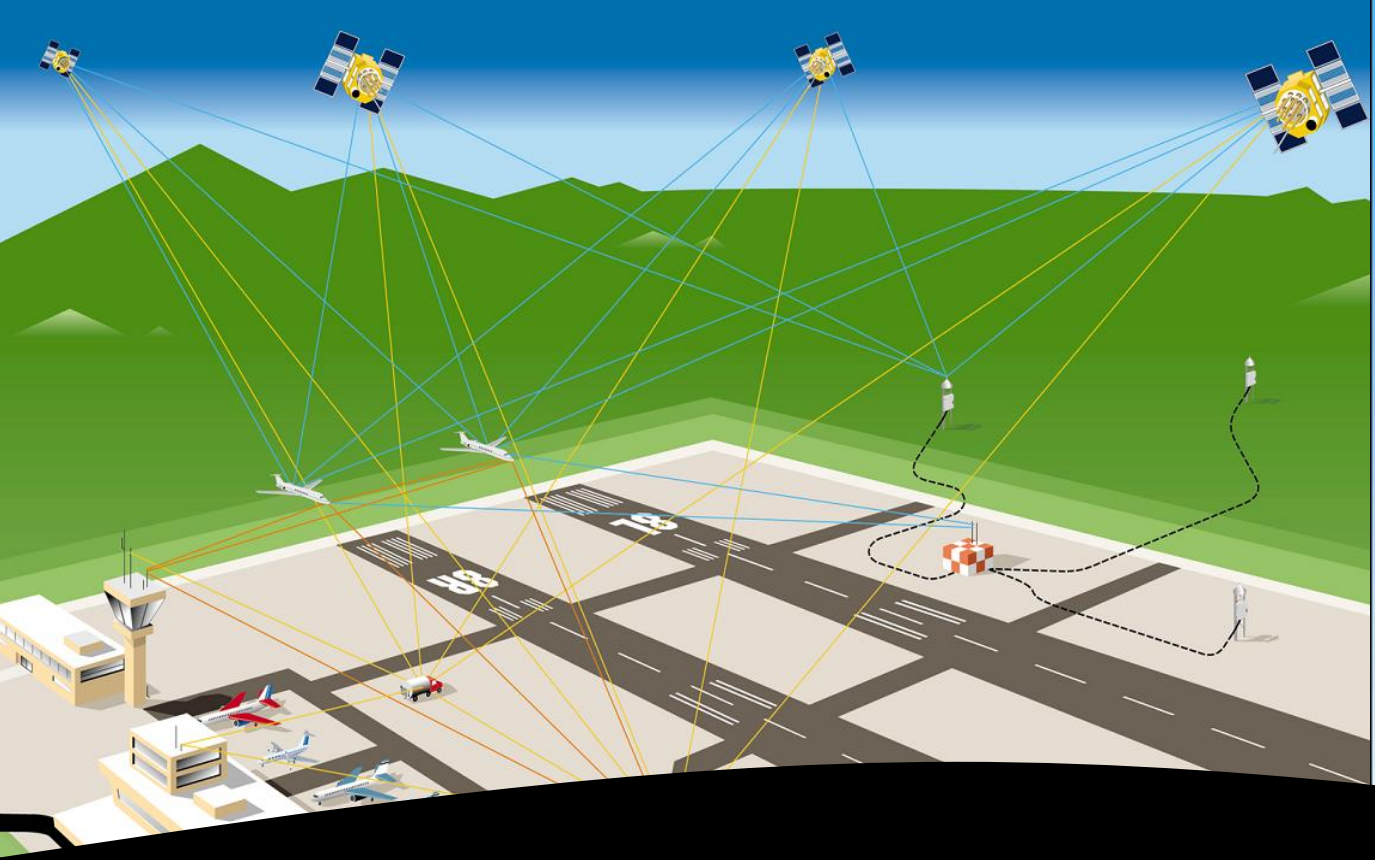
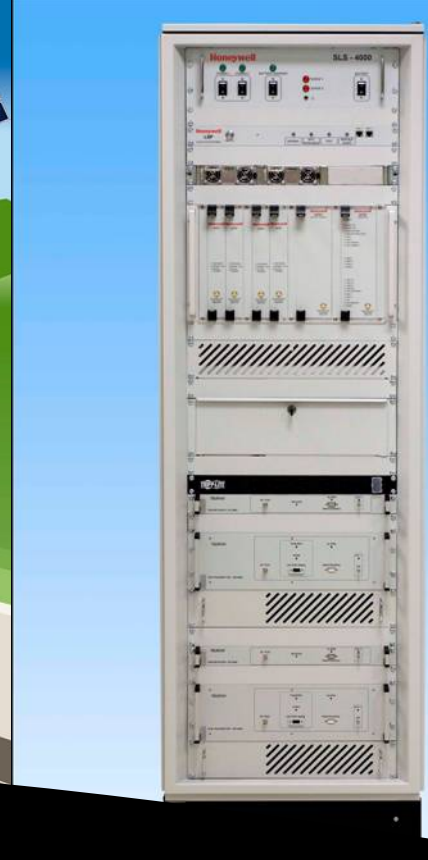




