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# GRID: A Methodology Integrating Witness Testimony and Satellite Imagery Analysis for Documenting Alleged Mass Atrocities

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**Methods:** The primary method used in this article is a case study of HHI's development and use of GRID. The GRID methodology was designed during HHI's work with the Satellite Sentinel Project. It was deployed to corroborate reports that mass graves were being created in Sudan in the summer of 2011.

**Results:** The results of this specific case study are examined, step-by-step guidelines for using GRID are provided, and possible areas for further research are discussed.

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This case demonstrates that the GRID methodology facilitates corroboration when differences exist between the local geographic knowledge of a witness and the more cursory geographic knowledge of an analyst.

**Conclusions:** The initial use of GRID warrants further research into potential applications in other regional and operational contexts. Future use cases will help advance GRID as a standardized methodology for use by different types of groups that utilize satellite imagery. Distinct research should also focus on operational, cultural, psychological, and ethical impacts of this methodology due to its involvement of the witness in the imagery analysis process.

Keywords.

humanitarian, human rights, mass atrocities, satellite imagery, mass graves, Sudan, remote sensing, testimony, witness

# GRID: A Methodology Integrating Witness Testimony and Satellite Imagery Analysis for Documenting Alleged Mass Atrocities

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# Abstract:

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# Introduction

The analysis of satellite imagery for humanitarian and human rights purposes during or after armed conflict has become more common over the past twenty years. Satellite imagery was first developed in the late 1950's during the Cold War by the United States and Soviet Russia as the governments sought new ways to gather intelligence on the other. This technology remained largely confined to government applications until the 1990's when the United States Government authorized the commercial collection and sale of satellite imagery. Since then, both high and low-resolution satellite imagery have become available to civilians.<sup>1</sup>

Although financial, technical and access barriers still exist; high-resolution satellite imagery analysis has become increasingly utilized by non-governmental organizations (NGOs), international agencies, and academic institutions for human rights and humanitarian operations.<sup>2</sup> This includes the employment of satellite imagery analysis to document destroyed civilian dwellings, the build-up of forces at military facilities, patterns of population fluctuation at displaced persons camps, and to help identify the apparent locations of alleged mass grave sites.<sup>3</sup>

As part of this work by NGOs, satellite imagery analysis has become increasingly employed to document evidence of a reported gross human rights violation and corroborate witness testimony relevant to that event.<sup>4</sup> Organizations such as NGOs, academic research centers, and local and international tribunals collect witness testimony through interviews of conflict-affected populations to document evidence of alleged violations of international human rights standards and humanitarian law. During these interviews, the populations may still be present in the conflict zone or they may have fled to other areas, including other countries. Reported acts

may include the specific targeting of certain populations, the intentional destruction of communities, and the creation and presence of mass graves.

Collecting and corroborating these reports are critical for advocacy, research, and accountability purposes but this can present many challenges. For example, the collection of testimony may be perceived as biased and the ground corroboration of reports may be difficult in locations that do not allow direct access to the areas where the events allegedly occurred.<sup>5</sup> Also, if interviews are secured with those involved in carrying out the acts, they may not want to provide self-incriminating information. Misleading or incorrect information may also be presented by victims if they believe revealing the truth would cause threats to their security.<sup>6</sup>

In light of these challenges, additional methods for collecting information about events have emerged. One of these methods is the use of remote sensing, particularly satellite imagery, to provide unique and otherwise unobtainable information about events that have occurred or are occurring on the ground. Satellite imagery analysis may offer visual evidence that documents and corroborates information provided by a purported witness.

Although the integration of these methods may appear simple, major analytic and methodological challenges exist. This paper examines one commonly repeating analytic limitation of employing this technology and details a methodology that was developed with the intent of solving this challenge. The common limitation is that profound differences routinely exist between the often hyper-local or indigenous level of geographic knowledge possessed by an alleged witnesses to a mass atrocity event while the analyst may have significantly cursory geographic knowledge of the area of interest (AOI) being examined through remote sensing. This discrepancy in geographic knowledge between the witness and the analyst can limit or even impede potential corroboration of the reported event through satellite imagery analysis. For example, if the analyst is unable to identify on a basic map the locations of alleged mass graves as described in a witness' testimony due to a lack of detailed geographic information of the area, then the ability of an analyst to identify that alleged gravesite's location within a satellite image is also limited.

Different types of organizations employing satellite imagery for purposes of corroborating witness testimony have experienced the challenges posed by a lack of location-based information. For example, the UN Fact Finding Mission on the Gaza Conflict commissioned satellite imagery analysis after it's founding in April 2009. The analysis produced primary and secondary evidence corroborative of witness testimony collected during the Mission's investigation that included evidence showing the destruction of industrial infrastructure, greenhouse complexes, and commercial and residential buildings. Although extensive evidence was collected:

There were significant and sometimes glaring limits to the applicability of satellite imagery analysis in the case of Gaza. Of particular concern was the inability, because of a systematic lack of accurate GPS data on important facilities throughout Gaza, to locate in the satellite imagery several important factories, schools, and hospitals of direct interest to the Mission investigations.<sup>7</sup>

The impacts of this limitation on the analytic process are extremely important to note. Evidence collection and corroboration may be limited by the inability to obtain location-based data for relevant areas, such as schools, hospitals, and neighborhoods, which appear in satellite imagery and cannot be determined by their unique observable features alone.

