IGS

SESSION 8

GPS INSTRUMENTATION OVERVIEW

First Dual Depth Dual Frequency Choke Ring Design

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Javad Positioning Systems

Introduction

In all existing choke ring designs the multipath rejection is optimized for L2 signal with much less effectiveness for L1. From this point of view, all known designs can be called as single frequency ground planes. Based on the new approach using numeric rigorous solution of the electromagnetic boundary problem, JPS launches the new design with the grove depth different for L1 and L2 signals.

Background

Being mounted in the center of the ground plane, the antenna receives the direct satellite signal and the signal reflected from the Earth surface. The impact of the ground plane on the direct signal is important only for low elevation angles near the horizon direction. For these angles, the impact of the ground plane leads to decreasing antenna's gain. For other directions in the upper semi-sphere, this impact is small and the choke ring ground plane works almost like the flat one. The main purpose of the choke ring ground plane is to eliminate the electromagnetic wave reflected from the Earth surface.

As it follows from the electromagnetic diffraction theory the electromagnetic field of the reflected signal in the vicinity of the choke ring ground plane can be considered as a sum of two field waves. One of them is a field wave surrounding the ground plane along an imaginary conductive surface S (Fig1). This surface attaches to the top edges of groves and continues to the backside of the ground plane. This wave is the same as the reflected wave in flat ground planes. We can call it the "primary" wave. The second wave is created by the electromagnetic field of the groves. We call this wave the "secondary" wave.

Likewise, the electromagnetic field in the groves can be considered as a sum of two waves (Fig1). The first one propagates from the top edges of the groves towards their bottom, and the second one propagates from the bottom towards the grove open ends. The first wave is exited by the above mentioned primary wave, and the second wave is the field reflected by the grove's bottom. This second wave causes the above-mentioned secondary wave.

The secondary wave like the primary one propagates along the ground plane towards the antenna and contributes to the total signal together with the direct signal from the satellite to the antenna. The objective of choke ring ground plane is for primary and secondary parts of reflected signal to substantially cancel each other and the direct signal to remain as the dominant one.

The phase relationship between the primary and secondary reflected waves at the antenna output depends on the difference in path lengths that each wave travels. The path difference is twice as much as. The amplitude ratio of the two waves depends on the characteristics of the antenna's element, its location on the ground plane, the width and the number of the groves, etc.

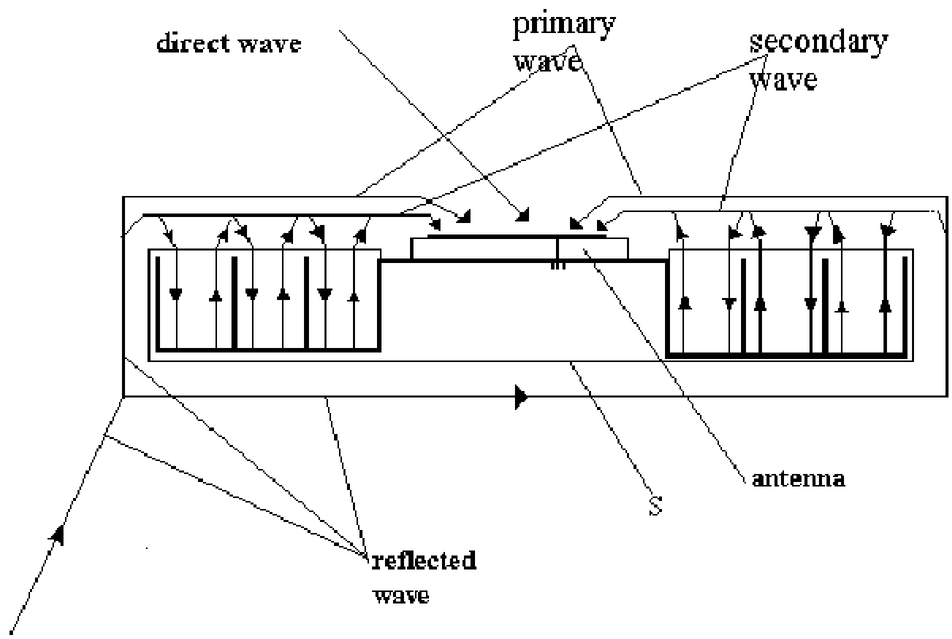

Figure 1. Schematic view of wave propagation in the ground plane vicinity the grove depths

If the amplitude of primary and secondary waves are equal and phase difference between them is 180 degrees, then two components of the reflected signal cancel each other at the antenna's output, so that multipath is suppressed.

As it follows from the said above, the grove depth has to be approximately equal to $\lambda/4$, where λ is wavelength. If it is less than the said distance the creation of a surface wave becomes possible. This wave will propagate along the grove structure if the depth is smaller than $\lambda/4$. The surface wave can destroy the required phase and amplitude ratios between primary and secondary waves and create resonance effects. That is why in the known designs the grove depth was a little bigger than $\lambda/4$.

Therefore, the grove depth depends on the wavelength of the intended signal and can be optimized for the intended frequency. As a result, in all existing choke ring designs the multipath rejection is optimized for L2 signal, the effectiveness being less for L1 signal.

Description of the New Design

In Fig.2, ground plane with slot filter in each grove is depicted.

For better performance in L1 band, here the new construction in each grove is arranged. Such a construction acts effectively as electromagnetic filter that reflects L1 signal (Fig2a) and passes waves of L2 signal (Fig2b). Therefore, grove depths become different for L1 and L2 signals. For L1 signal, it will be equal to the distance from grove open ends up to the said construction, and for L2 signal, it will be equal to the total grove depth. Therefore, multipath rejection can be optimal for both L1 and L2 signals. The main features of the filter construction are depicted in Fig.3. The electromagnetic filter includes a conductive ring (301) connected to the two grove walls (302), apertures (303) or "slots"

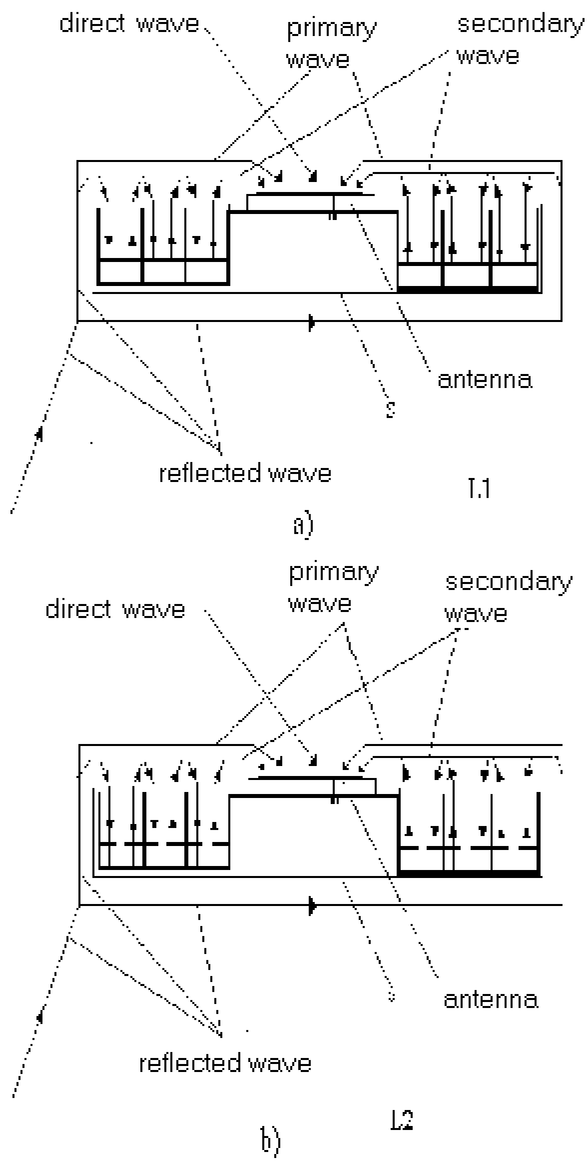

Figure 2. The ground plane with a slot filter in each grove

One end of each stub is shorted to the conductive ring near the slot edge and another end can be shorted or opened. The feeding network (304) can be made of pieces of wires or as the microstrip circuit arranged on the single-layer-PC-board. In the last case, the said boards are mounted in the vicinity of slots (303). All the filter structure can be made on the base of the microstrip technology. In this case, the filter is the dual-layer-PC board. One layer is a metal ring with slots (303), and another layer includes the microstrip network (304).

A system of slots (303) of each filter together with the network (304) is tuned to be transparent for L2 signal. For L1 band slots (303) are shorted by means of the network (304), so the conductive ring (301) acts as the solid one. It becomes the grove's bottom for L1.

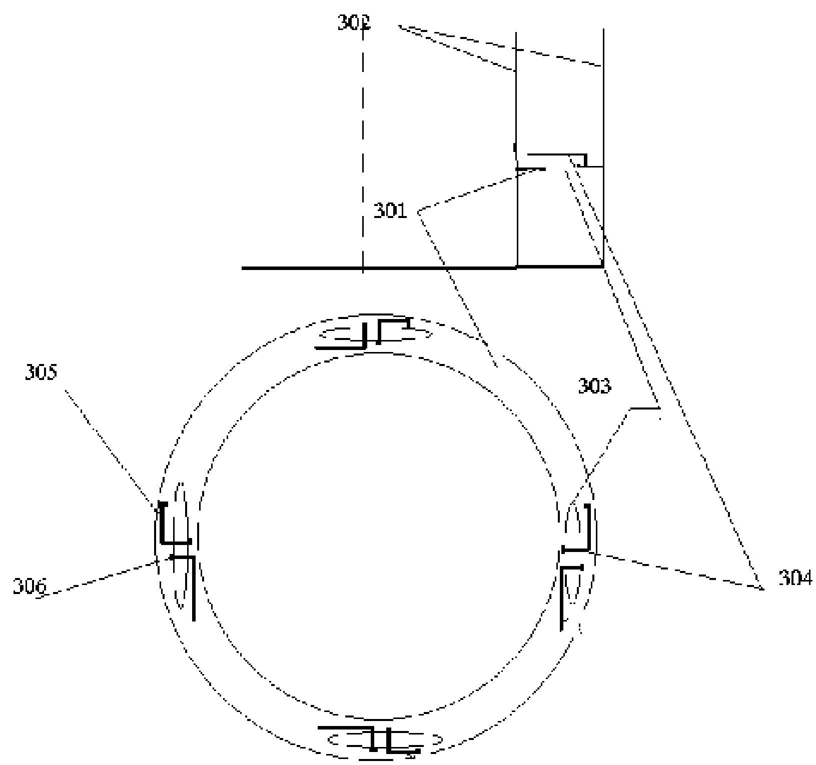

Figure 3. The main features of the filter construction

The dual frequency operation of the network (304) can be obtained as follows. One stub (for example, 305) must have zero input impedance near the slot for L1 frequency. If the opposite from slot end of this stub is shorted to the conductive ring, its length has to be $\lambda_{L1}/2$, where λ_{L1} – the wavelength of L1 signal. If the opposite end opened, then the length of this stub has to be $\lambda_{L1}/4$. The said stub shorts the slot for L1 signal. The length of another one (306) is chosen to make the entire system transparent for L2. The opposite from slot end of this stub can be shorted or opened. For better operation, several pairs of stubs can be connected to the each slot.

Total ground plane dimensions and grove depths like slot dimensions and the network (304) structure were chosen to obtain the necessary behavior within L1 and L2 bands. This was done numerically with the use of the electrodynamic wave analysis of the entire system.

Measured and Calculated Results

The new ground plane was created for the dual- frequency dual-system performance (L1-L2 GPS-GLONASS). It is 320mm in diameter with 3 groves of 22mm width each. The depth of groves is 60mm. The center part of the ground plane is 190mm in diameter. The antenna is put at the bottom of cylindrical tube (a piece of circular wave-guide) at the distance 20mm from the top. This ground plane is optimal for L2 and has comparatively well, but not optimal performance within L1 band.

So, the grove depth of this ground plane is smaller than the quarter of wavelength at low part of L2 band.

In Fig. 4 charts of Down/Up-behavior via the angle between the direction to a satellite and zenith is depicted.

It can be seen that the performance for the L2 signal is by 6-8dB better than for L1 signal. For comparison, the performance of the GPL choke ring with Dorn@Margolin antenna is shown also by dotted lines.

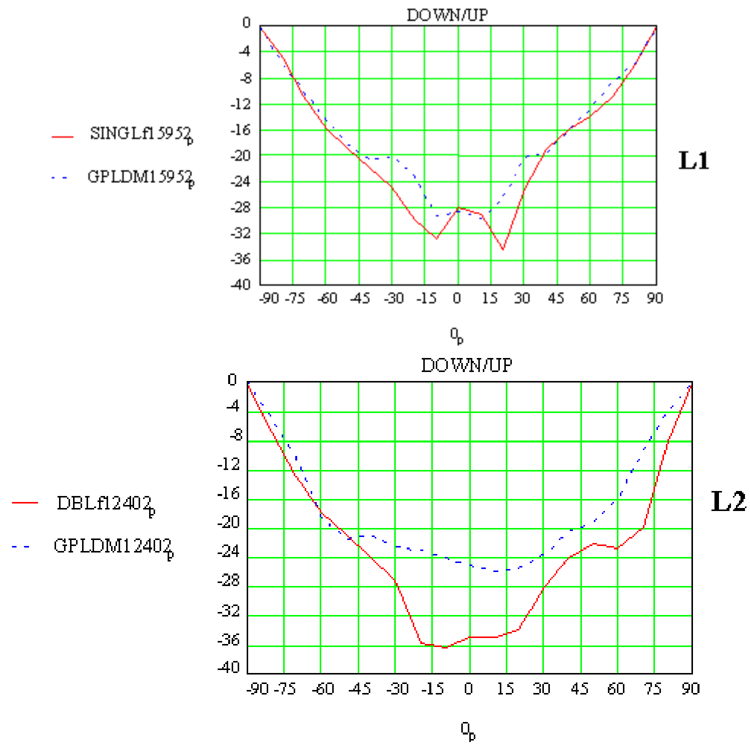

Figure 4. Charts of Down/Up behavior via angle between direction to satellite and zenith

In Fig.5, the measured Down/Up-behavior of the same ground plane in L1 is depicted. The parameter of the chart is the grove depth. It can be seen that if the depth is smaller than 42mm, then the multipath rejection becomes worse because of the excitation of the surface wave. If the depth is bigger than 50mm, then the multipath rejection becomes worse also because of the wrong secondary wave phase. The optimal depth is 48+-3mm. This result shows that demands for the distance between the slot filter and the grove edges are not too rigorous.

