Continuously Operating Reference Station(CORS)
&
Real Time Kinematic(RTK)
Global Navigation Satellite Systems(GNSS)

Concepts, Availability in Kenya and Applications

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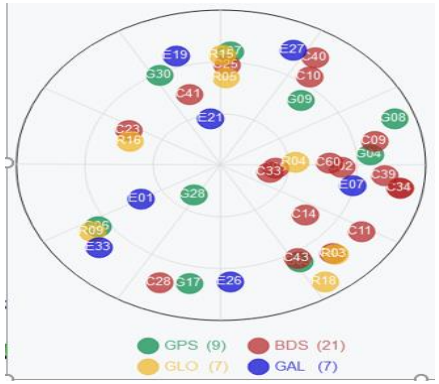
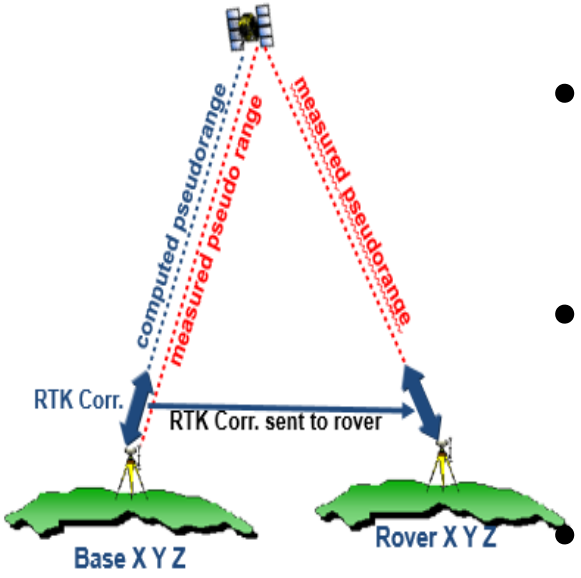
RTK Concepts

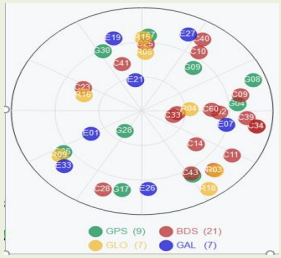




- Base/Rover receivers with UHF radio
- GNSS satellite positions known at any instant of time.
- Base positions is known or processed onsite via ambiguity resolution.
- Pseudo-ranges from phase measurements computed from known satellite and base positions on connecting with satellites
- Measured phase Pseudo-ranges measurements and RTK corrections determined at Base are broadcasted to Rover via UHF radio(now a days also via internet)
- Measured phase Pseudo-ranges measurements at Rover are improved by adding RTK corrections from Base making the rover position as good as the base!
- All taking place at same instant of time

- Suppose Base receiver is located somewhere permanently tracking satellites 24/7, it becomes-CORS, serving more than one rover receivers

Components of CORS



GNSS Receiver System

- Tracks GNSS satellite-GPS, GLONASS, BEDOIU, GALILEO
- Streams GNSS data to network control centre in real time

Internet

Network Control Centre

- Controls the network & Archival of GNSS RAW data
- Computes GNSS network DGPS and RTK corrections
- Disseminates the corrections and RAW GNSS data to user on request

Internet

User/Rover GNSS Receiver System; For all spatial applications

- Low applications(sub meter), uses DGPS corrections
- High accuracy applications(cm level), using RTK corrections
- Very high accuracy applications(mm Level) using Post processing

Reference Base station Components
Antenna & Receiver

- Independent Antenna and Receiver compared to single enclosures hosing both Antenna& Receiver in Base/Rover RTK systems

- GNSS Geodetic Antenna with Multipath litigation features
- Lightening protection systems

- GNSS Geodetic Receiver, at least dual frequency, triple frequency available
- Internet Communication devices(modem, port..)
- Communication with Antenna- cables(15m, 30m, 50m can be available)
- Power: mains power ports(primary) and where possible over the internet cables, internal batteries(secondary), Others- UPS, Solar…

Reference Base station Components

Site & station Distribution

Basic minimum

Clear sky, no objects which could cause multipath, no radio transmitters which could cause GNSS Signal Interference, security, roof tops of stable building bests sites.

Internet Availability;

- Field stations to CPC; Continuous data streams via internet/Dedicated lines, 3G/4G mobile networks
- CPC to Users(internet); NTRIP- Networked Transport of RTCM via Internet Protocol, RTCM-Radio Technical Commission for Maritime Services is a data transmission format.

Power Availability

- 24/7/365 /Back up systems /Internal GPS receivers batteries, Generators, UPS, Solar

Economic activities and population

- Establish the stations where they are economically required
- High population density reflects high economic activity

Control Processing Centre

CORS software Functions

Software components

- Network Server Management
- Client Server management
- Operator Management
- Antenna Management
- Receiver Management
- FTP Management
- Event Management
- RINEX converter

Site Parameters

- Site name & code
- Coordinate input
- Receiver type
- Antenna type & offsets
- Recording interval

Network Server

- Coordinate computation
- RTK processing
- Data archival
- Receiver configurations
- Site parameters

EXAMPLES

- SPIDER-LEICA
- TPP-Trimble
- Topcon
- GEO+++
- CDC-COMNAV

Receiver configuration

- General receiver setting
- Satellite tracking
- Data logging/streaming

Client management

- Registration
- Avail RTK corrections
- Subscription
- Users location

Communication

- **Antenna to receiver;** Cable or wireless(blue tooth in future)
- **Field CORS to Network server;** internet; CDMA, GSM, fiber,
- **Network server to Users;** Internet(GSM/CDMA) via internet

CORS: Products

- RAW GNSS DATA
  - Different products, based sampling intervals, file lengths etc
- DGPS CORRECTIONS
  - sub meter/decimeter accuracy
- RTK CORRECTIONS
  - cm accuracy/up to 30k for single base/70 for network
- Post processing GNSS data
  - User sends static survey data and automatic post processing of data is performed and reports generated and sent to user

User Components; Rover Receivers

All positioning applications

Basic minimum

- GNSS Geodetic receiver
- Communication with Network control Centre via internet/NTRIP(GPRS/GSM, CDMA)
- Store static GNSS data for post processing
- Process DGPS and RTK solutions using any of the Network positioning strategies

RTK Computation Strategies

Single CORS & Network RTK

- Single RTK- user selects CORS of their choice
- Nearest-Systems selects the nearest CORS to user
- Area/Network RTK – interpolated corrections from at least 3 CORS;
  - VRS(Virtual Reference System)
  - FKP(FlachenKorrekturParameters
  - MAX(Master Auxiliary concept)

