Evaluating EGNOS augmentation on a military helicopter

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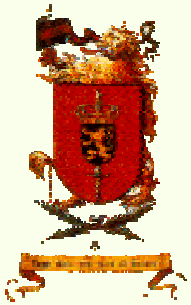
- **Van Hopplynus nv**
  - Joel Van Craenenbroeck, Leica SR520 receivers

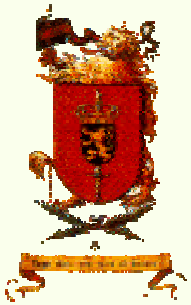


Overview

- Motivation
- Proposed solutions
- Test set-up
- Flight statistics
- Statistical analysis
- Conclusions

Motivation Lt Avn

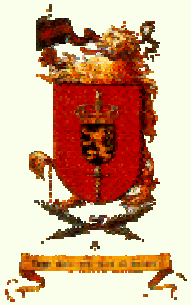
- **A109 helicopter**
  - Current configuration
    - Currently equipped with military-type receiver from Rockwell Collins MAGR
    - Updates the radar
  - Midlife update 2004
    - Increase availability, accuracy, integrity
    - consider DGPS
- **Contract open for new transportation helicopter**
- **Air Force several MUP programs in queue**



Motivation RMA & Septentrio

- **Tactical point of view (RMA)**
  - Peace keeping Ops ➔ large Ops Z
  - Rapid Reaction Forces (Eurocorps)
  - DGPS reference station deployment
  - SBAS is civilian system
  - SBAS does not need extra HW & Comm links
- **Scientific point of view (RMA & Septentrio)**
  - Opportunity to evaluate added value of SBAS under high dynamics
  - SBAS integrity through HPL & VPL

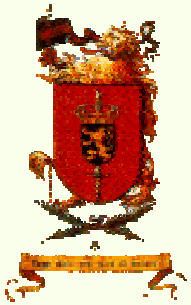
Test description



- **Navigation evaluation**
  - Tracking of SBAS under dynamics
    - **Liaison** flight
    - **Tactical** operations
  - PVT questions
    - **Accuracy** of position
    - **Comparison** of DGPS vs EGNOS augmented position
    - **Integrity** of the solution
- **Receiver operation**
  - Stress the receiver hardware by extreme manoeuvres
  - Find performance limits of SBAS system
  - Introduce high dynamics (variations) and foliage
- **Reference orbit determined by RTK**

Test description

- **Flight plan set-up**
  - Normal liaison flight in all directions
  - Special manoeuvres to create accelerations
    - crab-flight
    - continuous 360 degree turns with increased banking
    - parabolic paths
  - Typical tactical flight through a valley at high speed
  - Performed in southern part of Belgium



Receiver Survey

- **Criteria**
  - Dual-frequency, for RTK reference path
  - 10 Hz measurement rate to capture dynamics
  - SBAS capability
  - All-In-View
- **Candidates**
  - Thales - Aquarius 5002MK
  - TopCon (Javad) – AT4
  - Septentrio - PolaRx-1 (evaluation kit)

Test set-up

- **Installation on A109**
  - Integrate PolaRx-1 into helicopter
  - Active antenna mounted above rotor blades
  - Connected to onboard power

- **Reference trajectory**
  - 2 local reference stations (Leica SR530 & SR520)
  - Leica SR530 receiver as backup for RTK reference trajectory in A109

