Future GNSS – Precision Applications

Stuart Riley

Trimble

Major Trimble Precision Markets

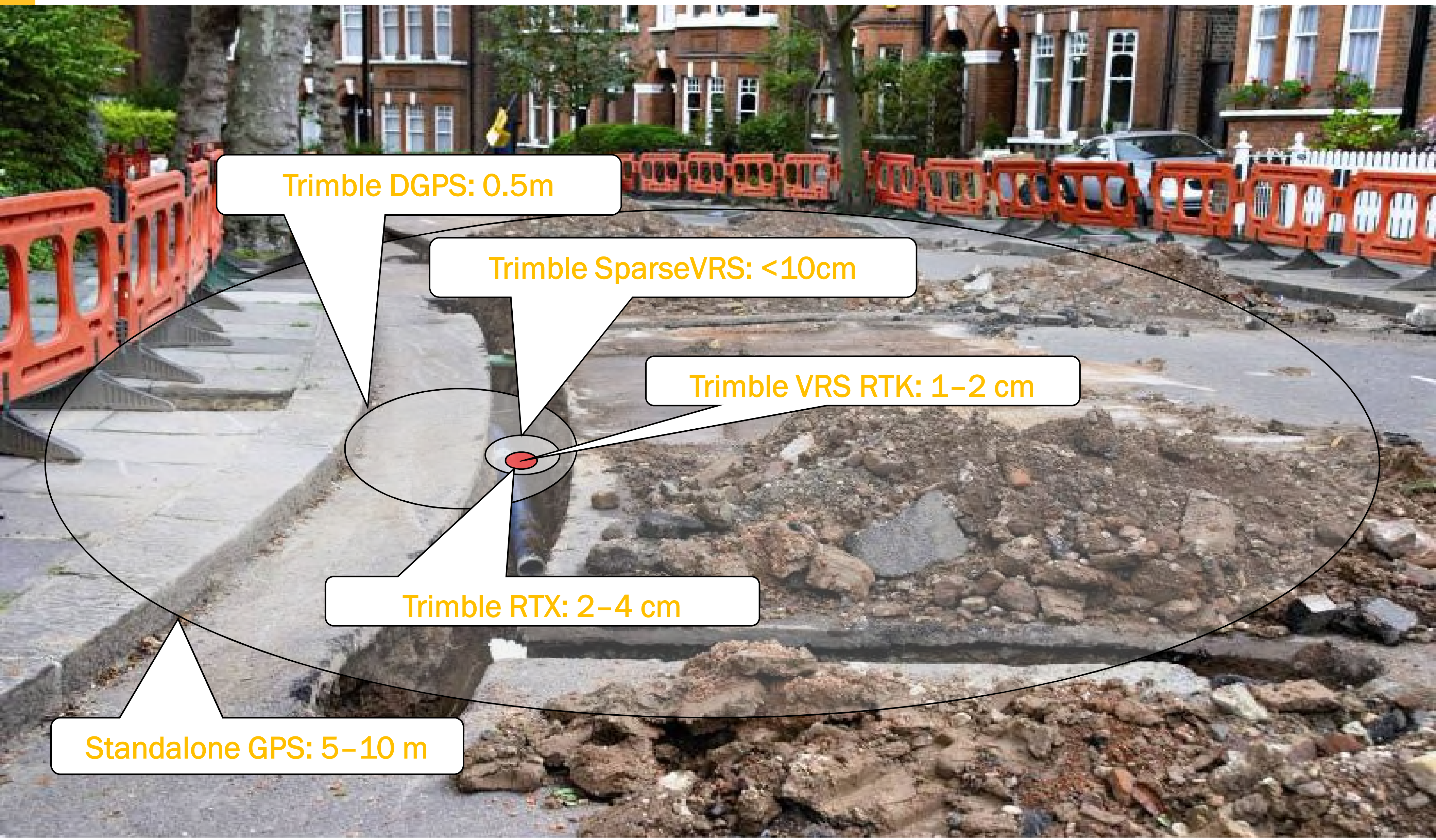
- Survey
  - Mostly person portable equipment
- Construction
  - Machine control and person carried equipment
  - Includes Marine applications
- GIS
  - From autonomous to RTK
- Agriculture
- Precision OEM
- Infrastructure
  - Includes deformation monitoring
  - RTK/CORS Base stations
  - VRS, RTX services etc