So, the slot filter has to be arranged at ≈48mm distance from grove edges. The distance between the filter and the grove bottom will not exceed 12mm.

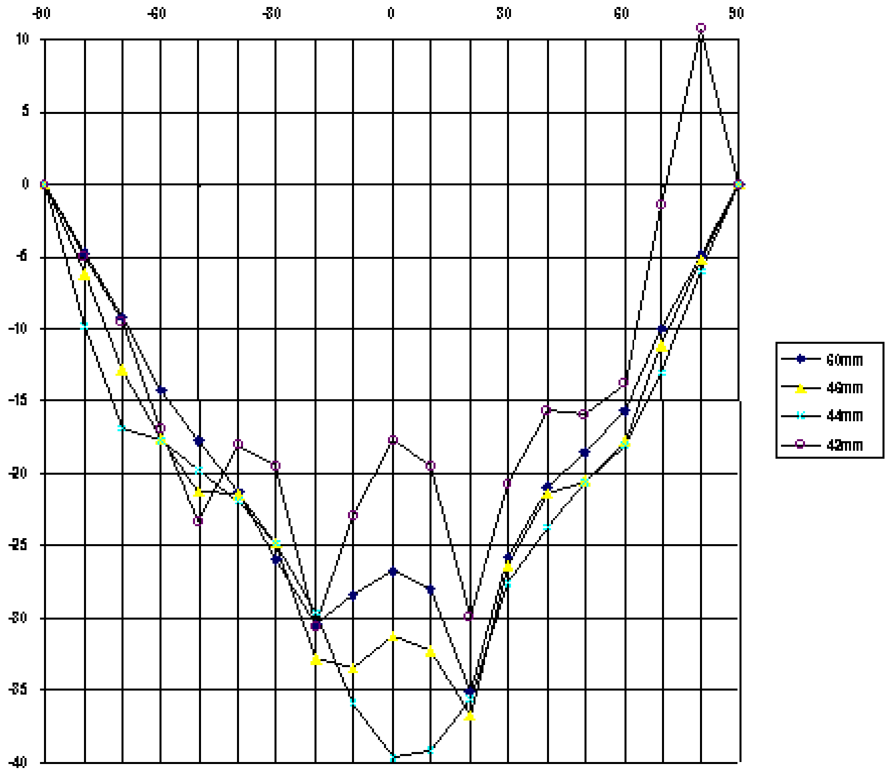

Figure 5. Measured Down/Up behavior of the same ground plane

In Fig.6 the difference in behavior of two ground planes for L1 signal is shown. One ground plane was described above in the text. It is tuned for L2 signal. Another one is of the same dimensions but optimally tuned for L1 by the proper choice of the grove depth. It can be seen that for some angles the difference is as much as 12dB.

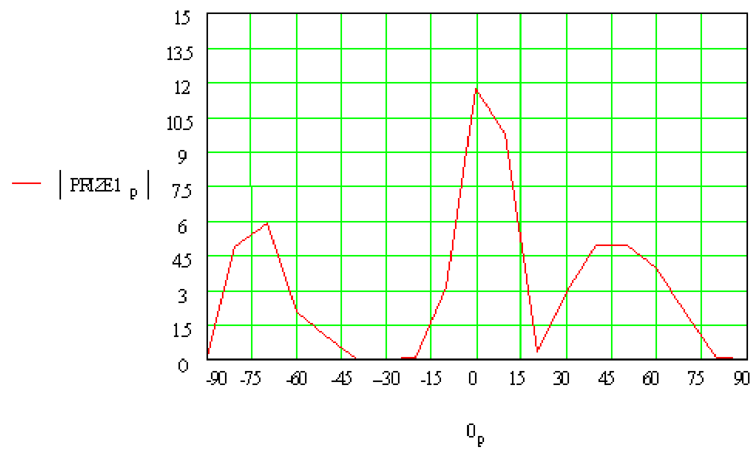

Figure 6. The difference between two ground planes behavior for L1 signal

In Fig.7 the general view of the dual-frequency dual- system ground plane with filters is depicted.

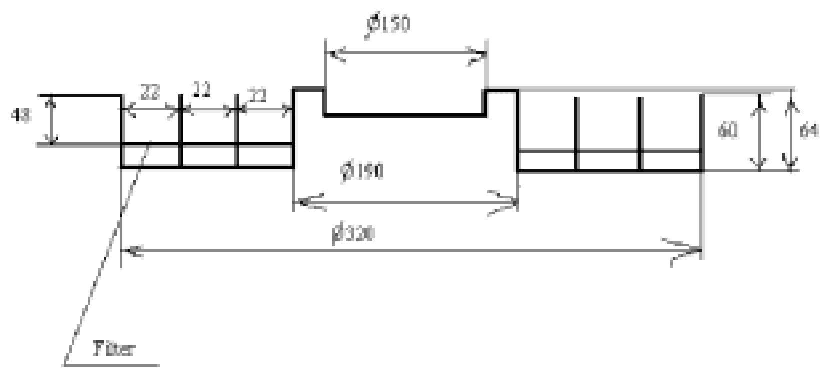

Figure 7. General view of dual- frequency dual- system ground plane with filters

To get such filter parameters as slots' lengths, their radius and the distance from filters to the bottom (the height of the diaphragm placement) of each grove of the choke ring were represented as a piece of the shorted coax wave-guide with a diaphragm. As it was shown above the exciting field in coax wave-guide is a falling TE_{11} mode. As the result of numerical analysis, the phase of the reflection coefficient of this mode at the point of coax opening was calculated. To provide dual band operation this phase in L1 band should be the same as for the shorted piece of coax wave-guide of length 48 mm without the diaphragm. In L2 band, this phase should be the same as for a piece of coax wave-guide with length of 60 mm. The number of slots on each diaphragm was chosen to cut-off coax wave-guide modes that are higher than TE_{11}. So in the first grove diaphragm there are 6, in the second one, there are 8, and in the third there are 10 slots. Two stubs were inserted into each slot. One of them shorts the slots in L1 band, while in L2 band two stubs help to make slot transparent.

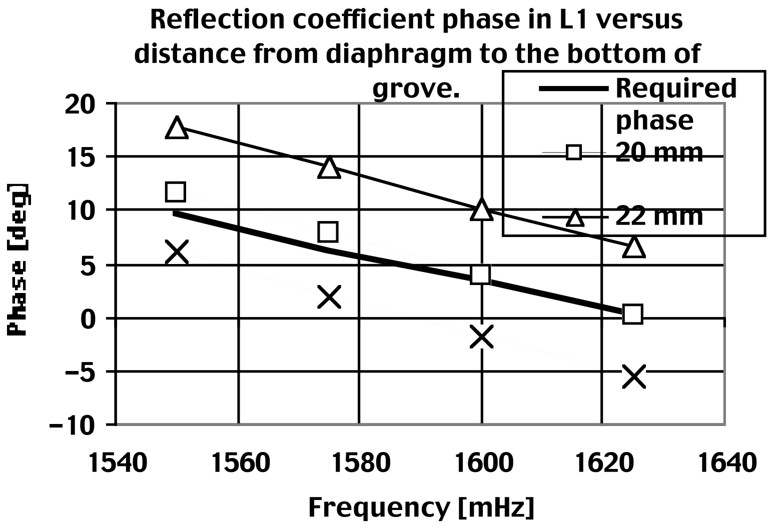

Figure 8. Reflection coefficient tuning by changing diaphragm height.

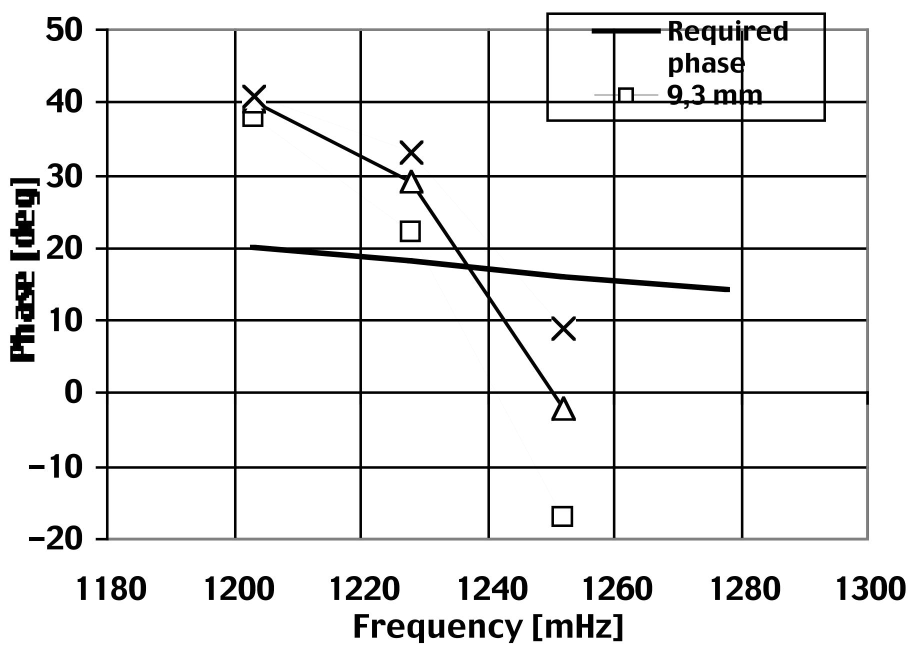

Figure 9. Measured Down/Up ratios for several diaphragm heights

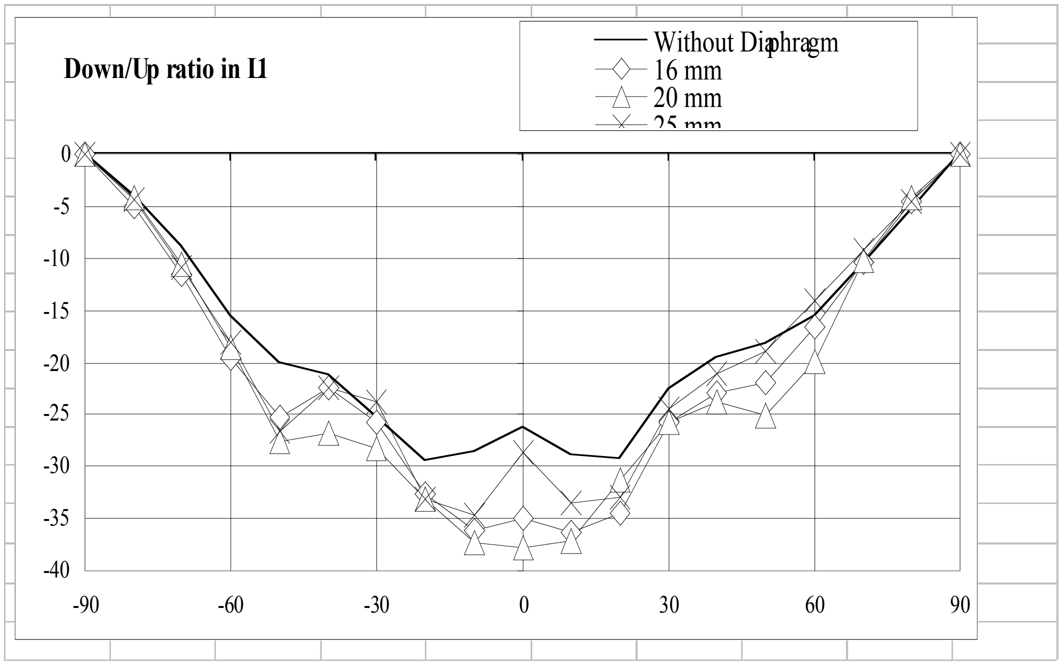

Figure 10. Reflection coefficients phase in L2 versus stub length. Height of the diaphragm is equal to 20 mm

Though one of stubs provides zero impedance at the center of the slot, the impact of the shorted slot on reflection coefficient phase is not negligible. Therefore, for providing the required phase one should increase the distance between the diaphragm and the grove bottom. Fig. 8 shows the reflection coefficient tuning by changing the diaphragm height. The required phase (smooth line) corresponds to the grove of depth of 48 mm without diaphragm. As one can see, the appropriate height of the diaphragm is 20 mm. Fig.9 shows measured Down/Up ratios for several diaphragm heights. As one can see, the best Down/Up ratio corresponds to the calculated height of 20 mm The length of the second stub is tuned to provide the required phase of the reflection coefficient in L2 band. Fig.10 shows that the appropriate stub length is equal to 9 mm. With this length of the stub the diaphragm is transparent and Down/Up- ratio is the same as in the original choke ring with the depth of the grove 60 mm.

Reference

1. T. Hekmat, N. Nilass, M. Maurer "Integrated GPS/GLONASS Antenna for High Performance Applications "ION GPS-95 Meeting September 12-15, 1995.

