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*Ufficio federale della topografia (Switzerland)*. See Bundesamt für Landestopographie

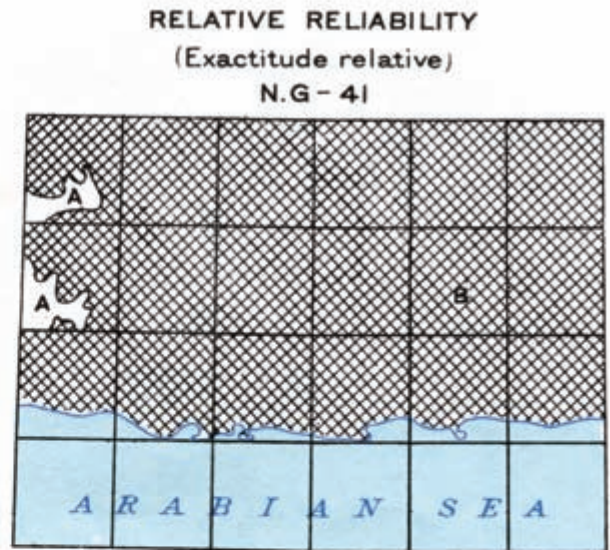
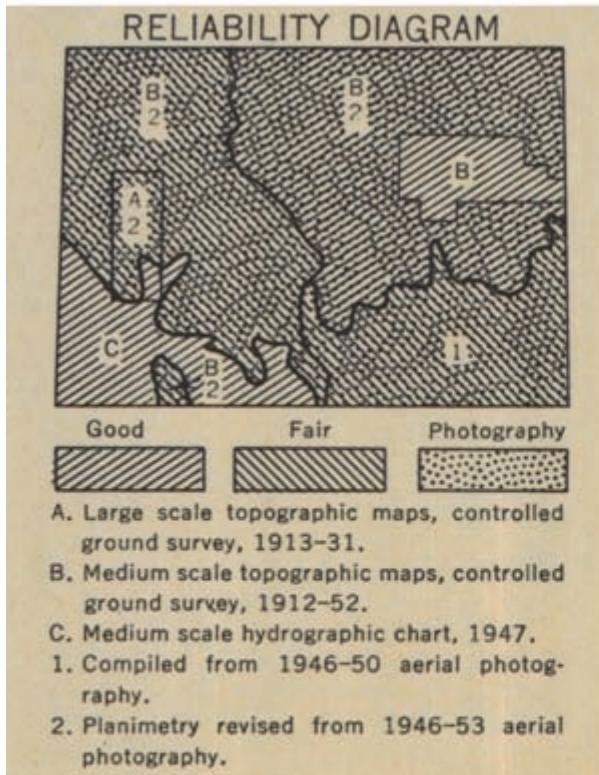
***Uncertainty and Reliability.*** During the twentieth century, concepts of map uncertainty and reliability changed substantially in definition, scope, and representation. At the beginning of the century, cartographers depicted incomplete or suspect data either with either blank spaces or decorative cartouches based on a graphical fantasy of Greek deities, cherubs, or personifications of the four winds. “Beyond this place there be dragons” might summarize these early representations of uncertainty, which left responsibility for traversing uncharted areas to the map user.

By midcentury emphasis had shifted to explicit representations of reliability. Maps compiled according to standardized production specifications such as the U.S. National Map Accuracy Standards, formalized in the 1940s, insured systematic control over the quality of cartographic data. Thresholds of horizontal and vertical accuracy used probabilistic guarantees (e.g., “90 percent of all well-identified points lie within  $\frac{1}{50}$  inch at scale”) to summarize data quality for an entire map sheet but could not validate individual map features. Reliability diagrams (fig. 1057) in the margins of maps produced by military agencies such as the U.S. Army Map Service (later renamed the Defense Mapping Agency) provided graphic depictions of source information, compilation date, and accuracy. The intention was to maximize trust in the reliability of paper maps compiled by federal agencies using ground survey and photogrammetry.

The advent of digital technologies democratized the use of spatial data and changed cartography dramati-

cally. Remote sensing platforms and automated data collection instruments began to multiply at the same time that computer storage costs dropped and processing speeds increased. When federal outsourcing of photogrammetric and other surveys as well as data conversion to private-sector contractors resulted in digital and analog data of varying quality a single centrally imposed accuracy standard became unrealistic. Arguments in favor of relaxing strict pass-fail thresholds led to the creation of extensive data dictionaries, which contained precise definitions of feature codes, geometry, and attribute categories for computer-formatted map data. Publication of data dictionaries became popular in the 1970s and 1980s. Although intended to help users assess a data set’s fitness for use in a given project, early data dictionaries lacked explicit descriptions of accuracy or uncertainty.

By the end of the twentieth century, downloaded digital data had replaced many, if not most, paper maps, and representations of uncertainty and reliability were subsumed by data quality reports. The result was a truth-in-advertising paradigm that used the actual amount of uncertainty to characterize a spatial data set. In addition to positional accuracy, both horizontal and vertical, uncertainty was extended to include reports of attribute accuracy, logical consistency (i.e., database validity), completeness, and lineage (processing chronology). Recognition that multiple editions of a data set carried important information about landscape histories and landscape change led to the adoption of currentness (that is, temporal characteristics) as a sixth uncertainty descriptor. In the United States, the Executive Branch imposed spatial data transfer standards (SDTS) on federal agencies and required each of these descriptors be included in a data quality report when data were to be shared among producers of federal data. European cartographers and agency officials also argued for data quality standards as an international spatial data infrastructure emerged and data dissemination over the Internet became commonplace (Guptill and Morrison 1995). With the transition to reporting multiple measures of uncertainty, the user was once again—as at the beginning of the century—responsible for choosing from available data most suit-



**A Rigorous survey 1916-32**  
 Levée rigoureuse 1916-32.

**B Reconnaissance survey 1889-1932**  
 Levée de reconnaissance 1889-1932.

MAP A

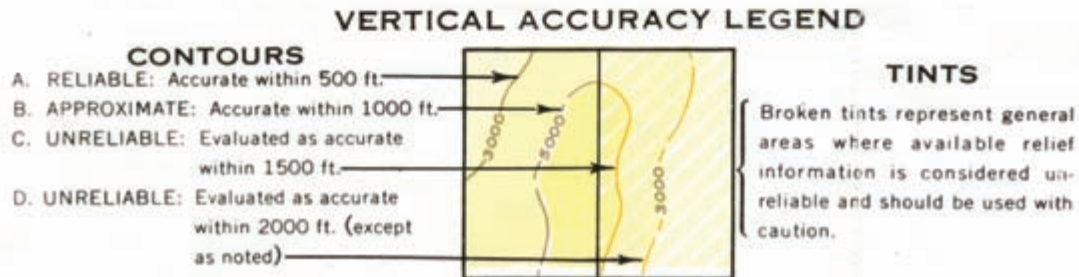


FIG. 1057. SEVERAL TYPES OF RELIABILITY DIAGRAMS FOUND ON TOPOGRAPHIC AND NAVIGATION MAPS. Upper left displays lineage and relative data quality for portions of a U.S. Army Map Service 1:250,000 map of an area in Southeast Asia; upper right shows information on dates of compilation and update for a 1:1,000,000 U.S. Army Ser-

vice map of a region in Iran and Pakistan; and bottom shows contour accuracy from a 1966 U.S. Air Force Jet Navigation Chart (JNC) at 1:2,000,000. Images courtesy of the Arthur H. Robinson Map Library, University of Wisconsin-Madison.

able products for a given mapping or analysis task. This time, though, the data quality reports provided information about the data, that is, metadata, explicitly intended to help users make an informed choice. Throughout this period, cartographers devised guidelines for map symbology, like the example in figure 1058, and recognized cognitive associations with specific types of uncertainty (Buttenfield and Weibel 1988; MacEachren et al. 2005).

Concurrent with these developments and also reliant on advances in computing technology, academic researchers focused on improving representations of un-

certainty and reliability in order to highlight localized spatial variations as well as support decision making and modeling. As metadata advocates Rodolphe Devillers and Robert Jeansoulin (2006, 18) argued, a decision based on spatial data should “be regarded as the conclusion of an informed and logical process, in which the treatment of uncertainty must be present.” Treatments in this context ranged from statistical analysis, such as the use of Monte Carlo simulation to establish probable ranges of variation, to data models and data architectures designed to record uncertain geographic phenom-

| QUALITY ASPECT<br>DATA TYPE                                   | POSITIONAL ACCURACY  | ATTRIBUTE ACCURACY        | LOGICAL CONSISTENCY         | CURRENTNESS                      | COMPLETENESS   | LINEAGE   |
|---|--|---------------------------|-----------------------------|----------------------------------|--|---|
| DISCRETE<br>Points and Lines                                  | Size<br>Shape  | Value<br>Color Saturation | Value<br>Shape              | Color Saturation                 | MAPPING METHODS:<br>reliability diagram,<br>misclassification matrix | MARGINALIA:<br>processing algorithms and parameters,<br>compilation source, error indices |
| CATEGORICAL<br>Aggregation and Overlay<br>(grids and mosaics) | Texture<br>Value   | Color Mixing<br>Value     | <i>lack of error models</i> | Texture                          |  |   |
| Partition and Enumeration<br>(metric class breaks)            | <i>not meaningful</i>  | Size                      | Size                        | <i>insert text in map margin</i> |  |   |
| CONTINUOUS<br>Interpolation<br>(surfaces and volumes)         | <i>no clear distinction between the two</i><br>Value<br>Color Saturation |                           | Size<br>Color Mixing        | Color Saturation                 |  |   |
| SYNTAX  | ← Graphical →  |                           |                             | ← Graphical / Lexical →          |  |   |

FIG. 1058. TAXONOMY OF CARTOGRAPHIC CONVENTIONS. Taxonomy of conventions or suggested practice to represent various aspects of data quality for discrete, categori-

cal, and continuous data. Some methods involve graphical and lexical elements. Gray boxes indicate quality aspects that are either illogical or redundant, or that lack a statistical basis.

ena characterized by gradients, indeterminate boundaries, or dynamically changing attributes (Burrough and Frank 1996). No longer should a representation simply be depicted or described; by the end of the twentieth century representations of uncertainty and reliability had matured from graphical caricature through various forms of map depiction, verbal description, and tabular reporting to become something worthy of modeling in and of itself.

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SEE ALSO: Accuracy in Mapping; Analytical Cartography; Kriging; Mathematics and Cartography; Scale; Standards for Cartographic Information; Statistics and Cartography

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**Underground Facilities Map.** See Facilities Map

**United Nations.** The many operations and activities of the United Nations (UN) depend on accurate maps. It is not surprising that the Cartographic Section was formed soon after the establishment of the United Nations. In order to stress the importance of cartography in member countries the UN established two additional units: (1) the United Nations Group of Experts on Geographical Names (UNGEGN) and (2) a series of United Nations Regional Cartographic Conferences (UNRCC). Just as the technological revolution of the late twentieth century forced changes on the discipline of cartography, by the turn of the century the UN became involved in

many strategic partnerships and collaborations with outside geospatial organizations to position itself for the cartography of the twenty-first century.

The Cartographic Section (UNCS)

From the beginning of the UN in 1945, discussions of boundary conflicts in the Security Council had to be supported by maps, and the council's resulting decisions on the location of the boundaries had to be described in such a way that it was possible to support the demarcation of boundaries on the ground. Such a map is shown in figure 1059. In order to serve the Security Council with adequate maps and other geographic information the UNCS was established as an independent section within the UN organization.

Over a half century earlier, at the fifth International

Geographical Conference, organized by the International Geographical Union (IGU) in Bern, Switzerland, in 1891, the German geographer Albrecht Penck advocated a plan to start an international map series of the world at the millionth scale. Although this project received acclaim, it was only sporadically supported. In 1949, the task of monitoring the project was handed over to the UNCS. However, the support for the project was limited and the project waned by the 1980s.

For its first fifty years the UNCS relied on traditional paper maps. One example is shown in figure 1060. By the end of the twentieth century, the UNCS, like other cartographic units in the world, was involved in the digital revolution in cartography and provided accurate and timely geospatial information not only to the UN Security Council and the UN Secretariat but also to such



FIG. 1059. UNITED NATIONS MAP, LINE OF WITHDRAWAL OF ISRAELI FORCES FROM LEBANON JUNE 2000. Produced by the UN Cartographic Section.

Image courtesy of the Cartographic Section, Dag Hammarskjöld Library, United Nations, New York.



FIG. 1060. MAP USE IN THE UNITED NATIONS SECURITY COUNCIL, 1979. A map showing Israeli settlements in the West Bank is displayed by Zehdi Labib Terzi, a representative of the PLO, as he addressed the Security Council 9 March 1979.

UN Photo/Yutaka Nagata. Image courtesy of the United Nations, New York.

UN departments as Peacekeeping Operations, Political Affairs, and Field Support. The UNCS also coordinates and supports the GIS (geographic information system) operations in the UN field missions. At the beginning of the twenty-first century, the UNCS was building and maintaining geospatial databases to support the needs of the UN departments and their field missions.

#### United Nations Group of Experts on Geographical Names (UNGEGN)

The second part of Penck's proposal to the 1891 IGU meeting was the adoption of standardized forms of geographical names. This part of the project was also adopted by the UN in 1949 and received the interest of the UN Statistical Office. The establishment in 1959 of the UNGEGN as a permanent advisory commission to the UN Economic and Social Council (ECOSOC) with the purpose of standardizing the transcription of geographical names is linked to the endeavors of one man, Meredith F. Burrill, a geographer who directed the U.S. Board on Geographic Names from 1943 to 1973 and assisted the military production program of maps of foreign countries by producing gazetteers for them. In 1955 Burrill suggested at the fifth ICOS (International Congress of Onomastic Sciences) conference in Salamanca that ICOS should encourage the UN to have a geographical names program. This happened in 1957, and at the request of the ECOSOC, Burrill wrote a statement describing a geographical names standardization program, which was circulated to all member countries. The result of this and of resolution 11 of the

first UNRCC for Asia and the Far East was that the UN established an ad hoc committee of geographical names experts (ECOSOC Resolution 715A [XXVII], 23 April 1959). This group convened for the first time in New York, 20 June to 1 July 1960, chaired by Burrill with André Pégorier from France as rapporteur. The result was an advisory statement, approved by the ECOSOC in 1964, to have a UN Conference on the Standardization of Geographical Names. Following an agenda-setting meeting in 1966 by the group, the conference was held 4–22 September 1967 and attended by 111 representatives from fifty-four countries. In its resolutions, later accepted by the ECOSOC, it advised the creation of a permanent UN Group of Experts on Geographical Names. This permanent group was chaired by Burrill until 1977.

