Balloon Project 2004 - 2007

A Remote data acquisition and air sampling system for quantitative and qualitative air quality research

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Abstract:

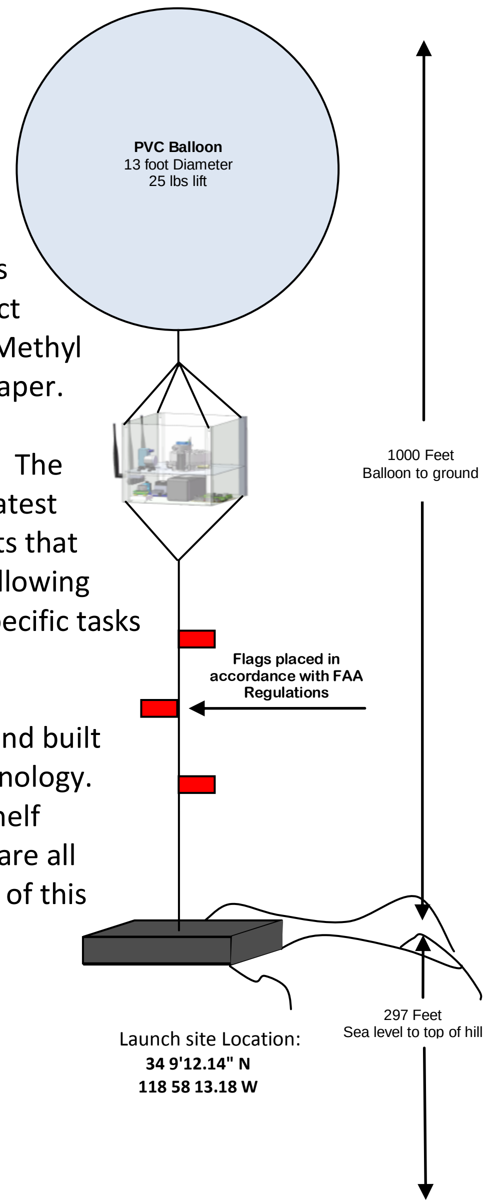
The Balloon Project fulfills two goals: (1) it is a research project designed to identify and understand the propagation of the pesticide methyl bromide in the atmosphere and (2) it demonstrates a research instrument that is designed to collect and store air samples, transmit and record pertinent data, and provide a secure and sustainable research platform for atmospheric research.

The purpose of this project is to employ a wide spectrum of technology to achieve the goals of autonomous, wireless, reliable, and precise air sampling and data collection.

Many different systems are utilized to provide services to the balloon and ground. These systems include the Air Sampling System, Power and Distribution Systems, Telemetry & Avionics Systems, and the structural components of the gondola and the balloon.

Introduction:

The Balloon Project is both a demonstration of environmental research on the front of pesticide research and also a project that is purely based in engineering. This dichotomy of both building a research tool and using it in a research project makes distilling the project to a few paragraphs and diagrams difficult. For the purposes of this paper the focus will be on the mechanics, engineering, and capabilities of the Balloon Project systems. The actual use of this project, the quantification of the pesticide Methyl Bromide in the inversion layer, will not be discussed in great detail in this paper.



The Air Sampler and its abilities are the most important part of this project. The sampler was designed and fabricated over a span of one year utilizing the latest in computer aided drafting and CNC machining techniques. The instruments that support the sampler were also very challenging to design and build. The following sections will provide an overview of the systems that were created to do specific tasks to facilitate air sampling and data collection.

Most of the components that make up the Balloon Project were designed and built by hand. Some of the components are adaptations of already existing technology. And almost none of the onboard systems are made up entirely of off-the-shelf hardware. The Air Sampler, Air Sampler Controller, Software, and Gondola are all examples of technologies and assemblies that did not exist before the start of this project. The purpose of these tools helps facilitate the greater need of autonomously collecting air samples and the storing and transmission of pertinent data.