*This presentation would not have been possible without supports and great work of my co-authors and colleaques: V. Filippov, D. Tatarnicov, A. Astakhov, and I. Sutiagin (Javad Positioning Systems).

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3S Navigation Products Overview

November 4, 1998

The R-100 Family

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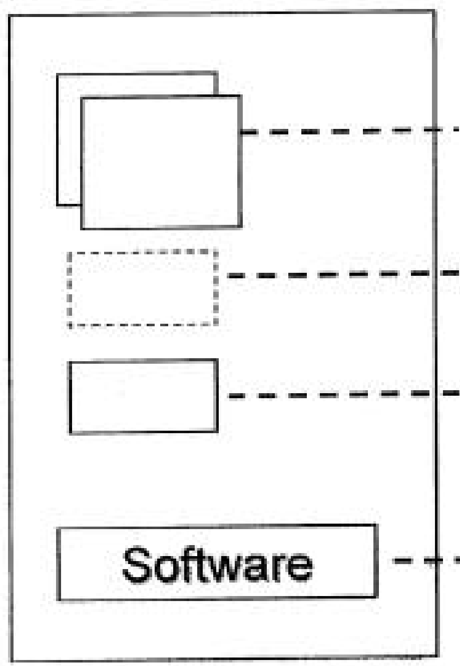

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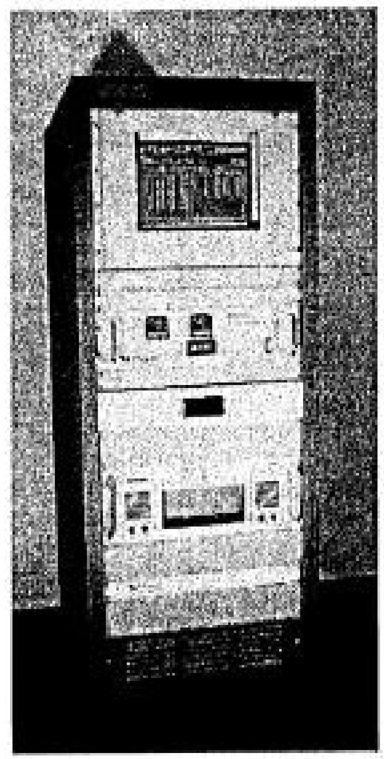

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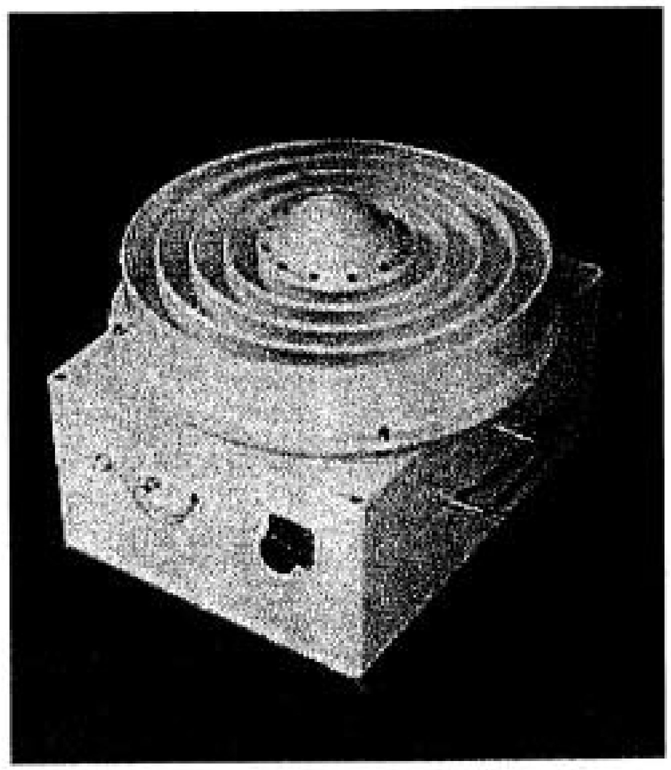

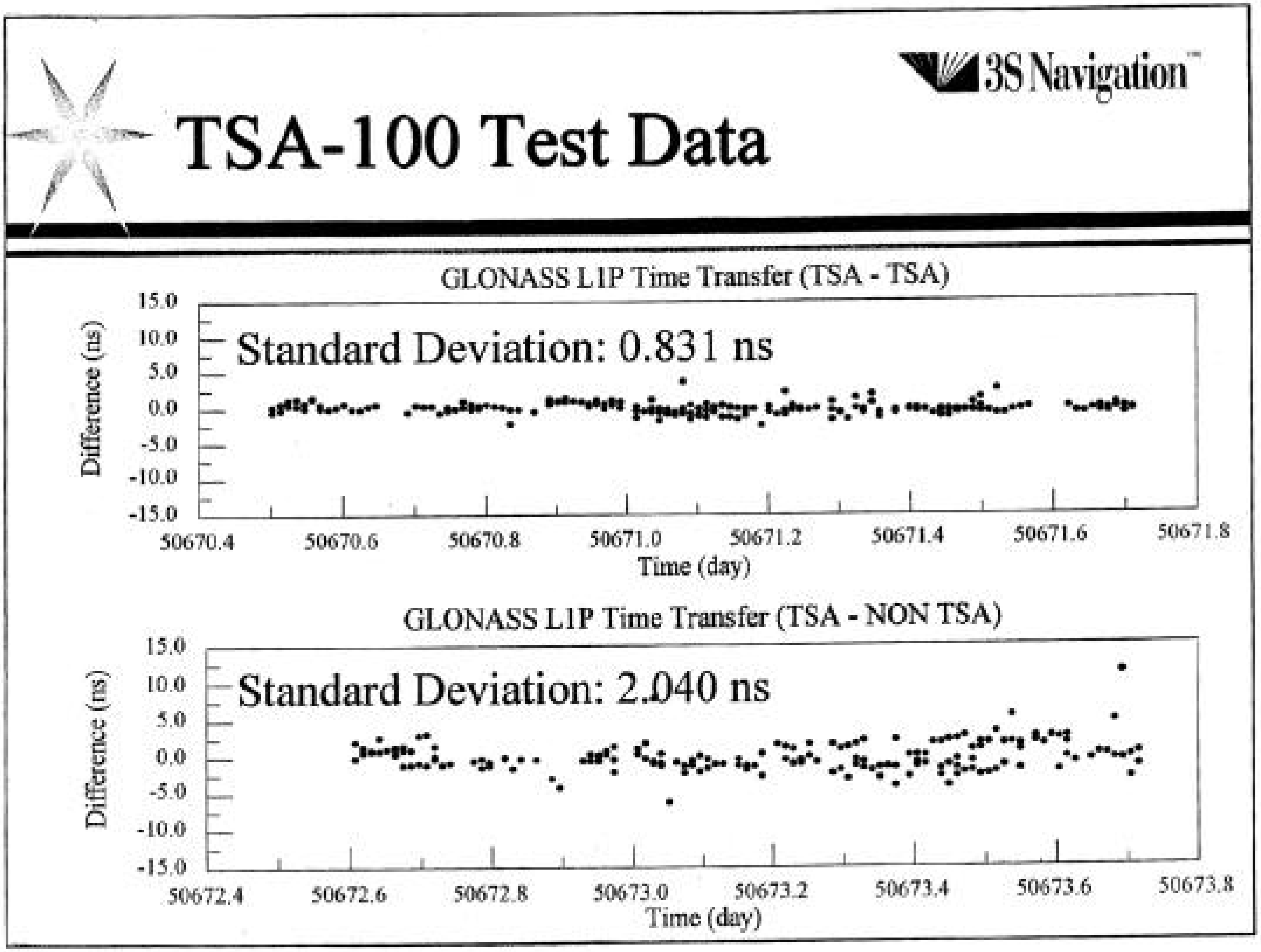
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TSA-100 Test Data
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Standard Deviation: 0.831 ns
Difference (ns)
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50670.8
50671.0
50671.2
50671.4
50671.6
50671.8
Time (day)
GLONASS L1P Time Transfer (TSA - NON TSA)
Standard Deviation: 2.040 ns
Difference (ns)
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-5.0
-10.0
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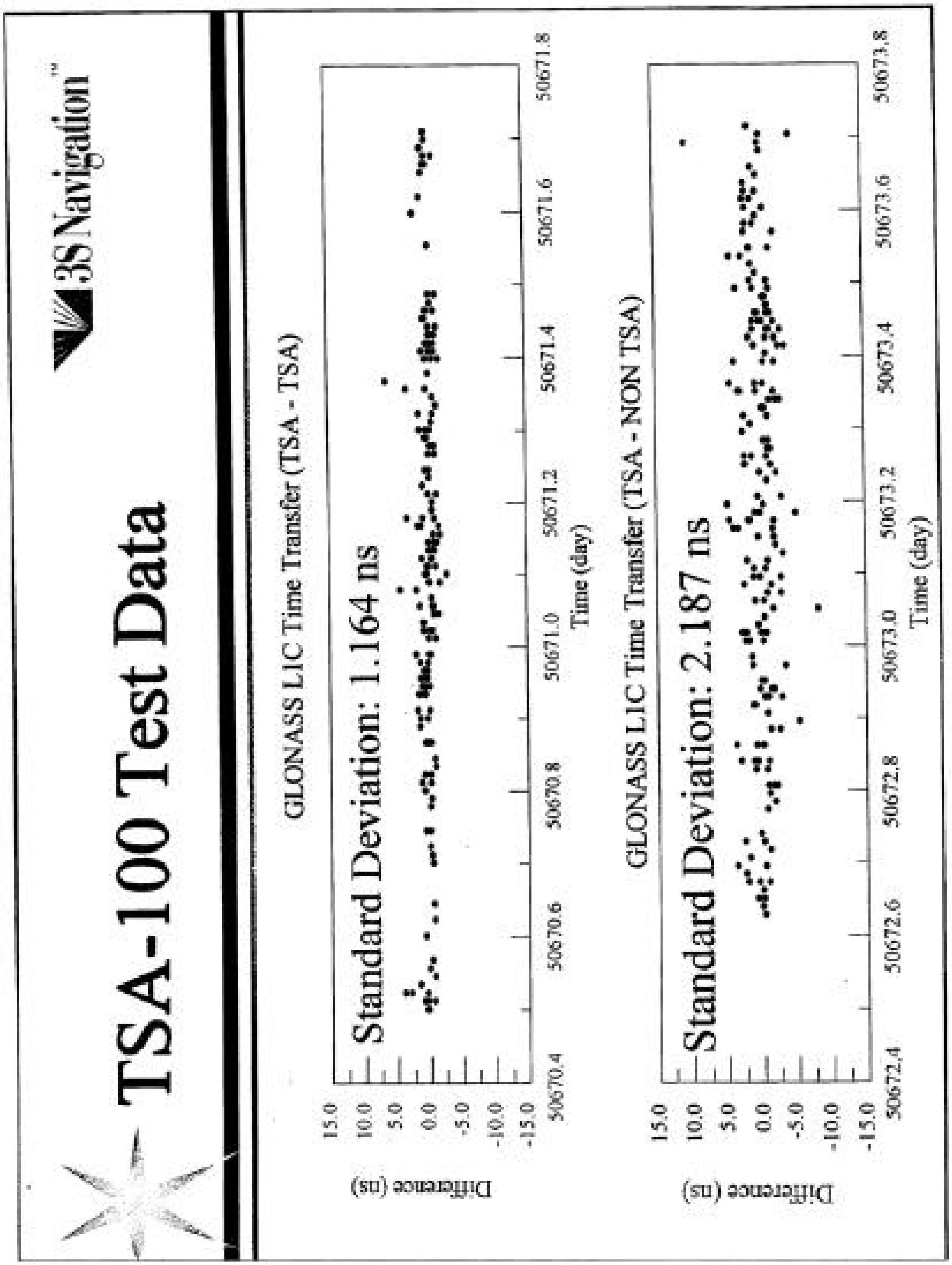
Time (day)


TSA-100 Test Data
3S Navigation™
GLONASS L1C Time Transfer (TSA - TSA)
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TSA-100 Test Data

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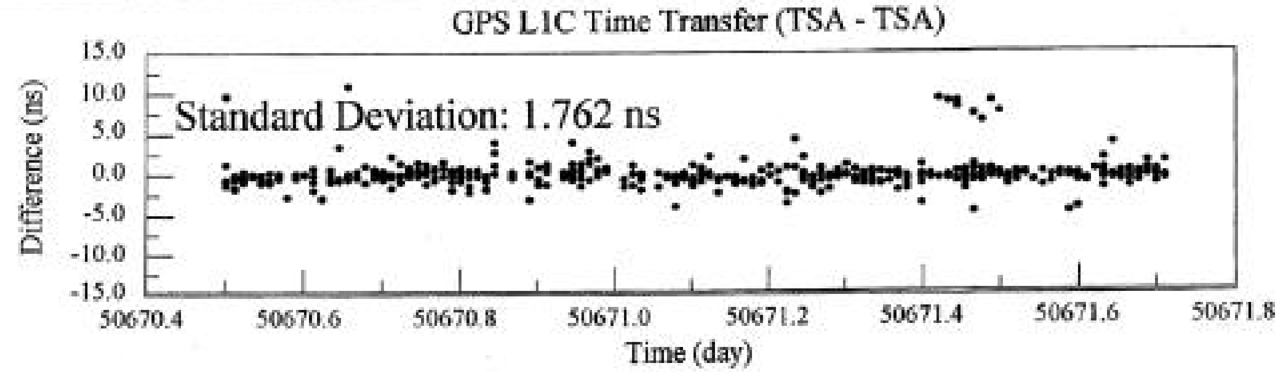

