SOCIO-ECONOMIC STUDIES OF GPS: PAST, PRESENT AND FUTURE

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OUTLINE

- NDP 2011 and 2013 Studies
- Leveson 2015 Study
- RTI 2019 Study
- Where Do We Go from Here?
- Supplementary Slides

COVERAGE OF US SOCIO-ECONOMIC STUDIES

- The focus here is on recent publicly available national studies
- Benefit studies
  - Include analysis of technologies, applications, customers and markets
  - Largely cover economic benefits, sometimes with limited discussion, but with little or no estimation of safety-of life and environmental benefits
  - Examine present and past but not future benefits
- Other socio-economic studies have addressed GPS costs and financing. Some work has not been public

NDP STUDIES

NDP CONSULTING (2011) prepared for the GPS Industry Council

- Covers direct economic benefits to commercial users
  - Sector estimates are for various dates from 2005-2010
    - Excludes government and households
    - Excludes induced benefits and non-economic benefits
  - Assumes generous rates of adoption in the covered sectors (crop farming, engineering construction and vehicle tracking)
  - Assumes the efficiency impact of GPS in the sum of *unexamined* commercial industries is the same as in those examined – despite the possibility that the examined sectors may be more capable of gains, e.g. because results there can be more readily measured
- Cost of disruption to users is estimated as *all* (or 50%) of the *full year* (lower bound) GPS contribution to productivity and efficiency, plus the loss to users in the value to past spending on GPS equipment and ongoing loss to manufacturers of GPS equipment sales

NDP ANALYTICS (2013) prepared for the PNT Board

- Restated data on global GNSS markets from the NDP 2011study
- Restated benefit data from NDP 2011
- Reported equipment units, sales and prices through 2010 from ABI
- Examined the contribution of manufacturers based on categories that were far to aggregate to be meaningful for GPS
- Presented international data from the GSA GNSS Market Report
- **The 2013 study did not make any new estimates of benefits**

LEVESON 2015

2015 GPS ECONOMIC REPORT

- EXCOM Action Item: "DOC to lead interagency team in consultation with the National Space-Based PNT Advisory Board to develop a way forward for an updated, authoritative GPS economic benefit assessment."
  - Conducted for the PNT Board under the auspices of the PNT Coordination Office
- Objectives of the study*
  - Describe the major uses of GPS and its position in the U.S. civilian value chain
  - Provide updated, more complete and methodologically sound estimates of economic scope and benefits of GPS to the U.S.
  - Provide an Interim Report that can serve as a core for development of follow-on analysis and final reports on GPS benefits in Part 2
- The first year of a 2-year effort was funded. See research recommendations supplementary slides for the proposed scope of the second year

*Irving Leveson, *GPS Civilian Economic Value to the U.S., Interim Report*, prepared for the National Executive Committee for Space-Based Positioning, Navigation and Timing, August 31, 2015 http://www.performance.noaa.gov/wp-content/uploads/2015-08-31-Phase-1-Report-on-GPS-Economic-Value.pdf and Irving Leveson, "The Economic Value of GPS," *GPS World* (September 2015), pp.36-42 http://gpsworld.com/the-economic-benefits-of-gps/

BENEFITS IN THE 2015 GPS STUDY

- Benefits were measured relative to what would have been expected if there was no GPS
  - Considering availability of alternative technologies and ways technologies and markets could have evolved in the absence of GPS
- Economic benefits were measured primarily by productivity improvements, cost savings and cost avoidance
- Indirect and induced economic benefits were calculated in a multiplier analysis
  - Safety-of-life and environmental benefits were not included
  - Less tangible values of GPS to the U.S. and other nations were discussed

- Benefits were estimated as $34.9-$62.4 billion in 2013, with a midpoint of $51.0 billion
- If benefits were updated from 2013 to 2019 for growth in nominal GDP, which includes both real growth and general inflation, they would be higher by 28%
- This would place the values in 2019 at $44.7-$79.9 billion, with a midpoint of $62.3 billion

