

LightSquared Aviation Impacts

Executive Summary

As requested by the Executive Office of the President's Space-Based Positioning, Navigation and Timing (PNT) Executive Committee's National Coordination Office (NCO) Director, the Federal Aviation Administration (FAA) has assessed the impacts of LightSquared's planned deployment on FAA infrastructure and the aviation community. This paper addresses specific questions asked by the PNT NCO.

LightSquared's June 30, 2011 proposal includes: use the *lower* 10MHz channel starting in 2012; operate at "reduced" power; and agree to a "standstill" in terrestrial use of the *upper* 10 MHz channel. LightSquared would begin full use of both bands in 2014.

- LightSquared's initial operations at the lower 10 MHz channel even at "reduced" power levels would impact the aviation use of high-precision GPS receivers.
- We estimate it would take 10 years to design, develop, certify and install modified equipment in the civil aviation fleet.
- LightSquared's planned operations would result in the loss of GPS-enabled operational, economic, and public safety benefits across the National Airspace System.
- The FAA would be compelled to return to dependency on ground-based navigation aids.
- Billions of dollars in existing FAA and GPS user investments would be lost.
- The FAA would also need to replan Next Generation Air Transportation System (NextGen) investments, which would result in additional development costs and delays.

The LightSquared proposal would severely impact NextGen, which relies heavily on GPS-based technologies. In the next ten years, it would result in an estimated impact to the aviation community of at least \$70 billion and an additional 30 million tons of CO₂ for the following reasons:

- Loss of benefits from delayed NextGen technologies and procedures
- Loss of existing GPS efficiency benefits
- Loss of existing GPS safety benefits
- Aircraft retrofit costs

A final consideration is the expected international impact of the proposal. The President's 2010 *National Space Policy for the United States of America* states that the U.S. must maintain its leadership in the service, provision, and use of global navigation satellite systems. We believe this proposal could adversely affect U.S. international leadership in aviation. Air carriers and other users could lose confidence in GPS, despite Presidential commitments to the International Civil Aviation Organization on its continued safety and availability. The international market for U.S. satellite navigation technology could be damaged. Demand for non-U.S. systems such as Russia's GLONASS in lieu of GPS, could be stimulated.

FAA Responses to PNT NCO Questions

1. Summarize and quantify current and future benefits provided by use of GPS-based applications and any cost-benefit analyses.

The FAA conservatively estimates that GPS currently provides at least \$200 million in efficiency benefits each year. More importantly, GPS safety enhancements are expected to prevent the loss of approximately 800 lives over the next 10 years, with an estimated public safety benefit of about \$5 billion. GPS is also an essential building block in the ongoing deployment of NextGen that builds upon current GPS based capabilities. The FAA estimates the cumulative benefits of NextGen to be \$23 billion through 2018; and by 2030, the cumulative benefits grow to \$123 billion and reduce CO₂ emissions by 64 million tons. These results likely underestimate the National economic benefits of aviation GPS use to the overall U.S. economy, since they do not include the productivity gains enabled by accelerated cargo delivery; nor the benefits provided to the operators of thousands of military and other public use aircraft used for homeland security, law enforcement, medical emergency and other applications.

NextGen is the transformation of the radar-based air traffic control system of today to a satellite-based system of the future. This transformation is essential to safely accommodate the growing number of people who fly in the United States. NextGen implementation makes use of GPS to provide precise and dependable navigation and to support required navigation performance (RNP) airspace and procedures that allow more aircraft to operate safely in a given volume of airspace.

GPS is also an indispensable tool in the daily operation of our Nation's air transportation system that enhances the safety and efficiency of over 35,000 instrument flights per day and an indeterminate number of visual flights. Current GPS aviation benefits include precise positioning and navigation that is used for thousands of instrument approach procedures providing vertical guidance. GPS enables the widespread use of area navigation procedures which provide more direct routes and improve the flexibility of operations and procedure design, thereby reducing delays and improve capacity.

There are three major aviation safety risks that are mitigated through the use of GPS: Approach and landing accidents, controlled flight into terrain (CFIT), and runway incursions.

