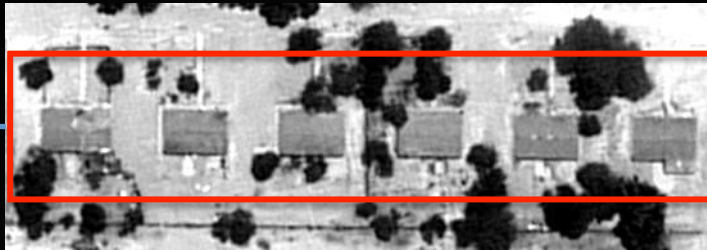


# SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA

Analysis conducted with satellite imagery recorded on July 28, October 21 and November 24, 2011 and May 25 and August 18, 2012.

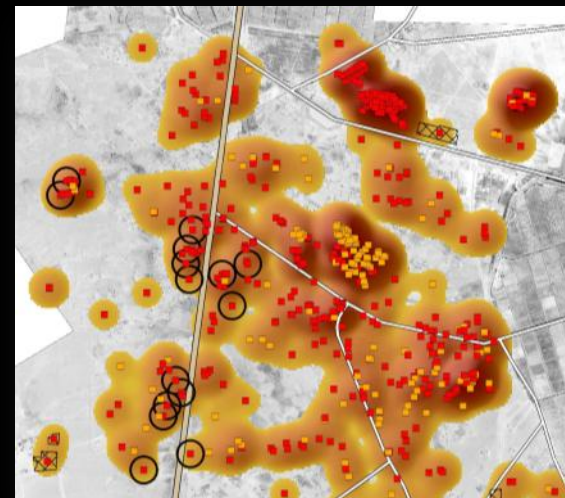


Imagery recorded on November 24, 2011



Imagery recorded on morning of May 25, 2012

Large residential housing complex likely destroyed in arson attack after November 24, 2011



Relative density of identified building damages and probable demolition locations in Tawergha

## Main Analysis Findings

### 1. Damage Summary

- A total of 1,690 likely damage sites were identified from a change detection analysis of five satellite images collected between July 28, 2011 and August 18, 2012. Of this total, 1,280 buildings were likely either destroyed or severely damaged in new Tawergha, and 410 buildings were likely damaged or destroyed in old Tawergha.
- It is probable that over 92% of all identified damages resulted from arson attacks, with the remainder of damages probably caused by controlled demolition with explosives (4.9%), air strikes (1.4%) and the remainder possibly by artillery fire (direct or indirect).
- There were likely at least two distinct phases of arson and demolition-related attacks in Tawergha. The first and smaller of the two phases immediately followed the capture of Tawergha (from mid-August to late October 2011) with a total of 240 damage sites, concentrated in new Tawergha. This first phase was followed by a lull in destruction for about one month (between October 21 and November 24) with 36 damage sites. The second and main phase of building destruction occurred between November 24, 2011 and May 25, 2012, with a total of 1,373 damage sites, representing over 81% of all detected damages. It is possible that a small number of additional buildings (35) were destroyed between May 25 and August 18, 2012, although these may be due to further building decay resulting from earlier, undetected damages.

## 2. Arson Attacks

- Of the 1,690 total damage sites, at least 92% likely resulted from fire. This determination was based on the identification of typical fire-related damage signatures (such as the presence of intact, load-bearing walls with partial or total roof collapse), as well as the presence of three active building fires captured in satellite imagery recorded on the mornings of October 21 and November 24, 2011. Because of the statistical improbability of accidental causes of over 1,500 building fires across town, the evidence strongly suggests that arson attacks were the most likely cause. Further, it is likely that such fire-related building damages have been significantly underestimated in specific residential housing complexes because of limited damage signatures visible in the imagery.
- Two residential housing complexes appear to have been burned to the ground. The majority of buildings in an additional five residential complexes appear to have been seriously damaged by fire. Virtually all large commercial and industrial/municipal facilities have likely been destroyed by fire, including the complex of poultry farms located on the northern edge of town.

