
Unmanned Aircraft Systems (UAS) at the Jornada Experimental Range

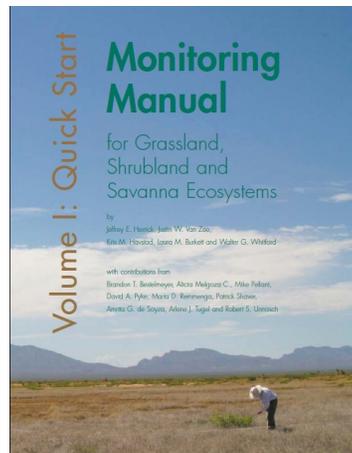
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The challenge for land management agencies

- Most land management agencies (for example, in the U.S., agencies like the Natural Resources Conservation Service (NRCS), Bureau of Land Management (BLM), and the U.S. Forest Service (USFS)) have enormous amounts of rangeland to monitor and manage
 - The status and condition of the vegetation/soil complex of these public lands must be assessed and reported on a regular basis
 - At the same time that much is required of the land management agencies, personnel and resources to do the job are seriously declining, as is true around the world
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Why is high resolution remote sensing needed?

- Increased precision of estimates of key rangeland indicators requires increasing the number of plots or transects that can be sampled
- When combined with satellite images and air photos, UAS images facilitate integration of landscape-scale indicators that cannot be assessed with field plots alone.

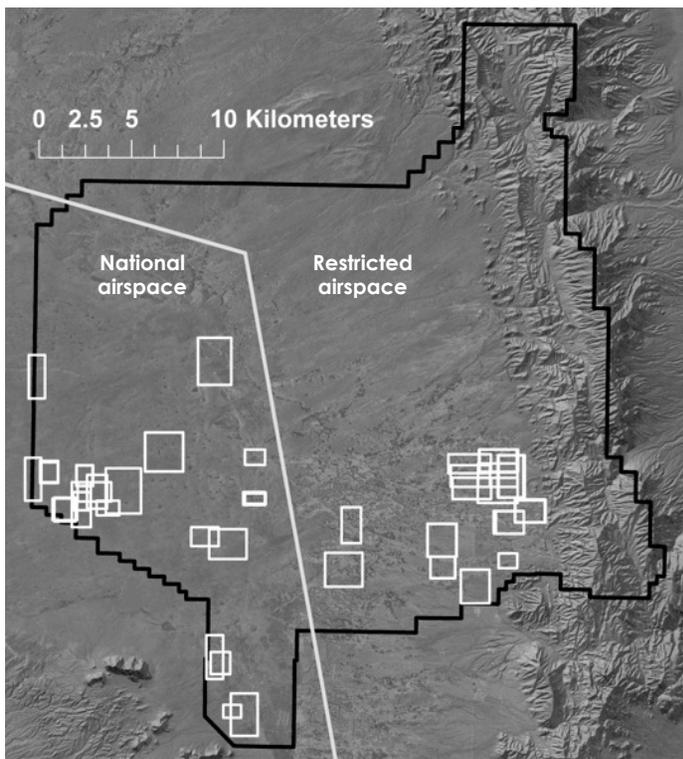


Line-Point Intercept



Gap Intercept

The primary test site is at the USDA-ARS-Jornada Experimental Range north of Las Cruces, NM. The advantages of this test site include that it is virtually unsettled, has little air traffic, possesses a long period of record (approx. 100 years), has over 6,000 aerial photos from 1936-present and numerous satellite images, such as, Landsat and ASTER, due to persistent clear skies. We are able to fly our UAVs there in the FAA National Airspace System thanks to our MOU with New Mexico State's Physical Science Lab Flight Test Center and in Restricted Military Airspace of the White Sands Missile Range. Because the two types of airspace are present at Jornada, we have become adept at flying in both the National Airspace and Restricted Airspace. We have also flown at test sites at ARS Reynolds Creek, ID and ARS Walnut Gulch, AZ.



- Operated 2 BAT-3 UAVs since 2006
- Acquired >25,000 images, 75 image mosaics
- 5-6 cm pixel resolution when flying at 215 m

Airspace at the Jornada Experimental Range,
783 km²

Then, what are the steps necessary to fly in FAA-NAS?

