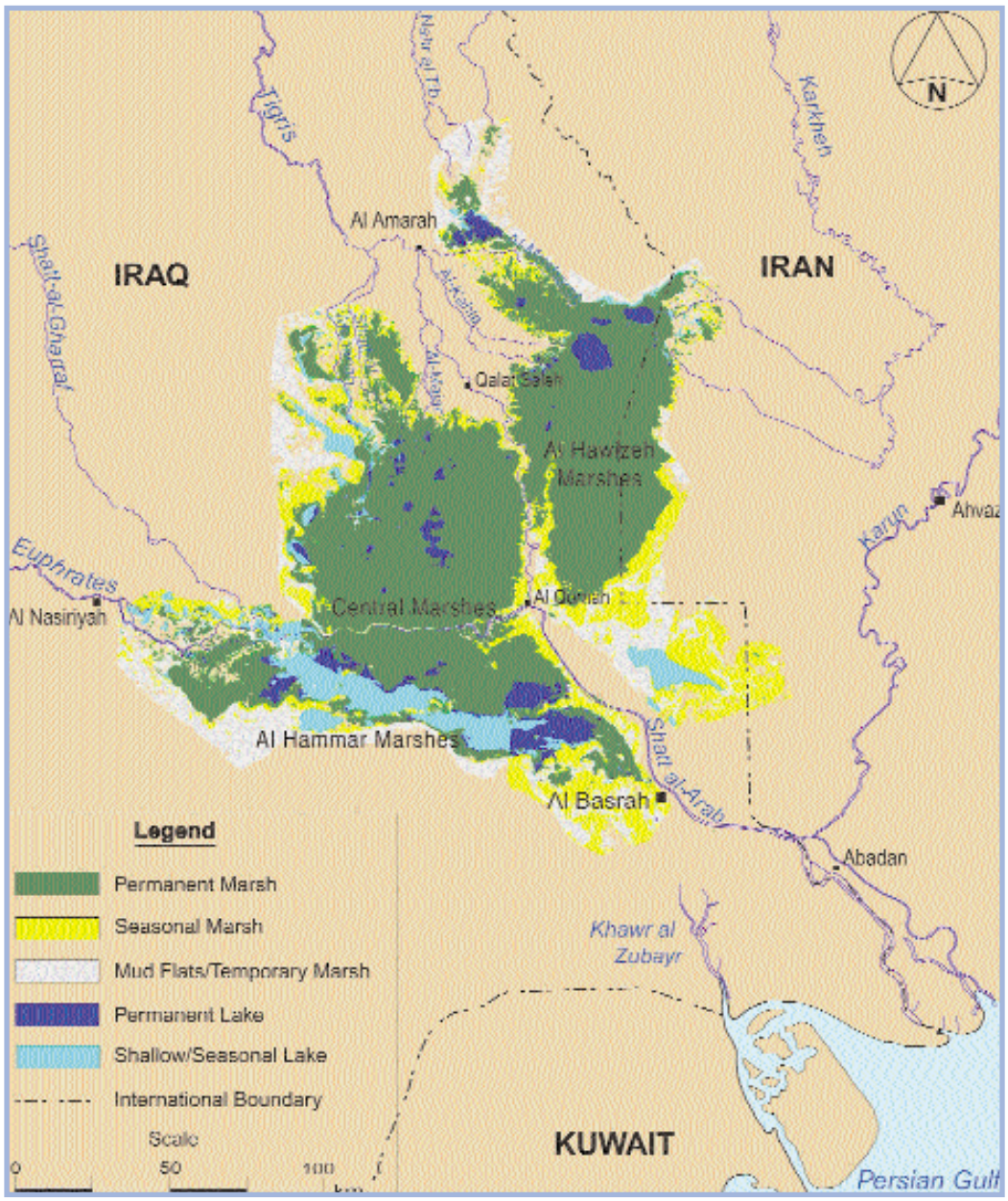
IRAQ



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Iraq was invaded by Coalition forces on 19 March 2003. Three weeks later, the regime of Saddam Hussein was defeated, the main cities of Iraq had been occupied and the war was over. With the end of the main military campaign, detailed accounts have now begun to appear in the press and on the web about the part that airborne and spaceborne imagery played in helping to lay the foundation of this successful military action. From these accounts, it is clear that the comprehensive, round-the-clock coverage of Iraq gave Coalition commanders a detailed knowledge of Iraqi military forces and infrastructure that provided a huge advantage for planning and successfully executing the ground and air attacks on the Iraqi forces.

