Geospatial Technologies and Human Rights Project

Documenting Conflict in Misurata, Libya, Using High-Resolution Satellite Imagery
The present conflict in Libya began in mid-February 2011 as a wave of protests in cities across the country. In some cities, such as the eastern cities of Benghazi and Tobruk, protesters have taken over all aspects of local governance and remain in control. In other cities, such as the western city of Zawiya, military forces have reinstated the authority of the central government. The focus of this report is Misurata, Libya’s third largest city, which is located on the northwestern coast of the country. Since early March, government forces and protesters in Misurata have continued to clash. Furthermore, since 23 March, Misurata also has been the target of airstrikes conducted by international forces. The conflict in Misurata has led to reports of heavy fighting, widespread indiscriminate shelling, and numerous civilian casualties. To investigate the veracity and details of these reports, Amnesty International-USA requested the assistance of the Geospatial Technologies and Human Rights Project of the American Association for the Advancement of Science (AAAS).

Imagery acquired on 4 March shows evidence of a citywide effort to erect improvised defensive positions. These were visible as checkpoints and barricades made from disabled vehicles, tires, and large piles of sand placed across major intersections and at the entrances to residential neighborhoods. While isolated burn marks on some arterial roadways suggest that minor skirmishes had taken place on the outskirts of the city at this time, most of the area appeared to be largely unaffected by fighting. Despite the many improvised checkpoints, cars were still visible on the streets of downtown Misurata. No significant damage was observed to buildings or infrastructure in the city, and the number of vehicles parked at the city's hospitals was similar to the number present in Google Earth's imagery from 2004, indicative of relatively normal activity.

Over the weekend of 5-6 March, according to media reports and eyewitness accounts from within the city, government forces mounted a major offensive to retake the city, involving tanks and heavy artillery. This offensive is reported to be ongoing as of 20 April. Imagery acquired by AAAS from the morning of 28 March reveals tanks and armored vehicles present along the main street in downtown Misurata, including in front of the medical technical college and the empty central hospital, consistent with reports of those facilities being used as a base of operations (Figure 1).

1 Excluding Misurata Central Hospital, which has been closed for renovations for the past two years.
February 17 Voices project. Military situation, shelling, day/night locations of Gaddafi forces. Interview with Misurata Resident, on 26 March 2011. Available at
The numerous improvised sand pile roadblocks along the street observed on 4 March have been demolished and are strewn across the pavement, with heavy vehicle tracks running through them. The street itself is littered with disabled vehicles and other debris. The asphalt is blackened in a manner that is consistent with fireworks. Craters from artillery fire are also evident (Figures 2-3). The central marketplace has been destroyed, apparently by fire; its roof is completely absent and only the principal supporting walls remain. The marketplace was targeted, according to eyewitness reports and video posted online, by government forces on the evening of 24 March (Figure 4). Its parking lot is marked by craters, as is the street outside the local Red Crescent Clinic (Figure 5). When these craters occur in a soft medium such as dirt or sand, the material excavated by the explosion is spread circumferentially about the impact site. In the case of several craters throughout the city, this ejecta blanket was measured as extending fifteen meters from the point of impact. Because fragments from exploding munitions travel farther than the blast wave itself, the potential for casualties from such shelling likely extends beyond this distance.

Reports indicate that the conflict in Misurata has led to thousands of people wounded, yet the parking lot of the city's major functioning hospital, the Polyclinic, is empty. This is consistent with eyewitness accounts that the building was evacuated due to its proximity to the fighting (Figure 6). Also supporting this conclusion is the significantly overcrowded parking lot of the Al-Hekma clinic in the protester-controlled suburb of Al-Jazeera, to which eyewitnesses reported many of the Polyclinic's patients were transferred (Figure 7). According to reports, medical facilities have been operating without electrical power, which is supported by the observed destruction of the main electrical station for Misurata (Figure 8).

As a result of the conflict, thousands of individuals are reported to have fled to the port area east of the city, waiting to evacuate by ship. Consistent with these reports, numerous temporary structures are visible along an access road north of the port’s steel mill (Figure 9). In addition to being an evacuation point, Misurata’s port is also reported to be one of the only locations through which aid can enter the city. Both of these uses are consistent with the 160-meter long queue of people observed at the main gate of the port (Figure 10), and with the group of vehicles seen gathering next to a small vessel at the pier (Figure 11). The port facilities as well as the nearby steel mill exhibit signs of bombardment, consistent with reports that the area has been the target of
heavy shelling. In some instances, shell craters were observed within 350 meters of tents erected by the displaced persons.

Evidence of international airstrikes is also present, but largely confined to the airport area on the outskirts of the city. Numerous fighter jets and helicopters have been destroyed on the ground in what appear to have been precisely targeted attacks (Figure 12). A military warehouse in that area also shows significant damage (Figure 13), consistent with eyewitness accounts of a large explosion at that facility. The size of the craters produced by these strikes and their extremely close proximity to identifiable military targets is distinct from the pattern of destruction observed in the center of the city and at the port. There, the damage appears to have involved smaller caliber weapons, and is often scattered throughout the area with no clearly discernable targets. Such haphazard targeting would be uncharacteristic of modern aircraft capable of deploying ordnance precisely, but would be expected from forces operating in a chaotic situation with 1970s-era military equipment, of which numerous examples are visible in the available imagery (e.g. Figure 12).

