Modern ARINC 743B
DO-229D and DO-253C
GLSSU Solutions
For Retrofit

Presented to
AEEC
March 2010
The Classic Retrofit Challenge

• Financial:
  – *Operating budget year financing*
  – *ROI payback: 1-2 years max*
  – *Investment usually comes from reduced fuel budget: save enough on gas in 1-2 years to pay off the investment in the avionics.*

• Retrofits make sense when the avionics bring new capability measurable in better fuel economy at a reasonable retrofit cost to airframes with long lives ahead.

• Retrofit aircraft equipage assumptions:
  – *GNSS with or without inertial navigation*
  – *Minimal or no FMS modifications*
  – *Retrofit solution must “bolt-on” solution, not a gut and re-equip*
What do these Terms have in Common?

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Some Answers:

• All are “added” features
  – Enabled through augmented GPS receivers & integrated with aircraft operation
  – Provide substantial new benefits to air transport operators
  – but which are not generally supportable by 1st gen GPS receivers, of which there are thousands in current airline service, even if updated as “SA-Aware”...
  – Positioned to take advantage of the “Next Gen” Airspace

• The ARINC 743B Characteristic captures the current GPS L1 receiver augmentations:
  – SBAS enabled navigation and LPV
  – GBAS GLS
  – All in one ARINC 743B GPS receiver (+ VDB receiver).

• The GPS L1 signal remains to be fully exploited:
  it remains to exploit SBAS&LPV + GBAS GLS in an all-in-one receiver as a total navigation and approach solution.

• The ARINC 743B Characteristic allows growth to an expanded GNSS receiver with essentially the same aircraft interface.
  – Equipment impact: the GPS receiver & antenna will probably be replaced as a minimum.
  – Remark: an expanded GNSS may bring additional benefits to commercial aviation, but these need better definition.
Focus on Augmented GPS: SBAS/GBAS Receivers

• Non-Augmented GPS receivers do not have the required integrity-availability-continuity to support the transition to a performance-based navigation infrastructure
  – *Shift from ground-based to satellite-based services*
  – *Eventually navaids like VOR and NDB will be “divested”*
  – *NAS-wide services for enroute, terminal and approach, including backup for approach and landing, are all GNSS based*

• With SBAS augmentation:
  – *By far the most accurate, highest integrity navigation system there is with Primary Means Navigation (not so with a SA-Aware only Rx)*
  – *Enhances RNAV, RNP navigation & RNP SAAAR (RNP0.1)*
  – *Meets ADS-B requirements (position integrity & velocity with FOM) especially in the terminal area*
  – *LPV, CAT-I equivalent available today*

• With GBAS augmentation:
  – *GLS CAT-I today, but no Federal Acquisition Program for LAAS*
  – *CAT-II/III in future, being worked, using GPS L1 only.*
Capability of an ARINC 743B Receiver

• Is self-contained and focuses only on GNSS navigation and approach capability (does not drag around classical receivers such as VOR, ILS, etc…) as part of its characteristic.

• Accounts for DO-229D, SBAS Navigation and LPV

• Accounts for DO-253C, GBAS GLS

• Enables RNP0.1 (RNP SAAAR) & Primary Means of Navigation

• Address ADS-B position & velocity outputs, including ADS-B operations in the Terminal Phase of Flight

• Address retrofit aircraft cost effectively

• Allows for growth to new GNSS and augmentations without significant impact to aircraft or systems.
SBAS/GBAS ARINC 743B Receiver

- GBAS and SBAS combined in one receiver
- New approach connector is defined for Alternate Form Factor GLSSU receiver
  - Glide Slope and Localizer look-alike guidance, identical to ILS provided on ILS look-alike bus
  - Provides DME look-alike, identical to DME provided on DME look-alike bus
  - Retain existing ILS, displays, FMS, and avionics in general
  - add “bolt-on” GPS/SBAS navigation & SBAS/GBAS approach solution
  - Has built-in digital High Integrity Switch to intercept ILS and DME busses and replace with GLSSU derived LOC/GS and DTG
  - Rectilinear guidance also provided as required by GBAS MOPS for both GBAS and SBAS approaches on GLS bus
  - Fresh 10 Hz navigation & approach data provided on GLS bus for flexibility to compute guidance on other equipment
SBAS/GBAS Navigation Receiver

