THE EVOLUTION AND DEVELOPMENT OF THE UNITED STATES NATIONAL WEATHER SERVICE UNIVERSAL RADIOSONDE REPLACEMENT SYSTEM

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ABSTRACT

The National Weather Service has been using a radiosonde "Universal Ground System" for close to 20 years. The development of the new 1680 MHz Global Positioning System ground receiver evolved through the interfacing of different vendor's radiosondes with the Radio-direction finding systems in use for the past 45 years. The basis of a universal system is that a given radiosonde signal can be received by a generic ground receiver, the engineering units for thermodynamic variables changed to meteorological units in a signal processor, and the output interfaced with a system computer to generate WMO coded messages. It is possible to use different radiosondes with a generic ground receiver and processing software without end-to-end specification. However, the use of pre-defined interface standards between a vendor's radiosonde and a generic ground receiver, the ground receiver and a specification compliant vendor provided signal processing system, and the interface between the signal processor and generic workstation data processing software ensure successful integration. This paper will detail the operational use of the early universal system by the National Weather Service, prototype development of a dual frequency navigation aided system (Omega and Loran-C) in the early 1990s, and the subsequent universal Global Positioning System radiosonde system the National Weather Service is deploying.

1. INTRODUCTION

The NOAA National Weather Service (NWS) is developing a Radiosonde Replacement System (RRS) to replace its old Microcomputer Automatic Radio-theodolite (Micro-ART) system. The RRS is comprised of a new Global Positioning System (GPS) tracking antenna referred to as the telemetry receiving system (TRS), 1680 MHz GPS radiosondes, a new workstation, and software. The requirement to use GPS with the 1680 MHz frequency was a technological challenge in combining of the GPS L1 frequency with the 1680 MHz Meteorological Aids frequency.

The RRS is required to:

Comply with Government direction to reduce radio frequency use.

Maintain or increase system availability and data accuracy.

Provide high resolution data to users.

Increase amount of data provided to users.

2. BACKGROUND

The earliest automated upper-air sounding systems used radio direction finding (RDF) of the radiosonde signal's emanating position in azimuth and elevation to acquire thermodynamic data as well as determine wind speed and direction of the radiosonde. The NWS has been using using the 1680 MHz band with its RDF system almost exclusively for 50 years with minimal interference from other users. Until 1986, the NWS relied on radiosondes from one vendor to supply the network. With the upgrade of the old Automatic Radiotheodolite (ART) wind finding minicomputer-based system to the Microcomputer Automatic Radio-theodolite (MicroART) was the introduction of the microcomputer interface card (ARTIC). The ARTIC card converts received signals from the radiosonde ground receiver into meteorological units. These meteorological units were subsequently input to the microcomputer for data processing into WMO coded messages. The introduction of the upgraded system with the microcomputer and ARTIC card enabled the participation of more than one radiosonde provider to satisfy the NWS radiosonde requirements. In 1987, VIZ and Space Data became qualified providers of radiosondes to the NWS. In the early 1990s, Vaisala also became a qualified provider. Their radiosonde required modification to interface with the NWS ground receivers and was not compatible with the ARTIC card interface. Vaisala provided the interface between the ground receiver and the microcomputer with the Vaisala Signal Processing Unit (SPU-11). This adaptation has been in use since the mid-1990s and has proven reasonably successful although it did much more than just change engineering units to meteorological units through the use of transfer equations. The use of ARTIC interface card and the Vaisala SPU-11 interface with the ART ground receivers and MicroART software enabled flying radiosondes from multiple manufacturers. This has been beneficial in that it provided two sources of radiosondes by two procurements, encouraged manufacturers to offer the best prices, and stimulated product improvements. Figure 1. is an example of the

ART-1, a Military GMD-1 that is over 45 years old and a key component in the aging network.

Figure 1. NWS ART-1 Ground Receiver

2. NETWORK REPLACEMENT CONSIDERATIONS AND REALITIES

In response to the end of system-life, parts obsolescence, increasing repair costs, and the limitations of the RDF technology to accurately determine winds without transponder capability over much of the mid-latitude part of the network where jet streams are prevalent during the winter season, the NWS set out to replace the existing radiosonde network. A key requirement was the ability to fly multiple radiosonde types from competing manufacturers. This would allow the NWS to continue purchasing expendable radiosondes through contract awards at competitive pricing.

