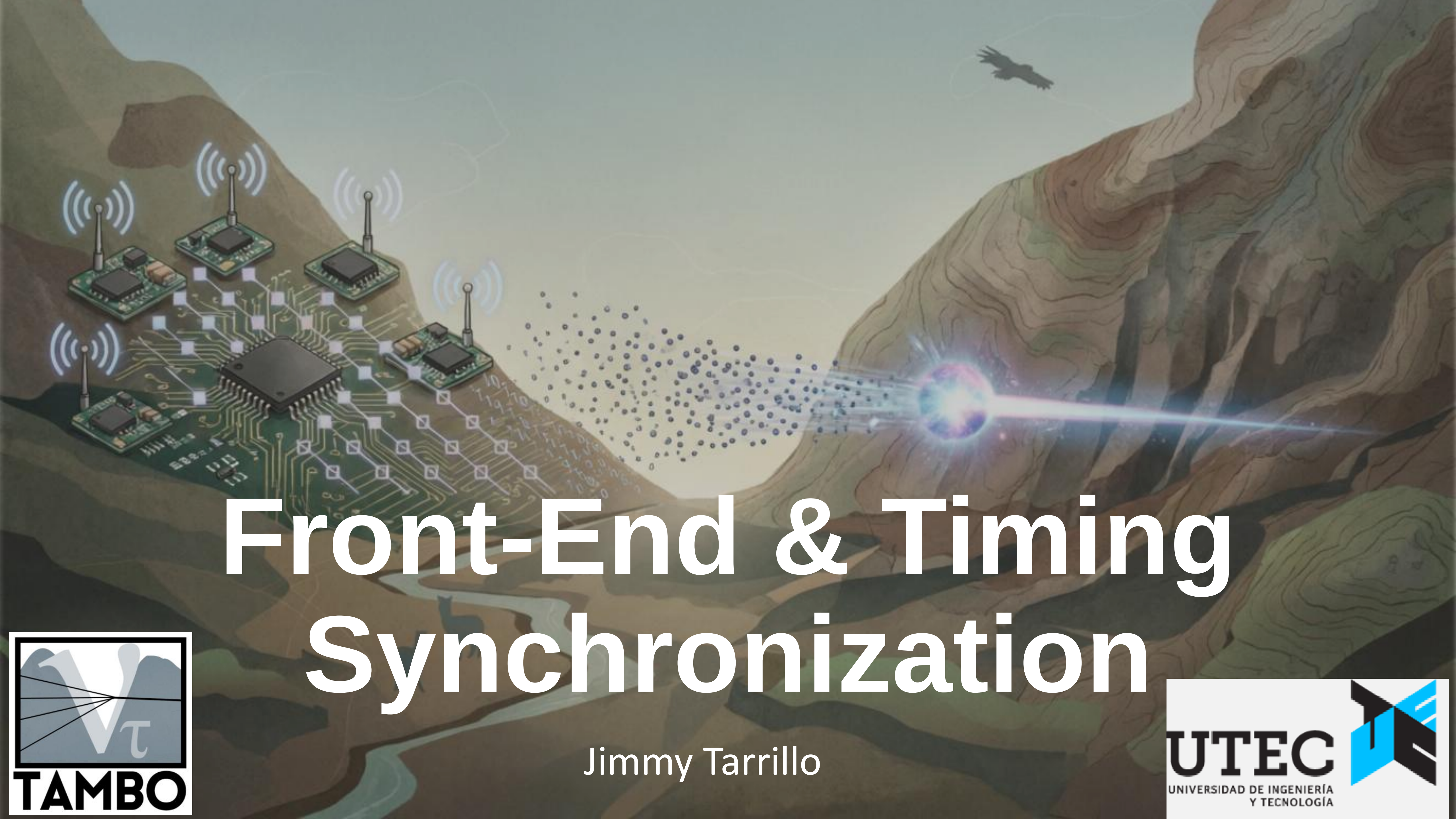

Front-End & Timing Synchronization

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