HELPING GLOBAL HAWK FLY WITH THE REST OF US

Paul Ostwald, The MITRE Corporation, Egg Harbor Township, NJ
William Hershey, The MITRE Corporation, Wright-Patterson AFB, OH

Abstract

When the United States Air Force (USAF) planned to start operations of the Global Hawk Unmanned Aircraft System (UAS) at Beale Air Force Base (AFB) they turned to the MITRE Corporation for an analysis of nearby air traffic that fly in the vicinity of Beale where a portion of the planned Global Hawk mission would occur. Using several data sources, MITRE analyzed flight paths of both transponding and non-transponding aircraft to characterize the air traffic patterns in the vicinity of Beale AFB. In addition to examining aircraft with beacon transponders, which represented flights under air traffic control and some uncontrolled flights, it was critical to examine operations of non-transponding flyers such as hang gliders, hot air balloons, and some general aviation aircraft. These airspace users may either not be equipped with transponders or may not be using them; they rely on their eyes to “see-and-avoid” other traffic.

Global Hawk’s cruise altitude is well above most other aircraft so the key flight phases to investigate were early in climb and late in descent, when the likelihood of encounters with low-altitude, non-controlled and non-transponding aircraft is greatest. Specifically, interest was in those operating in the altitude range from the ceiling of Class C airspace above Beale AFB (4100 feet) up to positive control airspace (Class A airspace with a floor of 18,000 feet).

The results offer insight into the air traffic around Beale AFB by quantifying hourly and day-of-the week patterns, showing an altitude distribution of the traffic, providing a breakdown of users by air carrier and general aviation operations and by class of aircraft flown, and by tabulating nearby origin/destination airports used. The Air Force used this information in requesting FAA permission to operate Global Hawk out of Beale AFB.

Introduction

Operators of an Unmanned Aircraft System (UAS) sometimes have a need to fly within civil airspace[1]—a need that is anticipated to increase steadily over the foreseeable future.[2] A basic requirement of such operations is to keep the Unmanned Air Vehicle (UAV) safely separated from all other aircraft in the airspace.

Ultimately, “sense-and-avoid” capabilities of the UAS, similar to “see and avoid” techniques employed by pilots operating in visual meteorological conditions, should be available to help keep the UAV safely separated.[3] In the meantime, before a full sense-and-avoid capability is available, other approaches will be required if UAS operation in civil airspace is to be allowed. One such approach would use surveillance systems that fuse together data from multiple surveillance sources to assist in the monitoring of all types of traffic in the vicinity of the UAV and help assure safe separation. A second approach is to employ a chase plane—with the pilot of the chase plane providing the “see” portion of “see-and-avoid.” Coordination between the pilot of the chase plane and the ground operator of the UAV would be required to avoid other traffic seen by the pilot.

For very near-term operations, however, a Temporary Flight Restriction[4] (TFR) is being used to constrain operation of other flights in a defined volume of airspace in the vicinity of the planned UAV operation within civil airspace. A detailed understanding of prevalent air traffic patterns in and around a TFR may be necessary to help give regulators and the public sufficient confidence in safe UAS operation under this approach. This paper describes one such study of the air traffic patterns in the vicinity of Beale AFB, just north of Sacramento, California. This study was conducted in support of planned operation of the Global Hawk UAV.

Background

The Global Hawk[5] is a large, jet-powered UAV. It has a wingspan of just over 116 feet (increased in later models to 130 feet), larger than that of a Boeing 737. Its cruising speed approaches 340 knots and has a service ceiling of 60,000 feet. It requires a paved runway for takeoffs and landings such as the 12,000 foot runway at Beale AFB. While the Global Hawk can operate its mission autonomously, a ground operator is required to make changes to its planned flight trajectory.

In 2003 the Global Hawk became the first UAS to receive a national Certificate of Authorization (COA) from the Federal Aviation Administration (FAA) allowing operation in the National Airspace System (NAS).[6] The COA allowed operations of the Global Hawk in restricted airspace during climb and descent, and operation outside of restricted airspace at its typical cruise altitude—at flight levels high above civil air traffic.

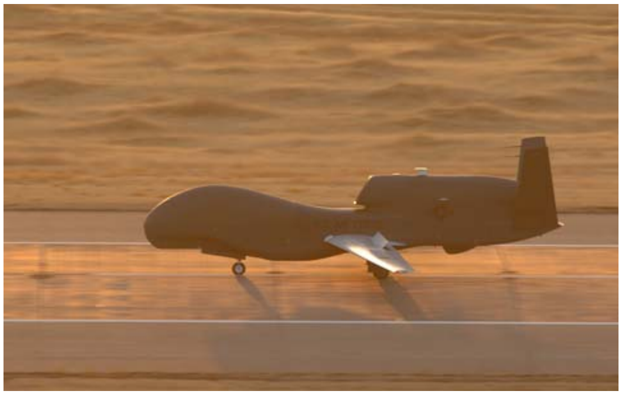

Figure 1. Nov 2006: Global Hawk Lands at Beale AFB, CA for the First Time, 11 Nov 2006

When the USAF planned to conduct Global Hawk training operations at Beale AFB, FAA approval was required. The airspace above Beale AFB is not restricted airspace—climbs and descents of the Global Hawk would occur through airspace where many civil air operations occur daily. USAF officials involved with the Global Hawk program had little quantitative data on traffic surrounding Beale AFB to support this specific request to the FAA. In June 2006, the Global Hawk program requested USAF 853rd ELSG/NT and MITRE support for a traffic analysis.