This limitation was also experienced by researchers at the Harvard Humanitarian Initiative (HHI) who utilized satellite imagery in an attempt to corroborate reports of recently created mass graves in Sudan in the summer of 2011 as part of their work with the Satellite Sentinel Project (SSP). To address this problem, HHI researchers created the GRID (Ground Reporting through Imagery Delivery) methodology as a process for cross-referencing witness testimony with extant satellite imagery. Although the general process of cross-referencing testimony with imagery was not new, the GRID methodology actively involved the witness in the analytic process. GRID is based on the premise that witness testimony can often provide critical, otherwise unavailable, location-based information that can guide remote sensing analysis to identify recent changes in the physical environment. To do this, the methodology offers guidelines for the creation of a GRID map using a satellite image. The GRID map is then sent to the witness so that the map, a satellite image overlaid with alphanumeric quadrants, can be used to help communicate information back and forth.

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Through GRID's controlled involvement of a witness in the workflow of satellite imagery analysis, relevant local geographic knowledge may be communicated from the witness to the analyst. GRID also maintains the integrity of the corroboration through a double blind process in which the witness is not allowed to view imagery captured on or after the day of the alleged event in question. By only being provided imagery captured before the alleged event, the witness cannot be influenced by the presence of any visual differences between a "before" and "after" image. The subsequent imagery analysis resulting from this process may yield more corroborative evidence, particularly from non-permissive environments, which can then facilitate further investigation.

# HHI's Challenge Identifying Locations in Kadugli

HHI developed and deployed GRID while monitoring Kadugli, South Kordofan, Sudan while working as part of SSP. SSP was a first-of-its-kind collaboration between HHI, DigitalGlobe, the Enough Project, Google, and Not On Our Watch. The project was launched with a stated mission of deterring a return to full-scale war between Sudan and then-southern Sudan by detecting threats to and documenting attacks on civilians along the contested border.<sup>8</sup>

Each organization played a unique role within the consortium. DigitalGlobe, a commercial highresolution satellite imagery provider, supplied the project with retrospective and near-real time imagery. HHI managed the day-to-day operations of the 18-month SSP pilot phase, which concluded in July 2012. These operations included the collection and corroboration of open source media, ground reports and nearreal time satellite imagery to document violence and predict threats to vulnerable populations. The Enough Project, a Washington D.C.-based advocacy organization, managed communication operations and provided reports from ground sources to analysts at HHI. Google provided some base layer imagery to SSP and access to Google Earth Pro. Not On Our Watch, an NGO founded by a group of celebrities, including George Clooney, Don Cheadle, Matt Damon, Brad Pitt, David Pressman and Jerry Weintraub, provided the seed money for the project. Not On Our Watch's stated mission is to utilize artists, activists and cultural leaders in an effort to end mass atrocities.<sup>9</sup>

At the end of May 2011, the primary focus of SSP was monitoring the aftermath of the Government of Sudan's invasion of Abyei Town. However, attention quickly shifted to Kadugli when fighting erupted between Government of Sudan-aligned forces and the Sudan People's Liberation Army on June 5, 2011. As fighting spread throughout the town, civilians, primarily the Nuba people, were targeted by forces, predominantly those aligned with the Government of Sudan. Roadblocks were constructed around the town that reportedly prevented civilians from fleeing. Freedom of movement restrictions also reportedly prevented civilians from accessing medical and humanitarian assistance. As violence continued throughout the summer, Government of Sudan-aligned forced reportedly committed atrocities against civilians. This included house-to-house searches, mass killings and the subsequent burials of Nuba civilians and others.<sup>10</sup>

The UN and media outlets reported some aspects of the atrocities allegedly committed in Kadugli. However, the increasingly non-permissive environment restricted the ability of humanitarian personnel, the United Nations Mission in Sudan (UNMIS) and international observers to access affected populations and investigate alleged atrocities being contemporaneously reported in that area, including the allegations that new mass graves had recently been created in the vicinity.

