Automated Weather Balloon Radiosonde Launcher Development

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Introduction

Balloon-borne radiosondes are a primary means used by the Atmospheric Radiation Measurement (ARM) Program to collect atmospheric data. Currently, three radiosondes are launched daily from the Central Facility at the ARM Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site during non-intensive observation periods (IOPs). During IOPs, eight radiosondes are launched daily from the Central Facility and from each of four boundary facilities, for a total of forty daily launches. Launching balloons during IOPs is a major effort, in terms both of logistics and manpower.

ERC, Incorporated is currently developing an automated weather balloon launcher under a U.S. Department of Energy (DOE) Phase I Small Business Innovation Research (SBIR) grant. The goal of the project is to develop an automated multiple balloon launcher capable of launching up to eight sondes at prescribed intervals, acquiring the data from each flight, and making the data available for network data transfer to a centralized data acquisition facility. If a reliable multiple balloon launcher can be developed, it will provide a substantial benefit for the ARM Program in terms of logistics and reduced manpower requirements.

During the Phase I research program, a prototype automated single balloon launcher was designed and constructed. The prototype launcher was field tested at the SGP CART site during January 1998. The launcher design, field test results, and plans for continuation of the project if Phase II is funded are discussed in the following sections.

Launcher Design

Automated launch of a helium balloon-borne radiosonde requires the accomplishment of a series of discrete steps. The steps are as follows:

1. Hydration of the radiosonde battery

2. Aspiration of the sonde to bring the instruments to ambient conditions

3. Ground check of sonde instruments to confirm correct operation of pressure, temperature and humidity sensors, and that the required Loran-C signals are being received

4. Filling of the balloon to the proper volume with helium and releasing.

Structural/housing requirements for an automated launch include a weather-tight enclosure to protect the balloon and sonde from the elements until time for launch and a wind screen to protect the balloon during filling. A particular concern in the wind screen design is preventing the sonde from impacting on the wind screen structure after the balloon is released, as the instruments can be damaged easily.

The features of our Phase I prototype automated launcher are most easily described in terms of the steps listed above.

Weather-Tight Enclosure. The weather-tight enclosure for our Phase I prototype single-balloon launcher is constructed from a unistrut framework with Plexiglas covering. All of the launcher components are inside the enclosure. The wind screen is a separate structure that surrounds the launcher. A sliding door on the top of the enclosure is opened at the start of the launch sequence. A prepacked cartridge containing the sonde, unwinder, parachute, spreader and balloon is inserted through this door. The enclosure is shown in Figure 1 and the launch cartridge is shown in Figure 2. Figure 3 shows a cartridge being loaded into the launcher. The sliding door design was selected because it minimizes the possibility of the door jamming due to ice or snow buildup and does not obstruct the top of the enclosure while the balloon is being inflated.

Wind Screen. The wind screen employed for the Phase I prototype consists of four 6 ft x 10 ft canvas tarpaulins mounted on a pipe framework. The launcher enclosure sits

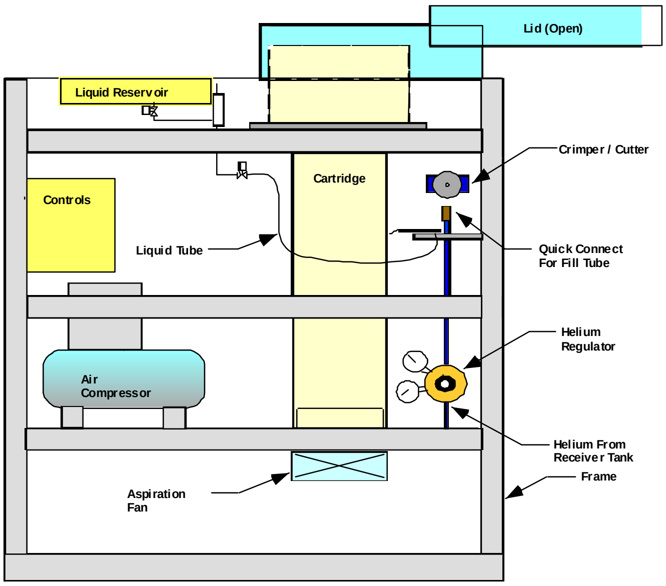

Figure 1. Phase I prototype balloon launcher arrangement. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/foote-98.pdf*.)

inside the windscreen so the launch cartridge is centered between the tarpaulins. The wind screen provides adequate protection for the balloon during field testing with wind speeds up to 5 m/s.

