University of Colorado
Department of Aerospace Engineering Sciences
ASEN 4018

Project Definition Document
BEACAN

Bouy-Enabled Analysis of Currents via Aerial Navigation

Monday 17$^{\text{th}}$ September, 2018

Approvals

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1. Problem Statement

Ocean currents are studied for applications involving search and rescue, navigation, and the spread of pollutants. In 2010, the Deepwater Horizons oil rig exploded causing an 87 day environmental emergency where an estimated 3.19 million barrels of oil leaked into the Gulf of Mexico [8]. During containment efforts, prediction of oil dispersion highlighted the need for better understanding of the currents in the Gulf of Mexico. In 2012, the University of Miami performed the first large scale deployment of ocean drifters in the Gulf, in efforts to study sub-mesoscale oceanic flows [9]. A drifter is a buoyant device that flows with ocean currents and records and transmits positional data. Current drifters are bulky and are typically deployed from ocean vessels. This presents multiple issues. Deployment costs are high; as ship time can exceed $10,000 per day [10]. The high cost of ship time leads to short deployment windows that result in bulk drifter deployment within a small area in a short period of time. Overall, deployment is costly due to the current structure of ocean drifters.

These highlighted issues can be addressed by designing a light-weight (under 0.5 [kg]), low cost (under $1000) NanoDrifter that can be deployed via an Unmanned Aerial Vehicle (UAV). Deployment costs will be drastically reduced along with an increase in deployment location precision via UAV. The team will design the lightweight NanoDrifter to track positional data up to 3 months along with designing a UAV wing mountable deployment mechanism that can store and deploy up to 2 drifters per wing. Once the drifter is deployed into a current, positional data will be recorded every 5 minutes and transmitted to a ground station up to 800 [km] away with a transmit latency of no longer than 24 hours. The team will also propose a method for comparing performance metrics of the NanoDrifter with drifters currently on the market. With a successful project, work will be initiated to release, in the Gulf of Mexico, 3-4 drifters per day over the span of 1 year. This work will further aid in environmental research by studying the large Loop Current and mesoscale eddies in the Gulf of Mexico. The Loop Current is a warm ocean current that flows northward between Cuba and the Yucatán Peninsula then loops clockwise across the Gulf of Mexico into the Gulf Stream.

2. Previous Work

Following the oil spill of 2010 in America's Gulf Coast, the Consortium for Advanced Research on Transport of Hydrocarbon in the Environment, or CARTHE, was put together in order to obtain an understanding of the oil spill's movements as well as the effects that it was having on the ecosystems of this region [1]. One of the main features of this team's research was the development and implementation of the drifters. These drifters were to collect Global Navigation Satellite System (GNSS) data as well as other scientific data while moving through near surface currents [3]. The drifters were successful in obtaining the desired data, however were required to be deployed from a boat in larger groupings [1]. Overall, CARTHE is a necessary study as they managed many of the requirements set before this team, but the mass requirements and deployment methods are an aspect that could be actively improved. One can find a similar theme when looking at MicroStar drifters. These drifters intended to improve mass requirements and general effectiveness of the process, but still require a boat or plane deployment method [5]. As mentioned before this is a very costly process. Despite the downfalls of these designs they are both successful implementations of near surface technology productive in the study of current, temperature, and various other forms of ocean data.

The Dropsonde is a weather device equipped with scientific instrumentation which is deployed from an aircraft. The Dropsonde uses a parachute to control falling velocity and help mitigate ocean impact force upon the drifter. Specifically, the Dropsonde uses a square cone-chute to stabilize velocity and aid in collecting atmospheric data during decent. The Dropsonde is unique in that the parachute deploys instantly after release due for reduction of the 'pendulum effect' [2]. The entire Dropsonde deployment process is an element to research when designing the team's NanoDrifter. The Dropsonde resulted in successful vertical screening profiles of atmospheric pressure, temperature, and wind speed. The gathered data is transmitted to a ground control station via radio transmission. Understanding these past methods are important to move forward with ideas and strategies for design of the NanoDrifter. The Dropsonde also incorporated levels of success categories which are similar to team BEACAN's specific objectives. The levels of success for Dropsonde were based on the information gathered pertaining to hurricane studies. The scientific systems for Dropsonde cover structures, environmental workings, and recognizing surface-based ducts in the hurricane where there is potential impact on electronic wave propagation [2].

The Lagrangian Drifter Laboratory's Autonomous Drifting Observatory Station (ADOS) is another brilliant drifter that undergoes an air deployment system. Several mission were conducted to measure the temperatures of the ocean currents that cut through inclement weather [7]. Transmissions for ADOS are performed with an Iridium Short Burst of telemetry.

