Figure 2. JHU/APL rocket scientist, Charles Etheridge prepares 3-inch back-fit rocketsonde for launch. A 2.5-inch back-fit rocketsonde is ready on the right.

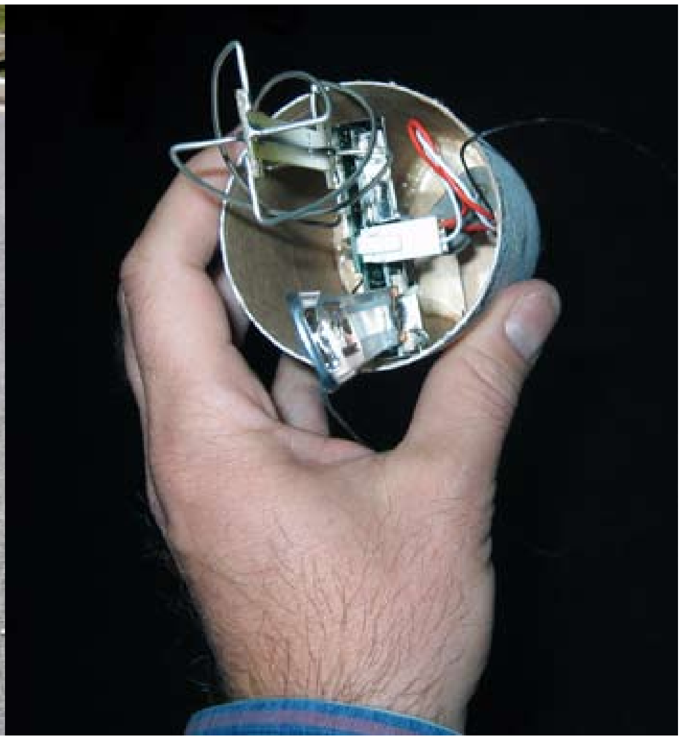

Figure 3. Sensor carriage for Vaisala Radiosonde RS92-SGP.

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This is rocket science

Johns Hopkins University uses Vaisala Radiosondes in model rockets

The Johns Hopkins University Applied Physics Laboratory (JHU/APL), located at Laurel, Maryland in the USA, regularly deploys Vaisala radiosondes for field test support. Most of the tests occur at sea and include investigations of radar and optical systems performance and the physics of air-sea interaction. The atmosphere over the ocean can have a significant impact on the propagation of energy at radar or optical wavelengths. The near surface marine atmosphere is one of the most refractive arenas in which to operate. For radar studies, vertical profiles of modified refractivity are required to model radar propagation effects over the ocean and environmental effects on radar performance.

JHU/APL has been using Vaisala Radiosondes RS92, deployed from balloons (Figure 1), and Vaisala Rocketsondes that are launched on model rockets and collect vertical profiles of PTU while descending on parachutes. At sea, it is important to take the vertical profile measurements away from the contaminated atmospheric wake of a ship. To achieve this, JHU/APL employs the rocketsonde or the balloon dropsonde, which is a radiosonde launched on a helium balloon, with some method to make it descend away from the ship. This is accomplished by using either a burning fuse to release the balloon tether or a slow leak in the balloon. Calibrated animal syringes are available to fit in the balloon nozzle with the optimum hole diameter. The goal is to achieve a descent rate of 3 m/s (10 fps) for proper resolution of modified refractivity.

Vaisala sensors survived the rough ride

Vaisala Rocketsondes have been used by JHU/APL when radiosonde profiles were requested from fast moving ships or research boats. Also, in very high seas and winds, the management of a rocketsonde is much easier than manhandling a balloon on deck. The rocketsonde is basically a radiosonde launched on a model rocket and released on a parachute. The RK-91 series of rocketsondes was discontinued after August 2006. As JHU/APL is using up the remainder of the last stock of these rockets, a new method of achieving a rocketsonde was devised. JHU/APL developed a back-fit rocketsonde, launching Vaisala Radiosondes RS92 in 2.5-inch (6.4 cm) and 3-inch (7.6 cm) model rockets (Figure 2). The 3-inch rockets were used initially because they allowed the direct use of the RS92 radiosonde with its plastic outer hull. The 2.5-inch rockets flew more efficiently and achieved greater altitudes, but require the removal of the outer hull to fit in the sensor carriage. The removal of the outer hull, especially the hot-glue joints, must be done carefully to avoid damaging circuits and sensors.