The requirement to fly competing vendor radiosondes marked reversal from the trend that has been in place since the early 1990s when radiotheodolites were largely displaced internationally by NAVAID systems. With the introduction of the first OMEGA systems, ground stations became integrated end-to-end by the same vendor. Multi-sonde compatibility disappeared and operators were faced with single-source radiosonde suppliers without competitive pressures after initial system investment.

The variety of NAVAID systems increased (OMEGA, Loran-C, coded/uncoded GPS) and the expendable navaid radiosondes became increasingly linked to the accompanying ground stations and vendor source code and processing systems.

Operators were also exposed to situations where manufacturers discontinued the only compatible radiosondes, making high cost ground stations instantly obsolete (the demise of OMEGA and the demise of the AIR IS-4A are two examples). This forced operators to make untimely, costly, and unproven technology changes ahead of schedule. Very Low Frequency windfinding systems that were deemed as adequate replacements for the OMEGA radiosondes and early GPS radiosondes were problematic. The data using community was the recipient of low quality data to no data for many of the radiosonde flights.

Commercial off-the-shelf Radiosonde system versus new system development

An assessment of readily available commercial off the shelf (COTS) radiosonde systems versus a development effort established the direction the NWS would follow with network replacement. Technology Management Corporation (TMC) was awarded a contract in 1991 to:

> Determine core requirements of the NWS upper air system of the future.
>
> Assess alternative commercially available upper air systems.

TMC evaluated five vendor's systems and determined that:

> No COTS approach supported multiple radiosonde vendors with one vendor's ground receiver and software.
>
> A reception range of 250km between the radiosonde and ground receiver was not possible with COTS systems

National Center for Atmospheric Research (NCAR) Next Generation Upper-Air Sounding System (NEXUS) Prototype Development

NEXUS was a prototype development effort between the National Weather Service and the NCAR. The purpose of the development for a navigation aided radiosonde sounding system was to determine the feasibility of a flexible, modular system design for radiosonde support, launch operations, wind-finding, and systems software. The developed prototype supported radiosondes from three manufacturers in both the 400 and 1680 MHz frequency bands. The wind-finding implementation was supported by Loran-C and OMEGA navigation aided (NAVAID) techniques. The system electronics were modular and adaptable to the emerging GPS wind-finding technique.

The requirements for the prototype follow:

> Support radiosondes from multiple vendors.
>
> Support both 403 and 1680 MHz frequency bands.

Support Loran-C and OMEGA navaid wind-finding and GPS as technology became available.

Employ automatic radiosonde tracking in both 400 and 1680 MHZ frequency bands.

Demonstrate semi automated balloon launcher.

One-person operation.

The NAVAID radiosondes used with the NEXUS were available in both 400 and 1680 MHz. An antenna and telemetry receiver switch allowed for easy selection and control of the hardware for either frequency type. For 400 MHz radiosondes, a 70 degree beam-width vertically polarized Yagi antenna was mounted on an antenna rotor mast on the system antenna tower. The antenna was pointed upward approximately 25 degrees from horizontal. The wide beam width provided signal reception from low to high elevation angles. The 400 MHz telemetry receiver had wide-bandwidth, and was digitally synthesized.

The 1680 MHz radiosondes were tracked using an electronically steerable, phased array patch antenna. Two identical antennas were mounted on the same tower as the 400 MHz Yagi antenna. Each antenna, through a phasing technique could be electronically steered in azimuth but not elevation. The first of the two antennas was mounted at an elevation angle of 75 degrees to track radiosondes at high elevation angles. The other was 15 degrees off horizontal for tracking low elevation angle portions of flights.

Automatic tracking of the 1680 MHz method as with the 400 MHz frequency used the telemetry receiver to measure the receiver signal strength from the radiosonde. The 1680 MHz antenna was accomplished differently however for elevation. Periodic signal strength measurements were determine for both antennas to determine which of the two antennas, the high angle or the low angle antenna were receiving the stronger signal. The antenna with the stronger signal electronically steered the beam steered the antenna plus or minus four degrees azimuth from the current pointing angle.

