Brigham Young University

AUVSI Capstone Team (Team 45)

Opportunity Development Artifacts

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AUVSI Capstone Team (Team 45)

Capstone Project Contract

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Revision History

ID	Rev.	Date	Description	Author	Checked By
PC-444	1.0	10-02-2018	Opportunity development initial stage	Andrew Torgesen	Kameron Eves & Ryan Anderson & Jacob Willis & Tyler Critchfield & John Akagi
PC-444	1.1	10-17-2018	Added Key Success Measure explanations	Andrew Torgesen	Jacob Willis

Introduction

Each year, the Association for Unmanned Vehicle Systems International (AUVSI) hosts a Student Unmanned Aerial Systems (SUAS) competition. While each year's competition has unique challenges, the general challenge is to build an Unmanned Aerial System (UAS) capable of autonomous flight, object detection, and payload delivery. This year's competition will be held June 12th to 15th, 2019 at the Naval Air Station in Patuxent River, Maryland.

The UASs entered into the competition are judged primarily on their mission success during the competition. Each team is also required to submit both a report and a flight readiness review presentation. The report should justify the UAS decision, explain design trade-offs, demonstrate the team's engineering process, and highlight the capabilities of the UAS. The flight readiness review presentation demonstrates that the UAS is capable of safely completing the competition. The overall score for a team is based on a combination of the points from the mission, report, and presentation.

For the last two years BYU has sponsored an AUVSI team to compete in the competition. The 2017 team was primarily volunteer based and placed 10th overall while the 2018 team was a Capstone team and placed 9th overall. This year's team is also a Capstone team consisting of BYU Mechanical, Electrical, and Computer Engineering students and looks to place as one of the top five teams.

Project Objective Statement

Improve upon last year's BYU AUVSI unmanned aerial system (UAS) by improving path planning, obstacle avoidance, visual object detection, and payload delivery by April 1, 2019 with a budget of $3,500 and 2,500 man hours.

Contact Information

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Project Approval Matrix

The Project Approval Matrix, as depicted in Table 1, lists the major stages of development for the project, as well as their due dates and constituent artifacts. A budget is also included for each stage.

Table 1: Project Approval Matrix for the UAS

Development Stage	**Expected Completion Date**	**Design Artifacts Required for Approval**	**Budget**
Opportunity Development	October 5, 2018	Project Contract System Requirement Matrix Last Year Results Scoring Breakdown	$100
Concept Development	November 2, 2018	Description of Vision Concept Description of Unmanned Ground Vehicle (UGV) Concept Description of Airframe Concept Test Procedures and Results Concept Selection Matrices Subsystem Interface Definitions	$500
Subsystem Engineering	January 18, 2019	Wiring Diagram Vision Logic Diagram Autopilot Logic Diagram Bill of Materials UGV CAD Model UGV Drop Model Subsystem Requirement Matrices Subsystem Test Procedures and Results	$2,000
System Refinement	March 22, 2019	Refined Integrated System Definition System Requirement Matrix UGV Engineering Drawings Refined Bill of Materials Integrated System Test Procedures and Results	$800
Final Reporting	April 1, 2019	Final Report Compilation Flight Readiness Video Technical Design Paper Safety Pilot Log Team Promotional Video	$100

Key Success Measures

We developed a system requirements matrix in conjunction with the AUVSI competition rules (see artifact RM-001). All system-wide performance measures were considered, and five measures listed in Table 2 were selected as key success measures. Over the course of the next two semesters, we will gauge the desirability of our product based on how well the product completes each of these performance measures. Each performance measure will be evaluated in an environment designed to mimic the competition.

Table 2: Key success measures for the UAS

Measures (units)	Stretch Goal	Excellent (A)	Good (B)	Fair (C)	Lower Acceptable	Ideal	Upper Acceptable
Obstacles Hit (#)	0	1	3	5	0	0	5
Average Waypoint Proximity (ft)*	5	20	25	30	0	0	100
Characteristics Identified (%)**	80	40	30	20	20	100	100
Airdrop Accuracy (ft)	5	25	50	75	0	0	75
Number of Manual Takeovers	0	1	2	3	0	0	3

* *Average Waypoint Proximity* refers to the norm of the distance between the UAS and the waypoint location at the point when the autopilot considers the waypoint to be captured.

** *Characteristics Identified* refers to the ability to classify the color, shape, and textual content of visual targets scattered on the ground using camera measurements.

