

# A Critical Perspective on Some Aspects of GPS Development and Use

**TeK**

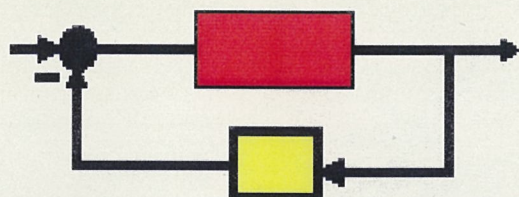
**Associates**

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CEO\Principal Investigator

26-28 May 1997

Start



4th Saint Petersburg International Conference  
on Integrated Navigation Systems

1 TSO C129

4 Non-Ideal

7 Multipath...

10 Constraints?

2 Baro/GPS

5 More...

8 More...

Other Concerns

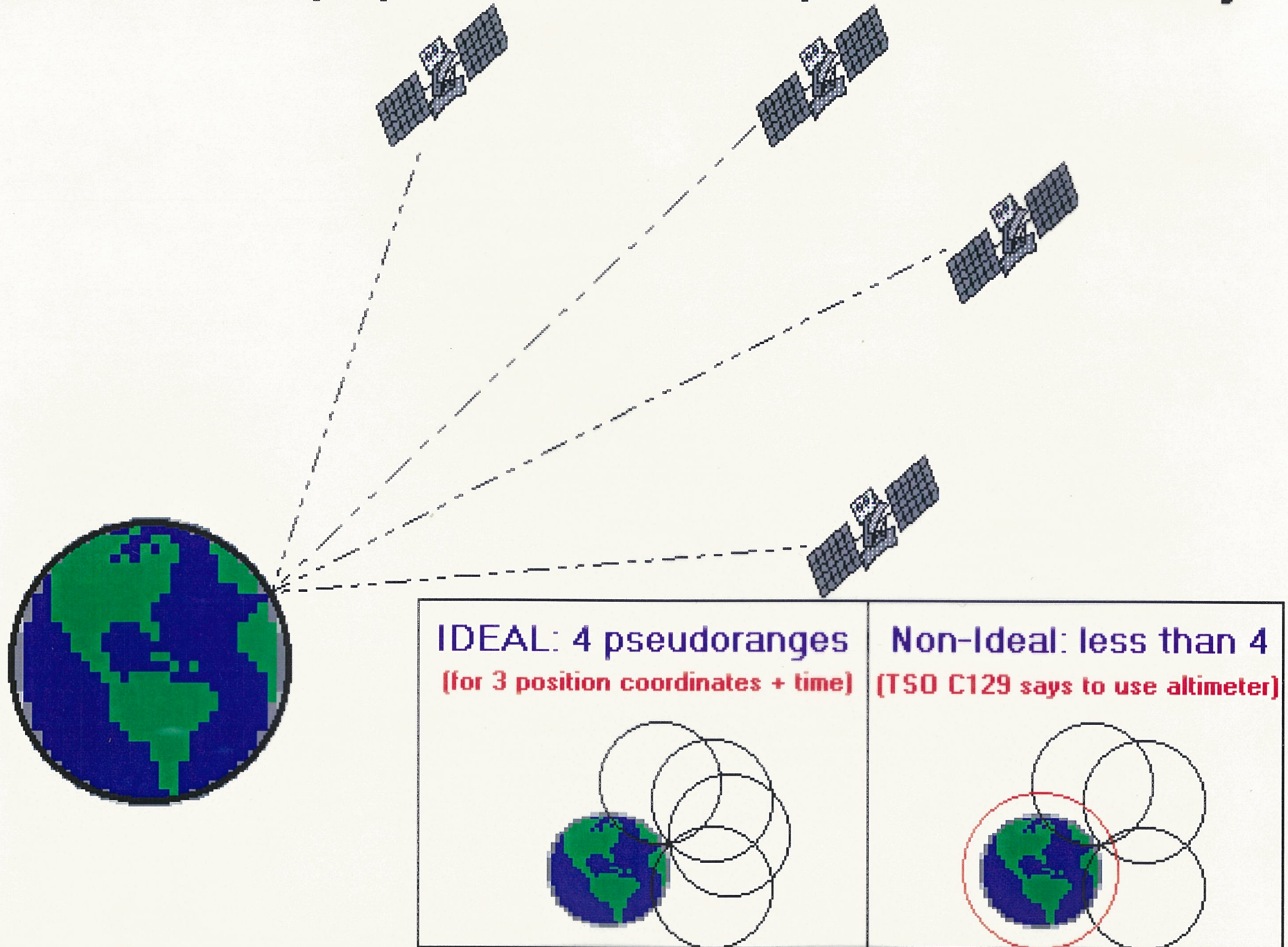
3 Vulnerability

6 Foliage...

9 Publicity:...

End

# Concerns about proposed methods to improve GPS Availability





**From 1992 Technical Standing Order (TSO) C129 entitled: Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS).**

### **To Increase GPS Availability**

**( to 0.9999 for D.o.D. and to 0.99999 for FAA ),**

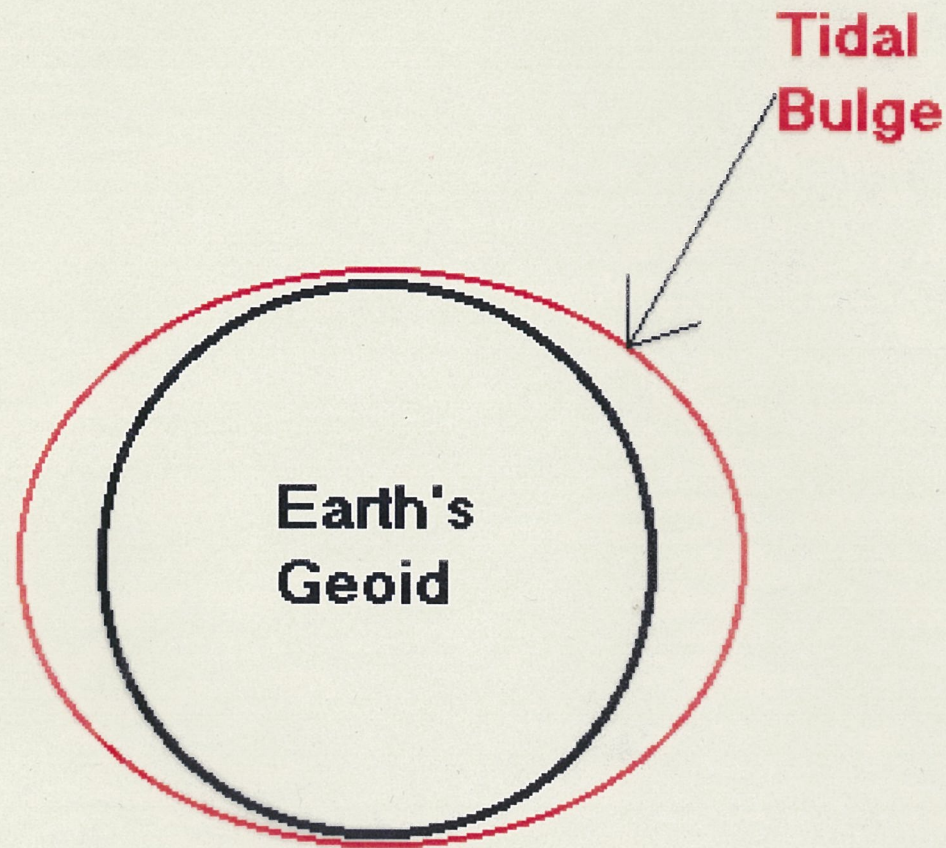
**1992 TSO C129 says to augment GPS using baro-altimeter for aircraft and known height above water level (taken to be = "geoid") is suggested for ships.**

# An Historical Source of Vulnerability...

- Historically, Baro-altimeter has been a significant source of Flight Technical Error (FTE) when pilot neglects to MANUALLY correct for changes in atmospheric pressure (where corrections are normally unavailable over oceans or over enemy territory).—Myron Kayton & Walter Fried, 1969
- Historical ICAO goal for baro-altimeter error was 325 feet FTE at 50,000 feet, but maximum errors of 1,000 feet have been reported in civil operations.
- Above 18,000 feet, all aircraft are compelled to (re)set their altimeters to 29.92 inches of mercury; however, “pressure altitude” has little relation to absolute altitude.
- It is, perhaps, worrisome to rely on something as fragile as barometric altimeter readings to augment GPS availability especially with baro-altimeter history of being vulnerable to Flight Technical Error.



