Surveying in the Year 2020

Johannes Schwarz

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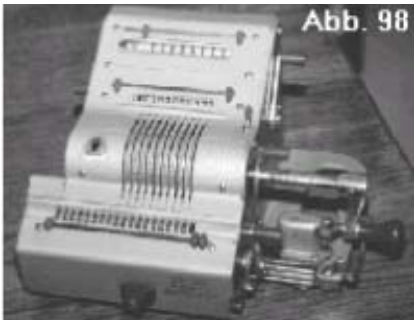
My first toys……



2

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3 Questions

- Why is a company like Leica Geosystems constantly developing new surveying products and instruments ?
- What surveying products will be of use in 10 years from now ?
- Will we need professional surveyors in future, or will modern instruments make surveyors redundant ?

3

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What is our objective ?

Sales	11'512
Cost of Sales	-5'180
Gross Profit	6'332
Gross Margin	55%
Operating Expenses	-4'421
OPEX%	-38%
EBIT	1'911
EBIT%	17%

- As a public company, shareholders expect from us to grow EBIT
- EBIT grows with additional sales
  - of new products
  - to existing and new customers
- Typically, 10% of revenue can be reinvested into the development of new products every year
- New products are derived from applying the core competencies of the company

4

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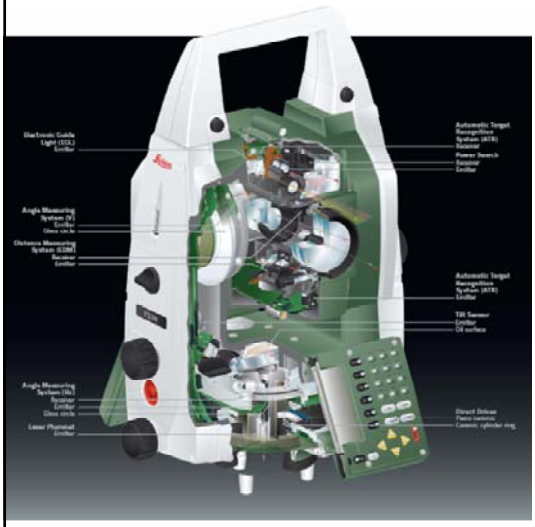
Core Competencies of Leica Geosystems



- Angle Reading
- Tilt Sensors
- EDM
- Lasers
- Automatic Target Recognition
- Motorization
- Opto-Mechanics

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Core Competencies of Leica Geosystems

- GNSS Signal Tracking
- GNSS Data-Processing
- GNSS Antenna Technology

- Surveying Application know-how
  - Terrestrial Positioning System
  - GNSS
- Scanning EDM

- Manufacturing

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Core Competencies of a Professional Surveyor

$$V = \sum_{n=0}^{\infty}\sum_{m=0}^{n}\frac{1}{l^{n+1}}\left[a_{nm}C_{nm}(\vartheta,\lambda)+b_{nm}S_{nm}(\vartheta,\lambda)\right]$$

$$a_{n0} = G\iiint_E l'^n P_n(\cos\vartheta')\,dm$$

$$a_{nm} = 2\frac{(n-m)!}{(n+m)!}G\iiint_E lr'^n C_{nm}(\vartheta',\lambda')\,dm$$

$$b_{nm} = 2\frac{(n-m)!}{(n+m)!}G\iiint_E lr'^n S_{nm}(\vartheta',\lambda')\,dm$$

7

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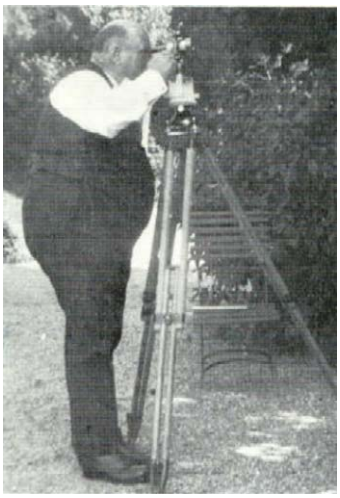
Core Competencies of a Professional Surveyor



- The surveyor's main core competency is x,y,z !
- Angle & distance measurements
- Measurement error propagation
- Least square adjustments
- Transformations, map projections
- Height systems, Geoid undulations, etc.
- **Only professional surveyors can determine coordinates or stake out points with accuracies better than a centimeter, and can judge the quality of measurements and coordinates**

