CENTER FOR SPACE POLICY AND STRATEGY

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BRACING FOR IMPACT: TERRESTRIAL RADIO INTERFERENCE TO SATELLITE-BASED SERVICES

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Foreword

Terrestrial wireless service providers are lobbying for more spectrum to meet the demand for mobile data. What does this mean for satellite-based services? How should regulators resolve interference disputes within this crowded spectrum space? How can regulators optimize the use of spectrum and encourage innovation while respecting both the existing investments in, and the unique physics of, satellite-based services, and the expectation that space-based services will operate without interference? This paper will explain why the limitless demand for spectrum and the finite supply will continue to present tough choices. Other papers within this series will provide further context to the ongoing debate and will examine policies for managing spectrum sharing.

The Issue

Due to the unique physics of tracking the faint radio signals from satellites in space, the radio waves used by satellite systems have historically been given special consideration by the agencies that regulate spectrum use in the United States: the Federal Communications Commission (FCC) and the National Telecommunications & Information Administration (NTIA). Through careful stewardship of the satellite radio spectrum, the FCC and NTIA have enabled a myriad of space services and applications to flourish; however, the era of special protection may be drawing to a close. With the proliferation of mobile wireless devices, the value of terrestrial radio spectrum has skyrocketed. In recent auctions of wireless spectrum, wireless providers have paid billions of dollars to increase capacity by accessing additional spectrum.[1]

The rapid growth of demand for this spectrum has led to calls for "sharing" with existing users, including satellite systems. However, one stakeholder's idea of "sharing" may seem like "encroachment" to another, and the potential for radio interference between dissimilar satellite and terrestrial radio applications is real and growing. Satellite systems and their stakeholders find themselves at a significant disadvantage, as they may be literally overpowered—both technically and financially—in the competition for this scarce resource.

One particular area of interest involves the L band, the chunk of spectrum that extends from about 1000 to 2000 MHz. Due to the relatively low frequencies involved, L-band signals are generally easy to process and do not require expensive, sophisticated equipment. They are also less likely to be degraded from weather effects in the atmosphere. The L band is currently used by weather satellites, GPS satellites, mobile operators, aircraft surveillance systems, and multiple other applications. These systems provide critical support to applications such as aviation safety, weather tracking, and flood control.

Aviation Safety

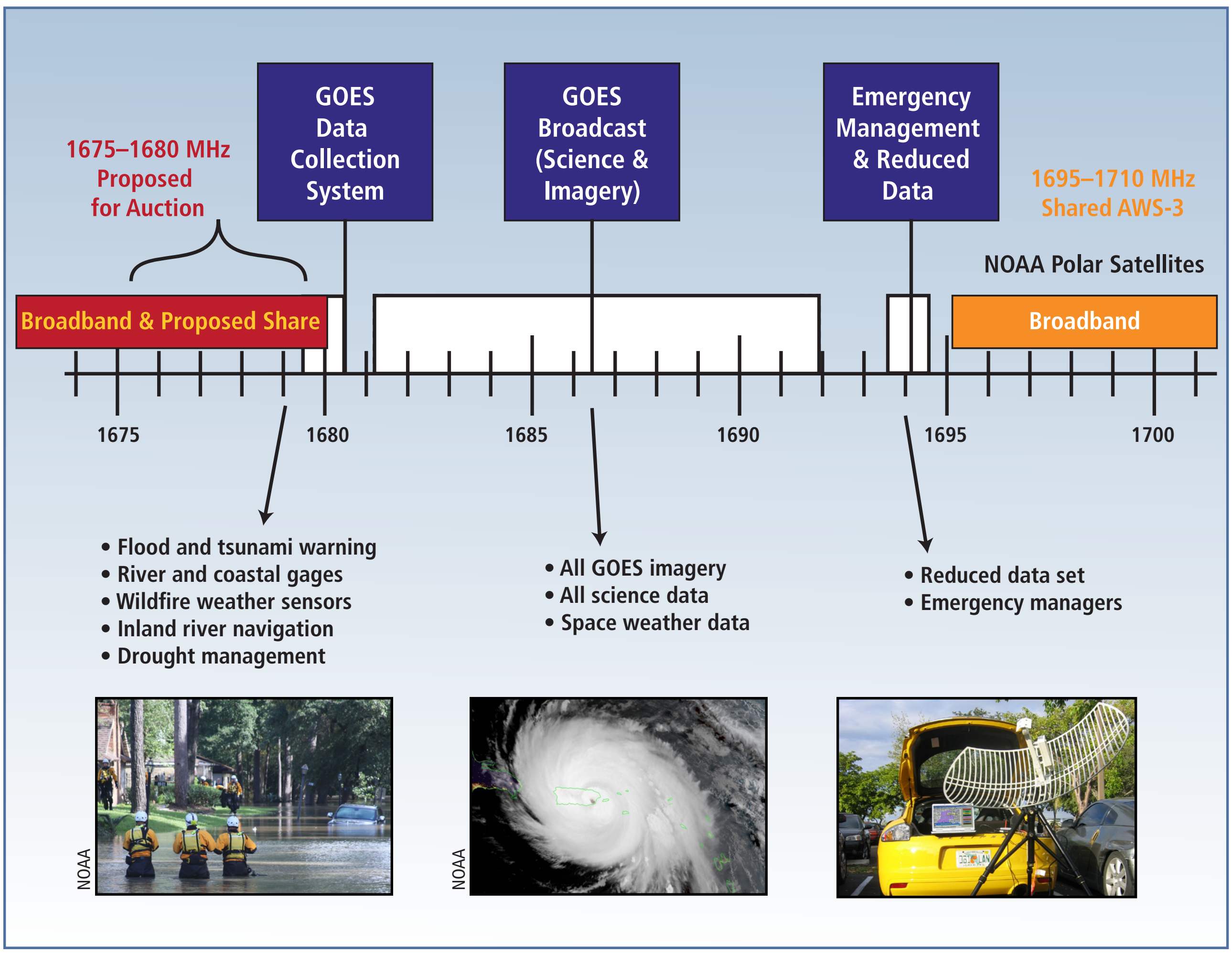
The aviation industry is increasingly dependent upon space-based position, navigation, and timing (PNT) information from GPS and associated systems. Nearly 4000 GPS precision approaches are in use today by aviation within the United States. GPS is also a central component of the Terrain Awareness and Warning System (TAWS), which combines precise aircraft position information with digital terrain elevation models to prevent collision with mountainsides, large structures, or other terrestrial obstacles. Therefore, recognizing the risks of potential interference to GPS receivers is critical.

