ICG WORKING GROUP A

WORKSHOP ON GNSS INTEROPERABILITY

30 November 2009

Surfers Paradise, Queensland, Australia

I C G International Committee on Global Navigation Satellite Systems

AGENDA

- SESSION 1 — GNSS Providers — System Updates
- SESSION 2 — GNSS Applications
- SESSION 3 — Discussions on Selected Interoperability Topics
  - Results of interoperability questionnaires completed to date
  - Signal and system characteristics important to interoperability
  - Time and geodesy aspects of GNSS interoperability and ground-based DGNSS interoperability
  - Multi-GNSS demonstration campaign in Asia proposed by the Government of Japan
- SESSION 4 — Continued Discussions (during iGNSS 2009)

INTEROPERABILITY QUESTIONNAIRE

ICG WG-A Questionnaire

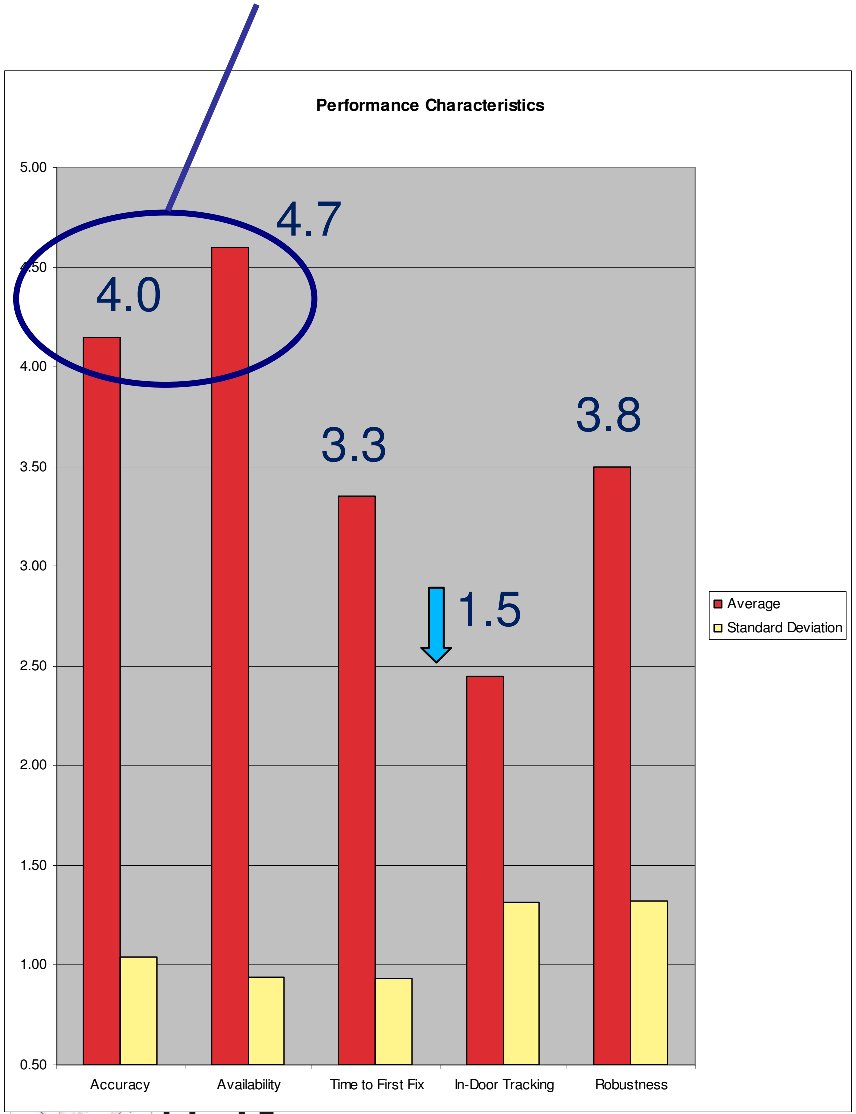
- Total number of respondents to-date: 20/**28**
  - Industry: 14/**7**
  - Government-sponsored organizations: 3/**1**
  - Academia: 2
  - Non-profit organizations: 1

Definition of interoperability - comments

- The geodetic and time systems should be <u>identical</u>.
- Interoperability should refer to the ability of global and regional navigation satellite systems and augmentations to be used together to provide better capabilities at the user level than would be achieved by relying solely on the one system.
- Sharing of monitoring stations among the authorized GNSS; expanding available PRN-code by international open coordination; setting standards for seamless PNT environment; studying collaborative; assuring international activities of monitoring illegal interferences.
- The definition would be more clear and specific, if words “and reliability” were added to the sentence as follows at the 3rd line : …to provide better capabilities “and reliability” at the user level than….
- More gain (better accuracy & acquisition time) for small pain (additional cost & hurt to specific interests).

