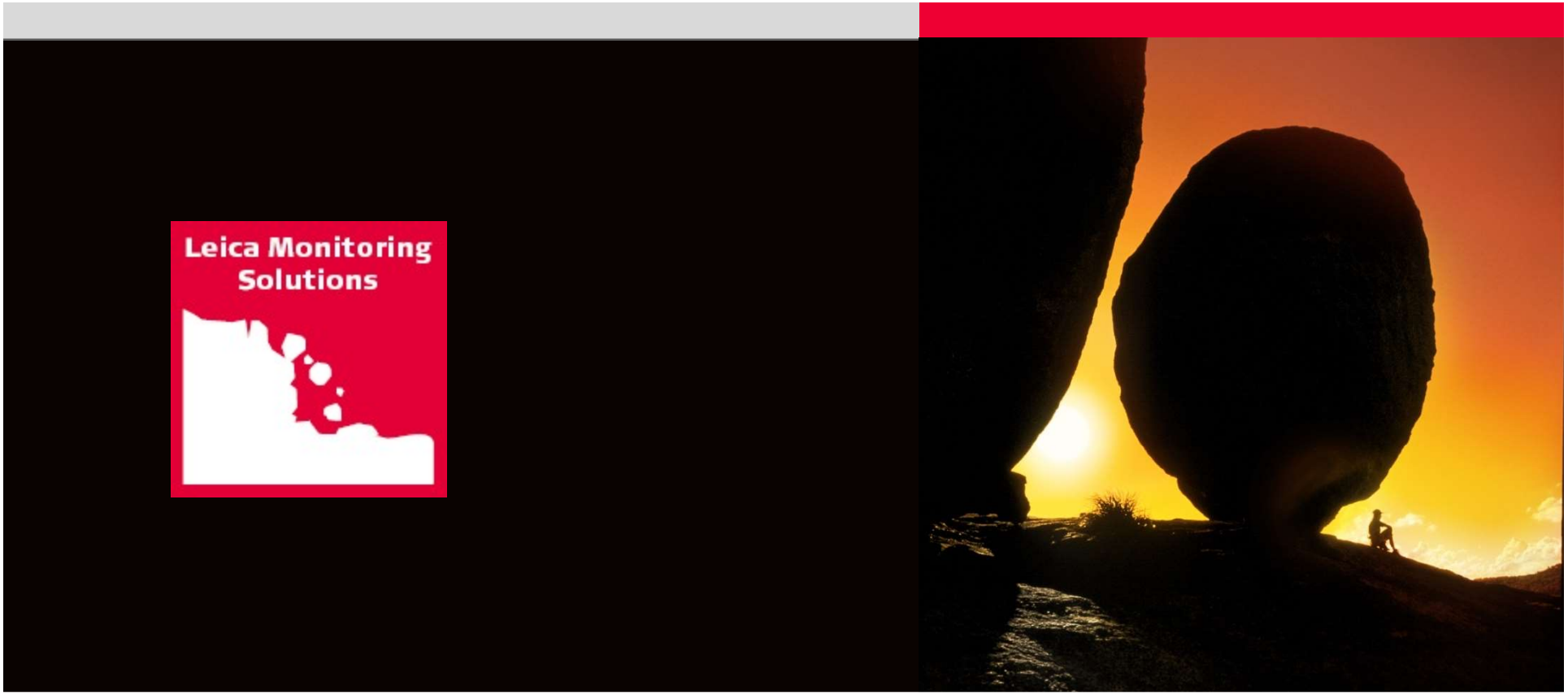


Automated Monitoring Systems

Innovative Solutions from Leica Geosystems

Presented by: William T. Derry, Prof. LS

- when it has to be **right**

Leica Geosystems

Leica Monitoring Solution
Overview

What is deformation monitoring?

- Deformation monitoring is the systematic measurement of objects or natural events
- Geodetic and geotechnical sensors deliver various observations, combining sensors
- Deformation analysis
- Generate information for the experts to analyze
- Warnings/Alarms

Sunshine Skyway Bridge - FDOT

External Links:

http://en.wikipedia.org/wiki/Deformation_Monitoring

http://en.wikipedia.org/wiki/Automatic_Deformation_Monitoring_System

Leica Monitoring Solution
Overview

When is monitoring required?

- Potential problem
- Construction creates instability
- Long-term deformation
- Safety of public and workers
- Erosion (extended life time)
- Climate changes
- Aging infrastructure

- when it has to be **right**

Leica Geosystems

Leica Monitoring Solution

Overview

Risk

Management!

- when it has to be **right**

Leica Geosystems

Planning the project and applying the proper technologies consider the following:

- What is being monitored?
- What is the required accuracy of the measurements?
- What type of movement are we looking for deformation or displacement? 1D, 2D, 3D?
- Frequency of measurements?
- The number of positions to be monitored?
- Real Time or post processed?
- What risk are we managing?
- Site Security?
- Power and Communication?

Automated Monitoring Systems

Leica Geosystems has along history of high precision instruments

- when it has to be **right**

Leica Geosystems

Leica Nova TM50/60 Monitoring Sensor
Built for prism monitoring

Structural Requirements

- **Improve structural rigidity**

  Gravity feed casting methods to allow casing material to crystallize in a more uniform manner

- **Increase Size and Weight**

  15% increase in circle diameter allows larger circles to be used for greater accuracy 0.5”

- **Long Range Automatic Targeting**

  Automatic Target Recognition 3000 Meters

  0.6mm EDM

Leica MS-50/60 Multistation Sensor
Flexible Monitoring Options

Multiple Data Acquisition Methods

- **Conventional EDM**

  1.5mm + 1 ppm EDM 1500 Meter ATR

- **Reflectorless EDM**

  2000 Meter Range

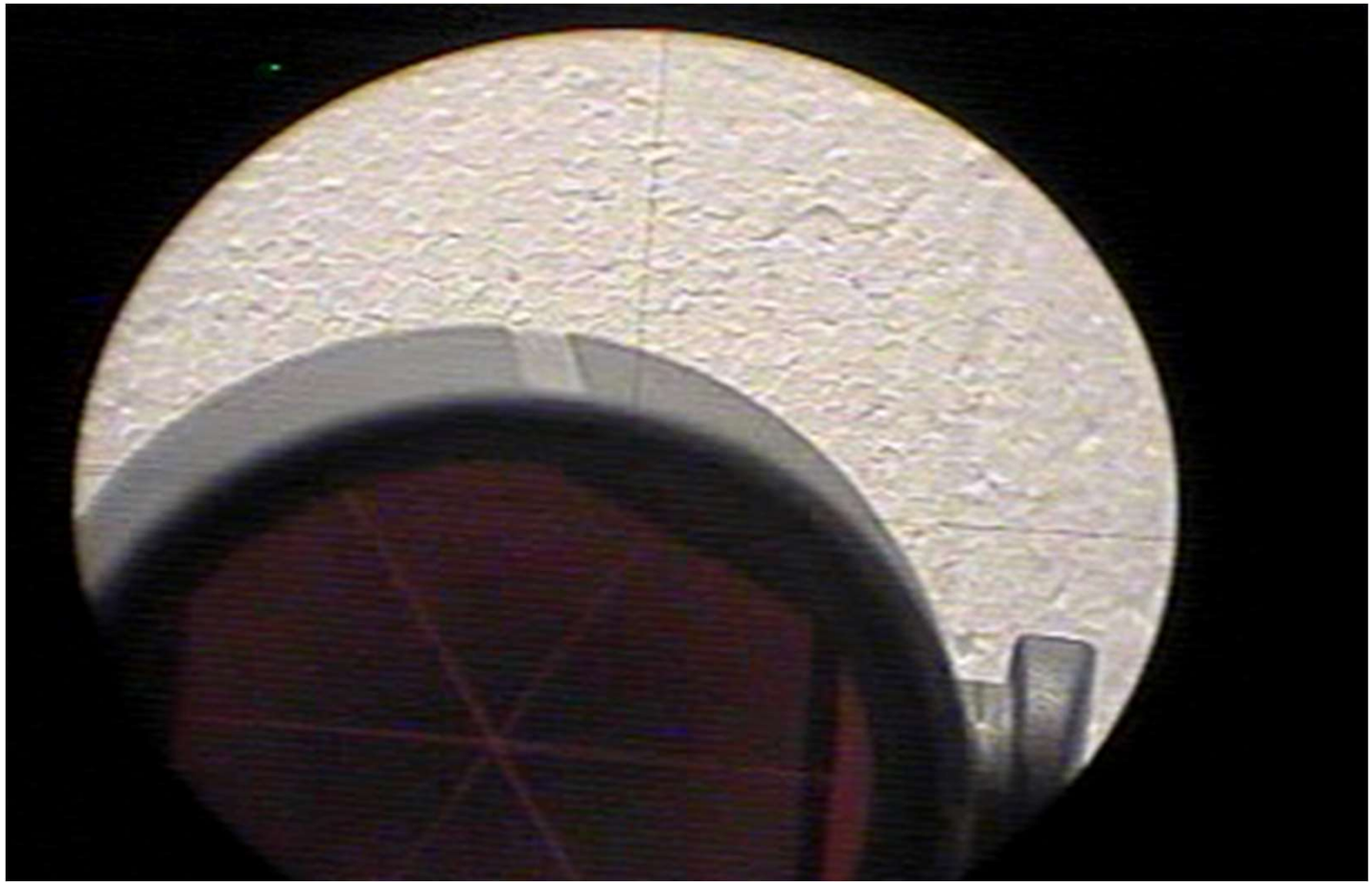
- **Scanning**

  1000 points per second fully automated scanning (more later)

