Block	Launch Period	Satellite launches				Currently in orbit and healthy
		Success	Failure	In preparation	Planned	
I	1978–1985	10	1	0	0	0
II	1989–1990	9	0	0	0	0
IIA	1990–1997	19	0	0	0	10
IIR	1997–2004	12	1	0	0	12
IIR-M	2005–2009	8	0	0	0	7
IIF	2010–2011	1	0	11	0	1
IIIA	2014–?	0	0	0	12	0

IIIB	0	0	0	8	0
IIIC	0	0	0	16	0
Total	59	2	11	36	30

(Last update: 24 May 2010)

PRN 01 from Block IIR-M is unhealthy
PRN 25 from Block IIA is unhealthy
PRN 32 from Block IIA is unhealthy

- In 1972, the US Air Force Central Inertial Guidance Test Facility (Holloman AFB), conducted developmental flight tests of two prototype GPS receivers over White Sands Missile Range, using ground-based pseudo-satellites.
- In 1978, the first experimental Block-I GPS satellite was launched.
- In 1983, after Soviet interceptor aircraft shot down the civilian airliner KAL 007 that strayed into prohibited airspace because of navigational errors, killing all 269 people on board, U.S. President Ronald Reagan announced that GPS would be made available for civilian uses once it was completed.
- By 1985, ten more experimental Block-I satellites had been launched to validate the concept.
- On February 14, 1989, the first modern Block-II satellite was launched.
- The Gulf War from 1990 to 1992, was the first conflict where GPS was widely used.
- In 1992, the 2nd Space Wing, which originally managed the system, was de-activated and replaced by the 50th Space Wing.
- By December 1993, GPS achieved initial operational capability (IOC), indicating a full constellation (24 satellites) was available and providing the Standard Positioning Service (SPS).
- Full Operational Capability (FOC) was declared by Air Force Space Command (AFSPC) in April 1995, signifying full availability of the military's secure Precise Positioning Service (PPS).
- In 1996, recognizing the importance of GPS to civilian users as well as military users, U.S. President Bill Clinton issued a policy directive declaring GPS to be a dual-use system and establishing an Interagency GPS Executive Board to manage it as a national asset.
- In 1998, US Vice President Al Gore announced plans to upgrade GPS with two new civilian signals for enhanced user accuracy and reliability, particularly with respect to aviation safety and in 2000 the US Congress authorized the effort, referring to it as *GPS III*.
- In 1998, GPS technology was inducted into the Space Foundation Space Technology Hall of Fame.
- On May 2, 2000 "Selective Availability" was discontinued as a result of the 1996 executive order, allowing users to receive a non-degraded signal globally.

- In 2004, the US Government signed an agreement with the European Community establishing cooperation related to GPS and Europe's planned Galileo system.
- In 2004, US President George W. Bush updated the national policy and replaced the executive board with the National Executive Committee for Space-Based Positioning, Navigation, and Timing.
- November 2004, QUALCOMM announced successful tests of assisted GPS for mobile phones.
- In 2005, the first modernized GPS satellite was launched and began transmitting a second civilian signal (L2C) for enhanced user performance.
- On September 14, 2007, the aging mainframe-based Ground Segment Control System was transferred to the new Architecture Evolution Plan.
- On May 19, 2009, the US Government Accountability Office issued a report warning that some GPS satellites could fail as soon as 2010.
- On May 21, 2009, the Air Force Space Command allayed fears of GPS failure saying "There's only a small risk we will not continue to exceed our performance standard."
- On January 11, 2010, an update of ground control systems caused a software incompatibility with 8000 to 10000 military receivers manufactured by a division of Trimble Navigation Limited of Sunnyvale, Calif.
- The most recent launch was on May 28, 2010. The oldest GPS satellite still in operation was launched on November 26, 1990, and became operational on December 10, 1990.

Awards

Two GPS developers received the National Academy of Engineering Charles Stark Draper Prize for 2003:

- Ivan Getting, emeritus president of The Aerospace Corporation and engineer at the Massachusetts Institute of Technology, established the basis for GPS, improving on the World War II land-based radio system called LORAN (*Lo*ng-range *R*adio *A*id to *N*avigation).
- Bradford Parkinson, professor of aeronautics and astronautics at Stanford University, conceived the present satellite-based system in the early 1960s and developed it in conjunction with the U.S. Air Force. Parkinson served twenty-one years in the Air Force, from 1957 to 1978, and retired with the rank of colonel.

GPS developer Roger L. Easton received the National Medal of Technology on February 13, 2006.

On February 10, 1993, the National Aeronautic Association selected the GPS Team as winners of the 1992 Robert J. Collier Trophy, the nation's most prestigious aviation award. This team combines researchers from the Naval Research Laboratory, the U.S. Air Force, the Aerospace Corporation, Rockwell International Corporation, and IBM Federal Systems Company. The citation honors them "for the most significant development for

safe and efficient navigation and surveillance of air and spacecraft because the introduction of radio navigation 50 years ago."

Basic concept of GPS

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include

- the time the message was transmitted
- precise orbital information (the ephemeris)
- the general system health and rough orbits of all GPS satellites (the almanac).

The receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite. These distances along with the satellites' locations are used with the possible aid of trilateration, depending on which algorithm is used, to compute the position of the receiver. This position is then displayed, perhaps with a moving map display or latitude and longitude; elevation information may be included. Many GPS units show derived information such as direction and speed, calculated from position changes.

Three satellites might seem enough to solve for position since space has three dimensions and a position near the Earth's surface can be assumed. However, even a very small clock error multiplied by the very large speed of light — the speed at which satellite signals propagate — results in a large positional error. Therefore receivers use four or more satellites to solve for the receiver's location and time. The very accurately computed time is effectively hidden by most GPS applications, which use only the location. A few specialized GPS applications do however use the time; these include time transfer, traffic signal timing, and synchronization of cell phone base stations.

Although four satellites are required for normal operation, fewer apply in special cases. If one variable is already known, a receiver can determine its position using only three satellites. For example, a ship or aircraft may have known elevation. Some GPS receivers may use additional clues or assumptions (such as reusing the last known altitude, dead reckoning, inertial navigation, or including information from the vehicle computer) to give a less accurate (degraded) position when fewer than four satellites are visible.

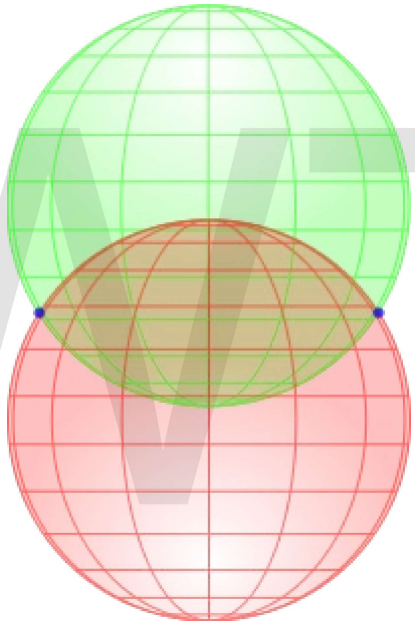
Position calculation introduction

To provide an introductory description of how a GPS receiver works, error effects are deferred to a later section. Using messages received from a minimum of four visible satellites, a GPS receiver is able to determine the times sent and then the satellite positions corresponding to these times sent. The x, y, and z components of position, and the time sent, are designated as $[x_i, y_i, z_i, t_i]$ where the subscript i is the satellite number and has the value 1, 2, 3, or 4. Knowing the indicated time the message was received tr, the GPS receiver can compute the transit time of the message as $(tr - t_i)$. Assuming the

message traveled at the speed of light, c, the distance traveled or pseudorange, $p_i$can be computed as $(tr-t_i)c$.

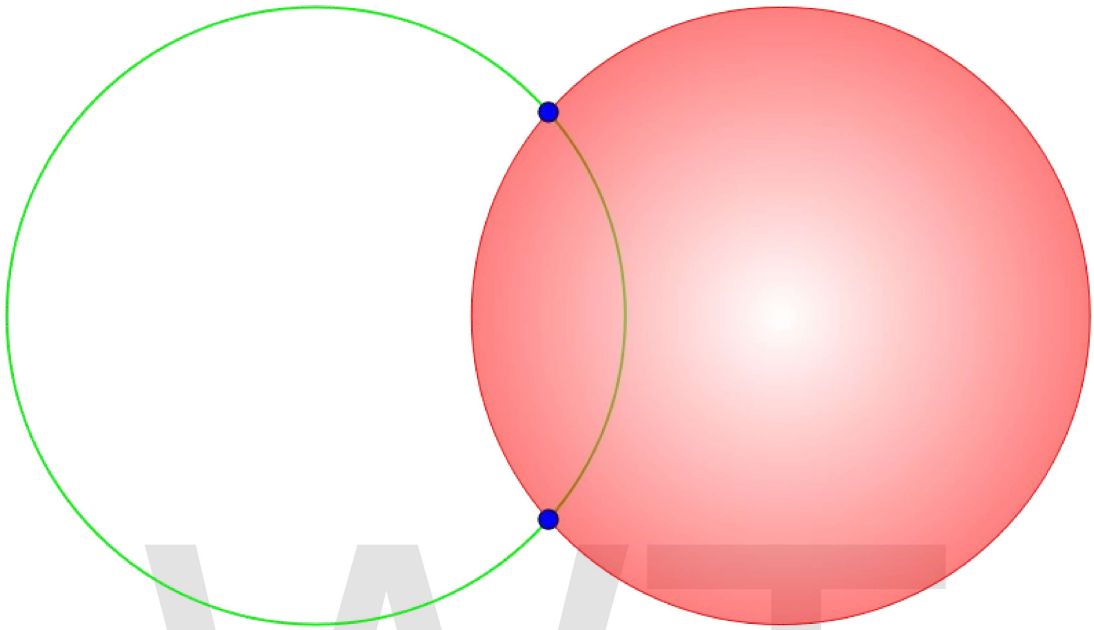
A satellite's position and pseudorange define a sphere, centered on the satellite with radius equal to the pseudorange. The position of the receiver is somewhere on the surface of this sphere. Thus with four satellites, the indicated position of the GPS receiver is at or near the intersection of the surfaces of four spheres. In the ideal case of no errors, the GPS receiver would be at a precise intersection of the four surfaces.

If the surfaces of two spheres intersect at more than one point, they intersect in a circle. A figure, *Two Sphere Surfaces Intersecting in a Circle*, is shown below. Two points where the surfaces of the spheres intersect are clearly shown in the figure. The distance between these two points is the diameter of the circle of intersection.



Two sphere surfaces intersecting in a circle

The intersection of a third spherical surface with the first two will be its intersection with that circle; in most cases of practical interest, this means they intersect at two points. Another figure, *Surface of Sphere Intersecting a Circle (not a solid disk) at Two Points*, illustrates the intersection. The two intersections are marked with dots.



Surface of sphere Intersecting a circle (not a solid disk) at two points

For automobiles and other near-earth vehicles, the correct position of the GPS receiver is the intersection closest to the Earth's surface. For space vehicles, the intersection farthest from Earth may be the correct one.

The correct position for the GPS receiver is also the intersection closest to the surface of the sphere corresponding to the fourth satellite.

Correcting a GPS receiver's clock

One of the most significant error sources is the GPS receiver's clock. Because of the very large value of the speed of light, *c*, the estimated distances from the GPS receiver to the satellites, the pseudoranges, are very sensitive to errors in the GPS receiver clock; for example an error of one microsecond (0.000 001 second) corresponds to an error of 300 metres (980 ft). This suggests that an extremely accurate and expensive clock is required for the GPS receiver to work. Because manufacturers prefer to build inexpensive GPS receivers for mass markets, the solution for this dilemma is based on the way sphere surfaces intersect in the GPS problem.

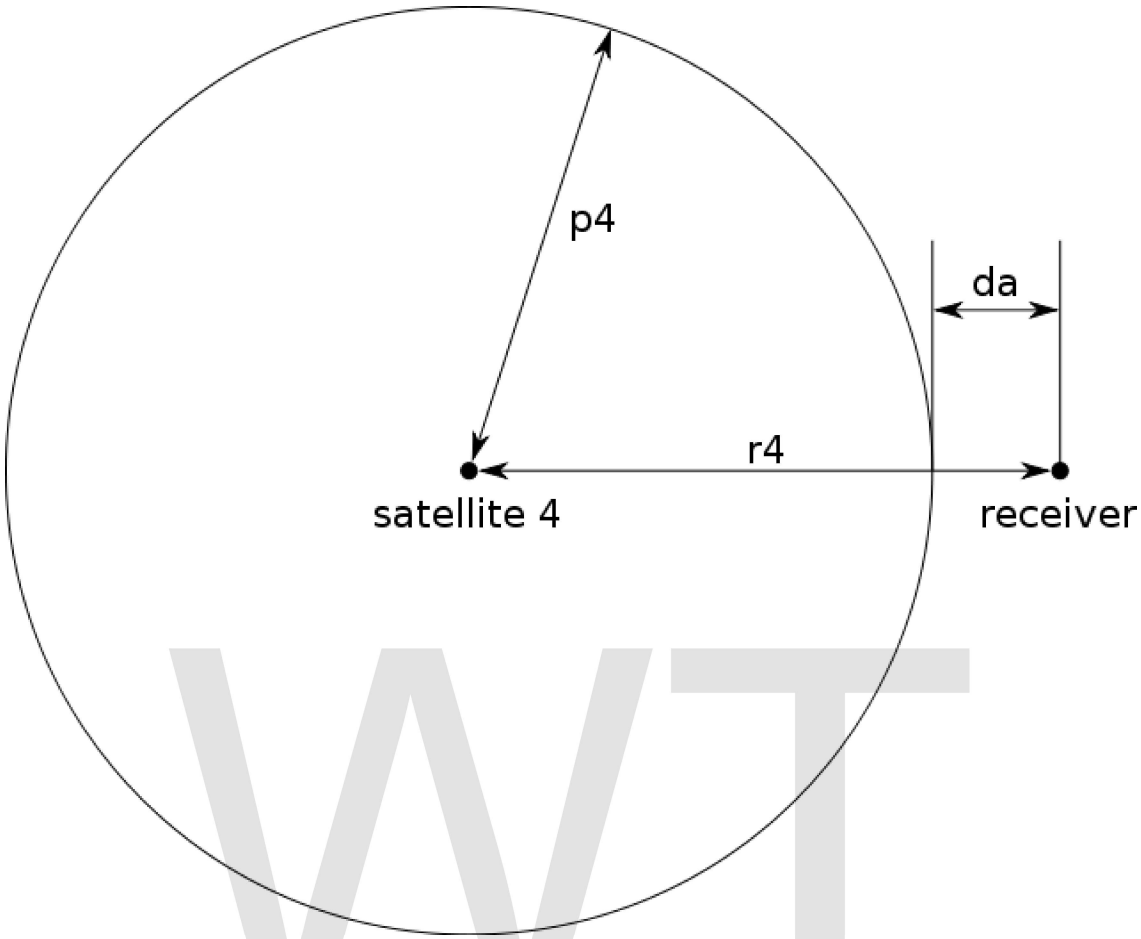


Diagram depicting satellite 4, sphere, p4, r4, and da

It is likely that the surfaces of the three spheres intersect, because the circle of intersection of the first two spheres is normally quite large, and thus the third sphere surface is likely to intersect this large circle. It is very unlikely that the surface of the sphere corresponding to the fourth satellite will intersect either of the two points of intersection of the first three, because any clock error could cause it to miss intersecting a point. However, the distance from the valid estimate of GPS receiver position to the surface of the sphere corresponding to the fourth satellite can be used to compute a clock correction. Let r_4 denote the distance from the valid estimate of GPS receiver position to the fourth satellite and let p_4 denote the pseudorange of the fourth satellite. Let $da = r_4 - p_4$. da is the distance from the computed GPS receiver position to the surface of the sphere corresponding to the fourth satellite. Thus the quotient, $b = da/c$, provides an estimate of

(correct time) − (time indicated by the receiver's on-board clock),

and the GPS receiver clock can be advanced if b is positive or delayed if b is negative. However, it should be kept in mind that a less simple function of da may be needed to

estimate the time error in an iterative algorithm as discussed in the Navigation equations section.

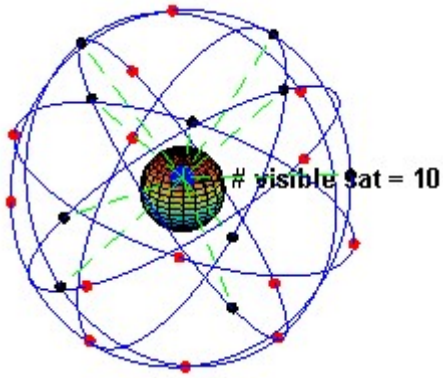
Structure

The current GPS consists of three major segments. These are the space segment (SS), a control segment (CS), and a user segment (US). The U.S. Air Force develops, maintains, and operates the space and control segments. GPS satellites broadcast signals from space, and each GPS receiver uses these signals to calculate its three-dimensional location (latitude, longitude, and altitude) and the current time.

The space segment is composed of 24 to 32 satellites in medium Earth orbit and also includes the payload adapters to the boosters required to launch them into orbit. The control segment is composed of a master control station, an alternate master control station, and a host of dedicated and shared ground antennas and monitor stations. The user segment is composed of hundreds of thousands of U.S. and allied military users of the secure GPS Precise Positioning Service, and tens of millions of civil, commercial, and scientific users of the Standard Positioning Service.

Space segment

Unlaunched GPS satellite on display at the San Diego Air & Space Museum



A visual example of the GPS constellation in motion with the Earth rotating. Notice how the number of *satellites in view* from a given point on the Earth's surface, in this example at 45°N, changes with time.

The space segment (SS) is composed of the orbiting GPS satellites, or Space Vehicles (SV) in GPS parlance. The GPS design originally called for 24 SVs, eight each in three circular orbital planes, but this was modified to six planes with four satellites each. The orbital planes are centered on the Earth, not rotating with respect to the distant stars. The six planes have approximately 55° inclination (tilt relative to Earth's equator) and are separated by 60° right ascension of the ascending node (angle along the equator from a reference point to the orbit's intersection). The orbits are arranged so that at least six satellites are always within line of sight from almost everywhere on Earth's surface. The result of this objective is that the four satellites are not evenly spaced (90 degrees) apart within each orbit. In general terms, the angular difference between satellites in each orbit is 30, 105, 120, and 105 degrees apart which, of course, sum to 360 degrees.

Orbiting at an altitude of approximately 20,200 kilometers (about 12,550 miles or 10,900 nautical miles; orbital radius of approximately 26,600 km (about 16,500 mi or 14,400 NM)), each SV makes two complete orbits each sidereal day, repeating the same ground track each day. This was very helpful during development because even with only four satellites, correct alignment means all four are visible from one spot for a few hours each day. For military operations, the ground track repeat can be used to ensure good coverage in combat zones.

As of March 2008, there are 31 actively broadcasting satellites in the GPS constellation, and two older, retired from active service satellites kept in the constellation as orbital spares. The additional satellites improve the precision of GPS receiver calculations by providing redundant measurements. With the increased number of satellites, the constellation was changed to a nonuniform arrangement. Such an arrangement was shown to improve reliability and availability of the system, relative to a uniform system, when multiple satellites fail. About eight satellites are visible from any point on the ground at any one time.

Control segment

Ground monitor station used from 1984 to 2007, on display at the Air Force Space & Missile Museum

The control segment is composed of

1. a master control station (MCS),
2. an alternate master control station,
3. four dedicated ground antennas and
4. six dedicated monitor stations

The MCS can also access U.S. Air Force Satellite Control Network (AFSCN) ground antennas (for additional command and control capability) and NGA (National Geospatial-Intelligence Agency) monitor stations. The flight paths of the satellites are tracked by dedicated U.S. Air Force monitoring stations in Hawaii, Kwajalein, Ascension Island, Diego Garcia, Colorado Springs, Colorado and Cape Canaveral, along with shared NGA monitor stations operated in England, Argentina, Ecuador, Bahrain, Australia and Washington DC. The tracking information is sent to the Air Force Space Command's MCS at Schriever Air Force Base 25 km (16 miles) ESE of Colorado Springs, which is operated by the 2nd Space Operations Squadron (2 SOPS) of the United States Air Force (USAF). Then 2 SOPS contacts each GPS satellite regularly with a navigational update using dedicated or shared (AFSCN) ground antennas (GPS dedicated ground antennas are located at Kwajalein, Ascension Island, Diego Garcia, and Cape Canaveral). These

updates synchronize the atomic clocks on board the satellites to within a few nanoseconds of each other, and adjust the ephemeris of each satellite's internal orbital model. The updates are created by a Kalman filter that uses inputs from the ground monitoring stations, space weather information, and various other inputs.

