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SAFE SKIES.
SUSTAINABLE FUTURE.

Building Resilient GNSS Receivers

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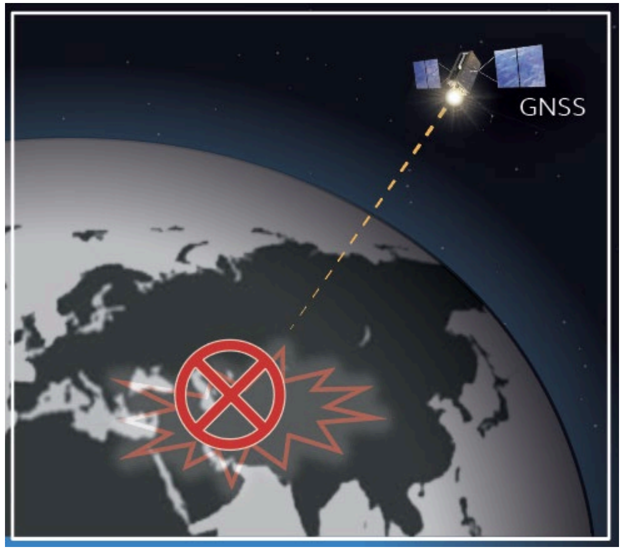
GNSS threats – Reported over last 2+ years

- Multiple RFI Reports received from the Field
  - Loss of GNSS for over 2 hours on some flights over the Middle East
  - Time Jumps noticed on Flights over the Syria/Iraqi Airspace
  - Corruption of GPS almanac observed on some flights near the Baghdad airport
  - Repeater based attacks observed on some flights in the Chinese Airspace
  - GPS interference observed in the Dallas Area
  - Spoofer attacks observed in the Baltic Region
- Attacks could result in
  - No impact.
  - Spoofing attacks that result in Time and/or Position Corruption.
  - 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 a factory reset.
  - Loss of a variety of functions (comm, surveillance, platform nav) at the aircraft level.



SPOOFING ISSUES REPORTED TO COLLINS

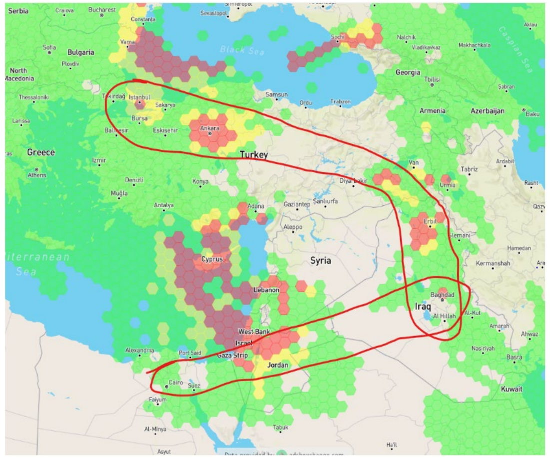
- Events observed on a periodic basis since December 2020
- RFI Events caused
  - Loss of GPS
  - Incorrect GPS position
  - Incorrect GPS date
- GPS time jumps forwards as A/C flies in and out of the spoofer region
- Loss of GPS occurs for many hours

No Spoof

Spoof
- Time advances ~12 hrs
- Loss of GPS or Position Error (depends on reset status)

No Spoof
- It will track correct satellites

- Following events observed on Collins GPS on XYZ Airways
  - Loss of GPS due to Jamming
  - Position Errors of up to 10 NM
  - Permanent loss of GNSS due to Spoofing
    - Corruption of almanac causes consistency checks to fail within the receiver



COLLINS GLU-2100 MULTI-mode receiver

- Collins GLU-2100 Multi-Mode Receiver
  - Level A certified to support SBAS, LPV, GLS CAT 1-2, ILS CAT 1-3, VOR and MB
  - Software defined GNSS Engine that uses Collins patented Universal Channel Technology to support all civil GNSS signals
  - Field Loadable to support DFMC SBAS and H-ARAIM
  - **Field Loadable to support RFI Mitigation techniques to perform jammer detection, spoofer detection and integrity coasting using NAV grade inertial data.**
  - **RASA and SENTRI are two techniques that are discussed**

COLLINS Phase 3 RFI TECH highlights

- Use of redundant techniques to ensure that the influence of Spoofed measurements on one technique can be detected by the other
- Ensures that Inertials cannot be initialized or blended with spoofed incorrect GNSS measurements
- Techniques allow robust recovery after exposure and flying out of Spoofed region
- Position Bounds that bound the position error that can go undetected by the Anti-Spoof Techniques
- Inertial Blending Architecture that can be easily extended when DFMC is introduced in the future

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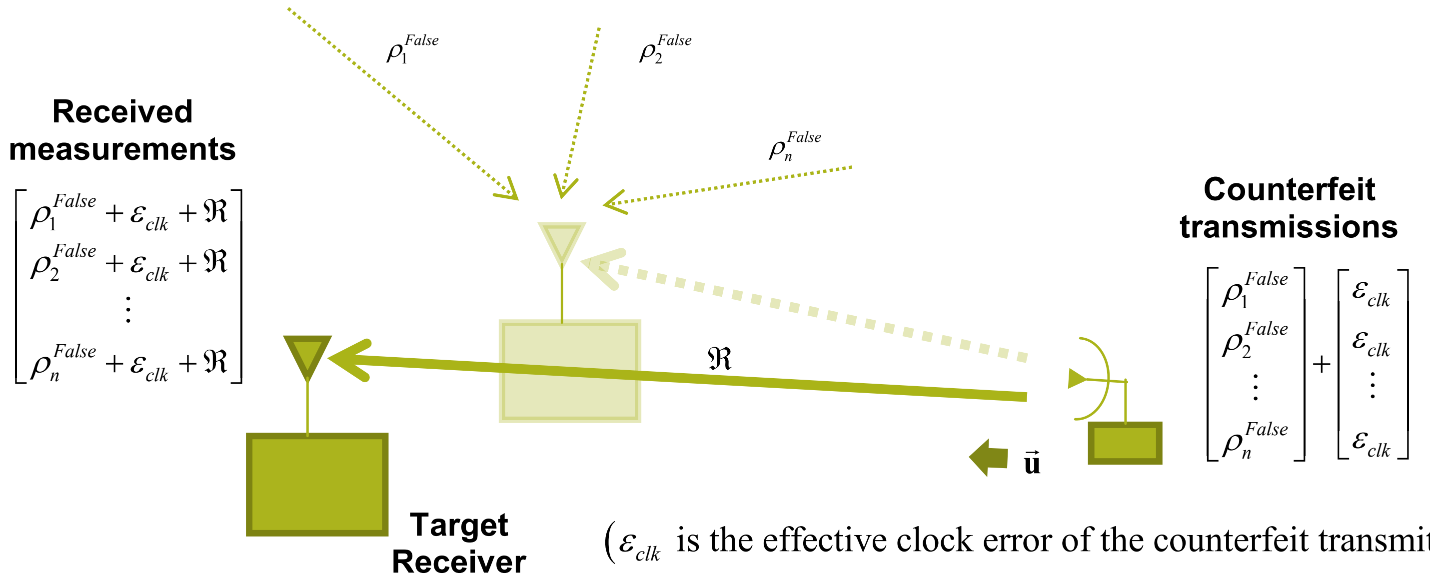
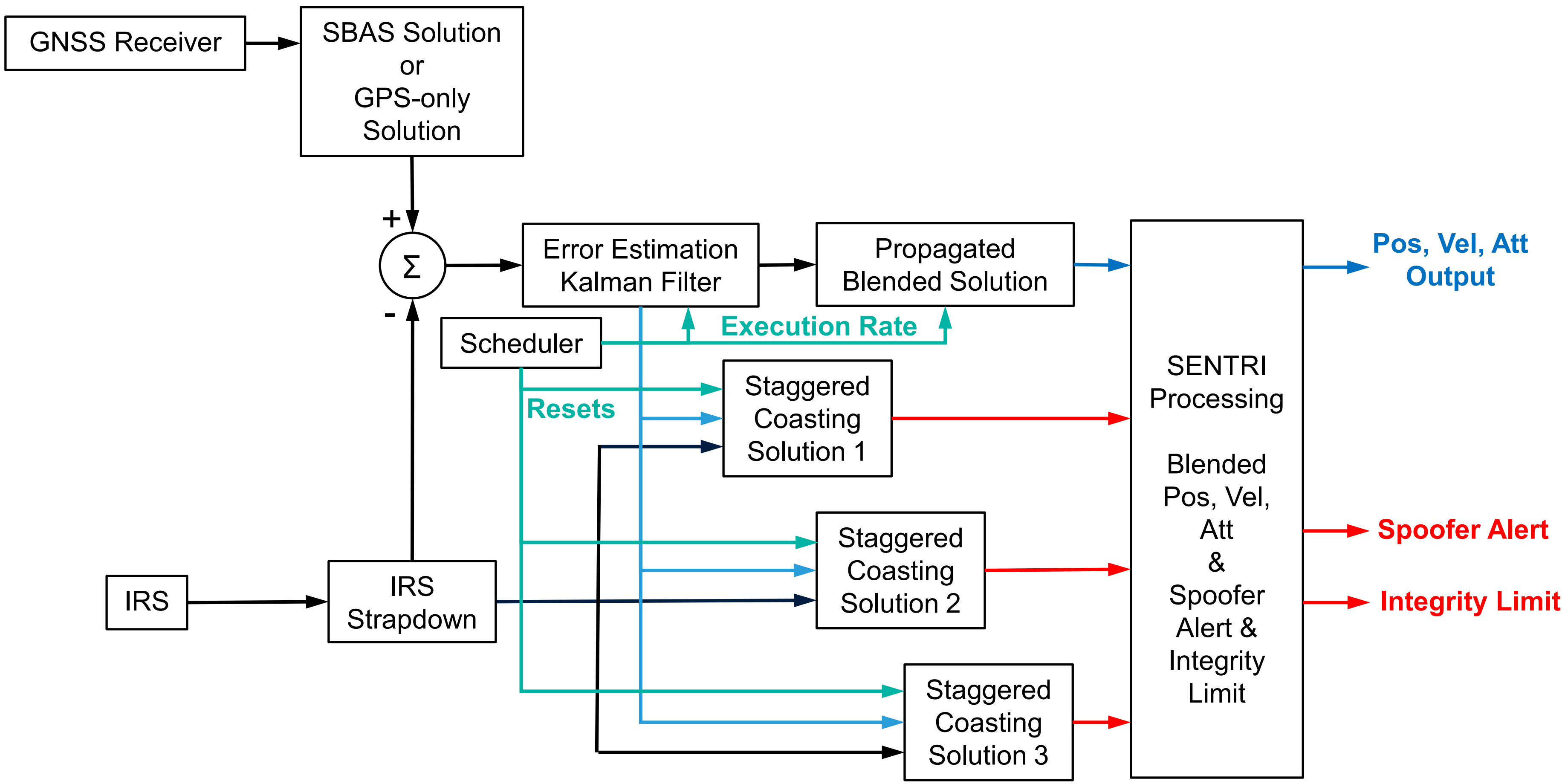
Receiver Autonomous Signal Authentication (RASA)



