

Climate Reference Network (CRN)

Test and Evaluation Master Plan

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Preface

This document comprises the National Oceanic and Atmospheric Administration (NOAA)/ National Environmental Satellite, Data, and Information Service (NESDIS) initial baseline publication of the *Climate Reference Network (CRN) Test and Evaluation Master Plan* (version DCN 0, January 31, 2003, publication). The document number is NOAA-CRN/OSD-2003-0006R0UD0.

This document presents the Test and Evaluation Master Plan (TEMP) for the United States Climate Reference Network (CRN). The TEMP identifies the primary functional requirements of the CRN, describes the major program phases, and identifies the Test and Evaluation (T&E) activities in each phase. This document provides a context for more detailed CRN test plans and procedures.

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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Acronyms and Abbreviations

ARL	Air Resources Laboratory (NOAA)
ATDD	Atmospheric Turbulence and Diffusion Division (NOAA)
CRN	United States Climate Reference Network
CSC	Computer Sciences Corporation
DCN	Document Change Notice
FRD	Functional Requirements Document
NCDC	National Climatic Data Center (NOAA)
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA)
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NWS	National Weather Service (NOAA)
OAR	Oceanic and Atmospheric Research (NOAA)
OSD	Office of Systems Development (NOAA)
QC	quality control
RCC	Regional Climate Center
S&A	Short and Associates
T&E	Test and Evaluation
TEMP	Test and Evaluation Master Plan
TRB	CRN Test Review Board
VDR	Version Description Record

References

1. National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data, and Information Service (NESDIS), *CRN Program Development Plan* (in preparation – to be published in 2003)
2. National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data, and Information Service (NESDIS), *CRN Functional Requirements Document* (in preparation – to be published in 2003)
3. National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data, and Information Service (NESDIS), *CRN Demonstration Phase Evaluation Plan*, NOAA-CRN/OSD-2003-0003R0UD0, DCN 0, December 2002

Section 1. Introduction

1.1 Purpose

The purpose of this Test and Evaluation Master Plan (TEMP) is to document the strategy used to verify that the Climate Reference Network (CRN) satisfies all functional, technical, and support requirements. This TEMP provides a context for more detailed CRN test plans and procedures.

1.2 Scope

This TEMP identifies the primary functional requirements of the CRN, describes the major program phases, and identifies the Test and Evaluation (T&E) activities in each phase. The TEMP documents the activities to test, evaluate, or demonstrate compliance with CRN requirements from development through continuing production, operational implementation, and into sustained operations. The TEMP also documents summary level T&E management responsibilities. The TEMP does not include detailed test plans, test procedures, or test resources.

1.3 Referenced Documents

The following CRN documents are referenced in the TEMP:

- CRN Program Development Plan (Reference 1)
- CRN Functional Requirements Document (Reference 2)
- CRN Demonstration Phase Evaluation Plan (Reference 3)

Section 2. CRN Overview

2.1 CRN Objective

The objective of the CRN is to measure, record, and report with the highest possible quality a thoroughly documented set of surface environmental observations, representative of the climate of the United States. The CRN will automate observations, including redundant temperature measurements, redundant and back-up precipitation measurements, solar radiation, ground surface temperature, and windspeed at 1.5 meters. The CRN will provide future long-term (50 to 100 years) high-quality climate observations that can be coupled to past long-term observations from other networks, and thus be adequate to meet the exacting demands of climate science. Reliable observations from the CRN will allow the detection of present and future climate change and enable scientists to increase our understanding of natural and human-induced effects.

2.2 CRN System Overview

When fully implemented, the CRN will collect observations from approximately 300 locations. Each location will be carefully selected to capture the representative climate regions of the nation. A communications network will link each location to the National Climatic Data Center (NCDC), where the observations will be quality controlled, archived, and made readily available to a worldwide clientele.

Air temperature and precipitation are the primary climate variables identified by the National Research Council (NRC) as important for climate monitoring. Provision of these measurements is the primary mission of the CRN. CRN sites also report three support parameters: surface (skin) temperature, solar radiation, and wind speed. These support parameters will allow development of physically based transfer functions between CRN temperature observations and the temperature observations made at current co-located or nearby (companion) stations that have historical data.

The overall CRN system operation is illustrated in Figure 1.