The tasks of the UNGEGN were to convene a quinquennial conference on the standardization of geographical names, provide continuity for the work between conferences, carry forward the program of cooperation, and monitor the implementation of the resolutions adopted at the conferences (table 56). The UNGEGN conferences have the mandate to provide a forum with the purpose of encouraging both national and international standardization of geographical names, promoting international dissemination of nationally standardized geographical names, and adopting single transliteration (romanization) systems for the transcription of all geographical names from non-Latin writing systems into the Latin alphabet. A further mandate was added at the end of the twentieth century: the incorporation of standardized geographical names into the national and international geospatial data infrastructures.

The organizational structure chosen for the UNGEGN consisted of a matrix of linguistic-geographical divisions (e.g., Nordic division, Dutch- and German-speaking division) and working groups addressing specific topics (e.g., education and training, terminology, lists of coun-

TABLE 56. UNGEGN conferences

| Year | City     | Chair (nationality)                 |
|------|----------|-------------------------------------|
| 1967 | New York | Meredith F. Burrill (United States) |
| 1972 | London   | H. A. G. Lewis (United Kingdom)     |
| 1977 | Athens   | L. Mavridis (Greece)                |
| 1982 | Geneva   | Dirk Peter Blok (Netherlands)       |
| 1987 | Montreal | Jean-Paul Drolet (Canada)           |
| 1992 | New York | Abdelhadi Tazi (Morocco)            |
| 1998 | New York | P. E. Raper (South Africa)          |
| 2002 | Berlin   | Klaus-Henning Rosen (Germany)       |
| 2007 | New York | Helen Kerfoot (Canada)              |

try names). In the divisions, cooperating countries help each other implement the resolutions. Individual experts collaborating in the working groups define topics that are of importance to all divisions. The number of working groups has gradually increased. Working groups on Names of Undersea and Maritime Features and on Extraterrestrial Topographic Names, established in 1970, submitted their final reports in 1987. The working groups in 2000 were: Working Group on Country Names; Working Group on Toponymic Data Files and Gazetteers; Working Group on Toponymic Terminology; Working Group on Publicity and Funding; Working Group on Romanization Systems; Working Group on Training Courses in Toponymy; Working Group on Evaluation and Implementation; Working Group on Exonyms; Working Group on Pronunciation; and Working Group on the Promotion of Recording and Use of Indigenous, Minority and Regional Language Group Geographical Names.

Highlights since its creation in 1967 include the UNGEGN's publication of a glossary of technical terminology for the standardization of geographical names (Kadmon 2002). Toponymic guidelines, explaining the peculiarities of geographical names within a given country, have been produced for over thirty countries. Also noteworthy is a series of international training courses in toponymy, first held in Cisarua, Indonesia, in 1982, and sponsored annually since 1987 by the Pan American Institute of Geography and History (PAIGH)/Instituto Panamericano de Geografía e Historia (IPGH) in Latin American countries. Another important achievement by the UNGEGN is the standardization of romanization systems, realized by the UNGEGN Working Group on Romanization Systems. Beginning in May 1988 the *United Nations Group of Experts on Geographical Names Newsletter* was published by the UN Department of Technical Cooperation for Development Issues. In 1994 the UN Department for Development Support and Management Services continued the publication, and since 1997 the newsletter has been directly published by the UNGEGN secretariat.

#### United Nations Regional Cartographic Conferences (UNRCC)

ECOSOC resolution 131 (VI) of 19 February 1948 called for coordination of cartographic services within the UN organization and for development of close cooperation with cartographic services of member state governments. The resolution recommended that governments of member states stimulate surveying and mapping of their national territories and that the UN secretary-general take appropriate action to further such efforts. A Committee of Experts on Cartography was appointed by the secretary-general to study the problem and advise

upon the means of its implementation. The committee meeting in March-April 1949 recommended the convening of regional cartographic conferences as an effective means to attain the objectives set forth in the resolution. At its ninth session the ECOSOC noted the report of the committee and requested that the secretary-general consult with governments concerning the early calling of such meetings.

ASIA AND THE FAR EAST. An impetus was given to the project when the government of India offered to act as host at the first conference for Asia and the Far East. Many governments expressed their desire to participate in the conference and proposed agenda items. The ECOSOC, after consideration of this response, adopted resolution 556 (XVIII) on 27 July 1954 to install regional cartographic conferences for Asia and the Far East to be held every three years (table 57).

At the suggestion of the Australia New Zealand Land Information Council (ANZLIC) a resolution by the thirteenth UNRCC-AP, Beijing 1994, called for the es-

TABLE 57. UN Regional Cartographic Conferences, Asia and Far East, Asia and the Pacific

| UN Regional Cartographic Conferences for Asia and the Far East |                         |
|--|-------------------------|
| 1955 (15–25 February)  | Mussoorie, India        |
| 1958 (20 October–1 November)                                   | Tokyo, Japan            |
| 1961 (27 October–10 November)                                  | Bangkok, Thailand       |
| 1964 (21 November–5 December)                                  | Manila, the Philippines |
| 1967 (8–22 March)  | Canberra, Australia     |
| 1970 (24 October–7 November)                                   | Tehran, Iran            |
| 1973 (15–27 October)   | Tokyo, Japan            |
| 1977 (17–28 January)   | Bankok, Thailand        |
| UN Regional Cartographic Conferences for Asia and the Pacific  |                         |
| 1980 (11–22 February)  | Wellington, New Zealand |
| 1983 (17–28 January)   | Bangkok, Thailand       |
| 1987 (5–16 January)  | Bangkok, Thailand       |
| 1991 (20–28 February)  | Bangkok, Thailand       |
| 1994 (9–18 May)  | Beijing, China          |
| 1997 (3–7 February)  | Bangkok, Thailand       |
| 2000 (11–14 April)   | Kuala Lumpur, Malaysia  |
| 2003 (14–18 July)  | Okinawa, Japan          |
| 2006 (18–22 September)   | Bangkok, Thailand       |

tablishment of a Permanent Committee for Geospatial Infrastructure in Asia and the Pacific (PCGIAP). The mandate of the committee is to support the development of national geospatial data infrastructures in order to obtain a harmonized geospatial data infrastructure for the region. The committee convened its inaugural meeting in Kuala Lumpur in May 1996 and initiated yearly meetings. The committee reports to UNRCC-AP, and every third year the PCGIAP meeting and the UNRCC-AP conference are co-located.

**AFRICA.** The success of the UNRCC for Asia and the Far East encouraged the ECOSOC to also prepare regional cartographic conferences in Africa. From 1963 until the 1990s nine such conferences were hosted by the Economic Commission for Africa (ECA) at the UN headquarters in Addis Ababa, Ethiopia. Since 1999 the regional cartographic conference for Africa has been part of the UN-ECA Committee for Development Information (CODI) and its subcommittee on geoinformation. CODI-Geo meets every second year and has organized its work into several working groups.

**THE AMERICAS.** Noting the success of the regional cartographic conferences, the ECOSOC, at its fifty-sixth session, 1974, adopted resolution 1839 (LVI), which “requests the Secretary-General to make the necessary arrangements to convene the First United Nations Regional Cartographic Conference for the Americas during the first quarter of 1976” (table 58).

In 1997, at the sixth UNRCC for the Americas, the delegates recognized the rapid emergence of the geospatial data infrastructure and its potential to maximize the benefits of geographic information for sustainable development. They recommended the establishment of a Permanent Committee for the Infrastructure of Geospatial Data of the Americas (PCIDEA). At a meeting in Aguascalientes, Mexico, in March 1998, the preliminary establishment of the PCIDEA was accomplished.

TABLE 58. UN Regional Cartographic Conferences, the Americas

|                            |             |
|----------------------------|-------------|
| 1976 (8–19 March)          | Panama      |
| 1979 (3–14 September)      | Mexico City |
| 1985 (19 February–1 March) | New York    |
| 1989 (13–27 January)       | New York    |
| 1993 (11–15 January)       | New York    |
| 1997 (2–6 June)            | New York    |
| 2001 (22–26 January)       | New York    |
| 2005 (27 June–1 July)      | New York    |

## Other UN Related Actions

**UN COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE.** The UN Committee on the Peaceful Uses of Outer Space was established in December 1959 by the UN General Assembly (Resolution 1472 [XIV]). It was a timely decision. Based on its first report, the General Assembly adopted a resolution that requested member states to report all launchings of satellites. In addition, it adopted a resolution that “outer space and celestial bodies are free for exploration and use by all States in conformity with international law and are not subject to national appropriation” (Resolution 1721 [XVI], 20 December 1961).

This early response by the UN to control the exploration of space created the fundamentals for the development of access to data from earth observation satellites. From the launch of Landsat 1 in 1972, society has benefitted from satellite data and remote sensing imagery for the production of cartographic products (Mack 1990). The United Nations Office for Outer Space Affairs (UNOOSA) located in Vienna, Austria, is responsible for promoting international cooperation in the peaceful uses of outer space and space applications.

**STANDARDIZATION OF MAPS FOR NAVIGATION.** The International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO), UN suborganizations, have been instrumental in the development of charts for navigation by air and sea respectively. The Air Navigation Bureau (ANB) in Montreal is responsible for maintaining the standards for aeronautical charts. The International Hydrographic Organization (IHO) in Monaco maintains the standards for sea charts. The national mapping organizations (NMO) that produce the aeronautical and nautical charts for their respective territories are obligated to follow these standards. Since the 1990s the standards for electronic navigation charts (ENC) have been developed by the IHO in accordance with IMO performance standards for Electronic Chart Display and Information System (ECDIS).

**GLOBAL MAP.** At the UN meeting in Rio de Janeiro in 1992, where Agenda 21 was adopted, Japan offered to produce a global map in digital format that everyone would be free to use. The rationale for a global map is that climate phenomena like El Niño do not follow national boundaries. The map is a reference map for thematic maps on climate problems and in a way a continuation of the earlier mentioned International Map of the World. An International Steering Committee for Global Map (ISCGM) supervises the Japanese project. Each country provides its own data. In countries without facilities for digital mapping, the Japan Inter-

national Cooperation Agency (JICA) supports training given by the Geospatial Information Authority of Japan. By the end of 2007, 159 countries were participating in the project.

BENGT RYSTEDT

SEE ALSO: Geographic Names: (1) Social and Political Significance of Toponyms, (2) Applied Toponymy; International Map of the World; League of Nations

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**Urban Mapping.** Urban cartography is the mapping of all spatially representable aspects of cities and the distinctively urban life within them at all relevant geographical scales, from individual structures and activities in particular places to the global distribution of urban land cover. In formal terms this encompasses all the property parcels, buildings, streets, and other corridors of movement that constitute an urban built environment. In functional terms it reflects the strong differentiation of settlement characteristics within small areas, massed concentration, highly specialized functional relationships, and socially determined spatial characteristics that distinguish urban areas from rural ones.

Maps of cities have been made since ancient times, yet the twentieth century is particularly notable in the history of urban mapping as the period in which it gained recognition as a distinct field of cartographic endeavor, with vast numbers and new types of maps appearing in response to the growing complexity and extent of urbanization worldwide. Urban mapping was an immediate beneficiary of the first cartographic revolution—the intellectual discoveries of the fifteenth and sixteenth centuries. At that stage, a fundamental shift in the human sensorium from oral to written and visual perception coincided with a transition in mathematics from abstract and theoretical interests to practical and commercial applications; the mathematization of the arts, especially with the adoption of perspective drawing; and the engagement of Ptolemaic discourse about the earth resulting in the incorporation in cartography of coordinate grids (Karrow 1999). These convergences created a profoundly fertile field for an expanding and socially relevant cartography across many sectors of human activity. In this intellectual setting, the principle behind urban cartographic imagery shifted historically (and in

viewpoint) from city profile to bird's-eye perspective to urban plan.

Urban mapping has been even more a factor in, and outcome of, the second cartographic revolution—the technocultural transitions of the twentieth century, culminating in their signature achievement, the digital approach to conceptualizing and producing maps for all manner of societal ends (Morrison 1989). As a result of this second revolution maps have become truly widespread and routine in everyday life and among ordinary people, and, while definitive measures are hard to come by, urban maps most likely make up a vastly greater proportion of all maps produced than in times past. Consequently, while the urban map as a plan view continues to be central to fulfilling most utilitarian needs, computer-driven carto-visualization has colonized many of the new media and spawned creative means of representing three-dimensional urbanscapes and incorporating the fourth dimension, time.

#### Changing Cultural Context of Urban Mapping

Developments in urban mapping worldwide in the twentieth century built upon the innovations and experience of the nineteenth century and to a considerable degree represent advances attributable to more or less continuous and cumulative changes. The advent and diffusion of the Industrial Revolution stimulated urbanization in Europe and North America that by the twentieth century had created greatly enlarged cities, many completely new urban places, and more urban complexity arising from the new scale and faster pace of urban life. These pressures produced problems of urban management that required increased mapping for measurement and planning as a prerequisite for their amelioration. As universities and government departments undertook research along scientific lines, new kinds of maps appeared to investigate and characterize urban conditions. Rising incomes and the emergence of mass education led to increased travel and broader cultural interests, raising the demand for maps of cities for navigation and exploration. Technological innovations such as photography, aerial survey, radiometry, and mechanical map production techniques broadened the scope and reduced the costs of city mapmaking. Cultural changes, such as increases in graphic literacy, mobility, and interest in identity and the significance of place, also fed the rise of a specialized urban cartography. The radical urbanization of many regions in the developing world over the last hundred years found many city governments ill-prepared to map their problems and resources, except where the legacy of colonial mapping provided some assistance.