8

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Important Trends in Surveying
Instrument Manufacturer Perspective

- **Perpetual need to increase the productivity of the field crews**
  - One-man solutions (GNSS-RTK, Robotic Totalstations)
  - Seamless dataflow & workflow between TPS and GNSS
  - Seamless dataflow & workflow between office – field – office
- **More and more complex structures being built, increasing the demand for surveying work**

9

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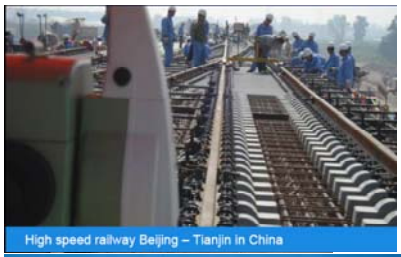
More and more complex objects and structures being built!



High speed railway Beijing – Tianjin in China

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Important Trends in Surveying
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- **Perpetual need to increase the productivity of the field crews**
  - One-man solutions (GNSS-RTK, Robotic Totalstations)
  - Seamless dataflow & workflow between TPS and GNSS
  - Seamless dataflow & workflow between office – field – office
- **More and more complex structures being built, increasing the demand for surveying work**
- **Average surveying-specific skill set of field-crews is decreasing**
- **Logical challenge for manufacturers:**

$$IQ_{Operator} + IQ_{Instrument} = const.$$

11

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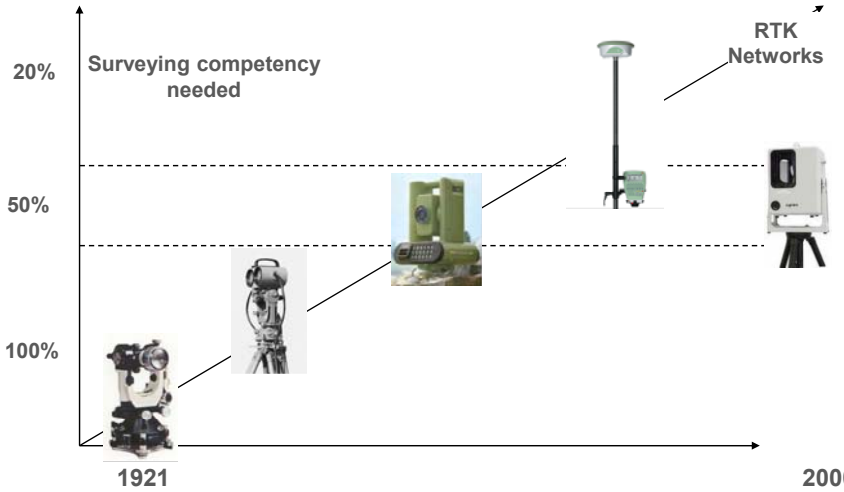
Significant Milestones in the Development of Surveying Instruments



12

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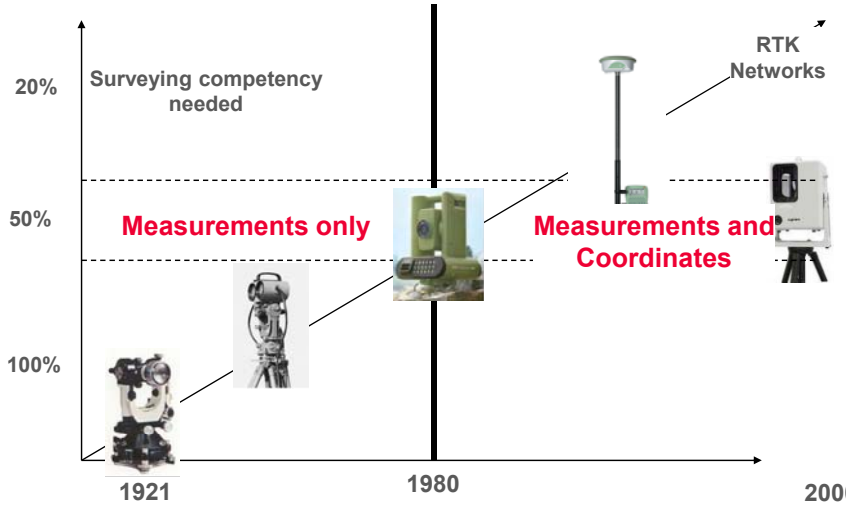
Significant Milestones in the Development of Surveying Instruments



