Precision Geolocation

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Agenda

- Introduction
- System Overview
- Implications of Positional Error
- Drive Test Results & Error Analysis
- Best Practices
- Conclusions
- Appendix - Hardware Specifications

Introduction

- Started project to address geopositioning errors

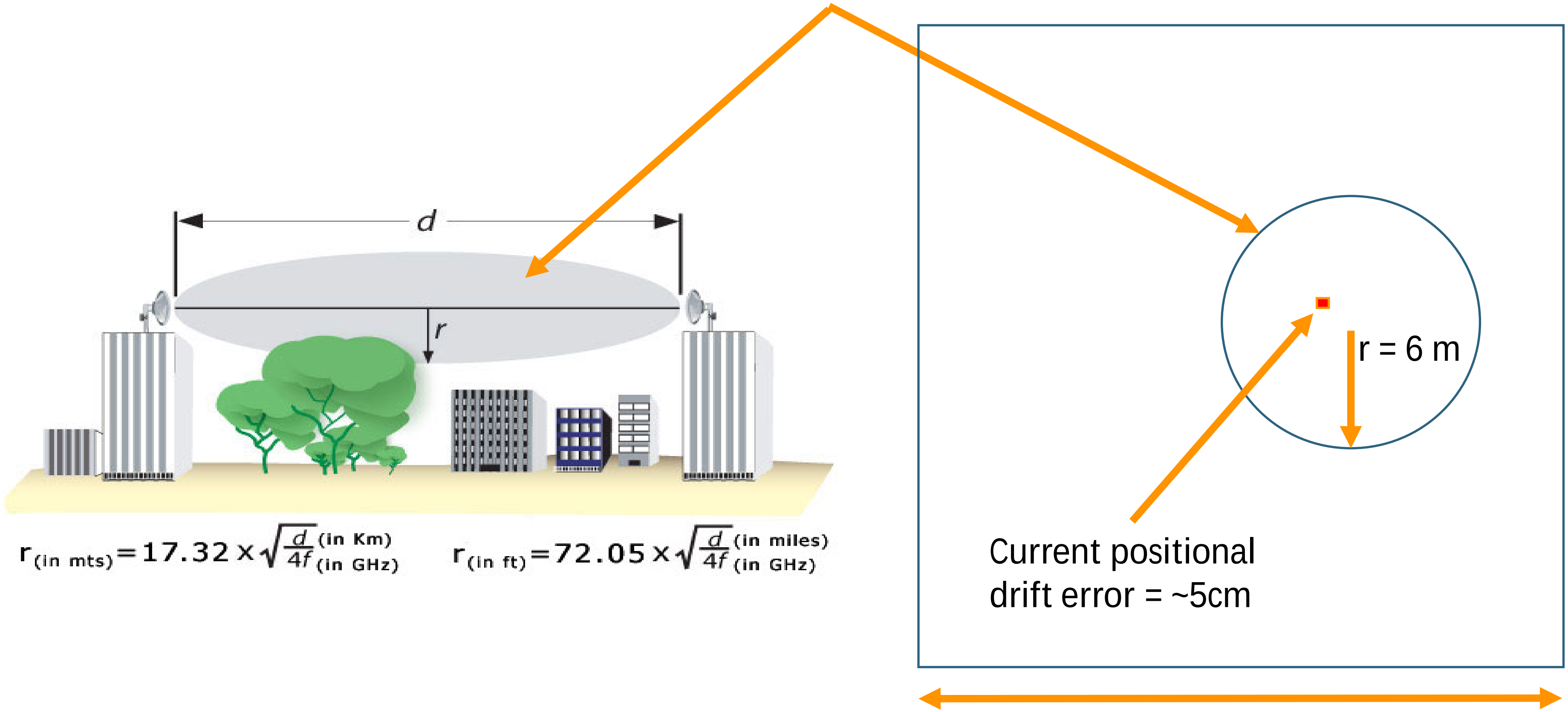
- When the program began, our static, horizontal positional uncertainty (drift) was:
  - ~2 to 5 m in rural/suburban areas
  - ~5 to 40 m in urban canyon areas;

- Goal is to produce an accurate, precise, cost-effective, and easy-to-use system

