HUMANITARIAN INNOVATION FUND

Development and Implementation Phase Grant Final Report

Organisation Name	ShadowView

Project Title	**OpenDroneMap**
Partner(s)	University of Wollongong (University), Cleveland Metroparks (Government), Vela Aerial (For Profit)
Problem Addressed / Thematic Focus	Scalable, accurate, easy-to-use drone image processing for humanitarian applications
Location	Indonesia
Start Date	23 Sep 2016
End Date	23 Sep 2017
Reporting Period	Final report

Total Funding	Total HIF and other contributions to this project
Total Spent	£144,939

Innovation Stage	Development and Implementation
Type of Innovation	Software
Project Impact Summary	OpenDroneMap allows humanitarian users to process UAV imagery to generate geospatial data products. This project has improved the accessibility and usability of the software so that OpenDroneMap is now fit-for-purpose in operational humanitarian contexts.

PROJECT ACTIVITIES AND OUTPUTS

*Please go to **Appendix 1** and attach the final workplan, showing all work that was actually completed.*

1. **With reference to the final workplan, what have been the key achievements of the project? (Workplan references with letter and number code for *Expected Results* and *Main Planned activities* respectively)**
    - Up to 20% improvements in processing time (A)
    - Improved performance with reduction in memory and processor usage (A)
    - Improved accuracy and fidelity with the inclusion of dense mapping (A1)
    - Improved options for mesh generation (A3)
    - Integration of PDAL library to allow for user and automated point cloud classification (A2)
    - Uptake for use by INGOs and government agencies for use in humanitarian and development contexts (A4 & B5)
    - Increased use of software as viable alternative to commercial software (A4 & B5)
    - Created opendronemap-ecs, a new methodology for processing drone images that will save orders of magnitude on the costs of processing imagery on hosted services like Amazon Web Services (B1)
    - Development of an interface for creating ground control points for easier creation of more accurate datasets (B2)
    - Improved usability through the development and refinement of OpenDroneMap's web interface, WebODM (B2)
    - Tested on a wide range of datasets from Indonesia, Tanzania, Haiti, Philipines, India (D, E, & F)
    - Coordinated with field deployed humanitarian users to improve software to meet their use cases (E)
    - Improved scalability with the development of a split-and-merge tool which breaks larger datasets into smaller datasets while improving the consistency between them (E)
    - Improved accessibility through ready-to-use Docker images (G1)
    - Built and refined documentation for use of the project (G1-3)

INNOVATION OUTCOMES

Whether this innovative project was successful, not successful, or a mix of both, the HIF would like you to report as much detail as possible, so that success can be built on and failures can be learned from. By 'success' we mean that the innovation has achieved the planned positive impact/outcome, or that it has performed better than the current process, product or system.

2. Has the project demonstrated the success of the innovation? *(Please choose only one answer.)*

☒ Completely successful
☐ Significantly successful
☐ Partially successful
☐ Completely unsuccessful

2b. Please select the successes that your project have achieved:
(You may choose more than one)

☒ There is real evidence that the project achieved the planned outcome(s)
☐ There were perceived contributions or improvements to the planned outcome(s)
☒ Learning was achieved within the project cycle

☒ 'Lessons learned' were gathered and circulated to humanitarian stakeholders and actors
☐The completion of this project has led to another innovation
☐ Other *(please comment)* _____

2c. Please select the challenges your project has encountered:
(You may choose more than one)

☐ The project did not complete its planned activities
☐ There is no real evidence that the project achieved the planned outcome(s)
☐ There were few perceived contributions or improvements to the planned outcome(s)
☐ Learning was not achieved within the project cycle
☐ 'Lessons learned' were not circulated to humanitarian stakeholders and actors
☒ Other *(please comment)*

While the project has explained success of technical developments to technical staff from humanitarian sector, a wider audience for OpenDroneMap includes smaller NGOs who can benefit from the increased usability that the software now provides as a direct result of this project. OpenDroneMap focus in the near future needs to include outreach targeting smaller NGOs, and possibly finding models for hosting and deploying OpenDroneMap to lower the barrier to entry.

