EMERGENCY MAPPING GUIDELINES

Building Damage Assessment Chapter

Working Paper

Version 1.0 – as of September **2018**

International Working Group on Satellite-based Emergency Mapping (IWG-SEM)

Contents

1. FOREWORD

This chapter is aimed at providing definitions and guidelines on how to interpret building damages (due to different types of events, e.g. earthquakes, windstorms/cyclones, conflicts) using vertical imagery data including satellite and aerial (both manned and unmanned) data. The initial idea was to work on an earthquake damage assessment chapter but while working on many recent Space-based Emergency Mapping activations the authors came to the conclusion that the damage that can be assessed from space (and more in general from vertical imagery) was actually quite similar.

The main goal is to propose a simple but standard building damage classification that can be internationally adopted, especially to increase consistency of the thematic information provided by different SEM entities for the same event, streamlining the exploitation of the crisis information by the end users.

Furthermore, a working group was set up in Copernicus EMS Rapid Mapping to assess building damage classes that were used in Rapid Mapping for their pertinence. While broaching this subject, it came to light that ITHACA, a Copernicus EMS Rapid Mapping consortium partner, had a concise diagram available from a M.Sc. thesis that was defended at Politecnico di Torino. This document was reviewed by other consortium members and used as the Copernicus EMS Rapid Mapping Building Damage Assessment guideline since October 2017.

Finally, the IWG-SEM Chair, who reviewed and discussed the document within, and ITHACA then suggested to use this as the principle input to an initial IWG-SEM Building Damage Assessment additional chapter associated with the Guidelines. Below you will find this concise best practice interpretation guide.

2. IWG-SEM Building Damage Assessment scale

In establishing this interpretation guide the authors decided to reduce the number of building damage classes to be interpreted as experience indicated it was not robust enough to continue with several damage classes based also on structural damages, as operationally adopted in the last years by some SEM entity (summarized in Table 1), e.g.:

- the 5 separate classes on which the old Copernicus EMS' building damage scale was based until October 2017, similar to the 3 classes adopted by UNOSAT for complex emergencies;
- the 4 levels of the "BAR Methodology" proposed by the Signal Program on Human Security and Technology at HHI (Harvard Humanitarian Initiative): the approach focuses on the categorization of structures visible in geospatial data and the assessment of visible wind disaster damage;
- the binary classification recently introduced by UNOSAT, i.e. damaged vs no damage, mainly in case of natural disasters.

<table>
<tr><th colspan="5">Building Damage Assessment classes - Nomenclature</th></tr>
<tr><th colspan="4">Example of classes used from different entities in past events</th><th>Current proposal</th></tr>
<tr><th rowspan="2">Copernicus (< ~2018)</th><th colspan="2">UNOSAT</th><th rowspan="2">BAR</th><th rowspan="2">IWG-SEM*</th></tr>
<tr><th>Complex emergencies</th><th>Natural disasters</th></tr>
<tr><td>Destroyed</td><td>Destroyed</td><td rowspan="4">Damaged</td><td>Critical Visible Damage</td><td>Destroyed</td></tr>
<tr><td>Highly damaged</td><td>Severe Damage</td><td>Significant Visible Damage</td><td rowspan="2">Damaged</td></tr>
<tr><td>Moderately damaged</td><td>Moderate Damage</td><td rowspan="2">Minimal Visible Damage</td></tr>
<tr><td>Negligible to slight damage</td><td></td><td>Possibly damaged</td></tr>
<tr><td>Not affected</td><td></td><td></td><td>No Visible Damage</td><td>No visible damage</td></tr>
</table>

**currently adopted by Copernicus EMS since October 2017*

Table 2-1 : Examples of different Building Damage Assessment classes compared to the proposed IWG-SEM classes (last column)

The target was to reduce the class nomenclature to a meaningful number of reliable classes and illustrate these with a description, aiming at developing and sharing a proposal fitting the requirements for a possible international standard.

