Emerging Capabilities, Applications, & Sectors (ECAS)

Subcommittee Membership and Study Areas

Members:

- Frank van Diggelen, Chair
- Penny Axelrad, 1st Vice-Chair
- Scott Burgett, 2nd Vice-Chair
- John Betz
- Renato Filjar
- Dorota Greiner-Brzezinska
- Matt Higgins
- Vahid Madani
- Terry Moore
- Tim Murphy
- Tom Powell
- Eileen Reilly
- Russ Shields
- Todd Walter

Role/ Study Areas:

- **High Accuracy and Resilience Service (HARS)**
  - *Intelligent Transportation Systems*
  - *Autonomous Platforms (UAVs etc)*
  - *Cislunar Service Volume*
  - *Integrated Energy Grid Concept*
  - *Positive Train Control*
  - *Communication Networks*
  - *MEOSAR (MEO Search & Rescue)*

Maintaining GPS Leadership

National Space Policy 9 December 2020:
"The U.S. must maintain its leadership in the service, provision, and responsible use of GNSS" [1]

GPS is currently the primary system in almost all GNSS chips, even chips made in Europe and Asia. That is: chips are designed to acquire GPS first, then the other systems.

The problem: GPS is falling behind the EU (Galileo) and China (Beidou), because it takes too long to implement new, more flexible capabilities while maintaining backward compatibility. This puts GPS primacy at risk and is a problem for commercial and US government users of GPS.

- *Galileo, QZSS, BeiDou: all now provide High Accuracy Services in their satellite broadcast signals.*
- *Galileo HAS will also be distributed over the internet.*

The question : Is it feasible to provide higher accuracy 0.1 – 1m and greater resilience with GPS?

[1] U.S. Space-Based PNT Policy Update March 2022, H.W. Martin III, Director, National Coordination Office, link
[2] "*Who's your Daddy? Why GPS rules GNSS*", F. van Diggelen, Keynote. Stanford PNT Symposium, Nov 2013, link
[3] "*Who's Your Daddy? Why GPS will continue to dominate consumer GNSS*", F. van Diggelen, Inside GNSS, Mar/Apr 2014, link

GPS High Accuracy & Resilience Service (HARS)

Innovative new services cannot wait for a full replenishment of the GPS constellation.
- *The alternative is to use flexible delivery mechanisms to implement them much more rapidly.*

Requirement for user equipment to have separate connectivity to the internet is not a severe limitation. Such capability already exists with mobile phones and other receiver implementations, and is only increasing with new satellite-based internet services.

