RTCA

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GPS Adjacent Band Compatibility: Feedback on Exclusion Zones

Report of the Tactical Operations Committee in Response to Tasking from

The Federal Aviation Administration

July 2015

GPS Adjacent Band Compatibility: Feedback on Exclusion Zones

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Background

In January 2012, the National Space-Based Positioning, Navigation and Timing Executive Committee (PNT-EXCOM) proposed the drafting of new GPS spectrum interference standards to inform future proposals for non-space commercial uses in frequency bands adjacent to GPS. As a result, the DOT developed a GPS Adjacent-Band Compatibility (ABC) Study Plan to provide the framework for definition of the processes and assumptions that will form the basis for development of the GPS adjacent-band compatibility for GPS civil applications.[1]

In October 2014, the FAA published "GPS Adjacent-Band Compatibility Study Methodology and Assumptions." Much of the study focused on analysis methodologies, aviation GPS receiver characteristics, RFI propagation path models, basic source emission parameters and interaction scenarios. One section of the study addressed operational impacts. RTCA was asked by the FAA to review the study and address six specific questions. Three questions were technical in nature (Questions 1-3) and three operational (Questions 4-6). RTCA requested Special Committee 159, "Global Positioning System," to respond to the first three questions which were technical in nature. RTCA requested the Tactical Operations Committee (TOC) to address the last three questions that were operational in nature.

In February 2015, the Tactical Operations Committee established the GPS ABC Task Group with an objective to develop the TOC's response to the three operational questions in the GPS ABC study by July 2015. This report serves as the Tactical Operations Committee's response to Questions 4-6 of the FAA's task request.

Executive Summary

This Committee reviewed the October 2014 GPS ABC study and evaluated the aviation safety and operational impact of proposed Exclusion Zones[2], which are 500 foot cylinders around GPS adjacent band transmission towers within which GPS accuracy may be compromised. These cylinders were created by the FAA as part of its assessment of potential interference to GPS receivers that are compliant with RTCA/DO-229D. A set of operational use cases were identified for helicopter operations, unmanned aerial systems, military operations and general aviation in which safety or operational performance would be impacted by these exclusion zones. These use cases formed the foundation for responding to the three operational questions posed in the FAA's October 2014 GPS ABC Study:

[1] FAA GPS Adjacent-Band Compatibility Study Methodology and Assumptions, FAA Spectrum Engineering Services, October 3, 2014

[2] One Committee participant, LightSquared Inc., offered an alternative and significantly smaller proposal for an exclusion zone. This alternative was not evaluated in this report. All conclusions drawn herein are only related to the proposed Exclusion Zones in the October 2014 FAA GPS ABC Study.

- The proposed Exclusion Zones have negative impacts to both flight safety and operations for multiple operational scenarios and multiple types of operators. This includes negatively impacting GPS-based TAWS/HTAWS alerts. Additionally, the exclusion zones are defined to go as low as 100 feet AGL, but there are some operational scenarios with negative impacts below 100 feet AGL.

- There is no "one-size-fits-all exclusion zone" definition of an Exclusion Zone that works everywhere in the National Airspace System (NAS). The use of radio spectrum needs to be evaluated against the different NAS use cases based on the proponent's spectrum signature and density of deployment in various environments. On a case by case basis, a particular definition of an exclusion zone may be acceptable in terms of operations and safety. The dimensions of new zones, their location and density need to relate to the specific operational scenarios and the impact on aviation safety.

- Some safety impacts and operational limitations from exclusion zones are unique to the *unmanned* nature of Unmanned Aerial Systems (UAS's). For example, geo-fencing, return to base, station keeping and elevated risk of loss of equipment are all Exclusion Zones impacts relevant to UAS with its reliance on GPS and no human within the operating vehicle to provide a visual backup.

GPS ABC Questions Posed to the TOC

At a high level, the TOC was requested to identify what the possible impacts are to aviation interests from certain assumptions made by the FAA in development of networks of ground based transmitters radiating on frequencies adjacent to the GPS band. GPS receivers on different types of airborne vehicles (commercial airplanes, general aviation airplanes, helicopters, unmanned vehicles) may be susceptible to higher strength signals in the adjacent bands. Hence, some GPS receivers may experience interference when in proximity of radiation on the GPS adjacent band.[3] Airborne vehicles may rely on GPS to determine safety of life information such as position, velocity, and position relative to obstacles or to drive flight controls. All of this suggests the critical need to identify the impacts to aviation from use of the GPS Adjacent Bands.