RTK concept, Single base
1 CORS+CNC+Multi User Rovers

CORS

Control Centre

RTK Rover

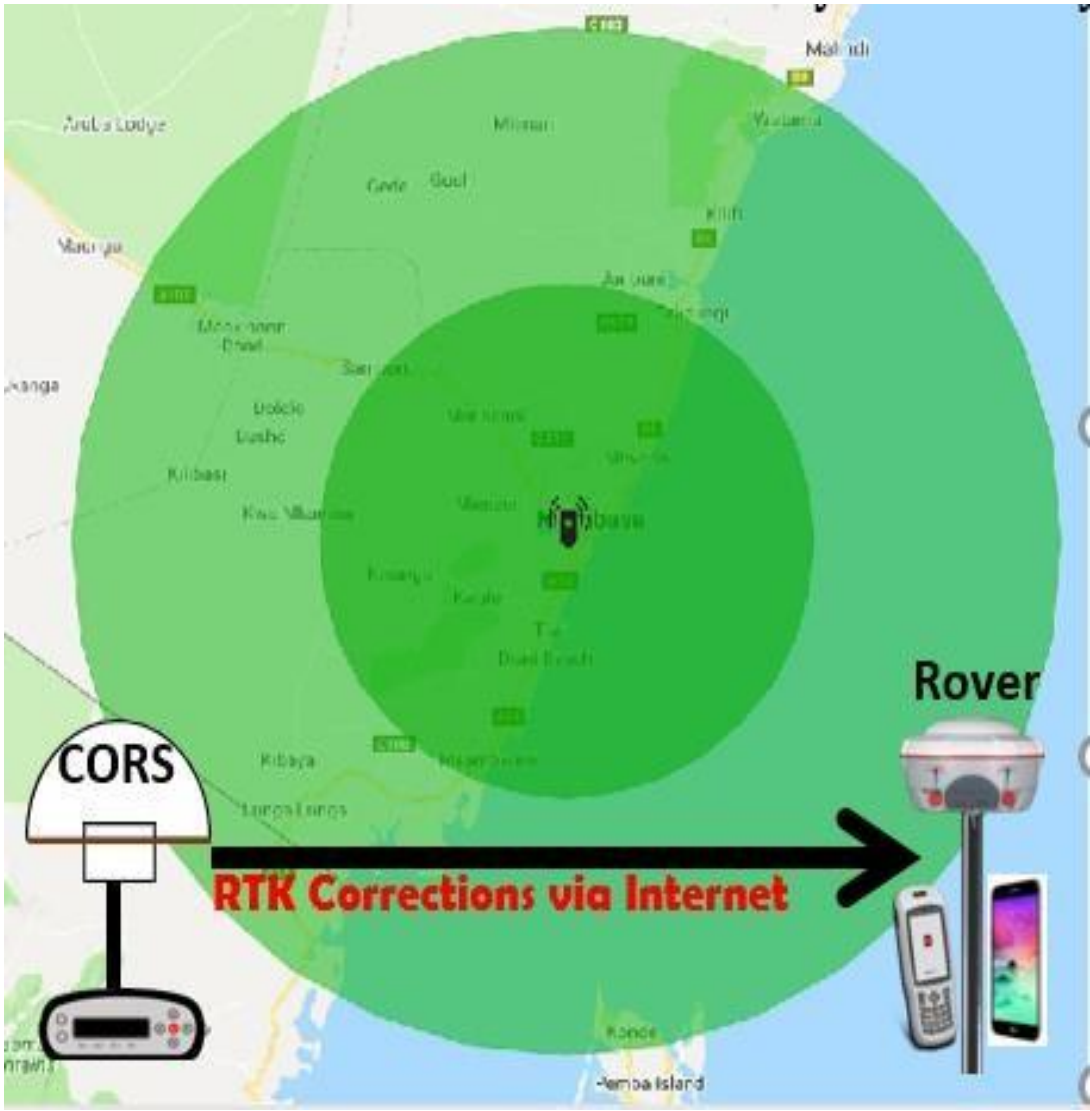
DGPS

- Continuous Operating Reference Station(CORS) tracks GPS satellites and send data to control centre via internet
- Control Centre with specialized software computes GPS data for RTK and DGPS corrections among other products
- RTK rover tracks satellites and receives RTK corrections via internet and updates her position
- Hand receiver with internet also receive DGPS corrections via internet

RTK- Single base

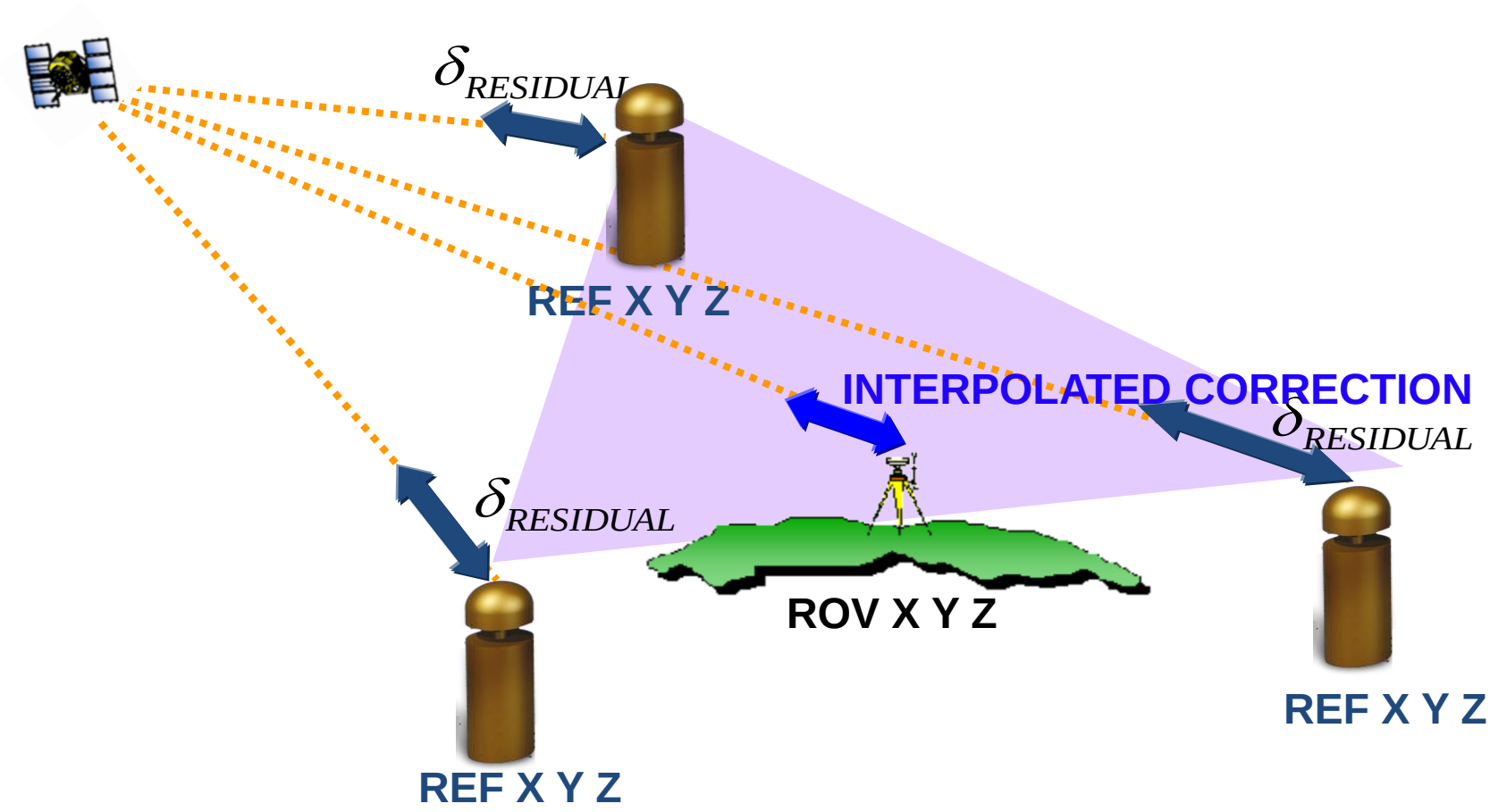
1 CORS+CNC+Multi User Rovers

- 1cm accuracy within 30km from the CORS as indicated by green circles
- <5cm accuracy within 50km from the CORS(dark green areas on the map)
- <10cm accuracy within 100km from the CORS(light green areas on the map)
- <50cm accuracy within 400km from the CORS



