Data Bus Technical Specifications for North American Synchro-Phasor Initiative Network (NASPInet)

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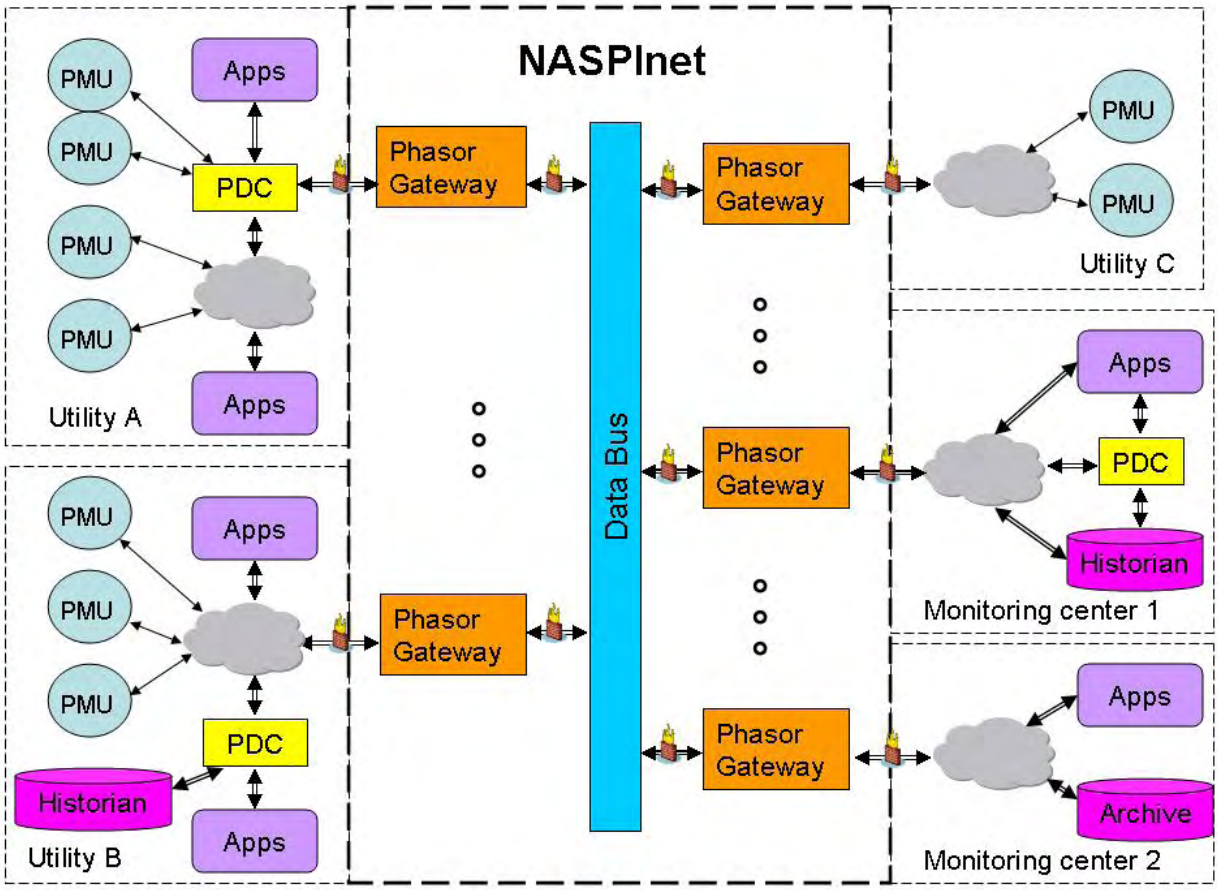

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1 Introduction and Project Overview

This Technical Functional Requirements Specification document is part of the Request for Proposal (RFP) of the "DB_REQUESTER"[1] for implementing a Data Bus (DB) for synchro-phasor data exchange. The DB_REQUESTER will assume ownership and operations of the DB assets. This section of the RFP contains an overview of the DB_REQUESTER's requirements for the DB. Overall project scope and responsibilities of the DB proponent, hereafter referred to as the "DB_SUPPLIER", and the DB_REQUESTER are also delineated in this section

1.1 About the DB_REQUESTER

<DB_REQUESTER will provide basic information about the DB_REQUESTER here.>

1.2 About NASPInet and Its Overall Objective

The North American Synchro-Phasor Initiative (NASPI) is a major effort by the North American electric power industry to create a robust, widely available and secure synchronized data (synchro-phasor) measurement infrastructure for the interconnected North American electric power system with associated analysis and monitoring tools for better planning and operation, and with improved reliability. NASPI's ultimate objective is to decentralize, expand, and standardize the current synchro-phasor infrastructure through the introduction of a NASPI network (NASPInet) that will be composed of Phasor Gateways (PGs) and a Data Bus (DB), both of which shall, where applicable, utilize, be compatible with, and integrate within the set of Common Services of the respective Requester's enterprise IT infrastructures. Once fully deployed, it is envisioned that the NASPInet could support hundreds of Phasor Gateways and thousands of Phasor Measurement Units (PMU), each typically sampling data at 30 times per second.

The NASPI data infrastructure currently consists of a number of devices, particularly PMUs and Phasor Data Concentrators (PDCs). PMUs are the sources of synchronized phasor data, taking power system measurements at stations and substations. They send the data to PDCs or other data collection device which may be located in the field or in a control center. Field collection devices typically send the data to a PDC at a control center where data from a number of stations is collected and combined. The PDC time-aligns the data and supplies it to applications as synchronized measurements. Applications include system visualization, alarming, data archiving, phasor data enhanced state estimator, congestion management, etc.

[1] It is envisioned that NASPInet will involve two separate procurements: Data Bus (DB) procurement and Phasor Gateway (PG) procurement. Two separate technical requirement specification documents were developed for DB and PG procurements respectively. To distinguish the types of customers referred to in each specification, the DB_REQUESTER refers to the entity that is issuing the specification to request proposals for a DB, and likewise the PG_REQUESTER refers to the entity issuing the Request for Proposal (RFP) for PGs. Similarly, the entity responding to the DB RFP is referred to as "DB_SUPPLIER", and the responder of the PG RFP is referred to as "PG_SUPPLIER".

Current synchro-phasor systems do not necessarily include the components and facilities to meet scalability and flexibility required to meet NASPI's mission, and to facilitate secure and Quality of Service (QoS) guaranteed phasor data exchange among various entities, such as utilities and ISOs/RTOs. NASPInet is designed to provide the communication infrastructure, including a set of IT services such as Quality of Service management and cyber security, for a phasor data exchange system that will support NASPI's mission for all of North America.

NASPInet will be a complete networked system composed of a wide-area communication network (WAN) and gateways that provide access to the network as shown in Figure 1-1. The DB of NASPInet, includes the NASPInet WAN and associated IT services to provide basic connectivity, quality-of-service management, performance monitoring, and cyber security and access policy enforcement over different service classes of data exchanged through the NASPInet. PG is the sole access point of an entity to the DB. It manages the connected devices on the entity's side, manages quality of service, administers cyber security and access rights, performs necessary data conversions, and interfaces utility's own network with the DB.

NASPInet facilitates the secure exchange of both real-time streaming data and historical data stored outside of NASPInet. It features a secure and distributed Publisher-Subscriber based data exchange mechanism. The owner of a PG that publishes the data to NASPInet maintains full control of its data distribution regarding who could subscribe to its data and which data could be subscribed to.

The PGs that provide connections to NASPInet DB may have very different data publishing/subscribing functionalities and capabilities that depend highly upon the needs of each entity connected to the NASPInet through the PG.

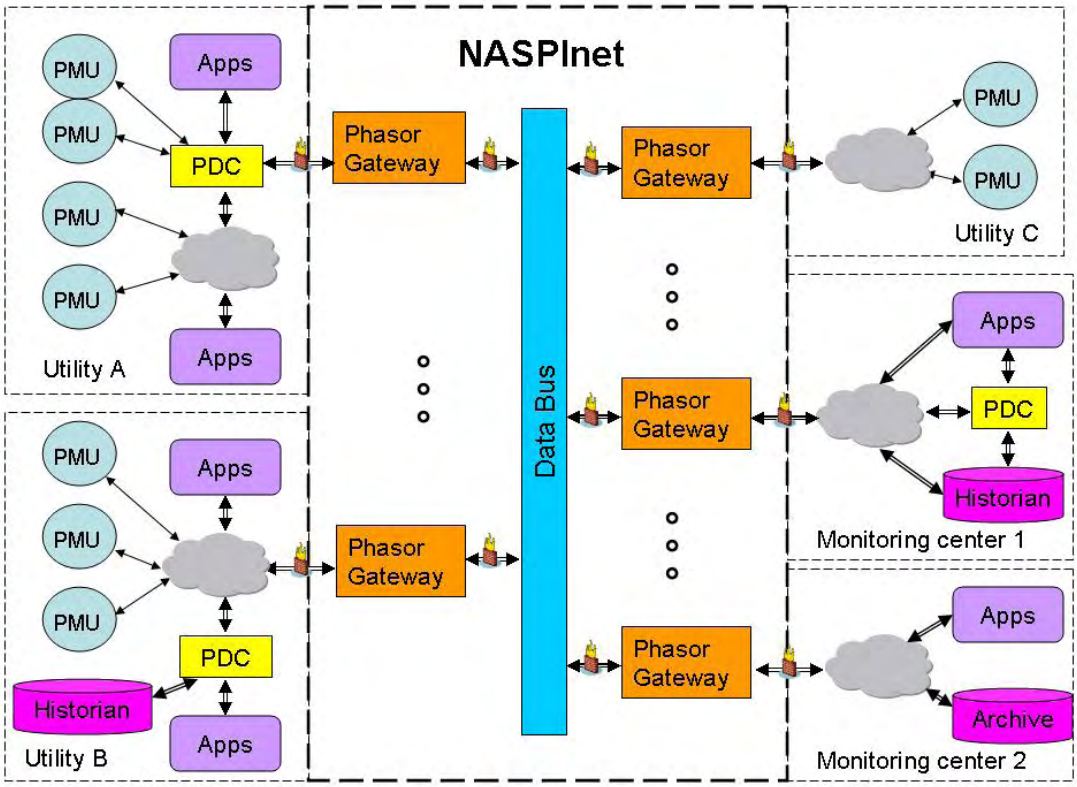

Figure 1-1: NASPInet Conceptual Architecture

1.3 Overview of Key DB Requirements

As a minimum, the DB shall perform the key functions listed below. These requirements are detailed in Sections 3 to 8 of this document.

1) Provide connectivity between Phasor Gateways (PGs) and all other elements of the NASPInet;

2) Facilitate reliable delivery of data and control flows of multiple data service classes;

3) Provide network access services including directory and naming, data accessibility, access control, and cyber security;

4) Enforce conformance with cyber policy, security, and access control policies and standards;

5) Provide network instrumentation and quality-of-service management; and

6) Be resilient to failures.

NASPInet will need to accommodate five classes of data services for supporting different types of applications

- **CLASS A:** This data service class supports the needs of high performance feedback control applications. This class is characterized by very low latency and a fast data rate (e.g., 60 messages per second). Class A data shall be transmitted and received as quickly as possible with a high level of data availability (there shall be no data gaps).
- **CLASS B:** This service class supports the needs of feed-forward control applications, such as state estimator enhancement. The latency requirement for Class B data is less strict than that for Class A data. High availability of the data is also required.
- **CLASS C:** This class of data supports view-only applications such as visualization by power system operators. The tolerance for accuracy and latency for Class C data are less stringent than Class B data. The system shall enable end-user applications to retrieve data from many PMUs across a wide geographical area.
- **CLASS D:** This service class supports the needs of post-mortem event analysis and other off-line studies. The system shall provide a high degree of data completeness and accuracy for this service class. However, latency of Class D data may be higher than Class A, B and C data since analysis of Class D data will generally conducted offline (hours or days later) with archived data, as opposed to an online data stream.
- **CLASS E:** Class E data primarily supports the needs for testing and Research and Development (R&D) applications. There are no guarantees on any attributes of this data class. Class E shall be given the lowest priority of all NASPInet data traffic.

The requirements contained in this specification may be considered mandatory for one class of data and desirable for another class of data service. However, since the final deployment of NASPInet Data Bus is expected to support all five classes of data services, unless noted otherwise ALL requirements for DB in this specification document are considered MANDATORY. On the other hand, the initial deployment of NASPInet DB may not need to support all five classes of data services. DB_SUPPLIER shall indicate in its response which requirements that DB_SUPPLIER may not fully comply with in the initial deployment and discuss its product roadmap to meet all DB requirements described herein.

1.4 Scope of Supply

The DB_SUPPLIER's scope of supply shall include the software, hardware, and services required to design, build, install, and test the required software and hardware for the DB. The DB_SUPPLIER scope of supply shall also include the DB telecommunication and IT infrastructures providing the performance and functionality needed to support the requirements specified in this document, Application

Programming Interfaces (APIs) for Phasor Gateway (PG) connections and system administration, documentation and training for DB_REQUESTER personnel, and commissioning of the DB.

The DB_SUPPLIER shall be responsible for implementing the telecommunication network, providing all DB hardware and software components, integrating the NASPInet components, and developing APIs. The DB_SUPPLIER shall work closely with DB_REQUESTER personnel and/or DB_REQUESTER's current sustainment organizations to ensure the correct end-to-end operation and satisfactory performance of all components and their interfaces.

The DB_SUPPLIER shall provide technical support to DB_REQUESTER during the installation, configuration, acceptance testing, correction, quality of service validation, performance tuning, and commissioning of the DB.

1.5 DB_REQUESTER and DB_SUPPLIER Responsibilities

The responsibilities of DB_REQUESTER and the DB_SUPPLIER for this project are summarized in the following subsections.

1.5.1 DB_SUPPLIER Responsibilities

The DB_SUPPLIER shall provide a complete DB system that includes all the necessary components and their integrations needed to satisfy DB_REQUESTER's requirements that are described in this specification document, except for components that will be supplied by DB_REQUESTER. The DB_SUPPLIER may subcontract the supply of portions of the system and/or services. However, the DB_SUPPLIER shall assume overall responsibility for supplying the complete DB that satisfies the requirements contained herein.

DB_SUPPLIER responsibilities shall include:

- Procure, design, build, integrate, test, ship, install, and perform site testing and system commissioning of all components of the DB except for components being supplied by DB_REQUESTER.

- Supply DB communication network and interfaces needed to satisfy DB_REQUESTER's requirements.

- Provide a full functional development system early in the project that will enable DB_REQUESTER personnel, working at DB_REQUESTER site, to test the interface of PGs to the DB. This will also enable DB_REQUESTER personnel to gain familiarity with the system, and develop commissioning and testing procedures.

- Develop integrated test plans and detailed test procedures for the DB.

- Coordinate and document the Factory Acceptance Test (FAT), if required by DB_REQUESTER, providing technical support and assistance during the test, providing the appropriate response to all variances identified during the FAT, and correcting and retesting all problems identified during the FAT. The DB_SUPPLIER shall supply suitable facilities to simulate the performance of NASPInet components that will not be available in the Factory. Test APIs and adaptors to PG with test PG units shall be provided.

- Conduct Site Installation/Startup test, Site Functional test, and Site Integration test, and provide the appropriate response to all variances identified during these tests, and correcting and retesting all problems identified during these tests to DB_REQUESTER's satisfaction.

- Provide technical support as needed during the Site End-to-End Test and the Site Availability Test, which will be conducted by DB_REQUESTER personnel. The DB_SUPPLIER shall provide the appropriate response to all variances identified during these tests, and correcting and supporting the retesting of all problems identified during these tests.

- Provide in depth technical assistance during the installation, configuration, tuning, troubleshooting, correction, and commissioning of the DB. The DB_SUPPLIER shall assist DB_REQUESTER in verifying that the DB is fully functional, including inputs, outputs, internal functions, and commissioning these systems.

- Provide detailed documentation and training to enable DB_REQUESTER personnel to operate and maintain the DB effectively with minimal outside assistance.

- Maintain all equipment through shipment and installation, and provide a warranty against defects on all deliverables for a period of at least <N> years following final acceptance by DB_REQUESTER.

- Provide maintenance support and spare parts supply following acceptance of the DB.

- Assess the DB system for security vulnerabilities and technical compliance before commissioning the system. Identified vulnerabilities shall be resolved before the system is commissioned.

- Provide APIs and Adaptors necessary for PG connections and interfaces, and other system administration functions.

1.5.2 DB_REQUESTER Responsibilities

DB_REQUESTER's responsibilities will include:

- Review and approve the technical architecture, design and deliverables.

- Provide information required by the DB_SUPPLIER, such as anticipated PG locations and expected data volume of each PG, preferred IT platforms and existing communication infrastructures and facilities, to complete the design of the DB.

- Define the basic objectives, constraints, and other information required by the DB_SUPPLIER to implement the DB, and provide information requested by the DB_SUPPLIER that is needed to build the DB system.

- Review and approve in a timely manner all documents, including designs, test plans and procedures, etc., as supplied by the DB_SUPPLIER.

- Participate in formal training courses conducted by the DB_SUPPLIER at the DB_SUPPLIER's offices and/or at DB_REQUESTER's offices.

- Conduct the DB FAT (if desired) and SAT with support from the DB_SUPPLIER as needed, perform all unstructured tests testing.

- Provide the DB_SUPPLIER with technical assistance during the installation of the DB equipment as needed.

- Witness and approve results of the Site Installation/Startup test, the Site Functional Test, and the Site Interface test.

- Conduct the Site End-to-End Test and the Site Availability Test. and retest all problems identified during these tests after the variances have been resolved by the DB_SUPPLIER.

- Do final system commissioning

- Acquire test PGs for use in DB testing

- Coordinate activities of representatives from the DB user base for reviewing the system design, test plans and test results.

1.6 Organization of the Technical Specifications

The procurement of NASPInet is divided into DB procurement and PG procurement. As such, there are two separate specifications for NASPInet: the Data Bus Specification and the Phasor Gateway specification.

The Data Bus specification (this document) covers the overall NASPInet requirements including the data communication network and IT services required for the Data Bus portion of the NASPInet system. Its communication network and links, as well as all the DB components and services are required to be flexible, extensible, and expandable from initial implementation to the full anticipated system. PGs of additional NASPInet members can be added by securing and attaching communication links. Capacity can be added by securing more bandwidth and additional equipment for providing the DB services. The methods and means for expansion, enhancement, and evolution are all covered by this specification. Since the DB is central to the NASPInet system, the DB_SUPPLIER shall specify and provide the APIs for attachment, management, and data exchange of PGs over the NASPInet. The APIs shall comply with any applicable interface standards at the time of implementation. These APIs will be used by PG_SUPPLIERS in implementing the DB interface.

The Phasor Gateway Specification, provided in a separate document, covers overall NASPInet requirements and specific requirements for the PG unit to be procured by PG_REQUESTERs. The PG specification contains all requirements for a full-featured PG that supports the publishing and subscribing capabilities of data service classes for real-time streaming data and stored historical data, as required by PG_REQUESTERs. The PG_SUPPLIER is expected to connect the PG to and interface it with the DB using the APIs supplied by the DB_SUPPLIER. The PG_SUPPLIER shall provide APIs for providing phasor data to PG_REQUESTER's applications; these APIs shall comply with any applicable standards at the time of implementation.

DB_SUPPLIER is encouraged to obtain the non-customized NASPInet Phasor Gateway Specification to gain an in-depth understanding of the PG functionalities and services, and the interactions between PGs and the DB.

The Data Bus Technical Specification is organized as follows:

- ***Section 1: Introduction and Overview of Requirements***: The current section contains introductory remarks and general corporate information about DB_REQUESTER, provides information on the background and general objectives of the project, and describes the organization of the RFP. This section also contains an overview of DB_REQUESTER's technical requirements. Specific responsibilities of DB_REQUESTER and the DB_SUPPLIER are also outlined in this section.

- ***Section 2: System Architecture****:* This section describes the overall NASPInet architecture framework and overviews of the DB and PG components. While DB_SUPPLIERs are encouraged to propose their standard, field proven system architecture design, the proposed architecture must adhere to the general framework and guidelines outlined in this section.

- ***Section 3: Overall NASPInet Functional Requirements***: This section details the overall system process, and overall functional requirements of NASPInet to be performed by the Data Bus and the PG systems in concert. To the fullest extent possible, the requirements are specified in "functional" terms ("what is required" rather than "how to do it") to provide maximum flexibility for the DB_SUPPLIER to propose standard, commercially available offerings with minimal customization.

- ***Section 4: Data Bus Functional Requirements***: This section details the specific functional requirements for the DB. To the fullest extent possible, the requirements are specified in "functional" terms ("what is required" rather than "how to do it") to provide maximum flexibility for the DB_SUPPLIERs to propose their standard, commercially proven offerings. The DB requirements include PG and data source registration management, PG connection and subscription management, streaming data and historical data transport, Quality of Service (QoS) management for all classes of services, data communication prioritization, network utilization management, quality of service monitoring, instrumentation, traffic management, and cyber security.

- ***Section 5: System Integration Requirements***: This section clarifies the points of demarcation for the overall NASPInet system integration requirements and describes the integration and API requirements for the DB_SUPPLIERs.

- ***Section 6: Network and Communication Requirements:*** This section describes the requirements for the data communication infrastructure to meet the needs of the DB covered by this specification. This section describes the communication system bandwidth, redundancy, security, and service requirements.

- ***Section 7: System Security:*** This section focuses on the security functions that are required for the DB. Primary focus is on cyber security though there are physical security issues that DB_SUPPLIER also needs to address, such as a physically secure environment for hardware components.

- ***Section 8: System Sizing, Performance and Availability:*** This section describes DB system sizing, performance, system availability, spare capacity and scalability requirements, etc.

- ***Appendix A: Abbreviations and Acronyms***: This appendix contains a list of common abbreviations and acronyms used in the document.

- ***Attachment I: DB_REQUESTOR Information***: This attachment is a placeholder for DB_REQUESTER to provide information that DB_SUPPLIER would need to design configurations of the proposed system. The information may include for example: anticipated PG locations and expected data volume of each PG, the DB_REQUESTER's preferred IT

platforms; IT governance, policies and guidelines; existing facilities and telecom infrastructures, etc.

- ***Attachment II: DB_REQUESTER Specific System and Service Requirements***: This attachment is a placeholder for the DB_REQUESTER to specific hardware, software, and system implementation and sustainment services to suite its operating environment and resource availability. Sample "boilerplate" specifications are included in the attachment for DB_REQUESTER reference. The DB_REQUESTER may tailor these materials for its own needs for the DB RFP or replace them in whole with its own standard materials. The reference boilerplate materials include the following:

  - ***Section 9: Hardware Requirements***: This section describes the preferred and required attributes for the DB_SUPPLIER-supplied equipment. Equipment covered in this section includes the DB servers, Local Area Network (LAN) facilities, communication interfaces, interconnecting cables, enclosures, power supply and distribution, and spare parts. This section also covers requirements of a general nature that shall apply to the overall system. This includes service conditions for equipment at the installation location (temperature, humidity, etc.).

  - ***Section 10: Software Requirements***: This section covers the required characteristics of the system software. Topics include operating system, network management facilities, database and display maintenance facilities, report writers, diagnostic tools (online and offline), etc.

  - ***Section 11: Implementation and Sustainment***: This section describes services that DB_SUPPLIER shall provide during and following the project. This includes project management services, cutover and commissioning plan, installation support, and hardware and software maintenance activities. It also covers requirements for system documentation, training, testing, and quality assurance.

2 NASPInet System Architecture

This section describes the overall NASPInet architecture framework and overviews of the DB and PG components. While DB_SUPPLIERs are encouraged to propose their standard, field proven system architecture design, the proposed architecture must adhere to the general framework and guidelines identified in this section. The section uses architectural views to depict the various aspects of interest inherent within the system. It also captures and conveys the significant architectural preferences of the system, and reflects the defined functional and non-functional requirements based on an understanding of the strategic goals and objectives for NASPInet.

This document depicts the envisioned system architecture of NASPInet by:

- Identifying the objectives, guiding principles, and constraints driving architectural choices;
- Specifying the logical (conceptual) model that will establish major architectural aspects and services, the components that will support those services, and the component interactions; and
- Specifying the system components, including for example only the possible products and other technologies that will map into the logical architecture specification to physically instantiate the architecture.

2.1 Architectural Foundation

2.1.1 Overview

This section discusses the key drivers that have influenced the decisions underlying the envisioned NASPInet architecture. The DB_SUPPLIER and PG_SUPPLIER proposed DB/PG designs shall support these key drivers. The key drivers have been derived from many areas, including but not limited to:

- NASPInet's current and envisioned Process, Technology, Organization and Information infrastructures;
- Specific functional and non-functional requirements;
- Existing and emerging standards for relevant Utility operations, including device communication standards, system integration standards, security standards, system and device interoperability standards, etc.;
- Existing and emerging relevant regulatory constraints such as SOX and others; and
- Existing and emerging best practices and packaged solutions for relevant Utility operations.

2.1.2 Objectives

The proposed System Architecture must enable the following objectives:

- The architecture shall provide the ability to share Phasor information and measurements, between the Publishers and Consumers of that information, under the auspices of defined interaction scenarios, message classifications, performance levels, security constraints and other governing criteria.
- Where practical and otherwise aligned with specific requirements for NASPInet, the DB_SUPPLIER/PG_SUPPLIER should consider commercially available solution components. The DB_SUPPLIER/PG_SUPPLIER shall explain the necessities or advantages of any proposed custom development.
- The System Architecture shall support fulfillment of the specified functional, non-functional, work process, information and technical goals specified in Section 3, Overall NASPInet Functional Requirements.
- NASPInet shall comply with all applicable regulatory constraints including but not limited to those specified by the FERC, SOX and others.
- The System Architecture shall enable the appropriate ongoing management and growth of NASPInet's investment in Information Technology resources consistent with NASPInet and PG_REQUESTER's IT Portfolio Management strategy and other relevant best practices.
- The architecture shall ensure end to end Quality of Service (QoS) for the spectrum of NASPInet data classes (A – E).
- The architecture shall ensure cyber security and information protection throughout the entirety of the lifecycle for NASPInet information.

2.1.3 Principles

Following are the key design principles which the NASPInet architecture must balance pragmatically in order to help enable the Objectives outlined above:

- Availability – Architectural elements shall exhibit sufficient fault tolerance, Mean Time Between Failure (MTBF), and Mean Time To Repair (MTTR) characteristics to enable defined functional and technical requirements, business goals and objectives, and business/technical values and constraints.
- Configurability – Architectural elements shall be sufficiently configurable, rather than requiring custom development, to enable defined functional and technical requirements, business goals and objectives, and business/technical values and constraints.
- Extensibility – Architectural elements shall exhibit sufficient ease of augmentation or aggregation to enable additional functional and technical requirements in the future.
- Flexibility – Architectural elements shall exhibit sufficient adaptive characteristics to rapidly enable changing operating environments.

- Instrumentation – Architectural elements shall exhibit sufficient visibility into their operations and "health" to enable defined functional and technical requirements, business goals and objectives, and business/technical values and constraints.
- Interoperability – Architectural elements shall exhibit sufficient integration mechanisms and capabilities to enable interoperability and facilitate replacements, upgrades, and/or addition of components.
- Knowledge – Sufficient knowledge transfer to appropriate stakeholders shall be provided to enable continued operations and development of the system.
- Maintainability – Architectural elements shall exhibit sufficient characteristics to support relative ease of maintenance to minimize maintenance costs.
- Manageability – Architectural elements shall exhibit characteristics that enable sufficient management of their operation and evolution to minimize system management costs.
- Performance – Architectural elements shall continuously and sufficiently deliver their solution functional capabilities within defined time and cost constraints.
- Portability – Architectural elements shall be instantiated on different development, test, and deployment platforms with relatively little effort.
- Reliability – Architectural elements shall exhibit sufficient capabilities and integrity to ensure that they and the services that they enable fulfill their functional contracts entirely.
- Scalability – Architectural elements shall exhibit a proportional (linear or greater) increase/decrease in supported load and performance given a similar increase/decrease in underlying system resources.
- Security – Architectural elements shall enable and exhibit sufficient controls on their access and use to ensure integrity of the system and data.
- Stability – Architectural elements shall exhibit sufficiently few defects relative to specifications, best practices, defined functional and technical requirements. Software defects, hardware problems, or data errors shall be detected at their source and isolated to the extent possible so as not inhibit functions of other unaffected system components and functions.
- Testability – Architectural elements shall exhibit sufficient mechanisms to enable the testing of their functional capabilities, implementation, performance, and reliability.
- Usability – Architectural elements shall exhibit sufficient overall capabilities for enabling ease of use by business users, technical developers, systems administrators, and other stakeholders.

2.2 Architectural Representation

This section provides an overview of the Architectural Representation used to describe NASPInet in subsequent sections of this document. This representation uses a set of views to describe the architecture, with each view describing the most significant aspects within a focused area of concern. The views that are reflected in this Specification document are:

- Use Case – This view describes architecturally significant usage scenarios that the proposed system must enable.
- Data Flow – This view describes, via data flow diagrams within and external to NASPInet, the high level scope and interactions to be supported by NASPInet.
- Logical – This view describes the high level conceptual components within the architecture and their various functions and relationships.
- Component – This view describes the components that instantiate the logical architecture.
- Security – This view describes the components that enable Security within NASPInet.
- Quality of Service (QoS) – This view describes functions that enable the management of QoS.
- Data – This view describes the high level logical and physical components that enable persistent and transient information flow and repositories within NASPInet.
- Network – This view describes the high level logical and physical components that enable data communication within NASPInet.
- Deployment – This view describes the high level physical instantiation of the NASPInet components identified in the Logical and Component views.

2.2.1 Use Case View

Section 3, Overall NASPInet Functional Requirements, encapsulates the envisioned processes and associated DB and PG functions for various system administration and operation activities. The processes include for example:

- Register a PG
- Change/Remove a PG registration
- Register a device and signal
- Change/remove a device/signal registration
- Subscribe streaming/historical data
- Unsubscribe streaming/historical data
- Start/stop streaming data

- Get historical data

As an example, Figure 2-1 below illustrates the use case of registering a streaming device in the form of a sequence diagram.

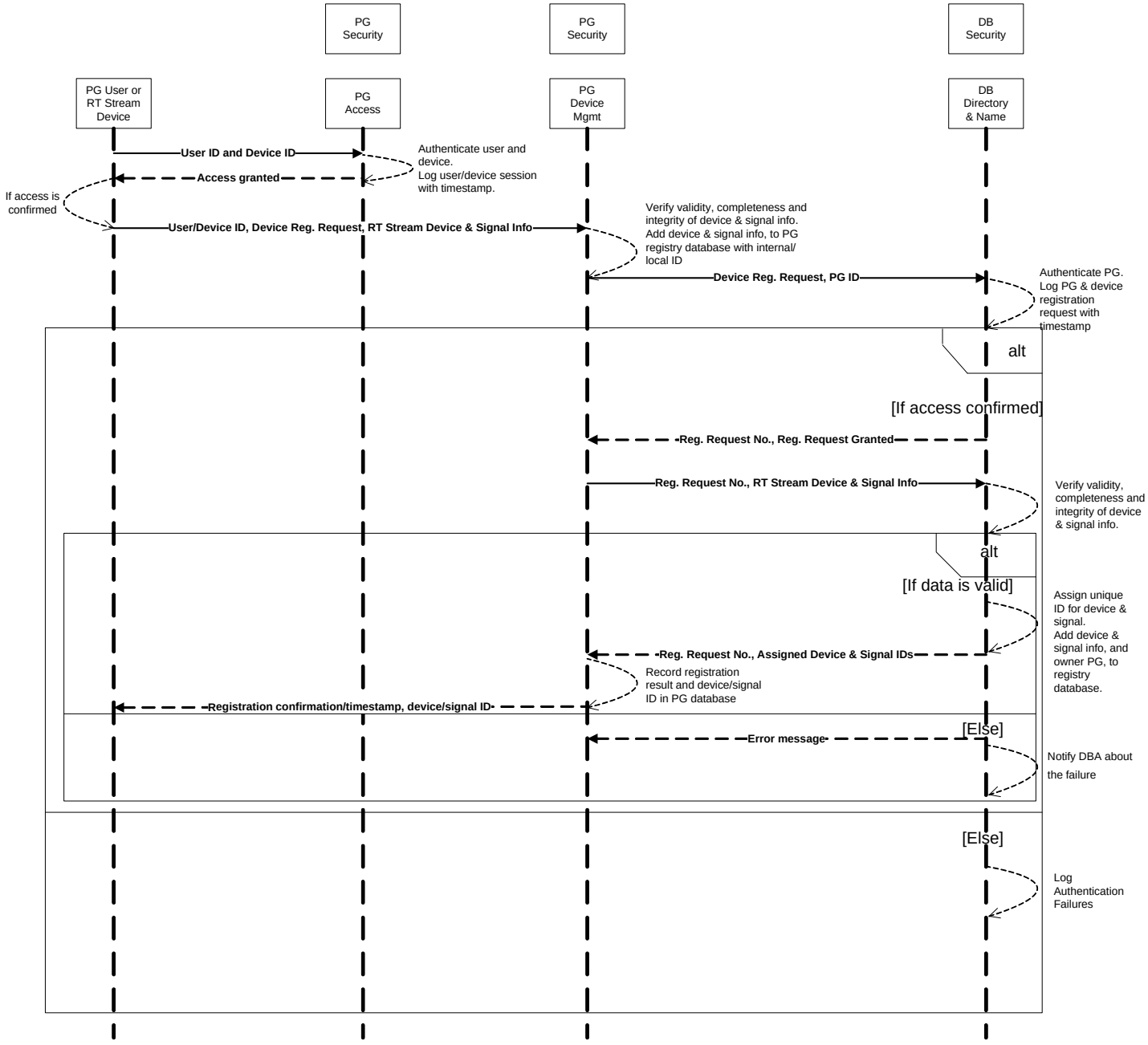

Figure 2-1: Use Case Example – Registering a Device in NASPinet

The other process sequence diagrams are interim working papers that have been translated to the overall NASPInet functional requirements in Section 3 and thus not included here in this specification document.

As part of the project implementation services, the SUPPLIER/PG_SUPPLIER shall provide detailed UML representation of the processes using the specific solution proposed.

2.3 Data Flow View

2.3.1 Data Flow Definitions

2.3.1.1 Context Diagram

The context diagram (Figure 2-2) shows the scope of the types of applications that might want to interact with NASPInet in the future. This was developed to ensure that all potential types of interactions were identified and is intended to illustrate the "big picture" of potential users and applications to improve understanding of the NASPInet architecture framework. The PG_SUPPLIER scope of the specific RFP is defined in other sections of this RFP. The flows of information depicted are not meant to represent any specific level of automation. The flow of information from one system to another could be automated directly through a point to point interface via one of the stream-engine based components or it could be automatically implemented through a web service on top of an enterprise service bus component. The system context diagram is exploded into data flow diagrams to illustrate the major flows that will be supported by NASPInet and identify major system components that form the functional building blocks of NASPInet.

Table 2-1 provides more details on the information flows depicted in the context diagram. For each information flow, the table contains the potential external system (shown on the outside boundary of the context diagram), the direction of the information flow (i.e. to NASPInet or from NASPInet), a brief description of the flow that indicates typical data items to be passed, and a description of the flow. Note that all data flows in and out of NASPInet will go through Phasor Gateways.

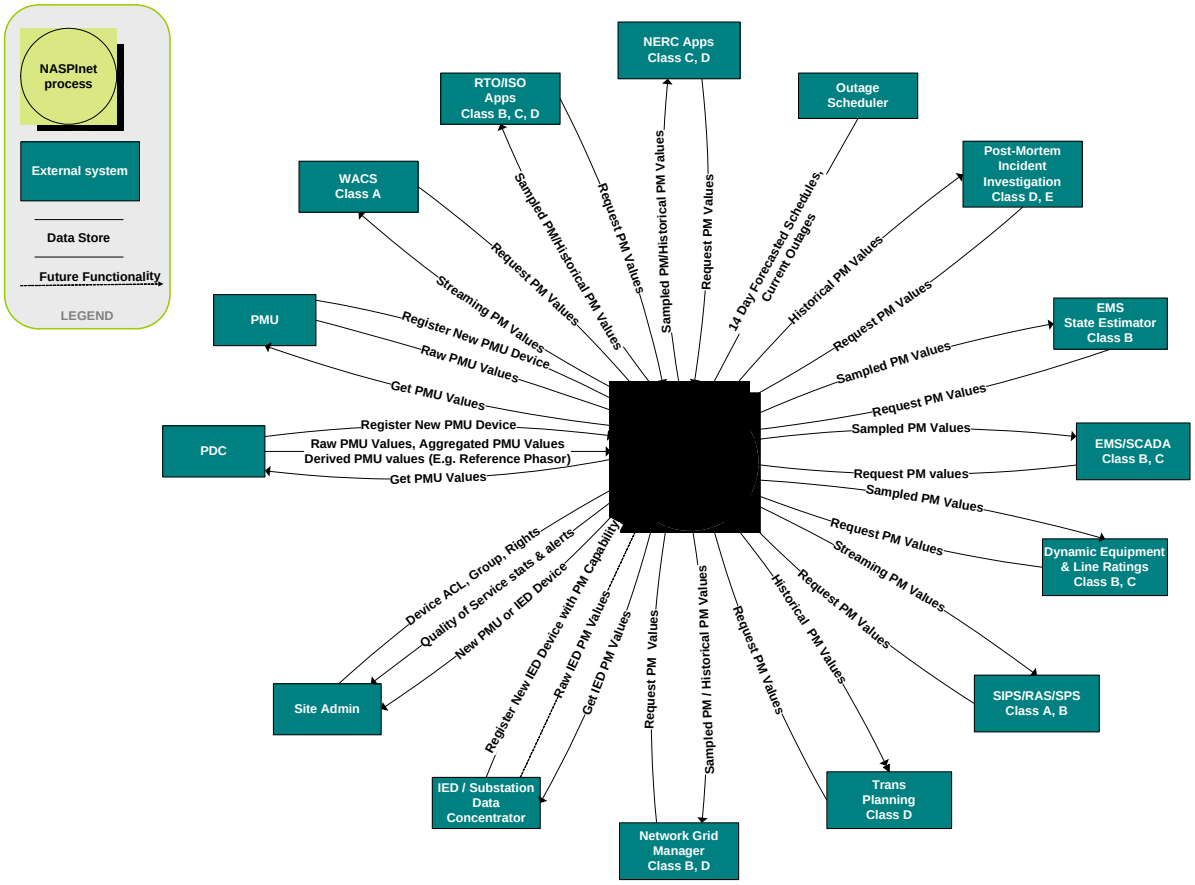

Figure 2-2: NASPinet System Context Diagram

Table 2-1: High Level NASPInet Data Flows

External System or Application	Direction	Flow Name	Description
PMU	To NASPInet	Register new PMU device	New PMUs shall be able to identify themselves to NASPInet and if they've been provisioned within the NASPInet system administration components, allowed to participate within the NASPInet community.
PMU	To NASPInet	Raw PMU data values	PMU synchro-phasor data values will typically be ingested at maximum data rate and for those applications that want less data, it will be filtered by the stream engine.
PMU	From NASPInet	Get PMU values	Request to establish a new source of PMU values for the NASPInet community.
PDC	To NASPInet	Register new PDC device	New PDCs shall be able to identify themselves to NASPInet and if they've been provisioned within the NASPInet system administration components, allowed to participate within the NASPInet community.
PDC	To NASPInet	Raw PMU data values, Derived PMU data values, Aggregated PMU values	PMU synchro-phasor data values will typically be ingested at maximum data rate and for those applications that want less data, it will be filtered by the stream engine. Need to support PDC's derived Phasor data and aggregation of signal values.
PDC	From NASPInet	Get PMU values	Request to establish a new source of processed PMU values for the NASPInet community.
Site Admin	To NASPInet	Device ACL, group, rights	NASPInet site administrator will define the access control list, groups and access rights on each PG, PDC/PMU device, and signal.

External System or Application	Direction	Flow Name	Description
Site Admin	From NASPInet	New PMU or IED device	Site Admin will be notified of when new devices are visible but not provisioned to be usable yet by the NASPInet community.
Site Admin	From NASPInet	QoS stats & alerts	Site Admin will receive QoS statistics and alerts relating to both ingested data and data received for distribution.
IED	To NASPInet	Register new IED device with PMU capability	In the future as IED functionality expands, NASPInet will allow new IED devices to register themselves.
IED	To NASPInet	Raw PM data values from IED	A potential future flow to provide synchro-phasor data values from IEDs.
IED	From NASPInet	Get PM values from IED	Request to establish a new source of PM values from IEDs for the NASPInet community.
Network Grid Manager Class B, C	To NASPInet	Request PM data and historical values	Local utility may request to visualize or to use PMU values in its own analysis applications.
Network Grid Manager Class B, C	From NASPInet	Historical PMU Values	Requested PMU values
Transmission Planning Class D	To NASPInet	Request PMU Historical Values	Local utility may request to high-quality historic values to do post-mortem analysis and to do forecasting simulations.
Transmission Planning Class D	From NASPInet	Historical PMU Values	Requested PMU values for post event investigation or forecasting and simulations.

