Full-Field-of-View Geodetic Target Range

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Introduction

A major impediment to widespread use of multispectral scanner imagery in commercial applications, such as precision farming, is aligning individual picture elements ("pixels") with their true locations on the Earth. This process is called "geolocation," and many organizations have developed various hardware and software methods to accomplish it. The only way to verify the accuracy of geolocation methods is to know the exact locations of ground features that are identifiable in the imagery and compare them to the locations predicted by the geolocation method. The best way to achieve consistency from one method to the next and minimize test program costs is to establish a target range with the following characteristics:

- Large areas of land (on the order of several kilometers).
- Each large area of land has a different terrain: flat, moderate, and steep
- As many cloud-free days as possible.
- Standard targets scaled in size to match the sensor's ground sampling distance (GSD).
- Targets located throughout the entire field of view and along the aircraft or satellite ground track.
- Targets located to correspond with anticipated error sources (for example, along-track and across-track).
- Targets precisely located with respect to the Earth (for example, target centers placed within 10 centimeters of their true location).
- Portable targets to minimize impact to the land and keep coordinates confidential.

The NASA Commercial Remote Sensing Program (CRSP) Verification & Validation Team is working in cooperation with the Hopi Nation to establish a Full-Field-of-View (FFV) geodetic target range that will allow sensor developers and operators to test the ability of global positioning and inertial navigation hardware and image processing algorithms to accurately predict the geographic position of pixels. The geodetic targets will be visible, identifiable, and strategically distributed throughout the entire field-of-view of an airborne or spaceborne imaging system. Figure 1 gives an overview of the Full-Field-of-View Target Range Project.