TREATMENT OF TIMING

- The 2015 study measured civilian US benefits of GPS timing as the avoided cost of an alternative system based on enhanced Loran or one using precise atomic clocks on geostationary satellites – which it assumed would have evolved in the absence of GPS
  - The alternatives would primarily address US civilian needs (as would current proposals for eLoran)
  - Avoided costs of alternatives are much lower than the potential costs of unexpected loss of availability of GPS timing in a world that depends on it
- Scenarios for the loss of timing today would have to consider whether there was a loss of timing information from other GNSSs as well since they provide a ready alternative

TREATMENT OF MULTI-GNSS

- The 2015 study estimates for 2013:
  - Did not have to consider Galileo and BeiDou because they were not yet operational
  - Did not account for GLONASS which was used in limited applications and was not as fully evolved
- Today it would be necessary to include benefits of all GNSSs or try to separate those attributable to GPS vs. other GNSSs, either proportionally or according to incremental benefits
  - Whatever is done should be made explicit

RTI 2019

OVERVIEW OF THE RTI STUDY*

- Extensive description of technologies and applications, precision needs, and history of GPS
- Extensive use of interview information and expert opinion along with data from studies and statistical sources
- Estimates cumulative benefits for 1984-2017 for 10 broad civilian private sector sectors/application areas
  - Within the sectors covered, does not include telecommunications other than wireless and wireline services such as home internet services, cable television and broadcast radio and television, inland navigation, geospatial activities other than those of professional surveyors, or onshore oil and gas production
  - **Implicitly includes benefits of all GNSSs**
- Contains limited environmental information: Telematics includes reduction in pollutants and their public health value. Consumer LBS includes analysis of avoided car crashes and benefits to emergency services but could not value the benefits
- Includes an initial analysis of losses from a 30-day outage
- Shows what can be done if there is a large, continuous multi-year effort and extensive knowledge of technologies is incorporated

*RTI International, *Economic Benefits of the Global Positioning System (GPS)*, Prepared for the National Institute of Standards and Technology, RTI Project Number 0215471, June 2019 https://www.rti.org/sites/default/files/gps_finalreport.pdf

90% OF CUMULATIVE BENEFITS WERE IN TELECOMMUNICATIONS, TELEMATICS AND CONSUMER LOCATION-BASED SERVICES AND HALF WERE IN TELECOMMUNICATIONS ($ BILLIONS)

Telecommunications	Telematics (use of in-vehicle monitoring equipment)	Location-based services	Other	Total
• $687	• $325	• $216	• $127	• **$1,355**

Note: Estimates are based on changes in production costs, changes in productivity or revenue, and/or willingness to pay, as data permit. Measurement is "relative to a counterfactual scenario that describes what would have been in place or would have occurred in the absence of the technology being analyzed." Excludes benefits before 1988.

TREATMENT OF TIMING

- Includes national Loran-C as the alternative source of timing for telecom, agriculture and maritime
  - Does not include use of eLoran or space-based alternatives such as dedicated timing GEO satellites
  - **Reliance on Loran-C would have prevented the development of 4G wireless technology**
- The electricity sector analysis focuses on the use of Phasor Measurement Units (PMUs) relative to an expanded Loran system
- Enhanced Loran was the primary alternative for the financial services sector and Loran was the alternative for Maritime

THE UNEXPECTED 30-DAY OUTAGE ANALYSIS

- The study was **limited to a 30-day outage** which was specified by the Department of Commerce at the request of the PNT Board
- Assumes **other GNSSs will not be available** during the 30-day window which makes it applicable to only some causes of outages which are not specified
- The magnitude for agriculture would be large if during the planting or harvesting seasons
- The electricity sector analysis assumes little or no physical damage to the system from the outage which would depend on only some unspecified causes of outage
- Losses would be large in the maritime sector because of lack of a comparable backup

COMMENTS

- The reporting of cumulative benefits yields very large numbers but is less useful than recent annual benefits for future allocation of resources and comparison with other studies
  - Annual benefits are generally not shown in the report but have been provided on request by the authors
- The large benefits and outage losses for telecommunications critically depend on excluding eLoran and space-based timing alternatives
- Costs to users are deducted for agriculture and telematics but not for other sectors
- Multiplier effects on the economy are not included for benefits or disruption costs
- RTI sector estimates differ greatly from those of the Leveson 2015 report in either direction for many reasons (see supplementary slide). Totals across a same combination of sectors (other than telecommunications) are of broadly similar orders of magnitude

WHERE DO WE GO FROM HERE?

