Sea Based Joint Precision Approach and Landing System (JPALS) Aircraft System Performance Specification

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REVISIONS

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1 Scope

1.1 Identification

This specification establishes the functional and performance requirements for the airborne segment of the Sea Based Joint Precision Approach and Landing System (JPALS) (Formerly known as the Shipboard Relative Global Positioning System (SRGPS)). It is not the intent of this specification to allocate requirements to hardware or software configuration items.

Requirements contained within this specification were derived from the *Sea Based JPALS System Requirements Document* (SRD) [9] to support the *Operational Requirements Document (ORD) for the Joint Precision Approach and Landing System (JPALS)* (USAF 002-94-I), Block I Shipboard Operating Environment (SOE) [4].

Note: This specification was developed to support the ORD referenced above. The ORD will be replaced by a Capability Development Document (CDD) and future versions of the Sea Based JPALS specifications will be developed to show traceability to the CDD.

1.2 System Overview

JPALS provides the Department of Defense (DoD) with a navigation, air traffic control (ATC), and landing capability for Shipboard operations and a terminal navigation, precision approach, and landing capability for Fixed Base, Tactical, and Special Mission operations ashore. JPALS consists of modular avionics and ground components to provide a range of navigation, air traffic control, and landing capabilities that can be tailored to satisfy mission needs. JPALS information will be broadcast from ground or ship systems to aircraft avionics. Aircraft will receive ranging and navigation data from the satellite constellation and differential ranging data or corrections from a ground/shipboard station via a data link (DL). The JPALS Operational View-1 (OV-1) is shown in Figure 1-1.

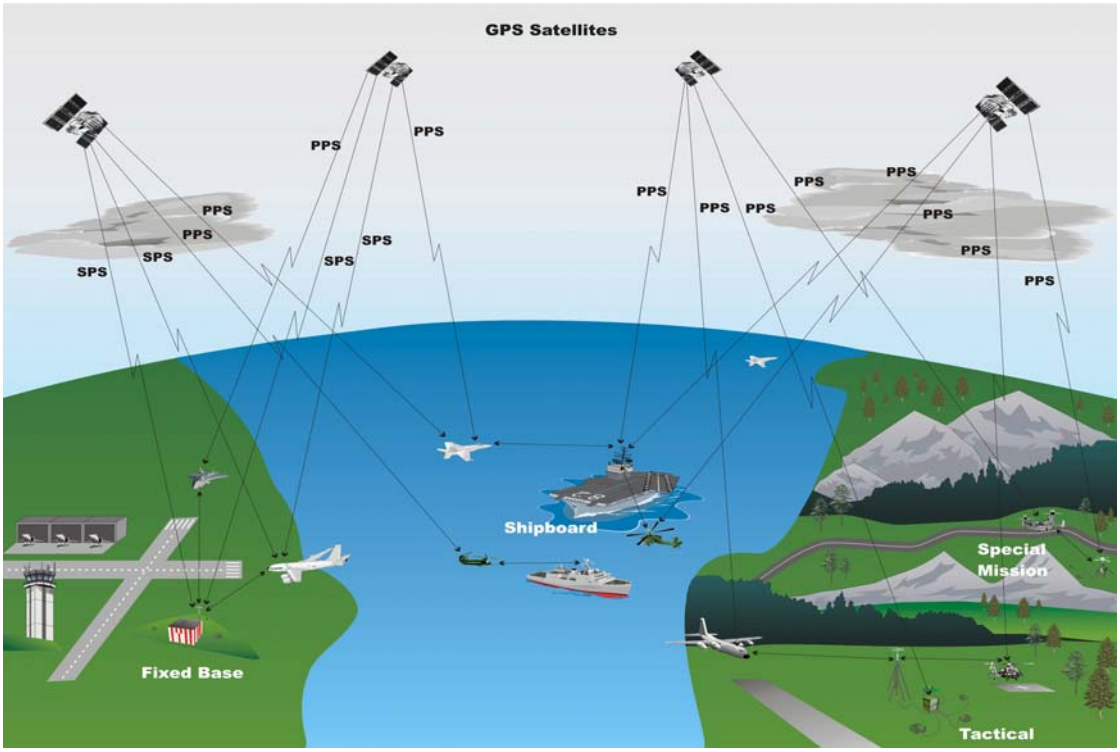

Figure 1-1: JPALS Operation View-1 (OV-1)

Sea Based JPALS supports three-dimensional positioning and guidance, secure two-way communications with the ship, separation of aircraft on approach, and monitoring of approach data by ship operators on military air-capable ships. Sea Based JPALS is a safety-critical system consisting of hardware and

software that uses the Navigation Satellite Timing and Ranging (NAVSTAR) Global Positioning System (GPS) Precise Positioning Service (PPS), and a DL network to perform relative navigation to JPALS-equipped U.S. Navy and North Atlantic Treaty Organization (NATO) ships. Relative measurement processing using GPS data is used to meet the accuracy, integrity, continuity, and availability requirements of Sea Based JPALS-supported operations. Sea Based JPALS augmentations to GPS PPS are based on relative GPS positioning concepts. GPS measurement functions within Sea Based JPALS are protected by GPS anti-jam (A/J) equipment. The DL network supports the relative navigation functions and is intended to aid in monitoring functions and to supplement ship-to-air and air-to-ship communications.

Sea Based JPALS consists of two main segments:

1. Sea Based JPALS-Ship, which is installed on air-capable ships, and
2. Sea Based JPALS-Air, which is installed on aircraft capable of landing on those ships or that have traditionally used the Tactical Air Navigation (TACAN) service from those ships for area navigation (RNAV).

The communication between the two Sea Based JPALS segments is performed via the Sea Based JPALS DL signal-in-space (SIS). The Sea Based JPALS-Ship segment and the Sea Based JPALS DL SIS are specified in separate documents.

1.3 Operating Environment

The Sea Based JPALS must be capable of conducting its primary functions, such as navigation, approach and landing operations, while at sea under potentially severe marine weather and ship motion conditions and in a challenging electromagnetic environment. Hostile enemy action will normally be targeted on the aviation ship and will typically include long-range missiles and subsurface threats. Information generated by Sea Based JPALS must be protected against enemy efforts to detect, classify, geo-locate, and/or target friendly forces (e.g., the aircraft carrier). Flight operations are conducted on multiple classes and types of ships that may be deployed individually or within a battle group or task force. The role and use of Sea Based JPALS in support of operations in this environment are described in detail in the *Concept of Operations (CONOPS) for Future Air Traffic Control Operations using the Sea Based Joint Precision Approach and Landing System (JPALS)* (CONOPS) [7].

1.4 JPALS Requirements Hierarchy

This Sea Based JPALS Aircraft System Performance Specification is part of a family of documents that establish the system, performance, and interface requirements for Sea Based JPALS. Figure 1-2 illustrates the hierarchy of the various Sea Based JPALS requirements documents.

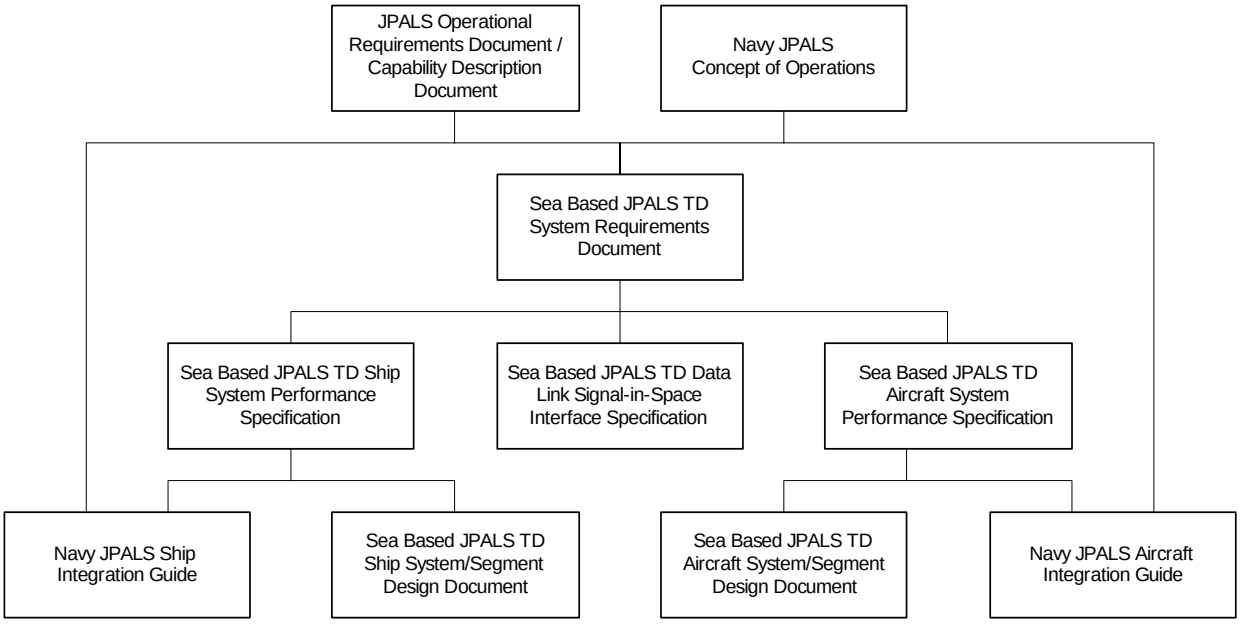

Figure 1-2: Sea Based JPALS Specification Tree

The JPALS ORD [4] contains the JPALS operational requirements, which are the primary source for the Sea Based JPALS performance requirements. Additional Sea Based JPALS performance requirements were derived to support the capabilities and operations described in the CONOPS [7]. The system level requirements derived from the JPALS ORD [4] and CONOPS [7] are documented in the Sea Based JPALS SRD [9]. From the SRD, performance requirements are then allocated to the Sea Based JPALS-Ship specification and the Sea Based JPALS-Air specification, as applicable. The interface between ship and air is defined in the Sea Based JPALS DL SIS Interface specification.

Both the Sea Based JPALS-Ship and Sea Based JPALS-Air specifications have companion integration guidance documentation. The integration guidance documents will provide detailed information pertaining to the installation and integration of Sea Based JPALS on ships and aircraft.

Design documents will be created during the Technology Development (TD) phase of the JPALS program to reflect the Sea Based JPALS-Ship and Sea Based JPALS-Air design used to validate these requirements and allocation decisions made during that phase.

This specification is to be used with the following specifications:

- Sea Based JPALS DL SIS Interface Specification [10]
- Sea Based JPALS-Ship System Performance Specification [11].
- JPALS Aircraft Integration Guide [6].

1.5 Document Overview

This document contains the following sections:

1. **Scope**: Contains the project identification, system and document overviews, and a list of assumptions used in this document.

2. **Reference Documents**: Provides a list of the documents referenced in this standard; references contain the document number, exact title, revision level and issue date.

3. **Requirements**: Specifies the requirements for the system to which this specification applies.

4. **Quality Assurance and Verification Requirements**: Ensures that the requirements of section 3 are satisfied.

5. **Terms and Acronyms**: Defines terms and acronyms defined in this document.

6. **Interface Definition**: Provides definition of data elements passed across the interfaces defined in this document.

7. **Example of Acceptable KCPT Algorithm**: Provides, as an example, a Kinematic Carrier-Phase Tracking (KCPT) algorithm that may be used to meet the requirements in this document.

The word "equipment", as used in this document, includes all components or units necessary (as determined by the equipment manufacturer or installer) to properly perform its intended function.

In this document, the term “shall” is used to indicate requirements. An approved design would comply with every requirement, which can be assured by inspection, test, analysis, or demonstration.

The terms “must” and "will" are used to identify items which are important but are either duplicated somewhere else in the document as a “shall”, or are specified in other documents.

The term “should” is used to denote a recommendation that would improve the Sea Based JPALS equipment, but does not constitute a minimum requirement.

While the specification development proceeds, a single term ("to be reviewed (TBR)") is used to identify any requirements that might ordinarily be labeled as to be determined/defined (TBD), to be specified (TBS), to be provided (TBP), or TBR.

1.6 Assumptions

1.6.1 Environment

It is assumed that the environment specified in section 3.2.5 in which Sea Based JPALS-Air must operate bounds the actual operational environment. If the environment is more severe than that specified in Section 3.2.5, the availability of Sea Based JPALS-Air may be reduced; however, requirements related to safety of flight will still be met.

1.6.2 GPS Signal-In-Space

It is assumed that GPS satellites transmit signals that comply with Interface Control Document (ICD) ICD-GPS-200C [1] and the *Global Positioning System Standard Positioning Service (SPS) Performance Standard* [5].

Note: The GPS PPS Performance Standard will be applicable and referenced when published.

JPALS performance assumes all GPS satellites in view support dual frequency code and carrier phase measurements all the time.

1.6.3 Sea Based JPALS Signal-In-Space

It is assumed that the Sea Based JPALS-Ship is providing a SIS in accordance with *Sea Based JPALS Data Link Signal-In-Space Interface Specification* [10].

1.6.4 Sea Based JPALS-Ship Subsystem

It is assumed that the Sea Based JPALS-Ship is operating in conformance with the requirements stated in the *Sea Based JPALS-Ship System Performance Specification* [11].

1.6.5 Sea Based JPALS Application

Sea Based JPALS technology is fundamentally different from current navigation and ATC systems such as SPN-41, SPN-46, air surveillance radar, and TACAN. Therefore, Sea Based JPALS will incorporate some new and different procedures for operations around Navy ships. However, even though some procedures are different, it is possible to overlay them with current operations in a way that JPALS and legacy aircraft can operate in a compatible manner. In general, these differences will be in specific operator actions versus the generic functions supporting navigation, communications, and separation. In other words, despite the differences in some procedures, Sea Based JPALS can be used to support the

same ATC functions as legacy systems. As the air wing approaches full JPALS equipage, it is anticipated that Sea Based JPALS procedures will be revised or extended to take greater advantage of the system's performance capabilities.

2 Reference Documents

The documents listed in this section are cited in this specification. This section also includes documents recommended for additional information or as examples. The following documents form a part of this specification to the extent specified herein.

[1] ICD-GPS-200C, *NAVSTAR GPS Space Segment/Navigation User Interfaces,* IRN-200C-005R1, 14 January 2003, ARINC Research Corporation, 2250 E. Imperial Highway, Suite 450, El Segundo, CA 90245-3509.

[2] MIL-HDBK-454, *General Guidelines for Electronic Equipment,* 28 April 1995, Department of Defense.

[3] MIL-STD-1472F, *Human Engineering Design Criteria for Military Systems Equipment and Facilities,* 23 August 1999, Department of Defense.

[4] *Operational Requirements Document (ORD) for Joint Precision Approach and Landing System (JPALS)*, USAF-002-94-I, 19 March 2003, Air Force Flight Standards Agency.

[5] *Global Positioning System Standard Positioning Service Performance Standard*, (no number), October 2001, Department of Defense.

[6] SRGPS-AIGD-0016, *Joint Precision Approach and Landing System (JPALS) Aircraft Integration Guidance Document,* Version 1.0, 25 March 2004, Naval Air Systems Command.

[7] Concept of Operations (CONOPS) for Future Air Traffic Control Operations using the Sea Based Joint Precision Approach and Landing System (JPALS) IOC (2012), Draft, 15 May 2004, Naval Air Warfare Center.

[8] MIL-STD-461E, *Requirement for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment,* 20 August 1999, U.S. Government Printing Office.

[9] SRGPS-SRD-0003-A, *Sea Based JPALS System Requirements Document*, Version 1.5, 25 June 2004, ARINC Engineering Services, LLC.

[10] SRGPS-SIS-0006-A, *Sea Based JPALS Data Link Signal-in-Space Interface Specification*, Version 1.5, 25 June 2004, ARINC Engineering Services, LLC.

[11] SRGPS-SPSS-0005-A, *Sea Based JPALS Ship System Performance Specification*, Version 1.5, 25 June 2004, ARINC Engineering Services, LLC.

[12] CJCSI 6130.01C, *2003 Chairman of the Joint Chiefs of Staff (CJCS) Master Positioning, Navigation, and Timing Plan*, 31 March 2003, Joint Staff, Washington, DC.

[13] *Joint Technical Architecture (JTA) Version 6.0*, 3 October 2003, Department of Defense.

[14} MCEB-M-067, *Frequency Plan for 225-400 MHz Band*, June 1999.

2.1 Order of Precedence

In case of a conflict between this document and the referenced documents, the order of precedence in descending order is as listed below unless otherwise noted herein:

1. Applicable Federal, State, or Local Laws and Regulations
2. JPALS ORD
3. Sea Based JPALS SRD
4. Sea Based JPALS-Aircraft System Performance Specification (this document)
5. Other Referenced Specifications and Documents Referenced in Section 2

In case of conflict between referenced documents at a lower order of precedence than this document, the more restrictive requirement applies, unless otherwise approved by the Government in the form of a change to this document or by contractually effective means.

Lack of a requirement at a higher level of precedence is not considered a conflict. The more detailed requirement applies.

3 Requirements

This section prescribes functional and performance requirements for Sea Based JPALS-Air. Functional requirements and their groupings do not imply allocation of functionality to hardware or software design. Only when required to establish interoperability, specific design and/or algorithms are specified. Certain other design-specific requirements are given to ensure the accuracy, continuity, availability, and integrity needed to support minimum performance levels required to operate safely in the ship environment.

3.1 System Definition

3.1.1 Major Functional Capabilities

Major functional capabilities of the Sea Based JPALS-Air segment include:

- Navigation Function:
  - Airborne Relative State Function: Consists of the following:
    - GPS Sensor Function: Determines ranging data from GPS satellites and any processing allocated to it
    - Relative Position Function: Use GPS data (air and ship) to locate the ship and determine relative position states
  - Airborne Guidance Function:
    - Computes the path the aircraft should follow and then determines the deviation states of the aircraft and the range and range rate along the commanded path.
    - For precision operations, the guidance function stabilizes the path and the relative position states of the aircraft to account for the motion of the ship. The path and position states are stabilized to a center of motion (COM) point on the ship. This is accomplished by sensing the movements of the ship in all six degrees of freedom (heave, surge, sway, pitch, roll, and yaw). The guidance function also generates deck motion compensation (DMC) data that may be used by the control function.
- Airborne Communications Function:
  - Data Link Tx/Rx Function: Allows for exchange of ATC data and commands between the pilot or unmanned vehicle, and the shipboard operators
  - Message Processing Function: Processing of Air Traffic Management (ATM), ATC, ship state, launch and recovery, and other data between the ship and aircraft
- Airborne Monitoring Function: Broadcasts messages containing aircraft state to support:
  - Shipboard ATM and final approach monitoring and
  - Flight crew situational awareness of nearby air traffic

3.1.2 States and Modes of Operation

3.1.2.1 States

The Sea Based JPALS-Air segment shall have the following two states:

1. Operational: Power is applied to the Sea Based JPALS-Air equipment, and
2. Non-Operational: No power is applied to the Sea Based JPALS-Air equipment.

Only one state shall exist at a time.

3.1.2.2 Modes

Sea Based JPALS-Air shall provide the following modes of operation:

1. Initialization,
2. Precision,
3. Carrier Control Area (CCA), and
4. Basic

Only one mode shall exist at a time.

Sea Based JPALS-Air shall operate in the best available mode (i.e., Precision mode when it is available, followed by CCA Mode, and lastly Basic mode when neither Precision nor CCA modes are available).

