CROPOS – positioning easier than ever

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Republic of Croatia

INF-0002
Agenda

- Intro – Croatia, State Geodetic Administration, Faculty of Geodesy
- CROPOS System
- National Geodetic GNSS Network
- New Geodetic Datum
- T7D – New Transformation Model
- HRG2009 – New Geoid Solution
- Implementation of Models in CROPOS
- Future Activities
- Conclusion
Croatia

- 56,594 sq. kilometers (21,851 sq. miles)
- Population 4.5 million
- Declaration of independance in 1991
State Geodetic Administration

- National mapping and cadastral agency
- Legal, financial and inspection tasks
- Cadastre
- State survey
- > 1150 employees
- Central office in Zagreb, 20 cadstral offices and 92 branch offices
Faculty of Geodesy

- University of Zagreb
- Institutes for Geomatics, Applied geodesy, Cartography and photogrammetry
- > 100 employees
- Since 2005 new curriculum in accordance with the Bologna Declaration process
- Graduate, postgraduate specialist and PhD studies

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CROPOS Project

- The goal of the project was to establish a national system of reference GNSS stations of the Republic of Croatia
- Project started in 2004
Importance of CROPOS Project

- Introduction and application of a new geodetic datum of the Republic of Croatia
- Homogenization of coordinate system
- Same accuracy of coordinate determination at the entire territory of the Republic of Croatia
- Implementation of the unique measurement methods - standardization in performing of geodetic works
- Faster and more efficient performing of geodetic works
CROPOS Project Activities (1)

- Feasibility study - GTZ support (2004)
- PHARE 2005 - Project Fiche
  Modernization and Capacity Building of Integrated Land Administration System in Croatia and Harmonization in the Pilot Area
  Component R3: CROPOS System
- Project approvement (September 2005)
- Financial agreement (December 2005)
CROPOS Project Activities (2)

- Network design – reference station locations
- Installation of antenna carriers
- IT/ITC infrastructure project
- Tender documentation and technical specifications
- Tender launch (May 2007)
- Tender open (July 2007)
- Contract sign with Trimble Europe BV (November 2007)
CROPOS Project Activities (3)

- Equipment delivery (July 2008)
- Installation and configuration of system (August & September 2008)
- CROPOS in full functionality (October 2008)
- Field measurements – system testing > 400 points (November 2008)
- CROPOS system launched on 9th of December 2008
CROPOS Project Budget

- PHARE-2005 Programme – R3 CROPOS System:
  - Contract value 1.396.000,00 €
    - 75% EU pre-accession funds
    - 25% Croatian State Budget funds
- Croatian State Budget funds
  - Contracts value 120.000,00 €
    - Manufacturing and installation of antenna constructions
    - Establishment of the required installations and telecommunications lines
CROPOS System - Definition

- CROPOS is a reference GNSS network of permanent stations of the Republic of Croatia enabling its users to determine a position with the GNSS technology in the real time with accuracy of 2 cm (position) and 4 cm (vertical) on the entire territory of the Republic of Croatia.
CROPOS System - Basics

- Collecting the data from the reference stations which are placed at 30 locations at the territory of the Republic of Croatia
- Reference station real-time GNSS data exchange with the neighbouring countries
- Networking and computing the real-time correction parameters
- Distribution of measuring data and real-time correction parameters to the users
- Monitoring of the system operation and users support
- 24/7 service availability
CROPOS System Components (1)
CROPOS System Components (2)

- **GNSS reference stations**
  - NetR5 GPS + GLONASS receiver, Zephyr 2 Geodetic GNSS antenna (Trimble)

- **Control centre**
  - System administration, processing and adjustment of data (HP)
  - GPSNet/RTKNet Software (Trimble)
  - Communication equipment - connecting of individual system components (CISCO)
  - Data distribution equipment - distribution of RTCM & VRS RTCM correction parameters, distribution of RINEX & Virtual RINEX data (HP + CISCO)
CROPOS Reference Stations
CROPOS System Functionality

- Very high system reliability due to high quality of all system components (GNSS, IT/ITC, software)

- ~16 hours unplanned system failure – power supply & Internet in 21 months (system availability 99.9%)

- Today - field surveying without CROPOS – mission impossible
### Synchronizer (RTKNet_2): Status

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CROPOS System Services

CROPOS

DSP
Real-time network solution
Code measurements
0.3 - 0.5 m

VPPS
Real-time network solution
Phase measurements
0.02 – 0.04 m

GPPS
Post-processing
RINEX, VRS RINEX
0.01 m
CROPOS Reference Frame (1)

