NOAA Technical Memorandum OAR GSD-56

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COST AND OPERATIONAL EFFECTIVENESS ANALYSIS

FOR THE NOAA PROFILER NETWORK – May 2004

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Cost and Operational Effectiveness Analysis for the NOAA Profiler Network

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DEPARTMENT OF COMMERCE

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Response to the Senate Appropriations Committee

Cost and Operational Effectiveness Analysis for the NOAA Profiler Network

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NOAA Assistant Administrator for Weather Services

Cover: Time-height graph of atmospheric winds from the NOAA Profiler Network (NPN) station at Tucumcari, New Mexico, on May 3, 1999 showing the jet stream strengthening from 60 mph to 110 mph in just five hours from 10:00 Central Daylight Time (CDT) to 15:00 CDT. Early detection of this jet stream by the NPN allowed the National Weather Service's Storm Prediction Center to upgrade the threat of tornados from "slight" to "high" giving the public advanced notice to this dangerous situation. Over 70 tornados were observed in Oklahoma and Kansas from this single event.

Time axis is from 09:00 CDT to 17:00 CDT. Height axis is from ground level to 40,000 feet. Wind speeds and directions are indicated by wind barb symbols. (Courtesy of the NOAA Office of Oceanic and Atmospheric Research, Forecast Systems Laboratory)

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Table of Contents

Annexes

Bibliography

Figures

1.0 Executive Summary

Updating the existing NOAA Profiler Network (NPN) is the most cost-effective alternative.

- **Recent studies show NPN winds improve severe weather warnings and forecasts adding minutes to warning lead time for tornadoes and flash floods.**
- **Modifying the existing network delivers the best over-all wind profiling performance.**
- **Terminating NPN costs degrades severe weather warnings, watches capability, and short-range weather prediction.**
- **Radiosonde performance could be made similar to NPN performance, but the cost would be prohibitive.**

1.1 Overview. This Cost and Operational Effective Analysis (COEA) is provided in response to a request by the Senate Appropriations Committee to compare the "… cost to upgrade the NOAA Profiler Network (NPN) over the next decade versus the short, medium, and long-term costs of ending the NPN program" (see Annex H for full text). The analysis answers two questions: 1) Are the NPN winds beneficial to NOAA National Weather Service (NWS) operational products and services; and 2) Is the NPN, including the cost to upgrade the network, the most cost-effective strategy for NWS operations?

A wind profiler is a vertically pointing Doppler radar which measures winds at various altitudes in the atmosphere above it every few minutes. The NPN consists of thirty-five wind profilers located mostly in the central U.S. and Alaska (see Fig. 1.1-1), each providing wind measurements also known as "wind profiles" containing 64 measurements through 16 kilometers above ground every six minutes.

When the NPN radar transmitters were installed in 1988, the NPN was authorized to use the 404 mega hertz (MHz) by the National Telecommunications and Information Administration (NTIA) for experimental use. Subsequently, NTIA has given usage of the 404 MHz frequency to a future series of search and rescue satellites (SARSAT) and granted the NPN permanent use of 449 MHz To comply with NTIA frequency regulations, NOAA must change its thirty 404 MHz wind profilers to 449 MHz by the end of the decade when the new SARSATs are expected to become operational.

The NPN is primarily deployed over the central U.S. and Alaska.

Figure 1.1-1 NOAA Profiler Network Station Locations

1.2 Analysis. Recent studies in 2003-4 document that high-temporal-frequency NPN wind profiles significantly improve performance in several NWS operational product and service areas for stations within the NPN:

- *Warnings:* NPN winds improve probability of detection (+27%), decrease false alarm rate (-20%), and improve lead time (+14%) for tornado warnings, as well as severe thunderstorms, flash floods, and winter storms (Wolf 2004). They also improve warnings related to aviation and fire weather.
- *Watches and Outlooks:* NPN winds improve watch and outlook accuracy for severe weather by 13% (Weiss 2002).
- *Numerical Weather Prediction:* NPN winds improve 0-12 hour wind forecasts with a 20% improvement at 3 hour forecast (Benjamin et al 2004).

Given these demonstrated weather warning and forecast benefits, an analysis was done to *determine the best strategy for acquiring wind-profile information in terms of performance and cost.* In other words, is the NPN, including the cost to upgrade the operating frequency of the network, the most cost-effective way to obtain these important wind profiles? To answer this question, a performance and cost analysis of the NPN and a range of alternatives for providing wind profile information was completed.

NPN saves lives by providing reliable early warning.

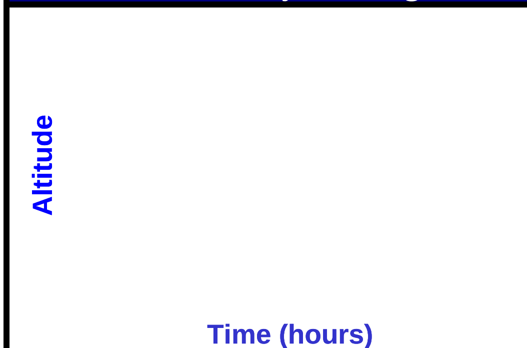

Figure 1.1-2 High Frequency Winds

1.3 Alternatives Considered. As shown in Figure 1.2-1, the analysis considered the two alternatives directed by the Senate Appropriations Committee: Changing the NPN operating frequency and maintaining the current network (Alternative 1) and terminating the NPN network (Alternative 2). The study also considered replacing the network with either existing or new technologies potentially capable of providing the necessary amount, timeliness, and accuracy of wind profile data. The additional alternative technologies considered were: Existing (Alternative 3a) and additional (Alternative 3b) use of radiosondes (weather balloons), automated aircraft reporting (Meteorological Data Collection and Reporting System (MDCRS)) (Alternative 4), WSR-88D Doppler radar (Alternative 5) , and object tracking by Geostationary Operational Environmental Satellite (GOES) (Alternative 6).

Alternative 1	**Change operating frequency of current NPN system**	**Sec. 4.1**
Alternative 2	**Terminate NPN without replacement**	**Sec. 4.2**
Alternative 3a	**Replace NPN system with existing radiosondes**	**Sec. 4.3**
Alternative 3b	**Replace NPN system with additional radiosondes**	**Sec. 4.3**
Alternative 4	**Replace NPN system with MDCRS aircraft observations**	**Sec. 4.4**
Alternative 5	**Replace NPN system with WSR-88D Doppler radar**	**Sec. 4.5**
Alternative 6	**Replace NPN system with GOES object trackers**	**Sec. 4.6**

Figure 1.2-1 Alternatives Evaluated

1.4 Methodology. Six independent attributes were used to judge wind-profiling system performance : 1) frequency of observation, 2) geographic coverage, 3) vertical reach, 4) horizontal spacing, 5) number of vertical levels, and 6) measurement accuracy. The relative value of each of these attributes was determined through a questionnaire submitted to a panel of weather professionals from academia, private industry, and NOAA (see Annex A). A single performance number was generated for each evaluated system. The annualized cost for development, production and deployment, and operations and maintenance for each alternative was determined. The ratio of performance to total cost was calculated to provide a measure of effectiveness.

1.5 Results. The results of this COEA demonstrate that high-frequency winds benefit several important NWS missions: severe weather warnings (for tornadoes, flash floods, and winter storms), watches, and short-term forecasts. These products are important for public safety, aviation, and wildfire support. A cost-effectiveness analysis shows that sustaining the NPN, including upgrading the frequency, is the most cost-efficient method of obtaining high-frequency wind profiles. Figure 1.5-1 depicts the cost and performance of each alternative. The NPN (Alternative 1) provides the best overall wind profile performance since no alternative provides equal or higher performance at lower cost. The only feasible way to approach NPN performance with an alternative system is by significantly increasing the frequency of radiosonde balloon launches from once every 12 hours (Alternative 3a) to hourly (Alternative 3b), but the cost is fourteen times greater. The remaining alternatives, winds from commercial aircraft (MDCRS) (Alternative 4), volume-averaged winds from WSR-88D Doppler weather radar (Alternative 5), and GOES object (e.g., clouds) tracking (Alternative 6) cost less but have much lower performance.

Modifying the existing NPN system provides the best value solution.

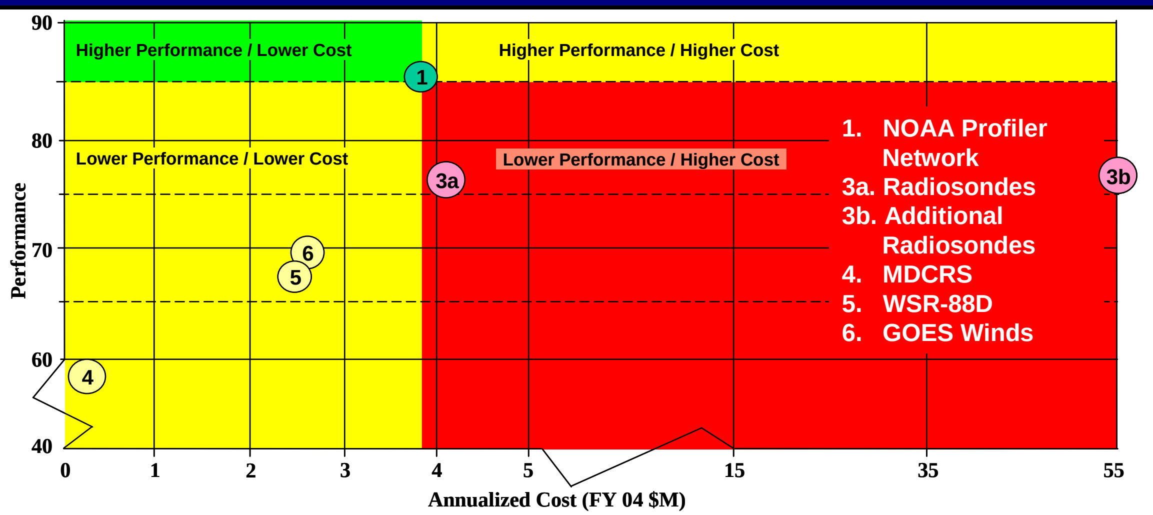

Figure 1.5-1 Results of Cost/Performance Analysis

2.0 Introduction to the NPN.

The NPN consists of thirty-five wind profilers (30 operating at 404 MHz and 5 operating at 449 MHz) located mostly in the central U.S. (Fig. 1.1-1). The major components of the system, illustrated in (Fig. 2.0-1), occupy about one-quarter acre. Each site has power, landline, and voice communications, environmental control, and capacity to add additional meteorological sensors.

The NPN uses three radar beams to measure winds.

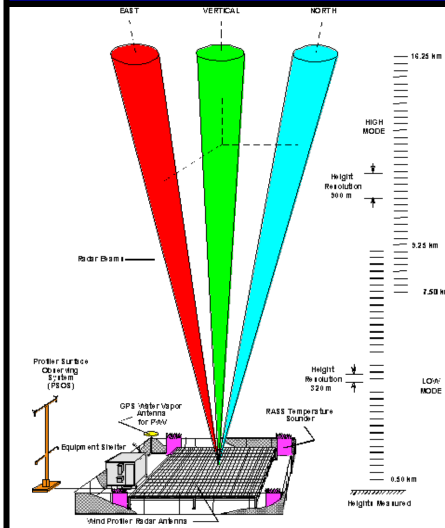

Figure 2.0-1 NPN Radar Beam Geometry

2.1 NPN System Components

A wind profiler is a vertically pointing Doppler radar that measures atmospheric winds directly above the site. A profiler consists of four components: a transmitter, an antenna, a receiver, and a data processor (Fig. 2.1-1). The transmitter sends out pulses of electromagnetic energy at a certain frequency (404 MHz in the case of the NPN) in three directions: east, north, and vertical. When the signal encounters small amounts of turbulence in the clear air, energy is returned to the antenna where it is detected by the receiver. The data processor measures the time it takes for the signal to return, and computes the range or height of the turbulent layer. If the turbulent parcel of air is moving, then the frequency of the returned signal is increased or decreased (the Doppler effect) in proportion to the velocity and direction of the air relative to the radar. The signals measured in the three beams are processed into the horizontal wind speed and direction at each altitude.

The NPN major system components

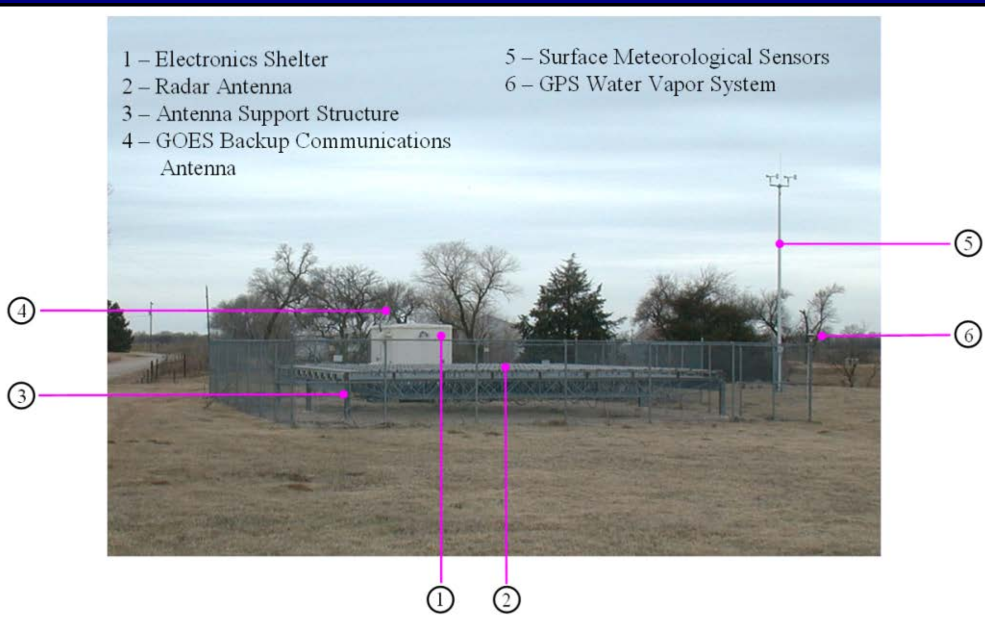

Figure 2.1-1 NOAA Profiler Network System Components

2.2 Rationale for NPN Frequency Change.

By the end of 2008, the NPN must be upgraded to operate at a different frequency because of interference with signals from new search and rescue (SAR) satellites, which will begin operating before the end of the decade. Currently, two polar-orbiting satellites are equipped with SAR receivers to detect distress signals from downed aircraft, lost hikers, floundering boats, etc. The SAR beacons operate at the same 404 MHz frequency as does the NPN. Consequently, the NPN wind profiling radars must turn off whenever a satellite with SAR capabilities (SARSAT) is overhead to avoid potential interference. However, as shown in Figure 2.2-1, this only occurs about 90 minutes per day, or 6% of the time the radars operate.

Current NPN profiler raw data transmissions

Figure 2.2-1. Raw data from NPN profiler. Vertical red bars show when a SARSAT satellite is overhead and transmitter turns off (less than 6% of the time).

The European Space Agency will begin launching a constellation of satellites called *Galileo* in 2005. Intended for Global Positioning System (GPS) applications, these satellites will also have a SAR capability that operates at 404 MHz frequency. These SARSATS will be in the sky for hours instead of minutes at a time, and there will be about 10 satellites in view simultaneously by late FY07 or early FY08 as opposed to only one or two as is the case today. Under these conditions, NPN profilers operating will have to shut down more than 23:30 hours per day, as illustrated in Figure 2.2-2, rendering the network virtually useless. The solution is to change the operating frequency to the non-interfering 449 MHz, a protected, assigned frequency for wind profilers.

Galileo era NPN profiler raw data transmissions

Figure 2.2-2 *Galileo* Satellite Era Profiler Shutdown Duration
Red = **System Shutdown**

3.0 Benefit of NPN Winds to NWS Operational Products and Services

Weather forecasters use wind profiles of the atmosphere for a variety of analytical forecasting tasks. In addition, wind profiles are used as input for numerical (computer) weather models that predict clouds, precipitation, and temperature. Wind profiles also provide important indicators of where severe weather such as tornadoes and winter storms may form, requiring weather advisories, watches, or warnings. Weather forecasters also use wind data for issuing aviation Significant Meteorological (SIGMET) advisories and to predict wildfires.

The traditional observing system used to obtain wind profiles is the balloon-based radiosonde network, which provides wind profiles every **12 hours** across the Nation at a spatial resolution of approximately one profile every 400 km. In contrast, wind profilers provide wind profiles every **six minutes** at a spatial resolution of approximately one profile every 250 km. The high temporal and spatial resolution wind profiles are found to improve NWS operational warning, watch and outlook, and numerical forecast products.

3.1 Warnings – A recently completed study (Wolf 2004) shows that the NPN wind profile information improves NWS operational warning performance statistics. Figure 3.1-1 from this study presents average tornado warning performance statistics for representative samples of NWS Weather Forecast Offices (WFOs) within and outside the NPN, as well as for all WFOs (national average) over the five years from 1999 through 2003. Comparison of the statistical elements listed (Probability of Detection, False Alarm Rate, Critical Success Index, and Lead Time) shows that WFOs within the NPN on average performed better for the four elements than those outside and the national average. A study by Wolf and Howerton (2003) using NPN wind data in NOAA's Warning Event Simulator indicates that these performance differences can be attributed to the improved forecaster "situational awareness." The time-critical NPN wind information helps forecasters more quickly detect environmental changes critical to the formation of tornadoes and other severe weather. **In summary, NPN wind data make forecasters more aware of changing weather situations enabling them to issue more accurate and longer lead-time warnings.**

Without NPN, tornado warning accuracy will be substantially degraded

	WFOs Within NPN*	WFO National Average	WFOs Outside NPN*
Probability of Detection	0.79	0.72	0.62
False Alarm Rate	0.68	0.74	0.85
Critical Success Index	0.29	0.24	0.14
Lead Time (Minutes)	12.9	11.5	9.5

Figure 3.1-1. Accuracy Performance Measures for Weather Forecast Offices, 1999 through 2003 (Wolf 2004).

* Selected Weather Forecast Offices in areas where tornadoes occur often

In addition to tornado warnings, NWS issues warnings for other high-impact weather with significant influence to the Nation's economy. For most of these warnings, studies indicate the NPN frequently provides information which improves these warnings. Examples are:

- Winter Storms: Forecasters use the NPN winds to identify surges of warm moisture air over cold fronts to anticipate formation of snow bands ahead of strengthening low pressure systems and better interpret numerical model-based winds and associated model-based winter storm forecasts. NPN winds showing a warm air surge helped forecasters in Wichita, Kansas, issue a winter storm warning six hours earlier than it would have without the NPN information.

- Aviation Weather Forecasts: Aviation Weather Center (AWC) forecasters use NPN winds to improve predictions of turbulence and wind-shear conditions. AWC forecasters used NPN winds to cancel a SIGMET warning for turbulence 90 minutes earlier than forecast, after the NPN showed decreasing winds and safe conditions in the warning area. This allowed air traffic controllers to use valuable airspace which would be otherwise closed. Because NPN winds help pilots avoid hazardous weather, the risk of crew and passenger injury in minimized. Using the NPN, forecasters identify and predict strong low level winds carrying moisture from the Gulf of Mexico into the Midwest. This results in better predictions of low clouds, low visibilities, and thunderstorms, which, in turn, reduces flight hazards and minimizes delays.

- Fire Weather Forecasts: Forecasting changes to surface wind speed and direction is essential in predicting fire and smoke plume behavior. NPN winds are used to help deploy and protect "hot-shot" fire-fighters from being over-run by wildfires driven by unpredicted winds. In Albuquerque, New Mexico, meteorologists used the NPN winds to detect a developing "mountain-gap" wind event allowing them to forecast increasing winds near the fire just as an urban wildfire was spreading. Because this wind event was well forecast, fire managers were prepared for the changing wind's impact on the fire and were able to safeguard homes in the area with no injuries to the fire fighters. NPN winds also help the U.S. Forest Service safely plan and execute prescribed burns helping to reduce fuels for future fires and safe-guard property and valuable timber. Scheduling burns so that the smoke plume does not drift over populated areas minimizes the impact to public health, especially to people sensitive to soot.

