GLU-2100

Resilient Navigation

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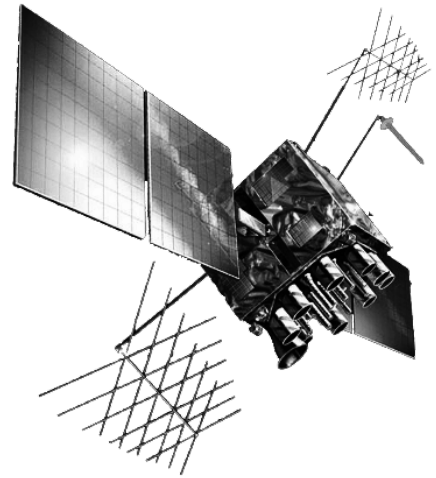
Name: Stuart Deathridge
Title: GNSS Resilience

DATE: November 2025

EVOLUTION OF GNSS NAVIGATION

ENHANCED NAVIGATION PERFORMANCE

July 1977
First GNSS signal received and decoded in Cedar Rapids, at Collins



1998
- GPS approved for sole means of navigation

2000
- Selective availability turned off

2003
- **First SBAS LPV approach**

2005
- GBAS Cat I implemented

2015
- Implementation of RNP/RNAV in global aerospace

2020
- **RFI Threats**
- US ADS-B GNSS req.
- GLS Cat II/III

2023
- RF Robustness
- **Dual-frequency/ Multi-constellation**

2025+
- Geo-political mandates
- **PBN Mandates**
- **LPV Rollout**

GLU-920

GLU-925

GPS-4000A **GPS-4000S**

GLU-2100

ORE EFFICIENT AIRSPACE

MANDATED PERFORM S

VED GLOBAL PABILITIES

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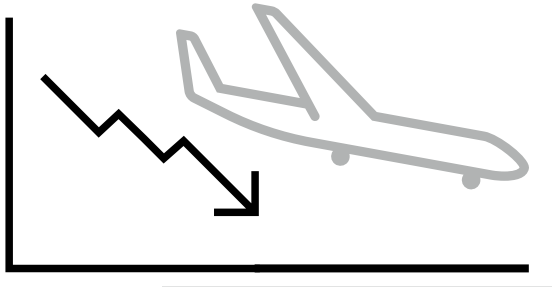
Navigation Challenges Being Faced

Evolving Airspace

- The challenges being solved today are different than what we'll face tomorrow



Aging Ground Infrastructure and Regional Changes

- Legacy solutions are aging and being phased out in favor of PBN requirements

Increased Jamming & Spoofing

- Intentional RFI has expanded at exponential rates in recent years

Landing globally is non-optional

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GNSS threats

70% of Commercial Air customers experience Radio Frequency Interference (RFI) on a weekly basis

RFI reports from the Field in the last 2 years:

- Loss of GNSS for over 2 hours on flights over the Middle East
- Time jumps on flights over the Syria/Iraqi Airspace
- Corruption of GPS almanac on flights near the Baghdad airport
- Repeater based attacks on flights in Chinese Airspace
- GPS interference observed in the Dallas Area
- GPS interference observed in the Baltic Region
- Spoofer attacks in the Baltic Region

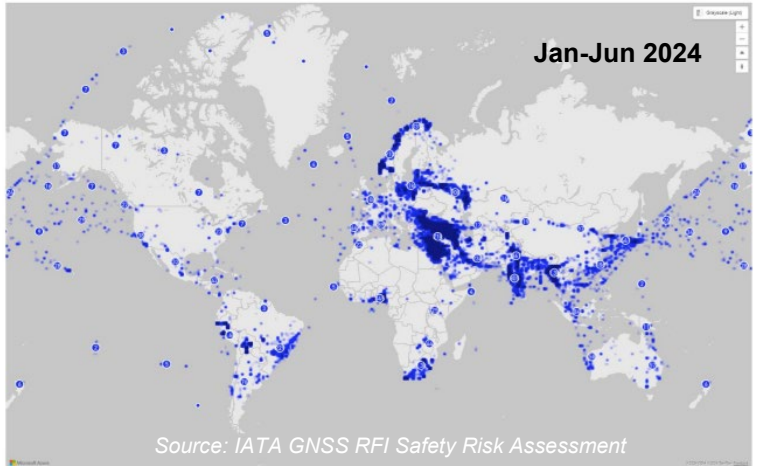
Impacts of RFI:

Severity ↓

No impact
Loss of GPS that recovers autonomously after flying out of RFI region
Loss of GPS that recovers after power cycle
Loss of GPS that recovers after NVM (non-volatile memory) reset
Erroneous GPS position, velocity and time outputs

GPS loss is becoming more prevalent on commercial flights

RFI is increasingly a worldwide concern



Jamming and Spoofing are real world issues demanding real solutions

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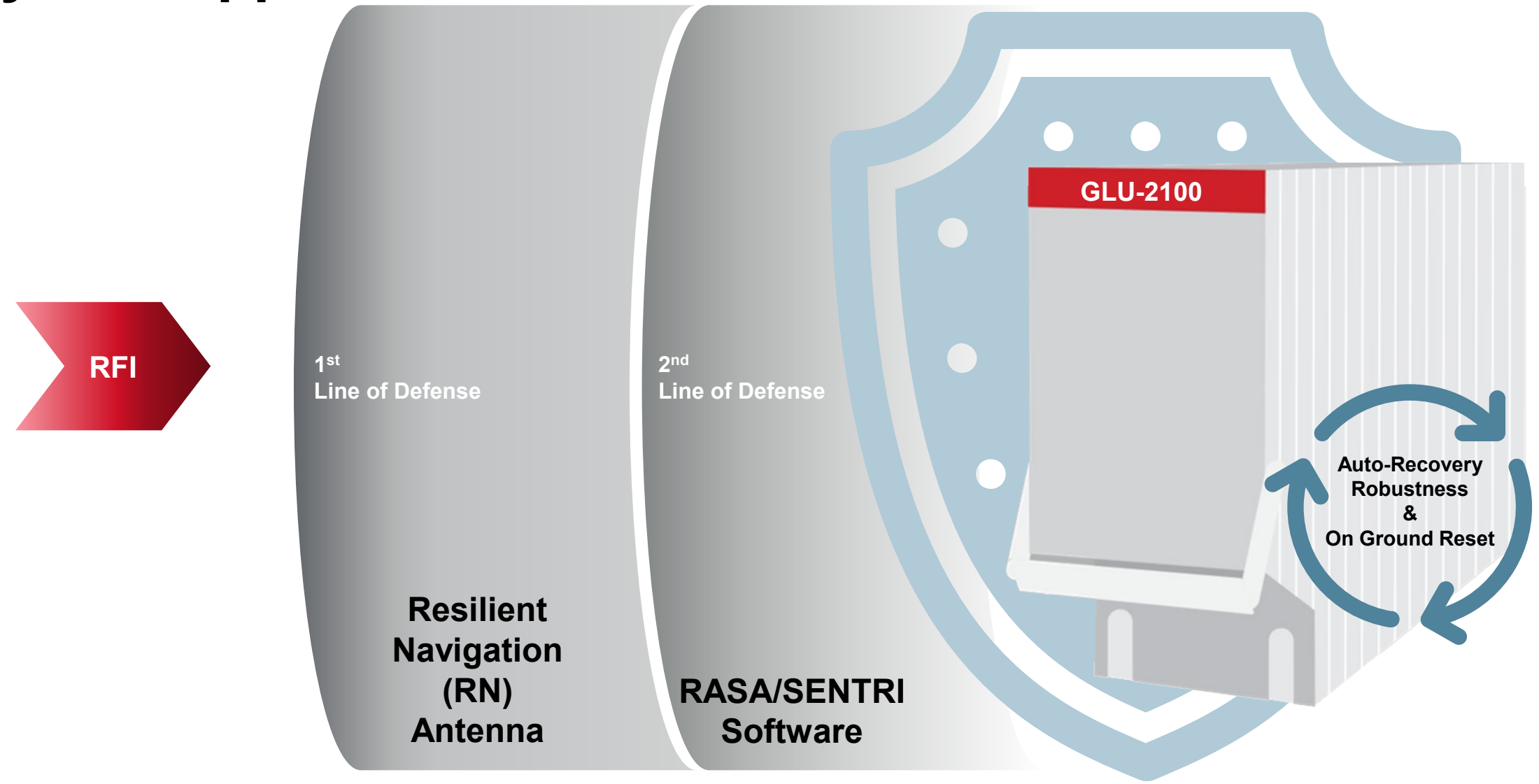
Layered Approach