CURRENT BENEFIT ESTIMATES

- Analyze benefits to the private and public sector, activities which were not covered in the RTI study – including space-based timing alternatives, space-based GPS applications and international benefits of GPS and GNSS
    - Explore allocation of benefits between GPS and other GNSSs
- Update and refine sector direct economic benefit estimates, incorporate economic multiplier effects on the economy, and assess impacts of GPS on tax revenues and jobs
- Estimate benefits in safety and reduced loss of life and environmental benefits in critical applications

- Aggregate benefit estimates are "ballpark," no matter how sophisticated the methodology because data doesn't support more than that
    - Nevertheless, it is possible to demonstrate orders of magnitude of benefits for many applications as well as their total, along with the nature of the technologies, beneficiaries, and markets, and to effectively communicate that information

FUTURE BENEFITS

- A fuller picture of the benefits of GPS for planning requires consideration of future as well as past and present benefits
  - Including expected improvements in the operational control system, atomic clocks and other capabilities of the GPS system and advances in application technologies such as 5G and modernization of the National Spatial Reference System (NSRS) scheduled for 2022

COSTS OF DISRUPTION

- Causes of outages that would be effective if other GNSSs were operative should be stated explicitly and their impacts estimated
- The appropriate durations of outages for understanding impacts varies greatly by application and the level of aggregation at which an application is specified. Much more research considering a greater number of applications and scenarios within applications is required
    - Some research should be allowed the flexibility to determine the time periods examined based on vulnerability assessed for each application under alternative threats and with alternative responses
- Provision should be made in advance to enable impacts of unanticipated disruptions and means of responding to them to be studied as soon as they occur so actions can be taken quickly

DISSEMINATION

Prepare **Showcase Reports** to present and illuminate the information for general audiences in addition to technical reports

THANK YOU

SUPPLEMENTARY SLIDES

VALUE OF GPS BENEFIT AND LOSS STUDIES

- Improving understanding of customers, applications, markets and requirements of the program
- Informing decisions about the allocation of resources among programs
- Advancing recognition of the contributions of the program
- Analyzing threats to the program and benefits of responses

RESEARCH RECOMMENDED BY THE 2015 GPS BENEFIT 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. Refine and apply 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 assess possible magnitudes of environmental benefits

Recommendations 1, 2 and 3 were carried out in the 2019 RTI study.