13

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Contributors to accurate positions

Survey instrument	Professional Surveyor
Precise direction reading	Judgement of
Precise vertical reading	▪ Atmospheric conditions
Precise distance measurements	▪ Existing control
Precise height difference readings	▪ Measurement reductions
Precise 3D vectors in WGS 84	▪ Error propagation
Data storage	▪ Measurement / set-up quality
Coordinate geometry (COGO)	▪ Instrument specifications
Data retrieval	

14

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2 Types of Surveying Instruments

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GNSS Products
Main Characteristics - Today

- **Within a network, GNSS receivers deliver 3D coordinates in real-time**
- **Prerequisite:**
  - Access to Reference Station data
  - Datalink (either GSM/GPRS etc. or UHF or Spread Spectrum / WLAN…)
  - Line of sight to minimum 4 / 5 satellites
- **Highly productive equipment (one-man, no tripod,…)**
- **Relatively "fool-proof"**
  - instruments give good indication of coordinate quality
- **Accuracy: Horizontal 5mm + 0.5ppm (rms), Vertical 10mm + 0.5 ppm (rms)**

16

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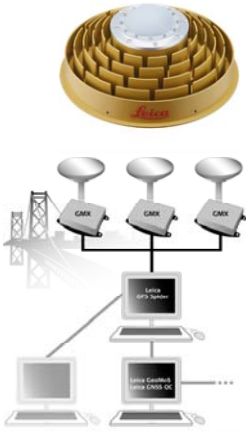
GNSS Products – RTK Networks
The backbone for the productive use of GNSS-RTK



NRS - Ireland

17

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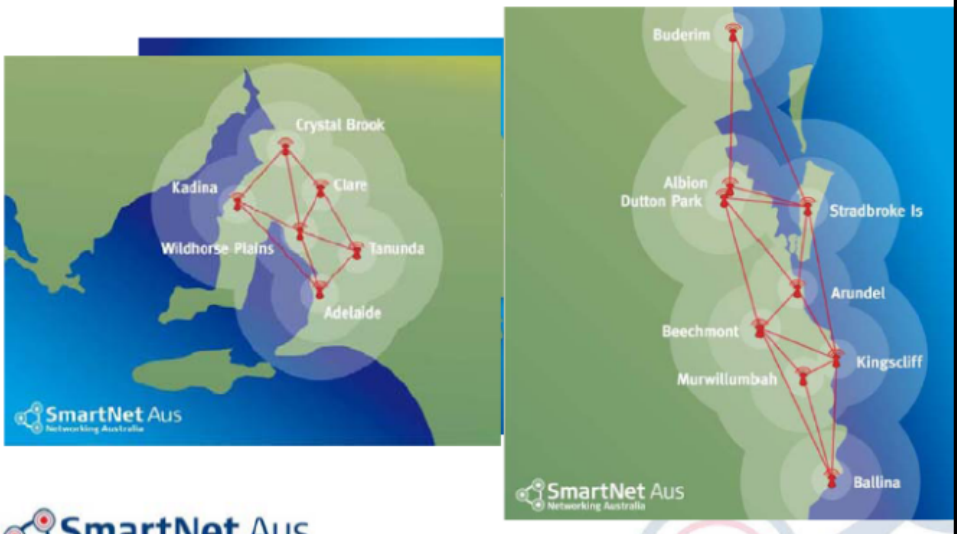
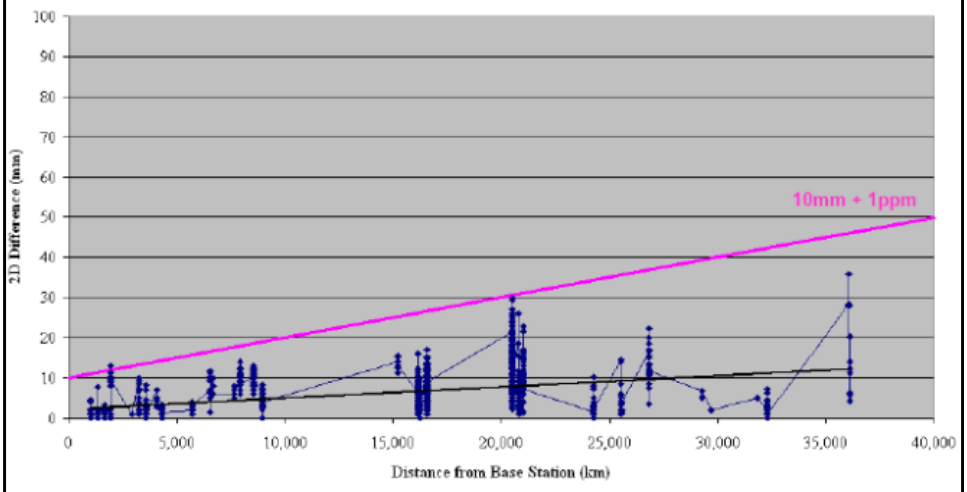
GNSS Data Service
Current Network RTK coverage areas



