Near Earth Network Data Acquisition Processing and Handling Network Environment

Concept of Operations

Original 09/19/12

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Preface

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Change Information Page

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| **List of Effective Pages** | | | | | |
| **Page Number** | | **Issue** | | | |
| Numerous pages | | General updates to improve flow and make terminology consistent with both architecture and requirements. Defined operating scenarios.  Name change from NENG Phase II to DAPHNE | |
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Contents

Section 1. Introduction 1

1.1 Purpose 1

1.2 Scope 1

1.3 Change Authority 1

1.4 Reference Documents 1

Section 2. Overview 2

2.1 Background 2

2.2 Context and Basic Operations 4

Section 3. Concept of Operations: Day in the Life of DAPHNE 5

3.1 Scenarios 5

3.2 Nominal Operations 6

3.3 Self-Service Mode Operations 7

Special Event Handling 7

3.4 Emergency Mission Operations 7

3.5 Degraded Mode Operations 8

Logistics 9

3.6 9

3.7 Phase 1 to DAPHNE Transition 9

3.8 Testing 9

3.9 End of Life (EOL) 9

Section 4. Development Phases 10

Section 5. Facilities 11

List of Figures

Figure 2‑1 Near Earth Element and Interactions with External Systems 2

Figure 2‑2 DAPHNE in context 5

List of Tables

Table 3‑1 Development phases. 10

Table 3‑2 Facilities 11

# Introduction

## Purpose

This Concept of Operations (ConOps) is to provide stakeholders a clear understanding of how the Near Earth Network (NEN) Data Acquisition Processing and Handling Network Environment (DAPHNE) system will function operationally from within the NEN Data Transfer System (DTS). This ConOp will also be used to develop and validate requirements levied against the DAPHNE.

## Scope

This document covers all aspects of operations through the life of the DAPHNE system in the context of the NEN which includes testing, operations, logistics, transitional events, and system end of life (EOL).

For the purposes of this document, DAPHNE is considered a single entity residing within the NASA Ground System Data Transfer Subsystem (DTS) discussed further below.

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## Reference Documents

1. *NASA Systems Engineering Processes and Requirements* (NPR 7123.A)
2. *NASA Software Engineering Requirements* NPR 7150.2B
3. *Requirements Specification for the Data Acquisition Processing and Handling Network Environment (DAPHNE)* SCNS-NEN-REQT-0008
4. *CCSDS 131.0-B-2 TM SYNCHRONIZATION* *AND CHANNEL CODING*

# Overview

## Background

NEN joins with Networks Integration Management Office (NIMO), and Communications Service Office (CSO)/NISN, to form an organization called the NASA Near Earth Element (NEE). The NASA NEE provides telemetry, commanding, and tracking (TCT) services to spacecraft through a diverse set of communication ground stations located around the world. NEE provides these TCT services to vehicles in various low-Earth orbits (LEO), geosynchronous orbits (GEOs), highly elliptical orbits, LaGrange orbits, and lunar orbits. NEE also supports suborbital missions, and launches. Figure 2-1 shows one ground station system within NEE and the major external interfaces. The NEN can use any of over 30 separate ground stations located at 12 sites strategically placed around the globe. Five of these sites are NASA-owned and operated; the others are owned by commercial providers.

The Networks Integration Management Office (NIMO) serves as a liaison for spacecraft and scientific customers needing access to NEE. NIMO provides networks coverage and loading analyses, RF compatibility testing, and assistance with networks testing for customers as well as on-console coordination launch services. NIMO can coordinate services from service providers throughout NASA and acts as a “one stop shop” for satellite missions who need TCT services. NIMO creates daily operations schedules for NEN as well as for the Space Network to provide TCT services for its satellite customers.



Figure 2‑1 Near Earth Element and Interactions with External Systems

The CSO/NISN provides data and voice communications throughout NASA using IP standard data networks. DAPHNE will interface with CSO/NISN firewalls to transfer the data to the customers MOC over their networks. NASA Information Technology (IT) security protocols are implemented throughout the network.

The five NASA owned stations that NEN provides TCT services from are referred to as NASA Ground Stations. Each station is made up of an antenna subsystem, a signal processing subsystem, and a data transfer subsystem as shown in Fig. 2-1. The single mission and control center (M&C) located in Wallops Flight Facility controls all NEN systems over CSO/NISN provided TCP/IP networks. The Antenna Subsystem includes the various tracking antennas and front end electronics needed to establish radio links to and from a satellite. The Signal Processing Subsystem contains transmission and reception hardware as well as equipment to provide necessary high level signal processing such as multiplexing, framing, synchronization, modulation and demodulation and implementation of CCSDS standards. This subsystem includes intermediate frequency (IF) receiver equipment that will feed telemetry data to DAPHNE.

