Automated Monitoring Systems
Innovative Solutions from Leica Geosystems
Presented by: William T. Derry, Prof. LS
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

External Links:

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

Sunshine Skyway Bridge - FDOT

- when it has to be right
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
Leica Monitoring Solution
Overview

Risk Management!
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?

- when it has to be right
Automated Monitoring Systems

Leica Geosystems has a long history of high precision instruments.

- when it has to be right
Leica Nova TM50 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
Example set up
Robotic Total Station on pedestal
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 -San Pablo Dam
Instrumentation Plan

Control Point(s)
AMTS – Example Dam
Instrumentation Plan

Monitoring Point(s)
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

- when it has to be right
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. It is 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.
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

- when it has to be right
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
Dual Frequency 20Hz
RT Stream to internet
Secure Data

GeoMoS Now!
Online Monitoring Data
Deformation Analysis
Secure data access

Spider & GeoMoS
GNSS Processing
Deformation Analysis
Limit check & Messaging

- when it has to be right
DYNAMIC GNSS – Example Bridge

Marine Parkway Bridge
GNSS – Example Bridge
Marine Parkway Bridge
GNSS – Example Bridge
Marine Parkway Bridge

Example communication enclosure
Leica GM30
Site Monitor – on board software

Incoming data stream wizard

Configure real time in data stream

- RTK data format
  - RTCM 18,19 v2

- Reference Sensor
  - Automatic

- Reference Antenna
  - Automatic

- Receive RTK corrections from RTK Network
  - Nearest

- Send user ID
  - i-Max
  - MAX
  - VRS
  - FKP

- Position type
  - Monitoring

- Max. position quality
  - RTK fixed position
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
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)

<table>
<thead>
<tr>
<th>VADASE</th>
<th>East (mm/s)</th>
<th>North (mm/s)</th>
<th>Height (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum velocity detected</td>
<td>3.6</td>
<td>3.6</td>
<td>8</td>
</tr>
<tr>
<td><strong>Recommended minimum velocity</strong></td>
<td>10</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>to be used for accurate displacement computation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Redundancy in positioning results

The baseline between the reference stations may also be monitored for long term stability.

Reference station 1.

Reference station 2.

Monitoring point

Monitoring point

- when it has to be right
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

\[ r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \]

\( r \) for DGPS vs. plumb line

= 0.91
# GNSS Position Accuracy

## Static & Dynamic Monitoring Solution

### Post Processing L1 Only

<table>
<thead>
<tr>
<th></th>
<th>2D Precision (95%)</th>
<th>Height Precision (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 minutes</td>
<td>7.2mm</td>
<td>12.4mm</td>
</tr>
<tr>
<td>1 hour</td>
<td>3.8mm</td>
<td>7.0mm</td>
</tr>
<tr>
<td>24 hours</td>
<td>2.2mm</td>
<td>1.8mm</td>
</tr>
</tbody>
</table>

- 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

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</thead>
<tbody>
<tr>
<td>10 minutes</td>
<td>5.2mm</td>
<td>11.8mm</td>
</tr>
<tr>
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<td>3.8mm</td>
<td>7.2mm</td>
</tr>
<tr>
<td>24 hours</td>
<td>1.8mm</td>
<td>2.0mm</td>
</tr>
</tbody>
</table>

- 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.

- when it has to be right
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
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

**Multi-baseline solution:**
All sites can be both reference and rover
Multiple reference stations may be used for redundancy and checking

**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

**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
- when it has to be right
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

- when it has to be right
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 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

- when it has to be right
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 displacement 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 mathematical model
- Mathematical 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 mathematical 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
Questions?
Thank you for your attention

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