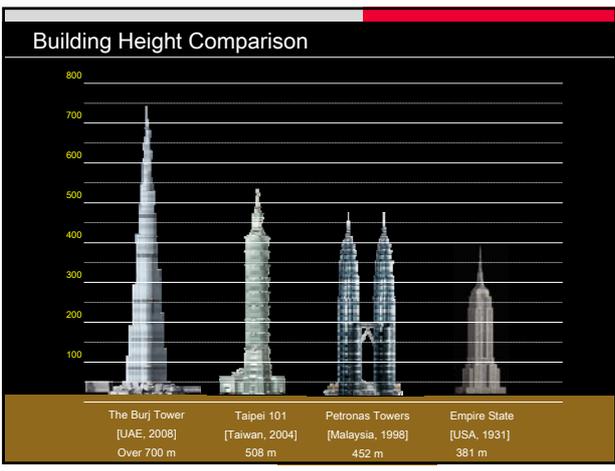


## Core Wall Survey Control System

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





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

**Date de Miseaux :** 31 mars 1885 (type de grappe en fer), éditée pour l'Exposition universelle qui devait célébrer le centenaire de la Révolution Française  
**Age :** 114 ans

**Entrepreneur :** Gustave Eiffel & Cie  
**Ingénieurs :** Maurice Koechlin & Eugène Boubouis

**Architecte :** Stephen Sauvestre  
**Édifié :** Commencé en 1884  
**Construction :** 1887 - 1889 (2 ans, 2 mois et 5 jours)

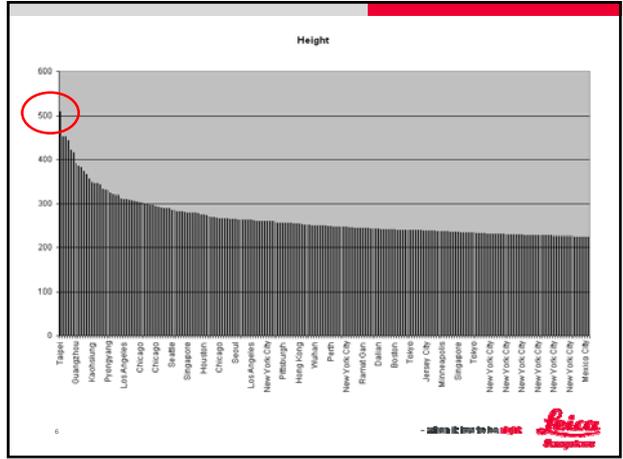
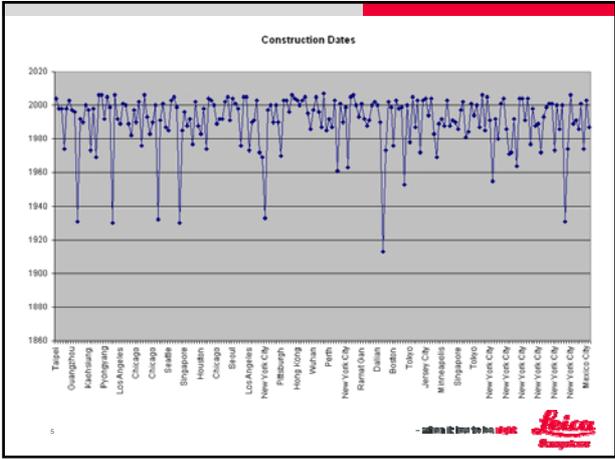
**Composition :** 18 038 pièces métalliques, 2 500 000 rivets  
**Poids de la charpente métallique :** 7 300 tonnes  
**Poids total :** 10 100 tonnes  
**Hauteur :** 324 m (hauteur avec antenne)