As a minimum, Sea Based JPALS supports the flight director displays in all modes except Initialization.

Figure 3-1 defines the modes and the transitions between the modes.

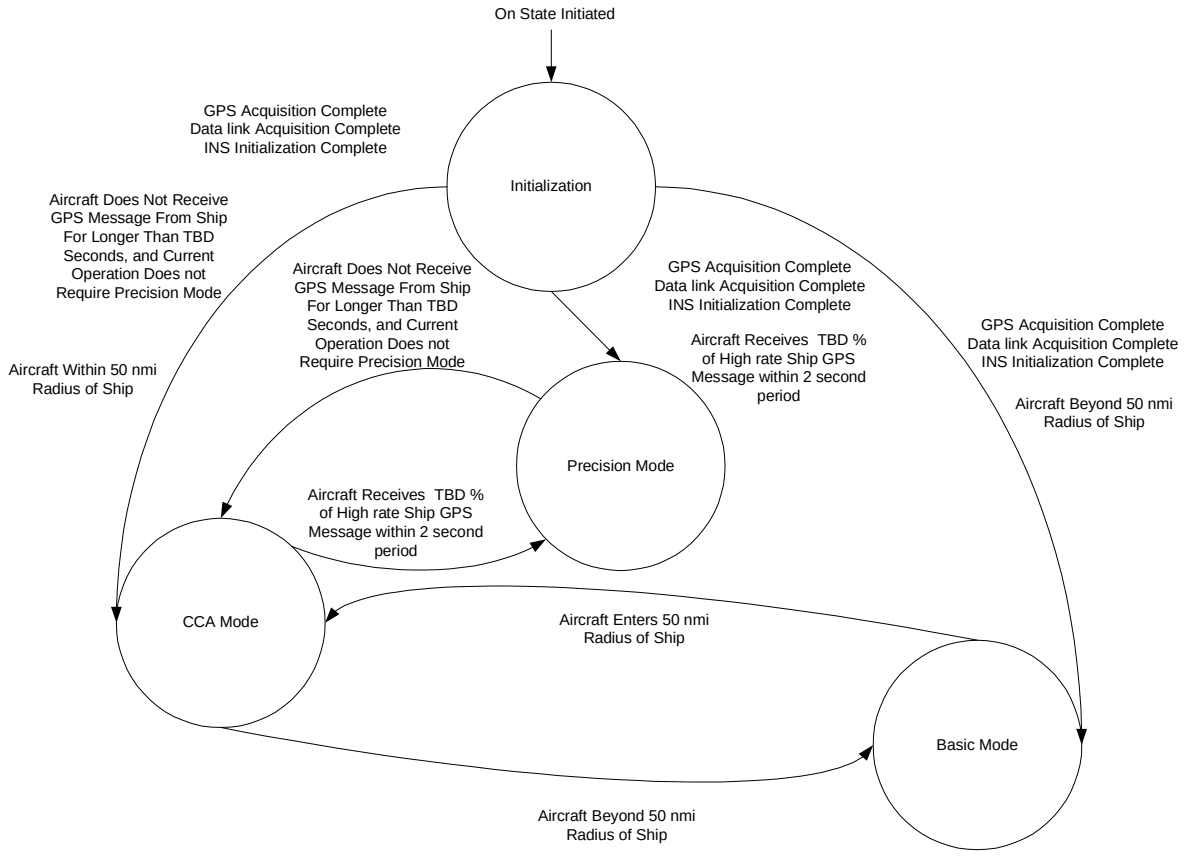

Figure 3-1: Sea Based JPALS-Air Modes

3.1.2.2.1 Initialization Mode

Sea Based JPALS-Air shall be in the Initialization Mode while the GPS, and/or DL are receiving set-up, configuration, or initialization data or are acquiring signals after power-on.

After initialization functions are completed, Sea Based JPALS-Air shall automatically transition from Initialization mode to Precision, CCA, or Basic Mode based on the criteria below.

3.1.2.2.2 Precision Mode

Sea Based JPALS-Air shall enter the Precision Mode when it has received TBR percent of the high rate Ship GPS messages addressed to it during any 2 second period from the selected ship.

In Precision Mode, Sea Based JPALS-Air maintains two-way data link communications with Sea Based JPALS-Ship, transmits Air State and Air Monitor (by request) reports, and supports deck, taxi, take-off, precision approach (PA) and landing, and precision missed approach operations.

3.1.2.2.3 CCA Mode

CCA Mode is defined as any aircraft participating within the CCA (50 nm radius from the selected ship) and not in Precision mode. In CCA Mode, Sea Based JPALS-Air maintains two-way data link communication with ship, transmits Air State reports, and supports departure, marshal, arrival, and non-precision approach (NPA) operations.

3.1.2.2.4 Basic Mode

Basic Mode is defined for any aircraft participating outside the CCA (radial distance greater than 50 nm), to at least 200 nm (line of sight) from the selected ship. In Basic Mode, Sea Based JPALS-Air outputs may be based either on received ship messages or, if messages are not being received, stored ship's Position and Intended Movement (PIM) data. Basic Mode supports departure, return-to-force (RTF), and ship-vicinity mission operations that occur beyond the CCA.

3.1.3 External/Internal Interfaces

3.1.3.1 Global Positioning System

Sea Based JPALS-Air receives GPS ranging signals and navigation data on two frequencies, denoted L1 and L2, in accordance with ICD-GPS-200C [1].

3.1.3.2 Network Related Interfaces

Sea Based JPALS requires a number of parameters to establish the DL network, including channel identification (ID), target ship ID, and ship ID. These may be internally generated by Sea Based JPALS functions or may be provided by external systems. External aircraft systems may identify a target ship ID or a channel ID for the DL to use for tuning and establishing a network connection. Sea Based JPALS also will provide the ship ID to the aircraft after it joins the network.

3.1.3.3 Status and Alerts

Sea Based JPALS-Air outputs status information for distribution to and for use by other aircraft systems.

3.1.3.4 Aircraft External Interfaces

The Sea Based JPALS aircraft external interfaces are described in Table 3-1. The data elements included in each data group listed in the table are defined in Section 6.1.

The use of Sea Based JPALS data provided to external aircraft functions is addressed in the *JPALS Aircraft Integration Guide* [6].

Table 3-1: Sea Based JPALS Aircraft External Interfaces

JPALS Function	Publishes	Subscribes To
Relative State	Absolute Aircraft State, Relative State Data, Ship Status Data	
Guidance	Guidance Data	Aircraft Approach Profile Changes, Aircraft Geometry, Aircraft Status, Path Definition Data
Monitoring	Aircraft ID, Aircraft Status, Relative State Data	Aircraft Configuration, Aircraft ID, Aircraft Status

Communication	ATM Broadcast Data, ATM Uplink Messages, Environmental Data, INS Alignment Data, Joint Unmanned Combat Air System (J-UCAS) Uplink Messages, Ship Wind Over Deck (WOD)	Aircraft ID, Aircraft Maintenance Data, ATM Downlink Messages, J-UCAS Downlink Messages

3.1.3.5 Aircraft Internal Interfaces

The Sea Based JPALS aircraft internal interfaces are described in Table 3-2. The data elements included in each data group listed in the table are defined in Section 6.2.

The Sea Based JPALS internal interfaces are shown in Figure 3-2 and described in Table 3-2.

Table 3-2: Sea Based JPALS Aircraft Internal Interfaces

JPALS Function	Publishes	Subscribes To
Relative State	State Data	
Guidance	Guidance Data	State Data
Monitoring		Guidance Data, State Data
Communications		

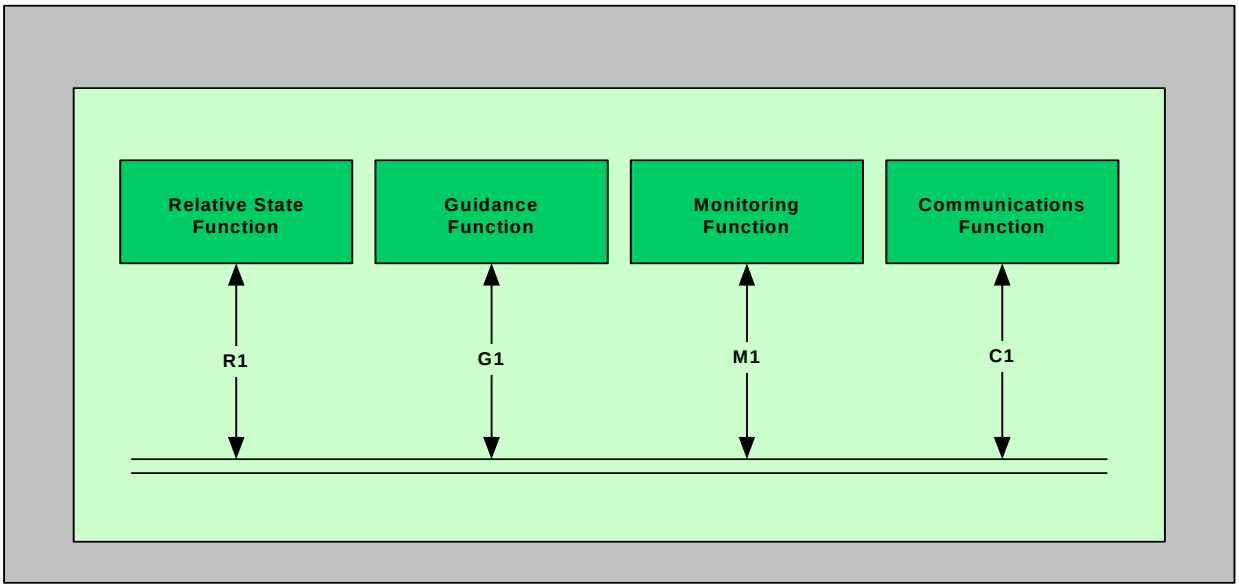

Figure 3-2: Sea Based JPALS Aircraft Internal Interfaces

3.2 Characteristics

3.2.1 Performance

3.2.1.1 General System Requirements

The requirements of this section apply to all Sea Based JPALS functions.

3.2.1.1.1 Probability of Detection, Classification, Location, and Exploitation

Sea Based JPALS-Air shall operate while precluding a hostile force's ability to identify the presence of a signal and use that signal or the data in it to threaten the ship when the hostile force is located beyond the distance specified in the classified (TBR) document.

Note: It is anticipated that this will be specified as a probability of detection (e.g., 5%) by an intercept receiver at a specified distance.

Per *the 2003 Chairman of the Joint Chiefs of Staff (CJCS) Master Positioning, Navigation, and Timing Plan* [12], Sea Based JPALS-Ship encrypts P(Y) code differential corrections. Sea Based JPALS-Air will be able to receive and use these corrections.

Sea Based JPALS communications between air and ship shall employ a consistent communication security (COMSEC) and transmission security (TRANSEC) such that they will be able to communicate with one another.

3.2.1.1.2 Flying Qualities

The performance of manned aircraft systems using Sea Based JPALS will be rated as equivalent to or better than current systems using the Pilot Handling Qualities Ratings (HQR), which is based on the modified Cooper-Harper rating scale and pilot-induced oscillation (PIO) rating scale.

3.2.1.1.3 Data Link Network

3.2.1.1.3.1 Network Selection

Sea Based JPALS-Air shall provide a means for the user aircraft to select the desired ship (or other Sea Based JPALS source).

3.2.1.1.3.2 Network Connectivity

Reception of a signal from the selected ship (within the coverage volumes specified in this SRD) shall be sufficient to establish a network connection.

Note: The acquisition of the DL network is determined by the reception of the data link signal from the ship. At this point the aircraft is part of the ship's DL network and begins to receive ship's location information. At the 200 nm threshold, this information will only be in a single direction and no transmissions take place from the aircraft to the ship.

Sea Based JPALS shall be capable of receiving the Channel ID or Target Ship ID to allow communication with a specific ship.

Sea Based JPALS shall output the Ship ID of the ship broadcasting on the selected Sea Based JPALS channel.

3.2.1.1.3.2.1 Acquisition Time

Within 50 nm region of the ship, an aircraft must make a request on the DL network to acquire a slot within the network and once the aircraft is granted a slot, it will begin transmitting data back to the ship.

This login request process shall be completed within TBR seconds.

Note: This assumes a network connection and is quantified as the amount of time from the initiation of a login request until an acknowledgment back to the aircraft that DL transmission may occur.

If the aircraft is on the deck of the ship prior to flight operations, it will initially receive the 200 nm DL content. The aircraft will initiate the login request in the same manner as done at the 50 nm threshold.

3.2.1.1.3.2.2 Reacquisition Time

There is no reacquisition time in the event of a loss of DL signal. Once an aircraft has had its login request processed, it is assigned a slot and will continue to use that slot even if a temporary loss of signal occurs. If, for example, the DL signal is not being received by the aircraft, the aircraft should continue DL transmission until the point after an aircraft completes deck operations on the ship.

3.2.1.1.4 Message Prioritization

Sea Based JPALS-Air shall prioritize the processing of messages received from the ship and to be transmitted by the aircraft.

3.2.1.1.5 Interoperability

To achieve interoperability, Sea Based JPALS-Air will comply with applicable information technology standards contained in the DoD Joint Technical Architecture (JTA) [13].

3.2.1.1.5.1 Geospatial Information and Services Support

Systems requiring geospatial information and services support shall be capable of accepting National Geospatial-Intelligence Agency (NGA) standard products.

Absolute position data shall be expressed in World Geodetic System 1984 (WGS-84) coordinates.

3.2.1.1.6 System Status

Sea Based JPALS-Air shall output system operational status at least once every 2 seconds.

3.2.1.1.7 Test Support

Sea Based JPALS-Air shall support test and qualification requirements for new aircraft/new ship installations.

Note: The Navy will be developing detailed requirements for this as the program and system development mature.

3.2.1.2 Navigation Functions

3.2.1.2.1 Performance Levels

Sea Based JPALS-Air must meet certain performance requirements depending on the operation supported and the conditions under which that operation is performed. To facilitate the requirements identification process, distinct performance levels are defined to support various operations. These Sea Based JPALS-Air Performance Levels (SPL) are Relative Navigation (RN) 1-3, Precision Relative State (PRS), PA, and Autoland (AL) as listed in Table 3-3. The table also indicates the typical operations that will be supported by each performance level and the unique outputs for that performance level. The performance required by each level is defined in various subsections of this document.

Note: A particular level of performance is a necessary but not sufficient condition for conducting the intended operation. The actual instrument approach minimums for a particular aircraft, at a particular ship, at a particular time, depend on other factors such as the availability of visual landing aids, aircraft and ship configuration, monitor downlink capability, crew qualifications, etc. The intent of organizing requirements by performance levels is to permit design and tailoring of the system to the needs of a particular ship and/or aircraft.

Table 3-3: Sea Based JPALS Operations and Performance Levels

Sea Based JPALS Performance Level (SPL)	Typical Operations Supported by Performance Level	Specified Navigation Output
RN 1 (Basic)	Relative navigation (outside 50 nm from ship)	Position, Velocity, Time (PVT), Deviations; Path error is assumed to be zero
RN 2 (Basic)	Marshal, Departure, Relative navigation (between 10 nm and 50 nm from ship)	PVT, Deviations; Path error is assumed to be zero
RN 3 (Basic)	Navigation within 10 nm from the ship; bolter pattern, departure, non-precision approach	PVT, Deviations; Path error is assumed to be zero
PRS (Precision)	Taxi (within 1 nm from the ship, including on the deck)	Position, Velocity, Acceleration, Time (PVAT), Deviations, Path error is assumed to be zero
PA (Precision)	3-D approach guidance for use to within ¼ nm /100 ft of the ship; waveoff	Deviation States

AL (Precision)	3-D approach guidance to support auto land through bolter deck roll to departure from the angle deck	Deviation States

The RN 1, RN 2, and RN 3 SPLs may be available in the Basic, CCA, and Precision modes. The Precision Relative State (PRS), PA and AL SPLs may be available only in the Precision mode. Requirements for the determination of the SPL are provided below.

3.2.1.2.2 Airborne Relative State Function

3.2.1.2.2.1 GPS Sensor Function

The GPS sensor function is made up of all the components (hardware, firmware and software) required to produce airborne GPS observable data. This includes antennas, antenna electronics, cables, GPS receivers, and any associated processors and software.

3.2.1.2.2.1.1 Output

The GPS sensor function shall output the following data at the rates defined:

- GPS Navigation Data - a complete set every 30 seconds per satellite vehicle (SV)
- 1 pulse per second derived from L1 or L2, accurate to 1.0 μS relative to top of epoch
- L1 and L2 Pseudorange data at 2 Hertz (Hz) minimum
- L1 and L2 Carrier Phase data at 10 Hz minimum
- Time of measurement - in GPS time, top of epoch and appropriate fraction of update rate

3.2.1.2.2.1.2 Ranging Sources

Sea Based JPALS-Air shall automatically select ranging sources for use in the navigation computation.

The aircraft shall be capable of using signals from the GPS satellites.

The GPS sensor function shall be capable of simultaneously tracking and continuously decoding the associated navigation data for at least 12 ranging sources on each frequency (L1 and L2).

3.2.1.2.2.1.3 Sensitivity and Dynamic Range

3.2.1.2.2.1.3.1 Input GPS Signal and Noise Levels

The GPS sensor function shall meet all requirements when receiving the minimum and maximum input signal and noise levels specified in *ICD-GPS-200C* [1].

3.2.1.2.2.1.4 Anti-Jamming Capability

The GPS sensor function shall have an A/J capability (TBD) for the GPS sensor function to meet the SV availability requirements in both intentional and unintentional jamming situations.

Note: Jamming environment is TBR and will be separately documented.

3.2.1.2.2.1.5 GPS Sensor System-Antenna Specific Requirements

3.2.1.2.2.1.5.1 Antenna Gain Characteristics

The antenna gain characteristics, internal low noise amplifier (LNA) noise figure, gain, and compression characteristics, and cable performance, shall be (TBD) to meet the overall GPS sensor function requirements.

3.2.1.2.2.1.5.2 Differential Group Delay

On L1 and L2, the differential group delay of the GPS sensor antenna, including integrated LNA, shall not exceed 50 ns. Differential group delay is defined below:

The differential group delay is defined as:

$$\left| \frac{d\phi}{d\omega}(f_c) - \frac{d\phi}{d\omega}(f_{3db}) \right| \qquad \textbf{(1)}$$

where

f_c is the pre-correlation band pass filter center frequency

f_{3db} are the 3 decibels (db) cut off points of the filter

ϕ is the phase response of pre-correlation ban pass filter

ω is the frequency

3.2.1.2.2.1.5.3 Out-of-band Rejection

The antenna out-of-band rejection characteristics shall be (TBD) to meet the overall GPS sensor function requirements.

3.2.1.2.2.1.5.4 Polarization

The GPS sensor function antenna shall receive right hand circularly polarized signals.

3.2.1.2.2.1.5.5 L1-L2 Propagation Delay

The difference in propagation delay in the antenna between L1 and L2 signals shall not exceed 1.5 nanoseconds (ns) (to be reviewed (TBR)).

3.2.1.2.2.1.5.6 Phase Center Variation

The corrected electrical phase center variation of the antenna at either L1 or at L2 shall not exceed 1.0 centimeters (cm) (TBR) over all environmental conditions.

3.2.1.2.2.1.6 GPS Signal Processing

3.2.1.2.2.1.6.1 Frequency

The GPS sensor function shall receive signals broadcast in accordance with SIS definitions specified in ICD-GPS-200C [1] at L1 and L2.