## 3. Building Demolitions

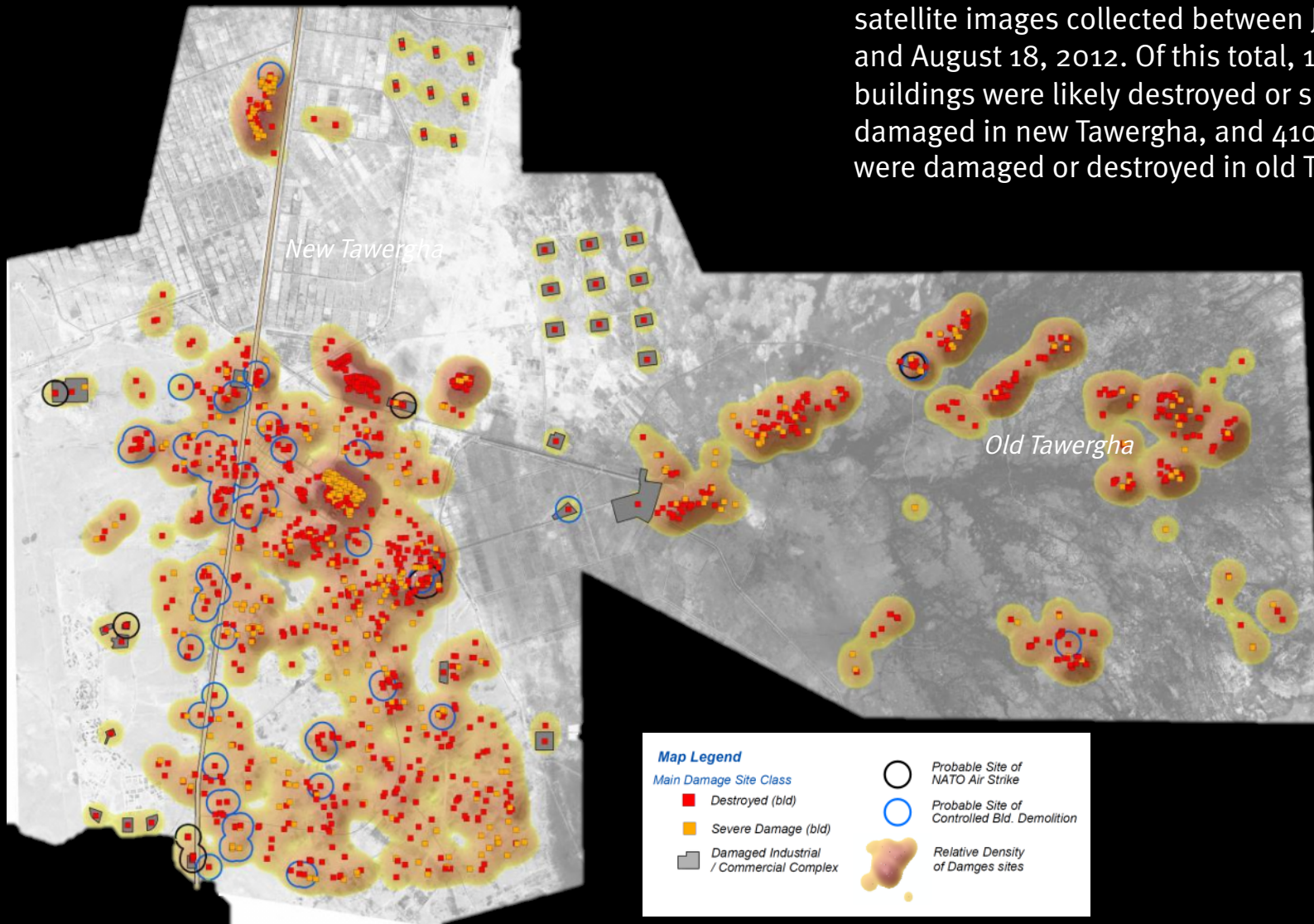
- A total of 81 buildings and two municipal water towers were identified as likely destroyed by controlled demolition with explosives. This determination was based on the distinctive pancake collapse signature with surrounding debris patterns, corroborated with publically-released video clips of militia forces demolishing buildings and water towers with explosive charges.

## **SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA (2011-2012)**

- Of the 83 sites identified as having been likely destroyed by controlled explosives, five of them were destroyed between July 28 and October 21, 2011, thus potentially during the period of active conflict between pro and anti-Gaddafi forces fighting for control of the town. (Gaddafi forces withdrew from Tawergha on or around August 10, 2011.) Four additional sites were identified as having been destroyed between October 21 and November 24, 2011. The remaining 74 instances of demolition likely occurred between November 24, 2011 and May 24, 2012, covering 89% of all identified sites.
- Demolished building sites were almost entirely located (96%) in new Tawergha, with 52% concentrated within 500 meters of the main road leading to Misrata (versus 21% for all detected damages). The imagery shows several distinct clusters of demolished building sites, the largest containing ten possible residential buildings that were destroyed after November 24, 2011.
- Video footage posted on YouTube in March and April 2012 that appears to show militias demolishing a municipal water tower and several residential buildings in Tawergha was reviewed in detail against known demolition sites identified in satellite imagery. In three instances, Human Rights Watch made a positive match between buildings in the videos and buildings identified in satellite imagery, confirming the location and time period in which the video was recorded.