AIRBORNE SURVEILLANCE

In particular, the Coalition forces implemented continuous or frequent coverage of much of Iraq using a mixed fleet of U-2 aircraft, Unmanned Aerial Vehicles (UAVs) and American and

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British tactical reconnaissance aircraft to generate the imagery required for surveillance, intelligence gathering and damage assessment. In daylight, this came mainly in the form of video or digital frame imagery generated by electro-optical (EO) imaging devices, supplemented by the high-resolution photography generated by film cameras. At night, lower-resolution but still useful imagery was generated using synthetic aperture radar (SAR) and thermal infrared (IR) imaging devices mounted on night flying aircraft and UAVs.

Through the use of direct line-of-sight data links between the reconnaissance aircraft and ground stations at shorter ranges, and communication satellites at longer ranges, Coalition commanders at headquarters and in the field received a continuous flow of airborne imagery on which they could plan military actions. In particular, change detection and analysis could be conducted on the imagery in order to detect the movements of vehicles and military formations. This information was often decisive in targeting and attacking these

Iraqi military assets, often using precision guided bombs and missiles.

Iraqi anti-aircraft defences

For one month prior to the actual invasion and the start of the ground war, Coalition aircraft made numerous attacks on Iraq's anti-aircraft defences including guns, surface-to-air missiles (SAMs) and their associated radars and control centres, especially in the heavily defended Baghdad area. These defences were systematically targeted, attacked and destroyed. As for Iraqi fighter aircraft, these were conspicuously absent. Most of the aircraft that survived the previous Gulf War in 1991 had been flown for safety to Iran, whose government, quite understandably, refused to return them to Iraq. Thus, almost all the Coalition reconnaissance aircraft were able to operate without too much interference by staying at altitudes beyond the range of shoulder-fired missiles.

U-2

In any case, with the U-2 reconnaissance aircraft, given its operating height of 70,000 feet (21 kilometres), only a very few batteries could fire SAM missiles that could even reach such an altitude, and nearly all of these had already been destroyed. Considering the current fleet of 30 U-2 aircraft in the USAF inventory, if 10 to 12 of these had been allocated to the Iraq campaign, then, given the 8 to 10 hour endurance of an individual aircraft and pilot, it would be quite possible to maintain at least one, if not two of them over Iraq during a 24-hour period. These aircraft could then be tasked to acquire continuous imagery of areas of interest using their EO imagers during daylight and their radar imagers at night. All of this imagery could be returned to ground stations via line-of-sight or satellite communication links on a near real-time basis.

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In this particular context, it should be realised that the current models of the U-2 aircraft are not at all the same as those used in the 1950s and 1960s – such as that piloted by Gary Powers and brought down over Russia in 1960. The present U-2R and S models were built in the 1980s and are 40 per cent larger. Furthermore, they were re-engined during the 1990s and re-wired with fibre-optic cabling and electronics to serve their SYERS electro-optical/infra-red (EO/IR) and ASARS radar imagers and their high bandwidth data links. The current U-2s can also collect radio signal traffic. Now they are being fitted with 'all-glass' cockpits with full colour displays and modern avionics (see figure 1).

UAVs

With regard to unmanned aircraft, according to the *New York Times* of 17 April, no fewer than 15 Predator UAVs operated over Iraq and, for the first time ever, several were in use simultaneously. Of course, the slow-flying Predator UAV has a maximum ceiling of only around 25,000 feet (7.6 kilometres), so it is more likely than the U-2 to have been used in a tactical role loitering over a specific area with a restricted ground coverage. According to news reports, many of the Predators have been

Figure 1(b): The new 'all-glass' cockpit of the U-2S aircraft equipped with large multi-function displays and modern avionics. (Source: Lockheed Martin)

Figure 1(a): The modern Lockheed U-2S reconnaissance aircraft still fulfils a major role as a platform for airborne imaging systems used for surveillance and intelligence gathering. Its wing pods contain radio signal monitoring systems and the aircraft's data links. The nose cone houses the SYERS EO/IR cameras or the ASARS imaging radar. A bay on the underside of the aircraft contains its photographic film cameras. (Source: USAF)

fitted with TV cameras equipped with zoom lenses to provide a continuous stream of colour video images that could be relayed to commanders in the battlefield area. Towards the end of hostilities, when the Iraqi air defence system had been sufficiently degraded, a Predator UAV was able to fly over Baghdad for a 12-hour period, continuously sending back imagery to its ground station.