• Primary Means Navigation with SBAS
  – SBAS receiver uses SBAS differential GPS data, and integrity information to:
    ✓ Produce a more accurate navigation solution
    ✓ Produce a better integrity (smaller HIL, HPL) and much better availability
  – RNP0.1 Integrity >= 99.999% under SBAS coverage
  – RNP0.3 Integrity = 100% under SBAS coverage
  – Coverage is entire SBAS satellite footprint (continental)
  – SA-Aware when not under SBAS coverage
  – Certification is TSO-C145c for navigation, TSO-C146c for approach guidance, may have both
  – In general, C145c equipment performs as well as or outperforms C196 (SA-Aware) equipment.

• Better Local Area Navigation with GBAS
  – GBAS receiver uses GBAS differential GPS data and integrity information to:
    ✓ Produce a more accurate navigation solution
    ✓ Produce a better integrity (smaller HIL, HPL) and much better availability
  – Coverage limited to 23 nmi operational radius defined by VDB link budget
  – LAAS TSO-C161a + base a certification, one of: TSO-C129a, TSO-C145c, or TSO-C196

• Impact of SBAS + GBAS on Aircraft Navigation Interface (ARINC 743A):
  – No impact on navigation interface, no impact on standard ARINC 743 navigation connector
  – Same labels for position solution, same label for integrity information
  – Only difference is that data is more accurate, better integrity availability
  – Impact on ARINC 743: no impact, aircraft is presented with a better solution
  – Optional labels exist, if exercised, then there will be modifications, but not needed.
SBAS/GBAS Approach Receiver

- **DO-229D GPS/SBAS receiver classes**
  - Defines a Beta and Delta class receiver (Gamma class not discussed)
    - Beta class is a navigation receiver, does NOT provide Glide Slope or Localizer guidance, relies on some other equipment to do guidance (FMS?)
    - Beta Class receiver interface is essentially unchanged for navigation, the standard connector is the “navigation connector” with same navigation interface definitions.
    - Delta class is an approach receiver, provides Glide Slope and Localizer guidance
    - Delta Class receiver interface defines a new approach connector
    - Delta class receiver can have its own FAS or it down-load the FAS from the FMS
  - Beta + Delta class receiver can be combined as one receiver
  - Beta + Delta class receiver can be a complete stand-alone navigation and approach receiver
    - Approach does not have to be driven by a FMS
    - Navigation solution used by FMS as if GPS only

- **DO-253C GBAS receiver**
  - No equipment classes
    - GPS or GPS/SBAS navigation outside range of GBAS ground station
    - GBAS Differential navigation within range of ground station if that service is provided by the GBAS ground station
    - Approach guidance within range of ground station
SBAS/GBAS Approach Receiver, How It’s Done

• The Guidance Solution
  – Must be ILS Look-Alike: Glide Slope and Localizer outputs
  – Must be DME Look-Alike: Distance to LTP/FTP
  – Delta Class receiver behaves exactly as an ILS receiver – aircraft systems see Delta Class receiver as an ILS receiver – true ILS look-alike. Result: no aircraft systems need to be modified
  – Ability to switch between ILS and GPS approach with built-in High Integrity Switch

• Impact on FMS and aircraft
  – In retrofits, maximize use of existing aircraft displays, autopilot without modifications. This is the key to low cost.
  – However, FMS must provide for:
    ✓ FMS procedures for GPS RNAV, guidance to FAF, “same as for ILS”
    ✓ FMS procedures for GPS RNAV missed approach, “same as for ILS”
  – FMS does not have to be modified to control GLSSU receiver, can be done with a separate control head
  – FMS does not have to host the LPV database, GLSSU can host 2 cycles of the entire world-wide LPV database, CMC GLSSU: 12Mb/cycle, 2 cycles (total = 24 Mb).

