Brigham Young University

AUVSI Capstone Team (Team 45)

Concept Development Artifacts

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AUVSI Capstone Team (Team 45)

UAS Subsystem Interface Definition

ID	Rev.	Date	Description	Author	Checked By
SS-001	0.1	10-25-2018	initial draft	Andrew Torgesen	Jake Johnson & John Akagi
SS-001	0.2	10-30-2018	adjusted wording	Andrew Torgesen	Kameron Eves
SS-001	0.2	10-30-2018	adjusted diagram	Andrew Torgesen	Brady Moon

Figure 1 gives a top-level description of the major hardware and software subsystems, as well as how they interact in the fully-functioning UAS. Table 1 lists descriptions of the functions of each software component listed in the figure.

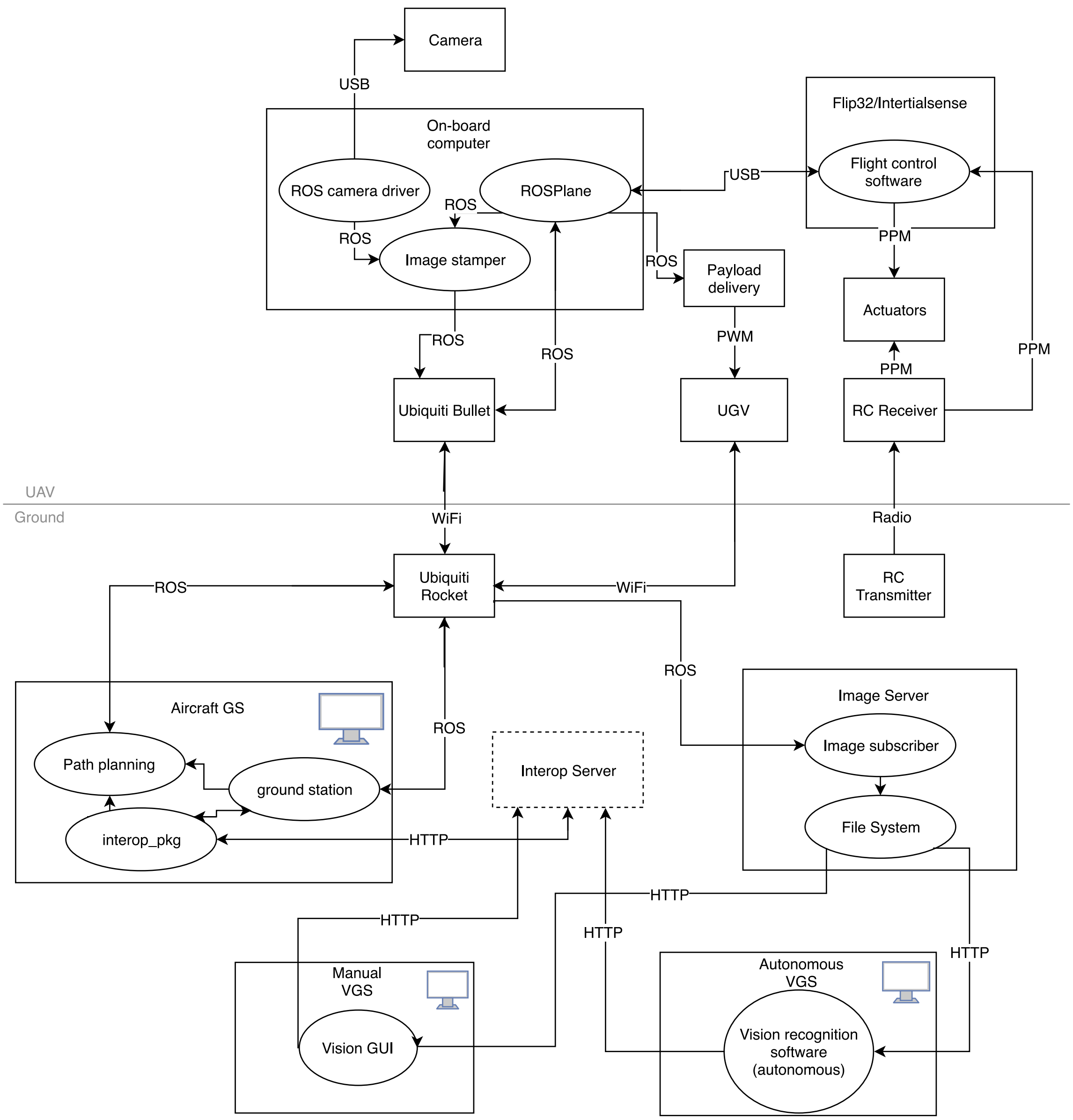

Figure 1: System-wide interface diagram for the UAS. Hardware is denoted by a box, and software is denoted by an oval.

Table 1: Descriptions of the functions of the software components listed in Figure 1.

Software Component	Description
ROS camera driver	Reads the serial input from the camera and streams it as ROS messages so that other ROS programs have access to the camera images in real time.
ROSPlane	Top-level autopilot. Takes a set of waypoints and converts them into low-level commands to be interpreted by the flight control software. Also constructs a state vector containing all of the dynamic states of the UAS.
Image stamper	Takes streamed camera images and stamps them with time and UAS state data. This facilitates subsequent geolocation of objects found in each image.
Flight control software	Converts low-level autopilot commands into actuation commands and reads in sensor data. Consists of: • ROSFlight: handles autopilot commands, reads in airspeed and barometer data • IntertialSense: reads in GPS and inertial sensor data
Path planning	Given the details of the competition (including obstacle and flight area data), plans a series of waypoints for the UAS.
ground station	Allows for the visualization of the UAS and provides an interface for sending waypoint, loiter, and return-to-home commands.
interop_pkg	Communicates with the judges' interop server, and serves up competition details over the ROS network. Also reports UAS data back to the judges' server.
Image subscriber	Captures streamed camera images from the ROS network.
File System	Stores images from Image subscriber on the computer's file system for direct HTTP access by ground station computers.
Vision GUI	Provides an interface for the manual classification of targets in images, as well as reporting the classification data to the judges' server.
Vision recognition software (autonomous)	Runs computer vision software that autonomously classifies targets in images, and reports the results to the judges' server.