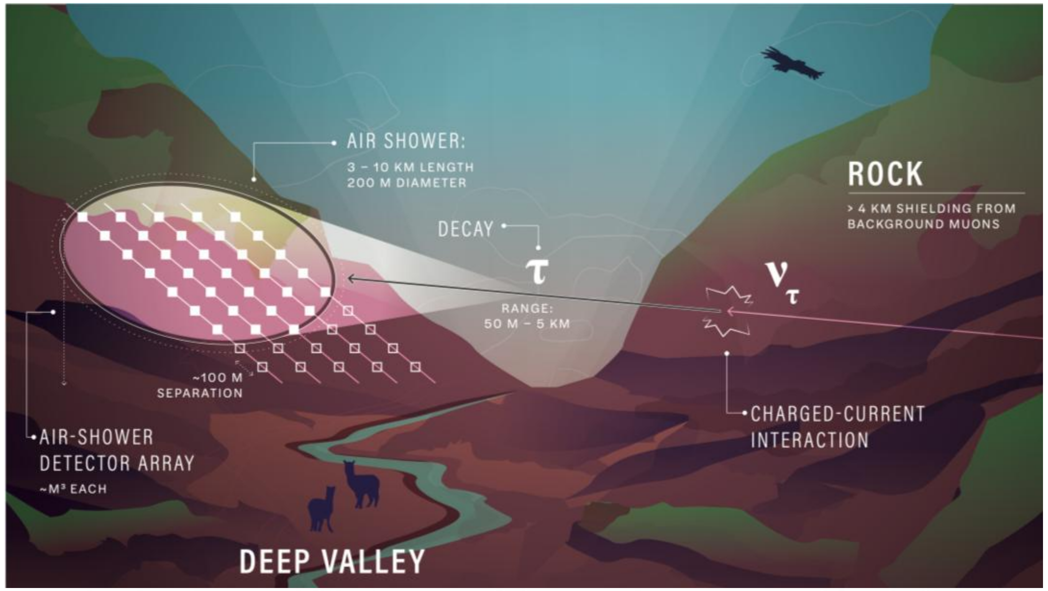
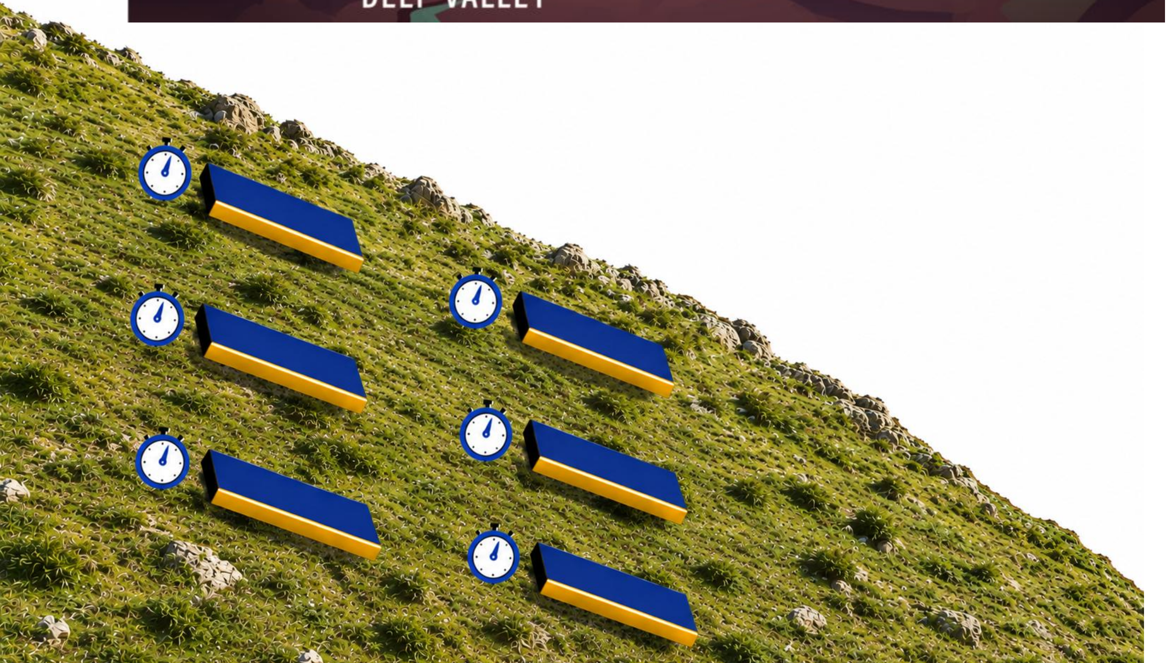
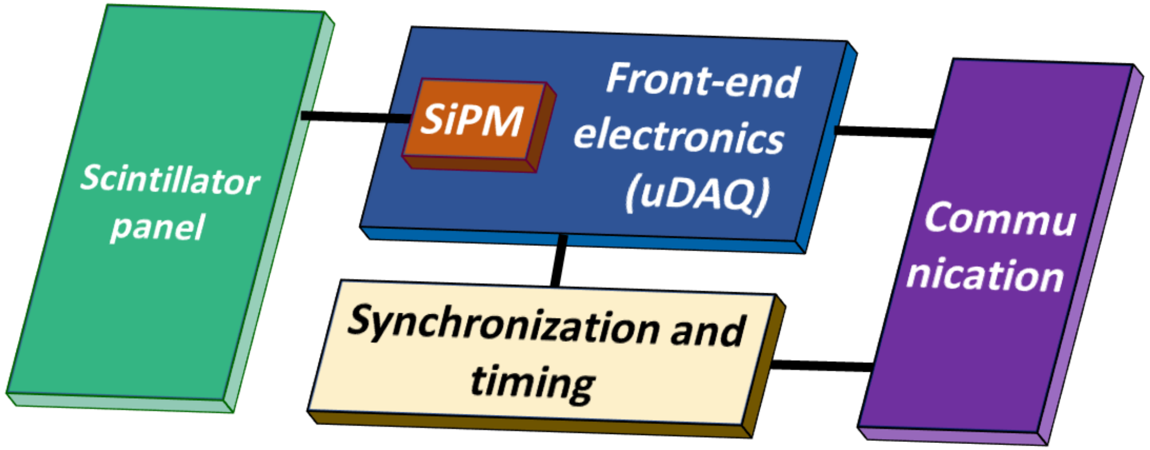
Synchronization and timing requirements

