Looking Ahead for GPtS ---

Bradford Parkinson
Emeritus Professor
Stanford University
Department of Aeronautics and Astronautics

GPtS – the Stealth Utility

- The Future
- Challenges

Note: t = TIME

"You've got to be very careful if you don't know where you are going,

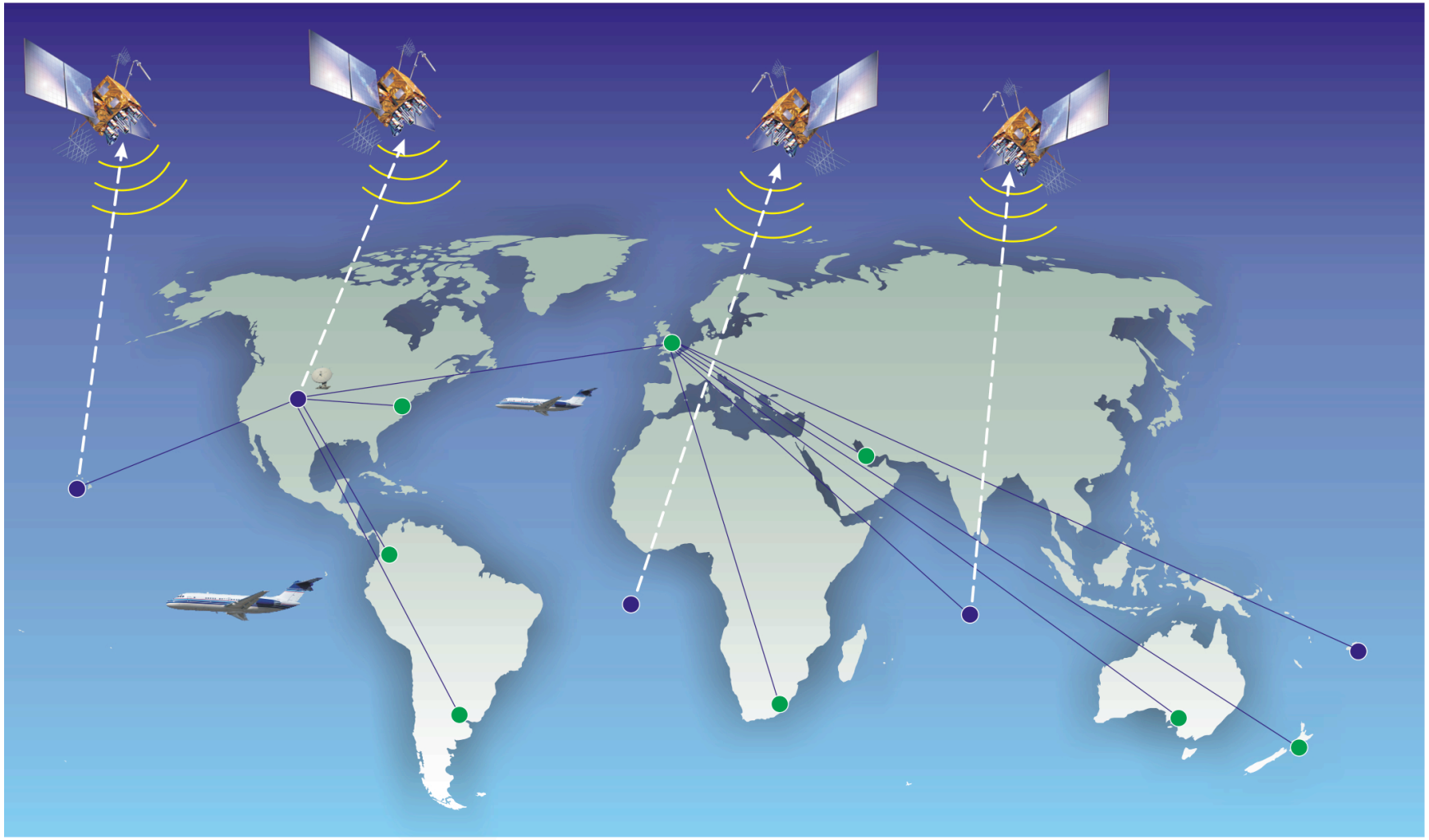
Because you might not get there! "

