TrigNet:
The South African Network of Continuously Operating GPS Base Stations

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Matjiesfontein
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Overview

- General Considerations
- TrigNet Architecture
- Post Processing and Real Time Services
- Methods of Delivery
- Co-ordinate System
- Current Status
- Non-positioning Applications
- Future
- Conclusion

Introduction

- **Chief Directorate: Surveys & Mapping mandated to “establish and maintain a national control survey network”**
- **Up until a few years ago we had a passive network of ~29000 trig beacons**
- **GNSS has been around for some time**
- **CDSM recognized change in philosophy and technology and has installed a network of active GNSS base stations**

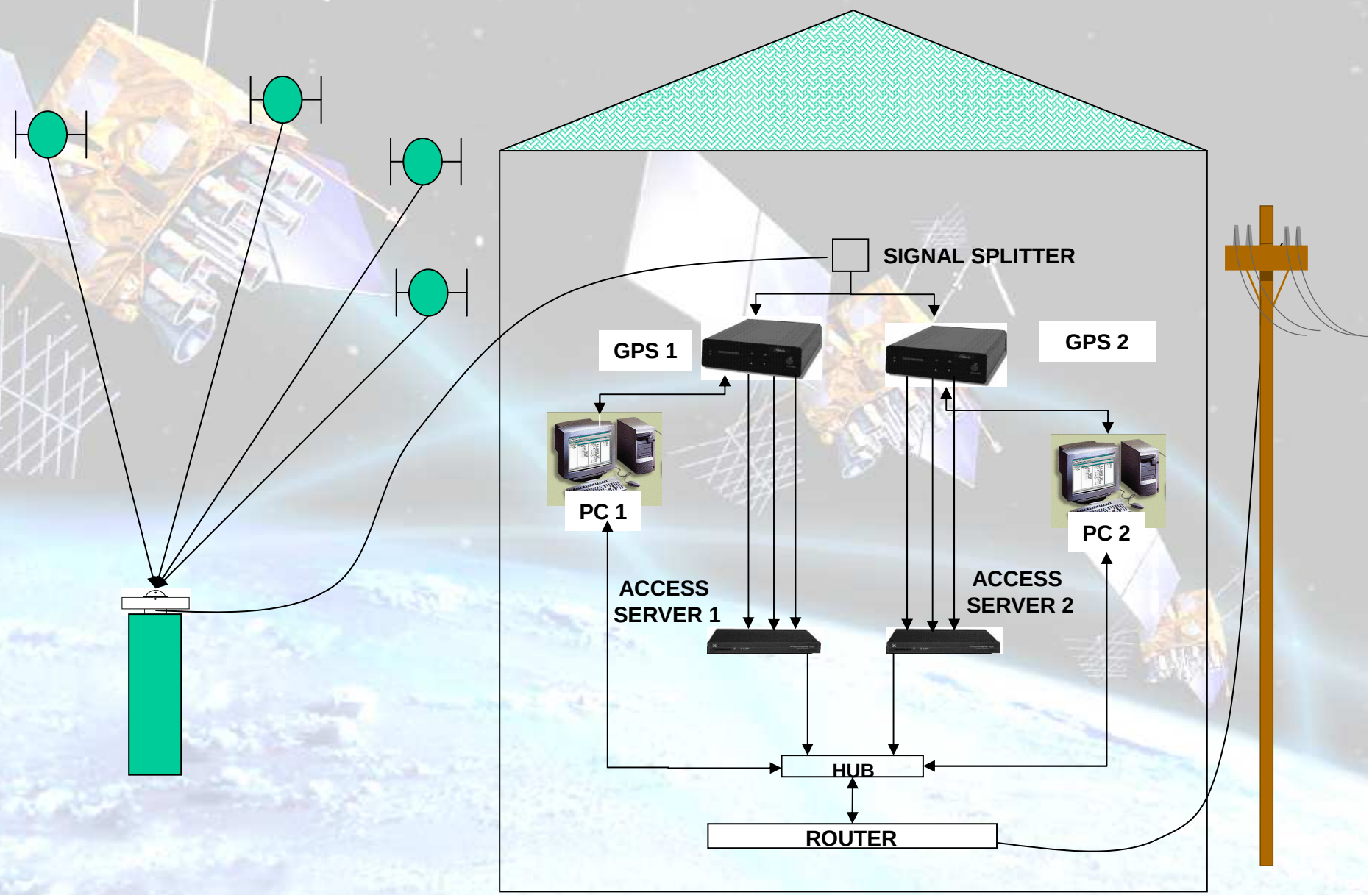
General Considerations

- System must be receiver independent - RINEX, RTCM
- System must be reliable through integrity monitoring and redundancy
- Post processing data must be as fresh as possible
- Cost of services must not be excessive to user
- System must be expandable and flexible
- System must meet the accuracy demands placed on it
- All stations must be equipped with same basic equipment such as receivers and antennas

