

Maps and Mapping Technologies of the Persian Gulf War

Keith C. Clarke

ABSTRACT. *Assessing the recent Persian Gulf War from a cartographic standpoint is now possible. Unlike in previous wars, which established new technologies for postwar cartographic exploitation, the gulf war is unique in having presented a proving ground for electronic cartographic technology. An analysis is given of map coverage of the war by the media, especially magazines and newspapers, and from a military perspective. From a cartographic standpoint, the winners in the war include hand-held Global Positioning System (GPS) technology, geographic information systems (GIS), workstation-based image processing and cartographic map-production systems, and radar imaging from aircraft. More fully exploiting and building on the success of these technologies in peacetime seems to be a clear mandate for academic and professional cartography.*

KEYWORDS: *Persian Gulf, mapping technology, cartography, war maps, Global Positioning System.*

Introduction

On August 2, 1990, Iraq invaded Kuwait, drawing immediate United Nations Security Council condemnation, and prompting the United States to seize Iraqi assets and ban trade with Iraq. The following day, President George Bush announced that naval forces would be sent to the Persian Gulf as a deterrent, and three days later, Operation Desert Shield began, with the United Nations' approval of worldwide sanctions against Iraq. On November 8, Bush ordered an additional 200,000 troops to the gulf, making the build-up of equipment and troops the largest military operation in history. The air and ground combat that followed proved to be full of surprises, both for the outcome of the war and for the multitude of new military technologies that were tested for the first time. As no surprise to cartographers, the mapping sciences technology emerged as central to the conduct of the war. Compared with previous wars, the effectiveness of mapping technology was unprecedented and its performance during the war was close to perfect, giving the military and the public a new respect for the tools and methods of our profession.

An analysis of the war's impact on the mapping sciences is now possible. The war focused attention on maps from three distinct technologies for mass communications: first, through the medium of television; second, and more traditionally, through newspaper and magazine maps; and third, through the use of maps by soldiers, sailors, and air crews in the field. In all three cases, the impact of the computer and high technology was clear, and the effectiveness of the cartographic products was obvious. Such success clearly was built on rapid and widespread adaptation to new technology, the result of the technological break-

throughs that largely have redefined our ever-evolving profession. It is worthwhile, perhaps, to analyze carefully the events and map coverage of the war, in light of the successes of this new technology. This would permit broader conclusions to be drawn that may have implications for the future of our discipline.

This paper will consider the impact of the war on cartographic activities in television, in the print media, and in the military. Historically, war has "forced" new technologies into operation. This time, due to the sheer magnitude of the operation and the speed with which events unfolded, the effect was, instead, to prove the effectiveness of existing cartographic and mapping technology. Some of the lessons learned from the war, therefore, have implications for how mapping should be done both now and in the years to follow.

Maps on Television

The Persian Gulf War was very much a television war. A lack of news due to military censorship, plus the "prime time" nature of the time difference (the beginning of night attacks during the air war corresponded with prime television viewing time in the eastern United States), led to a tendency to focus on "experts" and graphics such as maps. Mark Monmonier dates this "maps and experts" technique to the coverage of the Japanese attack on Pearl Harbor by WCBS in 1941 (Monmonier 1989, 204). Maps used on television reflected closely those shown in magazines and produced independently by map publishers such as Hagstrom.

The nature of broadcast maps is such that they can be used with tools for image overlay (pointers, symbols, etc.) or with news personalities, in the same way that the weather map and daily satellite weather maps are superimposed on an image of a person standing against a plain-blue background. This allowed television journalist Peter Jennings to appear to walk through a three-dimensional model map of the gulf region, pointing out strategic points. While the actual model was obviously quite small, photographs have

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shown that the actual Iraqi war room map was strikingly similar, if at a larger scale.

In general, television maps were highly message-specific, as time constraints did not allow interpretation of complex graphics. In addition, the color complexities of broadcasting impose severe limitations on the choice of colors for maps, particularly the color red. As a result, the gulf war maps on television were somewhat limited in scope, and were used as time fillers and additions to discussions rather than as primary tools for understanding the war. Their numbers fell off considerably once film from the war zone became available.

Notably, almost completely absent from broadcast television was satellite imagery of war-related places and events. While most of the war activity would not have been visible at the resolution of the commercial satellite systems, the fires and the oil spill should have been quite visible from space. *Scientific American* (Horgan 1991) suggested that satellite imagery had been withheld to minimize the visibility of the environmental damage. The rapidity with which the news media generally turned to satellite imagery during the fire at the Chernobyl nuclear plant in 1986 tends to support television stations' voluntarily or involuntarily suppressing satellite images.

