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Remote Sensing Systems for Monitoring Ecosystem / Landscape Change

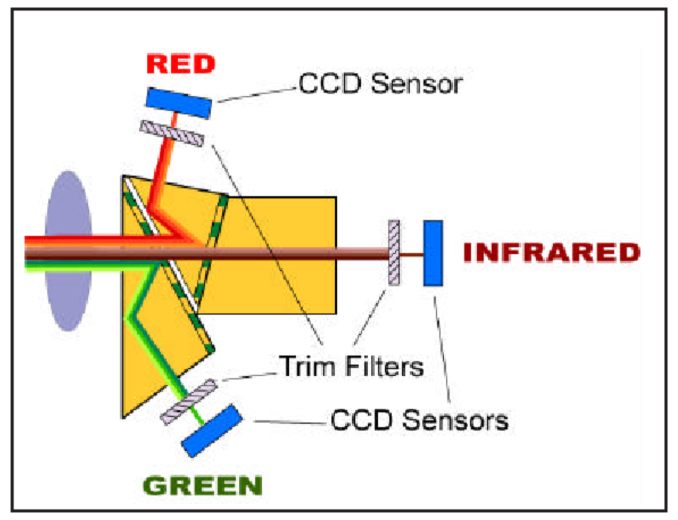
by Rian Bogle, Miguel Velasco, and John Vogel USGS Flagstaff Science Center

Introduction

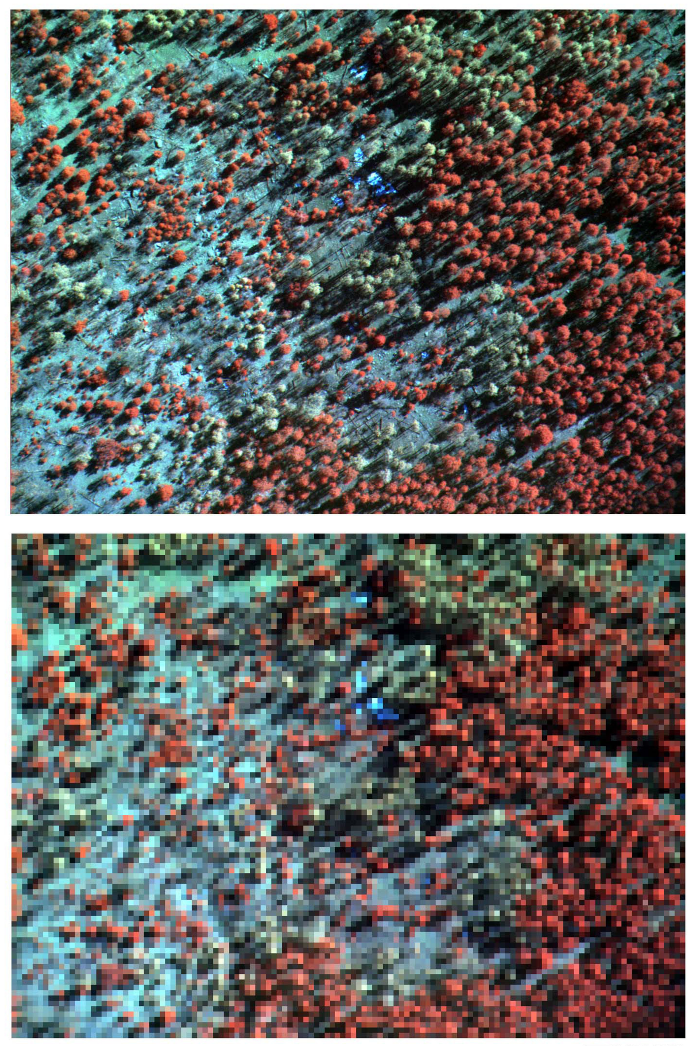
While the application of remote sensing technology has grown rapidly over the past several decades, there are shortcomings in the technology that prevent its widespread use in a broad class of problems. In the domains of Natural Hazards, and Short Lived Natural Events existing sensing platforms often cannot provide the high temporal resolutions and rapid on demand targeting that are necessary to study and track the causes and effects of short-term events. In the domain of Landscape/Ecosystem Monitoring and Resource Management, often small budgets and scarce resources prohibit the use of high spatial resolution data to do frequent, focused, repeatable or automated data collection and analysis. Methodologies and technologies that can fill in the temporal resolution, targeting, and cost, have the potential to open a wealth of new information for a broad spectrum of earth science and its understanding of many aspects of climate and landscape change. The USGS Southwest Geographic Science Team in Flagstaff, Arizona, has designed and developed several systems and instruments to help address these needs.