-- Yogi Berra

Manager New York Yankees Baseball Team

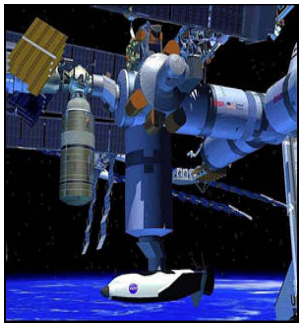
Today, GPS Serves over 300 *Million* Users

(from the FAA & C. Moon, AMTI)

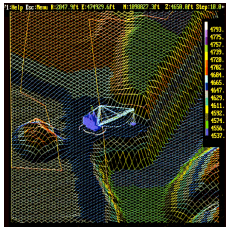


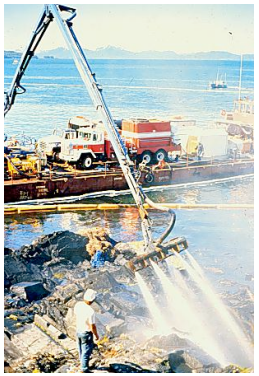
GPS Applications have Proliferated

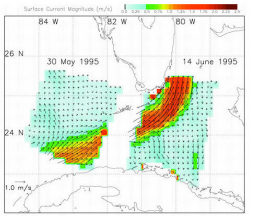
- Civil
  - Transportation
    - *Aviation*
    - *Automobile*
    - *Maritime*
    - *Rail Control*
  - Public Services
  - Timing & Frequency
  - Surveying
  - Surveillance
  - Other
- Military



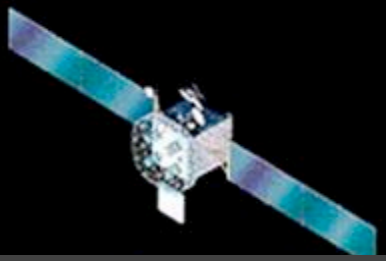







A Fundamental Change in Warfare

UFO Communication Satellite
Controlled via AFSCN



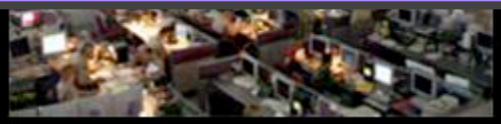
Improved Battlefield Situational Awareness

E-3 AWACS

F-16 Drops
GPS Guided JDAM

10th Mountain Division Soldiers
requesting close air support with
satellite radios
Operation ANACONDA, March 2002

Enable Precision, All-Weather Operations

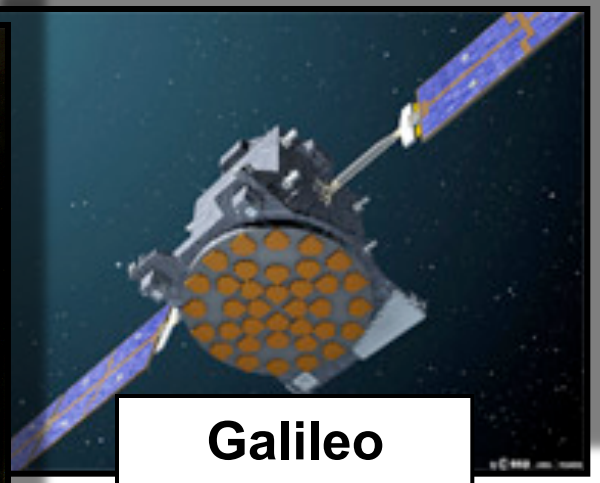


CAOC directs aircraft

al-Qaeda Target Destroyed

What's Next?

