

# **Annex E.4.1**

## **Public**

# High-Resolution Satellite Imagery and the Conflict in South Ossetia

Summary Report  
October 9, 2008

This report was produced by the Geospatial Technologies and Human Rights Project as part of the Science and Human Rights Program (SHRP; <http://shr.aaas.org>) at the American Association for the Advancement of Science (AAAS). SHRP brings scientists and scientific expertise to efforts to achieve human rights around the world. As a program of AAAS - the world's largest multidisciplinary scientific membership organization - SHRP engages individual scientists and scientific associations in human rights efforts; applies scientific tools and technologies to enhance human rights work; brings human rights standards to the conduct of science; and promotes the human right to enjoy the benefits of scientific progress.

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**Disclaimer**

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## I. Summary

The Science and Human Rights Program of the American Association for the Advancement of Science (AAAS), with funding from the MacArthur Foundation, the Oak Foundation, and the Open Society Institute, is working to expand the applications of geospatial technologies to human rights issues through its Geospatial Technologies and Human Rights Project. Geospatial technologies include a range of modern tools, such as satellite images, geographic information systems (GIS), and Global Positioning Systems (GPS) that allow for mapping and analysis of multiple layers of georeferenced data. The goals of this project are to assess the utility of applying geospatial technologies to human rights issues, and to determine what kinds of inputs and infrastructure are necessary to make these technologies more accessible to non-governmental human rights organizations. This report was conducted with funding provided by the Oak Foundation.

In August 2008, AAAS staff began a review of satellite imagery of the Tskhinvali region of South Ossetia. Amnesty International (AI) contacted AAAS over concerns in regard to hostilities between Georgia and Russia, which began approximately 7-8 August 2008. Specifically, AI was gathering field reports from local informants of violence occurring in multiple cities and smaller villages throughout Georgia. These reports indicated destruction and violence toward civilians in many areas, particularly near Tskhinvali, a city in South Ossetia close to the Georgia-Russia border.

Based on AI witness reports from the field, an initial set of target regions for satellite imagery acquisition was constructed. Significant challenges arose in the pursuance of this project in the early stages. Satellites operated by major commercial vendors (GeoEye, DigitalGlobe, and ImageSat International) were fully booked, preventing the tasking of a new image by AAAS for the duration of this conflict. Therefore, AAAS was forced to rely upon imagery requested by other entities to meet the needs of the project. Fortunately, it was possible to acquire imagery of the region surrounding Tskhinvali, one of the major sites of damage upon areas of civilian infrastructure, with a time scale concurrent to the conflict in the region. Specifically, AAAS acquired satellite imagery of the region for the dates of August 10 and August 19, 2008 to establish whether satellite imagery analysis supported AI's witness reports.

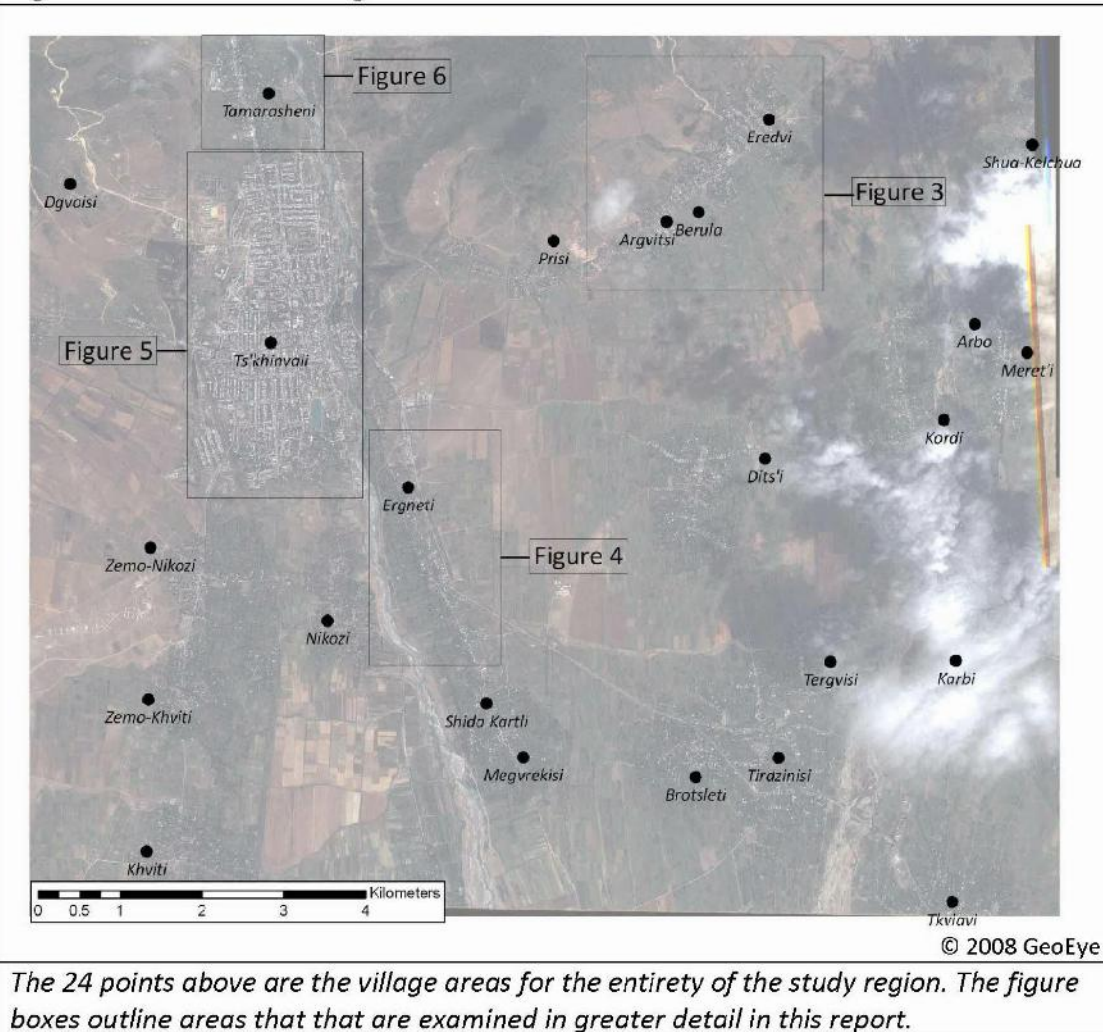
Correlating these images with on-the-ground reporting in a timely fashion remains a difficult task. However, reports from AI named a number of villages in the Tskhinvali region that were possibly the targets of attack. Based on this information, AI requested specific types of imagery analysis to demonstrate the scope of damage to civilian infrastructure in identified communities.

