UAVs for Collection of Farm Imagery

by Lee Johnson and Stan Herwitz
NASA-Ames, UAV Applications Center
Mountain View, Calif.

In 1938, on the occasion of the 34th anniversary of the first flight, Orville Wright was asked how far he thought airplanes would be developed. He replied, "There is no way of telling. Things are moving too fast. No one can predict where it will end."

It's a bird..., it's a plane..., it's a UAV!

Aerial images are increasingly being used by farmers to support "precision" agricultural management. At a minimum, imagery can be used to map relative differences in crop vigor and serve as a guide to field sampling efforts. In California premium winegrape vineyards, images have been combined with field data and models to map leaf area, vine "balance" (leaf area to fruit weight ratio), and evapotranspiration (see for example - http://geo.arc.nasa.gov/sge/vintage/vintage.html).

Light aircraft and more recently, high-resolution commercial satellites, are the workhorses for image collection. However, there is a veritable revolution ongoing in aeronautics with regard to development of unmanned aerial vehicles (UAVs). Among the performance capabilites offered are slow flight speed, high altitude, and long duration. These airframes, which are currently gaining much attention in the military arena, are set to compete for operational niches in the civilian sector.

In a demonstration project sponsored by NASA's earth science remote sensing applications program last August, a small UAV was used to collect imagery over the 5000 acre San Bernabe vineyard near King City, California. The aircraft, which is under development by RnR Products (Milpitas, Calif.) and Lockheed-Martin, can remain aloft for up to 8 hours at 45 mph, with an altitude ceiling of 9,000 ft and top speed of 90 mph. Minimal runway (or, roadway) clearance is required for takeoff and landing operations, and the craft can be partially disassembled for transport by small pickup truck. An autopilot system, developed by MLB Inc. (Palo Alto, Calif.), enables the aircraft to automatically negotiate a course defined by a number of pre-specified waypoints (geographic coordinates) that can be updated "on the fly" by ground personnel, and of course is necessary for flight operations beyond visual range. The UAV as configured supports a payload of appx. 11 pounds and drawing up to 40 watts of power.

The imaging payload for this flight was built around a small one-megapixel color camera from Basler Vision Technologies. A wireless communication system was designed to control the camera and downlink imagery directly to the farm within moments of collection. The payload included a transponder and altitude encoder to enable supervision by FAA Air Traffic Control. The entire package, including camera, on-board flight computer, GPS, transponder, and telemetry system, was integrated into the UAV payload bay (Figures 2, 3).

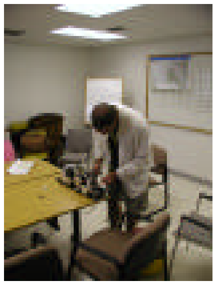

Figure 2. Final payload preparation

Figure 3. Payload integration onto UAV

A wireless network of ground-based air temperature sensors was deployed during the flight. The sensors were positioned at several locations throughout the vineyard, monitoring air temperature data every 10 sec during the flight period. Temperature data were collected both from top of canopy and from below canopy in the fruit zone. A total of 165 images were collected during a one hour flight, at a high spatial resolution of appx. 8 inches (Figure 4). Several images were registered to the grower's GIS and to the ground-based sensor web (Figure 5). Post-processing was performed to separate the images into vegetation and soil components, and subsequently to calculate *vigor* in terms of percent vegetation cover (Figure 6).

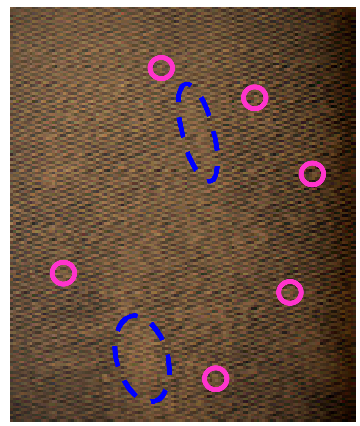

Figure 4. Image of 10 acre vineyard. Areas of weakness and missing vines circled.

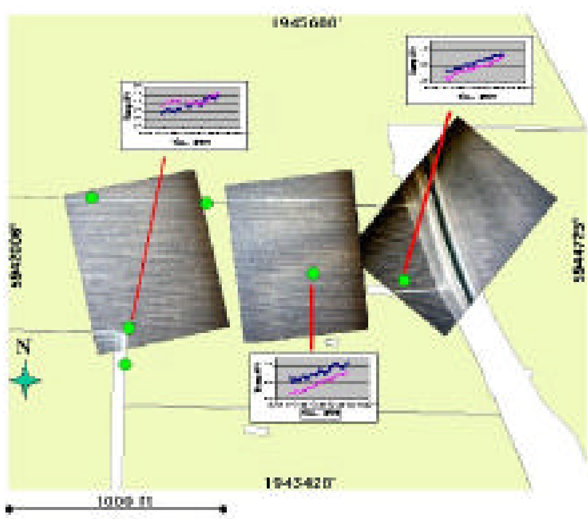

Figure 5. Vineyard canopy images aligned with ground-based sensor web (green circles), and superimposed on grower's GIS. Time-series of air temperature data from top-of-canopy (blue traces) and lower canopy fruit zone (purple). Map projection Calif. State Plane.

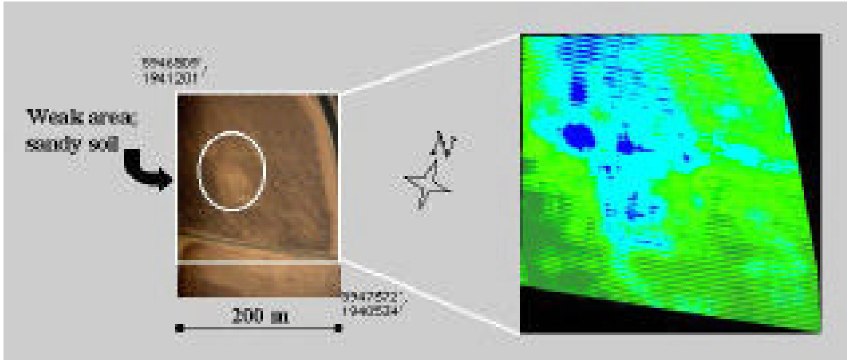

Figure 6. Left) Color image of 10 acre vineyard at degraded resolution. Right) Corresponding vigor map: dark blue = 35-40% cover; light blue = 40-45%; light green = 45-50%, dark green > 50%.

At the current time, total aircraft cost is around $40,000 including autopilot system and ground station. The developers estimate that, in the future, this number could decline by at least 50% through mass production. An experienced radio-control pilot is needed for takeoff and landing operations; additional personnel training investment is needed to operate the autopilot software interface. The 200 mpg gasoline engine (a variant of those used in consumer equipment such as chain saws and leaf blowers) has a nominal service life exceeding 1000 hours and may be replaced for about $800. Many of the aircraft parts are off-the-shelf components sold to the radio-control airplane market, and are thus reliable, inexpensive, and readily available. It is likely that these aircraft will ultimately be operated by dedicated service providers, as is generally the case in the agricultural remote sensing market today. Given the elements of a favorable fixed and operating cost structure as outlined above, one might expect that final delivery prices for imaging services will be highly competitive with those now delivered by satellite and conventional aircraft.

Further UAV advancements, along with continued refinement of imaging and communications systems, will potentially offer a *cost-effective* and *flexible* alternative for agricultural and other user communities requiring rapid delivery of high-spatial resolution pictures. Technology R&D will need to be combined with development of FAA guidelines facilitating routine UAV access to the US National Airspace System. [email contact: Ljohnson@mail.arc.nasa.gov]