Airborne Imaging System

The acquisition of aerial photography, and conversion to a digital format, has traditionally been a slow and costly process. With the advent of relatively inexpensive digital cameras and computer systems, along with GPS positional information, an opportunity has arisen to reduce the cost and time involved in digital image acquisition. Because of a need to monitor short-lived events and long-term trends, we designed and built a rapid response, low cost, digital aerial imaging system, and have been flying it for 6 years. This system, based around a Duncantech MS3100 CIR Multi-Spectral camera, can be deployed in a matter of hours, and enhanced digital photos can be viewed in real time as they are collected or within minutes after landing.

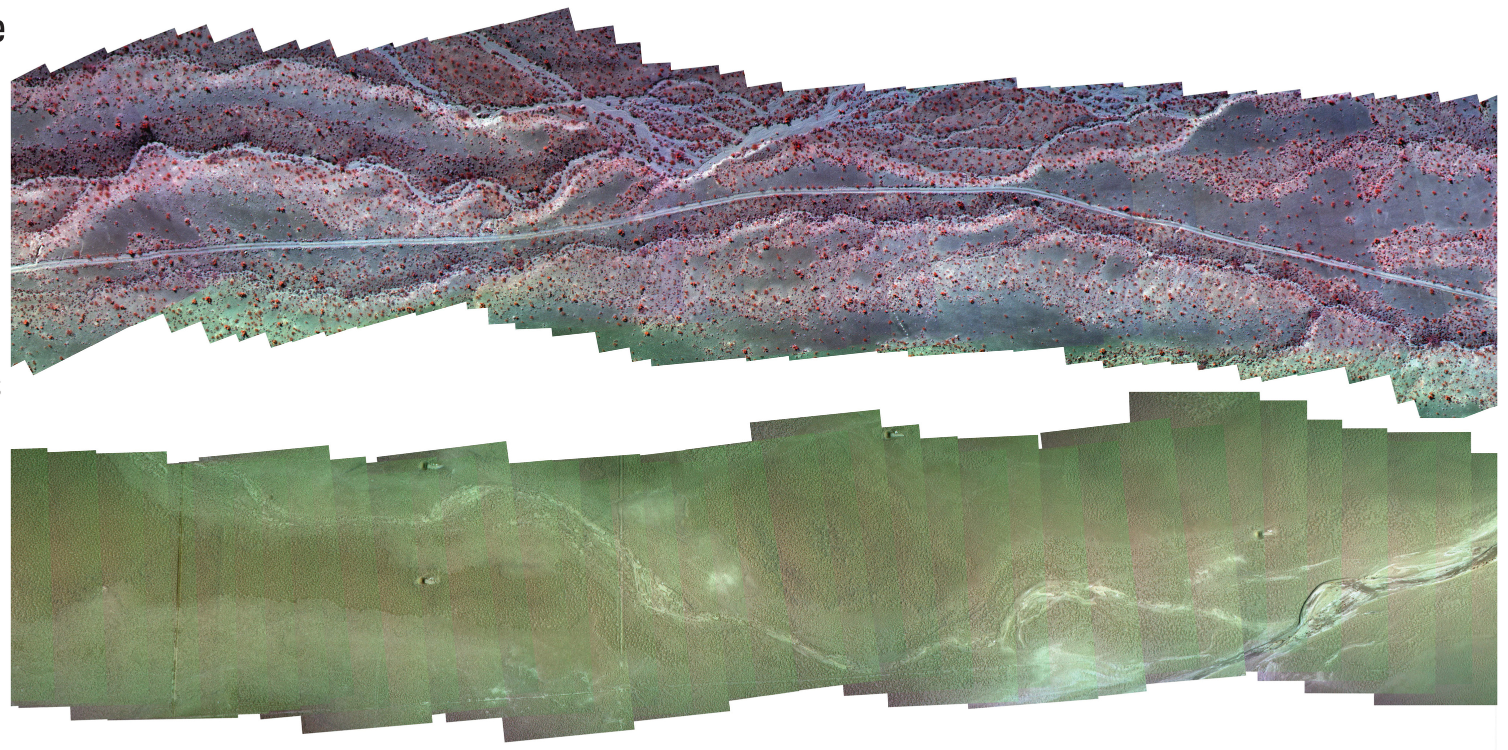


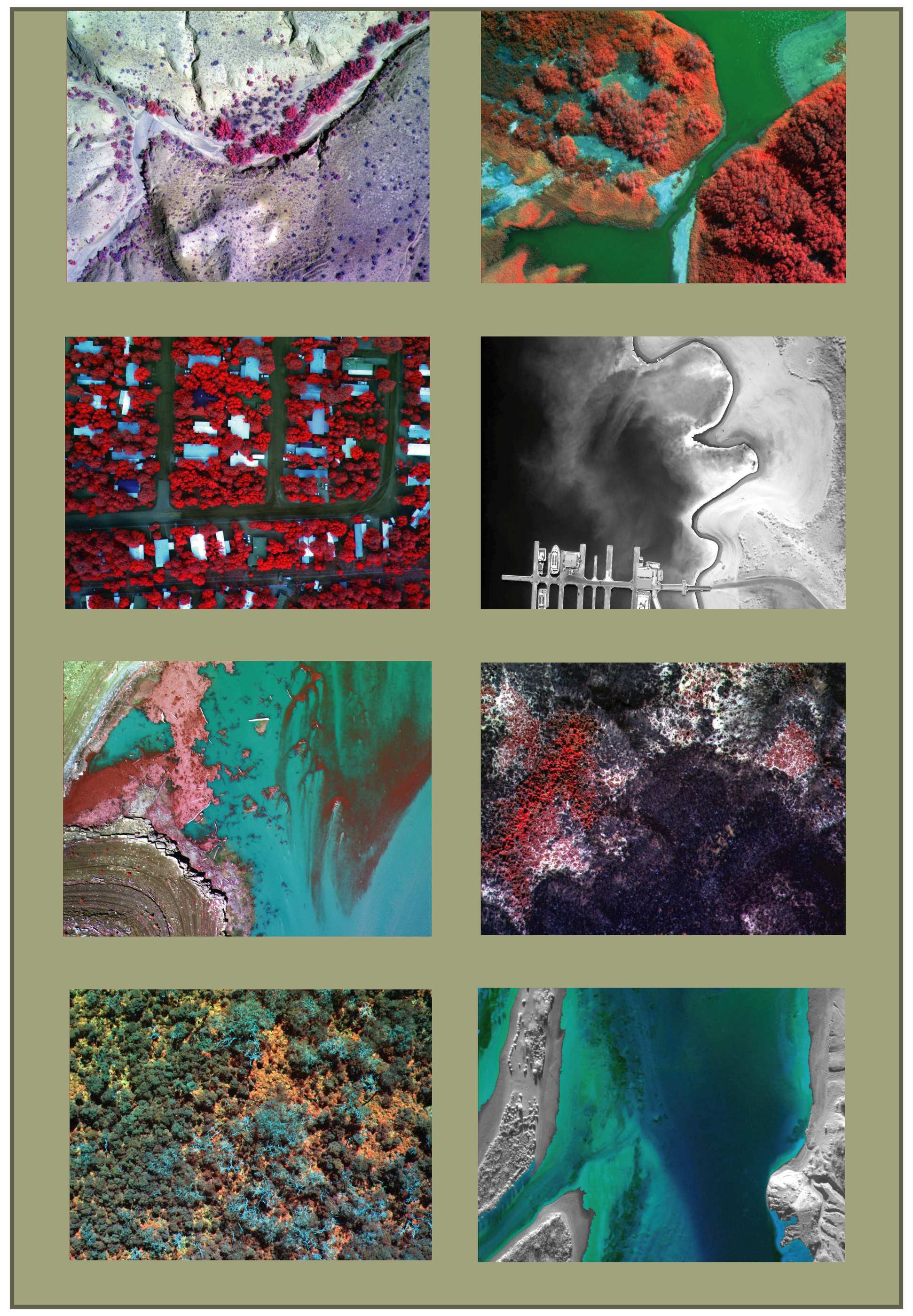
The Duncantech camera used in our system is a 3CCD system with independent gain controls for each CCD, which allows the use of different gains for each of the three bands. For example, high gain can be used for one of the bands to optimize clear water penetration while leaving the other two bands at normal gain settings. The camera has a resolution of 1392x1040 pixels per band, and has a 10-bits per band dynamic brightness range. Two to four images can be captured per second, allowing for flight speeds of 40 to 70 knots. Our typical flight altitude is 150 to 600 meters yielding image resolutions ranging from 0.05 to 0.25 meters per pixel.


Pixel resolution comparison
.2-meter (top) vs 2-meter (bottom)

This system has been used for a wide range of applications: from monitoring short-lived events, such as sediment re-suspension in coral reefs, to monitoring sand migration in streams using change detection techniques, to detecting invasive plant species along commercial-wilderness land corridors. The infrared band allows applications in monitoring plant stress health, such as bark beetle infestations. This system has also proven effective at repeat transect monitoring, or mapping in areas that are difficult for a traditional air survey to image, such as tropical forests with high altitude cloud coverage or steep and remote canyons.