As can be seen from Figure 1, both radio and WiFi will be used to facilitate connection between the subsystems on the ground and in the air. The Ubiquiti data link allows for communication between the ground and the aircraft over a WiFi network. A 2.4 Ghz radio link (independent)between the radio transmitter and receiver allows for manual control and arming/disarming of the aircraft.

The Robot Operating System (ROS) is what facilitates the majority of inter-component communication over the WiFi network. ROS is a Linux middle-ware and development protocol for creating modular programs for robotics. ROS allows for real-time communication between machines running individual nodes, or executables, over a WiFi network. In our system, all subsystems communicating via ROS either are or will be developed as ROS nodes to be run on a machine with Linux installed. For more information about ROS nodes and how they communicate over a network, see http://www.ros.org/.

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UAS Subsystem Testing

ID	Rev.	Date	Description	Author	Checked By
SS-002	0.1	10-29-2018	initial draft	Andrew Torgesen	Derek Knowles
SS-002	1.0	10-31-2018	pre-design review revisions	Andrew Torgesen	Tyler Miller

1 Motivation

As described in the UAS Subsystem Interface Definition document (SS-001), there are two main data links between the aircraft and the subsystems on the ground during a competition flight:

- The **900 Mhz Radio Link** between the RC transmitter and receiver constitutes the minimal level of communication necessary for flight. The RC link allows a safety pilot to arm/disarm the aircraft's throttle and toggle the autopilot. If RC is lost, then the autopilot should immediately activate a *failsafe* mode.
- The **Ubiquiti WiFi Link** between the Ubiquiti Rocket (on the ground) and Bullet (on the aircraft) allows for the exchanging of data over a ROS network. Effectively, the Rocket and the Bullet allow for network connectivity between all subsystems on the ground and in the air.

Almost all subsystem interfaces depend on these two data links. Outlined in this document are testing procedures and results to evaluate the quality and reliability of each of these vital data links for the UAS system as a whole.

2 Testing Descriptions and Procedures

Table 1 outlines key characteristics of the WiFi and RC data links that should be tested, as well as how they should be tested.

Table 1: Description of testing procedures for UAS WiFi and RC data links.

Test name	Characteristic being tested	Procedure
RC failsafe	If RC connection is lost, then the flight control software should execute a failsafe mode to avoid an uncontrolled crash.	While the aircraft's autopilot is active, kill the RC transmitter. Observe what the autopilot does. It should guide the aircraft into a loiter flight.

Network loss	If the network connection between the aircraft and the ground is lost, then the aircraft should still be able to complete the tasks allocated to it until connectivity is regained.	While the aircraft is flying a mission, point the Ubiquity Rocket away from the aircraft, killing the ground-to-air WiFi connection. There should be no visible deviation of the aircraft from its current mission, and RC the connection should still be active.
Network reliability	The network should be able to connect upon boot-up of all subsystem components. Connection should be robust to external conditions and allow for a satisfactory data transfer rate.	In an outdoor environment, turn on all subsystem components and ensure that they all connect to the network automatically. Max out the stream rate of the camera to the onboard computer. Activate all subsystems that communicate over the network, and measure data transfer rates–particularly the following: • Images should be able to stream over the network at a rate of ≥ 1 hz. • UAS state data should be viewable on the ground station machines at a rate of ≥ 4 hz. • JSON data packets should be able to be sent to the interop server at a rate of ≥ 4 hz.

ROS failure	If the ROS network fails, then the autopilot can no longer fly the aircraft. The safety pilot should be able to take back control of the aircraft over RC to guide it to safety.	While the autopilot is running, kill the ROS network on the aircraft's on-board computer with ssh. RC connectivity should still be active, and the safety pilot should theoretically be able to control the aircraft well enough to either recover the vehicle or prevent causing harm to surroundings as it crashes.

3 Testing Results and Conclusions

Table 2 gives the results of testing according to the procedures outlined in Table 1, as well as conclusions drawn from those results.

Table 2: Test results for the evaluation of the UAS WiFi and RC data links.

Test name	Test results	Conclusions
RC failsafe	After RC is lost for $\approx 30s$, the autopilot triggers a "return to land" protocol, landing near where it took off from.	The RC failsafe mechanism built into the autopilot has been found to be in line with the AUVSI competition rules.
Network loss	Loss of connection between the Ubiquiti Rocket and Bullet has no discernible impact on the autopilot–the only consequence is that the groundstation computers are unable to view the states of the aircraft over the ROS network. Communication resumes once the aircraft is back in range of the Rocket.	• It will be beneficial to have an on-board state recorder to record all ROS messages for later viewing, even if connection to the aircraft is lost temporarily. • We need to run tests to measure the range of the Rocket/Bullet connection when the Rocket is pointed directly toward the aircraft during flight.

Network reliability	Over the course of numerous flight tests, the network connection starts up reliably in all cases but one. There is a particular spot in a field in Springville where the network will never connect. Moving one block over, the network always connects. • *Image stream rate:* 3-4 hz • *State stream rate:* 40-45 hz • *JSON stream rate:* 3-4 hz	• The network streaming rate has been found to be adequate. It is possible that we will want to purchase a more powerful router to allow for faster streaming rates at longer distances. • We have only run the network speed test with the aircraft on the ground; it would be nice to run another speed test in conjunction with a test of the maximum range of the Ubiquiti network connection. • The instance of never being able to connect in a particular geographical location is troubling. This quirk merits further investigation.
ROS failure	The RC connection to the aircraft has been found to be reliable and capable of manual takeover in any situation, as long as the batteries of the transmitter are not depleted. It has been found that certain settings should be toggled on the transmitter to conserve power, otherwise it experiences a battery life of about half an hour, which is inadequate.	• The range of the RC connection has been found to be adequate within a radius of $\approx 300ft$. • We should run an additional test to determine the approximate maximum range of the RC connection.