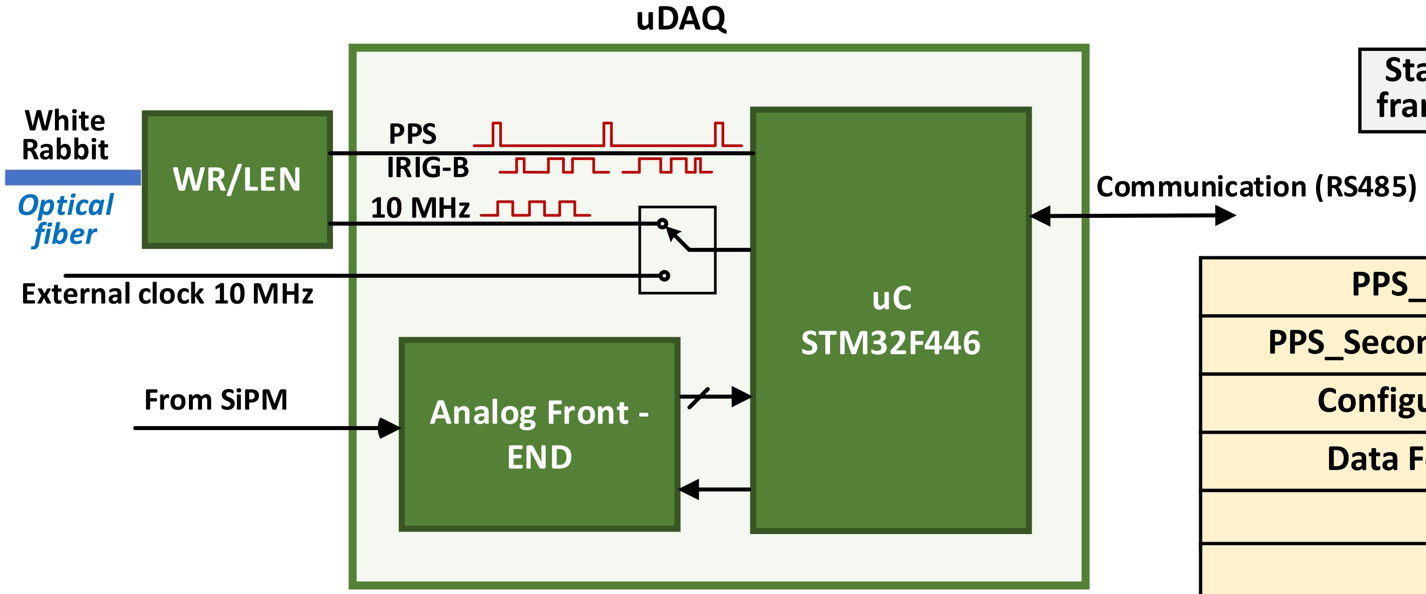


- No wired connection between nodes
- Each node has its own clock
- Synchronization accuracy: ≤ 10 ns
- Cost and energy are key considerations





uDAQ and timing



Start frame	ID 8 bits	Payload (Variable)	Checksum 16 bits	End frame

PPS_Year (32 bits)
PPS_Second-of-year (32 bits)
Configuration (64 bits)
Data Format (32 bits)
Hit 1
Hit 2
...

