Analysis of Satellite Imagery for Timbuktu and Kabara, Republic of Mali

Prepared for the International Criminal Court as Input to the Investigation on the Situation in the Republic of Mali (ICC-01/12)

3 November 2014

unitar
United Nations Institute for Training and Research

UNOSAT

Palais des Nations
1211 Geneva 10
Switzerland

[redacted]

Contents

unitar
United Nations Institute for Training and Research

UNOSAT

Introduction

In October 2014 the United Nations Institute for Training and Research Operational Satellite Applications Program (UNITAR/UNOSAT) conducted satellite imagery analysis of locations in the area of Timbuktu and Kabara, Mali at the request of the Office of the Prosecutor of the International Criminal Court (ICC)[1]. The ICC requested satellite imagery analysis of multiple monuments relating to the case ICC-01/12. UNOSAT acquired satellite images for ICC locations of interest (LOIs) and subsequently sought to document evidence of changes to the status and appearance of the LOIs. This report provides results of this analysis as well as an overview of methods and data sources used.

Methods and Data Sources

To document the status of monuments in the areas of Timbuktu and Kabara, UNOSAT reviewed the locations provided by the ICC and acquired and analyzed multiple commercial high-resolution satellite images. The satellite images used by UNOSAT were acquired by satellites prior to and after the reported destruction of the LOIs. UNOSAT analysis reviewed the images for each LOI and the appearance of the LOI was assessed in the image acquired prior to the events in question and again in the image acquired after the events. Dates of interest and the specific locations of the monuments were provided in detail by the ICC in their letter of request. Monument locations and associated metadata describing each image analysed for each monument are provided in Table One. Two maps describing the locations of the monuments in Timbuktu and Kabara are provided as Map One and Map Two.

Table 1: Summary of Locations and Imagery Analyzed

Monument	Longitude	Latitude	Date of Interest	Before Image	After Image
Mausolee Sidi Mouhammed Boukkou	-3.004542	16.770167	December 23, 2012	WV02, 22 December 2012 (103001001D987E00)	WV02, 25 December 2012 (103001001D83AF00)
Mausolee Sidi Al Bekkai	-3.011847	16.771083	December 23, 2012	WV02, 22 December 2012 (103001001D987E00)	WV02, 25 December 2012 (103001001D83AF00)
Mausolee de Taleb Abdallah (And his Disciple Sareikeyna)	-3.006869	16.769344	December 23, 2012	WV02, 22 December 2012 (103001001D987E00)	WV02, 25 December 2012 (103001001D83AF00)
Mausolee de Mahamane Askia	-3.005349	16.773882	December 23, 2012	WV02, 22 December 2012 (103001001D987E00)	WV02, 25 December 2012 (103001001D83AF00)
Mausolee Cheikh Mohamed Mahmoud al Arawani	-3.004758	16.782283	June 30, 2012	WV02, 18 June 2012 (1030010019914F00)	WV02, 15 July 2012 (103001001B4EBC00)
Mausolee Cheikh Nouh	-2.986097	16.707022	October 17, 2012 - December 23, 2012	WV02, 07 October 2012 (103001001C61AD00)	WV02, 25 December 2012 (103001001D83AF00)
Mausolee Cheikh Ousmane Alkabir	-2.983767	16.707086	October 17, 2012	WV02, 07 October 2012 (103001001C61AD00)	WV02, 29 October 2012 (103001001C7F9000)
Mausolee Cheikh Mohamed Alfullani Al Masini	-2.984142	16.706036	October 17, 2012 - December 23, 2012	WV02, 07 October 2012 (103001001C61AD00)	WV02, 25 December 2012 (103001001D83AF00)
Mausolee Cheikh Al Imam Said	-3.005131	16.768272	April 2012 - January 2013	WV02, 31 March 2012 (1030010011C73E00)	WV02, 01 February 2013 (103001001ECE6400)
Mausolee Cheikh Katib Moussa	-3.008506	16.772203	April 2012 - January 2013	WV02, 31 March 2012 (1030010011C73E00)	WV02, 01 February 2013 (103001001ECE6400)
(Next to the Tribunal)	-3.006858	16.766897	April 2012 - January 2013	WV02, 31 March 2012 (1030010011C73E00)	WV02, 01 February 2013 (103001001ECE6400)

[1] The request from the ICC was dated 19 August 2014 and is attached to this report as Appendix A. Initial discussions on this topic with the ICC began in November 2013.

