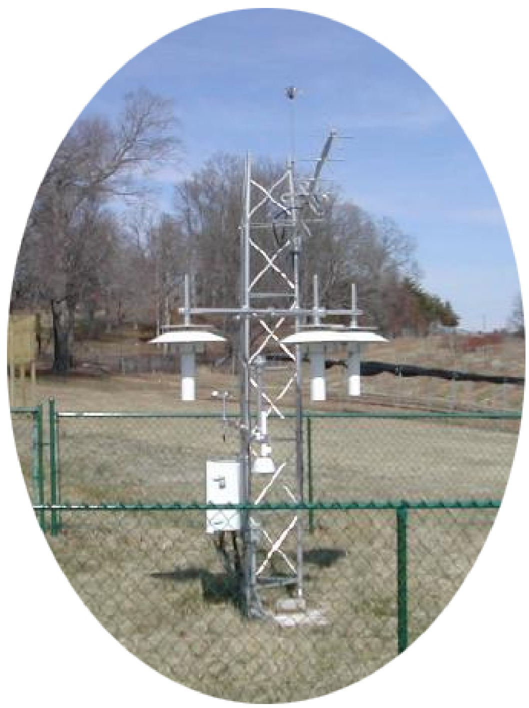
NOAA/NESDIS
CRN Series
X041

NOAA-CRN/OSD-2003-0010R0UD0
November 19, 2003
DCN 0

United States Climate Reference Network (USCRN)

Field Site Maintenance Plan



November 2003

Prepared by:

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Environmental Satellite, Data, and Information Service (NESDIS)

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Approval Page

Document Numbers:	
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Document Title Block:

United States Climate Reference Network (USCRN)

Field Site Maintenance Plan

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Document Change Notice

DCN NO.: **0**	DATE: **November 19, 2003**	PROGRAM : SYSTEM: **USCRN**	PAGE NO.: **1** of **1**
DOCUMENT TITLE: ***United States Climate Reference Network (USCRN)*** **Field Site Maintenance Plan**			
DOCUMENT NO. **NOAA-CRN/OSD-2003-00010R0UD0**			
CHANGE PAGE HISTORY			
No.	Page Numbers(s)	Update Instructions (Insert/Delete/Replace)*	Reason for Change
0	Complete Document	Baseline version of the document; first publication	See COMMENTS below
COMMENTS: This DCN 0 package consists of the initial NOAA/NESDIS baseline publication of this document.			
NOTE:			
*EXAMPLES: *"Insert change pages 6.2-6 through 6.2-9 following page 6.2-5"* *"Replace pages 3.4-1 through 3.4-10 with change pages 3.4-1 through 3.4-10b"* *"Replace pages 4.5-24 with change page 4.5-24; delete pages 4.5-25 through 4.5-30"*			

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NOTES:

Preface

This document comprises the National Oceanic and Atmospheric Administration (NOAA)/ National Environmental Satellite, Data, and Information Service (NESDIS) initial baseline publication of the *United States Climate Reference Network (USCRN) Functional Requirements Document* (version DCN 0; November 19, 2003, publication). The document number is NOAA-CRN/OSD-2003-00010R0UD0.

This document addresses the maintenance of all field site equipment, as well as the field components of the communications network unique to USCRN. Maintenance and operation of both the central facility and the communications infrastructure are not within the scope of this plan. It also includes a definition of the maintenance requirements, an assessment of the maintenance functions that can be adequately provided by USCRN partner and host organizations, and a characterization of supplementary maintenance providers, to the extent they become necessary.

The publication of this baseline document closes the following Document Configuration Change Request:

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NOAA/NESDIS acknowledges the efforts of the NOAA/NESDIS National Climatic Data Center (NCDC) and Short and Associates, Inc., for their preparation of the material in this document.

Future updates and revisions to this document will be produced and controlled by NOAA/NESDIS.

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List of Tables

Acronyms and Abbreviations

ARL	Air Resources Laboratory
ATDD	Atmospheric Turbulence and Diffusion Division
ATS	Anomaly Tracking System
CSI	Campbell Scientific
DCN	Document Change Notice
DCP	Data Collection Platform
DFIR	Double Fence Intercomparison Reference
GOES	Geostationary Operational Environmental Satellite
ILS	Integrated Logistics Support
IR	Infrared
IRs	Incident Report
LDP	Logistics Delay Period
MTBF	Mean Time between Failure
NADP	National Atmospheric Deposition Program
NCDC	National Climatic Data Center
NESDIS	National Environmental Satellite, Data, and Information Service
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OSD	Office of Systems Development
PDA	Personal Data Analyzer
PRT	Platinum Resistance Thermometer
SAT HDR	Satellite High Data Rate
SLA	Site Licensing Agreement
SMA	Site Maintenance Agreement
SNOTEL	Snowpack Telemetry
UPS	Uninterruptible Power System
USCRN	United States Climate Reference Network
VDR	Version Description Record

Section 1. Introduction and Background

The United States Climate Reference Network (USCRN or CRN) is a new climate-observing network supported by the National Oceanic and Atmospheric Administration (NOAA). The USCRN is being implemented and managed by NOAA's National Climatic Data Center (NCDC). Scientists and engineers from NOAA's Atmospheric Turbulence and Diffusion Division (ATDD) are assisting the USCRN program staff. Additionally, system engineering and acquisition support is provided by NOAA's NESDIS Office of System Development (OSD). The goal of the USCRN is to provide the best possible information on long-term changes in air temperature and precipitation. Through the development of transfer functions, the USCRN will become the reference network to which other meteorological and climatological networks, some in existence for centuries, will be corrected. As such, the USCRN must be highly reliable, long-lived, and provide data with more accuracy and precision than conventional observing networks. Clearly, maintenance of this network to the highest possible standards is a necessary prerequisite, if the USCRN is to meet its goals. Present plans envisage the network to encompass some 100-120 stations strategically located throughout the United States by 2009.

1.1 History and Present Status

As of September 2003, there are approximately 40 CRN field stations installed and operational in various climatic regimes. Monitoring and experience with this now more than 30% sub-set of the final network has been underway since August 2001, when data from the early stations were made available to NCDC's central processing facility in Asheville, NC. By December 2002, a plan for formal monitoring and evaluation of the CRN network were activated under the formal USCRN "Demonstration Evaluation" which was conducted between January and June 2003. The Demonstration Evaluation was completed in July of 2003 and the evaluation committee recommended continuing deployment of USCRN field systems and the commissioning of the network operations. This activity planned for December 2003 will enable release of the data to the scientific community and the general public.

In general, installation, field maintenance and calibrations, and their oversight have been performed by ATDD, although in some cases local site host technicians have been willing and able to perform some routine maintenance. The use of local resources will be discussed in some detail in later sections of this Plan. The Demonstration Evaluation has yielded valuable insights into full network maintenance needs and strategies. This Maintenance Plan therefore relies heavily on the experience gained with the Demonstration Evaluation sub-network.

1.2 Scope and Purpose of This Plan

The USCRN includes several major components such as the remote field sites, the communications network, and the central facility. The central facility is located at the NCDC, and is comprised of the NCDC assets in direct support of the USCRN program. The primary purpose of this plan is to characterize the overall projected maintenance effort and describe a proposed maintenance structure. This Plan addresses the maintenance of all field site equipment, as well as the field components of the communications network unique to USCRN. Maintenance and operation of both the central facility and the communications infrastructure are not within the scope of this plan. This plan includes a definition of the maintenance requirements, an assessment of the maintenance functions that can be adequately provided by USCRN partner and host organizations, and a characterization of supplementary maintenance providers, to the extent they become necessary.

Section 2. Current Maintenance Operations

Experience thus far has shown that factory calibrations of major components have been accurate and reliable. Nevertheless, ATDD calibrates the temperature, wind speed, and solar radiation sensors against National Institute of Standards and Technology (NIST) traceable standards that are re-certified annually. The Geonor precipitation gauges are calibrated in the field using calibration weights that were compared to a NIST traceable standard weight. The factory calibrations have been determined to be accurate and are used in the event that a site host needs to swap a sensor in the field. Factory calibrations have been accepted for the infrared surface temperature sensor in the past, but ATDD is evaluating the accuracy of these calibrations and will determine if a re-calibration is necessary. The datalogger is certified to be within the manufacturer's operational specifications annually at ATDD by a process that uses NIST traceable standards to supply reference voltages and frequencies to the datalogger input ports. Automated USCRN field observations are monitored at NCDC, where indications of missing messages or questionable observation data are identified. A formalized Quality Assurance program is under development at NCDC, which includes a fault detection routine for each sensor as well as for battery voltage, fan speed, and communications equipment. An anomaly tracking system (ATS) is well underway and in use (Appendix D). As appropriate, NCDC staff should notify the designated maintenance contact at ATDD via the ATS for problem analysis and correction. ATDD staff can elect to schedule a remedial maintenance visit to the site, or enlist the support of the site host. In a number of cases, ATDD has shipped major field site components to a site host, and remotely supported their efforts to replace suspect components. In other cases, field sites required a visit by ATDD maintenance staff. Field maintenance priorities, so far, have been more or less situation dependent. It is important to note that ATDD not only is the current USCRN maintenance provider, and is also responsible for field site preparation and installation efforts. A scheduled maintenance checklist and a logistics support plan are provided as Appendices C and G.

Any maintenance by USCRN field site hosts presents a significant cost advantage to the Program. The Demonstration Evaluation has shown that many on-site routine and maintenance activities have been performed successfully by using on-site Host resources. For example, a spot-check review of 22 recent maintenance actions on the demonstration network revealed that 16 of these corrections were performed successfully by host technical personnel, remotely overseen by ATDD. In view of this experience, ATDD is preparing agreements and checklists (Appendices A and B) for site host local maintenance actions as a supplement to the Site Licensing Agreement (SLA) wherever plausible. Additionally, ATDD reviews host maintenance potential, site by site, and will continue to do so for future installations. It is planned that local maintenance support, now springing from an early spirit of cooperation, can be formalized.