3.2 Watches – A 2002 study showed that the NPN is a critical source of information which materially improves forecasts of severe thunderstorms and specifically improves NWS Storm Prediction Center (SPC) watch and outlook products. The beneficial effect of NPN winds on SPC watches is illustrated in Figure 3.2-1 taken from a study by Weiss (2002). The figure shows that a 15 percent improvement in SPC watch accuracy occurred with the deployment of the NPN between 1988 and 1992. During this same time period no other new services and technology were fielded. The study concluded that the NPN winds are essential in monitoring rapidly changing conditions that characterize severe weather situations.

Storm Prediction Center (SPC) watch accuracy improvement

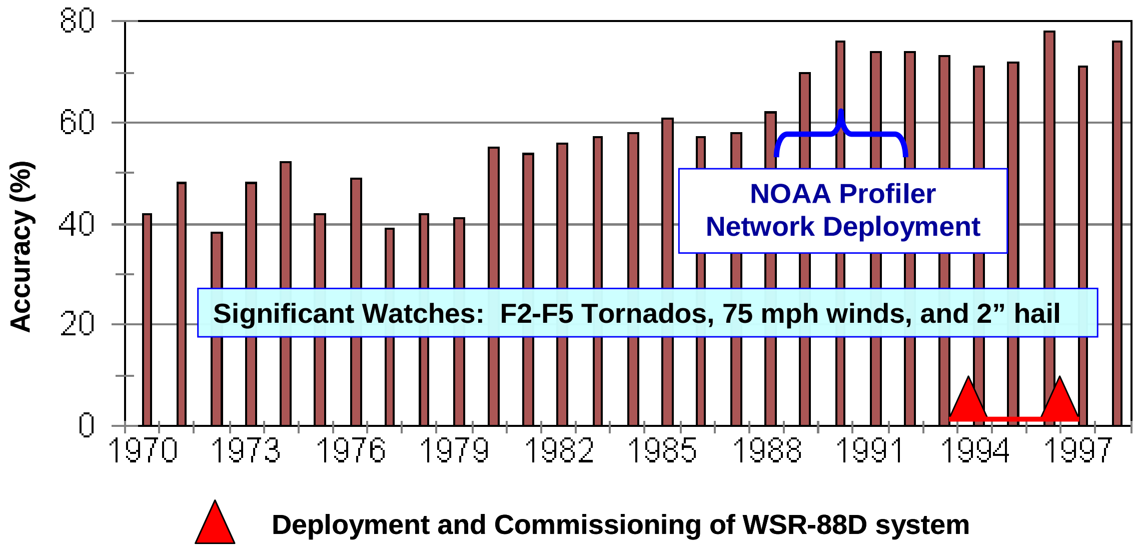

Figure 3.2-1 SPC Watch Accuracy Improvement Following NPN Deployment

3.3 Weather Model Forecasts – In a study entitled, “The Value of Wind Profiler Data in U.S. Weather Forecasting,” (Benjamin et al. 2004) assessed the impact of NPN wind data on numerical weather prediction. They determined the that addition of NPN wind profile data to the weather data base improved accuracy of three-hour wind forecasts by an average of 20% near 10,000 ft (see Fig. 3.3-1). Moreover, the study showed major impacts during inclement winter storms with the NPN winds reducing wind forecast errors by 6.0 to 8.0 meters per second in the extreme. Wind errors occasioned by addition of profiler data directly translate to a positive impact on the air travel industry in the form of decreased fuel consumption and weather delays (Clifford 2003 and Lindsey 1998).

Wind forecasts from computer guidance significantly improved by NPN winds.

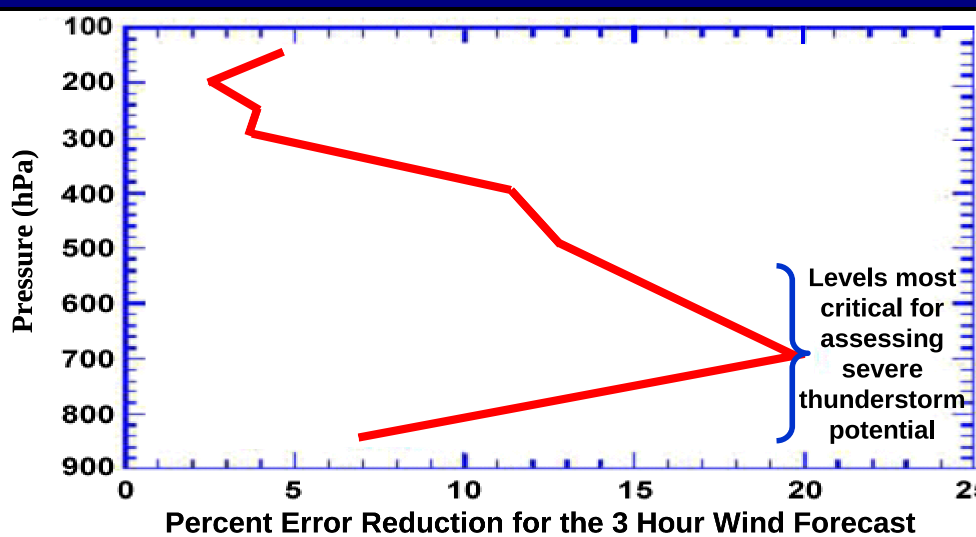

Figure 3.3-1 Percent increase in the error of three-hour wind forecasts when NPN data are not allowed to influence the model prediction. (Benjamin et al 2004)

In summary, access to NPN winds allowed forecasters to detect subtle environmental changes conducive to the formation of severe weather minutes to hours earlier then they would have otherwise. As a result, severe weather warnings, watches, and forecasts were disseminated to emergency managers and the public minutes to hours earlier, allowing the public and economic interests to take mitigating actions in advance of severe weather.

4.0 Analysis

Given these demonstrated weather warning and forecast benefits, the remainder of the *COEA focuses on determining the best strategy for meeting NWS requirements for wind-profile information in terms of performance and cost.* In other words, is the NPN, including the cost to upgrade the operating frequency of the network, the most cost-effective way to obtain these important wind profiles? To answer this question, a performance and cost analysis of the NPN and a range of alternatives for providing wind profile information was constructed.

4.1 Performance Model: Six independent attributes were used to judge wind-profiling system performance: 1) frequency of observation, 2) geographic coverage, 3) vertical reach, 4) horizontal spacing, 5) number of vertical levels, and 6) measurement accuracy. Frequency of observation is the number of profile reports per day. Geographic coverage is the size of the area covered by the alternate wind-profiling systems relative to the area covered by the current NPN (See Fig. 1.1-1). Vertical reach specifies the altitude range (measured in kilometers) of the observing system between the surface and 16-km altitude. Horizontal spacing (density) is measured by the number of observing locations within the area covered by the NPN. Vertical spacing is measured by the number of levels at which reports are available from the surface to 16-km altitude. Accuracy of the wind measurement is the measuring system root mean square wind error. For all these measures except the last, larger numbers represent improved performance.

The relative importance of these six wind-profiling system performance attributes was determined for four NWS operational product and service areas by surveying eleven weather professionals from academia, private industry, and NOAA (names and biographies in Annex A). The four product and service areas were: 1) warnings, 2) short-range forecasts, 3) watches, and 4) numerical weather prediction (NWP). These four areas were chosen because of their primary importance to the NWS mission – saving lives and property. Figure 4.1-1 shows the highest priority attributes as determined by the panel of weather professionals. The indicated split in priorities mandates that most effective wind observing system must be a strong performer in both update frequency and geographic coverage to meet the cross section of NWS missions.

The contribution of the six performance attributes to an overall performance score was modeled by assigning a weight to each of the four product and service areas according to their operational importance. These weights were: 40% for warnings – because warnings are most important for public safety, 30% for short-range forecasts, 20% for watches, and 10% for short-range NWP.

Finally, a single performance number (see Annex B) was generated for each evaluated system on a normalized scale from 0 to 100, with 100 being perfect. The annualized cost for development, production and deployment, and operations and maintenance for each alternative was also determined. The ratio of performance to total cost was calculated to measure effectiveness.

NWS Mission	Most Important Attribute
Short-Range Forecasts	Update Frequency
Warnings	Update Frequency
Watches	Geographic Coverage
Short-Range Numerical Weather Prediction	Geographic Coverage

Figure 4.1-1 Most Important Mission Performance Attribute

4.2 Performance Results.

Figure 4.2-1 provides the performance results averaged over all four NWS product and service areas. The NPN is the highest performer with a score of 85.2. Radiosondes score well relative to the NPN, but only twice per day soundings significantly affect their ability to support short-term forecast and warning missions. An increase in the frequency of launches to 24 times per day, does little to narrow the gap in performance scores between NPN and radiosondes because of NPN's 6-minute updates. The score for MDCRS suffers from the low density of airports within the central U.S. and infrequent soundings. WSR-88D radars are less effective than profilers or radiosondes because of too few vertical levels and lack of vertical reach in clear weather. GOES object tracking scores well mainly because it provides frequent and plentiful wind measurements, but GOES winds tend to appear in large horizontal clusters, not in vertical stacks, a handicap for measuring wind shear.

A modified NPN system delivers the best performance.

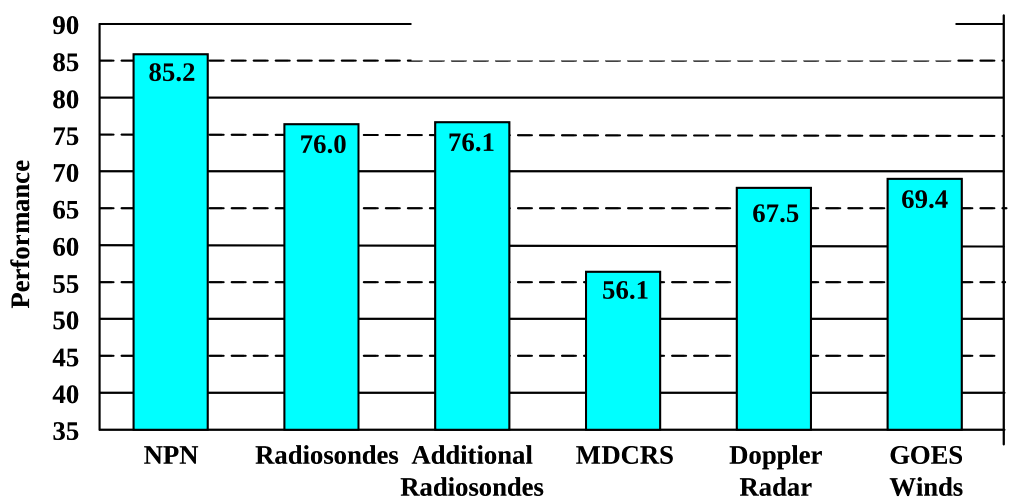

Figure 4.2-1 Comparative Performance of Wind Profiler Systems

4.3 The Cost Model.

The annualized total cost of each of the six alternative wind-profiling systems was calculated by averaging future development, acquisition, operations, and maintenance (see Annex E for calculation details). Of the six system costs shown in Figure 4.3-1, MDCRS is least costly and adding radiosondes is most costly.

Annualized costs include all lifecycle elements.

- **Development**
- **Production and Installation**
- **Operations and Maintenance**

Using additional radiosondes is the most expensive alternative.

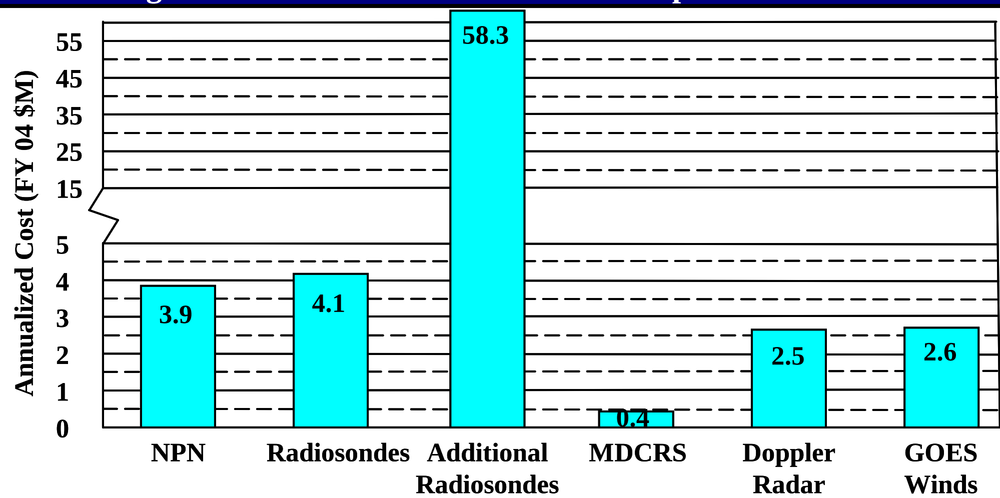

Figure 4.3-1 Cost of Alternatives for Obtaining Wind Profiles

4.4 Results of Analysis.

The result of this analysis is a plot of cost versus performance (Fig. 4.4-1), with quadrants defined using the NPN performance and cost as a center point. Any system that costs less and performs better than NPN falls in the green zone and is preferred. No system fits this category. Higher-cost, higher-performance and lower-cost, lower-performance alternatives lie in the yellow zones and are worth considering. Higher-cost, lower-performance options well inside the red zone should be avoided. The existing Radiosonde system (2) is about 11% lower in performance than NPN and approximately 8% more expensive. Adding enough radiosonde launches to attain hourly frequency of observation (3) does not significantly reduce the overall performance gap with the NPN, but increases annualized cost by more than 14 times. Though the annualized cost of alternatives (4), (5), and (6) is 30% to 90% lower than that for NPN profilers, the performance of these alternatives is between 21% and 41% percent worse, and none of them has even the potential to match the performance of NPN profilers.

Modifying the existing NPN system provides the best value solution.

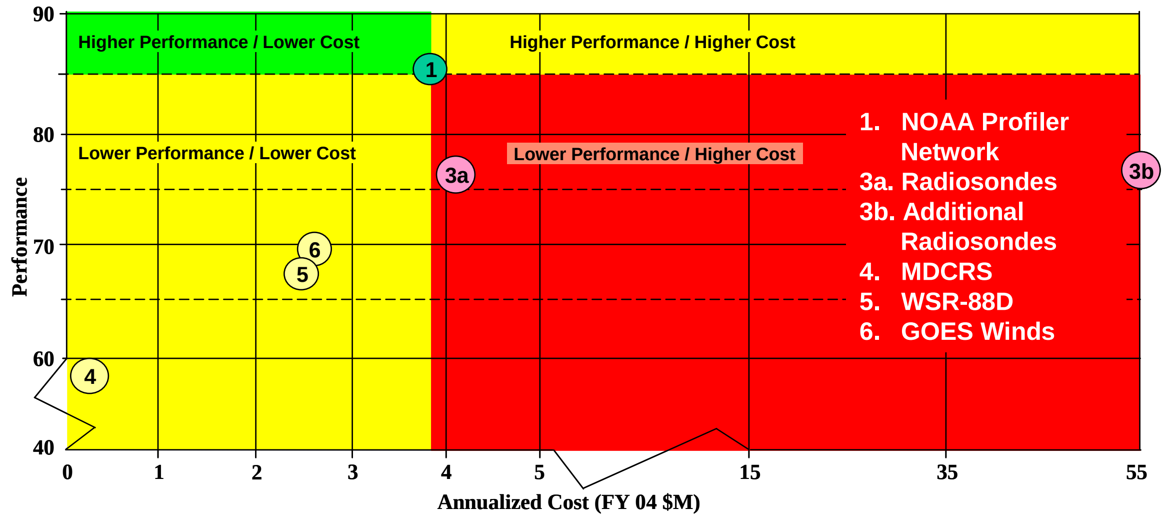

Figure 4.4-1 Results of Cost/Performance Analysis

5.0 Discussion of Options

5.1 Retain Current NPN; Change Operating Frequency.

This option will continue operation of all 35 NPN profilers. Continued operation of the NPN requires conversion of 30 of the 35 profilers from 404 MHz to the assigned and protected frequency of 449 MHz. The other five, located in Colorado, New York, and Alaska, already operate at 449 MHz. Figure 5.1-1 shows the major components that must be changed. To insure NPN data continuity, the conversion must be finished prior to completion of the *Galileo* satellite constellation. The first of these satellites is scheduled to be launched late in 2005; completion of the full constellation of 27 is scheduled to occur in 2008.

A refurbished NPN ensures that the NWS maintains its ability to issue earlier severe weather watches, make them more location- and time-specific, and reduce the false alarm rate of warnings. Moreover, continued availability of NPN data will sustain improvements in the accuracy of computerized weather forecasts and establish the foundation for resolving day-to-day forecasting problems in NWS offices.

The cost of this alternative is $13.2 Million to upgrade the 30 NPN operating sites, plus annual operations and maintenance costs of $3.2 Million (FY 04 $) for the network. Cost breakdowns for the frequency conversion, including its certification and coordination with other users of the frequency, any required environmental studies, and annual operations and maintenance are in Annex C. Over the next twenty years, the annualized cost of for the NPN is $3.9M (see calculation in Annex D).

Only modest modifications to NPN are required.

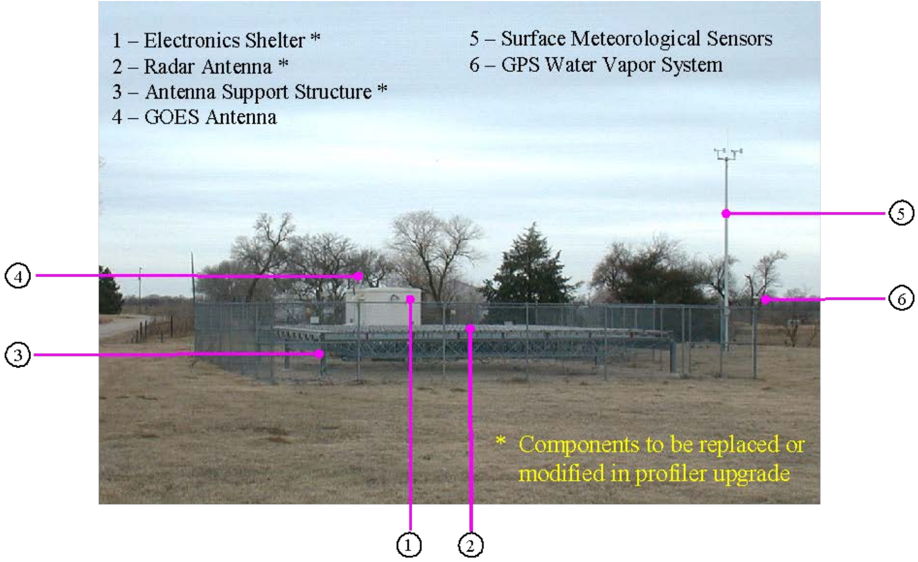

Figure 5.1-1 Major Components of a 404 MHz Wind Profiler, Highlighting Components That Must Be Modified or Replaced to Operate at 449 MHz

5.2 Terminate NPN Program.

This option takes the NPN out of service including sites like the one shown in Figure 5.2-1. Costs and impacts of this alternative include equipment disposal, site clean up, NPN Hub replacement, and impact on short-term forecasts, warnings, watches, and weather model guidance from loss of NPN wind observations and NPN complementary observations.

5.2.1 Cost of termination

This requires vacating the NPN sites, disassembling and disposing of equipment, and returning sites to their original condition. Two contractor estimates have been received for this work, one for $42,628 per site and the other for $27,918 per site. Another $10,000 per site would be needed for soil testing and removal if necessary. Taking an average of these estimates, the cost to clear, clean, and restore the sites and to manage the contract is $1.7M. The functions included in site shutdown are listed in Annex F.

Cost of equipment disposal and site remediation is $1.7M.

Figure 5.2-1 NPN Sites Are Generally Small and Will Require Limited Remediation

5.3 Replace NPN with Radiosonde Data.

The radiosonde (weather balloon) is the only observing system that provides a complete set of atmospheric measurements (wind, temperature, pressure, and moisture) from surface to mid-stratosphere (above 70,000 feet). Radiosondes have historically been the standard against which other observations are compared. They are also used to verify numerical weather prediction models. However, there are drawbacks to using radiosondes as a replacement for NPN.

The radiosonde's key limitation for warnings and short-term forecasts is its launch interval: once every 12 hours. By contrast, NPN radars deliver a vertical wind profile every six minutes, permitting forecasters to monitor rapidly changing weather conditions in detail. Launching radiosonde balloons (Fig. 5.3-1) even at hourly intervals is both costly and impractical. It would require a large increase in labor and a twelve-fold increase in the cost of expendable items that include the balloon, helium gas, and an instrument package. The incremental cost of hourly balloon launches at the 25 sites within the NPN boundaries would be $54.2M per year. This compares with the $4.5M annualized cost of operating the GPS Radiosonde system for two launches per day at the same 25 sites.