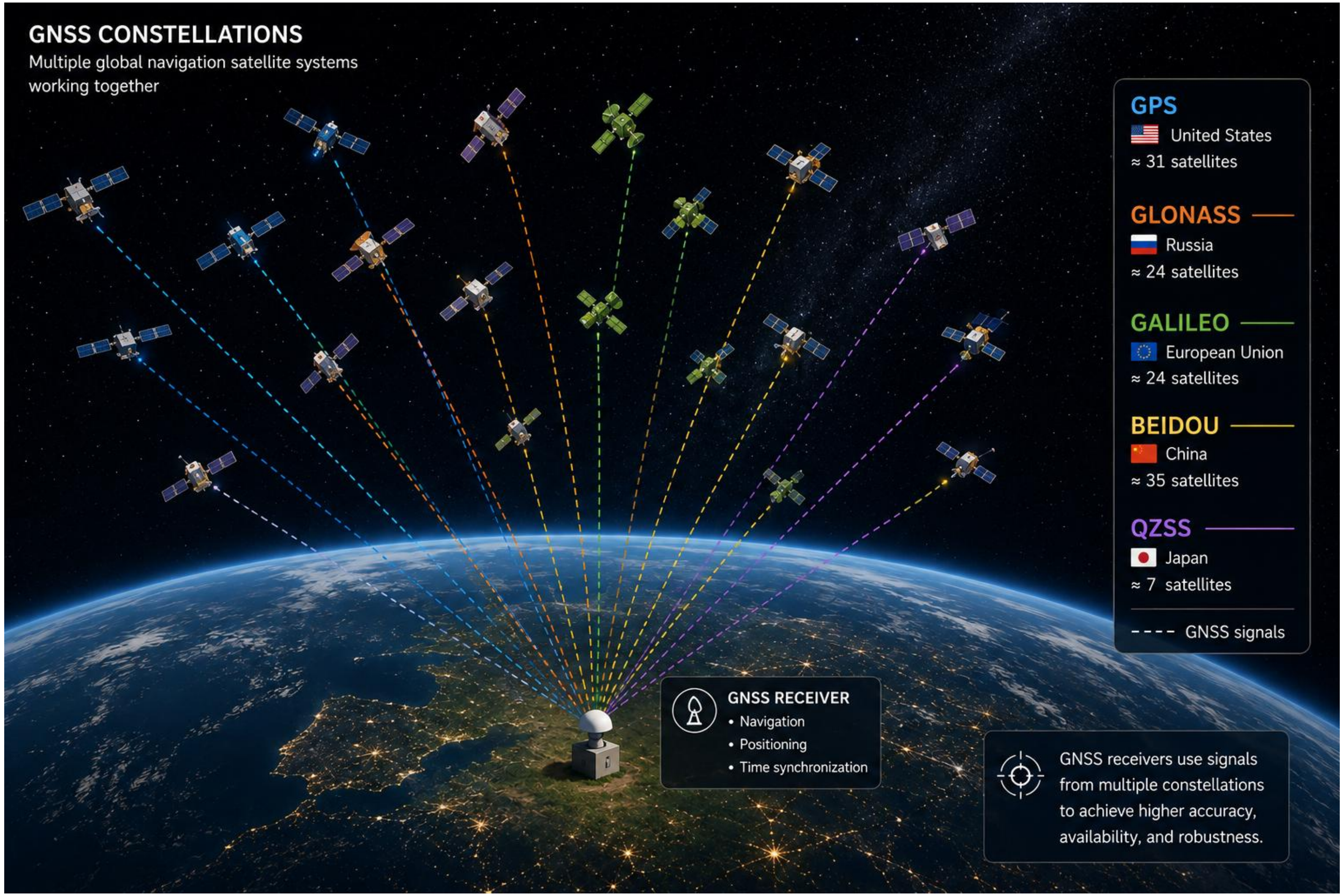
Hit

TIMESTAMP (32 bits)
nADC + ToT + ADC1 (32 bits)
ADC2 + ADC3 (32 bits)
ADC4 + ADC5 (32 bits)
...

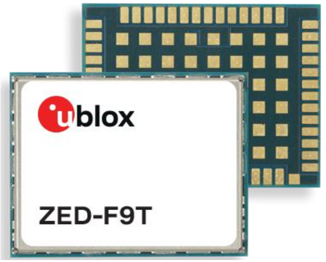
ADC information: # (4 bits) + amplitude (12 bits)

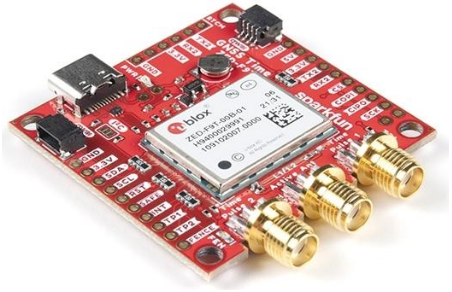
- The timestamp relies on a highly stable 10 MHz reference and an accurate PPS signal.
- These signals are normally provided by the White Rabbit synchronization system.
- uC internal counter (5.56ns resolution) needs a highly stable 10 MHz reference. uDAQ uses also delay-based circuit to complete the time information with 1ns resolution
- **Without White Rabbit, equivalent external timing references are required.**

GNSS and synchronization



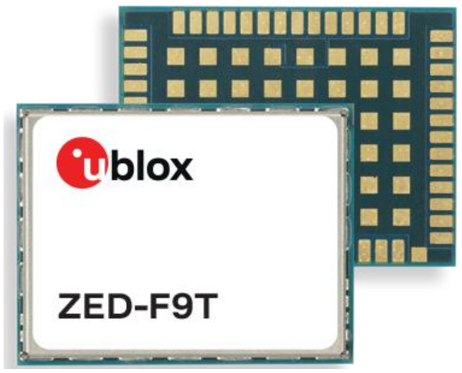
- GNSS satellites transmit time, orbit, and navigation information.
- The GNSS receiver combines signals from multiple satellites to estimate position and precise time
- Higher-performance receivers use more constellations, frequency bands, and measurements to achieve better timing accuracy and robustness.