Weather forecasts during the war were supplemented with weather satellite images of the gulf at low resolution, in addition to the more traditional weather maps. This was particularly characteristic of the air war, since the several periods of unusually poor weather for the desert and semidesert areas involved led to distinct breaks in the air assault, grounding many planes and helicopters. On the down side, the speculative nature of the treatment of the war by television, coupled with the ability to back up speculations with rapidly produced, but nevertheless convincing maps and graphics, led to some poor reporting and a popular outcry against television reporting in particular. However, television did, on the whole, manage to convey events with maps and images quickly and accurately, given the constraints under which stations were operating, especially Cable Network News, which retained correspondents in Baghdad during the air war. Colonel Al Whitley of the United States Air Force is quoted as saying that after returning from a sortie he could "watch the replays of what it's looking like from another perspective. Knowing where some of the broadcasts were coming from, and seeing the skyline ... we could actually pick out who some of the bombs belong to" (*Aviation Week and Space Technology* 1991b).

The Print Media

The print media, predominantly newspapers and news-oriented magazines, published vast numbers of maps during the gulf war. These maps fall into distinct categories, based on the phases of the war. During the build-up, the emphasis was on some rather elaborate general-informational maps, including the Hammond map, "The Middle East Crisis," and a map supplement to *National Geographic* magazine. During the face-off period immediately before the war, the majority of published maps were "caption"

and "balloon" maps, which, as a design, proliferated throughout the war. Typically, such a map shows a region of interest, and includes multiple surrounding boxes containing pertinent text connected to locations by geometric tapering lines pointing to key locations (Figure 1).

During the air war, media map coverage reached a peak. Most publications carried updates on a daily or weekly basis, and used captions and balloons to show events. All of the print news media reviewed included speculative maps of the impending ground war and its tactics, and, in particular, included several maps showing overviews of the war. The ground war itself saw an almost exclusive use of tactical maps which primarily used arrows to show broad-scale movements. These maps, obviously, showed a considerable amount of disagreement because of continuing censorship and the speed with which events were unfolding (Figure 2). The aftermath of the war included some of the most detailed cartography, with maps including city names and highway networks. Typical of this later period is Intergraph Corporation's demonstration satellite map of Kuwait City, and the maps used in General Schwartzkopf's summary war briefing.

Figure 3 shows the ground extent of four typical maps selected from each of the four major periods of the war. A total of 53 maps were collected from nine newspapers and magazines. Excluded were map insets, maps on undeterminable projections, and also the extremes of high- and low-geographic coverage from each period. Clearly visible is how maps moved from general to specific during the air war, and included the SCUD attacks on Israel; this was followed in the two remaining periods by a concentration on Kuwait, southern Iraq, and northeastern Saudi Arabia, all areas of ground-war activity.

General characteristics of the cartography in the print media were the reliance on automated drafting packages and high-end workstations. *TIME* magazine and the *New York Times*, for example, use similar combinations of scanning, the color Apple MacIntosh computers, and Adobe's Illustrator software. This combination left its distinctive style on many of the popular press maps. The print media, including *TIME*, the Associated Press, Hagstrom, and *National Geographic*, made extensive use of glossy pullouts. Cartographers who produced these maps have indicated that demand greatly exceeded supply, and that their use was extensive, from the troops in Saudi Arabia to the White House. Many maps were highly speculative in terms of events, and depicted the ground war, in particular, in an endless combination of ways.

Many publications prepared base maps to provide weekly or daily updates on the war, keeping totals of deployments, aircraft losses, sorties flown, etc., in the margins. These maps were increasingly detailed as the war proceeded, and included weather maps, insets of other map types, and locations of environmental and historical interest. The maps, in general, contained a high degree of news content, and as such were virtual replacements for the articles they accompanied, as opposed to the supplemental quality of television maps. Color was a strong selling point, and encouraged significant innovations, including *TIME*'s black coloring of water within the Persian Gulf. Also strongly