The Data Transfer Subsystem distributes the telemetry data received to the various users. The system separates telemetry data according to mission format and sends it to the Mission Operation Center (MOC) over the CSO/NISN network. The data is buffered in the DTS to provide backup, as well as, to accommodate the data networks which may be slower than the incoming data.

DAPHNE is part of an ongoing development effort to upgrade the DTS. DAPHNE will significantly increase the telemetry data rates and storage volume that NEN can provide to its science satellite customers.

The DAPHNE system architecture borrows heavily from the notional architectures of early Internet Protocol (IP) communications bridges. The system is made up of custom software developed at GSFC by Code 566 that runs on commercial computer servers and controls commercial network switches, and memory drives. The use of commercial standard hardware is intended to lower cost by reducing development time, and hardware expenses; while at the same time improving compatibility, and supportability.

DAPHNE has a long operational heritage. The software was initially developed to support the Solar Dynamics Observatory (SDO) within the Data Distribution System (DDS). The software was than modified and enhanced under Phase 1, to support the Lunar Reconnaissance Orbiter (LRO) mission, Interface Region Imaging Spectrograph (IRIS) mission, and Soil Moisture Active Passive (SMAP) mission. The system was called the NEN Gateway or NENG for these missions and was deployed to the White Sands (WS1) system, and to the McMurdo TDRSS Relay System (MTRS) Receive Ingest Portal (RIP) system. NENG has provided years of highly reliable service for these missions.

## Context and Basic Operations

As envisioned DAPHNE will provide a highly reliable data gateway to current and future space customers that are demanding ever increasing telemetry data rates. The unit will simplify NEN operations and lower cost by operating semi-autonomously. It will configure itself and run with minimal interactions from the M&C. The system further supports autonomous operations by self-detecting common malfunctions and even correcting for certain faults greatly improving its overall reliability and availability.

Once configured for a specific mission’s overpass/collection operation DAPHNE will receive and store one or two packetized telemetry data streams from the selected NEN receiver subsystem. The input format is typically CCSDS AOS frames. The system will than parse the data into CCSDS standard Virtual Channel (VC) separated files as defined by the mission’s protocol. These files are then transmitted using Secure Copy (SCP) in “near real-time” (NRT) and in priority order to the MOC through a CSO/NISN firewall. This is referred to as the “Automatic Delivery” (AD) mode and is performed by the Data Processing Delivery System (DPDS) within DAPHNE. Full details of the data format at both the input and output of DAPHNE are contained in the various mission specific Interface Control Documents that have been or will be developed.

The data files are sent to the MOC as quickly as possible; but that rate is limited by the network bandwidth the mission has arranged for with the CSO/NISN. To minimize overall delivery time for all the data, automatic delivery of each file is attempted only once.

In addition to the AD function, tVC data and are accessible directly by the mission in a “self-service” mode via the Secure File Transport Protocol (SFTP). DAPHNE memory will be allocated by the NEN to support a storage time agreed to with the mission. This function is implemented by the Storage System (SS) within DAPHNE.

The high-level description of the DAPHNE functionality within the NASA Ground Station context is depicted in figure 2-2. DAPHNE is controlled by the M&C over their Dewitt Hardware Control interface (HWCNTRL).DAPHNE will be able to input telemetry data from two receivers supporting any mission that uses dual polarized radio links. Data forwarding to selectable MOCs will also be supported.

The Predecessors to DAPHNE, called NEN Gateway, historically have been dedicated to specific missions from a single channel receiver. However, future versions will have the flexibility to be reconfigurable to support different missions. Memory allocation, IP addresses, data rates, interface protocols and similar parameters will all be store in mission specific configuration files that will be loaded prior to any given missions overpass operation.