Besides the Predators operated by the US Air Force, a number of other smaller short-range UAVs such as the Hunter, Shadow and Pioneer were operated directly over the battlefield by US Army and Marine Corps units. All of which only serves to emphasise the new availability and reliance on terrain imagery on the part of battlefield planners and commanders. At the other end of the UAV scale, two of the high-altitude, long-range Global Hawk UAVs were also deployed, sending their EO/IR and SAR imagery back to the Combined Air Operations Center (CAOC) at the Prince Sultan air base in Saudi Arabia.

J-STARS

The war in Iraq also saw the first deployment of the Joint Surveillance & Target Radar System (J-STARS) on a really large scale (see figure 2). The system comprises an all-weather stand-off surveillance radar system that can be operated either as a SAR imager or in moving target indicator (MTI) mode. This is interfaced to powerful computers and a command and control centre. All of this equipment is mounted on a re-manufactured Boeing 707–300 commercial

Figure 2: (a) One of the RAF's Canberra PR9 high-altitude reconnaissance aircraft that is equipped with the same SYERS EO/IR imagers and data links that are fitted to the U-2S. (Source: UK Ministry of Defence)

Figure 2: (b) The USAF's E-8 J-STARS aircraft based on a re-manufactured Boeing 707–300 airframe. The 12-metre (40-foot) canoe-shaped radome hung under the aircraft's forward fuselage houses a 7.3-metre (24-foot) long side-looking radar antenna. (Source: USAF)

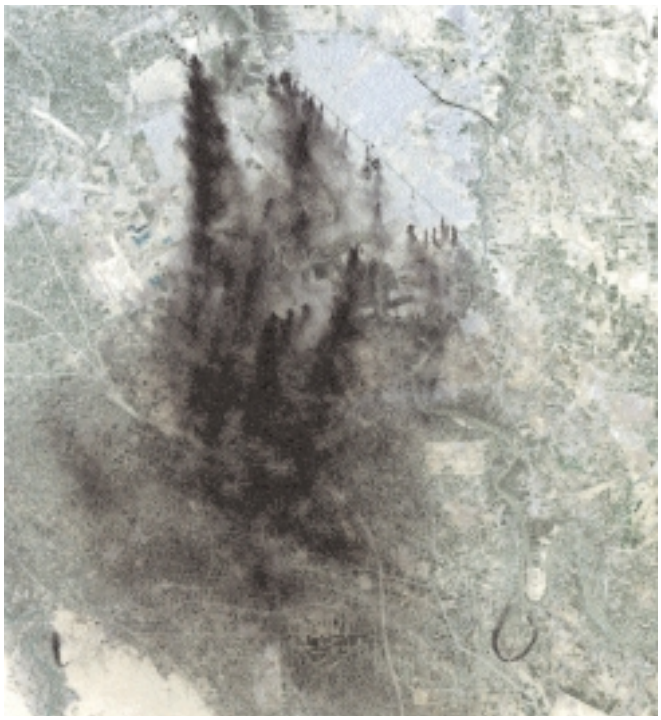

Figure 3: The city of Baghdad is partly covered by dark smoke plumes from pits and trenches filled with burning oil in north Baghdad and along the canal on the east side of the city. Baghdad International Airport can be seen to the left of the main plume. This image was acquired by Landsat-7's Enhanced Thematic Mapper (ETM+) on 2 April 2003. (Source: NASA Earth Observatory)

aircraft with a ceiling of over 40,000 feet (12 kilometres) and an endurance of 11 hours, if unrefuelled, or 20 hours with in-flight refuelling. Individual J-STARS development aircraft had been used previously during the Allied operations in Bosnia and Kosovo in the 1990s. However, delivery of the 17 production aircraft was only completed in February 2003. This allowed a number of J-STARS aircraft to be available for the Iraq war. These provided a picture of the situation on the ground equivalent to the air situation provided by the well-known AWACS airborne early warning system.

