When to use a Small Unmanned Aerial System (sUAS) for a project

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As a sUAS service provider, we often encounter customers who request imagery of an area. Sometimes customers are unsure about what sort of imagery or data they need. We assist them defining their imagery (or data) requirements using a two-step process. First, we try and understand the "why" of their imagery needs. More specifically, we seek to better understand the decision they are trying to make that compels them to seek geospatial imagery. Secondly, we try and match their imagery information requirements with available remote sensing data sources, including sUAS. We use an information hierarchy framework to analyze their "why" question. From this, we're able to determine their imagery requirements. Knowing those requirements, we determine how to collect that imagery using standard remote sensing resolutions as a guide. We've found that by using this analysis process, we can best match our customers with the imagery they need as well as the best method of collecting that imagery.

We will not attempt here to provide anything more than the briefest descriptions of information hierarchy or remote sensing. Our aim is to provide a better understanding of how the two connect to provide our customers with the right solutions.

Decision makers are at their best when they have knowledge that augments their already established wisdom. Knowledge, in turn, is based on information. In this context, information is some processed collection of data that, as a combination, augments the decision maker's knowledge. Here is why it is so critical to completely understand what decision the customer is attempting to make; without it, we cannot, except by chance, collect the right data from which to create information. Figure 1 represents a schematic of this information hierarchy.

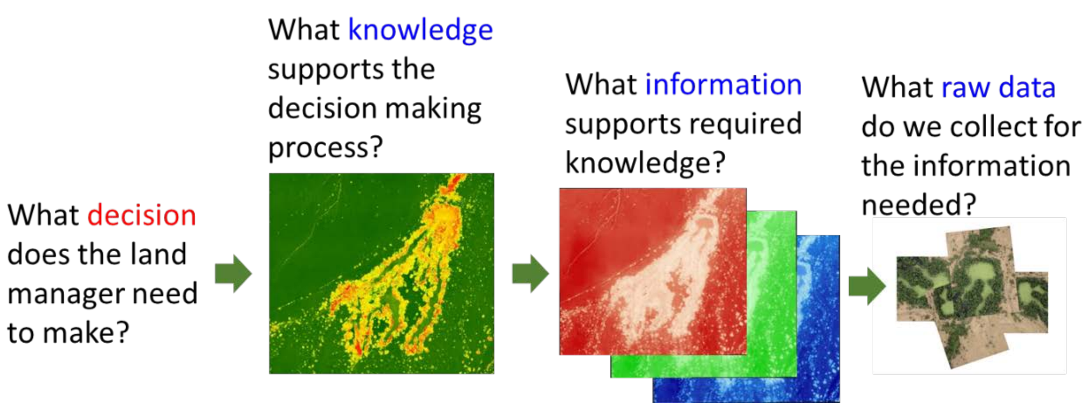

Figure 1. Information hierarchy as it applies to imagery development.

In the example depicted in figure 1, our customer, an intrepid land manager, is struggling with whether or not to continue the XYZ vegetation project. The land manager needs some sort of method of quantifying the health and amount of vegetation over a number of years within that project's area. That quantification requires information based on remote sensing data.

To determine which data source to use, or how to collect the data, we analyze the data based on resolution. Remote sensing data has four resolutions: spatial, which involves the detail, in terms of size, that the data describes; spectral, which involves the types of wavelengths the data represents; radiometric, which describes the range of brightness of the spectral data; and temporal, which describes how often the data is collected.[1]

For our purposes, spatial resolution of remote sensed data ranges from a low of about a centimeter using a sUAS to about 30 meters using the USGS land satellite (LandSat) program. Other easily available imagery include data collected by manned aviation providing spatial resolutions down to about eight centimeters and the National Agricultural Imagery Program (NAIP) providing 1-meter spatial resolution data.[2] There are many more remote sensing sources available, but the above represent the set we most often perform analysis with.

Spectral resolutions are generally referred to in terms of a range of wavelengths called "bands." For instance, the near Infrared band (NIR), or blue band, or infrared band. In this resolution, manned aviation and sUAS have the advantage of changing sensors to meet a customer's spectral needs, whereas satellites do not. On the other hand, the sensors in satellites can capture a rich array of spectral bands. The bands we tend to use the most are red, green, blue (collectively abbreviated RGB), and NIR.

Radiometric resolution is the range of the brightness in each spectral band. Frequently, this resolution is expressed in "bits." An "8-bit" radiometric resolution means that there are 2^8 variations of brightness possible in each spectral band. For instance, a normal point-and-shoot camera has and 8-bit resolution resulting in 256 variations of each spectral band (red, green, and blue). For most remote sensing purposes this is sufficient. Satellites tend to have more radiometric resolution, some with 11-bit resolutions (2,048 variations of each band), and LandSat 8 sporting 12-bit resolution (4,096 variations) in each of its nine Operational Land Imager (OLI) bands and its two infrared bands.[3]

Finally, we have temporal resolution, or how often we collect the data. Temporal resolutions range from daily (or even less) for sUAS and manned aviation to years for some satellite

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[1] James B. Campbell and Randolph H. Wynne, *Introduction to Remote Sensing*, 5th ed (New York: Guilford Press, 2011), 285, 286.

