Looking Ahead for GPS ---

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GPtS – the Stealth Utility

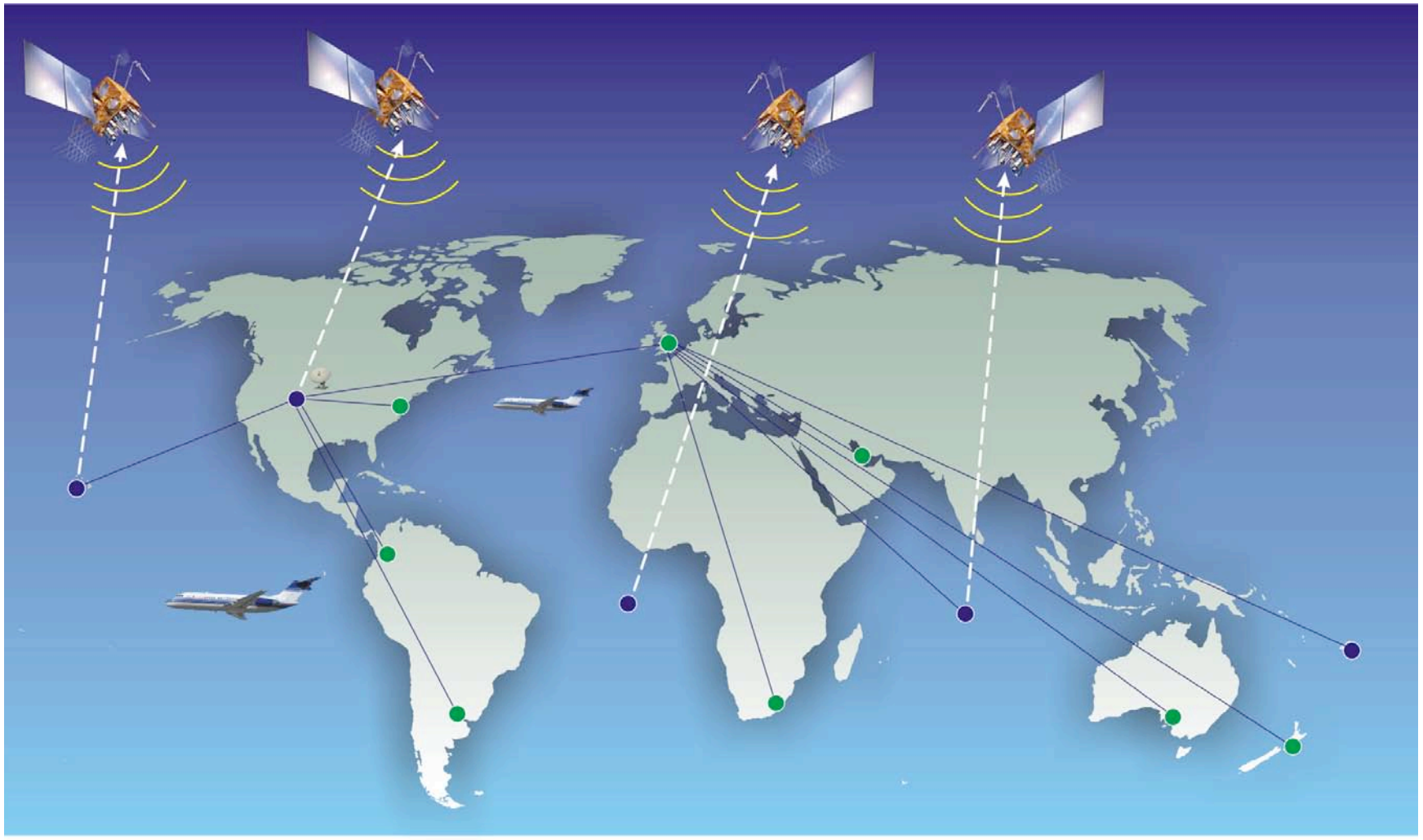
- The Future
- Challenges

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

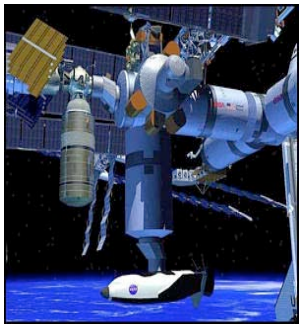
Today, GPS Serves over 300 *Million* Users