# Departures from the Ideal Geoid



Wave Crest



Wave Trough

Significant wave heights due to sea-state effects of wind and weather

## The Real-World Differs from the Ideal World...

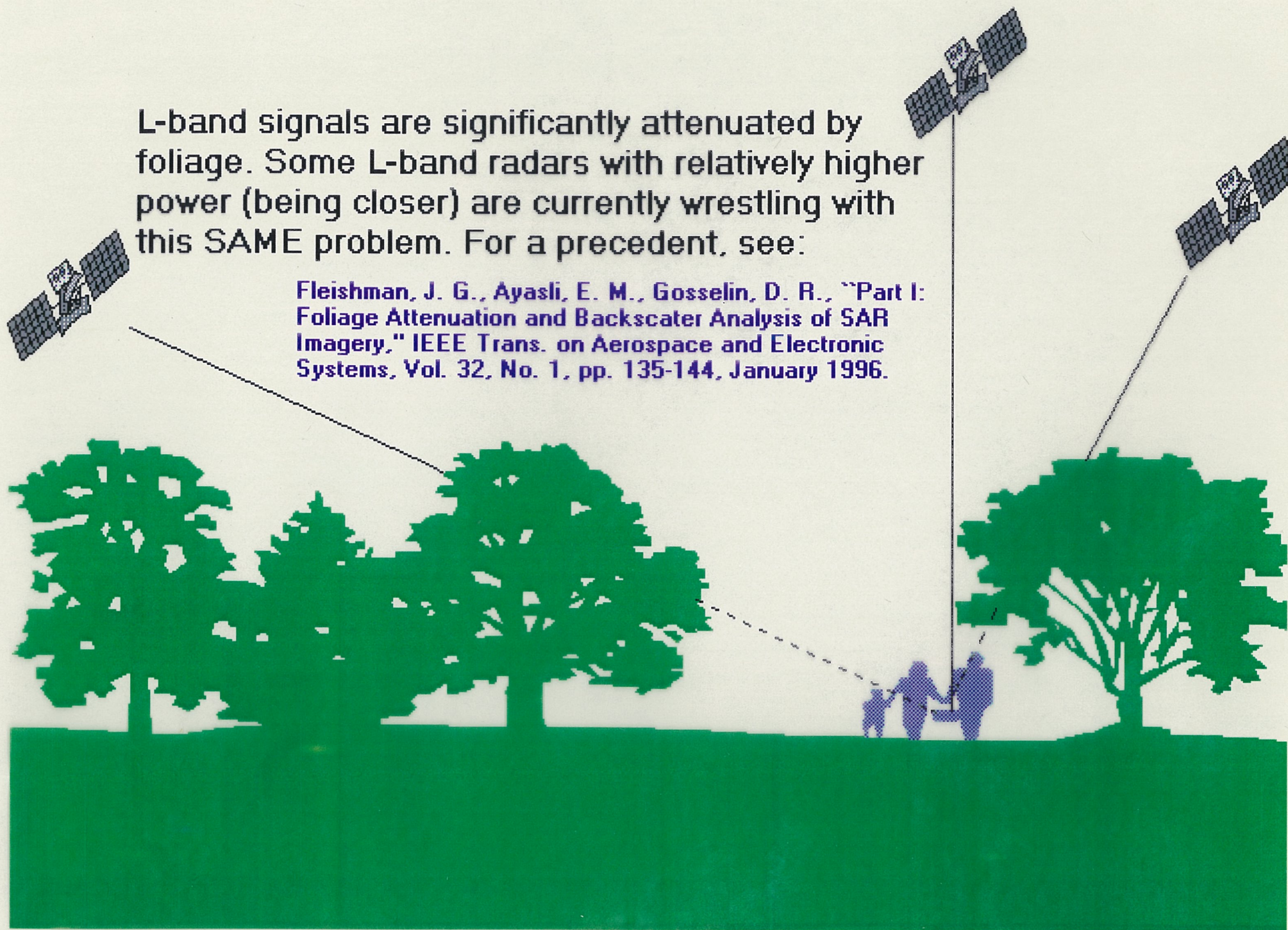


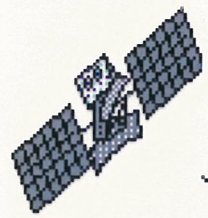
For Sea State = 0 (Beaufort Scale), the sea is as flat as glass.

However, 50 to 75 foot waves are not unheard of and the wind induces waves which, in turn, brings uncertainty into the location of the antenna phase center.

L-band signals are significantly attenuated by foliage. Some L-band radars with relatively higher power (being closer) are currently wrestling with this SAME problem. For a precedent, see:

Fleishman, J. G., Ayasli, E. M., Gosselin, D. R., "Part I: Foliage Attenuation and Backscatter Analysis of SAR Imagery," IEEE Trans. on Aerospace and Electronic Systems, Vol. 32, No. 1, pp. 135-144, January 1996.

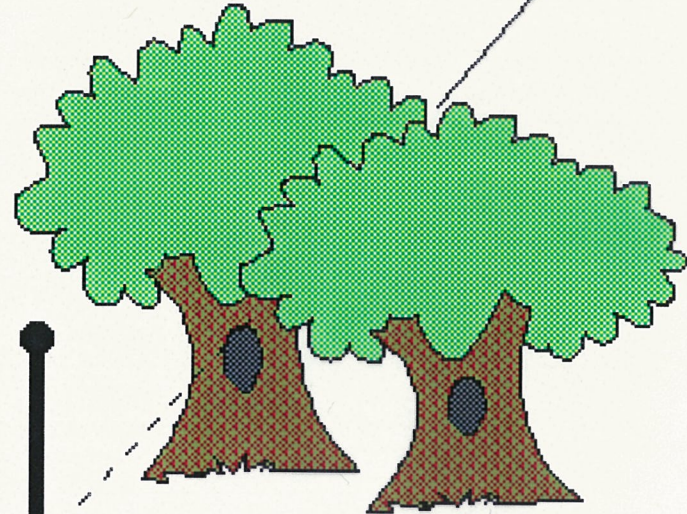
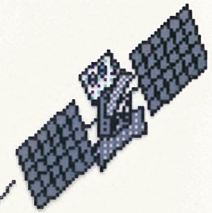