$(\varepsilon_{clk}$ is the effective clock error of the counterfeit transmitter$)$

Spoofer Detected by using the Spoofer's effect on the receiver's clock estimate

SENTRI (Staggered Examination Of Non-trusted Receiver Information)



Spoofer Detected by using divergence of Staggered coasted solutions from the Spoofer affected GNSS solutions

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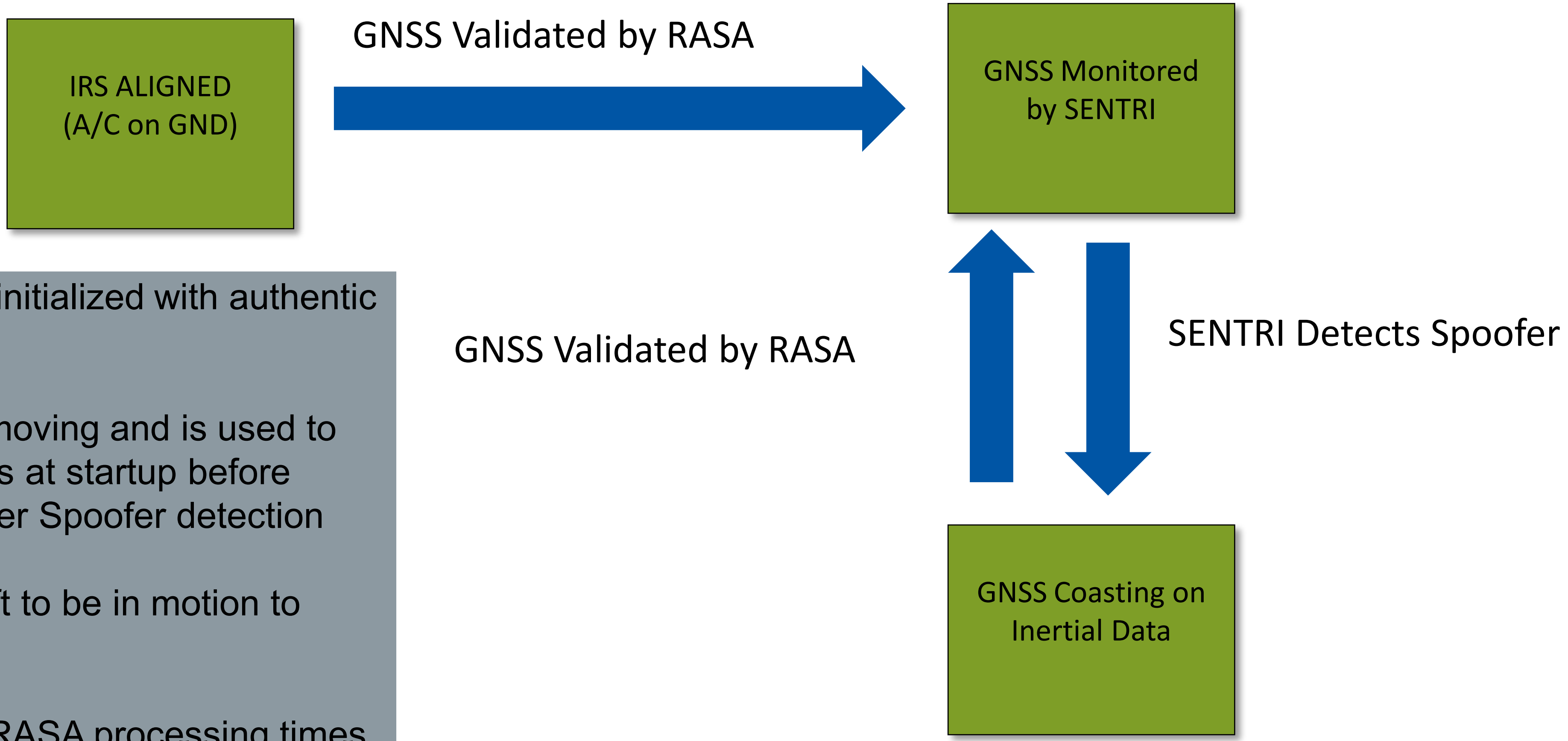
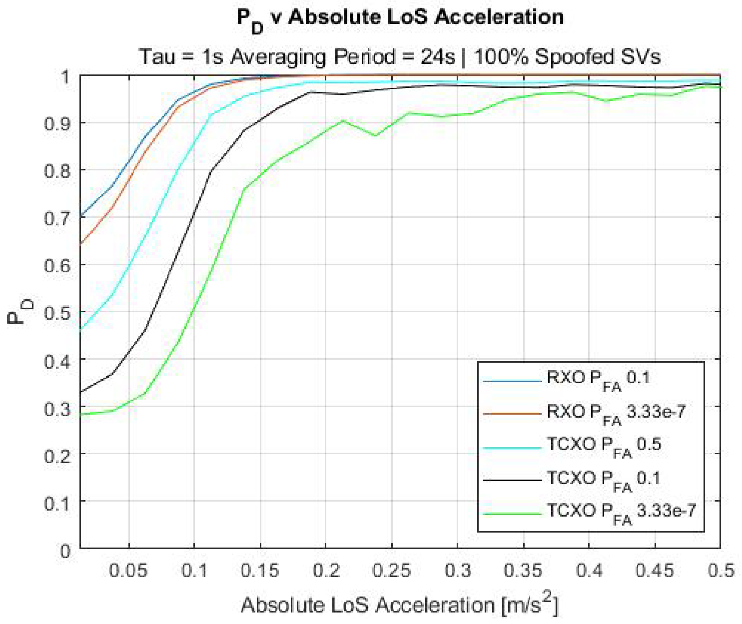
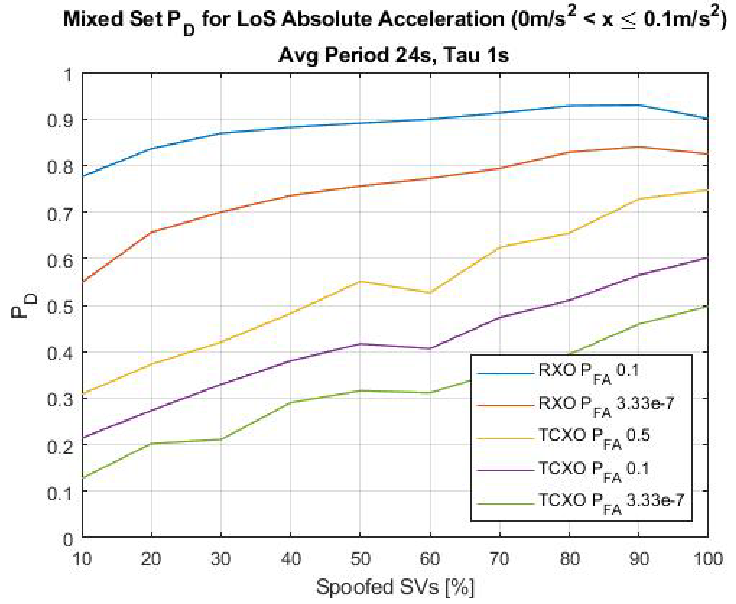
Optimal combination of SENTRI and RASA