MAP 1: ICC LOCATIONS OF INTEREST IN TIMBUKTU, MALI

Satellite Data: WorldView-2
Imagery Date: 18 June 2012
Resolution: 50 cm
Copyright: DigitalGlobe
Source: European Space Imaging

Analysis : UNITAR / UNOSAT
Production: UNITAR / UNOSAT
Analysis conducted with ArcGIS v10.2

Coordinate System: WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984

MAP 2: ICC LOCATIONS OF INTEREST IN KABARA, MALI

Satellite Data: WorldView-2
Imagery Date: 07 October 2012
Resolution: 50 cm
Copyright: DigitalGlobe
Source: European Space Imaging

Analysis : UNITAR / UNOSAT
Production: UNITAR / UNOSAT
Analysis conducted with ArcGIS v10.2

Coordinate System: WGS 1984 UTM zone 30N
Projection: Transverse Mercator
Datum: WGS 1984

Satellite Images and Processing

The main satellite images used in the analysis are portions of eight separate images acquired by the WorldView-2 satellite on multiple dates spanning 31 March 2012 to 1 February 2013. WorldView-2 is a commercial satellite owned by DigitalGlobe with an optical sensor that records imagery at 0.46 meter[2] resolution in the panchromatic band and 1.85 meter resolution in eight wavelengths of the electromagnetic spectrum[3]. The WorldView-2 satellite was launched on 8 October 2009 and, following a calibration period, has been used continuously by governments, industry, and other sectors around the world for many applications[4]. Images collected by the satellite are done so either via direct request from a client (a government, business, organization, individual, etc.) or by the company at its own discretion for internal reasons. Images can vary in size, though the spatial resolution stays the same, and can cover anywhere from a few square kilometres to more than 2,000 square kilometres in area.

As requested by the ICC in its August 2014 letter, a review of commercial high-resolution satellite images available for the ICC LOIs was conducted by UNOSAT. The best candidates for analysis were those images collected closest to the date of interest provided by the ICC, and each location had an image acquired both before and after the events in question. Summary metadata for images utilized in this analysis are presented in Table One with each location listed along with its corresponding images used for analysis. Note that as satellite images can span thousands of square kilometres, subsets of imagery were purchased by UNOSAT for the analysis requested by the ICC. To purchase subsets of the images, after reviewing available imagery and selecting candidates for purchase, UNOSAT defined an area of 25 square kilometers[5] which includes all the city of Timbuktu, and a similarly sized area for Kabara, and including all the ICC LOIs. The ICC request letter stated that analysis should be confined directly to the locations of monuments provided and so no analysis of surrounding areas was performed for this project[6].

These satellite images, all copyright 2014 DigitalGlobe, were purchased by UNOSAT from European Space Imaging[7] and downloaded in GeoTIF[8] format onto the UNOSAT computer network. Processing of the GeoTIF files to prepare them for analysis consisted of loading the images into an ArcMap 10.2 Geographic Information System (GIS)[9] using standard tools and specifications[10], then saving those GIS instances as MXD files[11] to link all associated data including the ICC LOIs, satellite imagery, and UNOSAT analysis. Once both the 'before' and 'after' images were loaded into the GIS then the precise location of each monument was viewed at the maximum level of detail possible. The two images were then directly compared with one another and changes between the two dates were visually assessed by UNOSAT.

When viewed in pairs of satellite images collected on two dates, the removal of entire buildings in a period between those dates is immediately apparent. Specifically, the building simply disappears from the 'after' image, in some cases debris or signs of destruction are visible, or discoloured soil, and the lack of a shadow cast by a standing structure after its removal is also visible in

[2] For non-US government clients the imagery is resampled to .50 meter resolution in accordance with US law.