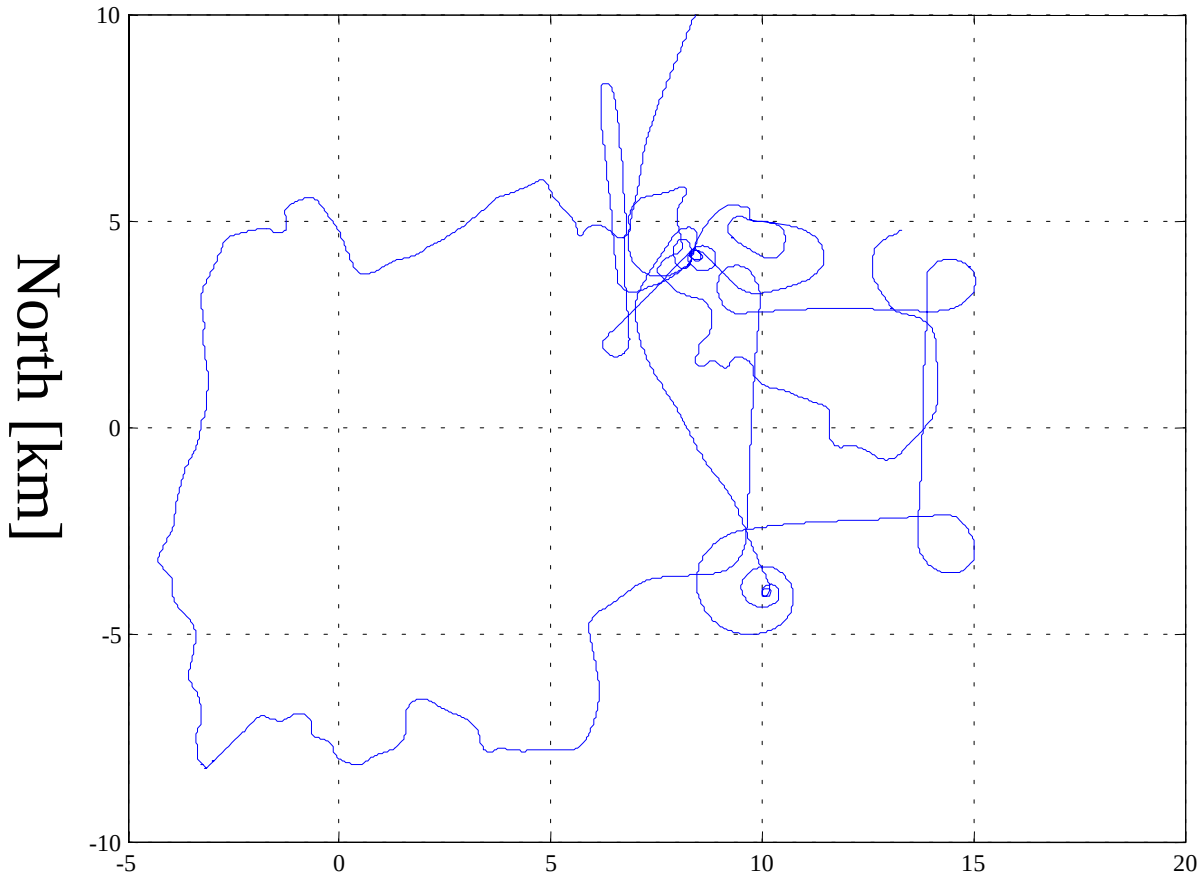
Test set-up (2)

Test set-up (3)

