THE ECONOMIC VALUE OF GPS: PRELIMINARY ASSESSMENT

National Space-Based Positioning, Navigation and Timing Advisory Board Meeting, June 11, 2015

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Outline

- Objectives and Scope
- Benefit Estimates – Overview
- Conclusions and Next Steps

- Appendix A: Benefit Estimates
- Appendix B: Applications and Markets
- Appendix C: Broad Benefit Studies
- Appendix D: Some Methodological Issues

OBJECTIVES AND SCOPE

EXCOM Tasking

"Lead interagency team in consultation with National Space-Based PNT Advisory Board to develop a way forward for an updated, authoritative GPS Economic Benefits Assessment (OPR: DOC; OCRs: DHS/NASA)"

Objectives

- Provide a Part 1 description and snapshot of GPS applications and benefits
  - Describe the major uses of civilian GPS and its position in the value chain
  - Provide updated, more complete and methodologically sound estimates of the scope and economic benefits of GPS to the U.S.
  - Provide an Interim Core Report that can serve as a nucleus for development of follow-on analysis and final reports on GPS benefits in Part 2
- The Part 2 analysis to include further examination of economic benefits, non-economic benefits, international benefits, future benefits, and selective estimation of orders of magnitude of costs of long-term denial of GPS
- Results of the combined analyses to be presented in:
  - A “showcase report” designed for a broad audience, with examples and stories that increase interest
  - A full analytic report documenting sources and methods

A Baseline in Support of Policy Analyses

- Assessing the economic implications of actions such as preventing or disallowing interference, spectrum sharing or reallocation, developing supplementary or backup systems and/or toughening receivers can be informed by value estimates and the data used to derive them
- Economic values can be used in planning for GPS modernization and in supporting budgets
- A baseline allows comparisons with future developments amid increasingly interrelated and rapidly evolving technologies, systems and applications

Improved legislative, regulatory and public understanding of GPS roles, applications and benefits can lead to better decisions.

Scope of GPS Benefit Estimates

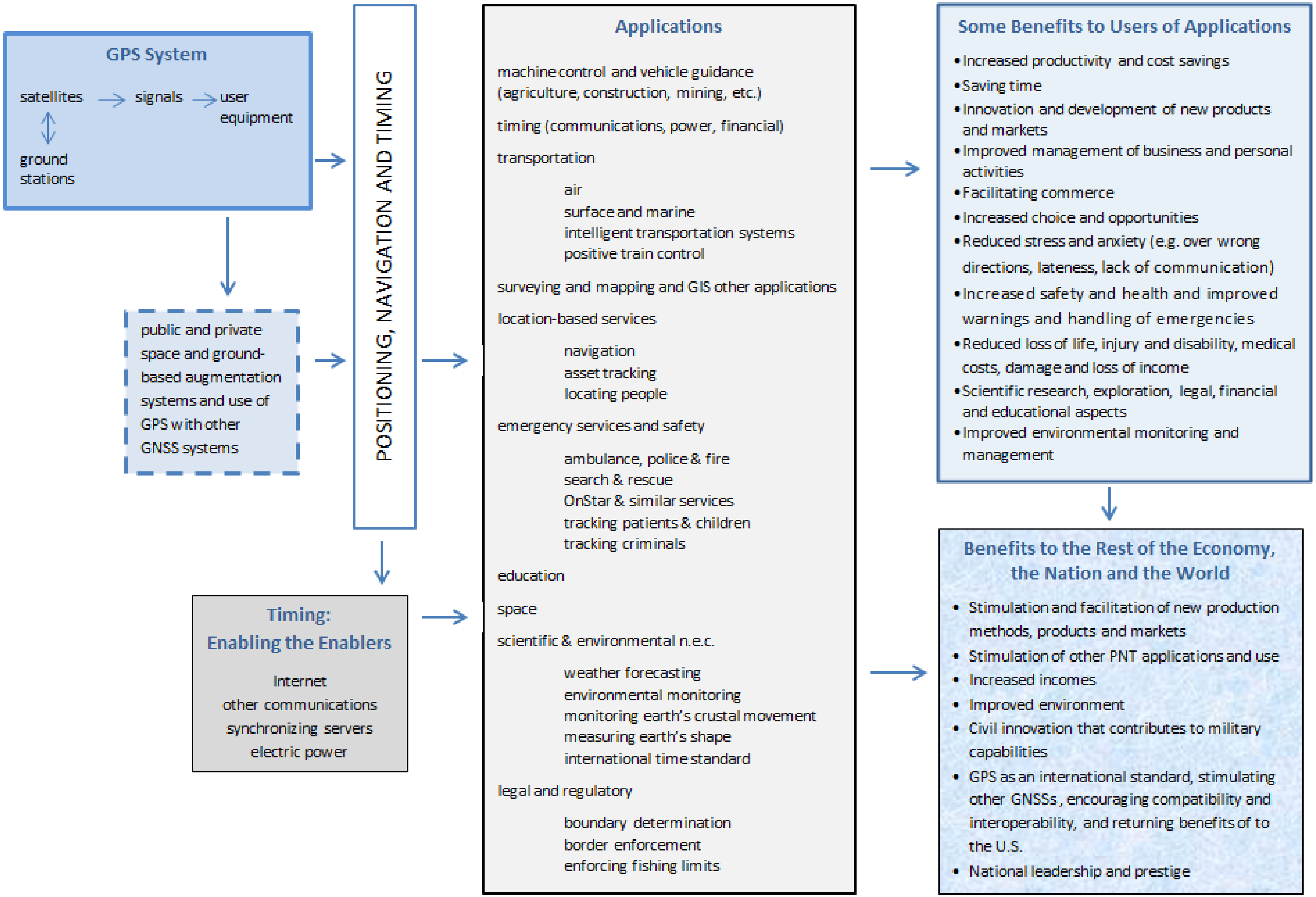
- The current study is an initial effort and is not meant to be comprehensive. More work will be done in the future to fill in the known data gaps
- Only economic benefits are included. Health and safety and environmental benefits will be considered later
- Benefits include payments for services plus the value to users above their costs
- Estimates are gross. Costs of achieving the benefits are not included
- Contributions of augmentations are included since a quantitative basis for separating them is not available
- Benefits are compared with alternatives without GPS or an application using it (counterfactuals)
- Initial estimates are primarily for direct benefits; indirect benefits are included where they involve documented cost savings
- Illustrative allowances are made for the contributions of other technologies and systems to the outcomes examined

Data Limitations

- **Emphasis was placed on including sectors with the most robust benefit estimates according to guidance from the Economists' Study Group**
  - Nevertheless, many assumptions and judgements were required
  - Sectors with lower quality estimates – rail and maritime transportation – were included because of their importance to the economy
- Estimates were not included for some sectors because of insufficient data
- Shares of benefits attributable to GPS were rough assumptions
- **More robust estimates would require extensive data collection and interviewing in studies greatly exceeding available time and resources**

BENEFITS OVERVIEW

GPS/GNSS Value Chain for the U.S.



Criteria for Selection of Application Categories for Estimation

BASIC

A. Confident	based on robust estimates
B. Indicative	based on less robust estimates
C. Notional	illustrative, if major contributions of other technologies are not separated and estimates must be based on a plausible percentage of a larger benefit, or if information is not available and estimates must be based on a percentage of market size

ADDITIONAL

1. The importance of the sector to the economy, especially as an enabler of other activities

2. The potential use of benefit estimates and/or component data for the category as an input into analysis of the effects of signal disruption

3. The possibility of making new estimates for the category

Benefit Information Table of Availability

Application and Source	Value Measure(s)	Date of Data	Form of Information	Date of Report	Reliability	Results and Comments
Machine Control and Vehicle Guidance						
Precision Agriculture						Major improvements have occurred since many of the studies were done.
ACIL Allen Consulting (precise positioning in agriculture)	saving in production costs in grain farming in Australia	2012	report	2013	Based on review of practices, studies and assumptions in other studies	Assumed controlled traffic, yield monitoring and variable rate application saved 12%-20% in costs. Very low benefit of GNSS in non-grain cropping and where weather is most variable.
ACIL Allen Consulting (augmented GNSS)	yield increases in broad crop production in Australia	2012	report	2013	Unknown	Cites estimates from ACIL Allen (precise positioning) and McCallum. States that the precise positioning study reported that productivity gains of 10%-20% "are possible." Page 5 states that in the grains industry: "Cost savings of around 67% in labour and 52% in fuel are reported" from automatic guidance and controlled traffic farming, variable rate fertilizer application and inter-row sowing. This is said to correspond to the productivity "estimate" of 10%-20%.
Benjamin Smith, John Deere	input cost savings and yield increases in U.S. grain production	about 2011	presentation slides	2012	Per acre estimates and description of case studies which were used to get national totals are not provided.	Input cost savings a minimum of $8.2b including reduced chemical and fertilizer $4.8b, reduced seed costs $1.5b, reduced fuel consumption $0.5b and labor saving $1.4b. In addition, minimum of $6 billion annually in improved yield as a result of changes in processes. Input costs do not include savings or additional costs of equipment.
McCallum	yield increases in Australia	2004-2006	report	2011	Controlled experiment	8% increase in wheat yields with inter-row sowing. 84% higher canola yields on standing than slashed stubble and 31% higher on burnt stubble. 30% higher yield

