



**Approved by the Tactical Operations
Committee March 2018**

Operational Impacts of Intentional GPS Interference

*A Report of the Tactical Operations Committee in Response to
Tasking from the Federal Aviation Administration*

March 2018

Operational Impacts of Intentional GPS Interference

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Executive Summary

The Federal Aviation Administration is implementing the Next Generation Air Transportation System (NextGen) based on the foundation of satellite-based technology, and the Global Positioning System is a key technology component for navigation and surveillance in NextGen. The DoD is mandated by Title 10, Section 2281, to provide a GPS system that is reliable and available for civil use but DoD is also required by National Security Presidential Directive 39 to train and test U.S. military forces and national security capabilities in operationally realistic conditions that include denial of GPS. The DoD carries out intentional GPS interference that are notified to the public and can result in degradation of GPS signals to civilian aircraft.

The number of tests and unique locations has been increasing in recent years, and operators in the National Airspace System would like to better understand the operational impacts of intentional interference. The RTCA Tactical Operations Committee was tasked to study these impacts and this report serves as the Committee's recommendations on the matter.

The FAA's current approach to notification of interference events presents a NOTAM with contours, represented by circles of different radii at different altitudes. The contours represent an area outside of which operators should expect no interference impact. They can be large, often hundreds of nautical miles wide. Both operators and FAA contend that most aircraft experience no interference impact even inside the contours. Operators recommend the FAA evaluate options to provide pilots and controllers improved understanding of where to expect interference impacts based on different equipment capabilities. Operators would integrate such information in their flight planning processes. NOTAMs and any enhanced information about interference events should be consolidated and provided in graphical formats.

There is wide variation in the impact of interference experienced by the aircraft based on different avionics, altitude and attitude of the aircraft, terrain, exact location at time of highest power output of the test, etc. The effects may include complete loss of GPS navigation, position errors, loss of ADS-B and/or impact to GPS-dependent systems such as TAWS, ELTs, etc. Perhaps the most well documented example of interference impact was in April 2016 when a business jet lost all GPS signal due to an interference event and, due to downstream effect to the flight controls, entered a Dutch Roll resulting in an emergency descent. This specific issue has been addressed by the aircraft and avionics manufacturers. However, the FAA and OEMs should maintain a clear understanding of known GPS dependencies in avionics and aircraft flight controls and educate pilots on what to expect if GPS becomes unavailable during flight. Given the impacts on ADS-B in particular, the FAA should confer with industry prior to decommissioning any secondary surveillance radar systems, ensure VORs in the MON are in service and alert pilots about impacts to ADS-B services.

During interference events, individual aircraft may experience interference while operational efficiency in a region may be impacted when capacity on PBN routes is restricted. This can drive Traffic Management Initiatives and delay. Additionally, some operators' such as photographers and surveyors are completely reliant on GPS and interference may have financial impacts. Intentional interference is often most impactful during high volume periods, in periods of overnight cargo traffic, in ADS-B only

airspace or when events are conducted back-to-back with other events. Operators encourage FAA to conduct outreach with civil aviation stakeholders around significant interference events to build a process of education, particularly for the events that are most impactful.

Pilots, dispatchers and controllers all require improved education and guidance regarding how intentional interference can impact them and the tools, information and mitigations available. Specifically, pilots require clarification on whether an intentional interference NOTAM provides authorization to deviate from FAR 91.227 within the affected area until arrival. There is limited data today on the frequency of operational impacts of interference, and pilots and controllers should be educated and encouraged to centrally report impacts in the operation. Additionally, data collected at the over 600 ADS-B ground stations on aircraft NIC/NAC values holds promise to inform real-time understanding of the effects of interference on individual aircraft.

Looking forward, operators would like to better understand the impacts intentional interference will have on NextGen operations, benefits and resiliency. Operators recommend the FAA collaborate with industry and between agencies to update the APNT CONOPs in a way that meets industry operator needs for continued navigation and surveillance services in the NAS when GPS signals are not available. The FAA's current GPS resiliency plan, namely VOR MON and DME/DME, is insufficient to maintain continuity of NextGen operations in the NAS.

Ultimately, whether GPS interference is from a known source or not, the FAA and operators need to collaborate to understand the impacts and mitigations for all types of interference. This report focuses on the DoD's intentional and planned events, but there are non-DoD sources such as solar weather, illegal personal GPS jammers, unlicensed GPS repeaters or spoofing that must be considered as well.

Summary of Recommendations

Interference Event Scheduling

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| Recommendation 1. | When scheduling interference events, the FAA should coordinate with DoD to avoid GPS interference events from taking place: (a) during high volume traffic periods; (b) during high periods of overnight cargo traffic; (c) in airspace that only has ADS-B surveillance; and (d) back-to-back with other events. |
| Recommendation 2. | The FAA should define a process and identify an appropriate forum to conduct outreach to civil aviation stakeholders on significant intentional GPS interference events such as those during conditions identified in Recommendation #1 and/or large events. |

Notification of Interference Events

- | | |
|--------------------------|--|
| Recommendation 3. | The FAA should pursue modifications to the current NOTAM so it provides pilots and controllers improved expectation of where operators would expect interference for different equipment capabilities. |
| Recommendation 4. | The FAA should consolidate the preflight resources that disseminate GPS interference event information to the NOTAM Search and ADS-B SAPT website and ensure the NOTAM's graphical information be available in legacy KML as well as AIXM formats. |
| Recommendation 5. | The Flight Advisory notice and process should be modified to be more effective for users: (a) relocate the notices from the FAA Safety Team website to NOTAM Search; (b) incorporate a link to the Flight Advisory notice within the NOTAM on NOTAM Search; and (c) change paragraph E in the notice to encourage anomaly reporting. |
| Recommendation 6. | The FAA should display the interference area defined in the NOTAM graphically on the NOTAM Search map page, and incorporate a list of airways and airports potentially affected. |
| Recommendation 7. | The FAA should have a process to ensure underlying air traffic facilities receive real-time notification when interference is taking place. |

During Event

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|---------------------------|---|
| Recommendation 8. | The FAA should work with OEMs to develop a clear understanding of known GPS dependencies in avionics and aircraft flight controls. |
| Recommendation 9. | Operators should be informed of known avionics and aircraft flight control GPS dependencies and what should be expected if GPS becomes unavailable during flight. |
| Recommendation 10. | The FAA should solicit industry feedback on the strategy to decommission secondary-surveillance radar systems. |
| Recommendation 11. | The FAA must keep the VORs that are part of the Minimum Operating Network (MON) maintained and in service. |
| Recommendation 12. | The FAA should proactively alert pilots when GPS interference will negatively affect the services provided by an ADS-B GBT. |

- Recommendation 13.** The FAA should update pilot guidance: (a) AIM/PCG should be reviewed for consistency of terms; (b) AIM should list resources for preflight information (i.e., NOTAM Search and ADS-B SAPT website); and (c) the FAA should publish an Advisory Circular specific to GPS interference and the resiliency of the NAS (VOR MON and NextGen DME).
- Recommendation 14.** The FAA should clarify that a GPS interference NOTAM gives pilots authorization to deviate from FAR 91.227 within the affected area and for the duration of that flight.
- Recommendation 15.** The FAA should review and streamline the report process pilots use involving failures or malfunctions to GPS dependent systems to ensure all reports are collected and sent to the correct FAA office.
- Recommendation 16.** The FAA should have the ability to correlate ADS-B NIC/NAC degradation to an interference event for improved data collection/metrics.
- Recommendation 17.** The FAA should disassociate the process of collecting and verifying pilot reported GPS malfunction or failures from the process used for pilot reported NAVAID malfunctions.
- Recommendation 18.** The FAA should ensure controllers document pilot reported GPS malfunctions or failures in a manner that supports data analysis and trend identification.
- Recommendation 19.** The FAA should update controller guidance to clarify controller responsibilities during a GPS interference event.
- Recommendation 20.** The FAA should educate controllers about the purpose of intentional GPS interference, how aircraft may be impacted, how to respond to a pilot reported GPS malfunction or failure, published mitigations, the controller’s responsibilities for reporting, and best practices for assisting aircraft that have lost GPS navigation capability.
- Recommendation 21.** The weather requirement for GPS only airports (WX less than 5,000’ ceiling and/or 5 miles visibility) is sufficient but must be enforced.

NextGen Concerns

- Recommendation 22.** The FAA should collaborate with industry and between agencies to update the APNT CONOPs in a way that meets industry operator needs for continued navigation and surveillance services in the NAS when GPS signals are not available.
- Recommendation 23.** The FAA should evaluate and document the impact of GPS interference on current and future NextGen capabilities and operator equipment in NextGen business plans and strategies.

Related Topics Beyond Scope of Tasking

- Recommendation 24.** The FAA should consider future taskings, of appropriate committees, to investigate the impact of GPS interference on emerging technologies and new entrants to the NAS.
- Recommendation 25.** The FAA should work collaboratively with industry to understand the impact of and identify mitigations for unexpected and unintentional GPS interference, GPS system spoofing, and IFF events.

Introduction

The Federal Aviation Administration (FAA) is implementing the Next Generation Air Transportation System (NextGen) based on the foundation of satellite-based technology. The Global Positioning System (GPS) enables aircraft to navigate accurately and reliably in narrower containment areas than previously possible with conventional navigation aids. Instrument procedures based on GPS allow cost effective access to more airports and lower minimums to most runway ends in the National Airspace System (NAS). GPS technology is fundamental to a more efficient surveillance system, called Automatic Dependent Surveillance – Broadcast (ADS-B), which allows for faster update rates for controllers and reduced separation standards over radar. Commercial and general aviation (GA) have universally adopted GPS as the core technology that will allow safer and more efficient operations.

The FAA is mandated by Title 49 of the U.S. Code to develop and maintain a sound regulatory system that is responsive to the air transportation system and national defense. This responsibility includes ensuring a safe and efficient NAS that supports both civil and military users. The FAA works closely with the Department of Defense (DoD) and other agencies to ensure each other's mission can be accomplished safely.

The DoD is mandated by Title 10, Section 2281, to provide a GPS system that is reliable and available for civil use. The DoD is also required by National Security Presidential Directive 39 to train and test U.S. military forces and national security capabilities in operationally realistic conditions that include denial of GPS. Intentional GPS interference, also referred to as jamming or testing, is carried out by the DoD in support of their directive. The GPS interference that the DoD conducts intentionally degrades or denies the GPS signal for training and testing. Interference can also result in the loss of GPS as a reliable position source for navigation or surveillance by all civil users. For purposes of this report, the definition of the term “interference” ranges from minor degradation of the GPS position accuracy that may not be obvious to the pilot, to obvious affects, such as total loss of GPS satellite tracking. Although the DoD is not the only government agency that conducts GPS interference, they are the principal user and account for most of the impact experienced by civil aviation.

Stakeholders generally acknowledge that intentional GPS interference has an operational impact on the NAS. This impact is increasing as more aircraft equip with systems that depend upon GPS being available, like ADS-B, Wide Area Augmentation System (WAAS), and Ground-Based Augmentation System (GBAS). For some operators, GPS is the only navigation equipment required to fly under Instrument Flight Rules (IFR)¹ and no alternative means of navigation may be available. Regulatory and operational restrictions further compound the impact of flying through an area publicized as subject to interference. The impacts of GPS interference on safety and efficiency are addressed throughout this report.

¹ Operators flying under FAR 91

In response to stakeholder concerns regarding the impact of intentional interference on operations in the NAS and on NextGen, the FAA tasked the RTCA Tactical Operations Committee (TOC) to review these events and make recommendations on six topics:

1. Evaluate GPS interference events and quantify the NAS impact
2. Recommend effective tracking and metrics to assess the impact of GPS interference events with NAS impact, including the economic impact on airports during the event
3. Evaluate and recommend an effective way for interference events to be defined and depicted based on the likelihood of interference and the level of impact
4. For interference events, recommend standard minimum weather requirement/criteria for airfields that have only GPS approach procedures and/or no cooperative terminal surveillance radar/Wide Area Multilateration (WAM) coverage
5. Evaluate the effectiveness of the alerting processes, including issuance of Notices to Airmen (NOTAM), used by air traffic and the notification process for pilots and make recommendations for improvements as needed
6. Recommend guidance/training material needed for controllers and pilots to increase understanding and awareness for current and proposed mitigations

The scope of this effort was limited only to intentional GPS interference conducted by the DoD and its impact on manned civil aviation. It does not address non-DoD sources of interference, such as solar weather, illegal personal GPS jammers, unlicensed GPS repeaters or spoofing². Additionally, this group did not review Identification Friend or Foe (IFF) activity³ which pilots sometimes confuse as interference.