- **Onboard monitoring app**

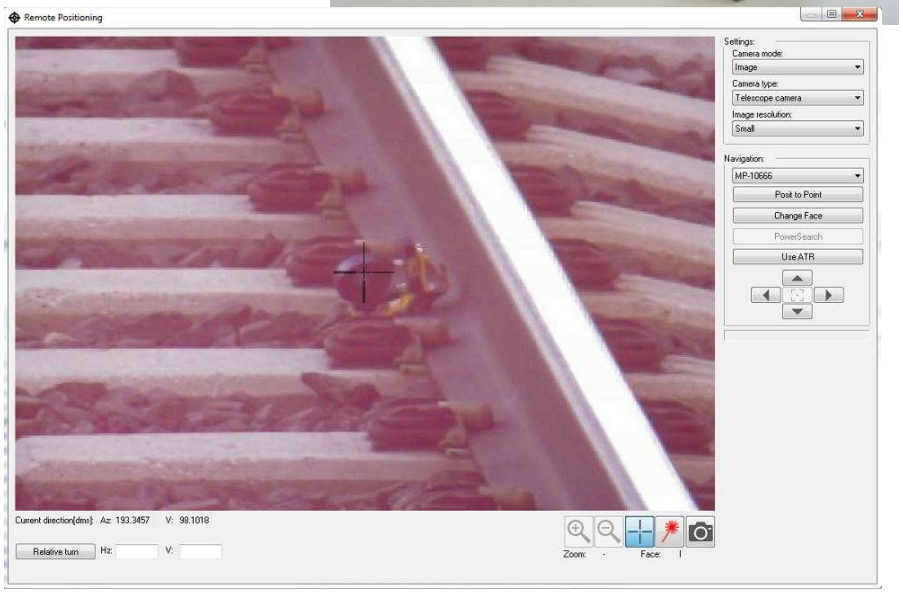
  for campaign type monitoring tasks

ATR at work..



Example Project- Providence, RI

Example project- Nashville, TN



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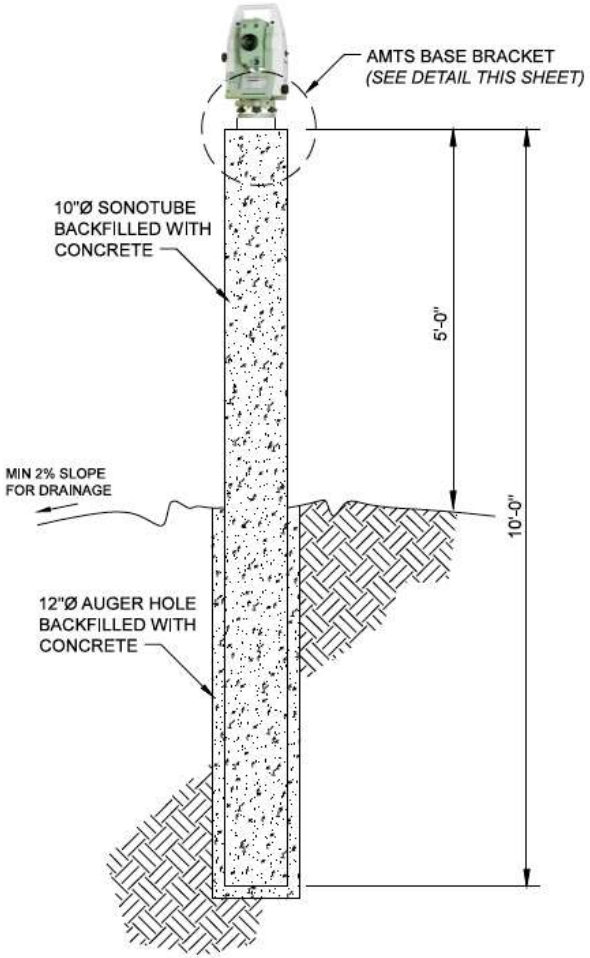
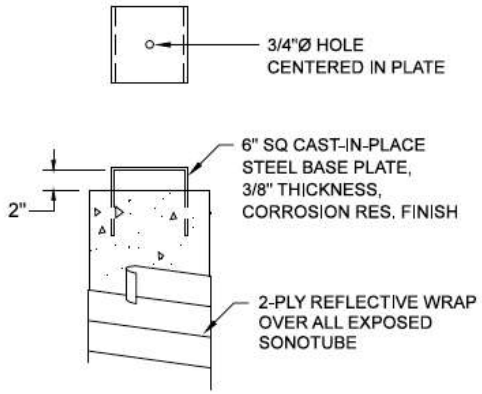
Example set up
Robotic Total Station on pedestal

AMTS example pedestal



AMTS REFERENCE PEDESTAL

NO SCALE



AMTS BASE PLATE

NO SCALE

13

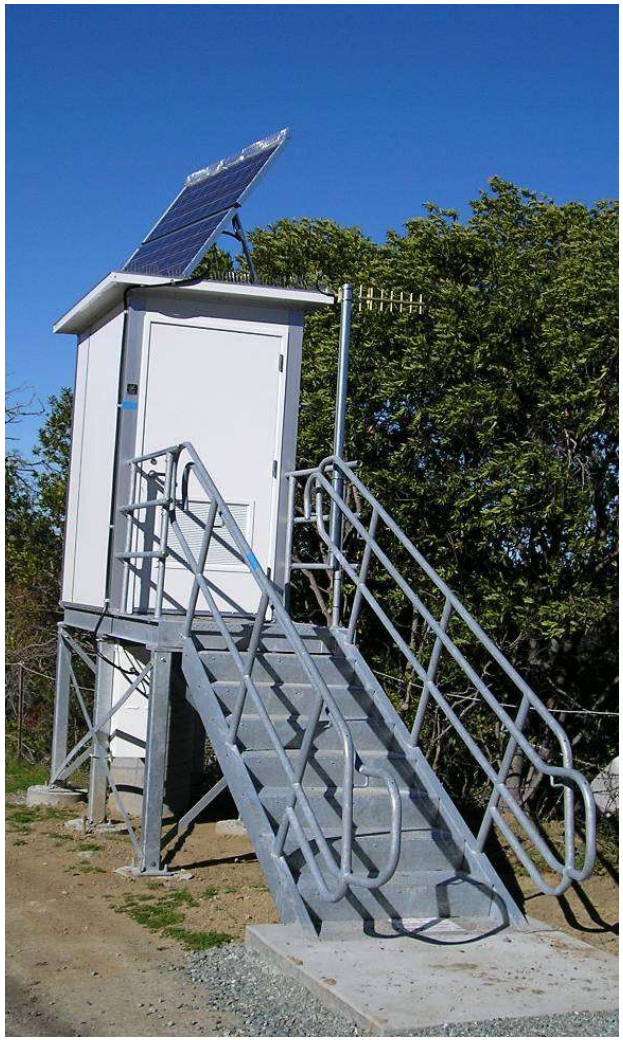
AMTS- controlling the instrument

Instruments inside the area of potential deformation controlled using freestation(resection)