[3] Satellites like WorldView-2 measure electromagnetic radiation originating from the sun and reflected off the surface of the earth. The full range of potential electromagnet radiation is referred to as the electromagnetic spectrum and includes multiple wavelengths. The spectrum includes light that is visible to the human eye in the red, green, and blue wavelengths, as well as wavelengths not visible to the human eye such as the near infrared. Common terms for describing other parts of the electromagnetic spectrum include X-rays, ultraviolet light, and radio waves. The satellites measure the electromagnetic radiation reflected off the Earth in different resolutions which results in different levels of detail. For example, the .46 meter resolution panchromatic sensor on WorldView-2 is able to image objects with a width of at least .46 meters, while the multispectral sensor can image objects 1.85 meters across.

[4] DigitalGlobe provides descriptive information on the WorldView-2 satellite online here: http://www.digitalglobe.com/sites/default/files/DG_WorldView2_DS_PROD.pdf

[5] This is the minimum area that can be purchased from DigitalGlobe, i.e. smaller areas cannot be purchased according to company policy.

[6] Note that UNOSAT did release a map related to the monuments of Timbuktu, Mali, on 31 January 2013, and also analyzed two refugee camps for Malians in Niger in October 2013. These products can be viewed at: http://www.unitar.org/unosat/maps/MLI

[7] European Space Imaging is one of many resellers of DigitalGlobe and other satellite imagery. It is a primary vendor for acquisition of satellite images by UNOSAT.

[8] A GeoTIF file format is one of many possible ways to store a satellite image on a computer system. The satellite image is stored in the Tagged Image File Format (abbreviated as TIF), a commonly used image storage format, and has additional geographic information embedded in the file to position it correctly within a coordinate system in a GIS or similar software.

[9] A geographic information system (GIS) is software commonly used for decades in many sectors for tasks involving satellite imagery, mapping, and related requirements such as calculation of distances and potential travel times. The ArcMap GIS is commercial GIS software produced by the Esri corporation (http://esri.com) and widely used around the world.

[10] Loading data on any computer or software requires certain tools and specifications to ensure proper display of the data. For ArcMap GIS the tool for loading data is simply a button found on the user interface, like opening a Word document, and the specifications dictate how the satellite image is displayed and viewed by the user.

[11] An MXD file is how an ArcMap GIS stores all information about particular datasets that the user would want to reload at a later time. It is the conceptual equivalent of a Word document (DOC) or an Excel document (XLS).

the imagery. Given these factors and the precise locations of the monuments provided by the ICC, documenting the removal of monuments and buildings was a simple and straightforward process for UNOSAT. Initial data review, image acquisition, and preliminary analysis was done by a UNOSAT [redacted] with full review then undertaken by the UNOSAT Principal Analyst (Lars Bromley), who also authored this report.

Satellite Image Analysis Results

Nine of the eleven LOIs provided by the ICC were determined to have been removed in some fashion by the analysis of satellite imagery, and a summary of results are presented in Table Two. The Google Earth screen captures provided by the ICC were highly detailed and indicated precisely the location of each structure in question. Thus, each monument was easily assessed by comparing the pre-event and post-event imagery and in almost all cases the structures comprising the monuments were certainly determined to have been removed in the time period between the collection of the two images used. Results of these analyses are summarized in Table Two and detailed in Figures One through Eleven on the following pages.

