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# The Economic Benefits of Commercial GPS Use in the U.S. and The Costs of Potential Disruption

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## Background and Summary

LightSquared is a company with plans to build a nationwide 4G-LTE wireless broadband network utilizing spectrum allocated for Mobile Satellite Service. The base stations of the LightSquared network will transmit signals in a radio band immediately adjacent to the Global Positioning System (GPS) frequencies, which has caused a great deal of concern that GPS signals may be desensitized, resulting in jamming and other forms of interference that will affect the reliability and functionality of GPS equipment.

If the LightSquared network is deployed on this spectrum, it is very likely that all GPS signal-receiving equipment will suffer signal degradation ranging from mild to severe. In response to concerns voiced from the military, industry and others, the Federal Communications Commission mandated tests be conducted and any conflicts resolved before LightSquared can begin operations. At present, the Technical Working Group, comprised of LightSquared members of the U.S. GPS Industry Council and other affected GPS users, is conducting tests of various GPS equipment under different operating scenarios to determine the depth and breadth of potential signal degradation.

The commercial stakes are high. The downstream industries that rely on professional and high precision GPS technology for their own business operations would face serious disruption to their operations should interference occur, and U.S. leadership and innovation would suffer. Although recreational and military applications for GPS equipment are larger in terms of equipment sales volume, commercial applications generate a large share of economic benefits for society. As shown later in this report, the direct economic benefits of GPS technology on commercial GPS users are estimated to be over $67.6 billion per year in the United States. In addition, GPS technology creates direct and indirect positive spillover effects, such as emission reductions from fuel savings, health and safety gains in the work place, time savings, job creation, higher tax revenues, and improved public safety and national defense. Today, there are more than 3.3 million jobs that rely on GPS technology, including approximately 130,000 jobs in GPS manufacturing industries and 3.2 million in the downstream commercial GPS-intensive industries. The commercial GPS adoption rate is growing and expected to continue growing across industries as high financial returns have been demonstrated. Consequently, GPS technology will create $122.4 billion benefits per year and will directly affect more than 5.8 million jobs in the downstream commercial GPS-intensive industries when penetration of GPS technology reaches 100 percent in the commercial GPS-intensive industries.

As is the case in all other innovative industries, the GPS industry directly creates jobs and economic activities, which spur economic growth. Evidence shows that innovative industries, such as the GPS industry, create both high- and low-skilled jobs during economic expansions and downturns, pay their employees higher-than-national-average wages, raise output and sales per employee, increase U.S. competitiveness, which is reflected in increased exports and reduced U.S. trade deficits, and spend large sums on R&D and capital investment. In addition to creating these direct economic benefits, innovative industries create productivity benefits to the downstream industries, including increased sales, profits, and investment returns. Empirical studies have shown sustained productivity benefits support further growth and job creation in downstream industries and the U.S. economy as a whole.[2]

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[1] This research received support from Coalition to Save Our GPS. The research team of this project includes Nam D. Pham, Daniel Ikenson, Mark Schmidt, Dylan Fox, Erin Fisher, and Tatiana Nikiforova. The analysis and views expressed here are solely those of the author.

[2] Pham, Nam D. 2010. "The Impact of Innovation and the Role of Intellectual Property Rights on U.S. Productivity, Competitiveness, Jobs, Wages, and Exports." NDP Consulting publication.

This analysis focuses exclusively on the direct economic benefits of GPS technology to commercial GPS users and, consequently, the economic costs of GPS signal degradation to commercial GPS users and GPS manufacturers. The full quantitative results presented, therefore, underestimate the economic benefits of the GPS to the U.S. economy, as they do not include the benefits that accrue to personal consumers or other noncommercial (consumer oriented) or military users.

The direct economic costs of full GPS disruption to commercial GPS users and GPS manufacturers are estimated to be $96 billion per year in the United States, the equivalent of 0.7 percent of the U.S. economy. This annual total cost is the sum of $87.2 billion and $8.8 billion imposed on commercial GPS users and commercial GPS manufacturers, respectively. GPS user costs consist of $67.6 billion per year in foregone GPS benefits—increased productivity and input cost savings—and another $19.6 billion book value of investment losses in GPS equipment. GPS manufacturer costs consist of $8.3 billion per year in foregone commercial GPS equipment sales and an additional $0.55 billion per year in R&D spending and associated costs to attempt to mitigate the "LightSquared Problem."

If the operation of LightSquared will disrupt 50 percent of commercial GPS equipment, the direct economic impacts are expected to be $48.3 billion per year. Except the R&D spending and the opportunity cost of R&D spending performed by GPS manufacturers to find attempt to mitigate interference, direct economic costs to commercial GPS users and foregone GPS equipment sales are assumed to be half of total direct costs under the scenario of 100 percent degradation. In addition to direct economic impacts, there are other forgone direct and indirect economic and social benefits that are threatened by the LightSquared Problem. On the macroeconomic level, GPS disruption would reduce productivity and, consequently, hinder the competitiveness of GPS downstream users (Summary Table).

**Summary Table. Estimated Annual Economic Costs of GPS Signal Disruption**

| | 100 percent Degradation (in $ billions) | 50 percent Degradation (in $ billions) |
|---|---|---|
| ***DIRECT ECONOMIC IMPACTS*** | | |
| Commercial GPS Users | $87.2 | $43.6 |
| Foregone increased in productivity and cost-savings | $67.6 | $33.8 |
| Precision agriculture (crop farming) | $19.9 | $10.0 |
| Engineering Construction (heavy & civil, and surveying/mapping) | $ 9.2 | $ 4.6 |
| Transportation (commercial surface transportation) | $10.3 | $ 5.1 |
| Other commercial GPS users | $28.2 | $14.1 |
| Investment losses in GPS equipment | $19.6 | $ 9.8 |
| GPS Manufacturers | $ 8.8 | $ 4.7 |
| Foregone GPS equipment sales | $ 8.3 | $ 4.1 |
| R&D spending | $ 0.5 | $ 0.5 |
| Opportunity costs of R&D spending | $ 0.1 | $ 0.1 |
| **TOTAL** | **$96.0** | **$48.3** |
| ***OTHER DIRECT & INDIRECT IMPACTS*** | | |
| Emission reductions from fuel savings | | |
| Health and safety gains in work place | | |
| Worker time savings | | |
| Public safety and emergency response times | | |
| Employment in GPS-related industries and supporting industries | | |
| Quality-of-life improvements from noncommercial (consumer) GPS products and services | | |
| Military, national defense, and public safety | | |
| Large tax base to fund federal and local government expenditures | | |