Satellite maneuvers are not precise by GPS standards. So to change the orbit of a satellite, the satellite must be marked *unhealthy*, so receivers will not use it in their calculation. Then the maneuver can be carried out, and the resulting orbit tracked from the ground. Then the new ephemeris is uploaded and the satellite marked healthy again.

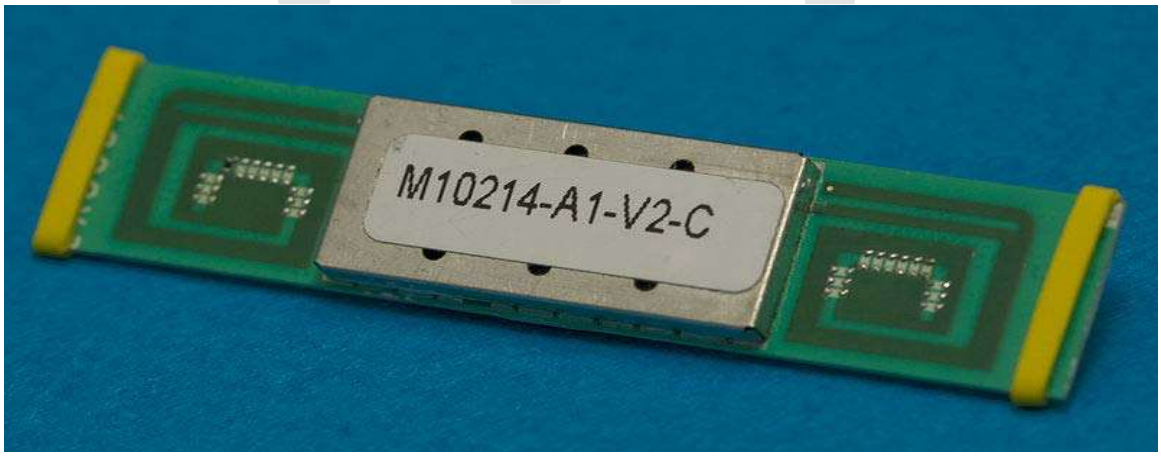
User segment

GPS receivers come in a variety of formats, from devices integrated into cars, phones, and watches, to dedicated devices such as those shown here from manufacturers Trimble, Garmin and Leica (left to right).

The user segment is composed of hundreds of thousands of U.S. and allied military users of the secure GPS Precise Positioning Service, and tens of millions of civil, commercial and scientific users of the Standard Positioning Service. In general, GPS receivers are composed of an antenna, tuned to the frequencies transmitted by the satellites, receiver-processors, and a highly stable clock (often a crystal oscillator). They may also include a display for providing location and speed information to the user. A receiver is often described by its number of channels: this signifies how many satellites it can monitor simultaneously. Originally limited to four or five, this has progressively increased over the years so that, as of 2007, receivers typically have between 12 and 20 channels.

A typical OEM GPS receiver module measuring 15×17 mm

GPS receivers may include an input for differential corrections, using the RTCM SC-104 format. This is typically in the form of an RS-232 port at 4,800 bit/s speed. Data is actually sent at a much lower rate, which limits the accuracy of the signal sent using RTCM. Receivers with internal DGPS receivers can outperform those using external RTCM data. As of 2006, even low-cost units commonly include Wide Area Augmentation System (WAAS) receivers.



A typical GPS receiver with integrated antenna

Many GPS receivers can relay position data to a PC or other device using the NMEA 0183 protocol. Although this protocol is officially defined by the National Marine Electronics Association (NMEA), references to this protocol have been compiled from public records, allowing open source tools like gpsd to read the protocol without violating

intellectual property laws. Other proprietary protocols exist as well, such as the SiRF and MTK protocols. Receivers can interface with other devices using methods including a serial connection, USB, or Bluetooth.

Applications

While originally a military project, GPS is considered a *dual-use* technology, meaning it has significant military and civilian applications.

GPS has become a widely deployed and useful tool for commerce, scientific uses, tracking, and surveillance. GPS's accurate time facilitates everyday activities such as banking, mobile phone operations, and even the control of power grids by allowing well synchronized hand-off switching. Farmers, surveyors, geologists, and countless others perform their work more efficiently, safely, economically, and accurately.

Civilian

This antenna is mounted on the roof of a hut containing a scientific experiment needing precise timing.

Many civilian applications use one or more of GPS's three basic components: absolute location, relative movement, and time transfer.

- Cellular telephony: Clock synchronization enables time transfer, which is critical for synchronizing its spreading codes with other base stations to facilitate inter-cell handoff and support hybrid GPS/cellular position detection for mobile emergency calls and other applications. The first handsets with integrated GPS launched in the late 1990s. The U.S. Federal Communications Commission (FCC) mandated the feature in either the handset or in the towers (for use in triangulation) in 2002 so emergency services could locate 911 callers. Third-party software developers later gained access to GPS APIs from Nextel upon launch, followed by Sprint in 2006, and Verizon soon thereafter.
- Disaster relief/emergency services: Depend upon GPS for location and timing capabilities.
- Geofencing: Vehicle tracking systems, person tracking systems, and pet tracking systems use GPS to locate a vehicle, person, or pet. These devices attach to the vehicle, person, or the pet collar. The application provides 24/7 tracking and mobile or Internet updates should the trackee leave a designated area.
- Geotagging: Applying location coordinates to digital objects such as photographs and other documents for purposes such as creating map overlays.
- GPS Aircraft Tracking
- GPS tours: Location determines what content to display; for instance, information about an approaching point of interest.
- Map-making: Both civilian and military cartographers use GPS extensively.
- Navigation: Navigators value digitally precise velocity and orientation measurements.
- Phasor measurement units: GPS enables highly accurate timestamping of power system measurements, making it possible to compute phasors.
- Recreation: For example, geocaching, geodashing, GPS drawing and waymarking.
- Surveying: Surveyors use absolute locations to make maps and determine property boundaries.
- Tectonics: GPS enables direct fault motion measurement in earthquakes.

Restrictions on civilian use

The U.S. Government controls the export of some civilian receivers. All GPS receivers capable of functioning above 18 kilometers (11 mi) altitude and 515 metres per second (1,001 kn) are classified as munitions (weapons) for which U.S. State Department export licenses are required. These limits attempt to prevent use of a receiver in a ballistic missile. They would not prevent use in a cruise missile because their altitudes and speeds are similar to those of ordinary aircraft.

This rule applies even to otherwise purely civilian units that only receive the L1 frequency and the C/A (Clear/Acquisition) code and cannot correct for Selective Availability (SA), etc.

Disabling operation above these limits exempts the receiver from classification as a munition. Vendor interpretations differ. The rule targets operation given the combination of altitude and speed, while some receivers stop operating even when stationary. This has caused problems with some amateur radio balloon launches that regularly reach 30 kilometers (19 mi).

Military

As of 2009, military applications of GPS include:

- Navigation: GPS allows soldiers to find objectives, even in the dark or in unfamiliar territory, and to coordinate troop and supply movement. In the US armed forces, commanders use the *Commanders Digital Assistant* and lower ranks use the *Soldier Digital Assistant*.
- Target tracking: Various military weapons systems use GPS to track potential ground and air targets before flagging them as hostile. These weapon systems pass target coordinates to precision-guided munitions to allow them to engage targets accurately. Military aircraft, particularly in air-to-ground roles, use GPS to find targets (for example, gun camera video from AH-1 Cobras in Iraq show GPS co-ordinates that can be viewed with special software.
- Missile and projectile guidance: GPS allows accurate targeting of various military weapons including ICBMs, cruise missiles and precision-guided munitions. Artillery projectiles. Embedded GPS receivers able to withstand accelerations of 12,000 *g* or about 118 km/s^2 have been developed for use in 155 millimeters (6.1 in) howitzers.
- Search and Rescue: Downed pilots can be located faster if their position is known.
- Reconnaissance: Patrol movement can be managed more closely.
- GPS satellites carry a set of nuclear detonation detectors consisting of an optical sensor (Y-sensor), an X-ray sensor, a dosimeter, and an electromagnetic pulse (EMP) sensor (W-sensor), that form a major portion of the United States Nuclear Detonation Detection System.

Communication

The navigational signals transmitted by GPS satellites encode a variety of information including satellite positions, the state of the internal clocks, and the health of the network. These signals are transmitted on two separate carrier frequencies that are common to all satellites in the network. Two different encodings are used, a public encoding that enables lower resolution navigation, and an encrypted encoding used by the U.S. military.

Message format

GPS message format

Subframes	Description

1	Satellite clock, GPS time relationship
2–3	Ephemeris (precise satellite orbit)
4–5	Almanac component (satellite network synopsis, error correction)

Each GPS satellite continuously broadcasts a *navigation message* at a rate of 50 bits per second. Each complete message is composed of 30-second frames, distinct groupings of 1,500 bits of information. Each frame is further subdivided into 5 subframes of length 6 seconds and with 300 bits each. Each subframe contains 10 words of 30 bits with length 0.6 seconds each. Each 30 second frame begins precisely on the minute or half minute as indicated by the atomic clock on each satellite.

The first part of the message encodes the week number and the time within the week, as well as the data about the health of the satellite. The second part of the message, the *ephemeris*, provides the precise orbit for the satellite. The last part of the message, the *almanac*, contains coarse orbit and status information for all satellites in the network as well as data related to error correction.

All satellites broadcast at the same frequencies. Signals are encoded using code division multiple access (CDMA) allowing messages from individual satellites to be distinguished from each other based on unique encodings for each satellite (that the receiver must be aware of). Two distinct types of CDMA encodings are used: the coarse/acquisition (C/A) code, which is accessible by the general public, and the precise (P) code, that is encrypted so that only the U.S. military can access it.

The ephemeris is updated every 2 hours and is generally valid for 4 hours, with provisions for updates every 6 hours or longer in non-nominal conditions. The almanac is updated typically every 24 hours. Additionally data for a few weeks following is uploaded in case of transmission updates that delay data upload.

Satellite frequencies

GPS frequency overview

Band	Frequency	Description
L1	1575.42 MHz	Coarse-acquisition (C/A) and encrypted precision P(Y) codes, plus the L1 civilian (L1C) and military (M) codes on future Block III satellites.
L2	1227.60 MHz	P(Y) code, plus the L2C and military codes on the

		Block IIR-M and newer satellites.
L3	1381.05 MHz	Used for nuclear detonation (NUDET) detection.
L4	1379.913 MHz	Being studied for additional ionospheric correction.
L5	1176.45 MHz	Proposed for use as a civilian safety-of-life (SoL) signal.

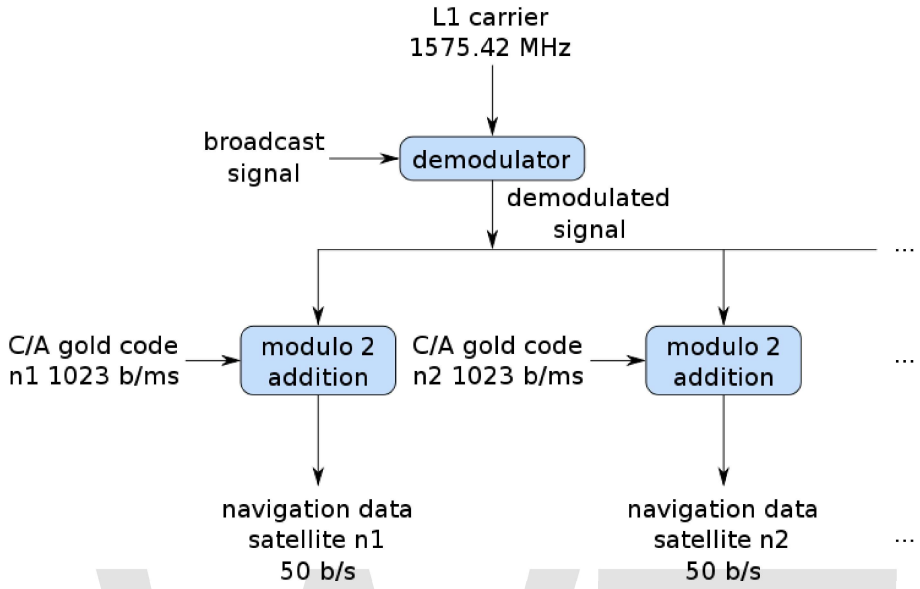
All satellites broadcast at the same two frequencies, 1.57542 GHz (L1 signal) and 1.2276 GHz (L2 signal). The satellite network uses a CDMA spread-spectrum technique where the low-bitrate message data is encoded with a high-rate pseudo-random (PRN) sequence that is different for each satellite. The receiver must be aware of the PRN codes for each satellite to reconstruct the actual message data. The C/A code, for civilian use, transmits data at 1.023 million chips per second, whereas the P code, for U.S. military use, transmits at 10.23 million chips per second. The L1 carrier is modulated by both the C/A and P codes, while the L2 carrier is only modulated by the P code. The P code can be encrypted as a so-called P(Y) code that is only available to military equipment with a proper decryption key. Both the C/A and P(Y) codes impart the precise time-of-day to the user.

The L3 signal at a frequency of 1.38105 GHz is used by the United States Nuclear Detonation (NUDET) Detection System (USNDS) to detect, locate, and report nuclear detonations (NUDETs) in the earth's atmosphere and near space. One usage is the enforcement of nuclear test ban treaties.

The L4 band at 1.379913 GHz is being studied for additional ionospheric correction.

The L5 frequency band at 1.17645 GHZ was added in the process of GPS modernization. This frequency falls into an internationally protected range for aeronautical navigation, promising little or no interference under all circumstances. The first Block IIF satellite that would provide this signal is set to be launched in 2009. The L5 consists of two carrier components that are in phase quadrature with each other. Each carrier component is bi-phase shift key (BPSK) modulated by a separate bit train.

Demodulation and decoding



Demodulating and Decoding GPS Satellite Signals using the Coarse/Acquisition Gold code

Because all of the satellite signals are modulated onto the same L1 carrier frequency, the signals must be separated after demodulation. This is done by assigning each satellite a unique binary sequence known as a Gold code. The signals are decoded after demodulation using addition of the Gold codes corresponding to the satellites monitored by the receiver.

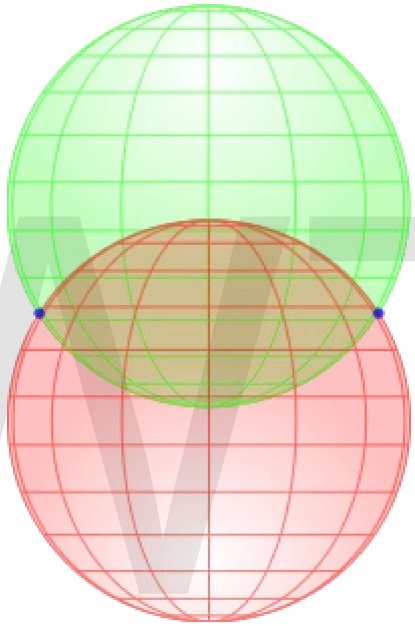
If the almanac information has previously been acquired, the receiver picks the satellites to listen for by their PRNs, unique numbers in the range 1 through 32. If the almanac information is not in memory, the receiver enters a search mode until a lock is obtained on one of the satellites. To obtain a lock, it is necessary that there be an unobstructed line of sight from the receiver to the satellite. The receiver can then acquire the almanac and determine the satellites it should listen for. As it detects each satellite's signal, it identifies it by its distinct C/A code pattern. There can be a delay of up to 30 seconds before the first estimate of position because of the need to read the ephemeris data.

Processing of the navigation message enables the determination of the time of transmission and the satellite position at this time.

Navigation equations

The receiver uses messages received from four satellites to determine the satellite positions and time sent. The *x, y,* and *z* components of position and the time sent are designated as $[x_i, y_i, z_i, t_i]$where the subscript *i* denotes the satellite and has the value 1, 2, 3, or 4. Knowing when the message was received tr_i, the receiver computes the

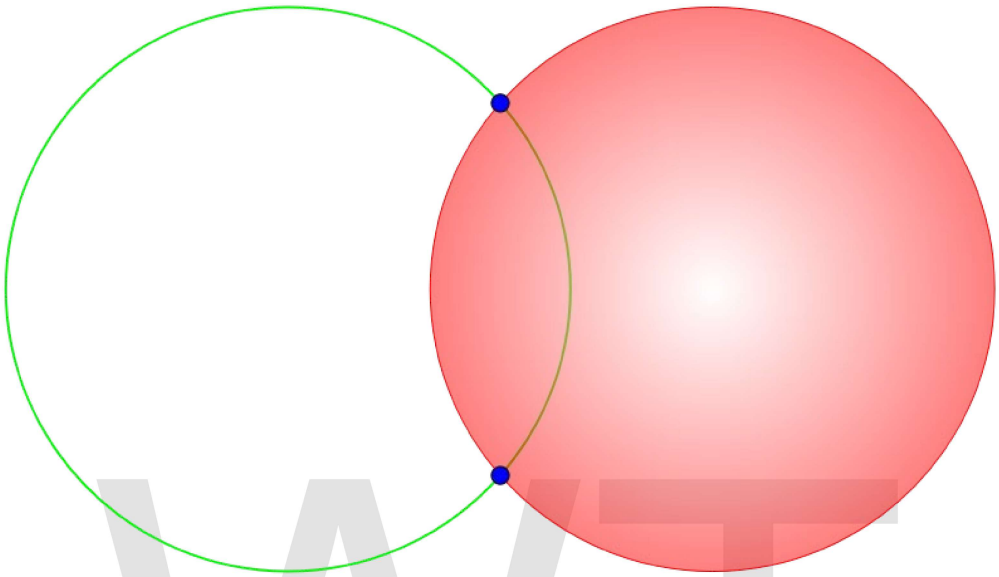
message's transit time as $(tr_i - t_i)$. Assuming the message traveled at the speed of light (c) the distance traveled, $p_i$is $(tr_i - t_i)\, c$. Knowing the distance from receiver to satellite and the satellite's position implies that the receiver is on the surface of a sphere centered at the satellite's position. Thus the receiver is at or near the intersection of the surfaces of four spheres. In the ideal case of no errors, the receiver is at the intersection of the surfaces of four spheres. Excluding the unrealistic case (for GPS purposes) of two coincident spheres, the surfaces of two intersecting spheres is either a point (if they merely touch) or a circle as depicted in the illustration below. Two of the points where the surfaces of the spheres intersect are clearly marked on the figure. The distance between these two points is the diameter of the circle of intersection.



Two sphere surfaces intersecting in a circle

This can be seen more clearly by considering a side view of the intersecting spheres. This view would match the figure because of the symmetry of the spheres. A view from any horizontal direction would look exactly the same. Therefore the diameter as seen from all directions is the same and thus the surfaces actually do intersect in a circle.

Having found that two sphere surfaces intersect in a circle, we now consider how the intersection of the first two sphere surfaces, the circle, intersect with the third sphere. A circle and sphere surface intersect at zero, one or two points. For the GPS problem we are concerned with the case of two points of intersection. Another figure, Surface of Sphere Intersecting a Circle (not a solid disk) at Two Points, is shown below to aid in visualizing this intersection. Trilateration algebraically confirms this geometric observation. The ambiguity of two points of intersection of three sphere surfaces can be resolved by noting the point that is closest to the fourth sphere surface.



Surface of a sphere intersecting a circle (i.e., the edge of a disk) at two points

Having provided a discussion of how sphere surfaces intersect, we now formulate the equations for the case when errors are present.

Let b denote the clock error or bias, the amount that the receiver's clock is off. The receiver has four unknowns, the three components of GPS receiver position and the clock bias $[x, y, z, b]$. The equation of the sphere surfaces are given by:

$$(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2 = \left([tr_i + b - t_i]c\right)^2,$$

$$i = 1, 2, 3, 4$$

Another useful form of these equations is in terms of *pseudoranges*, which are the approximate ranges based on the receiver clock's uncorrected time so that $p_i = (tr_i - t_i)\, c$. Then the equations becomes:

$$p_i = \sqrt{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2} - bc, \;\; i = 1, 2, 3, 4.$$

Methods of solution of navigation equations

- Bancroft's method is perhaps the most important method of solving the navigation equations because it involves an algebraic as opposed to numerical method. The method requires at least four satellites but more can be used.

Two numerical methods of computing GPS receiver position and clock bias are (1) by using trilateration and one dimensional numerical root finding and (2) multidimensional Newton-Raphson calculations.