AMTS – Example monitoring pedestal

Redundancy built it

AMTS - Example enclosures

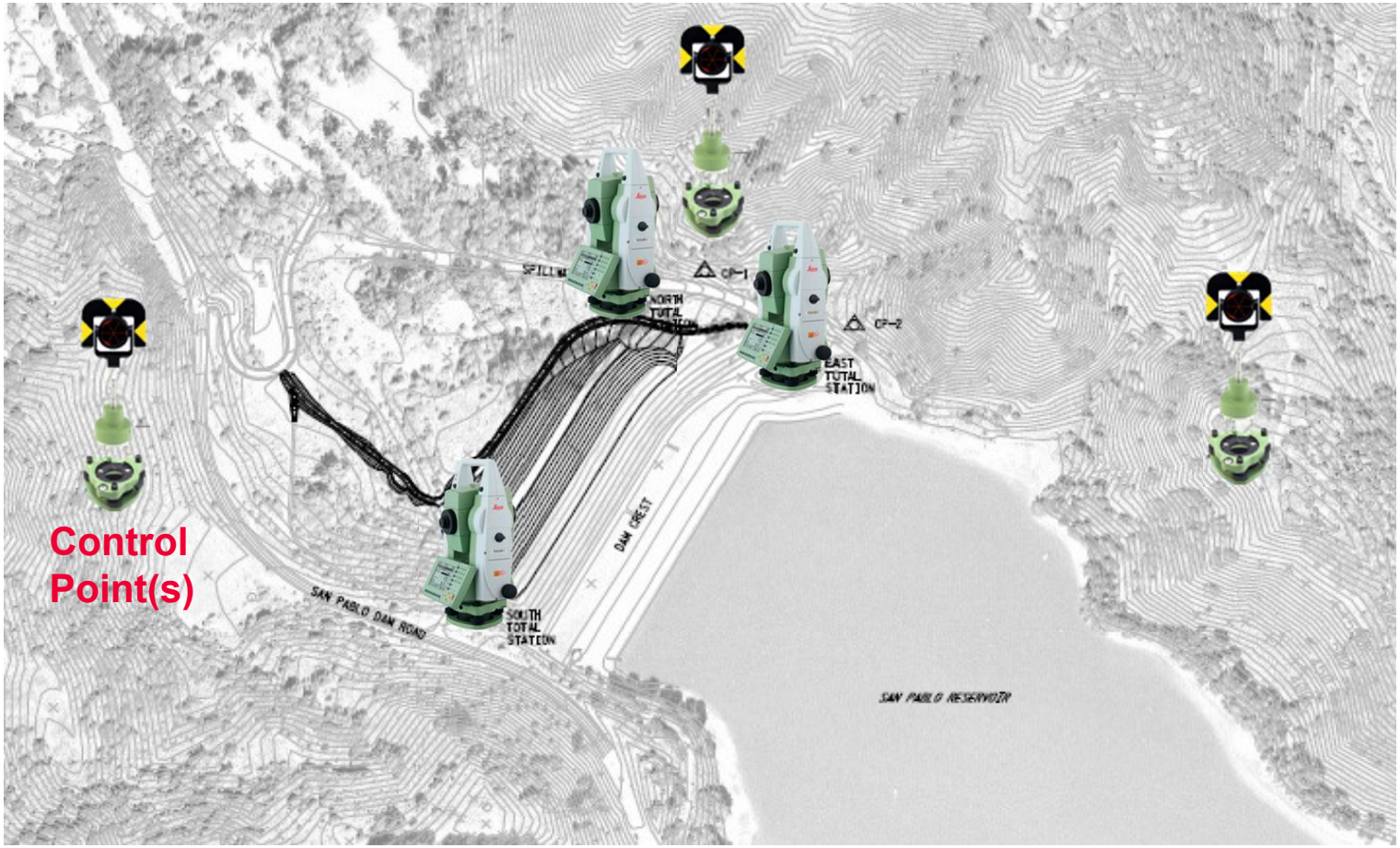


AMTS - Example enclosures

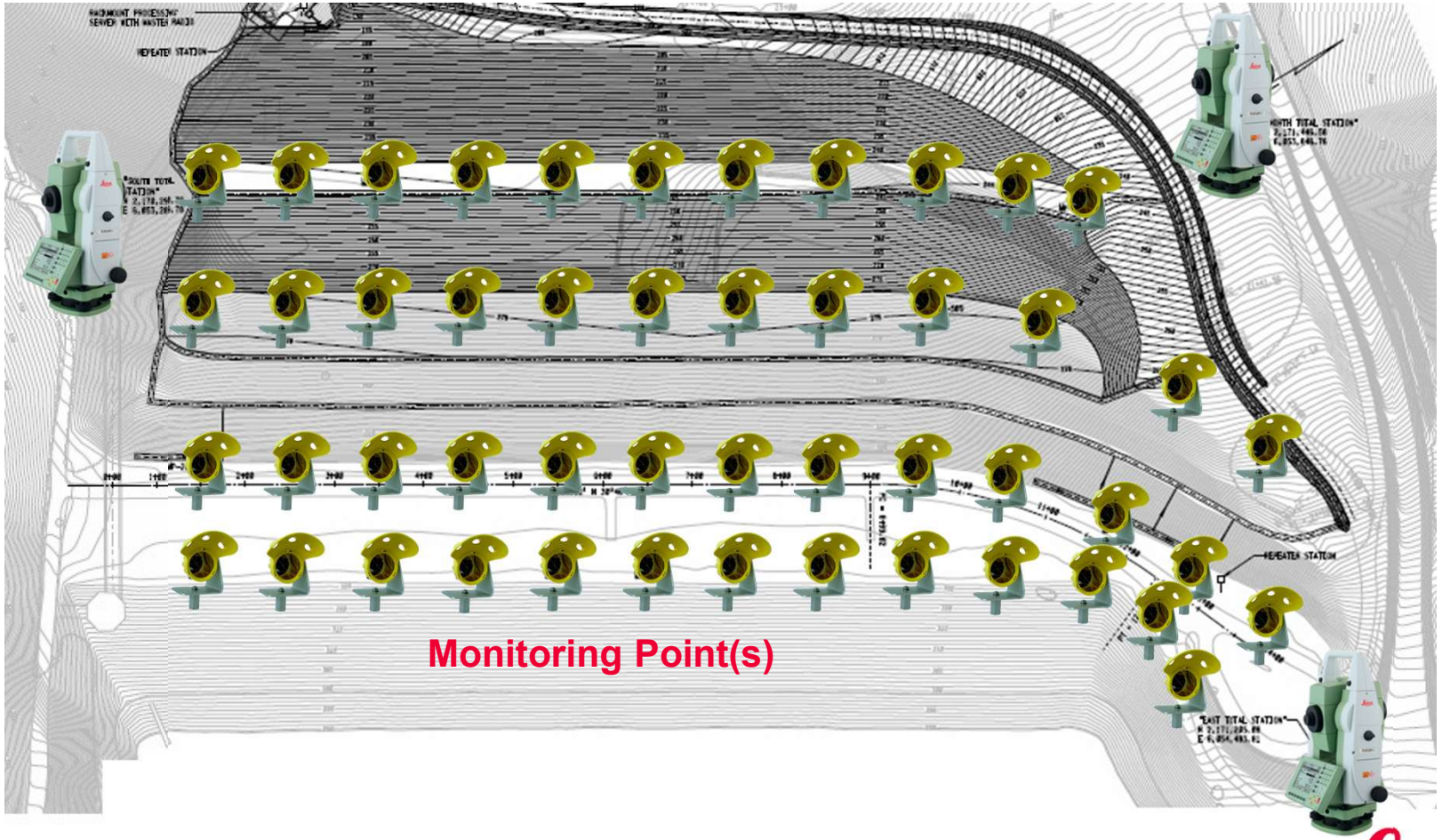
AMTS - Example enclosures

AMTS – Why use enclosures?

AMTS – Example project -Dam
Instrumentation Plan



AMTS – Example Dam
Instrumentation Plan



- when it has to be **right**

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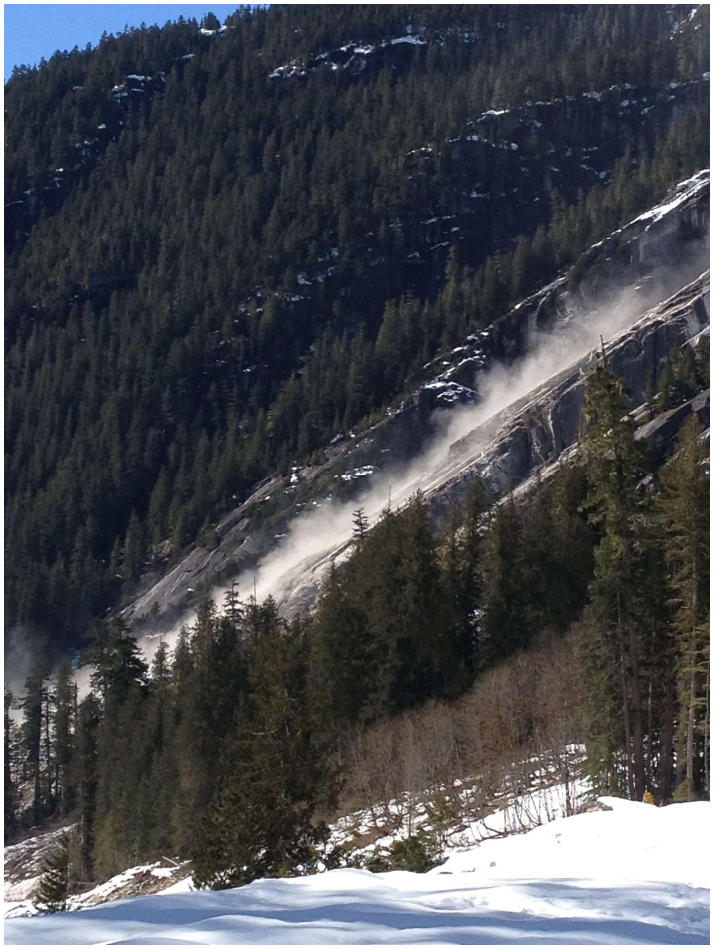
AMTS – Example Dam
Modifications