A second shortcoming of radiosondes is that accuracy of the wind measurement suffers whenever strong winds carry the balloon close to the horizon (a tracking problem). Accurate measurement of strong winds in the vicinity of the jet stream is important for diagnosing aircraft turbulence. This second problem may be solved through use of Global Positioning System (GPS) technology beginning in 2005.

Furthermore, additional radiosonde stations would be required to replicate the horizontal density of observations provided by NPN. Increasing the horizontal resolution of radiosonde sites would take years and millions of dollars for construction of new balloon shelters and installation of ground tracking stations.

Radiosondes provide high quality data twice daily.

Figure 5.3-1 Radiosonde Launch at WFO Tampa, Florida

5.4 Replace NPN with Data from the MDCRS

Automated observations from commercial aircraft are another important source of wind profiles. Through the MDCRS system, nearly 90,000 reports of wind and temperature are received each day, most of them from flight altitudes between 25,000 and 41,000 feet. This provides very good high-altitude coverage for about 60% of the country. Four passenger and two freight carriers participate in this program, with freight carriers providing the majority of nighttime data. Currently the government pays for only half of the communications costs and does not have to pay for the aircraft sensors, thus making this an inexpensive source of wind data.

MDCRS provides significant cruise altitude data; however, data at lower altitudes, collected during ascent and descent, are relatively sparse. Further, as seen in Figure 5.4-1, MDCRS provides non-uniform geographic and sparse coverage over the Northern Rockies and western Great Plains. Weather, schedules, and individual airline practices lead to variability in reporting. For example, large storms lead to numerous flight cancellations. Pilots carrying passengers generally try to avoid turbulence and foul weather, which means that fewer reports come from bad weather areas, where they are most needed.

Most MDCRS profiles contain data from only a few altitudes. Package carriers, the predominant source of nighttime data, do not fly on weekends. The costs associated with the current MDCRS system are low, annualized at $0.35M. However, this program relies partly on the good will of commercial carriers, and one cannot expect them to add flights at additional locations and times to generate the data that would be a viable alternative to NPN wind data.

Aircraft soundings leave significant gaps in the western Great Plains.

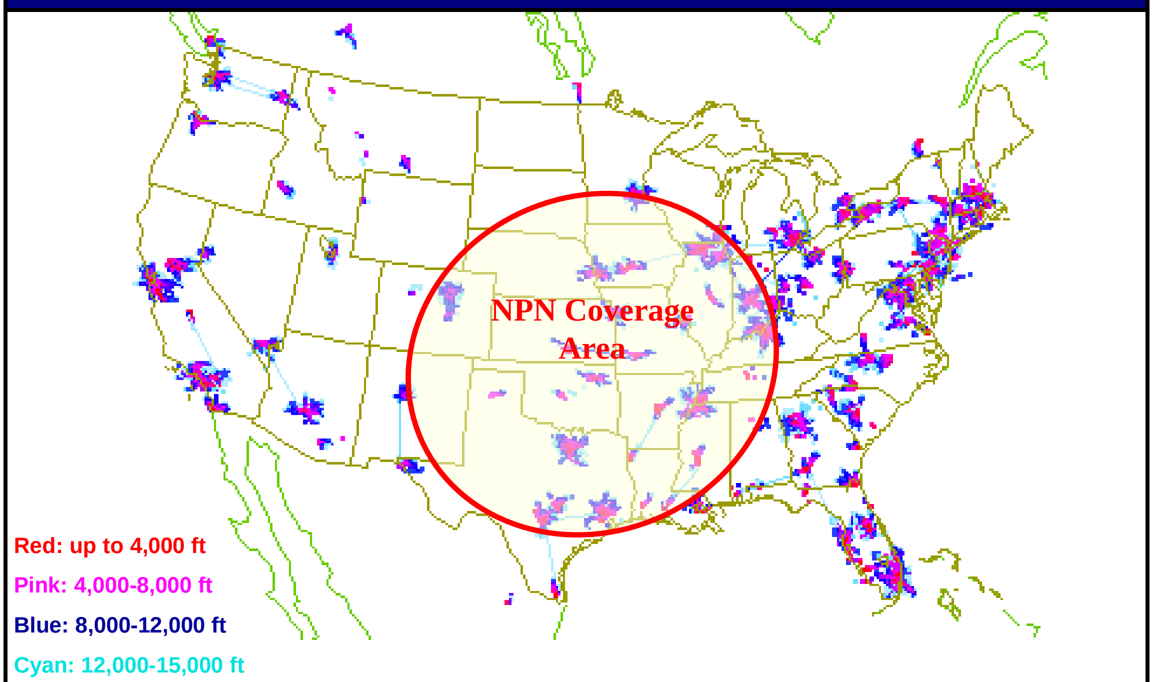

Figure 5.4-1 24 Hours of Aircraft Ascent and Descent Reports

5.5 Replace NPN with WSR-88D Doppler Weather Radar Data.

Doppler weather radars are unexcelled at providing highly detailed information on air motions inside of precipitating clouds under conditions ranging from light snowfall to severe thunderstorms. These systems provide data at five-minute intervals and scan the atmosphere at 14 elevation angles from 0.5^{o} to 19.5^{o} above the Earth's horizon. Doppler radars are an essential source of information for issuing severe weather warnings.

However, Doppler weather radars do not provide useful information about wind speed and direction unless a sufficient number of targets such as dust, large aerosols, large cloud droplets or ice crystals, insects, or precipitation are present in the air. In clear air, the strength of the radar return from altitudes above 10,000 feet is usually too small to be detected. It is also difficult to make wind measurements during the winter when insects are not present in large numbers. More importantly, data are not collected at elevation angles above 19.5^{o} or below 0.5^{o}. As shown in Figure 5.5-1, this means the radar cannot detect low-level air motion, no matter what the atmospheric conditions are, at distances greater than about 60 miles because of the curvature of the Earth. And, because of the 19.5^{o} maximum elevation, the radars cannot survey a large volume of atmosphere directly over the site. As a consequence, WSR-88D radars can only provide something approximating a traditional wind profile from the lower 10,000 feet in the atmosphere under most conditions.

Though the annualized cost of providing wind profiles from the existing Doppler radar network is only $2.5M, the physical limitations of the system do not permit it to replace the information lost if the NPN were to shut down.

WSR-88D radars point more horizontally than vertically.

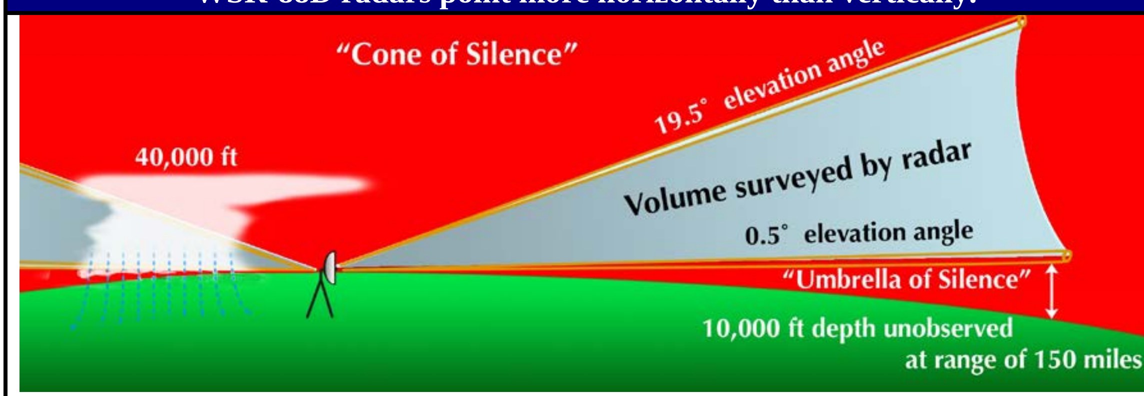

Figure 5.5-1 WSR-88D Radar – Red Area Includes Cone and Umbrella of Silence Where Radar Beam Cannot Detect Winds.

5.6 Replace NPN with GOES Object Tracking Data

As shown in Figure 5.6-1, it is possible to use successive images generated by GOES satellites to track targets and thus infer the speed and direction of the wind that moved the target. Object tracking requires the presence of an observable target (e.g., a cloud) that retains its identity between successive image frames, typically separated by 15 minutes. Because some clouds are anchored to the terrain (e.g., mountain-wave clouds), care must always be taken to select features that move with the wind. Winds estimated by tracking targets do not come in vertical stacks but rather in large horizontal clusters that are determined by the distribution of clouds. Clouds at different levels yield estimated winds at different levels, but seldom at the same geographic location.

Though the movement of a target can be accurately determined, the height of the target is estimated from a measurement of the cloud-top temperature. Since our knowledge of the relationship between atmospheric temperature and altitude is imprecise, the accuracy of the height of the target can only be approximated (rather than measured) and this degrades the accuracy of the inferred wind observation.

There are no additional sensors or instruments planned to be added to the GOES satellites that will improve the accuracy and amount of GOES winds; thus, there is no ability to generate the data that would be lost with the termination of NPN. The annualized cost of GOES object tracking is $2.6M.

Object tracking requires clouds or water vapor tracers;
altitude determination is coarse.

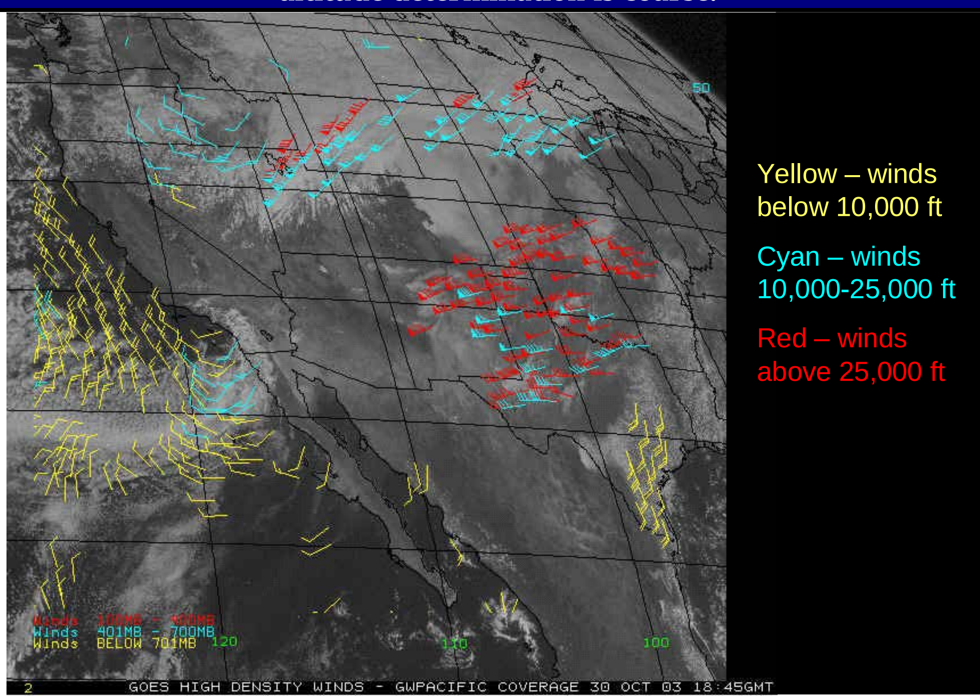

Figure 5.6-1. A Typical Selection of Winds Estimated from Target Tracking

5.7 Replace NPN with other Expanded Capabilities

This is not an option for several reasons. In the case of MDCRS, the number of ascent/descent soundings varies significantly according to time of day and day of the week, extensive bad weather causes flight cancellations, and the number and geographic distribution of airports is fixed. The vertical profiles of wind provided by Doppler radars are severely height limited unless there are thick clouds or precipitation. The operating wavelength of the radar is unsuitable for detecting clear-air winds much above 10,000 ft. The instrumentation aboard GOES satellites will not change for at least several years. The inability to see through clouds limits the number of levels at which winds can be derived. In a given small area, the wind can be determined at only a few levels at best. Our effectiveness model didn't fully characterize the negative impact to mission operations when, for a variety of reasons, the observation frequency of MDCRS, Doppler radar, or the GOES object tracker system becomes irregular. By contrast, NPN profilers consistently measure winds every six minutes, seven days a week.

6.0 Discussion and Conclusion

This Cost and Operational Effective Analysis (COEA) is provided in response to a request by the Senate Appropriations Committee to compare the "… cost to upgrade the NOAA Profiler Network (NPN) over the next decade versus the short, medium, and long-term costs of ending the NPN program."

Recent studies over the past year indicate there is benefit from the high-temporal-frequency wind profiles observed by the NPN to operational weather warning and forecast performance in NWS. Operational product and service areas benefiting from NPN wind profiles include:

- *Warnings:* NPN winds improve probability of detection, false alarm ratio, and lead time for warnings of tornadoes, severe thunderstorms, flash floods, and winter storms. They also improve warnings related to aviation and fire weather.

- *Watches and Outlooks:* NPN winds improve watch and outlook accuracy for severe weather.

- *Numerical Weather Prediction:* NPN winds improve 0-12 h wind forecasts.

Given these demonstrated weather warning and forecast benefits, this COEA focused on determining the best strategy for meeting NWS wind-profile information requirements in support of NOAA's forecast and warning mission in terms of performance and cost. The analysis considered the seven alternatives: 1) Changing the NPN operating frequency and maintaining the current network, 2) terminating the NPN network using 3a) existing and 3b) additional radiosondes, 4) automated aircraft reporting (MDCRS), 5) WSR-88D Doppler radar and 6) object tracking by GOES satellite.

The COEA results show that the best combination of performance and cost is to maintain the NPN system and modify its frequency so as not to interfere with reception by SARSAT satellites of signals from Search and Rescue beacons. While the other systems have individual attributes that may exceed the capability provided by NPN, there are significant physical or cost impediments that preclude their use in lieu of NPN.

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Annex A

Expert Panel Bibliography

Richard Anthes is President of the University Corporation for Atmospheric Research, which operates the National Center for Atmospheric Research under contract to the National Science Foundation. He has almost three decades of experience in regional numerical weather prediction.

Robert Aune works for NOAA's National Environmental Satellite, Data and Information Servcie (NESDIS) at the Cooperative Institute for Meteorological Satellite Studies, located in Madison, Wisconsin. He is an expert on the use of satellite observations for local and regional numerical weather prediction.

Mary Cairns is Observing Systems Focal Point, Office of the Federal Coordinator for Meteorology (OFCM). She currently coordinates weather observing system requirements within the U.S. Government. Mary was formerly the Science and Operations Officer (SOO) at the Reno, Nevada, Weather Forecast Office and an aviation researcher and modeler at the Forecast System Laboratory in Boulder, Colorado.

Frederick Carr is Professor and Director of the School of Meteorology, University of Oklahoma in Norman, Oklahoma. He specializes in the use of observations, especially radar data, in local and regional models for numerical forecasts.

Ed Mahoney is Chief of the Warning Decision Training Branch, National Weather Service, in Norman, Oklahoma. Ed is an expert on regional weather prediction including lake effect snow and severe thunderstorms. He was a key member of the team that developed the "Professional Development Series (PDS)" for standardizing meteorologist training within the National Weather Service. He also developed a "BUFKIT" application that allows meteorologists to visualize model sounding information.

John McGinley is a Branch Chief in the Forecast Research Division of the Forecast Systems Laboratory located in Boulder, Colorado. He led a team that developed the Local Analysis and Prediction System, software that assimilates diverse regional observations into local and regional models. The software is available through the Advanced Weather Interactive Processing System (AWIPS) at NWS offices around the country.

Robert Mullenax is a High Impact Weather Meteorologist at Universal Weather and Aviation, Inc, Houston, Texas. Robert is a member of the Universal Weather High Impact Weather forecast team and was formerly employed as a stratospheric meteorologist at the National Scientific Balloon Facility (NSBF) in Palestine, Texas. Universal Weather supports a diverse group of Fortune 500 companies in aviation, chemical, energy exploration and production, and marine shipping industries.

Dan Smith is Director of the Scientific Services Division at Southern Region Headquarters of the National Weather Service in Dallas, Texas. He has an abiding interest in the quality of public watches and warnings in advance of severe weather.

Roger Wakimoto was a student of Professor Tetsuya (Ted) Fujita at the University of Chicago, after whom the F-scale for tornadoes is named. Like his mentor, Dr. Wakimoto is a master at analyzing storm structure and behavior on the basis of regional weather observations.

Steven Weiss is Science and Operations Officer at the National Weather Service's Storm Prediction Center (SPC) in Norman, Oklahoma. Steven supports science infusion into SPC operations in order to improve forecasts and watches for severe thunderstorms, tornadoes, flooding rains, heavy snow, and conditions favoring the spread of wildfires. The SPC issues specific products for each of these hazards.

Peter Wolf is Science and Operations Officer at the National Weather Service's Forecast Office in Wichita, Kansas. Peter has written extensively on the importance of using near storm environmental data to improve tornado and flash flood forecast accuracy. His techniques have been incorporated into the NWS's Virtual Institute for Satellite Integration Training Program; they are also used as a "Best Practice" in the Central Region Headquarters.

Annex B

The Calculation of Performance Measures

National Weather Service missions served by wind profiler observations

- Short-range forecasts prepared by staff at Warning and Forecast Offices (WFOs) such as special weather statements, nowcasts, and aviation forecasts with emphasis on first 12 hours
- Watches (alerting the public about the likelihood of hazardous or damaging weather in a sizeable area hours in advance)
- Warnings (alerting the public that severe weather is imminent within a small region, usually minutes to an hour in advance)
- Data for computer models making regional, high-resolution, short-range predictions (~12 hours). Referred to as "Short-range numerical weather prediction (NWP)

Attributes of wind observing systems that make them valuable

We consider wind observations (rather than observations of temperature, pressure, humidity, etc.) first, because the subject of this COEA is the NOAA (Wind) Profiler Network and second, because wind observations are critical in most weather services involving short-lived, regional and local phenomena.

- Frequency of reporting (how often the reports come in)
- Geographical coverage (essentially, the size of the observing network; bigger is generally better)
- Vertical reach (specifies the altitude range of the observing system): for the applications above, observations from sea level to 50,000 ft (about 15 km) will be considered perfect, i.e., no additional credit for observations higher than that)
- Horizontal spacing of measurements (higher density is better)
- Vertical spacing of measurements (closer together is better)
- Accuracy (in meters per second - m s^{-1}; observations are considered useless if in error by more than 10 m s^{-1})

Weighting the attributes according to NWS mission

We contacted eleven acknowledged weather experts (see Annex A) and asked them to gauge the relative importance of each of the above attributes. The average of their responses appears in the following table. Note that the weights sum to 1.00 in each column.

Table B.1

	Short-range forecasts	Watches	Warnings	Short-range NWP
Frequency, w_1	.22	.14	.28	.09
Geographical Coverage, w_2	.19	.26	.15	.27
Vertical reach, w_3	.10	.13	.07	.13
Horizontal spacing, w_4	.17	.18	.17	.17
Vertical spacing, w_5	.14	.13	.13	.13
Accuracy, w_6	.18	.16	.20	.21

Observing systems apt for measuring atmospheric winds

$ Wind Profiling Radars in the NOAA Profiler Network (NPN): Doppler radars on the ground that point in three fixed directions, whose raw measurements permit the calculation of the horizontal wind speed and direction at multiple levels in the vertical. The network has been operating in the central U.S. for more than a decade.

$ Radiosondes: Employed since World War II for measuring not only winds but also pressure, temperature and relative humidity, these time-honored weather balloons, filled with helium, rise at about 1000 ft per minute, carrying aloft a lightweight package of instruments.

$ ACARS/MDCRS: Automated reports of wind and temperature from six commercial U.S. airlines that now number more than 100,000 per day. Most of these reports originate from flight level (25,000-41,000 ft) but a significant fraction is associated with takeoffs and landings. These latter reports are especially valuable because they describe conditions through a significant depth of the atmosphere.

$ WSR-88D radar: The Doppler radars currently used by the National Weather Service for tracking storms and precipitation. The radars can detect air motion toward or away from the radar, which, in turn can offer a telling glimpse into the inner workings of storms.