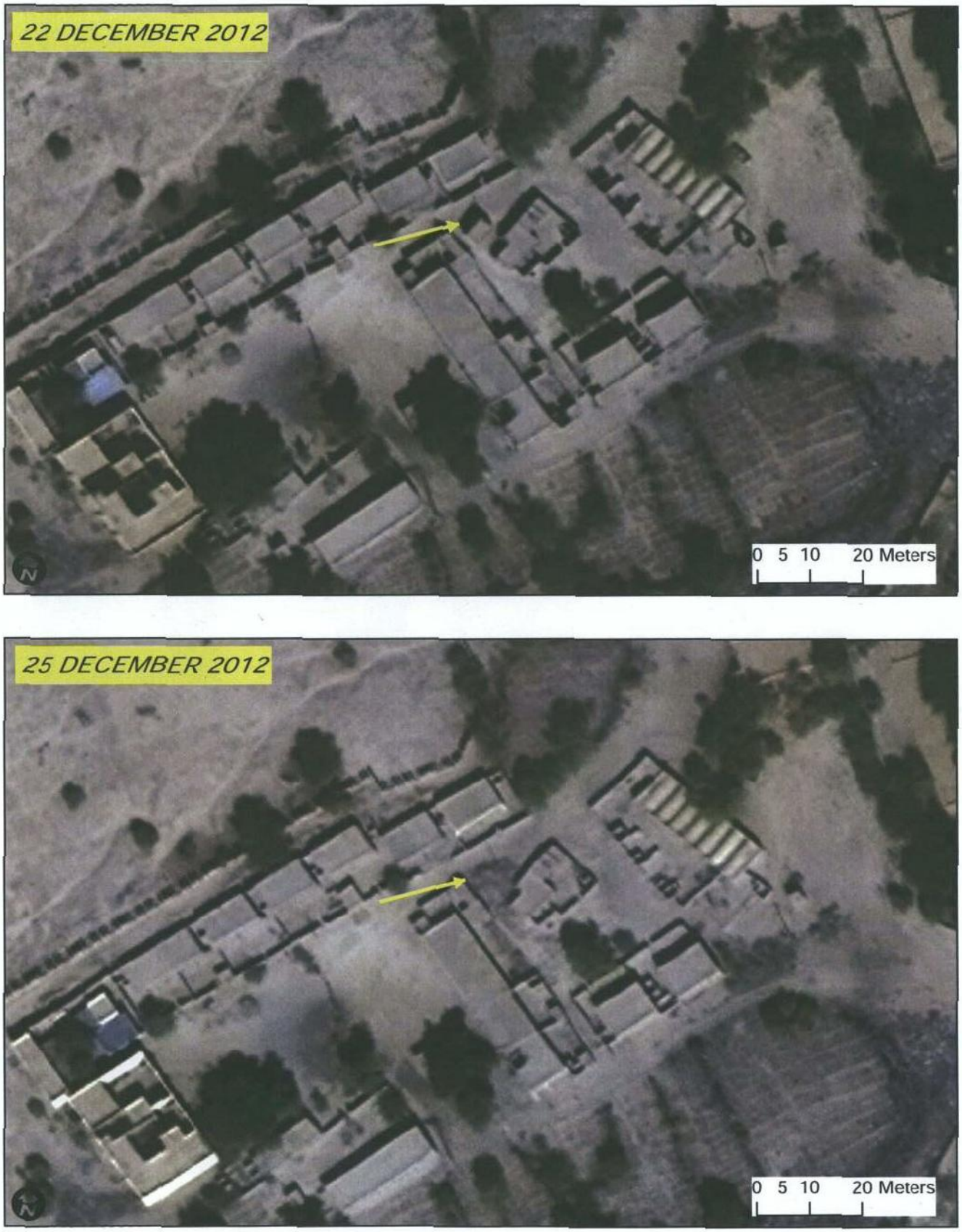
Table 2: Summary of Imagery Analysis Results

Monument	Longitude	Latitude	Figure	Results
Mausolee Sidi Mouhammed Boukkou	-3.004542	16.770167	1	Structure clearly removed.
Mausolee Sidi Al Bekkai	-3.011847	16.771083	2	Structure clearly removed.
Mausolee de Taleb Abdallah (And his Disciple Sareikeyna)	-3.006869	16.769344	3	Structure clearly removed.
Mausolee de Mahamane Askia	-3.005349	16.773882	4	Structure obscured but removed.
Mausolee Cheikh Mohamed Mahmoud al Arawani	-3.004758	16.782283	5	Structure clearly removed.
Mausolee Cheikh Nouh	-2.986097	16.707022	6	Structure clearly removed.
Mausolee Cheikh Ousmane Alkabir	-2.983767	16.707086	7	Structure clearly removed.
Mausolee Cheikh Mohamed Alfullani Al Masini	-2.984142	16.706036	8	Structure obscured but removed.
Mausolee Cheikh Al Imam Said	-3.005131	16.768272	9	Inconclusive and unable to verify damage.
Mausolee Cheikh Katib Moussa	-3.008506	16.772203	10	Structure partially removed.
Monument Next to the Tribunal	-3.006858	16.766897	11	Inconclusive and unable to verify damage.