Economic Benefits Are Underestimated

- Some sectors are not included in productivity and cost savings measures
  - Geographic information services and mapping other than nautical charts
  - Location-based services other than vehicle, including asset tracking and locating people
  - Forestry, fisheries, mining, and energy exploration and development
  - Land and coastal management
  - Weather, scientific applications and space
- Parts of others are not included
  - Non-grain agriculture
  - Construction other than earthmoving
  - Use of GPS in aviation for some Area Navigation (RNAV) Standard Instrument Departure Routes (SIDs) and Standard Arrival Routes STARS) and Required Navigation Performance (RNP)
  - Rail other than positive train control
- Some estimates are conservative
  - Value of time in non-fleet commercial and consumer vehicle transportation
- Some types of benefits are not included
  - Benefits of GPS timing applications
  - Avoided income loss, property damage and medical costs associated with reduced accidents and improved emergency response

Benefit Estimates for GPS for Timing Are a Minimum

- Benefits of applications using GPS for timing are not included because of insufficient data
- Benefits are estimated by the costs that are avoided by not having to install eLoran or a system of GEOs in the absence of GPS precise time
  - **The concern was not to attribute all of the benefits of timing to GPS when there was no basis for apportioning them**
  - Also, there was concern that 1) assuming earlier technologies would remain in place was not realistic, but that 2) assumptions about how alternatives would have evolved in the past would not have provided robust estimates
  - However, assumptions about the evolution of technology use can be more accurate, even though less precise

Summary of Preliminary 2013 US GPS Benefit Estimates

A. Confident

B. Indicative

C. Notional

	Application Category	Range of Benefits ($ billions)	Mid-range Benefits ($ billions)
A	Precision Agriculture – grain*	10.0-17.7	13.7
A	Earthmoving with machine guidance in construction*	2.2-7.7	5.0
A	Surveying	9.8-13.4	11.6
A	Air Transportation	.120 -.170	0.145
C	Rail Transportation – Positive Train Control	.010-.100	0.055
C	Maritime Transportation – nautical charts and related marine information	.106-.263	0.185
A	Fleet Vehicle Connected Telematics*	7.6-16.3	11.9
A	Timing 1 – Loran	.025-.050	0.038
A	Timing 2 – GEOs	.025-.075	0.05
B	Consumer Location-Based Services 1 – vehicle – willingness-to-pay*	4.7-6.3	5.5
A	Consumer Location-Based Services 2 – vehicle – value of time	9.8-31.4	20.6
	TOTAL (with alternative estimates for timing and consumer LBS averaged)	**37.1-74.5**	****68.7**

*** Includes indirect benefits from cost savings. Mid-ranges of alternative estimates are averaged.**

GPS economic benefits as measured thus far are about 0.4% of GDP. This does not include sectors that were omitted, some indirect benefits, economic benefits induced by each sector in the rest of the economy, or benefits to health, safety and the environment.

Additional Indications

Spending provides a minimum estimate of the value of services to users. Some users would have been willing to pay more than market prices (consumer surplus). Consumer surplus can be less than half of spending or even larger than spending.

For LBS and GIS, definitions and measures can vary greatly and often are not explicit.

Location-Based Services

- Frost & Sullivan estimated the *global* LBS market at €$22.8 billion in 2012 and forecast €32.0 billion in 2015
- Market and Markets estimated *global* LBS revenue at $8.1 billion in 2014
- Berg Insight estimated *North American* LBS revenue at $835 million in 2012

The US can be assumed to spend 20%-25% of the world value and about 80% of the North American value.

Geographic Information Systems

- BCG estimated the revenue of the U.S. GIS industry at $73 billion in 2011
- The global GIS market will reach $10.6 billion in 2015 according to a report of Global Industry Analysts in 2013
- The Canadian Geomatics study found private sector spending of $2.3 billion in 2013. If U.S private spending was the same percentage of GDP it would be $23.6 billion

Note: Not all of the revenue included in the estimates shown is enabled by GPS, when it is, the contribution of GPS is not separated, and some components may be included in estimates for other sectors.

CONCLUSIONS AND NEXT STEPS

What's Missing?

- Large gaps exist in information on productivity and cost savings
  - Existing studies often predate major technological advances while use of GNSS is increasing rapidly in many sectors
- Information on market size, penetration and growth from market research firms, which tends to capture recent developments, is based on greatly varying sources and methods, resulting in major gaps and great divergence in estimates, especially in new areas like LBS
  - Often definitions and descriptions of methods are insufficient or not provided and information is largely proprietary
- The North American Industrial Classification System (NAICS) and its use in federal data collection such as in the Economic Census lags far behind in recognizing new categories and providing sufficient detail
  - GNSS user equipment was consolidated into much larger categories a few years ago. An Internet category was first added in 2012
- Projections of markets and benefits of applications can be very helpful in gaining attention, but they are not being done specifically for GPS or GPS in the US

Lessons Learned for Research and Data Needs

- Systematic research is needed to fill in gaps in adoption, productivity and cost savings with comparative before and after studies as well as with case studies
- Robust studies require major and often multi-year efforts of targeted data collection which are rarely done by government or academics for GNSS
- Information needs to be much more granular, taking into account specific functions in which GNSS is used (e.g. plowing, seeding, fertilizing, harvesting), specific GNSS and non-GNSS technologies used in each, and extent of their use
- Lags in data collection and research lead to understatement of the use and benefits of GPS
- Special efforts are needed to assess the impacts of rapid integration of technologies
- The use of augmentations and the increasing use of other GNSSs should be tracked for major applications

Safety and Health Benefits, Which Are Not Included So Far, Are Expected to Be Very Large

- Safety and health benefits include avoidance of injury, death and disability
- Large safety benefits can be expected in
  - Vehicle and other transportation
  - First responder emergency services, search and rescue and use of location-based services to avoid or deal with emergencies
- There also can be reduced loss of benefits of services from risk avoidance
  - This may be reflected in greater use of services when they become safer or reduced use when they are less safe, or in customers' willingness to pay to avoid risks
- Avoided income loss, property damage and medical costs can be examined along with non-economic safety benefits because they often involve the same sources of data

Further Research That Would Be Useful in This Study (1 of 2)

1. Develop benefit estimates for **additional sectors** where possible, including sectors for which estimates could not be made in Part 1
2. Refine economic benefit estimates and update based on additional data and reports and more extensive interviews
3. Examine technologies in greater detail and seek expert opinion to better assess the shares of benefits attributable to GPS in each sector
4. Estimate economic multipliers and assess impacts of GPS on **tax revenues and jobs**
5. Estimate selected values of current **benefits in safety and reduced loss of life** in critical applications and explore possible magnitudes of environmental benefits

Further Research That Would Be Useful in This Study (2 of 2)