GBAS System Overview

John Howard
Honeywell, Precision Landing Systems
India ACP GBAS Seminar (New Delhi)
29 January 2010

Honeywell

GBAS Overview

- Global Navigation Satellite System (GNSS)
- GNSS Augmentation Types
- Ground-Based Augmentation System (GBAS)
- SmartPath™ CAT-I GBAS Ground Station
- System Certification
- SmartPath Development Roadmap

GNSS Status

GNSS	Compass	GPS	Galileo	GLONASS
Origin	China	USA	Europe	Russia
Operational	2015	1995	2012	1995
# Satellites	NA / 35	30 / 32	NA / 30	19 / 24
Orbits	21,150 km 12.6h	22,200 km 12.0h	23,222 km 14.1h	19,100 km 11.3h

- **Global Navigation Satellite Systems (GNSS)**
  - Have become a global utility
  - Providing civilian and military (precise) positioning services
  - Providing consistent, predictable, dependable performance
  - Agriculture, navigation, surveying, traffic, timing, tectonics, banking...
  - Now precision navigation

Applications for GNSS keep growing!

GNSS Overview

- **GNSS Becoming Cornerstone of All Navigation**
  - Air, marine, terrestrial, even in buildings...
- **However, GNSS Provides Limited Accuracy**
  - 5 - 7 m horizontal accuracy typical
  - 10 - 16 m vertical accuracy typical
- **And No Integrity...**
  - No independent monitoring of system
  - No alert of unexpected satellite, signal, or measurement failures
- **User is Responsible for Integrity (Protection)**
  - Or user relies on independent external system
- **Precision Navigation requires Accuracy, Integrity, Availability**
  - GNSS alone not capable of precision navigation
  - GNSS needs augmentation

GNSS user responsible for system integrity!

GNSS Augmentation Types

- **Space-Based Augmentation System (SBAS)**
  - Network of ground stations takes local measurements and monitors GNSS integrity
  - Control station determine local errors and transmits error “grid” to satellites
  - Satellite transmits corrections “grid” and integrity data to users
  - SBAS only capable of non-precision approach (LPV)
- **Ground-Based Augmentation System (GBAS)**
  - Ground station determines local errors
  - Ground station broadcasts local corrections, integrity data directly to users
  - GBAS capable of CAT-I/II/III precision approach
- **Receiver Autonomous Integrity Monitor (RAIM)**
  - Required in receivers approved for Instrument Flight Rules (IFR)
  - Provides integrity but does not improve accuracy
- **Aircraft-Based Augmentation System (ABAS)**
  - RAIM integrated with Inertial Reference System (IRS), altimeters, clocks

Only GBAS provides required integrity, accuracy and availability for precision approach!

Augmented GPS Performance

System	Serves	Horizontal Error[1] (95%)	Vertical Error[2] (95%)
GPS	Global	5 – 7 m	10 – 16 m
WAAS	CONUS	1.0 m	1.5 – 2.0 m
GBAS	Airport	< 0.50 m	< 1.0 m