Figure 2 illustrates a side view of the airspace overlying Beale AFB. Class C airspace is defined with a 10 nautical mile (NM) radius centered on Beale AFB—it extends from the surface to 4100 feet within a 5 nautical mile radius and from 2600 feet to 4100 feet in the area between 5 and 10 nautical mile radius*.

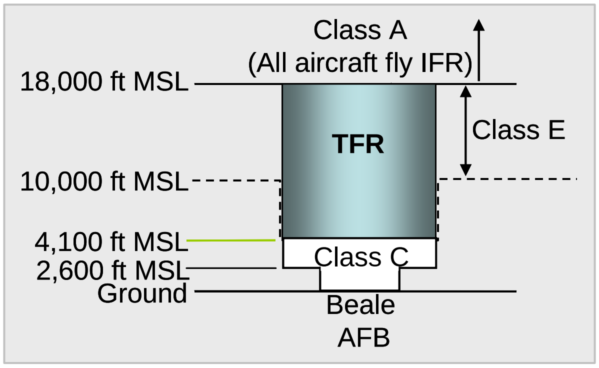

Figure 2. Airspace above Beale AFB

Aircraft operating within the Class C airspace must be equipped with and operating a beacon transponder with Mode C altitude reporting capability. Shown also is Class A airspace at 18,000' and above. All aircraft operating within this airspace must have beacon and Mode C transponders, must file an Instrument Flight Rules (IFR) flight plan and be under Air Traffic Control (ATC).

Class E airspace extends from 10,000 feet up to 18,000 feet. Mode C capability is required within this airspace. Note that a special condition exists for the airspace above the Class C airspace up to Class E airspace, from 4100 feet to 10,000 feet. In this airspace, a beacon transponder with Mode C altitude reporting is also required. This airspace is often referred to as a "Mode C veil." Outside the Class C airspace and below 10,000 feet, aircraft are permitted to fly under "Visual Flight Rules" (VFR), are not required to use a transponder, and are not under ATC.

Also show in Figure 2 is the location of TFR airspace. A TFR with these dimensions has been employed on several Global Hawk validation flights conduced at Beale AFB to date. It overlies the Class C airspace (has the same 10 nautical radius) and extends from 4100 feet up to 18,000 feet.

---

* Note that the actual Class C airspace above Beale AFB is more complex with two different floors between 5 and 10 nautical miles.

The TFR also specifies time period and procedure—in addition to airspace volume. It is typically activated for 45 minutes during Global Hawk's departure and climb and another hour during its descent and landing. The following restrictions apply:

1. All aircraft entering or exiting the TFR must be on a discrete code assigned by an Air Traffic Control (ATC) facility.
2. Aircraft must be squawking the discrete code at all times while in the TFR.
3. All aircraft entering or exiting the TFR must remain in two-way radio communication with the ATC.[7]

To remain with the TFR airspace, the Global Hawk must employ specific procedures during climb and descent. Figure 3 shows a typical flight path and vertical profile for a two-hour training mission. Such missions would begin and end at Beale AFB, at the center of the 10 nmi-radius TFR. The UAV executes a "teardrop" maneuver after its take-off, climbs to over 50,000 ft, and executes several loops over a military operations area (MOA). It then descends to the TFR and stays within the TFR and Class C airspace on its approach by executing a "bow-tie" pattern.

The FAA's Northern California Terminal Radar Approach Control (TRACON) controls the airspace above Beale AFB and monitors Global Hawk flights there.

Who Flies There?

Various types of air operations are conducted in the airspace examined near Beale AFB. For the purposes of this study, two main categories were identified: transponding flights and non-transponding flights.

A transponding flight was defined as one equipped with and that operated a beacon transponder—transmitting a beacon code when interrogated by a secondary radar. These flights may also transmit their altitude—reporting information obtained from the Mode C altimeter onboard the aircraft. In general flights must be equipped with and use both a beacon transponder and a Mode C altimeter when operating in Class C (directly above Beale AFB up to 4100 feet), Class E (from 10,000 to 18,000 feet) and the "Mode C veil" (above Class C up to the floor of Class E).[†8]