2.1 Field Site Maintenance Requirements

Field site maintenance consists of several components and requires differing levels of expertise and scheduling. Representative examples include the following:

- Facilities maintenance: Cut grass, repair Double Fence Intercomparison Reference (DFIR) slats, and maintain site integrity
- Preventive maintenance: Instrument cleaning, emptying/clearing the precipitation gauge, scheduled component replacement.
- Corrective maintenance: Equipment repair or replacement, downloading datalogger content to the Personal Data Analyzer (PDA), installing datalogger programs from PDA.

2.2 Facilities Maintenance

These more or less custodial duties are, in most cases, performed by the site host and are documented in the SLA. Monthly inspections are recommended. Technical expertise needed is minimal.

2.3 Preventive Maintenance Requirements

The preliminary requirements for preventive or periodic maintenance are based on manufacturer recommendations, experience with similar automated surface measurement systems, and that gained from the Demonstration sub- network. Although some USCRN component vendors do recommend specific periodic maintenance (e.g., replace wind sensor bearing annually, calibrate solar radiation sensor bi-annually, calibrate data logger annually), most vendor recommendations are on an as-needed basis. ATDD has initially adopted an annual maintenance requirement, which involves an on-site visit for routine and preventive maintenance, field calibrations, major component swap-out, etc. (Appendix C). Site metadata will be updated at this time by quantifying and photographing site changes. Evaluating site host technical support and determining how well hosts are performing their responsibilities to CRN is an important part of the annual maintenance process. As anticipated, experience so far has shown that the rain gauge and aspirator fans need the most frequent attention. Preventive maintenance includes:

- **Monthly:** Instrument cleaning, inspect for physical damage, etc. 1000 ml precipitation gauge calibration verification.
- **Annually:** Re-calibration and refurbishment in accordance with the Scheduled (Annual) Maintenance Checklist (see Appendix C).
- **As Needed**: Emptying of the precipitation gage upon reaching a predetermined threshold or in advance of a significant predicted rainfall event (see Appendix E for Preliminary Host Notification Procedures).

Training of site host technicians is needed, if they are to perform preventive maintenance.

2.4 Corrective Maintenance Requirements

This section estimates the number of annual USCRN corrective maintenance actions. The estimate is based on the projected failure rates of site components and the likelihood of vandalism and physical damage.

2.4.1 Projected Site Component Failure Rates

Table 1 shows the estimated failure rates for most of the "active" site components. Failure rate or "lifetime" information on the Precipitation Gauge heater assembly and the Low Voltage Disconnect is not available, but should be monitored for planning purposes over the life of the program. See Appendix F (Initial USCRN Component Failure Rate Estimates) for the failure estimate rationale.

Table 1. Component Failure Rate Estimates

Component	Mean Time Between Failures	Annual Failure Rate	
		Per Item [1]	Per Site [2]
Data Logger	683,280 hours	1.3%	
Transmitter	192,720	4.5%	
Precipitation Gauge	Each Wire: 876,000 hours	1%	3%
	Each Translator: 1,752,000 hours	0.5%	1.5%
Air Temperature PRT	Insignificant	Insignificant	
Aspirator Fan	180,000 hours[3]	5%[3]	15%[3]
Anemometer	Insignificant[3]	Insignificant[3]	
Solar Radiation Sensor	Insignificant	Insignificant	
Infrared (IR) Temperature Sensor	Insignificant	Insignificant	
Surge Suppressor	Insignificant	Insignificant	
Battery	87,600 hours	10%	19%
Battery Charger	650,000 hours	1.3%	

Notes:
1. *The likelihood that any given unit will fail in any given year.*
2. *The likelihood that any given site will experience a failure of this component in any given year, based on multiple units per site.*
3. *This assumes the currently planned routine annual replacements (see Appendix F.)*

2.4.2 Vandalism and Physical Damage

The remote and unmanned locations of USCRN field sites make them somewhat susceptible to physical damage caused by animals, vandals, or natural causes. For budget planning purposes, the program assumption has been that one site in forty will be completely destroyed each year. This assumption may prove conservative for estimating associated maintenance actions, considering that the effects of vandalism and physical damage are more likely to be distributed across multiple sites than be concentrated on one site in forty. Therefore, the estimate for maintenance actions associated with physical damage should be reviewed periodically and revised based on operational experience.

2.4.3 Annual Projection of Corrective Maintenance Actions

Table 2 provides an estimate of the annual corrective maintenance actions. Numbers in the "Estimated Per-Site Annual Corrective Maintenance Actions" column are taken from Section 2.4.1, with the exception of that for "Vandalism and Physical Damage", which is based on the assumption described in section 2.4.2.

Table 2. Initial Annual Projection of Corrective Maintenance Actions

Component	Estimated Per-Site Annual Corrective Maintenance Actions
Data Logger	.013
Transmitter	.045
Geonor Wire	.03
Geonor Translator	.015
PRT Assy.	0
Fan	.15
Anemometer	0
SR Sensor	0
IR Sensor	0
Surge Suppressor	0
Battery	.19
Battery Charger	.013
Vandalism and Physical Damage	.025
Per-Site Total	.481
Total corrective maintenance actions for 100 sites = 48.1	

This estimate indicates that, on average, the number of annual corrective maintenance actions is roughly equal to half the number of deployed sites. It ignores the likelihood that any site may sustain multiple concurrent failures, all of which would be corrected by one corrective maintenance action.

2.5 Required Maintenance Response

This section addresses the responsiveness with which the corrective maintenance actions must occur.

2.5.1 Maintenance Response Requirements

Table 3 presents the corrective maintenance or "Time to Restore" requirements for each USCRN site failure condition. These requirements are based on the effect each identified failure condition would have on the centrally archived air temperature and precipitation observations, in terms of both data quality control and continuity of the climate record.

Table 3. Corrective Maintenance / "Time to Restore" Requirements

Site Failure Condition	Time to Restore
Loss of site capability to sense, process, and record the required observations from ***all three*** Air Temperature sensors*	3 days
Loss of site capability to sense, process, and record the required observations from ***one*** (of 3) Air Temperature sensor*	3 weeks
Loss of site capability to sense, process, and record the required observations from ***two*** (of 3) Air Temperature sensors*, while retaining specified operation of Wind, IR, and Solar Radiation measurements	3 weeks
Loss of site capability to sense, process, and record the required precipitation observations	4 days
For any site where concurrent precipitation measurements are recorded from multiple sensors or transducers, loss of the site capability to sense, process, and record observations from one precipitation sensor or transducer, while retaining the specified processing and recording of the other(s)	2 weeks
Loss of site capability to sense, process, and record the required observations from the Ground Surface Temperature sensor	2 weeks
Loss of site capability to sense, process, and record the required observations from the Solar Radiation sensor	4 weeks
Loss of site capability to sense, process, and record the required observations from the Wind Speed sensor	8 weeks
Loss of Transmitted Air Temperature* and/or Precipitation Data, with Site Processing and Storage Operational, where this condition can be sufficiently verified remotely in the judgement of a designated data analyst	3 weeks
Ancillary Equipment	Repair during next site visit

** In order to satisfy the requirements for an air temperature sensor, the provisions to eliminate exposure to precipitation and solar heat loading must remain fully operational. For the current implementation, the aspirated shield must remain intact, the installation must not be compromised, and fan speed data must remain within the accepted range.*

2.5.2 Application of the Maintenance Response Requirements

The "Time to Restore" requirements of Section 2.5.1 show that the failure of some site functions must be corrected in short order, while others can be tolerated for an extended period. Considering the component failures that can lead to each of the "Site Failure Conditions" of Section 2.5.1, using the failure projections from section 2.4.1 for each such component, and making some assumptions regarding the likelihood and effects of physical damage, an approximation of the annual number of site failures that must be restored within each of the required time frames for 100 deployed sites is as follows:

- Three Day Required Restoration - 5
- Four Day Required Restoration - 4
- Two Week Required Restoration - 5
- Three Week Required Restoration - 27
- Four Week Required Restoration - 2
- Eight Week Required Restoration - 3
- Restoration During Next Site Visit - 2

Note - Although the battery charger could be a candidate for the three-day restoration, it is assumed that such a failure would be detected by network monitoring well before it affects the critical measurements. Therefore, restoration of a failed battery charger is considered to have a two week required restoration.

2.6 Maintenance Priorities

Priorities have been determined by NCDC for multiple outages. At the same location, temperature sensors have first priority for repair, precipitation second, and all ancillary equipment third. Obviously, any malfunctioning ancillary equipment that results in permanent temperature or precipitation data loss becomes a first priority event.

In the event of multiple outages at different CRN locations, NCDC has established the following priorities:

- Priority 1: Stations with both an MMTS and a nearby HCN
- Priority 2: Non-paired CRN stations not co-located with other networks except HCN
- Priority 3: Non-paired CRN stations co-located with networks other than HCN
- Priority 4: One of a paired CRN location
- Priority 5: CRN sites not specified above, or those with access difficulties due to weather, natural hazards, etc. and any situation that arises in which personnel safety is an issue.