The categorical scope of urban mapping in the twentieth century can be illustrated by a typology reflecting the variety of purposes urban maps fulfill, the agencies and



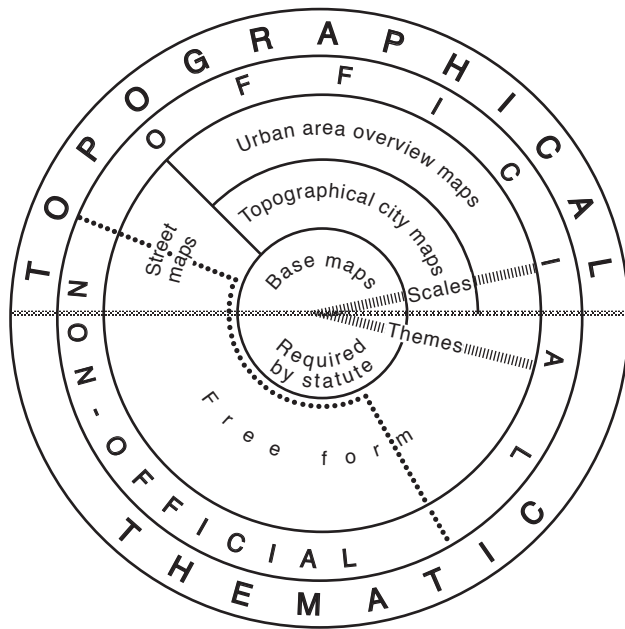


FIG. 1061. GORKI'S CONCEPTION OF URBAN CARTOGRAPHY.

Translated from Gorki and Pape 1987, 1:5.

individuals responsible for their creation and development, and their general content and design (fig. 1061). As with regional and world mapping, the biggest distinction is between topographical and thematic maps. Similarly, maps are produced by both official (public) and nonofficial sources. Most topographical maps have been made by government agencies because they stem from technically complex, time-consuming, and immensely costly surveys. Such maps present the general spatial structure of urban areas in the context of their site circumstances, particularly relief and hydrology. They come at a variety of scales and are overwhelmingly the product of official governmental sources. The larger the scale, the more likely such maps have been created by local authorities for more detailed orientation within their jurisdiction. Where official mapping took on a thematic character, it was when municipalities were responsible for infrastructure, taxation, property registration, zoning, and the like. Either this involves statutory maps required by law to administer programs and guide policy or broader social and economic mapping for better understanding of particular urban forces. This left a large sector of urban maps elaborating diverse themes usually by nonofficial sources, such as academic research centers and commercial firms serving a wide range of interests, both corporate and individual. Inevitably, thematic maps depended greatly on accurate topographic base map information produced by government bodies.

Detailed urban mapping in the early modern period was spurred by the desire to levy taxes based on property holding, giving rise to modern large-scale cadastral maps. The problems of urban growth led to the rise of urban planning, which gained official status in many advanced countries early in the twentieth century. This increased the need for very detailed topographical maps, and maps of land use, transportation, population distribution, health issues, and more, and resulted in the emergence of a cartographic specialty, urban mapping. As a distinct cluster of mapping activity, however, this specialty did not gain formal recognition until after World War II (Müller-Wille 1964; Gorki and Pape 1987).

### Phases of Change

No full account has yet been written of the history of urban mapping in the twentieth century, but it is possible to conceive of it as falling into three broad and necessarily overlapping phases. The first was essentially a continuation of the subject-matter, mapping techniques, and marketing methods of the late nineteenth century, which lasted in some respects well toward midcentury. This phase witnessed the modernization of field survey and hand techniques in map execution and production. The scope of urban topographical and cadastral mapping advanced particularly in countries with centralized bureaucracies in which professionalization slowly filtered down to the municipal level. Thematic mapping was more limited, but often most evolved among nonofficial interests, such as academic circles, social reform agencies, and some commercial firms. Examples would include maps depicting public health conditions, fire insurance atlases, and transit and tourist maps (such as the famous urban plans highlighting urban landmarks published by Baedeker). With the growth in demand for maps there was some loss of aesthetics, especially in the United States, but also a universal push to impart a modern look to maps by the 1920s. At the same time the first of the legally compulsory maps made their appearance, exemplified by new zoning maps for large cities, based on comprehensive land use surveys (Churchill 2004).

The second phase, evident as early as the 1920s and lasting in some respects well into the 1970s and 1980s, witnessed the widespread mechanization of traditional map design and production. Mechanical instruments replaced hand drafting for linework, symbols, and lettering. New materials, such as mylar and scribecoat, changed the artisan nature of mapmaking, and photography introduced new means of base map preparation and the reproduction of final artwork. The advent of aerial photography and photogrammetry radically accelerated the preparation of large-scale urban base maps, reducing costly fieldwork. At the same time, as urban thematic mapping became ever more varied and

complex, ingenious new methods were developed to show on maps conditions unique to the urban environment (figs. 1062 and 1063) (Raveneau 1972; Gorki and Pape 1987). The destruction of cities during World War II provided a decided stimulus to urban cartography, particularly in Germany and Japan, where urban planning for rapid reconstruction called for many new situation plans and cartographic projections (Mizuuchi, Katō, and Ōshiro 2008).

The third phase began in the immediate postwar period and continued through century's end, involving the development of the modern computer, the launching of earth-orbiting remote-sensing satellites, and the general digitalization of data capture and cartographic processing and production. This revolution, so profound for all types of mapping, was particularly significant for urban cartography because of the sheer welter of spatial data by then routinely collected and manipulated in order to produce maps of urban areas, a situation made only more complex by the voracious growth of cities worldwide (Jensen, Gatrell, and McLean 2005). An added dimension of this transformation was the diffusion of microcomputers, from desktop models to handheld digital devices, coupled with the rapid evolution of the Internet, which together with advances in user-friendly software made possible the electronic creation and transmission of online mapping and a seemingly infinite realm of interactive, customized maps of almost every conceivable kind (Gibson and Erle 2006). Because urbanization reached high proportions in many large countries worldwide, the vast bulk of such electronic mapping was inevitably urban oriented.

### Sequences of Urban Mapping

It is difficult to discern clear trajectories along which all types of urban mapping evolved during the twentieth century because so much cross-fertilization took place in rapid succession. It is even more difficult to characterize such trends worldwide because of regional differences in the cartographic legacies of the past. Nevertheless, some sequences and linkages can be highlighted that illustrate the profound shifts experienced during this century. Inevitably, they overlap with respect to purpose, sponsorship, technical character, and audience.

In 1900, most municipalities created and maintained basic orientation maps of their urban areas, as well as some kind of cadastral or real property maps for taxation and managing infrastructure. By 2000, most large cities produced a wide array of cadastral, land use, facilities, jurisdictional (political and administrative demarcation), and city and regional planning maps. Early on, transportation maps were frequently produced by the private operating companies, but as transport systems became more complex and integrated, eventually

under municipal ownership in most cases, such maps became official responsibilities, such as the iconic London Underground Map (see fig. 483). In some countries real property and fire insurance mapping remained largely in the private sphere, and with the advent of aerial photography specialized private firms, such as Fairchild Aerial Camera Corporation in the United States (beginning in 1920), contracted to provide a new generation of urban base maps for municipalities. Dedicated city planning departments became ever more common as the century progressed, and in Germany, especially during the rebuilding of cities bombed in World War II, elaborate thematic survey mapping was taken to a high level (see figs. 1062 and 1063 above).

Much urban mapping adopted by city planning agencies found its origin in academic research. Maps of disease outbreaks, population density, ethnology, and land use, for instance, were first published in scholarly journals, such as *Petermanns Geographische Mitteilungen*, or the studies of the Chicago School of urban sociology in the 1920s and 1930s. Over time, sophisticated land use studies in particular proved fundamental to urban analysis and planning (Bobek and Lichtenberger 1966; Pape 1977). Later in the century, additional perspectives made their appearance, such as the method of mapping the mental geography of cities (Lynch 1960). The growing urgency of coping with the physical deterioration, war damage, and social problems of cities led to major atlas compilations for individual urban areas, often based on detailed census data, such as the statistical *Atlas of London and the London Region* (1968) or the *Plan for New York City, 1969* (6 vols.). As data on urban conditions, physical and otherwise, emanated increasingly from government sources using costly instrumentation, urban mapping passed increasingly into the domain of multiagency scientific investigations, corporate processing firms, and hybrid, multiauthored cartographic products. By century's end, the European Commission Joint Research Centre, for example, at last explored ways to harmonize the different land use mapping systems of its member countries to establish European-wide standards for future urban sustainability (Lavalle et al. 2002). In China, meanwhile, uniform land use mapping regulations instituted by the central government yielded a remarkable cartographic document, *Zhongguo chengshi dituji* 中国城市地图集 = *Atlas of Cities of China* (2 vols., 1994), covering 450 urban areas.

National governments have long had an interest in urban mapping for military and security reasons, both offensive and defensive. Usually these have been contained within national topographical mapping programs, but special maps of cities for military targeting were common by World War II. In cases where large-scale urban maps were highly restricted by governments, other ob-

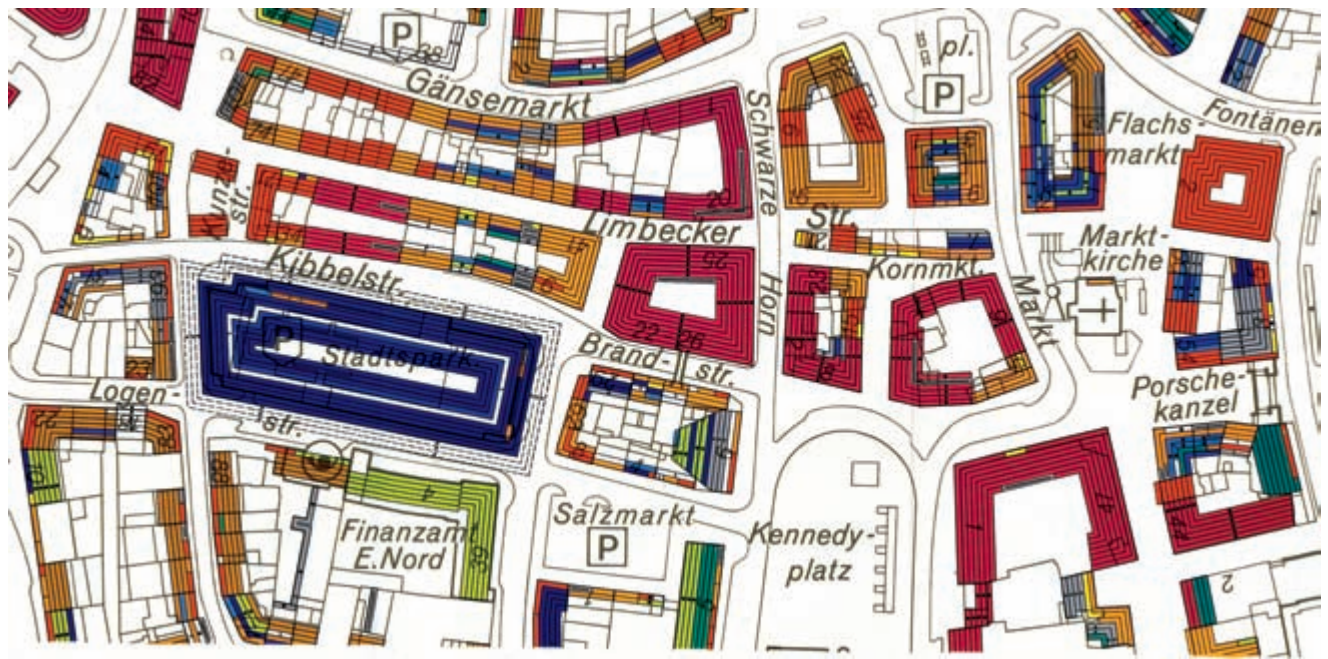


FIG. 1062. BUILDING USE (BY STORY) IN CENTRAL ESSEN, GERMANY, IN 1978. Detail from *Die Essener Innenstadt, Gebäudenutzung im April 1978*. Size of the entire original: 74.3 × 99.8 cm; size of detail:

24.5 × 49.9 cm. From *Die Essener Innenstadt: Analyse, Kritik, Probleme, Ziele, Ideen* (Essen: Amt für Entwicklungsplanung, 1980). Permission courtesy of Stadt Essen.

servers provided alternatives, as in the case of U.S. Central Intelligence Agency maps of cities in Communist countries (fig. 1064). During the Cold War it became well known that maps were sometimes selectively falsified to mislead unfriendly parties, as with topographic maps of strategic sites in the cities of short-lived East Germany (Brunner 2002, 168–69).

World War II had other consequences for urban cartography. Hermann Bollmann was so impressed by the rapid postwar rebuilding of devastated German cities that he devised artistically attractive bird's-eye views of many historic cities to document their revival (Hodgkiss 1973). The pictorial mapping genre had been around for centuries and continued in full force, especially for such magnificent capital cities as Paris (fig. 1065). But Bollmann's work, which continued from 1948 until the mid-1960s, touched a nerve that would come to be felt quite internationally regarding the significance of cultural patrimony for nations and their people. In the last third of the century, a steadily growing list of urban historical atlases attests to the deep reservoir of public interest in the unique visual character of cities. Some of these atlases are impressive assemblages of reproductions of old maps—*Atlante storico di Milano, città di Lombardia* (1989), for example—but others consist of newly designed thematic maps charting a city's spatial evolution, such as the *Atlas of Jerusalem* (1973). By far

the most ambitious program of historical atlas making is the multinational Historic Towns Atlas Programme, which began publishing in 1969, and by 2000 had published a staggering 317 volumes and fascicles covering towns and cities across Europe (Conzen 2008). Publishers also discovered a ready market for large-scale photo/map atlases, pairing same-scale topographical plan segments and aerial images of numerous major cities such as Venice (1990) and Rome (1991).