- BERNESE GPS SOFTWARE Ver. 5.0
- 7 sessions (24 hours)
- ITRF2005, 2008.83 (GPS week 1503)
  - 30 CROPOS GNSS stations
  - 5 IGS sites – reference (Graz, Matera, Wettzell, Zimmerwald, Penc)
  - 7 IGS sites – processing control
  - $\sigma = 1.5 \text{ mm}$
  - $\sigma_{\varphi} = 1.1 \text{ mm}$, $\sigma_{\lambda} = 1.2 \text{ mm}$, $\sigma_h = 3.4 \text{ mm}$
- ETRF00 (R05) (~ETRF89)
CROPOS Reference Frame (2)
<table>
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<tr>
<th>IGS Site</th>
<th>Country</th>
<th>DX (m)</th>
<th>DY (m)</th>
<th>DZ (m)</th>
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<td>0.008</td>
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<td>POTS</td>
<td>Germany</td>
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<td>KOSG</td>
<td>Nederland</td>
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<td>GOPE</td>
<td>Czech Republic</td>
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<td>CROPOS SERVICE</td>
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<td>PRICE</td>
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<td>DPS Differential positioning in real-time</td>
<td>RTCM 2.3</td>
<td>1 year</td>
<td>HRK 1,000.00 (~135 €)</td>
<td></td>
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<tr>
<td>VPPS High-precision positioning in real-time</td>
<td>RTCM 2.3</td>
<td>1 minute</td>
<td>HRK 0,35 (~0,05 €)</td>
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</tr>
<tr>
<td></td>
<td>RTCM 3.1</td>
<td>1 year</td>
<td>HRK 5,000.00 (~675 €)</td>
<td></td>
</tr>
<tr>
<td>GPPS Geodetic precise positioning Post-processing</td>
<td>RINEX</td>
<td>1 minute</td>
<td>HRK 0,50 (~0,07 €)</td>
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<tr>
<td></td>
<td>RINEX VRS</td>
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</table>

Registration fee - HRK 300.00 (~40 €)
CROPOS - User Support

- CROPOS flier
- CROPOS workshops (Rijeka, Split, Zagreb, Vinkovci – November, 2008) > 800 participants
- CROPOS brochure
- CROPOS web page – www.cropos.hr
- CROPOS user manual
- CROPOS newsletter
- CROPOS video
- 1. CROPOS users conference (Zagreb, 2009) > 350 participants (2. conference planned for 2011)
1. CROPOS users conference
CROPOS Statistics

- Increasing number of registered companies and users
- Average use of VPPS service (RTK) > 325 000 minutes/month
- Average of 40 users connected at the same time during working hours (max. 79)
Number of registered companies - in total 302
Number of service users - in total 773

- DPS
- VPPS
- GPPS

Service
System usage - VPPS service - in total 7 278 708 min.
System usage - GPPS service - in total 1 091 180 min.
CROPOS – Current Status (1)

- 43 GNSS stations included in CROPOS network solution
CROPOS – Current Status (2)

- Hardware upgrade: data storage (+ 2 TB), tape backup (1 GB)
- Software update: Trimble GPSNet Ver. 2.730, GNSS receiver firmware Ver. 4.03
- Implementation of system for remote administration and system control of servers
- New application for user administration and charging, additional system usage statistics
- Processing of RINEX data in order to monitor and analyse stability of CROPOS reference frame – GPS week solutions
National Geodetic GNSS Network (1)

- 1994 >1998 – In total 6 GPS campaigns
- 78 points – 0. & 1. order GNSS network
- Realization of HTRS96 (ITRF1996, 1995.55)
National Geodetic GNSS Network (2)

- 1997 – 2001: 1023 points – 2. order GNSS network (10 x 10 km)
National Geodetic GNSS Network (3)

- Central geodetic point database
- Renovation of fundamental geodetic network control points
- Revision of geodetic points
New Geodetic Datum

- Decree on establishing new official geodetic datums and map projections of the Republic of Croatia (August 2004)

- Horizontal datum – HTRS96
- Vertical datum – HVRS71
- Gravimetric datum - HGRS03
- Plane map projections
Horizontal Datum

- European Terrestrial Reference System 1989.0 (abbreviated as ETRS89), is defined to be the official inalterable and time independent positional reference coordinate system for the Republic of Croatia.
- GRS80 ellipsoid with the size of large half-axis $a=6378137.00$ m and the flattening $\mu=1/298.257222101$ is determined to be the official mathematical model for the Earth’s body in the Republic of Croatia.
Transformation Problem (1)

- **ETRF00 (R05), 1989.0 (ETRS89)**
  - GRS80
  - $\varphi, \lambda, h (X, Y, Z)$
  - Ellipsoidal height: $h$

- **HTRS96/TM**
  - GRS80
  - $N, E, H$ (Transverse-Mercator projection)
  - Orthometric height: $H = h - N$ (HVRS71)

- **HDKS**
  - Bessel
  - $y, x, H$ (Gauss-Krüger projection)
  - Orthometric height: $H = h - N$ (Trieste)
Transformation Problem (2)

- Transformation between geodetic datums:
  - HTRS96 (Ellipsoid GRS80) < > HDKS (Ellipsoid Bessel)
- Local transformation (smaller areas)
  - Satisfying accuracy – but coordinate differences in border areas (up to 20 cm) – inhomogeneity of trignometric network
- Global transformation (state level)

