RF Ranging with LoRa Leveraging RTL-SDRs and GNU Radio

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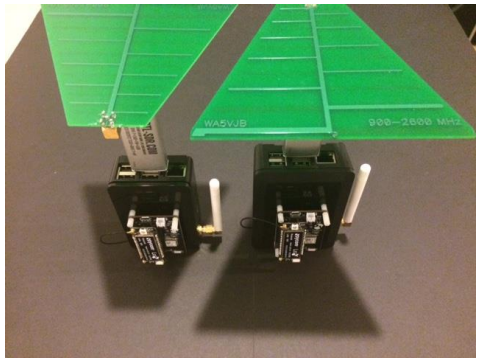
Exploring COTS, LoRa, GNU Radio, and RF Ranging

- **COTS Internet-of-Things (IoT) transceiver technology provides a useful set of features for RF aided complementary Positioning, Navigation, and Timing (PNT)**
  - **Long Range: More than 10km**
  - **Low Cost: IoT transceivers are inexpensive**
  - **Low Power Consumption: IoT transceivers can operate for many years**
  - **Majority of modules lack access to PHY for supporting PNT**

- **Leverage GNU Radio to prototype a LoRa RF ranging Python block without requiring access to physical layer measurements from the IoT transceiver**

GNU Radio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

- **Leverage this LoRa RF ranging block as part of a low cost experimental RF ranging system based on IoT transceiver technology with low SWAP-C SDRs**
  - **PNT Sub-GHz Software Defined Radio (PUGS)**



Low Cost SDRs and IoT RF Modules

RTL-SDR:

- Extremely Inexpensive
- Tuning: 500 kHz up to 1.75 GHz
- 1PPM TCXO
- Max sampling rate is 2.4 Msps
- ENOB is ~7 bits
- USB Interface

$21.00 USD

Pluto SDR:

- Inexpensive
- Tuning: 300 MHz up to 3.8 GHz
- Bandwidth: 200kHz to 20 MHz
- Max sampling rate is 61.44 Msps
- 12-bit bit DACs and ADCs
- USB Interface

$99.00 USD

LoRa Sub-GHz Modules:

- Inexpensive
- 433 MHz, 868 MHz, and 915 MHz
- Bandwidths: 125 kHz, 250 kHz, and 500 kHz
- 157 dB maximum link budget
- +14 dBm high efficiency PA

$40.00 USD

$30.00 USD

LoRa 2.4 GHz Modules :

- Inexpensive
- Ranging Engine, Time-of-flight function
- Bandwidths: 125 kHz, 250 kHz, 500 kHz, and 1.6 MHz
- +12.5 dBm high efficiency PA

Components of PNT Sub-GHz SDR (PUGS)

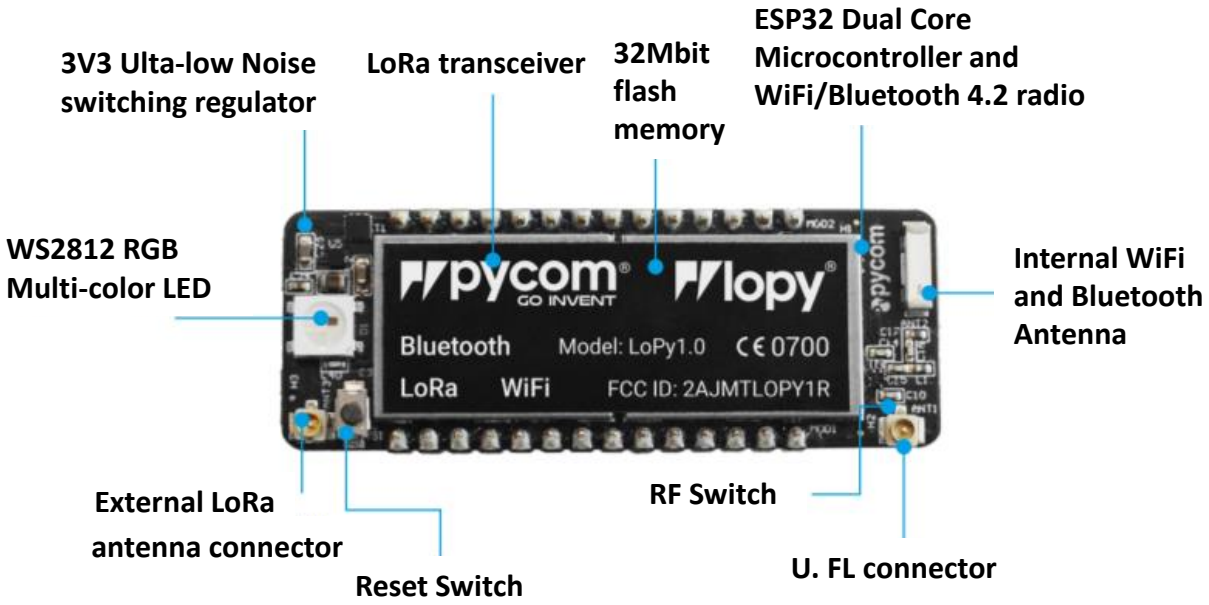


Image courtesy of https://docs.pycom.io/chapter/datasheets/downloads/lopy-specsheet.pdf