**The Development of Commercial GPS and Its Economic Benefits to the U.S. Economy**

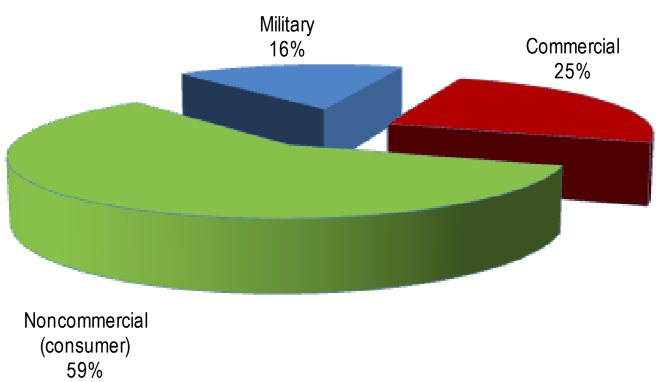
The Global Positioning System (GPS) is a U.S. government-owned technology that provides military and civilian users with positioning, navigation, and timing (PNT) services. The system was developed by the U.S. Department of Defense in 1978 strictly for military use, and played an important role in the 1991 Gulf War, as U.S. troops used it for navigation on land, sea and in the air for targeting of bombs and for on-board missile guidance. Following the Korean Airlines disaster in 1987, President Reagan announced that GPS would be available for civilian use once fully operational, which was initially established with a deliberate degradation of user position accuracy. On May 1, 2000, President Clinton announced the permanent end of the intentional degradation of the GPS signal to the public. Today, the GPS system consists of three components: the space component, the control component, and the user component. The space component consists of 30 operating satellites that transmit one-way signals that give the current GPS satellite position and time. The control component consists of worldwide monitor and control stations. And, the user component consists of GPS receiver equipment, which receives the signals from the GPS satellites and uses the transmitted information to calculate the user's three-dimensional position and time.[3]

During the past twenty years, GPS technology has transformed American businesses and lifestyles with myriad commercial applications across industries and spheres of life. GPS applications have improved business operations and best practices in a range of industries, including farming, construction, transportation, and aerospace. In addition to creating efficiencies and reducing operating costs, the adoption of GPS technology has improved safety, emergency response times, environmental quality, and has delivered many other less-readily quantifiable benefits. Although the market for GPS is already a multi-billion dollar industry, the future potential is still far reaching.

*Market segments*

Annual GPS equipment revenues in North America averaged $33.5 billion during the period 2005-2010.[4] The GPS market can be divided into three broad categories: commercial, noncommercial (consumer), and military. During the period, commercial equipment sales accounted for 25 percent of the total, while noncommercial and military equipment accounted for 59 percent and 16 percent, respectively (Figure 1).

**Figure 1. Revenue Shares of GPS Equipment, 2005-2010[5]**




Although a couple of industries dominate the commercial category, GPS technology is rapidly developing new applications across industries from construction to agriculture. During the period 2005-2010, commercial automobile

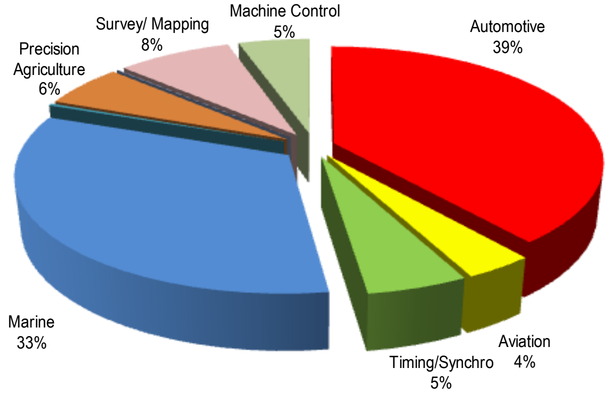
[3] GPS.gov.

[4] Bone, Dominique and Stuart Carlaw. 2009. "Global Navigation Satellite Positioning Solutions." ABI Research; and authors' estimates. North America consists of the United States, Canada, and Greenland. The U.S. markets are estimated to account for more than 90 of North America. Since disaggregated data is not available, we use North America data for this analysis.

[5] Bone, Dominique and Stuart Carlaw. 2009. "Global Navigation Satellite Positioning Solutions." ABI Research; and authors' estimates.

and marine industries accounted for 39 percent and 33 percent of commercial GPS equipment sales, respectively. The remainder of the commercial market comprises surveying/mapping (8 percent), precision agriculture (6 percent), machine control (5 percent), timing/synchronization (5 percent), and aviation (4 percent) (Figure 2).

### Figure 2. Commercial GPS Equipment Revenues, 2005-2010[6]




GPS equipment revenues increased more than 55 percent from $25.5 billion in 2005 to $39.6 billion in 2010. Revenues generated from the commercial segment increased by 120 percent from $4.7 billion in 2005 to $10.3 billion in 2010, and accounted for nearly 26 percent of total revenues in 2010. The noncommercial (consumer) segment, which includes passenger cars, recreational products (handhelds, fitness, and sports hardware solutions), and converged solutions (mobile handsets and portable consumer electronics devices) accounted for nearly 60 percent of total GPS equipment revenues during the period 2005-2010. Revenues generated from noncommercial (consumer) segments increased by 22 percent from $17.6 billion in 2005 to $21.3 billion in 2010. The military segment increased by 147 percent from $3.2 billion to $8.0 billion in 2010 (Table 1a).

### Table 1a. GPS Equipment Revenues by Segment, 2005-2010 (in $ billions)[7]

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Growth |
|---|---|---|---|---|---|---|---|
| Commercial | **$4.686** | **$6.538** | **$8.719** | **$9.980** | **$9.353** | **$10.298** | **120%** |
| Ground transport. | 1.205 | 2.145 | 3.479 | 4.233 | 4.085 | 4.213 | 250% |
| Aviation | 0.209 | 0.278 | 0.314 | 0.361 | 0.271 | 0.325 | 56% |
| Machine control | 0.320 | 0.367 | 0.408 | 0.443 | 0.467 | 0.551 | 72% |
| Marine | 1.650 | 2.351 | 2.978 | 3.254 | 2.766 | 3.254 | 97% |
| People-tracking | 0.013 | 0.014 | 0.016 | 0.018 | 0.035 | 0.060 | 352% |
| Precision Ag. | 0.480 | 0.497 | 0.499 | 0.490 | 0.467 | 0.499 | 4% |
| Railway | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 | 0% |
| Surveying/mapping | 0.517 | 0.563 | 0.673 | 0.736 | 0.700 | 0.833 | 61% |
| Timing/Synchron. | 0.287 | 0.317 | 0.346 | 0.439 | 0.558 | 0.558 | 94% |
| Noncommercial (consumer) | **$17.553** | **$19.083** | **$19.956** | **$20.214** | **$19.855** | **$21.332** | **22%** |
| Automobile | 2.167 | 3.897 | 5.050 | 4.921 | 3.828 | 3.587 | 66% |
| Converged | 15.077 | 14.815 | 14.461 | 14.677 | 15.409 | 16.939 | 12% |
| Recreational | 0.309 | 0.371 | 0.445 | 0.616 | 0.618 | 0.807 | 161% |
| Military | **$3.240** | **$4.255** | **$5.282** | **6.447** | **6.125** | **$7.989** | **147%** |
| TOTAL | **$25.479** | **$29.876** | **$33.957** | **36.641** | **35.332** | **$39.619** | **55%** |

Between 2005 and 2010, the number of GPS equipment units sold in North America rose by 75 percent from 69.8 million units to 122.4 million units in 2010. GPS equipment units sold in the commercial segment increased by 305 percent from 1.9 million units in 2005 to 7.7 million units in 2010. While revenues from the commercial segment accounted for 26 percent of total revenues in 2010, commercial units sold accounted for only 6.3 percent of total GPS

[6] Bone, Dominique and Stuart Carlaw. 2009. "Global Navigation Satellite Positioning Solutions." ABI Research; and authors' estimates.
[7] Bone, Dominique and Stuart Carlaw. 2009. "Global Navigation Satellite Positioning Solutions." ABI Research; and authors' estimates.

equipment units sold in 2010. In contrast, there were 109.9 million units sold in the noncommercial segment, a 68 percent increase from 65.2 million units sold in 2005. The military segment was the smallest destination for GPS equipment in 2010, with 4.7 million units sold (Table 1b).

