HOME ON THE WEB: THE UNIVERSITY OF TEXAS BUILDS A GPS SITE

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<http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html> is an address you'll want to add to your World Wide Web bookmarks. This is where you'll find the GPS Overview, an interactive introduction to the satellite system that features 50 graphic images, more than a dozen text files with computer algorithms and GPS specifications, and access to other GPS-related sites. This University of Texas, Department of Geography, site also features associated pages about geodetic datums, coordinate systems, and map projections.

A Global Positioning System Overview has been available on the World Wide Web (widely known as "the Web" or WWW) for more than a year as part of the Geographer's Craft Project at the Department of Geography, University of Texas at Austin. The evolution of this Internet WWW hypermedia page has resulted in a group of Internet teaching modules that includes not only the GPS page, but also the Geodetic Datum Overview, the Coordinate Systems Overview, and the Map Projection Overview. Together with other modules linked into the Geographer's Craft pages, this set of resources makes basic GPS information available to a worldwide audience.

This GPS resource has developed alongside rapidly expanding Internet client and server technologies and a growing GPS user community that now includes many new recreational users with an intense interest in the details of the now fully operational Global Positioning System. Its evolution has been the direct result of the interactive nature of the WWW and the willingness of more than 250 Web users to share their comments, suggestions, and criticisms with the Geographer's Craft development team.

GEOGRAPHER'S CRAFT PROJECT

Since 1992, a group of graduate students working under the guidance of Kenneth E. Foote, associate professor of geography at Texas, has been developing hypermedia and multimedia techniques to enhance the teaching of geography. Hypermedia, in this case, is the use of processes that allow the interactive linking of resource materials under the control of the user. Graphics, text, audio, and video are examples of the variety of media that can be linked together in a multimedia platform. The goal of this effort, operating as the Geographer's Craft Project, is to provide an "electronic textbook" with materials related to geographic information systems (GIS), cartography, remote sensing, and other geographic methods. In these rapidly evolving fields, traditional textbooks are often out of date or have not yet been written. Many of the course materials are continually changing, and often previous course projects are used as the basis for new projects. An electronic textbook that can be easily updated and that can use materials in many different forms provides a natural solution that also makes wide dissemination of the course materials possible. National Science Foundation grants support the project.

Texas's Department of Geography has provided courses in computer-assisted cartography since 1985 and in GIS since 1987. GPS has been included in courses on maps and map interpretation and GIS since 1990. As such, the need for GPS and GPS-related course sections was recognized early by the Geographer's Craft Project. Ever-increasing use of GPS within GIS technologies in the years since has supported this decision.

The Geographer's Craft team designed the first materials for the project not for the Web, but for distribution on a compact disc–read only memory (CD-ROM) platform. The team imagined that CD-ROMs might be distributed within the university's Department of Geography and to other interested geography departments at as low a cost as possible. The team investigated various software authoring systems and eventually selected a multimedia authoring package that operated under Windows and provided a platform for the production of complete multimedia presentations. The presentations allowed the user to navigate by clicking on-screen buttons and selecting materials of interest. The team developed a few test modules and some special scripts that made it possible to link resources throughout the Geographer's Craft modules. By the spring of 1994, several modules, including a glossary, a remote sensing module, and an early version of the GPS Overview, all aimed at CD-ROM distribution, had been produced.

Although these early project modules were effective, the time and care required to produce them were extensive. Data files designed to fit on 600-megabyte CD-ROMs were difficult to test on prototype systems with small hard drives (in 1992, 600-megabyte drives were uncommon), and large numbers of graphic files were difficult to transport between systems on standard 1.44-megabyte floppy disks.

THE WORLD WIDE WEB

The Web is a hypermedia-based Internet server concept developed by the European Laboratory for Particle Physics (more familiarly known by the acronym "CERN," from the earlier French name for the facility: Conseil Europèen pour la Recherche Nuclèaire) near Geneva. It allows users access to text, graphics, sound, video, and other media

linked to a single WWW document or "page." Transmitted over the Internet from server platforms to computers equipped with Web browser software packages, a Web page contains links to multimedia materials located anywhere on the Internet.

The primary Web document is the Hypertext Markup Language (HTML) script, which contains linking information in the form of the Uniform Resource Locator (URL). The URL is made up of a tag that specifies an Internet protocol followed by addressing information. Most Web browser packages allow for a multiplicity of protocols, from the well-established File Transfer Protocol (FTP) to the Web-specific Hypertext Transfer Protocol (HTTP). Following the protocol type, the URL contains location information in the form of Internet address and computer directory, subdirectory, and file name.