Section 3. Maintenance Structure

The proposed maintenance management structure consists of central and field components:

Central Component

- Oversees and plans all network maintenance activities
- Interfaces with CRN vendors, manufacturers and NCDC
- Provides configuration management and monitors system evolution
- Maintains logistics system and spares inventory
- Trains field technicians
- Performs calibrations/re-calibrations as needed
- Directs field technicians
- Interfaces with site hosts and monitors host compliance with CRN responsibilities
- Maintains maintenance records and ATS

Field Component

- Performs annual maintenance, refurbishment, and field calibrations
- Performs corrective maintenance as required
- Performs monthly routine and facilities-type maintenance
- Performs “on-demand” maintenance, e.g., emptying/clearing rain gauge

While the field component may consist of a mix of site-dependent resources such as site host technicians, partner government agency technicians, local maintenance contractors and field technicians directly responsible to the central facility, the central component needs to be a single entity, directed by a manager responsible for the overall health and well being of the CRN system.

Section 4. Full Network Maintenance Strategy

Clearly, maintaining a widely scattered network of some 120 instrument suites to the standards required by the purposes of the CRN requires a resourceful approach that is yet cost effective. As has been seen earlier, maximum use of host resources within the limits of their capabilities can be a critical aid. In cases where CRN sites have been located near other government networks such as SCAN, the National Atmospheric Deposition Program (NADP), and Snowpack Telemetry (SNOTEL), it has been learned that host technicians are capable of performing routine and even some of the more sophisticated CRN maintenance actions. ATDD has prepared a preliminary site-by-site assessment of host technical support potential for the Demonstration Evaluation sub network and will continue to do so as each new CRN station is installed. ATDD is also preparing training material and videotapes for site host technicians where local technical maintenance is possible. Since maintenance will likely grow to be a major CRN cost driver, future siting decisions should be biased toward co-location with other networks where skilled local technicians are available. In other cases, National Weather Service (NWS) or local contract maintenance should be considered as gap fillers, as costs will likely be less than field technician travel from the Central Facility. In special cases such as Alaska, maintenance by NWS technicians is likely to be the most cost-effective option. Annual maintenance in the lower 48, however, needs to be done by a field technician that is responsible to, and co-located with, the central maintenance entity.

Section 5. Possible Field Maintenance Scheme and Staffing Implications

5.1 Steady State

Experience with maintaining existing large and widespread networks suggests that relatively long, but not too long, maintenance swings are needed, as well as 2 person teams for safety reasons and burnout insurance. Other assumptions:

- 120 station network a day's drive apart (2.5 to 5 degree lat. grid)
- Annual maintenance requirement
- 20% unscheduled maintenance trips needed annually (most conservative estimate)
- 1 day required at each site
- 1 day travel between sites
- 2 week maintenance swing
- 1 day "bookend" before/after each trip

Thus, 120 scheduled site visits per year and 6 sites per swing*. Practically speaking, this translates to 2 teams who would be on travel about 19% of the calendar year, considering a 'bookended" day needed at the beginning and ending of each swing to arrive at start point and home. With the work year at 270 days, annual maintenance travel would consume about 26% availability. Unscheduled travel is estimated to (worst case) consume an additional 60 days or 16% of the calendar year*. Thus, each team would be in travel mode some 35% of the calendar year (42 % of the work year). Recalling that new site installations are taking place in parallel with annual and corrective maintenance, there will be a bubble period at some point necessitating more travel than needed in the steady state. A suggested way to fold this into the overall maintenance effort is to rotate central maintenance facility personnel into and out of travel; thus each technician or engineer would spend a portion of the year on maintenance swings, a much shorter time on installation travel for the temporary bubble period, and the remainder at the central facility, performing duties as in 3.0 preceding. This way, burn out and turn over might be minimized.

**Assumes a two-week swing, 2 day "bookend," 6 site days, 6 travel days between sites. Thus, 10 weeks needed for each team to complete 60 sites. The 24 unscheduled visits, by their nature, are more difficult to plan for. Assuming a well-scattered scenario in time and space (a worst case), as many as 5 days may be needed for one outage, (i.e., 60 days per team per year). If outage experience annually proves to be less than 20%, obviously less travel would be needed. Travel delays due to weather would be a problem; site locations making one day's travel between them optimistic would also expand scheduled travel requirements somewhat.*

5.2 Interim Network in 2004

Assumptions:

- 80 station network averaging 2 days drive apart
- Annual maintenance requirement
- 30% corrective maintenance trips annually (most conservative estimate)
- 1 day required at each site
- 1 day “bookend” before/after each trip
- 2 week swing
- 2 teams

Thus, 80 scheduled site visits/year, 4 sites per two-week trip, 20 trips, 10 trips/team, 20 weeks/team, which equals 38% of the calendar year per team. Additionally, 24 unscheduled trips, 12 trips/team, 60 days/team/year or 16% of the calendar year. Total travel related time therefore works out to 54% of the year for each team and about 73% of the 270-day work year. Considering that installations are taking place in tandem with maintenance, it seems clear that the same 4 technicians will not be sufficient for the workload, if account is to be taken of personal emergencies, weather delays, burnout avoidance, report writing upon return, etc. Maintenance of the interim network can be done with 2 teams, but there will need to be at least 6 technicians rotating in and out of the maintenance teams, so that individual travel is reduced to a more practical level (36%/49% calendar/work year respectively.)

Appendix A. Site Host Routine (Preventive) Maintenance Checklist

<u>USCRN Site Routine Maintenance by Site Host</u>

Site ID - Location: ____ ________

Site Contact: ________ **Date:** ________

Visual Inspection* * Indicate below any abnormalities, oddities, or obstructions removed

Tower	yes	no	*
Instruments	yes	no	*
Cables	yes	no	*
Aspirated Shields	yes	no	*
Geonor	yes	no	*
Terrain	yes	no	*
Vegetation	yes	no	*

Routine Maintenance

Geonor emptied?	yes	no			
Geonor verified?	yes	no			
Pyranometer cleaned?	yes	no			
Mow grass	yes	no	Date / Time		

Data Logger

Data collected?	yes	no	File Name:	
Program change?	yes	no	File Name:	

Final Steps

Key in *0 on keypad	yes	no
Lock data logger box	yes	no

Notes:

____

____

____

____

____

Appendix B: Site Host Maintenance Responsibility Addendum to SLA

CRN SUPPLEMENTAL SITE MAINTENANCE AGREEMENT (SMA)

FOR THE MAINTENANCE OF THE U. S. CLIMATE REFERENCE NETWORK (USCRN) EQUIPMENT

THIS AGREEMENT, effective as of ________________, (*insert date*) is by and between __________________________________, "Site Operator" and the National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), National Climatic Data Center (NCDC), through the Atmospheric Turbulence and Diffusion Division (ATDD).

WHEREAS Site Operator agrees to perform maintenance on the Climate Reference Network (USCRN) meteorological station on the following property ("Site")

____

____

WHEREAS annual maintenance of the USCRN equipment will be performed by the NOAA Atmospheric Turbulence and Diffusion Division (ATDD), the Site Operator agrees to perform routine maintenance such as to assure high quality readings from the instruments installed at the site.

WHEREAS from time to time there may be failures or other problems with instruments or components installed at the USCRN site, Site Operator agrees to provide trouble-shooting assistance as requested by ATDD technicians. In the instances where it is determined that equipment must be replaced, Site Operator agrees to remove equipment as instructed by ATDD technicians and to install new equipment provided by ATDD and per ATDD instructions. Corrective maintenance tasks will be determined by mutual agreement among ATDD technicians and the Site Operator depending on the skill level available at the time. If the Site Operator is unavailable, or believes the requested corrective maintenance action is beyond their capacity, responsibility for that corrective maintenance will revert to ATDD technicians as the primary maintenance provider.

NOW, THEREFORE, in consideration of the mutual covenants, terms and conditions herein contained, the parties hereto agree as follows:

1. Terms and Conditions of Maintenance Agreement.

This Agreement and the permission granted hereunder to conduct the activities described herein shall be effective as of the date stated above and shall continue in effect until this Agreement is terminated in writing by either party upon thirty (30) days prior written notice to the other party.

2. This Maintenance Agreement is independent of the Site License Agreement (SLA) previously signed for this location. The Maintenance Agreement may be terminated by either party without in any way affecting the SLA.

3. For the period of time this Maintenance Agreement is in effect, the maintenance activities referred to in the SLA, as well as the additional maintenance activities listed in Section 4 of this document, will be performed by the Site Operator.

4. Site Operator agrees to perform the following maintenance activities on the schedule described below. If modifications or corrective actions are made, the Site Operator agrees to notify ATDD by telephone or e-mail.

Routine Activities (Monthly or as otherwise instructed):

- Visual Inspection of following:
    - Tower
    - Instruments
    - Cables
    - Aspirated Shields
    - Geonor precipitation gage
    - Terrain near the site
    - Fences and shields
    - Vegetation in the vicinity of the site
- Routine Maintenance
    - Empty Geonor gage
    - Put proper amounts of anti-freeze and/or oil into the Geonor bucket per the ATDD recommendations for the site
    - Store used anti-freeze and/or oil in approved containers provided by ATDD
    - Verify Geonor operation
    - Clean Pyranometer
    - Mow grass

Corrective maintenance (to be performed at the request of ATDD technicians):

- Download data from data logger onto a PDA shipped by ATDD.
- As instructed by ATDD technicians, perform troubleshooting of instruments or components.
- As instructed by ATDD technicians, perform removal of instruments and components, and install replacement instruments and components shipped by ATDD.

5. Waiver of Compensation

Site Operator affirms that, in consideration of ATDD's acceptance of Site Operator's performance of the services mentioned in the Section 4 of this Agreement, Site Operator will not expect nor demand compensation for those services.

IN WITNESS WHEREOF, the parties by their duly authorized representatives have signed this Agreement as of the data stated above.