Specifically, the FAA posed the following three questions to the TOC:

Question	Question Text
4. Impact of Exclusion Zones on Flight Safety	(c) Are the size and aggregated density of aircraft and helicopter exclusion zones where GPS-based TAWS/HTAWS alerts cannot be assured (Appendix C, section above, and reference [4]) sufficiently

[3] It is also noted that GPS receivers may experience interference from transmitters in bands further away from GPS (Out of Band emissions) when operated in very close proximity to radio towers.

	small so as to not impact flight safety? (d) Alternatively, what TAWS/HTAWS exclusion zones parameters should be considered?
5. Operational Acceptability and Safety Implications	Comments are requested regarding the operational acceptability and safety implications for the proposed exclusions, operational limitations and safety considerations identified in Appendix C of this report and Annex A of the reference [4] report including any alternative suggestions and supporting rationale.
6. Unique Considerations for Small UAV Operations	(a) Considering the proposed fixed and rotary wing aircraft assumptions, exclusions, and limitations, are there safety impacts and operational limitations that are unique to small Unmanned Aircraft Vehicles (UAVs) operations? (b) If yes, please identify the unique operational use case scenarios and any associated safety and operational issues. (c) Propose additional assumptions and "exclusion zones" for consideration that would preclude the identified safety and operational issues (if any).

Exclusion Zones

To address the risk of GPS being unreliable in proximity of adjacent band transmissions, the GPS ABC Study proposed the construct of the Exclusion Zone. An Exclusion Zone is defined as a cylinder around a transmission tower within which GPS accuracy may be compromised. The power radiated from the transmitter would be limited such that GPS interference would not exceed a defined threshold at the exclusion zone boundary.

The October 2014 GPS ABC Study proposes the following exclusion zones:

Aircraft Type	Distance from Airport	Min Obstacle Height	Exclusion Zone
Fixed Wing	Within 7.5 nm	100 ft AGL	• Intersection of a cylinder centered on the obstacle (500' in radius and extending 100' above the top of the obstacle) and the region below the obstacle clearance surfaces (as defined by the FAA 8260 series orders) for all instrument procedures. The exclusion zone extends down to the minimum altitude where coverage would be required (see below).
Fixed Wing	Greater than 7.5 nm	200 ft AGL	• A cylinder centered on the transmitter (500' in radius and 100' above the top of the obstacle), but not above 1000' AGL (including effects of falling terrain). The exclusion zone extends

			down to the minimum altitude where coverage would be required (see below).
Helicopter	n/a	100 ft AGL	• Is the intersection of a cylinder centered on the obstacle (500’ in radius and extending 100’ above the obstacle) and the region below the obstacle clearance surfaces (as defined by the FAA 8260 series orders) for all instrument procedures. The exclusion zone extends down to 100’ AGL.

For Fixed Wing aircraft, the following determines the minimum altitude to which the exclusion zone extends:

- Between 5000’/10000’ and 7.5 NM of any airport: At and above 100' AGL
- Between 7.5 NM and 15 NM to any airport: At and above 300' AGL.
- Outside of 15 NM to any airport: At and above 500' (AGL).

Methodology

The GPS ABC Task Group conducted in-person meetings at RTCA offices in Washington, DC, to deliberate and discuss the questions posed by the FAA. The Task Group developed operational scenarios for various types of operators (helicopters, UAS’s, etc.) to compile feedback on the operational and safety impacts of exclusion zones. Using these scenarios, the Task Group then compiled its answers to the three questions posed by the FAA. Additionally, the Task Group documented all assumptions it made during the course of its deliberations. Assumptions, Operational Scenarios and Response to Questions are the three sections that follow.

Assumptions and Observations

To bound the work of this effort, the GPS ABC Task Group made the following assumptions or observations about this effort.

Exclusion Zones

1. The Exclusion Zone is a construct and not a physical zone. Given the limited explanation provided by the FAA regarding the exclusion zone construct, the Task Group recognizes that the definition could easily change.
2. The Exclusion Zone does not imply that an operator “shall not” operate in the zone. Instead it implies that the zone is accessible in Visual Flight Rules (VFR) or Marginal VFR (MVFR) conditions, and the operator cannot rely on GPS within the Exclusion Zone.

3. An Exclusion Zone implies that GPS may be unreliable, similar in the National Airspace System (NAS) to when the military tests interference and publishes NOTAMs indicating "GPS Unreliable."
4. Exclusion zones do not overlap.
5. The average distance between ground transmission sites is as small as 1.45 kilometers in dense urban areas (with the average intercell distance increasing in other environments as population density decreases). With a 500 foot radius for an exclusion zone, this implies an average 3800 foot corridor with no GPS interference in the middle of the approximately 4800 feet between base stations in dense urban areas.

