WAAS, EGNOS, AND MSAS FOR TELECOM SYNC

Hugo Fruehauf
Zyfer Inc., an Odetics Company
Tel: 714-780-7960
E-mail: Hxf@zyfer.com, www.zyfer.com

Abstract

The WAAS, EGNOS, and MSAS GPS Augmentation Systems bridge the gap between the military applications of GPS and the needs of civil aviation navigation. These USA, Europe, and Asian systems consist of a network of differential GPS ground stations, using principally the Inmarsat-3 geosynchronous satellite constellation as the means of relaying the differential corrections to the users. In the process of providing precise navigation signals, GPS time is maintained through the Inmarsat-3 downlinks. It is this functionality that provides for robust time retrieval for the synchronization needs of the telecommunications community. This paper discusses:

- ***The basic makeup and performance of the system***
- ***How time and frequency can be extracted for the telecom terminals***
- ***Added functionality and noise rejection capabilities using these signals for telecom timing applications***
- ***How the system offers the first true backup to the GPS C/A signal for telecom synchronization users.***

THE BASIC MAKEUP AND PERFORMANCE OF THE SYSTEM

First, let's define the meaning of the terms used (Figure 1).

Figure 1 - Definitions

WAAS, EGNOS, and MSAS is a Differential GPS, Ground-Based Augmentation System designed to fulfill the needs of Civil Aviation Navigation

– WAAS - Wide Area Augmentation System (USA)

– EGNOS - European Geostationary Navigation Overlay System

– MSAS - Multifunctional Transport Satellite Space-Based Augmentation System (Japan)

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **NOV 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**
4. TITLE AND SUBTITLE **WAAS, EGNOS, and MSAS for Telecom Sync**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Zyfer Inc,7321 Lincoln Way,Garden Grove,CA,92841-1428**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001509. 32nd Annual Precise Time and Time Interval (PTTI) Meeting, 28-30 Nov 2000, Reston, VA

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**13**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The GPS program began in 1973 with the design of the Block-I satellites at what was then Rockwell International, which won the contract award in 1974. Launches began in 1978 and have continued since then to form a worldwide, 24-hour, three-dimensional military navigation, positioning, and timing system. The civil community has from the beginning benefited from the use of the GPS clear (or coarse) acquisition signal (C/A) for both navigation and timing but only in an unofficial, uncertified manner as to navigation. The question might be asked, why has it taken 22 years for the civil aviation community to embrace the GPS capability in an official, certified manner for commercial aviation? The answer lies in the difference between warfighting requirements and the safety requirements for commercial aviation, as shown in Figures 2 and 3.

Figure 2 - Issues With GPS-SPS for Civil Aviation

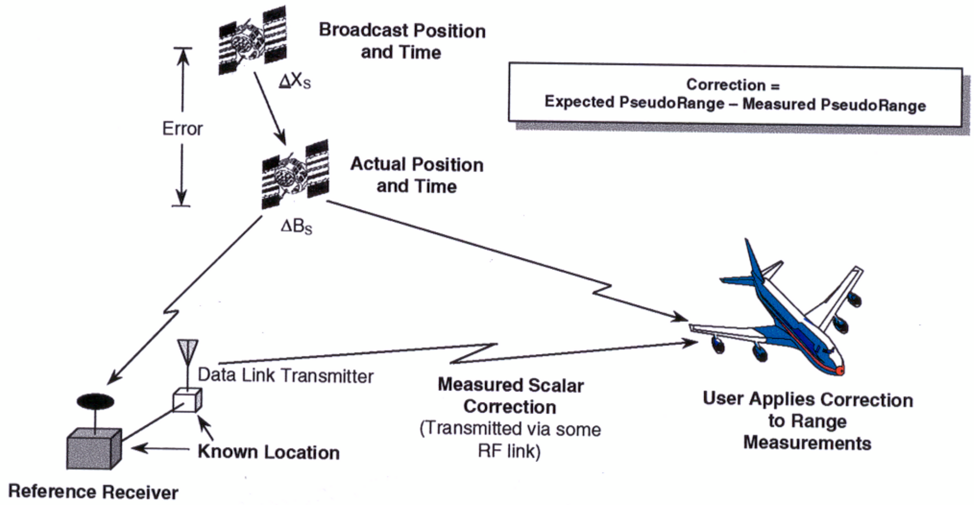
- With SPS, and in case SA is ON, accuracies are not good enough to meet FAA's Category I, II, and III requirements
  - Needs Differential Corrections (DGPS) and elimination of SA (in case SA is activated)
  - Needs improved Vertical Accuracy through use of added Range Signals from overhead satellites
  - Needs improved Ionospheric Corrections
- With SPS, Signal Reliability is not good enough; Can be out of limits without real-time user knowledge
  - Needs to be forward looking enough to allow a safe abort
  - Remote/Receiver Autonomous Integrity Monitoring (RAIM) addresses this need

