**Graduate Projects**

University of Colorado at Boulder

Aerospace Engineering Sciences

ASEN 5018/6028 –Fall 2015

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| **FlyNet**  **Testing Subsystem Summary/Continuity Document** |

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**1: Introduction & Summary**

The testing subsystem shows that all of the requirements are verified and validated by the current solution that the team has designed.

We currently have a test to verify that all of the components that make up each subsystem will meet the lower level functionality requirements. Each subsystem will also have a test to validate that the functionality meets the requirements for each subsystem. There is a final test demo designed to prove the overall functionality of the FlyNet system.

# **2: Semester Report**

## 2.1: Objectives and Tasks List

**Completed**:

1. Designed a Test Plan that will verify and validate the system requirements
2. Designed the end of semester demo to prove the current system functionality
3. Designed a method for constructing a mock building for test purposes
4. Designed, built, and tested a method for blade guards and landing gear

**Incomplete**:

1. Build enough walls and supports to mimic a building floor plan (estimated 20% complete)
2. Conducting all of the tests on the test plan

## 2.2: Issues

What problems prevented you from being able to complete the tasks above?

1. We were unable to build all of the materials for the building mock up because of an initial design flaw that has been fixed. Also the current progress of the project makes the mock up a low priority since there won’t be a need a complete floor plan for this semester. Lastly a lack of experience slowed the manufacturing process initially.
2. We lacked the knowledge of how long each subsystem design would take to design and implement. Each subsystem took more time to make functional and therefore the test plan ran over the predicted schedule.

## 2.3: Lessons Learned

1. Don’t expect a product to work exactly as the specifications indicate. The DJI Guidance component didn’t perform as expected which slowed the progress of the perception subsystem.
2. Be careful with the expected scope of the project for the semester. Nothing will go exactly according to schedule and setbacks will happen. Include a lot of margin in the schedule.
3. Correspond with facility leads before you plan on starting to manufacture. Almost any facility will require safety demonstrations before they can be used.
4. Ask for help and utilize resources early and often, they can help reduce the downtime spent trying to fix a problem or learn something new.

## 2.4: Procedures

To design the Test Plan, the list of requirements was consulted. Not all of the requirements listed for the entire FlyNet system were applicable to this semester so only specific requirements were chosen. Also some requirements could be verified or validated so a test was not designed for that requirement. The component level requirements were broken up into tests that would show that the component chosen met the requirement. For example, requirement 3.1.2 specifies that the quadcopter needs to take off autonomously. In order to meet this requirement, a test was designed to give the quadcopter a desired location of 2 meters above the origin of the VICON flight cage. Have the autopilot fly the quadcopter to that location and then hover there. Then switch over to manual flight to safely land the quadcopter. This test was conducted on November 11, 2015 but was not conducted using the guidance subsystem for location but instead using VICON position data. This proved that given accurate position information, the system can autonomously take off. The entire Test Plan can be found on the FlyNet GitHub under Technical/Testing/TestPlan.xlsx. Each test listed in the Test Plan has a corresponding test card that can be located via the hyperlink associated with the specific test. The test plan also lists the current progress percentage to completing the specific tests. A test was also designed for each specific subsystem to show that it meets the functionality requirements associated with it. The progress percentage to completion for each subsystem is a weighted sum of the component level tests and the subsystem test as a whole. That is that if all of the components level tests have been completed for a subsystem, the progress percentage is up to 75%. The other 25% is obtained once the subsystem test is completed. The same weighted sum is used for the End of Semester Demo and the subsystem tests. Assuming the End of Semester Demo would be conducted during the last week of classes, the Testing Subsystem created a testing schedule to meet that deadline. This meant that all subsystem tests would need to be completed the week before that, and the component level tests would need to be completed two weeks before the Final Demo. We fell behind in the schedule due to issues with the subsystems so certain tests were moved to next semester in order to still have some sort of current functionality demonstration at the end of the semester. Tests have been reevaluated based on the priority in which they should be conducted in the limited time left. Tests that were not feasible for this semester given the current state of the project were pushed to next semester.

The End of Semester Demo was initially designed to show all of the functionality that the system was expected to have at the end of this semester. The system was supposed to be able to fly autonomously through a building with a known floor plan and map the space while avoiding possible unknown obstacles. In order to show this functionality, a mock up floor plan would need to be designed and constructed in the Fleming VICON space. Although VICON was not planned on being used, this was the only available space for the space. Once the mock up was built, the floor plan would be given to the quadcopter in order for it to plan the trajectory to map the entire space. Some “roadblocks” were to be placed into the floor plan without the knowledge of the quadcopter system. These were going to be walls with a height that was 2’ compared to the full size 4’ walls. This would require that the quadcopter adjusted its altitude in order to avoid a collision and help proving the obstacle avoidance requirement. A complete roadblock would also be placed in the map. This would require that the quadcopter would reevaluate the trajectory to map the entire space because one hallway would be inaccessible. The entire time the system should be mapping the space as well to bring back to the ground station. Since the dimensions of the space would be known, the accuracy of the map would be confirmed after the test was complete. Although the system was not supposed to identify a target in this semester, the target should be mapped as well as the current floor plan. This will also help prove the accuracy of the map created by the quadcopter system. The floor plan was designed to have multiple rooms, some with only one doorway and some with multiple, and various doorway widths. The smallest doorway was designed to be 3’, which is average for a building, but some were made 6’ to mimic different types of buildings. The entire layout of the testing area can be found in the FlyNet/Technical/Testing/Final Flight Demo.xlsx document.