Change Management Procedure

An Engineering Change Order (ECO) will be used to facilitate the proposal, approval, and implementation of any future changes to this contract. The ECO template is found on page 249 of the Product Development Reference (Mattson and Sorenson). A change is initiated by filling out the template and submitting it to all involved parties for approval. Upon unanimous approval, this contract will be edited, the version number will be changed, and the revision history section will be updated with the relevant information, including a reference to the ECO created.

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Requirements Matrix

ID	Rev.	Date	Description	Author	Checked By
RM-001	0.1	09-07-2018	Fall camp draft	Brady Moon	Jacob Willis
RM-001	0.2	09-14-2018	Revisions after design review	Derek Knowles	Kameron Eves
RM-001	1.0	10-08-2018	Expansion for stage approval	Kameron Eves	Brandon McBride
RM-001	1.1	10-08-2018	Reordered requirements to match priority	Jacob Willis	Brady Moon
RM-001	1.2	10-17-2018	Fixed inconsistency in autonomous flight requirement	Andrew Torgesen	Kameron Eves

Product: UAS
Subsystem: N/A

Notes:
UAS = Unmanned Aerial System
UGV = Unmanned Ground Vehicle

		Units	Minutes	Minutes	Minutes	Percent	Feet	Percent	Percent	Percent	Percent	Percent	Feet	Feet	Yes/No	Count	
		Performance Measures	Flight Time	Post Processing Time	Autonomus Flight Time	Percent of Waypoints Hit	Average Minimum Distance to Waypoint	Percent of Obstacles Hit	Percent of Correct Characteristics Identified	Percent of Images Correctly Geolocated	Percent of Objects Submitted in Flight	Percent of Objects Autonomously Submitted	Payload Drop Distance to Target Location	UGV Stop Distance to Target Location	Complies with AMA Safety Code	Penalties	
	Market Requirements	**Importance**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Market Responce
1	The UAS shall be capable of autonomous flight.	20%			●	●	●	●				●				●	Very Good
2	The UAS shall be capable of avoiding static obstacles.	20%						●								●	Very Good
3	The UAS shall be capable of visual object classification.	20%							●	●	●	●				●	Very Good
4	The UAS shall be capable of delivering a payload.	20%					●						●	●		●	Very Good
5	The UAS shall be capable of safe operation.	10%					●								●	●	Good
6	The UAS shall be capable of a timely completion of the mission.	10%	●	●							●					●	Good
		Importance	6%	2%	8%	2%	10%	20%	4%	6%	6%	4%	10%	10%	10%	2%	
		Lower Acceptable	3	0	3	0	0	0	0	0	0	0	0	0	Y	0	
		Ideal	20	0	20	100	0	0	100	100	100	100	5	0	Y	0	
		Upper Acceptable	40	10	40	100	100	100	100	100	100	100	75	10	Y	15	

Figure 1: Top-level requirements matrix for the unmanned aerial system.

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Requirements Validation

ID	Rev.	Date	Description	Author	Checked By
DJ-005	0.0	09-05-18	Initial draft	Kameron Eves	John Akagi
DJ-005	0.1	10-08-18	Adjustments to account for changes to key success measures	Tyler Miller	Tyler Critchfield
DJ-005	0.2	10-09-18	Final edits for Design Review	Tyler Critchfield	Ryan Anderson
DJ-005	1.0	10-17-2018	Fixed points inconsistency	Andrew Torgesen	Jacob Willis

Purpose

This design artifact describes the methods used to develop the market requirements, performance measures, requirements-measures relationships, and ideal values to be found in the system requirements matrix. It also defines the market validation performed to demonstrate that these requirements, measures, relationships, and values are correct.

Market Representatives

The market for this product consists of the Association for Unmanned Vehicle Systems International (AUVSI) Student Unmanned Aerial Systems (SUAS) Competition judges. They will determine the ultimate success of the product through its performance in the AUVSI SUAS Competition. These judges provide a set of competition requirements that are our primary source for market requirements. On September 14th, 2018, the competition requirements for the 2019 competition year were released. From September 14th, 2018 to October 4th, 2018, the competition judges provided a comment period where team members requested clarification on the requirements. On October 4th, a final copy of the rules was released, and recourse continues to be provided for requesting further rules clarification.