Bird spikes installed to prevent damage to Monitoring prisms

AMTS – California- Oroville Dam

Smithsonian Excavation Washington, DC

AMTS – British Columbia- Rock slide



AMTS – British Columbia- Rock slide

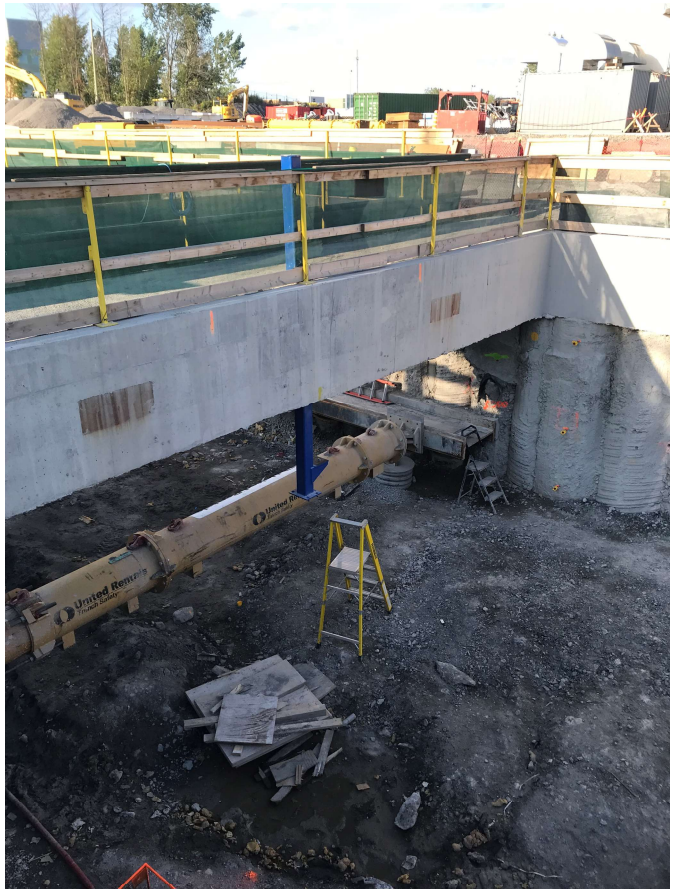
GNSS – Soil Landslide

GNSS –Soil Landslide

- when it has to be **right**

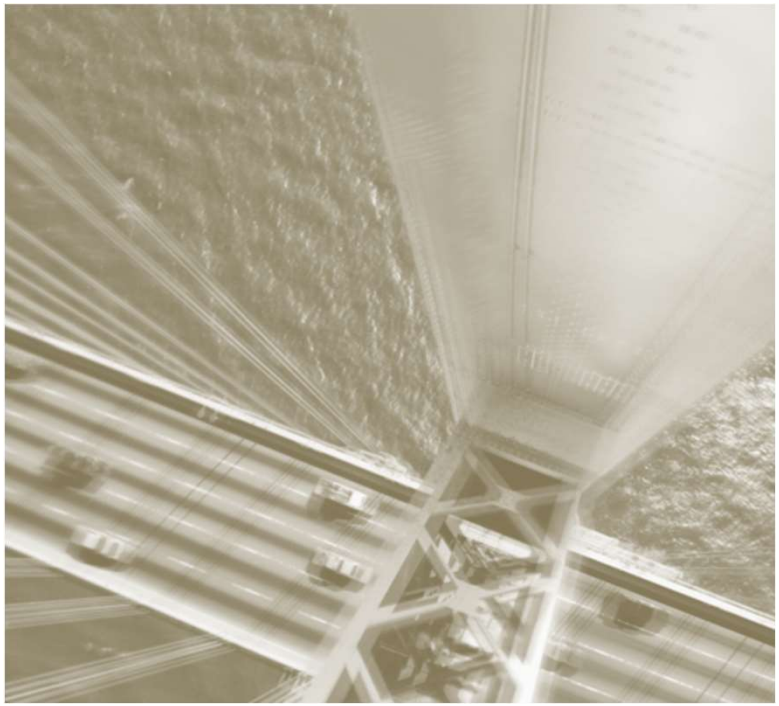
Leica Geosystems

AMTS – Example project- Montreal Airport- TBM Launch Pit



GNSS Monitoring - Monitoring Solution
Overview

- computation of 3D coordinates
- high measurement rate
- low latency
- all weather operation
- does not require line of sight to ground marks/targets
- High accuracy on long baselines (up to 1000km)
- can provide active control points for total stations
- can provide timing for other sensors, such as accelerometers



GNSS Monitoring Solutions

Overview

- **Static Monitoring Solution**

Post Processing monitoring on short baselines. Modular solution using flexibility of GNSS Monitoring Station and powerful PP algorithms of GNSS Spider to provide best possible results in near real time. Deformation analysis is supported with GeoMoS Monitor, Analyzer and advanced GeoMoS Adjustment tool.

- **Dynamic Monitoring Solution**

Real time monitoring for reliable and fast movement detection. Sophisticated RT solution takes advantage of powerful RT positioning module and high frequency measurements. GeoMoS Monitor performs high rate deformation analysis.

- **GLOBAL Monitoring Solution – Leica Cross Check**

Highest Performance GNSS Monitoring for long baselines and controlling of reference stations. Full service based on scientific GNSS processing package BERNESE integrated in IERS global earth monitoring provides absolute position control of reference points with highest accuracy.

GNSS Monitoring - Monitoring Solution
Leica GM30 - Hardware

Leica GM30 – All-in-one GNSS Sensor for Monitoring

- Single or dual frequency
- Modern communication (Ethernet)
- Web Interface for configuration
- Onboard Data Logging (Rinex, FTP)
- Up to 20Hz logging and streaming
- Simply to use for GNSS demo in the field
- Site monitor - onboard real-time processing (NMEA)
- Velocity and Displacement engine

GNSS Antennas - Hardware

AS10

AR10

AR20

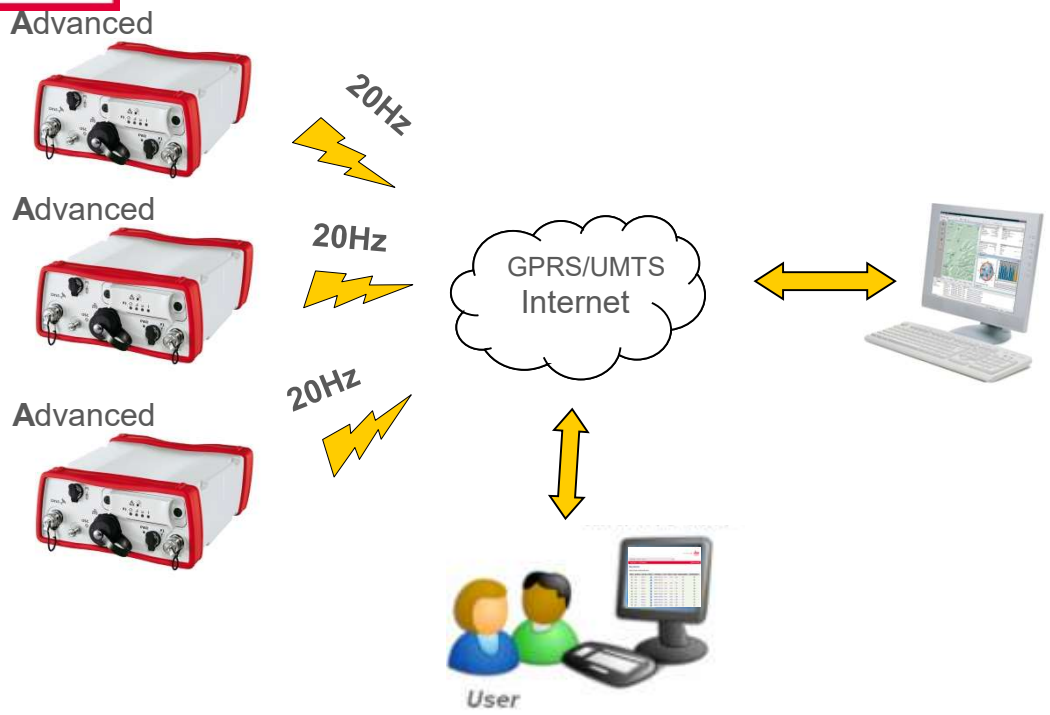
AR25

GNSS Monitoring - Monitoring Solution

GMX910 - Hardware

GNSS Monitoring Solutions

Dynamic Deformation Monitoring



Applications (High Speed Motion)

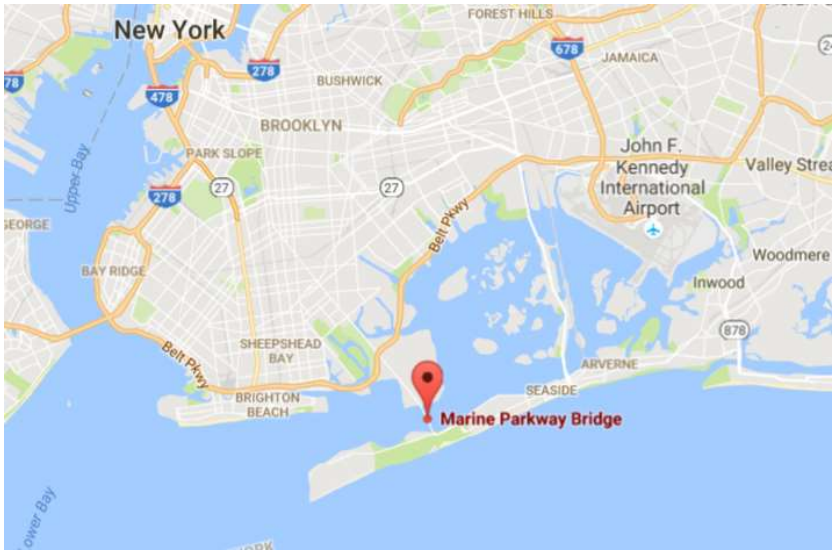
- High rise buildings
- Bridges
- Infrastructure
- Most anything

GM30 Advanced	*GeoMoS Now!*	*Spider & GeoMoS*
Dual Frequency 20Hz	Online Monitoring Data	GNSS Processing
RT Stream to internet	Deformation Analysis	Deformation Analysis
Secure Data	Secure data access	Limit check & Messaging
Sensors & Comm.	*Services & User*	*Analysis & Warnings*

