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Exploration of the use of unmanned aerial vehicles along with other assets to enhance border protection

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

EXPLORATION OF THE USE OF UNMANNED AERIAL VEHICLES ALONG WITH OTHER ASSETS TO ENHANCE BORDER PROTECTION

by

Bahri Yildiz

June 2009

Thesis Advisor: Gary E. Horne
Second Reader: Thomas Anderson

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13. ABSTRACT (maximum 200 words)

Border protection is a vital national security issue for most countries. The U.S. Customs and Border Protection (CBP) is responsible for protecting the borders of the U.S. from terrorism, human and drug smuggling and illegal migration. The U.S. CBP improves manpower, technology and infrastructure along the border through various projects.

In this study, part of the Tucson sector in Arizona is modeled in an agent-based model (MANA) to explore the effects of using a hand-launched, mini Unmanned Aerial Vehicle (miniUAV) along with other assets, such as Border Patrol (BP) agents, surveillance towers, the Predator B, seismic sensors and communication centers.

The results from the runs of different scenarios, created by a Nearly-Orthogonal Latin Hypercube (NOLH) design, are analyzed using comparison tests, linear regression, and regression trees.

As a result, the use of miniUAVs is found to be beneficial in capturing the illegal entrants in this analysis and thus could potentially provide more secure borders. Adequate manpower, in this case BP agents, and a reliable communication web to compose a Common Operational Picture (COP) emerge as the most important factors regarding border protection in this analysis.

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EXPLORATION OF THE USE OF UNMANNED AERIAL VEHICLES ALONG WITH OTHER ASSETS TO ENHANCE BORDER PROTECTION

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ABSTRACT

Border protection is a vital national security issue for most countries. The U.S. Customs and Border Protection (CBP) is responsible for protecting the borders of the U.S. from terrorism, human and drug smuggling and illegal migration. The U.S. CBP improves manpower, technology and infrastructure along the border through various projects.

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LIST OF ACRONYMS AND ABBREVIATIONS

AGL	Above Ground Level
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A&M	Air and Marine
ASI	America’s Shield Initiative
AoR	Area of Responsibility
ASB	Arizona-Sonora Border
BP	Border Patrol
C3I	Command, Control, Communications, and Intelligence
COP	Common Operational Picture
CBP	Customs and Border Protection
DHS	Defense Homeland Security
DOE	Design of Experiments
DTED	Digital Terrain Elevation Data
EO	Electro-Optical
FOV	Field Of View
GIDB	Geospatial Information Data Base
GAO	Government Accountability Office
GCU	Ground Control Unit
IT	Information Technology
IR	Infrared
ISIS	Integrated Surveillance Intelligence System
ICAD	Intelligent Computer Assisted Detection System
OT	International Trade
LH	Latin Hypercube
LECA	Law Enforcement Communication Assistant
LOS	Line of Sight
MANA	Map Aware Non-Uniform Automata
MEB	Marine Expeditionary Brigade

MOE	Measure of Effectiveness
MRVS	Mobile Remote Video Systems
MTS	Multi-Spectral Targeting System
NOLH	Nearly Orthogonal Latin Hypercube
OBP	Office of Border Patrol
OFO	Office of Field Operations
OIT	Office of Information and Technology
OIOC	Office of Intelligence and Operations Coordination
OTMs	Other Than Mexicans
PIR	Passive Infrared
POEs	Point of Entries
PRNs	Pseudo-Random Numbers
R&S	Reconnaissance and Surveillance
RVS	Remote Video Surveillance
RVSS	Remote Video Surveillance Systems
RVT	Remote Video Terminal
RSM	Response Surface Methodology
SBI	Secure Border Initiative
SUAV	Small Unmanned Aerial Vehicle
SAR	Synthetic Aperture Radar
TTPs	Tactics, Techniques, And Procedures
TRVS	Trailer Remote Video Systems
UGS	Unattended Ground Sensor
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle

EXECUTIVE SUMMARY

Border protection is a vital national security issue for most countries. The U.S. Customs and Border Protection (CBP) is responsible for protecting the borders of the U.S. from terrorism, human and drug smuggling, and illegal migration. The U.S. CBP improves manpower, technology and infrastructure along the border through various projects.

The southwest border of the U.S. contains the majority of the illegal activities. In this study, part of the Tucson sector in Arizona is modeled in MANA, an agent-based model, to explore the effects of using a hand-launched, mini Unmanned Aerial Vehicle (miniUAV) along with other assets, such as Border Patrol (BP) agents, surveillance towers, Predator B, seismic sensors and communication center.

The main focus of the Secure Border Initiative (SBI), one of the major projects regarding border protection, is the integration of border security programs to gain effective control of the U.S. borders through substantial investments in technology, infrastructure, and enforcement personnel. SBInet Technology Program is one of the two programs under SBI for acquiring, developing, integrating, and deploying an appropriate mix of surveillance technologies, such as cameras, radars, and sensors, and command, control, communications, and intelligence (C3I) technologies.

The elements and concept of SBInet are used to develop the border security model in MANA. Ground sensors, capable of detecting illegal activities, are the first layer of defense. Although ground sensors can not differentiate

between legitimate and illegal activities, they can transmit the detection information to the towers.

Towers have day and night capable video surveillance systems that can detect and classify illegal entrants. Construction of a surveillance tower takes years in some circumstances due to the land acquisition processes.

The Predator B is the mid-altitude UAV that is modeled. With its long endurance, high speed and state of the art airborne sensors, the Predator B is a high value asset that is currently used by the U.S. CBP to detect, classify and track illegal entrants.

At the tactical level, the Raven, a hand-launched miniUAV, is modeled in MANA, which can be used directly by BP agents without the need for any coordination. Although it contributes BP agents to classify and track the illegal entrants, the miniUAV has some limitations such as wind speed, short endurance and operational radius.

The BP agents patrol in their area of responsibility to prevent illegal activities. They can receive information from all of the sensors and proceed, mounted or dismounted, to the area where an illegal activity is classified by sensors. Only the BP agents are capable of capturing illegal entrants.

All the information gathered by sensors is transmitted to the BP agents via the communication center. This center is the essential part of the SBInet concept, the main focus of which is to create a COP.

Once a base model is created in MANA, a Nearly-Orthogonal Latin Hypercube (NOLH) design is used to create various scenarios to explore the effects of factors on different measures of effectiveness (MOEs). MOEs, determined for analysis, are number of captured immigrants or smugglers and number of classified immigrants or smugglers.

After running the model using 257 design points with 30 replications of each, 7710 data points are acquired for each of four MOEs. JMP is used as a statistical tool to examine this data through comparison tests, linear regression, and regression trees. In order to fit models, the 7710 data points are summarized by their means and standard deviations, thus collapsing the data set for analysis down to 257 data points.

According to a comparison test, the use of miniUAVs is found to be beneficial in capturing the illegal entrants and thus provides more secure borders. The mean values of the number of captured illegal immigrants are calculated as 3.04 and 5.49, out of 20, for the scenarios without miniUAV and with miniUAV, respectively. Although there is no significant difference for the number of classified illegal entrants, between the scenarios with the miniUAV and without mini UAV, it is found that using mini UAV decreases the time needed to classify all illegal entrants.

Adequate manpower, in this case BP agents, and a reliable communication web to compose Common Operational Picture (COP) emerge as the most important factors regarding border protection, according to linear regression models. Some other important factors are classification ranges of towers, the presence of the Predator B and miniUAV, endurance of the mini UAV, the probability of classification of the towers and Predator B, and the tower height.

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I. INTRODUCTION

A. BACKGROUND

Border protection is a vital security issue for many countries. Terrorists; human, drug, contraband, and weapons smugglers; and immigrants have been trying to cross the borders illegally for decades. These illegal activities cause security problems especially for the regions adjacent to borders and are threats for the whole of the country.

1. Overview of the U.S. Borders

U.S. shares roughly 7,000 miles of land border with Canada and Mexico, 1,900 miles of which is with Mexico where most of the illegal activities take place. Customs and Border Protection (CBP), under the Defense Homeland Security (DHS), is responsible for protecting the U.S. borders. According to U.S. CBP, they protect the borders of the U.S. from terrorism, human and drug smuggling, illegal migration, and agricultural pests while simultaneously facilitating the flow of legitimate travel and trade. There are 327 Ports of Entry along the U.S. and 144 CBP Border Patrol Stations within 20 sectors. The proposed budget of the CBP for FY2008 to protect the borders was $8.8 billion (U.S. CBP, 2008).

2. Organization and Key Offices

CBP has an organizational structure as depicted in Figure 1. Every individual office out of 15 under the CBP Commissioner is responsible for various types of issues regarding U.S. Border protection. Some of these offices that are important for this study are described as follows in the U.S. CBP's Performance and Accountability Report:

Office of Intelligence and Operations Coordination (OIOC): Combining targeting and analysis functions from the Office of Field Operations (OFO), the Office of Information and Technology (OIT), Office of International Trade (OT) and the Office of Border Patrol (OBP), OIOC is responsible for the entire intelligence cycle.

Office of Field Operations (OFO): OFO is responsible for conducting 327 Point of Entries (POEs) to prevent terrorists and terrorist weapons from entering the United States.

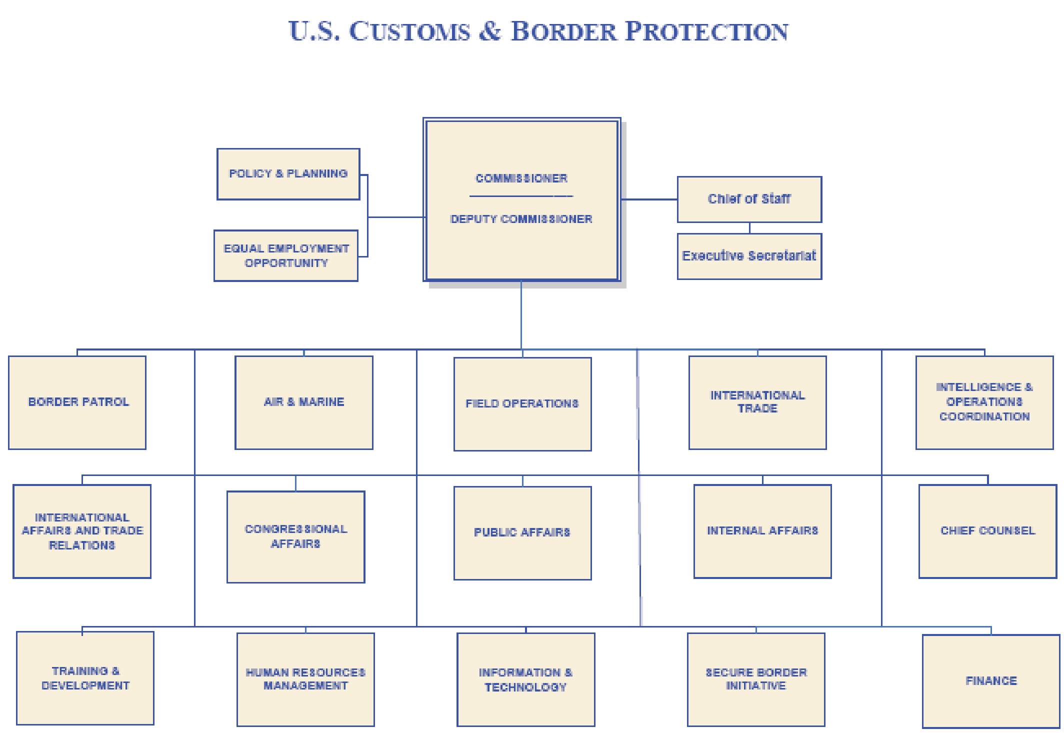

Figure 1. U.S. CBP Organization Chart (From: U.S. CBP, 2008)

Office of Information and Technology (OIT): OIT operates a high-performance Information Technology (IT) infrastructure, supports tactical communications, scientific solutions, and forensic services, and also implements and supports CBP’s IT, automation, and technology strategies.

Office of CBP Air and Marine (A&M): Main missions of CBP A&M, the world’s largest civilian law enforcement air force, are air and marine interdiction, air and marine law enforcement, and air and national border domain security. CBP A&M also supports DHS missions such as response and recovery to natural disasters and terrorism. CBP A&M operates from 74 air and marine locations, with more than 900 federal agents, 270 aircraft, and more than 180 maritime vessels.

Office of Border Patrol (OBP): OBP is the main office that is responsible for preventing terrorists, weapons of terrorism, illegal aliens, drugs, and smugglers from entering the United States between the POEs. Organization, mission, tactics and capabilities of BP are discussed under Border Patrol title in detail.

Office of Secure Border Initiative (SBI): SBI focuses on effective integration of border security programs. There are two current programs, SBI***net*** Technology Program and SBI Tactical Infrastructure Program, under SBI and various projects under these programs. The concept of SBI and its components are discussed separately in detail (U.S. CBP, 2008).

3. Overview of Illegal Activities

According to the CBP, 178,770 pounds of cocaine, 2,178 pounds of heroin, 2,471,931 pounds of marijuana and, 2,770 pounds of methamphetamine were seized along the border of the U.S. in 2008 (U.S. CBP, 2008). Drug smugglers can use illegal immigrants as a cover or distraction for their ground operations. They are also capable of using many kinds of vehicles, aircraft, vessels, and even semi-submersibles that have a low radar profile.

Illegal immigration is an important issue particularly along the southwest border with an average of 1 million apprehensions per year. According to Nuñez-Neto, this number represents approximately 97% of the all illegal alien apprehension along the U.S. borders (Nuñez-Neto, 2008).

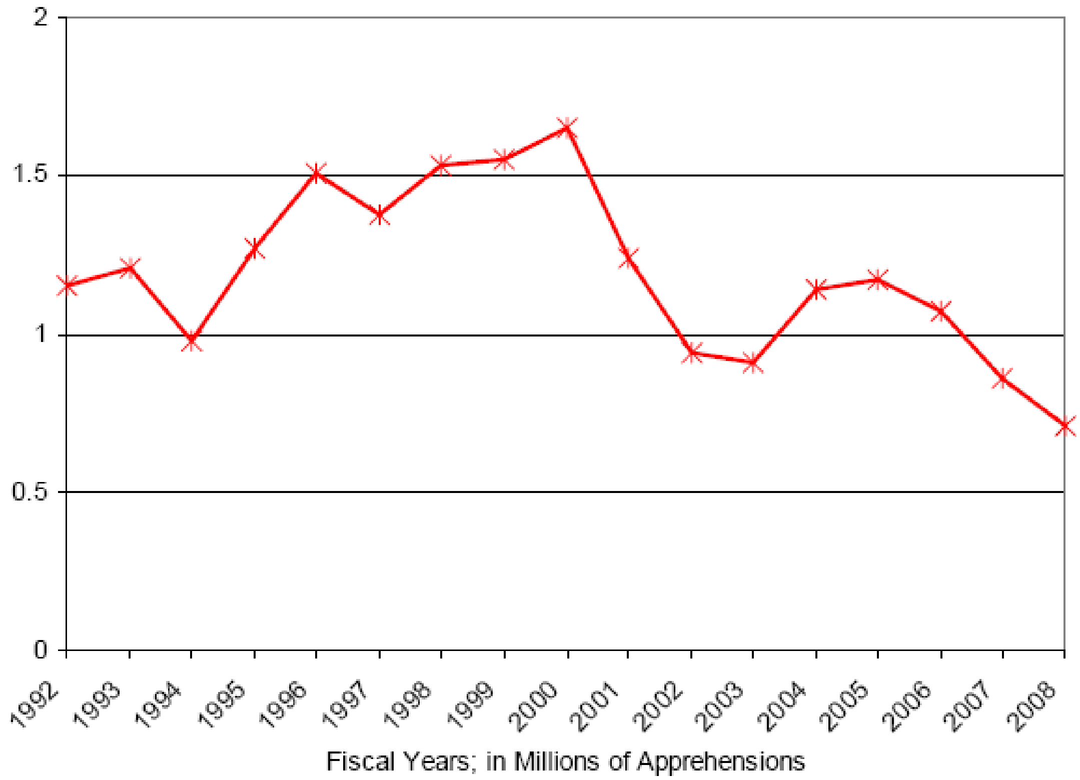

Figure 2. Southwest Border Apprehensions (From: Nuñez-Neto, 2008)

Nuñez-Neto and his co-authors also state that although more than 90% of the aliens trying to enter the U.S. illegally between POEs are Mexican nationals, the number of other than Mexicans (OTMs) being apprehended by the BP has more than tripled over the three years between 2002 and 2004. The majority of these apprehensions have come from four nations: Honduras, Brazil, El Salvador, and Guatemala (Nuñez-Neto et al., 2005).

Immigrants have to walk long distances in rough terrain and weather conditions while crossing the border and these difficulties cause many deaths. According to Seghetti, launch of the BP's "Prevention Through

Deterrence" strategy in 1995 that focused on pushing illegal immigration away from population centers led illegal immigrants to attempt to cross the border in remote desert regions, increasing the number of migrant deaths. Rates increased from 1.6 deaths per 10,000 apprehensions in FY1999 to 3.7 in FY2003 which indicates more than 300 deaths per year (Seghetti et al., 2005).

Apprehension rates are decreasing with the help of numerous projects and operations that improve technology, infrastructure and manpower to detect, identify, track and apprehend illegal immigrants, smugglers and contraband. These projects also enhance collaboration among the key agencies and develop new laws to deal with legislative issues.

B. RESEARCH QUESTIONS

This research is guided by the following questions:

- How might limited assets (such as UAVs, Border Patrol agents, ground sensors, and remote video surveillance systems) be configured in order to enhance detection and classification rates of illegal border crossings?
- What are the potential differences in illegal border crossing detection and classification when using miniUAVs with various capabilities?

C. SCOPE OF THE THESIS

This thesis discusses prevention of illegal border crossings without examining its social and economic effects on the U.S. To achieve that, a 30-mile-section of U.S.-Mexican border, near Nogales, AZ, is evaluated with various entities—Border Patrols, sensors, UAVs, smugglers, illegal immigrants, etc.—taken into consideration. The impact of various assets on detection and classification of illegal border crossings is examined by changing the configuration of these assets. This analysis gives insight into how to configure different assets used in the detection and classification process to explore the interactions of assets with each other.

The reason for choosing Tucson can be understood by looking at Figure 3, which displays the Southwest apprehension rates by sector. San Diego, El Paso and McAllen are the sectors with highest apprehension rates in the 1990's. While rates have decreased in California and Texas, with the help of Operation Gate Keeper in San Diego and Operation Hold-the-Line in El Paso, there has been an increase in Arizona sectors, especially in Tucson. The main reason is the success of the operations and projects of BP to push illegal immigration away from the populated areas. The shifting of immigration routes from more populated areas to the sparsely populated areas or from urban to rural is called the "Balloon effect" by Ordóñez in his thesis (Ordóñez, 2006).

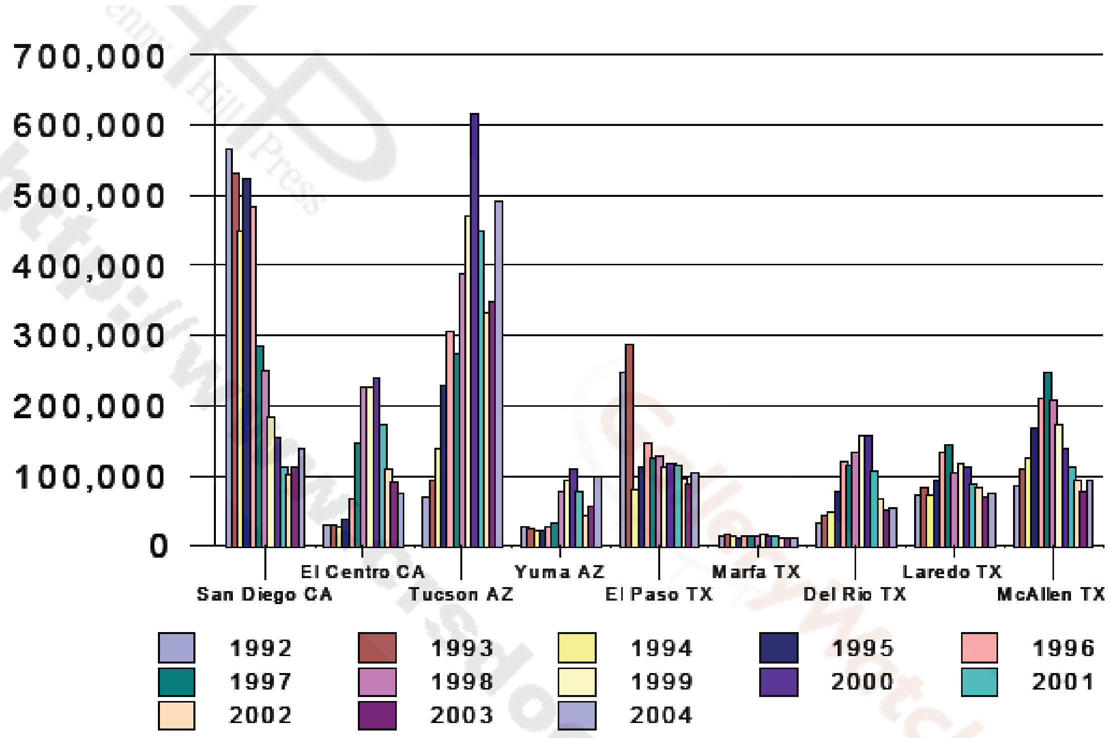

Figure 3. SW Border Apprehensions by Sector and Fiscal Year. (From: Nuñez-Neto, 2008)

The Tucson sector is the most active region for illegal activities. As a result, a majority of the technological projects under SBInet Technology Program are initiated in the Tucson sector, such as Project 28, a finalized proof-of-concept project, deployed along an approximately 28-mile section of the Tucson Sector.

D. LITERATURE REVIEW

In his thesis, Pulat (2005) develops an optimization model by maximizing the probability of escape of an infiltrator and then exploring the U.S. BP's courses of action to minimize the maximum achievable probability of escape. This model, focused on the U.S – Mexican border near Yuma, Arizona, provides an insight to identify critical road segments and areas to defend, and also evaluates the effects of employing different types of assets and strategies on the infiltration patterns.

Ordóñez (2006) illustrates the outcome apprehension probability of migrants given the implementation of various operational strategies by presenting the Arizona-Sonora Border (ASB) Model.

Patrascu (2007) develops a model in Microsoft Excel that maximizes the probability of detecting intruders by a distributed sensor network subject to a budgetary constraint.

Beeker and Page (2006) discuss a federation approach to simulate southern U.S. Border in MANA. Although there is no information about the model itself, the paper explains how they solve the issue of modeling a long border by dividing into smaller parts that overlap each other.

In his study, Raffetto (2004) analyzes Marine Expeditionary Brigade (MEB) commander’s 2015 unmanned aerial vehicle (UAV). He uses MANA to explore the impact of various capabilities of the UAV on intelligence gathering missions. Through modeling and data mining, this study provides insights into the importance of various UAV characteristics, such as airspeed, endurance, sweep width, and sensor capability.

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II. BORDER SECURITY CONCEPT

There are three legs of the border security concept: infrastructure, technology and manpower. Technology and infrastructure are developed by two different projects under the Secure Border Initiative (SBI) and Border Patrol agents are the main manpower to conduct the operations. Many types of sensors, radars, day/night cameras both on the ground and on airborne platforms form the technological barrier system along with a communication web to obtain operational pictures.

A. SECURE BORDER INITIATIVE

According to CBP website, the main focus of SBI, launched in 2005, is the integration of border security programs to gain effective control the U.S. borders through substantial investments in technology, infrastructure, and enforcement personnel. The Tactical Infrastructure Program and SBInet Technology Program are the two current programs under SBI (U.S. CBP).

1. SBI Tactical Infrastructure Program

According to a Government Accountability Office (GAO) Report, the SBI program received about $3.6 billion from FY2006 to FY2009 and about $2.4 billion of this amount has been allocated to complete approximately 670 miles of vehicle and pedestrian fencing along the border between the United States and Mexico. This program consists of building various kinds of pedestrian fences, vehicle fences, all-weather patrol roads and permanent lighting (Stana, 2009).

In the same report it is stated that most of the pedestrian fencing is single layer fencing and in some places, a secondary fencing is constructed parallel to existing primary fencing for additional operational advantage to deter illegal cross-border activities. Pedestrian fences are mostly constructed in urban areas (Stana, 2009). An example of the infrastructure system is illustrated in Figure 4. Sub-projects under SBI Tactical Infrastructure Program are listed in Table 1.

Fence projects	**Pedestrian fence miles**	**Vehicle fence miles**	**Total miles**
PF 70	81	N/A	**81**
PF 225	210	N/A	**210**
VF 300	N/A	227	**227**
Legacy pedestrian fence	67	N/A	**67**
Legacy vehicle fence	N/A	76	**76**
Total	**358**	**303**	**661**
Source: SBI.			
Note: N/A = not applicable.			
Seventy-eight miles of pedestrian fencing and 57 miles of vehicle fencing were in place before the SBI program began. However, since SBI began construction, some miles of fencing have been removed, replaced or retrofitted resulting in mileage totals that are different from those we have previously reported.			

Table 1. Border Fence Projects (From: GAO, 2009)

Figure 4. Border Infrastructure System in San Diego (From: Nuñez-Neto&Kim, 2008)

2. SBInet Technology Program

SBInet, launched in 2005 as a part of SBI, replaced two former programs, America's Shield Initiative (ASI) and the Integrated Surveillance Intelligence System (ISIS). A GAO report describes SBInet as the program under SBI for acquiring, developing, integrating, and deploying an appropriate mix of surveillance technologies, such as cameras, radars, and sensors, and command, control, communications, and intelligence (C3I) technologies (GAO, 2008).

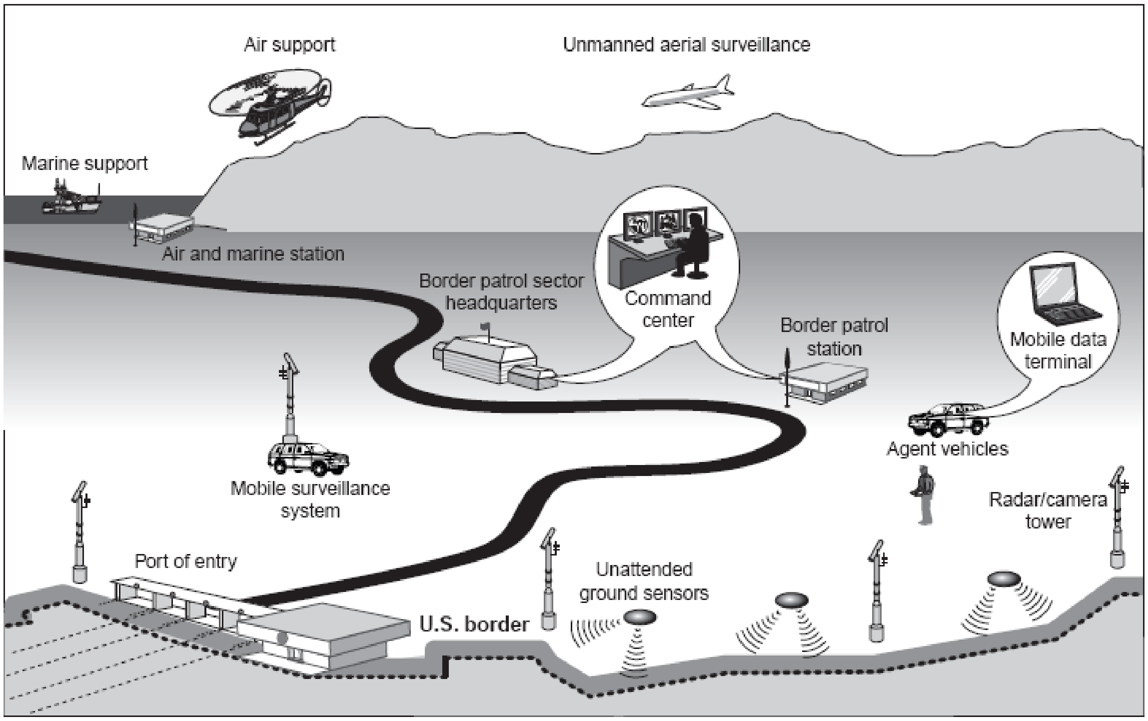

Figure 5. Conceptual Depiction of Long Term SBInet Operations (From: GAO, 2008)

In a review by DHS Office of Inspector General it is stated that ISIS was formally established in 1998 as a technological assistance program to provide continuous monitoring of the borders in all weather conditions. The main components of ISIS are sensors, Remote Video Surveillance Systems (RVSS) and the Intelligent Computer Assisted Detection System (ICAD). Sensors send a signal to the ICAD whenever detection occurs and then this area is investigated by a Law Enforcement Communication Assistant (LECA) by using RVSS or by a BP agent. Recognizing the need to improve border surveillance and remote assessment and monitoring technology, OBP began developing America's Shield Initiative (ASI) in June 2003, as a program to integrate surveillance technology, communications, and visualization tools by maintaining and modernizing ISIS (Office of Inspector General, 2005).

According to CBP website, SBInet develops and deploys new integrated technology solutions for front-line CBP personnel by providing enhanced detection, tracking, response, and situational awareness capabilities. An essential element of SBInet Technology Program is a Command, Control, Communications, and Intelligence (C3I) Common Operating Picture (COP), which provides real-time situational awareness of the area of responsibility of BP agents and allows fewer agents to cover more ground (U.S. CBP).

Current and completed SBInet projects that are mentioned in the CBP website include:

a. Ajo-1 Project

The Ajo-1 Project, expected to be fielded in calendar year 2010, is located south of Ajo, Arizona and is comprised of six sensor towers, six communication towers, 200 unattended ground sensors, and 20 miles of access road improvements and construction.

b. Command, Control, Communications, and Intelligence (C3I) Project

This on-going C3I project, launched in December 2007, focuses on obtaining a Common Operating Picture (COP).

c. El Paso Phase I & Phase II Projects

These projects include a tower system equipped with a camera, radar, sensors and communications equipment;

new and retrofitted vehicles; and unattended ground sensors. Phase I and phase II covers an approximately 74-mile area of the U.S./Mexico international border in the vicinity of Fort Hancock, Fabens, and Ysleta, Texas and a 194-mile area from New Mexico (Lordsburg, Deming, and Santa Teresa) into El Paso, Texas.

d. Northern Border Project

The Northern Border Project includes, but is not limited to, 16 Remote Video Surveillance Systems (11 sites in the Border Patrol’s Detroit Sector and 5 sites in the Border Patrol’s Buffalo Sector), and 3 Mobile Surveillance Systems.

e. Project 28

As a finalized proof-of-concept project, Project 28, deployed along an approximate 28-mile section of the Tucson Sector, in the vicinity of Sasabe, Arizona, has provided some insights on the operational and technical challenges of the SBInet program.

f. TUS-1 & Tucson Sector Projects

TUS–1, the first of two operational deployments of the SBInet technology solutions, includes nine sensor towers; eight communication towers, 200 unattended ground sensors, and six miles of access road improvements and construction over 23 miles of the U.S-Mexico border near the Sasabe Port of Entry. Once key elements of the project plan are strengthened, the Tucson Sector Project will cover all 262 miles of border in this sector.

g. Yuma Sector Project

Having the same components with the other projects, Yuma Sector Project covers approximately a 125-mile area in Yuma Sector, between the Camp Grip training facility and the El Centro Sector line near the Imperial Sand Dunes (U.S. CBP).

