Virtual Reference Stations (VRS) (RTN) **Presentad By Michael Woodel Vice President Survey Division** California Survey and Drafting Supply WWW.CSDSINC.COM

Overview

Why VRS/RTN ?
The Concept of Virtual Reference Stations
A typical network setup
Required Hardware
Data communication
VRS Performance



Classical RTK Surveying

Local reference station required
 Error growth with baseline length
 Rover/Reference distance is limited due to error growth
 Reliability and Performance decrease with distance from reference



Limitations of Classical RTK Surveying

 Limited range from single reference station Potential gross error in establishing reference station No integrity monitoring Dependency on single reference station Productivity loss Coordinate System Security **Communications FCC Power supply**



Classic RTK Example



VRS - How does it work?

Uses observations from multiple reference stations Continuously monitors integrity of reference station data Models systematic errors including:

ionosphere

- troposphere
- satellite orbit errors
- multipath

 Creates a unique virtual reference station for each user's location

Delivers the data in RTCM or CMR+ format to the rover



GPS Positioning

 Four distance measurements are needed to determine position and time





Troposphere and lonosphere affect signals





Troposphere

- Region of atmosphere where weather occurs (up to 50-80 km altitude)
- Wet and Dry component
- Varies largely based on water vapor content in the atmosphere
- Frequency independent
- Affects GPS heights



Ionosphere

Region of atmosphere 50-1000 km filled with charged particles

Creates non-linear dispersion of electromagnetic signals (frequency dependent) Varies substantially based on sunspot activity, solar flares, latitude and time of day and elevation of the satellite signal





Variable signal paths and piercing points



Satellite-Receiver Double Differences



e

What do we do about the differential lono and Tropo errors?

Keep distances between base and rover short.

- Assume that the remaining errors are the same at both base and rover
- Greater the distance is, the less likely this assumption is to be valid



What do we do about the differential lono and Tropo errors?

Model the iono and tropo

- Using observations from known stations, create a model of the biases
- Concept used for creating the broadcast models for the tracking segment of GPS
- Concept used for FAA WAAS Augmentation system on a national level
- VRS Concept



Why use VRS/RTN[™]?

Extended operating range with improved initialisation and accuracy
Increased productivity
Eliminates need to establish reference station

Set-up, power, physical security become non-issues

Provides integrity monitoring
All users in common, established coordinate frame

- Eliminates dependency on single reference station
- Uses established communications



Data Flow in Network using digital cell phone











Reference station data streams back to server through LAN, Internet, or radio links





Roving receiver sends an NMEA string back to server using cellular modem. Virtual Reference Station position is established.



Server uses VRS position to create corrected observables and broadcasts them to the rover



