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Integrating SX and X Series Data for Road Surveys – A User Experience

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  Trimble Distribution Partner

- Survey field assistant and office technician.
- **Trimble:**

  Technical support and product management
  Quantm and Trimble Business Center
- **LISTECH:**

  National Sales manager

Overview

Our Client

RPS (A Tetra Tech Company)
Damian Ling - Technical Director - Surveyor

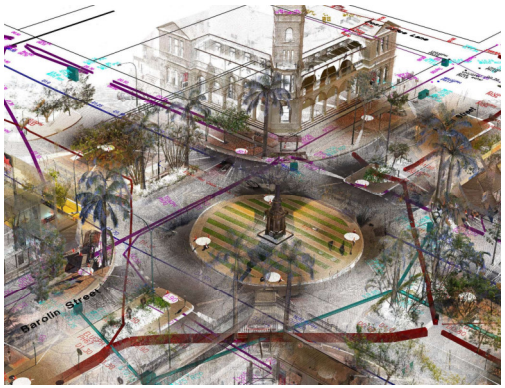
- **Part of Global Consulting Firm Tetra Tech:**

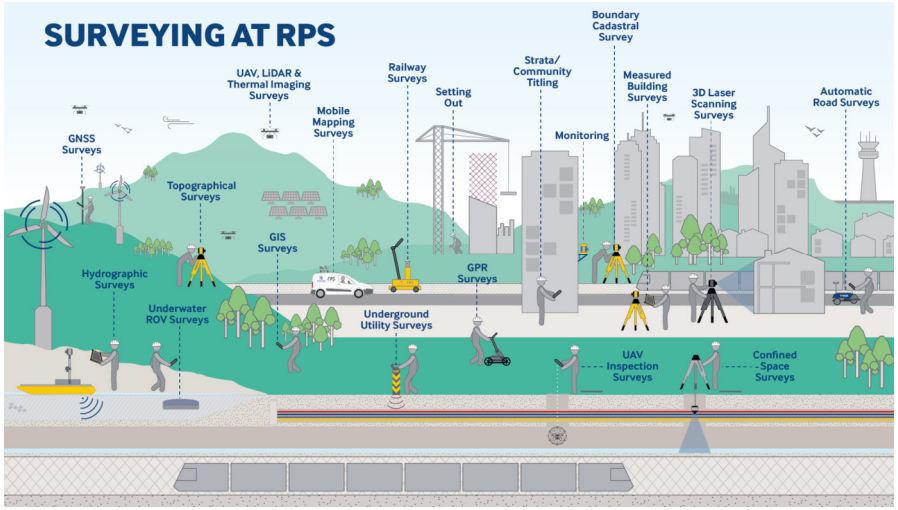
  Provides integrated solutions across environmental, engineering, and planning sectors, with a focus on sustainability and project delivery.
- **Expertise Across Multiple Industries:**

  Specializes in infrastructure, water, energy, resources, environmental, and property sectors, offering tailored services to clients worldwide.
- **Innovative and Sustainable Solutions:**

  Committed to delivering innovative, sustainable solutions that drive environmental and social value for clients.
- **Wide Geographic Reach:**

  Operates in over 20 countries, with a diverse team of professionals working across the Americas, Europe, Asia Pacific, and the Middle East.





The problem

Working on roads...

- Can be dangerous and more challenging for staff
- Road pavement level and feature information is critically important for engineering design
- Typically, this one done either:
  - At night with traffic control
  - During the day in gaps of traffic with a spotter
- Surveyors face issues with undertaking their work safely, even with these controls in place

- The risks had been experienced firsthand on a project that included 2.5km survey of road pavement

Client requirements

Clients survey standards needed to be considered

Scan Limits

Feature extraction to be no more than 50m from station and any point cloud data greater than 50m to be removed from final product.

Coordination

If setup on a known mark, standard B/S and F/S checks are required. If a setup is derived from a resection, a separate resection report is required.

Quality Assurance

All other control and benchmarks to be used as a point v cloud check. Independent QA check strings to be observed across the scan capture. Features extraction at no more than 5m intervals.

Initial solution

Staff safety whilst delivering the required data was their priority

- RPS needed to reduce or remove the requirement of working on pavement
- This meant remote capture of survey data being needed as a priority
- Our options included reflectorless, laser scanning, MLS or status quo
- At the time the SX10 had just been released allowing for new processes to be investigated
- Their road-based clients already had processes in place for laser scanning capture
- It seemed logical to RPS at the time to progress with future works utilizing the SX10

Why Scanning?

- Safer for surveyors in the field
- Minimal impact on the public
- It is easier to collect data
- More data collected
- Shorter time in the field
- Less need to return to the field
- Capture can be done on active sites
- Office workflows become streamlined
- More accurate models returned from scanning
- Easier to address any issues
- More ways to visualise data
- Continue working in all conditions

Why Scanning?

Why use Terrestrial Laser Scanning in particular?

Total Station

Conventional detail and feature survey with total station would be too time consuming and cost prohibitive.

GNSS

Whilst the PUP was being undertaken with GNSS they only required a surface model, The local authority standards do not allow use of GNSS for hardstand surveys.

Existing Lidar

Not accurate enough on pavement and not enough detail to model kerb as an example.

MLS

Along with initial cost outlay, most of the site area was covering grade separated verge, roads not accessible by vehicular traffic and footpath through parkland and open space.

Slam Scanning

Not accurate enough for the requirements of the project and the length of the project caused issues with point cloud float.

Trimble Scanning Range

A scanner for all occasions

- The X9 has been split into two editions where X9 core has replaced the X7
- X12 is a high precision scanner for greater range and precision

- SX12 is the Trimble scanning total station this replaced the SX10

- It is important to know scanner specifications when undertaking projects and make sure they meet the deliverable requirements

SX Series Scanners

Considerations & Parameters

Considerations

- Primary Control Spacing
- Additional benchmark requirements
- Resection v Observed control for additional scan stations
- Speed of Scan

Parameters Used

- Full dome scan with imagery
- Secondary polygon scan
- Course scan
- Pausing scans as required

SX Series Project

Juers Road

- First project with pavement capture from scans
- Total length of pavement around 900m
- Scanning completed with the SX10
- Primary control at approximately 100m spacing and scan stations every 30m
- Traverse and scanning to 28 hours to complete
- 423 million points captured with 1613 points extracted from the point cloud
- QA checks versus derived TIN was less than 5mm from a total of almost 90 check points

SX Series Project

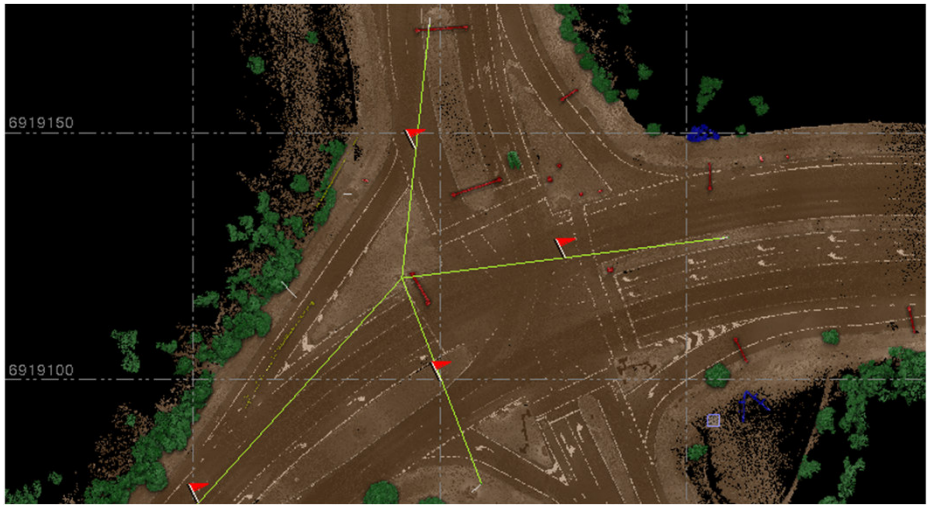
Benefits and Issues encountered

Benefits

- Not working at night or on pavement
- Reduced requirement for Traffic Control
- Data mining of missing features
- Extraction of overhead features
- Scans are already coordinated