Our current work with the system involves integrating the existing GPS information for each image with roll, pitch and yaw data for each image to allow us to ortho-rectify and mosaic these images much more accurately and quickly. Future work involves the miniaturization of the system so that it can be deployed on unmanned aerial vehicles for even more automated rapid response applications.



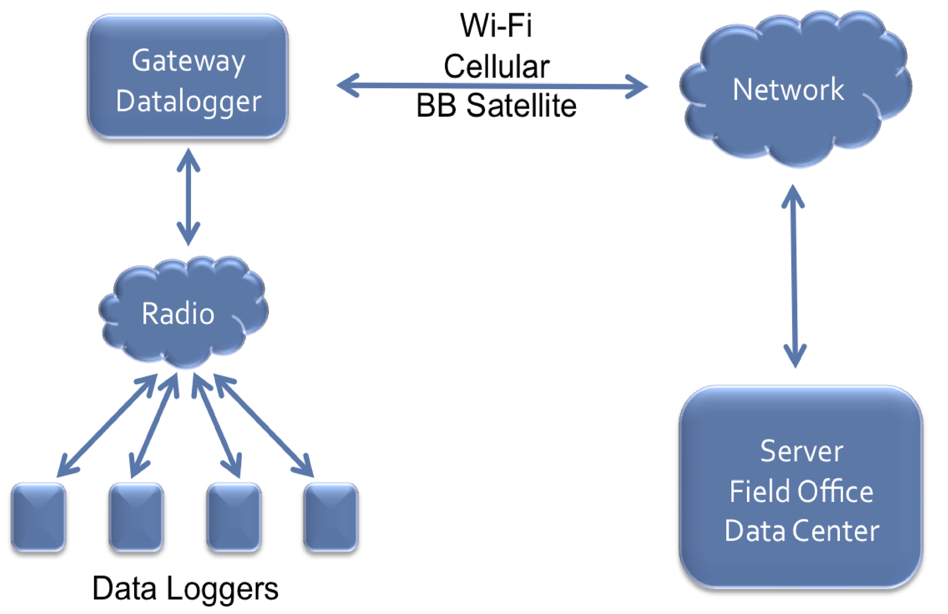


A low cost, rapid response imaging system is achievable with today's technologies. Our system has been successfully deployed on scores of flights around the US ranging from marshlands in Florida, to deserts, forests and canyons of the southwestern US, and rain forests in Hawaii. In every instance, we were able to optimize the camera settings and time of imaging for our project needs with minimal cost and time delays. This combination of hardware and software has allowed us to image remote places with a high level of quality control on the images, and to deliver important information quickly to scientists, land-managers and decision makers at very low costs.

In-Situ Camera Systems

The primary motivation for the development of our system was the need to place high-resolution digital cameras in remote locations in order to monitor and study environmental changes over time. When coupled with environmental sensors recording parameters such as wind, or soil moisture, cameras should be able to respond to changes in local conditions, as well as capture images under a scheduled regime.

While many study scenarios need a single station comprised of environmental sensors and a camera, a distributed 'network' of sensor stations and cameras, which can communicate and coordinate actions with each other over a wider area, might better serve other scenarios. Thus we wanted to develop a system, which could have the capability to wirelessly communicate sensor to sensor, as well as from the field to the home network. When communication infrastructure is available or feasible, we wanted stations to have the capability to be monitored, maintained, and updated remotely as well as to enable stations to automatically upload their data to servers on the home network.



Utilizing combinations of low-cost embedded Linux computers, commercial data loggers, cellular modems and radio frequency systems, these systems have allowed for the placement of networks of field-based digital cameras and environmental/weather monitoring stations in remote locations. With these systems we are not only able to update and maintain the stations remotely, reducing costs in physical maintenance and data collection, but also monitor landscapes in near real-time, retrieving high-density data (such as high-resolution images) on demand or on regular automated schedules in a secure manner.

Current and future work is focused on further developing web and command-line interfaces for administering and configuring the field systems, developing server-side support software for processing data as it arrives from the field, and developing and testing further the use of remote wireless networks of sensors. Future evaluation of new cameras and sensors will be necessary as commercial product lifecycles come to an end.

The system we have developed thus far has allowed us to collect valuable data on the occurrence of dust storms in the Mojave Desert and monitor coral reef health in the Hawaiian Islands. Similar deployments have been arrayed around the Salton-Sea to monitor dust sources, in Guam to monitor sediment run-off from a major river, and the Grand Canyon to study the ecological effects of various river flow regimes. In each of these cases, current traditional remote sensing technologies are unable to provide the information that we need, and so our system fills a niche in that technology gap.

Contact Info:

Rian Bogle
US Geological Survey
2255 N Gemini Dr
Flagstaff, AZ 86001
928 556 7212
rbogle@usgs.gov