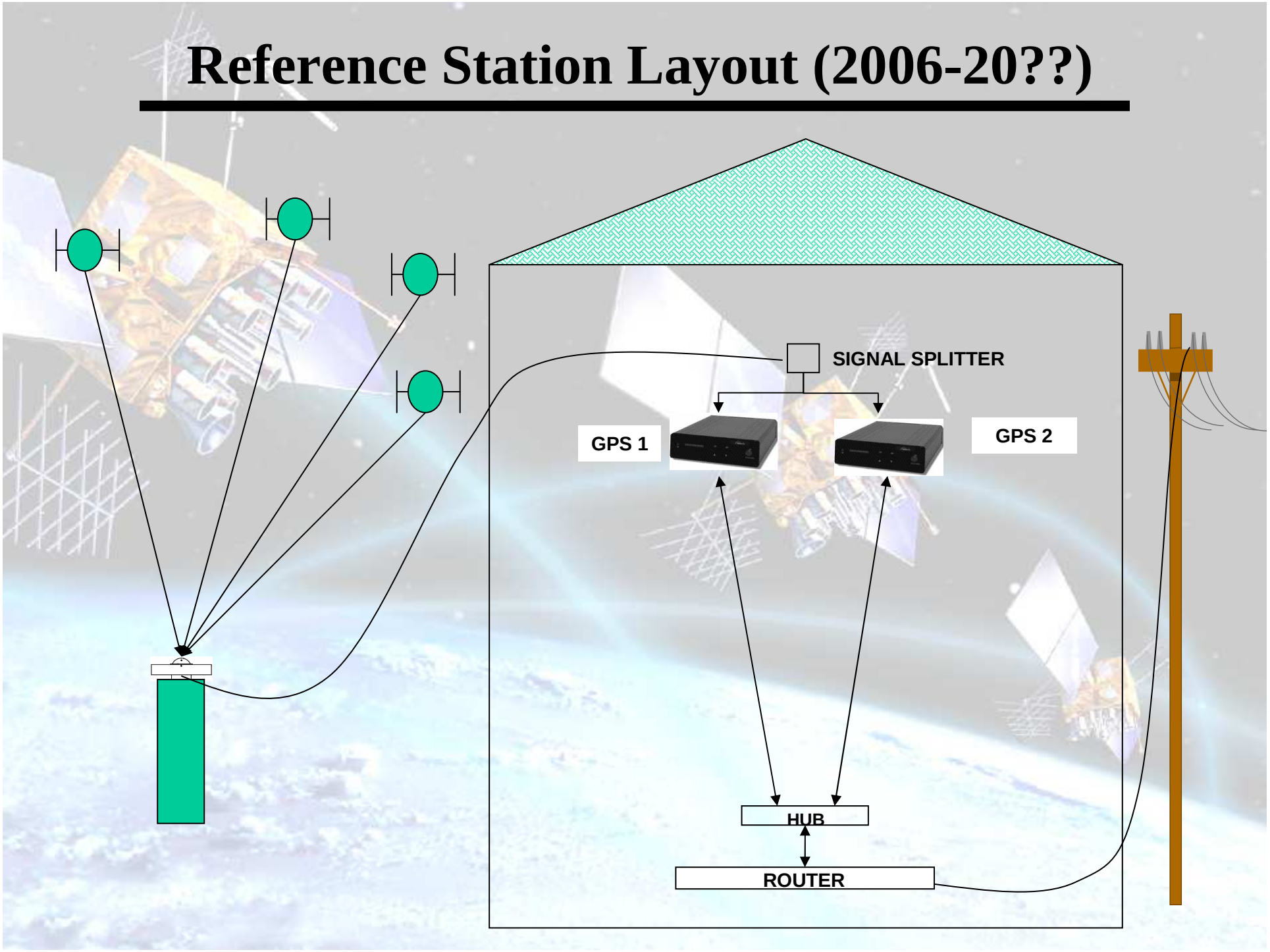
Basic Design

- **Use SWEPOS concept**
- **One control station at Mowbray**
- **Redundancy built into network**
- **Initially only post-processing service available**
- **Have 45 stations installed and in process of expanding**
- **Stations between 40 km and 300 km apart**

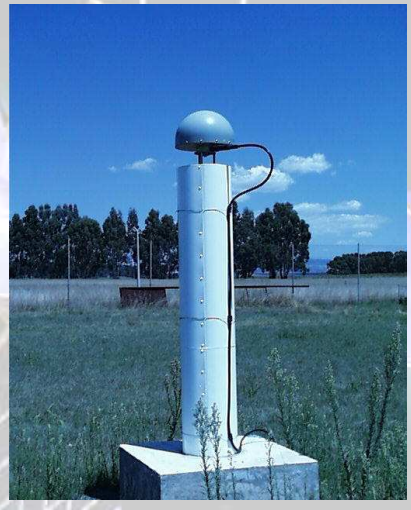
Reference Station Layout (1999-2006)

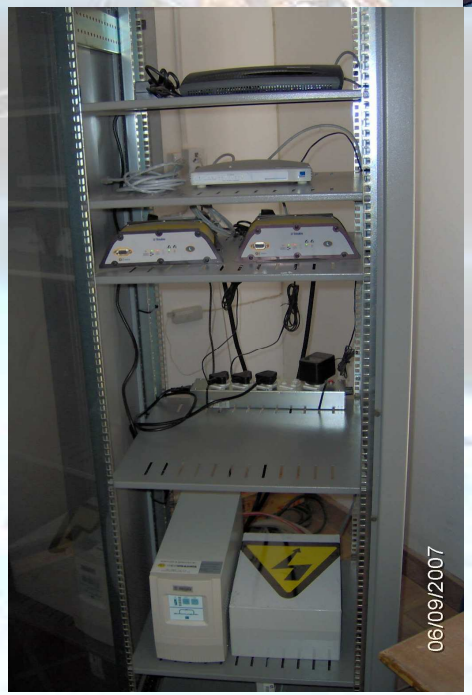


Reference Station Layout (2006-20??)

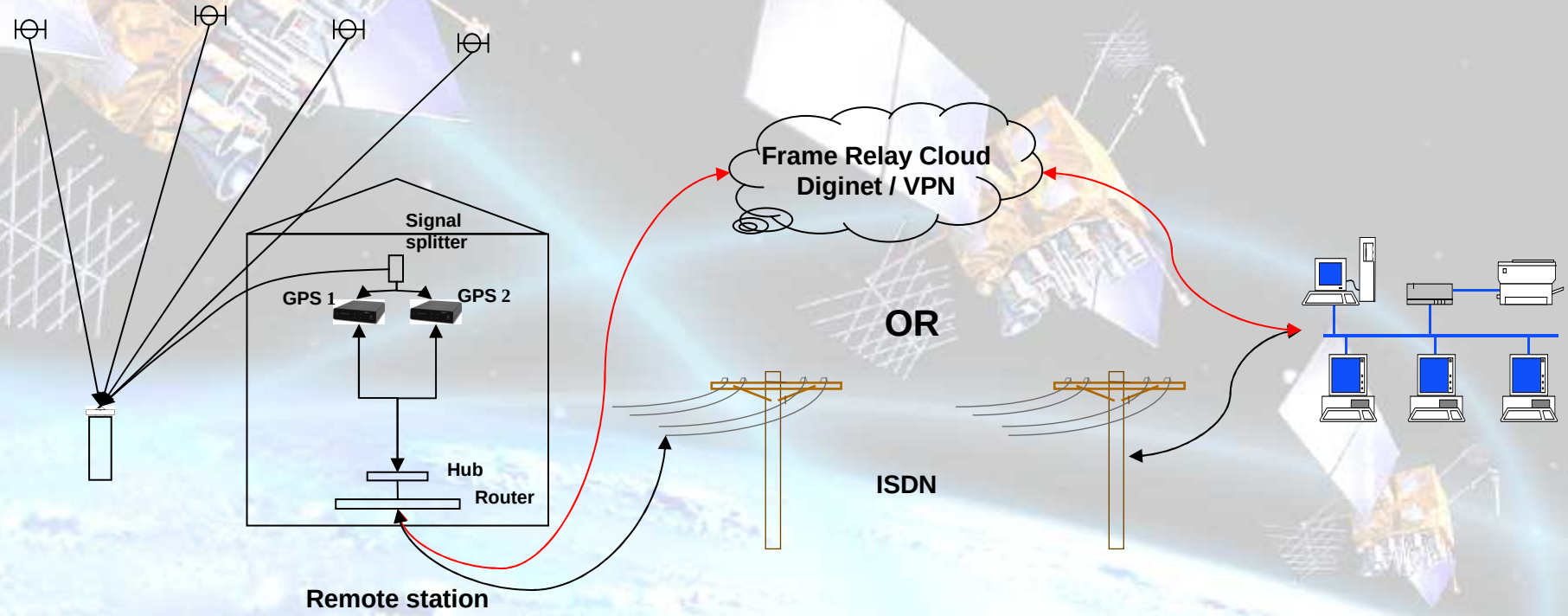


Examples of Stations





Communications



Post Processing Services

Data available in Receiver Independent Exchange format (RINEX)

- **Hourly data from 29 continuous feed stations available approximately 30 minutes after each hour of observation.**
- **24 hour data from continuous feed and daily download stations available on following day**
- **Data is available via internet (ftp) , e-mail, CD etc.**
- **Achievable accuracy could be 0,05 m or better depending on users receiver and antenna type, location, processing software, etc**

Real Time Service

- **Data available in Radio Technical Commission: Maritime format (RTCM)**

- **DGPS**
  - **pseudo range corrections provided in RTCM V 2.3**
  - **sub metre accuracy possible from single base station**
    - ✓ **RMS 35 cm Hor and 1 m Vert irrespective of distance**
  - **used for navigation and GIS applications**

- **RTK**
  - **carrier phase corrections provided in RTCM V 3.0**
  - **sub 10cm accuracy possible from single base station**
    - ✓ **RMS 8 cm Hor at ~100 km**
  - **used for precise navigation and by surveyors and engineers**