(Signatures)

______________________________	______________________________
Site Operator	FOR: Atmospheric Turbulence and Diffusion Division (ATDD)
Date: _________________________	Date: _________________________

Appendix C Scheduled (Annual) Maintenance Checklist

USCRN Scheduled Maintenance Checklist

Site ID - Location: | | |

Prepared By: | | **Date:** | |

--- Use initials to indicate step has been completed

	Inform Site Host of visit
	Gather components (see USCRN Annual Site Visit Components Checklist)
	Ship appropriate items
	Note shipment(s) tracking numbers
	Visually inspect site and note any abnormalities on Site Visit Accountability Sheet
	Retrieve data from data logger
	Retrieve program from data logger
	Note serial numbers of current equipment on USCRN Site Info. & Instrument Coeff. History Record
	Complete USCRN Site Visit Data Verification
	Take pictures as needed (see Photographical Documentation Checklist for USCRN Site)
	Empty rain gauge
	Exchange appropriate sensors/components
	Check wiring inside Geonor, secure wires and verify nothing touching bucket
	Calibrate rain gauge
	Add appropriate mixture to rain gauge
	Verify height of aspirated shield is 1.5 m
	All fans running with no noise
	Check flow rates of aspirated shields, clean if needed
	All mounts tight?
	Check all wiring connections, verify tightness
	Locks working properly, oil or replace if needed
	Replace any broken slats on SDFIR
	Relevel alter shield

USCRN Scheduled Maintenance Checklist (Continued)

	Check antenna connections
	Verify battery charger is set to correct temperature setting
	Verify door switch is working properly
	Complete USCRN Site Information & Instrument Coefficient History Record
	Program data logger
	Verify wiring matches wiring diagrams
	Complete USCRN Site Visit Data Verification
	Verify rain gauge heater works
	Key in *0 on data logger keypad
	Verify holes duct sealed
	Lock datalogger box and battery box
	Verify Transmission
	Ship appropriate items
	Note FedEx tracking numbers
	Complete Site Visit Accountability Sheet
	Enter MetaData into CRN Sites Database
	Archive files
	-- pictures
	-- program
	-- USCRN Site Inventory Record
	-- calibrations

Notes:

Appendix D: Manual Monitoring Handbook /Anomaly Tracking System

Please see the on-line copy of the Handbook, located at

http://www1.ncdc.noaa.gov/pub/data/uscrn/documentation/program/ManualMonitoringHandbook.doc

Appendix E. Interim and Proposed Final Notification Procedures for Emptying Rain Gauge

E.1 Handling Procedure for the Precipitation Gauge Anti-freeze Mixture

E.1.1 Purpose

The purpose of this procedure is to establish the guidelines for the handling and disposal of the anti-freeze mixture used in the GEONOR Precipitation Gauge.

E.1.2 Materials

ATDD:

- Methanol/Propylene Glycol mixture– 3-parts Methanol to 2-parts Propylene Glycol in 1, 2.5 and 5-gallon containers
- Chemical containers – 1, 2.5 and 5-gallon, shippable plastic chemical containers
- Polypropylene graduated cylinders – measurement
- Polypropylene funnel
- Waste disposal drum – 55 gallon drum
- Material Safety Data Sheets

SITE:

- Precipitation gauge pump – hand pump for removal of precipitation mixture
- Methanol/Propylene Glycol mixture– 3-parts Methanol to 2-parts Propylene Glycol, in 1, 2.5 and 5-gallon containers.
- Hydraulic Oil – to prevent evaporation, in one quart containers
- Empty 5-gallon Carboy Chemical containers – for waste mixture
- Polypropylene graduated cylinder
- Polypropylene funnel
- Material Safety Data Sheets

E.1.3 Storage

- All Methanol/Propylene Glycol containers will be left in their original shipping containers and kept the “White Building” at ATDD in the designated storage area. No more than 40 gallons will be kept at any one time.

- All waste material containing Methanol/Propylene Glycol, hydraulic oil and water will be kept in the Waste Disposal Drum located in the designated area in the “White Building”.

- All containers will be labeled according to their contents. There will be Material Safety Data Sheets in the designated area.

E.1.4 Method

- When the site is installed or during the annual site visit, ATDD will place an amount of the mixture equal to a site's projected annual requirement at the site. An empty container(s) for disposal will be left with the site host. Hydraulic oil will be left at the site in one-quart containers. Material Safety Data Sheets for each will also be left.

- ATDD will provide the site contact with a procedure detailing the amount of the anti-freeze mixture needing to be added, based on the climate. The required portion of the anti-freeze mixture will then be poured into the precipitation gauge. Throughout the winter months, the precipitation gauge will be emptied and the refuse placed in the disposal container. The oil requirement will then be poured on top. See Section E.2 for the Anti-freeze Service Procedure and the Anti-freeze table (Table 4).

- During the next annual visit ATDD will remove the waste anti-freeze/oil mixture and provide a new supply of mixture, oil and an empty container(s).

- Upon arrival at the Lab, ATDD will place the waste mixture in the 'waste disposal drum'. When the drum is near full, an approved Waste Disposal Service will pick it up. An empty drum will be left.

E.2 Explanation of Anti-Freeze Mixture Spreadsheet

The purpose of the USCRN Site Anti-Freeze Table (Table 4) is to estimate the timetable of the winterizing of the Geonor Precipitation Gauge, the amount of anti-freeze mixture for each site, the total amount of mixture required, and the amount of waste generated. The following methods and assumptions were used.

- Record minimum site temperatures were used to determine amount of mixture (Amount to add) added based on Geonor's recommendations of:

  -5°C – 1.5 liters
  -10°C – 2.6 liters
  -15°C –3.6 liters
  -20°C – 4.2 liters
  -25°C – 5 liters
  -30°C – 5.6 liters
  -35°C – 6 liters

  Mixture = 60% Methanol to 40% Propylene Glycol

- The "Add Mixture" date was determined from the first date of 10% probability of the temperature reaching -2°C. The "Remove Mixture" date was determined from the last day of 10% probability of a -2°C occurrence.

- Normal "Winter Precipitation" for each site was used to determine the number of times to empty the gauge. This is converted to liters in the "Vol Eq." column.

- The number of times to empty the bucket was calculated by doubling the winter precipitation (to allow for abnormalities) then dividing by the amount of precipitation in one collection period. Due to the large amount of anti-freeze mixture needed at some sites (reduced capacity), the assumption was made that a 75% full bucket (9 liters) would be the signal to service. This means the amount of precipitation in one collection period would equal to 9 liters minus the amount of mixture added. The calculated number of times to empty was, then, rounded to create a whole number.

- Due to small amounts of winter precipitation at some sites, there is no need to add the full amount of mixture for the minimum temperature. So, if doubling the winter precipitation and adding it to the amount of anti-freeze mixture added was less than 9 liters, the yearly requirement of anti-freeze is, therefore, double the winter precipitation. Example – Fairbanks, AK – with a minimum temperature = -48°C the amount of mixture to add would be 6 liters or 50% of full capacity. But, there is only 1.7 liters of precipitation each winter. So, when the precipitation is doubled or 3.4 liters to allow for abnormalities, the addition of 3.4 liters of mixture would maintain the minimum 50% ratio, prevent freezing, minimize the number of times to be emptied, and the total mixture required.

- The amount of anti-freeze mixture required per year (Yearly Req.) would be equal to the number of times the bucket is emptied multiplied by the amount of anti-freeze mixture volume added.

- The sizes of the containers available for the anti-freeze mixture are 1-, 2.5-, 5-gallon. These can be delivered in any combination to best fill the requirement (Container).

- "Total waste" is the total precipitation plus the total anti-freeze mixture requirement in gallons.

- The total number of carboys (Total Carboys) needed for waste is the total waste divided by 5 gallons.

- The total oil requirement (Oil qt.) is the number of times emptied divided by 2 (1/2 quart per service), and then rounded upwards.

Example: Versailles, KY

- First date of 10% prob. for 28°C is October 18 last date is April 20

- Record minimum temperature is -30°C – according to the Geonor chart 5.6 liters of anti-freeze per change are required

- Winter precipitation is 16.65 inches or the equivalent of 8.5 liters.

- The number of times the gauge will need to be emptied is the precipitation doubled (2 x 8.5) or 17 liters divided by 75% of bucket capacity minus the mixture added (9 liters – 5.6 liters). This gives the requirement of 4.98 or 5 times to be emptied.

- The total yearly anti-freeze requirement is equal to the number of times emptied (5) multiplied by the amount added (5.6 liters) or 28 liters or 7.4 gallons.

- To fill the yearly requirement, we would send a 2.5-gallon and a 5-gallon container of mixture.

- The total waste generated is the yearly requirement (7.4 gallons) plus double the winter precipitation (17 liters or 4.5 gallons) or 11.9 gallons

- The number of carboys needed for storage is the waste divided by 5 or 3 carboys

- The oil requirement is the number of times emptied divided by two (1/2 quart of oil per fill) or 3.