$ GOES drift winds: Derived by tracking features (targets) in successive satellite images. Often, these features are clouds (as viewed either at visible or infrared wavelengths), but it is also possible to obtain drift winds in clear air by tracking features in water vapor images.

Assigning performance numbers to each wind observing system; explaining choice of numbers

Frequency (number of reporting times per day)

Wind Profiling Radars (240): The U.S. standard is one stack of winds every hour, but these hourly reports are in fact the average of ten 6-min profiles collected during the hour. The National Weather Service's Storm Prediction Center requested 6-min data and receives them in real time.

Radiosonde (2): Twice a day is the U.S. standard.

Extra radiosondes (24): We estimated performance for a hypothetical radiosonde network having the same station locations as the current network but launching balloons hourly instead of just twice a day.

ACARS/MDCRS (30): This is the average number of ascent or descent soundings per day for the 45 metropolitan areas whose airports deliver at least 5 soundings per day.

WSR-88D radial velocities (288): VAD wind profiles are available once every 10 min when the radar operates in clear-air mode, and as often as every 5 min when it operates in precipitation mode.

GOES drift winds (24): The drift-wind product is available hourly.

Geographical Coverage (Because this COEA involves a head-to-head comparison of wind observing systems, full coverage is assigned where the geographical distribution of reports is roughly uniform throughout the area covered by the NOAA Profiler Network. The *density* of reports is considered separately.)

Wind Profiling Radars (100%) 31 profilers are sited throughout the NPN.

Radiosonde (100%): The rawinsonde network was designed to provide uniform coverage over the lower 48 states.

Extra radiosondes (100%): Same station locations assumed as in current network.

ACARS/MDCRS (70%): The airports that provide frequent wind reports on ascent or descent cover roughly 70% of the NPN area. The eastern half of the NPN area is well covered, whereas the western half has large gaps in coverage.

WSR-88D radial velocities (98%): Radial velocity data are extracted from the raw signal out to a radius of 230 km. The 142 sites in the lower 48 states are fairly evenly distributed; they provide overlapping coverage for radial velocity data in most areas except the Intermountain West, which is outside the NPN. At a few radar sites within the NPN, the terrain blocks the beam when it points in specific directions at low elevation angles.

GOES drift winds (75%): Though the potential exists to retrieve a drift wind at any location, the requirement is that a trackable feature be present. The coverage estimate comes from an examination of three real-time products available at http://cimss.ssec.wisc.edu/tropic/real-time/atlpac/winds/winds-wvir.html: high-level drift winds from IR and water vapor images, low-level IR drift winds, and drift winds from visible images (available only in the daytime). Coverage varies with cloudiness and, to a lesser extent, with the time of day (no visible targets at night).

Vertical Reach. If the observing system provides winds from near the surface to at least 50,000 ft, it gets full credit for this attribute. The reason: none of the four NWS missions under consideration requires wind data above 50,000 ft (about 15 km).

- Wind Profiling Radars (15 km): NOAA profilers routinely reach to 16 km.
- Radiosonde (15 km): Radiosonde balloons routinely ascend to 20 km and beyond.
- Extra radiosondes (15 km): The extra sondes have the same manufacturer as existing ones, and so they ascend just as high.
- ACARS/MDCRS (12.5 km): Standard flight altitudes extend to 41,000 ft (12.5 km).
- WSR-88D radial velocities (4 km): Velocity-Azimuth Display (VAD) Wind Profiles (VWPs) in clear air normally reach 3-4 km above the radar. In severe weather situations, VWPs become irrelevant, in that the 88D is used to observe internal storm motions rather than the near-storm environment.
- GOES drift winds (11 km): Clouds (or clear air features as seen in water vapor images) occur at all altitudes in the troposphere, which, in the U.S. Standard Atmosphere, extends to 11 km altitude. On average, the top of the troposphere is higher than this in summer, lower in winter.

Horizontal Spacing. The number of sites within the area covered by the NOAA Profiler Network (NPN) is a proxy for horizontal spacing.

- Wind Profiling Radars (31): There are 32 profiler sites in the lower 48 states. All are in the central U.S. except for the profiler at Syracuse, NY.
- Radiosonde (25): Of the 73 radiosondes in the lower 48 states, 25 lie within the NPN or very close to its boundary.
- Extra radiosondes (25): More frequent launches of balloons from the same locations.
- ACARS/MDCRS (15): This number is somewhat arbitrarily limited by the requirement that an airport has to deliver at least 5 ascent or descent soundings per day. There are 45 such airports in the lower 48 states, 15 within the NPN or very close to its boundaries.
- WSR-88D radial velocities (53): There are 142 WSR-88D radar sites operating in the lower 48 states, each one capable of generating a VAD Wind Profile. Of the 142, 53 lie within the NPN or very close to its boundary.
- GOES drift winds (167): Drift winds are customarily dense where targets are available for tracking. This results in a large number of winds each time the tracking algorithm runs. Chris Velden, a key figure for many years in the extraction of drift winds from GOES images, estimates that roughly 2000 water vapor (WV) and infrared (IR) vectors are nominally extracted each hour between 450-100 millibars (21,000 to 53,000 ft) and within the area bounded by 73^{o}-125^{o}W and 30^{o}-49^{o}N . Similarly 300 WV/IR vectors are extracted between 950-450 millibars (1,700 to 21,000 ft), and 700 vectors from visible cloud tracking (VIS) between 950 and 600 millibars (1,700 and 14,000 ft). The numbers vary widely from day to day, primarily because of the variation in cloudiness. This gives a total of 3000 vectors, sorted into six layers (as may be seen from examination of the products on the web). The NPN covers roughly one-third of the area for which counts were made. The number given above is thus 3000 x 1/6 x 1/3 = 167.

Vertical Spacing. (How many different reporting levels between the surface and 15-km altitude)

- Wind Profiling Radars (59): The NPN radars deliver wind estimates at approximately 59 distinct levels below 15-km altitude.
- Radiosonde (50): Could be more or less depending upon the number of significant levels.
- Extra radiosondes (50): The same reporting procedures as with current sondes leads to the same number of levels with reports from an average sounding.

ACARS/MDCRS (10): Most airlines do not yet use the recommended ARINC 620 format for reporting winds on ascent or descent, which can easily yield 40 levels. 10 levels may be generous as an average for the current data collection.

WSR-88D radial velocities (10): The 88D radars scan at 14 different elevation (tilt) angles, from 0.5^o to 19.5^o. The nominal VAD wind profile report has less than 10 levels in winter, sometimes more than ten in the summer.

GOES drift winds (6): The three drift wind products (High-Level WV/IR, Low-Level WV/IR, and VIS) together cover six distinct atmospheric layers. All derived winds come from GOES images. Polar orbiting satellites also yield drift winds, but only over high latitudes.

Accuracy. All numbers are expressed in meters per second (m s^{-1}). The accuracy figures are those used by the National Weather Service's Environmental Modeling Center (EMC). When EMC assimilates observational data into prediction models, it assigns an error to each type of observations.

Wind Profiling Radars (2.5)

Radiosonde (2.2): With the current position-finding system, wind errors increase with wind speed. An error of 8-10% of the wind speed is reasonable. This problem will disappear when and if the NWS begins to use GPS sondes. Then the position (and the wind speed) will be determined to within probably better than 1.0 m s^{-1}.

Extra radiosondes (2.2): Extra sondes will be of the same manufacture as present sondes; thus accuracy will be the same.

ACARS/MDCRS (2.5): GPS is used to determine the winds (difference between the aircraft velocity vector with respect to the moving air stream and that with respect to the ground.

WSR-88D radial velocities (6.0): EMC does not trust VAD winds. With effective quality control and the restriction to undisturbed conditions, the accuracy is probably at least as good as 3.0 m s^{-1}.

GOES drift winds (2.5): Chris Velden, an expert in the retrieval of drift winds, estimates that the probable error could be as high as 5.0-6.0 m s^{-1}, but we have used the EMC figures.

Table B.2. Performance of observing systems that measure wind. The best performance measure in each column is highlighted.

	Performance Measure					
Observing System	Frequency (per day)	Geographical Coverage (%)	Vertical Reach (km)	Horizontal Spacing[1]	# Levels in Vertical	Accuracy[2] ($m\ s^{-1}$)
Wind-Profiling Radar (NPN)	240	**100**	**15.0**	31	**59**	2.5
Rawinsonde	2	**100**	**15.0**	25	50	**2.2**
Extra Radiosondes	24	**100**	**15.0**	25	50	**2.2**
ACARS/MDC RS	30	70	12.5	15	10	2.5
WSR-88D Radar	**288**	98	4.0	53	10	6.0
GOES Drift Winds	24	75	11.0	**167**	6	2.5

[1] Horizontal spacing is expressed as the number of observations within the region covered by the NOAA Profiler Network.
[2] Estimates from the Environmental Modeling Center (EMC), one of the National Centers for Environmental Prediction

Normalized performance measures

Each performance measure in the table on the preceding page is normalized by the best performance in each column.

Table B.3. Normalized performance measures.

	Performance Measure					
Observing System	Frequency A_1	Geographical Coverage A_2	Vertical Reach A_3	Horizontal Spacing A_4	# Levels in Vertical A_5	Accuracy[1] A_6
Wind-Profiling Radar (NPN)	0.8333	1.0000	1.0000	0.1856	1.0000	0.8800
Rawinsonde	0.0069	1.0000	1.0000	0.1497	0.8475	1.0000
Extra Radiosondes	0.0833	1.0000	1.0000	0.1497	0.8475	1.0000
ACARS/MDCRS	0.1042	0.7000	0.8333	0.0898	0.1695	0.8800
WSR-88D Radar	1.0000	0.9800	0.2666	0.3174	0.1695	0.3667
GOES Drift Winds	0.0833	0.7500	0.7333	1.0000	0.1017	0.8800

[1] To be consistent with the other measures, for which a bigger number is better, the *inverse* of the accuracy must be used here. Thus, systems whose accuracy is poorer than that of the radiosonde will have a value less than one.

Calculating performance measures

We define a performance measure for each observing system that takes into account each of the six attributes of performance. For its contribution to any one of the four NWS missions under consideration the measure is defined as

$$P = 100\sqrt{w_1 A_1^2 + w_2 A_2^2 + w_3 A_3^2 + w_4 A_4^2 + w_5 A_5^2 + w_6 A_6^2}$$

A perfect hypothetical observing system—one having the best performance in every attribute—would attain a score of *P=100*. Performance scores for each observing system are listed in the table on the next page for each of the four NWS missions under consideration.

Table B.4. Observing system performance by NWS mission.

Observing System	NWS Mission				
	Short-Range Forecasts P_1	Watches P_2	Warnings P_3	Short-Range NWP P_4	Average P_{avg}
Wind Profiling Radar (NPN)	85.32	86.45	83.97	87.23	85.74
Radiosonde	75.79	80.46	71.92	84.09	78.07
Extra Radiosondes	75.89	80.52	72.05	84.13	78.15
ACARS/MDCRS	55.65	59.02	53.40	62.55	57.66
WSR-88D Radar	67.45	66.51	69.05	63.85	66.72
GOES Drift Winds	68.78	72.28	67.10	74.59	70.69

As shown in Table B.4, performance of a particular observing system varies with the NWS mission (application), sometimes significantly. In the last column of Table B.4, we list an overall performance; it is simply the average of the performances for each of the four applications, namely $P_{avg} = (P_1 + P_2 + P_3 + P_4)/4$

We decided to investigate the effect on performance if the importance of the four different applications is not equal. For this purpose, we weighted short-range forecasts by 0.3, watches by 0.2, warnings by 0.4, and short-range NWP by 0.1. We denote these weights C_1 through C_4, respectively; the weights add up to 1.0. For each observing system, we can form the weighted sum

$$P_w = C_1 P_1 + C_2 P_2 + C_3 P_3 + C_4 P_4$$

The result is indicated in **Table B.5**.

Observing System	Weighted Performance, P_w
Wind Profiling Radar (NPN)	85.20
Radiosonde	76.01
Extra Radiosondes	76.10
ACARS/MDCRS	56.11
WSR-88D Radar	67.54
GOES Drift winds	69.39

Weighting the mission contributions differently causes changes in the spread between observing systems but it does not cause any change in ranking. The numbers in Table B.5 also appear in Fig. 4.2-1 of the COEA.

Annex C

Cost Break-Down for Frequency Conversion

A. Background

Continued operation of the NPN requires conversion of the profilers from 404 MHz to the assigned and protected frequency of 449 MHz. Figure 4.1-1 below shows the changes that will have to be made to existing NPN stations. The conversion must be completed prior to completion of the constellation of European Union and European Space Agency GPS satellites that will also carry Search-and-Rescue receivers. The first of these satellites will be launched late in 2005; the full constellation of 27 will be deployed by 2008.

A refurbished NPN ensures that the National Weather Service (NWS) maintains capability to generate and issue severe weather watches earlier, makes them more location- and time-specific, and reduces the false alarm rate of warnings. Moreover, continued availability of NPN data will sustain improvements in the accuracy of computerized weather forecasts and establish the foundation for resolving day-to-day forecasting problems in NWS offices.

The cost of this alternative includes $13.2 Million to upgrade the 30 NPN operating sites and an allocated annual operations and maintenance cost of $2.5 Million (FY 03 $). Cost breakdowns for the frequency conversion Annex C, Section C.

Sidebar: European Update on Galileo
The first experimental satellite, part of the so-called Galileo System Test Bed (GSTB) will be launched in the second semester of 2005. The objective of this experimental satellite is to characterize the critical technologies, which are already under development under ESA contracts. Thereafter up to four operational satellites will be launched in the timeframe 2005-2006 to validate the basic Galileo space and related ground segment. Once this In-Orbit Validation (IOV) phase has been completed, the remaining satellites will be installed to reach the Full Operational Capability (FOC) in 2008.
http://www.esa.int/export/esaNA/GGGMX650NDC_index_0.html

B. Frequency Change Overview - Sub-System Description

1. Overview

Conversion of the existing 404 MHz profilers to the 449 MHz frequency requires changes in only the frequency dependent components of the radar. Some components require complete replacement while others require modification. There are five frequency dependent components in the 404 MHz profiler. Three require complete replacement and two require modifications.

2. Replacement components

   a. Antenna – The 404 MHz antenna is a coaxial collinear phased array antenna. It consists of power dividers, coaxial cables, a beam steering unit and two arrays arranged orthogonal to each other. Each array is formed from 20 rows of coaxial collinear subassemblies fed by a series of power dividers. The coaxial collinear subassemblies are made from sections of high impedance coaxial cable cut to a half-wavelength and packaged within a 1 ¾" diameter weather-proof fiberglass radome. It is the frequency and therefore the wavelength which dictate the lengths of the coaxial cable for the subassemblies and other cable lengths in the system. The entire antenna needs to be built specifically for a given frequency to obtain maximum performance and to adhere to RSEC-E requirements set by NTIA. Therefore, complete replacement of the antenna is required due to this frequency dependency.

   b. Transmitter – The 404 MHz transmitter is comprised of sixteen 1.2 kW solid state amplifiers, two RF drivers, four power supplies, and an interface/status monitor. The dual RF driver provides power to the sixteen amplifiers and consists of two identical drivers. In the event of a failure of one driver the other is automatically switched into service. The transmitter's sixteen amplifiers can also experience failures and continue to operate in a degraded fashion. The amplifiers and the RF drivers contain high power transistors that are tuned for 404 MHz. Similar to the antenna the transmitter is designed to operate at a fixed frequency or range of frequencies and must also meet RSEC-E requirements. The current 404 MHz transmitter would not be able to operate at 449 MHz and still perform satisfactorily. A complete replacement is thus required.

   c. Circulator – The circulator is located in the Beam Steering Unit cabinet and accepts the transmitted signal from the transmitter. It sends the signal out to the antenna and also accepts the return signal and sends it to the receiver. The circulator is a magnetic device and is built to handle specific frequencies. It too must be built to operate at the new 449 MHz frequency and has to be replaced.

3. Modified components

    a. RF Generator – The RF Generator produces three fixed frequency signals. The Local Oscillator (LO) and the Coherent Oscillator (COHO) signals are used by the receiver and a third 404 MHz signal is created by mixing the LO and the COHO frequencies to provide the RF input signal for the radar transmitter. The RF Generator contains crystal oscillators which generate the required frequencies needed to produce the three signals. By replacing the oscillators and a few other components the RF Generator can be made to operate at the 449 MHz frequency.

    b. Receiver – The Receiver is a superheterodyne design that performs an analog-to-digital (A/D) conversion of the returned Doppler-shifted signal before sending it for signal processing. The frequency dependent components of the receiver can be replaced to operate at 449 MHz without having to replace the entire unit.

4. Frequency change coordination

    a. The following discussion is based on previous experience with five existing 449 MHz profilers and on the guidance provided by the Director of the U.S. Department of Commerce/NOAA Office of Radio Frequency Management. The existing five 449 MHz profilers were specified by the government and built by industry to meet certain technical specifications regarding characteristics of the emitted signal into the atmosphere. These systems were approved for Operational Status (Stage 4) by the IRAC's Spectrum Planning Subcommittee (SPS) in documents SPS-11944/3 (IRAC Doc. 31143/2). It is planned that the 449 MHz equipment procured for the 30 units' frequency change will be provided by industry following the same technical specifications. The vendor will be required to demonstrate compliance with these specifications prior to government acceptance. The new equipment will meet the conditions in IRAC Doc. 27561 which is attached to the 1991 document by which NTIA originally authorized profiler operation at 449 MHz. The 449 MHz profilers now have a primary allocation as noted in Footnote G129 in the U.S. allocation table. A section for 449 MHz was also added to the Radar Spectrum Engineering Criteria in the NTIA manual that covers profilers.

    b. Repeater equipment used by the HAMS radio operators also operates at 449 MHz . However, the equipment's allocation is secondary to the profiler's primary allocation. This means a repeater must cease operation if it interferes with a profiler. Since NOAA and the amateur radio community, represented by the Amateur Radio Relay League (ARRL), have worked together on many occasions to support emergency operations, it is important that a supportive relationship be maintained. To do this, coordination meetings will be held with the ARRL over selected areas of the profiler network. The government will provide a schedule of frequency conversion and address any concerns raised by the ARRL. These meetings will be held sufficiently in advance of the conversion thus allowing the repeater operators to make whatever system changes needed to minimize the impact of the band change.

5. Environmental studies

   a. In preparation for installation of the original profiler network, NWS contracted (contract 50WCNW606070) with SRI International to investigate possible environmental impacts that might be caused by construction and operation of the profiler network. An Environmental Assessment report (SRI International Project No. 2174) was delivered to the government in October 1986. The findings documented in the report are: "Construction and operation of the Wind Profilers will have no significant environmental impacts. Impacts are generally either nonexistent or very minor. The operational site selection criteria, supplemented by careful examination of prospective candidate sites, will ensure that impacts are avoided or minimized."

   b. With the profilers remaining at their original site and frequency change being minimal (404.37 to 449.0 MHz), it is anticipated that no adverse impact will result from this change. However, a contingency is provided to accommodate changes in the National Environmental Policy Act that have occurred since the 1986 report and to account for requirements of NOAA Administrative Order 216-6, May 20, 1999, Environmental Review Procedures for implementing the National Environmental Policy Act. The contingency will provide for document preparation, coordination and specific review of impacts at representative sites.

C. Cost Estimate

1. Key Assumptions

The cost estimates were based upon previous conversions of three profilers from 404 MHz to 449 MHz. The Alaska profiler network was built using 404 MHz spare parts and converting the frequency dependent components to 449 MHz. The antenna, transmitter, and circulator were procured from separate contractors while the receiver and RF generator were modified by the original manufacturers. The cost estimates were calculated from the previous costs incurred and taking into account inflation.

2. Risks to Cost and Schedule

The risks would involve the manufacturers and obsolete parts. The manufacturers may not be available for producing or modifying the original equipment by not supporting that product line any longer. Also obsolete parts may hinder their ability to repair or modify certain components.

3. Alternative Deployment Strategies

The NOAA Profiler Networks ongoing operations of thirty-five profilers has involved having to alleviate obsolescence issues by locating second source vendors to supply End-Of-Life (EOL) components and to secure alternate contractors to service aging equipment and provide newer, more reliable designs. There are alternate contractors for the procurement of the transmitter and antenna. The receiver and RF generator can be replaced instead of being modified if the manufacturer was not capable of modifying the devices but would incur a higher cost.