Despite these restrictions, some details about purported mass gravesites were being publicly reported by sources, including UNMIS. In the leaked "UNMIS Report on the Human Rights Situation During the Violence In Southern Kordofan Sudan," UNMIS personnel confidentially reported to headquarters claims made by those they interviewed that alleged gravesites had been created during the fighting. However, UN forces were unable to successfully verify these claims because of pervasive insecurity. UNMIS reported in that same leaked report that when UN military observers (UNMOs) attempted to verify the presence of mass graves somewhere between the Sudan Armed Forces (SAF) 14th Division Headquarters and the Kadugli Market, UNMOs were "arrested, stripped of their clothes, and believed that they were about to be executed when a senior SAF officer intervened."<sup>11</sup>

HHI researchers also began directly receiving multiple eyewitness reports, which were communicated to HHI through a staff member of the Enough Project, that multiple mass graves had recently been dug throughout Kadugli. HHI researchers then sought to corroborate the witness testimony, ideally in near-real time, using satellite imagery. This documentation would also create and preserve a narrative of the deteriorating human security situation during that time. However, researchers quickly realized that they had no standard

practice for identifying the reported locations of the graves within the satellite imagery and corroborating features present within the imagery that may be consistent with the reported graves.

This problem arose because assessing the potential probative value of reports collected from ground sources proved contingent on identifying locations within satellite imagery of Kadugli. However, the locations were described in such granular and regionally specific details that HHI researchers could not locate the alleged location of the graves through the resources publicly available to them. Additionally, SSP did not have an available ground team that could be deployed, nor did the increasingly non-permissive and insecure environment allow for the deployment of a ground team to confirm these reports if one had been available. Without ground access, satellite imagery proved the only available means of corroborating the testimony of the alleged eyewitnesses.

As a result, HHI researchers integrated two primary sources of available data, witness testimony and remote sensing, to create the GRID methodology. By incorporating the witnesses' testimony into the remote sensing analysis workflow, researchers used GRID to utilize and capture local geographic knowledge that in some cases enabled researchers to understand an area on a similarly granular level as that of a ground source.

# **GRID Methodology**

HHI addressed these issues by creating a methodology to utilize the geospatial and temporal data provided by witnesses testimony to aid in the analysis of satellite imagery and corroborate the reports to more quickly, accurately and independently identify possible mass grave sites. The GRID platform utilizes remote sensing and geospatial analytics to corroborate ground reports, particularly those from non-permissive environments, by engaging the witness in the analytic process using a double blind method of inquiry to ensure independent corroboration.

## **Spatial and Temporal Data**

Witness testimony and satellite imagery each provide their own fields of temporal (time-specific) and spatial (location-specific) data about an event or observed phenomenon, such as the creation of an alleged mass gravesite. Temporal and spatial data contained in witness testimony can provide critical information to guide the analysis of satellite imagery. Additional details provided by witness testimony, such as the presence of a certain type of vehicle in proximity to the alleged gravesite, may also aid the analysis of the imagery. For this information to be of probative value, the analyst must have a process for integrating, analyzing and cross-referencing this data. The incorporation of this testimony can better guide the analyst to search a particular geographic area within the imagery.

Temporal and spatial data can be communicated in various ways. Both types of information serve distinct roles in the satellite imagery analysis process. Spatial data guides the analyst in identifying what specific geographic areas should be focused on during the analytic process. Examples of what type of information can be communicated include identifying a specific city, neighborhood, or street, as well as the presentation of information in context to a particular building, area, such as a park or other locally known geographic marker. The analyst must be able to identify where a specific location provided by the witness is located within available imagery if the testimony is to have probative value, let alone corroborative potential. For example, a witness reports observing a mass grave being dug near a specific school. Unless the imagery analyst knows where this school is located within the imagery, then this critical piece of information cannot be effectively used to locate the grave.

Location information can be obtained through publicly available geocoded datasets, like the United Nations "P-Codes",<sup>12</sup> regional, state, county or city maps; online crowd sourced mapping projects, such as OpenStreetMap, or platforms like Google Maps or Google Earth. Despite growth increases in available mapping data, not all areas of the world are equally mapped. If an analyst is unable to obtain location data relating to the AOI they are analyzing, the analyst may be limited in their ability to corroborate and identify the reported location of a mass grave or other mass atrocity-related phenomena.

Like spatial data, temporal data is equally essential information for the analyst to have during the imagery analysis process because this information guides what dates of available imagery should be analyzed by establishing the parameters for "before" and "after" imagery that will be analyzed. Examples of types of temporal information a witness may communicate about an alleged event includes the day on which the event allegedly occurred, the specific time (i.e. hour) the event occurred, and/or a specific part of the day, such as the morning, afternoon or evening, in which the event purportedly happened. For example, if a witness reports having seen a grave dug on April 16, 2011, then the imagery analyst would want to analyze imagery

captured on or after that date to determine if it contains any potential evidence corroborating the reported event through comparison with the most recent image collected before that day.

#### **Creating a GRID Map**

To create the GRID map, the analyst must first receive some basic spatial and temporal data from the witness about the alleged event. Core temporal data in the testimony, such as when the witness reports having first seen the grave, for example, allows the analyst to identify the most relevant "before image" from the imagery archive available to the analyst. The before image must have been collected on a date preceding the date on which the alleged event purportedly happened. To ensure a double blind process, the before image of the area is what will be deployed to the witness within the GRID frame so that no perceived visual features are present that may influence the reply of the witness.