Notifications

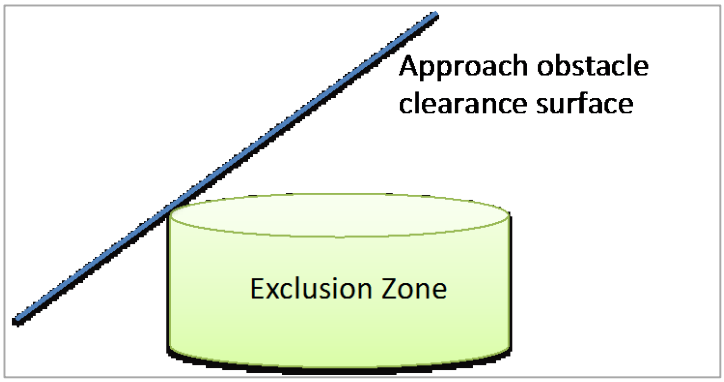
6. There is no existing mechanism to notify operators of the location of all exclusion zones where GPS will be unreliable; nor is an effective notification method anticipated to be in place in the future.
7. Exclusion zones will not be charted, either on paper or electronically, for aircraft operators.
8. Exclusion zones will not be part of Flight Management System navigation databases. Additionally, there is no guarantee that Terrain Awareness Warning System (TAWS) equipment and Helicopter TAWS (HTAWS) equipment will have an obstacle database, that an obstacle database will include exclusion zones or the frequency at which the obstacle database will be updated with respect to changes to the exclusion zones.

Ground Transmitters[4]

9. There is no planned symmetry to the grid of base stations radiating on the GPS Adjacent band.
10. The location, count and density of the transmitter sites have significant relationship to the impact on operations and safety.
11. It will be operationally impractical to attempt to deactivate specific ground transmitters.
12. Transmitters will not be installed within confines of protected airspace associated with arrivals or departures and in accordance with applicable FAA regulations. The following diagram drawn from the GPS ABC study presents a sample exclusion zone in which the exclusion zone size is adjusted to ensure it remains out of the departure or approach airspace.

[4] While out of scope of this report, it should be noted that existing infrastructure has the potential to interfere with GPS receivers.

Figure 1 Diagram of Exclusion Zone with Approach Obstacle Clearance



13. Future Instrument Procedures may require ground transmitter relocation or modification to comply with applicable FAA regulations.
14. Aggregate power for multiple transmitters will not exceed the threshold for a single exclusion zone at any point.

Aircraft

15. No change of legacy equipage on aircraft, manned or unmanned, is assumed.
16. Any emissions from any towers would be restricted to not interfere with aircraft at or above 1000 ft AGL.
17. Under current FAA GPS standards, the GPS ABC may impact ADS-B, particularly in lower altitude for which General Aviation is beginning to utilize ADS-B surveillance to aid in see and avoid operations. In addition, the FAA is starting to deploy various surface management systems at airports around the NAS that rely on accurate GPS positioning down to the surface. Additionally, after 2020, if secondary radars are decommissioned and the NAS has regions of ADS-B only surveillance, then reliance on ADS-B will only increase. Given the impacts to ADS-B are still emerging, these are noted here but not included in the operational scenarios that follow.

Operational Scenarios

Aircraft exclusion zones raise operational concerns from different types of aviation operators. The concerns range from obstacle avoidance to navigation to synchronizing position information with collaborators on the ground. The following summarizes operational scenarios for various operator types in which the Exclusion Zone concept poses an operational or safety risk.

Helicopter Operators

The helicopter community has a number of operational scenarios that would be impacted by the proposed Exclusion Zones. Helicopter operators rely on GPS for navigation, avoidance of obstacles as well for relaying positions to other units working in collaboration with helicopters. As helicopter operators tend to regularly conduct nape-of-the-earth operations, any degradation of situational awareness due to loss of GPS carries operational risk.

Emergency Medical Services (EMS)

EMS operations rely on GPS in a number of ways. Personnel on the ground provide GPS coordinates to EMS helicopter crews[5]. The crew then uses its navigation system to build a path to the destination and follows this path during its flight operation. Helicopters will rely on GPS to deviate en route around obstacles and to conduct its approach to reach its minimums to conduct a visual landing. Helicopters will regularly utilize GPS for guidance under 1000 feet AGL.