Air Sampling System

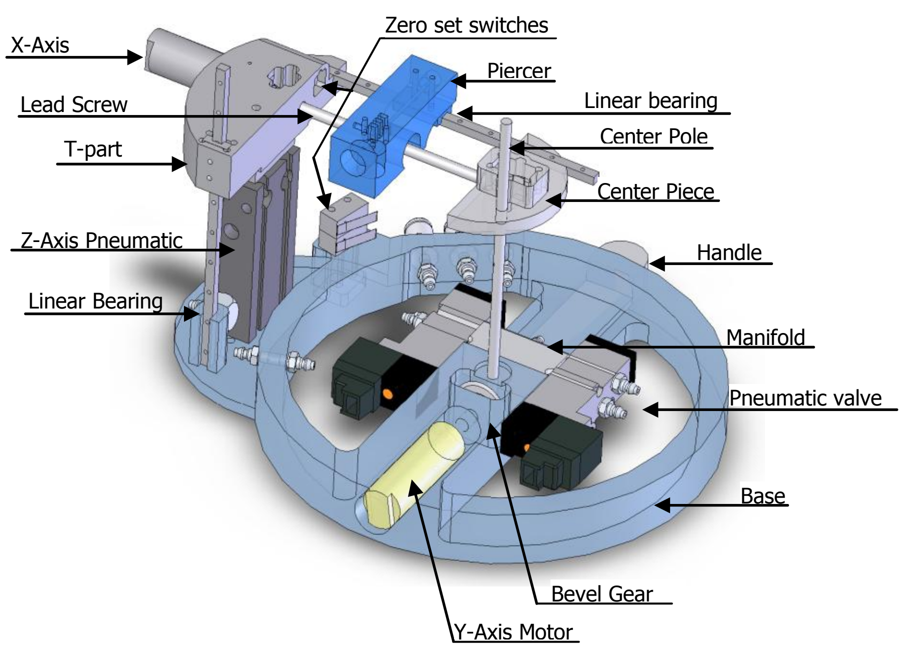
The techniques and technology employed to capture and store air samples can be used as a tool in a number of other environments that differ from our planned use of pesticide research. Volcanic research, hazardous waste areas, law enforcement, upper atmospheric air sampling, and ground based long term research, are all examples of places where an autonomous machine that can take air samples would be very useful to facilitate the acquisition of knowledge and information.

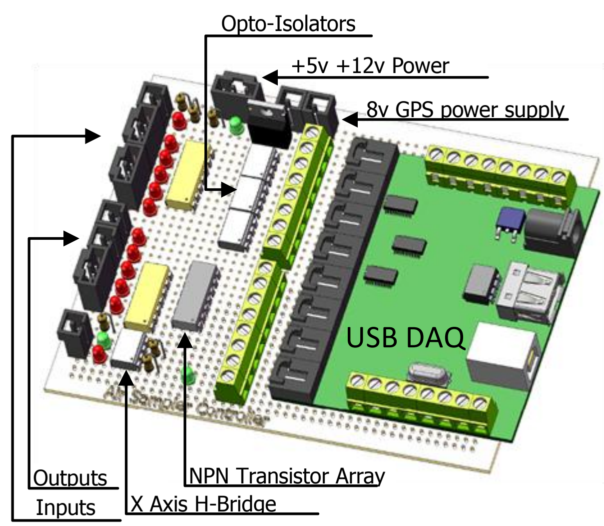
The Air Sampler was designed to solve the unique problem of taking air samples in places that are not easily accessible. It does so by being lightweight, remotely operated, and by including the ability to fulfill several niches in research by being expandable. This instrument supersedes the abilities of traditional air sampling techniques which involve the hands-on process of filling individual bags with air. The limitations of this process are apparent: (1) an individual must be present to take the sample; (2) the sample is limited by location and interval as the person filling the bag must be physically present; (3) the sample is susceptible to human error; and (4) cumbersome inflated bags are hard to handle.

The automated air sampler is a technology that can go places that researchers may not have easy access to. It can take samples at a set interval with no external controls, and can also capture other pertinent data in conjunction with its air sample such as GPS coordinates or temperature.

The Air Sampler is powered by both motors and pneumatics. The Sample Drum (not shown) is capable of holding up to 50 air samples for extended periods of time. The Air Sampler is controlled by hardware that interfaces with a computer by USB. The computer acts as a web server making it possible to remotely activate and monitor functions of the air sampler as well as other data.

The air sampler is expandable: with the current system sorbent tubes can be added for particulate collection. An interface between the air sampler and the gas chromatographs is being developed as well as the inclusion of valves that can accommodate water for automated water sampling.





