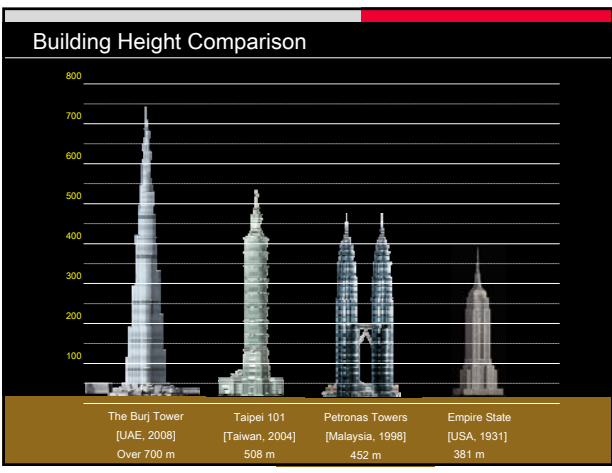




## Core Wall Survey Control System

International FIG 2006 Congress  
Munich, Germany, October 8-13, 2006  
Joël M. van Cranenbroeck, Douglas M. Hayes, Ian R. Sparks

**Leica**  
Surveying



### Citius, Altus, Fortus... Fastest, Highest, Strongest...

**Date de Mise en service :** 31 mars 1931 (type de Skyscraper en acier), édifiait pour l'Exposition universelle qui devait célébrer le centenaire de la Révolution Française  
**Age :** 114 ans

**Entrepreneur :** Gustave Kiefel & Cie  
**Ingénieurs :** Maurice Koehlin & Émile Soppet

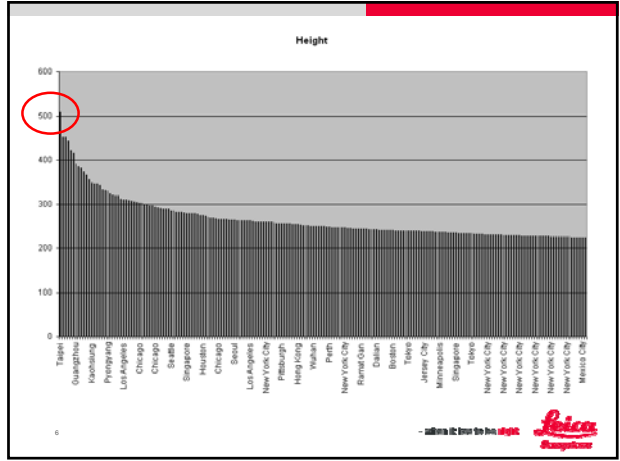
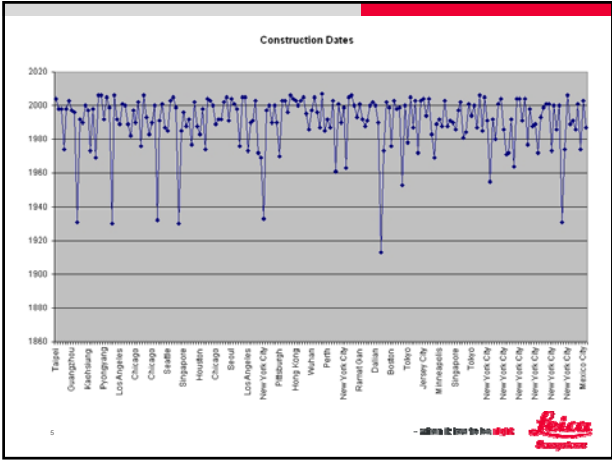
**Architecte :** Stephen Scaevette  
**Plan :** Commencé en 1924  
**Construction :** 1927 - 1931 (2 ans, 2 mois et 3 jours)

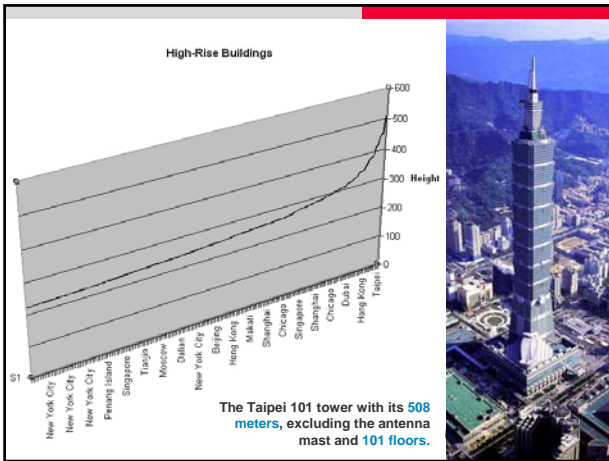
**Composition :** 18 038 pièces métalliques, 2 300 000 rivets  
**Poids de la charpente métallique :** 7 300 tonnes  
**Poids total :** 10 100 tonnes  
**Hauteur :** 324 m (hauteur avec antenne)  
**Construction géométrique :**  
**Latitude :** 40° 51' 30" Nord  
**Longitude :** 007° 17' 40" Est  
**Nombre de visiteurs jusqu'en 31 décembre 1985 :** 222 904 412  
**Signe particulier :** Reconnu comme étant le plus ancien  
**Nombre de marches :** 1665