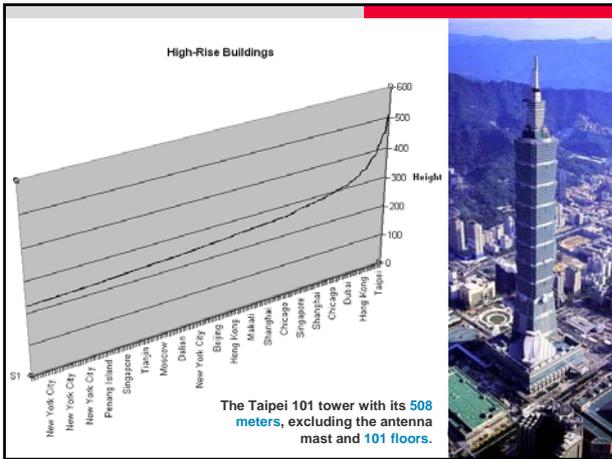
**Coordonnées géographiques :**  
**Latitude :** 48° 51' 30" Nord  
**Longitude :** 002° 17' 40" Est  
**Nombre de visiteurs jusqu'en 31 décembre 1985 :** 222 904 412  
**Signe particulier :** Reconnu comme étant le plus visité  
**Nombre de marches :** 1 665

**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.**







## The Burj Dubai Tower

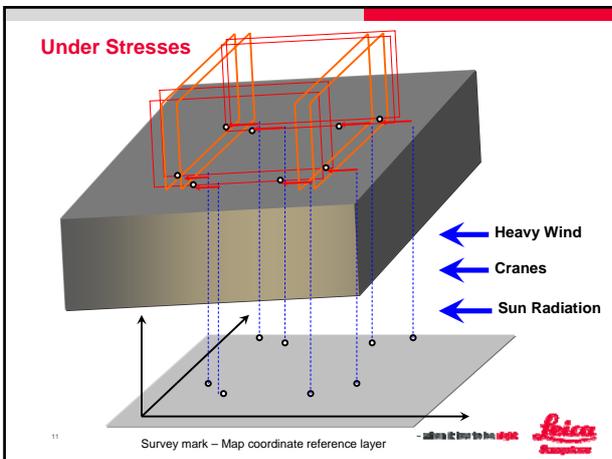
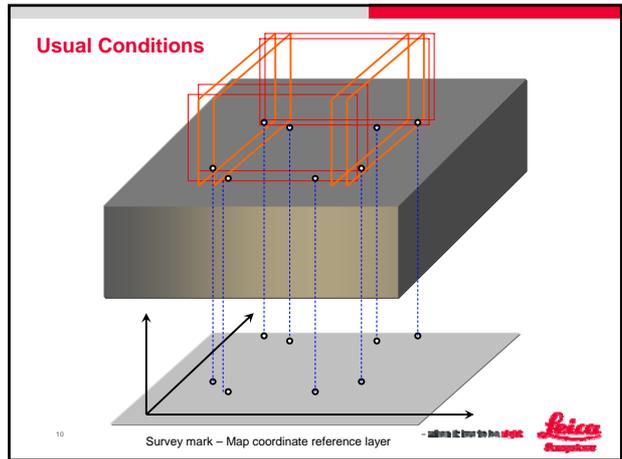
### Dubai (United Arabs Emirates)

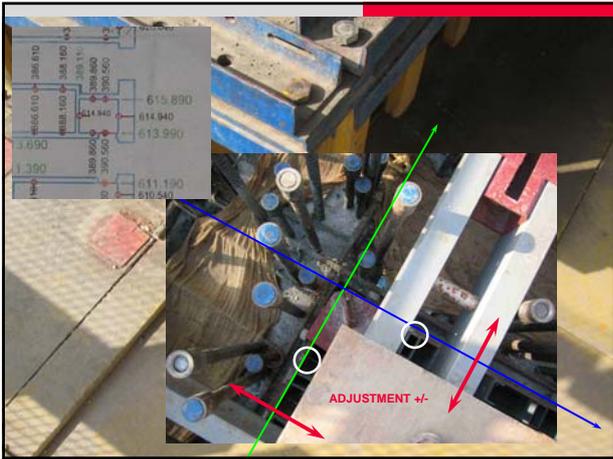
Place	: Dubai
Height	: 800 metres
Number of Floor	: 160
End of construction date	: 2008

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

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...