6. Estimate the nature and orders of magnitude of benefits of GPS to **other regions and the world**

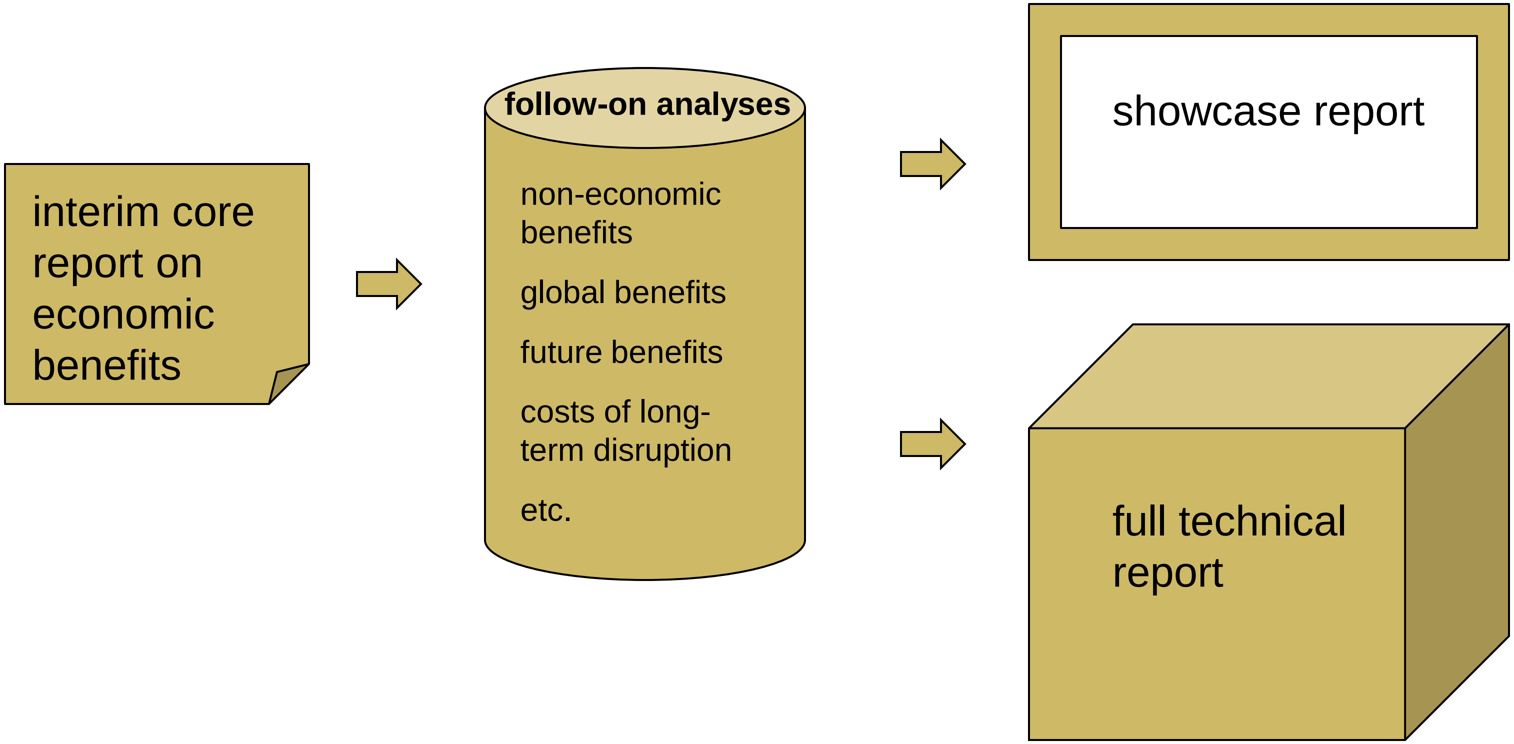
7. Assess potential future applications and markets and make projections of **future** market penetration and values of economic and safety **benefits** of GPS to the U.S. **under alternative scenarios**

8. **Estimate orders of magnitude of current economic costs of partial and complete long-term loss of GPS availability in selected applications** under alternative scenarios, including rough estimates of economy-wide impacts

9. Conduct **further analyses of the costs of loss of GPS** and explore possible values **in the context of rapidly evolving future use**

10. **Integrate analyses and findings into 1) a "showcase report" designed to appeal to a general audience, and 2) a full technical report and briefings covering all stages of the analysis**

Interim Report Flows Into Next Stages and Final Reports



Next Steps

- Address comments from the PNT Advisory Board Meeting
- Draft the Interim Core Report
- Circulate the report for comment and finalize the report
- Provide any requested briefings on the analysis
- It would be useful to extend and refine the analyses of economic benefits in Part 1 – either before proceeding with Part 2 or by allowing for it in Part 2

THANK YOU

APPENDIX A: BENEFIT ESTIMATES

Estimating GPS Benefits for Precision Agriculture

- The focus is on grain and large farms because of importance and availability of data
- The market value of grain sold in farms with sales of $250 million or more in 2012 was $111.5 billion after excluding government payments and non-grain items
  - This is taken as the value for 2013
- Systems using GNSS are estimated to save 10%-15% in operating costs and purchased inputs based on a composite of estimates of several studies
- Yield increases associated with improved plant health are estimated to increase yields by 8%-10%
  - These are in addition to cost savings and also applies to both operations and purchased inputs
  - They includes surveying only if integrated with machines

- Adoption of any GPS technology on heavy equipment is taken as 68% in 2013 based on John Deere estimate for large grain farms of 65% in 2011 and 70% in 2014
- The contribution of GPS vs. other technologies and GNSSs associated with its use is assumed to be 60%-70%

Calculation of Grain Farming Productivity Gains Associated with GPS in Large Grain Farms

	18% productivity gain	25% productivity gain
line 1. market value of grain products sold in 2013 net of government payments	$111.5	$111.5
line 2. value before productivity gain = 1/(1- fraction of gain) x line 1	$136.0	$148.7
line 3. productivity benefits if 100% adoption = line 2 x % productivity gain	$24.5	$37.2
line 4. benefits with adoption rate of 68% applied to line 3	**$16.7**	**25.3**
line 5. % of benefits assumed attributable to GPS vs. other technologies and GNSSs	60%-70%	60%-70%
line 6. adjusted benefits of GPS in grain farming (line 4 x line 5)	***$10.0-$11.7***	***$15.2-$17.7***

The range is $10.0-$17.7 billion and the midpoint of the range is $13.9 billion.

Estimating GPS Benefits in Earthmoving

- Sufficient information on GNSS-related impacts on construction is available only for earthmoving
- Productivity improvement of 10%-30% in earthmoving has been found in several studies
  - Since the wide range reflects variation in activities, sites and equipment, a more realistic range of 18%-22% is used for the industry as a whole
- The value of construction put in place was $898.4 billion in 2013
  - Total value is used instead of value added to include savings in purchased inputs
- The share of earthmoving is estimated at 8%-12% based on:
  - A 2013 Australian study that placed its value at "up to approximately 10-15% of non-residential construction"
  - A 2011 survey of members of the Commercial Real Estate Development Association that found site development costs at 16.6% of total costs

    Site development costs include grading, infrastructure, parking and landscaping

- Adoption rates apply to use of any GPS-related machine technologies
- Adoption of 20%-25% is estimated based on a 2013 study in Australia and a 2012 survey of state DOTs
  - Allows for higher use in the U.S. than Australia and growth after 2012
- The contribution of GPS vs. other technologies and GNSSs associated with its use is assumed to be 80% to 90%

Calculation of Earthmoving Productivity Gains Associated with GPS

	18% productivity gain		22% productivity gain	
	earthmoving 8% of construction	earthmoving 12% of construction	earthmoving 8% of construction	earthmoving 12% of construction
line 1. value of construction put in place in 2013	$898.4	$898.4	$898.4	$898.4
line 2. 2013 earthmoving value at 8% or 12%	$71.9	$107.8	$71.9	$107.8
line 3. value before productivity gain = 1/(1- fraction of gain) x line 2	$79.9	$154.0	$79.9	$154.0
line 4. productivity benefits if 100% adoption = line 3 x % productivity gain	$14.4	$27.7	$17.6	$33.9
line 5. benefits with adoption rates of 20%-25% applied to line 4	**$2.8-$3.6**	**$5.5-$6.9**	**3.5-$4.4**	**$6.8-$8.5**
line 6. % of benefits assumed attributable to GPS vs. other technologies and GNSSs	80%-90%	80%-90%	80%-90%	80%-90%
adjusted benefits of GPS in earthmoving (line 5 x line 6)	***$2.2-$3.2***	***$4.4-$6.2***	***$2.8-$4.0***	***$5.4-$7.7***

The average of the adjusted benefit estimates is $4.5 billion, the mid-range is $5.0 billion and the range is $2.2-$7.7 billion.

Estimating Cost Savings in Surveying

- Surveying is defined to include all land surveying, whether in private survey firms or in business and government organizations
  - Includes both horizontal and elevation measurement
  - Does not include surveying that is integrated with a dozer or other machinery
- Estimated 45%-55% savings over traditional surveying over all types of land surveying, including with various augmentations, as a composite of a large number of studies
- Size is estimated at $12.5 billion based on revenue in private surveying and mapping firms and employment data
- Adoption of modern surveying is 100%
- 80%-90% is assumed to be attributed to GPS vs. other technologies and GNSSs

Calculation of Surveying Productivity Gains		
	45% productivity gain	55% productivity gain
line 1. value of surveying in 2013 (billion)	$12.5	$12.5
line 2. value before productivity gain = 1/(1- fraction of gain) x line 1	$22.7	$27.8
line 3. productivity benefits at 100% adoption = line 2 x % productivity gain (billion)	**$12.3**	**$15.3**
line 5. % of benefits assumed attributable to GPS vs. other technologies and GNSSs	80%-90%	80%-90%
line 6. adjusted benefits of surveying (line 4 x line 5) (billion)	**$9.8-$11.1**	**$12.2-$13.4**

The range of the adjusted benefit estimates is $9.8-$13.4 billion and the midrange is $11.6 billion.