Based on the results documented in Table 2, we have determined that **our chosen princi-**

pal inter-component data links are adequate for the competition environment. Further tests are required to determine the boundary conditions (such as maximum possible distance) of their functional use.

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Airframe Subsystem Requirements Matrix

ID	Rev.	Date	Description	Author	Checked By
RM-002	0.1	10-23-18	Initial Draft	Tyler Critchfield & Ryan Anderson	[CHECKED BY]

Product: UAS
Subsystem: Airframe

		Units	Minutes	Minutes	Unitless	Unitless	meters/second	meters/second	Unitless	Meters	kilograms	Unitless	Unitless	Unitless	Unitless	Meters	Unitless	1-10 Scale	#	#	#	minutes	1-10 Scale	#	m^3
		Performance Measures	Flight Time	Battery Life	Lift-to-Drag Ratio	Lift Coefficient	Stall Speed	Average Flight Speed	Total Motor/Prop Efficiency	Turning Radius	Airframe Weight	Spiral Stability Eigenvalue	Static Margin	Cn,beta (Yaw)	Cl,beta (Roll)	Maximum Flight-Path Deviation	% of Payload Protruding from Airframe	Focus Group Coolness Rating	Number of components lost	Number of Damaged Components on crash landing	Number of Damaged Components on landing	Time to assemble from scratch	Focus Group Ease of repair	Number of AMA Safety Code Violations	Storage Volume
	Market Requirements	**Importance**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	19	19	20	21
1	Capable of flight for extended period of time	9	●	●	●				●		●														
2	Capable of traveling an extended distance	9	●	●	●			●	●		●														
3	Minimize flight path deviation	9					●			●		●	●	●	●	●									
4	Components are protected	9															●		●	●	●				
5	Capable of surviving a crash	9															●			●					
6	Complies with AMA safety code	9																						●	
7	Capable of carrying UGV and water bottle	3			●	●	●	●	●		●						●								●
8	Fast and cheap assembly/rebuild	3																		●	●	●	●		
9	Looks decent	1																●							
		Lower Acceptable	10	check	5	0.4	N/A	10	0.2	0	0	-0.1	0.1	0.05	-0.15	N/A	0	5	0	0	0	0	5	0	0.3
		Ideal	30	75	20	0.5	10	15	1	5	4	-0.05	0.1	0.1	-0.1	1	0	10	0	0	0	0	10	0	0.5
		Upper Acceptable	60	70	N/A	1	20	30	1	15	50	-0.01	0.2	0.15	0	5	100	10	0	1	0	60	10	0	1

Figure 1: Airframe subsystem requirements matrix.

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AUVSI Capstone Team (Team 45)

Unmanned Ground Vehicle Initial Concept Development

ID	Rev.	Date	Description	Author	Checked By
GV-002	0.1	2018-10-23	Initial Draft	John Akagi	Jacob Willis
GV-002	1.0	2018-10-31	Added introduction	Jacob Willis	Andrew Torgesen

1 Introduction

This document describes the initial concept generation of the Unmanned Ground Vehicle system.

2 System Objective

In the 2019 AUVSI SUAS competion, points are awarded for successfully delivering an "unmanned ground vehicle" (UGV) to a target location; additional points are awarded if the vehicle drives to another target location. The UGV must be capable of carrying an 8oz water bottle, and the impact must subjectively be "soft." During the delivery the airframe cannot drop below 100ft ASL, so a system or mechanism for landing the UGV without damage is required. Because points can be recieved for just delivering the UGV without it driving, and because the payload drop problem is the most challenging part of the UGV design, determining how to accomplish the payload drop is the subject of this concept development. The UGV is assumed to be a "black box" capable of driving to its target once it is on the ground.

3 Initial Concepts

Table 1: Description of initial ideas and decisions made. "Discarded" indicates the idea was considered unfeasible, "Investigate" indicates the idea was studied further, "Modify" indicates the idea was considered usable in conjunction with another idea or ideas.

Idea	**Description**	**Decision**	**Rationale**
Skycrane	UGV is lowered on a rope from the UAV	Investigate	Would eliminate the need for most cushioning and control surfaces on the UGV
Fins	Fins are used to give minimal control to a fast falling UGV	Investigate	Would be smaller than full glider wings but still allow decent control
Glider	Unpowered aircraft is used to control the falling UGV	Investigate	Would likely provide the greatest amount to control
Parasail	A controllable parachute is used to steer the UGV	Discarded	Difficult and unknown controls

Control Grids	Similar to SpaceX, grids are used to steer the descent of the UGV	Discarded	Too complex for this application
Magnus Effect	Spin the wheels of the UGV in the air to generate lift and control UGV attitude	Modify	Could be used in conjunction with other methods but unlikely to have much effect by itself
Autogyro	Unpowered helicopter rotors are used to slow descent and blades can be tilted to control the drop	Discarded	Mechanism was considered too complex
Bounce	UGV uses some elastic material under it to decrease the time of impact	Discarded	Bouncing would likely not reduce the impact forces to survivable levels
Airbag	An airbag is inflated just before lading to cushion the drop	Discarded	Needs precise measurements to determine when to inflate airbag, Airbag inflation mechanism is likely to require dangerous materials
Springs	Springs are placed under the UGV to absorb the energy from the drop	Modify	Could be used to reduce impact energy but unlikely to be able to dissipate all by itself
Counterweight	A large mass is ejected downwards just before impact in order to slow UGV descent	Discarded	Requires ejecting a large mass at high acceleration which is likely to be dangerous and impractical
Crumple Zone	Use a deformable material to break and absorb energy when UGV impacts ground	Modify	Could be used to reduce impact energy but unlikely to be able to dissipate all by itself
Balloons	Use balloons to increase drag and provide some lift	Discarded	Would be large and impractical to carry on board the UAV
Parachute	Use a parachute to slow the descent of the UGV	Investigate	Simplest idea and almost guaranteed to work
Seedpod	Attach a single propeller blade to the UGV which would cause the UGV to spin and slow its descent similar to how maple seeds work	Discarded	The UGV is likely too heavy to implement this properly