1. **Qualifications, Exams, Training** (Examples)

- FAA Ground School (for external and internal pilots)
 - Second class or higher FAA airman's medical certificate
 - FAA Private Pilot's License (Pilot-in-Command) (not always required but very useful)
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2. **Application for Certificate of Authorization (COA)**

- Ownership of UAV by public government entity
 - Submit COA application with a 3-4 month waiting period
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3. **Flying the UAV** (Examples)

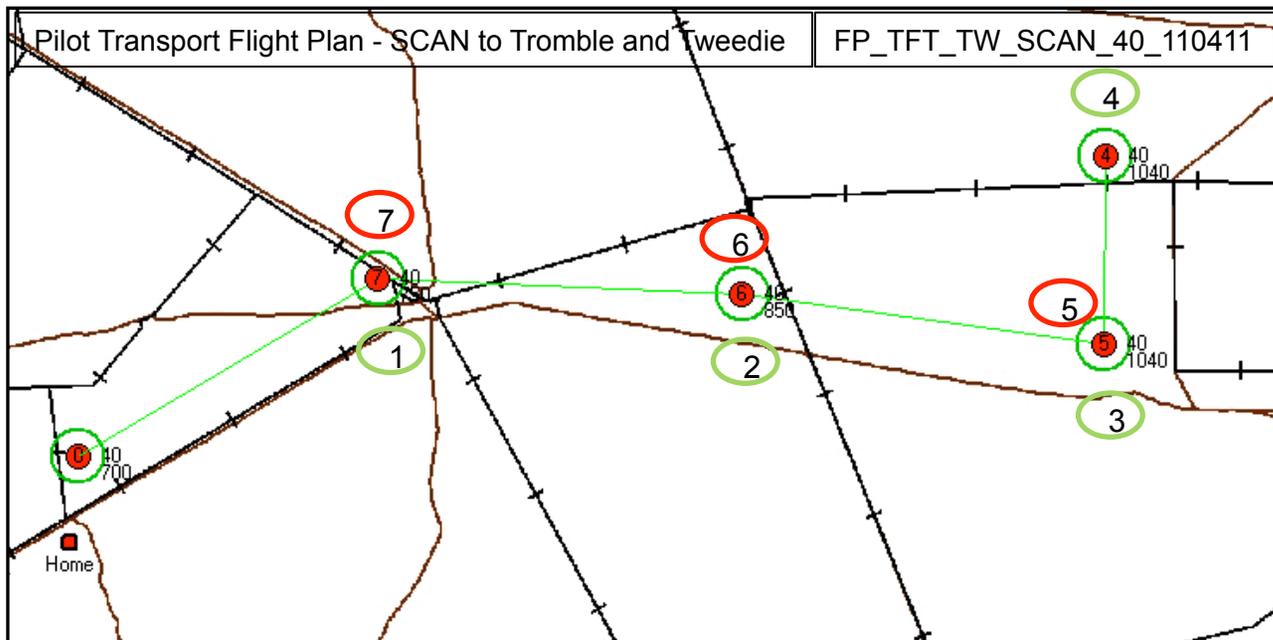
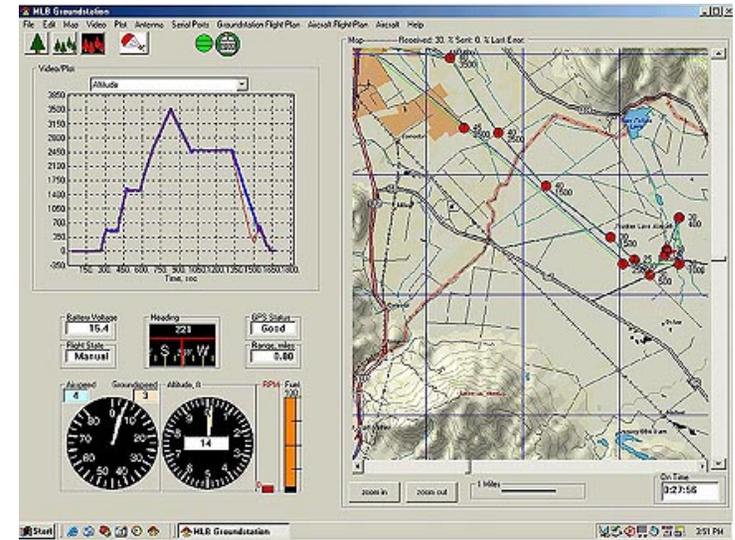
- Receive COA and fly according to all specifications in COA
 - Pre-flight planning to
 - establish home location coordinates for use after launch and in case of loss of link to UAV
 - establish flight pattern for travel to and from test site and for photography over test site with desired forward overlap and sidelap; always maintain line-of-sight contact
 - Flight Mission
 - issue Notice to Airman (NOTAM) 48 hours before flight
 - conduct flight crew briefing before flight and de-briefing after flight
 - conduct airplane and control center checklists
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4. **Documentation**