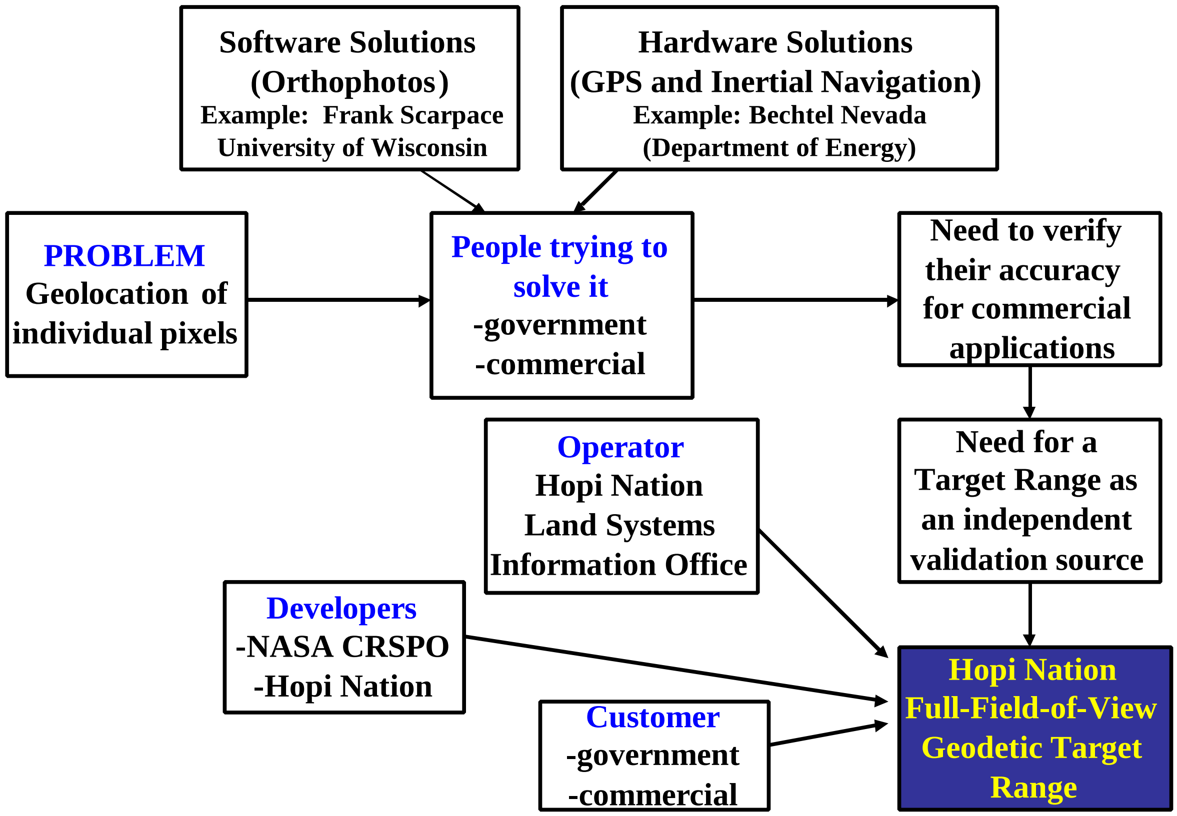

Figure 1. Overview of NASA/Hopi Nation Full-Field-of-View Geodetic Target Range Project.

The Importance of Geolocation

One of the many problems that geolocation errors create for image analysts is illustrated in Figure 2. The image in Figure 2a represents an orthorectified aerial photograph, or "orthophoto," in which all the ground features are precisely located within the image. This image is accurate enough to use as a map for measuring distances. So, we can use an orthophoto as a reference and assume it to be true, compared with the airborne scanner image in Figure 2b. The green cursor in both images is centered on the same geographic location, according to the computer. However, the scanner imagery classifies the chosen pixel as vegetated land, rather than water. The geolocation error in this example is about three pixels, or ten meters. Knowing this information, we could easily correct the location of this single pixel manually by entering the correct geographic coordinates.