Given an EMS operation may go almost anywhere to conduct an emergency evacuation, unreliability of GPS is a significant operational risk. The risk is applicable to the crew operating the helicopter that relies on GPS for navigation. Additionally, the risk applies to the evacuee who may lose time in an evacuation if an EMS crew cannot land in immediate proximity of the scene because of an exclusion zone.

Law Enforcement

Law Enforcement helicopters are utilized as aerial units and provide information to the ground. When an aerial unit identifies a vehicle or individual of interest, the crew will relay GPS coordinates back to the ground for ground units to know where to go. When such aerial units are overhead, they are often operating in the 100 to 600 foot height range affected by GPS unreliability. Even during visual conditions, exclusion zones pose a risk of relaying incorrect GPS coordinates to ground units.

Fire

During large-scale fire fighting, fire fighters will provide burn position coordinates to aerial units. In their efforts to fight or prevent spread of large fires, fire fighters may elect to drop fire retardant from helicopters at specific locations. Should such positions be within an exclusion zone, the helicopter risks making a drop at the wrong site.

[5] The Committee acknowledges this aspect of the use case is outside the scope of this tasking. However, the Work Group believes it is important and should be evaluated by the NTIA/FCC, which is the appropriate regulatory body for this topic.

Helicopter – Other

Helicopter charter operators generally operate missions specific to the demands of the owner or customer on board. If the operator is not aware of the location of exclusion zones, they may risk the safety of both their operation as well as the travelers on board.

Unmanned Aerial Systems (UAS)

UAS's, particularly small vehicles weighing less than 5 kg, with increasing frequency operate in the airspace below 500' AGL for commercial, public, and recreational purposes. At present, GPS is the primary and standard mode of navigation for these systems.[6] GPS is used in a variety of navigation tasks including en route operations, station keeping, and support of geo fencing capability. GPS receivers commonly installed in commercially available small UAS do not meet Technical Standard Order (TSO) requirements.

Recent FAA announcements that streamline approval for access to airspace under 200' AGL by small UAS under the provisions of Section 333 of the FAA Modernization and Reform Act 2012 may significantly increase the volume of UAS activity at altitudes likely impacted by the proposed transmitters and exclusion zones.

The following are included as potential key operational impacts specific to UAS operations:

Geo Fencing

Exclusion zones with compromised GPS signals or availability may result in a loss or degradation of geo fencing capabilities that are becoming more critical for UAS operations. Such degradation could lead to UAS encroachment on flight restricted airspace.

Lose C2 Link/Return to Base

When a UAS loses its link to its source of Command and Control, the UAS relies on GPS to autonomously return the unit to a preplanned safe recovery location. Any interference within exclusion zones on this process could result in unsafe UAS operations during a lost link scenario.

Station Keeping/ Payload

Some applications of UAS focus on collection of data or imagery from specific locations. If UAS have unreliable GPS positions with exclusion zones, this may compromise the value and accuracy of the payload obtained data or imagery.

[6] Current proposed guidance requires UAS operators to maintain line-of-sight control with UAS. The Group anticipates the Final Rule will be similar with accommodation for rapid allowance of beyond visual line-of-sight.

Loss of Equipment

There is potential for a higher probability of loss of equipment due to unreliable navigation (i.e., increased probability of crash). This increased risk could negatively impact UAS economics, making the overall costs higher than they would be without the exclusion zone risk.

The operational scenarios and impact on UAS as a result of the establishment of exclusion zones are similar to those identified by the helicopter community. Current and future small UAS operations potentially impacted by the proposed exclusion zones include the following:

Visual Range UAS Operations

This category of UAS involves entities deploying small UAS in populated areas. These may be negatively impacted if GPS reception is compromised and the operator is unable to reliably navigate the small UAS. There are multiple operator examples in this group including:

- Aerial photography (e.g., real estate, wedding)
- Land surveying (construction, land management)
- News gathering (e.g., sports)
- Agriculture (crop monitoring, livestock management)
- Tactical support for First responders

For Visual Range UAS, key negative impacts from GPS interference include potentially compromised geo-fencing and return-to-base capability. Additionally, the operational utility of the UAS may be impacted as the usable area is decreased, the operational burden to check an additional database may increase and there may be constraints to fly automatic grid patterns or use features such as station keeping.