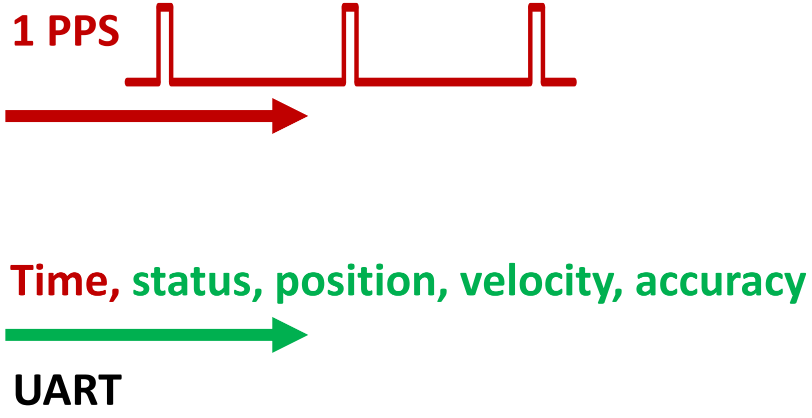


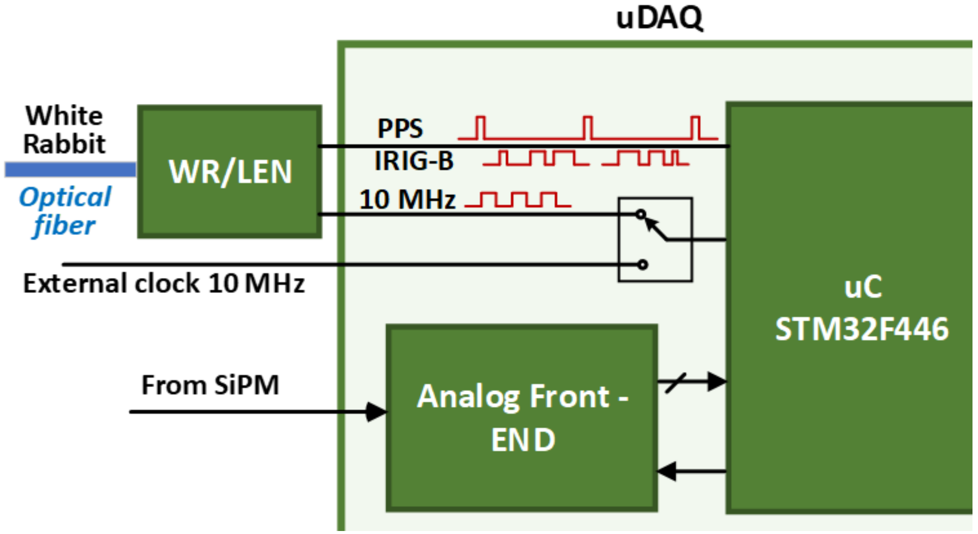


ZED F9T

GNSS and synchronization

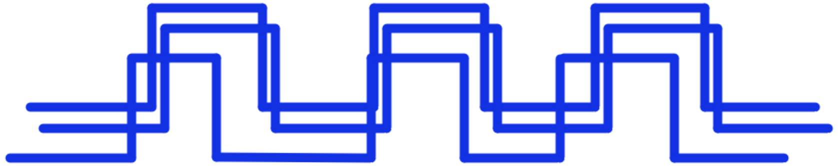




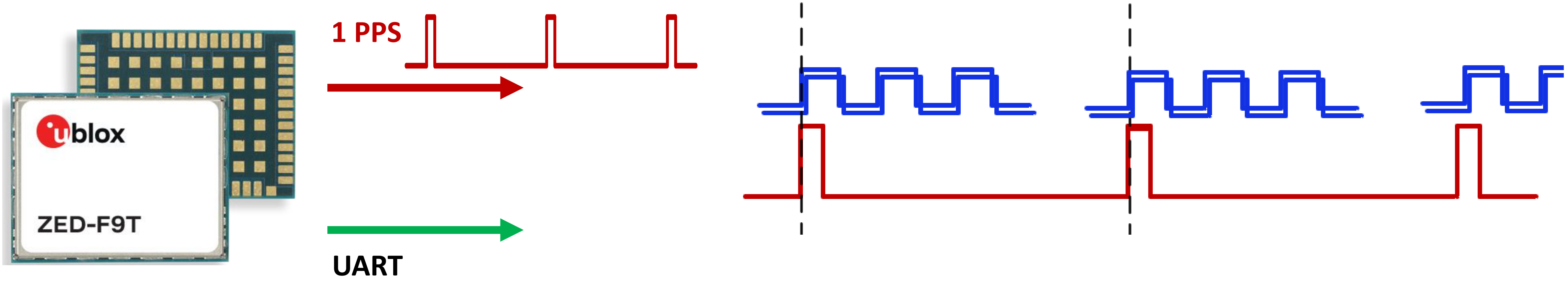


- We can use the ZED-F9T to have 1 PPS signal and UTC time to obtain the absolute timestamp
- How can we obtain a highly stable 10 MHz reference?

- **Typical crystals are very stable**
- **Common error: ± 50 PPM**
- **Average accumulated error in 1s: ± 50us**