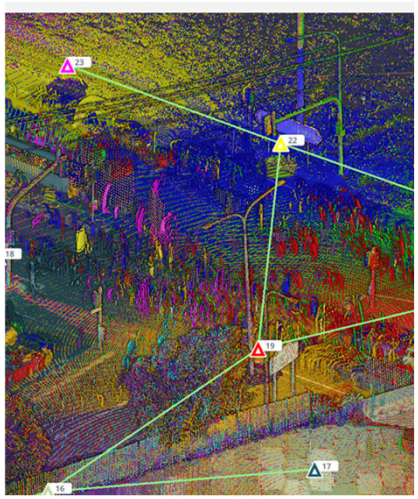
Issues

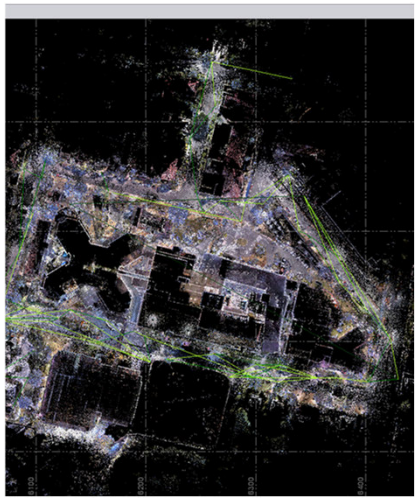
- Time to complete a full dome scan
- Additional scans required
- Effective range on pavement
- Size and weight of instrument



X Series Scanners

- RPS was an early adopter of the X Series starting with the X7
- At release, RPS were immediately looking at ways to integrate the unit into their existing workflows.
- Testing was undertaken on your more typical scanning projects including building internals, building facades, transition substations and a hospital which generated good results.
- Once confident of workflows, investigation was done to incorporate it into their Road projects.

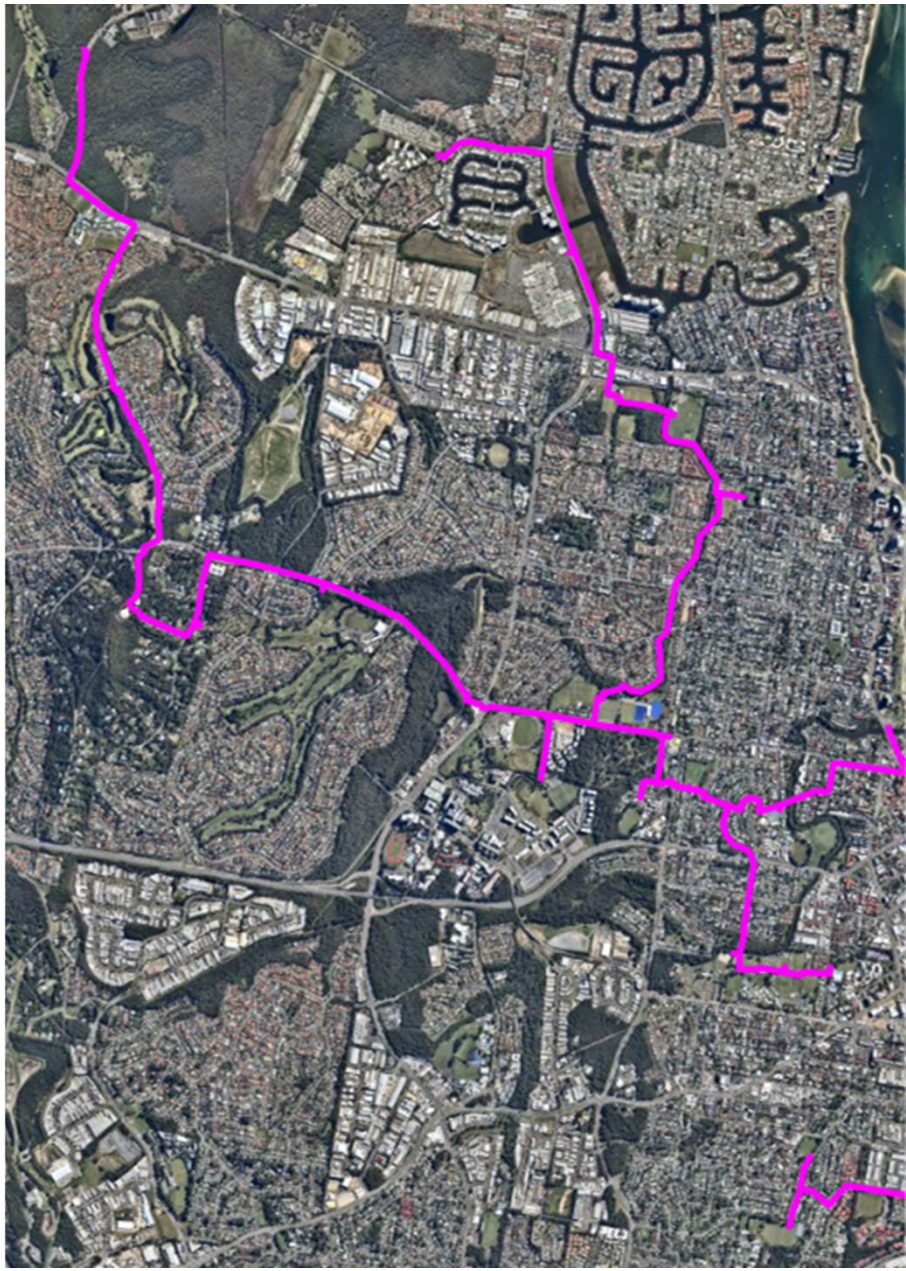




X Serie Project

GCRW Investigations

- Recycled Water Pipeline investigation study
- Primarily focused on utility investigations
- Utility location by EMR and GPR and surveyed with GNSS
- A surface model was also required
- Project covered 35km proposed alignment covering as mix of road, footpath, access tracks, sporting fields, green space, and existing infrastructure
- Project was split into 7 project investigation areas
- 1638 X Series scans were undertaken to cover the project