Beyond Visual Range UAS Operations

In this category, the UAS is flown out of sight of the pilot. This could rely exclusively on Area Navigation (RNAV) and some form of semi-autonomous operations. The FAA's current Pathfinder Program, which is exploring ways to safely expand unmanned operations in the NAS, has three tracks, two of which are focused on beyond visual range operations (crop surveying, rail inspection). This path will likely involve some level of certification.

Anticipated operations in this category include:

- Parcel delivery
- Right-of-way inspections (pipeline, rail)
- Traffic management
- Aerial photography (e.g., real estate, wedding)
- Land surveying (construction, land management)
- News gathering (e.g., sports)
- Agriculture (crop monitoring, livestock management, autonomous agricultural vehicles)

- Security
- First responders (e.g., search and rescue)

Similar to operations within the Visual Range, key negative impacts from GPS interference include potentially compromised geo-fencing and return-to-base capability. Additional impacts of exclusion zones for beyond line of sight operations include compromising GIS-based obstacle avoidance.

Again, the operational utility of UAS may be impacted with reduction in operational area, reduction in available flight corridors, added complexity to route planning, potential increase to operational burden due to checking an additional database and constraints to fly automatic grid patterns or use features such as station keeping.

Finally, exclusion zone operations would likely increase certification requirements and/or require additional navigation sources.

Military Impact

Based on the exclusion zones as defined, there may be some impact to military operations. Beyond the limited scope of the proposed exclusion zone, there may be significant impacts to military operations below 500’ AGL, particularly on Military Training Routes and Special Use Airspace, and therefore, safety to the NAS, which needs to be evaluated.

With respect to the three questions posed by the FAA to the TOC, the impact to military operations are at least the same as other NAS users. Not factored into the consideration of the question is the potential sensitivity of military grade GPS receivers. Additional studies on the potential impacts to military grade GPS receivers must be conducted before the military can analyze potential significance to military operations by the proposed use of exclusion zones.

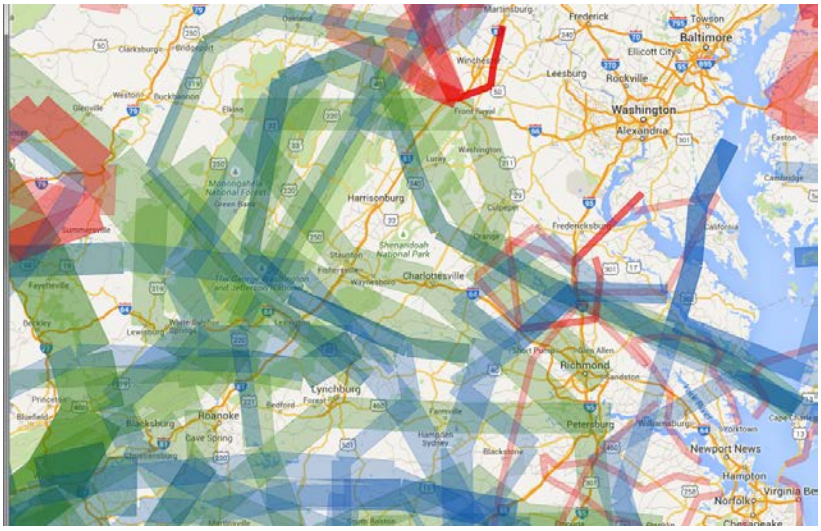
Military GPS systems are not only used for aircraft navigation, but also in the guidance systems for air-to-ground and ground-based weapon systems. When a GPS inside a weapons system encounters GPS interference or GPS signal loss, the guidance package reverts to inertial navigation. Inertial navigation is significantly less accurate; the weapon achieves a published Circular Error Probable (CEP) of 13 meters under GPS guidance, but typically only 30 meters under inertial guidance (with free fall times of 100 seconds or less).

Exclusion zones as presented extend down to: within 7.5 NM of an airport to the minimum altitude where coverage would be required; between 7.5 NM and 15 NM to any airport to the minimum altitude at and above 300' AGL; and outside of 15 NM to any airport to the minimum altitude at and above 500' AGL. The exclusion zones do not consider military operations which often extend to the surface during aircraft navigation and weapons employment. The logical

conclusion is that the exclusion zone having a lateral zone of 500' would have impacts at least on the level to downward plane of a 500' altitude and quite possibly more if the signal is conical and expands as it proceeds in a downward trajectory. Additionally, interference for GPS systems below this expanded zone looking upward to the GPS satellite constellation would also be affected. Therefore, the proposed exclusion zones would have an impact, creating significant operational and safety implications beyond the limited scope of question #5.

