Agenda

- DGPS Overview
- Land-Based JPALS Capabilities (Aircraft Perspective)
- Interoperability and the AIG
- Land-Based JPALS Aircraft System
- GPS, Data Link & Processor Subsystems
- Air Force Lead Platform
- Avionics Risk Reduction
DGPS System Overview

**GPS Satellites**

- Aircraft with DGPS Airborne System
  
  1. Airborne GPS receiver applies accuracy & integrity data from ground station data broadcast
  2. DGPS position is compared to approach path defined by ground station broadcast
  3. Lateral/vertical guidance deviations are generated

- DGPS Ground Station
  
  1. Ground station generates differential corrections
  2. Integrity of GPS satellite signals is continuously monitored
  3. Approach Path data is stored and provided to the aircraft
Land-Based Capabilities

- Civil GBAS defined in ICAO SARPS Annex 10 and RTCA MOPS (DO-253C) and ICD (DO-246D)
  - Uses C/A-code (L1) only
  - Processing algorithms, inputs/outputs
  - VHF Data Broadcast (VDB) structure and data content
- Military GBAS will be defined by Land-Based JPALS contractor in an Interface Control Document (ICD)
  - Uses P(Y)-code (most likely dual frequency)
  - Processing algorithms, inputs/outputs
  - Encrypted UHF data link structure defined in SRD
  - Data content defined in ICD
- Ship Relative Navigation will be defined by JPALS Increment 1A
  - Range and Bearing to the Ship using GMSK-25 Data Link
- Civil SBAS “Beta 3” Sensor
  - Supports “en-route, LPV and LPV-200” capabilities
**JPALS Interoperability**

- **Military Aircraft** (Sea-Based JPALS capable)
- **Military Aircraft** (Land-Based JPALS capable)
- **Civil Aircraft** (GBAS capable)

**JPALS equipped Ship**
- Military Aircraft (Sea-Based JPALS capable)
- Military Aircraft (Land-Based JPALS capable)

**Civil Aircraft with GBAS Ground System**
- Civil Aircraft (GBAS capable)

**Military Airport with JPALS Ground System**
- Military Aircraft (Land-Based JPALS capable)
- Civil Aircraft (GBAS capable)

**UHF encrypted, 1.2 MHz GMSK, P(Y)-code shipboard relative corrections and surveillance data**

**UHF encrypted, 25 kHz D8PSK, P(Y)-code corrections**

**VHF unencrypted, 25 kHz D8PSK, C/A-code corrections per ICAO SARPS**

- JPALS Interoperability
- Military Aircraft (Sea-Based JPALS capable)
- Military Aircraft (Land-Based JPALS capable)
- Civil Aircraft (GBAS capable)

**JPALS equipped Ship**
- Military Aircraft (Sea-Based JPALS capable)
- Military Aircraft (Land-Based JPALS capable)

**Military Airport with JPALS Ground System**
- Military Aircraft (Land-Based JPALS capable)
- Civil Aircraft (GBAS capable)

**Civil Airport with GBAS Ground System**
- Civil Aircraft (GBAS capable)
Aircraft Integration Guide Concept

- Aircraft System design flexibility extremely important
  - Large variation in aircraft architectures and mission requirements
  - Federated & integrated implementations on the aircraft possible
  - Aircraft platforms dictate level of performance “desired” in GPS threat environment; will drive aircraft GPS receiver and anti-jam technology
Aircraft System

- Aircraft System will consist of:
  - C/A and P(Y) capable GPS Receiver(s) with antenna (possibly AJ capable)
  - Data Link Receivers (UHF and VHF)
  - Navigation Processor for civil mode and military mode processing of differential GPS corrections, integrity monitoring and approach path generation

- Aircraft System Cockpit Interfaces
  - Integration with Primary Flight Displays (PFD), same display as ILS
  - Integration with Tuning Controls, same five digit entry and mode select as ILS
  - Integration with Autopilot, same autopilot input scaling as ILS
  - Integration with Warning and Caution System, same as ILS
AS Functional Block Diagram