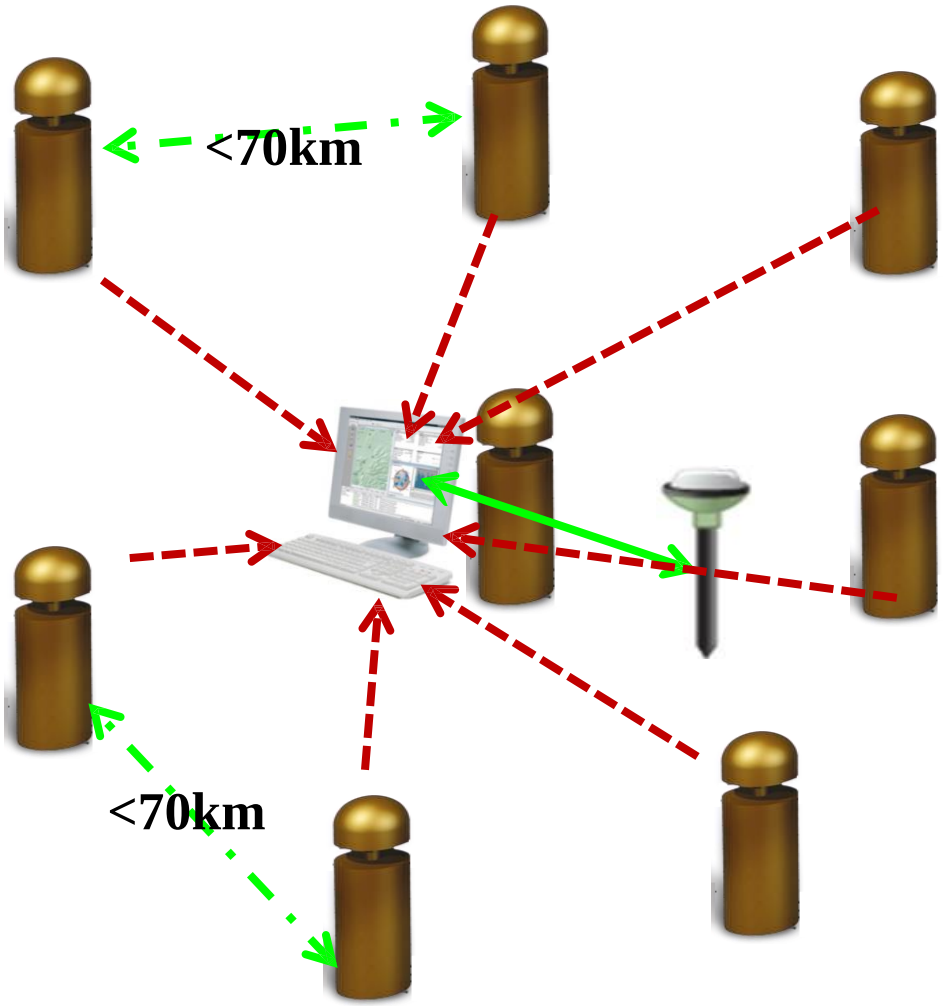
Network RTK

Multi-CORS+CNC+ Multi User Rovers



Network RTK

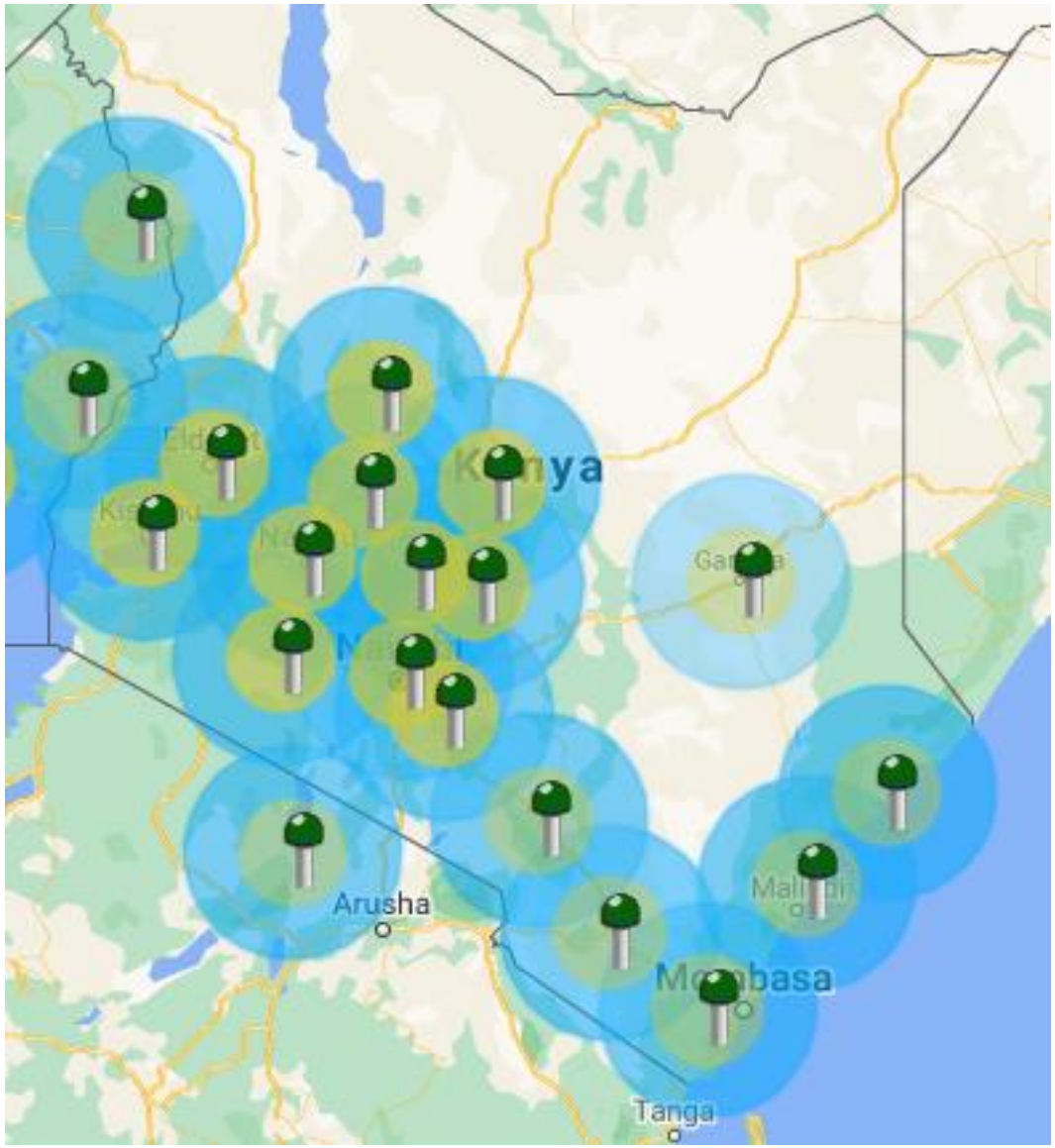
Multi-CORS+CNC- Multi User Rovers



- CORS at 70km spans
- All tracking and transmitting data streams to control processing centre(CPC) vie internet
- CPC computes and disseminates RTK and DGPS corrections to users
- Users receives corrections via internet. Only one receiver required per user.
- Requires high capacity servers and a network CORS software

RTK Concept- Network RTK

Multi-CORS/Multi User/Rovers



- <1cm accuracy within the area covered by a network of CORS, say 50km

- Available within the areas 50km-heavy yellow and 100km – Heavy blue areas bounded by Kisumu, Kitale, Eldoret, Maralal, Isiolo, Embu, Machakos.