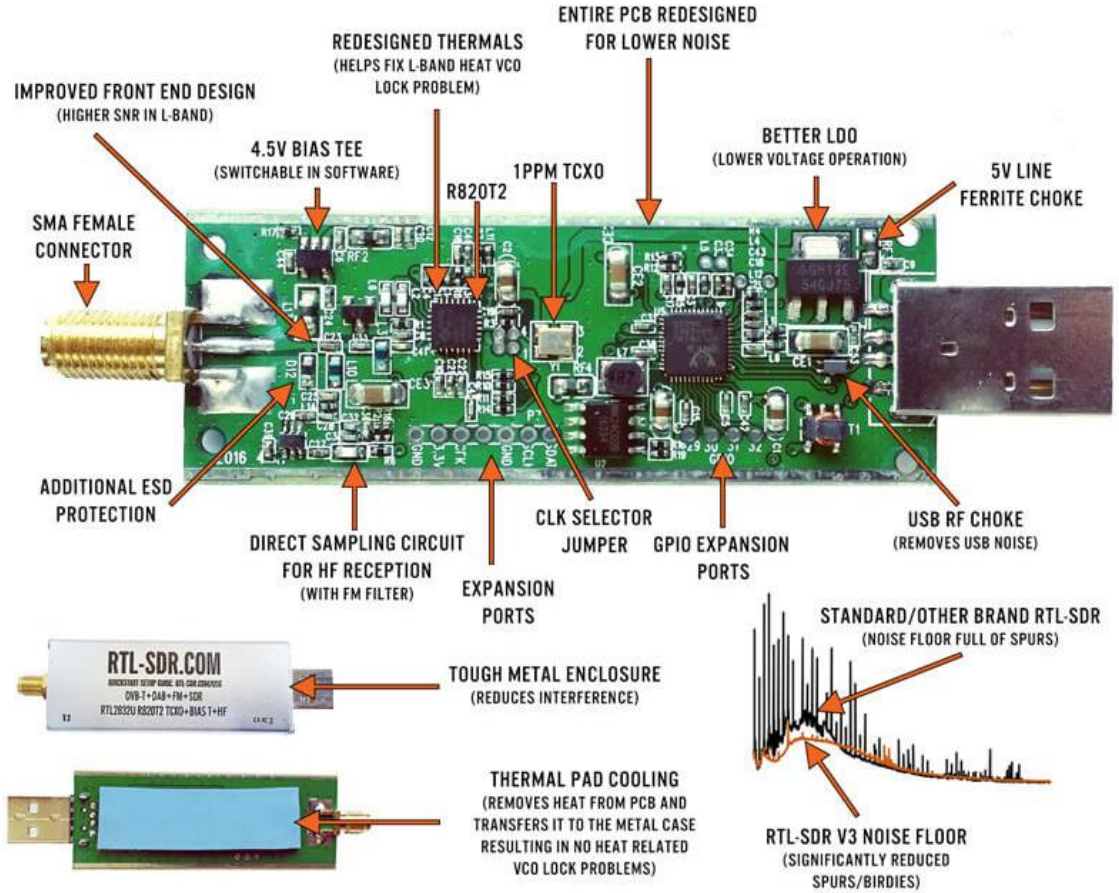


Image courtesy of https://www.rtl-sdr.com/buy-rtl-sdr-dvb-t-dongles/

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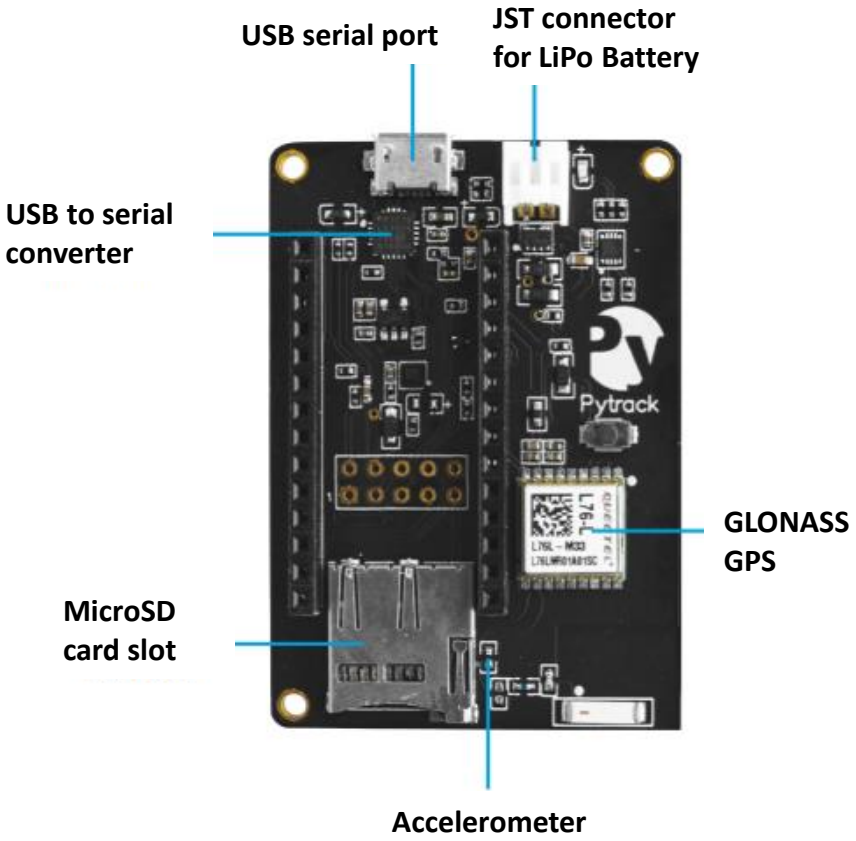


Image courtesy of https://pycom.io/wp-content/uploads/2017/08/pytrackSpecsheetAugust2017n.pdf

Raspberry Pi 3 Model B

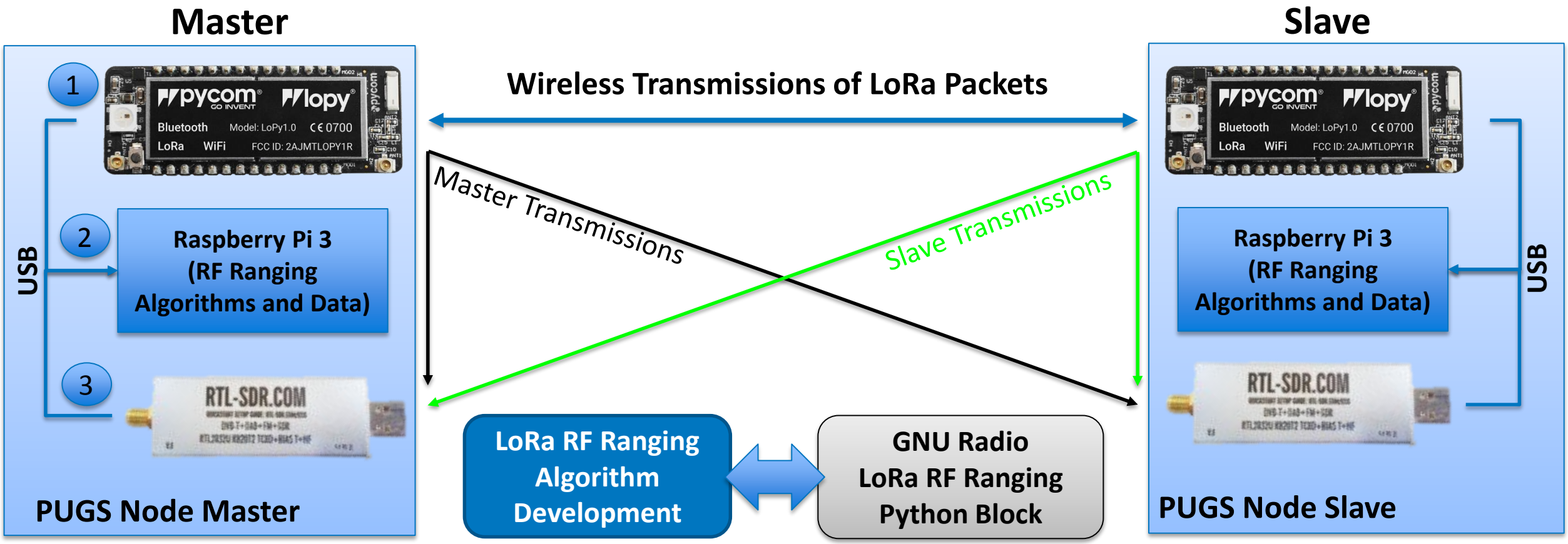
Image courtesy of https://www.raspberrypi.org/products/raspberry-pi-3-model-b/