The before image is marked with a vector compass and generally recognizable landmarks (i.e. a park, a bridge, well-known buildings, etc.) are annotated. This annotated image is overlaid with a GRID map format, which is comprised of alphanumeric labels in the margins that assign identities to each square of the GRID (A-1, B-3, C-5, etc.). These markers facilitate the communication of geospatial references of the location and provide a confined area of interest for imagery analysis.

These markers also allow the witness to communicate granular details through the common language provided by the alphanumeric quadrants. The gridded map format, including the alphanumeric margins, vector compass, and text annotation tools, are available in geospatial analysis software programs such as ArcGIS. This function may allow the GRID map to be created while the image file itself retains its key geospatial properties, such as coordinates and vectors. This approach was implemented by HHI in the early stages of GRID. HHI analysts would later develop a customized template using graphic design software in conjunction with ERDAS Imagine.

Next, a distance ruler is embedded in the image as a scale. The ruler's unit of measurement, meters, kilometers, inches, feet, etc., is subjective to the aperture and altitude (also referred to as the level of zoom) of the image. When imagery is presented at higher altitudes, more land area is visible in the image, but less overall detail is discernable because the resolution is poorer. By using remote sensing software, one can hone in on a specific area of interest and use a zoom function to set the aperture of the image at a lower altitude, allowing objects on the ground to be visualized in greater detail. This function is useful when a witness identifies a square on a high altitude GRID image, yet key landmarks needed for verification, such as a house or a trench are only visible at lower altitudes. The analyst could extract the identified square, zoom to a lower altitude, and resend to the witness for further comment.

The markings are annotated on the image based on the premise that when provided a vector, a distance, and generally known local landmarks, eyewitnesses will likely be able to utilize satellite imagery relevant to their community. The witness' participation in the analysis process gives the individual an active role in documenting the alleged atrocity. This active role occurs while also maintaining chain of custody of the potential evidence and helping to preserve the impartiality of the analytic process.

#### Transferring and Annotating the GRID Map

The GRID images can be transferred back and forth between the investigators or analysts and the witness in either digital formats or physical paper copies. When transferred digitally, a GRID image can be sent as an attached email file through an interlocutor, or directly to the witness, providing they have Internet access. Primary attention should be paid in all cases to assessing and mitigating potential threats to the witnesses' security stemming from digitally receiving and transferring this type and volume of digital information.

Once the GRID is received, the witness can download the image and annotate areas of interest with basic editing software on their computer. For example, a witness could use MS Paint to circle and label key locations so that investigators and analysts can better identify areas of interest. If computer and software access is not available, and if an investigator can physically reach the witness, a physical printout of the GRID can be used. The GRID can be annotated by pen and returned later to the analyst in person or it can be sent by email when the witness can access it safely.

## **Change Detection Process**

Once the GRID is transferred back to the analyst, at least two sets of images of the identified area must be obtained in order to begin the process of what is referred to as "multi-temporal" change detection.<sup>13</sup> The first image, or a before image, is captured by satellites before the date of the reported event. When selecting

the before image, it is important to find an image as close to the date of the event as possible in order to exclude other potentially similar occurrences such as construction, agricultural digging, or natural erosion that may have caused visual changes to the topography of an area over an extended period of time. The second image, or an after image, is an image taken of the area of interest after the event has been reported, still being as close as possible to the date of the report. Then, with time and resources permitting, a third image taken on an even later date may be used to show further evidence of change, which can create a time window for the event.

When the image set is ready, the identification process can vary depending on what type of imagery is available for analysis. Panchromatic imagery is black and white, multispectral 3-band imagery has three layers of red, green and blue which creates natural color, and multispectral near-infrared (NIR) has the three layers found in multispectral 3-band plus an additional layer of red, mainly used for remote sensing analysis of vegetation.

When conducting change detection using one of these three imagery types, the analyst needs to detect earth disturbance patterns by visually noticing changes present in images taken on two different dates. During visual change detection, information relating to landmarks and their distances in proximity to the grave that are provided by the witness are highly valuable to the analyst. For example, when the witness identifies an image square containing the alleged gravesite area, the witness could relay if it was 15 meters from a main road or approximately 20 meters from a farm. It is beneficial for the analyst to be experienced in identifying observables in the satellite imagery specific to the area they are monitoring. In the case of Sudan, the analysts at Harvard were knowledgeable of the typical housing and building structures, vehicles, farm and orchard layouts, and other important visual indicators of the areas under observation.