In particular, the J-STARS surveillance radar is capable of determining the location, direction, speed and activity of military vehicles moving on the ground. This analysis is carried out using the high-powered computers on board the J-STARS aircraft. According to the USAF, the system can detect these vehicle movements at ranges up to 150 miles (240 kilometres) from the aircraft. The resulting information is then relayed to army ground stations and command headquarters using secure data links. Again this data contributed greatly to the planning of the Coalition's military activities.

Unfortunately, examples of the actual imagery of the terrain and targets generated by this constellation of military reconnaissance aircraft are not yet available to illustrate this article. However, in summary, one can already say that the use of airborne imagery giving continuous surveillance of the areas held by Iraqi military forces contributed substantially to the planning of the successful military operations by the Coalition forces.

SPACEBORNE SURVEILLANCE

Imagery from satellites has undoubtedly supplemented imagery from airborne platforms (see figure 3). However, we need to realise that there are certain inherent limitations to the use of space imagery in a battlefield situation. These include the fact that only a very few high-resolution imaging satellites are in operation. They comprise the six military satellites – 3 KH-11/12s equipped with optical imagers and 3 Lacrosse radar satellites – operated by the National Reconnaissance Office (NRO), plus the three commercial high-resolution satellites: IKONOS, EROS-A1 and QuickBird. Each of these satellites is in a polar orbit and is moving at a speed of 6 to 7 kilometres per second (or 400 kilometres per minute) over the ground.

If we look at a map of Iraq, we can see that the north/south dimensions of the country are around 1,000 kilometres. So each satellite will pass from south to north (or north to south) in two minutes twice per day – once in daylight and once in darkness. Besides, a specific satellite may not pass again over Iraq for two or three days, even taking account of the fact that all of these satellites have side-pointing capabilities to image targets located to each side of the satellite ground track. Furthermore the swath width of the satellite imagery is quite limited – 11, 12.5 and 16 kilometres for IKONOS, EROS-1A and QuickBird respectively – keeping in mind that Iraq measures 800 kilometres in width from east to west.

What is sure is that satellites could not provide the flexibility and the continuous, often real-time, imagery coverage that was provided by the Coalition's fleet of reconnaissance aircraft. However, the high-resolution imagery acquired by the satellites would still be valuable when added to that provided by the aircraft. Although the military satellite imagery is unavailable, examples of the IKONOS and QuickBird satellite imagery have been published on the image galleries of Space Imaging's and DigitalGlobe's websites.

IKONOS

As mentioned in my previous article on 'Monitoring Iraq' published in the January/February issue of *GI News*, two new ground stations, each covering the whole of Iraq, had been constructed and brought into operation by the two regional affiliate companies of Space Imaging covering the Middle East. These are Space Imaging Eurasia, whose ground station is located in Ankara, Turkey, and Space Imaging Middle East, with its station located in Abu Dhabi in the United Arab Emirates. Undoubtedly both of these ground stations were kept busy taking down the images that IKONOS acquired whenever it crossed Iraq (see figure 4). Presumably Space Imaging decided in advance which of the two stations would receive the data from a specific overpass – since I am given to understand that only one of these stations can receive IKONOS data at a particular time.

Figure 4: These two IKONOS images show the Republican Palace in the centre of Baghdad before (above) and after (below) the precision strikes on its buildings. (Source: Space Imaging)

It may be assumed that, after processing, the image data was then transferred to the Coalition headquarters in Qatar, the CAOC in Saudi Arabia and the appropriate agencies in the USA, using satellite communication links. In contrast to its actions during the war against the Taliban in Afghanistan in November/December 2001, the US Department of Defense did not try to buy

Figure 5: This QuickBird image of part of Central Baghdad shows the parade ground with its grandstands and helicopter pads in the lower left part of the picture and the Unknown Soldier Monument in the upper right part of the picture. Between these two features is a smoke plume from a burning oil pit. (Source: DigitalGlobe)

exclusive rights to all the IKONOS imagery acquired over Iraq. So, at least in principle, anyone could buy this imagery. In practice, however, Space Imaging and the media were fairly circumspect with regard to the images actually shown on television, published in newspapers and magazines, and displayed on websites.

