TESTING OPERATIONAL STRATEGIES FOR A POTENTIAL MARS HELICOPTER USING A COMMERCIAL DRONE.

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Introduction: Unmanned Aerial Vehicles (UAVs), commonly referred to as "drones", are fast becoming essential tools in geosciences with variable applications including geological and atmospheric studies, archeological surveys, and hazard assessment. The NASA Mars 2020 mission might include a drone-sized helicopter scout (Fig. 1) to aid in mission operations as well as offer scientific context to the landing site area at higher spatial resolution than what is available from orbit [1]. During a GeoHeuristic Operational Strategies (GHOST) field test [2–4], we utilized a commercial drone (Fig. 1) to test a number of operational strategies for a hypothesized drone utilized in concert with a mobile platform on Mars. For drone capabilities, we used published capabilities of the Mars Helicopter Scout (MHS) originally proposed for Mars 2020 [1] (Table 1). The main results of the GHOST campaign are reported elsewhere [5]. Here we focus on drone testing and implications to future operations of scouts in future missions.

Study site: The field site that was chosen for the GHOST [5] campaign is located in the Uinta Basin of the Colorado Plateau province in northeastern Utah (39.8058°N, 109.0759°W). The main testing area was a canyon cutting through a 500 x 500 m study region where rock layers are well exposed on both sides of the canyon. The exposed strata mainly comprise units from the Eocene Green River Formation, which record a paleolake (Lake Uinta), which covered parts of northeastern Utah between 57 and 43 Mya.

Table 1. Technical specifications of the Mavic Pro (based on official model specs) vs. specs for MHS.

Ability/spec	MHS	Mavic Pro
Dimensions	N/A	8.3 cm-wide (folded, 19.8 cm-long
Mass	Max. 1 kg	0.734 kg
Flight time	3 min/day	Up to 27 min per battery
Flight height	Max 100 m due to low air density on Mars	Ceiling height of 5000m
Camera	Downward-looking	Gimbaled camera (pitch -90° to +30°) with FOV of 78.8°. , lens is 28 mm, f/2.2

Methods: Our main goal was to test different operational strategies of the drone to mimic MHS's capabilities so we could optimize operation for scientific purposes. The MHS was expected to operate individually from the rover. Daily flights would be limited to a short duration of approximately 3 minutes due to power, but it would attain ~100m altitude and ~600m ground track (Table 1, [1]). For our simulation, we used a Mavic Pro drone (built by DJI), which offers a wide-range of capabilities, small, portable and foldable design, and ability to pre-plan flights using third party software.

Fig. 1. [Top] Artist conception of the Mars Helicopter Scout, originally proposed for the Mars 2020 payload (adapted from [1]). [Bottom]: DJI Mavic pro drone, which was utilized to test different operational strategies for a Mars scout. Dimensions and other specs are listed in Table 1. Image credit: DJI.

Therefore, the main approach was to carry out multiple 3 minute-flights simulating daily campaigns on Mars to gain a better understanding of the nature and extent of scientific investigations that can be carried out on a daily basis. We also utilized a third property commercial drone mapping software (drone deploy, https://www.dronedeploy.com/) to construct a simulated flight plan with MHS activity constraints. This allowed us to estimate the maximum surface area that could be covered per day with acceptable image overlap for the creation of both regional mosaics and high resolution DTMs.

Results: We tested a number of operational modes by which a scout drone could be used for scientific investigations. We describe these briefly:

Nadir Reconnaissance Mode (NRM): Simulated flight plans on drone mapping software (fig.2) demonstrate that an area roughly 10^4 m^2 can be mapped within 3 minutes, including takeoff and landing time, to construct an image mosaic at ~3 cm/pixel and a corresponding high resolution DTM. A DTM of that scale would be sufficient for scientific planning over a significant traversable area, and therefore flight would not be required on a daily basis. Alternatively, a scout could be operated to fly at lower elevation (e.g., 5 m) if its camera remains in focus to create localized ultra-high resolution DTMs for traverse planning over potentially hazardous areas.

Vertical Stratigraphy Mode (VSM): We utilized the Mavic Pro to trace strata vertically that would be normally inaccessible to a rover. This would be particularly beneficial in a canyon setting but also applicable for 10s of meter-high outcrops outcrops, impact crater walls, etc. In one particular example, the GHOST teams [5] identified an interesting float rock with fossilized ripple marks. The drone was then utilized to trace its stratigraphic origin on the cliff wall.

Horizontal Scout Mode (HSM): This an optional mode we tested using the drone's gimbal capabilities to assess the benefits of having such a system in the future, or alternatively two cameras: one nadir-, and another horizon pointing. In these campaigns we tried different strategies. Our best operational plan consisted of first launching to maximum height (100m) to take a reconnaissance image then decrease the elevation to 20–30 m. The drone would then travel along a potential rover route for 30–50 m, acquire a set of horizontal images over at least a FOV of 180° for panoramic stitching, then repeat the sequence of travelling ahead and acquiring images until there were 30 seconds remaining for the drone to land and finish its simulated Martian sol traverse. This mode allowed us to acquire a context image as well as the opportunity to detect a number of regions of interest (e.g., float rocks, interesting outcrops) that would be potential targets for detailed investigation by the rover. Using this technique, we were able to cover a ground track of 150–200 m per operational planning period (i.e., for Mars, a single sol).

Fig. 2. Google-Earth view of the region of study in Utah. The image roughly covers a 500x500 m area. A 3 minute flight at 100 m elevation would cover an area ~200 x 50 m in adequate overlap for high resolution mosaics and DTM construction. Image credit: Drone Deploy and Google Earth.

Conclusions: Despite the apparent short sol window, careful planning of the scout path can result in substantial spatial ground-track coverage of ~200m. This preliminary work suggests that a scout's onboard memory, not battery life, may be the principle operational "bottleneck". However, given the large swath covered by the drone in one sol, upload rate should not be a major issue since the data returned could be enough for days (or even weeks) of actual rover operations. Once upload is finished, more specific tasks may be planned before another standard nadir reconnaissance campaign is needed.

References: [1] Volpe, R. (2014), International Symposium on Artificial Intelligence, Robotics and Automation in Space. [2] Yingst R.A. et al. (2011), Mars, 13-31. [3] Yingst R.A. et al. (2014), Acta Astron., 24-36. [4] Yingst R.A. et al. (2016), Acta Astron., in press. [5] Yingst R.A. et al., this meeting.

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