Rover surveying in normal RTK mode but data is relative to the VRS



CSVSN Coverage Map



Full Time Monitoring - 24/7/365

Show Operational Status (full) Show Downlime Log Show conclusional status (full) Show Downlime Log Show con	Show Operational Status (Sumin	Show Operational Status (summary)			ad scheduler state	Start so	cheduler	List Disabled Hos	ts/ Watches/ Svcs	Test Mon Config File			
Host Group Service (legged) Last Checked Est. Next Check Auburn top 4n15s 435 Berkeley top 3n40b 1n18s Livermore gind 51s 1m6s Lodi top 3n9b 1m18s Modesto top 4n15s 1m2s SatarAnni top 4n15s 1m2s SatarAnni top 4n15s 1m2s SatarAnni top 4n15s 1m2s SatarAnnia top 4n15s 1m2s SatarAnnia top 1m2s 1m2s SatarAnnias <td< th=""><th colspan="4">Show Operational Status (full) Show Downtime Lo</th><th colspan="2">Save scheduler state Stop scheduler</th><th>cheduler</th><th></th><th>List Mon PIDs</th><th>Reset Mon</th></td<>	Show Operational Status (full) Show Downtime Lo				Save scheduler state Stop scheduler		cheduler		List Mon PIDs	Reset Mon			
Auburn Isg 4a13 432 Berkeley Isg 3a40s 1inlis Livermore jaas 3a40s 1inlis Livermore jaas 3a40s 1inlis Lodi Kop 3a50s 1inlis Modesto Isg 3a50s 1inlis Modesto Isg 3a50s 1inlis MorganHill Isg 4m14s 444s BaloAlto Isg 3a7s 1inlis Sacramento Isg 3a7s 1inlis Saramento Isg 4m14s 445 SataRosa Isg 4m15s 40s SataRosa Isg 4m2s 3a58 ShingleSprings Isg 4m2s 3a69s 1inlis Turlock Isg 4m2s 3a64s 1inlis VSNServer2 Isg 4m2s 4m2s 3m2s Vacaville Isg 4m2s 1inlis 1inlis VoldaCity Isg 22s 23s 1inlis VubaCity Isg													
Berkeley top 3a40s 1mits Livermore ping 31s 1mits Lodi top 3mits 1mits Modesto top 3mits 1mits Modesto top 3mits 1mits MorganHill top 4mits 4mits PaloAlto top 3mits 1mits Sacramento top 3mits 1mits SartaRosa top 3mits 4mits ShingleSprings tap 3mits 1mits VSNServer2 top 3mits 1mits VSNServer2 top 3mits 1mits Voodland tains 1mits 1mits ValaCity tap 3mits 1mits ValaCity tap 3mits 1mits ValaCity tap 3mits 1mits Show Operational Status (summary) Show Alett History Iandachediletaste Show Operational Status (summary) Show Alett History Iandachediletaste	Host Group		Serv	ice (lege	end)		L	ast Checked	Est.	Next Check			
Livermore ping 51s tim5s Lodi top 3m39s tim19g Modesto top 3m30s tim28 MorganHill top 4m14s tim28 PaloAlto top 3m37s tim13s Saramento top 3m37s tim29 Saramento top 3m37s tim29 Saramento top 3m37s tim29 Saramento top 3m37s tim29 Saramento top 4m14s tim29 Saramento top 4m19s tim29 Saramento top 4m2s tim29 VSNServer2 top 3m2s tim29 Vacavilie top <td>Auburn top</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>-4m15s</td> <td></td> <td>+43s</td> <td></td>	Auburn top						-4m15s		+43s				
Lodi ssp 3m3% 1m19s Modesto ssp 3m3% 1m19s Modesto ssp 3m3% 1m28s MorganHill ssp 4m14s 44s PaloAlto ssp 3m37s 1m21s Saramento ssp 3m37s 1m21s Saramento ssp 3m37s 1m28s SantaCruz ssp 4m2s 1m28s SantaRosa ssp 4m2s 1m2s ShingleSprings ssp 4m9s 1m8s Turlock ssp 4m6s 1m3s VSNServer jmas 4m6s 1m3s VSNServer2 ssp 4m0s 1m3s Vacaville ssp 4m0s 1m3s Vacaville ssp 4m0s 1m3s VubaCity ssp 2m3s 1m3s VubaCity ssp 2m3s 1m3s Show Operational Status (summary) Show Aleft History Lond seteller sale Statuschedider List Disabled Hosts/Watches/Svcs TeclMon Condig His	Berkeley top	2					-3m40s		+1m18s				
Modesto trp sm30s tm28s MorganHill trp 4m14s t44s PaloAlto trp sm37s tm21s Sacramento trp sm29s tm29s SantaCruz trp sm29s tm29s SantaRosa trp 4m18s 40s SantaRosa trp 4m2s s38s ShingleSprings trp 4m2s s38s Turlock trp sm49s tm9s VSNServer fmg 4m6s s22s VSNServer2 trp sm26s tm32s Vacaville trp 4m0s t99s Voodland fmg 4m0s t99s YubaCity trp 22s t37s VubaCity trp 22s t37s Show Operational Status (summary) Show Alert History Load scheduler state Shot scheduler tiste List Disabled Hosts//Watches/ Svrcs Test Mon Contig File	Livermore ping	g					-51s		<u>+1m8s</u>				
MorganHill isp 4m14s 445 PaloAlto isp 3m37s 1m21s Sacramento isp 3m29s 1m29s SantaCruz isp 4m18s 449s SantaRosa isp 4m18s 449s SantaRosa isp 4m19s 58s ShingleSprings isp 3m49s 1m09 Turlock isp 4m6s 52a VSNServer fping 4m6s 52a VSNServer2 isp 4m2s 4m2s Vacaville isp 4m2s 3m26s 1m3z Vacaville isp 4m2s 23s 23s VubaCity isp 4m2s 3m26s 1m3z VubaCity isp 4m2s 23s 23s VubaCity isp 22s 23s 23s YubaCity isp 3cond failed (no alerts sent) failed josabled Moodiand Show Alert History Load scheduler shote Shot scheduler List Disabled Hosts/ Watches/ Svcs Text Mon Config Filed </td <td>_odi tep</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>-3m39s</td> <td colspan="2">-3m39s</td> <td></td>	_odi tep						-3m39s	-3m39s					
PaloAto top 3m37s +im21s Sacramento top 3m37s +im21s SantaCruz top 4m18s +40s SantaRosa top 4m21s +38s ShingleSprings top 4m19s +40s Turlock top 4m19s +40s VSNServer fpings +1m2s +40s VSNServer2 top 4m6s +22s VSNServer2 top	Modesto top						-3m30s	-3m30s		<u>+1m28s</u>			