3. Specific Objectives

	Level 1	Level 2	Level 3
Comms/ Radio/ Navigation	Navigation system and transmitter shall communicate over TBD link. System shall record position data at an average of every 5 minutes with an accuracy of 60 [m]. Stored data shall be transmitted every 24 hours.	Position data shall be accurate to 45 [m]. Stored data shall be transmitted every 6 hours.	Position data shall be accurate to 30 [m]. Stored data shall be transmitted every hour.
Structure	The total weight of two drifters and two deployment mechanisms shall be no more than 2.7 [kg]. Drifter shall remain fully functional after initial impact with water and shall continue to function for 3 months in standard ocean conditions.	The total weight of four drifters and two deployment mechanisms shall be no more than 2.7 [kg]. Each drifter shall be no more than 0.5 [kg].	Drifter shall remain fully functional in hurricane conditions. Drifter shall be biodegradable.
Deployment	Deployment mechanism shall release one drifter in a controlled environment via input signal.	Deployment mechanism shall function in an uncontrolled, high velocity environment.	Deployment mechanism shall release two drifters at separate times via input signals.
Electronics/ Power Budget	Electronics shall function as a subsystem to meet the Comms/Radio/Nav requirements. Power supply shall sustain electronics at full operation for 2 months.	Power supply shall sustain electronics at full operation for 3 months.	Power supply shall use renewable energy to last a maximum amount of time.
Hydro/ Aerodynamics	Drifter's hydrodynamic center shall remain 30 to 100 [cm] below the surface of the water resulting in reduction of disturbance from wind while in the water. Drifter shall land within 1 [km] of the desired drop location after being released from an altitude of 215 [m] under nominal wind conditions.	Drifter shall land within 1 [km] of the desired drop location after being released from an altitude of 300 [m] under nominal wind conditions.	Drifter shall land within 1 [km] of the desired drop location after being released from an altitude of 450 [m] under nominal wind conditions.
Cost	Each drifter shall cost $1000 to manufacture and build including the data budget cost.	Each drifter shall cost $800 to manufacture and build including the data budget cost.	Each drifter shall cost $600 to manufacture and build including the data budget cost.

4. Functional Requirements

Figure 1 shows the Functional Block Diagram (FBD) of the Nano-Drifter project. Key systems of the Nano-Drifter include: a micro-controller, a GNSS system, a ground communication transmitter, a power supply, a housing structure, and a deployment mechanism. The micro-controller will be responsible for regulating power among subsystems on the Nano-Drifter, as well as saving data to memory, and being able to process saved data for signal conditioning. The signal conditioner of the micro-controller will interface with the GNSS system and the ground communication transmitter. The GNSS system will consist of a simplex receiver for down-link only, and must be able to communicate to a GNSS Satellite, per protocol, successfully obtaining positional data every five minutes. The ground communication transmitter will have a one-way transmitting antenna that will enable the transmission of GNSS positional data to a ground station at a distance of at least 804.672 [km] at no longer than 24 hour intervals, by way of satellite communication (SATCOM). The Nano-Drifter power supply will provide power to the GNSS System, the micro-controller, and the ground communication transmitter. An optional renewable power source may be harnessed to feed additional power to the power supply, if there is sufficient need. All of the aforementioned subsystems will be housed inside of a structure. This structure will have a dual purpose of water proofing all water-sensitive electronics, as well as providing impact protection when the NanoDrifter is deployed at elevations ranging from 152.4 to 304.8 [m]. The structure of the micro-drifter will be attached to a TBD UAV through the use of a deployment mechanism. This deployment mechanism will secure two Nano-Drifters, per wing, to the UAV until a "high" voltage (3.3 Volts) is received by the mechanism, at which point one Nano-Drifter will be released. One NanoDrifter will be released per input voltage received, alternating between UAV wings. A summary of the functional requirements for the NanoDrifter is shown in the enumerated list below.