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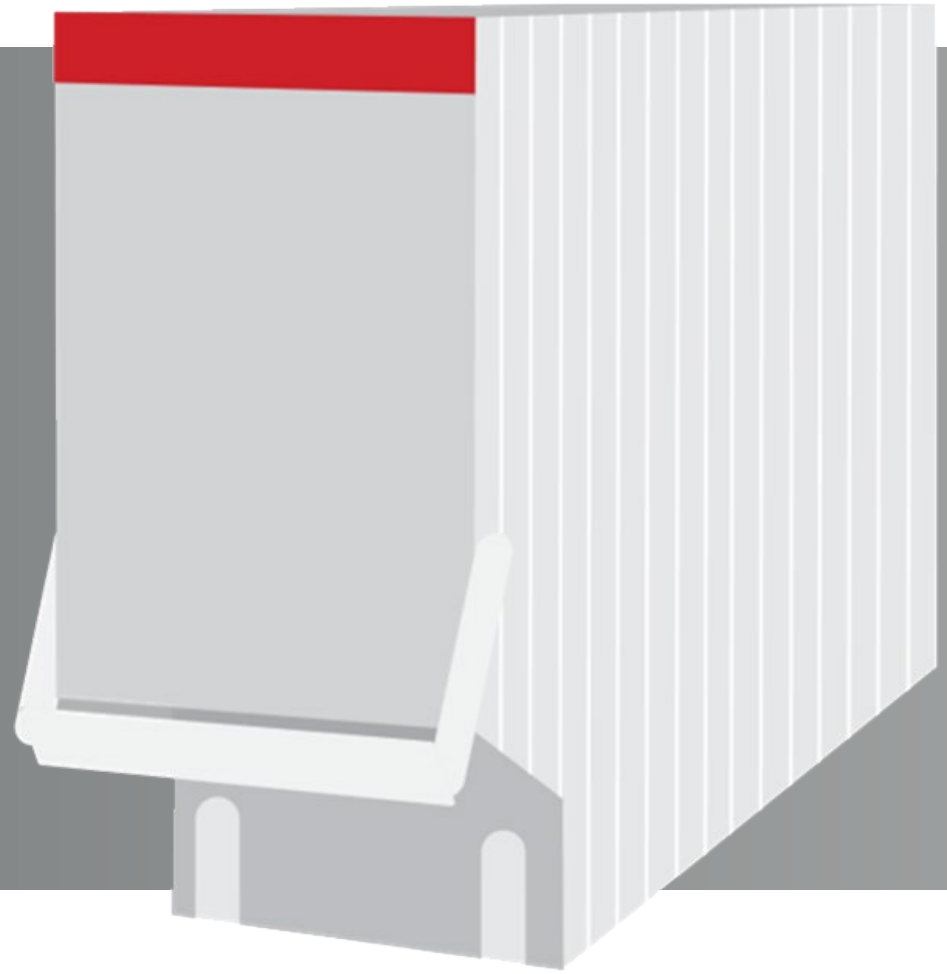
Collins GLU-2100 Multi-Mode Receiver (MMR)



- Growth Focused
  - Field-loadable, software-configurable packages
  - Adaptable to meet today and future needs: SBAS, LPV/SLS, RFI, DFMC, etc.
  - Future Development Capability Proven
    - Flew on B777 Eco Demonstrator
    - GLAD Global ARAIM for Dual Constellation
    - MUGG Multi-Mode GPS and Galileo Project
- Drop-in replacement for most existing MMRs
- Robust, DAL A hardware
- Reduced size, weight, & power requirements

Built for today – designed for tomorrow

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GLU Software Capability Progression