2d. If there is any evidence for the successful performance of the innovation, please describe it further:

- World Bank Tanzania is considering OpenDroneMap as the processing engine for their Zanzibar Mapping Initiative, the world's largest civilian drone mapping program. The advantages that ODM proffers in this context is scalability – scalability of licensing, and specific tools built for addressing the problems of errors in large drone mapping projects.
- American Red Cross have been using OpenDroneMap for processing imagery in the Philippines and Haiti in 2017/2018, and confirmed intent to use software for their UAV mapping projects in Eastern and Sub-Saharan Africa in 2018/2019.
- OpenDroneMap has been integrated into Portable OpenStreetMap as a tool for Humanitarian actors to do full offline mapping missions in remote parts of the world.
- OpenDroneMap trainings were performed with Humanitarian OpenStreetMap Team (HOT) Pacific Disaster Center (PDC) team, Indonesia Disaster Management Agency, and World Food Program Jakarta and is expected to be used in mapping programs with Indonesia's InAWARE project, a Jakarta "Mapping Lifeline Infrastructure" project.
- OpenDroneMap is an integral component to MSF's Locus project, an open source mapping drone meant for difficult field deployments for humanitarian actors.
- OpenDroneMap and requisite products have become a core part of John Carroll University's "Building a More Effective and Efficient Medical Brigade": a program to send nursing students to provide basic health care to rural Hondurans on an annual basis.
- The State Government of Kerala, India will use the software as part of its municipal geospatial data collection.
- Docker is a tool used in the HIF to improve the ease of use of OpenDroneMap. Docker deployments of OpenDroneMap have gone from 0 at the beginning of the HIF to 6100+ deployments, and more than 5400 deployments of WebODM.
- The number of users on the project's GitHub page and Gitter forum asking for advice as they use the software has continued to increase during and after the HIF funding period (see Figure 1).
    - Open Source Community Chat:

- https://gitter.im/OpenDroneMap/generalhelp
- https://gitter.im/OpenDroneMap/OpenDroneMap
- https://gitter.im/OpenDroneMap/web-development
- https://gitter.im/OpenDroneMap/web-development

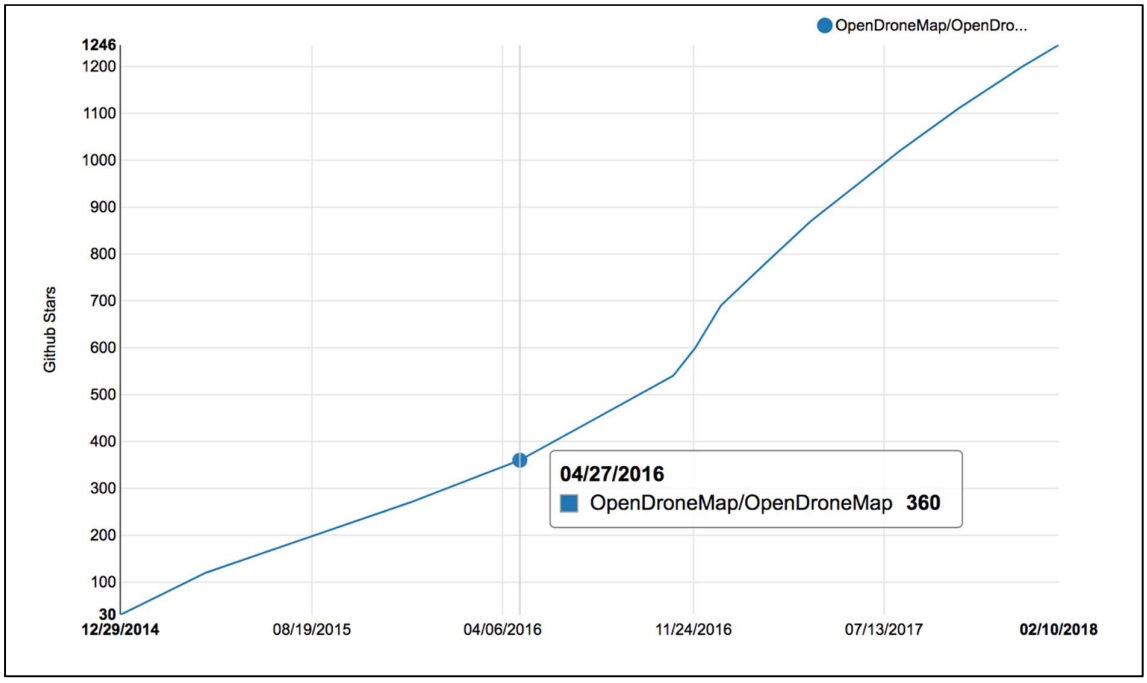


Figure 1. Interactions with the OpenDroneMap GitHub repository as quantified by the GitHub "stars" metric. The rate of change of users interacting with the project on GitHub increased during Q1 2016 and has continued to increase through duration of the funding period.