PNT to Explode with Opportunities

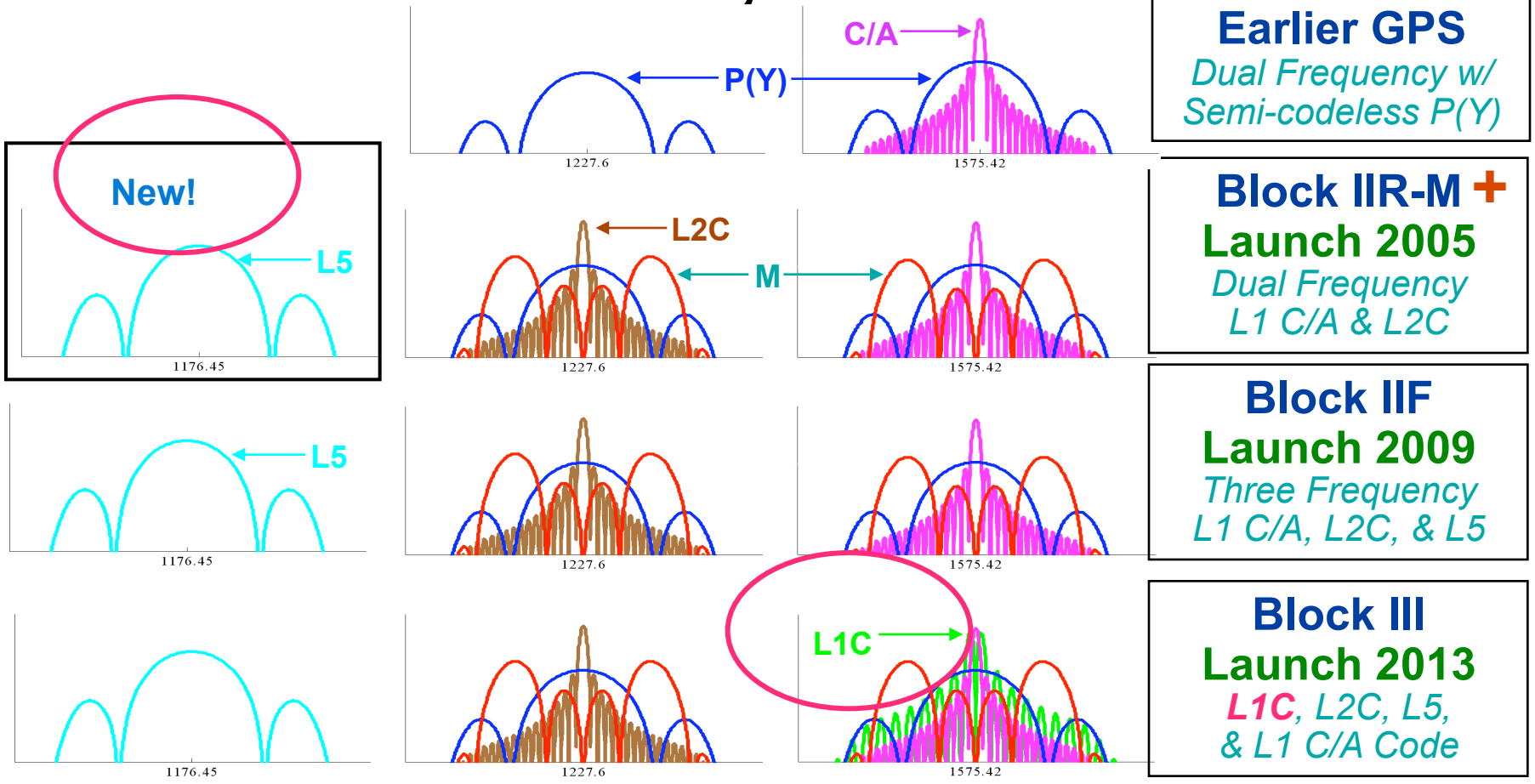


The Five Design Keys (& Barriers to Entry)