- The receiver can use trilateration and one dimensional numerical root finding. Trilateration is used to determine the intersection of the surfaces of three spheres. In the usual case of two intersections, the point nearest the surface of the sphere corresponding to the fourth satellite is chosen. The Earth's surface can also sometimes be used instead, especially by civilian GPS receivers, because it is illegal in the United States to track vehicles more than 60,000 feet (18,000 m) in altitude. Let da denote the signed magnitude of the vector from the receiver position to the fourth satellite (i.e. da = r4 - p4) as defined in the section "Clock correction". da is a function of the correction because the correction changes the satellite transmission times and thus the pseudoranges. The notation, da(correction) denotes this function. The problem is to determine the correction such that

$$da\,(correction) = 0.$$

This is the familiar problem of finding the zeroes of a one dimensional non-linear function of a scalar variable. Iterative numerical methods, such as those found in the chapter on root finding in *Numerical Recipes* can solve this type of problem. One advantage of this method is that it involves one dimensional as opposed to multidimensional numerical root finding.

- Alternatively, multidimensional root finding method such as Newton-Raphson method can be used. The approach is to linearize around an approximate solution, say $\left[x^{(k)}, y^{(k)}, z^{(k)}, b^{(k)}\right]$ from iteration *k,* then solve four linear equations derived from the quadratic equations above to obtain $\left[x^{(k+1)}, y^{(k+1)}, z^{(k+1)}, b^{(k+1)}\right]$. The Newton-Raphson method is more rapidly convergent than other methods of numerical root finding. A disadvantage of this multidimensional root finding method as compared to single dimensional root findiing is that, "There are no good general methods for solving systems of more than one nonlinear equations."
- When more than four satellites are available, the calculation can use the four best or more than four, considering number of channels, processing capability, and geometric dilution of precision (GDOP). Using more than four is an over-determined system of equations with no unique solution, which must be solved by least-squares or a similar technique. If all visible satellites are used, the results are as good as or better than using the four best. Errors can be estimated through the

residuals. With each combination of four or more satellites, a GDOP factor can be calculated, based on the relative sky directions of the satellites used. As more satellites are picked up, pseudoranges from various 4-way combinations can be processed to add more estimates to the location and clock offset. The receiver then takes the weighted average of these positions and clock offsets. After the final location and time are calculated, the location is expressed in a specific coordinate system such as latitude and longitude, using the WGS 84 geodetic datum or a country-specific system.

- Finally, results from other positioning systems such as GLONASS or the upcoming Galileo can be incorporated or used to check the result. (By design, these systems use the same frequency bands, so much of the receiver circuitry can be shared, though the decoding is different.)

Accuracy enhancement and surveying

Error sources and analysis

The analysis of errors in the information reported by the Global Positioning System is important to estimating the accuracy of position estimates and correcting for the errors. The positioning data provided directly by the satellites is extremely precise but there are many factors that can make the errors in the data non-trivial. In situations where high accuracy is necessary, understanding and compensating for these sources of error is important. Sources of error include atmospheric distortion (predominantly in the ionosphere), satellite clock inaccuracies, and the travel delays of the satellite signals.

Augmentation

Integrating external information into the calculation process can materially improve accuracy. Such augmentation systems are generally named or described based on how the information arrives. Some systems transmit additional error information (such as clock drift, ephemera, or ionospheric delay), others characterize prior errors, while a third group provides additional navigational or vehicle information.

Examples of augmentation systems include the Wide Area Augmentation System (WAAS), European Geostationary Navigation Overlay Service (EGNOS) , Differential GPS, Inertial Navigation Systems (INS) and Assisted GPS.

Precise monitoring

Accuracy can be improved through precise monitoring and measurement of existing GPS signals in additional or alternate ways.

The largest remaining error is usually the unpredictable delay through the ionosphere. The spacecraft broadcast ionospheric model parameters, but errors remain. This is one reason GPS spacecraft transmit on at least two frequencies, L1 and L2. Ionospheric delay

is a well-defined function of frequency and the total electron content (TEC) along the path, so measuring the arrival time difference between the frequencies determines TEC and thus the precise ionospheric delay at each frequency.

Military receivers can decode the P(Y)-code transmitted on both L1 and L2. Without decryption keys, it is still possible to use a *codeless* technique to compare the P(Y) codes on L1 and L2 to gain much of the same error information. However, this technique is slow, so it is currently available only on specialized surveying equipment. In the future, additional civilian codes are expected to be transmitted on the L2 and L5 frequencies. Then all users will be able to perform dual-frequency measurements and directly compute ionospheric delay errors.

A second form of precise monitoring is called *Carrier-Phase Enhancement* (CPGPS). This corrects the error that arises because the pulse transition of the PRN is not instantaneous, and thus the correlation (satellite-receiver sequence matching) operation is imperfect. CPGPS uses the L1 carrier wave, which has a period of $\frac{1 \text{ sec}}{1575.42 * 10^6} = 0.63475 \text{ nanoseconds} \approx 1 \text{ nanosecond}$, which is about one-thousandth of the C/A Gold code bit period of $\frac{1 \text{ sec}}{1023 * 10^3} = 977.5 \text{ nanosecond } \approx 1000 \text{ nanosecond}$, to act as an additional clock signal and resolve the uncertainty. The phase difference error in the normal GPS amounts to 2–3 metres (6.6–9.8 ft) of ambiguity. CPGPS working to within 1% of perfect transition reduces this error to 3 centimeters (1.2 in) of ambiguity. By eliminating this error source, CPGPS coupled with DGPS normally realizes between 20–30 centimetres (7.9–12 in) of absolute accuracy.

Relative Kinematic Positioning (RKP) is a third alternative for a precise GPS-based positioning system. In this approach, determination of range signal can be resolved to a precision of less than 10 centimeters (3.9 in). This is done by resolving the number of cycles that the signal is transmitted and received by the receiver by using a combination of differential GPS (DGPS) correction data, transmitting GPS signal phase information and ambiguity resolution techniques via statistical tests—possibly with processing in real-time (real-time kinematic positioning, RTK).

Timekeeping

Timekeeping and leap seconds

While most clocks are synchronized to Coordinated Universal Time (UTC), the atomic clocks on the satellites are set to *GPS time*. The difference is that GPS time is not corrected to match the rotation of the Earth, so it does not contain leap seconds or other corrections that are periodically added to UTC. GPS time was set to match Coordinated Universal Time (UTC) in 1980, but has since diverged. The lack of corrections means that GPS time remains at a constant offset with International Atomic Time (TAI) (TAI -

GPS = 19 seconds). Periodic corrections are performed on the on-board clocks to correct relativistic effects and keep them synchronized with ground clocks.

The GPS navigation message includes the difference between GPS time and UTC, which as of 2009 is 15 seconds because of the leap second added to UTC December 31, 2008. Receivers subtract this offset from GPS time to calculate UTC and specific timezone values. New GPS units may not show the correct UTC time until after receiving the UTC offset message. The GPS-UTC offset field can accommodate 255 leap seconds (eight bits) that, given the current rate of change of the Earth's rotation (with one leap second introduced approximately every 18 months), should be sufficient to last until approximately the year 2300.

Timekeeping accuracy

GPS time is accurate to about 14ns.

Timekeeping format

As opposed to the year, month, and day format of the Gregorian calendar, the GPS date is expressed as a week number and a seconds-into-week number. The week number is transmitted as a ten-bit field in the C/A and P(Y) navigation messages, and so it becomes zero again every 1,024 weeks (19.6 years). GPS week zero started at 00:00:00 UTC (00:00:19 TAI) on January 6, 1980, and the week number became zero again for the first time at 23:59:47 UTC on August 21, 1999 (00:00:19 TAI on August 22, 1999). To determine the current Gregorian date, a GPS receiver must be provided with the approximate date (to within 3,584 days) to correctly translate the GPS date signal. To address this concern the modernized GPS navigation message uses a 13-bit field that only repeats every 8,192 weeks (157 years), thus lasting until the year 2137 (157 years after GPS week zero).

Carrier phase tracking (surveying)

Another method that is used in surveying applications is carrier phase tracking. The period of the carrier frequency times the speed of light gives the wavelength, which is about 0.19 meters for the L1 carrier. Accuracy within 1% of wavelength in detecting the leading edge, reduces this component of pseudorange error to as little as 2 millimeters. This compares to 3 meters for the C/A code and 0.3 meters for the P code.

However, 2 millimeter accuracy requires measuring the total phase—the number of waves times the wavelength plus the fractional wavelength, which requires specially equipped receivers. This method has many surveying applications.

Triple differencing followed by numerical root finding, and a mathematical technique called least squares can estimate the position of one receiver given the position of another. First, compute the difference between satellites, then between receivers, and

finally between epochs. Other orders of taking differences are equally valid. Detailed discussion of the errors is omitted.

The satellite carrier total phase can be measured with ambiguity as to the number of cycles. Let $\phi(r_i, s_j, t_k)$ denote the phase of the carrier of satellite *j* measured by receiver *i* at time t_k. This notation shows the meaning of the subscripts *i, j,* and *k.* The receiver (*r*), satellite (*s*), and time (*t*) come in alphabetical order as arguments of ϕ and to balance readability and conciseness, let $\phi_{i,j,k} = \phi(r_i, s_j, t_k)$ be a concise abbreviation. Also we define three functions, :$\Delta^r, \Delta^s, \Delta^t$, which return differences between receivers, satellites, and time points, respectively. Each function has variables with three subscripts as its arguments. These three functions are defined below. If $\alpha_{i,j,k}$ is a function of the three integer arguments, *i, j,* and *k* then it is a valid argument for the functions, :$\Delta^r, \Delta^s, \Delta^t$, with the values defined as

$$\Delta^r(\alpha_{i,j,k}) = \alpha_{i+1,j,k} - \alpha_{i,j,k},$$
$$\Delta^s(\alpha_{i,j,k}) = \alpha_{i,j+1,k} - \alpha_{i,j,k}, \text{ and}$$
$$\Delta^t(\alpha_{i,j,k}) = \alpha_{i,j,k+1} - \alpha_{i,j,k}.$$

Also if $\alpha_{i,j,k}$ and $\beta_{l,m,n}$ are valid arguments for the three functions and *a* and *b* are constants then $(a\ \alpha_{i,j,k} + b\ \beta_{l,m,n})$ is a valid argument with values defined as

$$\Delta^r(a\ \alpha_{i,j,k} + b\ \beta_{l,m,n}) = a\ \Delta^r(\alpha_{i,j,k}) + b\ \Delta^r(\beta_{l,m,n}),$$
$$\Delta^s(a\ \alpha_{i,j,k} + b\ \beta_{l,m,n}) = a\ \Delta^s(\alpha_{i,j,k}) + b\ \Delta^s(\beta_{l,m,n}), \text{ and}$$
$$\Delta^t(a\ \alpha_{i,j,k} + b\ \beta_{l,m,n}) = a\ \Delta^t(\alpha_{i,j,k}) + b\ \Delta^t(\beta_{l,m,n}).$$

Receiver clock errors can be approximately eliminated by differencing the phases measured from satellite 1 with that from satellite 2 at the same epoch. This difference is designated as $\Delta^s(\phi_{1,1,1}) = \phi_{1,2,1} - \phi_{1,1,1}$

Double differencing computes the difference of receiver 1's satellite difference from that of receiver 2. This approximately eliminates satellite clock errors. This double difference is:

$$\Delta^r(\Delta^s(\phi_{1,1,1})) = \Delta^r(\phi_{1,2,1} - \phi_{1,1,1}) = \Delta^r(\phi_{1,2,1}) - \Delta^r(\phi_{1,1,1}) = (\phi_{2,2,1} - \phi_{1,2,1}) - (\phi_{2,1,1} - \phi_{1,1,1})$$

Triple differencing subtracts the receiver difference from time 1 from that of time 2. This eliminates the ambiguity associated with the integral number of wave lengths in carrier phase provided this ambiguity does not change with time. Thus the triple difference result eliminates practically all clock bias errors and the integer ambiguity. Atmospheric delay and satellite ephemeris errors have been significantly reduced. This triple difference is:

$$\Delta^t(\Delta^r(\Delta^s(\phi_{1,1,1})))$$

Triple difference results can be used to estimate unknown variables. For example if the position of receiver 1 is known but the position of receiver 2 unknown, it may be possible to estimate the position of receiver 2 using numerical root finding and least squares. Triple difference results for three independent time pairs quite possibly will be sufficient to solve for receiver 2's three position components. This may require the use of a numerical procedure. An approximation of receiver 2's position is required to use such a numerical method. This initial value can probably be provided from the navigation message and the intersection of sphere surfaces. Such a reasonable estimate can be key to successful multidimensional root finding. Iterating from three time pairs and a fairly good initial value produces one observed triple difference result for receiver 2's position. Processing additional time pairs can improve accuracy, overdetermining the answer with multiple solutions. Least squares can estimate an overdetermined system. Least squares determines the position of receiver 2 which best fits the observed triple difference results for receiver 2 positions under the criterion of minimizing the sum of the squares.

Other systems

Other satellite navigation systems in use or various states of development include:

- Galileo – a global system being developed by the European Union and other partner countries, planned to be operational by 2014
- Beidou – People's Republic of China's regional system, covering Asia and the West Pacific
- COMPASS – People's Republic of China's global system, planned to be operational by 2020
- GLONASS – Russia's global navigation system
- IRNSS – India's regional navigation system, planned to be operational by 2012, covering India and Northern Indian Ocean
- QZSS – Japanese regional system covering Asia and Oceania

Chapter- 3

DNA Computing

DNA computing is a form of computing which uses DNA, biochemistry and molecular biology, instead of the traditional silicon-based computer technologies. DNA computing, or, more generally, biomolecular computing, is a fast developing interdisciplinary area. Research and development in this area concerns theory, experiments and applications of DNA computing.

History

This field was initially developed by Leonard Adleman of the University of Southern California, in 1994. Adleman demonstrated a proof-of-concept use of DNA as a form of computation which solved the seven-point Hamiltonian path problem. Since the initial Adleman experiments, advances have been made and various Turing machines have been proven to be constructible.

In 2002, researchers from the Weizmann Institute of Science in Rehovot, Israel, unveiled a programmable molecular computing machine composed of enzymes and DNA molecules instead of silicon microchips. On April 28, 2004, Ehud Shapiro, Yaakov Benenson, Binyamin Gil, Uri Ben-Dor, and Rivka Adar at the Weizmann Institute announced in the journal Nature that they had constructed a DNA computer coupled with an input and output module which would theoretically be capable of diagnosing cancerous activity within a cell, and releasing an anti-cancer drug upon diagnosis.

In 2009, biocomputing systems were coupled with standard silicon based chips for the first time. In this experiment, an enzyme based OR-Reset/AND-Reset logic system was achieved using field-effect Silicon chips. This advancement could yield great potential in the fields of Synthetic Biology, and Biomedical Engineering, as it marks the integration of biological and electro-mechanical systems on a sub-cellular level.

Capabilities

DNA computing is fundamentally similar to parallel computing in that it takes advantage of the many different molecules of DNA to try many different possibilities at once.

DNA computing also offers much lower power consumption than traditional silicon computers. DNA uses adenosine triphosphate (ATP) as fuel to allow ligation or as a means to heat the strand to cause disassociation. Both strand hybridization and the hydrolysis of the DNA backbone can occur spontaneously, powered by the potential energy stored in DNA. Consumption of two ATP molecules releases 1.5×10^{-19} J. Even with a large number of transitions per second using two ATP molecules, power output is still low. For instance, Kahan reports 109 transitions per second with an energy consumption of 10^{-10} W, and similarly Shapiro reports a system producing 7.5×10^{11} outputs in 4000 sec resulting in an energy consumption rate of ~ 10^{-10} W.

For certain specialized problems, DNA computers are faster and smaller than any other computer built so far. Furthermore, particular mathematical computations have been demonstrated to work on a DNA computer. As an example, Aran Nayebi has provided a general implementation of Strassen's matrix multiplication algorithm on a DNA computer, although there are problems with scaling.

But DNA computing does not provide any new capabilities from the standpoint of computability theory, the study of which problems are computationally solvable using different models of computation. For example, if the space required for the solution of a problem grows exponentially with the size of the problem (EXPSPACE problems) on von Neumann machines, it still grows exponentially with the size of the problem on DNA machines. For very large EXPSPACE problems, the amount of DNA required is too large to be practical. (Quantum computing, on the other hand, *does* provide some interesting new capabilities.)

DNA computing overlaps with, but is distinct from, DNA nanotechnology. The latter uses the specificity of Watson-Crick basepairing and other DNA properties to make novel structures out of DNA. These structures can be used for DNA computing, but they do not have to be. Additionally, DNA computing can be done without using the types of molecules made possible by DNA nanotechnology.

Methods

There are multiple methods for building a computing device based on DNA, each with its own advantages and disadvantages. Most of these build the basic logic gates (AND, OR, NOT) associated with digital logic from a DNA basis. Some of the different bases include DNAzymes, deoxyoligonucleotides, enzymes, DNA tiling, and polymerase chain reaction.

DNAzymes

Catalytic DNA (deoxyribozyme or DNAzyme) catalyze a reaction when interacting with the appropriate input, such as a matching oligonucleotide. These DNAzymes are used to build logic gates analogous to digital logic in silicon; however, DNAzymes are limited to 1-, 2-, and 3-input gates with no current implementation for evaluating statements in series.

The DNAzyme logic gate changes its structure when it binds to a matching oligonucleotide and the fluorogenic substrate it is bonded to is cleaved free. While other materials can be used, most models use a fluorescence-based substrate because it is very easy to detect, even at the single molecule limit. The amount of fluorescence can then be measured to tell whether or not a reaction took place. The DNAzyme that changes is then "used," and cannot initiate any more reactions. Because of this, these reactions take place in a device such as a continuous stirred-tank reactor, where old product is removed and new molecules added.

Two commonly used DNAzymes are named E6 and 8-17. These are popular because they allow cleaving of a substrate in any arbitrary location. Stojanovic and MacDonald have used the E6 DNAzymes to build the MAYA I and MAYA II machines, respectively; Stojanovic has also demonstrated logic gates using the 8-17 DNAzyme. While these DNAzymes have been demonstrated to be useful for constructing logic gates, they are limited by the need for a metal cofactor to function, such as Zn^{2+} or Mn^{2+}, and thus are not useful in vivo.

A design called a *stem loop*, consisting of a single strand of DNA which has a loop at an end, are a dynamic structure that opens and closes when a piece of DNA bonds to the loop part. This effect has been exploited to create several logic gates. These logic gates have been used to create the computers MAYA I and MAYA II which can play tic-tac-toe to some extent.

Enzymes

Enzyme based DNA computers are usually of the form of a simple Turing machine; there is analogous hardware, in the form of an enzyme, and software, in the form of DNA.