(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

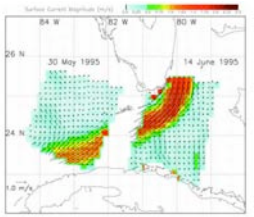













A Fundamental Change in Warfare

UFO Communication Satellite
Controlled via AFSCN

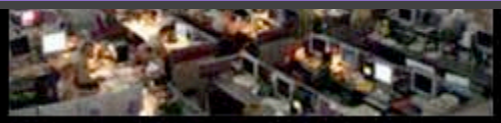
Improved Battlefield Situational Awareness

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

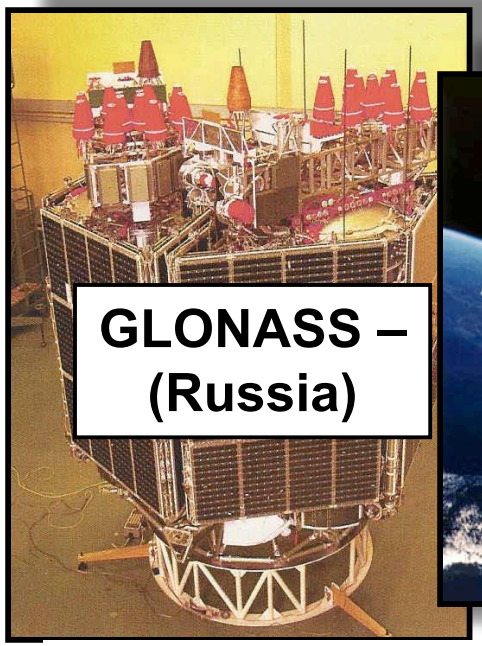


CAOC directs aircraft

al-Qaeda Target Destroyed

What's Next?