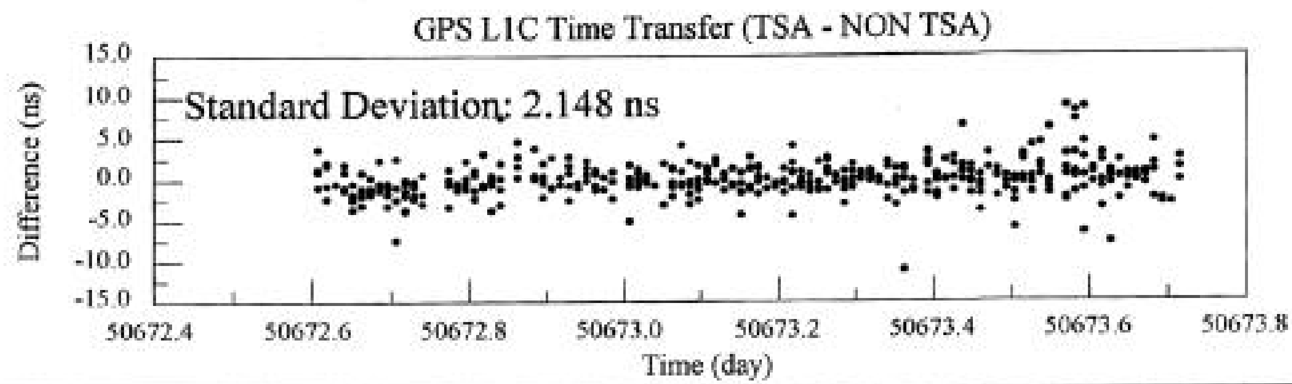

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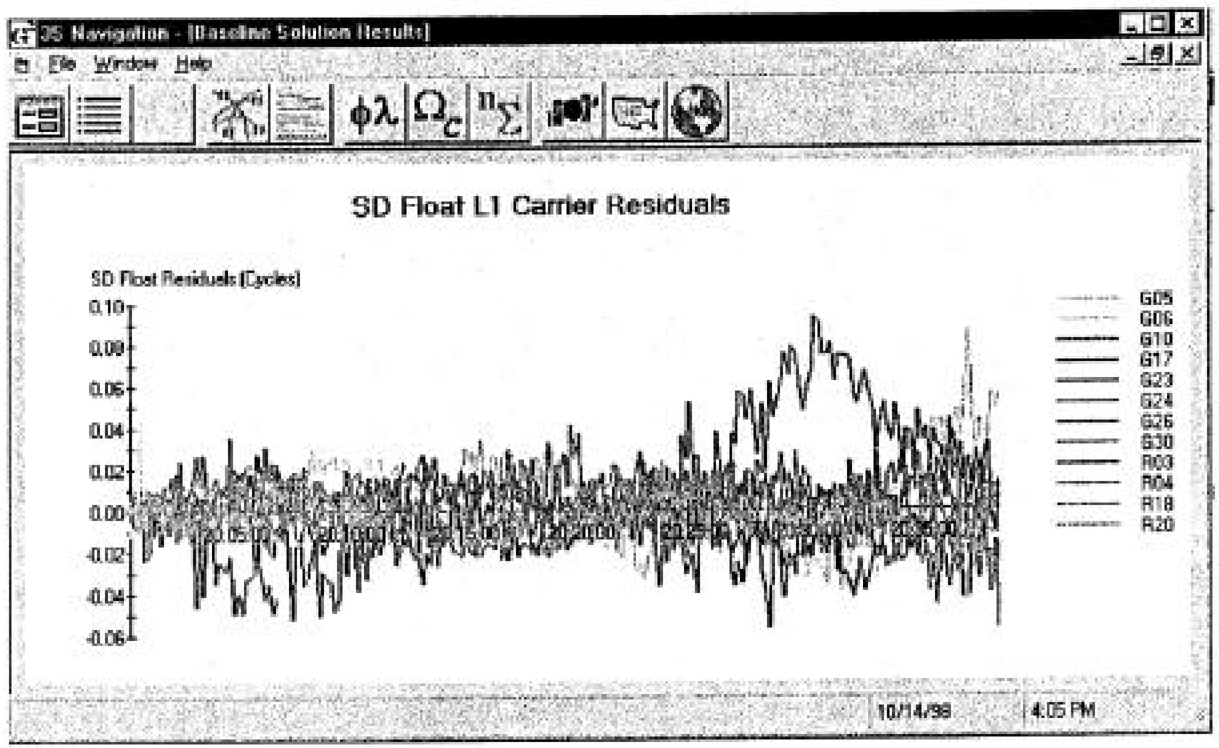