### Table 1b. GPS Equipment Units Sold by Segment, 2005-2010 (in millions)[8]

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Growth |
|---|---|---|---|---|---|---|---|
| Commercial | **1.909** | **3.054** | **5.335** | **6.804** | **7.287** | **7.738** | **305%** |
| Ground transport. | 0.612 | 1.183 | 2.895 | 3.998 | 4.836 | 4.828 | 689% |
| Aviation | 0.042 | 0.050 | 0.052 | 0.060 | 0.045 | 0.054 | 30% |
| Machine control | 0.016 | 0.020 | 0.025 | 0.030 | 0.032 | 0.042 | 163% |
| Marine | 1.100 | 1.650 | 2.200 | 2.530 | 2.151 | 2.530 | 130% |
| People-tracking | 0.019 | 0.022 | 0.025 | 0.029 | 0.059 | 0.100 | 427% |
| Precision Agi. | 0.024 | 0.028 | 0.031 | 0.034 | 0.032 | 0.038 | 58% |
| Railway | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0% |
| Surveying/mapping | 0.060 | 0.063 | 0.067 | 0.074 | 0.070 | 0.083 | 39% |
| Timing/Synchron. | 0.036 | 0.037 | 0.038 | 0.049 | 0.062 | 0.062 | 73% |
| Noncommercial (consumer) | **65.239** | **72.340** | **83.037** | **91.597** | **97.165** | **109.925** | **68%** |
| Automobile | 2.551 | 6.057 | 14.238 | 18.854 | 18.553 | 20.210 | 692% |
| Converged | 60.942 | 64.213 | 66.342 | 69.604 | 75.422 | 85.761 | 41% |
| Recreational | 1.747 | 2.070 | 2.457 | 3.140 | 3.190 | 3.955 | 126% |
| Military | **2.674** | **3.045** | **3.528** | **4.030** | **3.828** | **4.688** | **75%** |
| TOTAL | **69.822** | **78.438** | **91.899** | **102.432** | **108.280** | **122.351** | **75%** |

Between 2005 and 2010, technology advances caused GPS equipment prices to decline—most notably in the commercial segment. On average, commercial GPS equipment prices declined by 46 percent from $2,454 per unit in 2005 to $1,331 per unit in 2010. Prices of GPS equipment for commercial automobiles declined by 56 percent from $1,968 per unit in 2005 to $873 per unit in 2010, followed by 34 percent price declines in the precision agriculture and machine control segments. However, prices of commercial GPS equipment rose in the aviation (20 percent), surveying/mapping (16 percent), and timing/synchronization segments (13 percent) (Table 1c).

### Table 1c. Unit Price of GPS Equipment Sold by Segment, 2005-2010[9]

| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Growth |
|---|---|---|---|---|---|---|---|
| Commercial | **$2,454** | **$2,141** | **$1,634** | **$1,467** | **$1,283** | **$1,331** | **-46%** |
| Ground transport. | 1,968 | 1,813 | 1,201 | 1,059 | 845 | 873 | -56% |
| Aviation | 5,000 | 5,500 | 6,000 | 6,000 | 6,000 | 6,000 | 20% |
| Machine control | 20,000 | 18,000 | 16,200 | 14,580 | 14,580 | 13,122 | -34% |
| Marine | 1,500 | 1,425 | 1,354 | 1,286 | 1,286 | 1,286 | -14% |
| People-tracking | 700 | 665 | 632 | 600 | 600 | 600 | -14% |
| Precision Ag. | 20,000 | 18,000 | 16,200 | 14,580 | 14,580 | 13,122 | -34% |
| Railway | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 20,000 | 0% |
| Surveying/mapping | 8,600 | 8,900 | 10,000 | 10,000 | 10,000 | 10,000 | 16% |
| Timing/Synchron. | 8,000 | 8,500 | 9,000 | 9,000 | 9,000 | 9,000 | 13% |
| Noncommercial (consumer) | **$269** | **$264** | **$240** | **$221** | **$204** | **$194** | **-28%** |
| Automobile | 850 | 643 | 355 | 261 | 206 | 177 | -79% |
| Converged | 247 | 231 | 218 | 211 | 204 | 198 | -20% |
| Recreational | 177 | 179 | 181 | 196 | 194 | 204 | 15% |
| Military | **$1,212** | **$1,398** | **$1,497** | **$1,600** | **$1,600** | **$1,704** | **41%** |
| TOTAL | **$365** | **$381** | **$369** | **$358** | **$326** | **$324** | **-11%** |

[8] Bone, Dominique and Stuart Carlaw. 2009. "Global Navigation Satellite Positioning Solutions." ABI Research; and authors' estimates.
[9] Bone, Dominique and Stuart Carlaw. 2009. "Global Navigation Satellite Positioning Solutions." ABI Research; and authors' estimates.

The above sales figures have several important implications: (1) Although fewer GPS units were sold in the commercial segment, the value of each unit and the prices per unit in the commercial sector are higher than those in the noncommercial (consumer) segment; (2) the commercial segment became more GPS-intensive over the period examined, and; (3) as with other innovations, technological advances and economies of scale have driven down the prices of GPS equipment.

*Economic Benefits of Commercial GPS to the U.S. Economy*

The revenues from GPS equipment sales and services represent only a small portion of the economic benefits of GPS to the U.S. economy. As Edward Morris of the U.S. Department of Commerce testified before Congress in 2006, "*Equipment sales represent only the tip of the economic iceberg. As with personal computers, the true value of GPS is not in the cost of the equipment, but in the productivity and growth it enables*."[10]

Indeed, the economic benefits of GPS to the U.S. economy are substantial. GPS manufacturers create employment, provide earnings, add value, and generate tax revenues for governments. Importantly, GPS technology improves productivity and produces cost-savings for end-users. This section estimates the direct economic benefits of GPS to three industries--precision agriculture, engineering construction (heavy and civil engineering, and surveying/mapping), and commercial surface transportation.[11] These three industries account for approximately 58 percent of total commercial GPS equipment sales and 17 percent of combined commercial and noncommercial GPS equipment sales during the period 2005-10. In terms of quantity, these three industries account for approximately 60 percent of total commercial GPS equipment units sold but only 3.5 percent of combined commercial and noncommercial GPS equipment units sold during the period 2005-10. Again, there are fewer commercial GPS users than noncommercial users but the equipment they purchase is more expensive than the equipment purchased by noncommercial users.