Positioning Error Implications

Positioning Error Implications

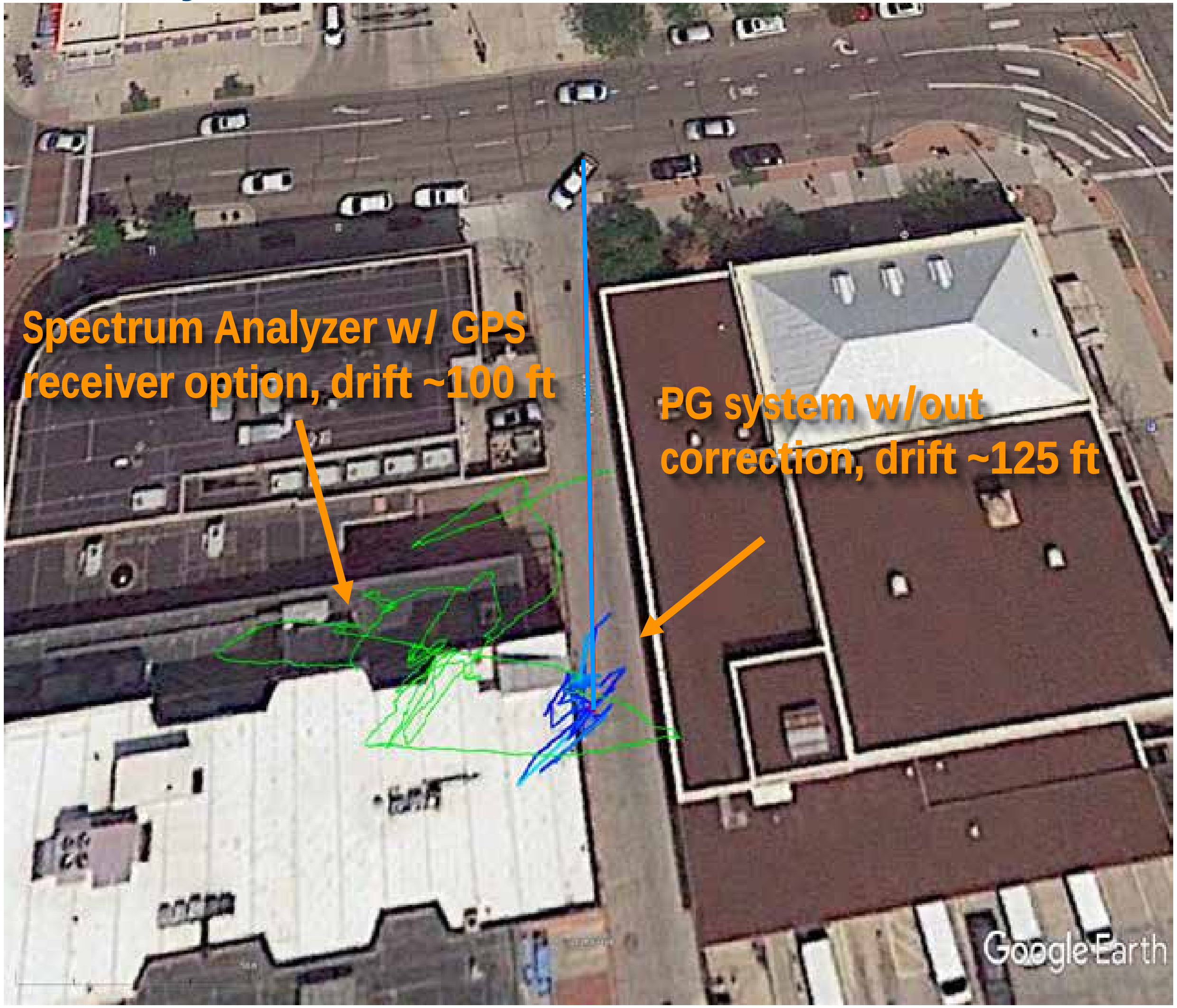
1st Fresnel Zone



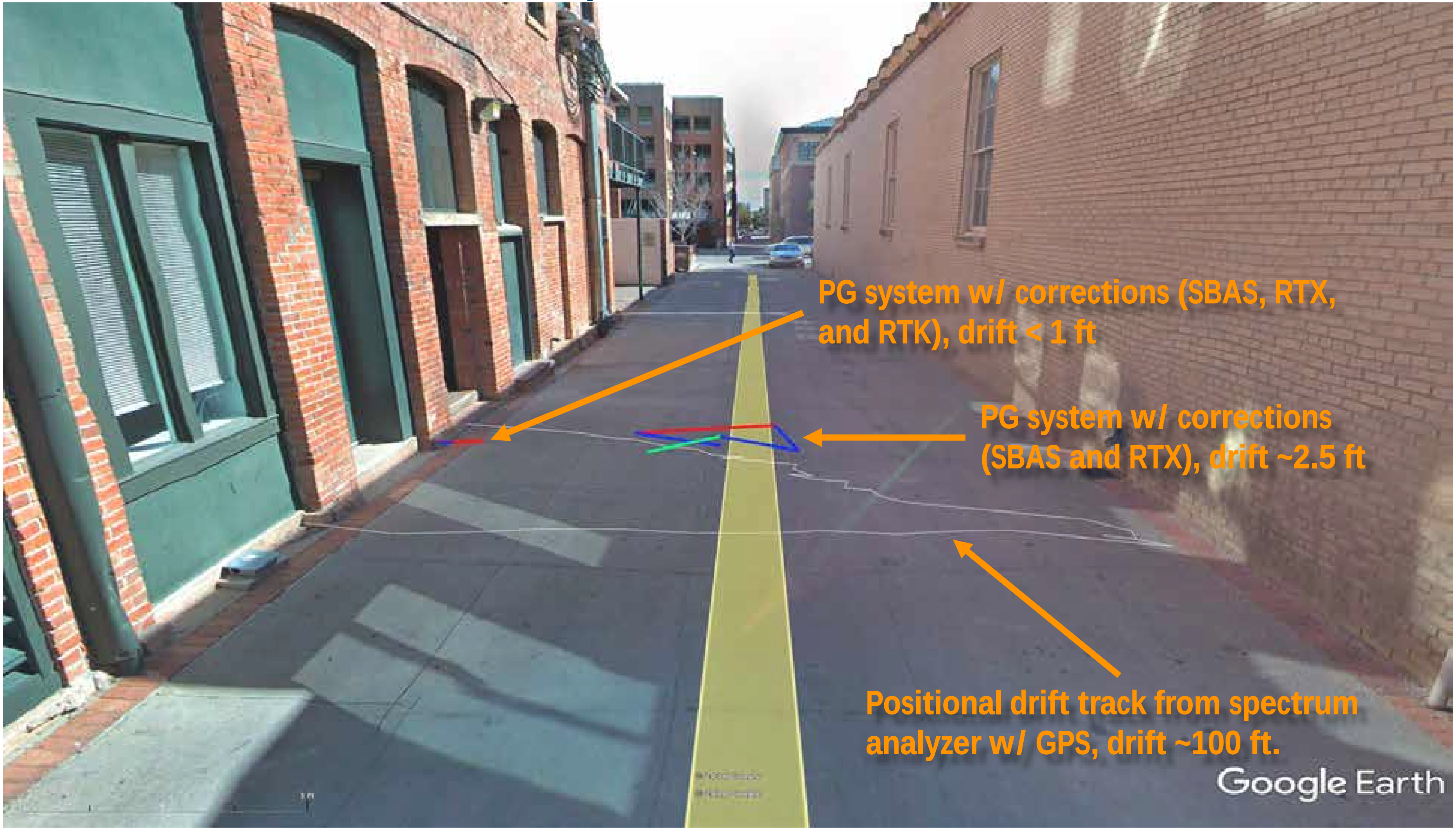
$$r_{(\text{in mts})} = 17.32 \times \sqrt{\frac{d_{(\text{in Km})}}{4f_{(\text{in GHz})}}} \qquad r_{(\text{in ft})} = 72.05 \times \sqrt{\frac{d_{(\text{in miles})}}{4f_{(\text{in GHz})}}}$$