The NEXUS modular design was not an open architecture system. It used the stand-alone PTU processors built by the individual radiosonde manufacturers and relied on COTS OMEGA and Loran-C receivers. These decoders acquired and converted the raw engineering data from the sensor suites into meteorological units. The standalone PTU processor concept permitted the NEXUS system to interface with virtually any radiosonde supported by a matching PTU processor. Minimal impact on the system hardware and software would be incurred if a new type of radiosonde was added to the system. Figure 2 is an example of the balloon inflation launcher, and antenna systems for the 403 MHz and 1680 MHz navaid Loran-C and OMEGA systems.

Wind information was input through an RS232 port into the receiver from either the Loran-C or OMEGA navigation signal processor for the navaid wind-finding capability.

The demise of the OMEGA navigation system and the uncertainties of a possible phas eout of Loran-C in the United States in the 1990s turned attention to GPS. The modular architecture of the NEXUS prototype could accept the GPS solution

Figure 2. NEXUS Prototype Navaid System

<u>NEXUS assessment</u>

The NWS carried out a broad assessment of NEXUS over a one-year period from 1993 to 1994 at 17 sites. The sites encompassed a wide variety of weather conditions and differing Loran-C and OMEGA geometries. The prototype system functioned in Loran-C and OMEGA in the 403 MHz and 1680MHz bands. VIZ, Vaisala, and AIR provided radiosondes and signal processing units for the modular integration effort.

The broad band telemetry characteristics of the receiver enabled use of multiple brand radiosondes but also increased vulnerability to interference. There were concerns over the long-term robustness of the prototype electronics and the hand-built 1680 MHz antenna required redesign for manufacturing. The Navaid receivers were obsolete and Loran-C and OMEGA were being replaced by GPS. The thermodynamic processors were essentially black-box configurations but proved the modular concept of decoder cards to isolate proprietary signals from main software. The NEXUS software while rich in functionality was developed as a research and prototype tool and was not of operational quality.

3. POST NEXUS REQUIREMENTS VALIDATION

Industry Request for Information

The NWS placed a Request for Information with industry to assess the state of development of radiosonde systems and to determine the best value approach. The basic information received was primarily vendor's proposals to sell existing closed architecture systems that would not facilitate the ability to fly multiple vendor's radiosondes with one generic ground system.

A reevaluation of the advantages of a COTS turn-key option was performed during 1995-1996. A turn-key approach would incur lower integration, schedule, and cost risks, but also had significant disadvantages. The COTS systems would not support anticipated radio spectrum limitations and other NWS requirements, and did not allow for follow-on competition for radiosonde purchases. The turn-key option was dropped.

Radiosonde Frequency Study

The Joint Spectrum Center surveyed both the 401-406 MHz band and the 1675-1700 MHz band for the NWS. After reviewing the density of the NWS sites and the heavy use of the 403 MHz band by the military and other civilian operations, the Joint Spectrum Center recommended use of the 1675-1683 MHz band for radiosonde operations.

Radio Direction Finding Versus GPS for Radiosondes

While a dual mode system (RDF/GPS) would provide lower operating costs, the advantages of GPS for mid-latitude operations were greater than potential cost savings from a dual mode system. The system specifications contained performance parameters only supported by GPS. The decision however to operate the radiosonde in the 1680 MHz band required a parabolic reflector to achieve the 250km range. The parabolic antenna was not optimized for good RDF performance.

4. RADIOSONDE REPLACEMENT SYSTEM ACQUISITION APPROACH

The acquisition approach was to develop a Radiosonde Replacement System comprised of a Telemetry Receiver System, Radiosondes and Signal Processing Systems, Software development support, Surface Observing Instrumentation, and a Balloon Inflation and launch shelters. Figure 3 depicts Radiosonde Replacement System and the sub-systems.

A contract was awarded to International Met Systems to build the Telemetry Receiver Systems (TRS). Some of the characteristics are that it has a 2 meter diameter parabolic dish, is lightweight in construction, and has a 19 inch environmentally controlled rack pedestal that contains the Signal Processing System. The unit is known as the IMS 2000. Figure 4 illustrates components of the basic telemetry receiver system.

