

# 5G NTN E2E Testbed Integration in the OAI CI Process

A large, semi-transparent blue globe is centered at the bottom of the slide, showing the outlines of continents against a dark background.

**Ciprian Badescu**  
Lasting Software

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# Lasting Software

Ongoing/active projects  
Projects in preparation

## feature development projects

### ST Engineering iDirect

- satcom platforms
- technology incubator
- devices products

### ALL.SPACE

- feature development

## governmental projects

### European Protected Waveform

Active member and lead  
contributor of consortium

### IRIS2

Member of the bidding consortium

### Other GOVSATCOM

Member of other consortiums  
bidding for EU governmental  
projects

## LSW Products

### CELEOS

Multi-orbit Channel Emulator

### FLEX SPACE 5G NTN

5G NTN in-a-box testbed solution  
Virtual gNodeB & onboard  
processing

### ESA SPACE Innovation Hub

Hosting ESA Space Innovation  
Hub in Romania

# Lasting Software Products

## CELEOS

Multi-orbit Channel Emulator

### Emulated Channel Impairments

- delay
- doppler
- attenuation
- noise/interference (AWGN, 5G, DVBX)
- weather

### Special Features

- Digital Intermediate Frequency Interoperability (DIFI)
- Signal Metadata Format (SigMF) data recordings
- Two Line Element (TLE) satellite positioning format
- Terminal mobility

## FLEX SPACE 5G NTN

5G NTN in-a-box testbed solution

### 5G NTN E2E integration test environment

- virtualized OAI based CN/gNB/nrUE
- multi-orbit satellite channel emulation
- O-RAN SMO/RIC enabler

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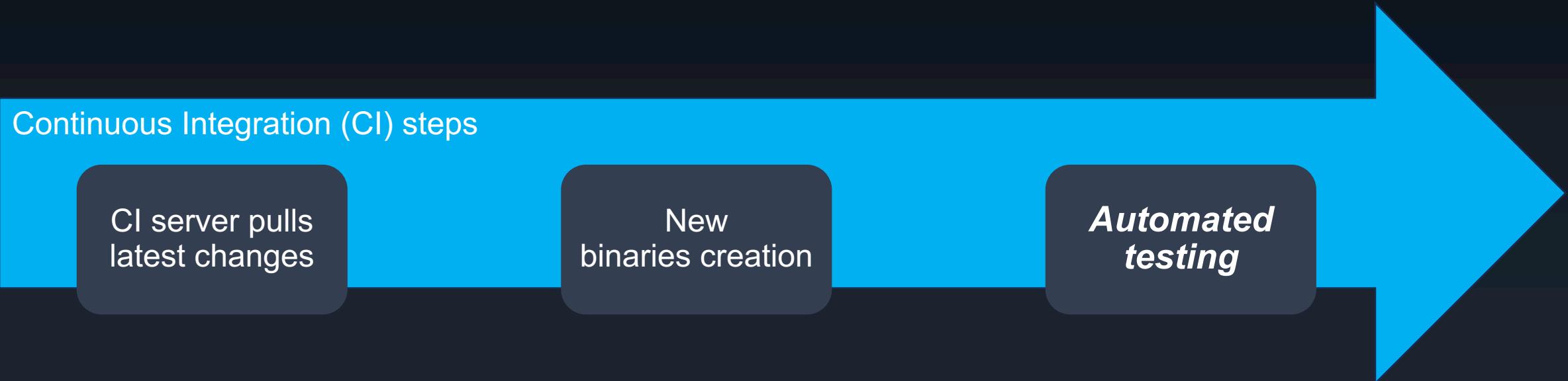
OAI CI overview

- Continuous Integration
- OAI CI Test Pipelines
- OAI CI Testbenches

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5G NTN E2E  
Testbench  
overview