1. The CDMA signal (PRN or Spread spectrum)
2. Van-Allen qualified atomic clocks
3. Orbit prediction to a few meters (URE) in 100,000 km of travel
4. Spacecraft that lasted about ten years (cost of ownership)
5. User Equipment that could (eventually) be miniaturized (<$)

New Signals are On the Way

Summary - Spectrum of Modernized GPS Signals



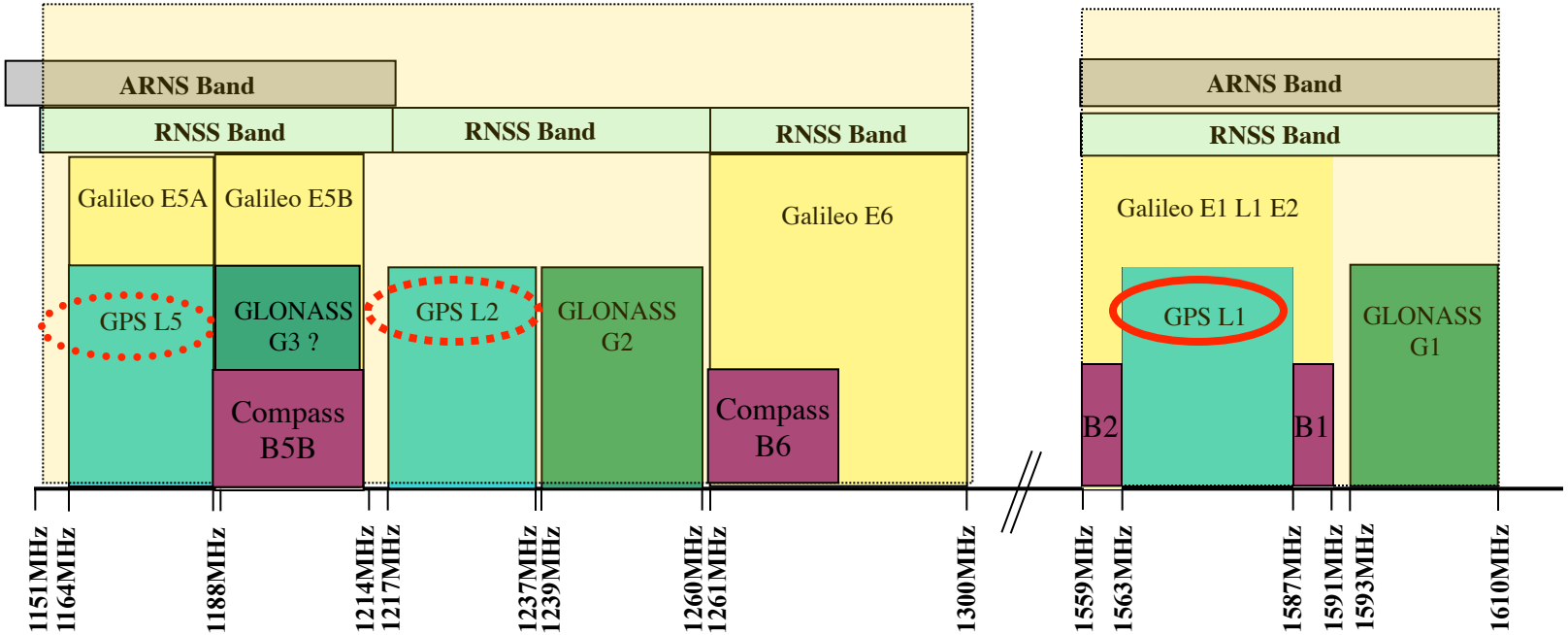
Earlier GPS
Dual Frequency w/ Semi-codeless P(Y)

Block IIR-M +
Launch 2005
Dual Frequency L1 C/A & L2C

Block IIF
Launch 2009
Three Frequency L1 C/A, L2C, & L5

Block III
Launch 2013
***L1C**, L2C, L5, & L1 C/A Code*

Coming: a Plethora of Signals



New Systems: Can't we just get along?