Battery Hydration. The Vaisala RS 80 radiosondes used by the ARM Program use a cuprous chloride-type battery that is hydrated shortly before launch. Our approach for automatically hydrating the battery is to place the battery into a waterproof, open top box. The boxed battery is installed in the sonde battery cavity and a hole is cut through the cardboard housing of the sonde to provide access for a water tube. The water tube is flexible, so the tube does not impede movement of the sonde when the balloon is released. To hydrate the battery, water stored in a small reservoir sized to hold 45 ml is allowed to gravity drain into the battery box.

Sonde Aspiration. Aspiration of the sonde with ambient air is required to bring the sonde instruments to ambient conditions. It is important for the sonde instruments to be at ambient conditions before launch for two reasons. First, the sonde instruments are compared to ground station instruments to confirm correct operation of the sonde instruments. Second, the data collected by the sonde during the first 100 m of ascent is of great interest, so it is important for the sonde to start the flight at the correct ground conditions.

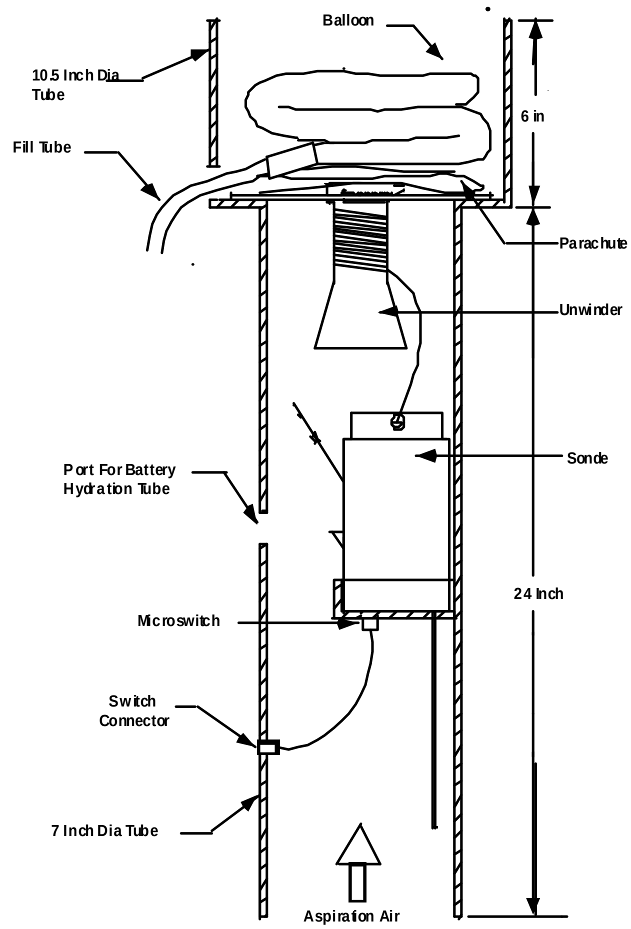

Figure 2. General arrangement of prototype launch cartridge.

In the Phase I prototype, our approach for sonde aspiration was to place a fan at the bottom of the launch cartridge, which draws in air through the top of the cartridge while the enclosure door is open. During field testing, it was found that the sonde temperature reading was consistently 1.0 °C to 1.5 °C higher than the ground instrument, with a corresponding relative humidity reading 10% to 15% lower than the ground reading. (Ambient temperature was near 0 °C.) The primary reason for the higher temperature reading was that the air inside the wind screen was warmer than the air outside. In the future, we plan to duct the aspiration air from outside the wind screen in order to maintain the correct ambient temperature, and it may also be necessary to insulate some of the launcher components to minimize heating or cooling of the aspiration air.