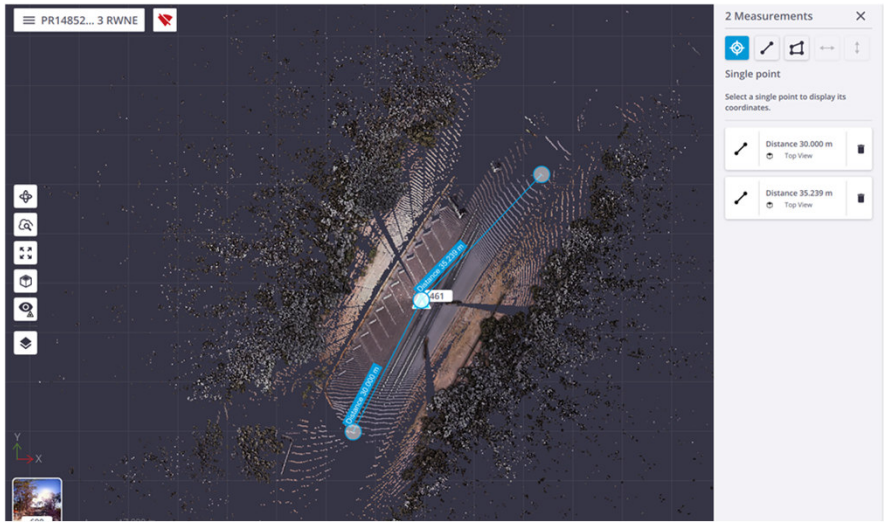


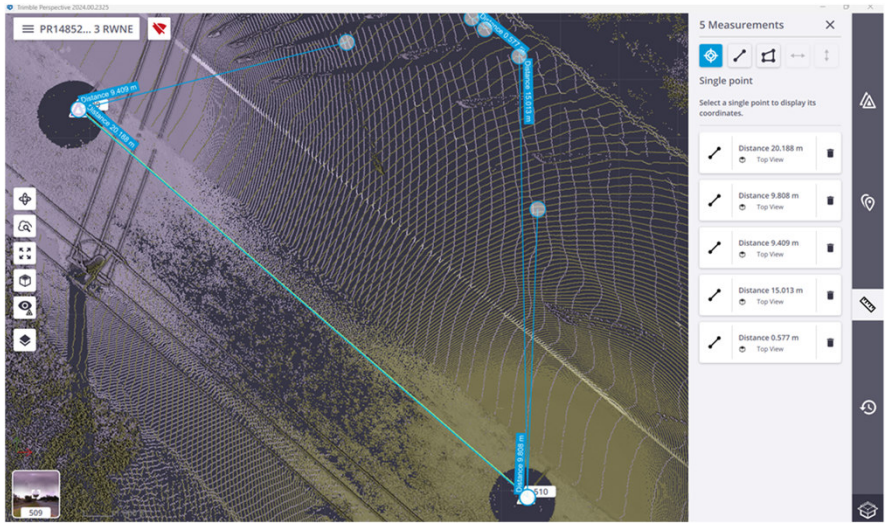
X Series Experience

Straight in the deep end

- Very easy to use in the field
- A lot was learnt about the X series and scanning workflows for linear projects on this job
- The first section of the project done in Perspective contained 230 scans and identified some early challenges in the original workflow
- UPG and Trimble worked with RPS to create processes to help achieve the goals on this type of project

- The outcome here was to
  - Use 3-minute scans + imagery
  - Position the project using the use of painted GCP's at around 200 – 250m spacing
  - Scan spacing was set at no more than 30m
  - Check and address registration issues in the office

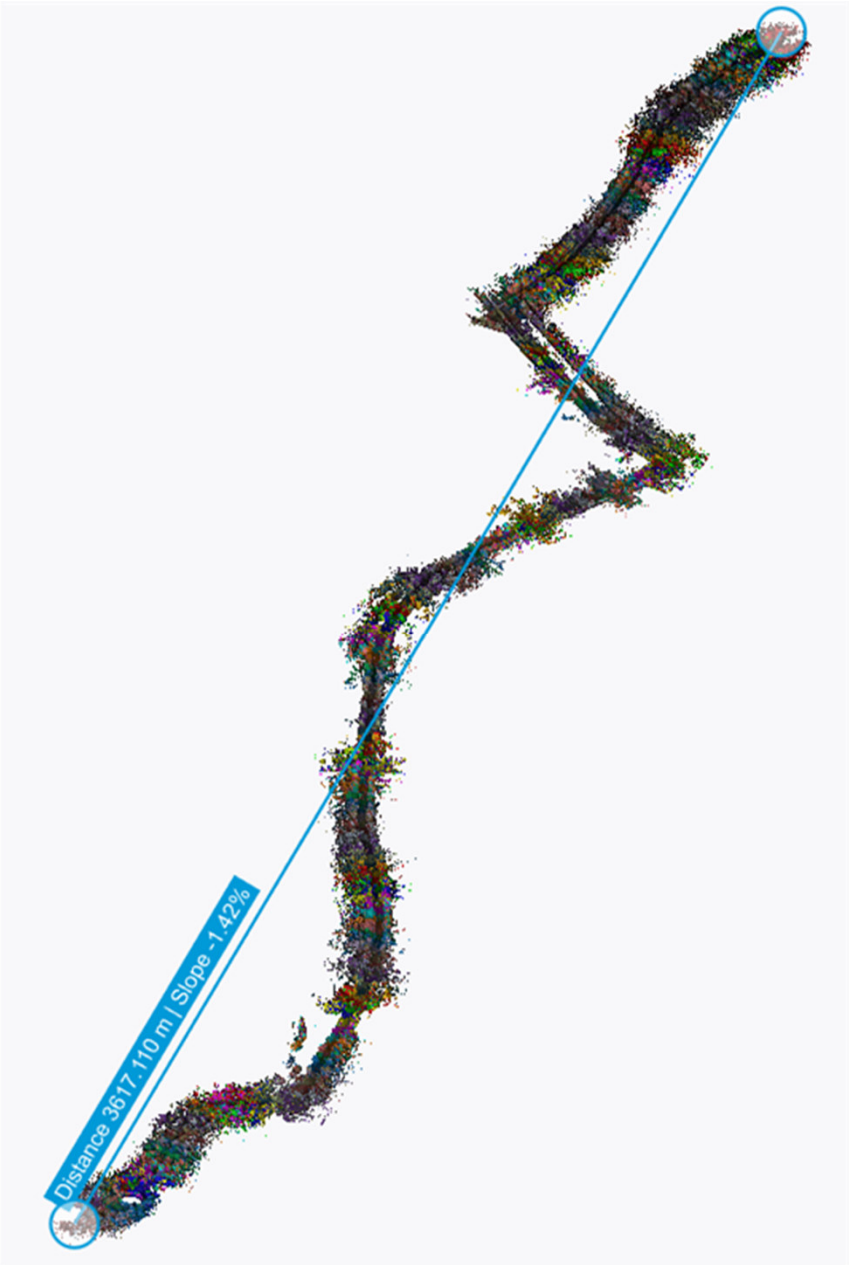




X Series Experience

What was found

- Initial workflow outdoors had less than ideal registration conditions
- Reporting confidence was distorted due to spread of points being mostly on horizontal plane
- Even with automatic registration, a number of misaligned field registrations were identified
- Due to the size of the project, Perspective was installed on a desktop in the office to review and QA (addressing registration), colorise and refine
- Export to TBC for geo-referencing (SF applied)
- Total accumulative error of 0.447m horizontally