Figure 3 - FAA Navigation Requirements vs. GPS Performance

Parameter	GPS with past SA	GPS w/o SA	FAA Requirements			WAAS
			CAT I	CAT II	CAT III	
Horizontal Position Accuracy (2σ)	100 m 300 m (99.99%)	20 m	16 m	6.9 m	6.1 m	7.6 m
Vertical Position Accuracy (2σ)	140 m	30 m	7.7m	2 m	2 m	7.6 m
Time Accuracy to UTC (2σ)	340 ns	40 ns	N/A	N/A	N/A	25 ns 12.5 ns (1σ)
Decision Height (DH)	—	—	200 ft	100 ft	50 ft	—

To accomplish the requirements of civil aviation navigation, a GPS augmentation system is required to bring the performance and signal reliability in line with the needs. The chosen method to accomplish this is the implementation of massive, worldwide ground-based differential GPS network supported by geosynchronous satellites to transmit the correction signals to the users. Differential GPS can be demonstrated by Figure 4.

Figure 4 - Local Area Differential GPS (DGPS) Concept



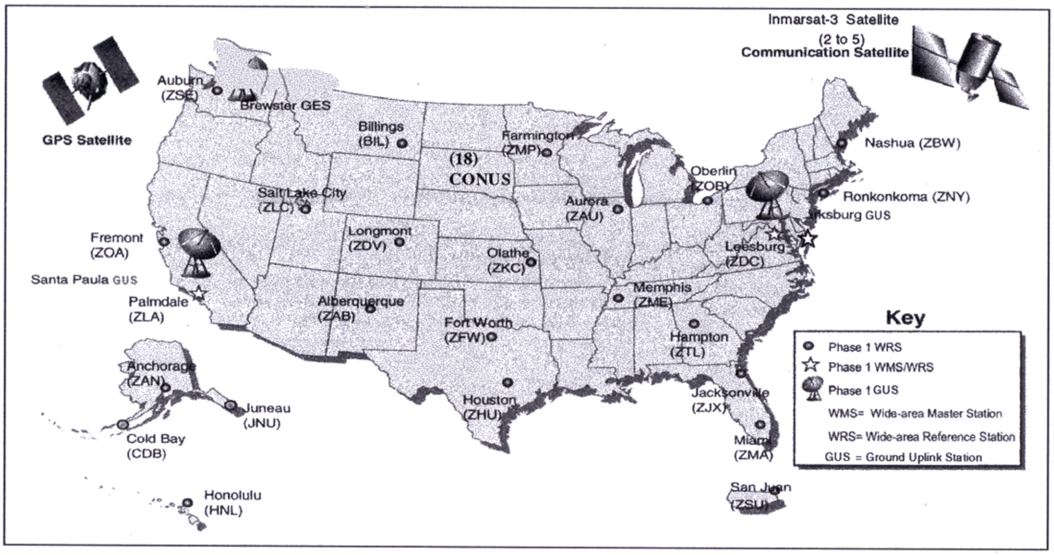
The GPS signals are measured by one or more ground reference stations that have been located precisely through surveying methods. There will be a difference between the GPS signal versus the known position of the ground station. This differential correction is then transmitted by some means to the user. The accuracy of the correction is best when the user is over the ground reference station, of course, but then degrades somewhat proportionally with the distance away from the reference. Local area augmentation, referenced in Figure 4, often called LAAS, is to differentiate between a specific local area and a wide area, country-wide system, called WAAS.

The North American portion of the world-network Wide Area Augmentation System (WAAS) is shown in Figure 5.

The basic functionality of the world-network GPS augmentation system concept is shown in Figure 6.

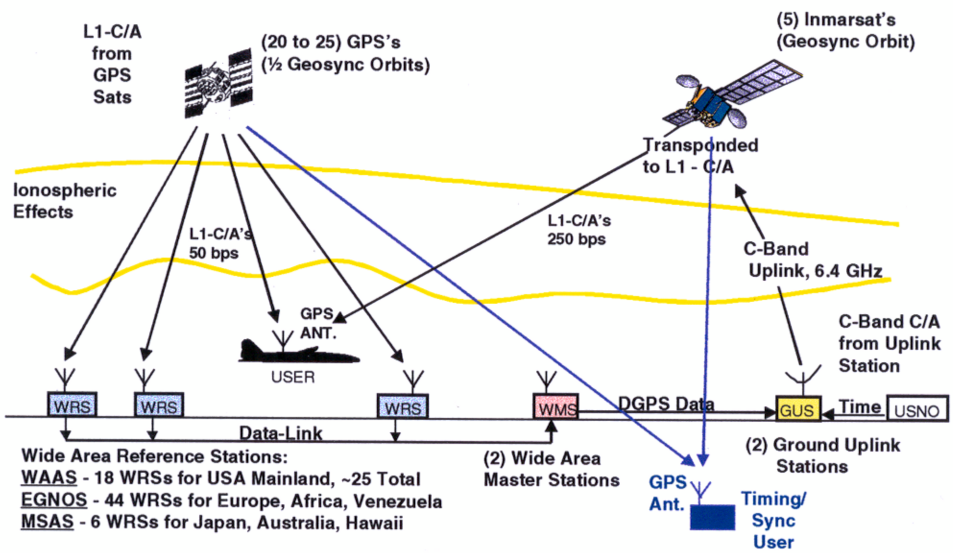
The data collected from the WRSs is fused at the WMS and sent to the GUSs for uplink. The Inmarsat-3 or equivalent geosynchronous constellation acts as a "bent-pipe," transponding the correction signals from the 6.4 GHz C-Band uplink to the L1-C/A GPS look-alike downlink signal. The signals do not originate in the Inmarsats, but come from the GUSs. The genius of the WAAS system is the GPS "look-alike" signals from the geosync satellites, which are received by the GPS receivers at the same signal strength and with the same antenna. This eliminates an otherwise separate and complex worldwide RF infrastructure that would be needed to transmit corrections to the users. There is a catch, however. Although the same GPS receiver can receive and process the RF portion of the Inmarsat signal as if it were a GPS satellite, it cannot process the data portion of the signal because of the data rate difference: GPS 50 bps and WAAS 250 bps.