Ground Check of Sonde Instruments. The sonde temperature, pressure, and humidity instruments are checked against ground station instruments before launch. The

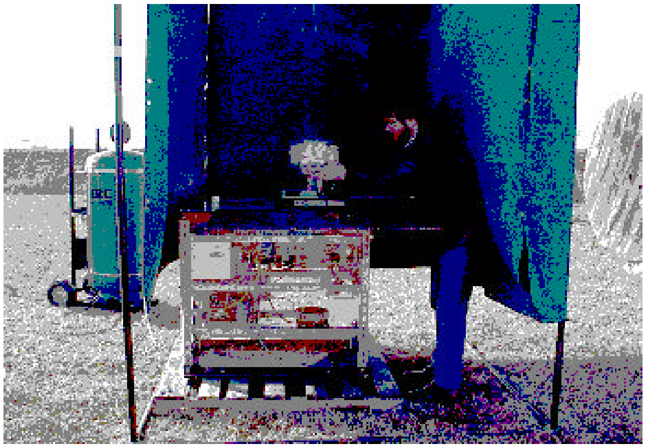

Figure 3. Launch cartridge being loaded. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/foote-8.pdf*.)

ground station computer also confirms that the required Loran-C signals are being received. If all instruments are operating correctly, the ground station generates an "OK to launch" message. Before starting the ground check, the ground station radio receiver must be tuned to the sonde transmission frequency, which is in the range of 400 MHz to 406 MHz. The Vaisala receivers used by ARM have an automatic tuning feature that scans from 400 MHz to 406 MHz and locks onto the strongest signal; however, it is possible for the receiver to lock onto a spurious frequency, in which case the operator must restart the scan. Also, before starting the ground check, the sonde calibration coefficients are read into the system. The coefficients are either read in through a paper tape reader or entered using the ground station keypad.

During our Phase I testing, the ground station functions were not integrated into the automated balloon launcher system, and all ground check functions were performed manually. Integration of the existing ground station instruments for pressure, temperature, humidity, wind speed and wind direction, which are presently read and recorded manually, into the automated system should be straightforward because all of the instruments have analog outputs.

Fill and Release Balloon. A volume fill method is used to automatically inflate the balloon. An 8-ft^3 receiver tank rated at 200 psig is pressurized to 180 psig with helium from high-pressure bottles. When a balloon is filled, the tank pressure is dropped to provide the desired helium volume in the balloon. Because the tank is at ambient temperature, no temperature compensation is required to calculate the gas volume. Computer-controlled valves are used to fill and dump the receiver tank and a pressure transducer is used to measure the tank pressure. For the 350-gram balloons used by the ARM Program, the maximum balloon diameter used is 5 ft, which requires 65.5 ft^3 of gas. To provide this amount of gas, the receiver tank pressure is dropped from 180 psig to 60 psig. The amount of gas to be supplied for a given launch is specified by the user by inputting the lower pressure limit. During testing we found that the balloon can be consistently filled to within 1% of the desired diameter.

To connect the balloon to the helium supply, a fitting is installed in the balloon neck. The fitting fits snugly inside the balloon neck and is secured by a wire band. A length of Tygon tubing is attached to the neck fitting. The tubing passes through a crimper/cutter assembly and is connected to the helium supply by a quick connect fitting. A copper crimp ring fits snugly over the Tygon tubing. When the balloon is completely filled, a pneumatic cylinder on the crimper/cutter assembly flattens the crimp ring to seal the tube and a cutter blade on the crimper/cutter assembly cuts the tube off. The balloon is released when the pneumatic cylinder is retracted. A balloon being inflated is shown in Figure 4.