The GPS sensor function shall be capable of simultaneous tracking of at least 12 SVs at L1 and at least 12 SVs at L2. (24 channels)

Note: No reference is made here of L1 coarse acquisition (C/A). These requirements will be imposed separately on the airborne system at the platform level. This document deals expressly with operation with Sea Based JPALS.

3.2.1.2.2.1.6.2 GPS Sensor Dynamic Filtering and Corrections

The GPS receiver shall output unfiltered pseudorange, delta range and carrier phase output data for use by Sea Based JPALS-Air. This includes carrier phase smoothing, dynamic filtering, and compensation for ionospheric and tropospheric effects.

1. The output observables shall not have Selective Availability (SA) removed.
2. No atmospheric corrections shall be applied to pseudorange measurements.
3. The SV clock correction and relativistic correction of ICD-GPS-200C [1] paragraph 20.3.3.3.3.1 shall be applied to pseudorange measurements.
4. The group delay correction of ICD-GPS-200C [1] paragraph 20.3.3.3.3.2 shall be applied to SPS mode pseudorange measurements.
5. The ionospheric correction of ICD-GPS-200C [1] paragraph 20.3.3.3.3.3 shall not be applied to any pseudorange measurements.
6. Earth rotation effects during signal transmission shall not be applied to any pseudorange measurements.

The GPS sensor function shall initialize with any filters disabled.

3.2.1.2.2.1.6.3 Navigation Data

The GPS sensor function shall decode ephemeris and clock parameters for all ranging sources being used in the navigation solution.

Note: Equipment should be able to track satellites under conditions of ionospheric scintillation that could occur during solar maximum at auroral and equatorial latitudes. There is insufficient information to characterize scintillation and define appropriate requirements and tests for inclusion in this document. However, equipment should be able to track satellites through phase jitter and amplitude fading that can result from scintillation. New requirements may be defined when ionospheric effects can be adequately characterized.

3.2.1.2.2.1.6.4 Tracking Characteristics

Given the current latitude, longitude, altitude, and time, the GPS sensor function shall have a nominal Time to First Fix (TTFF) on cold start of less than 300 seconds (TBR).

Time to subsequent fix (TTSF) shall not exceed 10 seconds (TBR). TTSF is defined as the time to re-acquire a SV after the removal of interference or blockage that caused loss-of-lock of the SV.

The GPS sensor function can use any correlator spacing as long as all other sensor requirements are met.

The strongest correlation peak shall be acquired taking into account the affect of any secondary peak found at any code offset within the entire code sequence.

The GPS sensor function shall maintain carrier phase tracking under the TBD specified input signal and noise environment.

3.2.1.2.2.1.7 Accuracy

The accuracy requirements specified in the following sections represent the performance in steady state conditions, including errors such as processing errors, thermal noise and interference. Steady state operation is defined to be following at least 3.6 time constants of the filter design of continuous operation.

3.2.1.2.2.1.7.1 Ranging Accuracy

When the GPS sensor function is operating with a satellite providing signals at the minimum input level, the pseudorange error attributed to the GPS sensor function, when filtered by a hypothetical 100-second carrier phase smoothing filter, after removal of clock bias, and excluding any multipath effects, shall not exceed 0.089 meters (m) (TBR) root-mean-square (RMS).

The pseudorange inter-channel bias of the GPS sensor function, when compared with the average of all channels, shall not exceed 1.0 cm.

The GPS sensor function pseudorange shall be referenced to a point at the specified antenna phase center.

The GPS sensor function pseudorange accuracy, including inter-channel bias, group delay variations, and multipath, when filtered by a hypothetical 100-second carrier phase smoothing filter must not exceed the limits identified herein for any satellite tracked within the coverage volume. (TBR when more data on airborne accuracy curves is known.)

The GPS sensor function pseudorange accuracy, including inter-channel bias, group delay variations, and multipath, when filtered by a hypothetical 100-second carrier phase smoothing filter shall be within 1.0 m (1-sigma) for any satellite tracked within the coverage volume at an elevation of 5 to 10 deg (degrees). (TBR when more data on airborne accuracy curves is known.)

The GPS sensor function pseudorange accuracy, including inter-channel bias, group delay variations, and multipath, when filtered by a hypothetical 100-second carrier phase smoothing filter shall be within 0.75 m (1-sigma) for any satellite tracked within the coverage volume at an elevation of 10 to 20 deg. (TBR when more data on airborne accuracy curves is known.)

The GPS sensor function pseudorange accuracy, including inter-channel bias, group delay variations, and multipath, when filtered by a hypothetical 100-second carrier phase smoothing filter shall be within 0.5 m (1-sigma) for any satellite tracked within the coverage volume at an elevation of 20 to 30 deg. (TBR when more data on airborne accuracy curves is known.)

The GPS sensor function pseudorange accuracy, including inter-channel bias, group delay variations, and multipath, when filtered by a hypothetical 100-second carrier phase smoothing filter shall be within 0.5 m (1-sigma) for any satellite tracked within the coverage volume at an elevation of 30 to 40 deg. (TBR when more data on airborne accuracy curves is known.)

The GPS sensor function pseudorange accuracy, including inter-channel bias, group delay variations, and multipath, when filtered by a hypothetical 100-second carrier phase smoothing filter shall be within 0.4 m (1-sigma) for any satellite tracked within the coverage volume at an elevation >40 deg. (TBR when more data on airborne accuracy curves is known.)

Note: These accuracy requirements are necessary to meet system availability requirements.

3.2.1.2.2.1.7.2 Carrier Phase Accuracy (TBR)

The GPS sensor function integrated Doppler error, including receiver noise, antenna phase variations, and multipath, shall be less than .05 wavelength RMS (TBR) for all SV's in view from 5.0 deg elevation to 90 deg elevation, at all azimuth angles.

Note 1: 0.05 wavelength is defined since L1 and L2 will have slightly different requirements if specified in cm.

Note 2: The GPS sensor function will likely be required to use beam steering techniques in order to independently maintain a high direct path to multipath ratio for all received satellites, as well as to control antenna phase variations in the direction of the SV's. The GPS sensor function antenna system will have to contain sufficient azimuth aperture to maintain a direct path to multipath ratio of 10.2 dB (TBR) or higher due to airframe obstructions and reflectors, and to defeat broadband jammers.

3.2.1.2.2.2 Relative Position Function

The relative state function computes the position, velocity and acceleration of the aircraft relative to the target ship. It uses GPS measurements from both ship and air, as well as the ship's PIM data (either received via data link in real time or preloaded into the aircraft database before launch).

3.2.1.2.2.2.1 Measurement Quality Monitoring

The satellite signal tracking quality shall be monitored such that the allocated integrity risk due to undetected cycle slip or other undetected measurement faults is within the manufacturer's allocation.

Sea Based JPALS-Air shall only use those satellites identified as healthy by the ship as sent in the Ship State messages.

Sea Based JPALS-Air shall monitor for excessive ionospheric gradients that would cause the differential ionospheric residual to exceed the uplinked ionospheric sigma terms.

3.2.1.2.2.2.2 Integrity in Excessive Interference

The aircraft shall not output misleading information in the presence of interference including interference levels above those specified in section 3.2.5.

N*ote 1: This requirement is comprehensive in nature in that it is intended to prevent the output of misleading information under unintentional interference scenarios that could arise during shipboard operations.*

Note 2. In order to support problem investigation and maintenance, it is recommended the equipment output the signal-to-noise ratio for each satellite. This data can be useful when determining if a particular outage is caused by the environment or by receiver anomalies. It is also possible that additional analyses will result in a requirement to output the signal-to-noise ratio for each satellite. (TBR)

3.2.1.2.2.2.3 Integrity in Abnormal Dynamics

Abnormal maneuvers are defined to be maneuvers having accelerations/jerks that exceed those specified for normal maneuvers in section 3.2.5.

During abnormal maneuvers, the equipment shall not output misleading information (i.e., the protection limits must bound the navigation and guidance errors).

When the aircraft returns to normal maneuvers from abnormal maneuvers, the equipment shall meet the accuracy requirements as specified for the GPS sensor function.

During the abnormal maneuver period, alerts shall function as specified in section 3.2.1.8.

3.2.1.2.2.2.4 Relative Position Determination

The Relative Positioning function determines the relative position of the ship reference point (SRP) with respect to the GPS antenna of the aircraft. This function provides two types of relative position determination:

<u>Precision relative positioning</u> is used when shipboard GPS observables are available. In this case, the shipboard and airborne GPS observables are combined using carrier-phase ambiguity resolution, and a precise vector is determined between the airborne antennas and the SRP.

Basic relative positioning is used when shipboard GPS observables are not available. In this case, the absolute positions of ship and aircraft are determined and differenced. The absolute position of the aircraft is determined from airborne GPS observables; the absolute position of the ship is either extracted from real-time ship position reports or extrapolated from PIM data.

3.2.1.2.2.2.4.1 Airborne GPS Observables

For either type of relative position determination described above, the following GPS observables from the GPS sensor function shall be collected from each ranging source in view:

T	- time (in seconds of week)
$PRm_{L1, air}$, $PRm_{L2, air}$	- pseudoranges measurement in L1 and L2
$CPm_{L1, air}$, $CPm_{L2, air}$	- carrier phase measurements in L1 and L2
$CS_{L1, air}$, $CS_{L2, air}$	- cycle slip counts in L1 and L2
Ephemeris data set	

3.2.1.2.2.2.4.2 Shipboard GPS Observables

Shipboard GPS observables are obtained by Sea Based JPALS-Air via the GPS data messages from Sea Based JPALS-Ship as described in the *Sea Based JPALS DL SIS Interface Specification* [10].

Sea Based JPALS-Air shall receive the GPS Block ID, GPS Pseudorange Data and GPS Carrier Phase Data messages in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

Sea Based JPALS-Air shall reconstruct the raw ship reference point-referenced GPS observables as described in the *Sea Based JPALS DL SIS Interface Specification* [10].

3.2.1.2.2.2.5 Precision Mode Relative Position

In Precision Mode, Sea Based JPALS-Air computes the precision relative position using GPS measurements from both shipboard and airborne receivers, using KCPT.

3.2.1.2.2.2.5.1 Conditions for Use of Ship Measurements

3.2.1.2.2.2.5.1.1 Ephemeris Cyclic Redundancy Check Conditions

A GPS ranging source shall not be used in the position solution until the ephemeris data received from that source is verified by calculating the ephemeris cyclic redundancy check (CRC) as defined in the *Sea Based JPALS DL SIS Interface Specification* [10] and comparing it to the Ephemeris CRC value broadcast in the GPS message.

For each ranging source used in the position solution, the calculated CRC shall be compared to the broadcast CRC within 1 second after receiving a new broadcast Issue of Data (IOD). A new broadcast IOD is one whose value is different from the broadcast IOD last received for the same ranging source.

The equipment shall cease using any satellite for which the computed and broadcast CRC values fail to match.

Note: The aircraft will not immediately base its corrections on the satellite clock and ephemeris values in the GPS navigation message that has just changed, as described in the Sea Based JPALS DL SIS Interface Specification [10].

3.2.1.2.2.2.5.1.2 Reference Time Conditions

All satellites used in the position solution shall use corrections with the same reference time as indicated by the GPS Time of Applicability (TOA), which is referred to as a set of corrections. The most recently received set of corrections shall be applied, including pseudorange corrections, carrier phase corrections, refractivity index, and scale height. If the "number of measurements" field in the GPS message indicates that there are no corrections, then the equipment shall not apply any corrections.

Note: Corrections that do not belong to the same set cannot be used in the position solution since the clock errors in the pseudorange corrections may be relative to different sets of conditions.

3.2.1.2.2.2.5.1.3 Other Ranging Source Conditions

The pseudorange and phase corrections for a ranging source shall only be used if all of the following conditions are met:

1. The ID for that ranging source is not set to “1111 1111”;
2. For GPS satellites, the IOD associated with the correction matches the Issue of Data Ephemeris (IODE) associated with the ephemeris used to determine the satellite location and matches the eight least significant bits of the Issue of Data Clock (IODC);
3. The elapsed time from the receipt of the last GPS message is less than 2 (TBR) seconds;

4. The difference between current time and the reference time of the corrections (derived from the GPS TOA) is less than 10 seconds (TBR).

3.2.1.2.2.2.5.2 Carrier-Phase Relative Positioning

Sea Based JPALS-Air shall compute a relative three-dimensional position, velocity, and acceleration based on the set of differential phase measurements meeting the requirements of Path Definition Processing. The position solution shall use *GPS* message data from the controlling ship.

Note: One acceptable means of deriving the state information is presented in Section 7. Any other method than the one provided must provide equivalent or better performance.

3.2.1.2.2.2.6 CCA and Basic Mode Relative Position

In both CCA and Basic modes, Sea Based JPALS-Air computes the basic relative position by determining the absolute positions of the ship and aircraft and forming the vector between them.

3.2.1.2.2.2.6.1 Conditions for Use of GPS Measurements

Sea Based JPALS-Air shall only use GPS pseudorange measurements from ranging sources identified as usable in the Ship State Message, if available. If ship state message data is unavailable, Sea Based JPALS-Air shall use an airborne-based integrity monitoring function to identify any failed satellites.

3.2.1.2.2.2.6.2 Pseudorange Based Relative Positioning

The aircraft shall compute a relative three-dimensional position, velocity, and acceleration based on the ship position and the aircraft derived position using pseudorange measurements.

Note: One acceptable means of deriving the state information is presented in Appendix B. Any other method than the one provided must provide equivalent or better performance.

3.2.1.2.2.2.6.3 Absolute Ship Position

Sea Based JPALS-Air shall determine the absolute position of the SRP in one of three ways:

- from real-time Ship State Messages
- from PIM data in previously-received Ship State Messages
- from PIM data stored before launch

The order of precedence is as shown above.

3.2.1.2.2.2.6.3.1 Ship State Messages

The aircraft shall receive the Ship State 200, Ship State 50 and Ship State 10 messages in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

The aircraft shall reassemble the Ship State messages in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

3.2.1.2.2.2.6.3.2 Ship PIM Data

Ship PIM data consists of the following:

- $T_{current}$ - current time
- $latitude_{current}$, $longitude_{current}$ - position of the ship at $T_{current}$
- $T_{intended}$ - time ship intends to be at a given position
- $Latitude_{intended}$, $longitude_{intended}$ - position where ship intends to be at $T_{intended}$

The aircraft shall extrapolate a ship's position using PIM data when real-time position reports are not currently available.

3.2.1.2.2.2.6.3.3 Old Ship State Message

If Ship State Messages are not being received by the airborne data link in real time, but have been received at some time since aircraft launch, the aircraft shall extrapolate the SRP from the PIM data in the most recently received Ship State Message.

3.2.1.2.2.2.6.3.4 Pre-Launch Data

If no Ship State Messages have been received since launch, the aircraft shall extrapolate the SRP from the PIM data stored in the mission plan database before launch.

In each case the uncertainty in the solution shall be estimated based on the source of data used in the solution.

3.2.1.2.2.2.7 Relative State Function Outputs

3.2.1.2.2.2.7.1 Precision Mode Relative State Output and Latency

The aircraft shall continuously determine the range and bearing from the aircraft to the ship in Precision Mode.

The aircraft shall output the relative position, velocity, and acceleration in the non-stabilized ship reference frame while in Precision Mode at a minimum rate of 20 Hz (TBR).

Sea Based JPALS-Air shall provide GPS TOA

The latency of the outputs with respect to GPS TOA shall be less than 200 milliseconds (ms) (TBR).

3.2.1.2.2.2.7.2 CCA and Basic Mode Relative State Output and Latency

The aircraft shall continuously output the range and bearing from the aircraft to the ship in Basic or CCA mode at a rate of 1 Hz.

The latency of the outputs with respect to GPS TOA shall be less than 250 ms (TBR).

3.2.1.2.2.2.7.3 Shipboard and Airborne Absolute Positioning

Sea Based JPALS-Air shall compute absolute aircraft WGS-84 geodetic coordinates in CCA, Basic and Precision modes at a rate of TBD.

Sea Based JPALS-Air shall compute absolute ship WGS-84 geodetic coordinates in CCA, Basic and Precision modes at a rate of TBD.

The absolute data shall be consistent with relative state outputs, such that differencing the absolute data will provide the same results.

The absolute data shall be computed using the most accurate data available based on the mode of operation.

3.2.1.2.2.2.8 Relative State Accuracy

(TBD)

3.2.1.2.2.2.9 Relative State Integrity

(TBD)

3.2.1.2.2.2.10 Relative State Continuity

(TBD)

3.2.1.2.2.2.11 Navigation Uncertainty

Sea Based JPALS-Air shall continuously compute position and velocity uncertainty values continuously at a rate of 1 Hz.

3.2.1.2.2.2.11.1 Position Uncertainty

The navigation uncertainty category (NUC) is reported so that controllers and LSO may determine whether the reported position has an acceptable level of integrity and accuracy for the intended use. A Horizontal Protection Level (HPL) must be computed dynamically by all receivers. The HPL is the primary basis for assigning the NUC. HPL is defined as "the radius of a circle in the horizontal plane (local plane tangent to the WGS-84 ellipsoid), with its center being at the true position, which describes the region which is assured to contain the indicated horizontal position."

Sea Based JPALS shall report a NUC of 0 for an HPL greater than or equal to 0.8 nm or if the HPL is unknown or unavailable.

Sea Based JPALS shall report a NUC of 1 for an HPL less than 1480 m.

Sea Based JPALS shall report a NUC of 2 for an HPL less than 524 m.

Sea Based JPALS shall report a NUC of 3 for an HPL less than 240 m.

Sea Based JPALS shall report a NUC of 4 for an HPL less than 96 m.

Sea Based JPALS shall report a NUC of 5 for an HPL less than 60 m.

Sea Based JPALS shall report a NUC of 6 for an HPL less than 20 m.

Sea Based JPALS shall report a NUC of 7 for an HPL less than 8 m.

Sea Based JPALS shall report a NUC of 8 for an HPL less than 4 m.

Sea Based JPALS shall report a NUC of 9 for an HPL less than 2 m.

Sea Based JPALS shall report a NUC of 10 for an HPL less than 1 m.

Note 1: It is anticipated that these requirements will be revised to use both horizontal and vertical parameters to determine the NUC.

Note 2. It is anticipated that these requirements will be revised to separately provide an integrity indication based on protection levels and an accuracy indication based on the estimate of position uncertainty (EPU).

Note 3. When PIM data is used to determine ships position, the uncertainty factor must account for its use.

3.2.1.2.2.2.11.2 Velocity Uncertainty

The Navigation Uncertainty Category Rate (NUCR) reflects the accuracy of the least accurate velocity component of the reporting aircraft's source of velocity data, and is denoted NUCR.

Sea Based JPALS-Air shall report the highest possible value for NUCR based on the current Horizontal and Vertical Velocity Errors.

Sea Based JPALS-Air shall report an NUCR of 0 when either the Horizontal Velocity Error (95%) exceeds 10 meters per second (m/s) or the Vertical Velocity Error (95%) exceeds 50 feet per second (fps).

Sea Based JPALS-Air shall report an NUCR of 1 when the Horizontal Velocity Error (95%) is less than 10m/s and the Vertical Velocity Error (95%) is less than 50fps.

Sea Based JPALS-Air shall report an NUCR of 2 when the Horizontal Velocity Error (95%) is less than 3m/s and the Vertical Velocity Error (95%) is less than 15fps.