- Requires special strategies to compute area RTK corrections including VRS, FKP and MAC

Carrying out survey with CORS

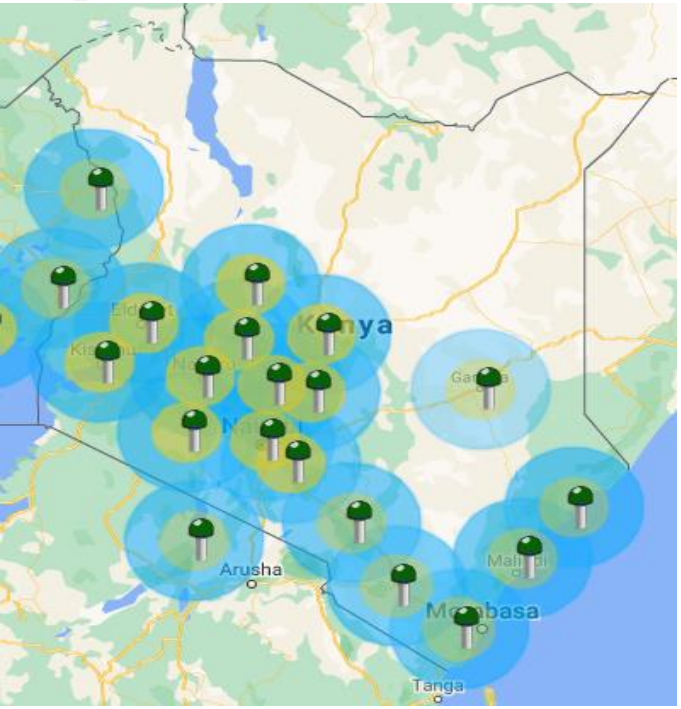
Following are the steps of carrying out a survey with CORS

- Visit the site
- Ensure internet availability on site and on GNSS rover device
- Create project file and configurations-GNSS field software
- Connect with RTK provider using IP/port and user name/password requesting the source provider table
- Select the desired mount points ensuring RTK streams are same in both rover and from the provider. Most providers will name their mount points according to RTCM formats for example Nairobi(station name) RTCM 2.x & 3.x, Nearest RTCM3.x & 2.x, VRS RTCM 2.x & 3.x etc

Advantages of CORS networks

1. Is a multi user-serves many people simultaneously
2. Reduced costs on GNSS equipment. only one Rover required
3. Reduced costs on time taken to carry out the survey. No base to set up nor configure. Users only need connect to RTN/RTK provider
4. Controls positioning accuracies on all users. Providers can tracks users and provide users logo files as evidence of survey works done. CORS network providers may be requested to avail users log files to National Mapping Organization during survey work approvals. The log contents of the log files may include the positional data including accuracies and RTK solutions(fixed/float/DGPS).

GNSS RTK Correction Service in Kenya



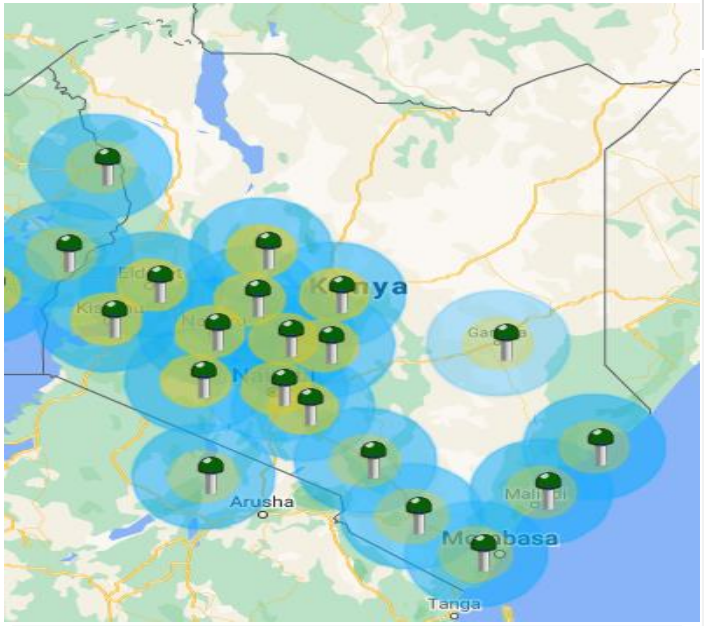
CORS & Distribution

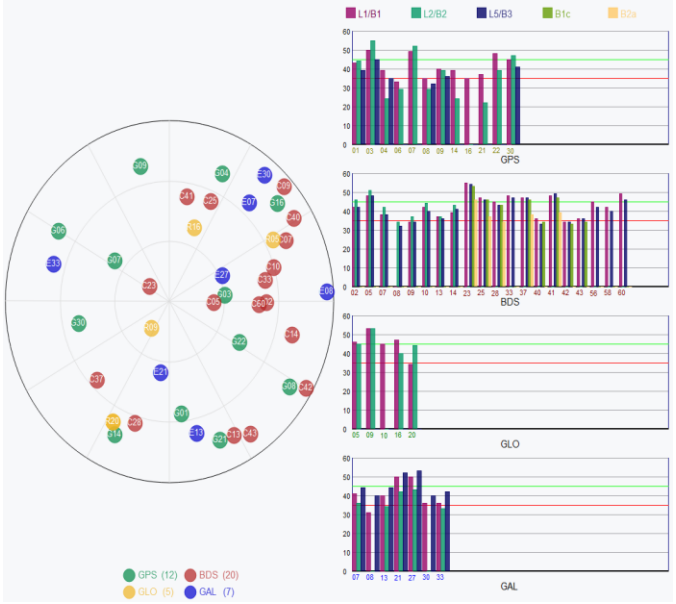
- Ten(13) under MSL in Nairobi, Machakos, Kajiado, Narok, Nyeri, Embu, Isiolo, Garissa, Nakuru, Eldoret, Kisumu, Rumuruti, Mombasa, Malindi, Lamu
- Using CORS from Partners in the region
- Others CORS are from Kenya Power(Private)
- SOK-some CORS already established-

Registration as a user via, www.muya-cors.com

- ✓ Register for user name & password
- ✓ Subscribe RTK corrections @ our service via a shopping cart
- ✓ Buy or Hire a GNSS rover @ our shop via our shopping cart
- ✓ Download CORS static data @ our shop via our shopping cart
- ✓ Free six months RTK correction on buying our rover
- ✓ Call Chris @ 0728909641for help