AAAS has conducted imagery analysis of close to 1,000 square kilometers (km<sup>2</sup>) of the region surrounding the city of Tskhinvali. This analysis covers the region in two different time periods during the Georgia-Russia conflict: August 10, just two days after events began to unfold, and August 19, by which time most fighting had ceased. The imagery



acquired on these dates was used to construct a timeline of damage to Tskhinvali and its surrounding villages. Analysis of these and other satellite images is the focus of this report, and the specific region covered by this analysis can be seen in Figure 1 below. Additional analysis of this region was conducted by the UN Institute for Training and Research (UNITAR) Operational Satellite Applications Programme (UNOSAT),<sup>1</sup> with whom AAAS cooperates. It is hoped that the analysis provided in this report will complement the reporting of UNOSAT, whose reports largely cover the city of Tskhinvali and numerous villages to the north of the city as they appeared on August 19, whereas this report covers regions to the east and south of Tskhinvali.

Figure 1: Overview of Damage Assessment Area



<sup>1</sup> <http://unosat.web.cern.ch/unosat/>

## II. Image Analysis

Satellite image analysis was conducted by AAAS and undertaken at the request of Amnesty International (AI) in order to document the destruction to civilian areas, and its timing, during the conflict between Russia and Georgia over the regions of South Ossetia and Abkhazia. As previously noted, AAAS image analysis was limited to the Tskhinvali area for the time frame of the conflict.

AI provided AAAS with the names of several villages throughout Tskhinvali region which on-the-ground informants indicated had been attacked in the course of the conflict. AAAS used these villages and public news sources to identify possible satellite imagery acquisitions. Unfortunately, no commercial satellites were available to AAAS at the time of the conflict, and thus AAAS could not actively task image acquisitions in the region. Based on imagery collected by commercial satellites at the request of other parties, AAAS determined that the city of Tskhinvali and its surrounding villages were the only viable targets for image analysis. As a result, AAAS acquired several images identified from available satellite imagery as likely to provide insight into the conflict. Other additional images, pre-dating the conflict, were also examined.

AAAS employed the software packages ERDAS Imagine and ArcView for processing satellite imagery and creating geo-referenced damage assessments. The sources of acquired imagery and other data included:<sup>2</sup>

- Google Earth base layers were used, where possible, for comparison to the state of the region prior to the conflict;
- QuickBird high-resolution imagery purchased in areas lacking a high-resolution base layer on Google Earth;
- an IKONOS image from August 10, 2008;
- a WorldView image from August 19, 2008;
- an EROS-B image from August 19, 2008;
- placenames compiled from the US National Geospatial Intelligence Agency;<sup>3, 4</sup>
- national and administrative unit borders compiled from Digital Chart of the World<sup>5</sup>

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<sup>2</sup> Detailed information concerning satellite imagery is included in Section III.

<sup>3</sup> National Geospatial Intelligence Agency: <http://www.nga.mil>

<sup>4</sup> A note on village names: some villages had multiple names attached; one has been chosen to be represented in the maps for sake of clarity. Best attempts have been made to associate damaged areas with village names. However, available datasets are never completely accurate, and some liberties were taken with associations between damaged locations and nearby village names. If any questions arise, locating a village on the map is always the more accurate option.

<sup>5</sup> University of Pennsylvania Digital Chart of the World Server: <http://www.maproom.psu.edu/dcw/>

Imagery analysis in this report is covered in the following sections:

1. Locations exhibiting no damage
2. Locations exhibiting damage on August 10 and August 19
3. Locations exhibiting damage on August 19 only
4. Full damage assessment not possible
5. Damage to unpopulated areas and evidence of conflict

These findings are discussed in depth in the upcoming pages, and highlight the types of damage sustained to different areas of the Tskhinvali region. Summary findings are found in Table 1 and a map indicating overall damage is located in Appendix One.<sup>6</sup>