Micropython

Python

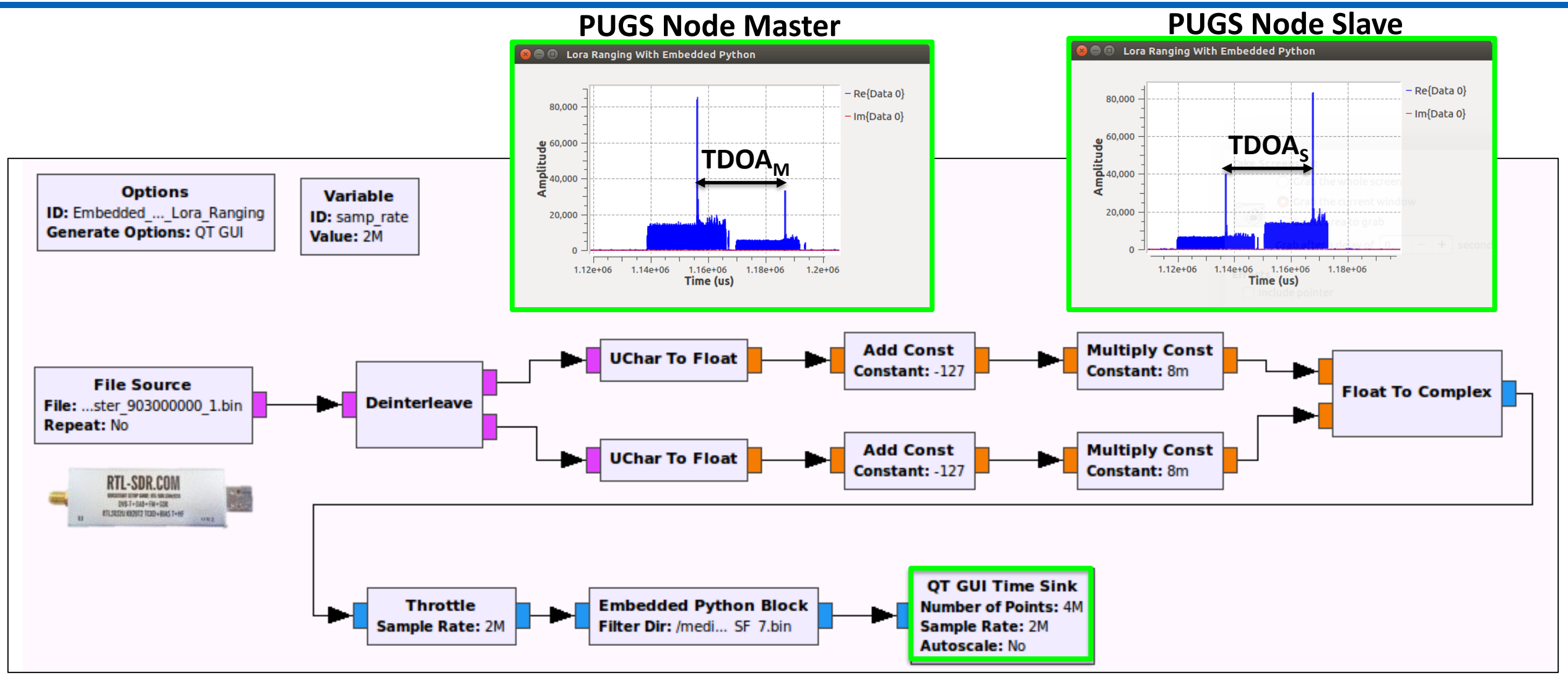
Images courtesy of https://commons.wikimedia.org

Low SWAP-C Hybrid RF Ranging SDRs



PUGS Hybrid (Active/Passive) RF Ranging Setup based on LoRa Transceiver Technology

GNU Radio Embedded Python Flow Graph



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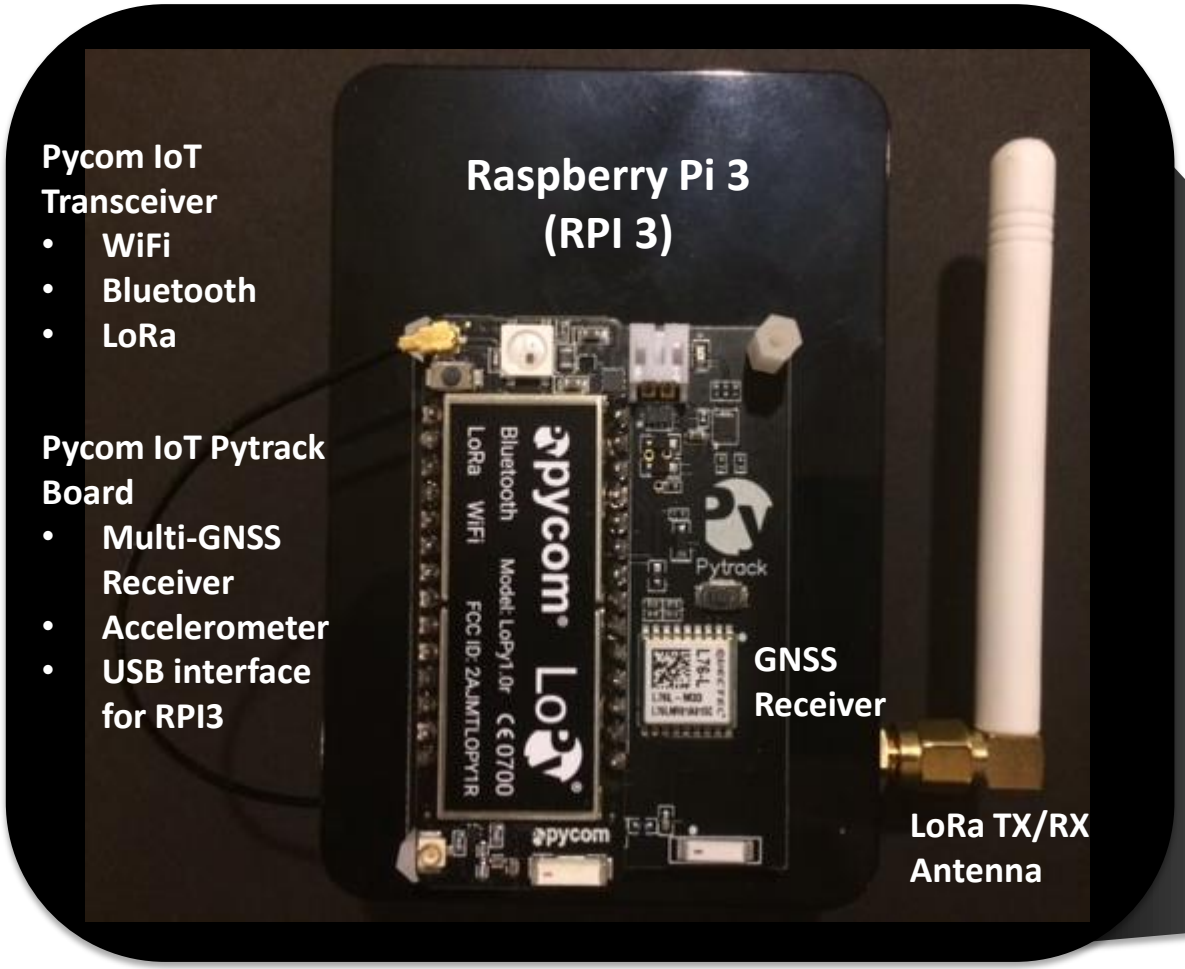
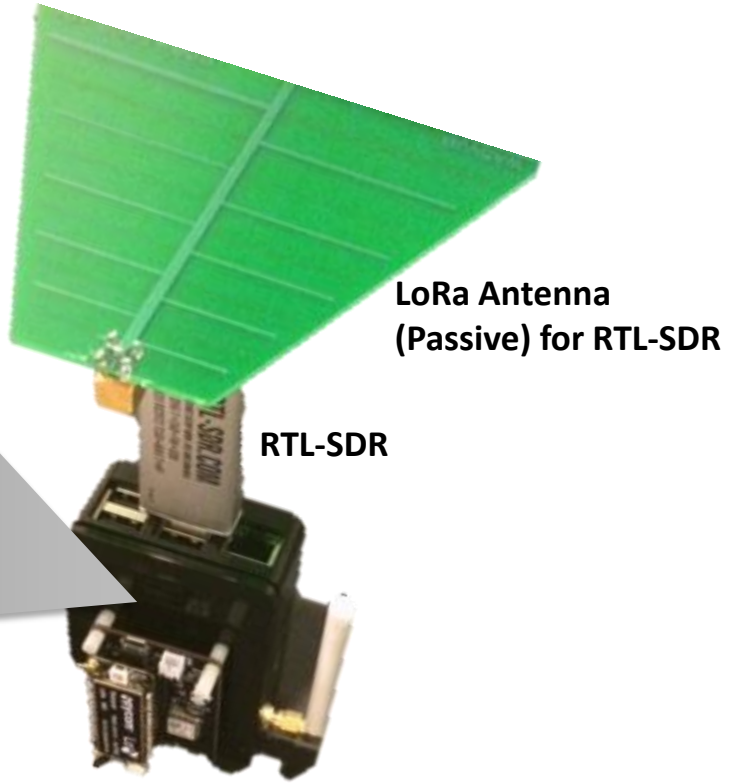
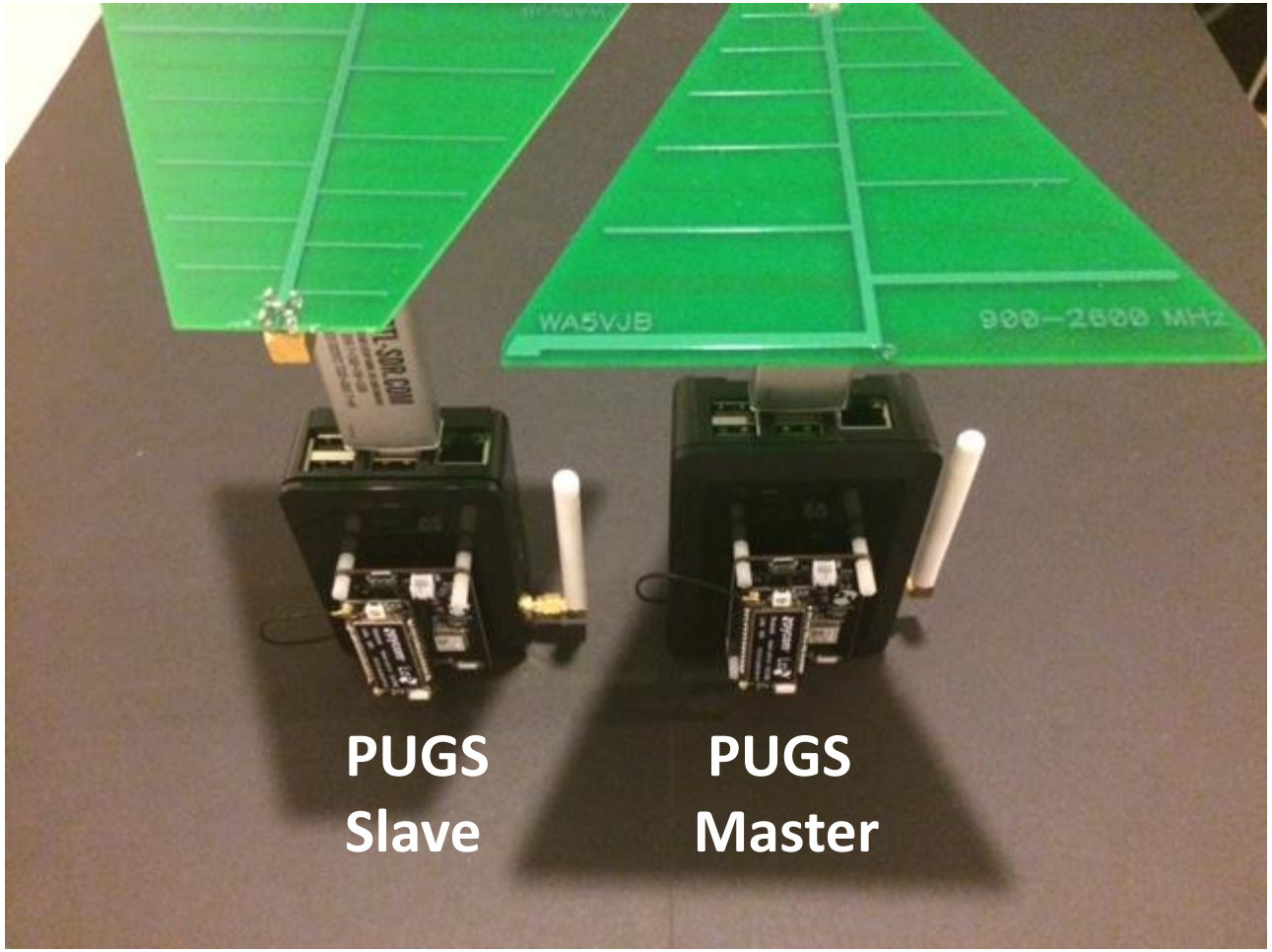