Methods of Delivery

NTRIP (Network Transport of RTCM by Internet Protocol)

- Users download RTCM (RTK and DGPS) corrections from an Internet site in real time.
- Corrections received are based either on one station or on a network solution.
- Field connection to internet can be via any technology eg GSM, GPRS, Satphone etc
- GSM & GPRS have disadvantages of coverage.
- Low cost GPRS costs ~R2/Mb. NTRIP uses ~400 Kb/hour
- Could be used for in-shore hydrographic work or navigation
- Being used extensively in Europe and California

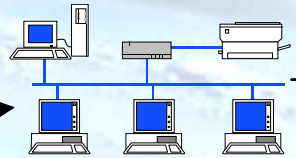
Delivery of Services

Telecom Sat
OMNISTAR

Real Time
Users

NTRIP Web Server
-DGPS
-RTK

GSM / GPRS



Network
Control Centre

RINEX Web Server

GSM / GPRS
Land Line
etc

Active GPS Base station

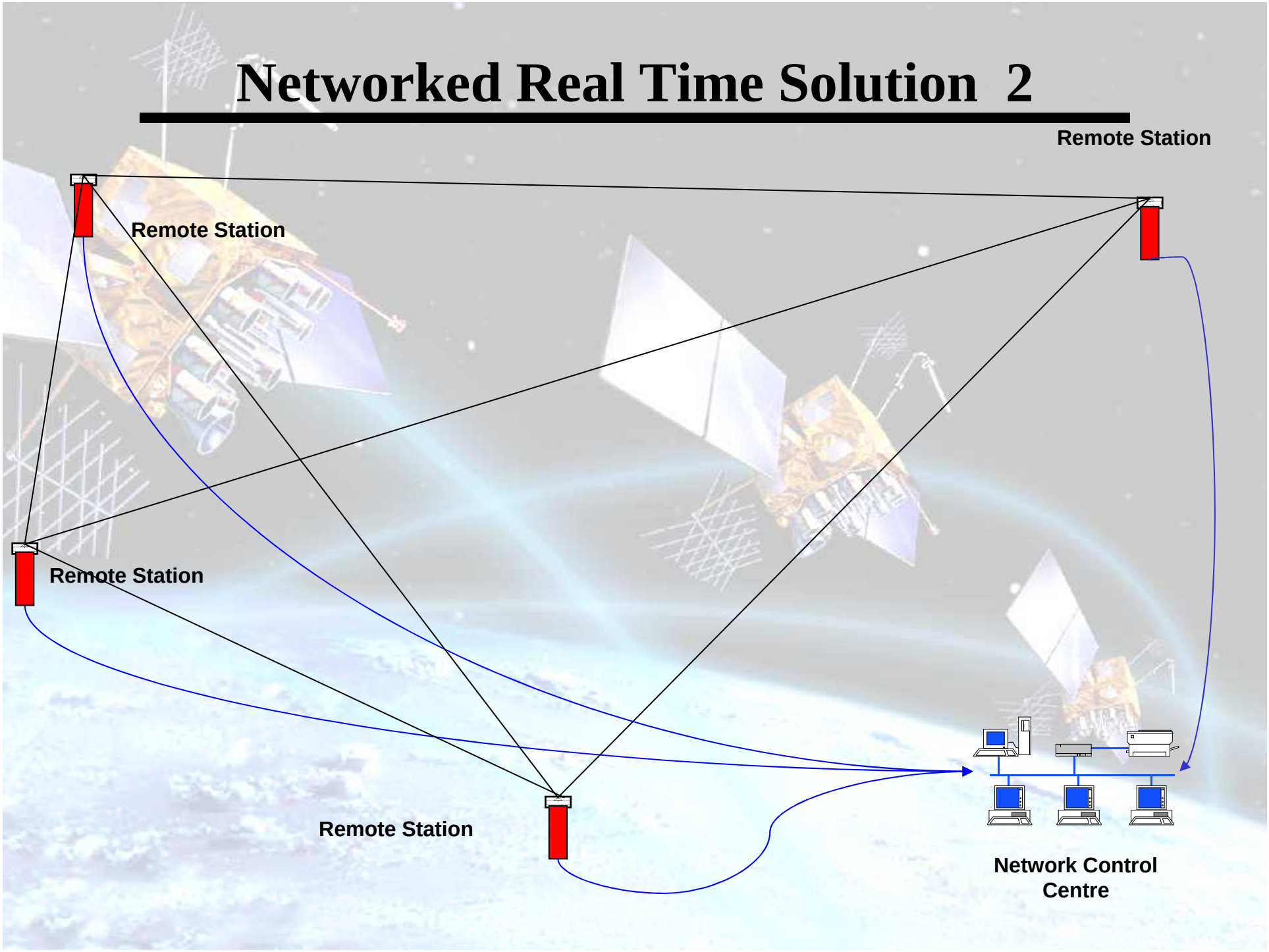
Post Processing Users

Base Station / User Seperation :	Post processing	– Possible to get <5cm @ 500km or greater
	DGPS	– 35cm irrespective of distance
	RTK	– 8cm @ ~100 km