Benefits of interoperability

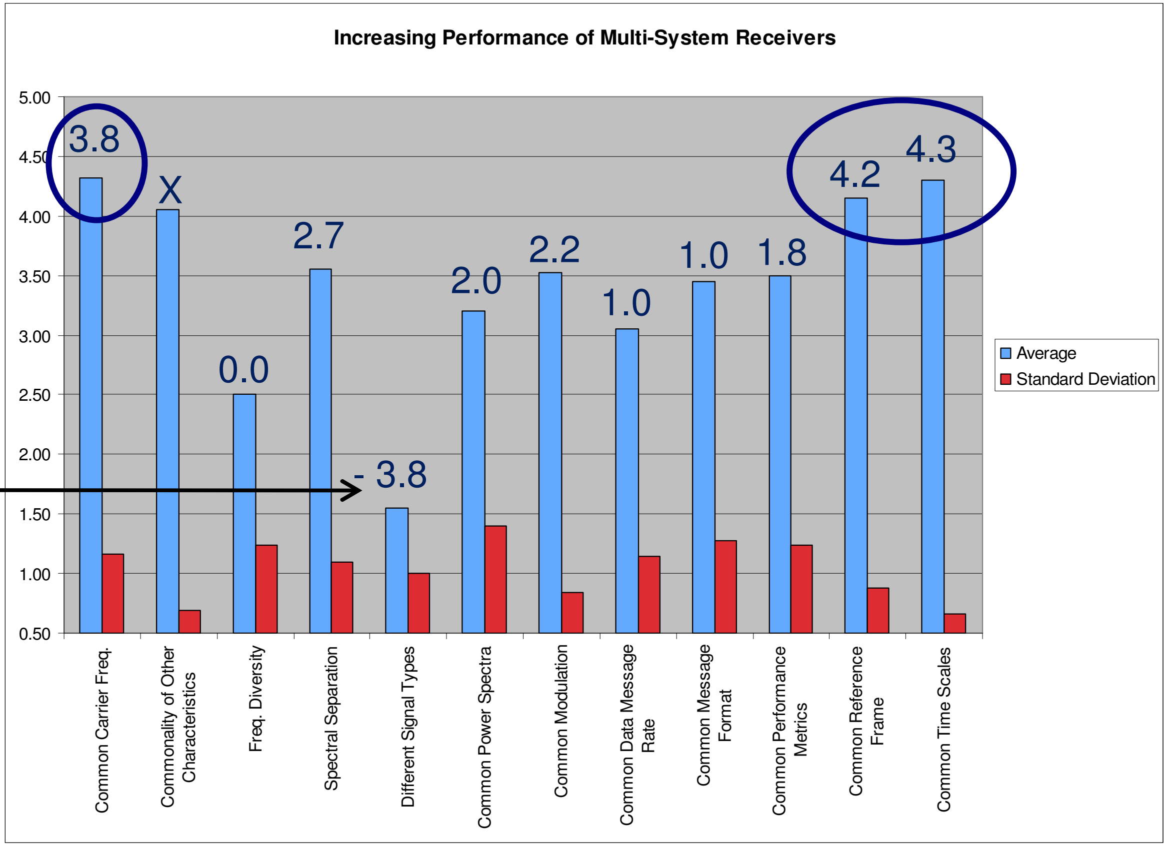
Improved availability/accuracy



Additional benefits

- Better RAIM
- Improved sampling density for occultation measurements
- Rapid and reliable carrier phase ambiguity resolution to support cm-level accuracy even over long baseline length
- Not having to depend on one nation
- Facilitates collocation of GNSS monitoring stations.
- Possibility to expand available PRN-codes through international open coordination
- Helps set standards for a seamless PNT environment
- Enables a collaborative development framework
- Facilitates international activities to monitor interference
- Enables to broadcast common messages for integrity, satellite health, etc.