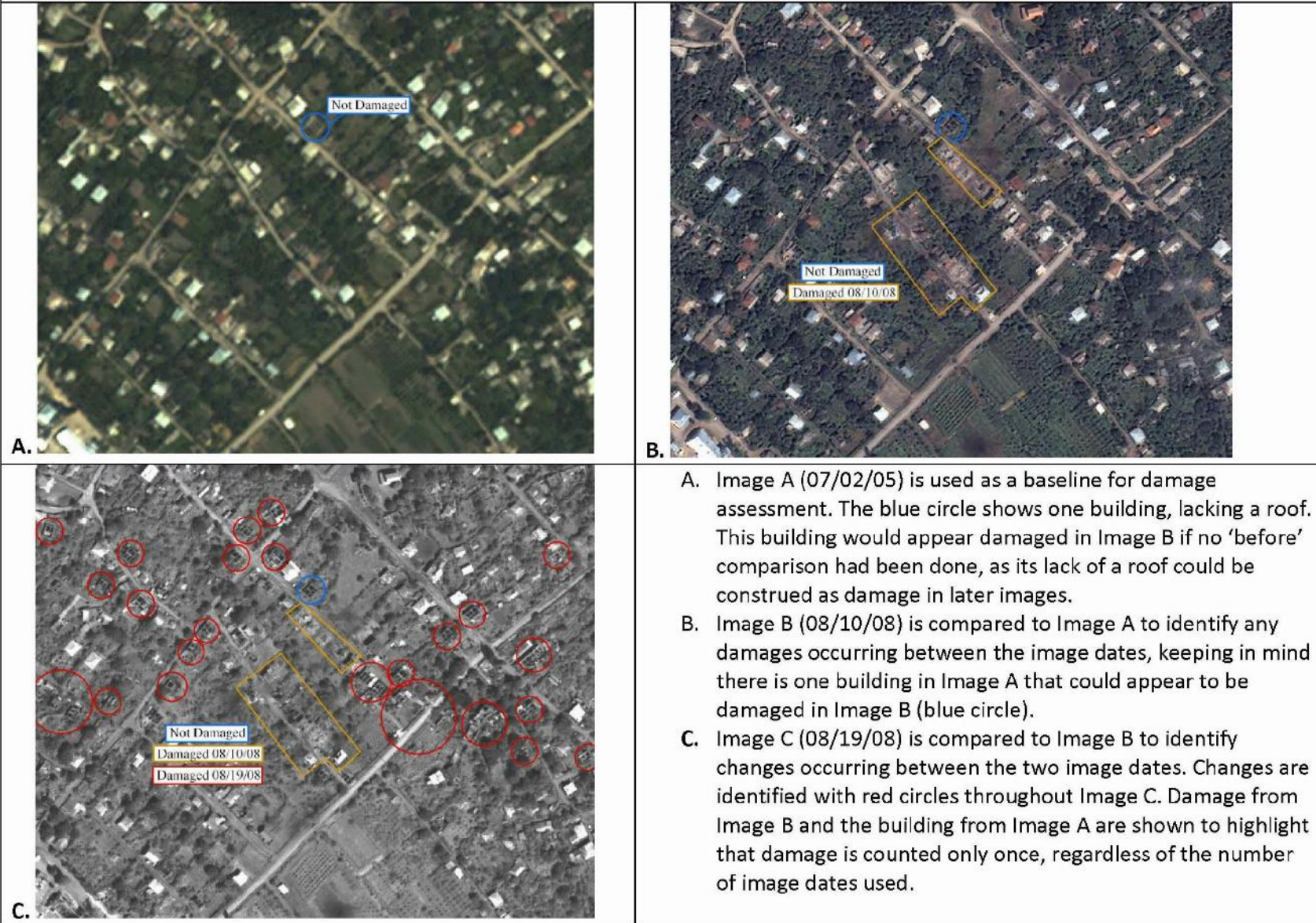
### **Image Interpretation**

Reference will be made regarding damage to various civilian structures and infrastructure in this report. This damage is a specific type of damage to structures and does not encompass all possible damage types. Analysis of satellite imagery constrains identification of damage to incidents which can be observed from above, and does not provide insight to any damage that may have been sustained to other portions of structures, such as sides of buildings. Damage assessment is conducted in geospatial software packages, whereby each image is compared to an image from an earlier date to determine if damage has occurred to each individual structure observed. Specifically, the two images are viewed alongside one another to quantify changes to structures through visual analysis.

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<sup>6</sup> In addition, all imagery and analysis is available for viewing using GoogleEarth by accessing: <http://www.aaas.org/international/geotech/ge/georgia.kml>



**Figure 2: Image Analysis Guide**

**Table 1: Results of Satellite Imagery-Based Damage Assessment for Tskhinvali Region**

Village	Damaged 8/10/2008	Damage Count 8/10/2008	Damaged 8/19/2008	Count of New Damage on 8/19/2008	Total Damage
Arbo	yes	1	no	0	1
Argvitsi	yes	1	yes	23	24
Berula	no	0	yes	70	70
Brotsleti	no	0	yes	5	5
Dgvoisi	no	0	no	0	0
Dits'i	yes	2	yes	2	4
Eredvi	yes	9	yes	54	63
Ergneti	yes	1	yes	52	53
Karbi	no	0	yes	4	4
Khviti	no	0	no	0	0
Kordi	no	0	no	0	0
Megvrekrsi	no	0	no	0	0
Meret'i	no	0	no	0	0
Nikozi	no	0	no	0	0
Prisi	yes	1	yes	7	8
Shida Kartli	no	0	no	0	0
Shua-Khelchua	yes	2	yes	35	37
Tamarasheni	no	0	yes	152	152
Tergvisi	no	0	no	0	0
Tirdzinisi	no	0	yes	7	7
Tkviavi	no	0	yes	3	3
Tskhinvali	yes	182	yes	4	186
Zemo-Khviti	yes	1	yes	5	6
Zemo-Nikozi	yes	2	yes	1	3
<b>Total by Date</b>		<b>202</b>		<b>424</b>	<b>626</b>

Table 1 provides an overview of the damage observed for the 24 populated places in the AAAS imagery analysis. After locating a place of interest, reading the table across indicates on which days that location exhibited damage (if any) as well as the damage observed for each image date. The far right column (Total Damage) sums the total damage at each location, and the bottom row (Total by Date) gives the complete tally of observed damage for each date. There were 202 damaged structures observed in the region on August 10, and 424 damaged structures on August 19, for a total damage count of 626.