5

Nearest Base vs MAC Correction
Fixed solutions at Stationery locations



SmartNet Aus
Networking Australia

23

GNSS Constellations – Today
GPS (USA)

- 29 satellites active (+2)
- 1 launches in 2008, 2 launches in 2009, 2 launches planned for 2010
  - On average: < 2 SV
- 8 are broadcasting L2C
- 1 is broadcasting L5 (test only)

Block	Launch Period	Satellite launches				Currently in orbit and healthy
		Success	Failure	In preparation	Planned	
I	1978–1985	10	1	0	0	0
II	1989–1990	9	0	0	0	0
IIA	1990–1997	19	0	0	0	11 of the 19 launched
IIR	1997–2004	12	1	0	0	12 of the 13 launched
IIR-M	2005–2009	8	0	0	0	7 of the 8 launched
IIF	2010–2011	0	0	10	0	0
IIIA	2014–?	0	0	0	12	0
IIIB		0	0	0	8	0
IIIC		0	0	0	16	0
Total		58	2	10	36	30

(Last update: 29 December 2009)

PRN 01 from Block IIR-M is unhealthy
PRN 25 from Block IIA is unhealthy
See the GPS almanac. For a more complete list, see *list of GPS satellite launches*

20

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GNSS Products - 10 Years from Now
GPS (USA)

- Replenishment Strategy will continue
- 2-3 new satellites to be launched every year
- By 2020, we can expect
  - Full triple-frequency constellation L1, L2, L5
  - All satellites broadcasting L2C, most tracking L1C
    - Somehow stronger signal, L2 signal as strong as L1 today

21

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GNSS Constellations – Today
Glonass (Russia)

- 21 + 2 satellites available
- All FDMA based (**F**requency **D**ivision **M**ultiple **A**ccess)
- Launch of 1st Glonass-K SV planned for 2010

GLONASS constellation status, 30.03.2010г.

Total satellites in constellation	23 SC
Operational	21 SC
In commissioning phase	-
In maintenance	-
Spares	2 SC
In decommissioning phase	-

22

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GNSS Constellations – 10 Years from Now
Glonass (Russia)

- 24 “guaranteed” by 2013
- 30 Glonass-K can be expected in 2020
- All CDMA based (Code Division Multiple Access), like GPS
  - No manufacturer/dependent biases anymore
- Broadcasting on 3 frequencies

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GNSS Constellations – Today
Galileo (Europe)

- Original Plan: Full constellation available in 2008
- 2010: $Weight_{Scientific\ Papers} \rangle\rangle Weight_{launched\ \_SV}$
- To date, only 2 test satellites in orbit
- Still debates about signal structure and frequencies (budget driven)
- Frequency debates with China and USA
- Limited funding (16 SV only)
- “Political” discussions

24

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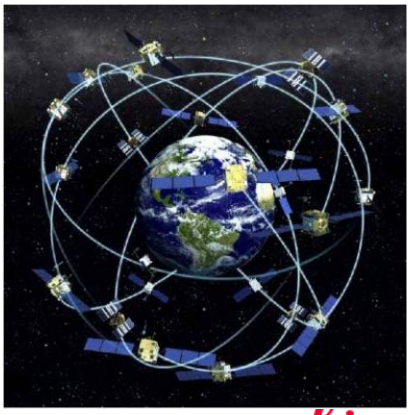
GNSS Constellations – 10 Years from Now Galileo (Europe)

- 2020: $Weight_{ScientificPapers} \approx Weight_{launched\_SV}$
- Personal view:
  - Less signals than planned
  - Maybe only 18 SV in orbit (minimum useful constellation)



25

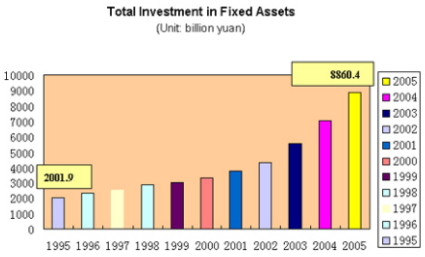
GNSS Constellations – Today Compass (China)

- 3 test satellites launched
- Signal Structure similar to GPS
  - L1, L2, L5
- ICD not published, currently only available to carefully selected Chinese companies
- Still open issue: Will Compass interfere with GPS and Galileo ?