The URL for the GPS Overview, for example, is as follows:

http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html

Here the Internet protocol is "http." The Internet address is "www.utexas.edu," one of the University of Texas Web servers. On the computer at that Internet address is a directory for departments, "/depts." The Department of Geography uses the "/grg" directory for most of its materials. The Geographer's Craft Project uses a subdirectory, "/gcraft," and the "Lecture Materials and Discussion Notes" modules use the "/notes" subdirectory. The GPS HTML script, "gps.html" is stored in the "/gps" subdirectory. The URL then contains all the information needed by a Web browser package to request, access, and parse the script.

Once downloaded into the Web user's computer, the HTML script is parsed, and the result is displayed on the user screen. Other URLs, embedded within the HTML script, are highlighted on the user screen, indicating links to other information that may be accessed by the Web user simply by clicking a mouse button on the highlighted link. These URL links can point to WWW resources anywhere on the Internet. Any time another URL is activated by the Web user, the browser software requests this new resource by protocol, Internet address, computer directory, and file name. By keeping track of the list of URLs the browser software has accessed, the Web browser package can help the Web user navigate through the links by activating "back" and "forward" buttons or by choosing from a list of previously selected URLs. An important part of the WWW concept is that the browser software actually accesses the Internet only when it requests and downloads resources. While the user is viewing the materials, no demand is made on the Internet pathways.

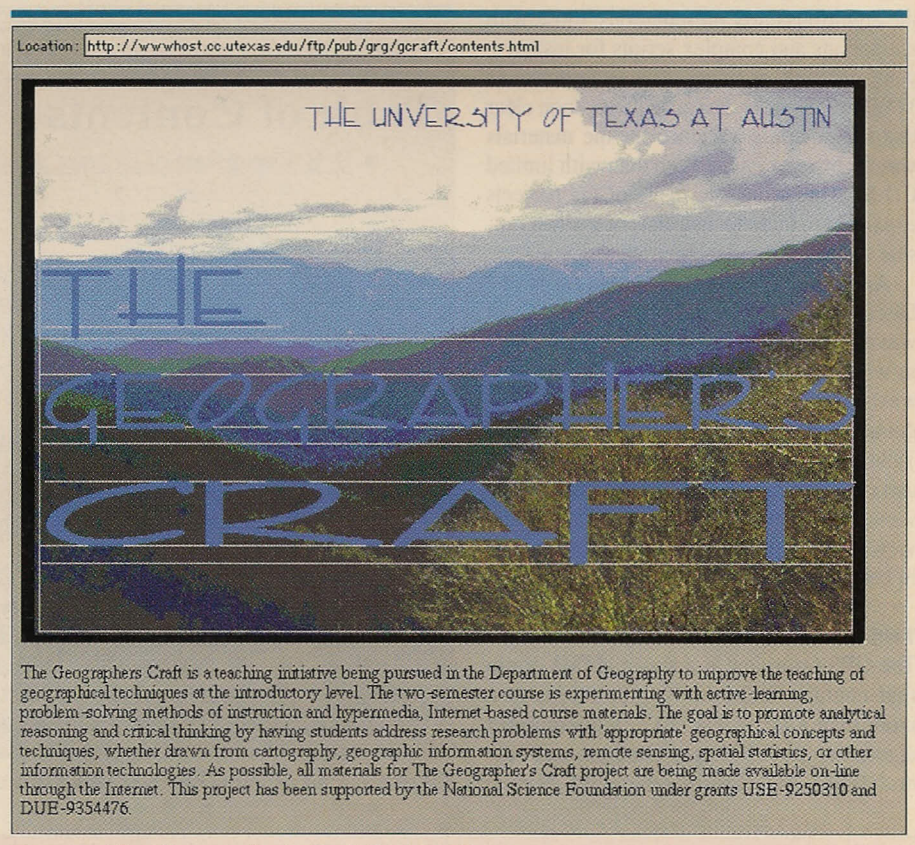

Figure 1. The Geographer's Craft Project title page

The WWW user can navigate from resource to resource, anywhere on the Internet, by following links of interest. This browsing process may result in a simple selection from materials stored on one computer directory, but more often the browsing process consists of dozens of requests for data files from many different servers located around the world.