To this aim, several thematic accuracy evaluations were carried out, exploiting SEM activations where different types of post-event vertical imagery (Very High Resolution satellite imagery, aerial imagery and UAV imagery) were available. The analyses of the quality metrics (Overall, User and Producer accuracy) highlighted that distinguishing among different grades of damage leads to low per-class accuracies, especially for the lower damage grades.

As summarized in Table 1 (right column) it is therefore proposed to:

- keep the “Destroyed” and “No visible damage” classes, fine-tuning their definition and the related interpretation guidelines to vertical imagery
- keep just one single “Damage” class, in addition to the destroyed and no visible damage ones
- include a “Possible damage” class, to provide information on the uncertainty level due to possible constraints (image quality, shadowed areas, presence of damage proxies, an unstructured look and feel).

A crucial point is also the need to make the users aware that building flagged as “No visible damage” may anyway have suffered damages that can’t be assessed from vertical satellite imagery (i.e. from no to slight structural damage).

In case the end-users are interested in a binary classification (i.e. Affected vs Not affected buildings) the proposed classification scheme can still be adopted, exploiting only the “Damaged” and “No visible Damaged” classes.

The proposed building damage scale, a brief description of the damage as well as pre-event aerial, post events satellite data, post-event aerial and post event UAV imagery are summarized in Figure 1.

2.1 Interpretation guide

More details on the interpretation guidelines for the building damage classes are provided:

- **Destroyed:** assigned to structures that are total or largely collapsed (>50%). This category shall be assigned also when only a portion of the building has collapsed to the ground floor. In these cases, the original building structure is no longer distinguishable.

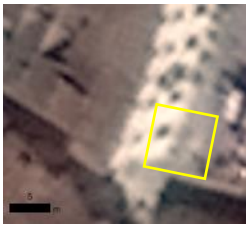
PRE Event Aerial (0.1m < GSD < 0.3m)	POST Event Satellite (0.3m < GSD < 0.5m)	POST Event Aerial (0.1m < GSD < 0.3m)	POST Event UAV (GSD < 0.1m)
			
	Building structure not distinguishable.	Total collapse of the building.	Total collapse of the building.

- **Damaged:** it shall be used when post satellite imagery is available and includes
    - Major visible damages, which shall be assigned to structures with part of the roof collapsed and serious failure of walls,
    - Minor visible damage level, i.e. buildings with a largely intact roof characterized by presence of partial damage (collapse of chimneys or roof tiles detach) or surrounded by large debris/rubble or sand deposit.

  The separation between Minor and Major "Damage" grades can be used only when imagery with a GSD of approximately 0.1 m is available (typical for aerial and UAV imagery).

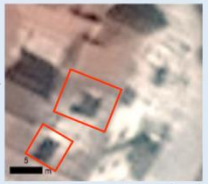
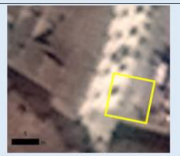
PRE Event Aerial (0.1m < GSD < 0.3m)	POST Event Satellite (0.3m < GSD < 0.5m)	POST Event Aerial (0.1m < GSD < 0.3m)	POST Event UAV (GSD < 0.1m)
			
	Black spots on the rooftop suggest collapse of part of the roof.	Partial collapse of the roof.	Partial collapse of the roof

- **Possibly damaged**: it shall be used for buildings whose interpretation is uncertain, due to lower image quality (e.g. shadow or degraded resolution due to high off-nadir angle) or to the presence of possible damage proxies like small traces of debris/rubble or sand deposits around the building. This class attribution can be given by inferring the state of the building from surrounding features. In flooding it could be traces of water currents leading up to and then leaving a building or set of buildings.

PRE Event Aerial (0.1m < GSD < 0.3m)	POST Event Satellite (0.3m < GSD < 0.5m)	POST Event Aerial (0.1m < GSD < 0.3m)	POST Event UAV (GSD < 0.1m)
			
	Small traces of debris deposit on the ground.	Small traces of debris deposit on the ground.	Small traces of debris deposit on the ground.