GNSS RTK Correction Service in Kenya

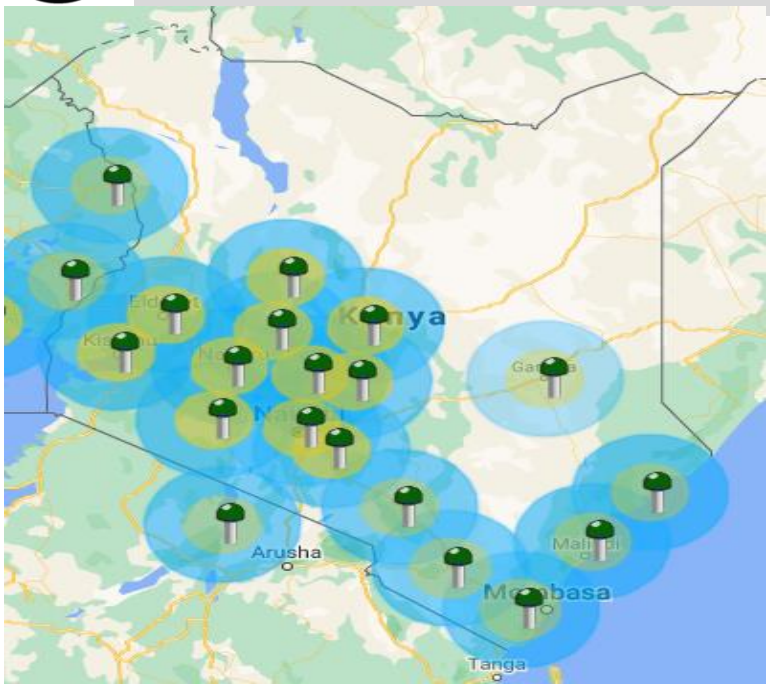


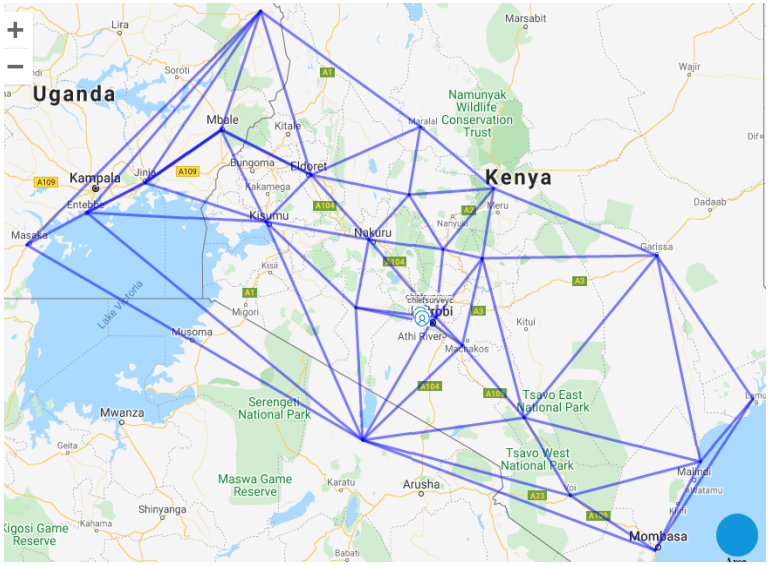


Using our RTK service

- ❑ Any GNSS rover with internet connectivity
- ❑ Check availability of RTK streams prior to going to the field via CORS condition in our web site
- ❑ Create your project using your desired coordinate systems
- ❑ Select your receiver model-most field soft support various receiver models
- ❑ Connect to RTK service via NTRIP
  - IP & Port: 173.249.45.63:2100
  - Request source tables
  - Select desired mount point-viz VRS RTCM MSM4 3.2
  - Localize your project to local datum and projections via GNSS RTK software in your rover and data collectors.

GNSS RTK Correction Service in Kenya



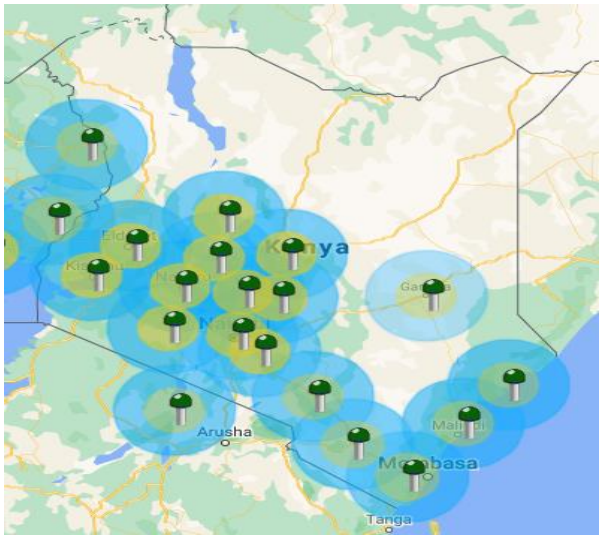


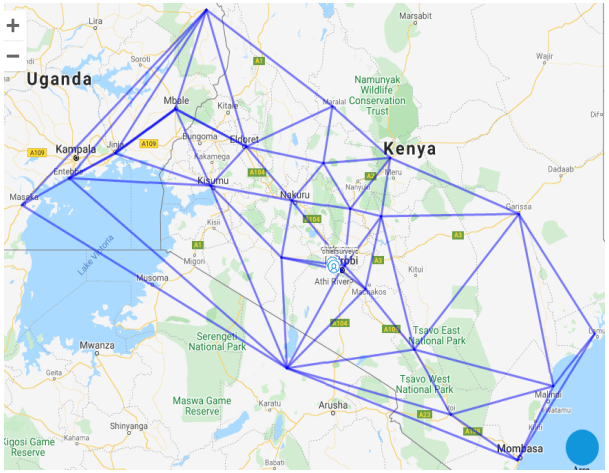
Our RTK data streams-Source Tables		
	Mount Points	Description
1	NEAREST RTCM 2.3	**Single RTK**: Corrections from the nearest CORS
2	NEAREST RTCM 3.1	
3	NEAREST RTCM 3.2	
4	VRS RTCM 2.3	**Networked RTK**: Corrections from more than one CORS, the best choice!
5	VRS RTCM 3.1	
6	VRS RTCM 3.2	

GNSS RTK Correction Service in Kenya

VRS RTK Streams @14.00hrs 17-11-2021

	ID	Cell	Status	Satellites
	0	EMBUUNI-NAIROBI-EMBU	fixed	10,GPS8,BDS0,GLO2,GAL0
	1	EMBUUNI-ISIOLO-EMBU	fixed	6,GPS5,BDS0,GLO1,GAL0
	2	DKUT-NAIROBI-EMBU	fixed	11,GPS4,BDS4,GLO3,GAL0
	3	EMBUUNI-NAIROBI-KIBWEZI	fixed	6,GPS6,BDS0,GLO0,GAL0
	4	DKUT-ISIOLO-EMBU	fixed	10,GPS5,BDS4,GLO1,GAL0
	5	EMBUUNI-ISIOLO-GARISSA	fixed	5,GPS5,BDS0,GLO0,GAL0
	6	NAKURU-DKUT-NAIROBI	fixed	12,GPS5,BDS4,GLO3,GAL0
	7	EMBUUNI-KIBWEZI-GARISSA	fixed	5,GPS5,BDS0,GLO0,GAL0
	8	KAJIADO-NAIROBI-KIBWEZI	fixed	13,GPS7,BDS3,GLO0,GAL3
	9	DKUT-ISIOLO-KIAWARA	fixed	13,GPS7,BDS3,GLO3,GAL0
	10	NAKURU-DKUT-KIAWARA	fixed	12,GPS7,BDS2,GLO3,GAL0
	11	NAKURU-NAIROBI-NAROK	fixed	21,GPS6,BDS10,GLO1,GAL4
	12	KIBWEZI-GARISSA-CHAMBUU	fixed	10,GPS2,BDS4,GLO2,GAL2
	13	KAJIADO-NAIROBI-OAKAR	fixed	11,GPS7,BDS0,GLO3,GAL1
	14	KAJIADO-KIBWEZI-VOI	fixed	15,GPS8,BDS4,GLO0,GAL3
	15	ISIOLO-RUMURUTI-KIAWARA	fixed	16,GPS5,BDS5,GLO2,GAL4
	16	NAKURU-RUMURUTI-KIAWARA	fixed	20,GPS7,BDS6,GLO2,GAL5
	17	TRIMBLE-NAIROBI-NAROK	fixed	15,GPS8,BDS3,GLO1,GAL3
	18	NAKURU-KISUMU-NAROK	fixed	20,GPS6,BDS8,GLO2,GAL4
	19	GARISSA-LAMU-CHAMBUU	fixed	10,GPS3,BDS5,GLO0,GAL2
	20	KIBWEZI-VOI-CHAMBUU	fixed	16,GPS6,BDS6,GLO0,GAL4
	21	TRIMBLE-KAJIADO-OAKAR	fixed	10,GPS7,BDS0,GLO3,GAL0
	22	TRIMBLE-NAIROBI-OAKAR	fixed	11,GPS8,BDS0,GLO3,GAL0
	23	ELDORET-ISIOLO-RUMURUTI	fixed	17,GPS6,BDS4,GLO2,GAL5
	24	NAKURU-ELDORET-RUMURUTI	fixed	26,GPS7,BDS11,GLO3,GAL5
	25	TRIMBLE-KAJIADO-NAROK	fixed	15,GPS6,BDS4,GLO1,GAL4
	26	NAKURU-KISUMU-ELDORET	fixed	25,GPS7,BDS11,GLO2,GAL5
	27	LAMU-CHAMBUU-MALINDI	fixed	5,GPS5,BDS0,GLO0,GAL0
	28	MOMBASA-VOI-CHAMBUU	fixed	11,GPS5,BDS6,GLO0,GAL0
	29	MOMBASA-LAMU-MALINDI	float	3,GPS3,BDS0,GLO0,GAL0
	30	MOMBASA-CHAMBUU-MALINDI	float	4,GPS4,BDS0,GLO0,GAL0