Often a WWW browsing session begins with local resources, such as a page with links to some of the many WWW search tools. By establishing a connection to a search engine that could well be in a computer in Switzerland, the user might find a link of interest in Germany. Clicking on that highlighted link would result in downloading a script from Germany containing information and additional links. If one of those links points to a file in Japan, the user can then establish a connection to that node and download an image, a text screen, a video, or even an audio clip. Even though the browsing process is really one of establishing a series of individual Internet connections from the Web user's computer to each remote site in turn, it can often seem to the Web user as though the final node was reached by establishing an illusory connection from the local server through computers in Switzerland and Germany and on to Japan.

By the spring of 1994, the Web had begun to revolutionize many educational projects around the world, and Texas signed on in April of that year by opening a WWW server. During the summer of 1994, after some initial work that included the establishment of a Department of Geography page, the Geographer's Craft Project abandoned the CD-ROM as the target platform in favor of the Web. The ability to provide text, high-quality graphics, and a flexible interactive learning environment over an international network made the WWW a natural platform for the Geographer's Craft (see Figure 1).

The Department of Geography Home Page went on line in the summer of 1994. Using one of the first Web browsers and various word processors to develop HTML scripts without benefit of authoring tools (now available from many sources), the Geographer's Craft team rapidly converted existing scripts and existing multimedia materials to WWW hypermedia form. Only some of

the ambitious early presentations, those with animations and complex scripts for instance, were difficult or impossible to translate to WWW techniques. Because it was soon clear that the potential audience for the materials was far broader on the Web than with limited CD-ROM distribution, many of the projects expanded to include materials of interest outside of geography departments.

An outline for the Lecture Materials and Discussion Notes for the Geographer's Craft was one of the first pages to begin to be filled in with active links, and the GPS Overview was one of the first completed modules, going on line in August 1994. By September 1994, the GPS Overview had links to two associated pages, the Geodetic Datum Overview and the Coordinate Systems Overview. The team added a Map Projection page in late October 1994.

THE GPS OVERVIEW

The GPS Overview is a single HTML script that contains links to 50 graphic images, more than a dozen text files with computer algorithms and GPS specifications, and several URLs pointing to other GPS-related

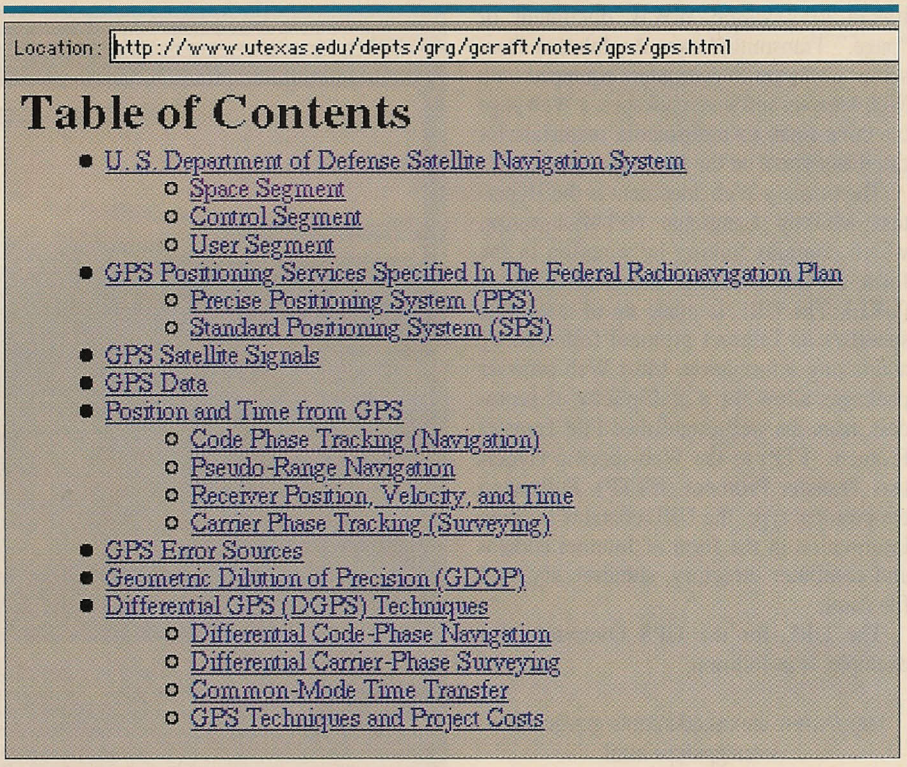

Figure 2. Part of the GPS Overview table of contents

sites. The title area, with an e-mail address for the project, has become an important part of the evolution of the overview, allowing it to mature from a one-way educational tool providing basic information for GIS users who needed GPS for their positioning projects, to an interactive learning site. E-mail responses to these materials have resulted in many substantive changes and additions to the pages. Two-way communication has allowed the GPS Overview to develop in unforeseen ways.