Table C.1. Schedule of Costs: Change 30 NOAA Profiler Frequencies from 404 MHz to 449 MHz

Item Description	Per Unit Cost ($K)	30 Units ($K)	Totals ($K)
<u>Antenna</u>			
Replacement of elements, dividers and cables	180.0	5,400.0	
Upgrade of beam steering unit	5.0	150.0	
Installation	7.0	210.0	
Non-Recurring Engineering		200.0	
Subtotal			$5,960.0
<u>Transmitter</u>			
New Transmitter - 449 MHz	180.0	5,400.0	
Removal of Old Transmitters	2.0	60.0	
Non-Recurring Engineering		400.0	
Subtotal			$5,860.0
<u>Other RF-Dependent Parts</u>			
449 MHz RF Generator	12.0	360.0	
449 MHz Receiver	10.0	300.0	
449 MHz Circulator	4.0	120.0	
Subtotal			$780.0
<u>Project Expenses</u>			
Frequency Change Coordination with ARRL (HAM Radio Members)		60.0	$60.0
Contingency for NEPA Required Environmental Studies		250.0	$250.0
Project Management and Acquisition Support		200.0	$200.0
Program Travel		50.0	$50.0
Grand Total			**$13,160.0**

D. Deployment Strategy -

1. Key Drivers

    a. Procurement of the antenna and transmitter would dictate the overall schedule. Of the five frequency dependent components the antenna and transmitter would require the most time and effort to acquire.
    b. Installation of the 449 MHz components or conversion of the 30 profilers would require a huge logistical effort. One or more installation teams would have to be assembled and required to be in the field constantly for possibly more than one year. All 449 MHz parts would have to be drop shipped to each location in a timely manner to ensure that there was no work stoppage. Estimate: one team given three weeks to convert a site multiplied by 30 would take 90 weeks or close to two years.

2. Schedule

    a. Secure funding
    b. Solicitation of bids for the antenna, transmitter and circulator, for installation of sites, for receiver and RF generator modification
    c. Secure contracts
    d. Start production of antenna, transmitter and circulator, modification of receiver and RF generator
    e. Assemble installation team(s) and begin installation
        i. Installation Phase
            1. Drop ship 449 MHz parts to profiler site
            2. Disassemble and discard 404 MHz antenna
            3. Remove 404 MHz transmitter, receiver, circulator and RF generator
            4. Realign antenna support structure to accept 449 MHz antenna
            5. Install 449 MHz antenna
            6. Install 449 MHz transmitter
            7. Install 449 MHz circulator, receiver and RF generator
            8. Test 449 MHz components
            9. Realign Profiler Hub to accept 449 MHz data
            10. Activate new 449 MHz profiler

Figure B.1 Components Requiring Modification

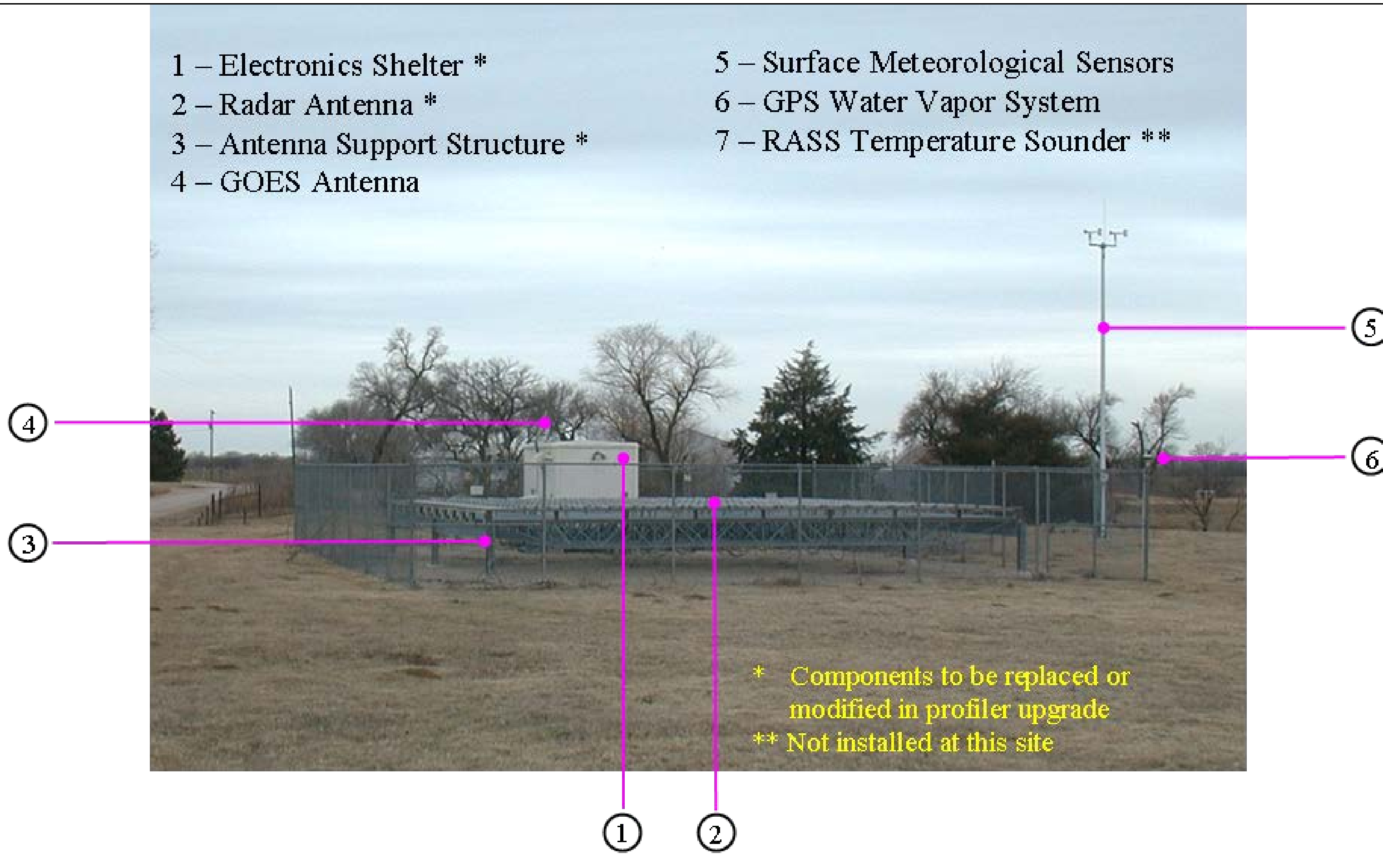


Figure B.2 Profiler System Block Diagram

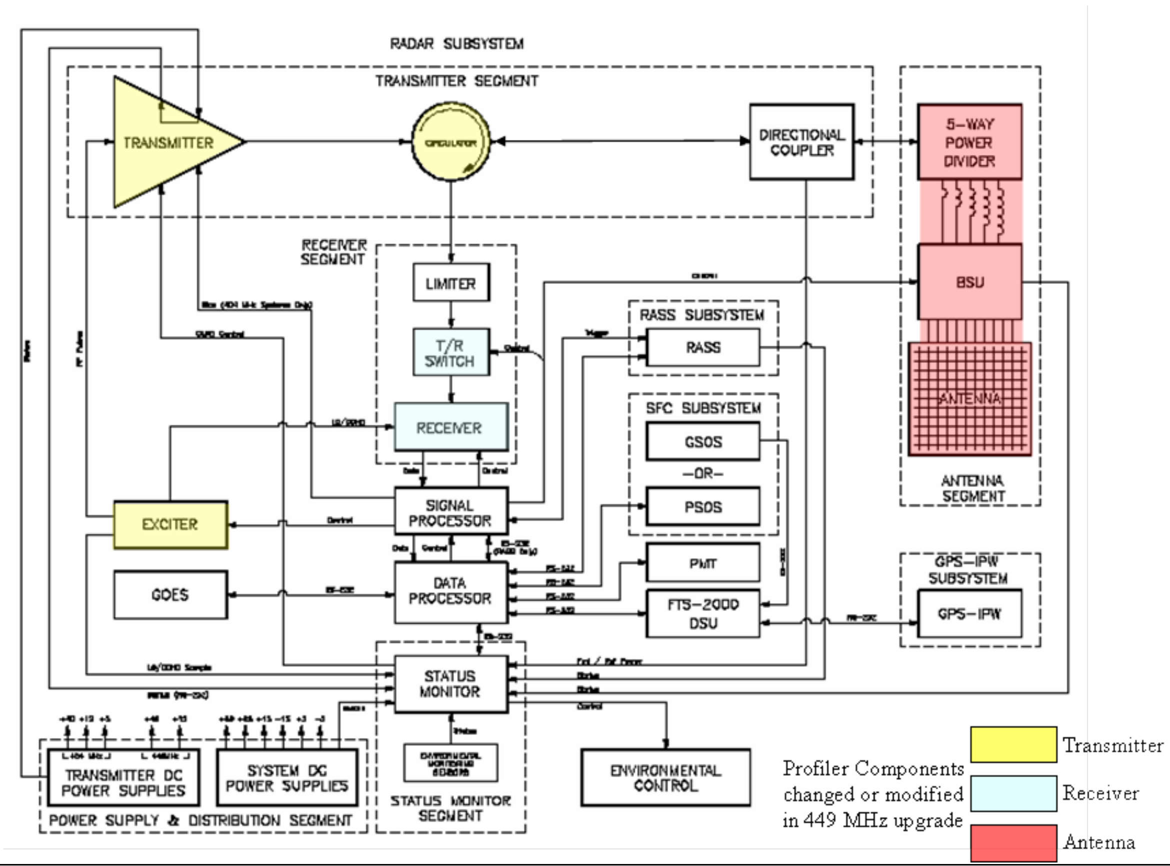


Figure B.3 – Antenna Assembly

404 MHz Antenna Assembly	**449 MHz Antenna Assembly**
	
A. Each collinear array subsection is a resonant array. This system uses two styles of collinear subassemblies. The east-west (Array #1) and north-south (Array #2) antennas are similarly constructed using these two styles. The coaxial dipole elements are formed from sections of high impedance coaxial cable, each a half-wavelength in the coaxial line. The completed coaxial subassembly is packaged within a cylindrical fiberglass radome 1-3/4 inches in diameter. The radome provides protection and forms a weather-tight seal around the elements.	B. This system uses only one style of collinear subassembly. Each subassembly is packaged in a weather proof radome. The antenna is formed from two coaxial collinear arrays arranged orthogonal to each other. Each array is formed from 20 rows of coaxial collinear subassemblies fed by a network of power dividers.

Figure B.4 – Antenna Specifications			
404 MHz Antenna		**449 MHz Antenna**	
Frequency	**404.37 MHz +/-0.5 MHz**	**Frequency**	**449.0 MHz +/- 0.5 MHz**
One-way peak side-lobe levels (all beams):		**One-way peak side-lobe levels (all beams):**	
For elevation angle >45 degrees	**< -20 dB relative to**	**For elevation angle >45 degrees**	**< -20 dB relative to**
For 5 degrees < elevation angle < 45 degrees	**< -25 dB on axis**	**For 5 degrees < elevation angle < 45 degrees**	**< -25 dB on axis**
For elevation angle < 5 degrees	**< -40 dB beam peak**	**For elevation angle < 5 degrees**	**< -40 dB beam peak**
On-axis gain above isotropic	**> 32 dB**	**On-axis gain above isotropic**	**> 32 dB**
Number of beams	**3 (sequential)**	**Number of beams**	**3 or 5**
North and East beam elevation angles	**73.7^o**	**N, S, W and E beam elevation angles**	**73.64^o**
Vertical beam elevation angle	**90.0^o**	**Vertical beam elevation angle**	**90.0^o**
Beam switching speed	**< 0.4 sec**	**Beam switching speed**	**< 0.03 sec**
Maximum beam pointing error from nominal position:		**Maximum beam pointing error from nominal position:**	
Elevation (0)	**+ 0.5 degrees E**	**Elevation (0)**	**+ 0.3 degrees**
Azimuth (0)	**+ 2.0 degrees E**	**Azimuth (0)**	**+ 0.5 degrees**
Input VSWR	**<1.2:1 max**	**Input VSWR**	**<1.2:1 max at Band Center <1.4:1 max at Band Edges**

Figure B.5 – 449 MHz Antenna Support Structure Modifications

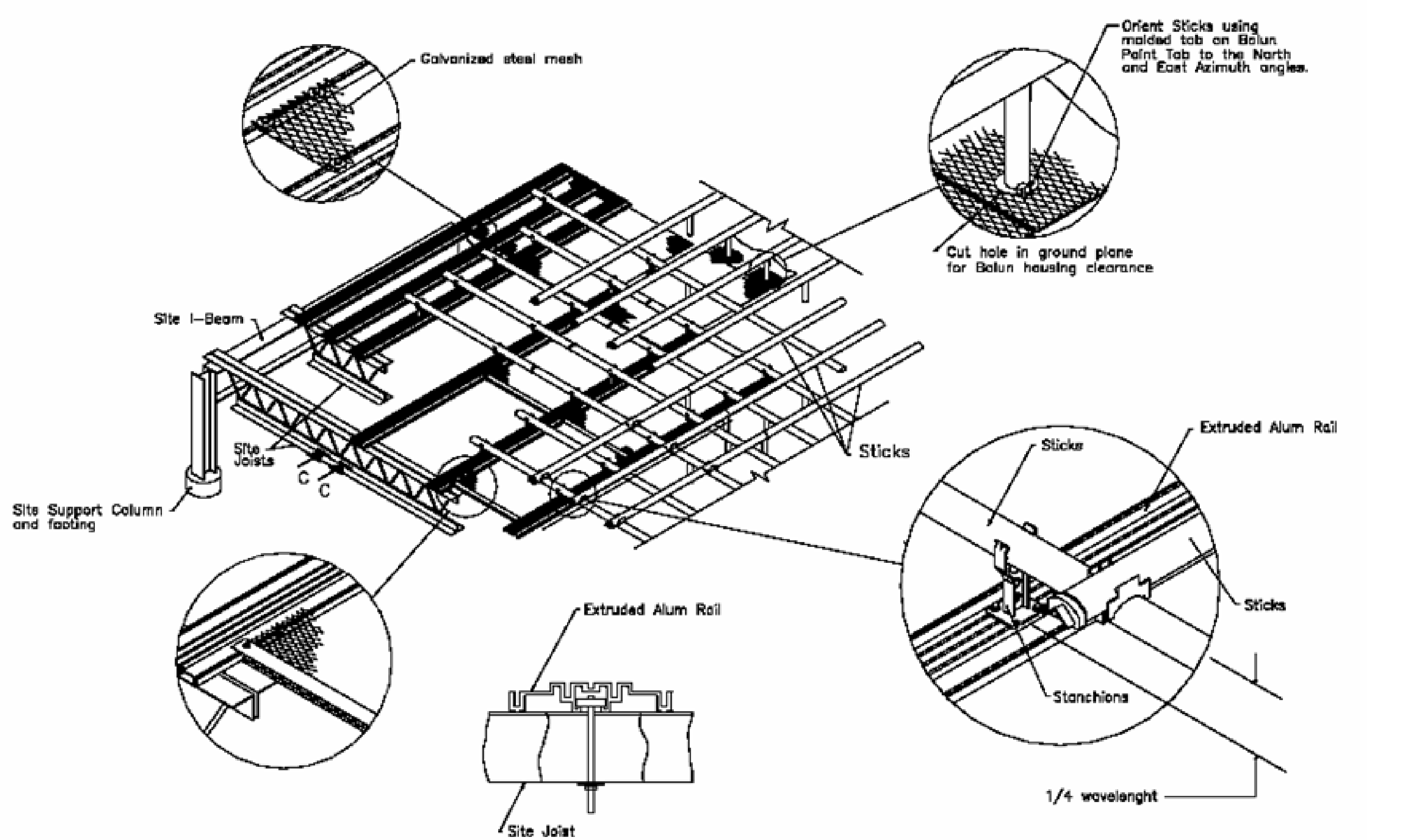


Figure B.6 – Orthogonal Coaxial Collinear Antenna Array Layout

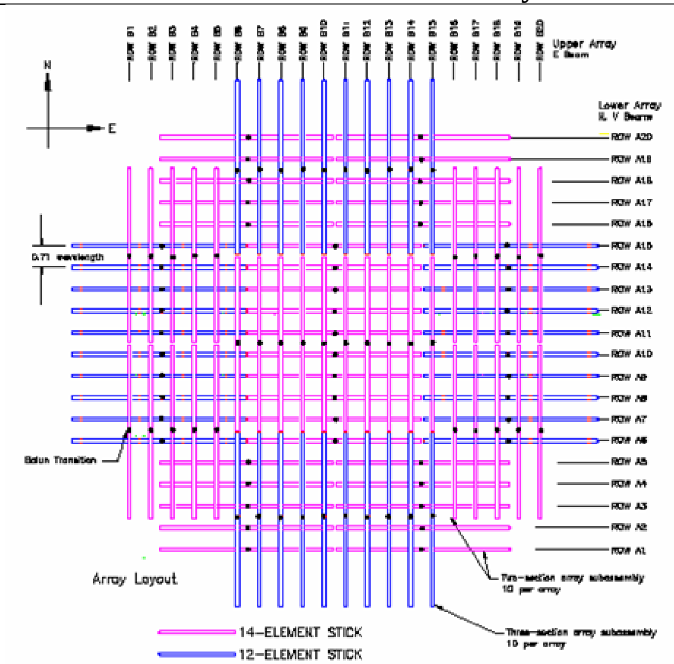
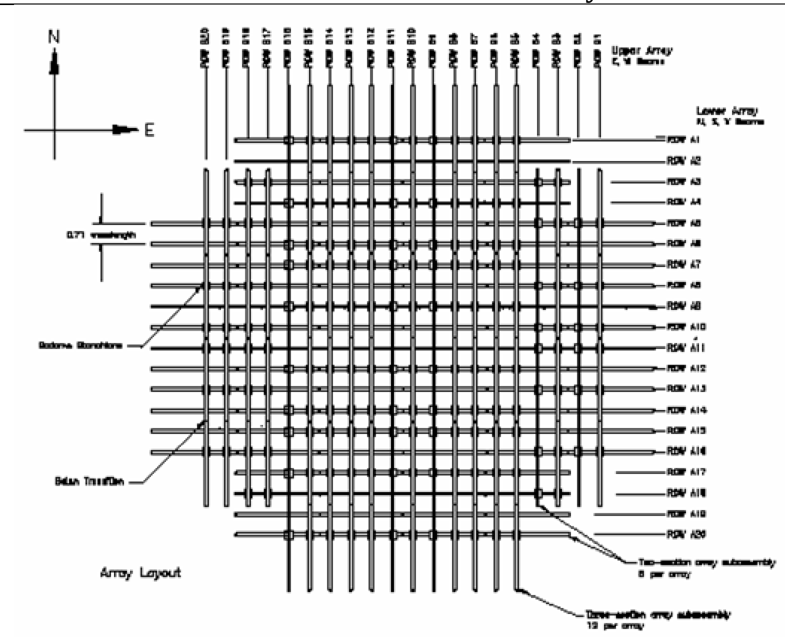
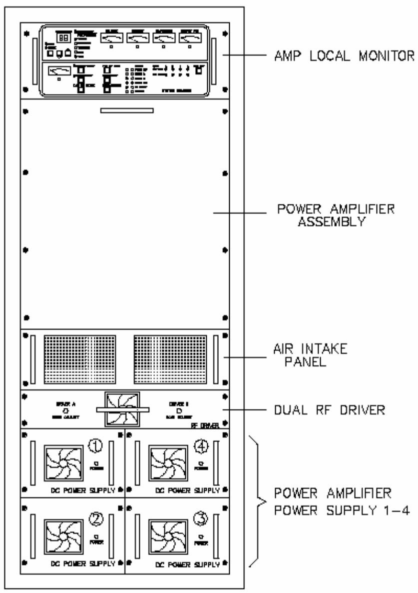
<table>
<tr><th>404 MHz Antenna Assembly</th><th>449 MHz Antenna Assembly</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>A. 404 MHz antenna layout showing the orientation of the upper (east beam) array with respect to the lower (north, vertical) array using the two styles of subassemblies; a 12-element and 14-element subassembly (stick).</td><td>B. 449 MHz antenna layout showing the orientation of the upper (east ,west) array with respect to the lower (north, south, vertical) array using only a12-element subassembly.</td></tr>
</table>

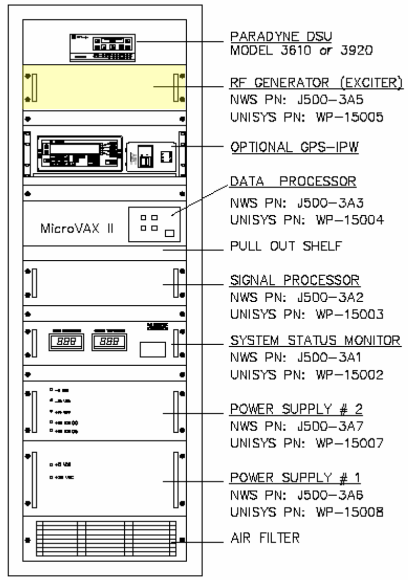
Figure B.7 – Transmitter Assembly

404 MHz Transmitter and Equipment Cabinet

Power Amplifier Cabinet



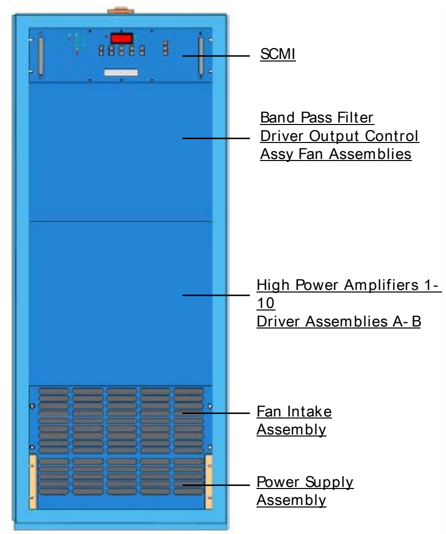
Equipment Cabinet



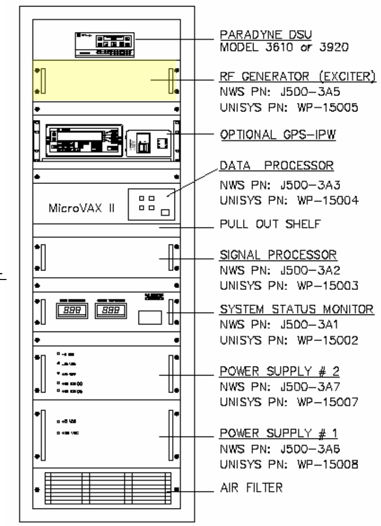
A. (Left) 404 MHz transmitter front panel layout. (Right) Profiler equipment cabinet showing the location of the RF Generator.