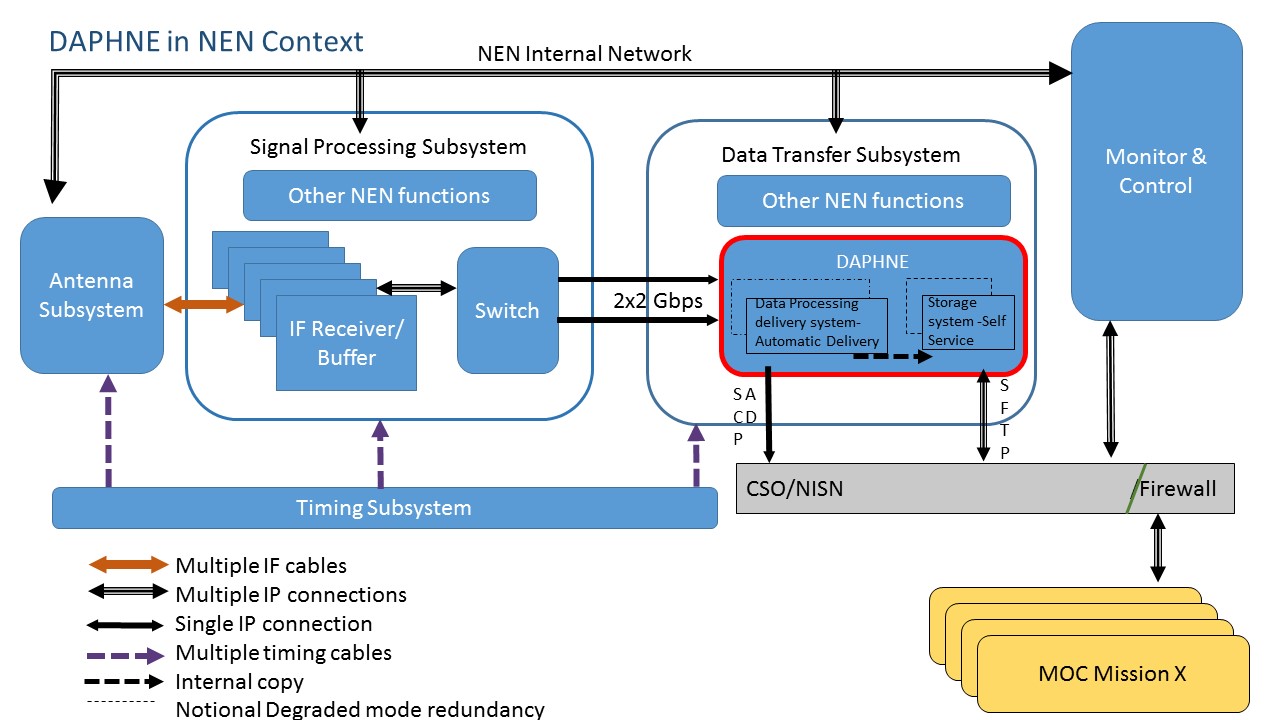


Figure 2‑2 DAPHNE in context

# Concept of Operations: Day in the Life of DAPHNE

## Scenarios

Detail concept of operations are discussed below for the following scenarios which have been identified for DAPHNE operating in the NEN DTS subsystem: nominal operations, Self-Service operations, special event/emergency operations, and degraded mode (single failure) operations. The testing, logistics, transitional and end of life scenarios are addressed separately.

## Nominal Operations

#### DAPHNE is manually turned on and performs an autonomous self-check.

#### DAPHNE waits for a command from M&C.

#### The NEN M&C will receive a conflict free schedule from NIMO’s Near Earth Network Scheduling Engine (NENSE).

#### Remote Configuration: NEN M&C will command DAPHNE to load a mission specific configuration to prepare for a satellite overpass.

#### Control: At the start of the overpass operation NEN M&C will command DAPHNE to start operations. The operation is as follows:

#### DAPHNE attempts to receive telemetry data from the receiver interface.

#### Telemetry data reception automatically begins when data is available from the two (or one) receiver interfaces. [[1]](#footnote-1)

#### The received telemetry data is processed by parsing it into CCSDS virtual channels (VC) and creating associated data files. Each file contains one VC and has a manageable time length set by the mission configuration (e.g. one minute).

#### The VC data files are buffered and sent to the customer’s MOC using Secure Copy Protocol (SCP). The files corresponding to the highest priority VCs, specified by the mission, and received at the time, are sent first. This operating mode is referred to as “Automatic Delivery” and is performed as quickly as possible (in “near real time” (NRT)) at the fastest rate both DAPHNE and the NISN data network can support.

#### VC data files are saved into the Storage System (SS).

#### DAPHNE continues to implement steps i.-v. above.

#### At the end of the overpass operation M&C sends the stop command. DAPHNE immediately stops receiving data. To avoid loss or corruption of data, at the transition, M&C must assure that data is not being input when sending the stop command.