When designing the method for constructing a mock floor plan, cost, weight, and accessibility was considered. I calculated that there was to be almost 200 linear feet of walls that needed to be built, a cheap and quick method for constructing walls was required. Also the walls needed to be light weight so that they could be easily moved and stored when they weren’t in use. It was determined that 4’x8’ sheets of plywood or insulation foam would be the cheapest materials and readily available. Since the price of the foam was less than $1 more than the plywood, it was chosen because of the largely reduced weight of the foam. The foam would need to be supported in some way in order to stay standing. Wooden frames were then designed to hold the foam sheets at the bottom corners. This would provide the structural rigidity needed as well as keep the cost of material low since wood is cheap and readily available. 2x3 wood studs were chosen as the material for the frames. This decision was made because of the availability of wood at local hardware stores and the mass quantity of frames needed to be manufactured. Each wall needs at least two frames supporting it at the bottom corners. The full length 8’ long sheets of foam would even need an extra frame in the middle to prevent the quadcopter from blowing over the walls. Over 40 of these brackets will need to be made which is also why wood was chosen. The wood can quickly be cut and fastened together with screws. The wood frame design can be found in the folder FlyNet/Technical/Testing/Solidworks/WoodFrame.SLDASM The total breakdown of wall specifications and the wood material breakdown can be found in the Final Flight Demo.xlsx document mentioned above. A SolidWorks model of the floorplan was designed to ensure that the proposed floorplan was feasible and that no detail of the construction was overlooked. While foam wall pieces have been cut, only a few of the wooden frames have been made thus far. Since the system is not believed to be functional enough to require a mock floor plan at this point in the semester, construction has been limited to move resources to more pressing tasks.

In order to test the functionality of the landing gear solution, test flights were conducted with various payload weights to ensure the quadcopter could safely land. To test the blade guard design, two sheets of plywood were positioned so that there was a gap between them the same distance as an average doorframe (36”). Then the quadcopter was manually flown through the plywood so that it would bounce off the “doorframe”. This proved that the blade guards would protect the blades from side collisions. Then the quadcopter was flown into the plywood from the front and back proving that the blade guards would protect the quadcopter from forward collisions.

Table 2.: Software list

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| Program Name | Version | Purpose |
| SolidWorks | 2014 x64 Edition | Designing the layout and connectivity of the floor plan. |
| Microsoft Excel | 2013 | Keeping track of the progress of the Test Plan. |

# **3: Next Semester/Future Expectations**

## 3.1: Prioritized List of Tasks and Objectives

1. Build enough walls and supports to mimic a building floor plan (estimated 20% complete)
2. Modify the test plan schedule for the next semester and conduct the tests
3. Design or modify test plan to only include the scope of the project for nest semester

## 3.2: Starting Points

1. Open up the wood frame SolidWorks part to familiarize yourself with the design. Located in FlyNet/Technical/Testing/SolidWorks/WoodFrame.SLDASM. Look at the design and build more frames utilizing the wood shop in the Idea Forge located in the Fleming building. If you have not, sign the safety contract on the internet to gain access.
2. Open up the test plan and start scheduling the upcoming semester of tests. Located in FlyNet/Technical/Testing/TestPlan.xlsx. The design of the quadcopter system should be pretty well finalized at this point so testing should commence almost immediately.
3. Again in the same Test Plan document, add or delete tests that either do or don’t pertain to the scope for this semester. The team should have a meeting at the beginning of the semester to discuss the expected progress to be made. Also make sure to add test cards for any tests that need to be added for this semester.

## 3.3: Improvement, Updates, Verification

For tasks you have completed, what could/should be done to improve or update them in the future? Here is a good place to blatantly state all the assumptions you have made, and prioritize them in order of the impact the assumption has on your result. As assumptions later get filled with more concrete data, your analysis will need to be updated and/or verified to ensure no issues have been raised.

Note: Be careful with improvements -- remember the goal is always to meet the requirement and not go any further.

1. We assumed that the test plan will meet the requirements for our current semester. Not all of these will be applicable anymore. Make sure to update the tests to ensure that all current requirements are met.
2. We assumed that we are able to open up the VICON cage to cover a larger area. If this is valid proceed, if not update the design to fit into the VICON cage.
3. We assumed that the current design once completely built will be structurally sound. If not make reinforcements with wood since the wood is much cheaper than the foam insulation sheets.
4. We assumed that the current design for blade guards and landing gear will last for the duration of the project. You may want to build extra pieces in case that damage occurs to the current design.