Figure 1: Mausolee Sidi Mouhammed Boukkou

The Mausolee Sidi Mouhammed Boukkou as seen on 22 December 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0089. By 25 December 2012 (bottom) the Mausolee has been largely destroyed though a faint outline of the structural wall is still visible (yellow arrow). Imagery Copyright 2014 DigitalGlobe.

Figure 2: Mausolee Sidi Al Bekkai



The Mausolee Sidi Al Bekkai as seen on 22 December 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0088. By 25 December 2012 (bottom) the Mausolee is no longer visible though probable debris remains (yellow arrow). Imagery Copyright 2014 DigitalGlobe.

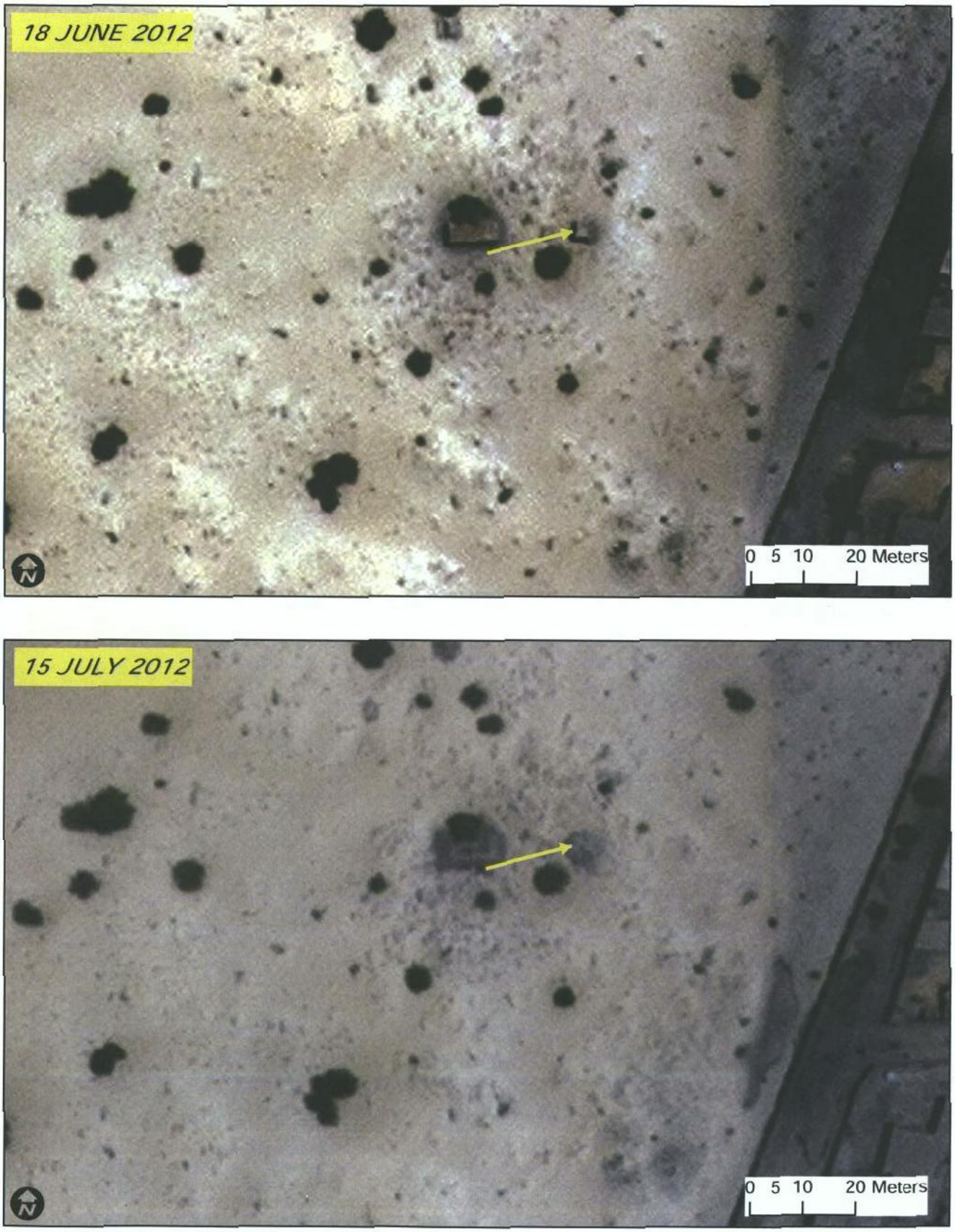
Figure 3: Mausolee de Taleb Abdallah

The Mausolee de Taleb Abdallah as seen on 22 December 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0087. By 25 December 2012 (bottom) the Mausolee is no longer visible (yellow arrow). Imagery Copyright 2014 DigitalGlobe.

Figure 4: Mausolee Mahamane Askia