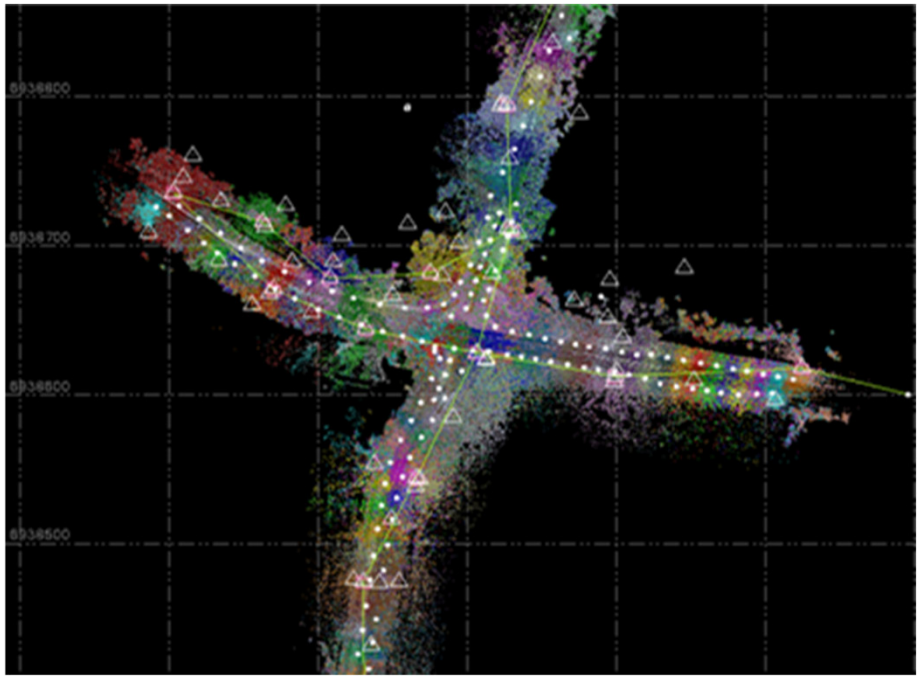
Let's get technical for a moment

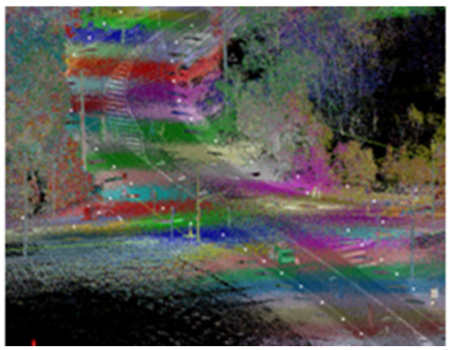
Scan Registration

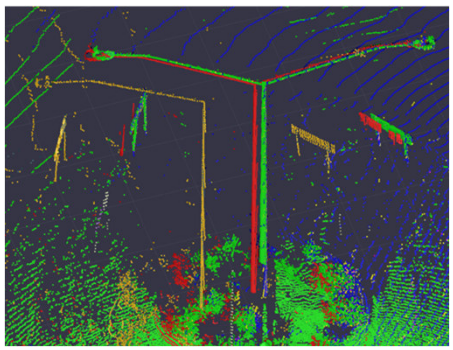
Scan Registration 101

- Registration looks at how scans are joined together to one another.
- Accuracies in scanning projects are dependent upon how well registration has worked.
- Registration can be done in the office or the field.
- There are different processes that can be used depending on the scanner.
- Multiple registration techniques can be used in a scanning project.

- AI does not always get it right.



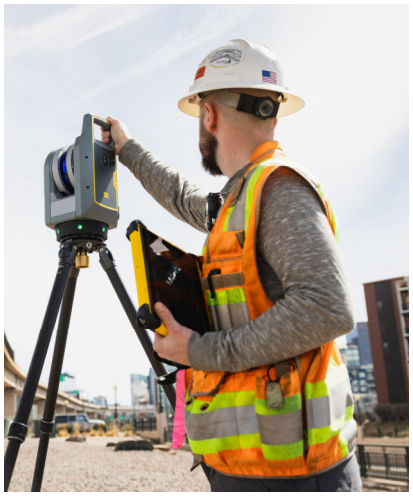


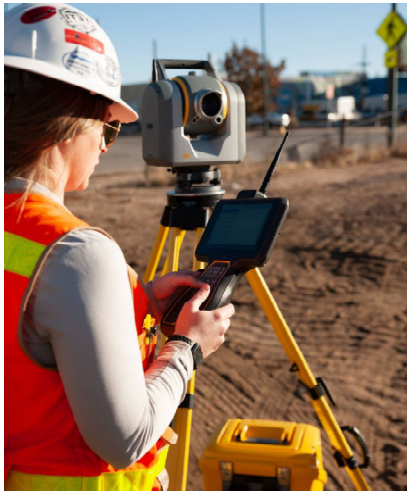


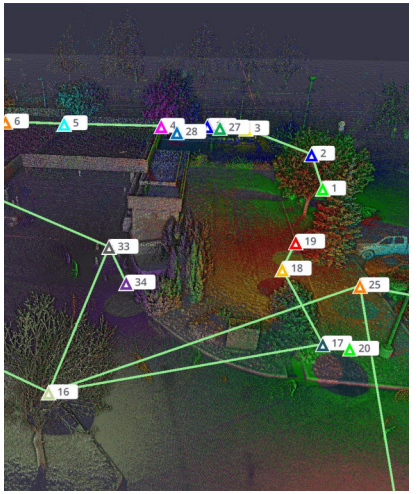
Scan Registration

Registration Considerations

- Identify what accuracies are to be chased from the start to determine best process.
- Size of the project and site access are significant driving factors when making a decision about which process is best to use.
- The type of registration process needed should be considered before starting out a project.
- A mix of scanner and registration types can be used in a single project.



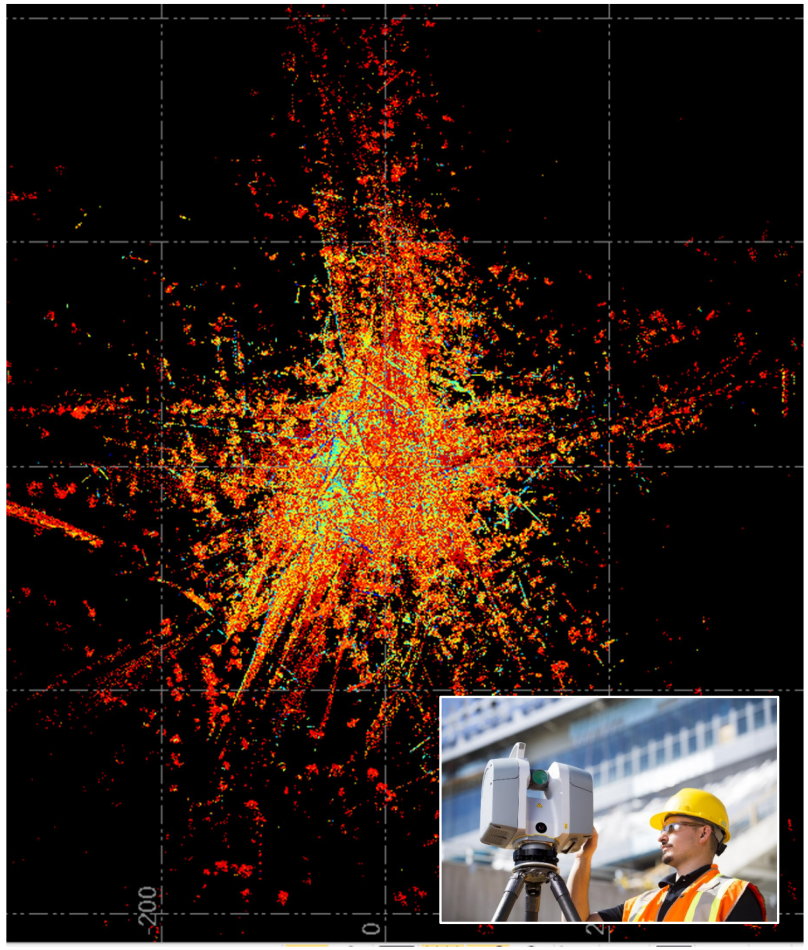




Scan Registration

Unregistered

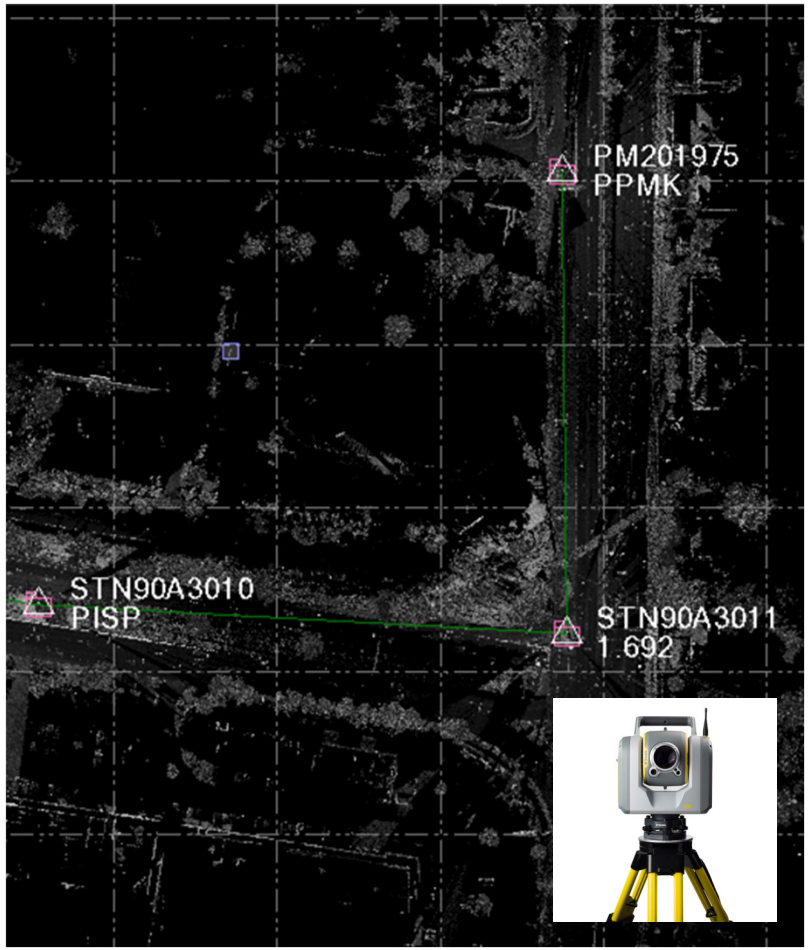
- Scan without any association to any other scans.
- All scans have the same setup point.
- Scans don’t have any specific orientation other than the direction of the scanner when it started.
- For projects with more than one scan, registration will need to be undertaken to connect the scans together.