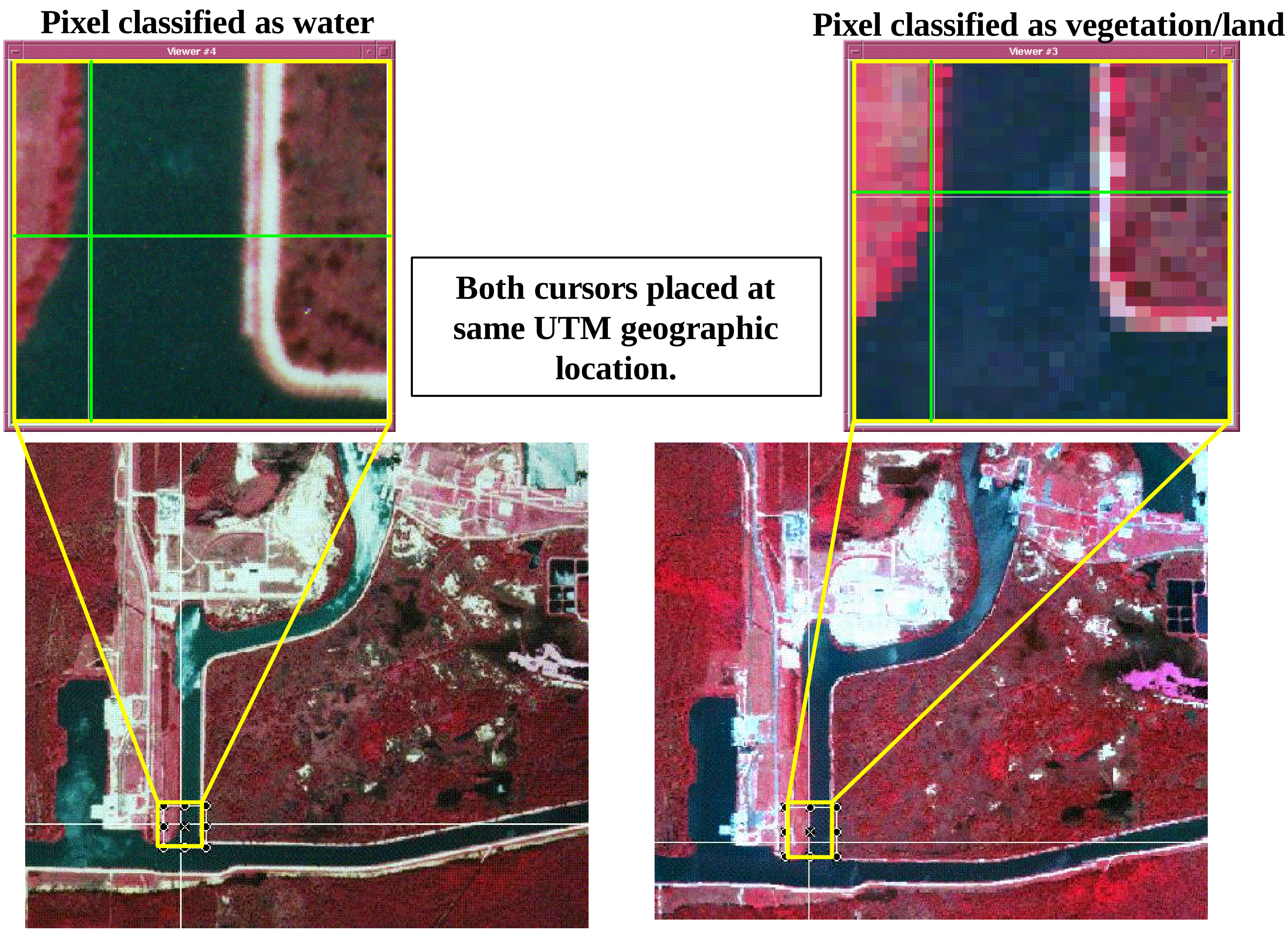

Figure 2a. Orthorectified aerial photograph.

Figure 2b. Across track scanner imagery.

The NASA Airborne Terrestrial Applications Sensor (ATLAS) collects over a half-billion pixels per year. One of CRSP's many commercial partners collects imagery of a half-million acres of farmland twice a week during the growing season. Another CRSP commercial partner is in the process of classifying land cover over the entire earth using 30-meter by 30-meter pixels from satellite imagery. Though this company has a reliable method of automatically geolocating these pixels, they will eventually need airborne multispectral scanner imagery of selected areas around the world to help validate their land use classification products. The vast quantities of geospatial data now being collected for commercial, government, and scientific use provides a huge incentive to develop more accurate and automatic geolocation methods and put them into operation as soon as possible

The accuracy and repeatability required of today's commercial airborne multispectral scanner data provide yet another incentive. For example, precision farming (NRC, 1997) seeks to scale customized farming practices down from acres to square meters. Applying fertilizer, herbicides, pesticides, and seeds in the exact amounts that they are required reduces chemical costs and damage to the environment, while increasing yield and profit. Remotely sensed imagery provides a key piece of information that makes precision farming possible (Moran et al., 1997). Now that the farmer is working with variable rate seeding, chemical applications, and harvesting technologies on a scale of ten meters, the typical geolocation errors found in airborne multispectral scanner imagery (10 to 100 meters) can cost the farmer money rather than save him money. Also, because the value of remotely sensed imagery is in monitoring the development of crops during the growing season, it is imperative that pixel geolocation be repeatable, to avoid showing changes that are not really happening and overlooking those that are (Moran, 1998).

Geolocation errors in typical multispectral imagery could have a dramatic impact on environmental applications of remotely sensed imagery. For example, an error of 50 meters in favor of a developer could result in destroying the habitat of an endangered owl. However, a 50-meter error in favor of the owl could cost a developer millions of dollars. Little or no geolocation error would result in wins for both the owl and the developer.

NASA-Hopi Nation Cooperative Effort

The proposed Full-Field-of-View (FFV) Target Range will be a cooperative effort between the Hopi Nation and NASA Stennis Space Center because of strong mutual interest and potential benefits to both parties (Figure 3). NASA CRSP contracted with Professor Frank Scarpace of the University of Wisconsin at Madison to develop a "software solution" to the geolocation problem (Scarpace, 1998).

Over the past five years, the Hopi Nation has established a Land Systems Information Office to study its vast holdings (two million acres) and provide the Tribal Council with critical information to help them make land management decisions. The Office is run by Phillip Tuwaletstiwa, a nationally recognized authority in geodesy and surveying. Their GPS survey equipment is state-of-the-art in accuracy and speed. The Office has installed a high-precision geodetic network throughout the reservation, enabling them to survey any location on the reservation with the highest accuracy achievable. The Office employs enough full- and part-time people to perform the GPS surveys and target fabrication required to build and maintain the FFV Target Range. They also conduct training for students and other members of the Hopi Tribe who want to work on specific projects.

