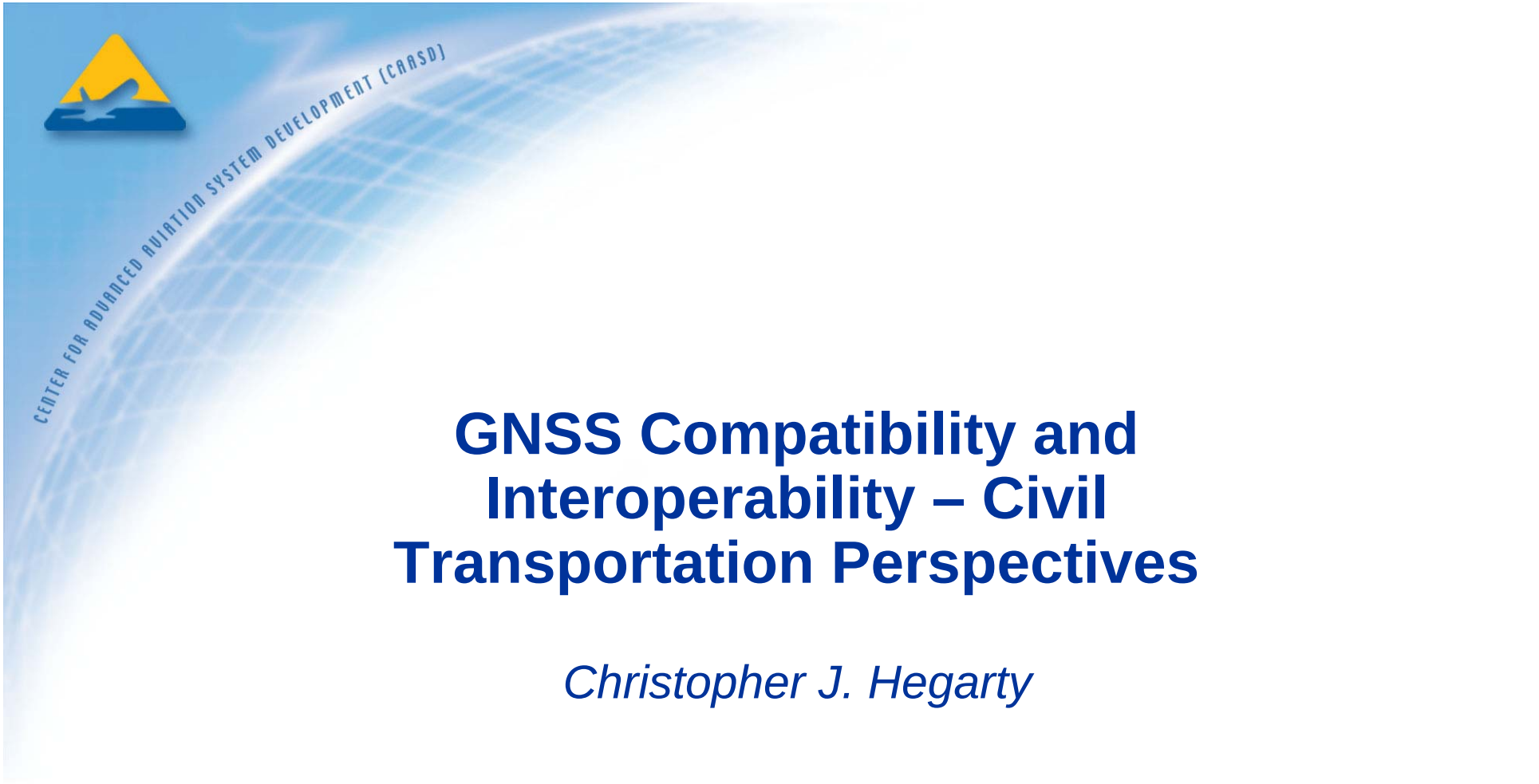


GNSS Compatibility and Interoperability – Civil Transportation Perspectives

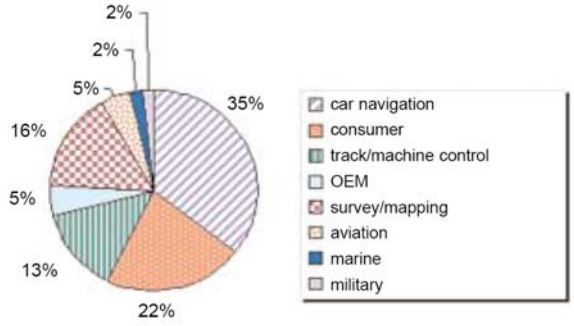
Christopher J. Hegarty

July 15, 2008

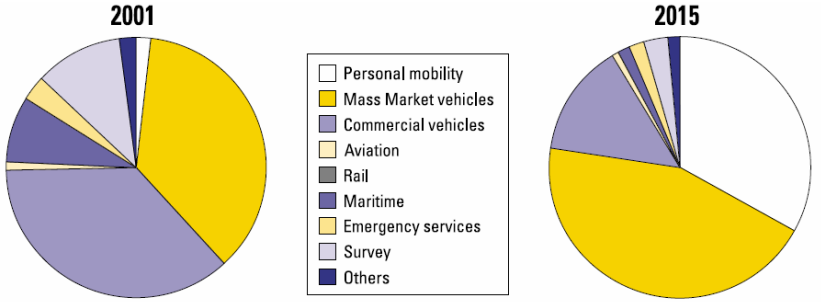
Disclaimer: The contents of this material reflect the views of the author. Neither the Federal Aviation Administration nor the Department of Transportation makes any warranty or guarantee, or promise, expressed or implied, concerning the content or accuracy of the views expressed herein.