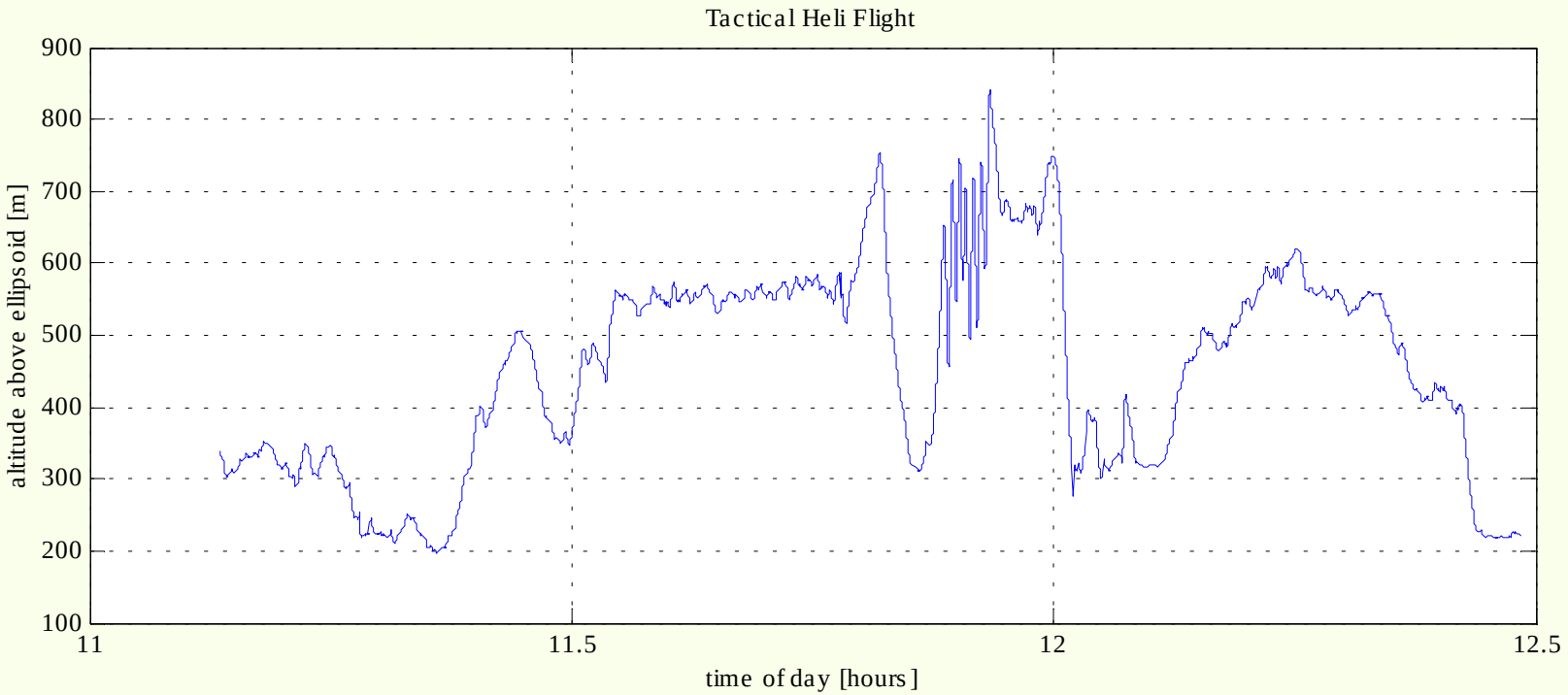
Flight statistics

- **General (17 August 2001 11:07 ➔ 12:29 GPSt)**
  - Flight duration depicted 81.3 minutes
  - 48 777 observation epochs
  - Tracked 9 GPS SVs above 12 degrees elevation mask
  - 4 GPS SVs under elevation mask
  - SV120 available during 98.3%
  - SV122 available during 40.1%