- when it has to be **right**

DYNAMIC GNSS – Example Bridge

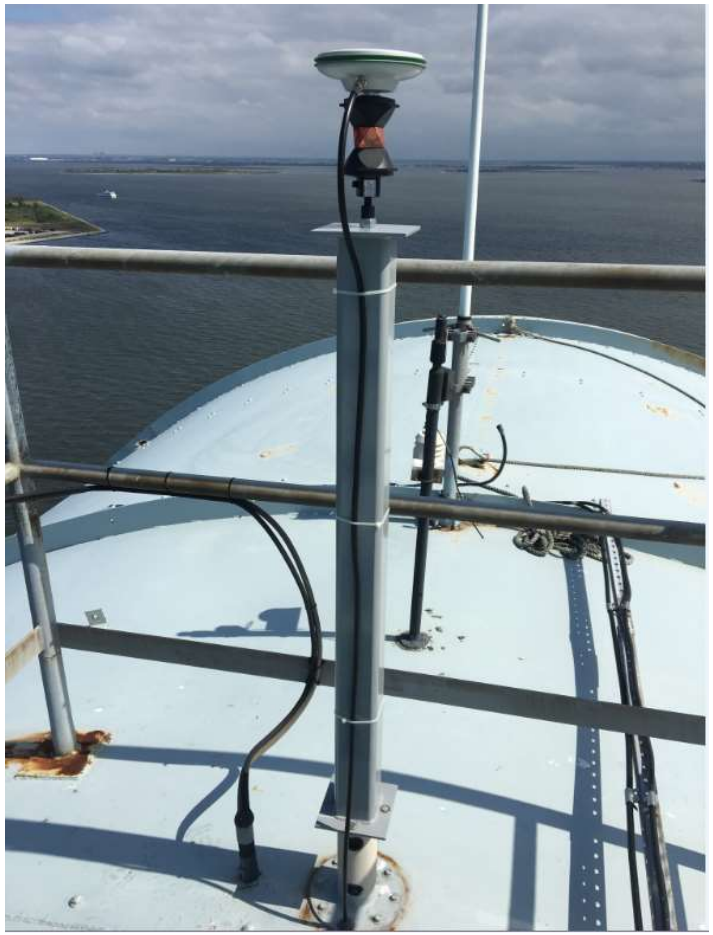
Marine Parkway Bridge



- when it has to be right

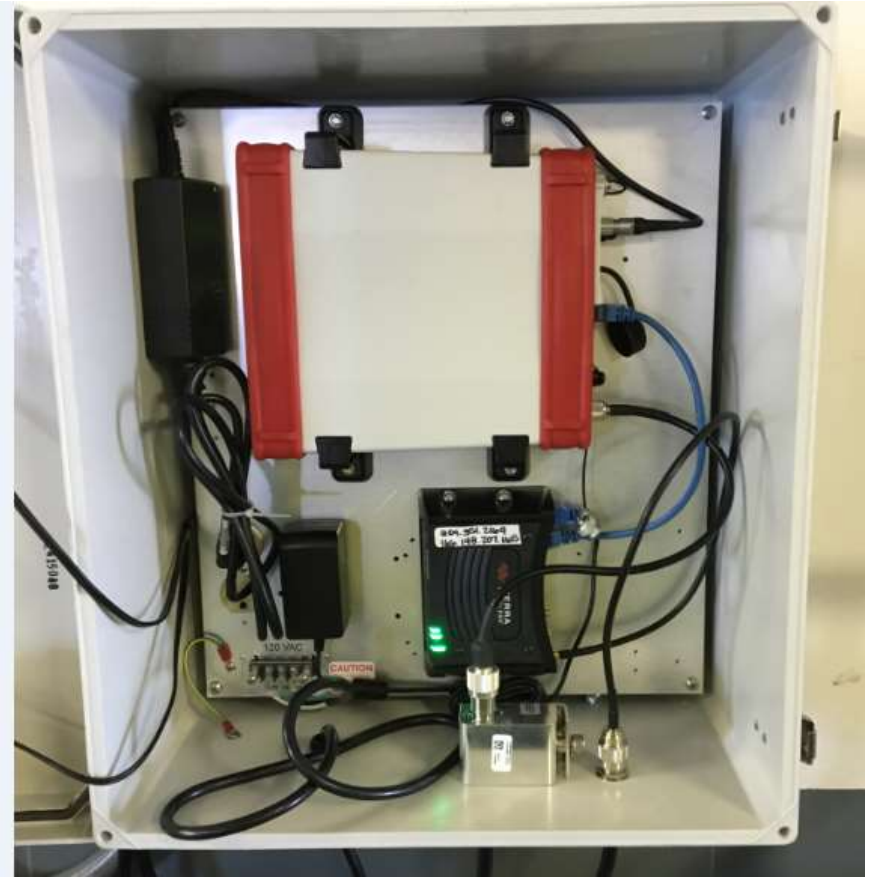
Leica Geosystems

GNSS – Example Bridge
Marine Parkway Bridge

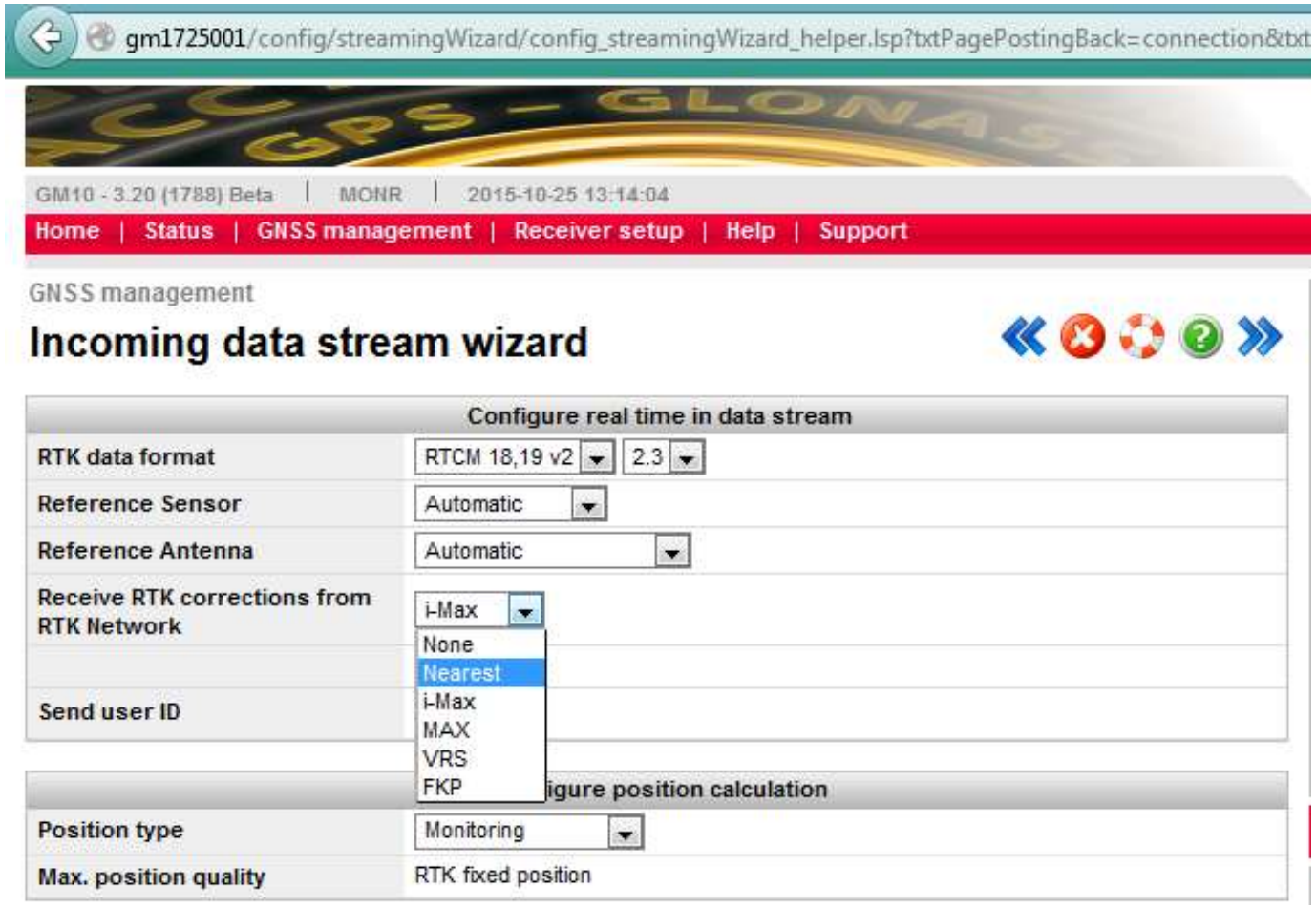


GNSS – Example Bridge
Marine Parkway Bridge

Example communication enclosure



Leica GM30
Site Monitor – on board software



- when it has to be **right**

Leica Geosystems

Leica GM30
VADASE – Short Term Solution

- Real time - Instantaneous
- Using only satellite broadcasted information -> autonomous
- Detecting fast movements based on computed velocities
- Informing about detected velocities and displacements

GNSS management

Velocity & Displacement Engine

Velocity & Displacement Engine	
Enable Engine	☑

Current thresholds used for displacement detection		
Threshold East	0.0080	m/s
Threshold North	0.0120	m/s
Threshold Up	0.0200	m/s

Computed thresholds		
Threshold East	0.0056	m/s
Threshold North	0.0078	m/s
Threshold Up	0.0130	m/s
Time remaining	23:59:34	
Time missing (data gaps)	00:00:00	

Leica GM30
VADASE

VADASE – Technical Data Summary

Velocity Accuracy: 3 mm/s rms horizontal, 5 mm/s rms vertical

Sensitivity (typical): 10 mm/s horizontal / 20 mm/s vertical change (for displacement detection)