<table>
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<tr>
<th>Transformation method</th>
<th>Accuracy</th>
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<td>Molodensky</td>
<td>5 m</td>
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<tr>
<td>3D – 7 parameters</td>
<td>1 m</td>
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<tr>
<td>GRID</td>
<td>0.1 – 0.3 m</td>
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</table>
T7D – new transformation model

- Unique transformation model HTRS96 <> HKDS - uniform, reliable and simple transformation system, primarily available to all users
- GRID transformation for the whole Croatian territory, consisting of 7-parameter transformation and a proper raster predicted values of distortion, both in plane coordinates and height
Identical points
(Datum transformation)

N=2000

N=5200

CROPOS
### T7

<table>
<thead>
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<th>N = 5200</th>
<th>Transformation parameters</th>
<th>Accuracy estimation (m₀=0.804 m)</th>
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<td>Tx</td>
<td>-546.616 m</td>
<td>±0.593 m</td>
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<tr>
<td>Ty</td>
<td>-162.375 m</td>
<td>±0.657 m</td>
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<tr>
<td>Tz</td>
<td>-469.482 m</td>
<td>±0.586 m</td>
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<tr>
<td>Rx</td>
<td>5.90498 ''</td>
<td>±0.0189 ''</td>
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<tr>
<td>Ry</td>
<td>2.07397 ''</td>
<td>±0.0218 ''</td>
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<tr>
<td>Rz</td>
<td>-11.50994 ''</td>
<td>±0.0187 ''</td>
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<tr>
<td>μ</td>
<td>4.43885 ppm</td>
<td>±0.075 ppm</td>
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</table>

| σ φ      | ±0.533 m               |
| σ λ      | ±0.587 m               |
| σ h      | ±0.129 m               |
| σ 2D     | ±0.793 m               |
| σ 3D     | ±0.804 m               |
T7D Transformation Program

- Consisting of 7-parameter transformation + proper raster predicted values of distortion (both in plane coordinates and height)
- Distortion prediction– least square collocation method (5200 points) > Grid in the regular 30” x 45” raster
**T7D**

7P + δφ, δλ

(bi-linear interpolation)

<p>| | |</p>
<table>
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<td>σ φ</td>
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<td>σ 2D</td>
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<tr>
<td>σ 3D</td>
<td>±0.058 m</td>
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</table>

Interpolirana vrijednost

Korekcija za φ, λ

GRID

20 cm
HRG2009 – New Geoid Solution

- First geoid solution – HRG2000
- Data:
  - Earth’s gravity field - free air anomalies (over 30000)
  - Satellite altimetry in the Adriatic Sea (400)
  - Global geopotential model EGM2008
  - High frequencies field structures modeled with the help of 3”x 3” Shuttle Radar DEM’s
  - Discrete geoid undulations obtained by GNSS/leveling on the mainland (495)
- Least squares collocation calculation technique
- Geoid surface point raster 30“ x 45“
- Internal accuracy $\sigma = \pm 0.03$ m
- Absolute accuracy based of comparison of GNSS/Leveling results (59 points – not included in model) $\sigma = \pm 0.04$ m
GNSS/Levelling points (495)

\[ N = h - H \]
Implementation of Models in CROPOS

- Trimble Transformation Generator
- New services > update CROPOS source table
  - CROPOS_VRS_HTRS96
    - HTRS96/TM – on-line geoid model
  - CROPOS_VRS_HDKS
    - HDKS – datum transformation & on-line geoid model
- RTCM 3.1
RTCM 3.1 Messages

- **Message 1021**
  - 7 parameter transformation
    - \((T_x, T_y, T_z, dM, R_x, R_y, R_z)\)

- **Message 1023**
  - Transformation corrections \((\delta \varphi, \delta \lambda \text{ or } N)\)
Transformation Data Flow

- NMEA
- RTCM Generator
- TTG Generator
- Transformation parameters
- NTRIP Caster
- NTRIP Server
- NTRIP Source
- NTRIP client 1
- NTRIP client 2
- NTRIP client n
Transformation Process

Step 1: Message 1021 (Transformation parameters)

Step 2: Message 1023 (Corrections - Grid)
Testing of on-line geoid model

- 1000 points (September/November 2010)
- Comparison of orthometric heights: on-line geoid model vs post-processing geoid model values
Testing on-line geoid model – first results (1)
## Testing on-line geoid model – first results (2)

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<th>$H$ (m) T7D</th>
<th>$\Delta H$ (mm)</th>
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<th>$H$ (m) T7D</th>
<th>$\Delta H$ (mm)</th>
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Future Activities

- Preparing of grid files for datum transformation and testing of on-line datum transformation (Spring 2011)
- Use of CROPOS data and processing results in geodynamic research
- Organization of 2. CROPOS users conference (2011)
Conclusion

- CROPOS project– Success story
  - system design, planning
  - installation
  - cooperation with suppliers
  - Trimble support
- Implementation of high quality hardware and software products
- User trust – reliable and accepted system
Thank you!