- Degrees of "Getting Along"
  - Compatible
    - *Lets not hurt each other*
  - Interoperable
    - *I'll try yours, you can try mine*
  - Interchangeable
    - *Any four will do*

So what are the major new (or expanded) applications going to be?

"Predicting the future is easy. It's trying to figure out what's going on now that's hard." - Fritz R. S. Dressler

- Expanded Crustal Tracking
- Precision Tracking and Reporting (Air Traffic ADS-B)
- Cell/GPS explosion – where will this go?

Robotic or "*Assisted*" *Control*
already a Major Application of GPS

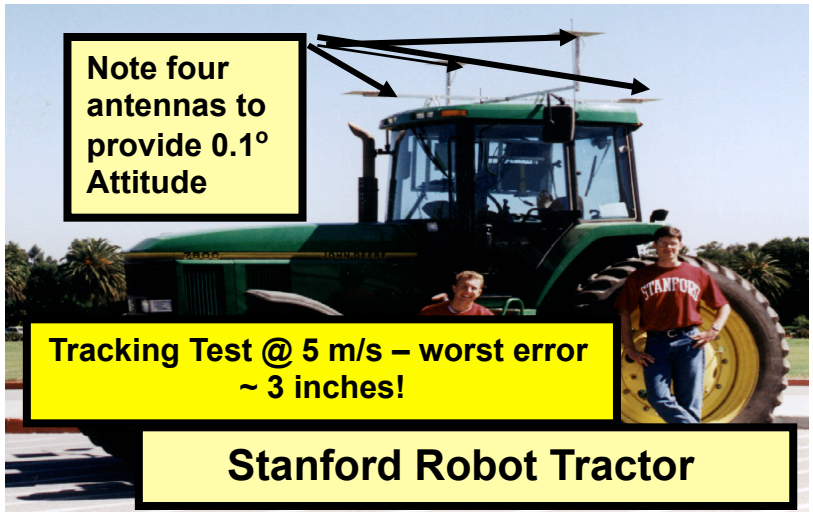
New Systems: Robotic Use Of GPS at Stanford