Scan Registration

Station based registration

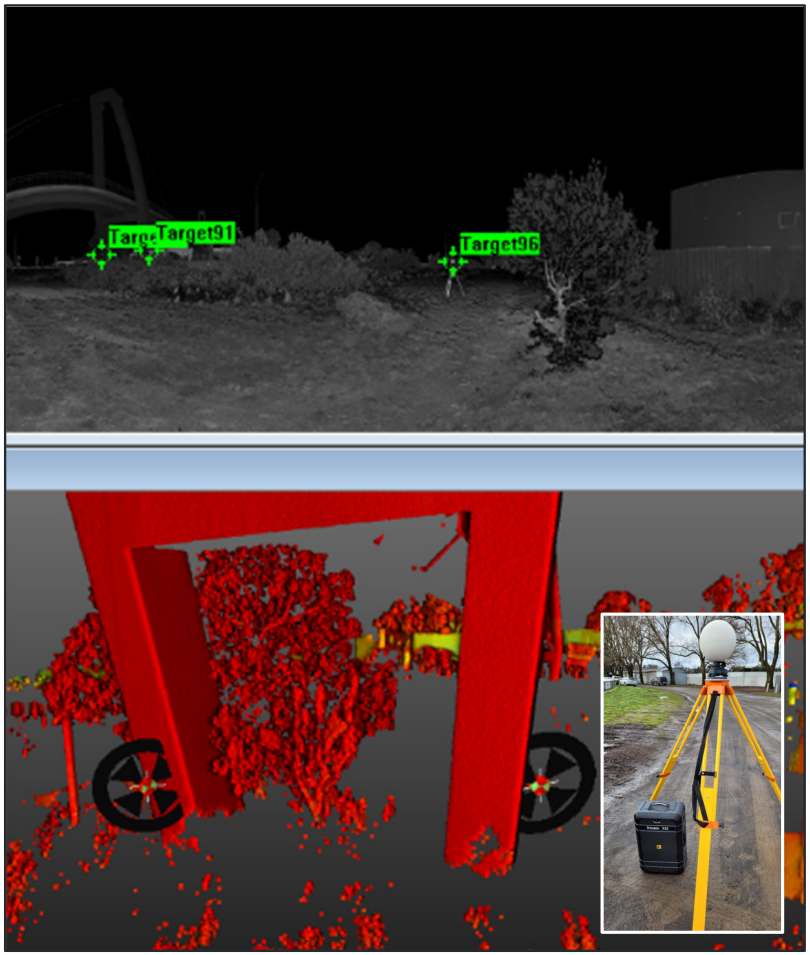
- Uses traditional survey practices to identify the location of the scanner.
- Scans are tied to setup locations which are linked by traversing.
- Registration is done through traverse and network adjustments and not through clouds.
- Georeferencing is done through traditional survey practices locating the setup points.
- Survey grade accuracies can be achieved through this process.



Scan Registration

Target based registration

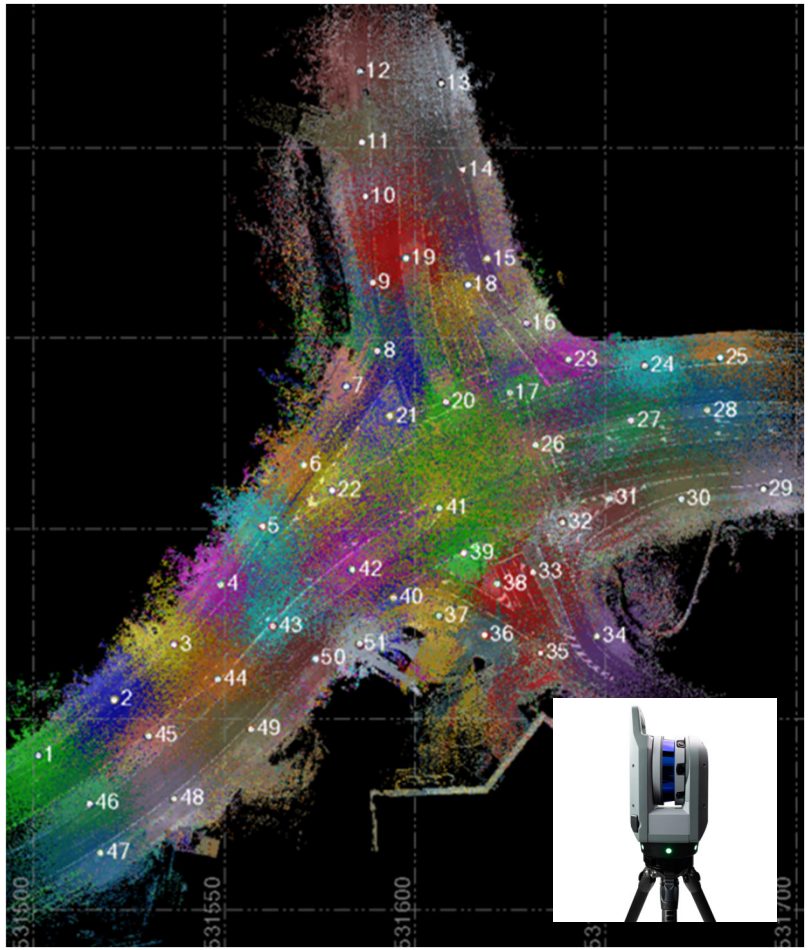
- The process of using targets and spheres in scans to align two point clouds together.
- Registration is done during the post processing step in the office.
- Targets need to be setup and located using traditional processes.
- Registering and georeferencing can be done in the same step if targets have been located.
- Survey grade accuracies can be achieved through this process.



Scan Registration

Cloud based registration

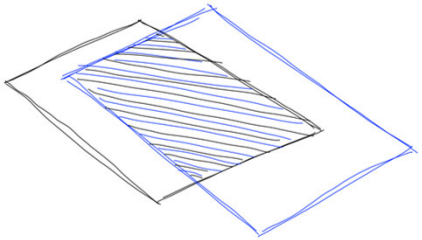
- The process of using similar recognised shapes to align two scans together.
- Fast and simple process for connecting scans together.
- Registration can be done using planes or manually.
- Small differences can occur in registration process.
- Large flat vertical surfaces will significantly help registration.
- It is can be difficult to achieve survey grade accuracies outdoors through this process.