• Impact on Aircraft Approach Interface:
  – Provides Glide Slope and Localizer look-alike guidance, identical to ILS
  – Provides DME look-alike, identical to DME
  – Retain existing ILS, displays, add “bolt-on” GPS approach solution
  – Potential FMS impact to provide RNAV and Missed Approach Guidance
SBAS/GBAS Approach Receiver, What It Delivers

• **DO-229D**
  - Defines a Beta and Delta class receiver
    ✓ Beta class is a navigation receiver, does NOT provide Glide Slope or Localizer guidance
    ✓ Delta class is an approach receiver, provides Glide Slope and Localizer guidance
    ✓ Delta class receiver can have its own FAS or have it down-loaded from the FMS
  - Beta + Delta class receiver can be combined as one receiver
  - Coverage tends to be entire continental airspace
  - Beta + Delta class receiver can be a complete stand-alone navigation and approach receiver, fully independent of a FMS

• **DO-253C**
  - GBAS receiver uses GBAS differential GPS data and integrity information to:
    ✓ Produce a more accurate navigation solution
    ✓ Produce a better integrity (smaller HIL, HPL) and much better availability
    ✓ Provides Glide Slope and Localizer guidance
    ✓ CAT-I Approach capability, CAT-II/III TBD approval with GPS L1 signal.
  - Coverage limited to 23 nmi operational radius as defined by VDB link budget

• **Impact on Aircraft Navigation Interface (ARINC 743):**
  - None foreseen
  - Same labels for position solution, same label for integrity information
  - Only difference is that data is more accurate, better integrity availability
  - Impact on ARINC 743: no impact, aircraft is presented with a better solution.
Practical Example of an ARINC 743B receiver retrofit

- **GLSSU** developed by CMC Electronics as an alternative to MMR
  - **ARINC 743B Alternate Form Factor**
  - **Today:** SBAS + LPV
  - **Tomorrow:** SBAS + LPV & GBAS + GLS in one receiver: **GLSSU**
    - ✓ External VDB receiver, same foot-print

- **Example:** classic B-757 Retrofit
  - **No GPS**
  - **VOR/DME & INS navigation**
  - **ILS approach**
A Practical Example of an ARINC 743B SBAS/GBAS receiver

• GLSSU dual purpose:
  – **SBAS Navigation**
    RNP0.1 performance
    ADS-B in terminal area
    Primary Mean Nav
    SA Aware built-in
  – **SBAS LPV + GBAS GLS**

• Complete GLSSU system:
  – **Built-in High integrity switch for ILS-GLS signal source selection**
  – **External VDB receiver for GBAS**
  – **Optional control head**
  – **Addition of guidance mode ILS-GLS/LPV selector**
  – **Active antenna, TSO C-190, required for LPV or GLS**
CMA-5024 IntegriFlight™ GLSSU SBAS/LPV

• GPS Landing + GLSSU in single unit
  – Certified (2008) to highest standards
    TSO-C145c Beta-3 & TSO-C146c Delta-4
    ✓ No “Waivers” of any sort
    ✓ Primary Means of Navigation
    ✓ Supports RNP0.1 certification
    ✓ Supports ADS-B requirements, NAC_V=2
    ✓ Built-In WAAS LPV + FAS Database
    ✓ Built-in High Integrity Switch ILS/GLS switch
  – SA-Aware world-wide
  – ARINC 743A-4/5 & 743B compliant
  – Unmatched 40,000MTBF
  – Aircraft Personality Data (APD) provision to configure interface to specific airframe type.
  – Upgradable to LAAS, external VDB required
  – CAT-IIIb ready: All-in-view 24-Channel Narrow Correlator technology

CMA-5024 GLSSU

CMA-5025 Control Panel
CMA-5025 IntegriFlight™ Control Panel - Overview

• TSO-C146c Delta-4
• Smallest “standard” form factor
  – 2.25” X 2.5” X 4.5”
• Connects to GLSSU:
  – Controls and selects WAAS LPV
    ICAO tuning range from
    (40000 to 99999)
  – Controls and selects LAAS GLS
    ICAO tuning range from
    (20000 to 39999)
• 20,000 hour MTBF