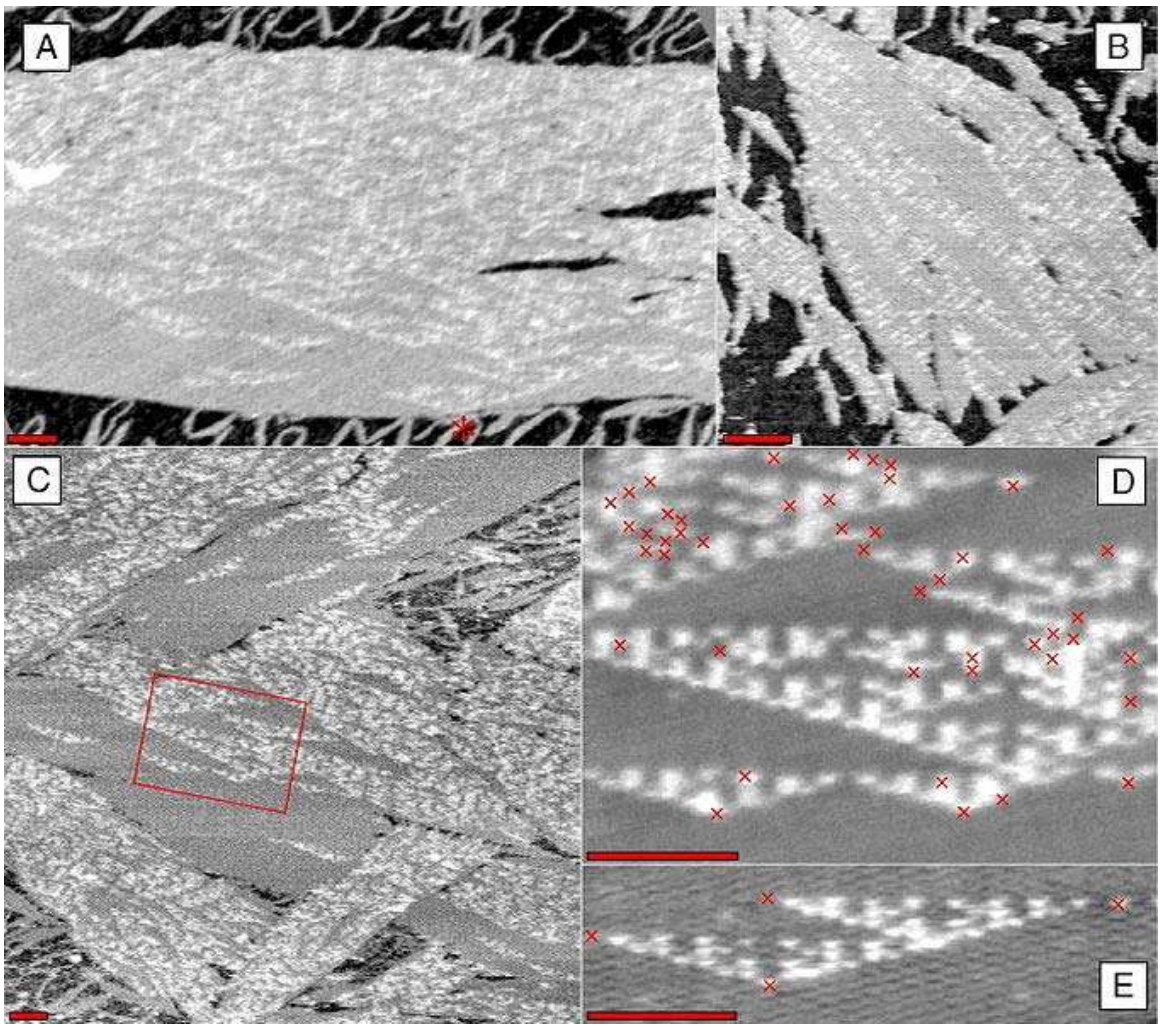
Shapiro has demonstrated a DNA computer using the FokI enzyme and expanded on his work by going on to show automata that diagnose and react to prostate cancer: under expression of the genes PPAP2B and GSTP1 and an over expression of PIM1 and HPN. His automata evaluated the expression of each gene, one gene at a time, and on positive diagnosis then released a single strand DNA molecule (ssDNA) that is an antisense for MDM2. MDM2 is a repressor of protein 53, which itself is a tumor suppressor. On negative diagnosis it was decided to release a suppressor of the positive diagnosis drug instead of doing nothing. A limitation of this implementation is that two separate automata are required, one to administer each drug. The entire process of evaluation until drug release took around an hour to complete. This method also requires transition molecules as well as the FokI enzyme to be present. The requirement for the FokI enzyme limits application *in vivo*, at least for use in "cells of higher organisms". It should also be pointed out that the 'software' molecules can be reused in this case.

Toehold exchange

DNA computers have also been constructed using the concept of toehold exchange. In this system, an input DNA strand binds to a sticky end, or toehold, on another DNA

molecule, which allows it to displace another strand segment from the molecule. This allows the creation of modular logic components such as AND, OR, and NOT gates and signal amplifiers, which can be linked into arbitrarily large computers. This class of DNA computers does not require enzymes or any chemical capability of the DNA.

Algorithmic self-assembly

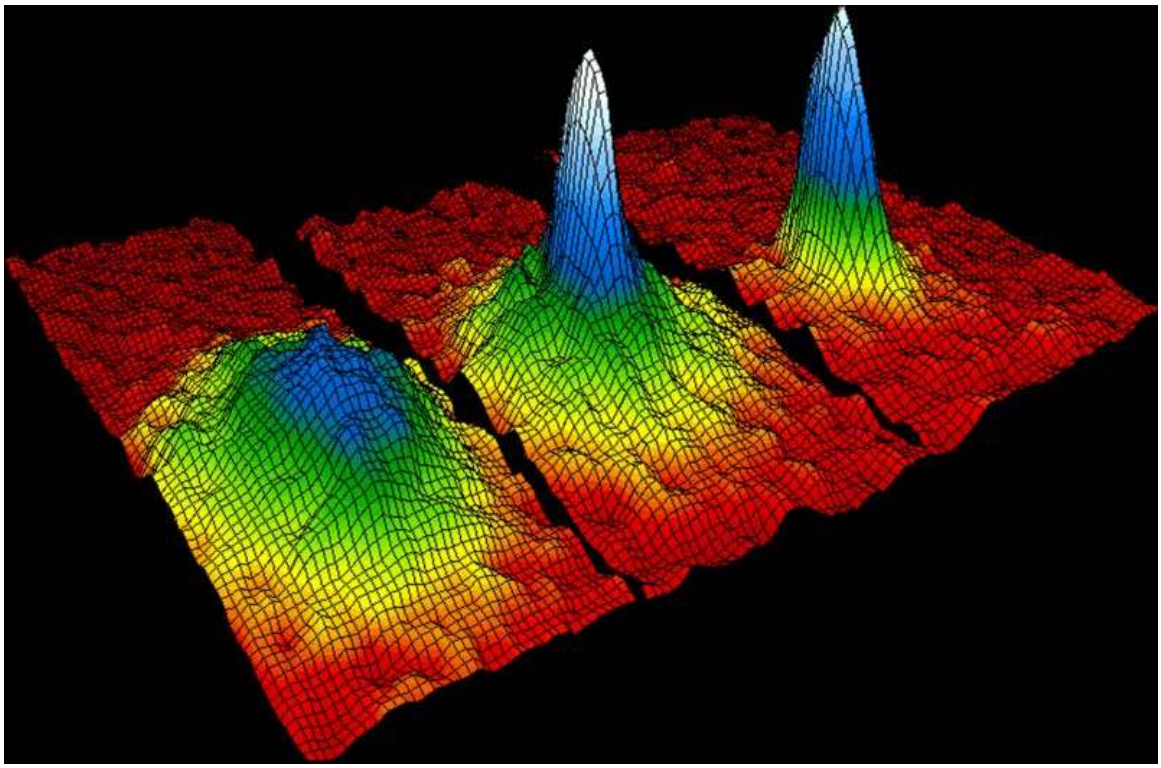


DNA arrays that display a representation of the Sierpinski gasket on their surfaces.

DNA nanotechnology has been applied to the related field of DNA computing. DNA tiles can be designed to contain multiple sticky ends with sequences chosen so that they act as Wang tiles. A DX array has been demonstrated whose assembly encodes an XOR operation; this allows the DNA array to implement a cellular automaton which generates a fractal called the Sierpinski gasket. This shows that computation can be incorporated into the assembly of DNA arrays, increasing its scope beyond simple periodic arrays.

Chapter- 4

Bose–Einstein Condensate



Velocity-distribution data of a gas of rubidium atoms, confirming the discovery of a new phase of matter, the Bose–Einstein condensate. Left: just before the appearance of a Bose–Einstein condensate. Center: just after the appearance of the condensate. Right: after further evaporation, leaving a sample of nearly pure condensate.

A **Bose–Einstein condensate (BEC)** is a state of matter of a dilute gas of weakly interacting bosons confined in an external potential and cooled to temperatures very near absolute zero (0 K or −273.15 °C). Under such conditions, a large fraction of the bosons occupy the lowest quantum state of the external potential, at which point quantum effects become apparent on a macroscopic scale.

This state of matter was first predicted by Satyendra Nath Bose and Albert Einstein in 1924–25. Bose first sent a paper to Einstein on the quantum statistics of light quanta (now

called photons). Einstein was impressed, translated the paper himself from English to German and submitted it for Bose to the *Zeitschrift für Physik* which published it. Einstein then extended Bose's ideas to material particles (or matter) in two other papers.

Seventy years later, the first gaseous condensate was produced by Eric Cornell and Carl Wieman in 1995 at the University of Colorado at Boulder NIST-JILA lab, using a gas of rubidium atoms cooled to 170 nanokelvin (nK) (1.7×10^{-7} K). For their achievements Cornell, Wieman, and Wolfgang Ketterle at MIT received the 2001 Nobel Prize in Physics. In November 2010 the first photon BEC was observed.

Theory

The slowing of atoms by the use of cooling apparatus produces a singular quantum state known as a **Bose condensate** or **Bose–Einstein condensate**. This phenomenon was predicted in 1925 by generalizing Satyendra Nath Bose's work on the statistical mechanics of (massless) photons to (massive) atoms. (The Einstein manuscript, once believed to be lost, was found in a library at Leiden University in 2005.) The result of the efforts of Bose and Einstein is the concept of a Bose gas, governed by Bose–Einstein statistics, which describes the statistical distribution of identical particles with integer spin, now known as bosons. Bosonic particles, which include the photon as well as atoms such as helium-4, are allowed to share quantum states with each other. Einstein demonstrated that cooling bosonic atoms to a very low temperature would cause them to fall (or "condense") into the lowest accessible quantum state, resulting in a new form of matter.

This transition occurs below a critical temperature, which for a uniform three-dimensional gas consisting of non-interacting particles with no apparent internal degrees of freedom is given by:

$$T_c = \left(\frac{n}{\zeta(3/2)}\right)^{2/3} \frac{2\pi\hbar^2}{mk_B} \approx 3.31 \ \frac{\hbar^2 n^{2/3}}{mk_B}$$

where:

- T_c is the critical temperature,
- n is the particle density,
- m is the mass per boson,
- $\hbar$ is the reduced Planck constant,
- k_B is the Boltzmann constant, and
- ζ is the Riemann zeta function; $\zeta(3/2) \approx 2.6124$. (sequence A078434 in OEIS)

Einstein's argument

Consider a collection of N noninteracting particles which can each be in one of two quantum states, $|0\rangle$ and $|1\rangle$. If the two states are equal in energy, each different configuration is equally likely.

If we can tell which particle is which, there are 2^N different configurations, since each particle can be in $|0\rangle$ or $|1\rangle$ independently. In almost all of the configurations, about half the particles are in $|0\rangle$ and the other half in $|1\rangle$. The balance is a statistical effect: the number of configurations is largest when the particles are divided equally.

If the particles are indistinguishable, however, there are only N+1 different configurations. If there are K particles in state $|1\rangle$, there are N-K particles in state $|0\rangle$. Whether any particular particle is in state $|0\rangle$ or in state $|1\rangle$ cannot be determined, so each value of K determines a unique quantum state for the whole system. If all these states are equally likely, there is no statistical spreading out; it is just as likely for all the particles to sit in $|0\rangle$ as for the particles to be split half and half.

Suppose now that the energy of state $|1\rangle$ is slightly greater than the energy of state $|0\rangle$ by an amount E. At temperature T, a particle will have a lesser probability to be in state $|1\rangle$ by exp(-E/T). In the distinguishable case, the particle distribution will be biased slightly towards state $|0\rangle$ and the distribution will be slightly different from half and half. But in the indistinguishable case, since there is no statistical pressure toward equal numbers, the most likely outcome is that most of the particles will collapse into state $|0\rangle$.

In the distinguishable case, for large N, the fraction in state $|0\rangle$ can be computed. It is the same as flipping a coin with probability p = exp(-E/T) to land tails. The probability to land heads is 1/(1+p), which is a smooth function of p, of the energy.

In the indistinguishable case, each value of K is a single state, which has its own separate Boltzmann probability. So the probability distribution is exponential:

$$P(K) = Ce^{-KE/T} = Cp^K.$$

For large N, the normalization constant C is (1-p). The expected total number of particles not in the lowest energy state, in the limit that $N \to \infty$, is equal to $\sum_{n>0} Cnp^n = p/(1-p)$. It does not grow when N is large, it just approaches a constant. This will be a negligible fraction of the total number of particles. So a collection of enough Bose particles in thermal equilibrium will mostly be in the ground state, with only a few in any excited state, no matter how small the energy difference.

Consider now a gas of particles, which can be in different momentum states labeled $|k\rangle$. If the number of particles is less than the number of thermally accessible states, for high temperatures and low densities, the particles will all be in different states. In this limit the gas is classical. As the density increases or the temperature decreases, the number of

accessible states per particle becomes smaller, and at some point more particles will be forced into a single state than the maximum allowed for that state by statistical weighting. From this point on, any extra particle added will go into the ground state.

To calculate the transition temperature at any density, integrate over all momentum states the expression for maximum number of excited particles p/(1-p):

$$N = V \int \frac{d^3k}{(2\pi)^3} \frac{p(k)}{1-p(k)} = V \int \frac{d^3k}{(2\pi)^3} \frac{1}{e^{\frac{k^2}{2mT}} - 1}$$
$$p(k) = e^{\frac{-k^2}{2mT}}.$$

When the integral is evaluated with the factors of k_B and $\hbar$ restored by dimensional analysis, it gives the critical temperature formula of the preceding section. Therefore, this integral defines the critical temperature and particle number corresponding to the conditions of negligible chemical potential. In Bose–Einstein statistics distribution, μ is actually still nonzero for BEC's; however, μ is less than the ground state energy. Except when specifically talking about the ground state, μ can consequently be approximated for most energy or momentum states as $\mu \approx 0$.

Gross–Pitaevskii equation

The state of the BEC can be described by the wavefunction of the condensate $\psi(\vec{r})$. For a system of this nature, $|\psi(\vec{r})|^2$ is interpreted as the particle density, so the total number of atoms is $N = \int d\vec{r} |\psi(\vec{r})|^2$

Provided essentially all atoms are in the condensate (that is, have condensed to the ground state), and treating the bosons using mean field theory, the energy (E) associated with the state $\psi(\vec{r})$ is:

$$E = \int d\vec{r} \left[\frac{\hbar^2}{2m} |\nabla \psi(\vec{r})|^2 + V(\vec{r}) |\psi(\vec{r})|^2 + \frac{1}{2} U_0 |\psi(\vec{r})|^4 \right]$$

Minimizing this energy with respect to infinitesimal variations in $\psi(\vec{r})$, and holding the number of atoms constant, yields the Gross-Pitaevski equation (GPE) (also a non-linear Schrödinger equation):

$$i\hbar \frac{\partial \psi(\vec{r})}{\partial t} = \left(-\frac{\hbar^2 \nabla^2}{2m} + V(\vec{r}) + U_0 |\psi(\vec{r})|^2 \right) \psi(\vec{r})$$

where:

m is the mass of the bosons,
$V(\vec{r})$ is the external potential,
U_0 is representative of the inter-particle interactions.

The GPE provides a good description of the behavior of BEC's and is thus often applied for theoretical analysis.

Discovery

In 1938, Pyotr Kapitsa, John Allen and Don Misener discovered that helium-4 became a new kind of fluid, now known as a superfluid, at temperatures less than 2.17 K (the lambda point). Superfluid helium has many unusual properties, including zero viscosity (the ability to flow without dissipating energy) and the existence of quantized vortices. It was quickly realized that the superfluidity was due to partial Bose–Einstein condensation of the liquid. In fact, many of the properties of superfluid helium also appear in the gaseous Bose–Einstein condensates created by Cornell, Wieman and Ketterle. Superfluid helium-4 is a liquid rather than a gas, which means that the interactions between the atoms are relatively strong; the original theory of Bose–Einstein condensation must be heavily modified in order to describe it. Bose–Einstein condensation remains, however, fundamental to the superfluid properties of helium-4. Note that helium-3, consisting of fermions instead of bosons, also enters a superfluid phase at low temperature, which can be explained by the formation of bosonic Cooper pairs of two atoms each.

The first "pure" Bose–Einstein condensate was created by Eric Cornell, Carl Wieman, and co-workers at JILA on June 5, 1995. They did this by cooling a dilute vapor consisting of approximately two thousand rubidium-87 atoms to below 170 nK using a combination of laser cooling (a technique that won its inventors Steven Chu, Claude Cohen-Tannoudji, and William D. Phillips the 1997 Nobel Prize in Physics) and magnetic evaporative cooling. About four months later, an independent effort led by Wolfgang Ketterle at MIT created a condensate made of sodium-23. Ketterle's condensate had about a hundred times more atoms, allowing him to obtain several important results such as the observation of quantum mechanical interference between two different condensates. Cornell, Wieman and Ketterle won the 2001 Nobel Prize in Physics for their achievements. A group led by Randall Hulet at Rice University announced the creation of a condensate of lithium atoms only one month following the JILA work. Lithium has attractive interactions which causes the condensate to be unstable and to collapse for all but a few atoms. Hulet and co-workers showed in a subsequent experiment that the condensate could be stabilized by the quantum pressure from trap confinement for up to about 1000 atoms.

The Bose–Einstein condensation also applies to quasiparticles in solids. A magnon in an antiferromagnet carries spin 1 and thus obeys Bose–Einstein statistics. The density of magnons is controlled by an external magnetic field, which plays the role of the magnon chemical potential. This technique provides access to a wide range of boson densities from the limit of a dilute Bose gas to that of a strongly interacting Bose liquid. A magnetic ordering observed at the point of condensation is the analog of superfluidity. In

1999 Bose condensation of magnons was demonstrated in the antiferromagnet $TlCuCl_3$. The condensation was observed at temperatures as large as 14 K. Such a high transition temperature (relative to that of atomic gases) is due to the greater density achievable with magnons and the smaller mass (roughly equal to the mass of an electron). In 2006, condensation of magnons in ferromagnets was even shown at room temperature, where the authors used pumping techniques.

Velocity-distribution data graph

The velocity-distribution data indicates the formation of a Bose–Einstein condensate out of a gas of rubidium atoms. The false colors indicate the number of atoms at each velocity, with red being the fewest and white being the most. The areas appearing white and light blue are at the lowest velocities. The peak is not infinitely narrow because of the Heisenberg uncertainty principle: since the atoms are trapped in a particular region of space, their velocity distribution necessarily possesses a certain minimum width. This width is given by the curvature of the magnetic trapping potential in the given direction. More tightly confined directions have bigger widths in the ballistic velocity distribution. This anisotropy of the peak on the right is a purely quantum-mechanical effect and does not exist in the thermal distribution on the left. This famous graph served as the cover-design for 1999 textbook *Thermal Physics* by Ralph Baierlein.

Vortices

As in many other systems, vortices can exist in BECs. These can be created, for example, by 'stirring' the condensate with lasers, or rotating the confining trap. The vortex created will be a quantum vortex. These phenomena are allowed for by the non-linear $|\psi(\vec{r})|^2$ term in the GPE. As the vortices must have quantized angular momentum the wavefunction may have the form $\psi(\vec{r}) = \phi(\rho, z)e^{i\ell\theta}$ where ρ,*z* and θ are as in the cylindrical coordinate system, and ℓ is the angular number. This is particularly likely for an axially symmetric (for instance, harmonic) confining potential, which is commonly used. The notion is easily generalized. To determine φ(ρ,*z*), the energy of $\psi(\vec{r})$ must be minimized, according to the constraint $\psi(\vec{r}) = \phi(\rho, z)e^{i\ell\theta}$. This is usually done computationally, however in a uniform medium the analytic form

$$\phi = \frac{nx}{\sqrt{2 + x^2}}$$

where:

n^2 is density far from the vortex,

$x = \frac{\rho}{\ell\xi}$,

ξ is healing length of the condensate.

demonstrates the correct behavior, and is a good approximation.

A singly charged vortex ($\ell = 1$) is in the ground state, with its energy ε_v given by

$$\epsilon_v = \pi n \frac{\hbar^2}{m} \ln\left(1.464 \frac{b}{\xi}\right)$$

where:

b is the farthest distance from the vortex considered.

(To obtain an energy which is well defined it is necessary to include this boundary *b*.)

For multiply charged vortices ($\ell > 1$) the energy is approximated by

$$\epsilon_v \approx \ell^2 \pi n \frac{\hbar^2}{m} \ln\left(\frac{b}{\xi}\right)$$

which is greater than that of ℓ singly charged vortices, indicating that these multiply charged vortices are unstable to decay. Research has, however, indicated they are metastable states, so may have relatively long lifetimes.

Closely related to the creation of vortices in BECs is the generation of so-called dark solitons in one-dimensional BECs. These topological objects feature a phase gradient across their nodal plane, which stabilizes their shape even in propagation and interaction. Although solitons carry no charge and are thus prone to decay, relatively long-lived dark solitons have been produced and studied extensively.

Attractive interactions

The experiments lead by Randall Hulet at Rice University from 1995 through 2000 showed that lithium condensates with attractive interactions could stably exist, but only up to a certain critical atom number. Beyond this critical number, the attraction overwhelmed the zero-point energy of the harmonic confining potential, causing the condensate to collapse in a burst reminiscent of a supernova explosion where an explosion is preceded by an implosion. By quench cooling the gas of lithium atoms, they observed the condensate to first grow, and subsequently collapse when the critical number was exceeded.