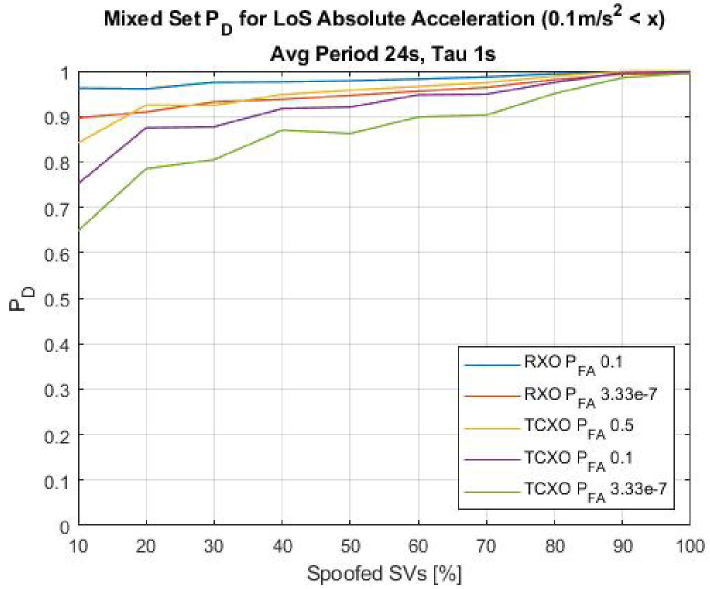


- SENTRI requires that it is initialized with authentic GNSS measurements
- RASA requires A/C to be moving and is used to pre-validate measurements at startup before initializing SENTRI and after Spoofer detection
- RASA also requires aircraft to be in motion to detect spoofers reliably
- Detection thresholds and RASA processing times are varied based on phase of flight and aircraft dynamics to maximize detection probability

Factors impacting RASA detection performance

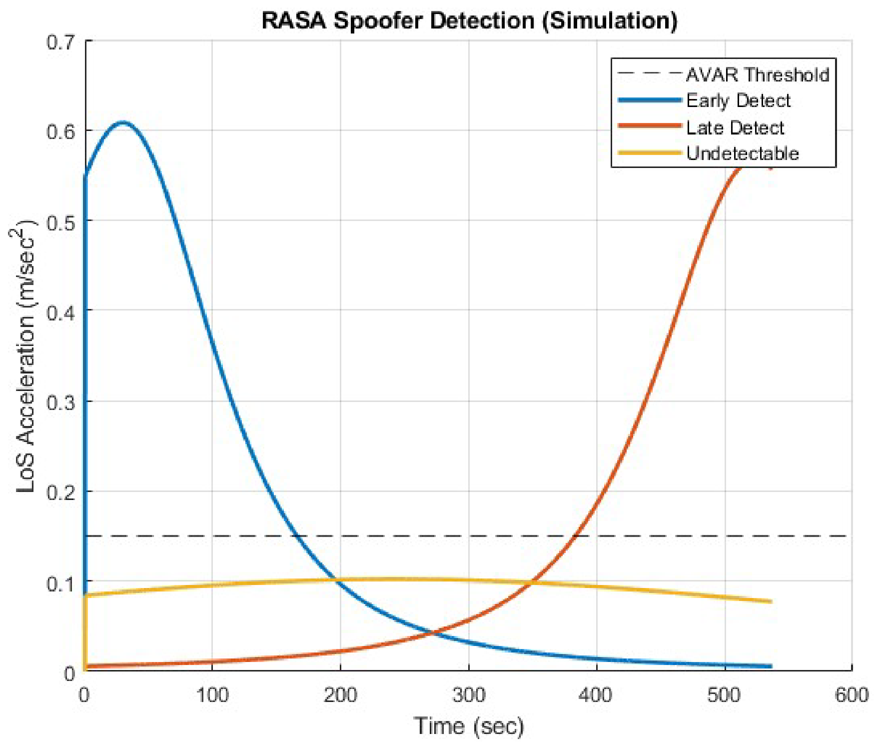


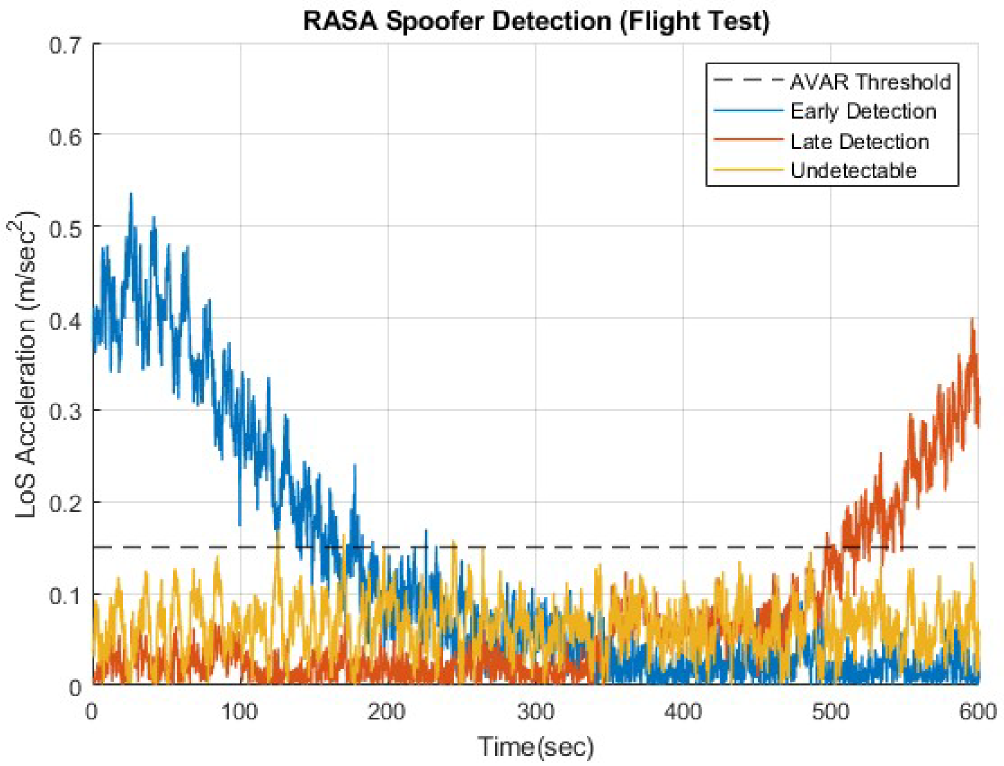




RASA performance compared against LOS acceleration and % of spoofed satellites when using a Rubidium standard oscillator and the GLU-2100 TCXO (Assume 5 deg C/min Ramp)