External System or Application	Direction	Flow Name	Description
SIPS/RAS/SPS Class A, B	To NASPInet	Request PM Values	Automation and protection systems may request real-time streaming PM data for feedback and feed-forward controls.
SIPS/RAS/SPS Class A, B	From NASPInet	PM Values	Real-time streaming PM data for feedback and feed-forward controls
Dynamic Equipment & Line Ratings Class B, C	To NASPInet	Request PM Values	Potential request of PMU data at a lower sampling rate for dynamic equipment and line rating calculations or for visualization associated with such applications.
Dynamic Equipment & Line Ratings Class B, C	From NASPInet	Sampled PM Values	Sampled PM values for calculating the ratings of equipment and subsections of transmission lines in near real-time and to visualize the results.
EMS/SCADA Class B, C	To NASPInet	Request PM Stream	Request of PM data at a desired sampling rate for EMS/SCADA applications and visualization.
EMS/SCADA Class B, C	From NASPInet	Sampled PM Values	Sampled PM values for EMS/SCADA system visualization and applications
EMS State Estimator Class B	To NASPInet	Request PM Values	Request of PM data at a desired sampling rate for EMS state estimator applications.
EMS State Estimator Class B	From NASPInet	Sampled PM Values	Sampled PM values for EMS State Estimator applications
Post-Mortem Incident Investigation Class D, E	To NASPInet	Request Historical PM Values	Request for historic values with various data quality requirements based on specific needs.

External System or Application	Direction	Flow Name	Description
Incident Investigation Class D,E	From NASPInet	Historical PMU Values	Signal file to be used as part of post event investigation.
Outage Scheduler	To NASPInet	14-day forecasted or scheduled outages and current outages	Potential future flow from various outage schedulers to NASPInet for determining and providing advanced warnings on the availability of data.
NERC Apps Class C, D	To NASPInet	Request PM Values/Historical PMU values	Requests to subscription of PM values at lower sampling rates and to get high-quality historical information.
NERC Apps Class C, D	From NASPInet	Sampled PM values, Historical PM values	NERC apps are envisioned to want to be able to subscribe to NASPInet to visualize current state and to request historical information to do post-mortem analysis.
RTO/ISO Apps Class B, C, D	To NASPInet	Request PM Values Historical PM values	Requests to setup a subscription for streaming PM data and to get historical information for various RTO/ISO applications.
RTO/ISO Apps Class B, C, D	From NASPInet	Sampled PMU values, Historical PMU values	Sampled PM values and historical data for RTO/ISO users and applications.
WACS Class A	To NASPInet	Request PM Values	Advanced Wide Area Control Systems (WACS) may request real-time streaming PM data for feedback controls.
WACS Class A	From NASPInet	PM Values	Real-time streaming PM data for WACS feedback controls

The use cases and information flows illustrated by the Context Diagram and outlined in Table 2-1 above can be encapsulated into two high-level dataflow diagrams, one for data usage and one for PG administration functions. These two representative dataflow diagrams are presented below.

2.3.1.2 Phasor Gateway Data Usage Dataflow Diagram

The PG data usage dataflow (Figure 2-3) shows the systems involved in collecting PMU data, publishing it to the NASPInet DB and distributing it to the subscribers of streaming and sampled PMU data and to the requestors of historical PMU data. This dataflow diagram also breaks out the NASPInet component represented in the context diagram and presents some of the building block architectural components of the NASPInet Phasor Gateway:

- Phasor Gateway Ingest Service: This is a logical component of the PG that uses and interfaces with the DB services through the DB APIs to ingest streaming and historical PM data from devices (PMU, PDC, IED) connected to the PG into the DB. In other words, the DB services enable these data functions in the PG through interfacing with the PG Ingest Service component.
- Phasor Gateway Distributor: This is a logical component of the PG that uses and interfaces with the DB services through the DB APIs to get streaming and historical PM data available from NASPInet, and distribute the data to users and applications connected to the PG via the PG APIs. A Gatway Cache is represented in the dataflow diagram to indicate some local memory and data storage capability in the PG to improve its performance and overall data availability, if needed.
- Phasor Gateway Historian: This is a logical component of the PG that uses and interfaces with the DB services through the DB API to get historical data from external PGs or other connected historical PM data sources, and distribute the data to users and applications connected to the PG via the PG APIs. A PMU Data Mart is represented in the dataflow diagram as a placeholder for the potential future possibility that the DB_REQUESTER may want to have data store capability for select data within the DB. Regardless, the logical service PG Historian component is still applicable as it would manage historical data requests and the resulting data processing in the PG as indicated above.

Figure 2-3 depicts the ingestion of streaming data from the PMUs and potentially in the future: IEDs via substation data concentrators, and shows the data being archived to support requests for historical information.

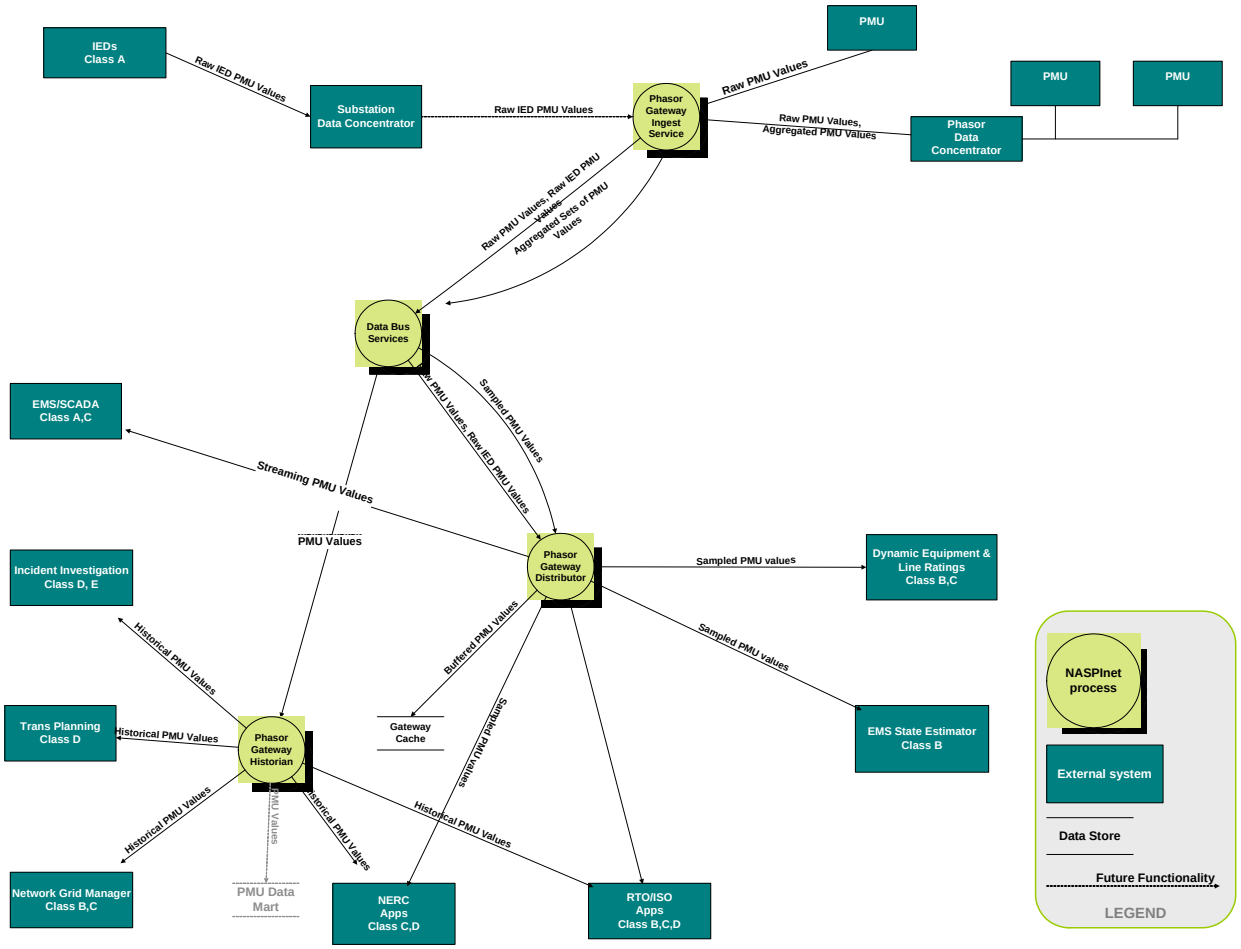

Figure 2-3: PG Data Usage DFD

2.3.1.3 Phasor Gateway Administration Dataflow Diagram

The PG administration dataflow (Figure 2-4) shows the various flows associated with managing PMU devices, granting access to new device signals, removing old devices, having applications setup subscriptions with NASPInet for PMU data, being authenticated and being able to monitor and view the current performance of NASPInet.

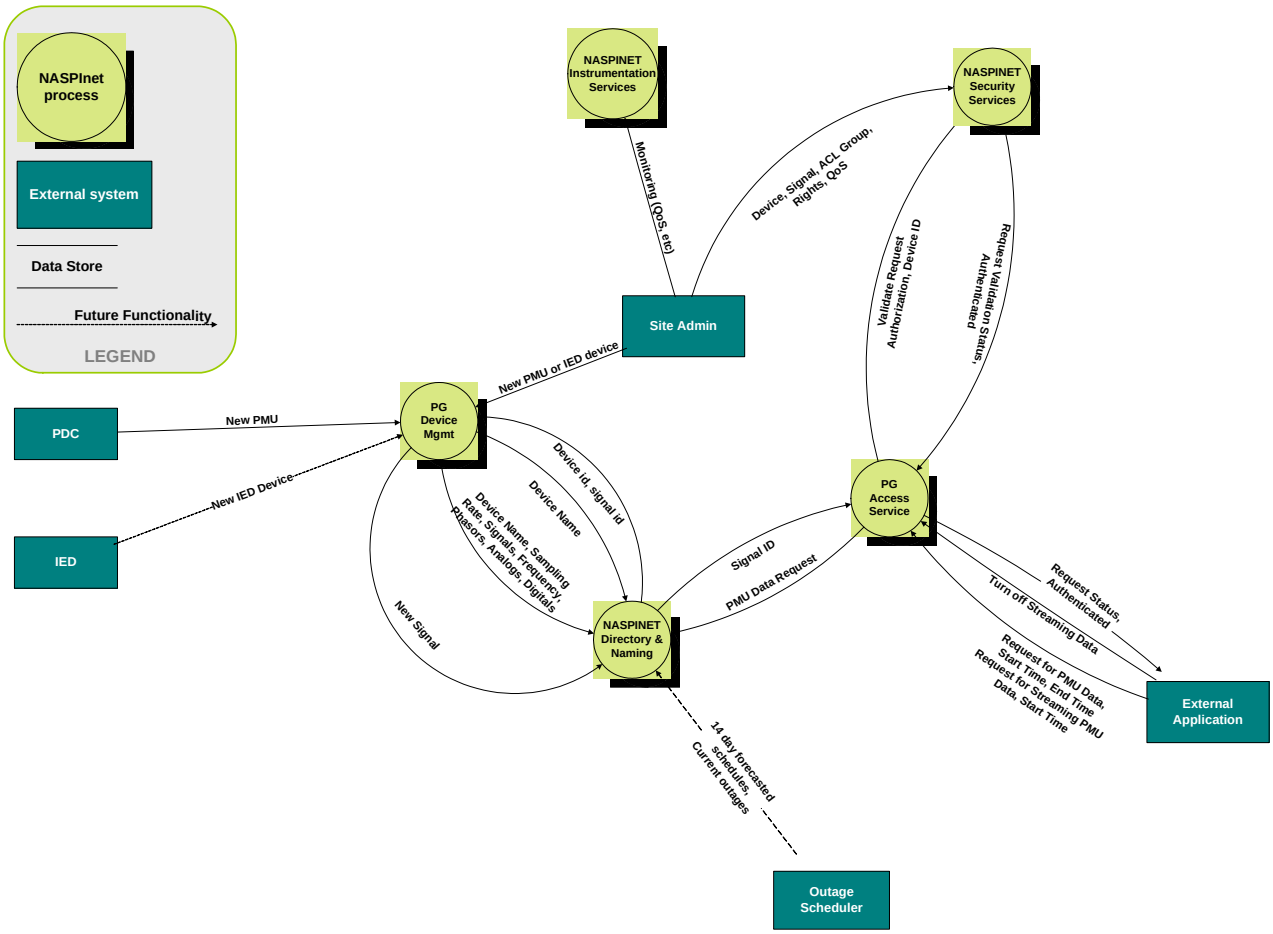

Figure 2-4: PG Administration DFD

2.4 Logical View

2.4.1 Introduction

The intent of this view is to describe the high level components that form the Phasor Gateway and Data Bus macro entities within the envisioned NASPInet architecture. The diagram (Figure 2-5) maps these components to the business entities in which they would most likely be deployed:

- Utility and Other User Organization (e.g. NERC) Enterprise Level
- Operational Centers
- Substations

The following assumptions apply to the Logical View:

- Services – Within the Data Bus and the Requester's enterprise IT Common Services domains, references are made to "services" such as Streaming Data Services or Security Services. At this level of abstraction, these components are not intended to represent instantiated services but are instead a blanket term to describe the general functionality delivered by a particular set of components.
- Service-Oriented Architecture – An SOA-based approach is one possible solution to parts of NASPInet development and integration, however the intent of this diagram is not to imply that SOA is a preferred or proscribed approach. Rather, SOA should be employed where it adds value (such as propensity for reuse, abstraction, etc.) and can meet the requirements of the functionality to be enabled (such as performance, latency, security, etc.).
- Web Services – Similarly to SOA, we allow for the possibility that a Web Services-based approach to development and integration, or even a derivative approach such as XML-RPC, may be viable where it adds value and meets requirements.

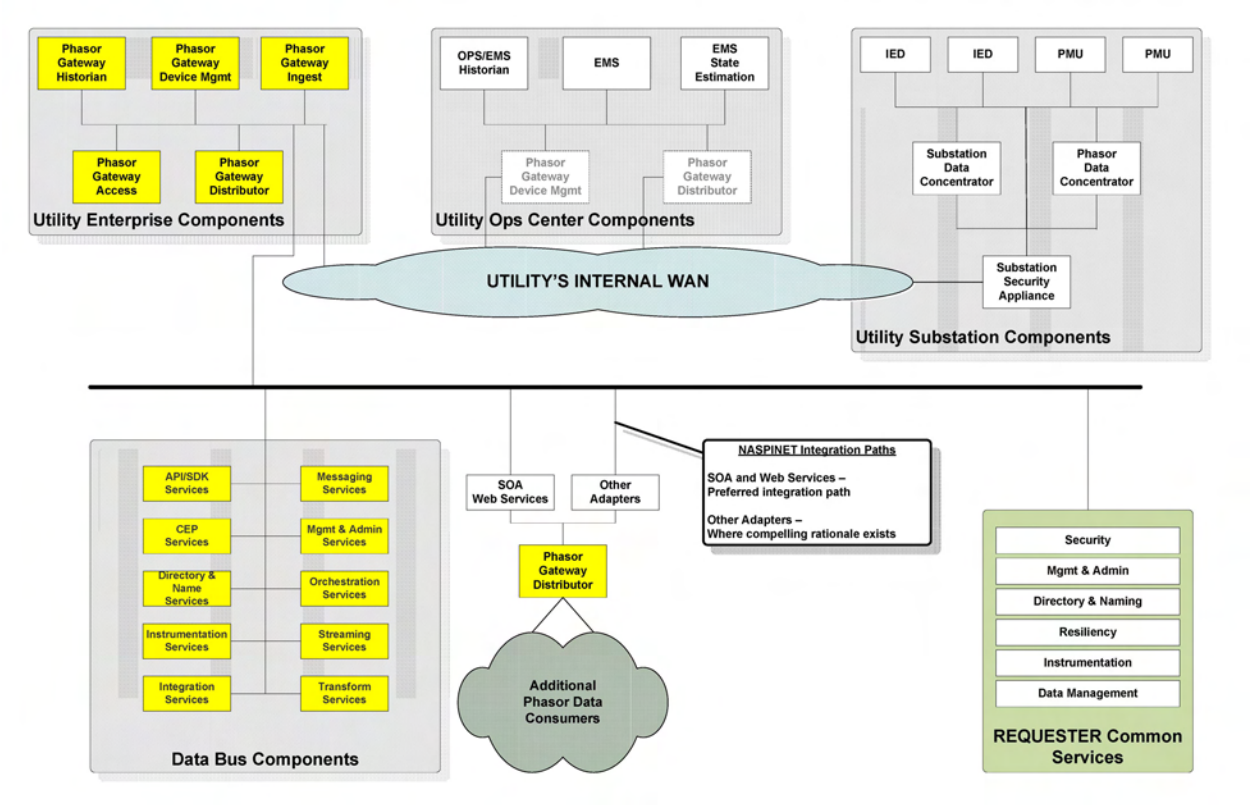

Figure 2-5: NASPInet System Components Logical View

2.4.2 Logical View Details

The Phasor Gateway components shall include:

- Phasor Gateway Distributor – all of the data request services shall be supplied by this component. All external applications and systems shall communicate to NASPInet via services provided by this system component. This component shall make use of Data Bus services providing the API/SDK and Directory/Naming services.
- Phasor Gateway Ingest – As depicted in the ingest Data Flow Diagram, the services provided by this component shall deal with communicating with devices in the substation and potentially aggregating them before putting them on the data bus for consumption.
- Phasor Gateway Device Management – This component shall make use of the NASPInet Data Bus services and the PG specific services to support adding, removing, activating and de-activating devices.
- Phasor Gateway Access - This component shall make use of the NASPInet Data Bus services and where appropriate the Requester's enterprise IT Common Services, as well as the PG specific services to provide the security administration services to grant user roles/application access to specific device and signal data.
- Phasor Gateway Historian – As far as having historical data stores within NASPInet, unless stated otherwise by the PG_REQUESTER, this component is out of scope of the PG_SUPPLIER but has been included to manage historical data requests and process the obtained data (data that is stored in sources connected to but not part of NASPInet.

The Data Bus infrastructure shall enable the flow of Phasor and other information between Phasor Gateways and additional appropriate entities interacting with NASPInet. The major functional characteristics of the Data Bus shall include:

- Implementation via middleware that provides QoS and security guarantees. The middleware shall provide abstractions for QoS and security services. An abstraction of a potential future extension of NASPInet is the notion "virtual signal" for a PMU signal, which is the sub-sampled (lower rate) data stream of the original PMU data stream, supporting subscribers who may not need the complete PMU data stream.
- Providing information connectivity between producers and consumers of Phasor data including streaming (message-based, publish/subscribe, asynchronous and synchronous with guaranteed delivery scenarios), historical Phasor data, and other non Phasor data such as NASPInet QoS metrics and event/error logs:
    - Unicast – Data Bus shall support secure unicast (point-to-point) information flow with specified security and QoS properties.

- Publish/Subscribe – Data Bus shall support multicast capabilities to implement publisher/subscriber model of data exchange in a resource-efficient manner. Security services shall ensure that published data will only reach those entities that have been authorized to receive that data; subscribed data will only come from the authorized publishers.

- Ensuring information flow relative to defined classes which specify latency, Quality of Service and other characteristics inherent to that class:
- QoS management – The middleware shall implement a distributed resource management architecture that encompasses a set of algorithms for resource monitoring, QoS mapping, admission control, resource reservation, resource negotiation and other attributes. The architecture shall support a diverse set QoS classes with wide range of rate, delay, delay-jitter and other requirements.
- The architecture shall support a set of predefined QoS (priority) and that application services are mapped onto these classes for resource management purposes. The QoS mapping function shall map application level QoS into system level QoS in terms of bandwidth, delay, jitter, CPU demand, etc.
- The admission control function shall determine if an incoming flow (with certain QoS and security specification) is admitted into NASPInet without jeopardizing the QoS and security guarantees that have been provided to the previously admitted flows. Admission control shall account for both QoS and security requirements of the information flow. If a higher priority flow cannot be admitted due to constrains on sufficient resources, a lower priority flow shall be degraded in QoS or even be dropped to accommodate the higher priority flow. This functionality is called QoS adaptation. For admitted flows, the QoS guarantees shall be ensured through resource reservations and run-time scheduling algorithms.
- Providing an integration framework for the entities communicating using the Data Bus.
- Enabling transformation of the data flowing through the bus.
- Providing the ability to execute business logic, including process and event-based logic, based on the data transiting the bus.
- Functioning under the broader auspices of Requester's enterprise IT Common Services including but not limited to Security, Management and Administration.

The Data Bus Components shall implement the following macro-level services generally within the Data Bus:

- API/SDK (Application Programming Interface / Software Development Kit) – This service shall enable applications, integration mechanisms, user interfaces, content delivery and other NASPINET components to be customized, developed and deployed.
- CEP (Complex Event Processing) – This service shall enable event-driven processing, such as actions to be performed based on the values of multiple phasor measurement units and/or IEDs.
- Name & Directory – This service shall enable the registry of services, components, processes, streams and other entities internal to the Data Bus for subsequent invocation.
- Instrumentation – In concert with Management and Administration Services, instrumentation services shall provide visibility into key aspects of Data Bus components and services, such as performance, utilization and general health indicators.
- Integration – This service shall enable external integration to NASPInet by exposing Data Bus services, processes and components via adapters.
- Messaging – This service shall enable synchronous and asynchronous message-based communication between NASPInet components and services with support for features such as guaranteed delivery, publish/subscribe and content-based routing.
- Management & Administration – This service shall enable the initial configuration and ongoing operation of Data Bus components and services.
- Orchestration – This service shall enable business process modeling, development, instantiation, execution and monitoring functionality. An example would be the processes to support the provisioning of new Phasor Gateway Devices.
- Streaming – This service shall enable massive volume, low latency delivery and processing of NASPInet data from Phasor Devices and other IEDs.
- Transform – This service shall enable data transformation to be performed on the information flowing through the Data Bus.

The NASPInet DB and PG shall utilize, be compatible and integrate with the Requester's enterprise IT Common Services to perform the following macro-level services throughout the NASPInet infrastructure. Contrasting some of these services with equivalent services within the context of the DB and PG, such as System Management and Administration, the Common Services shall perform similar functions but on a broader scale throughout the Requester's enterprise IT infrastructure.

- Security – this service shall provide enabling services and infrastructure to ensure the appropriate access to and usage of NASPInet resources and information. Key components typically include Authentication, Authorization, Access Control, Confidentiality, Auditing, Non-Repudiation and many others.

- Management & Administration – this service shall enable the initial configuration and ongoing operation of NASPInet components and services, and will likely integrate or aggregate the analogous but more focused services within the Data Bus.
- Name & Directory – this service shall enable the system-wide registry of Phasor Measurement devices as well as the services, components, processes and other entities required by the Phasor Gateway and/or Data Bus components.
- Resiliency – This service and infrastructure to ensure critical system attributes such as Fault Tolerance, Availability, Disaster Recovery, Business Continuity and similar aspects.
- Instrumentation – In concert with NASPInet Management and Administration Services, this service shall provide visibility into key aspects of the NASPInet infrastructure such as performance, utilization and general health indicators.
- Data Management – this service shall enable the logical and physical architecture, storage, access and management of persistent and transient data within NASPInet. Key components typically include Relational Database Management engines, Storage Area Network infrastructure, Metadata Management, Hierarchical Storage Management, Information Lifecycle Management and other services.

2.5 Component View

2.5.1 Introduction

The intent of the Architecture and Software Componemt views (Figure 2-6 and Figure 2-7) is to describe the next level of detailed components that form the Phasor Gateway and Data Bus macro entities within the envisioned NASPInet architecture. The diagrams further decompose the Logical View presented earlier into the macroscopic building blocks encapsulated within that view's components.

The following assumptions apply to the Component View and diagrams:

- The diagrams reference commercially available components at a high level, for example Enterprise and Streaming middleware. This is in no way intended as a constrained or preferred solution, but rather an assessment of classes of commercial components that could conceivably play a role within the NASPInet architecture.

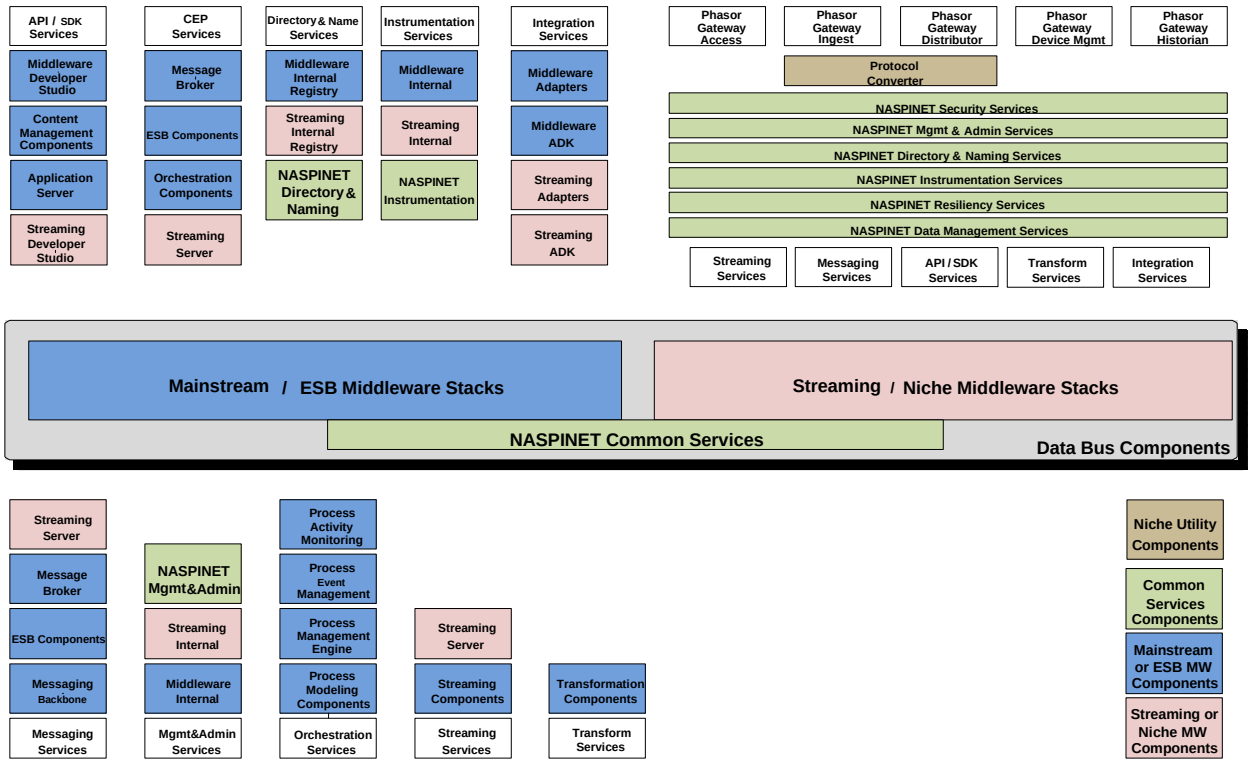

Figure 2-6: NASPInet Architecture Components

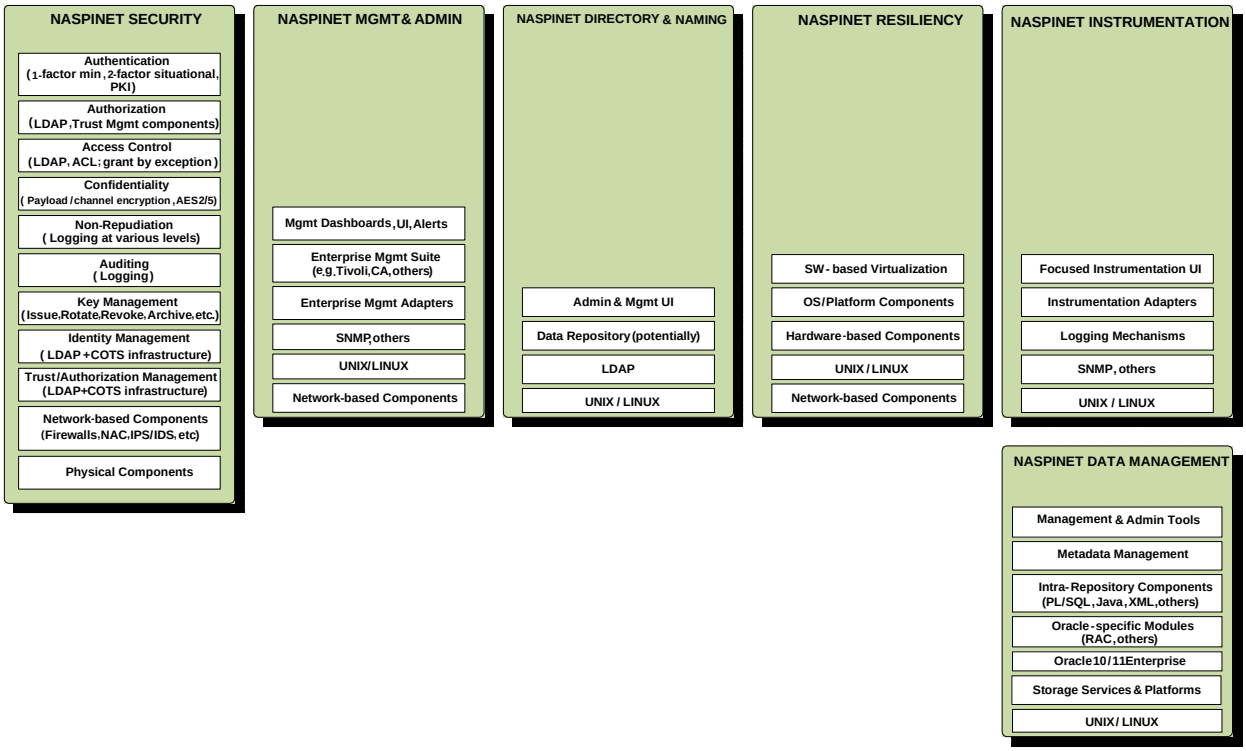

Figure 2-7: NASPInet Software Components

2.5.2 Component View Details

Note that some of the components depicted in Figure 2-6 are in different subsystems (DB, PG, and enterprise IT Common Services); they will be described once only in the following text. Also, the software components in Figure 2-7 are common IT terms (e.g. LDAP, SNMP, UNIX/LINUS, etc.) and hence not explained further here.

- Middleware & Streaming Developer Studios – shall enable solution developers to configure, customize and develop other NASPInet Data Bus components; examples would include adapters, business logic and many others.
- Content Management – shall enable the development, publishing and management of content such as web-based information, context-sensitive help and other textual and graphical content elements.
- Application Server – shall provide the framework in which Data Bus components can be instantiated and executed, monitored and managed to perform their intended functions; an example would be J2EE or managed code components.
- Message Broker – shall provide the framework for message delivery within the Data Bus and exposes functionality such as Publish/Subscribe, asynchronous messaging, guaranteed delivery and more.
- ESB Components – shall provide the framework for developing and exposing services for complex architectures within the Data Bus, as well as providing the features with which a Service-Oriented Architecture (SOA) may be implemented.
- Orchestration Services & Components – shall provide the mechanisms by which complex, process-based business logic can be modeled (via Process Modeling), instantiated and executed (Process & Event Management) and monitored (Activity Monitoring) within the Data Bus.
- Streaming Server – shall provide the framework for processing streaming data within the NASPInet Data Bus. Streaming Data is characterized by continuous (or nearly so) output, processing and delivery according to Quality of Service (QoS) tiers defined in terms of data volume, latency and other parameters.
- Enterprise and Streaming Middleware Internal Registry – shall provide mechanisms within the Data Bus middleware that manage the registry and discovery of services offered by the Data Bus.
- Enterprise, Streaming Middleware, and other NASPInet Internal Instrumentation – shall provide mechanisms within the Data Bus middleware components that measure and indicate the functional health of those components.

- Middleware & Streaming Adapters – shall provide pre-built integration functionality for Enterprise and Streaming middleware frameworks which can then be configured, customized or aggregated to deliver integration services for the Data Bus; examples could include adapters for 3rd party software products, protocol adapters such as XML-RPC and many others.
- Middleware & Streaming Adapter Development Kit (ADK) – shall provide the tools, such as language libraries and Application Programming Interfaces that enable developers to configure, customize or build new adapters for the Data Bus.
- NASPInet Security Services – described in more detail in the next subsection.
- Enterprise & Streaming Middleware Internal Management & Administration – shall provide mechanisms within the Data Bus middleware components that enable the management of those components and their internal functionality.
- Transformation Components – shall provide the mechanisms by which information flowing within the Data Bus can identified, segregated, transformed in terms of format/content/interpretation, aggregated or otherwise affected during its transit from source entity to destination entity; an example of transformation could include splitting a group of PG signals into its components preparatory to subscriber delivery.
- Name & Directory Services – shall enable the system-wide registry of Phasor Gateways, Phasor Measurement Units, and IED devices as well as the services, components, processes and other entities required by the Phasor Gateway and/or Data Bus components.
- Instrumentation Services – In concert with DB Management and Administration Services, shall provide visibility into key aspects of the NASPInet infrastructure, such as performance, utilization and general health indicators, for the DB network, hardware and software subsystems of DB and PG.
- Resiliency Services – shall ensure critical system attributes such as Fault Tolerance, Availability, Disaster Recovery, Business Continuity and similar aspects.
- Data Management Services – shall enable the logical and physical architecture, storage, access and management of persistent and transient data within NASPInet. Key components typically include Relational Database Management engines, Storage Area Network infrastructure, Metadata Management, Hierarchical Storage Management, Information Lifecycle Management and other services.

2.6 Security View

2.6.1 Introduction

The intent of this view (Figure 2-8 and Figure 2-9) is to describe at a high level those components which provide Security within the envisioned NASPInet architecture. The diagrams further decompose the Logical View presented earlier into the focused classes of components which provide security in the major areas of concern including Authentication, Authorization, Access Control, Confidentiality, Integrity, Non-Repudiation, Auditing, Platform, Network, and Physical Security.

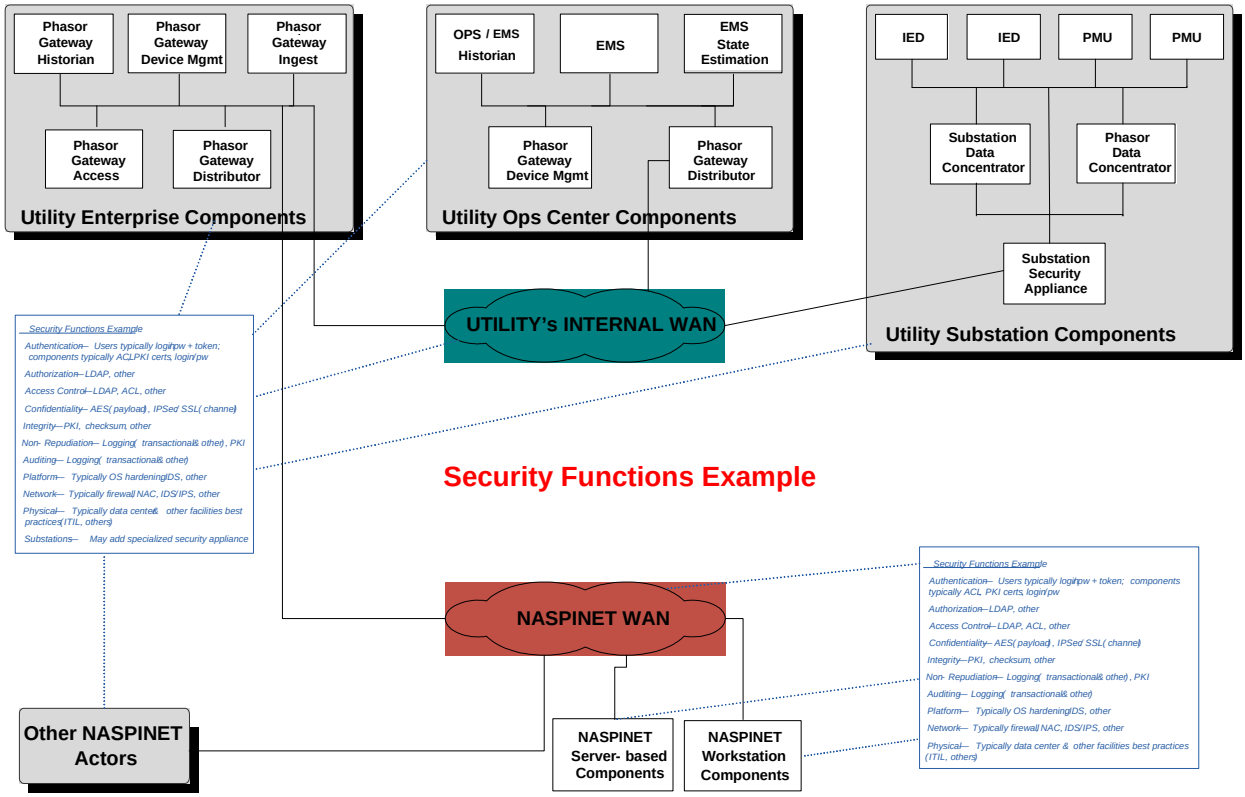

Figure 2-8: NASPInet Architecture – Security Functions Example

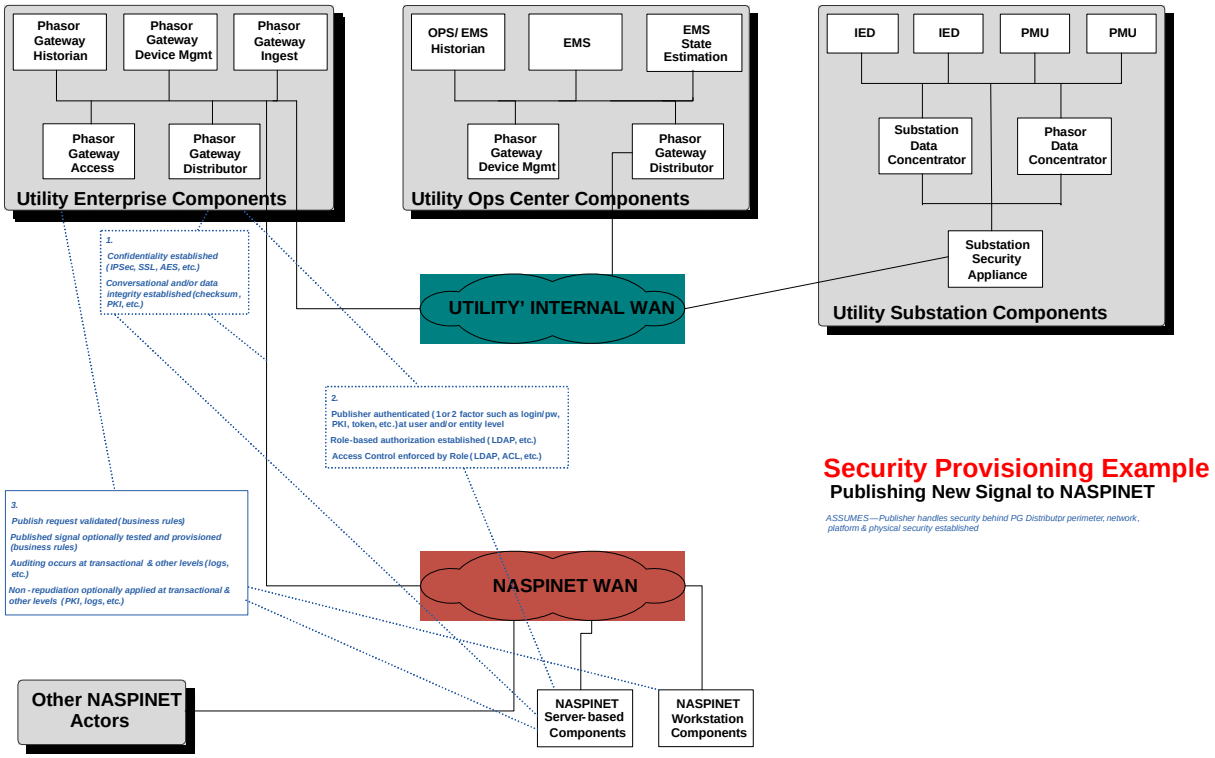

Figure 2-9: NASPInet Architecture – Security Provisioning Example

2.6.2 Security View Details

Ensuring QoS and maintaining cyber security are two main requirements of NASPInet. However, meeting one requirement may cause the degradation on meeting the other requirement. For example, increasing security by using longer encryption key will require more processing time at PGs during encrypting and decrypting processes, which may result in NASPInet not being able to meet QoS (e.g., end-to-end delay, delay jitter) requirement.