# 1. Damage Summary

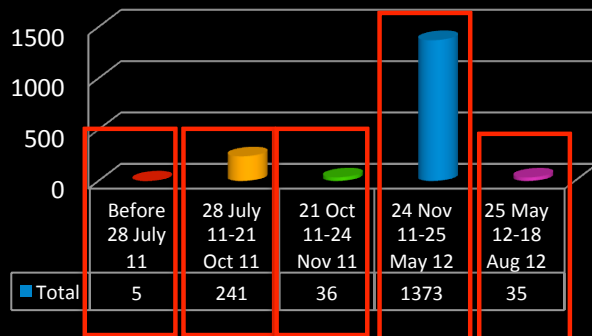
A total of 1,690 likely damage sites were identified from a change detection analysis of satellite images collected between July 28, 2011 and August 18, 2012. Of this total, 1,280 buildings were likely destroyed or severely damaged in new Tawergha, and 410 buildings were damaged or destroyed in old Tawergha.



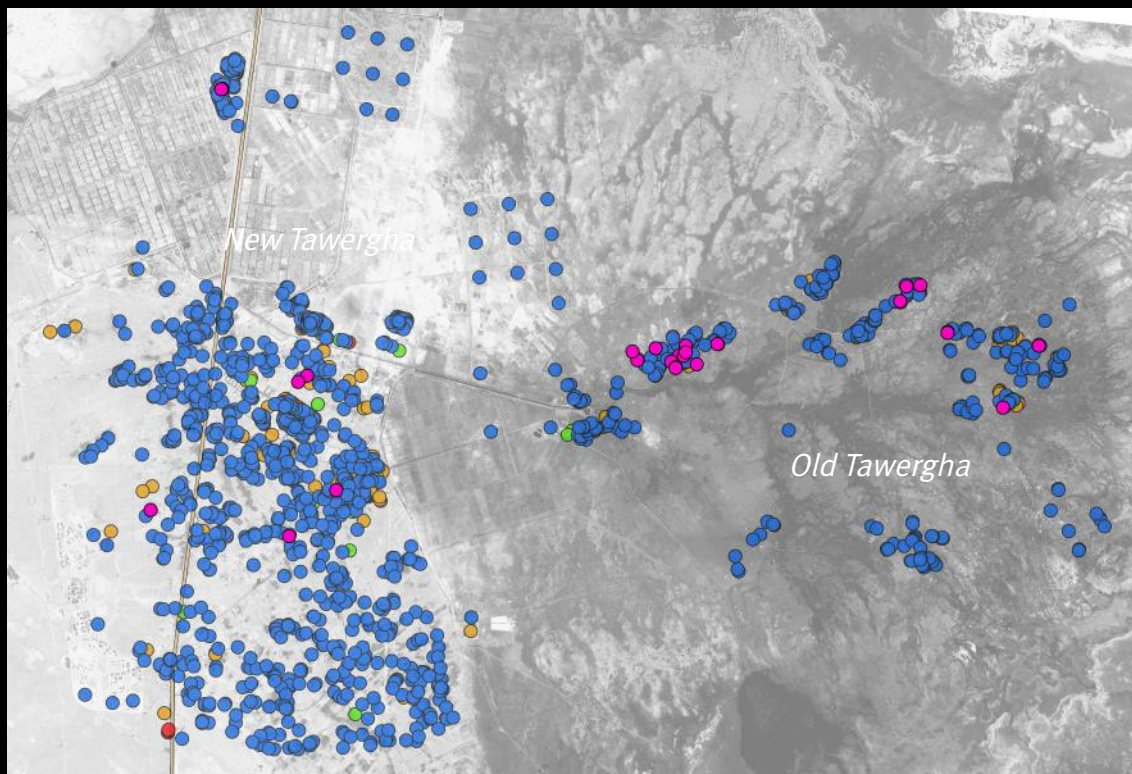


## SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA

### Building Damages by Date Period:



Building Damages by Date Period:	Total
Before July 28, 2011	5
July 28, 2011 to Oct 21, 2011	241
Oct 21, 2011 to Nov 24, 2011	36
Nov 24, 2011 to May 25, 2012	1373
May 25, 2012 to Aug 18, 2012	35
<i>Total Damage Sites Identified:</i>	<b>1690</b>