449 MHz Transmitter and Equipment Cabinet

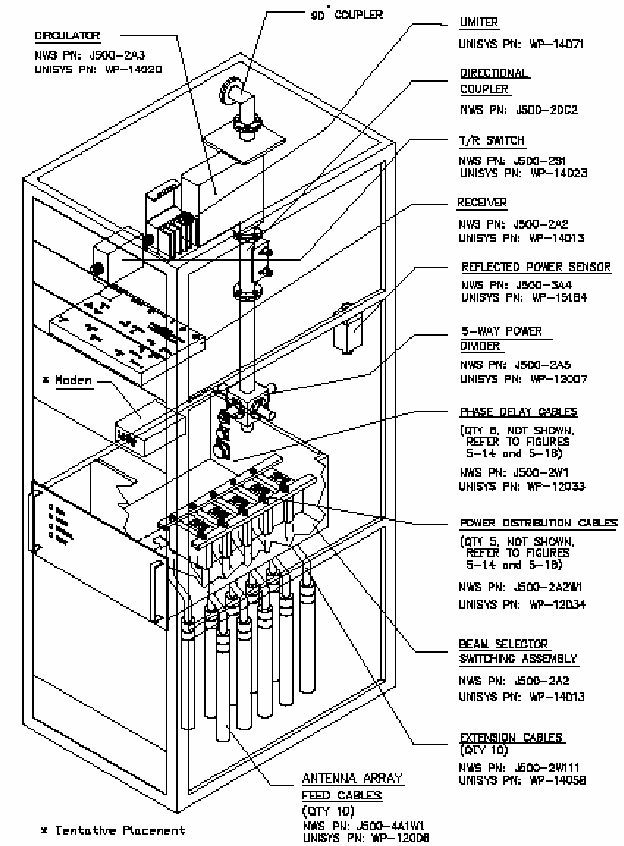
New Power Amplifier Cabinet

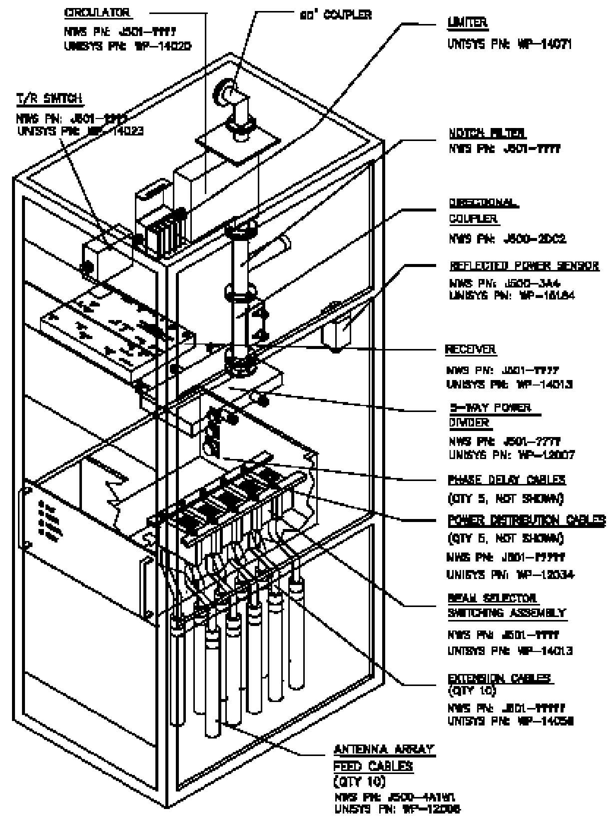


Equipment Cabinet w/ Modified RF Generator



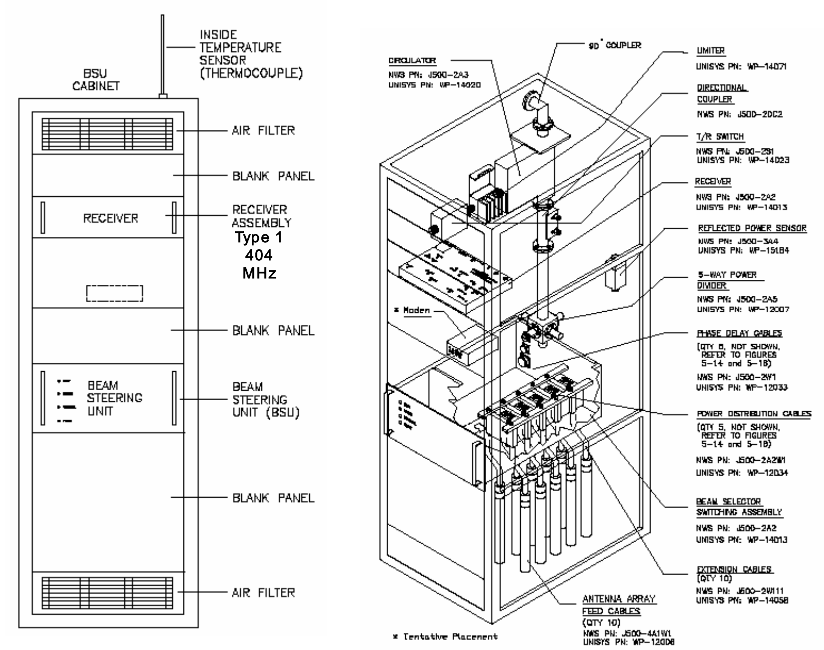
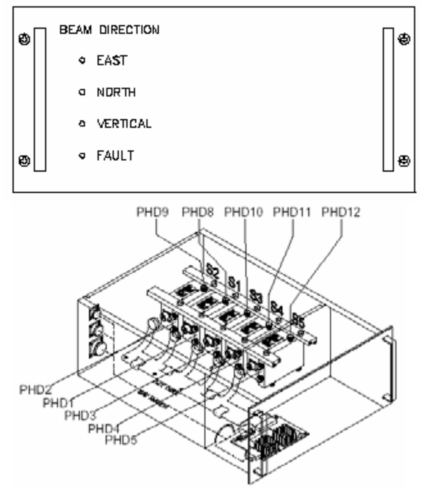
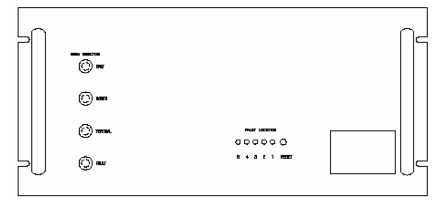
B. (Left) 449 MHz transmitter front panel layout. (Right) Profiler equipment cabinet showing the location of the 449 MHz RF Generator.

<table>
<tr><td colspan="2">Figure B.8 – Receiver Assembly</td></tr>
<tr><td>404 MHz Receiver Assembly</td><td>449 MHz Receiver Assembly</td></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>A. Beam Steering Unit (BSU) cabinet showing the location of the 404 MHz receiver and circulator.</td><td>B. Beam Steering Unit (BSU) cabinet showing the location of the 449 MHz receiver and circulator.</td></tr>
</table>

Figure B.9 – Beam Steering Unit

Beam Steering Unit Assembly	Beam Steering Unit
	Front Panel 404 MHz BSU  Front Panel 449 MHz BSU  Phase delay cables for 404 MHz and 449 MHz profilers are different lengths.
A. Front panel layout and internal layout of the 404 MHz Beam Steering Unit (BSU) Assembly showing the location of the BSU and 5-way power divider.	B. Side by side drawing of the front panels of the 404 MHz (left) and 449 MHz (right) BSU. Also shown is the internal layout of a BSU.

NPN Operations and Maintenance

35-Station 404/449 MHz NOAA Profiler Network Systems

Item Number	Item Description	Item Cost ($)	Totals ($)
1	**Field Site Facility Operations and Maintenance**		**205,325**
	Land Leases - 23 sites	20,925	
	Electrical Utilities - 31 sites	91,700	
	Voice Telephones - 32	13,500	
	FTS-2001 Voice Long Distance	700	
	Ground and Facilities Maintenance - Includes Weed Management, Road Upkee	5,000	
	Shelter Materials/Supplies	3,500	
	Site Maintenance Contingency - Major Facilities Damage; Vandalism/Weather	70,000	
2A	**Field System Operations and Maintenance**		**467,960**
	Government Labor (2 Staff - .75 FTE)	110,150	
	Contractor Labor (6 Staff - 3.08 FTE)	252,310	
	Travel - Government	5,000	
	Travel - Contractor	50,000	
	GSA Vehicles (2) for Field Travel	25,000	
	Supplies and Materials	14,500	
	NWS Electronics Technician Training - Boulder Facility	3,000	
	Alaska Support (El Tech and Forecaster Training, and Annual Site Inspection)	8,000	
2B	**Field System Operations and Maintenance - NWS Support**		**39,800**
	NWS/CR/SR Labor (Electronic Technician, Supervisory, Management)	51,350	
	NWS/CR/SR Travel (Electronic Technician, Supervisory, Management)	19,600	
	NWS/CR/SR Return Shipping	5,850	
	NWS/CR/SR Maintenance Credit per NWS/OAR Basic Agreement (.5 labor y	-37,000	
3A	**Logistics, Parts Repair/Replacement, CM and Site Admin**		**252,282**
	Contractor Labor (5 Staff - 2.65 FTE)	195,102	
	Shipping LRU's to Field	9,000	
	.5 Boulder Assembly Facility & DoC Warehouse - Rent	10,630	
	.5 Boulder Assembly Facility - Utilities	1,250	
	.5 Boulder Assembly Facility - Voice Telephone	300	
	Supplies, Materials, Storage Systems	5,000	
	LRU and Subcomponent Spare Parts including Air Conditioners	31,000	
3B	**Logistics, Parts Repair/Replacement, CM and Site Admin - NWS Support**		**225,000**
	NWS/OOS/NRC Labor - 1 FTE	74,300	
	NWS/OOS/NRC Outside Repair Contracts	109,200	
	NLSC Warehouse Rent (J500/J501 ASNs =118.3 *$171)	20,230	
	NLSC Warehouse Rent (J501 ASNs NWS/AK Part $6,617; Sent directly to NV	0	
	NLSC Labor to Ship Spare Parts to Field Offices	4,505	
	Shipping of LRU's to Field Electronic Technicians	6,625	
	Cataloging and EMRS Support	2,240	
	NWS/OOS Management Labor Support	4,900	
	NWS/OOS Management Travel Support	3,000	
4A	**Engineering and Sensor Testing and Development**		**228,443**
	Government Labor (2 Staff - .45 FTE)	74,940	
	Contractor Labor (3 Staff - 1.1 FTE)	125,823	
	Contractor Technical Services	0	
	.5 Boulder Assembly Facility - Rent	10,130	
	.5 Boulder Assembly Facility - Utilities	1,250	

	.5 Boulder Assembly Facility - Voice Telephone	300	
	Test Equipment and Supplies	9,000	
	Purchases; Supplies and Materials	7,000	
	Lockheed Martin Technical Support Contract	0	
4B	**Engineering and Sensor Testing and Development - NWS Support**		**75,000**
	NDBC (NWS/OOS) Engineering and Contract Management	75,000	
	Miscellaneous	0	
5	**NPN Network Monitoring, Command and Control Center**		**345,623**
	Government Labor (2 Staff - .75 FTE)	102,350	
	Government Part Time Student	15,000	
	Contractor Labor (5 Staff - 2.4 FTE)	198,273	
	FSL Monitoring Support	30,000	
6	**Hub Computer Processing Facility and Program IT Support**		**565,113**
	Facility Management/Operations - Government Labor (2 Staff - .9 FTE)	133,440	
	IT Specialists/System Administrators - Contract Labor (4 Staff - 2.55 FTE)	234,588	
	Hardware for Hub Modernization, CAPS, GPS Processing and Display System	21,985	
	Hardware for Data Archive	5,000	
	LAN Equipment	13,000	
	Firewall Hardware	30,000	
	Computer and Environmental Systems Hardware Maintenance	51,100	
	Contractor Technical Refreshment Training	7,500	
	Security Training	4,500	
	Highspeed Internet Connection	15,000	
	FSL IT Support	25,000	
	Staff PC Hardware and Software Support	24,000	
7	**Data Communications**		**248,201**
	Annual ATT Dedicated Circuits; 32 Sites to Boulder; 1 line Boulder to NWST	104,137	
	Government Communications Contract Management (.25 FTE)	37,775	
	Communications Technical Support - Contract Labor (.15 FTE)	16,516	
	GOES/DOMSAT Upgrade/HW-SW Maintenance Support	2,500	
	GOES High Data Rate Equipment Evaluation - Hardware/Supplies	6,000	
	GOES High Data Rate Equipment Evaluation - Government Labor (.25 FTE)	33,525	
	GOES High Data Rate Equipment Evaluation - Contractor Labor (.5 FTE)	43,748	
	Satellite Based Internet System Evaluation (4 Sites); HPCC Grant; $24,520	0	
	Travel - STWIG/SARSAT Meetings	4,000	
8	**Web Services**		**213,688**
	Web Services; Government Labor (2 Staff - .75 FTE)	102,525	
	Web Services; Contractor Labor (3 Staff - .95 FTE)	111,163	
9	**Software Maintenance and Development**		**496,027**
	Government Labor (2 Staff - 1.5 FTE)	148,760	
	Contractor Labor (5 Staff - 2.05 FTE)	202,403	
	Joint Institute Labor (1 Staff - 1FTE)	133,864	
	Software Maintenance	5,000	
	Purchases, Materials and Supplies	6,000	
10	**GPS-MET Support**		**159,100**
	Government Labor (1 Staff - .5 FTE)	84,700	
	Contractor Labor (3 Staff - 1 FTE)	0	
	Joint Institute Support - Satellite High Accuracy Orbits	30,000	
	Joint Institute Support - New Product Development	0	
	Joint Institute Support - Model Testing, Verification/Validation	0	
	U.S. Coast Guard Maintenance Support	16,000	

	Equipment Maintenance/Warranties	18,400	
	Purchases - New Receivers/Antennas	0	
	Purchases - Miscellaneous Hardware, Materials, Supplies	10,000	
11	**Program Management and Planning**		**630,929**
	Government Labor (3 Staff - 1.55 FTE)	295,145	
	Government Administrative Support (1 Staff - .1 FTE)	7,000	
	Contractor Administrative Support (2 Staff - .35 FTE)	22,384	
	Government Program Travel	20,200	
	Government Training (Programmatic, Technical, Safety)	4,500	
	Purchases, Supplies, Materials, Printing	29,000	
	Documentation Support (Government and Contractor)	3,000	
	Staff Office Rent and Voice Telephones	121,200	
	OMB, NOAA, FSL, Prior Year Budget Assessments	128,500	
	Total		**$4,152,491**

Information: Margot H. Ackley; 303-497-6791; Margot.H.Ackley@noaa.gov

Annex D - Budget Summary

NPN Operations and Maintenance

35-Station 404/449 MHz NOAA Profiler Network Systems

Item Number	Item Description
1	Field Site Facility Operations and Maintenance
2A	Field System Operations and Maintenance
2B	Field System Operations and Maintenance - NWS Support
3A	Logistics, Parts Repair/Replacement, CM and Site Admin
3B	Logistics, Parts Repair/Replacement, CM and Site Admin - NWS Support
4A	Engineering and Sensor Testing and Development
4B	Engineering and Sensor Testing and Development - NWS Support
5	Network Monitoring, Command and Control Center
6	Hub Computer Processing Facility and Program IT Support
7	Data Communications
8	Web Services
9	Software Maintenance and Development
10	GPS-MET Support
11	Program Management and Planning
	TOTAL

Information: Margot H. Ackley; 303-497-6791; Margot.H.Ackley@noaa.gov

Totals ($)
205,325
467,960
39,800
252,282
225,000
228,443
75,000
345,623
565,113
248,201
213,688
496,027
159,100
630,929
$4,152,491

Annex D

Budget Estimate

NPN Operations and Maintenance

***** Footnotes *****

November 16, 2017

General Comments:

$ NPN funds are sent to NWS under a Basic Agreement between NWS and OAR. This basic agreement reflects the collaborative nature of the NPN program. Four appendices to the Basic Agreement include support from: 1.) National Data Buoy Center (NDBC) to provide engineering, surface meteorological sensor support, and contract management for the contracts with Lockheed Martin (previously Sperry Rand then Unisys) who provide and support various hardware and software components of the NPN. These contracts are between NWS/NDBC and Lockheed Martin; 2.) Central and Southern Regions to provide profiler field maintenance by their Electronics Technicians (El-Techs); and 3.) Office of Operational Systems (OOS) to provide logistics and configuration management support, depot-level maintenance (NWS/OOS/NRC) and warehousing of spare parts (NLSC). A fourth appendix was with the NWS Office of Technical Services (known later as the Special Engineering Program Office) to provide one-time support for site surveys, site acquisition and site preparation. The Basic Agreement and its appendices were put in place prior to 2000; thus all joint work and funding for the NPN project are exempt from the new NWS/OAR Business Rules.

$ At the beginning of the Profiler Program in the late '80s, NWS assisted OAR in setting up an Operations and Maintenance program so that future transition of the system to NWS would be as smooth as possible. Every operational decision was formed by the answer to the question "How would NWS do it?" This philosophy is followed to this day.

$ Operations and Maintenance for NOAA's Alaska Profiler Network (three systems) are addressed in a July, 2000 Memorandum of Agreement between NWS's Headquarters, Alaska Region, OSO and OSD, OM, and OAR's Headquarters, and the Forecast Systems Laboratory (FSL - is located in Boulder, CO and coordinates the NPN program). In essence, the NPN staff provide day-to-day monitoring of the health of the profilers, their data processing and data quality control, and central control of the profilers. The staff determine when and what type of repair is required, dispatches NWS-Alaska Region technicians, and sends appropriate spare parts.

- $ The budget is based on costs for FY-2003. Historical cost data were also taken into account as appropriate. Each year different special activities are undertaken. This budget represents a "typical" year of operations.