Table 4. USCRN Site Anti-Freeze Table

Site ID	State	Location	Name	Mixture	Remove Mixture	Amount to Add (l) *	Rate per 12 (l)	Winter Prec	Vol Eq. (l)	Number of Fills	Yearly Req. (l)	Gal Eq.	Container	Total Waste (Gal)	Total Carboys	Oil Qt.
00F0B0	AK	Barro	NOAA (CMDL Observatory)	13-Sep	26-Jul	2.9	6.0	2.81	1.4	1	2.9	0.8	1 gal	1.5	1	1
0102CE	AK	Fairbanks	NOAA / NESDIS (FCDAS)	9-Sep	15-May	3.4	6.0	3.32	1.7	1	3.4	0.9	1 gal	1.8	1	1
12422	AZ	Elgin	AUDUBON (Appleton-Whittell Research Ranch)	11-Nov	10-Apr	3.6	3.6	6.77	3.4	1	3.6	1.0	1 gal	2.8	1	1
13754	AZ	Tucson	Sonora Desert Museum	21-Nov	15-Mar	2.6	1.5	5.02	2.6	1	2.6	0.7	1 gal	2.0	1	1
01745E	CA	Redding	Whiskeytown National Recreation Area (RAWS Site)	21-Sep	28-May	3.6	3.6	22.93	11.6	4	14.4	3.8	5 gal	10.0	2	3
16728	CO	Nunn	NSF (Long Term Ecological Research Site)	26-Sep	9-May	4.4	6.0	6.01	3.1	1	4.4	1.2	2-1 gal	2.8	1	1
02C0DE	GA	Newton	Robert W. Woodruff Foundation (Ichauway-Dubignon Site)	7-Nov	27-Mar	3.6	3.6	18.94	9.6	4	14.4	3.8	5 gal	8.9	2	2
02B64E	GA	Newton	Robert W. Woodruff Foundation (Ichauway-George Site)	7-Nov	27-Mar	3.6	3.6	18.94	9.6	4	14.4	3.8	5 gal	8.9	2	2
01D4A6	ID	Arco	Craters of the Moon National Monument	31-Aug	30-May	2.8	5.6	2.71	1.4	1	2.8	0.7	1 gal	1.5	1	1
01E13C	ID	Murphy	ARS, NW Watershed Research Cntr.(Reynolds Creek Site)	29-Sep	11-May	4.0	5.6	3.87	2.0	1	4.0	1.1	1 gal	2.1	1	1
03073A	IL	Champaign	Univ. of Illinois (Bondville Environ.& Atmos. Resrch. Stn.)	16-Nov	16-Apr	5.6	5.6	9.91	5.0	3	16.8	4.4	5 gal	7.1	2	2
27350	KY	Versailles	University of Kentucky (Woodford County Site)	18-Oct	20-Apr	5.6	5.6	16.65	8.5	5	28.0	7.4	2.5 &5 gal	11.9	2	3
0152B2	LA	Lafayette	University of Louisiana at Lafayette (Cade Farm)	15-Nov	1-Mar	2.6	2.6	15.94	8.1	3	7.8	2.1	2-1 gal	6.3	1	2
0141C4	LA	Monroe	Ouachita National Wildlife Refuge	3-Nov	15-Mar	3.6	3.6	12.96	6.6	2	7.2	1.9	2-1 gal	5.4	1	2
02E632	ME	Limestone	Aroostook National Wildlife Ref. (Fire Training Area)	18-Sep	18-May	6.0	6.0	8.81	4.5	3	18.0	4.8	5 gal	7.1	1	2
02D3A8	ME	Old Town	University of Maine (Rogers Farm Site)	18-Sep	19-May	6.0	6.0	9.78	5.0	3	18.0	4.8	5 gal	7.4	2	2
02F544	MS	Newton	Mississippi State University (Coastal Plain Exp. Station)	25-Oct	28-Mar	3.6	3.6	5.91	3.0	1	3.6	1.0	1 gal	2.5	1	1
O9556	MT	Wolf Point	Fort Peck Indian Res. (Poplar River Site)	6-Sep	27-May	3.3	6.0	3.27	1.7	1	3.3	0.9	1 gal	1.8	1	1
00A0CC	MT	Wolf Point	Fort Peck Indian Res. (Give Out Morgan Site)	6-Sep	27-May	3.3	6.0	3.27	1.7	1	3.3	0.9	1 gal	1.8	1	1
0255BC	NC	Ashevile	NC Mtn. Horticultural Crops Res. Ctr. (Backlund Site)	7-Oct	28-Apr	5.0	5.0	9.96	5.1	3	15.0	4.0	5 gal	6.6	1	2
0246CA	NC	Asheville	North Carolina Arboretum (Bierbaum Site)	6-Oct	5-May	5.0	5.0	9.96	5.1	3	15.0	4.0	5 gal	6.6	1	2
00B3BA	NE	Lincoln	Audubon Society (Spring Creek Prairie Site)	10-Oct	1-May	5.6	5.6	7.21	3.7	2	11.2	3.0	1 & 2.5 gal	4.9	1	2
00C52A	NE	Lincoln	University of Nebraska (Prairie Pines Site)	10-Oct	1-May	5.6	5.6	7.21	3.7	2	11.2	3.0	1 & 2.5 gal	4.9	1	2
34430	NH	Durham	University of New Hampshire (Kingman Farm Site)	24-Oct	22-May	5.0	5.0	9.44	4.8	2	10.0	2.6	2.5 gal	5.2	1	2
0332A0	NH	Durham	University of New Hampshire (Thompson Farm Site)	24-Oct	22-May	5.0	5.0	9.44	4.8	2	10.0	2.6	2.5 gal	5.2	1	2
01C7D0	NM	Socorro	Sevilleta National Wildlife Refuge (LTER Site)	13-Oct	28-Apr	3.8	5.0	4.46	2.3	1	3.8	1.0	1 gal	2.2	1	1
00D65C	OK	Stillwater	Oklahoma State Univ. (Ag. Research Farm Site)	24-Oct	10-Apr	4.2	4.2	12.08	6.1	3	12.6	3.3	1 & 2.5 gal	6.6	1	2
00E3C6	OK	Stillwater	Oklahoma State University (Efaw Farm Site)	24-Oct	10-Apr	4.2	4.2	12.08	6.1	3	12.6	3.3	1 & 2.5 gal	6.6	1	2
0184DA	OR	John Day	John Day Fossil Beds Nat. Mon. (Sheep Rock Hdq.)													
01F24A	OR	Riley	National Great Basin Experimental Range	24-Aug	6-Jul	3.9	5.6	3.88	2.0	1	3.9	1.0	1 gal	2.1	1	1
35746	RI	Kingston	University of Rhode Island (Plains Road Site)	2-Oct	7-May	4.2	4.2	12.74	6.5	3	12.6	3.3	1 & 2.5 gal	6.7	1	2
0362DC	RI	Kingston	University of Rhode Island (Peckham Farm Site)	2-Oct	7-May	4.2	4.2	12.74	6.5	3	12.6	3.3	1 & 2.5 gal	6.7	1	2
0283D4	SC	Blackville	Clemson University (Edisto Research & Edu. Ctr.)	3-Nov	28-Mar	4.2	4.2	12.09	6.1	3	12.6	3.3	1 & 2.5 gal	6.6	1	2
0290A2	SC	McClellanville	SCDNR (Santee Coastal Reserve)	18-Nov	21-Mar	2.6	2.6	11.11	5.6	2	9.2	2.4	2.5 gal	5.4	1	1
0111B8	SD	Sioux Falls	EROS Data Center	27-Sep	15-May	5.6	5.6	8.26	4.2	2	11.2	3.0	1 & 2.5 gal	5.2	1	2
01B140	TX	Monahans	(Sandhills State Park)	4-Nov	4-Apr	2.6	4.2	3.66	1.9	1	2.6	0.7	1 gal	1.7	1	1
01A236	TX	Palestine	NASA (National Scientific Balloon Facility)	7-Nov	23-Mar	4.2	4.2	9.81	5.0	2	8.4	2.2	2.5 gal	4.9	1	2
0197AC	WA	Darrington	North Cascades National Park (Marblemount)	16-Oct	1-May	4.2	4.2	31.22	15.9	7	29.4	7.8	2.5 & 5 gal	16.1	3	4

*Table mixture and amounts added based on Geonor T-200B Precipitation Gauge User Manual

26 1 gal
13 2.5 gal

Appendix F. Initial USCRN Component Failure Rate Estimates

F.1 Introduction

This Appendix provides initial estimates of USCRN site component failure rates, independent of those that may result from vandalism, weather extremes, or other external causes. The estimates result from an examination of the ATS, and an Internet search for manufacturer information, customer experience, and failure rate information for similar components. This initial estimate was done during the early summer of 2003, a time at which very little actual failure rate experience with USCRN sites was available. The ATS records generally covered the first half of 2003, during which an average of approximately 25 sites were deployed. For those components with a single unit per site, the associated operating period was on the order of 110,000 hours (4,380 hours x 25 sites). When experience indicates these estimates are in need of revision, they should be replaced by estimates based on additional USCRN specific experience.

Section F.5 provides an estimated site failure rate, based on component Meantime between Failure (MTBF) figures. Section F.6 provides some routine component replacement considerations. If the routine replacement suggestions are (or have been) implemented, it will likely reduce the estimated site failure rate considerably.

F.2 Application

The failure rate estimates should be a significant consideration in both logistics planning and maintenance workload projections, and should be kept current over the life of the program. In planning for logistics stocking levels, some reasonable estimates regarding stock disbursal rates must be made. For USCRN, the primary considerations include component failures, routine or preventive replacements, and external causes. An example site failure rate, and its application to maintenance planning, is provided in Section F.5.

F.3 Failure Rate Estimates

Table 5 shows the estimated failure rates for most of the “active” site components. Failure rate or “lifetime” information on the Precipitation Gauge heater assembly and the Low Voltage Disconnect is not available, but should be monitored for planning purposes over the life of the program. See Section F.4 for the estimate rationale.

Table 5. Component Failure Rate Estimates

Component	Mean Time Between Failures	Annual Failure Rate	
		Per Item [1]	Per Site [2]
Data Logger	683,280 hours	1.3%	
Transmitter	192,720	4.5%	
Precipitation Gauge	Each Wire: 876,000 hours	1%	3%
	Each Translator: 1,752,000 hours	0.5%	1.5%
Air Temperature PRT	Insignificant	Insignificant	
Aspirator Fan	180,000 hours[3]	5%[3]	15%[3]
Anemometer	Insignificant[3]	Insignificant[3]	
Solar Radiation Sensor	Insignificant	Insignificant	
IR Temperature Sensor	Insignificant	Insignificant	
Surge Suppressor	Insignificant	Insignificant	
Battery	87,600 hours	10%	19%
Battery Charger	650,000 hours	1.3%	

Notes: 1. *The likelihood that any given unit will fail in any given year.*
2. *The likelihood that any given site will experience a failure of this component in any given year, based on multiple units per site.*
3. *This assumes the currently planned annual maintenance - see rationale.*

F.4 Failure Rate Estimate Rationale

F.4.1 Datalogger

>ATS: ATS shows there have been two datalogger replacements (Kingston, Fairbanks) recorded as Incident Reports (IRs) 049 and NEW101. The datalogger operating life has been on the order of 110,000 hours (25 sites for 6 months). Based on this limited period, the MTBF is approximately 55,000 hours.