Customer goal is productivity Increase

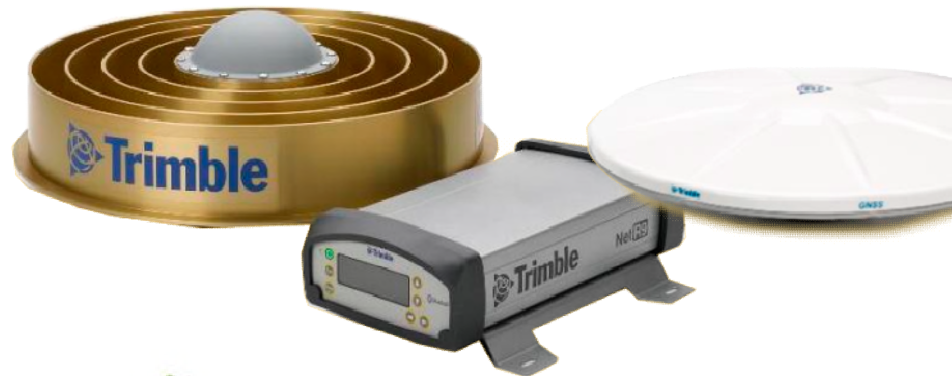
- GNSS
  - Allows more rapid data collection
  - Provides workflows that were not possible before GNSS
  - In many applications higher accuracy results
- Multiple other key technologies
  - Communications
  - Integration with the customer workflow
    - Integrate into CAD packages
    - Project and material planning
    - Billing
    - Business Intelligence
    - etc
  - Other key Trimble positioning technologies
    - Laser instruments
    - Inertial
    - Pseudolites (Terralites in mining)
    - VRS Network Infrastructure
    - RTX Infrastructure

Trimble Construction Connected Site

Accuracy is application dependent



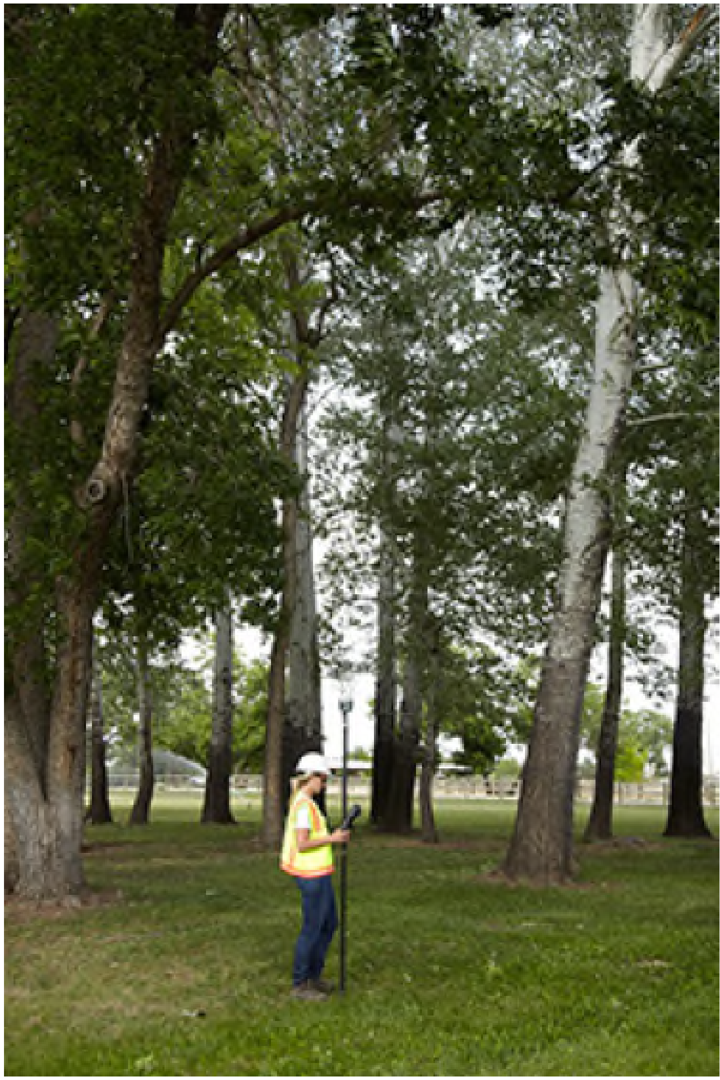
- Example Trimble Products
  - GPS/GLN/Galileo/QZSS/BeiDou/SBAS/OmniSTAR



