UTM Flight Planner

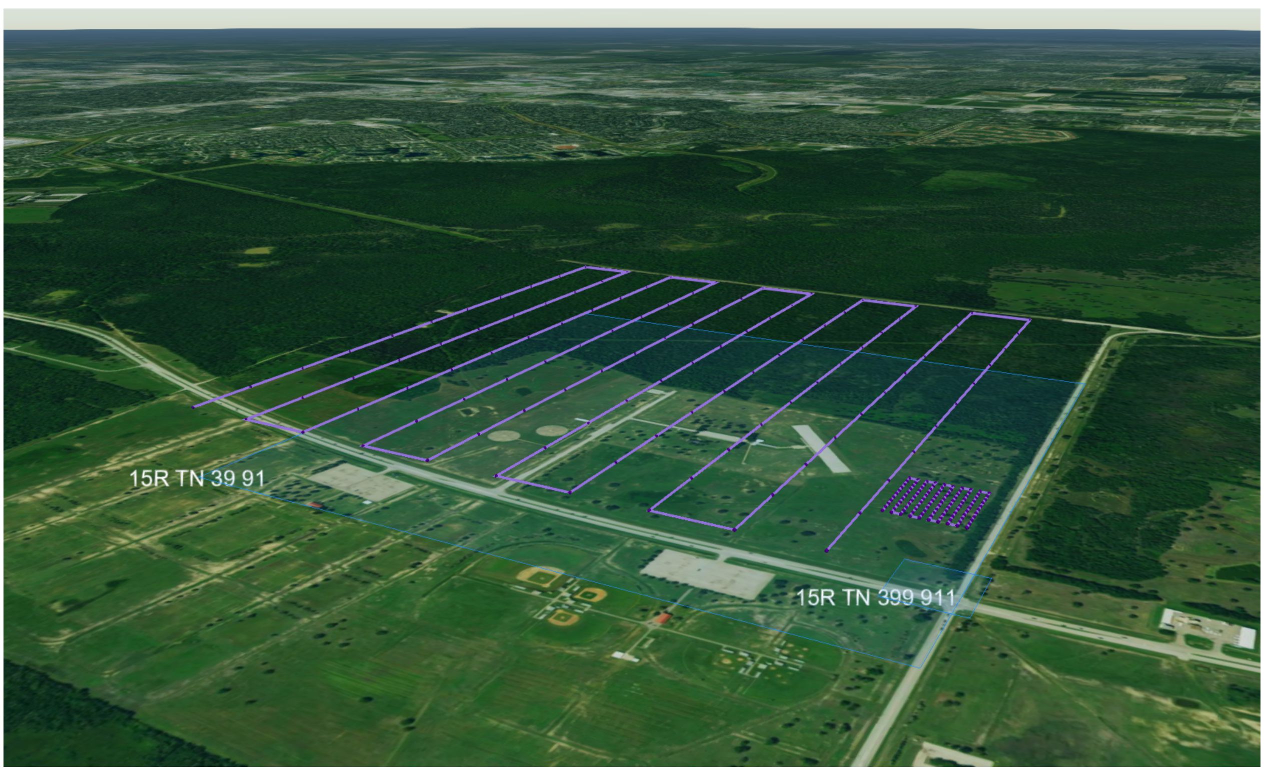
Collaborative 3D Geospatial for Humanitarian Drone Operations

Mark McDaniel, Capstone, The Fletcher School of Law and Diplomacy, Tufts University

Summary

UTM Flight Planner is an in-development, open source web application intended to facilitate the rapid deployment of low-accuracy humanitarian drone survey missions. Pilots can generate MavLink, ArduPilot Mission Planner, and QGroundControl compatible flight plans from UTM, MGRS, and USNG Grid inputs. This grid-based approach enables repeatable, consistent flightplan generation, as well as better communication about aerial imagery using a standard land navigation system for international disaster response and search and rescue.