The frequency of approach and landing accidents has decreased steadily since the FAA's predecessor agencies first began to introduce early instrument landing systems (ILS). As recently as the 1990s, however, this was still a relatively common accident scenario, with nine such accidents to U.S. air carrier aircraft in that decade, four of which were fatal accidents. Since 1999, U.S. carriers have had just two such accidents in U.S. airspace and at least one of those was not GPS-equipped. In addition, key precursors to these types of accidents, such as unstable approaches, have decreased in recent years. GPS and an aircraft capacity to identify its precise location relative to a precisely located touchdown point explain much of this improvement.

The experience has been comparable with CFIT accidents, which for decades had been the most lethal of all accident scenarios. Though CFIT achieved its biggest breakthrough prior to the advent of GPS, CFIT accidents continued through the mid-1990s in air carrier turboprop aircraft and in large U.S.-operated jets while flying in foreign airspace. We also had evidence from the relatively limited data systems of that era that the risk of striking terrain remained with us, as reports of on-board terrain alerts had become stubbornly stable. Enhance Ground Proximity Warning Systems (EGPWS) combine GPS and other technologies to provide look-ahead terrain information to the flight crew and give the crew time to avoid impact.

Protection against runway collisions is a third example of important safety improvements that could be forfeited with the loss of reliable GPS signals. The Volpe National Transportation Systems Center has concluded that the contemporary mix of airport surface moving map displays could prevent one-third of all runway incursions, and that effectiveness will increase as more of the fleet deploys upgraded versions of the equipment, particularly “own-ship” moving maps.¹ This equipment depends on GPS and has been a major factor in the sustained reduction of category A and B incursions, and in the effort to minimize severe ground collisions, as at Milano in 2001 and Quincy, Illinois in 1996. If GPS signals are compromised, all the benefits of this equipment will abruptly disappear.

With respect to General Aviation (GA) the situation is even more dramatic, particularly since glass cockpits became standard equipment in new aircraft, beginning about 2003. Nationally, in the past 5 years fatal CFIT accidents in GA and non-scheduled air carrier operations have decreased 44% from the preceding 5 years, while fatal approach-and-landing accidents and all fatal accidents at night have decreased by 30 percent. GPS and glass-cockpits are a primary explanation for these improvements, and those rapid improvements will likely continue for several more years as GPS-based equipment continues to penetrate the GA market.

With the loss of GPS, those benefits already achieved will be immediately reversed, and the opportunity for even more long-term benefits would be lost. Unlike air carriers, GA losses would not be offset by air traffic control and ILS systems because the GA fleet would either not be equipped with ILS or may not be under air traffic control. The safety impacts and costs to GA would be felt in full and would be severe.

FAA has quantified the safety impact of a 10-year loss of GPS functionality. Using the period 1991-1998 as a reference (the last significant period in which GPS was not in wide-spread civil use), there were nine air carrier accidents which might have been averted had Terrain Alerting and Warning Systems (TAWS) been available and installed on the aircraft. Four of these accidents resulted in a total of 51 fatalities (averaging 6.4 fatalities per year). Another two involved large transports with a total of 185 souls on board, which indicates the potential for higher casualties. On this basis, FAA assumes that the loss of GPS functionality over 10 years would result in at least 64 fatalities for air transportation operators.

¹ See “Mitigating Runway Incursions: A Safety Benefits Assessment of Airport Surface Moving Map Displays,” Stephanie Chase, Danielle Eon, and Michelle Yeh, 2010.

To estimate the same benefit for GA, FAA has observed that the number of fatalities attributable to CFIT, approach and landing, and night-flying accidents in the past 5 years versus the previous 5 years. After allowing for decreases attributable to reduced GA flight hours, the FAA estimates that at least 73 fewer deaths, and perhaps as many as 77, occurred annually during the second 5 year interval due to reductions in these kinds of accidents because of increased use of GPS technology. FAA's estimate of averted fatalities is shown in the following table.

Type Operations	Reduced Fatalities over 10 years	Nominal 10-year Benefit (\$ billions)
Air Carrier	64	0.4
General Aviation/Pt.135	730	4.4
Total	794	4.9

These figures are conservative for air transport operations because commercial traffic has increased since the base period, aircraft are getting larger, and they are flying with higher load factors. The total value estimate also does not include assumptions concerning serious injury, minor injury, or property loss. These would normally be considered in a benefit/cost analysis, but are not addressed due to time limitations. For GA, 730 is the low end of estimated fatalities. Thus these estimates should be considered to be the lower bounds of safety benefits directly attributable to GPS on-board functionality.