Though only partially visible, the Mausolee Mahamane Askia as seen on 22 December 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0086. By 25 December 2012 (bottom) the Mausolee is no longer visible (yellow arrow). Imagery Copyright 2014 DigitalGlobe.

Figure 5: Mausolee Cheikh Mohamed Mahmoud Al Arawani



The Mausolee Cheikh Mohamed Mahmoud Al Arawni as seen on 18 June 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0082. By 15 July 2012 (bottom) the Mausolee is no longer visible though probable debris remains (yellow arrow). Imagery Copyright 2014 DigitalGlobe.

Figure 6: Mausolee Cheikh Nouh

The Mausolee Cheikh Nouh as seen on 7 October 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0083. By 25 December 2012 (bottom) the Mausolee is no longer visible. Imagery Copyright 2014 DigitalGlobe.

Figure 7: Mausolee Cheikh Ousmane Alkabir

The Mausolee Cheikh Ousmane Alkabir as seen on 7 October 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0084. By 29 October 2012 (bottom) the Mausolee, and adjacent tree, are no longer visible though probable debris remains (yellow arrow). Imagery Copyright 2014 DigitalGlobe.

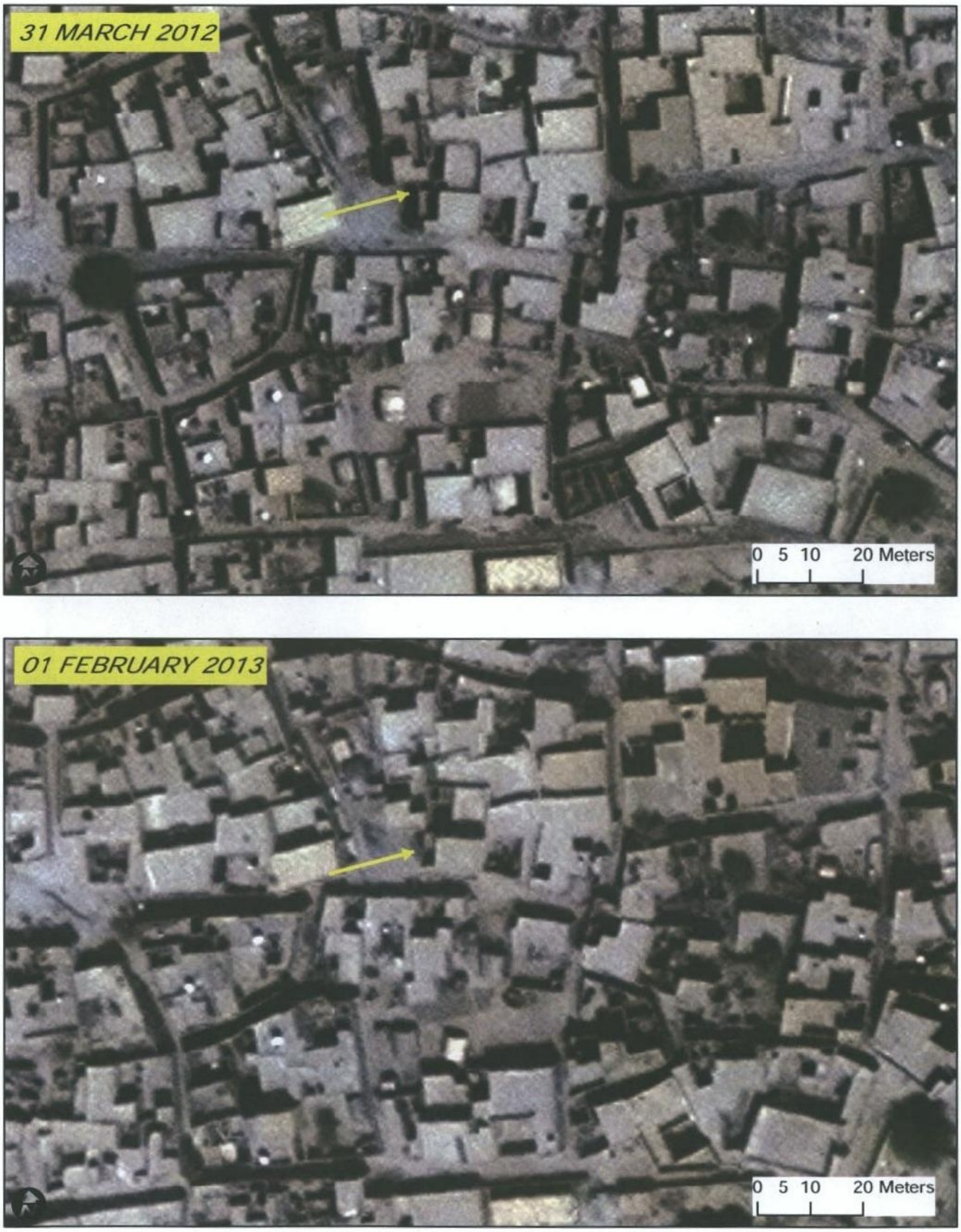
Figure 8: Mausolee Cheikh Mohamed Alfullani Al Masini