The design shall ensure that both the required QoS and security properties for the various flows are supported in the NASPInet. In case of overloads that arise due to unanticipated contingencies, suitable resource management mechanisms shall be in place to degrade QoS for low-priority flows, or even drop them if necessary, to support high-priority flows while protecting system integrity and security.

The design shall also address QoS and security guarantees for multicast flows for efficient implementation of publisher/subscriber model of data communication. The key distribution and rekeying overhead shall be kept small in order to meet this requirement.

Section **Error! Reference source not found.** of this RFP focuses on Security.

2.7 Quality of Service (QoS) Management

The proposed system shall support a distributed resource management architecture that encompasses a set of algorithms for resource monitoring, QoS mapping, admission control, resource reservation, resource negotiation. The architecture shall support a diverse set of QoS classes with wide range of rate, delay, and delay-jitter requirements. The architecture shall support a set of predefined QoS (priority), and the application services shall be mapped onto these classes for resource management purposes. The QoS mapping function shall map application level QoS into system level QoS in terms of bandwidth, delay, jitter, CPU demand, and other such items. The admission control function shall determine if an incoming flow (with certain QoS and security specification) can be admitted into the NASPInet without jeopardizing the QoS and security guarantees that have been provided to the previously admitted flows. The admission control shall account for both QoS and security requirements of the flow.

QoS adaption capabilities shall be provided. That is, if a higher priority flow cannot be admitted due to unavailability of sufficient resources, a lower priority flow shall be degraded in QoS or even be dropped to accommodate the high priority flow.

For admitted flows, the QoS guarantees shall be ensured through resource reservations and run-time scheduling algorithms. In summary, the middleware must support a distributed QoS management architecture, security architecture, and their interactions.

2.8 Risk-based Approach to System Design

It is quite possible that the designer will be faced with the dilemma of choosing among achieving the required QoS, robust dependability (reliability and availability), and strong information assurance guarantees. In some of these cases, it may not be possible to meet all these three key requirements simultaneously due to resource constraints, unavailability of suitable algorithms and technologies, and possibly lack of interoperability among various technologies. To address such cases, a risk based design approach should be adopted. Risk is the net negative impact of the exercise of a given security vulnerability, QoS violation, or fault condition, considering both the probability and the impact of occurrence. Risk management is the process of identifying risk, assessing risk, and taking steps to reduce risk to an acceptable level.

To balance the tradeoffs among QoS, security, and dependability metrics, a risk based system design approach should be adopted as the guiding principle to minimally relax guarantees on one metric over others. To practically achieve that, for each of the three metrics (QoS, security, dependability), multiple levels of guarantees should be defined. Each application, flow, and service specifies its guarantees at two levels: “desired level” – the guarantee level it ideally requires, and the “acceptable level” – the guarantee level that it can live with. In between a given “acceptable” and “desired” levels, there could be multiple discrete levels of guarantees that can be supported by the NASPSInet. When tradeoff arises in the design,

the risk-based approach would relax one or more metrics from their desired level to lower levels subject to the constraint that none of the metric is relaxed below the desired level. Also, the risk based design should attempt to improve the level of guarantees as much as possible beyond the "acceptable" level of each metric. In case if "acceptable" level itself is not guaranteed even for a metric, then the service/flow/application should not be realized, and exception must be generated and reported to the administrator.

The following NIST publications provide good practices for a risk-based design approach.

http://csrc.nist.gov/publications/nistpubs/800-30/sp800-30.pdf

http://csrc.nist.gov/groups/SMA/fisma/framework.html

2.9 Data View

2.9.1 Introduction

The intent of this view (Figure 2-10) is to describe at a high level those components which provide data management and persistence within the envisioned NASPInet architecture. The diagram describes the existence of data management and persistence components within the Utility enterprise, the NASPInet architecture itself, and externally to NASPInet. The following assumptions apply to the Data View:

- Persistent storage shall follow industry best practices for file system and enterprise Relational Database Management System (RDBMS) products including but not limited to logical data models and architecture, physical data deployment, storage services, performance and resiliency characteristics including RAID implementations, security, etc.
- Transient storage, such as in-memory databases, temporary storage or others, may exist in the NASPInet architecture as processing components (e.g. for streaming data) as appropriate.
- Storage characteristics may potentially include spatial data attributes, content-addressable storage, Hierarchical Storage and Information Lifecycle Management constructs, and other technology enabling NASPInet objectives.

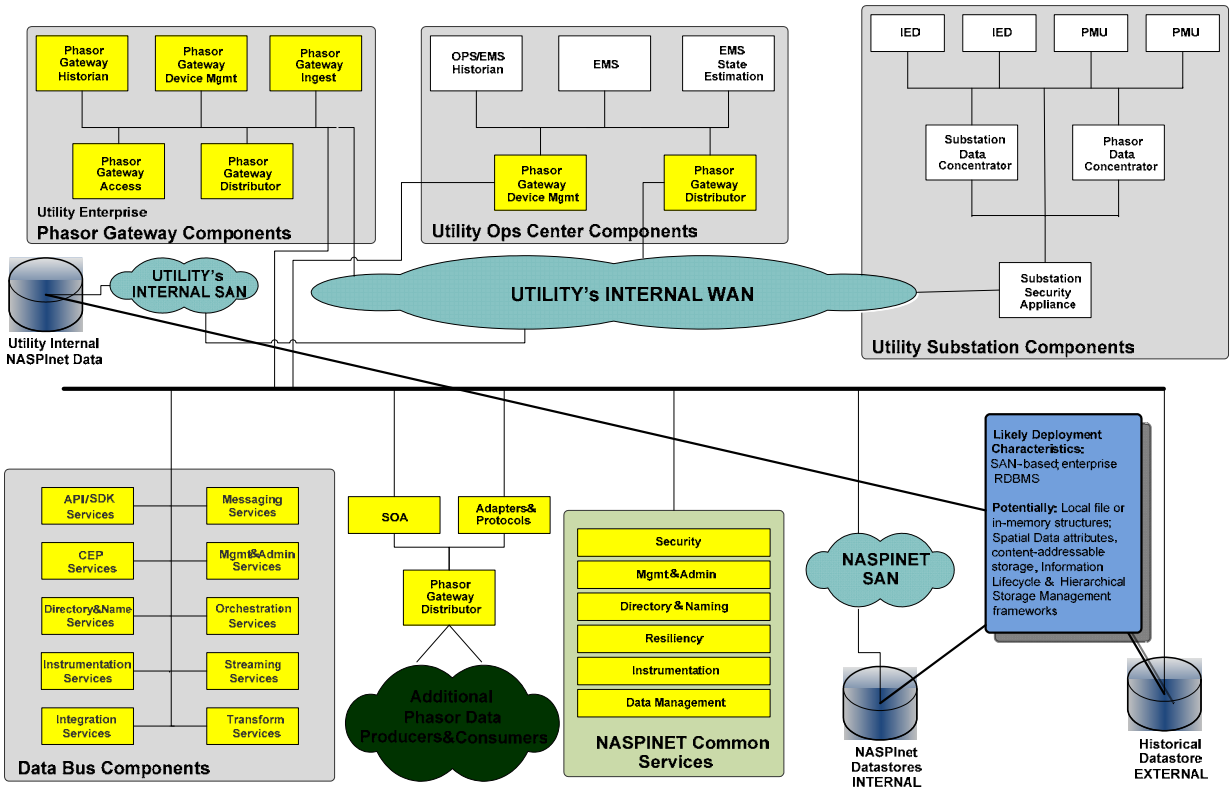

Figure 2-10: NASPInet Architecture – Data View

2.9.2 Data View Details

The proposed system architecture shall support the following types of data:

- Utility Enterprise – Data in the Utility will include but is not limited to: Phasor measurements and other Phasor information, and supporting data.
- NASPInet Internal – Data internal to NASPInet will include Directory and Naming constructs, Security credentials, auditing information, QoS history, and other supporting data.
- Historical External – Historical data may be stored outside of the primary NASPInet infrastructure, and may include raw data as well as derived, transformed or aggregated data. NASPInet entities request historical data assuming compliance with Security and other constraints.

2.10 Network View

2.10.1 Introduction

The intent of this view (Figure 2-11) is to describe at a high level potential Network deployment within the envisioned NASPInet architecture. The following assumptions apply to the Network View and diagrams:

- Network logical and physical partitioning shall be used to aggregate and separate NASPInet entities in order to optimize bandwidth and other network resources relative to evolving requirements.
- The network shall impose its own mechanisms for QoS, security and other attributes, which may complement or enable similar attributes for higher level components such as middleware, integration and application constructs.

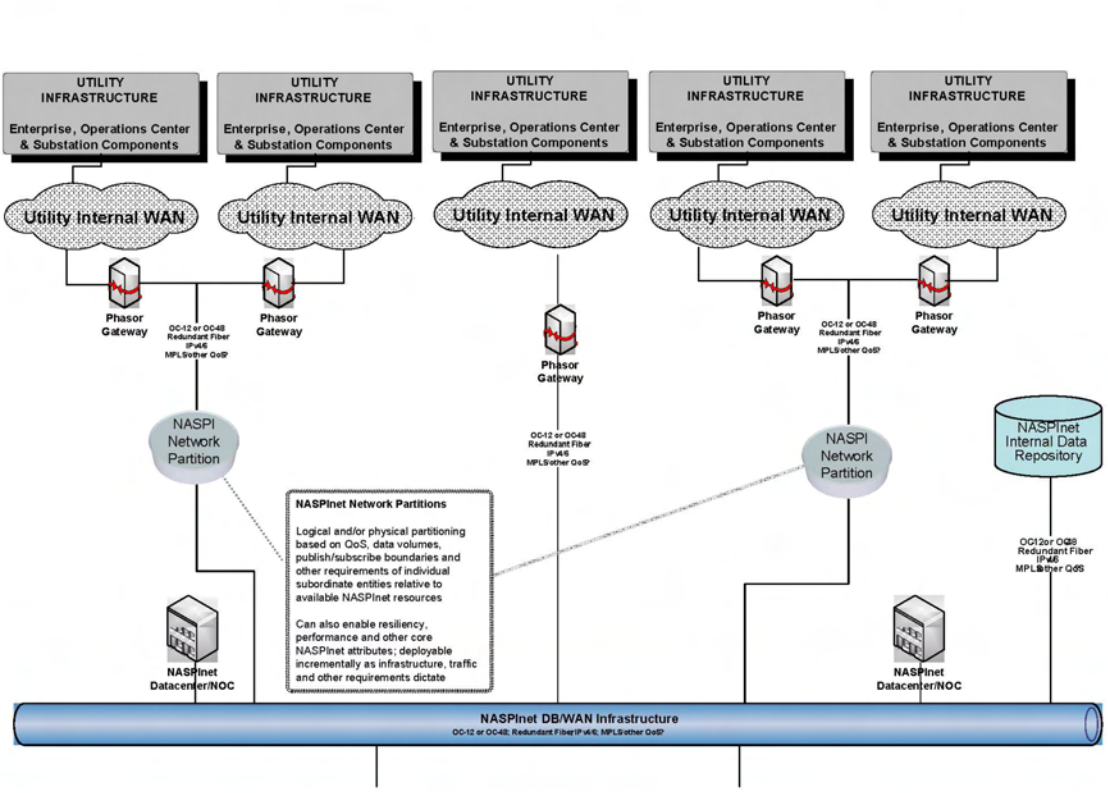

Figure 2-11: NASPInet Architecture – Network View

2.11 Deployment View

2.11.1 Introduction

The intent of this view (Figure 2-12) is to provide a high level example of how the NASPInet architecture could be instantiated physically for deployment. There are obviously myriad options for deploying a given technical architecture, and the optimal choice for NASPInet will depend on design recommended and proven for the DB_SUPPLIER proposed solution. The diagram below merely illustrates one possible alternative. The following assumptions apply to the Deployment View:

- NASPInet architecture does not mandate the use of virtualization, multiple instances of components, grid-based deployments or other deployment options; rather, the architecture should allow for a deployment design that is logically and physically partition-able in order to provide the widest range of deployment options.
- The NASPInet deployment architecture shall allow for logical and physical partitioning to achieve requirements for performance, fault tolerance and other functional and non-functional attributes.

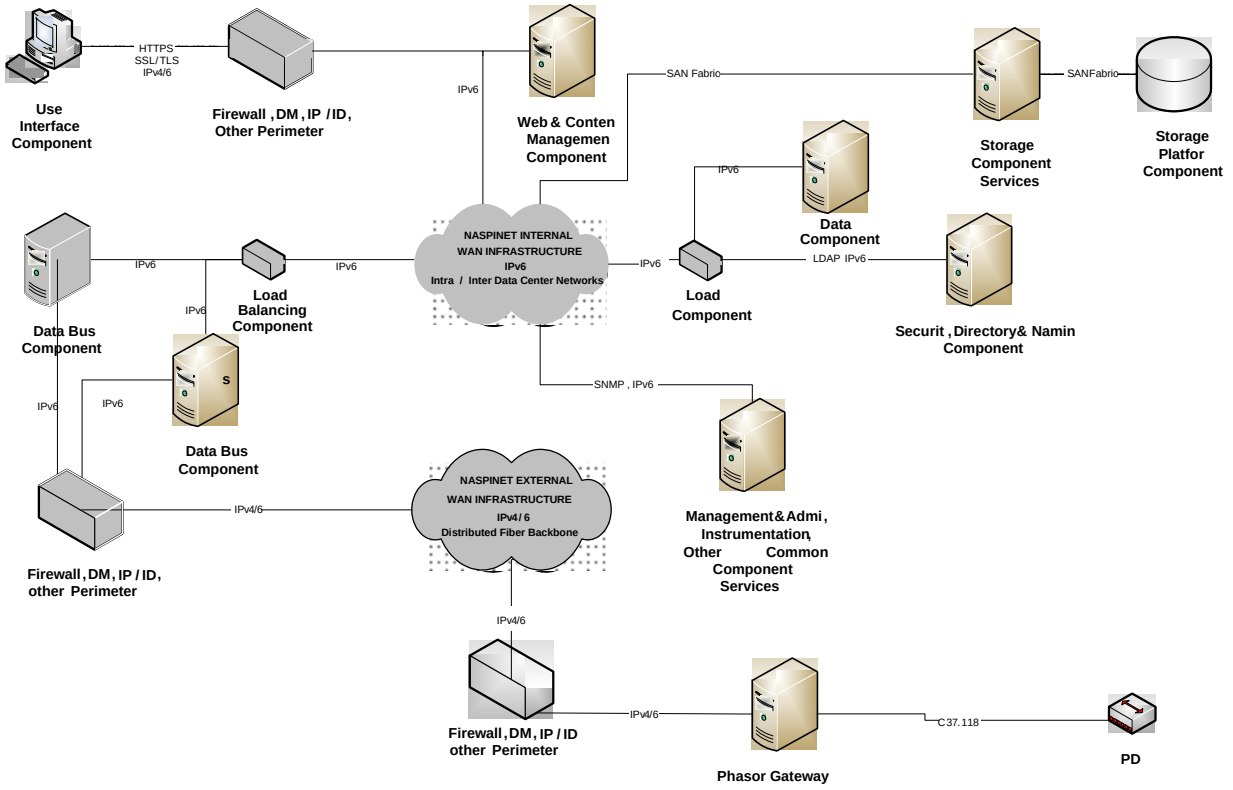

Figure 2-12: NASPInet Deployment Architecture - EXAMPLE

3 Overall NASPInet Functional Requirements

This section describes the major functions of NASPInet as a whole, including those to be performed by the Phasor Gateway (PG) and the Data Bus (DB) of NASPInet. The functional requirements in this section describe what functions that the overall NASPInet system is expected to perform, not how the functions will be designed and implemented. The DB_SUPPLIER is encouraged to propose a design that satisfies the functional requirements while making the best use of DB_SUPPLIER's standard offerings and commercial off-the-shelf products.

The NASPInet functional requirements are covered in this section in the following logical progression:

- ***NASPInet General Functional Requirements***: This subsection provides, at the system level, the general functional requirements of NASPInet.
- ***NASPInet System Administration Functions***: This subsection describes the main system administration functions of NASPInet to provide information for the DB_SUPPLIER to understand the subsequent DB Functional Requirements related to the NASPInet system administration functions.
- ***NASPInet Operational Functions***: This subsection describes the main operational functions of NASPInet to provide information for the DB_SUPPLIER to understand the subsequent DB Functional Requirements related to the NASPInet operation functions.

3.1 NASPInet General Functional Requirements

As a system, NASPInet shall provide secure and QoS guaranteed data exchange services for various types of data and control signals (See Data Service Classes below). Specifically, NASPInet shall provide the following data exchange service capabilities.

SYS-1. NASPInet shall provide a publish/subscribe based mechanism for its data exchange services. The mechanism shall enable a publisher (a publishing PG) to control the subscription to its data on a per-subscriber and per-signal basis. This means that the publisher shall be able to control the subscription to its published data at the signal granularity level for each subscriber (subscribing PG). This also means that non-subscribers shall be prevented from receiving the published data and/or decoding the data without a valid subscription.

SYS-2. NASPInet shall support publishing and subscription of both real-time streaming data and historical data available through one of the connected PGs . The publish/subscribe mechanism of real-time streaming data shall support both one-to-one and one-to-many publishing-to-subscription scenarios. The real-time streaming data exchange shall support, as a minimum, IEEE

C37.118-2005 synchro-phasor data exchange protocol for data coming into and leaving the NASPInet.

SYS-3. NASPInet shall provide a Name & Directory Service (NDS) to support the publish/subscribe mechanism. The NDS shall guarantee the unique identification of any publishing device and published signal across the entire NASPInet by using a 128-bit device ID and/or signal ID. The NDS shall provide secure means for NASPInet publishers to manage the registrations of their publishing devices, and for subscribers to obtain information of published data that are registered with the NDS and to manage their subscriptions.

SYS-4. NASPInet shall support the simultaneous data exchange of multiple subscriptions with different data service classes; each has its own QoS requirements. NASPInet shall guarantee the data exchange of each subscription meeting its QoS requirements under normal operating conditions while facilitating the data exchange of multiple subscriptions with different data service classes through network traffic management.

SYS-5. NASPInet shall monitor the QoS conformance of exchanged data to detect and report any non-conformance.

SYS-6. NASPInet shall be able to tolerate certain levels of system degradation, such as a single component failure, and shall provide emergency traffic management mechanism to sustain the best level of data exchange under degraded system conditions.

SYS-7. NASPInet shall ensure that access to its resources, such as PGs and DB components/services, are highly secure, both physically and in cyber space. The security of NASPInet shall meet corresponding NERC CIP, FIPS, and other relevant cyber security standards/guidelines.

SYS-8. NASPInet shall be flexible and expandable to support a gradual system expansion in a phased implementation approach.

SYS-9. NASPInet shall be based on open standards to the extent possible.

3.1.1 Data Service Classes

SYS-10. To support varying end-user application requirements with different data needs, NASPInet shall support, as a minimum, five (5) classes of synchro-phasor data services as identified below. Suitable service requirements shall be provided within the NASPInet to support the varying functional and performance requirements for each data class.

- **CLASS A:** This data service class supports the needs of high performance feedback control applications. This class is characterized by very low latency and a fast data rate (e.g., 60 messages per second). Class A data shall be transmitted and received as quickly as possible with a high level of data availability (i.e., there shall be minimum data gaps).

- **CLASS B:** This service class supports the needs of feed-forward control applications, such as state estimator enhancement. The latency requirement for Class B data is less strict than that for Class A data. High availability of the data is also required.
- **CLASS C:** This class of data supports view-only applications (i.e. visualization) by power system operators. The tolerance for accuracy and latency for Class C data are less stringent than Class B data. The system shall enable end-user applications to retrieve data from many PMUs across a wide geographic area.
- **CLASS D:** Class D service class supports the needs of post-mortem event analysis and other off-line studies. The system shall provide a high degree of data completeness and accuracy for this service class. However, latency of Class D data may be higher than Classes A, B and C data since analysis of Class D data will generally conducted off-line (hours or days later) with archived data, as opposed to an online real-time data stream.
- **CLASS E:** Class E data primarily supports the needs for testing and Research and Development (R&D) applications. There are no guarantees on any attributes of this data class. Class E shall be given the lowest priority of all NASPInet data traffic.

SYS-11. It is highly desirable that NASPInet is designed and implemented in an architecture framework that would provide for additional synchro-phasor data service classes in the future.

SYS-12. It is also highly desirable that NASPInet is designed and implemented in an architecture framework that would support non-synchro-phasor data exchange and non-synchro-phasor data service classes in the future, such as fault record data, non-electrical data (weather forecast data, video streams, etc.) through its publish/subscribe mechanism.

The attributes for each of the five data service classes identified above are summarized in Table 3-1 below. The QoS requirements for each data service class of NASPInet are specified in Section 8.

Table 3-1: NASPInet Traffic Attributes

NASPInet Traffic Attribute	Real-time streaming data			Historical data	
	CLASS A Feedback Control	**CLASS B Feed-forward Control**	**CLASS C Visualization**	**CLASS D Post Event**	**CLASS E Research**
Low Latency	4	3	2	1	1
Availability	4	2	1	3	1
Accuracy	4	2	1	4	1
Time Alignment	4	4	2	1	1
High message rate	4	2	2	4	1
Path Redundancy	4	4	2	1	1

Table key:
4 – Critically important, 3 – Important, 2 – Somewhat important, 1 – Not very important

3.1.2 Real-time Streaming Data and Historical Data

The five classes of data services for synchro-phasor data identified above can be grouped into two major categories: real-time streaming data and historical data. Real-time streaming data are used for real-time control and visualization applications, such as closed-loop voltage control, feed-forward remedial action control, and system stress display and visualization applications. Historical data is typically used for non-real-time applications, such as post-disturbance analysis and off-line studies.

Synchro-phasor measurement devices (e.g., PMUs) generate accurate time-tagged phasor measurement data as continuous real-time data streams. Phasor measurements are taken at pre-defined intervals with each measurement moment precisely synchronized to the UTC with a precision of < 1 u-second. The synchro-phasor data taken at each measurement moment typically is packaged into a data frame, such as IEEE C37.118-2005 data frame protocol; and the data frames are sent to applications/users as a steady data stream. The real-time streaming data from one or more measurement devices may be aggregated/disaggregated, time-aligned, and/or processed (e.g., down-sampling) by various intermediate devices, such as Phasor Data Concentrators (PDC), and then redistributed as different real-time data streams to end-users and applications. The real-time stream phasor data may also be stored and archived outside of NASPInet and become historical data for later retrieval via NASPInet.

The class A, B, and C data services of NASPInet are real-time streaming data services. The class D and E data services of NASPInet are historical data services. NASPInet shall limit the historical data that can be subscribed to data sources available via publishing PGs.

SYS-13. NASPInet shall support the real-time streaming data exchange on real-time basis, which typically must meet very strict QoS requirements for each class of the real-time streaming data. The real-time streaming data shall, as a minimum, be able to be delivered on a frame-by-frame basis.

SYS-14. The real-time streaming data may be subscribed in both one-publisher-to-one-subscriber and one-publisher-to-many-subscriber scenarios. NASPInet shall be able to deliver real-time streaming data in both scenarios.

SYS-15. NASPInet shall employ suitable techniques (e.g. IP multicasting) to optimize the communication network bandwidth usage in a one-publisher-to-many-subscriber scenario.

SYS-16. Historical data shall be delivered through NASPInet only on a one-publisher-to-one-subscriber basis. NASPInet shall deliver the historical data to subscribers as a self-sufficient data file including appropriate configuration information of the data (measurement devices, measured items, time period, data points, data format, etc.). NASPInet shall transport the historical data in a format that can be output by the data source as is – i.e., it will be up to the requesting application to transform and load the data.

3.1.3 Publish/Subscribe Mechanism

The publish/subscribe mechanism of NASPInet shall consist of three parts: device/signal registration by publishers, subscription setup between publisher and subscriber initiated by subscribers, and QoS and information assurance (data confidentiality and integrity through security measures) of the subscribed data. Publishers, i.e. publishing PGs, of the data generally would only register the data that they are willing to publish, and would not actively advertise the availability of their published data. NASPInet shall provide the following for supporting this publish/subscribe mechanism.

SYS-17. NASPInet shall limit data browsing capability to authorized subscribing PGs to minimize the risk of unauthorized access of the published data. Subscribers will be required to initiate the process of setting up a subscription by discovering available published data that they are allowed to access through data discovery requests, selecting the data to subscribe, and making the formal subscription requests for the selected data.

SYS-18. Publishers shall respond to subscribers' data discovery requests and subscription requests by granting access rights to part or all of their published data based on the authenticated identities of the subscribers.

SYS-19. NASPInet shall provide a Name & Directory Service (NDS) for its publish/subscribe mechanism, uniquely identifying each and every registered signal across the entire NASPInet. The NASPInet NDS shall also support PG registration and PG discovery for all PGs connected to the NASPInet DB. The NASPInet NDS shall be provided through DB NDS and PG device management functionality.

SYS-20. The NASPInet NDS shall enable publishers to register devices/applications and the associated signals for data publishing before their data can be published to NASPInet.

SYS-21. The NASPInet NDS shall enable subscribers to discover any accessible data that they could select and subscribe to.

SYS-22. NASPInet shall provide means for setting up subscriptions between a publisher and a subscriber for its publish/subscribe mechanism. The means shall include accessible signal discovery, subscription request, and subscription setup mechanisms.

SYS-23. The NASPInet publish/subscribe mechanism shall provide means for QoS and information assurance. Delivery of subscribed data shall meet the QoS requirements of the corresponding data classes.

SYS-24. The information assurance shall ensure the information confidentiality and integrity of the delivered data. NASPInet shall be designed to prevent published data to be received and understood by non-subscribers to maintain the data confidentiality between publisher and subscriber.

SYS-25. Information integrity assurance measures shall be implemented for detecting and reporting any tampering and degradation of the exchanged data.

3.1.4 Name & Directory Service

NASPInet shall provide a Name & Directory Service (NDS) to meet the following requirements.

SYS-26. NDS shall enable the system-wide registry of Phasor Gateways, Phasor Measurement Units, Phasor Data Concentrators, and IED devices and their associated signals as well as the services, components, processes and other entities required by the Phasor Gateway and/or Data Bus components.

SYS-27. NDS shall enable unique identification of any registered signal across the entire NASPInet on an individual signal basis.

SYS-28. NDS shall enable discovery of accessible device/application/signal.

SYS-29. NDS shall allow the concurrent use of different naming conventions.

SYS-30. NDS shall provide basis for resource management, subscription management, and traffic management.

SYS-31. NDS shall be based on metadata storage and retrieval systems to provide flexible and expandable metadata storage and retrieval capabilities. The number of fields and the size of each field of a metadata record, and the total storage capacity shall all be adjustable and expandable.

SYS-32. NDS shall provide unique IDs for each and every registered item. The IDs shall be a 128-bit random number.

SYS-33. NDS shall work in concert with NASPInet Security Service and PG Security Component to enable registered PGs to discover accessible signals by sending request to DB. NDS shall authenticate requesting PG's identity, granting access rights by source data owners, and provide accessible signal information to requesting PGs.

SYS-34. NDS shall not provide general browsing of all registered signals to minimize the risk of unauthorized access to registered signals, regardless whether the request is from registered PGs or unknown/unauthorized devices/applications.

SYS-35. NDS naming convention may include PG-OWNER's existing naming convention, NASPInet global naming convention (to be developed), and other naming conventions.

3.1.5 QoS Assurance

SYS-36. NASPInet shall implement QoS assurance based on the NASPInet resource management mechanism. The NASPInet resource management mechanism shall include resource condition monitoring, resource usage monitoring, QoS performance monitoring, QoS provisioning, and traffic management. NASPInet resources include PGs, DB components/services, and NASPInet data network components.

SYS-37. NASPInet resource condition monitoring shall provide both real-time and historical resource condition information for each resource, including logging, reporting and alarming. NASPInet resource condition monitoring shall be able to detect and report any failure and out-of-service conditions for any of its resources.

SYS-38. NASPInet resource usage monitoring shall provide both real-time and historical resource usage information on each resource through resource usage tracking, logging, reporting and alarming. The resource usage tracking shall include all resources that are involved in the data delivery chain from data entering NASPInet to data leaving NASPInet.

SYS-39. The resource usage information tracked, logged and reported shall include but not limited to detailed loading information (instant, peak, and average) of each resource for each class of the data services.

SYS-40. The NASPInet resource usage monitoring shall allow setting of alarm thresholds and generate alarms whenever tracked usage exceeds the threshold(s).

SYS-41. NASPInet QoS performance monitoring shall enable end-to-end QoS performance monitoring on a per subscription basis. NASPInet QoS performance monitoring shall provide both real-time and historical QoS information on a per subscription basis through measurement, logging, reporting and alarming.

SYS-42. NASPInet shall also provide statistical QoS information of the entire NASPInet using the logged per-subscription QoS information. The QoS information to be measured and logged shall include but not limited to latency (maximum and average), successful delivery rate, etc..

SYS-43. NASPInet shall provide accurate timing references for measuring the delivery latency for each subscription. NASPInet QoS performance monitoring shall also include the QoS performance monitoring of incoming data from registered publishing PGs.

SYS-44. NASPInet shall provide a QoS provisioning mechanism during the new subscription setup process. The QoS provisioning mechanism shall enable NASPInet to determine, once setup, if the QoS requirements of the new subscription could be satisfied based on the resource status, resource usage, and QoS performance of existing subscriptions and external publishing sources.

SYS-45. NASPInet shall provide a traffic management mechanism for QoS assurance under both normal and abnormal system conditions based on the traffic prioritization of different data service classes. NASPInet shall support data delivery based on the priority traffic levels, i.e. higher priority traffic shall always be delivered/processed before lower priority ones.

SYS-46. NASPInet shall provide means for setting the desired priorities of different types of traffic, such as the priorities for different class of data services, subscription requests/responses messages, network management traffic, control signals, etc..

SYS-47. The traffic management shall also provide means for setting traffic management policies of NASPInet for dealing with various normal and abnormal system conditions. The NASPInet shall be able to control the traffic based on the traffic management policies, resource availability, resource usage levels, and actual QoS performance measurement.

3.1.6 Security and System Resiliency

SYS-48. NASPInet shall implement a comprehensive cyber security framework to safeguard the reliable operation and the data exchange of NASPInet. The NASPInet security framework shall include secure mechanisms for identification and authentication, access control, information assurance, and security monitoring and auditing.

SYS-49. The NASPInet secure identification and authentication mechanism shall enable NASPInet to securely authorize, assign, and authenticate each and every device/equipment connected to the NASPInet and communicate through the NASPInet. The NASPInet secure identification and authentication mechanism shall enable NASPInet to securely authorize, assign, and authenticate each user who has access to NASPInet's resources.

SYS-50. The NASPInet access control mechanism shall enable NASPInet to set and enforce proper levels of access privileges and rights for each and every device/equipment connected to the NASPInet on an individual device/equipment basis. The NASPInet access control mechanism shall also enable NASPInet to set and enforce proper levels of access privileges and rights for each user of the NASPInet on an individual user basis. The objective of NASPInet access control is to ensure that only authorized and trusted users and device/equipment could gain access to the NASPInet PGs and DB components to utilize the NASPInet resources at a level that they are authorized to.

SYS-51. The NASPInet information assurance function shall enable NASPInet to guarantee the confidentiality and integrity of the data exchanged through NASPInet, which shall include secure

subscription setup, subscription based data and control flow security, key management, and information integrity assurance. These functions serve two main objectives: keep data and control flows from any unauthorized access and at the same time ensure that data and control flows have not been tempered with or degraded when traveling through the NASPInet.

SYS-52. All data traffic going through NASPInet, including administrative traffic, data/control flow, network management data, etc., shall be actively monitored, logged, analyzed and audited. Any anomaly shall be reported, traced and analyzed to determine whether it is the results of NASPInet own degradations/failures or intentional/unintentional intrusion attempts by unauthorized entities (hackers, intruders, unauthorized equipment connection, unauthorized user logins, etc.).

SYS-53. NASPInet shall generate regular security audit reports in compliance with NERC CIP reporting requirement.

SYS-54. NASPInet shall ensure a secure and reliable end-to-end data exchange for every subscription of the data.

SYS-55. NASPInet shall be resilient to external intrusions and system failures.

SYS-56. More specifically, NASPInet shall, as a minimum, implement a cryptographic key generation and management mechanism for real-time streaming data and historical data publishing and subscriptions, and implement PKI for all other message exchange communications among PGs, between PGs and DB, and within DB.

SYS-57. NASPInet's subscription cryptographic key generation and management mechanism shall ensure that all active subscriptions of real-time streaming data and historical data have no duplicated keys.

SYS-58. NASPInet's cryptographic key generation and management mechanism shall support dynamic key generation and distribution for real-time streaming data publishing and subscriptions.

3.1.7 Logging and Audit Trail

SYS-59. For auditing purposes, NASPInet shall log all user activities (e.g. access requests and the outcome of each request), system administration activities (e.g. data source registration and connection, PG's DB access requests and outcome), data subscription related activities (e.g. subscription requests and outcome), QoS alerts, cyber security alerts, application errors, etc.. Each record shall be time stamped and securely stored.

SYS-60. The PG shall allow the PG administrator to generate reports from the log, or export data from the log to a common data format such as Excel.

SYS-61. The DB components shall allow their administrators to generate reports from the log, or export data from the log to a common data format such as Excel.

SYS-62. The NASPInet shall maintain accurate audit trails of all NASPInet activities, such as user activities, system administration activities, and data subscription and delivery activities.

3.1.8 Flexibility and Expandability

SYS-63. The design and implementation of NASPInet shall provide the flexibility and expandability needed to support incremental deployment of the NASPInet.

SYS-64. The design and implementation of DB shall allow it to gradually increase the capacities of its various components and services to support the gradually increased number of PGs connected to it, the publishing devices (e.g. PMUs, PDCs) connected to publishing PGs, and the subscribing devices/applications connected to subscribing PGs.

SYS-65. The design and implementation of PG shall facilitate customization and configuration to support different data publishing and subscription capabilities of each PG.

SYS-66. The design and implementation of PG shall allow expansion from initial limited data publishing and subscription capabilities to the full capabilities described in these specifications.

SYS-67. The design and implementation of PG shall enable the increase of the processing capacity for each class of data that it supports when needed.

SYS-68. The NASPInet WAN design and implementation shall also support incremental growth in the deployment process of the NASPInet.

3.1.9 Common Services

SYS-69. The DB and the PG shall utilize, shall be compatible with, and shall integrate within the Common Services of the enterprise IT infrastructures of the respective Requester, where available and applicable. Contrasting some of these services with equivalent services within the context of the DB and PG, such as System Management and Administration, the Common Services shall perform similar functions but on a broader scale throughout the Requester's enterprise IT environment and shall integrate with it.

SYS-70. The Common Services shall include the logical components outlined below. These services may be grouped in a different set of product modules based on the commercial products used by the Requester for these services.

SYS-71. Security – this service shall provide enabling services and infrastructure to ensure the appropriate access to and usage of NASPInet resources and information. Key components typically include Authentication, Authorization, Access Control, Confidentiality, Auditing, Non-Repudiation and many others. Please see Section 7, Security Requirements, for details.

SYS-72. Management & Administration – this service shall enable the initial configuration and ongoing operation of NASPInet components and services, and will likely integrate or aggregate the analogous but more focused services within the Data Bus.

SYS-73. Name & Directory – this service shall enable the system-wide registry of Phasor Gateways, Phasor Measurement Units, and IED devices as well as the services, components, processes and other entities required by the Phasor Gateway and/or Data Bus components.

SYS-74. Resiliency – This service and infrastructure shall ensure critical system attributes such as Fault Tolerance, Availability, Disaster Recovery, Business Continuity and similar aspects.

SYS-75. Instrumentation – In concert with DB Management and Administration Services, this service shall provide visibility into key aspects of the NASPInet infrastructure, such as performance, utilization and general health indicators, for the DB network, hardware and software subsystems of DB and PG.

SYS-76. Data Management – this service shall enable the logical and physical architecture, storage, access and management of persistent and transient data within NASPInet. Key components typically include Relational Database Management engines, Storage Area Network infrastructure, Metadata Management, Hierarchical Storage Management, Information Lifecycle Management and other services.

3.2 NASPInet System Administration Functions

NASPInet shall include facilities that enable the PG administrators and DB administrators to perform system administration functions, such as registering a PG with the DB. As a minimum, the system shall provide the key System Administration functions that are described in the following subsections.

3.2.1 Register a PG with DB

SYS-77. The system shall include a function to enable the PG administrator to register a PG with the DB's NDS. PGs must be registered with the DB NDS before being allowed to publish or subscribe data on the DB and NASPInet. Attempts by an unregistered PG to publish and subscribe data on the DB of NASPInet shall be rejected by the DB of NASPInet. The DB shall generate an alarm message to alert the DB administrator to this occurrence.

SYS-78. After a PG has been installed and tested to function properly at an entity's facility for interacting with entity's own real-time streaming data devices/systems (PMUs, PDCs, etc.), historical data store, and/or applications, the PG shall be registered with NASPInet. The PG shall include a suitable function to assist the user in registering the new PG.

SYS-79. Only the PG administrator shall be allowed to register a PG with NASPInet. The PG shall prevent other users of the PG from accessing the PG registration process.

SYS-80. Following successful completion of the PG registration process, the PG shall receive a unique 128-bit PG identifier from the NASPInet administrator indicating that the PG has been registered in the DB NDS. The PG ID obtained via this process shall be required for all other system administration and operational functions to identify and authenticate a specific PG.

SYS-81. The PG ID supplied by NASPInet shall be encrypted to guard against any tempering and misuse.

SYS-82. Once a PG has been successfully registered with NASPInet, all streaming and historical data source devices/systems connected and registered with the PG shall also be registered with the NASPInet DB NDS before the PG can publish any data from these devices/systems to NASPInet.

SYS-83. After successful registration of a PG, the applications running on the PG owner's own network and PG administrator shall be able to inquire, subscribe and access available streaming and historical data from other PGs that are already registered with the NASPInet through the PG registration process.

SYS-84. A PG requesting registration shall also obtain the method from DB to authenticate identities of DB components and any messages that it receives from NASPInet DB.

SYS-85. A PG could have varied degrees of capabilities in terms of published/subscribed data classes, such as QoS requirements and support. A PG registered with NASPInet shall indicate its capabilities in terms of published/subscribed data classes.

SYS-86. The PG Registration function shall specify the PG throughput information for each class of published/subscribed data that the PG supports.

SYS-87. A PG's Registration shall provide information that is needed for other PG owners to identify the PG's owner and the PG capabilities. As a minimum, the information shall include:

- Owner information
- Location information
- PG capabilities information (e.g. classes of data services supported)

3.2.2 Update PG Registration with DB

SYS-88. The PG administrator shall be able to update the registration of a PG that has previously been registered to accurately inform NASPInet about changes in the functionalities and capabilities of the PG. For example, it shall be possible to change an existing publishing Class C data only PG to a publishing Class B and C data PG.

SYS-89. Only the PG administrator shall be permitted to update a PG's registration with NASPInet. The PG shall reject all attempts by persons other than the PG administrator to update the PG's registration.

SYS-90. The PG shall include a user interface function that shall enable the PG administrator to enter the updated registration information and send the requested changes to NASPInet. The PG administrator shall be validated locally by PG's security management logic (see Section 7 of the PG Technical Specifications).

SYS-91. The PG shall perform extensive validity checks of the inputs to ensure that the updated information is accurate and reasonable. The PG shall detect validity check failures and notify any errors to the PG administrator and allow the PG administrator to correct these errors. No registration update data shall be sent to the DB prior to successfully completing the validity checks.

SYS-92. After successful validation of the registration information, the PG shall send a registration update request message to the DB's NDS with the updated information.

SYS-93. If no errors are detected by the DB in the updated information, the PG shall receive a message from the DB indicating that the PG's registration with NASPInet has been successfully updated.

SYS-94. After the PG's registration with NASPInet has been successfully updated, the PG shall begin publishing data to NASPInet and/or subscribing data from NASPInet in accordance with the updated registration.

SYS-95. Data exchange of existing subscriptions shall be automatically stopped and resumed as needed during the PG registration update process.

SYS-96. The PG and DB shall ensure that all subscriptions to discontinued data services be terminated in an orderly way prior to updating the DB registration.

3.2.3 Remove a PG from DB

SYS-97. The PG shall include a function to enable the PG Administrator to remove a registered PG from NASPInet at any time.

SYS-98. The PG administrator shall be validated locally by PG's security management logic. Only the PG Administrator shall be allowed to remove a PG's registration with NASPInet; no other PG users shall have any access to the PG registration removal process.

