The Thunderstorm Project – Iowa State University

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Abstract

The High Altitude Balloon Experiments in Technology (HABET) program is located out of Iowa State University within the Make to Innovate program. The Make to Innovate organization is a group of college level engineers and students of other majors doing assorted projects dealing with high altitude ballooning. This paper will discuss a new project that looks at obtaining meteorological information from a thunderstorm using high altitude balloons. The main information that we are looking for is readings of pressure, temperature, humidity and eventually heavy metal testing of precipitation at various altitudes. Storm fronts can grow to extreme heights and this causes the storm to pull heavy metal gas substances from lower atmosphere levels. The wanted information will be obtained using a mesh network compiled of many sensors attached to several different nodes, this will allow for the collection of data at several locations in the thunderstorm and to aid in moving this data to the ground station. The types of sensors we will be using will include ones for the basic material that was discussed above. The information that we are planning on gathering will be used to aid research and class based activities with the meteorology department here on the Iowa State campus. Recently members from the meteorology program have joined forces with us and this has allowed us to expand our horizon on what we are capable of doing within this experiment. This paper will also discuss what testing has been done this last year and the future work for this project.

I. Introduction

All across the country thousands of college students and faculty members' wake up aspiring to do something ground breaking in their respective fields. The Make to Innovate (M2i) program is the means of doing this for many students of many different disciplines on the Iowa State University campus. The M2i program consists of many different educational and skill-building challenges that mainly revolve around engineering. One of the biggest groups from this large, diverse list is HABET. HABET stands for High Altitude Balloon Experiments in Technology. The primary goal of HABET is to research atmospheric phenomena and daily happenings at upwards altitudes of 150,000 feet above sea level. Due to the fact that HABET is such a large group, this being due to the fact it is one of the original groups in the M2i program and has had large success in popularity with students on campus, it has to be divided into subgroups. These subgroups each have their own individual challenges and missions that they are setting out to achieve. The group that will be primarily talked about during this paper will be a group called Thunderstorm.

II. Body

Thunderstorm is a relatively new project, and due to the overall HABET team's recent expansion, it has allowed Thunderstorm to begin serious work to achieving its mission requirements. The recent expansion that HABET has undergone is an outreach with the meteorology department here on campus. Several members from the school of meteorology have decided to join HABET in the interest of science and to aid in research. The mission requirements for the Thunderstorm project are to send a multi-node mesh network system into actual storm cells to relay and retrieve information to be used in aid of research and to gain a better understanding of what happens during a thunderstorm. Most places that launch ordinary weather balloons tend to not launch them into the heart of the storm, this is due to the fact that the balloons tend to have failures and not enough relevant information is gained from the flight. This is why a mesh network system has been the primary basis of how we are going to mitigate this problem. By sending up multiple nodes with the ability to communicate with each, and also communicate with our ground station, we plan on there being enough information gathered from different geological locations to be able to give us this understanding that has yet to be discovered of the internal happenings of a storm cell.

The fact that Thunderstorm is such a new project lead to us having a lot of internal work and structuring to be done during the beginning of the year. The new members being added to the team allowed the scientific aspects of our project to be the main focus of our early research this year. Bringing on the meteorology students was probably the best thing that we have done in recent years. Adding them has allowed us to broaden our horizons and add new facets to our experiment. The main contribution from the meteorology students this semester has been gaining a larger understanding of how thunderstorms function and eliminating some immediate risks that we believe were going to be substantial problems. The main risk that they laid to rest of the risk of icing. We believed that icing was going to cause us to have catastrophic issues with our equipment. A couple of the meteorology students reached out to an outside resource in Oklahoma to gain necessary information to allow us to find out that icing was not going to be a large problem.

Another major thing that the meteorology department has done for us is given us an extremely interesting engineering challenge. Mercury is an extremely harmful heavy metal for our ecosystem and when a storm cell because very large it reaches lower atmosphere and pulls gases from that general area that are then cascaded to the ground as precipitation. The task of being able to gather water samples at different geological locations and altitudes and then testing them for gas content was brought to us as one of our first challenges from them. Eventually in long-term we hope to have the Thunderstorm project be a group that is consistently given challenges, like this one, from outside sources, not just limited to the Iowa State campus. At first the idea of instantaneously vaporizing water at different locations and having gas sensors to analyze the vapor was tossed around. This was later substituted with an idea of capturing the water and bringing it down to a testing center to be analyzed. This is mostly because of the fact that Mercury content is going to be a rather important aspect to this experiment and there are no gas sensors to test Mercury that are obtainable by us. The basis of this prototype is a rotating table that will have collection vials in it that will be configured with a pressure sensor. This pressure sensor will be able to tell our table, which will be placed on top of a servo, to rotate at different altitude levels based on the pressure that is received. There will also be a funneling system located on the outside of the payload that will allow us to bring water into the desired vial at the desired altitude. The funneling system is still yet to be designed and is going to be one of the main focuses moving forward.

Another main experiment moving forward is one thing that the Thunderstorm group originally wanted to do, which is to rely on the updraft of storms to give us a large portion of our lift. This would cause our nodes to spread out more sporadically and hopefully will keep them in the girth of the storm cell, opposed to over the top of it. Our team did a lot of research into the types of storms in the general area of Ames, IA, and devised multiple charts with average updraft velocities. These charts can be seen in Figure – 1, Figure -2 and Figure 3. From the information that was gathered, a code was written to allow us to find the lift force that would be created from each type of storm that we could be hit by in our general area. This code was created towards the end of the spring semester and there was not a launch afterwards so the testing of it is going to come in our next few experiments. These experiments will allow us to find the accuracy of our generalization.