Blind Landing Tests – 110 straight successes with one go around

Typical Accuracy-
Four Inches

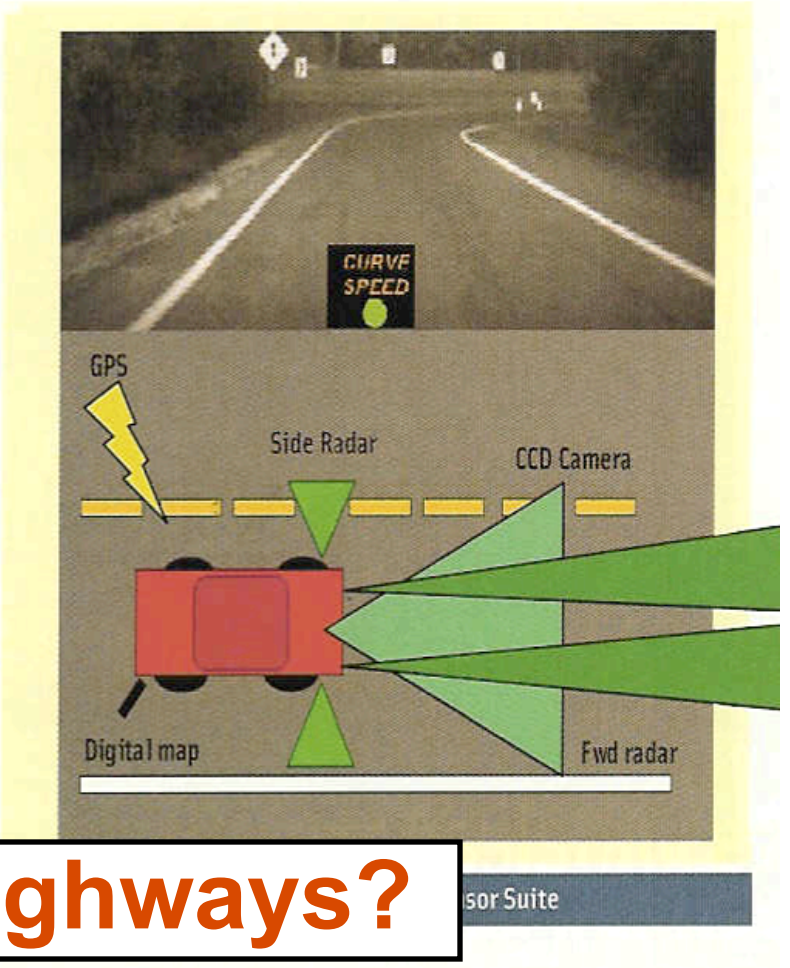
Autonomous Model Helicopter

GPS Position, Velocity and Attitude



A Future ***System***: Auto-guided Automobiles and Freeway Automatic Traffic Control

- Use all International Position Signals
- Vector Kinematic Receivers (10 cm or better)
- MEMS/IMU/CSAC
- Radars
- Cooperative Tracking of other vehicles



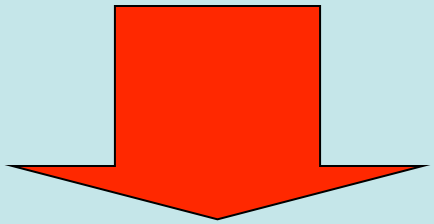
ADS-B for Highways?

A Caution: Three Critical Issues for GPtS

Preamble to the Issues

We are Victims of our success:

GPS Enormous Capability



Worldwide Dependency

What must we do to **insure** that the
Trust in GPtS
is not misplaced?

The *Three* Issues

- Sustainment
- Robustness
- Interchangeability

GPtS Issue #1 – (**Sustainment**)
Constellation Availability

- Average GPS on-orbit life 8.9 years
- First IIF currently available for launch:
  January 2009
- First GPS III currently available for
  Operations - April 2014
- When will Galileo be "certifiable"?

It is **imperative** the we avoid "GPtS Brownouts"

Needed: Sustained, high-level support
for earlier GPS III delivery and availability

GPS Issue #2 – *GPS Robustness (Deterrence)*

- Constellation size of 30+X for users in impaired environments (the GDOP imperative)

  Need: Full, urgent **Commitment** by US

- Affordable GPS Receiver Interference Rejection Technology (inertial integration and digital beam steering technology)

  Needs full development

- GPS Backup – eLoran?

  Needs decisions/funding

GPS Issue #3 –GPS and Galileo- True, Total ***Interoperability***

- ***Real Measure:*** ***Interchangeability*** "Mix and Match" with the same ranging accuracy
  - L1C defined, implemented, and operable – including all details
  - Seamless WAAS/EGNOS/+ ?
  - True clock Synchronization (Common Clock) **and** common grid
- **Payoff** – Availability, Accuracy and Robustness for ***Worldwide Users***

The Burden for the GPtS Community

As ***providers*** of GPtS

we must insure the Service

is ***Always Available*** - To meet:

the Safety, Economic, and Convenience

Needs of the World

And the ***Defense of Freedom***

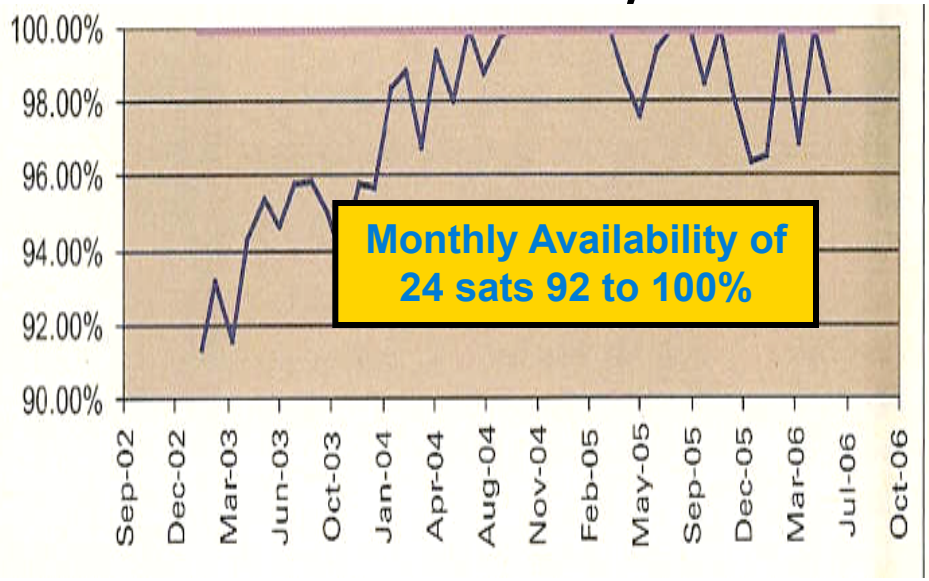
Thanks for your Attention -

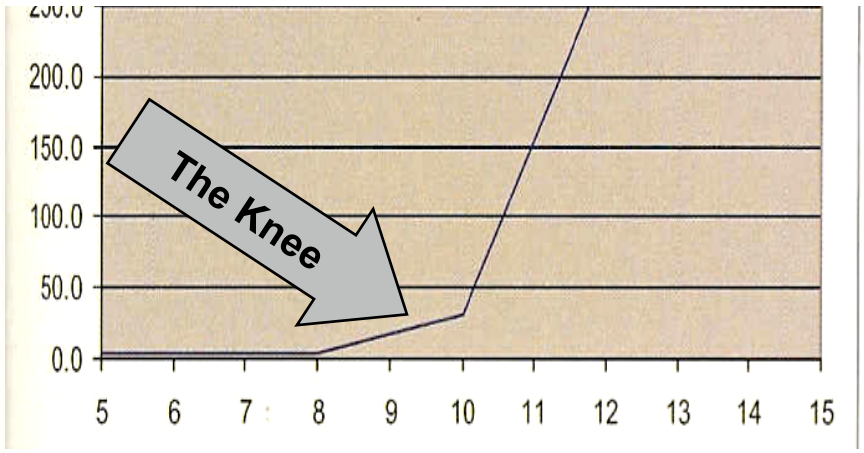
Questions?

Backups

Illustrating why current number of Satellites is Minimal (Courtesy GPS World and John Lavrakas)

- Accuracy is strongly driven by Masking Angle and number of satellites (the impaired user's problem)
- Above 10°, less than 30 satellites destroys accuracy and availability





Accuracy vs. Mask Angle (degrees)

THE "Big Five" Civil Goals for GPS

1. Assured Availability of GPS signals-Including impaired situations (mountains, urban areas, foliage, etc.)
   - **Number of GPS Satellites/Geometry**
   - Interoperability and Standardization with Galileo et al
2. Resistance to Interference (RFI)
   - Additional Satellite RF power and Frequency Diversity
   - More jam resistant GPS receivers
3. Accuracy
   - Require Prediction Accuracy (Satellite Clocks and Age of Update)
   - **Improved Satellite Geometry is essential**
   - Augmentations: WAAS LAAS EGNOS MSAS NDGPS PLs
4. Bounded
   - Conce
   - **Good**
5. Integrity
   - WAA
   - RAIM

Three of top four Goals are driven by the number of satellites – hence DSB & IRT 30+X satellite recommendation

The Five Biggest Development Challenges for GPS

1. **Selection and detailed design of the GPS CDMA (code-division, multiple-access) signal**
2. **Developing and verifying space-hardened (upper Van- Allen belt qualified) atomic clocks**
3. **Developing techniques for orbit prediction to a few meters (URE) in 20,000 miles of travel (this includes prediction of the clock behavior)**
4. **Designing and building spacecraft that lasted about ten years (cost of ownership issue)**
5. **Designing and demonstrating user equipment that could eventually be miniaturized and produced at low cost.**