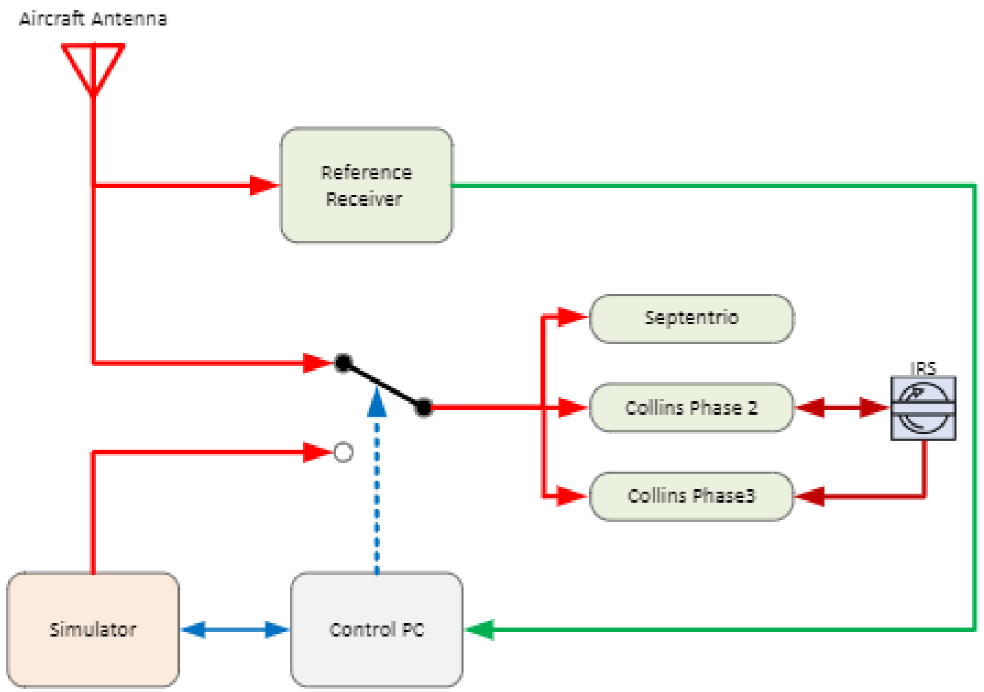
RASA Time to Detect – Line of Sight Acceleration analysis





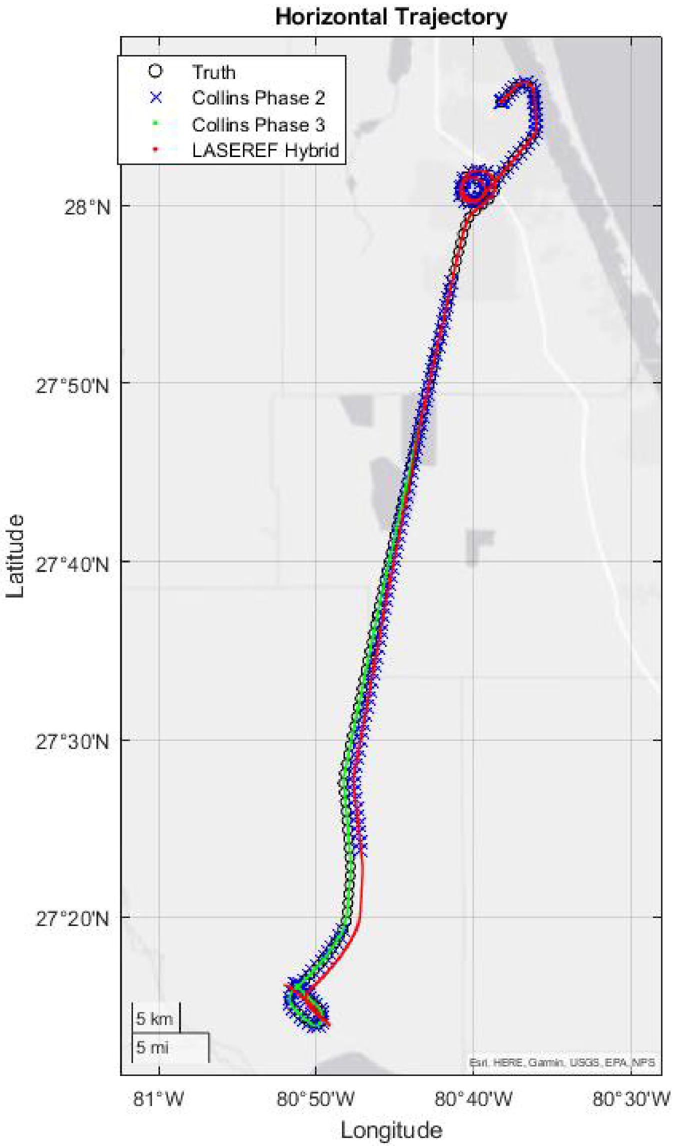
Flight Test verified that time to detect Spoofers varies based on LOS acceleration that is in turn dependent on Aircraft altitude and Ground speed