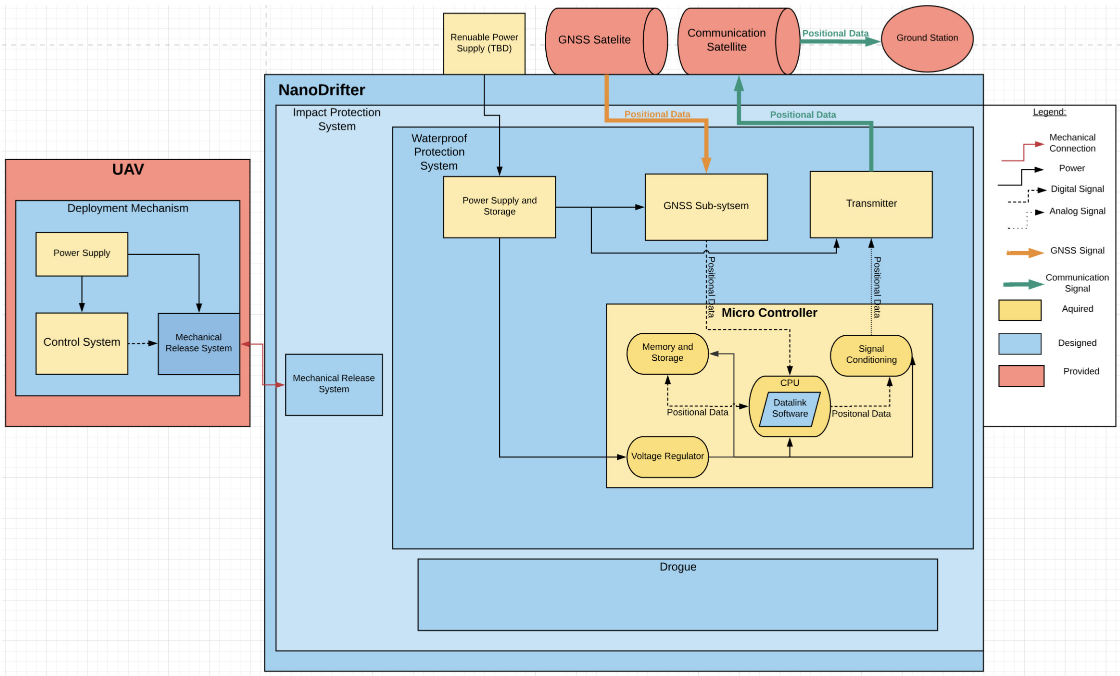

Figure 1. Functional Block Diagram

Figure 2 shows the Concept of Operations (CONOPS) for the NanoDrifter mission. Phase one begins with the launch of the UAV from Marcos Island, Florida, with the NanoDrifter payload attached underneath the wing. Phase one will be deemed successful with a successful mate between the NanoDrifter and its deployment mechanism. Phase two consists of the flight of the UAV to a target location with the NanoDrifter payload secured at an altitude between 152.4 and 304.8 [m]. Phase two success criteria is met if there is not an inadvertent deployment of the NanoDrifter when exposed to external disturbances. When the UAV reaches is target destination, phase three is initiated and a voltage signal is supplied to the deployment mechanism and one NanoDrifter is deployed into the Gulf of Mexico. Phase three is successful with the deployment of the NanoDrifter upon receipt of the input signal. Phase four of the mission encompasses the splashdown of the NanoDrifter. Success is achieved when the Nano-Drifter maintains full working capacity upon impact with the ocean. Phase five entails drifting and communication aspects. Success for phase five is defined as drifting with the desired ocean current at a depth of 30-100 [cm], receiving positional coordinates from GNSS every five minutes, and being able to transmit positional coordinates to a ground station up to 804.672 [km] away, with a latency of no longer than 24 hours