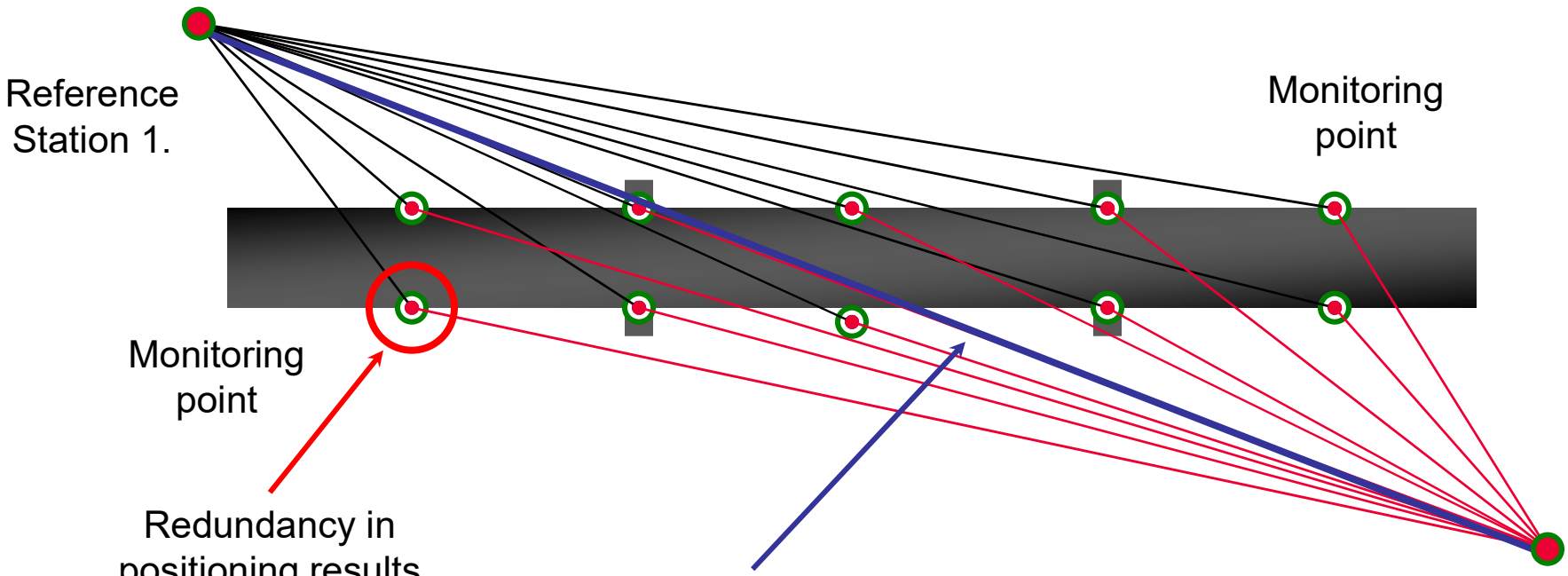
Supporting: 1-20 Hz rate. Multi-frequency, multi-constellation solution

Not intended for: Detection of absolute position or slow movement

Remark: LVM and LDM supported in GeoMoS only as offline .csv import (not GNSS NMEA)

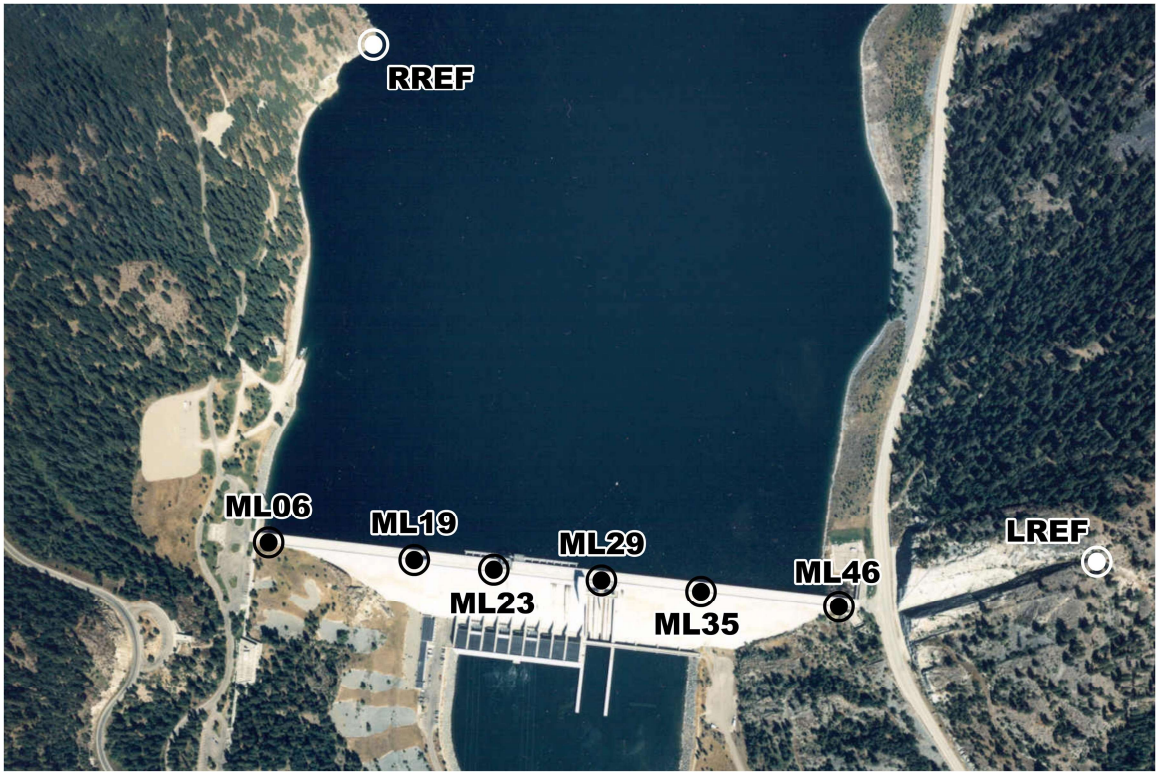
VADASE	East (mm/s)	North (mm/s)	Height (mm/s)
Minimum velocity detected	3.6	3.6	8
Recommended minimum velocity to be used for accurate displacement computation	10	10	20

GNSS Monitoring Solutions
Static Deformation Monitoring - Example



GNSS Monitoring Solutions

GNSS measurements correlated with a gravity plumb line



Libby Dam

Libby, Montana

(US Army Corps of Engineers)

GNSS Monitoring using static GNSS

DGPS measurements correlated with a gravity plumb line

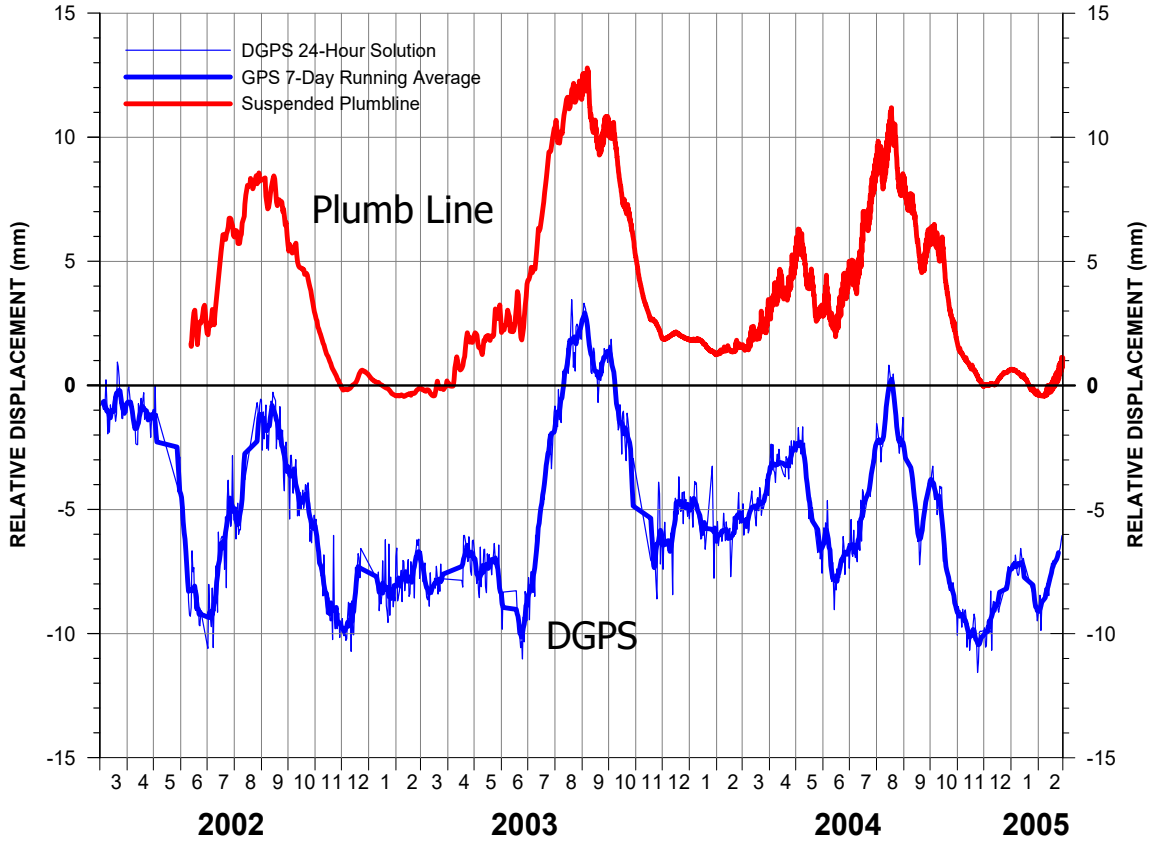
Mathematic Correlation:

Linear coefficient

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}$$

r for DGPS vs. plumb line

= **0.91**



DGPS and plumb line data

GNSS Position Accuracy

Static & Dynamic Monitoring Solution

Post Processing L1 Only

	2D Precision (95%)	Height Precision (95%)
10 minutes	7.2mm	12.4mm
1 hour	3.8mm	7.0mm
24 hours	2.2mm	1.8mm

- 3.3km baseline with 10m height difference
- PP Positioning with 10 minutes, 1 hour and 24 hours of data
- 27 days of data

Post Processing L1/L2

	2D Precision (95%)	Height Precision (95%)
10 minutes	5.2mm	11.8mm
1 hour	3.8mm	7.2mm
24 hours	1.8mm	2.0mm

Real Time Positioning L1/L2

	2D Precision (95%)	Height Precision (95%)
Real Time	14.0mm	16.0mm

- 3.3km baseline with 10m height difference
- RT Positioning with quasi static initialization and no smoothing
- 27 days of data (2287572 results)

Automated Monitoring Solutions
Combined Total Station and GNSS

- Total stations and control points often must be placed in an area that may be subject to movements
- With the combination of TPS and GNSS the stability of the total stations and reference points can be effectively managed
- GNSS co-located to the total station and on one or more reference points can be used to update the position and orientation of the total station
- GNSS receivers can also be used for direct monitoring of points of interest

Reflector with 5/8" thread adapter for mounting of GPS antenna.

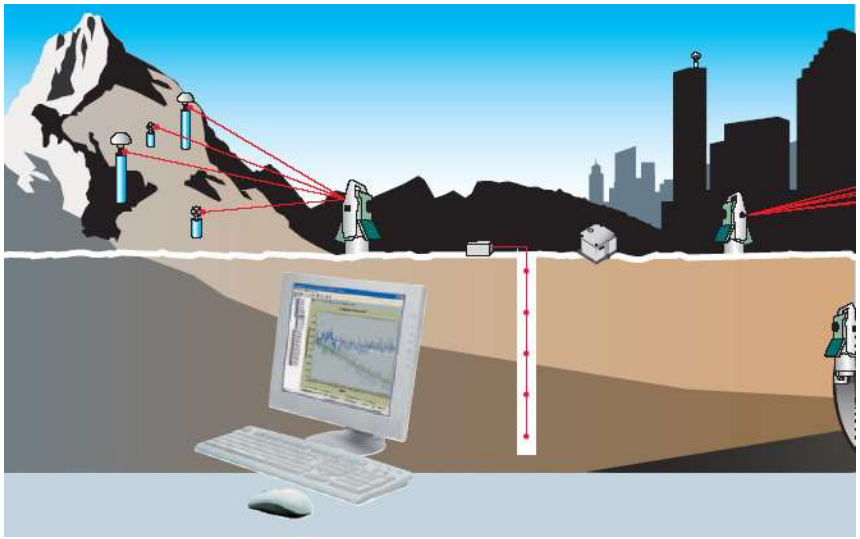
Automated monitoring
Leica Software

GeoMoS suite (Geodetic Monitoring Software)

GeoMoS Monitor, Analyzer, Adjustment – Data acquisition

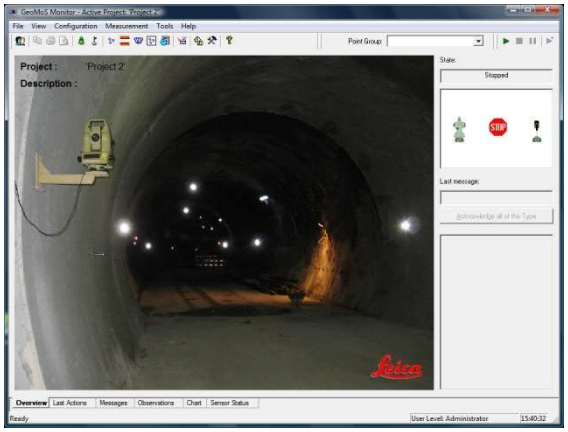
GeoMoS NOW! – Cloud based data presentation

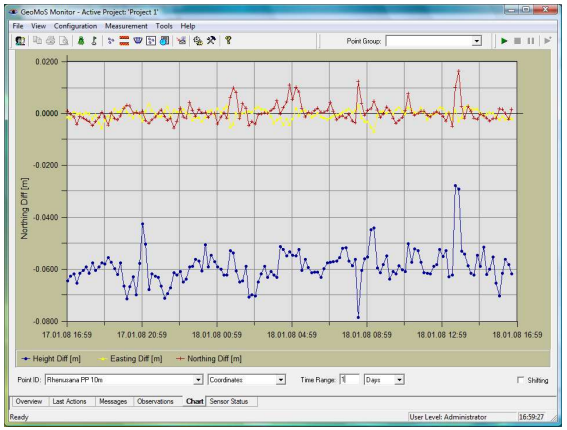
GNSS Spider, GNSS QC, Crosscheck - GNSS software



Leica GeoMoS
Multi-Sensor Monitoring Software

- Multi sensor monitoring with total stations, GNSS, tilt sensors, meteo sensors, extensometers and more.
- Advanced GPS monitoring via link to Leica GNSS Spider
- Calculation of movements using profiles for easy analysis
- Integrated analysis
- Configurable limit checks (displacements and measurements)
- Powerful event management and messaging system
- Customizable with flexible options and open SQL database
- Secure with robust data synchronization and backup
- Scalable and expandable from measurement engine to complete system
- API Output for custom software development





- when it has to be right

Leica Geosystems

Leica GNSS Spider
Overview

- Advanced control and configuration of GNSS sensors
- Centralized baseline processing for continuous GNSS monitoring
- Flexible communications with wide variety of technologies supported
- Distribution of RTK corrections to support surveying and other GNSS activities
- Network RTK processing for higher accuracy and reliability, supporting the new Master-Auxiliary Concept pioneered by Leica
- Use of MAX, VRS or FKP network corrections in Real-Time Positioning Products, bringing the accuracy and reliability of Network RTK
- Scalable and expandable
- Support for Leica and third party GNSS sensors

Software – GNSS Spider
Advanced GNSS Monitoring with Spider

High Accuracy and High Speed:

- Real time, centralized baseline processing at up to 20Hz rate
- Automatic post processing of 10 minutes to 24 hours of data
- World class performance (accuracy and reliability) with algorithms tuned specifically for monitoring applications

Low cost:

Lower cost monitoring sensors can be used (RTK sensors not required)

Single (L1 only) and dual (L1/L2) frequency RTK is supported

Reduced communications requirements than when computation is done on the sensor

Multi-baseline solution:

All sites can be both reference and rover

Multiple reference stations may be used for redundancy and checking

Open Solution:

Results sent directly to GeoMoS or in standard NMEA (GGA, GGQ, LLQ) formats

Results sent in real time using wide range of communication mediums

Direct logging of results to ASCII files for post analysis

Leica GeoMoS Now!

Customize, connect and stay in control

Overview

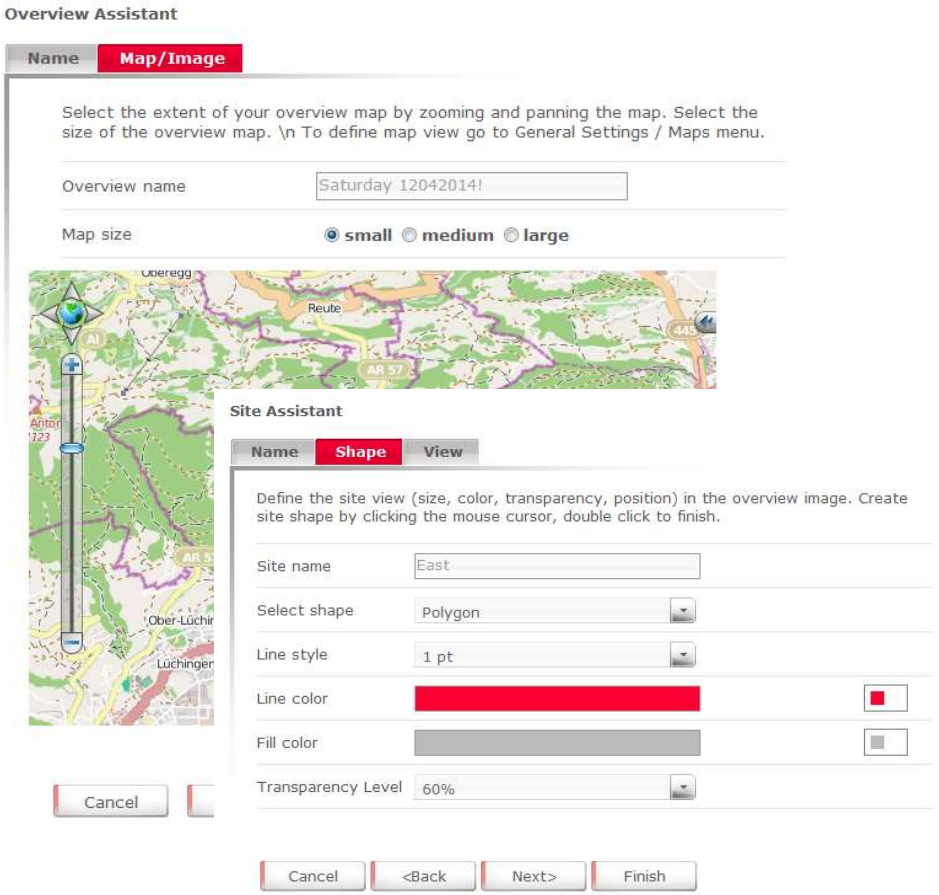
- Web-based or self hosted application to access round the clock monitoring data
- Develop your web site using intuitive configuration tools, without any programming
- Inspect with graphs, images, maps, tables and status reports
- Suit the needs of different user groups and projects
- Install securely on a local PC or as cloud-like company service (Intranet)
- Make fast and informed decisions with a quick and hassle-free views to your data

Leica GeoMoS Now!