>Manufacturer: Campbell Scientific (CSI) quotes an experienced MTBF of 78 years for the CR23X. This figure is apparently extrapolated from warranty (3 year) period returns. (See www.campbellsci.co.uk/aboutcsl.pdf). CSI indicates that this figure results from dividing the total service life for all units sold, by the number of failures during the warranty period. Using the formula $R=e^{-(t/MTBF)}$ where t is one operational year and MTBF is CSI's figure, the likelihood that a given datalogger will not fail during any given year is 98.7%.

>Conclusion: CSI's figure is obviously better than that experienced by USCRN at this early point in the program, and is probably more representative. If we use the CSI figure, the likelihood that any given datalogger will fail in any given year is 1.3%.

F.4.2 Transmitter

>ATS: ATS shows there have been two transmitter replacements (Kingston, Lafayette) recorded as IRs 012 and 048. With 110,000 operating hours (25 sites for 6 months), the MTBF for this limited period is approximately 55,000 hours.

>Manufacturer: Seimac Limited received NESDIS certification for their Satellite High Data Rate (SAT HDR) on or about November of 2000, and reliability information is apparently not readily available.

>Conclusion: An Internet search for GOES transmitter reliability information was not productive. A representative estimate of 22 years can be derived from using various manufacturers' overall Date Collection Platform (DCP) MTBF figures. Using this initial estimate of 22 years for a transmitter MTBF indicates that the likelihood of a given transmitter failing during any given year would be on the order of 4.5%. This is significantly better than the CRN experience, but given the limited period of the CRN evaluation and the likelihood of product infant mortality, the 22-year figure is considered to be more representative. Using this 22-year figure, the likelihood that any given transmitter will fail in any given year is 4.5%.

F.4.3 Precipitation Gauge

>ATS: ATS shows there have been three broken wires (Kingston, Limestone, Monroe) recorded as IRs 008, 016, and 034. In addition, there has been one broken bucket (Durham, 009), and one translator failure (Newton, 065). With approximately 328,000 operating hours (6 months, 25 sites, 3 wires), the wire MTBF has been 109,500 hours. The translator MTBF has been on the order of 328,000 hours, and the bucket failure is most likely not a predictor of overall bucket reliability.

> Other Sources: Although the Geonor T-200 has been in wide use for a number of years, an Internet search for failure rate information on Geonor T-200 or similar gauges was not productive. A small number of Geonor maintenance logs were found, but these were apparently for one or two gauges and not considered statistically significant. It has been reported that a statistically significant number of T-200 single wire gauges in Canada have exhibited a failure rate of one percent per year.

>Conclusion: The one percent per year wire failure rate translates to an MTBF of 876,000 hours. This figure is significantly higher than that experienced by USCRN at this point in the program, and is likely more representative due to the apparently larger number of operating hours. The initial conclusion is that the likelihood of any Geonor gauge, in any given year, experiencing a wire failure is 3%, and experiencing a translator failure is 1.5 percent.

F.4.4 Air Temperature PRT

>ATS: ATS shows there has been one PRT replacement (Blackville, IR#36), and multiple instances in which air temperature readings have differed significantly at particular sites. The recent incident at Wolf Point (IR#105, 6/3/03), which showed a difference of three degrees Celsius among that site's sensors is an example. Considering that a difference of 0.4 degrees has been a basis for replacing a PRT, this analysis will assume that one PRT at Wolf Point has failed. We will not assume a PRT failure at Barrow, although there have been on the order of five IRs associated with deviations in that site's temperature readings. Considering six months of operation with 3 PRTs at 25 sites, and two failures, the MTBF is 164,250 hours.

> **Other Sources:** Although PRTs are available from numerous sources, and have been in common use for some time, no failure rate information was found to be readily available on the web. For an approximate figure, the MIL-HDBK-217E failure rate figure for a low power active device can be considered representative, and this figure is .0152 failures per million hours, or an MTBF of over 15 million hours.

>**Conclusion:** The PRT does not have a representative use-based failure mode, and any failures will most likely be due to manufacturing defects and occur soon after installation. The initial conclusion is that PRT failures, not induced by external sources such as lightning or physical stresses, will be insignificant.

F.4.5 Air Temperature Aspirator

>**ATS:** At the conclusion of the January through June demonstration evaluation, ATS showed that there were three aspirator fan failures (IRs 042, 079, 107), as well as a number of cases in which fan speed has shown erratic behavior. Erratic fan speed may be an early indicator of fan failure. Considering six months of operation with 3 fans at 25 sites, and three failures, the MTBF is 109,500 operating hours.

>**Other Sources:** Papst specifies a service life of 62,500 hours at 40 degrees C. for their model 4212 (see www.papstplc.com). A number of other Papst fans were found on vendor web pages (http://www.pcsilent.de/en/products/quiet_fans_80.asp, for example), most of which showed an operating lifetime of 80,000 hours at 40 degrees C and 40,000 hours at 70 degrees C. Other brands of ball bearing cooling fans, such as those found in computers or power supplies, show an MTBF range generally between 60,000 and 100,000 hours.

>**Conclusion:** The Papst service life of 62,500 hours is generally consistent with the operating life quoted for similar fans. The figure of 109,500 hours, based on ATS entries during the demonstration, is about 75% higher, but it is based on a relatively brief average operating period of approximately 6 months. Six months is approximately 7% of the 62,500 hour (7 year) service life quoted by Pabst, indicating that these are "early" failures. The initial conclusion is that the aspirator fan MTBF is 62,500 hours, and this would be the initial estimate for USCRN if no routine replacements were planned. USCRN routine maintenance specifies replacement of one (of three) fan per site, each year, corresponding to an effective three-year replacement cycle. To reflect this three-year replacement cycle, the USCRN operational MTBF estimate is 180,000 hours, which reflects the projected fan failure rate expected in a three-year period. This revised MTBF for the fan is based on the following considerations: (a) if the failure rate of the deployed population is reasonably distributed with half having failed at 7 years, the expected MTBF in the first three years would be on the order of 250,000 hours; (b) to date (8/03), there have been on the order of a dozen recorded fan failures, which occurred over approximately 156 equivalent years of fan operation (based on three fans per site, and 52 site-years of operation to date). Note that, despite the 156 years of equivalent operation, none of the failed fans had approached their quoted service life. Dividing the 156 years by the 12 failures indicates an experienced MTBF on the order of 115,000 hours. The projected three-year failure rate of 180,000 hours is the average of these two figures, 250,000 and 115,000 hours. Using the 180,000-hour MTBF estimate, the likelihood of any fan failing in any given year is 5%. Considering that each site has three fans, the likelihood that a site will experience a fan failure in any given year is on the order of 15%.

F.4.6 Anemometer

>ATS: ATS has no apparent entries in which an anemometer has failed and been replaced. The only entries related to wind speed measurements are IRs 0001and 0043, both of which were attributed to icing, and both of which apparently conclude that the anemometer returned to normal operation with no maintenance action.

>Other Sources: An Internet search was not productive in identifying reliability information on the Met One model 014A anemometer. A number of web sites reported good experience with this sensor, and indicated two potential points of failure. The first is the bearing assembly, which the USCRN program currently plans to replace annually. The second is the reed switch, which some web sites recommended be replaced every three years. Modern sealed magnetic reed switches, such as that used in the 014A, are typically specified for “billions” of operations. For a site with constant winds on the order of 8 miles per hour, a billion operations would occur after roughly 34 months.

>Conclusion: Considering the durable construction of the anemometer, the planned annual bearing replacements, and the apparent positive experience of users, the initial conclusion is that anemometer failures will be a negligible cause for their replacement when compared to preventive maintenance and vandalism. If the reed switches are not to be routinely replaced, as some users have apparently determined to be appropriate, they may represent a potential source of anemometer failures after a few years of operation.

F.4.7 Solar Radiation Sensor

>ATS: ATS has no entries associated with solar radiation sensor failures.

>Other Sources: An Internet search was not productive in identifying reliability information on the Kipp & Zoen SP Lite. Considering that this sensor basically consists of a photodiode and resistor, an approximate MTBF can be derived from MIL-HDBK-217E. Considering the base failure rate data for these two components, the MTBF of their combination is on the order of 60,000,000 hours.

>Conclusion: The solar radiation sensor does not have a representative use-based failure mode, and any failures will most likely be due to manufacturing defects and occur soon after installation. The initial conclusion is that solar radiation sensor failures, not induced by external sources such as lightning or physical stresses, will be insignificant.

F.4.8 IR or Ground Surface Temperature Sensor

>ATS: ATS has no apparent entries showing replacement of the IR sensor. A number of entries associated with ground surface temperature readings reflect interesting events, and four indicate suspicious readings with no meteorological explanation (67, 72, 108, 146). It is assumed here that either the IR sensors at Stillwater, OK (67, 72, 146), or at Champaign, IL (108) has failed, and the other’s behavior has been due to transient obscuration of the sensor (spiders?). Based on this assumption, with six months of operation for 25 sites, the MTBF would be on the order of 110,000 hours.