- Update log books and keep complete records
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Site survey and mission planning

- Inspection of launch/landing site, collection of GPS points
- Mission planning using ArcGIS, Google Earth to determine line of sight, flight areas
- Final planning in UAS ground station software



Flights with the Bat 3

BAT 3 UAV (2 separate airframes)

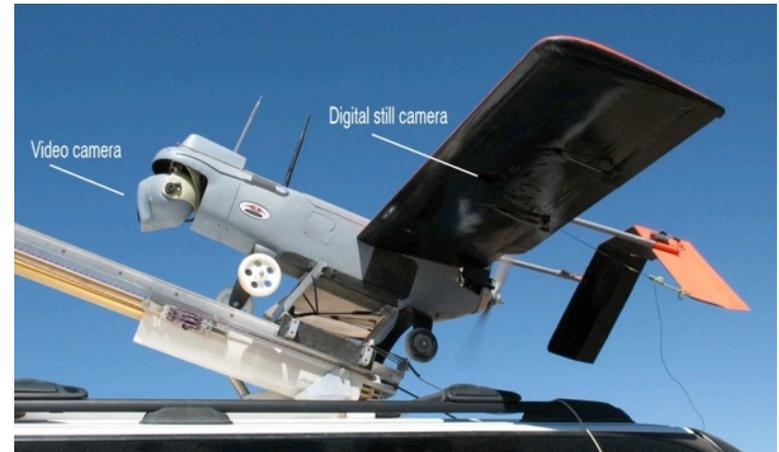
- 1.8 m wingspan, 10 kg weight, 1.4 kg payload
- Flight duration: 2-5 hours
- Cost \$48,000 (\$75,000 for 2 airplanes)

Sensors

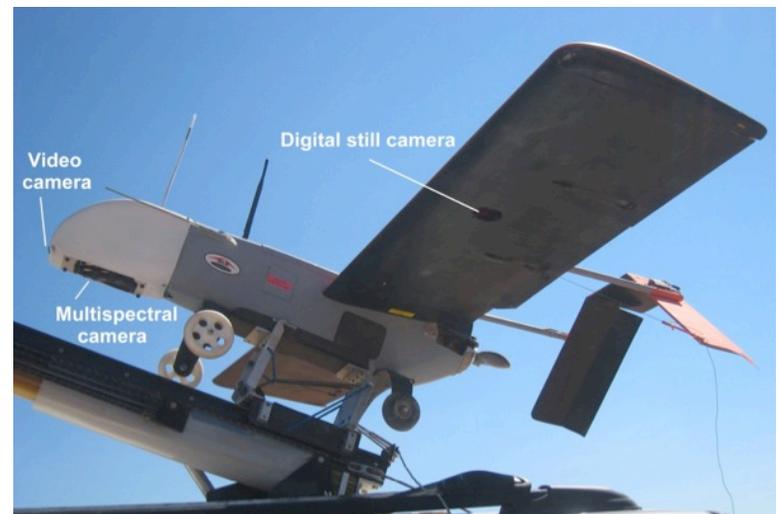
- Canon SD900 10 mp digital camera
- Tetracam MiniMCA, 6 narrow bands, blue to near infrared
- Daylight video

Image acquisition

- 215 m AGL
- 75% forward overlap, 40% sidelap for stereo analysis
- Data file: X,Y,Z, roll, pitch, heading



True color imagery



Multispectral + true color imagery



Observers placed on perimeter of flight pattern looking for oncoming traffic and in contact with external pilot by radio



External pilot takes over manually on final approach because it results in a smoother landing

Smooth landings possible even in challenging cross-wind conditions



What other things must be done?

- Grade a short runway which can only be 50 m and can just be a slightly improved dirt road without fencing on either side
- Line-of-sight must be maintained by the external pilot at all times, so if distance exceeds 1.1 km, we must move the external pilot. This is because we do not have sense-and-avoid capabilities on small airplanes.