GROUND WAR BRIEFING

FROM MILITARY POOL DISPATCHES

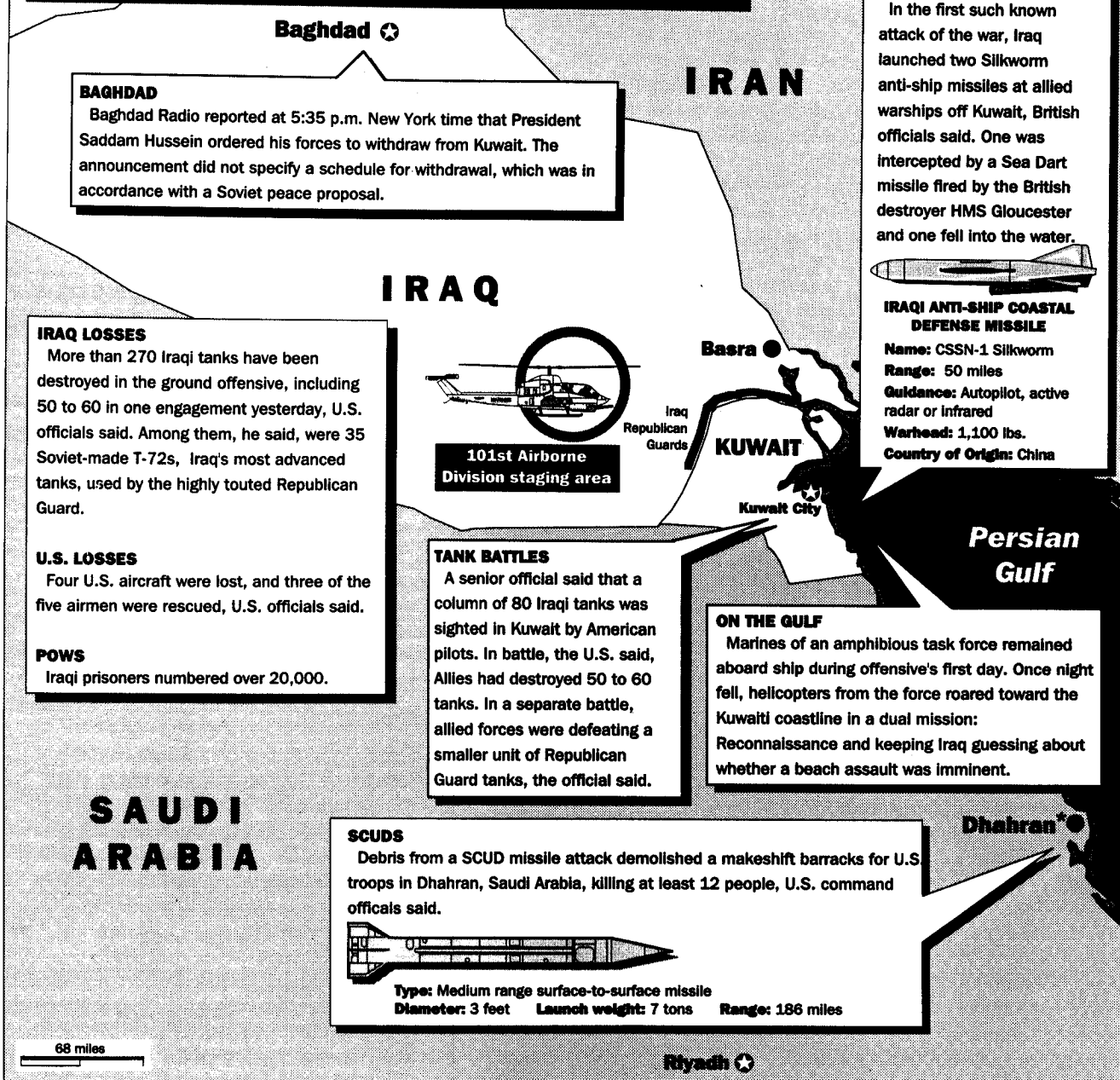


Figure 1. Daily update map (caption and balloon style). New York Daily News, ©1990 New York News Inc. Reprinted with permission.

represented were detailed, three-dimensional block diagrams showing strategies for everything from bombing bunkers to crossing mine fields, and stylized pictorial representations of weapons, aircraft, desalination plants, and tanks (Figures 1 and 2).

In summary, the print media published many maps, which changed as the events and phases of the war unfolded. The types of maps, and the symbols used, tended toward the simplistic, the colorful, and the informational. As examples

of wartime cartography, they represent a powerful set of case studies in the mass communication of visual information.