1. *Assuming HDOP of 2.5.*
2. *Assuming VDOP of 4.0.*

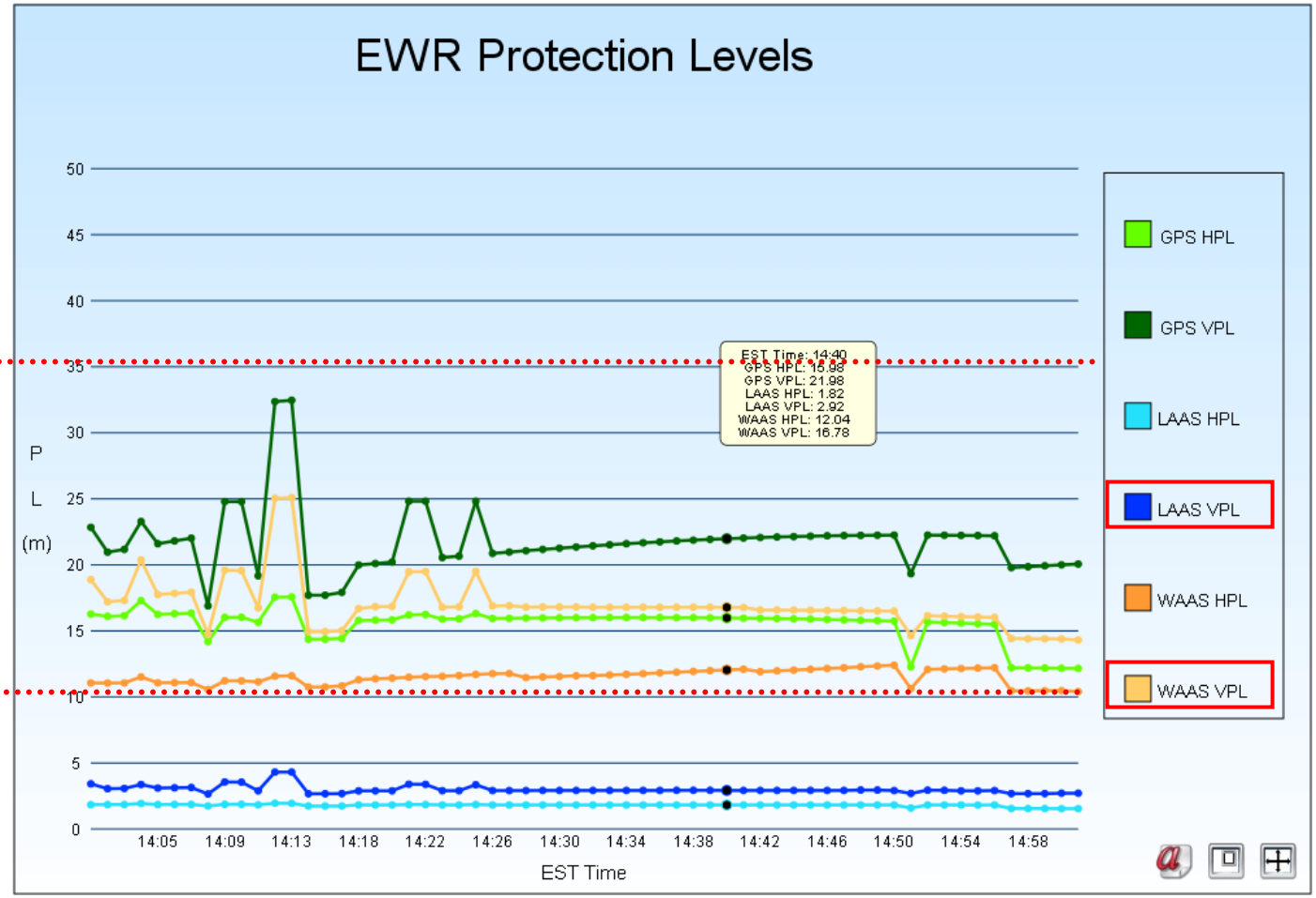
SmartPath™ at Newark International Airport

LPV:

VAL = 35m

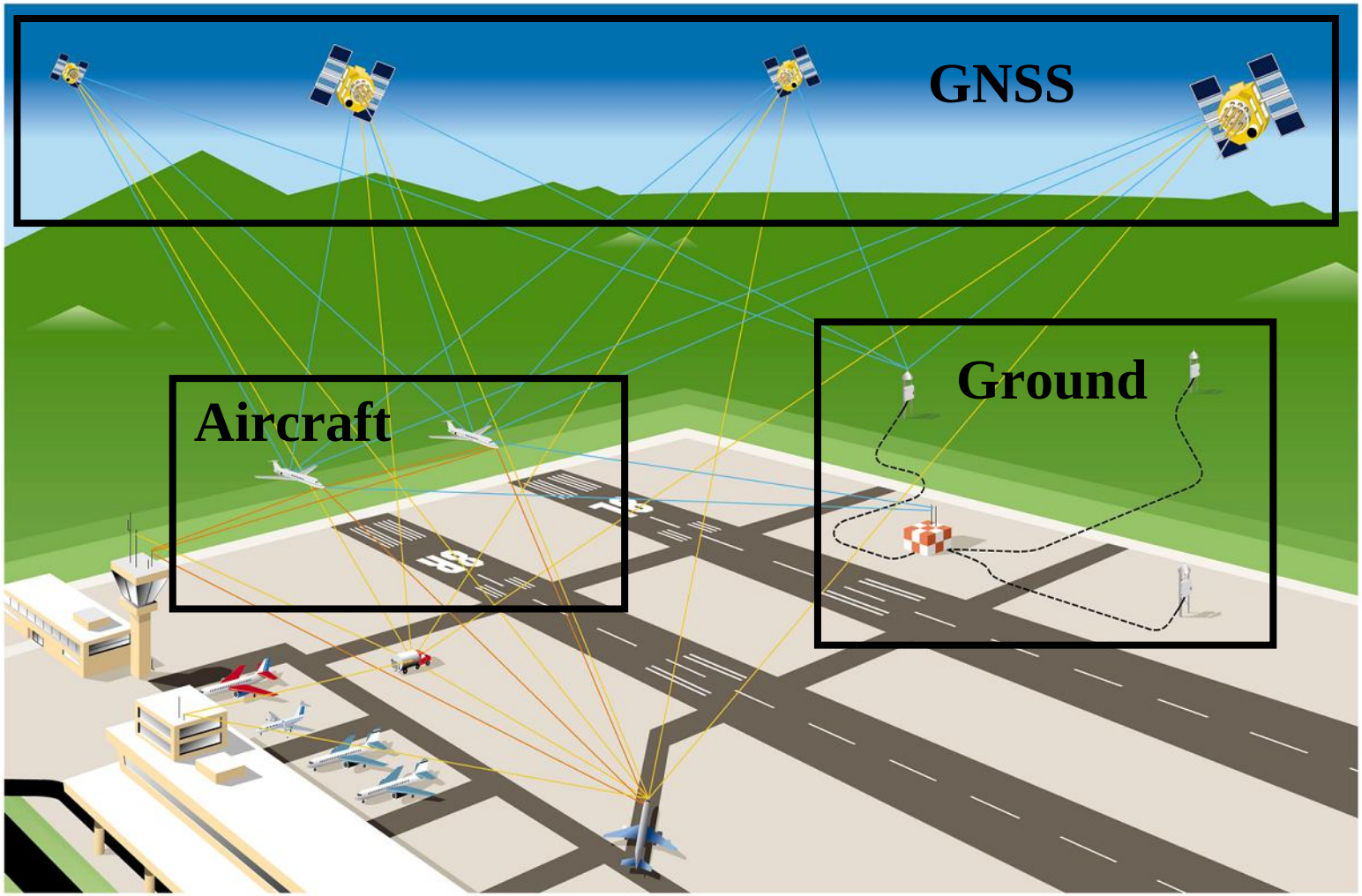
GLS:

VAL = 10m



(http://laas.tc.faa.gov/EWR_PL.html)

GBAS Augmentation



GBAS Operation

- **GNSS Subsystem**
  - 24-32 satellites (ranging sources) typical
  - Satellites broadcast position, health, and timing signal
- **Ground Subsystem**
  - Takes multiple measurements for each satellite
  - Determines which satellites can be used for GBAS solution
  - Computes corrections, integrity for those satellites only
  - VHF broadcast of corrections, approach paths, integrity data
- **Aircraft Subsystem**
  - Receives corrections, approach paths, integrity data
  - Corrects satellite measurements
  - Computes “corrected” position and protection levels
  - Computes deviation from approach path
  - Deviation guides aircraft to approach path

Ground subsystem responsible for system integrity.

GBAS Benefits/Capabilities

- **Cross-Over to Digital Technology**
  - GBAS Landing System (GLS) replaces Instrument Landing System (ILS)
  - GBAS provides virtual path in space for aircraft
  - ILS generates analog radio beam to guide approach
- **CAT-I Precision Approach Service**
  - GBAS exceeds 99.9% system availability
- **Ground Station Uplinks Final Approach Segments (FAS)**
  - No approach path database required on aircraft
- **Single System Supports entire Airport**
  - ILS requires system for each runway end served
  - GBAS has lower maintenance costs
- **Operational Improvements**
  - GBAS provides multiple approaches for each runway end
  - GBAS eliminates approach path interference
  - GBAS eliminates hold-short zones for reduced departure separation
  - GBAS reduces holding times, diversions
  - GBAS saves fuel, reduces emissions, reduces noise abatement
- **Flexible Siting**
  - GBAS installs in available airport space