26

GNSS Products - 10 Years from Now
Compass (China)

- Full constellation can safely be expected in 2020



27

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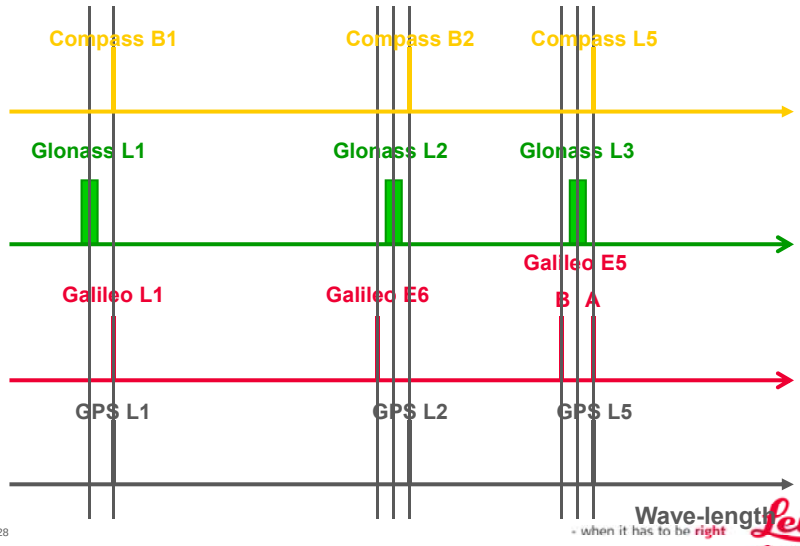
GNSS Frequency-bands
Stepping on each other's toes



28

Wave-length – when it has to be right

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Summary: GNSS in 2020

- 4 global constellations in place
- Plus several regional augmentation systems (Japan, India, Europe, etc.)
- Close to 100 active SV in orbit with 3 frequencies
- Minimum 30 SV in view under open sky
- This means, 30 x 3 observations instead of 15 x 2 today
- Robustness and reliability of ambiguity resolution will increase significantly
- However,
  - Unobstructed view to 4-5 SV with good geometry still needed
  - 2-D Accuracy will continue to be around 2 – 3 cm, maybe on 3σ level
  - Height accuracy will not be better than 2 cm at 1σ level

29

Terrestrial Measurement Devices - Totalstations

30

From Wild T2 to Leica System 1200 SmartStation

1921

2005

31

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Features and Technologies included in today's Totalstation

- 0.5" Angular reading, horizontal and vertical
- IR EDM to prism, up to 10km, 0.6 mm + 0.5 ppm
- Reflectorless EDM up to > 1000m, 2mm + 2 ppm
- Fast motorization (direct drive, based on Piezo technology)
- Automatic Target Recognition, 1" accuracy
- Power-Search for automatic prism detection
- GNSS add-on sensor for absolute positioning
- Software, Software, Software!

What else can be added into a totalstation ?

32

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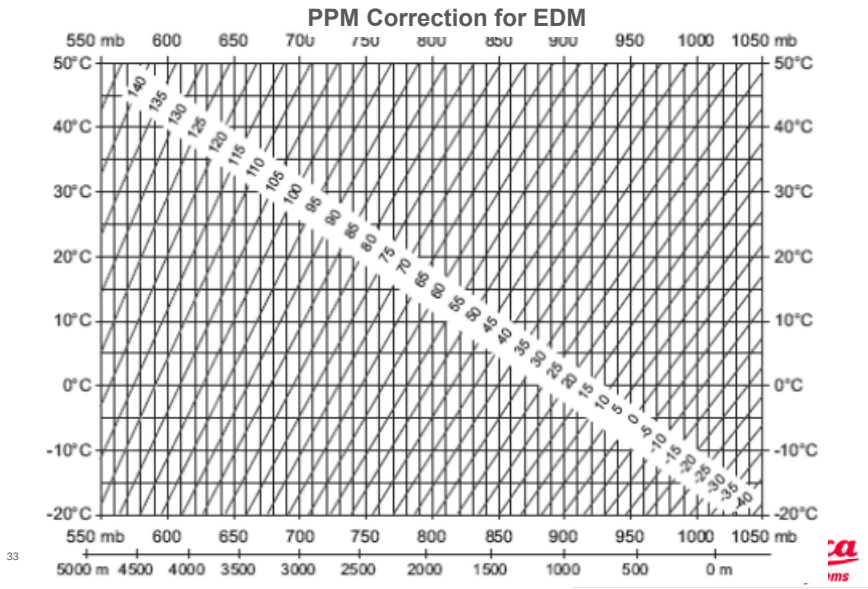
Surveying in the year 1980 and in 2010