Previous positional drift error = ~30 m

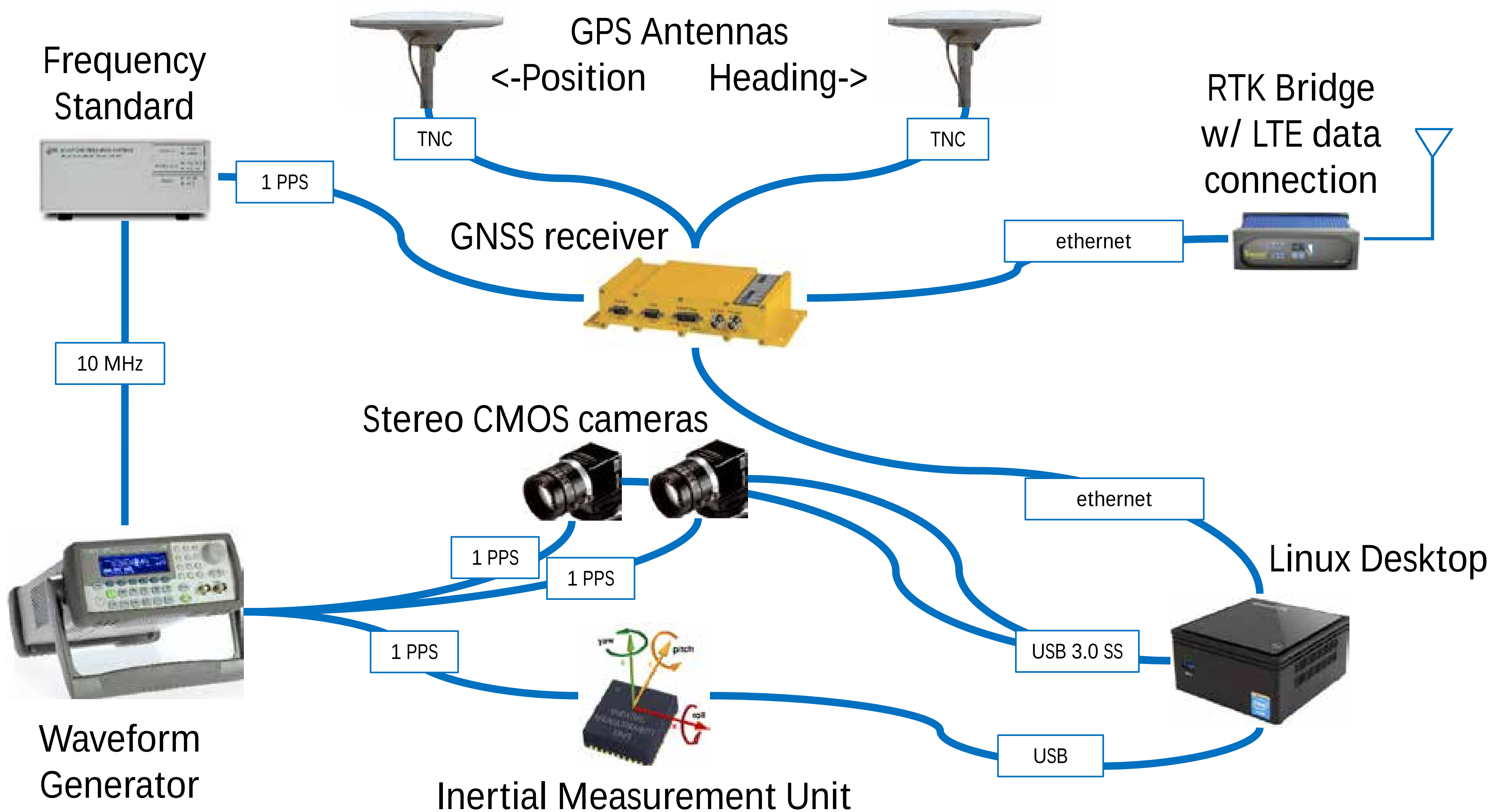
Spectrum Analyzer vs. Precision GPS



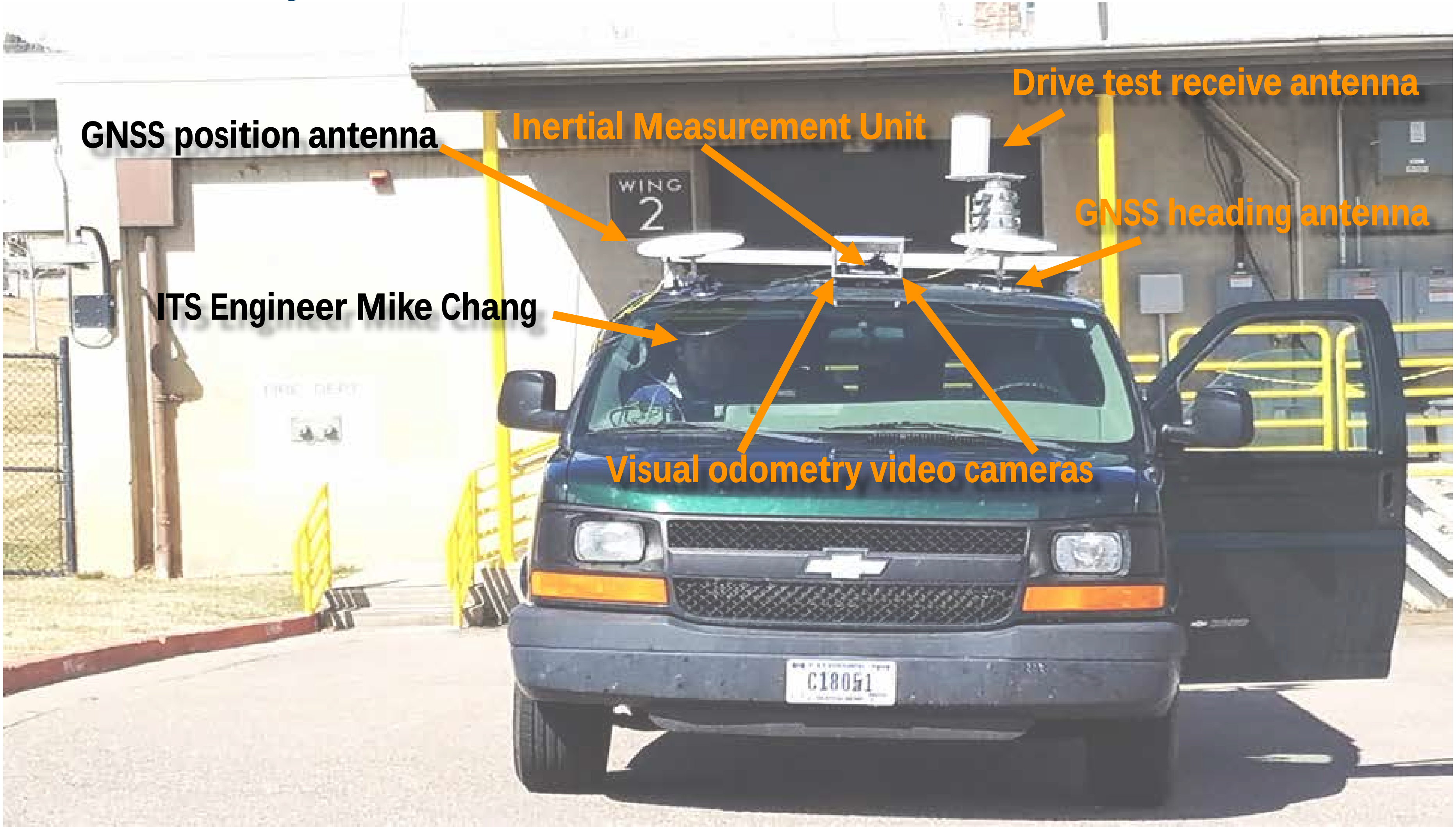