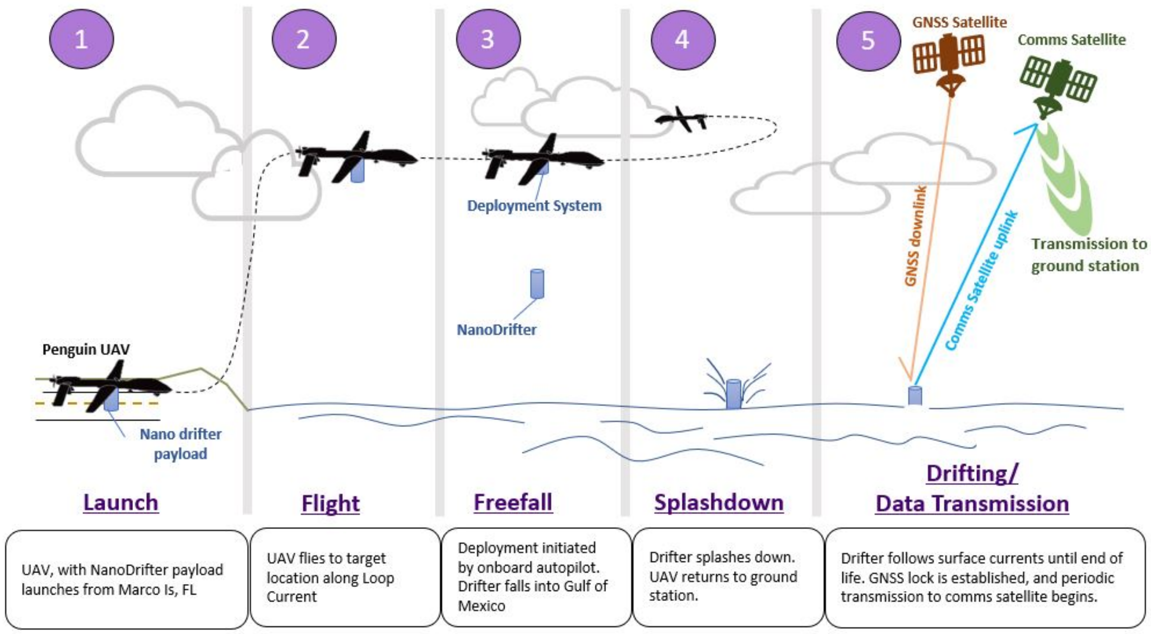

Figure 2. Mission Concept of Operations

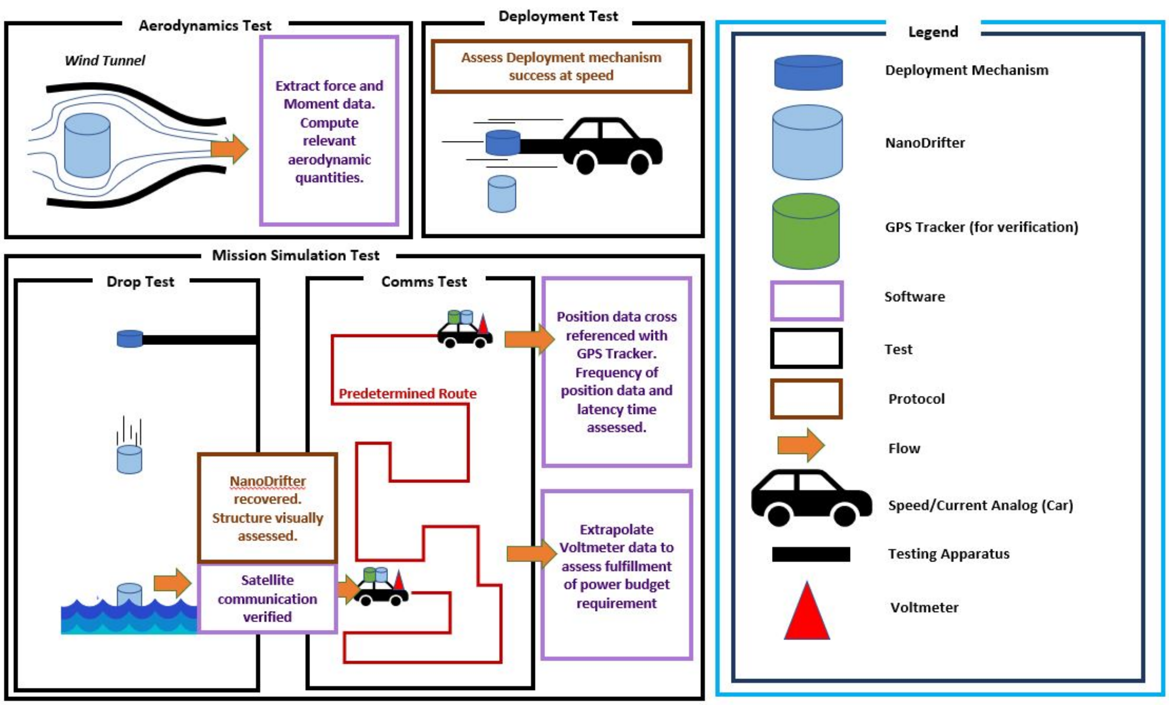

Figure 3. Project Concept of Operations

5. Critical Project Elements

5.1. Structure

The drifters will be transported via UAV. The UAVs have limited weight carrying capacity. Decreasing the weight of the payload will increase the range of the UAV. For this reason, each drifter shall not exceed 0.5 [kg] in order to meet the range requirement, which is carrying the drifters for 804.672 [km].

The deployment mechanism shall be able to drop each drifter individually as commanded by an autopilot. It is crucial to have a deployment mechanism that drops the drifters properly on target. If the drifters cannot be successfully deployed from the UAV, none of the project requirements can be accomplished.

The drifters shall remain fully functional after the impact once they are dropped from 152.4 and 304.8 [m]. Also, the drifters shall maintain structural integrity for up to 3 months after deployment.