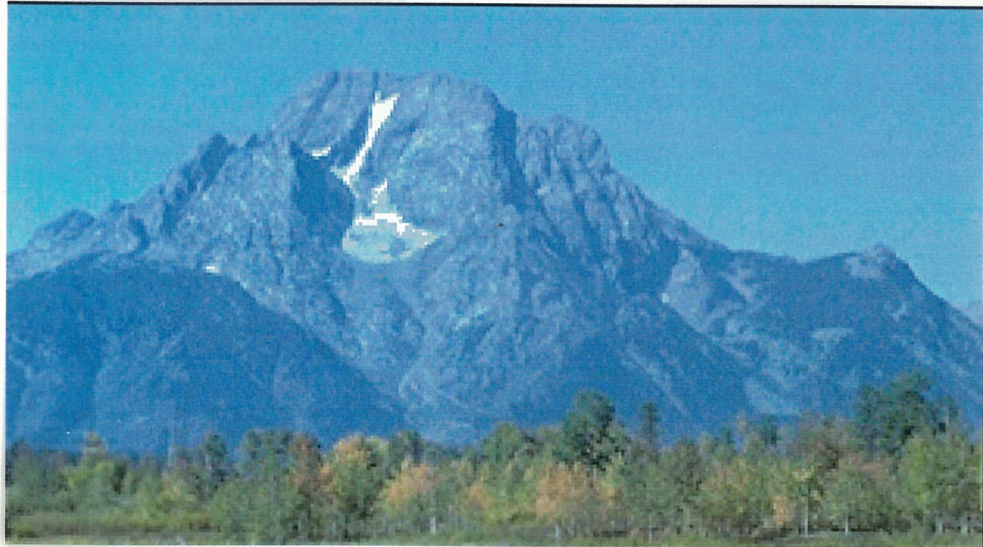
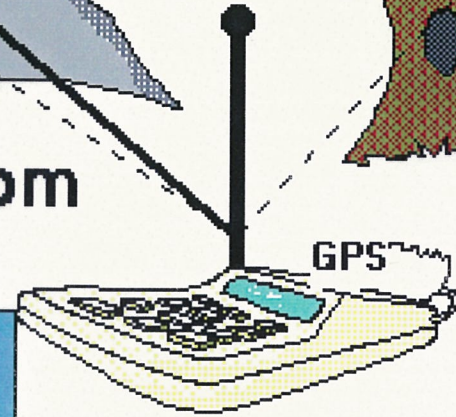
Signal reception can be aggravated by multipath too!