SYS-99. The PG shall send a removal request message to the DB. Following successful authentication by the DB, the PG shall be prompted to confirm its intention for PG removal. If confirmation of the request for PG removal is not received within a user specified time period, the request shall be cancelled.

SYS-100. Following confirmation of its intention for PG removal by the requesting PG, the DB shall attempt to remove the registration. If the PG registration cannot be removed, the DB shall log and inform the PG of the reason for unsuccessful registration removal.

SYS-101. After the PG's registration with NASPInet is removed, the PG shall no longer be able to publish streaming and historical data to NASPInet and the PG shall no longer be able to subscribe to and receive data from streaming and historical data sources of other registered PGs on NASPInet.

SYS-102. The DB shall ensure that all subscriptions related to the removed PG be terminated in an orderly way in the PG removal process.

3.2.4 Register a Real-Time Streaming Data Source (RT-SDS)

SYS-103. All real-time streaming data sources (RT-SDS) that will serve as a streaming data source through the NASPInet must be connected to and registered with a PG that is registered with NASPInet.

SYS-104. All real-time streaming data sources shall be registered with the NASPInet through the data source owner's PG before the data source can publish data to NASPInet through the PG.

SYS-105. The PG shall not publish any data from an unregistered RT-SDS device/system to NASPInet.

SYS-106. Prior to registering the data source, the data source owner shall verify that the data source is operating and communicating successfully with the PG. The PG shall include suitable communication/test facilities to verify that each data source is installed, operating, and communicating properly with the PG.

SYS-107. To enable a registered RT-SDS device/system and its signals to be queried and accessed by NASPInet subscribing PGs, the registering PG shall provide all required information to NASPInet DB, including the following as a minimum:

- Physical location of the device (Country, State, Geo-coordinates, etc.)
- Location identification (substation name, building name, etc.)
- Type of device (PMU, PDC, etc.)
- Device identification (device name, sequence number, etc.)
- Device configuration (physical & logical)
- Complete signal description (type of signal, reporting rate, data format, etc.)
- Signal origin (e.g., original PMU signal that a PDC signal is derived from)
- Signal source (measurement CT/PT, source devices, etc.)

- Signal processing methods (if not original signal)
- Signal quality (data class – latency, reliability, etc.)
- Signal access method through P-PG (1-to-1, 1-to-N, etc.)
- Ownership (entity name)
- Names according to PG owner naming convention
- Names according to NASPInet naming convention

SYS-108. It shall be possible to register an individual RT-SDS or small number of RT-SDSs interactively using the PG user interface.

SYS-109. The PG shall also include a convenient mechanism for registering a large number of RT-SDS devices/systems that frequently register/remove themselves with/from the NASPInet on a regular basis.

Human intervention to manage the timely registration and removal process of such RT-SDS devices/systems may be impractical. Requirements for interactive registration and automatic registration of a large number of RT-SDSs are described in the following subsections.

3.2.4.1 Interactive Registration

SYS-110. The PG shall include a function to allow interactively registering the RT-SDS with NASPInet. This function shall include display screens with data entry fields for entering information about the RT-SDS, such as device/system type, available signals, and other pertinent information about the RT-SDS.

SYS-111. The PG shall perform extensive error checking on the entered data shall inform the user if erroneous, invalid, or inconsistent data is entered. This function shall prevent erroneous, invalid, or inconsistent data from being submitted to NASPInet.

SYS-112. After the data errors have been corrected by the user, the registered PG shall send a RT-SDS Registration Request message to the DB with the pertinent RT-SDS information.

SYS-113. After authentication of PG and data source and validation of the data, DB shall send unique signal IDs (128-bit) and a RT-SDS device ID (128-bit) to the requesting PG along with a registration complete message. The requesting PG shall store the unique signal ID received from DB and acknowledge receipt of this information.

SYS-114. After successful completion of the interactive registration process, the PG shall be able to publish data from the registered RT-SDS device/system to other subscribing PGs registered with the NASPInet.

3.2.4.2 Automatic Registration

SYS-115. An alternative registration process that does not require PG administrator involvement shall be provided for RT-SDS devices that have been entered into the DB's NDS database via a registered PG, either through previous registration or other secure method. RT-SDS devices that satisfy this requirement shall receive secure unique IDs from NASPInet that shall be used to facilitate the automatic RT-SDS registration process.

SYS-116. The PG shall support automated registration of a RT-SDS device/system through the PG without PG administrator's involvement. After a successful automated RT-SDS device/system registration with the PG, the PG shall automatically send a "RT-SDS registration request" message to DB's NDS with the RT-SDS device/system's information to DB's NDS.

SYS-117. If no errors are detected by the DB in the registered RT-SDS device/system's information, the PG will receive unique signal IDs for all signals of the registering RT-SDS device/system, along with a "RT-SDS registration complete" message.

SYS-118. The PG shall acknowledge the receipt of the confirmation and shall store the signal IDs to complete the registration process.

SYS-119. After successful completion of the automatic registration process, the PG shall be able to publish data from the registered RT-SDS device/system to other subscribing PGs registered with the NASPInet.

SYS-120. In the event that the RT-SDS registration process is unsuccessful for any reason or the PG does not receive assigned signal IDs or RT-SDS registration complete message from the DB within a user specified time period, the PG shall log the RT-SDS incomplete registration request process in its application error log.

3.2.5 Update a Real-Time Streaming Data Source

SYS-121. The PG shall include an administration function to change the configuration of an existing registered RT-SDS device or system that is currently publishing streaming data to the NASPInet. For example, it shall be possible to update the registration of a Phasor Data Concentrator (PDC) when PMUs are added or removed from the PDC, resulting in the PDC supplying more or fewer signals to the NASPInet.

SYS-122. The PG shall support interactive updates and automatic updates, as described in the following sections.

SYS-123. Updating RT-SDS registration with PG and DB shall ensure that all subscriptions related to the RT-SDS will be terminated in an orderly way prior to the start of the RT-SDS updating process.

3.2.5.1 Interactive Updates

SYS-124. The PG shall include a function to allow interactively updating of the existing registered RT-SDS with NASPInet. This function shall include display screens with data entry fields to enable the PG Administrator to enter the information needed to update the registration of the RT-SDS. This includes device/system type, available signals, and other pertinent information about the RT-SDS. The PG shall perform extensive error checking on the entered data and shall inform the user if erroneous, invalid, or inconsistent data is entered so that the data can be corrected. This function shall prevent erroneous, invalid, or inconsistent data from being submitted to NASPInet.

SYS-125. After any data errors have been corrected by the user, the registered PG shall send an RT-SDS registration update request message to the DB's NDS with the updated RT-SDS information to be stored by the DB's NDS.

SYS-126. If the data is correct, the requesting PG shall receive unique signal IDs along with a "RT-SDS registration update complete" message. The requesting PG shall store the unique signal IDs received from DB and acknowledge receipt of this information.

SYS-127. After successful completion of the interactive registration update process, PG shall be able to publish data from the registered RT-SDS device/system that is just updated to other subscribing PGs registered with the NASPInet.

SYS-128. In the event that the RT-SDS registration update process is unsuccessful for any reason or the PG does not receive assigned signal IDs or RT-SDS registration complete message from the DB within a user specified time period, the PG shall log the RT-SDS incomplete registration update request process in its application error log. In addition, the DB administrator shall be notified about the failed RT-SDS registration request.

SYS-129. The DB shall automatically stop any active publish/subscribe data activities involving the RT-SDS before the registration update process, informing all subscribing PGs of the interruptions. After the registration is complete, the DB shall send a message to the publishing and subscribing PGs to reinitiate the publishing and subscriptions of the data.

3.2.5.2 Automatic Registration Updates

SYS-130. An alternative registration process that does not require PG administrator involvement shall be provided for RT-SDS devices that have been entered into the DB's NDS database, either through previous registration or other secure method. RT-SDS devices that satisfy this requirement will receive secure unique IDs from NASPInet that shall be used to facilitate the automatic RT-SDS registration update process.

SYS-131. The PG shall support automated registration updates for a RT-SDS device/system with the PG without PG administrator's involvement. After a successful automated RT-SDS device/system registration update with PG, the PG shall automatically send a "RT-SDS

registration update request" message to DB's NDS with the RT-SDS device/system's updated information to DB's NDS.

SYS-132. If the DB's data verification and validation process is successful, the PG will receive unique signal IDs for all signals of the updated RT-SDS device/system, along with a "RT-SDS registration updated complete" message to the requesting PG.

SYS-133. The PG shall acknowledge the receipt of the confirmation and shall store the unique signal IDs to complete the registration process.

SYS-134. After successful completion of the automatic registration update process, PG shall be able to publish data from the registered RT-SDS device/system that is just updated to other subscribing PGs registered with the NASPInet

SYS-135. In the event that the RT-SDS automatic registration update process is unsuccessful for any reason or the PG does not receive assigned signal IDs or RT-SDS registration complete message from the DB within a user specified time period, the PG shall log the RT-SDS incomplete registration update request process in its application error log. In addition, the DB administrator shall be notified about the failed RT-SDS registration request.

SYS-136. The DB shall automatically stop any active publish/subscribe data activities involving the RT-SDS before the registration update process, informing all subscribing PGs of the interruptions. After the registration is complete, the DB shall send a message to the publishing and subscribing PGs for the PGs to reinitiate the publishing and subscriptions of the data.

3.2.6 Remove a Real-Time Streaming Data Source

SYS-137. The system shall allow one or more registered and communicating RT-SDS devices to be taken offline in a planned and orderly manner for various reasons, such as testing, firmware upgrade, and other maintenance activities. No real-time streaming data will be published from phasor measurement devices that are offline.

SYS-138. After the RT-SDS is taken offline, it shall be possible to disconnect the RT-SDS from the PG for performing various work activities, such as firmware update, testing, and other maintenance activities.

SYS-139. The system shall facilitate return an RT-SDS that has been taken offline from the service. If no change to its registration is needed, PG and DB shall be notified of the RT-SDS returning to service, and confirmation shall be received before it can publish data again. If change to its registration is needed, then either a normal registration process or a registration update process must be conducted before it can publish data again.

SYS-140. The system shall support interactive removal and automatic removal of RT-SDS services, as described in the following requirements.

SYS-141. Removing a RT-SDS registration or service from DB shall ensure that all subscriptions related to the RT-SDS will be terminated in an orderly way prior to the start of the RT-SDS removing process.

SYS-142. The PG shall include a user interface function that shall enable the PG administrator to remove a registered, active RT-SDS device from service, or remove its registration. Upon request from the PG administrator, the PG shall send an RT-SDS removal request message to DB's NDS to initiate and complete the RT-SDS removal process.

SYS-143. The system shall include a function to support automatic removal of a RT-SDS from service. After confirming a removal request from a RT-SDS device/system, the PG shall automatically send an RT-SDS removal request message to DB's NDS to initiate and complete the RT-SDS removal process. Registration shall not be removed automatically through this process; the PG administrator will need to use the interactive method stated above to remove the registration when needed.

3.2.7 Register a Historical Data Source (HDS)

SYS-144. The PG shall be able to acquire data from historical data sources (HDS) external to the NASPInet such as phasor data concentrators (PDCs) that have data storage capabilities. As with streaming data sources, historical data sources can publish their data to NASPInet via a PG. Any HDS that supplies data to NASPInet subscribers shall be registered through the HDS owner's PG.

SYS-145. The PG shall include a user interface function to facilitate registering an HDS with NASPInet.

SYS-146. To register with NASPInet, each HDS shall be required to meet the minimum requirements listed below. The PG shall verify that these capabilities exist before attempting to register the HDS with NASPInet.

- Each HDS shall include a mechanism to enable PGs and subscribers to query, request, and obtain the stored data for selected signals for a specific period of time.
- Each HDS shall be able to provide on demand to any authorized PG or subscriber a complete description of the types of stored data (measurement points list, sampling rates, length of storage, maximum data file size per request, etc.) that it provides and the format of this data.
- Each HDS shall be able to accept and store the unique device and signal IDs assigned by the DB for all stored synchro-phasor data points originated from RT-SDSs as part of the data storage.

SYS-147. The PG of an HDS shall be able to provide access to phasor measurements that were originally supplied by the RT-SDSs of the PG's and HDS's owning entity. The PG of the HDS shall not provide access to phasor measurements supplied by RT-SDSs of other publishing entities (P-PGs) without the permission of the owning entities of these RT-SDSs.

SYS-148. Prior to registering the HDS with NASPInet, the PG shall confirm that the HDS has been installed, operating, and communicating properly with the PG.

SYS-149. The PG shall include suitable facilities to verify that the HDS is operating and communicating properly.

SYS-150. All RT-SDS devices that supply data to the HDS shall be registered with the HDS. The HDS shall store the unique signal IDs assigned by NASPInet to signals published by the RT-SDS devices/systems to NASPInet.

SYS-151. To initiate registration of a historical data source, the PG shall send an HDS registration request message to DB's NDS with the necessary HDS information, such as RT-SDS device IDs and signal IDs for publishable data points when prompted.

SYS-152. It shall be possible to register the HDS interactively or automatically, as described in the following sections.

3.2.7.1 Interactive Registration

SYS-153. The PG shall include a function to allow the PG administrator to register the HDS using interactive display screens. The PG shall include security management logic to validate the administrator locally. Once validated by the PG's security management logic, the PG administrator shall be able to initiate an HDS registration request message to the DB's NDS.

SYS-154. Upon successful authentication by DB's NDS, the PG shall be able to enter and send the HDS registration information. The PG's registration function for HDS devices shall include display screens with suitable data entry field for inserting the necessary registration information to register the HDS and the data it can provide. Following completion of data entry, the PG administrator shall be able to send this information to the DB's NDS.

SYS-155. If data verification and validation checks performed by the DB's NDS on the PG-supplied data are not successful, the DB shall send the PG an error message and log the error in its error log.

SYS-156. If the data verification and validation checks are successful, the PG shall receive the unique device and signal IDs of registered RT-SDSs for all signals of the registering HDS device/system, along with a unique ID for the HDS and an "HDS registration complete" message.

SYS-157. The PG shall acknowledge the receipt of the confirmation message and shall store the received device and signal IDs and forward them to HDS. After successful completion of the interactive registration process, the PG shall be able to publish historical data from the registered HDS device/system to other subscribing PGs registered with the NASPInet.

3.2.7.2 Automatic Registration

SYS-158. The system shall provide an automatic registration function for HDS devices/systems that support the automatic registration. To be accepted for automatic registration, the HDS device/system must have obtained a secure unique ID through previous registration with DB's NDS database or other secure method. The PG shall be configurable to support registration of an HDS device/system with or without the PG administrator's involvement.

SYS-159. The PG shall support automated registration of HDS device/system registration with PG without PG administrator's involvement. After a successful automated HDS device/system registration with PG, the PG shall automatically send an "HDS registration request" message to DB's NDS. Upon successful authentication by the DB's NDS, the PG shall send the registered HDS device/system's information to DB's NDS.

SYS-160. If the data verification and validation checks are successful, the PG shall receive the unique device and signal IDs of registered RT-SDSs for all signals of the registering HDS device/system, along with a unique ID for the HDS and an "HDS registration complete" message.

SYS-161. PG shall acknowledge the receipt of the confirmation and shall store the received device and signal IDs and forward them to HDS to complete the registration process.

SYS-162. After successful completion of the automatic registration process, the PG shall be able to publish data from the registered HDS device/system to other subscribing PGs registered with the NASPInet.

SYS-163. In the event that the automatic HDS registration process is unsuccessful for any reason, e.g. the PG does not receive assigned device IDs or HDS registration complete message from the DB within a user specified time period, the PG and DB shall log the HDS incomplete registration request process in its application error log and notify PG and DB administrators.

3.2.8 Update an Historical Data Source

SYS-164. The PG shall include an administration function to allow the update of changes in the configuration and/or available historical data points of an existing registered HDS device or system that is currently publishing historical data to the NASPInet. For example, it shall be possible to add or delete HDS stored data points resulting in the PG supplying more or fewer historical data points to the NASPInet.

SYS-165. The PG shall support both interactive updates and automatic updates, as described in the following sections.

SYS-166. Updating HDS registration with PG and DB shall ensure that all subscriptions related to the HDS will be completed or terminated in an orderly way prior to the start of the HDS registration updating process.

3.2.8.1 Interactive Updates

SYS-167. The PG shall include a function to allow interactive update of the existing registered HDS systems and devices with NASPInet. This function shall include display screens with data entry fields to enable the PG Administrator to enter the information needed to update the registration of the HDS. This includes device/system type, available signals, and other pertinent information about the HDS. The PG shall perform extensive error checking on the entered data and shall inform the user if erroneous, invalid, or inconsistent data is entered so that the data can be corrected before submitting this data to NASPInet. This function shall prevent erroneous, invalid, or inconsistent data from being submitted to NASPInet.

SYS-168. After any data errors have been corrected by the user, the registered PG shall send an HDS registration update request message to the DB's NDS with the updated HDS information when prompted.

SYS-169. If the registration update is successful, the PG shall receive the unique device and signal IDs for new devices and signals added to the HDS along with an "HDS registration update complete" message. The requesting PG shall acknowledge the receipt of this information, and store and pass the unique device and signal IDs for new devices and signals to HDS to complete the registration update process.

SYS-170. After successful completion of the interactive registration update process, PG is ready to publish data from the registered HDS device/system that has just been updated to subscribing PGs registered with the NASPInet.

SYS-171. If the registration update is not successful, the DB shall send the PG an error message and log the error in its error log.

3.2.8.2 Automatic Registration Updates

SYS-172. The system shall provide an automatic registration update function for HDS devices that support automatic registration update. To be able to perform automatic registration update, the HDS device/system must have obtained a secure unique ID either through previous registration or other secure method. HDS devices that satisfy this requirement shall receive a secure unique ID from NASPInet that shall be used to facilitate the automatic HDS registration update process. The PG shall be configurable to support registration of an HDS device/system with or without the PG administrator's involvement.

SYS-173. The PG shall support automated registration updates for a HDS device/system with the PG without PG administrator's involvement. After a successful automated HDS device/system registration update with PG, the PG shall send the registered HDS device/system's updated information to DB's NDS.

SYS-174. Following successful verification and validation of the information sent by the PG, the DB NDS shall send device and signal IDs for all affected signals of the HDS device/system to PG and the PG shall receive a "HDS registration update complete" message.

SYS-175. The PG shall acknowledge the receipt of this information, and store and pass the unique device and signal IDs for new devices and signals to HDS to complete the registration process.

SYS-176. After successful completion of the automatic registration update process, the PG shall be able to publish data from the registered HDS device/system that has just been updated to subscribing PGs registered with the NASPInet.

SYS-177. In the event that the automatic HDS registration process is unsuccessful for any reason, the PG shall log the HDS incomplete registration request process in its application error log. In addition, the DB and PG administrator shall be notified about the failed HDS registration update request.

3.2.9 Remove an Historical Data Source

SYS-178. The system shall allow one or more registered and communicating HDS devices to be taken off-line in a planned and orderly manner for various reasons, such as testing, software upgrade, and other maintenance activities. No historical data shall be published from HDS systems/devices that are off-line.

SYS-179. After the HDS is taken off line, it shall be possible to disconnect the HDS from the PG for performing various work activities, such as software update, testing, and other maintenance activities.

SYS-180. An HDS that has been taken off-line shall take steps as needed to return it to the service. If no change to its registration is needed, PG and DB shall be notified and confirmation shall be received before it can publish data again. If change to its registration is needed, then either a normal registration process or a registration update process must be conducted before it can publish data again.

SYS-181. The system shall support interactive removal and automatic removal of HDS devices.

SYS-182. Removing a HDS registration from DB shall ensure that all subscriptions related to the HDS will be completed or terminated in an orderly way prior to the start of the HSDS removing process.

SYS-183. The PG shall include a user interface to allow the PG administrator to remove a registered HDS device from service, or remove its registration. Upon request from the PG administrator, the PG shall send an HDS removal request message to DB's NDS to initiate and complete the removal process. Registration shall not be removed automatically through this process; the PG administrator will need to use the interactive method stated above to remove the registration when needed.

SYS-184. The system shall support automatic removal of an HDS from service. Upon receiving a request from an HDS device/system, the PG shall automatically send an HDS removal request message to DB's NDS to initiate and complete the automatic HDS removal process to remove it from the service.

3.3 NASPInet Operational Functions

3.3.1 Query Available Real-Time Streaming Data Sources

SYS-185. The PG with subscribing capability shall enable its user/application/subscriber to query the active registered RT-SDS devices/systems on NASPInet to determine what streaming data is available that it can access. Only subscribing PGs (S-PG) that are currently registered with the NASPInet DB NDS shall be able to query the active real-time streaming data sources. The S-PG shall be able to use the data obtained via the query process to select the proper signals for subscription.

SYS-186. The publishing PG (P-PG) shall have full control over the access rights to the data it publishes. The P-PG shall be able to grant or deny access to all or part of its data to the subscribing PGs.

SYS-187. To allow the P-PG full control of access to its data, all inquiries for a P-PG's published data shall be routed to the P-PG with S-PG's identification.

SYS-188. Only RT-SDS signals that can be accessed by the S-PG with access right granted by P-PG will be shown to the S-PG. The P-PG shall supply, as a minimum, the unique signal IDs, and part or all of the following RT-SDS signal information of accessible RT-SDS signals to the inquiring S-PG:

- Physical location of the device (Country, State, Geo-coordinates, etc.)
- Location identification (substation name, building name, etc.)
- Type of device (PMU, PDC, etc.)
- Device identification (device name, sequence number, etc.)
- Device configuration (physical & logical)
- Complete signal description (type of signal, reporting rate, data format, etc.)
- Signal origin (e.g., original PMU signal that a PDC signal is derived from)
- Signal source (measurement CT/PT, source devices, etc.)
- Signal processing methods (if not original signal)
- Signal quality (data class – latency, reliability, etc.)

- Signal access method through P-PG (1-to-1, 1-to-N, etc.)
- Ownership (entity name)
- Names according to PG owner naming convention

SYS-189. To inquire about available RT-SDS data sources, the inquiring S-PG shall send an RT-SDS data source inquiry request message to DB.

SYS-190. It shall be possible for the S-PG to submit either generic inquiries to all P-PGs or inquiries that are targeted to specific P-PGs.

SYS-191. Following successful authentication of the requesting S-PG, the DB shall forward the S-PG's request, its ID and pertinent registration information to targeted or all registered P-PGs.

SYS-192. The targeted or all registered P-PGs shall return to DB a list of the signal IDs that the inquiring S-PG is allowed to access. The DB shall, in turn, forward the information received from the P-PGs, including the available signal IDs, to the inquiring S-PG.

3.3.1.1 Interactive Query of P-PGs for Aavailable RT-SDS Signals

SYS-193. The S-PG shall include a function that shall enable the S-PG administrator to submit inquiries about available streaming data sources to either targeted or all P-PGs. The function shall enable the PG administrator to send a "show me the available RT-SDS signals" request to DB with or without a list of targeted P-PGs.

SYS-194. After the requesting S-PG's ID has been authenticated, DB shall forward the inquiry to the either targeted P-PGs or all P-PGs with requesting S-PG's ID and information.

SYS-195. The administrators of the targeted P-PGs shall identify RT-SDS signals that the requesting S-PG is allowed to access, and shall send a list of signal IDs and detailed signals information for those signals that S-PG is allowed to access (if any) to the S-PG via the DB.

SYS-196. The S-PG administrator shall be able to select from the available RT-SDS signals and shall be able to store available signal IDs and other necessary information in S-PG.

3.3.1.2 Automated Querying of P-PGs for Available RT-SDS Signals

SYS-197. An S-PG shall be able to query NASPInet periodically without the S-PG administrator's involvement to update the list of RT-SDS signals that it can access. The S-PG shall automatically send an inquiry request to all P-PGs or a select subset of P-PGs that are known to S-PG and are currently registered with NASPInet.

SYS-198. The S-PG shall be able to send a "show me the available RT-SDS signals" request to either all P-PGs or targeted P-PGs via the DB. The DB shall authenticate the S-PG before sending the request along with the S-PG ID and pertinent registration information to the P-PGs.

SYS-199. The P-PG shall examine the request to determine which signals that S-PG is allowed to access. The list of signal IDs for those signals that the S-PG is allowed to access (list may be empty) shall be sent to DB, which, in turn, will forward detailed signals information and along with the P-PG's ID to the requesting S-PG.

SYS-200. The S-PG shall then be able to store signal IDs, signals' information, and P-PG's ID. The stored data shall allow the PG administrator or authorized/authenticated application to select signals to subscribe to at a later time.

3.3.2 Subscribe to a Real-Time Data Stream

SYS-201. The S-PG shall include facilities to enable the S-PG and S-PG administrator to subscribe to real-time data streams that are available to it from NASPInet publishers (P-PGs). The S-PG and S-PG administrator shall first use the query function (Section 3.3.1) to discover the available signals and obtain detailed information about the available signals.

SYS-202. P-PG and P-PG administrator shall provide S-PG and S-PG administrator with data stream start and stop methods for subscribed signals as part of the subscription setup process.

SYS-203. DB shall provide subscription management and cryptographic key management to support RT subscription setup between an S-PG and a P-PG. DB shall ensure that there is no duplicated subscription IDs and security keys for all active subscriptions.

SYS-204. The DB cryptographic key management shall include various mechanisms, such as dynamically changing keys, to keep RT-SDS data secure from non-subscribers.

SYS-205. To subscribe to real time streaming data, registered S-PG shall send a "RT-SDS signals subscription request" message to the P-PG that publish the signals via the DB.

SYS-206. The DB shall authenticate the S-PG. After successful authentication, the DB shall send a subscription ID to S-PG and request the S-PG to send the signal IDs of the subscription and forward the information to the corresponding P-PG along with the subscription ID.

SYS-207. The DB and P-PG shall store the subscription ID, the requested signal IDs and S-PG ID as part of setting up the subscription. Once complete, the P-PG shall be able to send subscription related information, via DB, such as real time streaming data start/stop methods, to the S-PG.

SYS-208. The S-PG shall store the received information and shall at this point be able to start and stop receiving the subscribed data.

3.3.3 Start Receiving a Subscribed Real-Time Data Stream

SYS-209. Real-time data may only be received by a S-PG after obtaining authorization for a subscription as described in 3.3.2. Once an S-PG has a subscription, it shall be able to start and stop the data flow from a P-PG according to its data needs.

SYS-210. To start the data flow, the S-PG shall send the start data flow command to the P-PG via the DB with appropriate authentication information including its subscription number.

SYS-211. Once the P-PG has received the request, it shall send a response to the S-PG, via the DB, to acknowledge the command with a time that it will start sending data or a denial with a reason as to why it will not send data.

SYS-212. If the start request failed, the S-PG shall log the occurrence and take appropriate action, depending on the response. The P-PG shall also log the transaction.

SYS-213. If the start request succeeded, the S-PG shall prepare to receive the data and log the activity. The P-PG shall also log the transaction.

SYS-214. The PG shall also allow the PG administrator to schedule the start of the real-time data stream request, i.e., setting a time when the S-PG will send the signal to start receiving the subscribed real-time data.

SYS-215. The PG shall support manual request by the S-PG administrator to initiate real-time data flow by sending a signal to the P-PG, on demand via the DB, to request real-time data.

3.3.4 Stop a Subscribed Real-Time Data Stream

SYS-216. Real-time data will only be received from a publishing PG (P-PG) by a subscribing PG (S-PG) that has a valid subscription. After an S-PG has started receiving data, the data flow can be stopped by either the P-PG or the S-PG.

3.3.4.1 Stopping by P-PG Request

SYS-217. The P-PG shall be able to stop the real-time data flow by sending a stop data advisory to the S-PG via the DB. This advisory shall include reason for stopping including PG shutdown, PG maintenance, subscription change, access revocation, and loss of data input to PG, etc.

SYS-218. After sending a stop data advisory, the P-PG shall wait an administrator-configurable time for a reply acknowledgement (if possible) before stopping the data flow.

SYS-219. The PG shall allow the P-PG administrator to schedule the stop real-time data stream request, i.e., setting a time when the P-PG will send the stop data advisory and stop publishing the real-time data.

SYS-220. The PG shall support manual request by the P-PG administrator to stop the real-time data flow.

SYS-221. The data stop advisory may also be triggered automatically by certain events. The P-PG shall detect loss of data ingest from the RT-SDS and internal errors that could affect the publishing of the real-time data stream. When such conditions are detected, the P-PG shall send a stop data advisory to S-PGs that subscribe to the data, via the DB, and stop sending data.

SYS-222. The DB, S-PG, and P-PG shall all log the transaction.

3.3.4.2 Stopping by S-PG Request

SYS-223. An S-PG shall be able to stop the data flow at any time by sending a stop data command to the P-PG, via the DB, with appropriate authentication information including the subscription number. Once the DB receives the P-PG confirmation of the request, it shall send a response to the S-PG to acknowledge the command with a time that it will stop the data flow or a failed message with a reason as to why it could not stop the data.

SYS-224. If data flow will be stopped successfully, the S-PG shall prepare to stop receiving data , send a notice to connected applications, and log the activity.

SYS-225. The PG shall allow the S-PG administrator to schedule the stop real-time data stream request, i.e., setting a time when the S-PG will send the stop data request and stop receiving the real-time data.

SYS-226. The PG shall support manual request by the S-PG administrator to stop the real-time data flow.

SYS-227. The DB, S-PG, and P-PG shall all log the transaction.

3.3.5 Unsubscribe From a Subscribed Real-Time Data Stream

Both S-PG and P-PG shall be able to terminate a RT data subscription. This procedure assumes there is already a data subscription in place between the two PGs.

3.3.5.1 Subscription Revocation by P-PG

SYS-228. The P-PG shall allow the P-PG administrator to revoke a subscription. The P-PG shall send a subscription revocation notification to the targeted S-PG via the DB.

SYS-229. The S-PG shall send an acknowledgement of the notification.

SYS-230. The P-PG shall wait an administrator-configurable period of time for the acknowledgement. Whether a response is received or not within the waiting period, the P-PG shall revoke the subscription and send confirmation notice of the revocation to the S-PG.

SYS-231. The S-PG shall take appropriate action with connecting applications such that the data would be stopped gracefully.

SYS-232. If there is an active data flow under the subscription in question, the P-PG shall stop the real-time data flow using the Stop Real-Time Data Stream function outlined above.

SYS-233. If there is no more subscription to the data from any PGs after the removing the requested subscription, the P-PG shall stop ingesting the real-time data to NASPInet.

SYS-234. The DB, the P-PG and the S-PG shall all log the transaction and notify the PG administrator as needed.

3.3.5.2 Un-subscription Initiated by S-PG

SYS-235. The S-PG shall be able to unsubscribe from a RT data stream. The S-PG shall send a notification to unsubscribe a subscription to the appropriate P-PG, via the DB, with the subscription number. The DB shall authenticate the S-PG and confirm its intention to end the subscription before forwarding the request to the P-PG.

SYS-236. If there is an error in processing the unsubscribe request, the DB shall send a notice of failure with the reason for failure to the requesting S-PG. If there is a current data flow, the current data flow shall continue unaltered.

SYS-237. If the request is successful, the P-PG shall send an acknowledgement of success for the request to the S-PG via the DB, and remove the subscription from its list.

SYS-238. If there is an active data flow under the subscription in question, the S-PG shall stop the real-time data flow using the Stop Real-Time Data Stream function outlined above.

SYS-239. If there is no more subscription to the data from any PGs after the removing the requested subscription, the P-PG shall stop ingesting the real-time data to NASPInet.

SYS-240. Both the P-PG and the S-PG as well as the DB shall log the transaction and notify the PG administrator as needed.

SYS-241. The PG shall support manual request by the S-PG or P-PG administrator to cancel the subscription and stop the real-time data flow.

3.3.6 Inquiry for Available Historical Data Sources

SYS-242. The S-PG shall enable its user/application/subscriber to initiate a query to determine the availability of historical data available via the NASPInet.

SYS-243. Only S-PGs that are currently registered with the NASPInet shall be able to initiate a query to determine the availability of a historical data source (HDS).

SYS-244. The S-PG shall be able to use the data obtained via the query process to request a block of historical data.

SYS-245. The P-PGs for the underlying RT-SDS corresponding to the signals requested in the historical data query shall have full control over the access rights to the historical data, regardless where the historical data resides. The P-PG for the underlying RT-SDS shall be the only one to grant or deny access to all or part of the historical data that originate from its RT-SDS.

SYS-246. To allow the P-PGs for the underlying RT-SDS maintaining full control of access to their data, DB shall route all inquiries for historical data to the P-PGs associated with the corresponding registered RT-SDS signal of an HDS.

SYS-247. Historical data queries for a signal (data point) not associated with a corresponding registered RT-SDS signal shall be disallowed by the DB.

SYS-248. To inquire about available historical data sources, the inquiring S-PG shall send a historical data source inquiry request message to DB.

SYS-249. It shall be possible for the S-PG to submit either generic inquiries to all P-PGs or inquiries that are targeted to specific P-PGs.

SYS-250. Following successful authentication by the DB, the DB shall forward the S-PG request and its ID to targeted or all registered P-PGs. Each P-PG shall return to DB a list of the historical data sources that the inquiring S-PG is allowed to access.

SYS-251. The DB shall, in turn, forward the information received from the P-PGs, including the available historical data, to the inquiring S-PG. Information supplied to the S-PG shall include as a minimum:

- Location identification (substation name, building name, etc.)
- Type of device (PDC, Data Archiving Device, an operation data warehouse, etc.)
- Device identification (device name, sequence number, etc.)
- Signal origin (e.g., original PMU signal that a PDC signal is derived from)
- Signal processing methods (if not original signal)
- Signal quality (data class – latency, reliability, etc.)
- Ownership (entity name)
- Names according to PG owner naming convention
- Names according to NASPInet naming convention
- Time periods of data stored

SYS-252. The S-PG shall enable the PG administrator or authorized applications to submit inquiries about available historical data sources to a select set of P-PGs, including a list of targeted P-PGs or all P-PGs registered with the DB.

SYS-253. After authenticating the administrator or external application, the S-PG shall send a "show the available HDS data" request to the selected P-PGs via the DB.

SYS-254. After successful authentication and authorization of the requesting S-PG, the DB shall forward the inquiry to the select set of P-PGs. Each P-PG shall respond to the DB with a list of historical data available to the S-PG; the list could be null.

SYS-255. The DB shall forward available historical data sources that are accessible by the S-PG to the S-PG.

SYS-256. If the inquiry fails, the requesting S-PG shall be notified with a reason for failure and all PGs as well as the DB shall log the transaction.

SYS-257. The S-PG administrator shall be able to store HDS IDs and available historical data information in S-PG.

3.3.7 Request Historical Data

SYS-258. An S-PG shall allow an authorized user or application to request a block of historical data from a P-PG via DB. The signals to be requested shall first be identified using the historical data query function outlined above. The S-PG shall send the historical data request to the P-PG via DB. As a minimum, this request shall include the S-PG ID, the IDs of all signals requested and the start and stop times (in UTC time to an even second) of the interval of data requested.

SYS-259. The P-PG shall, via DB, authenticate the request and respond with an affirmative if the requested data will be sent or a denial if it will not be sent with the reason for denial.

SYS-260. If affirmative, the P-PG shall also send to the S-PG, via DB, information regarding the data that will be sent including a request ID, information for decoding the signals from the data transmission, scaling, data format, data rate, approximate volume (in bytes) of data, and any other available information required for reception and use of the data.

SYS-261. The S-PG shall provide the information regarding the requested historical data to the user or application for confirmation, and send the confirmation to the P-PG.

SYS-262. The P-PG shall discard the request if the confirmation is not received within a administrator-configurable time period.

SYS-263. Both the P-PG and the S-PG as well as the DB shall log the transaction and notify the PG administrators as needed.

3.3.7.1 Manual and Scheduled Start of Historical Data Transmission

SYS-264. The S-PG shall allow the S-PG administrator to schedule the start the historical data transmission, i.e., setting a time when the S-PG will send the start command to the P-PG.

SYS-265. The PG shall support manual request by the S-PG user or authorized application to start the historical data transmission on demand.

3.3.8 Start Receiving a Block of Historical Data

SYS-266. Once a request for historical data has been processed and approved, the S-PG shall send a start command which includes the historical data request ID to each P-PG of the historical data request within a requested data available period.

SYS-267. The S-PG shall allow sending of the start command to the P-PGs at different times.

SYS-268. The P-PG shall discard the historical data request if a start of data transmission request is not received within a requested data available period from the time of the historical data request. The requested data available period is configurable by the P-PG administrator.

SYS-269. When a P-PG receives the start data command it will first authenticate the S-PG and data request ID. If the P-PG will not grant the request, it shall respond to the S-PG with a reason for the denial.

SYS-270. If the P-PG will grant the request, it shall start sending the data and continue until the data transfer is complete or until it receives a request to stop the transmission.

SYS-271. If the P-PG received a start command after the data transfer has been paused (see below), it shall start the data transfer from the beginning of the data block rather than the point at which the transfer was paused.

3.3.9 Pause the Receipt of Historical Data

SYS-272. When historical data is being transmitted from a P-PG to an S-PG, either PG, and the DB shall be able to pause the receipt of data.

3.3.9.1 Historical Data Transmission Pause Initiated by S-PG

SYS-273. If the S-PG wishes to pause the transmission, the S-PG shall send a pause request including the historical request ID to the P-PG. When the P-PG receives a pause request, it shall authenticate the IDs of the data request and the S-PG.

SYS-274. If the request fails, the P-PG shall send a failure notice to the S-PG with a reason for the failure.

SYS-275. If request succeeds, the P-PG shall stop the data flow with appropriate information to be able to resume the transmission at the point of pause. It shall also send a reply to the S-PG that the data has been paused.

SYS-276. The P-PG shall be able to discard the historical data request if the S-PG does not resume or restart the transmission within a requested data available period (e.g. 24 hours) of the pause. The period is configurable by the P-PG administrator.

3.3.9.2 Historical Data Transmission Pause Initiated by P-PG

SYS-277. During transmission of historical data, the P-PG shall be able to pause transmission at any time. The P-PG shall send a pause notification which includes the historical data request ID, a reason for pausing, and an estimated availability time to the S-PG.

SYS-278. Once paused by the P-PG, the transmission of historical data shall not be resumed until the P-PG receives a resume or restart command from the S-PG. The P-PG shall determine if data transmission is allowed at the time of the resume/start request. If yes, it shall restart the data transmission.

SYS-279. The P-PG shall discard the historical data request if the S-PG does not resume or restart the transmission within a requested data available period of the pause. The period is configurable by the P-PG administrator.

3.3.9.3 Historical Data Transmission Pauses Initiated by DB

SYS-280. During transmission of historical data, the DB shall be able to pause transmission at any time. The DB shall send a pause notification which includes the historical data request ID, a reason for pausing, and an estimated availability time to the affected P-PG and S-PG.

SYS-281. Once paused by the DB, the transmission of historical data shall not be resumed until the P-PG receives a resume or restart command from the DB or S-PG. The P-PG shall determine if data transmission is allowed at the time of the resume/start request. If yes, it shall restart the data transmission.

SYS-282. The P-PG shall discard the historical data request if the DB or S-PG does not resume or restart the transmission within a requested data available period of the pause. The period is configurable by the P-PG administrator.

3.3.9.4 Support of Manual and Automated Operation

SYS-283. This function shall support both manual operation by the PG and DB administrators and automated operation. Automated operation shall include both timed and signaled operations. Timed operation shall allow the PG and DB administrator to set a time when a request shall be sent to pause a historical data transfer. Signaled operation shall allow the transfer of historical data to be paused by signals generated from predefined conditions, which are configurable by PG and DB administrators.

3.3.10 Resume the Receipt of Historical Data

SYS-284. After the transmission of historical data has been paused during transfer from P-PG to a S-PG, the S-PG (or DB) shall be able to resume the data transmission. When the S-PG (or DB) wishes to resume or restart a transmission, it shall send a resume or start request including the historical request ID to the P-PG (and S-PG if initiated by DB).

SYS-285. When the P-PG receives a resume or start request, it shall authenticate the IDs of the data request and the S-PG (or DB). If the authentication fails, it shall send a failure notice to the S-PG (or DB) with a reason for the failure.

SYS-286. If authentication succeeds, the P-PG shall resume the data flow from the point of pause, or restart from the beginning depend upon whether a resume or a start request is received. The P-PG shall also confirm to the S-PG (and DB) that the data transmission has been resumed or restarted.

SYS-287. The P-PG shall continue sending data until the request is fulfilled, the transmission is paused again, or the request is canceled.

SYS-288. The system shall allow the S-PG administrator or DB administrator to schedule the resume or restart request at a specific time and send the resume or start command to the P-PG at that time.

SYS-289. The PG shall support manual request by the S-PG user or authorized application to resume the historical data transmission on demand.