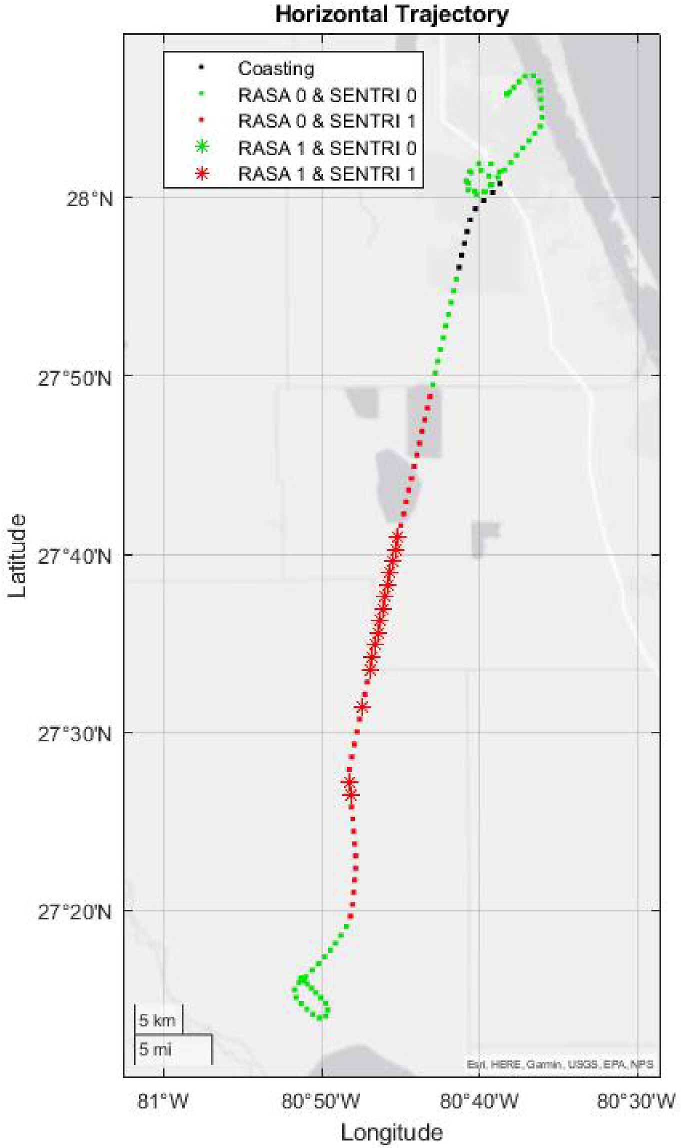
Live sky In Situ Spoofer testing



Flight Tests performed on the Collins Aerospace C208 aircraft

FLIGHT TEST KMLB to KOBE – 2 m/s DRIFT





Phase 2 and LASEREF position outputs impacted by the Spoofer

Collins Phase 2 vs Phase 3 vs LASEREF

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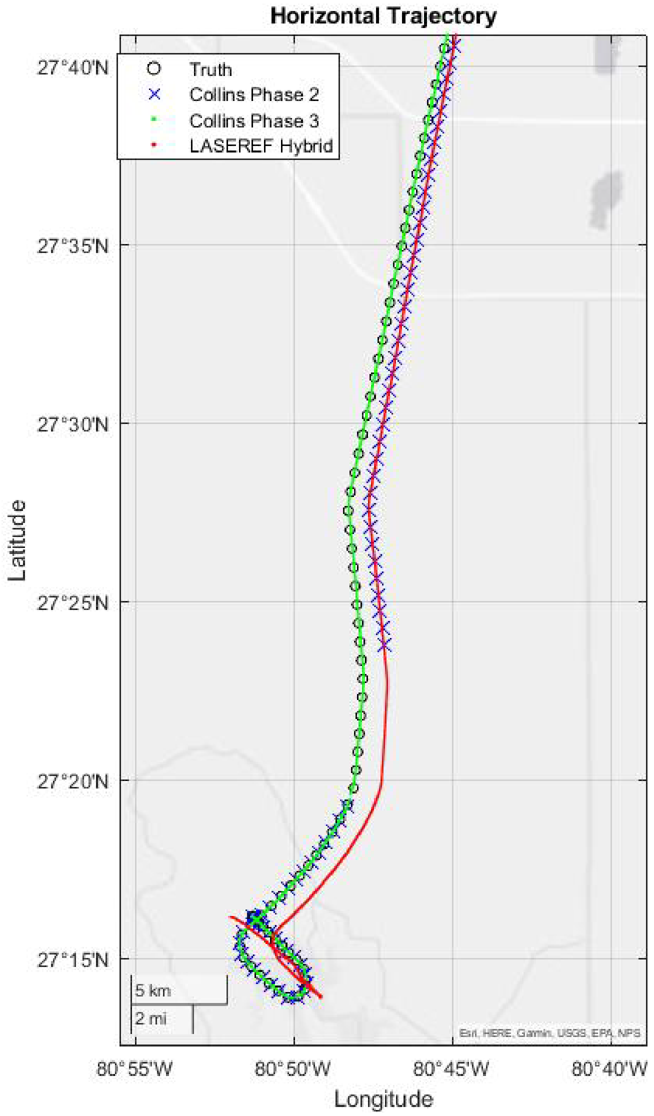

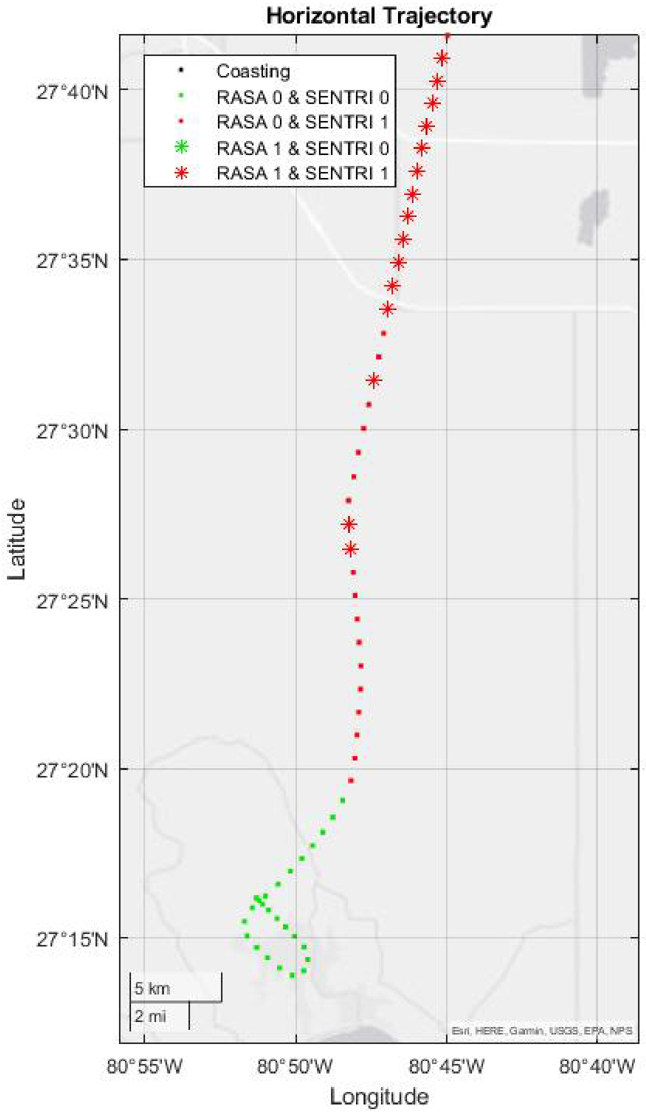

Collins Phase 2 vs Phase 3 vs LASEREF

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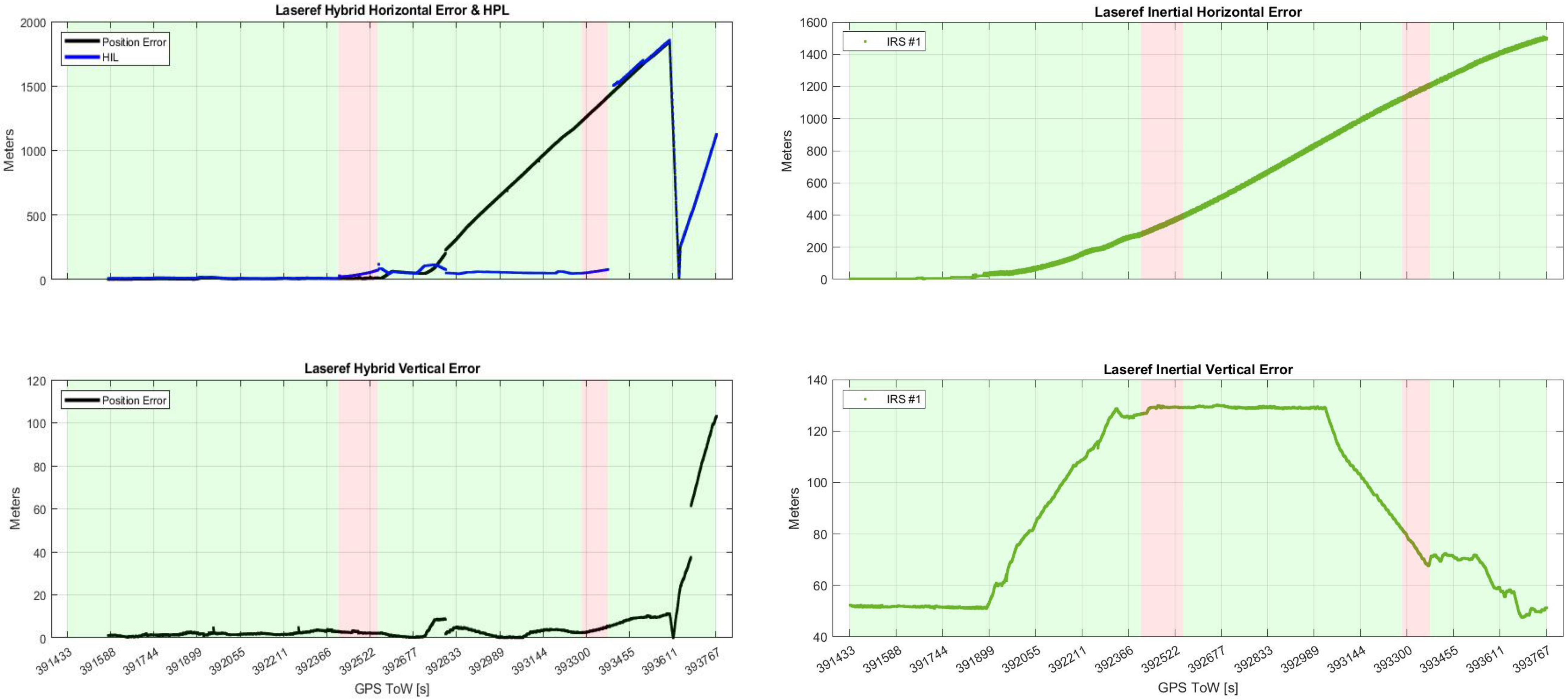