Honeywell SmartPath™

- **First FAA-Certified GBAS CAT-I Ground Station**
  - Complies with FAA “non-Fed” LAAS specification (FAA-E-AJW44-2937A)
  - Provides CAT-I Precision Approach Service (200 DH)
- **Integrity Monitors**
  - 14 monitors protect against satellite, space, and local measurement threats
- **Redundant Architecture**
  - Reference receivers, corrections processors, VHF radios, backplane, power
  - Provides “hot” backup in case of failure
  - Allows “live” maintenance of system
- **Remote Monitoring**
  - Provides status to Air Traffic, Airport Maintenance, and NavAid Monitoring centers
  - Alerts when constellation cannot support Precision Approach Service
- **Ready for CAT-II/III**
  - CAT-I ground station easily upgradeable to CAT-II/III
  - Reference receivers (antenna & GPS receiver) capable of CAT-III

World’s First FAA-Certified GBAS!

SmartPath™ Equipment

Reference Receivers

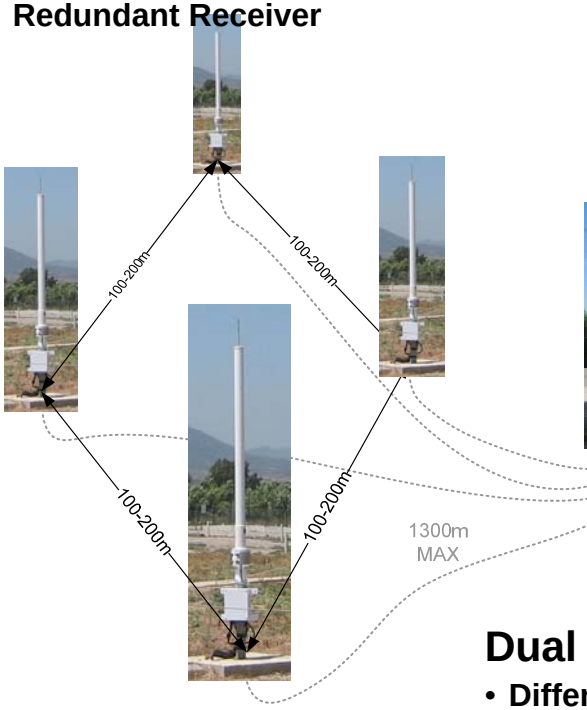
- Multipath Limiting Antenna (MLA)
- Narrow Correlator GPS Receiver
- 4 - 2 Hz Measurements
- Redundant Receiver

Maintenance Data Terminal

- System Status, Mode, Control
- System Alerts, Alarms
- Approach Control

VHF Broadcast

- Corrections, Integrity, Approaches
- Horizontally Polarized, Omni-Directional
- 108-118 MHz, 2 TDMA Time Slots
- 2 Hz Corrections
- Redundant Radio