[2] US Department of Agriculture, "NAIP Imagery," page, *Temp_FSA_02_Landing_InteriorPages*, accessed May 21, 2017, https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/.

[3] US Geological Survey, "Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) | The Long Term Archive," accessed May 21, 2017, https://lta.cr.usgs.gov/L8; US Geological Survey, "How Does Landsat 8 Differ from Previous Landsat Satellites? | Landsat Missions," accessed May 21, 2017, https://landsat.usgs.gov/how-does-landsat-8-differ-previous-landsat-satellites.

programs. LandSat 8 provides new imagery every 16 days and the NAIP provides new imagery every three years.[4]

Figure 2 represents a matrix that captures these four resolutions for common and easily available remote sensing sources. Since this analysis deals with practical decision making, we've also included another, practical, "resolution," cost.

Resolution/ Data source	Spatial	Spectral	Radiometric	Temporal	Cost
sUAS	High: 1-4 cm	Varies ~ 5 bands	Normally 8-bit	Immediate	Low
Manned Aviation	High: 8 cm and up	Varies ~ 5 bands	Normally 8-bit	immediate	High
Municipal	High: 8 cm and up	Varies, but normally RGB	Normally 8-bit	Low: Several years	Low
NAIP	Low: 1-meter	Four bands RGB and NIR	8-bit	Low: Three years	Low (free)
LandSat 8	Low: 30 meters	High: 11 bands	12-bit	High: 16 days	Low (free)

Figure 1. Common remote sensing sources and their resolutions.

A number of other factors may influence which data source to use. Manned aviation has more flexibility operating greater distances and in different types of airspace than do sUAS. Some of the data provided by municipal sources may have restrictions on use. Furthermore, in a practical sense, it's difficult to employ sUAS for areas greater than about 1,000 acres.[5]

Since the data sources listed in figure 2 have very little difference in radiometric resolutions, we can safely ignore this resolution in our decision making process. Additionally, unless there is a very specific need for a particular wavelength other than RGB and NIR, spectral resolution can also be ignored as a factor as all of these common sources provide data with those four bands.

We're left with several "critical" factors that will influence how we decide to acquire the data: size of the area we need data for (sometimes called the area of interest or AOI), whether or not sUAS are restricted from flying within the AOI, how often we need the data collected (temporal

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[4] US Department of Agriculture, "NAIP Imagery," page, Temp_FSA_02_Landing_InteriorPages, accessed May 21, 2017, https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/. We acknowledge that the combination of LandSat 7 and LandSat 8 create a "LandSat" temporal resolution of eight days.

[5] Regulatory requirements require a sUAS be within visual line of sight at all times by the pilot in command. This requirement forces a large are to be broken into several smaller flights and then combined. The added flights, planning, and processing may push the cost of these larger projects into a range that manned aviation becomes an option.

resolution), the size of a data cell (spatial resolution), and cost. Based on these factors, we can generate a differential tree (figure 3).