2. Summarize and quantify total sunk costs in GPS-based infrastructure (prior years to date) and planned investments going forward.

The FAA and civil aviation community would be facing an investment loss of \$6 to 7 billion in GPS-based infrastructure and equipment invested through FY 2011. The FAA notes that U.S. taxpayers have already invested over \$3 billion in GPS and NextGen through FY 2011. In addition to the FAA's investment on behalf of the taxpayer, the estimated aviation industry investment in GPS equipment for aircraft operating in the U.S. airspace through FY2011 is \$3 to 4 billion. This estimate does not include GPS equipage costs for over 13,000 Department of Defense aircraft, 1400 federal department and agency aircraft, and thousands of state, and local government public use aircraft.

If LightSquared deploys as currently proposed, the NextGen investments would need to be replanned and most corresponding benefits would be delayed by approximately 10 years. Planned NextGen investments from 2012 through 2018 that would need to be replanned total approximately \$17 billion. These investments include civil aviation industry estimated investments of \$9 billion and \$8 billion in FAA infrastructure investments. These investments leverage GPS for improved airport access, positioning, and enhanced Automatic Dependence Surveillance (ADS-B) capabilities, and provide the foundation for trajectory-based operations.

3. To the extent possible, qualify, quantify, and describe risks to your agency's GPS-based mission capability, including "lost benefits" if GPS performance were degraded (or lost) due to LightSquared's signals including the costs to modify (or replace) GPS receiver infrastructure and the time frame required to replace that infrastructure.

The effects of LightSquared deployment would be far-reaching and potentially devastating to aviation. Proposed LightSquared operations would severely impact the efficiency and modernization of the safest, most efficient aerospace system in the world. LightSquared operations would bring numerous current and planned safety, efficiency, environmental improvements to a halt—jeopardizing U.S. leadership in the modernization of the global airspace system.

More significantly than productivity impacts, if GPS were not available, there would be a public safety impact due to the loss of safety enhancements that are incorporated in aircraft today including TAWS, vertically guided approach capability to reduce CFIT, and “on-ship” displays that utilize GPS technology and reduce the number of runway collision accidents.

Estimated loss of life from 2014 to 2023 as a result of LightSquared impacts to GPS during the 10-year retrofit period is depicted in this table.

Type Operations	Estimated Fatalities during GPS retrofit	Value of Life (\$ billions)
Air Carrier	64	0.4
General Aviation	730	4.4
Total	794	4.9

Note that these figures are conservative because they do not include assumptions concerning serious injury, minor injury and property loss that would normally be considered, but are not included here. FAA considers this to be a lower-bound estimate of safety benefits directly attributable to GPS on-board functionality. This estimate could increase as commercial operations and aircraft size increase.

If LightSquared deploys as planned, all current GPS efficiency and safety benefits would be lost, or at least severely reduced, until all aircraft operating in U.S. airspace could be retrofitted over a period of 10 and possibly up to 15 years; however 10 years is used for the purpose of this estimate and is assessed as medium risk. The time required includes development of new GPS standards, product development, test, and standardization activities, and certification approvals. Additionally, an estimated \$17 billion in FAA and civil aviation NextGen investments from 2012 through 2018 would need to be replanned and most corresponding benefits would be delayed by approximately 10 years.

The FAA’s analysis indicates that hundreds of thousands of civil aircraft operators would be directly and detrimentally impacted by degradation of GPS services. Not later than 2014, the agency anticipates impacts to:

- 5,800 to 7,250 passenger, cargo, and regional U.S. operated aircraft;
- 2,800 to 4,000 international operators’ aircraft from 105 countries;

- more than 61,000 IFR-approved GPS navigation general aviation and air taxi aircraft; and
- the vast majority of 310,000 pilots without instrument ratings that use GPS equipment in visual conditions.

Additionally, there are over 13,000 Department of Defense aircraft, 1400 federal department and agency aircraft, and thousands of state, and local government public use aircraft supporting homeland security, firefighting, law enforcement, search and rescue, and other applications that are not addressed in this estimate.