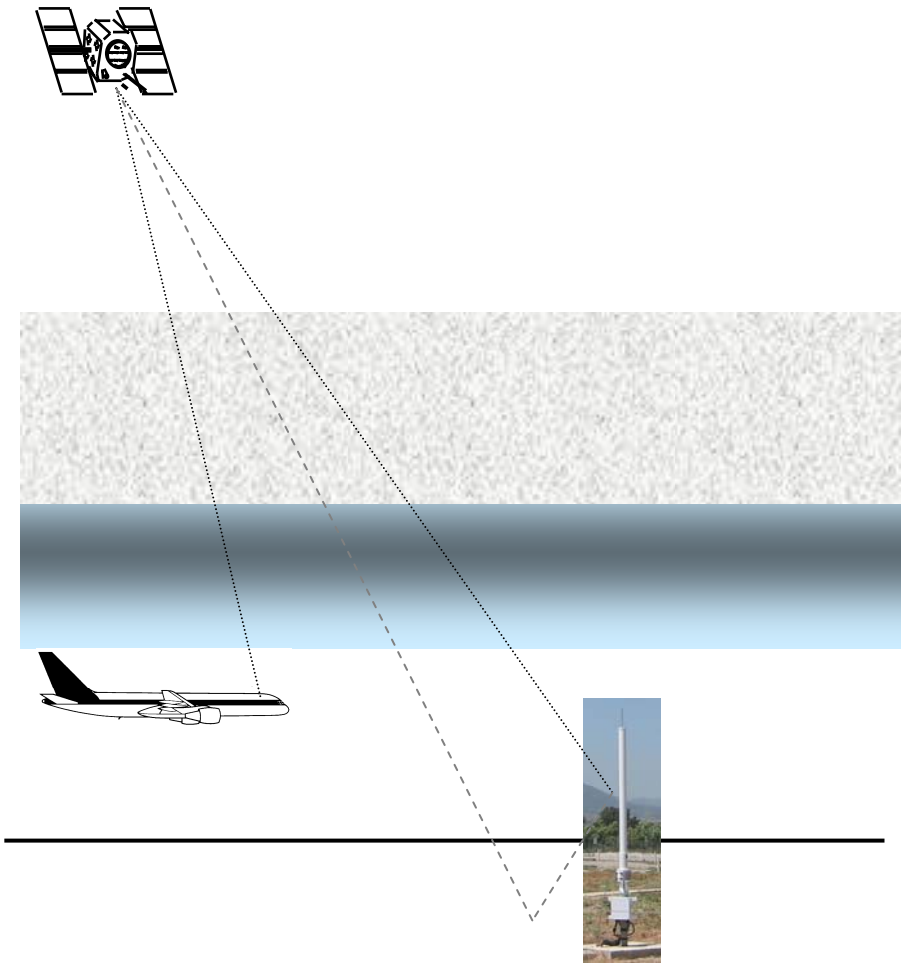
Air Traffic Status Unit

- System Mode
- System Availability

Dual Processor Channels

- Differential Corrections
- Overall System Integrity
- Approach Database
- Redundant Channel