What contributes most to interoperability



Signal differentiation (CDMA vs. FDMA)

New Questionnaire

-5 to +5 scale

1. Common carrier frequency
2. Common time scales
3. Common reference frame

1. Common time scales
2. Common reference frame
3. Common carrier frequency

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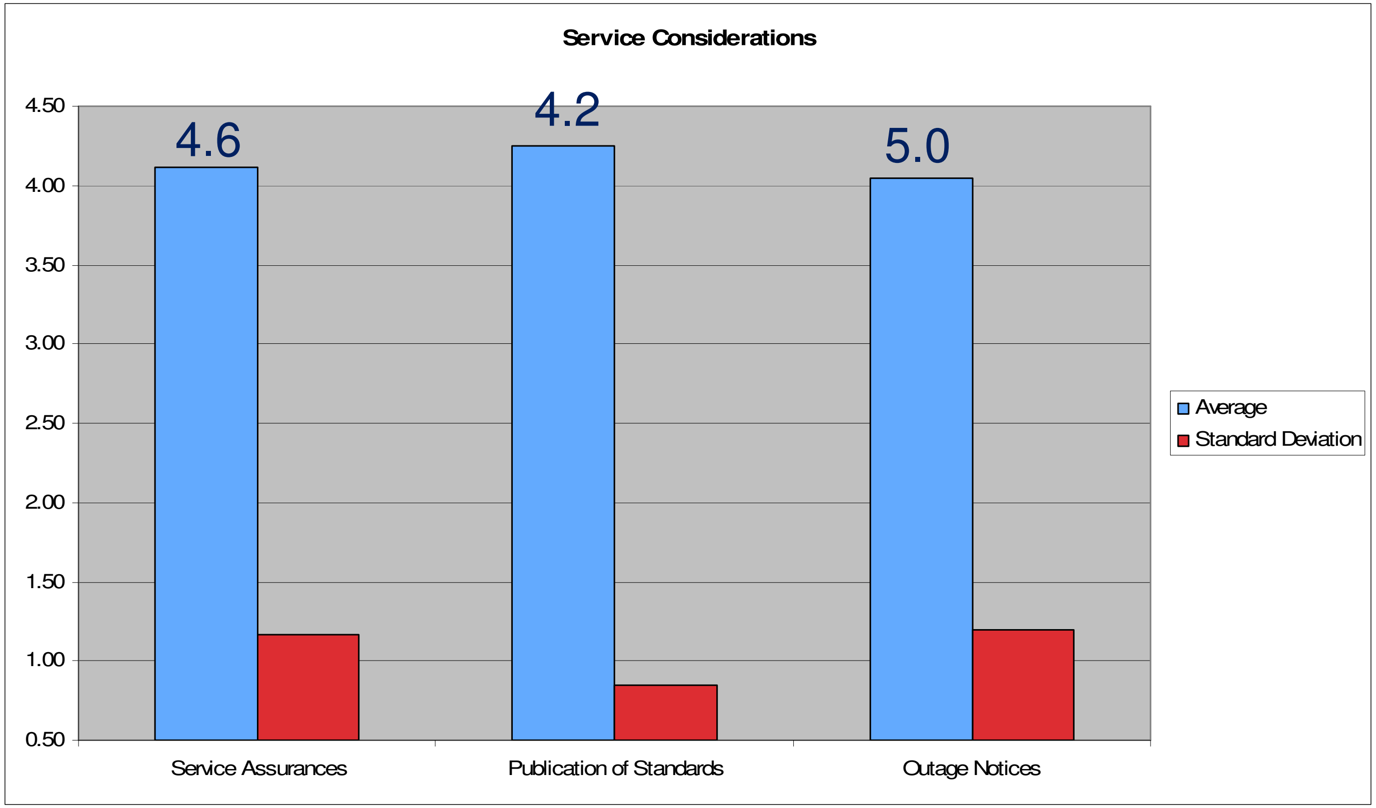
Importance of service-related assurances