- Comparison of older versions of the software with existing open data sets shows significant increase (~20%) in processing time, accounting for changes made in 2016 and 2017. In particular the recent addition of the fast-orthophoto generation at the end of the HIF work has had a significantly impact on processing time (see Figure 2).

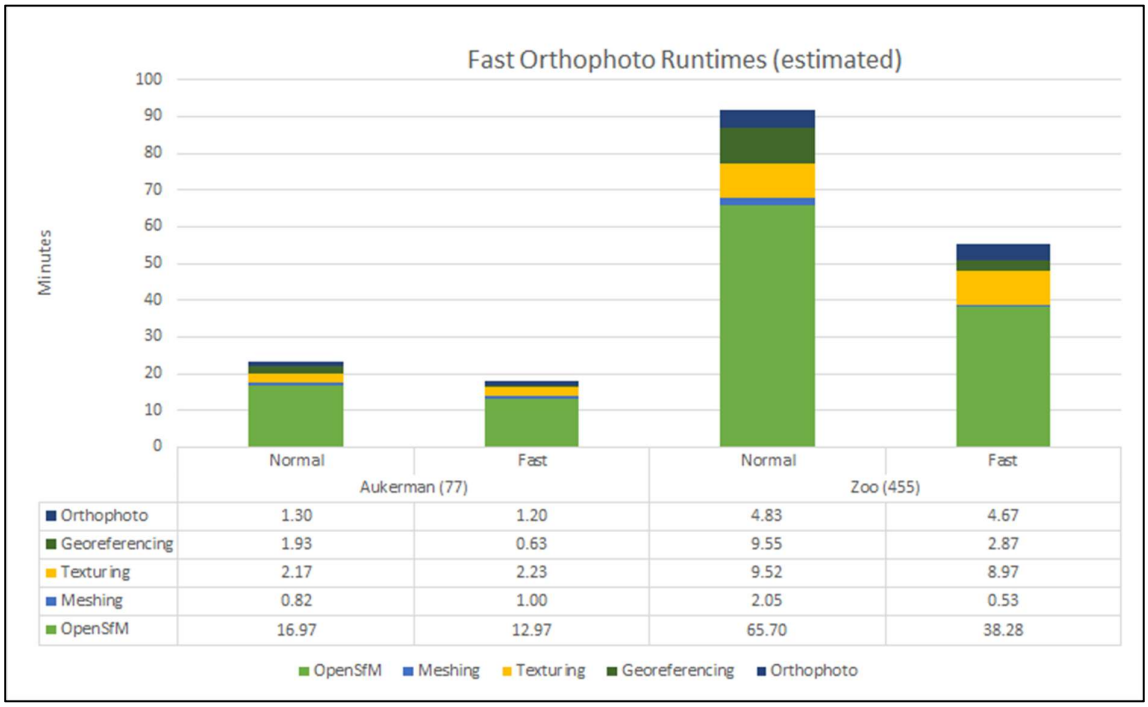


Figure 2. Latest processing times for two data-sets in OpenDroneMap comparing version 3 and the latest version including the fast orthophoto option.