<u>*Precision Agriculture*</u>. GPS technology is used extensively in agriculture for what is called precision or site-specific farming. GPS applications are used for farm planning, field mapping, soil sampling, tractor guidance, crop scouting, variable rate applications of seeds, fertilizers, and pesticides, and yield mapping. Before GPS, it was more difficult for farmers to match production techniques or crop yields with land variability. This limited their ability to develop the most effective strategies to increase yields. Today, GPS-guidance equipment enables more precise application of pesticides, herbicides, and fertilizers, and better control of the dispersion of those chemicals, which reduces expenses, increases yields, and creates a more environmentally-friendly farm. For example, ten years ago, a 4,000-acre farm might have required eight or nine tractors; today it needs just three or four machines and has the capacity to adopt 24 hour operations during critical planting and harvesting months. In surveys, studies, and other industry literature, GPS adoption rates (use of at least one GPS technology) in crop farming were found to range from 23 percent to 91 percent. Based on a measured consideration of those findings, we estimated an average adoption rate of 60 percent, which factors into our estimation of the current economic impact of GPS on crop farming.[12] Since firms are adopting GPS technology and equipment at an increasing rate, we provide an additional simulation to estimate the economic impact of GPS at the 100 percent adoption rate.

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[10] Morris, Edward. 2006. "Hearing on Space and U.S. National Power." The statement of Edward Morris, Director Office of Space Commercialization National Oceanic and Atmospheric Administration, U.S. Department of Commerce, on June 21, 2006 before the Committee on Armed Services Subcommittee on Strategic Forces U.S. House of Representatives.

[11] "Commercial Surface Transportation" is not an official U.S. industry with associated official statistics. We are assigning this designation for the aggregate transportation-related functions of firms across industries in the economy because the beneficiaries of fleet management technology comprise firms in manufacturing, services, transportation, warehousing, and others.

[12] For example, Winstead, Amy T. and Shannon H. Norwood. 2010. "Adoption and Use of Precision Agriculture Technologies by Practitioners." Auburn University Working Paper; The Allen Consulting Group. 2007. "The Economic Benefits of Making GPSnet Available to Victorian Agriculture." Report to the Department of Sustainability and Environment, Government of Victoria, Australia; and, Diekmann, Florian and Marvin T. Batte. 2010. "2010 Ohio Farming Practices Survey: Adoption and Use of Precision Farming Technology in Ohio." Ohio State University Department of Agricultural, Environmental, and Development Economics.

The measureable direct economic benefits of GPS to crop farming can be observed in greater output and reduced input costs.[13] Industry studies, surveys, and testimonials from farmers about a variety of crops grown in different regions under different conditions find that the use of GPS equipment is associated with yield gains ranging from 3 percent to 50 percent. On the operation side, GPS technology provides crop farming with cost-savings on labor, capital (machine and equipment), and raw materials (seed, fertilizers, pesticides, other chemicals, fuels and oils, electricity). Estimates of input cost reductions range from 1 percent to 50 percent of total input costs. Based on a considered weighting of those findings, we estimate the average GPS-induced yield gain to be 10 percent and the average input savings to be 15 percent.[14]

According to data from the U.S. Department of Agriculture, the value of U.S. crop production averaged $169.1 billion per year during the period 2007-2010. The industry spent an average of $108.4 billion per year on affected inputs including seed, fertilizer and lime, fuels and oils, electricity, pesticides, repair and maintenance, and hired and contract labor expenses during the same period.[15] With a GPS adoption rate of 60 percent, we estimate that the use of GPS technology accounted for $10.1 billion of industry output per year ($169 billion production x 0.60 adoption x 0.10 GPS yield gain) and reduced input costs by $9.8 billion per year ($108.4 billion input expense x 0.60 adoption x 0.15 GPS input cost-savings). The aggregate annual benefits of GPS to crop farming, thus, totaled $19.9 billion per year, the equivalent of 11.8 percent of total annual production (Table 2).

As GPS technology continues to prove its value, the adoption rate will approach and possibly reach 100 percent, raising the potential benefits of current GPS technology to the industry to $33.2 billion per year, the equivalent of 19.6 percent of the value of current annual U.S. crop production (Table 2).

### Table 2. Annual Benefits of GPS to Crop Farming

| | **Annual Value (in $ billions)** | **60% Adoption: Annual GPS Benefits (in $ billions)** | **100% Adoption: Annual GPS Benefits (in $ billions)** |
|---|---|---|---|
| Crop production (2007-2010) | $169.1 | $10.1 | $16.9 |
| Affected input expenses (2007-2010) | $108.4 | $ 9.8 | $16.3 |
| **Total** | | **$19.9** | **$33.2** |
| % of total annual production ($169.1 billion) | | 11.8% | 19.6% |

*Engineering Construction (Heavy & Civil and Surveying/Mapping)*. GPS equipment increases productivity in the construction industries by providing accurate machine guidance and measurement technology. The technology improves accuracy and increases efficiency in many related functions such as surveying, excavating, grading, sub-grading, transportation management, facility delivery, urban planning, and jobsite safety monitoring. Activities that once required a variety of tools and instruments such as measuring tapes, compasses, and levels, and weeks of intensive work by teams of specialists can now be done by one person with a GPS device in a matter of hours. With the GPS surveying instrument in his hand, the construction surveyor can take precise measurements without the requirement of line of sight. These devices work under any weather conditions, making the process of construction surveying fast, easy, and more precise. GPS technology in construction is also effectively used for material and equipment management, helping to improve efficiency, reduce costs, and increase profits. Based on industry surveys, GPS adoption rates are estimated to be about 40 percent in the heavy and civil engineering construction

[13] This study does not estimate indirect economic benefits of using GPS in crop farming such as the environmental benefits of more efficient land and chemical use and reduced farm equipment emissions.

[14] The Allen Consulting Group. 2007. "The Economic Benefits of Making GPSnet Available to Victorian Agriculture." Report to the Department of Sustainability and Environment, Government of Victoria, Australia; University of Illinois Extension. 2011. "Farm GPS Improves Profits and Quality of Life." News Release; Martin, Steven and James Hanks. 2005. "Estimating Total Costs and Possible Returns from Precision Farming Practices." *Crop Management;* Langcuster, James. 2010. "Experts: Precision Farming Does Save," Blog Post, Alabama Cooperative Extension System, November 23, 2010; and, Winstead, Amy. 2011. "Does Precision Ag Pay?" Blog Post, Alabama Cooperative Extension System, April 15, 2011.

[15] ERS database, U.S. Department of Agriculture.

industry. Again, we provide an additional simulation to estimate the economic benefits of GPS at the 100 percent adoption rate, as use is likely to increase as the technology's value continues to be proven.

