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**Small Satellite to Small UAS Operations (WIP)**

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Nhue Lac Betty Lam  
Kelly Ngo Levi Sagucio  
Nathan Zenger  
  
Advisor: Dr. Miguel Nunes**

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**Summary (Kelly Ngo, Betty Lam)** Operations between Small Satellites and sUAS (small Unmanned Aircraft System) is an emerging approach to scientific and technological operations. This project is focused towards developing the technology that allows for a satellite to operate a sUAS by using open-source software tools: the Comprehensive Open-Architecture Solution for Mission Operations Systems (COSMOS) developed by the Hawaii Space Flight Laboratory (HSFL), and the LSTS (Laboratório de Sistemas e Tecnologia Subaquática) toolchain. Currently, we have a working ground base station that is able to receive telemetry from the DJI M100 sUAS. At this point in our progression, we have no satellite to communicate with. Regardless, we must constantly prepare and update the drone so that it is available for flight and testing at any time.   
 We have certain goals we want to reach within a deadline. One deadline for reference is the Maritime Awareness Network of Teaming Autonomous Systems (MANTAS) event, which occurred twice during the Spring 2019 semester. Additionally, the Hawaii Space Flight Laboratory plans to launch a small satellite into space, and once done, we will be able to continue onwards with the communication between satellite and drone. In the mean time, we plan on tasking ourselves with writing and debugging software programs, attending and learning from flight events, as well as fabricating parts and accessories for the drone, and learning to fly the drone. We also have been collaborating with the rocket team of the HSFL as we work, assisting in their endeavours involving the drones in their own experiments. Further work is being developed to send mission plans and commands to the M100. The drone project endeavours to demonstrate new operational capabilities between small vehicles over long distances (satellite orbiting at 400 km and sUAS flying in Hawaii).

**Introduction (Kelly Ngo, Betty Lam)** Operations between Small Satellites and sUAS (small Unmanned Aircraft System), more commonly known as the Drone Project, is one of many projects that has a focus in Aerospace Technologies. An unmanned aerial vehicle (UAV) is are more popularly known as drone. Drones have a simple aircraft system that consists of the vehicle itself, a ground-based controller, and a medium for communication. Drones have the potential software to be programmed such that it does not need control from man. They can also achieve great altitude and go a far range given enough fuel and command.   
 There are many uses of drone, which includes teleportation of cargo, surveying (research), defense and security, and more. We haven’t chosen a specific use we want for the drone yet, but the options are unlimited. The model we use in this project is the DJI Matrice 100. It is a highly reliable drone, with many sensory systems to detect changes in atmosphere conditions (wind direction changes, change in humidity, weather forecast). The drone can communicate via remote control at ground base. It has flight control capabilities and stability. Components include rechargeable batteries, and GPS system.  
 In the next month, the Hawaii Space Flight Laboratory plans to launch a small satellite at the University of Hawaii. This satellite is an essential part of this project, for it will give us the means of communication between satellite and drone. The small satellite is being launched with the purpose of observing Earth.  
 The drone project has worked on establishing a working drone, and preparing it for flight. Many parts break down so we have to replace and reprogram it. Most programs for flight control were already previously worked on, so we are tasked to keep the software and parts up to date. We are also tasked with coming up with ways for improving the flight characteristics of drone. We constantly think of new ways to accomodate for unexpected conditions such as rainfall. One task that is being worked on is having a 3D print model box that will sit on top of the drone, that can secure parts that previously sat on top of the drone with no protection such as the Raspberry pi. Additionally, the box will prevent any damage sustained during flight and keep parts in position (so it doesnt fall off).  
 Before beginning the drone project, each team member was tasked with researching drones and aerospace technologies and their uses. One of the first exercises that Professor Nunes showed was if we were to change the speed of a four legged four wing drone, then which side would it lean on. Basically, he tested our understanding of drone flight and stability.   
   
 For our research, we looked at websites that specialized in drones and read articles, looked over the Matrice 100 Manual, and attended exercises including the MANTAS events, as well as collaborating with the rocket team. This project was started by Hawaii Space Flight laboratory and we got assistance from the lab in Portugal, there are three labs that represent sea, land, and space. Our drone team is the first experimental drone project to do this in the nation.