*Figure 5 - WAAS Network**



* From 'WAAS Briefing', Michel Gonthier, CMC/BA

Figure 6 - Wide Area Augmentation System Concept



The "times 5" data rate is needed to handle the added differential corrections, along with an approximate 6-second refresh rate versus the 30 seconds for GPS. As a minimum, then, the GPS receiver requires an updated software set, including among other things, recognition of the new WAAS signals (satellite numbers 100 and up, versus the GPS SV 01 to 40) and the 250 bps data processing.

The WAAS System downlink is a culmination of formidable parameters that augment the existing GPS System to meet the civil aviation navigation challenges. Figure 7 lists these parameters.

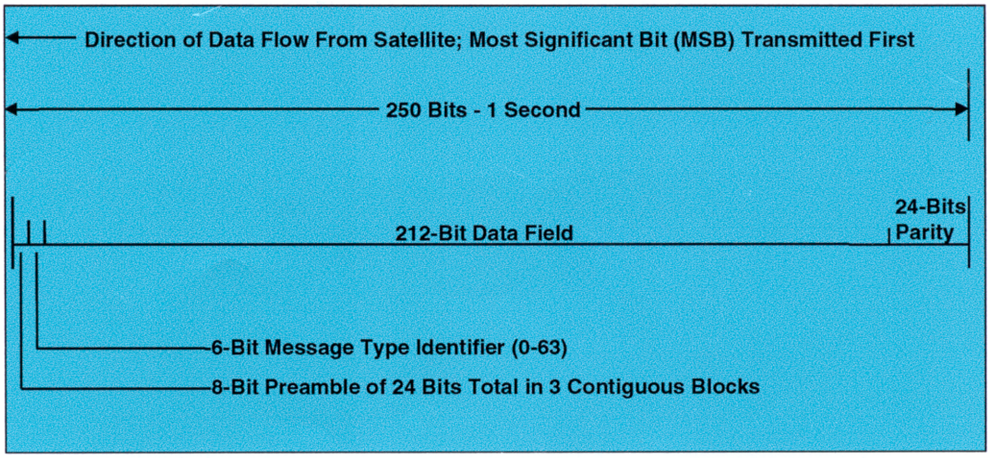
Figure 7 - WAAS Downlink

- L1-C/A GPS 'Look-Alike' signal from each GEO-Satellite with no SA (same signal strength as GPS satellites)
- DGPS Vector Corrections for each GPS Satellite
- Added Pseudo Range Signals via each GEO-Satellite
- Receiver Autonomous Integrity Monitor (RAIM) in Airborne WAAS receivers (a "Use/Don't Use" Flag)
- Improved Ionospheric Correction Model
- 250 bps data rate rather than the GPS 50 bps
  - Needed to transmit DGPS correction data for each GPS Sat
  - More frequent update - every 5 to 6 Sec. for DGPS and RAIM
  - Time to "Not-Use" alarm < 5.2 sec.

The Receiver Autonomous Integrity Monitor (RAIM) shown in Figure 7 is a very important part of making WAAS navigation useful for civil aviation. It provides the reliability function to give the signal integrity. In other words, the standard GPS navigation solution may be unreliable at times, unknown by the user in real time. RAIM considers a host of navigation data from GPS and WAAS and predicts for the next 5 to 6 seconds that the signal is correct. If the forward-looking calculations show an upcoming (estimated) out-of-spec conditions, the user has a 5 to 6 second warning before a "Not-Use" flag appears. This time is deemed sufficient to abort a critical operation, such as a landing or other critical flight phases.

The signal data structure of WAAS is referenced in Figures 8 and 9. The format of the WAAS signal is actually 500 bps, from which the usable 250 bps is formulated. There are a host of reasons for this, among which is jamming considerations. It may be prudent that the WAAS signal goes down before the GPS C/A signal becomes unusable in friendly military jamming scenarios.

