Flight Planning Guidelines for GEMS

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This document discusses guidelines for flight planning which enable users to get the best possible imagery from the GEMS payload. . .

1 Introduction

GEMS is a self-contained, multi-spectral camera with a built-in, tightly integrated navigation system. The cameras and optics are selected and calibrated to measure relative NDVI (Normalized Difference Vegetation Index) from the air. The system handles the alignment of spectral bands, geo-registration of the imagery, image processing and analysis to render vivid NDVI imagery in false-color, and stitching collected imagery into geo-referenced, ortho-rectified RGB, NIR, and NDVI moasics. These capabilities are provided through our software suite that is included with the GEMS payload. As a self-contained sensor, GEMS does not need to be integrated with external navigation systems, autopilots, or triggering systems. The system is powered up on the ground, where it will acquire GPS and initialize all of its onboard sensors (typically in under 35 seconds). Once the system is initialized, it will wait and monitor data from its sensors until it detects a take-off event. When it detects that is has taken off it will begin recording imagery and navigation data and will continue until it detects that you have landed. It will then power itself down and the collected data is conveniently available on a removable thumbdrive. While GEMS autonomously handles tasks like take-off and landing detection and camera triggering, it does not control what it is flown over, so there are some guidelines to follow when planning your flight to make sure you get proper coverage and the best possible imagery from the GEMS payload.

2 Flight Pattern

While no specific flight pattern is required in order to use GEMS, if you are trying to collect imagery of large areas (as opposed to linear stretches of land), we recommend flying a serpentine pattern as shown in Fig 1. If flying in a fixed-wing vehicle that tends to roll in turns, it is a good practice to overfly the area of interest at the end of each row and fly a little beyond the perimeter of the field. This ensures that you get good coverage of the entire region of interest. The choice of row spacing depends on your height above ground. See §3 for a discussion on choosing this parameter.

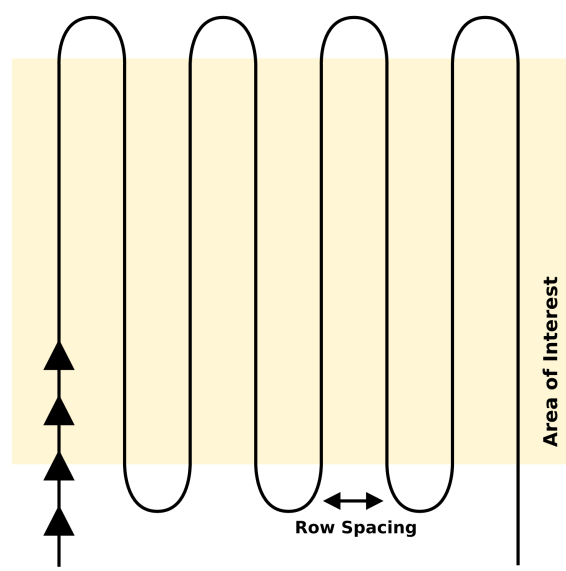

Figure 1: Recommended flight pattern when covering 2D areas.

3 Flight Profile and Row Spacing

The height at which you fly your vehicle is an important parameter which has a direct effect on the ground resolution of the collected imagery (your GSD[1]) and the time it takes to cover any given area (your coverage rate). Put simply, flying lower and slower gives you finer resolution on the ground (lower GSD) while flying higher and faster increases your coverage rate. Fig 2 shows the GSD as a function of height for the GEMS payload.

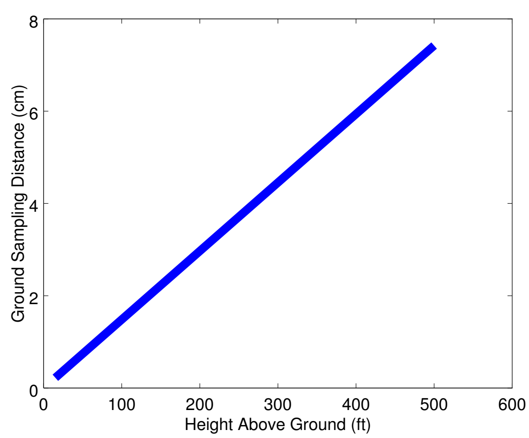

Figure 2: Ground Sampling Distance vs. height

In addition to affecting GSD, the height and speed of your vehicle affects the amount of motion blur (or image smear) in the collected imagery and the amount of image-to-image overlap, which in turn affects the reliability and quality of automatic image stitching.