# Continuous Integration



# Test Pipeline

Automated testing step definition

(Binary files + Test suite) / Test bench

# OAI CI Overview

## 5G Test Pipelines

- **RAN-PhySim-Cluster** (OpenShift, unitary simulators)
- **RAN-L2-Sim-Test-5G** (L2simulator, no physical layer)
- **RAN-RF-Sim-Test-5G** (RFsimulator, TDD 40MHz, FDD 40MHz, F1 split)
- **OAI-CN5G-COTS-UE-Test** (Attach/Detach, multiple PDU sessions)
- **RAN-Interop-F1** (Accelleran CU, OAI DU)
- **RAN-NSA-B200-Module-LTEBOX-Container** (basic NSA tests)
- **RAN-SA-B200-Module-SABOX-Container** (basic SA test, 20 MHz TDD)
- **RAN-SA-AW2S-CN5G**(Amarisoft UE)
- **RAN-SA-OAIUE-CN5G** (OAIUE, gNB running on containers)
- **RAN-gNB-N300-Timing-Phytest-LDPC** (performance test)
- **RAN-SA-AERIAL-CN5G** (OAI VNF + PNF/NVIDIA CUBB on Aerial2)

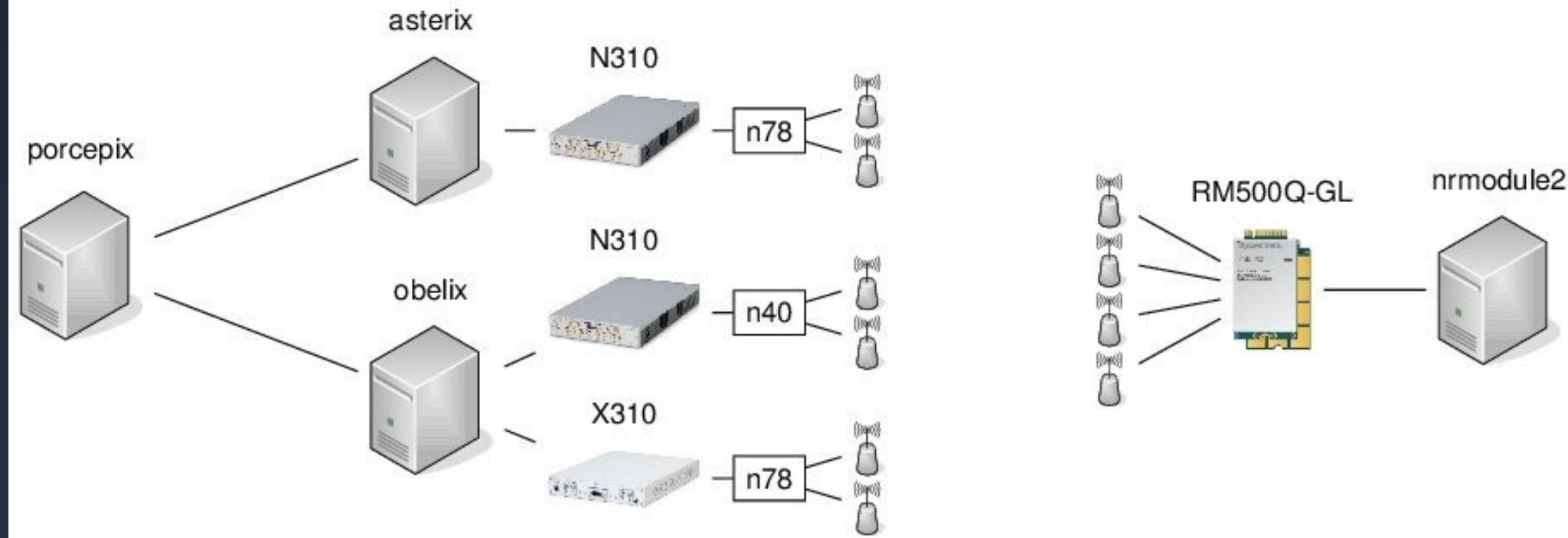
# OAI CI Overview

## 5G Test Benches

- 5G OTA Testbench
- 5G NSA/Faraday Cage Testbench
- 5G AW2S Testbench
- 5G UE OTA Testbench