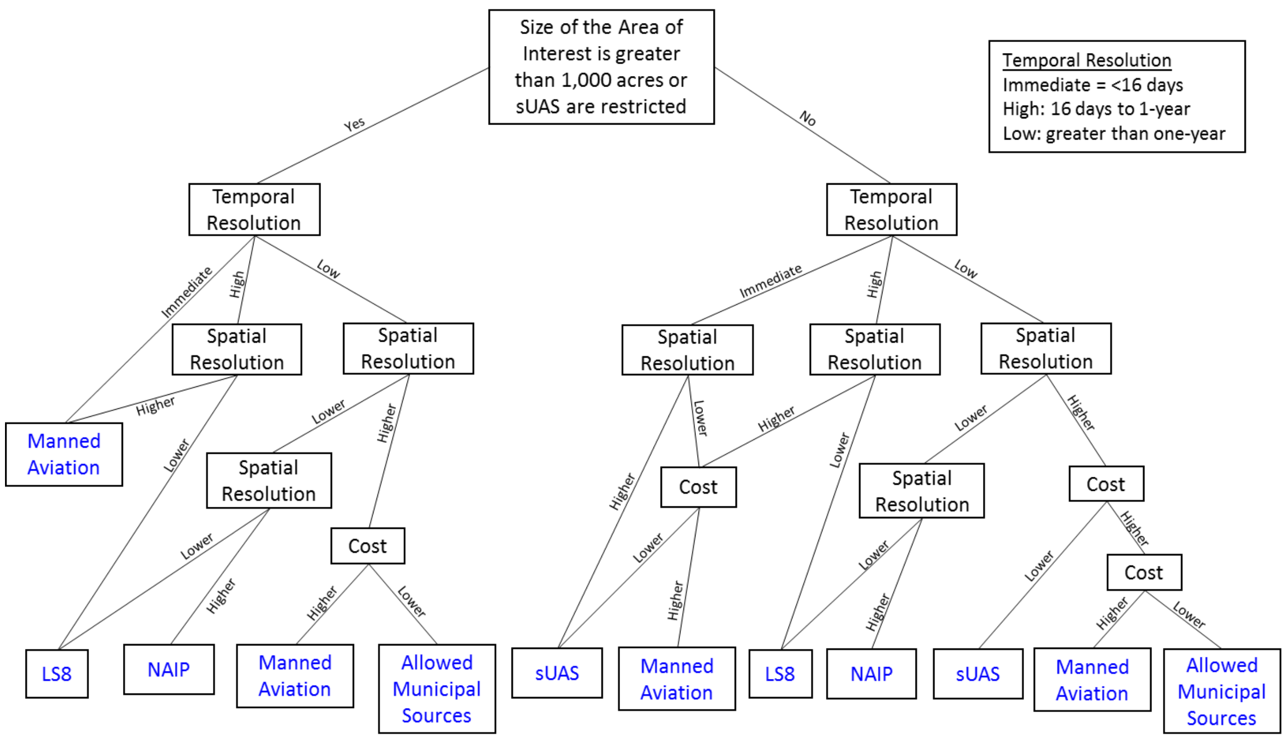

Figure 2. Differential tree.

The tree initially differentiates projects that can be accomplished with sUAS and those that cannot based on size of the AOI or some other regulatory restriction. We then follow the tree based on the temporal and spectral resolution requirements of the data. Finally, cost, where applicable, is included as a differential choice. Using the tree to support the land manager of the XYZ vegetation project, we determine that the project is only about 60 acres and has no airspace restrictions that would preclude a sUAS. We also know that data is required on a yearly basis over several years, so our temporal resolution is “high.” Based on the decision the land manager is trying to make and the size of the AOI, LandSat 8 imagery would have too coarse of spatial resolution, so our spatial resolution is “higher.” The land manager is always trying to save money, so cost is “lower,” leading us to sUAS.

It is very important to remember that the differential tree is designed to determine *how* to collect the raw data based on several critical factors. The *type* of raw data needed is based on the information demanded by the information hierarchy. That’s not to say they are independent of one another, indeed the linkage between the two now becomes obvious. The type of raw data needed informs the differential process to determine how the data is collected. Figure 4 nests the differential process within the decision maker’s information hierarchy.

Figure 3. Differential process nested within information hierarchy.

We've briefly described a two-step approach to collecting remote sensed geospatial data. The first step is determining the type of data needed and the second step is finding the best way to collect that data. Since the type of data informs how we collect the data, we were able to link the two steps. This method provides a rational approach to satisfying part of the information needed for a land manager to make decisions. Returning to our initial example, a land manager may wonder, "Should I continue with our XYZ vegetation program?" To answer that, the land manager needs knowledge of the relative health and volume of vegetation over a period of years. That knowledge can be achieved by comparative analysis of imagery of several spectral bands from each of several years. To that end, red, green, blue, and NIR remote sensed geospatial data is collected, yearly, by the most efficient method.

By no means is this an exhaustive analysis of how to inform a land manager's decision making process. There could be several types of data that could equally satisfy the information required. Here we've only mentioned a quick list of available satellite and airborne sources which provide examples of other, non-sUAS, options; there are dozens more[6]. Additionally, active measurements from LiDAR and manual field techniques can provide key information about elevation and structure not available from passive remote sensors. Nevertheless, it's hoped that what we've provided here will give a land manager at least a process to determine whether or not a sUAS is the right tool for the job at hand.

[6] NASA, "Remote Sensors | Earthdata," accessed May 21, 2017, https://earthdata.nasa.gov/user-resources/remote-sensors; US Geological Survey, "Satellite Imagery | Earth Resources Observation and Science (EROS) Center," accessed May 21, 2017, https://eros.usgs.gov/satellite-imagery.

Sources:

Campbell, James B., and Randolph H. Wynne. *Introduction to Remote Sensing*. 5th ed. New York: Guilford Press, 2011.

NASA. “Remote Sensors | Earthdata.” Accessed May 21, 2017. https://earthdata.nasa.gov/user-resources/remote-sensors.

US Department of Agriculture. “NAIP Imagery.” Page. *Temp_FSA_02_Landing_InteriorPages*. Accessed May 21, 2017. https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/.

US Geological Survey. “How Does Landsat 8 Differ from Previous Landsat Satellites? | Landsat Missions.” Accessed May 21, 2017. https://landsat.usgs.gov/how-does-landsat-8-differ-previous-landsat-satellites.

———. “Landsat 8 OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) | The Long Term Archive.” Accessed May 21, 2017. https://lta.cr.usgs.gov/L8.

———. “Satellite Imagery | Earth Resources Observation and Science (EROS) Center.” Accessed May 21, 2017. https://eros.usgs.gov/satellite-imagery.