It is the digital revolution, however, that most transformed urban cartography in the twentieth century, in two profound ways—democratization and globalization. Google Maps enabled anyone with a computing device to access maps of any portion of the ecumene, and “mashups” (external data overlaid on Google Earth base imagery) permitted virtually unlimited do-it-yourself mapmaking (Gibson and Erle 2006). This led to urban mapping of unprecedented thematic variety and, not surprisingly, highly variable authority. At the same time, regular remote sensing of the earth's settlement patterns led to sophisticated measurement of urban growth patterns and changing urban dynamics never before possible (fig. 1066) (Gamba and Herold 2009). Monitoring of urban expansion in relation to land resources and environmental effects became routine at practically all scales from local to global, given the urgent questions concerning the sustainability of contemporary urbanization.



FIG. 1063. LEGEND TO FIGURE 1062.  
Size of the legend: 23.3 × 18.6 cm. Permission courtesy of Stadt Essen.

Whether the digital mapping products created during the twentieth century will survive intact and widely accessible as long as traditional paper maps, only time will tell.

MICHAEL P. CONZEN

SEE ALSO: Administrative Cartography; Land Use Map; Planning, Urban and Regional; Wayfinding and Travel Maps: Indexed Street Map

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FIG. 1064. DETAIL FROM CENTRAL MOSCOW, 1980, 1:15,000. The Kremlin and Red Square are shown. U.S. Central Intelligence Agency, Washington, D.C.  
Size of the original: 110 × 87 cm; size of detail: 10.3 × 8.4 cm. Image courtesy of the Geography and Map Division, Library of Congress, Washington, D.C.

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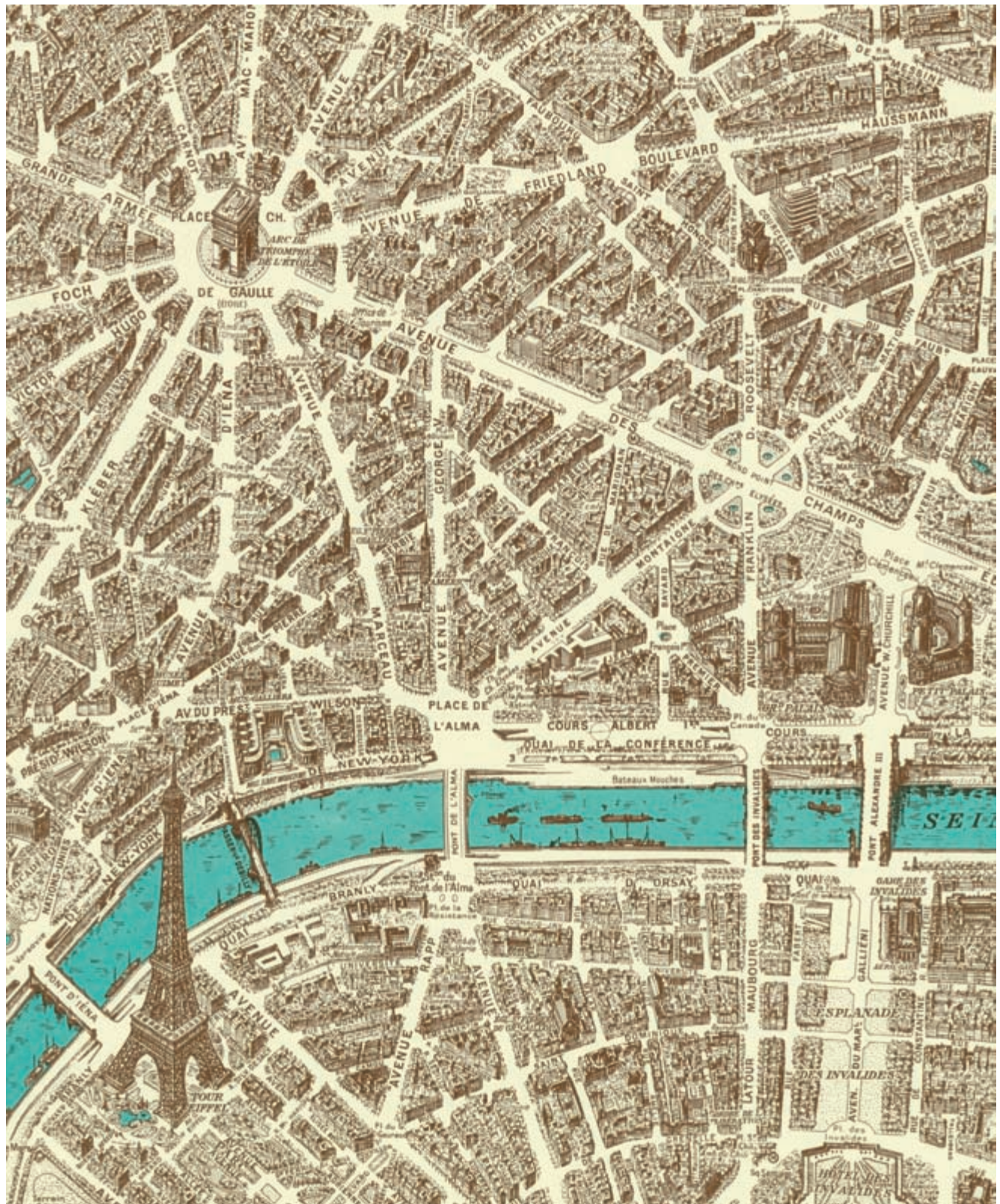


FIG. 1065. DETAIL FROM A BIRD'S-EYE VIEW OF CENTRAL PARIS, 1920–40, 1:8,000. *Plan du centre de Paris à vol d'oiseau* was inspired by Michel-Étienne Turgot's 1739 plan of Paris and was drawn between 1920 and 1940 by Georges Peltier (Paris: Blondel La Rougerey, 1981, c1959).

Size of the entire original: 66 × 93 cm; size of detail: 30 × 24.8 cm. Image courtesy of the American Geographical Society Library, University of Wisconsin–Milwaukee Libraries.



FIG. 1066. DETAIL OF NILE DELTA FROM COMPOSITE IMAGE OF THE WORLD AT NIGHT, 2000. Data from the OLS (Operational Linescan System) instrument on a DMSP (Defense Meteorological Satellite Program) satellite, provided by Christopher D. Elvidge, NOAA-NESDIS National Geophysical Data Center. Image courtesy of the National Geophysical Data Center, NOAA.

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**Urban Planning.** See Planning, Urban and Regional

**U.S. Army Corps of Engineers.** The U.S. Army Corps of Engineers (USACE) was founded in 1779 to protect America's shores by keeping ports open and building forts to defend the harbors. By the close of the twentieth century its responsibilities had expanded substantially. According to coastal scientist Orrin H. Pilkey and coauthor Katherine L. Dixon (1996, xi), the Corps of Engineers "builds seawalls, pumps up beaches, dredges inlets, stabilizes inlets with long rock jetties, gives permission to others to do any of these activities, and more." The

Corps has also prepared maps with detailed descriptions of the soils, terrain, topography, transportation, and other practical aspects of military installations. Many of its older maps became useful late in the century for cleaning up environmental hazards.

USACE mapping has typically reflected the design and construction requirements of specific projects and thus has been produced at larger scales than mapping by the U.S. Geological Survey (USGS). Even so, the mapping procedures used by the Corps since World War II were not much different from those of other federal and state mapping agencies. Organized according to geographic districts within and outside the United States, the Corps has produced maps for feasibility studies and navigation project condition surveys as well as geologic data maps and dynamic digital maps, among others.

During World War I and World War II, the USACE mission was expanded to cover the mapping of international regions (fig. 1067). The Army Map Service was formed during World War II from the consolidation of the Engineer Reproduction Plant, the Map Library, and the Cartographic Section of the War Department's General Staff. Initially, many of the maps produced were revisions of existing maps. Later, the cartographic work was changed to medium- and small-scale maps based on larger-scale native maps used as source materials. By the end of the war, considerable effort was devoted to large-scale mapping by stereo-photogrammetric methods.

In the early 1950s, the USACE produced 10,000,000 map sheets for the war in Korea. In 1954, the 29th En-



FIG. 1067. WORLD WAR I MAPMAKING. An officer and enlisted man, students in topography, possibly from the 29th Engineer Battalion TOPO, are making a map in Saumur, Maine-et-Loire, France, during World War I. Image courtesy of the U.S. National Archives, Washington, D.C. (111-SC-41377).

gineer Battalion TOPO absorbed the 64th Engineer Battalion TOPO and provided topographic support to combat commands in Southeast Asia. By May 1966, the unit was the primary map production unit for U.S. forces in Vietnam.

During the space age, geodetic investigations by the USACE determined the earth's size and shape and included precise geodetic and astronomic surveys in many remote areas. USACE geodesist Irene K. Fischer helped determine the parallax of the moon, and the Corps participated in the Vanguard artificial satellite program with the Army Signal Corps and the Navy to obtain astronomic, geodetic, and gravimetric observations to determine the size and shape of the earth, intercontinental relationships, and gravity fields. Alden P. Colvocoresses, who served in the USACE from 1941 to 1968 before joining the USGS, collaborated with John Parr Snyder in developing the Space Oblique Mercator projection, which was used with Landsat data in the late 1970s to make the first satellite image map of the United States.

More purely military endeavors included J. N. Rinker's terrain analysis skills, which led the field commander in the Gulf War (Operation Desert Storm) in 1991 to choose a classic flanking maneuver known as the "left hook"—a strategic surprise that resulted in the rapid defeat of Iraqi forces (see fig. 352). The USACE entered the twenty-first century with the diverse mission of satisfying the country's geospatial needs in both military and civilian arenas.

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SEE ALSO: Hazards and Risk, Mapping of; Military Mapping by Major Powers: United States; U.S. Geological Survey

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**U.S. Census Bureau.** U.S. Census Bureau, formally the Bureau of the Census, is an agency of the U.S. federal government that produces a wide variety of statistical information, including maps, for the public and private sectors. The U.S. Constitution states that "actual Enumeration shall be made within three Years after the first Meeting of the Congress of the United States, and within every subsequent Term of ten Years, in such Manner as they shall by Law direct" (art. 1, sec. 2, 1787). Based on this constitutional requirement that an actual enumeration serve as the basis for apportioning seats in the U.S. House of Representatives, the Census Bureau has

conducted a census of population every ten years since 1790.

The Census Bureau is administratively part of the federal Department of Commerce. Its data and statistics are necessary for the functioning of federal programs whose services are allocated on the basis of population. The same is true for some state and local programs. The decennial count is of major importance not only to these programs but also to elected officials at all levels of government whose districts are defined on the basis of population. The use of Census Bureau data by the private sector is likewise immense. Not only is the U.S. Census Bureau the federal government's largest statistical agency, but in the data collection phase of the 2000 Census alone, it produced in excess of eight million individual maps.

In fulfilling its mission to produce reliable statistics that provide nationwide coverage, the Census Bureau has created numerous technological and statistical innovations. Its most important innovations outside of geography and cartography have been in large-scale data processing and statistical sampling methodologies. Punch cards and electrical tabulating machines were developed for processing the 1890 census data by Herman Hollerith, who discovered the need for better tabulating techniques while employed by the Census. Later, the nation's first nonmilitary electronic computer, UNIVAC, was utilized to tabulate results of the 1950 census. New statistical sampling methods, utilizing probability theory to select respondents and to estimate the statistical reliability of tabulated data, were introduced in the 1940 census. Once these innovations and others in the areas of data collection and data formatting practices were introduced, they were quickly adopted in private- and public-sector practice as well.

Regulations governing the collection of statistics by the Census Bureau, formally codified in "Title 13—Census" of the *United States Code*, require that statistical information remain confidential, meaning that no individual, household, or organization can be identified or information about them be inferred from the statistics themselves. Important consequences for the geographic and cartographic presentation of statistics result from these regulations, especially when the capabilities of modern geographic information systems (GIS) are available. These confidentiality safeguards often result in the loss of place-specific geographic detail that could aid in a better understanding of the nation's human geography, especially with regard to settlement, population, and economic topics.

The general geographic and cartographic requirements—to locate and interview every household, person, business firm, or other unit of observation at a specific geographic location, usually a street address; add geo-

graphic identifiers when processing responses; and report the statistical information in tables, maps, etc., with geographic units that are useful to users—have remained essentially unchanged throughout the Census Bureau's history. The manner in which these requirements have been met has changed radically and represents an excellent case study in the changing technology throughout two centuries. The transformation of the nation from four million residents along the Atlantic seaboard to 300 million residents (2006) spread over a continental-scale country of 3.5 million square miles dramatically increased operational demands for collecting and processing data. Changing societal demands have continuously called for increased types of statistical information in ever greater geographic detail. By century's end, geographic operations in data collection and data processing included the production of detailed local-area maps to facilitate data collection in the field and the creation of enumeration areas, which facilitate spatial bookkeeping operations and provide basic spatial units for forming geographic units for tabulations.

From the censuses of 1790 through 1870, administrative districts for federal marshals served as enumeration districts. Under the direction of Henry Gannett, enumeration areas were created that accounted for both human settlement and physical landform features and that were displayed on maps at a scale of 1:2,500,000. In improving the bureau's place-specific information capacities during subsequent censuses, the number of enumeration areas increased to 70,000 in 1910, 240,000 in 1960, and about 8 million in 2000. The 2000 census aggregated these basic spatial units into geographic units for tabulations that ranged in scale from the block group, with between 300 and 3,000 residents, to the nation as a whole.

Prior to high-speed computers, detailed local-area maps were obtained from the best available sources, such as local governments, state highway departments, Sanborn fire insurance maps, and U.S. Geological Survey topographic quadrangles. Beginning with the 1970 census, detailed information from these sources was digitized to create reference maps that displayed geographic tabulation units in a new medium, the Metropolitan Map Series, which covered 100,000 square miles of the most intensively settled portions of the country. For the 1990 census, the Census Bureau introduced the TIGER (Topologically Integrated Geographic Encoding and Referencing) database for managing these geographic operations and for creating reference maps that displayed the geographic units in which statistics were tabulated.