**Technical Overview and Analysis (Kelly Ngo, Levi Sagucio, Betty Lam)** Systems Engineering: There are many components of the drone that we have to get working together in order for the drone to communicate with the ground base. The most of importance are the vehicle itself, the software that runs it, the remote that is controlled by a person, and the hardware attached to the drone. In the beginning, we were tasked to familiarize ourselves with C++ language, because most softwares such as flight control are written and linked in C ++ language. After learning that, some members were tasked with debugging DUNE, which allows for man made flight control. In this, we learned to engineer and come up with ways to handle technical problems.   
 The ultimate goal of the project is to Send mission planning commands to drone via satellite and relay information between the two, Create a program that can carry out automated commands and procedures  
Requirements Discussion  
 The Drone we are using is a DJI Matrice 100. There is a manual that lists its components and we need those components. Some key parts are the drone legs, drone battery, we can put together the drone quite easily.   
 This project requires a computer that can run Linux system. The importance of Linux is that it is compatible with COSMOS, a tool chain, and in addition, can easily run other application such as QT creator, which is used for Linking programs together. One of these programs include DUNE, which was developed by our affiliated team in Portugal and gave us permission to use. We use Github to download any necessary programs. In addition, we use Neptus -- which is a command and control framework that allows planning, supervision, control and post-mission analysis of all DUNE-compatible vehicles. And although not exclusive to Linux, we can reporgam Digi Xbee since one of the Xbee broke. The importance of Digi Xbee is that Digi Xbee wireless antennas hardware are used to make the connection between ground station and the Raspberry Pi attach to the M100 - as a temporary radio before installing the long range radios (5-10 miles range). We also can perform many essential programming on the Linux computer such as cross-platforming Raspberry Pi so that we can control the Drone. Other components needed is the Remote Control. Without a remote control, we cannot test the programs that M100 runs on. We have

**Design Process**Most of the design was done by Professor Nunes and his team belonging to Hawaii Space Flight laboratory, but we were able to contribute to it by designing a Pi and Xbee housing.

**Pi and Xbee Housing (Nhue, Betty, Nathan)**

In order for us to attach the Raspberry Pi and Xbee to the DJI M100, a mountable box with the ability to keep components safe from rain and debris was designed to house them. The box needed to be able to mount on top of the DJI M100 drone, and atop the battery housing. The first version of the housing had the dimension of 140mm x 120mm x 35mm, and a cover with the dimension of 140mm x 120mm x 3mm. However, it had some issue while it was being printed, and some of the design feature of the housing was also flawed, including fit and mountability: The notches of the housing did not aligned with the holes on the cover, and the hole to attach to the M100 also did not aligned with the hole on the drone. The second version of the housing was design with rail slot instead of individual holes in order to better adapt to fit, and the housing cover was also redesigned with rail slots. This design much improved the ease with which we could mount the casing, but it still has some flaws. Although the housing is currently functional, we will be working on a third iteration which will address space needed for wiring involved in troubleshooting, such as access to the USB and HDMI slots.

**Xbee Testing and Debugging (Nhue, Betty, Nathan)**

At some point during development Xbees seemed to be malfunctioning and not working correctly. So we tested if the devices had any issues with the XCTU which allowed us to test if the devices were working properly and install software updates onto them. After running at range test between the two Xbees with XCTU they both were working able to communicate with each other and were working properly again. After both device were updated and verified functional we went back to testing them between the raspberry pi and the laptop with Dune and Neptus via a wifi hotspot on a smartphone which was successful in displaying real time communication between both Xbees.

**Methodology and Assumptions (Kelly Ngo)** The general procedure is such that Study the M100 API, learn to cross compile software for Raspberry Pi (learn linux, git, C++, etc.), Deploy NEPTUS to operate the M100, Prepare for next MANTAS exercise to demonstrate M100 running a mission plan.Usually we start the day off with background research. Then Professor Nunes assigns us a task and a rough estimate on when it should be completed by. Tasks are independently pursued and assigned by Professor Nunes. Tasks vary depending on event schedule. For instance, when it was close to MANTAS demonstration, we were focused on preparing drone (by debugging programs). After the event, we were focused on coming up with ways to improve MANTAS event for next time it comes around.   
 The project we joined has a general goal: to develop a new technology that communicates between small satellite, ground base, and drone.  
We know that the steps and work we do will pave the way for future drone technologies, and issue pre-programmed commands to collect multiple data from drones (aerial, ground, and sea) using information obtained from satellite communications.  
  
**Manufacturing, Assembly, Testing, Modifications (Levi Sagucio)** For the most part, manufacturing was not a big issue for the Drone Project. Our drone, the DJI Matrice 100, was previously obtained by Professor Nunes. One modification we did make is that we assembled a payload housing for our Raspberry Pi and Xbee. This payload was then attached on top of our drone to keep our components intact. This housing was created using 3D-printing. Other than the payload, there was not much assemble and modifications added to our DJI Matrice 100. We had multiple occasions to test out our drone. One of the major test took place during the event called the Maritime Awareness Network of Teaming Autonomous Systems (MANTAS). This event was the first time we displayed the flight capabilities of the drone. During this time, we did not have the housing payload available. There were other times we casually tested the drone to get a better understanding of the drone flies. The last drone testing we conducted this semester is to test out how the payload handled during flight. To our understanding, the payload held its own for the duration of the flight.