**Propriétaire :** La ville de Paris

**The Empire State Building was at the time of construction the highest building worldwide. Fastest after, only several months, another building was erected in USA beating (strongest) that record.**

**Leica**  
Surveying





### The Burj Dubai Tower

Dubai (United Arabs Emirates)

Place : Dubai  
 Height : 800 metres  
 Number of Floor : 160  
 End of construction date : 2008

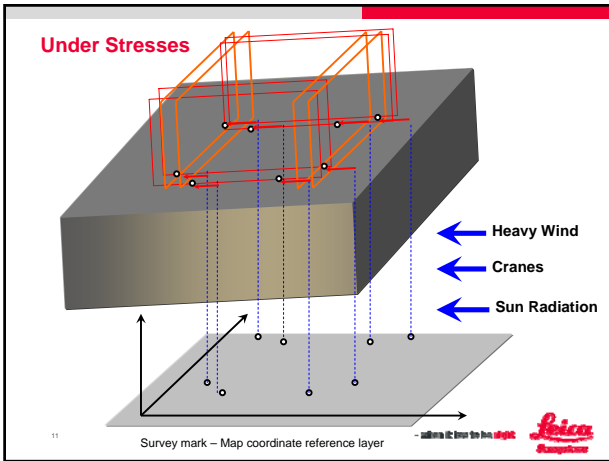
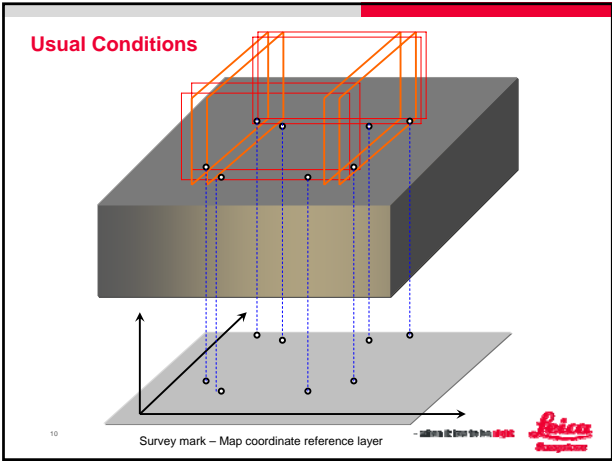
With its 800 meters height, the BURJ Dubai tower will become the tallest building in the world !