Background

The DoD conducts GPS interference in coordination with military exercises, system testing, and research and design of new systems. GPS interference is routinely conducted to ensure weapons systems can operate in a GPS degraded environment as GPS is inherently vulnerable due to its low signal power. Military aircraft must be able to navigate and their weapons operate in a degraded environment which can only be replicated in a realistic environment that includes purposeful denial of the signal.

The DoD, FAA, and other government agencies have developed guidelines via formal memorandums of agreement that facilitate intentional GPS interference in the National Airspace System under strict conditions and with certain mitigations required to be in place. Each interference event is coordinated

² Spoofing is the surreptitious replacement of a true satellite signal with a manipulated satellite signal that can cause a GPS receiver to output an erroneous position and time. Efforts are underway, including in RTCA's SC-159, Navigation Equipment Using the Global Navigation Satellite System (GNSS), to review and mitigate these events.

³ Identification Friend or Foe (IFF) events normally occur during U.S. Department of Defense and Joint Coalition exercises when many interrogators (i.e., navy ships, military aircraft, ground systems) operate in close proximity to each other operate simultaneously. The increase in the number of interrogations on 1030 MHz and replies on 1090 MHz generated by these events can degrade the capabilities of NAS equipment that depend on the integrity of these frequencies (i.e. Secondary Surveillance Radar, Transponders, TCAS, multilateration systems, Precision Runway Monitors, and ADS-B). There has never been a Stop Buzzer called for an IFF activity.

with the FAA’s Spectrum Engineering Services office which conducts additional coordination within the FAA and with civil stakeholders.

The table below lists the number of GPS interference events per year since 2012. It is clear the number of events and the number of unique locations are increasing, but it is important to also note that there has been a corresponding increase in coordination between the DoD and FAA. The increasing numbers reinforce that the aviation community needs a better understanding of the operational impacts of intentional interference as all impacts are not fully understood today. This report attempts to help define the operational impacts from interference as well as offer recommendations on gathering data to better understand the frequency of impacts. Also, as we approach the 2020 mandate for ADS-B and implementation of the PBN NAS Navigation Strategy, the effect of GPS interference has become more noticeable given additional operators are equipping with and dependent on GPS technology.

	2012	2013	2014	2015	2016	2017
Test Events	43	51	65	66	86	127
Test Locations	16	16	17	22	33	37
Stop Buzzers	10	9	14	8	7	24

Figure 1 Number of GPS Interference Events per Year Since 2012

Interference locations change depending on the purpose of the event, whether it is training, an exercise, testing, or a programmatic or system evaluation event. The DoD’s continued activities are the result of evolving threats which require evaluation of current and new systems and continuation of troop training and exercises to meet the nation’s security requirements. The following graphic presents locations of all intentional interference events from 2017:



Figure 2 Location of All Intentional Interference Events in 2017

The following graphic presents a summary depiction of the 4,000' Above Ground Level (AGL) contour⁴ for some of interference events from 2017 (Alaska, Hawaii and CONUS not shown at the same scale). Any one interference event may have hundreds of miles of impact in the NAS.

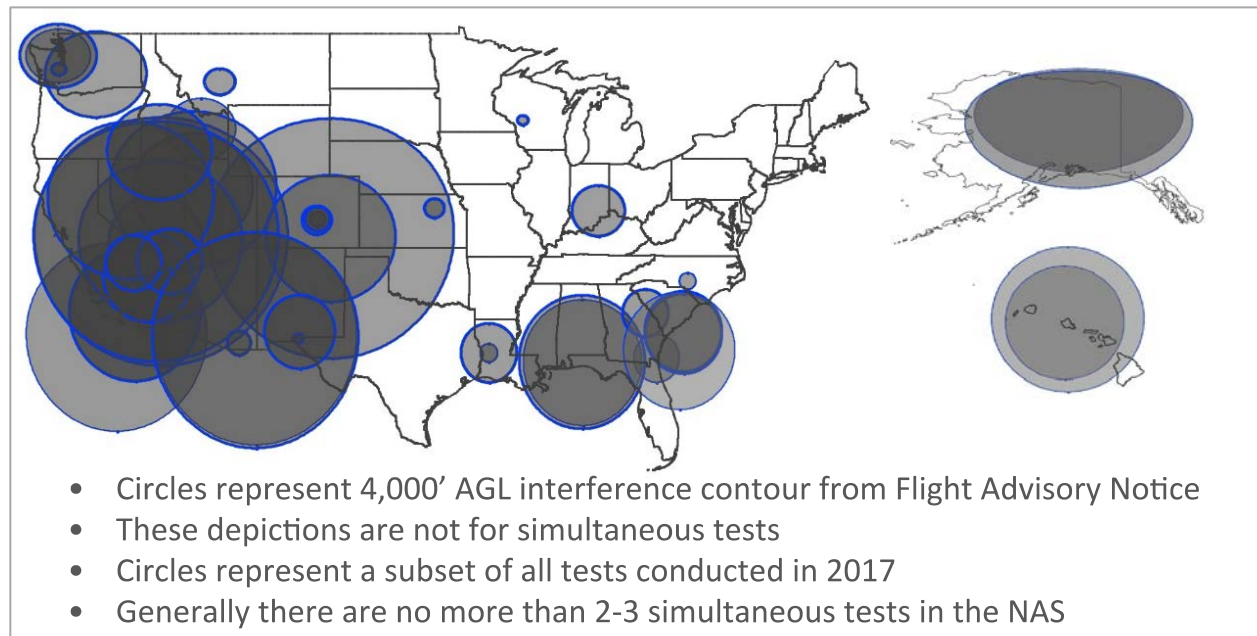


Figure 3 Summary Depiction of 4,000' AGL Contour for Non-Simultaneous Interference Events in 2017 (not all shown)

The interference normally originates from a ground-based system but can also be produced from airborne platforms like a helicopter or airplane. Each event is unique as the location of the interference transmitter, surrounding terrain, and power output (wattage) all impact how far and at what altitude the interference may be experienced. For the purposes that DoD conducts these interference events, the interference cannot always be contained to small geographic areas.

Methodology

The GPS interference Task Group was created by compiling a team of subject matter experts from industry representing general aviation, business aviation, air carriers, air traffic control, avionics manufacturers, and GPS experts. Government participation included the DoD and FAA subject matter experts who are involved in the day-to-day interference events and overall policy. Other committees, including the Communications, Navigation and Surveillance (CNS) Task Force and Performance-based Operations Aviation Rulemaking Committee (PARC), were briefed to increase awareness of the tasking.

⁴ This represents one altitude slice presented in the NOTAM for interference events. NOTAMs for interference also include higher altitudes.

Many anecdotal pilot reports of loss of GPS signal were reviewed, such as NASA Aviation Safety Reporting System (ASRS) reports. Several reports were further investigated using tools provided by the FAA's Surveillance and Broadcast Services (SBS) Program Office. The Task Group reviewed previous work done on this topic including case studies like the Embraer Phenom 300⁵. Through examination of case studies, review of previous work and group discussion, the Task Group developed a recommendation report comprised of defined GPS interference issues and recommendations.

Interference Event Issues and Impacts

Interference Event Scheduling

The FAA's process for GPS interference coordination is defined in the JO 7610.4, which is not publicly available. A redacted version is available but makes no mention of intentional GPS interference. The Air Route Traffic Control Center (ARTCC) is the focal point for determining what times of the day and week are acceptable for interference events based on volume of traffic expected. "Red times" (i.e., hours of the day when interference would have substantial operational impact) and "green times" (i.e., times that interference is acceptable) are provided in advance to the FAA Spectrum Engineering office and the Air Traffic Technical Advisory Group for negotiation with the interference proponent. The following graphic presents red and green times for various ARTCCs, which are updated at least once per year. ARTCCs not listed are all green times.

⁵ In April 2016, an Embraer Phenom 300 (EMB-505) equipped with a Garmin G3000 integrated flight deck lost all GPS signal due to an interference event. The loss of GPS eventually resulted in a miscompare between the dual Attitude and Heading Reference Systems (AHRS) and subsequent yaw damper and ventral rudder yaw stability augmentation system disengagement. The aircraft entered a Dutch Roll, resulting in an emergency descent. In February 2017, Embraer and Garmin implemented an improvement to the yaw damper algorithm allowing it to continue operating should an AHRS miscompare develop.



Figure 4 Red and Green Times by ARTCC as of April 1 2018

Currently, GPS interference requests are typically submitted to Spectrum Engineering at least 30 calendar days in advance of the requested start date. In some cases, interference events need to be coordinated on short notice due to national security.

FAA Spectrum Engineering validates the request, prepares the NOTAM and draft concurrence message, and sends to FAA System Operations Security. System Operations Security develops the NOTAM graphics, validates red time restriction compliance, and de-conflicts the schedule with other interference events or NAS priorities. System Operations Security will then notify Air Traffic Services, service areas, and air traffic facilities, as permitted, to obtain air traffic concurrence. Any concerns are resolved by Spectrum Engineering Services coordinating applicable restrictions and/or additional mitigations with US STRATCOM. Spectrum Engineering Services issues the final concurrence message 7 calendar days prior to start of the event.

Recommendation 1. When scheduling interference events, the FAA should coordinate with DoD to avoid GPS interference events from taking place: (a) during high volume traffic periods; (b) during high periods of overnight cargo traffic; (c) in airspace that only has ADS-B surveillance; and (d) back-to-back with other events.

GPS interference will continue to take place in the NAS, so it is important its effects are proactively

mitigated. Certain locations in the NAS are more susceptible and adversely impacted by GPS interference due to the reliance on ADS-B for surveillance, such as the Gulf of Mexico and Alaska. High volume traffic periods are also more impactful due to the inability to rely on GPS procedures, including those implemented during the Metroplex process.

Recommendation 2. The FAA should define a process and identify an appropriate forum to conduct outreach to civil aviation stakeholders on significant intentional GPS interference events such as those during conditions identified in Recommendation #1 and/or large events.

Today, interference proponents do not regularly conduct advanced coordination of significant GPS interference events directly with impacted NAS operators. A significant event consists of interference being conducted contrary to Recommendation 1. Coordinating these events with industry stakeholders like airlines and trade associations at forums like the National Customer Forum (NCF), would provide opportunity to reduce the adverse impact by increasing awareness.

The US Air Force (USAF) in Alaska conducts outreach and has even altered event times based on user feedback. The Task Group believes pre-coordination with the US Coast Guard (USCG) and helicopter operators in the Gulf of Mexico is particularly important whenever interference is planned to take place in the Gulf. In the case of interference in the Gulf and in Alaska, additional dialogue with civil stakeholders would be beneficial.

Additionally, the FAA should consider reinstating their annual stakeholder Working Group meetings that included DoD testers, ARTCC reps, regional FAA spectrum, DoD spectrum, and HQ FAA spectrum and Air Traffic. The purpose of these meetings were operational in nature and allowed DoD and FAA individuals to meet and discuss their respective GPS interference test programs, procedures, and policies highlighting challenges and their operational requirements. The face to face interaction and the opportunity for extensive transparent discussion on any other concerns or issues was invaluable. Airlines and pilots could also be included in such an activity in the future.

Notification of Interference Events

FAA Spectrum Engineering evaluates each test event request package to ensure engineering technical accuracy and completeness. The request package includes computer modeled graphics commonly referred to as “interference contours” or “bug splats”. These contours are designed to predict where aviation certified GPS receivers are “not” expected to experience interference during these test events (the areas outside of the contours). They are not designed or intended to depict where specific aircraft will experience interference, as this is impractical due to the large performance variations in specific GPS receivers, modeling limitations, and real-time factors that cannot be predicted or used in the modeling, such as environmental factors and aircraft attitudes that can greatly impact receiver interference levels.