Further experimentation on attractive condensates was performed by the JILA team in 2000. Cornell, Wieman, and their coworkers originally used rubidium-87, an isotope whose atoms naturally repel each other, making a more stable condensate. The JILA team instrumentation now had better control over the condensate so experimentation was made on naturally *attracting* atoms of another rubidium isotope, rubidium-85 (having negative

atom-atom scattering length). Through a process called Feshbach resonance involving a sweep of the magnetic field causing spin flip collisions, the JILA researchers lowered the characteristic, discrete energies at which the rubidium atoms bond into molecules, making their Rb-85 atoms repulsive and creating a stable condensate. The reversible flip from attraction to repulsion stems from quantum interference among condensate atoms which behave as waves.

When the scientists raised the magnetic field strength still further, the condensate suddenly reverted back to attraction, imploded and shrank beyond detection, and then exploded, expelling off about two-thirds of its 10,000 or so atoms. About half of the atoms in the condensate seemed to have disappeared from the experiment altogether, not being seen either in the cold remnant or the expanding gas cloud. Carl Wieman explained that under current atomic theory this characteristic of Bose–Einstein condensate could not be explained because the energy state of an atom near absolute zero should not be enough to cause an implosion; however, subsequent mean field theories have been proposed to explain it. The atoms that seem to have disappeared almost certainly still exist in some form, just not in a form that could be accounted for in that experiment. Most likely they formed molecules consisting of two bonded rubidium atoms. The energy gained by making this transition imparts a velocity sufficient for them to leave the trap without being detected.

Current research

Compared to more commonly encountered states of matter, Bose–Einstein condensates are extremely fragile. The slightest interaction with the outside world can be enough to warm them past the condensation threshold, eliminating their interesting properties and forming a normal gas. It is likely to be some time before any practical applications are developed.

Nevertheless, they have proven useful in exploring a wide range of questions in fundamental physics, and the years since the initial discoveries by the JILA and MIT groups have seen an explosion in experimental and theoretical activity. Examples include experiments that have demonstrated interference between condensates due to wave-particle duality, the study of superfluidity and quantized vortices, the creation of bright matter wave solitons from Bose condensates confined to one dimension, and the slowing of light pulses to very low speeds using electromagnetically induced transparency. Vortices in Bose–Einstein condensates are also currently the subject of analogue gravity research, studying the possibility of modeling black holes and their related phenomena in such environments in the lab. Experimentalists have also realized "optical lattices", where the interference pattern from overlapping lasers provides a periodic potential for the condensate. These have been used to explore the transition between a superfluid and a Mott insulator, and may be useful in studying Bose–Einstein condensation in fewer than three dimensions, for example the Tonks-Girardeau gas.

Bose–Einstein condensates composed of a wide range of isotopes have been produced.

Related experiments in cooling fermions rather than bosons to extremely low temperatures have created degenerate gases, where the atoms do not congregate in a single state due to the Pauli exclusion principle. To exhibit Bose–Einstein condensation, the fermions must "pair up" to form compound particles (e.g. molecules or Cooper pairs) that are bosons. The first molecular Bose–Einstein condensates were created in November 2003 by the groups of Rudolf Grimm at the University of Innsbruck, Deborah S. Jin at the University of Colorado at Boulder and Wolfgang Ketterle at MIT. Jin quickly went on to create the first fermionic condensate composed of Cooper pairs.

In 1999, Danish physicist Lene Vestergaard Hau led a team from Harvard University which succeeded in slowing a beam of light to about 17 metres per second. She was able to achieve this by using a superfluid. Hau and her associates at Harvard University have since successfully made a group of condensate atoms recoil from a "light pulse" such that they recorded the light's phase and amplitude, which was recovered by a second nearby condensate, by what they term "slow-light-mediated atomic matter-wave amplification" using Bose–Einstein condensates: details of the experiment are discussed in an article in the journal *Nature*, 8 February 2007.

Isotopes

The effect has mainly been observed on alkaline atoms which have nuclear properties particularly suitable for working with traps. As of 2010, using ultra-low temperatures of 10^{-7} K or below, Bose–Einstein condensates had been obtained for a multitude of isotopes, mainly of alkaline and alkaline earth atoms (^{7}Li, ^{23}Na, ^{39}K, ^{41}K, ^{85}Rb, ^{87}Rb, ^{133}Cs, ^{52}Cr, ^{40}Ca, ^{84}Sr, ^{86}Sr, ^{88}Sr, and ^{174}Yb). Condensation research was finally successful even with hydrogen with the aid of special methods. In contrast, the superfluid state of the bosonic ^{4}He at temperatures below 2.17 K is not a good example of Bose–Einstein condensation, because the interaction between the ^{4}He bosons is too strong. Only 8% of the atoms are in the single-particle ground state near zero temperature, rather than the 100% expected of a true Bose–Einstein condensate.

The spin-statistics theorem of Wolfgang Pauli states that half-integer spins (in units of $\hbar$) lead to fermionic behaviour, e.g., the Pauli exclusion principle forbidding that more than two electrons possess the same energy, whereas integer spins lead to bosonic behaviour, e.g., condensation of identical bosonic particles in a common ground state.

The bosonic, rather than fermionic, behaviour of some of these alkaline gases appears odd at first sight since their nuclei have half-integer total spin. The bosonic behaviour arises from a subtle interplay of electronic and nuclear spins: at ultra-low temperatures and corresponding excitation energies, the half-integer total spin of the electronic shell and the half-integer total spin of the nucleus of the atom are coupled by a very weak hyperfine interaction. The total spin of the atom arising from this coupling is an integer value leading to the bosonic ultra-low temperature behaviour of the atom. The chemistry of the systems at room temperature is determined by the electronic properties, which is essentially fermionic, since at room temperature thermal excitations have typical energies much higher than the hyperfine values.

Chapter- 5

Nanoimprint Lithography

Nanoimprint lithography is a method of fabricating nanometer scale patterns. It is a simple nanolithography process with low cost, high throughput and high resolution. It creates patterns by mechanical deformation of imprint resist and subsequent processes. The imprint resist is typically a monomer or polymer formulation that is cured by heat or UV light during the imprinting. Adhesion between the resist and the template is controlled to allow proper release.

History

Nanoimprint lithography was first invented by Princeton University professor Stephen Chou and his students. Soon after its invention, many researchers developed many different variations and implementations. At this point, nanoimprint lithography has been added to the International Technology Roadmap for Semiconductors (ITRS) for the 32 and 22 nm nodes.

Processes

There are many different types of nanoimprint lithography, but two of them are most important: thermoplastic nanoimprint lithography and photo nanoimprint lithography.

Thermoplastic nanoimprint lithography

Thermoplastic nanoimprint lithography (T-NIL) is the earliest nanoimprint lithography developed by Prof. Stephen Chou's group. In a standard T-NIL process, a thin layer of imprint resist (thermoplastic polymer) is spin coated onto the sample substrate. Then the mold, which has predefined topological patterns, is brought into contact with the sample and they are pressed together under certain pressure. When heated up above the glass transition temperature of the polymer, the pattern on the mold is pressed into the softened polymer film . After being cooled down, the mold is separated from the sample and the pattern resist is left on the substrate. A pattern transfer process (reactive ion etching, normally) can be used to transfer the pattern in the resist to the underneath substrate.

Photo nanoimprint lithography

In photo nanoimprint lithography (P-NIL), a photo(UV) curable liquid resist is applied to the sample substrate and the mold is normally made of transparent material like fused silica. After the mold and the substrate are pressed together, the resist is cured in UV light and becomes solid. After mold separation, a similar pattern transfer process can be used to transfer the pattern in resist onto the underneath material. The use of a UV-transparent mold is difficult in a vacuum, because a vacuum chuck to hold the mold would not be possible.

Schemes

Full wafer nanoimprint

In a full wafer nanoimprint scheme, all the patterns are contained in a single nanoimprint field and will be transferred in a single imprint step. This allows a high throughput and uniformity. An at least 8-inch (203 mm) diameter full-wafer nanoimprint with high fidelity is possible.

To ensure the pressure and pattern uniformities of full wafer nanoimprint processes and prolong the mold lifetime, a pressing method utilizing isotropic fluid pressure, named Air Cushion Press (ACP) by its inventors, is developed and being used by commercial nanoimprint systems.

Step and repeat nanoimprint

Nanoimprint can be performed in a way similar to the step and repeat optical lithography. The imprint field (die) is typically much smaller than the full wafer nanoimprint field. The die is repeatedly imprinted to the substrate with certain step size. This scheme is good for nanoimprint mold creation. It is currently limited by the throughput, alignment and street width issues.

Applications

Nanoimprint lithography has been used to fabricate devices for electrical, optical, photonic and biological applications. For electronics devices, NIL has been used to fabricate MOSFET, O-TFT, single electron memory. For optics and photonics, intensive study has been conducted in fabrication of subwavelength resonant grating filter, polarizers, waveplate, anti-reflective structures, integrated photonics circuit and plasmontic devices by NIL. sub-10 nm nanofluidic channels had been fabricated using NIL and used in DNA strenching experiment. Currently, NIL is used to shrink the size of biomolecular sorting device an order of magnitude smaller and more efficient.

Benefits

A key benefit of nanoimprint lithography is its sheer simplicity. The single greatest cost associated with chip fabrication is the optical lithography tool used to print the circuit

patterns. Optical lithography requires high powered excimer lasers and immense stacks of precision ground lens elements to achieve nanometer scale resolution. There is no need for complex optics or high-energy radiation sources with a nanoimprint tool. There is no need for finely tailored photoresists designed for both resolution and sensitivity at a given wavelength. The simplified requirements of the technology lead to its low cost.

Imprint lithography is inherently a three-dimensional patterning process. Imprint molds can be fabricated with multiple layers of topography stacked vertically. Resulting imprints replicate both layers with a single imprint step, which allows chip manufactures to reduce chip fabrication costs and improve product throughput. As mentioned above, the imprint material does not need to be finely tuned for high resolution and sensitivity. A broader range of materials with varying properties are available for use with imprint lithography. The increased material variability gives chemists the freedom to design new functional materials rather than sacrificial etch resistant polymers. A functional material may be imprinted directly to form a layer in a chip with no need for pattern transfer into underlying materials. The successful implementation of a functional imprint material would result in significant cost reductions and increased throughput by eliminating many difficult chip fabrication processing steps.

Concerns

The key concerns for nanoimprint lithography are overlay, defects, template patterning and template wear. However, recently Kumar et al. have shown that amorphous metals (metallic glasses) can be patterned on sub-100 nm scale, which can significantly reduce the template cost.

Overlay

The current overlay 3 sigma capability is 10 nm. Overlay has a better chance with step-and-scan approaches as opposed to full-wafer imprint.

Defects

As with immersion lithography, defect control is expected to improve as the technology matures. Defects from the template with size below the post-imprint process bias can be eliminated. Other defects would require effective template cleaning and/or the use of intermediate polymer stamps. When vacuum is not used during the imprint process, air can get trapped, resulting in bubble defects. This is because the imprint resist layer and the template or stamp features are not perfectly flat. There is an elevated risk when the intermediate or master stamp contains depressions (which are especially easy air traps), or when the imprint resist is dispensed as droplets just before imprinting, rather than pre-spun onto the substrate. Sufficient time must be allowed for the air to escape.

Template patterning

High resolution template patterning can currently be performed by electron beam lithography or focused ion beam patterning; however at the smallest resolution, the throughput is very slow. As a result, optical patterning tools will be more helpful if they have sufficient resolution. Such an approach has been successfully demonstrated by Greener et al. whereby robust templates were rapidly fabricated by optical patterning of a photoresist-coated metal substrate through a photomask. Other patterning techniques (including even double patterning) may also be used. Kumar and Schroers at Yale developed the nanopatterning of amorphous metals which can be used as inexpensive templates for nanoimprinting.

Template wear

The use of substantial pressure to not only contact but also penetrate a layer during imprinting accelerates the wear of imprint templates compared to other types of lithographic masks.

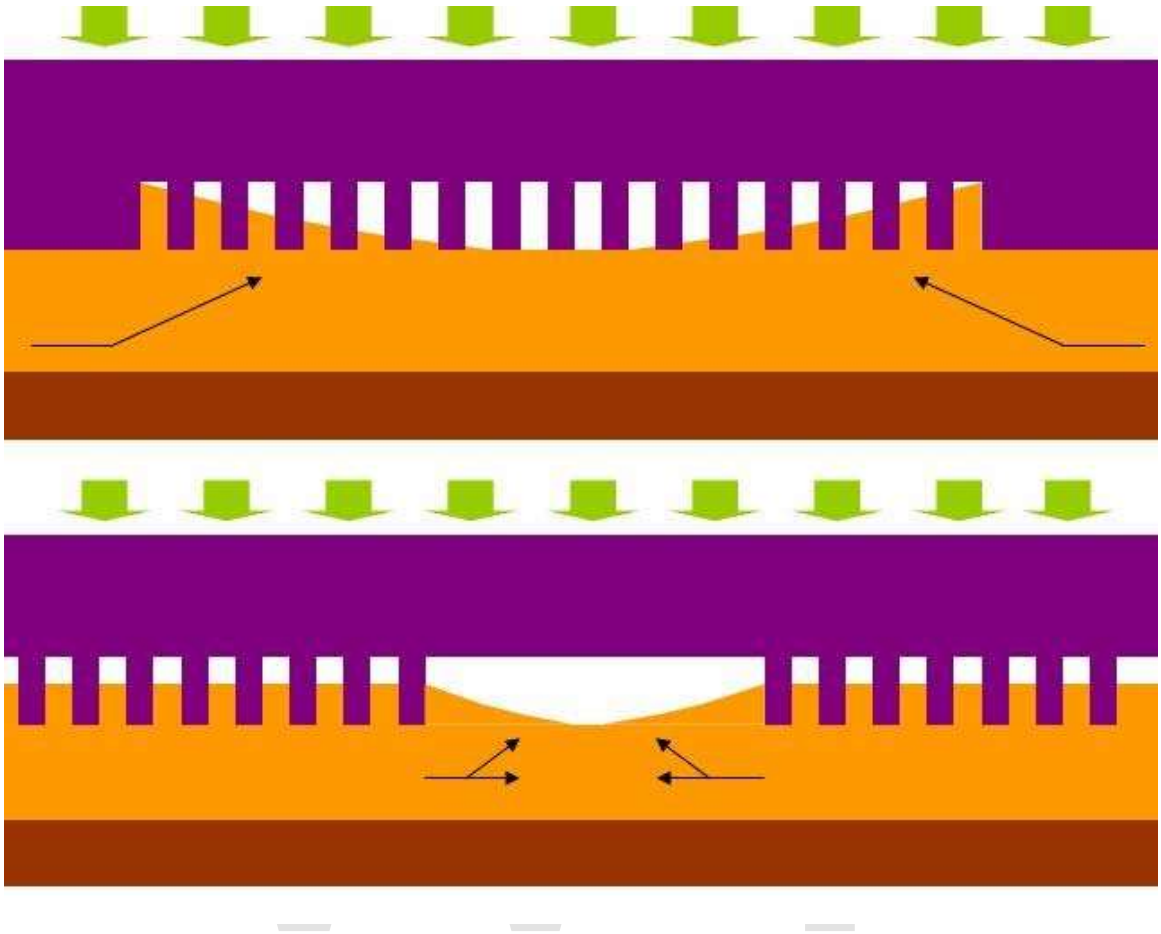
Other

Future applications of nanoimprint lithography may involve the use of porous low-k materials. These materials are not stiff and, as part of the substrate, are readily damaged mechanically by the pressure of the imprint process.

Removal of residual layers

A key characteristic of nanoimprint lithography (except for electrochemical nanoimprinting) is the residual layer following the imprint process. It is preferable to have thick enough residual layers to support alignment and throughput and low defects. However, this renders the nanoimprint lithography step less critical for critical dimension (CD) control than the etch step used to remove the residual layer. Hence, it is important to consider the residual layer removal an integrated part of the overall nanoimprint patterning process. In a sense, the residual layer etch is similar to the develop process in conventional lithography. It has been proposed to combine photolithography and nanoimprint lithography techniques in one step in order to eliminate the residual layer.

Proximity effects



Nanoimprint proximity effect. *Top:* Array of depressions is more quickly filled at the edge than the center, resulting in less imprinting at the center of the array. *Bottom:* The wide space between two groups of protrusions tends to be filled slower than the narrow spaces between the protrusions, resulting in the formation of holes in the unpatterned area.

Nanoimprint lithography relies on displacing polymer. This could lead to systematic effects over long distances. For example, a large, dense array of protrusions will displace significantly more polymer than an isolated protrusion. Depending on the distance of this isolated protrusion from the array, the isolated feature may not imprint correctly due to polymer displacement and thickening. Resist holes can form in between groups of protrusions. Likewise, wider depressions in the template do not fill up with as much polymer as narrower depressions, resulting in misshapen wide lines. In addition, a depression at the edge of a large array fills up much earlier than one located in the center of the array, resulting in within-array uniformity issues.

3D-patterning

A unique benefit of nanoimprint lithography is the ability to pattern 3D structures, such as damascene interconnects and T-gates, in fewer steps than required for conventional lithography. This is achieved by building the T-shape into the protrusion on the template.

Alternative approaches

Electrochemical nanoimprinting

Electrochemical nanoimprinting can be achieved using a stamp made from a superionic conductor such as silver sulfide . When the stamp is contacted with metal, electrochemical etching can be carried out with an applied voltage. The electrochemical reaction generates metal ions which move from the original film into the stamp. Eventually all the metal is removed and the complementary stamp pattern is transferred to the remaining metal.

Laser assisted direct imprint

Laser assisted direct imprint (LADI) is a rapid technique for patterning nanostructures in solid substrates and it does not require etching. A single or multiple excimer laser pulses melt a thin surface layer of substrate material, and a mold is embossed into the resulting liquid layer. A variety of structures with resolution better than 10 nm have been imprinted into silicon using LADI, and the embossing time is less than 250 ns. The high resolution and speed of LADI, attributed to molten silicon's low viscosity (one-third that of water), could open up a variety of applications and be extended to other materials and processing techniques.

The future of nanoimprint

Nanoimprint lithography is a simple pattern transfer process that is neither limited by diffraction nor scattering effects nor secondary electrons, and does not require any sophisticated radiation chemistry. It is also a potentially simple and inexpensive technique. However, a lingering barrier to nanometer-scale patterning is the current reliance on other lithography techniques to generate the template. It is possible that self-assembled structures will provide the ultimate solution for templates of periodic patterns at scales of 10 nm and less. It is also possible to resolve the template generation issue by using a programmable template in a scheme based on double patterning.

As of October 2007, Toshiba is the only company to have validated nanoimprint lithography for 22 nm and beyond. What is more significant is that nanoimprint lithography is the first sub-30 nm lithography to be validated by an industrial user.

Chapter- 6

Adobe Flash

Adobe Flash (formerly **Macromedia Flash**) is a multimedia platform used to add animation, video, and interactivity to web pages. Flash is frequently used for advertisements and games. More recently, it has been positioned as a tool for "Rich Internet Applications" ("RIAs").

Flash manipulates vector and raster graphics to provide animation of text, drawings, and still images. It supports bidirectional streaming of audio and video, and it can capture user input via mouse, keyboard, microphone, and camera. Flash contains an Object-oriented language called ActionScript.

Flash content may be displayed on various computer systems and devices, using Adobe Flash Player, which is available free of charge for common web browsers, some mobile phones and a few other electronic devices (using Flash Lite).

Some users feel that Flash enriches their web experience, while others find the extensive use of Flash animation, particularly in advertising, intrusive and annoying, giving rise to a cottage industry that specializes in blocking Flash content. Flash has also been criticized for adversely affecting the usability of web pages.

History

Originally developed by Macromedia, Flash was introduced in 1996, and is currently developed and distributed by Adobe Systems. The precursor to the Flash application was SmartSketch, a drawing application for pen computers running the PenPoint OS developed by Jonathan Gay, who began working on it in college and extended the idea for Silicon Beach Software and its successors. When PenPoint failed in the marketplace, SmartSketch was ported to Microsoft Windows and Mac OS. With the Internet becoming more popular, SmartSketch was re-released as FutureSplash, a vector-based web animation in competition with Macromedia Shockwave. In 1995, SmartSketch was further modified with frame-by-frame animation features and re-released as FutureSplash Animator on multiple platforms. The product was offered to Adobe and used by Microsoft in its early work with the Internet (MSN). In 1996, FutureSplash was acquired by Macromedia and released as **Flash,** contracting "Future" and "Splash".