*Figure 8 - WAAS Block Format**

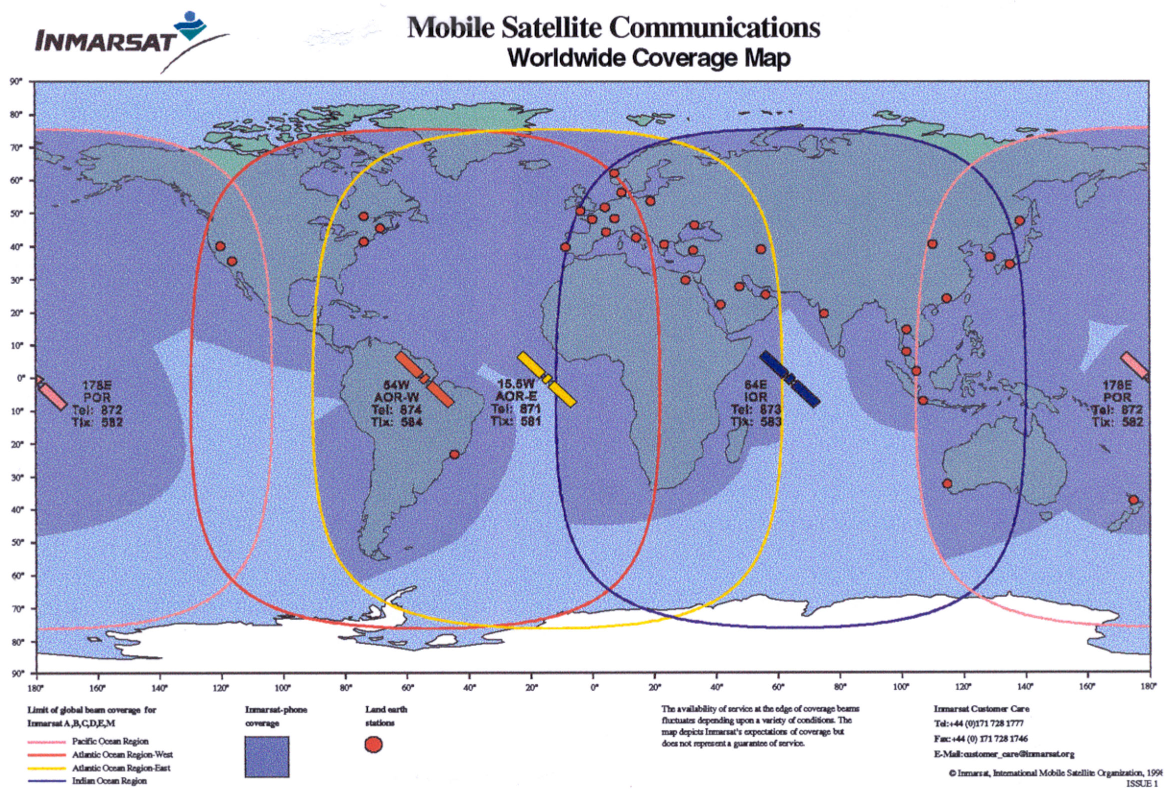


* From 'WAAS Briefing', Michel Gonthiar, CMC/BA

Figure 9 - WAAS Message Type

Type	Contents
0	Don't use this GEO for anything (for WAAS testing)
1	PRN Mask assignments, set up to 51 of 210 bits
2-5	Fast corrections
6	Integrity information
7	UDRE Degradation factor
8	Estimated RMS Error message
9	GEO navigation message (X, Y, Z, time, etc.)
10-11	Reserved for future messages
12	WAAS Network Time/UTC offset parameters
13-16	Reserved for future messages
17	GEO almanacs message
18	Ionospheric grid point masks
19-23	Reserved for future messages
24	Mixed fast corrections/long term satellite error corrections
25	Long term satellite error corrections
26	Ionospheric delay corrections
27	Reserved (WAAS Service Message)
28-61	Reserved for future messages
62	Reserved (Internal Test Message)
	Null Message

The Inmarsat-3 constellation is geosync and covers the earth. By this means, WAAS, EGNOS, and MSAS are linked to form a worldwide, 24-hour civil aviation navigation system that will eventually replace the existing and aging navigation aids. Since the satellite ground traces have significant coverage overlap, a robust redundancy is provided. The ground stations in each geographic area provide the navigation corrections to the user via the associated Inmarsat. The aircraft GPS/WAAS receiver extracts the applicable correction data which applies to the ground stations closest to its flight path.



With existing information WAAS officially began September 2000 with 2 to 5 Inmarsat-3 GEOS. A second C/A will be added to some GPS Sats (BLK IIR/F) at 1176.45 MHz (below GPS L2 of 1227.6 MHz) for direct Ionospheric Correction Solution in the year 2005(?). EGNOS officially begins in the year 2002. EGNOS uses two Inmarsat-3s and one Artemis GEOS (controlled by EU + ESA). There are 44 stations in Europe, Africa, and Venezuela. MSAS is expected to begin in the year 2003 (controlled by Japan). There are six stations in Japan, Australia, and Hawaii. Interoperability between WAAS, EGNOS, and MSAS is expected in the years 2002 to 2003.