The northern edge of the Mausolee Cheikh Mohamed Alfullani Al Masini as seen on 7 October 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0085. By 25 December 2012 (bottom) the Mausolee is no longer visible. Imagery Copyright 2014 DigitalGlobe.

Figure 9: Mausolee Cheikh Al Imam Said

The Mausolee Cheikh Al Imam Said as seen on 31 March 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0079. On 1 February 2013 (bottom) the Mausolee is still visible, and while it is possible that some aspects of its appearance have changed, indicating damage, this cannot be verified in the satellite imagery. Imagery Copyright 2014 DigitalGlobe.

Figure 10: Mausolee Cheikh Katib Moussa



The Mausolee Cheikh Katib Moussa as seen on 31 March 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0080. On 1 February 2013 (bottom), portions of the Mausolee are still visible, but the western wall has clearly been removed and likely the northern wall as well. Imagery Copyright 2014 DigitalGlobe.

Figure 11: Monument Next to the Tribunal

The Monument next to the Tribunal is barely visible on 31 March 2012 (top, yellow arrow), identified in the ICC Google Earth screen capture MLI-OTP-0017-0109. On 1 February 2013 (bottom) the Monument is still visible, and while it is possible that some aspects of its appearance have changed, indicating damage, this cannot be verified in the satellite imagery. Imagery Copyright 2014 DigitalGlobe.

Conclusion

Based on review of the LOIs provided by the ICC in their letter of request, UNOSAT acquired and analysed multiple satellite images to detect changes consistent with destruction of the LOIs. Of the 11 LOIs analysed, clear indications that the structure was destroyed or otherwise removed were found for nine locations. These LOIs generally showed complete removal of structures and oftentimes with visible debris and discoloured soil remaining at the location where the structure had been. For the remaining two locations, the Mausolee Cheikh Al Imam Said and the monument next to the tribunal, their destruction could not be definitively documented in the satellite imagery.

This is a preliminary assessment and has not yet been validated in the field. Please send feedback to UNITAR/UNOSAT at the contact information below. Report prepared by Lars Bromley, Principal Analyst, UNITAR/UNOSAT.

Signed:

[redacted]

3 November 2014

UNOSAT Contact:

[redacted]

Post address

[redacted]

unitar
United Nations Institute for Training and Research

UNOSAT