3. Key Components of SBInet

a. Unattended Ground Sensors (UGS):

Seismic and magnetic UGSs construct the primary layer for detection of illegal activities. There are mainly two types of ground sensors; older technology sensors, with high false alarm rates, that are deployed as a part of ISIS and new technology sensors as a part of SBInet.

For older sensors a report by the Office of Inspector General under DHS states that, these sensors are the most used as well as the easiest and least expensive to install and maintain. The sensor sensitivity level can be adjusted to help filter false alerts. There are more than 11,000 sensors along the northern and southwest borders (Office of Inspector General, 2005).

It is stated in a hearing before the U.S. Senate that average detection range for ground sensors is 10 meters (Senate Hearings, 2005). On the other hand, Dumpert and Dirksen claim 30 feet for the detection range. (Dumpert & Dirksen, 2006) Although effective in detecting activity or movement, these sensors cannot differentiate between illegal activity and legitimate events. Therefore, every detection needs to be investigated by either a BP agent or some other sensor that has classification capability. But, due to high false alarm rates caused by other than illegal alien activity, such as local traffic, outbound traffic, a train, or animals, this effort, to clarify detections by UGSs, is mostly ineffective. According to the analysis of sensor alerts along both U.S. borders in the same report by the Office of Inspector General, 90 percent or more of these alerts were false alarms. Data conducted by the analyst to determine this result is shown in Table 2.

Ticket Source	**Number of ICAD Tickets**	**Apprehensions**		**Staging, Turn or Got Away**	**Identified False Alarm**	**Unidentified, Unknown or Not Available**
Sensor Alerts	29,710	252	< 1 %	3%	34%	62%
RVS Camera Observations	155	89	57%	41%	1%	0%
Non-ISIS Sources	780	382	49%	4%	40%	7%
Source: OIG analysis of OBP ICAD report data. Note: Rows may not equal 100 percent due to rounding.						

Table 2. Southwest Border ICAD Ticket Results (From: Office of Inspector General, 2005)

Operation of a UGS is affected by moisture which can cause corrosion, and intentional or accidental physical damage by vehicles, machinery, or vandals. Also insects penetrating sensors can affect functionality (Office of Inspector General, 2005).

According to Knobler & Winston, due to these issues of the legacy sensors, a derivative of OmniSense® sensor system, developed by McQ, with terrestrial communications and no imaging capabilities has been delivered as part of the SBInet program. Five modalities of transducers are used in CORE sensors are seismic, acoustic, Passive infrared (PIR), magnetic, and tripwire. McQ developed a fusion architecture and protocol for passing the appropriate data among devices to achieve the following goals:

- Reduction of false alarms compared with detections from individual sensors
- Improved classification compared with detections from individual sensors
- The ability to track target speed and direction (Knobler & Winston, 2008).

b. Remote Video Surveillance Systems (RVSS)

According to a GAO report, while radars mounted on fixed and mobile towers detects movement, cameras on fixed and mobile towers are used to identify, classify, and track items of interest detected by the ground sensors and the radars (GAO, 2008).

According to the U.S. CBP, these systems are deployed on diverse platforms such as Static Remote Video Systems that are located on towers, buildings, and in some areas, poles, Mobile Remote Video Systems (MRVS) that are located almost exclusively on scope trucks with the exception of the tripod types and the man portable systems, and Trailer Remote Video Systems (TRVS) that are generally mounted on “Sky Watch” trailer systems (U.S. CBP, 2008).

Some characteristics of Remote Video Surveillance systems (RVSS) are specified by the Office of Inspector General (2005, p. 4) as follows:

> RVS systems provide the primary remote identification capability. RVS components include cameras, mounting poles, radio, and equipment, such as cabling and equipment enclosures. The RVS system includes both color (day) and thermal-

> infrared (night) cameras, which are mounted on sixty or eighty-foot poles or other structures. RVS camera signals are transmitted to the OBP sector or station communications center via a wireless system such as microwave signal, or, in one sector, via fiber optic cable. Personnel at designated communications centers can control most RVS cameras remotely using toggling keyboards. There are 255 operational RVS camera sites along the northern and southwest borders.

David Aguilar, Chief, Office of Border Patrol (OBP), stated in a hearing before the U.S. Senate that out of these 255 camera sites, Tucson Sector has 39, Yuma has 18, Swanton has six, El Centro Sector has 41, El Paso has 27, Laredo has 20 and, McAllen has 29 and each one of these poles has the capability of looking in either direction about six miles (Senate Hearings, 2005).

One of the problems with stable towers, he mentions in his speech, is that approximately 92 percent of the border is environmentally sensitive in Arizona. Therefore it takes a multi-year process to even plant a pole in the ground for an RVS camera, to build the tactical infrastructure or to build the roadways. Also some towers must be constructed in places that are feasible in terms of acquisition process instead of the places that provide the best coverage (Senate Hearings, 2005).

Another issue stated by the Office of Inspector General is that RVS cameras do not have the ability to detect movement by themselves. It should be monitored by a person, called a Law Enforcement Communication Assistant (LECA), in a BP station or in a command center. In case of a triggered alarm by a UGS, the LECA is required to select the appropriate RVS camera, manually maneuver the camera in the direction of the sensor and attempt to identify the cause of the sensor alert. However, the number of LECAs is inadequate. For instance, at one location they visited, only one LECA was on duty performing radio-dispatch duties, processing sensor alert information via ICAD, and monitoring 32 cameras (Office of Inspector General, 2005).

McDaniel states the specific requirements of EO/IR sensors as follows:

- Detection of Man-Sized Targets at 3500 meters (minimum)
- Recognition of Man-Sized Targets at 2200 meters (minimum)
- Detection of Vehicle-Sized Targets at 7500 meters (minimum) (McDaniel, Hughes, & Seibel, 2006).

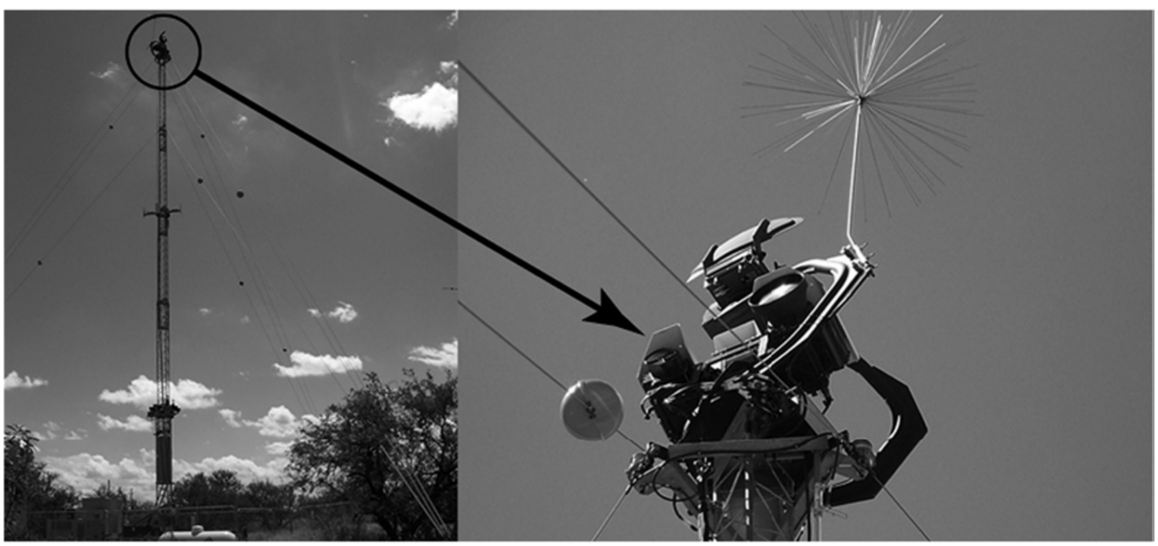

Figure 6. Tower Deployed in Tucson Sector with Camera and Radar(From: GAO, 2008)

c. *Unmanned Aerial Vehicle*

Another asset that supports Border operations is Unmanned Aerial Vehicles (UAVs) that are capable of detecting, classifying and tracking illegal activities. According to CBP, CBP A&M currently operates five Predator B UAVs; four are from the UAS Operations Center in Sierra Vista, Arizona, and one is from the UAS Operations Center in Grand Forks, North Dakota (U.S. CBP). The history of the UAV demonstrations sponsored by DHS is displayed in Table3.

Demonstration	Location	Unmanned Aircraft Used	Sponsor (Support)	Dates	Sorties Flown	Hours Flown
Operation Safeguard	Gila Bend, AZ	PredatorB	ICE (Air Force)	Oct-Nov 2003	15	106
Alaska Demo 1	King Salmon, AK	Predator	USCG (Navy)	Nov 2003	5	35
Alaska Demo 2	King Salmon, AK	Altair	USCG (NASA)	Aug 2004	3	36
	Wallops Island, VA	Aerosonde	USCG (NASA)	Nov-Dec 2004		
ABCI	Sierra Vista, AZ	Hermes 450	CBP (Navy)	Jun-Sep 2004	65	590.1
ABCI Follow-on	Sierra Vista, AZ	Hunter	CBP (Army)	Nov 2004 - Jan 2005	41	329.1
Coastal Areas	Borinquen, PR	Aerosonde	USCG	Feb 2005		

Table 3. DHS-Sponsored Unmanned Aircraft Demonstrations (From Unmanned Systems Roadmap 2007-2032, 2007)

According to Bolkcom and Nuñez-Neto, some benefits of using UAVs in border operations are that they could fill a gap in current border surveillance by improving coverage along remote sections of the U.S. border, UAVs can provide precise and real-time imagery to a ground control operator. UAVs also would have a greater chance of tracking an illegal entrant in dense woods or mountainous terrain, with thermal detection sensors than the stationary video equipment which is often used on the borders.

Despite potential benefits of using UAVs for homeland security, there are some common issues such as the high accident rate of UAVs, which is currently 100 times higher than that of manned aircraft, and UAVs equipped with only an EO and IR camera can suffer from cloudy conditions and high humidity climates that can distort the imagery produced by EO and IR equipment (Bolkcom & Nuñez-Neto, 2008).

(1) Predator B: According to CBP, the Predator B (Figure 7) is a tactical multi-mission UAV and the primary mission equipment consists of a Raytheon AN/AAS-52(V) MTS EO/IR sensor turret/laser designator and a General Atomics AN/APY-8 Lynx SAR (U.S. CBP, 2009).

Figure 7. Predator B (From: U.S. CBP)

Max level speed	240 kt (444 km/h; 276 mph)
Cruising speed	210 kt (389 km/h; 242 mph)
Max operating altitude	15,545 m (51,000 ft)
Mission radius	1,655 n miles (3,065 km; 1,904 miles)
Max range	4,950 n miles (9,167 km; 5,696 miles)
Endurance	35 h

Table 4. Predator B Performance(From: Jane's)

The AN/AAS-52 Multi-Spectral Targeting System (MTS), one of the mission components of Predator B, combines electro-optical (EO), infrared (IR), laser designation, and laser illumination capabilities in a single sensor package. The multi-use system offers long-range surveillance, target acquisition and tracking (Raytheon Company).

Parameters	Features	Parameters	Features
Fields of view, degrees:	Wide: 34-45	Elevation:	60 degrees up, -120 degrees down
	Medium-wide: 17 x 22	Gimbal slew rate:	3 radians/sec elevation
	Medium: 5.7 x 7.6	Maximum air speed:	>350kts IAS
	Medium-narrow: 2.8 x 3.7	Image Fusion:	Included
	Narrow: 1.2 x 1.6 (IR and TV)	Automatic video tracker:	Multimode (centroid, area, and feature)
	Ultra-narrow: 0.6 x 0.8 (IR)	Environmental:	Compliant with MIL-E-5400, MIL-STD-810
	Ultra-narrow: 0.21 x 0.27 (TV)	Interface:	1553 data bus and/or discrete controls
Electronic zoom, IR & TV:	2:1 – 0.3 x 0.4 (IR), 0.11 x 0.14 (TV)	Video outputs:	RS-170 (525-line), digital, other formats available
	4:1 – 0.15 x 0.2 (IR), 0.06 x 0.07 (TV)	Cooling:	Self contained
Gimbal angular coverage:	Azimuth: 360 degrees, continuous	Options:	Multiple sensors such as EO-TV, image intensified TV, illuminator, eyesafe rangefinder, spot tracker, image fusion, and other avionics

Table 5. AN/AAS-52 MTS Specifications (From: Raytheon Company Web Site)

Another component of Predator B is the high-resolution Lynx Synthetic Aperture Radar (SAR). In their study, Tsunoda, et al., state that the Lynx SAR weighs less than 120 lbs., has a slant range of 30 km, allows two resolution selections and is capable of 0.1 m resolution in spotlight mode and 0.3 m resolution in stripmap mode. In ground moving target indicator mode, the minimum detectable velocity is six knots with a minimum target cross-section of 10 dBsm. The Lynx user interface features a view manager that allows it to pan and zoom like a video camera. (Tsunoda et al., 1999) Detailed specifications of stripmap and spotlight mode are demonstrated in Table 6 and Table 7.

Resolution	0.3 to 3.0 m	Both slant range and azimuth
Range	7 to 30 km	Slant range (3-60 km at reduced performance)
Ground swath	2600 pixels	Only with 16-node system (to 3500 pixels at coarser resolutions)
View size	934 m	At 0.3 m resolution, 45 deg. depression
Squint angle	+/- (45 to 135) deg	Squint is difference between scene center-line and aircraft velocity vector

Table 6. Stripmap SAR Mode Specifications (From: Hensley et al., 1999)

Resolution	0.1 to 3.0 m	Select one of five
Range	4 to 25 km	Slant range (3-60 km at reduced performance)
Patch Size	2 x (640 x 480) pixels	
View size	640 x 480 pixels	Over NTSC video link
Squint angle	+/- (50 to 130) deg	
	+/- (45 to 135) deg	0.15 m resolution and coarser

Table 7. Spotlight SAR Mode Specifications (From: Hensley et al., 1999)

(2) Raven: Army Unmanned Aircraft System Operations Field Manual describes the Raven as a man-portable, hand-launched small unmanned aerial vehicle (SUAV) system designed for Reconnaissance and Surveillance (R&S) and remote monitoring.

Figure 8. Raven B (left), An Operator and Observer Team Assembling the SUAS (right). (From: Lifschitz et al., 2007)

Raven consists of three main components: UAV and sensors, Remote Video Terminal (RVT) and Ground Control Unit (GCU). For sensors it has three different interchangeable noses, one with front and side look CCD color videos and two for infrared cameras, one for front other for side look. Specifications of these cameras can be found in Table 9. It can easily be assembled in less than 3 minutes and reusable for more than 100 flights (Headquarters, Department of the Army, 2006).

There are many sources that give slightly different numbers for specifications of the Raven but according to the Directory of U.S. Military Rockets and Missiles it weighs about 1.9 kg (4.2 lb), has a flight endurance of 80 minutes and an effective operational radius of about 10 km (6.2 miles). Flying speed is 45-95 km/h (28-60 mph) at typical operating altitude between 30 and 300 meters (100-1000 ft). The Raven can be either remotely controlled from the ground station or fly completely autonomous missions using GPS waypoint navigation (Parsch, 2004).

<table>
<tr><th colspan="5">UAV Characteristics</th></tr>
<tr><th colspan="2">Feature Design</th><th>Specification</th><th>Feature Design</th><th>Specification</th></tr>
<tr><td colspan="2">Power</td><td>Li-Ion rechargeable battery</td><td>Airspeed</td><td>23 kt loiter, 34 kt cruise, 60 kt dash</td></tr>
<tr><td colspan="2">Wing Span</td><td>4.5 ft (1.37 m)</td><td>Altitude</td><td>150-1,000 ft (45.72-304.8 m) AGL</td></tr>
<tr><td rowspan="3">Weight</td><td rowspan="2">UA</td><td rowspan="2">4 lb (1.81 kg) (12 lb [5.44 kg] with carrying case)</td><td>Endurance</td><td>60 to 90 minutes (Li-Ion – rechargeable)</td></tr>
<tr><td>Payload(s)</td><td>EO/IR sensors</td></tr>
<tr><td>GCU</td><td>17 lb (7.71 kg)</td><td>Launch/Recovery</td><td>Hand-launched/auto land recovery on soft, unimproved surface</td></tr>
<tr><td colspan="2">Range</td><td>8-12 km</td><td>Crew</td><td>Two MOS nonspecific Soldiers</td></tr>
<tr><th colspan="5">Sensor Characteristics</th></tr>
<tr><th colspan="2">Feature Design</th><th>EO</th><th colspan="2">IR</th></tr>
<tr><td colspan="2">Pixels</td><td>768H X 494V</td><td colspan="2">160H X 120V</td></tr>
<tr><td colspan="2">Payload Nose Weight</td><td>6.2 oz</td><td colspan="2">6.5 oz</td></tr>
</table>

Table 8. Raven UAV and Sensor Characteristics (From: U.S. Army, 2006)

An OEF/OIF study of close combat missions, using small unmanned aircraft systems presents some limitations of a small UAV, such as Raven, as follows.

Because of its small size and required low overall weight, Raven has limitations in the imaging payloads it can carry. The best arrangement for cameras to view images at given slant ranges result in a narrow field of view. The test results show that to recognize man-sized objects, it should fly at 300 feet AGL or lower.

Another issue is the lack of stabilizing image capability. Even the slightest wind shift causes the vehicle to move in all three axes which produce images that when viewed through the video screen appear as a bobbing effect with the viewed image moving constantly.

The information provided by Raven is of limited use due to its short endurance, small area of coverage and inability to communicate with other information systems.

During the operational test, 21 of 61 hand launch attempts ended in failure and nineteen of the failed launch attempts occurred during nighttime and in zero to calm wind conditions (Lifschitz et al., 2007).

Despite all the limitations stated above, a small UAV like Raven is still promising in border operations with its inexpensive cost, lower coordination and personnel requirements in comparison with Predator B. It can be used by every individual mission package of BP agents, at the tactical level, as a forward eye with its airborne sensors, for detection, classification and tracking of illegal entrants.

B. BORDER PATROL

According to the CBP, the United States Border Patrol (BP) is the mobile, uniformed law enforcement arm of the U.S. CBP within the DHS. The BP, with more than 17,000 agents in FY2008, is charged with securing the U.S. international land border between POE, detecting and preventing the entry of terrorists, weapons of mass destruction, and illegal aliens into the country, and interdicting drug smugglers and other criminals along the border. The BP achieves this goal by maintaining surveillance, following up leads, responding to electronic sensor alarms and aircraft sightings, and interpreting and following tracks.

In some regions, due to diverse terrain features such as uninhabited deserts, canyons, or mountains, the BP utilizes a variety of equipment and methods to accomplish its mission. Electronic sensors, video monitors and night vision scopes are all used to detect illegal entries and agents patrol the border in vehicles, boats, manned and unmanned aircraft, and afoot. In some areas, the Border Patrol even employs horses, all-terrain motorcycles, bicycles, and snowmobiles (U.S. CBP, 2009).

BP conducts its mission within 20 sectors with 140 Border Patrol stations nationwide and 34 permanent checkpoints.

According to a GAO report, on the southwest border, the Border Patrol uses an integrated, multilayered border enforcement strategy. Along the border, between official ports of entry, are the first two layers, consisting of a first called line watch and a second, called line patrol. Together, these are where the majority of the U.S. Border Patrol agents are deployed, to maintain a high profile to deter, turn back, or arrest anyone attempting to illegally enter the country. The line patrol layer consists of smaller contingents of agents deployed behind the line watch units to provide direct support of the line watch units. The Border Patrol allocates personnel based on a combination of intelligence information about potential threats from terrorists and contraband smugglers, as well as on the estimated volume of illegal entries. In addition, a third layer of enforcement is composed of interior traffic checkpoints at which Border Patrol agents monitor and stop vehicles at checkpoints—both permanent and tactical (temporary)—on major U.S. highways and secondary roads that are generally 25 to 75 miles inland from the border (GAO, 2005).

Due to the scope of this study BP structure and capability in Tucson, AZ region is explained in detail.

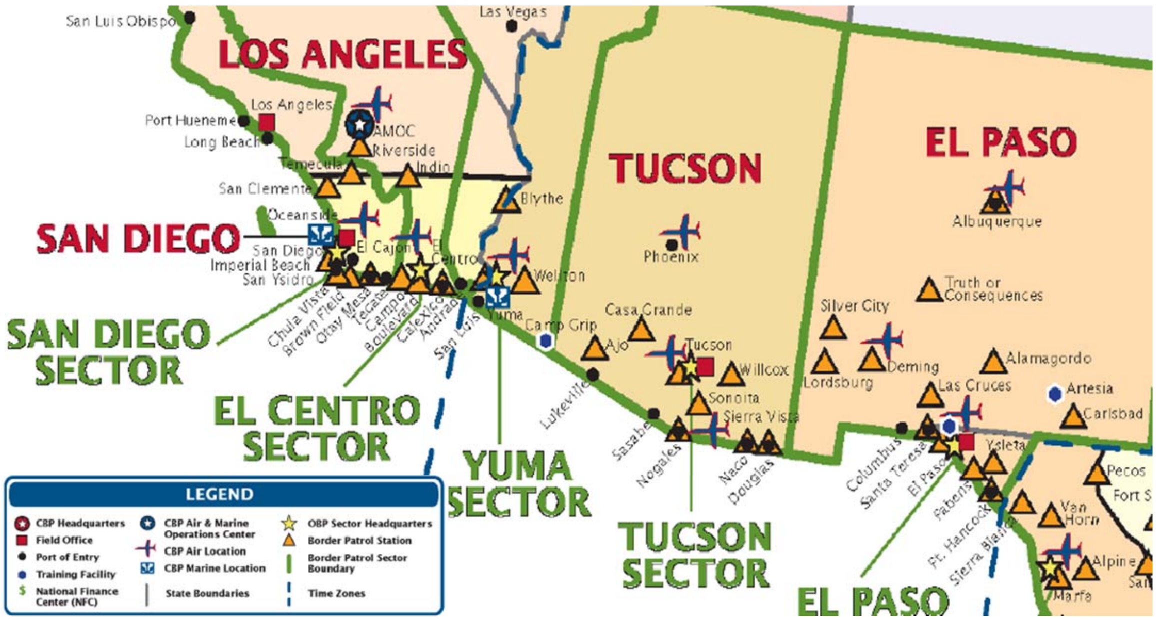

Figure 9. Tucson Sector Map (From: CBP)

The CBP website states that the Tucson Sector is the busiest sector on the Southwest Border with more than 2,900 agents and covering 262 miles of linear border from the Yuma county line to the Arizona/New Mexico state line. The eight stations, that the sector contains, are located in Ajo, Casa Grande, Tucson, Nogales, Wilcox, Sonoita, Naco, and Douglas (Figure 9) (U.S. CBP, 2008).

Apprehension rates currently are high in Tucson while rates have decreased in the other problematic sectors such as San Diego, CA and El Paso, TX. David Aguilar, Chief, Office of Border Patrol (OBP) has noted the shift of the illegal routes from urban to rural. This shift gives criminal organizations a wider array of action and also forces BP agents to deal with the rural environment, rural dynamics and, much broader area of operations with same personnel, technology, and tactical infrastructure (Senate Hearings, 2005).

Aguilar also mentions two typical characteristics of Arizona, unlike California and Texas, that hinder control of the border. One of them is the absence of checkpoints which are a very effective way of controlling major roadways. In Arizona, they are forced to use temporary or mobile checkpoints that are not as effective as permanent checkpoints due to the fact they do not have permanent infrastructure such as staging areas and detention centers. The second reason for an inefficient border control in Arizona is the environmental constraint due to the Federal ownership of the land. Any action to construct an infrastructure becomes a major Federal action subject and takes more than years to implement. The environmental sensitivity of the land is another issue. While the BP agents has to operate carefully to prevent damage to these sensitive areas, by not using cars for instance, the smugglers or immigrants can easily use these areas without any concern. This creates a disadvantage to the BP agents in tracking illegal entrants (Senate Hearings, 2005).

C. ILLEGAL ACTIVITIES

Illegal immigrants usually cross the border with the help of human smugglers, in other words, “Coyotes”. Ordóñez states that illegal immigrants meet coyotes in staging areas before crossing the border. Coyotes decide which gateway to use based upon information provided by personnel, known as “Scouts”, at observation posts in the border region to provide warnings to the Coyotes (Ordóñez, 2006).

According to Ordóñez, smugglers and illegal immigrants use three main corridors in the BP Tucson Sector to cross the U.S. borders: the West Corridor, Nogales Corridor and the Naco-Douglas Corridor. These main corridors contain the 13 most frequently used routes as illustrated in Figure 10:

• West Corridor: Organ Pipe National Park, Tohono O’odham Nation – San Miguel Port of Entry and the Tohono O’odham Nation – Pozos Verde.

• Nogales Corridor: Coronado National Forest, Mariposa Canyon, the Nogales POEs and Patagonia.

• Naco-Douglas Corridor: Fort Huachuca Mountains or Copper Canyon, the Naco POE, San Pedro Valley, Whitewater Wash area, the Douglas POE and the San Bernardino Valley (Ordóñez, 2006).

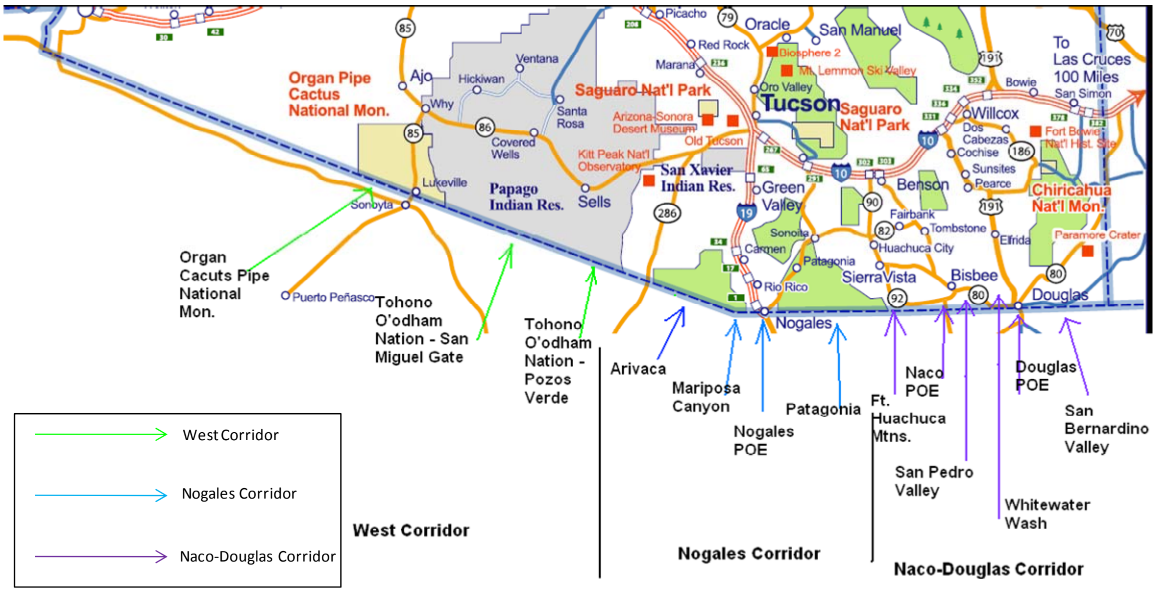

Figure 10. Identified Most Frequently Used Illegal Human and Drug Smuggling Routes (From: Ordóñez, 2006)

Ordóñez also states that drug and human smugglers usually respect their area of operation and use different routes. Nevertheless, in some cases they intersect with each other and use this as an advantage. For instance, drug smugglers use illegal immigrants to distract the BP agents (Ordóñez, 2006). Table 9 shows the classification of 13 smuggling routes as drug and human.

ROUTES (from E to W along border)	ROUTES	
	DRUG	**MIGRANT**
West Corridor (L3)		
Organ Pipe National Park	X	X
TO Nation – San Miguel	X	X
TO Nation - Pozos Verde		X
Nogales Corridor		
Coronado National Forest (Arivaca) (L3)	X	X
Mariposa Canyon (L2)		X
Nogales POE (L1)	X	X
Patagonia (L2)	X	
Naco-Douglas Corridor		
Ft. Huachuca Mountains (Copper Canyon) (L3)		X
Naco POE (L2)	X	X
San Pedro Valley (L3)	X	X
White Water (L2)		X
Douglas POE (L1)	X	X
San Bernardino Valley (L2)	X	

Table 9. Identification and Classification of Illegal Routes (From: Ordóñez, 2006)

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III. MODEL

A. WHY MANA

MANA (Map Aware Non-Uniform Automata) version 4.04.1, an agent-based model, is used to simulate the border in this study. With the help of emerging behaviors of agents, agent-based models are beneficial to simulate complex systems, which in particular contain humans as elements. Once general characteristics and propensities of the agents are defined, each agent decides how to act through the simulation to reach their goals. MANA allows us to create a border security model with BP agents, immigrants and smugglers.

Another reason for using MANA is the built-in feature for communication among agents. Due to the main focus of SBInet Technology Program as the integration of all these sensors to obtain Common Operation Picture (COP), communication is a critical element of Border Security Model, and communication links can be easily constructed in MANA by this built-in feature.

Once elevation and terrain maps are loaded, MANA calculates the line of sight (LOS) for agents automatically which is an important issue to model surveillance systems.

Finally, MANA as a distillation model is easy to understand for a first-time user and creating a scenario from scratch does not take too much time.

However, besides all these advantages, MANA has some limitations on simulating some BP operations that are different from military applications. Also it is not supported with sufficient analysis tools which cause an extra effort to interpret results.

B. MANA IN GENERAL

This part is a brief summary of the MANA user manual. Refer to the manual for detailed description and features of the model.

The main elements of the MANA model are squads and agents that construct these squads. A squad consists of either an individual agent or a group of agents with the same characteristics. Each squad can be either friend, enemy or neutral.

Each squad has some characteristics associated with its agents such as personality and physical capabilities and also characteristics of the assets that the agents use such as sensors, weapons and communication tools.