- $ Salaries for all Government Staff (OAR) are paid from appropriated NOAA OR&F funds. The overhead is approximately 79.5% of base labor and incorporates the OAR Level II and III, Laboratory Level IV and Leave and Benefits charges. The NPN operates as a distinct financial entity within the Forecast Systems Laboratory (FSL) and, as such, is exempt from additional FSL overhead charges applicable to other projects in FSL.

- $ Total overhead, including G&A and fee for all Profiler Program Contractor Labor is approximately 79% of base labor. "Other Direct Charges - ODCs" are non-labor costs and are subject to a 14% G&A charge only. The contract is a Cost Plus Fixed Fee (CPFF) 8(a) contract.

1 Field Site Facility Operations and Maintenance

- $ **Leases (35 total):** The annual cost for 23 of the NPN lower-48 leases ranges from $480-$2400. For the three Alaska sites (Glennallen, Talkeetna and Central) only the Glennallen site requires annual payment ($2,160) by NWS Alaska Region. The other two Alaska sites are on state land and, as such, are no-cost leases. The site/lease at the White Sands Missile Range is provided cost free by the US Army. Land for the newest profiler site at Ledbetter, TX, is provided at no cost by the Lower Colorado River Authority (LCRA). This contribution by LCRA represents a collaborative effort between them, the State of Texas, NOAA and Texas A&M University at Austin. The Syracuse, NY site lease at the Syracuse-Hancock International Airport is paid for by Lockheed Martin. This lease is expensive and is scheduled to terminate June 30, 2004. It is anticipated that Lockheed will execute a temporary renewal until another less expensive location can be found in the Syracuse area. The remaining six sites are located on Federal land and hence are covered under no-cost interagency agreements. Most of the leases are now written for 20 years with very inexpensive rates set for the duration of the lease. The amount of land for each site is approximately one acre.

- $ **Utilities:** The utilities for the three Alaska sites are paid directly by NWS Alaska Region. Utilities for the White Sands Missile Range are paid by the US Army. Utility service for the profilers is only electricity. The costs are higher in summer due to the increased use of the shelter's two air-conditioners. The shelter electric heaters are rarely used, even in Minnesota and Wisconsin, since the profiler transmitter generates sufficient heat to keep the shelter within normal operating temperatures. Electric heaters are used during the winter season for the three Alaska profilers - particularly the one at Central, which is located north of Fairbanks.

$ **Telephones:** The voice telephone costs for the three Alaska sites are paid directly by NWS Alaska Region. Again, White Sands Missile Range voice telephone is paid for by the US Army. The system at Platteville, CO, near Boulder has two voice lines for system testing.

$ Long distance voice communications from the sites is provided under the Government's GSA FTS-2001 Telecommunications contract and is normally used only during onsite maintenance activities. Also included are FTS-2001 Calling Card costs for resetting the profiler's main circuit breakers during off-hours from off-site telephones. This reset procedure is used to clear software and hardware difficulties.

$ Ground and facilities maintenance is performed on an as-needed basis. Although the site's original construction included a weed barrier under and around the equipment, it is still necessary to perform periodic weed control. Likewise, some road upkeep is occasionally needed, mainly due to erosion. Each of the shelters is stocked with expendable supplies for clerical and housekeeping functions.

$ Every year a site maintenance contingency fund is established to offset any major facility damage due to vandalism or severe weather. This fund is lower than normal NWS standards but has been sufficient for all the years of NPN operations.

2A Field System Operations and Maintenance

$ The NPN program provides field engineering and technician support for the network. Typically, staff are dispatched to repair a profiler when NWS Electronic Technicians (El-Techs) are not available, or the nature of diagnosis and repair requires a specialist in radar engineering. Almost all antenna work is handled by the NPN's government and contractor staff. Most travel is done by GSA vehicle from Boulder and is planned so that multiple sites can be visited in a single trip. This keeps travel costs low.

$ All repair at the White Sands Missile Range profiler site is handled by US Army civilian technicians and meteorologists. This support is provided "cost-free". Profiler equipment repairs and facility upkeep are provided by Lockheed Martin at the Syracuse, NY site. Work is handled through an Engineering and Technical Services contract with Lockheed Martin. Maintenance for the Platteville, CO system is handled by NPN field engineers from Boulder.

$ Each year profiler training is provided by OAR NPN Engineers for NWS Electronics Technicians and other technicians as appropriate. In the last few years, the training has been held in Boulder where there is a mock-up profiler system near the staff offices. Also, the Platteville, CO field site is within a 40 minute drive and has facilities to handle all day training as needed. These classes, along with appropriate training material, are provided cost-free to students, but the students must provide for their travel to Boulder.

Classes typically last three days with Monday and Friday designated as travel days.

- $ Every year NPN staff travel to Alaska, at no cost to NWS, to perform training. Usually, training alternates each year between use of the data in weather forecasting and system troubleshooting and repair. In addition to NWS Alaska Region staff training, NPN staff travel to all three sites for equipment inspections and repair as needed.

2B Field System Operations and Maintenance - NWS Support

- $ Per one of the Appendices of the Basic Agreement between NWS and OAR, NWS provides Electronic Technicians (El-Techs) for repair of the NPN profilers. The agreement specifies that work will be performed on a non-interfering basis with respect to NWS commissioned systems. Annual funding is based on the number of failures of the previous year plus a 10% increase. Likewise, the Appendix specifies that NWS will "donate" one-half staff year of El-Tech support. This credit is distributed between NWS's Central and Southern Regions based on the number of profilers for which each region has maintenance responsibility. Maintenance for the new Ledbetter, TX system is provided at no cost by NWS/Southern Region Headquarters as part of the collaborative effort noted under Item 1 - "Leases".

- $ Alaska Region is responsible for providing El-Tech support (with technical support from the Profiler Control Center in Boulder) for the three Alaska Profilers. NWS/Central Region is responsible for 17 systems and NWS/Southern Region for 11 systems plus the new Ledbetter, TX profiler.

- $ In addition to funding NWS maintenance labor and travel costs, funds are provided for shipping of parts. These funds cover the cost of returning a failed component back to the NWS/National Reconditioning Center (NRC) in Kansas City or the NPN offices in Boulder for repair.

3A Logistics, Parts Repair/Replacement, Configuration Management and Site Administration

- $ Following a profiler failure and identification of the failed part, NPN logistics staff order the part from the National Logistics Supply Center (NLSC) in Kansas City. NLSC warehouses profiler spare parts just as they do for commissioned NWS systems. NLSC sends the part to the NWS Forecast Office responsible for repair of the failed profiler. Though NLSC is the primary source of profiler components, the Boulder NPN facility stocks many small parts (brackets, generic cables, clamps, tape, breakers, surge protectors, etc). These parts are likewise shipped to NWS as needed.

- $ The NPN Boulder offices are not set up to test full systems, recondition parts, or perform other engineering functions. A warehouse, located less than 10 minutes away is used for these functions. This warehouse was originally acquired when the three Alaska Profilers were assembled and tested prior to shipment to Alaska. Support for this critical facility is shared with Item 4A - “Engineering and Sensor Testing and Development” cost item.

$ In order to save time and expense, some components are repaired in Boulder rather than at the NWS’s National Reconditioning Center (NRC) in Kansas City. Program field engineers have the necessary skill and the program has adequate testing and repair tools.

$ Replacement of highly specialized spares is normally handled through the Lockheed Martin contract. However, there are other sub-component parts available on the open commercial market that are procured by OAR/NPN rather than NWS. Included in this line item are the shelter air conditioners. Each shelter has two air conditioners. With 35 profilers this results in a total of 70 air-conditioners in operation all the time. After performing a cost analysis, we determined that it is generally more cost effective to replace an air conditioner rather to repair it. 10-12% of the air conditioners are replaced each year.

$ Each month over 150 separate financial items are reviewed, certified and tracked. These items are related to payments on site leases, utilities, voice telephone, voice long distance service and data communications.

3B Logistics, Parts Repair/Replacement, Configuration Management and Site Administration - NWS Support

$

Per another Appendix of the Basic Agreement between NWS and OAR, NWS provides logistics, depot repair, and maintenance support for the NPN. The National Reconditioning Center in Kansas City handles most Line Replaceable Unit (LRU) repairs by either repairing the parts in-house or by issuing repair contracts to external vendors. At the beginning of the program, the NRC was provided a complete profiler test set (more costly than a single profiler) to test individual components. This occurs any time a part is received back from the field or a repair vendor, or following internal repair. All parts are tested prior to restocking at the National Logistics Supply Center, which is housed next to the NRC.

- $ Additionally, NWS/OOS coordinates payment for the NLSC warehouse space. Cost is determined by the type of parts rather than the number of parts. A specific type is designated by a unique ASN (Agency Stock Number).

- $ NWS/OOS also assists in the purchase of new spares to replenish inventories. Agency and NWS stock numbers are assigned to all profiler parts and are included in various official NWS maintenance books and catalogs.

- $ Parts stocked at NLSC are for both 404 MHz and 449 MHz profilers. The 449 MHz profilers also utilize many 404 parts. In fact, with the exception of the antenna and transmitter, and a few other frequency-dependent components, the three Alaska profilers were assembled from 404 MHz spare parts, resulting in major cost savings. Hence a common spare parts inventory is shared between the 404 NPN systems and the three - 449 MHz Alaska systems. Except for the initial spares for the Alaska systems, all additional spares (404 MHz and 449 MHz) have been procured with OAR NPN funds.

- $ Funds are also provided to ship a good spare part from the NLSC to the appropriate NWS Forecast Office to replace a failed part removed by the NWS El-Tech.

- $ In prior years, NWS received a total of $50,000 to fund inclusion of 25 Wind Profiler Circuit Card Assemblies into the NWS Technology Obsolescence Risk Assessment (TORA) program. The 25 assemblies were selected based on NWS/OOS recommendations. This program acquires information regarding discontinuation of sub-components thus steps can be taken to prevent running out of essential parts. Included are seven assemblies that support the 449 MHz Alaska systems.

4A Engineering and Sensor Testing and Development

- $ The Boulder offices are not adequate for testing systems, performing repairs, or conducting hands-on training or other engineering functions. A warehouse, located less than 10 minutes away is used for these purposes. This warehouse space was originally acquired when the three Alaska Profilers were assembled and tested prior to shipment to Alaska. Support for this critical facility is shared with Item 3A - " Logistics, Parts Repair/Replacement, Configuration Management and Site Administration" cost item.

- $ Continuous evaluation, refinement and improvement of profiler components are handled by the NPN engineering staff.

- $ Due to technical and radio-interference considerations, most profilers are located in relatively remote areas. Most sites experience multiple severe weather events. Power is typically supplied by local rural electric cooperatives, and many times the systems are at the end of long service runs. Power surges and fluctuations are common and often cause the large main power service breaker to trip, resulting in loss of data. Because of the remote locations and higher priorities of the NWS El-Techs, it is sometimes several days before someone could travel to the site and reset the breaker.   The profiler engineers designed a “Remote Breaker Reset Box” that would perform a mechanical reset of the main power breaker using the site’s voice telephone. This capability was further extended to handle those cases where the system just “hung”. As in typical personal computer usage, sometimes a “hard reboot” would be required.   The rate of data delivery to NWS and other customers would decrease approximately 2.5% without this capability.

$ All engineering documentation and drawings are maintained by the engineering staff. For each system (404 MHz and 449 MHz) a document called the “The Guide to LRU Replacement” was prepared and maintained by the staff. This guide, available in both hard copy and on CD-ROM, is used in both training and standard profiler maintenance work. The document is the cornerstone of all profiler diagnostic and maintenance actions and consists of almost 400 pages with over 250 figures.   Any changes or improvements in maintenance are incorporated into the guide.   All site drawings and driving maps and instructions are maintained by the staff.

$ Over the years, the staff, working with the NWS, have designed and incorporated enhanced grounding, lightning and surge protection for the profilers. As with many electronic based systems, component failure and/or degradation are often the result of lightning strikes.

$ The staff also provide telephone technical support to the NWS El-Techs for exceptionally difficult problems that are encountered during field maintenance activities.

$ Staff also work with the profiler contractor, Lockheed Martin, to resolve problems arising from previous system upgrades. Due to obsolescence, about one-third of the original profiler system micro-VAX II computers underwent an upgrade to a DEC-Alpha hardware platform. When timing and software compatibility issues arise, the staff, working with the Lockheed engineers, develop suitable solutions.

$ Engineers are also working with staff from NWS’s NEXRAD Radar Operations Center (ROC) in Norman, OK on techniques to reduce the effects of signal contamination by ground clutter.

$ Although the original design specified a 20-year lifetime, computer and other electronic components are reaching various stages of obsolescence. Engineers have been studying both alternate sources of sub-components and also technical “workaround”solutions.

4B Engineering and Sensor Testing and Development - NWS Support

$ Per one of the Basic Agreement's Appendices, the National Data Buoy Center (NDBC) provides engineering, contract management and surface meteorological sensor support. One-time funds transfer is done each year. The NDBC Contracting Officer and Contracting Officer's Technical Representative (COTR) support all profiler contract activities including acquisition of systems and spare parts, specification of technical requirements and also the Lockheed Martin Technical and Engineering Services contracts. NDBC also supports monthly project status telephone conferences with Lockheed Martin. Processing of all DD250's (Material Inspection and Receiving Reports) and Lockheed invoices are handled by NDBC.

$ Since the inception of the program, NDBC has provided OAR with surface meteorological sensor package capability. NDBC has extensive technical experience and understanding in this area due to their work in placing similar instruments on buoys and coastal surface observation stations. NDBC has refined the instrumentation over the years, resulting in more cost-effective and reliable systems. All NPN sites have a suite of surface meteorological sensors. At this time there are thirteen sites, located mainly in the central and southern portion of the network, that have a full sensor complement including wind, temperature, humidity, pressure and rain gauge instruments. The wind sensor is located on a tower at the NWS 10-meter standard height. This sensor suite is referred to as the Profiler Surface Observing System (PSOS). At all other sites, including the three Alaska sites, the suite contains only temperature, humidity and pressure instruments. This suite is referred to as the GPS Surface Observing System (GSOS). Design, acquisition and depot level repair for both of these suites are managed by NDBC.

5 Network Monitoring, Command and Control Center

$ Central to the NPN is the Profiler Control Center (PCC), which is responsible for all aspects of the NPN operations and monitoring including the coordination of logistics associated with operating a sophisticated 35-station network. All field activities are coordinated by the PCC staff. The staff in the PCC routinely monitor the NPN only during normal working hours (27% of the total hours in a week). Improvements are constantly being made to allow remote monitoring of the NPN and its supporting data and communications systems. This capability allows "restart" of systems remotely, thus improving the total availability of NPN data for the NWS and other customers.

$ Besides monitoring to ensure that all the equipment is operating, the PCC also monitors the quality of the data. In the original specifications for the profiler systems, the Government required the contractor to build a system that could operate in a degraded mode rather than shutting down. Consequently, the transmitters and antennas sometimes operate in a degraded mode, thus decreasing the quality of the data. The quality is therefore also monitored to determine if maintenance action should be initiated or if the system should be taken out of operation until proper repairs can be made. Monitoring of collocated surface meteorological systems is augmented by model and surface analyses provided by another part of FSL separate from the NPN organization.

$ Once it is determined that field maintenance is required by either profiler technicians or staff from the power or communication companies, the PCC "opens a ticket", contacts the proper repair person, and monitors the repair process until the "fault" is removed and the system is brought back into operations. Any parts needed for replacement of failed parts are ordered from the appropriate depot and shipped to a convenient pickup location for transport to the site by the NWS El-Tech or other repair person. If the failure cannot be addressed by an NWS El-Tech within a reasonable period of time, a field engineer is usually dispatched from the Boulder NPN facilities to repair the system.

$ The PCC is responsible for logging all equipment faults and for collecting performance statistics on all aspects of the NPN. These data are later made available for analyses to help detect areas of weaknesses and strengths. The many years of fault logging will prove to be extremely valuable when new system specifications are developed. Additionally, weekly, monthly, quarterly and annual performance statistics are collected and presented to the appropriate staff and management. A network monitoring meeting is held weekly to review status and network performance. Management is advised weekly of the data availability. Monthly and annual performance statistics are made available to NWS.

$ PCC staff work closely with members of the program's Software Maintenance and Development team to develop additional monitoring software and processing software that helps to minimize the effects of ground clutter and profiler signal contamination by birds.

$ Likewise, information is collected and characterized as to when and how the data are used by the NWS in their twice-daily prepared Area Forecast Discussions (AFD) for each forecast office. Many of these discussions explain the rationale for decisions made and how observations were used to formulate the final forecast.

6 Hub Computer Processing Facility and Program IT Support

$ The architecture of the NPN is similar to a "spoke and hub" configuration. Each individual profiler ("spoke") collects wind and status information every six minutes and performs some processing of hourly data. The data, both six-minute and hourly averaged, are transmitted to the Profiler Hub located in Boulder, CO, where the data are checked for quality and further processed into profiles of horizontal wind speed and direction for 72 heights above the profiler site up to about 53,000 ft.

$ The Profiler Hub acquires and processes profiler data, monitors equipment status and distributes profiler data to all customers. This Hub is a "legacy" VAX/VMS cluster of micro computers, typically used during the 1980's, dedicated solely to processing of the NPN data. As with any dedicated operational system, changes are kept to a minimum. Currently all of the equipment is under hardware maintenance contract. Because the system is approaching obsolescence, efforts are under way to build a "modernized" Hub using state of the art architecture built on racks of low-cost off-the-shelf personal computers (PCs) operating under Red Hat Linux.

$ The facility also houses additional modern computer equipment for the collection, processing and distribution of other data sets that are complementary to the profiler data. Included are data from profilers operated by other organizations. These profilers are referred to as Cooperative Agency Profilers (CAPs). Currently, approximately 70 systems provide data at no additional program cost. These data are checked for quality and forwarded to the NPN customers. The CAP data contribute significantly to NWS forecasts in areas outside the NPN. Additionally, there are computers to support the distribution of the data via the NPN web site for many of the non-NWS customers.

$ In addition to providing Information Technology (IT) capabilities for the NPN and CAP profiler networks, the facility also houses all the computer equipment need to support the GPS-Met program which uses GPS technology to measure the amount of moisture in the atmosphere above a site.

$ Also included is equipment for archiving the data and supporting local area networks, communication devices and required security firewalls.

$ Since the NPN was declared Mission Critical under OAR's Y2K planning documents, capability was added to allow for emergency power and air conditioning separate from the building capabilities. Maintenance and upgrades of this environmental equipment are part of the operational requirements of the facility.

$ As part of the Forecast Systems Laboratory (FSL), the NPN program shares the highspeed Internet connection utilized by Laboratory staff and works cooperatively with other computer groups on system monitoring, security measures, and computer training.

$ Hardware, software and technical support for all of the scientific, technical, engineering and administrative desktop and laptop PCs utilized by program staff are handled by facility.

7 Data Communications

$ All of the NPN data are transmitted from individual profiler sites to the Boulder facility via

35 dedicated ATT circuits every six minutes. The cost of the three Alaska circuits is offset by NWS funding. Additionally, there is a single high-bandwidth dedicated line used to transmit the processed data from the Boulder facility to the NWS Telecommunications Gateway in Silver Spring, MD. From there the data are distributed to NWS locations, where they are utilized in numerical weather prediction models or by weather forecasters in forecast offices to prepare forecasts of the local weather.

$ When the General Services Administration awarded a new government telecommunications contract (FTS-2001) to MCI/WorldCom, the program applied and obtained the first Department of Commerce waiver to remain with the FTS-2000 vendor, ATT. This resulted in a significant cost savings since a previous communication equipment investment of $130,000 was preserved. Likewise, by joining with the Department of the Interior's Minerals Management Service (DOI/MMS) via a Memorandum of Understanding, pursuant to the Economy Act, significant additional savings were achieved because monthly recurring costs were already lower than those available under the new FTS-2001 contract. This arrangement with DOI/MMS is valid through fiscal year 2005.

$ In addition to dedicated data circuits, the NPN utilizes a satellite-based back-up communications system: the NOAA's Geostationary Operational Environmental Satellite (GOES/DOMSAT) data collection platform. This very low bandwidth system permits simple messages to be transmitted once per hour. If there is a failure in a dedicated data circuit, the data obtained via GOES can often still be used to calculate quality winds.