The use of NIR multispectral imagery provides an additional benefit to the change detection process when identifying disturbed earth patterns that could be difficult to see in non-NIR satellite imagery. The NIR imagery's fourth layer of red can help differentiate vegetation that is healthy or growing from damaged or desiccated vegetation. This is because vegetation in an active growth cycle exhibits a stronger reflective property. This growth would appear as a more prominent red color in unmanipulated NIR imagery, whereas surrounding vegetation that is desiccated or damaged, or earthen soil lacking vegetation would exhibit less of the red color, or not at all.

#### **Role of the Interviewer and Security Considerations**

For the necessary information to be obtained, an interviewer must have contact with the witness to not only obtain and relay testimony, but to also facilitate the witness' interaction with the GRID. As in traditional human rights interviews, a common language known by both the interviewer and interviewee must be identified so that the interview can be conducted. The interviewer may or may not be a third-party interlocutor. Additionally, an organization may choose to use an interlocutor so that their analysis team does not communicate directly with the ground source. Keeping these processes separate may ensure that a false identification does not occur because the interviewer cannot use their own knowledge of the analytic process to lead the witness during their communication.

Whether the interview process is conducted remotely, by phone or email, or in person, the interviewer should ensure that all communication occurs in an environment that is as secure as possible. An organization should also deploy GRID in accordance with their security standards. When communicating with a witness electronically, the interviewer may encrypt their email to mitigate the risk of electronic interception by an outside entity. This step is imperative if the witness is communicating to the interviewer within a non-permissive environment. The encryption of email transmissions, as well as a secure storage system for the data, may ensure that chains of custody procedures are better protected. Additionally, the interviewer should discuss security considerations with the witness before the interview so that measures can be taken to ensure the witnesses' safety.

# HHI's Use of GRID

HHI delivered GRID maps to multiple self-identified eyewitnesses to cross-corroborate reports of three alleged mass graves sites in Kadugli, including one site that was also independently reported by UNMIS. When GRID appeared to aid in the identification and cross-corroboration of these reported sites, SSP released public reports about the potential existence of the alleged mass gravesites. In all of the SSP reports, the eyewitnesses were never publicly identified and any potentially identifying information was removed from the public product, such as gender specific pronouns.

One example of such a corroboration was reported on August 17, 2011. Satellite imagery substantiated the testimony of an alleged eyewitness to the creation of an alleged mass grave outside the Khalil Yagoup Garden in Kadugli. In "Cover Up: New Evidence of Three Mass Graves in South Kordofan," SSP reported:

An eyewitness reported directly to SSP that on 9 June, while hiding in the Khalil Yagoup private garden in the Hagar Al Nar neighborhood of Kadugli, the individual witnessed a Sudanese Red Crescent Society (SRCS) land cruiser parked in front of the garden. According to the witness, two men wearing what appeared to be SRCS aprons took a dead body out of the vehicle and placed it on the ground. The eyewitness then reported seeing a yellow earthmover with five or six bodies in its bucket, which were subsequently dumped into a hole approximately four meters outside the fence surrounding the garden. The dead bodies had blood on their clothes, according to the eyewitness. On a map of the area, the eyewitness independently identified the location where the grave was allegedly dug. In imagery captured by DigitalGlobe on 2 June, there are no signs of disturbed earth at the location identified by the eyewitness. The next available satellite image of the site, taken on 4 July, shows disturbed earth at the location the eyewitness identified on the map. Additional imagery captured on 4 and 6 August, shows grass growing on the site the eyewitness claims is a grave.<sup>14</sup>

Although the report does not mention the GRID methodology specifically, it does recount the situation of the witness independently identifying the grave's location on a map that was used by SSP to corroborate the allegations. This report also highlights additional details communicated by the witness pertaining to the alleged event.

Four basic steps were taken by HHI researchers to create and deploy a GRID frame to corroborate the Khalil Yagoup Garden Grave in Kadugli. These steps are:

- Construct and dispatch the initial GRID map: A gridded map, which included the Hagar al Nar neighborhood and the main road leading north, was sent to the interlocutor who transmitted it to the ground source. The date of the image used in the GRID was collected before the alleged event seen by the witness. The witness was made aware of the date of the image. The map was annotated with specific points of interest, a vector, and alphanumeric bars to both orient the source and help them communicate geospatial references back to the interlocutor;
- 2) Analysis and verification from ground source: After recognizing the annotated areas and the vector (situated northward), the source then confirmed that the area of the grave excavation was in square B-3 of the map (Figure 1);
- 3) Construct and dispatch of a second, enhanced GRID map: Once the confirmation of square B-3 was received, the area was analyzed at a higher resolution, re-gridded and transmitted back to the source via the interlocutor to identify a more precise location of the excavation. The witness provided further confirmation of a precise location (Figure 2).



Figure 1. Using the alphanumeric quadrants on the GRID map, the witness identified square B-3 as the area of interest. Square B-3 was then enlarged at a higher resolution, reformatted as a GRID map and sent back to the witness for further inquiry. © [DigitalGlobe]. Reproduced by permission of DigitalGlobe. Permission to reuse must be obtained from the rightsholder. 4) Verification and confirmation through remote sensing analysis: Through the method of change detection, analytic imagery comparisons of the location before and after the event and the use of multispectral image processing, the HHI's imagery analyst was able to confirm the presence of the precise spot of recently disturbed earth consistent with the reported mass grave (Figure 3).