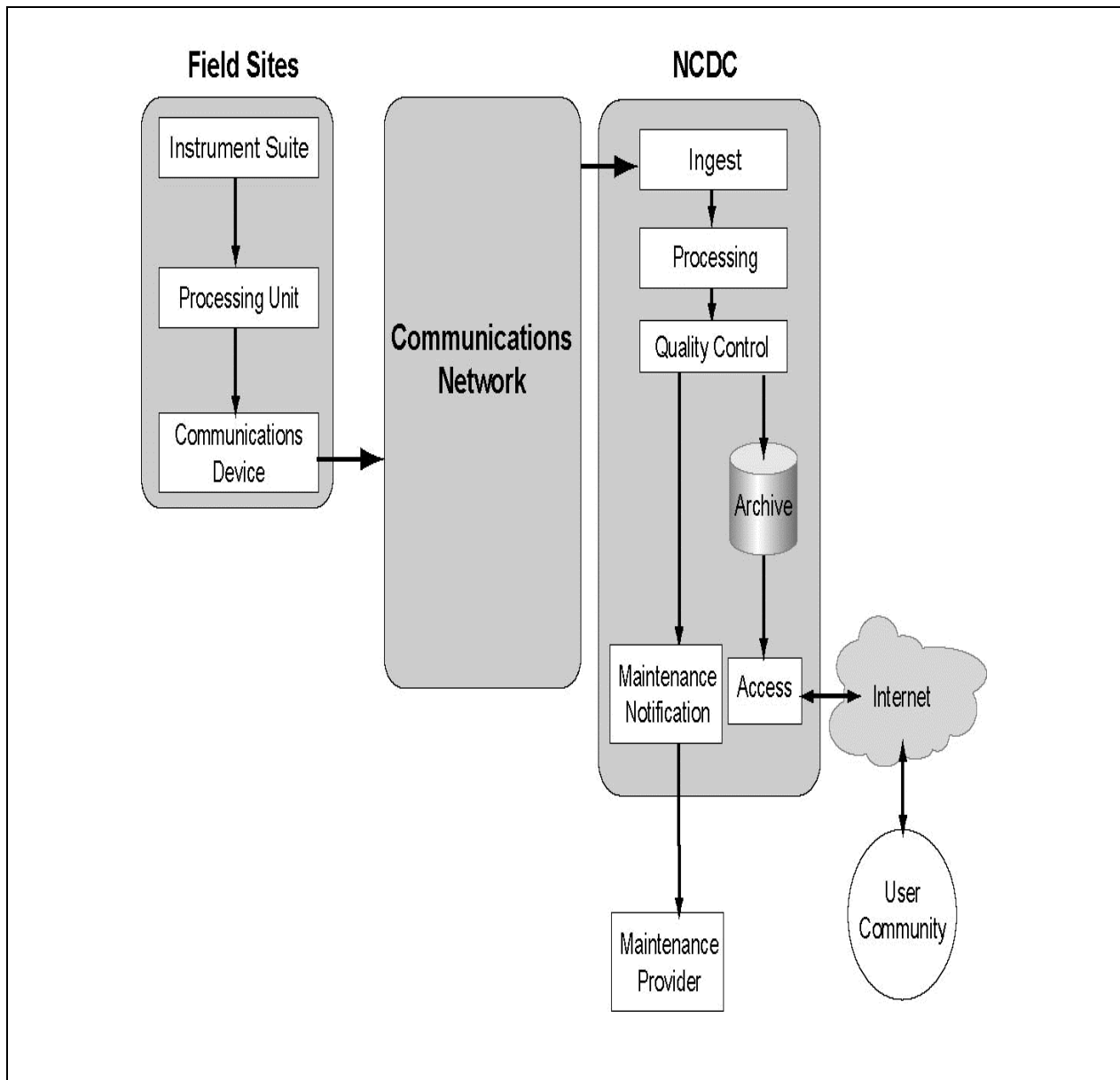


Figure 1. CRN System Operations

Section 3. Overall System Requirements

The following subsections characterize the required operation of the CRN and present an overview of the fundamental requirements. The complete set of CRN functional requirements is specified in the Functional Requirements Document (FRD) (Reference 2).