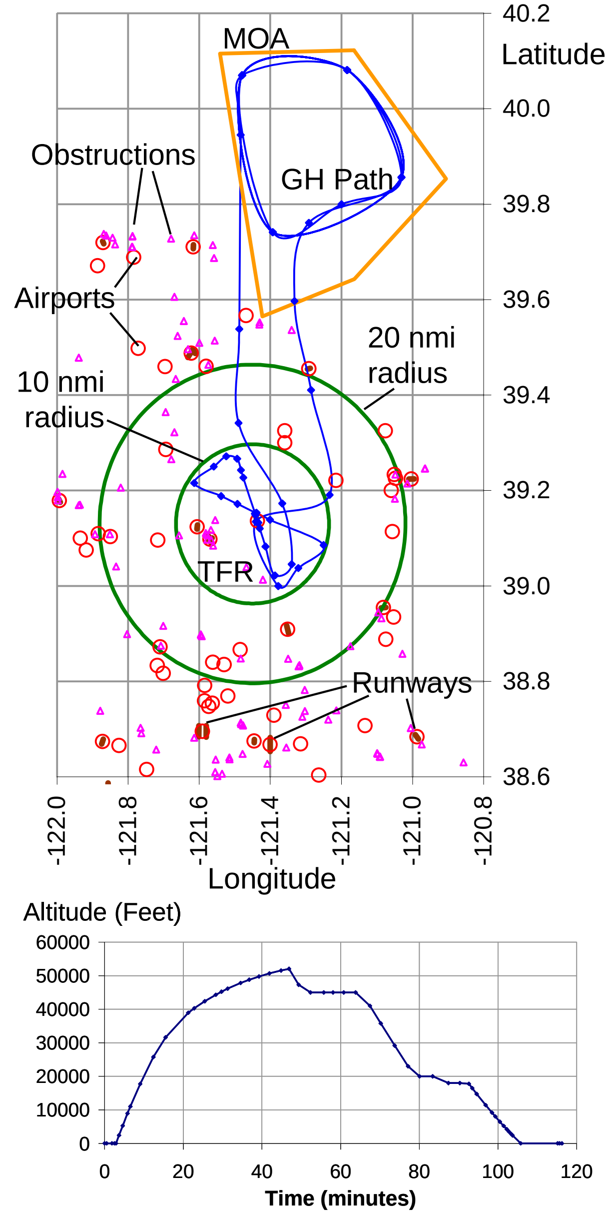

Figure 3. Global Hawk Training Mission at Beale AFB – Flight Path and Vertical Profile[9]

† There are some exceptions to these operating requirements. See FAA's Aeronautical Information Manual (reference 7) for details.

Transponding flights can be further categorized by the beacon code being transmitted. Those flights transmitting a discrete code assigned by air traffic control are categorized as "discrete." Those not under air traffic control and operating under Visual Flight Rules (VFR) transmit a non-discrete code—most often the code "1200." These flights are categorized as "VFR." Some flights were observed to transmit a discrete code during some portion of their flight and a non-discrete code during other portions[‡]. These flights were categorized as "mixed."

A non-transponding flight was defined as one not equipped with or not operating a beacon transponder. These flights are only "seen" by a primary radar—the radar generates a "search return" for such flights. Unfortunately, not all search returns represent actual aircraft. Returns can be generated for a variety of other reasons including flocks of birds and obstructions located near the radar.

Analysis Approach and Data

Two separate analyses were conducted. The first analysis focused on determining the traffic counts for the various categories of traffic identified above. This analysis examined flights within a 20 nautical mile radius cylinder centered on Beale AFB—the larger radius than the envisioned TFR allowed examination of traffic that operated both within the airspace of the TFR and those that operated nearby the TFR. A long enough traffic sample was desired to allow investigation of day-of-week and time-of-day traffic patterns. The analysis examined flights from the surface up to 18,000 feet.

The key to this part of the analysis was obtaining data for both transponding and non-transponding traffic. Several potential data sources were examined. The best source of data was determined to be the 84th Radar Evaluation Squadron (RADES) located at Hill AFB, Utah.[10] The 84th RADES maintains an archive of radar data from a large number of FAA and military radars. This data included "search" returns—that may include returns from non-transponding aircraft—required for this analysis. RADES also could process the radar data through a "tracker" that attempted to associate together returns that were likely from an individual flight—these associated returns were identified as a "track."

The radars contained in the RADES archive and their proximity to Beale AFB was also examined. The archive does not contain all radars—indeed the two closest to Beale AFB (including one located at Beale itself) were not archived. Figure 4 shows the location of radar sites near Beale contained in the archive. In data received from 84th RADES, three long-range radars (Red Bluff—RBL, Mill Valley—MIL, Rainbow ridge—RBR) and one short-range radar (Stockton—SCK) comprised the vast majority of the data provided. Small amounts of data were included from 5 other radars.

Data was obtained from 84th RADES for a five day period covering May 15th - 19th, 2006. This period was from a Monday through Friday. This corresponded to anticipated operation of the Global Hawk at Beale for training during the normal work week.