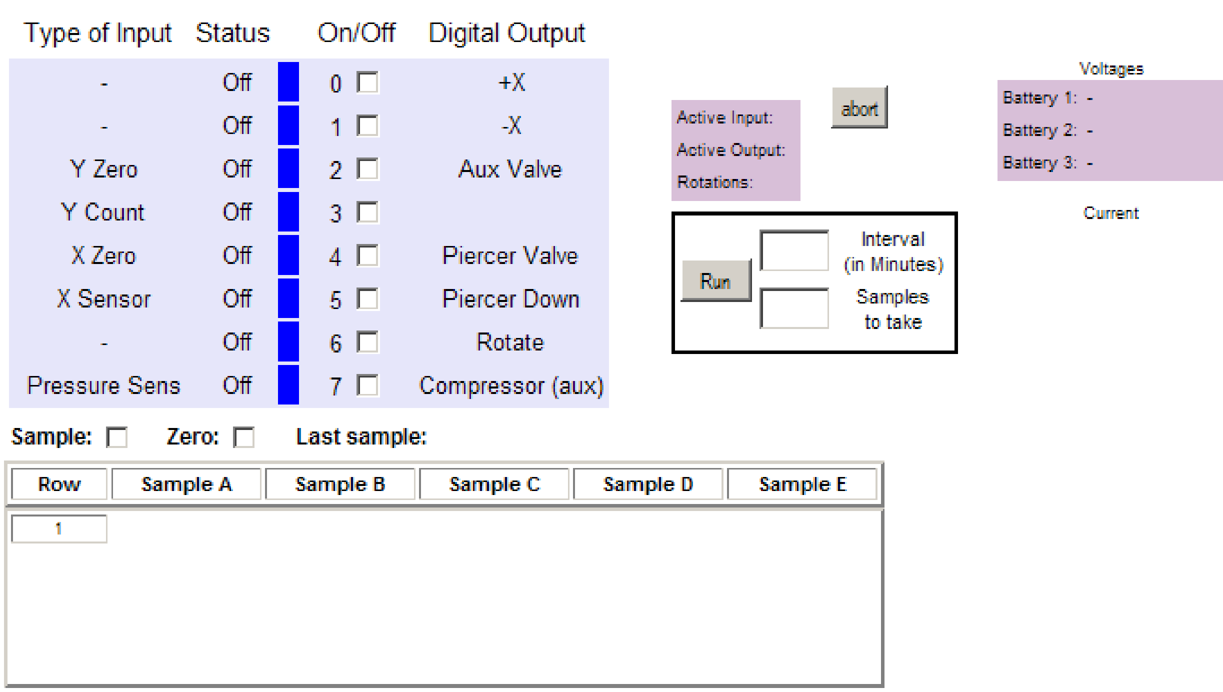
Telemetry & Avionics Systems

GPS, temperature, video, remote emergency deflation, and remote control of the air sampler are some of the most important telemetric capabilities of the balloon. GPS coordinates are logged and transmitted to the ground where a laptop in the field can track the location of the balloon in Google Earth software. Because of the limitations of GPS, altitude is tracked by a separate pressure sensor and is accurate to within 9 feet.

The electrical system is monitored as well as battery temperature, CPU temperature, and ambient temperature in the gondola of the balloon. These Devices can be physically monitored by a camera monitored inside the gondola providing a video feed of Air Sampler. Another camera that can be panned and tilted provides a live view from the balloon. These separate video feeds are transmitted by dedicated 500mW 900 MHz TV transmitters.

The balloon is equipped with a single control surface: in the event that the balloon escapes its moorings it can be brought down by an emergency deflation system. The system is built around a long range 2.4 GHz transmitter/receiver that is completely dedicated to the task of emergency response. When triggered, a circuit is activated that allows current to flow through a piece of nichrome wire that is affixed to the top of the balloon. The heating of the wire is sufficient to melt a small hole in the fabric of the balloon.

The onboard 1GHz VIA Epia Nano computer with 400mW wireless network card is more than capable of logging and transmitting data. It was chosen for the unique purpose of acting as a web server. The image below is a webpage that is served by the balloon. All Air Sampler functions can be controlled and the current status of the air sampler is logged and viewable. The onboard computer has the ability to join any standard wireless network and allows for wireless encryption to ensure data security.