Figure 2. A GRID map marked by a witness and sent back to an analyst can provide valuable location-based information to build a robust geospatial database. Possible marked areas may include neighborhoods, public gardens, infrastructure and buildings. © [DigitalGlobe]. Reproduced by permission of DigitalGlobe. Permission to reuse must be obtained from the rightsholder.



Figure 3. Near-infrared satellite imagery was used to conduct change detection analysis reveals disturbed earth consistent with the location and time period of the grave observed by the witness near the Khalil Yagoup Garden. © [DigitalGlobe]. Reproduced by permission of DigitalGlobe. Permission to reuse must be obtained from the rightsholder.

# **Potential Outcomes and Contributions**

GRID enhances the ability of organizations to corroborate reports of gross human rights violations by allowing them to investigate allegations from both permissive and non-permissive environments. Non-permissive environments create unique challenges for corroborating witness testimony. For example,

Human Rights Watch states that their researchers interview both victims and witnesses "when investigating reported human rights abuses in order to understand accurately what occurred."<sup>15</sup> The collection of location information relating to abuses is integral. As part of these interviews HRW researchers "always try to get to specific locations where violations are known to have occurred, or are ongoing." However, "security conditions and time limitations can greatly affect where researchers can conduct investigations."<sup>16</sup> In these types of environments, ground investigations may be restricted or prohibited, sometimes by the perpetrators themselves.

In these cases, remote sensing, particularly satellite imagery, is uniquely positioned to document evidence of events occurring in the area based on witness testimony. As it may be unknown when access to the area may be granted, this documentation can also allow an organization to more immediately capture information relating to a continuing crisis where evidence of alleged acts may be affected over time. This utilization of satellite imagery has been identified as a secondary source of information, meaning that satellite imagery analysis can "provide corroborative evidence to help evaluate the accuracy of reported incidents or claims from sources of unknown reliability."<sup>17</sup> This corroborative act may even produce evidence to support legal investigations into alleged violations of international humanitarian law.<sup>18</sup>

Further, satellite imagery analysis can be employed without witness testimony as a primary source of information. This means that the satellite imagery itself can provide direct evidence "when on-site investigations and access to witnesses are impossible normally due to insecurity, government prohibitions, or physical inaccessibility." It has further been argued that, "Under these conditions, satellite imagery has proved to be one of the only viable means of independent, objective, and systematic collection of significant evidence of possible war crimes."<sup>19</sup> The double blind nature of the GRID process can help protect the probative value of both satellite imagery and witness testimony. This is because the witness cannot be lead to an assumption when indicating the location of the event in the satellite image because the witness is only allowed to view imagery captured before the event reportedly occurred.

# **Additional Applications**

Although this paper discusses how GRID was employed to corroborate reports of mass graves, GRID can potentially be deployed in a diverse range of environments and conflict situations to help corroborate many different types of reported acts. These include, but are not limited to, the following:

# Confirming threats to civilian freedom of movement

GRID's deployment, particularly in non-permissive environments, may enhance the accurate, timesensitive identification of checkpoints set-up by alleged perpetrators during mass atrocity event scenarios. Checkpoints during mass atrocity events can be used to both prevent civilians from fleeing an area and block humanitarian actors from entering. GRID enables responders to collate multiple reports of a checkpoint's location on a regular basis. Satellite imagery analysis can then be used to confirm the reported locations of checkpoints in a map format. Information about the structure, size, color, disposition, and force capacity present at those locations are also key details provided by the witness that may be captured by GRID, potentially assisting analysts and organizations in documentation and decision making.

# Early warning of potential mass atrocities

GRID can be deployed before an atrocity occurs to help identify the alleged build-up of the military assets by potential perpetrators of mass atrocities. Witnesses or those who receive reports about the build-up of assets can communicate this information through GRID to governments, NGOs, and humanitarian personnel. For example, in the summer of 2011 reports were received by HHI from ground sources about the build-up of the Central Reserve Police training center in Kadugli. This force was originally created for riot control but was later reportedly used by South Kordofan Governor Ahmed Haroun as a paramilitary militia.

A ground source in close contact with an interlocutor reported that the location of the CRP training center was in the area of the El Shaeer neighborhood, near UNMIS' Kadugli headquarters. HHI created a GRID of the El Shaeer neighborhood, including UNMIS headquarters, and deployed it via the interlocutor to the ground source. The ground source was able to positively identify and mark the training center in quadrant C-2. Once the GRID map marked by the source was received, analysts were able to positively confirm the location, which it was then able to monitor its build-up during the days of fighting.