>Other Sources: An Internet search was not productive in identifying reliability information on the Apogee Instruments IRTS-P, similar devices, nor for the types of thermocouples, which this sensor employs. A number of devices with integrated thermocouples are associated with MTBFs well beyond 10 years, with anticipated failures more associated with their more complicated and sensitive components.

>Conclusion: The ground surface temperature sensor does not have a representative use-based failure mode, and any failures will most likely be due to manufacturing defects and occur soon after installation. The initial conclusion is that ground surface temperature sensor failures, not induced by external sources such as lightning, corrosion, or physical stresses, will be insignificant.

F.4.9 Surge Suppressor

>ATS: The only apparent entries regarding the surge suppressor are IR#7 and IR#13. IR#7 indicates the USCRN site in New Hampshire became inoperative in February of 2002 due to battery depletion. The correction was to plug the charger into a different socket on the surge suppressor, after which the site apparently had no related problems. IR#13 indicates the battery charger was shorted out due to lightning, which would imply the surge suppressor did not provide the intended protection. There are no ATS entries indicating replacement of a surge suppressor.

>Other Sources: An Internet search was not productive in identifying reliability information on the "ISOTEL4ULTRA" device. The manufacturer, Tripp-Lite, provides a lifetime warranty on this model.

>Conclusion: The initial conclusion is that surge suppressor failures, not induced by external sources, will be insignificant.

F.4.10 Battery

>ATS: There are no apparent entries attributing problems to the battery itself. There are a number of IRs indicating transmission stoppage during cold weather, and at least one (#98) indicating gaps in stored data. Although such problems may be associated with ambient temperatures beyond the operational range of the battery (-20 to +25 C), there is no real evidence that this was the case. There are no ATS entries indicating replacement of the battery.

>Other Sources: The manufacturer, East Penn Manufacturing Company, states a design life of 10 years at 77 degrees Fahrenheit. for the Unigy I 12GVR-100 battery. Similar products from other sources are in the same range, 10 yr @ 77 degrees, 5yr. @ 91, 3yr. @ 104. Uninterruptible Power Supplies (UPS) vendors typically specify battery MTBF figures in the 55,000-130,000 hour range.

>Conclusion: The manufacturer's stated design life is consistent with MTBF figures for similar products. The initial battery MTBF estimate is 87,600 hours. Because the USCRN battery configuration apparently uses two batteries in parallel, it's likely a failure in either battery would require prompt maintenance action (this analysis should be revised if the two batteries are sufficiently isolated). The initial MTBF estimate for the CRN battery configuration, is half that of a single battery, or 43,800 hours. With no scheduled replacement, the likelihood of any USCRN site requiring a battery replacement in any given year is 19%.

F.4.11 Battery Charger

>ATS: There are three IRs associated with the battery charger (13, 17, 50). Two indicate that operation was restored by manual wiring reconnection, and one (13) indicates charger replacement following a lightning event. There are no Irs which indicate a routine failure of the charger during the approximate 110,000 hours of operation (25 sites, 6 months).

>Other Sources: An Internet search was not productive in identifying reliability information on the "Statpower Truecharge" line of chargers. The manufacturer provides a one-year warranty on all Truecharge models. This charger is microprocessor controlled, and self protected from polarity reversal, short-circuits, and surges. An initial MTBF estimate of 650,000 hours can be made with reasonable assumptions regarding parts count and MIL-HDBK failure rates. The specified temperature range of this charger (0 to 30 C operating; -25 to 70 C storage) may be of some concern, considering that some USCRN sites are likely to see temperatures go below even the specified storage range.

>Conclusion: With no routine failures recorded in the ATS, and no failure information on the Internet despite an apparently large customer base, this charger does appear to be reliable. Using the 650,000-hour MTBF estimate, the likelihood that any given USCRN battery charger will fail, not induced by external sources, in any given year is on the order of 1.3%.

F.5. Example Site Failure Rate based on Component MTBF

Each active component of a USCRN site and its initial MTBF estimate is shown in Table 6 (components with "insignificant" failure rate estimates are excluded).

Table 6. USCRN Component MTBF Estimate

Component	MTBF
Battery Charger	650,000
Battery (2 of 2)	87,000 (43,800)
Datalogger	683,280
Geonor Wire (3 of 3)	876,000 (292,000)
Geonor Translator (3 of 3)	1,752,000 (584,000)
PRT and Aspirator (3 of 3 combinations)	179,533 (65,844)
Transmitter	192,720

These figures can be combined into an overall site MTBF of 19,489 hours, or roughly 2.2 years. This would indicate that, on average, a USCRN site would require an unscheduled maintenance visit approximately every 26 months to correct routine failures. To address externally induced failures, such as vandalism or weather extremes, an approximate estimate of "one site in forty per year" has been mentioned in USCRN budget and planning documents. Using this figure, a site "MTBF due to external causes" of 350,400 hours can be derived. Combining these two MTBF figures results in an overall MTBF of 18,450 hours, indicating that, on average, a USCRN site will require an unscheduled maintenance visit every 25 months, or 0.48 visits per year.

F.6 Additional Routine Replacement Considerations

The decision to replace the aspirator fan on a three-year cycle has effectively improved the estimated site MTBF from 11,486 hours to 18,450, reducing the projected annual corrective maintenance from 0.76 visits per site to 0.48. Scheduled replacement of the battery may result in an additional improvement. The quoted design life of the battery is 10 years (see Section F.4.10). It may be worthwhile to consider routine replacement at the five to seven year point.

The anemometer is currently scheduled for site replacement on an annual basis. Replaced anemometers will be refurbished with new bearings and put into ATDD stock. If not already planned, there are indications (see Section F.4.6) that the reed switch should be considered for replacement on a 3-year cycle.

Appendix G: USCRN Integrated Logistics Support (ILS) Plan

G.1 Introduction

This appendix provides an initial estimate of the efforts necessary to provide logistics support for the USCRN. Beginning with a USCRN logistics “concept of operations”, this plan quantifies projected stock disbursal rates, identifies the necessary stocking levels, and estimates the resources necessary to meet the logistics requirement.

G.2 The USCRN Logistics Support Concept of Operations

USCRN field sites are supported by a central logistics facility, currently operated by the AT DD, one of several divisions of NOAA’s Air Resources Laboratory (ARL). Field sites do not locally store replacement parts, nor are replacement parts sent from vendors directly to sites. The central facility provides the following logistics functions:

- Procurement
- Receiving and quality control
- Central calibration
- Selected component repair and reconditioning
- Component tracking and maintenance of logistics records
- Responsive delivery of replacement components to field sites
- Provision of sufficient stock to support routine annual component replacements, corrective maintenance component replacements, as well as whole system replacements
- Warranty administration
- Maintenance of site configuration data
- Documentation of failure rates
- Central engineering

G.2.1 Logistics Support of Scheduled Maintenance Activities

Each field site will receive an annual visit in accordance with the USCRN preventive maintenance plan. As a matter of routine, the following components will be replaced during each annual visit: (1) Data Logger, (2) One (of three) PRT assembly, (3) One (of three) aspirator fan, (4) Anemometer, and (5) Solar Radiation Sensor. With the exception of the aspirator fan, which will be discarded, the removed components will be returned to the central logistics facility for refurbishment/recalibration and then placed in the logistics stock.

The annual visit includes replenishment of each site’s anti-freeze and oil supply for the precipitation gauge. A year’s supply of each will be delivered to each site during the annual visit, along with a sealable container for local storage of liquid periodically emptied from the gauge during the coming year. The central logistics facility must ensure that sufficient stock is maintained to support the annual component replacements, as well as provide the necessary resources to test, refurbish, calibrate, track, and re-stock components. A sufficient supply of oil, anti-freeze, and sealable containers must be on hand, along with suitable means for disposal of the liquid returned from each field site.

G.2.2 Logistics Support of Corrective Maintenance Activities

The central logistics facility is the single source of replacement parts for field site corrective maintenance. The field site restoration requirements range from three days to two weeks, depending on the severity of the failure. The central logistics facility must be sufficiently responsive to support the restoration requirements, ensuring that replacement components are delivered to field sites within the required restoration period. In general, failed components will be returned to the central logistics facility, where they will be repaired or replaced to maintain the necessary stocking levels.

The central logistics facility must have appropriate stock on hand to support corrective maintenance, responsive shipping provisions, and the necessary resources for repair/replacement of returned components. The central logistics facility must have sufficient administrative resources to track warranties, failure rates, and maintain site configuration data.

G.2.3 Logistics Support for Restoration of Severe Physical Damage

The central logistics facility is the single source for new and replacement field site configurations. A number of field site components, such as tower components or fencing materials, could be expected to have a service life on the order of tens of years, and not be significant considerations for logistics planning. In the case of USCRN field sites, however, their remote and unmanned locations make them somewhat susceptible to physical damage caused by animals, vandals, or natural causes. In order to respond to such events, the central logistics facility must maintain an adequate supply of each physical component necessary to responsively replace a damaged site. For budget planning purposes, the program assumption is that one site in forty will be completely destroyed each year.

G.2.4 Logistics Support for System Evolution

Although the current system configuration may remain relatively stable for the coming decade, the projected program life is on the order of fifty to one hundred years. During this period, new or additional components will be phased in, and obsolete or unsupportable items will be phased out. The central logistics facility must retain sufficient engineering and test resources to insure that the evolving baseline remains supportable and that the integrity of the program is not compromised.

G.3 Projected Stock Disbursal Rates of “Active” Components

In this section, stock disbursal rates are projected for what are commonly considered “active” components, such as the sensors and electronic components. Disbursal of most of these components will primarily be associated with routine and corrective maintenance actions. Replacement of other components, such as tower, antenna, fencing, cabling, and mounting hardware, is assumed to follow the “one in forty per year” described in Section G.2.3.