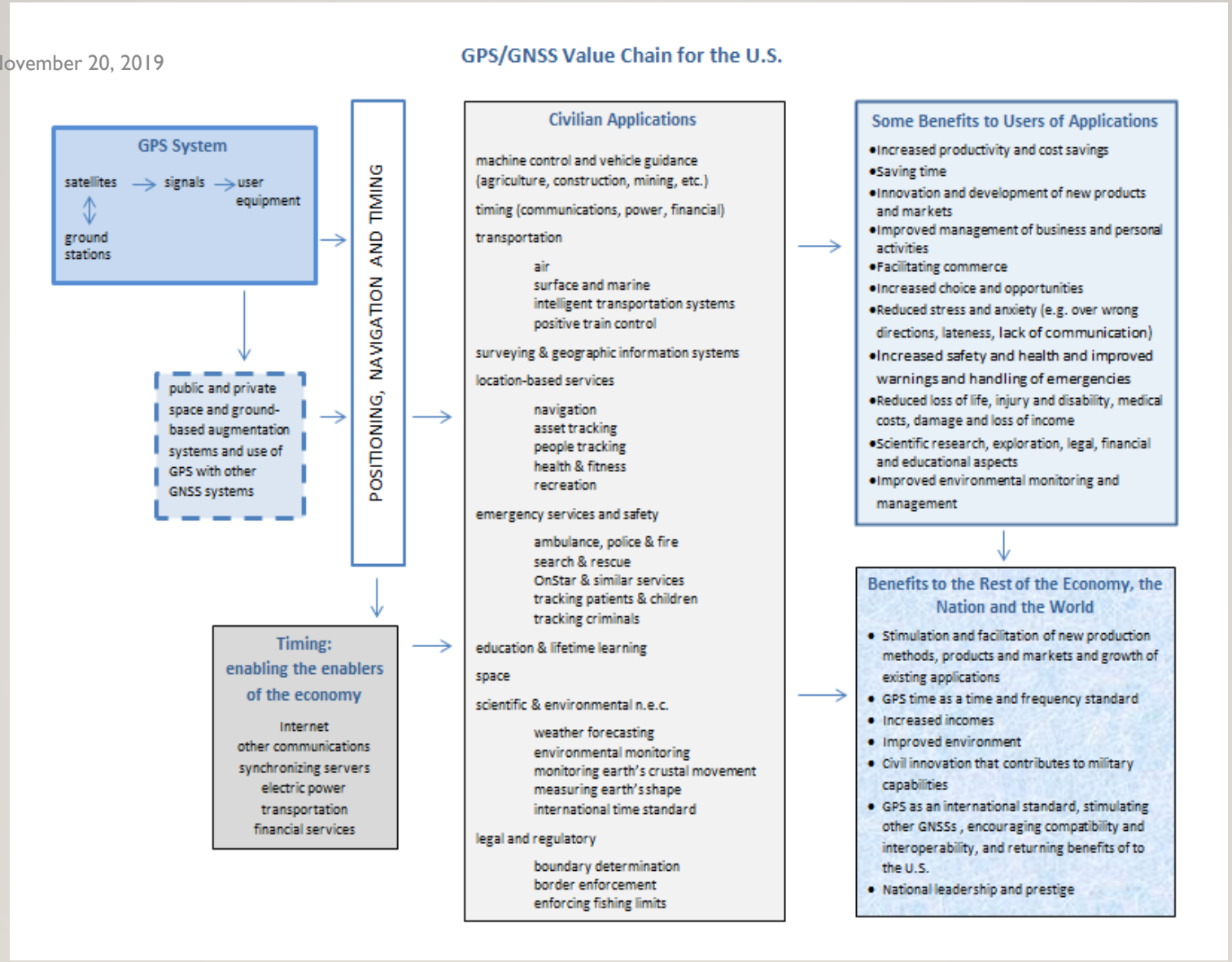
RESEARCH RECOMMENDED BY THE 2015 GPS BENEFIT STUDY (2 OF 2)

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 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**

UPCOMING STUDIES

- DHS is finalizing the results of its FY2017 NDAA requirements, approaching this from a risk management perspective which includes a cost-benefit analysis. It is not known what will be made public.

- The Spectrum Pipeline Reallocation Engineering Study (SPRES) for NOAA's satellite division is assessing the potential for and consequences of GOES geostationary weather satellites sharing the 1675-1680 MHz frequency band and adjacent frequency bands with commercial mobile wireless carriers. The report is expected in March 2020



Source: Leveson 2015 Report, p.4.

Comparison of RTI 2019 and Leveson 2015 Mid-Range Sector Benefit Estimates for 2013 (billions of dollars)				
Sector	**Leveson** (2013 dollars)	**Leveson** (2017 dollars)	**RTI** (2017 dollars)	**Comments**
Agriculture	13.700	14.297	0.480	RTI deducts costs ofadoption. Adoption rates from 2010 to 2017 were extrapolated based on expert opinion, with large differences between private sector and other experts. Leveson relied on expertise of John Deere
Electricity			1.743	
Location-based services (consumer)	5.500 or 11.200	5.740 or 11.688	22.954	Leveson's lower estimate is based on willingness-to-pay (WTP) and higher on value of time. RTI is based on willingness to pay. Leveson used a much lower WTP and assumed 30%-40% of the value was due to GPS rather than 100%
Mining			1.065	
Oil and gas			4.098	
Professional surveging	11.600	12.106	2.490	Leveson includes cartographers and photogrammetrists and savings in all support costs, and uses a higher adoption rate
Telematics	11.900	12.419	27.607	RTI covers all commercial vehicles rather than fleet vehicles and assumes the same adoption rate for non-fleet commercial vehicles. RTI subtracts costs of adoption.
Maritime	0.185	0.193	0.000	Leveson is for nautical charts and related marine information. RTI assumed adoption of Loran would have been
Telecommunications			62.026	based on willingness of telecom customers to pay for service without assuming lower cost alternatives such
Financial services			0.000	suffiicent alternatives
Timing	0.038 or 0.050	0.040 or 0.052		with enhanced Loran or GEOs
Construction	5.000	5.218		earth moving with machine guidance
Air transportation	0.145	0.151		DOT estimate
Rail	0.138	0.144		Positive Train Control
Note: Leveson estimates for agriculture, construction and location-based services with willingness to pay include indirect benefits. Conversion from 2013 to 2017 dollars is with the GDP deflator.				