The benefits of GPS to the industry can be measured in terms of savings of labor, capital, and materials. Industry studies, surveys, and testimonials indicate that the potential reduction in labor usage (reduced man-hours of foremen, operators, surveyors, and workers on construction projects) attributable to GPS technology ranges from 57.4 percent to 62.3 percent, averaging 59.8 percent. The capital savings component includes the reduced use of machinery attributable to time savings, and is estimated as the savings in rental equipment expenditures and capital machinery purchases. Studies and surveys point to a capital savings rate in the range of 17.5 percent to 42.5 percent, averaging 30 percent. Lastly, studies estimate average fuel savings of 32.4 percent, ranging from 22.2 to 42.5 percent.[16]

In the latest 2007 survey data published by the U.S. Bureau of the Census, heavy and civil engineering construction reports $32.0 billion in construction worker wages, $10.6 billion on capital equipment purchases and rentals, and $2 billion on fuels and lubricants for off-highway use.[17] At an estimated 40 percent adoption rate, we find that GPS technology produces $9.2 billion of cost savings for heavy and civil engineering construction, the equivalent of 3.8 percent of annual production. These savings include $7.6 billion in construction labor wages ($32 billion x 0.40 adoption x 0.598 GPS-labor-savings), $1.3 billion in capital machinery and equipment ($10.6 billion x 0.40 adoption x 0.30 GPS-capital-savings), and $0.3 billion in affected inputs ($2.0 billion x 0.40 adoption x 0.324 GPS-fuel savings). The potential benefits of GPS to the industry climb to $23 billion per year, the equivalent of 9.4 percent of the annual value of the industry, when the adoption rate is 100 percent (Table 3).

**Table 3. Annual Benefits of GPS to Engineering Construction (Heavy & Civil and Surveying/Mapping)**

| | **Annual Value (in $ billions)** | **40% Adoption: Annual GPS Benefits (in $ billions)** | **100% Adoption: Annual GPS Benefits (in $ billions)** |
|---|---|---|---|
| Labor (2007) | $32.0 | $7.6 | $19.1 |
| Capital (2007) | $10.6 | $1.3 | $ 3.2 |
| Affected input expenses (2007) | $ 2.0 | $0.3 | $ 0.7 |
| **Total** | | **$9.2** | **$23.0** |
| % of total annual production ($245.7 billion) | | 3.8% | 9.4% |

*Commercial Surface Transportation*. Businesses across the economic spectrum—from mid-sized manufacturers to large service providers—own or lease vehicles used to carry out various functions of the companies' operations. Businesses in transportation, warehousing, manufacturing, express delivery, home delivery, and carpet cleaning services operate and attempt to manage vehicle fleets. Such management simply cannot be imagined without the use of GPS today. Vehicle tracking, one of the fastest-growing applications for GPS technology, helps increase mobile workforce productivity and safety and enables enterprises to reduce labor and fuel expenses.

Studies, surveys, and other industry research indicate that between 50 and 86 percent of all firms that manage vehicle fleets have adopted GPS equipment for that purpose. We estimate the current GPS adoption rates in the U.S. to be 67.9 percent. Estimates from industry studies indicate GPS technology provides average savings of labor, fuel,

[16] Caterpillar. 2006. "Road Construction Production Study." MALAGA Demonstration and Learning Center; Adalsteinsson, Dadi. 2008. "GPS Machine Guidance in Construction Equipment." Working Paper; Trimble Navigation. 2005. "Soil Challenges and Complex Grading Test Machine Control." Testimonial, *Trimble Productivity*, Fall 2005; Trimble Navigation. 2006. "Mid-size Contractor Makes Bold Move Pay."Testimonial, *Trimble Productivity*, Spring 2006; Aliant Engineering Inc. 2007. "Best Practices: Machine Control Evaluation." Report Prepared for Minnesota Department of Transportation; Vonderohe, Alan. 2007. "Implementation of GPS Controlled Highway Construction Equipment." Final Report, University of Wisconsin (Madison), Construction Materials and Support Center; and, Clear Seas Research. 2009. "Survey and Mapping Industry Equipment Study 2009." CleaReport.

[17] U.S. Census Bureau; Heavy and civil engineering construction industry (NAIC 237) consists of highway, street, and bridge construction, oil and gas pipeline construction, power and communication line construction, and land subdivision, and others related construction.

and capital equipment (primarily vehicle maintenance and repair) of 11.3 percent, 13.2 percent, and 13.2 percent, respectively. Other reported benefits that are not factored into our calculations include a 25 percent increase in work orders (on account of faster completion rates), 45 percent fewer accidents, and 40 percent fewer issuances of speeding violations. [18]

Similar to the previous two industries evaluated, we estimate the economic benefits of GPS fleet management applications on businesses across the economy by calculating the labor, capital and fuel savings. The U.S. Census Bureau reports an annual average of 85.1 billion commercial miles traveled in the United States during the period of 2005 through 2009. The Bureau of Labor Statistics estimates the annual earnings of commercial drivers were $83 billion in 2009/2010. And to estimate capital and fuel expenditures, we used the IRS standard vehicle mileage tax deduction of $0.51 per mile (devoting $.255 per mile each to fuel and capital). Based on the commercial mileage figure, we estimate commercial fuel and capital expenditures to have been $21.7 billion each. Added to the labor expenditures of $83.0 billion, the recent total annual transportation-related expenditures of U.S. businesses was approximately $126.4 billion.[19]

With estimated fleet management equipment adoption rates of 67.9 percent, estimated fuel and capital savings of 13.2 percent, and estimated labor savings of 11.3 percent, the total annual benefits of GPS equipment are estimated to be $10.3 billion, which is 8.1 percent of annual U.S. expenditures on commercial surface transportation activities. The break-down of benefits are $6.4 billion in labor savings ($83 billion x 0.679 adoption x 0.113 GPS labor savings), $1.9 billion in capital savings ($21.7 billion x 0.679 adoption x 0.132 GPS capital-savings), and another $1.9 billion in fuel savings ($21.7 billion x 0.679 adoption x 0.132 GPS fuel-savings). Again, the benefits of GPS to the industry potentially reach $15.1 billion per year, the equivalent of 12 percent of annual U.S. commercial surface transportation expenditures, when adoption rates reach 100 percent (Table 4).

### Table 4. Annual Benefits of GPS to Commercial Surface Transportation

| | Annual Value (in $ billions) | 67.9% Adoption: Annual GPS Benefits (in $ billions) | 100% Adoption: Annual GPS Benefits (in $ billions) |
|---|---|---|---|
| Labor (2009-10) | $83.0 | $6.4 | $9.4 |
| Capital (2005-09) | $21.7 | $1.9 | $2.9 |
| Raw Materials (2005-09) | $21.7 | $1.9 | $2.9 |
| **Total** | **$126.4** | **$10.3** | **$15.1** |
| % of total annual related costs ($126.4 billion) | | 8.1% | 12.0% |

*All Commercial GPS Users in the U.S. Economy*. Under current GPS adoption rates, the aggregated benefits of GPS technology in the three industries examined here (precision agriculture, engineering construction (heavy & civil and surveying/mapping), and commercial surface transportation) total $39.4 billion per year, resulting from the investment of $4.8 billion in annual purchases of commercial GPS equipment during the period 2005-2010. The potential GPS benefits are as high as $71.3 billion per year when the GPS adoption rates reach 100 percent (Table 5).