Trimble

Trimble High Level GNSS Requirements

- As many satellites as possible
  - Allows operation in “GNSS Hostile” environments
  - Trimble track all GNSS signals in space today
  - Improves accuracy (averages multipath / better geometry)
- Compatible signals
  - Different codes, modulations are easy to manage
    - Moore’s law continues to shrink the digital electronics
  - Increasing number of RF bands harder to shrink
    - Result in higher power and more expensive products
  - Known coordinate reference frame offsets
- Spectrum Protection
- Open access to ICDs
- 2 or 3 frequencies per system
  - RTK/RTX etc.



Trimble.

Frequencies

- Already capable of tracking everything in space today
  - L1, L2, L5, E5A, E5B, E5AltBOC, LEX, B1, B2 etc
  - Where possible new signals should stick to the existing 4 bands:
    - "L1" - Greater L1 band (B1 thru to the top of GLONASS L1)
    - "L2" - GPS/GLONASS L2
    - "L5" - L5/E5A/E5B/B2
    - "L6" - E6/LEX/B3
  - Due to the number of available satellites on each band Trimble products are as follows:-
    - "L1" + "L2" – low end legacy devices
    - "L1" + "L2" + "L5" – becoming the minimum for precision markets
    - "L1" + "L2" + "L5" + "L6" – high end devices
  - Sticking to these frequencies prevents the need for more complex antennas (larger) and additional radio front-ends (size/power)
  - Frequency offsets within this band are relatively easy to handle in the digital baseband and data processing
  - CDMA is the preferred modulation, avoids biases of FDMA
    - Although committed to supporting GLONASS FDMA
  - We have not fully evaluated frequencies beyond L-Band
    - Challenge is developing a small antenna with a very stable phase center
    - Requires an extra down-converter (size/power)
- Already have tri-lane RTK capability in shipping products

Trimble®

Modulation

- Key requirement is low noise measurements
- Navigation data message is important, but the measurements are the most critical
  - Preference would be more power in a pilot versus data channel
- TTFF not as important in the precision market
- Common Spectrum (e.g. GPS MBOC and Galileo CBOC)
  - Both signals providing a lower noise (esp. multipath) signal compared to BPSK is very positive
  - However to optimally demodulate these signals there are differences required in the channel configuration for MBOC and CBOC.
- Favour future modulations that have inherent multipath mitigation, e.g. AltBOC compared to regular BPSK.
  - Wider bandwidths help with multipath mitigation
  - Select the lowest noise signal from each band/system (e.g. on Galileo E5 the preferred signal is AltBOC although the engine is capable of using the other signals)
- Code and carrier need to be locked together at transmission
  - All navigation signals transmitted from a common point in space

Trimble

Data Processing

- Today compute GPS, GLONASS, Galileo clock offsets
  - QZSS is treated as a GPS satellite and we have the advantage of not needing to compute the clock offset
  - When Galileo is active we'll evaluate whether the transmitted offset of the receiver calculated one is the most accurate
  - Preferred method of getting data is over the satellite to cover all user cases
    - Although internet delivery in some applications has advantages to rapidly bootstrap a receiver
- Datum Offsets
  - For short to moderate length baselines small datum offsets have minimal impact
  - Large datum offsets are an issue (e.g. PZ90 prior to PZ90.1)
  - For RTX Trimble compute our own orbits and clocks in the current epoch of ITRF
- BeiDou's transmission of differential corrections on the GEOs is an interesting concept and is being evaluated.
- Trimble's philosophy is track everything that is available
  - Analyze the data in real time and use everything that meets selection criteria
  - In a benign environment more signals relative to today have a marginal impact
  - The benefit is in a hostile environment (masking, trees etc)

Operators / International Community

- Spectrum Protection is very important
  - Products in the precision market have a very long life
- While small datum shifts can be tolerated knowledge of the datums is important
- Open ICD access
  - Preferably before the satellites are launched (the precision market has a lot of early adopters)
  - All current systems are now open!
- Publication of guaranteed performance levels
  - Even better real time access to current global performance