Although the contours cannot predict where interference will occur, they provide a “relative” indication of where it is more likely to occur: the closer an aircraft is to the center, the more likely it is to

experience interference. The Minimum Operational Performance Standards (MOPS) values⁶ used to compute the “contours” are based on worst-case assumptions that include conservative antenna gain values and internal receiver loss factors. These conservative values are used in the modeling to account for the remote possibility of interference in a worst-case scenario. For all the above stated reasons, most aircraft will not experience interference until well within the modeled contours, but an additional reason is many manufacturers design their receivers to perform better than the minimum required performance standard, thus allowing them to operate in a “noisier” electromagnetic environment.

The following diagram presents one example of interference contours. The contours are depicted based on altitude (lower on the inside, and going higher toward the outside). Due to limitations of the NOTAM system (contours are described in text, not as a graphic or picture), areas clearly not impacted by the interference are still listed in the NOTAM.

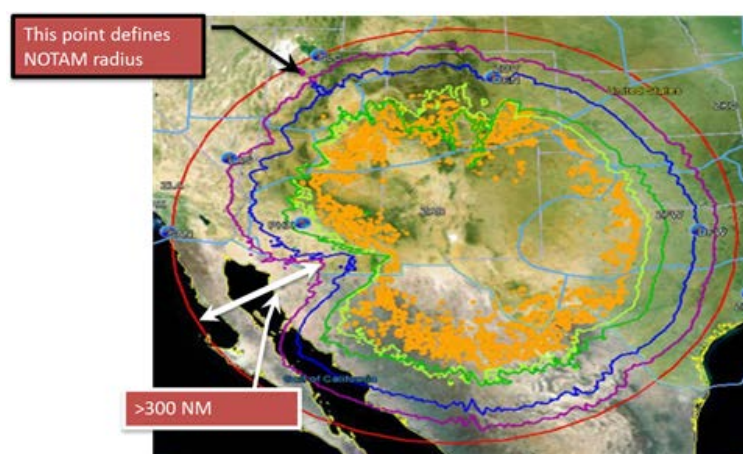


Figure 5 Sample Interference Contours from the YPG 17-02 GPS Interference Event

The interference patterns depicted in the contours result in an increase of the covered volume due to “rounding off” irregularly shaped modeled areas. The rounding off is necessary to be able to communicate the area affected in a textual NOTAM. Many aircraft inside the footprint of the publicized impact experience no interference. Many pilots report they do not trust this information and ignore the NOTAMs.⁷

The FAA converts the rounded off areas for the NOTAM into a graphic that is published in a Flight Advisory notice. This notice converts the NOTAM into plain language and provides additional details for pilots. A subset of these notices are published on the FAA’s Safety Team (FAAST) website⁸. The notice is emailed to pilots who subscribe to the Safety Program Airmen Notification System (SPANS) if their registered home address is within a certain distance of where the interference is taking place.

⁶ The in-band interference threshold (-120.5dBm) is the same for all IFR certified GPS.

⁷ If detailed interference contours were releasable to pilots, this could provide enhanced information for pilots

⁸ https://www.faa.gov/SPANS/notices_public.aspx

An example of such a graphic is presented below. This is the depiction provided with the YPG 17-02 Flight Advisory notice and associated NOTAM:

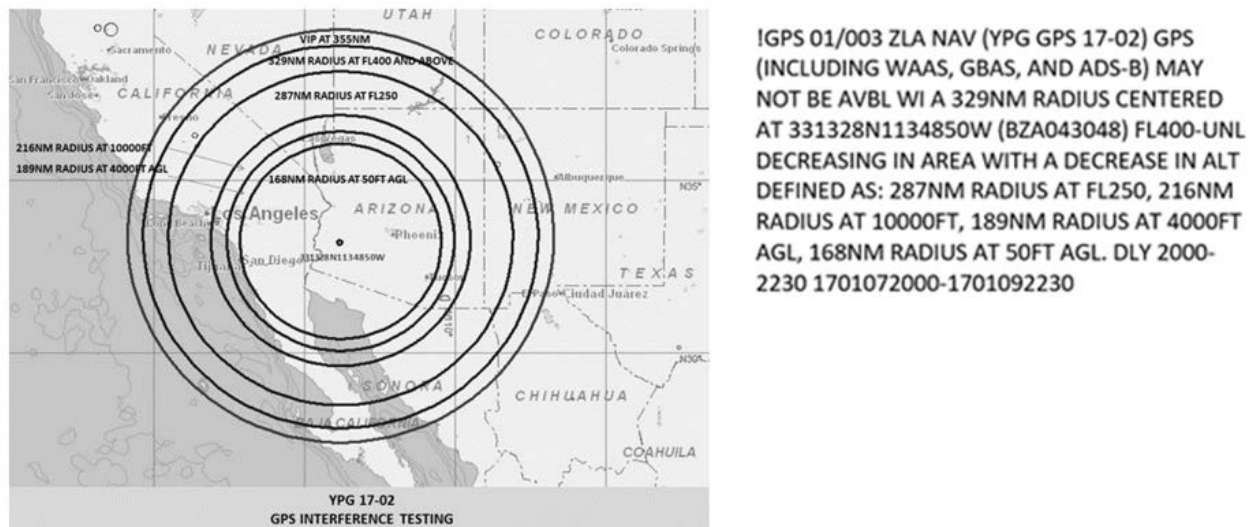


Figure 6 Graphic with YPG 17-02 Flight Advisory

NOTAMs are published by FAA System Operations Security (AJR-2) 72 to 96 hours in advance of a GPS interference event. GPS interference status information that is NOTAMed is publicly available on several websites including the FAAST website, ADS-B Service Availability Prediction Tool (SAPT) website⁹, and Coast Guard Navigation Center website¹⁰. FAA websites that are no longer supported that display GPS interference information, including the WAAS Test Team website¹¹ and FAA WAAS website¹², were identified by the Task Group and, subsequently, the out-of-date links were removed from public view.

Recommendation 3. The FAA should pursue modifications to the current NOTAM so it provides pilots and controllers improved expectation of where operators would expect interference for different equipment capabilities.

The existing contours indicate where interference will not occur and are thus poor indicators of where interference will be experienced. The corresponding NOTAMs are overly conservative and lead to many pilots simply ignoring them. The FAA should consider alternative calculation methods that reduce the size of the interference contours and focus on higher probabilities of impact being experienced. The NOTAMs need to be realistic and allow operators to make operational decisions, e.g., reroutes, based on their information. The Task Group discussed several opportunities worthy of evaluation to improve the NOTAMs and how the interference potential is described to pilots; however, this Task Group did not have the time or expertise to conduct this investigation to point to a definitive conclusion. The options discussed included:

⁹ <http://sapt.faa.gov/default.php>

¹⁰ https://www.navcen.uscg.gov/pdf/gps/gpsnotices/GPS_Interference.pdf

¹¹ <http://www.nstb.tc.faa.gov/>

¹² <http://waas.faa.gov/static/sog/notam/index.html>

- Likelihood of interference could be based on data analysis performed by the SBS office related to actual interference experienced by ADS-B equipped aircraft and the impact on the ADS-B Ground-Based Transceiver (GBT)¹³. The SBS office could include data provided by the Awareness & Operational Impact (AOI) systems data analysis (NIC/NAC levels of aircraft, WAAS PDOP, GBT's GPS logs).
- Consider changes to the contour calculation based on modifying knife edge diffraction and body masking¹⁴. Modernize the spectrum analysis tool. Any changes would involve multiple perspectives from within the FAA, including, but not limited to, aircraft certification, safety organizations, legal, etc.
- Investigate increased probability/risk of impact for the contours. This option could be investigated by an RTCA working group. Any effort to deliver a more probabilistic depiction of interference is a non-trivial task that would involve appropriate time and resources to effectively study the issue.

Discussion of this Task Group suggests that most pilots who fly through the impact area identified in the NOTAM do not experience any noticeable effect. Part of this is how the NOTAM is calculated, i.e., worst case scenario, and how the bug splat must be “rounded out” for the NOTAM. The DoD and FAA understand that the real world effects are substantially lower than what the model predicts. It is important the probability of the impact be closer to the real world effect.

While some pilots simply ignore these NOTAMs, several operators have proactively changed their operation when the NOTAM affects an area they fly in. One airline reported they cease all RNP operations in an area NOTAMed as affected by GPS interference. One ARTCC had previously shut off the ADS-B feed to controller scopes to proactively mitigate any map shifts. The operational impacts are inconsistent and the self-imposed mitigations may be causing further adverse effects.

The Task Group was able to validate that intentional GPS interference does in fact impact some operations through study of pilot reports, SBS data analysis, and the interference contours. It is clear that different aircraft, real-time conditions (e.g., environment, flight attitude, interference antenna orientation), and equipment combinations will cause variations in the degradation of GPS satellite tracking, which results in scenarios where one aircraft loses navigation and ADS-B capability and another aircraft flying at the same time and in the same area experiences no issues.

The following graphic shows ADS-B track data from an interference event, UTTR 17-01, on May 3, 2017 with multiple aircraft losing GPS reception while others are not affected. When the ADS-B Navigation Integrity Category (NIC) value exceeds the acceptable threshold, the track appears green. When the NIC value reported by the aircraft drops below the acceptable threshold, the color changes from green.

¹³ GBTs make up the infrastructure of the ADS-B network for surveillance, and TIS-B and FIS-B broadcasts. GBTs have two GPS systems and can be impacted by interference events.

¹⁴ Knife edge diffraction refers to the reflecting of interference off of terrain, and body masking refers signal loss due to the orientation of the airframe and the GPS antenna in relation to the interference source.

Other colors represent degraded but still reportable NIC values. At a certain level, the NIC value is low enough that the track becomes black and drops from the map.

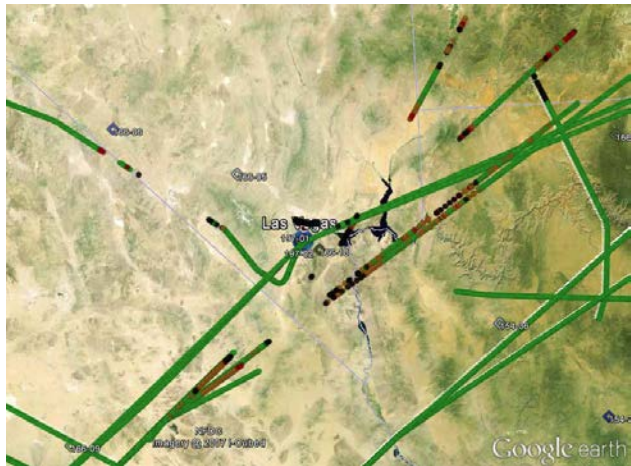


Figure 7 ADS-B Track Data from UTTR 17-01 - May 3, 2017

The graphic below, from YPG 17-02, shows the ADS-B track of a Cessna Citation with a map shift of 1.6 NM while descending through FL310. The contours of the interference are shown in green and orange representing various altitudes one may expect an impact. The ADS-B track of an aircraft with NIC less than 6 (black track) are not shown to ATC except under certain conditions.



Figure 8 ADS-B Track of Cessna Citation with Map Shift

Finally, the graphic below is drawn from the AOI tool. The image presents a polygon within which GPS is degraded.

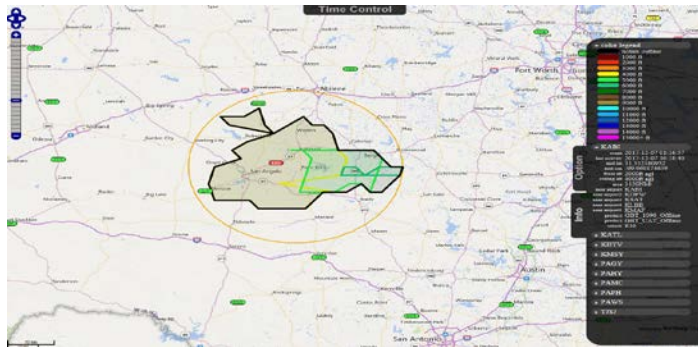


Figure 9 AOI Outage Polygon with Altitude Slices and Waypoints

Recommendation 4. The FAA should consolidate the preflight resources that disseminate GPS interference event information to the NOTAM Search and ADS-B SAPT website and ensure the NOTAM's graphical information be available in legacy KML as well as AIXM formats.