3. Please show the components of the project which contributed the most to any *successes*:

(where 1 = most influence 3 = least influence)

Component	*1*	*2*	*3*	*N/A*
Design and placement of the innovation	☐	☒	☐	☐
The methodology or approach to collecting evidence	☐	☐	☒	☐
Context	☒	☐	☐	☐
The availability of resources and capacities (financial, human, technical etc.)	☐	☒	☐	☐
Success in identifying and responding to different project and innovation risks	☐	☒	☐	☐
Strength of relationships and collaborations within the team and with other stakeholders	☒	☐	☐	☐
The process was flexible and responsive to emerging results	☒	☐	☐	☐
Ability to draw on experience and expertise of existing practice, codes and standards	☒	☐	☐	☐
Other:	☐	☐	☐	☐

4. Please show the components of the project which contributed the most to any unsuccessful elements of the project

Component	*Yes- contributed to failures*
Weaknesses in the design and placement of the innovation	☐
The methodology or approach to collecting evidence	☐
Context	☐
A lack of access to resources and capacities (financial, human, technical etc.)	☒
Difficulty in identifying and responding to different risks	☐
Lack of good relationships and collaboration within the team and with other stakeholders	☐
Having a process that was not flexible or responsive to emerging results	☐
No ability to draw on experience and expertise of existing practice, codes and standards	☐
Other:	☐
Other:	☐

5. What are the top three, key lessons learnt relating to the innovation? *This should relate to the innovation or the sector in which it operates, rather than project implementation.*

1.
The context of the implementation is key. Different users have extremely contrasting use cases and as such different requirements. OpenDroneMap is attractive as it provides flexibility and transparency to adapt to specific processes or processing flows not supported by commercial software.

2.
UAV Imagery is becoming more mainstream through the commercial "drone" sector. Closer partnerships with industry are required to best tailor the software to hardware available on the market (e.g. new camera sensors).

3.
Humanitarian organisations are still spending significant resources on commercial options that are not necessarily fit for purpose. Having partners from both industry and NGOs continue to champion ODM to reach non-tech community is more important the originally envisaged.

6. Do the final outcomes support the initial rationale for the innovation?

☒ Yes, completely
☐ Yes, significantly
☐ Partially
☐ No, not at all

Please describe further:

Our qualitative assessment over the past 12 months have shown that conversations with potential users have changed from "why would I use OpenDroneMap" to "how do I use OpenDroneMap", and then "how can we tune and modify OpenDroneMap for our use case". As UAV imagery and derived geospatial products gain traction in the humanitarian sector the utility and value of an open processing flow is becoming increasingly apparent to humanitarian organisations and municipalities. This is supported in the recent recognition by a major drone manufacturer of the potential viability of OpenDroneMap for use in STEM education initiatives, not currently possible due to prohibitive licensing fees of commercial UAV imagery processing solutions.

7. How has your understanding of the innovation changed through the project period?

OpenDroneMap was originally innovative in its ability to provide a UAV imagery processing flow that did not have a direct cost and also offered an open source solution. While OpenDroneMap was originally developed as a collection of software for technically-proficient developer community the user-base is shifting to become more mainstream and non-technical. The development of Web OpenDroneMap, which provided an easy-to-use graphical interface (as supported by this funding) has supported this. Critically, the team now recognise that humanitarian organisations are increasingly pushing the innovation envelope for UAVs and high-resolution aerial imagery for humanitarian use-cases and that OpenDroneMap can support this.

8. Did the innovation lead to any unexpected outcomes or results? How were these identified and managed?

The high uptake in the software in 2017 resulted in a large number of users posting issues on the project's GitHub page and Gitter forums, particularly asking for help with installation. Most of these requests were mitigated through the newly developed Docker packages which provide easy-to-run instances of the software. Furthermore, the project has developed a prototype implementation of OpenDroneMap using cloud-technology to alleviate the problem of user devices being underpowered for the computationally-intensive nature of the software's processes (a common source of errors in requests from the community).

Secondly, the project faced technical challenges from changes in upstream software resulting in bugs in OpenDroneMap. These issues were mitigated by using older versions and by employing best-practices in software development, including revision control and issue tracking.