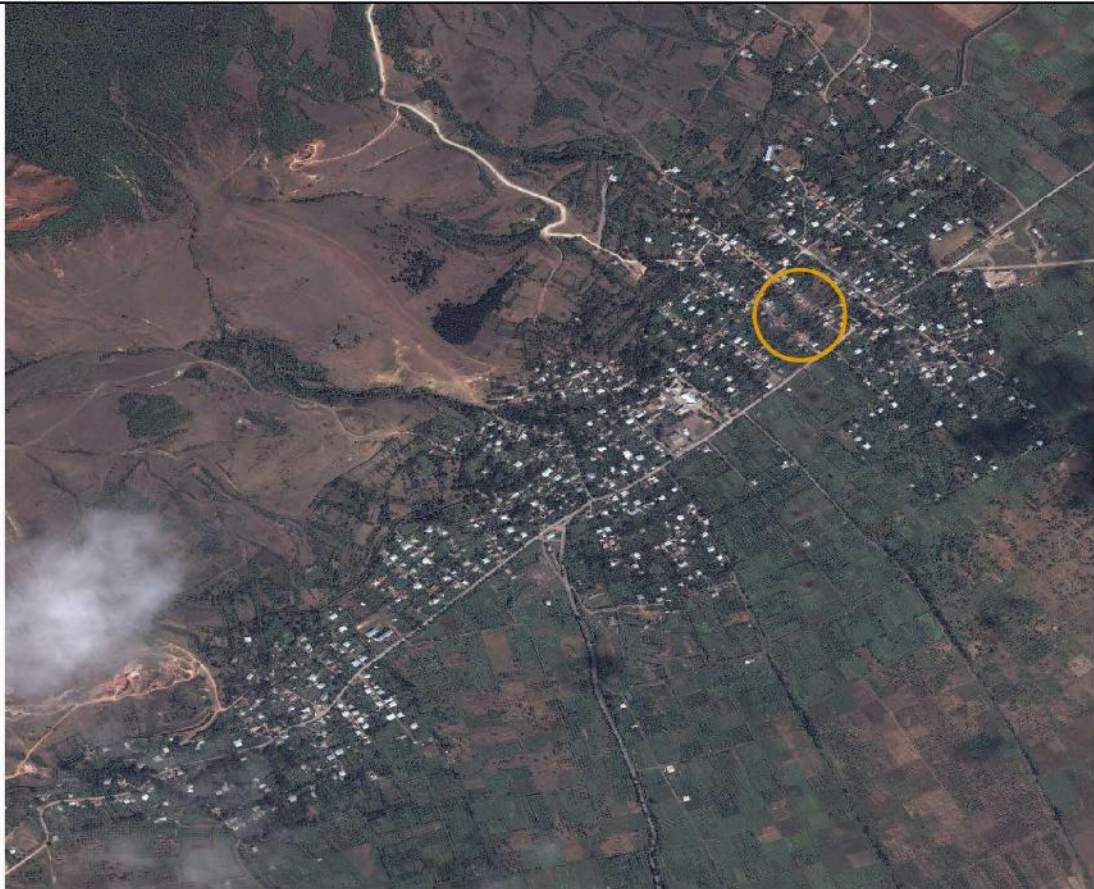
### ***2.1 Locations sustaining no damage***

There were a number of village areas in the region which did not sustain any quantifiable damage, according to the satellite imagery analysis. There were a total of nine villages in this category: Meret'i, Kordi, Shida Kartli, Tergvisi, Khviti, Megvrekrsi, Nikozi, and Dgvoisi. As can be seen in Figure 1, these villages are largely in the far eastern and southern areas.

### ***2.2 Locations exhibiting damage on August 10 and August 19***

Many of the areas had observable damage on both August 10 and 19. Notably, the majority of damage was sustained prior to August 19, but after August 10. These include the areas of: Argvitsi, Eredvi, Prisi, Ergneti, Dits'i, Zemo-Nikozi, and Zemo-Khviti (refer to Table 1 for specific damage assessments). Figures 3 (A-C) and 4 (A-C) highlight damage to the Eredvi-Berula-Argvitsi corridor and the village of Ergneti.

Figure 3A: Damage to the Eredvi-Berula-Argvitsi Region



© 2008 GeoEye

*Orange circle highlights the 9 structures in the main village area of the region destroyed by August 10, 2008.*



Figure 3B: August 19, 2008: Damage to the Eredvi-Berula-Argvitsi Region



© 2008 DigitalGlobe

*Village area showing August 10 destruction (orange circle) and August 19 damage (red markers). 147 structures are damaged or destroyed by August 19.*

Figure 3C: Subset of damage to the Eredvi-Berula-Argvitsi Region



© 2008 DigitalGlobe

*Subset of August 19, 2008 image. Red circles indicate damage typical to the region. Damage is apparent, and it can be seen that the roofs of buildings are no longer present, exposing interior walls.*