**Management and Cost (Kelly Ngo, Betty Lam)** The drone team designated Kelly Ngo to be our team lead, and she ultimately was tasked with managing the team by assigning tasks and keeping updated on the current status of the overall project. Tasks were mostly assigned via the Asana app or through the Discord app by Professor Nunes. The Drone members were to ask Professor Nunes for additional help with their tasks, or for hints to go about a problem.  
 At first, the team structure was individual work with future intention and hopes of coming together. It was up to the individual to schedule what hours they wanted to work, and Professor Nunes was the advisor who would find a suitable task that focused on that students’ interest. Students pursuing electrical or computer focus were encouraged to learn C++ language to understand the software side of the drone project. The team structure then became more consistent with each individual finding a suitable partner who had compatible work hours.  
 Meetings were later incorporated into the drone project, which discussed the strengths, weaknesses, and organization of the drone team. At these meetings, tasks were discussed, and methods were discussed on how to approach problems. This was also a convenient time to talk to Professor Nunes about the status of the tasks.  
 Communications between drone team members were via email, texting SMS, and Discord App. Official business such as meeting times were sent by email. Texting and Discord were more casual, but useful for responses.  
 Currently, we have not spent any money on the project, merely working with given materials and tools at the HSFL. However, we recently received approval for a budget of $1500. Team members have been asked to reflect on their past, current, and future tasks and events and think of drone parts or any materials would be useful to the project in the future. A spreadsheet of parts and materials we intend to purchase was created and shared on our project folder. The deadline of budget funds is May 15, so we must order parts before then. To further help us stay organized, we also created a data sheet noting where parts and tools we currently have access to are located after each use.

**Responsibility and Tasks (Kelly Ngo, Betty Lam)** Each student is responsible for updating their project log, which should lists the tasks and goals for that day. Each student are assigned different tasks depending on their focus. There are mostly two groups: Levi and Kelly; Betty, Nhue, and Nathan. Although different things are being done, the products we put out must come together. General tasks include research on long range communication technologies, software development for drone operations (command and telemetry), fabricating drone accessories, preparing the drone for demonstrations, partaking in networking events such as Maritime Awareness Network of Teaming Autonomous Systems (MANTAS), collaborating with other teams in the HFSL, and learning to fly the drones.

**Results/Experiments (Kelly Ngo, Betty Lam)** As our project is in the early stages of development, we do not have technical results that can be discussed at the moment. We do however have experimented several times with flying the drone, such as when we showcased our drone during the MANTAS Showcase in March, and participated in the rocket team's spectrometer payload test drops. Additionally, we have successfully experienced the long debugging process made by computer engineers, during the DUNE program debugging tasks.  
 The intention at MANTAS was to present the premise of our drone project, as well as fly and command the M100 to make a circuit around coconut island. However, weather conditions were extremely poor that day, with on-and-off rain and gusty winds. Thus, though we were able to speak with several people about our presentation, we were unable to execute our flight plans. We were however able to carefully fly the drone a little to make back and forth runs around our presentation area.  
 During our collaborations with the rocket team, we were able to test fly the drone with cargo aboard in order to simulate a rocket payload drop. The first time the payload was tested on the M100, the cargo was mounted too low and was much too heavy, unbalancing the drone and rendering it unable to take flight. Our second test drop collaboration with the rocket team was conducted at Bellows Air Force Station, with newly redesigned housing for the payload. The housing was much lighter, and this time the drone was able to take flight. The payload was dropped twice; the first time did not result in the intended deployment, but the second time was a success. Additionally, this second experimental drop was done with our Pi housing atop, which successfully housed and protected its intended equipment from the elements, and even fit comfortably in our cargo cases.

**Conclusion (Levi Sagucio)** The drone project’s goal is not something that will take half a semester to do, but instead, is an experimental ongoing personal and career-like journey that can potentially take years to develop with collaboration between the HSFL, ARL, and our Portuguese counterparts. Currently, we've only touched upon a few small accomplishments with our inexperienced team, such as: successfully running DUNE on the Raspberry Pi and installation on the M100, demonstrated telemetry data from the M100 using the LSTS toolchain at the MANTAS event, using DUNE program and Neptus. But this is only one finished trial in the beginning stages. Our future work includes developing the software to upload pre-scripted commands for the M100 to execute, develop the software to relay commands from the satellite to the M100, and Integrate COSMOS with LSTS toolchain.We would like to reiterate about how this project has just touched the surface of the water this semester. As a team of new members being introduced into a new project, significant results are not going to come flying through the door every month. We were all trying to produce results meeting Professor Nunes standards. The significance of this semester was to get a better understanding of what the drone project is and to lay down some of the groundwork for future experimentation. We have some good showing of the capabilities of the drone during our test during the Maritime Awareness Network of Teaming Autonomous Systems (MANTAS) event. Some people might say that since we did not get concrete results that this could be a lose, but there is so many possibilities in the future for this project. This drone project could be the future in military advancement if things such as recon, mapping, search and rescue can be perfected with the use of drones.