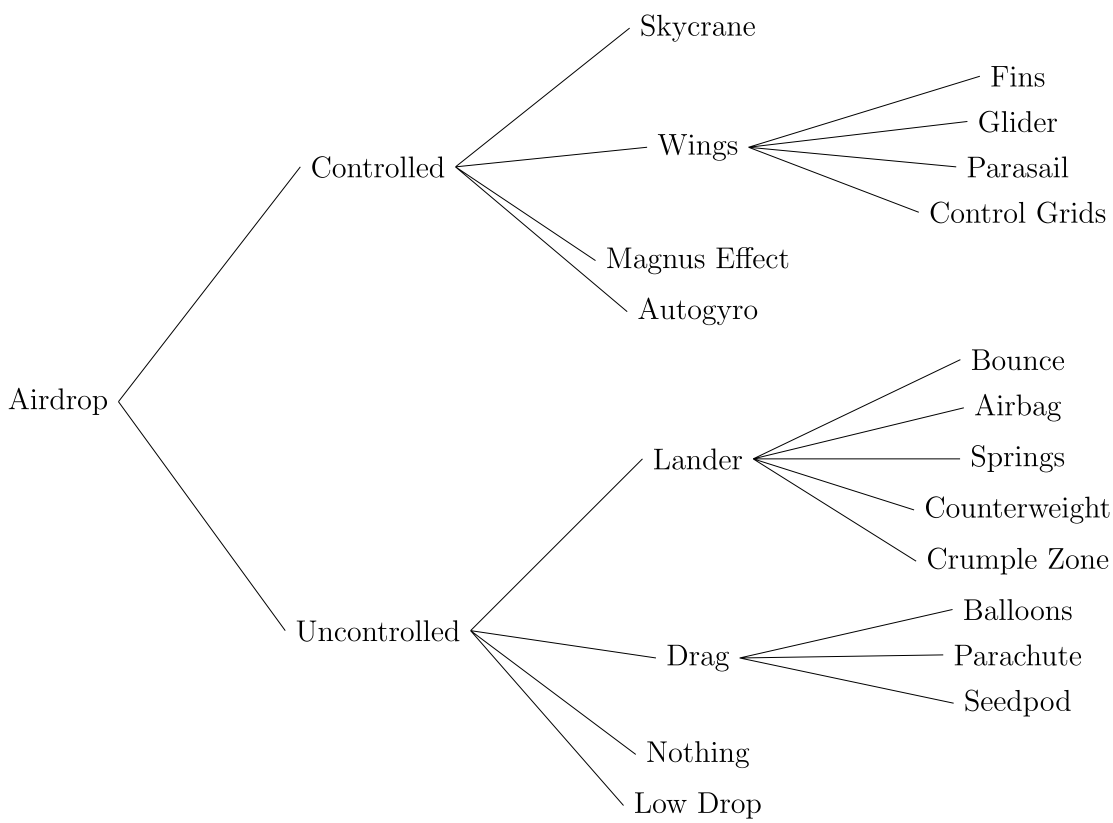

Figure 1: Concept development tree of the initial ideas generated for the payload delivery system.

Nothing	Make the UGV as rugged as possible and drop it from the UAV with no slowing mechanism	Discarded	Any UGV that is rugged enough to survive a 100 ft drop would be too heavy and bulky to carry on the UAV
Low Drop	Drop below the minimum allowable flight level and drop the UGV from a lower altitude for increased survivability	Discarded	Would violate rules that state we must remain above a certain altitude

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UGV Requirements Matrix

ID	Rev.	Date	Description	Author	Checked By
RM-001	0.1	10-23-2018	Initial requirements	Jacob Willis	Brady Moon
RM-001	1.1	10-26-2018	Better performance measures	Jacob Willis	Kameron Eves

Product: UAV
Subsystem: PAYLOAD/Unmanned Ground Vehicle (UGV)

Notes:
*normalized by the fusalage diameter cubed
**normalized by chord

			1	2	3	4	5	6	7	8
		Subsystem Performance Measures	Drop mechanism mass	Weight mechanism can support	Aircraft internal volume consumed*	Mounting distance from aircraft CG**	Stowed drop mechanism drag	Maximum landing velocity	UGV landing distance from target	Rule violations
		Units	kg	N	%	%	N	m/s	m	cnt
	Target Design Requirements	**Importance**	1	2	3	4	5	6	7	8
1	Complies with competition rules	5	●							●
2	Capable of lowering the payload to the ground	5	●	●						
3	Lands UGV within landing zone	3						●	●	
5	Delivers UGV without damage	3		●				●		●
6	Deployable from airframe	4			●	●	●			
7	Does not interfere with takeoff/landing	3	●			●	●			
8	Causes minimal aerodynamic interference	3				●	●			
9	Drop mechanism does not interfere with UGV movement	2						●	●	
		Lower Acceptable	0	0.6	-	-100	0	0	-	-
		Ideal	0.1	1.3	0	0	0.3	1	0	0
		Upper Acceptable	0.6	-	100	100	1.5	5	22	1

Figure 1: Requirements matrix for the subsystem which will deliver the UGV to the ground.