### How to Setup the Total Station ? Where are the control points ?

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Leica  
Geosystems



### How to Setup the Total Station ? Where are the control points ?

18

Leica  
Geosystems

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

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

20

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

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### 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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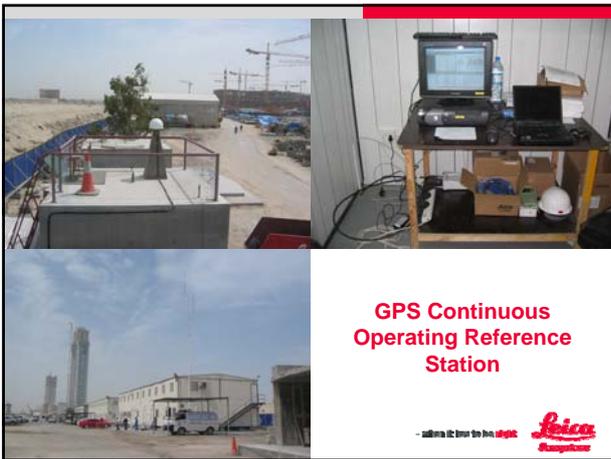
### Results obtained for the check point

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

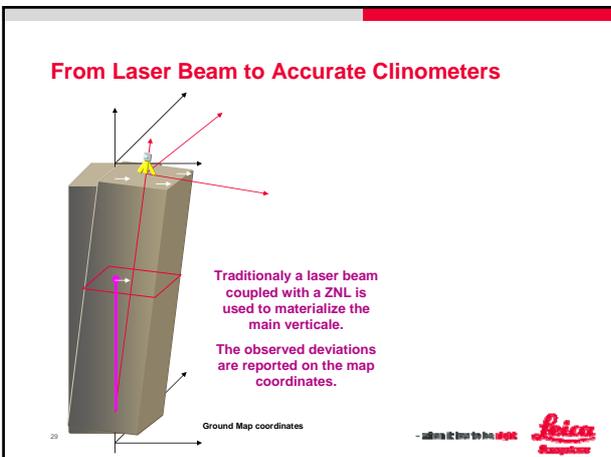
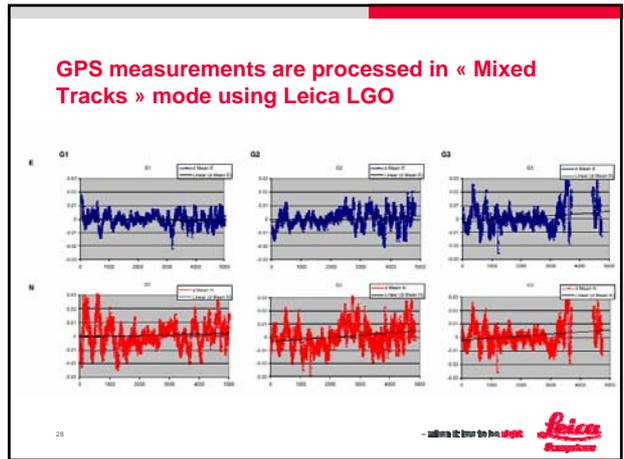
Tilted !

Tx updated : 12381.3842      Tx updated : 12352.6160  
 Ty updated : 10804.8800      Ty updated : 10807.7507  
 Tz updated : 1.1048      Tz updated : -483.3256  
 Scale Factor updated : .9999999929      Scale Factor updated : .9999999929  
 Updated Rotation Matrix      Updated Rotation Matrix  
 -0.6980183 -0.7160799 -0.0001290      -0.6991354 -0.7119652 0.0656903  
 0.7160799 -0.6980183 -0.0000045      0.7148607 -0.6977957 0.0453364  
 -0.0000868 -0.0000955 1.0000000      0.0135605 0.0786557 0.9968096  
 Rotations parameters      Rotations parameters  
 Rotation along X axis : -.00547      Rotation along X axis : 4.51172  
 Rotation along Y axis : .00497      Rotation along Y axis : -.77698  
 Rotation along Z axis : -45.73177      Rotation along Z axis : -45.63717

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**GPS Continuous Operating Reference Station**



**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

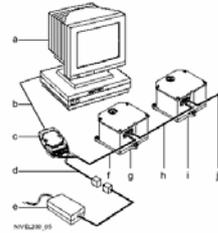
## Performances of the Leica NIVEL200

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

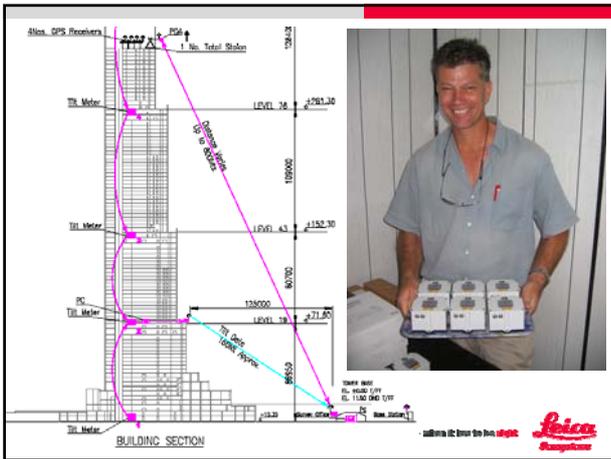
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## Up to 8 NIVEL200 will be networked ...