SmartPath™ Integrity Monitors

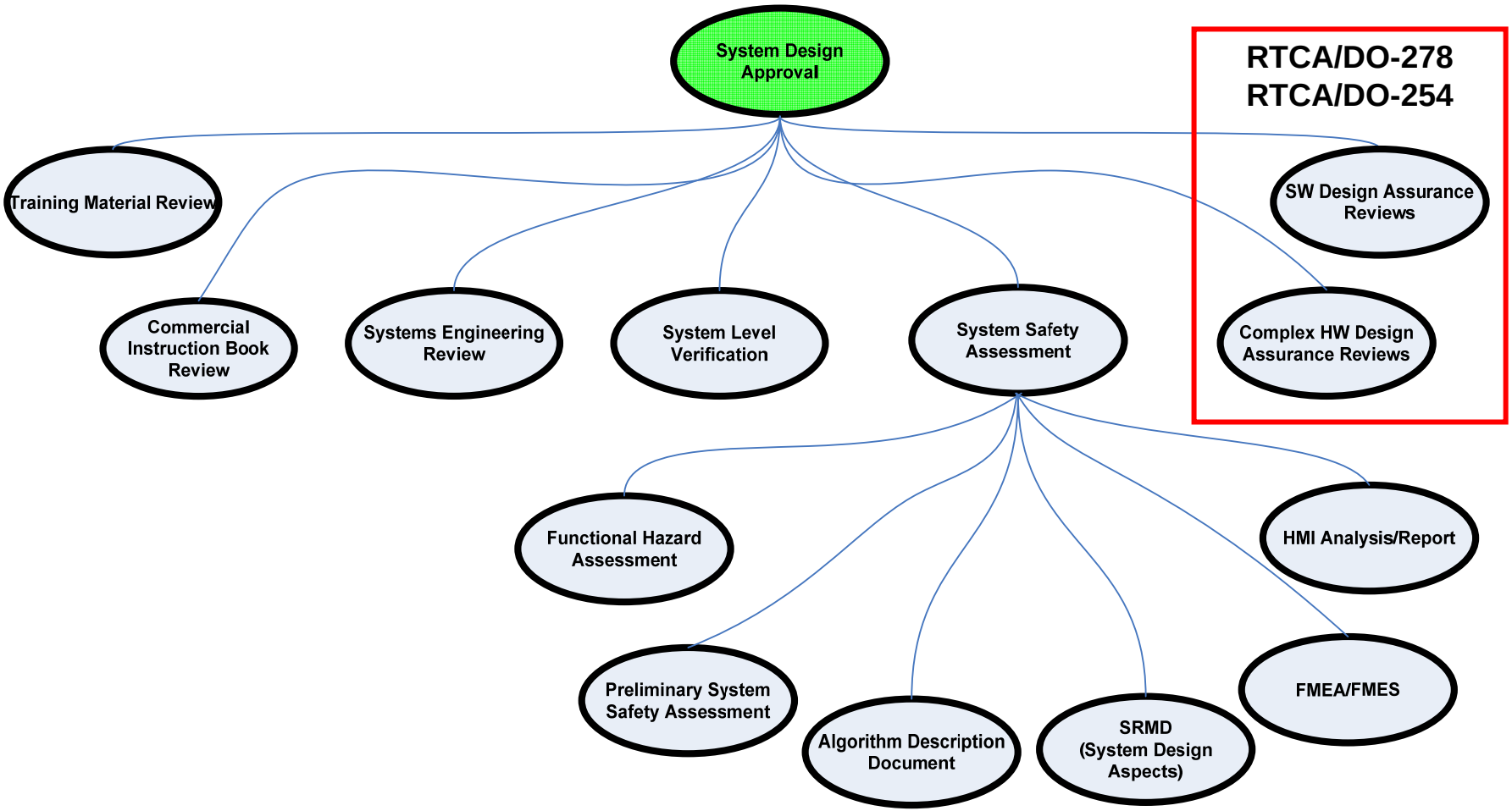


- **LAAS Integrity Panel (LIP)**
  - 10 years of development, verification
- **Satellite Errors**
  - Satellite Position (Ephemeris)
  - Satellite Clock
  - Code/Carrier Divergence (CCD)
  - Carrier Rate
  - Excessive Acceleration
- **Space & Signal Errors**
  - Signal Deformation
  - Low Signal Power
  - Anomalous Ionosphere
- **Ground & Receiver Errors**
  - Thermal Noise & Multipath
  - Radio Frequency Interference (RFI)
  - Cross-Correlation
  - Receiver Cycle Slip
  - Receiver Clock

SDA Process – Honeywell Effort

- **3+ Years of Design, Development, and Verification**
  - Peaked at ~100 engineers
  - ~70 engineers from Honeywell's Bangalore facility
- **Over 230 Documents Submitted for Review**
- **23 Formal FAA Audits and Reviews**
- **10 Formal Internal Design Reviews**
- **20 Technical Interchange Meetings (TIMs)**
  - with FAA, key technical advisors to develop and approve integrity monitors
- **Over 400 Basic Safety Events (Bottom Line Fault-Tree Nodes)**
- **Over 2500 Hardware and Software Requirements**
  - Representing 21 subsystems (peer-reviewed, change controlled)
- **Over 1500 GPS Corrections and Monitor Requirements**
  - Implementing 14 integrity monitors
- **Over 2000 Test Cases**
  - To fully verify 4000+ requirements
- **Over 1200 Test Procedures**
  - To implement 2000+ test cases (peer-reviewed, formally run)

SmartPath™ System Design Approval



HW/SW Design Assurance Items

SDA Item	Subsystem
Software Design Assurance ***(RTCA/DO-278)***	• Differential Corrections Processor (Level 2) • Real-Time Operating System (Level 2) • GPS Receiver (Level 2) • Ethernet Switch (Level 5) • VDB Receiver (Level 5) • VDB Transmitter (Level 5) • Environmental Concentrator (Level 5) • Data Recorder (Level 6) • Maintenance Data Terminal (Level 6) • Air Traffic Status Unit (Level 6)
Hardware Design Assurance ***(RTCA/DO-254)***	• Differential Corrections Processor (Level B) • GPS Receiver (Level B) • Ethernet Switch (Level D) • Data Recorder (Level E) • Maintenance Data Terminal (Level E) • Air Traffic Status Unit (Level E)

DO-278 Documentation

Assurance Level	Supporting Documentation
Software - Level 2 **• GPS Receiver** **• Differential Corrections Processor** **• Real-Time Operating System**	• Plan for Software Aspects of Approval (PSAA) • Software Development and Verification Plan (SDVP) • Software Standards • Software Configuration Index (SCI) • Software Structural Coverage Report • Software Tool Qualification Report • Software Transformation Procedure • Software High Level Requirements (HLR) • Software Low Level Requirements (LLR) • Software High Level Test Cases • Software Low Level Test Cases • Software High Level Verification Test Report (SVTR) • Software Low Level Verification Test Report (SVTR) • Operational Software CI Plan • Software Accomplishment Summary (SSA)