The preflight resources available online for pilots are fragmented and obscure. The FAA has failed to maintain several of these websites yet they were still publicly available until recently. The FAA should consolidate resources relevant to GPS interference to the ADS-B SAPT website and NOTAM Search. Both are already primary resources for pilots and dispatchers and include graphical depiction capabilities, though they must still be improved in order to be useful.

In one case an operator accessed the SAPT website to view relevant interference events but the website was out of date and erroneous. While the retrieval of active NOTAMs is not manual for this website, the process that provides those NOTAM graphics is manual because of the variability of the NOTAM text and challenges with parsing. In this case study, the individual responsible for manually reviewing the graphic was on leave so the website became out of date. At the same time, two of the FAA's WAAS websites included GPS interference information that is several years out of date. Once brought to the FAA's attention, there was discussion of removing these links from public access. Looking forward, the FAA must keep these resources current.



Figure 10 Out of Date Interference Event Depicted on the SAPT website (only shows FL400 contour)

Recommendation 5. The Flight Advisory notice and process should be modified to be more effective for users: (a) relocate the notices from the FAA Safety Team website to NOTAM Search; (b) incorporate a link to the Flight Advisory notice within the NOTAM on NOTAM Search; and (c) change paragraph E in the notice to encourage anomaly reporting¹⁵.

The Flight Advisory notices are an important resource for pilots but they are housed on an obscure website and can provide misleading information. The FAA should continue publishing and emailing the Flight Advisory notices as they do provide valuable information to users; however, where they are hosted today has limited visibility for a pilot preparing for a flight. It is important the FAA relocate and integrate these notices with the NOTAM on NOTAM Search, which is the default location for NOTAM related information.

Paragraph E in each Flight Advisory states “pilots are encouraged to report anomalies only when ATC assistance is required.” This guidance is repeated in Aeronautical Information Manual (AIM) paragraph 1-1-13, but this guidance is counter to FAR 91.187. Pilots operating under IFR are required at all times to “report as soon as practical to ATC any malfunctions of navigational, approach, or communication equipment occurring in flight.” It is important paragraph E in the Flight Advisory and AIM paragraph 1-1-13 are modified to be consistent with the regulatory obligation of all pilots. The Task Group recommends the notice encourage reporting to ATC and via the online Anomaly Reporting Form¹⁶, such

¹⁵ Note that later recommendations in the Pilot section include additional recommendations geared towards encouraging pilot reporting

¹⁶ https://www.faa.gov/air_traffic/nas/gps_reports/

as stating “pilots experiencing an anomaly should advise appropriate ATC facility and report online using FAA GPS Anomaly Reporting Form.”

The following presents an example of a Flight Advisory notice with paragraph E highlighted in red. It is important this language is changed to encourage reporting.

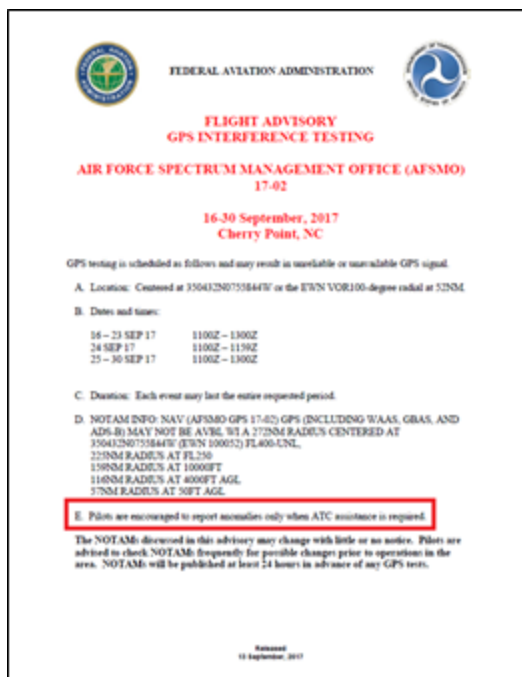


Figure 11 Example of a Flight Advisory Notice with Paragraph E Highlighted in Red

Recommendation 6. The FAA should display the interference area defined in the NOTAM¹⁷ graphically on the NOTAM Search map page, and incorporate a list of airways and airports potentially affected.

Based on currently provided notification, operators lack situational awareness for where the interference is anticipated in relation to their route of flight. There currently is not a good way for a pilot to map GPS interference to their flight. Enabling additional functionality to overlay the interference event impact area on one’s flight will further increase situational awareness. The FAA had previously provided complete lists of airways and airports affected by GPS interference events but stopped doing so in 2012. These resources are still available online but no longer fully supported. ATC and pilots would benefit from having this additional information.

The graphic below depicts the FAA WAAS Test Team website (top) and shows impacts of GPS interference on airways and lists all airports. The impact of interference on airways is shown on the FAA WAAS website (bottom). Both resources ceased being supported in 2012.

¹⁷ This is not necessarily intended to publish interference contours

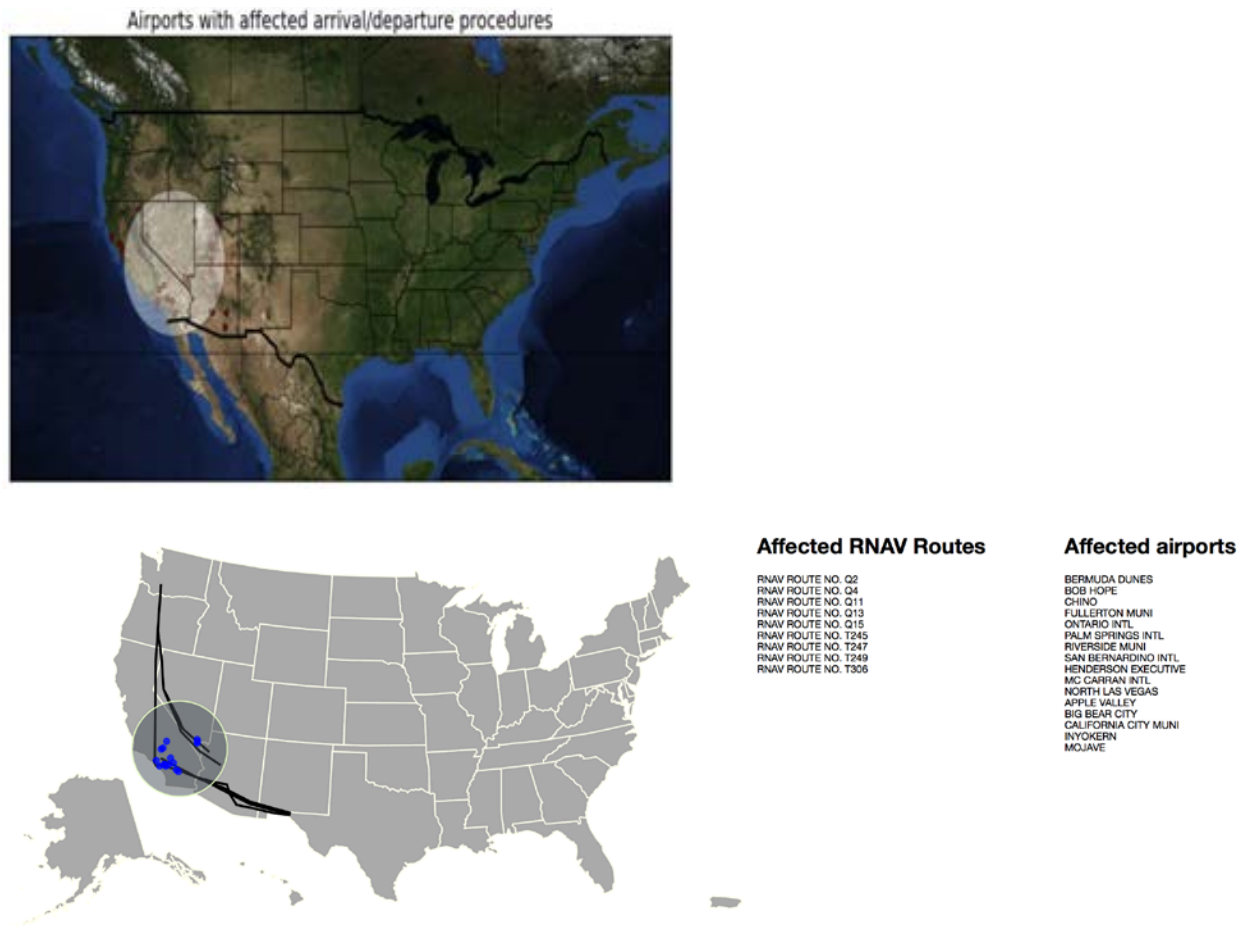


Figure 12 Resources for GPS Interference where Support has Ceased

This recommendation is consistent with FAA plans to implement graphical Temporary Flight Restrictions (TFR) on the NOTAM Search map page in 2018. This enhancement was a recommendation of the TOC’s “Improving Graphical Temporary Flight Restrictions in the National Airspace System” report provided in December 2016 because greater situational awareness is needed for pilots to understand where a TFR is in relation to their specific route.

Recommendation 7. The FAA should have a process to ensure underlying air traffic facilities receive real-time notification when interference is taking place.

The current process for notification of an interference event is for the interference proponent to contact the impacted ARTCC(s) via telephone in advance of interfering with the GPS signal. However, there is no process to ensure the status of the interference is also communicated to other impacted air traffic facilities such as TRACONS or underlying airport towers. A consistent and comprehensive communication process is needed for controllers to maintain awareness of an event. The DoD coordinator involved with the interference event will call the ARTCCs involved to give a 90 minutes advanced notice before conducting any interference and when they are finished. The existing process

limits the real-time awareness for controllers on position at other facilities who may need this knowledge to ensure mitigations are being properly utilized, such as the Stop Buzzer.

During Event

Operational Impacts

Large intentional interference events can generate significant system impacts that affect operational efficiency. The NAS is experiencing an increasing reliance on Performance Based Navigation (PBN) through use of Area Navigation (RNAV) Standard Instrument Departures (SIDs) and Standard Terminal Arrival Procedures (STARs) and Q routes as well as Metroplex implementations that may involve use of GPS for navigation. If interference impacts use of PBN routes and procedures, this can drive a loss of throughput, particularly in airspace, that can drive Traffic Management Initiatives (TMIs) and delay during high volume periods.

During a recent Red Flag event at the Nevada Test and Training Range, air traffic facilities informed operators about the potential for operational impact from the event. Los Angeles Air Route Traffic Control Center (ZLA) provided the following overview to operators of the anticipated effects of the Red Flag event:

Aircraft operating in ZLA airspace may be affected and experience navigational disruption. Arrivals and departures from airports within the Las Vegas, NV area may be issued Non-RNAV re-routes. Possibility of increased disruption of traffic flow in the vicinity of LAS may require airborne re-routes to the south and east of the affected area. Descend-via and Climb-via procedures may be suspended during affected times. Non-RNAV SIDs and STARs may be issued within ZLA airspace in the event of increased navigational disruption. Possible increased airborne mile-in-trail and departure mile-in-trail TMIs.

Arrival and departure delays may exceed 30 minutes during periods of peak demands in the initial implementation and during peak traffic periods – especially Thursday, Friday and Sunday nights

Arrival TMI's including GDP, AFP, GS, CFR, Metering, speed restrictions and MIT are possible during high volume periods. Departure TMIs are expected during the scheduled events.

The following procedures may be required: tactical re-routes for fix balancing; possible ATCSCC Playbook routes (Rocky South 2 partial; Hill City HLC Partial; Springs West Partial; Mojave East Partial).

The need for TMIs will be continuously evaluated throughout the duration of the event with heaviest impact expected during the first 7 days

An additional event affecting New York Oceanic airspace (ZNY) resulted in air traffic facilities imposing a pre-emptive closure of non-radar airways. One NOTAM (A0090/18) informed operators that “GPS Testing in the New York Center Oceanic CTA/FIR will be conducted” and that during the test period of 1300-1500 Zulu time, “the following non-radar airways will be closed west of 75W: M202, L375, L435,

L451.” A second NOTAM (A0091/18) informed operators of additional route closures at other times of the day.