The current competition requirements and the comment period are our primary means of determining the market requirements. In addition, our coach, Dr. Ning, and our sponsor, Dr. McLain, provide on-campus market representation and feedback on our capstone documents. Both individuals have been involved with competing teams in the past, so they have a good idea of the major competition expectations. We determined the most crucial portions of the competition requirements by benchmarking individual teams' performance in previous competitions (recorded in DJ-003 and DJ-006), and by breaking down the relative scoring weights of the competition requirements (recorded in DJ-004).

Justification and Validation of Key Success Measures

Using the information obtained from the market representatives, we created a list of key success measures which we will use as a measuring stick to validate our product. We feel strongly that if we do not achieve at least fair performance in all of these key success measures, then our product will be unsatisfactory and we will consider the project a failure. This is primarily because the unmanned aerial system (UAS) would not meet the market's needs, as it would not meet a level of competitiveness equivalent to last year's team. On the other hand, we feel equally as strongly that if we achieve excellent performance in most, or preferably all, of these key success measures, then our product will represent outstanding work that precisely fulfills the needs of the market. What follows is an enumeration and justification of the key success measures.

Because our product is inherently for a competition, most of these key success measures use the distribution of possible points as a framework. A break down of the point distribution can be found in DJ-004. Another important source for these decisions was the performance of last year's BYU team as well as the top 5 teams. This helped us determine what was possible and what isn't possible considering the resources available. The results of this analysis can be found in DJ-003 and DJ-006.

- **Obstacles Hit** This constitutes 20% of the competition points our UAS can obtain. This year, the judges have increased the number of obstacles that need to be avoided from 20 to 30. Last year's team hit 3 obstacles and only 48% of all teams in the competition received points for obstacle avoidance.
  - <u>Fair: 5 Obstacles</u> - If last years performance is scaled for the increased number of obstacles (a 50% increase) we would have to hit 5 obstacles to match last years performance. However, it is likely that the number of obstacles hit increases exponentially with the number of obstacles in the competition. This is because the likelihood of avoiding obstacles by luck decreases exponentially. Therefore, hitting 5 obstacles might be numerically equivalent to last years performance, but could still indicate some small improvement. Thus we choose 5 obstacles as a fair performance. Anything less then 5 would indicate a failure to improve last years system.
  - <u>Good: 3 Obstacles</u> - As in all aspects of the competition, we hope to improve upon last years performance. Therefore, we feel that hitting 3 obstacles (the same number as last year) constitutes merely a good performance. Again accounting for the increased number of obstacles, this would be a small improvement from last year.
  - <u>Excellent: 1 Obstacle</u> - Decreasing the number of obstacles hit from 3 to 1 represents a marked improvement from last year. As such we have set this as excellent performance.
  - <u>Stretch: 0 Obstacles</u> - The ideal is to avoid all obstacles. While this is difficult, we do feel it is possible and so have set this as our stretch goal.
- **Average Waypoint Proximity** Autonomous flight of a waypoint path constitutes 10% of the competition points our UAS can obtain. Among other things, points are awarded for how close the UAS comes to each waypoint. Only 56% of all teams were able to get points for autonomously flying a waypoint path. Last year's team

averaged 16 feet from the waypoints. As mentioned previously, there has been a significant increase in the number of obstacles, and this year we will need to increase the size and speed of our aircraft in order to carry an increased payload. Both of these factors will introduce more error into our flight path and make it more difficult to achieve waypoint accuracy. Because waypoint accuracy constitutes a large portion of the possible competition points, we determined that it was important to create this key success measure to make sure we don't deviate from the performance of last year's team. Our time will likely be spent more on the other measures, but this measure will ensure we don't sacrifice these points in our pursuit of improving performance in other areas.

  - Fair: 30 feet - Due to this year's increased difficulty, repeating last years results would actually indicate an improvement. After consulting with our market representatives, we have decided that anything below 30 feet would mark no improvement over last year's performance and would show no improvement in our path planning or flight control. Thus, we have chosen 30 feet to be the limit of a fair performance.
  - Good: 25 feet - To improve upon last years system we will need to make changes to the path planner and the flight control. An average of 25 feet from the waypoints, would only show improvement in one of these areas. Thus 25 feet indicates only a good performance.
  - Excellent: 20 feet - Because of this year's increased difficulty, repeating last years performance would be an excellent performance and would show significant improvement in both the airframe and path planner.
  - Stretch: 5 feet - The ideal is of course 0 feet away from the waypoint. However, due to uncontrollable factors such as weather conditions and our limited resources we feel that this ideal is unrealistic. Therefore, we have set our stretch goal to something we feel is possible, but very difficult. This stretch goal would be a very large improvement over last year and would reward us with 90% of the points possible for this portion of the competition.

