

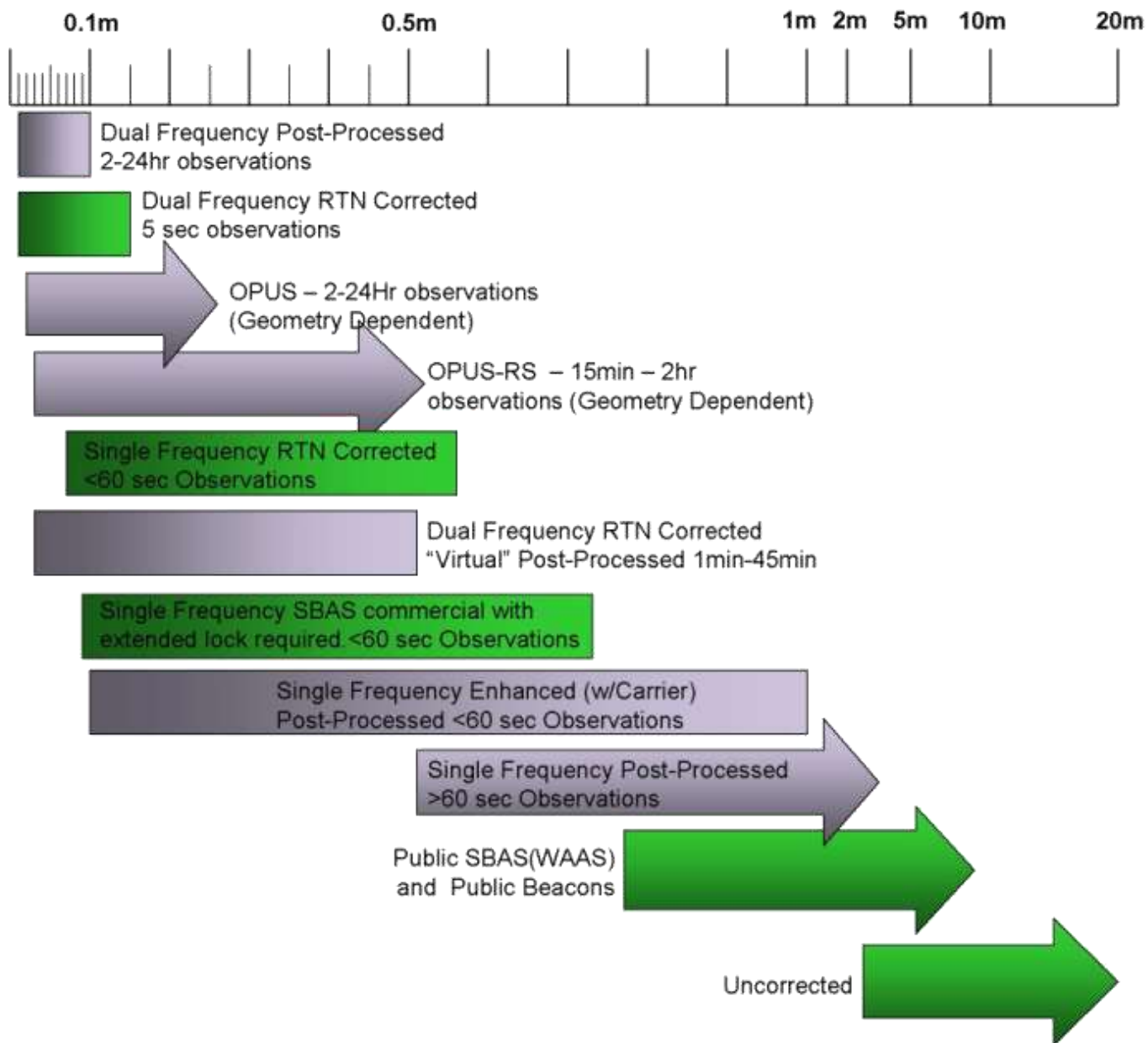
# Best Practices for the Development and Operation of RTN – Real-Time GNSS Networks