During the assumed 10-year replanning and aircraft retrofit schedule, the proposed LightSquared deployment would result in the loss of:

- At least \$2 billion in baselined GPS aviation efficiency benefits,
- \$6 billion for unplanned aircraft retrofit costs,
- \$59 billion in NextGen benefits
- 31 million additional tons of CO₂ emissions, and
- 794 lives lost with a public safety impact of \$5 billion

Total LightSquared aviation impacts are estimated to be over \$72 billion, not including \$6 to 7 billion in FAA and aviation user sunk costs.

Based upon input from the RTCA in its advisory capacity to the FAA as well as the National Space-Based Positioning, Navigation, and Timing Systems Engineering Forum, this estimate is based upon the replacement costs of modified GPS aviation antenna and receivers for which no approved technical specification exists today. The 10 year retrofit timeline is assessed as medium to high risk. The cost of retrofitting existing FAA GPS based ground infrastructure is not part of the basis of this estimate.

This estimate does not consider the aviation economic impacts if signal degradation continued unmitigated. Failure to achieve a high level of mitigation would carry a much larger cost. Additionally, the estimate does not account for the inefficiency and expense of replanning NextGen projects and programs.

This operational, economic, and public safety impact assessment is based upon LightSquared's June 30, 2011 proposal and June 23, 2011 LightSquared testimony to the House Transportation and Infrastructure Committee, including use of the lower 10MHz channel starting in 2012 and any use of the upper 10 MHz channel starting in 2014. This assessment assumes the planned power is one-tenth the current authorized power. LightSquared operations at the current power authorizations would be substantially worse than considered in this assessment.

Use of the LightSquared upper channel is unacceptable at any power level, since the LightSquared upper channel interference exceeds the GPS receiver MOPS-related environmental limit by a factor ranging from 4,000 to 80,000, depending upon the assumed operational scenario. LightSquared transmissions in the upper portion of the spectrum in the 2013-14 timeframe would result in the complete loss of GPS aviation capabilities. More significant than that, however, is the lost benefits of current GPS use and NextGen, moving U.S. aviation away from a safer, more efficient national airspace system based upon GPS and satellite technology, and returning the FAA to dependency on ground-based radionavigation aids.

The FAA cannot conclude that operations using just the lower portion of the spectrum are compatible with civil aircraft receivers without definition of LightSquared's end-state deployment and further study. However, based upon existing data, LightSquared's operations at the lower channel would preclude the following critical capabilities that rely upon high-precision GPS receivers: airfield and flight procedure surveys, flight test tracking, space weather monitoring, and GPS timing for computing resources and many mission critical systems. Impacted FAA GPS timing applications include multiple terminal, enroute, and oceanic automation systems and subsystems; surveillance systems; voice communications and voice recording systems; and maintenance support systems.

The FAA estimate considers several possible mitigation options to retain GPS aviation benefits to aviation. LightSquared's proposal for in-line filtering is assessed as high risk and not feasible. Aviation receiver/antenna sets typically use five or more filter/amplifier stages. Any stage saturated by the higher power LightSquared signal results in degraded GPS aviation performance with safety impacts. Additionally, the proposed in-line filters have not been prototyped and are not expected to meet international standards for GPS performance. The filters reject and interfere with the GPS signal in addition to the LightSquared signal. A medium risk solution requires replacement of both the GPS receiver and antenna. GPS antenna and receiver redesign is assessed as a moderate technical risk. Assuming such a design could be developed that could tolerate the LightSquared signals while still meeting aviation operational requirements, aircraft retrofit costs were estimate to be \$6 billion including a cost differential for new equipment and aircraft. Since this assumption is currently unproven, considerable risk is introduced in this estimate. It is also important to note that even if such mitigation could be developed, it is expected to take 6 to 10 years to deploy. U.S market leadership in space-based navigation aviation user and provider equipment and services would also be impacted as other countries could migrate away from GPS to other systems and signals impacting U.S. aircraft operations and national security.

The scope of degradation to GPS use due to LightSquared's operations is not scalable for the purposes of estimation since the future airspace structure is based upon GPS continuity throughout U.S. airspace. After the LightSquared network is deployed, GPS is expected to be unavailable for planned aviation use over the whole of the continental U.S. based upon FAA analysis and tests. Due to the ubiquitous use of GPS, most operators would find it extremely disruptive and very inefficient to revert to operations dependent upon ground-based radionavigation aids and forfeit the safety enhancements provided by GPS.