Figure 3. Gayl Shingoitewa-Honanie, Frank Scarpace, and Mohamed Mohamed (Lockheed Martin Stennis Operations) discuss target design and placement.

The Hopi Nation owns vast tracts of flat, relatively secure land with ideal atmospheric conditions (Figures 4 and 5). Besides allowing NASA to validate geolocation claims of commercial data providers, the FFV Target Range is of particular interest to the Hopi Nation. Automatic pixel geolocation of remotely sensed imagery is especially important in rangeland management applications, where there are few identifiable ground features.

Weather
- **50% cloud-free days per year**
- **8 inches of rainfall per year**
- **52% (6 am) average relative humidity**
- **28% (6 pm) average relative humidity**

Ground Cover
- **20% vegetation composition**
- **Soil composition is sedimentary**
- **Bedrock (Moenkopi Formation) with 20% windblown sand**

Terrain
- **4,856 feet above sea level**

Figure 4. General site characteristics of Hopi Nation lands.

Figure 5. Remote sensing/geographic information systems specialists from the Hopi Nation and NASA CRSP work with a botanist and surveyors from the Hopi Nation during ground truth exercises. Note the typical land characteristics and atmospheric conditions.

The proposed location for the first FFV Target Range is at the Clear Creek Ranch, just south of Winslow, Arizona (Figure 6a-d).

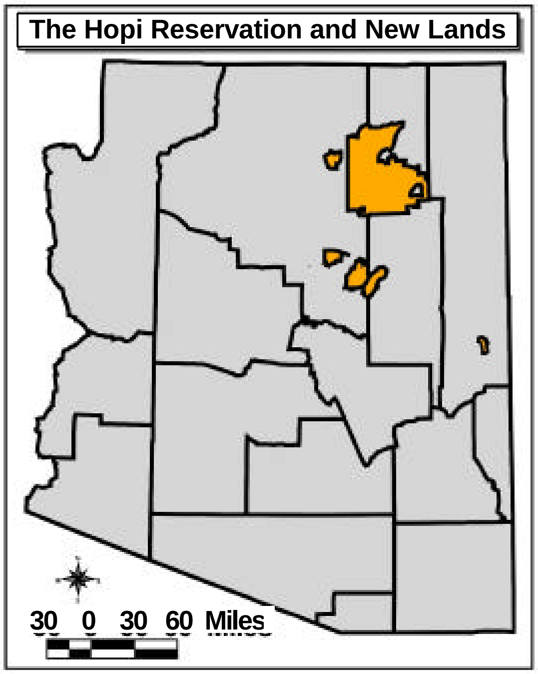

Figure 6a. The Hopi Reservation and New Lands in Arizona.