The $4.8 billion in annual purchases of the three examined industries accounted for 58.2 percent of total commercial GPS equipment sales during the period 2005-2010. Sales of commercial GPS equipment for other industries averaged approximately $3.5 billion per year. We use the weighted average benefits ratio of the three examined industries to project the benefits of GPS technology on all other U.S. commercial GPS users. We estimate those benefits to be in the range of $28.2 billion to $51.1 billion per year, depending on the rate of GPS adoption. Accordingly, the direct economic benefits on $8.3 billion in commercial GPS equipment sales are estimated to be

[18] Aberdeen Group. 2007. "The Impact of Location on Field Service," Industry Study, December 2007; Fletcher, Lauren. 2010. "Commercial Fleets See Cost Savings from Telematics," *Automotive Fleet*, February 2010; and, O'Hara, Kristy J. 2011. "Mark Leuenberger Takes Cox Enterprises to New Green Levels," *Smart Business,* June 1, 2011.

[19] U.S. Census Bureau; U.S. Bureau of Transportation Statistics; U.S. Bureau of Labor Statistics; and Internal Revenue Service.

between $67.6 billion and $122.4 billion per year—the equivalent of 0.5 percent to 0.9 percent of the U.S. economy. (Table 5).

**Table 5. Annual Benefits to All Commercial GPS Users in the U.S. Economy**

| | Annual GPS Equipment Spending (in $ billions) | Estimated Annual Benefits (in $ billions) |
|---|---|---|
| Precision agriculture (crop farming) | $0.5 | $19.9 - $33.2 |
| Engineering Construction (heavy & civil and surveying/mapping) | $1.1 | $9.2 - $23.0 |
| Transportation (commercial surface transportation) | $3.2 | $10.3 - $15.1 |
| Sub-total (3 industries examined) | $4.8 | $39.4 - $71.3 |
| Other commercial GPS users | $3.5 | $28.2 - $51.1 |
| Total commercial GPS users in the U.S. economy | $8.3 | $67.6 - $122.4 |

Our estimates of the benefits of GPS technology to the economy capture only the direct economic benefits to commercial GPS end-users generated by increased productivity and input cost-savings. Our figures underestimate the full economic benefits for several reasons. First, we have not analyzed the direct and indirect economic impact of GPS manufacturers on job creation and wage generation. Second, GPS equipment produces other social benefits, including emissions reduction (environmental benefit) and reduction in injuries and fatalities (health and safety benefit). Lastly, our estimates do not incorporate commercial benefits such as certain time-value benefits that flow from faster job completion rates, reduced food and other commodity prices, and a higher tax base from which to fund government expenditures.

In addition, our analysis considers the relatively small volume but high economic impact GPS user segment. We therefore underestimate benefits to noncommercial and military GPS users. For example, GPS technology provides value for community safety by improving response time and location accuracy for emergency responders and public safety officials. Indeed, response time is estimated to be improved by twenty percent with the use of GPS-enabled equipment installed in emergency response vehicles. In a recent survey, one local government estimated that a quarter of his staff would be required to spend two hours per day correcting coordinate and other location errors if GPS use is disrupted. On a larger scale, GPS technology can reduce the response time in the aftermath of natural disasters, which translates directly into saved lives.

**LightSquared Operations and Disruptions to GPS**

LightSquared is a mobile satellite service (MSS) provider with two space vessels that cover North America. The service plans to operate in the 1.5-1.6GHz zone, part of the L-Band. Although the company traces its roots back to 1988, when it was known as American Mobile Satellite Corporation and later as Mobile Satellite Ventures and Skyterra, it has only recently sprung to the forefront of public attention.

The FCC's decision to grant LightSquared permission to build a stand-alone network of 40,000 ground mobile stations has created serious concerns within the broader GPS industry and user community. LightSquared is not in competition for business with the GPS industry, but its plans have potential to wreak serious economic damage on both GPS users and equipment producers. The reason for alarm is that LightSquared's proposed LTE network will operate in spectrum space immediately adjacent to the spectrum used by the Global Positioning System, which might lead to unintentional jamming when LightSquared's terrestrial receivers overpower the much weaker GPS signals. LightSquared claims that it will be able to deploy the network in a manner that would be harmonious with GPS.

However, the FCC and a number of other governmental agencies concluded that LightSquared should not commence commercial operations until after conducting a thorough study of the potential interference to GPS.[20]

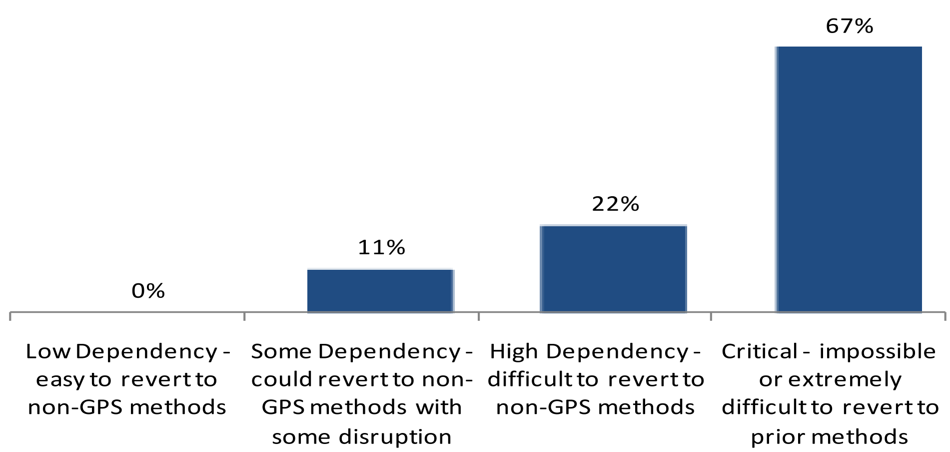
Initial testing of GPS receivers carried out by the National Position, Navigation and Timing Engineering Forum (NPEF -- a multi-agency governmental technical forum) confirms aircraft navigation systems will experience significant jamming from thousands of broadband-wireless transmitters planned to be deployed across the United States.[21] Based on the simulations conducted by NPEF, after the new network is launched, GPS is likely to be unavailable for aviation purposes over the whole U.S. East Coast.

According to a report by the Radio Technical Commission for Aeronautics, the effect of LightSquared's deployment is expected to be a complete loss of the GPS receiver function. The Departments of Homeland Security and Transportation also have expressed reservations about the plan.[22] Although the precise outcome of such a major and unprecedented disruption to GPS is hard to predict, it will have serious economic repercussions for the U.S. economy.