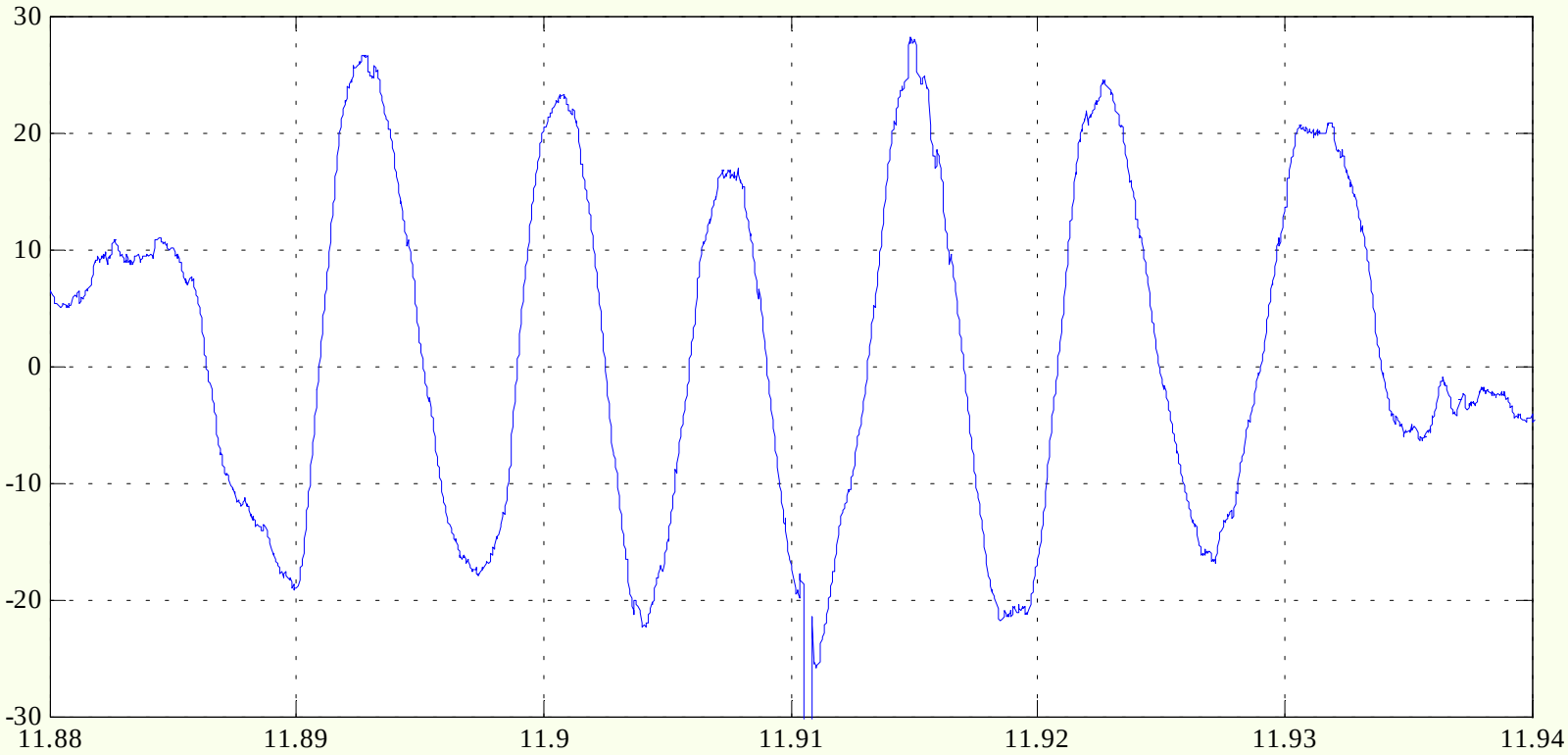
Flight Trajectory



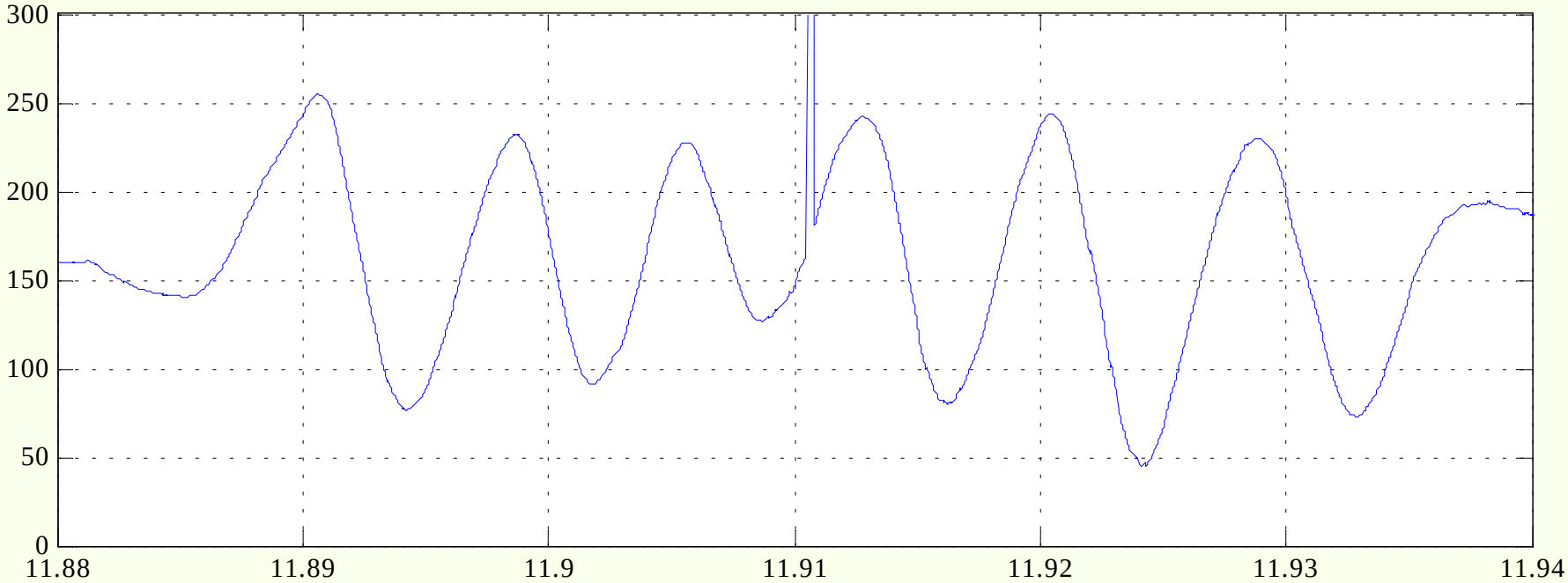
Flight trajectory



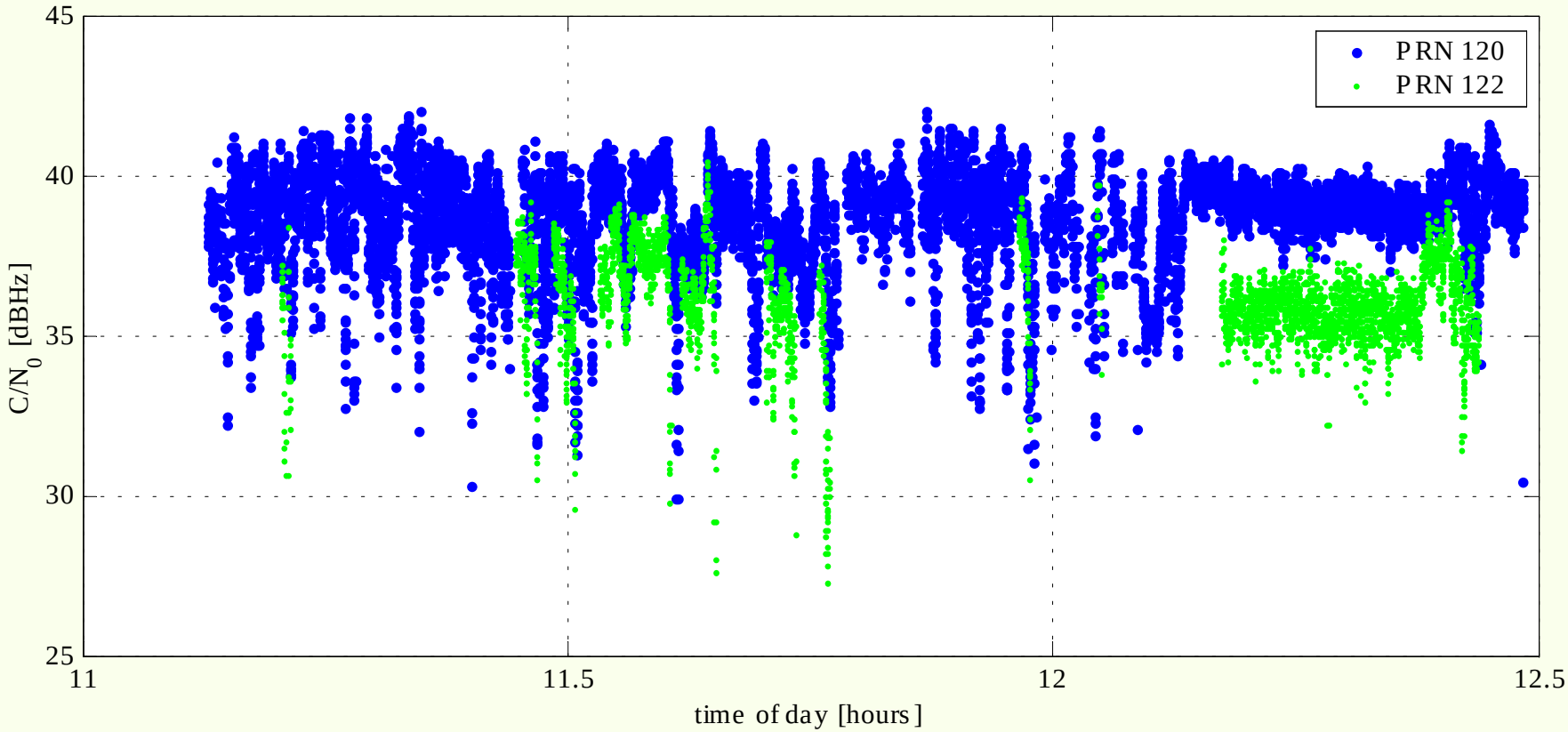
Vertical speed



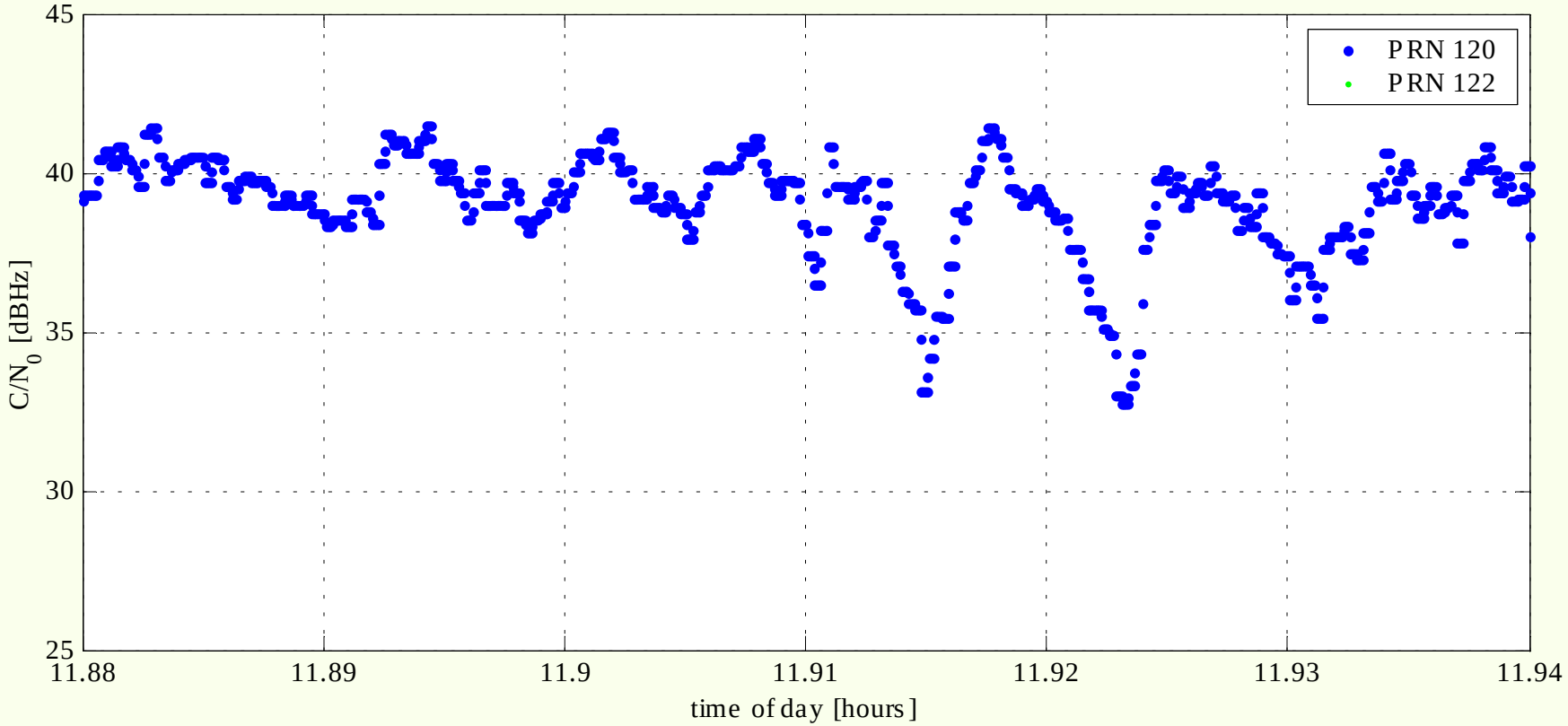
Horizontal speed



SBAS tracking



SBAS tracking under extreme maneuvres



Statistical Analysis of the flight

- **Objectives**
  - Unbiased comparison between DGPS & EGNOS position