Sea Based JPALS-Air shall report an NUCR of 3 when the Horizontal Velocity Error (95%) is less than 1m/s and the Vertical Velocity Error (95%) is less than 5fps.

Sea Based JPALS-Air shall report an NUCR of 4 when the Horizontal Velocity Error (95%) is less than 0.3m/s and the Vertical Velocity Error (95%) is less than 1.5fps.

Note 1: When an inertial navigation system (INS) is used as the source of velocity information, error in velocity with respect to WGS-84 is reflected in the NUC.

Note 2: When any component of velocity is flagged as not available, the value of NUCR will apply to the other components which are supplied.

Note 3: Navigation sources, such as the GPS and inertial, provide a direct measure of velocity which can be significantly better than that which could be obtained by position differences.

Note 4: Currently vertical velocity is specified in fps to match usual cockpit usage. This may be harmonized with metric units in the future.

3.2.1.2.3 Airborne Guidance Function

The Guidance function outputs the information necessary to direct the aircraft to the current target either automatically or manually. This target could be a waypoint en route to or from the ship or the touchdown point (TDP) for final approach.

3.2.1.2.3.1 Navigation Stabilization

Sea Based JPALS-Air must provide a common stabilization function across all ship types with respect to fixed wing, short takeoff vertical landing (STOVL), and vertical takeoff and landing (VTOL) aircraft with similar closure rates, respectively, to ensure consistent, repeatable, and predictable presentation to the aircrew.

Sea Based JPALS-Air shall receive the Ship Motion High, Ship Motion Medium and Ship Motion Low messages in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

Sea Based JPALS-Air will use the ship motion messages to determine a stabilized platform for precision operations.

In Precision Mode, Sea Based JPALS-Air shall, as part of normal initialization, data link outages or as a result of changes to the Path Definition data, take no longer than TBD seconds to converge the stabilized data.

Sea Based JPALS stabilization performance will be at least equivalent to the current Automatic Carrier Landing System (ACLS) and be range based.

Sea Based JPALS shall utilize standardized stabilization across all ship types with respect to fixed wing, STOVL, and VTOL aircraft with similar closure rates, respectively, to ensure consistent, repeatable, and predictable presentation to the aircrew.

3.2.1.2.3.1.1 Navigation Protection

In Precision Mode, Sea Based JPALS-Air shall provide a means of minimizing the effects of low GPS update rates if solution fix becomes unavailable or unusable.

In Precision Mode, Sea Based JPALS-Air shall compute the vertical acceleration bias.

Sea Based JPALS-Air shall smoothly transition across large transients in navigation data, which can be caused by changes in GPS solution fixes, algorithms or measurement sources.

Note: The criteria for these transitions are TBD and will be operation dependant.

3.2.1.2.3.1.2 Approach Reference Frame Designation

While in Precision Mode and in the air, Sea Based JPALS-Air shall compute the approach path using a locally level reference frame about a stabilized centerline or approach angle.

Sea Based JPALS shall support recovery operations during ship heading changes in the range of ± 0.5 deg/sec.

In Precision Mode, Sea Based JPALS-Air shall be stabilized for high frequency components of ship yaw. The Sea Based JPALS approach reference frame will be less stabilized for the yaw motion as the range to touchdown decreases.

While providing taxi guidance Sea Based JPALS-Air shall use the body axis as the approach reference frame.

In Precision Mode, Sea Based JPALS-Air shall compute the inertial aircraft accelerations required to follow the approach reference frame.

3.2.1.2.3.1.3 Touchdown Point Stabilization

In Precision Mode, Sea Based JPALS-Air shall compute the TDP states relative to the stabilized TDP in the approach reference frame.

In Precision Mode, Sea Based JPALS-Air shall have provisions to compute the DMC command synchronously with the stabilization algorithms using gains set by the control function.

In Precision Mode, Sea Based JPALS-Air shall stabilize the relative GCP to TDP states for surge, sway, heave, and yaw.

3.2.1.2.3.1.4 Navigation Stabilization Outputs

In Precision Mode, Sea Based JPALS-Air shall provide the instantaneous position, velocity, and acceleration of the TDP, relative to the stabilized TDP, in the stabilized centerline reference frame for use by the Guidance Function and by the DMC. These are known collectively as the touchdown motion states.

In Precision Mode, Sea Based JPALS-Air shall provide the stabilized relative position, velocity and acceleration. The stabilized relative position shall be defined as the GCP with respect to the stabilized TDP in the stabilized centerline reference frame.

In Precision Mode, Sea Based JPALS-Air shall provide the TOA corresponding to its Navigation & Stabilization outputs.

In Precision Mode, Sea Based JPALS-Air shall provide TBD status and TBD integrity indications corresponding to its PA Navigation & Stabilization outputs.

In Precision Mode, Sea Based JPALS-Air shall compute the GCP relative to CM in the ship locally level reference frame and provide it to the Monitoring Function for downlinking.

3.2.1.2.3.2 Current Operation Determination

Sea Based JPALS-Air shall by default determine the current operation that the aircraft is performing. If the aircraft user provides an alternative operation, Sea Based JPALS shall use it as the current operation. [Algorithms TBD]

Sea Based JPALS-Air should allow for the extension and update of operation determination algorithms.

Sea Based JPALS-Air shall accept input from the avionics designating the desired approach and landing operation (NPA, PA, or AL).

3.2.1.2.3.3 Future Operation Determination

Sea Based JPALS-Air shall determine the expected operation that the aircraft will perform or after TBD seconds based on relative position, heading, aircraft state data and current operation. If the aircraft user specifies a future operation, Sea Based JPALS shall use it as the future operation. [Algorithms TBD]

Sea Based JPALS-Air shall compute the time at which the future operation will occur.

Sea Based JPALS-Air should allow for the extension and update of future operation determination algorithms.

3.2.1.2.3.4 Sea Based JPALS Performance Level Determination

In all three modes, Sea Based JPALS-Air shall determine and output the SPL that is currently capable of being supported using the PL equations of 3.2.1.7.

In all three modes, Sea Based JPALS-Air shall determine the expected SPL at the time of the future operation.

3.2.1.2.3.5 Path Definition Processing

Sea Based JPALS-Air shall provide guidance consistent with current operation.

Sea Based JPALS-Air shall provide primary landing system guidance to support Case I, II, and III approaches. This includes lateral, vertical, and as needed longitudinal guidance along the approach path to the selected TDP.

Sea Based JPALS-Air shall compute the commanded path, commanded path rate, and commanded path acceleration, using the data from the path definition, based on environmental conditions, scenario and standard operational procedures.

When Precision Mode is not available, the horizontal commanded path shall be defined in either an absolute reference frame (WGS-84) or in north and east relative to the TBD (Ship COM or Ship GPS reference point).

When Precision Approach service is available, Sea Based JPALS-Air shall compute the horizontal commanded path relative to the stabilized TDP in the stabilized centerline reference frame.

When Precision Approach service is not available, the vertical commanded path shall be defined using barometric altitude.

When Precision Approach service is available, Sea Based JPALS-Air shall provide a means to compute the vertical commanded path relative to the stabilized TDP in the stabilized centerline reference frame.

3.2.1.2.3.5.1 Path Determination Data Management

Sea Based JPALS-Air shall be capable of receiving mission initialization data per standard operational procedures, and allow for its update per standard operational procedures.

Sea Based JPALS-Air shall forward changes to the path definition originating from the aircraft to the ship.

Sea Based JPALS-Air shall verify changes to the path definition data originating from the ship when within 50 nm of the ship via a data link message.

Sea Based JPALS-Air shall provide for aircraft use indication and/or confirmation as appropriate based on scenario and standard operational procedures.

Sea Based JPALS-Air will use the following information to compute the commanded path:

- Waypoints
- Ship's PIM
- Ship geometry, including offsets between the ship's TDPs, Ship Motion Sensor (SMS), COM and its reference point
- Aircraft geometry, including offset between the aircraft's landing reference point (LRP) and its GCP
- TDP selection or locations
- Centerline angle
- Glide slope

- Deck status
- Auto land status
- Missed approach point, turn downwind range, turn to final
- Case Recovery
- Type Approach
- Airspeed Command
- Vertical Hook bias (in addition to hook offset aircraft type and ship specific)
- Outbound heading
- Ship Altimeter
- Base Recovery Course (BRC) / Final Bearing (FB)
- Expected BRC / FB
- Case Launch
- Departure Reference Radial
- Marshal point, radius and altitude
- Emergency Marshal point, radius and altitude
- Take Off selection/location (or catapult location)
- Launch angle
- Hover altitude
- Hover offset location and perch position

Note: Which information needs pilot confirmation, verification, or forwarding is TBD.

Note: Which information will actually be used for path definition and how is TBD.

3.2.1.2.3.5.1.1 Data Link

The Sea Based JPALS-Air shall receive ship PIM data via the ship state 200 data link message or from the mission initialization data loaded prior to the mission.

The Sea Based JPALS-Air shall receive waypoint information from the ship via Sea Based JPALS data link messages.

The Sea Based JPALS-Air shall receive the offset between the target ship's reference point and the designated TDP via the Ship Survey block in the ATM Broadcast 10 message.

The Sea Based JPALS-Air shall receive reference radial, glide-slope angle, final bearing, etc. via the General Launch and Recovery Data block in the ATM Broadcast 50 message.

The Sea Based JPALS-Air shall receive the centerline angle via the General Launch and Recovery Data message in the ATM Broadcast 50 message.

The Sea Based JPALS-Air shall accept TDP designation from the target ship via standard operational procedures via the Ship Survey data link message.

The Sea Based JPALS-Air shall receive the missed-approach point via the General Launch and Recovery DL message.

The Sea Based JPALS-Air shall receive the current Landing Case and Deck Status in the General Launch and Recovery Data block of the ATM Broadcast 50 message.

Sea Based JPALS-Air shall provide the ability to fly an elevated TDP specified as vertically or along the glide slope to support certification testing.

3.2.1.2.3.5.1.2 Aircraft Configuration Data

Sea Based JPALS-Air shall receive the offset between the aircraft LRP and GCP via airborne configuration data.

Note: Vertical Hook bias (in addition to hook offset aircraft type and ship specific)

3.2.1.2.3.5.1.3 Air Crew Inputs

The Sea Based JPALS-Air shall accept waypoint information from the avionics as input by the aircrew.

Sea Based JPALS-Air shall provide the capability to fly an approach at a predetermined lateral offset upon request. The offset distance shall be applied to the flightpath and shall be available from the aircraft configuration data.

Note: This function is required to support emergency operations described in the CONOPS [7] where a lead aircraft would fly a lateral offset approach, parallel to the flightpath, while the distressed aircraft flies, "unguided" off the wing on the nominal flightpath.

The Sea Based JPALS-Air shall accept input of an aircrew selected centerline angle from the avionics subject to TBR limitations.

The Sea Based JPALS-Air shall accept input of an aircrew selected glide slope from the avionics subject to TBR limitations.

If the glide slope angle selected is different than that sent by the Sea Based JPALS-Ship, the new glide slope shall be reported to the ship via the TBR data link message.

The Sea Based JPALS-Air shall accept TDP selection from the aircrew of VTOL and STOVL aircraft subject to the limitations of section 3.2.1.2.3.5.1.1.

The Sea Based JPALS-Air shall not accept centerline angle or TDP selection from the aircrew of fixed-wing aircraft.

3.2.1.2.3.5.1.4 Parameter Change Lockout

For safety of flight, Sea Based JPALS-Air will provide the capability to prevent changes in the path definition data. (TBR for CONOPS acceptance)

Sea Based JPALS-Air shall not accept a change to the centerline angle, while providing guidance relative to the centerline.

Sea Based JPALS-Air shall not accept a change to the glideslope angle while on glideslope or causing the computed tipover point to move aft of the aircraft current location.

Sea Based JPALS-Air shall not accept a change to the TDP selection while on glideslope or causing the computed tipover point to move aft of the aircraft current location.

3.2.1.2.3.5.2 Path Determination

Sea Based JPALS-Air shall define a desired flight path based upon an active flight plan or aircrew specified parameters. The flight path will be defined relative to the ship and shall support use of fixed and relative waypoints; specified courses to or from a waypoint, including a direct-to function; arced paths (e.g., Radius-to-Fix legs); holding/marshal patterns specified in terms of course, turn direction, location, and time; standard approach patterns (outside final approach) based on stored data; and waypoint to waypoint defined paths (relative and fixed) with automatic sequencing. Specific requirements for defining the final approach path are provided in 3.2.1.2.3.5.2.7.

Note 1: Although path definition data may be sent from the ship via the Sea Based JPALS DL, it is envisioned that this data will not be directly acted on by the Sea Based JPALS-Air, but will be subject to crew acceptance. It is expected that this data will be received by the Sea Based JPALS-Air through an external on-aircraft interface.

Note 2: The Sea Based JPALS-Ship will broadcast the approach type expected (e.g., CV-1) in the Sea Based JPALS ATM Broadcast 50 DL message. It is anticipated that the parameters defining the standard approach patterns will be stored in an on-aircraft database. Upon selection by the flight crew, the parameters necessary to define the approach pattern will be available to and used by Sea Based JPALS-Air. However, Sea Based JPALS-Air will use the parameters provided by Sea Based JPALS-Ship to define the final approach, subject to crew overrides as specified in 3.2.1.2.3.5.1.3.

3.2.1.2.3.5.2.1 Waypoint Path Determination

[TBD]

Note: Sea Based JPALS will not directly provide absolute waypoint guidance.

3.2.1.2.3.5.2.2 Holding Marshall Pattern Path Determination

{TBD}

3.2.1.2.3.5.2.3 Radius to Fix

[TBD]

3.2.1.2.3.5.2.4 Departure Guidance

[TBD]

3.2.1.2.3.5.2.5 Taxi Guidance

[TBD]

3.2.1.2.3.5.2.6 Take-Off Guidance

[TBD]

3.2.1.2.3.5.2.7 Final Approach Path Determination

Sea Based JPALS-Air shall determine the final approach path (glide slope) as a path relative to the stabilized TDP.

Fixed-wing approach operations to the CV, CVN, and next generation CVN shall use an approach path reference point defined from the fixed-wing TDP. The approach path shall extend aft and upward at a glide slope angle from the set of {2.0 to 9.0} degrees in 0.25 deg increments.

For VTOL and STOVL operations, Sea Based JPALS shall support the use of multiple TDP spots per ship.

The TDP to be used for landing shall be selectable by ID number (e.g., Spot 1, Spot 5, etc.).

STOVL and VTOL operations to all ship classes shall use an approach path reference point offset from the ship landing area in the ship body frame (x, y, and z offsets). The course shall accommodate multiple segments/extensions with an angle selectable in 2 deg increments. The vertical approach path to the approach path reference point shall accommodate multiple segments/extensions with a glide slope angle selectable from the set of {2.0 to 9.0 deg} in 0.5 deg increments.

Note: The elements used to define approach procedures for VTOL and STOVL aircraft are still being developed and are not yet fully documented in this specification or the Sea Based JPALS DL SIS Interface Specification (TBR).

When flying automatic to the TDP, the aircraft will engage the DMC at approximately 12 seconds from touchdown, while synchronously fading in the TDP motion states into the computed deviations.

Note: Offset glideslope, for TDP and hook to GCP

3.2.1.2.3.5.2.8 Missed Approach Guidance

If the aircraft must execute a missed approach, the equipment shall continue to provide rectilinear lateral deviation with deflection referenced to the extended approach centerline or with respect to the path defined by a procedure, if provided.

The equipment shall sequence based on an external input commanding missed approach or by automatic sequencing to missed approach guidance. The automatic sequencing shall occur when all of following conditions are satisfied: 1) the computed aircraft position passes the TDP (i.e., when the bearing to the TDP is more than ±90 deg from the BRC), 2) the LRP height is greater than 30 feet above the deck height, and 3) the vertical deviation is full-scale fly down.

For unmanned aircraft, Sea Based JPALS-Air shall provide automatic transition to missed approach guidance, based on environmental conditions, scenario and standard operational procedures.

If a Sea Based JPALS waveoff or bolter condition occurs during a precision approach, which is not caused by a failure of Sea Based JPALS, Sea Based JPALS shall provide the appropriate precision output to support the missed approach procedure.

If a Sea Based JPALS waveoff or bolter condition occurs during a precision approach, which is caused by a failure of Sea Based JPALS, Sea Based JPALS shall provide the user aircraft with relative navigation and guidance to support the missed approach procedure.

Note 1: Some failure conditions may render the Sea Based JPALS incapable of providing any navigation and guidance information to the aircraft. Others may allow for relative navigation and guidance to be given and in this case, the requirement applies.

Note 2: One potential cause of a waveoff may be due to the performance level not being sufficient to support the operation. In this case Sea Based JPALS will determine the maximum performance level available and support what operations it can.

Sea Based JPALS-Air shall be capable of receiving a commanded waveoff command from the ship via a Sea Based JPALS DL message. Sea Based JPALS-Air shall output the waveoff command for display to the aircrew or mission control system (MCS) operator; however, missed approach guidance shall not be initiated until the conditions above are met. Receipt of a waveoff command from the ship does not constitute the external input commanding missed approach.

Note: Waveoff / missed approach for LH ships TBD.

3.2.1.2.3.5.3 Guidance Transition

Sea Based JPALS-Air will smoothly transition between navigation modes, fixes and changes in measurement source.

Sea Based JPALS-Air will smoothly transition between command path algorithms, operation mode changes and changes in the path definition data.

Note: With the exception of hover points this implies that there should not be an instantaneous jump in commanded position, velocity or acceleration as the algorithm changes.

Sea Based JPALS-Air shall smoothly transition the commanded path between each leg such that the commanded path acceleration does not exceed TBD.

Sea Based JPALS-Air shall, as a result of changes to the Path Definition data, smoothly transition to the new commanded path such that the path transition acceleration does not exceed TBD.

Prior to tipover, Sea Based JPALS-Air shall smoothly transition the horizontal commanded path to stabilized TDP such that the commanded path TBD does not exceed TBD.

Prior to tipover, Sea Based JPALS-Air shall smoothly transition the vertical commanded path to stabilized TDP such that the commanded path TBD does not exceed TBD.

When switching to Missed Approach operation and PA service is not available, Sea Based JPALS-Air shall smoothly transition the horizontal commanded path to north and east relative to the TBD such that the commanded path TBD does not exceed TBD.

When switching to Missed Approach operation and PA service is not available, Sea Based JPALS-Air shall smoothly transition the vertical commanded path barometric altitude such that the commanded path TBD does not exceed TBD.

3.2.1.2.3.5.4 Deviation States

The deviation states are the difference of the Relative Navigation position, velocity and acceleration states as compared to the desired states.

The deviation states are computed in a moving and rotating horizontal reference frame that is tangential to the horizontally projected commanded path with the orthogonal plane passing through the aircraft reference point. This reference frame is called the commanded path reference frame.

The desired states are those required to follow the commanded path reference frame.

For [TBD] operations the horizontal shall be defined as locally level at the ship location.

For all other operations horizontal shall be locally level at the aircraft location.

Note: The position of the aircraft in the tangential axis of the commanded path reference frame is by definition always zero.

Note: To avoid calculations where more than one orthogonal axis crosses a point, such as at the center of radius of an arch, the algorithms should define regions for which the path is valid.

In all cases the aircraft reference point on the aircraft shall be the GCP.