Customize, connect and stay in control

Create your website > Global settings

- Data is instantly available
- International units for all measurements and transformations / map projections
- Number of digits for all values
- Date and time format settings
- Language files
- Customizable company logos, links, re-direct URL, text, colors, etc.
- No knowledge of web programming is required



Create web pages by users who have no knowledge of web programming

- when it has to be **right**

Leica Geosystems

Leica GeoMoS Now!
Customize, connect and stay in control

Benefits > Distribute and share

- Quick and easy overview
- Share information with responsible staff e.g. with automatic PDF reports via Emails
- React fast and with confidence
- Always be in control and a step ahead

Leica GeoMoS Now!
Customize, connect and stay in control

Web-based monitoring data management system

Data visualization in real-time with one simple setup

Total access everywhere, at any time and with any device

Customize to fit any company branding

Easily handle large amount of data

With GIS shape files / raster data and layers

Automatic data sharing/reports to team/stakeholders

On premises (local hosting) or Cloud

Fast and informed decisions

User access control and authorization levels

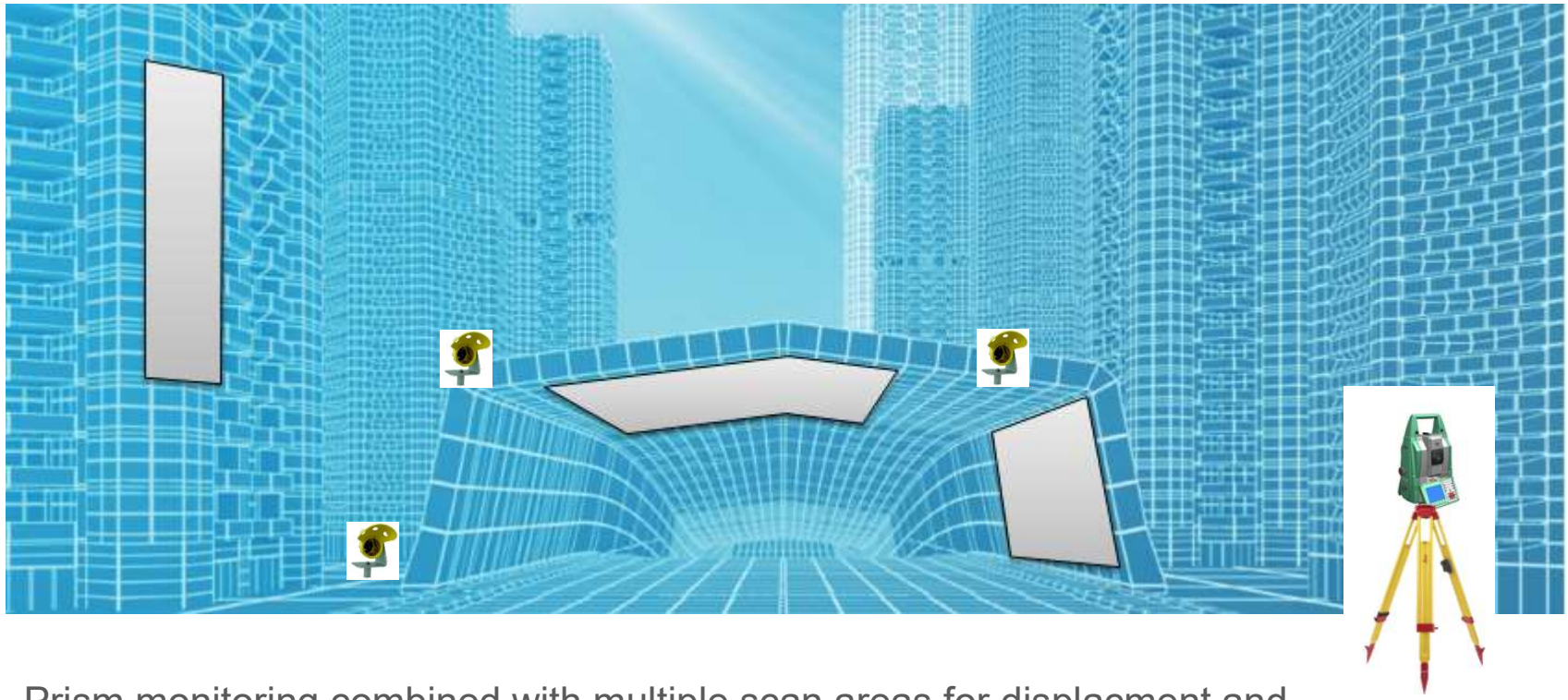
Integrated in the Leica GeoMoS monitoring solution

Full control and security to data

Software - Automated Scanning Deformation

MS50/MS60 with GeoMoS

First-ever automatic scanning solution in an integrated monitoring system



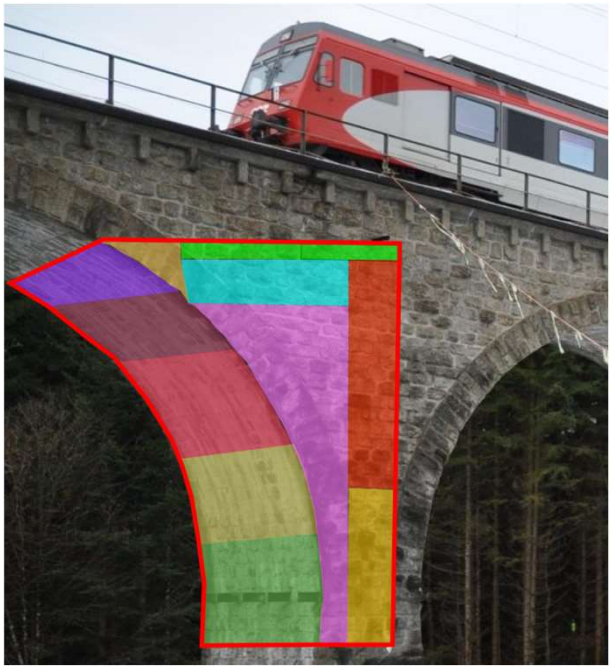
Prism monitoring combined with multiple scan areas for displacment and deformation

Software – Automatic deformation calculation

How it works.

Highlights of the new **n.Vec Technology**

- Each cloud is calculated to multiple best fitting surface areas → realistic mathmatical model
- Mathmatical model: plane or any curved surface
- Different than a model to model comparison
- Edges automatically calculated



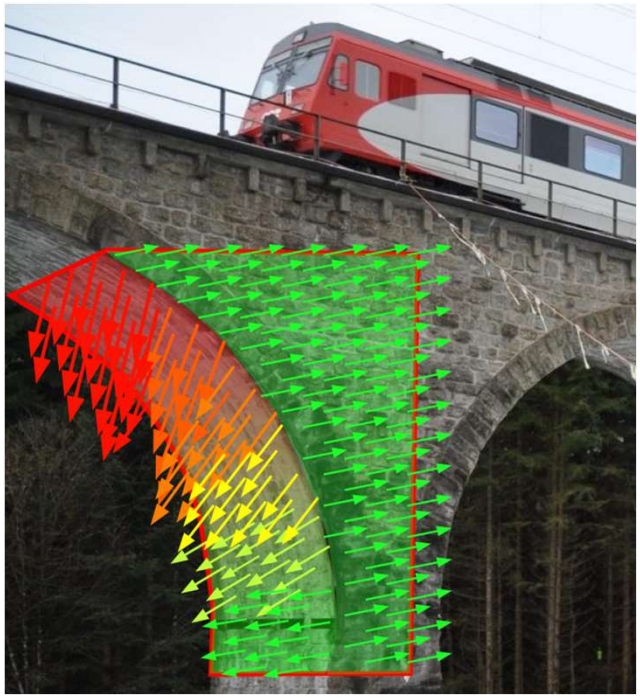
the benefit of n.Vec Technology is an optimized mathematic description of the scanned surface

Software - Automatic deformation calculation

Example of the normal vector

Highlights of the new **n.Vec Technology**

- On each point the normal vector in known and defines the deformation direction
- Filter, remove ghost data automatically
- This method will automatically detect edges more precisely then classical triangulation models
- Color coded deformation cloud, shortest distance to the closest patch of the Null Scan



GeoMoS Scanning

Any surface deformation may be detected

Monitoring Solutions

Questions?

- when it has to be **right**

Leica Geosystems

Thank you for your attention

Leica Geosystems, Inc.
Engineered Solutions

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Leica Geosystems