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Where are we going?
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weighed in excess of 25 pounds
took a truck to move
took 24 hrs to achieve cm level precision
cost $100,000 to $150,000
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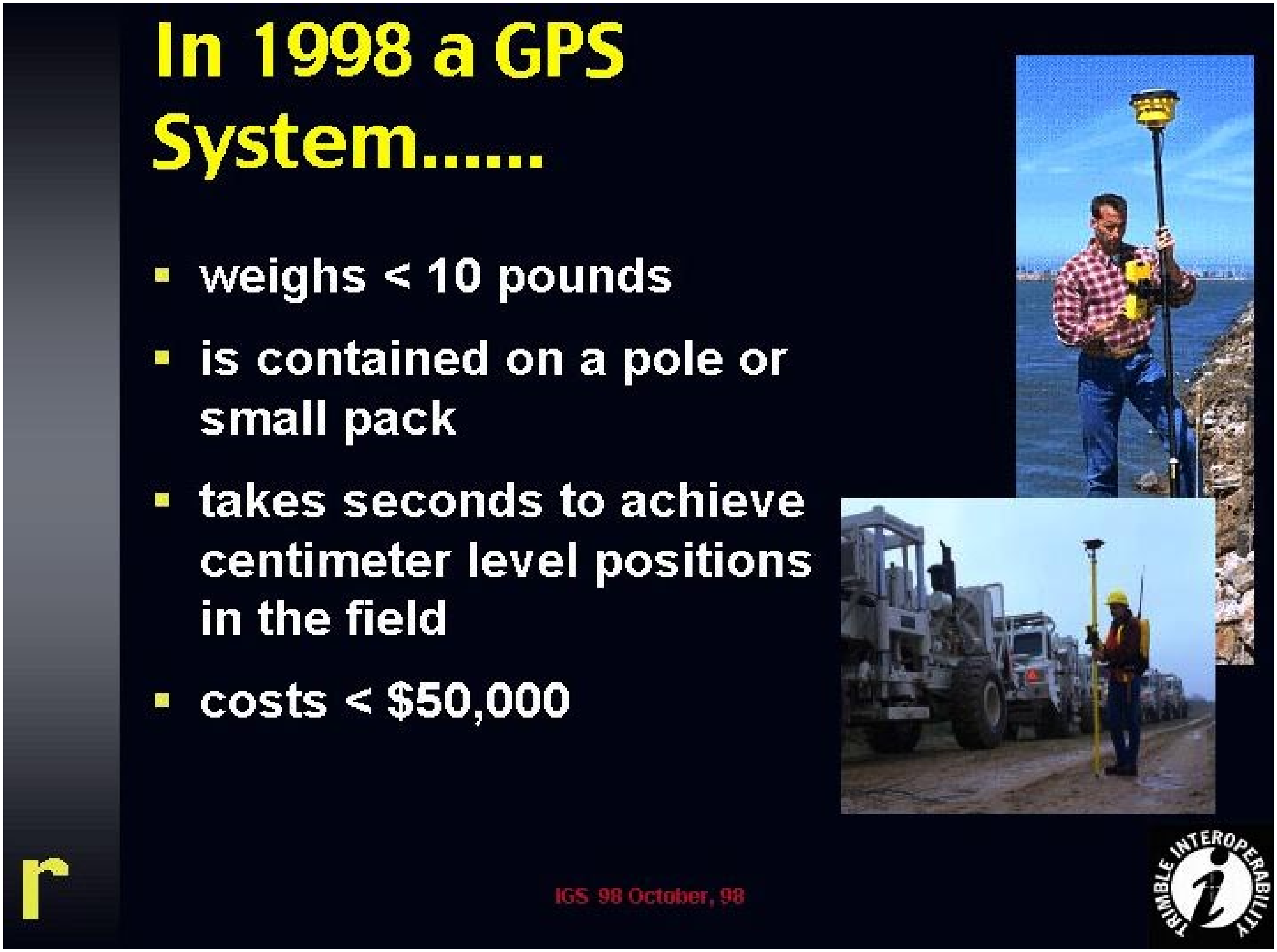
In 1998 a GPS System......
weighs < 10 pounds
is contained on a pole or small pack
takes seconds to achieve centimeter level positions in the field
costs < $50,000
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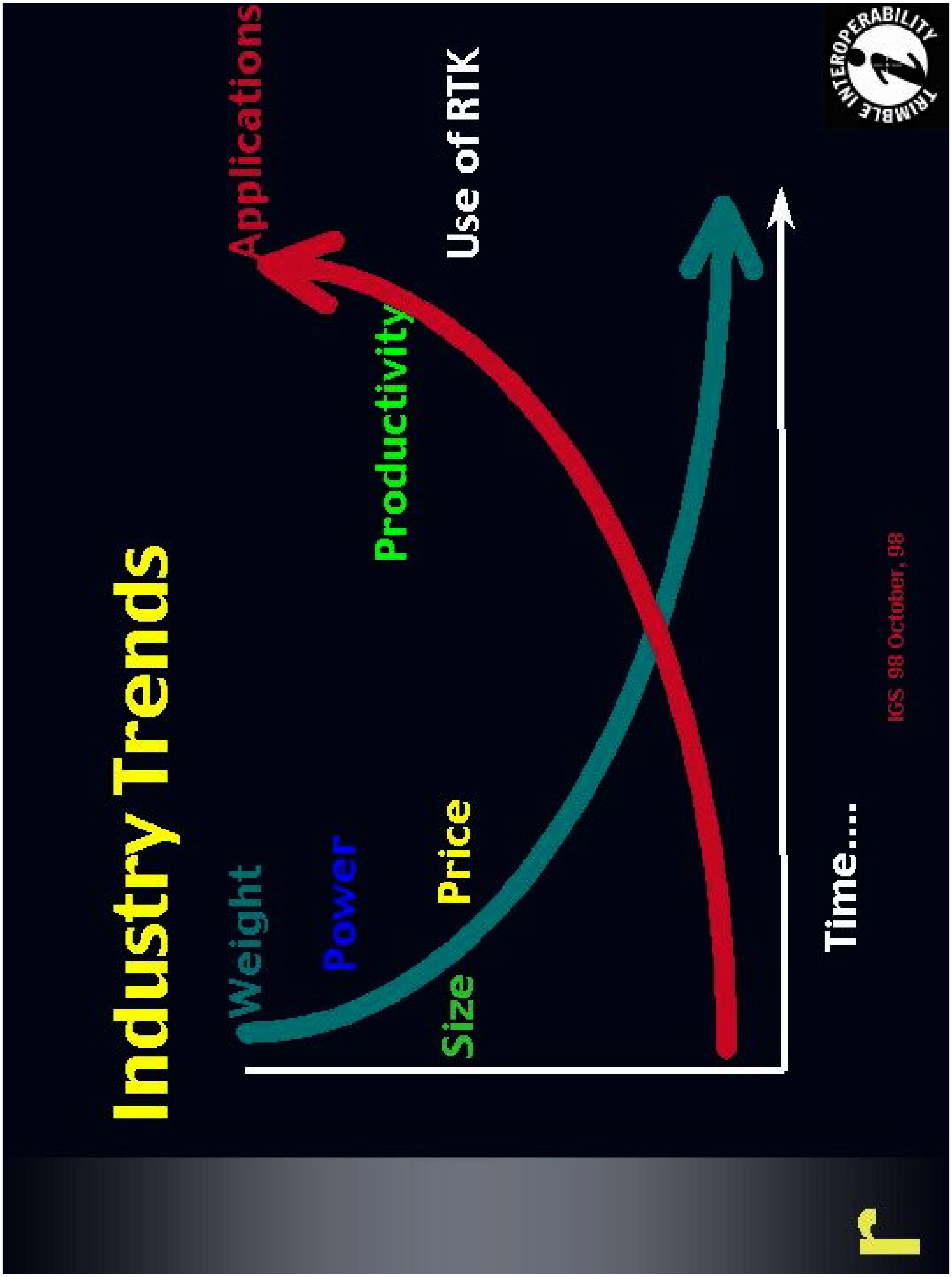
Industry Trends
Weight
Power
Price
Size
Productivity
Applications
Use of RTK
Time....
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Trimble Core Technology
GPS
4700
4000SSi
4600
MS750
4800
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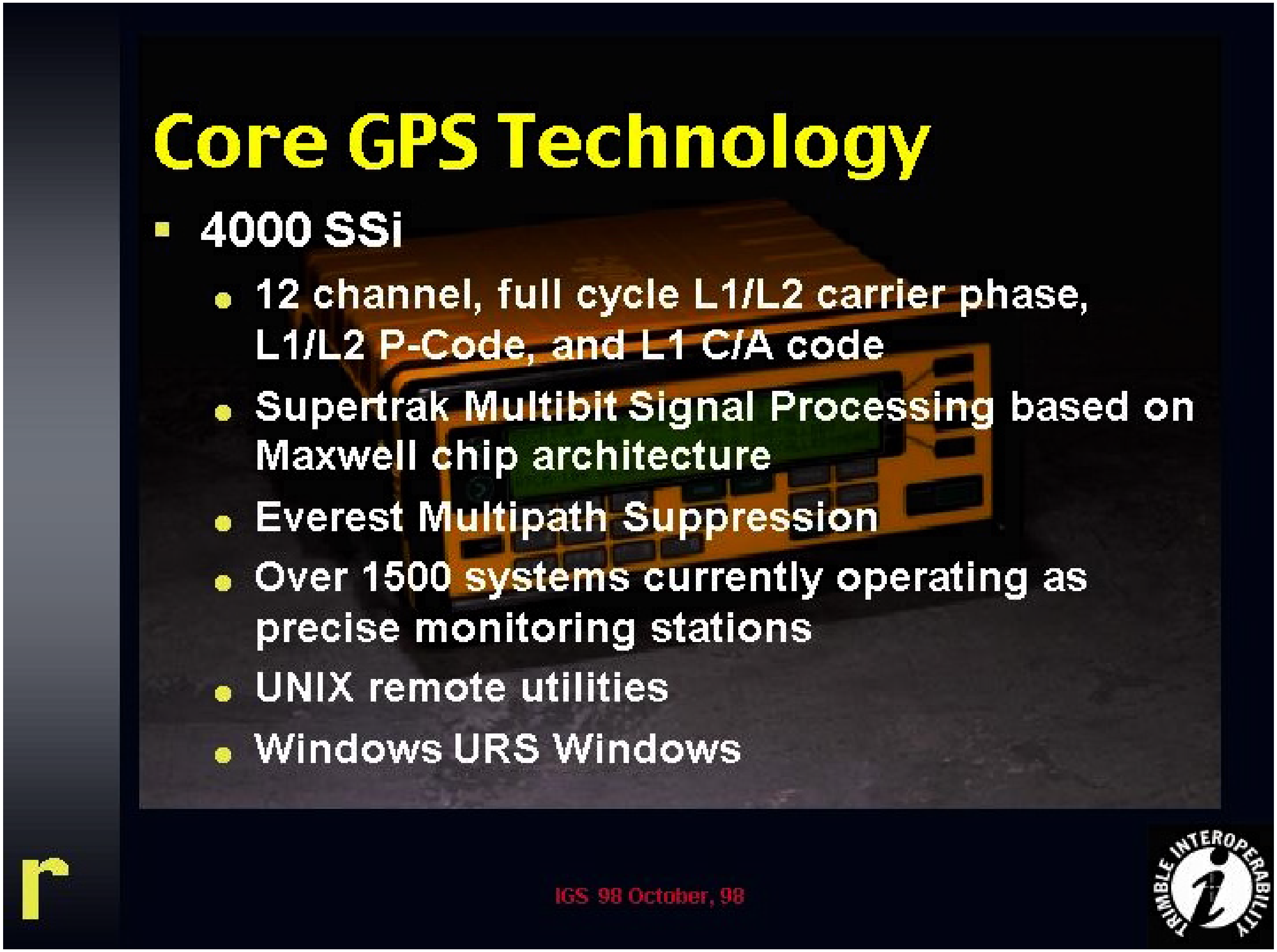
Core GPS Technology
4000 SSi
12 channel, full cycle L1/L2 carrier phase, L1/L2 P-Code, and L1 C/A code
Supertrak Multibit Signal Processing based on Maxwell chip architecture
Everest Multipath Suppression
Over 1500 systems currently operating as precise monitoring stations
UNIX remote utilities
Windows URS Windows
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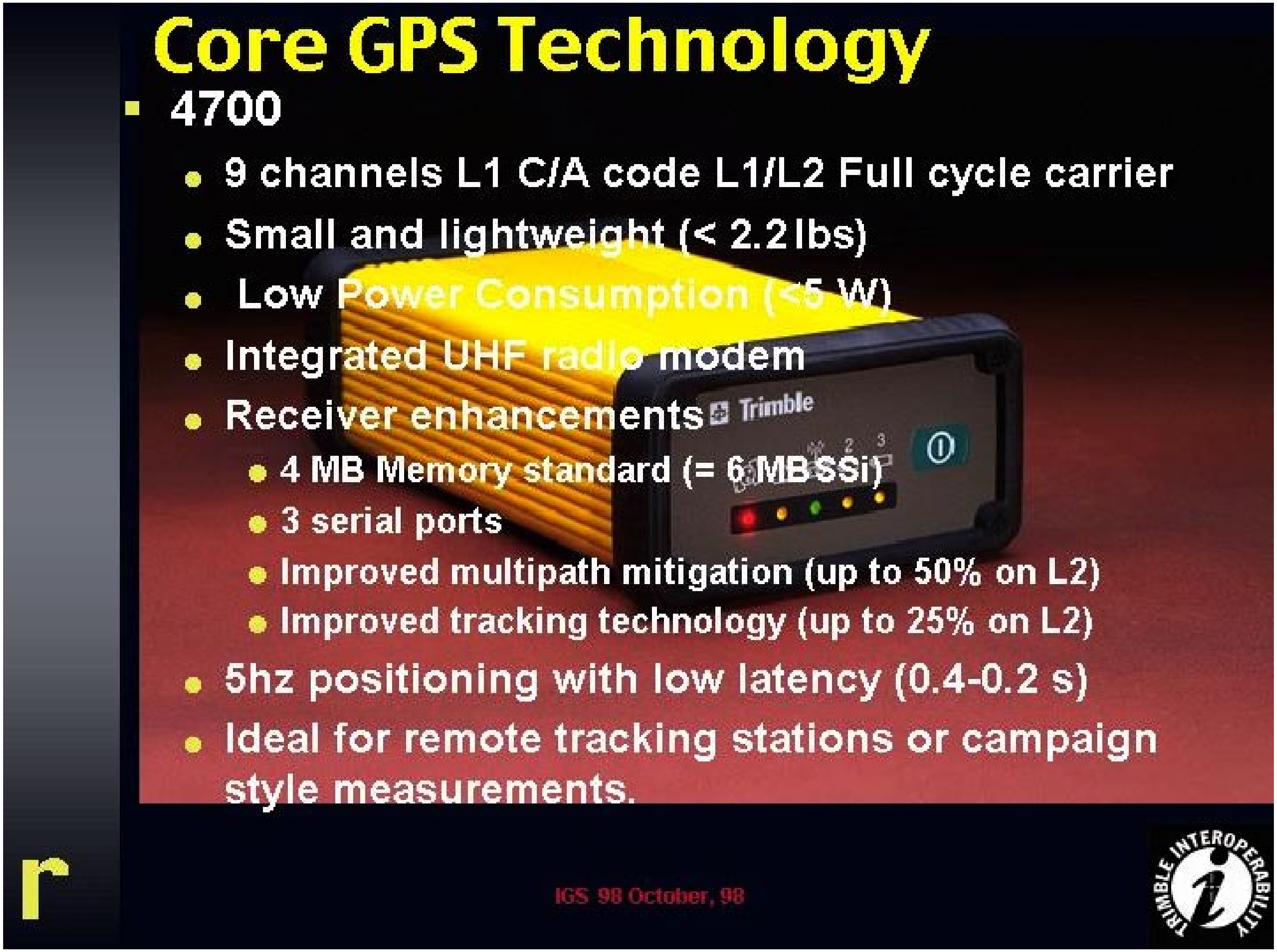
Core GPS Technology
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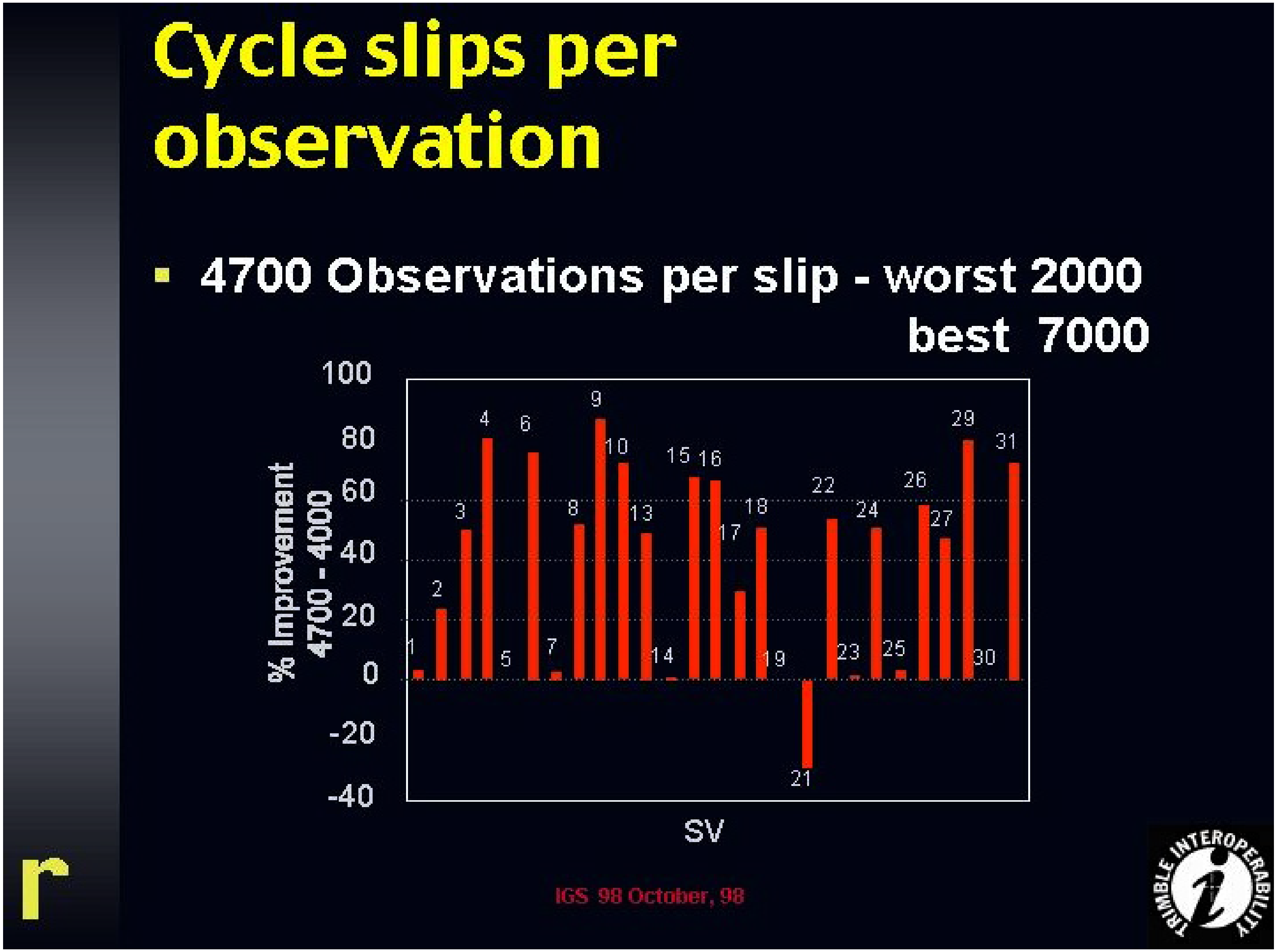
Cycle slips per observation
4700 Observations per slip - worst 2000
best 7000
% Improvement
4700 - 4000
100
80
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40
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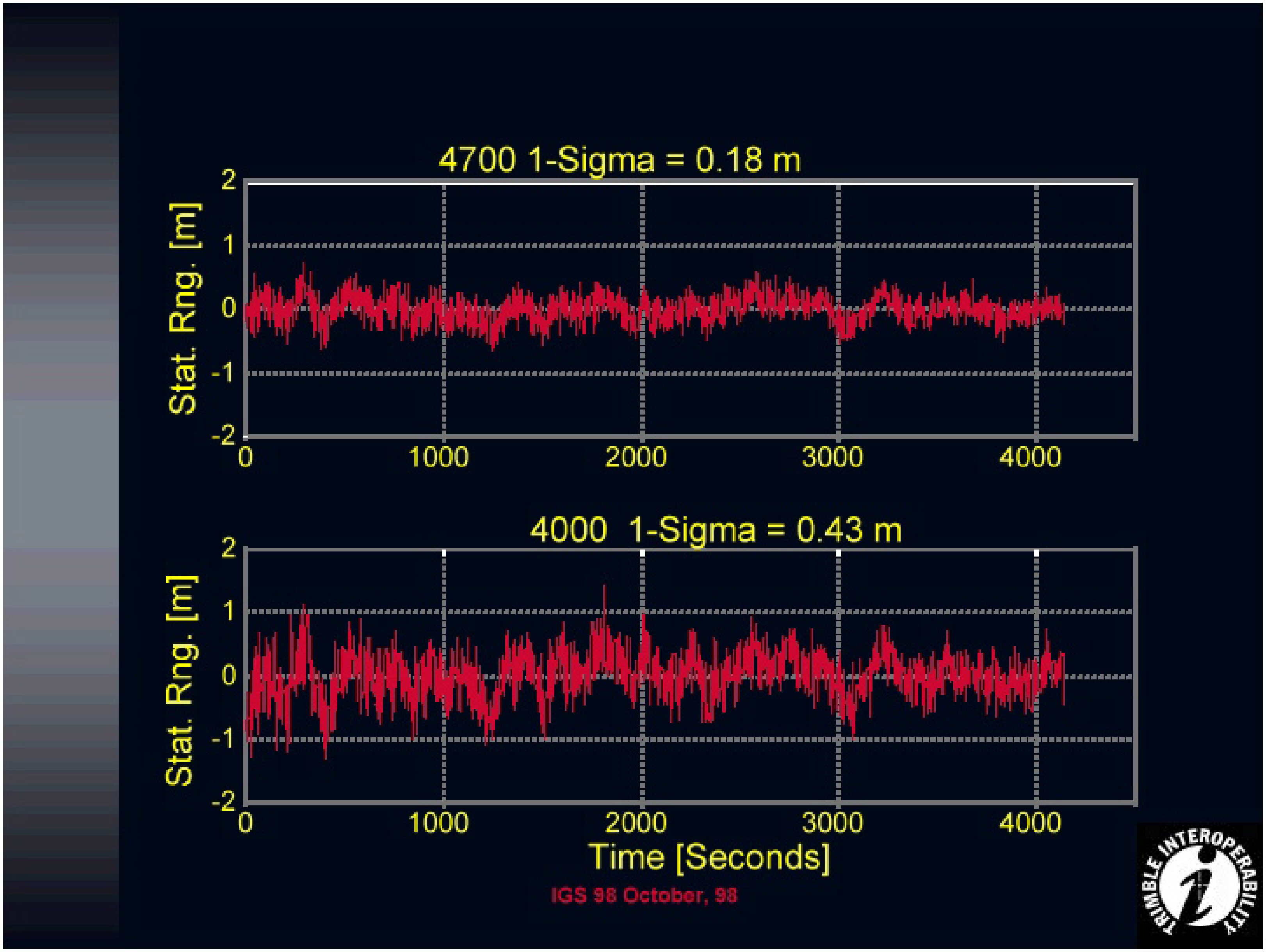
4700 1-Sigma = 0.18 m
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1000
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3000
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4000 1-Sigma = 0.43 m
Stat. Rng. [m]
Time [Seconds]
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Trimble Choke Ring
Industry standard
JPL/NASA Spec
DM element
Trimble L1/L2 Low Noise Amplifier (LNA)
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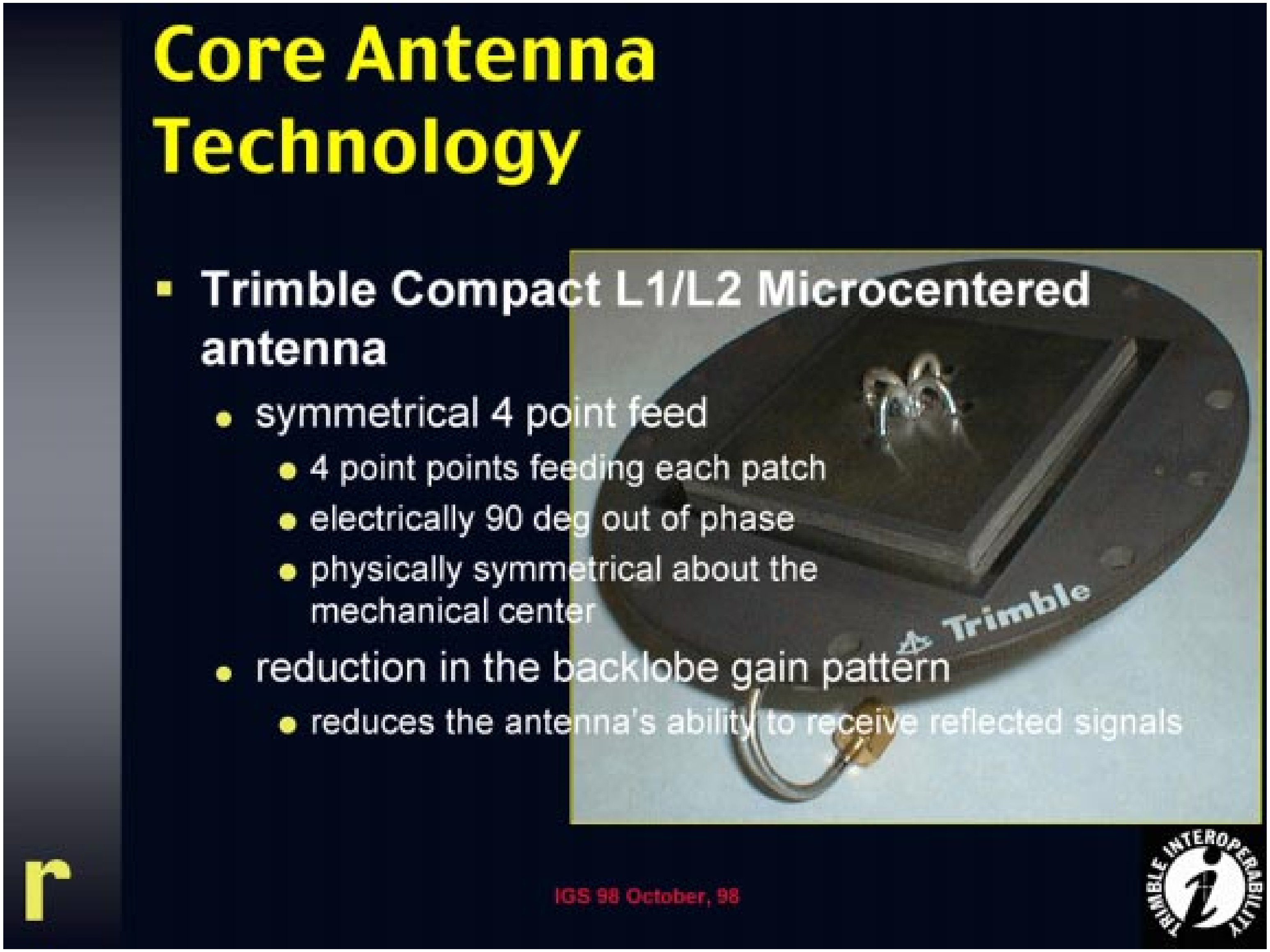

