OPERATIONAL EXPERIENCE WITH PASSIVE FALLING SPHERES ON THE AFETR*

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The use of small rockets to measure meteorological parameters above the altitude limits of the balloon rawinsonde systems began on the Air Force Eastern Test Range (AFETR) in 1957. The Range at that time was known as the Atlantic Missile Range and the first meteorological rockets used were of the Loki II type with radar-reflective-chaff payloads. The Army Ballistic Missile Agency at Huntsville, Alabama, the range user, conducted their own launch operations during the early part of their program. The high-altitude data were needed at that time to assess the environmental conditions affecting the R & D testing of the Jupiter and Redstone rocket systems.

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In 1959, the Air Force Cambridge Research Laboratories (AFCRL) implemented a development program to try and improve the performance of the Loki II meteorological rocket. Their version of this system was called the Overrange Wind Logging system (OWL) and also used a radar-reflective-chaff payload. Data for altitudes as high as 250 000 ft were required in 1959 and 1960 for programs such as testing of the Atlas and Titan missile systems. This was somewhat above the altitude capability of the Loki II system when launched from sea level. The effort to improve the performance of the system was not significantly successful and therefore was discontinued after a short flight-test series.

During the same period the Office of Naval Research was engaged in a development effort to develop the meteorological rocket system which became known as the Arcas. This development effort was also supported by the Air Force and Army. The Air Force Cambridge Research Laboratories developed the inflatable falling-sphere payload (Robin) for use with the Arcas rocket, while at approximately the same time, the Army was developing various configurations of parachute-borne sonde payloads, also for use with the Arcas.

The first flight tests of the Arcas/Robin system were conducted on the AFETR in 1959. This series consisted of 25 systems, 13 of which properly deployed the Robin sphere at or near apogee. The average apogee altitude reached by these 13 systems was over 200 000 ft. A number of the remaining 12 systems ejected the sphere successfully,

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*Activities reported upon in this paper were performed under contract to the Air Force Eastern Test Range, Air Force Systems Command.

although various malfunctions occurred with the payload, such as rupture and partial inflation. During the period 1960 through 1961 the Arcas rocket system was used interspersed with Loki II chaff systems. The payloads used with the Arcas at that time were mainly Delta, Gamma, and AN/DMQ-6 sondes developed by the Army and furnished to the AFETR to support the early Meteorological Rocket Network (MRN) effort. Concurrently, other series of flight tests of the Arcas/Robin system were conducted at Eglin AFB, Holloman AFB, and NASA Wallops Station.

To provide some idea of the Arcas/Robin performance of the system during the 1960-61 period, the 104 systems launched at Eglin AFB produced usable density data in 40 cases. The average apogee altitude of the 104 systems launched was 226 000 feet. Of the systems which produced usable density data, the average layer thickness of the density data was 69 000 feet. The average lower altitude limit of the density data for the 40 successful systems was 142 000 feet. The Arcas/Robins launched at Holloman and Wallops Station resulted in somewhat lower performance for the Robin sphere than that obtained at Eglin AFB during this period.

Beginning in late 1961, a number of Arcas/Robin systems were procured by the Air Force and made available for both missile test support and MRN activities. Fifty-six of these systems were launched in 1962 of which 45 produced usable density data. In 1963, 72 systems were launched, 48 of which produced usable density data. Thirty-four systems were launched on the AFETR in 1964, 31 of which were completely successful. The average apogee altitude for these three years of operation with the Arcas/Robin system was approximately 212 000 feet. The average lower limit for the usable density data obtained was about 145 000 feet. In 1965, 101 Arcas/Robins were launched, 89 of which produced usable density data for an 88-percent success rate. The average apogee altitude reached by these 101 launches was 210 000 feet, and the lower limit for the usable density data still averaged near 145 000 feet.

During the period 1962 through 1965, the Arcas/Robin systems were used primarily for MRN support. Several of the missile test programs on the Range during that period had stringent requirements for wind, density, temperature, and pressure data from the surface to about 250 000 feet. The Arcas/Robin system was performing well and producing what appeared to be good density and wind data in the region of from 145 000 to 200 000 feet. However, a severe gap in the density data existed between the upper limit of the rawinsonde observations at about 105 000 feet and the average Robin balloon collapse altitude near 145 000 feet. The acquisition of density and temperature data in the intervening 40 000-foot layer was significantly more important than the acquisition of the data to altitudes above 200 000 feet. This is because of the obviously greater effects of the atmosphere on missile system performance at the lower altitudes.