One limitation of the RADES data is that no flight plan information was available. Thus, no insight into who operated the flight or the type of aircraft used could be obtained. To gain insight into these aspects of the traffic around Beale AFB a second analysis was conducted. Data was obtained from the FAA's Enhanced Traffic Management System (ETMS).[11] To support various work programs, MITRE has a feed of ETMS data and maintains an internal archive of the data. This data was not used for the first analysis as it does not contain any information on non-transponding flights. The ETMS data was obtained for the same time period. Flights that operated within a ten nautical mile radius cylinder of Beale AFB, up to 18,000 feet were identified. The associated flight plans were examined, where available, to identify the operator (air carrier vs. general aviation, by specific air carrier), the type of aircraft flown, and if the flight departed from or flew to a nearby airport.

[‡] This commonly occurs for a flight operation under VFR that requests the "flight following" service from ATC. ATC will assign a discrete code to the flight when providing this service. This service is routinely provided by the Northern California Tracon (NCT), responsible for ATC in the airspace in the vicinity of Beale AFB. (See Reference 7.)

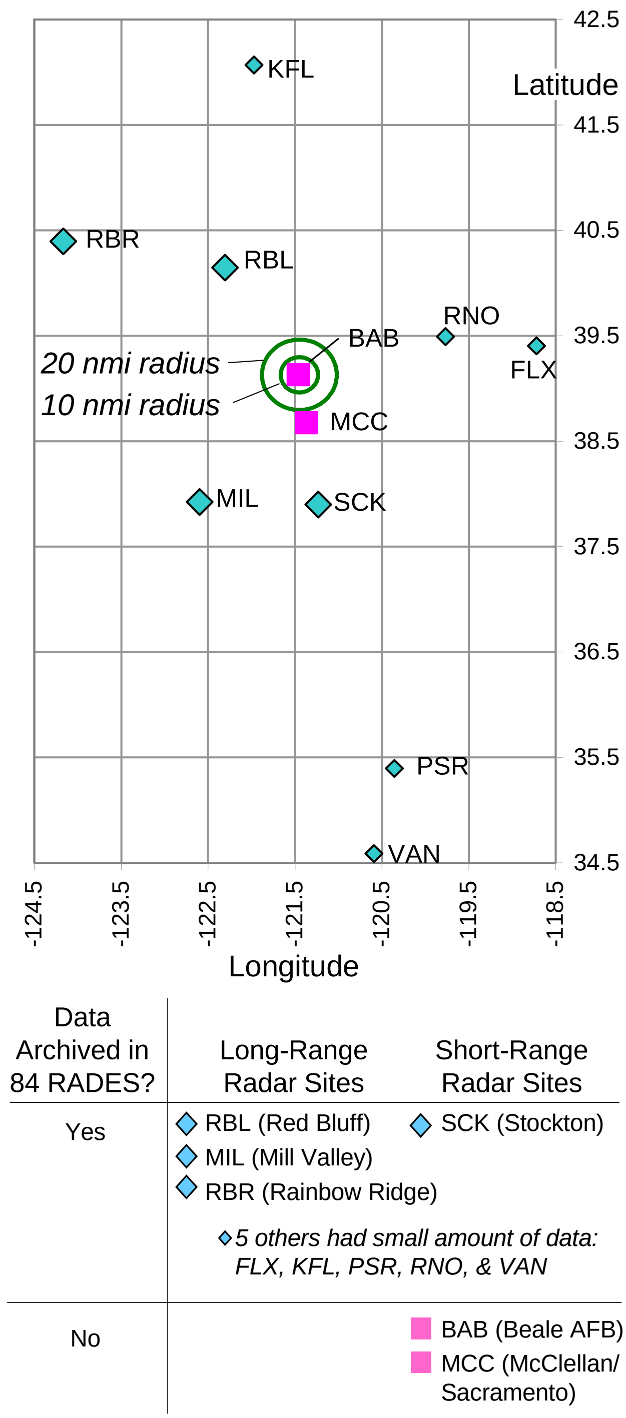

Figure 4. Radar Sites Near Beale AFB, CA

Results

Figure 5 shows the daily traffic counts of transponding traffic for each day of the period examined. Thursday is busiest with 278 tracks. Monday is least busy with 201 tracks. However, one week of data is not a reliable predictor of a regular day-of-week pattern.

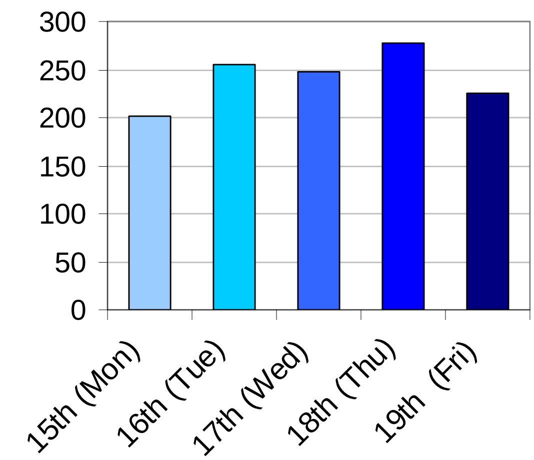

Figure 5. Daily Traffic Counts May 15-19

Figure 6 shows the traffic counts per hour for each day of the period examined. Low levels of traffic were seen during “off hours” (19:00 – 08:00)—less that 10 flights per hour were found during most hours. The morning hours (08:00 – 11:00) were consistently busy—all hours had over 10 flights per hour; most had over 20 flights per hour. The other hours (11:00 – 19:00) were slightly less busy than the morning hours on average, but showed spikes of several very busy 1-2 hour periods.