The military has Military Training Routes (MTRs) which are used for low-altitude, high speed training. MTRs are low-altitude corridors designed to support realistic training at speeds of more than 250 knots and at altitudes that range from ground level (surface) to 1,500 feet above ground level or higher. About half of the 500 routes are designated for Instrument Flight Rule (IFR) operations. Course widths vary between three NM to 20 NM either side of the reference line as depicted on the sectional and the routes are often 70 to 100 miles long and cover more than 1,916,000 square miles. MTRs often parallel or cross highways and even populated areas especially where legacy routes were encroached as cities expanded. Navigation is extremely difficult on high-speed low-altitude flights and GPS provides an essential aid to navigation. There exists a potential of a military aircraft touching up to 16 exclusion zones per minutes of low level training. Without knowledge of the locations and size of each exclusion zone or the length of time from GPS recovery, it could easily be assumed that GPS navigation would be unreliable. Hence, unreliable GPS at low altitudes provides a safety risk to the military operator of the aircraft as well as the communities underlying the Military Training Routes.

Figure 2 Location of Military Training Routes (MTRs) with respect to Major Highways



The proposed exclusion zones may have impacts to military operations due to the potential of flying through exclusion zones while on military training routes. The lack of proposed exclusion zones other than for air navigation with minimum altitudes are seen as a major flaw that may

have significant operational limitations to aircraft navigation and safety implications to weapons employment military operations.

Finally, the NTIA, DoD, and interested industry have been working in recent years to understand the extent of military concerns around terrestrial downlink use of the adjacent band spectrum. To the extent this report identifies any new concerns about GPS availability for military applications, these issues need to be explained and understood in greater detail. To accomplish a better understanding of the potential issues, the existing NTIA and DoD structure should be utilized for further study and analysis.

General Aviation Fixed Wing Operations

There are multiple General Aviation scenarios that are impacted by Exclusion Zones:

Agriculture Operations

Example missions include crop dusting and other low level application of fertilizers and pesticides utilizing aircraft and autonomous ground vehicles. These place aircraft a few feet above ground. Navigation to and from the destination would likely be affected. Also, operational effectiveness would be diminished for typical operations that use sophisticated GPS swath guidance.

Ultra Light and Light-Sport Aircraft (LSA) Operations

Ultra Light and LSA aircraft that routinely operate at low altitudes may rely on GPS for primary navigation. These operators often utilize non-TSO GPS equipment.

General Aviation Operations In and Out of Public Airports

No exclusion zones would be established in areas that currently have published procedures. However, procedure development is an ongoing process in the NAS and consideration may be required for relocation or modification of ground transmitters as a result of future published procedures.

General Aviation Operations In and Out of Private Airports

Private airport operators “build” approaches that are not published or known to potential sources to GPS interference. Safety could be negatively impacted by the unexpected loss of navigation guidance on unpublished approaches. This could preclude the use of unpublished private approaches.

Response to Questions Posed to the TOC

4. Impact of Exclusion Zones on Flight Safety

Question: (c) Are the size and aggregated density of aircraft and helicopter exclusion zones where GPS-based TAWS/HTAWS alerts cannot be assured (Appendix C, section above, and reference [4]) sufficiently small so as to not impact flight safety? (d) Alternatively, what TAWS/HTAWS exclusion zones parameters should be considered?

Answer: (4c) The Exclusion Zones proposed in the October 2014 "GPS Adjacent-Band Compatibility Study Methodology and Assumptions" study negatively impacts GPS-based TAWS/HTAWS alerts.[7]

(4d) The response to question 5 addresses question 4d.

5. Operational Acceptability and Safety Implications

Question: Comments are requested regarding the operational acceptability and safety implications for the proposed exclusions, operational limitations and safety considerations identified in Appendix C of this report and Annex A of the reference [4] report including any alternative suggestions and supporting rationale.

Answers: The Exclusion Zones proposed in the Oct 2014 GPS ABC study have negative impacts to both flight safety and operations for multiple operational scenarios as documented in the operational scenarios presented in this report. Additionally, the exclusion zones as defined only go as low as 100 feet AGL and there are some scenarios (Agriculture, UAS) that have negative impacts below 100 feet AGL.