DO-254 Documentation

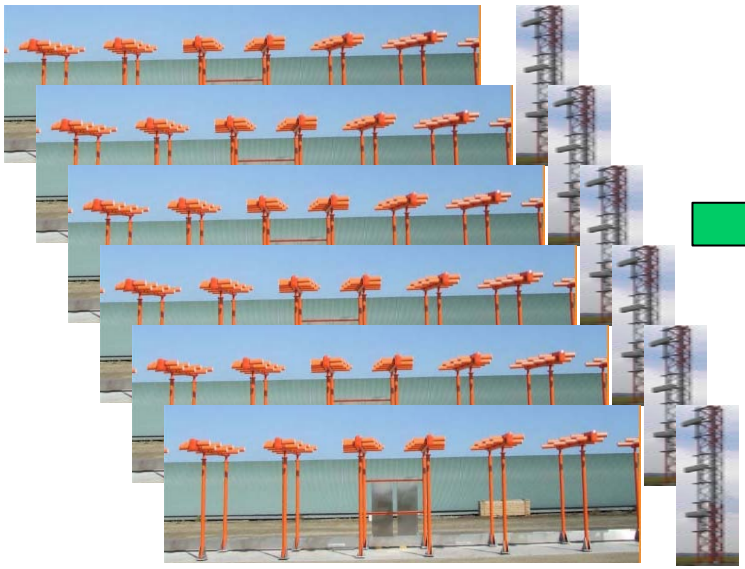
Assurance Level	Supporting Documentation
Hardware - Level B **• GPS Receiver** **• Differential Corrections Processor**	• Plan for Hardware Aspects of Certification (PHAC) • Hardware Development and Verification Plan (HDVP) • Hardware Configuration Index (HCI) • Hardware Process Assurance Plan (HPAP) • Hardware High Level Requirements (HLR) • Circuit Card Assembly (CCA) Requirements • PLD Requirements • PLD Simulation Verification Plan (SVP) • PLD Simulation Verification Results (SVR) • Hardware Test Cases • PLD Test Cases • Hardware Verification Test Report (HVTR) • PLD Verification Test Report • CCA Prediction Report • Hardware FMEA Report • PLD Implementation Report • Hardware Accomplishment Summary (HAS)

SmartPath™ Value

- **Lower Acquisition Cost**
  - Eliminates need for ILS at each runway end served
  - Single system serves entire airport
- **Increases Airport Capacity**
  - Eliminates ILS hold-short zones & keep-out areas
  - Eliminates ILS approach path interference
  - Eliminates ILS overlap for closely spaced parallel approaches
  - Provides multiple approaches for each runway end (glide slope, threshold)
  - Reduces aircraft holding patterns, diversions
  - Airlines save fuel, reduce emissions
- **Lower Maintenance Cost**
  - Single system to maintain, calibrate, inspect
  - Reduces annual flight inspection costs (recommended every 5 years)
- **Easy Upgrade**
  - Software upgrade with minimal hardware impact

SmartPath increases capacity without adding infrastructure.

SmartPath™ Value (3 Runways)



➔ 6 ILS Localizers
➔ 6 Glide Path Arrays

➔ 1 SmartPath GBAS

SmartPath™ Roadmap

- **Terminal Area Paths (TAP)**
  - Curved paths into GLS final approach
  - Provide missed approach path, guided departures
  - Potential to replace RNP/RNAV procedures
- **Differential Correction Positioning Service (DCPS)**
  - RNP/RNAV enabler
  - Surface Movement Guidance System (SMGS) enabler
- **Station Availability Enhancements**
  - Reduce system start-up time
  - Increase system availability
- **Category-II/III Precision Approach Service**
  - Software upgrade – minimal hardware impact
  - CAT-III ICAO/RTCA requirements currently being validated
- **System Design Approvals**
  - Germany, Spain, Brazil, Chile, China, Australia

SmartPath is on the way to CAT-III.

GBAS & SmartPath™

- **GNSS is Cornerstone of Navigation**
  - But requires augmentation for precision navigation
- **Only GBAS Augmentation can provide the Integrity, Accuracy and Availability required for Precision Approaches**
- **SmartPath is World's First FAA-Certified CAT-I GBAS Ground Station**
  - Germany, Spain, Brazil, Chile, Australia, China in progress
- **SmartPath Replaces ILS**
  - Single system serves entire airport
  - Eliminates many ILS operational constraints
  - Installs where airport has space
- **SmartPath Provides Value**
  - Increases airport capacity
  - Reduces maintenance costs
  - Reduces fuel costs and emissions
- **SmartPath is Leading the Way to**
  - Curved approach, missed approach, guided departure
  - Increased RNP availability
  - CAT-II/III precision approach

GBAS is the future of precision approach.

Thank You