The agents move in a battlefield consisting of a two-dimensional grid. The movement algorithm is a critical feature that constructs the emerging behaviors by using some penalty calculations. The movement constraints and the propensities of the agents to reach some goals such as going through the next waypoint, enemy, friend, unknown, etc., have the main effect on the direction of this movement. “Going” feature of the terrain map and speed of the agent determines the velocity. The agents that will be considered in that calculation are determined by situational awareness maps of the sensors of the agent organically or via communication link, inorganically. Characteristics and propensities of an agent can be altered through the simulation by using “trigger states.” For instance, a state for "fuel out" can be defined and speed of the agent can be set to zero for this state. In another example, a state can be defined for "enemy contact" and the propensity of the agent for going through the enemy can be increased while that for following waypoints is decreased.

The sensor of an agent has the capability of detection and classification within some ranges. There are simple and advance modes for the sensors. In simple mode, a cookie-cutter sensor is used for detection and classification. In advance mode, the user can define a cone-shaped field of view (FOV) with an associated slew rate and also define probabilities in a decreasing order by range. The first requirement for the detection is to have LOS between two agents. An elevation map and the concealment values of the terrain and the agent itself are the critical factors in LOS calculations.

The agents can be given weapons to kill each other within some range and with a probability of a hit. This feature is only used to represent capturing of illegal entrants by BP agents.

There two types of communication links, organic and inorganic. Organic or intra-squad communication links are between the agents of the same squad and have relatively basic settings. Inorganic or inter-squad communication links are between the squads and have more options to set such as range, latency, capacity, reliability, accuracy, etc. (McIntosh et al., 2007).

C. BATTLEFIELD

In MANA, the Battlefield is the surface where agents perform their missions and they cannot jump out of its boundaries. The Battlefield is divided by a predefined grid, each cell of which can be occupied by a single agent. For this study, a 1000x1000 grid is used as the battlefield to represent the 50x50 km border in the the Patagonia region of the Tucson sector, and every cell represents 50x50 m in the real world.

Three types of maps are used in MANA to form the battlefield: Background, Terrain and Elevation maps. Background is the user interface for the battlefield that has no effect on calculations. Terrain and Elevation map affect both speed and Line of Sight (LOS) calculations of the agents and corresponding sensors. Each type of terrain, represented with different RGB color codes, has specific characteristics in terms of going, cover and concealment. “Going” effects agent’s speed, “cover” effects shot probability and “concealment” effect sensor capability for detection and classification. Terrain types and characteristics can be found in Figure 11.

	Going	Cover	Conceal	Red	Green	Blue
BilliardTable	1.00	0.00	0.00	0	0	0
Wall	0.00	1.00	1.00	192	192	192
Hilltop	0.90	0.10	0.95	64	64	64
Road	1.00	0.00	0.00	255	255	0
LightBush	0.75	0.10	0.30	10	255	10
DenseBush	1.00	1.00	1.00	40	180	40
Mountain	0.20	0.00	0.75	59	23	18
OffRoad	0.75	0.00	0.50	200	200	160

Figure 11. Terrain Properties

The elevation map consists of black, white and shades of grey. The highest point is represented as white, while black is used for lowest point and shades of grey are used in between. For the battlefield of this study "Real World Elevation Range Max" is set to 1153 m, the difference between the highest and lowest point, where the highest point is 2588 m and the lowest point is 1435 m. This elevation range is converted to a range of 0 to 225 by MANA behind the scenes for LOS calculations. The terrain and elevation maps used for the model are presented in Figure 12.

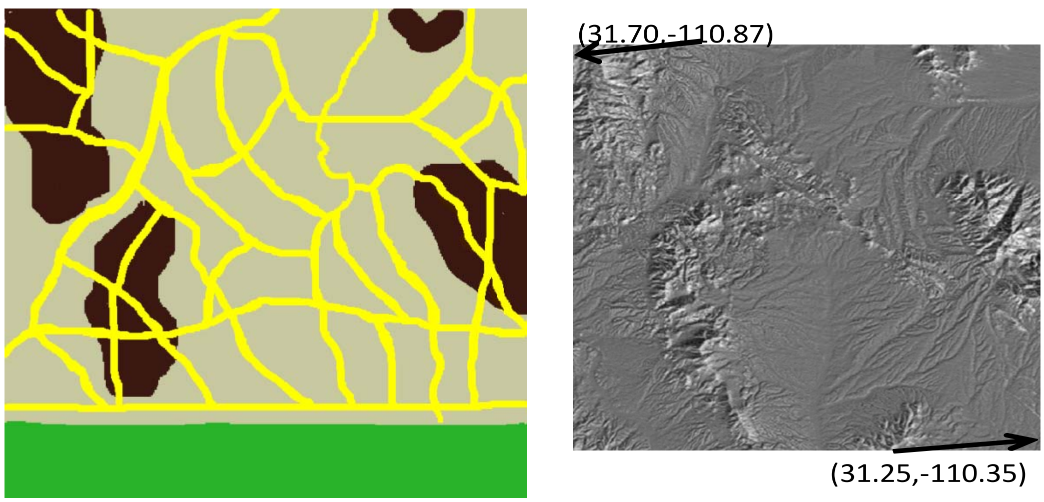


Figure 12. Terrain and Elevation Map (Created From: National Geospatial Intelligence Agency DTED)

The Elevation Map is constructed by viewing the Digital Terrain Elevation Data (DTED) level 2, from the National Geospatial Intelligence Agency, using Falcon View v3.3. After noting the difference between the highest and lowest points of elevation, the image is converted into a grey scale bitmap that MANA would understand.

While constructing the Terrain Map, the Naval Research Lab's Geospatial Information Data Base (GIDB) tool v2.2 is used to view the roads and other major terrain features of the area. Then the layers of available data are converted into a bitmap that MANA would understand using the open-source image editor, GIMP. As a final step, due to having only the information on the major hard-surface roads, the roads are extrapolated by adding artificial roads in the terrain file.

The time step, which is three seconds, is not defined explicitly. The model, however, it determines all speed, rate and run time values implicitly. In accordance with the three second-time step, the run time for the model is 10,800 time steps that corresponds to nine hours in the real world. This number is regarded as an adequate time for the illegal entrants to reach a secure region in the U.S.

Excluding some of the assets, such as mobile surveillance systems and U.S. A&M support, the SBInet concept is reflected in the model as shown in Figure 13. The battlefield is divided into responsibility areas for each BP car. Ground sensors are placed as the first layer of defense in locations where they can work in accordance with RVS Towers. Communication Centers are located inside the BP AOR to receive detection and classification information from sensors and transmit that information to the BP agents. The Predator B is modeled as an airborne sensor that is responsible for a larger area than the battlefield. The MiniUAV, Raven, is also modeled as an airborne sensor that is used by an imagery BP agent in each BP car. Scouts are located along the border to provide information to the smugglers. The illegal immigrants and the smugglers are spread along the Mexican side of the border heading north. Finally, neutrals spread around the Battlefield, crossing the border back and forth, to cause false alarms. Figure 13 depicts the locations of the agents.

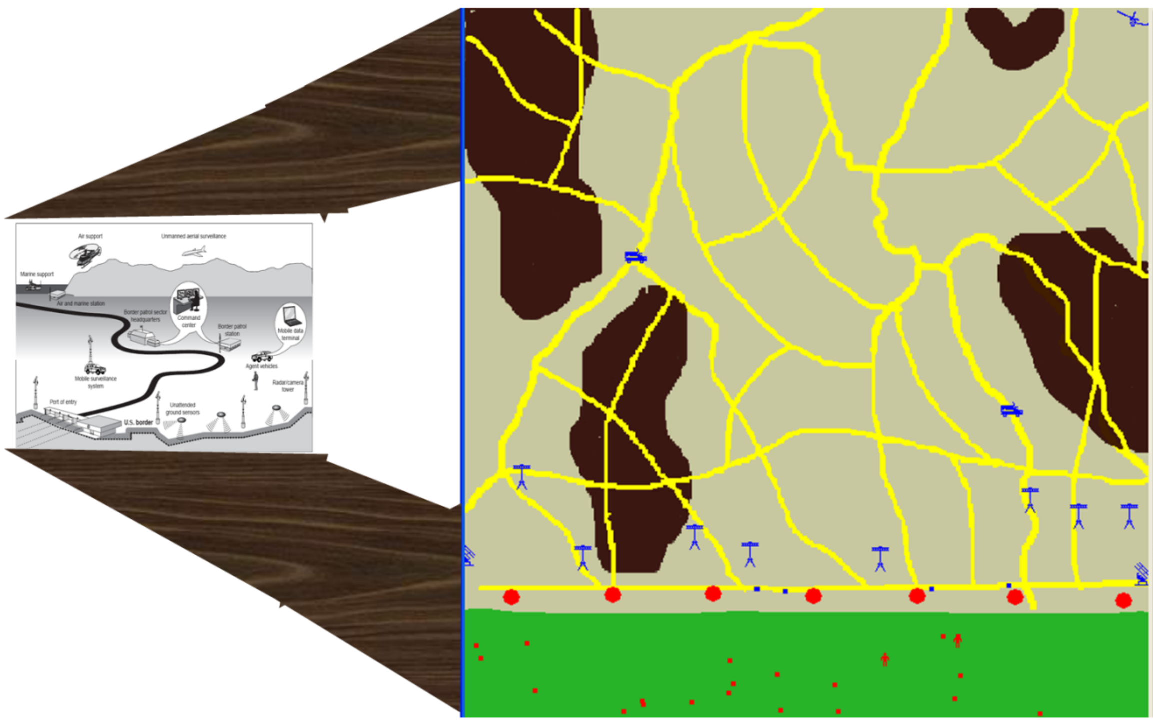


Figure 13. Reflection of SBInet Concept into MANA Model

D. AGENTS

1. Command and Communication Center

Command and Communication Centers are responsible for receiving and processing all information from the remote sensors and then transmitting that information to the BP agents or more appropriate sensors. There are two CCC's, each to cover half of the battlefield with 27.5 km communication range, to ensure that BP agents stay in their Area of Responsibility (AoR). Three seconds is designated for the communication delay for the base model; however, a broader range of values is used in experiments involving important factors such as latency, reliability and accuracy.

2. Remote Video Surveillance (RVS) Towers

RVS Towers are capable of detecting, classifying and tracking illegal activities within their sensor range. A RVS Tower can explore the type of activity by receiving detection information from ground sensors. Sensor of a RVS Tower, located 80 m above ground level (AGL) has a cone shaped Field of View (FOV) and can observe 360° around itself by some slew rate. It also is capable of zooming in and out to classify any detection with the help of trigger states.

There are two RVS Tower packages, four towers in each, one of which is responsible for the east half of the border and the other for the west. They can communicate with a corresponding Communication Center in their region with a three-second communication delay in the base model.

3. Predator B

There is one Predator B that is capable of detecting, classifying and tracking illegal entrants. It can feed information to BP via Communication Center. Predator B has a larger AOR than 50 km, which the model covers. Therefore, it is given a route that consists of zigzag shaped waypoints to represent flying in adjacent regions out of the battlefield. Predator B follows the waypoints initially. Once it detects an activity either by its own sensor or by other sensors, it then proceeds to the detection area to classify and track the illegal entrants. It can be refueled by a MiniUAV within 500 m to jump into a state that forces it to leave the current location and go for another mission. This prevents the use of two critical assets, the MiniUAV and Predator B, for the same target.

4. Unattended Ground Sensor (UGS) Agent

There are five UGS packages, each of which consists of 50 individual ground sensors. Having a 10-meter-detection range for every individual ground sensor, each UGS package covers one kilometer of the border. The UGS agent is given a very small cone shaped FOV to achieve this one kilometer detection line, and it only has the ability to detect. They need to co-operate with the RVS Tower to classify the detection. The UGS agents are invisible to the other sensors. There are 19 possible locations for UGS and five out of these 19 locations are selected randomly for each run.

5. Border Patrol Car

BP agents, "embussed" by BP car agent, patrol their AOR by driving their cars at the beginning. The term "embuss" is used in MANA to create parent-child relation. Child squads move together with their parent squad until they are released.

There are two BP car agents in the model, one for each region. Initially, they patrol their AOR by following their way points in the default state. Once they receive a detection of an illegal activity by their inorganic communication web, they fall into one of the contact states and proceed to the activity area. Due to inclination of driving off-road while going for the enemy, the BP Car agent is assigned a lower speed than the actual. After coming closer to the area of interest or detecting the entrant by its own sensor, the BP Car releases the BP agent and falls into an inactive, terminating state.

6. MiniUAV (Raven)

The MiniUAV agent, as an aircraft, has an airborne sensor that is capable of observing 360° around. It can detect, classify and track any activity within its sensor range. Initially the MiniUAV is embussed by the BP agent. Once the BP agent is dismounted near the area of interest and loses contact with the illegal entrant, it releases the MiniUAV to re-establish the contact.

Due to the high speed advantage and airborne sensor, 150 m AGL, the MiniUAV can detect, classify and track illegal entrants and provide direct, instantaneous image of the area of interest within a 10 km communication range. The MiniUAV goes toward the enemy as long as it has a contact, whether organic or inorganic. It also has a patrol route to search through in case of no contact. The MiniUAV flies one hour before it runs out of fuel and becomes permanently inactive. There is one MiniUAV for each BP car.

7. Border Patrol (BP) Agent

Initially embussed by the BP Car, the BP agent drives through its regular patrol route. After being released from the car near an area of an illegal activity, the BP agent tries to track illegal entrants and capture them. However, due to the short sensor range, it usually loses contact or never gains contact with enemy. Then the BP releases its child squad, the MiniUAV, to re-establish contact with enemy. With the help of the MiniUAV, the BP tracks the illegal entrants and finally captures them.

There are two BP agents in each BP Car, and the BP is the only agent that has the ability of capturing illegal entrants. The BP can get information directly from the MiniUAV or indirectly from other sensors via the Communication Center.

8. Scouts

There are seven scouts distributed along the border to provide information about BP activities to the illegal entrants. They are stationary in their observation posts and invisible to the other sensors. They also extend their sensor range by using binoculars. Scouts communicate with smugglers and illegal immigrants whenever there is a detectable movement along the border.

9. Illegal Immigrants

There are 20 illegal immigrants trying to cross the border in the base model. Initially, they all spread out along the Mexican part of the border at random. Illegal immigrants have a treat level of two which makes them a less valuable target for BP and other agents. They follow their waypoints into U.S. to the North and try to avoid the BP along their way. Immigrants have no communication capability with other agents but they can get information on the BP activities via Scouts. Once illegal immigrants are captured by a BP agent they are disregarded by the model.

10. Smugglers

There are two smugglers trying to cross the border by using illegal immigrants as distractions to the BP in the base model. They are randomly placed along the border and are given the same routes as the immigrants. Having a threat level of three, they are the most valuable targets for BP and other friendly agents. Smugglers have the capability of communicating with Scouts for the BP actions along the border. As with immigrants, they try to cross the border by avoiding the BP agents.

11. Neutrals

Neutrals can be detected by both enemy and friend and cause distraction until they are classified as neutral. They are distributed around the battlefield and given some waypoints to ensure they cross the border back and forth during the simulation. Neutrals are the agents that are used to create false alarms for the sensors.

IV. ANALYSIS

A. MEASURES OF EFFECTIVENES

The ultimate goal of the border protection system, with all of its sensors and manpower, is to deter and prevent illegal entries through the border. However, only using state of the art sensors that can detect and classify illegal activities are not enough to ensure protection. These sensors can detect and classify an activity, but without a tangible action, there is nothing to prevent illegal entrants. In the current border security system, this tangible action is provided by BP agents. Therefore, the percentage of captured illegal entrants is a considerable measure of effectiveness (MOE) of the overall system.

There are two types of illegal entrants in the model, illegal immigrants and smugglers. Smugglers are high-valued targets for BP agents. Therefore, to measure the effectiveness of the system, it is important to explore how well the system does on distinguishing between two types of illegal entrants. In other words, can the system focus on the targets of the highest value to prevent ineffective use of resources?

While the percentage of captured illegal entrants is a good measure of overall system, due to the fact that BP agents are the only entities that have the ability to capture, this MOE is highly dependent on the number and capabilities of the BP agents. Therefore, the number of illegal entrants classified is a more direct MOE to investigate the effectiveness of the sensors.

In the light of these ideas, the MOEs that are used in this study are as follows:

- Total number of illegal immigrants captured
- Total number of smugglers captured
- Total number of illegal immigrants classified
- Total number of smugglers classified

B. DESIGN OF EXPERIMENTS (DOE)

1. Overview

DOE plays an integral role in the conduct of the simulation study. The simulation study may use both qualitative and quantitative factors. Each factor can be set to two or more factor levels. A design point consists of the specification of each factor in the study. Also, different pseudo-random numbers (PRNs) are used to simulate the same scenario in stochastic simulations. Each run of the simulation scenario with a specific PRN is called a replicate (Kleijnenet al., 2005).

2. Important Factors and Ranges

There are numerous parameters in the MANA model that can be varied to explore the effects on the outcome. Due to computational limitations, a subset of these parameters, that is deemed to be most likely to cause major effects on the selected MOEs, is chosen as factors for the experimental design. Reasonable ranges of these factors are then determined. Current capabilities of the agents are extended to determine the maximum ranges for the factors. Table 10 shows the factors and their ranges that are used in the experimental design.

Categorical Factor			With MiniUAV	Without MiniUAV		
Ranges of Numeric Factors						
	Factor Name		Low Level (MANA Units)	Low Level (Real World)	High Level (MANA Units)	High Level (Real World)	decimals
1	MiniUAV	Fuel(Represent endurance)	800	40 min.	3200	160 min	0
2		Turret Height	150 m.	150 m.	400 m.	400 m.	0
3		Probability of Classification(max)	0.3	0.3	1	1	2
4		Classification Range(max)	4	200 m.	20	1000 m.	0
5		Detection Range	6	300 m.	30	1500 m.	0
6	Comm. MiniUAV	Latency	0	0 sec.	20	60 sec.	0
7		Reliability	60	60%	100	100%	0
8	Tower	Turret Height	20	20 m.	50	50 m.	0
9		Probability of Classification(max)	0.3	0.3	1	1	2
10		Classification Range(max)	50	2500 m.	200	10000 m.	0
11		Detection Range	75	3750 m.	300	15000 m.	0
12	Predator B	Probability of Classification(max)	0.3	0.3	1	1	2
13		Classification Range(max)	50	2500 m.	200	10000 m.	0
14		Detection Range	75	3750 m.	300	15000 m.	0
15	Comm. Center	Latency	0	0 sec.	20	60 sec.	0
16		Reliability	60	60%	100	100%	0
17	BP Car (Package)	# of BP car agents	2	2	5	5	0

Table 10. Important Factors and Ranges

3. NOLH Design

Minimum and maximum levels of these factors form the frame of the experimental region. To explore the main effects and the interactions of the factors, we need to select points to sample within that experimental region. Despite the technological improvements on computers, it is still practically impossible to run a model for all possible points in an experimental region. For example, if we have 10 factors with 10 levels each, we need 10^{10} = 10 billion design points for a factorial design. Therefore, we need sophisticated techniques to find an efficient number of design points, which together allow for maximum information to be gained from the experiment.

According to Sanchez, Latin hypercube (LH) designs provide a flexible way of constructing efficient designs for quantitative factors and have some of the space-filling properties of factorial designs, but require orders of magnitude less sampling (Sanchez, 2008).

Figure 14 shows the excellent space filling behavior of the Nearly Orthogonal Latin Hypercube (NOLH) design, with less sampling requirement, compared to factorial designs.

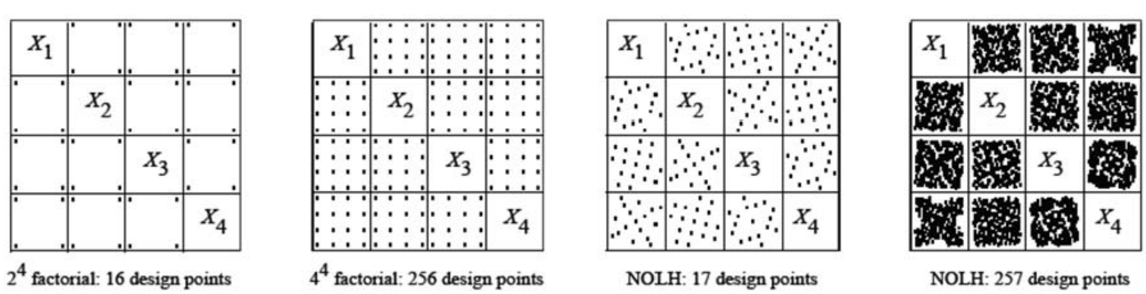


Figure 14. Scatterplot Matrices for Selected Factorial and NOLH Designs.(From: Sanchez, 2008)

An Excel spreadsheet, which was developed by Sanchez, is used to construct the NOLH experimental design for this study (Sanchez, NOLHdesigns spreadsheet, 2005). This spreadsheet provides five different NOLH designs for various numbers of factors. The first four designs, for up to 22 factors, are from Tom Cioppa's 2002 PhD dissertation (2002). The last one, for experiments with up to 29 factors, is provided by Andy Hernandez.

According to Table 10, 17 factors are chosen for the experimental design. However, classification ranges are set to 2/3 of the detection ranges in the model which makes these pairs linear combinations of each other. Therefore, the number of independent factors used in the experimental design was 14. Minimum and maximum values of these factors were then typed into the 29-factor spreadsheet in Sanchez's NOLH design spreadsheet. As a result, 257 levels of these 14 factors are acquired automatically. The reason for using the 29-factor design spreadsheet, despite having only 14 factors, is the presence of categorical factor, "with MiniUAV?." The inclusion of this binary factor, met the desire to have more design points, in order to reduce the maximum pairwise correlation and to increase the degrees of freedom for error.

The first seven rows of the NOLH design, constructed for this study, are shown in Figure 15 (See Appendix A for the whole design). There are additional columns for dependent factors in this experimental design spreadsheet. Three of them are the detection ranges for the sensors as mentioned above.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	low level	800	150	4		0	60	20	0.2	50							
2	high level	3200	400	20		20	100	50	0.9	200							
3	deci-mals	0	0	0		0	0	0	2	0							
4	Factor Name	MiniUAVFuel	MiniUAVTurretHt	MiniUAVClassRng	MiniUAVDetRng	MiniUAVCommLat	MiniUAVCommRel	TwrHt	TwrPClass	TwrClassRng	TwrDetRng	TwrPClass(2)	TwrDetRng(2)	TwrClassRng(2)	TwrPClass(1)	TwrDetRng(1)	TwrClassRng(1)
5		1756	371	14	21	12	85	47	0.9	181	272	0.93	182	121	0.97	90	60
6		1081	250	17	26	19	89	36	0.88	177	266	0.93	177	118	0.97	89	59
7		1184	298	6	9	11	98	44	0.86	184	276	0.92	185	123	0.97	92	61
8		1775	190	10	15	13	89	42	0.82	192	288	0.91	192	128	0.96	96	64
9		1681	290	14	21	8	97	44	0.73	153	230	0.89	153	102	0.95	77	51
10		1859	242	19	29	3	95	47	0.71	193	290	0.88	194	129	0.94	96	64
11		903	303	11	17	2	81	36	0.74	138	207	0.89	138	92	0.95	69	46

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
1	0.2	50								0	30	2	0				
2	0.9	200								20	100	5	1				
3	2	0								0	0	0	0				
4	PredPClass	PredClassRng	PredDetRng	PredPClass(2)	PredDetRng(2)	PredClassRng(2)	PredPClass(1)	PredDetRng(1)	PredClassRng(1)	CommCentLat	CommCentRel	NumBPCars	WithUAV?	BPCar5(Sqd9)	BPCar1(Sqd7)	BPCar4(Sqd8)	WithUAV?(Y/N)
5	0.33	60	90	0.63	60	40	0.73	30	20	5	57	2	0	No	No	No	No
6	0.58	141	212	0.82	141	94	0.9	71	47	13	82	5	1	Yes	Yes	Yes	Yes
7	0.65	104	156	0.86	104	69	0.93	53	35	4	47	2	0	No	No	No	No
8	0.31	132	198	0.61	132	88	0.71	66	44	19	85	5	1	Yes	Yes	Yes	Yes
9	0.25	172	258	0.53	173	115	0.63	86	57	2	34	3	0	Yes	No	No	No
10	0.71	119	179	0.88	119	79	0.94	60	40	17	83	5	1	Yes	Yes	Yes	Yes
11	0.67	138	207	0.87	138	92	0.93	69	46	0	49	3	0	Yes	No	No	No

Figure 15. Experimental Design Spreadsheet

There are also two sets of additional columns for sensor ranges and corresponding probability of classification values. While modeling Towers and Predator B in MANA, "advanced mode" is used for their sensors. What this means is that instead of giving only one classification range and thereby creating a "cookie-cutter" sensor, three levels of ranges and corresponding probabilities are used in decreasing order. Given a maximum classification range, medium and minimum ranges are calculated by multiplying max range by 2/3 and 1/3. Similarly, values for probability of classification are calculated for medium and minimum ranges by using P(Class) of the max range as an input. Formulas, used for medium and minimum ranges, are 1-exp(-3*P(Class for max range)) and 1-exp(-4*P(Class for max range)).

Finally, the last four columns describe the binary "WithUAV" variable as well as the specification of which specific BP cars are used in the model, corresponding to the various levels of the "Number of BP Cars" variable.

To see the space filling property of the NOLH design, a scatter plot is presented in Figure 16 that shows the pairwise projections of the levels of the factors used in the experimental design.

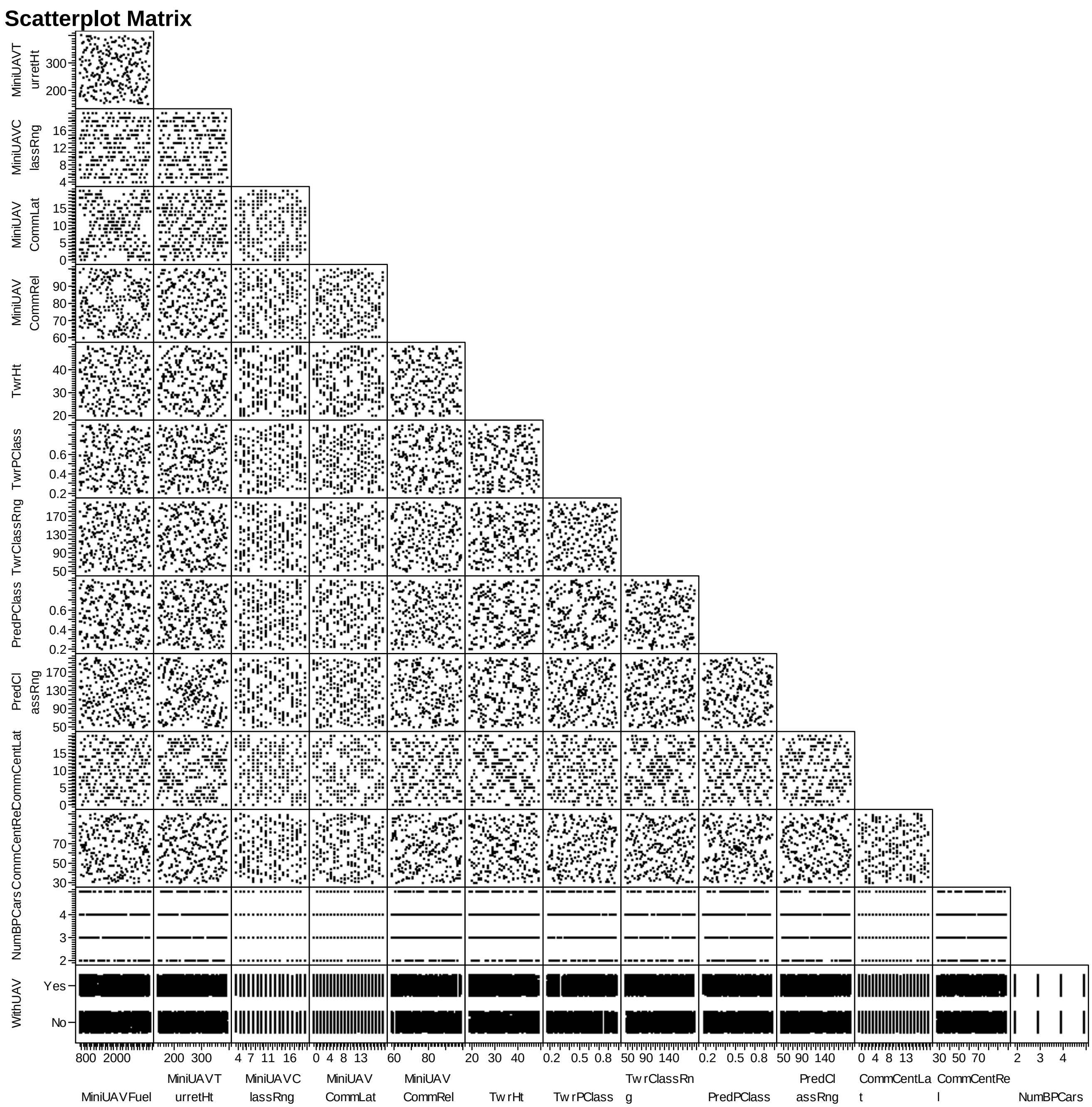


Figure 16. Scatterplot Matrix for the Experimental Design

C. MODEL RUN

1. Limitations of MANA

Although MANA has some simple tools for analysis, it is not capable of constructing a large scale experimental design and does not provide sufficient analysis capability. Therefore, Sanchez's NOLH design spreadsheet is used to construct the experimental design. Another piece of software, called XStudy, is used to create MANA scenario files, one corresponding to each design point. For every design point, 30 replications are run using the random seed generator of MANA, in order to see the variability within each scenario.

2. XStudy

The XStudy software is used to specify the number of random replications and the mapping of each column in the design to a particular element in the MANA scenario file. As a result, a study design file, in xml format, is generated. Next, software called OldMcData generates the individual MANA scenario files for each design point, using the design spreadsheet, the base case MANA scenario xml file, and the xstudy xml file. As the last step, software called Condor manages the distribution and collection of individual jobs across a set of processors. Condor is open source software available from the University of Wisconsin at http://www.cs.wisc.edu/condor. After the jobs have completed, OldMcData contains a postprocessor to gather all model outputs into one file, along with the design point values. XStudy and OldMcData were developed by SEED Center

Research Associate Stephen Upton, and are available for download at the SEED Center web site at http://harvest.nps.edu.

D. STATISTICAL TOOLS AND ANALYSIS

1. JMP

After running the model for 257 design points and 30 replications of each, 7710 data points are acquired for each four MOEs. JMP is the primary tool used to analyze the results.

According to the JMP website, JMP is a dynamic, interactive, visual, and easy to use statistical software package developed by SAS Institute, Inc. In JMP, commands are available to interactively extend analyses and further explore the results. The rows in JMP data tables are dynamically linked which allows the user to identify any data point in graphs easily.