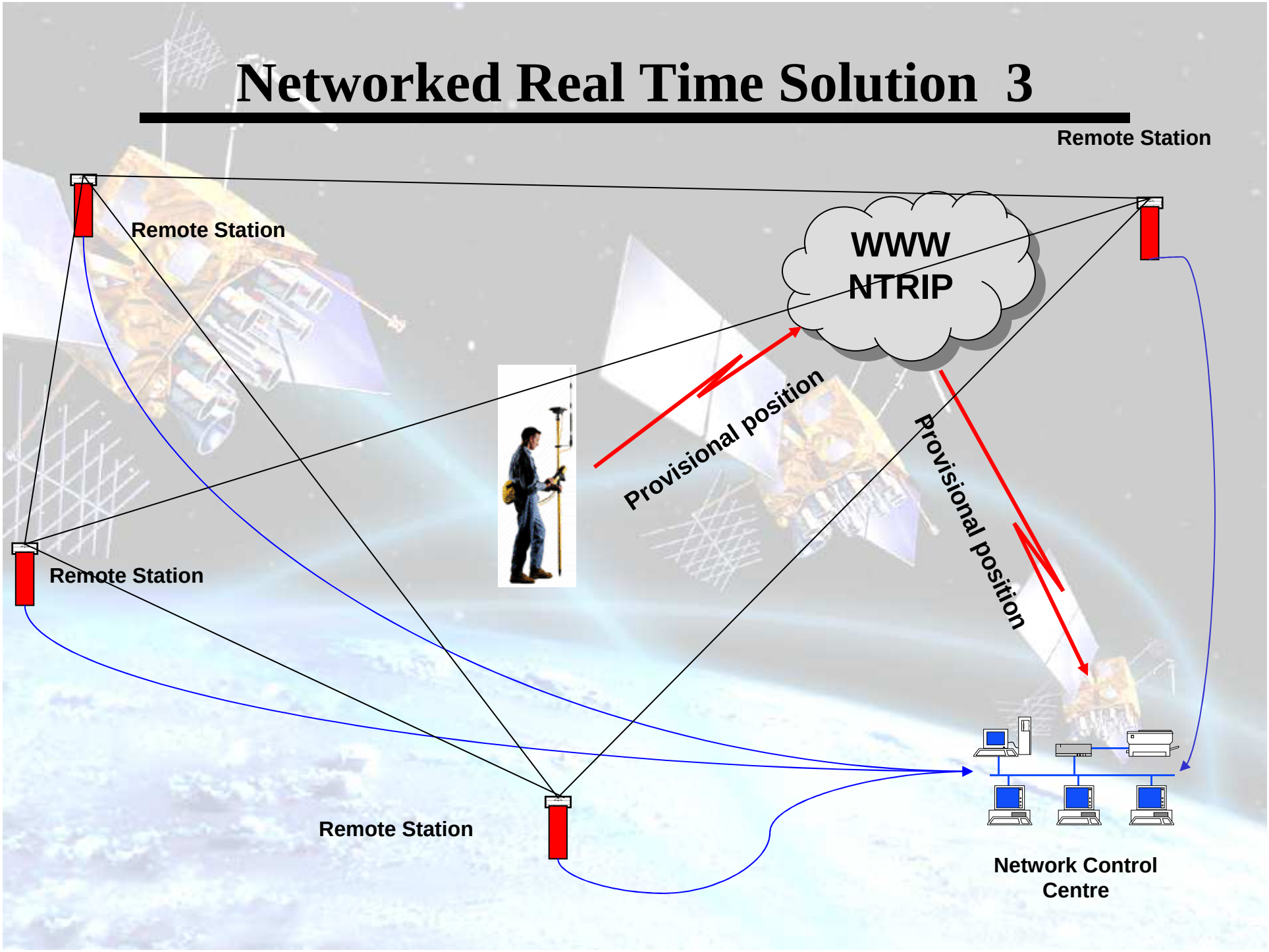
Networked Real Time Solution 1

- **Networked solution**
- **User connects to control centre via internet using Network Transport of RTCM via Internet Protocol (NTRIP)**
- **User's receiver sends provisional position to control centre**
- **A virtual reference station is computed close to user's provisional position based on data from at least 4 actual reference stations**
- **RTCM corrections then sent to user relative to the virtual station**
- **Are able to provide either**
  - ✓ **DGPS for the whole country or;**
  - ✓ **RTK solution in 2 clusters - Gauteng**
    - **Western Cape**
    - **KZN planned for March 2008**

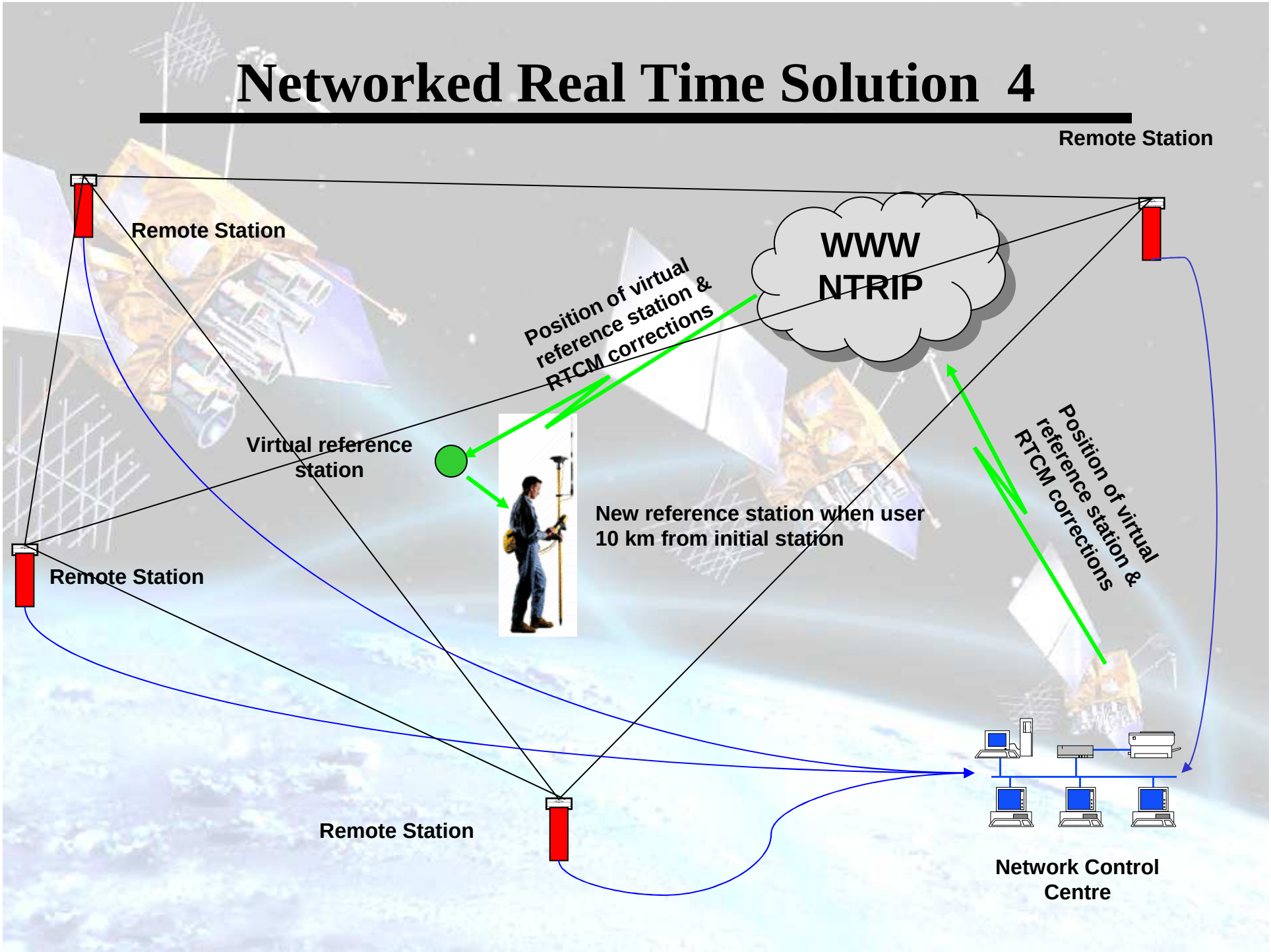
Networked Real Time Solution 2



Networked Real Time Solution 3



Networked Real Time Solution 4



Co-ordinate System 1

Hartebesthoek 94

- **Based on ITRF91 at epoch 1994.0 (International Terestrial Reference Frame)**
- **WGS84 (reference system for GPS) very close to ITRFxx within few tens of centimetres of centre of Earth**

ITRF 2005

- **This is latest realisation of ITRF. WGS84 is even closer to ITRF2005**

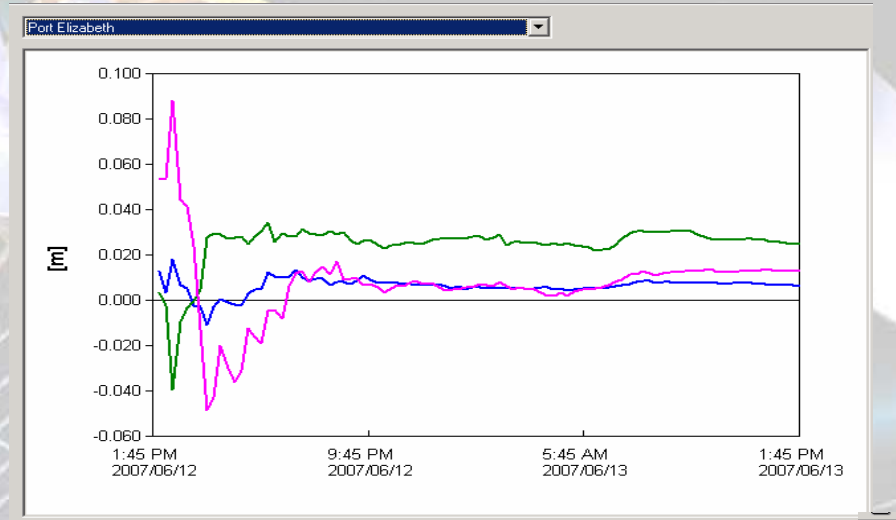
Testing ITRF 2005 (epoch 2007.237) against Hart94