Sacramento tep 3m29s 1m29s SantaCruz tep 4m18s 4d9s SantaRosa tep 4m22s 338s ShingleSprings tep 3m49s 1m9s Turlock tep 4m6s 52s VSNServer fping 4m0s 52s VSNServer2 tep 3m26s 1m32s Vacaville tep 4m0s 53s Voodland fping 4m0s 53s YubaCity tep 22s 537s Vacaville tep 22s 537s Service color legend: Unchecked Good Failed (no alerts sent) Disabled (alerts sent) Show Operational Status (summary) Show Alert History Load scheduler state Stat scheduler List Disabled Hosts/Watches/ Svcs Teat Mon Config Falled	MorganHill tcp						-4m14s		<u>+44s</u>	+44s			
SantaCruz top 4m18s 4d0s SantaRosa top 4m22s 384 ShingleSprings top 3m49s 1m0s Turlock top 4m19s 4m0s VSNServer fning 4m6s 52g VSNServer2 top 3m26s 1m32s Vacaville top 4m0s 1m32s Vacaville top 4m0s 138d Voodland fning 22s 137s YubaCity top 22s 137s Service color legend: Unchecked Good Failed (no alerts sent) Disabled (alerts sent) Disabled Show Operational Status (summary) Show Alert History Load scheduler state Start scheduler List Disabled Hosts/ Watches/ Svcs Test Mon Conling Felle	PaloAlto top						-3m37s	-3m37s		+1m21s			
SantaRosa top 4m22s 138s ShingleSprings top 3m49s 11m9s Turlock top 4m19s 4d0s VSNServer fping 4m6s 522s VSNServer2 top 3m26s 11m32s Vacaville top 4m0s 538s Voodland fping 4m0s 538s YubaCity top 4m0s 538s Vacaville top 4m0s 538s YubaCity top 4m0s 538s Vinchecked Good Failed (no alerts sent) Failed (alerts sent) Disabled Show Operational Status (summary) Show Alert History Load scheduler state Stat scheduler List Disabled Hosts/Watches/ Svcs Test Mon Config Fiele	Sacramento top						-3m29s		<u>+1m29s</u>	+1m29s			
ShingleSprings top 3m49s ±1m9s Turlock top 4m19s ±40s VSNServer fping 4m6s ±22s VSNServer2 tsp 3m26s ±1m32s Vacaville tsp 4m0s ±99s Woodland fping 4m0s ±58s YubaCity tsp 22s ±37s Voodland fping 500d Failed (no alerts sent) Failed (alerts sent) Disabled YubaCity tsp 500d Failed (no alerts sent) Disabled 500d Service color legend: Unchecked Good Failed (no alerts sent) Disabled 500d Show Operational Status (summary) Show Alert History Load scheduler state Stat scheduler List Disabled Hosts/Watches/ Svcs Test Mon Conlig Fel	SantaCruz top						-4m18s		<u>+40s</u>	+40s			
Turlock tsp 4m19s +40s VSNServer fping 4m6s 52s VSNServer2 tsp 3m26s +1m32s Vacaville tsp 4m0s +39s Woodland fping 4m0s +59s YubaCity tsp 4m0s +59s YubaCity tsp 22s +37s Service color legend: Unchecked Good Failed (no alerts sent) Disabled Service color legend: Unchecked Good Failed (no alerts sent) Disabled Show Operational Status (summary) Show Alert History Load scheduler state Stat scheduler List Disabled Hosts/Watches/ Svcs Test Mon Conlig Fele	SantaRosa top						-4m22s		<u>+38s</u>	<u>+38s</u>			
VSNServer fping 4m6s ±22s VSNServer2 tsp 3m26s 11m32s Vacaville tsp 4m0s ±39s Vacaville tsp 4m0s ±39s Woodland fping 4m0s ±58s YubaCity tsp 22s ±37s YubaCity tsp 10nchecked Good Failed (no alerts sent) Failed (alerts sent) Disabled Service color legend: (top of table) Unchecked Good Failed (no alerts sent) Ist is Disabled Hosts/Watches/ Svcs Test Mon Conlig File	ShingleSprings top							-3m49s		+ <u>1m9s</u>			
VSNServer2 tcp 3m26s ±1m32s Vacaville tcp 4m20s ±399s Woodland fping 4m0s ±58s YubaCity tcp 22s ±37s Service color legend: Unchecked Good Failed (no alerts sent) Failed (alerts sent) Disabled Show Operational Status (summary) Show Alert History Load scheduler state Statt scheduler List Disabled Hosts/Watches/ Svcs Test Mon Conlig File	Turlock top	tcp					-4m19s		+40s	+40s			
Vacaville tcp 4m20s ±39s Woodland fping 4m0s ±38s YubaCity tcp 22s ±37s Service color legend: Unchecked Good Failed (no alerts sent) Failed (alerts sent) Disabled Show Operational Status (summary) Show Alert History Load scheduler state Statt scheduler List Disabled Hosts/ Watches/ Svcs Test Mon Config File	/SNServer fpin	fping						-4m6s		<u>+52s</u>			
Woodland fping 4m0s 458s YubaCity tep 22s 437s Service color legend: Unchecked Good Failed (no alerts sent) Disabled Stow Operational Status (summary) Show Alert History Load scheduler state Statt scheduler List Disabled Hosts/ Watches/ Svcs Test Mon Config File	SNServer2 top						-3m26s		<u>+1m32s</u>	<u>+1m32s</u>			
YubaCity top 22s ±37s Service color legend: Unchecked Good Failed (no alerts sent) Disabled (top of table) Image: Color legend:	/acaville top							-4m20s					
Service color legend: Unchecked Good Failed (no alerts sent) Failed (alerts sent) Disabled Show Operational Status (summary) Show Alert History Load scheduler state Start scheduler List Disabled Hosts/ Watches/ Svcs Test Mon Conlig File		fping					-4m0s						
Service color legend: Unchecked Good (no alerts sent) Disabled (top of table) Image: Color legend:	/ubaCity top	2					-22s		<u>+37s</u>	<u>+37s</u>			
Show Operational Status (summary) Show Alert History Lead scheduler state Start scheduler List Disabled Hosts/ Watches/ Svcs Test Mon Config File			end:	Unchecked Good					Disabled				
	Show Operational Status (sum	nmary)	Show Alert Histo		Load scheduler sta	te Sta	rt scheduk	er List Disabled Ho	sts/Watches/ Svcs	Test Mon Config File			
					Save scheduler sta	te Sto	n schedule	er Reload auth file		Reset Mon			