Organized much like a conventional document, the current version of the GPS page is designed around a table of contents (see Figure 2) that links the user to each section of the document. At the end of each section is a button that takes the user back to the table of contents. Within each section are buttons that allow the user to request graphic images or text files or to activate links to other WWW sites (see Figure 3).

The GPS Overview contains a description of the Space, Control, and User Segments, as defined by the U.S. Department of Defense, and a description of both the Precise Positioning Service and the Standard Positioning Service. It describes GPS satellite signals and the modulating bit streams — including the C/A-code, the P(Y)-codes, and the navigation message. The overview outlines GPS receiver fundamentals and many of the details necessary to produce position and time estimates from GPS signals. It explains code and carrier tracking and lists GPS error sources, including selective availability. The overview shows geometric dilution of precision (GDOP) in an example that includes the computational details for a position solution from four pseudoranges. It describes differential techniques and includes a cost-accuracy matrix for different types of GPS positioning.

Much of the information included in the GPS Overview is presented in the form of linked images. Oftentimes, with other sites, Web users on telephone lines and with personal computers are forced to wait many minutes as images of no interest to them are downloaded as part of a WWW page. With the GPS Overview, except for the two GPS-related bit-pattern images that begin and end the page, these "inline images" have been avoided because the images are linked as individual URLs, enabling the Web user to download only those that are of immediate interest. Viewing these images and other links make the process of using the page an interactive one (see Figure 4).

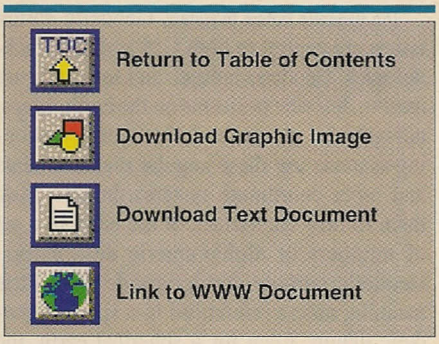

Figure 3. GPS Overview link buttons

RELATED PAGES

The four GPS-related pages all contain basic information that most *GPS World* readers will find familiar. The pages, originally designed for geography students, are now used by a broad range of GPS users from experts to novices.

The Geodetic Datum Overview. Geodetic datum issues are central to both GIS and GPS technologies. Geodetic latitude and longitude are used to describe positions on the earth. Maps, navigational charts, and electronic positioning systems use these angular measurements and other coordinate systems derived from them to map the surface of the earth to a set of numbers or alphanumeric designators. Geodetic latitude and longitude have little meaning unless referenced to a specific geodetic datum. Even for a spherical earth, the selection of a prime meridian — the zero point for the measurement of longitude — is an arbitrary one. The prime meridian has been defined by a plane perpendicular to the equator passing though Paris; Washington, D.C.; the Canary Islands; Greenwich, England; and dozens of other places more tied to national interests than to any natural origin. Once selected, a prime meridian can be combined with a latitude measurable from the position of the Pole Star above the local horizon and a spherical earth shape to form measurements suitable for approximate position, and somewhat risky marine navigation.

To be meaningful at the precision often called for by new positioning technologies, with GPS the most pervasive of these, geodetic coordinates (latitude and longitude) must be tied to a specific geodetic datum. Position errors of several hundred meters can