Current Software

	GLU-925	GLU-2100 Initial Version	GLU-2100 V2.6 (Boeing) L4.2 (Airbus)	GLU-2100 **Next SW** With Optional Detection and Mitigation feature	GLU-2100 Planned Future SW
Field Loadable SW	No	Yes	Yes	Yes	Yes
SBAS	A350 GLU-925S Only	Yes*	Yes*	Yes*	Yes*
GLS CAT 1	Yes	Option Enabled	Option Enabled	Option Enabled	Option Enabled
VOR and Marker Beacon	No	Yes*	Yes*	Yes*	Yes*
GLS CAT 2/3	No	No	Option Supported*	Option Supported*	Option Supported*
LPV	A350 GLU-925S Only	No	Option Enabled	Option Enabled	Option Enabled
DO-229E	No	No	Yes	Yes	Yes
RFI Improvement Robustness Improvements	No	No	Good	Better	Best
RFI Detection and Mitigation SENTRI & RASA	No	No	No	Option Enabled	Option Enabled
DFMC	No	No	No	No	Option Enabled

*Options may vary by OEM and platform

An evolving software solution for evolving needs

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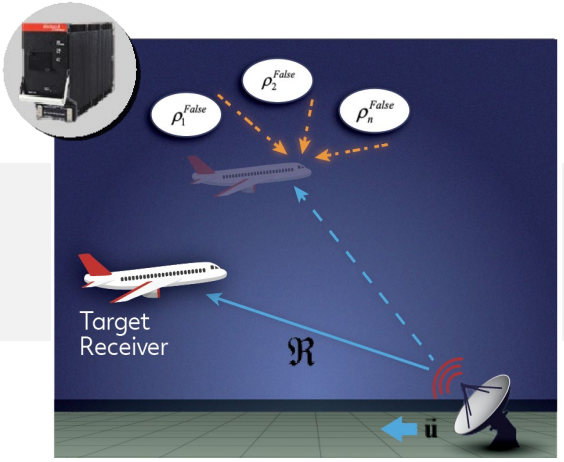
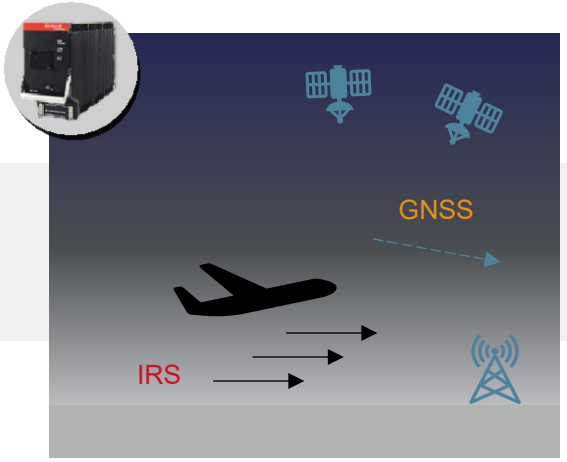
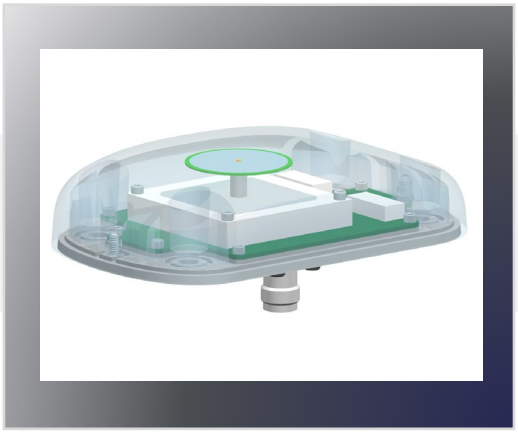
Resilient GNSS Technology
Current solutions for Commercial Aviation







GLU-2100 MMR
Multi-Mode Receiver
- Software-defined GNSS receiver
- Supports Satellite-Based Augmentation System (SBAS)
- Supports Ground-Based Augmentation System (GBAS)

RASA
Receiver Autonomous Signal Authentication
- Monitors receiver clock stability to detect spoofers

SENTRI
Staggered Examination Of Non-trusted Receiver Information
- Uses nav-grade Inertial Reference System (IRS) units on the aircraft together with GNSS data to detect spoofing

Concentric CRPA
2-Element Controlled Reception Pattern Antenna
- Meets ARINC 743 footprint and connectivity
- Retrofit compatible
- Power Compatible
- I/O to report Nulling Status
- Field loadable

Addresses jamming and spoofing challenges in commercial aviation

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RFI Detection and Mitigation Software In Development

UPCOMING SOFTWARE UPGRADE PACKAGE

- RFI Detection and Mitigation features introduced via field-loadable software update

- Utilizes the following techniques:
  - SENTRI (IRS-Aided Spoofer Detection)
  - RASA (Effect of Spoofer on receiver clock estimate)
  - Miscellaneous robustness improvements that handle corrupted time, ephemeris and almanac.