1. Costs of eLoran As an Alternative to GPS

- The Institute for Defense Analysis January 1999 report estimated 20-year infrastructure and operating and maintenance costs at about $67 million per year for a full system
- The Volpe November 1999 benefit cost assessment refresh estimated costs at about $30 million per year for a full system
  - These numbers do not include decommissioning costs
- The upgrades of Loran C are assumed not to have been completed by 2013, the base year for this analysis
- Based on the two studies an estimated cost of $25-$50 million per year is used as the alternative cost of a configuration that would have been completed and adapted to by users in 2013

2. Cost of GEOs As an Alternative to GPS

- Precise time could be provided with a system of 3 geostationary satellites, 1 to cover CONUS, 1 for Alaska and 1 for redundancy
- Very preliminary calculations by Tetra Tech AMT, a consultant to FAA, done for this study suggest a cost somewhat higher than $50 million per year
  - The estimate was based on small satellites with clocks. Other possibilities include rented or shared space on other satellites and clocks on the ground
  - 2-way satellite transfer was not considered viable since each user would have to do their own broadcasts and that would be expensive
- Using the cost of eLoran or GEOs as an alternative, the value of GPS for timing is likely in the range of $25-$75 million per year

GPS in U.S. Aviation

- Area navigation (RNAV) provides flight procedures for properly equipped aircraft
- Required Navigation Procedures (RNP) define the level of performance required for a specific block of airspace
- The Wide Area Augmentation System (WAAS) augments the GPS signal to improve accuracy during all phases of flight
  - Performance-Based Navigation (PBN) includes RNAV, RNP and WAAS
- Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance system using GPS that enables an aircraft to determine its position in relation to a satellite and broadcast the position so the aircraft can be tracked. It is an alternative to radar. ADS-B was used very little in 2003.
- A Ground-Based Augmentation System (GBAS) augments GPS by providing corrections to aircraft in the vicinity of an airport in order to improve accuracy and provide integrity for GPS navigational positions

For navigation, GPS is the principal position source for those aircraft equipped with RNAV or RNP, and is the only position source for satellite-based augmentation systems (SBAS or WAAS)

- GPS was used in 2011 by 5,800-7,250 passenger cargo and regional U.S. operated aircraft, 2,800-4,000 international operators' aircraft, 61,000 instrument flight rule-approved GPS navigation and general aviation and air taxi aircraft, and 310,000 pilots without instrument ratings (Molly Smith, FAA, presentation to the PNT Advisory Board, August 14, 2012)
- No other GNSS constellation system is certified for aircraft use in the U.S.

Estimates of Economic Benefits of GPS in Air Transportation

- The FAA NextGen Systems Analysis Office estimated in 2011 that GPS provided at least $200 million in efficiency benefits for aviation each year (Joel Szabat, DOT, testimony regarding LightSquared, July 21, 2011)
- The 2009 WAAS Business Case Analysis Report found economic benefits to users compared to instrument landing systems (ILS) of $46 million, of which $39 million was savings in passenger time. Aircraft operator cost savings were not included
  - The projection for 2013 was $122 million
- The NextGen Systems Analysis Office prepared new estimates for 2013 for this study with a contribution from MITRE
  - Benefits came primarily from flight efficiency (time and fuel) with Performance-Based Navigation (PBN) and reduced delays in taking off to airports with low visibility made possible by WAAS
  - The analysis attributed benefits of $198 million to systems using GPS including WAAS
- To obtain a value for benefits of GPS, this is modified to $120-$170 million to roughly exclude the contribution of other components of the systems and equipment using GPS, such as communications, weather information and databases
  - This is a minimum estimate since the analysis didn’t include Area Navigation (RNAV) Standard Instrument Departure Routes (SIDs) and Standard Arrival Routes (STARS) or Require Navigation Performance (RNP) which may use GPS

Railroad: GPS Benefits

- The focus of benefit estimation is on Positive Train Control (PTC) because it accounts for much of GPS benefits to railroads and several studies have been done
- PTC is a family of technologies that often include RF communications and GPS positioning to keep track of train locations and movement authorities
- The Federal Railroad Administration (FRA) 1999 PTC Working Group defined the core functions of PTC to include:
  - Prevention of train-to-train collisions (positive train separation)
  - Enforcement of speed restrictions, including civil engineering restrictions (curves, bridges, etc.) and temporary slow orders
  - Protection of roadway workers and their equipment

Other uses of GPS besides PTC include:

Track defect location

Locating trucks with rail workers (high limit compliance)

Readers in freight cars to track them (still experimental)

Using track geometry to find defects

- The Rail Safety Improvement Act of 2008 expanded the core functions of PTC to also include:
  - Prevention of movement through misaligned switches
  - Seamless interoperability between different rail carriers

PTC Implementation and Its Implications for GPS Railroad Benefits

- Railroads are far behind the December 31, 2015 deadline for implementation of PTC
  - PTC has been installed on about 8,200 miles of track out of 60,000 miles that are federally required
  - At the end of 2014, about 15% of locomotives were fully equipped and railroads had installed about 56% of the track systems
  - Only 1 or 2 rail lines are expected to meet the deadline. For most completion is expected in 2017-19
- Costs have been coming in much higher than expected, double and more in the public cases
  - However, railroads may get greater than projected business benefits from use of GIS databases to support maintenance and track planning and from optimizing trips and changing signal systems for efficiency

- Railroads that have completed implementation of track, back office, wayside and communications subsystems can still get safety benefits but many have not
- Business benefits depend on the functionality implemented

Positive Train Control Economic Benefit Estimate for 2013

- Estimates of PTC efficiency benefits vary greatly among studies because of differing definitions of PTC and partisan interests
- Because of the difficulties in deriving unbiased estimates a wide range is used based on the high and low from available studies
  - Economic benefits include both benefits to railroads and those passed on to shippers
- The range of benefits is roughly $0.5-$2.5 billion per year at full implementation
- Adoption in 2013 is assumed to provide 5%-10% of benefits that would occur at full implementation
- That places 2013 benefits at $25-$250 million per year
- Assuming 40% of benefits are attributable to GPS* results in benefits of $10-$100 million

*Allowing for some PTC not using GPS and for GPS being used with other technologies.

Ship Systems that Incorporate GPS

- GPS receivers that display constant latitude and longitude positions
- Integrated ship systems
  - Global Marine Distress and Safety System (GMDSS)
  - Electronic Chart Display and Information System (ECDIS)
  - Radar/ARPA displays
  - Ship Steering Systems utilizing GPS Waypoints
  - Ship Security Alert System (SSAS)
  - Emergency Position Indicating Radio Beacon (EPIRB)
  - Automatic Identification System (AIS)
  - INMARSTAT or Fleet Broadband Terminals
- Many pilot organizations in the U.S. also use DGPS pilot laptop systems with electronic charts with enhanced features to promote safer transits than the ship's equipment alone is capable of providing

Several ship systems rely on U.S. Coast Guard messages for identification and tracking, vessel traffic services, weather and safety broadcasts, and distress and rescue assistance

Source: Szabat, Joel, "Letter to Karl B. Nebbia, Associate Administrator, National Telecommunications and Information Administration, on the impact of the LightSquared Concept of Operations, and Appendices," U.S. Department of Transportation, Office of the Secretary, July 21, 2011 http://science.house.gov/sites/republicans.science.house.gov/files/documents/Letters/2011%2007%2021%20DOT%20LSQ%20Impact%20Assessment.pdf

Maritime Benefits from Nautical Charts and Related Navigation Information (1 of 2)

- Maritime benefits of GPS are estimated based on the value of nautical charts and related systems
- An estimate of the value of electronic nautical charts above the value of paper charts for commercial and recreational boating was made by Kite-Powell (2007) using survey data from 2005-2006
  - Since the benefits are those above paper charts they do not include the benefits of the data collection and charting required to produce charts at the level of those on paper
  - Benefits applied to “ideal” rather than currently available charts and were measured by consumer surplus
- Willingness-to-pay likely includes some safety as well as economic benefits to users. However, it may not put full value on the economic benefits to others. These influences are assumed to be off setting and the estimates are taken as economic benefits
- Leveson (2012) updated the estimates to 2011 based only on industry size, added commercial fishing, and calculated total benefits including spending and consumer surplus of $236.2-$262.5 million

Maritime Benefits from Nautical Charts and Related Navigation Information (2 of 2)

- Benefits of the systems available in 2013 are assumed to be 50%-100% higher than those in the more limited calculations for 2011 because of the increase in the number of ship systems using GPS since 2005. That places benefits at $354.3-$525.0 million
- There is no specific way to allocate a share of benefits to GPS relative to the contributions of databases, software, communications systems and other elements of navigation
- However, many of the other systems would not come into play if there were no GPS and alternative means of navigation would be required
- The annual contribution of GPS to economic benefits, including that of augmentations, is assumed to be 30%-50% of the total or $106-$263 million
- In comparison,
  - The NOAA NOS Physical Oceanographic Real Time System (PORTS®) Program which provides information on tides, currents, salinity, wind and other measures to ships in major ports was estimated to be able to save $170 million per year in economic benefits as a result of increased cargo capacity if it had been applied to 175 ports nationally
  - The European GSA 2015 GNSS Report estimated maritime core GNSS device revenue in North America at about $250 million (read from chart)
  - Frost & Sullivan estimated the *global* market for maritime GNSS applications at $1.63 billion in 2012