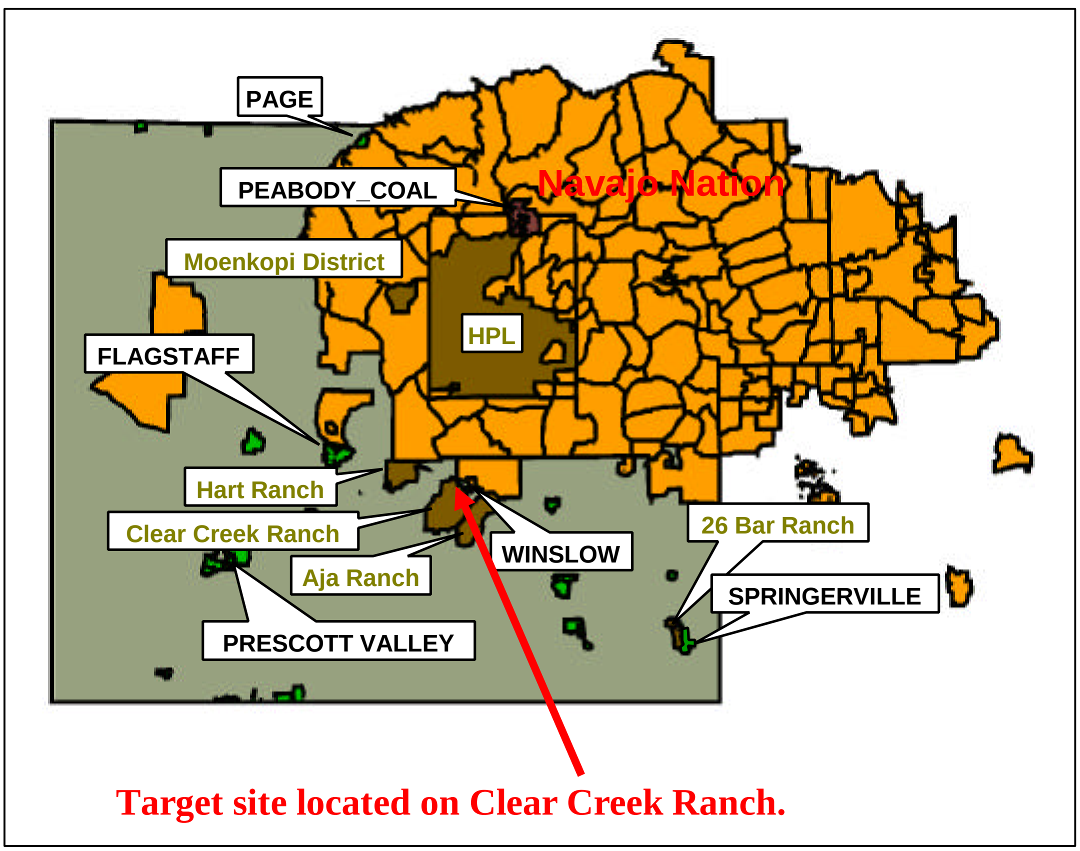

Figure 6b. Regional map of Hopi Nation lands.