The evolution of geographic units serving to report statistical information mirrors the historic increase in expectations for data in general—an increased variety of

units with ever greater geographic specificity. In 1790, the census only required states as geographic units, as it was conducted explicitly to allocate seats in the U.S. House of Representatives and apportion the Revolutionary War debt. The number of geographic units provided by the Census Bureau increased dramatically throughout the nineteenth and twentieth centuries. These include large-scale subnational regions (e.g., New England, the Midwest, and the Mountain West); physiographic regions to link the nation's human and physical geographies; units to represent residential settings, such as neighborhoods and community areas; units to represent settlement areas, such as populated places, urbanized areas, and metropolitan areas; and units to represent school districts and voting districts for state legislatures and the U.S. Congress mandated by U.S. Public Law 94-171, enacted in 1975. At the end of the twentieth century, the visual representations of current geographic units were available electronically or as printed reference maps.

The Census Bureau's history of innovative statistical cartographic products spans the nineteenth and twentieth centuries. The first map in a Census publication was for the 1850 census and simply titled *United States—1854*. This map, published in J. D. B. DeBow's *Statistical View of the United States* (1854), announced cartographically that the United States formally controlled the midsection of the North American continent from coast to coast. The cartographic portrayal of census results from 1870 through 1920 was presented in a series of six statistical atlases, the earliest of which served as the United States' first national atlas. Through 1910, these atlases included one of the federal government's most spectacular cartographic achievements—a series of maps depicting the geographic evolution of the nation's expanding and increasingly intensifying settlement census-by-census from 1790. The Census Bureau also pioneered the production of maps by computer-assisted cartography. Examples include maps in the Graphic Summary series, issued every five years with the *Census of Agriculture* beginning in 1969, and the atlas series *Urban Atlas: Tract Data for Standard Metropolitan Statistical Areas* (1974–75), which presented 1970 census tract-level statistical maps for the nation's sixty-five largest metropolitan areas. For that same census, Census Bureau cartographers produced a revolutionary depiction of the nation's settlement system, *Population Distribution, Urban and Rural, in the United States: 1970* (1973), known more popularly as the Nighttime Map. Versions of this map have appeared with each subsequent census (fig. 1068).

From the very first decade of its existence, the federal government of the United States has collected statistics and made them publicly available. The operational challenges presented to the Census Bureau in producing nationwide statistical data projects such as the decennial



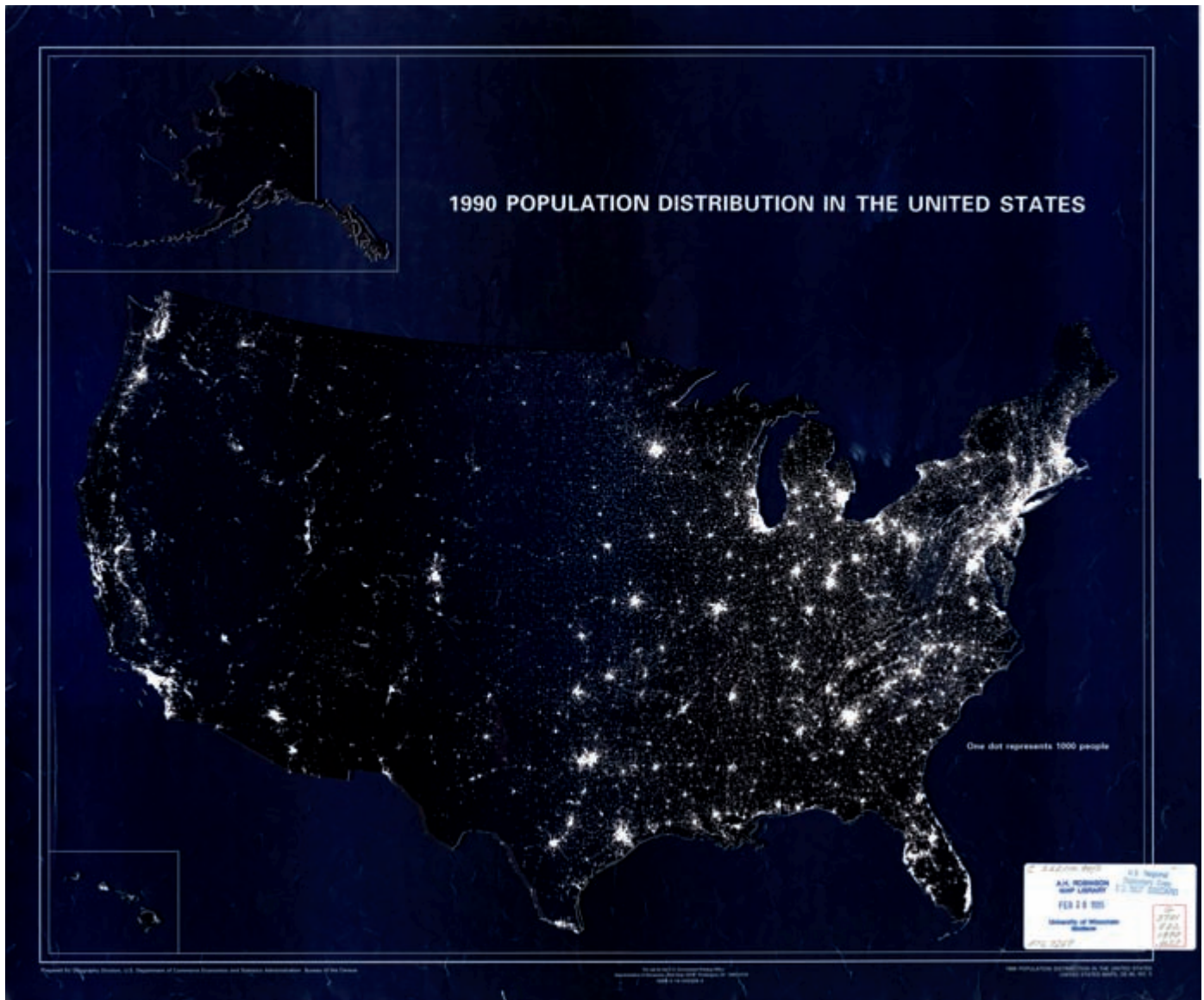


FIG. 1068. 1990 POPULATION DISTRIBUTION IN THE UNITED STATES. Prepared by Geography Division, U.S. Department of Commerce Economics and Statistics Administration, Bureau of the Census, United States Maps, GE-90, No. 5.

Size of the original: 55.2 × 65.5 cm. Image courtesy of the Arthur H. Robinson Map Library, University of Wisconsin-Madison.

census resulted in countless innovations in geographic operations and cartographic representation. Once instituted at the Census Bureau, these innovations readily crossed over into the private and public sectors both within the United States and elsewhere in the world. Census Bureau mapping has not only transformed the nation's visualization of its statistical base of knowledge but the very means by which we are capable of creating it and our expectations from it.

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SEE ALSO: Administrative Cartography; Bivariate Map; Census Mapping; Gannett, Henry; Race, Maps and the Social Construction of; Urban Mapping

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**U.S. Geological Survey.** Founded in 1879, the USGS became the principal general-purpose land mapping agency in the U.S. federal government for the exploitation of the nation's natural resources in the decades following the Civil War. USGS cartographers entered the twentieth century rooted in techniques that reflected existing nineteenth-century technologies and work processes of field-based surveying and chromolithography (McHaffie 1993). By the close of the twentieth century USGS mappers sat at workstations of powerful computing devices, their eyes focused on remotely sensed imagery collected by space-borne sensors, set to a new task: creating a detailed digital map of the country that is never more than seven days out of date (McMahon et al. 2005). The contribution of the USGS to cartography through the century, while primarily focused on topographic mapping, included involvement in many projects that were significant within the discipline.

Through the early twentieth century the agency focused on general-purpose topographic mapping as necessary support for geological surveys, mineralogical and structural geological mapping, and water resource investigations. The results were topographic surveys and published topographic maps of increasing precision, detail, scale, and scope along with the establishment of a national network of high-order horizontal and vertical control positions that supported civilian and private-sector cartographic activities related to land subdivision and natural resource appropriation. During this period, mappers worked through an apprenticeship system, starting as junior topographers and being promoted through the ranks from assistant topographer to topographer. By 1912 the Topographic Division employed a technical force of 172 comprising 1 chief geographer, 10 geographers, 10 topographic engineers, 42 topographers, 43 assistant topographers, 55 junior topographers, and 11 draftsmen (USGS 1912, 103). The number does not include the support staff and temporary assistants that were typically part of the field parties, i.e., cooks, porters, and mule skinnners.

A description of a topographer's job written in 1919 included field duties such as "making instrumental surveys which enable the preparation of a topographic map in the field showing culture, drainage, and physical features; making field reports and training assistants" (USGS 1919). These assistants consisted of one recorder and two rodmen whose aggregate annual salary totalled \$2,500. In that year new junior topographer salaries

ranged from \$80 to \$110 per month. By World War I most topographic maps were published on 15-minute quadrangles at a scale of 1:62,500. Earlier the USGS had tried smaller scales of 1:250,000 and 1:125,000 but had settled on the approximate 1 inch = 1 mile scale in the late nineteenth century. Mapping was accomplished largely through methods of triangulation using transits and plane tables (fig. 1069) with topography being established and controlled by vertical level lines completed in the field. W. A. Radlinski painted a vivid picture of a surveying party during the early twentieth century (Radlinski 1970, 17). Areas that were rugged or inaccessible were mapped using less precise techniques. Topographers also had office responsibilities—normally conducted during winter months—that included "drafting and inking completed maps; preparing lettering diagram, military report, and a classification of the land surface" (USGS 1919).

The finances of the topographic division during the



FIG. 1069. EARLY TWENTIETH-CENTURY PLANE TABLE USE. Willard D. Johnson and the Johnson plane table, Wasatch Range, Salt Lake County, Utah, July 1901. Image courtesy of the U.S. Geological Survey, Denver.

early twentieth century were somewhat tenuous. A fiscal model for topographic mapping accomplished with the cooperation of client agencies at the state and federal level became institutionalized. Contributions by state cooperators began in the 1890s, after earlier experiments with Massachusetts and Connecticut. Starting at a modest level, these funds swelled to nearly 30 percent of the division budget by 1910, and in the mid-1920s to almost 45 percent. Federal agencies such as the U.S. Forest Service also entered into long-term cooperative mapping agreements with the USGS. Special funds were allocated for mapping federal forest land between 1898 and 1919, at one point amounting to over 40 percent of the Topographic Division budget. These sources of funding tended to smooth the fluctuations of War Department contributions (over 50 percent in 1918 to less than 2 percent in 1925) and the boom-and-bust funding in the annual appropriations from the Department of the Interior (USGS 1927).

During World War I, many Topographic Division personnel were selected for overseas duty. In 1918 the director reported: "Since March 26, 1917, when military mapping was begun for the War Department, 110 members of this branch have received commissions in the Engineer Officers' Reserve Corps [EORC], ranging from second lieutenant to major; 66 of this number are either in France or have been selected for overseas duty and 7 are reporting direct to the Chief of Engineers" (USGS 1918, 87). One of these officers was William O. Tufts, who was employed as a topographic engineer working in the Atlantic Division of USGS. In June 1917 he was terminated by the USGS, conscripted into the U.S. Army, assigned to the EORC, and, after a period of training in Texas, transferred to France at the rank of captain to assist with the preparation of maps and to coordinate with French military mapping specialists. In France he became involved with the training of mapping personnel. With the assistance of the French and of other former USGS mappers, including E. L. Hain, and working with former USGS topographer Joseph H. Wheat, Tufts taught courses to hundreds of American mappers in France, focusing on the use of aerial photography in compilation; topics included the interpretation, restitution, and exploitation of aerial photographs in the military mission. The rapid conversion of these field mappers to instructors in photo mapping methods leads one to believe that the French attaches and liaisons whom they worked with were instrumental in introducing these methods to EORC and by way of extension USGS personnel (USGS 1917–18).

At the USGS, war work by the Topographic Division included surveys of balloon fields, ordnance proving grounds, artillery sites, airplane and truck routes, and aviation fields, as well as creating a training school for topographers in Washington and the purchase and ship-

ment of "airplane cameras" and other instruments. "Practically all the funds available for topographic mapping were allotted to areas selected by the War Department for special military surveys, and the sums contributed by the States for cooperation were done so with the understanding that they were to be used on these military surveys" (USGS 1918, 90). Arthur H. Robinson was later to write, "In the modern history of cartography, it is a fact that periods of war have generally led to developments in mapmaking" (Robinson 1979, 97) (fig. 1070).

After the war, soldiers who were conscripted into mapping service returned to the USGS Topographic Division convinced of the value and efficiency that could be achieved through the use of aerial photography in civilian mapping operations (USGS 1918). These men were charged with producing "economy through efficiency" by USGS director George Otis Smith:

The invention of new surveying instruments has added to the field man's productivity, but at the same time the field standards have advanced so that the cost of mapping per square mile has not been materially reduced. . . . Similarly, new processes devised for use in map publication have resulted in a larger output of the map-printing plant, so that each year more and better maps are issued for the same expenditure of funds. Yet the larger public demand for these maps, which expresses itself in increased sales, necessitates larger appropriations (USGS 1921, 5).

This need for economy and efficiency led to experiments using air photos for topographic mapping, resulting in the early adoption of photogrammetric methods for compiling maps—first for air charts and then the first compilation of a fifteen-minute quadrangle (Schoolcraft, Michigan) using photogrammetry (planimetry only). In 1921 the Section of Photographic Mapping was established. The acquisition and installation of stereoscopic instruments from Germany (the stereoautograph in 1924 and the aerocartograph in 1927) resulted in more operational use of aerial photography for the compilation of topographic maps. The benefits of this approach became readily apparent. In 1928 Thomas P. Pendleton added a section titled "Map Compilation from Aerial Photographs" to the *Topographic Instructions of the United States Geological Survey* (Thompson 1952, 53).