GPS is also the primary source of PNT information for unmanned aerial systems. Interference to GPS could not only have a direct economic impact on businesses commercializing this technology, but could also pose a safety risk if it causes operators to lose control of their unmanned systems.

In addition, the Federal Aviation Administration (FAA) NextGen air control modernization program entails a migration from ground-based navigation aids to GPS-based positioning. Interference to GPS may pose a serious threat to modernization efforts that have been planned for more than a decade, and may place the flying public at risk. As part of the NextGen initiative, U.S. airlines and aircraft owners are now equipping their aircraft, at considerable expense, to comply with the FAA's Automatic Dependent Surveillance-Broadcast mandate by the deadline of January 1, 2020. This industry-wide effort to install onboard equipment represents billions of dollars in private-sector investment. Moreover, the GPS receivers in the new equipment cannot be easily modified. The total cost of retrofitting the aviation industry to mitigate interference, including equipment development and replacement, could add several billion dollars more. In addition, the FAA would need to spend time and money to certify new equipment. Aviation users also depend upon weather data passed through this spectrum. Many airlines obtain weather data via privately-owned ground stations, which could also be adversely affected by interference.

Weather Forecasting

Many critical weather events require that forecasters receive timely information from the Geostationary Operational Environmental Satellites (GOES) operated by the National Oceanic and Atmospheric Administration (NOAA). These spacecraft continually watch over the western hemisphere, providing essential situational awareness for weather professionals, industry, and the general public.



Different GOES transmissions are broadcast at different frequencies, which may be in danger of interference from powerful terrestrial sources.

A part of the L band from 1675 to 1680 MHz is a candidate for sharing. Current commercial proposals would share this spectrum by placing high-powered terrestrial signals in the same frequencies as the weak signals relayed from space. That could cause problems for GOES, which uses the spectrum from about 1675 to 1695 MHz to transmit weather data to Earth receivers.

Federal agencies use GOES data to support aviation safety, protect the electrical power grid from solar storms, route aircraft away from sources of radiation and volcanic ash,[2] warn local communities about oncoming tornados, control navigation in the nation's ports and waterways, and much more. Products generated from GOES data foreshadow hurricane movements, identify growing wildfires, provide condition reports for firefighters, relay water levels and enhance warnings for tornados and severe weather. Private-sector meteorologists also use GOES data to create value-added products and to provide local warnings and safety information in specific industry segments.