*Lat: 42.241 Long:44.03*



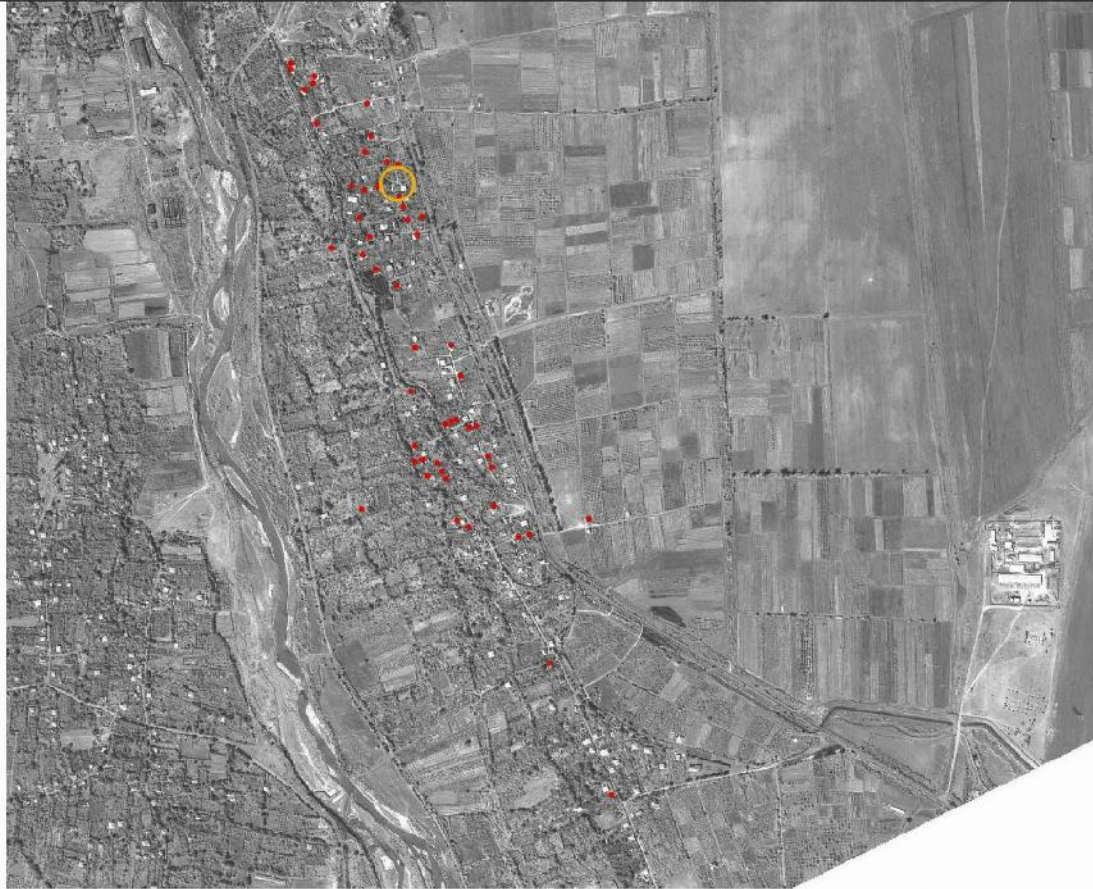
Figure 4A: Ergneti on August 10, 2008



© 2008 GeoEye

*One damaged structure was identified for Ergneti on August 10.*

Figure 4B: Damage to Ergneti on August 19, 2008



© 2008 ImageSat

*52 damaged structures in Ergneti were observed in the August 19 image.*



Figure 4C: Subset of Ergneti



© 2008 ImageSat

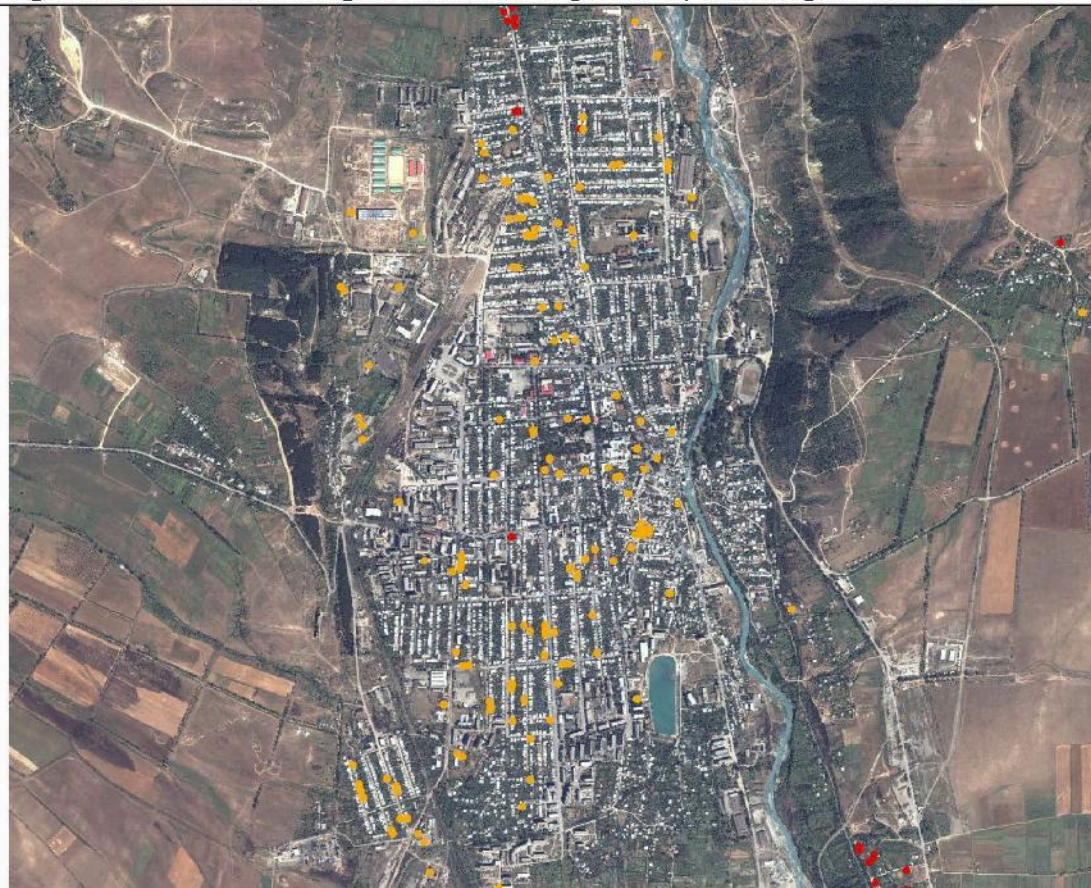
*Red circles highlight damaged structures in Ergneti on August 19.*

*Lat: 42.206 Long: 43.988*

Unlike the areas described above, which sustained major damage between August 10 and August 19, the city of Tskhinvali sustained the majority of its damage (182 structures) on or before August 10. Only a small amount of damage (4 structures) appears to have occurred after this date. Figures 5 (A-C) illustrate the extent and spatial distribution of the destruction.