### Damages by Date Period:

- Before July 28, 2011: Five destruction sites (probable NATO air strikes; one site confirmed with video);
- Between July 28 and October 21, 2011: Additional air strike building damages (<25) with initial round of arson attacks and demolitions, concentrated in new Tawergha;
- Between October 21 and November 24, 2011: Apparent pause in building destruction with 36 identified damage sites, all in new Tawergha;
- Between November 24, 2011 and May 25, 2012: Main phase of building destruction with arson and controlled demolition with explosives, representing over 80% of all identified damage sites;
- Between May 25 and August 18, 2012: Indications of additional building damages over this period (35), but some are due to further building/roof collapse at sites of earlier damage (thus likely within the November 24 to May 25, 2012 period).

## 2. Arson Attacks

Multiple indications of a systematic and large scale campaign of arson directed at buildings in old and new Tawergha were identified, including three probable arson attacks in progress: active fires on the mornings of October 21 and November 24, 2011.

Imagery recorded on November 24, 2011



Site Location: 32.013N, 15.0572E

Imagery recorded on October 21, 2011



Site Location: 32.0194N, 15.0688E

Imagery recorded on November 24, 2011



Site Location: 32.0156N, 15.0548E

## SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA



Imagery recorded on July 28, 2011



Site Location: 32.0007N, 15.0599E

Imagery recorded on August 18, 2012

### Probable Fire-Related Building Damages: Case One

A common damage signature strongly associated with fire was the distinct collapse of the ceiling of stair headroom structures on building rooftops. In the case above, the ceiling has apparently burnt away or collapsed due to the channeling of fire upwards through the stairwell, indicating severe internal building damages.



Imagery recorded on July 28, 2011

## Probable Fire-Related Building Damages: Case Two

A total of ten destroyed and severely damaged buildings were identified in a remote section of old Tawergha occurring between November 24, 2011 and May 25, 2012. The presence of intact load-bearing walls with destroyed rooftops strongly suggests that fire was the likely cause of these damages.



Imagery recorded on August 18, 2012



Site Location: 32.0252N, 15.1795E

## SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA

Site Location: 32.0296N, 15.0578E



Imagery recorded on November 24, 2011



Imagery recorded on May 25, 2012

### Probable Fire-Related Building Damages: Case Three

A total of 22 destroyed buildings were identified within an apparent residential housing complex of new Tawergha. The damage signatures are fully consistent with fire as the likely cause of this destruction, which occurred between November 24, 2011 and May 25, 2012.



### Probable Fire-Related Building Damages: Case Four

A total of 57 destroyed buildings were identified within an apparent large residential housing complex in new Tawergha. The damage signatures are fully consistent with fire as the likely cause of this destruction, which occurred between November 24, 2011 and May 25, 2012.

Imagery recorded on November 24, 2011



Imagery recorded on May 25, 2012



Site Location: 32.0266N, 15.061E



### Probable Fire-Related Building Damages: Case Five

A total of 163 destroyed and severely damaged buildings were identified within two large residential housing complexes in new Tawergha. The damage signatures strongly suggest that fire was the cause of these damages—a conclusion reinforced by the presence of two active building fires on the morning of November 24, 2011. Because of the relatively light to moderate damage signatures common in these specific buildings (often limited to the ceiling collapse in stair headroom structures: see Case One) it is highly probable that fire-related damages have been significantly underestimated in this area. A majority of the structures (95) were damaged between July 28 and October 21, 2011, with the remainder of damages occurring after November 24, 2011.



## SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA

Site Location: 32.0195N, 15.0892E



Imagery recorded on July 28, 2011



Imagery recorded on August 18, 2012

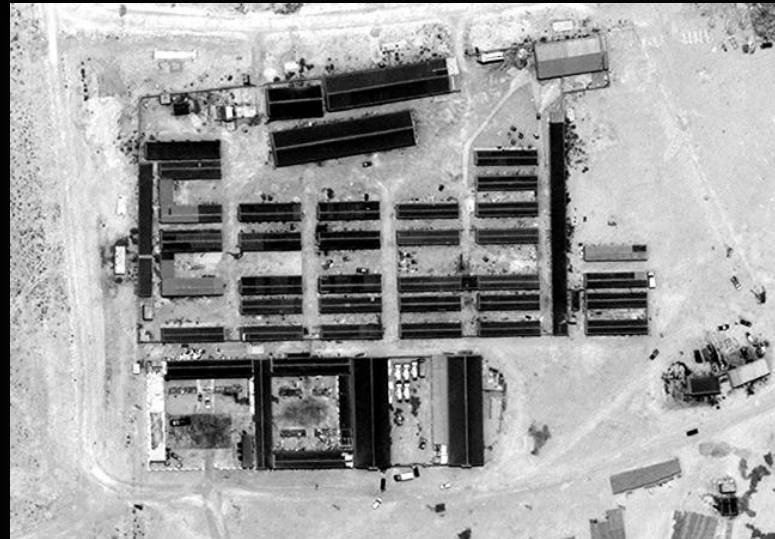
### Probable Fire-Related Building Damages: Case Six

A large warehouse complex located in eastern Tawergha was likely destroyed by fire, as indicated by the distinctive rooftop collapse, the presence of intact metal cross-beams and load-bearing walls, as well as the absence of artillery related impact cratering or debris signatures. Several smaller buildings within the complex were likely destroyed by fire between October 21 and November 24, 2011, with the destruction of the main warehouse occurring between November 24, 2011 and May 25, 2012.

## Probable Fire-Related Building Damages: Case Seven

A large warehouse complex in western Tawergha with over 40 structures was likely destroyed by fire, as indicated by the distinctive rooftop collapse, the presence of intact metal cross-beams and load-bearing walls, as well as the absence of artillery related impact cratering or debris signatures. The entire complex was likely destroyed by fire between November 24, 2011 and May 25, 2012.