Future plans involve the use of a larger UAV (Bat 4) (cost \$130,000) with the following characteristics:

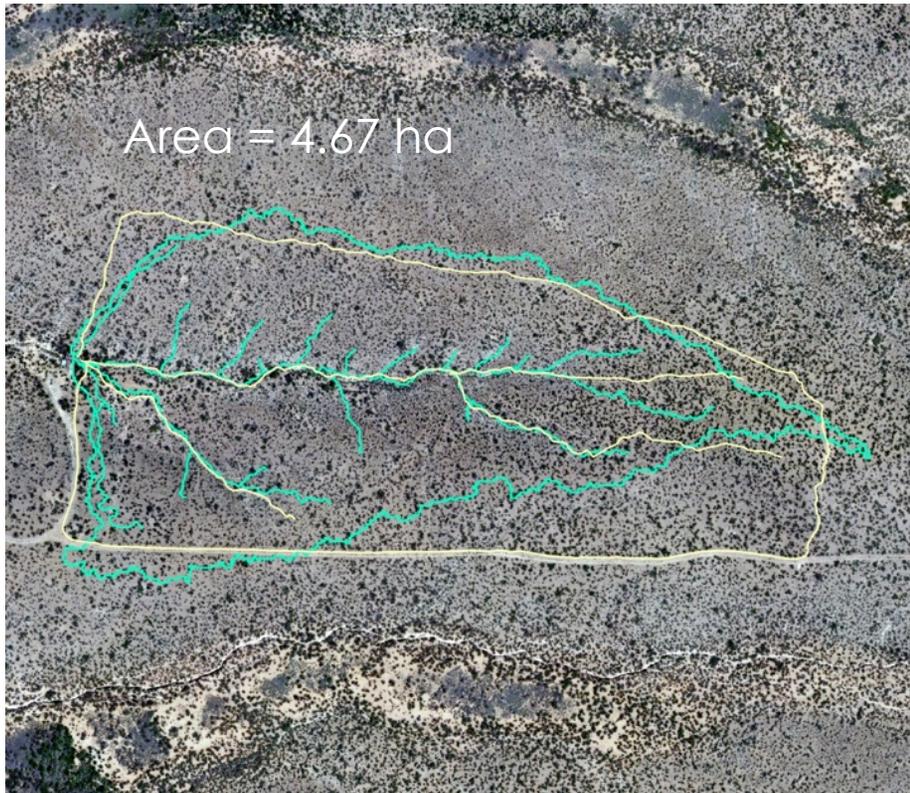
- Wingspan 4 m vs 1.8 m (more stable flight)
- Weight 45 kg vs 10 kg
- Payload 14 kg vs 1.4 kg
- Takeoff on wheels vs from catapult
- Significant room for additional instrumentation vs currently no additional space for new instruments

Outcome

1. The line-of-sight method is legal but somewhat slow. It takes at least 4 times as long to get the data and much more time planning the missions, BUT, we get the data we need.
2. We now have a highly trained UAV flight crew who potentially can fly anywhere in the United States. Two of the crew have their FAA private pilot's licenses. The flight team has allowed us to be recognized as working on the cutting edge of civil UAV applications.
3. We are integrating different remote sensing approaches into the National Airspace System.
4. We have an operational system that can acquire UAV data over rangelands which make up 50-70% of the Earth's land cover.
5. Other capabilities at Jornada:
 - ❑ Good technical and troubleshooting support from UAV manufacturer
 - ❑ All around in-house technical support
 - ❑ 8-10 people qualified in FAA ground school, medicals and observer training
 - ❑ Several RC pilots and trainer
 - ❑ Several remote sensing experts
 - ❑ Several vegetation measurement teams