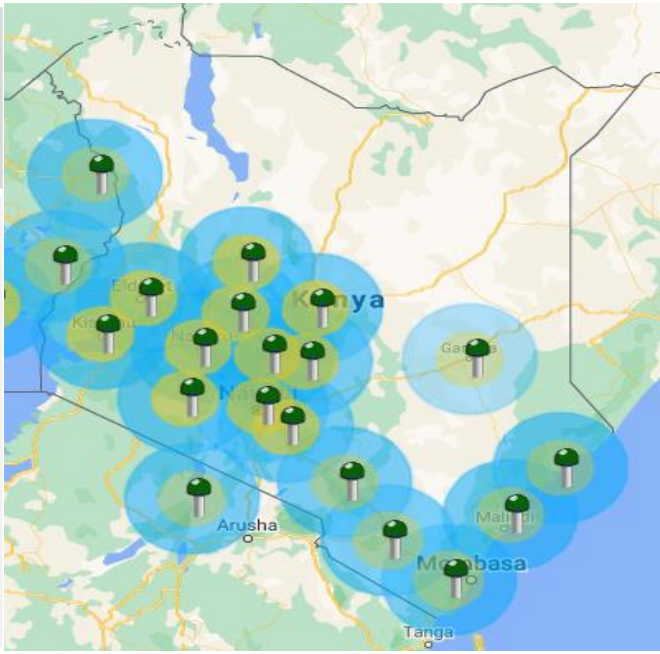




GNSS RTK Correction Service in Kenya

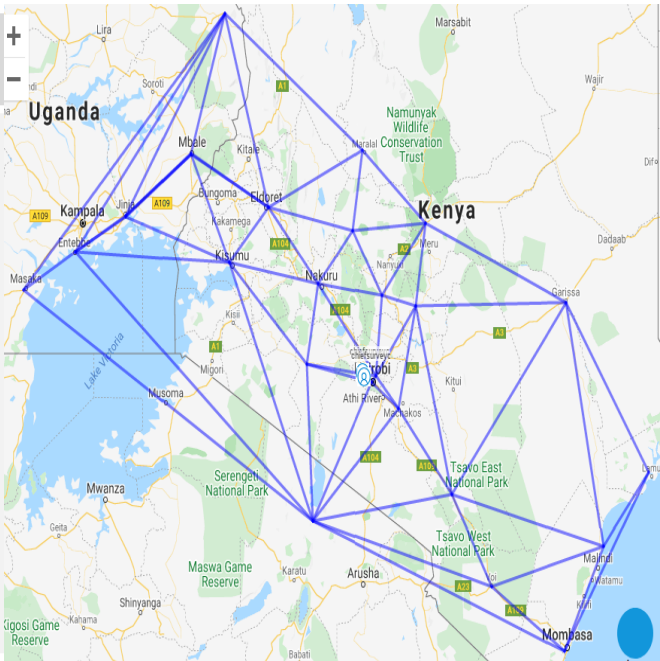
Coordinate System; Base/CORS coordinates

- ITRF2014 reference frame and coordinate systems. Monthly updates.
- CORS coordinated to ARC'60 datum
- ARC 1960-UTM and Cassini available in our website and SOK



Coordinate System; Rover co-ordinates

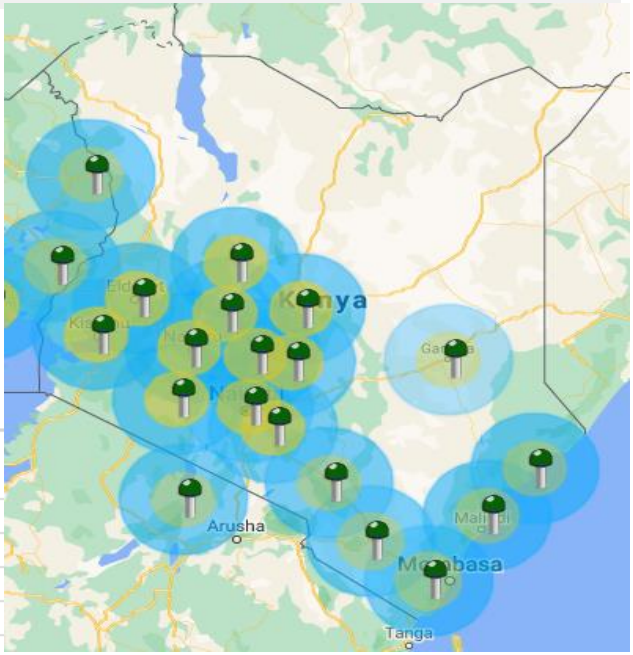
- Desired rovers coordinates are as configured in your field GNSS RTK software. ARC'60/UTM or Cassini
- Localize with known points for ARC 60 datum coordinates UTM or Cassini for beacon search/placings



RTK Correction Services-Achievable Accuracies!

- MSL base have been computed by static methods and constrained from RCMN UTM/WGS84/ITRF2014 coordinates. Coordinates of the MSL base were then measured from the various CORS
- Here below are the solutions of the MSL base with their residuals indicating that less than 5cm accuracy can be achieved with CORS at 50km, 20cm up to 150km and 50cm up to 300km
- This means General boundary surveys can easily be carried out using few CORS across the country at spans of 2-300km.