QuickBird

As discussed in the previous 'Monitoring Iraq' article, QuickBird's Iraq imagery (see figure 5) is handled quite differently. It is stored in the satellite and downlinked, not in the Middle East, but to one or other of the two polar ground stations located in Tromsø, Norway, or Fairbanks, Alaska. After this, it is passed on directly to DigitalGlobe's headquarters and processing centre in Colorado. After processing, the image data is then transferred back to the US military forces in Iraq as well as to the appropriate intelligence and mapping agencies in the USA.

POST-CONFLICT IRAQ

Imagery has several potential uses for reconstruction in post-conflict Iraq.

Oil well fires

The oil well fires in southern Iraq that Iraqi forces set alight as they retreated northwards had only short-term effects. Luckily, thanks to the prompt action of the Coalition forces, only a very few were ignited – in stark contrast to the situation in Kuwait during the Gulf War in 1991. Still, the smoke plumes from these few fires did show up clearly even on the low-resolution images collected by weather satellites (see figure 6).

Mesopotamian Marshlands

Another matter of great concern to the international environmental community for some time is the destruction of one of the world's great wetlands, the Mesopotamian Marshlands. Formerly these covered extensive areas around the confluence of the Tigris and Euphrates rivers and their delta close to the sea in Southern Iraq (and extending into Iran). As space imagery has shown, only 25 years ago these marshlands covered an area of 20,000 square kilometres. Now they amount to only 1,500 square kilometres spread along the Iraq/Iran border (see figure 7 overleaf).

The causes of the loss of this distinctive environment are varied. On the one hand, these two rivers have been dammed extensively upstream, especially in southern Turkey, but also in Syria, as well as in Iraq. This has resulted in a much reduced water supply and the loss of the flood pulses that helped to sustain the marshlands.

During the 1980s, the area was the scene of bitter fighting during the Iran/Iraq war, causing much damage to the environment. Then, during the 1990s, Saddam Hussein's government pursued a very active campaign of draining the area. This was carried out for land reclamation to create new farms and to try to remove some of the salt encrustation that affects much of the area lying between the two rivers. However, it also resulted in the drainage of the marshlands that gave sanctuary to various dissident groups. Large numbers of the distinctive Marsh Arab people have been displaced, either to Iraq's cities or to refugee camps located across the border in Iran. The UN Environment Programme (UNEP) has already signalled this situation as being one of extreme concern. In response, NASA has made a huge gift of its Landsat imagery taken over many years to help the UNEP studies. Those readers interested in this particular topic can obtain more detailed information and view some of the images on two of UNEP's websites – GRID Arendal (www.grida.no) and GRID Geneva (www.grid.unep.ch) – and on the USGS EarthShots site (http://edc.usgs.gov/earthshots).

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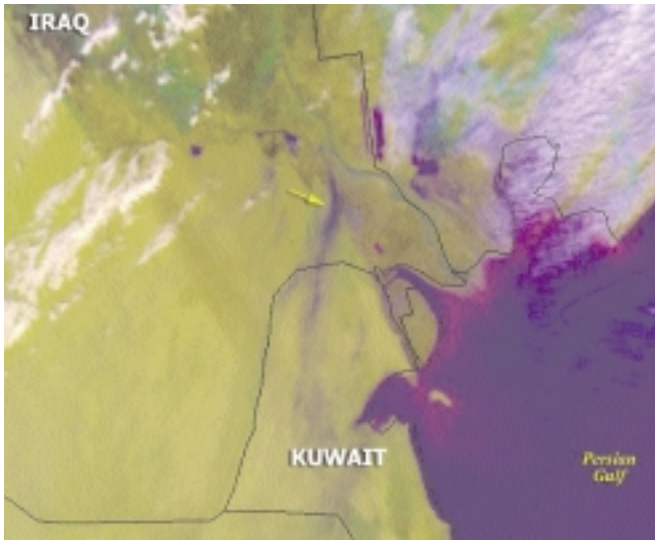
Mapping Iraq

During the 1960s, substantial parts of Iraq were mapped by European air survey contractors. Later, Iraq built up its own

Figure 6: A false-colour AVHRR image of the southern part of Iraq acquired by the NOAA-17 polar-orbiting weather satellite. It shows the smoke plume being emitted from burning oil wells in the area of the Rumeila oilfield and drifting over the western part of Kuwait. (Source: NOAA)