$ After a decade of study and development, high data rate (1200 baud) GOES capability is now available. The NPN program is in the process of evaluating four currently commercially available and government certified GOES transmitters for possible upgrade of the back-up communication system. Since the upgrade will involve a major expenditure, it was deemed prudent to conduct an in-depth evaluation prior to commitment of funds.

$ Since recurring data communication costs are a significant portion of the NPN budget, exclusive of labor, alternative less expensive technologies are being investigated. In anticipation of a nationwide profiler network, evaluation of new communication methods is called for. One of these technologies is a satellite-based Internet system based on the same equipment and services that provide commercially available satellite-based television signals. Due to the technology utilized, data could be lost during periods of inclement weather. Through a government grant, the program has obtained funding to install four systems in diverse parts of the network for a one year evaluation to determine if transmission failures have little or no effect on the availability of the data. At present, the cost of this type of system is less than half the cost of traditional dedicated data circuits.

$ In addition to the above communication capability, the facility also has 15 dial-up lines, used to acquire data from the CAP profilers scattered throughout the country. Costs for these lines are incorporated in the phone system used to provide voice capability to the program and, as such, are covered under Item 11 - "Program Management and Planning".

8 Web Services

$ The profiler web site (http://www.profiler.noaa.gov) provides comprehensive information on the NPN. Additionally, it gives non-NWS users access to all data collected by the program, either for display or downloading to the user's computer. The Web is the program's primary connection to the public.

$ Access to the CAP profiler data is currently only through the web site. Progress is being made, though, to make the data available through normal NWS data communications channels.

$ For network evaluations, research, scientific studies and educational projects, archived profiler data can be retrieved via the web site. At least one year's of data reside "online" and are immediately available. Plans are to restore all data beginning with the operation of the full network in 1992. Since the data set contains more than a decade of profiler data, it is most useful to scientists studying climatology and particularly aspects of possible global warming.

$ Many of the NWS Area Forecast Discussions (AFD; see Section 5) use the data from the web site. Typical counts of the use of profiler data are on the order of 6-7 per day and 12-18 during bad weather.

$ The average daily number of "hits" per day on the NPN web site is over 1200. The site serves over 800 different web "customers", three-quarters of them being government, commercial and educational users.

$ Information on the web site is constantly monitored and updated as needed.

9 Software Maintenance and Development

$ Dedicated maintenance of legacy systems is critical for systems that are deemed operational. Since all NPN profiler data are processed on a single legacy system cluster, a system outage results in a loss of all NPN data. Though the legacy system is a single point of failure, good initial design with built-in redundancy has resulted in a fairly robust system. Any system weaknesses that evolve are dealt with immediately to assure the best throughput of data possible. It is even more important that software maintenance is kept current as problems are uncovered. Even in software functioning for many years, "bugs" can still be found. Some software used by the NPN program is procured commercially. If deemed prudent, software maintenance is purchased from the vendor.

$ As the Profiler Hub legacy system nears the end of its functional lifetime, a large and growing effort is under way to modernize all of the software. The program must take advantage of new, more efficient and cost effective hardware, modern computer architectures and more flexible software languages and tools. The new, modernized Hub will be able to accommodate new field observing system network architectures, variable types of data acquisition methodologies and greater flexibility in data processing and data quality control techniques.

10 GPS-MET Support

$ Since 1994, under the auspices of the NOAA Profiler Program, ground-based Global Positioning System (GPS) observations have been studied as one of the components of the next-generation upper-air moisture observing system. The studies leverage both the NPN existing infrastructure and other agency assets. The GPS program has achieved success through integration of existing capabilities. In its original conception, the NPN was to provide profiles of three important atmospheric variables; wind, temperature and moisture. The GPS project partially addresses the moisture variable.

$ GPS technology was originally developed for very accurate positioning in diverse civilian and military applications. Over the years, however, GPS technology has proven valuable in meteorology because it can measure the total amount of water vapor in the atmosphere directly above the GPS instrument.

$ Through several interagency agreements, the GPS project uses GPS equipment belonging to others - particularly the U.S. Coast Guard and U.S. Army Corps of Engineers who have many systems installed in the U.S. along the coasts and rivers for navigation. In order to measure the moisture content, the project only has to provide a small suite of surface instruments that measure temperature, humidity and pressure.

$ The GPS network is nearing almost 300 stations across the country. All data are sent to the Boulder facility for processing, quality control and distribution to the NWS and other customers. The data processing system relies on PCs and can easily be expanded as needed. The primary processing software is provided at no cost to the Government by the Massachusetts Institute of Technology (M.I.T.).

$ Maintenance of the GPS instrumentation and/or surface instrumentation is performed by the Profiler field engineers, NWS El-Techs or members of the U.S. Coast Guard.

$ In order to measure the amount of moisture accurately, the individual positions of the GPS satellite constellation (24 satellites) must be known with more precision then required for most navigational uses. The Scripps Institution of Oceanography, which houses one of the GPS orbit facilities, provides high accuracy orbit information, along with scientific and technical support to the GPS program. The calculation of high precision orbits within minutes is critical for retrieving the moisture information used in weather prediction models and real-time atmospheric monitoring.

11 Program Management and Planning

$ As mentioned in "General Comments", the NPN program, including the GPS network, operates with a certain amount of financial autonomy within the Forecast Systems Laboratory. The program provides funds for both its Government and Contractor staff and its own administrative and budget support. All travel and training costs come from project funds. Costs for computer support of the NPN and GPS processing systems, along with the needed communications equipment, are also include in the program's budget. Likewise, cost of staff offices, laboratory and warehouse rent and all voice telephones used by staff and dial-up communication comes from program funds. Any annual "taxes" imposed by OMB, NOAA, OAR are prorated within the Laboratory's base funding with the Profiler/GPS program paying the appropriate prorated portion.

$ Operation of the network generates monthly bills for utilities, telephone, data communication service, and land leases. The time required to review, certify and track these bills is significant.

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Annex E

Cost Analysis of Alternative Wind Sensing Systems

Table E.1 shows estimated annual sensor costs to observe the wind with future research, development, deployment, and sustaining costs averaged over the remaining program lifecycle using the FY04 budget. The costs contained in Table E.1 are detailed in items 1 through 7.

Table E.1. Annual and Lifecycle Costs for Wind Parameters

Wind Observing System	**Annualized Cost**	**# Years System Availability**	**Lifecycle Cost**
1. NOAA Profiler Network (NPN) - Cost to Operate	$3.86M	20	$77.20M
2. NOAA Profiler Network (NPN) - Cost to Terminate and Replicate Hub Functions for non-NPN data	$2.25M	N/A	N/A
3.a GPS Radiosonde (2 per day)	$4.05M	20	$81.00M
3.b GPS Radiosonde (24 per day within NPN Domain)	$58.25M	20	$1165.00M
4. MDCRS Aircraft Observations	$0.35M	20	$7.00M
5. WSR-88D Doppler Radar	$2.52M	15	$37.80M
6. GOES Object Tracker	$2.57M	11	$28.27M
7. LIDAR Satellite	$23.25M	20	$465.00M

1. NOAA Profiler Network (NPN) Winds

A. Development/Acquisition:
New Frequency: $13.16M
Estimate a 20-year lifecycle for antennas and transmitters; this gives $0.66M/yr.

B. Product Development: $0.8M
NPN product development includes algorithm development such as bird migration filters and system efficiencies such as improved system availability.

C. Maintenance and Operations: $2.4M
Wind Profiles are the primary product created by the NPN funding. Others products are signal power, radial velocity, GPS moisture soundings, RASS temperature soundings, and Cooperative Agency Profiler (CAP) network wind data. Funding for CAP and GPS moisture soundings account for $0.9M of the total $4.1M NPN budget. CAP and GPS funding are not included here.

D. Annualized Costs of NOAA Profiler Network Winds (A+B+C):
($0.66M/yr)+($0.80M)+($2.40M] = $3.86M

2. Cost to Terminate: See Annexes F and G.

3.a GPS Radiosonde Winds (2 sondes per day):

A. Development/Acquisition - Cost to deploy the GPS system: $39.2M
Program Lifecycle: 20 Years
Burdened R&D Lifecycle Costs: $2.0M/yr

B. Maintenance and Operations
Basic Radiosonde Program: $8.8M
Additional Cost of GPS: $5.4M ($4.1M is currently reflected in the FY04 budget, but the rising cost of GPS sonde expendables boosts the figure to $5.4M.)
Total Annual Base (GPS Operations): $14.2M

C. Percent Costs: Winds are responsible for 25% of the total cost:
25% of radiosonde parameter sensors (1 of 4, including temperature, pressure, humidity, and winds).

D. Annual Costs of GPS Radiosonde Winds [(A+B)*C]: $16.2M*0.25 = $4.05M

3.b GPS Radiosonde Winds (24 sondes per day): Incremental cost of supporting hourly frequency requirement

A. 25 sites within the NOAA Profiler Network (NPN) domain (about the same as the number of NPN sites)

B. Estimated burdened cost per GPS sonde per launch (includes labor, facilities, and expendable changes): $270 / sonde

C. Additional 22 sonde launches per site required to attain hourly frequency

D. Additional sondes needed 365 days per year

Percent costs: Winds are 100% of incremental sonde cost

Incremental costs of hourly sondes: A*B*C*D = (25 sites) * ($270 / sonde) * (additional 22 sondes / site / day) * (365 days / year) = $54.20M / year
24 sondes / site / day = ($54.20M + $4.05M) / year = $58.25M / year

Note: 24 sondes per day per site is a technical challenge for ground processing resources because preparations for a second balloon launch will have to be started before the prior balloon has reached 15-km altitude. Costs for upgrading ground processing capabilities are not included in this analysis.

4. Meteorological Data Collection and Reporting System (MDCRS): NWS pays 50% of government cost to downlink and process MDCRS data (FAA pays the rest); the government and the air carriers share communication costs equally. All costs to measure winds are incurred by the participating air carriers.

A. Development/Acquisition: $0.00M

B. Maintenance and Operations: This is the total government cost
Ground Processing: $0.30M
Communications: $0.40M

C. Percent Costs: MDCRS data include temperature and wind parameters; the contribution of wind to the total cost is 50%

D. Annual Costs of NOAA Profiler Network Winds [(A+B)*C]:
$0.70M*0.50 = $0.35M

Note: Due to the financial weakness of some of the airlines participating in the MDCRS program, the government's share of communications costs could rise substantially in the future. The volume of data collected is also expected to rise substantially, thus further increasing costs.

5. WSR-88D Doppler Winds

A. Development/Acquisition:

FY05-09 Procurement, Acquisition, and Construction: Open-Radar Data Acquisition (ORDA) and Dual Polarization: $98.2M
Program Lifecycle: 15 years
DEV/ACQ Cost per year: $98.20M / 15 yrs = $6.60M / yr

B. Maintenance and Operations: Includes Radar Operations Center (ROC), Electronic Technicians, Logistics and Utilities (FY04): $41.30M

C. Percent Costs: VAD Wind Product is 1 of 19 unique products (5.26%) generated by the WSR-88D

D. Annualized Costs of WSR-88D VAD Winds [(A+B)*C]:
[($98.20M/15 yrs)+($41.30M / yr)]*5.26% = $47.9M / yr * 0.0526 = $2.52M / yr

6. GOES Object Tracker Winds: Winds from the Geostationary Operational Environmental Satellite (GOES) are created from the GOES Imager sensor. The current GOES series first became operational in 1994 (GOES-7) through GOES N); the life cycle of this series satellite is expected to last until 2014.

A. Development/Acquisition:
GOES N, O, P (Lifecycle costs through FY09, including FY04): $700.00M

Note: GOES N (2004), O (2005), and P (2008) are replacement satellites for GOES 10 and GOES 12 (current operational satellites); lifecycle 2004-2014

Annual Development/Acquisition Costs (11 year program lifecycle): $63.64M

B. Maintenance and Operations (annual costs):
Product Development (FY04): $10.50M
Satellite Operations Center (SOC) (FY04): $13.70M [Polar Operational Environmental Satellite (POES) and GOES]
Total M&O Costs: GOES Product Development+50% of SOC or $10.50M+$6.85M = $17.35M

C. Percent Costs: 6 Object Tracker wind products (water vapor, infrared, and visible winds) are 3.17% percent of all NESDIS products generated (189 individual products).

D. Annualized Costs of GOES Object Tracker Winds [($63.64M+$17.35M)*3.17%]: $80.99M*0.0317 = $2.57M

7. <u>LI</u>ght <u>D</u>etection <u>A</u>nd <u>R</u>anging (LIDAR) Satellite Winds – Costs are estimated based on the following paper:
Cordes, Joseph J., March 1995: "Economic Benefits and Costs of Developing and Deploying a Space-Based Wind Lidar," NOAA Contract 43AANW400223.

A. Development/Acquisition: $440.0M
Research and Development: $20.0M, Acquisition: $420.0M

B. Maintenance and Operations: $490.0M for 20 years

Note: LIDAR Satellite Program estimated 20 years.

C. Percent Costs: Winds are the primary parameter generated from the Polar Operational Environmental Satellite (POES) Satellite Lidar. However, the POES satellite lidar will also sense aerosols and trace gases. Estimate 50% of costs for development and maintenance are associated with the wind parameter.

D. Annual Costs of POES Satellite Lidar Winds [(A+B)*C]: Years
($440.0M+$490.0M)*0.50/ Program Lifecycle = $465.0M / 20 years = $23.25M / yr

Annex F

Cost to Terminate the NOAA Profiler Network (NPN)

A number of actions are required to shut down a profiler site:

- Remove shelter that houses computers and communication equipment.
- Dismantle antenna; salvage parts.
- Remove dual-channel GPS receivers at all sites and Radio Acoustic Sounding System equipment at eleven sites.
- Take down fence; dig out approximately 50 fence posts set in concrete.
- Remove electrical conduit and grounding.
- Transport salvageable parts to Kansas City, Missouri, for GSA government auction.
- Remove ten concrete pillars that support the antenna and the equipment shelter.
- Remove landscaping plastic and six-inch bed of rock over an area 65 ft by 65 ft.
- Haul debris to nearest landfill.
- Reseed and restore site to its original condition.
- Test soil to certify that no contaminants remain.
- Terminate commercial power and telecommunications.
- Terminate property leases, giving at least 60 days notice.

Written bids from two contractors have been received. One will charge $27,918 per single site restoration. The other will charge $42,628 per site. The average of these two numbers is $35,273. Soil remediation will cost an additional $10,000 per site as estimated by one of the contractors. This brings the average total per site to $45,273. Oversight and management of the contract including travel, writing specifications and awarding the contract would require a ½ person year at a cost of $70k. Thirty-five sites must be cleared and restored, bringing the total to $1.65M.

Other indirect costs accrue from closing down the NPN. The Profiler Hub, located at NOAA's Forecast Systems Laboratory in Boulder, Colorado, processes data not only from the NPN but also from:

- a network of about 300 GPS sites around the U.S. that provides estimates of total column water vapor
- a network of approximately 75 Cooperative Agency Profilers that deliver winds from near the surface up to 10,000 ft
- Radio Acoustic Sounding Systems (RASS), collocated at many Cooperative Agency Profiler sites, which provide frequent low-level temperature profiles.

If funding for the NPN is terminated, operation of the Profiler Hub will cease, and data from these observing systems, collectively valued at over $13M will no longer flow through the Hub to the National Centers for Environmental Prediction, where these same data help to specify the starting conditions for computer forecasts.

The three Alaska profilers were acquired through a supplemental Congressional appropriation to the National Weather Service. If these profilers are to remain in service after the $4.15M supporting the other NPN profilers is withdrawn, then a new hub must be built because data from the Alaska profilers are currently routed through the NPN Hub in Boulder, Colorado. The new Hub will provide an alternative method for collecting, processing, monitoring, and disseminating the Alaska data.

To avoid loss of the Alaska profiler data and valuable non-NPN data sources mentioned earlier, it will be necessary to replicate many of the functions of the NPN Hub. The associated costs are discussed in Annex G.

Annex G

Cost to Replicate the NOAA Profiler Network (NPN) Hub

As noted in the main body of the COEA, the Profiler Hub at the Forecast Systems Laboratory in Boulder, Colorado, processes data from several non-NPN sources. If funding for the profiler program is terminated, the Hub will cease to operate, thus stopping the processing, quality control, and transmission of these non-NPN data sources to the National Centers for Environmental Prediction, where they are used for computerized weather predictions, and to local forecast offices, where they are used to monitor and forecast rapidly changing weather. Processing and distribution of data from the three NPN profilers in Alaska would also cease.

This Annex lists the costs associated with building a substitute for the NPN Hub that will handle the non-NPN and Alaska data flows. All costs are rounded to the nearest $1000.

One-Time Cost to Replicate the Hub for non-NPN Data Flows

Cooperative Agency Profiler (CAP) program –75 sites (boundary-layer wind profiles and RASS data)

Procure processing and network hardware		$ 50,000
Communications equipment/modems, multiplexers		15,000
Data Processing/monitoring software conversion (1.5 person year)		198,000
	CAP Total	$263,000

GPS Network – about 300 sites (estimates of total column water vapor)

Processing and network hardware	GPS Total	$ 80,000
	Sub-Total, non-NPN Data	$343,000

One-Time Hardware/ Software Cost for Upgrading the Three Alaska Profilers and Providing Mini-Hubs at the Anchorage and Fairbanks Forecast Offices

A separate Profiler Hub must be developed for the NWS Alaska Region to process data from its three profilers.

Profiler hardware (computer and communications upgrade)	$ 8,000
Forecast Office (FO) hardware (computer comms and LAN)	4,000
Profiler software upgrade and new FO software	173,000
Training for monitoring profiler performance and diagnosing problems	75,000
Sub-Total, Alaska Profilers	$260,000
Grand Total, One-time Cost	**$603,000**

Recurring Annual Cost to Operate Hub for non-NPN Data Flows

<u>CAP Program</u>

Communications	
15 dial-up communications lines ($60/month/line)	$ 11,000
Long-distance communication charges (15,000 hours)	45,000
High-speed Internet connection and dedicated circuit to National Weather Service Telecommunications Gateway	9,000
Labor	
IT support (0.5 person year)	47,000
Monitoring support (1.0 person year)	83,000
Software and engineering support (1.0 person year)	66,000
Meteorological quality control (0.25 person year)	38,000
CAP Total	$299,000

<u>GPS Network</u>

External Support	
U.S. Coast Guard maintenance support	$ 28,000
GPS Surface Observing System, spares and repair	50,000
GPS antenna/receivers maintenance contract	20,000
Real-time orbit support: Scripps Institution of Oceanography	60,000
High-speed Internet connection and dedicated circuit to NWSTG	9,000
Labor	
IT support (0.5 person year)	47,000
Monitoring and quality control support	86,000
Software and engineering support (1.0 person year)	150,000
Applications support (1.0 person year)	154,000
GPS Total	$604,000
Sub-Total, non-NPN Data	$903,000

Recurring Annual Cost for Alaska Profilers

Communications	$ 10,000
Labor	
IT support (1.0 person year)	$ 94,000
Monitoring support (1.0 person year)	83,000
Software and engineering support (1.0 person year)	66,000
Meteorological quality control (0.50 person year)	76,000
Sub-Total, Alaska Profilers	$329,000
Grand Total, Annual Cost	**$1,232,000**

Annex H

Appropriations Bill Language Directing the National Weather Service to Undertake the NOAA Profiler Network Cost and Operational Effectiveness Analysis

From the

108TH CONGRESS - *1st Session*
SENATE REPORT #108–144
DEPARTMENTS OF COMMERCE, JUSTICE, AND STATE, THE JUDICIARY, AND RELATED AGENCIES APPROPRIATION BILL, 2004

Bill: S. 1585. Page 103 stated:

> *NOAA Profiler Network [NPN]*.—The abrupt decision to shutdown the NPN came as a surprise. Though the Committee is aware that the 404 MHz frequency being used by the NPN will be unavailable by mid-decade, no analysis has been done to determine the value of the data produced by the NPN, the method and cost of collecting valuable NPN data by other means, or the cost of shutting the NPN down. Lacking adequate justification, the Committee recommendation funds NPN operations for at least 1 more year. The NWS is directed to undertake a cost and operational effectiveness analysis [COEA] comparing the $10,000,000 cost to upgrade the NPN over the next decade versus the short, medium, and longterm costs of ending the NPN program. The COEA shall be delivered to the Committees on Appropriations not later than March 31, 2004.

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First compiled by B.L. Weber - December 2001
Updated by D. van de Kamp – March 2004

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