A. Confident

B. Indicative

C. Notional

Summary of 2013 US GPS Benefit Estimates in the 2015 Study

	Application Category	Range of Benefits ($ billions)	Median Benefits ($ billions)
A	Precision Agriculture – grain*	10.0-17.7	13.7
A	Earthmoving with machine guidance in construction*	2.2-2.7	5.0
A	Air Transportation	.120 -.170	.145
C	Rail Transportation – Positive Train Control	.025-.250	.138
C	Maritime Transportation – nautical charts and related marine information	.106-.263	.185
A	Fleet Vehicle Connected Telematics*	7.6-16.3	11.9
A	Timing 1 – Loran	.025-.050	.038
A	Timing 2 – GEOs	.025-.075	.050
A	Surveying	9.8-13.4	11.6
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	5.3-17.0	11.2
	TOTAL (with alternative estimates for timing and consumer LBS averaged)	**34.9-62.5**	**51.0**

* Includes indirect benefits for this category.

GPS economic benefits as measured thus far were about 0.3% of GDP. This does not include sectors that were omitted, some indirect benefits, economic benefits induced in the rest of the economy, or benefits to health and safety and the environment.

BENEFITS OF GPS FOR GEOSPATIAL ACTIVITIES ARE MUCH GREATER THAN COST SAVINGS IN SURVEYING

- RTI estimate for professional surveying was limited to the 43,430 surveyors and support personnel
  - Leveson (2019)* estimated 170,000-190,000 in occupations (benefitting from systems utilizing GPS), including cartographers and photogrammetrists, geoscientists except hydrologists and geographers, hydrologists, geographers, and civil engineers doing surveying
- RTI uses $7.2 billion in revenue in 2017 to apply to changes in costs of surveying with GPS
  - Leveson (2019)* estimated direct spending on core geospatial activities of $22.1-$30.4 billion in 2018
- The 1998 Dewberry & Davis and Psomas & Associates *Height Modernization Study Report to Congress* found over $2 billion in benefits of the then capabilities of GPS for Digital Elevation Maps alone
- The RTI estimate does not include the cost savings for overall projects of which surveying and related activities are a part, or the value of reduced project delays and effects on need for rework and length of lives of projects
- While some mapping benefits are included in other RTI sector estimates, this suggests that **benefits of GPS for geospatial activities** (that are not addressed elsewhere in the report) **may be several times greater than the $3.0 billion RTI estimated for reduced cost of professional surveying in 2017**

* Leveson, Irv, *Scaling the Heights: Socio-Economic Study of the NGS Gravity Program*, prepared for the National Geodetic Survey, ARCBridge Consulting and Training, September 22, 2019 https://geodesy.noaa.gov/library/pdfs/NGS-Gravity-Program-Socio-Economic-Report.pdf

THE MODERNIZATION OF THE NATIONAL SPATIAL REFERENCE SYSTEM IN 2022 WILL ENABLE GREATER BENEFITS IN THE FUTURE

The National Spatial Reference System (NSRS) is a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States

> "To improve the National Spatial Reference System (NSRS), NGS will replace the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD 88) with a new geometric reference frame and geopotential datum in 2022."
>
> > "NAD 83 is non-geocentric by about 2.2 meters. NAVD 88 is both biased (by about one-half meter) and tilted (about 1meter coast to coast) relative to the best global geoid models available today."
>
> "The new reference frames will rely primarily on Global Navigation Satellite Systems (GNSS), such as the Global Positioning System (GPS), as well as on a gravimetric geoid model resulting from our Gravity for the Redefinition of the American Vertical Datum (GRAV-D) Project.
>
> These new reference frames will be easier to access and to maintain than NAD 83 and NAVD 88, which rely on physical survey marks that deteriorate over time."
>
> The new system will include regular updates to the geopotential datum where substantial geological or other changes occur
>
> Sources: https://www.ngs.noaa.gov/datums/newdatums/index.shtml and https://www.ngs.noaa.gov/datums/newdatums/background.shtml