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ID	Rev.	Date	Description	Author	Checked By
GV-003	[REVISION NUMBER]	[DATE]	[DESCRIPTION]	[AUTHOR]	[CHECKED BY]

1 Descriptions

Each of the primary concepts is described in further detail below.

1.1 Parachute

A parachute is attached to the UGV, and is opened upon release of the UGV from the aircraft. To improve the accuracy of this concept, the effect of wind on the parachute and payload is characterized and used to calculate the optimal drop location given the estimated wind speed at the time of drop. No control mechanisms are used during the drop.

1.2 Parachute w Controls

Similar to the Parachute concept, but control surfaces (fins) are attached to the payload and actuated as the payload drops. This provides some controlability to stabilize the drop and to improve accuracy.

1.3 Skycrane

The UGV is lowered on a string or rope while the airframe circles overhead. The circling motion causes the UGV to orbit in a smaller circle as it is lowered. When the UGV hits the ground, it releases itself from the string to prevent interrupting the flight of the airframe. Preferably the UGV controls the rate of descent so it can easily feed back its distance from the ground.

1.4 Glider

A glider is carried onboard the airframe and is released when the UGV drop is attempted. The glider either incorporates or carries a ground vehicle. The glider is unpowered, but is controled like a normal aircraft.

2 Evaluation Methods and Results

As can be seen from the decision matrix in Table 1,

Table 1: A decision matrix the UGV Drop Method. A scale of 1-5 was used for weights with 5 having high importance and 1 having low importance. A 1-5 scale was also used to rate each option's performance under each requirement. In this case, a 1 was used to indicate poor performance while a 5 indicates favorable performance.

UGV Drop Method	Weight	Glider	Sky Crane	Parachute	Un-aided Drop (Reference)
UGV Weight	1	0	0	0	0
Stowed Drag	1	0	0	0	0
Max Drop Height	1	0	0	0	0
Max Landing Velocity	1	0	0	0	0
Accuracy in Hitting Target	1	0	0	0	0
Totals	.	0	0	0	0

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UGV Drop Mechanism Concept Test Procedures and Results

ID	Rev.	Date	Description	Author	Checked By
GV-004	0.1	10-26-2018	Initial creation proceedures listed	Jacob Willis	CHECKED BY

1 Introduction

This document describes the proceedures used to test each of the UGV concepts. Some of the tests were unecessary for selecting between concepts, so they will not be performed until subsystem engineering.

2 Test Proceedures and Results

2.1 Drop mechanisim mass

Proceedure

Weigh all mechanisms related to landing the UGV using a scale, and sum with weights given on datasheets.

Results

Concept	Result
Parachute	.026 kg
Parachute w/ control	.124 kg
Skycrane	.160 kg
Glider	.08 kg

2.2 Weight mechanism can support

Proceedure

Calculated based on maximum load ratings of mechanism components.

Result

Concept	Result
Parachute	
Parachute w/ control	
Skycrane	
Glider	

2.3 Aircraft internal volume consumed

Proceedure

The volume of all of the UGV drop mechanisms, and the volume needed for the UGV if the mechanism requires it be inside the aircraft is measured. This measurement is normalized by the internal diameter of the aircraft fuselage.

Result

Concept	Result
Parachute	
Parachute w/ control	
Skycrane	
Glider	

2.4 Mounting distance from aircraft CG

Proceedure

The distance between the center of gravity of the UGV and drop mechanism is measured and normalized by the chord length of the aircraft.

Result

Concept	Result
Parachute	
Parachute w/ control	
Skycrane	
Glider	

2.5 Stowed drop mechanism drag

Proceedure

A preliminary estimate of this is made using the area of the mechanism that is exposed outside of the airframe. An accurate measurement of the mechanism drag is done by using a wind tunnel to measure the difference in drag between the airframe without the mechanism and the airframe with the mechanism.

Result

Concept	Result
Parachute	
Parachute w/ control	
Skycrane	
Glider	

2.6 Maximum landing velocity

Proceedure

A preliminary estimate of this is made using calculations to determine the speed

Result

Concept	Result
Parachute	
Parachute w/ control	
Skycrane	
Glider	

2.7 UGV Landing distance from target

Proceedure

A preliminary estimate of this is made by dropping a representative load with the mechanism from a height of 40 feet. The distance between where the load lands and the target is scaled to a 100 foot drop height.

Result

Concept	Result
Parachute	
Parachute w/ control	
Skycrane	
Glider	

2.8 Rule violations

Proceedure

A checklist of the relevant rules is checked for the concept. The number of violations for the concept is summed.

2.8.1 UGV Rules Requirements

The following outline the rules which must be followed in order to achieve any points.

- Must carry 8 oz water bottle

- Must not fly below minimum altitude
- Must land gently and without damage (subjective measure)
- Max weight of 48 oz
- Max speed of 10 mph
- UGV must terminate driving after 30 seconds of communication loss or after driving out of the boundary specified
- Drive termination must be activated by member of team
- No exotic fuels or batteries
- Batteries must be brightly colored (bright tape)
- The UGV may only drive autonomously

Result

Concept	**Result**
Parachute	
Parachute w/ control	
Skycrane	
Glider	

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UGV Delivery System Selected Concept Description

ID	Rev.	Date	Description	Author	Checked By
GV-04	1.0	10-30-2018	Wrote concept description	Jacob Willis	Andrew Torgesen

Introduction

This document gives a more detailed description of the selected concept for the UGV delivery system. As can be seen from our selection matrix (GV-003) and test results (GV-004), the selected concept is a parachute with fins.