3.1 CRN Field Site

CRN field sites are required to report automated observations with specific accuracies, ranges, and resolutions. The observation parameters and their required characteristics are summarized in Table 1.

Table 1. CRN Field Site Measurement Requirements

Parameter	Accuracy	Resolution
Air Temperature	$\pm 0.3^{\circ}\text{C}$	0.1°C
Precipitation	± 0.25 millimeter	0.25 millimeter
Wind Speed	± 1 meter per second	1 meter per second
Global Solar Radiation	± 70 watts per square meter	10 watts per square meter
Ground Temperature	$\pm 0.5^{\circ}\text{C}$	0.1°C

Note: Potential additions to CRN measurement parameters include relative humidity, soil moisture, temperature, and atmospheric pressure. Requirements for these parameters are being assessed.

CRN field sites are required to operate virtually unattended, while experiencing extremes in temperature, humidity, wind, precipitation, and other environmental factors. With few exceptions (see Reference 2), a CRN field site is required to operate over the environmental range given in Table 2.

3.2 CRN Communications Network

The CRN Communications Network is required to provide all required data and information from each field site to a central interface at the NCDC. The network must have sufficient capacity to provide reports from all field sites within a specified time frame and sufficient reliability to support the overall CRN data availability requirement.

Table 2. CRN Field Site Operating Environment

Parameter	Range
Temperature	-60 to +60°C
Relative Humidity	to 74% at 35° C; to 100% at 27° C
Wind	to 50 meters per second
Rain	to 30 millimeters per minute
Freezing Rain	25 millimeters per hour with 9-meter-per-second-wind
Dust	Exposure to dust-laden environment
Sunshine	1400 watts per square meter at 50° C
Altitude	-500 to +10,000 feet

3.3 NCDC

NCDC is the hub of the CRN and serves as the interface between the field sites and the users of the CRN data site surveys, engineering, and deployment. CRN data will flow from the network communications central interface to the NCDC processing and storage infrastructure and then be posted to the web-accessible CRN database for direct online access. NCDC will maintain CRN documentation online and use automated quality-control processes to automatically detect the need for maintenance at field sites. Table 3 provides an overview of the NCDC CRN requirements.

Table 3. Summary of NCDC CRN Requirements

Function	Representative Requirements
Data Ingest	<ul style="list-style-type: none"> • Provide the communications network with data receipt/acknowledgement • Provide temporary data storage
Processing	<ul style="list-style-type: none"> • Provide automated inventory and report (sites and parameters) • Provide automated data quality control and error detection • Attach quality control (QC) flags • Initiate maintenance notifications
Storage	<ul style="list-style-type: none"> • Provide permanent archive for the following: <ul style="list-style-type: none"> – CRN data – CRN metadata
Data Access	<ul style="list-style-type: none"> • Provide Internet access for all CRN information to a worldwide clientele

3.4 System Integrity/Data Availability

Data from the CRN must be collected by field sites, relayed by the communications network, stored at the central archival facility, and made available to users with accuracy and reliability sufficient to meet the demands of the climate community. Table 4 below summarizes the CRN data integrity requirements specified in the FRD (Reference 2).

Table 4. Summary of CRN Data Integrity Requirements

Category	Requirements
System Reliability	Hierarchical Availability Specifications: <ul style="list-style-type: none"> • 95% – Temperature and Precipitation Reports • 90% – All Field Site Functions • 97% – Communications Network
Security	<ul style="list-style-type: none"> • Prevent unauthorized access and/or modification to data
Data Recovery	Sites and the communication network provide back-up data storage: <ul style="list-style-type: none"> • Sites: 30 days • Network: Until acknowledgement of receipt

3.5 Documentation

CRN data users need to know everything about how a measurement is taken and how the resulting reported observational values are computed. The CRN FRD (Reference 2) specifies documentation requirements for both Station History and Central Processing. Representative elements of each are identified in Table 5.