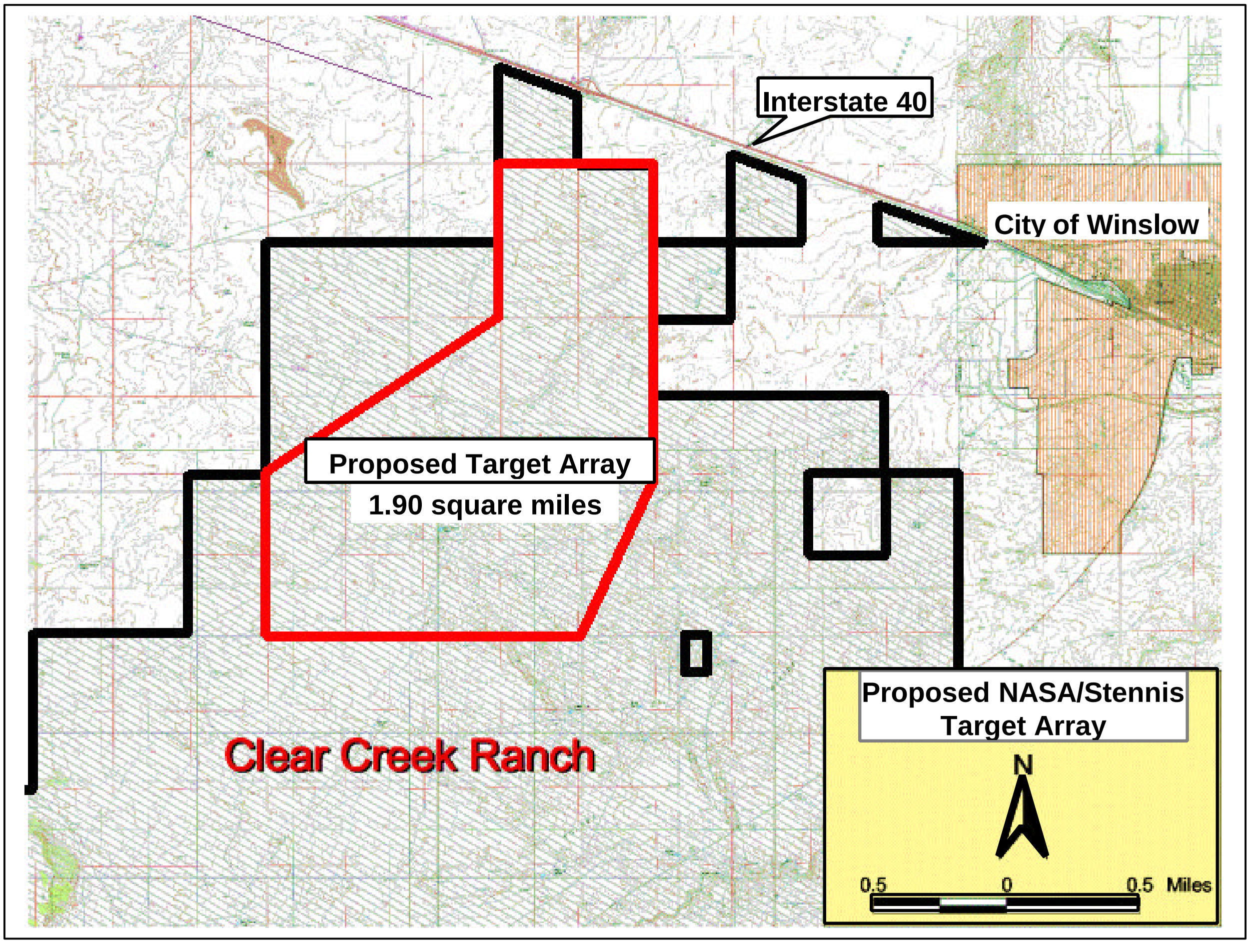

Figure 6c. Proposed FFV Target Range at the Clear Creek Ranch.