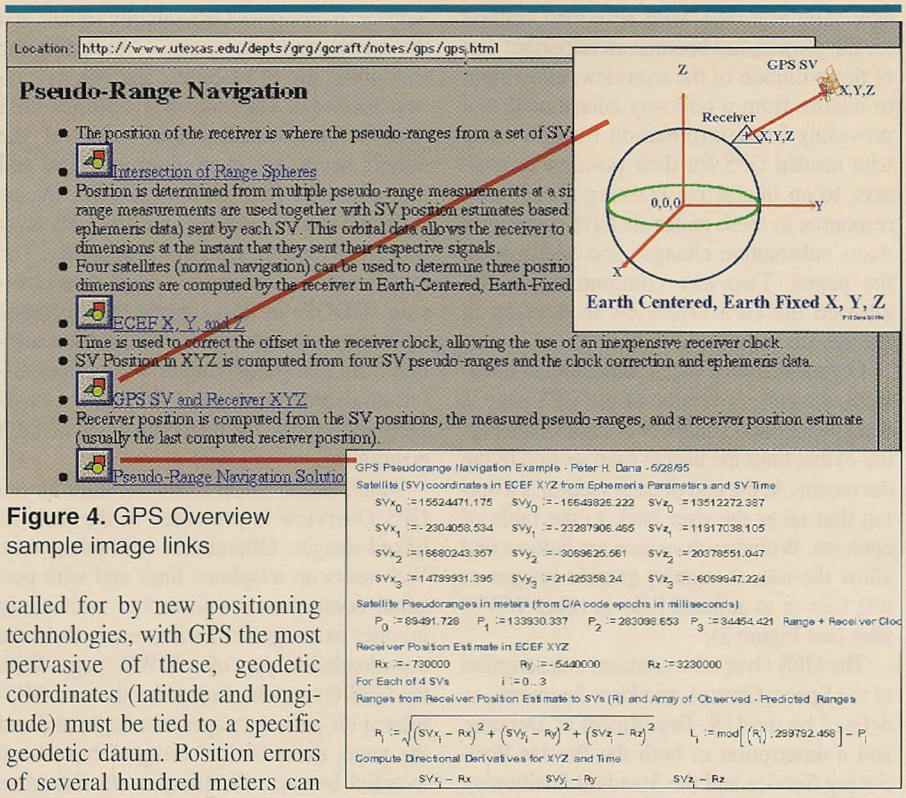

Figure 4. GPS Overview sample image links

result from using a latitude and longitude and assuming the wrong geodetic datum.

GPS receivers output position in three dimensions. The third dimension (height or elevation) is often the least understood. Early GPS receivers usually provided the user with latitude, longitude, and height above the reference ellipsoid. This meaning of *height* was often confused with height above mean sea level, height above a specific geoid model, or, in some cases, height above the topographic surface of the earth (altitude). For the WGS84 (World Geodetic System of 1984) geoid, the difference in geoid height and height above the reference ellipsoid can reach 100 meters. Some receivers now include a geoid height model and provide the user with an approximation of height above mean sea level. The Geodetic Datum Overview addresses these definitions and conventions and provides some basic insights into the meaning of various GPS-derived "height" parameters.

The Coordinate Systems Overview. Positions in latitude and longitude from GPS receivers are often converted by the receiver or by the user into other conventional reference coordinate systems. The Coordinate Systems Overview provides descriptions of geodetic latitude and longitude systems, the Universal Transverse Mercator system, military grid reference systems, various national grids, and other coordinate systems used by navigators and GIS users.

The Map Projection Overview. Often, GPS position data are used with maps. The Map Projection Overview describes the fundamental problem of mapping an ellipsoidal earth to flat paper or computer map displays. It shows some common map projections in graphic form and explains their fundamental characteristics. It also includes links to the Geodetic Datum and Coordinate Systems pages.

INTERACTIVE BENEFITS

From the beginning, e-mail addresses for the authors of the various modules were provided on screen. In addition, educational users, those who offer their pages free of charge, were encouraged to use the materials and to link the modules into their own pages. Consequently, since October 1994, the team has received more than 250 e-mail contacts from Web users. Many of these messages have helped shape the overviews. A note asking for source materials, which originated from an Internet domain in India, resulted in the addition of a reference section to the GPS page. Questions about selective availability have continued to arrive, resulting in several revisions of the GPS page. Permission to use images and text for educational projects is frequently requested and always given. In one case, a commercial site requested permission to mirror the pages. This request was refused because it was a commercial site with fees attached and also because mirroring pages requires that the source materials be placed on a remote computer, making it impossible to revise the materials without cooperation from the mirroring organization.

Because the WWW is evolving at the same time as the GPS Overview, messages are often received indicating problems with software platforms and software users. Hints to click on highlighted links and to upgrade to newer versions of client browser software usually help. When new browsers became available, the team replaced the older graphics with newer interlaced versions that worked with newer browsers. At the sugges-

tion of a Web user, the team implemented a "mailto" function in April 1995 resulting in a marked increase in responses.

Several requests for a printable version of the script spurred the production of a document, GPS.DOC that contains both text and graphics but does not contain the important hypermedia links to other materials and other sites. Web users have downloaded that six-megabyte document (now somewhat out-of-date) from Texas's WWW server many times. One e-mail message came from a user who had received a paper copy of the GPS Overview but had no idea what the URL was. That problem has been mitigated by the large number of search engines that will return the URL of the GPS Overview when prompted by the search term "GPS."