- Position error bounds (integrity levels) computed during coasting and when protecting against Spoofers
- Fine control of RFI detection and mitigation features using the OSS
- An antenna change is not required

Next Software Package Introduces RFI Detection and Mitigation capability

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Prototyping: RFI First Line of Defense

Resilient Navigation (RN) Antenna Solution

- Resilient Navigation antenna prototype underway at Collins
  - Prototypes are being tested for effectiveness in spoofing and jamming scenarios
  - Viability currently being determined
    - Navfest 2025 – positive results
    - Jammertest 2025 – positive results
    - Operator installing prototypes – performance data expected by early 2026

- Expected to be a drop-in replacement of existing GPS antenna
  - Dependent on regulatory and OEM design requirements

More information + timeline coming soon

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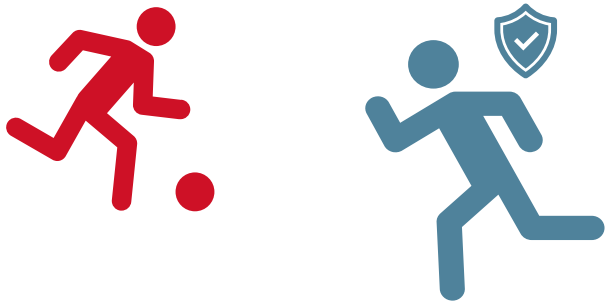
Two-Fold Approach: Strong Defense



Defenders: RN Antenna

- Will keep RFI (jamming & spoofing) from reaching the receiver most of the time
  - No anti-jam or CRPA antenna is foolproof

Goalie: RASA/SENTRI

- Last defense to defend the receiver from a spoofed signal
  - Prevents corrupt PVT from being used and distributed to the flight deck

Need both for a solid defense against RFI

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MUlti mode GPS and Galileo project
MUGG

GLU-2100 Future Potential Options

Evaluating & Prototyping

- Dual Frequency / Multi-Constellation Option (DFMC)
  - Upgradable via software and dual-frequency antenna
  - Additional navigation modes
  - Further RFI improvements
- MUGG Project
  - Extensive DFMC work being done by Collins in support of the European Global Navigation Satellite System Agency (GSA)

Exploration

- Alternate Position Navigation and Timing (APNT)
  - Use of non-GNSS APNT sources
  - Dependent on industry alignment, regulatory acceptance, and OEM Integration

GLU-2100 designed to grow for continued future flexibility

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MUGG Project: GLU-2100 –> DFMC Prototype

- The MUGG DFMC Prototype is built from Collins GLU-2100 Product and includes:
  - New navigation modes: DFMC SBAS PA/NPA, DFMC H-ARAIM, L5 H-ARAIM
  - Implementation of ED-259A MOPS acquisition and tracking requirements
  - Optimizations to DSP functions and resource re-allocations
  - Specific forced modes for test purposes…
- Why DFMC?
  - GPS L1/L5 and Galileo E1/E5a
  - Integrity of the GNSS solution is increased, meaning more trust can be placed in the accuracy of the PVT
  - Accuracy is improved thanks to less noisy measurements and the ability to remove some error sources such as ionospheric delay
  - Specifically in aviation, there is the possibility to operate at more airports in locations with limited or no ground-based landing systems or SBAS coverage
  - Increased resilience in case of an L1/E1 outage