Drift comparison: RTX vs. RTK



System Architecture



PG System Mounted on Drive Test Vehicle



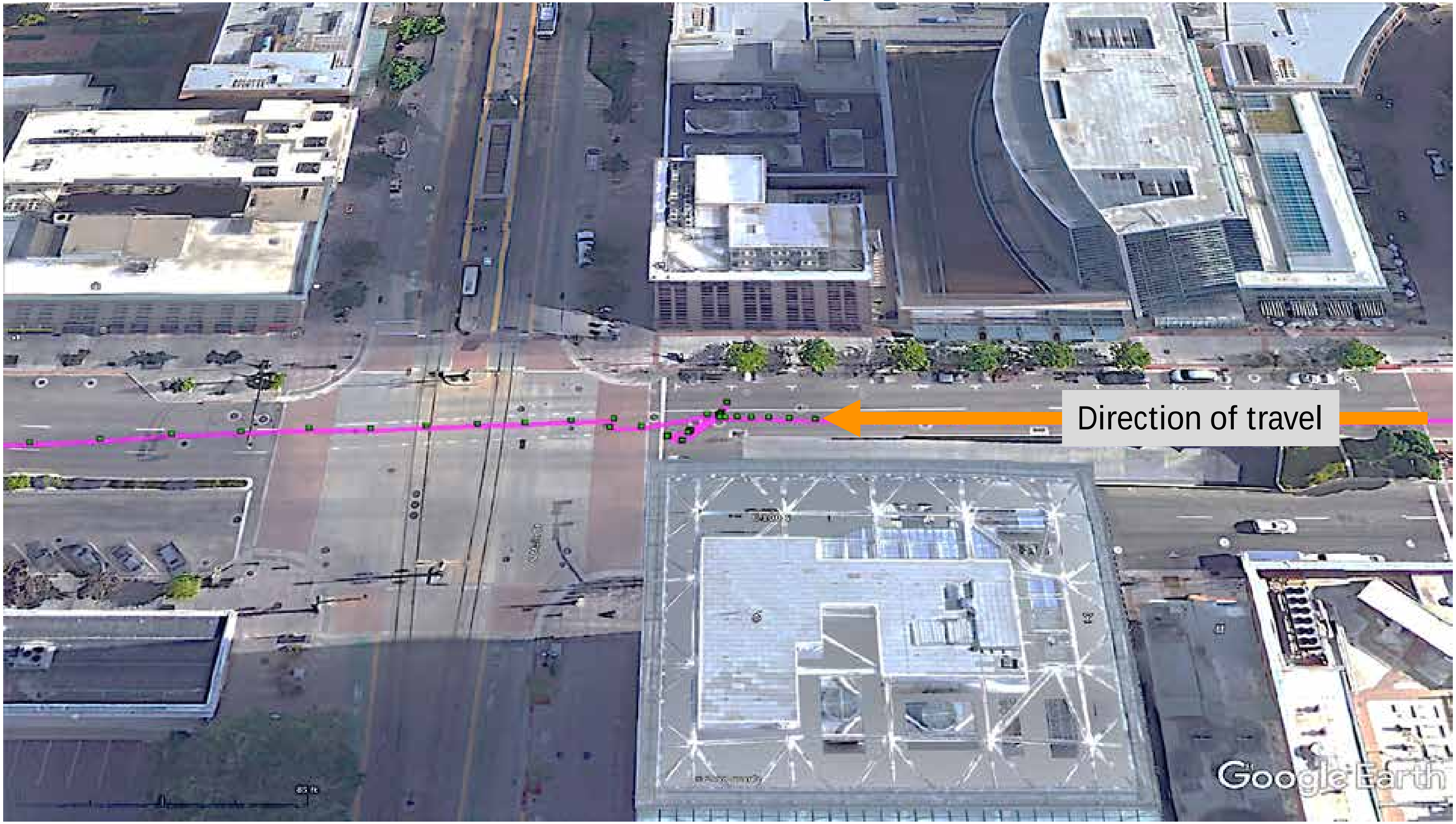
Stereoscopic Landmark Detection