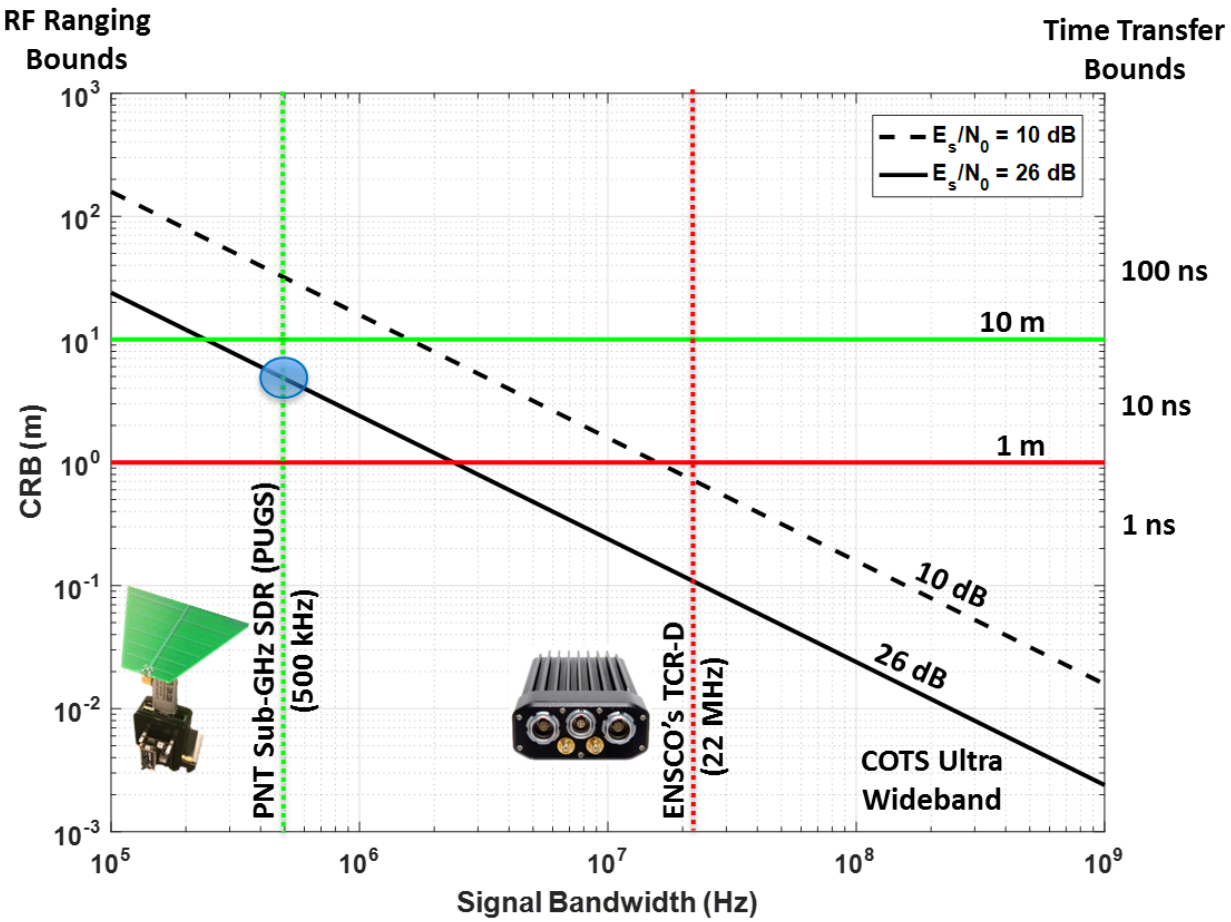
Features of PUGS

- RF Ranging protocols written in Micropython
- Python based I/Q data capture scripts on RPI 3
- RTL-SDR for LoRa Packet Capture
- GNU Radio Installation with a modified gr-lora OOT