Note: Selection of the GCP will be covered in the aircraft integration guide.

Deviation states shall be computed from dynamically independent position updates at a nominal rate of at least 10 times per second (TBR) in Precision Mode and 5 times per second in CCA or Basic Mode.

Note: A dynamically independent position update is one that captures aircraft acceleration that occurs after the previous computation. Position updates developed by extrapolating from previous position and velocity computations are not dynamically independent.

Sea Based JPALS-Air shall measure range and range rate along the commanded path to/from the TDP or other specified rendezvous point to the commanded path reference frame origin.

3.2.1.2.3.6 Guidance Outputs

Sea Based JPALS-Air shall provide Guidance outputs at a minimum of 20 Hz while in Precision Mode, and at 5 Hz while in CCA or Basic modes.

The overall latency, defined as the total delay between normal maneuver dynamic inputs and the completion of transmission of the deviation state outputs reflecting the inputs, shall not exceed 100 ms. in Precision Mode or 1 second in CCA or Basic modes for inputs with frequency content in the range of zero to 1 radian per second.

Sea Based JPALS-Air shall output the deviation states.

Sea Based JPALS-Air shall output the range and range rate along the commanded path.

Sea Based JPALS-Air shall output the commanded path velocities and accelerations.

Sea Based JPALS-Air shall output the Time-to-Go (TTG) to the TDP based on the current commanded path.

Sea Based JPALS-Air shall output the TOA corresponding to the Guidance outputs.

Sea Based JPALS-Air shall output status and integrity indications corresponding to its Guidance outputs.

Sea Based JPALS shall provide path range and velocity to the selected TDP for precision approach operations.

3.2.1.2.3.7 Precision Approach Region

The Precision Approach Region (PAR) associated with an approach procedure is the region defined by the following conditions:

1. Distance to the TDP in the horizontal plane < 10 nm;
2. Bearing to TDP is within ± 90 degrees of the approach path;
3. Rectilinear lateral deviation is within 2 times the current full-scale deflection (FSD) value; and
4. Rectilinear vertical deviations are within 2 times the current FSD value or the aircraft is below a height of 30 feet above the TDP.

Note: The deviation conditions are necessary to limit the application of alert limits when the aircraft is not intending to land.

3.2.1.2.3.8 Guidance Function Performance Requirements

3.2.1.2.3.8.1 Guidance Function Coverage

(TBD)

3.2.1.2.3.8.2 Guidance Function Capacity

(TBD)

3.2.1.2.3.8.3 Guidance Function Accuracy

(TBD)

3.2.1.2.3.8.3.1 Deviation Accuracy

(TBD)

3.2.1.2.3.8.3.2 Deviation Rate Accuracy

(TBD)

3.2.1.2.3.8.3.3 Deviation Acceleration Accuracy

(TBD)

3.2.1.2.3.8.4 Guidance Integrity

(TBD)

3.2.1.2.3.8.5 Guidance Continuity

(TBD)

3.2.1.2.3.8.6 Guidance Availability

(TBD)

3.2.1.3 Monitoring Functions

The Monitoring functions compose the Air State Report and Air Monitor Report messages by which other Sea Based JPALS segments are made aware of the aircraft state.

3.2.1.3.1 Message Processing

Sea Based JPALS-Air shall receive the Air State Report and Air Monitor Report messages from other aircraft in the same ship network in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

These messages shall be decoded and output to external systems in the aircraft.

Note: If and how this data is used and displayed in the aircraft is subject to other aircraft systems and is addressed in the JPALS Aircraft Integration Guide [6].

3.2.1.3.2 Air State Report

The Air State Report message shall be transmitted in CCA and Precision modes. Its primary function is to send position information for the controllers. The information may also be used by other aircraft in the vicinity to perform area surveillance functions.

3.2.1.3.2.1 Rate

The aircraft shall compose and output the Air State Report message at a rate of 1 Hz.

3.2.1.3.2.2 Format

The aircraft shall broadcast the Air State Report message formatted in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

3.2.1.3.2.3 GPS Time of Applicability

The GPS TOA Field shall denote the reference time for all the message parameters in the Air State Report message. The GPS TOA for Air State Report message shall advance every frame.

3.2.1.3.2.4 Position Grid

The position grid shall denote the coarse location of the aircraft within a 4 x 4 grid surrounding the ship.

3.2.1.3.2.5 Latitude Fine

The Latitude Fine shall denote the latitude offset of the aircraft within the grid defined in the field above in degrees.

3.2.1.3.2.6 Longitude Fine

The Longitude Fine shall denote the longitude offset of the aircraft within the grid defined in the field above in degrees.

3.2.1.3.2.7 Height Coarse

The Height Coarse shall denote the height of the aircraft in feet referenced to the SRP

3.2.1.3.2.8 Height Fine

The Height Fine shall provide an increase in the resolution of the Height Coarse datum.

3.2.1.3.2.9 Baro Alt Coarse Delta

The Baro Alt Coarse Delta shall combine with the Baro Alt Fine value to give an offset from the Height fields above.

3.2.1.3.2.10 Baro Alt Fine

The Baro Alt Fine value shall denote the offset from the Height Field shown above. Its' value shall be multiplied by the value in the Baro Alt Coarse Delta field to produce the total Baro vs Height delta. This value shall then be added to the Height value for representation of Baro Altitude.

Barometric pressure altitude shall be reported referenced to standard temperature and pressure.

Altitude shall be provided with a range of -1,000 ft up to 100,000 ft.

3.2.1.3.2.11 Velocity Vector

The velocity vector data shall denote the aircraft horizontal and vertical velocity.

The horizontal velocity vector components are ship-relative, defined in the ship stabilized coordinate frame.

The vertical velocity shall denote the altitude rate of the aircraft and shall indicate if the aircraft is climbing or descending.

The relative altitude rate of the state vector is measured along the line from the ship to the current position of the aircraft. For NUC, values 8 and 9, relative altitude rates shall be reported.

For NUC values other than 8 and 9, barometric altitude rate or inertially augmented barometric altitude rate shall be reported.

Note: It is planned that Sea Based JPALS will eventually also transmit east-west and north-south velocity vector components relative to the WGS-84 reference system. These will be likely transmitted simultaneously with and in the same message as the ship-relative vector components (TBR).

3.2.1.3.2.12 Airspeed

The Airspeed shall denote the aircraft velocity as output from an air data computer.

3.2.1.3.2.13 Heading

The Heading shall denote the offset from the Heading Sector in degrees.

3.2.1.3.2.14 Heading Rate

The Heading Rate shall denote the rate of change of the heading field.

3.2.1.3.2.15 NUC

The NUC Position shall denote the uncertainty of the reported position information.

3.2.1.3.2.16 NUCR

The NUCR shall denote the uncertainty of the reported rate information.

3.2.1.3.2.17 Malfunction and Priority Status

The Malfunction and Priority Status shall denote shall denote urgent information about the aircraft.

3.2.1.3.2.18 Maintenance Codes

The Maintenance Codes shall denote any maintenance issues existing on the aircraft.

3.2.1.3.2.19 Ordnance Loadout Code

The Ordnance Loadout Code shall denot the current status of ordnance on the aircraft.

3.2.1.3.2.20 Expected Approach Time

The Expected Approach Time (EAT) shall denote the time at which an aircraft, following a delay, will be able to leave the holding point.

3.2.1.3.2.21 Fuel State

The Fuel State shall denote the current aircraft fuel in thousands of pounds (k-lbs).

3.2.1.3.2.22 Aircraft Identification

The basic identification information to be conveyed by monitoring function shall be the aircraft call sign.

The call sign shall convey an aircraft call sign of up to 7 alphanumeric characters in length. This will usually be the aircraft's assigned carrier and the aircraft tail number.

3.2.1.3.3 Air Monitor Report

The Air Monitor Report message is sent from the aircraft to the ship for final approach and recovery operations. This information consists of high rate positioning information in relationship to approach path, aircraft status and attitude. These messages shall be sent when the aircraft is within 10 nm of the ship and Sea Based JPALS-Air is in Precision Mode.

Note 1: Sea Based JPALS-Air must have a time slot allocated to it by Sea Based JPALS-Ship in order to transmit the Air Monitor Report messages. The time slot may be activated by Sea Based JPALS-Ship or may require Sea Based JPALS-Air to "check-in". There may be both a "trigger" specified to identify when the Sea Based JPALS-Air should attempt to check-in and a check-in mechanism specified. These requirements are still being developed (TBR).

Note 2: Sea Based JPALS-Ship will only be able to support a finite number of aircraft with each Sea Based JPALS-Air providing Air Monitor Reports. Sea Based JPALS-Ship may be equipped to de-select a given aircraft in favor of a higher priority aircraft. Therefore, the requirements for providing these reports are subject to change (TBR).

3.2.1.3.3.1 Rate

The aircraft shall compose and output the Air Monitor Report message at a rate of 10 Hz.

3.2.1.3.3.2 Format

The aircraft shall broadcast the Air Monitor Report message formatted in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

3.2.1.3.3.3 GPS Time of Applicability

The GPS Time of Applicability field shall denote the reference time for all the message parameters in the Air Monitor Report message. The GPS Time of Applicability for Air Monitor Report message shall advance every frame.

3.2.1.3.3.4 Cycle Index

Cycle Index shall denote the current index into the following data items that are sequenced through in consecutive messages.

3.2.1.3.3.5 Position Cycle Data

Position Cycle Data shall denote the 3D position information as a delta from the TDP. This information is rotated through latitude, longitude and height in consecutive messages. Indication of current transmitted parameter is denoted with the Cycle Index field described above.

3.2.1.3.3.5.1 Delta Latitude

The Delta Latitude shall denote the deviation in latitude from the TDP.

3.2.1.3.3.5.2 Delta Longitude

The Delta Longitude shall denote the deviation in longitude from the TDP.

3.2.1.3.3.5.3 Delta Height

The Delta Height shall denote the deviation in height from the TDP.

3.2.1.3.3.6 Velocity Cycle Data

Velocity Cycle Data is information describing the current velocity of the aircraft in terms of x, y , and z values representing eastward, northward and upward velocities. This information is rotated through east velocity, north velocity and vertical velocity in consecutive messages. Indication of current transmitted parameter is denoted with the Cycle Index field described above.

3.2.1.3.3.6.1 East Velocity

The East Velocity shall denote the velocity of the aircraft in an eastward direction.

3.2.1.3.3.6.2 North Velocity

The North Velocity shall denote the velocity of the aircraft in a northward direction.

3.2.1.3.3.6.3 Vertical Velocity

The Vertical Velocity shall denote the velocity of the aircraft in the vertical direction.

3.2.1.3.3.7 East Acceleration

The East Acceleration shall denote the acceleration of the aircraft in an eastward direction.

All acceleration information shall be referenced relative to the ship.

3.2.1.3.3.8 North Acceleration

The North Acceleration shall denote the acceleration of the aircraft in a northward direction.

3.2.1.3.3.9 Vertical Acceleration

The Vertical Acceleration shall denote the acceleration of the aircraft in a vertical direction.

Altitude acceleration shall be designated as climbing or descending.

Altitude acceleration shall be reported up to ± 1 g.

3.2.1.3.3.10 Elevation Deviation

The Elevation Deviation shall denote the angular deviation from the selected glidepath.

3.2.1.3.3.11 Azimuth Deviation

The Azimuth Deviation shall denote the angular deviation from the selected course.

3.2.1.3.3.12 Horizontal Protection Level

The HPL shall denote the calculated horizontal limit for the current recovery operation and approach type.

3.2.1.3.3.13 Vertical Protection Level

The Vertical Protection Level (VPL) shall denote the calculated vertical limit for the current recovery operation and approach type.

3.2.1.3.3.14 Airspeed

The Airspeed shall denote the true airspeed of the aircraft.

3.2.1.3.3.15 Attitude Cycle Data

Attitude Cycle Data contains data pertaining to the orientation of the aircraft. These parameters consist of heading, pitch and roll. The data is cycled in consecutive Air Monitor messages and the relevant data is indicated by the Cycle Position Data field described above.

3.2.1.3.3.15.1 Heading

The Heading shall denote the current heading of the aircraft relative to true north.

3.2.1.3.3.15.2 Pitch

The Pitch shall denote the current pitch attitude of the aircraft relative to level flight.

3.2.1.3.3.15.3 Roll

The Roll shall denote the current wing attitude relative to wings level flight.

3.2.1.3.3.16 Heading Rate

The Heading Rate shall denote the rate of change for the Heading parameter.

3.2.1.3.3.17 Pitch Rate

The Pitch Rate shall denote the rate of change for the pitch parameter.

3.2.1.3.3.18 Roll Rate

The Roll Rate shall denote the rate of change for the Roll parameter.

3.2.1.3.3.19 Angle of Attack

The angle of attack shall denote the aircraft angle of attack in degrees.

3.2.1.3.3.20 Data Cycle

Data Cycle field refers to various aircraft parameters and their current state or measurement. These parameters are cycled through in consecutive messages. Indication of current transmitted parameter is denoted with the Cycle Index field described above.

3.2.1.3.3.20.1 Estimate Gross Weight

The Estimate Gross Weight shall denote the estimated gross weight of the aircraft in thousand pound units.

3.2.1.3.3.20.2 Engine Speed

The Engine Speed shall denote the current speed of the engine in percent revolutions per minute (RPM).

3.2.1.3.3.20.3 Throttle Setting

The Throttle Setting shall denote the current amount of throttle in percent range (Power Lever).

3.2.1.3.3.20.4 Configuration Status

The Configuration Status field is a combination field containing the state of various aircraft systems. These systems typically exist in a fixed or limited range of states (i.e. gear up or down). The systems and their allowable states are described below and are limited by what the data bus reports:

3.2.1.3.3.20.4.1 Landing Gear Position

The Landing Gear Position shall denote the current position of the landing gear. A value of 1 in this field shall indicate the landing gear is locked in the DOWN position.

3.2.1.3.3.20.4.2 Hook Position

The Hook Position shall denote the current state of the aircraft hook. A value of 1 in this field shall indicate the hook is DOWN.

3.2.1.3.3.20.4.3 Autopilot Engage

The Autopilot Engage shall denote the current state of the autopilot. A value of 1 in this field shall indicate the autopilot is ENGAGED.

3.2.1.3.3.20.4.4 Autothrottle Engage

The Autothrottle Engage shall denote the current state of the autopilot. A value of 1 in this field shall indicate the autothrottle is ENGAGED.

3.2.1.3.3.20.4.5 Engine Status

The Engine Status shall denote a code related to the current state of the engines.

3.2.1.3.3.21 Aircraft Identification

The basic identification information to be conveyed by monitoring function shall be the aircraft call sign.

The call sign shall convey an aircraft call sign of up to 7 alphanumeric characters in length. This will usually be the aircraft's assigned carrier and the aircraft tail number.

3.2.1.3.4 Monitoring Performance Requirements

3.2.1.3.4.1 Basic Monitoring Coverage

3.2.1.3.4.1.1 Ship Coverage

Sea Based JPALS shall meet all requirements of the basic monitoring function when the aircraft is within a 360 degree cylinder from the deck altitude to 60,000 feet operating height, has a clear line of sight to the ship, and is within 50 nm of the ship.

3.2.1.3.4.1.2 Aircraft Coverage

Sea Based JPALS shall meet all requirements of the basic monitoring function when the receiving aircraft is within 15 nm of the transmitting aircraft and both aircraft are on the same Sea Based JPALS network.

3.2.1.3.4.2 Basic Monitoring Capacity

3.2.1.3.4.2.1 Aircraft Capacity

Sea Based JPALS shall receive basic monitoring function information from all aircraft within the aircraft coverage volume.

3.2.1.3.4.3 Basic Monitoring Accuracy

Given the following definitions:

σ_{hp}: standard deviation of horizontal position error.

σ_{hv}: standard deviation of horizontal velocity error.

σ_{vp}: standard deviation of vertical position error.

σ_{vv}: standard deviation of vertical velocity error.

The basic monitoring function position output shall exhibit a σ_{hp} <= 20 m for 1 sigma, 1D.

The basic monitoring function position output shall exhibit a σ_{hv} <= 0.25 m/s for 1 sigma, 1D.

The basic monitoring function position output shall exhibit a σ_{vp} <= 30 ft for 1 sigma, 1D.

The basic monitoring function position output shall exhibit a σ_{vv} <= 1 fps for 1 sigma, 1D.

These limits are in order to assure satisfaction of basic monitoring function report accuracy.

The errors referred to in this section are specifically due to monitoring function quantization of state vector information and other effects.

3.2.1.3.4.4 Basic Monitoring Integrity

(TBD)

3.2.1.3.4.5 Basic Monitoring Continuity

(TBD)

3.2.1.3.4.6 Basic Monitoring Availability

(TBD)

3.2.1.3.4.7 Monitoring Latency Requirements

For NUC < 8, the monitoring function latency of the reported information shall be less than 1.2 s with 95% confidence.

For NUC >= 8, monitoring function latency shall be less than 0.4 s with 95% confidence.

Compensation may be applied to the reported information in order to adjust, at least approximately, for the changes in aircraft state between the time of measurement and the time of the report. Compensation may be applied to position information while not being applied to velocity information. As a result, the two parts of a state vector may apply to two different times. This produces a velocity lag error if the reporting aircraft is accelerating.

The standard deviation of the report time error shall be less than 0.5 s (1 sigma).

The mean report time error for position shall not exceed 0.5 s.

The mean report time error for velocity shall not exceed 1.5 s.

Note: Differential delay errors should be considered and, if necessary, compensated for by the using application. The monitoring function is not required to compensate for differential delays; however, all necessary information to perform such compensation is included in the monitoring function state vector report.

3.2.1.3.5 Precision Monitoring Performance Requirements

3.2.1.3.5.1 Precision Monitoring Coverage

Sea Based JPALS shall meet the requirements of the precision monitoring function when the aircraft is within a 360 degree cylinder from the deck altitude to 6,000 feet operating height and is within 10 nm of the ship.

3.2.1.3.5.2 Precision Monitoring Integrity

(TBD)

3.2.1.3.5.3 Precision Monitoring Continuity

(TBD)

3.2.1.3.5.4 Precision Monitoring Availability

(TBD)

3.2.1.4 Communications Functions

Refer to *Sea Based JPALS DL SIS Interface Specification* [16] for all classified requirements.

Note: Waveform design using the 1.2 Megahertz (MHz) bandwidth (BW) is in its design stage. Associated requirement parameters are being developed and are listed here as placeholders.

3.2.1.4.1 Coverage

Sea Based JPALS-Air supports a variety of operations, ranging from precision approach to situational awareness.

For each operation, there is a defined set of messages to be transmitted or received by the Sea Based JPALS-Air, and a corresponding volume throughout which these messages are required to meet the signal strength, accuracy, integrity, continuity, and availability requirements for the corresponding operation.

3.2.1.4.1.1 Coverage Volume

The Sea Based JPALS coverage volumes are depicted in Figure 3-3.