Signal Blocking

L-Band Foilage attenuation

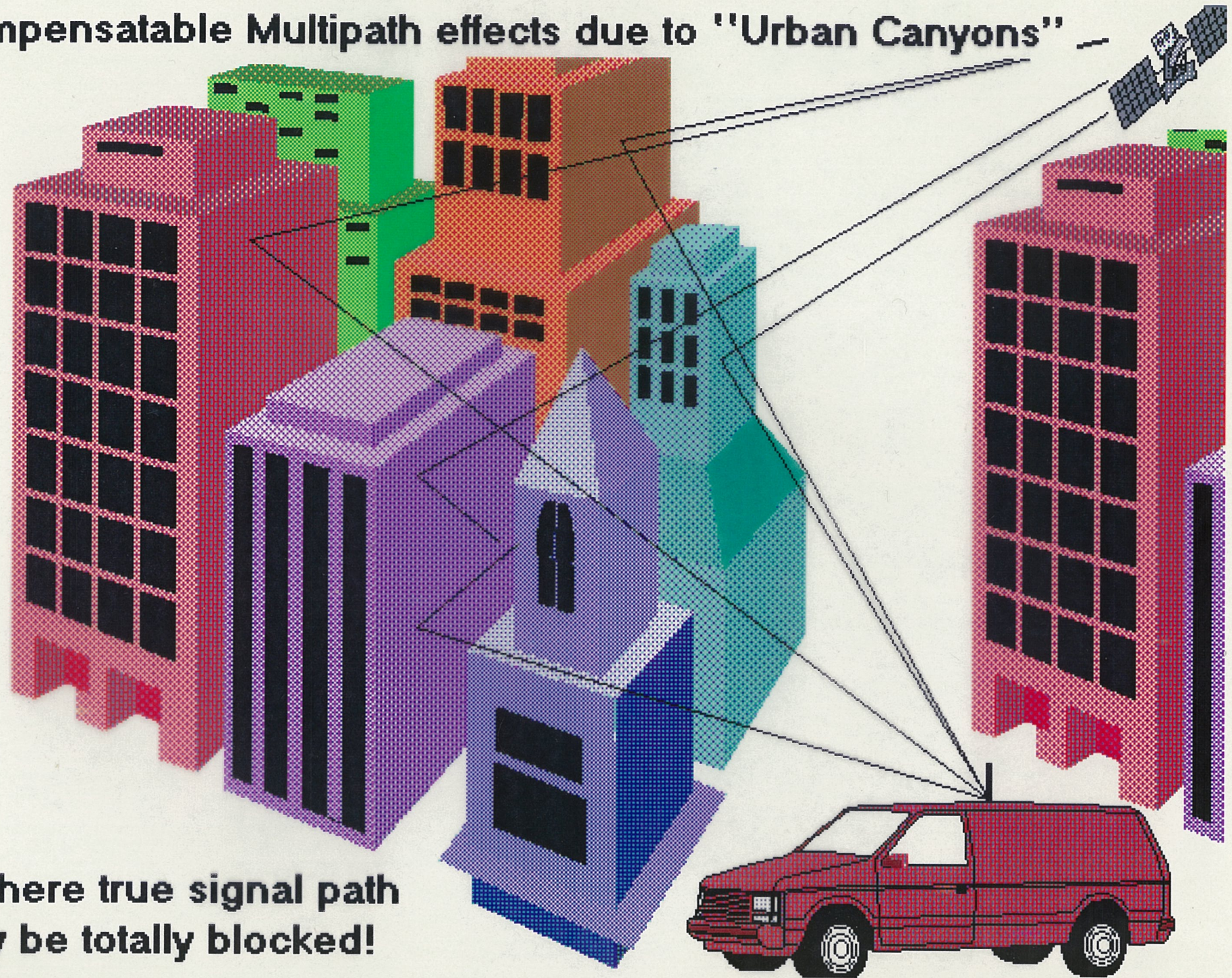


The Real-World Differs from the Ideal World...





# Uncompensatable Multipath effects due to "Urban Canyons"



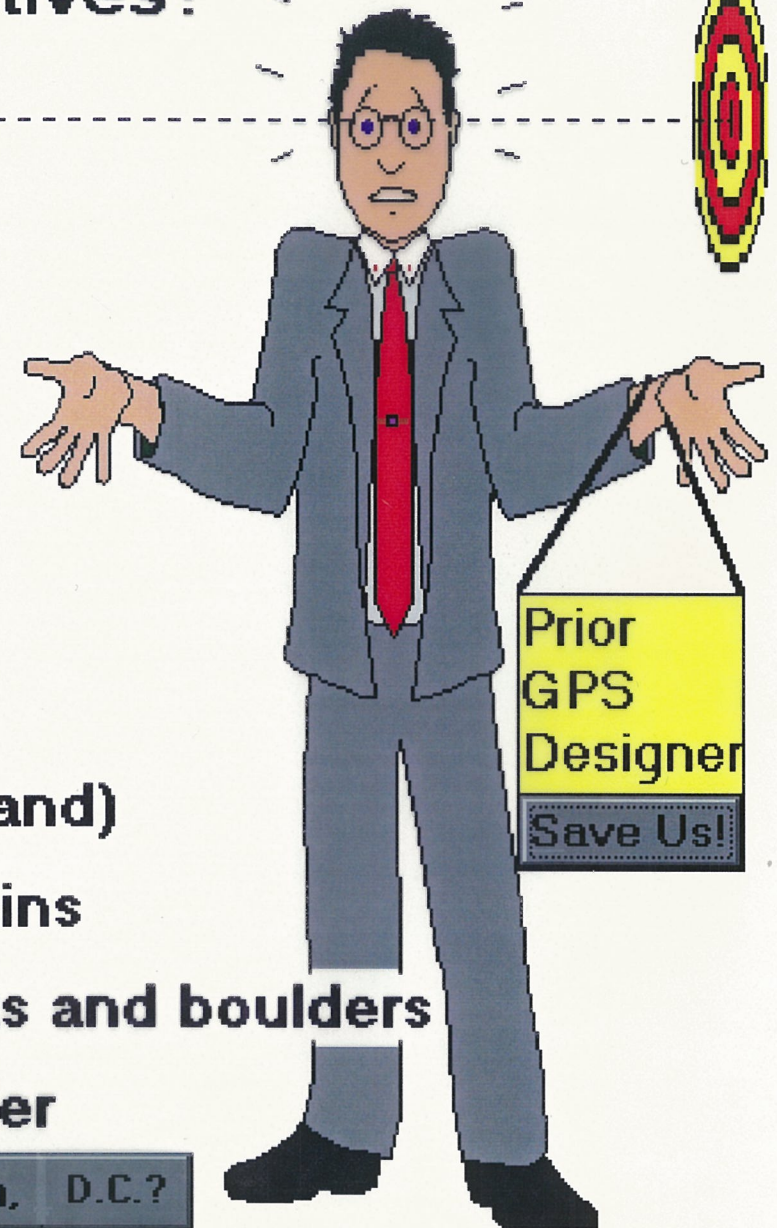
...where true signal path  
may be totally blocked!