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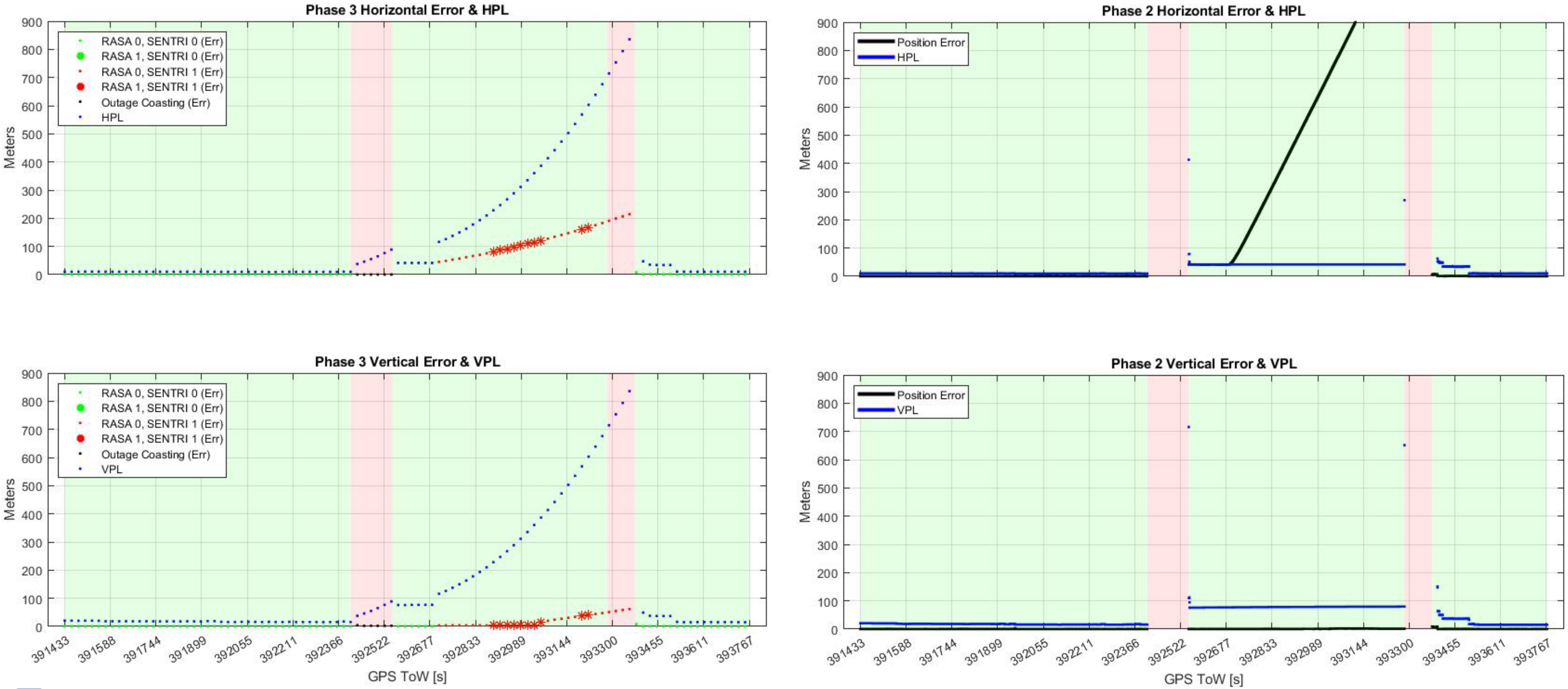
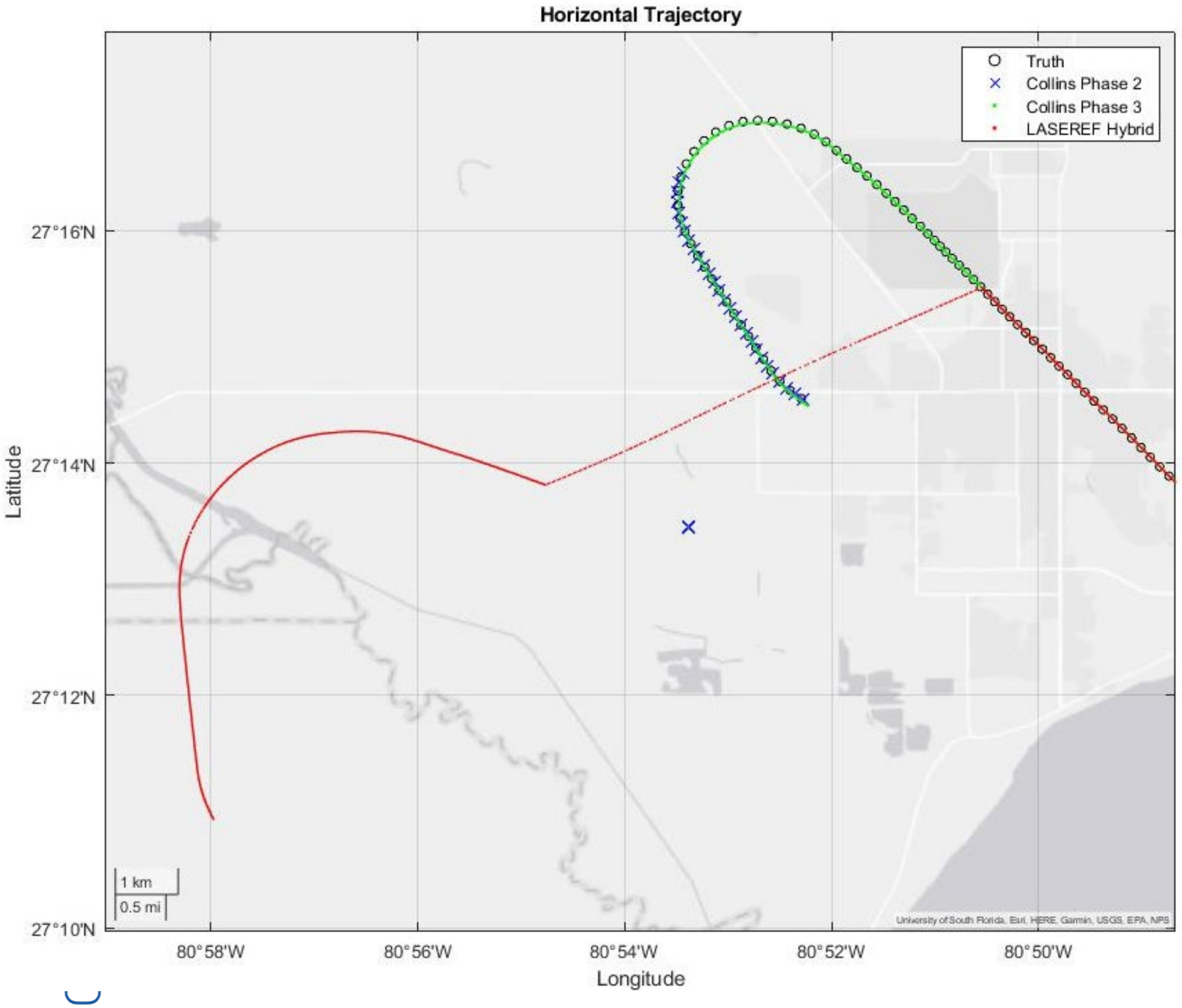
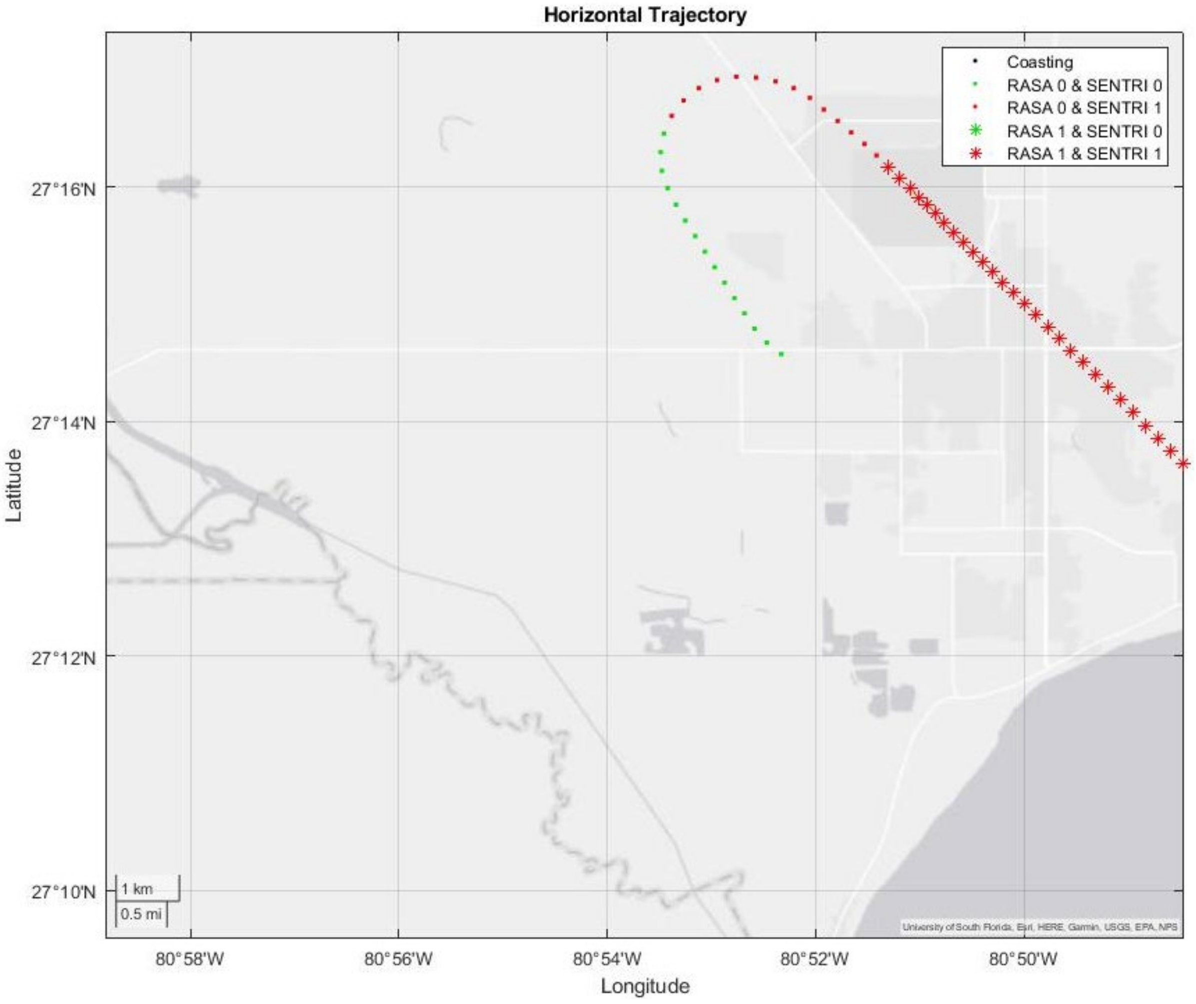