Table 5. Summary of CRN Documentation Requirements

Station History Components	Central Processing Components
<ul style="list-style-type: none"> • Site location • Local terrain • Sensor descriptions • Field site processing algorithms • Calibration history • Maintenance records 	<ul style="list-style-type: none"> • Quality control processing • Flag definitions • Software code

Section 4. Test and Evaluation Management

A CRN Executive Board has been established jointly by the National Oceanic and Atmospheric Administration (NOAA)/National Environmental Satellite, Data, and Information Service (NESDIS) Office of System Development (OSD) and NCDC to provide overall policy and program direction. OSD has established a CRN Acquisition Office that has overall responsibility to manage, coordinate, and direct certain implementation activities. The CRN Acquisition Office oversees the functional test and evaluation process and coordinates with NCDC-related activities of other contributing organizations [e.g., National Weather Service (NWS), Atmospheric Turbulence Diffusion Division (ATDD)]. The program organization also includes an extended T&E activities team, functioning as a matrix team bringing to bear expertise and support from various parts of NOAA.

Functional managers will have responsibility for specified test or evaluation activities. These functional managers will be assigned responsibility for directing, conducting, and reporting periodically to the CRN Acquisition Manager on progress and problems.

The results of CRN test and evaluation activities will be a major factor in a number of significant program decisions. Examples include potential changes to the overall design, replacement of significant system components, revisions to the planned system support structure, and modifications to the implementation schedule.

To provide an independent evaluation of CRN testing, test results, and associated program risk, a CRN Test Review Board (TRB) will be established to conduct independent assessments of CRN performance and testing. The TRB will consist of designated members who have been selected from the CRN Science Review Committee, as agreed to by the CRN Executive Board. The TRB will review the test methodology and test results of the developmental tests, production tests, and other operational tests and evaluations as required. Based on their independent assessments of program risks and performance, the TRB will make recommendations to the CRN Executive Board in support of the Executive Board's key program decisions.

Section 5. CRN Implementation Phases and Associated Test Activities

Overall implementation of the CRN will be accomplished in phases, with specific test activities associated with each phase. Each phase will conclude with a key program decision point, where the results of the program phase will be evaluated and will serve as a basis for major program decisions regarding future plans for implementation, deployment, and system support.

The following subsections provide an overview of each phase, identification of the associated test activities, and a summary of each key decision point.

5.1 Development Phase

The scope of the Development Phase extends from the definition of functional requirements through implementation of a prototype demonstration network. Although the Development Phase activities include limited test and evaluation of prototype system components, the primary focus is on the organization and planning of the overall program. Basic program strategies (e.g., site survey, system acquisition, operation, and maintenance) are formulated during this phase, as is planning and organization of cooperative interagency activities. These program strategies will be examined within the existing NOAA infrastructure that is already in place, and the scalability will be determined.

The primary T&E objective of the Development Phase is to verify readiness to initiate the Demonstration Evaluation Phase (see Section 5.2). The CRN TRB will attend a Demonstration Readiness Review and make recommendations to the Executive Board regarding the Demonstration Evaluation Phase test period.

T&E during the Development Phase is focused on the prototype network and includes the following activities:

- Validate criteria for site selection
- Evaluate candidate instrumentation based on documented specifications
- Conduct structured accuracy, reliability, and environmental withstanding capability testing of all field site components
- Evaluate candidate communications solutions based on cost and performance
- Conduct environmental testing of prototype instrumentation
- Evaluate approaches for NCDC data ingest and processing
- Evaluate tools for CRN configuration management
- Evaluate algorithms for conversion of sensor measurements into reportable meteorological data

- Evaluate tools for metadata collection and management
- Evaluate site survey, system acquisition, installation, and maintenance approaches
- Perform test and evaluation of the prototype field site configuration

These activities will be conducted in cooperation with NOAA/NESDIS NCDC and the NOAA Oceanic and Atmospheric Research (OAR) Air Resources Laboratory (ARL) ATDD.

5.2 Demonstration Evaluation Phase

The Demonstration Evaluation Phase is a formal test during which the CRN prototype network and its supporting provisions will operate and their performance will be documented. The objective is to verify that the CRN program should proceed with incremental installation and operation of the national network. Demonstration Evaluation Phase assessments will identify areas of CRN design, operation, and support that must be revised prior to further implementation.