Transponding aircraft provide altitude information in their replies to secondary surveillance radar. Figure 7 shows the Mode C altitude breakdown for the 1114 transponding aircraft observed during the five-day period. The radar tracks are broken down into five categories with long tracks (ten or more radar returns per track) with discrete beacon codes being the predominant type of track observed. Few VFR aircraft were observed above 10,000 ft. The Mode C altitude data also gives a rough picture of how many aircraft are climbing or descending.

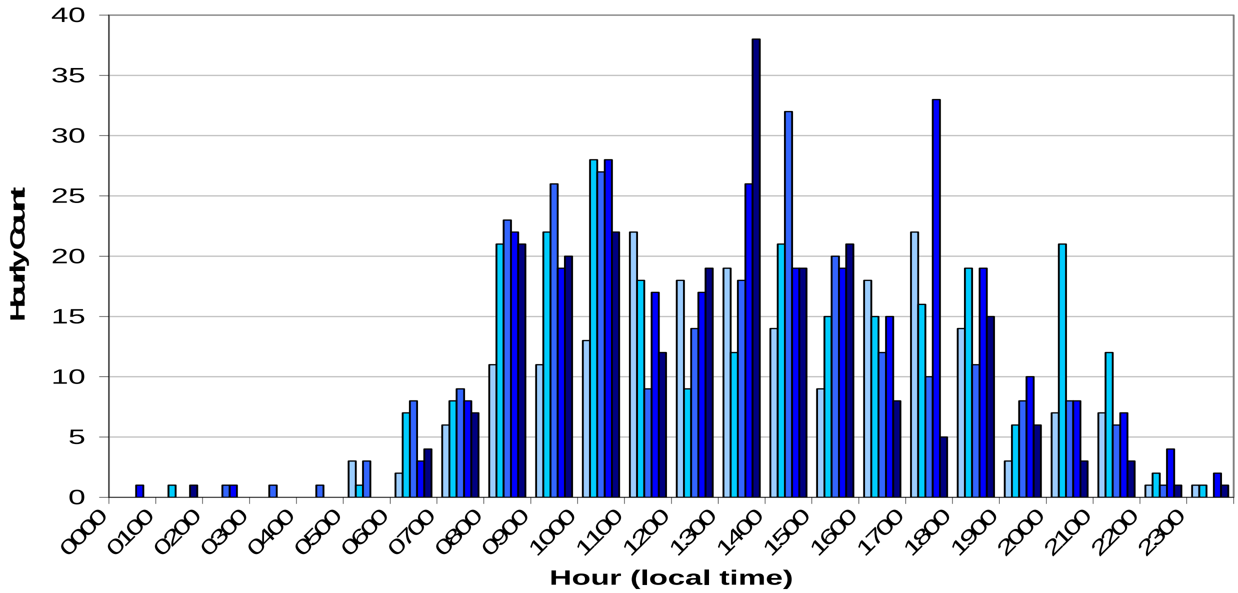

Figure 6. Traffic Counts by Hour of Day for All Five Days (Each Hour Shows Daily Breakdown)