Description

The UGV will be loaded within the aircraft. Upon a command from the flight controller system small hatch will open and the UGV will fall out. Strings will attach the UGV to a lightweight fabric parachute. The fabric parachute will be loaded onto the aircraft in a tube that will allow the UGV to pull it out of the aircraft as it falls. This will help stop tangling that can come from a folded parachute. After exiting the aircraft the parachute will be opened by drag. The drag caused by the fabric will slow down the aircraft to a speed sufficient to allow the UGV to survive impact with the ground without damage. A visual depiction of our chosen system can be seen in Fig. 1.

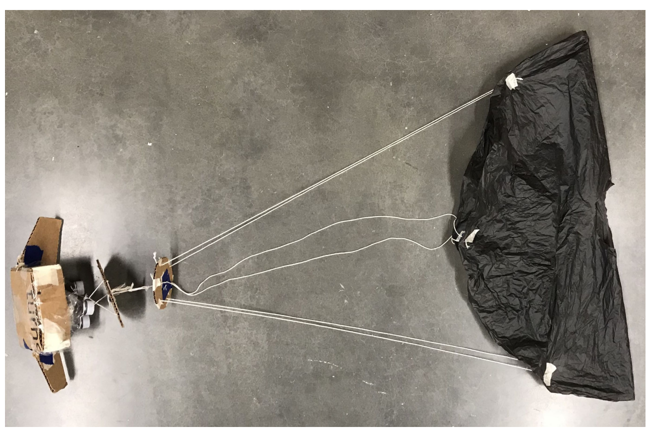

Figure 1: A simple prototype of our parachute seen from the side.

An accurate landing is another important part of the competition. A hole in the top of the parachute will improve the accuracy of the system. As can be seen in Fig. 2 we tested this hole in our prototype. This hole is known in the industry as a spill hole because it allows the air to spill out of the center of the parachute. This does increase the speed with which the system falls, but it also provides a market increase in the accuracy. This is because without the hole, the air become trapped within the system and excess air must move around the outside of the parachute as it falls through the air. Imperfections in manufacturing and weather conditions mean that this this overflow around the outside of the parachute is always uneven. Thus the parachute is pushed to the side by the uneven overflow. A spill hole allows the overflow to "spill" out the top in a way that won't affect the lateral velocity of the system.

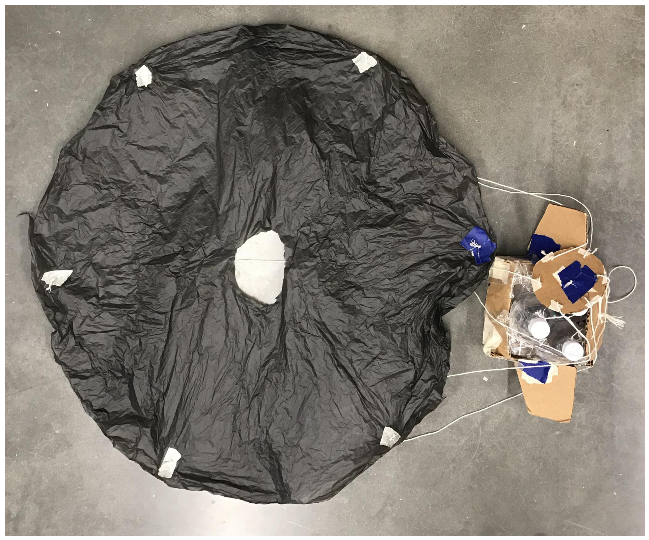

Figure 2: A simple prototype of our parachute seen from the top. Note the hole in the middle of the parachute. As mentioned above, we found that this greatly improved the accuracy of the parachute.

Fins are another way the accuracy of the system can be effected. These fins can be seen in one prototype in Fig. 3. As can be seen in our testing results artifact (GV-004) the fins did push the system one direction. This should allow us to slightly control our system as it falls. While this will not be enough to correct for large errors, it should be enough to ensure we don't drift randomly. The protocol for dropping objects from a UGV, as detailed in *Small Unmanned Aircraft: Theory and Practice* by Randy Beard and Tim McLain should also help improve our accuracy. This protocol uses the wind and velocity of the aircraft to predict the best location to release the payload.

Using the system described above, we are confidant in our ability to achieve a landing accuracy of within 25 feet. This is considered excellent performance in our key success measures and will give us 75% of the points possible in this portion of the competition.

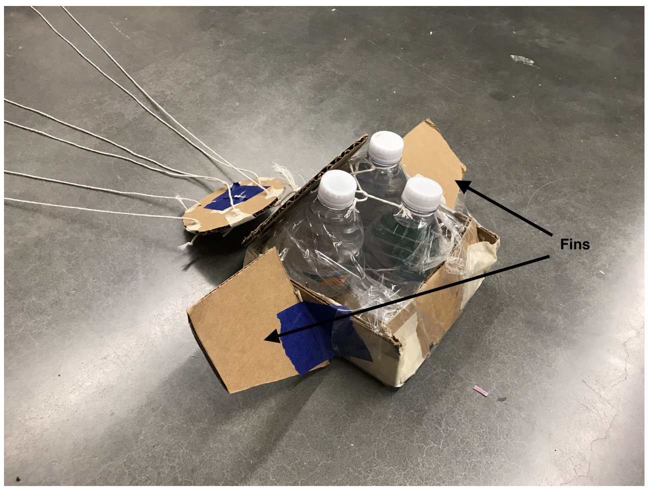

Figure 3: The payload we used to simulate the UGV. Note the fins. As mentioned above, preliminary results seem to indicate that these fins provided a small amount of control authority over the parachute's trajectory. This will help us improve accuracy

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Concept Selection

ID	Rev.	Date	Description	Author	Checked By
CS-002	0.1	10-24-2018	Initial release	Tyler Miller	Derek Knowles