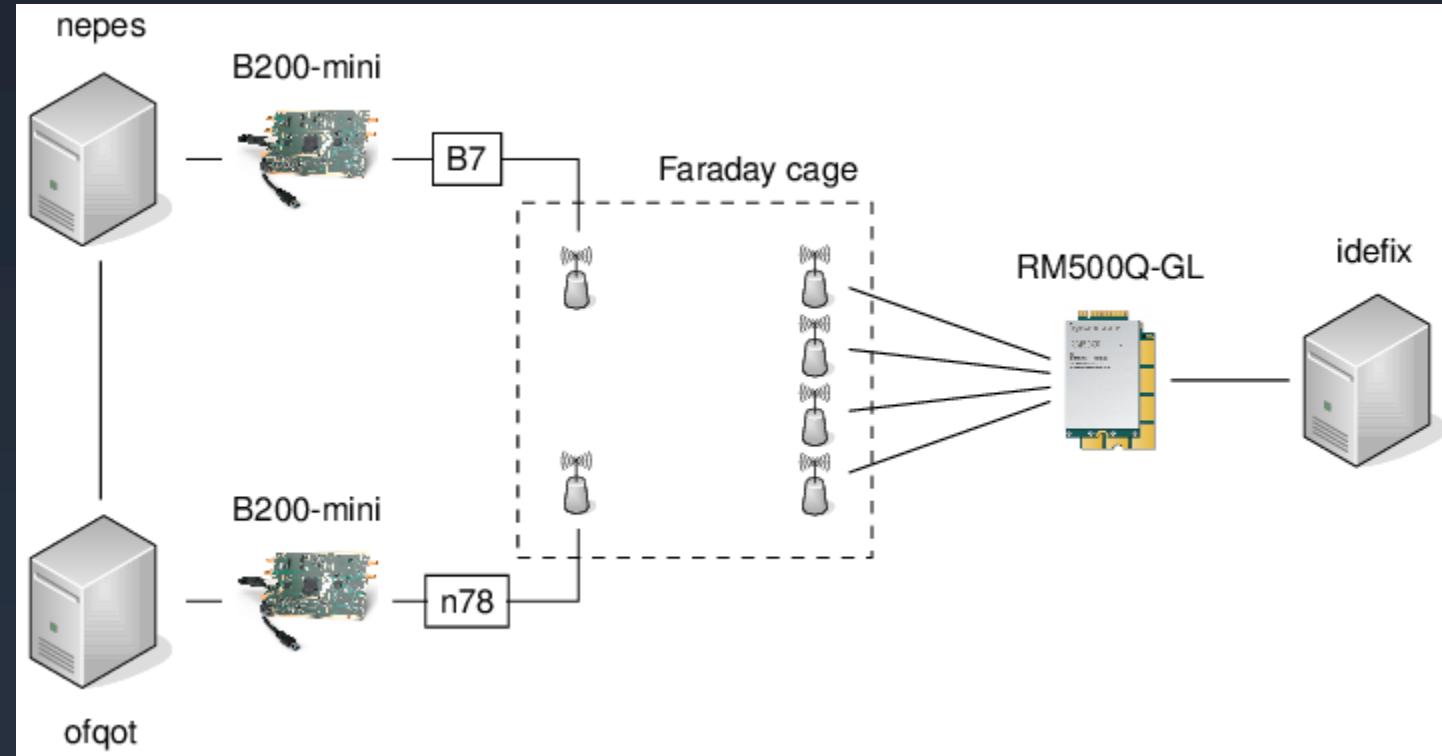
# 5G OTA Testbench

Purpose: Over-the-air 5G SA tests, performance tests



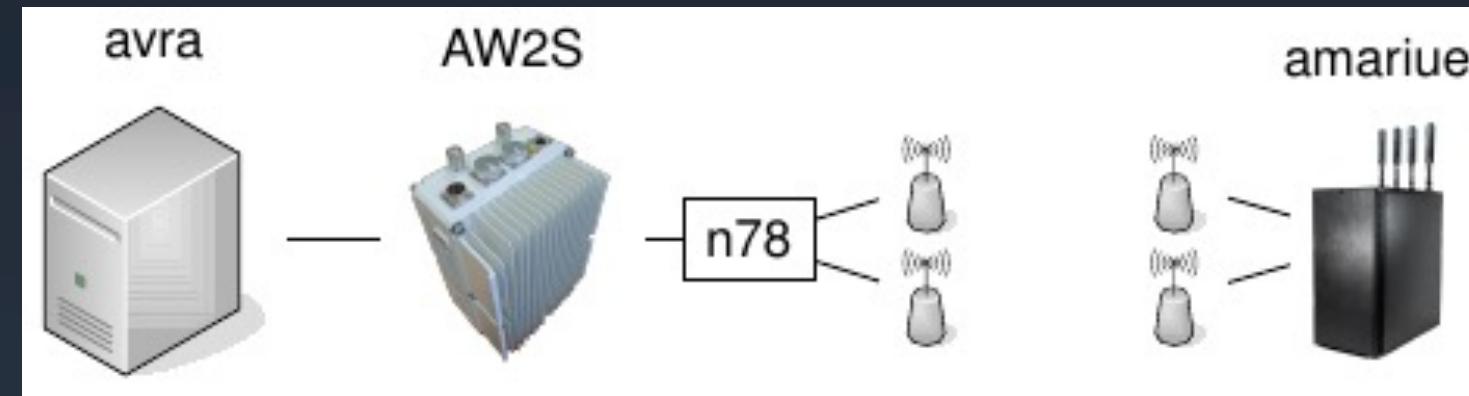
# 5G NSA/Faraday cage Testbench

Purpose: Faraday cage 5G tests, functional tests



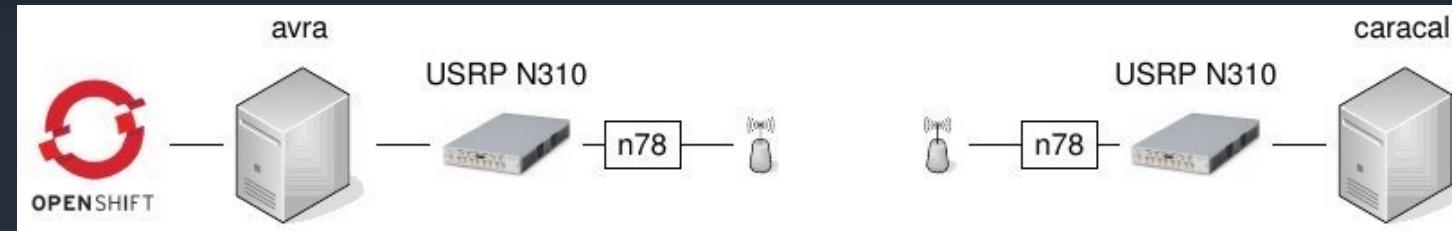