In February 1925 the passage of H.R. 4522 of the 68th Congress (the so-called Temple Act) charged the USGS with completion, "within a period of twenty years from the date of the passage of this Act, [of] a general utility topographical survey of the territory of the United States," and \$950,000 was appropriated (U.S. Statutes at Large [1923–25], vol. 43, pt. 1, chap. 360). Photogrammetry opened the possibility of reconfiguring the topographic production system to methods of industrial and managerial organization.



FIG. 1070. MEN SCRIBING COPPERPLATES FOR MAP PRODUCTION, WASHINGTON, D.C., 1917.

Image courtesy of the U.S. Geological Survey, Denver.

Reenergized by changes brought on by the technological developments resulting from the war and the mandates of the Temple Act, the Topographic Division became an efficient and highly integrated organization by midcentury. The division adopted at several levels the characteristics of commercial manufacturing enterprises. What was created during this period was unique in U.S. mapmaking; an industrial system to produce and revise thousands of standardized large-scale maps. Mapmaking at the USGS became the product of an industrial system, rather than a craft. It is during this period that photogrammetric methods became the dominant technology, relegating field survey to the necessary but subservient role of establishing horizontal and vertical control. The consequences of these changes for the workers at the USGS meant a reconfiguring of their culture, identity, and vision.

Following its creation in 1933, the Tennessee Valley Authority (TVA) asked the USGS for assistance in mapping its region (Thompson 1952, 53–54). This oppor-

tunity came at a fortuitous time; the survey was in the process of converting field-based mapping to more efficient photogrammetric techniques. As earlier in the century, USGS mappers were able to accomplish their mission while reconfiguring their work processes through alliances with state governments and federal agencies. The states were able to provide additional fiscal support, while federal agencies (in particular the War Department during the world wars and the Department of Defense during the Cold War) did likewise.

During World War II the USGS once again became heavily involved in military mapping. TVA work was set aside, and the Topographic Division worked largely as a subcontractor to the Army Corps of Engineers (Morris M. Thompson, personal interview 2001). A significant occurrence during this period was the recruitment of women into the mapping profession. This occurred across the government mapping community. A five-course sequence (including topographic map draft-

ing and photogrammetry) recommended by the American Congress on Surveying and Mapping in 1942 to engineering schools and liberal arts colleges would qualify the student for the Federal Civil Service examination as a cartographer. Many of the students completing these courses—perhaps a majority—were women. In government mapping agencies Millie the Mapper (cartographic version of Rosie the Riveter) was born (Tyner 1999).

Perhaps the most significant outcome of World War II was the establishment of a large federal presence in the funding of basic science and technology (much of which became adapted to cartographic needs). At the USGS the result was a continuation of mass production that had been made expedient by war needs. The labor processes were reproduced in regional mapping centers that had previously served as bases for field mapping.

Defense-sponsored applied research during the war years had allowed major advances to be made, particularly in the areas of electronics and precision electrical controls. As a direct result and with unprecedented cooperation between the military, university research centers, and private industry, early digital computers were created. Similar machines were developed in the United Kingdom and Germany at about the same time (Ceruzzi 2003). These “objects-to-think-with” (Turkle 1984, 22) would ultimately have a stunning impact on cartography, mapping, and information storage and retrieval.

Immediately after the war the Topographic Division was still in transition from the field-based mapping of the nineteenth century to the technologically enabled factory system, heavily reliant on photogrammetry (fig. 1071). The alliance with TVA and the war years cemented the

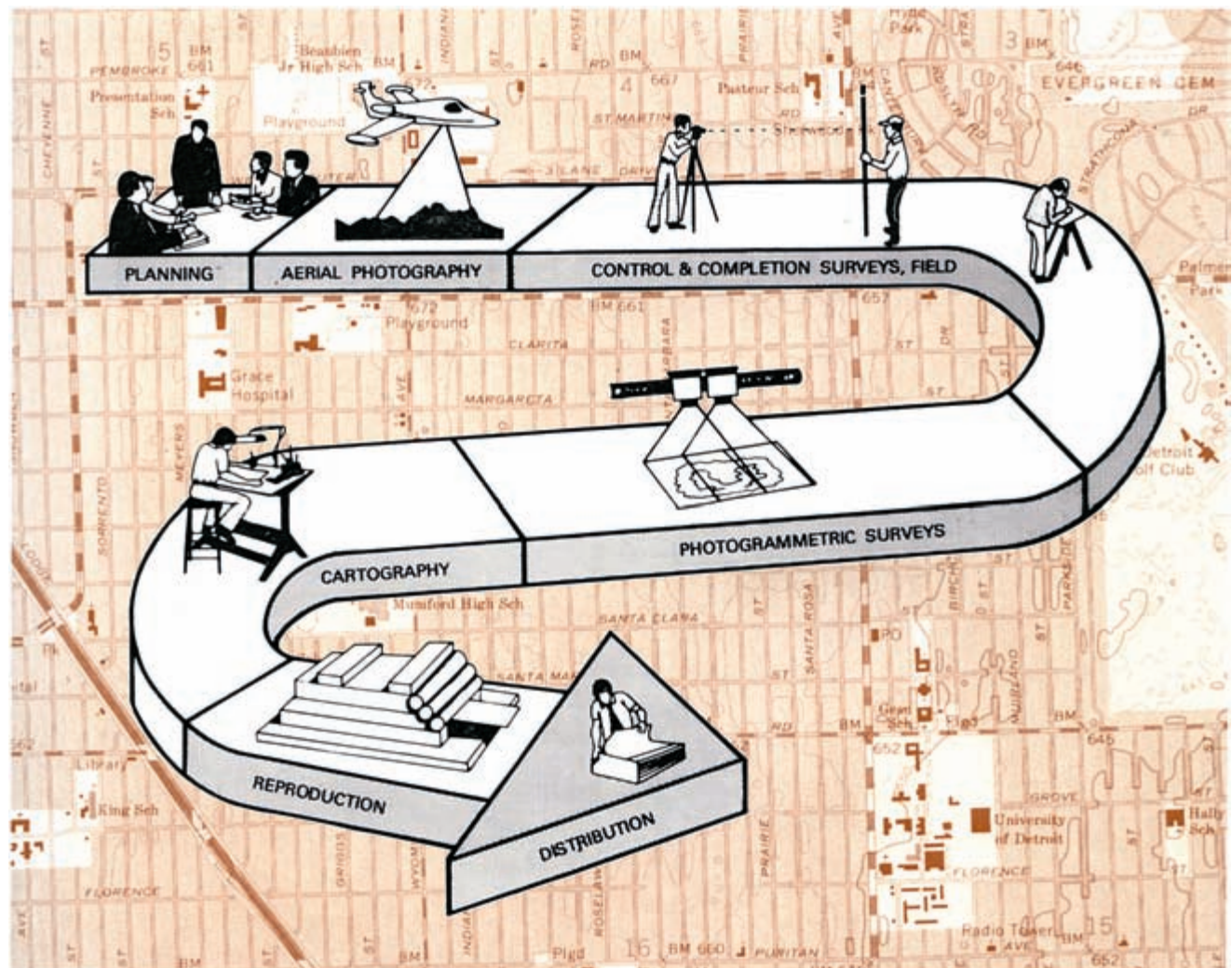


FIG. 1071. SEQUENCE OF STANDARD TOPOGRAPHIC MAPPING OPERATIONS. Topographic mapping operations depicted as a linear, segmented, industrial process. Size of the original: 14.3 × 18 cm. From Morris M. Thompson,

*Maps for America: Cartographic Products of the U.S. Geological Survey and Others*, 2d ed. (Reston: U.S. Department of the Interior, Geological Survey National Center, 1981), 24 (fig. 19).

dominance of photogrammetry in the mapping process with its clear productivity and quality improvements. Other changes in the early 1950s (such as the introduction of scribing) made map finishing a more standardized operation. In the *Topographic Division Bulletin* it was noted regarding scribing: "It was found that new employees can produce acceptable work much earlier, and that their line work is generally sharper and more consistent than by drafting process. . . . A substantial increase in production per man-year is also indicated, and we expect that this will be in the neighborhood of 25 or 30%" (Fuechsel 1953, 49–50).

During the 1950s the USGS began to use digital computers in the areas of photogrammetry and control surveys. A paper by Irving I. Shulman (1956) is the earliest documented discussion of the use of digital computers in mapping at the USGS. This paper, which focused on analytical problems in photogrammetry, concluded that there are significant advantages to using electronic computers for the solution of photogrammetric problems.

By the end of the 1950s the USGS was fully committed to new ways of making and using maps. The MAP III program was illustrative of this turn. USGS personnel working with the Office of Civil and Defense Mobilization used the Army Map Service 1:500,000 map series as a base to prepare more than 2,000 six-inch-square templates to code information for keypunching. Included were political boundaries, natural features, and major cities for the continental United States. These templates were punched onto standard computer cards and, using a Univac Scientific 1103 computer and a Sperry-Rand high-speed printer, provided an outline map for use with vulnerability studies (Collins 1959) (fig. 1072).

Around this time the Topographic Division established a Research and Design Branch (later renamed the Office of Research and Technical Standards, or RTS). Russell K. Bean headed the branch and organized it as a way for the agency to be directly involved in the development of new instruments and techniques for use in the division. In addition to a staff of several engineers and career cartographers, the office included full-time machinists and a fully equipped instrument laboratory. The pace of innovation at the USGS had increased (Patterson 1960).

Early in the 1960s a division systems analyst wrote a speculative piece in the internal *Topographic Division Bulletin* that predicted very substantial change in American society due to automation, cybernation, the widespread adoption of operations research, and automatic data processing in the private and public sectors (Wong 1963). Wong suggested that the USGS must aggressively adopt and incorporate these changes into the ways that maps were made. USGS managers accepted his recommendations and began shifting resources into the development of automated systems for map production. RTS

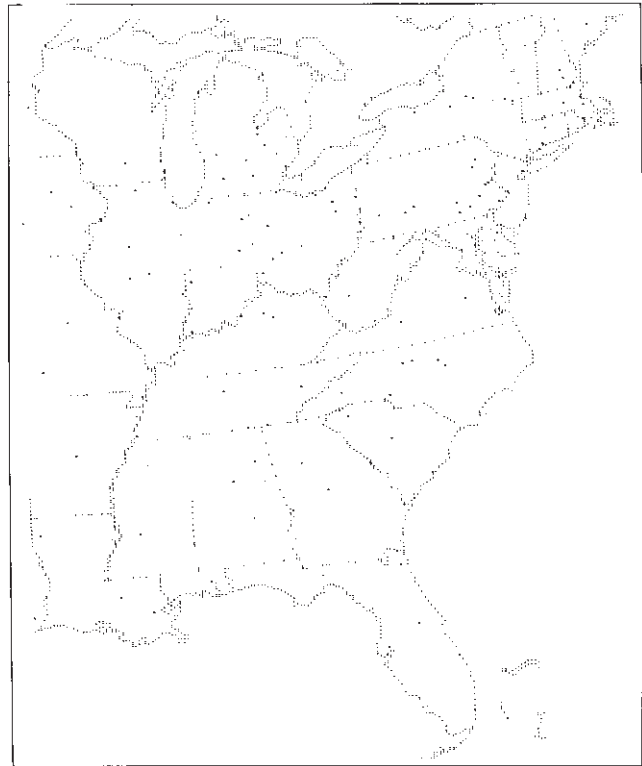


FIG. 1072. EARLY USGS COMPUTER-PRODUCED MAP, 1959. This simplified printout showing state boundaries and some major cities was made by USGS personnel in cooperation with the National Center for Damage Assessment in 1959. Size of the original: 19.9 × 16.4 cm. From Henry C. Collins, "The National Damage Assessment Center's MAP III Program," *Topographic Division Bulletin* 9, no. 2 (1959): 37–40, esp. 39 (fig. 2).

began work on systems to automate major steps in the topographic mapping production system, namely, graticule construction and line tracing. These efforts resulted in the development and deployment of the Autoplot system by the late 1960s. Autoplot produced graticules and plotted control points on topographic base manuscripts. Another system (Autoline) attempted to automate map tracing. This effort was less successful, although it did result in some spin-off applications in the area of orthophotoquad production. Eventually the Autoline was scrapped in the early 1970s and the division began investigating other options for automated line tracing and the collection of digital (vector) cartographic data (McHaffie 2002). This episode is an early example of the division's eventual shift from the in-house development of hardware solutions to the reliance on commercial contract-developed hardware. It also signaled the realization that the division was no longer in the mapmaking business but in the creation of cartographic data. The major focus of the division would become the collection and creation of digital cartographic data, the

creation and maintenance of digital cartographic data standards (in the 1970s and 1980s), and the promulgation of widespread public-domain cartographic data in the 1980s and 1990s.

Throughout the 1970s the change in cartographic work and conceptions about cartographic information and data can be seen. However, work on the completion of the 7.5-minute topographic map series continued in an environment of gradually automating work processes and shifting priorities regarding the missions and responsibilities of the mapping agency.

By 1975 Autoline was replaced by automated scanners from Dest Data Corporation that sped digitization by a factor of three to four times, and offered completely automated operation and batch process editing. Likewise the Autoplot was replaced by a Gerber "computer-controlled automated drafting system" that was capable of "inking, scribing, or exposing film" (USGS 1975, 49). At the Auto-Carto II conference, Warren E. Schmidt announced a new National Mapping Program with a "pledge to produce maps in both analog and digital form" (Schmidt 1975, 121). Later in the decade the division took steps toward building mass digitizing capabilities and more routine automation of map compilation with the purchase and deployment of a Gestalt Photo Mapper system (used to generate orthophotomaps and digital elevation models), several large-format digitizing tablets, high-speed plotters, automated typesetters, and the retrofitting of stereoplotters with digitizers (with the help of the Department of Defense). They also adapted the Cartographic Automatic Mapping (CAM) program from the Central Intelligence Agency (USGS 1976, 31–33).