HOW TIME AND FREQUENCY CAN BE EXTRACTED FOR THE TELECOM TERMINALS

So What's New for Timing/Sync? The WAAS/EGNOS/MSAS capability is designed for large/high-end airborne GPS receivers for civil aviation navigation ($5K to 10K?). There are no thoughts given to other users. Making the typical low cost <$100), small telecom GPS timing receiver capable of receiving and processing WAAS will be new. Some of the advantages are a more accurate timing signal, greater robustness in noisy environments using low-cost commercial DBS dish antennas, and an alternate timing signal in case of GPS C/A loss. Refer to Figure 11 for more details.

Figure 11 - Advantages for Timing/Sync

A more accurate UTC Timing Signal (<100 ns GPS vs. <25 ns for WAAS/EGNOS/MSAS)	**- Due to the D-GPS corrections - If SA is ON, it is removed from C/A - Added Ranging Signals with the WAAS/EGNOS/MSAS Geo-Stationary Satellites**
A more robust timing signal in noisy environments	**- Contrary to GPS, WAAS/EGNOS/MSAS Geo-stationary Inmarsats allow the use of a fixed DBS dish aimed at the satellite - This can reduce ambient noise, multi-path, intentional and unintentional jamming - A 2 ft. DBS can achieve upwards of 18 dB of added noise rejection (Pat Fenton - NovAtel)**
An alternate UTC Timing Signal to GPS L1-C/A (A WAAS/EGNOS/MSAS "only" mode)	**- WAAS/EGNOS/MSAS Systems generate their own L1-C/A GPS "look-alike" signals - Uplink Station Clocks are referenced to UTC via Ground-Link to USNO - If position is known through GPS or other surveying means, a single WAAS/EGNOS/MSAS Inmarsat Satellite signal can maintain Network Sync, independent of GPS L1-C/A**

ADDED FUNCTIONALITY AND NOISE REJECTION CAPABILITIES USING THESE SIGNALS FOR TELECOM TIMING APPLICATIONS

There are some additional benefits using the WAAS signal for telecom. First, it provides two to three more range signals from the geosync Inmarsats, which improves the timing accuracy by at least a factor of 2 to 3. With SA turned off, the improvement is not as dramatic as it was earlier when SA was still active. Second, and more significant, is the ability to reduce ambient noise, multipath, and intentional and unintentional jamming. This can be accomplished through the use of commercially available low-cost Direct Broadcast Satellite dishes (DBS). Unlike GPS, the Inmarsats are stationary and, therefore, allow for the pointing of a DBS antenna toward the Inmarsats. Due to the higher gain nature of a dish antenna, telecom terminals can be made more robust in high noise areas or in areas where significant GPS signal obstruction occurs, such as high-rise downtown buildings, etc. Figures 12, 13, and 14 show antenna options.

Figure 12 shows the standard GPS antenna used with a WAAS-capable receiver. As stated earlier, since the Inmarsat signal is a GPS "look-alike," the antenna of course receives both. Since it sees all available GPS satellites, the terminal locates itself and then corrects the timing to the WAAS-capable levels.

Figure 12 - Antenna Options, GPS Antenna Only

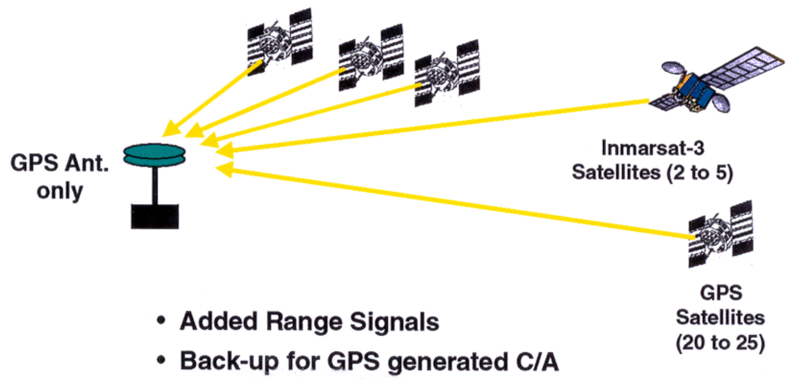


Figure 13 shows a combination of both standard GPS antenna and a DBS dish. The Figure 12 mentioned capabilities apply, in addition to significantly higher noise rejection from the dish. This means that the terminal is not likely to go down due to extreme permanent or temporary electromagnetic conditions. The potential problem with this configuration, however, is the 2 to 3 dB loss from an RF splitter between the GPS antenna and the dish. This can be mitigated, however, by various means in addition to multiplexing the antenna's signals.

Figure 14 shows a DBS Dish only. This configuration may not always be self-erecting. In other words, it may not be able to position itself due to lack of GPS satellites in view of the directional dish. If the position is known and programmed in, the DBS can completely support the timing requirement without any further need to see GPS satellites. This confirmation also eliminates the need for a RF splitter.