Finally the last thing that was worked on throughout this school year was the creation of our mesh network system. Early on we were faced with the difficult task of find the hardware we were to use. There are tons of different boards that we could have used for our mesh networking system. Some of them can grow to become an extremely expensive investment. One of the first thoughts that went into deciding the hardware was getting something that was relatively inexpensive. This idea was brought on by the fact that we may not be able to recovery all of our nodes, and having something that is not going to break our budget would allow us to be able to lose a payload without it being catastrophic. Eventually the hardware decision came down to the Adafruit Huzzah Feather boards. These would give us the durability needed, the functionality required, and would not damage our budget substantially. Another great facet of these boards is that they can communicate through WiFi signals on a personal SSID. Once the boards were ordered and received, a code in C was created to allow them to freely communicate to one another. This code for the time being is extremely low-tech for what we need and can be considered just a "Hello World" code. This will be expanded upon later on and will allow the nodes to independently transfer the information we are attempting to gather from the storm cells. A screen shot of the code can be seen in Figure – 4.

III. Conclusion

The Thunderstorm Project is a relatively new one, and in my opinion, and the opinion of many others, is an extremely interesting one. The basis of the experiment is to combat normal difficulties of sending weather balloons into actual storm cells by sending multiple nodes up in a mesh network system. This mesh network will allow us to push our boundaries as growing engineers along with giving us a more accurate picture of what actually is happening in different meteorological phenomena. With the recent acquisition of students from the meteorology program here at Iowa State University we have now made our boundaries increasingly farther away, making what we can accomplish an astronomically larger amount. While this semester was mostly revolved around the starting structure of our group and getting everyone on board, we were still able to work on some smaller side projects. The water catching apparatus that was spoke of early to gather water samples is going to be a large part of our work moving on from here on out, as well as the updraft velocity work that has been done. Once the bugs of our system are worked out and everyone finds a spot that most suits them and their skill set we plan on taking flight and not looking back. The fact that this is a new project makes for an exciting future within the Make to Innovate program for our group. We hope to one day be in a stable enough situation where we can consistently receive missions from outside sources, not just limited to our campus, and be able to smoothly and quickly execute the tasks at hand.

IV. Figure Library

Figure – 1

	CAPE Values (J/kg)	Maximum Possible Updraft Velocity (m/s)
Marginally Unstable	200	10.0
	1000	22.4
Moderately Unstable	1000	22.4
	2500	35.4
Very Unstable	2500	35.4
	3500	41.8
Extremely Unstable	3500	35.4
	6000	54.8

Figure – 2

Iowa Events (for an idea of what to expect storm wise)						
Date	Time (UTC)	Storm Type	Formation	Severe Reports	CAPE (J/kg)	Stability
11/11/2015	20:00	Clustered Supercells	Low Triple Point	Tornadoes	200	Marginal
8/22/2015	22:00	Linear	Cold Front	None	2900	Very
7/27/2015	12:00 - 18:00	MCS / Linear	Stationary Front	Hail/Wind	1500-2000	Moderate
7/6/2015	1:00	Supercells	Cold Front	Tornadoes	2500	Mod/Very
6/24/2015	0:00	Supercells/Multicells	Warm Front	Tors/Hail/Wind	1500	Moderate
6/20/2015	23:00	Linear	Cold Front	Wind	3000	Very
5/10/2015	1:00	Supercell	Cold Front	Tornadoes	800-1000	Marginal
4/8/2015	3:00	Single Cell	Outflow	Hail	<100	Below Marginal
6/30/2014	18:00	MCS	Shortwave	Tors/Hail/Wind	2200	Moderate
5/3/2012	0:00	Single Cell	Cold Front	Hail	1500	Moderate
5/1/2012	8:00	Squall Line	Stationary Front	Wind	100-200	Below Marginal

Figure – 3

Documented Updraft Soundings			
Storm Type	Launch Position	Still Air Rise Rate* m/s	Max Ascent Rate** m/s
Multicell hailstorm	behind convective core	3.5	8
Isolated supercell	behind wall cloud	5	5
Multicellular line	behind line	3	4
Squall line	gust front ahead of line	4	8
Multicellular line	leading edge of line	6	13
Tornadic Supercell	beneath mesocyclone	6	15
Tornadic Supercell	beneath mesocyclone	6	45
Bow echo MCS	leading edge of line	5	20
Multicellular line	gust front ahead of line	4.5	16
Isolated supercell	behind convective core	3.5	13
Tornadic line	near convective core	5	8

Figure – 4

HelloMesh §

```
#include <ESP8266WiFi.h>
#include <ESP8266WiFiMesh.h>
unsigned int request_i = 0;
unsigned int response_i = 0;
String manageRequest(String request);
/* Create the mesh node object */
ESP8266WiFiMesh mesh_node = ESP8266WiFiMesh(ESP.getChipId(), manageRequest);
/**
 * Callback for when other nodes send you data
 *
 * @request The string received from another node in the mesh
 * @returns The string to send back to the other node
 */
String manageRequest(String request)
{
  /* Print out received message */
  Serial.print("received: ");
  Serial.println(request);

  /* return a string to send back */
  char response[60];
  sprintf(response, "Hello world response #%d from Mesh_Node%d.", response_i++, ESP.getChipId());
  return response;
}
void setup()
{
  Serial.begin(115200);
  delay(10);
  Serial.println();
  Serial.println();
  Serial.println("Setting up mesh node...");
  /* Initialise the mesh node */
  mesh_node.begin();
}
void loop()
{
  /* Accept any incoming connections */
  mesh_node.acceptRequest();
  /* Scan for other nodes and send them a message */
  char request[60];
  sprintf(request, "Hello world request #%d from Mesh_Node%d.", request_i++, ESP.getChipId());
  mesh_node.attemptScan(request);
  delay(1000);
}
```