THE EARLIER TRANSITION TO GPS IN GEODETIC POSITIONING

The 1998 National Height Modernization Study* clearly described the transition from traditional leveling that depended on triangulation and leveling networks that require line of sight to the transformation that took place with the use of GPS.

> "Until recently, NGS has relied on using conventional line-of-sight survey measurements… through a network of physical reference points accessible to users throughout the nation….
> Conventional leveling methods required crews of geodetic surveyors to have literally walked from border to border and coast to coast, carrying surveying equipment and taking geodetic surveying measurements every hundred yards or so, to establish and maintain a national coordinate system accessible to all users. In this fashion, a system of more than a million reference points was eventually built and serves today as the nation's geodetic reference framework.
>
> The advent of the Global Positioning System (GPS), however, has irreversibly transformed this landscape…. GPS…enables geodetic positioning to be accomplished without having to physically see between points. Using GPS, a survey that once took days to complete can now be done in a few hours at a much lower cost. GPS has also introduced the fourth dimension of time, enabling more accurate modeling of the earth's crustal motion. In addition, GPS techniques have enabled "realtime" positioning applications. As a result, GPS has not only revolutionized the traditional civilian navigation, surveying, and mapping professions, but has spawned numerous new applications…"

*Dewberry & Davis and Psomas & Associates, *National Height Modernization Study: Report to Congress*, Washington, DC: National Oceanic and Atmospheric Administration, National Geodetic Survey, June 1998, pp.xi-xii
https://www.ngs.noaa.gov/PUBS_LIB/1998heightmodstudy.pdf

ECONOMIC MULTIPLIERS

- Benefits to the economy can be direct, indirect and induced
  - Indirect effects are impacts on demand for goods and services of supporting industries
  - Induced effects include resulting product and process innovation and expansion in the economy
- Multipliers are lower at full employment because the economy cannot grow by more fully utilizing the existing labor force and capital equipment
- Multipliers have been estimated from input/output models and econometric models of the economy to determine secondary effects
- Adapting multipliers from existing studies that use these methods to allow for their limitations and differences among applications can be a substitute for new formal modeling

MODELS AND MULTIPLIER EFFECTS

- Input/output models trace purchases across industries. They require use of fixed past inter-industry relationships even when the greatest interest is in how those relationships are changing
- Computable General Equilibrium models (CGE) are one type of economy-wide econometric model. They may incorporate an input/output framework for calculating inter-industry effects but have some flexibility in allowing for structural changes and include other impacts
- Econometric models of the economy tend to disproportionately capture shorter-term effects while input/output models reflect some long-run impacts but are more rigid
    - Econometric models that try to capture industry detail by incorporating an input/output framework can be limited in accuracy by differences between the industry structure of the model and that of the benefit analysis
- All models are limited by the nature and completeness of the PNT benefit data

THE ECONOMIC VALUE OF LIFE AND HEALTH

- Health and safety improvements can be assigned dollar values based on reductions in loss of income, medical costs, injury, disability, and the value of lost lives
- Savings in lives is measured by economists in terms of the value of a statistical life (VSL)
  - The value of a statistical life is used to compare risks associated with small changes in probabilities of death for large groups. It is not intended to be used to assign values to the worth of individuals
  - VSL has been estimated in several studies primarily based on the higher incomes people are willing to accept to go into risky occupations. However, a wide range of estimates are in use
  - Some federal agencies have standardized the methods they use
- Costs of injury and disability are typically based on scales of functionality and related to the value placed on loss of life

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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 worked on GNSS markets and issues over the last 17 years and has consulted extensively to NOAA.

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 of the New York City Health Services Administration and as a research director for the New York City Planning Commission. He also served 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, the National Association for Business Economics and the American Meteorological Association.

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.).