SYS-290. This function shall support both manual operation by the PG and DB administrators and automated operation. Automated operation shall include both timed and signaled operations. Timed operation shall allow the PG and DB administrator to set a time when a request shall be sent to pause a historical data transfer. Signaled operation shall allow the transfer of historical data to be paused by signals from connected devices or generated from predefined conditions, which are configurable by PG and DB administrators.

3.3.11 Cancel the Historical Data Request

SYS-291. The P-PG or the S-PG shall be able to cancel a historical data request at any time.

SYS-292. It shall be possible to cancel a historical data request during transmission, if necessary.

SYS-293. If there is a data transfer in progress when an authorized and authenticated cancellation request is received, the P-PG shall discontinue the transmission.

3.3.11.1 Historical Data Request Cancelation Initiated by S-PG

SYS-294. When the S-PG wishes to cancel the request, the S-PG shall send a cancellation request including the historical request ID to the P-PG.

SYS-295. When the P-PG receives the request, it shall authenticate the IDs of the data request and the S-PG. If the authentication fails, it shall send a failure notice to the S-PG with a reason for the failure.

SYS-296. If authentication succeeds, the P-PG shall cancel the data request and stop the data flow if it is currently occurring. It shall also send a reply to the S-PG that the data request has been canceled.

3.3.11.2 Historical Data Request Cancellation Initiated by P-PG

SYS-297. It shall be possible for the P-PG to cancel a historical data request. To do this, the P-PG shall send to the S-PG a cancellation notification which includes the historical request ID and a reason for canceling. A cancellation notice shall be sent any time the P-PG cancels a request, including timeout of the requested data available period.

3.3.11.3 Manual and automated historical data request cancellation

SYS-298. This function shall support for both manual operation by the PG administrators and automated operation. Automated operation shall include both timed and signaled operations. Timed operation shall allow the PG administrator to set a time when a request shall be sent to pause a historical data transfer. Signaled operation shall allow the transfer of historical data to be paused by signals generated from predefined conditions, which are configurable by PG administrators.

4 Data Bus Functional Requirements

The Data Bus (DB) consists of telecommunication network and applications to manage the system administration, the data transport, security, and Quality of Services. This system shall be designed to be scalable to allow expansion by adding communication network connections and capacities and applications capabilities to meet the ultimate growth plans for the NASPInet, which are enumerated in this specification. Requirements for expansion of the system to include more participants, more Phasor Gateways (PG) connections and more PMU's connected to these PGs, increased system bandwidth, communication networks, and system services are detailed in this specification.

This section describes the major functions to be performed by the DB in concert with connected PGs to meet the overall NASPInet requirements described in Section 3. The functional requirements in this section describes what functions that the DB is expected to perform, not how the functions will be designed and implemented. DB-Suppliers are encouraged to propose a design that satisfies the functional requirements while making the best use of DB-Supplier's standard offerings and commercial off-the-shelf products.

The DB functional requirements are divided into two groups:

- **General System Functions:** This subsection provides the overall requirements of major DB components and functions. The overall functional requirements in this subsection are for supporting NASPInet's system administration, operation, and data traffic Quality of Service management functions.
- **Detailed Functional Requirements:** This subsection provides detailed functional requirements of the DB components and services.

A requirement applicability check list is included in this specification as Appendix A, which clearly indicates which requirements are mandatory, which are desirable, etc. in relation to the data service classes that it supports.

As Section 1 indicated, other DB requirements are detailed in the sections following this section: the DB system integration and interface requirements are detailed in Section 5; networking and communications requirements in Section 6; security requirements in Section 7; and sizing, performance, and availability requirements in Section 8. DB_REQUESTER should tailor the sample texts in Attachment II to its specific IT governance and resource availability, including hardware and software technical requirements in Sections 1 and 10 respectively; and project implementation and system sustainability services in Section 11.

4.1 General DB System Functions

This section first outlines requirements at the system component level and then the system functions in the three major areas (system administration, operation, and data traffic Quality of Service management) using these component services. These functions will then be detailed in Section 4.2 below.

4.1.1 DB Components Functional Requirements

The DB_SUPPLIER shall provide the system services represented by the following logical components. The DB_SUPPLIER may group the services of these components in a different set of product modules based on commercial products included in the proposed solution. The proponent shall provide mapping of the required services below to the proposed product modules.

DB Services - 1: API/SDK (Application Programming Interface / Software Development Kit) – The DB shall include API/SDK toolkit for developing, configuring, customizing, and deploying applications, integration mechanisms, user interfaces, content delivery, and other Data Bus components.

DB Services - 2: CEP (Complex Event Processing) – The DB shall provide services to enable event-driven processing, such as actions to be invoked based on NASPI system diagnostics, instrumentation measurements (QoS), security service alerts, PG registration/connection status and errors, etc.

DB Services - 3: Name & Directory – The DB shall include a core function for the registry of services, components, processes, streams and other entities internal to the Data Bus for subsequent invocation.

DB Services - 4: Instrumentation – In concert with Management and Administration Services, the DB shall include instrumentation services to provide visibility into key aspects of Data Bus components and services, such as performance, utilization and general health indicators.

DB Services - 5: Integration – The DB shall include an Integration infrastructure to facilitate integration of the DB with Phasor Gateway services by exposing Data Bus services, processes and components via adapters.

DB Services - 6: Messaging – The DB service shall enable synchronous and asynchronous message-based communication between DB and PG components and services with support for features such as guaranteed delivery, publish/subscribe and content-based routing.

DB Services - 7: Management & Administration – This DB service shall enable the initial configuration and in concert with the Instrumentation service, manage ongoing operation of Data Bus components and services.

DB Services - 8: Orchestration – The DB shall include capabilities to enable process modeling, development, instantiation, execution and monitoring functionality. An example would be the processes to support the provisioning of new Phasor Gateway Devices.

DB Services - 9: Streaming – The DB shall include a data streaming service to manage the transport and processing of massive volume of streaming Phasor measurements from PMU/PDC and other IEDs via the connected Phasor Gateways.

DB Services - 10: Transform – The DB shall include data transformation services for processing data flowing through the Data Bus, if required.

DB Services - 11: Security – The DB shall provide security services for PG and DB components authentication and authorization, NASPInet logical access policy control, NASPInet security key management, data integrity assurance, and activity logging and auditing.

4.1.2 DB System Administration Functional Requirements

The DB shall provide appropriate Graphical User Interfaces (GUI) and Application Programming Interfaces (See API requirements in Section 5) for handling all NASPInet administrative requirements.

DB Admin - 1: The DB shall provide user account management capability for authorized system users. These shall include providing and restricting the access rights to DB administrative account access.

DB Admin - 2: The DB shall provide services to manage PG registration and connection (create, cancel, change), including verification of registration data and error logging.

DB Admin - 3: The DB shall provide services to manage registration of real-time streaming data source devices and signals, such as PMUs and PDCs, (create, cancel, change) via a registered PG, including verification of registration data and error logging.

DB Admin - 4: The DB shall provide services to manage registration of historical data sources (new, delete, change) via a registered PG, including verification of registration data and error logging.

DB Admin - 5: The DB shall allow an authorized system administrator to set communication media (e.g. email, SMS, etc.) and destination addresses (email address, mobile phone number for SMS, etc.) for each type of events (e.g. PG registration failures, security warnings, QoS warnings, etc.).

DB Admin - 6: The DB shall provide services to monitor, log and send event notifications to system administrators of the NASPInet, the DB, and affected PGs' for events such as failed PG connection attempts, failed PG registration attempts, intrusion attempts, etc.

4.1.3 DB System Operations Functional Requirements

The DB shall provide appropriate services and Application Programming Interfaces (See API requirements in Section 5) for managing NASPInet system operations.

DB Ops - 1: The DB shall provide services for facilitating queries of published data availability for both real-time streaming and historical data by connected PGs.

DB Ops - 2: The DB shall provide services to manage NASPInet's data subscription processes (setup and cancel) for real-time streaming data.

DB Ops - 3: The DB shall provide services to manage the distribution of streaming data from registered data sources via publishing PGs.

DB Ops - 4: The DB shall provide services to manage subscription processes (setup and cancel) for historical data from selected data sources via registered PGs.

DB Ops - 5: The DB shall provide services working in concert with involved PGs to manage PGs' response to requests for historical Phasor measurements for a select set of PGs, PMU/PDCs, or data sources over a specified time periods via a registered PG.

DB Ops - 6: The DB shall provide services to log and send event notifications to system administrators of the NASPInet, the DB, and affected PGs for events such as failed publishing and subscription attempts, data signals received from unidentified/unregistered devices, etc.

4.1.4 DB Instrumentation and Traffic Management Functional Requirements

DB QoS - 1: The DB shall provide services to manage data transport through DB based on the priority settings of different data service classes (Class A, B, C, D, and E data).

DB QoS - 2: The DB shall allow an authorized user to set or change priority settings and target QoS requirements for one or more data classes. See Section 8 for QoS requirements.

DB QoS - 3: The DB shall manage NASPInet resources such that the QoS requirements of higher service class data will be satisfied before lower service class data, such as Class A data will be satisfied before Class B data, class B data before class C data, etc.

DB QoS - 4: The DB shall manage the efficient distribution of a real-time data stream from one publishing PG's DB distributor to multiple subscribing PGs' DB ingest.

DB QoS - 5: The DB shall provide services to monitor and log status and loading conditions of DB components and related services.

DB QoS - 6: The DB shall provide services to query, receive and log status and loading information of NASPInet WAN network equipment/links, DB components, DB services, and PGs.

DB QoS - 7: The DB shall provide services to query, receive and log status and loading information of each registered PG.

DB QoS - 8: The DB shall provide services for subscription DB resource provisioning for QoS assurance in response to PGs' subscription setup request.

DB QoS - 9: The DB shall provide services working in concert with PG instrumentation services to log and send event notifications for QoS requirements violations of active data subscriptions of any data class.

DB QoS - 10: The DB shall provide periodic reports on QoS statistics, violation of QoS requirements, and trends by region and by PG.

DB QoS - 11: The DB shall provide services to allow query of historical NASPInet QoS measurements for a select set of PGs, PMU/PDCs, or data sources over a period of time via a Graphical User Interface directly or via a registered PG using a DB API.

4.2 Detailed Data Bus Functional Requirements

The following provide detailed functional requirements for system administration functions, data subscription management functions, and quality of service management functions of Data Bus.

As Section 1 indicated, other Data Bus requirements are detailed in the sections following this section: the DB system integration and interface requirements are detailed in Section 5; networking and communications requirements in Section 6; security requirements in Section 7; and sizing, performance, and availability requirements in Section 8. DB_REQUESTER should tailor the sample texts in Attachment II to its specific IT governance and resource availability, including hardware and software technical requirements in Sections 1 and 10 respectively; and lastly project implementation and system sustainability services in Section 11.

DB-1. The DB supplied by DB_SUPPLIER shall meet all DB mandatory requirements (DB-xxx) listed in this section and the following sections. For non-compliance items, DB_SUPPLIER shall provide details and explanations for each non-compliant item.

DB-2. DB_SUPPLIER's proposal shall respond to all highly desirable DB requirements (DB-xxx) listed in this section and the following sections, indicating whether the DB_SUPPLIER will provide the function and meet the functional requirement, or not provide the function.

DB-3. DB_SUPPLIER's proposal shall include responses to desired requirements listed in this section and the following sections, indicating which of these functions that DB_SUPPLIER elected to provide and meet the requirements, and which of these functions that DB_SUPPLIER will not provide.

DB-4. DB_SUPPLIER's proposal shall include responses to optional requirements (not a requirement) listed in this section and the following sections that the DB_SUPPLIER elected to provide and meet the requirements, and which of these functions that DB_SUPPLIER will not provide.

DB-5. DB_SUPPLIER shall deploy the DB, as a minimum, to support at least Class C and Class D synchro-phasor data services in its initial implementation, and to support all five (A, B, C, D and E) classes of synchro-phasor data services in its full implementation.

DB-6. It is highly desirable that the DB deployed by DB_SUPPLIER is expandable to support additional synchro-phasor and non-synchro-phasor data service classes and data services other than the five synchro-phasor data service classes, such as non-phasor real-time data and control messages, digital fault recordings, etc..

DB-7. DB shall provide a Name & Directory Service (NDS) for NASPInet resources management and administration, which shall include, as a minimum, secure and expandable metadata storage and retrieval system for PGs' and RT-SDS devices/signals' data, 128-bit RT-SDS/historical device/signal ID generation and management, and device/application registration management functions.

DB-8. DB shall provide a Security Service (SS) working in concert with PG Security Components for NASPInet security management and administration, which shall include, as a minimum, PGs' and DB components' ID assignment, authorization, and management; PGs' and DB components' authentication; and subscription cryptographic key generation and management functions.

DB-9. DB shall provide an Instrumentation Service (IS) for DB and NASPInet Quality of Service management, which shall include, as a minimum, DB components status monitoring, DB components usage monitoring, PG status inquiring, PG usage inquiring, resources provisioning, and traffic management functions.

4.2.1 Data Bus administration functions

This section covers requirements for overall administration functions related to Data Bus management and administration, access management of PGs and RT-SDS/HDS connected to the PGs, and DB user management.

4.2.1.1 NASPInet internal device/service administration

DB-10. DB shall provide GUIs and other supporting system administration functions to enable DB and its administrator to enter PG and DB components registration information with DB NDS interactively. The GUI and the supporting functions shall allow DB NDS administrator, as a minimum, to view and monitor the registration process, verify PG registration information, and interact with the registering PG and DB components. DB shall not provide system functions that allow for automated PG and DB components registration without DB administrator's interaction.

DB-11. DB shall provide system administration functions for the following: authenticating PG and DB components through DB SS; responding to PG and DB components' registration request for PGs' and DB components' registration information; receiving, validating and storing registration information in DB NDS metadata storage; providing authentication methods to authenticate other registered PGs and DB components; confirming successful PG registration or declining PG registration; and logging the registration processes.

DB-12. DB's system administration functions shall include a PG and DB component ID generation and management function, which shall be able to generate unique 128-bit IDs for a registering PG or DB component. The PG ID and DB component ID shall be used for all future communications between registered PGs and DB components, including registration update and cancellation. The ID shall be securely provided to the registering PG or DB component and DB SS for future use.

DB-13. DB shall provide GUIs and other supporting system administration functions to enable DB and its administrator to update existing PG's registration information with DB NDS either interactively or automatically in response to PG registration information update request. The administration functions shall include those for authenticating PG and DB components through DB SS; responding to PGs' and DB components' registration information update request; receiving, validating and storing updated registration information in DB NDS' metadata storage; confirming successful PG registration information update, and logging the registration update processes. The registration information update functions shall not interrupt continued data delivery of existing subscriptions of the PG requesting the registration information update.

DB-14. DB's system administration functions shall enable the removal of an existing PG or DB component from the service or its registration by DB or in response to PG or DB component's request. DB system administration functions shall be able to positively confirm that the request is

from a registered PG or DB component. DB system administration functions shall perform an orderly shutdown of data delivery of all data subscriptions; and confirming the successful removal from the service or cancellation of the registration to the requesting PG in the case that the request is from a registered PG.

DB-15. DB shall provide system administration functions for logging its interactions with PGs and DB components/services. Logged information shall be stored locally and securely. Logged information shall not be editable by anyone, including DB administrator.

4.2.1.2 DB user administration

DB-16. DB shall only provide administrator user accounts for all DB components and servers. DB shall not provide administration functions for creating and managing general user accounts for other users. Only DB administrators shall be allowed to log into DB components and servers.

DB-17. DB shall provide a default DB administrator account for each DB component/server for DB administrator to administer and manage the DB and its component/server, for which the default login information (user ID and password) shall be changed at the first login process.

DB-18. DB administrator accounts shall use, as a minimum, a two-factor login scheme with one factor being dynamic.

4.2.1.3 NASPInet external device/application administration

DB-19. DB shall provide GUIs and system administration functions for registering devices/applications with DB that are external to NASPInet, such as RT-SDSs (PMUs, PDCs, phasor applications, etc.) and HDS (Data Archive, etc.), either interactively by DB administrators responding to PG initiated external device/application registration request or automatically by DB responding to device/application's registration request passed through by the PG.

DB-20. DB shall provide GUIs and system administration functions for DB administrator to setup the DB for automatic external devices/applications registration (such as assigning device/application ID, entering key information of a device/application for authentication, registration information validation methods, etc.), so that it will be able to respond to device/application's registration request directly.

DB-21. The DB external device/application registration system administration functions shall support the registration process that include DB responding to external device/application registration request from a PG to authenticate the PG through DB SS; requesting authenticated PG supplying registration metadata of the external device/application; validating and storing received metadata of external device/application to DB NDS metadata storage; generating 128-bit unique device/application and signal IDs for registering devices and its signals; sending assigned device/application ID and signals IDs of the registering external device/application to PG; and confirming the successful completion of the registration process.

DB-22. DB shall provide GUIs and system administration functions for updating device/application's registration information for registered external devices/applications, either interactively with DB administrator responding to update request initiated by a PG administrator or automatically without PG and DB administrators' involvement.

DB-23. The DB external device/application registration update system administration functions shall support the registration update process that include DB responding to external device/application registration update request from a PG to authenticate the PG through DB SS; requesting authenticated PG supplying registration update metadata of external device/application; validating and storing received updated metadata of external device/application to DB NDS metadata storage; generating updated 128-bit unique device and signal IDs for additional signals of the registered devices/applications; sending updated device/application ID and signals IDs of the registered external device/application to the PG; and confirming the successful completion of the registration updating process. The DB external device/application registration update system administration functions shall not interrupt continued data delivery of existing unaffected subscriptions of the PG requesting the external device/application registration information update.

DB-24. DB shall provide GUIs and supporting functions for the DB administrator to configure DB for automatic external device/application registration information update.

DB-25. DB shall provide GUIs and functions for taking a device or an application out the service with DB for a registered device/application, either interactively with PG and DB administrators' involvement or automatically by responding to device/application's service removal request directly. The interactive service removal process could be initiated by either DB administrator or by PG administrator.

DB-26. The DB external device/application service removal function shall support the process initiated by PG or PG administrator that include: DB responding to external device/application service removal request to authenticate the PG through DB SS; confirming with requesting PG of its intention to remove the registered external device/application from the service; setting external device/application's status to out-of-service; and confirming the successful completion of the service removal process to requesting PG.

DB-27. The DB external device/application service removal function shall also support the process initiated by DB administrator that include DB sending to external device/application service removal advisory to corresponding PG; receiving acknowledgement from the PG; setting external device/application's status to out-of-service; and confirming the successful completion of the service removal process to the PG.

DB-28. DB shall provide GUIs and functions for canceling device/application's registration with DB for a registered device/application only interactively with PG and DB administrators'

involvement. The interactive registration cancellation could be initiated by either DB administrator or by PG administrator.

DB-29. The DB external device/application registration cancellation function shall support the registration cancellation process initiated by PG administrator that include: DB responding to external device/application registration cancellation request to authenticate the PG through DB SS; confirming with requesting PG of its intention to cancel the registered external device/application registration; canceling external device/application's registration; and confirming the successful completion of the registration cancellation process to requesting PG.

DB-30. The DB external device/application registration cancellation function shall also support the registration cancellation process initiated by DB administrator that include DB sending to external device/application registration cancellation advisory to corresponding PG; receiving acknowledgement from the PG; canceling external device/application's registration; and confirming the successful completion of the registration cancellation process to the PG.

DB-31. DB shall provide secure storage for storing and retrieving the metadata of the external device/applications and the signals metadata of these external devices/applications that are registered with DB NDS, and the DB NDS assigned device/application ID and signal IDs.

4.2.2 Data Bus data publish/subscribe management

Data Bus shall provide the following data publish/subscribe operation management functions to support NASPInet real-time streaming data and historical data publish/subscribe operations.

4.2.2.1 DB publish/subscribe general requirements

DB-32. DB shall provide functions for data publish/subscribe operation management for both real-time streaming data and historical data. The functions shall include accessible data discovery support, subscription setup/cancel, publishing/subscription ID generation and management, publishing/subscription cryptographic key generation and management, QoS provisioning/monitoring/management, and subscription fulfillment.

DB-33. DB shall provide a subscription ID generation and management function that shall generate a 128-bit subscription ID in response to a subscription request from an S-PG, and ensure that the subscription ID is unique among all active subscriptions. The subscription ID shall be used by S-PG, P-PG and DB in all subscription management and fulfillment related communications. The function shall store all relevant information about the subscription, such as S-PG ID, P-PG ID, signal IDs, original data frame protocol configuration information, and so on, of the subscription, for use by DB in subscription fulfillment and subscription management.

DB-34. DB shall provide a Quality of Service management function that include real-time QoS instrumentation, subscription QoS provisioning, subscription QoS performance monitoring, and traffic management functions.

DB-35. DB real-time QoS instrumentation function shall be able to obtain real-time NASPInet resources status and usage level information from various resources. NASPInet resources include PGs, DB components, and NASPInet WAN network equipment.

DB-36. DB subscription QoS provisioning function shall enable DB to determine whether the QoS requirements of a new subscription, when requested, can be supported by the NASPInet in addition to all existing subscriptions and traffic based on QoS requirements of these subscriptions that are already provisioned. If the QoS requirements of a new subscription can be satisfied, the DB subscription QoS provisioning function shall reserve the required resources for the subscription.

DB-37. DB subscription QoS performance monitoring function shall interact with PG subscription QoS monitoring functions time to time to determine the actual QoS performance of each subscription. The function shall alarm DB and PG administrators for any QoS violations, log QoS performance statistics, and generate QoS performance report using logged performance data.

DB-38. DB shall provide GUI and related functions for DB administrator to configure the DB QoS instrumentation functions.

4.2.2.2 Real-time streaming data publish/subscribe management

DB-39. DB shall provide functions for data publish/subscribe operation management for real-time streaming data. The functions shall include accessible real-time streaming data discovery support, subscription ID generation and management, publishing/subscription cryptographic key generation and management, QoS monitoring/provisioning/management, subscription setup/update/cancel, and subscription fulfillment. The subscription fulfillment refers to the delivery of real-time streaming data from publishing PG to subscribing PGs according to their subscriptions to the stream.

DB-40. DB accessible real-time streaming data discovery support function shall facilitate both general and specific (with a list of targeted PG IDs) accessible real-time streaming data discovery query from registered PGs. The function shall direct a general accessible real-time streaming data query of a requesting PG to all registered publishing PGs of real-time streaming data. The function shall direct a specific accessible real-time streaming data query of a requesting PG to all targeted publishing PGs of real-time streaming data.

DB-41. DB accessible real-time streaming data discovery support function shall authenticate requesting PG's identity through DB SS before forwarding the accessible real-time streaming data query request along with requesting PG's ID to publishing PGs.

DB-42. DB accessible data discovery support function shall only forward detailed signal information of registered real-time streaming data signals along with their IDs and the publishing PG IDs to requesting S-PG for those signals that have granted access rights for the S-PG by the

publishing PGs of real-time streaming data. DB shall perform this function based on signal IDs received from publishing PGs that responded to DB relayed data query from requesting S-PG.

DB-43. DB shall provide a real-time streaming data publishing/subscription cryptographic key generation and management function that shall be able to generate and manage cryptographic keys for a published data stream and for subscriptions of the stream in response to requests from PGs, and ensure that no duplicated keys will be generated among all active published data streams and subscriptions.

DB-44. The publishing cryptographic keys shall only be used by P-PGs to encrypt the published data stream, and by DB to decrypt the published data stream wherever needed in the subscription fulfillment process.

DB-45. The subscription cryptographic keys shall only be used by DB to encrypt the subscribed real-time streaming data, and by S-PG to decrypt the subscribed real-time streaming data.

DB-46. The cryptographic key generation and management function shall support, as a minimum, AES128 or other approved cryptography methods with higher strength and/or better performance than that of AES128.

DB-47. DB real-time streaming data publishing/subscription cryptographic key generation and management function shall include a dynamic key generation, distribution and management mechanism. The mechanism shall, as a minimum, enable cryptographic keys to be dynamically changed on a periodical basis.

DB-48. DB shall provide GUI and supporting functions to enable DB administrator to set and configure cryptographic method, dynamic key generation, distribution and management mechanism for real-time streaming data publishing/subscriptions.

DB-49. DB shall provide a subscription setup/cancel function for real-time streaming data subscription management.

DB-50. The DB subscription setup function for real-time streaming data shall be able to support, as a minimum, PG-to-PG subscription setup process via DB. In a PG-to-PG subscription setup process, DB shall support the steps of authenticating the S-PG through DB SS, storing subscription details, provisioning resources through QoS provisioning function, generating a subscription ID, and sending the subscription ID to S-PG in response to S-PG's subscription setup request. S-PG then shall send its subscription request to P-PG via DB for setting up the subscription with P-PG. Once S-PG notifies DB that the setup of the subscription with P-PG is completed after S-PG received confirmation from P-PG, DB shall generate a subscription cryptographic key and provide it to S-PG using DB cryptographic key generation and management function. If it is the first time that a subscription to P-PG's data stream is made, DB shall also generate a publishing cryptographic key and provide it to P-PG using DB cryptographic key generation and management function.

DB-51. The DB subscription cancellation function for real-time streaming data shall be able to support, as a minimum, both S-PG initiated and P-PG initiated subscription cancellation processes.

DB-52. In an S-PG initiated subscription cancellation process, DB subscription cancellation function for real-time streaming data shall support the steps of authenticating the S-PG through DB SS, archiving subscription details, and removing resources provisions through QoS provisioning function in response to S-PG's subscription cancellation request. S-PG then shall send its subscription cancellation request via DB to P-PG for canceling the subscription with P-PG. Once S-PG notifies DB that the cancellation of the subscription with P-PG is completed after S-PG received confirmation from P-PG, DB shall retire the subscription ID with DB subscription management function and the subscription cryptographic key using DB cryptographic key generation and management function. If it is the last subscription of the published data stream of the P-PG, DB shall also retire the publishing cryptographic key using DB cryptographic key generation and management function.

DB-53. In a P-PG initiated subscription cancellation process, DB subscription cancellation function for real-time streaming data shall support the steps of authenticating the P-PG through DB SS, archiving subscription details, and removing resources provisions through QoS provisioning function in response to P-PG's subscription cancellation request. P-PG then shall notify its subscription cancellation intention to S-PG via DB for canceling the subscription of the S-PG. Once P-PG notifies DB that the cancellation of the subscription with S-PG is completed after P-PG received acknowledgement from S-PG, DB shall retire the subscription ID with DB subscription management function and the subscription cryptographic key using DB cryptographic key generation and management function. If it is the last subscription of the published data stream of the P-PG, DB shall also retire the publishing cryptographic key using DB cryptographic key generation and management function.

DB-54. DB shall provide subscription fulfillment functions for real-time streaming data subscriptions fulfillment and management. The DB subscription fulfillment functions shall ensure that each subscription of a published real-time data stream receives the data of its subscribed signals and only these data of these signals. The DB subscription fulfillment functions shall include, as a minimum, the functions to decrypt a published data stream with its publishing key, to create subscribed data stream by removing non-subscribed data values or replace non-subscribed data values with random numbers, and to encrypt the subscribed data stream with the subscription key of the subscription for delivering the subscribed data to each subscribing PG.

4.2.2.3 Historical data publish/subscribe management

DB-55. DB shall provide functions for data publish/subscribe operation management for historical data. The functions shall include accessible data discovery support, subscription ID generation and management, publishing/subscription cryptographic key generation and

management, QoS monitoring/provisioning/management, subscription setup/cancel, and subscription fulfillment. The subscription fulfillment refers to the delivery of historical data from the publishing PG to the subscribing PG. The historical data publishing and subscription shall always be between one publishing PG and one subscribing PG.

DB-56. DB accessible data discovery support function shall facilitate both general and specific (with a list of targeted PG IDs) accessible historical data discovery query from registered PGs. The function shall direct a general accessible historical data query of a requesting PG to all registered historical data publishing PGs. The function shall direct a specific accessible historical data query of a requesting PG to all targeted historical data publishing PGs.

DB-57. DB accessible data discovery support function shall support accessible historical data discovery query for historical data that reside either at the P-PG of the original streaming data or at a different P-PG that stores the original streaming data. In the case that the historical data residing in a P-PG different from the P-PG that publishes the original real-time streaming data, DB accessible history data discovery support function shall first direct the query to the P-PG of the original streaming data to obtain the list of accessible signals' IDs from the P-PG of the original streaming data and then direct the query to the P-PG that publishes the historical data to obtain further information of the stored historical data for those signals, such as the length and periods of the historical data for accessible signals granted access by the P-PG of the original streaming data.

DB-58. DB accessible data discovery support function shall authenticate requesting PG's identity through DB SS before forwarding the accessible historical data query request along with requesting PG's ID to historical data publishing PGs.

DB-59. DB accessible data discovery support function shall only forward detailed historical data signal information of registered historical data signals along with their IDs and the publishing PG IDs to requesting PG for those signals granted access rights to the P-PG by the publishing PGs. DB shall perform this function based on signal IDs received from publishing PGs that responded to DB relayed data query from the requesting PG.

DB-60. DB shall provide a historical data publishing/subscription cryptographic key generation and management function that shall generate a cryptographic key for each historical data subscription in response to requests from PGs, and ensure that no duplicated keys will be generated among all active published data streams and subscriptions. The cryptographic key of a subscription shall be used by the P-PG of the subscription to encrypt the published historical data, and by the S-PG of the subscription to decrypt the published historical data in the subscription fulfillment process. The cryptographic key generation and management function for historical data subscriptions shall support, as a minimum, AES128 or other approved cryptography methods with higher strength and/or better performance than that of AES128.

DB-61. DB shall provide GUI and supporting functions to enable DB administrator to set and configure cryptographic key strength, key generation, distribution and management mechanism.

DB-62. DB shall provide a subscription setup/cancel function for historical data subscription management.

DB-63. The DB subscription setup function for historical data shall be able to support, as a minimum, PG-to-PG subscription setup process via DB. In a PG-to-PG subscription setup process, DB subscription setup function for historical data shall support the steps of authenticating the S-PG through DB SS, storing subscription details, provisioning resources through QoS provisioning function, generating a subscription ID, and sending the subscription ID to S-PG in response to S-PG's subscription setup request. S-PG then shall send its subscription request to P-PG via DB for setting up the subscription with P-PG. Once S-PG notifies DB that the setup of the subscription with P-PG is completed after S-PG received confirmation from P-PG, DB shall generate a subscription cryptographic key and provide it to P-PG and S-PG using DB cryptographic key generation and management function.

DB-64. The DB subscription cancellation function for historical data shall be able to support, as a minimum, both S-PG initiated and P-PG initiated subscription cancellation process.

DB-65. In an S-PG initiated subscription cancellation process, DB subscription cancellation function for historical data shall support the steps of authenticating the S-PG through DB SS, archiving subscription details, and removing resources provisions through QoS provisioning function in response to S-PG's subscription cancellation request. S-PG then shall send its subscription cancellation request via DB to P-PG for canceling the subscription with P-PG. Once S-PG notifies DB that the cancellation of the subscription with P-PG is completed after S-PG received confirmation from P-PG, DB shall retire the subscription ID with subscription ID generation and management function and the cryptographic key using DB cryptographic key generation and management function.

DB-66. In a P-PG initiated subscription cancellation process, DB subscription cancellation function for historical data shall include steps of authenticating the P-PG through DB SS, archiving subscription details, and removing resources provisions through QoS provisioning function in response to P-PG's subscription cancellation request. P-PG then shall notify its subscription cancellation intention to S-PG via DB for canceling the subscription of the S-PG. Once P-PG notifies DB that the cancellation of the subscription with S-PG is completed after P-PG received acknowledgement from S-PG, DB shall retire the subscription ID with subscription ID generation and management function and the cryptographic key using DB cryptographic key generation and management function.

DB-67. DB shall provide subscription fulfillment functions for historical data subscriptions fulfillment and management, such as facilitating the start, pause, and resume or restart of the data

transmission of a subscription. The DB subscription fulfillment functions shall ensure that each historical data subscription delivers the data from P-PG to S-PG as provisioned.

4.2.3 Data Bus Resources and Traffic Management

DB-68. DB shall provide resources and traffic management functions for managing system resources and traffic under both normal and abnormal system conditions.

DB-69. The DB resources management functions shall maintain accurate information of all system resources, including but not limited to resource capacity and capability, resource status, and resource loading level. The resources include PGs, DB components and NASPInet WAN network components.

DB-70. The DB resources management functions shall be capable of obtain resources information through either automatically receiving such information from resources or making query for such information to resources.

DB-71. DB shall provide GUI and related functions for DB administrator to setup and configure DB resources management functions. The GUI and functions shall also allow DB administrator to interact with resources to obtain desired resource information on an individual resource basis.

DB-72. DB traffic management functions shall be capable of managing traffic under both normal and abnormal system conditions according to DB traffic control policies under these conditions.

DB-73. DB shall provide GUI and related functions for DB administrator to setup and configure DB traffic control management policies. The GUI and functions shall also allow DB administrator to set traffic control policies for each system condition. The traffic control policies shall target to balance the loading of system resources and at the same time ensure that the QoS requirements of all subscriptions are satisfied.

DB-74. DB traffic management functions shall be able to obtain traffic control policies from individual resource and distribute global traffic control policies to individual resource.

5 System Integration Requirements

This section describes the system integration requirements of the DB system and/or the DB_SUPPLIER such that the DB will function in concert with the connected PGs to enable the overall NASPInet and DB functions described in Sections 3 and 4 above.

5.1 Point of Demarcation

Figure 5-1 outlines the roles and responsibilities of the DB_SUPPLIER versus the PG_SUPPLIER and other related parties. Basically, the DB_SUPPLIER shall provide a set of Application Programming Interfaces (API) to facilitate PG connection and integration of PG/DB services. The PG_SUPPLIER shall (1) integrate the PG with the DB using the DB_SUPPLIER provided APIs and (2) provide the APIs for other DB_REQUESTER IT systems and applications to access the PG services and for data integration between the PG and those DB_REQUESTER systems. DB_REQUESTER or its selected System Integrator, if applicable, shall use the PG_SUPPLIER-supplied APIs to integrate the DB_REQUESTER systems with the PG. The required DB APIs and PG APIs are listed in Sections 5.3.1 and 5.3.2 respectively.

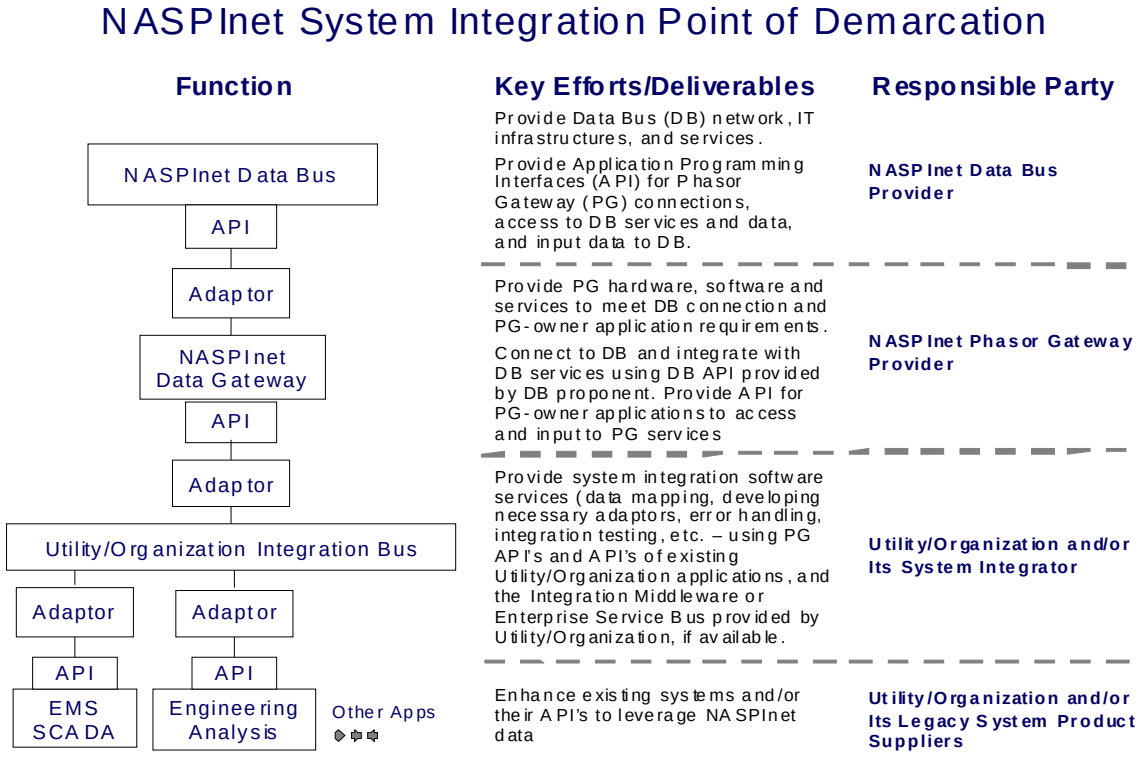

Figure 5-1 System Integration Role & Responsibility of PG and DB_SUPPLIERs and others

5.2 System Integration Services

As stated in Section 5-1 above, as part of the PG implementation services, providers or implementers of PGs will be responsible for connecting the PGs to the DB and integrate with the DB services using the Application Programming Interfaces (API) to be provided by the DB_SUPPLIER. Nevertheless, the DB_SUPPLIER shall provide the following services to support PG integration in general:

1. Provide specific constraints on technical architecture and standards as distilled from functional requirements (Sections 3 and 4). Document the overall set of technical requirements and standards compliance/impacts on major commercially available PGs.

2. Provide the DB APIs, including design documentation and application guide, as specified in Section 5.3.1 below.

3. Provide Implementation and Sustainment Services, including the installation, testing, training, documentation, and other service requirements (See Section 11,).

In addition, the DB_SUPPLIER may be requested by DB_REQUESTER to support the connections and integrations of selected sample of PGs for testing NASPInet. Following are possible examples of such efforts.

4. Review selected PG_SUPPLIERs' documentation of detailed functional and technical requirements for PG system interfaces. Functional requirements shall include detailed use cases and information requirements to support those use cases. Technical requirements shall include response time, scalability, security, and availability requirements.

5. Review elected PG_SUPPLIERs' integration requirements including detailed system integration design and detailed PG configurations needed to support the DB integration.

6. Review major PG_SUPPLIERs' detailed integration design documenting the technical and physical architecture of the integrated PG environment, including input/output data mapping, data transformation, adaptors, enterprise service/message mapping, frequency and latency, expected transaction rates and performance requirements, data validation and exception handling, etc. The designs will consider integration requirements for both analytic and transaction processing.

7. Support integration testing of the DB and the selected sample of PGs, including development of test plans, test procedures, test harnesses, and test executions.

8. Implement enhancements to DB, DB API, and related documentation as needed based on outcome of the technical reviews and integration testing above.

5.3 Application Programming Interfaces

The DB_SUPPLIER shall deliver APIs for access to the DB data and services as outlined below, including software, documentation, and sample test data sets.

5.3.1 Common API Requirements

5.3.1.1 Security

All API functions shall enable security assurance for appropriate access to and usage of NASPInet resources and information, including authentication and authorization, encryption and decryption of API and response data, audit trail, etc. All security violations, such as a failed authentication or authorization, shall be logged, and the DB System Administrator as well as the corresponding PG Administrator would be notified of the event.

5.3.1.2 Error Handling and Error Tolerance

All APIs shall include appropriate error and exception handling and have the ability to insulate the system from data errors sent through the API and from problems occurred in other systems. In other words, the system shall continue to function normally in all areas not directly associated with the data from the API and not directly relying on the functions of the faulted external system. All interface errors shall be time stamped, error coded, and logged.

5.3.1.3 API Results Confirmation

All APIs shall reply to the requesting system with a success/failure code. The success code may be CREATED, CANCELED, CHANGED, etc. The error code should provide a reason for the failure (e.g. “invalid data field XXX”. “Device ID not recognized”, etc.)

5.3.2 Data Bus API

The DB_SUPPLIER shall provide APIs for PGs to access DB data and services. The APIs shall include the following function requirements as a minimum. The DB_SUPPLIER shall describe details of the API constructs. Please see Section 3 for data requirements.

5.3.2.1 System Management/Common Services API

This set of APIs is intended for enabling access to historical data stored in data sources available to NASPInet. They shall follow IEC 61970 Interface Standards, Part 407, Time Series Data Access.

5.3.2.1.1 Create PG Registration API

The DB API shall allow a PG to provide data that can be used to identify itself to the DB to facilitate the PG registration with the DB Name Services. The PG registration data may include the following for example:

- Physical location of the PG (Country, State, etc.)
- Owner information (company name, type of organization, region, address, etc.)
- System administrator information (name, email, phone, SMS address, etc.)
- PG functions – subscribe or publish only, publish and subscribe, classes of data services to be supported (latency, availability, sampling rate), etc.
- Default data access rights by organization type, region, and class of data
- Data access right exceptions (list of PG IDs and their owner organization names with specific access right by data class for each PG/owner)
- Authentication information

Upon authenticating the owner information, validating the owner authority to connect PG to NASPInet, and checking for logical registration data errors, the DB API shall return a message to the PG with "CREATED" and a unique PG ID assigned by the NASPInet Name & Directory Services. If errors occur in the registration process, the API shall return an error code and log the error in the Data Bus.