• Left and Right CMA-5025 connect to Left and Right CMA-5024s
• GLSSUs crosstalk tuning at all times, all GLSSUs tuned to same approach
• Both CMA-5025s will display same active approach (GLSSUs will cross-talk the
  tuning among themselves and to the opposite control panel)
• Either side can select tuning, opposite control panel will display same selected
  approach, all GLSSUs will tune to same selected approach.
CMA-5010 IntegriFlight™ VDB Receiver - Overview

• Dedicated VBD Receiver (planned)
  – RTCA/DO-253C
  – ARINC 755 I/O compliant

• 3 Connectors:
  – Data and Power Connector
    Connected only to GLSSU
  – 2 RF Connectors: (In and Out)
    Configurable RF ILS/VDB switch, 3dB power split or active RF

• Controlled only by GLSSU and ILS/GLS Approach Select Switch

• > 40,000 hour MTBF target

• An “Add-Below” to existing GLSSU
  – Identical “footprint” to GLSSU
  – Slim deck height, approx 1 inch
CMA-5010 IntegriFlight™ VDB Receiver - Overview

CMA-5024 GLSSU

CMA-5010 VDB Receiver
Representative Unit

Mounting Bolts

VDB Data Connection

2 VHF RF Connectors
ILS / DME Top Level Diagram

Radio Management Unit

DME

ILS Receiver

Cockpit Avionics and Displays

Autopilot Source Select

Autopilot Flight Director
ILS/DME + GLS Approach Top Level Diagram

GLS Control Head
  ↓
GLS Receiver
  ↓
VDB Receiver
  ↓
High Integrity Switch
  ↓
Cockpit Avionics and Displays
  ↓
Radio Management Unit
  ↓
DME
  ↓
ILS Receiver
  ↓
Autopilot GLS/ILS Source Select
  ↓
Autopilot Flight Director

Cockpit Avionics and Displays
  ↓
Radio Management Unit
  ↓
DME
  ↓
ILS Receiver
  ↓
Autopilot GLS/ILS Source Select
  ↓
Autopilot Flight Director
Architecture in a classic 757 NO GPS

Existing Auto Pilot + Instruments Without Modification
ILS and ILS Look-Alike (GLS LOC and GS) Signals
Architecture in a classic 757 + SBAS (SA-Aware)

Existing Auto Pilot + Instruments Without Modification
ILS and ILS Look-Alike (GLS LOC and GS) Signals
Architecture in a classic 757 + SBAS + LPV

GLSSU Bus is a cross-talk bus:
All tuning data shared
All GLSSUs tuned to same approach

Existing Auto Pilot + Instruments Without Modification
ILS and ILS Look-Alike (GLS LOC and GS) Signals
Architecture in a classic 757 + SBAS + LPV + GBAS + GLS

Existing Auto Pilot + Instruments Without Modification
ILS and ILS Look-Alike (GLS LOC and GS) Signals
Concluding Remarks

• SBAS and GBAS in one receiver as a simple retrofit solution for classic aircraft is possible.

• GLSSU with SBAS available today

• GLSSU with GBAS coming soon.

• To consider future standards:
  – Radio box with classical radios (ILS, VOR, etc) in one box, but NO GPS
  – Separate GNSS box
    ✓ GPS, SBAS, GLS today
    ✓ Coming: GPS L1 & L5, Galileo, and still newer things on drawing boards
    ✓ The GNSS receiver will undergo changes for decades to come. Does it make sense to integrate it with ILS, VOR, etc…?
On the Button Accuracy
The Precision Upgrade Solution for Existing Aircraft

IntegriFlight® SBAS/WAAS GPS Receiver
- Worldwide Primary Means Navigation
- Meets or exceeds ADS-B requirements
- Navigation solution supports RNP0.1
- Fully coupled autopilot LPV guidance
- Growth to LAAS/GBAS

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