CORS	North	Residual	East	Residual	Distant from Base	Solution type	Horizontal Residual
BASE	9863859.007		262657.781				
24th september 2019 1650-1720hrs							
RCMN	9863859.017	-0.010	262657.787	-0.006	3142.373	FIXED	0.012
Trimble	9863859.001	0.006	262657.790	-0.009	9903.788	FIXED	0.011
Machakos	9863859.009	-0.002	262657.763	0.018	52082.049	FIXED	0.018
Nyeri	9863858.956	0.051	262657.778	0.003	92738.269	FLOAT	0.051
Embu	9863858.830	0.177	262657.698	0.083	103514.865	FLOAT	0.195
Nakuru	9863858.888	0.119	262657.709	0.072	141123.761	FLOAT	0.139
Eldoret	9863858.922	0.085	262658.146	-0.365	260393.411	FLOAT	0.375
Kisumu	9863858.964	0.043	262658.254	-0.473	270883.155	FLOAT	0.475
Mombasa	9863859.223	-0.216	262658.156	-0.375	439826.623	FLOAT	0.433
25th September 2019 1050-1100hrs							
RCMN	9863859.021	-0.014	262657.793	-0.012	3142.373	FIXED	0.018
Trimble	9863859.006	0.001	262657.789	-0.008	9903.788	FIXED	0.008
Machakos	9863859.008	-0.001	262657.816	-0.035	52082.049	FIXED	0.035
Nyeri	9863858.966	0.041	262657.593	0.188	92738.269	FLOAT	0.192
Embu	9863858.838	0.169	262657.733	0.048	103514.865	FLOAT	0.176
Nakuru	9863858.819	0.188	262657.721	0.060	141123.761	FLOAT	0.197
Eldoret	9863858.788	0.219	262657.758	0.023	260393.411	FLOAT	0.220
Kisumu	9863858.866	0.141	262657.799	-0.018	270883.155	FLOAT	0.142
Mombasa	9863859.238	-0.231	262658.268	-0.487	439826.623	FLOAT	0.539



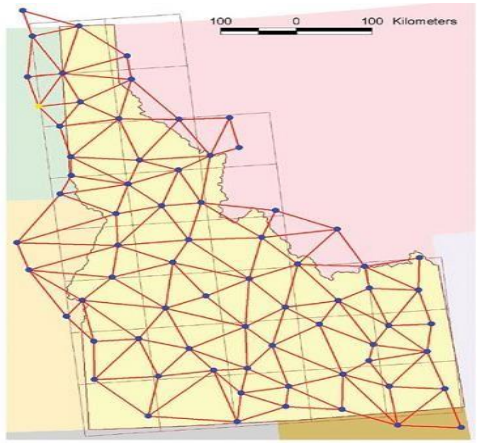
Try it in your next survey.
Any RTK Rover brand is OK!
Hire Rover from MSL @ KES.6000
For more information
Call Chris @0728909641

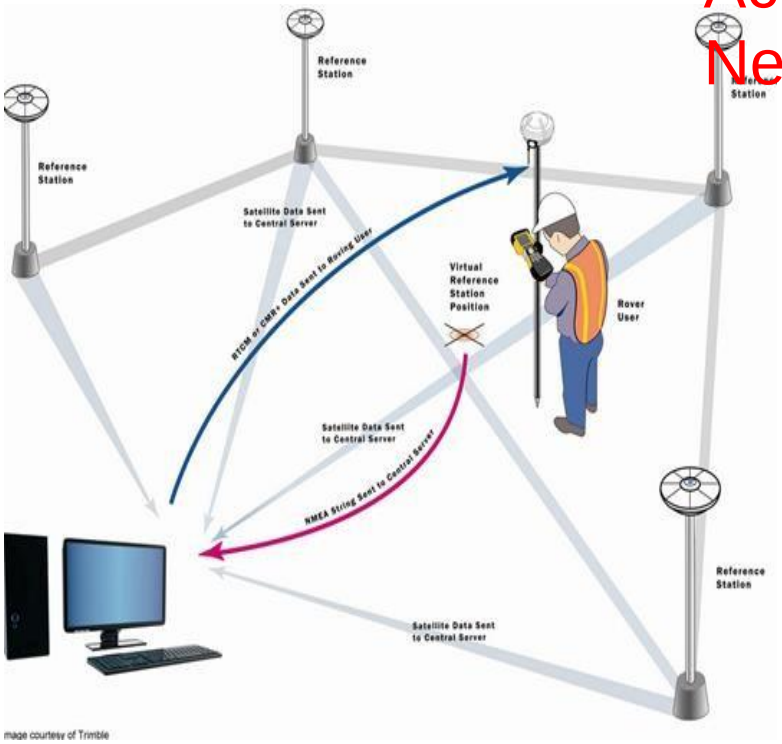
Measurement Systems Ltd
www.measurementsystems.org

CORS & Real Time Geodetic Network(RTN)

Non Active(traditional)

- Similar to what we have traditionally but accurate
- Based on modern Technologies, such as Global Navigation Satellite Systems (GNSS) & International Terrestrial Reference Frame(ITRF)





Active networks/Real Time Geodetic Networks(RTN)

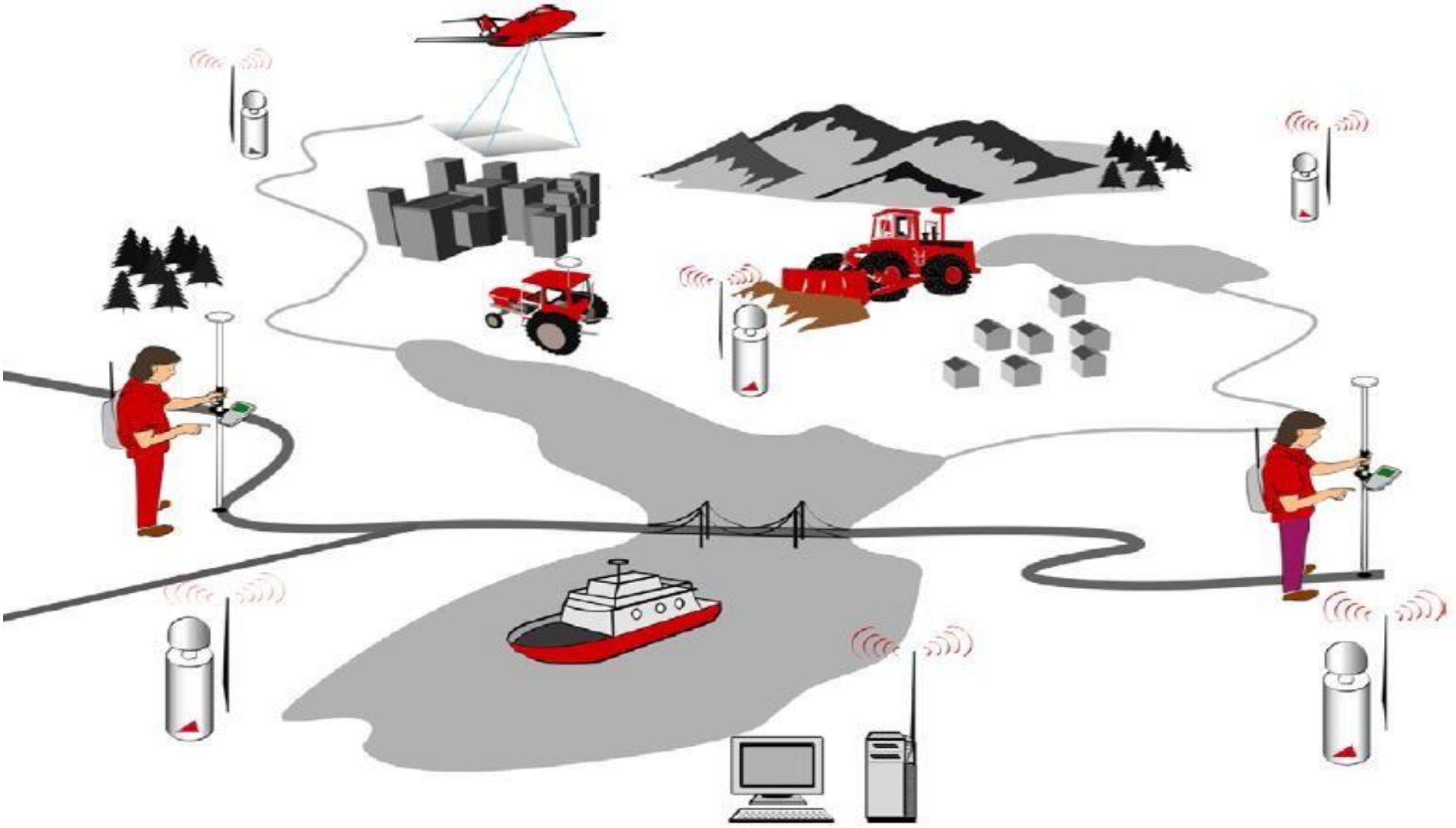
- Based on Continuously Operating Reference Station(CORS) as field GNSS base stations, operating 24/7
- Acts as reference stations /controls for all applications
- User Controlled
  1. By registration- user name and password
  2. Multi-users
  3. Products-RTK, Raw data, and postprocessing