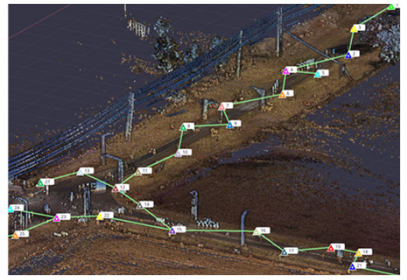


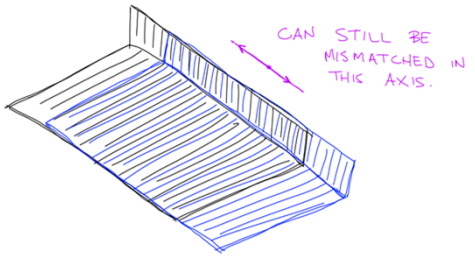
Scan Registration

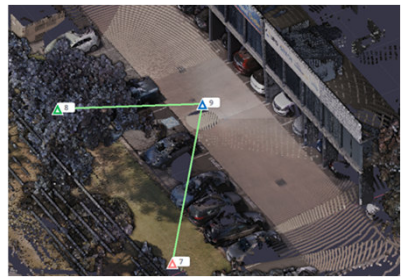
Cloud based registration

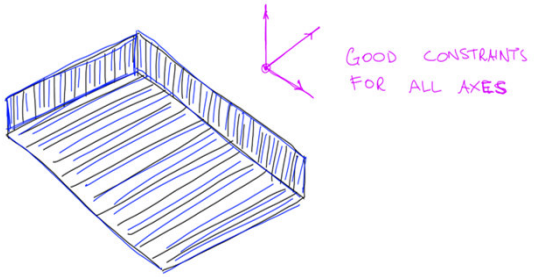
- Cloud Based Registration looks at the two clouds and uses only algorithms to best fit the scans together.
- Cloud based registration is impacted by the data within a point cloud.
- Relies heavily on flat vertical faces to be present in the scans for registration.
- The closer the scans to one another the better the results.
- Tress (forest/bush) and poles do not make great vertical data for registration as they change depending on the angle.

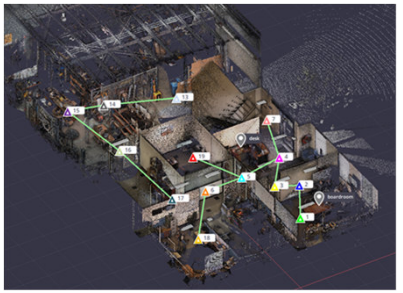








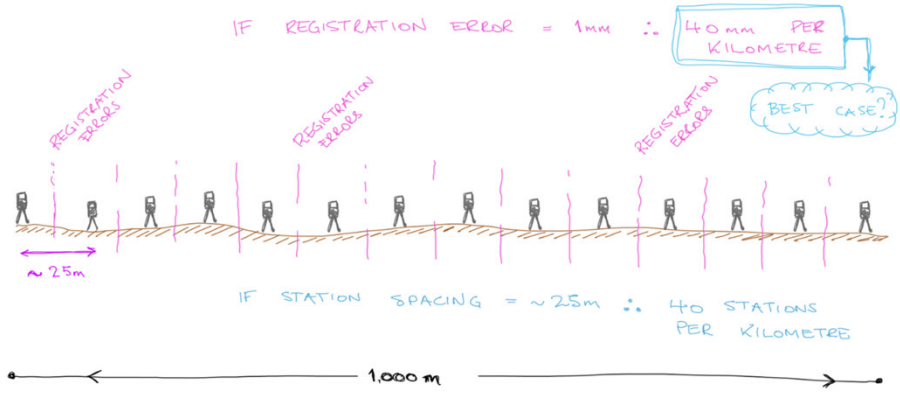


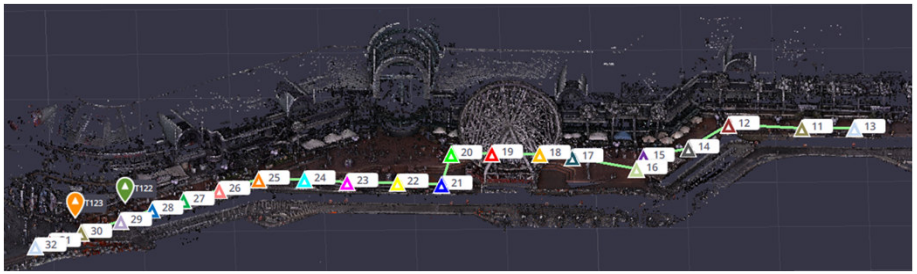


Scan Registration

Cloud based registration

- Important to check every connection made with cloud-based registration.
- Errors introduced in registration will propagate through the registration set.
- Registration errors are not in a single direction.
- Shorter distances between scans gives good registration but produces large project sizes.
- Larger distances between scans gives smaller project sizes but impacts registration.
- When using unlevelled scans, incorporate levelled scans every about 8th scan.
- Consider desired accuracies when determining the best registration type to use.

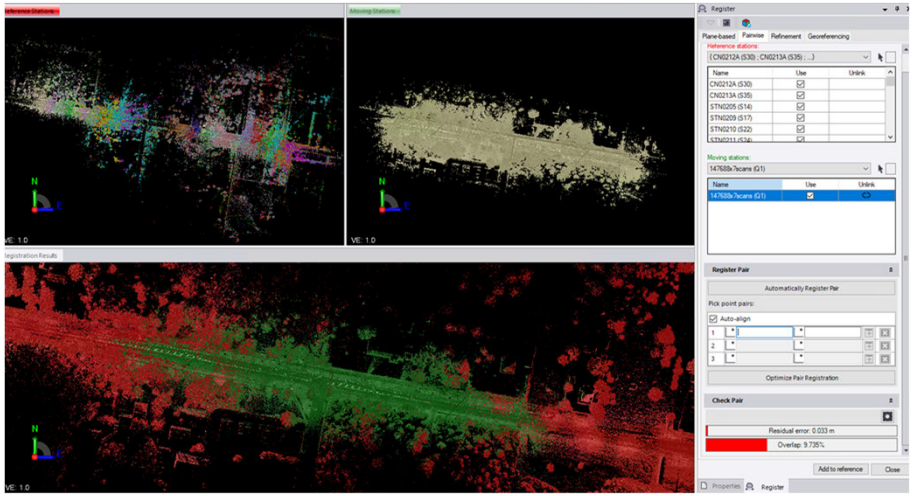




Ok…let’s get back to it

Combining SX and X Series Scan Data

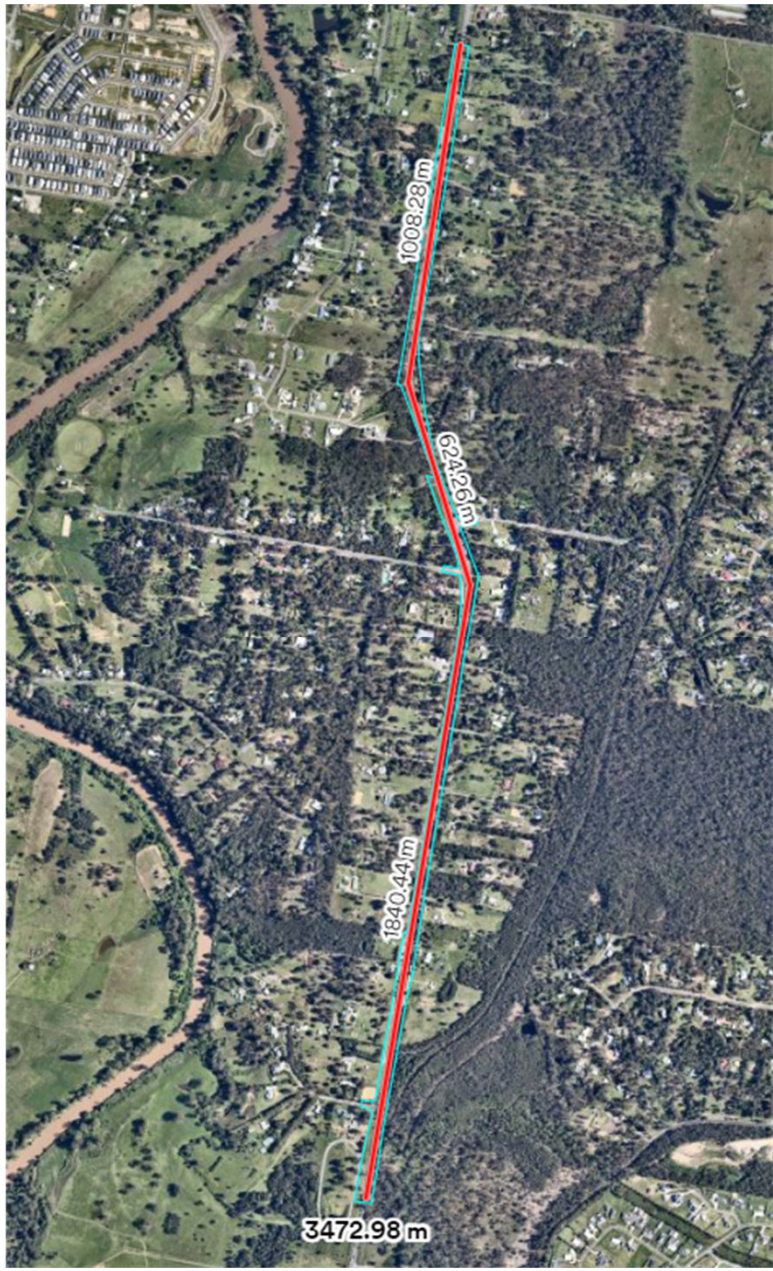
- At this point RPS had completed:
  - 30 projects with SX12
  - One (VERY LARGE) X7 project
- Soon after a project presented itself try workflow utilizing both scanners
- SX12 scans completed over site control
- X7 scans used to complete a 400m section of pavement
- X7 positioned utilizing GCP’s on pavement
- Residuals between SX12 and X7 was 30mm
- Completed another 15 projects using this method with good results