Figure 3 shows which combinations of speed and height result in good, crisp imagery with sufficient image-to-image overlap to enable automatic image stitching. Every profile in both the "Good" and "OK" regions results in very low motion blur (in fact, in typical daylight conditions many profiles outside of these regions will also give crisp images). The difference between the "Good" and "OK" regions is determined by the amount of image-to-image overlap they entail. The "OK" region results in overlaps between 50% and 70%, while the "Good" region results in overlaps above 70%. The amount of image overlap that is required for robust automatic image stitching depends greatly on the content of the imagery. In a lot of generic aerial imagery there tends to be a great deal of distinctiveness between images. That is, there are many interesting features that make it easier to align different images. In this case, overlaps of 50% are often perfectly sufficient for robust automatic stitching, and any profile in either the "Good" or "OK" regions will suffice. In instances where there is not a lot of distinctiveness between images, which can be the case in some agricultural applications, greater image-to-image overlap may be needed for robust stitching. In these situations we recommend employing a flight profile falling in the "Good" region.

In addition to determining acceptable speeds, vehicle height also determines what row spacings can be used when flying a serpentine pattern (see Fig 2) to enable robust automatic image stitching. Figure 4 shows which combinations of row spacing and height result in "OK" and "Good" overlap. Again, which region to shoot for depends on the content of the imagery.

Important Note: We do not recommend flying below 15 ft because beneath this height there is a risk that the imagery will not be entirely in focus. Also, if flying below 40 ft, there is a chance that the system may have difficulty accurately detecting take-off and landing events (e.g. it may think you have landed if you are hovering at low altitude). If you fly below 40 ft, we recommend using the "manual" recording mode to ensure that you do not run into problems with this feature (refer to the user manual for details).

[1] Ground Sampling Distance (GSD) is the linear distance between the points on the ground seen by adjacent pixels in your cameras focal plane array. If your GSD is 2 cm, it means that a single pixel in your imagery sees a region on the ground of size 2 cm **x** 2 cm (an area of 4 cm^2).

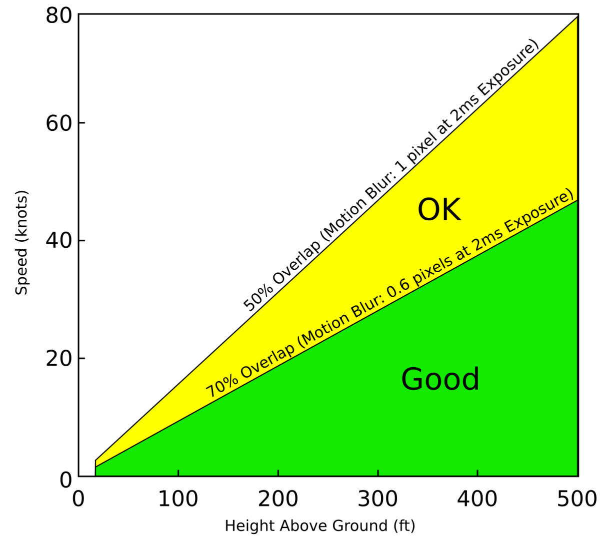

Figure 3: Recommended Flight Profiles

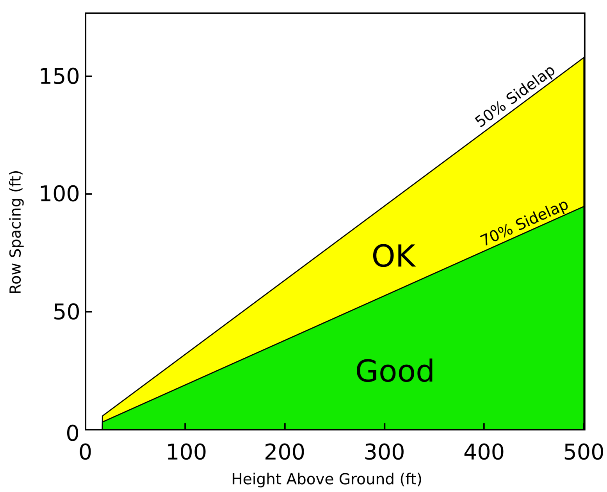

Figure 4: Recommended Row Spacing vs. Height

4 Parameters for Flight Planning Software

If you use additional software for flight planning, you may need to provide it with some information about your imaging system so it can set an appropriate flight plan. When using tools such as these, set your overlap target to an appropriate value for your subject matter (if you are unsure, start with 70%). The system will collect images automatically at a rate around $0.7-0.9$ seconds between images. Enter the following values as needed:

- Image sensor resolution: 1280 x 960 pixels
- Sensor dimensions (active area): 4.8 x 3.6 mm
- Pixel size: 3.75 x 3.75 μm
- Horizontal Field of View: 34.622 deg
- Vertical Field of View: 26.314 deg
- Focal length: 7.70 mm

Some tools may require more detailed information about your sensor and optics. The "Intrinsic Calibration Matrix", sometimes also called the "Camera Calibration Matrix", and frequently denoted **K** is:

$$\mathbf{K} = \begin{pmatrix} 2053.42 & 0.0 & 639.50 \\ 0.0 & 2053.42 & 479.50 \\ 0.0 & 0.0 & 1.0 \end{pmatrix}$$

The GEMS payload uses low-distortion optics and for the purpose of flight planning any distortion (radial and tangential) can be assumed negligible.