Aircraft Impacts

Intentional GPS Interference has multiple potential impacts on aircraft systems. However, given the variety of systems operating in the NAS, the impacts will not be homogenous across all fleets and equipage. A generalized assessment of aircraft impact is presented below with focus on identification of categories of aircraft impacts that NAS stakeholders may anticipate.

The most common impact is complete loss of GPS reception, which results in loss of GPS position, velocity, and time (PVT). In some cases the GPS signal may be degraded but not completely lost, resulting in decreased position accuracy.

Receiver autonomous integrity monitoring (RAIM) and fault detection and exclusion (FDE) ensure that position errors are bounded by the horizontal alert limit (HAL) unless a position failure is annunciated within the time to alert (TTA). GPS position errors may exceed the HAL for a period before the required TTA. TTA is generally 8 seconds, but can be up to 30 seconds for some Enroute applications. HAL Thresholds are 2NM for En Route, 1 NM for Terminal and 0.3 NM for LNAV and LNAV/VNAV final approach.

The following table presents an overview of different potential impacts from GPS interference. This is a snapshot of impacts based on input from two manufacturers and not intended to be a comprehensive list of all impacts:

Effect	Affected Operations	Impact
Loss of GPS-based navigation	Enroute/ Terminal/ Approach NAV	<p>Loss of all RNAV and Required Navigation Performance (RNP). Higher end aircraft with Inertial Reference Unit (IRU) or Distance Measuring Equipment (DME)/DME may have degraded RNP/RNAV.</p> <p>May result in missed approaches for GPS-based or low RNP procedures with associated increase in flight crew workload. May use conventional approach (ILS, VOR Minimum Operating Network).</p> <p>Risk of diverting if Instrument Landing System (ILS) (lower minimum) not available.</p> <p>Simultaneous loss of GPS navigation in a wide area could increase ATC workload.</p>
Larger than normal GPS position errors prior to loss of GPS	Enroute/ Terminal NAV	<p>Interference could cause the GPS position to be pulled off but not exceed the HAL (2NM or 1NM for enroute and terminal, respectively).</p> <p>There could be navigation impacts such as causing VNAV descent on a STAR significantly before or after the intended top of descent.</p> <p>Technical Standard Order (TSO) GPS receivers incorporate integrity monitors that will prevent these errors from persisting longer than the required time-to-alert.</p>

Loss of ADS-B Out over wide area.	Surveillance	Loss of all surveillance in areas such as Alaska where there are large gaps in Secondary Surveillance Radar (SSR) coverage.
GPS/SBAS Nav/ GPS Measurements	Surveillance	<p>If aircraft depends on Satellite Based Augmentation System (SBAS) and is in areas without primary or secondary radar coverage, this will cause a larger airspace management issue.</p> <p>Some aircraft use GPS-Inertial blended solutions to support ADS-B needs.</p>
Loss of TAWS/HTAWS	Enroute/ Terminal NAV	<p>Reduced situational awareness and safety for equipped aircraft. Terrain Awareness and Warning System (TAWS) is required equipment for turbine-powered airplanes > 6 passengers. Helicopter TAWS (HTAWS) is required for helicopter air ambulance.</p> <p>Loss of GPS results in loss of terrain/obstacle alerting. Position errors as GPS degrades can result in false or missed alerts.</p>
Loss of GPS aiding to AHRS	Flight Control	Can result in degradation of AHRS pitch and roll accuracy with potential downstream effects such as was experienced by a Phenom 300 flight.
Missing/ degraded ADS-B In targets	All flight phases	<p>Complete loss of GPS in an ADS-B Out equipped aircraft will cause that aircraft to be lost as a target for ADS-B In systems. ADS-B In systems with Traffic Collision Avoidance System (TCAS) will continue to display target.</p> <p>If GPS position accuracy exceeds reported NACp prior to loss of GPS, ADS-B In systems with TCAS may display multiple symbols for the same target. Overall impact is reduced situational awareness.</p> <p>TCAS II systems with hybrid surveillance will be unaffected because target position will be validated with active interrogations.</p>
Loss of GPS position to SATCOM	Communications, Surveillance	<p>Geosynchronous satellite networks generally require valid position to attach a SATCOM terminal to the network. If position is not available, connectivity will not be enabled. Primarily a concern at system startup on ground or for in-air satellite handoffs.</p> <p>During all flight phases, SATCOM position reporting could be impaired with associated impacts to aircraft fleet tracking.</p>
Loss of GPS to PFD/MFD	All flight phases	<p>Can result in:</p> <ul style="list-style-type: none"> -Loss of synthetic vision display and flight path marker on PFD -Loss of airplane icon on lateral and vertical electronic map displays, georeferenced charts, and airport surface maps without DME-DME or IRU -Loss of airspace alerting and nearest waypoint information without DME-DME or IRU <p>Overall loss of situational awareness to flight crew and increased workload.</p>
No GPS	Search and	GPS provides increased position accuracy to newer Emergency Locator

position for ELT	rescue	Transmitters (ELTs). Loss of GPS could result in larger search radius.
Reduced ability to determine flight phase	Terminal NAV	GPS-derived ground speed is a key component in determining the current phase of flight to perform workload-reducing functions such as entertainment audio or telephone audio muting. Loss of this feature could increase crew workload when preparing to land.
Loss of runway alerting	Approach, On-Ground, Takeoff	Loss of GPS results in loss of runway alerting (wrong runway, taxiway landing/takeoff, runway too short). Reduced situational awareness and safety for equipped aircraft.
No GPS position for EFB	Situational Awareness	Loss of own-ship position for Electronic Flight Bag (EFB)

Recommendation 8. The FAA should work with OEMs to develop a clear understanding of known GPS dependencies in avionics and aircraft flight controls.

Modern GPS equipment is required to recover from interference conditions that cause loss of position/navigation¹⁸. However, older GPS equipment may not have been developed to similar requirements¹⁹.

Additionally, as part of meeting their obligations under 2x.1309 “Equipment, systems, and installations”²⁰, aircraft and equipment manufacturers are required to consider foreseeable “loss of” failure conditions and “misleading information” failure conditions and to develop appropriate mitigations for both types of failures.

Today, the FAA and operators do not have a clear understanding of what critical aircraft systems have GPS dependencies and what the impact of interference and GPS failure would be on each of those systems. It is important that known GPS dependencies for aircraft primary and secondary systems, such as those described to back up any system, are identified in the context of a failure of that GPS system and what may be impacted following such a failure. The FAA should work with aircraft and equipment manufacturers to develop a clear understanding of known GPS dependencies in avionics and aircraft flight controls. These dependencies are important to be communicated to the DoD for awareness purposes, and to operators so that they can be properly trained (see following recommendation).

¹⁸ For example, TSO-C145()/TSO-C146() GPS/SBAS equipment must meet the requirements of DO-229C/D/E section 2.1.1.12 “Integrity in the Presence of Interference” that includes (**emphasis added**):

“The GPS/SBAS equipment shall satisfy the applicable integrity requirement within the time-to-alert (...) for the output of misleading information **in the presence of interfering signals higher in power than the values specified in Appendix C**. Under these extreme conditions, it is acceptable to output a navigation alert, but not to output misleading information. **The equipment shall autonomously return to steady state accuracy (...) within 5 minutes after the interference conditions return to those specified in Appendix C for initial acquisition.**”

TSO-C196 GPS equipment must meet the same requirements in DO-316 section 2.1.1.10.

¹⁹ For example, TSO-C129() does not have similar requirements to recover from interference conditions that cause loss of position/navigation.

²⁰ Part 23 Amendment 23-64 moved requirements for consideration of failure conditions to 23.2510.

Recommendation 9. Operators should be informed of known avionics and aircraft flight control GPS dependencies and what should be expected if GPS becomes unavailable during flight.
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The FAA’s existing guidance may not be sufficient to address the dependencies identified in the table in the Aircraft Impacts section. Additional updates to the FAA Advisory Circular (AC) 20-138D or other ACs may be required as an outcome of Recommendation 8.

FAA AC 20-138D Chg 2 “Airworthiness Approval of Positioning and Navigation Systems”, section 15-4 “Documenting Effects of GNSS Outage” describes GNSS outages as “a normal operating condition in areas with routine interference testing, and can occur anywhere in the NAS due to unintentional interference.” AC 20-138D section 15-4 also provides several examples of systems dependent on GNSS including “TAWS/HTAWS, synthetic vision systems, ADS-B, and micro-electro-mechanical system (MEMS) accelerometers/sensors in air data attitude heading reference system (ADAHRS) inputs to electronic primary flight displays.” This section also describes the AFM(S)/RFM(S) content that must be documented to describe aircraft-level effects as well as information TSO equipment manufacturers should include in their operating guide and installation instructions.

Other FAA ACs dedicated to functions that are dependent on GNSS include more specific guidance about what should be included in the AFM(S)/RFM(S) relative to those functions. Examples of these ACs include but are not limited to:

- AC 20-165B “Airworthiness Approval of Automatic Dependent Surveillance – Broadcast OUT Systems” section 2.2
- AC 20-167A “Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment” Appendix F and Appendix H, section H.6
- AC 23-18 “Installation of Terrain Awareness and Warning System (TAWS) Approved for Part 23 Airplanes” section 7.f.(1)(c)
- AC 25-23 “Airworthiness Criteria for the Installation Approval of a Terrain Awareness and Warning System (TAWS) for Part 25 Airplanes” section 11.a.(g)

NAS Equipment

Recommendation 10. The FAA should solicit industry feedback on the strategy to decommission secondary-surveillance radar systems.
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This recommendation echoes Recommendation 10 published in the “Performance Based Navigation (PBN) Route System” report published by the TOC in August 2017. The SBS program office is considering decommissioning more than 80% of terminal radars in CONUS as ADS-B equipage increases. Without radar as a backup, areas prone to GPS interference will experience increased periods of inefficient non-radar or procedural separation as the position source for ADS-B may be degraded. Concerns regarding

this drawdown were also recently raised in a January 2018 Government Accountability Report²¹. Once the FAA drafts the decommissioning CONOPs, industry should be involved in its validation.

Recommendation 11. The FAA must keep the VORs that are part of the Minimum Operating Network (MON) maintained and in service.

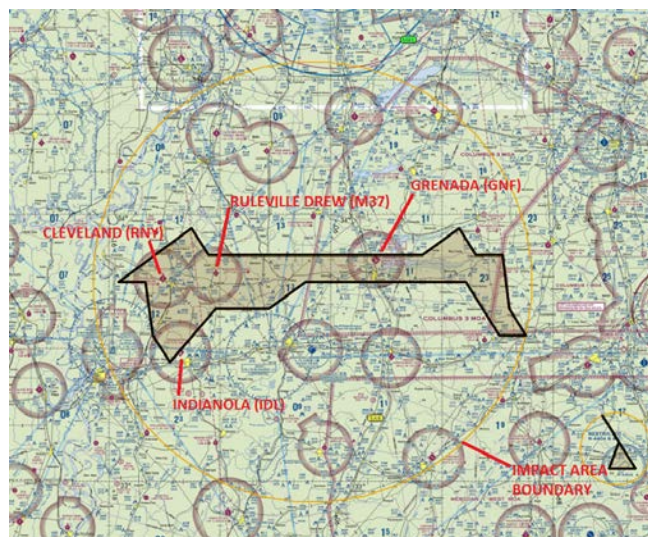
Given the impacts experienced during interference events, it is critical the resiliency plan in place be effective. Many VORs that are part of the MON are out of service, sometimes for years at a time. The FAA must make an effort to keep these systems functional for the MON to be useful. This recommendation is similar to Recommendation 11 from the “Performance Based Navigation (PBN) Route System” that stated “the FAA should ensure there is a long-term, funded sustainment plan for those NAVAIDs determined to be integral to the NAS.”

Recommendation 12. The FAA should proactively alert pilots when GPS interference will negatively affect the services provided by an ADS-B GBT.

Large GPS interference events can negatively affect the ability of GBTs in a given service volume to provide the services pilots are expecting. Interference can negatively affect the system’s ability to provide ADS-Rebroadcast (ADS-R), Traffic Information Services- Broadcast (TIS-B) and Flight Information Services-Broadcast (FIS-B), which should be communicated to pilots via NOTAM in advance.