Built on the 3D geospatial Cesium.js library, UTM Flight Planner offers a unique perspective for UAS and drone mission development. 3D geospatial opens the door to more sophisticated automated flight plan generation that takes terrain analysis into account, less warping from projected web-map systems, and enables more useful waypoint visualization compared to 2D alternatives. Planned features include public collaboration and tasking mechanisms, as well as tools for interfacing with image processing software like [Open Drone Map] and tools to help contribute to the [Open Aerial Map] imagery network.



Waypoints and flight paths generated from USNG grids using UTM FLight Planner

Limitations of Aerial Imagery in Humanitarian Action

Updated, rapidly accessible aerial imagery has become an integral part of disaster response over the past decade. Imagery from satellites, planes, helicopters and drones help inform initial damage assessments, assist in search and rescue efforts, and are invaluable in mitigation and prevention efforts.[1] However, despite technological improvements that have enabled a proliferation of high quality aerial images, there are some challenges that limit image accessibility, particularly for organizations with smaller budgets.

Openly available satellite services, like the European Space Agency's Sentinel-2 satellite program offer a broad spectrum of satellite images that are updated daily (roughly) for most of the planet. This is particularly useful for rapid assessment, however, the primary disadvantage is that it's relatively difficult to access, and while rapid, it's certainly not on-demand. Higher resolution satellite imagery from companies like Maxar, while extremely detailed, can be prohibitively expensive[2] and take longer to access. Satellites can also be limited by atmospheric conditions and cloud cover. In much the same way, traditional manned aircraft can be expensive to operate, limited in capability and appropriate landing zones following a disaster,

Survey drones and UAVs can be a great intermediary: easy to deploy, transport, and comparatively inexpensive. However, despite a massive amount of speculation, drones have yet to find a place in the humanitarian response and emergency relief system.[3] This—in part—may be due to a lack of institutional knowledge and systems, as well as cross organization image availability. It's often easier to wait for satellite images and to live with the lower resolution.