Exploring RF Ranging and Time Transfer with PUGS





Decoupling RF Ranging Algorithms for COTS

ENSCO's Timing, Communications, and Ranging Device (TCR-D)

Communications Transceiver

Embedded System

RF Ranging Algorithms + SDR

1

One example of a Sub-GHz COTS Communications Transceiver for PUGS Narrowband RF Ranging (BW = 500 kHz)

2

Communications Transceiver

Comms Embedded System

Interchangeable COTS Modules

Ranging Embedded System

RF Ranging Algorithms + SDR

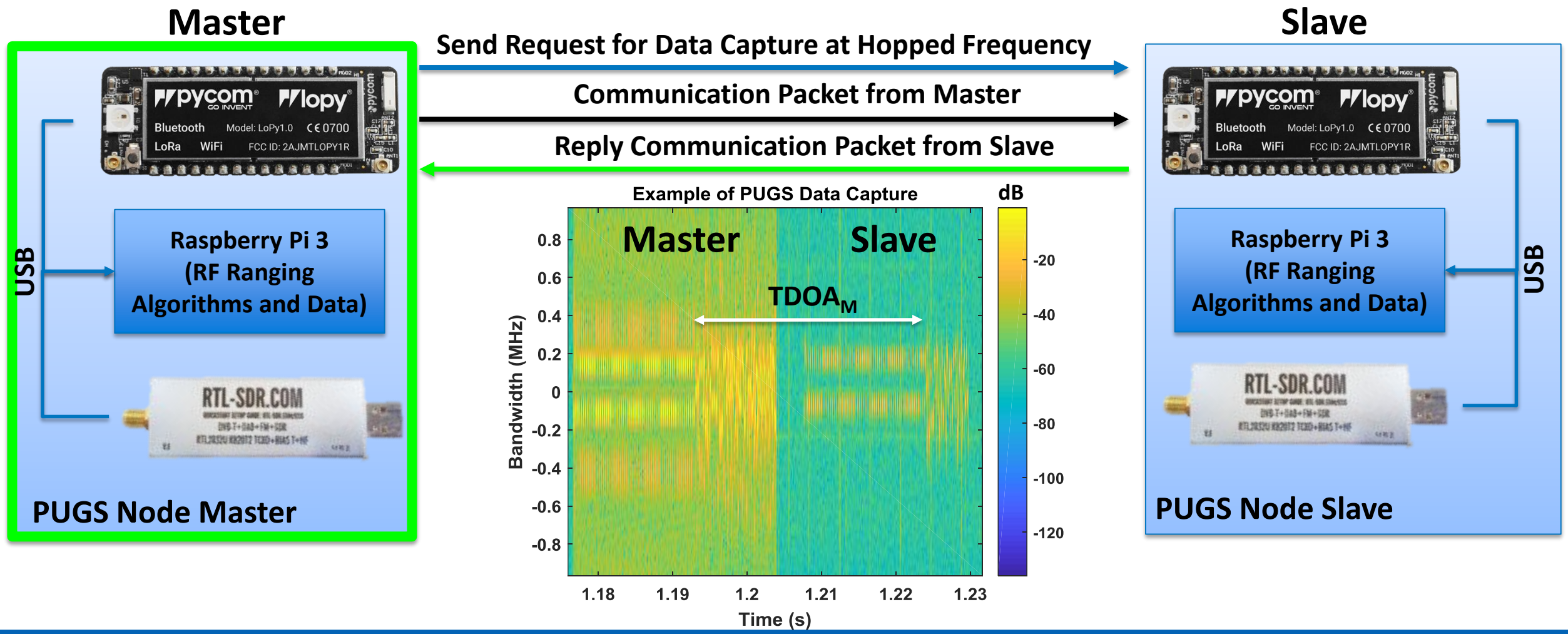
"Assured PNT with a Cell Phone IMU and Carrier Phase RF Measurements for GNSS Denied Environments" (JNC 2018)

"Wireless Synchronization Approach to Create Distributed Coherent Phased Arrays" (JNC 2018)

3

One example of a receive only SDR for Narrowband Sampling (Fs = 2Msps)