JMP has a Custom designer tool to construct experimental design, supporting screening, Response Surface Methodology (RSM), and mixture experiments. JMP also has the main fitting tools such as linear fitting, mean-dispersion models, partition trees, nonlinear regression, and Neural Nets, supported by visual interfaces (Creightonet al., 2005).

2. Statistical Methods Used To Analyze Results

In order to fit models, the 7710 data points are summarized by their means and standard deviations, thus collapsing the data set for analysis down to 257 data points. The distribution of these means for each MOE is explored graphically and with basic summary statistics. The data are also examined for outliers or any type of anomaly.

To further explore the effects of the categorical factor, MiniUAV, a comparison test is conducted for each MOE. The T-Test is used to reveal any significant difference between the means of MOEs with MiniUAV and without MiniUAV.

Linear stepwise regression models are fitted to explore the effects of various factors on different MOEs. For each MOE, the regression models are fit separately for the subset of points where the MiniUAVs are in the scenario, and then fit for the subset of points where the MiniUAVs are not in the scenario. The difference between the two is that the UAV performance factors are considered for inclusion in the model only when the MiniUAVs are in the scenario. Main effects and two-way interaction terms of the factors are considered for inclusion in these models.

Finally, regression trees are used to discover the threshold values of the factors that are found to be important in linear regression models.

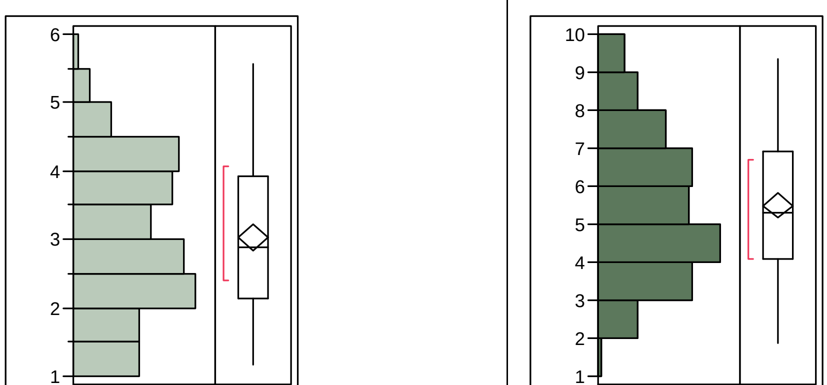
V. RESULTS

A. SUMMARY OF STATISTICS

1. Total Number of Captured Immigrants

There are 20 immigrants that are trying to cross the border during the simulation. They can only be captured by BP agents. Figure 17 shows the distribution of the number of captured immigrants and the summary statistics. Although the number of BP agents is varied between four and ten, the mean of the number of captured immigrants is 3.04 for the "without MiniUAV" scenarios and 5.49 for the "with MiniUAV" scenarios. Despite the slight improvement in mean by using the MiniUAV, these mean values are still low compared with the number of immigrants.

Total Number of Captured Immigrants without MiniUAV(Mean) | **Total Number of Captured Immigrants with MiniUAV(Mean)**



Moments (without MiniUAV)

Mean	3.0304688
Std Dev	1.0914607
Std Err Mean	0.0964724
upper 95% Mean	3.2213702
lower 95% Mean	2.8395673
N	128

Moments (with MiniUAV)

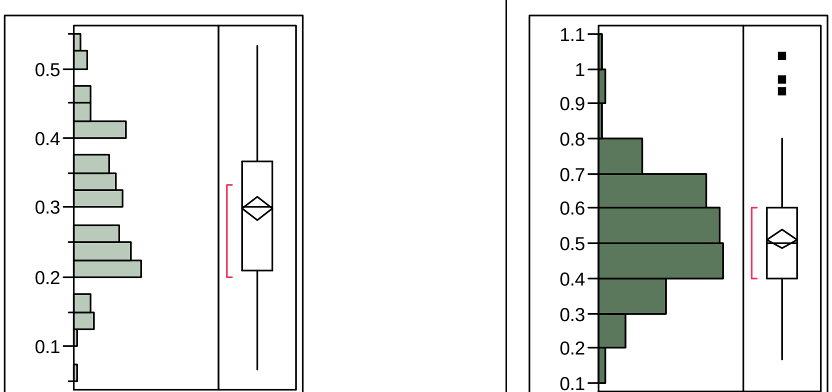
Mean	5.4937984
Std Dev	1.89234
Std Err Mean	0.1666113
upper 95% Mean	5.8234673
lower 95% Mean	5.1641296
N	129

Figure 17. Distribution of Total Number of Captured Immigrants

2. Total Number of Captured Smugglers

There are only two smugglers within 20 illegal immigrants that are trying to cross the border during the simulation. They are high priority targets for the sensors and BP agents, and they can only be captured by BP agents. Figure 18 shows the distribution of the number of captured immigrants and the summary statistics. The distribution of the captured smugglers has some gaps, due to the small number of smugglers used. The mean of the total number of captured smugglers is 0.3 for the “without MiniUAV” scenarios and 0.51 for the “with MiniUAV” scenarios. Similar to the number of captured immigrants, the effectiveness of BP agents in capturing smugglers is not satisfactory in both scenarios.

Total Number of Captured Smugglers without MiniUAV(Mean) | **Total Number of Captured Smugglers with MiniUAV(Mean)**



Moments (without MiniUAV)

Mean	0.2986979
Std Dev	0.1023266
Std Err Mean	0.0090445
upper 95% Mean	0.3165953
lower 95% Mean	0.2808005
N	128

Moments (with MiniUAV)

Mean	0.5129199
Std Dev	0.1566971
Std Err Mean	0.0137964
upper 95% Mean	0.5402185
lower 95% Mean	0.4856213
N	129

Figure 18. Distribution of Total Number of Captured Smugglers

3. Total Number of Classified Immigrants

Because only BP agents are capable of capturing illegal entrants, the total number of classified immigrants is examined to see the effectiveness of the sensors more independently. With a slight difference, mean of the total number of classified immigrants is 18.9 for "without MiniUAV" and 19.02 for "with MiniUAV" (Figure 19). This result means that, in both cases, almost every illegal immigrant is classified with one of the sensors at least once.

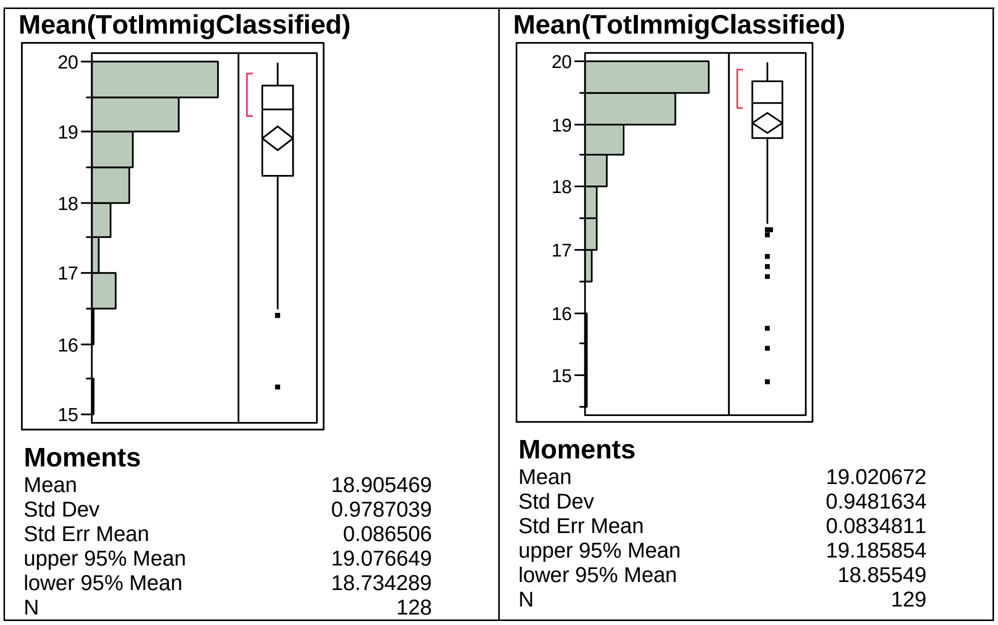


Figure 19. Distribution of Total Number of Classified Immigrants

4. Total Number of Classified Smugglers

Similar to the case with illegal immigrants, in most scenarios all of the smugglers are classified with one of the sensors at least once. Figure 20 shows that mean of the total number of classified smugglers is roughly 1.93 whether the MiniUAV is used or not.

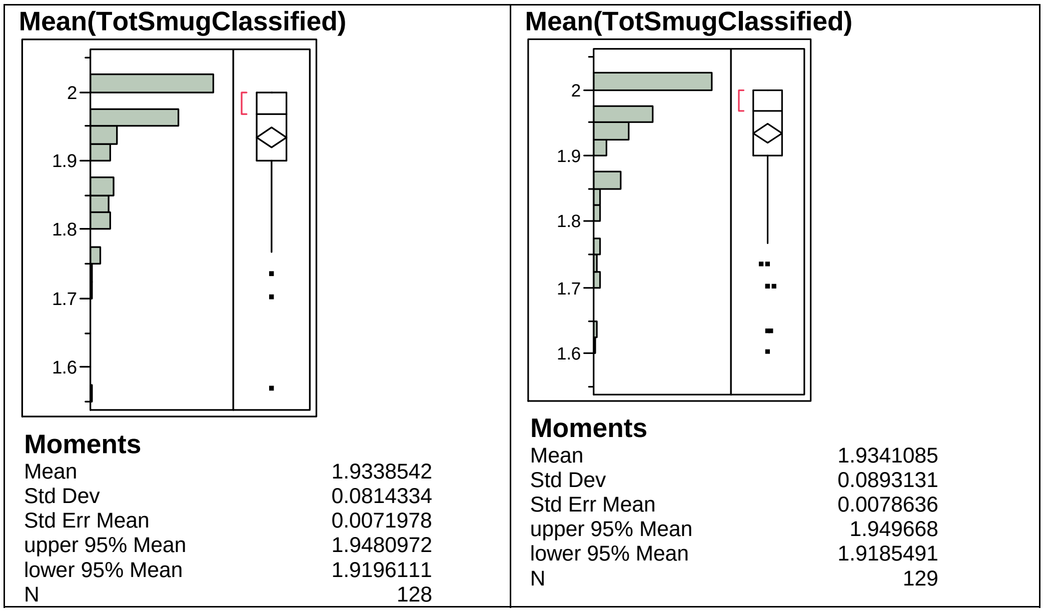


Figure 20. Distribution of Total Number of Classified Immigrants

B. T-TEST FOR COMPARISON OF SAMPLE MEANS

To answer the second research question, which is how the UAV can contribute to border protection, scenarios "without MiniUAV" and "with MiniUAV" are compared in terms of their corresponding MOEs.

1. Total Number of Captured Immigrants

According to the t-Test for the means of total number of captured immigrants, there is a significant difference in 95% confidence level between the scenarios "without MiniUAV" and "with MiniUAV". It is seen in Figure 21 that using the MiniUAV has a positive effect on the mean of the total number of captured immigrants.

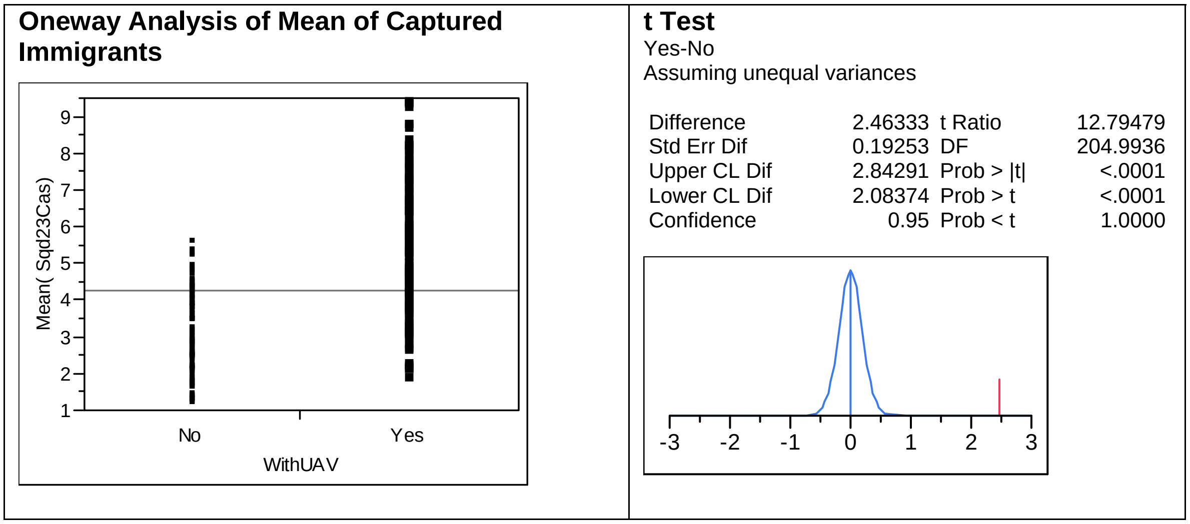


Figure 21. Comparison Test for Total Number of Captured Immigrants

2. Total Number of Captured Smugglers

The comparison test yields the same overall result for the total number of captured smugglers. We are 95% confident that there is a significant difference between the scenarios "without MiniUAV" and "with MiniUAV" (See Figure 22).

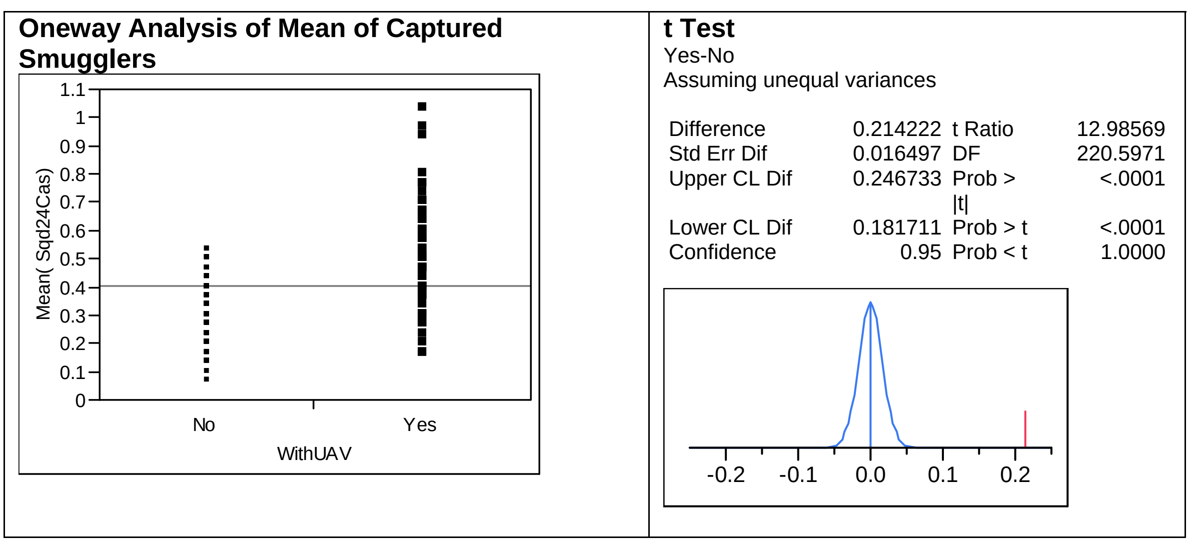
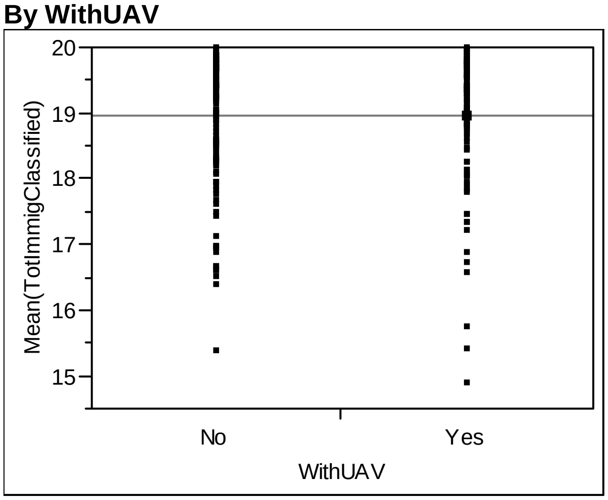


Figure 22. Comparison Test for Total Number of Captured Smugglers

3. Total Number of Classified Immigrants

Although there is significant evidence of the contribution of the MiniUAV in capturing illegal immigrants, there is no significant difference between the means of the total number classified immigrants. For most scenarios, the sensors classify all of the immigrants, and the distribution of the total number of classified immigrants is highly skewed towards the upper end. Thus there is very little variability between the two scenarios. Increasing the number of illegal immigrants or their concealment parameter would make it hard for sensors to classify the immigrants, and may produce different results.

Oneway Analysis of Mean(TotImmigClassified) By WithUAV



t Test

Yes-No

Assuming unequal variances

Difference	0.11520	t Ratio	0.958284
Std Err Dif	0.12022	DF	254.6028
Upper CL Dif	0.35195	Prob > |t|	0.3388
Lower CL Dif	-0.12155	Prob > t	0.1694
Confidence	0.95	Prob < t	0.8306

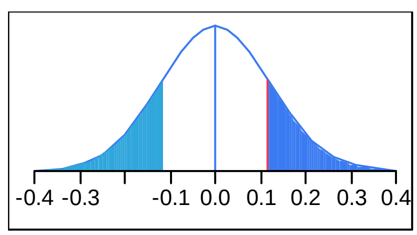
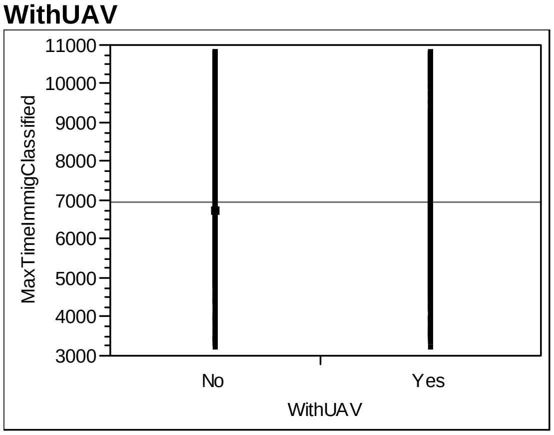


Figure 23. Comparison Test for Total Number of Classified Immigrants

Due to the lack of information gained from examining the total number of classified immigrants, another measure of effectiveness, the time to classify, was sought. Thus, if all of the immigrants are classified through the simulation, how long does it take?

The mean time to classify all of the immigrants was 7028 time steps, 5.86 hours, for the “without MiniUAV” and 6846 time steps, 5.7 hours, for the “with MiniUAV” scenario (See Figure 24). According to the comparison test, there is a significant decrease in mean time to classify all immigrants when the MiniUAV is used.

Oneway Analysis of MaxTimeImmigClassified By WithUAV



Moments(without MiniUAV)

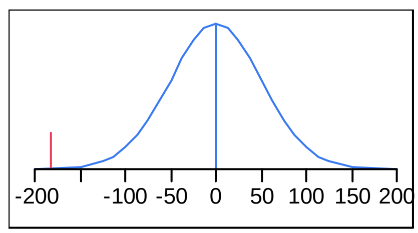
Mean	7028.1598
Std Dev	1585.432
Std Err Mean	36.353176
upper 95% Mean	7099.4561
lower 95% Mean	6956.8635
N	1902

Missing Rows
3818

t Test

Yes-No
Assuming unequal variances

Difference	-181.26	t Ratio	-3.54748
Std Err Dif	51.10	DF	3885.238
Upper CL Dif	-81.08	Prob > |t|	0.0004
Lower CL Dif	-281.44	Prob > t	0.9998
Confidence	0.95	Prob < t	0.0002



Moments(with MiniUAV)

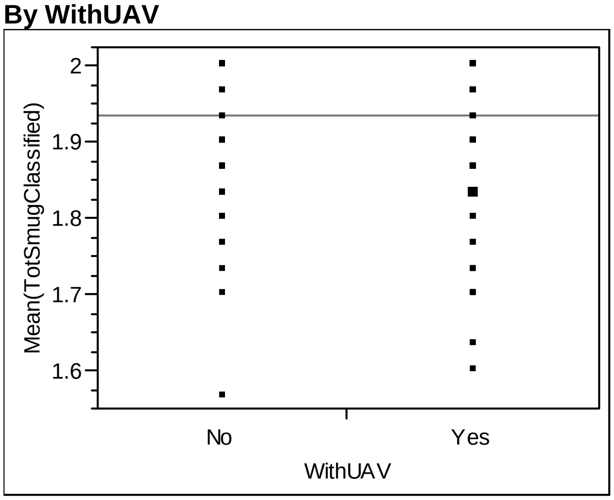
Mean	6846.898
Std Dev	1601.7441
Std Err Mean	35.905965
upper 95% Mean	6917.3152
lower 95% Mean	6776.4807
N	1990

Figure 24. Comparison Test for the Time All Immigrants are Captured

4. Total Number of Classified Smugglers

The result of the comparison test for the total number of classified smugglers is very similar to immigrants. There is no significant difference between the means of classified smugglers in terms of MiniUAV usage (Figure 25). Due to the similarly skewed distribution of classified smugglers, the same conclusion can be made as with the immigrants.

Oneway Analysis of Mean(TotSmugClassified) By WithUAV



t Test

Yes-No

Assuming unequal variances

Difference	0.00025	t Ratio	0.02386
Std Err Dif	0.01066	DF	253.1998
Upper CL Dif	0.02125	Prob > |t|	0.9810
Lower CL Dif	-0.02074	Prob > t	0.4905
Confidence	0.95	Prob < t	0.5095

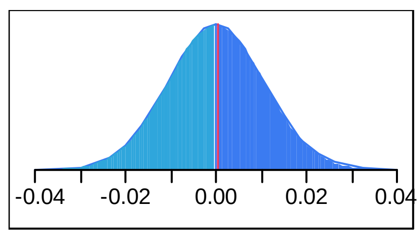
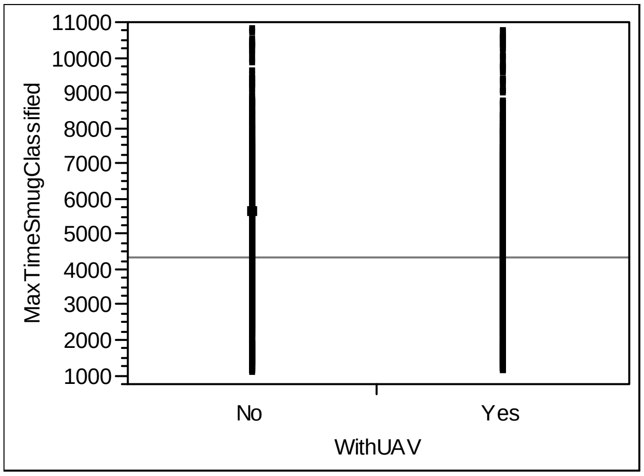


Figure 25. Comparison Test for Total Number of Classified Smugglers

However, there is a significant difference between the means of the time to classify all of the smugglers. The mean time to classify all of the smugglers is 4398 time steps, 3.67 hours, for the "without MiniUAV" and 4228 time steps, 3.52 hours, for the "with MiniUAV" scenario (Figure 26).

Oneway Analysis of MaxTimeSmugClassified By WithUAV



Moments(without MiniUAV)

Mean	4398.3201
Std Dev	1589.4047
Std Err Mean	26.493758
upper 95% Mean	4450.2644
lower 95% Mean	4346.3758
N	3599

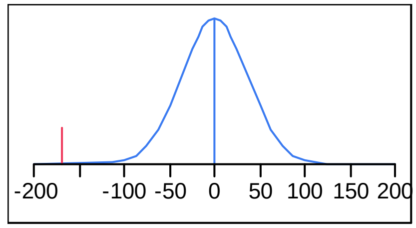
Missing Rows
486

t Test

Yes-No

Assuming unequal variances

Difference	-169.70	t Ratio	-4.60733
Std Err Dif	36.83	DF	7211.35
Upper CL Dif	-97.50	Prob > |t|	<.0001
Lower CL Dif	-241.90	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001



Moments(with MiniUAV)

Mean	4228.6234
Std Dev	1540.5122
Std Err Mean	25.586514
upper 95% Mean	4278.7888
lower 95% Mean	4178.458
N	3625

Figure 26. Comparison Test for the Time All Smugglers are Captured

C. LINEAR REGRESSION

A linear multiple stepwise regression model is fitted to examine the effects of the factors on the MOEs. As stated previously, these models are fit in two stages for each MOE – first selecting all of the points "with MiniUAV" (and considering the UAV performance factors for inclusion), and then selecting all of the points "without MiniUAV". All factors that are used in the experimental design and their two-way interaction terms are considered for inclusion in the models.

1. Total Number of Captured Immigrants

a. Without MiniUAV

The p-value of the linear regression model for the number of captured immigrants is less than 0.0001, meaning that there is a significant linear relation between the response and at least one of the regressors. The RSquare value is 0.91, which indicates that the regressors explain successfully the variability of the response, in this case the total number of captured immigrants.

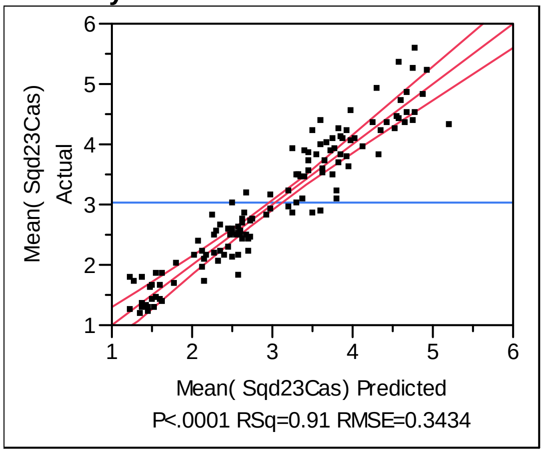
There are six important terms that affect the response at the 0.95 confidence level (Table 11). The most important one is the "Number of BP Cars." This is very meaningful, because BP agents are the only agents that are capable of capturing illegal immigrants. Because there are two BP agents in each BP car, the number of BP cars directly affects the number of BP agents.

Another highly important factor is "Communication Center Reliability". A perfect (100%) reliability for communication systems means that a communication message (containing contact location information) from one agent to another is always successfully delivered. Because the Communication Center is the most important element of the communication system, it is not surprising to see "Communication Center Reliability" as the second important factor.

"Tower Classification Range" shows up as another important factor. There are also some interactions that are important. Interactions of "Communication Center Reliance" with "Tower Height" and also with "Predator Probability of Classification" are two of them. Finally "Tower

Classification Range" and "Tower Probability of Classification" is another important interaction.

Response Mean(Sqd23Cas)
Actual by Predicted Plot



Summary of Fit

RSquare	0.910388
RSquare Adj	0.901037
Root Mean Square Error	0.343356
Mean of Response	3.030469
Observations (or Sum Wgts)	128

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	12	137.73569	11.4780	97.3592
Error	115	13.55771	0.1179	**Prob > F**
C. Total	127	151.29339		<.0001

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
NumBPCars	0.969351	0.041503	23.36		<.0001
CommCentRel	0.0086565	0.001515	5.71		<.0001
TwrClassRng	-0.003402	0.001022	-3.33		0.0012
(TwrHt-35.1875)*(CommCentRel-63.5547)	-0.00068	0.00022	-3.08		0.0026
(TwrPClass-0.54305)*(TwrClassRng-126.367)	-0.011695	0.004585	-2.55		0.0121
(PredPClass-0.54633)*(CommCentRel-63.5547)	0.0137206	0.006856	2.00		0.0477

Table 11. Linear Regression Results for Total Number of Captured Immigrants without MiniUAV

b. With MiniUAV

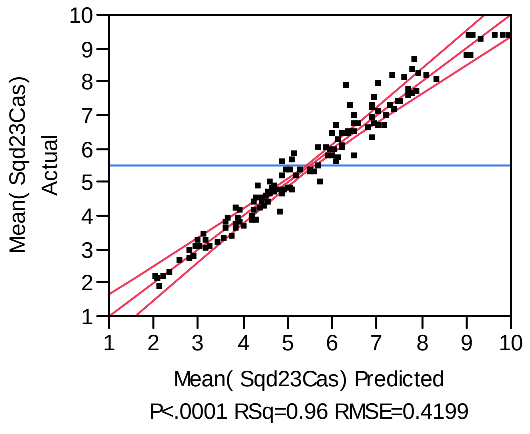
With a p-value of less than 0.0001 and RSquare value of 0.965, the regressors explain successfully the variability of the response for the scenarios with the MiniUAV.

Now that the factors related to the performance of the MiniUAV are added to the model there are some differences in the important factors. “Number of BP Cars” is still the most important factor, though with a slight difference from the “without MiniUAV” scenario. This factor is more important in this model because increasing the number of BP cars also increases the number of MiniUAV used.

Two new important factors related with MiniUAV are “MiniUAV Classification Range” and “MiniUAV Fuel”, which designates the endurance of the MiniUAV.

Interaction between probability of classification of Tower and Predator is the fourth important factor. See Table 12 for the other less important factors and interactions.