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# Outline

- I. RTN components
- II. Features and services
- III. Reference framework
- IV. Design
- V. Operations
- VI. Drivers and sustainability



# I. RTN Components

- a) CORS Communications
  - Hard (landline)
  - Broadband/Cellular
  - Satellite
  - Radio Networks
  
- b) Central Processing Center (CPC)
  - Physical servers
  - Virtual Servers
  - Cloud
  - Hosted
  
- c) Rover Access and Communications
  - Cellular
  - Satellite
  - Radio networks
  - Cell-radio bridges

## II. Features and Services

- a) Real-time network corrections
  - Non-physical (VRS, virtual)
  - Master-auxiliary (MAC)
  - Flächen Korrektur Parameter (FKP)
  - Other
  
- b) Real-time single base corrections
  - Degradation over distance
  - Broadcast-only possible
  
- c) Network integrity monitoring
  - Relative to fiducial reference framework
  - Internal relative integrity
  - Multiple motion engines
  - User access to integrity data

## II. Features and Services

- d) Network Transport of RTCM over Internet Protocol
  - Non-proprietary protocol
  - Caster, Client, and Server components
- e) Ionospheric condition monitoring
  - Developed from network infrastructure
  - Total electron content (TEC)
  - Expressed in terms of potential user error (I95)
  - User access for mission planning
- f) Tropospheric condition monitoring
  - Perceptible water index
  - Operator monitored network health

## II. Features and Services

- g) Field results monitoring
  - Rover monitors
  - Monitors in each functional subnet
- h) Ionospheric condition monitoring
  - Developed from network infrastructure
  - Total electron content (TEC)
  - Expressed in terms of potential user error (I95)
  - User access for mission planning
- i) Tropospheric condition monitoring
  - Perceptible water index
  - Operator monitored network health

## II. Features and Services

- j) Web portal
  - User access to account
  - User access to system quality info
  - User access to static files
  - Operator access to accounts and system status
- k) Virtual static files for post-processing
  - Based on network solution processors
  - Generated based on rover location or input
- l) Online post-processing
  - Automated baseline processing of user submitted observations
  - Automated PPP processing of user submitted observations



# III. Geodetic Reference Framework

- a) Global reference frameworks
  - Operational framework
  - Outputs can be in different frameworks
  - Operate on global- output in regional
- b) Integrity monitoring
  - PPP
  - Baseline
  - Motion engines
- c) Relative integrity
  - Network-wide
  - Subnets
  - 2cm (3D) minimum

## IV. Design

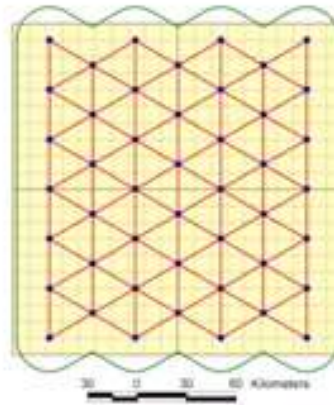
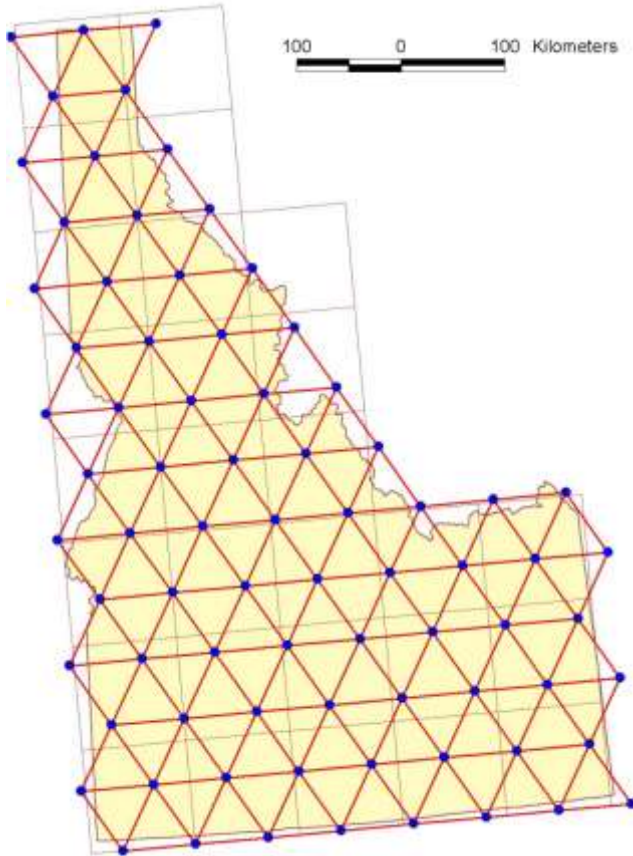
- a) Central Processing Center (CPC)
  - Redundant and robust
  - In-house
  - Cloud and/or hosted
  