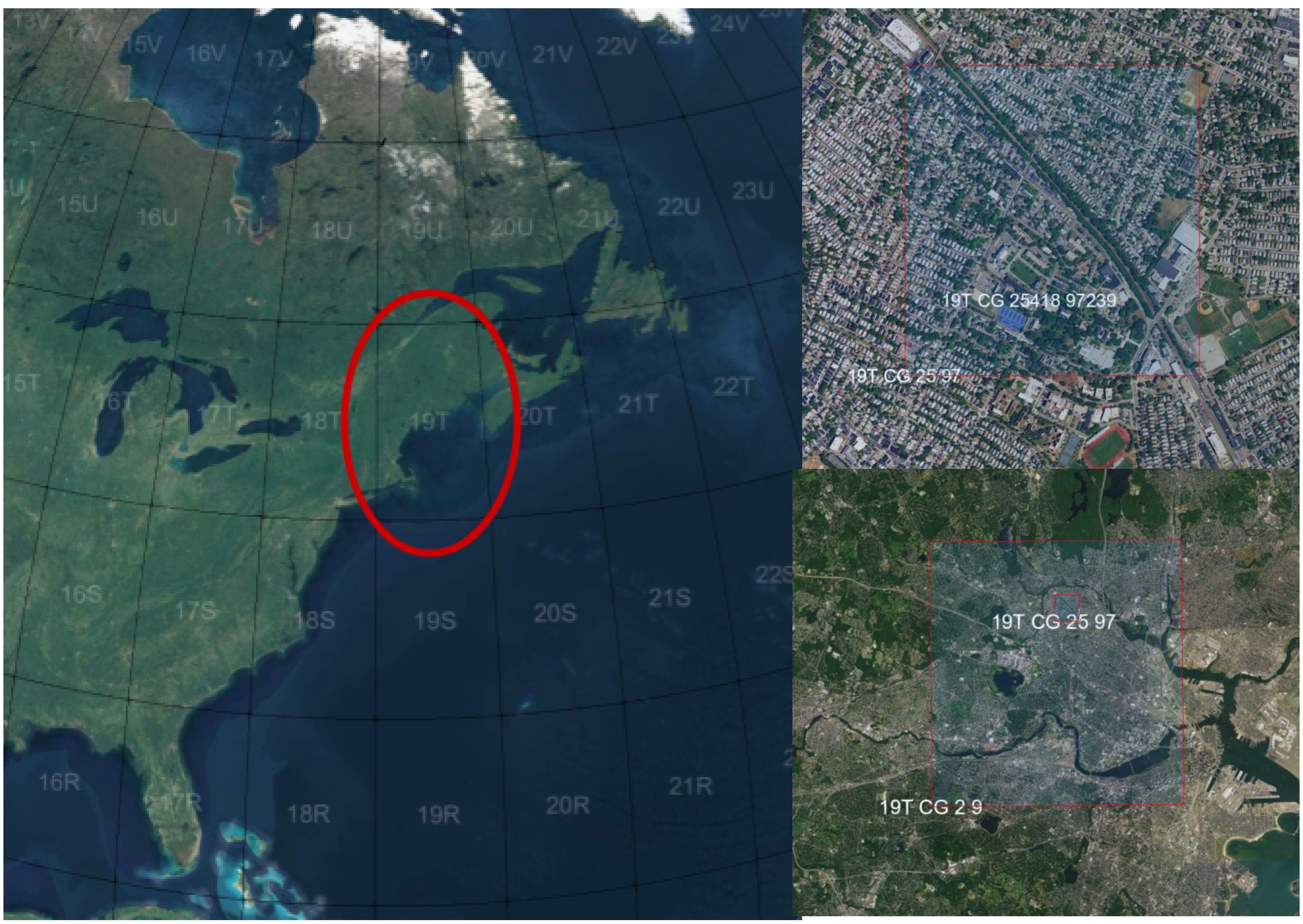
Sharing and collaboration on UAV based aerial image capture could dramatically increase the sectoral penetration and availability of UAV survey images. Organizations like the Humanitarian OpenStreetMaps Team have tried to address this through projects like Open Aerial Maps, a federated network of individuals and organizations who host and make available aerial images released under a Creative Commons license. However, the number of contributors is relatively small, with no way to organize or request image capture.

Concepts Behind UTM Flight Planner

[1] FSD, UAViators. (2016). *Drones in Humanitarian Action: A guide to the use of airborne systems in humanitarian crises.* European Union Humanitarian Aid.
[2] FSD, UAViators. (2016). *Drones in Humanitarian Action: A guide to the use of airborne systems in humanitarian crises.* European Union Humanitarian Aid.
[3] UNOCHA. (2014). *Unmanned Aerial Vehicles in Humanitarian Response*. OCHA Policy and Studies Series.

UTM Flight Planner is an effort to bridge some of the gaps outlined above. It's an in-development, open source application with the goal of incorporating UTM, MGRS, and USNG grid systems as a common language to communicate about UAV mapping, and reducing the friction of capturing aerial imagery. By using MGRS/USNG grid squares as units for mapping, we can easily and rapidly generate flight plans from the boundaries of the grid, and associate precise, human readable locations with the images.

The US National Grid (USNG) and the Military Reference Grid System (MGRS) are based on the Universal Transverse Mercator (UTM) system that divides the world by square meters, rather than decimal degrees. The globe is first divided up into 6° longitude by 8° latitude bands, and given a number and letter label. The zone for Boston, Massachusetts is **19T**. Each band is divided into 100 km grids and given additional identifying letters. Boston falls into 100 km grid **19T CG**. Each 100km grid is further subdivided by 10 and assigned a number for its place in the parent grid, down to 1 meter grids. The doorstep of the Fletcher School in Medford, MA can be located at **19T CG 25418 97239.**



Few alternative grid systems have the same levels of institutional adoption, particularly in search and rescue, disaster response, and military coordination. The USNG has been adopted by the United States National Search and Rescue Committee (NSARC) as the primary system for land based search and rescue, and the MGRS is widely used by NATO members. The only meaningful difference between the two systems is naming convention. UTM includes spaces between the grid divisions,and MGRS does not (19T CG 343 517 vs 19TCG343517.) Because both are UTM based, it interfaces nicely with the standard USGS practice of inserting 1km UTM tick marks into their topographic maps. While they may seem a bit obtuse, the systems generally make sense after a small amount of interaction and can become an easy way to communicate about both precise locations and large areas.