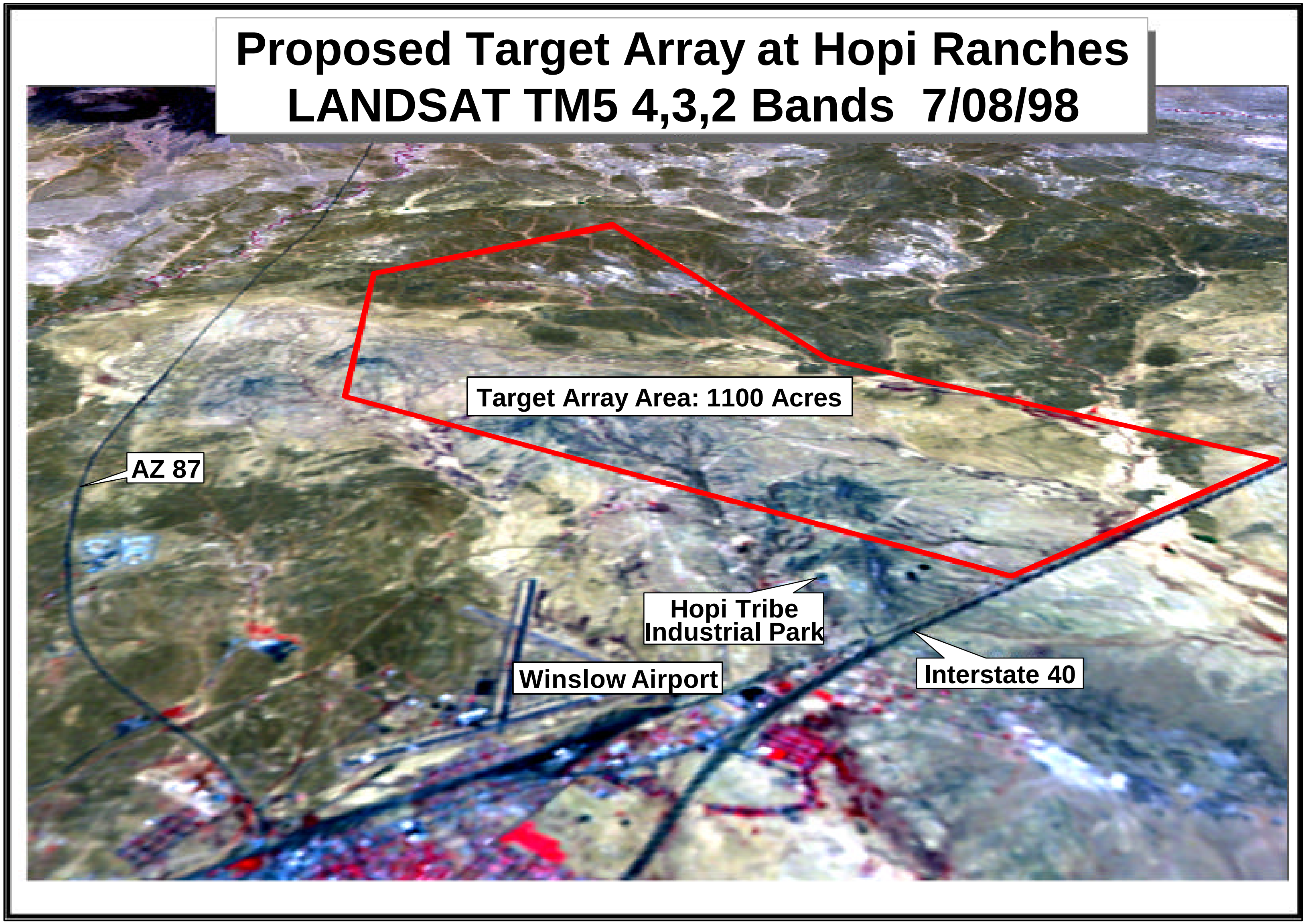

Figure 6d. Aerial view of the proposed FFV Target Range site.

Target Design

The preliminary design of the FFV Target Range is based on validating the software method being developed at the University of Wisconsin. Two types of targets are needed for this particular method: Imagery (Figure 7) and Aerial Photograph Control (Figure 8).

- **Entire solid white background.**
- **Crossbars are solid black**
- **Crossbar dimensions: 0.5 meter wide X 1.5 meters long**
- **5-meter radius**
- **Rotates about center.**

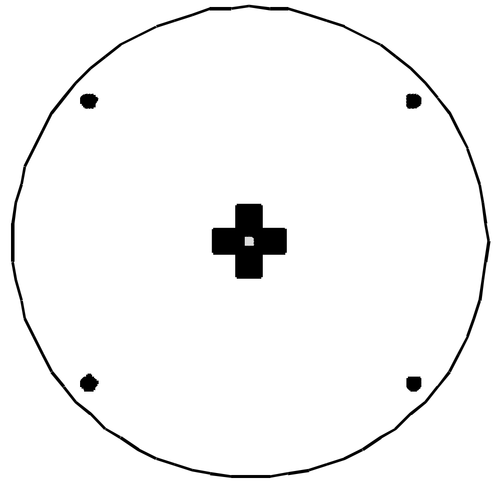

Figure 7. Proposed Imagery Target.

- **Entire background is black.**
- **Center box and crossbars are solid white.**
- **0.5-m X 0.5-m center box.**
- **Each crossbar 0.5 m X 1.5 m**
- **Rotates about center.**

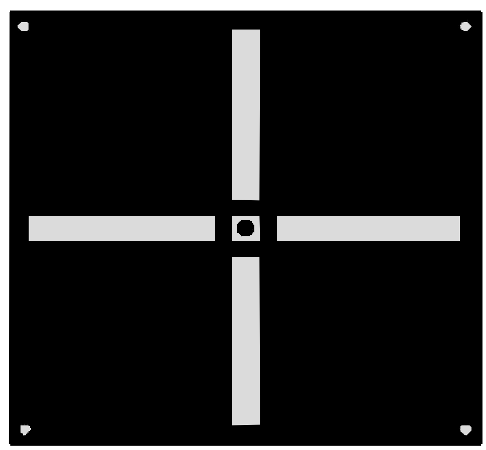

Figure 8. Proposed Aerial Photo Control Target.

The proposed distribution of the targets is shown in Figure 9. This first version of the FFV Target Range is designed for airborne multispectral scanners (with aerial mapping cameras) flying at altitudes resulting in a GSD of about 3 meters. Geolocation methods are fairly well established for medium and coarse resolution imagery (10 to 30-meter GSD), and they can use existing identifiable ground features with great success. As the GSD begins to approach the accuracy of the GPS survey methods (0.1 to 1 meter), we are less confident in the accuracy and repeatability of the method, and natural ground features become less useful.