Combined Project Example

- 3.5km road project on high traffic volume road
- First RPS project registering X7 scans to SX12 scans
- Average spacing of SX12 scans 200 – 250m
- 27x SX12 scans in total
- 388x X7 scans in total
- Completed by 3x surveyors in 2x days
- Average registration set contained 12x X9scans
- QA checks resulted in an average deviation of -3mm
- 40 registration sets were imported from Perspective
- Cloud to cloud registration residuals no greater than 10mm when compared to the SX12 scans

- Have recently uploaded the project in to Trimble Connect



Combined Project Example

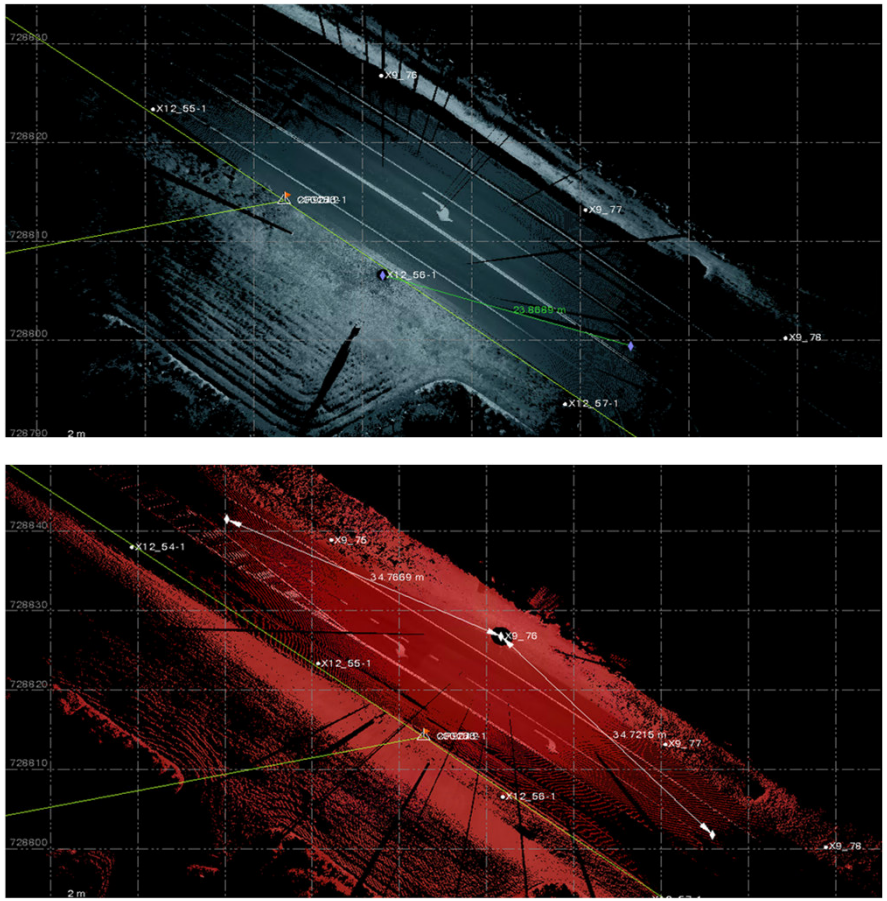
- Most recent project example (updated to an X9)
- 1.8km of road pavement for design
- Was a trial of the current scanning systems, so was a mix of SX12, X9 and X12 scan capture
- SX12 scans optimal distance at 100m apart
- Primary traverse and scanning with the SX12 took 15 hours for a solo operator
- Completed 99 X9 scans and 85 X12 scans
- X9 and X12 scanning each took 7 hours
- Capture of around 3 billion points
- Having split the project into registration sets, the worst residual was 7mm with an average of between 3mm – 5mm on the 38x scan sets

Combined Project Example

Review of effective point range (X9 / X12)

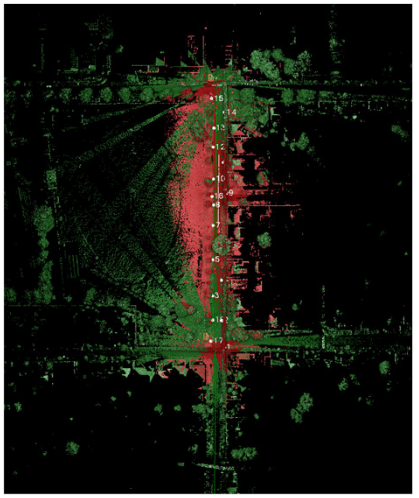
- X12 produced nice results with approximately 19m points per scan and effective range on road pavement surface of around 25m but good point density at the edge of the effective range.

- X9 also produced great results with around 11m points per scan and effective range on road pavement surface of around 35m and maintaining pretty good point density at the edge of the effective range for each scan.



Field Lessons Learnt

- Download the Mobile App for Perspective.
- Limit the distance between primary SX12 scan stations
- Use precise points.
- Run total check strings across scan areas.
- At 3 minutes a scan, don’t skimp on scans
- Limit each perspective project to a day’s capture
- Visually check EVERY scan registration
- Consider scanner minimum and maximum distances
- Consider the geometry of scans.
- Where vertical featuring is limited, consider the placement of each scan.
- Park your vehicle to make use of it where possible.