METHODOLOGY

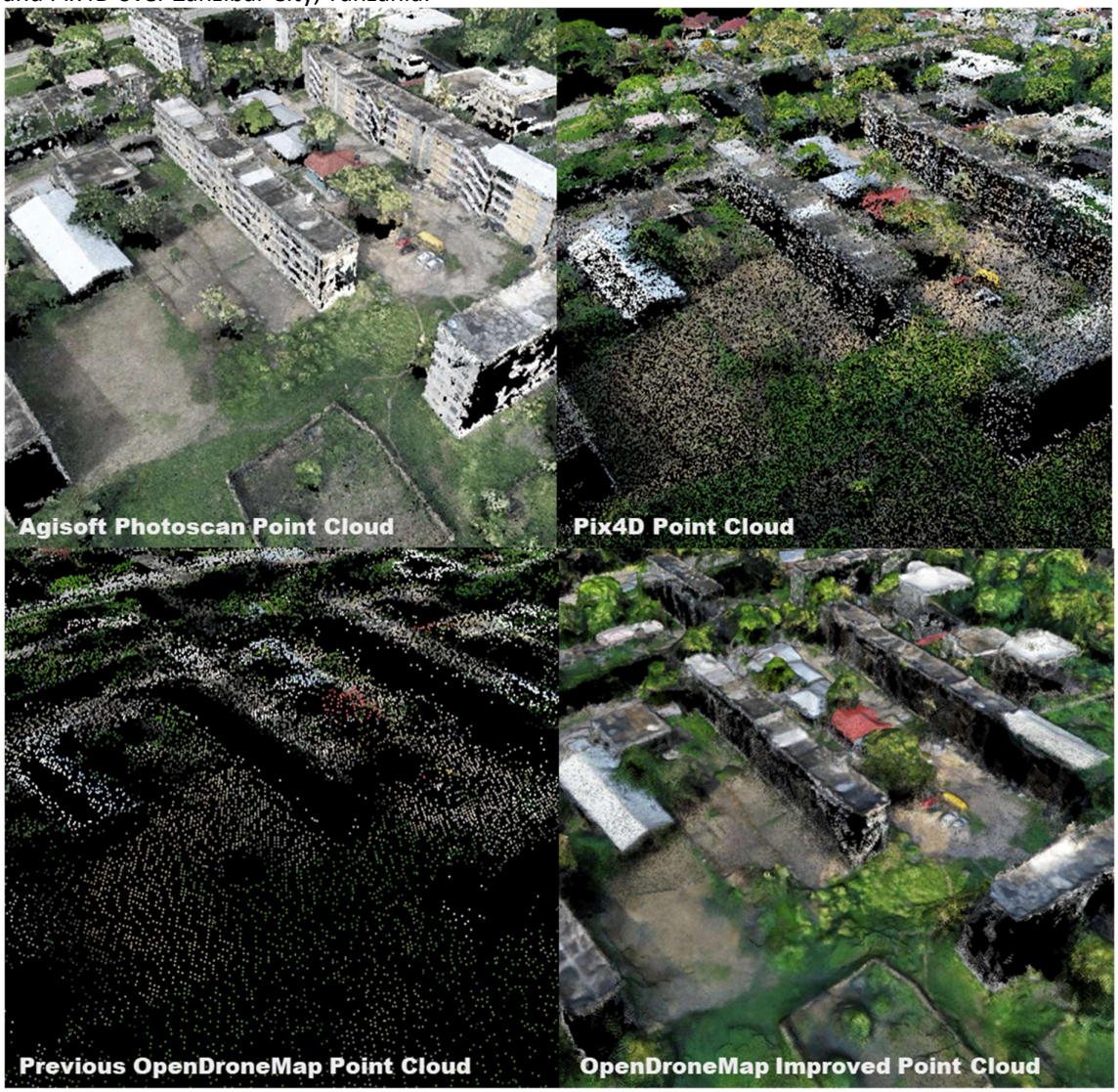
9. Was the methodology successful in producing credible evidence on the performance of the innovation?

☒ Yes, completely
☐ Yes, significantly
☐ Partially
☐ No, not at all

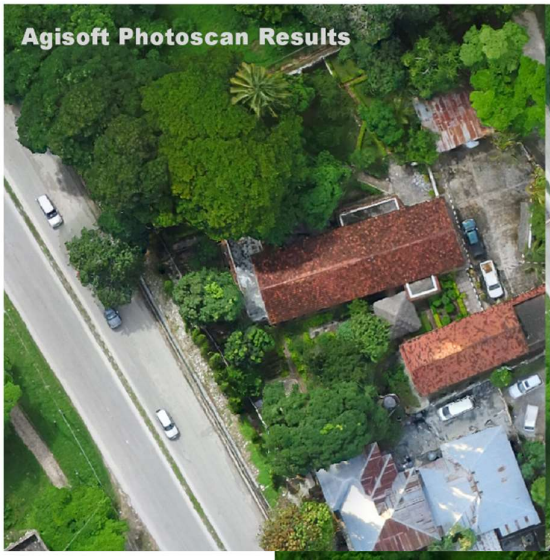
Please describe further:

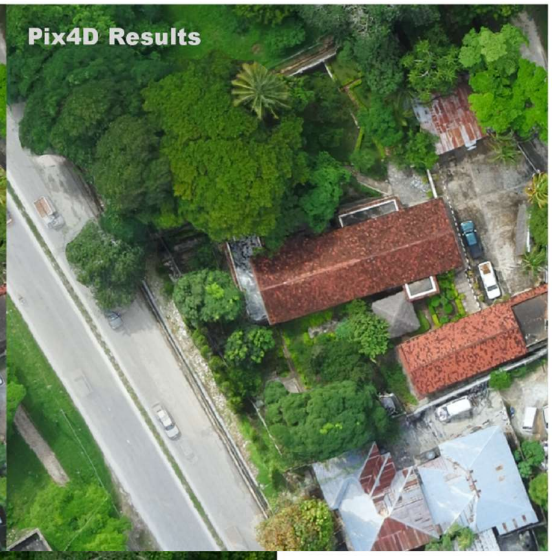
- Benchmarking previous versions of software provide quantitative information on improvements

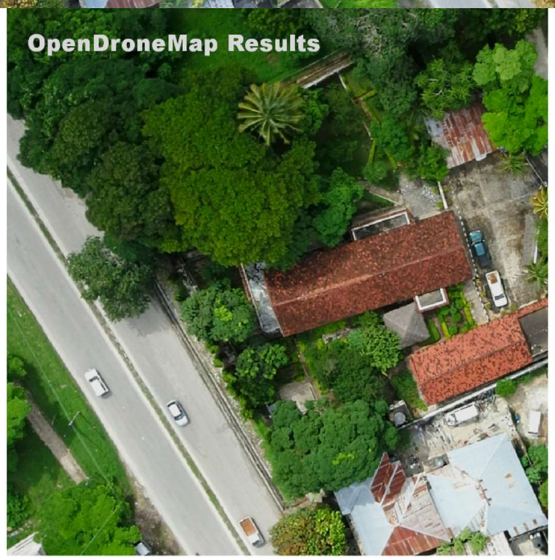
- Workshops sessions where users provided qualitative feedback on utility of improvements / ease of use etc.
- Comparisons with industry-leading commercial-closed source software are favourable. Below is a comparison of the 3D output from two industry leaders, Agisoft Photoscan and Pix4D over Zanzibar City, Tanzania.



- OpenDroneMap's orthophoto output is also quite favourable relative to industry leaders. The orthos work quite well under a range of conditions, from vegetation to buildings.







PARTNERSHIPS AND COLLABORATION

10. How and why did the partnership change during the course of the project?

One team member (Tomas Holderess) left the University of Wollongong to take up employment at Massachusetts Institute of Technology. This change was mitigated by continued involvement in the project by Tomas, and collaborating with colleagues in Wollongong to ensure continuity of project.

Due to increasingly stringent flight restrictions Vela Imagery was not able to acquire imagery from Indonesia which was consistently good enough for ODM processing. As an alternative the project was gifted imagery data from Eidara Matadata Presisi (EMP) (http://www.eidaramata.com/) an Indonesian UAV imagery company. This data is under an open license and has been used to evaluate OpenDroneMap for use in Indoensia. The EMP team have stated their re-evaluation of OpenDroneMap as a viable alternative to commercial software they use.

During the project proposal phase, we assumed that the ODM team would join MSF partners in the field working directly on use cases for MSF staff. In the end, due to the variety of constraints that MSF has in operating drones in the field, we focused the collaboration instead on Working with their projects for building mapping drones, including the Locus project with MSF Japan. Travel fund match instead focused on dissemination of ODM in a variety of context in Africa, Asia, Europe, and North America.

In the meantime, American Red Cross' International Services Division began using drones for mapping in the Philippines and Haiti. The OpenDroneMap team provided extensive support and software development in support of these projects, and in that way better focused OpenDroneMap's capacity for supporting real humanitarian use cases.