- **Differences between ITRF 2005 and Hart94 co-ordinates of TrigNet stations:**

dy = -0.139 m	**std dev = 0.074 m**	**Lo Co-ordinates**
dx = -0.358 m	**std dev = 0.059 m**	
dh = 0.105 m	**std dev = 0.167 m**	

- **Consistency within TrigNet is better using ITRF2005 co-ordinates for TrigNet.**
- **Users have to transform from GPS/TrigNet based co-odrinates to official Hart94 co-ordinates.**

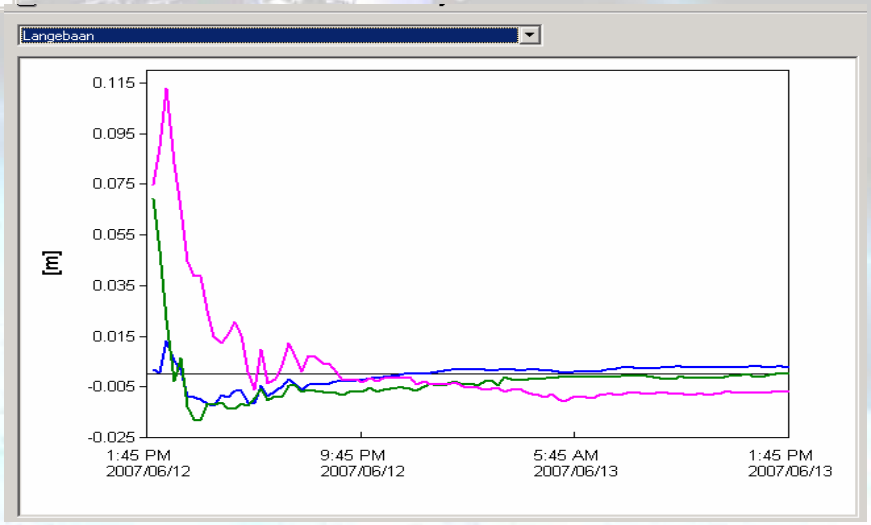
Co-ordinate System 2



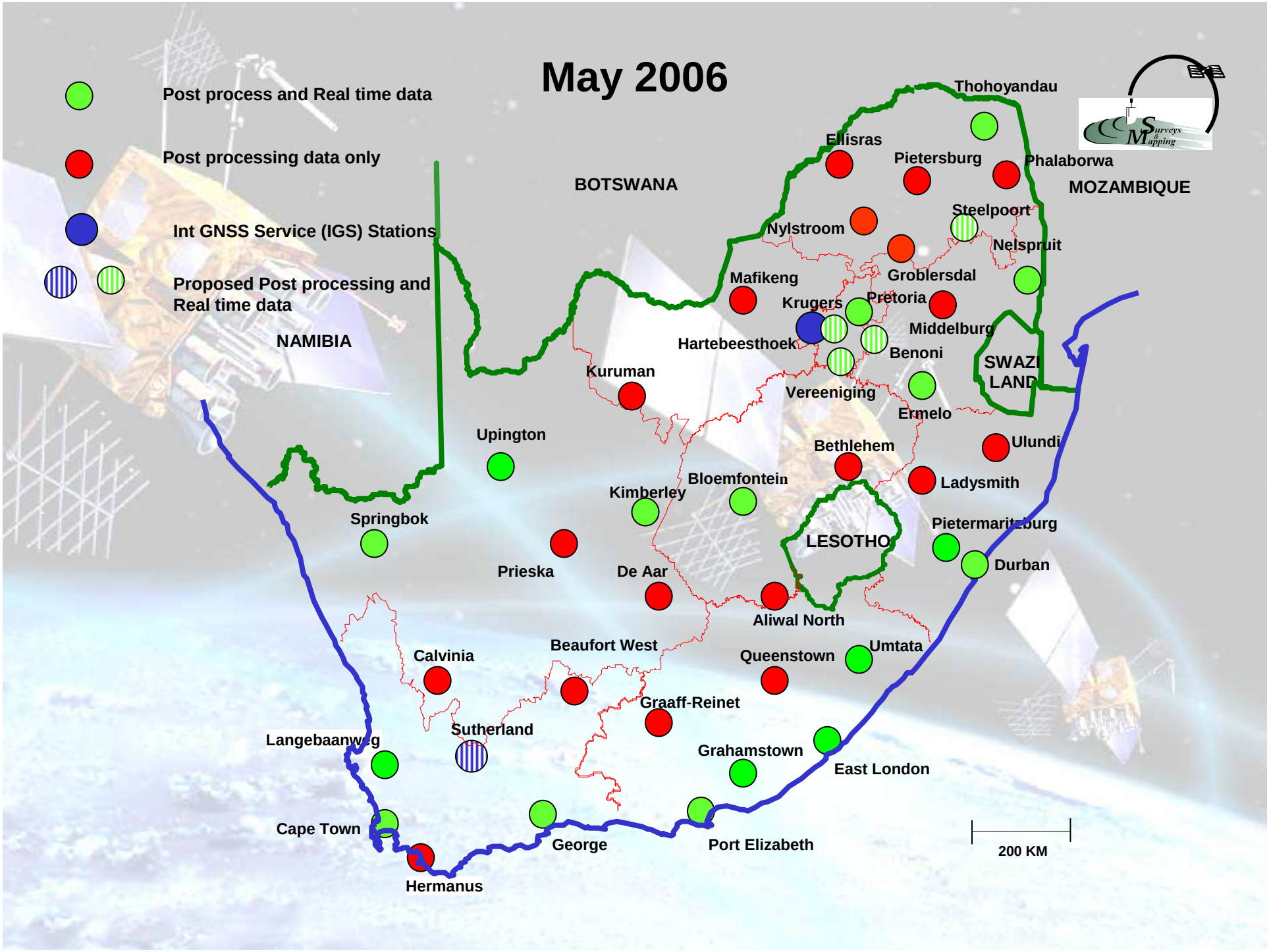
Sample of TrigNet co-ordinates before and after introduction of new ITRF 2005 co-ordinates.