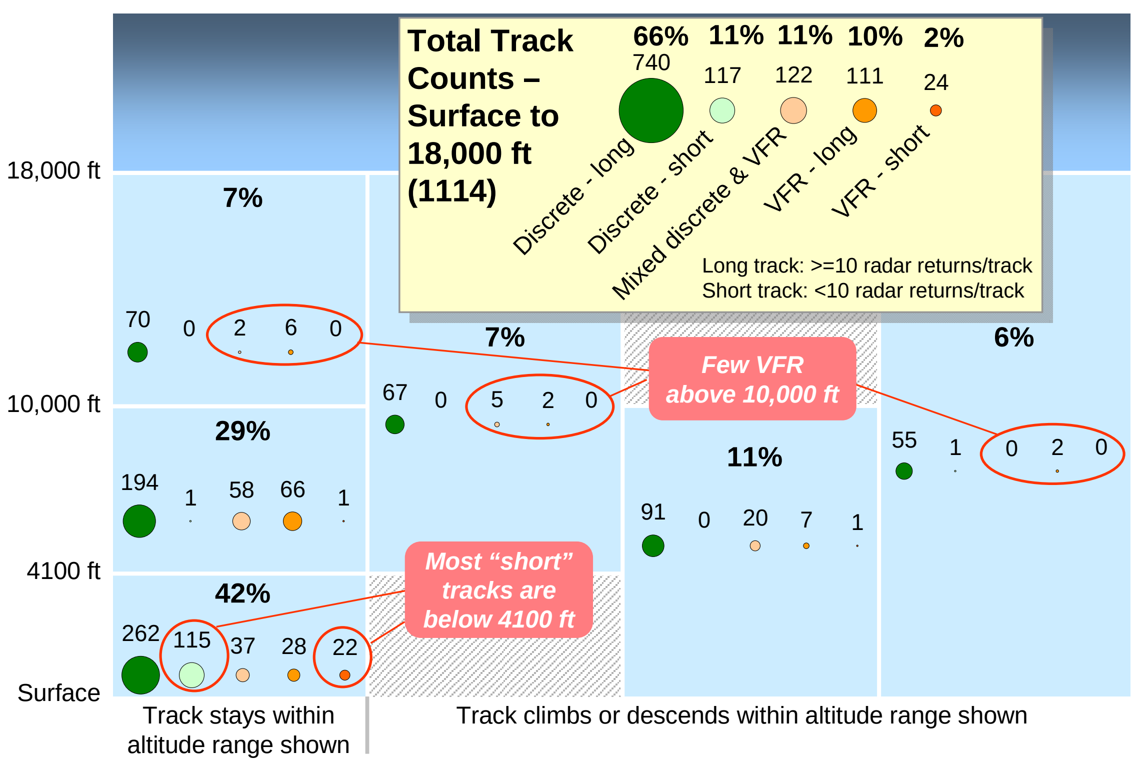

Figure 7. Distribution of Traffic by Altitude (Within 10 nmi Radius Cylinder, Surface to 18,000 ft)

The RADES data also contained tracks, as generated by the RADES post-processing tracker. These were tracks generated for primary, search-only radar returns. Note that this tracker was not tuned or optimized in way that might have eliminated some false tracks not on real aircraft. Many such tracks were generated. A challenge of this portion of the analysis was to examine these tracks and discard those that did not appear to be tracks of real aircraft. The objective was to characterize non-transponding traffic that operated close to the proposed TFR boundary. Particular attention was paid to potential tracks that operated just outside the proposed TFR—these represent aircraft that operated close to the airspace planned for the Global Hawk flight profile.

The search-only tracks in the RADES data were examined within a 20 nautical mile radius cylinder centered on Beale AFB. The first step taken was to eliminate "short" tracks—defined as those with ten or fewer search-only radar returns. This corresponds to a time period of about two minutes. This filtering step eliminated the vast majority of the search-only tracks. The remaining tracks were visually examined for "reasonableness," that is having flights paths and speeds that were within the bounds of typical aircraft that would be operating in the area. Most of these remaining tracks were also discarded. They did not appear to be actual aircraft due to reasons such as:

- Very long duration but largely stationary.
- Shorter duration but largely stationary at or near a known obstacle.
- Had height above 10,000 feet as determined by the radar.[§]
- Comprised widely scattered radar returns.

Further analysis could perhaps identify additional potentially real aircraft in the large amount of search-only track that were discarded.

In the five days of data, fewer than 30 search-only tracks were identified as "reasonable," thus likely to be real, non-transponding aircraft. On a per-radar basis, ten tracks from RBL, and six each from MIL and RBR were identified as potentially "good" search-only tracks. Of these, only three were seen by more than one radar—an expected result for a real aircraft. Figure 8 shows one such track that was seen by both RBL and MIL radars.

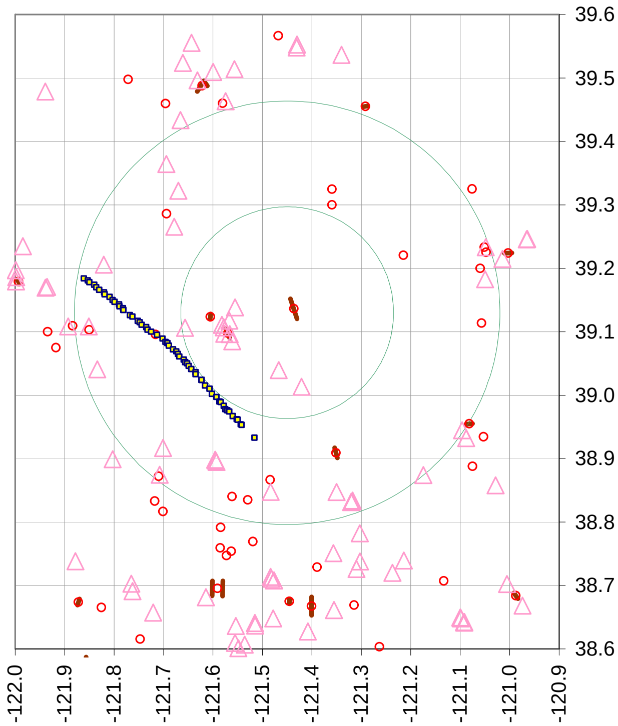

Figure 8. Track 12617 (seen by MIL & RBL radars)

Several of the potential non-transponding aircraft were observed to fly very close to the airspace where Global Hawk operations are planned. Fortunately, none of the non-transponders during the five days of data flew within the Class C airspace or the 5 nmi radius cylinder above it (the proposed TFR). This observation means that all of the non-transponders (who were not equipped with or not using a Mode C transponder) followed the rule not to enter this airspace. However, their proximity to the boundary should be taken into account in planning Global Hawk operations—to maintain ample separation from the boundary.