Below is an example of how the FAA can model a GBT outage. The FAA is implementing new NOTAM policy that will allow for outage information to be disseminated to pilots. This is an example NOTAM:

IFDC #/#### ZAN SVC ADS-R, TIS-B, and FIS-B MAY NOT BE AVBL WI AN AREA DEFINED AS 50NM RADIUS OF 334500N0900504W (MEM F/R/D) SFC-UNL. AFFECTED AIRSPACE MAY INCLUDE RNV, M37, IDL, GNV. YYMMDDhhmm-YYMMDDhhmm



²¹ GAO-18-177; <https://www.gao.gov/assets/690/689478.pdf>

This Graphic shows the airports affected by a GBT outage.

Pilots and Dispatchers

Recommendation 13. The FAA should update pilot guidance: (a) AIM/PCG should be reviewed for consistency of terms; (b) AIM should list resources for preflight information (i.e., NOTAM Search and ADS-B SAPT website); and (c) the FAA should publish an Advisory Circular specific to GPS interference and the resiliency of the NAS (VOR MON and NextGen DME).

The guidance published in the AIM/Pilot Controller Glossary (PCG) is inconsistent in the use of terms, does not point operators to important resources, and is counter to pilot’s regulatory obligations. The FAA should update these resources to provide effective and consistent guidance for pilots and dispatchers.

The Task Group identified several issues with the current AIM guidance. The use of “unreliable” is outdated and should be replaced with the correct phrase of “may not be available.” There is a note stating “GPS interference or outages associated with known testing NOTAMs should not be reported to ATC.” However, pilots must always report malfunctions to navigation equipment per FAR 91.187. AIM guidance should also be updated to alert pilots of the availability of the ADS-B SAPT website, NOTAM Search, and the Flight Advisory notices.

The Task Group believes GPS interference and the resiliency plan should be discussed in greater detail in an Advisory Circular or other form of guidance document. Without clear guidance, operators will continue to overcompensate (not fly, operational impact) or undercompensate (no planning or pilot training) in the face of planned interference event. The following topics from an operational/pilot perspective should be covered in the guidance:

- GPS interference background;
- The FAA’s mitigations for GPS interference events, particularly for those airports dependent on GPS approaches (i.e., weather less than 5,000’ ceiling and/or 5 miles visibility);
- The safety concerns related to GPS interference identified in the APNT CONOPs, such as lack of understanding of back-up systems and inability to smoothly transition to reversionary systems, should be addressed with realistic scenarios and in the context of the VOR MON and NextGen DME navigation;
- GPS interference’s impact on various systems (see OEM contributions), including map shifts and vertical navigation changes;
- Scenario training (See FAA’s 2012 Alternative Position, Navigation, Timing (APNT) CONOPs);
- How to communicate and report interference to ATC;
- The availability of GPS approaches during periods of interference;
- FAR 91 equipment requirements and operator best practices.

Operators are not given adequate education on the impact of GPS interference to their systems. In the example depicted below from a 2017 Red Flag military exercise, an Alaskan operator that tracks their ADS-B equipped fleet for safety reasons witnessed a significant shift in position from an aircraft. This

shift, although not provided to ATC, raises questions for search and rescue, and the reliance of some operators on GPS for monitoring aircraft.

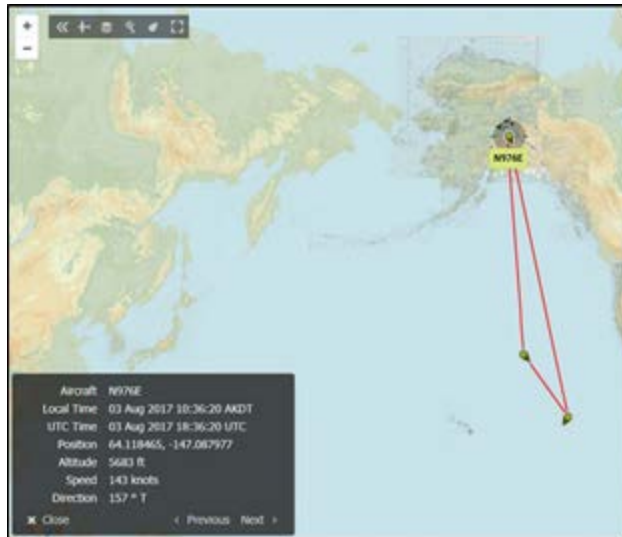


Figure 13 ADS-B Position Shift During 2017 Red Flag exercise

Recommendation 14. The FAA should clarify that a GPS interference NOTAM gives pilots authorization to deviate from FAR 91.227 within the affected area and for the duration of that flight.

The FAA has not yet provided a process for operators to be informed they are exempt from FAR 91.227 requirements when GPS and/or WAAS may not be available due to intentional interference. FAR 91.227 details the performance requirements for ADS-B Out systems including the required position accuracy. When GPS interference is taking place, an operator may have their position accuracy (NIC/NAC) go below that required by the regulation. The FAA's current guidance, AC 90-114, ADS-B Operations, states:

It may be necessary for ATC to authorize operations in airspace for which ADS-B Out is required at times when the required performance cannot be met. During interference outages of [GPS] (scheduled or unscheduled), the FAA may revert to alternate surveillance, as necessary, for affected areas. ATC will issue a Notice to Airmen (NOTAM) that authorizes such operations and identifies the airspace and time periods that the authorization is in effect. ATC will also issue a NOTAM to authorize performance outages when the FAA-provided preflight availability prediction tool is not available.

The FAA has not yet issued guidance to operators as to when and where they are exempt from compliance with FAR 91.227. The Task Group believes a lack of exemption from this requirement would have significant impacts including delaying flights until performance requirements can be met, changing flight routing to avoid the affected area, or flight cancellation.

It is important the notification provide an exemption from ADS-B performance requirements for the duration of the flight as it is apparent that some GPS systems²² may not recover while airborne from the interference despite no longer being exposed to the effects²³. Example phraseology for the NOTAM could be “pilots transiting area are exempt from 14 CFR Section 91.227 requirements for duration of flight.” The notification of exemption from FAR 91.227 should be included in the NOTAM, on NOTAM Search, and on the SAPT website. Air traffic controllers will also need to be notified of a specific aircraft’s exemption status.

The image below is of a commercial airline flight during a May 2017 GPS event. Note the red and yellow flight track which indicates the ADS-B NIC/NAC values were degraded below performance specifications during this interference event. The system remains degraded through the region identified by the NOTAM as well as outside the NOTAM area. The system never recovered even when outside the interference area.

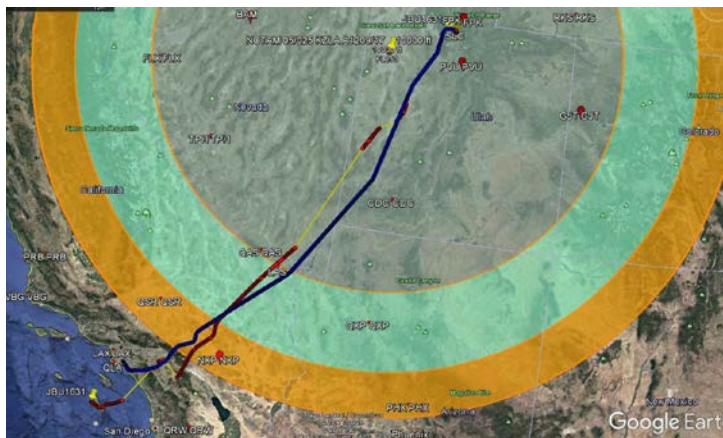


Figure 14 Flight track and ADS-B NIC/NAC Degradation Inside and Outside of Interference Event Area

Recommendation 15. The FAA should review and streamline the report process pilots use involving failures or malfunctions to GPS dependent systems to ensure all reports are collected and sent to the correct FAA office.

The FAA office that needs to know in real-time, or after the fact, about an adverse impact from GPS interference is not receiving all relevant reports today. The 7210.3 and 7110.10 note the Traffic Management Unit (TMU) should be informed of GPS anomaly reports so that the TMU can pass these reports to the appropriate FAA office with responsibility: currently the WAAS Operations-East Desk at the ATCSCC in Warrenton, Virginia. It is clear from the ATCSCC’s annual report numbers that those reports verbally given to ATC and Flight Service rarely make it to the ATCSCC.

²² While modern GPS equipment is required to recover from interference conditions, older GPS equipment may not have been developed to similar requirements (see footnotes 18 and 19). Recovery time will vary based on the system and the dependencies connected to that system.

²³ The lack of restoration of navigation and ADS-B equipment on board aircraft has been reported via several sources: (a) ASRS reports; (b) individual air carrier crew reports; and (c) the SBS office’s ADS-B data analysis.

To have a representative picture of how many aircraft are experiencing an impact from intentional interference, the reporting process should be reviewed and improved upon to ensure all reports from pilots are correctly being passed on to the ATCSCC. Additionally, the ATCSCC should have a pathway to receive relevant pilot reports submitted via the NASA ASRS system or through an airline reporting system, as well as any Mandatory Occurrence Reports (MORs) or Air Traffic Safety Action Program (ATSAP) reports. It is not widely known among pilots that their report, if submitted via ASRS or to the airline, may not be reviewed by the appropriate FAA office.

The FAA should work with industry to emphasize the need for pilots to report GPS navigation and ADS-B malfunctions via the online Anomaly Reporting Form. Consolidating guidance to focus on this online reporting form should improve the collection of data. This online form also needs to be updated for it to be effective for the ATCSCC. For example, the questionnaire asks the reporter to state the time the event occurred; however, it is not clear if the time is UTC or local. The FAA should implement the recommendations of the ATCSCC to improve the data collection of pilot reports.

Recommendation 16. The FAA should have the ability to correlate ADS-B NIC/NAC degradation to an interference event for improved data collection/metrics.

The FAA relies on subjective anecdotes to identify interference despite aircraft automatically reporting the elements necessary to determine a real-time picture of GPS interference in the NAS. These reports are inconsistent and frequently are not provided to those in the FAA who need them. Automatic ADS-B aircraft messages provide information on where GPS signals are degraded and where recovery occurs. This data can form the foundation for data-driven decision making. The FAA should leverage the reports automatically provided by ADS-B aircraft and the over 600 GBTs to gauge the impact of GPS interference. Improving data processing will facilitate the ability to identify trends, improve metrics, and attribute the cause. Anecdotal pilot reports will continue to inform the extent of the impacts.

Controllers

Controllers are instructed to record when an aircraft reports an issue with GPS or WAAS. The controller will then request a report from a second aircraft. This information may then be passed to a supervisor or controller-in-charge for inclusion on the 7230-4, Daily Record of Facility Operation. The second aircraft may be receiving a GPS or WAAS signal and, in that case, no action may be taken. As noted earlier, most pilot reported GPS malfunctions or failures are not reported from the controller who receives it to the appropriate FAA Office . It is important all data and reports collected are passed to this office so trends and metrics can be identified.

Recommendation 17. The FAA should disassociate the process of collecting and verifying pilot reported GPS malfunction or failures from the process used for pilot reported NAVAID²⁴ malfunctions.

²⁴ The Pilot/Controller Glossary defines a NAVAID as any visual or electronic device airborne or on the surface which provides point-to-point guidance information or position data to aircraft in flight.

In the JO 7110.65, paragraph 2-1-10, the FAA defines how controllers are to collect and verify pilot reported NAVAID malfunctions or failures. However, this paragraph creates an inadvertent and incorrect connection between a ground-based NAVAID and a GPS malfunction. Specifically, this paragraph makes it appear that two aircraft reports noting malfunction or failure are required before any formal action will be taken to forward the reports to those who need them. We believe this paragraph is contributing to the underreporting of pilots reports provided to controllers.

The FAA could address this paragraph in the controller order by:

- a) Reorganizing it to ensure a GPS anomaly report is not treated like a pilot reported ground-based NAVAID malfunction;
- b) Adding guidance that promotes the passing of all GPS anomaly reports to the appropriate office at the ATCSCC via the process outlined in the JO 7210.3, paragraph 3-5-3;
- c) Emphasizing two pilot reports for a GPS anomaly are not required and may have no bearing on the validity of the first aircraft's impact; and
- d) Removing the outdated term "unreliable" and replacing it with the phrase "may not be available."