- b) Receivers and Antennas
  - Geodetic antennas with IGS models
  - Purpose built RTN receivers
  - Remote operation interfaces
  - Tightly coupled software/hardware
  
- c) Enclosures, power, and communications
  - Environmental enclosures
  - AC, solar, power-backups

## IV. Design

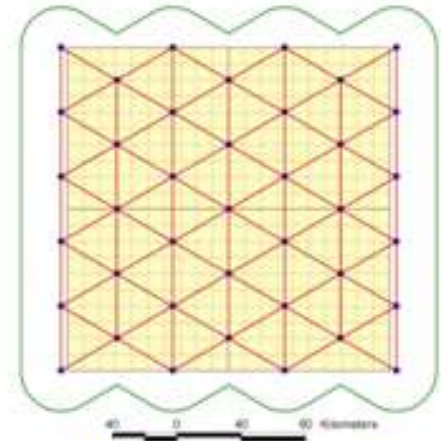
- d) Antenna mounts (monuments)
  - Drill-brace
  - Cantilevered posts
  - Concrete monoliths
  - Building mounts
  - Leveling heads
  - Domes
  
- e) Communications
  - Geodetic antennas with IGS models
  - Purpose built RTN receivers
  - Remote operation interfaces
  - Tightly coupled software/hardware
  
- f) CORS spacing
  - Density for geodetic consideration
  - Density for tropospheric considerations
  - Standard 50km-70km
  - Optimal vs. opportunistic