Applications

- All application including Kenya Government BIG4 agenda requires positioning/locating…
- CORS would provide seamless and accurate but application dependent positioning solutions and in real time….
- CORS would address Kenya geodetic problem
  - UTM-Clarke 1880, ARC 1960 datum; most monuments destroyed, only 3D-translation parameters(XYZ-157/2/299) and, not accurate(2-3m)
  - Cassini-Clarke 1858, Not consistent, no transformation parameters
  - Cadastral mapping
    - ❑ not seamless - solved by localizing as near possible to sites
    - ❑ most areas are not georeferenced, PID areas- pick physical boundaries and update
- Propose adoption of modern geodetic systems based on ITRF coordinate systems or even create our own suitable for Kenya

Applications

All applications require to answer the question ‘WHERE’



Our Products
Network RTK Rovers/Handhelds

MEASUREMENT Sytems Ltd
for measuring tools, instruments & equipment

P78 RTK
GNSS/GIS HANDHELD SYSTEM

- 184 Channels U-blox ZED-F9P engine board
- Multi- constellation, triple frequency and concurrent tracking
- GPS, GLONASS, GALILEO, BEIDOU Satellite tracking
- GNSS RTK Network Rover, compatible with any CORS
- Android Operation System(7.0)
- Quad Core 1.3.GHz CPU, 3GB ROM & 16GB Flash
- 2GB internal Flash storage & Standard 4GB supports up to 32G SD-Card
- RTCM 3.X RTK data format supported
- Big and sunlight-readable 8'' touch screen, high resolution 1280*800 pixel
- WCDMA/GSM/3G, Bluetooth, Wi-Fi, USB, sim card, SD communication
- Front 5 MP, real 13MP Autofocus dual Camera
- Microphone recording Audio & Gravity sensor
- Android based SurPad data collection software
- Supports other Android based mobile GIS/CAD field software
- 6200mAh Lithium-ion rechargeable battery
- External GNSS Antenna and GPS pole for precise centering
- Dust & weather resistant, IP65, 1.2m drop
- Light weight; 550gms with battery
- Small in size; 220x147x20.9mm

GPS Pole & External antenna optional

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MEASUREMENT Sytems Ltd
for measuring tools, instruments & equipment

M9 RTK GNSS
Network Rover System

- 432 channels tracking ALL available satellites including GPS+GLONASS+GALILEO+ BEIDOU
- Full 90° Tilt compensation Technology
- Static and RTK surveys with less than a cm accuracy
- Compatible with any CORS
- Supports CMR CMR+ RTCM 2.x RTCM 3.x data formats
- RS232/Bluetooth/4G/WIFI/NTRIP/WebUI
- 32GB internal memory
- Data logger with SurPad field software with Android operating systems
- Support other Android field software including Field Genius, Carlson Ce
- Built-in battery 9750mAh 7.4V ≥15hrs continuous operation
- Compact durable magnesium alloy casing
- Withstand 1.5m pole drop onto the cement ground
- Dust & weather resistant-IP65
- Light weight and pocket size

Package

1. M90 GNSS receiver with USB charging/download cable/adapter
2. Data logger with SurPad field software
3. GPS Pole

60% deposit and 6 consecutive instalments acceptable

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Our Products
Base/Rover RTK Systems

MEASUREMENT Sytems Ltd
for measuring tools, instruments & equipment

SinoGNSS By ComNav Technology Ltd.

N3 Base/Rover GNSS RTK System

- 1198 Channels SinoGNSS Quantum Engine Board
- Satellite signals tracked: GPS(USA), GLONASS(Russia), GALILEO(Europe), BEIDOU(China), IRNSS(India), QZSS(Japan)
- Triple Frequency
- IMU & Tilt compensation technology
- Static, RTK, Supports long Baseline E-RTK , Compatible with any CORS
- Base/Rover Internet communication, No baseline limitation
- Static horizontal/vertical accuracy: 2.5mm +/5mm + 0.5ppm
- RTK horizontal/vertical accuracy: 8mm/15mm + 1ppm
- RTK formats CMR, CMR+, RTCM 2.x, RTCM 3.x
- RS232, Bluetooth, USB, GSM, GPRS, EDGE ,WebUI
- Internal/External UHF Radio, 15km baseline with internal radio
- Voice messages, Automatic Firmware updating
- 8GB internal & up to 32 GB pluggable memory
- Swappable internal batteries 2x3400mAh up to 25hrs typically
- Rugged magnesium-aluminum alloy housing to survive 2m drop on concrete
- Dust & weather resistant, IP67
- Data collector R550 with Android Survey Master Field Software
- Support other data collection software; FieldGenius, Carlson SurvCe
- Light weight; 950gms with two batteries
- Small in size; 158mm diameter and 75mm height

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MEASUREMENT Sytems Ltd
for measuring tools, instruments & equipment

e-survey UniStrong E300 Base/E200 Rover RTK GNSS System

- 800 Channels Hemisphere Phantom™ 40 GNSS Engine Board (Canada)
- Multi-constellation and multi-frequency, all available satellite signals tracked including GPS(USA), GLONASS(Russia), GALILEO(Europe), BEIDOU(China), IRNSS(India), QZSS(Japan)
- IMU/Tilt Survey compensation technology
- Static, RTK Supports long Baseline E-RTK
- Static horizontal/vertical accuracy: ±2/3mm+0.1/0.4ppm
- RTK horizontal/vertical accuracy: ±8/15mm+1ppm
- RTK formats CMR, CMR+, RTCM 2.x, RTCM 3.x
- 1-watt internal UHF Radio extending up to 5km supported protocols includes Satel, Trim Talk, South, Hi-Target
- Rechargeable built-in Li-ion 6800 mAh, 12hrs continuously field operation, USB type-C quick charger supporting vehicle charging
- Comes with data collector with Android SurvPad Field Software
- Support other data collection Android/Windows software
- Compatible with any CORS
- Standard package; E300 Base/E200 Rover, Android data logger with SurvPad field software, GPS pole and Tripod

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Other General Products

MEASUREMENT Sytems Ltd

for measuring tools, Instruments & equipment

RTK Correction Service
IP:173. 249.45.63
PORT:2100

Register at;
www.muya-cors.com

We offer following services:

- Instrument Sales Calibration & Service
- Hiring of Measuring Instruments
- Easy monthly payments terms
- RTK Correction Service
- Post processing Service
- Land Surveying & Mapping Service

Our online shop: www.measure-it.africa

"Our Product caters for applications in Land Surveying & Mapping, Engineering, Soil, Weather , Precision Agriculture, Machine Control, which includes RTK GNSS, GIS/GNSS Handhelds, Total Stations, Theodolites, Optical & Digital Levels, Laser Distance meters, Laser lines & Levels, Laser Scanners, LiDAR, UAVs/Drones, Walkie Talkie, Precision Agriculture, Soil and related Accessories"

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I acknowledge LEICA Geo-Systems, Trimble, Pentax from where most of the materials and images in this presentation have been drawn from.

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Thanks you very much for your attention!