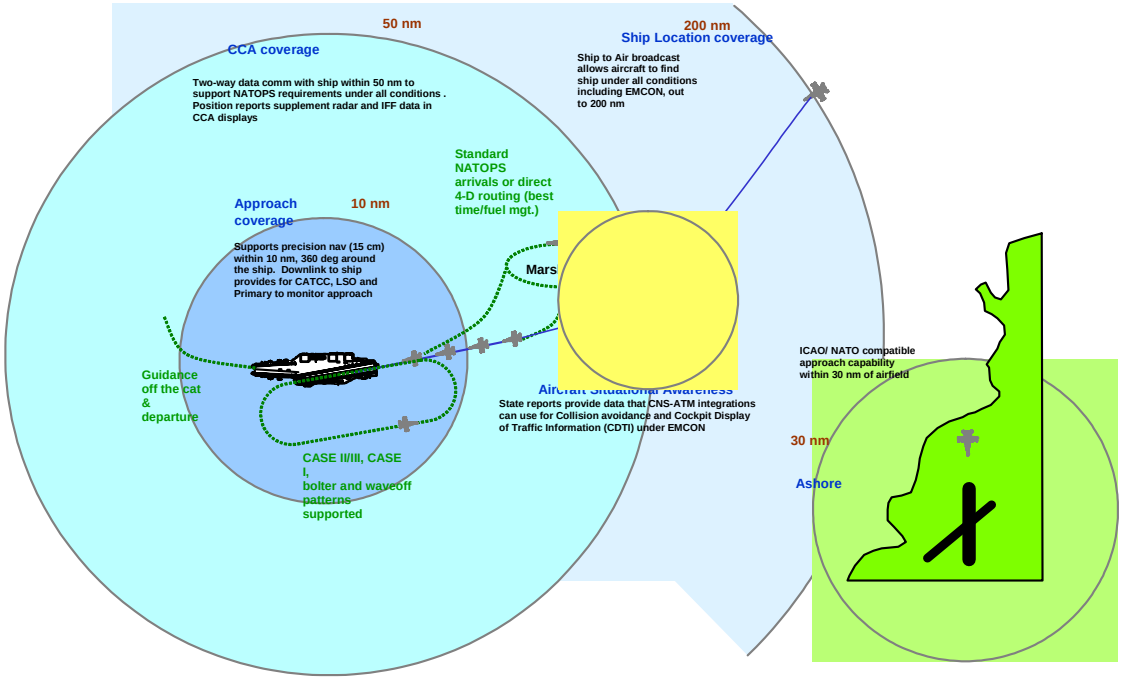

Figure 3-3: Sea Based JPALS Coverage Volume

All coverage requirements assume a clear line of sight and 360 degree coverage.

Sea Based JPALS-Air shall support basic navigation (Sea Based JPALS-Air CCA and Basic modes) when the aircraft is within a 360 degree cylinder from the deck altitude to 60,000 feet operating height, has a clear line of sight to the ship and is within 200 nm from the ship.

Sea Based JPALS-Air shall support two-way communications with a Sea Based JPALS equipped ship when the aircraft is within a 360 degree cylinder from the deck altitude to 60,000 feet operating height, has a clear line of sight to the ship, and is within 50 nm of the ship.

Sea Based JPALS-Air shall support precision navigation (Sea Based JPALS-Air Precision Mode) when the aircraft is within a 360 degree cylinder from the deck altitude to 6,000 feet operating height, and is within 10 nm from the ship.

3.2.1.4.1.2 Signal Characteristics

Sea Based JPALS-Air shall operate while precluding a hostile force's ability, when located beyond the distance specified in Sea Based JPALS DL SIS Interface Specification [10], to identify the presence of a signal and use that signal or the data in it to threaten the ship.

3.2.1.4.2 Initialization

The Sea Based JPALS DL shall accept input of initialization data, including mission planning and information security (INFOSEC) data.

Note: It is envisioned that mission planning initialization data will be available through the avionics bus on the aircraft and that INFOSEC initialization data will be provided through a fill port. Refer to the JPALS Aircraft Integration Guide [6] for additional guidance.

3.2.1.4.3 Tuning

3.2.1.4.3.1 Frequency Range

Sea Based JPALS-Air shall operate over the frequency range of 225 - 400 MHz within the channels designated for 1.2 MHz wideband use by *Frequency Plan for 225-400 MHz Band* [14].

Sea Based JPALS-Air shall operate with a BW of 1.2 MHz.

3.2.1.4.3.2 Frequency Selection

Sea Based JPALS-Air shall tune to the center frequency of any 1.2 MHz wideband channel as defined in *Frequency Plan for 225-400 MHz Band* [14].

3.2.1.4.3.3 Tuning Time

The Sea Based JPALS-Air shall support a maximum tune time of 10 ms to settle within 1 kilohertz (kHz) of final frequency.

3.2.1.4.3.4 Switching Times

Receive-to-Transmit (R/T) and Transmit-to-Receive (T/R) switching times shall be less than or equal to 100 μs.

3.2.1.4.3.5 Internal Timing Standard

Once the Sea Based JPALS-Air has Coordinated Universal Time (UTC) time, it shall operate per specification for a period of at least 4 hours without resynchronization.

3.2.1.4.4 Information Security

Sea Based JPALS-Air shall accept an alternate absolute time of day (TOD) source if GPS time is not available.

All application data over the Sea Based JPALS data link shall be encrypted. No cryptographic bypass capability is required.

3.2.1.4.4.1 Communication Security

Sea Based JPALS-Air shall use a TOD-based communication security (COMSEC) algorithm with no over-the-air COMSEC synchronization to protect all user data sent over the link.

TOD shall be based on UTC time.

3.2.1.4.4.2 Transmission Security

Sea Based JPALS-Air shall use a TOD-based transmission security (TRANSEC) algorithm with no over-the-air TRANSEC synchronization.

3.2.1.4.4.3 Time Slot Number Format

Sea Based JPALS INFOSEC will use a daily, non-multiple net TOD format for the time slot number (TSN). The TSN is used to initialize the INFOSEC algorithm for each INFOSEC operation. With a daily, non-multiple net TSN format, the 39-bit TSN is divided into a net number field that occupies the 7 Most Significant Bits, and a 32-bit TOD field. The net number field (TSN bits 39 to 33) is set to all 0s for Sea Based JPALS operation.

INFOSEC TSN format is identical to the TOD format for the network at the Time Division Multiple Access (TDMA) slot level as defined in the *Sea Based JPALS DL SIS Interface Specification* [10] (TSN bits 32 to 5). Below the TDMA slot level, bit 4 is used to denote COMSEC (bit 4 = 1) or TRANSEC (bit 4 = 0) operation. Bits 1-3 are currently being defined.

3.2.1.4.4.4 Rollover

At the beginning of the first TDMA epoch after midnight UTC, the crypto-variables in use will expire. The old crypto-variables will be erased and automatically replaced with new crypto-variables for the next 24 hour crypto period that were loaded as part of the pre-mission fill.

3.2.1.4.5 Message Quality and Integrity

The message error rate (MER) is defined as the portion of total transmitted messages that are not passed from the transmit function or passed with one or more errors.

The MER is computed after sync acquisition. Operating conditions that these rates are valid over are identified in paragraph 3.2.5 of this document.

The MER for application data shall be less than or equal to 0.5 (TBR) for Basic Mode.

The MER for application data shall be less than or equal to 0.05 (TBR) for CCA Mode.

The MER for application data shall be less than or equal to 10^{-3} (TBR) for Precision Mode.

3.2.1.4.6 Receive Function

3.2.1.4.6.1 Sensitivity

The Sea Based JPALS-Air shall achieve a Message Error Rate (MER) per 3.2.1.3.5 with the following inputs at the RT:

-120 Decibels referenced to one milliwatt (dBm) for Basic Mode
-108 dBm for CCA Mode
-98 dBm for Precision Mode

3.2.1.4.6.2 Selectivity

The Sea Based JPALS-Air BW shall be as follows:

+/- 185 kHz minimum at 3 dB point referenced to tuned frequency
+/- 450 kHz minimum at 20 dB points referenced to tuned frequency
+/-670 kHz minimum at 60 dB points referenced to tuned frequency

3.2.1.4.6.3 Out-of-Band Rejection

Out-of-band rejection requirements are TBR.

3.2.1.4.6.4 Receive Signal Processing

The receiver subsystem shall incorporate measures to mitigate multi-path interference.

3.2.1.4.6.5 Data Latency

Data latency from input at the antenna to availability for output from the communication function shall not exceed TBD.

Note: The latency requirements in the Sea Based JPALS DL SIS Interface Specification [10] define end-to-end latency from data input to the transmitting DL to data availability at the output queue of the receiving DL. Transmit, receive, and network latencies will be allocated portions of the end-to-end latency specifications as part of the system design process and documented in the system/segment design document. Latencies including controller polling, bus transfer times, and application data processing will be allocated outside of the Sea Based JPALS Data Link Subsystem latency budget.

3.2.1.4.6.6 Data Format Decoding

Sea Based JPALS-Air shall demodulate and decode the data link signal specified in the *Sea Based JPALS DL SIS Interface Specification [10]*.

3.2.1.4.6.6.1 Source Validation

Sea Based JPALS-Air shall perform the CRC on all messages received, and ignore any message for which the CRC, as defined in the *Sea Based JPALS DL SIS Interface Specification* [10], does not pass.

Sea Based JPALS-Air shall ignore any uplink message whose source ID does not match the source designated by the aircrew for the selected ship.

3.2.1.4.6.7 Receiver-to-Antenna Interface

RF signal loss from input at the antenna to input at the RT shall not exceed 4 dB.

3.2.1.4.7 Transmit Function

3.2.1.4.7.1 Frequency Accuracy

The transmit frequency accuracy shall be within +/- 16 Hz. Rate of drift shall be less than 1 Hz per second.

3.2.1.4.7.2 Power Output

3.2.1.4.7.2.1 Power Control Enabled

During normal data link operation, power control per the Sea Based JPALS DL SIS Interface Specification [10] shall be employed to set the output power.

3.2.1.4.7.2.1.1 Power Control Reference

Under all service conditions, when power control is enabled and set for no turn down, normal mode transmit power at the RT output shall be +10 Decibels reference to one watt (dBW) (10 watts) +/- 1 dB.

3.2.1.4.7.2.1.2 Turn Down Range

Transmit power shall be able to be reduced 30 dB +/- 3 dB in 30 steps from the reference level. Each step shall be 1 +/- 0.5 dB.

3.2.1.4.7.2.1.3 Initial Power Control Setting

A means shall be provided to set an initial power control level as part of a pre-mission fill. If not specified in the pre-mission fill, the initial level shall be 4 dB turn down (+6 dBW).

3.2.1.4.7.2.1.4 Operational Power Limit Setting

A means shall be provided to set an upper limit for the automatic power control range as part of a pre-mission fill. If not specified in the pre-mission fill, the limit shall be 4 dB turn down (+6 dBW).

3.2.1.4.7.2.2 Power Control Disabled

A means shall be provided to disable the normal power control mode. With this selection, under all service conditions, the full radio frequency (RF) power output at the RT output shall not be less than 15 watts over the operating frequency range.

3.2.1.4.7.3 Transmit Noise Floor

The transmit broadband noise level shall be no more than -117 dBm/Hz at any frequency greater than 10 MHz, but less than 15 MHz from the carrier frequency.

Above 15 MHz, the transmit broadband noise level shall be no more than -120 dBm/Hz.

3.2.1.4.7.4 Transmit Energy Spectrum

3.2.1.4.7.4.1 Spectral Containment

For Sea Based JPALS operations, 95 percent of the transmitted energy shall be contained within the operating channel.

3.2.1.4.7.5 Transmit Spurious

The transmit function shall comply with the transmit spurious requirements of CE106 - Conducted Emissions, Antenna Terminal, 10 kHz to 8 Gigahertz (GHz) in MIL-STD-461 [8].

3.2.1.4.7.6 Transmit Signal Processing

The transmit function performs all necessary application data translation, encryption, error correction coding, modulation, network timing and frequency selection of the transmit signal. See the Sea Based JPALS DL SIS Specification for specific transmit processing requirements.

3.2.1.4.7.7 Data Latency

Data latency from input to the communication function to output at the transmit antenna shall not exceed TBD, excluding any delays for slot alignment.

Note: The latency requirements in the Sea Based JPALS DL SIS Interface Specification [10] define end-to-end latency from data input to the transmitting DL to data availability at the output queue of the receiving DL. Transmit, receive, and network latencies will be allocated portions of the end-to-end latency specifications as part of the system design process and documented in the system/segment design document. Latencies including controller polling, bus transfer times, and application data processing will be allocated outside of the Sea Based JPALS Data Link Subsystem latency budget.

3.2.1.4.7.8 Data Format Encoding

The transmitter subsystem shall modulate and encode the data link signal specified in the Sea Based JPALS DL SIS Interface Specification [10].

3.2.1.4.7.9 Timing Accuracy

The Sea Based JPALS-Air shall begin a slot transmission with an accuracy of +/- 10 microseconds from the nominal time specified by the waveform.

3.2.1.4.7.10 Transmit Rise Time

The Sea Based JPALS-Air shall transition from 10% of power output to 90% of power output in 10 to 20 microseconds.

3.2.1.4.7.11 Transmit Fall Time

The Sea Based JPALS-Air shall transition from 90% of power output to 10% of power output in 10 to 20 microseconds.

3.2.1.4.8 Message Processing Function

3.2.1.4.8.1 ATM Broadcast Message Processing

Sea Based JPALS-Air shall receive the ATM Broadcast 50 and ATM Broadcast 10 messages in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

Note: The Sea Based JPALS system will output the ATM contents of each message. How each message is presented to the aircrew is subject to the particular aircraft integration.

3.2.1.4.8.2 ATM Uplink Message Processing

Sea Based JPALS-Air shall receive those ATM messages designated by the *Sea Based JPALS DL SIS Interface Specification* [10] as uplink messages in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

Sea Based JPALS-Air shall output the application data contained in ATM uplink messages as described in the *Sea Based JPALS DL SIS Interface Specification* [10].

3.2.1.4.8.3 ATM Downlink Message Processing

Sea Based JPALS-Air shall receive those ATM messages designated by the *Sea Based JPALS DL SIS Interface Specification* [10] as downlink messages, from other aircraft systems in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

Sea Based JPALS-Air shall encode these ATM messages into ATM downlink messages in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

Sea Based JPALS-Air shall send these ATM downlink messages to the ship via the data link.

Sea Based JPALS-Air shall prioritize transmission of ATM downlink messages in accordance with the priority assigned in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10] by the message-generating function.

J-UCAS shall receive those ATM messages designated by the *Sea Based JPALS DL SIS Interface Specification* [10] as downlink messages, in accordance with the *Sea Based JPALS DL SIS Interface Specification* [10].

3.2.1.4.8.4 Automated Routine Transmissions

Sea Based JPALS-Air may send ATM messages to the ship without stimulus from the aircrew when certain conditions are satisfied. Use of these messages is not required and is subject to both ship and aircraft integration. These messages shall be in accordance with the Sea Based JPALS DL SIS Interface Specification [10].

3.2.1.4.8.5 INS Alignment Data

Sea Based JPALS shall provide the capability to supply INS Alignment Data (defined in section 6) to the air vehicle INS so it can accomplish an alignment while the air vehicle is on the flight deck.

3.2.1.4.9 Receive Signal Processing

3.2.1.4.10 Source ID Selection and Reporting

Sea Based JPALS-Air shall output the ship ID of the ship from which it is receiving data link traffic.

Sea Based JPALS-Air shall output the ship ID of the target ship.

By default, Sea Based JPALS-Air shall select the aircraft's launch platform as the target ship for all navigation and recovery functions. The ship ID of the launch platform shall be retrieved from the mission planning database.

Sea Based JPALS-Air shall ignore data link traffic from all ships except the designated target ship.

The system shall accept input from the avionics of an aircrew designated ship ID as the target ship for navigation and recovery functions.

3.2.1.5 Control and Display Function

Sea Based JPALS-Air does not have unique aircraft display and control requirements. Sea Based JPALS-Air will accept inputs and provide outputs as delineated in the various sections of this specification. The control and display mechanisms required to provide these inputs and to display the outputs in a manner appropriate to the pilot(s) and/or maintenance personnel, though necessary, are not considered part of Sea Based JPALS-Air. Requirements and guidance for the integration of Sea Based JPALS-Air with an aircraft's existing display and control capability are provided in the *JPALS Aircraft Integration Guide* [6].

3.2.1.6 Data Recording

There is no requirement for recording at the Sea Based JPALS-Air-airborne level. Recording requirements will be as specified in the *JPALS Aircraft Integration Guide* [6].

3.2.1.7 Alerts and Alarms

3.2.1.7.1 Loss of Guidance

Sea Based JPALS-Air shall provide an indication when the system is no longer adequate to conduct or continue the currently determined basic relative position operation. This happens when the HPL exceeds the corresponding alarm limit.

3.2.1.7.1.1 Horizontal Alert limits

Sea Based JPALS-Air horizontal alert limit for RN 1 shall be 0.8 nm (TBR).

Sea Based JPALS-Air horizontal alert limit for RN 2, shall be 1132 m (TBR).

Sea Based JPALS-Air horizontal alert limit for RN 3 shall be 440 m (TBR).

3.2.1.7.1.2 Horizontal Protection Level

Sea Based JPALS-Air shall compute the HPL for the RN 1, RN 2, and RN 3 performance levels as defined by the following equations:

$$HPL_{H0} = \mathrm{K} d_{major} \qquad \textbf{(2)}$$

where:

$$d_{major} = \sqrt{d_{major_air}^2 + d_{major_ship}^2} \qquad \textbf{(3)}$$

where d_{major_ship} is uplinked from the ship and d_{major_air} is defined as

$$d_{major_air} = \sqrt{\frac{d_x^2 + d_y^2}{2} + \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}} \qquad \textbf{(4)}$$

The variance of model distribution that over bounds the true error distribution in the "1" axis is

$$d_x^2 = \sum_{i=1}^{N} s_{1,i}^2 \sigma_i^2 \qquad \textbf{(5)}$$

The variance of model distribution that over bounds the true error distribution in the "2" axis is

$$d_y^2 = \sum_{i=1}^{N} s_{2,i}^2 \sigma_i^2 \quad \textbf{(6)}$$

The covariance of model distribution in the "1" and "2" axes is

$$d_{xy} = \sum_{i=1}^{N} s_{1,i} s_{2,i} \sigma_i^2 \quad \textbf{(7)}$$

and for each ith ranging source

$$\sigma_i^2 \equiv \sigma_{tropo}^2[i] + \sigma_{iono}^2[i] + \sigma_{multipath}^2[i] + \sigma_n^2[i] \quad \textbf{(8)}$$

Note 1: The models used for determining the sigma values will be approved by the Navy certifying team. K = TBR.

Note 2: Still need to investigate the contributions of path definition error (PDE) (TBR).

3.2.1.7.2 Loss of Precision Guidance

Sea Based JPALS-Air shall provide an indication when the system is no longer able to conduct or continue the approach. The lateral and vertical deviation outputs shall be invalidated within one second of the onset of any of the following conditions:

1. The absence of power (loss of function is an acceptable indicator);
2. Probable equipment malfunction or failure.

The lateral and vertical deviation outputs shall be invalidated within 0.4 seconds from the onset of any of the following conditions:

1. The lateral protection level exceeds the lateral alert limit;
2. The elapsed time from the receipt of the last ship GPS message or ship motion message is equal to or greater than 10 seconds (TBR) seconds and the aircraft is within the PAR;
3. The difference between the current time and the reference time of the data in the ship GPS message or ship motion message (derived from the time of applicability) is equal to or greater than 10 seconds (TBR) seconds and the aircraft is within the PAR.

Note: If approach guidance is being provided, the loss of a valid differential position solution also causes the loss of valid approach guidance regardless of whether the aircraft is inside or outside the PAR.