In 1979 the Topographic Division established the Digital Cartographic Applications Program (DCAP). The intent was to enable the USGS by 1980 to supply major users with digital cartographic data within a reasonable time (Mullen 1979). Layers of data (from the 7.5-minute topographic map series) included reference systems, hypsography, hydrography, transportation systems, and geographic names (along with several others). Intermediate-scale maps were used when the larger-scale series was unavailable. The principal stated purposes of the program were support for producing graphic (analog) products, expediting revision cycles, and improving production efficiency. A secondary purpose was to support the development of geographic information systems (GIS). The DCAP program was to assemble a system of hardware and software components to create a prototype production facility and to begin to test it with several pilot projects. Simultaneously defining digital data formats, feature types, and attribute codes took place. The newly created standards of digital line graphs (DLGs) for planimetric data and digital elevation

models (DEMs) for hypsometric data were used initially with new standards added as needed.

By 1981 the USGS had developed a general-purpose map editing system, the Digital Cartographic Software System (DCASS), that allowed streamlined collection of digital cartographic data directly from the stereo-model as maps were compiled. The Topographic Division was renamed the National Mapping Division (NMD), and GIS was being considered as a possible organizational and structural framework for managing the growing digital cartographic database (DCDB) (USGS 1982).

Late in 1981 the USGS and the U.S. Census Bureau began a cooperation that would prove highly beneficial to both. The two agencies agreed to produce digital cartographic data that would assist the Census Bureau in its enumeration of the 1990 census and that would create a new 1:100,000-scale series of complete coverage of the United States. As an additional benefit, this project ultimately enabled the USGS to complete, in 1991, the mapping of the conterminous United States at the 1:24,000 scale, since the 1:100,000 base sheets were compiled photographically by the USGS largely from 1:24,000 source materials.

Beginning with a pilot project that covered the state of Florida, the USGS took the lead in creating a detailed transportation and hydrographic digital data set from 1:100,000-scale maps. High-volume digital production plants were created in both the USGS and the Census Bureau, with the goal being an intermediate-scale digital cartographic database by 1987. This joint project resulted in the completion of the Topologically Integrated Geographic Encoding and Referencing (TIGER) files. "This data base may well serve as the key catalyst for the widespread use of geographic information systems technology in the United States" (USGS 1985, 4). In hindsight, this statement appears rather prescient. The inexpensive public availability of these data (combined with the explosive growth of the Internet) has indeed spurred unprecedented growth in the GIS industry in the United States since 1990.

In 1985 the USGS purchased two Global Positioning System (GPS) receivers and began testing them for use in the completion of field surveys. The agency was an early supporter of civilian use of the system, developed by the Department of Defense, in fact helping to fund the first portable GPS used for field survey (USGS 1988). Both the ubiquitous personal vehicle navigation systems and the geospatially enabled tracking and routing systems in widespread use by the end of the century are direct results of the combination of the TIGER data set with inexpensive GPS receivers. Clearly the USGS's contributions to the establishment and population of a national DCDB, completed using source material created in vari-

ous technology systems, ranks as an achievement of the first order.

During the twentieth century the mapmaking process at the USGS passed through two complete technological cycles. The first was the advent of photogrammetric techniques and their substitution for field survey as the principal method of topographic map compilation. This produced a mapping process that was easily thought of as a "production line" management model. The second cycle was the insertion of partially and fully automated devices driven by computers into the cartographic production process. This changed the nature of producing maps by shifting the focus to the information associated with the features being mapped. In both cycles, career workers in the Topographic Division were forced to retrain themselves and learn new techniques, to use (and sometimes create) new instruments and technologies, and to see the world through maps in a different way.

There is some danger in interpreting recent events as historical, however; it appears that during the last decade of the century, the USGS's mapping programs were emerging as an important component of the cartographic commons. By far the most significant change during the 1990s was the coming of the World Wide Web (WWW) and the mass acceptance and reliance by developed world consumers on the personal computer. The significance for cartography has been the requirement for cartographic information to be made available to a suddenly spatially aware public. As the new century began the USGS had repositioned maps, geospatial data, and GIS at the center of their mission.

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SEE ALSO: Board on Geographic Names (U.S.); Gannett, Henry; Landsat; *National Atlas of the United States of America, The*; Remote Sensing: Satellite Imagery and Map Revision; Topographic Mapping: United States

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### *U.S. Intelligence Community, Mapping by the.*

Three themes permeate any examination of mapping by the U.S. intelligence community in the twentieth century: (1) pervasive and sweeping technological change, even in the early part of the century, but accelerating during the space and digital computing eras; (2) a creative tension between detail and synopsis, best represented by the tactical need for detailed local information and the complementary need for coarser broad-scale overviews of strategic interest alone; and (3) demands imposed on intelligence organizations by the evolving nature of conflict and doctrine, moving from traditional state-to-state conflict to global and asymmetrical conflicts later in the century. Indeed, the terrorist attacks on 11 September 2001 reflect trends in intelligence that date back to 1903, when Reginald Baliol Brett, 2d Viscount Esher, in a report to the United Kingdom War Office on the Boer War, recommended an expanded intelligence service as necessary for the twentieth century. These British origins led to a chain of war-related expansions and refinements that left the United States after World War II with a large and highly sophisticated intelligence structure that shaped the intelligence community through the Cold War and beyond.

With origins stretching back millennia (Sweeney 1924, 2), military intelligence has always required mapping and cartographic analysis. Even so, almost all of the technological innovations that characterize contemporary cartography were twentieth-century developments. In the years leading up to World War I the desire to improve mapping in the theater of operations coincided with rapid developments in cameras, films, and map reproduction, primarily in Europe. In the United Kingdom, the Naval Intelligence Department (NID) was formed after an 1883 Royal Commission report, and Esher’s 1903 report led to the Secret Service Bureau, established in 1906. By the outbreak of World War I, the United Kingdom had an established intelligence service, with Military Operations divisions (later renamed Military Intelligence divisions, or MI), of which MO4 was, in the words of Michael Heffernan (1996, 507) “the preserve of map-making, map collection and topography.” Prior to World War II in the United States, military intelligence operations were “scattered, with no clear chain

of command, and subject to internecine struggles over jurisdiction” (Barnes 2006, 151), “primitive and inadequate,” and “timid, parochial” (U.S. CIA [2000], 2).

This ended with the U.S. entry into World War I in April 1917. It is not clear who took the first aerial photographs during the war, but they were probably taken by Lieutenant George F. Pretyman, a pilot of No. 3 Squadron who took five photographs of the Aisne battlefield on 15 September 1914 (Finnegan 2011, 43). By the last year of the war, production facilities for maps and photography had been expanded and as many as 10,000 photographs were taken each night with specialized cameras and used for updating trench maps (fig. 1073). During the Meuse-Argonne offensive, the first and largest frontline commitment of troops by the U.S. Army in World War I, intense collaboration with French and British air photo units allowed 56,000 aerial prints to be made and delivered to the American Expeditionary Forces in four days. In addition to supporting tactical-scale products like trench maps, aerial photography also contributed to small-scale mapping for strategic purposes, particularly in the Middle East, where pressing needs led to important innovations (Collier 1994). Cartographic intelligence in the form of map libraries and academic knowledge involved the active participation of professional geographical societies, notably the Royal Geographical Society (RGS), which led the effort in the United Kingdom to make maps at small cartographic scales, especially 1:1,000,000. Within one short year, the



FIG. 1073. WORLD WAR I AIRCRAFT WITH EARLY MAPPING CAMERA. Observer receiving French camera with Berthiot color lens for reconnaissance and photo work, Gondreville-sur-Moselle, France, 6 August 1918. Image courtesy of the U.S. National Archives, Washington, D.C.

use of imagery and map intelligence by the U.S. military drove home the value of this form of intelligence to the pursuit of warfare and the postwar reallocation of colonies and spheres of influence (Heffernan 1996).

Despite these accomplishments, U.S. intelligence reverted to isolationism and inactivity after the war. Although aerial mapping and cartography continued to benefit from technological gains, especially in agriculture and forestry, the intelligence community did not pursue these activities. Both cartography and photogrammetry found a role in university curricula, especially at land grant institutions, and the U.S. Department of Agriculture's Agricultural Adjustment Administration and the U.S. Geological Survey (USGS) began to rely increasingly on air photos for topographic surveying, as did the Tennessee Valley Authority and the U.S. Forest Service (Avery 1962). In spite of these developments, very little innovation took hold between the wars in the intelligence community.

This complacency ended abruptly on 7 December 1941, when Japan attacked the American naval base at Pearl Harbor, but this was not a typical rude awakening. Ongoing collaboration with British intelligence after World War I had led to the creation, on 11 July 1941, of the U.S. Office of the Coordinator of Information (OCI), which was reorganized on 13 June 1942 as the Office of Strategic Services (OSS). The global nature of World War II led to a marked change in the mindset of intelligence agencies and various institutional partners. American academic geographers were active in the OSS during the war (Barnes 2006); the New York Public Library and the American Geographical Society played a role similar to that of the RGS in England during World War I (Hudson 1996). Cartographer Arthur H. Robinson and geographer Richard Hartshorne held positions of leadership in the Research and Analysis Branch of the OSS, which assembled a collection of over 2 million maps and produced more than 8,000 new maps. Nevertheless, interagency rivalry arose, with the Office of Naval Intelligence, the Army's G2 branch, the Federal Bureau of Investigation (FBI), and the State Department each pursuing its own intelligence mapping activities (Barnes 2006). An above-average number of the cartographers and computers (a job title) were women (Tyner 1999). As in the United Kingdom, detailed battlefield maps and coarser strategic planning maps competed for attention and resources. As the war concluded with the rise of the atomic age, small-scale cartography once again underscored the susceptibility of the coterminous United States to over-the-pole attack by aircraft and later by intercontinental ballistic missiles (Henrikson 1975).

In many respects the Cold War, traditionally considered the period 1947 through 1991, really began while the Allies were still fighting Nazi Germany. In the rush to capture Berlin in 1945, a small group of intelligence

officers acting as a special unit of the Military Intelligence Division of the Office of the Chief of Engineers of the Army and under the command of Floyd W. Hough, who later became chief geodesist with the Army Mapping Service (AMS), captured and returned to the United States much of the map collections and cartographic technology of the German Army, including captured Russian geodetic and mapping records for the trans-Siberian railroad (Cloud 2002, 264). As attention turned to what rapidly became "denied territory" in the Soviet Union and China, these materials became of great use in mapping efforts by the AMS and the Central Intelligence Agency (CIA), which developed out of the OSS in 1947. Much of the early literature in the newly institutionalized field of photogrammetry—the American Society of Photogrammetry was formed in 1934—focused on the reverse engineering of German surveying and mapping instruments, including methods resembling those now common in geographic information systems (Cloud 2002). Both the Korean War and the Vietnam War saw increasing use of these methods, including point target databases, trafficability mapping, and terrain analysis.

A major shift in intelligence mapping took place in 1958. Increasingly, Cold War imaging of otherwise inaccessible Soviet territory used aircraft equipped with specialized cameras. Oblique long-view cameras could spy on military bases and other places, but overhead reconnaissance was possible only by highly risky overflights. A deeply classified development program by Lockheed called Aquatone, started in 1954, produced a series of high-altitude aircraft eventually known as the U-2. Flying across European and Asian Russia at an altitude of 65,000 feet, the U-2 used a camera with a 36-inch focal length that could resolve features as small as 2.5 feet (fig. 1074). Although the Air Force and Navy eventu-



FIG. 1074. LOCKHEED U-2A "DRAGON LADY" PAINTED IN CIA BLACK.

Image courtesy of the National Museum of the U.S. Air Force, Dayton.

ally used the U-2, it was originally a CIA operation run through the Office of Scientific Intelligence, which required pilots to resign their military commissions and join the CIA as civilians, a process called “sheep dipping” (Huntington 2007, 43). Imagery from the U-2 allowed the CIA and other agencies to make detailed maps of specific targets such as air force bases, shipyards, naval bases, anti-aircraft batteries, and nuclear power plants. Images taken with the U-2 played a key role in the peaceful resolution of the Cuban missile crisis of 1962—how else could the United States confirm the removal of Soviet missiles (fig. 1075)? While the U-2 was designed to be invisible to radar, it was known from the outset that Soviet aircraft would eventually be able to track and in-

tercept the plane, so it was used sparingly. An alternative to the U-2, a program called Genetrix, beginning in January 1956, sent 516 balloons carrying high-resolution cameras to drift across the Eurasian continent, but the system retrieved little usable intelligence. With the deepening of Cold War rhetoric and the shift from aircraft (for which the SAGE [Semi-Automatic Ground Environment] radar system was developed) to intercontinental ballistic missiles, feasible defense against attack seemed next to impossible. It was this climate of hostility and suspicion that gave birth to the principle of open skies, a scheme found workable only after the end of the Cold War.