GPS Subsystem

- GPS Antenna
- Antenna Electronics
- Beta 3 SBAS C/A & P(Y) GPS Receiver

Processor Subsystem

- Control and Display Interfaces

Civil Data Link Subsystem

- VDB Data Link Receiver
- VHF Data Link Antenna

Military Data Link Subsystem

- UDB Data Link Receiver
- UHF Data Link Antenna
- GMSK-25 Data Link Receiver

Aircraft System Software Functions

- C/A-code Measurement Processing
- C/A-code Navigation Solution
- C/A-code Integrity
- P(Y)-code Measurement Processing
- P(Y)-code Navigation Solution
- P(Y)-code Integrity
- P(Y)-code RFI Characterization
- P(Y)-code Emerg. Threat Detection
- Ship Rel Nav SS-200 Processing
- Approach Path Guidance
- Control & Status Software

(Civil GBAS) (Military GBAS) (Ship Rel Nav) (Common)
Aircraft Architecture Overview

**Processor Subsystem**

- **GPS Subsystem**
  - GPS Antenna
  - Antenna Electronics
  - Beta 3 SBAS C/A & P(Y) GPS Receiver

- **Civil Functions**
  - VHF Data Link Antenna
  - VDB Data Link Receiver

- **Military Unique Functions**
  - UHF Data Link Antenna
  - UDB Data Link Receiver
  - GMSK-25 Data Link Receiver

- **Aircraft Control Interface**
- **Aircraft Guidance Interface**

**XOR**
Outputs GPS pseudorange, carrier phase measurements, and navigation message data

GPS Antenna

Tracks C/A and P(Y)-code signals from multiple GPS satellites

GPS Receiver

Hardware/Software Dependent On Desired GPS Anti-Jam Capability
GPS Subsystem Details

Four possible configurations (Each with increasing Anti-Jam capability)

- **FRPA Antenna**
  - RF (L1 and/or L2)
  - Multi-channel P(Y)-code Receiver

- **CRPA Antenna**
  - RF (L1 and/or L2)
  - Analog Nulling AE
  - Multi-channel P(Y)-code Receiver

- **CRPA Antenna**
  - RF (L1 and/or L2)
  - Digital Nulling AE
  - Multi-channel P(Y)-code Receiver

- **CRPA Antenna**
  - RF (L1 and/or L2)
  - Digital Nulling & Beamsteering AE
  - Multi-channel P(Y)-code Receiver

**OR**

- **CRPA Antenna**
  - RF (L1 and L2)
  - Multi-channel P(Y)-code Receiver with integrated Digital Nulling and Beamsteering AE

Receivers with Integrated Digital Nulling and Beamsteering AE

- **Raytheon DAR**
- **Rockwell Collins DIGAR**
- **Lockheed Martin G-STAR**
Data Link Subsystem Details

- VHF antenna and civil data link receiver needed to decode VDB uplink data – Defined in RTCA DO-246D
- UHF antenna and military mode data link receiver needed to decrypt and decode UHF uplink data
  - Data link physical structure (modulation, bandwidth, encryption, etc.) defined in Land-Based JPALS System Requirements Document (FY11)
  - Data link data content defined by Land-Based JPALS contractor (FY14)

VHF and/or UHF Data Link Antenna

UDB, GMSK-25, and/or VDB Data Link Receiver

Military and/or Civil Data Link Subsystem

GPS Corrections, Integrity Data and Approach Path Data

Honeywell H764 EGI with MMR

BAE MMR-2055

Raytheon ARC-231

Rockwell Collins ARC-210

HPOL VHF Rx Antenna

VPOL VHF Rx Antenna

VPOL UHF Rx Antenna
Processor Subsystem Details

- Aircrew mode and channel selection inputs
- Generates lateral/vertical deviations and range-to-go guidance
- GPS Corrections, Integrity Data and Approach Path Data
- GPS pseudorange, carrier phase measurements, and navigation message data
- Calculates differentially corrected position solution
- Performs integrity monitoring and generates alerts
- Formats precision approach path data
- Does NOT interact with aircraft aeronautical database
Air Force Lead Platform

- HQ USAF A3/5 (Gen Breedlove) message to AMC/ACC/AETC to nominate primary and alternate lead platforms for JPALS
  - AMC – C-130J as primary, C-27J as alternate
  - ACC – F-35 as primary, no alternate
  - AETC – T-1 as primary, T-6 as alternate