11. Are there plans to continue your partnership, either while scaling up this innovation or on other projects?

☒ Yes, with this innovation
☐ Yes, with another project
☐ Maybe
☐ No

Please describe further:

The core OpenDroneMap team will support the following projects in 2018:

- World Bank Tanzania has contracted for the use of OpenDroneMap for use in their massive mapping projects in Dar es Salaam and Zanzibar.
- Collaboration with American Red Cross will continue as their GIS team continues to use drone mapping as a disaster preparedness and recovery analysis tool. ARC also serves as a potential future funding partner.
- State of Kerala, India has built a team around OpenDroneMap for municipal data gathering in return for developer support (see below)
- Uptake of OpenDroneMap by commercial drone manufacturer for use in STEM education outreach projects

DISSEMINATION

12. Please describe any steps taken to disseminate the outcomes of the project.

Please include all completed and forthcoming, as well as all planned and unplanned products (for example, research and policy reports, journal articles, video blogs, evaluations).

OpenDroneMap was presented at the following conferences, workshops, and meetings:

Free and Open Source Software for Geospatial	25/08/2016	Bonn, Germany
Ramani Huria Closing Workshop	08/11/2016	Dar Es Salaam, Tanzania
State University Zanzibar	22/10/2017	Tunguu, Zanzibar, Tanzania
North Carolina GIS	22/02/2017	Raleigh, NC, USA
OSGEO Code Sprint	02/06/2017	Daytona Beach, FL, USA
E384 Training with American Red Cross	20/03/2017	Akron, OH, USA
InAWARE project presentation	15/03/2017	Jakarta, Indonesia
Geospatial Web Services Working Group	15/03/2017	Chantilly, VA, USA
Harvard CGA 2017 Conference	27/04/2017	Cambridge, MA, USA
WB Tanzania Tanzanian Urban Resilience Program	27/05/2017	Dar Es Salaam, Tanzania
FOSS4G Africa	28/06/2017	Johannesburg, South Africa
State of the Map Africa	07/07/2017	Kampala, Uganda
Free and Open Source Software for Geospatial	14/08/2017	Boston, MA, USA
State of the Map US	19/10/2017	Boulder, CO, USA
MSF Japan / OpenDroneMap Meeting	07/10/2017	Barcelona, Spain
Deltares	06/10/2017	Delft, The Netherlands
MSF's Locus Drone + OpenDroneMap	12/10/2017	The Hague, The Netherlands
Drones for Development, Ethiopian WB	14/11/2017	Dar Es Salaam, Tanzania
Super Compute Summit, Colorado	14/11/2017	Denver, CO, USA
Drone Program Training	15/01/2018	Trivandrum, Kerala, India

Two publications are currently planned:

- A White Paper describing the use of OpenDroneMap for imagery processing, focusing on humanitarian contexts
- A Scientific Paper describing OpenDroneMaps processing flow and comparing it to commercially available alternatives

13. Has the project received any third party coverage during the project (from news media, third party blogs, researchers or academics etc.)?

American Red Cross blogged about their work with drone mapping in the Philippines using commodity drones and OpenDroneMap on their Tindog Tabang Leyteño (Stand Up, Help Leyteños) project. The blog post details the value of drones in recovery tracking, covers technical details of the process, and references the larger ecosystem of related tools into which OpenDroneMap is now a part, including OpenAerialMap and OpenStreetMap.

ARC also has an upcoming blog post on their use of OpenDroneMap for mapping in Canaan, Haiti, now the second largest population center in Haiti.

SCALE UP AND DIFFUSION – WHAT NEXT?

14. Is the project or innovation to be replicated or scaled up?

☐ Yes, we will scale up in the same or similar context
☐ Yes, we will scale up within our organisation (including running more pilots or trials)
☒ Yes, we will replicate the innovation/project in another context or country
☐ Yes, the innovation/project will be replicated or scaled up by another organisation or stakeholder
☐Yes, other
☐ No

If you answered *yes* to question 14, please answer 14b:

14b. What model are you pursuing to scale up or sustain your innovation?