1 Camera Concept Selection

Requirement	Weight	Basler Ace	Basler Ace Increased Focal	PtGrey Chameleon 3	Sony a6000
Resolution	3	2	2	1	5
Weight	1	3	3	5	2
Ease of System Integration	3	5	5	5	3
Clarity @ 150ft	5	1	4	4	5
Stability @ 150ft	5	1	1	2	5
Cost	2	5	1	4	3
Capture Rate	2	3	3	5	2
TOTAL		**50**	**57**	**71**	**86**

2 Measured Camera Values

	Basler Ace	**Basler Ace Increased Focal**	**PtGrey Chameleon 3**	**Sony a6000**
Description	Baseline. The camera from last year with a 12.5mm focal length lens	Last years Basler with a 35mm focal length lens. This decreases field of view, but increases pixels/inch.	Camera from two years ago. Powerful lens, but low Resolution	Camera most commonly used by other AUVSI teams. Low cost, and high resolution
Resolution	5MP	5MP	1.3MP	24MP
Weight	217g	250g	55g	410g
Ease of System Integration	Integrated	Integrated	Previously Integrated	Feasible
Clarity	Blurry, readable	Likely blurry, readable	Readable	Readable
Stability	Target unreadable	Target likely unreadable	Target unreadable	Target readable
Cost	$0	$600	$310	$550
Capture Rate	5Hz	5Hz	30Hz	1Hz

Brigham Young University
AUVSI Capstone Team (Team 45)

Camera Test Procedures

ID	Rev.	Date	Description	Author	Checked By
TP-002	0.1	10-26-2018	Initial release	Connor Olsen	Tyler Miller

1 Purpose

Due to the flaws discovered with the camera used for the 2018 BYU AUVSI aircraft, It has been determined that a set of tests be outlined to test the effectiveness and reliability of cameras to meet the needs of the imaging team. These tests are designed to prove a camera's ability to show clear images at a long range to facilitate the machine learning algorithm which will identify and categorize targets.

2 Test Objectives

The camera will be tested for the following features:
Focal Length: The camera must be able to focus on targets at a range of at least 150 feet.
Depth of Field: Targets must remain in focus with a tolerance of 50 ft.
Image Clarity: The image must be clear, and its details visible.
Image Stability: The image must remain reasonably clear when camera is unsteady.

3 Required Hardware and Software

- Camera to be tested
- Computer to control camera
- Measuring wheel to measure distance
- Test target with letter

4 Test Procedure

Mount the camera in a location that is sturdy (tripod or on a secure flat surface. Measure 150 feet with the measuring wheel and have someone hold the target with letter at that distance. Have someone capture an image and inspect the quality and detail of the captured target.

Disturb the camera to simulate the instability of flight and capture another image. Inspect the pixels of the image for sharpness and clarity

5 Special Instructions

To eliminate excessive variables, all camera tests (outside of the plane) are performed in the long alleyway between the EB and the CB, using the cement half-wall as a mount for the camera.

6 Test Results

Concept testing results are shown in artifact CS-002.

BRIGHAM YOUNG UNIVERSITY

AUVSI CAPSTONE TEAM (TEAM 45)

Vision Subsystem Concept Definition

ID	Rev.	Date	Description	Author	Checked By
CD-002	0.1	10-25-2018	Initial release	Tyler Miller	Derek Knowles

1 Purpose

Last year's vision subsystem achieved less than 25% of possible points related to the subsystem. As such, it was determined that major improvements will be made at both the manual and autonomous levels.

The competition gives points for correct classification of ground targets' shape, shape color, alphanumeric, alphanumeric color, alphanumeric orientation, and geolocation. Additional points are given if the process between taking the image and submitting the classified image to the judges' server is fully autonomous without the intervention of a human. There is a penalty, however, if false positive targets are submitted to the judges' server.

2 Concept Selected

Vision's competition requirements are complex and as such required multiple concepts to fit into a larger system. After internal discussion, we decided to pursue a base concept of manual and autonomous classification systems running in parallel.

3 Definition

This year's vision team is changing our system architecture for classifying targets which will allow for better communication and organization. Instead of downloading each image and image state onto someone's personal computer, the computer oboard the plane will send image and vehicle state data to a server on the ground. This server will have a compiled database of all images captured and will attach classification data onto each image as it is manually processed. Our autonomous detection script will also be querying the server image database and classifying images. One team member will be monitoring the autonomous output ready to kill the program if it is sending too many false positives (which cause the team to incur a penalty). Our system architecture is outlined in Figure 1.