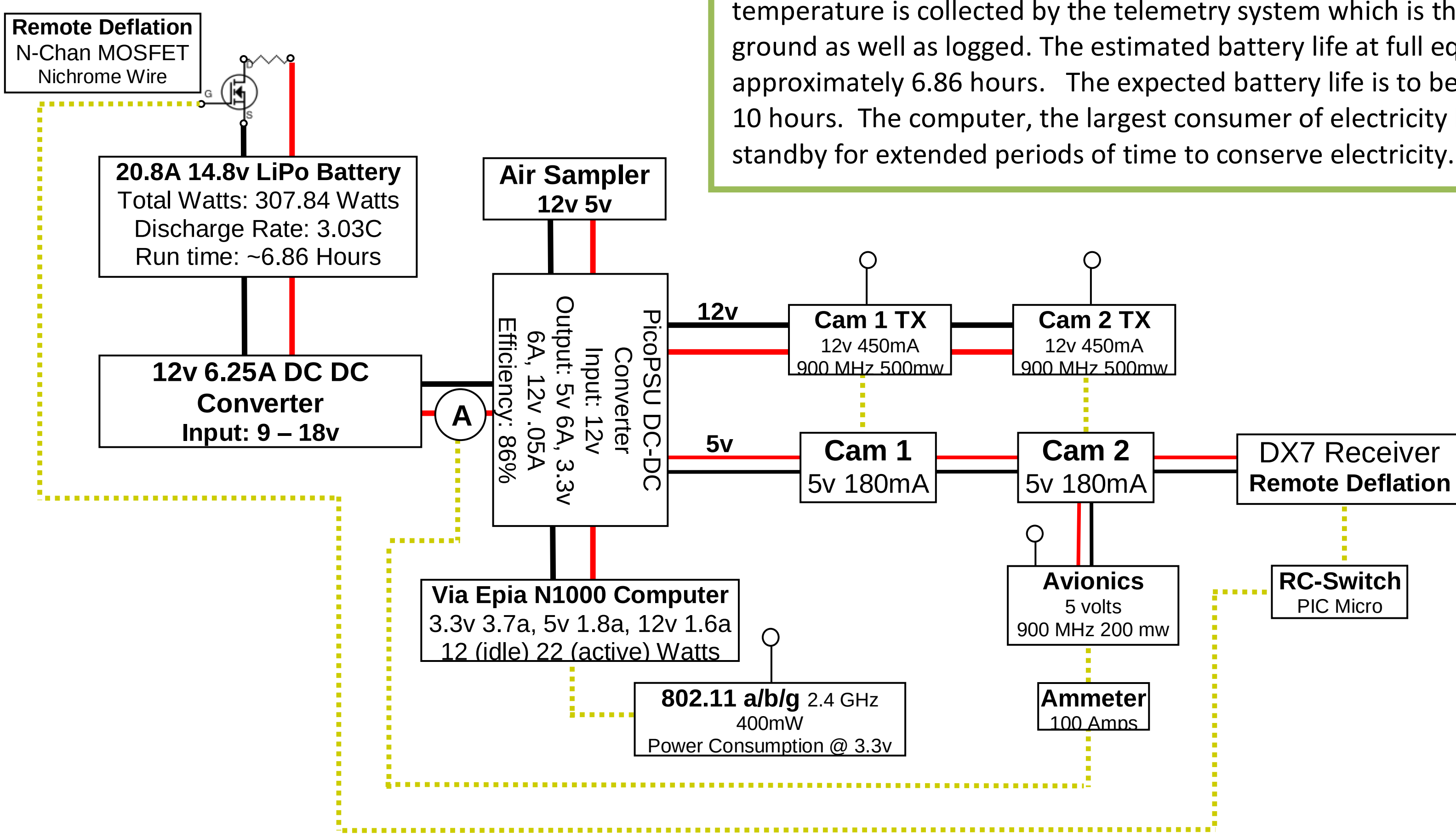


Power Distribution Systems

A battery-operated system was chosen after much research on a power source that could serve the project best. Much time was put into the consideration of a system that was powered from the ground. The problems with this type of system are immense—resistance in the wire to the balloon led to a considerable voltage drop.

The stepping down of high voltages required expensive custom manufactured toroidal transformers. AC to DC conversion was heavy and inefficient. And the hazards of high voltage electricity were immense. The benefits of an always-on system were heavily outweighed by the drawbacks. Battery power was a more viable solution.

Power for the instrumentation is supplied by a 14.8 volt 20.8 amp lithium polymer battery. The power from the battery is conditioned to usable voltages by two high efficiency DC to DC converters. Current consumption, voltage, as well as battery temperature is collected by the telemetry system which is then transmitted to the ground as well as logged. The estimated battery life at full equipment usage is approximately 6.86 hours. The expected battery life is to be somewhat closer to 9 to 10 hours. The computer, the largest consumer of electricity has the ability to go on standby for extended periods of time to conserve electricity.