Civil Transportation

- **Worldwide fleet includes (not all GNSS-equipped):**
  - **Over 20,000 passenger aircraft**
  - **Over 30,000 merchant ships of 1,000+ gross tons**
  - **Over 60,000 diesel locomotives**
  - **Over 300,000 general aviation aircraft**
  - **Over 600,000,000 land motor vehicles**
- **Civil transportation represents a large segment of the satellite navigation market**



Source: U.S. Department of Commerce, *Trends in Space Commerce*, 2001.



Source: GJU, EC, and ESA, *Business in Satellite Navigation*, 2003.

MITRE

Radio Frequency Compatibility (RFC)

- Many transportation users rely on GNSS today
- The majority of these users employ receivers that either:
  - Process only GPS L1 C/A-code signals
  - Process GPS and satellite-based augmentation system (SBAS) L1 C/A-code signals
- Equipage for other satellite navigation systems anticipated to grow rapidly after constellations are fully populated

Protection of existing user equipment against radio frequency interference for many years is a priority for transportation users.

MITRE

User Equipment Standards- Aviation

- International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs)
  - Current SARPs address only two core constellations and augmentations
    - GPS
    - GLONASS
  - ICAO Navigation Systems Panel (NSP) is responsible for updating GNSS SARPs
    - Updates to material on GPS, GLONASS and augmentations; new material on GALILEO
- Receiver standards developed by RTCA, Inc., and EUROCAE

MITRE

User Equipment Standards - Maritime

- International Maritime Organization (IMO) Performance Standards
- Receiver and differential GNSS standards developed by:
  - International Electrotechnical Commission (IEC)
  - Radio Technical Commission for Maritime Services (RTCM)

MITRE

User Equipment Standards – Land Vehicles and Rail

- **No prevalent user equipment standards pertinent to RFC**
  - **(Popular voluntary industry standards, e.g., National Marine Electronics Association [NMEA], primarily address receiver data input/output)**

MITRE

Observations on Radio Frequency Compatibility

- Wide variety of GNSS user equipment in civil transportation
- Tolerance to interference, e.g., from other GNSS signals, is:
  - Well-understood for some applications, e.g., air navigation in instrument conditions
  - Not as well understood for other applications
- Recommended that classes of user equipment be considered in bi-/multi-lateral RFC discussions
  - Such as within International Telecommunication Union development of recommendations to protect GNSS
- Service Providers should establish compatible technical system characteristics to promote timely development of user equipment standards and recommended practices by ICAO, IMO, RTCA, etc