Maps for the Military

The primary agency for the production of military maps is the Defense Mapping Agency (DMA), which dates from 1972, and is the centralized source of all air, sea, and land

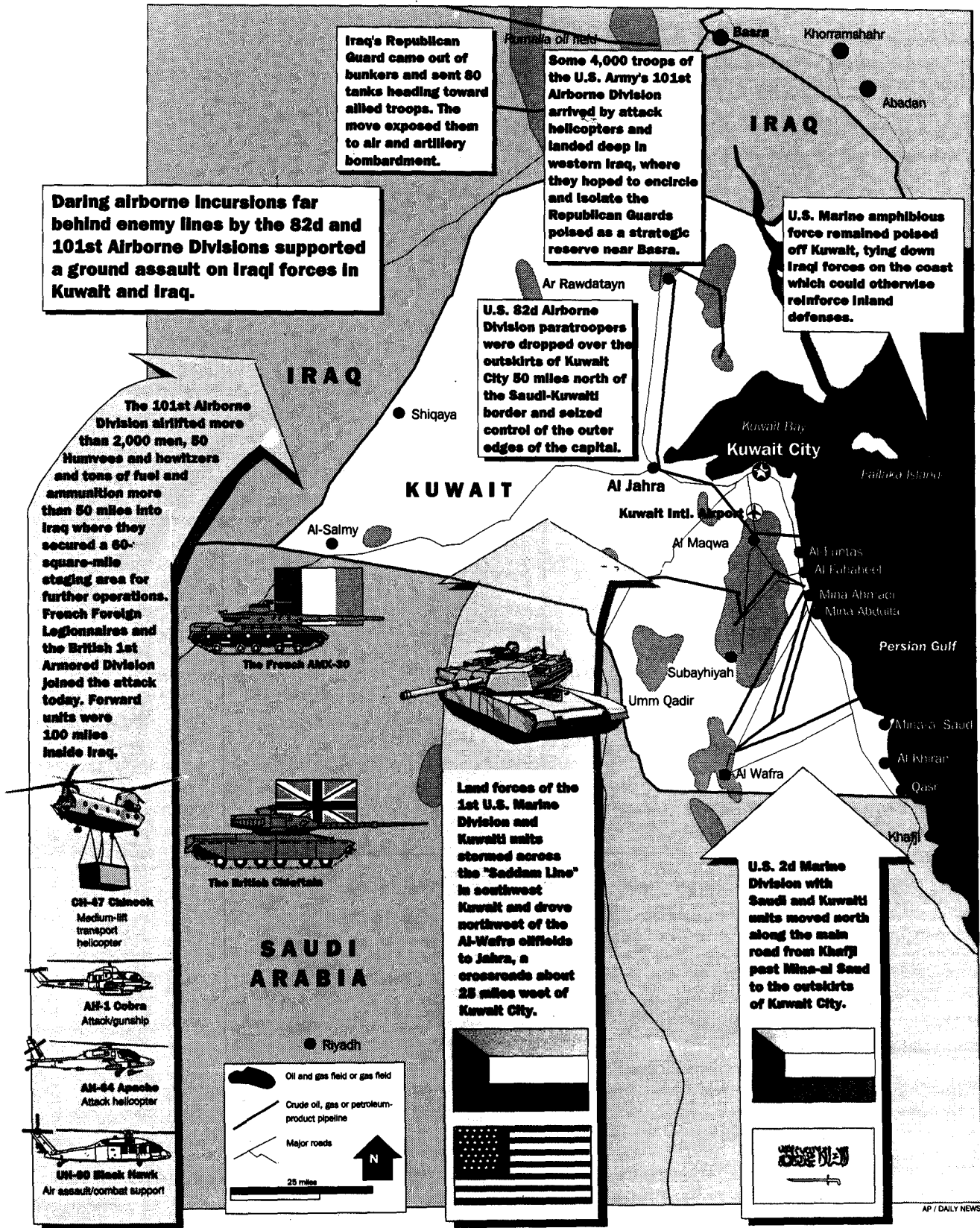
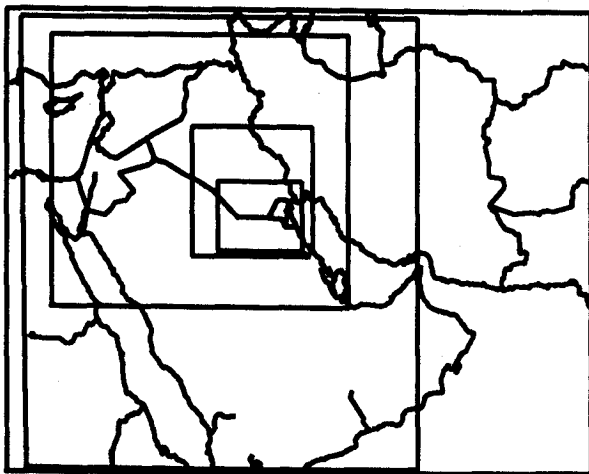
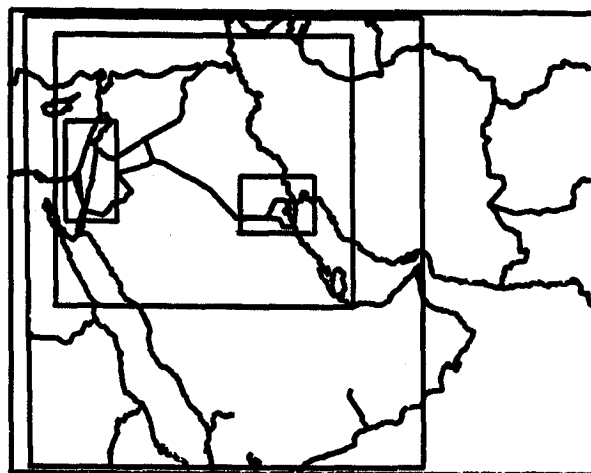