Recent developments

Adobe Labs (previously called *Macromedia Labs*) is a source for news and pre-release versions of emerging products and technologies from Adobe. Most innovations, such as Flash 10, Flex 3, and ActionScript 3.0 have all been discussed and/or trialled on the site.

One area Adobe is focusing on (as of February 2009) is the deployment of Rich Internet Applications (RIAs). To this end, they released Adobe Integrated Runtime (AIR), a cross-platform runtime environment which can be used to build, using Adobe Flash, rich Internet applications that can be deployed as desktop applications. It surpassed 100 million installations worldwide in February 2009. Flash is installed silently when Acrobat Reader is installed.

Two additional components designed for large-scale implementation have been proposed by Adobe for future releases of Flash: first, the option to require an ad to be played in full before the main video piece is played; and second, the integration of digital rights management (DRM) capabilities. This way Adobe can give companies the option to link an advertisement with content and make sure that both are played and remain unchanged.

Flash Player for smart phones is available to handset manufacturers at the end of 2009.

Open Screen Project

On May 1, 2008 Adobe announced *Open Screen Project*, which hopes to provide a consistent application interface across devices such as personal computers, mobile devices and consumer electronics. When the project was announced, several goals were outlined: the abolition of licensing fees for Adobe Flash Player and Adobe Integrated Runtime, the removal of restrictions on the use of the Shockwave Flash (SWF) and Flash Video (FLV) file format, the publishing of application programming interfaces for porting Flash to new devices and the publishing of The Flash Cast protocol and Action Message Format (AMF), which let Flash applications receive information from remote databases.

As of February 2009, the specifications removing the restrictions on the use of SWF and FLV/F4V specs have been published. The Flash Cast protocol—now known as the Mobile Content Delivery Protocol—and AMF protocols have also been made available, with AMF available as an open source implementation, BlazeDS. Work on the device porting layers is in the early stages. Adobe intends to remove the licensing fees for Flash Player and Adobe AIR for devices at their release for the Open Screen Project.

The list of mobile device providers who have joined the project includes Palm, Motorola and Nokia, who, together with Adobe, have announced a $10 million Open Screen Project fund.

Format

Flash files are in the *SWF* format, traditionally called "**S**hock**W**ave **F**lash" movies, "Flash movies," or "Flash applications", usually have a .swf file extension, and may be used in the form of a web page plug-in, strictly "played" in a standalone Flash Player, or incorporated into a self-executing Projector movie (with the .exe extension in Microsoft Windows). Flash Video files have a .flv file extension and are either used from within .swf files or played through a flv-aware player, such as VLC, or QuickTime and Windows Media Player with external codecs added.

The use of vector graphics combined with program code allows Flash files to be smaller — and thus for streams to use less bandwidth — than the corresponding bitmaps or video clips. For content in a single format (such as just text, video, or audio), other alternatives may provide better performance and consume less CPU power than the corresponding Flash movie, for example when using transparency or making large screen updates such as photographic or text fades.

In addition to a vector-rendering engine, the Flash Player includes a virtual machine called the ActionScript Virtual Machine (AVM) for scripting interactivity at run-time, support for video, MP3-based audio, and bitmap graphics. As of Flash Player 8, it offers two video codecs: On2 Technologies VP6 and Sorenson Spark, and run-time support for JPEG, Progressive JPEG, PNG, and GIF. In the next version, Flash is slated to use a just-in-time compiler for the ActionScript engine.

Flash Player is a browser plugin, and cannot run within a usual e-mail client, such as Outlook. Instead, a link must open a browser window. A Gmail labs feature allows playback of YouTube videos linked in emails.

Flash Video

Virtually all browser plugins for video are free of charge and cross-platform, including Adobe's offering of Flash Video, which was first introduced with Flash version 6. Flash Video has been a popular choice for websites due to the large installed user base and programmability of Flash. In 2010, Apple publicly criticized Adobe Flash, including its implementation of video playback for not taking advantage of hardware acceleration, one reason Flash is not to be found on Apple's mobile devices. Soon after Apple's criticism, Adobe demoed and released a beta version of Flash 10.1, which takes advantage of GPU hardware acceleration even on a Mac. Flash 10.2 beta, released December 2010, finally adds multicore CPU hardware acceleration for h.264, three years after most other decoders.

Flash Audio

Flash Audio is most commonly encoded in MP3 or AAC (Advanced Audio Coding) however it does also support ADPCM, Nellymoser (Nellymoser Asao Codec) and Speex

audio codecs. Flash allows sample rates of 11, 22 and 44.1 kHz. It does not support 48 kHz audio sample rate which is the standard TV, DVD sample rate.

On August 20, 2007, Adobe announced on its blog that with Update 3 of Flash Player 9, Flash Video will also support some parts of the MPEG-4 international standards. Specifically, Flash Player will have support for video compressed in H.264 (MPEG-4 Part 10), audio compressed using AAC (MPEG-4 Part 3), the F4V, MP4 (MPEG-4 Part 14), M4V, M4A, 3GP and MOV multimedia container formats, 3GPP Timed Text specification (MPEG-4 Part 17) which is a standardized subtitle format and partial parsing support for the 'ilst' atom which is the ID3 equivalent iTunes uses to store metadata. MPEG-4 Part 2 and H.263 will not be supported in F4V file format. Adobe also announced that they will be gradually moving away from the FLV format to the standard ISO base media file format (MPEG-4 Part 12) owing to functional limits with the FLV structure when streaming H.264. The final release of the Flash Player supporting some parts of MPEG-4 standards had become available in Fall 2007.

Adobe Flash Player 10.1 does not support acoustic echo cancellation, unlike the VoIP offerings of Skype and Google Voice. This makes Flash less suitable for group calling or meetings, as use of headphones for all participants is essential, or at least highly advised.

Proprietary restrictions

The proprietary nature of Flash has been a concern to advocates of open standards and free software. Its widespread use has, according to such observers, harmed the otherwise open nature of the World Wide Web. A response may be seen in Adobe's Open Screen Project: Adobe's restrictions on the use of the SWF/FLV specifications have been lifted.

Representing open standards, inventor of CSS and co-author of HTML5, Håkon Wium Lie explained in a Google tech talk entitled "the <video> element" the proposal of Theora as the format for HTML5 video:

I believe very strongly, that we need to agree on some kind of baseline video format if [the video element] is going to succeed. Flash is today the baseline format on the web. The problem with Flash is that it's not an open standard.

Disclosure

In October 1998, Macromedia disclosed the Flash Version 3 Specification to the world on its website. It did this in response to many new and often semi-open formats competing with SWF, such as Xara's Flare and Sharp's Extended Vector Animation formats. Several developers quickly created a C library for producing SWF. In February 1999, the company introduced MorphInk 99, the first third-party program to create SWF files. Macromedia also hired Middlesoft to create a freely available developers' kit for the SWF file format versions 3 to 5.

Macromedia made the Flash Files specifications for versions 6 and later available only under a non-disclosure agreement, but they are widely available from various sites.

In April 2006, the Flash SWF file format specification was released with details on the then newest version format (Flash 8). Although still lacking specific information on the incorporated video compression formats (On2, Sorenson Spark, etc.), this new documentation covered all the new features offered in Flash v8 including new ActionScript commands, expressive filter controls, and so on. The file format specification document is offered only to developers who agree to a license agreement that permits them to use the specifications only to develop programs that can export to the Flash file format. The license forbids the use of the specifications to create programs that can be used for playback of Flash files. The Flash 9 specification was made available under similar restrictions.

In June 2009, Adobe launched the Open Screen Project (Adobe link), which made the SWF specification available without restrictions. Previously, developers could not use the specification for making SWF-compatible players, but only for making SWF-exporting authoring software. The specification still omits information on codecs such as Sorenson Spark, however.

Authoring tools

Adobe Flash Professional

Adobe Flash Professional

Adobe Flash CS5 Professional (11.0.2.489)

Developer(s)	Adobe Systems (formerly by Macromedia)
Stable release	CS5 (11.0.2) (December 7, 2010; 57 days ago) [+/−]

Written in	C++
Operating system	Microsoft Windows and Mac OS X
Type	Multimedia
License	Proprietary commercial software

The Adobe Flash Professional multimedia authoring program is used to create content for the Adobe Engagement Platform, such as web applications, games and movies, and content for mobile phones and other embedded devices.

History

Adobe Flash Professional is the successor of a software product known as **FutureSplash Animator**, a vector graphics and vector animations program released in May 1996. FutureSplash Animator was developed by FutureWave Software, a small software company whose first product, SmartSketch, was a vector-based drawing program for pen-based computers. In 1995, the company decided to add animation capabilities to their product and to create a vector-based animation platform for World Wide Web; hence FutureSplash Animator was created. Initially, the only way to deploy such animations on the web was through the use of Java platform; however, the Java platform was later replaced with the Netscape's plug-in architecture. The FutureSplash animation technology was used on several notable websites such as MSN, the official *The Simpsons* website and *Disney Daily Blast* of The Walt Disney Company.

In December 1996, Macromedia bought FutureWave and so re-branded and released FutureSplash Animator as *Macromedia Flash* v1.0. In 2005, Adobe Systems acquired Macromedia; subsequently, in 2007, *Adobe Flash CS3 Professional*, the next version of Macromedia Flash was released.

Release	Year	Description
FutureSplash Animator	1996	Initial version of Flash with basic editing tools and a timeline
Macromedia Flash 1	1996	A re-branded version of the FutureSplash Animator
Macromedia Flash 2	1997	Released with Flash Player 2, new features included: the object library
Macromedia Flash 3	1998	Released with Flash Player 3, new features included: the movieclip element, JavaScript plug-in integration, transparency and an external stand alone player
Macromedia Flash 4	1999	Released with Flash Player 4, new features included: internal variables, an

		input field, advanced ActionScript, and streaming MP3
Macromedia Flash 5	2000	Released with Flash Player 5, new features included: ActionScript 1.0 (based on ECMAScript, making it very similar to JavaScript in syntax), XML support, Smartclips (the precursor to components in Flash), HTML text formatting added for dynamic text
Macromedia Flash MX(6)	2002	Released with Flash Player 6, new features included: a video codec (Sorenson Spark), Unicode, v1 UI Components, compression, ActionScript vector drawing API
Macromedia Flash MX 2004(7)	2003	Released with Flash Player 7, new features included: Actionscript 2.0 (which enabled an object-oriented programming model for Flash, although it lacked the Script assist function of other versions, meaning Actionscript could only be typed out manually), behaviors, extensibility layer (JSAPI), alias text support, timeline effects. Macromedia Flash MX Professional 2004 included all Flash MX 2004 features, plus: Screens (forms for non-linear state-based development and slides for organizing content in a linear slide format like PowerPoint), web services integration, video import wizard, Media Playback components (which encapsulate a complete MP3 and/or FLV player in a component that may be placed in an SWF), Data components (DataSet, XMLConnector, WebServicesConnector, XUpdateResolver, etc.) and data binding APIs, the Project Panel, v2 UI components, and Transition class libraries.
Macromedia Flash 8	2005	Macromedia Flash Basic 8, a less feature-rich version of the Flash authoring tool targeted at new users who only want to do basic drawing, animation and interactivity. Released

		with Flash Player 8, this version of the product has limited support for video and advanced graphical and animation effects. Macromedia Flash Professional 8 added features focused on expressiveness, quality, video, and mobile authoring. New features included Filters and blend modes, easing control for animation, enhanced stroke properties (caps and joins), object-based drawing mode, run-time bitmap caching, FlashType advanced anti-aliasing for text, On2 VP6 advanced video codec, support for alpha transparency in video, a stand-alone encoder and advanced video importer, cue point support in FLV files, an advanced video playback component, and an interactive mobile device emulator.
Adobe Flash CS3(9) Professional	2007	Flash CS3 is the first version of Flash released under the Adobe name. CS3 features full support for ActionScript 3.0, allows entire applications to be converted into ActionScript, adds better integration with other Adobe products such as Adobe Photoshop, and also provides better Vector drawing behavior, becoming more like Adobe Illustrator and Adobe Fireworks.
Adobe Flash CS4(10) Professional	2008	Contains inverse kinematics (bones), basic 3D object manipulation, object-based animation, a text engine, and further expansions to ActionScript 3.0. CS4 allows the developer to create animations with many features absent in previous versions.
Adobe Flash Professional CS5(10.1)	2010	Flash CS5 was released on April 12, 2010 and launched for trialling and normal buying on April 30, 2010. Flash CS5 Professional includes support for publishing iPhone applications. However, on April 8, 2010 Apple changed the terms of its Developer License to effectively ban the use of the Flash-to-iPhone compiler and on April 20, 2010 Adobe announced that they

will be making no additional investments in targeting the iPhone and iPad in Flash CS5.

Other features of Flash CS5 are a new text engine (TLF), further improvement to inverse kinematics, and the Code Snippets panel.

Third-party tools

Open Source projects like Ajax Animator and the (now defunct) UIRA aim to create a Flash development environment, complete with a graphical user environment. Alternatively, programs such as swfmill, SWFTools, and MTASC provide tools to create SWF files, but do so by compiling text, actionscript or XML files into Flash animations. It is also possible to create SWF files programmatically using the Ming library, which has interfaces for C, PHP, C++, Perl, Python, and Ruby. haXe is an open source, high-level object-oriented programming language geared towards web-content creation that can compile Flash files.

Many shareware developers produced Flash creation tools and sold them for under US$50 between 2000 and 2002. In 2003 competition and the emergence of free Flash creation tools had driven many third-party Flash-creation tool-makers out of the market, allowing the remaining developers to raise their prices, although many of the products still cost less than US$100 and support ActionScript. As for open source tools, KToon can edit vectors and generate SWF, but its interface is very different from Macromedia's. Another, more recent example of a Flash creation tool is SWiSH Max made by an ex-employee of Macromedia. Toon Boom Technologies also sells a traditional animation tool, based on Flash.

In addition, several programs create .swf-compliant files as output from their programs. Among the most famous of these are Screencast tools, which leverage the ability to do lossless compression and playback of captured screen content in order to produce demos, tutorials, or software simulations of programs. These programs are typically designed for use by non-programmers, and create Flash content quickly and easily, but cannot actually edit the underlying Flash code (i.e. the tweening and transforms, etc.) Screencam is perhaps the oldest screencasting authoring tool to adopt Flash as the preferred output format, having been developed since the mid-90s. The fact that screencasting programs have adopted Flash as the preferred output is testament to Flash's presence as a ubiquitous cross-platform animation file format.

Other tools are focused on creating specific types of Flash content. Anime Studio is a 2D animation software package specialized for character animation which creates SWF files. Express Animator is similarly aimed specifically at animators. Question Writer publishes its quizzes to Flash file format.

Users who are not programmers or web designers will also find on-line tools that allow them to build full Flash-based websites. One of the oldest services available (1998) is FlashToGo. Such companies provide a wide variety of pre-built models (templates) associated to a Content Management System that empowers users to easily build, edit and publish their websites. Other sites, that allows for greater customization and design flexibility are Wix.com and CirclePad.

Adobe wrote a software package called Adobe LiveMotion, designed to create interactive animation content and export it to a variety of formats, including SWF. LiveMotion went through two major releases, but failed to gain any notable user base.

In February 2003, Macromedia purchased Presedia, which had developed a Flash authoring tool that automatically converted PowerPoint files into Flash. Macromedia subsequently released the new product as Breeze, which included many new enhancements. In addition, (as of version 2) Apple's Keynote presentation software also allows users to create interactive presentations and export to SWF.

User experience

Flash as a format has become widespread on the desktop market; one estimate is that 95% of PCs have it, while Adobe claims that 98 percent of U.S. web users and 99.3 percent of all Internet desktop users have installed the Flash Player, with 92 to 95% (depending on region) having the latest version. Numbers vary depending on the detection scheme and research demographics.

The Adobe Flash Player exists for a variety of systems and devices: Windows, Mac OS 9/X, Linux, Solaris, HP-UX, Pocket PC/Windows CE, OS/2, QNX, Android, Symbian, Palm OS, BeOS, and IRIX, although the performance is typically best on Windows.

Some websites rely on Flash so heavily that they are totally unusable without this plugin

Among mobile devices, Flash has less penetration because Apple does not bundle or allow third-party runtimes on its iPhone, which accounts for more than 60% of global smartphone web traffic, or the iPod touch, which makes up more than 95% of "mobile

Internet device" traffic. This hurts Adobe's ability to market Flash as a ubiquitous mobile platform. However, Flash is enabled on competing mobile platforms, including the version 2.2 Android while other O.S.s such as Symbian and Palm have versions coming.

Downloading Flash is blocked in countries that are under U.S sanctions (such as Syria & Sudan). Users in these countries are blocked (by Adobe) from downloading Flash plug-ins for both Internet Explorer and Firefox browsers.

Flash content is usually embedded using the <object> html tag, or the nonstandard <embed> tag. Software that does not support either of these tags, and users who cannot or will not install a plugin, will see the replacement text if this is supplied by the web page.

Accessibility

Using Flash tends to break conventions associated with normal HTML pages. Selecting text, scrolling, form control and right-clicking act differently than with a regular HTML webpage. Many such interface unexpectancies are fixable by the designer. Usability expert Jakob Nielsen published an Alertbox in 2000 entitled, *Flash: 99% Bad* which listed issues like these. Some problems have been improved upon since Nielsen's complaints:

- Text size can be controlled using full page zoom, found in many modern browsers.
- It has been possible for authors to include alternative text in Flash since Flash Player 6. This accessibility feature is compatible only with certain screen readers and only under Windows.

Performance

- Any Flash player has to be able to animate on top of video renderings, which makes hardware accelerated video rendering at least not as straightforward as with a purpose built multimedia player. Therefore, even when only displaying video, Flash players are more resource intensive than dedicated video player software.
- Comparisons have shown Adobe Flash Player to perform better on Windows than Mac OSX and Linux with the same hardware. However, the 10.1 update significantly improved performance for Mac OS X.

Flash blocking in web browsers

Some web browsers default to not play Flash content before the user clicks on it, e.g. Konqueror, K-Meleon. Equivalent "Flash blocker" extensions also exist for many popular browsers: Firefox has NoScript and Flashblock, and Opera versions since 10.5 feature native Flash blocking. Opera Turbo requires the user to click to play Flash content. Internet Explorer has Foxie, which contains a number of features, one of them also named Flashblock. WebKit-based browsers under Mac OS X, such as Apple's Safari, have ClickToFlash.

Flash client security

Flash's security record has caused several security experts to recommend to not install Flash or to block it. The US-CERT recommends to block Flash using NoScript. Charlie Miller recommended "not to install Flash" at the computer security conference CanSecWest. As of October 31, 2010, The Flash Player has over 100 CVE entries, 65 of which have been ranked with a high severity (leading to arbitrary code execution), and 40 ranked medium. In February 2010, Adobe officially apologized for not fixing a known vulnerability for over 1 year. In June 2010 Adobe announced a "critical vulnerability" in recent versions, saying there are reports that this vulnerability is being actively exploited in the wild against both Adobe Flash Player, and Adobe Reader and Acrobat. Later, in October 2010, Adobe announced another critical vulnerability, this time also affecting Android-based mobile devices. Android users have been recommended to disable Flash or make it only on demand.

Symantec's Internet Security Threat Report states that a remote code execution in Adobe Reader and Flash Player was the second most attacked vulnerability in 2009. The same report also recommends to employ browser add-ons wherever possible to disable Adobe Flash Player when visiting untrusted sites. McAfee predicts that Adobe software, especially Reader and Flash, will be the primary target for attacks in 2010. Adobe applications had already become the most popular client-software targets for attackers during the last quarter of 2009.

Local Shared Objects (“Flash cookies”)

Like the HTTP cookie, a flash cookie (also known as a “Local Shared Object”) can be used to save application data. Flash cookies are not shared across domains. An August 2009 study by the Social Science Research Network found that 50% of websites using Flash were also employing flash cookies, yet privacy policies rarely disclosed them, and user controls for privacy preferences were lacking. Most browsers' cache and history suppress or delete functions do not affect Flash Player's writing Local Shared Objects to its own cache, and the user community is much less aware of the existence and function of Flash cookies than HTTP cookies. Thus, users having deleted HTTP cookies and purged browser history files and caches may believe that they have purged all tracking data from their computers when in fact Flash browsing history remains. Adobe's own Flash Website Storage Settings panel, a submenu of Adobe's Flash Settings Manager web

application, and other editors and toolkits can manage settings for and delete Flash Local Shared Objects.