In humanitarian action, part of the rapid aid deployment process is rapid decision making. The primary advantage of organizing UAV flights by UTM grid square is that it lends itself well to systematically deciding where to map using easily repeatable, pre-defined grid coordinates. For example, you could select a series of grids in a disaster zone, generate flight plans for each one, and iteratively make your way through the zones and mapping the area. Generating flight plans based on grid squares isn't strictly necessary, but may have an impact on the deployment speed and repeatability of flights. Rather than an arbitrary approach to a larger area, you could divide it up by grid and assign image capture to several teams, avoiding redundancy. For search and rescue operations, division like this could help teams cover more ground using the zonal systems they already have in place.

How UTM Flight Planner Works

Built on the 3D geospatial Cesium.js library, UTM Flight Planner offers a unique perspective for UAS and drone mission development. Users can input a single—or series—of UTM grid segments, and, following conversion standards and ellipsoidal distance calculations developed by the National Geospatial-Intelligence Agency,[4] the bounding box and the corresponding longitude and latitude of the vertices are calculated. The coordinates are then passed to a function that builds a flight plan with camera actions that can be exported and loaded onto any UAV autopilot running the MavLink protocol like ArduPilot. Selectable parameters for specific cameras, camera actions and angles, much like those found in QGroundControl or Drone Deploy, are currently in development. The flight plans can be imported, altered, and initiated by standard ground control and mission planning software like Mission Planner and QGroundControl.

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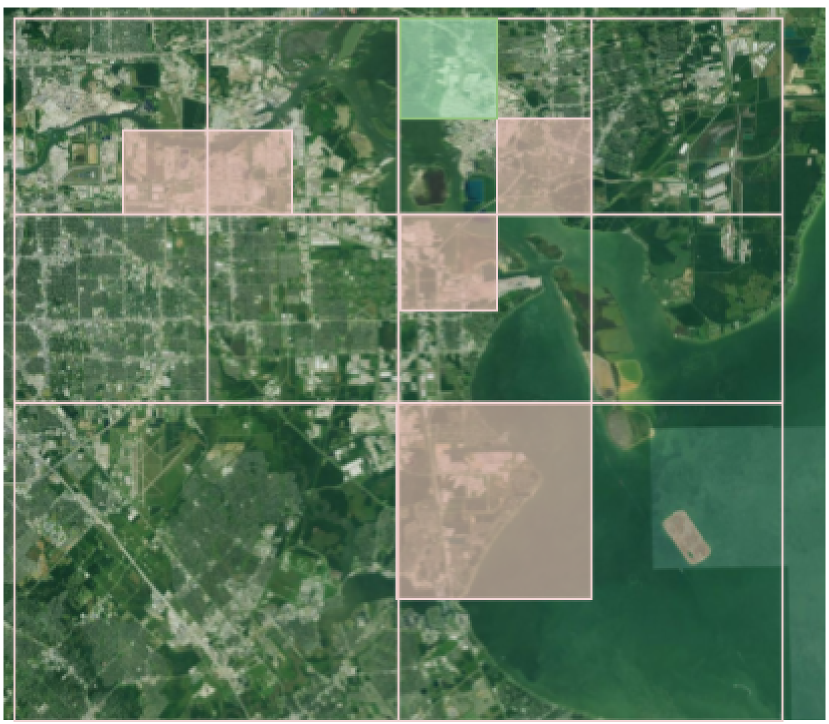
[4] NGA. (2014). *The Universal Grids and the Transverse Mercator and Polar Stereographic Map Projections.* Office of Geomatics.