Response Mean(Sqd23Cas)
Actual by Predicted Plot



Summary of Fit

RSquare	0.965
RSquare Adj	0.950769
Root Mean Square Error	0.419875
Mean of Response	5.493798
Observations (or Sum Wgts)	129

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	37	442.31890	11.9546	67.8102
Error	91	16.04281	0.1763	**Prob > F**
C. Total	128	458.36171		<.0001

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
NumBPCars	1.6287062	0.055248	29.48		<.0001
MiniUAVClassRng	0.1122961	0.008246	13.62		<.0001
MiniUAVFuel	0.0007129	6.734e-5	10.59		<.0001
(TwrPClass-0.55698)*(PredPClass-0.55372)	5.9925185	1.09983	5.45		<.0001
(MiniUAVTurretHt-275.651)*(TwrHt-34.8217)	-0.000321	9.368e-5	-3.43		0.0009
(PredClassRng-124.209)*(CommCentRel-66.4419)	-0.000139	4.982e-5	-2.78		0.0066
(MiniUAVFuel-2016.79)*(CommCentRel-66.4419)	1.2168e-5	4.396e-6	2.77		0.0068
(MiniUAVFuel-2016.79)*(TwrPClass-0.55698)	0.0007813	0.000285	2.74		0.0074
(MiniUAVCommRel-79.3256)*(NumBPCars-3.51938)	0.0097734	0.003841	2.54		0.0126
(MiniUAVFuel-2016.79)*(TwrClassRng-123.651)	4.4024e-6	1.838e-6	2.40		0.0186
MiniUAVCommRel	0.0083524	0.003525	2.37		0.0199
(MiniUAVFuel-2016.79)*(NumBPCars-3.51938)	0.0001571	6.683e-5	2.35		0.0209
(TwrHt-34.8217)*(TwrPClass-0.55698)	0.0648917	0.029069	2.23		0.0280
TwrHt	0.009718	0.004499	2.16		0.0334
(TwrPClass-0.55698)*(TwrClassRng-123.651)	0.0125866	0.006103	2.06		0.0420
PredPClass	-0.385112	0.190985	-2.02		0.0467
(PredPClass-0.55372)*(CommCentLat-10.2403)	0.0635376	0.031699	2.00		0.0480

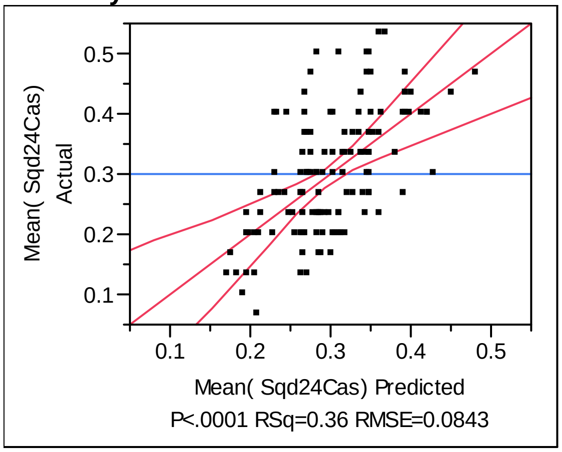
Table 12. Linear Regression Results for Total Number of Captured Immigrants with MiniUAV

2. Total Number of Captured Smugglers

a. Without MiniUAV

Although the p-value is less than 0.0001, which means at least one regressor has a linear relation with the number of captured smugglers; the RSquare value is rather low, 0.36, meaning that the regressors are not enough to explain the variability in the response. The reason for that may be that there is a non-linear relation with some of the independent variables, or there are some other uncontrollable factors such as the random patterns of the smugglers. The only important factor that has a linear relation with this MOE is again the number of BP cars.

Response Mean(Sqd24Cas)
Actual by Predicted Plot



Summary of Fit

RSquare	0.361828
RSquare Adj	0.318925
Root Mean Square Error	0.084338
Mean of Response	0.298438
Observations (or Sum Wgts)	128

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	0.4799115	0.059989	8.4337
Error	119	0.8464426	0.007113	**Prob > F**
C. Total	127	1.3263542		<.0001

Sorted Parameter Estimates

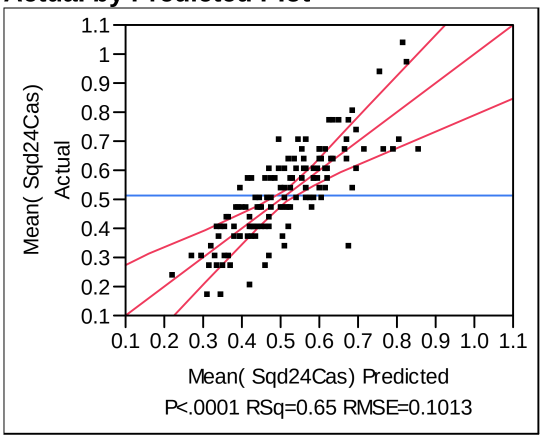
Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
NumBPCars	0.0566461	0.007861	7.21		<.0001
(PredPClass-0.54633)*(NumBPCars-3.48438)	0.0786461	0.044517	1.77		0.0799
(PredPClass-0.54633)*(CommCentLat-9.77344)	-0.01051	0.006007	-1.75		0.0828
TwrClassRng	-0.000249	0.000172	-1.45		0.1506
TwrPClass	0.0531324	0.036804	1.44		0.1515
(CommCentLat-9.77344)*(NumBPCars-3.48438)	-0.002017	0.001444	-1.40		0.1650
PredPClass	0.0409693	0.036936	1.11		0.2696
CommCentLat	0.0013002	0.001281	1.01		0.3122

Table 13. Linear Regression Results for Total Number of Captured Smugglers without MiniUAV

b. With MiniUAV

The variability in the number of captured smugglers is better explained in "with MiniUAV" scenarios, with an RSqaure value of 0.65. The important factors other than the number of BP cars are "MiniUAV Classification Range", "MiniUAV Fuel" and interaction between probability of classification of the Tower and Predator, which is very similar to the model for the number of captured immigrants. See Table 14 for the other less important factors and interactions.

Response Mean(Sqd24Cas)
Actual by Predicted Plot



Summary of Fit

RSquare	0.654576
RSquare Adj	0.582884
Root Mean Square Error	0.101296
Mean of Response	0.512145
Observations (or Sum Wgts)	129

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	22	2.0610968	0.093686	9.1304
Error	106	1.0876543	0.010261	**Prob > F**
C. Total	128	3.1487511		<.0001

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
NumBPCars	0.0669452	0.009713	6.89		<.0001
MiniUAVClassRng	0.0110488	0.001968	5.61		<.0001
MiniUAVFuel	5.8111e-5	1.325e-5	4.39		<.0001
(MiniUAVClassRng-11.8682)*(PredPClass-0.55372)	0.0346784	0.009309	3.73		0.0003
(TwrHt-34.8217)*(PredPClass-0.55372)	-0.022985	0.007644	-3.01		0.0033
(MiniUAVClassRng-11.8682)*(TwrHt-34.8217)	0.0006875	0.00025	2.75		0.0071
(MiniUAVFuel-2016.79)*(MiniUAVClassRng-11.8682)	7.9672e-6	2.939e-6	2.71		0.0078
CommCentRel	0.0011936	0.000466	2.56		0.0118
(MiniUAVClassRng-11.8682)*(CommCentRel-66.4419)	0.0003533	0.00014	2.52		0.0133
(PredPClass-0.55372)*(CommCentRel-66.4419)	-0.005364	0.002498	-2.15		0.0340
(MiniUAVFuel-2016.79)*(PredPClass-0.55372)	-0.000136	6.579e-5	-2.07		0.0408
(MiniUAVClassRng-11.8682)*(PredClassRng-124.209)	0.0001034	5.055e-5	2.04		0.0433

Table 14. Linear Regression Results for Total Number of Captured Smugglers with MiniUAV

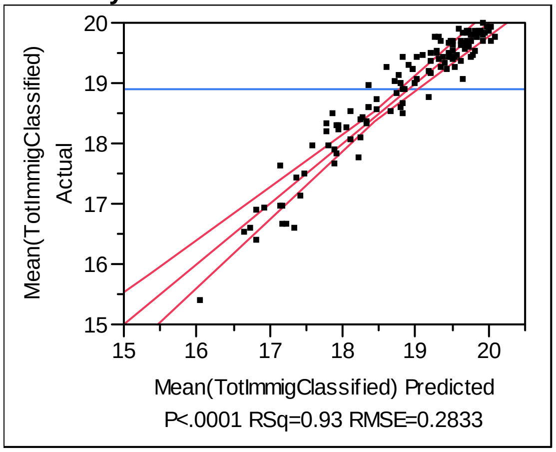
3. Total Number of Classified Immigrants

a. Without MiniUAV

The model for the number of classified immigrants can explain most of the variability with an RSquare value of 0.93. Because this MOE measures the effectiveness of the sensors, it is to be expected not to see the number of BP cars as an important factor in this model.

The two most important factors for this model are "Predator Classification Range", "Tower Classification Range" and the interaction term of these two. See Table 15 for the other important terms and interactions.

Actual by Predicted Plot



Summary of Fit

RSquare	0.925451
RSquare Adj	0.916214
Root Mean Square Error	0.283293
Mean of Response	18.90547
Observations (or Sum Wgts)	128

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	14	112.57959	8.04140	100.1982
Error	113	9.06881	0.08025	**Prob > F**
C. Total	127	121.64839		<.0001

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
PredClassRng	0.0149257	0.000589	25.35		<.0001
TwrClassRng	0.0124413	0.000583	21.34		<.0001
(TwrClassRng-126.367)*(PredClassRng-125.805)	-0.000185	1.467e-5	-12.63		<.0001
TwrHt	0.0147774	0.002913	5.07		<.0001
(TwrHt-35.1875)*(PredClassRng-125.805)	-0.000319	7.431e-5	-4.30		<.0001
TwrPClass	0.3688509	0.123735	2.98		0.0035
PredPClass	0.3487601	0.123999	2.81		0.0058
(TwrPClass-0.54305)*(PredPClass-0.54633)	1.5661243	0.689581	2.27		0.0250

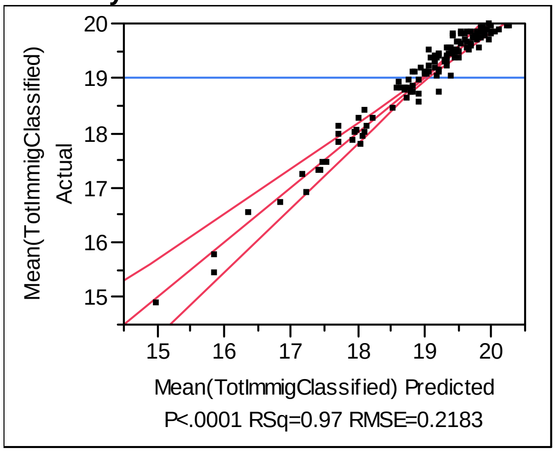
Table 15. Linear Regression Results for Total Number of Classified Immigrants without MiniUAV

b. With MiniUAV

The model for the total number of classified immigrants with MiniUAV is very similar to the model without MiniUAV with an RSquare value of 0.97. The first three important factors are exactly the same, and there are some other factors and interactions added to the model, related to the performance of the MiniUAV (See Table 16).

Response Mean(TotImmigClassified)

Actual by Predicted Plot



Summary of Fit

RSquare	0.966884
RSquare Adj	0.947014
Root Mean Square Error	0.218255
Mean of Response	19.02067
Observations (or Sum Wgts)	129

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	48	111.26293	2.31798	48.6608
Error	80	3.81083	0.04764	**Prob > F**
C. Total	128	115.07376		<.0001

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
PredClassRng	0.0125466	0.000646	19.44		<.0001
TwrClassRng	0.011258	0.000734	15.34		<.0001
(TwrClassRng-123.651)*(PredClassRng-124.209)	-0.000188	1.726e-5	-10.89		<.0001
(MiniUAVCommLat-10.1783)*(PredClassRng-124.209)	0.0006386	0.00011	5.83		<.0001
(MiniUAVTurretHt-275.651)*(MiniUAVCommLat-10.1783)	-0.000275	5.325e-5	-5.16		<.0001
TwrHt	0.0172466	0.003501	4.93		<.0001
(MiniUAVTurretHt-275.651)*(NumBPCars-3.51938)	0.0020441	0.000451	4.53		<.0001
CommCentRel	0.0048627	0.001075	4.52		<.0001
MiniUAVClassRng	0.019402	0.004467	4.34		<.0001
(MiniUAVCommRel-79.3256)*(PredPClass-0.55372)	-0.048294	0.011251	-4.29		<.0001
(MiniUAVClassRng-11.8682)*(CommCentLat-10.2403)	0.0041055	0.000971	4.23		<.0001
(MiniUAVCommRel-79.3256)*(TwrClassRng-123.651)	0.0002207	5.936e-5	3.72		0.0004
MiniUAVFuel	0.0001132	3.143e-5	3.60		0.0005
(MiniUAVCommLat-10.1783)*(NumBPCars-3.51938)	0.0153324	0.004492	3.41		0.0010
(MiniUAVCommRel-79.3256)*(TwrHt-34.8217)	0.0010605	0.000316	3.35		0.0012
(MiniUAVTurretHt-275.651)*(CommCentLat-10.2403)	0.0001851	5.574e-5	3.32		0.0014
(PredPClass-0.55372)*(CommCentRel-66.4419)	-0.016376	0.004949	-3.31		0.0014
(TwrPClass-0.55698)*(NumBPCars-3.51938)	-0.474212	0.144842	-3.27		0.0016

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
(TwrClassRng-123.651)*(CommCentRel-66.4419)	-0.000112	3.489e-5	-3.21		0.0019
(MiniUAVFuel-2016.79)*(TwrHt-34.8217)	0.0000159	4.975e-6	3.19		0.0020
(MiniUAVFuel-2016.79)*(PredPClass-0.55372)	-0.000647	0.000207	-3.13		0.0025
(CommCentLat-10.2403)*(NumBPCars-3.51938)	-0.013412	0.004459	-3.01		0.0035
(TwrHt-34.8217)*(TwrPClass-0.55698)	-0.035852	0.0125	-2.87		0.0053
(MiniUAVFuel-2016.79)*(MiniUAVCommLat-10.1783)	1.3088e-5	4.657e-6	2.81		0.0062
(MiniUAVTurretHt-275.651)*(CommCentRel-66.4419)	-0.000055	2.013e-5	-2.73		0.0077
(MiniUAVTurretHt-275.651)*(MiniUAVCommRel-79.3256)	-7.865e-5	2.887e-5	-2.72		0.0079
(PredClassRng-124.209)*(CommCentRel-66.4419)	-8.441e-5	0.000033	-2.57		0.0122
(MiniUAVTurretHt-275.651)*(MiniUAVClassRng-11.8682)	0.000197	8.676e-5	2.27		0.0259
(MiniUAVClassRng-11.8682)*(PredClassRng-124.209)	-0.000258	0.000115	-2.24		0.0277
(TwrClassRng-123.651)*(CommCentLat-10.2403)	-0.000242	0.000111	-2.18		0.0320
(MiniUAVCommLat-10.1783)*(CommCentRel-66.4419)	0.0004773	0.00022	2.17		0.0332
(MiniUAVFuel-2016.79)*(TwrPClass-0.55698)	-0.000474	0.000226	-2.10		0.0391

Table 16. Linear Regression Results for Total Number of Classified Immigrants with MiniUAV

4. Total Number of Classified Smugglers

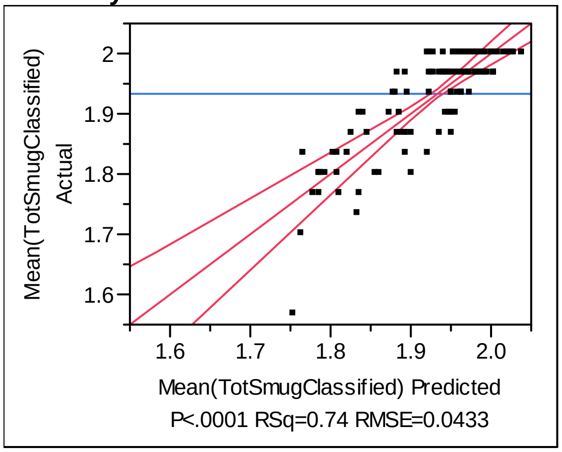
a. Without MiniUAV

Although the p-value is less than 0.0001, regressors are less successful at explaining the overall variance of the MOE, with an RSquare value of 0.74, than the model for the number of classified immigrants.

Despite the lower RSquare value, the important factors are in accordance with the model for the number of classified immigrants. Tower classification range becomes the most important term, instead of the Predator classification range, and the number of BP cars emerges as an important factor for this MOE (Table 17).

Response Mean(TotSmugClassified)

Actual by Predicted Plot



Summary of Fit

RSquare	0.7413
RSquare Adj	0.716768
Root Mean Square Error	0.043339
Mean of Response	1.933854
Observations (or Sum Wgts)	128

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	11	0.62431321	0.056756	30.2177
Error	116	0.21787429	0.001878	**Prob > F**
C. Total	127	0.84218750		<.0001

Sorted Parameter Estimates

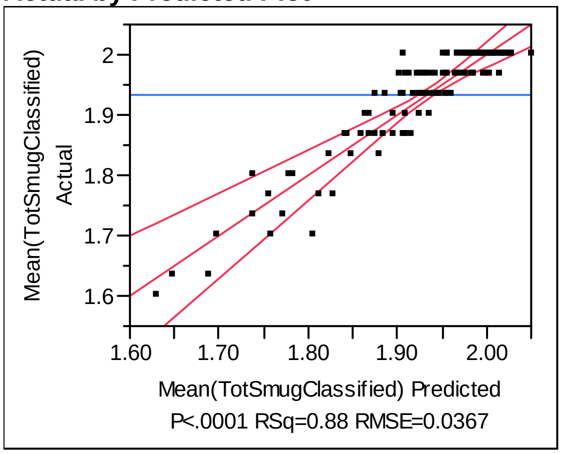
Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
TwrClassRng	0.0010978	8.863e-5	12.39		<.0001
PredClassRng	0.0008979	8.939e-5	10.05		<.0001
(TwrClassRng-126.367)*(PredClassRng-125.805)	-1.483e-5	2.223e-6	-6.67		<.0001
NumBPCars	0.0128331	0.004003	3.21		0.0017
(PredClassRng-125.805)*(CommCentRel-63.5547)	-1.18e-5	4.802e-6	-2.46		0.0154
(CommCentRel-63.5547)*(NumBPCars-3.48438)	-0.000504	0.000209	-2.41		0.0175
TwrPClass	0.043929	0.018993	2.31		0.0225
TwrHt	0.0009921	0.000443	2.24		0.0270
(TwrHt-35.1875)*(PredClassRng-125.805)	-2.541e-5	1.141e-5	-2.23		0.0279

Table 17. Linear Regression Results for Total Number of Classified Smugglers without MiniUAV

b. With MiniUAV

The model for the number of classified smugglers with MiniUAV explains less variability in the MOE, with an Rsuared value of 0.88, compared to the model for the number of classified immigrants. However, important factors are in accordance with the without miniUAV scenarios. The main difference between these two cases is the order of the first three most important factors. Tower classification range becomes the most important term instead of Predator classification range (Table 18).

Response Mean(TotSmugClassified)
Actual by Predicted Plot



Summary of Fit

RSquare	0.88387
RSquare Adj	0.831083
Root Mean Square Error	0.036707
Mean of Response	1.934109
Observations (or Sum Wgts)	129

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	40	0.9024606	0.022562	16.7442
Error	88	0.1185730	0.001347	**Prob > F**
C. Total	128	1.0210336		<.0001

Sorted Parameter Estimates

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
TwrClassRng	0.0013447	0.000116	11.64		<.0001
(TwrClassRng-123.651)*(PredClassRng-124.209)	-2.246e-5	2.593e-6	-8.66		<.0001
PredClassRng	0.0007661	0.000101	7.62		<.0001
(MiniUAVCommLat-10.1783)*(CommCentRel-66.4419)	-0.000212	3.738e-5	-5.67		<.0001
(MiniUAVFuel-2016.79)*(TwrHt-34.8217)	3.81e-6	8.577e-7	4.44		<.0001
(MiniUAVCommRel-79.3256)*(CommCentLat-10.2403)	-0.000335	7.649e-5	-4.38		<.0001
(MiniUAVTurretHt-275.651)*(NumBPCars-3.51938)	0.0002075	5.23e-5	3.97		0.0001
(MiniUAVFuel-2016.79)*(TwrClassRng-123.651)	-5.161e-7	1.521e-7	-3.39		0.0010
(MiniUAVCommLat-10.1783)*(TwrClassRng-123.651)	6.0182e-5	1.78e-5	3.38		0.0011
(MiniUAVTurretHt-275.651)*(TwrHt-34.8217)	-2.023e-5	6.134e-6	-3.30		0.0014

Term	Estimate	Std Error	t Ratio	t Ratio	Prob>|t|
(MiniUAVTurretHt-275.651)*(CommCentRel-66.4419)	-0.000011	3.372e-6	-3.29		0.0014
(TwrHt-34.8217)*(CommCentRel-66.4419)	0.0000926	2.94e-5	3.15		0.0022
(MiniUAVClassRng-11.8682)*(PredClassRng-124.209)	-0.00006	1.946e-5	-3.08		0.0028
(MiniUAVTurretHt-275.651)*(TwrClassRng-123.651)	-4.708e-6	1.553e-6	-3.03		0.0032
TwrPClass	0.0682418	0.0236	2.89		0.0048
MiniUAVTurretHt	0.0001615	5.873e-5	2.75		0.0072
(MiniUAVClassRng-11.8682)*(CommCentLat-10.2403)	0.0004365	0.00016	2.72		0.0078
MiniUAVFuel	1.7017e-5	6.274e-6	2.71		0.0080
(MiniUAVFuel-2016.79)*(PredPClass-0.55372)	-6.576e-5	0.000025	-2.62		0.0103
(MiniUAVFuel-2016.79)*(PredClassRng-124.209)	-3.064e-7	1.172e-7	-2.61		0.0105
(MiniUAVFuel-2016.79)*(MiniUAVCommRel-79.3256)	1.6373e-6	6.652e-7	2.46		0.0158
(CommCentLat-10.2403)*(CommCentRel-66.4419)	-0.000072	3.025e-5	-2.38		0.0194
(MiniUAVTurretHt-275.651)*(CommCentLat-10.2403)	-3.075e-5	1.316e-5	-2.34		0.0218
(MiniUAVCommRel-79.3256)*(PredPClass-0.55372)	-0.004234	0.001831	-2.31		0.0231
(MiniUAVCommRel-79.3256)*(TwrClassRng-123.651)	2.1533e-5	9.315e-6	2.31		0.0231
CommCentLat	-0.001787	0.000799	-2.24		0.0278
(PredPClass-0.55372)*(CommCentRel-66.4419)	-0.001692	0.000764	-2.21		0.0293
CommCentRel	0.0003503	0.000171	2.05		0.0435

Table 18. Linear Regression Results for Total Number of Classified Smugglers with MiniUAV

D. REGRESSION TREES

Regression, or partition, trees are another way of analyzing classification and regression problems. Because regression trees are constructed by if-then conditions, it is non-parametric and interactions between the factors emerge automatically. Regression trees present some threshold values which are hard to determine by linear regression, and also it is easy to interpret the results in most cases.

Regression trees for all MOEs are presented in Appendix B.

1. Total Number of Captured Illegal Entrants

a. Without MiniUAV

The important factors emerged from linear regression, such as the number of BP cars, communication center reliability and tower classification range, were in accordance for the number of captured immigrants and smugglers. The result from partition trees for these scenarios complies with linear regression. Because number of BP cars is too dominant for these MOEs, the tree initially splits on all possible levels of this factor. The mean of the captured illegal entrants for the scenarios with more than three BP cars appears to be larger than the mean for the scenarios with fewer BP cars. While the threshold for communication center reliability for immigrants is around 40 for the scenarios with three and four BP cars, it is 73 for the scenarios with five BP cars. This indicates that more reliable communication systems are needed when the manpower is increased.

b. With MiniUAV

Although the number of BP cars is the most important factor for the scenarios with the MiniUAV too, some additional factors also are very important and come into play for these scenarios, such as MiniUAV classification range and MiniUAV endurance. Also, it is possible to see some differences between the trees for immigrants and smugglers. While the endurance of the miniUAV seems to be as important as miniUAV classification range for capturing immigrants, classification parameters for the sensors (miniUAV, towers and Predator B) become more important for capturing smugglers. The threshold value for miniUAV endurance is roughly 90 minute (minimum of 60 minutes, maximum of 120 minutes). It becomes relevant to have extended endurance for the miniUAV when its classification range is more than 500 meters, which means that endurance and classification range should be improved simultaneously.

2. Total Number of Classified Illegal Entrants

a. Without MiniUAV

The most important factors emerging from the partition tree for the total number of classified immigrants and smugglers are Predator B classification range and tower classification range, just as the results from linear regression. With their large classification ranges, it is normal to see these factors in the partition tree; however, they have unexpected interaction effects. If the classification range for the Predator B is low, the classification range for tower needs to be high. However, if the classification range for the Predator B is high, the classification range for the tower becomes less important. The same relationship is true for Predator B, as with the cases of tower classification range. This result is an indication of negative correlation between the classification ranges of the Predator B and towers. This negative correlation can be seen by looking at the negative coefficient of the interaction term of these factors in the linear regression models. Due to the strong relationship between these two factors, it is not possible to determine stand-alone threshold values. However, 5000-6000 m for the towers and 5000-6500 m for the Predator B can be accepted as the threshold values that make significant differences for the mean of classified illegal entrants.

b. With MiniUAV

Similar to the scenarios without the miniUAV, the classification ranges of towers and Predator B are the most important factors and they have a strong correlation. The relatively small classification range of the miniUAV, compared to the Predator B and towers, can explain the reason that the miniUAV does not emerge as an important factor. The threshold values for the classification range of the towers are 3300 m for classified immigrants and 5500 meters for classified smugglers.

VI. CONCLUSION

To achieve an improved border security, the CBP focuses on improving manpower, technology and infrastructure along the border. Due to the long land border and limited assets, it is difficult or impossible to fully protect every point along the border. Therefore, CBP must direct its resources in an intelligent way, determining the assets to invest in and the best way to employ them.

A border model is constructed in MANA for this study to explore the effectiveness of the assets used in border security. According to the analysis, three important factors or systems need to be taken into account for an effective border security system: Manpower, MiniUAV usage and communication systems.

An infrastructure such as a fence along the border or a state of the art sensor system may be used to prevent illegal entrants. However, although it is very expensive to construct an infrastructure, it is easy to destroy it or find a way to avoid it if there is nothing to protect this infrastructure. Similarly, illegal entrants may not care if they are detected by the sensors when there is no physical deterrence to stop them. The only asset that can protect the infrastructure or provide a physical deterrence is manpower, particularly BP agents. Without a sufficient number of BP agents to assist the overall security system, other measures become ineffective in stopping illegal activities. Particularly for this model where 50 km of land border is used, an average of seven BP agents can only capture roughly 25% of the 22 illegal entrants.

Comparison tests for various MOEs reveal that using a hand-launched miniUAV improves the effectiveness of the system. Because miniUAVs are controlled directly by BP agents, they need less coordination effort. Any other sensor that can be used directly by BP agents may give similar results, but airborne sensors have some advantages compared with ground sensors. For example, it is not necessary to acquire land to construct any facility, and this fact is especially important in the modeled region, which contains many sensitive lands. Also they can track the illegal immigrants without any need for a road in rough terrains. To improve the border security system, MiniUAV classification range and endurance are the two most important factors that emerge in the regression models. For the sensors other than the miniUAV, classification ranges of the Towers and Predator B are other important factors regarding the border security system.

Having found the usage of the miniUAV to be an important contribution to the border security system, further analysis should be done by developing more specific models to reveal the effectiveness of different tactics, techniques, and procedures (TTPs).

A reliable communication web is another important factor regarding an effective border security system. Having perfect sensors that can detect and classify illegal activities is not sufficient if this information is not successfully transmitted to the BP agents. Better communication systems should be sought, which integrate sensors with each other and the BP. Other than reliability, communication latency, which is the time to transmit data from one agent to another, is another factor that emerges as important in the linear regression models. Further analysis can be done to find the critical levels of these important factors by using higher-resolution models and examining their marginal contribution to the MOEs.

Border protection is a vital national security issue. Although gaps in the security system of the border contribute to the surge in the number of illegal activities along the border, it is not possible to completely stop all illegal trafficking, even with a perfect security system. But this fact does not mean that the number of the illegal activities will remain the same regardless of the security measures that are taken. A better security system decreases the number of the illegal activities by deterring the illegal entrants. And this thesis has explored the use of UAVs to enhance border security with the results indicating the potential effectiveness of these assets.