64-bit support

Adobe's 64-bit Flash player is available as a preview2 release ("Square"), which was released in September 2010. The "Square" preview is available for Windows, Mac and Linux. This new version can be downloaded at the Adobe lab site.

The key new capabilities in the Flash Player "Square" preview are:

- 64-bit support — Native support for 64-bit operating systems and 64-bit web browsers on Linux, Mac OS, and Windows. (Hulu and Amazon which depends on RTMPE are not currently functioning because there are some 64-bit libs that need to be integrated into the branch"Adobe Forums: Flash Player "Square": 64-bit".
- Internet Explorer 9 hardware accelerated rendering support — Enhanced support for Internet Explorer 9 Beta. It takes advantage of hardware accelerated graphics in Internet Explorer 9 Beta, utilizing hardware rendering surfaces to improve graphics performance and enable seamless composition.

The first experimental release of 64-bit builds of Adobe Flash Player was for the Linux platform, on November 11, 2008.

The project was closed temporarily on June 15, 2010, while Adobe was preparing for the preview release on September 15, 2010.

The official 32-bit player is still distributed in 64-bit Linux distributions e.g. Ubuntu, openSUSE, of which some users have reported problems with the 32-bit player on some websites. Affected users can install the 64-bit player manually or through a special repository.

Adobe expects to provide 64-bit versions of its Flash Player for Windows, Macintosh and Linux with an upcoming major release of Adobe Flash Player.

Usage

One of the uses of Adobe Flash is to create a **flash intro**, a piece of animated content displayed at the beginning of a website. Often, the main content is loading in the background, while the animated content is displayed in the foreground. The intent is to captivate the user's attention so that he or she does not stray from the site, although it may do the opposite as it slows the user from accessing the actual site and can be tedious for users with slow internet connections. Often a "skip" or "skip intro" button is prepared to allow more immediate access to the site's homepage.

Alternatives to Flash

HTML5

HTML 5 is gaining ground as a competitor to Flash: the canvas element assists animation, and text can be more easily synchronized with audio and video element timeupdate events. In one example of this, Scribd, a 50 million user a month document sharing website, announced in May 2010 that after three years of investment in Flash, it is changing from that platform to the HTML5 standard. Youtube introduced HTML5 support in January 2010, and on Jan 11 2011, the Google Chromium Project announced on their blog that support for closed codecs (particularly H.264) would be removed from future releases of Chrome. The Chromium announcement specifically mentioned that this was an effort to increase the use of license-free HTML5 and the <video> tag, and drive web-wide adoption of the open-source codecs VP8 and Theora.

Microsoft Silverlight

In recent years, Microsoft Silverlight has emerged as a strong competitor to Flash. While not yet as prevalent on websites as Flash, Silverlight has been used to provide video streaming for many high profile events, including the 2008 Summer Olympics in Beijing, the 2010 Winter Olympics in Vancouver, and the 2008 conventions for both major political parties in the United States. Silverlight is also used by Netflix for its instant video streaming service.

Java

Java applets are used both to create interactive visualisations and to present video, three dimensional objects and other media. Java applets are more appropriate for complex visualizations that require significant programming effort in high level language or communications between applet and originating server. Sun's new JavaFX is considered as another competitor for Rich Internet Applications.

Other open alternatives

There are equivalent open standards for many simple uses of Flash. Most notably the SVG and SMIL file formats, the *canvas*, *audio* and *video* HTML elements, and the JavaScript programming language. More complex use cases can be achieved by combining these.

The W3C's SVG and SMIL standards are seen as the nearest equivalents of Flash. Opera has supported SVG since version 8 and Safari has since version 3, and Mozilla Firefox's built-in support for SVG continues to grow. Adobe formerly developed and distributed the 'Adobe SVG Viewer' client plug-in for MS Internet Explorer, but discontinued support and distribution on January 1, 2009. This was in a time when Adobe went from competing with Macromedia's Flash to owning the technology itself.

UIRA was a free software project that intended to become a complete replacement for Adobe Flash. The project collapsed in mid 2007, though people are now discussing reviving or continuing it, and a few other projects like Ajax Animator still exist.

Third-party players

Since Flash files do not depend on an open standard such as SVG, this reduces the incentive for non-commercial software to support the format, although there are several third party tools which use and generate the SWF file format. Flash Player cannot ship as part of a pure open source, or completely free operating system, as its distribution is bound to the Macromedia Licensing Program and subject to approval.

There is, as of late 2008, no complete free software replacement which offers all the functionality of the latest version of Adobe Flash Player.

Presenting the free software movement, Richard Stallman stated in a speech in October 2004 that:

The use of Flash in websites is a major problem for our community.

Stallman's argument then was that no free players were comparatively good enough. As of February 2010, Gnash and Swfdec have seen limited success in competing with Adobe's player. Many important and popular websites require users to have a Flash player, sometimes with no fallback for non-Flash web users. Therefore, the lack of a good free Flash player is arguably an obstacle to enjoying the web with free software, and the aforementioned ubiquity of Flash makes the problem very evident for anyone who tries. The continual high ranking of Gnash on the Free Software Foundation's list of high priority projects might indicate the severity of the problem, as judged by the free software community.

Gnash is an active project that aims to create a free player and browser plugin for the Adobe Flash file format and so provide a free alternative to the Adobe Flash Player under the GNU General Public License. Despite potential patent worries because of the proprietary nature of the files involved, Gnash supports most SWF v7 features and some SWF v8 and v9. Gnash runs on Windows, Linux and other operating systems on 32-bit, 64-bit and other architectures.

Swfdec is another open-source flash player available for Linux, FreeBSD and OpenBSD.

Lightspark is a new implementation aiming to create a more modern and fast player. Besides hardware-accelerated rendering, it exploits multithreading and JIT compilation. It supports only the new ActionScript 3 VM introduced in Flash 9.

Scaleform GFx is a commercial alternative Flash player that features full hardware acceleration using the GPU and has high conformance with both Flash 10 ActionScript 3 and Flash 8 AS2. Scaleform GFx is licensed as a game middleware solution and used by

many PC and console 3D games for user interfaces, HUDs, mini games, and video playback.

rtmpdump is an open source software implementation of an RTMP client, Flash's own streaming protocol. rtmpdump was removed from Sourceforge on request by Adobe.

flvstreamer is an open source software implementation of an RTMP client, Flash's own streaming protocol. It is a fork of rtmpdump which has all the cryptographic support (i.e. RTMPE and SWF verification) removed from the code.

Smokescreen allows playback of Flash files using javascript in the webpage.

Chapter- 7

Mars Rover

MSL mockup compared with the Mars Exploration Rover and Sojourner rover by the Jet Propulsion Laboratory on May 12, 2008

Mars rover Sojourner atop its lander Pathfinder at the National Air and Space Museum

A **Mars rover** is an automated motor vehicle which propels itself across the surface of the planet Mars after landing.

Rovers have several advantages over stationary landers: they examine more territory, they can be directed to interesting features, they can place themselves in sunny positions to weather winter months and they can advance the knowledge of how to perform very remote robotic vehicle control.

There have been three successful Mars rovers, all of which were robotically operated. The Jet Propulsion Laboratory managed the Mars Pathfinder mission with its Sojourner rover and currently manages the Mars Exploration Rover Mission with its two rovers, Spirit and Opportunity, for NASA's Office of Space Science, Washington, DC. (There have also been two successful non-Martian robotic rovers: in the 1970s the USSR sent two *Lunokhod* rovers to the Moon.)

There are also three Mars Rover missions planned for the future, including the European ExoMars Rover from ESA, the American Curiosity and MAX-C Rovers from NASA.

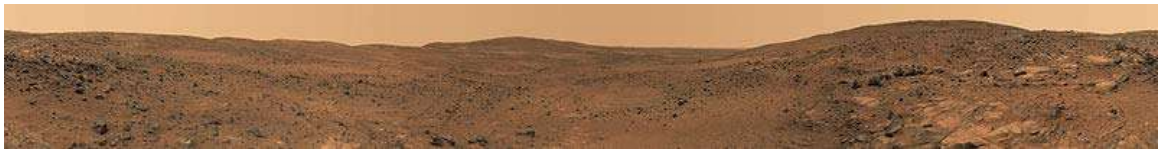
Rover synopsis

A Martian sunset at Gusev Crater. Spirit rover, May 19, 2005

Five rovers have been sent to Mars:

- *Mars 2*, *Prop-M* rover, 1971, failed.
- *Mars 3*, *Prop-M* rover, 1971, failed.
- *Sojourner* rover, Mars Pathfinder, landed successfully on July 4, 1997. Communications were lost on September 27, 1997.
- *Spirit* (MER-A), Mars Exploration Rover, landed successfully on January 4, 2004. Nearly 6 years after the original mission limit, Spirit had covered a total distance of 7.73 km (4.80 miles) but its wheels were trapped in sand. Around January 26, 2010, NASA admitted defeat in its efforts to free the rover and stated that it would now function as a stationary science platform. Since March 22, 2010 there has been no communication from the rover, though there is still hope that it may resume communication because the opportunity for energy generation will increase in its current location until mid-March 2011.
- *Opportunity* (MER-B), Mars Exploration Rover, landed successfully on January 25, 2004. Rover was still operating as of January, 2011, surpassing the previous record for longevity of a surface mission to Mars on May 20.

The *Mars 2* and *3* spacecraft from the USSR, had identical 4.5 kg *Prop-M* rovers. They were to move on skis while connected to the landers with cables. The *Mars 2* rover crashed into the Mars surface. The *Mars 3* rover failed less than a minute after landing and never moved. *Mars 2* and *Mars 3* both had companion orbiters which were successful.



Panorama of Husband Hill taken by MER-A *Spirit Rover*, November 23–28, 2005.

The first successful Mars rover was *Sojourner*. It was launched by NASA on December 4, 1996, and landed July 4, 1997. It was the first to use a new radical landing technique whereby the impact of the spacecraft was mitigated by its placement inside a multi-cell balloon that bounced and rolled across the Martian surface, killing its momentum. Mars rover *Spirit* launched June 10, 2003. *Opportunity* launched July 7, 2003. *Spirit* landed in Gusev crater on January 4, 2004. *Opportunity* landed in the Meridiani Planum on the opposite side of Mars, January 25, 2004. The computer used in these rovers was a radiation hardened PowerPC called the IBM RAD6000.

These Mars rovers are in development:

- *Curiosity*, Mars Science Laboratory, by NASA. Planned Mars launch 2011.
- *MAX-C*, Mars Astrobiology Explorer-Cacher, by NASA. Planned Mars launch 2018.
- *ExoMars*, by the ESA. Planned Mars launch 2018.

One experimental design, not proposed for any actual mission, is:

- *Mars Tumbleweed Rover*, a wind-propelled rover.

NASA rover mission goals

Wheel size comparison: Mars Pathfinder, Mars Exploration Rover, Mars Science Laboratory.

NASA distinguishes between "mission" objectives and "science" objectives. Mission objectives are related to progress in space technology and development processes. Science objectives are met by the instruments during their mission in space.

The details of rover science vary according to equipment carried. The primary goal of the *Spirit* and *Opportunity* rovers is to discover "the history of water on Mars". (The presence of usable water would greatly reduce manned mission cost.)

The four science goals of NASA's long-term Mars Exploration Program are:

- Determine whether life ever arose on Mars
- Characterize the climate of Mars
- Characterize the geology of Mars
- Prepare for human exploration

Chapter- 8

Digital Video Recorder

Foxtel iQ, a combined digital video recorder and satellite receiver.

V+, a combined digital video recorder and cable TV receiver.

A **digital video recorder** (**DVR**) or **personal video recorder** (**PVR**) is a consumer electronics device or application software that records video in a digital format to a disk drive, USB flash drive, SD memory card or other local or networked mass storage device. The term includes set-top boxes with recording facility, portable media players (PMP) with recording facility, recorders (PMR as camcorders that record onto memory cards) and software for personal computers which enables video capture and playback to and from disk. A television set with built-in digital video-recording facilities was introduced by LG in 2007, followed by other manufacturers.

History

Hard-disk based digital video recorders

Back view of a TiVo Series2 5xx-generation unit

Consumer digital video recorders ReplayTV and TiVo were launched at the 1998 Consumer Electronics Show in Las Vegas, USA. Microsoft also demonstrated a unit with DVR capability, but this did not become available until the end of 1999 for full DVR features in Dish Network's DISHplayer receivers. TiVo shipped their first units on March 31, 1999. ReplayTV won the "Best of Show" award in the video category with Netscape co-founder Marc Andreessen as an early investor and board member, but TiVo was more successful commercially. While early legal action by media companies forced ReplayTV to remove many features such as automatic commercial skip and the sharing of recordings over the Internet, newer devices have steadily regained these functions while adding complementary abilities, such as recording onto DVDs and programming and remote control facilities using PDAs, networked PCs, and Web browsers.

Hard-disk based digital video recorders make the "time shifting" feature (traditionally done by a VCR) much more convenient, and also allow for "trick modes" such as pausing live TV, instant replay of interesting scenes, chasing playback where a recording can be viewed before it has been completed, and skipping of advertising. Most DVRs use the MPEG format for compressing the digitized video signals.

Digital video recorders tied to a video service

At the 1999 CES, Dish Network demonstrated the hardware that would later have DVR capability with the assistance of Microsoft software. Users would have to wait until June 1999 for simple time shifting capabilities in the 7100, rebranded as the DISHPlayer satellite receiver, which also included WebTV Networks internet TV. By the end of 1999 the Dishplayer had full DVR capabilities and within a year, over 200,000 units were sold.

In the UK, digital video recorders are often referred to as "plus boxes" (such as BSKYB's Sky+ and Virgin Media's V+ which integrates an HD capability, and the subscription free Freesat+ and Freeview+). British Sky Broadcasting markets a popular combined EPG and DVR as Sky+. TiVo launched a UK model in 2000, and while no longer on sale, the subscription service is still maintained. South African based Africa Satellite TV beamer Multichoice recently launched their DVR which is available on their Dstv platform. In addition to ReplayTV and TiVo, there are a number of other suppliers of digital terrestrial (DTT) DVRs, including Thomson, Topfield, Fusion, Pace Micro Technology, Humax and AC Ryan Playon.

Many satellite, cable and IPTV companies are incorporating digital video recording functions into their set-top box, such as with DirecTiVo, DISHPlayer/DishDVR, Scientific Atlanta Explorer 8xxx from Time Warner, Total Home DVR from AT&T U-verse, Motorola 6xxx from Comcast, Moxi Media Center by Digeo (available through Charter, Adelphia, Sunflower, Bend Broadband, and soon Comcast and other cable companies), or Sky+. Astro introduced their DVR system, called Astro MAX, which was the first PVR in Malaysia. Sadly, it was phased out two years after its introduction.

In the case of digital television, there is no *encoding* necessary in the DVR since the signal is already a digitally encoded MPEG stream. The digital video recorder simply stores the digital stream directly to disk. Having the broadcaster involved with, and sometimes subsidizing, the design of the DVR can lead to features such as the ability to use interactive TV on recorded shows, pre-loading of programs, or directly recording encrypted digital streams. It can, however, also force the manufacturer to implement non-skippable advertisements and automatically-expiring recordings.

In the United States, the FCC has ruled that starting on July 1, 2007, consumers will be able to purchase a set-top box from a third-party company, rather than being forced to purchase or rent the set-top box from their cable company. This ruling only applies to "navigation devices," otherwise known as a cable television set-top box, and not to the security functions that control the user's access to the content of the cable operator. The overall net effect on digital video recorders and related technology is unlikely to be substantial as standalone DVRs are currently readily available on the open market.

Introduction of dual tuners

In 2003 many Satellite and Cable providers introduced dual-tuner digital video recorders. In the UK, BSkyB introduced their first PVR Sky+ with dual tuner support in 2001.

These machines have two independent tuners within the same receiver. The main use for this feature is the capability to record a live program while watching another live program simultaneously or to record two programs at the same time, possibly while watching a previously recorded one. Kogan Technologies introduced a dual-tuner PVR in the Australian market allowing free-to-air television to be recorded on a removable hard drive. Some dual-tuner DVRs also have the ability to output to two separate television sets at the same time. The PVR manufactured by UEC (Durban, South Africa) and used by Multichoice and Scientific Atlanta 8300DVB PVR have the ability to view two programs while recording a third using a triple tuner.

Where several digital subchannels are transmitted on a single RF channel, some PVRs can record two channels and view a third, so long as all three subchannels are on two channels (or one).

In the United States, DVRs were used by 32 percent of all TV households in 2009, and 38 percent by 2010, with viewership among 18 to 40 year-olds 40 percent higher in homes that have them.

Integrated TV-set digital video recorders

Integrated LCD DVR

Side view: Even with all the DVR components inside the LCD monitor is still slim.

Media type	LCD DVR

Digital video recorders are often integrated in the LCD and LED TV-sets. These systems let the user simplify the wiring and installation, because they do not use ports (SCART or

HDMI), and they only need to use only one device and power and the same remote control instead of two.

There are examples of security systems integrated into such DVRs, and thus they are capable of recording more input streams in parallel. Some of them include wireless ports such as (Bluetooth and WiFi), so they can play and record files to or from cellular phones and other devices. Such devices can also be used as disguised observation systems, displaying pictures or videos as typical store display.

VESA Compatible digital video recorders

VESA Compatible DVR

The underside of a VESA compatible DVR

Media type	DVR
Developed by	Lorex Technology

VESA compatible DVR are designed small and light enough to mount to the back of an LCD monitor that has clear access to VESA mounting holes (100x100mm). This allows users to use their own personal monitor to save on cost and space.

PC-based digital video recorders

Software and hardware is available which can turn personal computers running Microsoft Windows, Linux, and Mac OS X into DVRs, and is a popular option for home-theater PC (HTPC) enthusiasts.

Linux

There are many free DVR applications available for Linux, each released as free and open source software under the GNU General Public License:

- MythTV
- VDR
- LinuxMCE
- Freevo

A commercial and proprietary application called SageTV is available for most popular Linux distributions.

Mac OS

Elgato makes a series of digital video recording devices called EyeTV. The software supplied with each device is also called EyeTV, and is available separately for use on compatible third-party tuners from manufacturers such as Pinnacle, TerraTec, and Hauppauge.

SageTV provides DVR software for the Mac with built in placeshifting for watching TV remotely and sells and supports the Hauppauge HVR-950, myTV.PVR and HDHomeRun hardware with its DVR software. SageTV software also includes the ability to watch YouTube and other online video with a remote control.

MythTV also runs under Mac OS X, but most recording devices are currently only supported under Linux. Precompiled binaries are available for the MythTV front-end, allowing a Mac to watch video from (and control) a MythTV server running under Linux.

Apple provides applications in the FireWire software developer kit which allow any Mac with a FireWire port to record the MPEG2 transport stream from a FireWire equipped cable box (for example: Motorola 62xx, including HD streams). Applications can also change channels on the cable box via the firewire interface. Only broadcast channels can be recorded as the rest of the channels are encrypted. *FireRecord (formerly iRecord)* is a free scheduled-recording program derived from this SDK.

Windows

There are several free digital video recording applications available for Microsoft Windows including GB-PVR, MediaPortal, and Orb (web-based remote interface).

There are also several commercial applications available including CyberLink, SageTV, Beyond TV, Showshifter, InterVideo WinDVR, the R5000-HD and Meedio (now a dead product - Yahoo! bought most of the company's technology and discontinued the Meedio line, and rebranded the software Yahoo! Go - TV, which is now a free product but only works in the U.S.). Most TV tuner cards come bundled with software which allows the PC to record television to hard disk. For example, Leadtek's WinFast DTV1000 digital TV card comes bundled with the WinFast PVR2 software, which can also record analog video from the card's composite video input socket.

Windows Media Center is a DVR software by Microsoft bundled with the Media Center edition of Windows XP, the Home Premium / Ultimate editions of Windows Vista, as well as most editions of Windows 7.

Source video

Television and video are terms that are sometimes used interchangeably, but differ in their technical meaning. Video is the visual portion of television, whereas television is the combination of video and audio modulated onto a carrier frequency (i.e., a television channel) for delivery. Most DVRs can record both.

Analog sources overview

The first digital video recorders were designed to record Analog television in NTSC, PAL or SECAM formats.

To record an analog signal a few steps are required. TV tuner card tunes into a particular frequency and then functions as a frame grabber, breaking the lines into individual pixels and quantizing them into a format that a computer can comprehend. Then the series of frames along with the audio (also sampled and quantized) are compressed into a manageable format, like MPEG-2, usually in software.