Hydrology applications

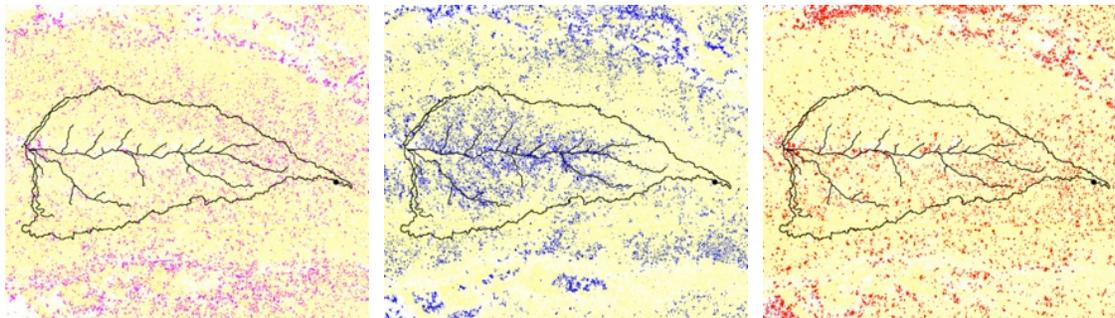


- Ground survey drainage area = 56,988 m² (yellow)
- UAV DEM drainage area = 46,734 m² (blue)
 - 22% difference
- Ground survey drainage density = 0.0128 (yellow)
- UAV drainage density = 0.032 (blue)

The products derived from UAV flights depend upon the sensors that can be flown. In most cases, video coverage is only useful for military or security applications. But, broadband camera coverage and multispectral camera coverage are very useful for hydrological, ecological, agricultural, and other civilian applications. The following products can result: mosaics covering entire watersheds; DEMs at 1m resolution; vegetation and land cover classification; and changes over time of environmental variables. Because UAVs can be programmed to re-fly the same locations at an optimum revisit interval, change detection at very high resolution can be accomplished. Ground surveys of the basin boundary and drainage network of the Tromble Weir watershed are shown in yellow, whereas the same properties are shown in blue as derived from UAV data. The UAV approach making use of overlapping stereo photography provides a much more detailed drainage basin and network.

Spatial distribution of vegetation in the Tromble Weir watershed

Classification of the vegetation was done using the UAV data as part of a regional classification using an object-oriented approach. 34% of the basin was covered by vegetation and 66% was bare soil. These values are very indicative of this part of the Chihuahuan Desert. It was noted that the vegetation types were not spread uniformly across the watershed. The most common shrub was mariola followed by mesquite and creosote. Combining the UAV DEM and vegetation classification capabilities allows more detailed information needed for input to hydrologic models such as tRIBS. When comparing the UAV vegetation classification with the best field measurements employing the line-point intercept (LPI) approach, we have determined that the UAV vegetation classification is 78 to 98% accurate. When this approach was further compared to the LPI method in Idaho flights, it was concluded that the UAV approach was cost effective after only eight plots were measured. After those eight plots, the UAV saves money and effort in additional measurements in the region of interest.