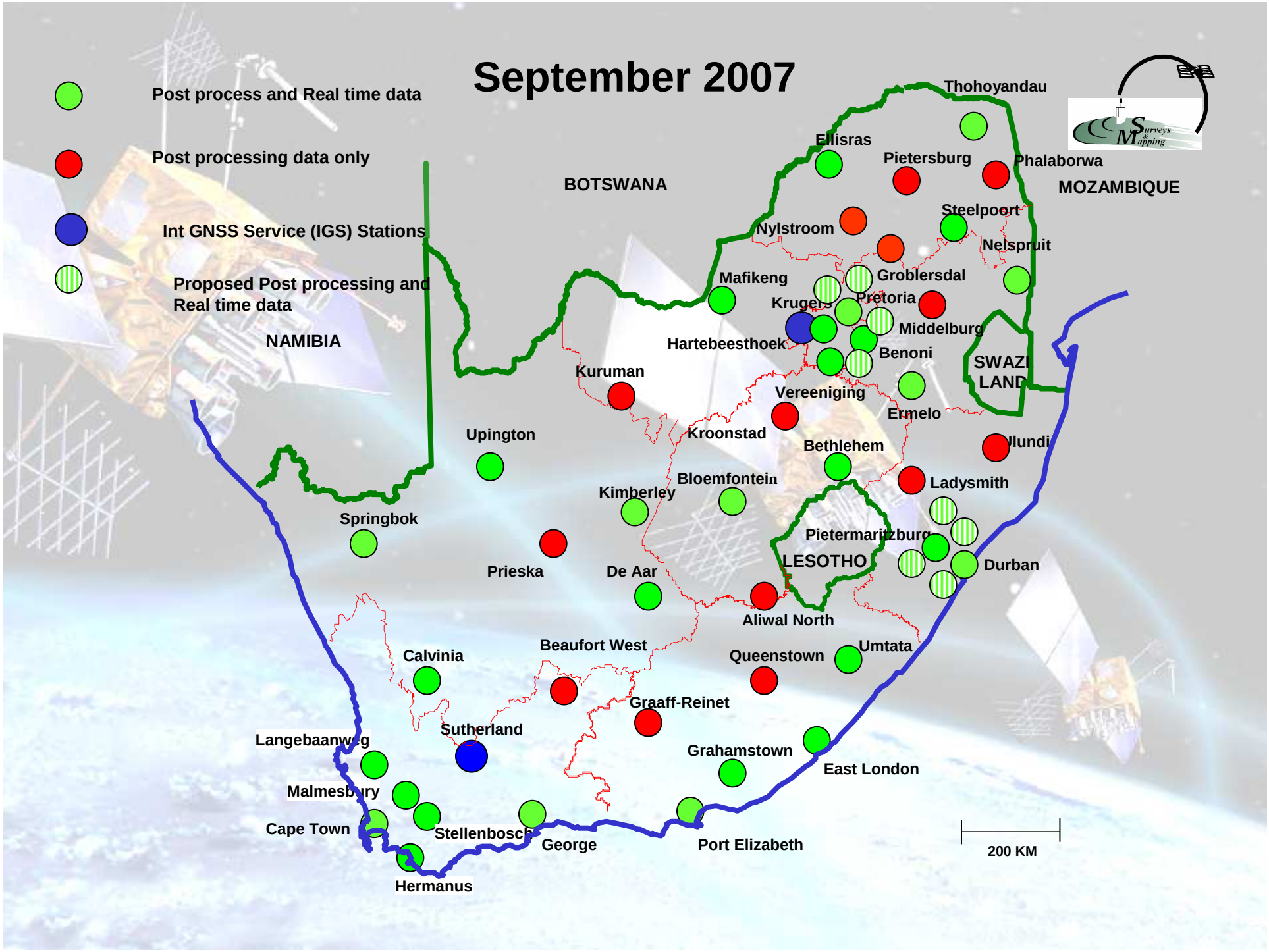
Port Elizabeth

Northings
Eastings
Height



Langebaan


May 2006
Post process and Real time data
Post processing data only
Int GNSS Service (IGS) Stations
Proposed Post processing and Real time data
Thohoyandau
Ellisras
Pietersburg
Phalaborwa
BOTSWANA
MOZAMBIQUE
Steelpoort
Nylstroom
Nelspruit
Groblersdal
Mafikeng
Krugers
Pretoria
Middelburg
Hartebeesthoek
Benoni
SWAZI LAND
Kuruman
Vereeniging
Ermelo
NAMIBIA
Upington
Bethlehem
Ulundi
Bloemfontein
Ladysmith
Kimberley
Springbok
LESOTHO
Pietermaritzburg
Durban
Prieska
De Aar
Aliwal North
Beaufort West
Umtata
Calvinia
Queenstown
Graaff-Reinet
Sutherland
Langebaanweg
Grahamstown
East London
Cape Town
George
Port Elizabeth
Hermanus
200 KM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200 KM

Applications of TrigNet data

Post processing applications

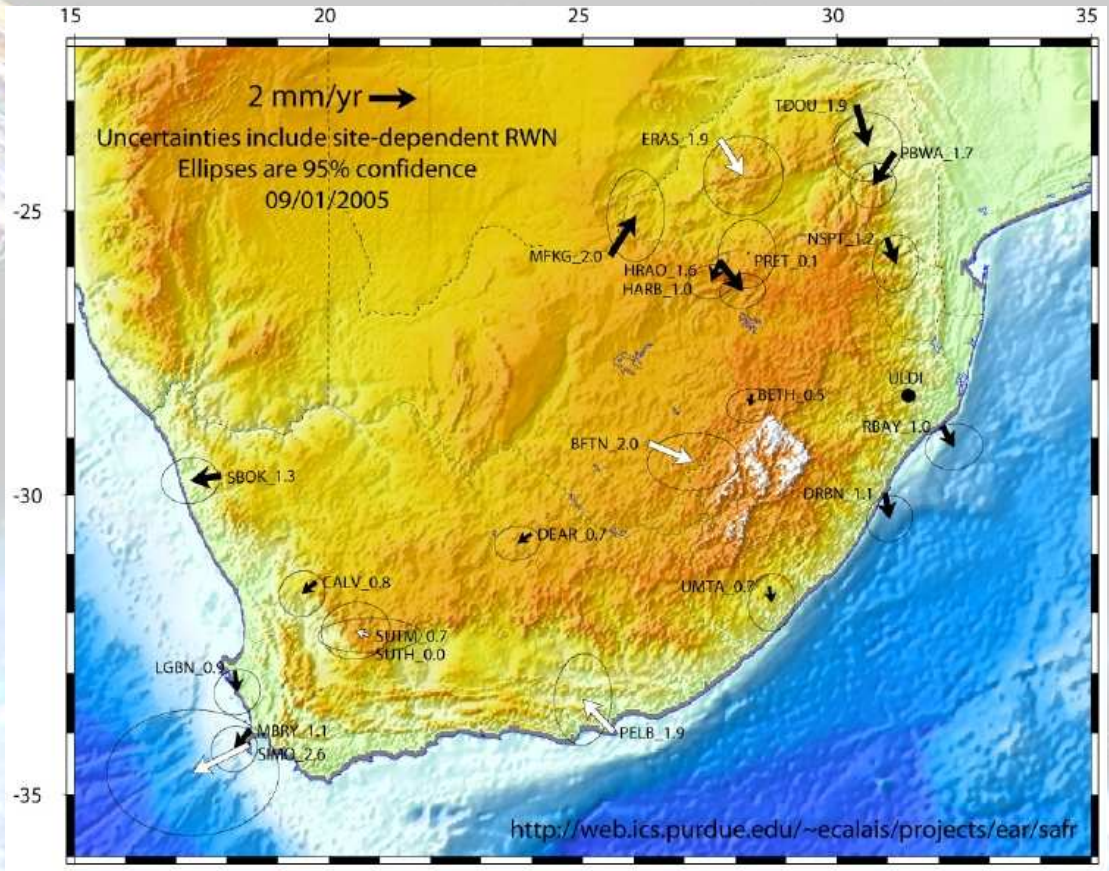
- **Surveying and GIS**
- **Atmosperic science**
  - **Monitoring of atmospheric water vapour for climate monitoring**
  - **Monitoring of ionosphere for communication and positioining**
- **Geophysics**
  - **Long term monitoring of station positions – plate techtonics**

Real time applications

- **Surveying and GIS**
- **Navigation**
- **Weather forecasting & ionosphere mapping**
- **Timing**