Figure 2. Pictorial symbols and arrows used to show ground-war activity. New York Daily News, ©1990 New York News Inc. Reprinted with permission.

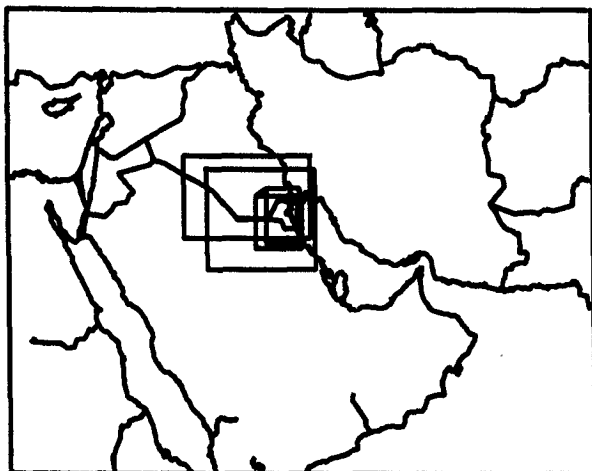
The Build Up (8/3/90-1/15/91)



The Air War (1/16/91-2/24/91)



The Ground War (2/24/91-2/27/91)



The Aftermath (2/28/91)

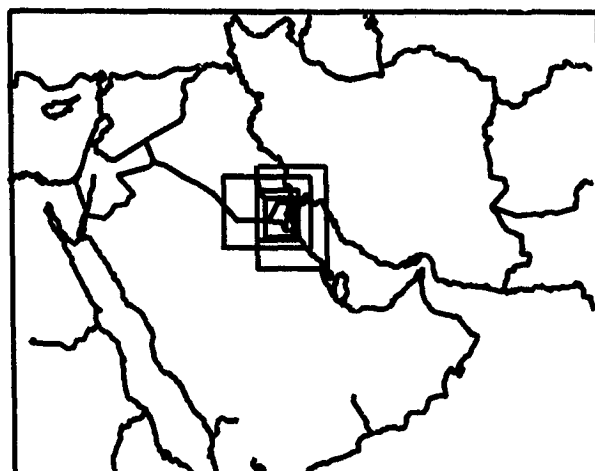


Figure 3. Ground extent of 16 typical print media maps of the gulf war. Map by Bruce Alexander.

maps and images for military use. With the start of Operation Desert Shield, the DMA moved into 24-hour production. The agency, primarily at its two plants in St. Louis and in the Brookmont area of suburban Maryland, had employees work 10- to 12-hour shifts, seven days a week, with even the DMA school's map printing press drafted into 24-hour use. Two hundred years of overtime were expended in producing 12,000 new map products, 600 of them all-digital, and in printing more than 100 million sheet maps for the field. Why so many? According to A. Clay Ancell, deputy director of the St. Louis DMA center, "You've got these things folded up and stuffed in your pocket, so after a sweaty day in the desert, they literally come apart." In addition, many maps intended for air-sortie support were used and destroyed after the completion of each mission (Associated Press 1991).