- 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



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

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

$$z = l$$

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

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

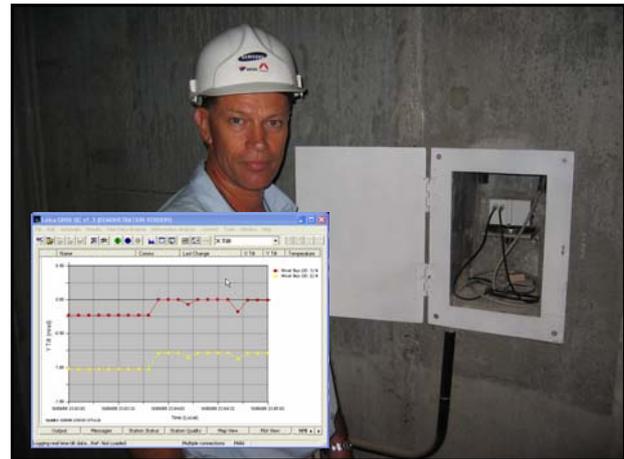
$$\tan \omega = \frac{a}{z}$$

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

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

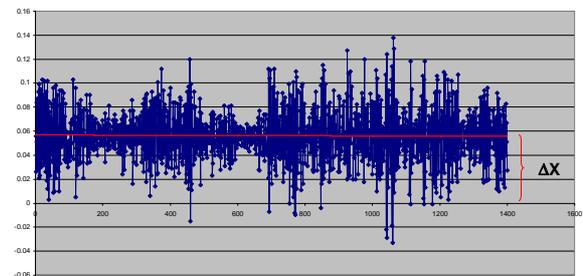
$$a = z \cdot \tan \omega$$

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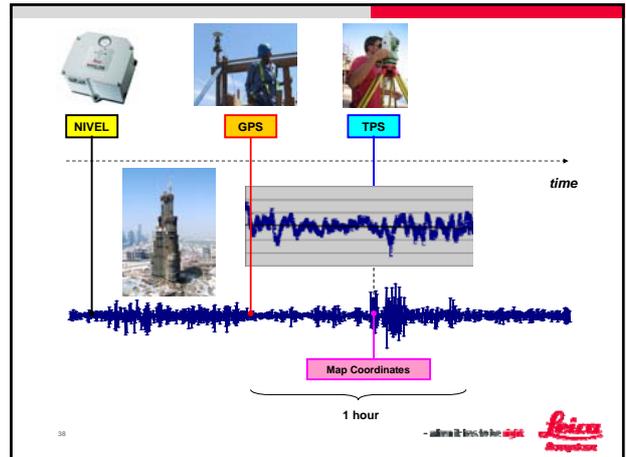
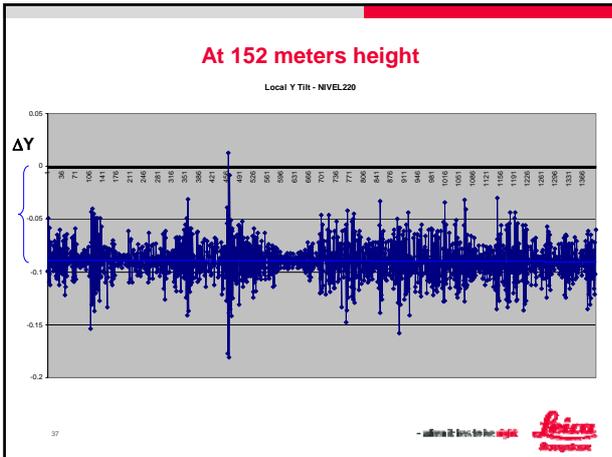


## At 152 meters height

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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- università di Brescia - Dipartimento di Ingegneria e Architettura **Leica** *Geosystems*