  - Analyse the influence of type of flight on the precision
- **Statistics**
  - Descriptive analysis
    - characterise trends during the flight
    - univariate/bivariate decision criteria
  - Analysis of variance
    - significant influences of flight type on the precision ?
    - significant difference between precision given by DGPS and EGNOS ?

Descriptive statistical analysis

Comparison of DELTA X

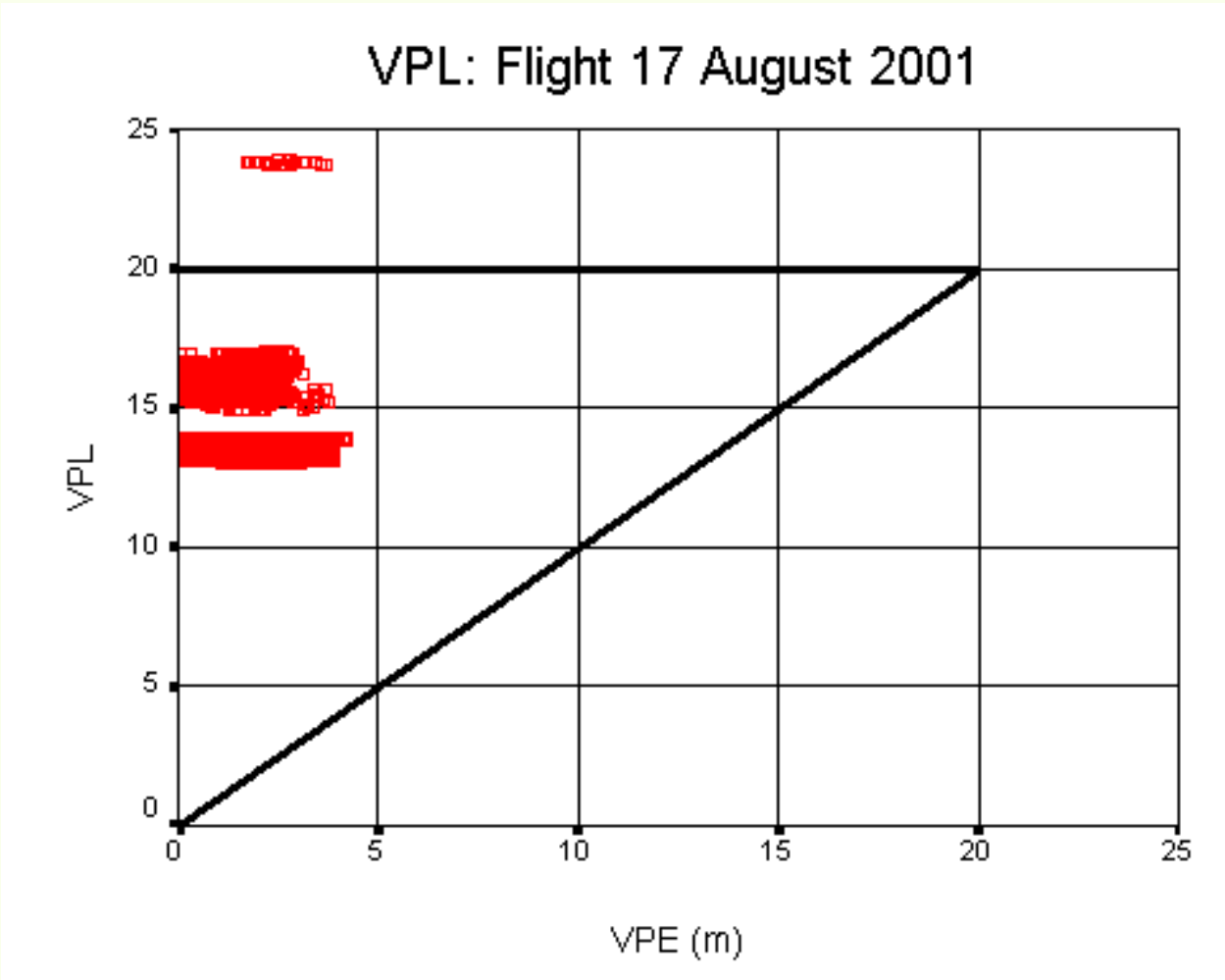
		GPS stand alone	DGPS	EGNOS
N	Valid	2000	2000	2000
	Missing	0	0	0
Mean		22.6382	2.0982	2.0658
Std. Deviation		7.7615	.6493	.6696
Variance		60.2403	.4216	.4484
Range		33.92	3.18	3.08
Minimum		.07	.01	.00
Maximum		33.99	3.19	3.08
Percentiles	95	32.7816	2.8852	2.9194
	97.5	33.3408	2.9461	2.9650
	99	33.7741	3.0166	3.0146