GOES data provides critical information to emergency managers during hurricanes and other catastrophic weather events. Advance forecasts allow officials to prepare for such events, and real-time data during and after such storms help them to respond and recover. Small ground-based antennas feeding battery-powered GOES receivers can sometimes be the only source of weather information for emergency managers during a disaster. Interference within the GOES transmission band could have a significant impact on the safety of life and property.

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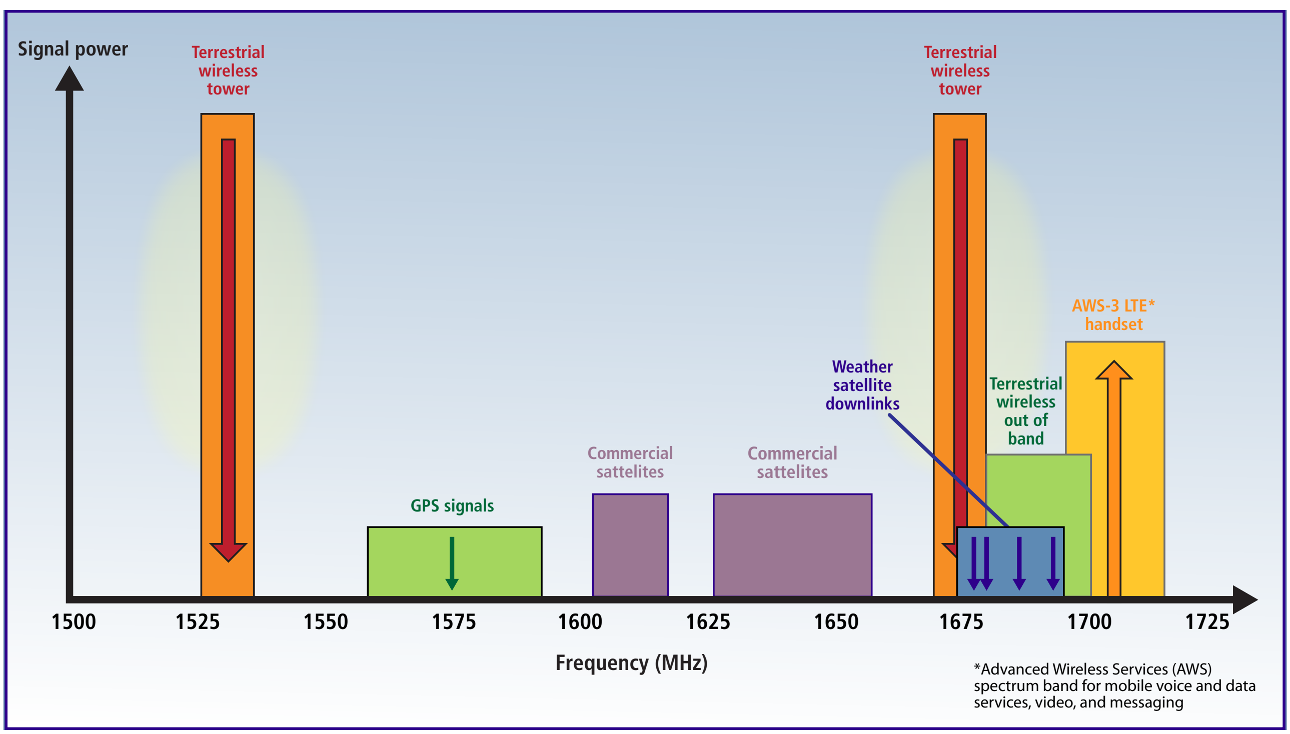
A 2011 study funded by the National Science Foundation and NOAA[3] established the groundwork for assessing the value of current and improved weather forecast information. The study estimated that variation in U.S. economic activity as a result of weather variability was roughly $485 billion, or 3.4% of the 2008 gross domestic product. Some portion of this amount could



The massive difference in received power between signals from terrestrial sources and those arriving from orbiting satellites raises serious concerns about compatibility of radio services in the same band or in adjacent frequency bands. When the power difference between desired and undesired signals is significant enough, the weaker signal within the receiver can be drowned out.

be mitigated by investments in improving weather forecasts. In a related study, the National Weather Service estimated the economic value from weather knowledge (roughly $13 billion across sectors, if fully monetized) and from a thriving private weather industry (roughly $7 billion) that provides businesses and other customers with the tailored products needed to unlock that value.[4] By comparison, the projected revenue from the proposed auction of 1675–1680 MHz amounts to $600 million over 10 years.[5]

Flood Control and Water Monitoring

Flood warnings are also issued using data carried in the spectral band of 1675–1680 MHz. Flooding, caused by both inundation and hurricane-induced storm surge, can cause billions of dollars in damage. The news reporting from Battery Park during Hurricane Sandy, tracking the rise in water levels that flooded Manhattan, was available through the near-real time data via GOES in this radio spectrum. Safe passage over causeway bridges and flooding Florida interstates are determined by measurements relayed by GOES. Deaths caused by flooding can be reduced, but only if forecasters and emergency managers have the indicators needed to develop timely warnings.