Planned features include public collaboration and tasking mechanisms inspired by the HOTOSM Tasking Manager, along with tools for interfacing with image processing software like Open Drone Map and contributing to the Open Aerial Map creative commons imagery network. Some items on the road map:

- Allow users to define a region of interest in which they wish to start a collaborative project, mark a grid to request images.
- Allow users (organizations or volunteers) to take responsibility for a series of grid segments, indicating an intent to generate open access aerial imagery for use on Open Aerial Maps.
- After the flight, users can then process the images themselves, or upload the GeoTIFFs to be processed in the backend by WebODM. Finally, we can use the OAM API to feed the final orthographic images back into the Humanitarian OpenStreetmaps Team ecosystem for further use.



An early look at the tasking system

As the generated flight plans are part of the ArduPilot ecosystem, they are compatible with DJI systems through the excellent Rosetta Drone2 project. This is particularly useful for organizations who bought DJI drones, but never fully integrated them into their workflow. It's also great for sidestepping DJI's "walled garden" approach to hardware and software.

Project Vision

UTM Flight Planner is currently in early development, with the core flight plan generation in place. Given the observed instability of existing MGRS and UTM libraries, I have implemented the NGA UTM standards from scratch in both javascript and a stand-alone python package. The program takes an MGRS or USNG string, calculates the bounding box, and reliably returns a polygon representing the grid square for display in Cesium. It then uses a pathing algorithm to calculate a series of waypoints covering the entire grid based on user parameters and translates this to a MavLink compatible flight plan file.

While that's cool functionality, the overall goals of the project are more ambitious. Ideally, the ability to interact with and visualize UTM grid squares in a three dimensional space will facilitate the ability to communicate about—and organize around—the real life spaces they represent. My vision for the project, if you'll humor me for a moment, looks like this:

> A natural disaster has struck near your home. Say, an unexpected flood brought on by the unusually heavy rain. Fortunately, you work for a local NGO and log on to Slack to see that your colleagues have already started discussing how they can help. One of them, a GIS analyst, says that she's been working on local vulnerability models for the town and has a fairly good idea of which areas are likely to be hardest hit, but could use some updated imagery to assess the damage and form a better response. Unfortunately, the persistent cloud cover has made satellite images unusable, and the organization certainly can't afford to pay for a plane. The rain finally lets up, so you decide to take the drone out to capture some images. Your colleague gave you the areas in USNG coordinates to cover a 2 sq km area. You open up UTM Flight Planner to generate the flight plans and flag the grids as in-progress and notice some grids to the west of your destination are flagged by another local NGO requesting images. It's only a five minute drive and will only take you an extra 20 minutes to fly it. Besides, you *do* have an extra charged battery on hand so you indicate you'll take responsibility for the grid.
>
> Your primary flights go well, as well as the grids you volunteered for. On your way back to the car though, you notice some power lines are down. You've heard that search and rescue crews have been moving through the area, and begin to worry that it might be dangerous for anyone moving through the water. One of your colleagues has worked with the SAR folks before, so you give him a call and ask if he'll pass along the USNG coordinates for the area.

> You don't know much about power lines, or what they'll do with the information, but you feel good to have at least let them know. Once you return to the office, you process and upload the images to the Open Aerial Map network.

This might be a silly or simplistic example, but I think it paints a good picture of how a system like this might be useful. At its core, it's a means of coordination using an established, shared language about *areas* and sharing aerial images of those places.

If organizations in the disaster response space are already using the USNG or MGRS to communicate, this should extend their existing capabilities, while facilitating the contribution of smaller groups or individuals to a response effort. It would also be a natural extension of the Humanitarian OpenStreetMap Team's existing ecosystem. HOTOSM volunteers from all over the planet help map disaster areas using Open Street Maps, and because UTM Flight Planner will direct image output to their Open Aerial Map network, it will be an additional resource to bolster that system.