Descriptive statistical analysis

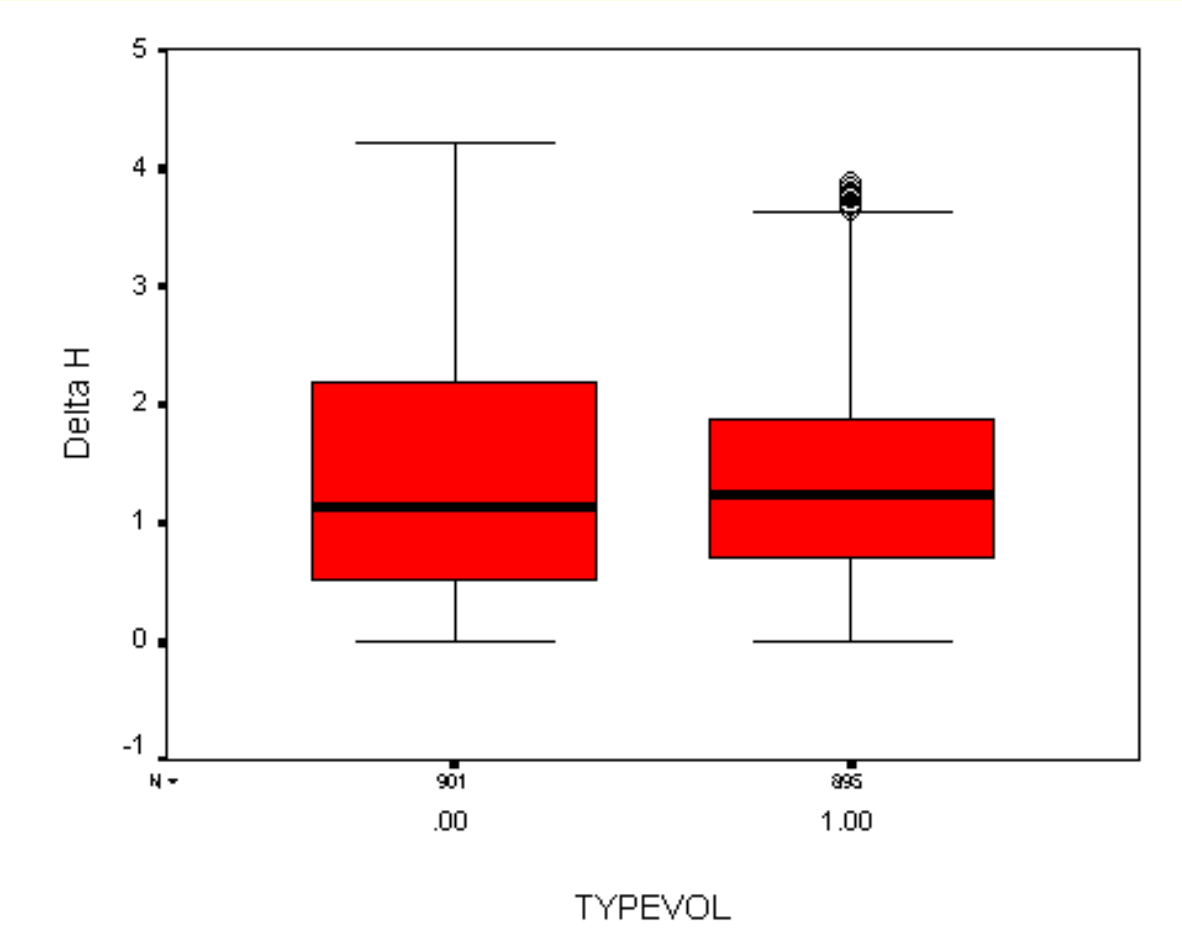
Comparison of the height

		GPS stand alone	DGPS	EGNOS
N	Valid	1918	1918	1828
	Missing	82	82	172
Mean		1.3641	1.3442	1.2123
Std. Deviation		.9686	.9567	.9712
Variance		.9381	.9153	.9433
Range		5.75	4.30	4.22
Minimum		.00	.00	.00
Maximum		5.76	4.30	4.22
Percentiles	95	3.2125	3.0724	3.2726
	97.5	3.6194	3.3531	3.5955
	99	4.3870	3.6365	3.8461