Experimental Operation with PUGS



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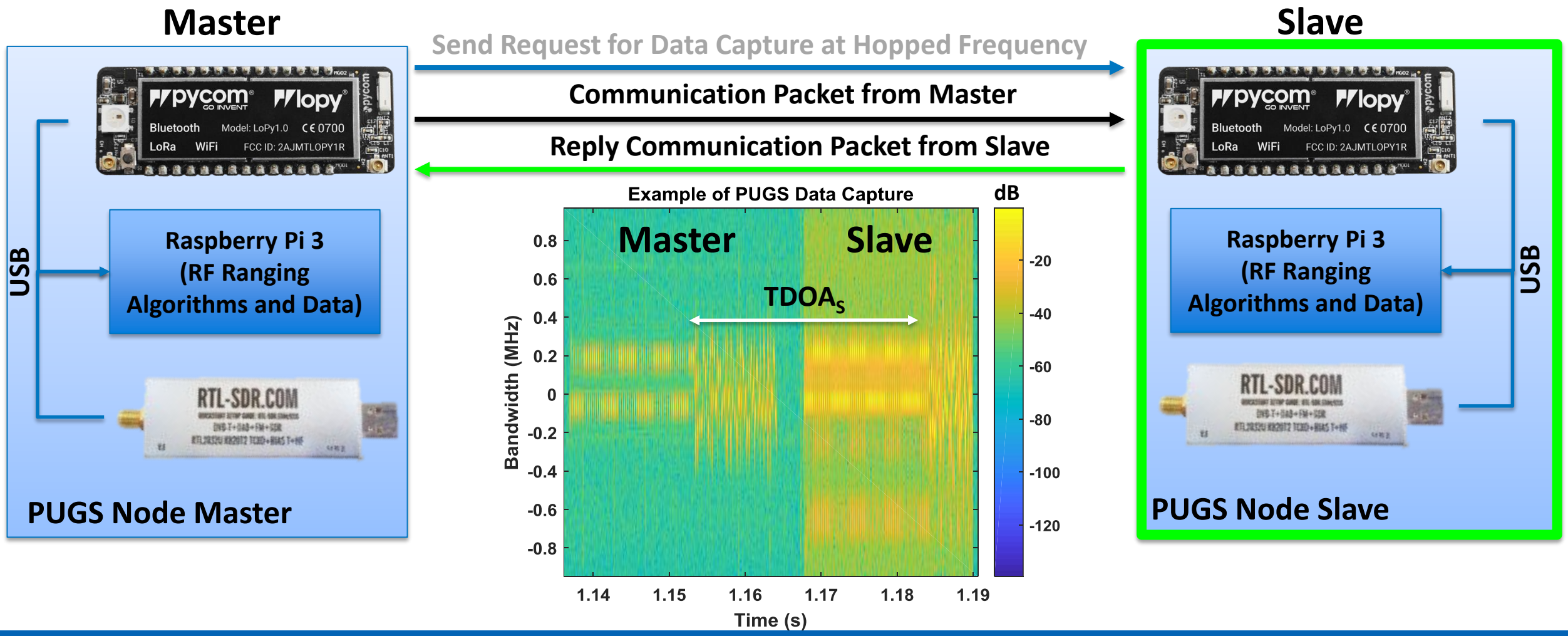
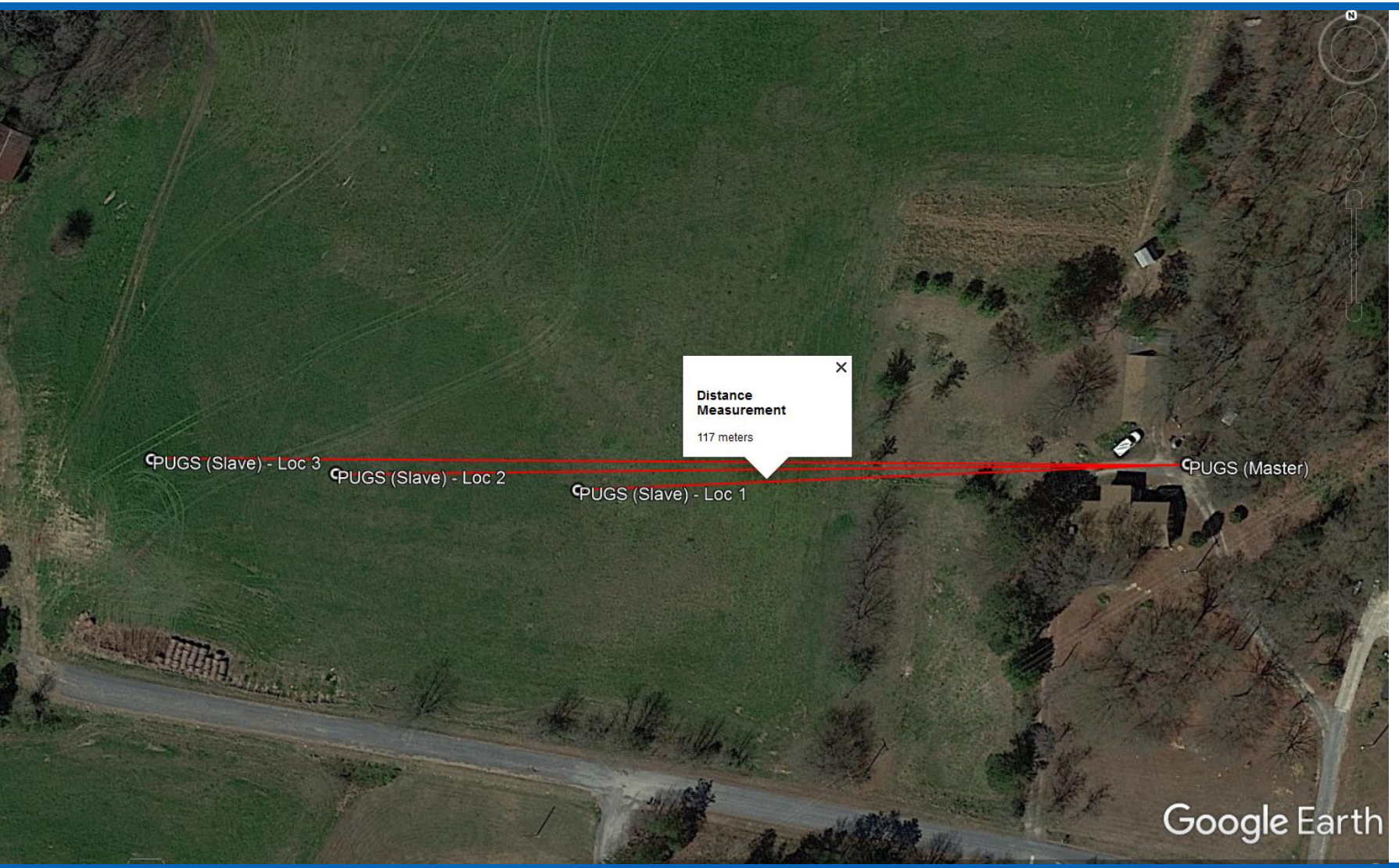
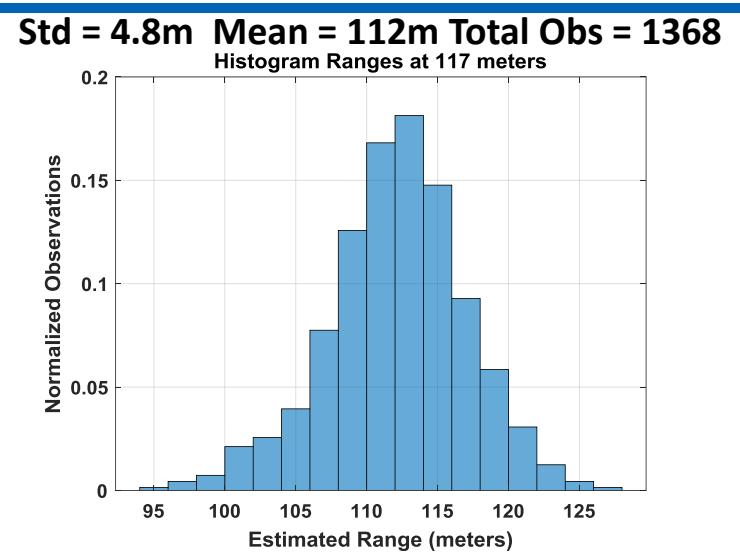


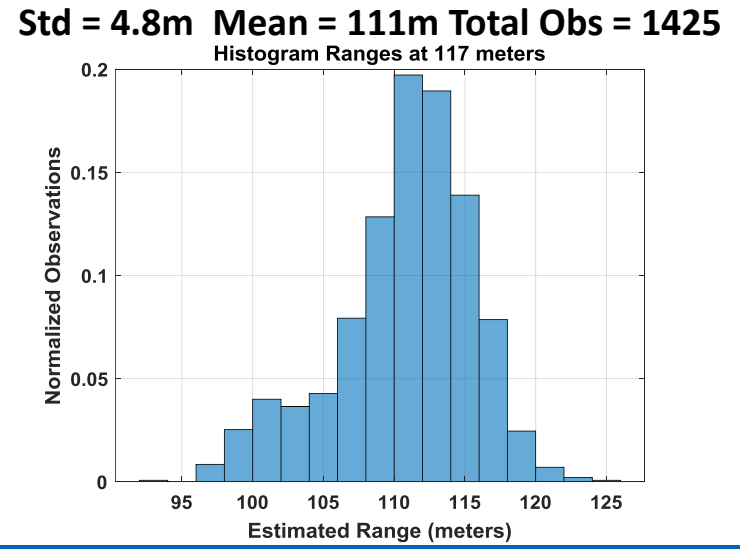
Two-way Ranging Experiments with PUGS

- Leveraged Low SWAP-C 2.4 GHz RF Ranging Transceiver to support PUGS Experimentation
- MicroPython based operation of IoT transceivers provided rapid RF ranging protocol exploration
- Hopped over 26 frequencies in 900 MHz ISM Band
- RTL-SDR data capture at each PUGS for RF ranging algorithm exploration based on post processing analysis
- Transmitter operating level of PUGS at 5 dBm
- RF ranging measurements up to ~200 meters
- GPS measurements collected on each PUGS