The vertical deviation output shall be invalidated within 0.4 seconds from the time the vertical protection exceeds the vertical alert limit (VAL).

3.2.1.7.3 Alert Limits

3.2.1.7.3.1 Lateral Alert Limits

When the aircraft is inside the PAR, the lateral alert limit shall be as defined in this section. When the computed position is inside the PAR distance criteria and the bearing to the TDP is more than +/- 90 deg of the approach path, the lateral alert limit shall be equal to the Uplinked Lateral Alert Limit (ULAL) (TBR) in the General Launch and Recovery message. When the approach has been selected and the computed position is outside of the PAR, the lateral alert limit shall be the sum of the ULAL and the Maximum ULAL (MULAL) uplinked in the General Launch and Recovery message.

The values for SPL lateral alert limits are those required for the intended operation at the shortest Distance From Touchdown (DFT), if applicable.

The SPL PA lateral alert limit shall be ULAL meters where DFT is in the range -100m to 498m (TBR).

The SPL PA lateral alert limit shall be [ULAL+ (DFT-498)* MULAL/6910] meters where DFT is in the range 498m to 7408m (TBR).

The SPL PA lateral alert limit shall be [ULAL + MULAL] TBR meters where DFT is beyond 7408 meters (TBR).

The SPL AL lateral alert limit shall be ULAL m where DFT is in the range -100m to 70m (TBR).

The SPL AL lateral alert limit shall be [ULAL+(DFT-70)* MULAL/6910] meters where DFT is in the range 70m to 7408m (TBR).

The SPL AL lateral alert limit shall be [ULAL + MULAL]m where DFT is beyond 7408 meters (TBR).

3.2.1.7.3.2 Vertical Alert Limits

When the aircraft is inside the PAR, the VAL shall be as defined in this section. When the computed position is inside the PAR distance criteria and the bearing to the TDP is more than +/- 90 deg of the approach bearing, the VAL shall be equal to the Uplinked Vertical Alert Limit (UVAL) in the General Recovery and Launch message. When the approach has been selected and the computed position is outside of the PAR, the vertical alert limit shall be equal to the sum of the Maximum UVAL (MUVAL) uplinked in the General Recovery and Launch message and the UVAL.

The SPL PA VAL shall be UVAL meters where DFT is in the range -10 m to 498 meters (TBR).

The SPL PA VAL shall be [UVAL+(DFT-498)* MUVAL/6910] meters where DFT is in the range 498m to 7408 meters (TBR).

The SPL PA VAL shall be [UVAL + MUVAL] meters where DFT is beyond 7408 meters (TBR).

The SPL AL VAL shall be UVAL meters where DFT is in the range -10 to 70m (TBR).

The SPL AL VAL shall be [UVAL+(DFT-70)*0.0011] meters where DFT is in the range 70m to 7408m (TBR).

The SPL AL VAL shall be [UVAL + 10.0] meters where DFT is beyond 7408 meters (TBR).

3.2.1.7.3.3 PA and AL Lateral and Vertical Protection Levels

Sea Based JPALS-Air shall compute the VPL and the Lateral Protection Level (LPL) during PA and AL as defined by the following equations:

$$VPL_{H0} < VAL \text{ and } LPL_{H0} < LAL \quad \textbf{(9)}$$

where:

$$VPL_{H0} = K_{ffmd}(\sigma_{vert,pos} + \sigma_{vert,vel} t + 0.5\sigma_{vert,acc} t^2) \quad \textbf{(10)}$$

and

$$LPL_{H0} = K_{ffmd}(\sigma_{lat,pos} + \sigma_{lat,vel} t + 0.5\sigma_{lat,acc} t^2) \quad \textbf{(11)}$$

and

$$\sigma_{vert,pos} = \sqrt{C_{xhat,DD_H0}(3,3)} \quad \textbf{(12)}$$

and

$$\sigma_{lat,pos} = \sqrt{C_{xhat,DD_H0}(2,2)} \quad \textbf{(13)}$$

(note: technically sigma_crosstrack, not strictly sigma lateral!)

$$C_{xhat,DD_H0} = S_{DD_H0} C_{z,DD_H0} S_{DD_H0}^T \quad \textbf{(14)}$$

$$G_{DD} = BG_{SD} \quad \textbf{(15)}$$

$$W_{DD_H0} = C_{z,DD_H0}^{-1} \quad \textbf{(16)}$$

$$C_{z,DD_H0} = BC_{z,SD_H0} B^T \quad \textbf{(17)}$$

and for each double difference ith ranging source

$$\sigma^2_{N,H0} \equiv \sigma^2_{tropo}[i] + \sigma^2_{iono}[i] + \sigma^2_{multipath}[i] + \sigma^2_{n}[i] + \sigma^2_{amb}[i] \quad \textbf{(19)}$$

Note 1: The models used for determining the sigma values will be provided. Kffmd = TBR.

Note 2: The uncertainty in the velocity and acceleration terms will depend on how they are determined. The method will differ if the inertial sensor is used or if only GPS is used.

B is transform matrix for key satellite or round robin double difference transform.

$$B_{key} = \begin{bmatrix} 1 & -1 & 0 & \cdots & 0 \\ 1 & 0 & -1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & 0 & 0 & \cdots & -1 \end{bmatrix} \quad \textbf{(20)}$$

$$B_{roundrobin} = \begin{bmatrix} 1 & -1 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 \\ 0 & 0 & \ddots & \ddots & 0 \\ 0 & 0 & 0 & 1 & -1 \end{bmatrix} \quad \textbf{(21)}$$

$$B_{roundrobin} = \begin{bmatrix} 1 & -1 & 0 & \cdots & \cdots & 0 \\ 0 & 1 & -1 & 0 & \cdots & 0 \\ 0 & 0 & \ddots & \ddots & 0 & 0 \\ \vdots & \vdots & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 & -1 \end{bmatrix} \quad \textbf{(22)}$$

Note: The contribution of PDE is still being evaluated (TBR).

3.2.2 Physical Characteristics

3.2.2.1 Aircraft Compatibility

Sea Based JPALS-Air shall not adversely impact aircraft requiring low observable performance.

Sea Based JPALS-Air avionics shall not exceed the weight and size of existing systems that perform Sea Based JPALS functions.

Sea Based JPALS-Air avionics shall operate on existing aircraft power within existing aircraft power bus capacity.

Sea Based JPALS avionics must be capable of being interoperable with host aircraft interface requirements including analog systems, DoD Multiplex Data Bus, and ARINC interfaces as applicable.

3.2.3 Reliability

3.2.3.1 Operational Availability

Operational availability (A_O) measures the inherent probability that the JPALS system is ready to perform its specified function, in its specified operational environment, when called for at a random point in time.

Sea Based JPALS-Air shall have an operational availability consistent with the host platform avionics.

3.2.4 Maintainability

If Sea Based JPALS-Air is implemented in standalone avionics, personnel shall be able to perform organization level maintenance tasks wearing biological and chemical protective ensembles and cold weather gear.

Organizational level maintenance shall utilize built-in-tes equipment (BITE) to the maximum extent possible.

Organic depot support equipment shall be that type of automatic test equipment approved by the DoD Service selected to be the source of repair.

3.2.4.1 Built-In-Test

The system design shall include the use of built-in-test (BIT) prognostics and diagnostics, permitting system health monitoring of critical attributes to accurately predict remaining useful life before failure, the isolation, removal, and replacement of those units to avoid critical failure, or actual removal of diagnosed faulty units. Sea Based JPALS-Air shall output diagnostic results.

Continuous BIT of 100% of the critical components of the GPS Receiver System shall be performed on the GPS Receiver System, with an exposure (test time) not to exceed 5 minutes. The BIT must include a test of all memory and processor calls used.

If Sea Based JPALS-Air provides a manually-initiated BIT function, only non-intrusive diagnostics can be performed while the aircraft is airborne. Non-intrusive diagnostics do not affect the current Sea Based JPALS-Air operation. A manually-initiated BIT function shall only perform intrusive diagnostics when Sea Based JPALS-Air is on the ground. Intrusive diagnostics may affect Sea Based JPALS-Air operation and shall only be available to maintenance personnel.

The Sea Based JPALS BIT prognostics and diagnostics shall permit the Condition Based Monitoring (CBM) of system critical attributes to accurately predict remaining useful life before failure, alarm detection and isolation, line replaceable unit (LRU) removal and replacement to avoid a critical failure, or actual removal of diagnosed faulty units.

3.2.4.2 Fault Detection

If Sea Based JPALS-Air is implemented in standalone avionics, the fraction of failures detected (FFD) using self-test shall be greater than 95% (threshold) with a goal of 98%. The FFD using periodic BIT shall be greater than 90% for the selected mode. 100% of critical failures will be detected. If Sea Based JPALS-Air is a modification to existing system, fault detection will be in accordance with host system requirements.

3.2.4.3 Fault Isolation

If Sea Based JPALS-Air is implemented in standalone avionics, 95% of failures detected shall be isolated to a single line replaceable unit (LRU) using periodic BIT and self-test. 100% of failures detected shall be isolated to a single LRU using BIT, self-test, support equipment and technical orders. If Sea Based JPALS-Air is a modification to existing system, fault isolation will be in accordance with host system requirement.

3.2.4.4 Fault Storage

The system shall be capable of storing fault and fault-related data in a non-volatile memory medium for recall on demand by operator or maintenance personnel. Fault history data shall include the last 100 detected faults at a minimum, and shall be erasable by maintenance technicians only.

3.2.4.5 Failure Detection False Alarms

If standalone avionics, less than 2% of all indicated faults shall be attributed to Sea Based JPALS avionics periodic BIT and self test false alarms. If Sea Based JPALS-Air is a modification to existing system, false alarm rates will be in accordance with host system requirements.

If new avionics, less than 2% of all indicated faults shall be attributed to the avionics periodic BIT and self test false alarms.

The BIT false alarm probability for the GPS Receiver shall not exceed 2.5 x 10^{-9}. (TBR)

3.2.4.6 Predictive Health and Maintenance Data

Sea Based JPALS-Air shall output predictive health and maintenance (PHM) data as defined in the *Sea Based JPALS DL SIS Interface Specification [10]* upon request and automatically after recovery.

3.2.5 Environmental

Sea Based JPALS-Air shall provide safe landing guidance in all terrain, environments, and conditions of adverse weather (i.e., rain, humidity, snow, freezing rain, winds, turbulence, fog, sea spray, extreme temperature, lightning, ionospheric scintillation. sand, and dust) in which an aircraft may be expected to conduct an approach to a landing. Sea Based JPALS-Air shall be consistent with the environmental requirements of the host platform.

Sea Based JPALS-Air shall meet all requirements of this specification in the presence of precipitation in the amount of 16 mm/hr in a 5 nm wide rain cell without signal degradation below precision landing system parameters/minima.

Sea Based JPALS-Air shall meet the requirements of section 3.2.1.1 for basic and CCA modes, when the aircraft is operating at speeds up to 550 knots true airspeed (KTAS), at sustained coordinated turns of up to 60 deg angle of bank, at climb rates between ± 6,000 feet per minute (fpm), and at a maximum acceleration of ± 2g (TBR).

Sea Based JPALS-Air shall meet the requirements of section 3.2.1.1 for Precision Mode when the aircraft is operating at speeds up to 250 KTAS, at sustained coordinated turns of up to 30 deg angle of bank, at climb rates between ± 1800 fpm, and at a maximum acceleration of ± 2g (TBR).

Note 1: Additional requirements will be added to bound the maximum expected jerk (TBR).

Note 2: Additional requirements will be added to indicate the dynamic environment Sea Based JPALS-Air must continue to operate in, though not necessarily meet the performance requirements during exposure (TBR).

Note 3: An abnormal maneuver requirement will not be included.

3.2.5.1 Electromagnetic Compatibility

Electromagnetic Compatibility requirements are contained in the *JPALS Aircraft Integration Guide* [6].

3.2.5.2 Interference Environment

Note: These requirements are only representative of the type of requirements that will be specified using the civil GPS example. When completed for Sea Based JPALS PPS applications, many of these requirements may necessitate a classified appendix.

3.2.5.2.1 Out-of-Band Continuous Wave Interference

The GPS receiver shall meet all requirements with out-of-band continuous wave (CW) interfering signals resulting in the jammer power to signal power ratio (J/S) levels below. The requirement shall be met with at any level below straight lines drawn between the following points:

1525 MHz, +92.5 dB J/S

1618 MHz, +94.5 dB J/S

1315 MHz, +110 dB J/S

2000 MHz, 106 dB J/S

+/-20 MHz of L1; +25 dB J/S

+/- 10 MHz, of L2; +14 dB J/S.

Note: TBR pending further identification of the airborne interference environment.

3.2.5.2.2 Out-of-Band Pulse Interference

The GPS receiver shall meet all requirements in the presence of Out-of-Band Pulse Interference of amplitude:Peak Pulse Power: +20 dBm, Pulse Width: 1 ms, Pulse Duty Cycle10%, at frequencies of 1525 MHz, 1618 MHz, 1315 MHz, 2000 MHz, +/- 20 MHz of L1, and +/- 10 MHz of L2.

Note: TBR pending further identification of the airborne interference environment.

3.2.5.2.3 In-Band and Near-Band Interference

The GPS receiver system shall meet all requirements with the in-band and near-band interference level of 14 dB J/S for 0 $\leq$ Bandwidth Interference (BW_I) $\leq$ 700 Hz.

The GPS receiver system shall meet all requirements with an in-band and near-band interference level of 15 dB J/S + 6 log10(BW_I/1000) for 700 Hz $< BW_I \leq$ 10 KHz.

The GPS receiver system shall meet all requirements with the in-band and near-band interference level of 21 dB J/S +3 log10(BW_I/10000) for 10 KHz $< BW_I \leq$ 100 KHz.

The GPS receiver system shall meet all requirements with the in-band and near-band interference level of 24 dB J/S for 100 KHz $< BW_I \leq$ 1 MHz.

The GPS receiver system shall meet all requirements with the in-band and near-band interference level linearly increasing from +24 dB to 37 dB J/S* for 1 MHz $< BW_I \leq$ 20 MHz.

The GPS receiver system shall meet all requirements with the in-band and near-band interference level linearly increasing from +37 J/S -43 dB J/S* for 20 MHz $< BW_I \leq$ 30 MHz.

The GPS receiver system shall meet all requirements with the in-band and near-band interference level Linearly increasing from 43 dB J/S to 45 dB J/S* for 30 MHz $< BW_I \leq$ 40 MHz.

The GPS receiver system shall meet all requirements with the in-band and near-band interference level of 45 dB J/S* for BW_I greater than 40 MHz.

*Interference levels will not exceed 24 dB J/S/MHz in the frequency range of 1575.42 ± 10 MHz.

3.2.5.2.4 In-Band and Near-Band Pulse Interference

The GPS receiver system shall meet all requirements in the presence of In-Band and Near-Band Pulse Interference of amplitude: Peak Pulse Power: +20 dBm, Pulse Width: 1 ms, Pulse Duty Cycle10%, at frequencies from 1525 MHz to 1618 MHz. The signal bandwidths are specified to be at least 100 kHz.

Note: TBR pending further identification of the airborne interference environment.

3.2.5.3 Equipment Burnout Protection

Sea Based JPALS equipment shall withstand, without damage, an in-band CW signal of +20 dBm input to the preamplifier (at the receiver port or antenna port, as applicable).

3.2.6 Transportability

NA

3.3 Design and Construction

NA

3.3.1 Materials, Processes, and Parts

3.3.1.1 Design, Construction, and Workmanship

NA

3.3.1.2 Design Assurance

Sea Based JPALS-Air will be designed and developed so that the probability of providing misleading information and the probability of loss of function are acceptable based on the system integrity and continuity requirements, respectively. In order to demonstrate compliance, it will be necessary to conduct a safety assessment to evaluate the system implementation against known failure conditions.

Note: Unannunciated and unmitigated failure conditions of Sea Based JPALS-Air that cause out-of-tolerance error conditions during any operation can be classified as severe/hazardous major. Failure conditions of Sea Based JPALS-Air which cause an aborted approach, can be classified as severe/hazardous major.

3.3.1.2.1 Software Design Assurance

The software will be developed in a manner to support system integrity and continuity requirements.

Note: An acceptable means to demonstrate integrity and continuity compliance for Sea Based JPALS is to develop all software using established development processes that are compliant with known industry standards.

3.3.1.2.2 Hardware Design Assurance

The hardware will be developed in a manner to support system integrity and continuity requirements.

All new Sea Based JPALS-Air complex electronic hardware devices including, but not limited to, Application Specific Integrated Circuits (ASICs) and Programmable Logic Devices (PLDs), shall be produced with structured development, verification, configuration management, and quality assurance processes.

The level of production process rigor associated with electronic hardware shall be based on the contribution of the hardware to potential failure conditions as determined by the System Safety Assessment (SSA) process.

Note 1: An acceptable means to demonstrate integrity compliance for Sea Based JPALS is to show that no failure of the equipment can result in misleading information. This may be accomplished by designing the hardware in accordance with known industry standards.

Note 2: Demonstration of compliance with the continuity requirements depends on the required probability of a detected failure. The required probability will depend on the level of redundancy. Hardware design assessment must consider the Mean Time Between Failures (MTBF) of the equipment as well as the independence of failure modes for redundant equipment.

3.3.1.3 Product Marking

NA

3.3.2 Interchangeability / Modularity

NA

3.3.3 Safety

NA

3.3.4 Human Factors

Except for use of pre-existing displays, any aircraft or ship visual display, readout, or operator message shall be compatible with the applicable night vision system.

User interface commands shall be designed to minimize operator performance errors and preclude operator errors on critical tasks through the use of error checking user validation, or other methods.

3.3.5 System Security

(TBD)

3.3.6 Computer Resource Reserve Requirements

Sea Based JPALS avionics shall have TBR spare memory, multiplex bus throughput, computation time, and other growth capability to meet future growth requirements.

3.4 Logistics

All new technical manuals, electronic technical manuals, and interactive electronic technical manuals shall be acquired in Extendable Markup Language format.

3.5 Personnel and Training

3.5.1 Personnel

Sea Based JPALS-Air will be designed so that operation and maintenance of Sea Based JPALS-Air shall not increase current DoD Service manpower authorizations or required skill levels.

3.5.2 Training

Sea Based JPALS-Air should be designed to minimize unique pilot training requirements.

3.6 Documentation

At a minimum, the following documentation will be developed for Sea Based JPALS-Air:

- Test plans and reports for qualification, flight, and production tests and evaluation.

4 Quality Assurance and Verification Requirements

This section will define and describes the activities that ensure the system requirements are satisfied. It will ensure that the requirements of section 3 are satisfied. The following requirements may be included in this section:

Responsibility for inspection-The assignment of the responsibility to perform inspections on delivered products, materials, or services to determine compliance with all specified requirements

Special tests/examinations-Special tests and examinations required for sampling, qualification evaluation, or other tests or examinations, as necessary

Requirements cross-reference-The correlation of each system requirement stated in sections 3 to the quality assurance provisions specified in this section.

4.1 Verification Strategy

4.1.1 Responsibilities

TBR

4.1.2 Special Tests and Examinations

4.1.2.1 Development Test

Development test activities shall be conducted to verify that the implemented hardware and software design meets the functional and performance requirements of Sea Based JPALS-Air specification. Specific tests for verification are not conveyed, but normally include the verification of software and hardware requirements, stability and dry running, and system level testing.