- All are considered very important

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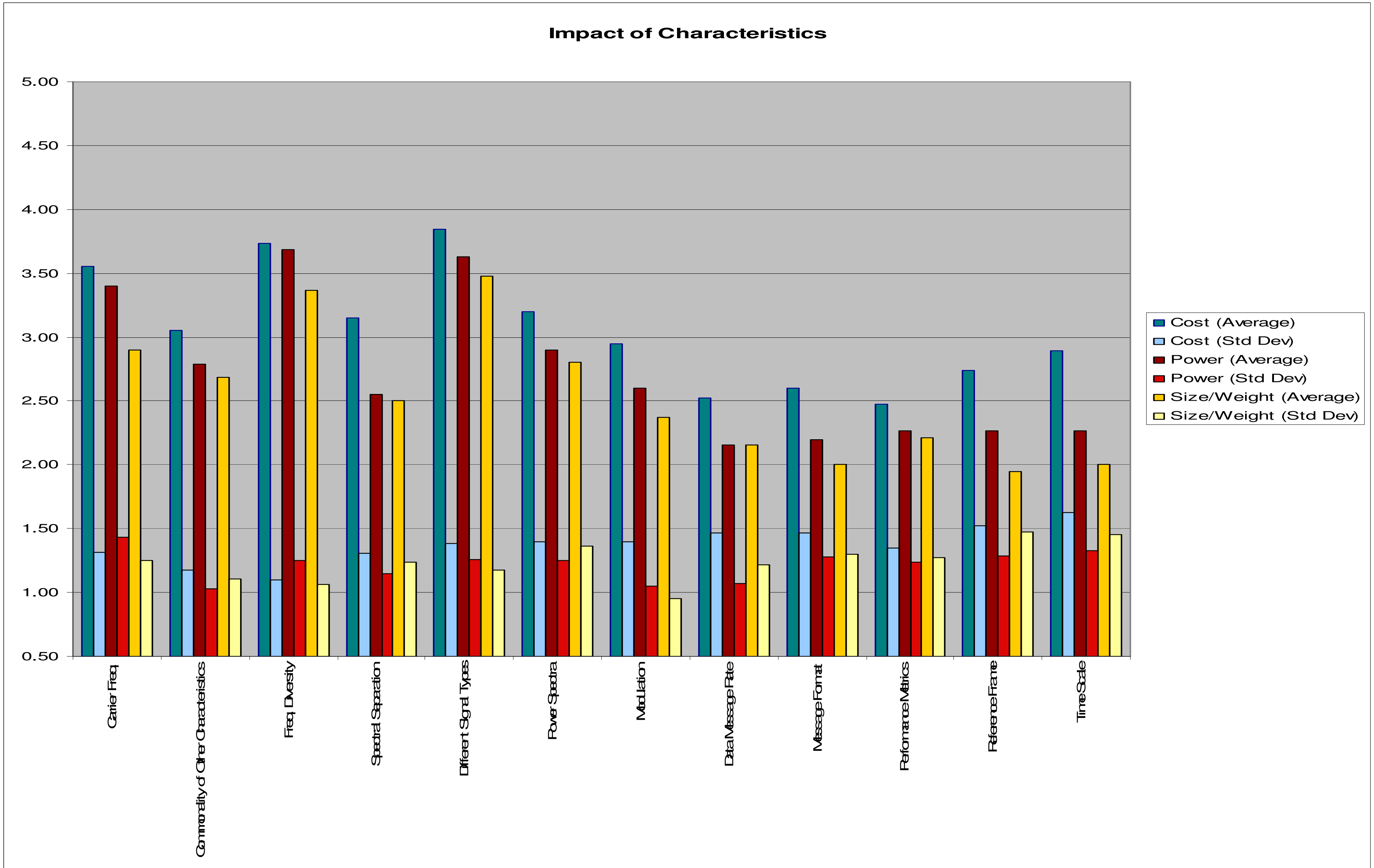
Benefits in terms of receiver cost/power/weight



Impact in terms of differential systems and data processing

- Common carriers would help reduce:
  - Complexity of real-time and post-processing algorithms
  - Cost of differential GNSS systems
  - Cost of data post-processing
  - Number of inter-frequency biases that need to be estimated and book-kept
  - Receiver costs
    - Number of parallel operating channels
    - Complexity of front-end to acquire and demodulate different signals on different bands

Other criteria to consider

- Government restrictions
  - Service access fees
  - Integration costs
  - Certification costs
- Polarization of the signal direction
- Initial non-recurring costs and, potentially, longer time to market and/or less incentive to implement if the return of investment is not clear
- Preference for similar GNSS signal bands
- GNSS system orbit/altitude and compliance to support COSPAS-SARSAT missions
- Interoperability at the integrity level for safety-of-life applications, and implications to the complexity and certification of receivers
- Cost of integrity monitoring

Other signal parameters to consider

- Received power
- Broadcast antenna gain shape
- Space volume coverage
- Broadcast antenna phase center definition and variations of phase vs. angle
- Signal to Noise Ratio
- Cross correlation related to modulation types and message format
- Heterogeneity of broadcast data

Impact of small carrier frequency shifts (up to 200 - 250 KHz) for signals in common frequency bands)