5.3.2.1.2 Change PG Registration API

The DB API shall allow a PG to change data of the existing registration of itself (see example data in the Create PG Registration API) with the DB Name & Directory Services. After proper authentication of the registered PG and verification of the request, the API shall automatically stop any data ingests through the registered PG before making the change and provide a message to the PG requesting restart of the data ingests.

In addition to the new registration data, the PG must also provide via the API the unique PG ID assigned during the registration process along with the authentication information provided with the registration. If the changes are successful, the API will return a message "CHANGED" to the PG. If errors occur in the process, the API shall return an error code and log the error in the Data Bus.

5.3.2.1.3 Cancel PG Registration API

The DB API shall allow a PG to remove itself from the registration with the DB Name Services. Upon proper authentication and authorization checks, the API shall automatically stop any data ingests through the registered PG before deleting the registration. The DB shall automatically cancel the registrations of

all PMU/PDC devices and signals connected via the PG. This API shall also allow deletion from an authorized 3rd party source, such as the PG owner through an external user interface application.

Note that all registration records should be archived in the DB server. This API would deactivate the PG and remove its entry in the NASPInet Name & Directory Service, so no NASPInet services can be accessed after processing of the API.

The PG or requesting application must provide via the API the unique PG ID assigned during the registration process along with the authentication information provided with the registration. If the cancellation is successful, the API will return a message "CANCELED" to the PG or requesting application along with a list of Device IDs and Signal IDs that have been automatically canceled. If errors occur in the process, the API shall return an error code and log the error in the Data Bus.

5.3.2.1.4 Create Device Registration API

The DB API shall allow a PG to register, with the DB Name & Directory Services, a PMU/PDC device connected to the PG. The registration data may include the following for example:

- PG ID
- Device owner information
- Physical location of the device (Country, State, etc.)
- Location identification (substation name, etc.)
- Type of device (PMU, PDC, etc.)
- Device identification (owner organization name, device name, sequence number, etc.)
- Device configuration (physical & logical)
- Highest signal quality supported (data class – latency, reliability, etc.)
- Signal access method through P-PG (1-to-1, 1-to-N, etc.)
- Authentication information

Upon authenticating the PG and owner information and checking for logical registration data errors (e.g. the highest signal quality supported must be below the highest level supported by the PG), the DB API shall return a message to the PG with "CREATED" and a unique Device ID assigned by the NASPInet Name & Directory Services. If errors occur in the registration process, the API shall return an error code and log the error in the Data Bus.

5.3.2.1.5 Change Device Registration API

The DB API shall allow a PG to change data of the existing registration of an PMU/PDC device connected and "owned" to it with the DB Name & Directory Services. Upon proper authentication and authorization checks, the API shall automatically stop any data ingests from the PMU/PDC before making the change and provide a message to the PG requesting restart of the data ingests.

In addition to the new registration data (see Create Device Registration API for sample data), the PG must also provide via the API the unique PG ID and Device ID assigned during the registration process along with the authentication information provided with the registration. If the changes are successful, the API will return a message "CHANGED" to the PG. If errors occur in the process, the API shall return an error code and log the error in the Data Bus.

5.3.2.1.6 Cancel Device Registration API

The DB API shall allow a PG to remove an existing PMU/PDC device registration with the DB Name & Directory Services. Upon proper authentication and authorization checks, the API shall automatically stop any data ingests of all data signals connected to the registered PMU/PDC device and cancel the registration of these data signals before canceling the device registration.

Note that all registration records should be archived in the DB server. This API would deactivate the Device and remove its entry in the NASPInet Name & Directory Service.

The PG must provide via the API the unique PG ID and Device ID assigned during the registration process along with the authentication information provided with the registration. If the cancelation is successful, the API will return a message "CANCELED" to the PG along with a list of all registered signals that have been automatically canceled. If errors occur in the process, the API shall return an error code and log the error in the Data Bus.

5.3.2.1.7 Create Data Signal Registration API

The DB API shall allow a PG to add a data signal from a registered PMU/PDC that will be available through NASPInet. The registration data may include the following for example:

- PG ID
- Device (PMU/PDC) ID
- Complete signal description (type of signal, reporting rate, data format, etc.)
- Signal origin (e.g., original PMU signal that a PDC signal is derived from)
- Signal source (measurement CT/PT, source devices, etc.)

- Signal processing methods (if not original signal)
- Signal quality (data class – latency, reliability, etc.)
- Signal access method through P-PG (1-to-1, 1-to-N, etc.)
- Authentication information

Upon authenticating the PG and Device ID and checking for logical registration data errors (e.g. the signal quality must be below the highest level supported by the registered PG and Device), the DB API shall return a message to the PG with "CREATED" and a unique Signal ID assigned by the NASPInet Name & Directory Services. If errors occur in the registration process, the API shall return an error code and log the error in the Data Bus.

5.3.2.1.8 Cancel Data Signal Registration API

The DB API shall allow a PG to cancel a data signal from a registered PMU/PDC device that will be available through NASPInet. Upon proper authentication and authorization checks, the API shall automatically stop any data ingests from the data source before canceling the registration.

Note that all registration records should be archived in the DB server for auditing purposes. This API would deactivate the Signal and remove its entry in the NASPInet Name & Directory Service.

The PG must provide via the API the unique PG ID, Device ID, and Signal ID assigned during the registration process along with the authentication information provided with the registration. If the cancelation is successful, the API will return a message "CANCELED" to the PG. If errors occur in the process, the API shall return an error code and log the error in the Data Bus.

5.3.2.2 Streaming Data API

This set of APIs is intended for enabling the operational functions associated with streaming data. They shall follow IEC 61970 Interface Standards, Part 404, High-Speed Data Access.

5.3.2.2.1 Show Streaming Data API

The DB API shall enable the DB to request one or more streaming data signals from a registered PMU/PDC device through its owner PG to start ingesting through the DB to NASPInet. The DB shall provide the following information through the API:

- Source Data PG ID
- Device (PMU/PDC) ID
- Signal IDs
- Requester PG ID

- Authentication information
- Encryption/decryption information
- Date/time of request

Upon authentication of the request, the source data PG will start ingesting the requested signal data to the DB – if the request is the first request for the data signal. The data source PG shall return a "STARTED" message to the DB. The streaming data will continue until a cancelation is received for all active requests.

The DB shall automatically encrypt the streaming signal at the data entry node and decrypt it at data receiving nodes.

5.3.2.2.2 Cancel Streaming Data API

The DB API shall enable the DB to stop ingesting data from one or more registered PMU/PDC data signals through the DB to NASPInet. The DB shall provide the following information through the API:

- Source Data PG ID
- Device (PMU/PDC) ID
- Signal IDs
- Requester PG ID
- Authentication information
- Date/time of request

The DB shall authenticate and verify the Requester PG and determine if the cancellation is for the last subscription of the data signal. If the request is authenticated and verified, and if it is the last subscription, the DB shall send the request to the Source Data PG. Upon authentication of the request, the Source Data PG will stop ingesting the requested signal data to the DB –The PG shall return a message "CANCELED" to the DB.

5.3.2.2.3 Subscribe Streaming Data API

The DB API shall allow a PG to subscribe to data from one or more registered PMU/PDC data signals on the NASPInet through the DB. The API shall include provisions for selecting the data source signals and specifying the desired sampling rate for potential future NASPInet enhancements. The PG shall provide the following information via the API:

- Requester PG ID
- Source Data PG ID

- Device (PMU/PDC) ID
- Signal IDs
- Authentication information
- Data quality desired (data rate, etc.)
- Date/time of request

The DB shall authenticate the requester PG and check its data access authorization against the data source PG records before sending the request to the data source PG. Upon authentication of the request and data from the data source, the DB shall publish the streaming data to the requester PG.

The receiving node of the Requester PG shall decrypt the data from the Source PG and encrypt the data with a key that is specific to the streaming data subscription request. The DB API shall return a message "STARTED" with the decryption key to the Requester PG. If the streaming data is not successful, the DB API shall return an error code to the Requester PG.

5.3.2.2.4 Unsubscribe Streaming Data API

The DB API shall allow a PG to cancel an existing subscription of data from one or more registered PMU/PDC data signals. This API shall also allow the unsubscription request from an authorized 3rd party source, such as the PG owner or site administrator through an external user interface application. The PG shall provide the following information via the API:

- Requester PG ID
- Source Data PG ID
- Device (PMU/PDC) ID
- Signal IDs
- Authentication information
- Date/time of request

The DB shall authenticate the Requester PG and verify the unsubscribe request before sending the request to the data source PG. Upon confirmation of cancelation from the data source PG, the DB shall return a "CANCELED" message to the requester PG.

5.3.2.2.5 Browse Available Streaming Data API

The DB API shall allow a PG to get a list of available streaming data sources that it has access to through the DB Name & Directory Service. The PG shall send the following information via the API:

- Requester PG ID
- Authentication information
- Requester information (organization name, etc.)
- Organization and region of data of interest
- Signal types of data of interest

The DB shall authenticate the Requester PG and return with an error code, "NULL" if no data is available that the Requester PG has authority to access, or a list of data sources available, including source data PG ID and owner information, Device ID and location information, Signal ID, data types, and data quality (reliability, data rate, etc.)

5.3.2.3 Historical Data API

This set of APIs is intended for enabling access to historical data stored in data sources available to NASPInet. They shall follow IEC 61970 Interface Standards, Part 407, Time Series Data Access.

5.3.2.3.1 Browse Historical Data API

The DB API shall allow a PG to get a list of available historical data sources through the DB Name & Directory Service. The PG shall send the following information via the API:

- Requester PG ID
- Authentication information
- Requester information (organization name, etc.)
- Organization and region of data of interest
- Signal types of data of interest
- Begin and end date/time of data of interest

The DB shall authenticate the requester PG and return with an error code, "NULL" if no data is available that the Requester PG has authority to access, or a list of data sources available, including source data PG ID and owner information, Device ID and location information, Signal ID, data types, time period when historical data is available, and format of available data.

5.3.2.3.2 Get Historical Signal Data API

The DB API shall allow a PG to request historical data available from an external PG for a specified data source/signal, PMU/PDC (including all data signals connected to the PMU/PDC), or the external PG

(including all PMU/PDCs and all their data sources) for a specified period of time. The requester PG or application shall provide the following information via the API:

- Requester PG ID
- Authentication information
- Data source PG ID
- PMU/PDC Device ID
- Signal IDs
- Begin and end date/time

The DB shall authenticate the requester PG before sending the request to the source data PG. The source data PG shall return with a historical request ID and data-available period, which DB shall forward to the requester PG. (Note: The historical data will be in whatever format is available. The DB is not required to do any data conversions.)

5.3.2.3.3 Start Historical Data Transmission API

The API shall enable a PG to start transmission of the requested historical data. The PG will provide the historical data request ID along with information needed for its authentication.

Upon authentication of the request, DB will send the request to the source data PG to start the historical data transmission. The transmission will continue until the requested data is completely transferred or until a pause or cancel command is received.

5.3.2.3.4 Pause Historical Data Transmission API

The API shall enable a PG to pause an ongoing historical data transmission. The PG will provide the historical data request ID along with information needed for its authentication.

Upon authentication of the request, DB shall send the request to the source data PG to pause the historical data transmission.

5.3.2.3.5 Resume Historical Data Transmission API

The API shall enable a PG to resume a paused historical data transmission. The PG will provide the historical data request ID along with information needed for its authentication.

Upon authentication of the request, DB shall send the request to the source data PG to resume the historical data transmission.

5.3.2.3.6 Cancel Historical Data Transmission API

The API shall enable a PG to cancel a historical data request. The PG will provide the historical data request ID along with information needed for its authentication.

Upon authentication of the request, DB shall send the request to the source data PG to cancel the historical data request. If there is ongoing data transmission for the requested historical data, the source PG shall stop start the historical data transmission.

5.3.2.4 System Performance Management API

This set of APIs is intended for enabling access to data related to the Quality of Services history and system events of NASPInet.

5.3.2.4.1 Get NASPInet QoS Data API

The DB API shall allow a PG to query the DB for the quality of service measures within the DB and NASPI network for a specified data signal, PMU/PDC device (including all data signals connected to the PMU/PDC), or the PG (including all PMU/PDCs and all their data sources) over a specified period of time.) The DB will authenticate the requested PG and return the requested information to the PG. This API shall follow IEC 61970 Interface Standards, Part 403, Generic Data Access.

5.3.2.4.2 Get PG QoS Data API

The DB API shall allow the DB system administrator or application to query a PG for the quality of service measures on the PG side of the overall system for a specified data signal, PMU/PDC device (including all data signals connected to the PMU/PDC), or the PG (including all PMU/PDCs and all their data sources) over a specified period of time.) The PG is expected to authenticate the request and return the requested information to the DB. This API shall follow IEC 61970 Interface Standards, Part 403, Generic Data Access.

5.3.2.4.3 Get Transaction and Error Log API

The DB API shall allow a PG to query the DB for obtain a digital copy of the log of transactions and errors associated with the PG over a specified period of time. This API shall also allow queries from an authorized 3rd party source, such as the PG owner or site administrator through an external user interface application. The DB will authenticate the requested PG and email the requested information to the PG System Administrator that has been registered with the PG. This API shall comply with IEC 61970 Interface Standards, Part 403, Generic Data Access.

5.3.2.4.4 Subscribe Event Notification API

The DB API shall allow a PG to receive notifications of events associated with the PG, on event driven basis. The notification shall include originator of the event, timestamp, and type of event. The type of event may include, for example, (a) new device visible but not registered and provisioned for NASPInet, (b) an intrusion attempt through the PG, (c) a fatal error detected in an attempted API/transaction, etc. The DB will authenticate the requested PG and send the requested information to the PG System Administrator (via email and/or SMS) that has been registered with the PG. This API shall comply with IEC 61970 Interface Standards, Part 405, Generic Eventing and Subscription.

6 Networking and Communications Requirements

This section describes overall networking and communication requirements for NASPInet including the NASPInet WAN and Data Bus (DB) of NASPInet, and specific requirements for NASPInet WAN. This section includes an overview of the overall networking and communication needs and requirements of the NASPInet. While the DB_SUPPLIERs are encouraged to use their standard, field proven system architecture and standard external system interfaces to the fullest extent possible, the proposed system interfaces **must** adhere to DB_REQUESTER's Information Technology (IT) standards and guidelines identified in this section.

6.1 Overall NASPInet Networking and Communication Requirements

As shown in Section 1 and Section 2 of this specification, the NASPInet consists of two major parts: the Phasor Gateways (PG) and the Data Bus (DB) that connects all PGs. The DB is the logical entity facilitating data transportation among connected PGs. A PG will be the portal for a connected entity that enables it to publish its own synchro-phasor data to the DB and/or subscribe to data from other PGs through the DB.

All services and functionalities of NASPInet are provided through various PG specific components/services, DB specific components/services and enterprise IT Common Services of Requester as described in Section 2. All PGs and DB components are connected through a wide-area network (NASPInet WAN) to interact with each other for providing required functionalities and services. PGs also interface with their phasor data publishers/subscribers' own networks to forward the data received from publishers' networks to DB and the data received from DB to subscribers' networks.

DB-75. **Support multiple classes of data.** The NASPInet WAN and the PGs shall be able to simultaneously transport different classes of data with different QoS requirements and ensure the Quality of Service (QoS) for each class of the data. As a minimum, the NASPInet WAN and PGs shall support the data classes with QoS requirements specified in 8.2.

DB-76. **Phased implementation.** The NASPInet WAN is expected to be built through multiple phases to be in step with the growth of the number of connected PGs, external devices such as PMUs/PDCs and the network traffic. The NASPInet WAN design shall enable a gradual build-out of the network in steps of the increase of the connected PGs, traffic growth and overall network reliability requirement change. The PG locations and their data requirements at different phases of NASPInet deployment are provided as Attachment I of this RFP for NASPInet WAN network design and provisioning.

DB-77. **Life expectancy**. The minimum life expectancy of the NASPInet WAN shall be 30 years.

The following describes NASPInet networking and communications requirements for NASPInet WAN that connects DB and PGs, and for PGs.

6.2 NASPInet WAN requirements

DB-78. **Private network design.** The NASPInet WAN network shall be a private networking environment consisting of Local Area Networks (LANs) and Wide Area Networks backbone to interconnect the PGs and DB components, and employing, wherever practical, industry standards for hardware, software, and user interfaces. The goal of this type of "open" network architecture is to allow the addition of future functionality and the replacement of hardware without disruption to the NASPInet normal operation. The private network in this RFP is defined as that all network assets are owned by and under the control of the owner. This shall include all physical components of the network including the routers or interconnectivity between PG and DB components.

DB-79. The conceptual NASPInet WAN network configuration is illustrated in Figure 6-1, NASPInet Network Interfaces Diagram. The conceptual NASPInet configuration depicts at a high level the main scope that the DB_SUPPLIERs shall address with their response.

DB-80. **Path redundancy.** The NASPInet WAN network shall utilize redundant architecture design with fully redundant paths. The network design shall ensure the data delivery for each class of data meets its latency, interruptability, and system recovery time performance requirements in section 5. For data classes (Class A and B) requiring high availability and short interruption time, the NASPInet WAN network shall implement independent redundant paths for uninterrupted data transfer under any single point failure condition. The independent paths are defined as paths that do not share any devices/components along their paths, be it virtual channel or physical devices/components.

DB-81. **Quality-of-Service (QoS) guarantee.** The NASPInet WAN network shall guarantee end-to-end QoS requirements specified for each class of data between any paired publishing PG and subscribing PG. The QoS requirements for each class of data include the delivery time, availability and maximum interruption time requirements as specified in section 8.

DB-82. **Traffic Prioritization**. The NASPInet WAN network shall support prioritized transmission of different data service classes. The NASPInet WAN shall provide means for NASPInet WAN administrator to configure the transmission priorities of different classes of data without changing network equipment software or hardware. The DB_SUPPLIERs shall provide a detailed description of how the proposed NASPInet WAN network supports communications prioritization.

DB-83. **Interfaces**. The NASPInet WAN network shall provide direct and/or adapted interfaces for connecting PGs and DB components at the network interface points NI1 and NI3 as shown in Figure 6-1 “NASPInet Network Interfaces Diagram”. The interfaces shall allow PG owners to select a bandwidth that is suitable for its traffic.

DB-84. **Support multiple traffic patterns.** The NASPInet WAN shall support the following traffic patterns – one-to-one, and one-to-many. In the case of one-to-many traffic pattern, QoS shall be ensured for all receiving parties.

6.2.1 Network Protocols

DB-85. **IPv6 network protocol support.** The final implementation of NASPInet WAN network shall fully support IPv6 network protocol. All network equipment of NASPInet WAN shall fully support IPv6 network traffic. As a minimum, the core components making up the backbone of NASPInet shall fully support IPv6 protocol.

DB-86. **Migration plan.** Shall DB_SUPPLIERs propose the use of IPv4 network protocol for pilot and/or initial phase implementation for part of NASPInet WAN, DB_SUPPLIERs must provide a detailed description of pros and cons of the proposed design, the strengths of proposed solution with details regarding why the proposed solution is better suited for this application as to other competing migration methodologies, its migration plan to transition the pilot/initial implementation to final implementation fully supporting IPv6 network protocol.

6.2.2 Public Network Use

The NASPInet WAN network prefers the use of communication links and networking equipment dedicated to NASPInet WAN network. Shall the DB_SUPPLIER make the use of public network and communication facilities as part of or whole NASPInet WAN, the following requirements shall be met.

DB-87. **Limitations:** The use of public network shall be limited to networks containing dedicated facilities with service and bandwidth guaranties. These facilities shall be part of a larger network that is either switched, dedicated point-to-point, TDM legacy or switched. The network shall be private by nature of the TDM infrastructure or segmented using industry standard protocols in a switched environment. Network purchase in the configuration typically is reliable, provides alternate routes, and contains fault tolerant transport equipment. Typical forms of transport are fiber, DS1s, DS3s, and OCx.

DB-88. **Performance:** If DB_SUPPLIER's solution makes use of public communications networks, DB_SUPPLIER shall demonstrate certification from the carrier to operate on the public communications network, availability of network within physical boundaries of NASPInet WAN targeted territory, ability of the overall system to meet the information and performance requirements, such as QoS requirements, detailed herein under worst-case operating scenarios for the public network (e.g. maximum data retrieval, outage, and events), and provide detailed monthly public network usage estimates for the operating and extended life of the system based upon the base system load defined in the NASPInet System Design section.

DB-89. **Security.** DB_SUPPLIER shall demonstrate that the proposed public network(s) fully support the security provisions of System Security section (Section 7)

DB-90. **Reliability.** DB_SUPPLIER shall demonstrate that the public network supports the reliability requirements of the NASPInet.

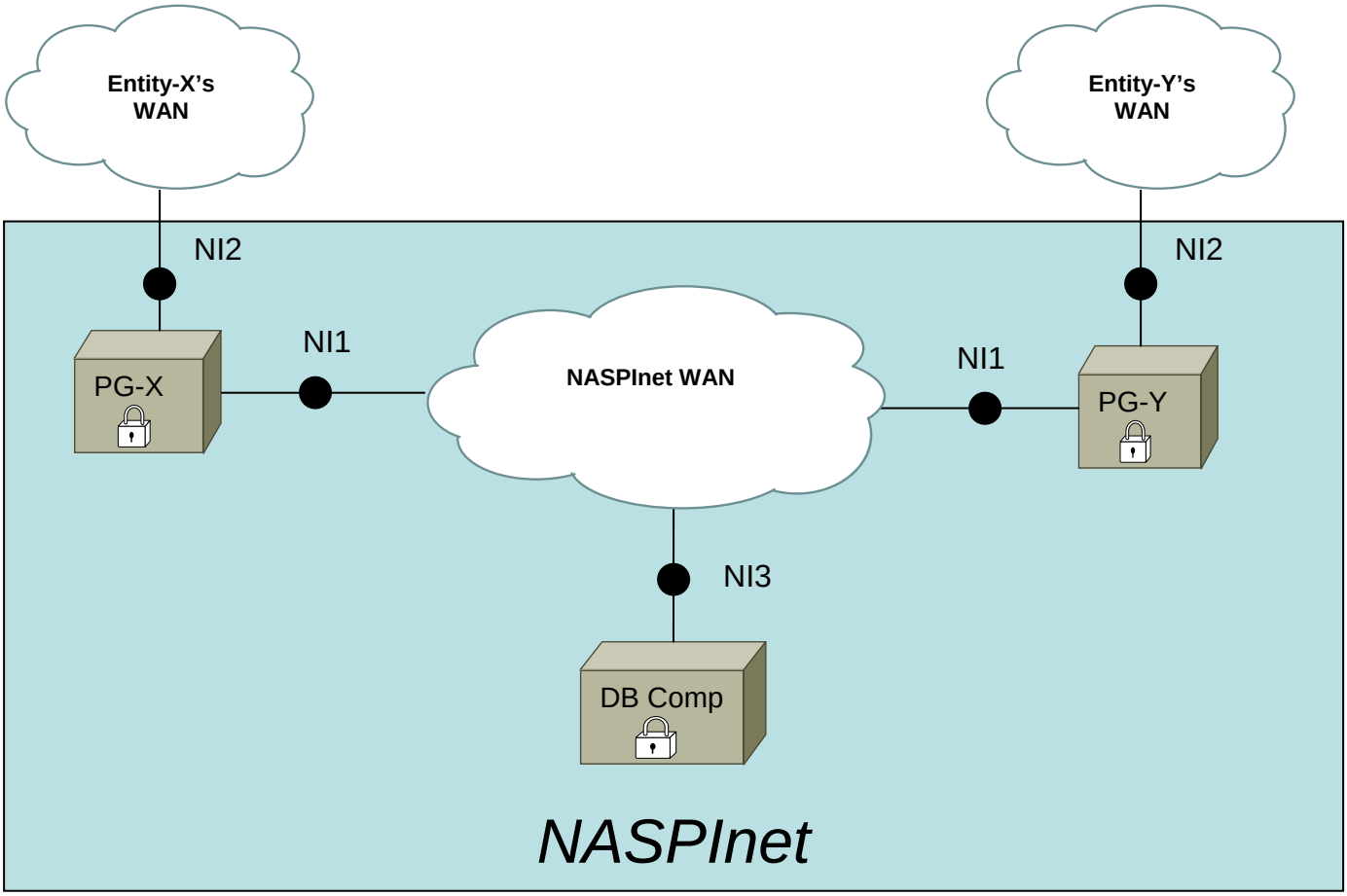

Figure 6-1 NASPInet Network Interfaces Diagram

6.2.3 Network Availability and Quality

DB-91. **Quality Control**. DB_SUPPLIER shall describe in detail mechanisms and processes used during the designing and implementation process to ensure system reliability (e.g. FMEA – Failure Mode and Effects Analysis).

DB-92. **Predictive/Preventative Reliability**. DB_SUPPLIER shall describe in detail the mechanisms and processes used to track and report performance of all elements of the NASPInet WAN network to ensure network reliability and proactively identify potential situations that could become network problems. Network reliability shall be measured in terms of the performance criteria established herein for required timeliness and accuracy of delivered network data, and tracking and reporting systems shall be adequate to conclusively demonstrate system performance.

DB-93. **Disaster Recovery**. The network shall support disaster recovery in case of a major network failure. In general, critical data flows (Class A and B) shall not be interrupted and the interruption of other data flows shall be within the allowed maximum interruption period.

6.2.4 Network Engineering

DB-94. **Engineering/Operating Requirement.** DB_SUPPLIER shall comply with all DB_REQUESTER's engineering, operating requirements concerning installation of equipment on DB_REQUESTER's facilities, obtaining access to DB_REQUESTER facilities, and adhering to operating rules and requirements involving safe contact with DB_REQUESTER equipment.

DB-95. **Open Standards**. DB_REQUESTER strongly encourages the use of open standards throughout the NASPInet WAN network. DB_SUPPLIER shall provide detailed description of the use of open standards, including, but not limited to, protocols, discovery, authentication, and system monitoring, diagnostics and management within the proposed solution. DB_SUPPLIER shall provide detailed description of all system elements (LAN, WAN, Backhaul, and network equipment, head-end) that employ open standards and all system elements that employ proprietary standards. DB_SUPPLIER shall describe what interoperability is supported across all the elements of their proposed NASPInet WAN network.

DB-96. **Upgradeable**. DB_SUPPLIER shall describe in detail the mechanisms and processes used to upgrade the network software/firmware and database for all necessary network components including, but not limited to: routers, switches, other network equipment, head-end; without network service interruption. Software/firmware updates shall be processed remotely and run automatically once initiated.

DB-97. **Scalability**. NASPInet WAN network design shall meet capacity requirements at each phase of implementation based on the phased implementation scenarios provided in Attachment I. DB_SUPPLIER shall provide a detailed explanation of how the proposed network meets this requirement.

DB-98. **Network Growth**. The proposed NASPInet WAN network shall allow for expected growth and shall be able to support the growth with only incremental system costs (i.e. proportional to PG and PMU growth and territory/network coverage). DB_SUPPLIER shall detail capacity of proposed system, and describe how the proposed system will meet growth requirements.

DB-99. **Network Enhancement.** DB_SUPPLIER shall describe how network bandwidth and capacity can be incrementally increased to handle additional network traffic beyond the PMU and PG growth (e.g., service additional data, more frequently delivery of interval data, etc.).

DB-100. **Technical Obsolescence**. DB_SUPPLIER shall describe what network elements of the proposed NASPInet WAN network are at risk of technical obsolescence over the operating life of the network.

DB-101. **Technology Plan**. DB_SUPPLIER shall describe their current technology plan and procedures for implementing enhancements over the operating life of the system.

DB-102. **Forward/Backward Compatibility**. DB_SUPPLIER shall ensure that proposed technology solutions will be supported for the life of the network, and that network parts, equipment and software will be available to maintain the required level of system performance. DB_SUPPLIER shall provide historical evidence of compatibility provisions.

6.2.5 Network Management

DB-103. **Network Management**. The proposed NASPInet WAN network shall include communication system and network equipment management functionalities for configuration, monitoring, and diagnose the network. The NASPInet WAN network management functionalities shall also be accessible through NASPInet DB administrators and system administration functions.

DB-104. **Communication System diagnosis capabilities**. The proposed NASPInet WAN network shall support local (on-site) and remote (system head end) diagnostics capable of detecting and autonomously alerting abnormal operating parameters in network communications.

DB-105. **Network Equipment diagnosis capabilities**. The proposed NASPInet WAN network shall support local (on-site) and remote (system head end) diagnostics capable of detecting and autonomously alerting abnormal communication network equipment operating parameters including, but not limited to, memory failure, power supply degradation, microprocessors(s) failures (e.g. computer operating system watchdog events), firmware/software problems, excessive device temperature, etc.

6.2.6 Network and Data Security

DB-106. **NASPInet WAN network security**. The proposed NASPInet WAN network shall have security provisions preventing unauthorized connection and access to any system elements connected to NASPInet.

DB-107. **Data Integrity**. DB_SUPPLIERs shall provide a systematic description of how data integrity is maintained between the PGs.

DB-108. **Data Security**. DB_SUPPLIERs shall provide a systematic description of how data security is maintained between PGs at the network level.

DB-109. **Authentications**. DB_SUPPLIERs shall describe how all communications in the system is authenticated between all communicating elements of the system and what mechanisms are employed to detect and announce non-authenticated communication attempts.

DB-110. **Network Access Control**. DB_SUPPLIERs shall provide a systematic description of how system and data access control is maintained across all NASPInet elements with remote access provisions (PGs through DB administration head end as applicable).

DB-111. **Network Access Histories**. NASPInet WAN network shall have provisions for access histories (logs) that at a minimum maintain date and time, equipment (PG and DB components), and data or functionality accessed and/or modified.

DB-112. **Network Security Administrations**. DB_SUPPLIERs shall describe how network security is configured enabling the creation and maintenance of NASPInet DB administrative access, user accounts, passwords, and information and functionality access levels.

DB-113. **Network Intrusion Detections**. DB_SUPPLIERs shall describe how the NASPInet WAN network monitors security provisions and reports any abnormalities or suspected intrusion.

DB-114. **Physical Securities**. DB_SUPPLIERs shall describe provisions of all NASPInet WAN network elements to maintain physical security preventing on-site tampering.

DB-115. **Testing/Certification**. DB_SUPPLIERs shall describe the types of the network security testing/certification that can be performed on the network, PGs, network endpoints, network elements, and head-ends.

DB-116. **Vulnerabilities**. DB_SUPPLIERs shall provide a detailed list of any potential network security vulnerabilities for PGs, DB components, endpoints, network elements, and system head-end. Analysis shall include types of protocols utilized, all open/utilized ports, use of public networks, etc.

6.2.7 Network Equipment Requirements

This section pertains to all network equipment deployed for the NASPInet WAN network to meet the NASPInet WAN network system requirements.

6.2.7.1 Equipment Standards

DB-117. All Network Communications Equipment of NASPInet WAN shall, as a minimum, meet the following equipment standards.

DB-118. All Network Communications Equipment of NASPInet WAN shall also meet additional equipment standard requirements appropriate for its operating environment. For example, meeting higher seismic standard in areas where earthquake is a possibility.

6.2.7.1.1 Environmental

DB-119. Operating and Storage Temperature: -40° to +85° Celsius

DB-120. Vibration: IEC 60068-2-6 (ANSI C12.1 Test #34)

DB-121. Shock: IEC 60068-2-27 (ANSI C12.1 Test #32)

DB-122. Humidity: ANSI 12.20 § 5.4.3.18

6.2.7.1.2 Electromagnetic environment compatibility

DB-123. Electromagnetic Radiation: DB_SUPPLIERs shall provide FCC electromagnetic radiation standards that met by all network equipment.

DB-124. Electromagnetic Susceptibility: ANSI C37.90.2

DB-125. Surge withstand Capability: ANSI C37.90.1 and ANSI C62.41

DB-126. Electrostatic Discharge: IEC 801.2

6.2.7.1.3 Power Supply

DB-127. **Power Source.** All network communications equipment shall be capable of connecting to a main 60 Hz AC voltage ranging from 120V to 240V nominal (with a ±5% tolerance).

DB-128. **Power Consumption.** DB_SUPPLIERs shall supply consumption requirements of each network equipment of NASPInet WAN network.

DB-129. **Backup power.** Backup power shall be provided to meet the power supply reliability requirements and provide a minimum of eight (8) hours of communications infrastructure operation after the loss of the main power supply. Batteries employed shall be rechargeable.

6.2.7.1.4 Upgradeability

DB-130. All network communications equipment shall support head end, remote and on-site software and firmware upgrades.

6.2.7.1.5 Certification of compliance

DB-131. **FCC certifications.** All network communications equipment shall comply with FCC Regulations and documentation/certification of compliance shall be included in Response.

DB-132. **Carrier Certification.** If necessary, DB_SUPPLIER shall obtain all necessary carrier certifications and provide documentation in Response.

DB-133. **Industrial Compliance.** DB_SUPPLIER shall provide all documentation to the DB_REQUESTER regarding product compliance to industrial standards. DB_REQUESTER may, if desired, request additional compliance from the DB_SUPPLIER.

6.2.7.1.6 Failure Rate

DB-134. **During required life span.** Less than 0.75% failure rate per annum for all network communications equipment, including but not limited to any auxiliary equipment necessary to

obtain and maintain communications (e.g. capacitor bypass or external antennas), over the required operating life of the network.

DB-135. **During extended life span.** Less than 1.50% failure rate per annum for all network communications equipment, including but not limited to any auxiliary equipment necessary to obtain and maintain communications (e.g. capacitor bypass or external antennas), over the extended operating life of the system.

6.2.7.1.7 Diagnostics

DB-136. **Network diagnostics.** All network communications equipment shall support local (on-site) and remote (system head end) diagnostics capable of detecting any abnormal operating parameters including, but not limited to, network communications, memory failure, power supply degradation, microprocessors(s) failures (ex. watch dog events), firmware/software problems, excessive device temperature, etc. All diagnostics shall be integrated and accessible via NASPInet WAN network management and administration infrastructure.

DB-137. **Network equipment diagnostics.** DB_SUPPLIERs shall provide a detailed list of supported diagnostics for each piece of network communications equipment.

6.3 DB-PG Network Interfaces NI1

DB-138. The DB shall provide network interfaces that will communicate with the registered PGs. The NI1 network interface between PG and NASPInet WAN of DB shall meet the following requirements.

6.3.1.1 Interface Options

DB-139. **Default interface options.** The PG to NASPInet WAN network interface shall offer as a minimum two default options: optical Ethernet interface and galvanic Ethernet interface.

DB-140. **Optical Ethernet interface option requirement.** The PG optical network interface option shall meet the following technical requirements. The interfaces shall provide interconnectivity from 300 meters to 80 kilometers.

Function	Value	
Applicable standard	IEEE 802.3u 100BASE-FX	IEEE 802.3z 1000BASE-SX
Communication speed	100 Mbps full-duplex	1000 Mbps full-duplex
Connectors	ST RX/TX Style connectors	ST RX/TX Style connectors
Cable	62.5/125 μm multi-mode fiber optic cable (glass)	50/100 μm multi-mode fiber optic cable (glass)
Optical wavelength	1270-1380 μm	850 nm
LED Indicators	Link Active, Receive Data, 100 MB/s, Transmit Data	Link Active, Receive Data, 100 MB/s, Transmit Data

DB-141. **Galvanic Ethernet interface option requirement.** The PG Galvanic network interface option shall meet the following technical requirements.

Item	Value	
Applicable standards	IEEE802.3u 100BASE-TX	IEEE802.3ab 1000BASE-T
Communication speed	100 Mbps for full-duplex	1000 Mbps for full-duplex
Connector	RJ-45	
Cable	2-Pair UTP Cat 5 up to 100m	2-Pair UTP Cat. 5, 5e, 6, and 7, up to 100m

7 Security Requirements

This section describes the NASPInet cyber security framework and mechanisms, as well as specific cyber security requirements of DB, for ensuring a high level of security of the NASPInet. The specific security requirements for PG are provided in the Security Requirements section of PG specification.

7.1 NASPInet Overall Security Requirements/Considerations

The two key components of the NASPInet - the Phasor Gateway and Data Bus – will together satisfy the overall NASPInet security requirements contained in this subsection. The NASPInet security requirements are stated in three levels: System level (This subsection), Data Bus (DB) level (Subsections 7.2 and 7.3 below of this Specification), and Phasor Gateway (PG) level (Subsections 7.2 and 7.3 of the Phasor Gateway Specification). The security requirements of PMU, PDC, and the associated NASPInet access networks are beyond the scope of this NASPInet specification. However, it is expected that PG_REQUESTER would adapt the security requirements of PG to its PMU and PDC security requirements, and adapt the DB security requirements to the security requirements of its access networks to NASPInet.

The overall (system level) NASPInet cyber security requirements are as follows.

7.1.1 End-to-End Security

All traffic of NASPInet shall be transmitted through the NASPInet with an end-to-end security guarantee, which means that the required security properties (e.g., confidentiality, integrity, authentication) of a given traffic flow must be satisfied by all the system components involved in the flow, namely, the end systems (e.g., PGs, servers) and the Data Bus. It shall prevent man-in-the-middle from intercepting the data traffic and tamper with it, and also shall prevent traffic replay attacks, colluding attacks, and masquerading attacks.

7.1.2 Flow Security

The data flow and control flow supported by the NASPInet shall satisfy security properties of confidentiality, integrity, authentication, non-repudiation, and availability. The implementation shall comply with the Federal Information Processing Standards (FIPS) relative to cryptographic infrastructure where applicable. FIPS PUB 140-2 titled “Security requirements for cryptographic modules” defines Security Levels 1-4 with increasing level of security from level 1 through 4. Many of NASPInet’s data services shall as a minimum, support “FIPS 140-2 Level 1” security. FIPS 140-2 Level 2 or higher levels of security shall also be supported as appropriate for certain applications to enhance the "physical security" (e.g., tamper resistance) of devices and cryptographic modules, e.g., to protect private keys. In addition, the overall system design shall meet the specified security level stated above for each data flow,

service, and protection functions of the NASPInet. (Refer to http://www.itl.nist.gov/fipspubs/by-num.htm for other relevant FIPS standards).

7.1.3 Heterogeneous Security Needs

The NASPInet shall support a diverse mix of security properties and priorities for different traffic classes, i.e., while some traffic shall require data integrity and authentication only, other traffic shall require data confidentiality in addition to integrity and authentication. For example, the PMU stream data flow shall prioritize data integrity property over confidentiality property, whereas infrastructure services such as the naming service and registration service shall require both confidentiality and integrity.

7.1.4 Security Infrastructure

NASPInet shall incorporate a FIPS compliant infrastructure, with relevant components including but not limited to certificate authorities, registration servers, naming servers, etc. to enable the required security functions for the various data flows supported. The infrastructure design shall specify how any private and/or PKI-based components will function relative to public and private key management.

There shall be no single point of failure in the security architecture and overall NASPInet resource management architecture. The architecture shall incorporate sufficient degree of redundancy of security services at the PG and Data Bus.

7.1.5 Infrastructure Security

The NASPInet infrastructure shall provide appropriate mechanisms to protect from, detect and stop infrastructure based attacks such as protocol-based, service-based, intrusion-based, man-in-the-middle (data modification, interruption, replay), denial of service, and other malicious attacks. It shall also be resilient, in terms of extensible pattern-matching, heuristic, parameter-based and other detection and alerting capabilities, to emerging and zero-day attacks via a suitable real-time security monitoring and mitigation framework.

7.1.6 Vulnerability Assessment

The PG_SUPPLIER and DB_SUPPLIER shall support vulnerability assessment and mitigation which collectively includes instrumentation of security event logs, real-time log analysis, vulnerability testing, and remedial measures such as security upgrades and patch management.

7.1.7 Trust Management

Establishing credentials among NASPInet components shall be an important design consideration. It is expected that a central authority (e.g. a NERC organization) would handle the credential management for

NASPInet connected entities, which includes entity registration, verification, credential distribution and revocation. As a minimum, this authority shall be able to:

- Define the various services and the type of credentials that are needed to access the given service.
- Define the various credentials and the superset/subset relation among credentials and union/intersection operation among credentials.
- Establish methods to grant and revoke credentials to a user/machine.
- Establish methods to upgrade/degrade the credentials required to access a given service.