Vehicles and Telematics Use

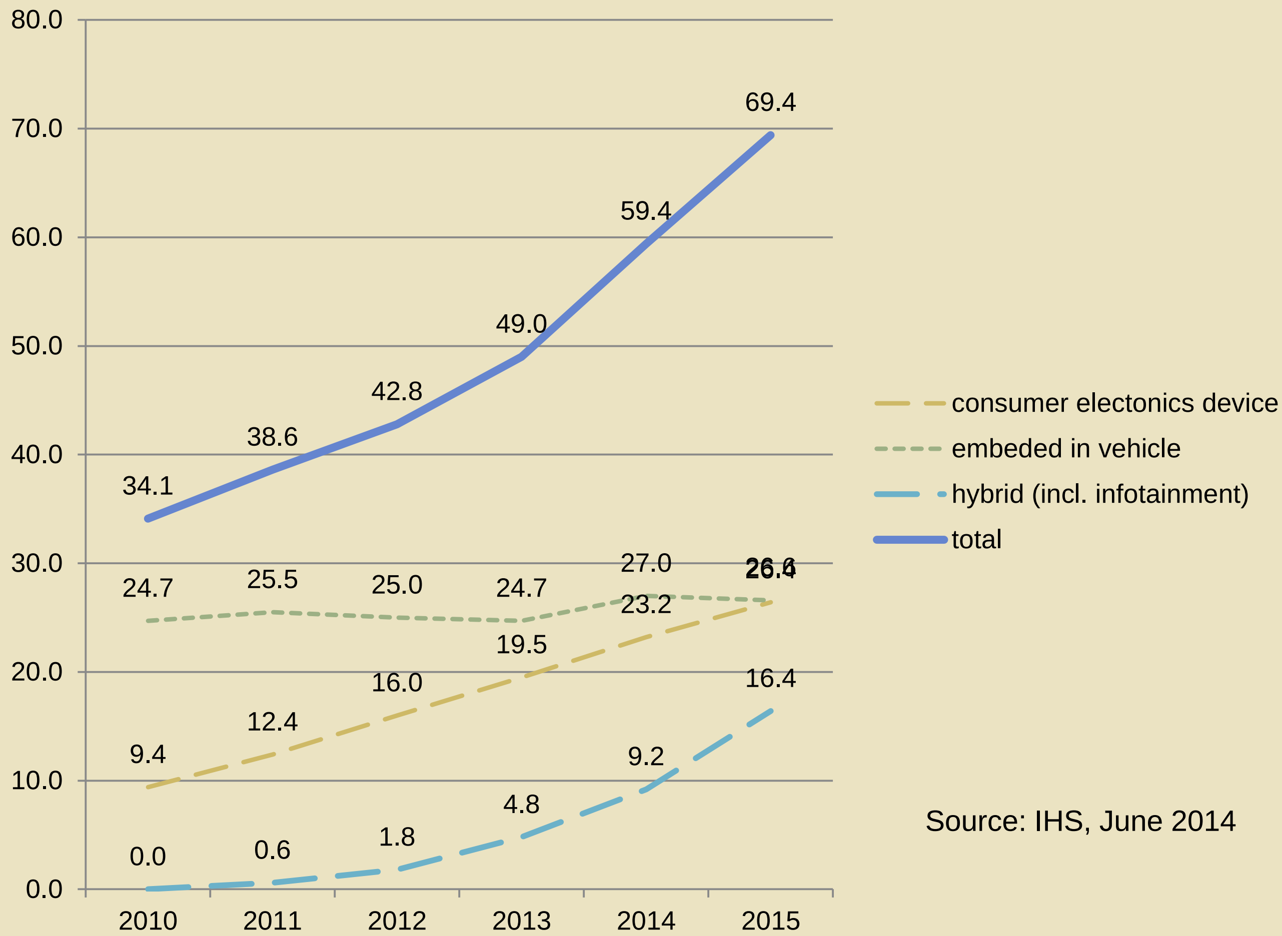
- 244.4 million vehicles were in use in 2012 according to the Federal Highway Administration; 251.5 million according to R.L. Polk
- 29.5% of vehicles had embedded or hybrid (including infotainment) systems installed in 2013 (IHS)
- An additional 19.5% of vehicles used personal navigation devices (IHS)
- 11.7 million fleet vehicles were in service in Jan. 2013, including leasing and government (Bobbit Publishing Co., *Automotive Fleet Factbook, 2013-2014*)
- The fleet management market was $10.9 billion in 2013 (Fleetmatics *Fleetbeat Report*, 2014)
- 12.6% of all commercial [fleet] vehicles in the U.S. and Canada were optimized by a fleet management telematics solution in 2012 (Frost & Sullivan study conducted for Fleetmatics)

Telematics is generally defined to include the combination of computer and mobile communications systems.

Vehicle telematics also relies on GPS, and on maps and other databases. Maps themselves rely on GPS.

Vehicle Telematics Adoption, Actual and Projected. 2000-2015

(percent)



Source: IHS, June 2014

Fleetmatics Study of Benefits of Vehicle Telematics

- In the 2014 *Fleetbeat Report*, Fleetmatics compared its customers – roughly 20,000 commercial fleets and 417,000 actively subscribed vehicles in the U.S. and Canada – before and after using a fleet management system. The study found:
  - A 13% increase in stops after implementing a fleet management solution
  - A 15% increase in utilization of vehicles
  - A 20% decrease in the average workday from 10.6 hours to 8.5 hours across verticals (types of businesses) studied
  - Annual fuel cost savings worth $540 per vehicle per year from reduced driving and idle time
  - If the technology were applied to all commercial vehicles in the U.S. and Canada with the results of Fleetmatics customers, there would have been fuel savings of $2.2 billion, 1.3 billion fewer payroll hours and payroll savings of $34.9 billion

The Fleetmatics study is significant because of the large number of vehicles and the sophisticated information systems of the company.

The 12.6% estimate of adoption of vehicle telematics is much lower than the IHS data which includes much more than connected systems.

Note: The U.S. is 88.9% of the U.S. plus Canada total of all vehicles.

Estimating Direct Fleet Vehicle Benefits from Telematics

- The number of fleet vehicle in the U.S. with telematics is 1.4 million based on 12.6% adoption in 11.7 million fleet vehicles
- Fuel savings are $748 million for U.S. fleet vehicles with telematics based on the Fleetmatics estimate of $540 per vehicle per year
- Payroll savings are 16.22 times as large as fuel savings in Fleetmatics extrapolation of telematics benefits if they applied to all commercial vehicles. This ratio is multiplied by the estimate of fuel savings to derive a value of payroll savings for fleet vehicles with telematics of $12.13 billion
- For the remainder of value added, the Fleetmatics finding of a 15% increase in vehicle utilization is used
  - Since Fleetmatics found a 20% saving in payroll for fleet users of telematics, the 15% benefits for increased vehicle utilization are ¾ of those for payroll times the ratio of non-payroll value added to payroll as calculated below
    - First the ratio of payroll to value added is calculated by multiplying the ratio of revenue to value added for commercial vehicle transportation industries from NIPA and the 2012 Services Annual Survey. This is multiplied by the ratio of payroll to revenue for the total of the truck and the transit and ground passenger transportation industries using data from the 2012 Economic Census
    - The ratio of revenue to value added is 2.04 and the ratio of payroll to revenue is .258. Multiplying the two yields 0.526 for the ratio of payroll to value added. Hence the ratio of non-payroll to value added is 0.474
  - The ratio of non-payroll value added to payroll is 0.474/0.526 or 0.901. Multiplying this by ¾ of the value of fuel savings or $9.10 billion yields $8.20 billion as the value of savings in non-payroll value added, which is referred to as “other direct savings.”