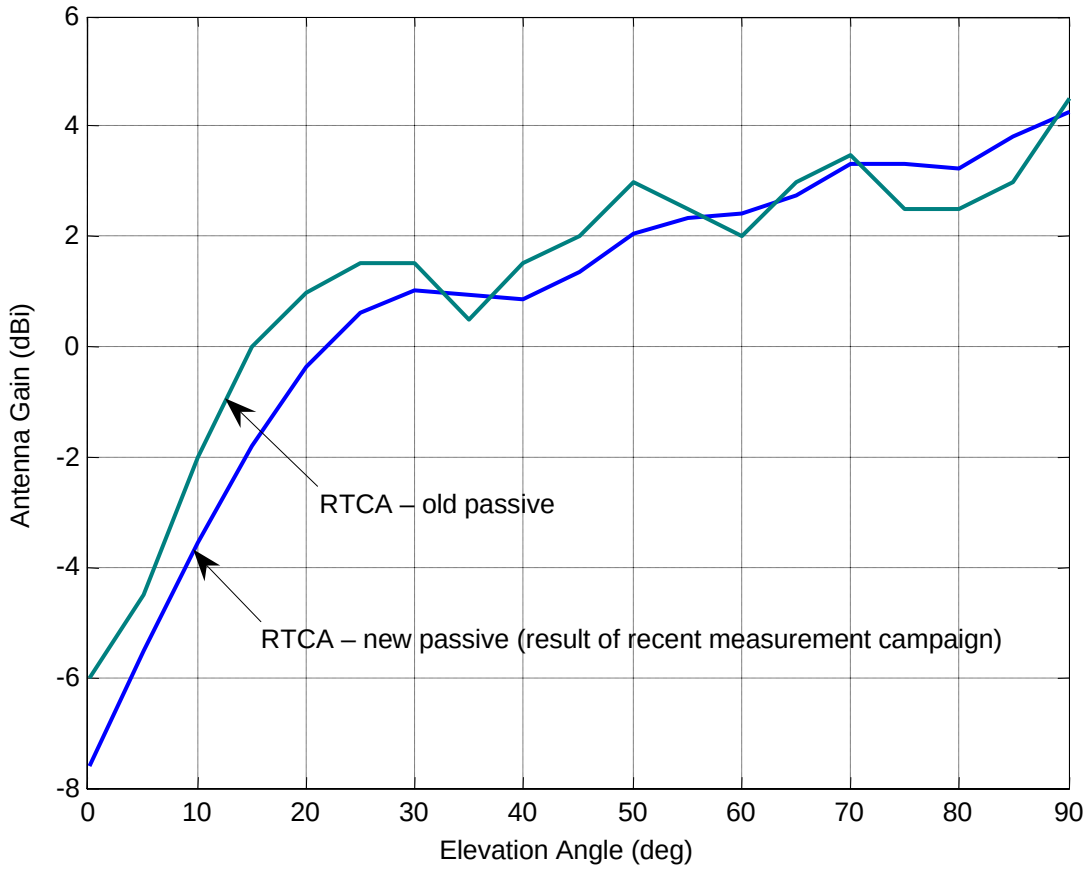
MITRE

RFC Assessment Parameters that Vary Among Transportation Applications

- Desired signals
- Mask angle
- Signal-to-noise thresholds
- User antenna gain patterns
- Receiver implementation and excess propagation losses
  - For desired and towards undesired signals
- Levels/types of external interference (e.g., consider L5/E5 band at 40,000 feet vs. mean sea level)

MITRE

Aviation User Antenna Gain Patterns

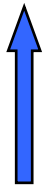


Even within aviation community with mature standards, understanding of user equipment characteristics is evolving.

MITRE

Interoperability

- **Most transportation applications would benefit from additional signals**
  - **However many users will *not* immediately employ new GNSS signals/systems**
    - **Some may *never* be used for some applications**
    - **Incremental benefit/cost ratio must be sufficient to warrant retrofit or initial investment**
    - **Particularly in some transportation applications where installation/certification costs are very high**
  - **To simplify user equipment, it would be desirable for GNSS Service Providers to implement signals with:**
    - **Common carrier frequencies (e.g., L1 and L5/E5a)**
    - **Common/interoperable modulations**
    - **Common pseudorandom noise (PRN) code families**
    - **Common data elements**

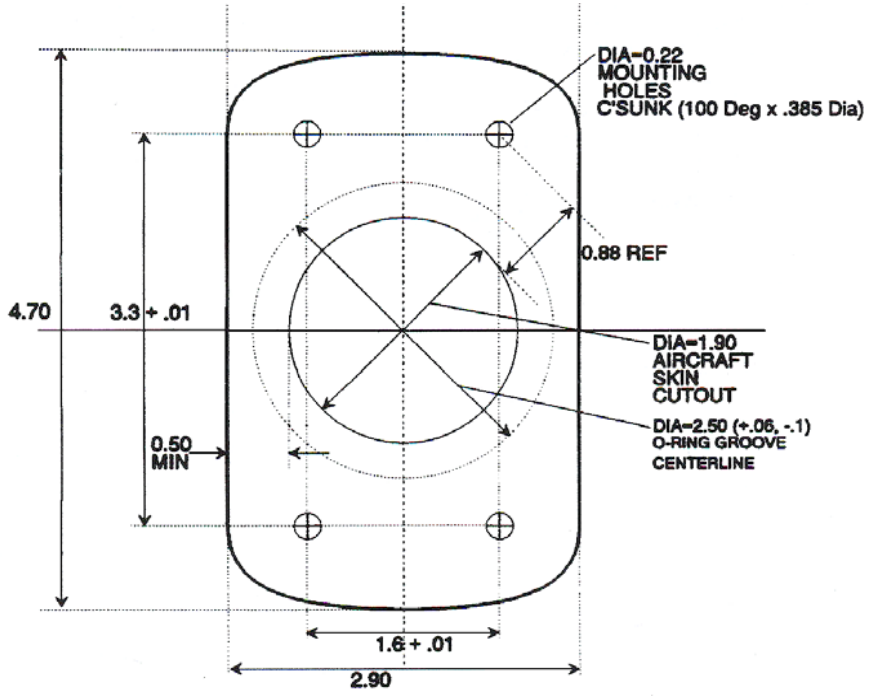


- **Common/consistent geodetic and time systems are also important**
  - **E.g., ICAO's adoption of WGS-84**

MITRE

User Antennas – A Current Aviation GNSS Interoperability Topic

- **Utilization of existing form factor and performance standards for aviation GNSS antennas with emergence of new signals/frequencies**
  - **L1-only to L1/L5 or L1/E5**



MITRE

Summary

- Civil transportation is, and is expected to remain, a very large GNSS market segment
- As with most GNSS users, RFC is of tremendous importance to protect significant investments and preserve safety
  - Recognizing the diversity of user equipment, it is recommended that representative user classes be identified
  - Service Providers should establish compatible technical system characteristics to promote timely development of user equipment standards
- Transportation users look forward to additional interoperable GNSS components/signals
  - Common signal characteristics and consistent coordinate/time systems will encourage use

MITRE