7.1.8 Considerations of PMU Data Characteristics

7.1.8.1 Data Size and Static Data

The size of PMU signal data is typically small (4 to 8 bytes). Also, part of the PMU data does not change from one measurement cycle to another (e.g. signal header, PMU and signal IDs, etc.). The DB/PG encryption algorithms shall be utilized correctly considering these unique characteristics.

7.1.8.2 Security Granularity

The NASPInet system shall support security at different levels of granularity depending on class-specific requirements and implementations. The design shall weigh the pros and cons associated with security implementation at different levels to support fine-grained data publishing and accessibility. For example:

- The system shall support streaming data flow's security at the "signal" granularity level and at the data "frame" level. Data arrives at a "publisher gateway" in, for example, IEEE C37.118-2005 frames typically containing multiple PMU signals, e.g., one C37.118 frame may contain a voltage phasor and a current phasor. The subscriber shall be able to receive data down to the individual signal level. In this example, the publisher shall be able to grant permission to view the voltage phasor but not the current phasor even though they are in the same C37.118 frame.

- The publisher gateway shall be able to break C37.118 frames down to the constituent signals. It shall also be possible to reconstruct a valid C37.118 frame on the subscriber side if needed. Alternatively, the system may restrict access to, encrypt and/or otherwise secure each signal within a C37.118 data frame, and then send the entire frame out on NASPInet. The subscriber shall only have access to the signals for which they are authorized.

- Conversely, for a different class of data, the information may be stored in a file containing post-event data, and effective security might encompass an encrypting file system, Secure FTP, and/or other approaches.

7.1.9 Security and Controllability in a Dynamic Multicast Group

7.1.9.1 Dynamic Groups

It is expected that more and more entities will be connected to NASPInet and applications will be deployed/removed on a continuous basis by entities connected to the NASPInet. As a result, the subscribers for a published data stream of a multicast group, should multicast be used, will frequently change. Therefore, NASPInet must maintain security and controllability of a dynamic multicast group, accounting for specific restrictions that are inherent in the way multicast works:

- The PG of an entity shall be able to maintain its full control over which PGs it would share/receive data through NASPInet, not only in the initial setup but also during day-to-day operations.
- The DB shall provide secure multicast communications with applicable and appropriate security measures, including but not limited to source authentication as in unicast communications

7.1.9.2 Key Management

The system shall enforce dynamic key control. Because a multicast group, or any other group constraining access to any class of NASPInet information, is dynamic (i.e., members join and leave the group dynamically), the key management protocol shall ensure that the keys are updated dynamically to ensure changing data access rights due to joining and leaving of PG members through "join secrecy" and "leave secrecy". *Join secrecy* ensures that members that just joined the group will not able to decrypt existing data unless specifically allowed, and *leave secrecy* ensures that members who left the group will not be able to decrypt future data sent to the group.

Additionally, Key Management shall at a higher level provide the functionality to implement best practices including but not limited to on-demand, regular and random key rotation; and key revocation with appropriate levels of granularity.

7.1.9.3 Security and QoS Assurance

The system design shall ensure that the QoS guarantees of NASPInet be sustained considering the overhead associated with secure multicast communication, such dynamic key management, encryption and decryption. Meeting one requirement shall not degrade other requirements. For example, proposed systems with increasing security by using longer encryption keys shall have provisions in the hardware specifications for PGs to support encrypting and decrypting processes while meeting the QoS requirements.

In case of overloads that arise due to unanticipated contingencies, suitable resource management mechanisms shall be in place to temporarily degrade QoS for low-priority data flows, or even drop them if necessary, to support high-priority flows.

Similarly, the system design shall also address QoS and security guarantees for multicast flows for efficient implementation of publisher/subscriber model of data communication. The system design shall support key distribution and rekeying overhead without degrading QoS requirements.

7.1.9.4 A Key Management Example in Multicast Environment

The example below assumes the use of multicast capability of IPv6 protocol for real-time streaming data subscription fulfillment in a one-publisher-to-many-subscriber scenario. Separate cryptographic keys are used for a published data stream and for all subscriptions of the data stream that may subscribe to different portions of the data stream. The example illustrates a key management scheme that satisfies the above considerations.

In this generalized complex one-publisher-to-many-subscriber scenario for real-time streaming data distribution, a published data stream is subscribed by multiple subscribers, each subscribing to a different portion of the signals contained in the data stream with some overlaps between different subscriptions. Such scenario could occur as a result of different access rights were granted by the publishing PG to different subscribing PGs for signals contained in the data stream, or subscribing PGs subscribed to different signals of the data stream.

In this example, when a data stream is first published, P-PG would obtain a publishing cryptographic key from NASPInet. The publishing cryptographic key would be used by P-PG to encrypt the published data stream, and by the DB to decrypt the data stream wherever needed.

For each subscription to the published data stream, the subscribing S-PG would obtain a subscription cryptographic key from NASPInet. The subscription cryptographic key would be used by the DB to encrypt the subscribed data at the node serving the S-PG and by the S-PG for decrypt the subscribed data stream.

NASPInet DB key generation and management function would ensure that all publishing cryptographic keys and subscription cryptographic keys are not duplicated for all active published data streams and subscriptions.

The encrypted data stream from P-PG will be transported across the NASPInet WAN in IPv6 multicast protocol. The stream middleware of the NASPInet at the node serving the S-PG of a subscription will decrypt the data with the publishing cryptographic key of the data stream upon receipt of each frame of the data stream, extract the subscribed data, and encrypt the subscribed data with the subscription cryptographic key before delivering the data to the S-PG.

This scheme example takes the advantage of the efficient real-time data stream delivery of the multicast data distribution capability of the IP network, while only requires one additional decryption/encryption

process for fulfilling each subscription. With separate publishing/subscription keys, the *join* and *leave* secrecy of the published data stream can be maintained.

7.1.10 NERC CIP Compliance

The cyber security requirements of NASPInet shall comply with the relevant subcategories of NERC Critical Infrastructure Protection (CIP) standards CIP-003, CIP-005, and CIP-007. http://www.nerc.com/page.php?cid=2%7C20

The NERC required level of "security management control" (CIP-003) shall be supported including information protection (CIP-003-4), access control (CIP-003-5), and change control and configuration management (CIP-003-5).

The notion of "electronic security perimeter (CIP-005-1)" covering critical cyber assets (CIP-002-1) of NASPInet shall be identified. The security perimeter architecture (CIP-005-1) shall effectively enforce electronic access control (CIP-005-2), monitoring electronic access (CIP-005-3), and enable cyber vulnerability assessment (CIP-005-4), and generate necessary logs and documentations (CIP-005-5).

The NERC required "system security management" (CIP-007) shall be supported including security patch management (CIP-007-3), malware software protection (CIP-007-4), account management (CIP-007-5), and security status monitoring (CIP-007-6).

7.2 Data Bus General Security Requirements

7.2.1 Unicast

The DB shall support secure unicast (point-to-point) flows with specified security and QoS properties.

7.2.2 Publish/Subscribe Model

The DB shall also support multicast capabilities to implement a publish/subscribe model of data exchange in a resource efficient manner while maintaining the data confidentiality and integrity. The security services shall ensure that published data will only reach subscribers who have been authenticated and authorized to receive that data; subscribed data shall only come from the subscribed publishers authenticated and authorized to publish that data. The DB design shall describe how these security functions are provided for the Publish/Subscribe Model, including but not limited to approaches such as subscription limits on specific data, Group Key Management, and general audit controls.

7.2.3 Data Bus Middleware

DB shall be implemented in the form of a real-time middleware that provides QoS and security guarantees for real-time streaming data subscription fulfillment. The middleware shall provide

abstractions for QoS and security services. One of the important abstractions that shall be provided is the notion of a "virtual stream" for a data stream, which is a representation of a time tagged quantity similar in all respects to a measured PMU signal but which differs from a "raw" PMU signal derived from base measurements and analytics. An example of virtual signals is a subset sample of the original data stream, for the use of certain subscribers who do not need the complete data stream; or a signal representing a fictional quantity such as the eastern interconnection reference bus.

7.2.4 Access Control

All the real-time and non-real-time data and control services supported by the middleware shall be accessible through "role-based access control", which shall encompass a set of security services for managing roles and their privileges (security policy), authorizing roles to users (security authorization), and identifying users and track security behaviors (security registration). These security services shall be part of the system administration functions to manage roles by granting/revoking privileges, setting classification levels, assigning clearances and authorizing roles to end users/applications, and delegation of responsibilities from user to user.

7.3 Data Bus Specific Security Requirements

DB-142. The DB shall meet the following security requirements for Identification and Authentication, Logical and Physical Access Control, Information Assurance, Monitoring and Auditing

7.3.1 Identification & Authentication Requirements

DB-143. The DB shall be able to positively identify and authenticate each entity with which it communicates and any end users that have access to the DB infrastructure for administrative or other internal functions. The DB shall be able to positively identify and authenticate each NASPInet publisher and subscriber, as well as each communication session instantiated by these entities.

DB-144. Since the DB is envisioned to encompass and implement many of the enterprise IT services, including Security services, the DB shall use the Common Services of the DB_REQUESTER IT enterprise as appropriate to meet Security requirements. Specifically, the DB shall meet the following I&A requirements:

DB-145. **PG identification and authentication:** Prior to allowing connections to the DB, DB administrators shall securely obtain unique identifiers for PGs. These identifiers shall be used for positively identifying and authenticating messages received from PGs connected to the DB. The identifiers shall be signed, encrypted and stored securely. It shall not be possible for any entity to alter these identifiers, however they can be managed (generated, aged, revoked, etc.) by appropriate NASPInet administrative entities.

DB-146. **Subscription identification and authentication:** The DB shall assign a unique identifier for each approved data publication and subscription. These identifiers shall be used for positively identifying and authenticating subscriptions supported by the DB. The identifiers shall be signed, encrypted and stored securely. It shall not be possible for any entity to alter these identifiers, however they can be managed (generated, aged, revoked, etc.) by appropriate NASPInet administrative entities.

DB-147. **DB administrator identification and authentication:** The DB shall provide capabilities to manage DB users limited to DB administrators only. DB users shall be identified and authenticated by no less than an approved 2-factor authentication framework.

7.3.2 Logical & Physical Access Control Requirements

DB-148. **Access Control:** The DB shall meet all access control requirements specified in the NERC CIP standard.

DB-149. **Access Control Policy:** DB shall provide facilities for DB administrators to define and enforce access control policies at the user, application, network and other relevant entity levels. The DB shall enable administrators to define and enforce these policies based on multi-factor scenarios including but not limited to identity, roles, location, time, transaction, service constraints and others. The DB shall allow DB administrators to define these policies on an individual entity basis as well as for higher-level roles defined within the DB. The DB shall also allow administrators to modify access for each entity as long as it does not exceed simultaneous constraints associated with any other roles and scenarios in place for the entity.

DB-150. **Access control administration:** DB administrators shall be the only entities with privileges to administer the DB access control. It shall not be possible for other DB entities to administer the DB access control.

DB-151. **PG Access Control:** It shall not be possible to gain PG access via the DB.

DB-152. **DB Physical Access Controls:** The DB shall meet at minimum all physical access control requirements specified in NERC CIP, and meet FIPS 140-2 Levels 1-4 standards where appropriate.

7.3.3 Information Assurance Requirements

DB-153. The DB shall ensure that all transiting communications the information assurance requirements of confidentiality and integrity. The DB shall provide means to appropriately ensure that any information that it carries is secure and can only be understood by the intended recipients. The DB shall also provide facilities to enable recipients and itself to verify the integrity of transiting information.

DB-154. DB traffic shall be rendered confidential and verifiable, as appropriate according to traffic requirements, using means implemented via PGs and/or the DB. These methods shall include but are not limited to secret key and/or PKI encryption, publisher/subscriber segmentation, transformation to canonical formats within the DB, and others as appropriate. For example, PGs may implement secret key based cryptographic methods for streaming data and control flows, and support PKI for other traffic such as system administration (e.g. PG registration, device registration, etc.), provision publication and subscription entities, historical data exchange, etc.

7.3.4 Monitoring & Auditing Requirements

DB-155. The DB shall provide means to ensure that all activities within its domain are monitored and audited as appropriate for compliance with NERC CIP standards. The implementation of monitoring and auditing shall minimally include, but is not limited to, the following areas of concern:

- Activity & event logging that cannot be changed once recorded
- Key stroke monitoring
- User activity audit trails
- Transaction level audit trails
- System level audit trails
- Intrusion detection
- Anomaly analysis
- CIP compliance reporting

8 Sizing, Performance, and Availability

This section describes DB performance requirements, including system availability, spare capacity and expansion requirements, quality of service, sizing, latency, normal and worst-case loading, maximum number connections of PGs, PMUs, PDCs, and users.

8.1 System Sizing and Scalability

The NASPInet WAN and DB hardware components (including CPU memory, disk, number of processors, etc.) and software services (dimensioning, licensing, etc.) shall be sized to ensure delivery of the required system performance specified in this document for the PG locations and traffic levels of different data service classes of each PG, for each deployment phase provided in Attachment I.

For each deployment phase, the DB network, components and services shall support the numbers of PGs, PMU/PDC devices, and signals specified in Attachment I provided by the DB_REQUESTER as part of the RFP, plus a 100% margin at each PG location, without adding new system components (e.g. servers) and telecom network. Furthermore, the NASPInet WAN design and the DB components and services shall be able to expand from meeting initial traffic level to the ultimate traffic level of final deployment, plus a 100% margin, without requiring changes to technology platforms or requiring system software regeneration or replacement.

8.2 System Performance Requirements

The DB in its initial configuration shall meet the performance requirements defined herein. The loading for the DB in its initial configuration shall be simulated during the Factory Acceptance Tests.

8.2.1 System Activity Level Definition

For the purpose of identifying the DB performance under different system activity levels, the terms "steady state" and "high activity state" are defined below for each system. The DB_SUPPLIER shall simulate these activity levels during factory acceptance testing.

8.2.1.1 Steady State

The DB is said to be in a steady state when all the following are true (and are continuously recurring) over a 15-minute period:

1) Ten percent of the PG system administrators are performing system administration functions such as registering and removing phasor measurement data sources, modifying the list of published signals, modifying subscriptions to real-time streaming data sources or historical data sources, and other NASPinet administration functions.

2) Seventy percent of all registered analog and digital streaming data signals are being delivered to subscribers at a rate of 30 samples per second and the remaining thirty percent of registered analog and digital streaming data signals are being sampled and delivered to subscribers at 10 samples per second.

3) Fifteen NASPInet users are retrieving one hours worth of historical data via NASPInet from an average of 20 substations per user

The steady state conditions listed above may be modified as necessary to reflect the additional loading imposed by optional functions selected by DB_REQUESTER.

8.2.1.2 High Activity State

The DB is said to be in a high activity state when all the following conditions are happening (and are continuously recurring) over a 15-minute period:

4) The DB is performing all normal operational functions including injesting and processing data from all phasor measurement data sources in the system configuration.

5) Twenty percent of the PG system administrators are performing system administration functions such as registering and removing phasor measurement data sources, modifying the list of published signals, modifying subscriptions to real-time streaming data sources or historical data sources, and other NASPInet administration functions.

6) All registered analog and digital streaming data signals are being sampled and delivered to subscribers at a rate of 30 samples per second.

7) Thirty NASPInet users are retrieving one hours worth of historical data via NASPInet from an average of 20 substations per user

The high activity state conditions listed above may be modified as necessary to reflect the additional loading imposed by optional functions selected by DB_REQUESTER.

8.2.2 Time Reference Unit Accuracy and Stability

Time Reference Units shall be used to synchronize all clocks within DB processors and workstations to a common time standard. All DB clocks shall be synchronized to an accuracy of plus or minus 1 microsecond (μs) or better to the Universal Coordinated Time (UTC). UTC may be obtained from the Global Positioning System (GPS) time.

Upon loss of the time signal, the time reference unit shall revert to an internal time base. The internal time base shall have a stability of 1 μs per hour or better. The time shall return to within ±1.5 μs of UTC within five minutes of reacquisition of time sync signal.

8.2.3 System Latency

The latency (delay) for transferring data from publishers to subscribers shall not exceed the following amounts under normal and high activity conditions:

(1) The latency associated with real-time streaming data sources shall vary depending on class of data, as shown in Table 8-1 for Class A, B, and C data.

(2) The latency associated with historical data transfers (Class D and Class E data) shall not exceed thirty seconds for a thirty minute event involving 20 substations.

Table 8-1: **NASPInet Availability and Latency Requirements for Each Data Class**

Description	Class	Data rate	Availability	Maximum interruption	Latency	Max event length
Feedback control	A	30, 60, 120	99.9999%	< 5 ms	< 50 ms	N/A
Feed forward control	B	20, 30, 60	99.999%	< 25 ms	< 100 ms	N/A
Display	C	10, 15, 20 or 30	99.99%	< 100 ms	< 1 s	N/A
Disturbance analysis	D	30, 60, 120	99.99%	N/A	< 2 s for request/ response, best efforts for data transfer	30 min./event
Research	E	30, 60, 120	99.99%	N/A	< 2 s for request/ response, best efforts for data transfer	30 min./event

8.2.4 System Utilization

This section lists the utilization figures for each activity level along with response times expected during those activity levels that the DB_SUPPLIER shall demonstrate during the Factory Acceptance Test.

8.2.4.1 Steady State Utilization

When the DB is in the steady state (as defined in Section 5.2.1.1), the DB utilization shall be as follows:

1) The utilization of each server in the DB over any fifteen (15) minute period measured over the fifteen (15) minute interval shall be 30 percent (30%) or less.

2) Over any fifteen (15) minute period, each hard disk device in the DB system shall not be busy with data transfer for more than 30 percent (30%) of the time. The average data access time shall be used in any bulk memory timing analysis.

8.2.4.2 High Activity State Utilization

When the System is in the high activity state (as defined in Section 5.2.1.2), the DB utilization shall be as follows:

3) The utilization of each processor in the DB over any fifteen (15) minute period shall be 50 percent (50%) or less measured over the fifteen (15) minute interval.

4) Over any fifteen (15) minute period, each hard disk in the DB shall not be busy with data transfer for more than 50 percent (50%) of the time.

8.2.5 Alarm Response Time

With the DB in the steady state or the high activity state, all alarms shall be reported by audible and visual alarms at a DB Administrator's workstation within three (3) seconds. For the purpose of verification during FAT, an alarm message shall be displayed and alarmed facilities highlighted on displays within this time period:

8.2.6 Display Response Time

The display response time is defined as the elapsed time from the instant the display request is made by the user to the instant the requested display is completely shown on the console screen. Display response time shall not exceed one (1) second under steady state and high activity state conditions).

8.2.7 System Fail Soft Capability

The DB shall be designed to prioritize DB application functions to ensure that critical functions are carried out without excessive degradation in performance during DB overload periods (DB load exceeds the limit for the high activity state). Under no circumstances shall the DB fail to run due to "bursts" of input data changes and alarms. During a "fail soft" condition, the DB shall be designed to maintain the same level of function, reliability, and security.

8.3 System Availability

The individual DB components, and the DB as a whole, shall satisfy the availability requirements described in this section. The DB_SUPPLIER shall determine the level of redundancy required for each system component needed to satisfy these requirements. Redundant facilities shall maintain the same

level of function, reliability, and security. The capability of the DB to satisfy the availability requirements shall be demonstrated in DB Availability Tests during FAT.

The DB availability requirements shall vary for each data class (data class general requirements are contained in Section 2 of this RFP document). The DB availability is defined as the ratio of total time minus downtime, to total time. The availability and latency requirements for each class of data are shown in Table 8-1. The DB availability, transmission time, and processing time limit requirements for real-time streaming data service classes are shown in Table 8-2. In addition to the system availability requirements for each class of data, each DB_SUPPLIER-furnished device shall individually exhibit a minimum availability of at least 99.99%.

The proposed configuration shall have no single point of failure and shall protect against multiple device failures where devices have high failure rates or long repair times. The DB_SUPPLIER shall identify critical equipment, software, and processes. If the failure of any single device will cause the DB to become unavailable, a redundant unit shall be provided for that device. Automatic failover to backup facilities shall be completed with no loss of data.

Table 8-2 DB Availability, Transmission Time and Processing Time Limit Requirements

Class	Data rate (fps)	Availability	DB total transmission time limit (ms) – 1/4 of the NASPInet latency	DB total processing time limit (ms) – ½ of the NASPInet latency	DB individual component processing time limit (ms) – Min. of a) ½ of the reporting period, or b) 1/8 of NASPInet latency
	30		12.5	25	6.25
	60		12.5	25	6.25
A	120	99.9999%	12.5	25	4.17
	20		25	50	12.5
	30		25	50	12.5
B	60	99.999%	25	50	8.3
	10		250	500	50.0
	15		250	500	33.3
	20		250	500	25.0
C	30	99.99%	250	500	16.7

8.3.1 System Availability Definition

For the DB to be considered "available" all "critical" functions of the DB shall be executing properly without any degradation in response time AND the minimum complement of hardware must be operational.

"Critical" functions shall include all periodic and on-demand DB functions.

8.4 Equipment Operating Life

The DB system equipment shall be designed to have a useful life of at least fifteen (15) years with minimal servicing, part replacement, and software subsystems. .

Appendix A: Abbreviations and Acronyms List

The definitions and meaning of the abbreviations and acronyms used in this specification are list below.

ACL – Access Control Level or Access Control List
ADK – Adapter Development Kit
ANSI – American National Standards Institute
API – Application Programming Interface
AS – Authorization Server
CIA – Confidentiality, Integrity, & Authentication (also Central Intelligence Agency)
CIP – Critical Infrastructure Protection
CoS – Class of Service
COTS – Commercial Off-The-Shelf (product)
CPU – Central Processing Unit
CRC – Cyclic Redundancy Check
CT – Current Transformer
DB – Data Bus
ECO – Equipment Change Order
EMS – Energy Management System
FAT – Factory Acceptance Test
FCO – Field Change Order
FERC – Federal Energy Regulatory Commission
FIPS – Federal Information Processing Standards
FTP – File Transfer Protocol
GPS – Global Position System
GUI – Graphical User Interface
HDS – Historical Data Source (device that supplies recorded phasor data)
HMAC – Heavy Message Authentication Codes
HMI – Human-Machine Interface
IA – Information Assurance
ID – Identification number (for NASPInet, all IDs are 128-bit)
- Application ID – identifier for an individual application on a device that sends data to or receives data from NASPInet
- Device ID – identifier for any device that sends data to or receives data from NASPInet
- PG ID – identifier for any PG connected to the NASPInet DB
- Signal ID – identifier for every signal that is published and can be accessed on NASPInet
- Subscription ID – identifier for a subscription to a signal available on NASPInet
- User ID – identifier for any user of the net with access to any PG or the DB

IEEE – Institute of Electrical and Electronic Engineers
IEC – International Electrotechnical Commission
IED – Intelligent Electronic Device
IP – Internet Protocol (also Intellectual Property)
ISO – International Organization for Standardization
IT – Information Technology
J2EE – Java 2 platform Enterprise Edition
l-to-l – line to line (connection)
l-to-N – line to neutral (connection)
kB – Kilobytes (1 kB = 1024 bytes)

LAC – Logical Access Control
LAN – Local Area Network
MAC – Message Authentication Codes
MB – Mega-bytes (1 MB = 1024000 bytes)
MTBF – Mean Time Before Failure
MTTR – Mean Time To Repair
NASPI – North American Synchro-phasor Initiative
NDS – Name & Directory Service
NERC – North American Electric Reliability Corporation
NEC – National Electric Code
NEMA – National Electrical Manufacturers Association
NFPA – National Fire Protection Association
NI1 – Network Interface 1; interface on PG connecting to the NASPInet DB
NI2 – Network Interface 2; interface on PG connecting to devices external to NASPInet
NI3 – Network Interface 3; interface on internal NASPInet DB components
OEM – Original Equipment Manufacturer
PC – Personal Computer
PDC – Phasor Data Concentrator
PKI – Public Key Infrastructure
P-PG – Publishing Phasor Gateway
PG – Phasor Gateway
    PG-A – Phasor Gateway Access; PG logical component
    PG-D – Phasor Gateway Distributor; PG logical component
    PG-DM – Phasor Gateway Device Management; PG logical component
    PG-H – Phasor Gateway Historian; PG logical component
    PG-I – Phasor Gateway Ingest; PG logical component
PMU – Phasor Measurement Unit
PT – Potential Transformer
QoS – Quality of Service
RAID – Redundant Array of Independent Discs
RDBMS – Relational Database Management System
RFP – Request For Proposal
RPC – Remote Procedure Call
RT – Real Time
RT-SDS – Real-Time Streaming Data Source (device that streams phasor data in real-time)
S-PG – Subscribing Phasor Gateway
SAN – Storage Area Network
SAT – Site Availability Test or Site Acceptance Test
SCADA – Supervisory Control And Data Acquisition (system)
SDK - Software Development Kit
SDS – Streaming Data Source (device that streams phasor data)
SOA – Service Oriented Architecture
SOX – Schema for Object-oriented XML
SS – Security Service or Security Server
UTC – Coordinated Universal Time
WAN – Wide Area Network
XML – eXtensible Markup Language

Attachment I

This attachment is intended for the DB_REQUESTER to put in information regarding its company that the DB_SUPPLIER would need to know to develop specific solution configurations for the DB_REQUESTER and thus a more precise bid, including the following materials for example:

- PGs locations and projected data volume for each class of data service (publishing/subscribing, initial and final)
- IT policies and guidelines – e.g. IT governance, security policy, preferred IT platforms, etc.
- Operating procedures – e.g. safety procedures, equipment connection guidelines, etc.
- Existing and planned infrastructures – e.g. major facility locations, telecom network, etc.
- Existing IT systems – Enterprise IT common services (e.g. Enterprise Service Bus or middleware), Database Management System, Enterprise Performance Management tools, etc.

Attachment II

This attachment is intended for the DB_REQUESTER to put in specifications for hardware, software, and project implementation and system sustainment services based on the DB_REQUESTER's specific requirements and guidelines. Following are examples of these specifications that the DB_REQUESTER may tailor for its own needs or replace in whole with its standard Request for Proposal materials. Note that the following sections in this attachment follow the section numbering of the main text of the specifications so that DB_REQUESTER can conveniently move the tailored text to the main specifications body.

9 Hardware Requirements

This section of the Specification describes the hardware requirements for DB, which includes all DB hardware components that are included in the DB_SUPPLIER's scope of supply.

It is DB_REQUESTER's intention to procure a DB system that generally satisfies the requirements of this section but which is adapted to best use of the DB_SUPPLIER's standard products.

In some cases, preferences are identified for a particular manufacturer's equipment or a particular equipment design. Strict compliance with these preferences is recommended but not required. Compliances with preferences stated in this Specification shall not release the DB_SUPPLIER from the contractual obligations to satisfy the functional, availability, performance, capacity, security and other requirements of this Specification.

9.1 General Hardware Requirements

All hardware shall be manufactured, fabricated, assembled, finished, and documented with workmanship of the highest production quality and shall conform to all applicable quality control standards of the original equipment manufacturer(s) and the DB_SUPPLIER. All hardware components shall be new and suitable for the purposes specified.

The DB_SUPPLIER shall supply the most up to date hardware that is available at the time of shipment. Delivered hardware shall include all engineering changes and field changes announced by the manufacturer since it was produced. As part of the Site Acceptance Test, the DB_SUPPLIER shall have all hardware inspected and certified as acceptable for service under a maintenance contract by the local service offices representing the equipment manufacturers.

All hardware features described in the Proposal and in the Proposal's supporting reference material shall be fully supported by the system.

9.2 Processors and Auxiliary Memory

All processors shall be current models selected for the efficient operation of a real-time system.

The DB_SUPPLIER shall supply all processors that are used in servers and other equipment.

The DB System shall include a suitable user interface for accessing the servers. The server user interface devices shall be rack mounted in the same cabinet as the servers, and shall be equipped with a suitable draw out shelf (or equivalent device) so that the server user interface devices can be stored when not being used.

The processors shall include facilities for orderly shutdown and resumption of processor operation upon detection of power loss and subsequent resumption of power. The DB processors shall ensure that only authorized personnel can perform system shutdown/restart. All such operations shall be logged as system events.

9.3 Archive Storage

Archive storage devices shall be used for backup of the DB system data and software and archival storage for the historical data functions, such as QoS history, event logs, etc.

9.4 Local Area Networks

The DB system local area network (LAN) shall support the necessary throughput to meet overall system performance requirements. The DB system "backend" LAN shall be based on 1-Gbps Ethernet. Connections to clients (workstations) shall be based on 100 Mbps LAN. Suitable grade cabling for the application shall be provided.

9.5 Time Reference Unit

Time Reference Units shall be used to synchronize all clocks within DB processors and workstations to a common time standard. The accuracy and stability of the Time Reference Unit shall meet the requirement specified in Section 8.

The time reference unit shall include digital displays that, as a minimum, are capable of displaying the time in formats that conform to ISO 8601 standard specifications.

9.6 Spare Parts and Test Equipment

The DB_SUPPLIER shall deliver with the system all spare parts and special test equipment for all DB system components that will be maintained by DB_REQUESTER. DB_REQUESTER-maintained components will include all system components that cannot be maintained using OEM-supplied maintenance contracts. In particular, spare parts for critical DB system components that are **not** readily available from multiple sources shall be supplied to satisfy the availability requirements specified above.

Spare parts and test equipment shall also be supplied for other system components if necessary to satisfy the availability requirements specified above.

For multiple devices of the same type, the quantities of spare parts and test equipment shall be sufficient to maintain the equipment even if two similar failures occur simultaneously.

The DB_SUPPLIER proposal shall contain a list of spare parts that are included in the DB_SUPPLIER's base offering. The proposal shall also include a list of recommended spare parts that are not included in the base proposal.

9.7 Interconnecting Cables

The DB_SUPPLIER shall supply all cabling between components of the DB system. Plug-type connectors with captive fasteners shall be used for all interconnections. The connectors shall be polarized to prevent improper connections. Each end of each interconnection cable shall be marked with the cable number and the identifying number and location of each of the cable's terminations; this information shall agree with the drawings. Each cable shall be continuous between components; no intermediate splices or connectors shall be used. Terminations shall be entirely within the enclosures.

All interconnecting cables shall be rated as NEC Class 2 Plenum cable. Cables shall be tested to NFPA 262-1985 Test for Fire and Smoke Characteristics of Wires and Cables to a maximum peak optical density of 0.5, a maximum average optical density of 0.15, and a maximum allowable flame travel distance of five feet.

9.8 Equipment Enclosures

All DB_SUPPLIER-supplied equipment shall be mounted in DB_SUPPLIER-supplied enclosures.

The equipment enclosures shall be type HP Universal Rack 10642 G2 Pallet Rack Enclosure Cabinets or equivalent.

The enclosures shall meet the following requirements:

1) The enclosures shall meet or exceed NEMA 1 requirements

2) The enclosures shall be finished inside and out. All cabinet metal shall be thoroughly deburred, cleaned and sanded, and welds chipped to obtain a clean, smooth finish. All surfaces shall be treated. All edges and corners shall be rounded to prevent injury.

3) Enclosures shall be floor mounted with front and rear access to hardware and wiring. Enclosure height shall not exceed 80 inches.

4) Enclosures shall be lockable.

5) Moving assemblies within the enclosures, such as swing frames or extension slides, shall be designed such that full movement of the assembly is possible without bending or distortion of the enclosure or the moving assembly. Enclosures shall not require fastening to the floor to prevent tipping of the enclosure when the moving assembly is extended.

6) Wiring within enclosures shall be neatly arranged and securely fastened to the enclosure by non-conductive fasteners. Wiring between all stationary and moveable components, such as wiring across hinges or to components mounted on extension slides, shall allow for full movement of the component without binding or chafing of the wire.

7) Wiring within and between enclosures shall be secured and insulating devices (such as grommets) installed such that wire-to-metal contact is not possible.

8) All materials used in the enclosures, including cable insulation or sheathing, wire troughs, terminal blocks, and enclosure trim shall be made of flame retardant material and shall not produce toxic gasses under fire conditions.

9) Cable entry for DB equipment shall be through the bottom and sides of the enclosures.

10) Cooling air shall be drawn from the conditioned air within the room.

11) Wherever operating voltages in the hardware exceed 50 volts, the hardware shall be covered or shielded from accidental contact and shall be labeled accordingly.

12) All DB_SUPPLIER-supplied enclosures shall be suitable for mounting on DB_REQUESTER-supplied seismically-qualified “mounts”.

9.9 Power Supply and Distribution

9.9.1 Uninterruptible Power Supply

All DB equipment will be powered via DB_REQUESTER-supplied Uninterruptible Power Supplies that furnish single phase 110/220V AC power output with a maximum voltage variation of ±5% from nominal. The DB_SUPPLIER shall identify the maximum power demand for all DB_SUPPLIER-supplied components.

9.10 General Hardware Requirements

All DB system equipment shall satisfy the general hardware requirements described in the following sections.

9.10.1 Operating Environment

All DB equipment will be installed in facilities in which the temperature and humidity are controlled. DB equipment shall be designed to operate over an ambient temperature range of 60 to 90 °F with a maximum rate of change of 15 °F per hour. Relative humidity will range from 40% to 90% non-condensing.

9.10.2 Equipment Noise

The noise generated by the equipment in any enclosure, including desktop equipment, located in the computer room shall not exceed 60 dbA 1 meter (3 feet) from the enclosure. The noise generated by the equipment in any enclosure, including console equipment, located outside the computer room shall not exceed 50 dbA 1 meter (3 feet) from the enclosure. Sound-deadening enclosures shall be provided where necessary to meet these requirements.

9.10.3 Assembly and Component Identification

Each assembly in the system, to the level of printed circuit cards, shall be clearly marked with the manufacturer's part number, serial number, and the revision level. Changes to assemblies shall be indicated by an unambiguous change to the marked revision level. All printed circuit card cages and all slots within the cages shall be clearly labeled. Printed circuit cards shall be keyed for proper insertion orientation.

9.10.4 Enclosure Grounding

A safety ground in accordance with the National Electrical code shall be provided within each enclosure and shall connect to the ground (green) wire of the ac power input. Enclosure grounding shall be subject to DB_REQUESTER's approval.

9.11 System Environments and Facilities

9.11.1 System Environments

The DB_SUPPLIER shall provide the hardware needed to support the following environments:

- Production, including redundant servers, power suppliers, LAN/WAN connections, cluster and/or automated backup/failover, SAN and/or RAID disks, etc.
- Development
- Testing and staging
- Training
- Disaster Recovery

The Production environment shall meet all system sizing and performance requirements as specified in Section 8. The DB_SUPPLIER is requested to provide recommendations for the other environments.

9.11.2 Facilities

The DB_SUPPLIER shall provide estimates of the total facility and infrastructures needed to host the required equipment enclosures, installation space and admin workspaces, power supply, cooling, etc. for all system environments specified above, for the initial deployment phase and for each of the subsequent phases.

The DB_SUPPLIER shall itemize all facility requirements that it assumes that DB_REQUESTER would provide, for example electrical wiring, AC, LAN/WAN connections, etc.

10 Software Requirements

DB_REQUESTER's goal is to acquire a software platform that will be economical to maintain and upgrade over the life of the system. DB_REQUESTER expects to incorporate additional functionality in the system throughout the lifetime of the DB to keep pace with changing requirements.

The software delivered to DB_REQUESTER shall be the latest version/release that is available at the time of shipment so that additional software upgrades are not required within six months following shipment.

10.1 Conformance to Industry Standards

DB_REQUESTER requires that the DB conform to mainstream computing standards and *de facto* standards wherever those standards are appropriate in the context of the DB design.

10.2 Use of DB_SUPPLIER Standard Support Software

Although a specific set of software support requirements are presented in this section, the primary intent of this section is to elicit a clear statement from the DB_SUPPLIER as to the nature of the proposed software support environment. In any case, DB_REQUESTER will require the DB_SUPPLIER to adhere to its proposal and will verify this during testing.

10.3 Distributed Computing Environment

The DB_SUPPLIER shall provide a distributed computing environment that assures adequate flexibility for the evolution of the DB. Use of any of the services described in this section shall be restricted to users with proper authorization. The term "product", as used in this section, refers to established, recognized commercial offerings with a significant installed base.

10.3.1 Computer Operating Systems

The DB_SUPPLIER shall not modify the computer operating systems. The DB_SUPPLIER may use value-added utilities and subroutines that utilize the operating system services, provided they are fully supported by the DB_SUPPLIER or by the OEM of the utility.

The DB shall be designed such that upgrades to the operating systems may be performed independently of application functions, without interruption of the DB operations. It shall be possible to update redundant components one at a time.

10.3.2 Computing Network Communications

Communications within and among the computing networks supplied by the DB_SUPPLIER shall conform to OSI (Open Systems Interconnection) standards, as well as the TCP/IP ("Internet") protocols. The distributed computing environment shall be able to use both local area networks and wide area networks transparently, such that there shall be no restriction (other than capacity limitations) on the geographic dispersal of applications among the processors of the DB.

10.3.3 Open System Interfaces

The DB_SUPPLIER shall publish and make readily available for use by DB_REQUESTER detailed interface documents for all hardware and software subsystems that are part of the DB. These interface documents shall be sufficiently detailed to permit DB_REQUESTER to replace hardware or software subsystems with enhanced hardware or software and to integrate applications supplied by DB_REQUESTER with the DB.

10.3.4 Management and Monitoring of Computing Networks

Commercially available, standards based network management products shall be provided, and shall employ SNMP standards. All DB resources, including processors and network devices, shall include SNMP agents for use by the configuration management tools.

DB network and IT management toolset shall be compatible with the monitoring tools used by the DB_REQUESTER, which are provided in Attachment I provided by DB_REQUESTER as part of this RFP.

10.3.5 Network Time Synchronization

Network time shall be maintained for all elements of the DB. Synchronization among the DB processors shall be made through the use of distributed time services. Each processor and console in the network shall periodically synchronize to the timeserver.

Processor clocks shall be automatically synchronized to within 1 μsec of the time reference unit. In the event that the time reference unit is not available, synchronization shall be suspended. The authorized system maintenance person shall be able to manually suspend the time synchronization service and manually update the processor clock through the user interface. If a processor's internal clock and the time standard differ by more than an adjustable amount, synchronization shall be suspended and an alarm shall be generated.

10.3.6 Distributed Backup and Archiving

The DB shall include hardware, services, and procedures to backup, archive, and restore all DB software and data independently of its location on the DB networks. Once initiated, the distributed backup and archiving services shall automatically back up all information needed to recover from failures or data corruption without manual intervention by users. Although the devices being backed up may be physically separate, the backup system shall be managed centrally.

10.3.7 Diagnostics

The DB shall include all diagnostic software provided by the manufacturers of all hardware, including processors and peripheral devices, supplied with the DB. The DB shall also include error detection and diagnostic tools.

10.4 Application and System Development

DB_REQUESTER intends to incorporate new DB_SUPPLIER product offerings as well as product offerings from other suppliers on the DB. To manage and integrate these products and applications DB_REQUESTER requires tools to track changes that have been applied to the DB_SUPPLIER products and tools.

10.4.1 Off-Line Development Environment

The DB shall include an off-line Development Environment that shall enable DB_REQUESTER to update and test all system software (including operating system software, application software and associated models, database, and displays) in a manner that does not interfere with or jeopardize the integrity of the real-time operation of the DB. DB_REQUESTER prefers that the Training/Development system be used for this purpose.

The Development environment shall include all utilities required to develop and test new and modified software using a copy of the DB software. Facilities that shall enable DB_REQUESTER to transfer new and updated software from the Development Environment and integrate the new and modified software into the production (real-time) system without disrupting the operation of the production system shall also be provided.

10.4.2 Delivery of Source Code

The DB_SUPPLIER shall supply a compiled version of all executables with debug option to enable DB_REQUESTER personnel to view the source code for initial troubleshooting purposes. This compiled software shall be provided for all DB applications and for all DB software that has been developed specifically for DB_REQUESTER's purposes.

10.4.3 Software Configuration Management

The DB shall include a software configuration management system to define the elements and the associated attributes of the applications provided in the DB. Currently, DB_REQUESTER uses software configuration products listed in Attachment I. Source definitions for the application's elements (such as source code, display formats, etc.), the residency requirements (such as local, shared), and any access attributes shall be defined through the software configuration management system.

10.4.4 Communications Diagnostics

The diagnostics for all communications interfaces shall provide at least the following capabilities:

1) Select any communications channel for test.

2) Select a request message for transmission to another computer.

3) Select single or cyclic message transmissions to another computer for test purposes.

4) Monitor displays of information received from another computer.

The DB_SUPPLIER shall provide a comprehensive set of communication support tools to support all communication interfaces. The communication support tools shall be integrated with the DB database, report, and display tools.

The support tools package shall provide at least the following capabilities:

1) Provide interactive access to all communication database parameters.

2) Facilitate the addition and modification of communication elements.

3) Provide error detection and recovery procedures.

4) Monitor and display data communication device status.