Direct and Indirect Benefits from Fleet Telematics and the Contribution of GPS

- Combining the estimates, the direct benefits of vehicle telematics for fleet vehicles are:
Payroll savings	$12.13 billion
Other direct savings	$8.20 billion
Total	$20.33 billion
- Purchased inputs are about the same magnitude as all of value added based on the Economic Census data for commercial vehicles, so savings can substantial
  - Savings can come from reduced purchases of vehicles and other equipment, tires and other parts, maintenance and repair, insurance and other items as well as fuel
- Assuming savings in indirect costs were 50%-100% of savings in direct costs they would be $10.16-$20.33 billion (including fuel savings) and the combined savings in direct and indirect costs would be $30.49-$40.66 billion
- While GPS is indispensable, a number of other technologies are as well. Consequently, the contribution of GPS is placed in a wide range of 25%-40%
- The resulting direct benefits from GPS are $5.08-$8.13 billion and the combination of direct and indirect benefits are $7.6-$16.26. The midpoint of the range of combined benefits is $11.93 billion

Benefits of Consumer LBS – Vehicle – Estimate 1: Willingness-to-Pay (1 of 2)

- This estimate is for consumer and commercial benefits other than connected fleet telematics. It includes use of vehicle or cell phone navigation systems and personal navigation devices
- A study by Patel examined U.S. consumers' willingness to pay for maps and directions on mobile phones in 2008 when use of personal navigation devices was still dominant Half of respondents were willing to pay for maps and directions. The average amount was $3.80 per month (read from graph) which equals $45.60 per year
- Google announced free cell phone navigation in October 2009 and others followed. Before the shift the typical charge for phone navigation was $10 per month, albeit with few users
- The price for mobile services since is being paid for by advertising on navigation and mapping apps and by collection of location data that supports even more advertising
- A McKinsey study of the value of Web services by Bughin for the U.S. and Europe found that consumers would be willing to pay one third of their perceived value of free services on the Web to avoid advertising clutter and privacy concerns
  - Since privacy is much more of a concern in Europe that the U.S. but advertising clutter may be greater in the U.S., the percent is taken to be 25% of perceived value in the U.S.
- It is assumed that mobile navigation and maps were worth $5 per month or $60 per year to U.S. consumers in 2013 after deducting for unwanted aspects. This allows for increased capabilities and hence value of mobile mapping and directions between 2008 and 2013

Benefits of Consumer LBS – Vehicle – Estimate 1: Willingness-to-Pay (2 of 2)

- Many people paid far more than $60 per year in 2013, often paying $1,500 for a navigation system which translates into about $150 per year over the life of the vehicle or the system.
- IHS estimated that 29.5% of autos were equipped with an embedded system vs.19.5% that used a personal navigation device or cell phone. Using $150 for 29.5% and $60 for 19.5% puts the average at $124.50. This doesn't yet count the surplus – the value to some embedded system users above their purchase price. The average value to consumers is therefore taken to be at least $130 per year
- A count of commercial vehicles is not publicly available and the public IHS data does not distinguish between commercial and personal vehicle telematics use. As a result, an estimate of benefits of vehicle navigation is made that combines consumer use with commercial use other than for commercial connected telematics systems in fleet vehicles.
- The average of the number of vehicle in 2012 reported by the Federal Highway Administration and R.L. Polk is 248 million. With 49% using any vehicle telematics systems in 2013, the number of users is 121.5 million.
- With 121.5 million users of any type of vehicle telematics except connected fleet systems and benefits of $130 per year, the total value of benefits is $15.8 billion
- Consumer navigation and location applications depend on software, maps and communication systems as well as GPS. However, the maps depend on GPS. The share of benefits attributable to GPS is assumed to be 30%-40% of the $15.8 billion or $4.7-$6.3 billion

Benefits of Consumer LBS – Vehicle – Estimate 2: Value of Time (1 of 2)

- Levinson tabulated 10 earlier studies containing estimates of time saved with advanced traveler information systems such as those expected to appear in vehicle navigation systems. The median value of time saved was 7%, among estimates with a wide range
  - This is the most generalizable of the studies available because of the number of studies and range of conditions covered
- There were 122.46 million households in 2013 of which 90.8% or 111.19 million owned a vehicle. Multiplying by an adoption rate of 49% yields 54.48 million household users
- The Federal Highway Administration estimated that the average household travelled 19,900 vehicle-miles in 2009. If users of navigation travelled the same number of vehicle-miles their total number of miles would have been 1.084 trillion
- If the travel took 2.0 minutes per vehicle mile (30mph) the total time using the systems would be 2.168 trillion minutes
- If 7% of that time were saved with a phone or vehicle navigation system, the savings would be 152 million minutes or 2.53 million hours (4.6 hours per household)

Benefits of Consumer LBS – Vehicle – Estimate 2: Value of Time (2 of 2) and Combined Estimate

Value of Time Method (continued)

- Applying the Department of Transportation's value of personal time of $34.50 per hour (70% of the business rate) to savings of 2.53 million hours would result in a value of $87.3 billion.
- A more conservative assessment comes from The Transportation Research Board (TRB) of the National Academies, Transportation Economic Committee, which states that: "Personal travel time is usually estimated at 25% to 50% of prevailing wages."
- The conservative range is used to reflect a variety of economic factors. Taking 25%-50% of the DOT business hourly rate yields $15.50-31.00 per hour. This values the 2.79 billion hours at $39.22-$78.43 billion.
- Consumer navigation and location applications depend on software, maps and communication systems as well as GPS. However, the maps depend on GPS
- If GPS contributed 25%-40%, its value based on time saved would be $9.8-$31.4 billion, with a midpoint of $20.6 billion.

Combining the Willingness to Pay and Value of Time Estimates

- Averaging the highs and lows of two methods results in a range of $7.3-$18.9 billion, with a midpoint of $13.1 billion

APPENDIX B; APPLICATIONS AND MARKETS

Snippets

Snippets are indications of varying scope, definition and quality, that illuminate market size, character and/or direction. These indicate aspects of the environment in which GPS operates and to which it contributes

- 900 million mobile phones were sold globally in 2012 that incorporated GPS (Frank Van Diggelen, "Who's Your Daddy: Why GPS Will Continue to Dominate Consumer GNSS," *Inside GNSS*, March/April 2014)
- The U.S. had 188 million smart phone subscribers and 263 million Internet users in 2013 (Mary Meeker, *KPCB Internet Trends 2014* based on several sources)
- 20% of U.S. mobile phone users get up-to-the-minute traffic or transit information (DOT, *Beyond Traffic*, *2015*)
- The new industry category "Internet publishing and broadcasting and web search portals" had revenue of $87 billion and 181,000 employees in 2012 (U.S. Census Bureau, *2012 Economic Census*)
- Google estimated that it generated $54 billion of economic activity for U.S. businesses, website publishers and non–profits in 2009 (Google, *Google's Economic Impact*, United States, 2009)
- Facebook estimated that it enabled $104 billion of economic impact and 1.2 million jobs in North America in 2014 (Deloitte, *Facebook's Global Economic Impact*, January 2015)
- Google Play and the Apple App Store each had more than 1.2 million apps in 2014 (www.statistica.com)
- In OECD countries, gaining 4 Mbps of broadband increases household income by USD 2,100 per year (Ericsson, Arthur D. Little and Chalmers University of Technology, *Socio-Economic Effects of Broadband* Speed, September 2013)

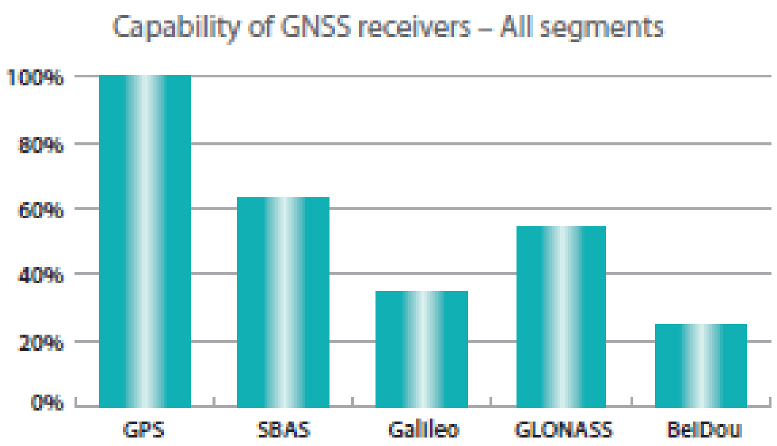
GSA GNSS Market Report 2015: Some Findings

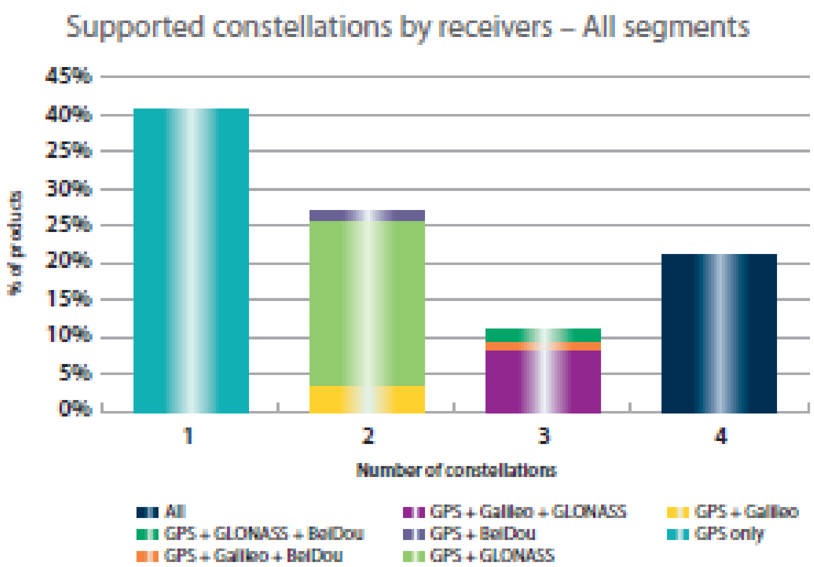
- 3.6 billion GNSS devices were in use globally in 2014
  - 3.08 billion were smart phones and .26 billion were for road
- North America had about 450 million devices installed (about 80% U.S.)
  - North America had 1.4 devices per capita in 2014
  - North American shipments were 250-300 million in 2013 (read from chart)
- Global core revenue was estimated at roughly €62 billion and enabled revenue at €227 billion in 2014 (read from chart)
  - Core revenue includes GNSS devices, software and services while enabled revenue relates to applications
  - LBS was projected to account for 53.2% of 2013-2023 revenue and road 38%
  - (Core revenue has no relation to socio-economic value. Timing was 0.1%, aviation 1%)
- North American-based companies had a 44% market share of value-added services revenue in 2012