Feature Extraction

Basic Overview

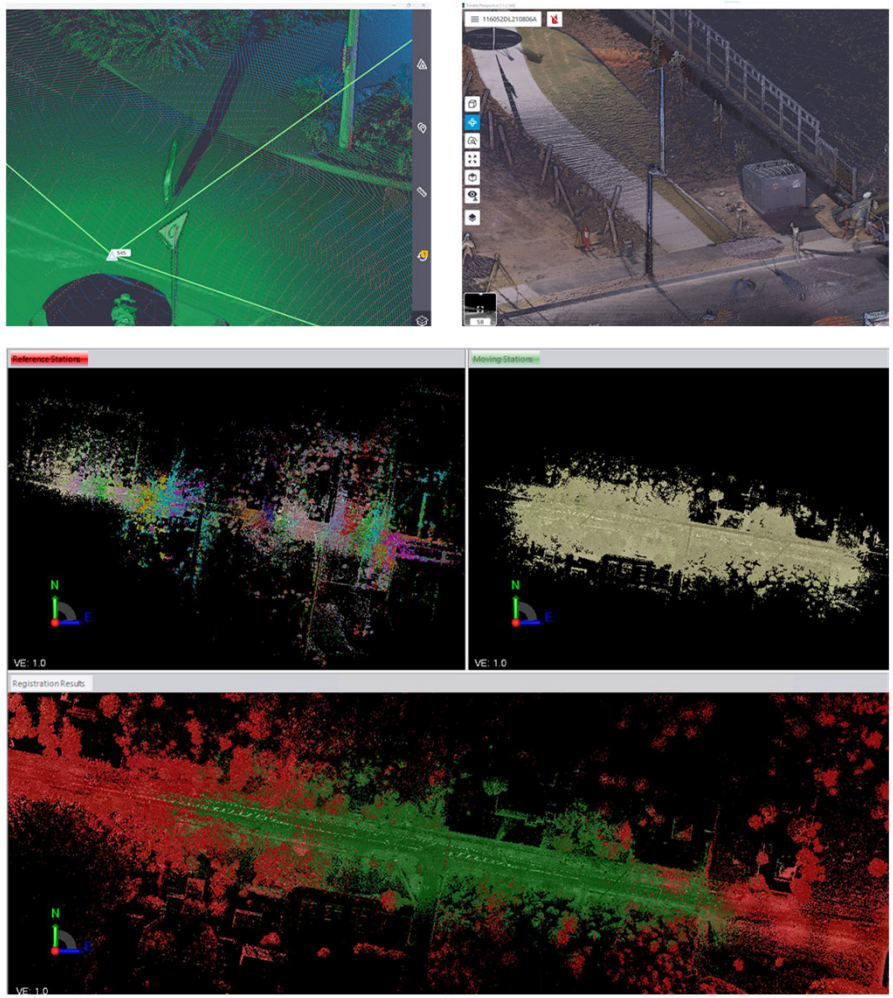
- TBC as used to manually create CAD points and process against feature codes
- Minimal use of automated tools were needed using the above process
- They created an alignment and alignment labels

General Tips

- Think about accuracies and ways to track them.
- Use classified regions to categorise scan data.
- Intensity views are better for digitisation that true colour.
- Colour coded intensity is good for digitisation.
- Colourisation can be done later.
- Utilise the broad spectrum of tools to get the finite detail out of point cloud data.
- View filters can be used to quickly change between displayed data.
- Spend time fully defining a good feature code library for both office and field.
- Extraction tools are handy for bulk processing of scan data

Office Lessons Learnt

- Visually re-check EVERY scan registration
- Look particularly for ghosting on light poles, signs and trees for shadowing in the scans
- Colourise in Perspective on PC
- Split the scan into scan registration sets that correspond to stations or GCP's / control points
- The more scans in a registration set, the more potential error introduced and carried
- Problems can be contained to and identified in local areas with smaller registration sets
- Review points from different scans on whatever vertical features are available
- Import control and SX scans into TBC prior to X9 scans
- Treat TBC as a Single Source of Truth for all your project data



Office Lessons Learnt

- Pairwise should be considered for registration workflows in TBC.
  - Turn off Auto-Align until picking the final point pair
  - Position can (and should) be optimised prior to moving on to the next registration set
  - Don’t add registration sets to the reference cloud until all registration sets are positioned correctly (if at all)
- Manually check scan v scan for vertical distortions
- Classify and refine scan data and then apply radius filters as required
- Continually evolve with software and client requirements
  - Have your dealer technical consultant on speed dial
- Most importantly, QA and more QA

Basic Workflow

Field

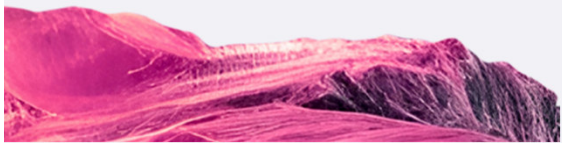
Personnel
Briefing on spacing, settings, photos
Project setup
Max number of scans
On board registration
Point pairs

Perspective

Export from tablet to PC
Colourise on PC
Review all scan registrations
Point pair any difficult scans (and manually link)
Refinement
Split refined point cloud into sets

TBC

Correct coordinate system selected
Import control
Import SX12 data
Import X9 data
Use pairwise to position each set to the SX12 data
Pick point pairs and optimize if needed
Check vertical features

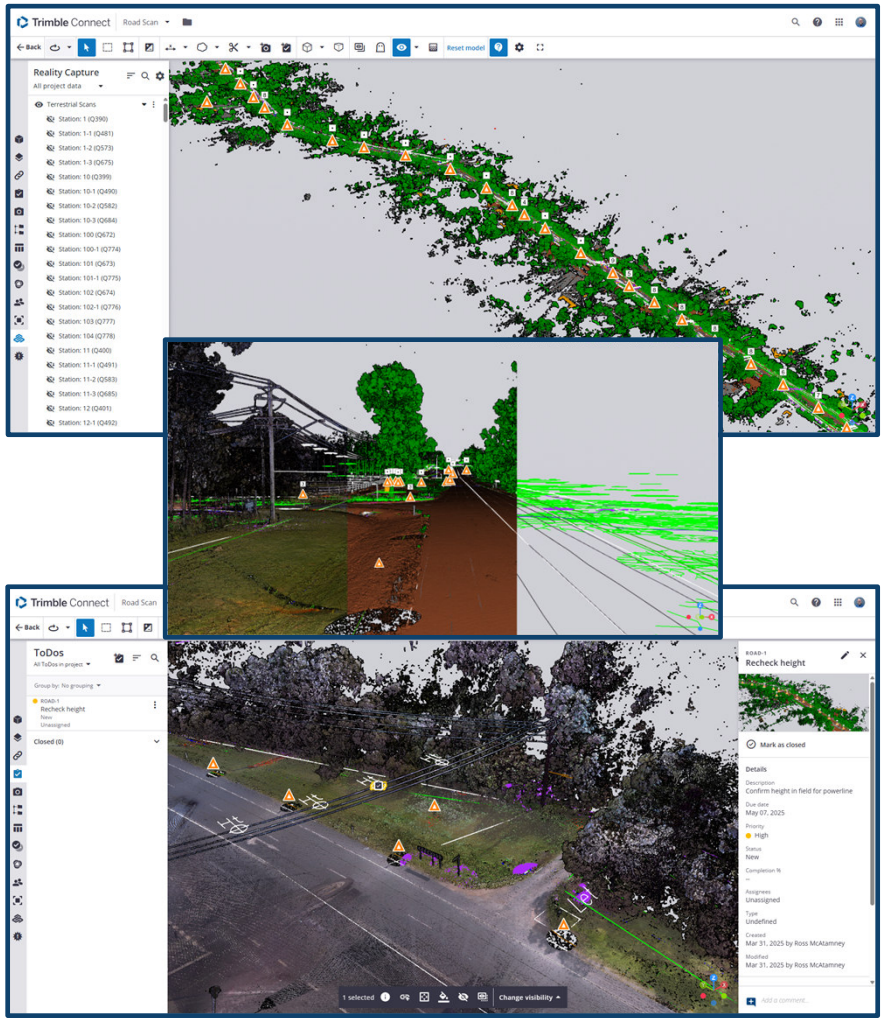


Sharing the Project

What to do with the data?

- Standard point cloud and ReCap outputs can be generated from both Perspective and TBC
- Standard CAD and 12D outputs can be generated from TBC

- Trimble Connect (TRCPs) can be used to store, share and collaborate on project data internally and externally
- Shown here is the 3.7km road project discussed earlier with 388 X7 scans and 27 SX scans, along with the CAD work generated from the point cloud data



General Lessons Learnt

RPS Summary

- Accept accuracies within the limits of your job. Whilst there may be a few mm on discrete vertical features, this didn't have any effect on the features being extracted and were within the same tolerances to convention surveys.

- 4km seems to be about the break-even point for time and cost if contracting MLS. Anything more workflow efficiencies and data management become an issue.