G.3.1 Disbursal in Support of Routine Annual Replacements

To support routine annual component replacements, the following items will be disbursed from the central logistics facility, each year, for each deployed site:

- One data logger
- One PRT assembly
- One aspirator fan
- One anemometer
- One solar radiation sensor.

G.3.2 Disbursal in Support of Corrective Maintenance

Disbursal in support of USCRN corrective maintenance is based on the projected failure rates of the active components. Derivation of the projected failure rates is provided in a separate appendix, entitled "Initial USCRN Component Failure Rate Estimates". The failure rates, or MTBF, identified in Table 7 are taken from that appendix. As appropriate, the MTBF figures should be revised in accordance with future operational experience.

Table 7. Projected Annual Disbursal in Support of Corrective Maintenance

Component	USCRN Site Failure Rate Estimates			Projected Annual Disbursal per Deployed Site
	MTBF	Annual Failure Rate		
		Per Item[1]	Per Site[2]	
Data Logger	683,280 hours	1.3%		.013
Transmitter	192,720	4.5%		.045
Precipitation Gauge	Each Wire: 876,000 hours	1%	3%	.03
	Each Translator: 1,752,000 hours	0.5%	1.5%	.015
Air Temperature PRT	Insignificant	Insignificant		0
Aspirator Fan	180,000 hours[3]	5%[3]	15%[3]	.15
Anemometer	Insignificant[3]	Insignificant[3]		0
Solar Radiation Sensor	Insignificant	Insignificant		0
IR Temperature Sensor	Insignificant	Insignificant		0
Surge Suppressor	Insignificant	Insignificant		0
Battery	87,600 hours	10%	19%	.19
Battery Charger	650,000 hours	1.3%		.013

Notes: *1. The likelihood that any given unit will fail in any given year.*
2. The likelihood that any given site will experience a failure of this component in any given year, based on multiple units per site.
3. This assumes the currently planned annual maintenance

G.3.3 Annual Active Component Disbursal Summary

The anticipated annual stock disbursal of active components due to routine replacement, corrective maintenance, and physical damage is shown in Table 8. For planning and logistics stocking purposes, the occurrence of physical damage due to vandalism, animals, and natural causes is assumed to be total destruction to one site in forty. Numbers in the "physical damage" column below are based on this "one site in forty" assumption, and the quantity per site.

Table 8. Initial Annual Projection of Active Component Disbursal

Component	Annual Disbursal for Each Deployed Site				Average Annual Disbursal Based on Site Count	
	Routine Replacement	Corrective Maintenance	Physical Damage	Total	40 Sites	100 Sites
Data Logger	1	.013	.025	1.038	41.52	103.8
Transmitter	0	.045	.025	.07	2.8	7
Geonor Wire	0	.03	.075	.105	4.2	10.5
Geonor Translator	0	.015	.075	.09	3.6	9
PRT Assy.	1	0	.075	1.075	43	107.5
Fan	1	.15	.075	1.225	49	122.5
Anemometer	1	0	.025	1.025	41	102.5
SR Sensor	1	0	.025	1.025	41	102.5
IR Sensor	0	0	.025	.025	1	2.5
Surge Suppressor	0	0	.025	.025	1	2.5
Battery	0	.19	.05	.24	9.6	24
Battery Charger	0	.013	.025	.038	1.52	3.8

G.4. Logistics "Pipeline" Delay

The time interval that begins when a component is removed from stock, and ends when it or its replacement is put back into stock, is typically considered to be the logistics pipeline delay. As a representative USCRN-specific example, consider an anemometer. When an anemometer is drawn from stock in support of a routine annual replacement, the anemometer that it has replaced is returned to the logistics facility, where it is refurbished with new bearings and reed switch, calibrated, and put into stock. It's likely that these actions may not take place immediately upon return to the central logistics facility, but may be somewhat of a batch process performed on a small number of returned anemometers for efficiency considerations. In some cases, a returned anemometer may not be worthy of refurbishment, and a new one will be ordered, tested, calibrated, and stocked. The batch process will likely apply to this case as well, considering that procurement of single anemometers may not be efficient.

Calculating the logistics delay for each USCRN component is somewhat impractical, considering that it would depend on unpredictable variables such as return time, available manpower at any given time, procurement delays for components or repair parts, and the quantity of components that constitute an efficient "batch". Based on apparent experience to date, an initial logistics pipeline delay for each USCRN component is considered to be one month. Logistics delay is a significant consideration in establishing stocking levels. For any USCRN components for which this initial one-month estimate is not realistic, the stocking estimate in Section G.5 of this appendix should be revised.

G.5 Initial Determination of Stocking Levels

G.5.1 Minimum Stocking Levels

The goal of the USCRN logistics system is to insure that necessary replacement components are readily available to field sites when needed, without an inappropriate investment in replacement components. This can be accomplished by establishing minimum stocking levels sufficient to cover all disbursements during the logistics delay period (LDP). If incidents of routine replacement, corrective maintenance, and physical damage are in accordance with estimates stated earlier in this appendix, and are uniform throughout each year, the minimum stocking level for each USCRN component would be one twelfth the projected annual disbursal (assuming the one-month logistics delay), rounded to the next higher integer. Because such incidents are not uniformly distributed, the following assumptions appear appropriate:

- For routine annual maintenance, the assumption is that scheduling considerations and inclement weather will restrict site visits to nine months during the year. As a result, the LDP disbursements for routine maintenance will be one-ninth of that projected for the year.
- For corrective maintenance, the assumption is that in any given month, any given component can experience a failure rate five times the projected failure rate. As a result, the LDP disbursements for corrective maintenance will be five-twelfths that projected for the year.
- For physical damage, the assumption is that the total annual incident rate will take place during any given month. As a result, the LDP disbursements for physical damage will be equal to that projected for the year. A minimum of two of each component should be in stock. Application of these assumptions to the "initial annual projection of active component disbursal" presented in Section G.3.3, leads to the minimum stocking levels shown in Table 9.

Table 9. Estimated Minimum Stocking Levels for USCRN Active Components

Component	Monthly Site Multiplier	For 40 Deployed Sites	For 100 Deployed Sites
Data Logger	.14	6	14
Transmitter	.044	2	5
Geonor Wire	.088	4	9
Geonor Translator	.081	4	9
PRT Assy.	.186	8	19
Fan	.248	10	25
Anemometer	.136	6	14
SR Sensor	.136	6	14
IR Sensor	.025	2	3
Surge Suppressor	.025	2	3
Battery	.129	6	13
Battery Charger	.03	2	3

G.5.2 Application of the Minimum Stocking Levels

The minimum stocking levels presented in Section G.5.1 are considered to be the lowest stock necessary to sustain USCRN site operations. As such, they represent not a recommended stock level, but a level below, which the logistics system should not fall. The recommendation is that, when the ready supply of any component begins to approach the stated minimum level, responsive replenishment actions are taken. Because the calculated minimums are based on a number of assumptions and projections, stock disbursal rates should be closely monitored over a representative period of time in order to verify or revise the information presented in this appendix.

G.5.3 Procurement Quantity

This appendix does not attempt to establish “maximum” stocking levels or recommend specific procurement quantities. These decisions should be based on a number of considerations, including storage space, shelf life, quantity discounts, funding constraints, and near term plans for system evolution. Secondary to these considerations, a reasonable guideline to procure a minimum six-month quantity appears reasonable.

G.6 Central Logistics Facility Resource Estimate

The central logistics facility must have sufficient staff, test equipment, and calibration equipment to perform the functions identified in this appendix. This resource estimate assumes 100 deployed sites and a uniform distribution of effort over one year. Although efforts specifically associated with field site maintenance and new site installation may be performed by the central facility, such efforts are beyond those required for steady-state logistics support and are not considered in the estimate.

G.6.1 Annual Central Logistics Facility Workload

Based on the information presented in Section G.3.3 of this appendix, the following quantities of "active" components will cycle through the central logistics facility each year:

- 104 Data Loggers
- 7 DCP Transmitters
- 11 Geonor Wires
- 9 Geonor Translators
- 108 PRT Assemblies
- 123 Fans
- 103 Anemometers
- 103 Solar Radiation Sensors
- 3 IR Sensors
- 3 Surge Suppressors
- 24 Batteries
- 4 Battery Chargers

In addition, based on projections for physical damage, all "passive" components for three entire sites will require replacement by the central logistics facility. The passive components include all hardware and wiring, or an entire site configuration less the active components.

G.6.2 Staffing

Table 10 provides an estimate of the annual staff effort necessary to process the components identified in Section G.6.1. Time estimates, in hours, for each listed activity are presented on a single component basis, added, and multiplied by the quantity of components to be processed during one year.

Table 10. Central Logistics Facility - Projected Annual Staff Effort for 100 Systems

Component	Receiving and Quality Control	Repair or Replace, and Calibration	Admin	Stocking	Quantity	Annual Effort
Data Logger	1	.5	.25	.25	104	208
Transmitter	.25	.3	.5	.25	7	9.1
Geonor Wire	.25	.5	.25	.25	11	1.25
Geonor Translator	.25	0	.25	.25	9	6.75
PRT Assy.	.3	.5	.25	.25	108	140.4
Fan	.25	0	.1	.25	123	73.8
Anemometer	.25	2	.25	.25	103	283.25
SR Sensor	.25	1	.25	.25	103	180.25
IR Sensor	.25	1	.25	.25	3	5.25
Surge Suppressor	.25	0	.25	.25	3	2.25
Battery	.25	0	.25	.25	24	18
Battery Charger	.3	.25	.25	.25	4	4.2
Passive Components	16	0	4	3	3	69
TOTAL STAFF HOURS PER YEAR						1,001.5
APPROXIMATE EQUIVALENT FTE						0.5

G.6.3 Calibration and Test Equipment

(To be provided)

G.6.4 Facilities

(To be provided)

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			TOTAL	13	39