North America-Based Company Shares of Global GNSS Core Market, 2012		
	Component Manufacturers	System Integrators
LBS	80%	31%
Road	25%	21%
Aviation	63%	65%
Rail	41%	17%
Maritime	13%	35%
Agriculture	63%	46%
Surveying	62%	48%

Source: GSA GNSS Market Report 2015

Capabilities of Receivers Currently Being Offered by Manufacturers





Note: **Offerings, not share of purchases or installed base or extent currently using capabilities.** Based on an analysis of more than 300 receivers, chipsets and modules of 31 companies from publicly available information.

Source: GSA GNSS Market Report 2015

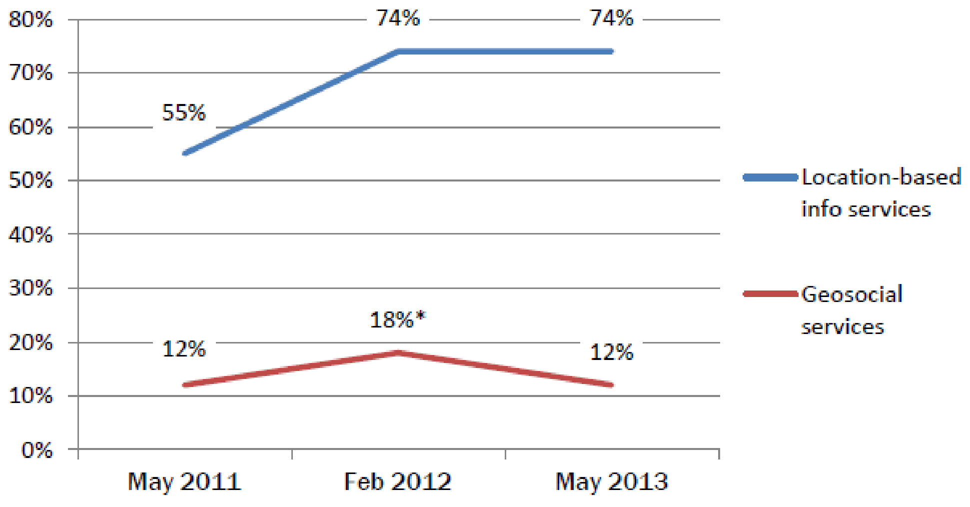
U.S LBS Use by Persons 18 and Older

- The Pew Survey of Internet and American Life found that:
  - 74% of smart phone owners say they use their phone to get directions or other information based on their current location
  - 30% say that at least one of their social media accounts is set up to include their location in their posts
  - 12% use a geosocial service to “check in” to certain locations or share their location with friends

Use of location-based information and geosocial services among smartphone owners, 2011-2013

For location services: % of smartphone owners who use their phone to get directions, recommendations, or other information related to a location where they happen to be.

For geosocial services: % of smartphone owners who use a service such as Foursquare or Gowalla to “check in” to certain locations or share their location with friends.



* Slight wording change since previous survey

Scope of GIS Market

- "A geographic information system (GIS) lets us visualize, question, analyze, and interpret data to understand relationships, patterns, and trends." (ESRI)
  - GIS application includes integration of technologies and types of information and analytics and modeling tied to location references
- Its many uses include business intelligence, supply chain tracking, asset management, reinsurance, environmental monitoring and disaster response

Nascent Applications Include

- Indoor positioning
- Mobile payment systems
- Wearables and prosthetics
- Internet of things
- UAVs and robotics
- Infotainment and other connected vehicle systems
- Intelligent Transportation Systems
- Autonomous vehicles
- NextGen and other aviation systems
- Global improvements in aircraft tracking
- Electronic tolling and insurance rate-setting
- Next Generation (NG) 911
- Improvements in environmental monitoring

APPENDIX C: RECENT BROAD BENEFIT STUDIES

NDP Analytics, *The Economic Benefits of Global Navigation Satellite System and Its Commercial and Non-Commercial Applications*, Dec. 2013

- Presented data from the European *2013 GNSS Market Report*
- Restated data on global GNSS markets from the NDP Consulting 2011 report that were based on proprietary ABI Research data
- Analyzed data on US manufacturing categories that were vastly larger than GNSS and described them as GNSS
- Cited various data on the size of LBS and other markets
- Cited findings of several studies of GNSS benefits, including BCG and Oxera
- Restated benefit data from the NDP Consulting 2011 report
- The study did not make any new estimates of benefits

Comparison of Leveson Current Study with NDP Consulting Study for the Coalition to Save Our GPS

Aspect	NDP Consulting (June 2011)	Leveson (in progress)
coverage of benefit estimates	commercial only	commercial, some consumer and some government
date of benefits	various years from 2005-2010	2013
upper limit of benefits	assumes 100% adoption without saying when or whether possible	upper limit is part of each sector's range of estimates
adoption rates	higher than available studies support	based on available studies
overall benefits	assumes the same ratio of benefits to equipment sales as in agriculture, construction and commercial vehicle for all other	calculates for each sector, selecting sectors for which information is most robust and/or economic importance
indirect benefits	includes all based on assumptions about their size and carries to other sectors	few estimates of indirect benefits since others were not supported by the literature
contribution of GPS	assumes 100% of benefits of an application are attributable to GPS	takes a rough percentage (range) as attributable to GPS

Comparison of Leveson Current Estimates with NDP 2011

- Agriculture
- NDP: $19.9b for crops
- Leveson: 13.7b for grain
- Construction and surveying
- NDP: heavy and civil engineering and surveying and mapping in construction $9.2b
- Leveson: earthmoving in construction ($5.0b) and all surveying ($11.6b) totaling $16.6b
- Vehicle transportation
- NDP: for commercial vehicle transportation $10.3b
- Leveson: $11.9b for fleet vehicle telematics plus $13.1b for the combination of consumer and non-fleet commercial vehicle telematics

Note: NDP numbers are the lower of the ranges since the assumption of 100% adoption in the upper range isn't a current estimate. Leveson estimates are midpoints of the ranges.

GSA Market Report Issue 3, Oct. 2013

- Includes extensive estimates and projections of GNSS market size and growth for Europe, North American and the rest of world global
- Contains estimates of "core" and "enabled" revenue
  - General approach is stated but the basis of estimates and sources is not provided
- Sector detail is provided for many categories spread over the series of GNSS market reports

Use of projections in the GSA reports has proven to be a powerful tool for generating interest.

Oxera GEO Services Benefits Study

- Provides global estimates of the economic impact of GEO services and four cases using data from various years and reported in 2003
  - GEO services are defined as all interactive digital mapping and location-based services, including satellite positioning signals
- Revenue is estimated by a “bottom up” method using data from companies in related activities and a “top down” method extrapolating global revenue from the U.S. estimate from the BCG study
  - The lower revenue estimate is thought by the authors to be an understatement. However, the higher estimated based on BCG is largely undocumented
  - A measure of gross value added which deducts the costs of inputs obtained from other sectors is also provided
- Quantitative benefit calculations of greatly differing reliability are made for:
  - Fuel and time savings from use of navigation devices in motor vehicles
  - The value of lives saved from reduced emergency response time for cardiac arrest
  - Illustrative effects of use of GIS in secondary education on future earnings
  - Implications of alternative assumptions about the savings from increased competition and search

BCG

- The Boston Consulting Group was charged with assessing the size of the U.S. geospatial services sector and the benefits to businesses and consumers. Years of the data are not specified
  - Geospatial services were defined as those that let decisions be made based on geographic data
  - The geospatial services industry was defined as “groups of companies and organizations providing the tools and technologies for end users to benefit from location-based information
- Information was reported in a 3-page report and a set of 9 slides issued in 2012
  - Estimates were provided for the size of the industry, the size of affected industries, jobs, cost savings to the economy and household consumer surplus.
  - Estimates of cost savings were huge at $1.4 trillion
  - Only limited information was provided on sources and methods

Boston Consulting Group Conclusions on Geo-spatial Services (including defense)

- The U.S. geospatial industry generated approximately $73 billion in commercial revenues in 2011 and comprises at least 500,000 high-wage jobs [including government jobs]."
- "Geospatial services are used on a daily basis by roughly 5.3M U.S. workers today."
- $1.6 trillion of revenues is heavily influenced by geospatial services.
- $1.4 trillion in cost savings annually is claimed by the study based on a survey of 1,000 business managers
- "…,U.S. consumers place a direct value on geospatial services at $37B annually…"

	Revenues ($ billions)	Jobs (thousands)
Geo-expert industries	2.6	125
Geo-applications and devices	54	175
Location-based geo-data	17	200
Total	72.8	500

Note: Revenue is commercial; jobs includes non-commercial.
Source: BCG, "Putting the U.S. Geospatial Industry on the Map," December 2012.