Figure 15 provides a summary of setup and performance requirements versus antenna options.

HOW THE SYSTEM OFFERS THE FIRST TRUE BACKUP TO THE GPS C/A SIGNAL FOR TELECOM SYNCHRONIZATION USERS

In retrospect, the telecom sync community has done a terrific job selling GPS as the main synchronization tool worldwide in light of the fact that it is military system. The question,

Figure 13 - Antenna Options, GPS and DBS Dish Antennas

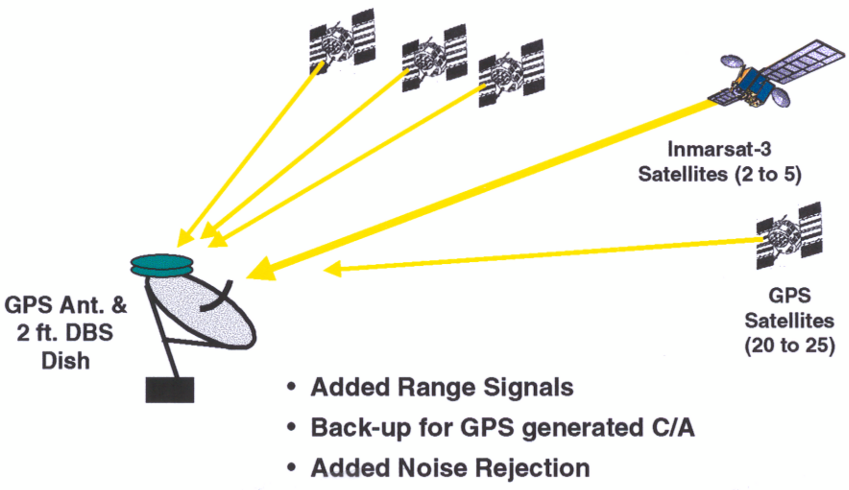
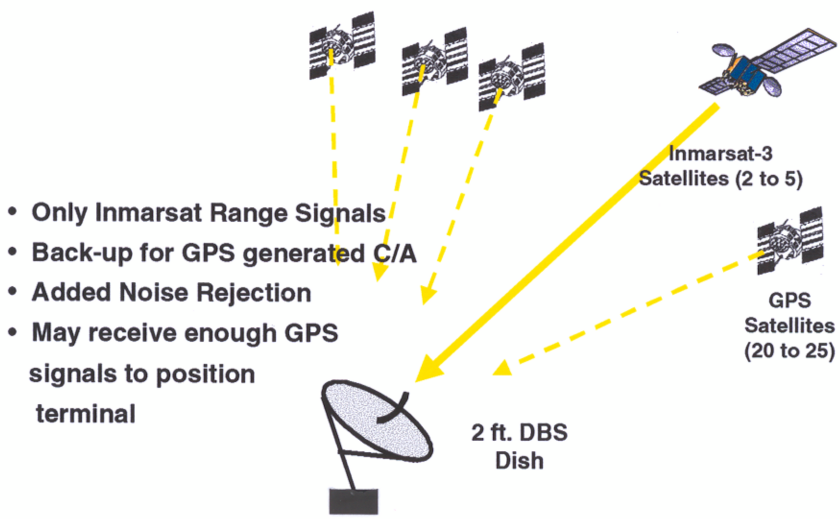


Figure 14 - Antenna Options, DBS Dish Only



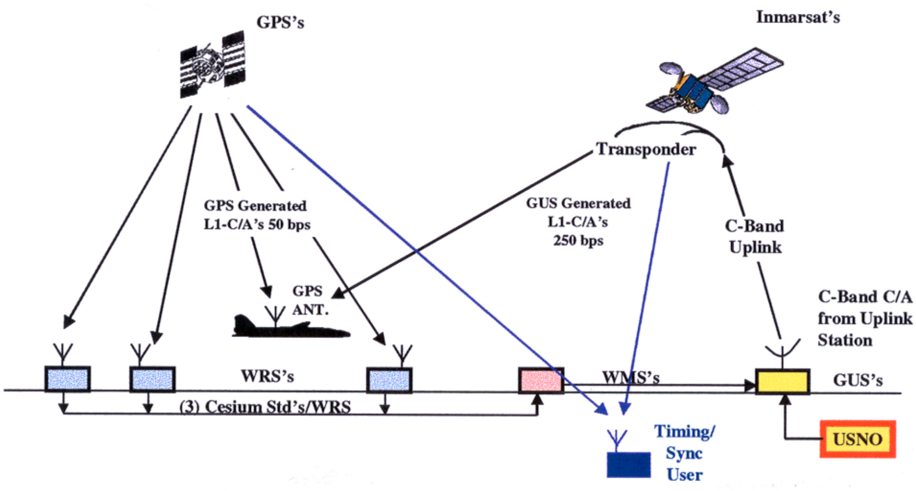
especially from foreign customers, is continually raised, "What if the military significantly degrades or even turns off the clear, civil C/A signal?" Since the U.S. government could do this without notice, the question has been addressed by the use of flywheel precision oscillators which can carry the network for some time. Cost-cutting service providers demand no more than 1 day of flywheel without a GPS C/A signal. More responsible providers demand a week or more, requiring more expensive atomic oscillators. In any event, neither option could handle a protracted military event. But this is where the most significant advantage for telecom comes in, the unintentional WAAS backup to the GPS C/A signal for timing.