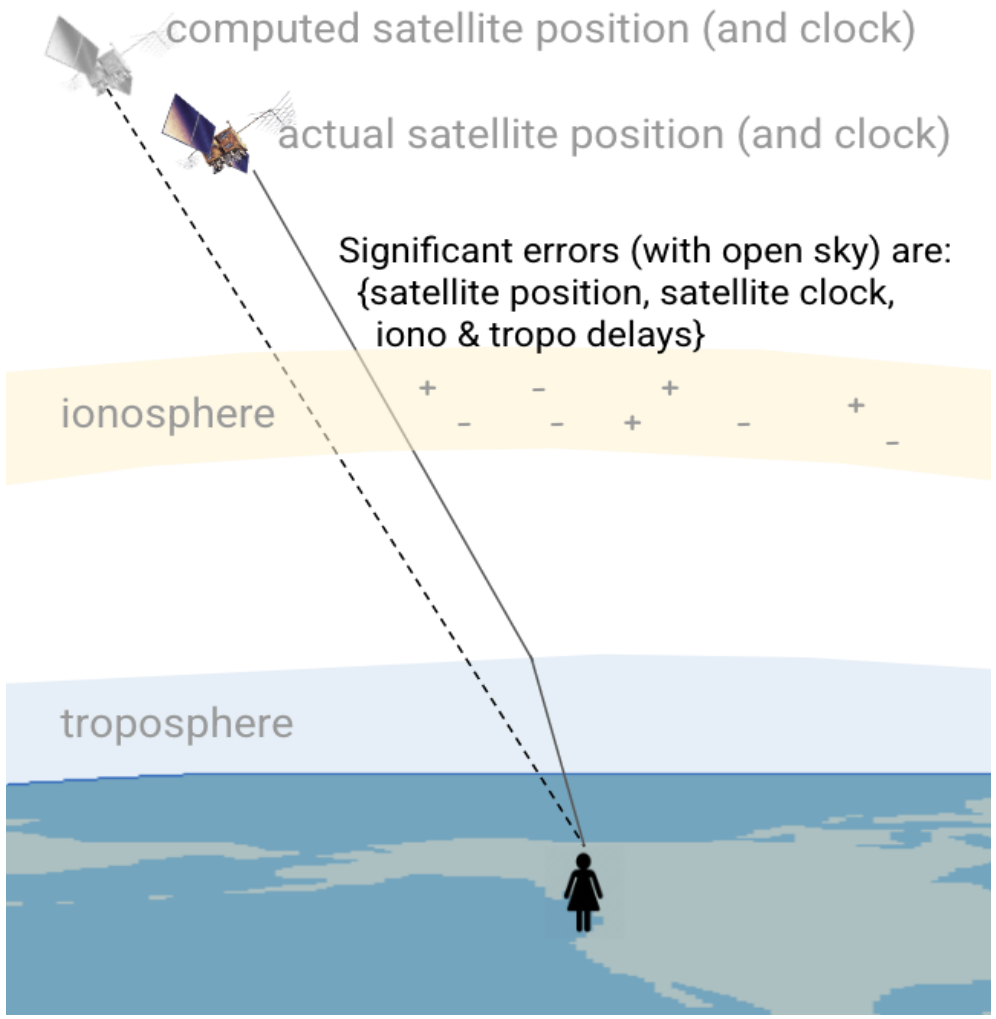
New services made available to the user community securely through the internet would not be restricted by GPS's low bit rate and need for backwards compatibility.

GPS HARS can leverage existing capabilities of US government organizations to determine corrections for GNSS satellite orbits and clocks.

Improved models and techniques for ionospheric and tropospheric effects are also well established and can be quickly implemented.

Initial performance at the < 1m, with flexibility in the service for continued enhancement

HARS Content



State Space Corrections

- Satellite orbit, clock errors, differential code biases
- Ionospheric corrections – improved empirical model or machine learning based predictions
- Tropospheric corrections – seasonal & weather models