As described above, the daily operations of thousands of businesses in a variety of industries and economic industries rely on GPS. Signal interference could affect the functionality of GPS equipment used by U.S. federal agencies, state and local governments, first responders, airlines, industry, civil engineering, construction and surveying, agriculture, and everyday consumers in their cars and on hand-held devices—causing severe financial losses and having adverse national security implications.

Indeed, GPS has become essential to U.S. businesses. A recent industry survey sent out to 149 users in the agricultural, construction, and surveying/mapping industries inquired about their operational dependency on GPS technology. Nearly 67 percent of respondents said that it is *impossible or extremely difficult* to revert to prior methods; 22 percent said that their daily operations are highly dependent on GPS and it is difficult to revert to non-GPS methods; and only 11 percent of respondents said that their operations have only some dependency and could revert to pre-GPS methods with some disruption (Figure 3).

**Figure 3. Operational Dependency on GPS in Commercial GPS Users[23]**




[20] Space-based Positioning, Navigation and Timing Executive Committee.
[21] Warwick, Graham. 2011. "LightSquared Tests Confirm GPS Jamming." Aviation Week.
[22] Halsey, Ashley. 2011. "LightSquared wireless Internet plan concerns officials pushing GPS for aviation". The Washington Post.
[23] An only survey conducted by Trimble Navigation Ltd. in May 2011.

**LightSquared's Adverse Economic Impact on GPS Users and GPS Manufacturers**

LightSquared broadband operations will inflict costs on both GPS users and GPS manufacturers. The total economic cost of signal degradation includes explicit and implicit costs to firms and workers in the GPS equipment manufacturing industries,[24] firms and workers in the GPS equipment end-user industries, and firms and consumers of the products and services produced by the GPS equipment end-user industries. For commercial GPS users, the disruption caused by LightSquared operations will inflict real costs. The observed benefits and impressive productivity gains attributable to GPS technology in recent years would disappear. Additionally, there would be a loss of value—equal to the depreciated stock—of already-purchased commercial equipment that is no longer functional.

For GPS manufacturers, the cost of the disruption caused by LightSquared would include R&D spending costs devoted to attempting to mitigate the interference from LightSquared's operations, the opportunity costs of committing resources to such mitigation efforts (instead of improving or developing new products), and the value of foregone commercial sales, which would shrink if the GPS signal is impaired. At present there is substantial doubt about the availability and effectiveness of any available technical means of mitigation that could be developed in the future by GPS manufacturers. Nonetheless, as discussed fully below, GPS manufacturers will have no choice but to invest in R&D to attempt to reduce interference to the greatest extent feasible short of making GPS products unprofitable by doing so.

Even though LightSquared is not yet operational, the expectation of signal problems has already created mitigation costs in the form of research and development (R&D), public relations, lobbying, customer relations, outreach, and legal, testing and evaluation analyses. Those are sunk costs regardless of the magnitude of signal degradation, if and when LightSquared goes live. If mitigation is possible, there are likely to be manufacturing, replacement, and retrofitting costs, depending on the nature of available mitigation options. During the period in which GPS product performance is significantly degraded, manufacturers will also suffer the cost of foregone sales, as the U.S. market for GPS equipment shrinks.

Though it is widely assumed that the implementation of LightSquared's operations will cause GPS signal degradation (and loss of functionality of GPS equipment), the likely scope and magnitude of signal degradation is unknown as of the date of completion of this study. Accordingly, so as to provide maximum utility once the scope of the problem is better understood, the model developed herein could be scalable for estimations of different signal degradation.[25]

Using the model described below, we estimate the economic cost of signal degradation on an annual, retrospective basis. In other words, our estimates should be considered the annual economic cost of signal degradation in the absence of a high level of mitigation. Implementation of interference mitigation carries a cost, but it is a one-time cost, not an annual cost. Likewise, failure to implement achieve a high level of mitigation would carry a much larger one-time cost (up to the U.S.-attributed portion of the value of the GPS equipment manufacturing industry). The cost of implementing interference mitigation and the cost of not achieving mitigation are tallied separately from the annual cost figures developed below. The aggregate cost (of any estimate of signal degradation) should be interpreted as the annual economic cost of the "LightSquared Problem."

The main cost components in our methodology are:

[24] We include the costs of developing and implementing interference mitigation techniques, if they exist, in this broad category of costs, although that is not to imply that GPS manufacturers and GPS users should ultimately be responsible for covering those costs.

[25] The estimated economic costs are based on 100 percent signal degradation. However, degradation may affect some GPS products and not others, or some geographic locations and not others. Thus, 50 percent of our estimated costs equates roughly the cost of a 50 percent signal degradation. By assuming a linear relationship, we are effectively treating equally the economic impacts of all categories of GPS equipment. Although the true relationship between the degree of signal degradation and the cost to the U.S. economy may not be linear, our estimated costs could be used as a base for discounting the degree of disruption. We believe this is a reasonable approach to estimating the impact across the full range of possible signal degradations.

*1. Commercial GPS Users – Loss of productivity and efficiency*. As shown earlier, the annual economic benefits of GPS to commercial users range from $67.6 billion to $122.4 billion. GPS disruption would erase those benefits. To estimate the cost of the LightSquared Problem, we use the lower bound in the range of costs estimates. Thus, we estimate $67.6 billion to be the cost of lost of productivity and efficiency for commercial GPS users.

*2. Commercial GPS Users -- Investment losses in GPS equipment*. Commercial GPS users purchase GPS equipment to make themselves more efficient or their operations more productive. The value of existing stock of already-deployed GPS equipment will decrease proportionally with the degree with GPS disruption caused by LightSquared. At 100 percent signal degradation, no equipment will be functional. The economic loss would be the total loss of the entire stock of GPS equipment. The annual sales of commercial GPS equipment ranged from $6.5 billion to $10.3 billion during the period 2006-2010. We estimate the book value of the current stock of commercial GPS equipment by applying a 5-year straight line average annual depreciation of 20 percent of original purchased value. As a result, we estimate the investment losses in GPS equipment for commercial users to be $19.6 billion.

In sum, the economic losses to commercial GPS users will be $87.2 billion, if GPS is fully disrupted (Table 6).

*3. GPS Manufacturers -- Foregone sales of GPS equipment*. GPS equipment sales will suffer if their functionality is impaired by a degraded GPS signal. Few people are willing to purchase products that are known to suffer from performance issues, whatever the cause. Under a scenario of 100 percent signal degradation, no GPS products would be functional and the GPS degradation caused by LightSquared potentially puts $8.3 billion of annual commercial GPS equipment sales at risk.

*4. GPS Manufacturers -- R&D to develop mitigation measures*. GPS manufacturers and related parties have spent resources to test and evaluate means of mitigating interference from LightSquared. As of this writing, engineers, scientists, and industry experts have not yet identified effective mitigation measures and there is substantial uncertainty whether interference can be significantly reduced. Estimating the cost of mitigating a problem under such circumstances presents certain obvious complications.