Two-way Ranging Experiments with PUGS







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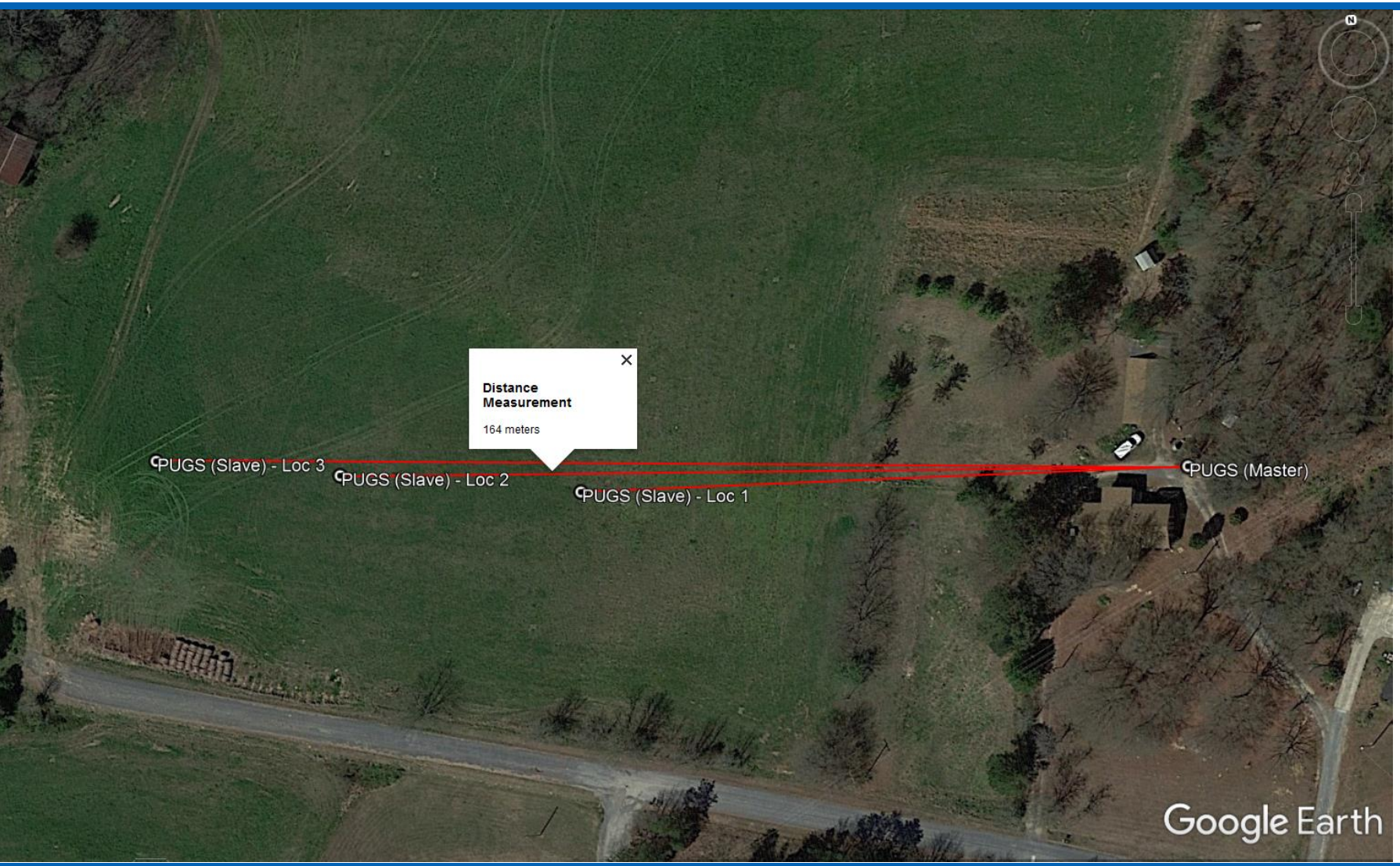