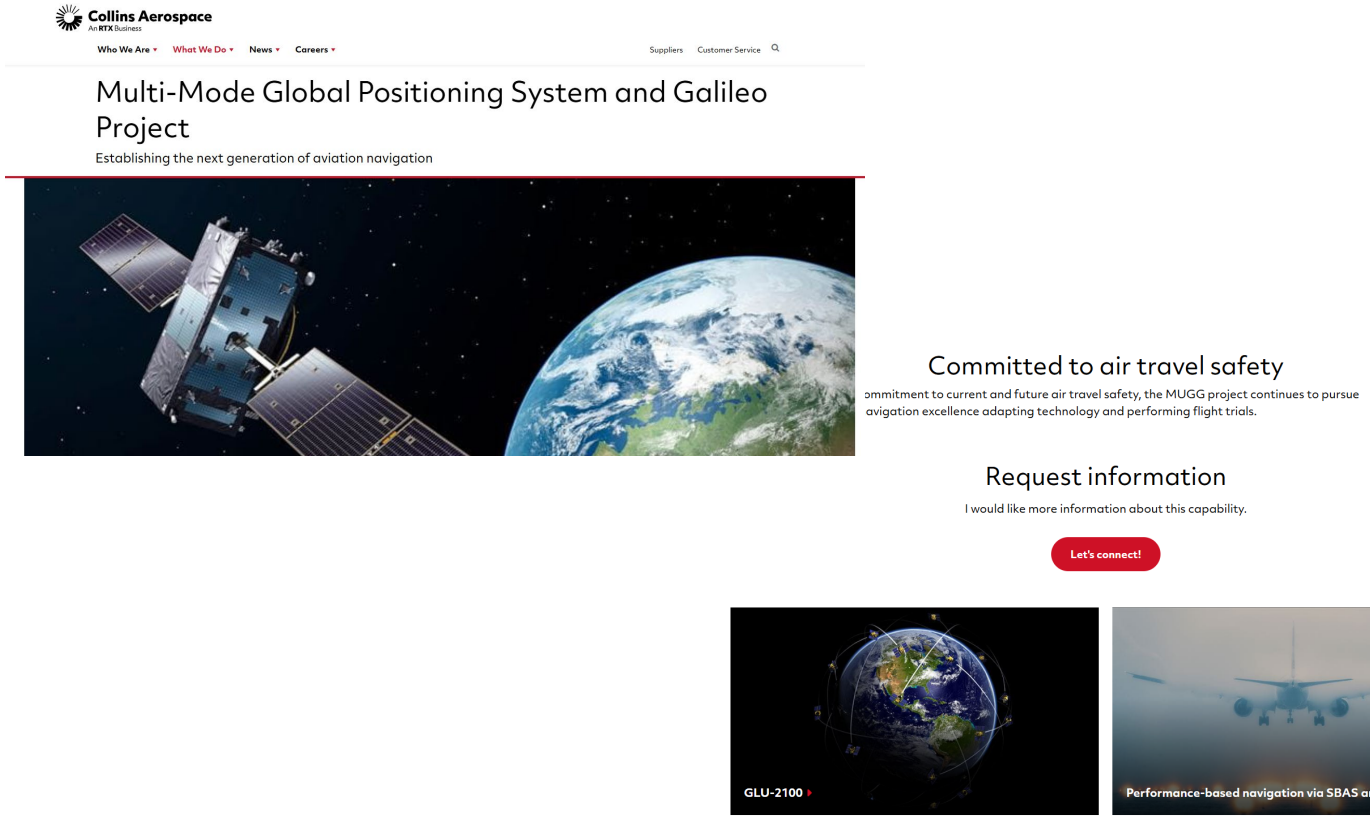
Project main achievements

- HARAIM
  - For the first time on the certified platform GLU-2100, H-ARAIM developed in the scope of MUGG have been demonstrated in a representative operational conditions
  - With improved Pconst for the Galileo constellation, a significant improvement for the Protection Levels performance would be achieved: down to 20 meters
- SBAS DFMC
  - MUGG project demonstrated the implementation of DFMC SBAS capability on an Avionics certified hardware platform
  - Comparison of L1 SBAS, GPS L1L5 SBAS and DFMC SBAS shows significant improvement for LPV and CAT1 coverage
- Implementation of MOPS in a representative avionics receiver is key to mature/consolidate MOPS requirements

For further information…

- MUGG project website:

[Multi-Mode Global Positioning System and Galileo Project | Collins Aerospace]



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Thank You!