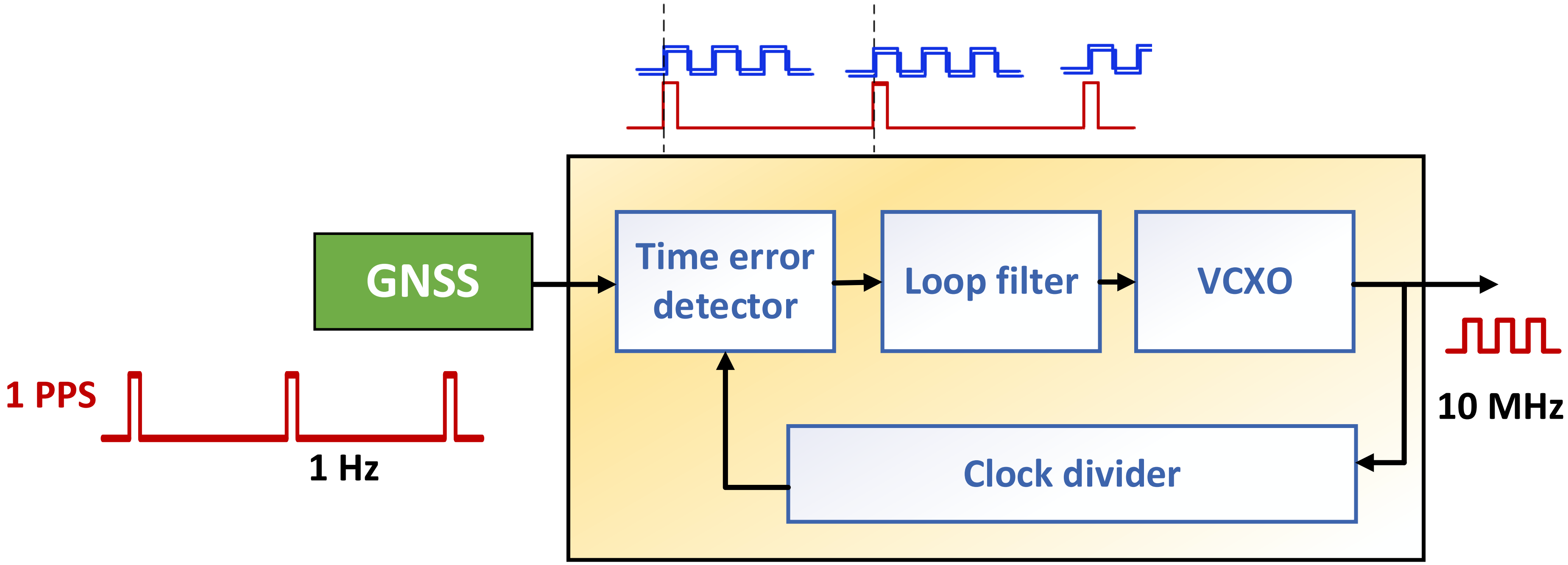


GNSS and synchronization



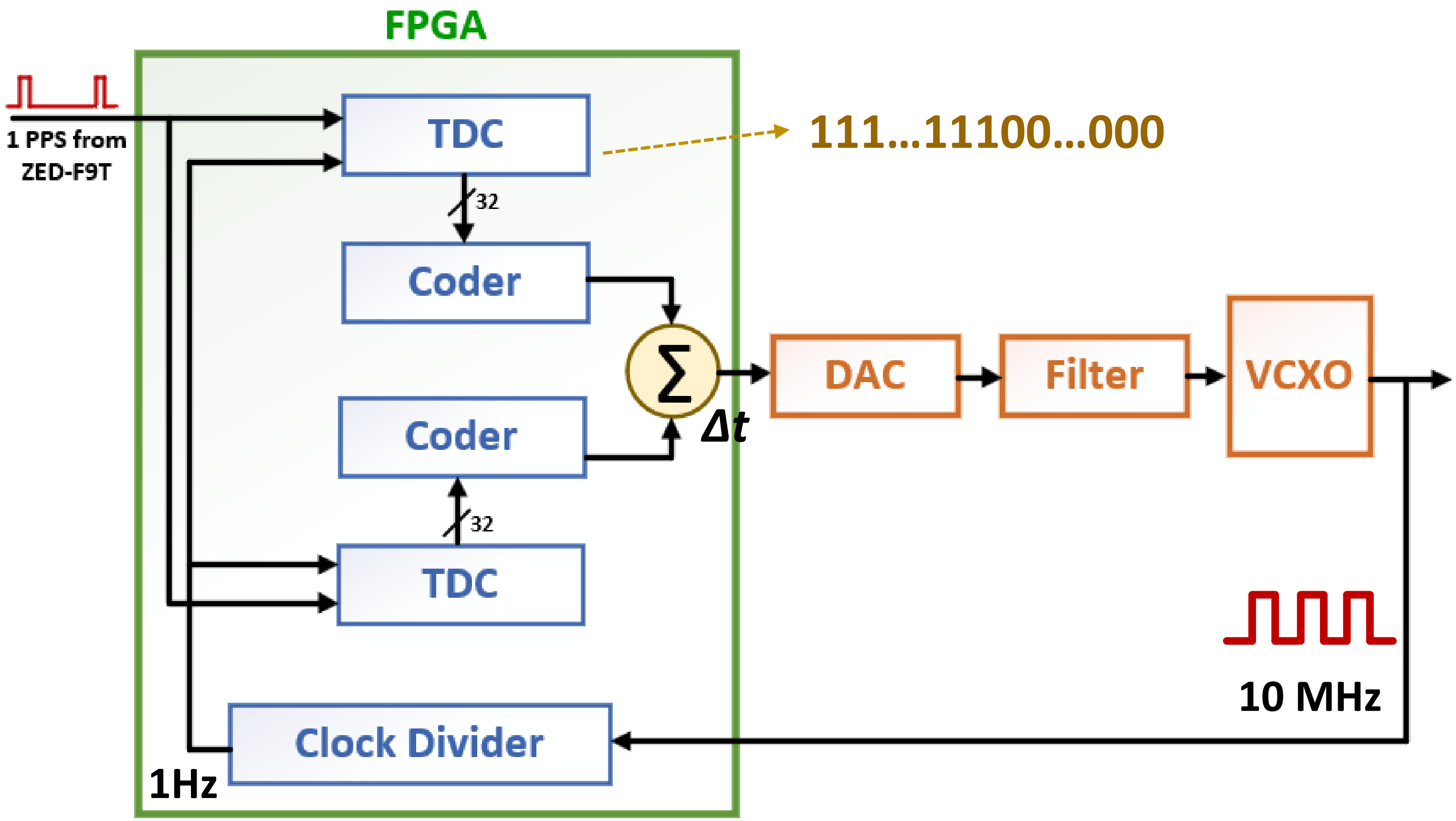
- We can use the 1PPS signal to periodically correct the local clock and limit accumulated timing error
- A standard crystal can still drift by tens of µs between PPS pulses
- A more stable and controllable oscillator is therefore required
- Correct = measure the error + adjust the oscillator. Continuous correction is called ***disciplining***
- **This motivates the use of a GNSS-disciplined oscillator (GNSSDO)**