Hey, there's NO problem with GPS reception above tree line or on a golf course!  
(or on TOP of a mountain!)



Plenty of GOOD publicity and other useful applications in "GPS World" and at ION GPS Conferences!

## Useful Perspectives?

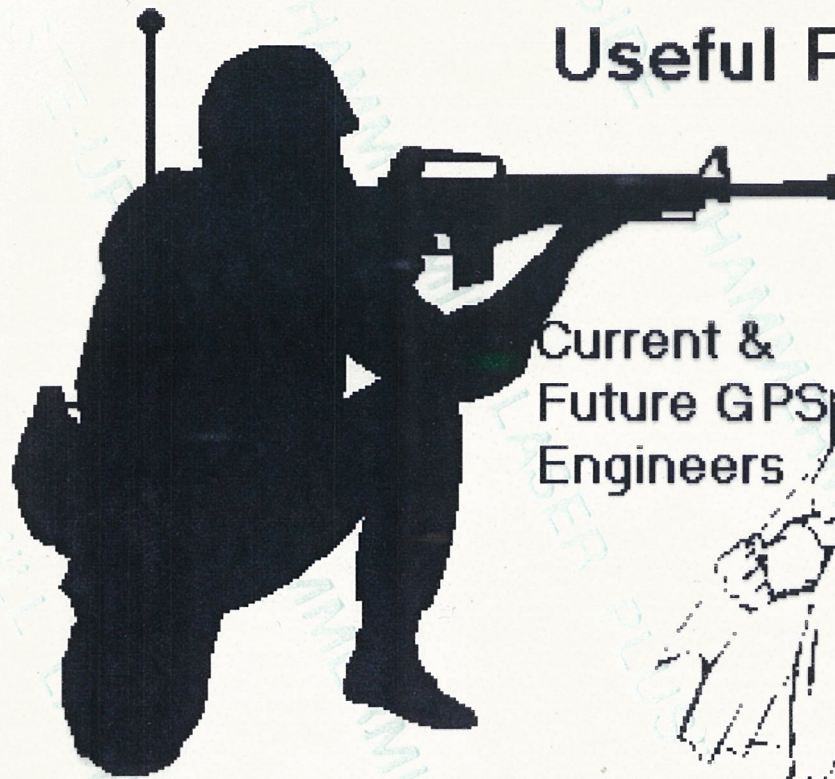


- Avoid foliage (which attenuates L-band)
- Avoid valleys near blocking mountains
- Avoid multipath from metallic objects and boulders
- Avoid multipath reflections from water