33

2 Main Types of Surveying Instruments

And what about new & emerging technologies ?

34

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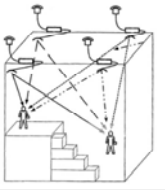
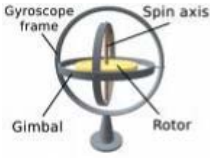
2 Types of Surveying Instruments
And what about new & emerging technologies ?

- Laser Scanning
- Inertial Systems
- Pseudsolites ?
- Indoor GPS ?
- …..





35

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Development of TOF Scanners

Range	100 m	300 m	300 m
Accuracy	6 mm	6 mm	6 mm
Points/sec	1'000	4'000	50'000
Power	100 W	80 W	50 W
Weight	21 kg + car battery + PC	19 kg + 12kg battery + PC	13 kg "all inclusive"

2000 2006 2009

36

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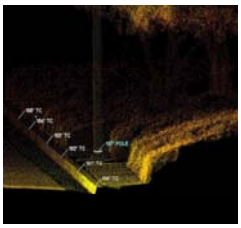
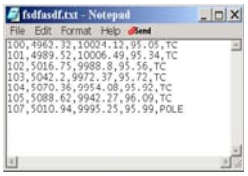
Will a scanner replace conventional totalstations ? Concept of Virtual Surveying





- Stake-out ?
- obstructed details (e.g. manhole behind curb) ?

37

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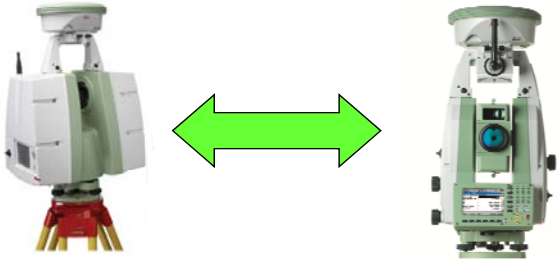
Scanning – 10 Years from now

- **Scanners get more and more powerful**
  - Significant improvements in speed, range, and size of equipment
  - Time of Flight and Phase shift technologies will merge
  - TPS features will get into Scanners
- **Scanning will become an additional feature of a totalstation**
- **Scanners and Totalstations will continue to co-exist**



38

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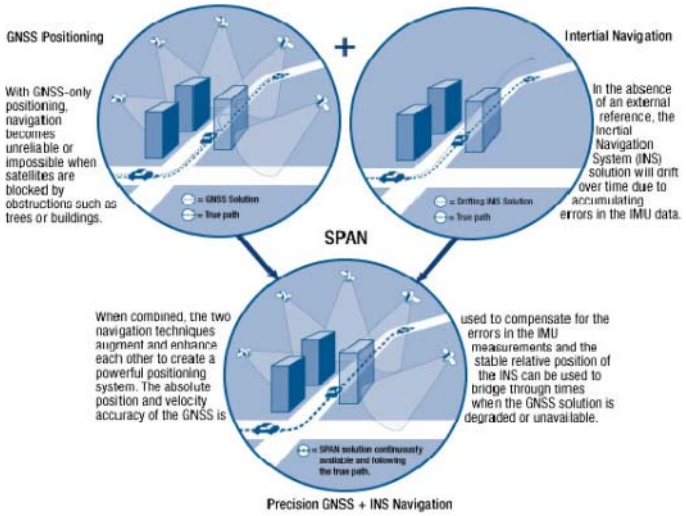
Inertial Systems - SPAN Technology
Synchronized Position Attitude Navigation



39

SPAN Technology
Relevant for Surveying ?