Test and evaluation is the primary focus of the Demonstration Evaluation Phase, where each of the following will be examined:

- Site selection, acquisition, and installation process
- Accuracy, reliability, and operational support of selected sensors
- Field site performance under environmental extremes
- Communications performance and capacity
- Data quality control processing at NCDC
- Timely fault recognition
- Provisions for routine field site maintenance
- Provisions for field site remedial maintenance
- Metadata collection and management
- Data archive and access
- Configuration management
- System, operation, and support documentation
- Overall support provisions
- Overall system expandability

Information for the Demonstration Evaluation Phase is given in the CRN Demonstration Phase Evaluation Plan (Reference 3). Tasks will progress before, during, and shortly after the Demonstration Evaluation Phase period; and these tasks will be considered in the final evaluation findings.

Results of the activities below may be introduced into the demonstration:

- Precipitation gauge qualification and comparison testing
- Communications studies and analyses
- Windscreen study
- Three transducer analysis underway at the National Center for Atmospheric Research
- Additional sensor research
- Maintenance analysis

Demonstration Evaluation Phase results will be documented and presented to the CRN TRB. Based on their assessment, the TRB will recommend to NOAA/NESDIS management areas for revision prior to proceeding with the installation and operation of the national network.

5.3 Preparation for Limited Implementation Phase

Based on the CRN Demonstration Evaluation Phase results and CRN TRB recommendations, revisions of the CRN system, its support provisions, or its operation will be identified. Changes will also undergo integration and acceptance testing. The following T&E activities will be undertaken:

- Evaluation and analysis of specifications
- Assessment of operational impact and cost attributes
- Component testing based on coordinated test plans and procedures
- System integration testing
- Minimum 6-month period of system demonstration and evaluation
- Evaluation of results by the CRN TRB

The process of evaluating documented characteristics, rigorous component and system testing, demonstration, and TRB presentation will continue until the CRN Executive Board is satisfied that all aspects of the CRN have been satisfactorily demonstrated and are acceptable for incremental national implementation.

5.4 Limited Implementation Phase

Activities in this phase include evaluation of production components and the acceptance and commissioning of CRN field sites. There is a shift in the T&E focus from the Demonstration Evaluation Phase to the Limited Implementation Phase. Key Limited Implementation Phase activities are ramped up to the proposed incremental installation of 40 to 75 stations per year. Satisfactory limited implementation activities are necessary before committing to full production and nationwide implementation activities.

5.5 Full Implementation Phase

When limited production systems and support have been proven in the operational environment, nationwide production and implementation will begin. The full implementation phase covers all activities necessary to complete the CRN network and its operational and support capabilities. T&E activities will continue to evaluate incoming components, site implementation, and overall end-to-end system performance.

Section 6. Evaluation of CRN Configuration Changes

CRN operations will be closely monitored and performance metrics collected throughout the system life. Metrics will include measurement accuracy, system reliability, and system support. Procedures for onsite calibration, maintenance, and ongoing system support will be periodically reviewed for sufficiency and cost effectiveness.

Throughout its 50- to 100-year life, the CRN is likely to undergo numerous changes. Each change in equipment or operation will be carefully controlled and documented through formal configuration management processes and subjected to rigorous T&E. For changes that may affect collection quality, quantity, and veracity of climate data (e.g., sensors, algorithms), new components will operate in parallel with the earlier components for a minimum of 1 year prior to operational, standalone use. Specific details of the data comparison methodologies will be given in the associated change control documentation.

Section 7. T&E Activity Summary

In the initial program phases, all aspects of the CRN system and its supporting infrastructure are analyzed and evaluated, and specific components undergo rigorous testing. As the program progresses through general implementation, the T&E focus shifts from individual site characteristics to overall end-to-end system performance, with concentration on the communications network and the central operation components of the NCDC. Following national implementation, the T&E focus will be on sustaining operations. T&E activities will include analysis of both additional and replacement sensors and site components, new communications technologies, and improvements to NCDC's central operation components. This general shift in CRN T&E focus is depicted in Table 6.

All T&E activities will be conducted in concert with NCDC and ATDD.

Table 6. T&E Activity Summary

T&E Item	Program Phase				
	Development	Demonstration	Limited Implementation	Full Implementation	Ongoing System Operation
System Siting	X	X	X	X	
Instrumentation	X	X	X	X	X
Site Processing	X	X	X	X	X
Communications	X	X	X	X	X
QC Monitoring	X	X	X	X	X
Fault Detection	X	X	X	X	X
Metadata Management	X	X	X	X	X
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