Non-Navigation Applications 1

Plate motions

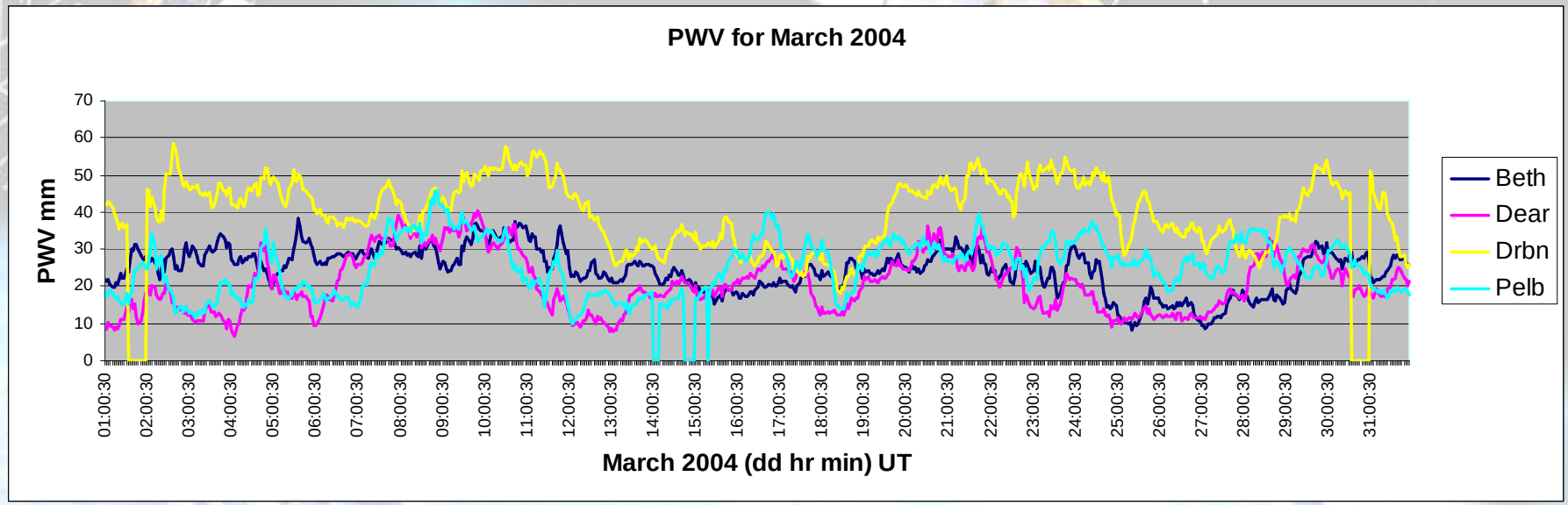


C.J.H. Hartnady, E. Calais & R. Wonnacott (2007): "ITRF2000 velocity field from the South African TrigNet GPS array and the African GNSS network: Implications for Nubia-(Rovuma-Lwandle-)Somalia plate motions" East African Rift Conference, Kampala

Non-Navigation Applications 2

Climate & Weather

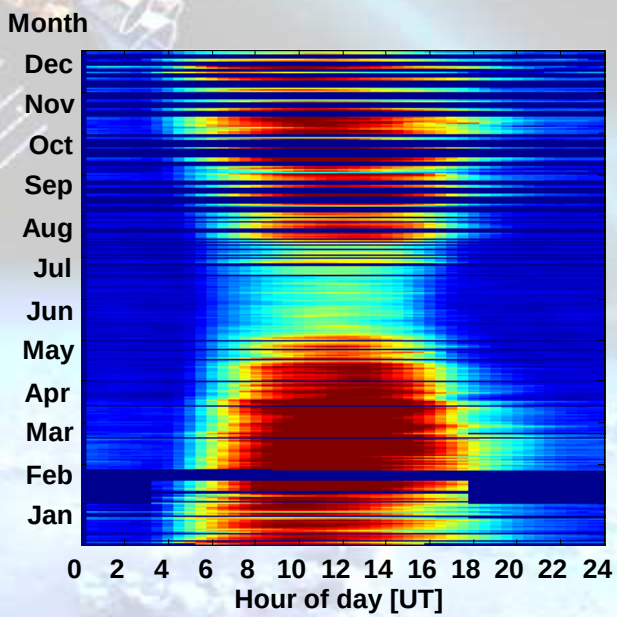
- **Estimation of precipitable water vapour from network of GNSS stations in South Africa**



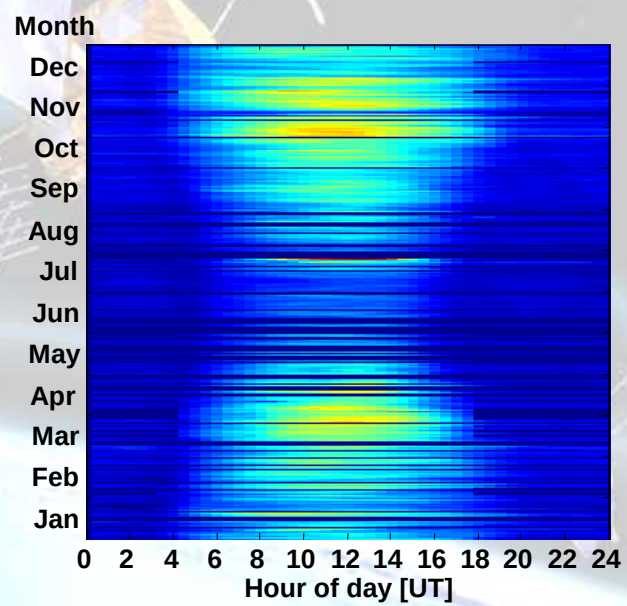
Non-Navigation Applications 3

Space weather

- **Ionospheric mapping of variation of annual TEC over South Africa from network of GNSS base stations**



2002



2004

Thanks to B Opperman of Hermanus Magnetic Observatory for plots

Future

- **Establish VRS cluster in KZN – Drbn, Pmbg+ 3 others by March 2008**
- **Converting to VPN as means of remote and control station communication by March 2008**
- **Are in the process of purchasing 12 GPS/GLONASS receivers for installation in WC & Gauteng by March 2008**
- **Operationalize ionospheric mapping in co-operation with HMO by end 2007**
  Implications on single frequency positioning
- **Will have to consider a rebuild in about 2010 to cater for GPS modernization plus GLONASS and Galileo**
- **Increase co-operation with SAWS for weather forecasting and climate monitoring applications**

Conclusion

- **The passive network of Trigonometrical beacons has served South Africa well for nearly 100 years.**
- **There is a confidence that TrigNet will serve the country just as well.**
- **The services available from TrigNet are easily available.**
- **NTRIP is “state of the art” in real time service provisison.**
- **The applications of TrigNet are not confined to positioning.**
- **A rebuild is planned to accommodate GPS modernization, GLONASS and Galileo.**

Thank You

Website for further information and data

www.trignet.co.za

Extra Slides

South African Active GPS Base Station Network

- **Chief Directorate: Surveys & Mapping (CDSM) mandated in terms of Land Survey Act (8 of 1997) to "establish and maintain a national control survey network"**
- **Up until a few years ago we had a passive network of ~29000 trig beacons**

South African Active GPS Base Station Network

- **GPS has been around for some time**
- **CDSM recognized change in philosophy and technology and has installed a network of active GPS base stations**
- **Consultancy was provided by National Land Survey of Sweden – strong SWEPOS influence**