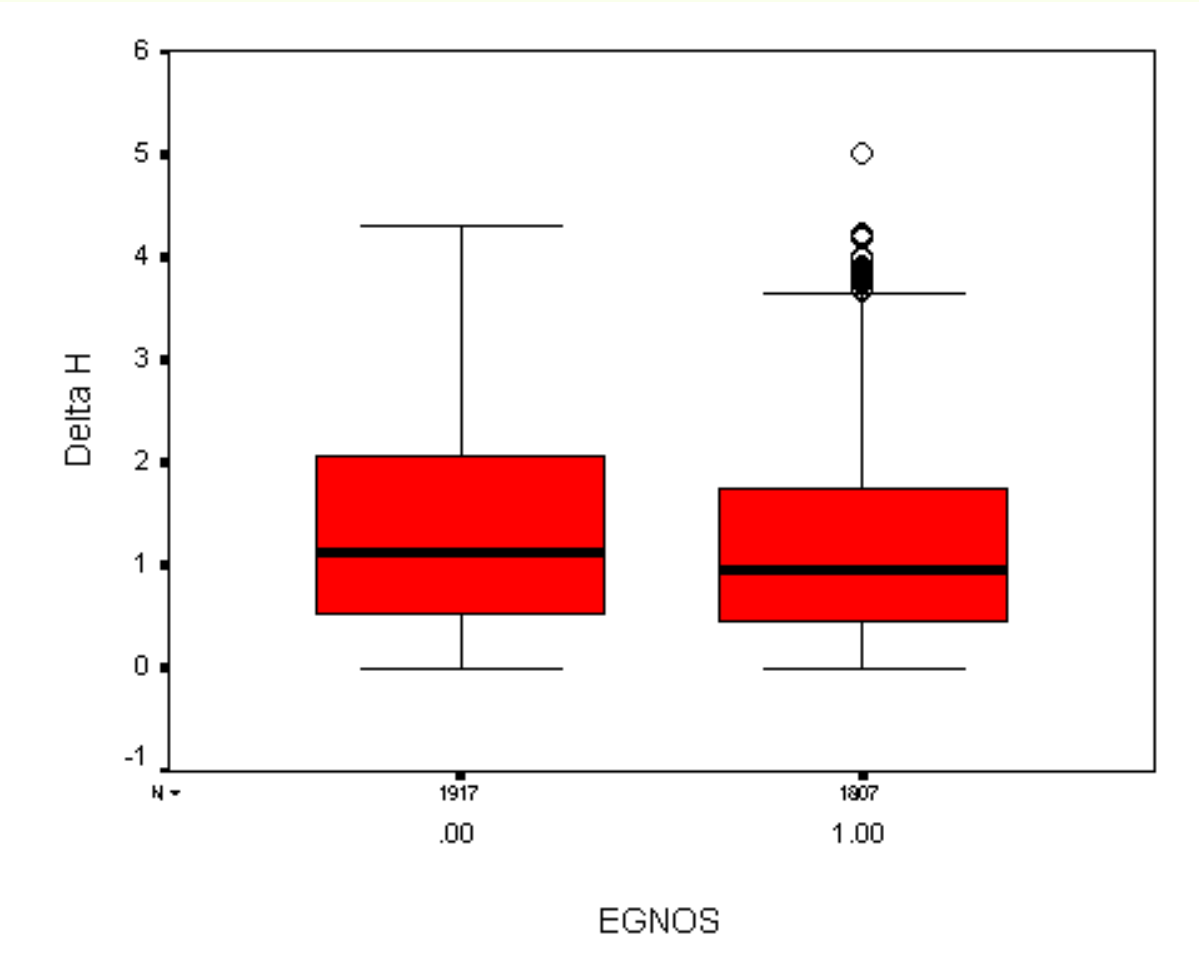
Descriptive statistical analysis



Descriptive statistical analysis



Descriptive statistical analysis



Variance analysis

ANOVA

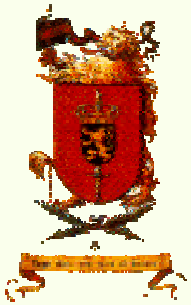
DELTAHEE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.142	1	1.142	1.174	.279
Within Groups	1744.197	1794	.972		
Total	1745.339	1795			

ANOVA

VAR00001

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12.289	1	12.289	13.198	.000
Within Groups	3465.630	3722	.931		
Total	3477.919	3723			



Conclusions

- **Navigation performance**
  - Did not expect to track the EGNOS during
    - Parts of the tactical flight
    - High dynamic parts which stress the hardware
  - G-forces had no apparent effect on the tracking loops
  - Static testing demonstrates
    - HPL = 6 m, VPL = 8 m
    - If similar values, than SBAS is very interesting option
  - Type of flight do not have influence on precision of EGNOS receiver
  - Precision EGNOS better than DGPS during this flight (confidence interval of 95%)

Conclusion

- **Tactical considerations**
  - Military *doctrine* has changed
  - Use of a civil navigation system as an augmentation can be considered (personal point of view)