The second portion of the analysis was performed using ETMS data. Note that this data was for aircraft that were being tracked by the Oakland Center and Northern California Tracon

---

[§] Several of the radars had a height finding capability—that added a radar determined height to a search return. Some search-only tracks had heights much above 10,000 feet and may have been associated with beacon tracks flying above 18,000 feet that were not included in the data sample.

FAA facilities. This data does not contain any non-transponding or military flights and does not include most VFR flights (in particular, those reporting 1200 beacon codes). The frequency of the track positions was about one per minute, much less often than the RADES data, which contained positions at least every ten to twelve seconds. However, the ETMS data did contain the aircraft identification, aircraft type, and origin and destination airports for many of the flights. This information was used for this second part of the analysis.

Figure 9 shows the breakdown by stakeholder and the types of aircraft flown. Figure 10 shows the breakdown by air carrier operator. Southwest Airlines and Alaska Airlines were the “top two” air carrier operators with over 50% of the operations. Over 2/3 of air carrier operations were jet aircraft.

General aviation operations included some jets but consisted of mostly prop and turboprop aircraft. Over 2/3 of the general aviation operations did not have associated flight plan information—many were likely VFR traffic receiving flight following service from the Northern California Tracon.

	No Flight Plan (AC type, departure and arrival airport information not available)	**Prop**	**Turbo Prop**	**Jet**	**Total**
General Aviation	**232** 45%	**36** 7%	**36** 7%	**15** 3%	**319 (62%)**
Air Carrier	**1** 0%	**16** 3%	**41** 8%	**136** 27%	**194 (38%)**
					513 Total flights in Discrete and Mixed Categories

Does not include military aircraft or aircraft under VFR transponding with 1200 code.

Figure 9. Breakdown by Stakeholder and Aircraft Type

Carrier	Carrier name	Type	Day (GMT) 15	16	17	18	19	20	Total
SWA	SOUTHWEST AIRLINES CO.	Jet	7	10	11	12	10	7	57
ASA	ALASKA AIRLINES INC.	Jet	4	8	8	9	9	5	43
QXE	HORIZON AIRLINES, INC.	Turboprop	2	3	3	3	2	1	14
BXR	REDDING AERO ENTERPRISES, INC.	Prop		3	3	2	3	2	13
AMF	AMERIFLIGHT, INC.	Turboprop		2	4	1	3	1	11
MRA	MARTINAIRE	Turboprop		2	3	2	2	1	10
QXE	HORIZON AIRLINES, INC.	Jet	1	3	1	1	1		7
UAL	UNITED AIR LINES INC.	Jet		2		2	1	1	6
EJA	EXECUTIVE JET AVIATION, INC.	Jet		1	2		2		5
Others			2	6	4	7	6	3	28
Total			16	40	39	39	39	21	194

Southwest and Alaska have the largest number of flights transiting the 10 nmi radius cylinder

Figure 10. Breakdown by Air Carrier Operator

Figure 11 lists the count of flights that departed from nearby airports. Figure 12 lists the number of arrivals to the nearby airports. Air carrier operations included 127 arrivals to Sacramento International Airport (SMF), by far the single largest number of arrivals or departures at an airport. No departures were observed from SMF—it is likely that the departure pattern was to the south on the days examined. Note that these numbers could change significantly if a different airport configuration were used at SMF. Other air carrier and general aviation operations, including both departures and arrivals, were distributed across several dozen nearby airports.

Departure Airport	Distance from Beale AFB	General Aviation	Air Carrier	Total
BAB	0.0	1	0	1
MYV	7.0	6	1	7
LHM	14.8	7	0	7
AUN	20.7	2	0	2
OVE	23.9	2	0	2
SMF	28.7	0	7	7
MCC	29.5	3	3	6
E36	31.0	1	0	1
O61	35.9	1	0	1
O41	36.0	1	0	1
MHR	37.2	4	13	17
SAC	39.3	0	2	2
CIC	46.2	3	9	12
APC	71.2	1	0	1
O05	72.6	1	0	1
CPU	73.2	1	0	1
RBL	75.0	0	1	1
STS	78.0	0	1	1
CCR	78.2	3	0	3
SCK	78.6	2	0	2
LVK	92.6	1	0	1
RDD	95.7	5	10	15
OAK	96.9	0	1	1

Figure 11. Flights Departing Nearby Airports

Arrival Airport	Distance from Beale AFB	General Aviation	Air Carrier	Total
BAB	0.0	1	0	1
MYV	7.0	4	1	5
LHM	14.8	7	0	7
OVE	23.9	2	0	2
O08	27.3	1	0	1
SMF	28.7	3	127	130
MCC	29.5	4	4	8
MHR	37.2	11	14	25
SAC	39.3	4	4	8
WLW	44.9	1	0	1
CIC	46.2	3	2	5
O70	57.1	1	0	1
RBL	75.0		3	3
STS	78.0	1	0	1
SCK	78.6	2	0	2
RNO	84.2		1	1
LVK	92.6	1	1	2
RDD	95.7	6	13	19
OAK	96.9	1	0	1
MOD	97.8	2	0	2

Figure 12. Flights Arriving at Nearby Airports

Summary of Findings

This study examined air traffic operations in the vicinity of Beale AFB. While the limited sample of five days was not large enough to investigate longer-term traffic characteristics such as seasonal or year-to-year variations, it did provide insight into shorter term trends.