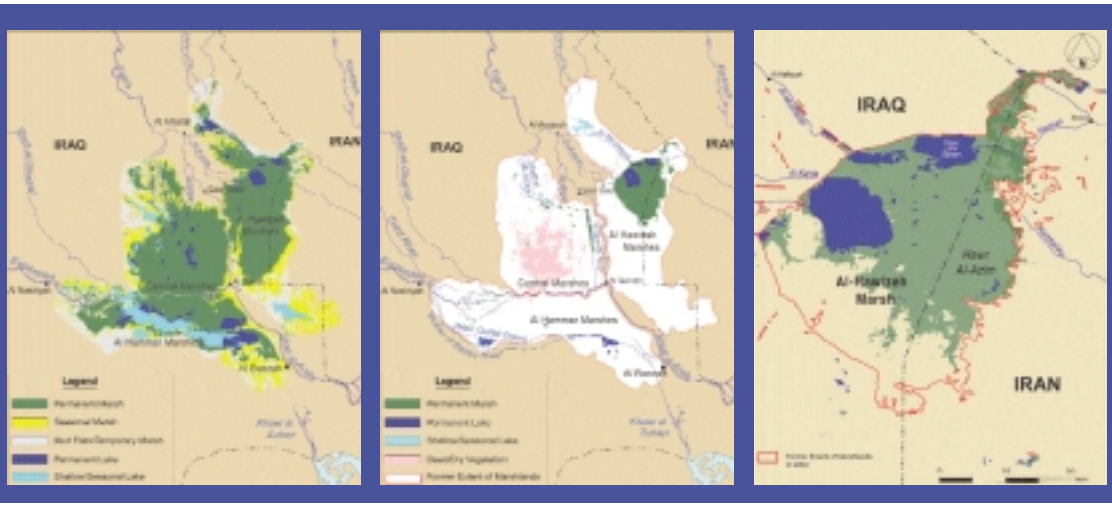


Figure 7: The extent of the Mesopotamian Marshlands (near left) during the period 1973–76; and (middle) in 2000, as derived from analysis of Landsat imagery.

Far right: This map shows the further shrinkage of the residual Al-Hawizeh Marshes located along the Iran/Iraq border between 2000 and 2002, as derived from Landsat-7 images. (Source: UNEP/DEWA/GRID-Geneva)

substantial national mapping capabilities. However, as in other Middle Eastern countries, because of concerns about military security the resulting maps were never made available to the public. Besides these nationally produced series, the whole of Iraq was mapped from satellite imagery by Russian (Soviet) mapping agencies at 1:100,000 and 1:200,000 scales. These maps are now available from East View Cartographic based in Minneapolis in the USA. Given the long period of difficulties over Iraq before, during and after the Gulf War, one presumes that similar systematic map coverage has also been produced by the USA and its NATO allies, though this mapping is not publicly available either.

However, in February 2003, just before the start of the recent war, NIMA (the US National Imagery and Mapping Agency) released a new overall map of Iraq at 1:1,250,000 scale and a detailed map of Baghdad at 1:40,000 scale (see figure 8). During the war, a further map of Tikrit at 1:14,500 scale was also published. Further maps of Basra (at 1:30,000 scale), Mosul (at 1:40,000 scale) and Kirkuk (at 1:15,000 scale) will be available soon, both in digital as well as in hard-copy form.

An article published in the *Washington Post* on 22 April gives a surprisingly detailed account of the procedures used to compile the Tikrit map based on IKONOS imagery. This article also mentioned a series of 16 maps of Iraqi cities that Space Imaging is producing in collaboration with NIMA under the US State Department's 'Future of Iraq' project. On 17 March, Space Imaging also announced that the State Department had selected its Geobook GIS for use with the maps produced under the project. This will allow users to inspect and analyse the geospatial data contained in the maps and imagery. It is intended that the data and software will be made available to international relief and humanitarian agencies as well as to working groups set up by the interim American administration.

Not only have airborne and spaceborne images played a decisive role during the recent war, but they promise to be most useful in helping to resolve environmental problems and support reconstruction efforts in post-conflict Iraq.

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Figure 8: The new 1:40,000 scale map of Baghdad released by NIMA in February 2003. (Source: NIMA)