5.2. Communication

The NanoDrifter shall record position data every 5 minutes, and shall transmit stored data in less than 24 hours of latency. Drifter shall be equipped with a TBD tracker to record position data, and a transmitter to send data to a communication satellite in orbit. A server, at most 804 [km] away, shall receive position data and maintain communication with the drifter at least every 24 hours. It is essential to report position data with minimum location error since the data will be used to study ocean currents. Communication link shall be classified into three categories, link budget and data budget, to ensure the functionality of these systems.

5.3. Aerodynamics and Hydrodynamics

A UAV that carries 4 drifters and 2 deployment mechanisms will experience an increase in drag and therefore fuel consumption. The drifter and deployment pairing will be designed minimize the drag effect upon the wing of a UAV. The drifter shall land in the target zone within 1 [km] of intended location. The hydrodynamics center shall follow the minimum 30 [cm] current depth and shall be minimally affected by surface effects including wind.

5.4. Cost

The customer is planning to drop 3-4 drifters per day over a 1 year period in the Gulf of Mexico. Thus, the manufacturing and assembling cost of a single drifter shall not exceed $1000. If the cost of a drifter exceeds this value, the project will not be financially feasible, since the purpose of this project is to provide an easier and less expensive solution for mass production.

5.5. Power Budget, Electronics, and Software

A power system shall supply enough power to all electronic hardware associated with a GNSS tracker and an analog communication transmitter for at least 3 months. In addition, a software shall link all electronic hardware to successfully send a signal to initiate deployment mechanics, signal process a received position data every 5 minutes, and transmit stored position data to a server at 804 [km] away. The weight of all electronic hard shall meet the minimum weight requirement.

6. Team Skills and Interests

Team Member:	Skills and Interests:	Relevant CPE
Omar Alshamsi	Enrolled in MicroAvionics, Worked on Radar system research, experience with STK, AnsysFluent and simulink	5.2 5.5
Meer Baker	Proficient in 3D Modeling (CATIA + Solidworks), Aerodynamics CATIA FEM Flow simulation. Interested in EE Electronics Embedded Systems Raspberry PI.	5.1, 5.3, 5.5
Eric Bergman	Machine shop experience including CAD/CAM, lathing, drilling, and g-code integration. Interested in mechanical design, manufacturing, and testing.	5.1, 5.3, 5.4
Elijah Landers	Experience in low level programming and algorithms. Interested in Aerodynamic and Hydrodynamic testing and design, along with Communications	5.2, 5.3, 5.5
Jack Lambert	Experience drafting in Solidworks and using fabrication work-spaces for manufacturing. Computer science minor. Interested in software and mechanical design.	5.1, 5.2, 5.5
Quentin Moore	Proficient in C. Experienced in statistical analysis. Interested in computational fluid dynamics	5.1, 5.3, 5.5
Alex Mulvaney	Electronics prototyping, PCB design, embedded experience, manufacturing and sourcing, financial, power budget, solar panels, COMs systems, RF	5.4, 5.2, 5.5
Donald Palomino	Experience in manufacturing and design of UAVs and payloads. CFO of DBF 2018. Interested in Aerodynamic and Hydrodynamic testing.	5.1, 5.3, 5.4
Brody Rosipajla	Experience in manufacturing and design of FPGAs, circuits, and other electronic's hardware	5.1, 5.3, 5.5
Wyatt Raich	Experience with multiple full-scale wind tunnel tests and wind tunnel data analysis. Experience designing CAD for CFD. Computer science minor. Experience with 3D printing and manufacturing. Interested in aerodynamics/hydrodynamics and cost analysis	5.1, 5.3, 5.5
Aytac Teker	Experience with using AnsysFluent. Interested in analyzing the drag calculations of the drifter, minimizing the impacts of dropping the drifter from 152.4 and 304.8 [m].	5.1, 5.3
Eric Zhao	Experience with creating models and meshes for FEA, work with dynamic/mechanic simulations. Computer science minor. Interested in structural analysis and software	5.1, 5.2, 5.5

7. Resources

Critical Project Elements	Resource/Source
Aerodynamics / Hydrodynamics	Wind Tunnel (Dr. Farnsworth), Computing Power
Structure	ITLL Stress Testers
Communications / Navigation	System Tool Kit (STK), GMAT (General Mission Analysis)
Power Budget / Electronics / Software	ITLL Electronics Lab
Construction Manufacturing	Bobby Hodgkinson, Trudy Schwartz, Matt Rhode, Senior Projects Lab, Composites Lab
Funding	Robert Leben, Michael Shannon

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