PNT to Explode with Opportunities

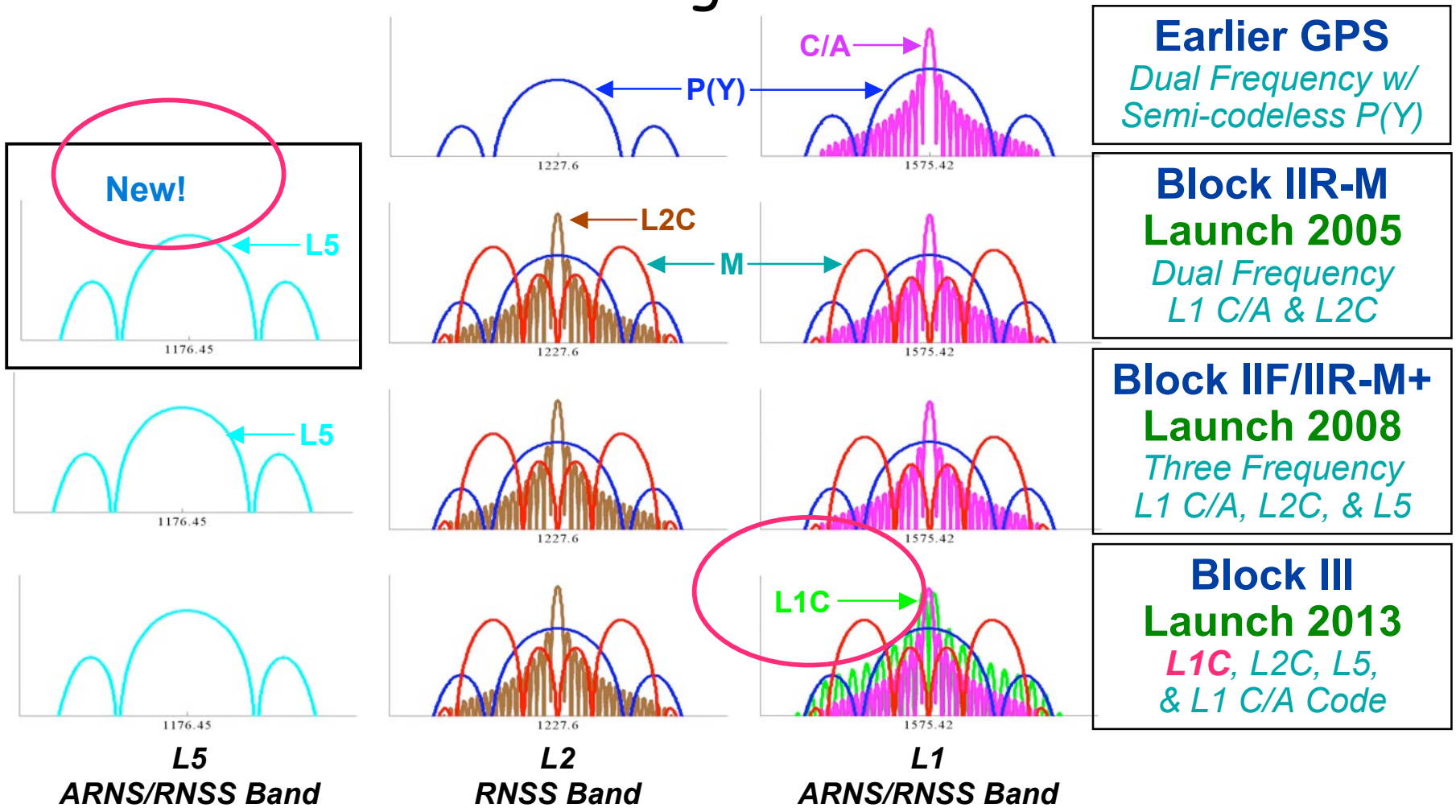


The Five Design Keys (& Barriers to Entry)

1. The CDMA signal (PRN or Spread spectrum)
2. Van-Allen qualified atomic clocks
3. Orbit prediction to a few meters (URE) in 20,000 miles 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



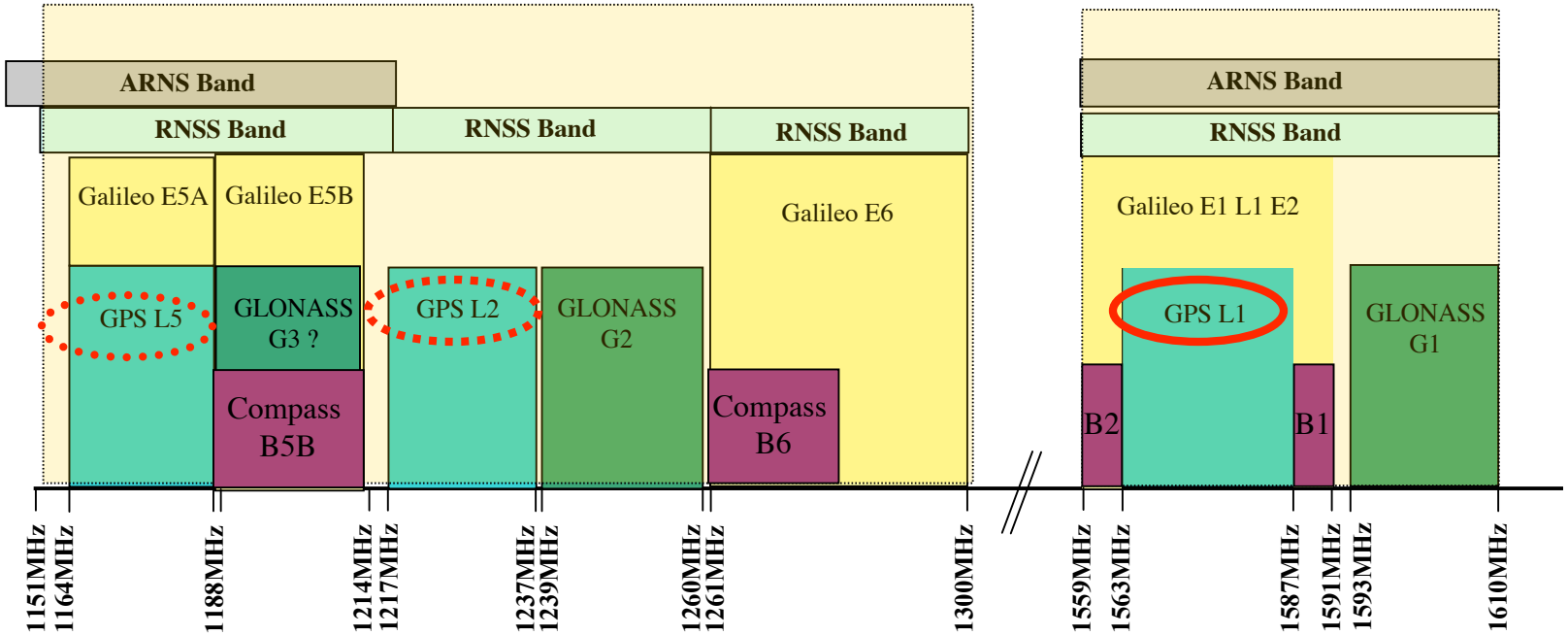
Earlier GPS
Dual Frequency w/ Semi-codeless P(Y)