# Location of extrajudicial detention centers

GRID can be used to locate centers where civilians are being allegedly held illegally and subjected to torture, extrajudicial killing, and other gross human rights abuses. Data gathered from GRID would allow an organization's ground staff and headquarters to quickly triangulate reports of centers where human rights abuses are reportedly being committed, allowing fact finding and human rights monitors to more easily locate those facilities and deploy monitors to these centers.

# Satellite Imagery Acquisition and Analysis

A key component of GRID's methodology is the use of either open source imagery or purchased commercial imagery. Creating the GRID from open source imagery, imagery that is publicly available, is free and can be deployed in its basic form. Sources like Google Earth, Google Maps or Bing Maps often have high-resolution imagery of different areas around the globe. Access to these websites and software allows groups to be able to develop their own versions of GRID tailored to their objectives and context. If an organization uses open source imagery to create the initial GRID that is deployed, purchasing imagery may be necessary to conduct analysis for near-real time corroboration.

If an organization has an imagery budget available, purchasing commercial satellite imagery can occur through an imagery provider, like Astrium or DigitalGlobe. Additionally, third party retailers that specialize in digital GIS and remote sensing data, like MapMart, may sell satellite imagery from major companies. The cost structure of purchasing satellite imagery is typically dependent on if the imagery is archival or a new acquisition. For example, as of October 2013, Astrium's standard archive imagery captured by their Pleiades very-high resolution satellites is \$13 (USD) per square kilometer and a standard new acquisition is \$23 (USD) per square kilometer. These prices can make purchasing imagery expensive depending on the number of square kilometers in the area of the interest. Most commercial companies have online catalogues of the imagery in their archive available for purchase. The aforementioned imagery catalogues of these providers also include various search filters that factor in attributes like cloud cover percentage and image quality. Entering relevant dates and additional data such as weather conditions may also yield positive results for imagery.

Employing GRID may shorten the amount of time spent analyzing the satellite imagery because the analyst may be more quickly guided to areas of interest by the witness testimony. Subsequently, the ability of an organization to only purchase what imagery that is necessary for their analytic process may be increased. This is because an analyst can focus their imagery purchases to areas identified by the witness through GRID. In cases where near-real time satellite imagery can be obtained and analyzed, the length of time between the testimony collection and its corroboration may be reduced.

# Limitations

The GRID methodology appears to have successfully cross-referenced information from witness testimony and remote sensing data in the instances described above. However, limitations to the acquisition of potentially relevant satellite imagery and factors affecting the quality of available imagery may hinder and/ or prevent GRID's application in some cases.

The acquisition of the imagery necessary to perform multi-temporal change detection, the main imagery analysis method employed as part of GRID, can be difficult if the satellites do not frequently capture imagery of the area of interest. The analysts at HHI benefitted from a robust imagery archive of Kadugli captured both before and after the creation of alleged mass graves as a result of intensive, persistent monitoring of the area. This rare operational context, which yielded large volumes of relevant imagery data at high temporal resolution, shortened the duration between before and after imagery, likely producing more reliable results. Similar archives resulting from proactive monitoring may not always be available to an organization, however.

Although analysts may be able to acquire current imagery over an area of interest, other avenues may be required to obtain a before image captured closer to the date of an event to obtain the baseline data necessary for multi-temporal change detection. When using open source imagery, like from Google Earth, it is important to verify the date of the image capture. Google Earth currently provides the date of the image capture, as well as the company or organization whose satellites captured the image. The time-slider tool in Google Earth allows the analyst to view images taken on different dates over an area. In particular, the analyst should pay attention to the top left of the viewer window to see the date of the image acquisition, and the bottom center of the viewer window to see which company or organization captured the image. To verify that the information is correct, the analyst can record this information and see if the company has an online catalogue of their

imagery. Most of these catalogues, like DigitalGlobe's ImageFinder or Astrium's GeoStore, allow the user to draw a polygon precisely around any area of a digital map of the earth, and see what imagery, along with the dates, has been collected within that polygon. If the dates coincide with the information provided by Google Earth, the probability is high that the data is accurate. Also, the results provided by these catalogue searches are often accompanied by a low-resolution image sample (i.e. 10 meter image sample of a 0.5 meter image), of the collect. A more experienced imagery analyst can use unique visual indicators within the sample image specific to the date of collection, such as large cloud formations or scorched earth patterns, and match them to the image on Google Earth.

If the analyst needs to perform multispectral analysis to assess vegetation, this cannot be performed using imagery available from Google Earth. This is because the exported image from Google Earth is a standard image format, such as a JPEG. It is important to note that the analysis of vegetation, as it relates to disturbed earth, can be an important factor in the analysis of satellite imagery to identify alleged mass grave locations.