- **Object Characteristics Identified** Identifying the characteristics of several objects on the ground constitutes 12% of the competition points our UAS can obtain. Points are awarded for the number of characteristics correctly reported. These characteristics include the object's color, the object's shape, the alphanumeric character on the object, and the object's location. Last year's team correctly identified only 23% of the possible characteristics. Only 17% of all teams in the competition received points for identifying any characteristics.

  - Fair: 20% - Below 20% would mark no improvement over last years performance. As such this is our limit for a fair performance.

- Good: 30% - While this level would indicate improvement over last year's performance, it would not indicate significant improvement. There are several difficult, but obvious, changes that could result in this improvement. Such changes could include finding and fixing a known geolocation bug, as well as improving the usability of the vision ground station GUI. This proverbial low hanging fruit would constitute only a good performance.
- Excellent: 40% - Achieving this level would mean nearly doubling last year's performance. To achieve this we would need to identify at least one more characteristic per object. Whether this is accomplished autonomously or manually, this will be difficult to achieve and will require innovative changes to the current system. As such we have labeled this excellent performance.
- Stretch: 80% - Additional points are awarded for each characteristic identified. This is very difficult. Many teams, including last years, was unable to achieve this accuracy. Thus we have set this as our stretch goal.

• **Airdrop Accuracy** Payload delivery constitutes 10% of the competition points our UAS can obtain. Last year's team received no points for this portion of the competition. However, this was because of other factors not relevant to the payload delivery. Because we can not compare our results to last year's results, we have set these goals primarily off of feedback received from the judges in recent weeks. This year, the payload delivery has increased significantly in difficulty. Last year only involved dropping a water bottle. This year includes dropping an autonomous, remote-controlled (RC) car capable of driving itself to a specified location. Accuracy for our drop will be extremely difficult to achieve. Our payload will need to land softly to avoid breaking. However, most mechanisms for ensuring a soft landing would also involve significant decreases in the accuracy of the drop (e.g. a drifting parachute). Last year, only 29% of teams received points for payload delivery.

  The competition also allots 10% of points to driving accuracy of the UGV. This part of the competition is novel and challenging, and while we plan to pursue those points, we are deciding to not include it as a key success measure. This is planning for the case that as the competition approaches, we may decide it is in our best interests to focus our time and effort on other areas.

  - Fair: 75 feet - No points are awarded for an airdrop with an accuracy of less then 75 feet. As such this is our lower acceptable limit.
  - Good: 50 feet - The next tiered level of performance given us by our market representatives is from 50 feet to 75 feet. Any accuracy within this range would reward us 25% of the points for this portion of the competition.

  - Excellent: 25 feet - An accuracy of less then 25 feet would result in 50% of the possible points for this portion of the competition being awarded to us. If our stretch goal is not achieved, then this is the maximum amount of points we can obtain. Thus this is our excellent performance.
  - Stretch: 5 feet - Our market representatives have indicated that their ideal is an UAS capable of dropping it's payload within 5 feet of the designated target. The judges have indicated that this would result in full points awarded for this section of the competition. While possible, we do not feel that this is feasible with our given resources. As such we have set it as our stretch goal.

- **Number of Manual Takeovers** The ethos of this competition is autonomy. Autonomous flight directly constitutes 8% of the competition points our UAS can obtain. However, most other tasks can not be completed without autonomous flight. During the competition, if our autopilot failed in any way, it would necessitate a manual takeover. A manual takeover is when our safety pilot performs an RC override and pilots the aircraft manually for a short time. Doing so results in a points penalty equal to 10% of the autonomous flight points. Last years team only needed 1 manual takeover; however, we feel that this is not a good indication of how many takeovers we'll need. The code base for our system is complex and interconnected, as such every change in our software (of which we will be making many) could cause a manual takeover. Excluding our predecessors, there is no data available for the number of manual takeovers needed by teams last year.
  - Fair: 3 Takeover - Any number of manual takeovers more then this would be unsatisfactory and indicate an inability to autonomously control the UAS.
  - Good: 2 Takeovers - This is one more takeover then last year and would indicate that we made the same number of system critical mistakes as last year's team.
  - Excellent: 1 Takeovers - This would equal last year's results, however, it would also indicate that none of our changes resulted in a system critical error.
  - Stretch: 0 Takeover - This is of course the ideal, but very difficult to achieve as it would require developing and testing bug-free code.