GNSSDO proposed



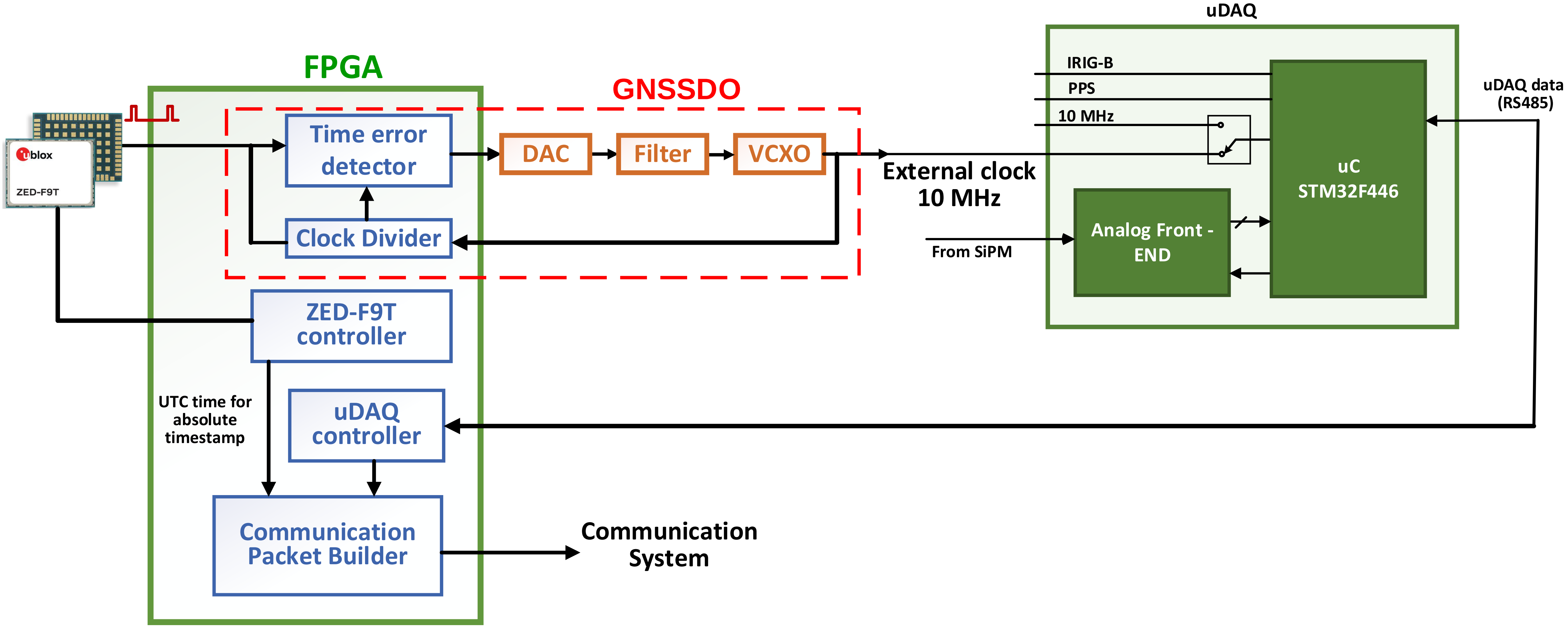
- VCXO: Voltage-Controlled Crystal Oscillator. 566BFA001152BCG: 0.2-3000MHz
- GNSS receptor: ZED-F9T-10B ($227.19)
  - Accuracy of time pulse signal: 5 ns
  - Frequency of time pulse signal: 0.25 Hz to 25 MHz (configurable)
  - Time pulse jitter: ±4 ns

Proposed GNSSDO



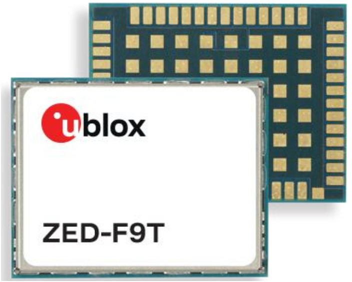
- TDC: Time-to-digital converter
- Implemented using delay-chain elements
- The TDC measures the relative timing of the clock edges and produces a digital code
- The encoder converts this code into a signed time error used to correct the VCXO
- The FPGA provides high timing resolution and fast processing
- FPGA: concurrent processes