The group acknowledges that some level of GPS interference exists in the NAS today. Examples include shadowing, solar flares, DoD jamming, unintended emissions from radio transmitters, etc. However, the group cannot define a one-size-fits-all exclusion zone that works everywhere in the NAS. The use of radio spectrum needs to be evaluated against the different NAS use cases based on the proponent's spectrum signature and density of deployment in various

[7] a) TAWS is not mandatory equipment in all airplanes since it is only required by specific operating rules. These rules are 121.354 (all turbine-powered airplanes) and 135.154 (TAWS A for turbine-powered airplanes configured with 10 or more pax and TAWS B for turbine-powered airplanes configured with 6 to 9 pax).
b) A similar issue exists for helicopters where HTAWS is not mandatory equipment in all helicopters since it is only required by the recently published 135.605 operating rule for air ambulance operators.
c) Neither the TAWS TSO-C151() nor the HTAWS TSO-C194 require an obstacle database, let alone include requirements for the content of the obstacles that must be included in an obstacle database or the frequency at which an obstacle database must be updated.

environments. On a case-by-case basis, a particular definition of an exclusion zone may be acceptable in terms of operations and safety. The dimensions of new zones, their location and density need to relate to the specific operational scenarios and the impact on aviation safety. Current, accurate exclusion zone location and size data would need to be readily available to operators in the NAS.

6. Unique Considerations for Small UAV Operations

Question: (a) Considering the proposed fixed and rotary wing aircraft assumptions, exclusions, and limitations, are there safety impacts and operational limitations that are unique to small Unmanned Aircraft Vehicles (UAVs) operations? (b) If yes, please identify the unique operational use case scenarios and any associated safety and operational issues. (c) Propose additional assumptions and "exclusion zones" for consideration that would preclude the identified safety and operational issues (if any).

Answers: (6a-b) While there are multiple similarities between UAS and other operator types, particularly helicopters, some safety impacts and operational limitations from exclusion zones are unique to the *unmanned* nature of UAS. For example, geo-fencing, return to base, station keeping and elevated risk of loss of equipment are all more relevant to UAS with its reliance on GPS and no human within the operating vehicle to provide a visual backup. Finally, the UAS segment of aviation is also unique because of its current rapid growth and maturation.

The details of UAS-specific impacts are contained in the operational scenarios discussed above.

(6c) Please see the response to question 5 above. Additionally, exclusion zone definitions will be dependent upon receiver design resiliency and there is no standard for UAS.

Appendix A: Members of the GPS ABC Task Group

Clay Barber, Garmin International

Mark Cato, Air Line Pilots Association

Perry Clausen, Southwest Airlines

Santanu Dutta, LightSquared, Inc.

Rob Eagles, International Air Transport Association

John Foley, Garmin AT

William Geoghagan, National Air Traffic Controllers Association

Larry Hills, FedEx Express

Robert Ireland, Airlines for America

Margaret Jenny, RTCA

Bob Lamond, National Business Aviation Association (Co Chair)

Kelly Markin, The MITRE Corporation

Paul McDuffee, Insitu Inc. (Co Chair)

Ben Miller, Mesa County, CO Sheriffs Department

Trin Mitra, RTCA

Harold Moses, RTCA

Kieran O'Carroll, International Air Transport Association

Ajay Parikh, LightSquared, Inc.

Paul Railsback, Airlines for America

Melissa Rudinger, Aircraft Owners and Pilots Association

Geoff Stearn, LightSquared, Inc.

Harold Summers, Helicopter Association International

Gary Viviani, Insitu Inc.

Appendix B: FAA Tasking Letter

U.S. Department
of Transportation
Federal Aviation Administration

OCT 07 2014

RTCA Paper No. 219-14/SC159-1021

Margaret Jenny
President
RTCA Inc
1150 18th St. NW, Suite 910
Washington, DC 20036

Dear Ms. Jenny,

As stated in my letter dated February 21, 2014, the Federal Aviation Administration (FAA) is participating in a Department of Transportation plan to determine and refine the processes, assumptions and analyses believed necessary as the basis of proposals for non-space, commercial applications in the frequency bands adjacent to the Global Positioning System (GPS) signals. The FAA proposed use of RTCA, Inc., as the forum for vetting assumptions for the Adjacent Band Compatibility assessment in order to increase transparency and maximize acceptance by the civil GPS aviation community.

The attached document addresses the planned approach for the first phase of the FAA's Adjacent Band Compatibility assessment. This first phase is intended to inform future proposals for the use of spectrum adjacent to GPS and ensure existing and evolving aviation uses of GPS are not affected. The document includes scenarios, assumptions and methodologies, and proposes questions for RTCA to address. Please coordinate with SC-159 and other committees (e.g., TOC and SC-228) that might provide perspective on the proposed "exclusion zones". Should the committees have any questions, please contact Ken Alexander, AIR-131 Navigation Team Lead, (202) 236-9794, ken.alexander@faa.gov. To facilitate our efforts, we would appreciate receiving your response by March 31, 2015.