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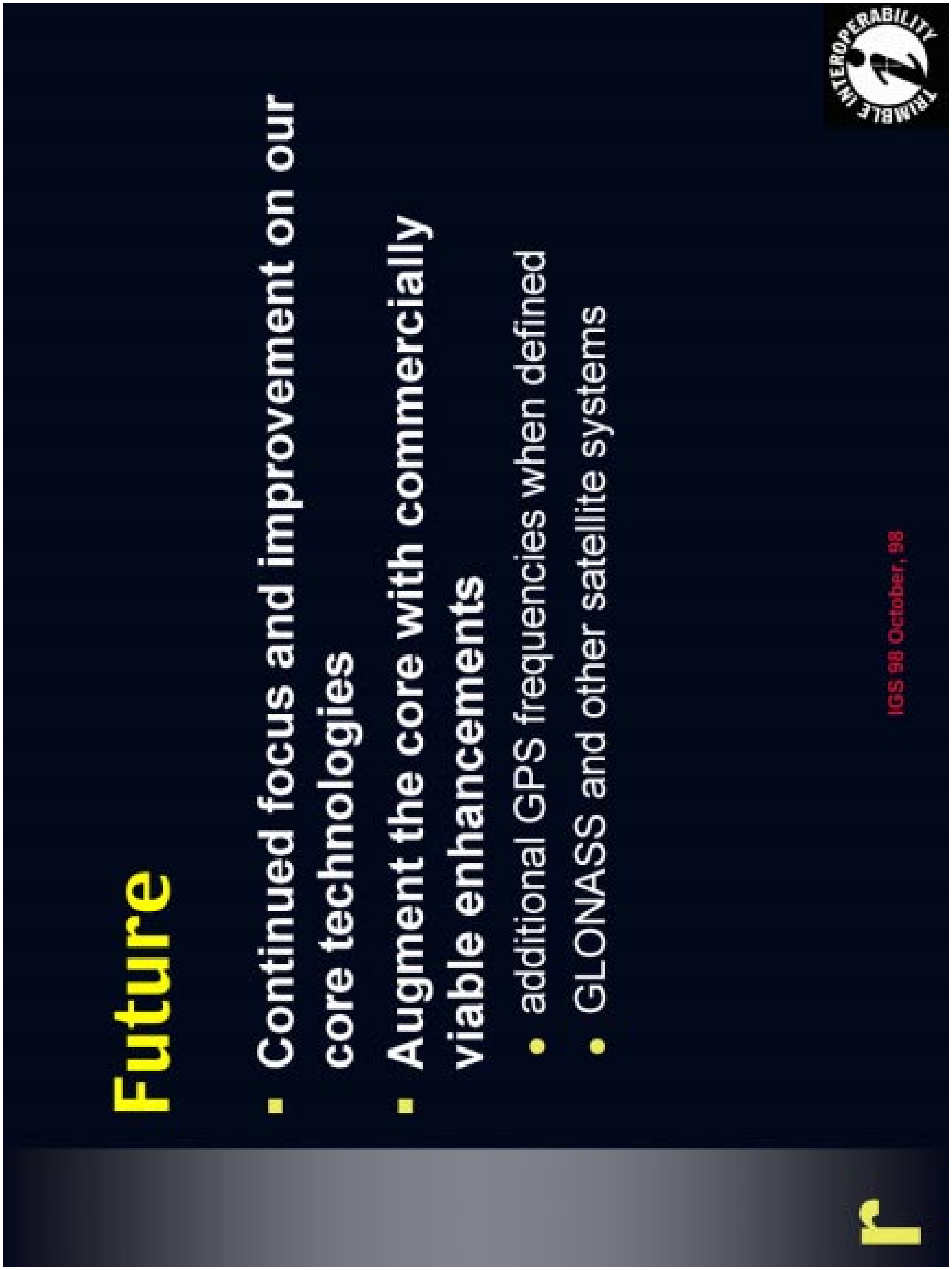
Future
Continued focus and improvement on our core technologies
Augment the core with commercially viable enhancements
additional GPS frequencies when defined
GLONASS and other satellite systems
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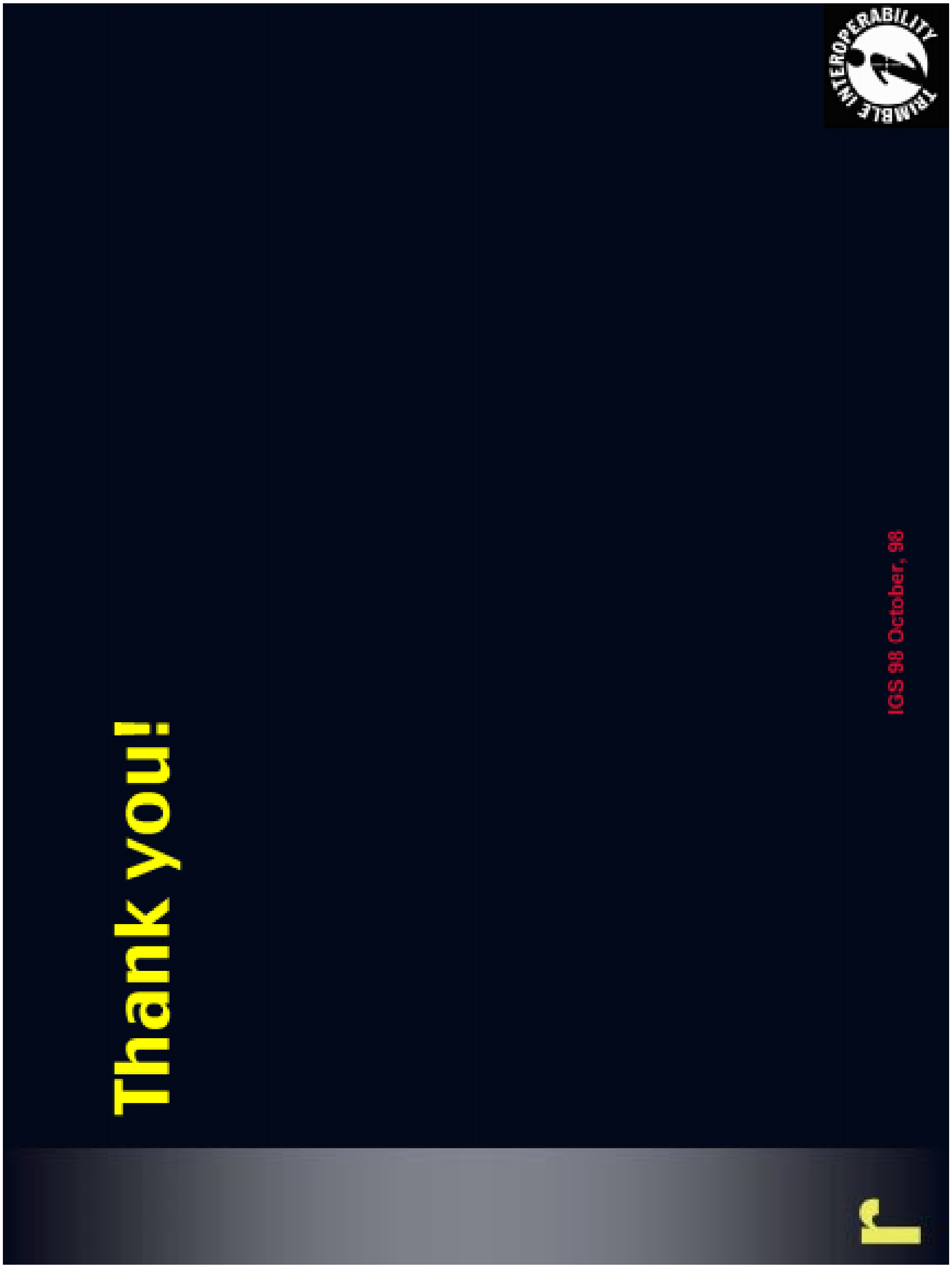
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Future of High Precision GPS Tools