Water monitoring also extends to monitoring droughts and their effects. As droughts increase the chances for wildfires, fire chiefs use data relayed by GOES in this spectrum to make timely decisions on where to deploy resources and firefighters under dynamic conditions.

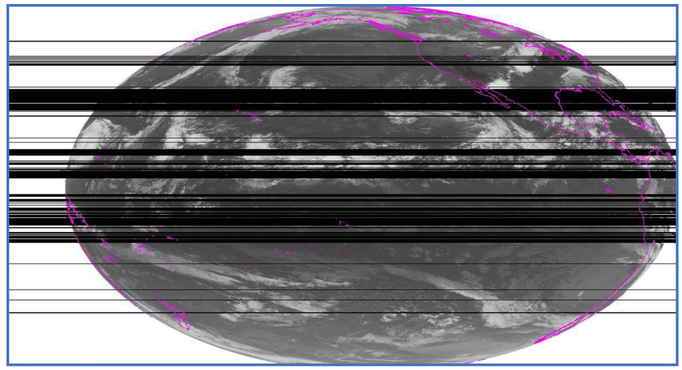
The management of water reservoirs is guided by measurements of water levels relayed via GOES in this radio spectrum. The petition to share portions of the L-band have elicited responses by numerous users of NOAA data, including the World Meteorological Organization, American Meteorological Society, Group on Earth Observations, American Weather and Climate Industry Association, International Association of Emergency Managers, National Hydrologic Warning Council, and Interstate Council on Water Quality.[6] These groups represent a complex and important ecosystem of data users who rely on timely and reliable delivery of information to monitor water resources. Meteorological data collection platforms at approximately 28,000 sites[7] support the GOES data collection system. Sensors located at these sites collect measurements such as dissolved oxygen, turbidity, temperature, water levels, and precipitation. Meteorological, environmental, and public safety communities rely upon the timely transmission of this data, which is relayed through the GOES network. Mitigation options, such as upgrading receivers for this vast network of sensors, would require significant time and expense. Moreover, installation of filters to mitigate interference is not a viable option if satellite and terrestrial users are using the same frequencies because the filter would reduce both desired and undesired signals.

A Path Forward

Calls for sharing spectral bands previously allocated for space-based applications, and encroachment of high-power terrestrial transmitters into the bands adjacent to space-based services, could place many critical national security, navigation, weather, and water monitoring systems at risk. The current and future costs to agencies, industry, and the American public should be weighed against the revenue benefits to the U.S. Treasury and future licensees.

Current and future costs to agencies, industry, and the public should be weighed against the one-time revenue benefit to the U.S. Treasury. . . .

Liberalizing spectrum is often viewed as a means to encourage innovation, yet innovation can occur on both sides of the fence—incumbents and new entrants. The speculative benefits derived from proposed new entrants should be weighed fairly against the fully monetized benefits of L-band satellite incumbents—a complex and enormous group of stakeholders operating in the public interest. With the slow erosion of exclusive spectrum, operators and users of space-based systems can no longer presume interference-free operation guaranteed by the FCC and NTIA. Preparation and mitigation will be time-consuming and expensive and may still not prevent service degradation or interruption. All space-based systems and their users—including the aviation, weather, national security, and intelligence communities—need to "brace for impact."



This degraded GOES image shows the scanning gaps due to RF interference.

Ideally, the FCC and its spectrum policy decision-makers would fully consider the significant network investments already made by the PNT, aviation, and weather stakeholders and the benefits that they are producing for society. Considerations should include the technical differences between radio and wireless applications, the value of precedence in regulatory matters, and the consequences of abrupt changes to traditional spectrum allocations that contradict decades of careful planning. Regulatory decisions should also consider the unique physics of space-based services compared to terrestrial radio services, including potentially large differences in received signal power. There are unintended consequences to waivers or ad hoc, impromptu service rules. If existing spectrum users are not protected, they will view their spectrum assets as less valuable. Therefore, ad hoc regulatory rulings and waivers could actually reduce spectrum value.