☒ Applying for more donor funding
☐ Selling the innovation or patent
☒ Cost recovery (for example, selling your service or being paid as a consultant to implement the innovation)
☒ Innovation to be taken up by organisation or government as standard and included in standard planning and core funding by them
☐ Other_____

Please describe further:

OpenDroneMap will seek additional use cases where its demonstrated scalability is a necessary asset. These use cases may include projects in Tanzania where some of the largest civilian drone mapping projects have been undertaken.

OpenDroneMap will support State of Kerela, India in their use of the software for generation of geospatial products from UAV imagery. In return the Kerela government will provide developer support to further improve the software as part of their core funding.

OpenDroneMap will work with a major drone manufacturer to develop educational materials for STEM outreach – this is anticipated to help with cost recovery for creation of ancillary materials such as user documentation.

15. If the project or innovation could be replicated or scaled up, please list the three most important issues or actions that will need to be considered:
(where 1 = most important and 3 = least important)

Suggestion/issue	***1***	***2***	***3***
1 Integration with existing flight platforms and imaging hardware (e.g. camera calibration)	☒	☐	☐

2 User documentation explaining process flow and how the software operates.	☐	☒	☐
3 Ease of software use, and in particular installation.	☐	☒	☐

Appendix 1. Final Workplan

Below is a table that is the same as the workplan that you submitted with your original application. There are **three ways** to respond to this section.

1. If there have been no changes at all through the project you may cut and paste your original workplan here**.**

2. If there have been changes to the project but these changes **were previously reported to the HIF** in an *Agreement Amendment* form, please adjust your original workplan so that these changes are recorded in it here.

3. If there have been changes which were **not previously reported to the HIF,** please **also** fill in Table 2 (which is on the next page). In particular, please make sure to explain any budget various greater than 15% in Table 2.

Please paste your final workplan in here >

Expected Results	**Main Planned activities**	**Implementation period** Months												**Responsible party / person**	**Amount**			
															2015		**2016…**	
		7	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**		**HIF**	**Others**	**HIF**	**Others**
A: Improvements to Core ODM processing chain	1: Add dense point cloud generation ***completed***													CM			£81,400	
	2: Integrate user image classification ***completed***	X	X				X	X	X	X								
	3: Improve mesh generation ***completed***				X	X	X	X	X	X								
	4: Evaluation by team + community, and revision **completed**								X	X	X	X	X					
B: Platform for fully automated generation of	1: Platform architecture work ***completed***	X	X	X	X	X	X							UW			£30,233	£4,743 (UoW in kind)

web-based maps from UAV imagery.	2: Web development ***completed***																	
	3: Integration & testing ***completed***							X	X	X	X							
	4: Deployment ***completed***										X							
	5: Evaluation by team + community, and revision ***completed***							X	X	X	X	X	X					
C: Communication and community building	1: Community Meetings ***completed***	X	X	X	X	X	X	X	X	X	X	X	X	SV, CM			£9,000	£12,000
	2: Social Media ***completed***	X	X	X	X	X	X	X	X	X	X	X	X					
	3: Blog Posts ***completed***	X	X	X	X	X	X	X	X	X	X	X	X					
D: UAV Flights	UAV flights ***completed***				X	X	X	X						Vela Aerial			£800	£4,000
E: Consulting on field needs, liaison with operational data users	Field logistics, coordination with emergency teams and first responders ***See changes in workplan below***								X	X	X	X	X	MSF			£4,000	In kind consulting and field support
F: UAV Data	UAV Test Data ***See changes in workplan below***	X	X	X	X	X	X	X	X	X	X			MSF London				In kind data

G: Documentation	1: Deployment / Administrator Documentation ***Complete***				X	X	X	X	X	X	X	X		UW, SV, CM			covered as part of work above	
	2: Developer Documentation ***Complete***				X	X	X	X	X	X	X	X						
	3: User Documentation ***Complete***					X	X	X	X	X	X	X						
	4: White Papers ***Still in progress***				X	X				X	X	X	X					
	5: Journal Articles ***Still in progress***				X	X					X	X	X					
	6: Final Project Report ***Complete***											X	X					

Table 2: Changes to Workplan

For every change in the final workplan that is different to your original worktable AND that has not already been reported to the HIF, please add a record in this table. Changes can include alterations to the methodology, project process or innovation design, for example.

Change (as referenced in workplan above)	Reason for change	Overall impact of change
1.		
2.		
3.		
4.		