4.1.2.2 Production Acceptance Test

Production Acceptance Test (PAT) shall be performed on each end-item before it leaves the factory to verify that the end-item conforms to applicable requirements, is free from manufacturing defects, and is substantially identical to the qualified system.

4.1.2.3 Site Acceptance Test

Site Acceptance Test (SAT) is conducted after completion of hardware installation and checkout and the installation has been inspected and approved for workmanship and configuration. SAT is accomplished initially for the developmental system, and is repeated for each production system after PAT. Testing shall be performed at each field site to verify that the new system is installed and operating properly on site.

4.2 Verification Methods

4.2.1 Inspection

Inspection is a method of verification to determine compliance with specification requirements and consist primarily of visual observations, mechanical measurements of the equipment, physical locations, and technical examination of engineering-supported documentation.

4.2.2 Analysis

Analysis is a method of verification that consists of comparing hardware or software design with known scientific and technical principles, technical data, or procedures and practices to validate that the proposed design will meet the specified functional and performance requirements. Analysis may also include the use of modeling and simulation.

4.2.3 Demonstration

Demonstration is a method of verification where qualitative versus quantitative validation of a requirement is made during a dynamic test of the equipment. Demonstration activities are further characterized by the following:

1. If a requirement is validated by test during first article qualification testing and the requirement has enough significance that it is re-tested during acceptance test, then this acceptance testing can be indicated in the matrix as a Demonstration.,

2. Software functional requirements are validated by demonstration since the functionality must be observed through secondary media.

4.2.4 Test

Test is a method of verification that will measure equipment performance under specific configuration-load conditions and after the controlled application of known stimuli. Quantitative values are measured, compared against previous predicted success criteria, and evaluated to determine the degree of compliance.

4.2.5 Qualification by Similarity

Qualification by similarity consists of the review of certified/approved test data in conjunction with design evaluation data to substantiate the following:

1. A similar item of equipment has been previously qualified to the requirements of this specification, or a higher level, and;

2. The new item does not incorporate differences that would invalidate this criteria.

4.3 Requirements Traceability

Note: To be provided in a future revision (TBR).

5 Terms and Acronyms

5.1 Terms

The following terms are used throughout this document:

Term	Definition
Accuracy	The degree of conformance between the estimated or measured quantity and its true position and/or velocity.
Availability	The ability of the Sea Based JPALS system to perform its function at the initiation of the intended operation.
Base Recovery Course	The ship's magnetic heading during flight operations.
Cant Offset Angle	The difference between the final bearing and the base recovery course.
Continuity	The ability of the total system to perform its intended function without interruption during the intended operation.
Modified Cooper-Harper Rating	A uni-dimensional rating scale used to assess pilot workload qualities. It allows pilots to rate aircraft handling qualities on a numerical scale.
Failure	An event, either software or hardware, inherent or inducted, or combination of events that prevents or degrades an item from performing a specified mission while in an operational environment.
Final Bearing	The magnetic bearing assigned by CATCC for final approach. It is an extension of the landing area centerline.
Integrity	Integrity is the assurance that all functions of a system perform within operational performance limits, and its ability to provide timely warnings to users when the system should not be used for navigation.
Interoperable	One system's ability to seamlessly communicate/interface with another system.
Latency	Latency, for cases in which compensation is not used, is the time difference between the time of measurement and the time it is reported at the function output (the latter minus the former). For cases in which compensation is used, latency is the difference between the time of applicability and the time the information is reported at the function output (the latter minus the former). Latency includes the total time differences, whether it is constant with time or variable, and whether it is known by the application or uncertain.
Maintenance	All actions necessary for retaining an item in or restoring it to specified condition.
Marshal	A bearing, distance, and altitude fix designated by CATCC from which pilots will orient holding and from which initial approach will commence.

Mission Reliability (R_m)	The probability that the system is operable and capable of performing its required function for a stated mission duration or at a specified time into the mission. R_m is based on the effects of system reliability during mission time only. R_m does not take into account system maintainability. $R_m = e^{-(t/MTBCF)}$.
Nautical Mile	A unit of distance used principally in navigation. The International Nautical Mile is 1,852 meters long.
Navigation Sensor Error	Navigation Sensor Error that results from the residual composite errors from both the ground subsystem and airborne receiver after correcting the ranging source used to calculate deviations (The difference between the actual position of the airplane and the position fix provided by the navigation system).
Operational (Ao) Availability	The probability that a system or equipment, when used under stated conditions in an actual operational environment, will operate satisfactorily when called upon.
Reliability	The probability that a system will operate within the specified tolerances.
Scheduled maintenance	A series of planned inspection, detection, service and/or hardware replacement actions performed at a prescribed point in the item's life in an attempt to retain it in a specified condition and prevent an unacceptable condition from occurring.

5.2 Acronyms

The following abbreviations, acronyms, and mnemonics are used throughout this document:

Acronym	Description
ACLS	Automatic Carrier Landing System
AGL	Above Ground Level
A/J	Anti-Jam
AL	Auto Land
ATC	Air Traffic Control
Ao	Operational Availability
ASICS	Application Specific Integrated Circuits
ATC	Air Traffic Control
ATM	Air Traffic Management
BIT	Built-In-Test
BITE	Built-In-Test Equipment
BRC	Base Recovery Course
BW	Bandwidth
BW_I	Bandwidth Interference
C/A	Coarse Acquisition
CBM	Condition Based Monitoring
CCA	Carrier Control Area
CDD	Capability Development Document

cm	Centimeters
COM	Center of Motion
COMSEC	Communication Security
CONOPS	Concept of Operations
CRC	Cycle Redundancy Check
CV/CVN	Aircraft Carrier / Aircraft Carrier Nuclear
CW	Continuous Wave
DA	Decision Altitude
deg/sec	Degrees per Second
dB	Decibel
dBm	Decibel referenced to one milliwatt
dBW	Decibel referenced to one watt
Deg	Degrees
DFT	Distance From Touchdown
DL	Data Link
DMC	Deck Motion Compensation
DoD	Department of Defense
EAT	Expected Approach Time
ECEF	Earth Centered, Earth Fixed
EMCON	Emissions Control
EPU	Estimate of Position Uncertainty
FB	Final Bearing
FFD	Fraction of Failures Detected
FPM	Feet Per Minute
FPS	Feet Per Second
FSD	Full-Scale Deflection
g	Gravity
GCP	Guidance Control Point
GHz	Gigahertz
GPS	Global Positioning System
HAT	Height Above Touchdown
HPL	Horizontal Protection Level
HQR	Handling Qualities Rating
Hz	Hertz
ICD	Interface Control Document
ID	Identification
INFOSEC	Information Security
INS	Interial Navigation System
IOD	Issue of Data
IODC	Issue of Data Clock

IODE	Issue of Data Ephemeris
JPALS	Joint Precision Approach and Landing System
J/S	Jammer Power to Signal Power Ratio
JTA	Joint Technical Architecture
J-UCAS	Joint Unmanned Combat Air System
k-lbs	Thousands of Pounds
KCPT	Kinematic Carrier-Phase Tracking
kHz	Kilohertz
KTAS	Knots True Airspeed
LNA	Low Noise Amplifier
LPL	Lateral Protection Level
LRP	Landing Reference Point
LRU	Line Replaceable Unit
m/s	Meters per Second
m	Meters
MCEB	Military Communications-Electronics Board
MCS	Mission Control System
MCS	Mission Control Station
MER	Message Error Rate
ms	Millisecond
MTBF	Mean Time Between Failures
MULAL	Maximum Uplinked Lateral Alert Limit
MUVAL	Maximum Uplinked Vertical Alert Limi
NATO	North Atlantic Treaty Organization
NAVSTAR	Navigation Satellite Timing and Ranging
NED	North, East, Down
NGA	National Geospatial-Intelligence Agency
nm	Nautical Mile
NPA	Non-Precision Approach
ns	Nanosecond
NUC	Navigation Uncertainty Category
NUCR	Navigation Uncertainty Category Rate
ORD	Operational Requirements Document
PA	Precision Approach
PAR	Precision Approach Region
PAT	Production Acceptance Test
PDE	Path Definition Error
PHM	Predictive Health and Maintenance
PIM	Position and Intended Movement
PIO	Pilot-induced Oscillation

PLDs	Programmable Logic Devices
PPS	Precise Positioning Service
PRS	Precision Relative State
PVAT	Position, Velocity, Acceleration, Time
PVT	Position, Velocity, Time
P(Y)	GPS Precision Code
RF	Radio Frequency
RMS	Root-Mean-Square
RN	Relative Navigation
RNAV	Area Navigation
RPM	Revolutions Per Minute
R/T	Receive-to-Transmit
RTF	Return to Force
SA	Selective Availability
SAT	Site Acceptance Test
SIS	Signal-in-Space
SMS	Ship Motion Sensor
SOE	Shipboard Operating Environment
SPL	Sea Based JPALS Performance Level
SPS	Standard Positioning Service
SRD	System Requirements Document
SRGPS	Sea Based JPALS
SRP	Ship Reference Position
SSA	System Safety Assessment
STOVL	Short Takeoff Vertical Landing
SV	Satellite Vehicle
TACAN	Tactical Air Navigation
TBD	To Be Determined
TBP	To Be Provided
TBR	To Be Reviewed
TBS	To Be Supplied
TD	Technology Development
TDMA	Time Division Multiple Access
TDP	Touchdown Point
TOA	Time of Applicability
TOD	Time of day
T/R	Transmit-to-Receive
TRANSEC	Transmission Security
TTFF	Time To First Fix
TTG	Time-To-Go

TTSF	Time To Subsequent Fix
TSN	Time Slot Number
ULAL	Uplinked Lateral Alert Limit
UTC	Coordinated Universal Time
UVAL	Uplinked Vertical Alert Limit
VAL	Vertical Alert Limit
VPL	Vertical Protection Level
VTOL	Vertical Takeoff and Landing
WGS-84	World Geodetic System 1984
WOD	Wind Over Deck

6 Interface Definition

6.1 External Interface Data Definition

6.1.1 Absolute Aircraft State

Data	Input	Output	Definition
Position (Earth Centered Earth Fixed (ECEF)) x, y, z coordinates		X	
Velocity (ECEF) x, y, z coordinates		X	
Acceleration (ECEF) x, y, z coordinates		X	

6.1.2 Aircraft Approach Profile Changes

Data	Input	Output	Definition
Approach Centerline Angle	X	X	Changes made by the aircrew or unmanned aircraft to these approach profile parameters must be made available to the ship's personnel.
Glideslope	X	X	
TDP	X	X	

6.1.3 Aircraft Configuration

Data	Input	Output	Definition
Autopilot Engage	X	X	
Flaps/Slats	X	X	
Hook Position	X	X	
Launch Bar Command and Status	X	X	
Landing Gear Position	X	X	
Parking Brake Engage	X	X	
Weight on Wheels	X	X	
Wing Fold	X	X	

6.1.4 Aircraft Geometry

Data	Input	Output	Definition
LRP Geometry	X		Defines LRP with respect to the aircraft GCP (e.g., GCP to Hook offset).
LRP Correction	X		Correction for LRP Geometry of specific aircraft at specific ship based on certification.

6.1.5 Aircraft ID

Data	Input	Output	Definition
Tail Number	X	X	

6.1.6 Aircraft Maintenance Data

Data	Input	Output	Definition
PHM Data	X	X	
Maintenance Codes	X	X	

6.1.7 Aircraft Status

Data	Input	Output	Definition
Air Data - Airspeed	X	X	
Air Data - Angle of Attack	X	X	
Air Data - Barometric Altimeter	X	X	
Air Data - Sideslip	X	X	
Attitude Data - heading and Heading Rate	X	X	
Attitude Data - Pitch and Pitch Rate	X	X	
Attitude Data - Roll and Roll rate	X	X	
Direct Lift Control Status	X	X	
EAT	X	X	
Malfunction and Priority Status	X	X	1=No malfunction / Not reported, 2 =Hydraulic, 3=Electric, 4=Fuel, 5 =Oxygen, 6=Engine, 7 =Communications, 8=NAVAIDS, 9 =Other
Engine Data - Autothrottle Engage	X	X	
Engine Data - Engine Speed	X	X	In Percent
Engine Data - Engine Throttle Position	X	X	In Percent
Engine Data - Jet Pipe Temperature	X	X	
Engine Data - Nozzle / Nacelle Position	X	X	
Estimated Weight	X	X	
Fuel State	X	X	

Ordnace Loadout Code	X	X	

6.1.8 ATM Broadcast Data

Data	Input	Output	Definition
ATM Broadcast Data	X	X	Defined in CONOPS [7]

6.1.9 ATM Downlink Messages

Data	Input	Output	Definition
ATM Downlink Messages	X	X	Defined in CONOPS [7]

6.1.10 ATM Uplink Messages

Data	Input	Output	Definition
ATM Uplink Messages	X	X	Defined in CONOPS [7]

6.1.11 Environmental

Data	Input	Output	Definition
Ceiling	X	X	
Relative Humidity	X	X	
Sea State	X	X	
Visibility	X	X	

6.1.12 GPS Space Segment

Data	Input	Output	Definition
GPS Ranging Signals and Navigation Data	X		Per ICD-GPS-200C

6.1.13 Guidance Data

Data	Input	Output	Definition
Bearing to Navigation Point		X	
Commanded Path		X	
DMC Data - TDP Instantaneous Position		X	All DMC measurements are relative to the average TDP in the vertical, longitudinal, and lateral directions (designated heave, surge, and sway).
DMC Data - TDP Instantaneous Velocity		X	
DMC Data - TDP Instantaneous Acceleration		X	
Guidance protection Level		X	

Path Deviation Data - Deviation		X	Angular and rectilinear lateral deviations and angular and rectilinear vertical deviations from the defined path.
Path Deviation Data - Deviation Rate		X	Angular and rectilinear lateral deviation rate and angular and rectilinear vertical deviation rate from the defined path (precision operations only).
Path Deviation Data - Deviation Acceleration		X	Angular and rectilinear lateral deviation acceleration and angular and rectilinear vertical deviation acceleration from the defined path (precision operations only).
Range Along Commanded Path		X	
Range Rate Along Commanded Path		X	
TTG		X	
TOA		X	

6.1.14 INS Alignment Data

Data	Input	Output	Definition
East Velocity	X	X	Pass-through data from the Ship's INS for purposes of aligning the aircraft's INS that is available prior to departure from the ship.
East Acceleration	X	X	
Latitude and Longitude	X	X	
North Velocity	X	X	
North Acceleration	X	X	
Pitch, Pitch Rate, and Pitch Acceleration	X	X	
Roll, Roll Rate, and Roll Acceleration	X	X	
TOA	X	X	
True Heading	X	X	
Vertical Lever Arm	X	X	

6.1.15 J-UCAS Downlink Messages

Data	Input	Output	Definition
J-UCAS Downlink Messages	X	X	Vendor Defined

6.1.16 J-UCAS Downlink Messages

Data	Input	Output	Definition

J-UCAS Downlink Messages	X	X	Vendor Defined

6.1.17 Network Parameters

Data	Input	Output	Definition
Channel ID	X		Commanded communication frequency
Ship ID	X	X	ID of ship establishing network
Target Ship ID	X		Ship ID as input from aircraft for selecting desired network or channel

6.1.18 Path Definition Data

Data	Input	Output	Definition
Altitude	X		
Approach Angle / Centerline Angle	X		Horizontal path to offset approach reference point or TDP
Approach Type	X		
BRC	X		
Cant Offset Angle	X		
Decision Altitude (DA)	X		
Glideslope	X		
Leg Type	X		
Operation ID	X		Input that identifies the current operation to Sea Based JPALS
Speed	X		
TDP	X		
Waypoint Position	X		Defined in North, East, Down (NED) for ship relative and geodetic frame for absolute.
Waypoint Type	X		Relative or absolute

6.1.19 Relative State Data

Data	Input	Output	Definition
Navigation State Data - Position		X	Relative vector defined in NED between the ship reference point and the aircraft GPS antenna.
Navigation State Data - Velocity		X	
Navigation State Data - Acceleration		X	Precision Relative State output only.
Navigation Status - Decision Altitude Indication		X	Indication when the aircraft is at the DA for the assigned approach type (precision only).
Navigation Status - Protection Levels		X	Indication of the estimated error in the state information provided by Sea Based JPALS.

NUC		X	
NUCR		X	
Position Data - Magnetic Bearing to Ship		X	
Position Data - Range to Ship		X	Distance from aircraft reference point to ship reference point
TOA		X	

6.1.20 Ship Geometry

Data	Input	Output	Definition
Cant Offset Angle	X		
CM to GPS Geometry	X		
CM to SMS Geometry	X		
CM to TDP Geometry	X		

6.1.21 Ship Status Data

Data	Input	Output	Definition
Ship Magnetic Variation	X	X	
PIM	X	X	
PIM TOA	X	X	
Ship Position		X	Latitude and Longitude
Ship True Heading		X	

6.1.22 Ship Wind Over Deck

Data	Input	Output	Definition
WOD Direction	X	X	
WOD Magnitude	X	X	

6.1.23 Status and Alerts

Data	Input	Output	Definition
Status and Alerts		X	

6.2 Internal Interface Data Definition

6.2.1 Relative State Function to Guidance Function

Data	Definition
TOA	
Relative Position	
X Position - GCP relative to SRP	

Y Position - GCP relative to SRP	
Z Position - GCP relative to SRP	
Range	
Bearing	
Protection Level	

6.2.2 Relative State Function to Monitor Function

Data	Definition
TOA	
Relative Position	
X Position - GCP relative to SRP	
Y Position - GCP relative to SRP	
Z Position - GCP relative to SRP	
Navigation Uncertainty Position	
Navigation Uncertainty Velocity	

6.2.3 Guidance Function to Monitor Function

Data	Definition
Relative State	
X Position - GCP relative to SRP	
Y Position - GCP relative to SRP	
Z Position - GCP relative to SRP	
X Velocity - GCP relative to SRP	
Y Velocity - GCP relative to SRP	
Z Velocity - GCP relative to SRP	
X Acceleration - GCP relative to SRP	
Y Acceleration - GCP relative to SRP	
Z Acceleration - GCP relative to SRP	

7 Example Of Acceptable KCPT Algorithm

7.1 Airborne GPS Widelane Observables

NOTE: The material in this appendix may be moved to the Aircraft System Segment Design Document when that document is developed and released.

Shipboard GPS Widelane Measurements

The following data are formed by Sea Based JPALS-Ship from shipboard GPS observables and received via data link, for each ranging source in view:

T - time (in seconds of week)

$PR_{WL,ship}$ - widelane shipboard pseudorange measurements

$CP_{WL,ship}$ - widelane shipboard carrier phase measurements

$CS_{WL,ship}$ - sum of shipboard cycle slips for L1 and L2

The airborne GPS observables identified in section TBR above are used to compute the following airborne widelane measurements:

$$PR_{WL,air} = \left(\frac{\lambda_{L2}}{\lambda_{L2} + \lambda_{L1}}\right) PR_{L1,air} + \left(\frac{\lambda_{L1}}{\lambda_{L2} + \lambda_{L1}}\right) PR_{L2,air} \quad \textbf{(23)}$$

$$CS_{WL,air} = CS_{L1,\ air} + CS_{L2,\ air} \quad \textbf{(24)}$$

where

$PR_{WL,air}$ - widelane airborne pseudorange measurements

$CP_{WL,air}$ - widelane airborne carrier phase measurements