Misurata lies at the center of a large metropolitan region covering over one hundred square kilometers. A comprehensive review of satellite imagery covering the study area illustrates the spatial distribution of conflict-related observations (Figure 14). In conjunction with the focus areas presented in Figures 1-13, this distribution reveals the city sustained considerable damage throughout the month of March and into April. Considerable levels of damage were observed along the three major roads leading toward the center of the city, in particular those entering from the south and southwest (Benghazi and Tripoli streets, respectively).

Numerous fresh craters are visible throughout the city and port area, including in close proximity to known medical facilities. Many civilian structures show signs of damage and some, such as the central food market and main electrical station, have been destroyed completely. In many areas, the makeshift defenses that had been erected at the beginning of March have been destroyed. Based on available satellite imagery, the evidence supports eyewitness reports describing widespread shelling, destruction of property, and conflict in the streets of Misurata.

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On 4 March (top), there is little activity outside Misurata Central Hospital apart from the beginnings of a sand-pile barricade. On 28 March (bottom), a large complex of these barricades appears to have been demolished (C), and a column of armored vehicles (A) is parked outside the hospital grounds (B). The wall enclosing the hospital also appears to have been breached (E), consistent with reports of its use as a staging area for government forces. An intact barricade (D) is visible at the entrance to a side-street. Imagery ©2011 DigitalGlobe.
Compared with 4 March (top), the image from 28 March (bottom) shows substantial damage to the buildings facing the main street (A), as well as streets blackened by explosions (B). Further up the street, beyond the remains of a sand barricade, an armored vehicle (C) is visible. Imagery ©2011 DigitalGlobe.
Between 4 March (top) and 28 March (bottom), the street has become littered with debris and disabled vehicles (A). The black scars on the asphalt (B) are consistent with eyewitness reports of heavy shelling, as are the three fresh impact craters (C) that have appeared between the two dates. Based on the ejecta pattern of the craters around (C), the blast radius of the munitions used is at least 15 meters. Imagery ©2011 DigitalGlobe.
The central food market, clearly intact on 4 March (top), has been destroyed by 28 March (bottom, A), consistent with an online video which purporting to show its destruction by government forces on the night of 24 March. Probable impact craters are visible in the parking lot of the market. Confirmed craters are present at (B) and (C). At (B), the ejecta blanket indicates a blast radius of at least 15 meters, as in Figure 3. Imagery ©2011 DigitalGlobe.
Between 4 March (top) and 28 March (bottom), four shell craters (A) can be seen in the street at distances between 50 and 80 meters from the Misurata Red Crescent Clinic (B). Imagery ©2011 DigitalGlobe.
On 4 March (top), the area around the Misurata Polyclinic (A) shows signs of activity; traffic is visible in the streets, and vehicles are present in its parking lot. By 28 March (bottom), despite reports of large numbers of injured, the clinic appears deserted. Additionally, a number of temporary structures (B) have been erected on the athletic field of the adjacent girls’ high school. Their function is not known at this time. Imagery ©2011 DigitalGlobe.
In a sharp contrast with the apparent abandonment of the Polyclinic, Al-Hekma hospital (A) in the rebel-held suburb of Al-Jazeera appears to show an extraordinary increase in activity between 4 March (top) and 28 March (bottom), consistent with reports of patients being evacuated there due to the security situation at the Polyclinic. Additionally, makeshift fortifications (B) appear to have been erected to guard the facility. Imagery ©2011 DigitalGlobe.
On 4 March (top) the main electrical plant for Misurata (A) is intact. By 28 March (bottom), the entire facility has been destroyed, and shell craters (B) have appeared in the adjacent intersection. Imagery ©2011 DigitalGlobe.
A road near Misurata’s port on 4 March (top) has become crowded with temporary shelters by 13 April (bottom). In this subset image, structures cover a 620 meter length of roadway. The length of structures in the full image covers approximately 1.14 kilometers. Imagery ©2011 DigitalGlobe.
The main entrance to Misurata’s port facilities (A) is empty on 4 March. On 13 April, by contrast, a 160 meter-long queue of people (B) is present in front of the gate. This is consistent with reports of residents attempting to evacuate the city by sea and/or receive aid. Imagery ©2011 DigitalGlobe.
Several heavy trucks have gathered around a small ship (B) which is docked just inside the breakwater on 13 April (bottom). Evidence of shelling is present in the marks left by low-angle explosive bursts (yellow arrows) and high-angle explosive bursts (red arrows).\textsuperscript{14} The commercial shipping activity evident on 4 March (A, top) is gone. Imagery ©2011 DigitalGlobe.

\textsuperscript{14} For further explanation of shell crater morphology, see the AAAS report “High-Resolution Satellite Imagery and the Conflict in Sri Lanka,” available at http://shr.aaas.org/geotech/srilanka/srilanka.shtml#6.
Figure 12: Probable international airstrike on military facilities at Misurata airport

Libyan Air Force Su-22s\textsuperscript{15} (A) and helicopters (B) are destroyed one-by-one as they sit idle on the flight line. The caliber and precision of the weaponry employed is distinct from that visible in the city center. Imagery ©2011 DigitalGlobe.

Figure 13: Probable international airstrike

A military warehouse south of Misurata, which according to eyewitness reports was destroyed by international aircraft. Imagery ©2011 DigitalGlobe.
Figure 14: Misurata analysis overview