#### Tskhinvali Damage Assessment

Figure 5A: Tskhinvali on August 10 with damage overlay from August 10 and 19

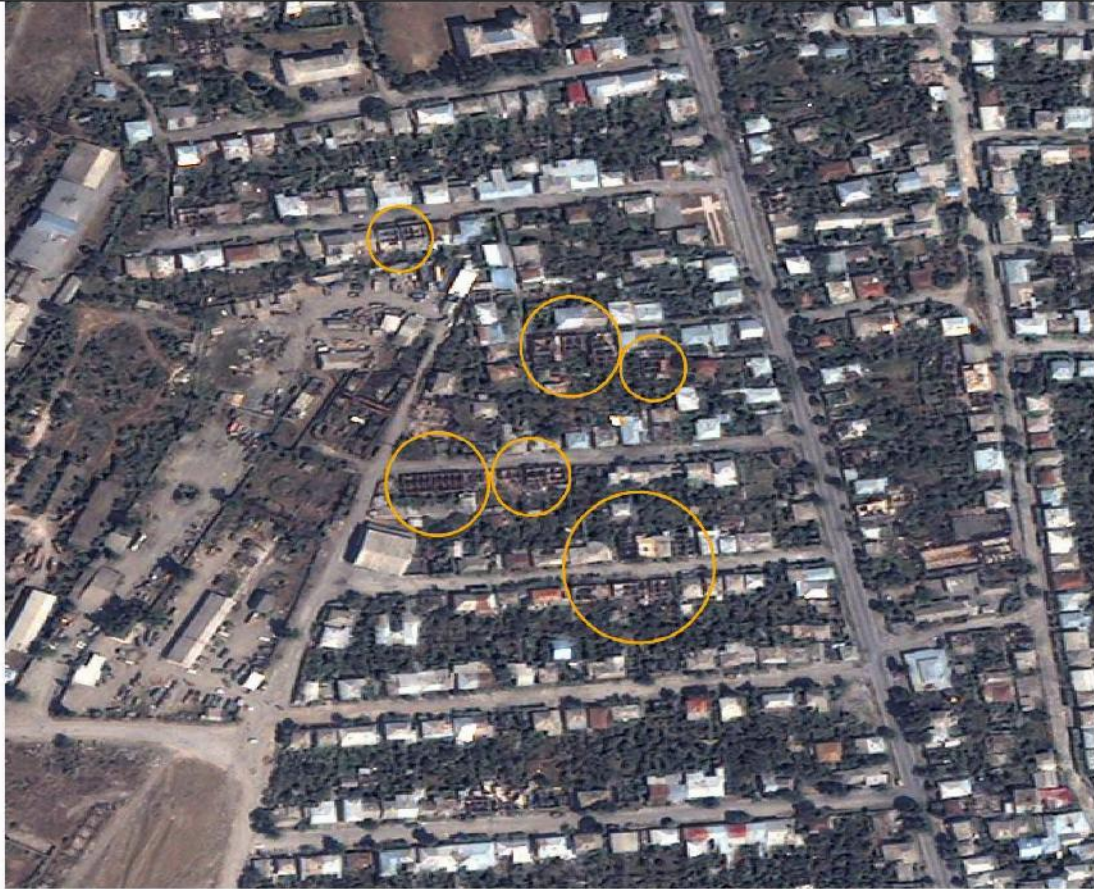


©2008 GeoEye

*Orange dots represent damage present on August 10, red dots on August 19. Dots in the far north and southeast are included in assessments for Tamarsheni and Ergneti, respectively. Note that the majority of damage to Tskhinvali occurred prior to or on August 10, with 182 structures damaged, while only 4 additional damaged structures have been identified for the city on August 19.*



Figure 5B: Subset of August 10 image showing Tskhinvali



©2008 GeoEye

*Subset of August 10 image of Tskhinvali city, highlighting damage to multiple structures, covering an area of approximately 0.6 km<sup>2</sup>.*

*Lat: 42.235 Long: 43.966*

Figure 5C: Subset of damage within the city of Tskhinvali



*Illustration of damage occurring to the city of Tskhinvali prior to August 19, 2008, but occurring after August 10. The building within the red circle is intact in the first image and visibly damaged, with its roof destroyed, in the second image.*

*Lat: 42.221 Long:43.966*

### **2.3 Locations exhibiting damage on August 19 only**

Berula was a village which sustained major damage in the nine days between the two image dates (Figure 3). There was no observed damage to this location on August 10, and 70 damaged or destroyed structures on August 19. Additionally, the villages of Brotsleti and Tirdzinisi were observed to be damaged only on August 19, with damaged structures numbering 5 and 7 structures, respectively.

Tamarsheni (Figure 6 A-C) is the village area which exhibited the most substantial damage on August 19. Tamarsheni exhibited no damage on August 10 and a damage count of 152 structures on August 19. This area was also analyzed by UNOSAT using an image from August 19, which confirmed nearly complete destruction of Tamarsheni.<sup>7</sup>

<sup>7</sup> This report may be accessed from the UNOSAT website, <http://unosat.web.cern.ch/unosat/>