- **No Visible Damage**: it shall be assigned to the structures that appear to have complete structural integrity, i.e. when the walls remain standing and the roof is virtually undamaged. It is important to remark that this class don't exclude the presence of structural damages, i.e. the building may anyway have suffered damages that can't be assessed from vertical satellite imagery regardless of is spatial resolution.

PRE Event Aerial (0.1m < GSD < 0.3m)	POST Event Satellite (0.3m < GSD < 0.5m)	POST Event Aerial (0.1m < GSD < 0.3m)	POST Event UAV (GSD < 0.1m)
			
	The structure appears intact.	The structure appears intact.	The structure appears intact.

Damage Grade	Description of the related Damage	PRE Event Aerial (0.1m < GSD < 0.3m)	POST Event Satellite (0.3m < GSD < 0.5m)	POST Event Aerial (0.1m < GSD < 0.3m)	POST Event UAV (GSD < 0.1m)
Destroyed	Total collapse; collapse of part of the building; building structure not distinguishable (the walls have been destroyed or collapsed).		 Building structure not distinguishable.	 Total collapse of the building.	 Total collapse of the building.
Damaged Major and Minor shall be used only when Aerial/UAV imagery (GSD < 0.3 m) is available. Only "Damaged" grade when using Satellite imagery..	**Major**: Total/partial collapse of the roof; serious failure of walls (Tip: black spots on the rooftop suggest collapse of part of the roof).		Only "Damaged" grade when using Satellite imagery.  Black spots on the rooftop suggest collapse of part of the roof.	 Partial collapse of the roof.	 Partial collapse of the roof
	Minor: The roof remains largely intact, but presents partial damage (Tip: white spots on the rooftop suggest tiles' lack or displacement and collapse of chimneys). Presence of damage proxies like large debris/rubble or sand deposit around the building.	 	 The structure appears intact; large debris deposit on the ground.	 Roof tiles detach.  The structure appears intact; large debris deposit	 Collapse of chimneys, roof tiles detach.  The structure appears intact; large debris deposit
Possibly Damaged	Uncertain interpretation due to image quality (e.g. shadow or degraded resolution due to high off-nadir angle). Presence of possible damage proxies like small traces of debris/rubble or sand deposit around building. Building surrounded by damaged/destroyed buildings.		 Small traces of debris deposit on the ground.	 Small traces of debris deposit on the ground.	 Small traces of debris deposit on the ground.
No Visible Damage	The structure appears to have complete structural integrity; the walls remain standing; the roof is virtually undamaged. **The building may anyway suffered damages that can't be assessed from vertical satellite imagery (from no to slight structural damage).**		 The structure appears intact.	 The structure appears intact.	 The structure appears intact.

Based on the Master Degree thesis "Building damage assessment after earthquake events: Damage Scale proposal based on vertical imagery", Silvana Cotrufo, Politecnico di Torino/ITHACA, 2017

Figure 1 – IWG-SEM Building damage scale: proposal, definitions and visual examples

3. Acknowledgements

The IWG-SEM Chair and Members would like to acknowledge the following members for their contribution to this IWG-SEM Guidelines Building Damage Assessment Chapter:

Building Damage Assessment Guidelines Lead:

ITHACA - Information Technology for Humanitarian Assistance, Cooperation and Action
(http://www.ithacaweb.org/)

Contributors:

GAF AG, an e-GEOS (ASI/TELESPAZIO) Company
(https://www.gaf.de/)

ICube-SERTIT, University of Strasbourg
(http://sertit.u-strasbg.fr/)

European Commission, Directorate-General Joint Research Centre, Disaster Risk Management Unit
(https://ec.europa.eu/jrc/en/research-topic/disaster-risk-management)

e-GEOS, an ASI/TELESPAZIO Company
(http://www.e-geos.it/)

UNOSAT, United Nations Institute for Training and Research (UNITAR)
(www.unitar.org/unosat)

Any further contributions or comments should be addressed to the IWG-SEM Chair at:

members@iwg-sem.org