Online Helpdesk

Welcome to the	California Survey V	irtual Survey Network Helpo	<u>lesk</u>						
Home Products Support	Logout Ticket-Overview New Ticket FAQ Preferences Welcome Demo User (demo@csvsn.com/csvsn01)								
Online-Support	Ticket-Overview								
Contact	Ticket 1 - 0 of 0 - Site: - (Sh	ow closed Tickets)							
	Ticket# <u>U</u> / <u>D</u>	Age <u>U</u> / <u>D</u>	Subject	State <u>U</u> / <u>D</u>	Queue <u>U</u> / <u>D</u>	Owner <u>U</u> /D			
CSDS Inc.	www.csvsn.com								

Powered by CSDS Inc. I.S. Department

irimble

Real-Time Test Setup in the Network

- Operation of rover (32 km from the nearest reference station)
- After each fix the RTK system outputs position data for 30 seconds
- After that the RTK system initializes the ambiguity search again, no data from the past is used
- All position output is stored on an extra PC and analyzed statistically



VRS Performance Analysis



70 km



Error in North – 32 km Baseline





Error in East – 32 km Baseline





Error in Height – 32 km Baseline



Trimble

RTK Initialization – 32 km Baseline





Initialisation Times in the SAPOS Network





Advantages of VRS/RTN[™]

Extended operating range with improved initialisation and accuracy
Increased productivity
Eliminates need to establish reference station

Set-up, power, physical security become non-issues

Provides integrity monitoring
All users in common, established coordinate frame
Eliminates dependency on single reference station

Uses established communications Cellular data



GPS Deformation Monitoring

Purpose:

To monitor and model the movement of man made and natural structures to prevent and warn against potential catastrophes using GPS and integrated sensors.
 To monitor the integrity of high order geodetic networks





GPS Deformation Monitoring

Target Markets
Oilfield Subsidence
Dam deformation monitoring
Landslide monitoring
Volcano monitoring
Geodetic network monitoring