IGS Network Systems Workshop, Annapolis Nov.2-5, 98

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- *BenchMark is an evolution of the TurboRogue, I.e., backwards compatible re. interfaces and control*
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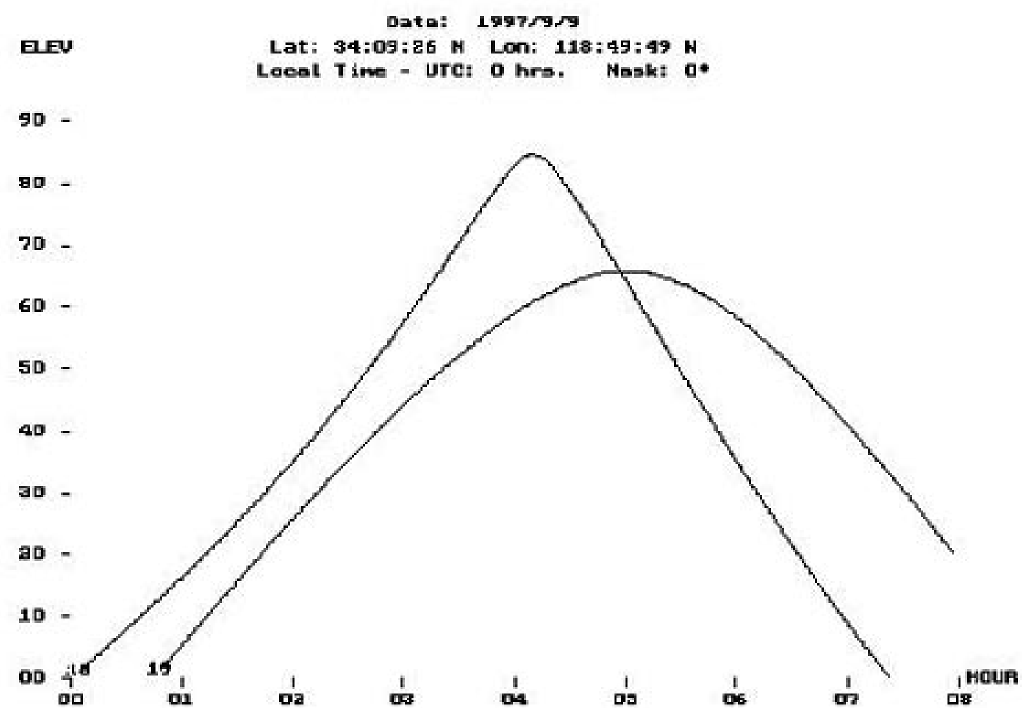
Satellite Elevation vs. Time



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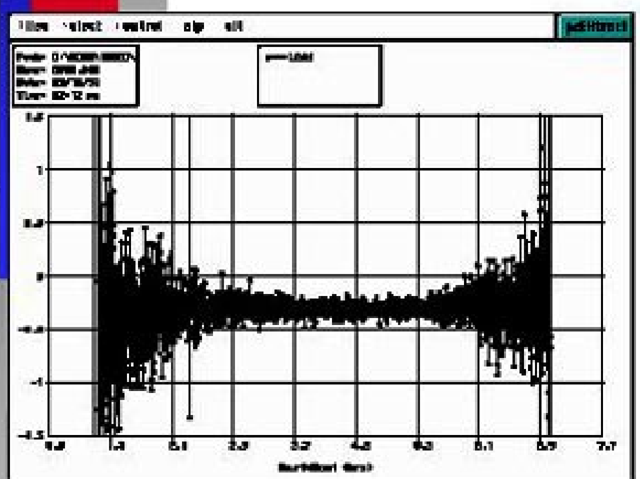
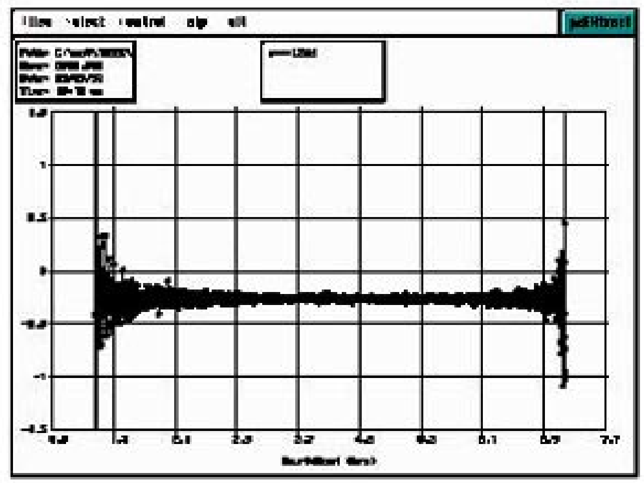
L2 Phase Double Difference Residuals 10-sec Data





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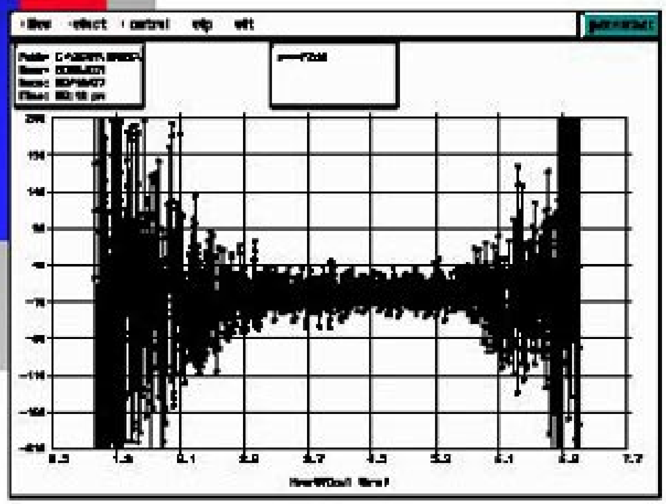
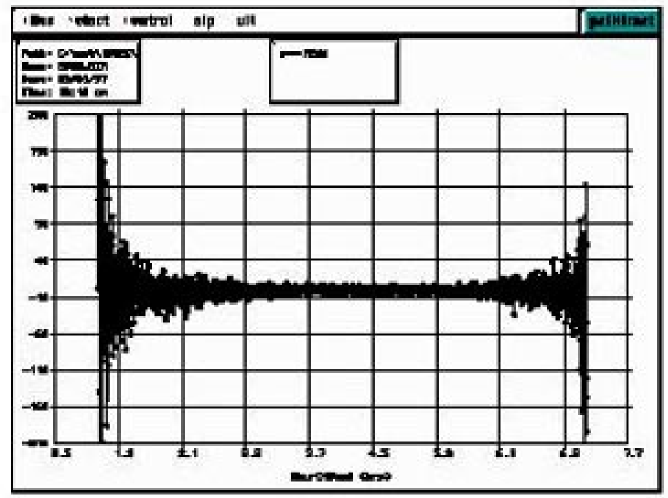
P2 Code Double Difference Residuals
10-sec Data



Cross Correlation



ACT

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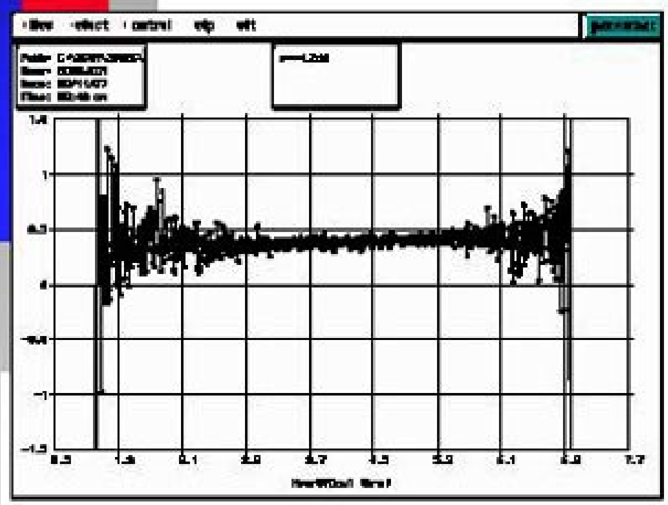
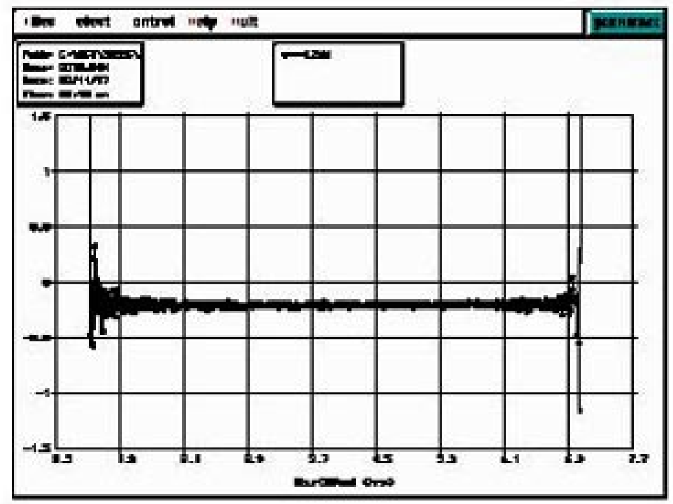
L2 Phase Double Difference Residuals
30-sec Data



Cross Correlation



ACT

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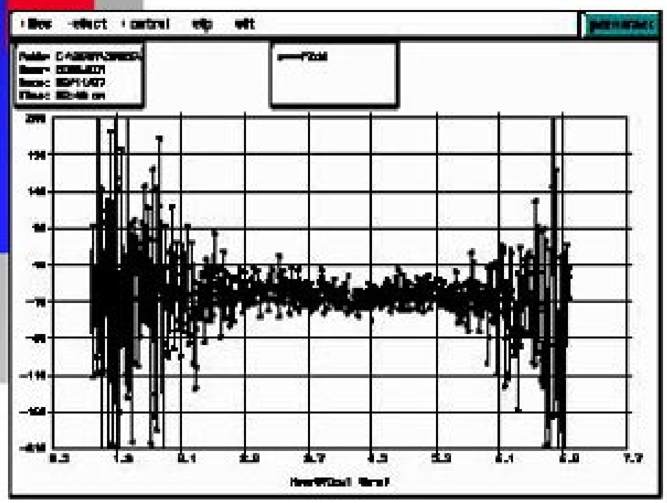
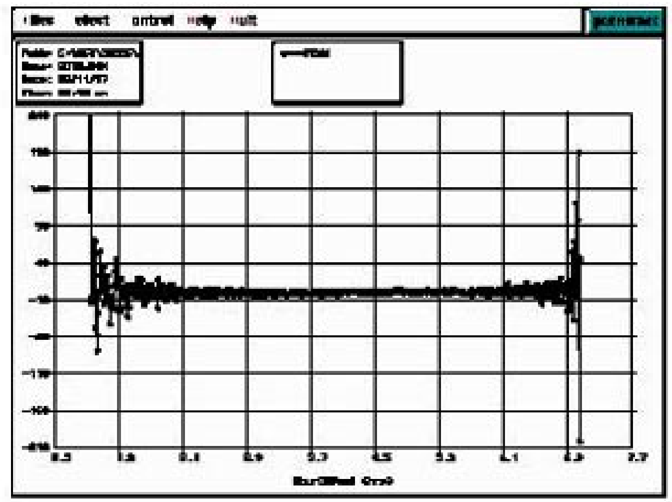
P2 Code Double Difference Residuals 30-sec Data



Cross Correlation



ACT

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Cycle Slip Statistics 30-sec Data

Observation	ACT	Cross-Correlation
Average Observations per Slip	**1654**	458
Average Ionosphere Slips < 10°	4	45
Average Ionosphere Slips > 10°	**0**	20
Average Ionosphere or Multipath < 10°	8	57
Average Ionosphere or Multipath > 10°	8	29

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Retrofit of TurboRogue with ACT

- *AOA is offering to retrofit TurboRogue receivers with ACT technology to:*
  - *minimize required investment for user*
  - *upgrade receivers with latest hardware and firmware*
  - *address GPS week rollover and Y2K issue**

Note: Wk 1024 / Y2K software for most TurboRogues will be available free of charge even without the retrofit!

- *Retrofit will mainly consist of replacing baseband board and re-wiring the receiver*

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Future of High Precision GPS Tools

- ***Issues:***
  - *Power Management*
  - *Data Volume & required Storage*
  - *Communications*
- ***Product Requirements:***
  - *Offer Access to Global Communications*
  - *Integrate geodetic Receiver into commercial PC (e.g. ruggedized notebook)*
  - *Open Software Architecture (LINUX?)*