# 5G AW2S Testbench

Purpose: AW2S tests with Amarisoft UE simulator



# 5G UE OTA Testbench

Purpose: Over-the-air 5G tests with OAI UE



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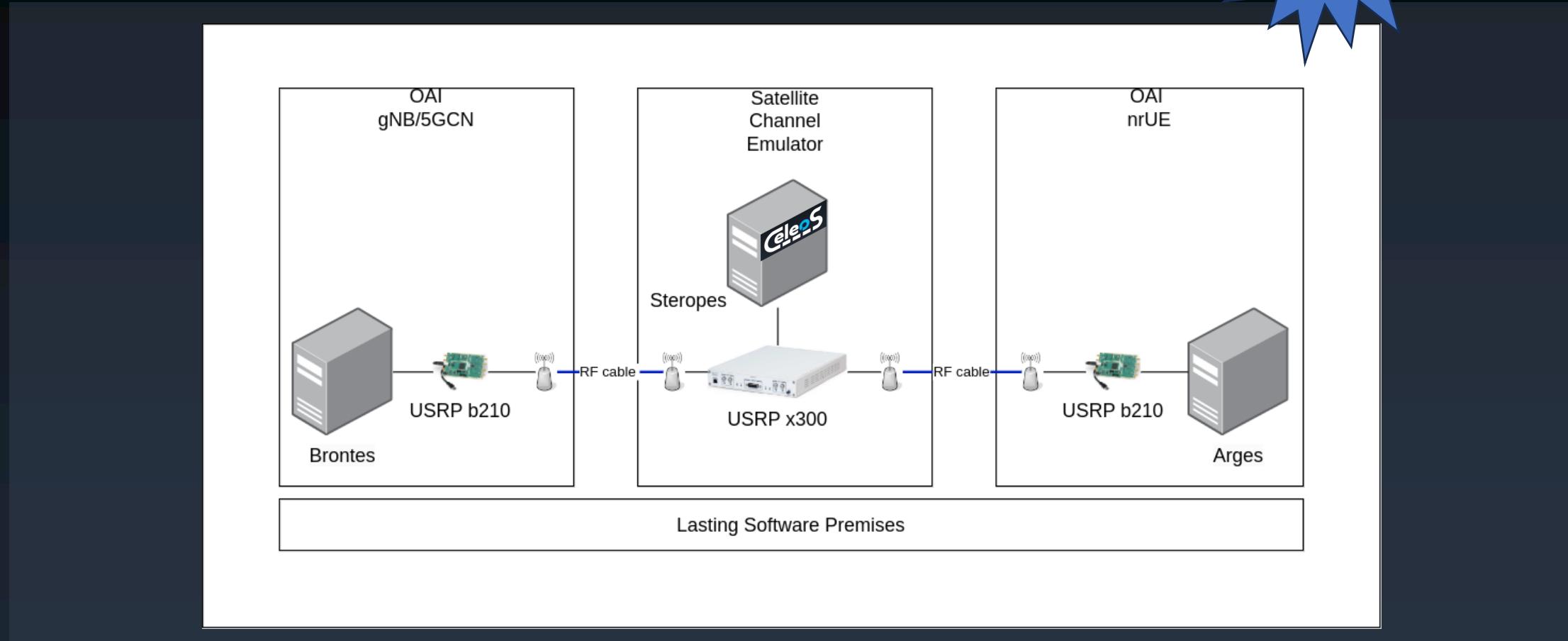
**5G NTN E2E  
Testbench  
overview**