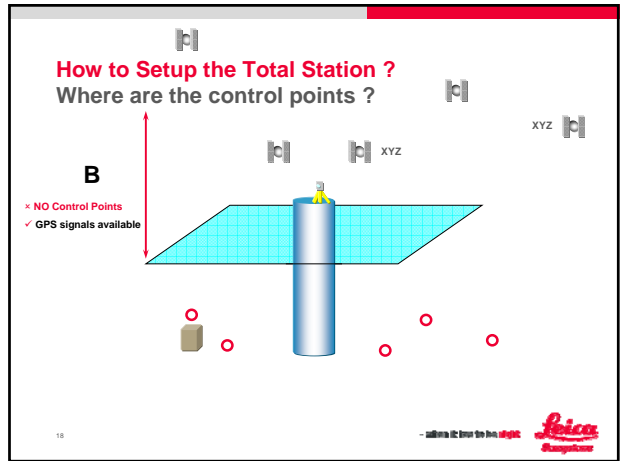
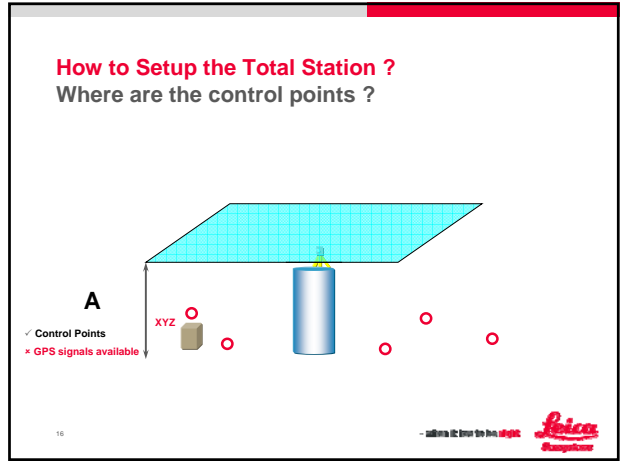
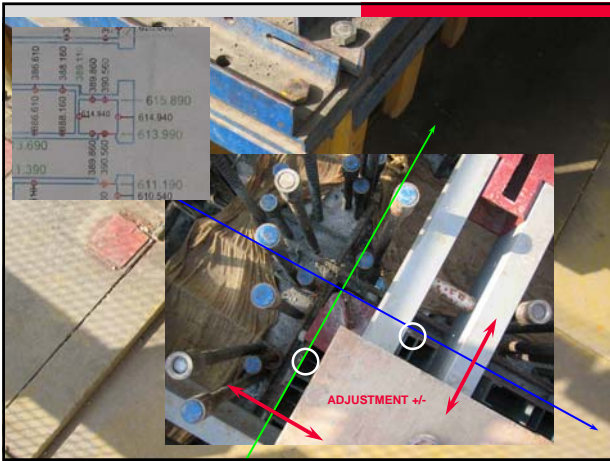
9

In addition to being very tall it will be quite slender and during the construction there is a lot of movement of the building at upper levels mainly due to :

- Wind loads,
- Crane loads,
- Construction sequence and
- Other factors...

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### How to Setup the Total Station ? It's all about gravity ...

x NO Control Points  
v GPS signals available

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### How to Setup the Total Station ? When the tower will move ...

x NO Control Points  
v GPS signals available

20

### How to Setup the Total Station ? When the tower will move ...

x NO Control Points  
v GPS signals available

21

### Active GPS Based Control Point Concept

1. The TPS measures on the prism/GPS - compensator OFF

2. Then measures the other points on the formwork.

3. The GPS fixes are computed and used as « known points ».

4. A 7 parameters transformation is applied on the other points.

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### Proof of Concept October 2005

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### Results obtained for the check point

SETUP	Absolute Differences			Relative Differences		
	$\Delta X$	$\Delta Y$	$\Delta Z$	$\Delta x$	$\Delta y$	$\Delta z$
S1	0.0022	-0.0095	-0.0071			
S2	0.0022	-0.0105	-0.0043	0.0000	-0.0010	0.0028
S3	0.0025	-0.0130	-0.0031	0.0003	-0.0035	0.0040
S4	0.0030	-0.0113	-0.0048	0.0008	-0.0018	0.0023
S5	0.0027	-0.0121	-0.0052	0.0005	-0.0016	-0.0009
S6	0.0028	-0.0108	-0.0026	0.0006	-0.0013	0.0045

Tilted !

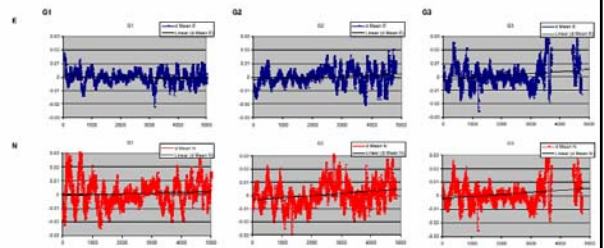
Tx updated : 12381.3842  
Ty updated : 10804.8800  
Tz updated : 1.1048  
Scale Factor updated : .9999999929  
Updated Rotation Matrix  
-0.6980183 -0.7160799 -0.0001290  
0.7160799 -0.6980183 -0.0000045  
-0.0000068 -0.0000055 1.0000000  
Rotations parameters  
Rotation along X axis : -.00547  
Rotation along Y axis : .00497  
Rotation along Z axis : -45.73177

Tx updated : 12352.6160  
Ty updated : 10807.7507  
Tz updated : -483.3256  
Scale Factor updated : .9999999929  
Updated Rotation Matrix  
-0.6991354 -0.7119652 0.0656903  
0.7148607 -0.6977957 0.0453364  
0.0135605 0.0786557 0.9968096  
Rotations parameters  
Rotation along X axis : 4.51172  
Rotation along Y axis : -.77698  
Rotation along Z axis : -45.63717

24



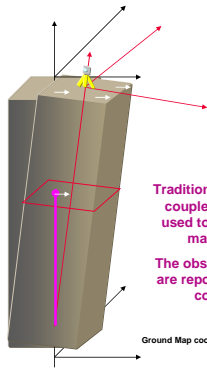
**GPS measurements are processed in « Mixed Tracks » mode using Leica LGO**



**GPS Continuous Operating Reference Station**



**From Laser Beam to Accurate Clinometers**



Traditionally a laser beam coupled with a ZNL is used to materialize the main verticale.  
The observed deviations are reported on the map coordinates.