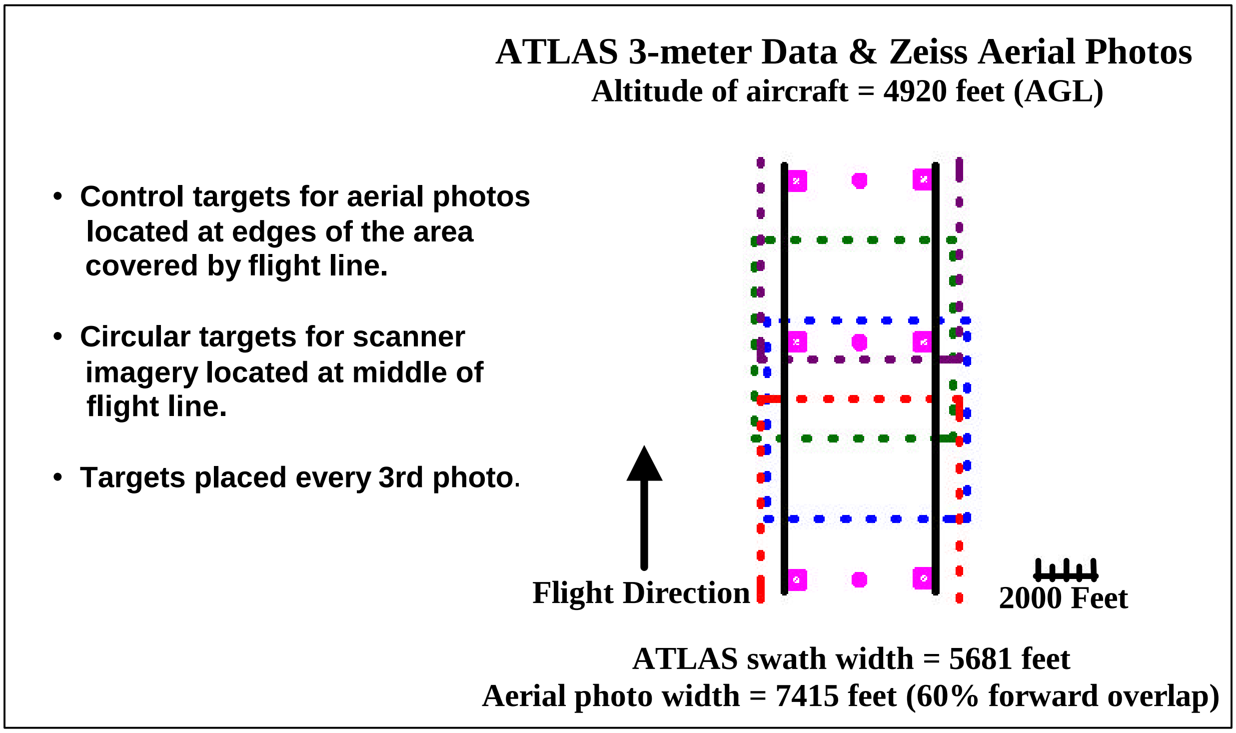

Figure 9. Proposed distribution of targets. The different colored dashed lines represent successive photographs along the aircraft track.

Development Schedule

The schedule for the first proposed use of the FFV Target Range is as follows:

• **Requirements Complete**	**October 1, 1998**
• **Target Fabrication**	**October-November 1998**
• **Identify Non-NASA Development Test Participants**	**October-November 1998**
• **Target Placement**	**November 1998 or March 1999**
• **Test Flight**	**November 1998 or March 1999**

Any commercial or government remotely sensed data provider will be welcome to participate in this first test. We will make the GPS coordinates of the targets available through our DCMDS (Robinson and Farve, 1998) and coordinate flight schedules, weather information, and target availability with all participants. Contact the NASA CRSP Verification and Validation Program Manager if you are interested in participating in this program or have suggestions or recommendations on how we can make the FFV Target Range more useful.

References

Moran, M. S., Y. Inoue, E. M. Barnes, 1997. Opportunities and Limitations for Image-Based Remote Sensing in Precision Crop Management, *Remote Sensing of Environment*, 61:319-346.

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