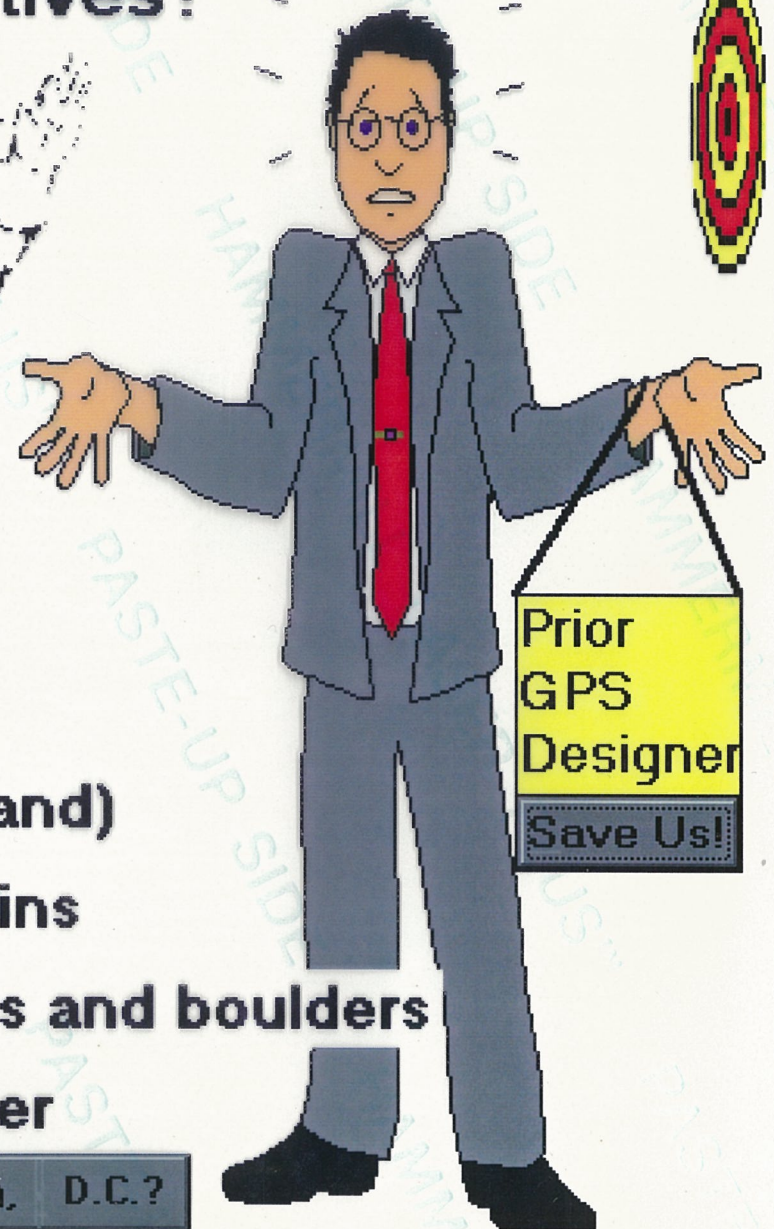
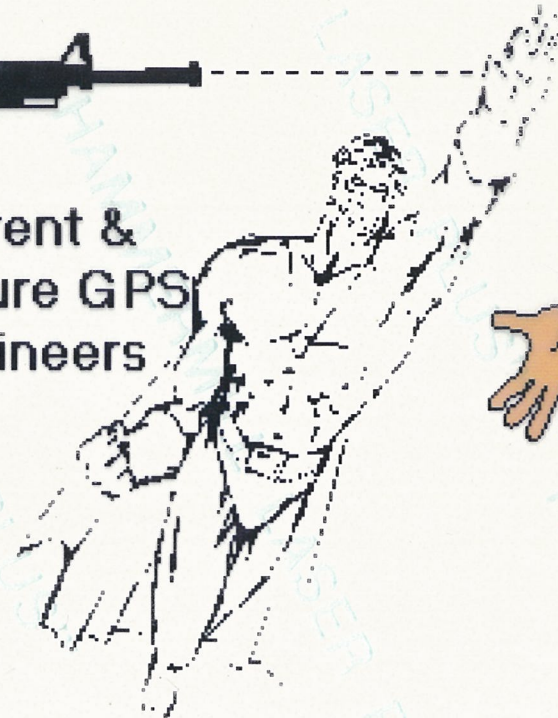
Take complaints to Washington, D.C.?