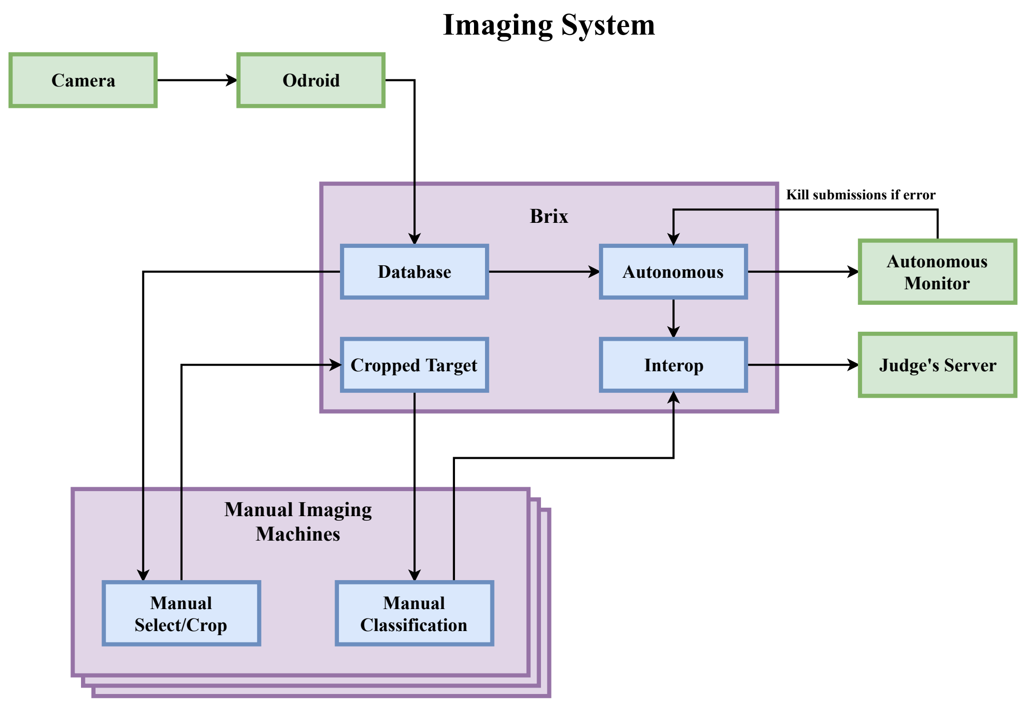

Figure 1: Target classification system architecture

Our autonomous classification system design is outlined in Figure 2. These concepts for autonomous target recognition are based on methods that other competition teams were able to successfully use at the comptition to identify targets. We will continue to iterate on the autonomous process, but we are confident that we can create a reliable and robust system for autonomous target classification.

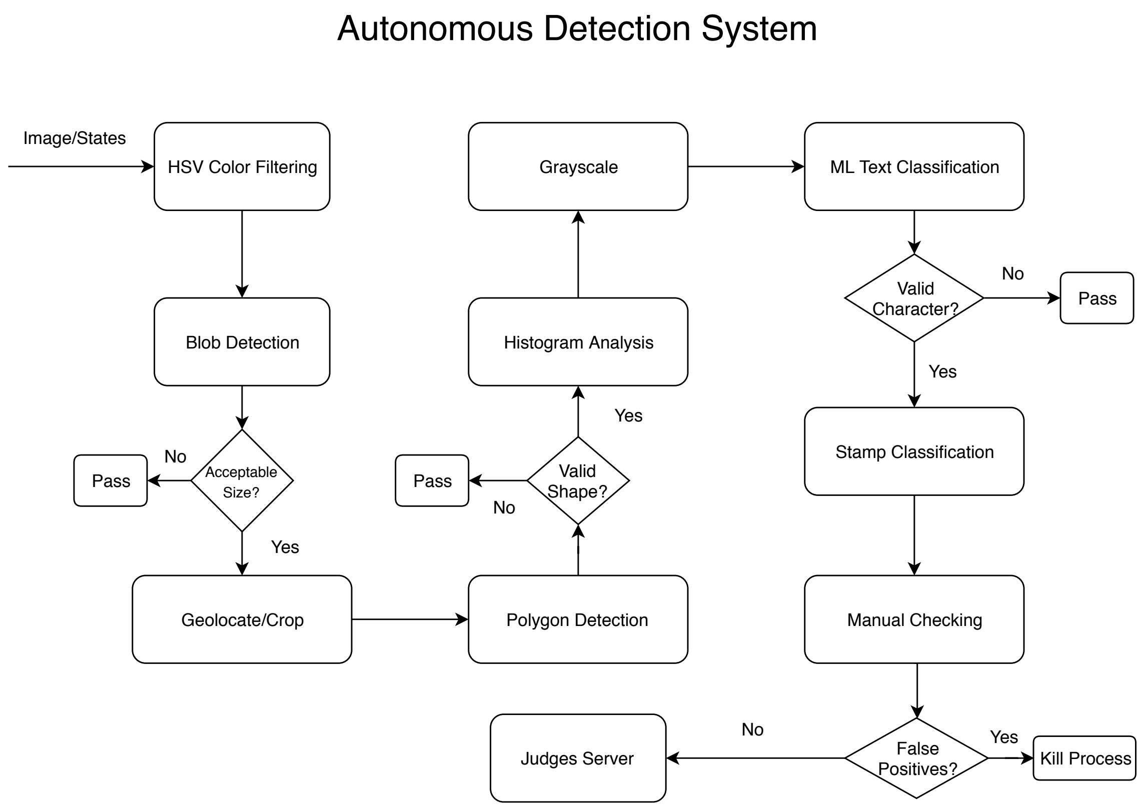

Figure 2: Autonomous classification system design

4 Justification

Since all of our high-level concepts depend on our imaging hardware, we decided it would be beneficial for us to choose a camera as soon as possible. Our list of potential cameras came from previous years systems as well as cameras used by last years top-placing teams. Critical performance measures are shown in our measured camera values table (CS-002). This table was directly translated into a selection matrix(CS-002). Based off the camera concept selection matrix, it was decided that the Sony a6000 would give us the greatest cost to performance. Its large 24MP sensor will improve image quality when flying at higher altitudes and make autonomous classification easier. Its auto-stabilization and fast exposure time also remove a lot of burden from the user to adjust settings mid-flight. Additionally 7 of the top 15 teams used the a6000 or the earlier generation (but basically equivalent) a5100.

The autonomous classification system is the largest undertaking of this year's vision subteam. Each of the 6 characteristics we are required to identify could potentially be done using a different method. Given the high-enumeration of concepts this generates, we determined it would be most beneficial for us to select one high level concept which would help define the rest of the system.

Concepts for autonomous classification were formed in three ways. The first was discussing our system requirements with market experts. They offered excellent advice on how to best go about the classification problem. The second was researching how top-placing teams from previous years tackled the problem. Teams are required to submit a design report which is made publicly available, allowing us understand from a high level how their image classification systems worked. Third, we did extensive online research on available software libraries and tools that could be used. As we pursued these three methods, our best concept for autonomous classification evolved into its current form. We feel that this final concept is the best combination of these three sources.