Recent Drive Test Results – Boulder Campus

Campus Loop Closeup – SW corner

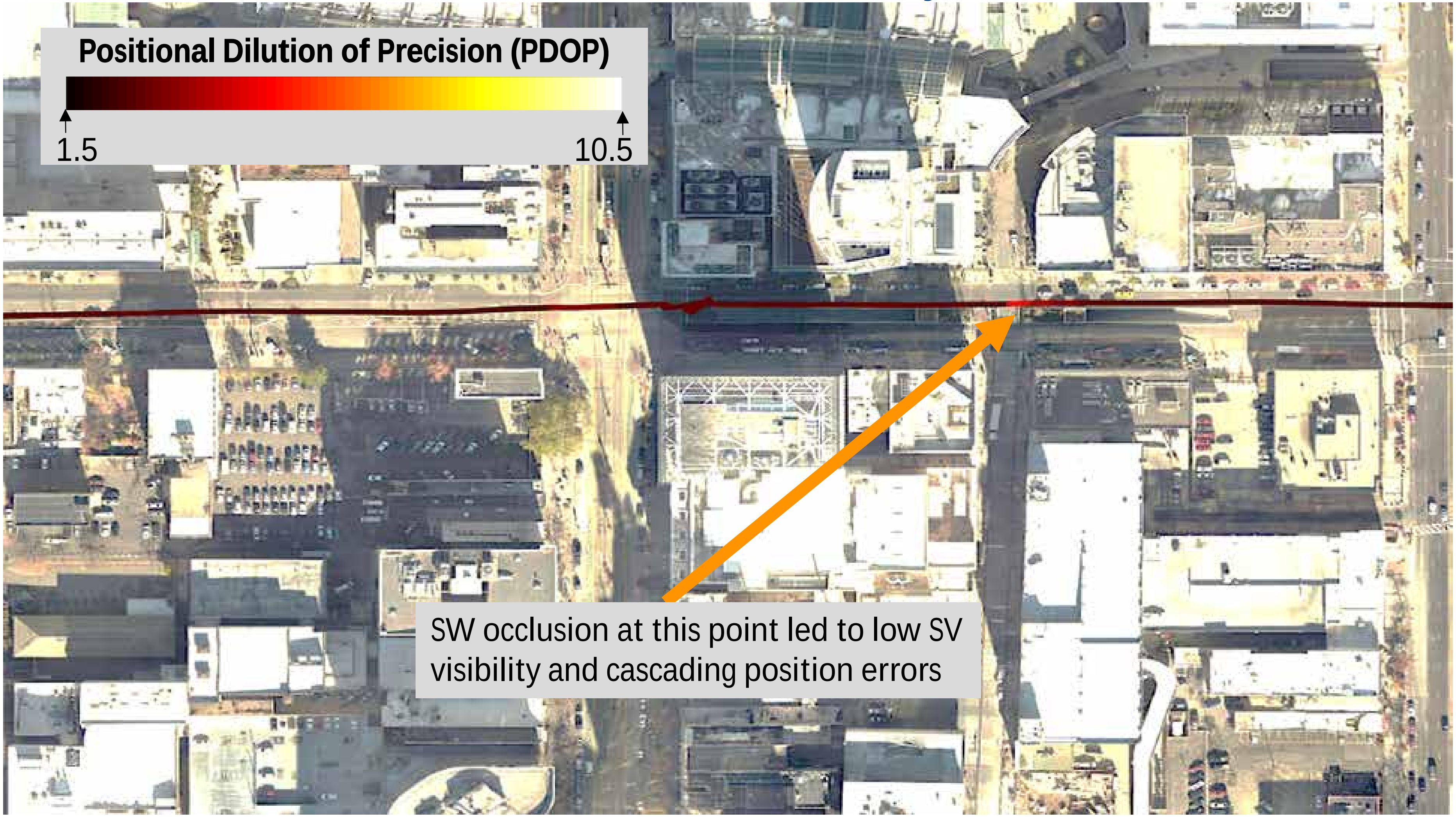
High Drift Area #4-Street View (Pearl & 16th)