Based on annual financial reports of major GPS manufacturers, annual research and development (R&D) expenditures averaged 9 percent of annual sales between 2008 and 2010. As a percentage of the $39.6 billion total GPS equipment sales in 2010, that amounts to approximately $3.6 billion. Since the LightSquared Problem presents a unique challenge, the industry might need to spend the entire $3.6 billion annual R&D budget or even more to ways of mitigating the problem. From a cost-benefit-analysis perspective, the industry would be willing to spend as much as the expected economic losses (i.e., the industry value) to try to fix the problem.

For the purpose of referencing the experiences in somewhat analogous situations, we considered the reactions of business to the Y2K problem, as well as the expenditures of Sony to address a disruptive privacy breach with respect to its Playstation product. In the late 1990s, U.S. businesses were concerned about the potential impact of the so-called Y2K bug. Although different from the LightSquared problem in several ways, Y2K was similar in that some kind of costly technical disruptions were expected and the magnitude of the problem could not be predicted with certainty.

Between 1995 and 2001, U.S. businesses spent an estimated $130 billion on R&D to find solutions and insulate their operations from disruptions expected to be caused by the Y2K problem. The amount spent comes to about 13 percent of annual U.S. business spending on R&D (and about 0.23 percent of U.S GDP) in those years.[26] In response to the recent data privacy breach concerning Sony "Playstations," Sony spent $170 million (that is more than 21 percent of the value of Playstation sales) just to respond to one hacking incident.[27] That is equivalent to GPS equipment manufacturers spending $8.3 billion to attempt to mitigate the LightSquared problem. To be conservative, we used the lower number of Y2K experience as a benchmark. We estimated that approximately 13 percent of

[26] Kliesen, Kevin L. 2003. "Was Y2K Behind the Business Investment Boom and Bust?" *Review*, Federal Reserve Bank of St. Louis.
[27] Forbes.com.

aggregate R&D spending of GPS equipment manufacturers will be required to attempt to mitigate LightSquared Problem. In that case, the annual industry cost amounts to an estimated $460 million (13 percent of R&D expenditure of GPS manufacturers).

5. *Opportunity costs of R&D spending to mitigate interference*. Every R&D dollar devoted to fixing the problem is a dollar of foregone investment toward creating new and improved products. The opportunity cost of that foregone investment can be calculated as the expected rate of return that would have been generated from that investment had it been made. There is a vast empirical academic literature on the topic of returns to research and development expenditures. A survey of the literature yields estimated returns in the United States to be in the range of 7 percent to 76 percent, with the mode clustered in the 20-30 percent range.[28] For our purposes, we assume conservatively that the expenditures devoted to mitigation measure would have produced a 20 percent return had those dollars been invested in new or improved products. The opportunity costs of R&D spending to interference mitigation are estimated at nearly $100 million for $460 million R&D spent.

On top of the $87.2 billion cost to GPS users, the economic costs to GPS manufacturers are estimated to be over $8.8 billion per year until a high level of mitigation can be achieved. The estimate includes nearly $8.3 billion average annual sales of GPS equipment during 2005-10, and nearly $0.6 billion in R&D expenses related to LightSquared Problem. The largest component for manufacturers is expected to be the foregone GPS equipment sales, which will depend on the degree of GPS signal degradation caused by the LightSquared Problem. Although smaller than other cost components, GPS manufacturers face a fixed cost of R&D and its opportunity costs until a high level of mitigation can be achieved.

If the LightSquared operations will disrupt GPS 50 percent, the economic costs are estimated to be $48.3 billion per year, $43.6 billion to commercial GPS users and $4.7 billion to GPS manufacturers. Regardless if the disruption is fully or partial, GPS manufacturers will spend the same amount of R&D and consequently the opportunity cost of R&D spending. All cost components to commercial GPS users and GPS manufacturers' foregone GPS equipment sales are assumed to be half of the fully degradation scenario.

Thus, the LightSquared Problem is estimated to cost the U.S. economy $96 billion per year if the LightSquared operations disrupt GPS fully and $48.3 billion per year if the disruption is 50 percent (Table 6).

**Table 6. Estimated Annual Economic Costs of GPS Signal Disruption**

| | 100 percent Degradation (in $ billions) | 50 percent Degradation (in $ billions) |
|---|---|---|
| Commercial GPS Users | $87.2 | $43.6 |
| Foregone increased in productivity and cost-savings | $67.6 | $33.8 |
| Precision agriculture (crop farming) | $19.9 | $10.0 |
| Engineering Construction (heavy & civil and surveying/mapping) | $ 9.2 | $ 4.6 |
| Transportation (commercial surface transportation) | $10.3 | $ 5.1 |
| Other commercial GPS users | $28.2 | $14.1 |
| Investment losses in GPS equipment | $19.6 | $ 9.8 |
| GPS Manufacturers | $ 8.8 | $ 4.7 |
| Foregone GPS equipment sales | $ 8.3 | $ 4.1 |
| R&D spending | $ 0.5 | $ 0.5 |
| Opportunity costs of R&D spending | $ 0.1 | $ 0.1 |
| **Total** | **$96.0** | **$48.3** |

[28] Hall, Bronwyn H., Mairesse, Jacques, Mohnen , Pierre, 2009, "Measuring the Returns to R&D," National Bureau of Economic Research Working Paper 15622.

## Conclusion

The advent of the Global Positioning System and its subsequent commercialization has delivered enormous benefits to the U.S. economy. Production tasks that were once time-intensive, labor-intensive, capital-intensive, and material resource-intensive have been streamlined and simplified on account of the innovative adaptation of GPS technology to business functions across the economic spectrum. Productivity gains, input cost reductions, time savings, and environmental, health, and safety benefits are among the various fruits of GPS commercialization. We estimate that the value to the U.S. economy of the productivity gains and input cost reductions alone amounts to between $68 billion and $122 billion per year, or 0.5 to 0.9 percent of annual U.S. gross domestic product.

But those benefits and more are at risk due to the operational plans of LightSquared—the "LightSquared Problem." LightSquared's operations are expected to adversely affect the quality of GPS signal transmission and reception, which could impair or render useless all forms of commercial GPS equipment. The largest cost would be the lost benefits described above, estimated conservatively at $68 billion per year. But there would be other costs, including investment in nonfunctioning GPS equipment ($20 billion per year), the value of lost or foregone GPS equipment sales ($8.3 billion per year), and the costs associated with research and development devoted to solving the problem ($0.6 billion per year). In total, the economic cost of the LightSquared Problem could reach $96 billion per year, the equivalent of 0.7 percent of the U.S. economy. The economic costs are expected to be $48.3 billion per year under the scenario of 50 percent GPS disruption caused by LightSquared.

The stakes are indeed very high. Policymakers and authorities would need to decide whether it is worth risking those enormous and growing benefits to enable the far lower amount of investment in broadband made by LightSquared to attempt to create the value that already exists from use of GPS. In fact, the U.S. government has already invested some $35 billion taxpayer money in the GPS constellation alone and continues to invest at a rate approaching $1 billion per year in the GPS constellation.

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