Essentially, don't take cover, stay in the open, and **be a good target!**

## Useful Perspectives?



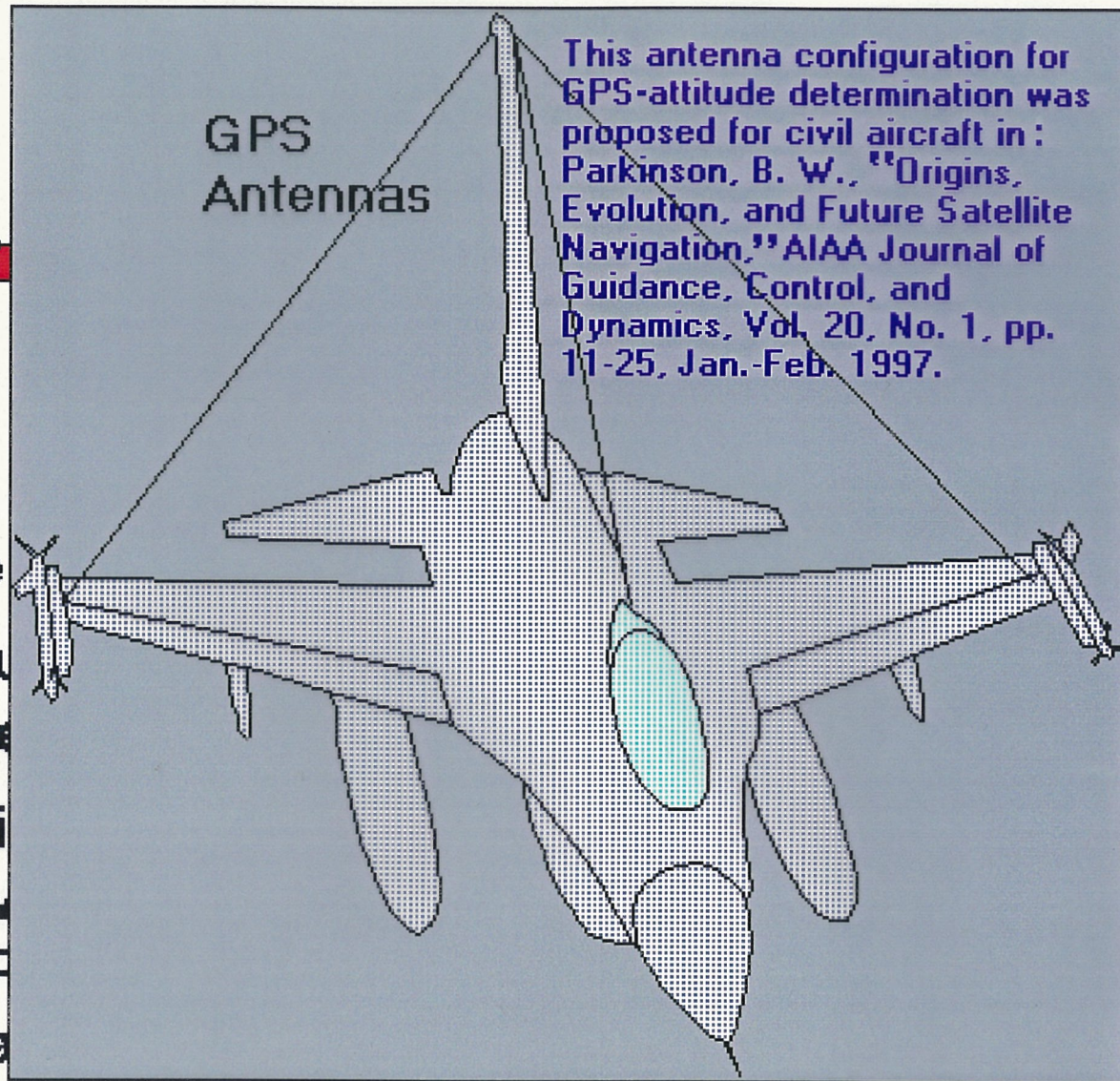
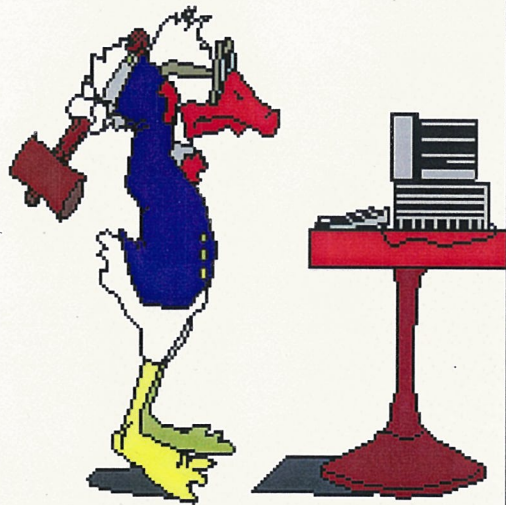
Current &  
Future GPS  
Engineers



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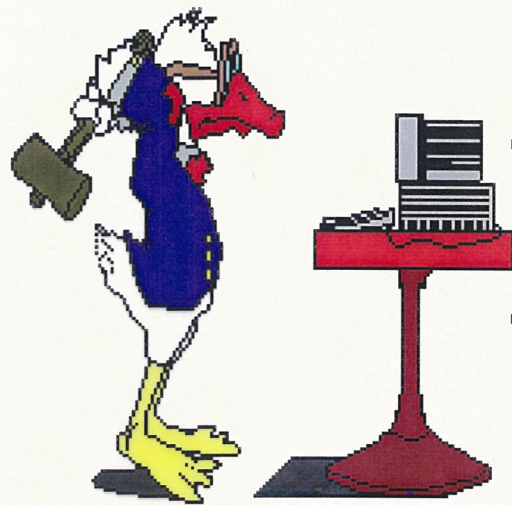
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## Other Concerns:

- **Manufacturer compliance with RAIM coverage apparently is neither monitored nor certified.**
- **Tightly Coupling INS with GPS enhances nominal performance but hampers RAIM isolation of culprit subsystem failures.**

- **Vulnerability to Electromagnetic interference and jamming/spoofing.**
- **Mandated agricultural use of GPS as additional financial squeeze to farmers yet benefit (to farmers) is questionable at best.**
- **Use of INS in applications where interferometry is being applied to GPS signals received on multiple antennas of precisely known location to infer GPS-derived attitude, YET attitude provided by INS ALONE is MORE accurate.**
- **GPS-derived attitude being proposed for aircraft apparently without concern for deleterious effect of wing flutter, vibration, flexure, coefficient-of-thermal-expansion, and other lever-arm effects which interfere with CRITICAL exact knowledge of antenna phase center.**