Figure 15 -GPS/WAAS Receiver System Configurations

Parameters	Standard GPS RCVR, L1, C/A-Code (SPS) Reception	Standard GPS RCVR, L1, C/A-Code (SPS), + WAAS Reception	Standard GPS RCVR, L1, C/A-Code (SPS), Receiving only WAAS Signal; (1 to 5 Inmarsats)
Self-Erect GPS System (from Cold Start)	Needs minimum of (4) GPS Sats in view for position location	Needs minimum of (4) GPS Sats in view or (3) GPS Sats and (1) WAAS Signal	Cannot determine position on its own
	Needs at least 15 min. to filter SA, if ON	Needs only seconds to meet Time Spec (WAAS has no SA)	N/A
Manual Erect with surveyed position accuracy of 10 m or better	Needs only (1) GPS Sat; Time Spec depends on Fly-Wheel Osc.	Needs Only (1) GPS Sat or (1) WAAS Signal Not both. Time Spec determined by WAAS and Fly-Wheel Osc.	Meets WAAS Time Spec w/o GPS signals
	Needs only seconds to meet Time Specs	Needs only seconds to meet Time Specs	Needs only seconds to meet Time Specs.
Antenna Options	- (1) Standard GPS Antenna	- (1) Standard GPS Antenna (Omni-Dir, receives both GPS and WAAS) or - (1) Standard GPS Ant. on a DBS type com'l Antenna. Dish for high performance WAAS reception	DBS Dish for High Performance Reception (reduction of ambient noise, mutipath, and intentional and un-intentional jamming.)
Timing Accuracy	50 to 100 ns	~25 ns, 95%; 12 ns 1σ	~25 ns, 95%; 12ns 1σ

No C/A or a significant degradation of C/A will bring down the civil community navigation. Inmarsats are only transponders for correction data and cannot be used for navigation. In this event however, a "don't-use" flag must be transmitted by WAAS, telling the community not to use the signal. This "don't-use" signal comes from the ground station system which creates the L1-C/A look-alike signal relayed to the users via Inmarsat. This C/A signal is generated from the C-band uplink, transponded to L1 by the Inmarsats. In addition, this C/A is synchronized to USNO, the same agency which time-syncs all the GPS satellites. In this respect, the telecom terminals will remain on line when the GPS C/A is severely degraded by SA or even denied. Since this capability is inherent in EGNOS and MSAS as well, the backup to C/A can be realized worldwide. See Figure 16 for an illustration of this significant feature.

Figure 16 - The Independent L1-C/A Signal from WAAS/EGNOS/MSAS



Figures 17 and 18 portray potential military scenarios and the operation of the GPS and WAAS systems in light of these threats. Particular emphasis should be noted in the far right column, where a telecom terminal is equipped with a WAAS capable GPS timing receiver.

Figure 17 - GPS Signals vs. WAAS Signals Availability

Conditions	Navigation Users			T/F Users
	GPS SPS (CIVIL)	GPS PPS (MIL)	WAAS/EGNOS/ MSAS Signals	At Telecom Terminal (for T/F Sync)
Normal GPS Service Under Standard Conditions	C/A, No SA (Nav. Solution <10 m, Time Error ~100 nanosecs)	P(Y)	C/A w/o SA, even if SA is On, DGPS Corrections (Nav. Solution <7.6 m)	GPS + WAAS/ EGNOS/MSAS C/A w/o SA +Corrections (Time Error <25ns)
Foreign Tactical Conflict (USA Jams GPS C/A in Local Battlefield Area)	No GPS C/A (SPS Goes Down in Local Jammed Area)	Normal PPS P(Y) Continues (Need Direct P(Y) Acquisition Receivers for Cold-Start in Jammed area)	No WAAS/ EGNOS/MSAS C/A in local Jammed area (Civil Navigation goes down in the local area only)	Terminal in Local Jammed Area Goes on "Hold-Over" (Jammer may be defeated with a DBS aimed at GEO Inmarsat)