Tamarsheni Damage Assessment

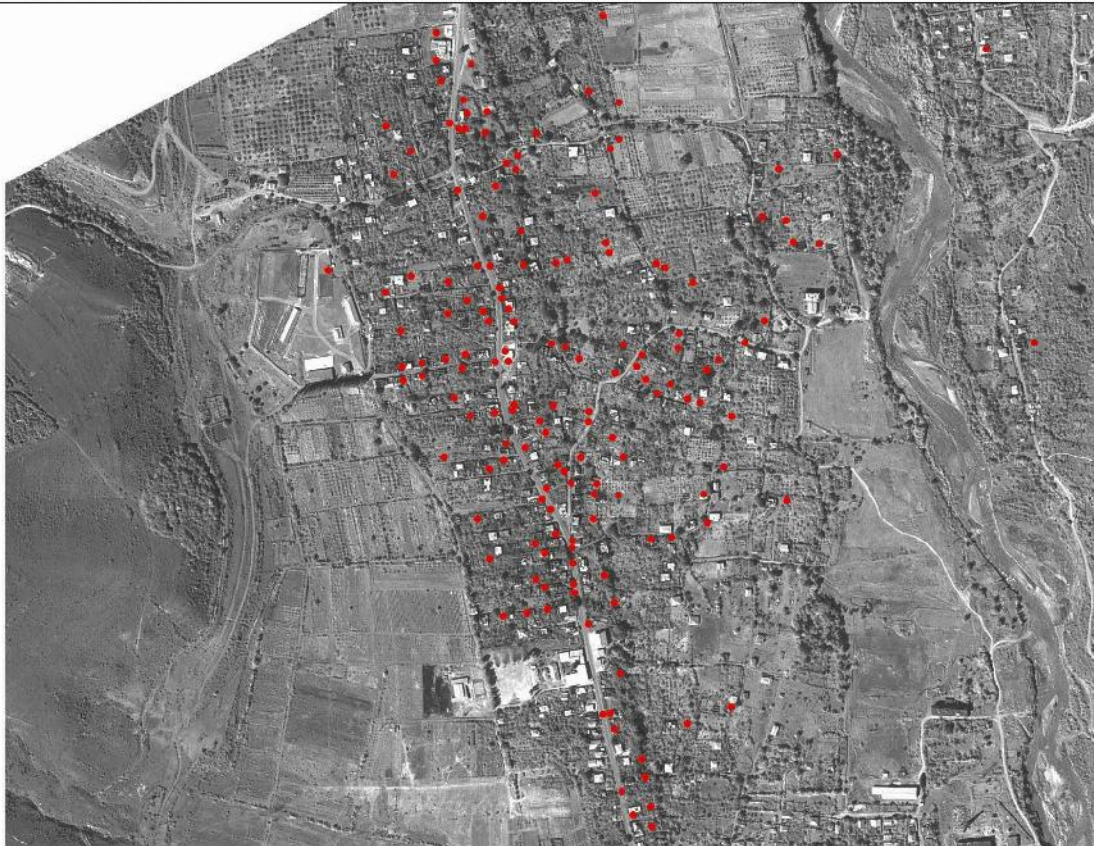
Figure 6A: Overview of village on August 10



© 2008 GeoEye

*Tamarsheni on August 10. No damage is visible in any part of the image.*

Figure 6B: Overview of Tamarsheni on August 19



© 2008 ImageSat

*Village of Tamarsheni on August 19, with red dots representing all buildings sustaining damage (152 total structures).*



Figure 6C: Subset of Tamarsheni



© 2008 ImageSat

*Subset of image covering Tamarsheni on August 19. Widespread damage is visible to nearly all the buildings in the area, indicated by their lack of rooftops.*

*Lat: 42.247 Long: 43.963*

#### **2.4 Full damage assessment not possible**

In addition to the areas described above, there were areas that were partially obscured by clouds and/or cut-off from the image bounds, resulting in incomplete damage analysis. These three locations were Tkviavi, Shua-Khelchua, and Karbi. Partial damage assessment results for these locations can be found in Table 1.

### **2.5 Damage to unpopulated areas and evidence of conflict**

Although a large amount of the destruction observed in the August 10 and 19 images takes the form of structural damage, there are also numerous other indications of conflict visible throughout the region. In many areas, track marks from large vehicles can be seen crossing agricultural fields (Figure 7 A-B). Numerous craters dot the region, with 455 visible between the two image dates (Figure 7C). Lastly, significant amounts of military hardware, including vehicles, helicopters, and tents, are found throughout the imagery.