Spectrum sharing or reallocation studies should follow Office of Management and Budget guidance for cost-benefit analysis and should take into account much more than the near-term profits of spectrum license holders. Such studies should consider the direct and indirect costs and benefits to all stakeholders, especially the American taxpayers. At a minimum, these studies should consider:

- **Economic benefits of existing satellite-based services.** Satellite-based services provide significant direct and indirect contributions to the national economy and increase the efficiency of countless terrestrial applications such as aviation, weather, and agriculture. Therefore, any studies should consider whether a societal benefit would be generated by spectrum repurposing.
- **Technical feasibility of mitigating terrestrial interference.** While some mitigations, such as geographic separation and radio-frequency filters, have been proposed for some space-based applications, these solutions will not be practical in all cases. Some ground stations cannot move. Some stations are too small, underpowered, or inaccessible to be retrofitted. Mitigation technology may irreversibly degrade the original services. Notably, many impacts of terrestrial interference may not be realized until it is too late, as many stakeholders may not actively monitor regulatory matters.
- **Costs of technical mitigations.** One key question is, "who pays to mitigate terrestrial interference?" The FCC, in its 2003 Rule and Order authorizing Ancillary Terrestrial Component (ATC) operations in the Mobile Satellite Service (MSS) allocation (47 CFR 25.255), seemed to provide clear, unambiguous guidance: "If harmful interference is caused to other services by ancillary MSS ATC operations, either from base stations or mobile terminals, the MSS ATC operator must resolve any such interference." If acceptable solutions are discovered that can protect PNT, weather, and water-monitoring missions from spectrum encroachment due to new and adjacent spectrum users, public stakeholders will need to implement costly design and operational changes. These costs should be weighed against the societal and economic benefits that are forecast by various new terrestrial spectrum applicants.
- **Time to develop, test, manufacture, and install technical mitigations.** Migration to new and different technologies and systems will require time, investment, training, and additional costs. To this end, public stakeholders will need to develop reasonable timelines while the FCC works with affected stakeholders to agree to a transition period. For example, NOAA has just brought the first of four new geostationary weather satellites into operation—an effort that required more than a decade of development and upwards of $10 billion in appropriations. Those satellites will operate until at least 2036 in the spectrum under consideration for sharing. A decision now to share all or part of the 1675–1695 MHz band could cripple the investment already made by Congress in this critical new weather satellite family.

The above studies, analysis, and adjustment period may require a substantial period of time, during which the PNT, weather, and water-monitoring communities will need to continue delivering vital information. Understanding these costs and time requirements will help to determine whether spectrum reallocation of adjacent L-band frequencies results in a welfare gain.

Ultimately, if there is no net benefit, it would not be in the public interest for the FCC to grant licenses to new applicants. If the cost-benefit analysis shows a positive societal benefit, then it would be reasonable to expect the commission to determine that allocation of adjacent GPS and GOES spectrum to terrestrial users is an efficient use, and that spectrum licenses should be granted to new applicants while allowing the public spectrum stakeholders adequate time to prepare. A balanced approach will allow the FCC in coordination with NTIA to encourage high-value wireless innovations while fully considering the significant and expansive investments that have already occurred to meet safety-of-life missions.

References

[1] Spectrum values vary widely, depending on the amount of bandwidth offered and whether it is paired for two-way communication. Although nationally paired spectrum in the AWS-3 auction sold for about $42 billion, smaller unpaired segments sold for about 20 times less than that amount. The recent broadcast spectrum auction brought in about $10 billion.

[2] Volcanic ash can harden on the blades of jet engines, causing them to stall, and can damage windshields and other aircraft surfaces.

[3] J. Lazo, M. Lawson, P. Larsen, and D. Waldman, "U.S. Economic Sensitivity to Weather Variability," American Meteorological Society; June 2011.

[4] National Weather Service, "National Weather Service Enterprise Analysis Report: Findings on Changes in the Private Weather Industry," June 8, 2017.

[5] Legislative Proposals, Federal Communications Commission, Budget Estimates to Congress, May 2017 https://apps.fcc.gov/edocs_public/attachmatch/DOC-344998A1.pdf.

[6] Federal Communications Commission; Docket RM-11681: "Petition for Rulemaking to Allocate the 1675-1680 MHz Band for Terrestrial Mobile Use."

[7] NOAA Satellite Information System—National Environmental Satellite, Data, and Information Service website; http://www.noaasis.noaa.gov/DCS/history.html