- CELEOS Multi-orbit Satellite Channel Emulator
- 5G NTN E2E Test Pipeline
- 5G NTN E2E Testbench Evolution(s)

# 5G NTN E2E Testbench

Purpose: RF Test Cable 5G NTN tests with OAI UE

New



# CELEOS

## Multi-orbit satellite channel emulator - Impairments

### Delay

- Constant and variable delay support
- Variation rate supports the most challenging mobility use cases e.g. LEO
- Min: 2ms
- Max: 1000ms

### Path attenuation

- Constant and variable attenuation support
- Variation rate supports the most challenging mobility use cases e.g. LEO
- Range: 0dB to 70dB

### Noise/Interference

- AWGN and 5G/DVB-S2X interference support
- Two type of configurations:
  - fixed power
  - Specific SNR target level
- Custom noise could be added on request

### Weather effects

- Attenuation and phase change due to the atmospheric conditions support
- Clear sky
- Rain
- Heavy rain

### Doppler shift

- The most challenging scenario support: LEO in Ka band

### Phase noise

- Support of random changes to signal phase, configurable severity

### Doppler spread

- Rayleigh distribution support for non-line-of-sight path

### Satellite amplifier non-linearity

- Two amplifier model support:
  - Traveling wave tube amplifier
  - Solid-state power amplifier.

### Customer Specific Development

Impairments or features

#### Examples:

- RF antenna misalignment related to ground or satellite
- specific impairments: e.g. GEO in-box movement, helicopter

# CELEOS

## Multi-orbit satellite channel emulator - Special features support

### DIFI

- Digital Intermediate Frequency Interoperability protocol I/O (input/output)
- RF conversion to DIFI
- DIFI conversion to RF

### SigMF

- SigMF data recordings
- Recording of I/O as SigMF
- Import and export of recordings
- Conversion from RF/DIFI to SigMF and SigMF to RF/DIFI

### TLE

- Two Line Element satellite positioning format
- Automatic configuration based on TLE file: LEO/MEO/GEO
- Channel emulation depending on the satellite position, speed, and trajectory in time

### Terminal mobility

- Configuration of static and moving terminals together with moving satellite (TLE)
- Possibility to integrate with navigation database (maps)