Another challenge is the presence of heavy clouds in the imagery that may obscure the areas of interest. It is necessary to not only be aware of the weather conditions of an area being monitored by remote sensing, but to also factor that into the decisions of when to task a satellite company for image requests. In the case of Sudan, it was important for the analysts at HHI to not only be cognizant of what days would present the most cloud cover over an area of interest, but to be knowledgeable of when the rainy season occurs annually throughout the country.

The landscape of an area of interest is also a significant factor in the acquisition and analysis of imagery. For example, the landscape in Sudan varies from heavily forested areas, mountainous, rocky terrain, to flat, sparsely vegetated desert lands. When analyzing areas of interest within the town of Kadugli in particular, the imagery analysis benefitted from the region being lightly forested with developed neighborhoods that provided unobstructed surface area throughout the imagery. Locations that are heavily forested can be more difficult, sometimes impossible, to analyze due to dense tree cover obscuring activity. Certain land formations, such as caves, can also be used to conceal any activity that could be captured by satellites, thus making positive identifications through change detection improbable.

In the event that imagery would need to be acquired to document activity occurring at night, the options to acquire and analyze night-time imagery are currently limited, and can be much more costly to purchase. Many commercial satellite companies do not provide the imagery due to their satellites incapability of capturing adequate high-resolution imagery at night. Though it is currently not common, some satellites such as ImageSat International's EROS B are capable of capturing detailed, panchromatic night-time imagery. However, it is important to consider that if immediacy of the acquisition is required, the revisit rate over an area for EROS B averages every 3.5 days, as opposed to other commercial satellites daily revisit rate.

# **Conclusion: Overcoming Barriers to Adoption, Pursuing Future Research**

Based on the experience of researchers at HHI, gaps in an analyst's knowledge of hyper-local location-based information relating to a specific AOI can limit or prohibit the cross-corroboration of witness testimony through satellite imagery analysis. The ad hoc development of GRID by HHI was specific to the operational context of Kadugli, Sudan in the summer of 2011. GRID provided analysts unique, otherwise unavailable location-based information for the cross-corroboration of alleged mass graves. This successful initial use warrants further research into GRID's potential application in other regional and operational contexts is urgently required.

It is acknowledged that due to this methodology's reliance on access to imagery recently collected relative to the date of event, the ability of an organization to utilize this method may be contingent on one or more of several institutional and technical factors. To overcome these barriers, increased amounts of data and access to geospatial resources are required. Currently, the landscape of the commercial geospatial data is rapidly changing. The emergence of micro-satellite providers such as Skybox Imaging may eventually deliver less costly and more timely geospatial data to organizations undertaking similar types of data collection. The expanding availability of open source data, such as imagery loaded to Bing and Google Earth, is also critical for increasing potential sources of no-cost data.

The development of GRID can benefit two distinct groups currently using or seeking to utilize geospatial technology. First, professionals, like researchers and practitioners, who employ satellite imagery to corroborate testimony can integrate GRID into their current practices as a complimentary methodology. Second, digital mapping projects led by citizens can employ GRID as a standardized methodology. The rise of neogeography over the past five years has resulted in citizens, primarily volunteers, with little to no training participating

in crowdsourcing projects to produce and analyze geographic data, including volunteered geographic information.<sup>20</sup> Some of these projects involve the analysis of geospatial data like satellite imagery.<sup>21</sup> As work by these groups is continuing to increase, standardized methodologies and tools must be made available, especially for those who do not have access to formal training.

Additionally, GRID raises questions as to how the active participation of the witness impacts this type of mixed methods approach. Marguerite Madden and Amy Ross (2009) explored "mixed quantitative and qualitative methods of GIScience technologies and field-collected narratives" to assess violence in Uganda. This research raised critical questions pertaining to viability of this mixed methods approach. As part of this research, Madden and Ross collected narratives from the field to support the analysis of satellite imagery accessed using Google Earth.<sup>22</sup> This work led to the conclusion that, "In some respects quantitative data extracted from the satellite imagery support verbal accounts of personal histories, events, and experiences."<sup>23</sup> The experience of HHI in developing GRID supports Madden and Ross' conclusion. However, it must be noted that although the combination of these data sources is not a novel approach, the purposeful involvement of the witness is a unique dynamic that must be researched further.

This paper's discussion of the GRID supplements current practice by outlining specific methodological and technical details of how to involve a witness in the analytic process. In turn, additional areas that future research may address includes understanding the role cultural differences may play in transmitting information related to mass atrocities; the potential positive and negative psycho-social implications and impacts GRID may have for alleged witnesses; and most critically, how to technically ensure both witness security and chain-of-custody of evidence.

Such research may further develop GRID as a standard evidence collection methodology for other organizations engaged in this space. It is the hopes of the authors that this research can lead to the development of a standardized tool that can be made widely available to the human rights, humanitarian, and remote sensing communities. Future applications of GRID, including the development of a common GRID tool, must be developed in accordance with accepted research ethics and prioritize the serious security concerns vulnerable populations face in non-permissive, mass atrocity-producing environments.

#### Endnotes

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