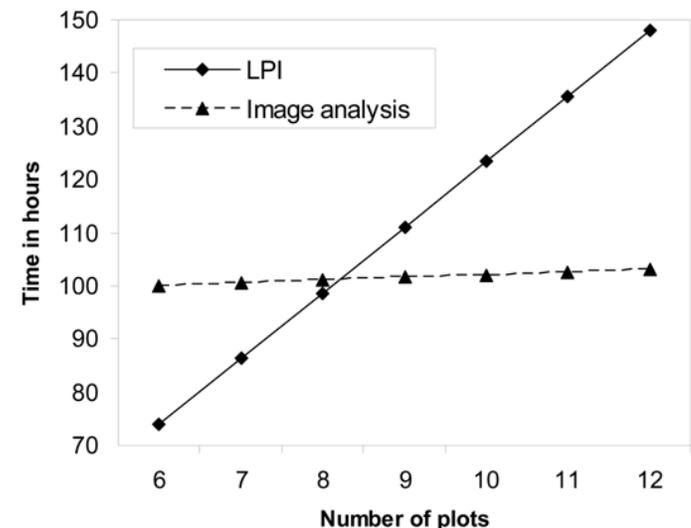


Creosote

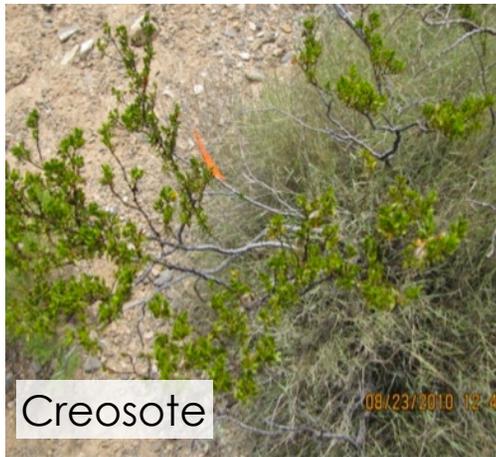
Mariola

Mesquite

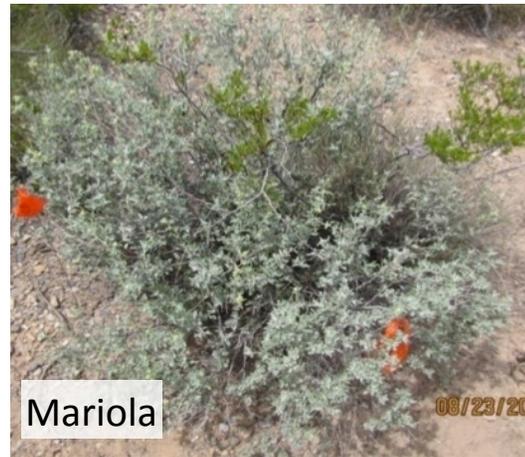
High resolution, UAV data classification shows that individual mesquite and creosote shrubs tend to prefer the flatter, deeper soil areas of the Tromble Weir basin, whereas the mariola shrubs prefer the steeper hillslope areas with more shallow soils.



Watershed shrub cover over the Tromble Weir watershed

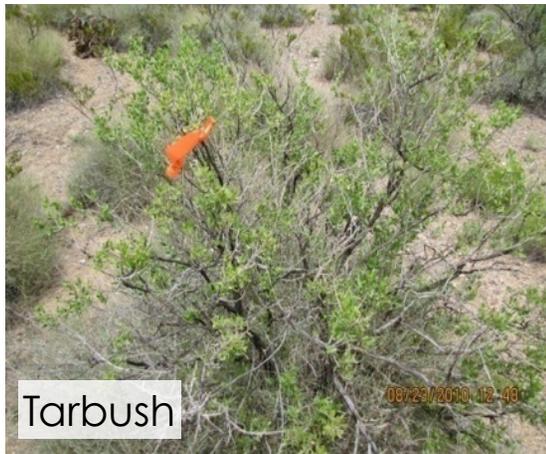


Creosote



Mariola

- Historically a grassland, the watershed is now shrub dominated
- ~34% of the watershed is covered by vegetation
- Large shrubs (e.g. mariola, creosote, mesquite, and tarbush) account for ~80% of vegetation cover



Tarbush



Mesquite

UAV Object-Oriented Classification

Vegetation	Type	% Cover
Tobosa Grass/ Dropseed	Grass	1.40
Bush Muhly	Grass	2.89
Mesquite	Shrub	6.47
Tarbush	Shrub	2.48
Creosote	Shrub	5.82
Mariola	Shrub	11.9
Snakeweed	Shrub	1.82
Sumac	Shrub	1.15
Intercanopy	Bare soil	66.0

Conclusions

- ❑ Research with UAVs has shown it is possible to use remote sensing to measure rangeland health:
 - ❑ Gap sizes (and number) between vegetation/patches
 - ❑ Size of vegetation patches and patterns of vegetation
 - ❑ Bare soil and vegetation cover amounts
 - ❑ Eroded runoff channels
 - ❑ Vegetation type using object-oriented classification
 - ❑ Using the UAV approach we can obtain high resolution images that under normal circumstances we can't get using other methods
 - ❑ We are making progress developing a complete and efficient workflow for UAV operational missions consisting of flight planning, FAA approvals and image acquisition/rectification/mosaicking/classification
 - ❑ If you are going to try to employ a UAV for acquiring data, you need to be aware of the regulations FAA will impose and devote time and effort into meeting those requirements nearly equal to the technical effort
 - ❑ One result of the UAV approach may be able to deliver usable remote sensing data to U.S. land management agencies like NRCS, BLM, and the USFS
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Training at Jornada

- ❑ ARS has a very valuable location at Jornada; it is referred to as the ARS UAS Launch and Recovery Airfields by our colleagues at the Physical Science Lab at NMSU.
- ❑ ARS Jornada has hosted two different efforts of the AeroVironment Company in 2012 that consisted of training and experiments with both the Raven B and Puma AE UAS's. Larger UAS operators have shown significant interest in using Jornada as a base of operations.

Raven B



The training is mostly for US Border Patrol personnel.