Downtown Salt Lake City – Problem Area



Downtown Salt Lake City – # of Satellites

Downtown Salt Lake City – PDOP

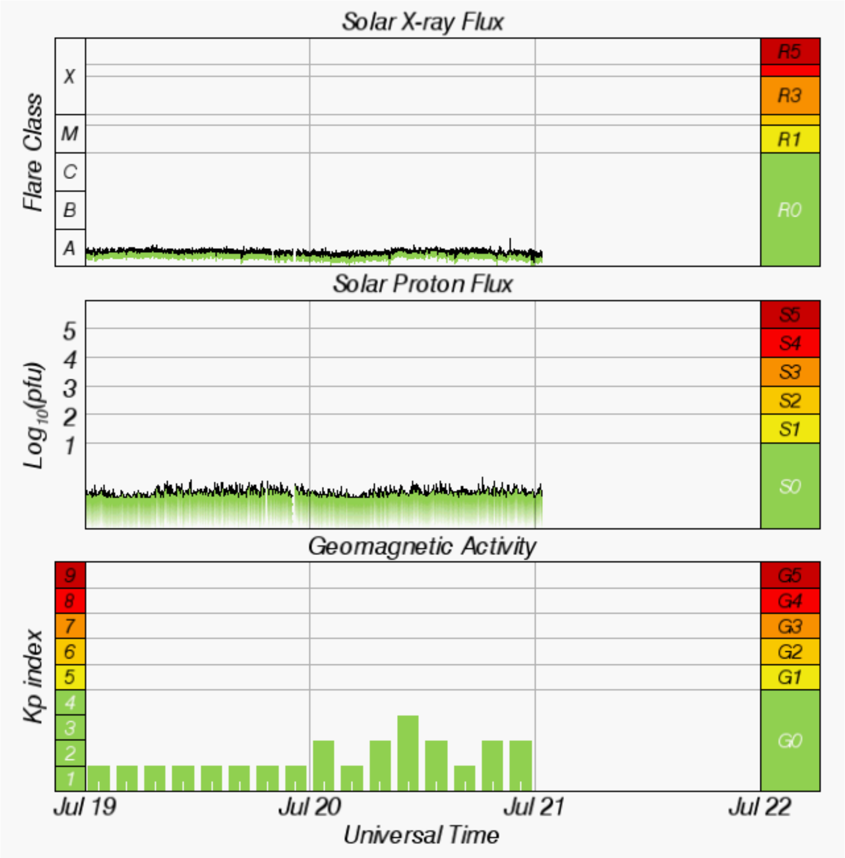


Best Practices

- **Know your equipment**
  - use multiple, redundant correction sources, e.g. Real-Time Kinematic, CenterPoint RTX™, Satellite Based Augmentation System (SBAS and SBAS+), etc.
  - static vs. dynamic, accuracy vs. precision
  - quality matters
- **Read the manual**
  - NOAA/NGS' *User Guidelines for Single Base Real Time GNSS Positioning* is a great reference!
- **Keep an eye on the satellite conditions during testing**

Best Practices

Extraordinary solar flux or geomagnetic conditions = bad times



Source: https://www.swpc.noaa.gov/communities/global-positioning-system-gps-community-dashboard

Conclusions

- We have achieved a ***6,000x increase*** in positional accuracy (30 m to 5 cm) when conducting static measurements
- A properly-configured GPS system has the biggest impact on positional accuracy
- Comparable civilian systems, e.g. Leica Pegasus 2 start at $600k
  - ***An identical system at the current level of development can be replicated in less than a year for just under $250,000***

Thank you!