Just as important as the key success measures are several other features of the aircraft. Our team is inherently a competition team. As such, our main goal and biggest indicator of success is how we perform in the competition. However, our final place in the competition was excluded from our key success measures intentionally because we can not control how the other teams perform. As such we could perform very well compared to other teams, but still not have a satisfactory aircraft. Therefore, despite the fact that this is the primary goal of our aircraft, we have purposely excluded it from our key success measures.

Successfully achieving excellent performance in our key success measures should ensure excellent performance the competition regardless of the performance of the other teams.

Validation of the Completed Sections of the Requirements Matrix

It is vital for requirements matrices to be developed in consultation with the market representatives. Our requirements matrix was not developed in a vacuum. Its requirements closely mirror the desires of the market. This was achieved through communication with the judges through the rules. The rules are divided into several sections which list the places where points are to be obtained. The titles of these rules were used as market statements, which we turned into market requirements. The points distribution within these sections was used to develop requirement measures. These measures indicate whether or not our product is capable of meeting the market requirements. The higher and lower acceptable values were chosen from the points distribution itself. Finally, and most importantly, we confirmed our results with Dr. McLain. Dr. McLain indicated that each requirement was good and correctly differentiated a successful product from a failed product. As an aside, the key success measures listed above were developed in tandem with the market requirements. An effort was made to ensure that at-least one key success measure can be used somewhat comprehensively to measure each market requirement. If we successfully achieve excellent performance in the key success measures then we will have created a product which the market also feels is excellent.

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2019 Rules Breakdown

ID	Revision	Date	Description	Author	Checked By
DJ-004	0.1	10-08-2018	Initial creation	Jacob Willis	Andrew Torgesen

Category	Category Score	Overall Worth
Mission Demonstration	60%	60%
Timeline	10%	6%
Mission Time	80%	4.8%
Timeout	20%	1.2%
Autonomous Flight	20%	12%
Autonomous Flight	40%	4.8%
Waypoint Capture	10%	1.2%
Waypoint Accuracy	50%	6%
Obstacle Avoidance	20%	12%
Object Classification	20%	12%
Characteristics	20%	2.4%
Geolocation	30%	3.6%
Actionable	30%	3.6%
Autonomy	20%	2.4%
Air Drop	20%	12%
Drop Accuracy	50%	6%
Drive Accuracy	50%	6%
Operation Excellence	10%	6%
Technical Design Paper	20%	20%
Systems Engineering	20%	4%
Systems Design	50%	10%
Safety & Risks	20%	4%
Writing Style	10%	2%
Flight Readiness Review	20%	20%
Experience, Roles	5%	1%
Systems Overview	15%	3%
Development Testing	50%	10%
Mission Testing	30%	6%

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AUVSI CAPSTONE TEAM (TEAM 45)

Last Year's Performance

ID	Rev.	Date	Description	Author	Checked By
DJ-006	0.1	10-03-2018	Initial Draft	Kameron Eves	Ryan Anderson
DJ-006	1.0	10-08-2018	Fixed math errors and improved clarity	Jacob Willis	Andrew Torgesen

Introduction

As our objective statement states, the goal of our capstone team is to improve upon last year's design. Therefore, an important consideration in developing requirements and key success measures is the performance of last years team. Analysis of this performance will reveal which areas require the most development as well as which areas are already optimized.

Last Year's Performance

*Table 1: The results from last year's mission tabulated. Category Scores are scoring weights from last year's competition rules, with each subsection's Category Score given as a percentage of its section. Last year's results are shown on the same scale as it's corresponding section. E.g., a perfect performance means that the percentage listed under **Last Year's Results** exactly matches the corresponding section percentage listed under **Category Score**. All of last year's results are rounded to the nearest integer.*

Category	Category Score	Last Year's Results
Timeline	**10%**	**0%**
Mission Time	80%	2%
Timeout	20%	0%
Autonomous Flight	**20%**	**16%**
Autonomous Flight	40%	36%
Waypoint Capture	10%	10%
Waypoint Accuracy	50%	42%
Obstacle Avoidance	**20%**	**10%**
Object Classification	**20%**	**4%**
Characteristics	20%	6%
Geolocation	30%	0%
Actionable	30%	15%
Autonomy	20%	0%
Air Drop	**20%**	**0%**
Operation Excellence	**10%**	**8%**
Total	**100%**	**38%**

Discussion

As shown in Table 1, last year's team performed very well in the Autonomous Flight section and the Operational Excellence section. However, they underperformed in the Timeline, Obstacle Avoidance, Object Classification, and Air Drop sections. This year, we have specifically assigned subteams to focus on the Air Drop and Object Classification, respectively, since these are the two areas in need of the largest improvement. Because Object Detection was the primary obstacle to last year's performance in the Timeline section, improving Object Detection performance should also allow improve the Timeline section for this year.