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

Block IIF/IIR-M+
Launch 2008
Three Frequency L1 C/A, L2C, & L5

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

Coming: a Plethora of Signals



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

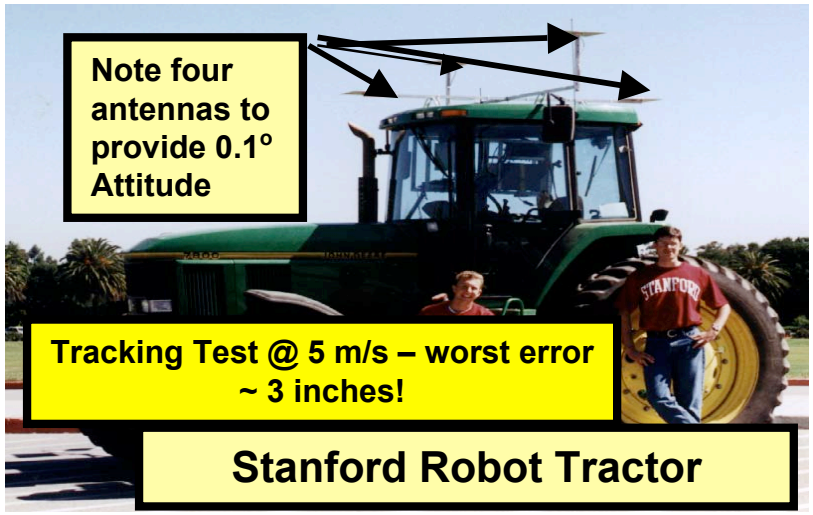
New Systems: Robotic Use Of GPS at Stanford

Blind Landing Tests – 110 straight successes with one go around

Typical Accuracy-
Four Inches

Autonomous Model Helicopter

GPS Position, Velocity and Attitude



Note four antennas to provide 0.1° Attitude

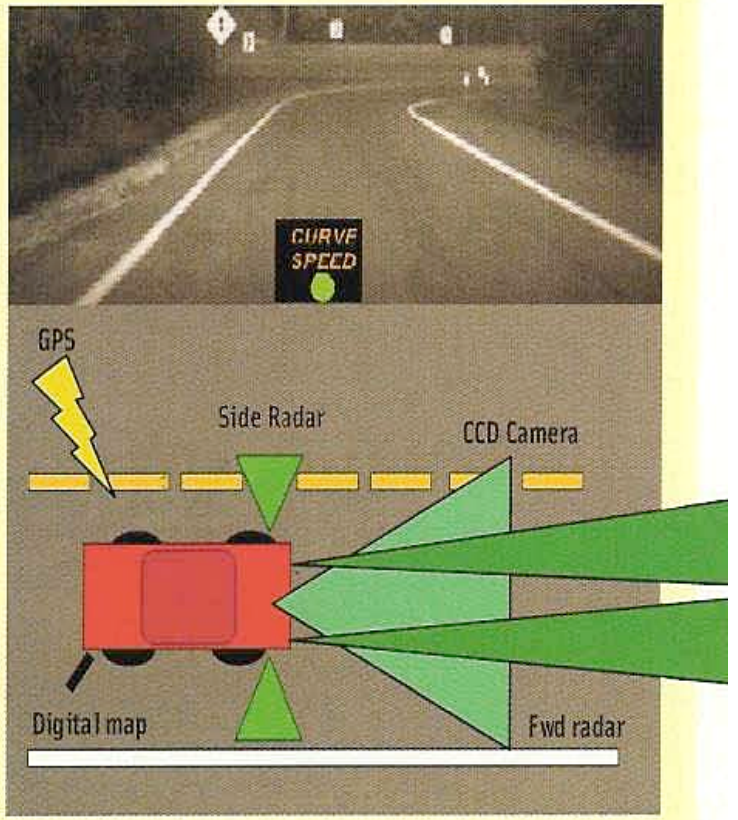
Tracking Test @ 5 m/s – worst error ~ 3 inches!