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APPENDIX A: EXPERIMENTAL DESIGN

low level	800	150	4		0	60	20	0.2	50								0.2	50								0	30	2	0				
high level	3200	400	20		20	100	50	0.9	200								0.9	200								20	100	5	1				
deci-mals	0	0	0		0	0	0	2	0								2	0								0	0	0	0				
Factor Name	MiniUAVFuel	MiniUAVTurretHt	MiniUAVClassRng	MiniUAVDetRng	MiniUAVCommLat	MiniUAVCommRel	TwrHt	TwrPClass	TwrClassRng	TwrDetRng	TwrPClass(2)	TwrDetRng(2)	TwrClassRng(2)	TwrPClass(1)	TwrDetRng(1)	TwrClassRng(1)	PredPClass	PredClassRng	PredDetRng	PredPClass(2)	PredDetRng(2)	PredClassRng(2)	PredPClass(1)	PredDetRng(1)	PredClassRng(1)	CommCentLat	CommCentRel	NumBPCars	WithUAV?	BPCar5(Sqd9)	BPCar1(Sqd7)	BPCar4(Sqd8)	WithUAV?(Y/N)
	1756	371	14	21	12	85	47	0.9	181	272	0.93	182	121	0.97	90	60	0.33	60	90	0.63	60	40	0.73	30	20	5	57	2	0	No	No	No	No
	1081	250	17	26	19	89	36	0.88	177	266	0.93	177	118	0.97	89	59	0.58	141	212	0.82	141	94	0.9	71	47	13	82	5	1	Yes	Yes	Yes	Yes
	1184	298	6	9	11	98	44	0.86	184	276	0.92	185	123	0.97	92	61	0.65	104	156	0.86	104	69	0.93	53	35	4	47	2	0	No	No	No	No
	1775	190	10	15	13	89	42	0.82	192	288	0.91	192	128	0.96	96	64	0.31	132	198	0.61	132	88	0.71	66	44	19	85	5	1	Yes	Yes	Yes	Yes
	1681	290	14	21	8	97	44	0.73	153	230	0.89	153	102	0.95	77	51	0.25	172	258	0.53	173	115	0.63	86	57	2	34	3	0	Yes	No	No	No
	1859	242	19	29	3	95	47	0.71	193	290	0.88	194	129	0.94	96	64	0.71	119	179	0.88	119	79	0.94	60	40	17	83	5	1	Yes	Yes	Yes	Yes
	903	303	11	17	2	81	36	0.74	138	207	0.89	138	92	0.95	69	46	0.67	138	207	0.87	138	92	0.93	69	46	0	49	3	0	Yes	No	No	No
	1728	161	10	15	8	97	42	0.69	152	228	0.87	152	101	0.94	77	51	0.54	61	92	0.8	62	41	0.88	30	20	9	67	4	1	Yes	Yes	No	Yes
	978	279	19	29	13	75	44	0.72	197	296	0.88	197	131	0.94	99	66	0.32	107	161	0.62	107	71	0.72	54	36	19	46	3	0	Yes	No	No	No
	1963	169	18	27	14	62	38	0.6	133	200	0.83	134	89	0.91	66	44	0.87	163	245	0.93	164	109	0.97	81	54	8	78	4	1	Yes	Yes	No	Yes
	1128	382	12	18	19	78	35	0.88	140	210	0.93	140	93	0.97	71	47	0.83	93	140	0.92	93	62	0.96	47	31	13	45	3	0	Yes	No	No	No
	969	184	5	8	15	75	40	0.74	143	215	0.89	143	95	0.95	72	48	0.54	198	297	0.8	198	132	0.88	99	66	9	64	5	1	Yes	Yes	Yes	Yes
	1447	390	14	21	1	76	44	0.65	150	225	0.86	150	100	0.93	75	50	0.46	191	287	0.75	191	127	0.84	96	64	15	44	2	0	No	No	No	No
	894	217	16	24	3	66	44	0.89	127	191	0.93	128	85	0.97	63	42	0.7	77	116	0.88	77	51	0.94	39	26	7	84	4	1	Yes	Yes	No	Yes
	1475	307	5	8	10	65	36	0.73	134	201	0.89	134	89	0.95	68	45	0.72	196	294	0.88	197	131	0.94	98	65	11	49	2	0	No	No	No	No
	1691	220	8	12	1	76	42	0.86	178	267	0.92	179	119	0.97	89	59	0.27	126	189	0.56	126	84	0.66	63	42	0	67	4	1	Yes	Yes	No	Yes
	1466	282	17	26	16	96	31	0.65	149	224	0.86	149	99	0.93	75	50	0.31	105	158	0.61	105	70	0.71	53	35	10	76	2	0	No	No	No	No
	1934	219	17	26	12	81	28	0.8	151	227	0.91	152	101	0.96	75	50	0.74	168	252	0.89	168	112	0.95	84	56	18	47	4	1	Yes	Yes	No	Yes
	1278	349	12	18	10	93	21	0.81	168	252	0.91	168	112	0.96	84	56	0.67	85	128	0.87	86	57	0.93	42	28	5	81	2	0	No	No	No	No
	1288	200	8	12	13	90	28	0.74	188	282	0.89	188	125	0.95	95	63	0.53	115	173	0.8	116	77	0.88	57	38	16	31	5	1	Yes	Yes	Yes	Yes
	1597	276	17	26	4	92	22	0.89	195	293	0.93	195	130	0.97	98	65	0.46	161	242	0.75	161	107	0.84	81	54	1	86	2	0	No	No	No	No
	1991	233	14	21	4	96	24	0.81	174	261	0.91	174	116	0.96	87	58	0.74	68	102	0.89	68	45	0.95	35	23	15	33	5	1	Yes	Yes	Yes	Yes
	1738	346	12	18	9	81	35	0.75	159	239	0.89	159	106	0.95	80	53	0.68	161	242	0.87	161	107	0.93	81	54	4	93	3	0	Yes	No	No	No
	1316	248	9	14	6	90	22	0.77	148	222	0.9	149	99	0.95	74	49	0.53	108	162	0.8	108	72	0.88	54	36	10	65	4	1	Yes	Yes	No	Yes
	1419	280	17	26	18	69	32	0.57	199	299	0.82	200	133	0.9	99	66	0.25	123	185	0.53	123	82	0.63	62	41	12	88	3	0	Yes	No	No	No
	1953	214	19	29	11	76	21	0.68	183	275	0.87	183	122	0.93	92	61	0.73	185	278	0.89	185	123	0.95	93	62	4	48	3	1	Yes	No	No	Yes
	1025	348	12	18	16	80	33	0.62	171	257	0.84	171	114	0.92	86	57	0.7	86	129	0.88	86	57	0.94	44	29	13	69	3	0	Yes	No	No	No
	1297	173	8	12	15	73	31	0.69	131	197	0.87	131	87	0.94	66	44	0.53	171	257	0.8	171	114	0.88	86	57	10	60	4	1	Yes	Yes	No	Yes
	1409	353	18	27	4	68	32	0.79	166	249	0.91	167	111	0.96	83	55	0.54	196	294	0.8	197	131	0.88	98	65	15	84	3	0	Yes	No	No	No
	1250	213	13	20	2	68	25	0.73	136	204	0.89	137	91	0.95	68	45	0.83	81	122	0.92	81	54	0.96	41	27	3	60	4	1	Yes	Yes	No	Yes
	1925	375	7	11	10	79	24	0.67	187	281	0.87	188	125	0.93	93	62	0.7	150	225	0.88	150	100	0.94	75	50	14	72	3	0	Yes	No	No	No
	1044	267	8	12	5	71	32	0.58	190	285	0.82	191	127	0.9	95	63	0.35	121	182	0.65	122	81	0.75	60	40	8	40	4	1	Yes	Yes	No	Yes
	1906	318	17	26	11	86	50	0.27	156	234	0.56	156	104	0.66	78	52	0.43	110	165	0.72	110	73	0.82	56	37	3	32	4	0	Yes	Yes	No	No
	1588	265	16	24	14	94	49	0.53	137	206	0.8	137	91	0.88	69	46	0.83	137	206	0.92	137	91	0.96	69	46	12	98	2	1	No	No	No	Yes
	1400	359	9	14	12	95	48	0.33	136	204	0.63	137	91	0.73	68	45	0.6	97	146	0.83	98	65	0.91	48	32	4	42	4	0	Yes	Yes	No	No
	1194	213	11	17	14	91	46	0.38	195	293	0.68	195	130	0.78	98	65	0.5	140	210	0.78	140	93	0.86	71	47	17	96	3	1	Yes	No	No	Yes
	1531	301	13	20	3	99	43	0.34	175	263	0.64	176	117	0.74	87	58	0.49	160	240	0.77	161	107	0.86	80	53	1	52	5	0	Yes	Yes	Yes	No
	1747	226	15	23	5	95	42	0.27	137	206	0.56	137	91	0.66	69	46	0.6	76	114	0.83	77	51	0.91	38	25	19	89	3	1	Yes	No	No	Yes
	1559	284	10	15	7	91	43	0.54	154	231	0.8	155	103	0.88	77	51	0.73	131	197	0.89	131	87	0.95	66	44	3	52	4	0	Yes	Yes	No	No
	1916	229	9	14	9	93	41	0.38	157	236	0.68	158	105	0.78	78	52	0.53	96	144	0.8	96	64	0.88	48	32	15	90	3	1	Yes	No	No	Yes
	1241	345	20	30	13	79	42	0.35	157	236	0.65	158	105	0.75	78	52	0.31	80	120	0.61	80	53	0.71	41	27	14	55	4	0	Yes	Yes	No	No
	1325	196	18	27	17	73	37	0.47	143	215	0.76	143	95	0.85	72	48	0.88	157	236	0.93	158	105	0.97	78	52	10	75	3	1	Yes	No	No	Yes
	1119	396	8	12	17	76	49	0.55	192	288	0.81	192	128	0.89	96	64	0.84	92	138	0.92	92	61	0.97	47	31	13	43	4	0	Yes	Yes	No	No
	838	183	7	11	16	72	43	0.43	144	216	0.72	144	96	0.82	72	48	0.38	188	282	0.68	188	125	0.78	95	63	8	98	4	1	Yes	Yes	No	Yes
	1334	368	14	21	0	67	39	0.34	126	189	0.64	126	84	0.74	63	42	0.34	193	290	0.64	194	129	0.74	96	64	14	33	4	0	Yes	Yes	No	No
	1109	206	18	27	3	70	50	0.34	185	278	0.64	185	123	0.74	93	62	0.76	69	104	0.9	69	46	0.95	35	23	1	77	3	0	Yes	No	No	No
	1156	310	6	9	4	73	43	0.53	138	207	0.8	138	92	0.88	69	46	0.8	176	264	0.91	176	117	0.96	89	59	9	39	4	0	Yes	Yes	No	No
	1663	187	8	12	4	78	48	0.39	132	198	0.69	132	88	0.79	66	44	0.34	86	129	0.64	86	57	0.74	44	29	5	92	4	1	Yes	Yes	No	Yes
	950	340	14	21	15	100	31	0.46	129	194	0.75	129	86	0.84	65	43	0.21	107	161	0.47	107	71	0.57	54	36	1	91	4	0	Yes	Yes	No	No
	1372	166	20	30	11	99	24	0.4	188	282	0.7	188	125	0.8	95	63	0.62	148	222	0.84	149	99	0.92	74	49	20	50	3	0	Yes	No	No	No
	828	311	8	12	20	98	24	0.23	179	269	0.5	179	119	0.6	90	60	0.82	63	95	0.91	63	42	0.96	32	21	3	87	4	0	Yes	Yes	No	No
	1653	153	5	8	15	95	27	0.39	147	221	0.69	147	98	0.79	74	49	0.31	177	266	0.61	177	118	0.71	89	59	20	41	2	1	No	No	No	Yes
	1353	394	16	24	7	90	20	0.25	133	200	0.53	134	89	0.63	66	44	0.48	189	284	0.76	189	126	0.85	95	63	6	95	5	0	Yes	Yes	Yes	No
	856	208	13	20	0	89	24	0.3	148	222	0.59	149	99	0.7	74	49	0.71	91	137	0.88	92	61	0.94	45	30	14	38	2	1	No	No	No	Yes
	1841	335	4	6	5	91	27	0.54	199	299	0.8	200	133	0.88	99	66	0.76	175	263	0.9	176	117	0.95	87	58	5	94	5	0	Yes	Yes	Yes	No
	1428	258	8	12	1	88	26	0.25	177	266	0.53	177	118	0.63	89	59	0.22	68	102	0.48	68	45	0.59	35	23	15	54	3	1	Yes	No	No	Yes
	1522	341	16	24	20	70	34	0.47	164	246	0.76	164	109	0.85	83	55	0.38	55	83	0.68	56	37	0.78	27	18	12	69	5	0	Yes	Yes	Yes	No
	1363	225	16	24	19	77	29	0.23	173	260	0.5	173	115	0.6	87	58	0.71	199	299	0.88	200	133	0.94	99	66	7	58	3	1	Yes	No	No	Yes
	1438	338	8	12	19	61	32	0.51	174	261	0.78	174	116	0.87	87	58	0.69	72	108	0.87	72	48	0.94	36	24	16	76	4	0	Yes	Yes	No	No
	1391	216	9	14	18	69	29	0.46	184	276	0.75	185	123	0.84	92	61	0.33	194	291	0.63	194	129	0.73	98	65	1	52	3	1	Yes	No	No	Yes
	1091	385	20	30	5	74	25	0.48	155	233	0.76	155	103	0.85	78	52	0.22	158	237	0.48	158	105	0.59	80	53	20	79	4	0	Yes	Yes	No	No
	941	180	20	30	5	60	28	0.31	171	257	0.61	171	114	0.71	86	57	0.89	97	146	0.93	98	65	0.97	48	32	7	37	3	1	Yes	No	No	Yes
	866	400	5	8	5	70	30	0.28	146	219	0.57	146	97	0.67	74	49	0.85	151	227	0.92	152	101	0.97	75	50	18	77	4	0	Yes	Yes	No	No
	800	157	6	9	6	63	34	0.48	187	281	0.76	188	125	0.85	93	62	0.26	83	125	0.54	83	55	0.65	42	28	4	56	2	1	No	No	No	Yes
	1006	309	15	23	15	81	41	0.81	50	75	0.91	50	33	0.96	26	17	0.3	82	123	0.59	83	55	0.7	41	27	3	53	3	1	Yes	No	No	Yes
	1672	171	17	26	16	97	37	0.79	54	81	0.91	54	36	0.96	27	18	0.65	165	248	0.86	165	110	0.93	83	55	11	75	5	0	Yes	Yes	Yes	No

Factor Name	MiniUAVFuel	MiniUAVTurretHt	MiniUAVClassRng	MiniUAVDetRng	MiniUAVCommLat	MiniUAVCommRel	TwrHt	TwrPClass	TwrClassRng	TwrDetRng	TwrPClass(2)	TwrDetRng(2)	TwrClassRng(2)	TwrPClass(1)	TwrDetRng(1)	TwrClassRng(1)	PredPClass	PredClassRng	PredDetRng	PredPClass(2)	PredDetRng(2)	PredClassRng(2)	PredPClass(1)	PredDetRng(1)	PredClassRng(1)	CommCentLat	CommCentRel	NumBPCars	WithUAV?	BPCar5(Sqd9)	BPCar1(Sqd7)	BPCar4(Sqd8)	WithUAV?(Y/N)
	1269	326	10	15	17	94	37	0.82	59	89	0.91	59	39	0.96	30	20	0.8	58	87	0.91	59	39	0.96	29	19	8	31	2	1	No	No	No	Yes
	1513	199	5	8	18	86	49	0.86	68	102	0.92	68	45	0.97	35	23	0.45	175	263	0.74	176	117	0.83	87	58	18	68	5	0	Yes	Yes	Yes	No
	1053	357	16	24	6	82	45	0.68	87	131	0.87	87	58	0.93	44	29	0.33	178	267	0.63	179	119	0.73	89	59	7	59	2	1	No	No	No	Yes
	1213	176	17	26	4	86	37	0.87	90	135	0.93	90	60	0.97	45	30	0.73	102	153	0.89	102	68	0.95	51	34	10	86	4	0	Yes	Yes	No	No
	1231	339	7	11	7	100	41	0.61	85	128	0.84	86	57	0.91	42	28	0.84	183	275	0.92	183	122	0.97	92	61	3	57	3	1	Yes	No	No	Yes
	1381	195	6	9	2	94	41	0.68	95	143	0.87	95	63	0.93	48	32	0.32	99	149	0.62	99	66	0.72	50	33	19	88	4	0	Yes	Yes	No	No
	1166	398	13	20	10	70	41	0.89	89	134	0.93	89	59	0.97	45	30	0.44	71	107	0.73	71	47	0.83	36	24	17	51	3	1	Yes	No	No	Yes
	819	188	14	21	18	67	39	0.59	115	173	0.83	116	77	0.91	57	38	0.56	137	206	0.81	137	91	0.89	69	46	6	73	5	0	Yes	Yes	Yes	No
	1634	289	4	6	17	67	48	0.62	54	81	0.84	54	36	0.92	27	18	0.8	114	171	0.91	114	76	0.96	57	38	19	58	3	1	Yes	No	No	Yes
	1869	237	6	9	13	64	39	0.63	85	128	0.85	86	57	0.92	42	28	0.21	187	281	0.47	188	125	0.57	93	62	4	98	4	0	Yes	Yes	No	No
	1644	365	12	18	9	72	35	0.66	103	155	0.86	104	69	0.93	51	34	0.24	147	221	0.51	147	98	0.62	74	49	16	34	3	1	Yes	No	No	Yes
	1138	238	19	29	7	68	47	0.56	52	78	0.81	53	35	0.89	26	17	0.58	133	200	0.82	134	89	0.9	66	44	6	64	4	0	Yes	Yes	No	No
	988	281	6	9	0	75	38	0.59	86	129	0.83	86	57	0.91	44	29	0.69	177	266	0.87	177	118	0.94	89	59	17	68	2	1	No	No	No	Yes
	1944	170	10	15	3	63	36	0.8	59	89	0.91	59	39	0.96	30	20	0.29	53	80	0.58	53	35	0.69	27	18	7	74	4	0	Yes	Yes	No	No
	1888	297	12	18	14	88	34	0.66	104	156	0.86	104	69	0.93	53	35	0.23	106	159	0.5	107	71	0.6	53	35	9	94	3	1	Yes	No	No	Yes
	1784	263	18	27	12	83	22	0.67	72	108	0.87	72	48	0.93	36	24	0.5	149	224	0.78	149	99	0.86	75	50	16	59	4	0	Yes	Yes	No	No
	1034	277	11	17	19	83	24	0.75	69	104	0.89	69	46	0.95	35	23	0.51	98	147	0.78	98	65	0.87	50	33	2	71	2	1	No	No	No	Yes
	1981	174	11	17	13	99	31	0.84	83	125	0.92	83	55	0.97	42	28	0.42	181	272	0.72	182	121	0.81	90	60	12	38	4	0	Yes	Yes	No	No
	1700	386	15	23	10	93	33	0.88	52	78	0.93	53	35	0.97	26	17	0.41	184	276	0.71	185	123	0.81	92	61	9	73	3	1	Yes	No	No	Yes
	931	244	14	21	2	83	30	0.78	70	105	0.9	71	47	0.96	35	23	0.69	123	185	0.87	123	82	0.94	62	41	16	63	5	0	Yes	Yes	Yes	No
	1719	328	5	8	8	88	20	0.71	83	125	0.88	83	55	0.94	42	28	0.55	117	176	0.81	117	78	0.89	59	39	6	96	3	1	Yes	No	No	Yes
	1494	246	10	15	9	89	25	0.66	78	117	0.86	78	52	0.93	39	26	0.21	100	150	0.47	101	67	0.57	50	33	15	33	4	0	Yes	Yes	No	No
	1484	323	17	26	14	72	27	0.9	120	180	0.93	120	80	0.97	60	40	0.45	116	174	0.74	116	77	0.83	59	39	13	79	2	1	No	No	No	Yes
	1541	221	13	20	12	75	25	0.82	97	146	0.91	98	65	0.96	48	32	0.74	154	231	0.89	155	103	0.95	77	51	6	41	5	0	Yes	Yes	Yes	No
	1803	358	9	14	11	62	25	0.77	109	164	0.9	110	73	0.95	54	36	0.66	52	78	0.86	53	35	0.93	26	17	12	92	3	1	Yes	No	No	Yes
	1203	254	9	14	19	75	23	0.58	96	144	0.82	96	64	0.9	48	32	0.32	126	189	0.62	126	84	0.72	63	42	3	39	4	0	Yes	Yes	No	No
	875	293	15	23	3	80	29	0.74	75	113	0.89	75	50	0.95	38	25	0.48	136	204	0.76	137	91	0.85	68	45	18	87	3	1	Yes	No	No	Yes
	1831	158	13	20	8	64	26	0.6	88	132	0.83	89	59	0.91	44	29	0.66	78	117	0.86	78	52	0.93	39	26	10	48	4	0	Yes	Yes	No	No
	1813	327	11	17	6	76	31	0.84	99	149	0.92	99	66	0.97	50	33	0.86	160	240	0.92	161	107	0.97	80	53	11	95	2	1	No	No	No	Yes
	1503	255	5	8	6	78	23	0.85	119	179	0.92	119	79	0.97	60	40	0.47	83	125	0.76	83	55	0.85	42	28	8	61	5	0	Yes	Yes	Yes	No
	959	378	16	24	20	86	46	0.41	65	98	0.71	65	43	0.81	33	22	0.51	76	114	0.78	77	51	0.87	38	25	8	37	4	1	Yes	Yes	No	Yes
	1016	167	13	20	18	87	45	0.5	120	180	0.78	120	80	0.86	60	40	0.77	200	300	0.9	200	133	0.95	101	67	14	90	3	0	Yes	No	No	No
	1822	343	5	8	16	92	47	0.5	78	117	0.78	78	52	0.86	39	26	0.86	121	182	0.92	122	81	0.97	60	40	2	37	5	1	Yes	Yes	Yes	Yes
	1344	256	5	8	11	97	48	0.22	88	132	0.48	89	59	0.59	44	29	0.28	166	249	0.57	167	111	0.67	83	55	16	100	3	0	Yes	No	No	No
	1897	352	20	30	5	99	41	0.32	81	122	0.62	81	54	0.72	41	27	0.29	134	201	0.58	134	89	0.69	68	45	3	35	4	1	Yes	Yes	No	Yes
	1259	264	18	27	9	93	49	0.49	64	96	0.77	65	43	0.86	32	21	0.9	94	141	0.93	95	63	0.97	47	31	20	79	3	0	Yes	No	No	No
	1072	399	7	11	2	89	38	0.42	122	183	0.72	122	81	0.81	62	41	0.58	188	282	0.82	188	125	0.9	95	63	6	63	4	1	Yes	Yes	No	Yes
	809	178	11	17	1	86	40	0.4	89	134	0.7	89	59	0.8	45	30	0.35	59	89	0.65	59	39	0.75	30	20	14	80	3	0	Yes	No	No	No
	1625	332	19	29	13	60	49	0.4	82	123	0.7	83	55	0.8	41	27	0.36	122	183	0.66	122	81	0.76	62	41	19	55	4	1	Yes	Yes	No	Yes
	1456	236	17	26	14	65	37	0.47	109	164	0.76	110	73	0.85	54	36	0.88	163	245	0.93	164	109	0.97	81	54	0	94	3	0	Yes	No	No	No
	1222	391	8	12	16	68	38	0.24	124	186	0.51	125	83	0.62	62	41	0.68	64	96	0.87	65	43	0.93	32	21	11	60	4	1	Yes	Yes	No	Yes
	884	194	10	15	18	78	39	0.46	100	150	0.75	101	67	0.84	50	33	0.38	170	255	0.68	170	113	0.78	86	57	5	69	2	1	No	No	No	Yes
	997	347	15	23	1	69	40	0.54	80	120	0.8	80	53	0.88	41	27	0.47	185	278	0.76	185	123	0.85	93	62	11	66	5	1	Yes	Yes	Yes	Yes
	1306	171	15	23	4	77	35	0.27	80	120	0.56	80	53	0.66	41	27	0.68	55	83	0.87	56	37	0.93	27	18	4	84	4	0	Yes	Yes	No	No
	1578	315	7	11	5	64	37	0.49	121	182	0.77	122	81	0.86	60	40	0.87	155	233	0.93	155	103	0.97	78	52	18	44	4	1	Yes	Yes	No	Yes
	1616	231	5	8	7	63	46	0.52	92	138	0.79	92	61	0.88	47	31	0.39	104	156	0.69	104	69	0.79	53	35	1	76	3	0	Yes	No	No	No
	1147	291	15	23	20	95	30	0.53	106	159	0.8	107	71	0.88	53	35	0.51	112	168	0.78	113	75	0.87	56	37	5	74	5	1	Yes	Yes	Yes	Yes
	1850	186	12	18	11	94	30	0.25	92	138	0.53	92	61	0.63	47	31	0.63	192	288	0.85	192	128	0.92	96	64	18	58	3	0	Yes	No	No	No
	1972	316	11	17	12	96	26	0.3	56	84	0.59	56	37	0.7	29	19	0.75	95	143	0.89	95	63	0.95	48	32	2	99	4	1	Yes	Yes	No	Yes
	1606	272	6	9	12	98	22	0.45	90	135	0.74	90	60	0.83	45	30	0.44	120	180	0.73	120	80	0.83	60	40	19	50	2	0	No	No	No	No
	1709	299	20	30	7	88	21	0.51	61	92	0.78	62	41	0.87	30	20	0.46	120	180	0.75	120	80	0.84	60	40	2	90	4	1	Yes	Yes	No	Yes
	1766	245	13	20	10	98	25	0.44	71	107	0.73	71	47	0.83	36	24	0.85	88	132	0.92	89	59	0.97	44	29	15	35	3	0	Yes	No	No	No
	1878	395	10	15	9	83	28	0.21	123	185	0.47	123	82	0.57	62	41	0.61	171	257	0.84	171	114	0.91	86	57	7	83	5	1	Yes	Yes	Yes	Yes
	847	262	10	15	3	87	30	0.31	61	92	0.61	62	41	0.71	30	20	0.48	109	164	0.76	110	73	0.85	54	36	12	60	2	0	No	No	No	No
	1569	296	15	23	18	61	20	0.37	108	162	0.67	108	72	0.77	54	36	0.2	71	107	0.45	71	47	0.55	36	24	13	89	4	1	Yes	Yes	No	Yes
	1794	230	19	29	17	78	23	0.33	56	84	0.63	56	37	0.73	29	19	0.59	180	270	0.83	180	120	0.91	90	60	3	30	3	0	Yes	No	No	No
	913	322	11	17	18	76	26	0.32	116	174	0.62	116	77	0.72	59	39	0.61	51	77	0.84	51	34	0.91	26	17	14	66	5	1	Yes	Yes	Yes	Yes
	1550	162	9	14	19	75	34	0.27	105	158	0.56	105	70	0.66	53	35	0.47	184	276	0.76	185	123	0.85	92	61	9	43	2	0	No	No	No	No
	922	373	18	27	6	73	27	0.41	111	167	0.71	111	74	0.81	56	37	0.28	194	291	0.57	194	129	0.67	98	65	11	68	4	1	Yes	Yes	No	Yes
	1063	163	18	27	1	80	33	0.34	74	111	0.64	74	49	0.74	38	25	0.82	103	155	0.91	104	69	0.96	51	34	7	49	3	0	Yes	No	No	No
	1175	369	6	9	8	78	23	0.45	68	102	0.74	68	45	0.83	35	23	0.81	139	209	0.91	140	93	0.96	69	46	18	99	5	1	Yes	Yes	Yes	Yes
	1100	189	5	8	6	66	22	0.26	110	165	0.54	110	73	0.65	56	37	0.24	106	159	0.51	107	71	0.62	53	35	9	45	3	0	Yes	No	No	No
	2000	275	12	18	10	80	35	0.55	125	188	0.81	125	83	0.89	63	42	0.55	125	188	0.81	125	83	0.89	63	42	10	65	4	1	Yes	Yes	No	Yes
	2244	179	11	17	8	75	23	0.2	69	104	0.45	69	46	0.55	35	23	0.77	190	285	0.9	191	127	0.95	95	63	15	73	5	1	Yes	Yes	Yes	Yes
	2919	300	7	11	1	71	34	0.22	73	110	0.48	74	49	0.59	36	24	0.52	109	164	0.79	110	73	0.88	54	36	8	48	2	0	No	No	No	No
	2816	252	18	27	9	62	26	0.24	66	99	0.51	66	44	0.62	33	22	0.45	146	219	0.74	146	97	0.83	74	49	16	83	5	1	Yes	Yes	Yes	Yes
	2225	360	14	21	7	71	28	0.28	58	87	0.57	59	39	0.67	29	19	0.79	118	177	0.91	119	79	0.96	59	39	1	45	2	0	No	No	No	No
	2319	260	10	15	12	63	26	0.37	97	146	0.67	98	65	0.77	48	32	0.85	78	117	0.92	78	52	0.97	39	26	18	96	4	1	Yes	Yes	No	Yes
	2141	308	5	8	17	65	23	0.39	57	86	0.69	57	38	0.79	29	19	0.39	131	197	0.69	131	87	0.79	66	44	3	47	2	0	No	No	No	No
	3097	247	13	20	18	79	34	0.36	112	168	0.66	113	75	0.76	56	37	0.43	112	168	0.72	113	75	0.82	56	37	20	81	4	1	Yes	Yes	No	Yes
	2272	389	14	21	12	63	28	0.41	98	147	0.71	98	65	0.81	50	33	0.56	189	284	0.81	189	126	0.89	95	63	11	63	3	0	Yes	No	No	No
	3022	271	5	8	7	85	26	0.38	53	80	0.68	53	35	0.78	27	18	0.78	143	215	0.9	143	95	0.96	72	48	1	84	4	1	Yes	Yes	No	Yes
	2038	381	6	9	6	98	32	0.5	117	176	0.78	117	78	0.86	59	39	0.23	88	132	0.5	89	59	0.6	44	29	12	52	3	0	Yes	No	No	No
	2872	168	12	18	1	82	35	0.22	110	165	0.48	110	73	0.59	56	37	0.27	157	236	0.56	158	105	0.66	78	52	7	85	4	1	Yes	Yes	No	Yes
	3031	366	19	29	5	85	30	0.36	107	161	0.66	107	71	0.76	54	36	0.56	52	78	0.81	53	35	0.89	26	17	11	66	2	0	No	No	No	No
	2553	160	10	15	19	84	26	0.45	100	150	0.74	101	67	0.83	50	33	0.64	59	89	0.85	59	39	0.92	30	20	5	86	5	1	Yes	Yes	Yes	Yes
	3106	333	9	14	17	94	26	0.21	123	185	0.47	123	82	0.57	62	41	0.4	173	260	0.7	173	115	0.8	87	58	13	46	3	0	Yes	No	No	No
	2525	243	19	29	10	95	34	0.37	116	174	0.67	116	77	0.77	59	39	0.38	54	81	0.68	54	36	0.78	27	18	9	81	5	1	Yes	Yes	Yes	Yes
	2309	330	16	24	19	84	28	0.24	72	108	0.51	72	48	0.62	36	24	0.83	124	186	0.92	125	83	0.96	62	41	20	63	3	0	Yes	No	No	No
	2534	268	7	11	4	64	39	0.45	101	152	0.74	101	67	0.83	51	34	0.79	145	218	0.91	146	97	0.96	72	48	10	54	5	1	Yes	Yes	Yes	Yes
	2066	331	7	11	8	79	42	0.3	99	149	0.59	99	66	0.7	50	33	0.36	82	123	0.66	83	55	0.76	41	27	2	83	3	0	Yes	No	No	No
	2722	201	12	18	10	68	49	0.29	82	123	0.58	83	55	0.69	41	27	0.43	165	248	0.72	165	110	0.82	83	55	15	49	5	1	Yes	Yes	Yes	Yes
	2713	350	16	24	7	70	42	0.36	62	93	0.66	62	41	0.76	32	21	0.57	135	203	0.82	135	90	0.9	68	45	4	99	2	0	No	No	No	No
	2403	274	7	11	16	68	48	0.21	55	83	0.47	56	37	0.57	27	18	0.64	89	134	0.85	89	59	0.92	45	30	19	44	5	1	Yes	Yes	Yes	Yes
	2009	317	10	15	16	64	46	0.29	76	114	0.58	77	51	0.69	38	25	0.36	182	273	0.66	182	121	0.76	92	61	5	97	2	0	No	No	No	No
	2263	204	12	18	11	79	35	0.35	91	137	0.65	92	61	0.75	45	30	0.42	89	134	0.72	89	59	0.81	45	30	16	37	4	1	Yes	Yes	No	Yes