It is important to note that the RS92 circuits and Vaisala sensors survived the acceleration of the rocket launch, on a G80-13T model rocket motor with speeds that approached Mach 0.9, and the black powder ejection blast. The JHU/APL carriage design allowed deployment of

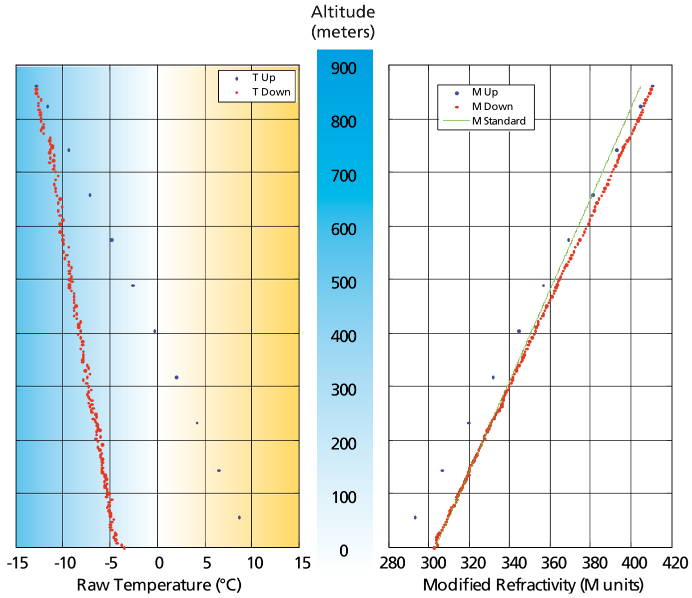

Figure 4. Vertical profiles of raw temperature and calculated modified refractivity, from the JHU/APL back-fit rocketstonde, February 15, 2007, Wallops Island, Virginia, U.S.A.

In very high seas and winds, the management of a rocketsonde is much easier than manhandling a balloon on deck.

the sensors without damage (Figure 3). This requires careful attention, especially to protect the thin wires that attach to the capacitive temperature sensors. The JHU/APL back-fit design put the exposed sensors in the rocket nose cone to minimize contact with other structures at ejection time. It is also important to make sure the sensors are properly exposed during descent to provide proper air circulation. In initial designs, an apparent recirculation in the carriage showed up in low RH readings with differences between the two RH sensors as they swapped measurement cycles. JHU/APL experimented with several designs and settled on intakes on the radiosonde carriage to increase air flow.

Data collected successfully

The initial carriage design required the radiosonde to be mounted upside-down. This approach also increased airflow over the sensors during descent. JHU/APL found that the GPS antennas did not work when deployed upside-down and the radiosondes had to be mounted vertically to make proper satellite receptions. The goal for maximum altitude was 2500 to 3000 ft (0.75 to 0.9 km), which was achieved. The launches were successful. Vertical profiles of temperature and relative humidity were collected and successfully supported field test analysis. Both RS92-K (PTU) and RS92-SGP (PTU and winds) were successfully launched. Figure 4 is an example profile of temperature and modified refractivity collected from the RS92-SGP sonde launched near Wallops Island, Virginia in the USA. The RS92-SGP radiosondes also produced vertical profiles of wind speed and direction. Figure 5 is believed to be the first wind profile measured by a Vaisala Radiosonde RS92 deployed from a rocket. This profile was measured during January, 2007, near Wallops Island.

JHU/APL engineers noticed that the radiosonde altitude ended when the radiosonde was believed to have landed in the ocean. The range at final transmission was short enough that the Vaisala DigiCORA® receiver had plenty of excess signal power and it was believed the radiosonde terminated on contact with the water. The final pressure was also consistent with ending at the sea. Therefore it was concluded that the difference was due to the process of calculating height from measured data on the ascent. The rocket ascends quickly after launch and the (P,T,RH) measurements are not valid inside the rocket body. A continuous profile of (P,T,RH) is necessary in order to translate atmospheric pressure into height. Meteorologists use the hypsometric equation to calculate height from the (P,T,RH) profiles. The hypsometric equation is basically an integrated combination of the ideal gas equation and the hydrostatic equation. Height was calculated in reverse, assuming the last data occurred at the surface and back calculating the height from the last data to the height of apogee, and this worked well. ■

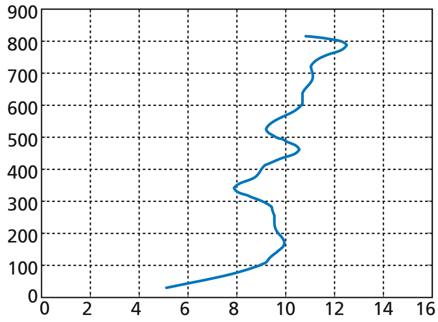

Figure 5. First vertical profile of wind speed measured from JHU/APL backfit rocketsonde launched from R/V Chessie during January 2007 near Wallops Island, Virginia, U.S.A.,

Figure 1. Vaisala Radiosonde RS92-SGP.