From the early days of the development of the Robin sphere payload for the Arcas rocket, there were several reservations in the minds of meteorologists at the AFETR regarding the reliability of the density data being obtained. These reservations stemmed from our experience with numerous chaff payload launches, which on many occasions seemed to indicate the presence of significant vertical components to the high-altitude wind field. This, in our opinion at that time, caused uncertainties in the mean layer densities computed from the Robin data. We suspected other uncertainties in the data caused by the questionable reliability of drag information available at that time for use in the data-reduction routine. Several times during the development of the Robin data-reduction process, changes in drag data were made as a result of additional data analyses and study. This had the effect of changing density values previously computed by several percentage points and, in one case, by a range of from 10 to 15 percent.

Some of the AFETR test programs required temperature data for use in evaluation of heat-transfer processes in the development testing of ablative materials and reentry vehicles. A particular program having important needs for density and temperature data in the critical region from 100 000 to 200 000 feet was the aerothermodynamic structural systems environmental test (ASSET) program. Since these data requirements were not being met by the Arcas/Robin system, the launch sites that were activated at Eleuthera, San Salvador, Grand Turk, and Antigua to support this program used the Arcas rockets with sonde-type payloads.

During the mid-1960's, a sonde payload was developed for the Loki II meteorological rocket system. There was also a Robin payload adapted to the Loki system but this was never employed on the AFETR. With the advent of the sonde payload for the low-cost Loki system and its marked advantage over the Robin in the measurement region between 100 000 and 150 000 feet, nearly all test support data since 1965 have been provided on the AFETR by sonde-type payloads with either the Arcas or Loki II rockets. The exception to this has been the use of the Viper-Dart-Robin system to acquire data above 200 000 ft. Some of our MRN requirements have been partially met by the use of Arcas rockets with outdated Robin payloads which were not expected to inflate properly for density determinations but were used only for wind measurements.

The Viper-Dart rocket system with Robin payload became available for use on the ETR in the fall of 1968 in time to support the high-altitude data requirements of the Apollo 7 launch from Cape Kennedy. The Viper systems used on the ETR during the past year have been a combination of developmental flight-test models launched in support of an AFCRL development project and a quantity of preproduction models purchased by the ETR for Apollo launch support.

For the Apollo support, density and wind data to 295 000 feet are required. At the present time, the Viper-Dart vehicle with a Robin payload is the only near-operational system capable of supplying these data to this altitude. Of 20 similarly configured Viper-Dart systems with Robin payloads, 12 produced the required wind and density data to 295 000 feet. The average apogee altitude achieved by these 12 systems was 430 000 feet, and the average lower limit of usable density data was about 170 000 feet. The average thickness of the layer through which density data were obtained was therefore 125 000 ft. Wind data were generally usable beginning at about 20 000 feet above the altitude for the usable density data, and of course, the wind data were obtained well below the minimum altitude for the density data by continuing to track the partially collapsed sphere.

Of the eight systems which failed to produce the required data, three failed because of no inflation of the sphere; one, because of a motor malfunction; one, because of no payload separation; and three, because of late radar acquisition of the payload.

We plan to continue the use of the Viper-Dart system with the standard Robin payload during the immediate future to obtain density and wind data above the altitude of the Loki-Dartsonde system. By using Rawinsonde, Loki-Dartsonde and Viper-Dart-Robin systems, complete profiles of winds and densities are obtained to approximately 295 000 feet, with additional parameters such as temperature and pressure being obtained from the surface to the top of the Loki-Dartsonde profile at about 200 000 feet.

The data from the three different observations, Rawinsonde, Dartsonde, and Robin, display remarkable agreement in the overlap regions. One area presently causing some difficulty is in the transonic-fall-rate region of the high-altitude Robin system where some unusual oscillation in the density profile is evident. Recent investigations of this problem by AFCRL and the University of Dayton Research Institute have resulted in the experimental use of some revised drag data which, in most cases, seems to improve the consistency of the computed density in the area of concern. The fall rate of the Robin sphere when deployed at above 400 000 feet with the Viper-Dart rocket system is transonic at approximately 233 000 feet. The layer of questionable density data usually extends over several thousand feet on either side of this point, though predominantly on the subsonic side. In general, density data computed throughout the altitudes where the sphere is falling supersonically appear quite consistent, which seems to suggest somewhat more reliable data than those obtained in the subsonic-fall-rate region.