Specifically, findings for transponding air traffic:

- Over 200 flights were found on each day, mid-week days were slightly busier.
- Low levels of traffic were seen during "off hours" (19:00 – 08:00)—less than 10 flights per hour during most hours.
- Morning hours (08:00 – 11:00) were consistently busy—all hours had over 10 flights per hour; most had over 20 flights per hour.
- Other hours (11:00 – 19:00) were slightly less busy than the morning hours on average, but showed spikes of several very busy 1-2 hour periods.
- Transponding air traffic reporting discrete beacon codes were distributed across all altitudes examined, with many flights transitioning in altitude.
- Transponding air traffic reporting non-discrete beacon codes were mostly below 10,000 ft.
- "Short tracks" (less than 10 returns) are almost exclusively below 4100 ft.

Specifically, findings for non-transponding air traffic:

- Most non-transponding tracks do not appear to be actual aircraft.
- A small number (less than 5 flights per day) do appear to be actual aircraft.
- Further analysis might identify some additional non-transponding tracks.

Specifically, findings for air carrier traffic:

- Southwest Airlines and Alaska Airlines were the "top two" with over 50% of the operations.
- Over 2/3 of air carrier operations were jet aircraft.
- Over 2/3 of air carrier operations were arrivals to Sacramento International Airport (SMF).

Specifically, findings for general aviation traffic (those reporting a discrete beacon code):

- General aviation operations included both departures and arrivals from several nearby airports.
- General aviation operations included some jets but consisted of mostly prop and turboprop aircraft.
- Over 2/3 did not have associated flight plan information—possible VFR traffic receiving flight following service form the Northern California Tracon.

Potential Application to Other Situations

This paper discusses an initial look into air traffic in the vicinity of Beale AFB, a location where Global Hawk operations are planned. A similar analysis could be undertaken for other locations where Global Hawk operations may occur or for locations where operations of a different UAS (e.g., Predator) may be planned.

References

[1] OSD UAS Planning Task Force, November 2004, Airspace Integration Plan for Unmanned Aviation, Office of the Secretary of Defense, www.acq.osd.mil.uas.

[2] OSD UAS Planning Task Force, 2005, Unmanned Aircraft Systems Roadmap 2005-2030, Office of the Secretary of Defense, www.acq.osd.mil.uas.

[3] DeGarmo, Mathew T., November 2004, Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace, McLean, Virginia, The MITRE Corporation, www.mitre.org/work/tech_papers/tech_papers_04/04_1232/.

[4] Federal Aviation Administration, 2007, What Are TFRs?, Federal Aviation Administration, tfr.faa.gov/tfr2/about.jsp.

[5] Air Force Link, 2007, U. S. Air Force Fact Sheet—Global Hawk, USAF, www.af.mil/factsheets.

[6] Northrop Grumman, 15 August 2003, Global Hawk Becomes the First UAV to Receive National Certificate of Authorization to Fly in the National Airspace, Northrop Grumman, www.is.northropgrumman.com/media_news/2003_data/mn03_gh_national_coa.pdf.

[7] Temporary Flight Restriction, NOTAM Number FDC 6/6607, Issue Date: November 20, 2006 at 19:32 UTC, ARTCC: ZOA—Oakland Center, POC: Northern California TRACON.

[8] Federal Aviation Administration, 2007, Aeronautical Information Manual, Official Guide to Basic Flight Information and ATC Procedures , Federal Aviation Administration, http://www.faa.gov/airports_airtraffic/air_traffic/publications/ATpubs/AIM/.

[9] Flight plans provided by Global Hawk program, Beale AFB, CA.

[10] 84 RADES, 2007, RADES Public Home Page, 84th Radar Evaluation Squadron, www.rades.hill.af.mil.

[11] Federal Aviation Administration, 2007, FAA Operations and Performance Data, Enhanced Traffic Management System (ETMS), Federal Aviation Administration, www.apo.data.faa.gov

Email Addresses

postwald@mitre.org

william.hershey@wpafb.af.mil

Acknowledgments

The authors thank Mr. John Morris, and Ms. Kelly Connolly of MITRE CAASD for their valued support and review. Thanks also to LtCol Joe Pacheco and John Schuller at Beale AFB, Tee Mans and Roger Elstun at Langley AFB, and Jeff Richardson at Hill AFB.