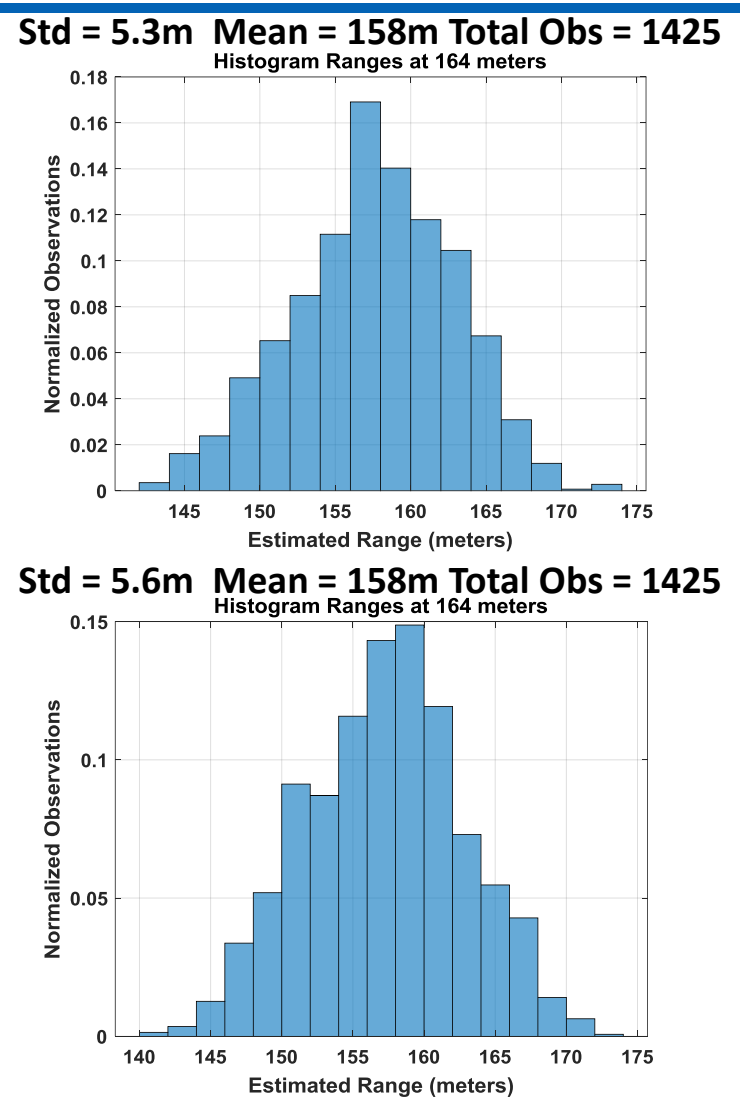

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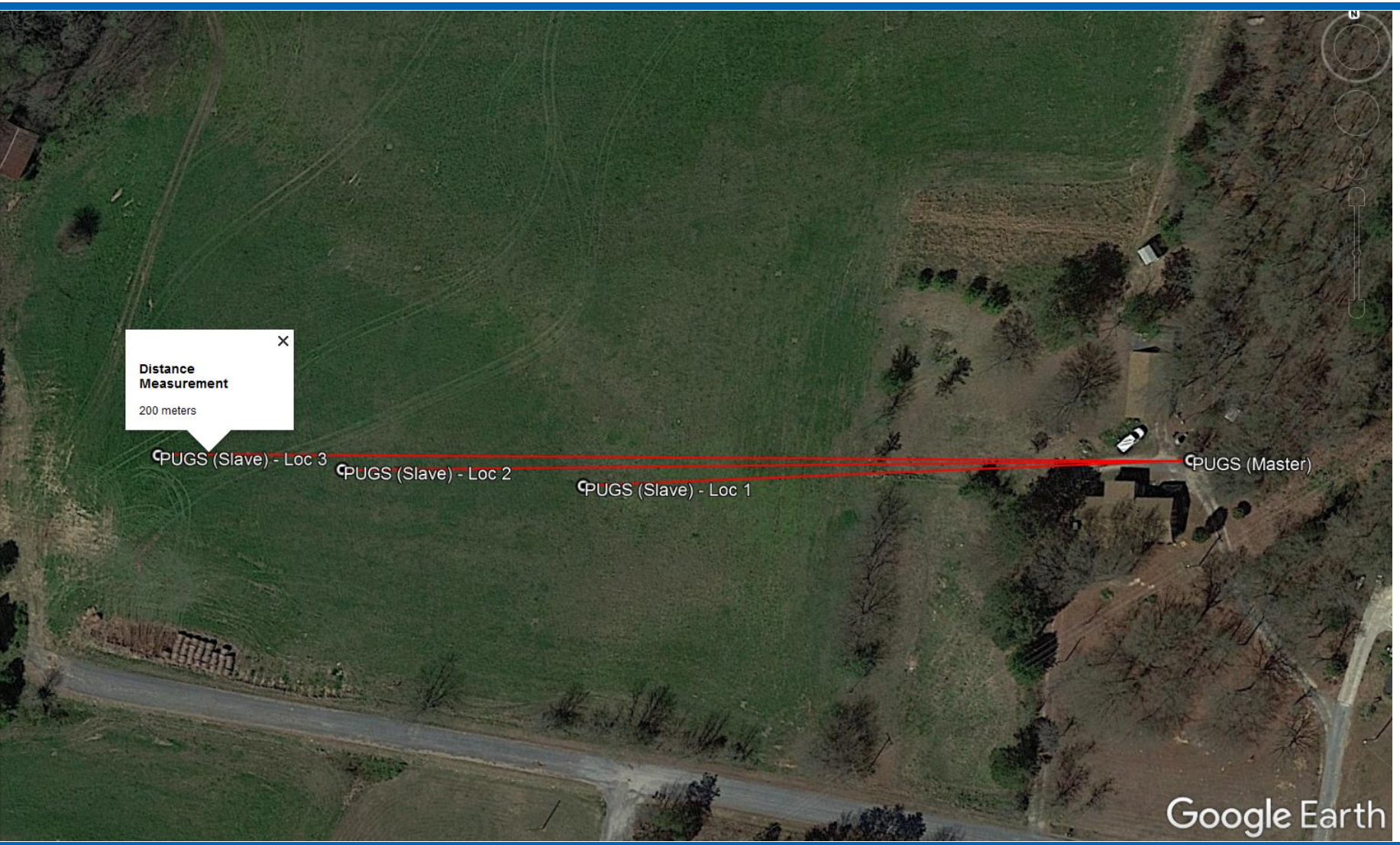
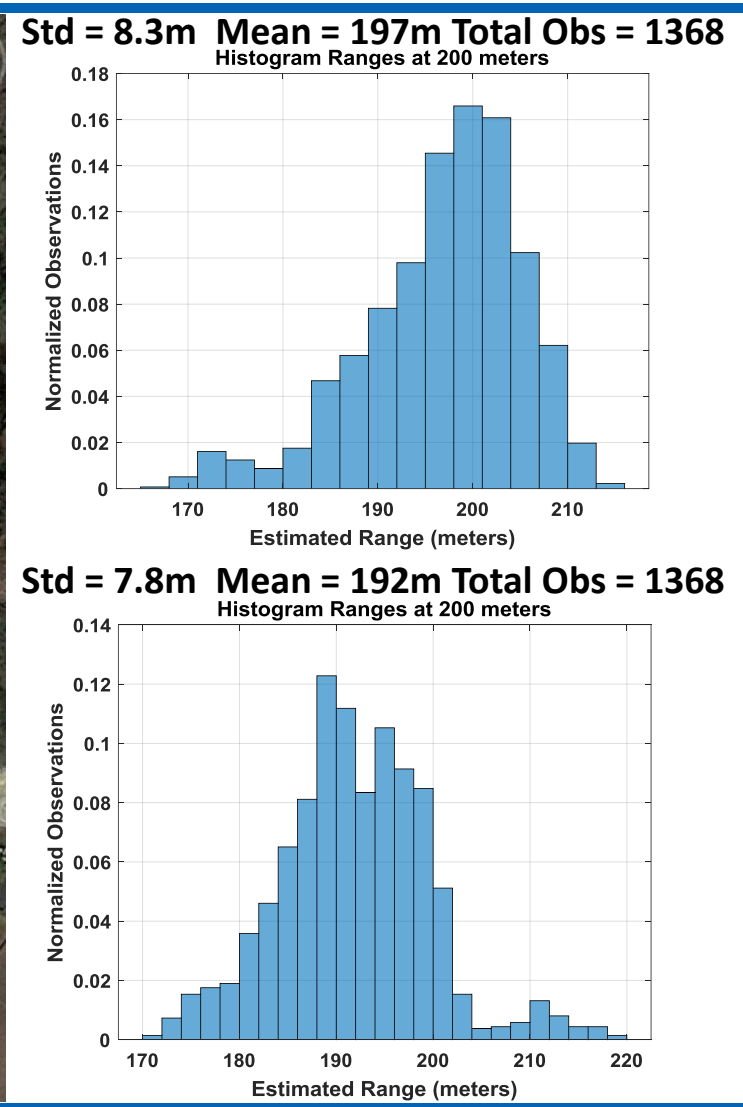
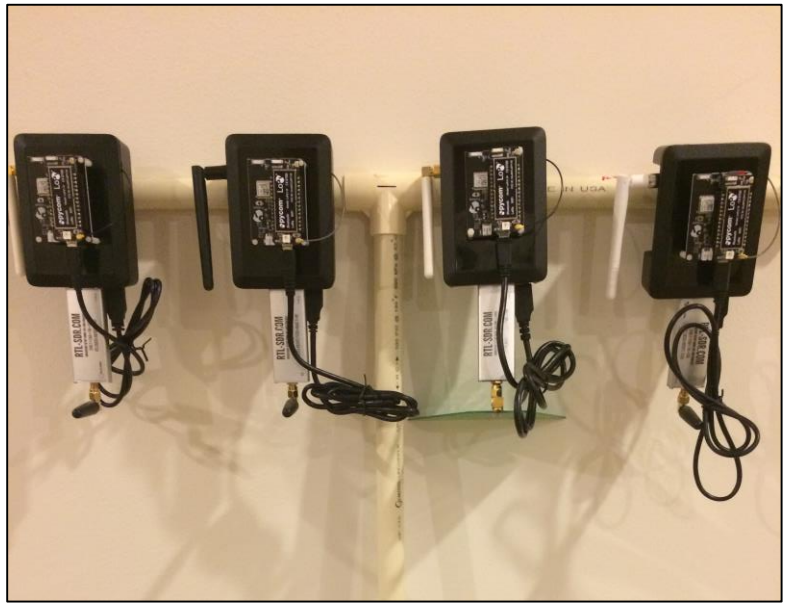




Summary and Next Steps with GNU Radio

- LoRa RF Ranging Python Block with PUGS demonstrates the feasibility of < 10 meter level ranging with low SWAP-C COTS IoT transceivers and SDRs without access to RF physical layer measurements
- LoRa RF Ranging Python block provides a great experimental framework for exploring additional PNT research topics with respect to IoT transceivers and low cost SDRs
- Further GNU Radio Python block development is planned based on Angle-of-Arrival algorithms in a distributed PUGS configuration



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Questions?

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Ideas to Reality™