Stanford Robot Tractor

"Stanley" Vehicle the Winner
Stanford-Berkeley

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



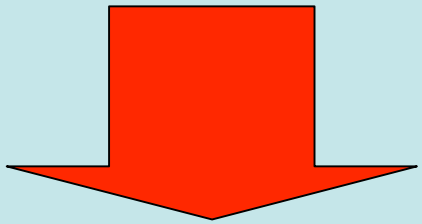
ADS-B for Highways?

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

GPS Issue #1 – (Availability)
Constellation Sustainment

- Average on-orbit life 8.9 years
- First IIF currently available for launch:
  January 2009
- First GPS III currently available for Operations - April 2014

It is **imperative** the we avoid "GPS 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

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
  - Seamless WAAS/EGNOS/+ ?
  - True clock Synchronization (Common Clock) **and** common grid
- **Payoff** – Availability, Accuracy and Robustness for ***Worldwide Users***

The Burden for the GPS 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***

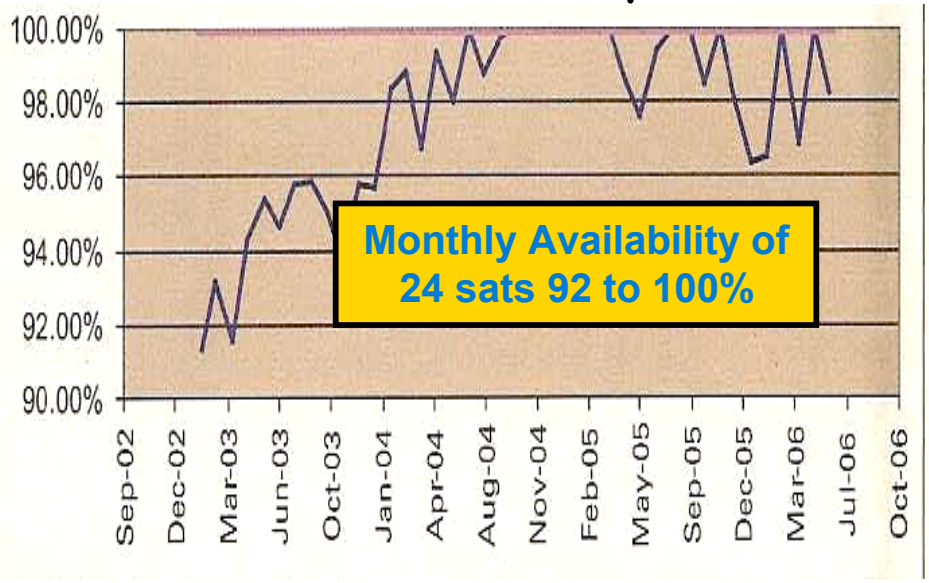
Thanks for your Attention -

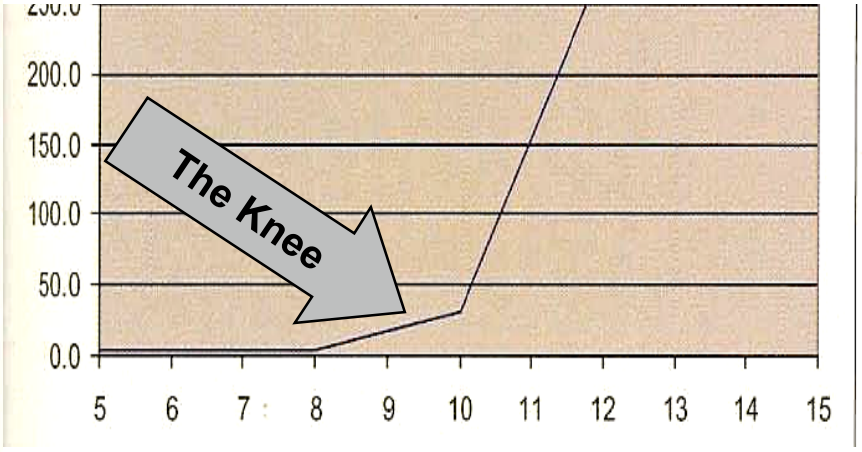
Questions?

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