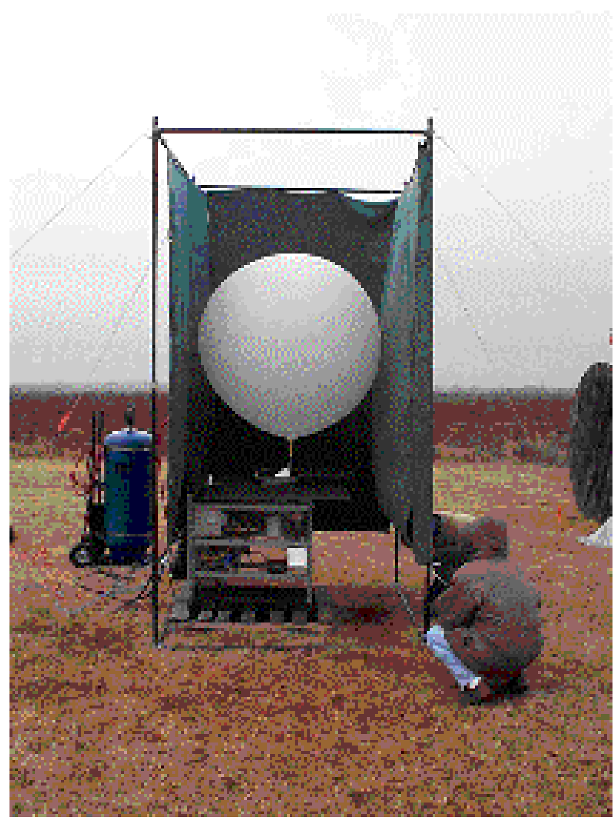

Figure 4. Inflated balloon after completion of fully automated launch sequence. (For a color version of this figure, please see *http://www.arm.gov/docs/documents/technical/conf_9803/foote-98.pdf*.)

The requirement for a neck fitting and fill tube on the balloon, together with the battery box and extra water required for automatic battery hydration, result in an additional weight of 78 grams for the balloon/sonde assembly above the 656-gram weight of the manual launch assembly. By optimizing the battery box and neck fitting to minimize weight, we should be able to reduce the added weight of the automatic launch assembly to under 60 grams.

Computer-Based Control System. The control system developed for the automated single balloon launcher is based on National Instruments software and hardware. The control software was written using the Labview graphical software package. The launcher was interfaced with the computer through a 32-channel multiplexer amplifier board and an 8-channel power relay board.

The control program developed during Phase I was designed to automatically perform all control functions necessary for a single balloon launch. After initiation by the operator, the program takes the launcher through a complete cycle, or shuts down in the event of a failure. Control functions are carried out based on preset timing and signals input from sensors located on the launcher. The control system has one analog and three digital inputs, including a pressure measurement in the helium receiver tank and “sonde present,” “lid open,” and “lid closed” switches. Six computer-controlled relays are used to actuate the launcher functions.

Field Test Results

A field test of the Phase I automated single balloon launcher was conducted at the ARM SGP CART site on January 14-16, 1997. During this period, several balloons with dummy sondes were released to confirm correct operation of the automatic launcher, and three launches were made with active sondes with data being collected. Two launches were made simultaneously with the normally scheduled ARM balloon launches, which were performed manually. The two sondes were tuned to different frequencies and tracked by two separate ground stations. Data collected by the automatically launched sonde was comparable to the data collected by the manually launched sonde.

The field test was extremely successful, with all of the automated launcher components working as designed.

Plans for Phase II

Our Phase II proposal is currently being evaluated by DOE. If Phase II is funded, our first activity will be to modify the single balloon launcher based on the Phase I field test results. An extended field test of the single launcher at the SGP CART site will then be performed. After the single balloon launcher design has been finalized, an automated launcher capable of launching up to eight balloons will be designed based on the single launcher design. A prototype will be constructed and field tested. Plans call for implementation of a multiple balloon launcher for routine use at the SGP CART site, at DOE discretion, before the end of Phase II. Production designs for commercial single and multiple launchers will also be completed. Study of advanced design concepts will be conducted throughout the project.