Questions, comments, and suggestions have arrived from 24 countries (identified by Internet domains) and from more than 250 different correspondents. They range from U.S. military nodes, educational institutions, private companies, and individual recreational GPS users. Questions have come from amusement park ride designers looking for ways to locate ride vehicles; national laboratories searching for ways to distribute time; and educators and students seeking source materials, clarifications of GPS details, and help with papers (which always seem to be due within days!).

Addresses of Related University of Texas Pages

Home Page, Department of Geography, University of Texas at Austin
http://www.utexas.edu/depts/grg/main.html

The Geographer's Craft Project
http//www.utexas.edu/depts/grg/gcraft/contents.html

Geodetic Datum Overview
http://www.utexas.edu/depts/grg/gcraft/notes/datum/datum.html

Coordinate Systems Overview
http://www.utexas.edu/depts/grg/gcraft/notes/coordsys/coordsys.html

Map Projections Overview
http://www.utexas.edu/depts/grg/gcraft/notes/mapproj/mapproj.html

The interactive nature of the Geographer's Craft Project has benefited several long-term projects. In one case, a user was able to develop a GPS mapping program with occasional help from the pages and two-way e-mail correspondence, resulting in a gracious acknowledgment in the Users Guide. In an ongoing discussion, a U.S. Army research laboratory has asked several questions about GPS GDOP, which have resulted in an expansion of the GDOP and navigation materials linked to the GPS page.

Most valuable to the project were the messages pointing out errors on the pages. One correspondent from a major GPS-related equipment manufacturer found some small but important mistakes in graphics related to time transfer. Others found errors of fact and omission that, once corrected, significantly improved the quality of the pages for everyone.

Whereas some e-mail messages resulted directly in changes to the pages, in most cases a simple question was asked and answered using e-mail. Often, though, an apparently "simple" question or comment would point to an error in the test or graphics. On occasion, an e-mail message would arrive requiring a change to some part of the page or within one of the hundreds of graphic images. Many times in response to an e-mail

message, a new graphic was produced, the file FTP'd to the university and checked using a WWW browser, and a thank-you note e-mailed back to the originator within minutes.

Another category of e-mail message notified us that the GPS pages had been linked into pages at other sites, and usually a convenient cross-linking resulted. As of the fall of 1995, the Geographer's Craft GPS Overview page has been linked to more than 30 sites worldwide. Reciprocally, the GPS page currently links six of the major GPS Internet sites, which in turn lead to hundreds of GPS-related resources.

Of course, interaction goes both ways. Responding to e-mail and maintaining the GPS-related pages takes about five hours each week. It is but a small part of the team effort that supports the Geographer's Craft Project.

CONCLUSION

The GPS Overview was started as a limited introduction to GPS for use within the Department of Geography at the University of Texas at Austin. Expanded in directions often dictated by the suggestions of WWW users, the GPS page is now averaging about 2,500 "hits" each week from Internet users around the world. The Geographer's Craft Project WWW pages form a growing and changing "electronic textbook" that accounts for about seven percent of the files and bytes transmitted by the "www.utexas.edu" WWW server.

The interactive nature of the Internet, the Web, and e-mail has resulted in the evolution of the GPS Overview from its original brief outline to its present state. With the rapid changes in the GPS user community since the system was declared operational in the spring of 1995, further changes, inevitably spurred by users, will guarantee the "healthy status" of the Geographer's Craft GPS Overview.

ACKNOWLEDGMENTS

The author would like to thank all of the people who have sent comments and suggestions to the GPS Overview, Dr. Kenneth E. Foote, and the entire Geographer's Craft Project team. ■

MANUFACTURERS

When the Geographer's Craft Project team first began working in the CD-ROM format, it used the ToolBook multimedia authoring package from **Asymetrix Corporation** (Bellevue, Washington). Once on the Web, the project initially used the Mosaic web browser, developed at the **National Center for Supercomputing Applications** (University of Illinois at Champaign-Urbana). Newer browsers include WinWeb, MacWeb, Netscape, and Internet Assistant. WinWeb and MacWeb were developed at the Microelectronics and Computer Technology Corporation by the Enterprise Integration Network Group, now doing business as the **TradeWave Corporation** (Austin, Texas). Netscape is a product of **Netscape Communications Corporation** (Mountain View, California). Internet Assistant is a product of the **Microsoft Corporation** (Redmond, Washington), which also makes Word 6.0 the program used to compose the GPS.DOC.