Site Location: 31.9948N, 15.0251E

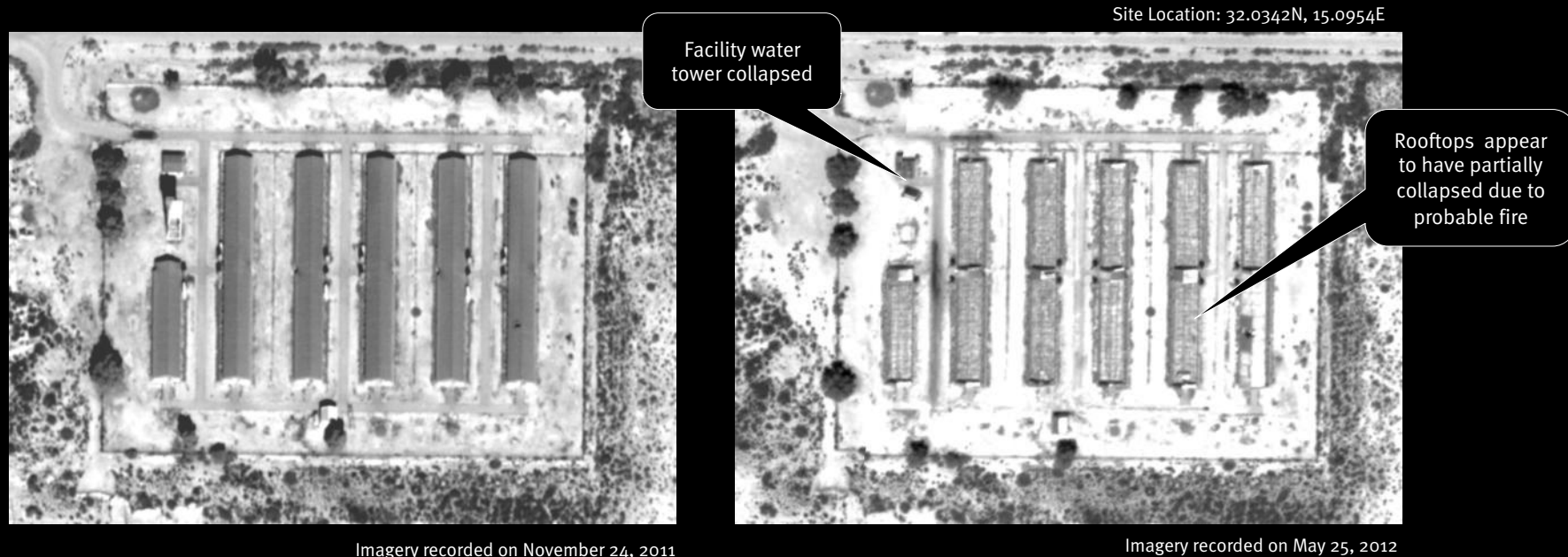


Imagery recorded on July 28, 2011



Imagery recorded on August 18, 2012

## SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA



### Probable Fire-Related Building Damages: Case Eight

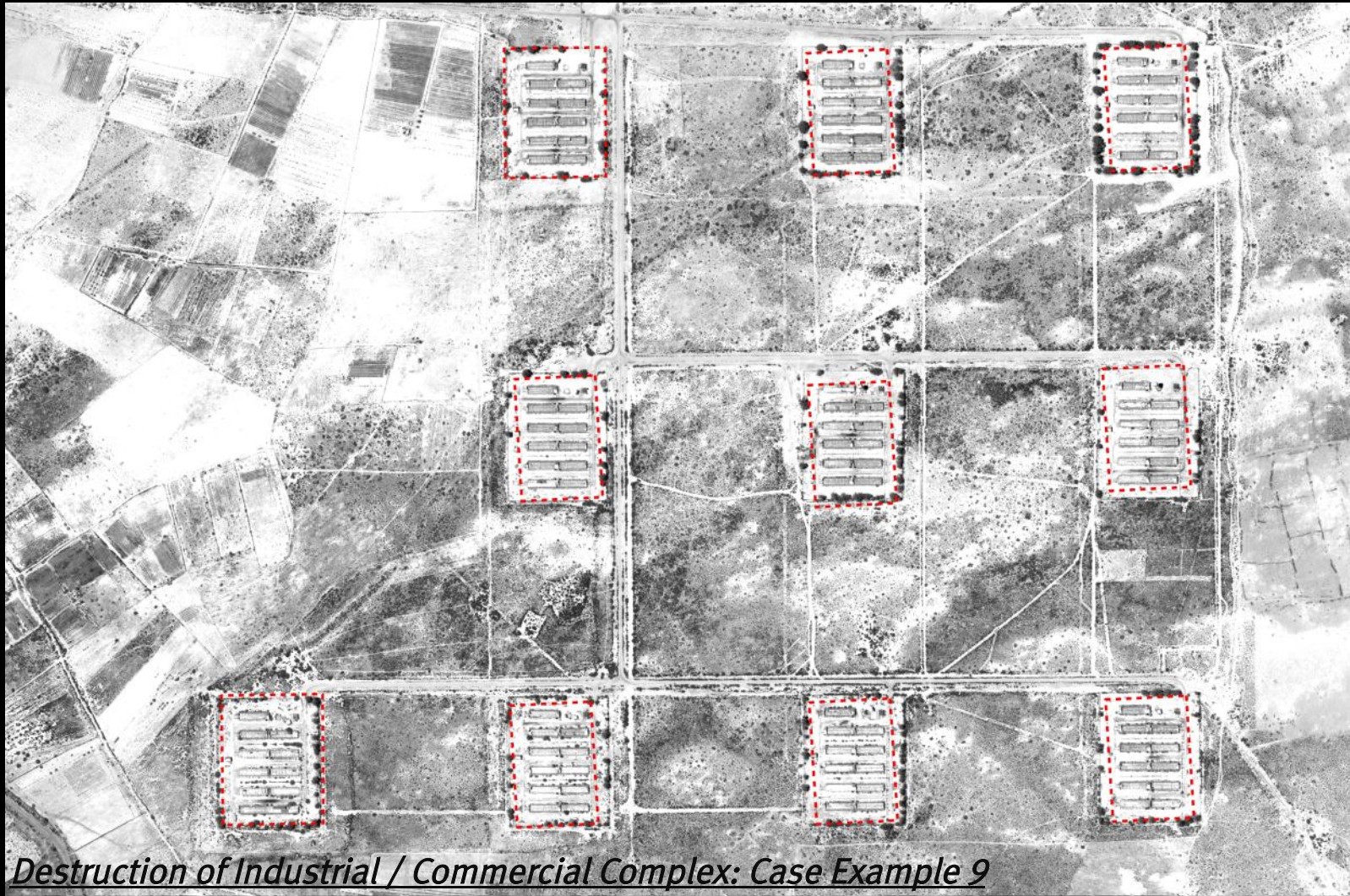
The large complex of poultry farms located on the northern edge of Tawergha was likely destroyed by fire, as indicated by the distinctive rooftop collapse, the presence of intact load-bearing walls, as well as the absence of artillery related impact cratering or debris signatures. The facility water tower was also knocked down. The entire poultry complex was likely destroyed between November 24, 2011 and May 25, 2012.



## SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA

Site Location: 32.037N, 15.095E

Images recorded on November 24, 2011 and May 25, 2012

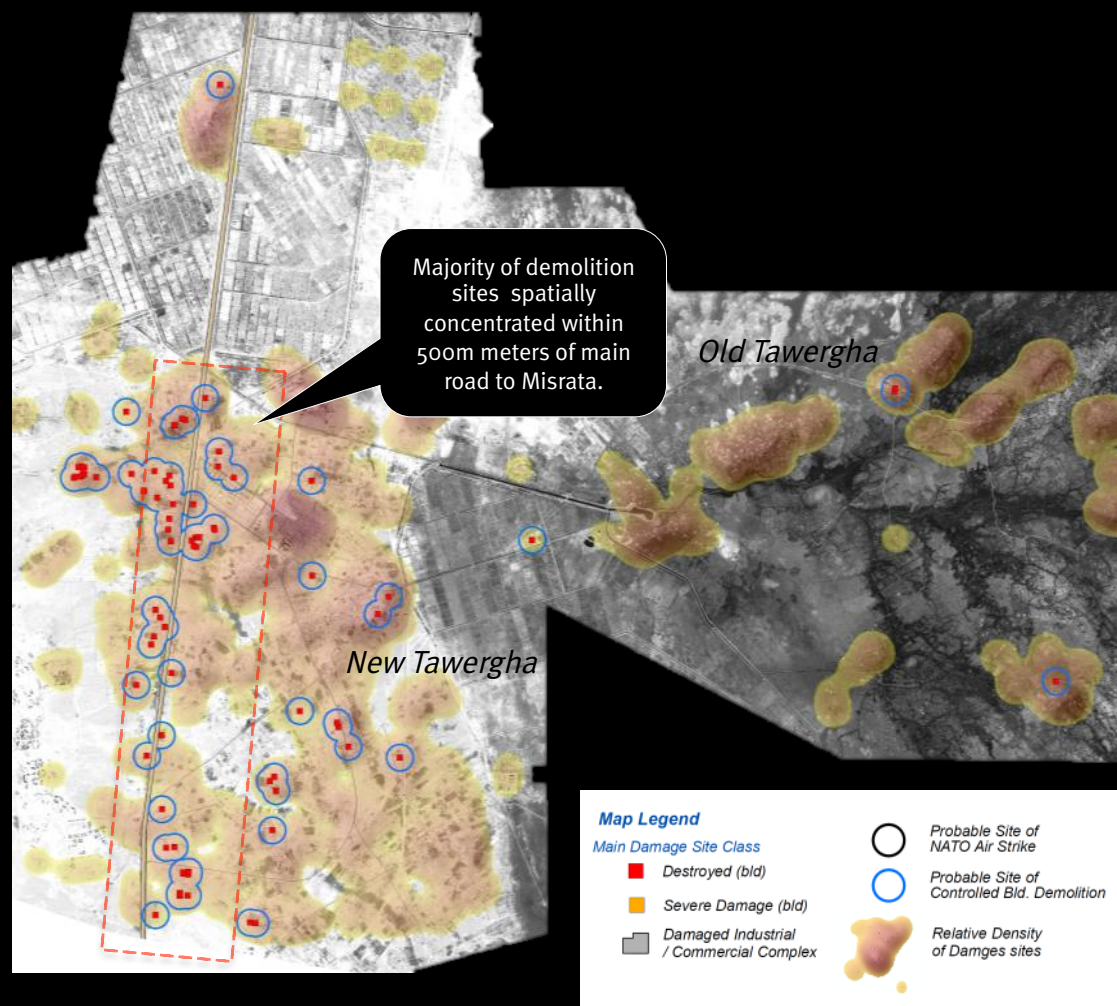


***Destruction of Industrial / Commercial Complex: Case Example 9***

Overview of 10 poultry farm units destroyed between November 24, 2011 and May 25, 2012.



### 3. BUILDING DEMOLITIONS



#### Demolition Overview

A total of 81 buildings and two municipal water towers were identified as likely destroyed by controlled demolition with explosives. Ninety-six percent of the demolished building sites were in new Tawergha, with 52% of them concentrated within 500 meters of the main road leading north to Misrata. Satellite imagery corroborated videos that apparently showed several demolitions, representing further evidence of an organized campaign to destroy the town.