Leveson 2010 (Aerospace) - *Current U.S. Economic Benefits of GPS*: Basis

- Objective: To provide an overall estimate of present and future U.S. benefits of GPS, with detail on benefits in many sectors and applications and information on users and uses
  - Unofficial interim internal study of benefits for the National Coordination Office
    - Half of 2-year study; unfunded second phase was to refine estimates and focus on future benefits
  - Applications, users and market sizes were examined in a “bottom up” approach
  - “Ball park” estimates of civilian U.S. benefits in 2008 were built up from detailed estimates of major applications within 18 application areas
  - Includes multipliers for both indirect and induced benefits
  - Includes some non-economic benefits which were partly notional
  - Not all important applications could be included so the overall estimates were referred to as “at least”

Subsequent work extrapolates U.S. to 2025 under a preliminary notional baseline scenario that considers market growth and penetration in each covered application area and makes a rough calculation of global benefits

ACIL Allen – The Value of Augmented GNSS In Australia (2013)

- Consists of a summary report and reports covering 10 sectors
- Emphasizes productivity and related benefits in 2012
  - Relies on case studies, discussions with industry and findings of previous studies
  - For some sectors, the quality of the estimates is constrained by the limited numbers and scope of case studies and interviews. Quantitative benefit estimates are not provided for all sectors
  - Benefit information outside of Australia is not utilized
  - Market penetration rates appear to be very rough
- Aggregate effects are calculated using an econometric input-output model of the economy

Canadian Geomatics Environmental Scan and Economic Value Study

- Natural Resources Canada's Mapping Information Branch, in collaboration with the Canada Centre for Remote Sensing and the Surveyor General Branch, commissioned a study to include:
  - The state of the geomatics sector in Canada
  - Global trends involving geospatial information and Canada's position relative to those trends
  - The significance and value of the geomatics sector and geospatial information to the Canadian economy
  - The current new and alternative roles for government, industry and academia in driving, supporting and using geospatial information
- The economic value study estimates the direct and indirect value and contribution to the Canadian economy and determination of the value of open geospatial information within the Canadian economy
- The study was carried out by Hickling Arthurs Low in partnership with ACIL Allen Consulting, Fujitzu Canada and ConsultingWhere
- The summary report was released in May 2015 and two reports with more detailed are expected

Findings of the Canadian Geomatics Study Based on the Summary Report

- Firms in the private sector contributed $2.3 billion to Canada’s GDP in 2013
  - The sector includes location-based services, broadly defined, and appears to include navigation services
- Geospatial information use resulted in
  - $20.7 billion or 1.1% of GDP
  - 19.6 additional million jobs
  - A $2.8 billion increase in the net trade surplus
- The economy-wide effects are based on inter-industry and international relationships **estimated from productivity data for sectors** in a Computable General Equilibrium (CGE) model
  - The productivity estimates are not included in the summary report
- The results imply increases of over $1 million per added job. This is not surprising because productivity improvements reduce some jobs at the same time as lower prices raise demand for others

APPENDIX D: SOME METHODOLOGICAL ISSUES

Measures of Economic Benefits

- Productivity and cost savings, including
  - Productivity gains
  - Cost reductions
  - Avoided costs
  - Value of time saved
- Willingness to pay and consumer surplus
- Producer surplus
- Effects on value of property
- Value of information

Classification of Application Categories

- Application categories are defined to avoid duplication
  - Communications within other sectors is treated as part of the communications category which is included in the timing estimate
  - Maritime transportation benefits are represented by those of nautical charts which are primarily used for navigation
  - Surveying within sectors such as agriculture and construction is in the separate surveying category

Consumer Surplus Is Largely Included In The Ways Economic Benefits Are Measured

- Consumer surplus is the value consumers place on a service above its market price or cost
  - Consumer surplus arises because some buyers would have been willing to pay more than the market price or cost
- When benefits are measured by productivity gains or cost savings, consumer surplus is included to the extent the goods or services are acquired to obtained those savings
  - This is especially true among commercial and government users, but it is also true for personal users who, for example, may save time and fuel with better information
- When estimates of willingness-to-pay for services are used, consumer surplus is included
- **Where benefits are measured by consumer surplus, revenue is added to obtain total benefits**

Multiplier Effects

- Changes in productivity and cost influence industries from which a sector purchases inputs (indirect effects) and lead to changes in the rest of the economy (induced effects)
  - Reduced use of inputs from cost savings can be more than offset by increases in demand as price declines cause the using sector to expand
- Price declines in the initial sector cause increased use of its products which can raise the size and efficiency of other industries
  - Computable General Equilibrium (CGE) models have been used to trace price and other effects through the economy and internationally
- The Canadian Geomatics Study found that the $2.3 billion geospatial information industry added $20.7 billion or 1.1% to the Canadian economy, a multiplier of 10
- BCG found that the impact of geospatial services on the US economy is 15-20 times the size of the geospatial industry
  - **These multipliers are much higher than has been found using input/output models for other sectors, for which values around 2 are most common. Details on the studies are not available**

Some Reasons the Value of Consumers' Time May be Lower than Wage Rates

- Productivity can be lower for workers taking on additional hours because of fatigue
- People may not have opportunities to take on additional hours at their usual wage rate
- Consumer driving includes youth and retirees
- In multiple person households with children, a person at home may not develop the same earning power because of less experience and a less regular attachment to the labor force
- Market conditions or household decisions can result in the person with lower earning power taking care of children and/or aging parents
- People who expect to remain at home may be less likely to make investments in education, training and moving where job opportunities are better for them
- Those with greater household responsibilities may be less likely to commute farther for a better paying job
- Opportunities available to less regular workers tend to be concentrated in lower paying service industries and part time jobs
- Effects of past or present discrimination could reduce labor force participation and pay

An Example of a Type of Study that Could Provide More Accurate Estimates of GPS Benefits to Agriculture, etc.

- Take an existing sample of farms that have introduced or enhanced GPS technology during the last few years (such as the USDA Agricultural Resource Management Survey)
- Obtain information for each farm or section of farm on:
  - A full set of GPS and non-GPS technologies used before and after the changes
  - Crop costs and yields before and after the changes
  - The mix of crops (or sample just one crop), farm size and shape, soil conditions, weather and other factors that may influence the outcomes
- Perform a multivariate before and after analysis of changes across farms to estimate the contribution of GPS
  - Allow for lagged effects on productivity and yield
  - Examine cases where mainly GPS changed
  - Test for interaction effects between GPS and other technologies among all farms with the same crop or with adjustment for crop mix
- **A similar approach might be used for construction and for examining the impacts of improvements in surveying or mapping on agriculture, construction, etc.**

Leveson Biography

- Dr. Leveson has strong analytical skills in economics, business and public policy and extensive experience analyzing programs, markets and technologies. His background includes strategic and economic consulting and research in private industry, prominent research organizations, and government. Dr. Leveson has done extensive work on GNSS markets and issues for over 10 years. He has been an independent consultant since 1990. He has served as a consultant to the Aerospace Corporation and is an Adjunct Fellow at the Hudson Institute. He currently serves as a consultant to ASRC Federal Research and Technology Solutions, LLC.
- Dr. Leveson holds a Ph.D. in economics from Columbia University. Prior to establishing Leveson Consulting he served as Senior Vice President and Director of Research of Hudson Strategy Group, Director of Economic Studies of the Hudson Institute, Assistant Administrator for Health Systems Planning for the New York City Health Services Administration and as a research director for the New York City Planning Commission. He also was an economist for the RAND Corporation and an analyst with the National Bureau of Economic Research. Dr. Leveson is a member of the Institute of Navigation, the American Economic Association and the National Association for Business Economics.
- His books include *Economic Security*, *American Challenges*, *Western Economies in Transition* (co-ed.), *The Future of the Financial Services Industry* (main author), *Analysis of Urban Health Problems* (co-ed.) and *Quantitative Explorations in Drug Abuse Policy* (ed.).

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