Appendix

Hardware Specifications

Hardware Specifications

Trimble BX982 GNSS receiver

- Position and vector antennas based on a 220-channel Maxwell 6 chip:
  - GPS: Simultaneous L1 C/A, L2E, L2C, L5
  - SBAS: Simultaneous L1 C/A, L5
- High precision multiple correlator for GNSS pseudorange measurements
- Unfiltered, unsmoothed pseudorange measurements data for low noise, low multipath error, low time domain correlation and high dynamic response
- Very low noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- Code differential GPS positioning accuracy*
  - 0.25 m + 1 ppm Horizontal
  - 0.50 m + 1 ppm Vertical
- SBAS accuracy*
  - <5 m 3DRMS
- RTK positioning accuracy(<30 km)**
  - Horizontal: ±(8 mm + 1 ppm) RMS
  - Vertical: ±(15 mm + 1 ppm) RMS
  - Heading: 2 m baseline <0.09°; 10 m baseline <0.05°

*this functionality is included with our current receiver
**this functionality requires additional equipment and/or subscriptions

- Initialization time
  - Typically, less than 10 seconds, 99.99% reliability

Hardware Specifications

Gladiator Technologies LandMark 01 IMU

- 3 degrees of freedom: Gyro rotation (X,Y,Z in °/s), Acceleration (X, Y, Z in g's), Temperature (°C)
- 4 kHz
- NON-ITAR Low Noise MEMS IMU 1" Cube
- Gyro Range: 490°/s
- In-Run Gyro Bias: *5°/hour 1σ*
- Low Gyro Noise: *0.003°/sec/√Hz*
- Accelerometer range: 10 g's
- Low Accel Noise: *0.09mg/√Hz*
- Compensated Misalignment: *1mrad* and g-Sensitivity: *<0.001°/sec/g 1σ*
- External Sync Input: *(5kHz)*
- Low Power: *<240 mW typical*
- Power: 3.3 V
- Wide Sensor Bandwidth: *250 Hz*
- RS422/RS485 Serial Interface
- Data Rate *2.5kHz (user selectable)*
- Fully Temperature Compensated Bias and Scale Factor
- Bandwidth Filtering Capability

Hardware Specifications

Gigabyte BRIX ultra-compact gaming PC

- CPU: Intel Core i7, 8 x 2.5 GHz CPU core
- GPU: NVIDIA GeForce GTX 870M
  - CUDA Cores: 1344
  - Graphics Clock (MHz): 941 + Boost
  - Memory Specs:
    - Memory Clock: Up to 2500 MHz
    - Standard Memory Configuration: GDDR5
    - Memory Interface Width:192-bit
    - Memory BW: 120.0 Gb/sec
- 256 GB SSD, 15.6 GB RAM
- Ubuntu 16.04 LTS (64 bit)
- Ports:
  - 2 x miniHDMI
  - 1 x Mini DP
  - 4 x USB 3.0SS
  - 1 x RJ-45
  - Headphone and mic jack

Hardware Specifications

Ximea XiQ Cameras

- Model: MQ022CG-CM
- Resolution: 2048x1088
- Pixel size: 5.5 µ m
- 10 bit ADC
- Dynamic Range: 60 dB
- 2/3“ lens
- Maximum Frame Rate: 170 fps @ 8 bits/pixel
- Sensor types: CMOS, Global shutter sensor
- Acquisition Modes: Continuous, software and hardware trigger, defined fps, exposure defined by trigger, pulse(*1) and burst
- Image data formats: 8, 10 or 12 bit RAW pixel data(*2)
- Color image processing: Host based de-Bayering, sharpening, Gamma, color matrix, true color CMS
- Auto adjustments: Auto white balance, auto gain, auto exposure
- Flat field corrections: Host assisted pixel level shading and lens corrections
- Image Data and Control Interface: USB 3.0 standard Micro B with screw lock threads compliant to USB3 Vision standard
- Synchronization Hardware: trigger input, software trigger, exposure strobe output, busy output