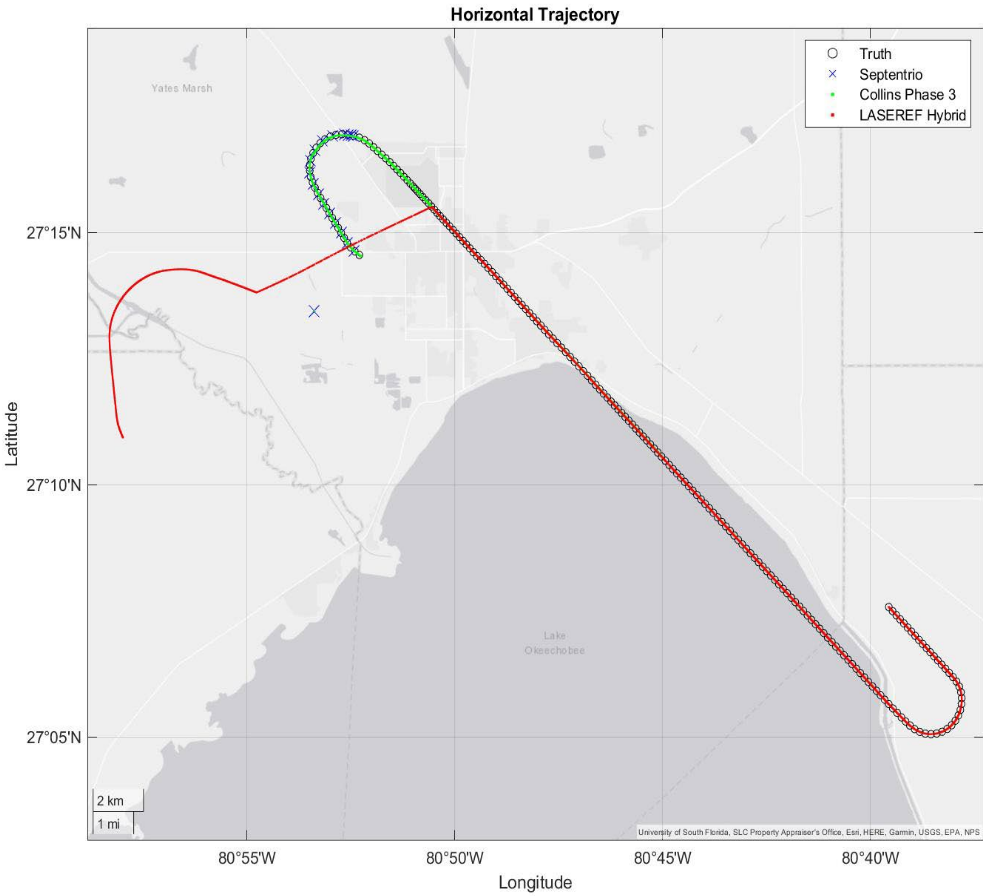
KOBE APPROACHES –Repeater

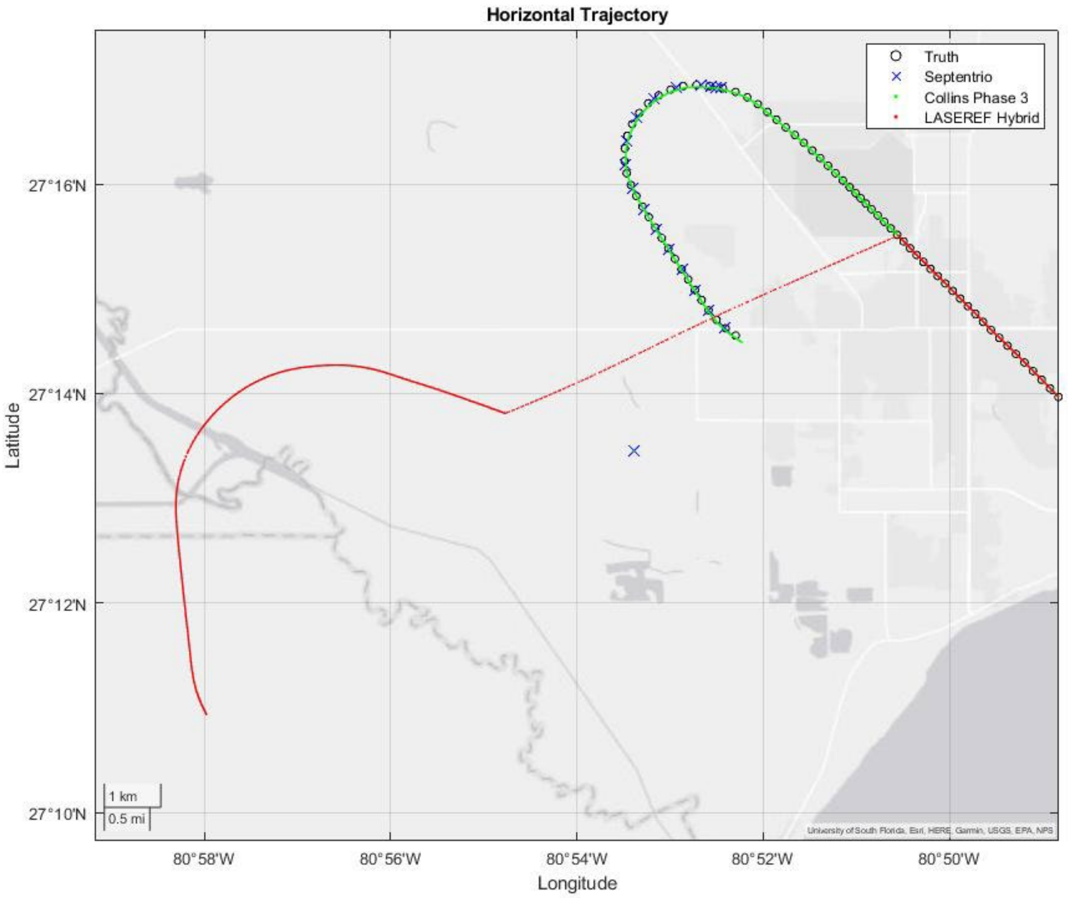




Collins Phase 2 vs Phase 3 vs LASEREF

KOBE APPROACHES –Repeater

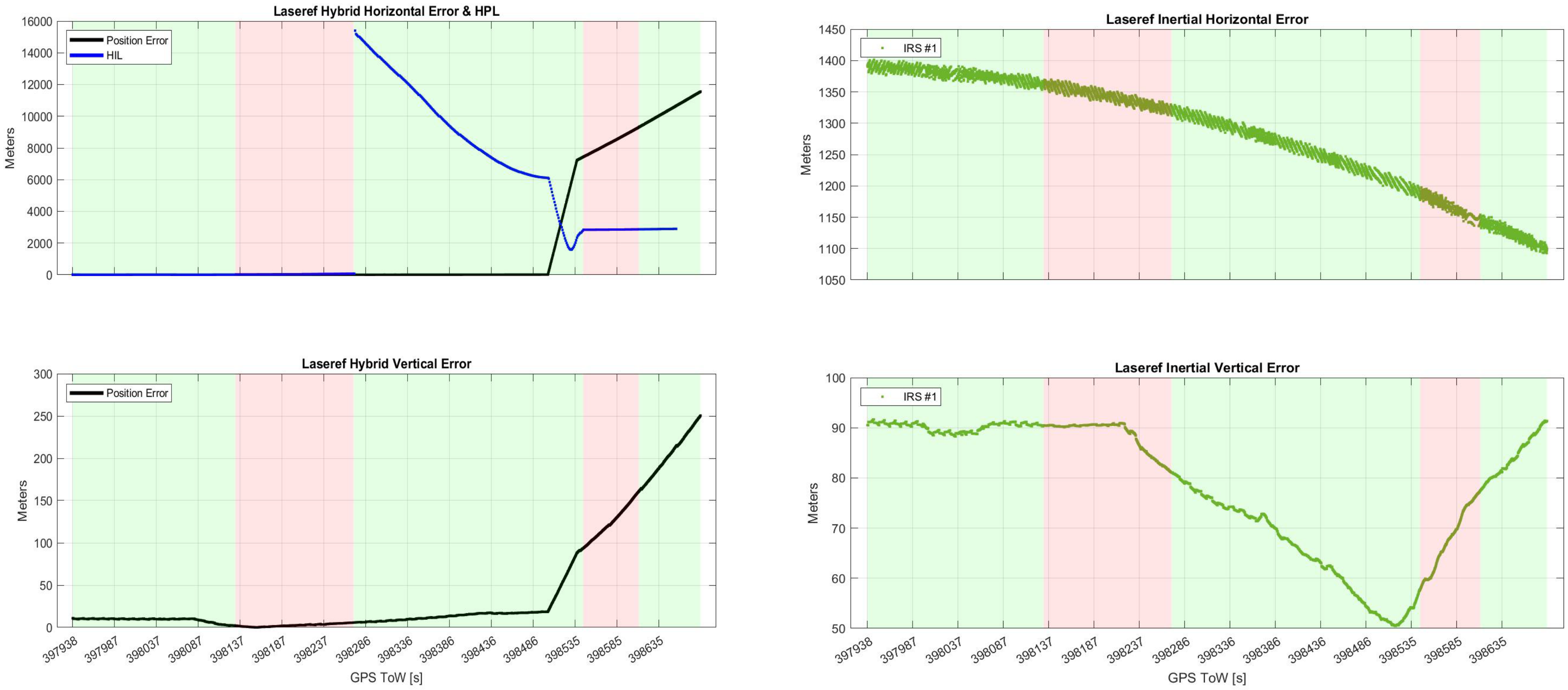




Septentrio and LASEREF position outputs impacted by the Spoofer

Septentrio vs Phase 3 vs LASEREF

KOBE APPROACHES – REPEATER



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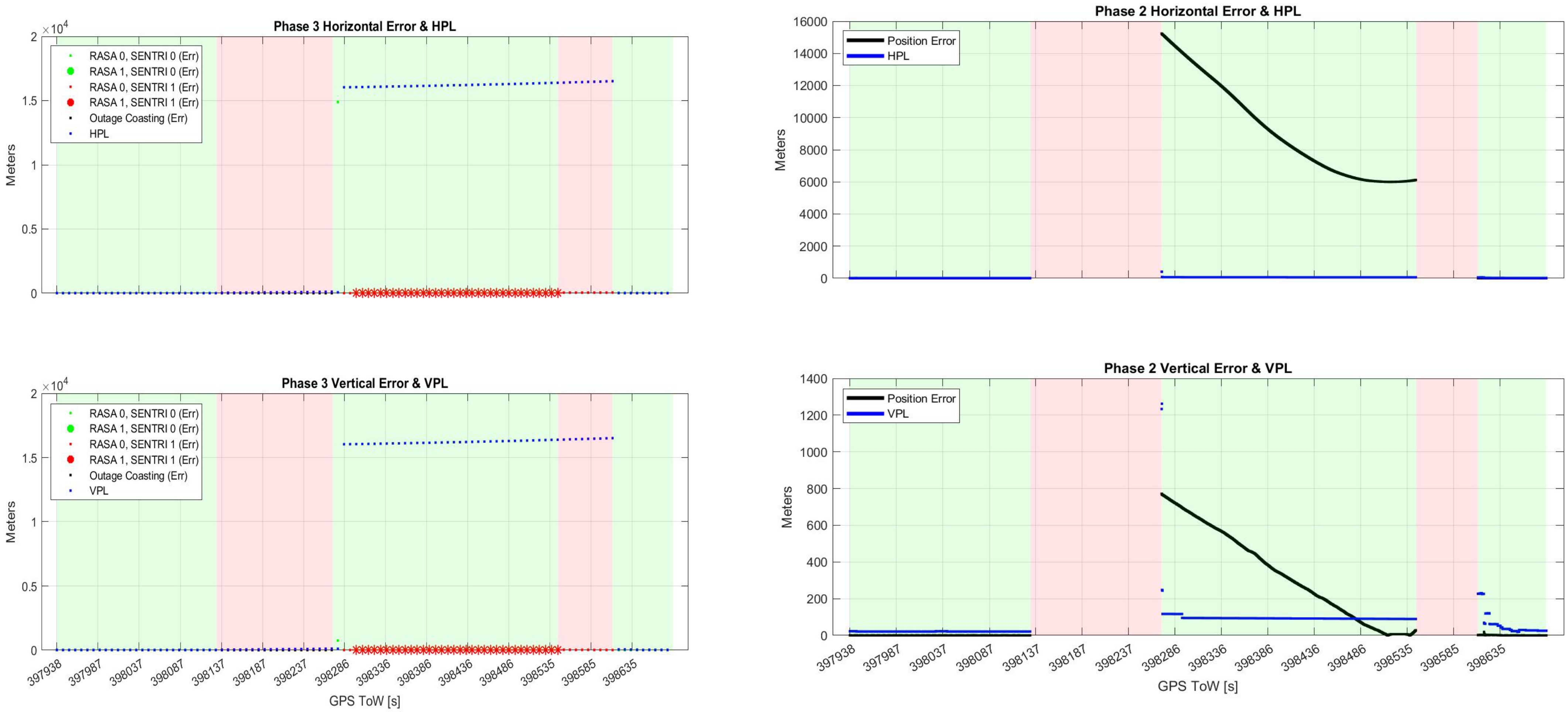

GNSS Receiver ROADMAP - Poised for Growth

2022 | 2023 | 2024 | 2025 | 2026 | 2027 | FUTURE

Phase 1
Baseline GNSS Functionality with SBAS and GLS CAT 1 (MMR)

Phase 2
GLS CAT II/III and LPV Database Hosting (MMR)

Phase 3
Resilient GNSS (MMR)

Phase 4
Dual-Frequency
Multi-Constellation (MMR)

Phase 5
APNT (MMR and /or new HW)

Conclusion

- Given the impacts to aircraft integration and airspace management, airborne GNSS Resiliency is needed in the immediate term.

- RASA and SENTRI are complementary PNT resiliency techniques that will improve the sensor resiliency of the Collins Aerospace GLU-2100 product to GNSS spoofing and jamming.

- Extensive Flight test results presented indicate the GNSS resiliency improvements that are expected due to the Phase 3 software update on the GLU-2100.

- Future technologies will leverage antenna techniques, signal analysis, DFMC + SBAS signals (with authentication) and APNT to increase the robustness to new and evolving threats.

- Collins Aerospace is committed to improving airborne GNSS resiliency leveraging both GNSS sensor and antenna techniques.

Team Members

- Cook, George – Principal Systems Engineer
- Griggs, Joseph – Senior Systems Engineer
- Malhotra , Vikram – Principal Systems Engineer
- Phan, Huan – Senior Principal Systems Engineer
- Joseph , Angelo – Senior Technical Fellow
- Schnaufer, Bernard, Ph.D. – Associate Director, Systems