## IV. Design

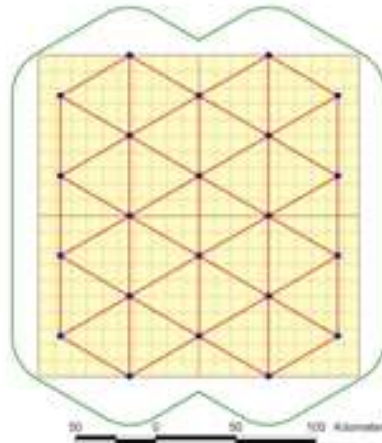
### f) CORS spacing



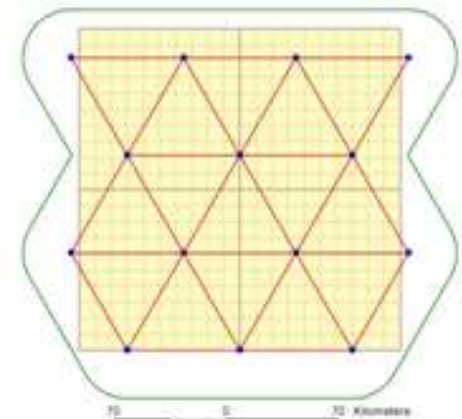
**30km – 46 Stations**



**40km – 39 Stations**



**50km – 22 Stations**



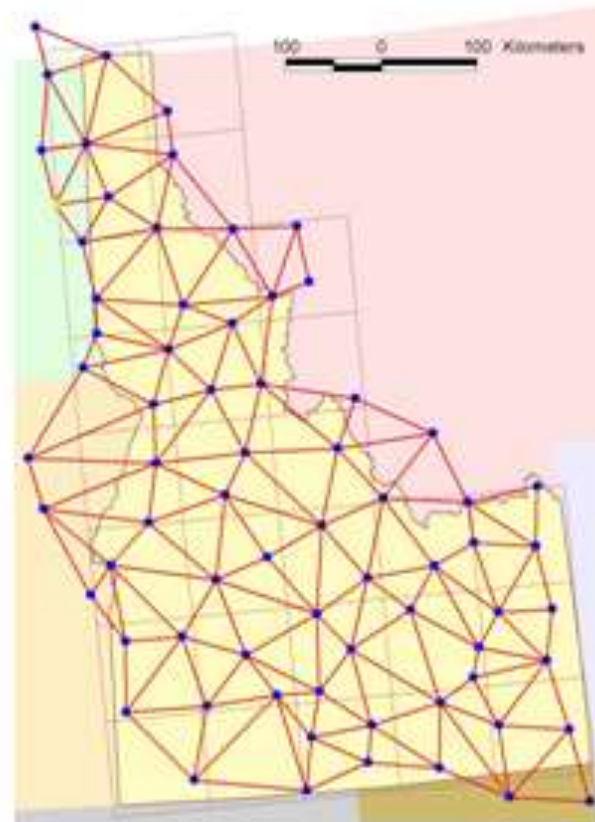
**70km – 14 Stations**

## IV. Design

### f) CORS spacing



**Overlay of Adjacent  
Network Stations**



**Revised Design – 71 Stations  
(50 'intra', 21 'inter')**

# V. Operations

- a) Geodetic determinations and monitoring
  - Initial reference framework ties
  - Ongoing integrity monitoring
  - Rover integrity monitoring
  - Ancillary monitoring services
  
- a) Information technology and communications
  - Closed IT networks, VPN, et al
  - DMZ
  - Hosted and cloud
  
- a) GNSS science and technology
  - Constellations
  - Signals
  - Future proofing

# V. Operations

## d) Management

- User agreements
- Partnerships
- Contracts
- Infrastructure management

## e) Customer support

- Staffing
- Operator training
- Customer training
- Limitations of service

## f) Primary and backup operators

- Surveying and geodesy fundamentals
- IT fundamentals
- Succession planning

## V. Operations

- g) Hosted RTN operations and services
  - RTN software vendors
  - In-house staffing issues
  - In-house expertise issues
  - Overcoming internal bureaucratic and IT issues



# VI. Drivers and Sustainability

## a) RTN uses

- Land Surveying and Geodetic Surveying
- Construction, Machine Control, and Grading
- Heavy Construction, Structural Assembly, and Construction Inspection
- Compliance Inspection, Grade Checking, and Site Safety
- GIS, Resource Mapping, Utility Location and Clearances
- Preliminary Engineering and Engineering Studies
- Mobile Mapping, Aerial Mapping, and UAVs
- Asset Inventory, Physical Plant, and Infrastructure Inventory
- Dams, Bridges, Buildings, and Structural Integrity Monitoring
- Geophysical Studies, Tectonic Plate Movement Research
- Earthquake, Tsunami, and Volcanic Warning Systems
- Landslide Monitoring, Geological Deformation
- Communications Networks and Utility Infrastructure
- Atmospheric Studies, Ionospheric and Tropospheric Modeling
- Precise Navigation, Snowplow Guidance, and Maritime Portage
- Rail, Port, Mining, and Airport Operations
- Intelligent Transportation, and Route Delineation
- Incident Mapping, Emergency Response, and Post-Event Analysis
- Environmental Mapping and Monitoring
- Disaster Preparedness, Recovery and Reconstruction
- Precise Guidance, Hazard Clearances, and Precise Geofencing
- Forensics, Scene Investigation, and Incident Mapping
- Archaeology, Restoration, and Monument Preservation
- Science, Timing, and Robotics

## VI. Drivers and Sustainability

- a) Initial investment funding
  - Single entity/agency
  - Interagency
  - Cooperative
- b) Recurring costs
  - Software maintenance
  - Staffing
  - Replacement
  - Power, leases, comms
- c) Partnering with the scientific community
- d) Partnering with geodetic reference frameworks
- e) Partnering with transportation departments
- f) Commercial hosting and partnerships

Thank You



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