IMU-LN200

14 cm

3 kg

16 cm

US$ 60.000

Potential benefits:

- would deliver a position “everywhere”
- height accuracy much better than GNSS only
- no need for a totalstation anymore !

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SPAN Technology
Relevant for Surveying ?

IMU-LN200

Outage Duration	Positioning Mode	Position Accuracy (m) RMS	
		Horizontal	Vertical
0s	RTK	0.02	0.05
	HP	0.10	0.08
	SP	1.20	0.06
	PP[6]	0.01	0.02
10 s	RTK	0.12	0.07
	HP	0.39	0.32
	SP	1.34	0.67
	PP[6]	0.02	0.02
60 s	RTK	2.79	0.63
	HP	3.12	0.76
	SP	3.51	0.96
	PP[6]	0.11	0.04

41

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SPAN Technology
Relevant for Surveying ?

- **Different technologies to be considered**
  - Inertial platforms: heavy & expensive, but interesting from accuracy point of view
  - MEMS: light and cheap, but very high drift and poor accuracy
- **Once an IMU-LN200 type of sensor delivers cm accuracy after 2 minutes of GNSS outage, SPAN will become a main-stream device for surveyors!**
- **Will this happen in the next 10 years ?**

42

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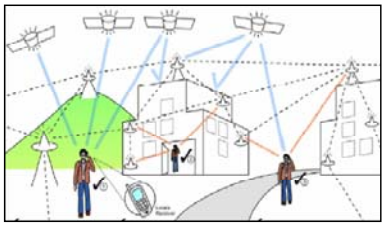
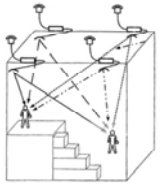
"Indoor-GPS" and Pseudolites





43

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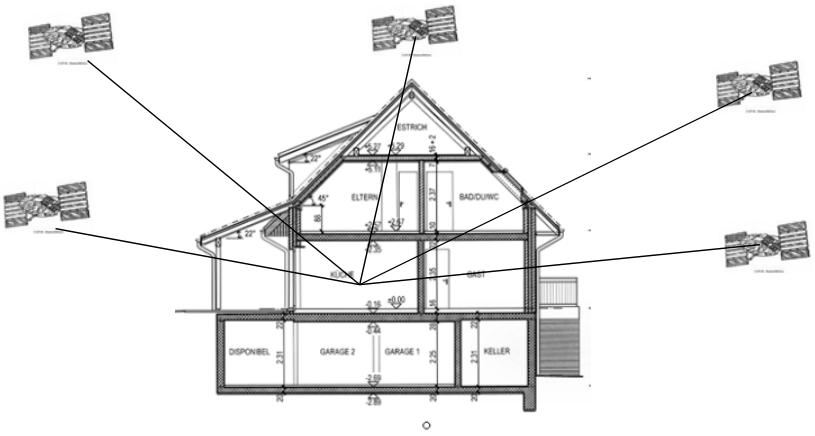
Indoor GPS

Precise Range-Measurements without line-of-sight?



44

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Pseudolites
Excellent tool to augment GNSS coverage

- Pseudolite = ground-based GNSS “satellite”
- Requires accurate position in order to contribute to solution
- Rover needs to have line-of-sight to pseudolite, thus
- Coverage of a pseudolite is limited

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Pseudolites
A useful tool for standard surveying ?

- Logistics effort to set up a pseudolite network is quite high
- Quite useful for mines in which precise positions are needed in the same area by many different users and GNSS-controlled machines, and where 2-3 cm accuracy is sufficient
- Probably not very efficient for standard survey work
  - Setting up pseudolite network is quite time consuming
  - Sub-centimeter accuracy not achievable

46

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How many Surveyors are needed in future ?

TQM
ISO 9001 / ISO 14001

47

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2 Main Types of Surveying Instruments
Are Professional Surveyors needed in 2020 ?

Yes!

48

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Tools of a surveyor in the year 2020

GPS + Glonass + Compass + Galileo

Web enabled

+ Scanning

+ Imaging features

Web enabled

49

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Why will surveyors continue to buy instruments

- Perpetual need to optimize productivity and efficiency
- Need to further simplify field operations
- Need for high quality products
- Need for high reliability and robustness of equipment
- Need for competent (on-line) support

50

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Thanks for Listening

51

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