## Probable Building Demolition: Case One

Two single story buildings next to the main irrigation facility were destroyed between October 21 and November 24, 2011. Both sites show signs consistent with controlled demolition with explosives (i.e. the partial collapse of each structure, limited associated debris fields and partially intact rooftops).



Images taken on October 21 and November 24, 2011

Site Location: 32.0109N, 15.1044E

## **Probable Building Demolition:** **Case Two**

A three-story building located in central Tawergha was likely destroyed between October 21 and November 24, 2011. The apparent near vertical collapse of approximately half of the building is consistent with the use of explosives.



*November 24, 2011*

Images taken on October 21 and November 24, 2011

Site Location: 32.0044N, 15.0709E



### Probable Building Demolition: Case Three

The largest concentration of demolished buildings was located on the western edge of Tawergha, approximately 1.4 km from the main road to Misrata. A total of ten apparent residential buildings (nine pictured at right) were destroyed between November 24, 2011 and May 25, 2012. All building sites show signs consistent with a controlled demolition: the partial collapse of each structure, associated debris fields, and the rooftops partially intact.





### Probable Building Demolition: Case Four

The second largest concentration of demolished buildings was located approximately 120 meters from the main road to Misrata. A total of six apparent residential buildings were destroyed between November 24, 2011 and May 25, 2012. All buildings have been completely destroyed with damage signatures consistent with large explosive events. Such signatures are typical of air strikes or heavy artillery shelling, but ground fighting and NATO air strikes had stopped three months before the period of destruction (after November 24, 2011). These buildings were therefore likely demolished with significantly more explosives than the other suspected demolition sites in Tawergha.



## SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA

Photomosaic of video immediately before detonation



Militia truck involved in building demolition.



Detonation of explosives



Unidentified man carrying RPG immediately after explosion

Site Location: 31.9657N, 15.0515E



Building before demolition

Imagery recorded on November 24, 2011



Building after demolition

Second house also demolished

Imagery recorded on August 18, 2012

### Video of Housing Demolition – Site Identified in Satellite Imagery: Case Five

Video posted on YouTube in March 2012 shows the controlled demolition of an apparent residential compound. The site was identified in satellite imagery, confirming the demolition location in southern Tawergha, as well as the time period the video when was likely recorded (between November 24, 2011 and March 2012).

## SATELLITE-BASED DAMAGE ASSESSMENT: TAWERGHA, LIBYA

Video Link on YouTube:  
<http://www.youtube.com/watch?v=J5e425dqsZk>

Site Location: 32.007N, 15.0602E



Imagery recorded  
on July 28, 2011



Imagery recorded  
on May 25, 2012



### Video of Water Tower Demolition – Site Identified in Satellite Imagery: Case Six

Video posted on YouTube in April 2012 shows the controlled demolition of a municipal water tower. The site was identified in satellite imagery, confirming the demolition location in central Tawergha, as well as the time period in which the video was likely recorded (between November 24, 2011 and April 2012).



## Data Sources and Methodology

- Imagery analysis was based on six images recorded on the mornings of October 20, 2010, July 28, October 21 and November 24, 2011, and May 25 and August 18, 2012.
- Commercial Imagery was provided by the U.S. government under the NextView License as well as through European Space Imaging (EUSI). Imagery copyright DigitalGlobe 2012.
- The determination of fire as the probable source of damages identified from satellite imagery is normally made at the level of individual buildings, each evaluated separately based on the relative presence (or absence) of a set of usually distinct signatures including, for example: the presence of intact, load-bearing walls with a collapsed rooftop, the presence of fire burn scars on or immediately adjacent to the property, along with the absence of significant debris fields external to the building foundation. When possible, this is corroborated with thermal anomaly data collected by environmental satellite sensors, which can generally locate the presence of active fires to within one square kilometer. The determination of arson as the probable cause of fire-related damages is possible using satellite imagery only in distinct circumstances when there is a statistical improbability of large numbers of buildings accidentally catching fire in multiple separate locations around the same time. Although for any individual building damaged by fire it is not possible to rule out accidental sources of ignition, it is possible to statistically show at the macro scale that a major fire event(s) involving hundreds or thousands of buildings (as identified from satellite imagery) could only be reasonably accounted for by arson. This determination is verified when possible by direct evidence gathered by Human Rights Watch researchers on the ground.
- Identified damage sites are likely to represent high confidence minimum estimates; actual damages are likely to be larger; quantitative figures are subject to revision or correction pending additional imagery review or ground verification.
- Ancillary GIS data from OSM, NGA, NASA and ESRI was also referenced.