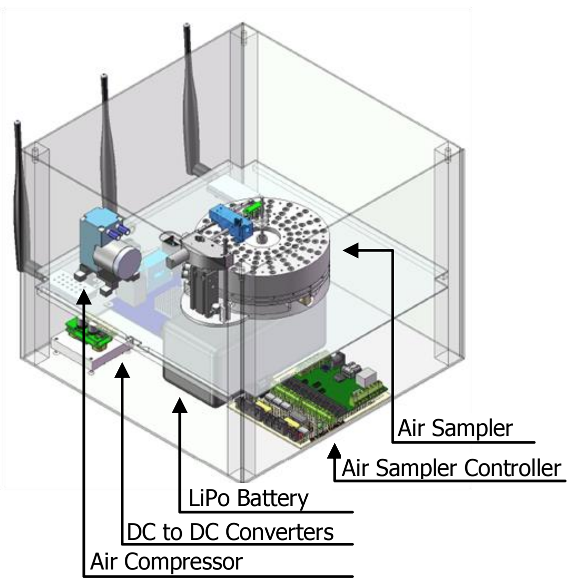
Average Power Consumption	
Epia N1000	17
802.11 a/b/g	2.48
Cam 1	0.9
Cam 2	0.9
Tx 1	5.4
Tx 2	5.4
DX7 Receiver	0.15
Avionics	0.25
Air Sampler	0.3
Pico PSU Loss	5.90
12v DC DC Loss	6.19
Total Watts/Hour	44.87

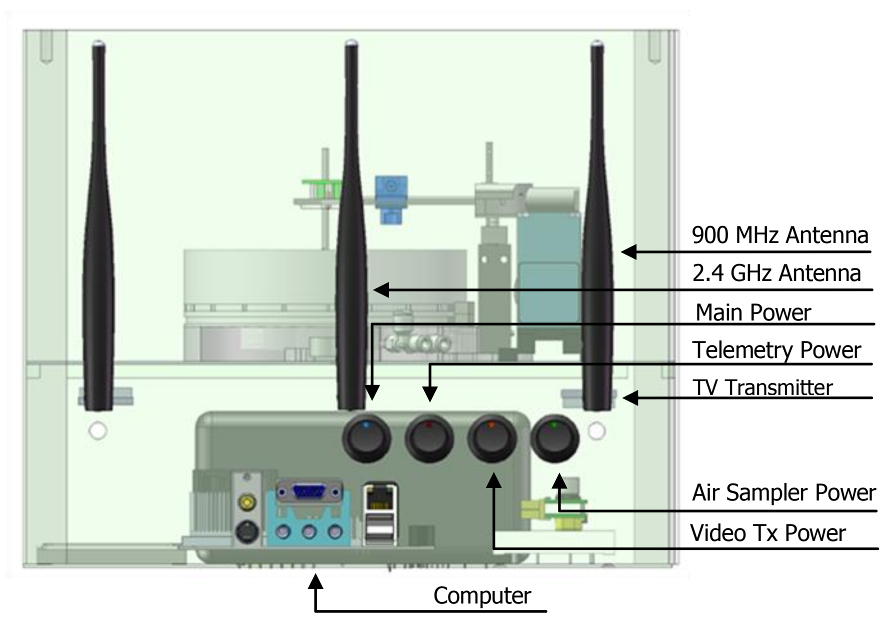
The Gondola and the Balloon

The gondola is made entirely of clear acrylic. It was designed to distribute load between the balloon and the tether effectively while remaining lightweight. Four ¾" acrylic beams in each corner of the box provide vertical strength while ¼" spars provide horizontal strength and prevent against lateral divergence. The ¾" acrylic beams are the mounting point for ¼" eye bolts which are the connection point between the balloon, tether, and the gondola. The tether, 3000 lb test "Spektra" line, is affixed to the bottom of the gondola.

The balloon is 13 ft in diameter, made of PVC, and can lift up to 25 lbs. It has been custom manufactured to meet specific demands: the ability to withstand wind gusts, low porosity ensuring <1% losses of helium per day, and low cost.

The winching system was salvaged and re-purposed for this use. It can be operated on site by a remote controller and allows for quick and easy deployment of the balloon.





Conclusion:

The Balloon Project is significant not only in the realm of its technical accomplishments but also in the many different fields of science that it is applicable. The air sampling instrument and sampling techniques developed are not only limited to balloon-based research. Telemetric and data acquisition techniques utilized in the gondola of the balloon can also be extrapolated to fit the needs of a myriad of different uses and applications. The systems and instrumentation of the Balloon Project offer a unique set of tools to researchers looking to answer some of the most vexing of questions. This alone is the most significant characteristic of the Balloon Project: its unique ability to scale to the needs of other research goals and provide itself as a tool to researchers in a number of different fields.