#### DAPHNE waits for the next command (“start” or “configure”) and will concurrently continue;

#### Saving VC data files into the Storage System (SS).

#### Automatic delivery of the VC data files until all files have been sent.

#### DAPHNE finishes processing received data.

#### On an ongoing basis

#### NEN monitors DAPHNE’s operational status routinely sent.

#### Degraded mode: self-monitor and repair: DAPHNE will continually and autonomously monitor itself for and address critical fault conditions. See the section below for more details on the degraded mode.

## Self-Service Mode Operations

Concurrently during any other operation, DAPHNE will make data files that are in the Storage System, available to the MOC with the self-service mode using the Secure File Transfer Protocol (SFTP) over the NISN data network. The following caveats apply:

#### The M&C must manage the files to prevent an overflow condition. The files will be stored for an agreed amount of time before being overwritten.

#### The M&C must manage the NISN network data rate allocated to this service as usage may impact the data rate of the Automatic Delivery mode.

## Special Event Handling Emergency Mission Operations

In the event that NEN needs to support a high priority mission during an ongoing overpass operation, the M&C can quickly stop the current operation with the stop command. At that time DAPHNE will:

###### Stop receiving new telemetry data from the current operation. Note: that the AOS frame currently being received may be discarded.

###### Continue processing previously received data. Note: the current data files being built will be truncated.

###### Continue the ongoing Automatic Delivery operations for the previous mission overpass.

###### Continue the ongoing copy to SS of data files processed for the previous mission.

###### Continue any ongoing Self-Service mode file transfers.

###### M&C will command DAPHNE to load a mission specific configuration to prepare for the high priority satellite overpass.

#### DAPHNE will commence nominal operations for the high priority overpass when M&C sends the start command. Note: The old and new mission’s data will be sent in parallel over the same data network. NEN must control the NISN data network to assure that the high priority mission’s receives the network bandwidth needed.

#### 

## Degraded Mode Operations

### DAPHNE development is a phased progression as mentioned. Methods for handling system failures have changed with the development phase of the project and will be described for each phase here.

### NENG Initial and Phase 1: System failures were manually detected. Offline procedures to permanently fix the failure were provided with local operating procedures (LOPs). Data recovery was manually implemented with instructions given in the LOP.

### DAPHNE will be designed to autonomously operate despite a single critical failure in its hardware at any time. The type of failure is of the nature of a server locking up or failing, or memory unit breaking. Redundant units of these critical components will be online and operating so that a hot swap can be performed with minimal data loss.

#### DAPHNE monitors itself for critical fault conditions.

#### If fault conditions are detected DAPHNE will perform automatic reconfiguration of its hardware and software to continue operation. The intent of this reconfiguration is to failover to a redundant path that is operating in parallel. There may be minimal loss of data during this transition.

#### DAPHNE will send a critical alert warning to the M&C.







NEN must perform maintenance on the system to restore it to full operation. A recommended spares list will be included in the DAPHNE Local Operation Procedures document.

## Logistics

As noted above under the Degraded Mode Operation section the system is designed to run autonomously despite a single critical failure. NEN must use standard maintenance procedures to repair other failures. A recommended spares list will be included in the DAPHNE Local Operation Procedures document.



## Phase 1 to DAPHNE Transition

It is expected that all operational units in the field will be upgraded to the most current capabilities. Significant hands on work is required for these transitions and nominal operations are not supported during this period.

## Testing

DAPHNE will undergo two primary sets of testing. Firstly, verification for compliance with all requirements. Secondly, the units will be operationally tested after integration into each NASA Ground Station. The details for these activities will be documented in DAPHNE test planning and procedures documents.

## End of Life (EOL)

The DAPHNE unit will provide years of service to the NEN missions. However, commercial computer hardware does have a limited life span. Quality manufacturers can accurately estimate the expected end of life of their components. A component replacement schedule for DAPHNE will be provided to the NEN in the local operating procedures. NEN should replace DAPHNE components according to these recommendations. EOL consists of termination analysis, roles and responsibility planning, and proper disposal of equipment. Headquarters gives the notification of mission termination based on end of money for a mission, or mission failure. De-activation activities include shutdown of each component, disabling the power, and pulling any floor cables installed for the system. The NEN should dispose of the old hardware using best NASA practices.