Figure 18 - GPS Signals vs. WAAS Signals Availability

Conditions	Navigation Users			T/F Users
	GPS SPS (CIVIL)	GPS PPS (MIL)	WAAS/EGNOS/ MSAS Signals	At Telecom Terminal (for T/F Sync)
Broader Foreign Conflict (Satellite SA is On and cranked High)	C/A with sever SA (Nav. Solution 1000 m?? Time Error >1 sec ??)	Normal PPS P(Y) Continues Increased SA does not materially affect P(Y)	C/A w/o SA from Inmarsat, but DGPS Corrections may be out of 7.6 m Spec (Most SA is filtered by DGPS Grd. Sta.) Note (1)	Terminal filters much of the GPS SA, WAAS/ EGNOS/MSAS C/A is w/o SA, Time Error may stay in 25ns area
Strategic Conflict (C/A is Unavailable from Satellite, unthinkable scenario, but possible)	No GPS C/A (SPS Goes Down Worldwide)	Normal PPS P(Y) Continues (Need Direct P(Y) Acquisition Receivers for Cold-Start)	GPS/WAAS/EGNOS/ MSAS Civil Aviation Navigation goes down Worldwide. (GUS generated C/A continues to transmit "Don't Use" message)	WAAS/EGNOS/ MSAS- GUS generated C/A will maintain Timing/Sync - GUS Cesiums locked to USNO via Ground-link Note (2)

Note (1): USA <u>may ask</u> EGNOS/MSAS to be turned off because it filters out some of the SA

Note (2): With no GPS C/A, all civil navigation is down. No need to shut down WAAS, EGNOS & MSAS; signals cannot be used for navigation.

CONCLUSION

The WAAS, EGNOS, and MSAS system is a significant step forward in expanding the use of the military GPS system to a reliable, certified civil navigation system. It brings a very robust 3σ military capability to a 6σ and beyond civil system. In the process, the telecom synchronization community is an unintentional beneficiary when the low cost time receivers are made WAAS-capable. But more than the improved accuracy in timing for this community is the proposed C/A backup, a fallout certainly not contemplated by the very capable WAAS systems designers–we thank you.

ACRONYMS

WAAS	Wide Area Augmentation System (USA)
EGNOS	European Geostationary Navigation Overlay System
MSAS	Multifunctional Transport Satellite Space-Based Augmentation System (Japan)
GPS	Global Positioning System
C/A	Clear (or Coarse) Acquisition Signal
P(y)	Precision Code When Crypto Keyed
SPS	Standard Positioning Service
PPS	Precise Positioning Service
SA	Selective Availability
DGPS	Differential GPS
Inmarsat	International Maritime Satellite
WRS	Wide Area Reference Station
WUS	Wide Area Master Station
GUS	Ground Uplink Station
USNO	United States Naval Observatory
RAIM	Receiver (Remote) Antonymous Integrity Monitor
DBS	Direct Broadcast Satellite

Questions and Answers

THOMAS CLARK (NASA Goddard Space Flight Center): Well, I'll play devil's advocate and ask another unpopular question, Hugo. There's one jamming scenario you didn't cover, and that is the fact that the Inmarsat satellites are functioning as a bent-pipe repeater with a 6.4 gigahertz uplink standard C-band satellite uplink. We have had the experience with C-band uplinks when Captain Midnight jammed the TV and was able to somehow generate a signal on the right frequency and jam things.

It would seem to me that probably the greatest vulnerability that this type of WAAS system faces comes at two different levels. One is that you generate enough uplink signals that spoof the WAAS signal, giving you invalid corrections, but still legal WAAS readings. The data become invalid.

The second is that you crank up the power even a bit more. In which case the bent-pipe transponder that is sitting there in geostationary orbit now has enough signal to actually capture many of the GPS downlinks. This is because of the limited dynamic range that you end up with in this type of spread-spectrum situation. So to me, it looks like the most vulnerable part of this, not by U.S. Government jamming, which was the scenario that you talked about, but malicious jamming, whether from a terrorist or a hacker, lies with 6.4 gigahertz uplink.

HUGO FRUEHAUF: Okay, very good points. Remember, though, that Johns Hopkins did a very detailed study on the susceptibility of the WAAS system as a whole to both smart and dumb jammers, and apparently the risk is acceptable. But, of course, your scenario certainly can play out.

CLARK: Yes, the Johns Hopkins study was basically a "trust me" type of study of the Inmarsat satellites; it was virtually impossible for someone on the ground to generate those powers. But that's where I find fault in this, that I could easily generate a signal that is stronger than the normal Inmarsat uplink that's carrying these things, in which case I can grab the link.

WILLIAM KLEPCZYNSKI (Innovative Solutions International): That's true, Tom. But there are some things within the architecture of the system which try to prevent that. There are two uplink stations to each of the geos, one on the East Coast, one on the West Coast. So there would have to be a simultaneous coordinated effort to simultaneously jam both uplink signals on the East and West Coast. In addition, the EGNOS signal is also being received in the US, too, as a supplement. They also have, within Europe, two uplink stations to the AOR East. They would have to simultaneously do that.

So yes, there are possibilities of doing that, but it might be a little difficult. The other aspect of it is that right now the Inmarsat satellites are being used, but that architecture won't necessarily be there in the future. The only thing that probably will stay the same is that the downlink frequency will be L1. However, the architecture might change. The uplinks and the satellites being used will probably also change in the future. At some point in time, the system will evolve and change.

But yes, for now, for the test, there is that possibility, but I think it's very small. It would have to really be a coordinated effort to do that.