Factor Name	MiniUAVFuel	MiniUAVTurretHt	MiniUAVClassRng	MiniUAVDetRng	MiniUAVCommLat	MiniUAVCommRel	TwrHt	TwrPClass	TwrClassRng	TwrDetRng	TwrPClass(2)	TwrDetRng(2)	TwrClassRng(2)	TwrPClass(1)	TwrDetRng(1)	TwrClassRng(1)	PredPClass	PredClassRng	PredDetRng	PredPClass(2)	PredDetRng(2)	PredClassRng(2)	PredPClass(1)	PredDetRng(1)	PredClassRng(1)	CommCentLat	CommCentRel	NumBPCars	WithUAV?	BPCar5(Sqd9)	BPCar1(Sqd7)	BPCar4(Sqd8)	WithUAV?(Y/N)
	1513	199	5	8	18	86	49	0.86	68	102	0.92	68	45	0.97	35	23	0.45	175	263	0.74	176	117	0.83	87	58	18	68	5	0	Yes	Yes	Yes	No
	1053	357	16	24	6	82	45	0.68	87	131	0.87	87	58	0.93	44	29	0.33	178	267	0.63	179	119	0.73	89	59	7	59	2	1	No	No	No	Yes
	1213	176	17	26	4	86	37	0.87	90	135	0.93	90	60	0.97	45	30	0.73	102	153	0.89	102	68	0.95	51	34	10	86	4	0	Yes	Yes	No	No
	1231	339	7	11	7	100	41	0.61	85	128	0.84	86	57	0.91	42	28	0.84	183	275	0.92	183	122	0.97	92	61	3	57	3	1	Yes	No	No	Yes
	1381	195	6	9	2	94	41	0.68	95	143	0.87	95	63	0.93	48	32	0.32	99	149	0.62	99	66	0.72	50	33	19	88	4	0	Yes	Yes	No	No
	1166	398	13	20	10	70	41	0.89	89	134	0.93	89	59	0.97	45	30	0.44	71	107	0.73	71	47	0.83	36	24	17	51	3	1	Yes	No	No	Yes
	819	188	14	21	18	67	39	0.59	115	173	0.83	116	77	0.91	57	38	0.56	137	206	0.81	137	91	0.89	69	46	6	73	5	0	Yes	Yes	Yes	No
	1634	289	4	6	17	67	48	0.62	54	81	0.84	54	36	0.92	27	18	0.8	114	171	0.91	114	76	0.96	57	38	19	58	3	1	Yes	No	No	Yes
	1869	237	6	9	13	64	39	0.63	85	128	0.85	86	57	0.92	42	28	0.21	187	281	0.47	188	125	0.57	93	62	4	98	4	0	Yes	Yes	No	No
	1644	365	12	18	9	72	35	0.66	103	155	0.86	104	69	0.93	51	34	0.24	147	221	0.51	147	98	0.62	74	49	16	34	3	1	Yes	No	No	Yes
	1138	238	19	29	7	68	47	0.56	52	78	0.81	53	35	0.89	26	17	0.58	133	200	0.82	134	89	0.9	66	44	6	64	4	0	Yes	Yes	No	No
	988	281	6	9	0	75	38	0.59	86	129	0.83	86	57	0.91	44	29	0.69	177	266	0.87	177	118	0.94	89	59	17	68	2	1	No	No	No	Yes
	1944	170	10	15	3	63	36	0.8	59	89	0.91	59	39	0.96	30	20	0.29	53	80	0.58	53	35	0.69	27	18	7	74	4	0	Yes	Yes	No	No
	1888	297	12	18	14	88	34	0.66	104	156	0.86	104	69	0.93	53	35	0.23	106	159	0.5	107	71	0.6	53	35	9	94	3	1	Yes	No	No	Yes
	1784	263	18	27	12	83	22	0.67	72	108	0.87	72	48	0.93	36	24	0.5	149	224	0.78	149	99	0.86	75	50	16	59	4	0	Yes	Yes	No	No
	1034	277	11	17	19	83	24	0.75	69	104	0.89	69	46	0.95	35	23	0.51	98	147	0.78	98	65	0.87	50	33	2	71	2	1	No	No	No	Yes
	1981	174	11	17	13	99	31	0.84	83	125	0.92	83	55	0.97	42	28	0.42	181	272	0.72	182	121	0.81	90	60	12	38	4	0	Yes	Yes	No	No
	1700	386	15	23	10	93	33	0.88	52	78	0.93	53	35	0.97	26	17	0.41	184	276	0.71	185	123	0.81	92	61	9	73	3	1	Yes	No	No	Yes
	931	244	14	21	2	83	30	0.78	70	105	0.9	71	47	0.96	35	23	0.69	123	185	0.87	123	82	0.94	62	41	16	63	5	0	Yes	Yes	Yes	No
	1719	328	5	8	8	88	20	0.71	83	125	0.88	83	55	0.94	42	28	0.55	117	176	0.81	117	78	0.89	59	39	6	96	3	1	Yes	No	No	Yes
	1494	246	10	15	9	89	25	0.66	78	117	0.86	78	52	0.93	39	26	0.21	100	150	0.47	101	67	0.57	50	33	15	33	4	0	Yes	Yes	No	No
	1484	323	17	26	14	72	27	0.9	120	180	0.93	120	80	0.97	60	40	0.45	116	174	0.74	116	77	0.83	59	39	13	79	2	1	No	No	No	Yes
	1541	221	13	20	12	75	25	0.82	97	146	0.91	98	65	0.96	48	32	0.74	154	231	0.89	155	103	0.95	77	51	6	41	5	0	Yes	Yes	Yes	No
	1803	358	9	14	11	62	25	0.77	109	164	0.9	110	73	0.95	54	36	0.66	52	78	0.86	53	35	0.93	26	17	12	92	3	1	Yes	No	No	Yes
	1203	254	9	14	19	75	23	0.58	96	144	0.82	96	64	0.9	48	32	0.32	126	189	0.62	126	84	0.72	63	42	3	39	4	0	Yes	Yes	No	No
	875	293	15	23	3	80	29	0.74	75	113	0.89	75	50	0.95	38	25	0.48	136	204	0.76	137	91	0.85	68	45	18	87	3	1	Yes	No	No	Yes
	1831	158	13	20	8	64	26	0.6	88	132	0.83	89	59	0.91	44	29	0.66	78	117	0.86	78	52	0.93	39	26	10	48	4	0	Yes	Yes	No	No
	1813	327	11	17	6	76	31	0.84	99	149	0.92	99	66	0.97	50	33	0.86	160	240	0.92	161	107	0.97	80	53	11	95	2	1	No	No	No	Yes
	1503	255	5	8	6	78	23	0.85	119	179	0.92	119	79	0.97	60	40	0.47	83	125	0.76	83	55	0.85	42	28	8	61	5	0	Yes	Yes	Yes	No
	959	378	16	24	20	86	46	0.41	65	98	0.71	65	43	0.81	33	22	0.51	76	114	0.78	77	51	0.87	38	25	8	37	4	1	Yes	Yes	No	Yes
	1016	167	13	20	18	87	45	0.5	120	180	0.78	120	80	0.86	60	40	0.77	200	300	0.9	200	133	0.95	101	67	14	90	3	0	Yes	No	No	No
	1822	343	5	8	16	92	47	0.5	78	117	0.78	78	52	0.86	39	26	0.86	121	182	0.92	122	81	0.97	60	40	2	37	5	1	Yes	Yes	Yes	Yes
	1344	256	5	8	11	97	48	0.22	88	132	0.48	89	59	0.59	44	29	0.28	166	249	0.57	167	111	0.67	83	55	16	100	3	0	Yes	No	No	No
	1897	352	20	30	5	99	41	0.32	81	122	0.62	81	54	0.72	41	27	0.29	134	201	0.58	134	89	0.69	68	45	3	35	4	1	Yes	Yes	No	Yes
	1259	264	18	27	9	93	49	0.49	64	96	0.77	65	43	0.86	32	21	0.9	94	141	0.93	95	63	0.97	47	31	20	79	3	0	Yes	No	No	No
	1072	399	7	11	2	89	38	0.42	122	183	0.72	122	81	0.81	62	41	0.58	188	282	0.82	188	125	0.9	95	63	6	63	4	1	Yes	Yes	No	Yes
	809	178	11	17	1	86	40	0.4	89	134	0.7	89	59	0.8	45	30	0.35	59	89	0.65	59	39	0.75	30	20	14	80	3	0	Yes	No	No	No
	1625	332	19	29	13	60	49	0.4	82	123	0.7	83	55	0.8	41	27	0.36	122	183	0.66	122	81	0.76	62	41	19	55	4	1	Yes	Yes	No	Yes
	1456	236	17	26	14	65	37	0.47	109	164	0.76	110	73	0.85	54	36	0.88	163	245	0.93	164	109	0.97	81	54	0	94	3	0	Yes	No	No	No
	1222	391	8	12	16	68	38	0.24	124	186	0.51	125	83	0.62	62	41	0.68	64	96	0.87	65	43	0.93	32	21	11	60	4	1	Yes	Yes	No	Yes
	884	194	10	15	18	78	39	0.46	100	150	0.75	101	67	0.84	50	33	0.38	170	255	0.68	170	113	0.78	86	57	5	69	2	1	No	No	No	Yes
	997	347	15	23	1	69	40	0.54	80	120	0.8	80	53	0.88	41	27	0.47	185	278	0.76	185	123	0.85	93	62	11	66	5	1	Yes	Yes	Yes	Yes
	1306	171	15	23	4	77	35	0.27	80	120	0.56	80	53	0.66	41	27	0.68	55	83	0.87	56	37	0.93	27	18	4	84	4	0	Yes	Yes	No	No
	1578	315	7	11	5	64	37	0.49	121	182	0.77	122	81	0.86	60	40	0.87	155	233	0.93	155	103	0.97	78	52	18	44	4	1	Yes	Yes	No	Yes
	1616	231	5	8	7	63	46	0.52	92	138	0.79	92	61	0.88	47	31	0.39	104	156	0.69	104	69	0.79	53	35	1	76	3	0	Yes	No	No	No
	1147	291	15	23	20	95	30	0.53	106	159	0.8	107	71	0.88	53	35	0.51	112	168	0.78	113	75	0.87	56	37	5	74	5	1	Yes	Yes	Yes	Yes
	1850	186	12	18	11	94	30	0.25	92	138	0.53	92	61	0.63	47	31	0.63	192	288	0.85	192	128	0.92	96	64	18	58	3	0	Yes	No	No	No
	1972	316	11	17	12	96	26	0.3	56	84	0.59	56	37	0.7	29	19	0.75	95	143	0.89	95	63	0.95	48	32	2	99	4	1	Yes	Yes	No	Yes
	1606	272	6	9	12	98	22	0.45	90	135	0.74	90	60	0.83	45	30	0.44	120	180	0.73	120	80	0.83	60	40	19	50	2	0	No	No	No	No
	1709	299	20	30	7	88	21	0.51	61	92	0.78	62	41	0.87	30	20	0.46	120	180	0.75	120	80	0.84	60	40	2	90	4	1	Yes	Yes	No	Yes
	1766	245	13	20	10	98	25	0.44	71	107	0.73	71	47	0.83	36	24	0.85	88	132	0.92	89	59	0.97	44	29	15	35	3	0	Yes	No	No	No
	1878	395	10	15	9	83	28	0.21	123	185	0.47	123	82	0.57	62	41	0.61	171	257	0.84	171	114	0.91	86	57	7	83	5	1	Yes	Yes	Yes	Yes
	847	262	10	15	3	87	30	0.31	61	92	0.61	62	41	0.71	30	20	0.48	109	164	0.76	110	73	0.85	54	36	12	60	2	0	No	No	No	No
	1569	296	15	23	18	61	20	0.37	108	162	0.67	108	72	0.77	54	36	0.2	71	107	0.45	71	47	0.55	36	24	13	89	4	1	Yes	Yes	No	Yes
	1794	230	19	29	17	78	23	0.33	56	84	0.63	56	37	0.73	29	19	0.59	180	270	0.83	180	120	0.91	90	60	3	30	3	0	Yes	No	No	No
	913	322	11	17	18	76	26	0.32	116	174	0.62	116	77	0.72	59	39	0.61	51	77	0.84	51	34	0.91	26	17	14	66	5	1	Yes	Yes	Yes	Yes
	1550	162	9	14	19	75	34	0.27	105	158	0.56	105	70	0.66	53	35	0.47	184	276	0.76	185	123	0.85	92	61	9	43	2	0	No	No	No	No
	922	373	18	27	6	73	27	0.41	111	167	0.71	111	74	0.81	56	37	0.28	194	291	0.57	194	129	0.67	98	65	11	68	4	1	Yes	Yes	No	Yes
	1063	163	18	27	1	80	33	0.34	74	111	0.64	74	49	0.74	38	25	0.82	103	155	0.91	104	69	0.96	51	34	7	49	3	0	Yes	No	No	No
	1175	369	6	9	8	78	23	0.45	68	102	0.74	68	45	0.83	35	23	0.81	139	209	0.91	140	93	0.96	69	46	18	99	5	1	Yes	Yes	Yes	Yes
	1100	189	5	8	6	66	22	0.26	110	165	0.54	110	73	0.65	56	37	0.24	106	159	0.51	107	71	0.62	53	35	9	45	3	0	Yes	No	No	No
	2000	275	12	18	10	80	35	0.55	125	188	0.81	125	83	0.89	63	42	0.55	125	188	0.81	125	83	0.89	63	42	10	65	4	1	Yes	Yes	No	Yes
	2244	179	11	17	8	75	23	0.2	69	104	0.45	69	46	0.55	35	23	0.77	190	285	0.9	191	127	0.95	95	63	15	73	5	1	Yes	Yes	Yes	Yes
	2919	300	7	11	1	71	34	0.22	73	110	0.48	74	49	0.59	36	24	0.52	109	164	0.79	110	73	0.88	54	36	8	48	2	0	No	No	No	No
	2816	252	18	27	9	62	26	0.24	66	99	0.51	66	44	0.62	33	22	0.45	146	219	0.74	146	97	0.83	74	49	16	83	5	1	Yes	Yes	Yes	Yes
	2225	360	14	21	7	71	28	0.28	58	87	0.57	59	39	0.67	29	19	0.79	118	177	0.91	119	79	0.96	59	39	1	45	2	0	No	No	No	No
	2319	260	10	15	12	63	26	0.37	97	146	0.67	98	65	0.77	48	32	0.85	78	117	0.92	78	52	0.97	39	26	18	96	4	1	Yes	Yes	No	Yes
	2141	308	5	8	17	65	23	0.39	57	86	0.69	57	38	0.79	29	19	0.39	131	197	0.69	131	87	0.79	66	44	3	47	2	0	No	No	No	No
	3097	247	13	20	18	79	34	0.36	112	168	0.66	113	75	0.76	56	37	0.43	112	168	0.72	113	75	0.82	56	37	20	81	4	1	Yes	Yes	No	Yes
	2272	389	14	21	12	63	28	0.41	98	147	0.71	98	65	0.81	50	33	0.56	189	284	0.81	189	126	0.89	95	63	11	63	3	0	Yes	No	No	No
	3022	271	5	8	7	85	26	0.38	53	80	0.68	53	35	0.78	27	18	0.78	143	215	0.9	143	95	0.96	72	48	1	84	4	1	Yes	Yes	No	Yes
	2038	381	6	9	6	98	32	0.5	117	176	0.78	117	78	0.86	59	39	0.23	88	132	0.5	89	59	0.6	44	29	12	52	3	0	Yes	No	No	No
	2872	168	12	18	1	82	35	0.22	110	165	0.48	110	73	0.59	56	37	0.27	157	236	0.56	158	105	0.66	78	52	7	85	4	1	Yes	Yes	No	Yes
	3031	366	19	29	5	85	30	0.36	107	161	0.66	107	71	0.76	54	36	0.56	52	78	0.81	53	35	0.89	26	17	11	66	2	0	No	No	No	No
	2553	160	10	15	19	84	26	0.45	100	150	0.74	101	67	0.83	50	33	0.64	59	89	0.85	59	39	0.92	30	20	5	86	5	1	Yes	Yes	Yes	Yes
	3106	333	9	14	17	94	26	0.21	123	185	0.47	123	82	0.57	62	41	0.4	173	260	0.7	173	115	0.8	87	58	13	46	3	0	Yes	No	No	No
	2525	243	19	29	10	95	34	0.37	116	174	0.67	116	77	0.77	59	39	0.38	54	81	0.68	54	36	0.78	27	18	9	81	5	1	Yes	Yes	Yes	Yes
	2309	330	16	24	19	84	28	0.24	72	108	0.51	72	48	0.62	36	24	0.83	124	186	0.92	125	83	0.96	62	41	20	63	3	0	Yes	No	No	No
	2534	268	7	11	4	64	39	0.45	101	152	0.74	101	67	0.83	51	34	0.79	145	218	0.91	146	97	0.96	72	48	10	54	5	1	Yes	Yes	Yes	Yes
	2066	331	7	11	8	79	42	0.3	99	149	0.59	99	66	0.7	50	33	0.36	82	123	0.66	83	55	0.76	41	27	2	83	3	0	Yes	No	No	No
	2722	201	12	18	10	68	49	0.29	82	123	0.58	83	55	0.69	41	27	0.43	165	248	0.72	165	110	0.82	83	55	15	49	5	1	Yes	Yes	Yes	Yes
	2713	350	16	24	7	70	42	0.36	62	93	0.66	62	41	0.76	32	21	0.57	135	203	0.82	135	90	0.9	68	45	4	99	2	0	No	No	No	No
	2403	274	7	11	16	68	48	0.21	55	83	0.47	56	37	0.57	27	18	0.64	89	134	0.85	89	59	0.92	45	30	19	44	5	1	Yes	Yes	Yes	Yes
	2009	317	10	15	16	64	46	0.29	76	114	0.58	77	51	0.69	38	25	0.36	182	273	0.66	182	121	0.76	92	61	5	97	2	0	No	No	No	No
	2263	204	12	18	11	79	35	0.35	91	137	0.65	92	61	0.75	45	30	0.42	89	134	0.72	89	59	0.81	45	30	16	37	4	1	Yes	Yes	No	Yes
	2684	302	15	23	14	70	48	0.33	102	153	0.63	102	68	0.73	51	34	0.57	142	213	0.82	143	95	0.9	71	47	10	65	3	0	Yes	No	No	No

Factor Name	MiniUAVFuel	MiniUAVTurretHt	MiniUAVClassRng	MiniUAVDetRng	MiniUAVCommLat	MiniUAVCommRel	TwrHt	TwrPClass	TwrClassRng	TwrDetRng	TwrPClass(2)	TwrDetRng(2)	TwrClassRng(2)	TwrPClass(1)	TwrDetRng(1)	TwrClassRng(1)	PredPClass	PredClassRng	PredDetRng	PredPClass(2)	PredDetRng(2)	PredClassRng(2)	PredPClass(1)	PredDetRng(1)	PredClassRng(1)	CommCentLat	CommCentRel	NumBPCars	WithUAV?	BPCar5(Sqd9)	BPCar1(Sqd7)	BPCar4(Sqd8)	WithUAV?(Y/N)
	2581	270	7	11	2	91	38	0.53	51	77	0.8	51	34	0.88	26	17	0.85	127	191	0.92	128	85	0.97	63	42	8	42	4	1	Yes	Yes	No	Yes
	2047	336	6	9	9	84	49	0.42	67	101	0.72	68	45	0.81	33	22	0.37	65	98	0.67	65	43	0.77	33	22	16	82	4	0	Yes	Yes	No	No
	2975	202	12	18	4	80	37	0.48	79	119	0.76	80	53	0.85	39	26	0.4	164	246	0.7	164	109	0.8	83	55	7	61	4	1	Yes	Yes	No	Yes
	2703	377	16	24	5	87	39	0.41	119	179	0.71	119	79	0.81	60	40	0.57	79	119	0.82	80	53	0.9	39	26	10	70	3	0	Yes	No	No	No
	2591	197	6	9	16	92	38	0.31	84	126	0.61	84	56	0.71	42	28	0.56	54	81	0.81	54	36	0.89	27	18	5	46	4	1	Yes	Yes	No	Yes
	2750	337	12	18	18	92	45	0.38	114	171	0.68	114	76	0.78	57	38	0.27	169	254	0.56	170	113	0.66	84	56	17	70	3	0	Yes	No	No	No
	2075	175	17	26	10	81	46	0.43	63	95	0.72	63	42	0.82	32	21	0.4	100	150	0.7	101	67	0.8	50	33	6	58	4	1	Yes	Yes	No	Yes
	2956	283	16	24	15	89	38	0.52	60	90	0.79	60	40	0.88	30	20	0.75	129	194	0.89	129	86	0.95	65	43	12	90	3	0	Yes	No	No	No
	2094	232	7	11	9	74	20	0.83	94	141	0.92	95	63	0.96	47	31	0.67	140	210	0.87	140	93	0.93	71	47	17	98	3	1	Yes	No	No	Yes
	2413	285	8	12	6	66	21	0.57	113	170	0.82	113	75	0.9	57	38	0.27	113	170	0.56	113	75	0.66	57	38	8	32	5	0	Yes	Yes	Yes	No
	2600	191	15	23	8	65	22	0.77	114	171	0.9	114	76	0.95	57	38	0.5	153	230	0.78	153	102	0.86	77	51	16	88	3	1	Yes	No	No	Yes
	2806	338	13	20	6	69	24	0.72	55	83	0.88	56	37	0.94	27	18	0.6	110	165	0.83	110	73	0.91	56	37	3	34	4	0	Yes	Yes	No	No
	2469	249	11	17	17	61	27	0.76	75	113	0.9	75	50	0.95	38	25	0.61	90	135	0.84	90	60	0.91	45	30	19	78	2	1	No	No	No	Yes
	2253	324	9	14	15	65	28	0.83	113	170	0.92	113	75	0.96	57	38	0.5	174	261	0.78	174	116	0.86	87	58	1	41	4	0	Yes	Yes	No	No
	2441	266	14	21	13	69	27	0.56	96	144	0.81	96	64	0.89	48	32	0.37	119	179	0.67	119	79	0.77	60	40	17	78	3	1	Yes	No	No	Yes
	2084	321	15	23	11	67	29	0.72	93	140	0.88	93	62	0.94	47	31	0.57	154	231	0.82	155	103	0.9	77	51	5	40	4	0	Yes	Yes	No	No
	2759	205	4	6	7	81	28	0.75	93	140	0.89	93	62	0.95	47	31	0.79	170	255	0.91	170	113	0.96	86	57	6	75	3	1	Yes	No	No	Yes
	2675	354	6	9	3	87	33	0.63	107	161	0.85	107	71	0.92	54	36	0.22	93	140	0.48	93	62	0.59	47	31	10	55	4	0	Yes	Yes	No	No
	2881	154	17	26	3	84	21	0.55	58	87	0.81	59	39	0.89	29	19	0.26	158	237	0.54	158	105	0.65	80	53	7	87	3	1	Yes	No	No	Yes
	3163	367	17	26	4	88	27	0.67	106	159	0.87	107	71	0.93	53	35	0.72	62	93	0.88	62	41	0.94	32	21	12	32	3	0	Yes	No	No	No
	2666	182	10	15	20	93	31	0.76	124	186	0.9	125	83	0.95	62	41	0.76	57	86	0.9	57	38	0.95	29	19	6	97	3	1	Yes	No	No	Yes
	2891	344	6	9	17	90	20	0.76	65	98	0.9	65	43	0.95	33	22	0.34	181	272	0.64	182	121	0.74	90	60	19	53	4	1	Yes	Yes	No	Yes
	2844	240	18	27	16	87	27	0.57	112	168	0.82	113	75	0.9	56	37	0.3	74	111	0.59	74	49	0.7	38	25	11	91	3	1	Yes	No	No	Yes
	2338	363	16	24	16	82	22	0.71	118	177	0.88	119	79	0.94	59	39	0.76	164	246	0.9	164	109	0.95	83	55	15	38	3	0	Yes	No	No	No
	3050	210	10	15	5	60	39	0.64	121	182	0.85	122	81	0.92	60	40	0.89	143	215	0.93	143	95	0.97	72	48	19	39	3	1	Yes	No	No	Yes
	2628	384	4	6	9	61	46	0.7	62	93	0.88	62	41	0.94	32	21	0.48	102	153	0.76	102	68	0.85	51	34	0	80	4	1	Yes	Yes	No	Yes
	3172	239	16	24	0	62	46	0.87	71	107	0.93	71	47	0.97	36	24	0.28	187	281	0.57	188	125	0.67	93	62	17	43	3	1	Yes	No	No	Yes
	2347	397	19	29	5	65	43	0.71	103	155	0.88	104	69	0.94	51	34	0.79	73	110	0.91	74	49	0.96	36	24	0	89	5	0	Yes	Yes	Yes	No
	2647	156	8	12	13	70	50	0.85	117	176	0.92	117	78	0.97	59	39	0.62	61	92	0.84	62	41	0.92	30	20	14	35	2	1	No	No	No	Yes
	3144	342	11	17	20	71	46	0.8	102	153	0.91	102	68	0.96	51	34	0.39	159	239	0.69	159	106	0.79	80	53	6	92	5	0	Yes	Yes	Yes	No
	2159	215	20	30	15	69	43	0.56	51	77	0.81	51	34	0.89	26	17	0.34	75	113	0.64	75	50	0.74	38	25	15	36	2	1	No	No	No	Yes
	2572	292	16	24	19	72	44	0.85	73	110	0.92	74	49	0.97	36	24	0.88	182	273	0.93	182	121	0.97	92	61	5	76	4	0	Yes	Yes	No	No
	2478	209	8	12	0	90	36	0.63	86	129	0.85	86	57	0.92	44	29	0.73	195	293	0.89	195	130	0.95	98	65	8	61	2	1	No	No	No	Yes
	2638	325	8	12	1	83	41	0.87	77	116	0.93	77	51	0.97	39	26	0.39	51	77	0.69	51	34	0.79	26	17	13	72	4	0	Yes	Yes	No	No
	2563	212	16	24	1	99	38	0.59	76	114	0.83	77	51	0.91	38	25	0.41	178	267	0.71	179	119	0.81	89	59	4	54	3	1	Yes	No	No	Yes
	2609	334	15	23	2	91	41	0.64	66	99	0.85	66	44	0.92	33	22	0.77	56	84	0.9	56	37	0.95	29	19	19	78	4	0	Yes	Yes	No	No
	2909	165	4	6	15	86	45	0.62	95	143	0.84	95	63	0.92	48	32	0.88	92	138	0.93	92	61	0.97	47	31	0	51	3	1	Yes	No	No	Yes
	3059	370	4	6	15	100	43	0.79	79	119	0.91	80	53	0.96	39	26	0.21	153	230	0.47	153	102	0.57	77	51	13	93	4	0	Yes	Yes	No	No
	3134	150	19	29	15	90	40	0.82	104	156	0.91	104	69	0.96	53	35	0.25	99	149	0.53	99	66	0.63	50	33	2	53	3	1	Yes	No	No	Yes
	3200	393	18	27	14	98	36	0.62	63	95	0.84	63	42	0.92	32	21	0.84	167	251	0.92	167	111	0.97	84	56	16	74	5	0	Yes	Yes	Yes	No
	2994	241	9	14	5	79	29	0.29	200	300	0.58	200	133	0.69	101	67	0.8	168	252	0.91	168	112	0.96	84	56	17	77	4	0	Yes	Yes	No	No
	2328	379	7	11	4	63	33	0.31	196	294	0.61	197	131	0.71	98	65	0.45	85	128	0.74	86	57	0.83	42	28	9	55	2	1	No	No	No	Yes
	2731	224	14	21	3	66	33	0.28	191	287	0.57	191	127	0.67	96	64	0.3	192	288	0.59	192	128	0.7	96	64	12	99	5	0	Yes	Yes	Yes	No
	2488	351	19	29	2	74	21	0.24	182	273	0.51	182	121	0.62	92	61	0.65	75	113	0.86	75	50	0.93	38	25	2	62	2	1	No	No	No	Yes
	2947	193	8	12	14	78	25	0.42	163	245	0.72	164	109	0.81	81	54	0.77	72	108	0.9	72	48	0.95	36	24	13	71	5	0	Yes	Yes	Yes	No
	2788	374	7	11	16	74	33	0.23	160	240	0.5	161	107	0.6	80	53	0.37	148	222	0.67	149	99	0.77	74	49	10	44	3	1	Yes	No	No	Yes
	2769	211	17	26	13	60	29	0.49	165	248	0.77	165	110	0.86	83	55	0.26	67	101	0.54	68	45	0.65	33	22	18	73	4	0	Yes	Yes	No	No
	2619	355	18	27	18	66	29	0.42	155	233	0.72	155	103	0.81	78	52	0.78	151	227	0.9	152	101	0.96	75	50	1	42	3	1	Yes	No	No	Yes
	2834	152	11	17	10	90	29	0.21	161	242	0.47	161	107	0.57	81	54	0.66	179	269	0.86	179	119	0.93	90	60	3	79	4	0	Yes	Yes	No	No
	3181	362	10	15	2	93	31	0.51	135	203	0.78	135	90	0.87	68	45	0.54	113	170	0.8	113	75	0.88	57	38	14	57	2	1	No	No	No	Yes
	2366	261	20	30	3	93	22	0.48	196	294	0.76	197	131	0.85	98	65	0.3	136	204	0.59	137	91	0.7	68	45	1	72	4	0	Yes	Yes	No	No
	2131	313	18	27	7	96	31	0.47	165	248	0.76	165	110	0.85	83	55	0.89	63	95	0.93	63	42	0.97	32	21	16	32	3	1	Yes	No	No	Yes
	2356	185	12	18	11	88	35	0.44	147	221	0.73	147	98	0.83	74	49	0.86	103	155	0.92	104	69	0.97	51	34	4	96	4	0	Yes	Yes	No	No
	2863	312	5	8	13	92	23	0.54	198	297	0.8	198	132	0.88	99	66	0.52	117	176	0.79	117	78	0.88	59	39	14	66	3	1	Yes	No	No	Yes
	3013	269	18	27	20	85	32	0.51	164	246	0.78	164	109	0.87	83	55	0.41	73	110	0.71	74	49	0.81	36	24	3	62	5	0	Yes	Yes	Yes	No
	2056	380	14	21	17	97	34	0.3	191	287	0.59	191	127	0.7	96	64	0.81	197	296	0.91	197	131	0.96	99	66	13	56	3	1	Yes	No	No	Yes
	2113	253	12	18	6	72	36	0.44	146	219	0.73	146	97	0.83	74	49	0.87	144	216	0.93	144	96	0.97	72	48	11	36	4	0	Yes	Yes	No	No
	2216	287	6	9	8	77	48	0.43	178	267	0.72	179	119	0.82	89	59	0.6	101	152	0.83	101	67	0.91	51	34	4	71	3	1	Yes	No	No	Yes
	2966	273	13	20	1	77	46	0.35	181	272	0.65	182	121	0.75	90	60	0.59	152	228	0.83	152	101	0.91	77	51	18	59	5	0	Yes	Yes	Yes	No
	2019	376	13	20	8	61	39	0.26	167	251	0.54	167	111	0.65	84	56	0.68	69	104	0.87	69	46	0.93	35	23	8	92	3	1	Yes	No	No	Yes
	2300	164	9	14	10	67	37	0.22	198	297	0.48	198	132	0.59	99	66	0.69	66	99	0.87	66	44	0.94	33	22	11	57	4	0	Yes	Yes	No	No
	3069	306	10	15	18	77	40	0.32	180	270	0.62	180	120	0.72	90	60	0.41	127	191	0.71	128	85	0.81	63	42	4	67	2	1	No	No	No	Yes
	2281	222	19	29	12	72	50	0.39	167	251	0.69	167	111	0.79	84	56	0.55	133	200	0.81	134	89	0.89	66	44	14	34	4	0	Yes	Yes	No	No
	2506	304	14	21	11	71	45	0.44	172	258	0.73	173	115	0.83	86	57	0.89	150	225	0.93	150	100	0.97	75	50	5	97	3	1	Yes	No	No	Yes
	2516	227	7	11	6	88	43	0.2	130	195	0.45	131	87	0.55	65	43	0.65	134	201	0.86	134	89	0.93	68	45	7	51	5	0	Yes	Yes	Yes	No
	2459	329	11	17	8	85	45	0.28	153	230	0.57	153	102	0.67	77	51	0.36	96	144	0.66	96	64	0.76	48	32	14	89	2	1	No	No	No	Yes
	2197	192	15	23	9	98	45	0.33	141	212	0.63	141	94	0.73	71	47	0.44	198	297	0.73	198	132	0.83	99	66	8	38	4	0	Yes	Yes	No	No
	2797	296	15	23	1	85	47	0.52	154	231	0.79	155	103	0.88	77	51	0.78	124	186	0.9	125	83	0.96	62	41	17	91	3	1	Yes	No	No	Yes
	3125	257	9	14	17	80	41	0.36	175	263	0.66	176	117	0.76	87	58	0.62	114	171	0.84	114	76	0.92	57	38	2	43	4	0	Yes	Yes	No	No
	2169	392	11	17	12	96	44	0.5	163	245	0.78	164	109	0.86	81	54	0.44	172	258	0.73	173	115	0.83	86	57	10	82	3	1	Yes	No	No	Yes
	2188	223	13	20	14	84	39	0.26	151	227	0.54	152	101	0.65	75	50	0.24	90	135	0.51	90	60	0.62	45	30	9	35	5	0	Yes	Yes	Yes	No
	2497	295	20	30	14	82	47	0.25	131	197	0.53	131	87	0.63	66	44	0.63	167	251	0.85	167	111	0.92	84	56	12	69	2	1	No	No	No	Yes
	3041	172	8	12	0	74	24	0.69	185	278	0.87	185	123	0.94	93	62	0.59	174	261	0.83	174	116	0.91	87	58	12	93	3	0	Yes	No	No	No
	2984	383	11	17	2	73	25	0.6	130	195	0.83	131	87	0.91	65	43	0.33	50	75	0.63	50	33	0.73	26	17	6	40	4	1	Yes	Yes	No	Yes
	2178	207	19	29	4	68	23	0.6	172	258	0.83	173	115	0.91	86	57	0.24	129	194	0.51	129	86	0.62	65	43	18	93	2	0	No	No	No	No
	2656	294	19	29	9	63	22	0.88	162	243	0.93	162	108	0.97	81	54	0.82	84	126	0.91	84	56	0.96	42	28	4	30	4	1	Yes	Yes	No	Yes
	2103	198	4	6	15	61	29	0.78	169	254	0.9	170	113	0.96	84	56	0.81	116	174	0.91	116	77	0.96	59	39	17	95	3	0	Yes	No	No	No
	2741	286	6	9	11	67	21	0.61	186	279	0.84	186	124	0.91	93	62	0.2	156	234	0.45	156	104	0.55	78	52	0	51	4	1	Yes	Yes	No	Yes
	2928	151	17	26	18	71	32	0.68	128	192	0.87	128	85	0.93	65	43	0.52	62	93	0.79	62	41	0.88	32	21	14	67	3	0	Yes	No	No	No
	3191	372	13	20	19	74	30	0.7	161	242	0.88	161	107	0.94	81	54	0.75	191	287	0.89	191	127	0.95	96	64	6	50	4	1	Yes	Yes	No	Yes
	2375	218	5	8	7	100	21	0.7	168	252	0.88	168	112	0.94	84	56	0.74	128	192	0.89	128	85	0.95	65	43	1	75	3	0	Yes	No	No	No
	2544	314	7	11	6	95	33	0.63	141	212	0.85	141	94	0.92	71	47	0.22	87	131	0.48	87	58	0.59	44	29	20	36	4	1	Yes	Yes	No	Yes
	2778	159	16	24	4	92	32	0.86	126	189	0.92	126	84	0.97	63	42	0.42	186	279	0.72	186	124	0.81	93	62	9	70	3	0	Yes	No	No	No
	3116	356	15	23	2	82	31	0.64	150	225	0.85	150	100	0.92	75	50	0.72	80	120	0.88	80	53	0.94	41	27	15	61	5	0	Yes	Yes	Yes	No
	3003	203	9	14	19	91	30	0.56	170	255	0.81	170	113	0.89	86	57	0.63	65	98	0.85	65	43	0.92	33	22	9	64	2	0	No	No	No	No
	2694	379	9	14	16	83	35	0.83	170	255	0.92	170	113	0.96	86	57	0.42	195	293	0.72	195	130	0.81	98	65	16	46	3	1	Yes	No	No	Yes