Thank you for your consideration.

Sincerely,

Richard Jennings
Acting Assistant Manager
Design, Manufacturing and Airworthiness Division, AIR-101

Enclosure:
FAA Adjacent-Band Compatibility Study Methodology and Assumptions, October 3, 2014

5 Areas of Operation

Appendix C contains an excerpt from the January 20, 2012, DOT/FAA *Status Report: Assessment of Compatibility of Planned LightSquared Ancillary Terrestrial Component Transmissions in the 1526-1536 MHz Band with Certified Aviation GPS Receivers.* . One key part of that assessment was the determination of where aircraft would operate relative to the LightSquared transmitter locations. In particular, the study introduced assumptions regarding effective aircraft "exclusion zones" including:

> "For fixed wing aircraft: "In order to accommodate LightSquared transmitters that are mounted on towers where the tower may be included in the TAWS obstacle database, an exclusion zone is permissible as follows:
>
> a. For transmitters within 7.5 NM of an airport, if they are mounted on an obstacle that is taller than 100' AGL, then an exclusion zone that is the intersection of a cylinder centered on the obstacle (500' in radius and extending 100' above the top of the obstacle) and the region below the obstacle clearance surfaces (as defined by the FAA 8260 series orders) for all instrument procedures. The exclusion zone extends down to the minimum altitude where coverage would be required by paragraph 1c, d, or e above. The FAA must also retain the ability to publish new instrument procedures and establish new airports without undue constraints.
> b. For transmitters more than 7.5 NM away from any airport, if they are mounted on an obstacle that is taller than 200' AGL, then an exclusion zone that is a cylinder centered on the transmitter (500' in radius and 100' above the top of the obstacle), but not above 1000' AGL (including effects of falling terrain). The exclusion zone extends down to the minimum altitude where coverage would be required by paragraph 1c, d, or e above."

"For helicopters: In order to accommodate LightSquared transmitters that are mounted on towers where the tower is included in the HTAWS obstacle database, an exclusion zone is permissible. If they are mounted on an obstacle that is taller than 100' AGL, then an exclusion zone is defined that is the intersection of a cylinder centered on the obstacle (500' in radius and extending 100' above the obstacle) and the region below the obstacle clearance surfaces (as defined by the FAA 8260 series orders) for all instrument procedures. The exclusion zone extends down to 100' AGL. The FAA must also retain the ability to publish new instrument procedures or establish new heliports without undue constraints."

Appendix A of the January 20, 2012 report provides additional detail, including operations not addressed in this excerpt. This annex should be consulted and additional comments provided as appropriate.

Question #4 to RTCA: *(c) Are the size and aggregated density of* aircraft and helicopter *exclusion zones where GPS-based TAWS/HTAWS alerts cannot be assured (Appendix C, section above, and reference [4]) sufficiently small so as to not impact flight safety? (d) Alternatively, what TAWS/HTAWS exclusion zones parameters should be considered?*

Question #5 to RTCA: Comments are requested regarding the operational acceptability and safety implications for the proposed exclusions, operational limitations and safety considerations identified in Appendix C of this report and Annex A of the reference [4] report including any alternative suggestions and supporting rationale.

Question #6 to RTCA: (a) Considering the proposed fixed and rotary wing aircraft assumptions, exclusions, and limitations, are there safety impacts and operational limitations that are unique to small Unmanned Aircraft Vehicles (UAVs) operations? (b) If yes, please identify the unique operational use case scenarios and any associated safety and operational issues. (c) Propose additional assumptions and "exclusion zones" for consideration that would preclude the identified safety and operational issues (if any).

Please note that non-TSO compliant GPS equipment interference susceptibility may be substantially greater, or less than TSO approved receivers and antenna. Non-TSO GPS/GNSS

equipment is used for UAV navigation, positioning, attitude control and payload systems; electronic flight bags, installed equipment for situational awaremess, experimental and Light Sport Aircraft. Susceptibility needs to be characterized for each make, model and antenna pair. operators, manufacturers and GPS suppliers should participate in the parallel DOT Volpe center GPS Adjacent-Band Compatibility activities to ensure any unique operational use cases are considered and their GPS equipment susceptibility is characterized (http://www.rita.dot.gov/pnt/)Volpe POC: Steve Mackey stephen.mackey@dot.gov.