New maps produced for the war included detailed coverage at 1:50,000 and other scales of Kuwait (which had

been previously mapped in detail by the British), Saudi Arabia, Iraq, and about half of Syria. This mapping effort consisted of 760 line maps, 26 city maps, 125 joint operations graphic maps, 380 interim coverages (terrain maps), 125 satellite and other image maps, and 76 hydrographic charts.

General Joseph Pratt, who gave a briefing on the DMA's mapping activities at the 1991 Baltimore ACSM/ASPRS meeting, made a series of observations about the agency's wartime activities. Pratt noted that a primary accomplishment was the sheer volume of maps produced and placed in the field, the greatest number of maps produced for a single purpose in history. Equally important was the acceptance of maps as necessary, indeed essential, to the war effort. For the first time, maps were sent to Saudi Arabia as priority shipments on a daily C130 transport plane, exceeding in priority even medical supplies, and falling behind only spare parts for Patriot missile launchers. In the

past, according to Pratt, "maps had always been put on the slow boat." Other accomplishments included the use of Global Positioning System (GPS) and image maps (discussed below), and an image data base—the video point positioning data base—that enabled a workstation or microcomputer attached to a CD-ROM to locate a point by image and coordinate, with a turn-around time of two minutes or less. Also, a major success was the ease with which the military was able to call on and work with private contractors when required.

Such a massive mapping effort raised problems, of course. Among them were the lack of trained digital cartographers in the field, the inflexibility of propriety software when systems integration was necessary, the need to sacrifice precision and accuracy for speed, the need to buy imagery from commercial satellite companies to produce image maps, the backlog in cataloging and storing the flood of map products, and the need to rectify generalized and inaccurate maps on different projections and datums with extremely high precision GPS data.

The Army's own cartographic efforts were significant. Major Paul Harwig reported that image maps were produced and printed in the field using PC-ERDAS on 486 microcomputers, and later with SUN and Linotronics equipment, to generate maps that were printed on a mobile Heidelberg press (Harwig 1991). In addition, the Army's Engineering Topographic Laboratory placed in the field a quick-response, multicolor printer prototype, and an off-the-shelf, Canon-based, large-format, full-color copier (Engineering Topographic Laboratory 1991). While the volume of products produced did not match that of the DMA, the Army was able to move cartographic production on demand, moving the presses and workstations eight hours by road only a week before the start of the ground war, and coming back into production almost immediately.

In general, the military-map component of the war effort was a remarkable example of organized, large-scale production and flexibility with very new technology, often against severe obstacles. Clearly, the importance of sheet maps and digital map products came to the forefront during the war. This, however, is only part of the story.

GPS and the Gulf War

Perhaps more than any other technology, GPS, also known by its military name, NAVSTAR, more than proved its worth during the gulf war. GPS is a \$10 billion Air Force system designed to provide almost instantaneous, precise locational information in the field in all weather. It eventually will consist of 21 operational orbiting satellites and three orbiting spares. The satellites orbit at an altitude of 10,900 nautical miles, once every 12 hours, with three satellites on a single track. Atomic clocks on the satellites transmit a signal continuously. A GPS decoder/receiver interprets signals from three or four satellites, and in conjunction with ephemeris information about the satellite's orbital track, trilateration from distances allows precise two- and three-dimensional positioning. Small, portable, hand-held units can provide accuracy of about 18 meters horizontally, and 28 meters vertically, although higher precision is possible using two units together in differential mode. Larger back-

pack-size units are capable of precision at the submeter level. Hand-held units have been broadly available and relatively inexpensive—less than \$5,000—for some time.

GPS was used to some extent in mine-sweeping operations in the Persian Gulf during the Iran-Iraq War, and in the invasion of Panama. However, GPS was used extensively by all branches of the forces and by the Iraqis in the gulf war. The GPS system originally was designed to be completed by 1993, but at the beginning of August 1990, only 14 GPS satellites were in orbit. This number gave 24-hour, two-dimensional coverage, but only intermittent three-dimensional coverage over the Kuwait area. Six of the satellites were the aging prototypes in Block I, some dating from the 1970s. Two additional satellites were rush-launched during the build-up (Kiernan 1991).

On the eve of the air war, a Block I satellite's stabilization system failed. By spinning the satellite with commands from earth, the orbital trajectory was saved, and on January 17, 1991, ground controllers were able to point the satellite's antennas at earth briefly, once a day, during the pass over the gulf. In addition, on December 12, 1990, a solar panel control circuitry on one of the newer Block II satellites failed. Although the satellite continued to work using backup systems, the launching of additional satellites was halted until the problem was eliminated (Kiernan 1991).