The Task Group has learned through this process that GPS interference is affected by terrain, aircraft altitude, aircraft attitude, direction of flight reference the center of the interference, distance from the center of the interference, equipage, and many other factors. Asking a second aircraft may have no bearing on the validity of the other aircraft's experience. The GPS interference NOTAMs can cover large areas with aircraft experiencing vastly different effects depending on where they are. In one NOTAM, the smallest footprint was at 50FT AGL with a radius of 172NM. This is an area of 120,687 square miles or an area roughly the size of the State of New Mexico or the States of Florida and Georgia combined.

Recommendation 18. The FAA should ensure controllers document pilot reported GPS malfunctions or failures²⁵ in a manner that supports data analysis and trend identification.

Documenting a pilot reported GPS malfunction or failure in the Daily Record of Facility Operation does not allow for efficient evaluation of the impact GPS interference has on the NAS. The FAA should ensure these reports are documented in such a way that the reports can easily be identified and additional details ascertained. The Task Group recommends this type of report should be a MOR item and GPS interference given its own category on the form to allow easy keyword searching.

Recommendation 19. The FAA should update controller guidance to clarify controller responsibilities during a GPS interference event.

Controller guidance provided in JO 7110.65, paragraph 4-8-1(k) and (m), is out of date and has proven to be confusing to controllers. This paragraph is clear, when a NOTAM is published affecting GPS in the

²⁵ These reports should be submitted regardless of whether a NOTAMed interference event is active

area, “Do not resume RNAV Approach operations until certain that GPS interference is no longer a factor or such GPS testing exercise has ceased.” But this is further complicated in guidance provided by two memos (See Appendix C) from FAA Department AJV-8, Air Traffic Procedures, dated July 17, 2015 that state:

3. During testing, if a pilot indicates that they wish to proceed with a GPS instrument approach, can a controller clear them to do so?

Yes. If the pilot has determined that he/she is receiving a GPS signal and requests a GPS-dependent RNAV approach, the controller may issue it.

And in a second memo from AJV-8, dated the same day:

If a pilot advises the controller that he/she still wants the RNAV approach, is the controller allowed to issue the RNAV approach?

Yes. If a pilot is receiving a signal, it is useable. Under 14 CFR Part 91.3 (a): The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft.” Therefore, if the pilot has determined that he/she is receiving a suitable GPS signal and requests a GPS-based RNAV approach, the controller may issue it.

This is a very important topic as the implementation of the VOR MON and the decommissioning of almost all of the remaining Non-Directional Beacons (NDBs) means many airports only have GPS approaches. A pilot may leave on a flight, meet the requirements for verifying RAIM, meet all of the requirements for checking the NOTAMs at his airport of departure and intended destination, and, despite maybe never having experience interference before, have a GPS malfunction or failure due to a GPS interference event. It may be that their alternate also lies inside the area covered by the GPS interference NOTAM and that there is no approach which is unaffected by the interference.

A controller may advise the pilot of the NOTAM and that GPS “may not be available.” The pilot may be receiving the GPS signal suitable for navigation and decide to attempt the approach. Per the AJV-8 memo, the controller is allowed to issue the approach clearance. But the Task Group has learned that the interference may be done at different power levels, terrain can have a big influence, and that interference may start and stop at any time during the approved window. In this case, a pilot who decides to fly an approach may find his signal abruptly lost or degraded.

With ADS-B Out beginning to be used by more aircraft, the GPS interference begins to take on an even greater significance. ADS-B Out sends the aircraft’s location to the controller. If, as has been the case with many aircraft, the aircraft loses its ability to process GPS as a result of flying over or near one of the test sites, the ability for that aircraft to properly report its position via ADS-B Out is lost. If this is in an area of ADS-B only coverage, radar contact with the aircraft will be lost and controllers will be limited in what, if any services they can offer.

Recommendation 20. The FAA should educate controllers about the purpose of intentional GPS interference, how aircraft may be impacted, how to respond to a pilot reported GPS malfunction or failure, published mitigations, the controller’s responsibilities for reporting, and best practices for assisting aircraft that have lost GPS navigation capability.

The FAA does not provide operational context or best practices to controllers on a topic that is a near daily occurrence in the NAS. Educating controllers on these important topics would promote more effective reporting and controller responses in the future. The FAA should also work with field facilities to compile best practices.

Additional education topics the Task Group believes should be emphasized include:

- The effect interference has on GPS navigation systems and ADS-B receivers, and the fact these system may not recover quickly or at all inflight;
- The impact on air traffic and the flight crew if ADS-B surveillance is lost;
- What mitigations the FAA has in place and the controller’s responsibility for when and how to employ those mitigations;
- Why a loss of GPS for one aircraft may not translate to another aircraft in the same area also losing GPS;
- Best practices for alerting pilots of active GPS interference in the area;
- The reporting process and how all reports need to go to ATCSCC and be captured as MOR;
- How enroute and terminal facilities can effectively coordinate with one another to ensure real-time awareness of interference events;
- For air traffic facilities regularly affected, annual training on GPS interference events and mitigations.

Mitigations

The FAA does not publicize the mitigations in effect during intentional GPS interference but there would be operational value in doing so (see Recommendation 9). Those mitigations that are known are listed below.

- Interference occurs during ARTCC “green times” (considered low impact times)
- Moratorium for interference events during Thanksgiving and Christmas holidays
- The FAA will de-conflict other NAS priorities and other regional priorities (e.g., special events, space rocket launch)
- Restrict GPS testing events from overlapping at FL250 and below
- A NOTAM is published at least 72 hours in advance of the event
- The Flight Advisory notice is disseminated to HAI, BLM, AOPA, and NBAA and emailed to subscribers of SPANS who live within a certain distance of the event; notice sometimes published on FFAST website

- FAA SAPT website and Coast Guard Navigation Center website publish information on NOTAMed GPS interference
- Interference proponent and ATC monitor Guard frequencies
- No critical NAVAIDs or radars out of service during interference event
- Stop Buzzer can be called by ARTCC with immediate initiation of cessation of interference.

Reasons include:

- Safety of flight issue identified
- VIP flight enters the airspace
- Firefighting activities that indicate a need for protection
- Weather that requires aircraft to be able to self-navigate (e.g., thunderstorms)
- Traffic flow into airports dependent on GPS approaches (WX less than 5,000 foot ceiling and/or 5 SM visibility)

Recommendation 21. The weather requirement for GPS only airports (WX less than 5,000' ceiling and/or 5 miles visibility) is sufficient but must be enforced.

The FAA does not have clear guidance as to when the 5,000 and 5 weather requirement should be enforced. There is confusion in the field related to this mitigation and its use. For example, should a Stop Buzzer be called proactively when an aircraft is landing at an airport with only GPS procedures and that aircraft has not reported any navigation malfunction? Should a Stop Buzzer only be called for commercial airports or does this policy apply to any airport? Most TRACONs do not see the concurrence message for interference events so miss out on the reminder of this mitigation being available. The FAA should provide clear guidance to facilities so that this mitigation is effective.

Initiating a Stop Buzzer can take time due to the coordination process within an air traffic facility. In some cases, an FAA manager must call the DoD after being alerted to an issue from a controller working traffic or another supervisor. In many cases, a Stop Buzzer is called in response to increased controller workload. The Stop Buzzer protocol is important to maintain during intentional interference events, although the Task Group considers a Stop Buzzer as a reaction to a hazard already being present, and a Stop Buzzer may not always be effective. There are several examples of aircraft GPS systems never recovering from interference, which could be dangerous in areas where there is no backup system such as Alaska and the Gulf of Mexico. The Stop Buzzer is effective when used proactively such as when a medevac aircraft needs to transit the affected airspace.

NextGen Concerns

Recommendation 22. The FAA should collaborate with industry and between agencies to update the APNT CONOPs in a way that meets industry operator needs for continued navigation and surveillance services in the NAS when GPS signals are not available.

The Task Group understands the PBN NAS Navigation Strategy defined the resiliency plan for operators as the VOR MON and NextGen DME; however, we believe this is insufficient long-term and are

concerned that it was never clearly articulated to industry that the work on APNT had ceased progressing. An APNT solution is still needed that will meet the APNT program objectives: (1) RNP backup to GPS; (2) enable RNP-0.3 for terminal operation outside the final approach fix; and (3) provide backup ADS-B positioning. VOR MON and NextGen DME were considered by operators to be part of a transitional phase as an APNT solution was fielded. The FAA should lead in the multi-agency effort to find an APNT solution.

The APNT CONOPs is from 2012 and its conclusions need validation. New requirements by operators may need to be considered, such as providing a minimum NIC/NAC value of 6 to allow ADS-B enabled interval management. A timeline for APNT implementation should be briefed to industry.

There are several APNT solutions being discussed in different forums, including eLORAN, enhanced DME, and hybrid ranging (WAM and Pseudolite Network), and it is important the FAA take a leading role to determine the strategic direction that will work for aviation. GPS degradation must be appropriately factored into the development of the resiliency plan and work on APNT should be expedited to ensure efficient operations continue when GPS is unavailable or unreliable.

Recommendation 23. The FAA should evaluate and document the impact of GPS interference on current and future NextGen capabilities and operator equipage in NextGen business plans and strategies.

NextGen relies on GPS for accurate aircraft position reports for the modern air traffic and aircraft automation systems being implemented; however, the business plans supporting these NextGen program do not fully consider the disincentive intentional interference is for operators equipping with applicable technology. There is concern among operators that the business case for equipage could be impacted by knowing that intentional GPS interference will continue. As the interference is predominantly occurring in the southwestern US, there is at least a regional concern certain NextGen programs may not deliver all the benefits originally envisioned.

FAA programs like Metroplex where new RNAV and RNP instrument flight procedures replace conventional procedures create the opportunity for better throughput and efficiency, but impacting the navigation system used to fly these procedures could result in high workloads for controllers and pilots while decreasing efficiency. New decision-support tools like Time Based Flow Management (TBFM) rely on GPS to work most effectively. ADS-B, Flight Interval Management, and other programs also rely on GPS. It is important the FAA consider the impact of the continued interference on operator decision making as they determine whether to equip.

Related Topics Beyond Scope of Tasking

Recommendation 24. The FAA should consider future taskings, of appropriate committees, to investigate the impact of GPS interference on emerging technologies and new entrants to the NAS.

This Task Group did not review the impact of intentional GPS interference on operators other than commercial and general aviation. However, the Task Group is aware of the reliance on GPS among other users like Unmanned Aircraft Systems (UAS) and commercial space operations. The future strategies and business plans for these operators likely does not account for a GPS system that is routinely interfered with. The criticality of GPS to these users may not be fully appreciated by the FAA. For example, many UAS rely on GPS for geofencing, navigation, and lost-link/return to station functions. The FAA should engage with these users to conduct outreach and education, and to determine other necessary mitigations.

Recommendation 25. The FAA should work collaboratively with industry to understand the impact of and identify mitigations for unexpected and unintentional GPS interference, GPS system spoofing, and IFF events.

Intentional GPS interference events represent the bulk of the impact to the aviation community today, but news reports and international events highlight the need for preparedness for other types of unexpected interference. GPS spoofing is one example of a hazard that pilots get limited training on and may have little awareness for how to identify an event. Additionally, IFF events, which impact spectrum bandwidth, should be evaluated for their actual impact to aviation systems and to determine if public notification is even warranted.