Proposed Synchronization and Timing System

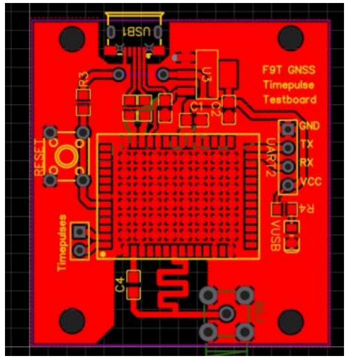


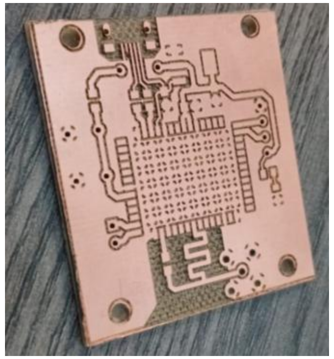
Current Status

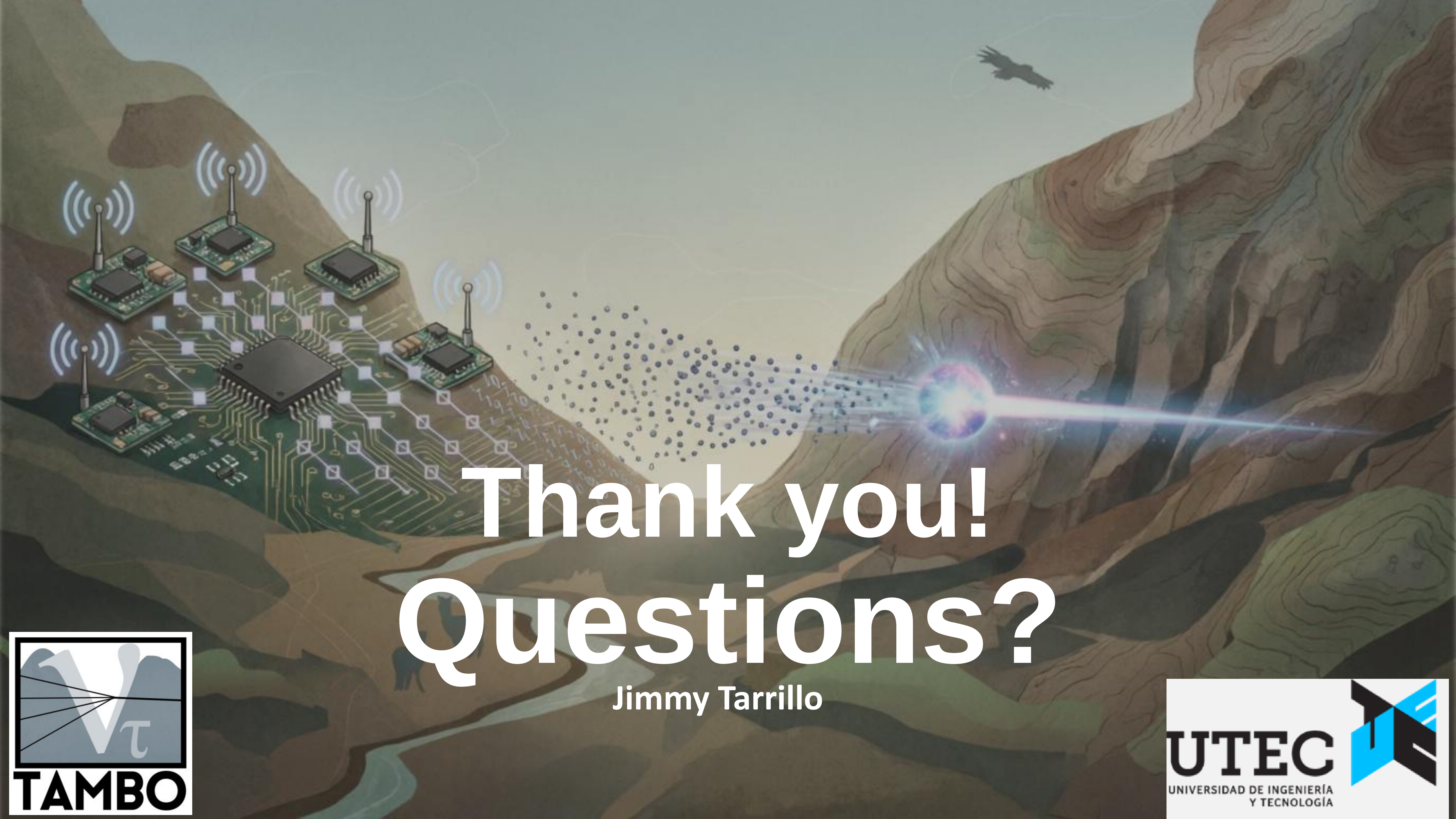
- Initial ZED-F9T tests: issues with the evaluation board
- L89 GNSS receiver under test: lower cost, but lower timing accuracy
- TDC development in progress
- DAC and loop filter design in progress
- First GNSS measurements collected in Arequipa using L89; data analysis in progress



ZED-F9T testing board







Thank you!
Questions?

Jimmy Tarrillo