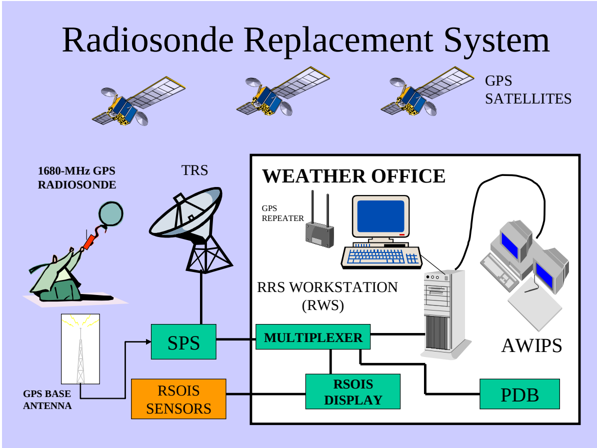

Figure 3. Radiosonde Replacement System

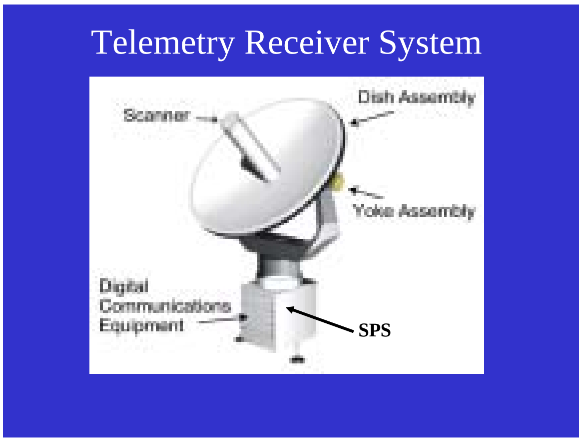

Figure 4. IMS Telemetry Receiver System

Figure 5 shows the IMS 2000 with the added wide angle antenna affixed to the top of the large parabolic antenna. The wide angle antenna is used for close-in automatic lock-on to the radiosonde signal at release.

Other efforts directly related to RRS are the software and workstation, and the radiosonde and signal processing system (SPS). The purpose of the SPS is to acquire radiosonde PTU telemetry data and the radiosonde GPS position data from the telemetry receiver. The SPS processes Global Positioning Data for use in wind finding and any necessary processing for position accuracy and error correction. The SPS generates raw data from the data transmitted by the radiosonde. The SPS in turn interfaces with the Government developed and operated computer system using specified communication protocol to transmit data, report subsystem status and process control commands.

One of the major features of the RRS is the use of state-of-the-art GPS radiosondes operating in the 1680 MHz radiosondes frequency band. Until recently, commercial systems/radiosondes sold worldwide were operated in the 403 MHz frequency band. The interfacing of the GPS technology with 1680 MHz radiosonde transmitters created technological challenges for the commercial vendors. Two vendors,

Figure 5. IMS 2000 Radiosonde Ground Receiver

Intermet and Sippican have produced functional radiosondes and Vaisala is in the process of qualifying a radiosonde and Signal Processing System for the TRS. Vaisala has demonstrated that their developmental SPS functions with the TRS and the Vaisala 1680 MHz GPS radiosonde prototype. radiosonde. The combining of the GPS with the 1680 MHz was not as difficult as envisioned. However, different sensor technologies have required extensive testing and evaluation.

The software development for the workstation will allow for continuous monitoring of a flight. The RRS design maximizes data acquisition capabilities for all angles of radiosonde position with respect to the ground system to include very low elevation angles associated with high winds aloft or at zenith.

5. STATUS AND CONCLUSIONS

Operational Acceptance Testing of the RRS will commence this summer. As testing commences, prior to full-commissioning, the flights will become official synoptic flights of record.

A contract has been awarded to Sippican to provide the early GPS radiosondes for the operational network.

New procurement activities are underway to establish the next Qualified Products List for the next radiosonde procurement. The next procurement will include the radiosondes and their respective signal processing systems.
The combined GPS radiosonde receiver and the 1680 MHz transmitter do not interfere with each other. With the GPS capability, it is routine to get accurate winds during the most extreme wind conditions.

The open architecture approach to radiosonde systems is already in operation. The NWS contracted with Intermet to provide ten IMS 1500 ground receivers for the Caribbean Hurricane Upper Air Stations. Intermet assembled a system using Sipican B-2 radiosondes, the Sippican SPS for RDF radiosondes, and Intermet software to process data and produce WMO coded messages. This system configuration works well in the tropical and sub-tropical areas where high wind speeds are not encountered.