Ground Map coordinates

**Leica NIVEL200 Series Overview**

- Two-axis high precision sensor
- Measuring range +/- 3mrad
- High precision and resolution of 0.001 mrad
- Short measuring time of 300ms
- Long-term stability
- Real-time data
- Inboard serial interface ( NIVEL210 ) or RS-485 bus ( NIVEL220 )



Precise information about inclination displacements

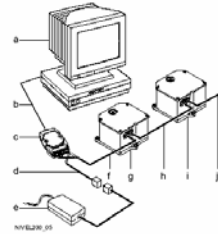
## Performances of the Leica NIVEL200

At **1000 meters** height, the NIVEL 200 can detect a tilt variation of **maximum +/- 2.5 m** with an accuracy of **1 mm**.

Tilt X	Tilt Y	z meter	b	a	tan φ	tan ω	l	z'	b'	a'	T <sub>x</sub> mm	T <sub>y</sub> mm
0.000001	0.000001	10	0.000	0.000	0.000001	0.000001	10.000	10.000	0.000010	0.000010	0.01	0.01
0.002500	0.002500	10	0.025	0.025	0.002500	0.002500	10.000	10.000	0.025000	0.025000	25.00	25.00
0.000011	0.000011	50	0.000	0.000	0.000011	0.000011	50.000	50.000	0.000050	0.000050	0.05	0.05
0.002500	0.002500	50	0.125	0.125	0.002500	0.002500	50.000	50.000	0.124999	0.124999	125.00	125.00
0.000001	0.000001	100	0.000	0.000	0.000001	0.000001	100.000	100.000	0.000100	0.000100	0.10	0.10
0.002500	0.002500	100	0.250	0.250	0.002500	0.002500	100.000	99.999	0.249998	0.249998	250.00	250.00
0.000001	0.000001	250	0.000	0.000	0.000001	0.000001	250.000	250.000	0.000250	0.000250	0.25	0.25
0.002500	0.002500	250	0.625	0.625	0.002500	0.002500	250.000	249.998	0.249998	0.249998	625.00	625.00
0.000001	0.000001	500	0.001	0.001	0.000001	0.000001	500.000	500.000	0.000500	0.000500	0.50	0.50
0.002500	0.002500	500	1.250	1.250	0.002500	0.002500	500.000	499.997	1.249992	1.249992	1249.99	1249.99
0.000001	0.000001	1000	0.001	0.001	0.000001	0.000001	1000.000	1000.000	0.001000	0.001000	1.00	1.00
0.002500	0.002500	1000	2.500	2.500	0.002500	0.002500	1000.000	999.994	2.499984	2.499984	2499.98	2499.98

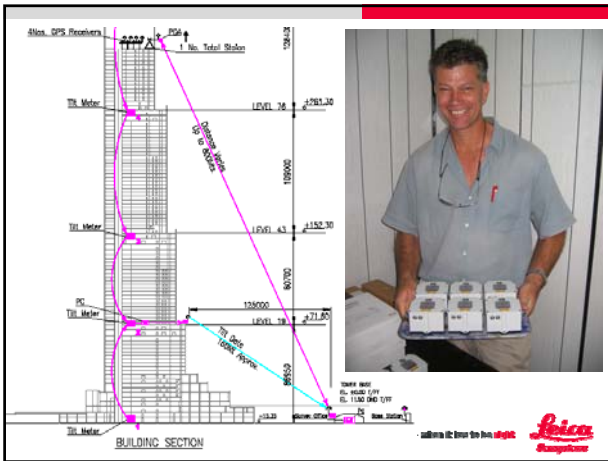
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## Up to 8 NIVEL200 will be networked ...