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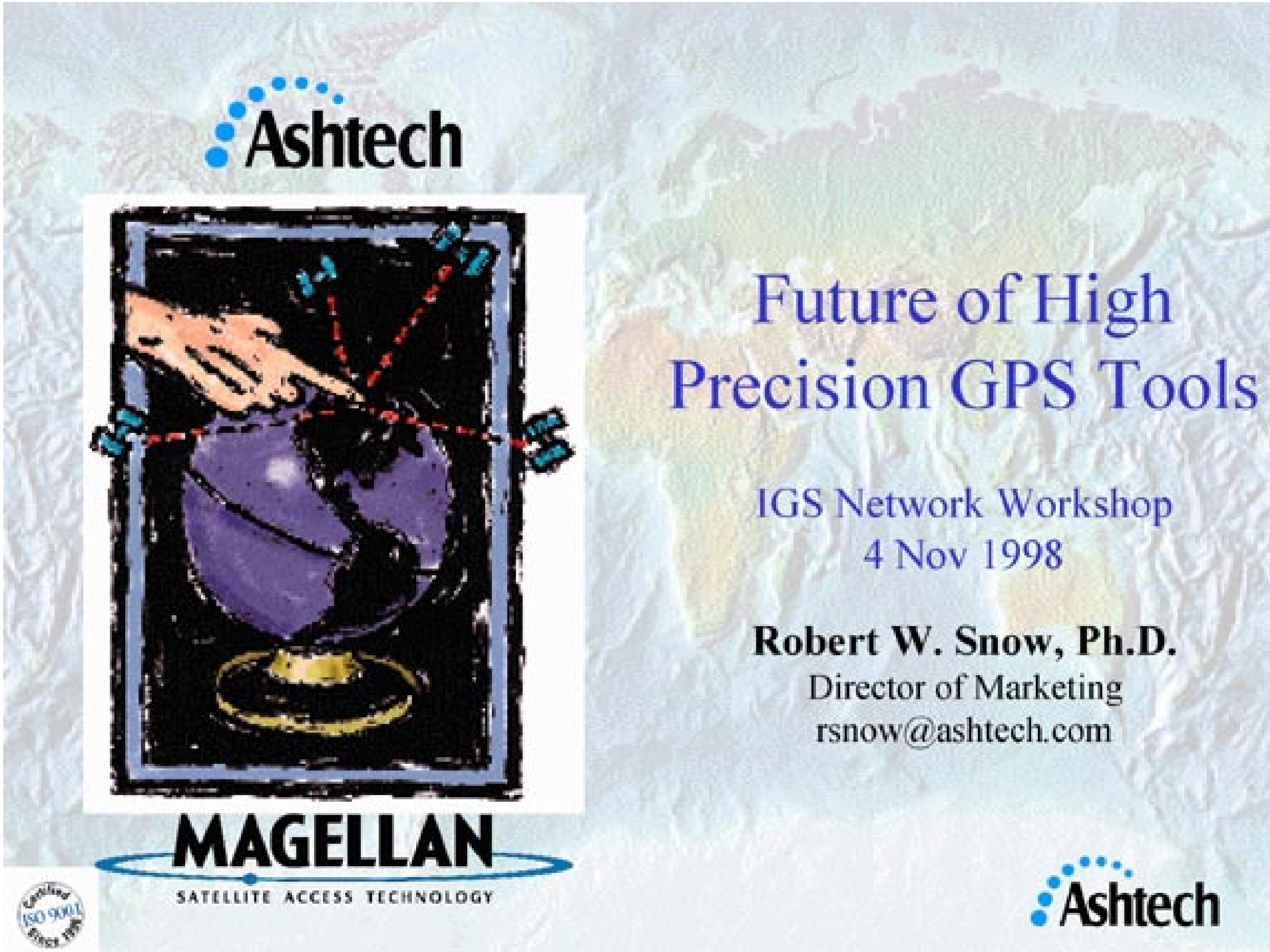
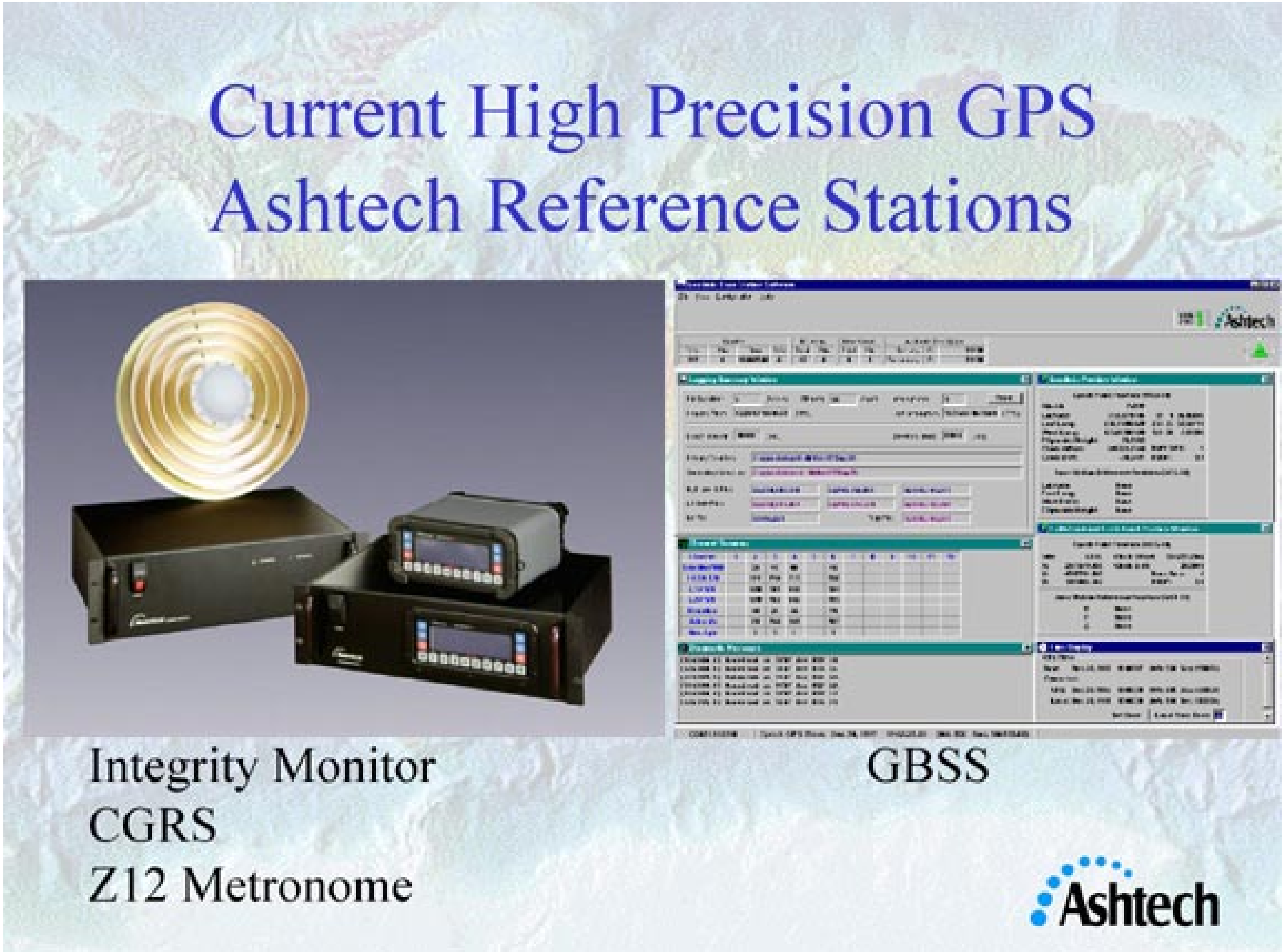

Ashtech
MAGELLAN
SATELLITE ACCESS TECHNOLOGY
Future of High
Precision GPS Tools
IGS Network Workshop
4 Nov 1998
Robert W. Snow, Ph.D.
Director of Marketing
rsnow@ashtech.com
Ashtech


Current High Precision GPS
Ashtech Reference Stations
Ashtech
Integrity Monitor
CGRS
Z12 Metronome
GBSS
Ashtech

Z-18

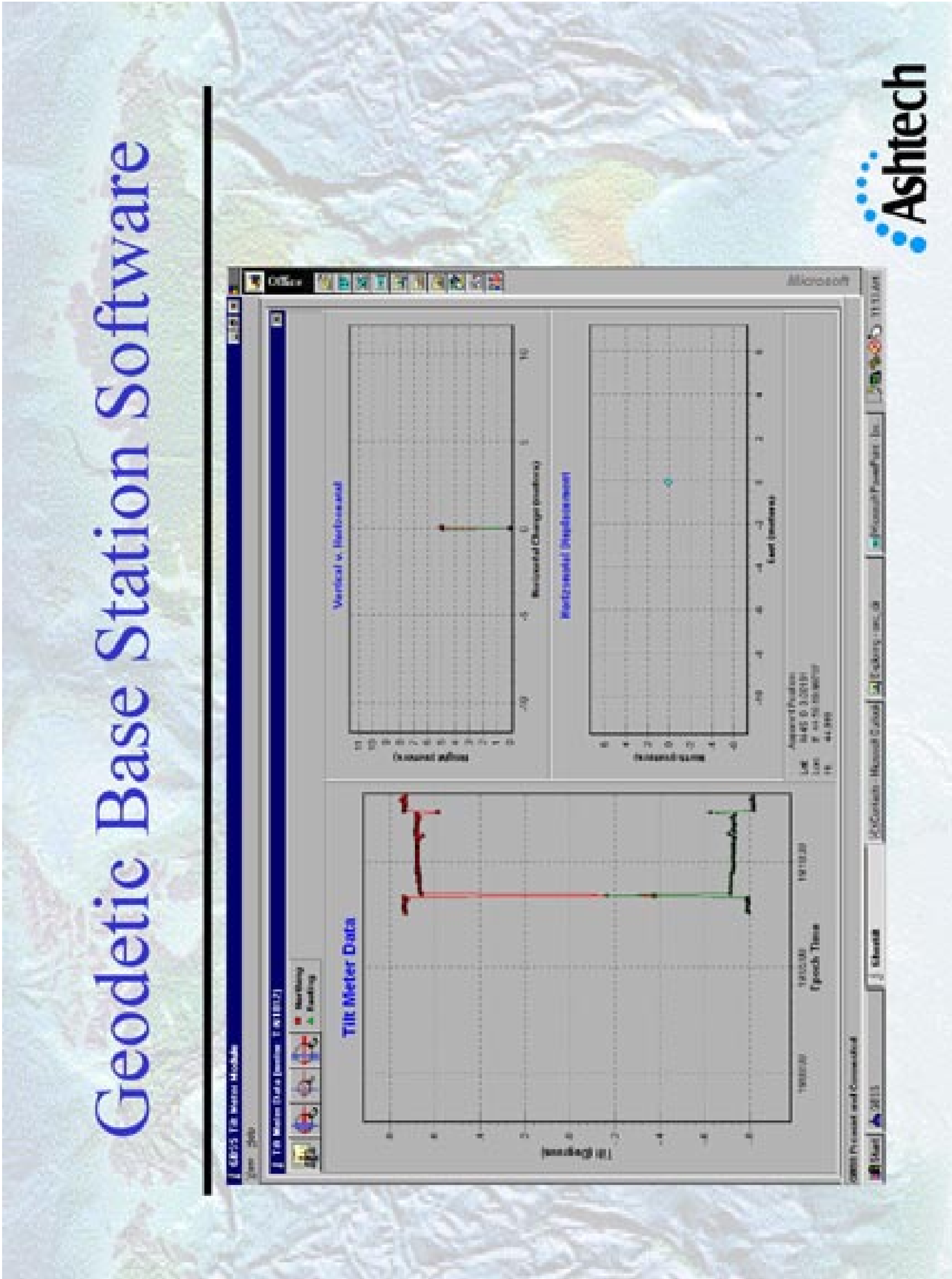
- 10 GPS *plus* 8 GLONASS
- Dual Frequency
  - Code and Carrier
- Choke Ring Antenna
- GBSS bundled with system
- RINEX converter in GBSS

Ashtech

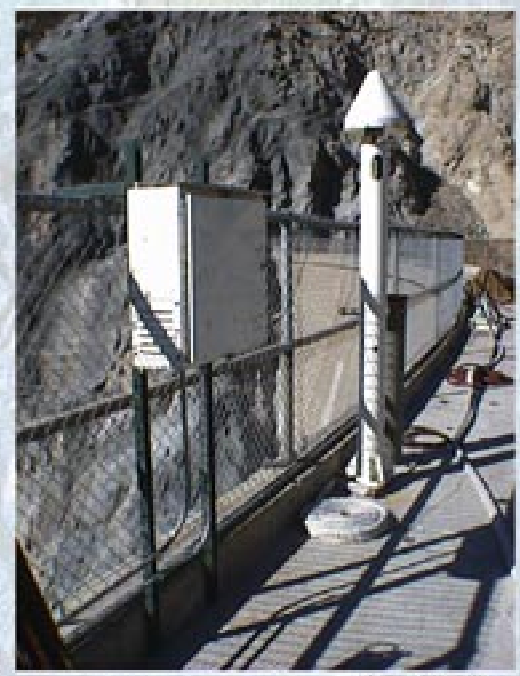
Geodetic Base Station Software (GBSS)

- 32-bit multitasking and multithreaded
- Designed for Windows 2000 and the Internet
- Logs simultaneously
  - single-frequency and dual-frequency files
  - files at different data rates (e.g., 1 s & 30 s)
- Automatic RINEX converter and compression
- Integrated tilt meter module
- ftp data push capability

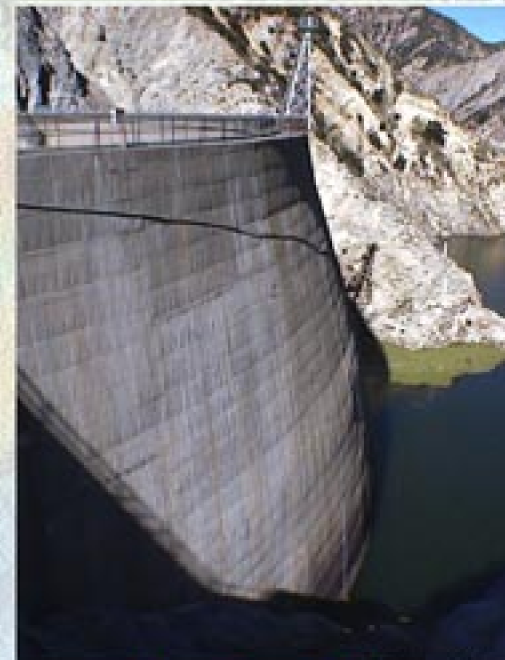
Ashtech


Geodetic Base Station Software
Tilt Meter Data
Epoch Time
Vertical v. Horizontal
Horizontal Displacement
Office
Microsoft
Ashtech

Applications - Monitoring Structure Deformation



Courtesy of SCIGN



Courtesy of SCIGN

Pacoima Dam

Ashtech

Future Developments

- GPS alone is insufficient
- GPS + Augmentation is the future
  - “GPS + GLONASS”™
  - WAAS/EGNOS
  - Tilt meters
  - Met packs
  - Precise timing option (Z12 Metronome)
  - Integrated communications
  - Base station software
  - TCP/IP and web browser compatibility

Ashtech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