Deeply embedded in the level of compartmentalized

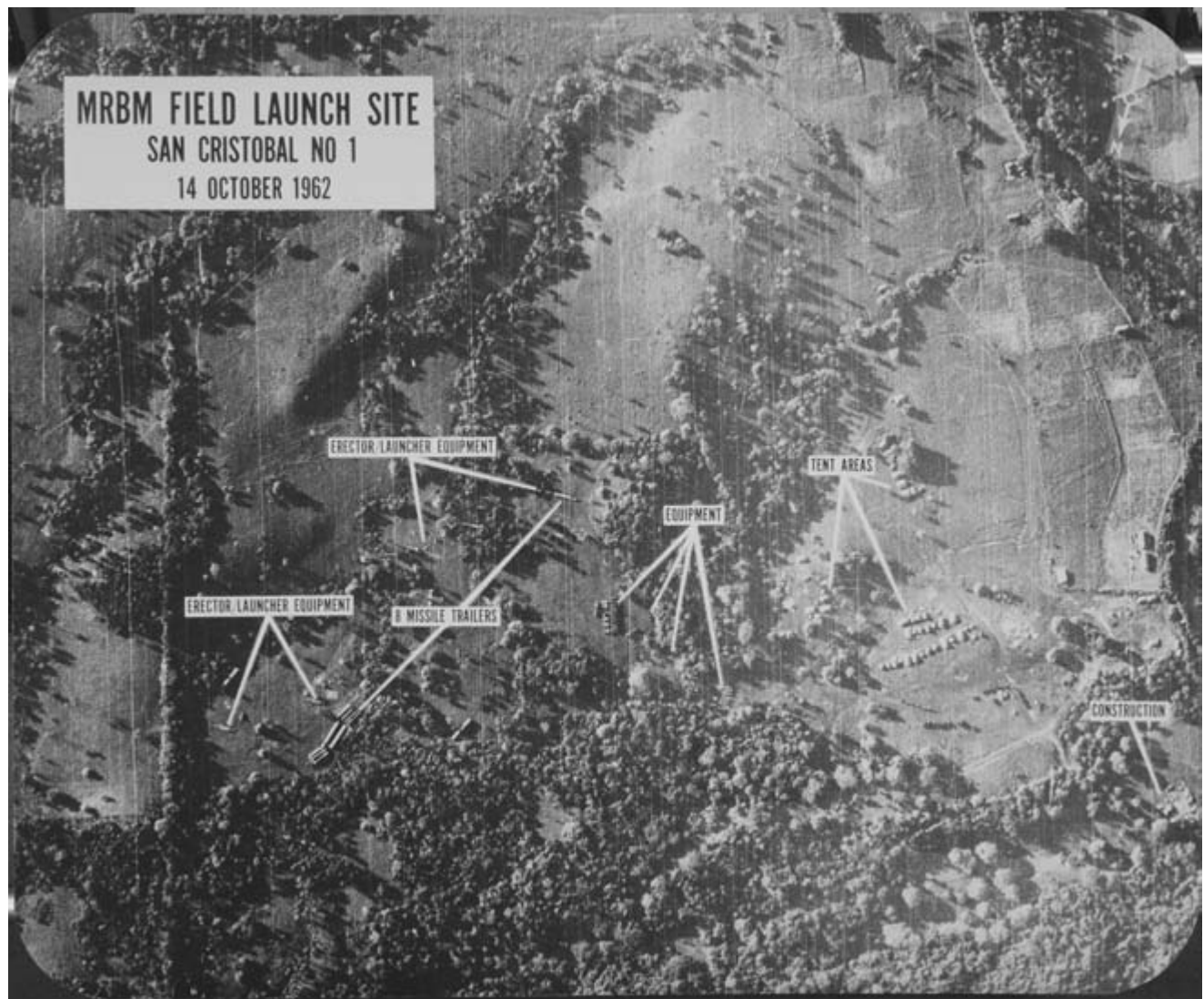


FIG. 1075. U-2 AIRCRAFT IMAGE OF SOVIET MISSILE SITE ON CUBA, 1962. Taken at the height of the Cuban missile crisis, 14 October 1962.

Image courtesy of the U.S. National Archives, Washington, D.C. (ARC Identifier: 193926).

security that exists above “top secret” were a set of space-based reconnaissance programs for intelligence mapping. The original SAMOS (Satellite and Missile Observation System) satellite was an ambitious attempt to jump two generations of space technology for the direct transmission to earth of photographic images taken in space. SAMOS proved technically too difficult, although missions were successful and the camera was later reused in lunar mapping (Hall 2002). A backup system based on de-orbiting film canisters and recovering them while still in flight after reentry into the atmosphere, originally called WS-117L, was relaunched as project Corona. After a series of notorious failures, and under the cover of the nominally civilian Discoverer biological satellites, Discoverer 14, launched on 18 August 1960, became the first successful Corona mission two days later when an Air Force C-119 based at Hickam Air Force Base in Honolulu, Hawaii, retrieved its film “bucket.” While technological progress was complex, the system evolved through a series of camera improvements identified by the designations KH-1 through KH-6. (Keyhole, abbreviated to KH, was the security designation for space imagery, and Talent was the similar codeword for aircraft imagery). The KH-5 camera, also called Argon and later DISIC (Dual Improved Stellar Index Camera), was used for comparatively coarse mapping and geodetic imaging, while the rotating panoramic stereo cameras (epitomized by the KH-4B) pushed imaging to higher levels of detail and contrast (Peebles 1997; Day, Logsdon, and Latell 1998; McDonald 1997).

Once fully operational, Corona proved a game-changer as far as intelligence operations and mapping were concerned (fig. 1076). Entire continental mosaics were created, including Antarctica and Africa (Cloud 2002, 272–74). Institutionally, Corona led to the creation of a new agency, the National Reconnaissance Office (NRO), in 1961. A Navy counterpart, the National Underwater Reconnaissance Office (NURO), was formed in 1969 (Sontag, Drew, and Drew 1998, 82–83). The disciplines of geodesy and cartography were profoundly influenced (Cloud 2000). There were also major impacts in geophysics and intelligence mapping, with the creation of a civilian agency (the Civil Applications Committee); the use of classified imagery for numerous civilian purposes, such as environmental monitoring by the new Environmental Protection Agency; and topographic map updating by the USGS (Clarke and Cloud 2000). Corona was terminated in 1972, and its successors took over: the KH-7 and KH-8 Gambit (1963–67 and 1966–84, respectively) with resolution as detailed as 0.6 meter (2 ft.), used for 1:50,000-scale mapping within the Department of Defense, and the KH-9 Hexagon, also known as Big Bird (1973–80), with a synoptic 70 nautical mile-by-140 nautical mile footprint, which



FIG. 1076. CORONA SPY SATELLITE IMAGE OF THE PENTAGON, 25 SEPTEMBER 1967. Image courtesy of the USGS Earth Resources Observation and Science Center (EORS).

provided key cartographic information for level 1 digital terrain elevation data (DTED) and 1:200,000-scale maps at the Defense Mapping Agency (DMA), CIA, and USGS. These systems in turn were replaced by the electro-optical satellites—KH-11, KH-12, and KH-13; satellites designed by Future Imagery Architecture (FIA); and the Lacrosse imaging radar satellite—extending into the twenty-first century.

Able to image the earth worldwide in real time, the U.S. intelligence community became highly dependent on overhead reconnaissance systems, often collectively called the “national technical means of verification.” New roles such as treaty verification and detailed image mapping for computer-based military and intelligence support emerged. Imagery from the Corona and KH-7 to KH-9 programs, as well as most technical information, was declassified by U.S. Executive Order in February 1995, with the imagery moved to the National Archives and the USGS. During the 1991 Persian Gulf War, the need to integrate space imagery with other intelligence, maps, and weapons systems became evident (Clarke 1992) and led to a major effort on the integration of multisource intelligence, also called intelligence data fusion. The use of multisource data in large-scale three-dimensional visualization systems came to prominence in 1995, when the Dayton Peace Accords led to a settlement of the war in Bosnia-Herzegovina (1992–95) (Boyd 1998).

In the closing years of the twentieth century, the broadened, greatly increased openness of the intelligence mission led to a wider use of classified intelligence materials in science, planning, emergency response, and humanitarian relief. A good example is the creation of the MEDEA (Measurement of Earth Data for Environmental Analysis) Group in 1993, after requests by Senator Al Gore to use intelligence data for global climate change research. This involved clearing top environmental scientists to evaluate intelligence images and assets for use in such research, including global oceans data used in the submarine warfare during the Cold War (Sontag, Drew, and Drew 1998). Projects included creating early-warning centers for natural and technological disasters, declassifying U.S. and Russian oceanographic and bathymetric data, and a global disaster information network. MEDEA ended in 2000 (Richelson 1998). Intelligence information was shared with allies and used politically to counter terrorist groups and hostile nations. As the twenty-first century started, the specter of global terrorism loomed large, with consequences that would permanently reorient the intelligence community after 2001. Technically, overhead satellite imagery yielded its dominance in intelligence gathering to streaming video from unmanned aerial vehicles like the Global Hawk and the Predator, while image intelligence would lead to a more comprehensive approach to intelligence curiously reminiscent of the World War I and World War II models, a world of integrated geospatial intelligence, intelligence czars, and human terrain systems relying on social and behavioral scientists, linguistics experts, and regional specialists.

#### The Intelligence Community's Institutions

The various institutional components of U.S. intelligence merit a more systematic inventory, separate from the foregoing treatment of salient trends. Prior to World War II, U.S. intelligence was synonymous with military intelligence, and its activities were relegated to the armed services. The Engineer Reproduction Plant (ERP), at the U.S. Army War College in Washington, D.C., was the U.S. Army Corps of Engineers' (ACE) first attempt to centralize map production, printing, and distribution. This unit took over the Army's map collection in 1939.

Creation of the OSS in 1942 concentrated intelligence activity within a single agency, but the separate service-related units survived. Creation of the CIA in 1947 and its subsequent rapid growth during the Cold War again led to major rivalries, especially as the CIA sought exclusive control over space- and aircraft-based reconnaissance systems. As Corona and other programs grew during the 1960s, new CIA fragments formed (NRO, NURO) and new means to focus science on intelligence needs emerged (e.g., Advanced Research Projects Agency,

Defense Advanced Research Projects Agency, Office of Naval Research). President Dwight D. Eisenhower authorized the creation of the National Photographic Interpretation Center (NPIC) in 1961 to combine CIA, Army, Navy, and Air Force assets to solve national intelligence problems. NPIC was a component of the CIA's Directorate of Science and Technology (DS&T), and its primary function was the analysis of imagery, including Talent and Keyhole information. A small thematic mapping unit served a niche market of sorts by producing simple city maps for operatives and other customers where no equivalent was available locally (Baclawski 1997). CIA cartographers produced other notable information products, including the *World Factbook*, published annually and updated on the Internet every two weeks. CIA mapping products available to the general public include thematic atlases like the *People's Republic of China: Atlas* (1971) and the *Atlas of the Middle East* (1993) as well as a series of small-scale reference maps for the world's nations and contested territories like the West Bank.

The AMS grew out of the ERP in May 1942, and was based in Montgomery County, Maryland. Focused on creating and updating maps for the army, it received mapping, charting, and geodetic support from the CIA and other agencies. It was redesignated the U.S. Army Topographic Command (USATC) in 1968 and continued as an independent organization until 1972, when it was merged into the new DMA and renamed the DMA Topographic Center (DMATC). The Army Air Corps Map Unit was renamed the Aeronautical Chart Plant (ACP) in 1943 and based in St. Louis, Missouri, where it was known as the U.S. Air Force Aeronautical Chart and Information Center (ACIC) from 1952 to 1972. Demands of the Vietnam War and the increasingly integrated use of maps and imagery led to calls for consolidation and increased sharing of data. As a result, the DMA was created in 1972 to consolidate all U.S. military mapping activities. The DMA's headquarters was initially located at the U.S. Naval Observatory in Washington, D.C., but later moved to Falls Church, Virginia, where other mapping agencies were collocating, notably the USGS, in nearby Reston. Its mostly civilian workforce was concentrated at production sites in Bethesda, Maryland; northern Virginia; and St. Louis, Missouri. The DMA was formed from the Mapping, Charting, and Geodesy Division, Defense Intelligence Agency (DIA), and other mapping-related organizations of the military services.

The DMA years were marked by rapid automation and computerization of mapping and intelligence operations and systems. The Special Program Office, funded through political pressure, researched the DMA's requirements and began a much-criticized series of ma-

for systems purchases (termed Mark 85, Mark 87, and Mark 90) for a digital map production system. Within these systems, many interpretation, rectification, registration, and drafting functions were converted from manual to automated tasks.

After the declassification of the NRO in 1992, and with increasing Congressional pressure for transparency in funding intelligence activities, a consolidation of most of the intelligence agencies working with maps and other spatial analysis tasks took place. The result was the creation of the National Imagery and Mapping Agency (NIMA) in 1996. NIMA integrated eight predecessor agencies and departments—the DMA, the Central Imagery Office (CIO), the Defense Dissemination Program Office (DDPO), the CIA's NPIC, parts of the DIA, the NRO, the Defense Airborne Reconnaissance Office, and the CIA's DS&T—to provide mapping, charting, imagery, and geospatial information and products to a wide variety of customers, including the Armed Forces and the government. Nevertheless, the institutionalized distinction between the agency's map production function (synoptic) and the imagery function (detailed imagery and intelligence) proved stressful. The 2004 National Defense Authorization Act changed the name of the agency from NIMA to the National Geospatial-Intelligence Agency (NGA) to reflect the changing role of technology and its uses in intelligence-related mapping. As the country's leading government mapping agency, the NGA and its precursors had immense influence in shaping the content, challenges, research, and achievements of twentieth-century cartography. Most mapping accomplishments at the turn of the century, such as online maps, have deep origins in the twentieth-century research and development activities of these agencies.

While the Office of the Director of National Intelligence predates the 11 September 2001 attacks on the Pentagon and the World Trade Center, the idea of central control over all U.S. intelligence agencies dates to 1955, when Congress commissioned a blue-ribbon study. In 2005, following the creation of the Office of Homeland Security, sixteen intelligence agencies were at least nominally joined under a single director. These agencies form the "intelligence community" encompassed by this entry. A listing of their names reveals the varied nature of the twentieth-century's legacy to the intelligence world: Air Force Intelligence, Army Intelligence, CIA, Coast Guard Intelligence, DIA, Department of Energy, Department of Homeland Security, Department of State, Department of the Treasury, Drug Enforcement Administration, FBI, Marine Corps Intelligence, NGA, NRO, National Security Agency, and Navy Intelligence. While many of these agencies have stand-alone mapping functions, the NGA assumed overall responsibility for mapping, charting,

and geodesy; remote sensing and photogrammetry; and cartographic science, spatial analysis, and geographic information science.

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SEE ALSO: Digital Worldwide Mapping Projects; Geodesy: Geodesy and Military Planning; Office of Strategic Services (U.S.); Cold War; Military Mapping by Major Powers: United States; Remote Sensing: (1) Earth Observation and the Emergence of Remote Sensing, (2) Satellite Imagery and Map Revision

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