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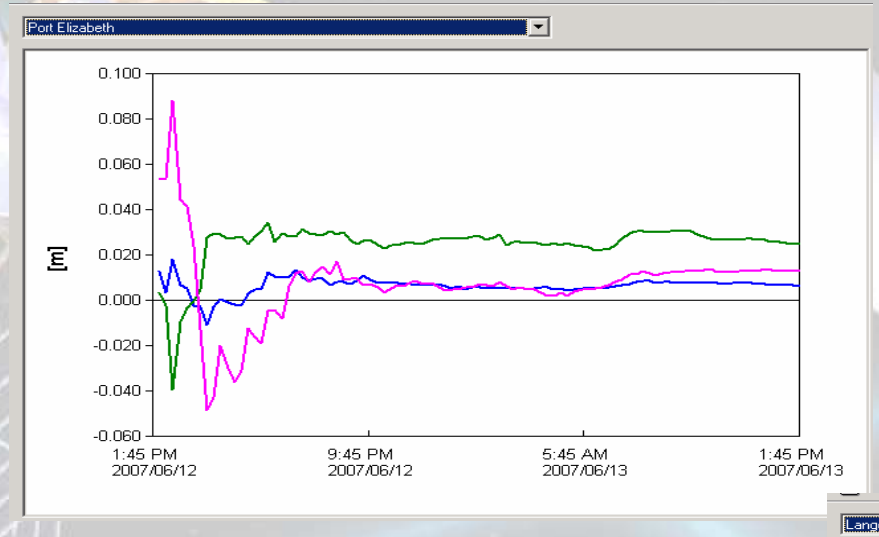
Hartebeesthoek 94 remains the official co-ordinate reference frame

Co-ordinate System



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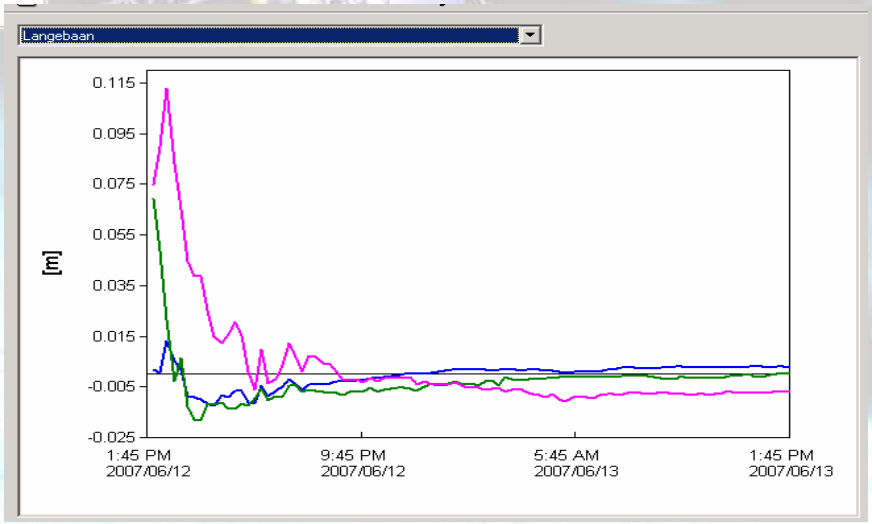
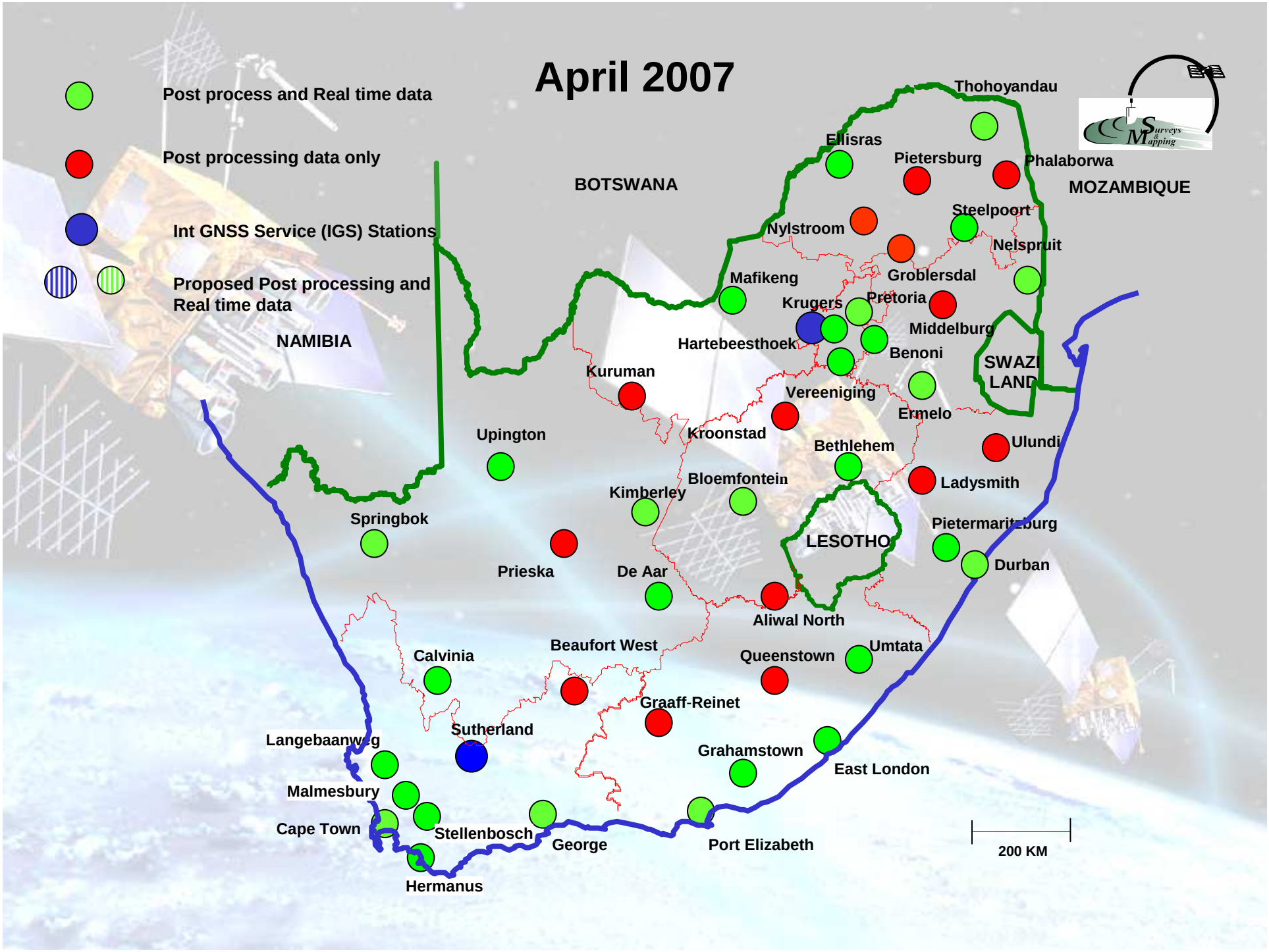


Langebaan

Co-ordinate System

Hartebeesthoek 94 will remain the official co-ordinate system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Bloemfontein
Ladysmith
Kimberley
Springbok
Pietermaritzburg
Durban
Prieska
De Aar
Aliwal North
Beaufort West
Umtata
Calvinia
Queenstown
Graaff-Reinet
Sutherland
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200 KM

Old setup

New setup