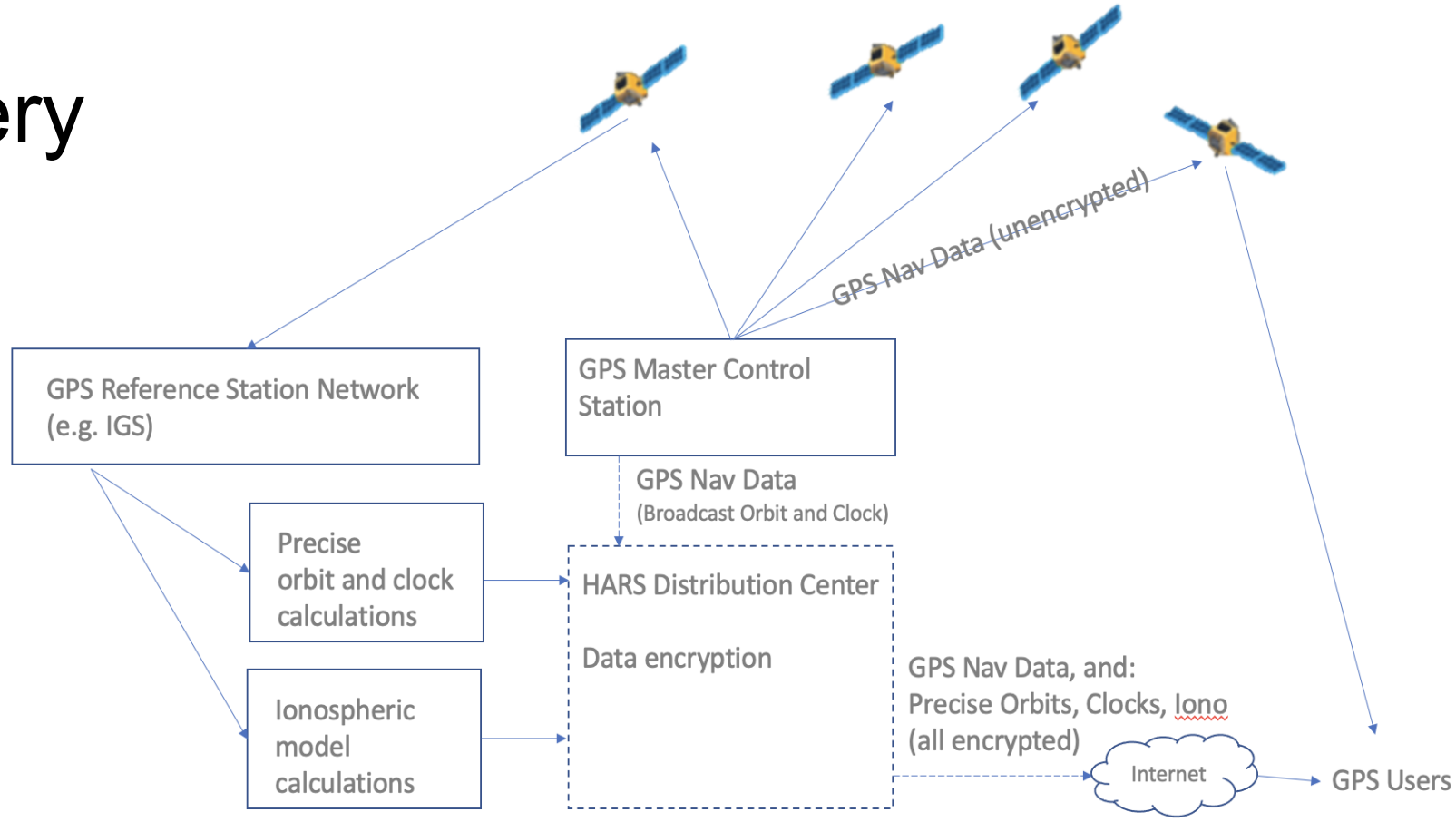
JPL presentations showed that existing GDGPS has the capability to gather required observation data and to generate high accuracy products

Nav Data Bits

- Allows for authentication of transmitted signal
- Alternatively allows for tracking under more challenging signal conditions

Nav data would need to be provided by GPS operations

Secure data delivery over the internet



Data encryption and delivery block diagram for a High Accuracy and Resilience Service (HARS).
All the components exist except for the HARS-specific encryption and distribution center.

The service would provide GPS users with higher accuracy and security of their GPS signals than they currently experience.

HARS Data distribution supports user resilience

- Providing encrypted Nav data over the internet frees receivers from full reliance on the open data service broadcast from space.

- Comparable to the distribution of “Assisted GPS” data to cell phones
- Cryptographic means for authentication can ensure that the data received by the user is actually the real data sent by the HARS service provider.
- Such secure connections are well known and supported by widely used current standards.

- HARS service could be delivered to users via the internet using a Virtual Private Network (VPN) type connection. Additional commercial services for enhanced security and validation can be built from the government-provided data.

- Pre-broadcast of the raw navigation data is also a key HARS feature, enabling receivers to compare to received nav data as a means detect spoofing, or to facilitate energy-efficient snapshot approaches or long-coherent tracking in more challenging environments.