# CELEOS in 5G NTN E2E Testbench

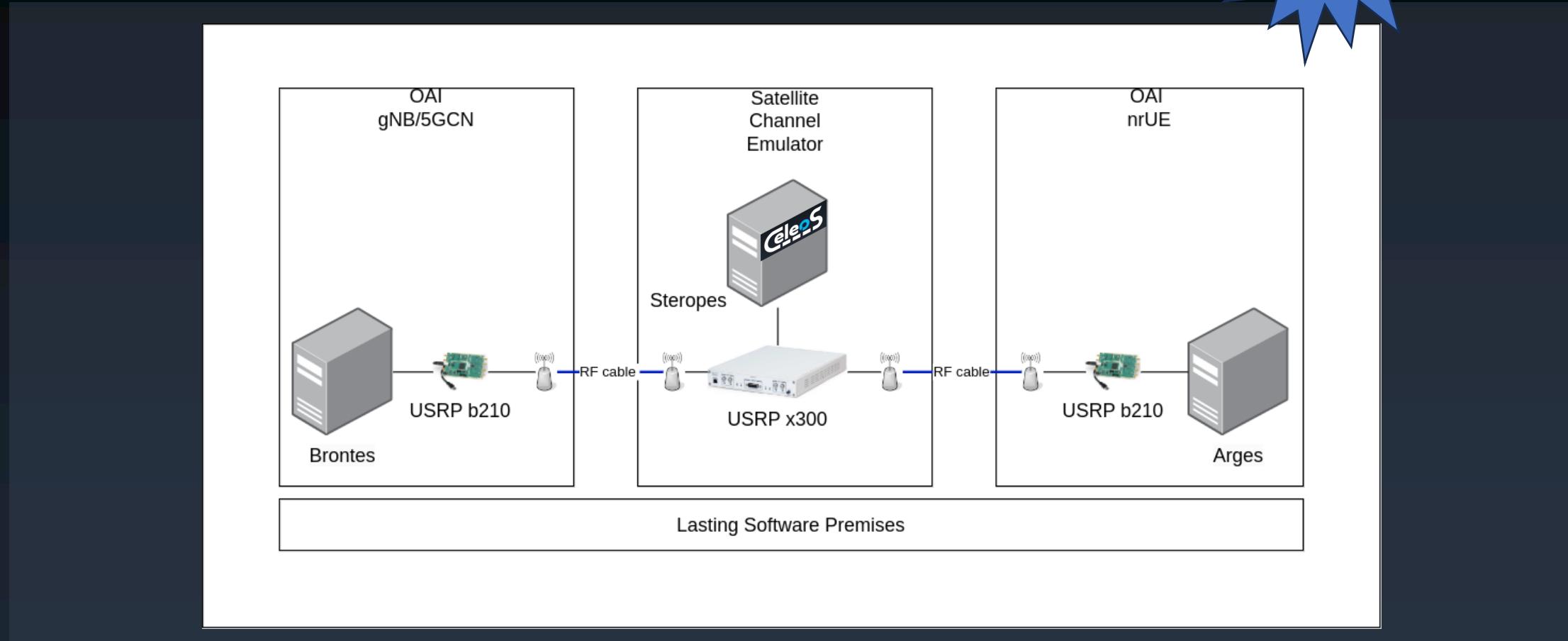
## Multi-orbit satellite channel emulator - Setup options

- **Orbit type** (LEO / GEO)
- **Uplink frequency band** (S / C / Ku / Ka), **downlink frequency band** (S / C / Ku / Ka)
- **Rx and Tx central frequencies**
- **Bandwidth 5/10/?? MHz**
- **Pre-defined noise profile** (enabled or disabled)
- **In-box movement** (enabled or disabled, only for GEO orbit type)

# 5G NTN E2E Testbench

Purpose: RF Test Cable 5G NTN tests with OAI UE

New



# 5G NTN E2E Test Pipeline

Using 5G NTN E2E Testbench



Use binaries from *leo-5g-ntn* branch (initially) and/or from develop branch (when NTN support is merged)

- **CELEOS** channel emulator custom development to orchestrate interaction with UE (initial attach)