Acronyms and Definitions

ADAHRS	Air data attitude heading reference system
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-R	ADS-Rebroadcast
AGL	Above Ground Level
AHRS	Attitude and Heading Reference Systems
AIM	Aeronautical Information Manual
AOI	Awareness & Operational Impact
APNT	Alternative Position, Navigation, Timing
ARTCC	Air Route Traffic Control Center
ASRS	Aviation Safety Reporting System
ATSAP	Air Traffic Safety Action Program
CNS	Communications, Navigation and Surveillance
DME	Distance Measuring Equipment
DoD	Department of Defense
EFB	Electronic Flight Bag
ELTs	Emergency Locator Transmitters
FAA	Federal Aviation Administration
FAAST	FAA’s Safety Team
FDE	Fault detection and exclusion
FIS-B	Flight Information Services-Broadcast
GA	General aviation
GBAS	Ground-Based Augmentation System
GBT	Ground-Based Transceiver
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAL	Horizontal alert limit
HTAWS	Helicopter Terrain Awareness and Warning System
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IRU	Inertial Reference Unit
MEMS	micro-electro-mechanical system
MON	Minimum Operating Network
MOPS	Minimum Operational Performance Standards
MOR	Mandatory Occurrence Report
NAS	National Airspace System
NCF	National Customer Forum
NDBs	Non-Directional Beacons

NextGen	Next Generation Air Transportation System
NIC	Navigation Integrity Category
NOTAM	Notices to Airmen
PARC	Performance-based Operations Aviation Rulemaking Committee
PBN	Performance Based Navigation
PCG	Pilot Controller Glossary
PVT	position, velocity, and time
RAIM	Receiver autonomous integrity monitoring
RNP	Required Navigation Performance
SAPT	Service Availability Prediction Tool
SBS	Surveillance and Broadcast Services
SIDs	Standard Instrument Departures
SPANS	Safety Program Airmen Notification System
SSR	Secondary Surveillance Radar
STARs	Standard Terminal Arrival Procedures
TAWS	Terrain Awareness and Warning System
TBFM	Time Based Flow Management
TCAS	Traffic Collision Avoidance System
TIS-B	Traffic Information Services- Broadcast
TMIs	Traffic Management Initiatives
TMU	Traffic Management Unit
TOC	Tactical Operations Committee
TSO	Technical Standard Order
TTA	Time to alert
USAF	US Air Force
USCG	US Coast Guard
WAAS	Wide Area Augmentation System
WAM	Wide Area Multilateration
ZLA	Los Angeles Air Route Traffic Control Center

Appendix A: Tasking Letter



U.S. Department
of Transportation
**Federal Aviation
Administration**

MAY 09 2017

Mission Support Services
800 Independence Avenue, SW.
Washington, DC 20591

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

Dear Ms. Jenny:

Intentional global positioning system (GPS) interference exercises in the National Airspace System (NAS) are critical to the mission of the Department of Defense (DoD) in meeting national security requirements. As the Federal Aviation Administration (FAA) implements the PBN NAS Navigation Strategy 2016, there will be increased reliance on satellite-based positioning systems as the primary, and in some cases, sole method for safe and efficient navigation and airport access. There is concern that the large size of impacted areas and the lack of clear, detailed information leads to confusion around the interference events and the magnitude of their impact. This confusion can lead to increased pilot workload during flight and can hinder preplanning as well as leading to unnecessary cancelation of flights. In addition, GPS interference/jamming testing may also impact future plans to reduce the number of cooperative surveillance radars in the NAS.

A recent survey of general aviation pilots by the Aircraft Owners and Pilots Association (AOPA) noted more than a third had experienced a GPS outage or issue with availability during flight and over 60% were concerned about the impact of intentional interference with GPS. Many pilots find the current practice of alerting them of an exercise and/or outages via Notices to Airmen (NOTAMs) ineffective even though a majority of the pilots check GPS NOTAMs before flights. As situations increase where satellite-based technology is routinely disrupted, industry has questioned how the NAS can transition to primary use of this technology without a better and more comprehensive understanding of the issues around the impact of purposeful degradation, and the exploration and adoption of effective mitigations.

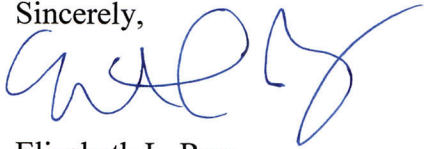
FAA asks the Tactical Operations Committee (TOC) at RTCA to provide recommendations to improve the processes and practices associated with intentional global navigation satellite system (GNSS) interference events to better accommodate the safe and efficient operation of civil aircraft during those events. Specifically:

1. Evaluate GNSS interference events and quantify the NAS impact.

2. Recommend effective tracking and metrics to assess the impact of GNSS interference events with NAS impact, including the economic impact on airports during the event.
3. Evaluate and recommend an effective way for interference events to be defined and depicted based on the likelihood of interference and the level of impact.
4. For interference events, recommend standard minimum weather requirement/criteria for airfields that have only GNSS approach procedures and/or no cooperative terminal surveillance radar/WAM coverage.
5. Evaluate the effectiveness of the alerting processes, including issuance of NOTAMs, used by air traffic and the notification process for pilots and make recommendations for improvements as needed.
6. Recommend guidance/training material needed for controllers and pilots to increase understanding and awareness for current and proposed mitigations.

FAA requests this work be accomplished within the 1st quarter of FY2018. FAA would like to discuss task group membership with RTCA as well as establish deliverables and milestones once the task group is formed.

Sincerely,



Elizabeth L. Ray
Vice President, Mission Support Services
Air Traffic Organization

Appendix B: Participants in the GPS Interference Task Group

Darrell Pennington, Air Line Pilots Association (ALPA)

Ric Peri, Aircraft Electronics Association, Inc.

Rune Duke, Aircraft Owners and Pilots Association (Co-Chair)

Robert Ireland, Airlines for America

Oscar Vela, Alaska Airlines

Ric Babcock, Allied Pilots Association

Lev Prichard, Allied Pilots Association

Wes Googe, American Airlines, Inc. (Co-Chair)

Andrew Roy, Aviation Spectrum Resources, Inc.

Rodney Holder, Booz Allen Hamilton (USAF Exempt)

Kurt Kleiner, Bureau of Land Management

Allan Storm, DoD Policy Board on Federal Aviation

Ken Alexander, Federal Aviation Administration (FAA)

Ian Atkins, Federal Aviation Administration (FAA)

Jorge Boubion, Federal Aviation Administration (FAA)

John Cabala, Federal Aviation Administration (FAA)

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Tim Wallace, Federal Aviation Administration (FAA)
Larry Hills, FedEx Express
Clay Barber, Garmin Ltd.
John Foley, Garmin Ltd.
Jens Hennig, General Aviation Manufacturers Association
Tony Boci, Harris Corporation
Matt Callan, Helicopter Association International (HAI)
Kieran O'Carroll, International Air Transport Association
Noppadol Pringvanich, International Air Transport Association
Jon Reisinger, Jeppesen
Joe Bertapelle, JetBlue Airways
Geoff Stearn, Ligado Networks
William L Geoghagan, National Air Traffic Controllers Association (NATCA)
Heidi Williams, National Business Aviation Association
Sai Kalyanaraman, Rockwell Collins, Inc.
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Scott Dehart, Southwest Airlines
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Josh Kuntzman, U.S. Air Force
Deborah Plunkett, U.S. Air Force
Robert Tarcza, U.S. Air Force
Mario Verrett, U.S. Air Force
David Manville, U.S. Army
Glenn Morse, United Airlines, Inc.
Rocky Stone, United Airlines, Inc.
Christian Kast, United Parcel Service (UPS)
Katie Harskamp, US Department of Defense
Raymond Swider, US Department of Defense
Karl Shallberg, ZETA Associates

Appendix C: AJV-8 Memos of Interpretation



Federal Aviation Administration

Memorandum

Date: *July 17, 2015 (Original signed document on file)*

To: Anthony D. Roetzel, Director, Air Traffic Operations, Central Service Area South, AJT-CS

From: Heather Hemdal, Director, Air Traffic Procedures, AJV-8

Subject: Interpretation, JO 7110.65, Paragraph 4-8-1, Approach Clearance

We have reviewed the request for interpretation submitted by the Kansas City Air Route Traffic Control Center (ZKC) dated January 23, 2015 concerning the January 8, 2015 change to FAA JO 7110.65, Chapter 4, Section 8, Paragraph 1, Subparagraphs 'j' and 'k'. Kansas City stated that the language in this change is ambiguous and raised several questions: Specifically, ZKC's questions were:

1. *Why did the language change from GPS UNRELIABLE NOTAMS to GPS TESTING NOTAMS?*

The titling of GPS Testing NOTAMS was a joint decision between Flight Standards, the Spectrum Engineering and Policy Office, the US NOTAM Office and Air Traffic. The primary reason for removing "unreliable" in favor of "may not be available" was because unreliable was considered confusing and repetitive. The Aeronautical Information Manual (AIM) and Pilot Controller Glossary define unreliable as meaning "may not be available". Although "GPS Testing" does not appear in the NOTAM, the term is an all-inclusive moniker for any number of events the Department of Defense (DOD) chooses to enhance or interfere with the system.

2. *Why did the language change from "inform pilots that GPS is unreliable" to "inform pilots that GPS may not be available"?*

The group, indicated above, determined "may not be available" better described the effect on the system than "unreliable". The language changed because, during times of GPS testing, the GPS signal is either on or off. If a pilot is receiving a GPS signal during testing times, it is a usable signal for navigation.

3. *During testing, if a pilot indicates that they wish to proceed with a GPS instrument approach, can a controller clear them to do so?*

Yes. If the pilot has determined that he/she is receiving a GPS signal and requests a GPS-dependent RNAV approach, the controller may issue it.

4. Is a pilot report sufficient to indicate that GPS interference is no longer a factor?

Yes, if the question is in reference to second report for a reported anomaly outside of published testing times.

However, if it is during NOTAM'd testing times, then the answer is no. A report of positive GPS reception during testing times is only an indication that at that time that aircraft is receiving a signal and thus is not experiencing interference. As indicated above, the signal is either on or off. Interference could happen at any time during the testing period. Continue to advise aircraft that GPS may not be available and request intentions until advised that the testing organization has terminated its testing or until the testing times have expired

5. Shouldn't the restriction only apply to GPS approaches [sic GPS-dependent]?

Yes, the restriction only applies to GPS-dependent RNAV approaches.

Should you have any further questions, please contact Daryl Daniels, AJV-83, En Route Standards and Procedures at (202) 267-0860 or Daryl.Daniels@faa.gov.

cc: Lowell Hought, Air Traffic Manager, Kansas City ARTCC



Federal Aviation Administration

Memorandum

Date: *July 17, 2015 (Original signed document on file)*

To: Anthony D. Roetzel, Director, Air Traffic Operations, Central Service Area South, AJT-CS

From: Heather Hemdal, Director, Air Traffic Procedures, AJV-8

Subject: Interpretation, JO 7110.65, Paragraph 4-8-1, Approach Clearance

We have reviewed the request for interpretation submitted by the Albuquerque Air Route Traffic Control Center dated January 23, 2015 concerning the January 8, 2015 change to FAA JO 7110.65, Chapter 4, Section 8, Paragraph 1, Subparagraphs 'j' and 'k'. Albuquerque stated that the language in this change is ambiguous and possibly contradictory. Additionally Albuquerque noted that controllers were unsure if RNAV operations could continue during published times of GPS testing and, if GPS operations were suspended, when could controllers resume normal operations. Specifically, ZAB's questions were:

1. *If a pilot advises the controller that he/she still wants the RNAV approach, is the controller allowed to issue the RNAV approach?*

Yes. If a pilot is receiving a signal, it is usable. Under 14 CFR Part 91.3(a): "The pilot in command of an aircraft is directly responsible for, and is the final authority as to, the operation of that aircraft". Therefore, if the pilot has determined that he/she is receiving a suitable GPS signal and requests a GPS-based RNAV approach, the controller may issue it.

2. *What triggers the statement, "Do not resume RNAV approach operations until certain that GPS interference is no longer a factor or such GPS testing exercise has ceased"? When does a controller need to discontinue issuing RNAV approaches?*

The times published within the GPS testing NOTAM triggers both. The discontinuance of the GPS-dependent RNAV approach means you must not automatically assign the GPS approach to the pilot, but must advise the pilot that GPS may not be available and request the pilot's intentions. Until the testing organization advises that testing has been terminated or until the times of the testing period has expired, continue advising aircraft that GPS may not be available and request their intentions.

3. *Does this new paragraph apply to all RNAV procedures including RNAV STARS, RNAV SIDS, RNAV (RNP), RNAV (GPS), and GPS approaches?*

No, this paragraph only applies to GPS-dependent RNAV approaches.

If you have any further questions, please contact Daryl Daniels, AJV-83, En Route Standards and Procedures at (202) 267-0860 or Daryl.Daniels@faa.gov.

cc: Terry L. Locke, Air traffic Manager, Albuquerque ARTCC