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Benchmarking Artifact

ID	Rev.	Date	Description	Author	Checked By
DJ-003	0.1	10-05-2018	Initial Draft	Kameron Eves	Andrew Torgesen
DJ-003	0.2	10-09-2018	Final Edits for Design Review	Ryan Anderson	Tyler Critchfield

Introduction

This project is inherently a competition. Therefore, the way in which the product compares against other teams is an important metric. A quick search through results of previous years shows that the same several teams tend to finish at the top, only swapping places among themselves. For this reason, it is valuable to examine the performances of these top 5 teams. At this stage of the product development process, the main focus of this external examination is to see where we should focus our time. Finding where last year's BYU team was deficient and where the best teams performed well will provide an indication of where we should focus our efforts.

Method

The AUVSI-SUAS administration publishes copies of each team's final report. From these reports we were able to parse what the teams attempted. The competition organizers also distributed a summary of the points for each team. From this we found what each team successfully achieved. This information is tabulated in Table 1

Table 1: Last years performance of the top 5 teams. Note that if the table indicates that a team "Achieved" something, it only indicates that they got some points for that task - not that they were 100% successful.

Key

AF = Autonomous Flight
OA = Obstacle Avoidance
AOD = Autonomous Object Detection
OC = Object Classification
OL = Object Localization
PD = Payload Delivery

Rank	Team		AF	OA	AOD	OC	OL	PD
1	UdeS	Tried	Y	Y	Y	Y	Y	Y
		Achieved	Y	Y	Y	Y	Y	Y
2	Flint Hill School	Tried	Y	Y	Y	Y	Y	Y
		Achieved	Y	Y	Y	Y	Y	Y
3	VT & VSU	Tried	Y	Y	N	Y	Y	Y
		Achieved	Y	Y	N	N	N	Y
4	Cornell	Tried	Y	Y	Y	Y	Y	Y
		Achieved	Y	Y	Y	Y	Y	Y
5	MPSTME & NMIMS	Tried	Y	Y	N	N	N	Y
		Achieved	Y	Y	N	N	N	Y
9	BYU	Tried	Y	Y	N	Y	Y	Y
		Achieved	Y	Y	N	Y	N	N

Results

As can be seen in Table 1, the teams that won the competition attempted and succeeded at all of the tasks. However, the table indicates that when a top team does not succeed at something, it is in the object detection section of the competition. One team, MPSTME & NMIMS, did not even attempt this portion of the competition. VT & VSU did not successfully achieve object detection despite the fact that they attempted to do so manually (the easier method) rather then autonomously. However, three of the five best teams did successfully achieve autonomous object detection. For this reason, we feel that achieving autonomous object detection is a worthwhile goal. Autonomous object detection is a difficult task. Thus, for the sake of redundancy, we will also manually detect the objects. The competition allows for both methods to be employed. Points are only awarded for the method that results in the highest final score.

Also of note in Table 1 is that every team in the top five attempted and achieved payload drop. Last year's BYU team did attempt payload drop, but did not achieve it due to unrelated technical issues. This is were the highest improvement to cost ratio can be obtained. This is especially true this year because the percentage of competition points awarded for the payload drop has increased. Therefore, we feel that focusing on the payload drop will be a worthwhile use of our time.

Discussion

The current system upon which we are iterating was successful at autonomous flight and obstacle avoidance. These system components are designed such that they will continue to work well for this year's competition. However, as shown above, effort must be put into the payload delivery and autonomous obstacle detection. Because there is not currently an autonomous object detection system and because the payload delivery is significantly more complicated then previous years, these two tasks will consume most of our time. We have divided our teams into two sub teams: one for payload delivery and one for object detection. By focusing on these two tasks we feel that our performance in the competition will rise to and even exceed the performance of the top teams.