Development Milestones and What's Next

To realize the more ambitious visions for the project, I've laid out several major goals for the project:

1) Continued design and iteration of the flightplan generation. This will include more sophisticated pathing algorithms that leverage the 3D capabilities of Cesium.js to take terrain, airspace classifications, and obstacles like Open Street Maps buildings or FAA designated hazards.
2) Real world testing of the flight plans, and further iteration to ensure reliable, safe, and configurable flights.
3) Once flights have been verified in a variety of circumstances and locations, publication of the code to GitHub, both as a stand-alone flight plan generator and as a Cesium.js web application.
4) Publication of comprehensive software documentation.
5) Development of an interactive environment where users can request aerial images, volunteer to capture them, or see which grids are covered by existing images on Open Aerial Map.
6) Integration of the OAM API and uploading tools.
7) Integration of OpenDroneMap image processing software. Either on the backend, and hosted as a public service, or integration for client-side processing.

8) Present the project at an open tech conference like the Open Street Maps State of the Map conference. This should serve to get more exposure and gauge the potential reach, as well as identify people who may want to collaborate on the continued development.

The project will be published as open source and will maintain transparency. As a general rule, it will not enforce any regulatory scheme on the users. Different countries have made varying amounts of progress on implementing drone regulations and there is no international standard. At the end of the day, the pilot is responsible for their aircraft. In humanitarian contexts, there are sensitivity and protection concerns for the use of drones and UAVs. The site and software will refer users to the Humanitarian UAV Code of Conduct and Guidelines as laid out by UAVcode.org, the Harvard Humanitarian Initiative, and WeRobotics.

An important, but necessary caveat: this project is not in any way, shape, or form ready to be used in a serious manner—definitely not with a drone you are not willing to lose. It began as a thought experiment exploring the use of drones in a humanitarian environment and how we might better organize collaborative disaster response efforts outside of the established "Humanitarian System(TM)." Rather than just speculate about it, I decided to build something. I'm not a professional developer or a professional humanitarian, just an idealistic dork.

That said, I certainly believe it *could* be used in a serious manner. Recent efforts to bring localization into the forefront of humanitarian response and the resurgence of mutual aid organizing into the cultural zeitgeist are developments that should be fostered and encouraged. Open source tools and software are a means through which local organizations and actors can build meaningful capacity in a way that challenges, but is capable of working in tandem with, existing institutional frameworks. I want to help build and expand on cooperative frameworks. This is my contribution.

A working example of the software can be found at www.texflight.com.

Code and resources will be published at:
https://github.com/McDanielMedia/UTM-Flight-Planner

Links and References:

ArduPilot
https://ardupilot.org/

FSD, UAViators. (2016). *Drones in Humanitarian Action: A guide to the use of airborne systems in humanitarian crises.* European Union Humanitarian Aid.
https://irevolution.files.wordpress.com/2011/07/drones-in-humanitarian-actionemail.pdf

Harvard Humanitarian Initiative and WeRobotics. (2022). *Humanitarian UAV Code of Conduct & Guidelines*
https://docs.google.com/document/d/1Wb_M5tFfEwZMfZS4w64nLUW2ShI_ECbnRUWmWdioZ4Q/edit

Mission Planner
https://ardupilot.org/planner/
MavLink Autopilot Protocol
https://mavlink.io/en/

Open Imagery Network
https://openimagerynetwork.github.io/

Open Drone Map
https://opendronemap.org/

Rosetta Drone 2
https://github.com/The1only/rosettadrone

UNOCHA. (2014). *Unmanned Aerial Vehicles in Humanitarian Response*. OCHA Policy and Studies Series.
https://www.unocha.org/sites/unocha/files/Unmanned%20Aerial%20Vehicles%20in%20Humanitarian%20Response%20OCHA%20July%202014.pdf

WeRobotics
https://werobotics.org/

Yu, Yang, and Li. (2018). *Big Data in Natural Disaster Management: A Review.* Geosciences.
https://www.mdpi.com/2076-3263/8/5/165