- Evaluated based on accommodation of JPALS in existing avionics architecture by ESC
  - Recommendation was C-130J as JPALS Lead Platform
  - Coordinated with AMC, ASC and ANG by AF A3O-B
  - A3O-B has the action to send the package forward for A3/5 signature

- TIMs with Lockheed Martin Aerospace and ASC/WLNNA (C-130J) indicated a study is required to select between an MMR or EGI based architecture

- Discussions with platforms indicate a preference for “one box solutions” versus a federated approach
  - “one box solutions” can save integration costs
Avionics Risk Reduction (BAE)

- BAE Systems Precision Landing Systems Receiver (PLSR)
  - Promising solution that could be used by all Services for Land-Based applications
  - Technology shared with other BAE products such as Army Doppler GNS
  - Existing Avionics on:
    - C-17
    - F-16 Block 50/55/60 (Int’l)
    - P-3C
    - B-52
    - E-2D
  - Work Plan - Prototype a UHF radio capability and a C/A and P(Y) Code GPS Receiver for the PLSR. Perform trade studies to assess establishing a full Land-Based JPALS Aircraft System capability within the PLSR.
  - Goal – Achieve a laboratory test of the prototype JPALS PLSR. Complete trade studies and analysis that identify the gaps for closure to fully integrate a Land-Based JPALS Aircraft System within the PLSR.
• Northrop Grumman Radio Systems UDB Demonstration

• Work Plan
  • Porting the JSF UDB software waveform to NGRS Software Defined Tactical Radio (SDTR)
  • 2 SDTRs used for end-to-end link demonstration to include threat analysis

• Contract option for flight demonstration

• Looking at flight demonstration with SDTR on ground and BAE MMR in the air

• Pathfinder towards JTRS implementation

• Goal – Gather data to ensure UDB will meet Land-Based JPALS Increment 2 requirements. Supports finalizing the LB JPALS System Requirements Document.
Avionics Risk Reduction (HI)

- Honeywell - Embedded GPS/INS (H-764) with MMR Top-Hat
- JPALS Army Risk Reduction (JARR) effort preceded the JCATD
  - Established MMR Prototype – VHF Data Broadcast (VDB - LAAS) System Engineering
- Army JPALS Common Avionics Technology Development (JCATD)
  - Architecture Description to Standardize the EGI+JPALS to Single Configuration feasibility analysis
  - MMR Prototype – Distance Measuring Equipment (DME) System Engineering
  - MMR Prototype – Sea Based and Land Based UHF Crypto System Engineering
  - Evaluate SBAS (WAAS) Capability IAW MSO-C145
  - M-Code GPS Receiver JPALS Requirements Definition
  - SAS A/J GPS Antenna AoA and Flight Testing
  - JPALS Data link ARC-231 Implementation Assessment
  - JPALS EGI Navigation Error Budget
  - Continuation of SRGPS AIG Support
Avionics Risk Reduction (Government)

- Joint Service JPALS Aircraft Integration Working Group (AIWG)
- Meet several times a year (attempt is for quarterly meetings) to:
  - Review Avionics risk reduction activities
  - Coordinate development of platform integration estimates
  - Examine Lead Platform schedules and technical solutions
  - Discuss Test Program platform support
  - Discuss avionics and aircraft integration related risks
- Participants
  - Principals
    - ESC/HBA
    - PMA 213
    - PM AME
  - Invited Participants
    - C-130J
    - AFRL
    - PMA-209
Summary

- Land-Based JPALS is not developing a dedicated JPALS LRU
- Platforms are expressing the greatest interest in “single LRU” JPALS solutions based on existing avionics
- Civil modes enable JPALS equipped aircraft to land at civil airfields:
  - Equipped with GBAS/LAAS ground system
  - Where WAAS LPV-200 approaches have been TERPS’d
- LB JPALS aircraft will operate in military mode when supporting critical military ops – per CJCSI 6130.01
- Does NOT interact with aircraft aeronautical database
- Detailed AIG should be available in FY14
- Air Force and DoD need to understand platform integration costs
  - ESC/HBAB working on Air Fleet costs
  - Technical architecture coordination with platforms is vital
  - Assistance in reviewing/adjusting cost methodology is also necessary

The JPALS Program Office Is Here To Help Aircraft Platforms Evaluate Integration Alternatives