#### **Evidence of Military Activity**

**Figure 7A: Fields and roads outside of Tskhinvali August 10, 2008**

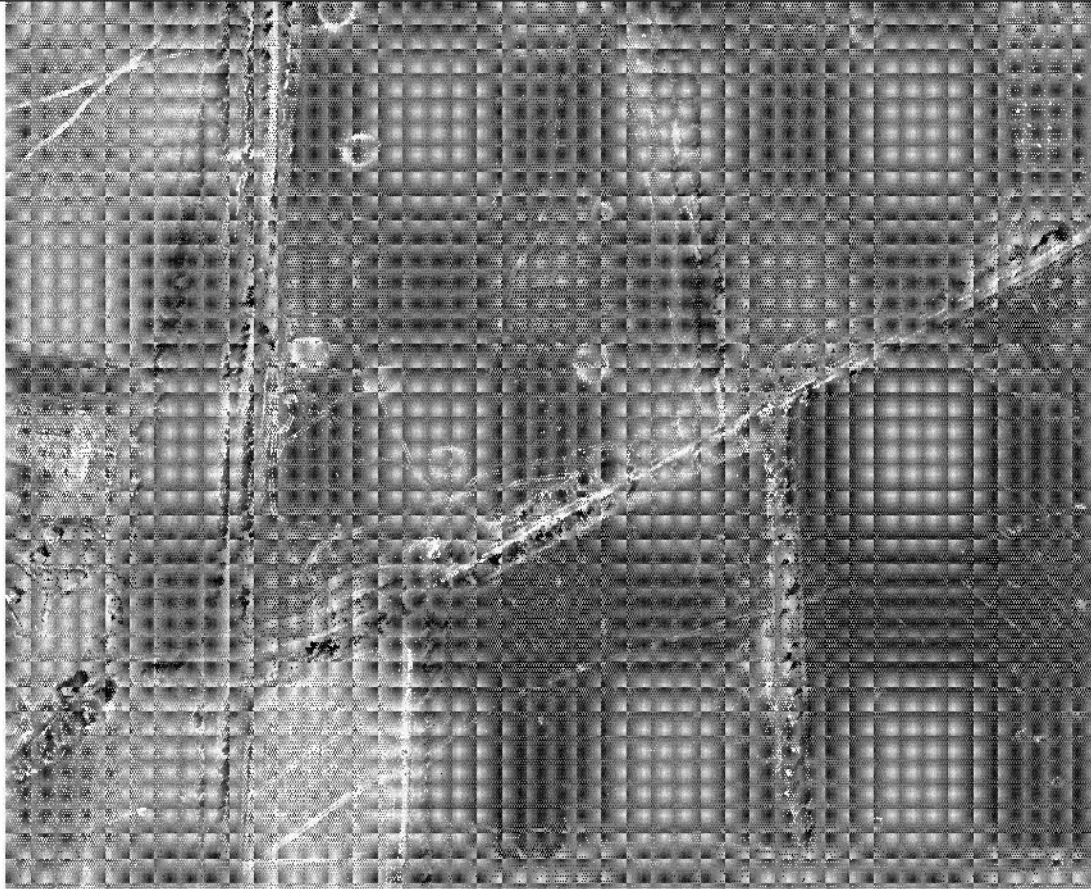


© 2008 GeoEye

*Portions of the August 10 image, such as the one above, show a lack of military presence in many areas on or before that date.*



Figure 7B: Fields and roads outside of Tskhinvali August 19, 2008



© 2008 ImageSat

*Tracks from large vehicles can be seen throughout this image, as well as a large number of disturbed areas on the ground, measuring approximately 3-4 meters in diameter, which are possibly craters from munitions. Note that while the August 10 image is a multi-spectral image (full color) and the August 19 image is panchromatic (black and white), the images are comparable for analysis purposes.*

*Lat: 43.994 Long: 42.226*



Figure 7C: Signs of conflict near Ergneti on August 10, 2008



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*This image subset covering the village of Ergneti highlights further signs of conflict occurring on August 10. The red circles indicate possible craters from munitions, which occur in a roughly linear pattern toward the village. Each circular area has a diameter of approximately 30-40 meters.*

*Lat: 40.039 Long: 42.244*

### III. About the Imagery

Ordering satellite imagery does not occur on a ‘first-come, first-served’ basis. Rather, commercial considerations can largely dictate where and when imagery is acquired. As such, satellite tasking priority generally falls to the United States Government (USG), which has the ability to purchase as much satellite time as it wants and can legally have its orders to US companies take priority above those of other customers. After the USG, priority is given to commercial customers with similarly large requests. Lowest priority is given to small-budget requests. Therefore, when AAAS requested a new acquisition of the Tskhinvali region, there was no satellite time available for purchase. Despite the inability to acquire new imagery of the region, AAAS utilized a number of different high-resolution imagery sources, each with spatial resolution of one meter or better. All of the images used were originally requested by other organizations. A full list of image sources is found in Table 2.

Table 2: Imagery Information			
Sensor/Source	Image Date	Acquisition Time (UTC)	Image Information
Ikonos	08/10/2008	08:22	2000001015000R08
WorldView	08/19/2008	08:13	10200100033C0C00
EROS-B	08/19/2008	11:00	MBS1-E2128631
QuickBird	07/02/2005	08:18	1010010004580900
Google Earth (QuickBird)	07/26/2007	-----	-----

One source was the Ikonos satellite, operated by the GeoEye<sup>8</sup> corporation. Ikonos is a multispectral (color) satellite with one meter panchromatic (black and white) resolution that has been in operation since 2000. The other satellites utilized were WorldView and QuickBird, operated by DigitalGlobe,<sup>9</sup> which have panchromatic 60 centimeter spatial resolution and 50 centimeter<sup>10</sup> resolution, respectively. QuickBird became operational in 2002, while WorldView began delivering imagery in late 2007. QuickBird also has multispectral capabilities, while WorldView is solely panchromatic. The last sensor used was EROS-B, operated by ImageSat International<sup>11</sup> and launched in 2006, which has a panchromatic sensor with 70 centimeter resolution.

Of special note, the general public cannot request WorldView to acquire images of specific locations, but the public can purchase such images if they are in the DigitalGlobe archives. Only the US Government can direct WorldView to acquire new imagery. While QuickBird and WorldView provide the greatest level of detail and are thus preferred for new image acquisitions, Ikonos was the only sensor that had acquired imagery of the South Ossetia region prior to August 19, and therefore was used as the main image in this analysis.

<sup>8</sup> <http://www.GeoEye.com>

<sup>9</sup> <http://www.digitalglobe.com>

<sup>10</sup> While WorldView has 40 centimeter capability, it is degraded to 50 centimeter resolution for non-US Government (USG) client as required by US law.

<sup>11</sup> <http://www.imagesatintl.com/>



#### **IV. Conclusion**

AAAS conducted a damage assessment for 24 village areas in the region of Tskhinvali, Georgia, to corroborate field reporting provided by Amnesty International. This imagery assessment sought to ascertain the damage sustained by the region and its infrastructure as a result of the conflict between Russia and Georgia. The report documents the scope and extent of damage between August 10 and August 19, 2008. Imagery analysis demonstrates initial concentrated damage to the city of Tskhinvali and small amounts of damage to outlying areas that had occurred by August 10. By August 19, a much broader range of destruction occurred in the village areas surrounding Tskhinvali (see Appendix One). Other significant sign of military actions were also shown to have occurred in the region, including many obvious craters from munitions, and tracks from the presumed movement of military vehicles, which resulted in clear damage in the vegetated areas throughout the region (Figure 7).

### Appendix One: Overview of Damage to Tskhinvali Region by Date