# Development Phases

As mentioned, the DAPHNE system is continually evolving to improve capability and support new missions. Development of the system is summarized in Table 3-1. The systems basically operate the same under nominal operations. The data format, though standard (CCSDS), do vary by mission and the software is modified accordingly. The main difference between phase 1 and DAPHNE (phase 2) are: higher data rates, increased storage, two input streams, increased availability through automatic failover, and more data format options. Future phases may add additional advanced features and support higher data rates.

Table 3‑1 Development phases.

|  |  |  |  |
| --- | --- | --- | --- |
| Phase | Description | Mission Data Rate | Completion Date |
| DDS | Initial development for SDO Mission | 150 Mbps | February 2010 |
| WS1 | Update M&C Interface  Added multi-mission support  Support LRO mission | 150 Mbps | June 2009 |
| DAPHNE Phase 1 | Update M&C Interface  Streamline file generation  Support IRIS mission | 20 Mbps | June 2013 |
| MTRS RIP Phase 1 | OS port from Macintosh to Linux  Integrate into MTRS system  Support SMAP mission | 20 Mbps | January 2015 |
| DAPHNE | Add automatic failover\*  Two inputs at 2 Gbps data rate  SLE support | 4 Gbps | Jan 2018 (est.) |

\*DAPHNE can be built in a low cost configuration without built in redundancy. This configuration is referred to as “DAPHNE minimal”. This configuration operates the same as DAPHNE but without the degraded mode and so has lower reliability specifications and requires repairs with external parts.

# Facilities

The plans for future DAPHNE installations are determined by NEN. The DAPHNE team’s current understanding for these installations is summarized in Table 3-2. Currently, Phase 1 units are deployed to White Sands One (WS1) system, and to the McMurdo TDRSS Relay System (MTRS) Receive Ingest Portal (RIP) system. The deployed Phase 1 units will be upgraded to Phase 2 as NEN resources permit.

Table ‑ Facilities

|  |  |  |  |
| --- | --- | --- | --- |
| Facility | Location | Version/Phase | Copies |
| Alaska Satellite Facility (ASF) | Fairbanks, Alaska | DAPHNE Currently Phase 1 | 3 |
| Wallops Ground Stations (WGS) | Wallops, Virginia | DAPHNE Currently Phase 1 | 1 |
| White Sands One (WS1) | White Sands, New Mexico | DAPHNE Currently Phase 1 | 1 |
| McMurdo TDRSS Replay System (MTRS) | McMurdo, Antarctica | DAPHNE Currently Phase 1 “Minimal” | 1 |

Abbreviations and Acronyms

| **Acronym** | **Definition** |
| --- | --- |
| AOS  CCSDS  CSO  CM | Acquisition of Signal  Consultative Committee for Space Data Systems  Communications Service Office  Configuration Management |
| ConOps  CRB | Concept of Operations  Configuration Review Board |
| DAPHNE  DCN | Data Acquisition Processing and Handling Network Environment  Document Change Notice |
| DDS | Data Distribution System |
| DTS  EOL | Data Transfer System  End of Life |
| IT  IP  IRIS | Information Technology  Internet Protocol  Interface Region Imaging Spectrograph |
| LEO  LOP  LRO | Low Earth Orbit  Local Operating Procedures  Lunar Reconnaissance Orbiter |
| M&C  MOC  MTRS | Monitor Control System  Mission Operations Center  McMurdo TDRSS Relay System |
| NASA  NEN  NENG  NEE  NENSE  NISN  NIMO  NPR | National Aeronautics Space Administration  Near Earth Network  Near Earth Network Gateway  Near Earth Element  Near Earth Network Schedule Engine  NASA Integrated Services Network  Networks Integration Management Office  NASA Procedural Requirements |
| NTR  NRT  RIP | New Technology Report  Near-real time  Receive Ingest Portal |
| SCP  SDO | Secure Copy  Solar Dynamics Observatory |
| SFTP  SMAP | Secure File Transport Protocol  Soil Moisture Active Passive |
| SS  TCT  VC  WGS | Storage System  Tracking  Virtual Channel  Wallops Ground Station |
| WS1 | White Sands One |

1. It is understood that: **a)** AOS frame removal is the last formatting step typically performed by the receiver b) Data is sent to DAPHNE in the form of IP packets, and at the maximum rate the receiver, interface switch and DAPHNE can all support c) the NEN receiver will only forward AOS frames of data that were received without error. [↑](#footnote-ref-1)