Analog broadcast copy protection

Many mass-produced consumer DVRs implement a copy-protection system called CGMS-A or *Copy Generation Management System—Analog*. This encodes a pair of bits in the VBI of the analog video signal that specify one of the following settings:

- Copying is freely allowed
- Copying is prohibited
- Only one copy of this material may be made
- This is a copy of material for which only one copy was allowed to be made, so no further copies are allowed.

CGMS-A information may be present in analog broadcast TV signals, and is preserved when the signal is recorded and played back by analog VCRs, which of course don't understand the meanings of the bits. But the restrictions still come into effect when you try to copy the tape onto a PVR.

DVRs such as Tivo also detect and act upon analogue protection systems such as Macrovision and DCS Copy Protection which were originally designed to block copying on analog VCRs.

Digital sources overview

Recording digital signals is generally a straightforward capture of the binary MPEG data being received. No expensive hardware is required to quantize and compress the signal (as the television broadcaster has already done this in the studio).

DVD-based PVRs available on the market as of 2006 are not capable of capturing the full range of the visual signal available with high definition television (HDTV). This is largely because HDTV standards were finalized at a later time than the standards for DVDs. However, DVD-based PVRs can still be used (albeit at reduced visual quality) with HDTV since currently available HDTV sets also have standard A/V connections.

ATSC broadcast

ATSC television broadcasting is primarily used in North America. The ATSC data stream can be directly recorded by a digital video recorder, though many DVRs record only a subset of this information (that can later be transferred to DVD. An ATSC DVR will also act as a Set-top box, allowing older televisions or monitors to receive digital television.

Copy protection

The U.S. FCC attempted to limit the abilities of DVRs with its "broadcast flag" regulation. Digital video recorders that had not won prior approval from the FCC for implementing "effective" digital rights management would have been banned from interstate commerce from July 2005, but the regulation was struck down on May 6, 2005.

DVB

DVB Digital television contains audio/visual signals that are broadcast over the air in a digital rather than analog format. The DVB data stream can be directly recorded by the DVR. Autonomous devices (this is, that can be used without a computer/tablet) that can store in an external hard disk are called a telememory.

Digital cable and satellite television

Recording satellite or digital cable signals on a digital video recorder can be more complex than recording analog signals or broadcast digital signals. There are several different transmission schemes, and the video streams may be encrypted to restrict access to subscribers only.

A satellite or cable set-top box both decrypts the signal if encrypted, and decodes the MPEG stream into an analog signal for viewing on the television. In order to record cable or satellite digital signals the signal must be captured after it has been decrypted but before it is decoded; this is how DVRs built into set-top boxes work.

Cable and satellite providers often offer their own digital video recorders along with a service plan. These DVRs have access to the encrypted video stream, and generally enforce the provider's restrictions on copying of material even after recording.

DVD

Many DVD-based DVRs have the capability to copy content from a source DVD (ripping).

In the U.S. this is prohibited under the Digital Millennium Copyright Act if the disc is encrypted. Most such DVRs will hence not allow recording of video streams from encrypted movie discs.

Digital camcorders

A digital camcorder combines a camera and a digital video recorder.

Some DVD-based DVRs incorporate connectors that can be used to capture digital video from a camcorder. Some editing of the resulting DVD is usually possible, such as adding chapter points.

Some digital video recorders can now record to solid state flash memory cards (called *flash camcorders*). They generally use secure digital cards, can include wireless connections (Bluetooth and Wi-Fi), and can play SWF files. There are some digital video recorders that combine video and graphics in real time to the flash card, called DTE or "direct to edit". These are used to speed-up the editing workflow in video and television production, since linear videotapes do not then need to be transferred to the edit workstation.

File formats, resolutions and file systems

DVRs can usually record and play H.264, MPEG-4 Part 2, MPEG-2 .mpg, MPEG-2 .TS, VOB and ISO images video, with MP3 and AC3 audio tracks. They can also display (JPEG, PNG) images and play music (MP3, Ogg) files.

Some devices can be updated to play and record in new formats.

Recordings from standard-definition television usually have 480p/i/576p/i while HDTV is usually in 720p/1080i.

DVRs usually record in proprietary filesystems for copy protection, although some can use FAT filesystems.

Applications

TV recording

TV DVRs generally uses the electronic programming guide (EPG).

Security

Digital video recorders configured for physical security applications record video signals from closed circuit television cameras for detection and documentation purposes. Many are designed to record audio as well. DVRs have evolved into devices that are feature rich and provide services that exceed the simple recording of video images that was previously done through VCRs. A DVR CCTV system provides a multitude of advanced functions over VCR technology including video searches by event, time, date and camera. There is also much more control over quality and frame rate allowing disk space usage to be optimized and the DVR can also be set to overwrite the oldest security footage should the disk become full. In some DVR security systems remote access to security footage using a PC can also be achieved by connecting the DVR to a LAN network or the internet. videoNEXT also makes a NVR surveillance application for the Mac OS X. Some of the latest professional digital video recorders include video analytics firmware, to enable functionality such as 'virtual tripwire' or even the detection of abandoned objects on the scene.

Security DVRs may be categorized as being either PC based or embedded. A PC based DVR's architecture is a classical personal computer with video capture cards designed to capture video images. An embedded type DVR is specifically designed as a digital video recorder with its operating system and application software contained in firmware or read only memory.

Hardware features

Hardware features of security DVRs vary between manufacturers and may include but are not necessarily limited to

- Designed for rack mounting or desktop configurations.
- Single or multiple video inputs with connector types consistent with the analogue or digital video provided such as coaxial cable, twisted pair or optical fiber cable. The most common number of inputs are 1, 2, 4, 8, 16 and 32. Systems may be configured with a very large number of inputs by networking or bussing individual DVRs together.
- Looping video outputs for each input which duplicates the corresponding input video signal and connector type. These output signals are used by other video equipment such as matrix switchers, multiplexers, and video monitors.
- Controlled outputs to external video display monitors.
- Front panel switches and indicators that allow the various features of the machine to be controlled.

- Network connections consistent with the network type and utilized to control features of the recorder and to send and/or receive video signals.
- Connections to external control devices such as keyboards.
- A connection to external pan-tilt-zoom drives that position cameras.
- Internal CD, DVD, VCR devices typically for archiving video.
- Connections to external storage media.
- Alarm event inputs from external security detection devices, usually one per video input.
- Alarm event outputs from internal detection features such as motion detection or loss of video.

Software features

Software features vary between manufacturers and may include but are not necessarily limited to

- User selectable image capture rates either on an all input basis or input by input basis. The capture rate feature may be programmed to automatically adjust the capture rate on the occurrence of an external alarm or an internal event
- Selectable image resolution either on an all input basis or input by input basis. The image resolution feature may be programmed to automatically adjust the image resolution on the occurrence of an external alarm or an internal event.
- Compression methods determine quality of playback. H.264 hardware compression offers fast transfer rates over the internet with high quality video.
- Motion detection: Provided on an input by input basis, this feature detects motion in the total image or a user definable portion of the image and usually provides sensitivity settings. Detection causes an internal event that may be output to external equipment and/or be used to trigger changes in other internal features.
- Lack of motion detection. Provided on an input by input basis, this feature detects the movement of an object into the field of view and remaining still for a user definable time. Detection causes an internal event that may be output to external equipment and/or used to trigger changes in other internal features.
- Direction of motion detection. Provided on an input by input basis, this feature detects the direction of motion in the image that has been determined by the user as an unacceptable occurrence. Detection causes an internal event that may be output to external equipment and/or be used to trigger changes in other internal features.
- Routing of input video to video monitors based on user inputs or automatically on alarms or events.
- Input, time and date stamping.
- Alarm and event logging on appropriate video inputs.
- Alarm and event search.
- One or more sound recording channels.
- Archival.
- Commercial hopping. Rather than fast-forwarding through commercials, an undocumented feature of the TiVo box is that the user can reprogram the tab-to-

end button by entering a sequence of buttons on the remote: SELECT-PLAY-SELECT-3-0-SELECT and listening for the confirming chimes that signal the feature has been activated (or deactivated). The tab-to-end button no longer jumps to the end of a recording when so activated: It skips 30 seconds, which is the length of U.S. commercials. In combination with the 8-second rewind button, most viewers can completely miss commercial breaks in programming.

Privacy concerns

Some digital video recorders which are designed to send information to a service provider over a telephone line, Internet, (or any other way) can gather and send real-time data on users' viewing habits.

The future of TV advertisements

Digital video recorders are also changing the way television programs advertise products. Watching pre-recorded programs allows users to fast-forward through commercials, and some technology allows users to remove commercials entirely. Half of viewers in the United States, for example, use DVRs to skip commercials entirely. This feature has been controversial for the last decade, with major television networks and movie studios claiming it violates copyright and should be banned.

In 1985, an employee of Honeywell's Physical Sciences Center, David Rafner, first described a drive-based DVR designed for home TV recording, time-slipping, and commercial skipping. U.S. Patent 4,972,396 focused on a multi-channel design to allow simultaneous independent recording and playback. Broadly anticipating future DVR developments, it describes possible applications such as streaming compression, editing, captioning, multi-channel security monitoring, military sensor platforms, and remotely piloted vehicles.

The first DVR which had a built-in Commercial skipping feature was ReplayTV with its "4000 Series" and "5000 Series" units. In 2002 five owners of the ReplayTV DVR sued the main television networks and movie studios, asking the federal judge to uphold consumers' rights to record TV shows and skip commercials claiming that features such as commercial skipping help parents protect their kids from excessive consumerism. ReplayTV ended up filing for bankruptcy in 2003 after fighting a copyright infringement suit over the ReplayTV's ability to skip commercials. A third-party add-on for Windows Media Center called "DVRMSToolbox" has the ability to skip commercials. There is a command-line program called Comskip that detects commercials in an MPEG-2 file and saves their positions to a text file. This file can then be fed to a program like MEncoder to actually remove the commercials.

Many speculate that television advertisements will be eliminated altogether, replaced by advertising in the TV shows themselves. For example, *Extreme Makeover: Home Edition* advertises Sears, Kenmore, Kohler, and Home Depot by specifically using products from

these companies, and some sports events like the Sprint Cup of NASCAR are named after sponsors.

Another type of advertisement shown more and more, mostly for advertising TV shows on the same channel, is where the ad overlays the bottom of the TV screen, blocking out some of the picture. "Banners", or "Logo Bugs", as they are called, are referred to by media companies as Secondary Events (2E). This is done in much the same way as severe weather warnings are done. Sometimes these take up only 5-10% of the screen, but in the extreme, can take up as much as 25% of the viewing area. Some even make noise or move across the screen. One example of this is the 2E ads for *Three Moons Over Milford* in the months before its premiere. A video taking up approximately 25% of the bottom-left portion of the screen would show a comet impacting into the moon with an accompanying explosion, during another television program.

Because of this widely-used new technology, advertisers are now looking at a new way to market their products on television. An excerpt from the magazine *Advertising Age* reads: "As advertisers lose the ability to invade the home, and consumer's minds, they will be forced to wait for an invitation. This means that they have to learn what kinds of advertising content customers will actually be willing to seek out and receive."

With ad skipping and the time-sensitive nature of certain ads, advertisers are wary of buying commercial time on shows that are heavily digitally video-recorded. However, the DVR enables dynamic ad insertion. Advertisers could inject time-relevant ads to recorded programs when the program is viewed. This way the ads could be not just topical but also personalized to viewers interests.

Patent and copyright litigation

On July 14, 2005, Forgent Networks filed suit against various companies alleging infringement on U.S. Patent 6,285,746, entitled "Computer controlled video system allowing playback during recording". The listed companies included EchoStar, Directv, Charter Communications, Cox Communications, Comcast, Time Warner, and Cable One.

Scientific-Atlanta and Motorola, the manufacturers of the equipment sold by the above mentioned companies, filed a counter-suit against Forgent Networks claiming that their products do not violate the patent, and that the patent is invalid. The two cases were combined into case 6:06-cv-208, filed in the United States District Court for the Eastern District of Texas, Tyler Division.

According to court documents, on June 20, 2006, Motorola requested that the United States Patent and Trademarks Office reexamine the patent, which was first filed in 1991, but has been amended several times.

On March 23, 2007 Cablevision Systems Corp lost a legal battle against several Hollywood studios and television networks to introduce a network-based digital video recorder service to its subscribers. However, on August 4, 2008, Cablevision won its

appeal. John M. Walker Jr., a Second Circuit judge, declared that the technology "would not directly infringe" on the media companies' rights. An appeal to the Supreme Court was rejected.

In court, the media companies argued that network digital video recorders were tantamount to video-on-demand, and that they should receive license fees for the recording. Cablevision and the appeals court disagreed. The company noted that each user would record programs on his or her own individual server space, making it a DVR that has a "very long cord."

Chapter- 9

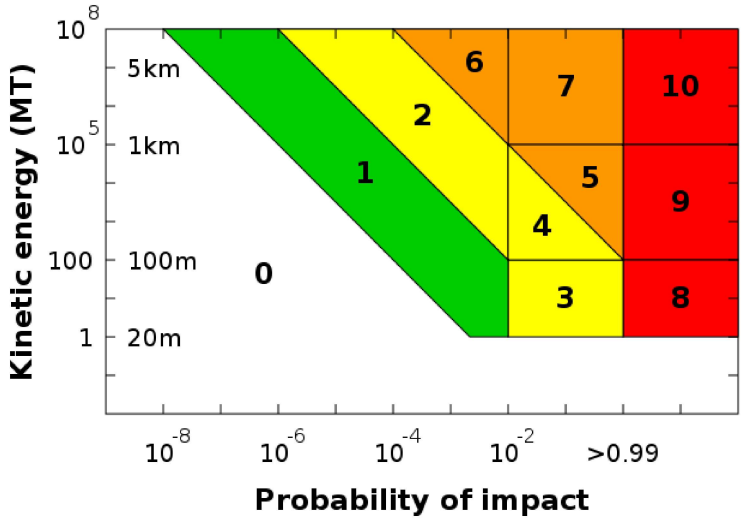
Torino Scale

The **Torino Scale** is a method for categorizing the impact hazard associated with near-Earth objects (NEOs) such as asteroids and comets. It is intended as a tool for astronomers and the public to assess the seriousness of collision predictions, by combining probability statistics and known kinetic damage potentials into a single threat value. The Palermo Technical Impact Hazard Scale is a similar, but more complex scale.

The Torino Scale, invented by Richard P. Binzel in 1999.

Overview

The Torino Scale uses a scale from 0 to 10. A 0 indicates an object has a negligibly small chance of collision with the Earth, compared with the usual "background noise" of collision events, or is too small to penetrate the Earth's atmosphere intact. A 10 indicates that a collision is certain, and the impacting object is large enough to precipitate a global disaster. Only integer values are used.



Torino Scale. The scale in metres is the approximate diameter of an asteroid with a typical collision velocity.

An object is assigned a 0 to 10 value based on its collision probability and its kinetic energy (expressed in megatons of TNT).

History

The Torino Scale was created by Professor Richard P. Binzel in the Department of Earth, Atmospheric, and Planetary Sciences, at the Massachusetts Institute of Technology (MIT). The first version, called "A Near-Earth Object Hazard Index", was presented at a United Nations conference in 1995 and was published by Binzel in the subsequent conference proceedings (*Annals of the New York Academy of Sciences,* volume 822, 1997.)

A revised version of the "Hazard Index" was presented at a June 1999 international conference on NEOs held in Torino (Turin), Italy. The conference participants voted to adopt the revised version, where the bestowed name "Torino Scale" recognizes the spirit of international cooperation displayed at that conference toward research efforts to understand the hazards posed by NEOs. ("Torino Scale" is the proper usage, not "Turin Scale.")

Due to exaggerated press coverage of Level 1 asteroids such as 2003 QQ_{47}, a rewording of the Torino Scale was published in 2005, adding more details and renaming the categories: in particular, Level 1 was changed from "Events meriting careful monitoring" to "Normal".

Current Torino Scale

The Torino Scale also uses a color code scale: white, green, yellow, orange, red. Each color code has an overall meaning:

NO HAZARD (white)

0. The likelihood of a collision is zero, or is so low as to be effectively zero. Also applies to small objects such as meteors and bodies that burn up in the atmosphere as well as infrequent meteorite falls that rarely cause damage.

NORMAL (green)

1. A routine discovery in which a pass near the Earth is predicted that poses no unusual level of danger. Current calculations show the chance of collision is extremely unlikely with no cause for public attention or public concern. New telescopic observations very likely will lead to re-assignment to Level 0.

MERITING ATTENTION BY ASTRONOMERS (yellow)

2. A discovery, which may become routine with expanded searches, of an object making a somewhat close but not highly unusual pass near the Earth. While meriting attention by astronomers, there is no cause for public attention or public concern as an actual collision is very unlikely. New telescopic observations very likely will lead to re-assignment to Level 0.

3. A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of *localized destruction*. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.

4. A close encounter, meriting attention by astronomers. Current calculations give a 1% or greater chance of collision capable of *regional devastation*. Most likely, new telescopic observations will lead to re-assignment to Level 0. Attention by public and by public officials is merited if the encounter is less than a decade away.

THREATENING (orange)

5. A close encounter posing a serious, but still uncertain threat of regional devastation. Critical attention by astronomers is needed to determine conclusively whether a collision will occur. If the encounter is less than a decade away, governmental contingency planning may be warranted.

6. A close encounter by a large object posing a serious but still uncertain threat of a global catastrophe. Critical attention by astronomers is needed to determine conclusively whether a collision will occur. If the encounter is less than three decades away, governmental contingency planning may be warranted.

7. A very close encounter by a large object, which if occurring this century, poses an unprecedented but still uncertain threat of a global catastrophe. For such a threat in this century, international contingency planning is warranted, especially to determine urgently and conclusively whether a collision will occur.

CERTAIN COLLISIONS (red)

8. A collision is certain, capable of causing localized destruction for an impact over land or possibly a tsunami if close offshore. Such events occur on average between once per 50 years and once per several thousand years.

9. A collision is certain, capable of causing unprecedented regional devastation for a land impact or the threat of a major tsunami for an ocean impact. Such events occur on average between once per 10,000 years and once per 100,000 years.

10. A collision is certain, capable of causing global climatic catastrophe that may threaten the future of civilization as we know it, whether impacting land or ocean. Such events occur on average once per 100,000 years, or less often.

Objects with high Torino ratings

The current record for highest Torino rating is held by 99942 Apophis, an about 350 m near-Earth asteroid, which was later downgraded to 0. On December 23, 2004, NASA's Near Earth Object Program Office announced that Apophis (then known only by its provisional designation 2004 MN_4) was the first object to reach a level 2 on the Torino Scale, and it was subsequently upgraded to level 4. It is now expected to pass the Earth on Friday, April 13, 2029 quite closely but with no possibility of an impact. Future uncertainties in the orbit of Apophis will occur because of gravitational deflection during the 2029 encounter, so a Torino rating of 1 (for an encounter in 2036) applied until August 2006, when Apophis was downgraded to 0.

Prior to Apophis, no NEO had ever been given a Torino Scale value higher than 1. In February 2006, the rating for 2004 VD_{17} was upgraded to a value of 2 due to a possible encounter in the year 2102, making it the second asteroid to ever be given a Torino Scale value higher than 1. Additional observations of 2004 VD_{17} resulted in a downgrade to 0.

1950 DA is rated above Level 0 by NEODyS, it is rated Level 2. It, however, is not listed by the Sentry program because its risk is not within 100 years.

2007 VK_{184} is the second object, an asteroid, which is listed on the Near Earth Object Risk List with a Torino Scale of Level 1. The object was discovered on November 12, 2007, by the Catalina Sky Survey. According to the Near-Earth Object list, 101 observations over 60 days suggest 2007 VK_{184} has a probability of 1 in 3,030 chance to hit the Earth during June 2048. These figures translate into a 0.033% chance to hit (or 99.967% to miss). The asteroid is estimated to have a diameter of 130 meters, and travels through space with a speed of 15.63 km/s relative to the Earth.

2008 AF_4 is another object on the Torino Scale of 1. It is thought to have a 1 in 909,000 chance of impacting the Earth in 2096, 2099, or 2100. It was downgraded to 0 by 14 February 2008.

2009 KK, discovered in May 2009, was rated with a value of 1. It was downgraded to 0 on 17 June 2009.

2009 WM_1, discovered on November 17, 2009, was rated with a value of 1. It was downgraded to 0 by the end of November.

2009 YG, discovered on December 17, 2009, was rated with a value of 1. It was downgraded to 0 by the end of December.

2005 YU_{55}, in February 2010 was rated with a value of 1. It was downgraded to 0 on 9 April 2010.

2010 XC_{25}, in December 2010 was rated with a value of 1. It was downgraded to 0 on 2 January 2011.