- a) PC
- b) Cable, Converter - PC
- c) RS232 / RS485 bus converter
- d) Cable, Lemo 1 (female) - Converter
- e) Power supply
- f) Cable, Converter - Lemo 0 (male)
- g) NIVEL200 RS485
- h) Cable, Lemo 0 (male) - Lemo 0 (male)
- i) NIVEL200 RS485
- j) Cable, Lemo 0 (male) - Lemo 0 (male)

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## Data Modelling



$$b = l \cdot \sin \phi$$

$$a = l \cdot \sin \omega$$

$$z = l$$

$$a^2 + b^2 + z^2 = l^2$$

$$\tan \phi = \frac{b}{z}$$

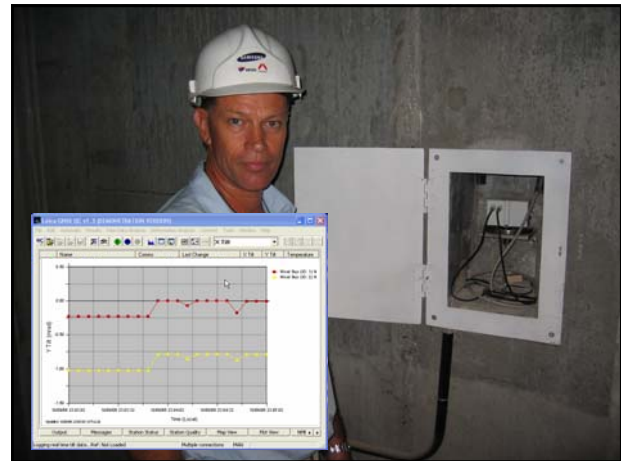
$$\tan \omega = \frac{a}{z}$$

$$z = \frac{l}{\sqrt{\tan^2 \phi + \tan^2 \omega + 1}}$$

$$b = z \cdot \tan \phi$$

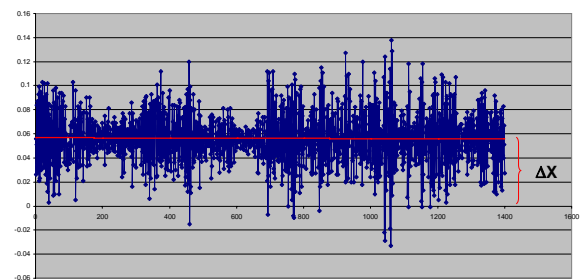
$$a = z \cdot \tan \omega$$

35

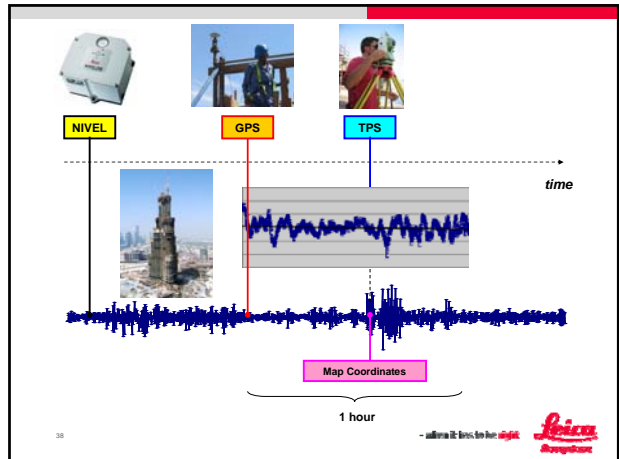
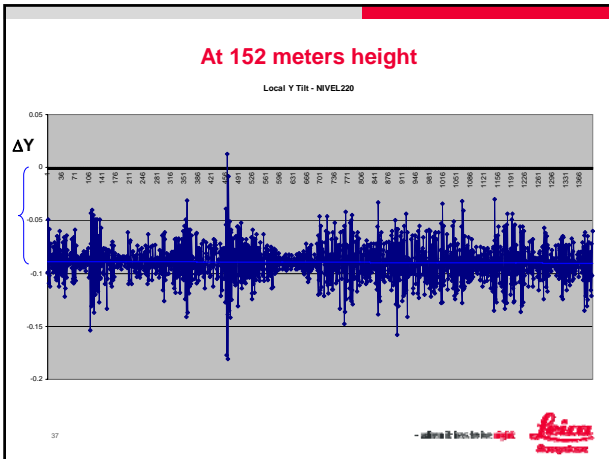


## At 152 meters height

Local X Axis tilt - NIVEL200



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### Prospectives ...

- We are compiling data for a better understanding of the near stage of construction.
- Up to 200 temperature sensors are already implemented and the number will be expanded.
- Wind speed sensors will be deployed soon.
- A dynamic functional model is developing to « predict » building behaviours.
- Other concepts will be investigated, tested and implemented.
- Other sensors will be evaluated as well as new positioning systems...

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Geosystems