Factor Name	MiniUAVFuel	MiniUAVTurretHt	MiniUAVClassRng	MiniUAVDetRng	MiniUAVCommLat	MiniUAVCommRel	TwrHt	TwrPClass	TwrClassRng	TwrDetRng	TwrPClass(2)	TwrDetRng(2)	TwrClassRng(2)	TwrPClass(1)	TwrDetRng(1)	TwrClassRng(1)	PredPClass	PredClassRng	PredDetRng	PredPClass(2)	PredDetRng(2)	PredClassRng(2)	PredPClass(1)	PredDetRng(1)	PredClassRng(1)	CommCentLat	CommCentRel	NumBPCars	WithUAV?	BPCar5(Sqd9)	BPCar1(Sqd7)	BPCar4(Sqd8)	WithUAV?(Y/N)
	2422	235	17	26	15	96	33	0.61	129	194	0.84	129	86	0.91	65	43	0.23	95	143	0.5	95	63	0.6	48	32	2	86	3	0	Yes	No	No	No
	2384	319	19	29	13	97	24	0.58	158	237	0.82	158	105	0.9	80	53	0.71	146	219	0.88	146	97	0.94	74	49	19	54	4	1	Yes	Yes	No	Yes
	2853	259	9	14	0	65	40	0.57	144	216	0.82	144	96	0.9	72	48	0.59	138	207	0.83	138	92	0.91	69	46	15	56	2	0	No	No	No	No
	2150	364	12	18	9	66	40	0.85	158	237	0.92	158	105	0.97	80	53	0.47	58	87	0.76	59	39	0.85	29	19	2	72	4	1	Yes	Yes	No	Yes
	2028	234	13	20	8	64	44	0.8	194	291	0.91	194	129	0.96	98	65	0.35	155	233	0.65	155	103	0.75	78	52	18	31	3	0	Yes	No	No	No
	2394	278	18	27	8	62	48	0.65	160	240	0.86	161	107	0.93	80	53	0.66	130	195	0.86	131	87	0.93	65	43	1	80	5	1	Yes	Yes	Yes	Yes
	2291	251	4	6	13	73	49	0.59	189	284	0.83	189	126	0.91	95	63	0.64	130	195	0.85	131	87	0.92	65	43	18	40	3	0	Yes	No	No	No
	2234	305	11	17	10	62	45	0.66	179	269	0.86	179	119	0.93	90	60	0.25	162	243	0.53	162	108	0.63	81	54	5	95	4	1	Yes	Yes	No	Yes
	2122	155	14	21	11	77	42	0.89	127	191	0.93	128	85	0.97	63	42	0.49	79	119	0.77	80	53	0.86	39	26	13	48	2	0	No	No	No	No
	3153	288	14	21	17	73	40	0.79	189	284	0.91	189	126	0.96	95	63	0.62	141	212	0.84	141	94	0.92	71	47	8	70	5	1	Yes	Yes	Yes	Yes
	2431	254	9	14	3	99	50	0.73	142	213	0.89	143	95	0.95	71	47	0.9	179	269	0.93	179	119	0.97	90	60	7	41	3	0	Yes	No	No	No
	2206	320	5	8	3	82	47	0.77	194	291	0.9	194	129	0.95	98	65	0.51	70	105	0.78	71	47	0.87	35	23	17	100	4	1	Yes	Yes	No	Yes
	3088	228	13	20	2	84	44	0.78	134	201	0.9	134	89	0.96	68	45	0.49	199	299	0.77	200	133	0.86	99	66	6	64	2	0	No	No	No	No
	2450	388	15	23	1	85	36	0.83	145	218	0.92	146	97	0.96	72	48	0.63	66	99	0.85	66	44	0.92	33	22	11	87	5	1	Yes	Yes	Yes	Yes
	3078	177	6	9	14	87	43	0.69	139	209	0.87	140	93	0.94	69	46	0.82	56	84	0.91	56	37	0.96	29	19	9	62	3	0	Yes	No	No	No
	2938	387	7	11	19	80	37	0.76	176	264	0.9	176	117	0.95	89	59	0.28	147	221	0.57	147	98	0.67	74	49	13	81	4	1	Yes	Yes	No	Yes
	2825	181	18	27	12	83	47	0.65	182	273	0.86	182	121	0.93	92	61	0.29	111	167	0.58	111	74	0.69	56	37	2	31	2	0	No	No	No	No
	2900	361	19	29	14	94	48	0.84	140	210	0.92	140	93	0.97	71	47	0.86	144	216	0.92	144	96	0.97	72	48	11	85	4	1	Yes	Yes	No	Yes

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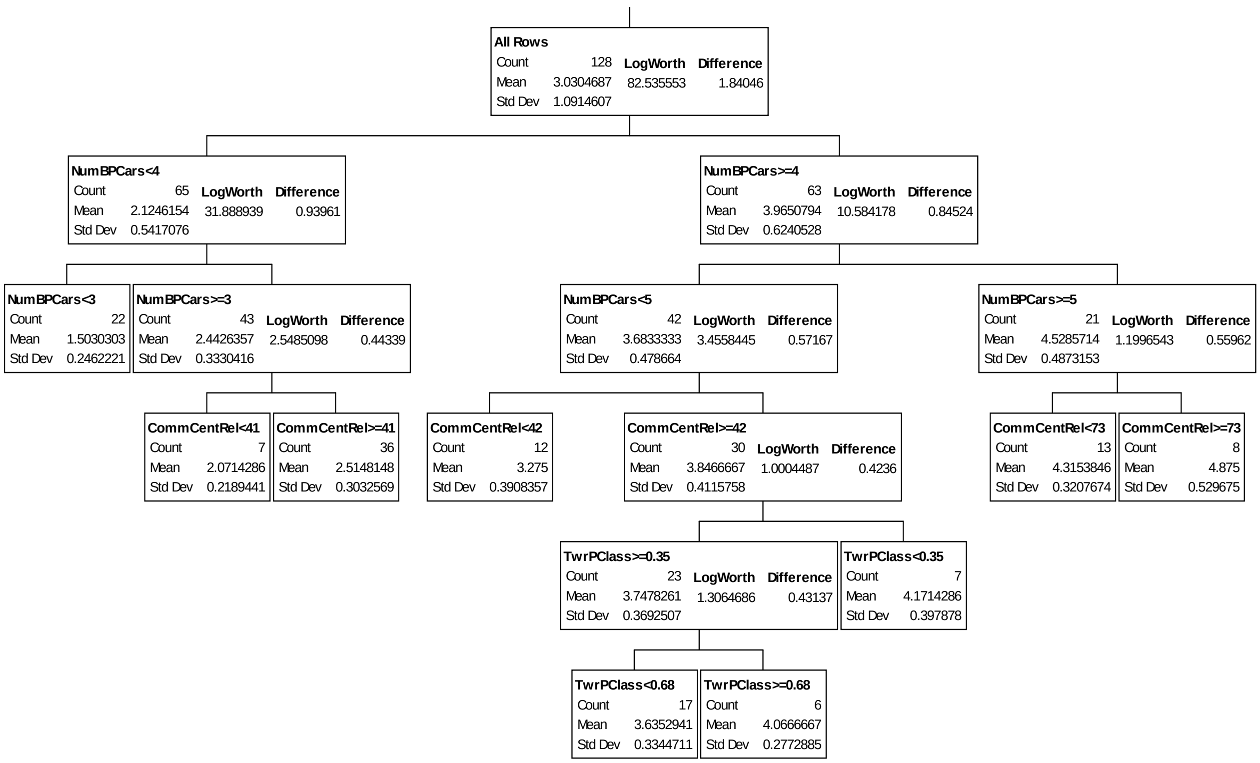
APPENDIX B: REGRESSION TREES

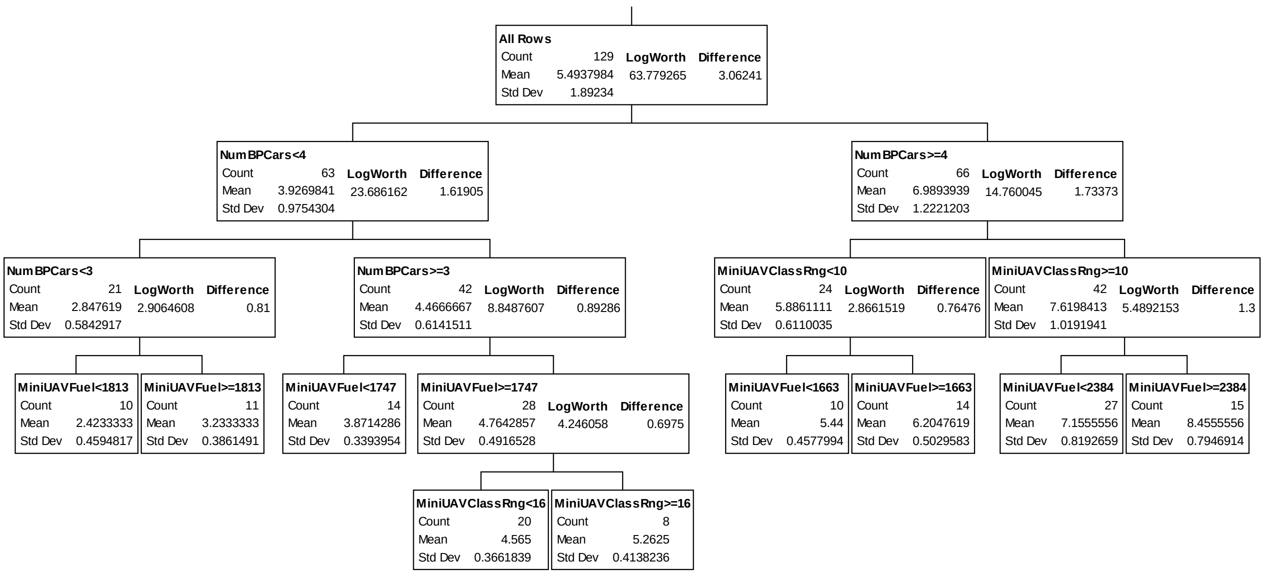
A. Regression Tree for the Mean Number of Captured Immigrants

RSquare	N	Number of Splits
0.916	128	8



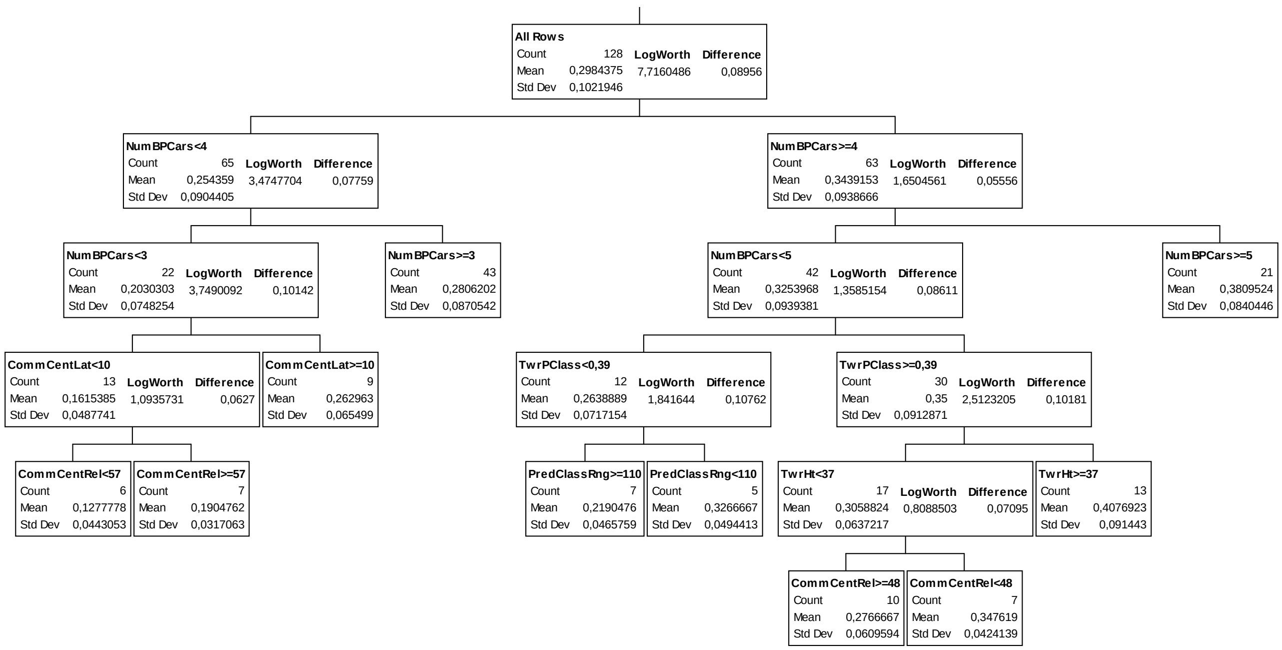
B. Regression Tree for the Mean Number of Captured Immigrants with MiniUAV

RSquare	N	Number of Splits
0.913	129	8



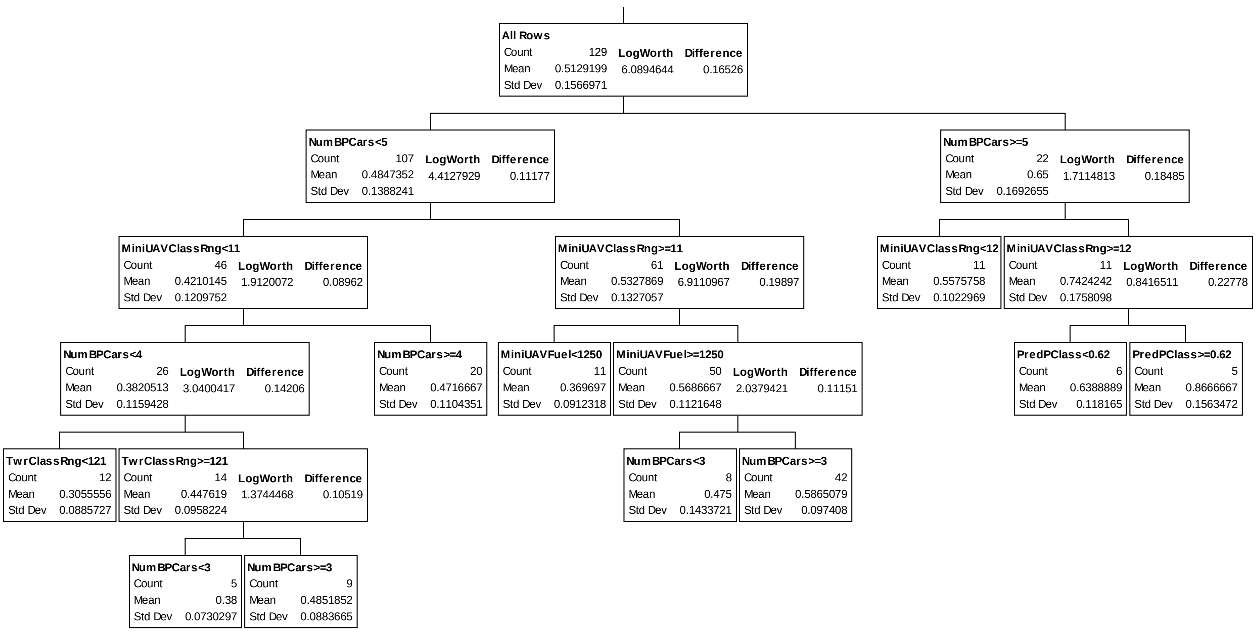
C. Regression Tree for the Mean Number of Captured Smugglers

RSquare	N	Number of Splits
0,489	128	9



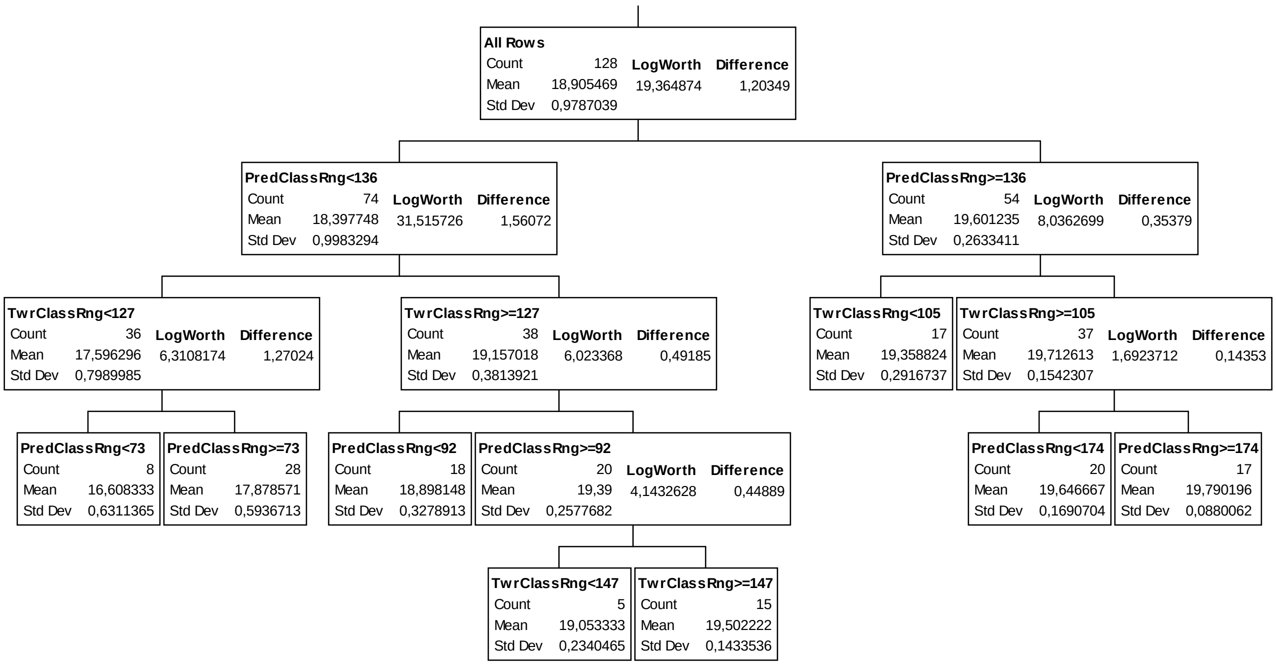
D. Regression Tree for the Mean Number of Captured Smugglers MiniUAV

RSquare	N	Number of Splits
0.589	129	9



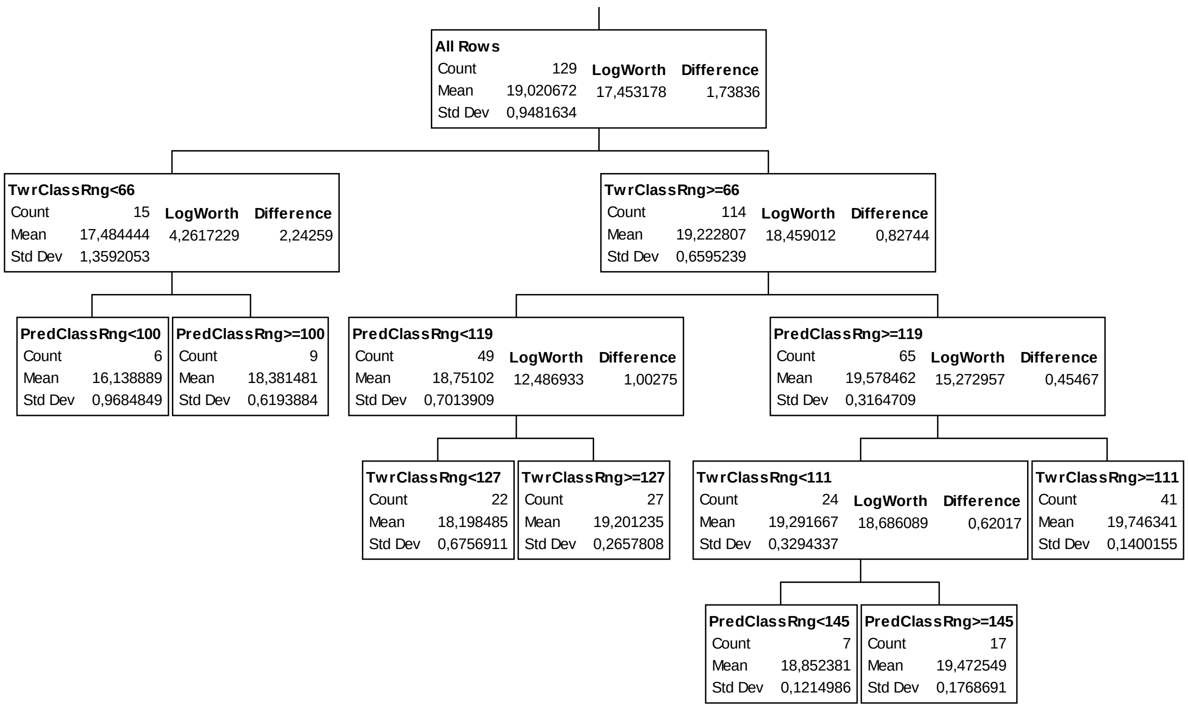
E. Regression Tree for the Mean Number of Immigrants Classified

RSquare	N	Number of Splits
0,863	128	7



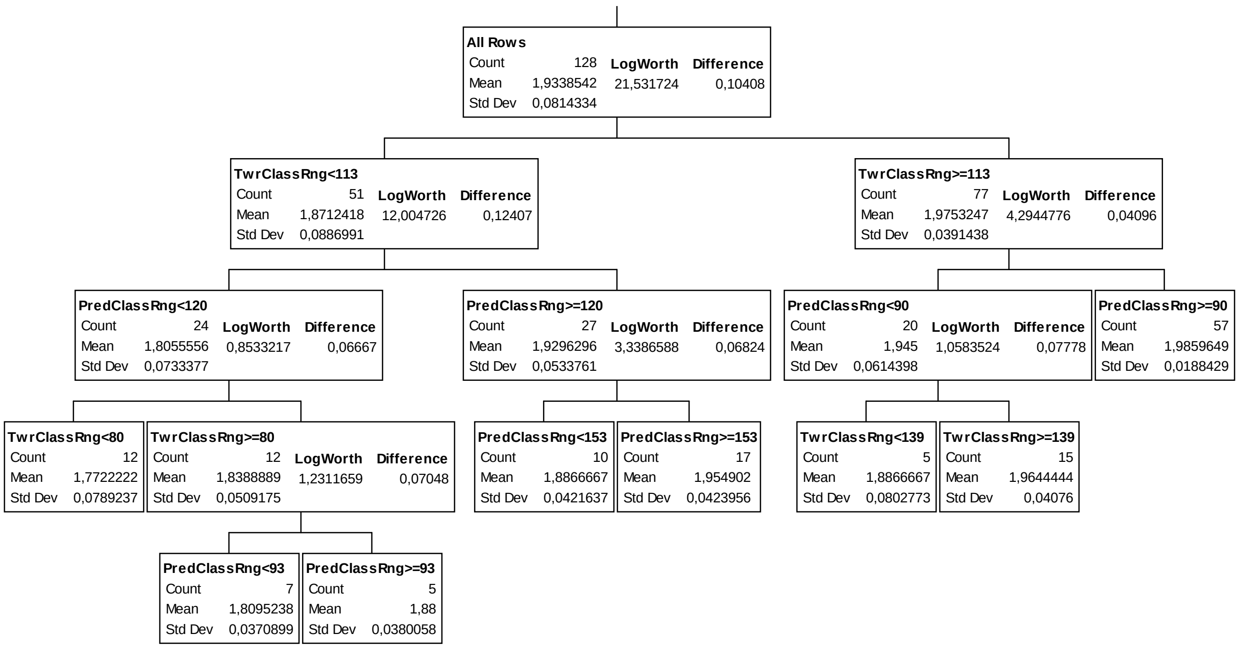
F. Regression Tree for the Mean Number of Immigrants Classified with MiniUAV

RSquare	N	Number of Splits
0,821	129	6



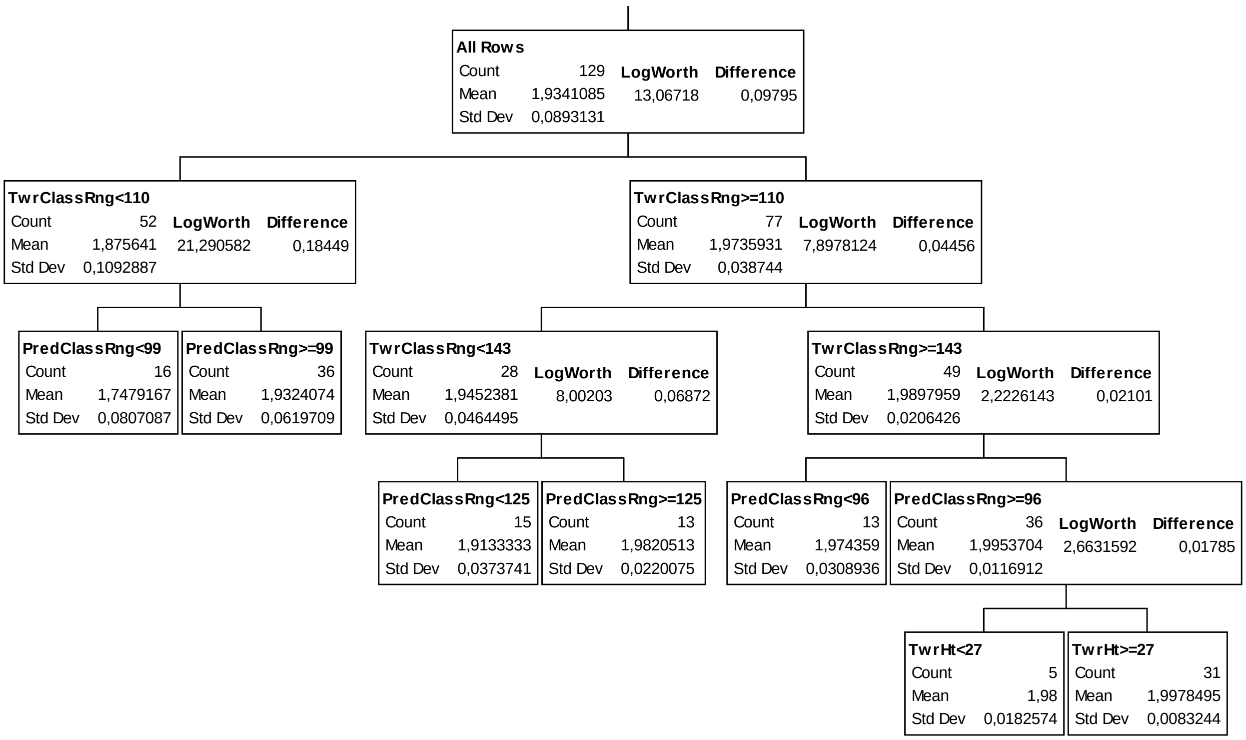
G. Regression Tree for the Mean Number of Smugglers Classified

RSquare	N	Number of Splits
0,767	128	7



H. Regression Tree for the Mean Number of Smugglers Classified with MiniUAV

RSquare	N	Number of Splits
0,733	129	6



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