5) Provide communication statistics including the number of errors, retries, bytes transferred, etc.

Once modifications to the database or configuration have been validated, the database editor shall interface with network management services to re-initialize the appropriate links. Link reconfiguration shall not adversely affect the current communications processor functions.

Communications parameters shall be stored in the DB. On user request, the database management system shall print an annotated report listing all such parameters.

10.5 System Environments and IT Infrastructures

10.5.1 System Environments

The DB_SUPPLIER shall provide the software needed to support the following environments:

- Production
- Development (See Section 10.4.1 Off-Line Development Environment)
- Testing and staging
- Training
- Disaster Recovery

The Production environment shall meet all system sizing and performance requirements as specified in Section 8. The DB_SUPPLIER is requested to provide recommendations for the other environments.

10.5.2 Facilities

The DB_SUPPLIER shall itemize all IT infrastructure requirements that it assumes that DB_REQUESTER would provide, for example, database management system, enterprise performance management, etc. Please see Enterprise IT common services in Sections 2 and 3 above.

11 Implementation and Sustainment Services

11.1 Quality Assurance and Testing

To ensure that the DB_SUPPLIER produces a well-engineered and contractually compliant DB, a quality assurance program shall be followed and both structured and unstructured tests shall be performed. DB testing and test documentation shall be performed in accordance with IEEE 829-1998 "Standard for Software Test Documentation"

All hardware and software furnished by the DB_SUPPLIER, including the DB_SUPPLIER's standard functions and features that were not developed specifically for DB_REQUESTER, and all work performed under this Contract shall be inspected and tested. Except when early shipment of DB equipment is required, no hardware or software shall be shipped until all required inspections and tests have been made, thereby demonstrating that the system conforms to this Specification, and until the hardware and software have been approved for shipment by DB_REQUESTER.

DB_REQUESTER personnel and/or DB_REQUESTER-appointed representatives will conduct all DB factory tests with support as required from the DB_SUPPLIER. Some portions of the Site Acceptance Tests (SAT) will be conducted by the DB_SUPPLIER with DB_REQUESTER's assistance as described in Section 11.1.8 of the RFP. Other portions of the SAT will be conducted by DB_REQUESTER with DB_SUPPLIER assistance (as described in Section 11.1.8). All tests shall be performed using DB_REQUESTER's actual DB equipment.

11.1.1 Quality Assurance Program

The DB_SUPPLIER shall provide and maintain a Quality Assurance program that encompasses the entire project life cycle to ensure that all activities that affect the quality of the DB are adequately identified, controlled and documented. The QA program shall provide for the minimization of defects, the early detection of actual or potential deficiencies, timely and effective corrective action, and a method to track all such deficiencies. All DB deliverables, whether produced by the DB_SUPPLIER or a DB_SUPPLIER's Subcontractor, shall be developed and maintained under a Quality Assurance (QA) program that meets the intent of the ISO 9000 quality assurance standards.

As a minimum, the DB_SUPPLIER's inspection and testing procedures shall conform to Quality Standard ISO 9003. Such conformance shall be certified by an independent organization that is qualified and accredited to perform such certification. A copy of the Quality System Certificate shall be included in the proposal.

11.1.2 Inspection

Following proper notification, DB_REQUESTER shall have free entry into any of the DB_SUPPLIER's or the DB_SUPPLIER's SubDB_SUPPLIER's facilities where the DB hardware and software is being fabricated or tested. The intent of these inspections is to prove that the system is being fabricated in accordance with this Specification.

11.1.3 Test Plans and Procedures.

DB_REQUESTER-approved test plans and test procedures are required for all factory and site acceptance tests. Test plans and procedures for factory acceptance tests and site acceptance tests shall be developed and documented by the DB_SUPPLIER to ensure that each test is comprehensive and that any part of the test can be readily repeated. Test plans and procedures shall be designed so that DB_REQUESTER personnel can conduct the actual testing, including setting up the test, running the test, and monitoring the test results.

Test plans shall identify and describe in detail what tests will be performed, the test configuration for each stage of testing, the schedule for performing these tests, the "ground rules" and guidelines for conducting the tests, witness sign-off procedures, and procedures for handling variances.

11.1.3.1 Test Plans

Test plans shall identify and describe in detail what tests will be performed, the test configuration for each stage of testing, the schedule for performing these tests, the "ground rules" and guidelines for conducting the tests, witness sign-off procedures, and procedures for handling variances.

Particular attention shall be given in the test plan to the methods of simulating facilities that will not be available in the factory (such as interface to external systems and communication facilities), the method of simulating ultimate system loading conditions, and the method of demonstrating and verifying the results of DB applications.

Specifically, the test plans shall include the following:

- Definition of individual tests to be performed and purpose of each test
- Interdependencies between tests (i.e., what functions must be successfully tested prior to starting each test.)
- Test schedule
- Responsibilities of DB_REQUESTER and DB_SUPPLIER personnel
- Methodology for classifying, tracking and correcting variances

- Copies of certified test data to be used in lieu of testing
- Block diagrams of the hardware configuration(s) to be used during the testing
- Description of test equipment to be used during testing
- Methods used to verify the correct operation of advanced DB functions, whose results may be voluminous
- Method used to simulate equipment that will not be available during factory testing (communication facilities, DB interfaces to external systems, etc.)
- Method used to simulate the ultimate system loading under steady state and high activity state conditions during the performance tests
- Time allotted for unstructured testing.

Test plans shall be submitted to DB_REQUESTER for approval at least twelve (12) weeks prior to the start of the preliminary factory acceptance testing (Pre-FAT).

11.1.3.2 Test Procedures

The DB_SUPPLIER shall provide detailed test procedures for each DB function at least eight (8) weeks prior to the start of the Pre-FAT. The test procedures shall be written so that the tests can be conducted by DB_REQUESTER personnel who have completed the recommended DB training but are not intimately familiar with the DB functions and user interface. That is, the test procedures shall include exact step-by-step instructions on conducting each step (all steps shall be included – not steps shall be implied or omitted) with specific observations that should be made by test personnel following each step to ensure that the step was properly completed. Test procedures that are not sufficiently detailed will be rejected by DB_REQUESTER.

DB_REQUESTER shall have approval rights over all test plans and procedures. DB_REQUESTER will review the procedures to ensure that they thoroughly test each specified function, including DB requirements contained in this Specification that will be handled by the DB_SUPPLIER's standard and customized system functions.

As a minimum, factory test procedures shall include the following:

- Purpose of each test
- Function to be tested
- Pre-requisites for conducting the test (i.e., what tests must be successfully completed prior to beginning the test)

- Set-up and conditions for testing, including methods of simulating ultimate sizing and high/normal activity level and external interface.
- Exact step-by-step procedures to be followed
- Expected results
- Acceptance criteria
- Special equipment needed.

11.1.4 Test Records

The DB_SUPPLIER shall maintain complete records of all factory and site acceptance tests. Test records shall include:

- Test results for each test step, including a passed/failed indication.
- Description of any special conditions or deviations from the approved test plan
- Identification of persons conducting the test
- Descriptions of variances, if any, and their resolution.
- Signatures of authorized DB_SUPPLIER and DB_REQUESTER personnel participating in the test

11.1.5 Variances

A variance report shall be prepared each time a deviation from the approved test procedures is detected during testing. Variance reports shall also be generated upon observance of anomalies that are not specifically identified as necessary observations in the test procedures.

Variance reports shall also be used to track anomalies identified following the completion of the FAT and the SAT.

The variance report shall include a complete description of the variance, including:

- Time and date when the variance was discovered
- Description of test conditions at the time of the variance
- Identification of the specific test and test step (where applicable) during which the variance was identified
- Identification of witnesses

- Classification of the variance. The variance shall be assigned to one of the following classes by mutual agreement of DB_REQUESTER's test personnel and the DB_SUPPLIER's test personnel.
- Actions taken to eliminate the variance, including the repeat of testing of related functions that may have been impacted by changes implemented to eliminate the variance.
- Results of retesting following correction of the problem.

11.1.6 Communication Protocol Conformance Testing

The DB_SUPPLIER shall furnish evidence that all communication protocols used by DB_REQUESTER's DB have been conformance tested by an approved agency independent of the DB_SUPPLIER to demonstrate that all relevant requirements of the standard that defines the protocol have been satisfied.

11.1.7 Factory Acceptance Test (FAT)

Shipment of the DB shall be contingent upon the achievement of satisfactory results for the factory acceptance test conducted at the DB_SUPPLIER's factory. Factory testing shall demonstrate that all system hardware and software, including the DB_SUPPLIER's standard hardware and software that is not developed specifically for DB_REQUESTER, complies with these terms of reference.

All specified functions and interfaces between functions shall undergo thorough testing. DB functions that require facilities that will not be completely available in the factory (such as DB equipment that is shipped early, communication facilities, and interfaces to external systems) shall be simulated during factory acceptance testing.

11.1.7.1 Preliminary Factory Acceptance Test (Pre-FAT)

The DB_SUPPLIER shall conduct a Preliminary Factory Acceptance Test (Pre-FAT) that includes a complete "dry run" of the FAT using the approved test procedures. DB_SUPPLIER personnel shall conduct the Pre-FAT and shall certify to DB_REQUESTER that the Pre-FAT has been successfully completed..

DB_REQUESTER personnel shall have the right to witness all or part of the Pre-FAT; however, the presence of DB_REQUESTER personnel at Pre-FAT shall not be required. DB_REQUESTER will identify portions of the Pre-FAT that DB_REQUESTER is interested in witnessing, and the DB_SUPPLIER shall identify the specific dates on which the Pre-FAT testing of interest will be performed so that DB_REQUESTER may schedule its attendance during such portions of the test.

The Pre-FAT shall be successfully completed, and certification of successful completion shall be supplied to DB_REQUESTER, at least two (2) weeks prior to the start of FAT,

11.1.7.2 Test Setup

The following sections describe the required test configuration and the requirements for a test database and software simulators to support factory testing.

11.1.7.3 Test Configuration

The configuration of equipment used during testing shall include a fully configured DB including servers, communication processors, etc. and simulated interfaces to external systems to which the DB will be interfaced.

To the extent possible, the actual equipment that will be supplied to DB_REQUESTER shall be used during testing. The DB_SUPPLIER shall not use substitute equipment or cables except as a consequence of the early delivery requirements of these terms of reference.

This test setup shall be used to demonstrate the proper operation of the DB for the required DB application functions under all anticipated loading conditions (including the normal activity state and the high activity state).

The DB_SUPPLIER shall supply all necessary test equipment to simulate inputs to the DB during factory testing. This test equipment shall provide convenient mechanisms to vary DB simulated substation inputs over the full signal range of each point.

This equipment shall also enable the test personnel to simulate simultaneous changes to groups of points. This capability shall be used to simulate normal activity and worst case loading during the performance test.

Facilities that cannot be included in the factory test configuration, such as field communication facilities and the interfaces to external systems shall be simulated during factory testing. The proposal shall identify the proposed technique for simulating each external system.

11.1.7.4 Test Database

The database built by DB_REQUESTER using the DB development system shall be used during testing so that test personnel can demonstrate that this database has been properly implemented. In addition to DB_REQUESTER's database, the test database shall include additional test points that can be used to demonstrate all the functions and requirements of this specification, including the ultimate system capacity.

11.1.7.5 Basic DB Factory Acceptance Test

The basic DB test shall fully demonstrate that all DB_SUPPLIER-supplied hardware and software satisfies all requirements contained in this Specification. The basic test shall include, but not be limited to:

1) Demonstration that all hardware operates by a thorough exercising of devices, both individually and collectively.

2) Thorough demonstration of proper operation of all specified DB functions, including test cases with normal and exception data.

3) Demonstration of interfaces to external systems using DB_SUPPLIER-supplied facilities and DB_REQUESTER-supplied data files for simulating these interfaces.

4) Simulation of alarm and status change conditions

5) Simulation of failure conditions and failure of each system device that has a backup unit

6) Demonstration that spare utilization requirements have been met for the ultimate sized system.

11.1.7.6 Performance Tests

System performance and response shall be demonstrated during normal activity (steady state) and peak loading conditions (high activity state) by creating appropriate loading on the system and monitoring the response time, equipment utilization, and other items to determine the system performance under these conditions. The normal activity (steady state) conditions and worst-case conditions described in Section 5 of this Specification (RFP) shall be simulated during the performance tests.

11.1.7.7 Unstructured Testing

A minimum of twenty (20) percent of the scheduled factory test time shall be set aside for "unstructured" exercising of the system hardware and software by DB_REQUESTER personnel. All variances identified during such testing shall be classified and resolved in similar fashion to variances uncovered during structured testing. Time delays caused by the system failures and the resolution of variances occurring during the unstructured testing shall be added to the total time allowed for unstructured testing.

11.1.8 Site Acceptance Testing

Site Acceptance Testing (SAT) shall be performed to verify that the system has been properly installed, and to demonstrate the proper operation of functions that could only be simulated during factory testing. The SAT shall also include an availability (endurance) test to verify that the DB is exhibits the required availability for each class of data over the specified test period when communicating with the full complement of DB_REQUESTER systems and components.

Special test equipment needed to conduct the site tests (if any) shall be provided by the DB_SUPPLIER.

The scheduling of all site-testing activities shall be coordinated with DB_REQUESTER. To avoid major impacts on DB_REQUESTERs, some of the site testing activities may be conducted at night or on weekends.

The following types of tests shall be included in the Site Acceptance Tests:

- Site Installation/Startup Testing (Section 11.1.8.1)
- Site Functional Testing (Section 11.1.8.2)
- Site Interface Testing (Section 11.1.8.3)
- Site "End-to-End" Testing (Section 11.1.8.4)
- Site Availability (Endurance) Testing (Section 11.1.8.5)

Some portions of the Site Acceptance Tests (SAT) will be conducted by the DB_SUPPLIER with DB_REQUESTER assistance. Other portions of the SAT will be conducted by DB_REQUESTER with DB_SUPPLIER assistance.

11.1.8.1 Site Installation/Startup Test

Site Installation/Startup test shall verify the proper installation of individual system components. This test shall verify that the individual major components of the DB have been properly installed and are operating correctly as individual units.

The Site Installation/Startup test shall be conducted by the DB_SUPPLIER with oversight by DB_REQUESTER personnel. DB_REQUESTER shall have the right to witness this test to ensure that the test is conducted as specified and to ensure that all variances that occur during the test are properly recorded and corrected by the DB_SUPPLIER.

11.1.8.2 Site Functional Testing

After the successful completion of the Site Installation/Startup tests, Site Functional Tests shall be performed on the DB. The site functional test shall be a subset of the basic functional performance test performed in the factory. Particular emphasis during this test shall be placed on verifying that all outstanding variances from FAT have been corrected.

The Site Functional test shall be conducted by the DB_SUPPLIER with oversight by DB_REQUESTER personnel. DB_REQUESTER shall have the right to witness this test to ensure that the test is conducted as specified and to ensure that all variances that occur during the test are properly recorded and corrected by the DB_SUPPLIER.

11.1.8.3 Site Interface Testing

After the successful completion of the Site Functional tests, Site Interface Tests shall be performed on the DB. The objective of this test is to verify that the individual interfaces to external systems are functioning properly. During this test, the DB_SUPPLIER shall demonstrate that each external interface is capable of performing the DB_REQUESTER functional requirements for each interface using the specified integration architecture The DB_SUPPLIER shall simulate data transfers the DB and each external system in both directions (where applicable) using the actual interface hardware (adapters) and network facilities.

The Site Interface test shall be conducted by the DB_SUPPLIER with oversight by DB_REQUESTER personnel and its service providers. DB_REQUESTER shall have the right to witness this test to ensure that the test is conducted as specified and to ensure that all variances that occur during the test are properly recorded and corrected by the DB_SUPPLIER.

11.1.8.4 Site End to End Test

After the site interface test has been successfully completed for the individual major components of the DB and all system components have been installed and individually tested, an integrated system test shall be performed to demonstrate the complete end-to-end operation of the DB. The objective of this test is to verify that data transfers from DB are properly received and executed by the external system, and that external system transfers are properly received by DB. DB_REQUESTER personnel shall conduct this test, with technical support as needed from the DB_SUPPLIER.

The integrated system test shall include a full demonstration of system failure and recovery modes that are included in the dual primary redundant system. This test shall verify that the system fails over properly with no loss of data following individual processor failures and following the transfer of the controlling facilities between sites. System performance during communication network failures shall be demonstrated.

11.1.8.5 Availability (Endurance) Test

Following successful completion of the site installation/acceptance tests, an availability test shall be conducted to verify the DB's ability to meet its availability requirements while communicating with the full complement of devices and external systems. All variances against the system shall be resolved prior to the start of the availability test.

The DB shall exhibit the specified availability for each class of data over a 720-hour period in accordance with the availability criteria identified in Section 8 of this Specification. Total system availability shall be computed after adjusting for "hold" time. Hold time includes contingencies that are beyond the control of either party, and therefore will not be considered "down" time for the purposes of measuring system

availability. Examples of “hold” time include power interruption and service response time. Such periods may be declared “hold” time by mutual agreement of DB_REQUESTER and the DB_SUPPLIER.

DB_REQUESTER will be responsible for conducting the availability test, which shall consist of normal system operation without special test equipment or procedures.

11.2 Documentation and Training

The DB_SUPPLIER shall furnish DB documentation and training that shall provide DB_REQUESTER personnel with a thorough understanding of the DB’s capabilities, use, administration, and maintenance. DB_SUPPLIER-supplied documentation and training shall enable DB_REQUESTER to develop a self-sufficient maintenance and support team. It is DB_REQUESTER’s intent to have complete operational and maintenance knowledge of the DB so that after the system has been installed and accepted, DB_REQUESTER’s technical staff may use, modify, and maintain the system with minimal assistance from the DB_SUPPLIER.

11.2.1 Documentation

The DB_SUPPLIER shall provide all of the documentation items described in this section for all DB hardware and software whether the hardware and software was developed by the DB_SUPPLIER or purchased from an Original Equipment Manufacturer (OEM). Documentation shall be subject to review and, for some documents, approval by DB_REQUESTER as described in Section 11.2.1.2.

The documentation supplied with the DB shall reflect exactly the final as-built system. Errors or modifications to the DB resulting from the factory or site testing shall be incorporated in this documentation. The DB_SUPPLIER shall submit new manuals or drawings as required to ensure that the documentation supplied with the DB does in fact reflect the final system as delivered.

If the DB_SUPPLIER provides DB_REQUESTER with its own software or third party software, the DB_SUPPLIER shall submit a list detailing the function of the software and the latest revision of the software supplied to DB_REQUESTER.

11.2.1.1 General Requirements

All DB documentation shall accurately describe the DB as delivered. All changes to the standard documentation that are needed to accurately describe DB_REQUESTER’s DB shall be fully integrated into the document text.

All DB documentation shall be delivered in electronic and hardcopy form. The required quantities of electronic and hardcopy versions of the documentation are specified in Section 11.2.1.4. All text materials shall be typewritten including all revisions, notes, and corrections. Handwritten texts and/or notes are not acceptable.

Where a manual is revised to reflect a change in design, or a change for any other reason, each such revision shall be shown by a revision number, date, and subject in a revision block.

11.2.1.2 Documentation Approval Process

DB_REQUESTER shall have the right to review the documentation for all standard and non-standard hardware and software to ensure that the documentation is complete and accurately describes DB_REQUESTER's DB. In addition, non-standard hardware and software (i.e., developed or modified specifically for DB_REQUESTER) shall be subject to approval by DB_REQUESTER. The intent is to ensure that all required documentation is provided and that the documentation accurately describes the DB.

The DB_SUPPLIER shall submit documentation for approval by DB_REQUESTER for all hardware and software modifications to the DB_SUPPLIER's standard hardware and software required to conform to the requirements of this RFP. The DB_SUPPLIER shall not proceed with implementation of any modifications to standard hardware or software until the documentation has been submitted by the DB_SUPPLIER and approved by DB_REQUESTER. Any purchasing, manufacturing, and programming associated with changes to standard hardware or software initiated prior to DB_REQUESTER's approval shall be performed at the DB_SUPPLIER's risk. DB_REQUESTER will approve the document or submit comments to the DB_SUPPLIER within 10 working days after receipt of average sized documents. The design review schedule shall allow more time for larger documents.

The design document review schedule shall be arranged to minimize the burden on DB_REQUESTER's document reviewers. That is, draft documents for review shall be submitted on a schedule that minimizes the number of design documents DB_REQUESTER needs to review at any given time. More time shall be allotted for the review of large documents than small documents.

Documentation for the DB_SUPPLIER's standard hardware and software shall be furnished for DB_REQUESTER's review to verify the overall quality of the documents, but approval by DB_REQUESTER of these documents will not be required.

11.2.1.3 Document Identification

All documentation submitted by the DB_SUPPLIER shall be accompanied by a letter of transmittal and shall be submitted in a sequence that matches the project milestones of the DB. Each document shall be identified by a document number, drawing number, revision or issue number, and the date of release.

11.2.1.4 Document Submittals and Quantities

DB documents shall be submitted in the following quantities at the indicated steps of document delivery:

1) *Approval Submission* — One hard copies and one electronic copy (that can be edited by DB_REQUESTER for inserting comments) of all documentation shall be submitted for DB_REQUESTER's review and (for non-standard documents) approval.

2) *Final Submission* — Four hard copies and one electronic copy that can be reproduced by DB_REQUESTER shall be submitted of each final document that has been reviewed and (for non-standard documents) approved by DB_REQUESTER.

3) *As-Built Documents* — The final as-built DB_SUPPLIER-produced and OEM documentation shall be supplied in both hardcopy (paper) and electronic form (Microsoft Word so that the document is editable by DB_REQUESTER – PDF versions are not acceptable). Four (4) hard copies and two (2) electronic copies of all documentation shall be submitted of the as-built version of all documents.

4) *As Built Drawings* — The final as built drawings shall be supplied in hardcopy (Mylar) form and electronic (Microsoft Visio) form. Four paper copies and two electronic copies of each as-built drawing shall be supplied.

11.2.1.5 Document Management Process

The DB_SUPPLIER shall utilize a quality control procedure for managing all documentation changes. The DB_SUPPLIER shall use a DB_REQUESTER-approved change management process for the DB_SUPPLIER copy of DB_REQUESTER's DB documentation.

11.2.1.6 Required Documents

As a minimum, the documents identified in the following sections shall be submitted.

11.2.1.6.1 System Functional Description

The System Functional Description document shall include a complete description of the functions performed by the DB. This document shall serve as a complete introduction to the DB and to the more specific hardware and software documents.

The document shall include an overview of the hardware configuration and indicate the functions of all major hardware components and/or subsystems. The Functional description document shall also identify the functions to be provided by the software. High-level hardware configuration block diagrams and software subsystem block and/or flow diagrams shall be included.

11.2.1.6.2 Hardware Documentation

The DB_SUPPLIER shall provide documentation for all DB hardware furnished to DB_REQUESTER. The hardware manuals provided for each OEM component of the system shall be supplied with the system.

The Hardware documentation shall describe the operational procedures and preventative maintenance procedures required as appropriate to keep the system in good operating condition. Hardware documentation shall included, but not be limited to, the items listed below. An inventory of all hardware documentation shall also be provided. The following hardware documentation shall be provided:

1) Configuration block diagrams showing the network configuration, as well as the logical and physical interconnections between the major hardware components,

2) Inventory of all DB hardware, including the manufacturer's name, model number, serial number, nameplate data, power consumption, and overall dimensions.

3) Physical planning/site preparation manuals containing detailed mechanical drawings of all equipment enclosures. Environmental requirements, such as operating temperature range, EMI/RFI susceptibility and standards certification, humidity operating range, vibration and shock limitations, and other such information, shall be identified for each hardware component.

4) Table of electrical power supply requirements for each hardware component.

5) Detailed installation wiring diagrams and cabling diagrams.

6) Assembly drawings for each enclosure

7) Jumper and/or switch settings for all applicable hardware components

8) OEM reference manuals and instruction books for all hardware.

9) Maintenance documentation, including manuals and other descriptive material, which will enable DB_REQUESTER personnel to maintain all DB equipment and test equipment.

10) Instructions for performing preventive maintenance

11) Diagnostic program user's manuals providing complete step-by-step instructions on the operation and interpretation of all on-line and off-line hardware diagnostic programs. These manuals shall identify symptoms, guides for locating faults, possible causes of trouble, and suggested remedial action.

12) Complete parts lists and breakdowns with sufficient descriptions to identify each component in the system, and ordering information for all hardware units.

13) Drawings showing the layout, detail dimensions, and mounting details of components

14) Control wiring diagrams

11.2.1.6.3 Software Documentation

The DB_SUPPLIER shall provide documentation for all software (including relevant firmware) to be supplied to DB_REQUESTER. An inventory of all software documentation shall be included. Software documentation shall include:

1) Description of the DB_SUPPLIER's change management process for all software.

2) A software overview document describing the system software on a subsystem basis.

3) Inventory of all software programs and modules and a cross-referenced index to the software documentation.

4) Software functional requirements document

5) Detailed description of interfaces between the DB and PG

6) Database documentation

7) Reference and user manuals for all third party software packages.

11.2.1.6.4 Training Materials

The DB_SUPPLIER shall supply all materials used during training sessions, including all instructor materials and student materials.

11.3 Training Requirements

This section describes the requirements for DB_SUPPLIER-furnished training of DB_REQUESTER personnel. The training courses shall be oriented towards providing DB_REQUESTER personnel with a thorough understanding of the DB capabilities, comprehensive instruction in the operation of all DB components, and all hardware and software maintenance instruction required to develop a self-sufficient maintenance team.

11.3.1 Training Plan

The DB_SUPPLIER shall provide a training plan and schedule to support the DB implementation schedule. The Training plan shall describe the specific training activities for each user group (e.g. system administrator, system maintenance, etc.)

The training plan shall identify the recommended training courses for each user group. The Plan shall describe in detail the objectives and content of each course, recommendations on who should attend the course, the location of each course, the schedule for each course relative to other DB development and

implementation activities, training course interdependencies (i.e., what courses must be taken before other courses), and required pre-requisites for each type of participant.

The Training plan shall be subject to approval by DB_REQUESTER.

11.3.2 Instructors

All training shall be conducted by qualified instructors that speak fluent English. Each instructor shall have had previous, formal classroom instructor experience in DB training and shall have a complete and thorough technical knowledge of the hardware and software supplied under this contract. The hardware instructor shall have a complete and thorough knowledge of test and laboratory hardware, diagnostic software, handbooks, guides and the use of tools and other aids in maintenance trouble-shooting and proper corrective actions for the system.

The instructors shall be able to present the materials in a manner that is most effective for the specific participants. Courses for control room operators shall be presented in terms that are familiar to the operators. Highly theoretical discussion of DB operations and algorithms is not acceptable for the control room operators and other non-engineers.

11.3.3 Training Materials

The DB_SUPPLIER and/or OEM shall prepare training manuals and instructor materials, and submit them to DB_REQUESTER ***prior*** to the start of classroom instruction with sufficient time for review. Each trainee shall receive an individual copy of the training materials.

The DB_SUPPLIER may utilize videotaped lectures as supplementary training material. However, videotaped lectures shall not serve as a replacement for a classroom instructor or as the primary training vehicle.

11.3.4 Course Content

The following sections identify the basic content of courses that shall be provided by the DB_SUPPLIER and/or OEMs.

11.3.4.1 Overall System Maintenance Training

The overall system maintenance course shall provide participants with an overview of, and hands on experience with, the DB functional capabilities and hardware and software diagnostic tools. This course shall cover all troubleshooting and debugging techniques available in the DB.

11.3.4.2 Hardware Training

The DB hardware training course shall provide all hardware training necessary to allow DB_REQUESTER to develop a self-sufficient hardware maintenance team, if desired. The hardware training courses shall cover the operation, maintenance, and repair of all DB_SUPPLIER-supplied hardware. These courses shall cover actual equipment operation, interfaces between equipment, preventive maintenance procedures, and troubleshooting procedures, including the use of all special test equipment.

11.3.4.3 Software Training

The DB_SUPPLIER shall provide all training courses to allow DB_REQUESTER to develop a self-sufficient software development and maintenance team, if desired. The software courses shall provide DB_REQUESTER personnel with thorough training on all DB software and all software tools and techniques used by the DB_SUPPLIER.

11.3.4.4 DB System Administrator Training

DB_SUPPLIER shall train designated system administrators of DB_REQUESTER on how to manage PG and device and signal registration requests, handle system events and alarms, monitor and tune DB QoS, etc.

11.4 System Implementation and Sustainment

This section specifies project installation, implementation, maintenance and sustainment requirements, including project management procedures, project documents, and other activities leading up to shipment of the DB. This section of the Specification also describes DB_REQUESTER's requirements for post-warranty maintenance and upgrade services.

11.4.1 DB Testing, Shipment, and Commissioning

The transition of activities from the implementation of the system in the DB_SUPPLIER's facilities through testing, shipment, installation, and commissioning is crucial to the success of the project. This section sets out the sequence of these activities and expands on the responsibilities of DB_REQUESTER and the DB_SUPPLIER for these activities.

11.4.1.1 Authorization for Shipment

Acknowledgement of the successful completion of all factory acceptance tests shall be deemed as authorization for the DB_SUPPLIER to ship the tested hardware and software to DB_REQUESTER's site. However, the DB_SUPPLIER shall submit an official notice of intent to ship at least one month prior to completion of the factory test. The notice shall indicate the contents, names of all carriers, estimated

shipping weight, size of shipment, insurance provisions, date scheduled to leave the factory, and estimated date and time of arrival at DB_REQUESTER's facilities.

11.4.2 DB Installation Support

DB_REQUESTER will oversee the DB_SUPPLIER's personnel during installation and startup of the DB equipment DB_REQUESTER will also supply resources to assist with on-site coordination and logistics. DB_REQUESTER will also provide all field equipment and communication backbone facilities. DB_SUPPLIER will perform the Site Installation/Startup tests, the Site Functional Test, and the Site interface test with the DB_SUPPLIER's resource team to demonstrate that the system is operating correctly under DB_REQUESTER oversight. DB_REQUESTER will conduct the site end-to-end testing and the availability test with assistance from the DB_SUPPLIER as needed. During these site activities, the DB_SUPPLIER shall be on-site to ensure that the system is being properly installed and to ensure that problems experienced during equipment installation, startup, and testing are promptly addressed and corrected. The DB_SUPPLIER shall also provide on-site technical support to DB_REQUESTER throughout this period. The DB_SUPPLIER shall identify the required levels of support and skill sets for information or integration to external systems that DB_REQUESTER needs to provide. DB_SUPPLIER shall include the engagement models for working with DB_REQUESTER service providers and application sustainment teams.

11.4.3 Maintenance and Upgrade Program

This section specifies the requirements for hardware and software maintenance for the DB. This section also includes options for hardware and software maintenance after the warranty period.

11.4.3.1 Definitions

The responsibility for maintenance of hardware and software will vary depending on the time during the Contract. So that the times for changes in responsibility can be determined, the following definitions shall be used:

- *Delivery* – Delivery of any item shall be interpreted as receipt of the item at DB_REQUESTER's facility.

- *Commissioning* – Commissioning of any item shall be interpreted as receipt of the item at DB_REQUESTER's facility, installation on-site, successful completion of the site tests, correction of all variances from the tests and completion of formal acceptance by DB_REQUESTER.

11.4.3.2 Early Shipment of Equipment

Upon approval by DB_REQUESTER, some components of the DB may be shipped to DB_REQUESTER's site prior to the successful completion of the factory acceptance test. The objective of early shipment is to expedite equipment installation and site testing activities.

As a minimum, the DB development system shall be shipped at an early stage (within two (2) months after award of contract) to enable DB_REQUESTER to gain familiarity with basic DB functionality and begin working on the DB_REQUESTER specific database and displays.

Early shipment will only be approved for components that are not required during factory acceptance testing to demonstrate that the functional and performance requirements contained in this Specification have been completely satisfied.

11.4.3.3 Hardware Maintenance

This section describes the DB_SUPPLIER's and DB_REQUESTER's responsibilities for maintaining the DB_SUPPLIER-supplied DB hardware. The DB_SUPPLIER's hardware maintenance responsibilities shall vary depending on the stage of the project and the location of the DB equipment.

11.4.3.3.1 Prior to Shipment

The DB_SUPPLIER shall be responsible for maintaining all DB_SUPPLIER-supplied DB hardware components prior to shipping this equipment to DB_REQUESTER. This maintenance may be performed under a maintenance contract with OEMs or other parties or by DB_SUPPLIER staff using spare parts from the DB_SUPPLIER's stores or other sources. However, the DB_SUPPLIER shall not use spare parts to be delivered to DB_REQUESTER for this maintenance. DB_SUPPLIER is responsible to ensure no production hardware equipment is older than 6 months at the time of shipment.

11.4.3.3.2 Maintenance During Installation, Startup, and Commissioning

After delivering the DB hardware, but prior to the commencement of the availability test, the DB_SUPPLIER shall have the responsibility for maintaining all DB_SUPPLIER-supplied hardware that is installed in the operating control centers. DB_SUPPLIER-supplied maintenance for this equipment may be performed under a maintenance contract with OEMs or other parties or by DB_SUPPLIER staff using spare parts from the DB_SUPPLIER's stores or other sources. However, the DB_SUPPLIER shall not use spare parts to be delivered to DB_REQUESTER for this maintenance.

During this period, the DB_SUPPLIER shall be responsible for maintaining all DB_SUPPLIER-supplied DB components. DB_REQUESTER shall be responsible for DB_REQUESTER-supplied components of the system.

Failed equipment shall be replaced or repaired and spares inventories replenished to their delivered level throughout this period. Any spare parts found to be defective during initial delivery inspection or during this period shall be replaced within one week after notification. There shall be no charges to DB_REQUESTER for these replacement parts, including delivery charges. All spare parts replaced under maintenance shall be new parts unless otherwise accepted by DB_REQUESTER.

11.4.3.3.3 Maintenance Under Warranty

Maintenance during the warranty shall be in conformance with the terms of the warranty sections of this Contract. During the warranty period, DB_REQUESTER hardware maintenance responsibilities will include the following:

- Performing preventive maintenance and installing engineering changes as needed on the equipment
- Performing initial troubleshooting when problems occur.
- Performing corrective maintenance with remote support and (if necessary) on-site support from the DB_SUPPLIER
- Providing local assistance to the DB_SUPPLIER during the DB_SUPPLIER's on-site problem resolutions.

DB_SUPPLIER hardware maintenance responsibilities during this period shall include the following:

- Providing materials and instruction for appropriate engineering changes.
- Provision of technical guidance towards the resolution of all hardware problems for the DB equipment.
- When needed, the DB_SUPPLIER shall respond to requests for technical support using a remote diagnostic, dial-up connection within four hours, 24 hours a day, seven days a week
- Providing on site corrective maintenance if DB_REQUESTER is unable to make the necessary repairs

Failed equipment shall be replaced or repaired and spares inventories replenished to their delivered level throughout this period. Any spare parts found to be defective during delivery inspection or during this period shall be replaced within one week after notification. There shall be no charges to DB_REQUESTER for these replacement parts, including delivery charges. All spare parts replaced under maintenance shall be new parts unless otherwise accepted by DB_REQUESTER.

The DB_SUPPLIER's technical support staff shall work with DB_REQUESTER's technical staff to establish a strategy to efficiently resolve each identified problem. If at any time, DB_REQUESTER believes that the DB_SUPPLIER's technical support is not effectively resolving a problem,

DB_REQUESTER may request that DB_SUPPLIER's staff or staff from the equipment's manufacturer be dispatched to DB_REQUESTER's facility. The DB_SUPPLIER's technical team shall be at DB_REQUESTER's facility within 24 hours to provide hands-on support towards the problem resolution. DB_REQUESTER will not be responsible for any expenses connected to the technical support, including travel expenses.

11.4.3.3.4 Post-Warranty Maintenance (Option)

As an optional service, post-warranty maintenance services shall be provided for select DB_SUPPLIER-supplied hardware:

The maintenance contracts shall cover preventative and remedial maintenance, spare parts, and installation of all engineering, equipment, and field change orders and upgrades. DB_REQUESTER agrees to notify the DB_SUPPLIER of their intent to install any changes or upgrades so that their compatibility with the other elements of the DB may be determined.

11.4.3.3.5 Spare Parts, Tools, and Test Equipment

The DB_SUPPLIER shall recommend on-site spare parts for field-replaceable and -repairable modules for DB_SUPPLIER-supplied DB equipment. The spare parts to be supplied shall be adjusted by the DB_SUPPLIER during the project so that the delivered set is consistent with the delivered DB configuration. The recommended spare parts shall include any special tools and test equipment that the DB_SUPPLIER and the original equipment manufacturer (OEM) use and which are applicable for DB_REQUESTER’s maintenance.

All spare parts used to make repairs prior to and during the warranty period shall be replaced or repaired by the DB_SUPPLIER and spares inventories replenished by the DB_SUPPLIER to their delivered level throughout this period

11.4.3.3.6 Hardware Minimum Support Period

The DB_SUPPLIER shall guarantee the availability of spare parts and hardware maintenance support services for all DB equipment for a minimum period of ten years after the expiration of the warranty. Subsequent to this minimum support period, the DB_SUPPLIER shall provide to DB_REQUESTER a minimum of one year's advance notice of their intent to terminate such services.

11.4.3.3.7 Expendable Supplies

The DB_SUPPLIER shall supply all expendable supplies required for use during the project while the equipment is at the DB_SUPPLIER's facility. The DB_SUPPLIER shall also provide a list of recommended expendable supplies one month prior to any delivery of hardware to DB_REQUESTER's site.

11.4.3.4 Software Maintenance

The term software shall include all software delivered under this Contract, as well as the associated installation kits, release media, documentation, and support media such as on-line help facilities and maintenance tools.

11.4.3.4.1 Software Categories

Software shall be divided into two categories:

- *Category 1* – All software, whether supplied by the DB_SUPPLIER or a SubDB_SUPPLIER, exclusive of that software defined as Category 2.

- *Category 2* – Commercial 3rd party software, such as operating systems.

11.4.3.4.2 Pre-Delivery Maintenance

The DB_SUPPLIER shall have the responsibility for maintenance for all software prior to delivery. This maintenance may be carried out under a maintenance contract with OEMs or other parties or by DB_SUPPLIER staff.

11.4.3.4.3 Maintenance During Commissioning

The DB_SUPPLIER shall have the responsibility for maintenance of all Category 1 software after delivery and prior to commencement of the availability test. This maintenance may be carried out under a maintenance contract with OEMs or other parties or by DB_SUPPLIER staff.

DB_SUPPLIER shall have the responsibility for maintenance of all Category 2 software after delivery and prior to commencement of the availability test.

During this period, DB_SUPPLIER will make changes to databases, displays, reports, and application programs as necessary to meet DB_REQUESTER's operational needs. DB_REQUESTER agrees to inform the DB_SUPPLIER of all such changes at least 24 hours prior to installation of the changes. If the DB_SUPPLIER believes that the changes may adversely affect the operation of software for which the DB_SUPPLIER is responsible, DB_REQUESTER shall be notified of the potential problem and the changes shall be reviewed. Both parties shall work towards a mutually agreeable implementation of the desired changes.

11.4.3.4.4 Maintenance under Warranty

Maintenance during the warranty shall be in conformance with the terms of the warranty sections of this Contract. The DB_SUPPLIER shall have the responsibility for maintenance for all Category 1 software

during the warranty period. This maintenance may be carried out under a maintenance contract with OEMs or other parties or by DB_SUPPLIER staff.

DB_REQUESTER shall have the responsibility for maintenance for all Category 2 software during the warranty period.

The DB software will likely be composed of DB_SUPPLIER's standard system elements, customized or specially developed elements, and several third party products. In order to facilitate the efficient maintenance of the DB software, the DB_SUPPLIER shall follow the general principle that software that is specific to DB_REQUESTER shall be implemented in specific libraries that are properly identified. This principle shall ensure that changes and upgrades to the DB_SUPPLIER's standard system software, applications, or third-party products can be implemented without affecting or interfering with the specific DB_REQUESTER software.

During this period, DB_REQUESTER will make changes to databases, displays, reports, and application programs as necessary to meet DB_REQUESTER's operational needs. DB_REQUESTER shall be under no obligation to inform the DB_SUPPLIER of such changes.

11.4.3.4.5 Post-Warranty Maintenance (Option)

As an optional service, post-warranty maintenance services shall be provided for select Category 1 software:

11.4.3.4.6 Software Minimum Support Period

The DB_SUPPLIER shall guarantee the availability of upgrades, technical support for all DB software, and announcements of software and hardware releases applicable to the system for a period of ten years after the expiration of the warranty. Subsequent to this minimum support period, the DB_SUPPLIER and/or the DB software subDB_SUPPLIERs shall provide to DB_REQUESTER a minimum of one year's advance notice of their intent to terminate such support.