GPS equipment was used in many ways during the war. Units varied from five-channel air and naval navigation units, to two-channel aircraft units, and one-channel portables (GPS World 1991). One-channel units, such as the portables, can only receive the coarse acquisition (C/A) code, while the multichannel units used the precise (P), militarily encrypted code. During the war, the deliberate degrading of the C/A code, known as selective availability (SA), was turned off, making the signals comparable in terms of ground precision. Jacobson (1991) expanded on *Wall Street Journal* reports that Iraq used C/A GPS systems in positioning and aiming SCUD missile sites in eastern Iraq, arguing that SA should be used to "deter those with hostile intentions," including terrorists.

More than 60 different air, sea, and land systems and vehicles used GPS, including planes, AWACS, helicopters, tanks, missile launchers, and even missiles themselves. Four thousand units had been delivered to the Air Force by August 3, 1990, and an additional 10,000 were supplied. The Army rounded up and shipped to the gulf 5,000 hand-held units, which were being evaluated and used in training. Trimble Navigation of Sunnyvale, California, and Magellan Systems Corporation of Monrovia, California, supplied most of the units, with Magellan supplying Great Britain, France, and Saudi Arabia. The use of GPS systems on the French Puma helicopter allowed some effective search-and-rescue operations, including the rescue of a U.S. Air Force pilot on January 13, 1991, in stormy weather (*Aviation Week and Space Technology* 1991a).

Kiernan (1991) quotes Vice Admiral Jerry Tuttle, the U.S. Navy's director of space, command, and control, as saying that GPS will "revolutionize tactics in every warfare area," a fact that indeed seems true of the gulf war. The broad availability of hand-held units will place an especially rigid demand on digital and printed cartographic products, especially at large scales such as 1:50,000. Pratt of the DMA

noted that GPS units caused some confusion in the field over the use of datums and map projections, and forced the revision of many older map products to meet the increased need for geodetic accuracy.

GIS, Remote Sensing, and the War

The Persian Gulf War also led to different uses of remotely sensed imagery and geographic information systems (GIS) than those in peacetime. The DMA and Engineering Topographic Labs used digital terrain elevation data, interim terrain data, ARC-digitized raster graphics, and gazetteers during the war (ACSM 1991). The Navy accelerated the deployment of an experimental system, the Joint Operations Tactical System, which is a "complete" battlefield management system capable of data fusion, control, and display, and makes use of large-format displays, workstations, plotters, and other peripherals. More than 200 such systems were in service by January 1, 1991, including versions with the British, Canadian, and Australian navies (Hewish 1991).

In terms of space-based remote sensing, the primary tool was a series of KH-11 satellites in elliptical low orbits, which provided overlapping coverage of the gulf area (Denton 1991). These satellites provided high-resolution infrared imagery, primarily for bomb damage and other assessments. Denton noted that other satellites, such as the Lacrosse radar-imaging satellite and other defense support program satellites in geosynchronous orbits, were used, but there were gaps in coverage, caused in large part by poor weather.

More traditional commercial satellite imagery also was used. SPOT and Landsat coverage was used to assemble several image maps of areas of interest, even by commercial companies such as Intergraph (see map list). This imagery was processed into annotated and printed maps by the Army's topographic engineers, with limited early success. Where no map coverage existed, these image maps, of which the DMA produced 125, proved helpful.

By far the greatest success story, however, was an imaging radar system developed by the Air Force and known as JointSTARS (JSTARS), an aircraft-based synthetic aperture radar (SAR) system. The two JSTARS aircraft were ordered to the gulf area on December 18, 1990, and required extensive crash training in the field. The two planes flew one 10- to 12-hour mission per day during the war, providing large amounts of radar imagery (Sweetman 1991). The radars operate in two modes—a moving-vehicle detection mode, capable of covering a million square kilometers per mission, and the regular SAR imaging mode for fixed targets. A particular advantage of the system over other satellite- and aircraft-imaging systems was its ability to work at night and in bad weather. While detecting whether moving vehicles were wheeled or tracked proved impossible (Boatman 1991), the system was judged to have performed above expectations. *Aviation Week and Space Technology* (1991b) reported that the system worked despite jamming by the Iraqis.