- Moderate increase of complexity
- Moderate reduction of accuracy
- Overall it's difficult to answer without discussing specific receivers and applications
- New responses – almost no impact on the complexity of a multi-system receiver or the quality of signal processing and performance

Upper limit on overall number GNSS satellites beyond which there is no benefit, or even a detriment

- Interference Issues
  - Increase in noise floor
  - Issues with contemporary active CDMA signals that are never really orthogonal causing mutual jamming.
  - Upper limit estimate:
    - Approximately 45 satellites for the C/A code
    - Approximately 90 satellites for the BOC (1, 1) signal
    - Much higher for higher rate signals
- Practical Uses
  - Many applications would use all-in-view to full effect, some of which benefit in direct proportion to the total number of GNSS satellites.
  - More satellites provide benefit when there is masking due to buildings, trees etc.
  - Potential receiver issues in selecting the most appropriate satellites in view
  - Generally 10-20 satellites in-view are enough for applications such as high accuracy RTK position calculation, but to ensure tracking under severe conditions it would be better to have 20-30 satellites in-view
  - At the present stage, QZSS can process up to 32 GPS satellites other than its own satellites.
  - Tracking up to 50 GNSS SVs would be a win-win combination for most applications.

Benefit of collaboration between system providers and integration of one or more GNSS at the space segment and/or ground control segment-level

- Yes, would be very beneficial – **4.7 out of 5**
- Comments:
  - Co-location of ground tracking sites would provide identical spatial and temporal reference frames.
  - It is essential that integration result in completely synchronized clocks and reference frames

Summary of Interoperability Questionnaires

- Benefits of interoperability
  - Better availability
  - Better accuracy
  - Better ability to support RAIM
- Priorities
  - Common carrier frequencies
  - Common time scale & reference frames
  - Common modulation
  - Collocation of reference stations
- Other
  - **Almost no** user impact in small carrier frequency shifts (up to 200 - 250 KHz) of signals in common frequency bands
  - Include 'received power' as a parameter in evaluating priorities

Possible changes to definition of interoperability – based on completed questionnaires

Interoperability: The ability of global and regional navigation satellite systems, their augmentations, and the services they provide to be used together to provide better capabilities at the user level than would be achieved by relying solely on the open signals of one system.

- Interoperability allows navigation with signals from different systems with minimal additional receiver cost or complexity;
- Multiple constellations broadcasting interoperable open signals will result in improved observed geometry, increasing end user accuracy everywhere and improving service availability and reliability in environments where satellite visibility is often obscured
- Signal and system characteristics important to interoperability include:
    - Common carrier frequencies
    - Common time scale & reference frames
    - Common modulation
- Geodetic reference frames realization and system time steerage standards should adhere to existing international standards to the maximum extent practical;
- Monitoring stations should be collocated, and data shared, where practical;
- Any additional solutions to improve interoperability are encouraged.

DISCUSSION

SIGNAL AND SYSTEM CHARACTERISTICS IMPORTANT TO INTEROPERABILITY

Signal Characteristics for Discussion

- Common/diverse carrier frequencies
- Common [power Spectral density][modulation][signal power spectra]
- Common maximum power levels, based on the same link budget assumptions

DISCUSSION

Time and geodesy aspects of GNSS interoperability and ground-based DGNSS interoperability

DISCUSSION

MULTI-GNSS CAMPAIGN

WORKING GROUP A WORK PLAN AND NEXT STEPS

Working Group A Recommendations adopted at ICG-4

1. Revised work plan
   - Compatibility
   - Interoperability
   - Open service information sharing
   - Service Performance Monitoring
   - Spectrum Protection
2. Continue seeking inputs on interoperability from industry and users
   - Conduct a workshop at iGNSS 2009
3. Conduct a compatibility-focused meeting prior to ICG-5 – scheduled for June 2010 in Vienna
4. Endorse the multi-GNSS demonstration campaign and encourage Provider participation
5. Principle of Transparency - every GNSS provider should publish documentation that describes the signal and system information, the policies of provision and the minimum levels of performance offered for its open services

Next Steps for WG-A

- Continue to disseminate updated questionnaires
  - Follow up with respondents when necessary
- Identify additional venues where a meeting/workshop may be of value
  - For example - a joint meeting of Working Groups A & D to consider the time and geodesy aspects of GNSS and ground-based DGNSS interoperability
- Develop interoperability report for ICG-5
- Prepare for compatibility-focused meeting to be held in June in Vienna
- Address additional work plan items