## Automated Tests

- UE Attach
- Ping
- UDP uplink/downlink traffic using Iperf

# 5G NTN E2E Testbench

## UDP encapsulated IQ samples

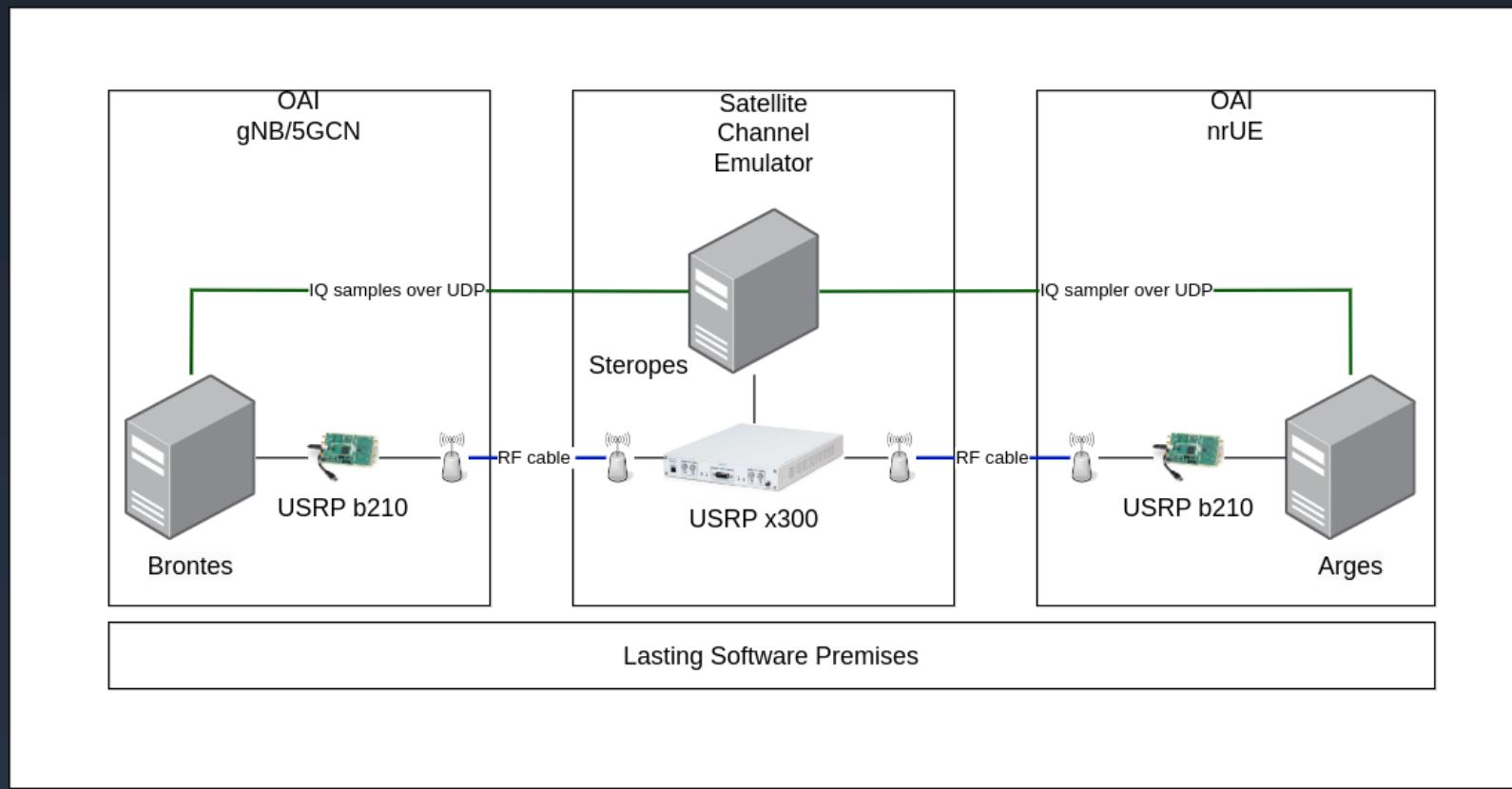


Evolution

- Use UDP encapsulated of IQ Samples between gNB/UE and **CELEOS** Channel Emulator (instead of USRP SDRs)
- Easier to scale without dependency to USRP SDR (BW/number of channels)
- Running E2E NTN 5G simulation on development workstations (intermediate step)
- DIFI integration enabler

# 5G NTN E2E Testbench

**UDP encapsulated IQ samples**



Evolution

# 5G NTN E2E Testbench

## Virtualized E2E NTN 5G simulation

- Run all components (gNB/UE/Channel Emulator) on virtualized environment
  - Using UDP encapsulated IQ samples
  - Based on virtualized **CELEOS** satellite channel emulator
- Provide images to run virtualized E2E NTN 5G simulation on development workstations



Evolution

# 5G NTN E2E Testbench

## Take aways

- CELEOS/OAI 5G NTN E2E Testbench can be used to validate OAI 5G NTN non-regression/smoke tests or basic scenarios
- **CELEOS** multi-orbit Satellite Channel Emulator for various use cases:
  - Virtualization
  - UDP Encapsulation/DIFI
  - Custom Channel Impairments
- Virtualization and IQ Samples over UDP enables E2E NTN 5G simulation on development workstations

# Thank you!



lasting  
s o f t w a r e