Conclusion

This paper began by noting that cartography traditionally receives a technological boost in wartime. Aerial photog-

raphy, radar, digital photogrammetry, digital cartography in general, and even the DMA itself all have early origins in the major wars of this century. The gulf war, however, was an exception to this rule. Perhaps because the war was over so quickly, and was prepared for over an extended period, it proved a testing ground for new technologies that already had been developed. Many of these technologies were rushed from testing to first field use in a matter of weeks, and most performed impeccably. As a result, the broad-scale acknowledgment that advanced, high-technology cartographic systems are essential was probably the single most important outcome of the war, from a cartographic standpoint.

Postwar analysis has pointed to some easily attainable goals for cartography, including: (1) more, and better trained, digital cartographers and photogrammetrists; (2) better, faster, more flexible and reliable digital cartographic systems; and (3) more large-scale digital map coverage of unmapped parts of the world. Pratt's call for better systems integration is itself an endorsement for current trends within cartography, where common data formats and spatial data transfer standards have been years in development, and are now close to reality.

Just as interesting, the mapping at 1:50,000 of extensive land areas was achieved quickly with a high-technology, concentrated effort. With an even larger global effort, using satellite imagery and GPS ground truth, it now seems possible that the entire land surface area of the earth could be mapped at 1:50,000 with a standard symbol set and identical accuracy standards. Such a map would be extremely useful, the cartographic equivalent of the current biological project to complete the DNA mapping of the human genome.

From the point of view of the media, maps have been portrayed as snapshots of the societies and technologies that produced them, therefore containing their biases (Harley and Woodward 1989). With this view in mind, noting that some of the worst cases of lying with maps have been during wartime (Monmonier 1990), and that the gulf war was fought under conditions of extensive censorship, this author was surprised to see almost exclusively good-faith and accurate map coverage of the war. The British satirical journal *Private Eye* published, during the conflict, a spoof war map entitled "3 a.m. Massive Space Filling Graphic Goes In!" While it is possible to laugh at captions and information boxes with entries such as "Large Arrow Here," and "Nobody Reads These Little Boxes Anyway," the truth is that the media, to the best of their ability, filled their boxes with pertinent information that did keep the public well informed about the progress of the war. Monmonier (1989, 19) called the news media "society's most significant cartographic gatekeeper and its most influential geographic educator." If the public is to gain its geographical knowledge primarily from the news media, then the obligation of media cartographers to portray geography accurately is of critical importance, especially in the international sphere.

Finally, the war's cartographic legacy has led to some less-destructive uses. Some of these include managing the relief effort for the Kurdish population of Iraq, after their abortive rebellion; attempting to extinguish the many burning oil wells in Kuwait, which were pumping 50,000 tons of sulfur a day into the atmosphere and which left pools

of surface oil sometimes a kilometer wide; controlling large, deliberate oil spills into the gulf; and rebuilding Kuwait and Iraq. At the United Nations, maps are now being drafted to help delineate boundaries, especially the boundary between Iraq and Kuwait.

The repercussions of the Persian Gulf War for the Middle East will last a lifetime at least, and are at best indistinct. For cartography, however, the war's effects have been immediate—accelerating technological change; proving the value of new mapping-science technologies; and moving cartography ever further from the pen-and-ink, scribe coat, and stereo viewers of only a generation ago.

Appendix

Following are some of the important maps produced or used during the Persian Gulf War:

1. DMA, ONC H6 Edition 6GSGS, scale 1:1,000,000, covers Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates.
2. Intergraph Corporation, Kuwait City, 1:100,000 Landsat TM False Color image map of Kuwait City and surrounding area, Huntsville, Alabama, 1991.
3. Central Intelligence Agency color map of modern Iraq, with insets showing population, economic activity, land use, and religious and ethnic makeup, 1978, Washington.
4. DMA, "Survival Charts of the Iran/Iraq Area," evasion chart, St. Louis, DMA Sheet EVC NI38A:C.
5. *TIME* magazine, "The Gulf: War Map," pullout section.
6. Hammond, "War in the Gulf: An Associated Press News Map," 1991.
7. *Newsweek* magazine, "The Gulf War Zone," a series of Hammond pullout maps.
8. DMA, "Operation Desert Storm Planning Graphic," Hydrographic/Topographic Center Series 1211S, Edition 1, DMA Stock No. 1211SDSTORMPLN, 1:3,500,000.
9. Ministry of Defence (United Kingdom), "Gulf Briefing Map," Series GSGS 5664, ED. 1GSGS, 1:1,750,000.

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